

SMR.1148 - 40

*COLLEGE ON MEDICAL PHYSICS
AND
WORKSHOP ON
NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY:
MEDICAL APPLICATIONS
(20 SEPTEMBER - 15 OCTOBER 1999)*

**"Nuclear Data for Medical Applications
Available from IAEA-NDS"**

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AUSTRIA**

These are preliminary lecture notes, intended only for distribution to participants

Nuclear Data for Medical Applications Available from IAEA-NDS

O. Schwerer and P. Oblozinský

Nuclear Data Section

International Atomic Energy Agency

Vienna, Austria

I. Lecture

1. Data centers and their services
2. Nuclear data types
3. Review of important data libraries
4. Data access
5. Conclusion

II. Demonstrations

III. Exercises

Nuclear data

- ***describe*** properties of atomic nuclei and the fundamental physical relationships governing their interactions
- ***characterize*** physical processes underlying all nuclear technologies
- ***Examples:*** cross sections, half-lives, decay modes and decay radiation properties, γ -rays from radionuclides
- ***Scope:*** all 85 natural elements with 290 stable isotopes and more than 2500 radionuclides

Applications of nuclear data

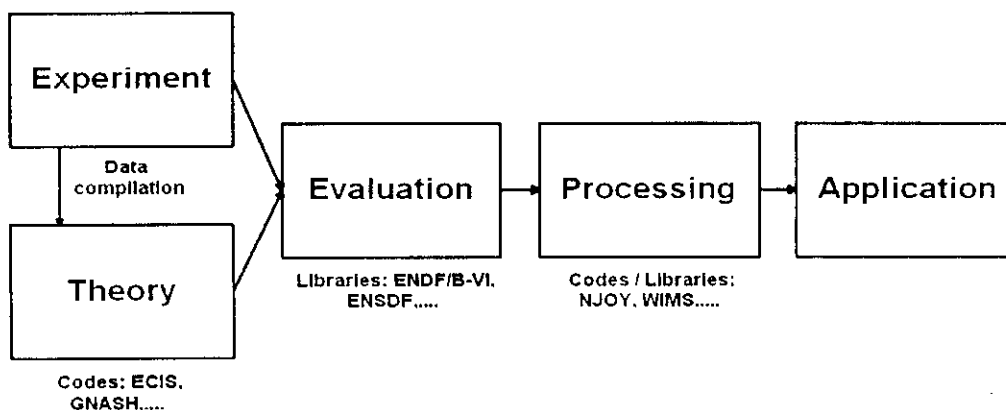
- Energy applications
 - Fission power
 - Fusion reactor technology
- Non-energy applications
 - Nuclear medicine
 - Materials analysis and process control
 - Safeguards
 - Radiation safety
 - Waste management
 - Environmental research
 - Basic research (e.g. nuclear astrophysics) and education

Nuclear data centers

- organize collection and distribution of nuclear data on a world-wide scale
- are involved in all stages of data preparation between measurement and application: compilation, review, evaluation, processing, distribution
- The work of international, regional and national nuclear data centers is co-ordinated by the IAEA in two specialized **data center networks** for maximum efficiency and work sharing

From experimental nuclear data to applications

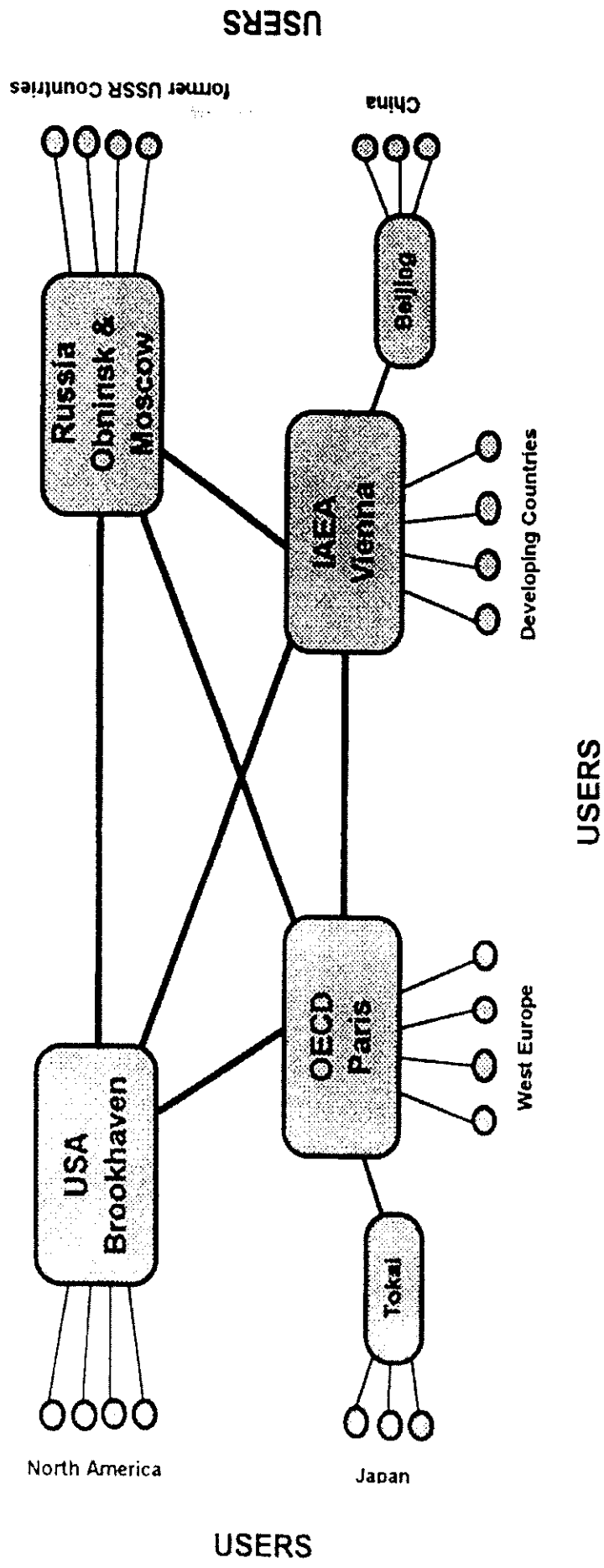
Laboratory → Data Center → User



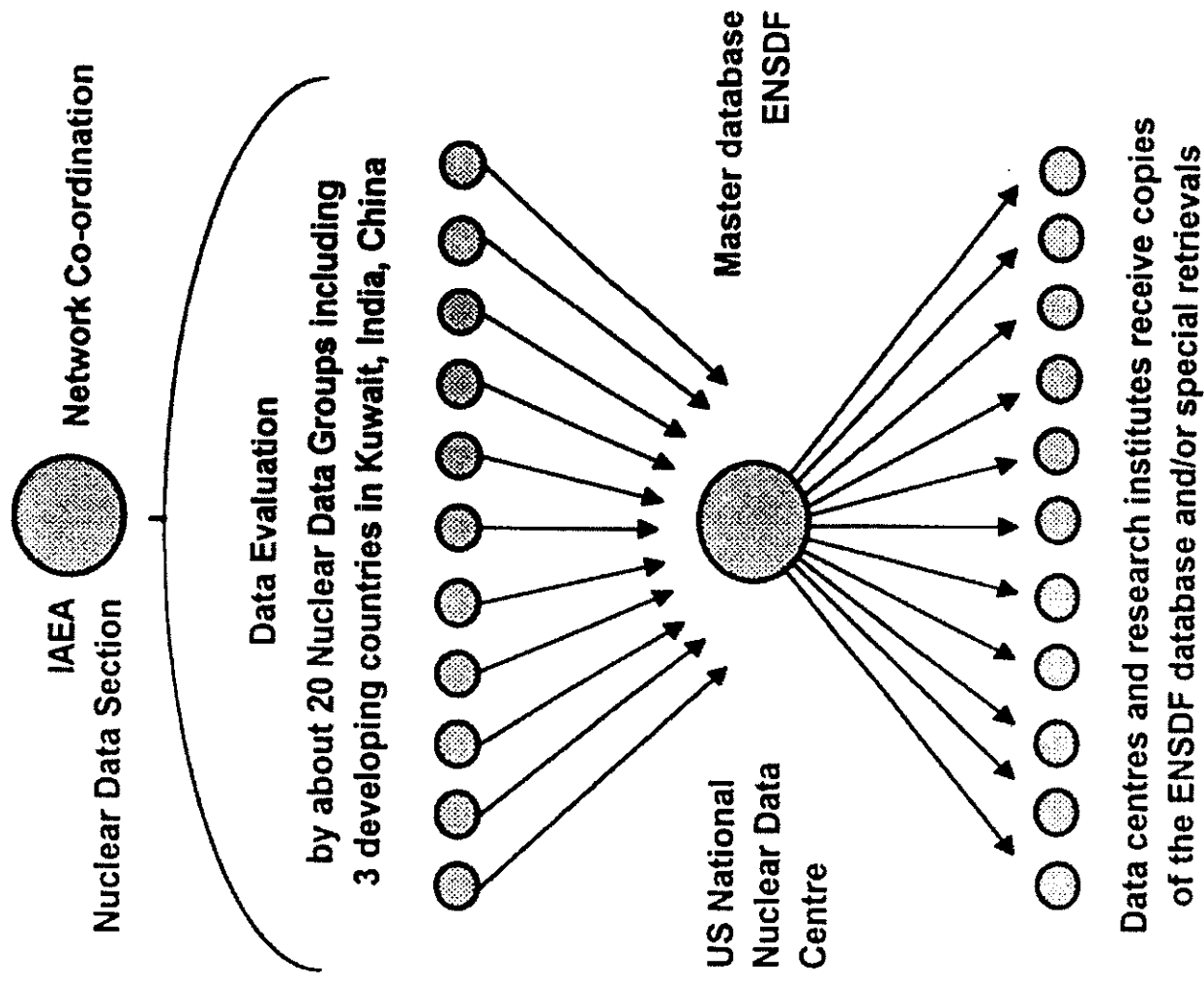
Nuclear Data Centers Networks

- **Nuclear Reaction Data Centers Network**
 - **IAEA Nuclear Data Section**, Vienna, Austria
 - **OECD NEA Data Bank**, Paris, France
 - **U.S. National Nuclear Data Center**, Brookhaven, USA
 - **Russian Nuclear Data Centers**, Obninsk and Moscow, Russia
 - **China Nuclear Data Center**, Beijing, China
 - **Japanese Nuclear Data Center**, Tokai, Japan
 - **Additional co-operating specialized centers** (Russia, Japan, Hungary, Ukraine, USA)
- **Nuclear Structure Data Centers Network**
 - **IAEA Nuclear Data Section**, Vienna, Austria (Co-ordination)
 - **U.S. National Nuclear Data Center**, Brookhaven, USA (Master database)
 - **17 data evaluation centers** in USA, Russia, Netherlands, China, France, Japan, Kuwait, Belgium, Canada, UK
 - **Data dissemination centers** (IAEA, OECD-NEA, USA, France, Sweden)

Network of Nuclear Reaction Data Centers



Network around the Evaluated Nuclear Structure Data File (ENSDF)

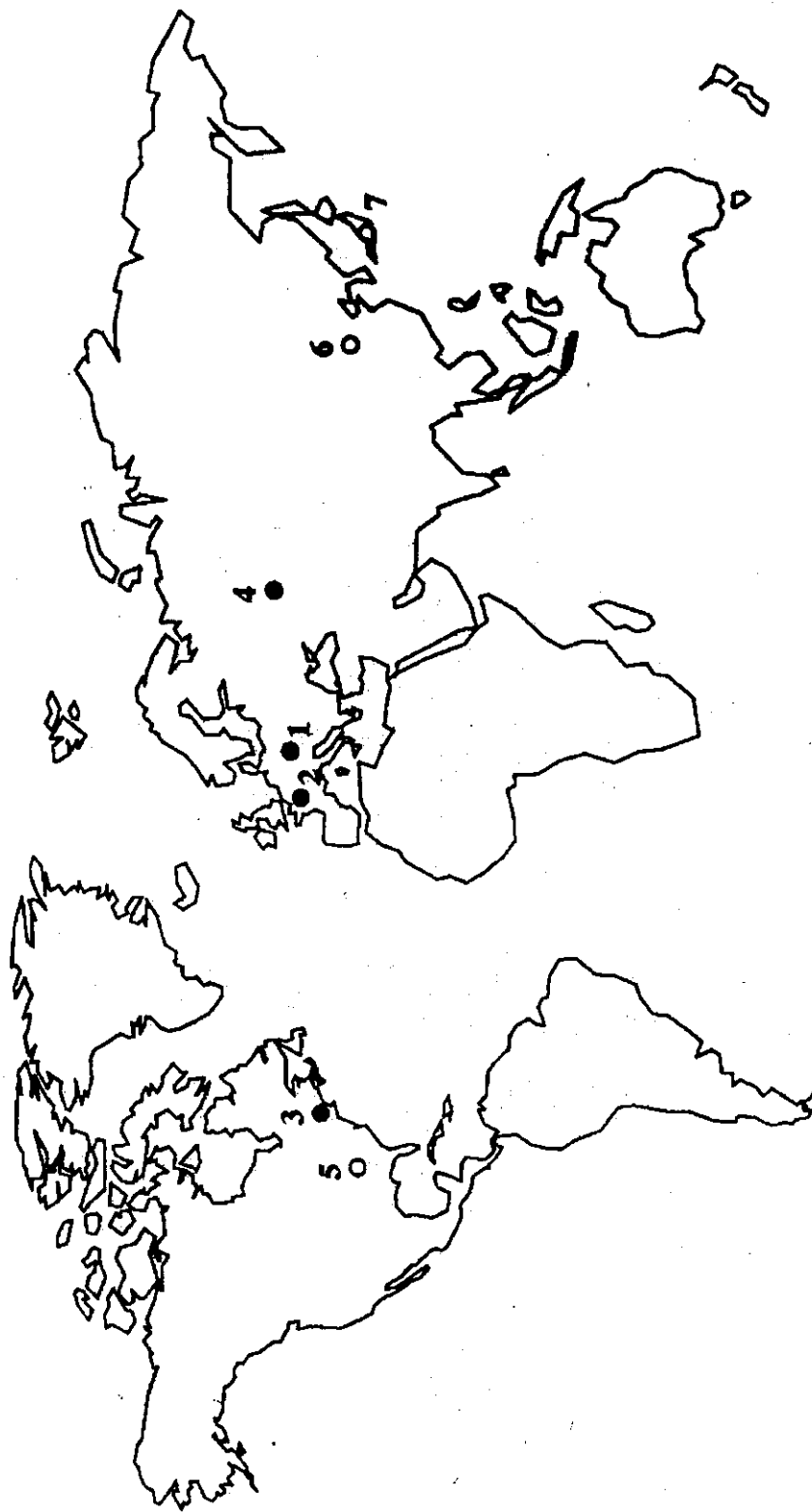


Web addresses of main dissemination centers

Major nuclear data dissemination centers. Additional dissemination centers with specialized scope exist e.g. in USA, Russia, Japan, Korea and other countries, and more centers contribute to data compilation and other data center functions.

Data center	Web address	Main services	Main area of responsibility
IAEA Nuclear Data Section, Vienna, Austria	http://www-nds.iaea.or.at	Reaction data, structure and decay data, reports; computer programs through OECD NEA Data Bank	IAEA member states with special emphasis on developing countries
US National Nuclear Data Center, Brookhaven, USA	http://www.nndc.bnl.gov	Reaction data, structure and decay data	USA, Canada
OECD NEA Data Bank, Issy-les-Moulineaux, France	http://www.nea.fr/html/databank/	Reaction data, structure and decay data, computer programs	OECD member states
Russian Nuclear Data Centers, Obninsk and Moscow, Russia		Reaction data	Russia
China Nuclear Data Center, Beijing, China		Reaction data	China
Isotope Project, Berkeley, USA	http://isotopes.lbl.gov/isotopes/	Structure and decay data	
Department of Physics, Lund University, Sweden	http://nucleardata.nuclear.lu.se/nucleardata/	Structure and decay data	
Atomic Mass Data Center, Orsay, France	http://csnwww.in2p3.fr/amdc/	Structure and decay data	

Major Nuclear Data Centers



- 1 • IAEA Nuclear Data Section, Vienna
- 2 • OECD NEA Data Bank, Paris
- 3 • U.S. National Nuclear Data Center, Brookhaven
- 4 • Russian Nuclear Data Centers, Obninsk + Moscow

- 5 ○ U.S. Radiation Safety Information
Computational Center (RSIC), Oak Ridge
- 6 ○ Chinese Nuclear Data Center, Beijing
- 7 ○ Japanese Nuclear Data Center, Tokai

Nuclear Data Services (1)

- Data by mail (*IAEA-NDS*)
 - Complete files on magnetic tape, CD-ROM or diskette
 - Specific retrievals on diskette, printout or by e-mail
- Hardcopy documents (*IAEA-NDS*)
 - Manuals and data library documentation
 - Handbooks
 - Meeting reports
 - Research reports
 - Nuclear Data Newsletter

Many new documents are made available also through Internet.

Nuclear Data Services (2)

- Online Services (*IAEA-NDS*):
 - WWW (Worldwide Web):
 - Interactive access to most important libraries
 - IAEA Nuclear Data Guide
 - Documents, Links, General information
 - FTP (Internet File Transfer):
 - downloading complete files, libraries and documents
 - Telnet service (NDIS):
 - Interactive access to most important libraries, some utilities and documents
- *US-NNDC, OECD/NEA Data Bank* (restricted), partly other centers, offer similar services

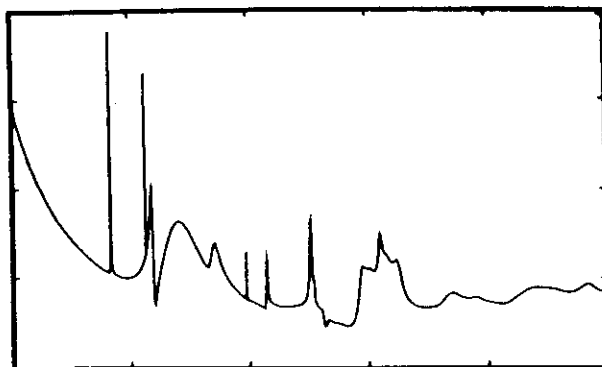
Nuclear Data Services (3)

- Nuclear data-related computer codes
 - Mostly distributed by *OECD/NEA Data Bank* (also for IAEA member states which are not NEA members)
 - Emphasis: nuclear reaction models, fission reactors
 - Some US-originated codes only through *Radiation Shielding Information Computational Center (RSICC)*, Oak Ridge, USA
 - Some utility programs and PC packages available directly from *IAEA-NDS*
- Processed data (Multigroup libraries): *NEA Data Bank*, partly *RSICC*

Nuclear Data Services (4): Trends

- Databases on CD-ROM with retrieval software (and perhaps update possibility through Internet), in parallel to online service
- “Mirror sites” to improve WWW accessibility worldwide
- *IAEA-NDS* intends to keep all ways of data distribution for medium term future, with emphasis shifting increasingly to WWW and CD-ROM

NUCLEAR DATA



NEWSLETTER

Nuclear Data Section (NDS)

International Atomic Energy Agency
Vienna

Issue No. 27

March 1999

Personnel Items

Announcement

Online News

Offline News

New Data Libraries

Computer Codes

Selected Reports and Documents

IAEA Nuclear Data Activities

Coordinated Research Projects

Workshops and Meetings

All services provided to users are free of charge.

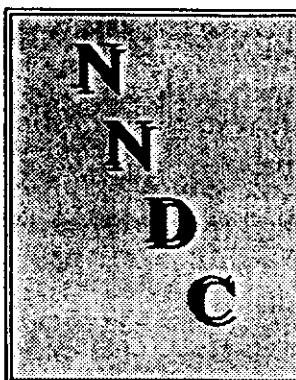
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cable: INATOM VIENNA
telex: 117645
telephone: (43-1) 2600 71/70

Online: TELNET or FTP
username: IAEANDS for interactive Nuclear Data Information System
usernames: ANONYMOUS for FTP file transfer;
FENDL2 for FTP file transfer of FENDL-2.0;
RIPL for FTP file transfer of RIPL;
NDSONL for FTP access to files sent to NDIS "open" area

WWW: <http://www.nucand.iaea.org>



National Nuclear Data Center Newsletter



Issue # 98-3

International Cooperation in Nuclear Data

December 1998

Web News

The CINDA database now links through the EXFOR line to the EXFOR data set.

Links have been added from the NSR database to the ENSDF database, and also links to American Physical Society (APS) journal abstracts.

Other Data Center News

The NNDC Online System has a new database. UNSDF contains unevaluated experimental nuclear structure and radioactive decay data.

Jonghwa Chang of the Korea Atomic Energy Research Institute is visiting the NNDC from October 15, 1998 to January 24, 1999.

Network News

Victor Zerkin of the Kiev Institute for Nuclear Research has joined the staff of the IAEA Nuclear Data Section in Vienna, Austria.

"Man does not live by words alone, despite the fact that sometimes he has to eat them."

Adlai Stevenson

The 129th issue of the NNDC Newsletter lists recent activities in the area of Nuclear Data.

Editor: Marion Blennau
Associate Editor: Vicki McLane

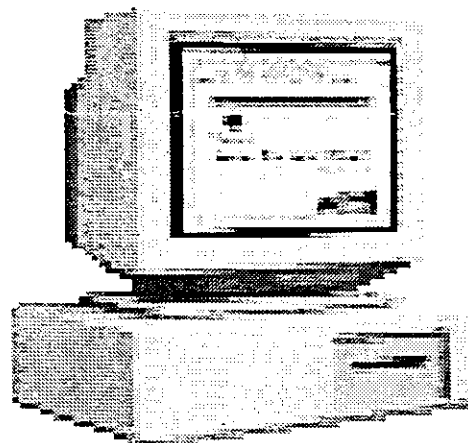
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Telephone: 516 344 2901

FAX: 516 344 2806

(Esnet) bnl::nndc
(Internet) "services@bnl.gov"

BNL-PCP-319



The IAEA Nuclear Data Services homepage

IAEA Nuclear Data Services - Netscape

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Bookmarks Location: <http://www.nds.iaea.or.at/> What's Related

**NUCLEAR
DATA
SERVICES**



Welcome to the IAEA's Nuclear Data Centre

You are being served by our main server
located at the IAEA, Vienna, Austria

Upcoming IAEA Workshops on Nuclear Data

- **ICTP Trieste, Italy, 13 March to 14 April 2000** Deadline: 31-Oct-99
[Workshop on Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety](#). ***new!***
- **IAEA, Vienna, 13 December to 17 December 1999** New Deadline: 8-Oct-99
[Workshop on Installation and use of Linux for Nuclear and Atomic Data Computation on Personal Computers](#). ***new!***
- **IAEA, Vienna, 29 November to 3 December 1999** Deadline: 15-Jul-99
[Workshop on Advanced Nuclear Data Online Services](#).
- **ICTP Trieste, 20 September - 15 October 1999** Deadline: 15-May-99
[College on Medical Physics and
Workshop on Nuclear Data for Science and Technology: Medical Applications](#).

IAEA Nuclear Data Services: We offer numerical nuclear physics data with related bibliographic information.

For the latest news on our services see the current issue of our [Nuclear Data Newsletter](#).

For a complete overview of all data resources available from the IAEA Nuclear Data Section, consult our [IAEA Nuclear Data Guide](#) and the [Index to the IAEA-NDS-Documentation Series](#) (Document IAEA-NDS-0).

- [Introduction to the Nuclear Data Section](#).

Document: Done

The IAEA Nuclear Data Services homepage (bottom of page)

IAEA Nuclear Data Services - Netscape

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Bookmarks Location: <http://www.nds.iaea.or.at/> What's Related

Direct WWW access to Databases, Documents, Programs and Files

Databases and Files

- [ENDF - evaluated nuclear reaction data library](#)
- [EXFOR - experimental nuclear reaction data](#) Since 06-May-99 with Graphics
- [CINDA - neutron reaction data bibliography](#)
- [NGATLAS - Atlas of neutron capture cross sections](#)
- [NUDAT - selected evaluated nuclear data](#)
- [ENSDF - evaluated nuclear structure and decay data](#)
- [MIRD - medical internal radiation dose tables](#)
- [Wallet cards - Ground and metastable state properties](#)
- [Thermal neutron capture \$\gamma\$'s](#)
- [IRDF-90 \(International Reactor Dosimetry File\)](#)
- [Masses \(Atomic Mass Evaluation Data File\)](#)
- [FENDL-2 - Fusion Evaluated Nuclear Data Library, Version 2.0](#)
- [RIPL - Reference Input Parameter Library for theoretical calculations of nuclear reactions](#)

Documents (in PostScript or PDF)

- [Selected INDC Reports](#)
- [ENDF Format Manual \(1997 version\)](#)
- [ENDF/B-6 Summary Documentation, Supplement 1](#)
- [ENSDF and NSR Manuals](#)
- [Online Service \(NDIS\) Manual and Citation Guidelines](#)
- [CSEWG Documents](#)
- [Links to Reports from other institutions and laboratories](#)
 - [Argonne ANL/NDM Reports Series](#), Argonne National Laboratory, USA

Programs

- [ENDF Preprocessing and Utility Codes](#)
- [Overview of ENSDF programs](#) available from various sites
- [ENSDF Analysis and Utility Programs](#)
- [PC Programs \(PCNudat, ENSDAT, COMTRANS\)](#)

To search for particular keywords in our WWW site, use our experimental [Search engine](#). At present it covers all core pages of the "Nuclear Data Services".

2. Nuclear Data Types

- Bibliographic data
- Experimental data
- Evaluated data
- Nuclear reaction data
- Nuclear structure and decay data

Bibliographic data: important examples

- **CINDA** (*Computerized Index of Neutron Data*)
 - Comprehensive bibliography to neutron reaction data
 - 1935 - present
 - Published regularly as a book
- **NSR** (*Nuclear Science References*)
 - Bibliographic database for low and intermediate energy nuclear physics. Main bibliography for structure and decay data and for non-neutron reaction data
 - 1910 - present
 - Published regularly in the journal *Nuclear Data Sheets (Recent References)*

Another nuclear bibliography: INIS

- INIS (International Nuclear Information System): a multi-gigabyte general nuclear bibliography maintained by IAEA
- **Not** specialized on nuclear data, **not** maintained by Nuclear Data Section. Wide scope, including reactor technology, nuclear law, nuclear medicine. Occasionally useful for nuclear data searches
- Available through WWW (license required, or through scientific library) or commercial CD-ROM

Experimental nuclear reaction data

- EXFOR
 - database for experimental nuclear reaction data for reactions induced by neutrons, charged particles and photons
 - numerical data supplemented by bibliographic and explanatory information
- CSISRS: US-NNDC implementation of EXFOR
- Related bibliographies: CINDA (neutron data), NSR

Evaluated data

- **Evaluated data** = recommended data, based on all data available from experiments and theory (critical analysis of experimental data and their uncertainties, inter- and extrapolation, supplemented with nuclear model calculations)
- **Formats** = strict rules for computerized storage of data. Most important evaluated data formats (named after main libraries):
 - **ENDF-6** (Evaluated Nuclear Data File)
 - **ENSDF** (Evaluated Nuclear Structure Data File)
- **Major libraries:**
 - Several for neutron reactions up to 20 MeV
 - One for structure and decay data: ENSDF
 - No major library for higher energy and non-neutron reaction data (only sporadic evaluations available so far)

Nuclear reaction data

- **Neutron data:** very complete collection up to 20 MeV, sporadic data for higher energies.
 - Bibliography: CINDA
 - Experimental: EXFOR
 - Major evaluated libraries in ENDF format (mostly up to 20 MeV):
 - ENDF/B-VI (USA), JEF-2 (Europe), BROND-2 (Russia), JENDL-3 (Japan), CENDL-2 (China), FENDL-2 (IAEA, fusion applications)
 - Some intermediate evaluations up to 100 MeV or 1 GeV
- **Charged particle-induced and photonuclear reactions:** selected experimental data in EXFOR, few evaluations
- **Heavy ion data:** some experimental data in EXFOR

Some Important Evaluated Cross Section Libraries

Main Application	Library	Origin	Comments
Neutron transport calculations	ENDF/B-VI	USA	Complete evaluations of neutron cross sections from 0 - 20 MeV for 322 materials from ^1H to ^{253}Es
Fusion	FENDL-2.0	IAEA-coordinated	Neutron, photon-atom, photon production, neutron activation, and charged-particle cross sections for fusion and other applications
Reactor Dosimetry	IRDF-90 Version 2	IAEA-coordinated	Neutron activation cross sections for reactor neutron dosimetry by foil activation, selected radiation damage cross sections and benchmark neutron spectra
Activation	RRDF-98	Russia	Neutron cross sections for 22 dosimetry reactions
Transmutation	NGATLAS	IAEA-coordinated	Neutron capture cross sections from 10^{-5} eV to 20 MeV for 739 targets
	MENDL-2, MENDL-2P	Russia	Activation cross sections for 505 stable and unstable targets between Al and Po for neutrons up to 100 MeV and protons up to 200 MeV
Medical Radioisotope Production	Reference Charged Particle Cross Section Database	IAEA-coordinated project (under completion)	Production cross sections for γ -emitters, positron emitters and for monitor reactions, for protons through α -particles up to about 30 MeV
Medical Applications, Shielding	IAEA Photonuclear Library	IAEA-coordinated project (under completion)	Evaluated photonuclear cross sections for energies up to 25 MeV, partly up to 140 MeV

Nuclear structure and decay data

- Main database: ENSDF (Evaluated Nuclear Structure Data File)
 - Half-lives, decay schemes, level properties for all known nuclides
 - Evaluations published in the journal *Nuclear Data Sheets*
 - Related bibliography: NSR (Nuclear Science References)
- NUDAT
 - Most important data extracted from ENSDF
 - Related thermal neutron data

Structure and decay data (2)

- Most other structure and decay data libraries are derived from or related to ENSDF, e.g.:
 - *Table of Isotopes* (ed. By R.B. Firestone et al., 1996), book with CD-ROM
 - *Nuclear Wallet Cards* (ground and isomeric states properties, booklet and database)
 - *NUBASE* (library of experimentally known nuclear properties: mass, half-life, decay modes of ground and isomeric states, for more than 3000 nuclides, published by G. Audi et al. in Nucl.Phys. A 624 (1997) 1 and available online)
 - *Isotope Explorer*, software for retrieving and viewing ENSDF-formatted data, available online

3. Review of Important Data Libraries

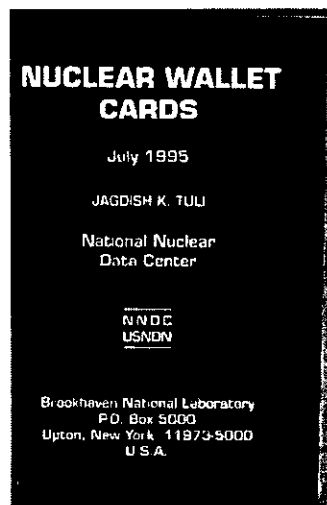
- Nuclear Wallet Cards
- NUDAT
- MIRD
- ENSDF
- CINDA
- EXFOR
- ENDF
- FENDL-2
- MENDL-2, MENDL2-P
- RIPL
-

Nuclear Data Libraries at IAEA

- Most comprehensive collection of nuclear data libraries worldwide - enormous value
- More than 100 libraries
- All data available free of charge to scientists in IAEA member states, on informal request or through Internet
- Overview:
 - “Index of Nuclear Data Libraries available from the IAEA Nuclear Data Section”, Report IAEA-NDS-7, ed. by H.D. Lemmel and O. Schwerer (August 1998), see also
<http://www-nds.iaea.or.at/reports/nds-7.pdf>
 - IAEA Nuclear Data Guide,
http://www-nds.iaea.or.at/indg_intro.html
- Brief documentations of contents and/or format for most libraries are published in the *IAEA-NDS*- report series (some reports and index IAEA-NDS-0 available also online), e.g.
IAEA-NDS-1: EXFOR, IAEA-NDS-100: ENDF/B-VI, IAEA-NDS-136: MENDL-2

Nuclear Wallet Cards

- Basic properties of ground and metastable states
- Available in several formats:
 - Pocket booklet (available from US-NNDC)
 - WWW: (display of tables for each element)
 - WWW as part of NUDAT (interactive retrievals by various criteria)
 - Telnet: as part of NUDAT, same functions as in WWW

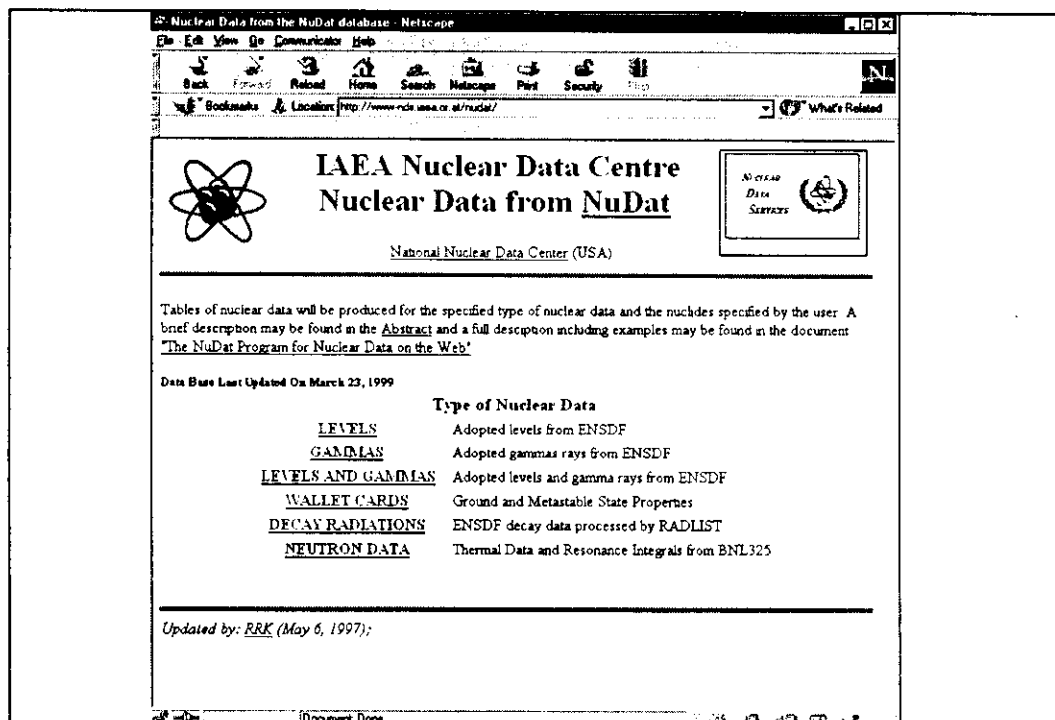


Nuclear Wallet Card - Z(24)

Isotope [1]		Jpi [2]	delta (MeV) [3]	T1/2 or Abundance [4]	Decay Mode [5]
Z	El A				
=====					
24	CR	42	0+	6.0s	
		43	(3/2+)	-2.14s	EC, EP, EA ?%
		44	0+	-13.5s	EP
		45		-19.4s	EC, EP > 27%
		46	0+	0.26 s	EC
		47	3/2-	500 ms	EC
		48	0+	21.56 h	EC
		49	5/2-	42.3 m	EC
		50	0+	> 1.8E+17 y	2EC
				4.345% 13	
		51	7/2-	27.702 d	EC
		52	0+	83.789% 18	
		53	3/2-	9.501% 17	
		54	0+	2.365% 7	
		55	3/2-	3.497 m	B-
		56	0+	5.94 m	B-
		57	3/2-, 5/2-,	21.1 s	B-
		58	0+	7.0 s	B-
		59		0.74 s	B-
		60	0+	0.57 s	B-
		61		> 200 NS	B-
		62	0+	> 200 NS	
		63		> 150 NS	
		64	0+	> 1 us	

NUDAT

- User-friendly extract of most important data (for applications) from ENSDF, plus thermal neutron data (cross sections and resonance integrals)
- Consists of 6 modules:
 - Levels / Gammas / Levels and Gammas / Wallet Cards / Decay Radiations / Neutron Data
- Available online through WWW and Telnet. Interactive retrievals by various criteria
- PC version can be downloaded (PCNUDAT). (Superseding 1996 CD-ROM version "Nuclear Data and References")



NUDAT/ Adopted Levels and Gammas for ^{60}Ni

File
Edit
View
Go
Communicator
Help

Back
Forward
Reload
Home
Search
Netscape
Print
Security
Stop

Bookmarks
Location:
http://www.nds.iaea.or.at/hbin/nudat.cgi

What's Related

Nuclear Data (NuDat) Retrieval

Adopted Levels and Gammas

Mass Number: 60

Jpi:

Element: NI

$T_{1/2}$:

Neutron:

E_{gamma} (keV):

Odd/Even:

Multipolarity:

E_{level} (keV):

Sort order: Gamma Energy, Mass number, Proton number, and Level Energy

A	ELEMENT	Z	Level		Jpi	Gamma			PUB	
			Energy (keV)			Energy (keV)	Intensity	YEAR		
60	NI	28	2626.08	0.10	3+	120.5	0.3	5.5	0.5	93
60	NI	28	5348.9	0.5	7-	200.3		4.6		93
60	NI	28	4407.45	0.14		242.0		43		93
60	NI	28	5348.9	0.5	7-	334.0		20.0		93
60	NI	28	2505.766(7)		4+	346.93	0.07	0.0076(5)		93
60	NI	28	5348.9	0.5	7-	362.9		10.2		93
60	NI	28	3588.1	1.0	0+	394		30		93
60	NI	28	4191	4		462				93
60	NI	28	2626.08	0.10	3+	467.3	0.2	100	5	93
60	NI	28	8520.5	1.0		476.8		100		93
60	NI	28	3119.70	0.09	4+	493.90	0.20	8.7	2.2	93
60	NI	28	3875.0	2.4	1+, 2+	494	5	30		93
60	NI	28	3124.02	0.13	2+	497.9	0.2	3.68	0.20	93

NUDAT/ Wallet Cards Retrieval for A=30-40, $T_{1/2} > 1$ min

Nuclear Data (NUDAT) Retrieval Program - Netscape
File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: http://www.nds.iaea.or.at/cgi-bin/tb/nudat.cgi

Nuclear Data (NuDat) Retrieval Wallet Cards (Ground & Metastable States)

Mass Number: 30-40 Jpi:
Element: T_{1/2}: 1M-
E_{level}(keV): Decay Mode:
Sort order:

ELEM- A	Z	Level Energy (MeV)	Mass Excess M-A (MeV)	Jpi	Half-Life	Decay	
						Mode	Branch %
30 SI	14	0.0000	-24.4329	0+	STABLE		0.000
30 P	15	0.0000	-20.2006	1+	2.498 M 0.004	EC	100.00
31 SI	14	0.0000	-22.9490(10)	3/2+	157.3 M 0.3	B-	100.00
31 P	15	0.0000	-24.4410(20)	1/2+	STABLE		0.000
32 SI	14	0.0000	-24.0809	0+	172 Y 4	B-	100.00
32 P	15	0.0000	-24.30530(20)	1+	14.262 D 0.014	B-	100.00
32 S	16	0.0000	-26.01600(10)	0+	STABLE		0.000
33 P	15	0.0000	-26.3377	1/2+	25.34 D 0.12	B-	100.00
33 S	16	0.0000	-26.58620(10)	3/2+	STABLE		0.000
34 S	16	0.0000	-29.93190(10)	0+	STABLE		0.000
34 CL	17	0.1460	-24.29460(10)	3+	32.00 M 0.04	EC	55.40
34 CL	17	0.1460	-24.29460(10)	3+	32.00 M 0.04	IT	44.60
35 S	16	0.0000	-28.84640(10)	3/2+	87.51 D 0.12	B-	100.00
35 CL	17	0.0000	-29.0135	3/2+	STABLE		0.000
36 S	16	0.0000	-30.66400(20)	0+	STABLE		0.000
36 CL	17	0.0000	-29.52190(10)	2+	301000 Y 2000	B-	98.10
							0.709

NUDAT/ Decay Radiations for ^{66}Cu

File Edit View Go Communicator Help

Location: <http://www.nds.iaea.org/nuDat/nuDat.cgi>

Nuclear Data (NuDat) Retrieval

Decay Radiations

Mass Number: 66 Radiation:
 Element: CU Radiation Energy (keV):
 T_{1/2}: Radiation Intensity:
 Decay Mode:
 Sort order: Mass number, Proton number, Half-Life, and Radiation

ELE- A	MENT Z	Decay Mode	Half-Life	Rad. Type	Radiation Energy (keV)	Radiation Intensity (%)	Dose (G-RAD /UCI-H)
66	CU	29	B-	5.120 M 0.014	B-	79.2	0.7 0.0037 0.0003 0
66	CU	29	B-	5.120 M 0.014	B-	266.2	0.6 0.220 0.005 0.0012
66	CU	29	B-	5.120 M 0.014	B-	628.1	0.6 9.01 0.09 0.121
66	CU	29	B-	5.120 M 0.014	TOT	1066.6	0.7 100.00 0.13 2.27
66	CU	29	B-	5.120 M 0.014	B-	1112.1	0.6 90.77 0.09 2.15
66	CU	29	B-	5.120 M 0.014	G	833.0	1.0 0.220 0.005 0.0039
66	CU	29	B-	5.120 M 0.014	G	1039.20	0.20 9.23 0.09 0.204
66	CU	29	B-	5.120 M 0.014	G	1332.5	1.5 0.0037 0.0003 0.0001
66	CU	29	B-	5.120 M 0.014	G	1872.	0.00023 (23) 0

This program and the accompanying data base has been produced by the National Nuclear Data Center located at the Brookhaven National Laboratory Upton, N.Y., USA, with funding from the U.S. Department of Energy. Neither the BNL nor the USDOE make any warranty or assume any legal responsibility for the contents of the data base.

Document: Done

MIRD - "Medical Internal Radiation Dose"

- Based on ENSDF, data processed with code "RADLST"
- Output: Tables with intensities, energies and dose of all produced radiations, including X-rays, Auger electrons, etc., and decay scheme plots
- Output only in PostScript (no editing, no selection except nuclide)
- NUDAT option "Decay radiations" provides similar function (table only)
- "Advanced" or "custom" tables: use RADLST separately (available for downloading)

MIRD Output ("Medical Internal Radiation Dose")



26-IRON-59

Half-life = 44.503 Days
Decay Mode(s): β^-

Nov. 1993

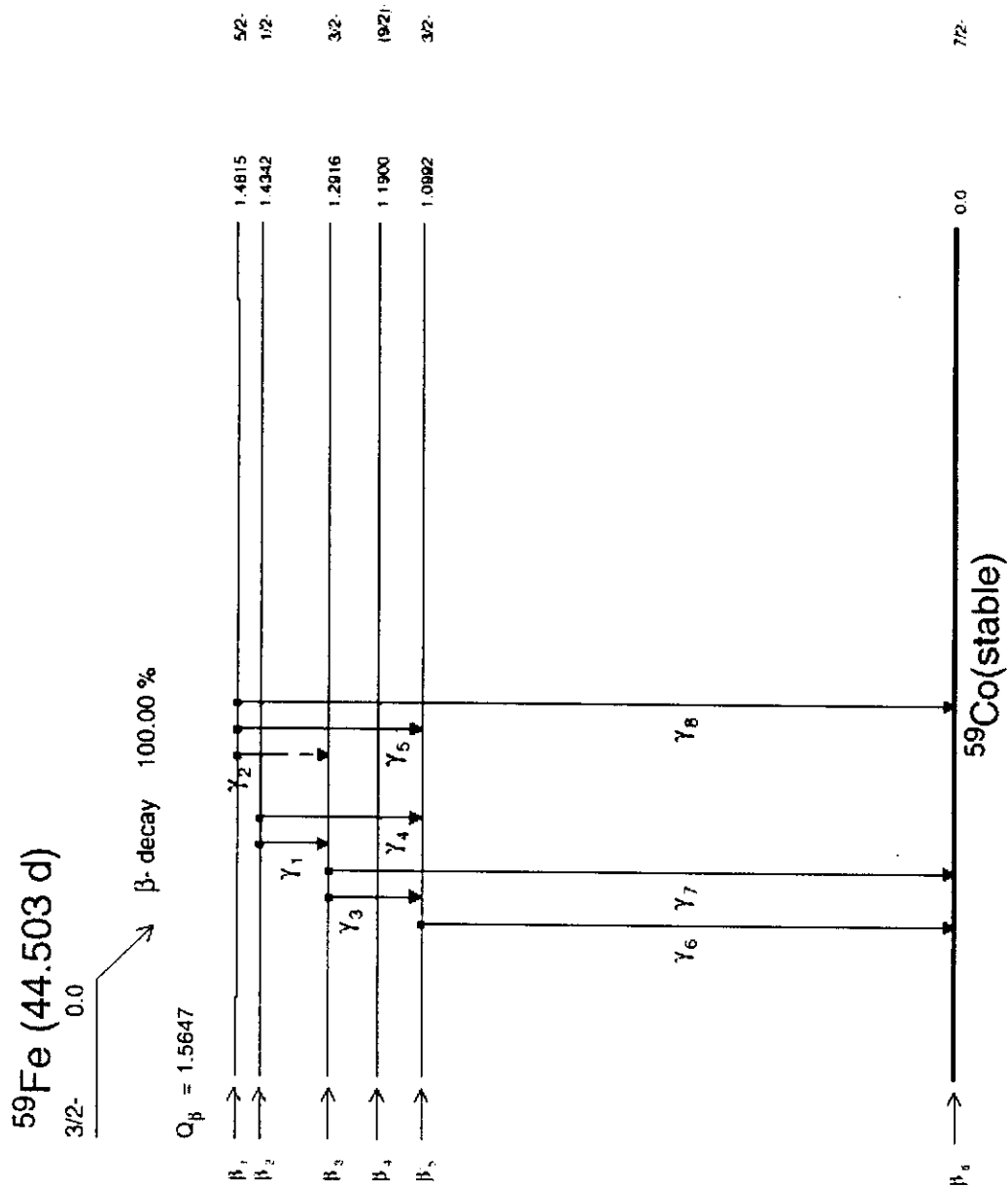
RADIATIONS			$\lambda(t)$ (Bq-s)	$E(t)$ (MeV)	$\lambda(t) \times E(t)$
β^- 1			7.80E-04	2.194E-02	1.71E-05
β^- 2			1.31E-02	3.559E-02	4.66E-04
β^- 3			4.53E-01	8.084E-02	3.66E-02
β^- 4			5.00E-05	1.160E-01	5.80E-06
β^- 5			5.31E-01	1.491E-01	7.92E-02
β^- 6			1.80E-03	6.143E-01	1.11E-03
γ 1			1.02E-02	1.427E-01	1.46E-03
ce-K, γ 1			1.50E-04	1.349E-01	2.02E-05
ce-L, γ 1			1.51E-05	1.417E-01 ^a	2.14E-06
γ 2			9.00E-06	1.890E-01	1.70E-06
γ 3			3.08E-02	1.923E-01	5.92E-03
ce-K, γ 3			2.51E-04	1.846E-01	4.63E-05
ce-L, γ 3			2.49E-05	1.914E-01 ^a	4.78E-06
γ 4			2.70E-03	3.348E-01	9.04E-04
ce-K, γ 4			4.72E-06	3.271E-01	1.55E-06
ce-L, γ 4			4.59E-07	3.339E-01 ^a	1.53E-07
γ 5			1.80E-04	3.820E-01	6.88E-05
ce-K, γ 5			5.65E-01	1.099E+00	6.21E-01
γ 6			9.04E-05	1.092E+00	9.87E-05
γ 7			4.32E-01	1.292E+00	5.58E-01
ce-K, γ 7			4.75E-05	1.284E+00	6.10E-05
γ 8			5.90E-04	1.482E+00	8.74E-04
K α_1 X-ray			1.23E-04	6.930E-03	8.51E-07
K α_2 X-ray			6.28E-05	6.915E-03	4.34E-07
K β X-ray			2.55E-05	7.650E-03	1.95E-07
L X-ray			5.84E-06	7.800E-04	4.56E-09
Auger-K			3.32E-04	6.070E-03	2.02E-06
Auger-L			8.05E-04	7.500E-04	6.04E-07

Listed X, γ and γ^- Radiations
Listed β^- , ce and Auger Radiations
Listed Radiations

^a Average Energy (MeV)
^a Maximum Energy (MeV) for subshell

Cobalt-59 Daughter is stable.

MIRD Output ("Medical Internal Radiation Dose")

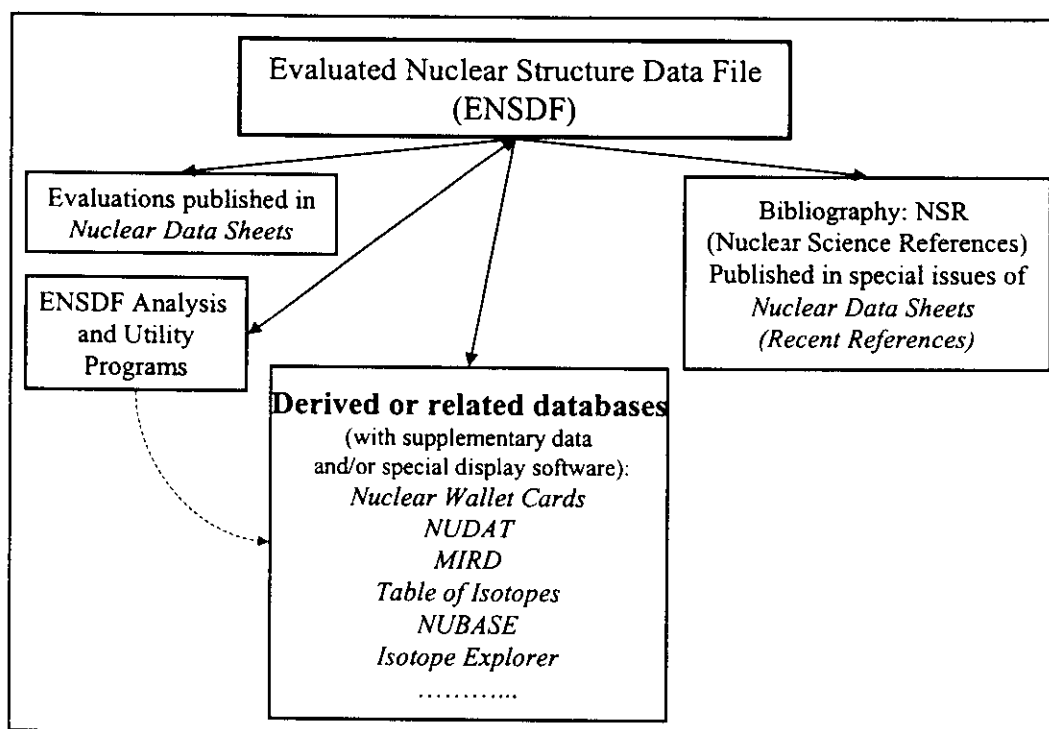


Radiation doses in MIRD, NUDAT

- MIRD and NUDAT calculate *Equilibrium Dose Rates* ("Dose") from ENSDF decay data
- Units: MeV/decay (MIRD),
g·rad/ μ Ci·h (NUDAT/Decay Radiations)
- 1 MeV/decay = 2.13 g·rad/ μ Ci·h
- Reference: T.W.Burrows, *The Program RADLST* (documentation available online in PostScript)

ENSDF (Evaluated Nuclear Structure Data File)

- "Master library" for structure and decay data
- International evaluation effort coordinated by IAEA, master file maintained by US-NNDC
- Covers mass range 1 - 266
- Organized by nuclide; several "data sets" per nuclide
- Evaluations done for mass chains (e.g. A=235), published in journal *Nuclear Data Sheets*
- Special internal format
- Standard output: Tables and/or plots (ASCII, PostScript)
- Retrievals: full functionality only through Telnet, WWW interface has (so far) limited options



ENSDF: Data sets for ^{82}Kr

QV171.m - second issue or al (1) [default]

File Edit View Setup Language Font Display Commands Help

Evaluated Nuclear Structure Data File

SELECT	NUCLIDE	DATA_SETS
Archive Data Set ID's		Records
	82KR	ADOPTED LEVELS, GAMMAS 476
	82KR	82SE 2B- DECAY 17
	82KR	82BR B- DECAY (6.13 M) 69
	82KR	82BR B- DECAY (35.38 H) 286
	82KR	82AB B+ DECAY (1.273 M) 168
	82KR	82AB B+ DECAY (6.472 H) 172
	82KR	76GE (12C, A2NG) 72
	82KR	79BR (A, P) 31
	82KR	80SE (A, 2NG) 199
	82KR	81BR (3HE, 0) 13
	82KR	82KR (P, P') 20
	82KR	COULOMB EXCITATION 61
	82KR	84KR (P, T) 11

UP_ARROW -- move up one line. DOWN_ARROW -- move down one line.
 RETURN -- toggle SELECT/DESELECT. X -- selection completed.

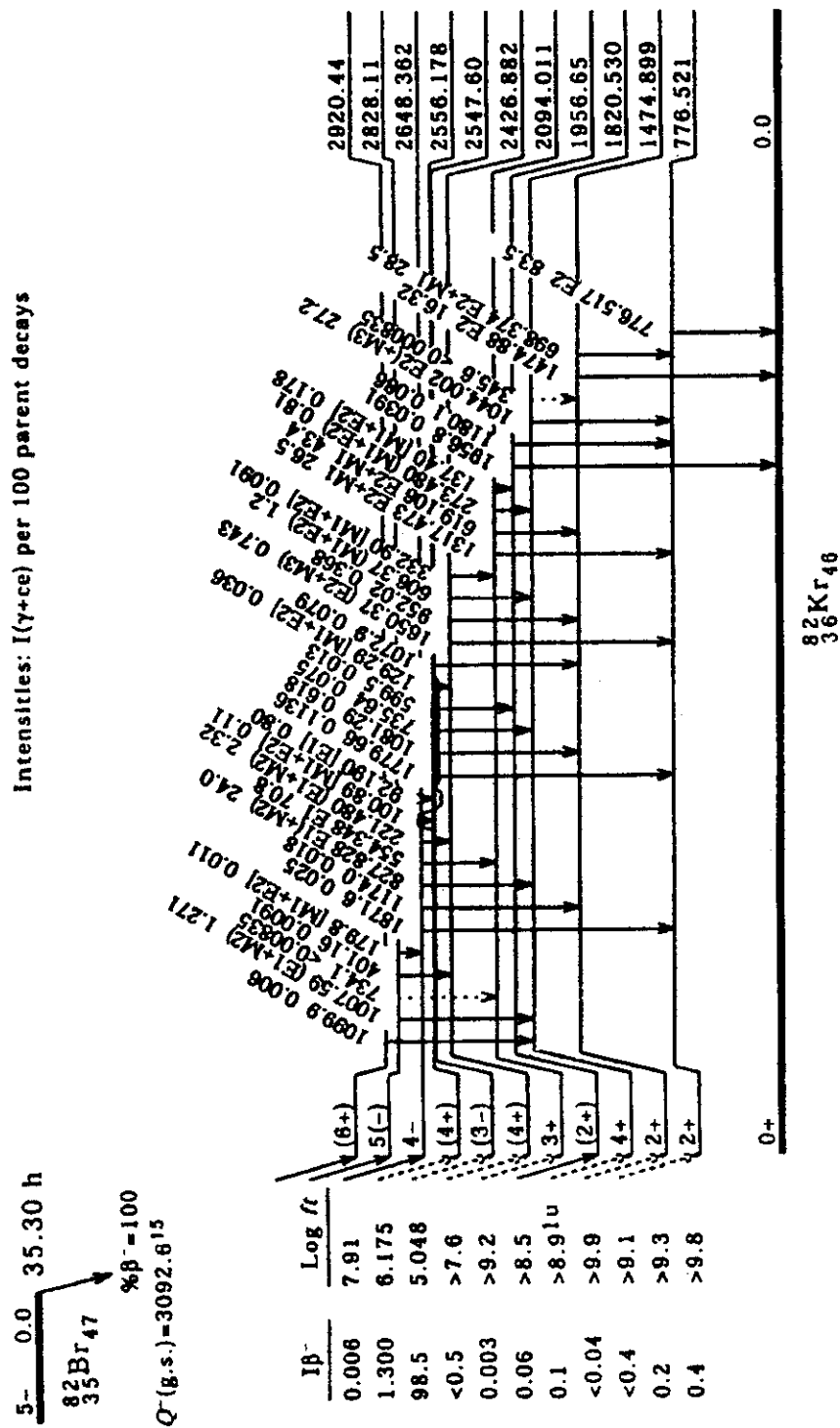
2480 (9.2) Connected Printer Off Logout Off NUM Ready

ENSDF Plot (^{82}Br β -decay)

^{82}Br β^- Decay (35.30 h) 1983Me08 (continued)

Decay Scheme

Intensities: I(γ +ce) per 100 parent decays



ENSDF: Table output

⁸²Br β⁻ Decay (35.30 h) 1983Me08 (continued)

γ(⁸²Kr) (continued)

Measurement of anisotropy of γ's emitted by oriented nuclei: 1977Ca26. Deduced δ.
Measurements of conversion coefficients: 1983Ba81, 1986Wz24. Magnetic spectrometer. Measured I_c. Deduced α(exp) from comparison with entire β spectrum. Quoted values are weighted averages of both measurements.
If normalization: ΣI(γ+cc) to g.s.=100 since g.s. β transition is highly forbidden.

E _γ [†]	E(level)	I _γ ^b	Mult. [‡]	δ [§]	α	Comments
92.190 16	2648.362	0.86 [±] 4	[E1]		0.115 ^a	α(K)=0.102; α(L)=0.0110; α(M)=0.00178.
100.89 8	2648.362	0.084 8	[M1+E2]		0.5 4	α(K)=0.4 4; α(L)=0.06 5; α(M)=0.010 8.
128.29 3	2556.178	0.036 7	[M1+E2]		0.21 15	α(K)=0.18 13; α(L)=0.024 16; α(M)=0.004 3.
137.40 5	2094.011	0.182 2	[M1+E2]		0.17 ^a 12	α(K)=0.15 10; α(L)=0.019 14; α(M)=0.0031 23.
178.8 2	2828.11	0.012 9	[M1+E2]		0.07 ^a 4	α(K)=0.06 4; α(L)=0.007 5.
221.480 [⊖] 2	2648.362	2.71 [±] 8	[E1+M2]	+0.5 3	0.025 15	α(K)=0.021 13; α(L)=0.0025 16.
273.480 8	2094.011	0.96 [±] 3	[M1+E2]	+0.18 8	0.0098 4	δ: or δ=+2.6 5.
332.90 3	2426.882	0.108 5	[M1+E2]		0.009 ^a 4	α(K)=0.0085 3; α(L)=0.00093 4.
(345.6)	1820.530	<0.001				α(K)=0.008 3; α(L)=0.0009 4.
401.16 8	2828.11	0.0109 9				
554.348 [⊖] 2	2648.362	84.7 [±] 8	E1			α(exp)=0.00069 7.
599.5 3	2556.178	0.016 9				α=0.00077; α(K)=0.00087.
606.37	2426.882	1.45	(M1+E2)	-0.34 10		E _γ : the value 559.5 quoted by 1983Me08 is probably a misprint (compare 599.57 observed by 1970Me02).
619.105 [⊖] 4	2094.011	52.0 [±] 5	E2+M1	+1.97 6		α=0.00144 3; α(K)=0.00126 2; α(L)=0.00013.
698.374 [⊖] 5	1474.899	34.1 [±] 3	E2+M1	+2.1 4		α(exp)=0.0015 2.
(734.1)	2828.11	<0.01				δ: either: δ=2.2 4 from oriented nuclei (1977Ca26).
735.64 7	2556.178	0.09 1				α=0.00165; α(K)=0.00144; α(L)=0.00016.
776.517 [⊖] 3	776.521	100.0 [±] 10	E2			α(exp)=0.00090 13.
827.828 [⊖] 6	2648.362	28.77 [±] 29	E1(+M2)	+0.09 4		δ: other: δ=2.7 3 from oriented nuclei (1977Ca26). δ(E0)=0.1 +δ-1 (1973Ca10).
952.02 3	2426.882	0.44 2				α=0.00120 2; α(K)=0.00105 1; α(L)=0.00011.
1007.59 3	2828.11	1.522 [±] 15	(E1+M2)	+0.07 5		α(exp)=0.00085 9.
1044.002 [⊖] 5	1820.530	32.6 [±] 3	E2(+M3)	+0.05 4		α=0.00093; α(K)=0.00082.
1072.9 1	2547.60	0.095 19				α(exp)=0.00029 4.
						α=0.00033 1; α(K)=0.00029 1.
						α=0.00019 1; α(K)=0.00019 1.
						α(exp)=0.00038 3.
						α=0.00040 1; α(K)=0.00040 1.

CINDA (Computer Index of Neutron Data)

- Bibliography of neutron data (literature, unofficial publications, computer files); (γ,n), (γ,f) and spontaneous fission data also included
- Entries primarily sorted by nuclide, reaction/quantity, laboratory; therefore separate entries for each measured reaction of one publication
- Unique feature: all entries describing the same experiment are listed together ("CINDA blocks")
- Extension of database to include **charged-particle induced** and (all) **photonuclear** reactions is under preparation (2001?)

CINDA products and retrievals

- CINDA book
 - Complete file contained in several volumes:
 - Archival 1935-1987 (5 volumes)
 - CINDA97 (1988-1997)
 - CINDA98 (Supplement to CINDA97)
- Selective online retrievals through WWW and Telnet. WWW output with hyperlinks to EXFOR
- Complete file on CD-ROM about to be released

CINDA98
Supplement to CINDA 97 (1988-1998)



THE INDEX TO LITERATURE AND COMPUTER FILES ON
MICROSCOPIC NEUTRON DATA

PUBLISHED ON BEHALF OF
USA National Nuclear Data Center
Russian Nuclear Data Centre
NEA Data Bank
IAEA Nuclear Data Section

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1998

CINDA Retrieval for $^{55}\text{Mn}(n,p)$

CINDA Retrieval - Netscape

File

Edit

View

Go

Communicator

Help

Back

Forward

Reload

Home

Search

Netscape

Print

Security

Stop

Bookmarks

Location: <http://aeand.iaea.org/ai/ndout/cinda1793.html>

What's Related

CINDA Retrieval

15-SEP-1999

Element : MN
 Mass : 55
 Quantity : NP
 Laboratory :
 Publication Date :
 Energy Range(eV) :
 Publication Type : ALL
 Work Type : ALL

MIN-55

Quantity	Energy range	Lab	Reference	Comments
(n,p)	Fiss	CRC	Rept CRC-1003	Roy+, ESTIMATED AVG SIG=0.4MB
(n,p)	1.4+7	CBR	Jour AUJ 13 186 6006	Weigold.25MB DEDUCED PAUL, CLARK 1953
(n,p)	1.4+7	CBR	Data EXFOR31039.008 8412	.1 PT. SIGMA.
(n,p)	1.4+7	HAR	Jour NP 24 274 6104	Allan+ 120DEG.PHOTOPL.CFD STAT MDL.
(n,p)	1.4+7	HAR	Data EXFOR20004. 7011	2PTS.CMPD.NUC.
(n,p)	1.4+7	HAM	Priv LANGMANN 6209	Langmann.
(n,p)	1.4+7	HAM	Data EXFOR20903.004 7904	1PNT.SIGMA.
(n,p)	1.5+7	ARK	Jour PR 131 2649 6309	Bramlitt+ LESS THAN 0.30MB N2P
(n,p)	1.5+7	ARK	Rept TID-16949 6200	.THESIS
(n,p)	1.5+7	ARK	Data EXFOR11590.016 7606	.1 PT. MAX SIGMA, N,2P.
(n,p)	1.4+7	IRK	Jour OAWS 174 11 6500	Hille+.CF XPT/TH INTERPRET SIG N2N
(n,p)	1.4+7	SAH	Jour NUC 23 8 112 6508	Chatterjee. TABLE WITH REFS.
(n,p)	1.4+7	SAH	Jour NP 60 273 6411	Chatterjee.MEAN OF EXPT CFD SHELLMOD
(n,p)	1.5+7	BOS	Prog AEET-267 62 6608	Mitra+.ACT.REL CU-63(N,2N).TBL SIG
(n,p)	1.5+7	BOS	Data EXFOR30013.009 7008	.1 PT: SIGMA = 59.5+-5.9 MB

EXFOR

- Unified computerized system (library and format) by which international, regional and national data analysis centers exchange experimental nuclear reaction data
- Compilation and exchange coordinated by IAEA
- CSISRS = US implementation of EXFOR
- Coverage is complete for neutron data (in particular up to 20 MeV)
- Coverage less complete (but improving) for higher energy neutrons, charged particle-induced and photonuclear data
- More than 60 000 data sets, more than 3 million data points

More on EXFOR

- Library contains numerical tables and structured abstract with experimental and bibliographic information
- Neutron data: bibliographic link to CINDA (non-neutron data will be added to CINDA in 1-2 years)
- Main users:
 - Evaluators (EXFOR database is starting point for all evaluations)
 - Applied users, if no evaluation available
 - Anybody measuring or calculating cross section data

Access to EXFOR

- Available for interactive retrievals through WWW and Telnet (~one reaction at a time)
- CD-ROM with retrieval program (similar functionality as WWW/Telnet)
- Complicated retrievals available individually on request from IAEA-NDS (diskette, tape, file transfer, e-mail, printout)
- Output in various formats:
 - Standard format (EXchange FORmat)
 - Computational formats for plotting and further processing
 - “Edited listing” (abbreviations expanded): on request from IAEA
 - Online plots for intercomparison with evaluated data

SUBENT	C0484002	19990420		C0484002	1
BIB	4	14		C0484002	2
REACTION	(12-MG-24 (A,N)14-SI-27,,SIG)			C0484002	3
SAMPLE	Magnesium oxide target enriched to 99.94% 24Mg with a thickness 150 (30) microg/cm**2, prepared by evaporation onto 0.025 cm thick tantalum disc.			C0484002	4
				C0484002	5
				C0484002	6
DECAY-DATA	(14-SI-27,4.16SEC,B+)			C0484002	7
ERR-ANALYS	(DATA-ERR) Overall uncertainty of 23% includes uncertainties from:			C0484002	8
				C0484002	9
	- target thickness		20.0%;	C0484002	10
	- calibrated source strength		5.6%;	C0484002	11
	- least squares fitting and variation in counting efficiency		6.0%;	C0484002	12
	- correction factor for absorption in the tantalum backing		8.0%;	C0484002	13
	- effective number of incident particles		3.0%.	C0484002	14
				C0484002	15
ENDBIB	14			C0484002	16
NOCOMMON	0	0		C0484002	17
DATA	3	15		C0484002	18
EN-CM	DATA	DATA-ERR		C0484002	19
MEV	MB	MB		C0484002	20
7.27	1.8	.4		C0484002	21
7.48	27.4	6.3		C0484002	22
7.7	8.8	2.		C0484002	23
7.91	9.6	2.2		C0484002	24
8.13	24.3	5.6		C0484002	25
8.34	34.1	7.8		C0484002	26
8.55	44.9	10.3		C0484002	27
8.77	49.9	11.5		C0484002	28
8.98	40.3	9.3		C0484002	29
9.2	51.2	11.8		C0484002	30
9.41	49.8	11.5		C0484002	31
9.63	50.2	11.6		C0484002	32
9.84	51.3	11.8		C0484002	33
10.06	62.7	14.4		C0484002	34
10.27	59.2	13.6		C0484002	35
ENDDATA	17			C0484002	36
ENDSUBENT	3			C0484002	37
				C048400299999	

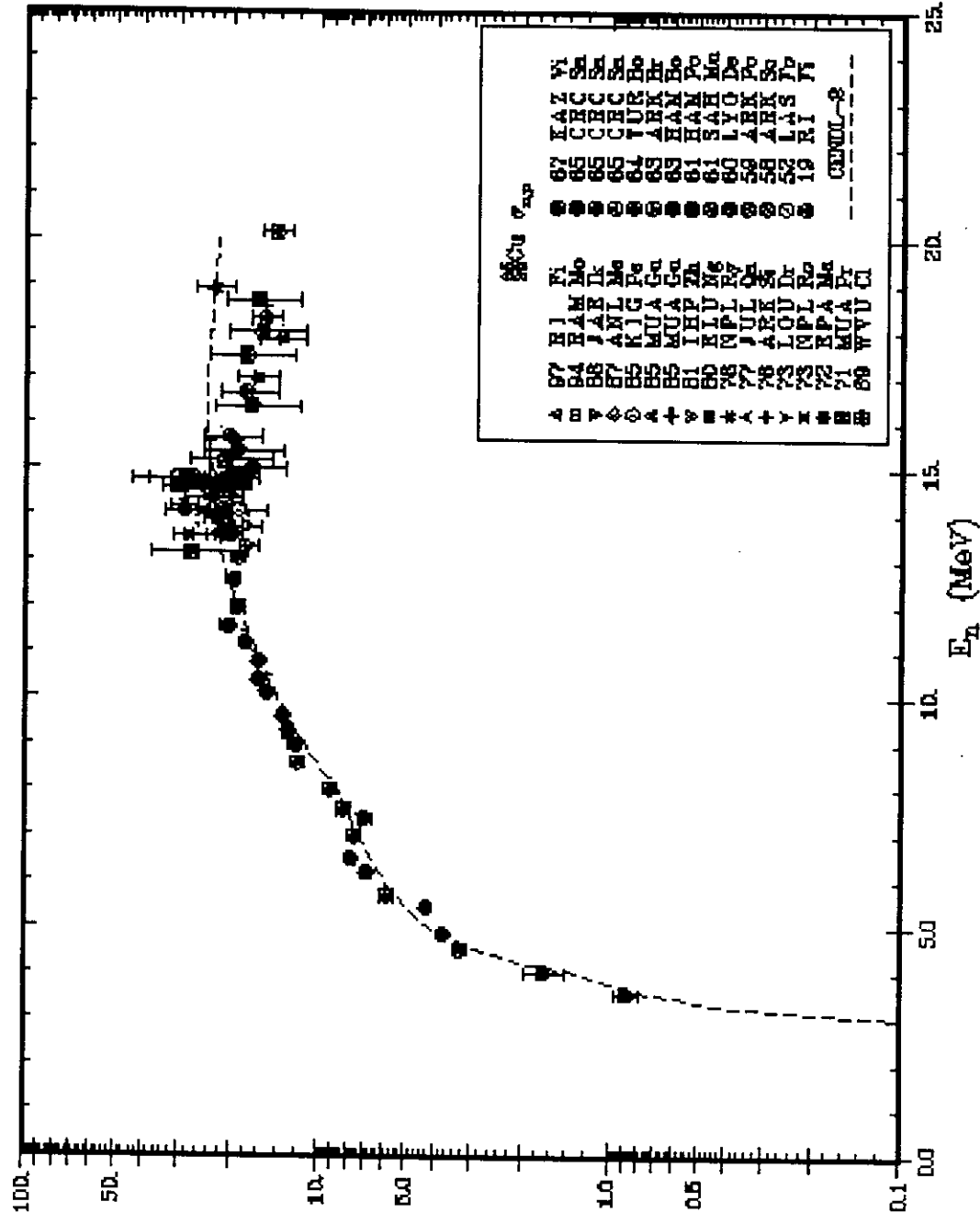
STANDARD
FORMAT
(EXFOR)

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PHYSENT	1	0	15	7.2700E+06	1.0270E+07	1	0	0
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1	1	0
7.2700E+06	0.0000E+00	0.0000E+00	1.8000E-03	4.0000E-04	4.0000E-04	1	1	1
7.4800E+06	0.0000E+00	0.0000E+00	2.7400E-02	6.3000E-03	6.3000E-03	1	1	1
7.7000E+06	0.0000E+00	0.0000E+00	8.8000E-03	2.0000E-03	2.0000E-03	1	1	1
7.9100E+06	0.0000E+00	0.0000E+00	9.6000E-03	2.2000E-03	2.2000E-03	1	1	1
8.1300E+06	0.0000E+00	0.0000E+00	2.4300E-02	5.6000E-03	5.6000E-03	1	1	1
8.3400E+06	0.0000E+00	0.0000E+00	3.4100E-02	7.8000E-03	7.8000E-03	1	1	1
8.5500E+06	0.0000E+00	0.0000E+00	4.4900E-02	1.0300E-02	1.0300E-02	1	1	1
8.7700E+06	0.0000E+00	0.0000E+00	4.9900E-02	1.1500E-02	1.1500E-02	1	1	1
8.9800E+06	0.0000E+00	0.0000E+00	4.0300E-02	9.3000E-03	9.3000E-03	1	1	1
9.2000E+06	0.0000E+00	0.0000E+00	5.1200E-02	1.1800E-02	1.1800E-02	1	1	1
9.4100E+06	0.0000E+00	0.0000E+00	4.9800E-02	1.1500E-02	1.1500E-02	1	1	1
9.6300E+06	0.0000E+00	0.0000E+00	5.0200E-02	1.1600E-02	1.1600E-02	1	1	1
9.8400E+06	0.0000E+00	0.0000E+00	5.1300E-02	1.1800E-02	1.1800E-02	1	1	1
1.0060E+07	0.0000E+00	0.0000E+00	6.2700E-02	1.4400E-02	1.4400E-02	1	1	1
1.0270E+07	0.0000E+00	0.0000E+00	5.9200E-02	1.3600E-02	1.3600E-02	1	1	1
ENDPHYSENT								199999999
ENDREQUEST								9999999999999

↑
COMPUTATIONAL (TABLE) FORMAT

Plot for $^{65}\text{Cu}(\text{n},\text{p})$

Comparison of experimental data with evaluation from CENDL-2



ENDF (Evaluated Nuclear Data File)

- ENDF-6: internationally agreed format for evaluated nuclear reaction data (and related decay data). Used for major libraries ENDF/B-VI, JEF, BROND, JENDL, CENDL, and others
- ENDF/B-VI: Version 6 of the U.S. nuclear data library and released by NNDC Brookhaven
 - Contents: for summary see report IAEA-NDS-100
 - Format Manual: IAEA-NDS-76 Rev.5 (1997) (=BNL-NCS-44945=ENDF-102)
 - Summary documentation of evaluations: BNL-NCS-17541, 4th ed. (=ENDF-201), 1991, with supplement (1996)

ENDF/B-VI Library Organization

- | | |
|---|--|
| <ul style="list-style-type: none">• ENDF/B-VI General Purpose Library (neutron data 0-20 MeV, 320 materials from ^1H to ^{99}Es. <i>Sept. 1999 update: some materials extended to 150 MeV</i>)<ul style="list-style-type: none">– Basic file– 300 K point data file (Resonance parameters converted to cross sections)• Subfiles for <i>Standards, Dosimetry, Neutron activation, Fission products cs data, Actinides cs data</i> are included in General Purpose file but are available separately | <ul style="list-style-type: none">• Other sublibraries for:<ul style="list-style-type: none">– Incident charged particles (<i>Additional materials added to proton sublibrary in Sept. 1999 update</i>)– Decay data– Photo-atomic interaction– Thermal scattering law data– Fission product yields (neutron-induced and spontaneous)– High-energy (up to 1 GeV), incident neutrons and protons, few materials only• Kept separately, to be requested separately (partly integrated in online service) |
|---|--|

Access to major ENDF libraries

- Major libraries ENDF/B-VI, JEF, BROND, JENDL, CENDL available online through Telnet and WWW (interactive, retrieval by material, reaction and data type, energy)
- Various utilities for file handling, plotting, pre-processing: ENDF *Pre-Processing Codes* and *Utility Codes*, available for downloading
- CD-ROM (libraries and codes), only from IAEA (*WINENDF*)
- Output:
 - ENDF-format (all definitions coded with numerical flags)
 - Table format and plots available online

ENDF File Structure

- “Sublibrary” determines incident particle and basic data type (neutron data, proton data, decay data,...)
- Hierarchical file organization:
 - “Tape” (Unit of data release, full sublibrary or update)
 - Material (MAT number, up to 4 digits)
 - File (MF number): Data category
 - Section (Reaction Type, MT number).

File numbers (MF):

1=General information
2=Resonance parameters
3=reaction cs
4=angular distributions
5=energy distributions
6=energy-angular distributions
8=decay data
etc.

Reaction Type numbers (MT):

1=total cs
16=(z,2n) cs (z=projectile dep. on sublibrary)
102=(z, γ) cs
103=(z,p) cs
etc.

ENDF-6 format ("File 3" = cross sections)

Mass

various flags

2.605600+4	5.545400+1	0	0	0	02631	3103	1
-2.913000+6	-2.913000+6	0	0	3	492631	3103	2
2	2	12	4	49	22631	3103	3
2.965500+6	0.000000+0	3.000000+6	7.001900-9	4.000000+6	6.001600-6	2631	3103
4.250000+6	3.201000-5	4.500000+6	1.403800-4	4.600000+6	2.406500-4	2631	3103
4.800000+6	5.775600-4	5.000000+6	1.069500-3	5.250000+6	2.294100-3	2631	3103
5.500000+6	4.798200-3	5.750000+6	8.479100-3	6.000000+6	1.273100-2	2631	3103
6.200000+6	1.645300-2	6.400000+6	1.917500-2	6.600000+6	2.375600-2	2631	3103
6.800000+6	2.758300-2	7.000000+6	2.728100-2	7.500000+6	3.534700-2	2631	3103
8.000000+6	4.173200-2	8.500000+6	4.767000-2	9.000000+6	5.514500-2	2631	3103
9.500000+6	5.907100-2	1.000000+7	6.690700-2	1.050000+7	7.572400-2	2631	3103
1.100000+7	8.241000-2	1.150000+7	9.069500-2	1.200000+7	1.033500-2	2631	3103
1.220000+7	1.056500-1	1.240000+7	1.093000-1	1.260000+7	1.116300-2	2631	3103
1.280000+7	1.143600-1	1.300000+7	1.152300-1	1.340000+7	1.169200-2	2631	3103
1.380000+7	1.166700-1	1.420000+7	1.135900-1	1.460000+7	1.093400-2	2631	3103
1.500000+7	1.042200-1	1.550000+7	9.512100-2	1.600000+7	8.625100-2	2631	3103

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MAT
File No.
Reaction Type No.

Library 300 K, ENDF/B-VI
 Projectile Neutron projectile
 Target 26-Fe-56
 Reaction MT = 103 (n,p)
 Quantity MF = 3 Reaction Cross Section
 Q-value = -2.9130 MeV

Retrieved energy range is 2.9655 to 150.0 MeV.

Average cross section = 6.956 millibarns
 Average 1/E weighted cross section = 20.25 millibarns

Energy MeV	Sigma Barns	Energy MeV	Sigma Barns	Energy MeV	Sigma Barns
2.9655	0.00000E+00	3.0000	7.00190E-09	4.0000	6.00160E-06
4.2500	3.20100E-05	4.5000	1.40380E-04	4.6000	2.40650E-04
4.8000	5.77560E-04	5.0000	1.06950E-03	5.2500	2.29410E-03
5.5000	4.79820E-03	5.7500	8.47910E-03	6.0000	1.27310E-02
6.2000	1.64530E-02	6.4000	1.91750E-02	6.6000	2.37560E-02
6.8000	2.75830E-02	7.0000	2.72810E-02	7.5000	3.53470E-02
8.0000	4.17320E-02	8.5000	4.76700E-02	9.0000	5.51450E-02
9.5000	5.90710E-02	10.000	6.69070E-02	10.500	7.57240E-02
11.000	8.24100E-02	11.500	9.06950E-02	12.000	0.10335
12.200	0.10565	12.400	0.10930	12.600	0.11163
12.800	0.11436	13.000	0.11523	13.400	0.11692
13.800	0.11667	14.200	0.11359	14.600	0.10934
15.000	0.10422	15.500	9.51210E-02	16.000	8.62510E-02
16.500	7.97880E-02	17.000	7.16250E-02	17.500	6.62760E-02
18.000	6.12960E-02	18.500	5.68120E-02	19.000	5.26480E-02
19.500	5.09680E-02	20.000	5.05530E-02	20.000	0.00000E+00
150.00	0.00000E+00				

Same data in "Narrow Table" format

FENDL-2 (Fusion Evaluated Nuclear Data Library)

- Result of worldwide effort coordinated by IAEA
- Aimed at fusion applications (ITER project)
- Extensively tested, therefore recommended also for other applications
- Sublibraries:
 - FENDL-E/2.0: Transport: n-interactions, γ -production for 57 nuclides; photon-atom interactions for 34 elements; basic data as well as processed data for MCNP and multigroup calcs
 - FENDL/A-2.0: Activation (636 nuclides, 11000 reactions)
 - FENDL-C-2.0: Fusion (light charged-particle fusion reactions)
 - FENDL/D-2.0: Decay data for 2900 nuclides
 - FENDL/DS-2.0: Neutron activation reactions from IRDF-90
- Available for downloading from IAEA web pages and on CD-ROM
 - 47 directories, 810 files, 1 Gbyte data

MENDL-2 and MENDL2-P (Medium Energy Nuclear Data Library)

- Libraries for activation and transmutation (formation of radioactive product nuclides) at intermediate energies, for 505 stable and unstable target nuclides between ^{26}Al and ^{210}Po , by Shubin et al., Obninsk, Russia
- Based largely on calculations
- MENDL-2: Neutron-induced reactions up to 100 MeV, altogether 57500 reactions
- MENDL2-P: Proton-induced reactions up to 200 MeV, altogether 87000 reactions
- Available by FTP or off-line

RIPL (Reference Input Parameter Library for Nuclear Model Calculations)

- Result of IAEA coordinated project
- Input parameters for theoretical calculations of nuclear reaction cross sections
- Contents:
 - Atomic masses and deformations
 - Discrete level schemes
 - Average neutron resonance parameters
 - Optical model parameters
 - Level densities
 - Gamma-ray strength functions
 - Continuum angular distributions
- Available for downloading from IAEA web pages and on CD-ROM. Description available also as a handbook (IAEA-TECDOC-1034)

X-ray (Photo-atomic) Cross-Section and Attenuation Data

- Several databases with different user interfaces, partly identical data (mostly based on work by J.H. Hubbell et al., N.I.S.T., USA)
 - “**XCOM**” (Photon cross sections 1 keV - 100 GeV) and “**X-ray Form Factors, Attenuation and Scattering Tables**” (up to 1 MeV), N.I.S.T. web server <http://physics.nist.gov/PhysRefData/contents-xray.html>
 - **EPDL97** (Evaluated Photon Data Library, 1 eV - 100 GeV), Livermore Nat.Lab, USA (available on CD-ROM from IAEA)
 - “**XRAY**” and “**POLSCAT**” modules of IAEA Telnet service (1 keV - 100 GeV)
 - **ENDF/B-VI Photo-Atomic Interaction Library** (10 eV - 100 MeV) (WWW)
 - **JEFF-2/Photo-Atomic Interaction Library** (10 eV - 100 MeV)
 - **XMuDAt**: Photon attenuation data on PC. Mass attenuation, mass energy-transfer, mass energy-absorption coefficients for photons between 1 keV and 50 MeV. Program by R. Nowotny (Univ. Vienna), data sources: Boone and Chavez (1996), Hubble and Seltzer (1995). Diskettes or downloading from WWW

Some other useful data...

- *X-ray and gamma-ray standards* for detector calibration (1991). Handbook IEA-TECDOC-619, diskette, WWW under <http://www.nts-ltd.demon.co.uk/IAEA/menu619.htm>
- *Thermal neutron capture gammas*: spectra by target or by energy, available from WWW
- *NGAtlas*: Neutron capture cross sections from 10^{-5} to 20 MeV compiled from various evaluations, by Kopecky et al. Tables (WWW) and graphs (handbook INDC(NDS)-362) Graphs available online through K.A.E.R.I. webserver under <http://hpngp01.kaeri.re.kr/CoN/index.html>
- *QCALC*: Utility for calculation of Q values and reaction threshold energies (Telnet)
- *ESTAR, PSTAR, ASTAR*: PC package for calculating stopping powers and ranges of electrons, protons and helium ions, by M.J. Berger (N.I.S.T., USA), 1993. Available on diskette

Kerma factors

- | | |
|--|---|
| <ul style="list-style-type: none"> • Effect of fast neutrons in matter: through charged particles produced. • 2 steps: <ul style="list-style-type: none"> – Initial production of charged particles by neutron interactions
Kerma = Kinetic Energy Released in MATter – Subsequent interaction of these charged particles with matter (ionization, excitation):
Absorbed dose • Kerma factor (coefficient) = kerma produced per unit neutron fluence • Unit: Gy · m² | <ul style="list-style-type: none"> • Not included in nuclear data libraries • Calculated from (evaluated) cross section data (e.g. ENDF) e.g. with NJOY (Los Alamos processing code) • References: see e.g. <ul style="list-style-type: none"> – "Nuclear data for neutron therapy: Status and future needs", IAEA-TECDOC-992 (Dec.1997), chapter 6 – M.B. Chadwick et al., A consistent set of neutron kerma coefficients from thermal to 150 MeV for biologically important materials, Med.Phys. 26, 974 (1999) |
|--|---|

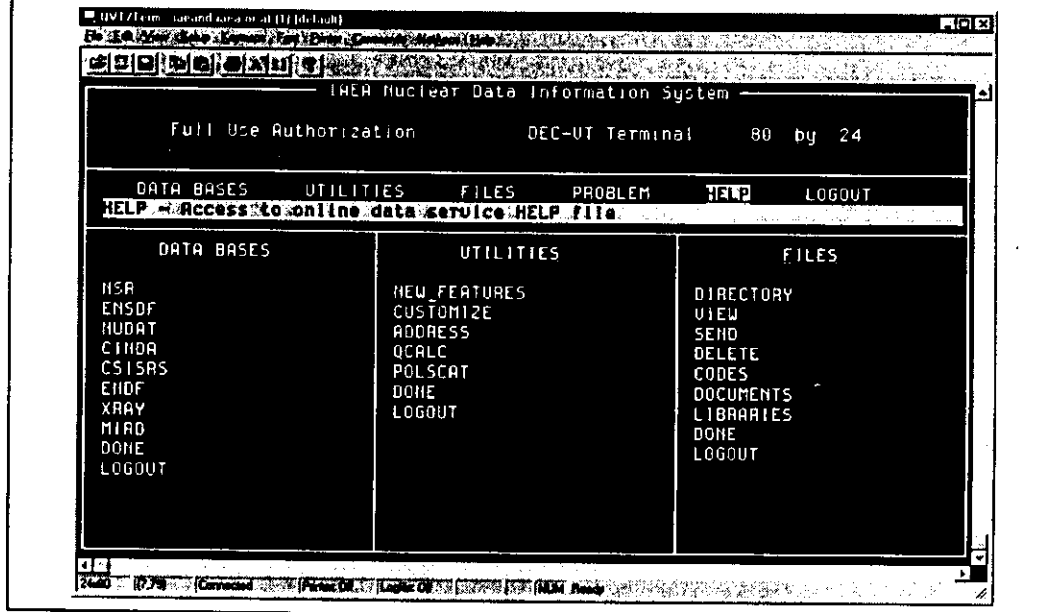
4. Data Access

- WWW (Worldwide Web)
 - *IAEA Nuclear Data Services* homepage:
<http://www-nds.iaea.or.at>
Software: Web browser; recommended: Adobe Acrobat Reader (for PDF files), GhostScript/GhostView (for PostScript documents)
 - General IAEA homepage:
<http://www.iaea.org> “Worldatom”
<http://www.iaea.org/tecatom.html> “Tecatome”

Telnet: NDIS (*Nuclear Data Information System*)

- Remote login to IAEA-NDS computer
Access dialog:
telnet iaeand.iaea.or.at
iaeands (*username*)
guest (*or authorization code*)
y (*for ANSI type terminal*), then follow menu
- Telnet program: start directly from PC, or through your Web browser (follow link from *Nuclear Data Services* homepage)
Highly recommended: Use VT Terminal Emulator such as *QVT/Term*, for convenient usage
- NDIS = the IAEA's first online service (since 1992).
Interactive access to main databases, files, programs and utilities
- Reason for using NDIS:
 - Still some unique features not yet available through WWW
(Full ENSDF and NSR functionality, QCALC (Q-values), Address database)
 - Technical alternative to WWW

Telnet service NDIS: Starting screen



FTP (Internet file transfer)

- Command: `ftp iaeand.iaea.or.at`
- IAEA-NDS keeps several FTP accounts requiring no password:
 - ANONYMOUS contains several complete libraries and utility codes
 - FENDL2 contains FENDL-2 files
 - RIPL contains RIPL files
 - NDSONL contains files saved by NDIS users
 - NDSOPEN for bilateral file exchange

Off-line

- Data on tape, CD-ROM, diskette, hardcopy
- Customized retrievals, questions
- e-mail:
services@iaeand.iaea.or.at for data requests,
online@iaeand.iaea.or.at for questions on online services, or
schwerer@iaeand.iaea.or.at
- Fax: +43-1-26007
- Mail:
Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100
A-1400 Vienna, Austria

Alternative entry points

- Same basic data are available online (or on CD-ROM) from various sources
- Possible reasons for using alternative sources:
 - Better network connection to your location
 - Different user interface
- Possible problems:
 - Sources from outside the *Data Centers Networks* may not always be fully up-to-date
 - Some products available only commercially

Alternative entry points: Examples

- **U.S. National Nuclear Data Center (NNDC)**
<http://www.nndc.bnl.gov>
Close cooperation with IAEA-NDS, similar WWW and Telnet services
- **Isotope Explorer**
Software for interactive access and display of ENSDF data, from Lawrence Berkeley National Lab.(USA) and Lund Univ.(Sweden)
<http://ie.lbl.gov/isoexpl/isoexpl.htm> (Windows version)
<http://www.pixe.lth.se/ensdf/> (New experim.version without installation)
- **K.A.E.R.I. Table of Nuclides** (Korea Atomic Energy Res.Inst.)
Basic nuclear properties and cross sections
<http://hpngp01.kaeri.re.kr/CoN/index.html>
- **T-2 Information Service**, Los Alamos, USA
Nuclear Data Viewer and other services
<http://t2.lanl.gov/data/data.html>

How to reference the data

- Data obtained from databases of the Nuclear Data Centers Networks should be properly cited
- Citation should include
 - original source of information and
 - database from which data were extracted (which may contain essential information not existing in a published article)
- Example: How to cite the MENDL-2 library
 - Yu.N. Shubin, V.P. Lunev, A.Yu. Konobeyev, A.I. Ditjuk, "Cross-section data library MENDL-2 to study activation as transmutation of materials irradiated by nucleons of intermediate energies", report INDC(CCP)-385 (International Atomic Energy Agency, May 1995). Data library MENDL-2 received from the IAEA Nuclear Data Section
- Detailed citation guidelines for data retrieved online:
 - V. McLane, Citation Guidelines for Nuclear Data Retrieved from Databases Resident at the Nuclear Data Centers Network, Report BNL-NCS-63381 (July 1996). Available online in PostScript from <http://www-nds.iaea.or.at/ndspub/documents/online/>

5. Conclusion

- Most important nuclear databases for medical applications:
 - Nuclear Wallet Cards, NUDAT, MIRD, ENSDF, ENDF, EXFOR, MENDL-2,...
 - Add your favorites!
- Starting point for nuclear data searches:
IAEA Nuclear Data Services, <http://www-nds.iaea.or.at>
 - Most complete collection of nuclear data libraries with documentations published in *IAEA-NDS*- report series
 - Online services (WWW, Telnet service "NDIS", FTP)
 - Customized retrievals and off-line data service available cost-free on request
- Data requests and feedback: e-mail to services@iaeaand.iaea.or.at

The Vienna International Centre (IAEA headquarters)



