INDC (NDS)-0479
Distr. SD

INDC International Nuclear Data Committee

Summary Report

First Research Coordination Meeting on

Updated Decay Data Library for Actinides

IAEA Headquarters
Vienna, Austria

17 - 19 October 2005

Prepared by
Mark A. Kellett

IAEA Headquarters, Vienna, Austria
January 2006

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Nuclear Data Section
International Atomic Energy Agency
PO Box 100
Wagramer Strasse 5
A-1400 Vienna
Austria

Produced by the IAEA in Austria
January 2006

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International Atomic Energy Agency
IAEA Nuclear Data Section
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A-1400 Vienna
Austria

Abstract

The first meeting of the Co-ordinated Research Project on "Updated Decay Data Library for Actinides" was held at the IAEA, Vienna on 17-19 October 2005. A summary of the presentations made by participants is given, along with the subsequent discussions on the evaluation procedure and list of radionuclides to be considered. The participants adopted the current procedures of the Decay Data Evaluation Project (DDEP) for producing a recommended decay data scheme, and each participant was allocated a number of radionuclides for evaluation.

January 2006

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1. Introduction

Actinide nuclides and their decay chains need to be well characterised and their decay parameters quantified with high confidence, particularly for power-related applications, and fuel manufacture, reprocessing and waste storage. These significantly improved decay data are directly applicable to a wide range of energy and non-energy applications – facility design, safety assessments, waste management, and safeguards/proliferation issues. A previous Co-ordinated Research Project (CRP) from 1978 to 1986 addressed the preparation of such a database directly, and provided the catalyst for a series of new measurements that continued well into the 1990s. All of this new work and earlier data need to be compiled and evaluated to produce an updated set of recommended decay data to replace the current IAEA database (of 1985/86).

The International Nuclear Data Committee (INDC) which advises the Nuclear Data Section (NDS) on nuclear data issues has noted that the need for such databases is an important issue in a wide range of applications. The INDC recommended in the Summary Report of their meeting of May 2002 that a CRP on "*Updated Decay Data Library for Actinides*" be initiated in 2005, and re-emphasised their support in May 2004. Hence the first Research Co-ordination Meeting (RCM) of this CRP was held at the IAEA Headquarters in Vienna, Austria from 17 - 19 October 2005. The Agenda and List of Participants for this meeting are given in Appendices A and B, respectively.

A. L. Nichols, Head of the IAEA-NDS, opened the meeting and M. A. Kellett (IAEA-NDS), the Project Officer, presented some opening comments covering the aim and scope of the CRP, including questions which needed to be addressed during the first RCM. F. G. Kondev (ANL, USA) was unanimously elected Chair of the meeting and M. A. Kellett Rapporteur. Following the adoption of the Agenda the Chair invited each participant to present a brief summary of their recent work of relevance to the CRP.

2. Presentations

2.1. F. G. Kondev: Nuclear Data Activities at ANL

The Argonne Nuclear Data Program includes a variety of scientific activities carried out within the broader framework of the Coordinated Work Plan of the US Nuclear Data Program. Among these are the compilation and evaluation of nuclear structure and nuclear reaction data, and the development of nuclear data measurement, analysis, modelling, and evaluation methodologies for use in basic science and technology applications.

More specifically the Argonne Nuclear Data Program includes activities on nuclear structure and decay data evaluations for both ENSDF and DDEP and data dissemination. In particular:

- for ENSDF, ANL has newly appointed responsibility for the A = 199-209 mass chains following it officially joining the Nuclear Structure and Decay Data (NSDD) network at the November 2003 meeting. Evaluations for the A = 201, 203 and 205 mass chains have already been completed and published and it is anticipated that all remaining mass chains will be evaluated in the next 4-5 years. ANL also acts as reviewer for other mass chain evaluations as required, recently mass chains A = 88, 176 and 179 have been reviewed.
- for DDEP, an evaluated decay dataset for ^{177}Lu, a nuclide that is relevant to medical applications, was submitted to the DDEP Chairman, reviewed and published on the DDEP web site. Evaluations of decay properties of the $K^{\pi} = 16^{+}$, $T_{1/2}$ = 32 y isomer in ^{178}Hf and the $K^{\pi} = 23/2^{-}$, $T_{1/2}$ = 160 d isomer in ^{177}Lu that are of relevance for detector calibration applications are continuing. Reviews of evaluations for the ^{65}Zn, ^{204}Tl, and ^{240}Pu nuclides were also performed upon request from the DDEP chairman.

- Argonne continues to develop, update and maintain the ANL Nuclear Data and Measurements Report Series (http://www.td.anl.gov/reports), ANL Nuclear Data Information (http://www.td.anl.gov/NDP) and Experimental Resources for Nuclear Data Studies (http://www.td.anl.gov/nrs) websites. Significant modifications were made to these websites in the past two years and extensive upgrades are planned in the future.

2.2. M.-M. Bé: Decay Data Evaluation at LNHB

The Laboratoire National Henri Becquerel (LNHB) is a member of the Commissariat à l'Energie Atomique (CEA) and also of the French National Metrology Office. The LNHB is the primary standard laboratory for ionizing radiation metrology in France. Due to this position the LNHB has been involved in the field of decay data evaluation for many years.

The LNHB has been involved in a number of previous IAEA CRPs:

- Decay Data for the Transactinium Nuclides
  Technical Reports Series No. 261 (1986)
- X-ray and γ-ray Decay Data Standards for Detector Calibration
  IAEA-TECDOC-619 (1991)
- Update of X-ray and γ-ray Decay Data Standards for Detector Calibration and Other Applications – (1997- 2002), to be published.

The Decay Data Evaluation Project (DDEP) - an international working group - was formed in 1995 at the initiative of LNHB and PTB with the objective of providing carefully recommended data. It is now composed of members from: LNHB, PTB, LBNL, KRI, ANL, IAEA, NPL, IFIN and KRISS. A list of a variety of publications produced by this project includes:

- "Tables of Data" - available on paper as a BIPM Monographie
- Tables and Comments are available within the NUCLÉIDE CD-ROM
- The Monographie can be downloaded from the BIPM website:
  http://www.bipm.fr/fr/publications/monographies-ri.html
- All the Data and Comments are also available on the DDEP webpages:
  http://www.nucleide.org/DDEP_WG/DDEPdata.htm

The DDEP has also produced a set of tools for evaluators of decay data including:

- A "Read/Write" version of NUCLÉIDE
- LWEIGHT (Fortran and Excel): for weighted mean determination
- ICC V3: Internal Conversion Coefficients
- EC CAPTURE: electron capture probabilities in the sub-shells
- EMISSION: X-ray and Auger electron emission intensities
- Exportation to the ENSDF format

The current status of decay data evaluation work was presented, particularly the evaluation of the ^{226}Ra decay chain, which followed the γ-ray intensities evaluation of R. Helmer for the previous CRP, and a technical note was published. The evaluation of ^{234}U, ^{238}U and ^{252}Cf are ongoing.

Recently evaluated nuclides of relevance to this CRP as published by the DDEP were shown:

Nuclide	Laboratory	Date	Reference	Mode
^{212}Pb	AEA	01/07/2004	2004 - Monographie5	β^- decay
^{212}Bi	AEA	01/07/2004	2004 - Monographie5	α decay
^{212}Po	AEA	10/06/2004	2004 - Monographie5	α decay
^{216}Po	AEA	04/06/2004	2004 - Monographie5	α decay
^{220}Rn	AEA	04/06/2004	2004 - Monographie5	α decay
^{224}Ra	AEA	04/06/2004	2004 - Monographie5	α decay
^{226}Ra	LNHB, INEEL	02/03/2004	2004 - Monographie5	α decay
^{227}Th	LBNL	04/06/2004	2004 - Monographie5	α decay
^{228}Th	AEA	01/07/2004	2004 - Monographie5	α decay
^{233}Th	KRI	21/03/2005		β^- decay
^{233}Pa	KRI	16/02/2005		β^- decay
^{238}Pu	KRI	04/06/2004	2004 - Monographie5	α decay
^{240}Pu	KRI	10/09/2004	2004 - Monographie5	α decay
^{242}Pu	KRI	26/05/2004	2004 - Monographie5	α decay
^{241}Am	KRI	24/02/2005	2004 - Monographie5	α decay
^{243}Am	LBNL, INEEL	21/10/2004		α decay
^{242}Cm	KRI	09/05/2005		α decay
^{244}Cm	KRI	01/08/2005		α decay

2.3. A. Luca: Experimental determination of photon emission probabilities

Accurate photon emission probability measurements require high-quality calibrated X- and γ-ray spectrometric systems with semi-conductor detectors (such as planar and coaxial HPGe) and standard radioactive sources with very low uncertainties associated to their activity values.

The procedure was successfully applied to studies of ^{237}Np/^{233}Pa (EUROMET Project 416, during 1998-2001) and ^{65}Zn (twice – during 2000-2002 and in the frame of EUROMET Project 721 in 2004).

In the case of ^{237}Np/^{233}Pa, the emission probabilities of the K_α and K_β X-ray components and about 40 γ-rays were measured.

The results were obtained in co-operation with scientists from the Laboratoire National Henri Becquerel, CEA-Saclay, France.

2.4. X. Huang: Re-evaluation of the decay data of ^{233}Pa

A recently completed and published re-evaluation of the decay data of ^{233}Pa was presented. The method of evaluation was described and analysis methods for determining various quantities were outlined. The evaluation took into account all published measurements up to and including those published in 2004. A complete description of the recommended values was given and also a complete decay scheme was presented which included the placement of a further eight γ-rays as compared to a previous scheme proposed in 1990. The evaluation also included details of internal conversion coefficients as calculated with the BrIcc code and X-ray and Auger electron emissions as calculated with the RADLIST and LOGFT codes as appropriate. A number of discrepant measurements of the γ-ray emission probabilities exist, particularly for the 28.559(10)-keV line, which could warrant further experimental investigation. For the particular line mentioned, Huang selected the emission probability

as measured by Luca *et al.* (as detailed in the previous presentation), but this value still has a relative uncertainty of 30%.

2.5. M. Gopal: Isomer decay in heavy nuclei and structure of light exotic nuclei by γ-ray spectroscopy

The high spin isomers play an important role in nuclear structure physics. Excited isomeric states in heavy nuclei are sometimes longer lived than the ground state and thus affect the ground state decays. The techniques for measuring the half-lives and the decay properties of isomers vary, depending mostly on the half-life of the isomer. For heavy exotic nuclei, with low production cross sections, a selective device, like a fragment mass analyzer (FMA) at Argonne National Laboratory, is used to identify the products from the background of the other products with larger cross section.

Similar measurements were performed for the ^{217}Th nucleus. An isomer with a half-life of 20(5) μs at excitation energy of about 2.1 MeV and its decay have been discovered for the first time. The decay scheme indicates a stronger octupole correlation for the N = 127 isotones as the proton number increases from Z = 82. The presence of a high-K isomer in the ^{140}Dy nucleus helped in establishing a rotational ground state band in this very neutron deficient nucleus up to the spin of 8^+. The half-life of the 8^- isomer was measured to be about 7 μs. Many new high-K isomers with half lives from a few μs to a few ms have been established in neutron-rich hafnium nuclei, ^{181,182}Hf.

2.6. V. P. Chechev: Evaluation of the decay characteristics of transactinium radionuclides at the Khlopin Radium Institute

Decay data evaluation work for actinides at the Khlopin Radium Institute (V.P. Chechev and N.K. Kuzmenko) was presented. Initial evaluations were published in the Russian hand-book: Evaluated Values of Nuclear Characteristics of Transuranium Radionuclides (V. P. Chechev, N. K. Kuzmenko, V. O. Sergeev, K. P. Artamonova - Moscow, Energoatomizdat, 1988). At a later time the evaluation technique was improved, and at present the new updated decay data evaluations for transactinium radionuclides are being carried out by V. P. Chechev and N. K. Kuzmenko within the Decay Data Evaluation Project.

The evaluation work undertaken over the previous two years was summarized which covers the decay scheme data of the following actinides: ^{233}Th, ^{233}Pa, ^{237,239}U, ^{238,239,240,241,242}Pu and ^{242,244}Cm. These studies have been undertaken with financial support through a 3-year IAEA research contract. All evaluations have been completed and placed on the DDEP web site, apart from ^{237,239}U and ^{239,241}Pu that remain on-going.

Problems of note include:

- ^{233}Th: all emission probabilities are reported without uncertainties (thus, new measurements are required with uncertainties);
- ^{233}Pa: precise new measurements are required for low-energy γ-rays and L X-rays using pure ^{233}Pa sources to resolve various discrepancies between recent evaluations.

3. Evaluation Methodology and Final Data Presentation

A general discussion on the method to be used for carrying out the evaluations to be undertaken within the CRP resulted in the adoption of the procedures used within the Decay Data Evaluation Project (DDEP).

The procedures outline the basic method of data and uncertainty propagation analysis to be employed, as well as the definition of a well defined report format for the publishing of the evaluated data which includes detailed tabulated results. There is also a review procedure included which participants will follow. It may be necessary to assess this review procedure as the CRP progresses since the potential production of a large number of evaluations could overwhelm the current system.

A small suite of computer tools exist in order to carry out DDEP style evaluations, (see Section 2.2). This package is developed and maintained by members of the group at the Laboratoire National Henri Becquerel and more specifically by M.-M. Bé, who has agreed to supply all CRP members with a copy.

Action 1: M.-M. Bé - to supply each participant with a copy of the computer tools used within the DDEP for evaluations.[†]

It was also agreed by participants that the Q-values should be taken from the recent Audi *et al.* evaluation ("The AME2003 atomic mass evaluation (II). Tables, graphs and references", Nuclear Physics A 729 (2003) 337-676). For the calculation of internal conversion coefficients the BrIcc code with the "frozen orbital" approximation should be used. M.-M. Bé also agreed to assess the impact of the use of the BrIcc code on recent evaluations.

Action 2: M.-M. Bé - to assess the impact of the BrIcc code use on recent evaluations.

Although the DDEP procedures specify a detailed tabular format for data presentation, it was felt by participants that a standard computer readable format should be adopted for the final dissemination of the data. It was agreed that data would be made available in two reputable formats already in wide use internationally, that is the ENSDF and ENDF formats. Some participants are familiar with the former of these and so their production should be relatively simple. However outside help may be required, in the form of a consultant, to allow these files to be converted to the latter format. It should be noted that for applications the latter ENDF format is more widely used and it was stressed that their creation is of importance to the success of the CRP.

[†] See Appendix C for a complete list of actions

4. Measurement Requirements and Possibilities

A small number of measurements are planned at ANL which coincide with the needs of this CRP, these are on ^{243,244,245,246}Cm. A further possibility might be to measure the γ-ray emission probabilities for ^{233}Pa to try and resolve the discrepancy that currently exists between previous measurements for the 28.559-keV line (see section 2.4).

A large number of sources are available at ANL, a list of which was provided to participants (see Appendix D). However, the requirement for new measurements can only be truly assessed following initial evaluation work and it is expected that further measurement requests will be made in the coming year. The evaluations carried out over the last two decades or so by one participant (A. L. Nichols) and included in the current UKHEDD-2.3 file should be assessed for required measurements, as should other recent evaluations. It is only following this type of procedure that a well-defined measurement request can be made.

Action 3: A. L. Nichols - to assess the requirement for new measurements based on the evaluations in the UKHEDD-2.3 library.

Action 4: All participants - to assess the requirement for new measurements based on their recent evaluations.

It was also noted that some measurements on ^{240}Pu are currently underway at IRMM Geel, with the involvement of LNHB, France and NPL, UK. Further details of these measurements are to be sought. Other measurement possibilities by these groups are limited, but it might be possible to undertake a measurement or two during the period of the CRP.

Action 5: M.-M. Bé and A. Pearce - to seek further details of current and planned measurements within Europe, specifically those at IRMM Geel (^{240}Pu).

5. Selection of Radionuclides

Since this CRP is aimed at updating the data produced in a previous CRP, from the early 1980s, it was unanimously agreed that any starting list of radionuclides must contain all of those previously studied - see IAEA Technical Reports Series No. 261 (1986).

Therefore the initial list must contain at least the following 23 actinides;

$$^{229,\,231}\mathrm{Th},\ ^{231,\,233}\mathrm{Pa},\ ^{232,\,233,\,234,\,235,\,237,\,239}\mathrm{U},\ ^{237,\,239}\mathrm{Np},$$
$$^{238,\,239,\,240,\,241,\,242}\mathrm{Pu},\ ^{241,\,242\mathrm{m},\,243}\mathrm{Am},\ ^{242,\,244}\mathrm{Cm},\ ^{252}\mathrm{Cf},$$

all of which were fully evaluated previously for the 1986 publication.

Also included in the previous CRP report were recommendations for the half-lives and branching ratios of a large number of radionuclides from ^{206}Hg to ^{253}Es, which includes the decay daughters of the studied actinides. γ-ray and alpha-particle emission energies and probabilities were also provided for ~50 and ~30 nuclides respectively. Again it was felt necessary to try and improve on and provide this information through the CRP.

6. Allocation of Radionuclides

In order that the work of the CRP members can progress smoothly and be correctly co-ordinated each member was allocated, by consensus, a number of radionuclides to be evaluated. Table I shows the radionuclides as allocated and chosen for inclusion in the evaluation and/or measurements effort. Where possible any one participant has been allocated the decay daughters of the major actinide(s) being evaluated.

A small number of decay daughters have, as yet, not been allocated as these have a lower priority and it may not be possible for complete evaluations to be performed due to the limited manpower available. However, it is envisaged that recommended values can still be provided by the end of the CRP for these few radionuclides, as was the case in the previous CRP, *e.g.* half-life, branching fraction, emission energies and their associated probabilities through ENSDF.

Table I: Radionuclides allocated to each CRP participant

Participant	**Actinides**	**Decay daughters**
A. Luca	^{234}Th, ^{236}U	^{228}Ra
A. L. Nichols	^{228}Th, $^{242m, 244}$Am	^{208}Tl, ^{212}Pb, ^{212}Bi, ^{212}Po, ^{220}Rn, ^{224}Ra
A. Pearce	^{232}Th, ^{231}Pa, ^{232}U	^{228}Ac
F. G. Kondev	$^{243, 245, 246}$Cm	^{206}Hg, ^{206}Tl
M. Gopal	^{229}Th, ^{233}U	
M.-M. Bé	^{243}Am, $^{234, 238}$U, ^{252}Cf	$^{210, 214}$Pb, $^{210, 214}$Bi, $^{210, 214, 218}$Po, ^{222}Rn, ^{226}Ra
V. P. Chechev	^{233}Th, ^{233}Pa, $^{237, 239}$U, $^{236, 236m, 237, 238, 239}$Np, $^{238, 239, 240, 241, 242}$Pu, ^{241}Am, $^{242, 244}$Cm	
X. Huang	^{231}Th, ^{235}U	^{213}Bi, ^{225}Ra, ^{225}Ac
Unallocated		$^{207, 209, 210}$Tl, $^{209, 211}$Pb, $^{209, 211, 215}$Bi, $^{211, 213, 215, 216}$Po, $^{215, 217, 218, 219}$At, $^{217, 218, 219}$Rn, $^{221, 223}$Fr, ^{223}Ra, ^{227}Ac

7. Additional Comments

A CRP website (http://www-nds.iaea.org/act_ddl/) has been established and has already been used for disseminating information for this meeting. All presentations made at this meeting are also available. The website is maintained by the Project Officer (M. A. Kellett) for the efficient exchange of information between interested parties, but no link is given from the Nuclear Data Section's main website. None of the participants objected to making the address known to potential contributors, who are not formally CRP participants.

8. Next meeting

The next RCM meeting is scheduled in Spring 2007. It was noted that the forthcoming International Conference on Nuclear Data for Science and Technology (ND2007) will take place in Nice, France, 22-27 April 2007, and so it was suggested that it would be sensible to organise the next meeting during the week preceding this, i.e. 18-20 April 2007. The venue is likely to be Vienna, unless any of the participants are willing to organise the meeting at their home institute. It should be noted that the IAEA requires that the meeting be held in Europe due to travel cost restrictions.

Appendix A: Agenda

International Atomic Energy Agency

First Research Co-ordination Meeting on

UPDATED DECAY DATA LIBRARY FOR ACTINIDES

IAEA Headquarters, Vienna, Austria

17-19 October 2005

Meeting Room A1241

AGENDA

Monday 17 October

08:30 – 09:20	**Registration** (IAEA Registration Desk, Gate 1)
09:30 – 10:00	**Opening Session**
	Opening (A.L. Nichols)
	Introductory Remarks (M.A. Kellett)
	Election of Chairman and Rapporteur
	Discussion and Adoption of the Agenda (Chairman)
	Election of Task Co-ordinators
10:00 – 11:00	**Coffee break and Administrative Matters**
11:00 – 12:30	**Session 1: Presentations by Participants**
	(15 mins per presentation + 5 mins discussion)
12:30 – 14:00	**LUNCH**
14:00 – 15:30	**Session 2: Presentations by Participants (cont'd)**
	(15 mins per presentation + 5 mins discussion)
	General Discussion
15:30 – 16:00	**Coffee break**
16:00 – 17:30	**Session 3: Identification of Relevant Nuclei**

Identification of relevant nuclei

Importance/priority of identified nuclei

Availability of data

19:00 - **Dinner at the Gasthaus Pürstner Restaurant**

Tuesday 18 October

09:15 – 10:30 **Session 4: Review of Current Status**

Current status of evaluations

Current status of published data

10:30 – 11:00 **Coffee break**

11:00 – 12:30 **Session 5: Measurements to be undertaken**

Participants' measurement capabilities and plans

Needs and priorities

Other measurements expected or underway

12:30 – 14:00 **LUNCH**

14:00 – 15:30 **Session 6: Definition of Evaluation Procedure and Rules**

Evaluation procedure and reference coverage

Available software

15:30 – 16:00 **Coffee break**

16:00 – 17:30 **Session 7: Definition of Expected Output**

Evaluation Report – style and content

Data table format

Data-file formats, e.g. ENSDF, ENDF

Wednesday 19 October

09:15 – 10:30 **Session 8: Allocation of nuclei**

Nuclei to be measured

Nuclei to be evaluated

10:30 – 11:00 **Coffee break**

11:00 – 12:30 **Session 9: Summary Report Preparation**

Drafting of the 1st RCM Summary Report

12:30 – 14:00 **LUNCH**

14:00 – 15:30 **Session 10: Summary Report Preparation (cont'd)**

Finalisation of the 1st RCM Summary Report

15:30 – 16:00 **Coffee break**

16:00 – 17:30 **Session 11: Review and Agreement of the Summary Report**

Review and Agreement of the 1st RCM Summary Report

17:30 – 17:45 **Final Remarks and Close of the Meeting**

Any other business and time schedule for the 2nd RCM

Appendix B: List of Participants

International Atomic Energy Agency
First Research Co-ordination Meeting on

"Updated decay data library for actinides"

IAEA Headquarters, Vienna, Austria

17-19 October 2005
Meeting Room A1241

LIST OF PARTICIPANTS

CHINA
Xiaolong Huang
China National Nuclear Corp. (CNNC)
China Institute of Atomic Energy (CIAE)
Nuclear Data Center
Division of Nuclear Physics
P.O. Box 275-41
Beijing 102413
Tel. + 86-10-69357830
Fax. + 86-10-69357008
E-mail: huangxl@iris.ciae.ac.cn

FRANCE
Marie-Martine Bé
Commissariat à l'énergie atomique (CEA
Laboratoire National Henri Becquerel
F-91190 Gif sur Yvette CEDEX
Tel. + 33 1 69 08 46 41
Fax. + 33 1 69 08 26 19
E-mail: mmbe@cea.fr

ROMANIA
Aurelian Luca
National Institute of R&D for Physics and
Nuclear Engineering „Horia Hulubei"
Department of Radioisotope
Radionuclide Metrology Laboratory
Atomistilor Street 407
PO Box MG-6 Com. Magurele
RO-76900 Bucharest Magurele
Tel. + 40 21 404 23 00 / 4517 or 4521
Fax. + 40 21 457 44 32 or 457 44 40
E-mail:aluca@ifin.nipne.ro

RUSSIAN FEDERATION
Valery Chechev
V.G. Khlopin Radium Institute
Isotope Department
2nd Murinsky pr. 28
194021 St. Petersburg
Tel. 007 812 247 37 06
Fax. 007 812 247 80 95
E-mail: Chechev@atom.nw.ru

UNITED KINGDOM
Andrew Pearce
Quality of Life Division
National Physical Laboratory
Hampton Road
Teddington
Middlesex TW11 0LW
Tel. + 44 020 8943 8582
Fax. + 44 020 8943 8700
E-mail: andy.pearce@npl.co.uk

UNITED STATES OF AMERICA
Filip Kondev
Argonne National Laboratory (ANL)
Division of Nuclear Engineering
9700 South Cass Avenue
Argonne, IL 60439
Tel. + 1 630 252 4484
Fax. + 1 630 252 4978
E-mail: kondev@anl.gov

ADVISER FRANCE
Gopal Mukherjee
Grand Accelerateur National D'Ions Lourds
(GANIL)
Boulevard Henri Becquerel
B.P. 55027
F-14076 Caen, Cedex
Tel. + 33 2 31-45-46-44
Fax. + 33 2 31-45-46-65
E-mail: mukherjee@ganil.fr

IAEA
Mark A. Kellett
Nuclear Data Section
Division of Physical and Chemical Sciences
Department of Nuclear Sciences and Applications
Wagramer Strasse 5
A-1400 Wien
Tel. + 43 1 2600-21708
Fax. + 43 1 2600 7
Email: m.a.kellett@iaea.org

IAEA
Alan L. Nichols
Nuclear Data Section
Division of Physical and Chemical Sciences
Department of Nuclear Sciences and Applications
Wagramer Strasse 5
A-1400 Wien
Tel. + 43 1 2600-21709
Fax. + 43 1 2600 7
Email: a.l.nichols@iaea.org

Appendix C: List of Actions

Action 1: M.-M. Bé - to supply each participant with a copy of the computer tools used within the DDEP for evaluations.

Action 2: M.-M. Bé - to assess the impact of the BrIcc code use on recent evaluations.

Action 3: A. L. Nichols - to assess the requirement for new measurements based on the evaluations in the UKHEDD-2.3 library.

Action 4: All participants - to assess the requirement for new measurements based on their recent evaluations.

Action 5: M.-M. Bé and A. Pearce - to seek further details of current and planned measurements within Europe, specifically those at IRMM Geel (^{240}Pu).

Appendix D: List of sources available at ANL

April 20, 2005
File # srsafe2.txt

Alpha Sources (Open):

	Name	Description	Activity	Alpha dpm	Date of
	Cf9-MS2	mass separated	1 µCi	1.6E06	1974
	Cf9-MS3	mass separated	0.7 µCi	1.4E06	6-3-1974
	Cf9-Pt1	TEG spread, old	0.5 µCi	8.8E05	1971
	Cf9-V2	volatalized	0.2 µCi	Greene	1971
	Cf9-ub	uball frame	3.3 µCi		2-19-1998
	Cf9-IA2	Pt disk, gamma frame	0.7 µCi	1.4E06	2-3-1998
	Cf9-IA3	Pt disk, unmounted	0.5 µCi	1.0E06	2-24-1998
Am:	Aml-MS1	mass separated	0.5µCi	1.0E06	1-26-1977
	Am3-MS1	mass separated	0.7 µCi	1.45E06	10-2-1969
	Am3-MS2	mass separated	0.2 µCi	4.5E05	4-30-1970
	Aml-W1	mass separated	40 nCi	7.5E04	1-26-1977
	Am1-003	on Pt for Rehm inside spectrograph	~2 nCi		5-15-2000
Th:	Th8-S	Isotope Products	0.4 µCi		10-20-1993
	Th8-1	Isotope Products	40 nCi		10-20-1993
	Th-ub	uball, in 1998	0.3 µCi		12-9-1998
	Th-98	0ne inch frame	0.3 µCi		12-9-1998
	Th-02	on quartz plate	1.0 µCi		
	Th9-MS1	mass separated	0.5 µCi	1.0E06	10-20-1986
Pu:	Pu8-MS1	mass separated, Pt	0.5 µCi	8.0E05	4-17-1980
	Pu8-MS2	mass separated	1.O µCi	1.7E06	4-17-1980
	Pu9-MS1	mass separated	0.1 µCi	2.8E05	1980
	Pu0-MS1	mass separated	0.2 µCi	3.5E05	7-26-1974
	Pu240-Cm244	TEG spread	0.5 µCi		6-2-1993
	Batch #003-030-01859-1409				
Cm:	Cm3-MS1	mass separated	0.1 µCi	2.6E05	1974
	Cm3-MS2	volatalised	1.0 µCi	1.3E06	1-26-1973
	Cm3-MS3	mass separated	0.1 µCi	1.4E05	12-19-1973
	Cm4-MS1	mass separated	5 nCi	4.OE04	1-5-1973
	Cm5-Vl	electroplated	0.1 µCi	1.4E05	8-29-1989
	Cm7-Vl	TEG spread, glass	300 dpm		1-20-1973
Strong sources:					
	Aml-S2	mass separated	5 µCi		1977
	Cm5-S1	broken, not usable	1 µCi		8-29-1989
Uranium: U3-MS1		mass separated	4 nCi	7.5E03	6-5-1972
Gadolinium: Gd-1		On Pt disk, Horwitz	4 nCi	7.5E03	12-8-1964
	Gd-3	mass separated	100 dpm		12-8-1964
	Gd-148	double-sided for Rehm			
Np7-msl	mass separated Np-237		~4 nCi		12-7-1971
Np6-10	old, from chemistry		~10 nCi		
Th9-01	mass separated on carbon		~10 nCi		11-22-1978
Th9-02	mass separated on carbon		~10 nCi		11-22-1978

Nuclear Data Section
International Atomic Energy Agency
P.O. Box 100
A-1400 Vienna
Austria

e-mail: services@iaeand.iaea.org
fax: (43-1) 26007
cable: INATOM VIENNA
telex: 1-12645
telephone: (43-1) 2600-21710