



*The Abdus Salam
International Centre for Theoretical Physics*



1939-2

**Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data:
Theory and Evaluation**

28 April - 9 May, 2008

**IAEA-NSDD Network: Recent Relevant CRPs and other activities
(Evaluation of Decay Data: Relevant IAEA Coordinated Research Projects)**

A.L. NICHOLS

*IAEA, Nuclear Data Section, Dept. Nuclear Sciences and Applications, Vienna,
Austria*



International Atomic Energy Agency

**Evaluation of Decay Data:
Relevant IAEA Coordinated Research Projects**

**Alan Nichols
Nuclear Data Section
Vienna, Austria**

18 March 2008

IAEA Nuclear Data Section

- Provision of atomic and nuclear data services to scientists worldwide (data libraries, bibliographies and related materials) through the internet, CD and other media
- Coordination of three international atomic and nuclear data networks
- Production of new databases through Coordinated Research Projects (CRPs) and Data Development projects
- Assist developing countries through technology transfer activities

Applications of Nuclear Data

- Energy applications
 - fission power
 - fusion technology
- Non-energy applications
 - **safeguards**
 - **radiation safety**
 - waste management
 - environmental research
 - **nuclear medicine**
 - **materials analysis**
 - process control
 - basic research (e.g. nuclear astrophysics) and education

Nuclear Data Files

- Compiled bibliographic data (e.g. **CINDA, NSR**)
- Compiled experimental data (e.g. **EXFOR**)
- Evaluated data (e.g. **ENDF, ENSDF**)
- Calculated data (e.g. **EMPIRE, TALYS**)
- Nuclear reaction data (e.g. **EXFOR, ENDF**)
- Nuclear structure and decay data (e.g. **ENSDF**)



Data Centre Activities

- **Compilation**
 - new cross-section data in EXFOR**
 - master files in cooperation with other centres**
 - collect evaluated and specialized libraries**
- **On-line and off-line data services with particular emphasis on the needs of developing countries**
- **Co-ordination of Data Centre Network**



IAEA Nuclear Data Section

<http://www-nds.iaea.org/>



Nuclear Data Services

Search

Go

Hot Topics » ENDF/B-VII.0 • Safeguards data • WIMS-D Library News » 2008/04 New NDS main Web page

About

Request



CD/DVD with documentation, data, codes, etc.

Quick Links

- ADS-Lib
- Atomic Mass Data Centre
- CINDA
- ENDF
- ENSDF
- EXFOR
- FENDL-2.1
- IAEA-NDS-0
- IBANDL
- INDL/TSL
- IRDF-2002
- MIRD
- Minsk Actinides Library
- NGATLAS
- NSR
- PADF 2007
- PGAA
- POINT2004
- POINT2007
- Photon and Electron Interaction Data
- Q-values, Thresholds

April 2008 **New NDS main Web page** Old page can be found [here]

- Main
- Old style
- Reaction Data
- Structure & Decay
- by Applications
- Doc & Codes
- Index



EXFOR
Experimental nuclear reaction data



CINDA
neutron reaction bibliography



ENSDF
evaluated nuclear structure and decay data (+XUNDL)



ENDF
Evaluated nuclear reaction libraries



NSR
Nuclear Science References



A+M
Atomic and molecular data AMBDAS, ALADDIN, GENIE, etc.

NuDat 2.2
selected evaluated nuclear structure data

RIPL
reference parameters for nuclear model calculations

IBANDL
Ion Beam Analysis Nuclear Data Library

Medical
Charged-particle cross section library

PGAA
Prompt gamma rays from neutron capture

FENDL-2.1
Fusion Evaluated Nuclear Data Library, Version 2.1

Photonuclear
cross sections and spectra up to 140MeV

IRDF-2002
International Reactor Dosimetry File

NGATLAS
atlas of neutron capture cross sections

Standards
Neutron Cross-section Standards 2006

Safeguards Data
recommendations, 2007

MIRD
medical internal radiation dose tables

IAEA Nuclear Data Section



IAEA-NDS
Mission, Staff and more



Meetings Workshops



Newsletters



Coordinated Research Projects



Nuclear Reaction Data Center Network



Nuclear Structure & Decay Data Network



Selected Documents



Technical Reports, TECDOCs



INDC-NDS Reports

Partners

Events » 12..



Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation
28 April - 9 May, 2008
ICTP, Trieste, Italy



Joint ICTP-IAEA Workshop on Nuclear Reaction Data for Advanced Reactor Technologies
18-30 May, 2008
ICTP, Trieste, Italy





> NDS Mirror Sites



Welcome to the IAEA Nuclear Data Centre Nuclear Data Services

> Navigation

Content Browser

> Quick Links

- ADS-Lib
- AMDC
- CINDA
- DROSG-2000
- ENDF
- ENSDF
- ENSDF ASCII Files
- EXFOR
- FENDL-2.1
- IBANDL
- INDL/TSL
- IRDF-2002
- Masses 2003
- Medical Radioisotopes Production
- MIRD
- Minsk Actinides
- NGATLAS
- NuDat 2.1
- NSR
- PADF Proton Activation Data File
- PGAA-IAEA
- Photonuclear
- Photon+Electron Interaction
- POINT2007

Search NDS

Major Databases

- [CINDA](#) - neutron reaction data bibliography
- [ENDF](#) - evaluated nuclear reaction cross section libraries
- [EXFOR](#) - experimental nuclear reaction data
- [ENSDF](#) - evaluated nuclear structure and decay data (includes XUNDL)
- [NSR](#) - Nuclear Science References
- [NuDat 2.2](#) - selected evaluated nuclear data

Nuclear Databases and Files

General

- [Atomic Mass Data Center](#) - 2003 atomic mass evaluation, NUBASE, PC-NUCLEUS, etc.
- [Q-values, Thresholds](#) - atomic masses, Q-values and threshold energies
- [RIPL](#) - reference parameters for nuclear model calculations
- [Thermal neutron capture gamma rays](#) - by target and by energy
- [Wallet cards](#) - ground and metastable state properties

Other evaluated data libraries in ENDF format

- [IAEA Photonuclear Data Library](#) - cross sections and spectra up to 140MeV
- [INDL/TSL](#) - IAEA Evaluated Nuclear Data Library / Thermal Scattering Law
- [IRDF-2002](#) - International Reactor Dosimetry File
- [Minsk Actinides Library](#) - evaluated neutron reaction data (Maslov et al.)
- [NGATLAS](#) - atlas of neutron capture cross sections ([old-version](#) is here)
- [PADF 2007](#) - Proton Activation Data File
- [POINT2007](#) - Pointwise data of ENDF/B-VII.0 processed into temperature dependent form
- [POINT2004](#) - Pointwise data of ENDF/B-VI Release 8 at 8 temperatures
- [RNAL](#) - Reference Neutron Activation Library
- [Standards](#) - Neutron Cross-section Standards 2006
- [Th-U](#) - Evaluated nuclear data for the Thorium-Uranium fuel cycle

Evaluated libraries in different formats

- [ADS-Lib](#) Application test library in ACE and MATXS format for ADS neutronics design
- [Charged-particle cross section database for medical radioisotope production](#)
- [FENDL-2.1](#) - Fusion Evaluated Nuclear Data Library - Version 2.1

> NDS Events



Meetings & Workshops



Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation

28 April - 9 May, 2008

ICTP, Trieste, Italy



Joint ICTP-IAEA Workshop on Nuclear Reaction Data for Advanced Reactor Technologies

18 - 30 May, 2008

ICTP, Trieste, Italy



Nuclear Data Networks

- Network of Nuclear Reaction Data Centres

- four core centres:
 - IAEA Nuclear Data Section, **Vienna**
 - OECD NEA Data Bank, **Paris, France**
 - US National Nuclear Data Center, **Brookhaven, USA**
 - Russia Nuclear Data Centre, **Obninsk, Russian Federation**
- Expanded network includes additional co-operating specialized centres in **Russian Federation (3), China, Japan (2), Hungary, Korea and Ukraine**

- Network of Nuclear Structure and Decay Data Evaluators

- IAEA Nuclear Data Section, **Vienna (Co-ordination)**
- US National Nuclear Data Center, **Brookhaven, USA (Master database)**
- 18 data evaluation centres in **Australia, Bulgaria, Canada, China (2), France, IAEA, India (2), Japan, Kuwait, Russian Federation, USA (6),**
- Data dissemination centres **IAEA, NNDC/USA**



Major consequences of nuclear databases for nuclear physics

- **archive of all nuclear data for future generations**
- **beneficial to many applied areas such as nuclear medicine, reactor engineering, activation analysis, environmental monitoring and impact assessments, etc.**
- **encourages interplay between decay data and reaction data**
- **beneficial consequences for developments in nuclear theory**
- **resolves differences between overlapping and contradictory results**
- **identifies needs for and stimulates new measurements**

International Network of Nuclear Structure and Decay Data Evaluators

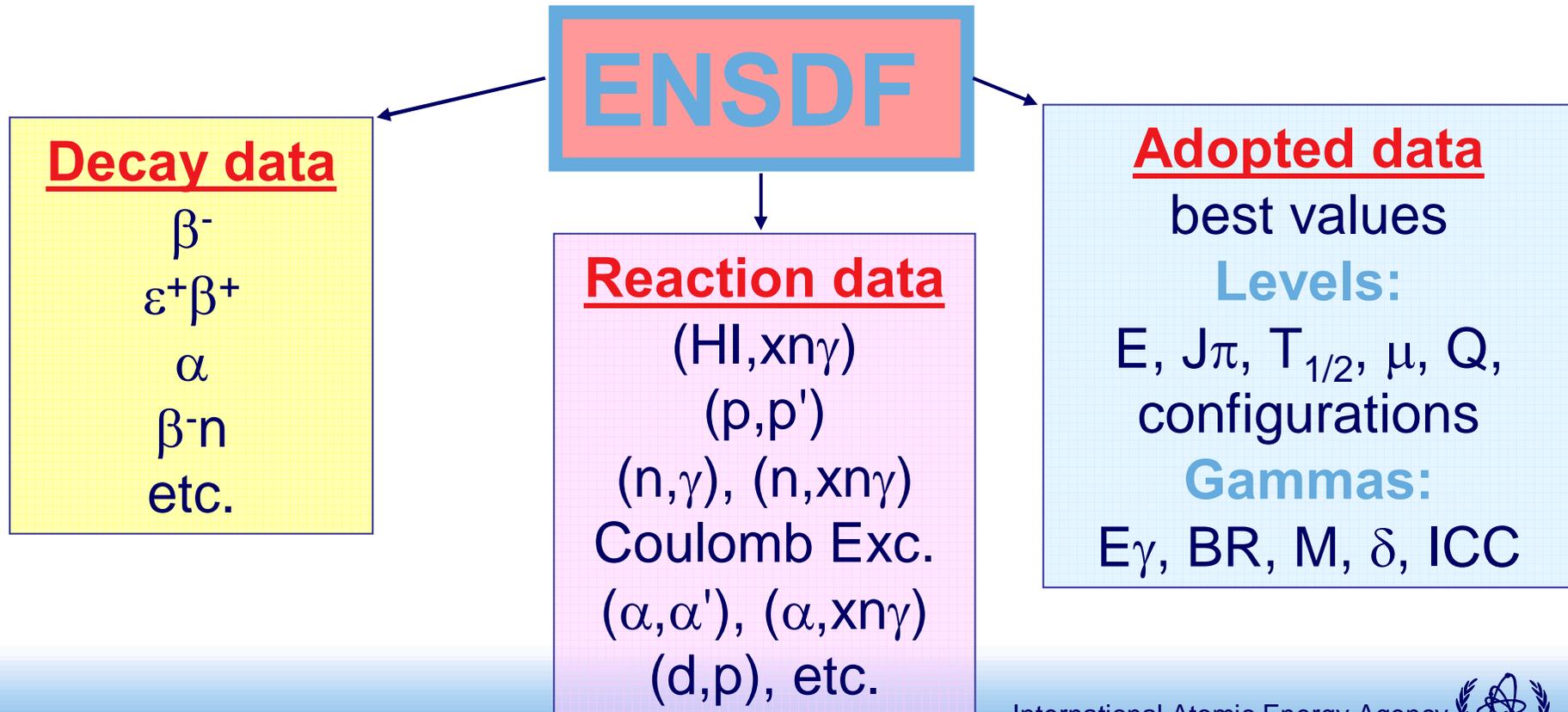
- Collaborating multinational team of nuclear structure and decay data evaluators
- Maintain and update **ENSDF** (**E**valuated **N**uclear **S**tructure **D**ata **F**ile)
- Master database held at NNDC, BNL, USA
- Individual regular communications
- Biennial meetings held since 1974 under the auspices of the IAEA



Major NSDD products

ENSDF - www.nndc.bnl.gov/ensdf - J.K. Tuli, NNDC

Contents: Evaluated nuclear structure and decay data for all known nuclei, organized into over 290 mass chains



ENSDF: Major Data Sources and Derivatives

Contributing Databases:

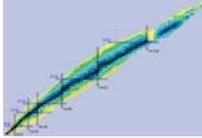
Atomic Masses
(Wapstra & Audi)

Nuclear Science
References (NSR)

MC Codes
 MCNPX
 GEANT

ORTEC & CANBERRA

ENSDF



IE

NuDat

Derivative Databases:

NUBASE

MIRD

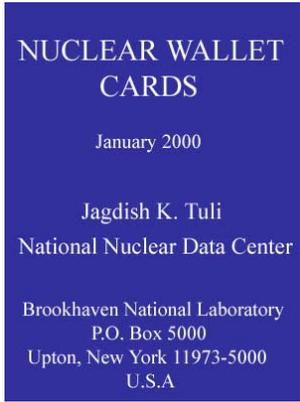
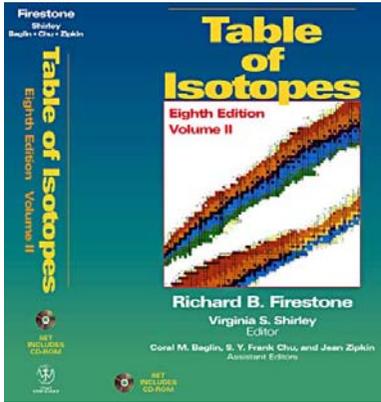
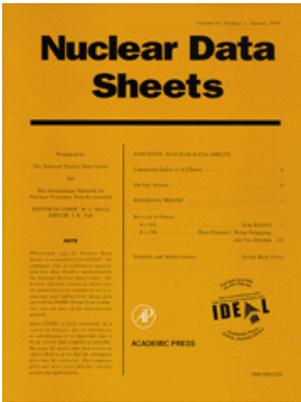
RIPL

JANIS

RADWARE

...

Derivative Publications:



International Network Connections

International Nuclear Structure and Decay Data Evaluators' Network

Long-Term Contributors:

BELGIUM
CANADA
CHINA
FRANCE
JAPAN
KUWAIT
RUSSIA
USA

Emerging New Contributors:

[ARGENTINA]
AUSTRALIA
BULGARIA
INDIA

8.4 FTE (US & Canada)

2.0 FTE

Total: 10.4 FTE



International Network Connections

International Nuclear Structure and Decay Data Evaluators' Network: responsible centres – June 2008

<i>Centre</i>	<i>FTE</i>	<i>Centre</i>	<i>FTE</i>
CNDC, Beijing, China	0.25	NNDC, USA	3.40
Jilin, China	0.25	ORNL, USA	0.25
B-le-Châtel, France	0.20	LBNL, USA	1.95
JAEA, Japan	0.45	TUNL, USA	0.60
Kuwait	0.20	ANL, USA	1.20
PNPI, Russia	0.25	McMaster, Canada	1.00
ANU, Australia	0.20		<hr/> 8.40 <hr/>
IIT, India	0.20		
	<hr/> 2.00 <hr/>	TOTAL	10.4



International Network Connections

**International Nuclear Structure and Decay Data Evaluators' Network:
responsible centres**

Total of ~ 10.4 FTE per annum

**“12 FTE per annum required to keep ENSDF in reasonably
good shape”**

**- quoted by Jagdish Tuli (coordinator of ENSDF, NNDC),
Summary Report of an IAEA Technical Meeting,
Coordination of the International Network of Nuclear
Structure and Decay Data Evaluators, 6-10 June 2005,
McMaster University, Hamilton, Canada**

Multinational mass chain evaluations for ENSDF: numbers of responsible laboratories/institutes

	Year			
	1981	1986	1996	2008
North America	6	6	6	6
Europe	6	5	4	1 → 0
Russia	2	2	2	1
Japan	1	1	1	1
China	-	-	1	2
Rest of the World	1	1	1	3
	16	15	15	14 → 13

Multinational mass chain evaluations for ENSDF: numbers of responsible laboratories/institutes

1981: Europe

BELGIUM

FRANCE

FRG

NETHERLANDS

SWEDEN

UK

2008: Europe

[[BELGIUM]] *

[FRANCE] *



Multinational mass chain evaluations for ENSDF: numbers of responsible laboratories/institutes

Long-Term Contributors:

BELGIUM *

CANADA *

CHINA

FRANCE *

JAPAN *

KUWAIT

RUSSIA

USA *

~ 60% of the evaluators are close to retirement age (or beyond!)

IAEA/ICTP NSDD training workshops have achieved some success



IAEA-ICTP NSDD Workshops

**Abdus Salam International Centre for Theoretical Physics
(ICTP), Trieste, Italy**



IAEA-ICTP NSDD Workshops

Nuclear Structure and Decay Data: Theory and Evaluation

One-week pilot workshop

IAEA Headquarters, Vienna, Austria

18 – 22 November 2002: 8 students only

Two-week workshops

**Abdus Salam International Centre for Theoretical Physics
(ICTP), Trieste, Italy**

17 – 28 November 2003: 24 students

4 – 15 April 2005: 27 students

20 February – 3 March 2006: 23 students

28 April – 9 May 2008: 30 students



Challenges

Long-Term Contributors:

BELGIUM *
CANADA *
CHINA
FRANCE *
JAPAN *
KUWAIT
RUSSIA
USA *

~60% of the evaluators are close to retirement age (or beyond!)

IAEA/ICTP NSDD training workshops have achieved some success

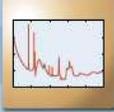
Compilation and evaluation work is a useful service to the research community. We would like to ask you for your help and support. If we don't act today, it may be too late tomorrow! *NEW MASS CHAIN EVALUATORS REQUIRED NOW !!!* YOUR COUNTRY (AND ENSDF) NEEDS YOU !!!

- contact JK Tuli (NNDC, BNL)



Want to be kept informed?

Available as hardcopy and
from WWW in pdf format

 <p>IAEA International Atomic Energy Agency</p>	<h2>Nuclear Data Newsletter</h2>
	<p>A newsletter of the Nuclear Data Section (NDS) Issue No. 44, September 2007</p> <p>ISSN 0257-6376</p>
<h3>In This Issue</h3> <ul style="list-style-type: none">• On-line News, p.1• Staff Items, p.1• Coordinated Research Projects, p.1• Database News, p.2• Computer Codes and Data Libraries, p.2• Selected Charts, Reports and Documents, p.3• Meetings Reports, p.5 <p>All services provided to users are free of charge. Please contact us on the following addresses:</p> <p>Nuclear Data Section International Atomic Energy Agency P.O. Box 100 A-1400 Vienna, Austria</p> <p>Internet: http://www-nds.iaea.org Email: services@iaea.org Fax: +43 (1) 26007 Cable: INATOM VIENNA Telex: 1-12645 Telephone: +43 (1) 2600-21710</p>	<h3>On-line News</h3> <h4>Ongoing Service</h4> <p>The Nuclear Data Section is currently compiling an accessible electronic library of all documents produced by the IAEA pertaining to our Nuclear Data Services. These documents include IAEA-NDS, INDC and other NDS technical reports. Many only existed on microfiche or in paper form. All known documents will eventually be converted to PDF and placed on our web site.</p> <p>This project continues to be ongoing and can be accessed on: http://www-nds.iaea.org/reports-new/</p> <h4>Staff Items</h4> <p>Otto Schwerer retired from the Nuclear Data Section at the end of August 2007 after over 31 years of service with the Agency, covering his full working life. Over recent years, Otto has been extensively involved with improvements to and maintenance of the EXFOR nuclear reaction cross-section database and the associated CINDA bibliographic database. Much of this work has been undertaken through the cooperative studies of members of the IAEA-sponsored International Network of Nuclear Reaction Data Centres (NRDC), for which he was the IAEA representative, sometime chairman and most recently the coordinator of all database entries. His day-to-day input to this work will be sorely missed, although the Section is hoping to retain his expertise through a series of Special Service Agreements as appropriate, with Otto and his family planning to remain in Vienna.</p> <h4>Coordinated Research Projects</h4> <p>IAEA Coordinated Research Projects (CRPs) are a valuable mechanism for stimulating research in IAEA Member States of relevance to IAEA programmes. CRPs of the Nuclear Data Section, both active and recently completed, can be found at: http://www.iaea.org/programmes/ripc/nd/crps.htm</p>



Data Access and Services

- **WWW**
 - IAEA Nuclear Data Services homepage:
<http://www-nds.iaea.org/>
 - BARC, India mirror server:
<http://www-nds.indcentre.org.in/>
 - IPEN, Brazil mirror server:
<http://www-nds.ipen.br/>

- **Mail services (request hardcopies, CD-ROMs etc.):**
e-mail to ***services@iaeand.iaea.org***



Recent IAEA-NDS Coordinated Research Projects

Short Title	Duration	Participants
Neutron Cross Section Standards	2002-06	14
RIPL-III: Parameters for Nuclear Reaction Calculations – Non-energy Applications	2003-07	12
Nuclear Data for Th-U Fuel Cycle	2002-07	11
Cross Sections for Production of Therapeutic Radionuclides	2003-07	8
Updated Decay Data Library for Actinides	2005-09	9
Reference Database for Ion Beam Analysis	2005-09	9
Reference Database for Neutron Activation Analysis	2005-09	8
Minor Actinide Neutron Reaction Data	2007-11	12



Nuclear Structure and Decay Data: Relevant IAEA-NDS Coordinated Research Projects

Title	Duration	Participants
Decay Data of the Transactinium Nuclides (Technical Reports Series No. 261, IAEA Vienna, 1986)	1977-85	6
X-ray and Gamma-ray Standards for Detector Calibration (IAEA-TECDOC-619, IAEA Vienna, 1991)	1986-90	9
Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications (Vols. 1 and 2, STI/PUB/1287, IAEA Vienna, 2007)	1998-2003	13
Updated Decay Data Library for Actinides	2005-09	9

X-ray and Gamma-ray Standards for Detector Calibration

IAEA-TECDOC-619, September 1991

Primary Objective

- produce a recommended set of decay parameters for selected radionuclides judged as the most important for the efficiency calibration of equipment used to detect and quantify x-ray and gamma-ray emissions



X-ray and Gamma-ray Standards for Detector Calibration

Participants

- **W. Bambynek, CEC-JRC, Central Bureau for Nuclear Measurements (CBNM), Geel, Belgium**
- **Y. Yoshizawa, Hiroshima University, Hiroshima-shi, Japan**
- **R.G. Helmer, Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho, USA**
- **N. Coursol, Laboratoire de Metrologie des Rayonnements Ionisants (LMRI), Gif-sur-Yvette, France**
- **F.J. Schima, National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, USA**
- **T. Barta and R. Jedlovsky, National Office of Measures (OMH), Budapest, Hungary**
- **P. Christmas, National Physical Laboratory (NPL), Teddington, Middlesex, UK**
- **K. Debertin, Physikalisch Technische Bundesanstalt (PTB), Braunschweig, Germany**
- **A.L. Nichols, AEA Technology, Winfrith Technology Centre, Dorchester, Dorset, UK**



X-ray and Gamma-ray Standards for Detector Efficiency Calibration

Ancillary Objectives

- selection of appropriate (efficiency) calibration nuclides
- assessment of the status of existing data
- identification of data discrepancies and limitations
- stimulation of measurements to meet data needs
- evaluation and recommendation of improved efficiency calibration data

X-ray and Gamma-ray Standards for Detector Efficiency Calibration

- **cover as wide a range of photon energy as possible (5 keV to approximately 10 MeV)**
- **x-ray and low-energy gamma-ray emitting radionuclides from 5 to 100 keV**
- **commonly used and readily available nuclides**
- **nuclides used and offered as standards by national laboratories, multi-line nuclides for rapid calibrations**
- **definition of a set of single-line nuclides to avoid the need for coincidence summing corrections**
- **choice of nuclides with accurately known emission probabilities**



X-ray and Gamma-ray Standards for Detector Calibration

**International Atomic Energy Agency,
IAEA-TECDOC-619, September 1991**

- **coordination of measurements within the project,**
- **stimulation of measurements outside the project,**
- **recommended decay data for 36 radionuclides up to a γ -ray energy of 3.6 MeV,**
- **recommended X-ray data from 5 to 90 keV,**
- **consideration of neutron and proton capture reactions for higher γ -ray energies (up to 14 MeV)**



X-ray and Gamma-ray Standards for Detector Efficiency Calibration

Half-life inconsistencies: further measurements recommended

Priority 1 – ^{55}Fe , ^{56}Co , ^{125}I and ^{155}Eu

Priority 2 – ^{54}Mn , ^{75}Se and ^{109}Cd

Priority 3 – ^{22}Na , ^{58}Co , ^{65}Zn and ^{133}Ba



X-ray and Gamma-ray Standards for Detector Efficiency Calibration

Higher-energy gamma rays?

^{66}Ga decay

Neutron and proton reactions:



**Update of X-ray and Gamma-ray
Decay Data Standards for Detector
Calibration and Other Applications
(1998 – 2003)**

M. Herman
IAEA Nuclear Data Section

Update of X-ray and Gamma-ray Decay Data Standards

International Nuclear Data Committee, 1997:
strongly recommended IAEA to re-visit and
place further emphasis on the development
of improved decay data for “standards”
applications

- detector efficiency calibration
- other applications (e.g. nuclear medicine, dosimetry, safeguards and environmental monitoring)

Update of X-ray and Gamma-ray Decay Data Standards

Participants

- M.-M. Bé, BNM-CEA/LNHB, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
- V.P. Chechev, VG Khlopin Radium Institute, St. Petersburg, Russia
- O. Helene and V.R. Vanin, Instituto de Física, Universidade de São Paulo, Brazil
- R.G. Helmer, Idaho National Engineering and Environmental Laboratory, Idaho Falls, USA
- S. Hlaváč, Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
- A. Marcinkowski, The Andrzej Soltan Institute for Nuclear Studies, Warsaw, Poland
- G.L. Molnar, Institute of Isotope and Surface Chemistry, Budapest, Hungary
- A.L. Nichols, AEA Technology plc, Harwell, UK
- E. Schönfeld and R. Dersch, Physikalisch Technische Bundesanstalt, Braunschweig, Germany
- M.J. Woods, Centre for Ionising Radiation Metrology, National Physical Laboratory, Teddington, UK



Update of X-ray and Gamma-ray Decay Data Standards

Main issues

1. Update of the current database
IAEA-TECDOC-619 data for 36 radionuclides were revisited and revised -experimental data measured and published after 1990,
 - average x-ray energies and emission probabilities are given in IAEA-TECDOC-619 – require systematic analysis of the energies and emission probabilities of the individual $K_{\alpha 1}$, $K_{\alpha 2}$, $K_{\beta 1}$, and $K_{\beta 2}$ components
2. Additional radionuclides
68 radionuclides formulated at Consultants' Meeting, and adopted as a suitable starting point; re-defined as 62 radionuclides and two heavy element decay chains
3. Extension of energy range
 - new nuclear techniques (for example radiotherapy) suffer from a lack of high-energy calibration standards,
 - data required for the calibration of γ -ray detectors up to 25 MeV,
 - appropriate radionuclides (^{56}Co , ^{66}Ga) and nuclear reactions identified, and γ -ray emission probabilities were compiled and evaluated



Update of X-ray and Gamma-ray Decay Data Standards

Main issues (cont.)

4. γ - γ coincidence: absolute γ -ray detection efficiency without absolutely calibrated γ -ray source:
 - angular correlation coefficients of specific nuclei from 136 keV to 2.75 MeV,
 - ^{24}Na , ^{46}Sc , ^{60}Co , ^{66}Ga , ^{75}Se , ^{88}Y , ^{94}Nb , ^{111}In , ^{134}Cs , ^{152}Eu and ^{207}Bi

5. Covariances
 - lack of necessary data (and detail) in published measurements,
 - instructions proposed for communication to authors concerning data requirements for covariance analysis



Update of X-ray and Gamma-ray Decay Data Standards

Evaluations undertaken in conjunction with Decay Data Evaluation Project (DDEP) – member laboratories of the International Committee for Radionuclide Metrology (ICRM)

- co-ordinator: E. Browne (Lawrence Berkeley National Laboratory),
- CRP evaluations carried out under agreed DDEP methodology/procedures for consistency,
- recommendations reviewed and approved by DDEP prior to acceptance for CRP,
- adopted by DDEP

http://www.nucleide.org/DDEP_WG/DDEPdata.htm



Update of X-ray and Gamma-ray Decay Data Standards

Selected radionuclides and applications.

Nuclide	X/ γ -Ray Standard	Dosimetry Standard	Medical Applications	Environmental Monitoring	Waste Management	Safeguards
^{22}Na	P	-	X	-	-	-
^{24}Na	P	-	-	-	-	-
^{40}K	S	-	-	X	-	-
^{46}Sc	P	-	-	-	-	-
^{51}Cr	S	-	X	-	-	-
^{54}Mn	P	-	-	X	X	-
^{56}Mn	P	-	X	-	-	-
^{55}Fe	S	-	X	-	X	-
^{59}Fe	S	-	X	-	-	-
^{56}Co	S	-	-	-	-	-
^{57}Co	P (122 keV)	-	X	-	-	X
^{58}Co	P	-	-	X	-	-
^{60}Co	P	-	X	X	X	X
^{64}Cu	-	-	X	-	-	-
^{65}Zn	S	-	-	X	X	-
^{66}Ga	S	-	X	-	-	-
^{67}Ga	S	-	X	-	-	-

Update of X-ray and Gamma-ray Decay Data Standards

Selected radionuclides and applications (cont.).

Nuclide	X/ γ -Ray Standard	Dosimetry Standard	Medical Applications	Environmental Monitoring	Waste Management	Safeguards
^{68}Ga	-	-	X	-	-	-
^{75}Se	S	-	X	-	-	-
^{85}Kr	-	-	-	X	-	-
^{85}Sr	P	-	X	X	-	-
^{88}Y	P (1836 keV) S (898 keV)	-	-	-	-	-
$^{93\text{m}}\text{Nb}$	-	X	-	-	-	-
^{94}Nb	P	-	-	-	-	-
^{95}Nb	P	-	-	X	-	X
^{99}Mo – $^{99\text{m}}\text{Tc}$	P (140.5 keV)	-	X	-	-	-
$^{99\text{m}}\text{Tc}$	P (140.5 keV)	-	X	-	-	-
^{103}Ru	-	-	X	X	-	X
^{106}Ru – ^{106}Rh	S	-	X	X	-	X
$^{110\text{m}}\text{Ag}$ (^{110}Ag)	S	-	-	X	X	-
^{109}Cd	S	-	-	X	-	-
^{111}In	P	-	X	-	-	-
^{113}Sn	P	-	-	-	-	-
^{125}Sb	-	-	-	X	-	X

Update of X-ray and Gamma-ray Decay Data Standards

Selected radionuclides and applications (cont.).

Nuclide	X/ γ -Ray Standard	Dosimetry Standard	Medical Applications	Environmental Monitoring	Waste Management	Safeguards
^{123m}Te	-	-	X	-	X	-
^{123}I	P	-	X	-	-	-
^{125}I	S	X	X	-	-	-
^{129}I	S	-	-	X	X	-
^{131}I	S	X	X	X	-	X
^{134}Cs	S	-	-	X	-	X
^{137}Cs	P	X	-	X	X	X
^{133}Ba	S	-	X	-	-	-
^{139}Ce	P	-	-	X	-	-
^{141}Ce	S	-	-	X	-	X
^{144}Ce – ^{144}Pr	S	-	X	X	-	X
^{153}Sm	-	-	X	-	-	X
^{152}Eu	S	-	-	X	X	X
^{154}Eu	S	-	-	X	X	X
^{155}Eu	S	-	-	X	X	X
^{166m}Ho – ^{166}Ho	S	-	X	-	-	X

Update of X-ray and Gamma-ray Decay Data Standards

Selected radionuclides and applications (cont.).

Nuclide	X/ γ -Ray Standard	Dosimetry Standard	Medical Applications	Environmental Monitoring	Waste Management	Safeguards
^{170}Tm	S	-	-	-	-	-
^{169}Yb	S	-	X	-	-	-
^{192}Ir	S	X	X	-	-	-
^{198}Au	P	-	-	-	-	-
^{203}Hg	P	-	-	-	-	-
^{201}Tl	-	-	X	-	-	-
^{207}Bi	P (569.7 keV)	-	X	-	-	-
^{226}Ra decay chain	S	X	-	X	X	X
^{228}Th decay chain	P	-	-	X	-	X
$^{234\text{m}}\text{Pa}$	-	-	-	X	X	-
^{241}Am	P	-	-	X	X	X
^{243}Am	-	-	-	-	X	X

P primary efficiency calibration standard.
S secondary efficiency calibration standard.

Update of X-ray and Gamma-ray Decay Data Standards

High-energy Gamma-ray Standards:

^{226}Ra up to 2.45 MeV

^{56}Co up to 3.55 MeV

^{66}Ga up to 4.8 MeV

$^{14}\text{N}(\text{n}, \gamma)^{15}\text{N}^*$ up to 10.8 MeV

$^{35}\text{Cl}(\text{n}, \gamma)^{36}\text{Cl}^*$ up to 8.6 MeV

$^{48}\text{Ti}(\text{n}, \gamma)^{49}\text{Ti}^*$ up to 6.8 MeV

$^{50,52,53}\text{Cr}(\text{n}, \gamma)^{51,53,54}\text{Cr}^*$ up to 9.7 MeV

$^{11}\text{B}(\text{p}, \gamma)^{12}\text{C}^*$ up to 13.9 MeV

$^{14}\text{N}(\text{p}, \gamma)^{15}\text{O}^*$ up to 8.3 MeV

$^{23}\text{Na}(\text{p}, \gamma)^{24}\text{Mg}^*$ up to 11.6 MeV

$^{27}\text{Al}(\text{p}, \gamma)^{28}\text{Si}^*$ up to 10.8 MeV



Update of X-ray and Gamma-ray Decay Data Standards

CRP

IAEA technical document:

Update of X Ray and Gamma Ray Decay Data Standards for
Detector Calibration and Other Applications, Volumes 1 and 2

M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer,
M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols,
E. Schönfeld, V.R. Vanin and M.J. Woods

STI/PUB/1287, May 2007

International Atomic Energy Agency, Vienna, Austria

ISBN 92-0-113606-4

Update of X-ray and Gamma-ray Decay Data Standards

DDEP

Recommended complete decay schemes available through

http://www.nucleide.org/DDEP_WG/DDEPdata.htm

**LNHB, Centre d'Etudes Nucleaires de Saclay,
F-91191 Gif-sur-Yvette Cedex, France**

Decay Data Evaluation Project (DDEP)

^{56}Mn – Comments on evaluation of decay data

Evaluated: November 1999

Re-evaluated: January 2004

Evaluation Procedures:

Limitation of Relative Statistical Weight Method (LWM) was applied to average numbers throughout the evaluation. The uncertainty assigned to the average value was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

Decay Data Evaluation Project (DDEP)

Reference	Half-life (days)
1968Sh07	0.10771(4)
1971GoYM	0.10742(33)
1972Em01	0.10779(25)
1973La12	0.107438(8)
1980RuZY	0.107350(33)
1992An13	0.107454(4) [§]
1994Ya02	0.1040(20) [*]
Evaluated value	0.107449(19)

[§] Uncertainty increased to ± 0.000008 to ensure weighting factor not greater than 0.50.

^{*} Method development study: removed from data set due to uncharacteristically large uncertainty.

Decay Data Evaluation Project (DDEP)

Gamma-ray Emission Probabilities: Relative to $P_{\gamma}(846.7638 \text{ keV})$ of 100%

$E_{\gamma}(\text{keV})$	P_{γ}^{rel}						Recommended Value*
	1967Au01	1968Sh07	1973Ar15	1974Ho25	1974Ti01	2004MiXX	
846.7638(19) [†]	100(3)	100(3)	100(3)	100(3)	100(3)	100.000(103)	100(3)
1037.8333(24) [†]	-	-	0.06(1)	0.03(1)	0.040(5)	-	0.040(4) [§]
1238.2736(22) [†]	-	-	0.14(3)	0.13(1)	0.10(1)	0.097(2)	0.098(2) [§]
1810.726(4) [†]	30(3)	29.4(16)	28.6(15)	26.9(13)	27.5(8)	26.610(72)	27.2(4)
2113.092(6) [†]	17.4(17)	16.0(9)	16.0(8)	14.3(7)	14.5(4)	13.956(53)	14.4(3) [§]
2523.06(5) [‡]	1.10(15)	1.6(5)	1.14(5)	1.01(5)	1.00(3)	1.025(9)	1.03(2)
2598.438(4) [†]	-	-	0.026(5)	0.02(1)	0.019(2)	-	0.020(2)
2657.56(1) [‡]	0.60(10)	0.66(6)	0.71(4)	0.66(7)	0.66(2)	0.648(8)	0.652(7) [§]
2959.92(1) [‡]	0.31(6)	0.26(3)	0.30(2)	0.32(3)	0.31(1)	0.314(6)	0.311(5) [§]
3119.3(5) [#]	-	0.08(4)	-	-	-	-	-
3369.84(4) [‡]	0.22(5)	0.20(4)	0.15(2)	0.16(2)	0.17(1)	-	0.17(1)

[†] Energy adopted from 2000He14.

[‡] Energy calculated from the nuclear level energies specified by 1999Hu04.

[#] Energy from 1968Sh07, but transition not included in proposed decay scheme.

* Weighted mean values adopted using LWEIGHT, unless stated.

[§] Recommended values adopted from a combination of the normalised residuals and Rajeval methods (see 2004MaYY).



Decay Data Evaluation Project (DDEP)



1 Decay Scheme

Mn-56 decays by beta minus emission to excited levels of Fe-56.

Le manganèse 56 se désintègre par émission bêta moins vers les niveaux excités du fer 56.

2 Nuclear Data

$$T_{1/2}({}^{56}\text{Mn}) : 2,57878 \quad (46) \quad \text{h}$$

$$Q^{-}({}^{56}\text{Mn}) : 3695,5 \quad (3) \quad \text{keV}$$

2.1 β^{-} Transitions

	Energy keV	Probability $\times 100$	Nature	lg <i>ft</i>
$\beta_{0,7}^{-}$	250,2 (3)	0,020 (2)	Allowed	6,57
$\beta_{0,6}^{-}$	325,7 (3)	1,20 (3)	Allowed	5,17
$\beta_{0,5}^{-}$	572,6 (3)	0,040 (4)	Allowed	7,5
$\beta_{0,4}^{-}$	735,6 (3)	14,5 (3)	Allowed	5,34
$\beta_{0,3}^{-}$	1037,9 (3)	27,5 (4)	Allowed	5,621
$\beta_{0,2}^{-}$	1610,4 (3)	0,057 (6)	Allowed	9,06
$\beta_{0,1}^{-}$	2848,7 (3)	56,6 (7)	Allowed	7,101

Decay Data Evaluation Project (DDEP)

2.2 Gamma Transitions and Internal Conversion Coefficients

	Energy keV	$P_{\gamma+ce}$ $\times 100$	Multipolarity	α_K	α_L	α_{M+}	α_T
$\gamma_{1,0}(\text{Fe})$	846,776 (5)	98,88 (3)	E2	0,000270 (8)	0,0000250 (8)	0,0000037 (1)	0,000300 (9)
$\gamma_{5,2}(\text{Fe})$	1037,85 (2)	0,040 (4)	M1+0.04%E2	0,000130 (4)	0,0000120 (4)	0,0000060 (2)	0,0001500 (45)
$\gamma_{2,1}(\text{Fe})$	1238,300 (12)	0,097 (2)	E2	0,000110 (3)	0,0000100 (3)	0,00000200 (6)	0,000120 (4)
$\gamma_{3,1}(\text{Fe})$	1810,786 (15)	26,9 (4)	M1+3%E2	0,0000460 (14)	0,00000430 (13)	0,00000063 (2)	0,0000510 (15)
$\gamma_{4,1}(\text{Fe})$	2113,15 (1)	14,2 (3)	M1+4%E2				

	Energy keV	$P_{\gamma+ce}$ $\times 100$	Multipolarity	α_K	α_L	α_{M+}	α_T
$\gamma_{6,1}(\text{Fe})$	2523,06 (5)	1,02 (2)	M1+E2				
$\gamma_{7,1}(\text{Fe})$	2598,53 (2)	0,020 (2)	M1+E2				
$\gamma_{3,0}(\text{Fe})$	2657,56 (1)	0,645 (7)	E2				
$\gamma_{4,0}(\text{Fe})$	2959,92 (1)	0,307 (5)	E2				
$\gamma_{6,0}(\text{Fe})$	3369,84 (4)	0,17 (1)	E2				

Decay Data Evaluation Project (DDEP)

3 Atomic Data

3.1 Fe

$$\omega_K : 0,355 \quad (4)$$

$$\bar{\omega}_L : 0,0060 \quad (6)$$

$$n_{KL} : 1,447 \quad (4)$$

3.1.1 X Radiations

	Energy keV	Relative probability	
X _K	K α_2	6,39091	51
	K α_1	6,40391	100
	K β_1	7,05804	}
	K β'_5	7,1083	
			20,6

3.1.2 Auger Electrons

	Energy keV	Relative probability
Auger K		
KLL	5,370 – 5,645	100
KLX	6,158 – 6,400	27,4
KXY	6,926 – 7,105	1,87
Auger L	0,510 – 0,594	307

Decay Data Evaluation Project (DDEP)

4 Electron Emissions

		Energy keV	Electrons per 100 disint.
eAL	(Fe)	0,510 - 0,594	0,0428 (3)
eAK	(Fe)		0,0180 (1)
	KLL	5,370 - 5,645	}
	KLX	6,158 - 6,400	}
	KXY	6,926 - 7,105	}
$\beta_{0,7}^-$	max:	250,2 (3)	0,020 (2)
$\beta_{0,7}^-$	avg:	73,5 (1)	
$\beta_{0,6}^-$	max:	325,7 (3)	1,20 (3)
$\beta_{0,6}^-$	avg:	99,1 (1)	
$\beta_{0,5}^-$	max:	572,6 (3)	0,040 (4)
$\beta_{0,5}^-$	avg:	190,4 (2)	
$\beta_{0,4}^-$	max:	735,6 (3)	14,5 (3)
$\beta_{0,4}^-$	avg:	255,2 (2)	
$\beta_{0,3}^-$	max:	1037,9 (3)	27,5 (4)
$\beta_{0,3}^-$	avg:	381,9 (2)	
$\beta_{0,2}^-$	max:	1610,4 (3)	0,057 (6)
$\beta_{0,2}^-$	avg:	636,3 (2)	
$\beta_{0,1}^-$	max:	2848,7 (3)	56,6 (7)
$\beta_{0,1}^-$	avg:	1216,8 (2)	

Decay Data Evaluation Project (DDEP)

5 Photon Emissions

5.1 X-Ray Emissions

		Energy keV		Photons per 100 disint.	
XK α_2	(Fe)	6,39091		0,00295 (4)	} K α
XK α_1	(Fe)	6,40391		0,00578 (7)	}
XK β_1	(Fe)	7,05804	}	0,00119 (2)	K' β_1
XK β_5''	(Fe)	7,1083	}		



Decay Data Evaluation Project (DDEP)

5.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{1,0}(\text{Fe})$	846,7638 (19)	98,85 (3)
$\gamma_{5,2}(\text{Fe})$	1037,8333 (24)	0,040 (4)
$\gamma_{2,1}(\text{Fe})$	1238,2736 (22)	0,097 (2)
$\gamma_{3,1}(\text{Fe})$	1810,726 (4)	26,9 (4)
$\gamma_{4,1}(\text{Fe})$	2113,092 (6)	14,2 (3)
$\gamma_{6,1}(\text{Fe})$	2523,06 (5)	1,02 (2)
$\gamma_{7,1}(\text{Fe})$	2598,438 (4)	0,020 (2)
$\gamma_{3,0}(\text{Fe})$	2657,56 (1)	0,645 (7)
$\gamma_{4,0}(\text{Fe})$	2959,92 (1)	0,307 (5)
$\gamma_{6,0}(\text{Fe})$	3369,84 (4)	0,17 (1)

Decay Data Evaluation Project (DDEP)

6 Main Production Modes

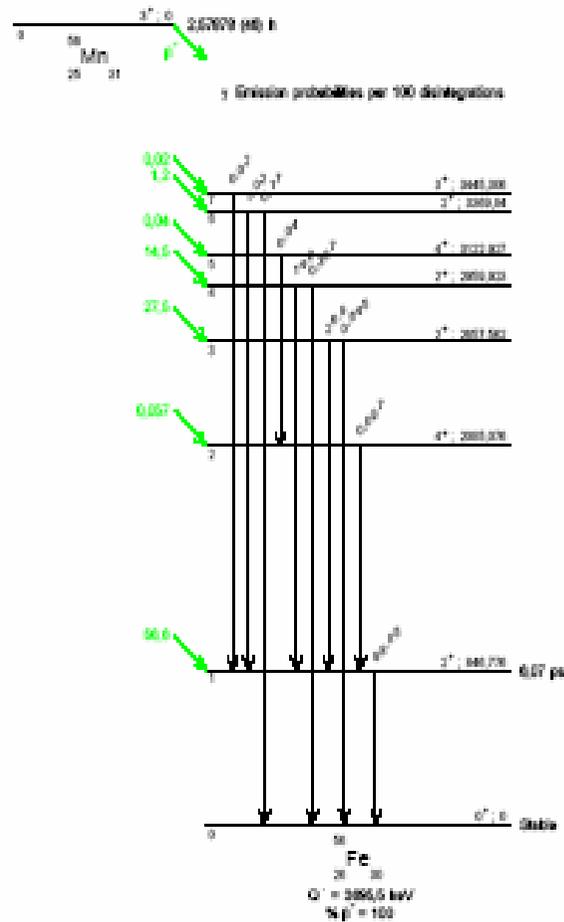
Cr – 56(β^-)Mn – 56
Mn – 56(n, γ)Mn – 56
Mn – 56(d,p)Mn – 56
Fe – 58(d, α)Mn – 56

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Decay Data Evaluation Project (DDEP)



Decay Data Evaluation Project (DDEP)

8 Remarks

8.1 Nuclear Data

Half-life adopted from the evaluation of Woods for the IAEA-CRP: Update of X- and Gamma-ray Decay Data Standards for Detector Calibration. The measurements of 1968Sh07, 1971GoYM, 1972Em01, 1973La12, 1980RuZY, 1992An13 and 1994Ya02 were considered.

8.2 β^- Transitions

All beta-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of 1999Hu04 and the Q-value were used to determine the energies and uncertainties of the beta-particle transitions to the various levels. The beta-particle emission probabilities were calculated from recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of 1976Ba63 (latter estimated by interpolation of data). Log ft systematics can be applied to the beta-particle transition to the ground state of Fe-56, with a lower limit for log ft of 13.9 (1998Si17), to give a beta-particle emission probability of ≥ 0.0005 (set to zero).

Decay Data Evaluation Project (DDEP)

8.3 Gamma Transitions and Conversion Electron Coefficients

Energies

A number of well-defined gamma-ray energies were adopted from the recommended standards of 2000He14. All other gamma-ray energies were calculated from the structural details of the proposed decay scheme and the nuclear level energies of 1999Hu04 (as derived from the energy measurements of 1973Ar15, 1974Ho25 and 1974Ti01). An additional gamma ray with an energy of 3119.3(5) keV was only detected by 1968Sh01, and has been discarded due to a lack of evidence in all of the other studies.

Emission Probabilities

Weighted mean relative emission probabilities were determined for all of the gamma rays assigned to the decay scheme, using the relevant data from the measurements of 1967Au01, 1968Sh07, 1973Ar15, 1974Ho25, 1974Ti01 and 2004MiXX. All gamma-ray emissions were expressed relative to the 846.7638 keV transition, which was arbitrarily assigned an uncertainty of 3% (100(3)%).

The normalisation factor for the gamma-ray emission probabilities was calculated from the proposed decay scheme via two routes:

(a) beta population of all Fe-56 nuclear levels derived from gamma-ray depopulation/population and summed, assuming beta decay to Fe-56 ground state is zero (spin and parity considerations).

for all nuclear levels populated by beta decay $\sum P(\text{beta}) = 101.163(1479)$ $NF = 100$

$NF = 0.9885(145)$

etc.

Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications

Volume 1:

Recommended Decay Data, High Energy Gamma Ray
Standards and Angular Correlation Coefficients

Volume 2:

Data Selection, Assessment and Evaluation Procedures



Recommended radionuclide half-lives

Nuclide	Half-life (days)	
	value	uncertainty
11-Na-22	950.57	± 0.23
11-Na-24	0.62329	± 0.00006
19-K-40	(4.563	$\pm 0.013) 10^{+11}$
21-Sc-46	83.79	± 0.04
24-Cr-51	27.7009	± 0.0020
25-Mn-54	312.29	± 0.26
25-Mn-56	0.107449	± 0.000019
26-Fe-55	1002.7	± 2.3
26-Fe-59	44.494	± 0.013
27-Co-56	77.236	± 0.026
27-Co-57	271.80	± 0.05
27-Co-58	70.86	± 0.06
27-Co-60	1925.23	± 0.27
29-Cu-64	0.52929	± 0.00018
30-Zn-65	243.86	± 0.20
31-Ga-66	0.3889	± 0.0034

Recommended gamma-ray energies and emission probabilities ordered by radionuclide

Nuclide	Energy (keV)		Emission Probability per decay		Comments
	E_γ	uncertainty	P_γ	uncertainty	
11-Na-22	511	-	1.798	± 0.002	annihilation radiation
11-Na-22	1274.537	± 0.003	0.99940	± 0.00014	
11-Na-24	1368.626	± 0.005	0.999935	± 0.000005	
11-Na-24	2754.007	± 0.011	0.99872	± 0.00008	
19-K-40	1460.822	± 0.006	0.1066	± 0.0013	
21-Sc-46	889.271	± 0.002	0.999833	± 0.000005	
21-Sc-46	1120.537	± 0.003	0.99986	+0.00004 -0.00036	
24-Cr-51	320.0835	± 0.0004	0.0987	± 0.0005	
25-Mn-54	834.838	± 0.005	0.999746	± 0.000011	
25-Mn-56	846.7638	± 0.0019	0.9885	± 0.0003	
25-Mn-56	1810.726	± 0.004	0.269	± 0.004	
25-Mn-56	2113.092	± 0.006	0.142	± 0.003	
25-Mn-56	2523.06	± 0.05	0.0102	± 0.0002	
26-Fe-59	142.651	± 0.002	0.00972	± 0.00015	
26-Fe-59	192.349	± 0.005	0.0292	± 0.0003	
26-Fe-59	1099.245	± 0.003	0.5659	± 0.0021	
26-Fe-59	1291.590	± 0.006	0.4321	± 0.0025	

Decay Data of the Transactinium Nuclides

Technical Reports Series No. 261, May 1986

Objectives

- **assess status of existing data**
- **identify data discrepancies and unfulfilled requirements**
- **encourage measurements to meet requirements**
- **evaluate the data**
- **assemble final set of recommended decay data (satisfy required accuracies)**

Decay Data of the Transactinium Nuclides

Participants

- **A.J. Fudge, UKAEA Atomic Energy Research Establishment (AERE), Harwell, UK**
- **R. Vaninbroukx, Central Bureau for Nuclear Measurements (CBNM), Geel, Belgium**
- **C.W. Reich, Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho, USA**
- **H. Okashita (and H. Umezawa), Japan Atomic Research Institute, Tokai-mura, Japan**
- **J. Legrand (and N. Coursol, F. Lagoutine and G. Malet), Laboratoire de Metrologie des Rayonnements Ionisants (LMRI), Gif-sur-Yvette, France**
- **A.L. Nichols, UKAEA Atomic Energy Establishment Winfrith (AEEW), UK**



Decay Data of the Transactinium Nuclides

International Atomic Energy Agency,

Technical Reports Series No. 261, May 1986

- assessed the status of the existing data,
- identified data discrepancies and unfulfilled requirements,
- encouraged measurements to meet requirements, both within and beyond the project,
- recommended half-lives for 40 nuclides (^{228}Th to ^{253}Es) → extended to 125 nuclides (mainly based on three existing evaluated data files),
- recommended α -particle and γ -ray emission probabilities, many based directly on ENSDF (*Nuclear Data Sheets*):
 - 29 nuclides (α -particle emission probabilities),
 - 47 nuclides (γ -ray emission probabilities)

“..... much remains to be done.”



Decay Data of the Transactinium Nuclides

International Atomic Energy Agency, Technical Reports Series No. 261, May 1986

Nuclide	Data type	Accuracy (%)		Needs	CRP activities	
		Required	Achieved		Measurements	Evaluations
Pu-239	$T_{1/2}$	0.5	0.1	Mass determination, non-destructive assay and environmental studies	AERE, CBNM, +	CBNM
	P_{α}	1	1-2		+	JAERI
	P_{γ}	1	<1		INEL, LMRI, +	JAERI
	P_X	3	3		-	-
Pu-240	$T_{1/2}$	0.5	0.1	Mass determination, non-destructive assay and environmental studies; $T_{1/2}$ (SF) for waste management	+	CBNM/LMRI
	$T_{1/2}$ (SF)	2	3		CBNM	+
	P_{α}	1	1-2		+	LMRI
	P_{γ}	1	1-2		INEL, LMRI	LMRI
	P_X	3	3		-	-
Pu-241	$T_{1/2}$	0.5	0.7	Mass determination and non-destructive assay	AERE, CBNM, +	CBNM
	$T_{1/2}$ (α)	1	0.8		CBNM	-
	P_{γ}	1	1-2		INEL, +	LMRI
Pu-242	$T_{1/2}$	1	0.3	Mass determination, non-destructive assay and environmental studies	+	+
	$T_{1/2}$ (SF)	5	1.5		-	+
	P_{α}	5	<1		-	-
	P_{γ}	5	2-5		CBNM	-
	P_X	3	unknown		-	-
Am-241	$T_{1/2}$	0.2	0.1	Non-destructive assay and low energy gamma emission standard. 0.5% accuracy requested for 59.5 keV gamma emission probability	-	CBNM
	P_{α}	not requested	1-2		+	CBNM
	P_{γ}	0.5-1	1-10		CBNM, LMRI	CBNM
	P_X	2	3		-	-

**International Nuclear Data Committee, May
2002 and May 2004:**

**recommended “Updated Decay Data Library
for Actinides” by means of a Co-ordinated
Research Project**

2005 to 2008/09

**Updated Decay Data
Library for Actinides
(2005 – 2009)**

M.A. Kellett
IAEA Nuclear Data Section

Updated Decay Data Library for Actinides

Participants

- **M.-M. Bé, LNHB, CEA Saclay, France**
- **V.P Chechev, KRI, Russian Federation**
- **X. Huang, CNDC, PRChina**
- **F. G. Kondev, ANL, USA**
- **G. Mukherjee, VECCAL, India**
- **M.A. Kellett, IAEA**
- **A.L. Nichols, IAEA**
- **A. Luca, IFIN-HH, Romania**
- **A. Pearce, NPL, UK**



Updated Decay Data Library for Actinides

- **M.A. Kellett, *Summary Report of the First Research Coordination Meeting on Updated Decay Data Library for Actinides*, 17 – 19 October 2005, IAEA report INDC(NDS)-0479, IAEA, Vienna, Austria, 2006**

See <http://www-nds.iaea.org/reports-new/indc-reports/indc-nds/indc-nds-0479.pdf>

- **M.A. Kellett, *Summary Report of the Second Research Coordination Meeting on Updated Decay Data Library for Actinides*, 28 – 30 March 2007, IAEA report INDC(NDS)-0508, IAEA, Vienna, Austria, 2007**

See <http://www-nds.iaea.org/reports-new/indc-reports/indc-nds/indc-nds-0508.pdf>

Radionuclides allocated to each CRP participant

Participant	Actinides	Decay daughters
M.-M. Bé	$^{234,238}\text{U}$, ^{243}Am , ^{252}Cf	^{210}Tl , $^{210,214}\text{Pb}$, $^{210,214}\text{Bi}$, $^{210,214,218}\text{Po}$, ^{218}At , $^{218,222}\text{Rn}$, ^{226}Ra
V.P. Chechev	^{233}Th , ^{233}Pa , $^{237,239}\text{U}$, $^{236,236\text{m},237,238,239}\text{Np}$, $^{238,239,240,241,242}\text{Pu}$, ^{241}Am , $^{242,244}\text{Cm}$	^{227}Ac
Huang Xiaolong	^{231}Th , ^{235}U	^{213}Bi , ^{213}Po , ^{217}At , ^{217}Rn , $^{221,223}\text{Fr}$, ^{225}Ra , ^{225}Ac
F.G. Kondev	$^{243,245,246}\text{Cm}$	^{206}Hg , $^{206,207,209}\text{Tl}$, $^{209,211}\text{Pb}$
A. Luca	^{234}Th , ^{236}U	^{228}Ra
G. Mukherjee	^{229}Th , ^{233}U	-
A.L. Nichols	^{228}Th , $^{242,242\text{m},244,244\text{m}}\text{Am}$	^{208}Tl , ^{212}Pb , $^{212,215}\text{Bi}$, $^{212,216}\text{Po}$, $^{211,219}\text{At}$, $^{219,220}\text{Rn}$, ^{224}Ra
A.K. Pearce	^{232}Th , ^{231}Pa , ^{232}U	^{223}Ra , ^{228}Ac
Unallocated, April 2007	-	^{211}Bi , $^{211,215}\text{Po}$, ^{215}At



Updated Decay Data Library for Actinides

Measurements:

- F.G. Kondev, I. Ahmad, J.P. Greene, M.A. Kellett, A.L. Nichols, *Measurements of the half-life of ^{246}Cm and the α -decay emission probabilities of ^{246}Cm and ^{250}Cf* , *Appl. Radiat. Isot.* 65 (2007) 335-340
- I. Ahmad, F.G. Kondev, J.P. Greene, A.L. Nichols, M.A. Kellett, *Measurement of the ^{240}Pu half-life*, 11th Symp. on Radiation Measurements and Applications, 23-26 May 2006, University of Michigan, Ann Arbor, USA, *Nucl. Instrum. Meth. Phys. Res. A*579 (2007) 458-460
- F.G. Kondev, M.A. Kellett, I. Ahmad, J.P. Greene, A.L. Nichols, *Experimental studies to improve specific actinide decay data*, Int. Conf. on Nuclear Data for Science and Technology (ND2007), 22 – 27 April 2007, Nice, France
- M.A. Kellett, F.G. Kondev, A.L. Nichols, *IAEA Coordinated Research Project: Updated decay data library for actinides*, 16th Int. Conf. on Radionuclide Metrology and its Applications (ICRM 2007), 3-7 September 2007, Cape Town, South Africa; to be published in *Appl. Radiat. Isot.*
- F.G. Kondev, I. Ahmad, M.P. Carpenter, C.J. Chiara, J.P. Greene, R.V.F. Janssens, M.A. Kellett, C.J. Lister, A.L. Nichols, G. Savard, D. Seweryniak, S. Zhu, *Decay studies of minor actinide nuclides, and future opportunities for improving the decay data of neutron-rich fission products*, submitted for presentation at Int. Conf. Reactor Physics, Nuclear Power: a Sustainable Resource, PHYSOR-2008, 14-19 September 2008, Interlaken, Switzerland



Updated Decay Data Library for Actinides

Evaluations:

- V.P. Chechev, *Evaluation of ^{242}Cm and ^{244}Cm Decay Data*, Physics of Atomic Nuclei 69 (2006) 1188-1197
- V.P. Chechev and N.K. Kuzmenko, *Decay Data Evaluation Project (DDEP): Evaluation of the ^{237}U , ^{236}Np , $^{236\text{m}}\text{Np}$ and ^{241}Pu Decay Characteristics*, Int. Conf. on Nuclear Data for Science and Technology (ND2007), 22 – 27 April 2007, Nice, France
- V. Chisté, M.-M. Bé and C. Dulieu, *Evaluation of Decay Data of Radium-226 and Its Daughters*, Int. Conf. on Nuclear Data for Science and Technology (ND2007), 22 – 27 April 2007, Nice, France

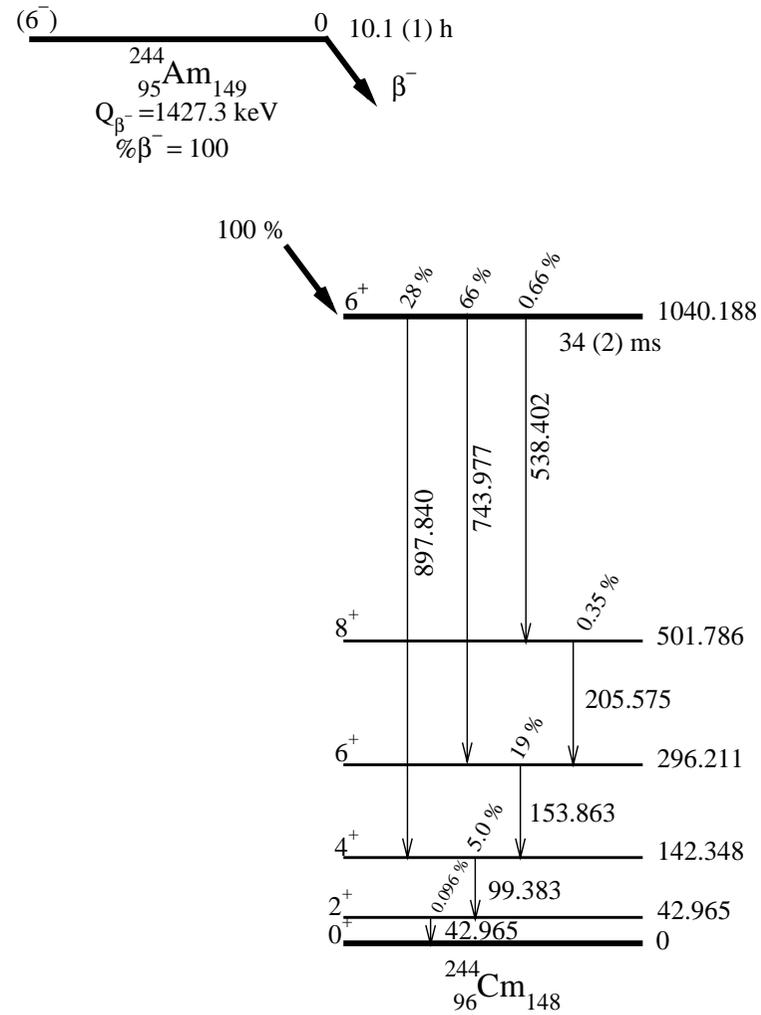


Updated Decay Data Library for Actinides

^{244}Am

100% β^- decay to 1040.188-keV nuclear level and of ^{244}Cm , followed by cascade of seven γ rays

Update on the Decay of ^{244}Am to ^{244}Cm for Actinides



Updated Decay Data Library for Actinides

Radionuclide

Anomalies and inadequacies

^{224}Ra	Discrepancy between related measurements of absolute emission probability of 240.99-keV γ ray and the α -particle emission probabilities to the ground and first excited states of ^{220}Rn
^{226}Ra	Modest discrepancy between related measurements of absolute emission probability of 186.21-keV γ ray and the α -particle emission probabilities to the ground and first excited states of ^{222}Rn
^{225}Ac	Only two measurements of the half-life (most recent in 1950)
^{233}Th	Measured γ -ray emission probabilities are reported without uncertainties
^{233}Pa	Precise measurements of low-energy γ rays and LX-rays would assist greatly in resolving difficulties in decay scheme evaluation.
^{237}U	Half-life measurements merited to fortify earlier experimental studies



Updated Decay Data Library for Actinides

Radionuclide

Anomalies and inadequacies

^{239}U

Large numbers of observed γ rays are unplaced in decay scheme

^{236}Np , $^{236}\text{Np}^m$

Inadequate experimental data

^{239}Pu

Determination of the multiplicities of the lower-energy γ rays would be beneficial

^{241}Am

Specific γ -ray transitions require more detailed measurements (27.0, 54.1 and 95.0 keV), including conversion-electron emission probabilities



Updated Decay Data Library for Actinides

Radionuclide

Anomalies and inadequacies

^{242}Am

Half-life studies merited to fortify the three existing measurements; γ -ray studies would also be beneficial

^{244}Am

Half-life studies required to fortify only one known measurement; γ -ray studies would also be beneficial

$^{244}\text{Am}^m$

Half-life measurements are required to quantify the value and uncertainty with much greater confidence; γ -ray studies would also be extremely beneficial (only one known decay data measurement)

^{242}Cm

Accurate measurements of 44-, 102-, 157- and 210-keV γ -ray emission probabilities merited

Updated Decay Data Library for Actinides

Recommended data files will be made available after completion and full review:

www-nds.iaea.org

and

www.nucleide.org/DDEP_WG/DDEPdata.htm

also in ENSDF and ENDF-6 formats for nuclear applications libraries

IAEA Co-ordinated Research Project (CRP)

Financial Support

- 1. Lump-sum cost-sharing contract**
 - average IAEA contribution of \$5,000,
 - also provision to attend RCMs
- 2. Cost-free agreement (Developed Countries)**
 - only provision to attend RCMs



IAEA Co-ordinated Research Project (CRP)

- 1. Must assist Agency programmes (particularly CRPs)**
- 2. Proposed project must be compatible with the Agency's approved programmes and functions**

IAEA Co-ordinated Research Project (CRP)

Research contracts: one year – renewable up to total period of project (normally for 3 years (two one-year renewals))

Reports: yearly progress report and final report

Publications: acknowledge IAEA support of the work

Other provisions: equipment