

Introduction to IAEA Nuclear Data Services



*Workshop on Nuclear Data for Science and Technology:
Medical Applications*

Trieste, 12 – 23 November 2007

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1.1 The Mission of NDS

The IAEA Nuclear Data Section (NDS)

- provides nuclear data services to scientists worldwide (data libraries, bibliographies and related materials) through Internet, CD-ROM and other media
- produces new databases through its data development programme
- assists developing countries through technology transfer activities



Data Center Activities

- Compilation
 - Compile new data in EXFOR and CINDA
 - Keep master files in cooperation with other centers
 - Collect evaluated and specialized libraries for users
- Online and Off-line data services with particular emphasis on meeting the needs of developing countries
- Data Center Network Co-ordination



Data Development Activities

- Main mechanism: *Co-ordinated Research Projects (CRPs)*
 - 5-15 participating groups, duration 3-4 years
 - Research contracts, research agreements
 - Research co-ordination meetings
 - Objectives: new or upgraded database
 - Results (data and documentation) made available (TECDOC, Web, CD-ROM)
- Smaller, less formal: *Data Development Projects*



Recent Coordinated Research Projects

Short Title	Duration	Participants
Nuclear data for Th-U cycle	2002-2006	13
Standard Cross Sections for Light Elem.	2002-2006	9
N.D.for prod.of therapeutic radionuclides	2002-2006	8
Param.f.Calcul.of Nucl.Reactions Relevant for Non-Energy Applications(RIPL-III)	2003-2007	10
Reference Database for Neutron Activation Analysis	2005-2008	12
Updated Decay Data Library for Actinides	2005-2008	8
Reference Database for Ion Beam Analysis	2005-2009	10
Eval. Nuclear Data Files of Charged Particle Interactions for Medical Therapy Applications	2007-2010	15
Minor Actinide Neutron Reaction Data (MANREAD)	2007-2011	11



Technology Transfer Activities

- **“Mirror servers” for Nuclear Data Services**
 - IPEN, Sao Paulo, Brazil
 - BARC, Mumbai, India
- **Workshops at ICTP (since 1978)**
 - “Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety” (bi-annually until 2004)
 - “Nuclear Data for Science and Technology”
 - ◆ 1999, 2007: Medical Applications
 - ◆ 2001: Accelerator Driven Waste Incineration
 - ◆ 2003: Materials analysis
 - ◆ 2005: Activation analysis
 - “Nuclear Structure and Decay Data: Theory and Evaluation” (2003, 2005, 2006, 2008)
- **Occasionally small workshops at IAEA Vienna**



Atomic and Molecular Data Unit

- Databases for fusion energy and other plasma research and other applications
- Additional CRPs
- Separate database server (AMDIS)
 - Numerical data: ALADDIN
 - Bibliographic data: AMBDAS
- Publications, e.g. *Bulletin on A+M Data for Fusion*
- Separate activity under NDS organizational unit



1.2 What is “nuclear data”?

- *Quantitative* results of any scientific investigation of the nuclear properties of matter: nuclear physics data, or “nuclear constants”.
- ***Examples:*** cross sections, half-lives, decay modes and decay radiation properties, γ -rays from 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 Types

- **Bibliographic data**
(e.g. CINDA, NSR)
- **Experimental data**
(e.g. EXFOR)
- **Evaluated data**
(e.g. ENDF)
- **Nuclear reaction data**
(e.g. EXFOR, ENDF)
- **Nuclear structure and decay data**
(e.g. ENSDF)



1.3 Data center networks

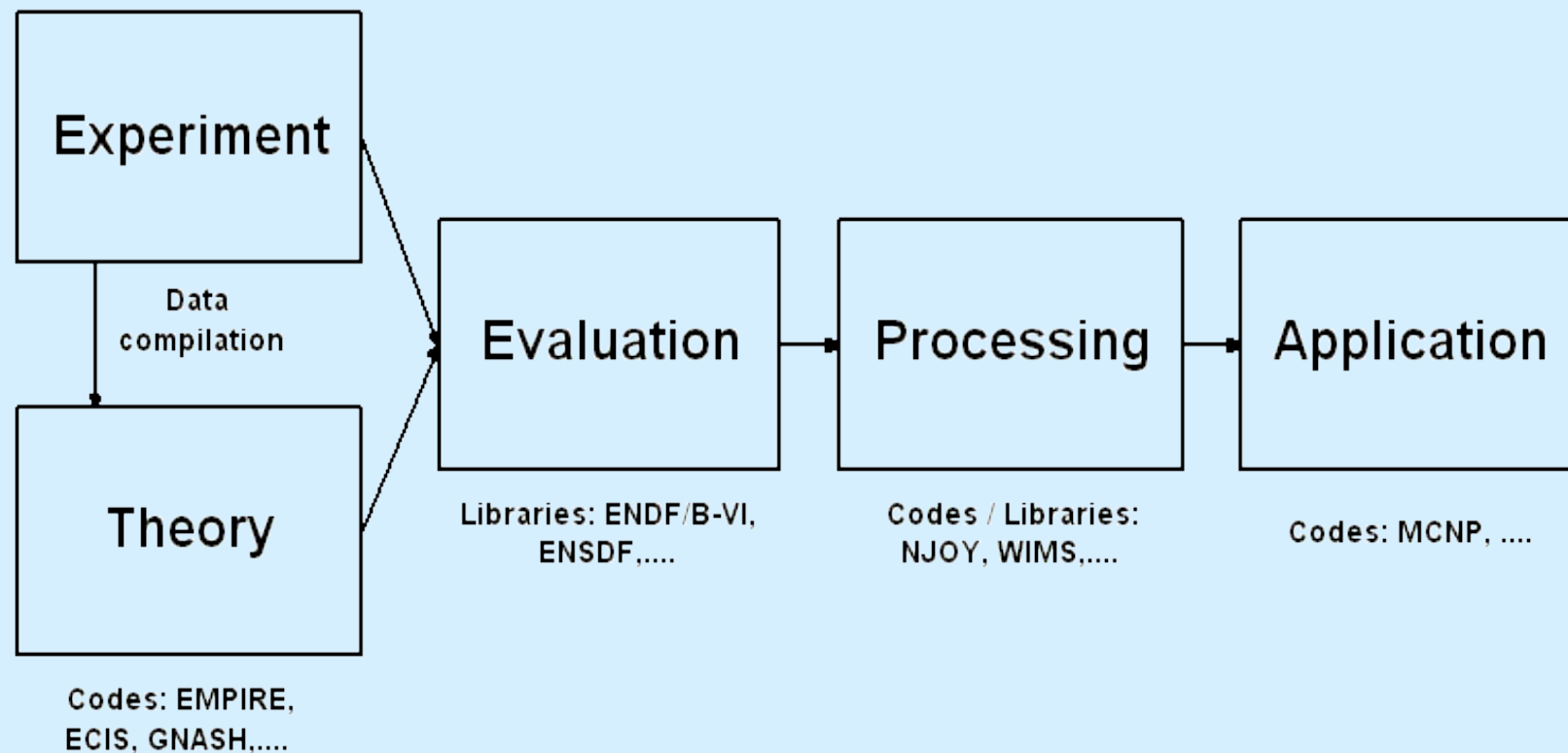
Nuclear data centers:

- 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 Center Networks

- **Network of 13 Nuclear Reaction Data Centers**
 - 4 “core centers”:
 - ◆ IAEA Nuclear Data Section, Vienna
 - ◆ OECD NEA Data Bank, Paris, France
 - ◆ U.S. National Nuclear Data Center, Brookhaven, USA
 - ◆ Russia Nuclear Data Center, Obninsk, Russia
 - Expanded network includes additional co-operating specialized centers in Russia, China, Japan, Hungary, Korea, and Ukraine
- **Nuclear Structure Data Centers Network**
 - IAEA Nuclear Data Section, Vienna (Co-ordination)
 - U.S. National Nuclear Data Center, Brookhaven, USA (Master database)
 - 14 data evaluation centers in USA, Russia, China, France, Japan, Kuwait, Belgium, Canada, India, Australia
 - Data dissemination centers (IAEA, OECD-NEA, USA, France)



2. Overview of libraries and databases

- Most comprehensive collection of nuclear data libraries worldwide - enormous value
- All data available free of charge to scientists in IAEA member states, on informal request or by Internet
- Overview:
 - “Index of Nuclear Data Libraries available from the IAEA Nuclear Data Section”, Report IAEA-NDS-7, ed. by O. Schwerer (July 2007)
see also
<http://www-nds.iaea.org/reports/nds-7.pdf>
- Brief documentations of contents and/or format for many libraries are published in the **IAEA-NDS-** report series (some reports and index IAEA-NDS-0 available also online)



2.1 General Purpose Libraries

- Nuclear Wallet Cards
- NUDAT
- MIRD
- ENSDF
- NSR
- CINDA
- EXFOR
- ENDF



Nuclear Wallet Cards

- Basic properties of ground and metastable states
- Available in several formats:
 - Pocket booklet
 - WWW: (display of tables for each element)
 - WWW as part of NUDAT (interactive retrievals by various criteria)

NUCLEAR WALLET CARDS

April 2005

Jagdish K. Tuli

**National Nuclear
Data Center**

www.nndc.bnl.gov

**Brookhaven National Laboratory
P.O. Box 5000
Upton, New York 11973-5000
U.S.A.**

Results for Z=26

Nucleus	E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Abundance	Decay Modes
⁴⁵ ₂₆ Fe	0.0000	(3/2+)	13.5790 Syst	3.8 ms +20-8		2p
⁴⁶ ₂₆ Fe	0.0000	0+	0.7550 Syst	12 ms +4-3		
⁴⁷ ₂₆ Fe	0.0000		-6.6230 Syst	21.8 ms 7		ϵ : 100.00 % sp
⁴⁸ ₂₆ Fe	0.0000	0+	-18.1600 Syst	44 ms 7		ϵ : 100.00 % sp > 3.60 %
⁴⁹ ₂₆ Fe	0.0000	(7/2-)	-24.5820 Syst	70 ms 3		ϵ : 100.00 % sp \geq 52.00 %
⁵⁰ ₂₆ Fe	0.0000	0+	-34.4755	155 ms 11		ϵ : 100.00 % sp \approx 0.00 %
⁵¹ ₂₆ Fe	0.0000	5/2-	-40.2223	305 ms 5		ϵ : 100.00 %
⁵² ₂₆ Fe	0.0000	0+	-48.3316	8.275 h 8		ϵ : 100.00 %
^{52m} ₂₆ Fe	6.8200	(12+)	-41.5116	45.9 s 6		ϵ : 100.00 %
⁵³ ₂₆ Fe	0.0000	7/2-	-50.9453	8.51 m 2		ϵ : 100.00 %
^{53m} ₂₆ Fe	3.0404	19/2-	-47.9049	2.526 m 24		IT : 100.00 %
⁵⁴ ₂₆ Fe	0.0000	0+	-56.2525	STABLE	5.845% 35	
⁵⁵ ₂₆ Fe	0.0000	3/2-	-57.4794	2.737 y 11		ϵ : 100.00 %
⁵⁶ ₂₆ Fe	0.0000	0+	-60.6054	STABLE	91.754% 36	
⁵⁷ ₂₆ Fe	0.0000	1/2-	-60.1801	STABLE	2.119% 10	
⁵⁸ ₂₆ Fe	0.0000	0+	-62.1534	STABLE	0.282% 4	
⁵⁹ ₂₆ Fe	0.0000	3/2-	-60.6631	44.495 d 9		β^- : 100.00 %
⁶⁰ ₂₆ Fe	0.0000	0+	-61.4118	1.5E+6 y 3		β^- : 100.00 %
⁶¹ ₂₆ Fe	0.0000	3/2-, 5/2-	-58.9214	5.98 m 6		β^- : 100.00 %
⁶² ₂₆ Fe	0.0000	0+	-58.9007	68 s 2		β^- : 100.00 %

Wallet Cards

Z=26



NUDAT

- User-friendly extract of most important data (for applications) from ENSDF, plus thermal neutron data (cross sections and resonance integrals)
- 3 main search modes:
 - Levels and Gammas
 - “Wallet Cards” (properties of ground and metastable states, neutron resonances and thermal cross sections)
 - Decay Radiations
- Available online (new user interface)
Interactive retrievals by various criteria



NUDAT

Levels and
Gammas

Search Screen



NUDAT Gamma information for ^{60}Ni

Levels Results - Microsoft Internet Explorer provided by IAEA

File Edit View Favorites Tools Help



Address http://www.nndc.bnl.gov/nudat2/adopted_searchi.jsp

Gamma Information

Nucleus	$E_{\text{level}}(\text{keV})$	J^{π}	$T_{1/2}$	$E_{\gamma}(\text{keV})$	I_{γ}	γ mult.	γ mix. ratio	γ conv. coeff.
60Ni	1332.518 5	2+	0.91 ps 2	1332.501 5	100	(E2)		
60Ni	2158.64 3	2+	0.59 ps 17	826.06 3	100.0 24	D+Q	+0.9 3	
60Ni	2158.64 3	2+	0.59 ps 17	2158.57 10	17.6 24	(E2)		
60Ni	2284.87 14	0+	> 1.5 ps	952.4 2	100			
60Ni	2284.87 14	0+	> 1.5 ps	2284.87		E0		
60Ni	2505.766 7	4+	3.3 ps 10	346.93 7	0.0076 5			
60Ni	2505.766 7	4+	3.3 ps 10	1173.237 4	100.00 2	E2(+M3)	-0.0025 22	
60Ni	2505.766 7	4+	3.3 ps 10	2505.766 7	2.0E-6 4	[E4]		
60Ni	2626.08 10	3+	\approx 0.6 ps	120.5 3	5.5 5			
60Ni	2626.08 10	3+	\approx 0.6 ps	467.3 2	100 5	D(+Q)	+0.02 +11-27	
60Ni	2626.08 10	3+	\approx 0.6 ps	1293.7 2	53 5			
60Ni	3119.70 9	4+	0.24 ps 10	493.90 20	8.7 22			
60Ni	3119.70 9	4+	0.24 ps 10	1787.20 10	100.0 22	Q(+O)	-0.16 +50-20	
60Ni	3124.02 13	2+	> 0.6 ps	497.9 2	3.68 20			
60Ni	3124.02 13	2+	> 0.6 ps	839.2 4	1.01 16			
60Ni	3124.02 13	2+	> 0.6 ps	965.2 3	0.66 14			
60Ni	3124.02 13	2+	> 0.6 ps	1791.6 3	100 5	D+Q	-0.21 4	
60Ni	3124.02 13	2+	> 0.6 ps	3124.1 3	10.5 6			
60Ni	3186.02 7	2+,3+	0.14 ps 4	680.30 15	86 14			
60Ni	3186.02 7	2+,3+	0.14 ps 4	1027.33 8	100 14			
60Ni	3186.02 7	2+,3+	0.14 ps 4	1853.8 3	92 14			
60Ni	3194.02 13	1+	53 fs 14	909.2 2	42.6 19			
60Ni	3194.02 13	1+	53 fs 14	1035.2 2	78 4			
60Ni	3194.02 13	1+	53 fs 14	1861.6 3	100 6			
60Ni	3194.02 13	1+	53 fs 14	3194.1 3	42.6 19			
60Ni	3269.38 16	2+	71 fs 21	643.2 3	44.0 24			



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

File Edit View Favorites Tools Help



Address http://www.nndc.bnl.gov/nudat2/sigma_searchi.jsp

Nucleus	E(level) (MeV)	J π	Δ (MeV)	$T_{1/2}$	Abundance	Decay Modes
$^{31}_{9}\text{F}$	0.0000		56.2890 Syst	> 250 ns		β^- β^-n
$^{34}_{10}\text{Ne}$	0.0000	0+	53.1210 Syst	> 60 ns		β^-n β^-
$^{37}_{11}\text{Na}$	0.0000		55.2750 Syst	> 60 ns		β^- β^-n
$^{37}_{12}\text{Mg}$	0.0000	(7/2-)	29.2490 Syst	> 260 ns		β^- : 100.00 % β^-n
$^{38}_{12}\text{Mg}$		0+	34.9960 Syst	> 260 ns		β^- ?
$^{40}_{13}\text{Al}$	0.0000		29.2950 Syst	> 260 ns		β^-n β^-
$^{30}_{14}\text{Si}$	0.0000	0+	-24.4329	STABLE	3.087% 5	
$^{31}_{14}\text{Si}$	0.0000	3/2+	-22.9490	157.3 m 3		β^- : 100.00 %
$^{32}_{14}\text{Si}$	0.0000	0+	-24.0800	153 y 19		β^- : 100.00 %
$^{38}_{14}\text{Si}$	0.0000	0+	-4.0673	> 1 μs		β^- : 100.00 % β^-n
$^{30}_{15}\text{P}$	0.0000	1+	-20.2006	2.498 m 4		ϵ : 100.00 %
$^{31}_{15}\text{P}$	0.0000	1/2+	-24.4409	STABLE		
$^{32}_{15}\text{P}$	0.0000	1+	-24.3052	14.262 d 14		β^- : 100.00 %
$^{33}_{15}\text{P}$	0.0000	1/2+	-26.3375	25.34 d 12		β^- : 100.00 %
$^{32}_{16}\text{S}$	0.0000	0+	-26.0157	STABLE	95.02% 9	



NUDAT Decay Radiations for ^{240}Pu

Search parameters:
Nucleus: ^{240}Pu

Results:

Dataset #1:

Authors: E. BROWNE, J. K. TULI Citation: Nuclear Data Sheets 107, 2649 (2006)

Parent Nucleus	Parent E(level)	Parent J^π	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme
$^{240}_{94}\text{Pu}$	0.0	0+	6561 y 7	α : 100 %	5255.75 14	$^{236}_{92}\text{U}$	

Alphas:

Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
4217.3	3E-8 % 3	1.1E-9 11
4224.1	3E-8 % 3	1.1E-9 11
4226.1	5E-8 % 5	2.1E-9 21
4264.38 21	5.9E-7 % 7	2.5E-8 3
4436.4	1.3E-8 % 7	6E-10 3
4492.07 17	2.00E-5 % 10	9.0E-7 4
4654.69 16	4.6E-5 % 5	2.14E-6 23
4863.60 15	0.00106 % 3	5.16E-5 15
5021.23 15	0.084 % 3	0.00422 15
5123.68 23	27.10 % 10	1.389 5
5168.17 15	72.80 % 10	3.762 5

Electrons:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
Auger L	9.89	9.6 % 4	9.5E-4 4



MIRD - “Medical Internal Radiation Dose”

- Based on ENSDF, data processed with code “RADLST”. Input: only nuclide selection
- Output: Tables with intensities, energies and dose of all produced radiations, including X-rays, Auger electrons, etc., and decay scheme plots
- Output in HTML/GIF or PDF / PostScript
- 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 = 44.495 Days

Decay Mode(s): β^-

Apr-2002

RADIATIONS	y(i) (Bq·s) ⁻¹	E(i) (MeV)	y(i)×E(i)
β^- 1	7.80E-04	2.208E-02*	1.72E-05
β^- 2	1.31E-02	3.574E-02*	4.68E-04
β^- 3	4.53E-01	8.101E-02*	3.67E-02
β^- 4	5.31E-01	1.493E-01*	7.93E-02
β^- 5	1.80E-03	6.146E-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
γ 6	5.65E-01	1.099E+00	6.21E-01
ce-K, 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^\pm Radiations	1.19E+00
Listed β , ce and Auger Radiations	1.18E-01
Listed Radiations	1.31E+00

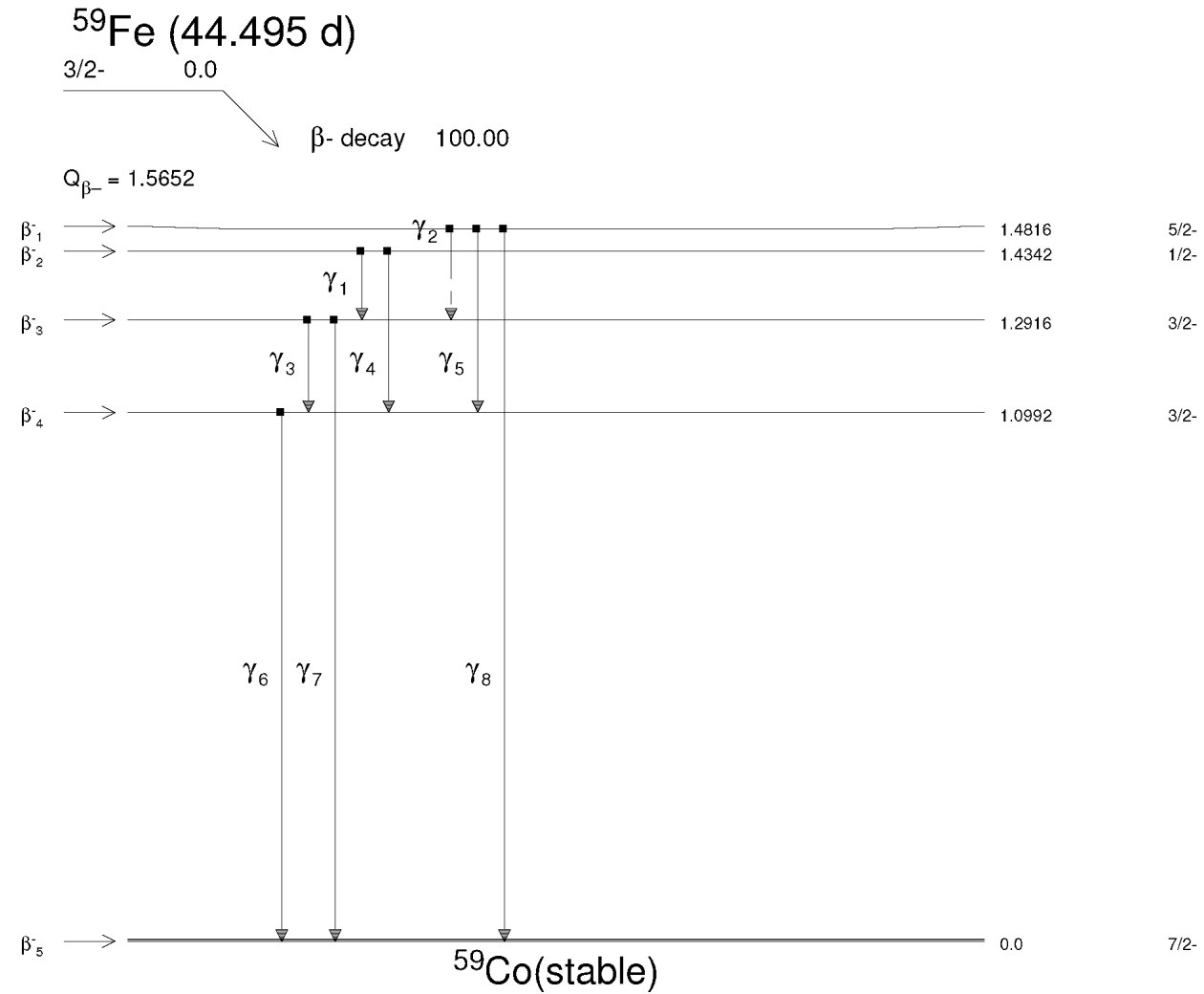
* Average Energy (MeV).

^a Maximum Energy (MeV) for subshell.

Cobalt-59 Daughter is stable.



**MIRD
Output
(“Medical
Internal
Radiation
Dose”)**





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 – 277 (~3000 nuclides)
- 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 (HTML, PDF)
- XUNDL: Experimental unevaluated data in ENSDF format



Evaluated Nuclear Structure Data File (ENSDF)

Evaluations published in
Nuclear Data Sheets

Bibliography: NSR
(Nuclear Science References)

ENSDF Analysis
and Utility
Programs

Derived or related databases

(with supplementary data
and/or special display software):

Nuclear Wallet Cards

NUDAT

MIRD

Table of Isotopes

NUBASE

Isotope Explorer

.....



ENSDF: Data sets for ^{82}Kr

Datasets for ^{82}Kr - Microsoft Internet Explorer provided by IAEA

File Edit View Favorites Tools Help



Address http://www.nndc.bnl.gov/ensdf/quicksrch_act.jsp

Go Links

Datasets for ^{82}Kr

Matching datasets in ENSDF:

<input type="checkbox"/>	^{82}Kr	ADOPTED LEVELS, GAMMAS	References
<input type="checkbox"/>		82SE 2B- DECAY	References
<input type="checkbox"/>		82BR B- DECAY (35.282 H)	References
<input type="checkbox"/>		82BR B- DECAY (6.13 M)	References
<input type="checkbox"/>		82RB B+ DECAY (1.273 M)	References
<input type="checkbox"/>		82RB B+ DECAY (6.472 H)	References
<input type="checkbox"/>		79BR(A,P)	References
<input type="checkbox"/>		80SE(A,2NG)	References
<input type="checkbox"/>		81BR(3HE,D)	References
<input type="checkbox"/>		82KR(P,P')	References
<input type="checkbox"/>		COULOMB EXCITATION	References
<input type="checkbox"/>		84KR(P,T)	References
<input type="checkbox"/>		(HI,XNG)	References

Get selected ENSDF datasets: [HTML](#) [Download](#) [View ENSDF](#)

Get all ENSDF datasets : [HTML](#) [Download](#) [View ENSDF](#)

[Reset](#)

[Main](#) [Nuclide](#) [Reaction](#) [Decay](#) [Browse](#) [Help](#)

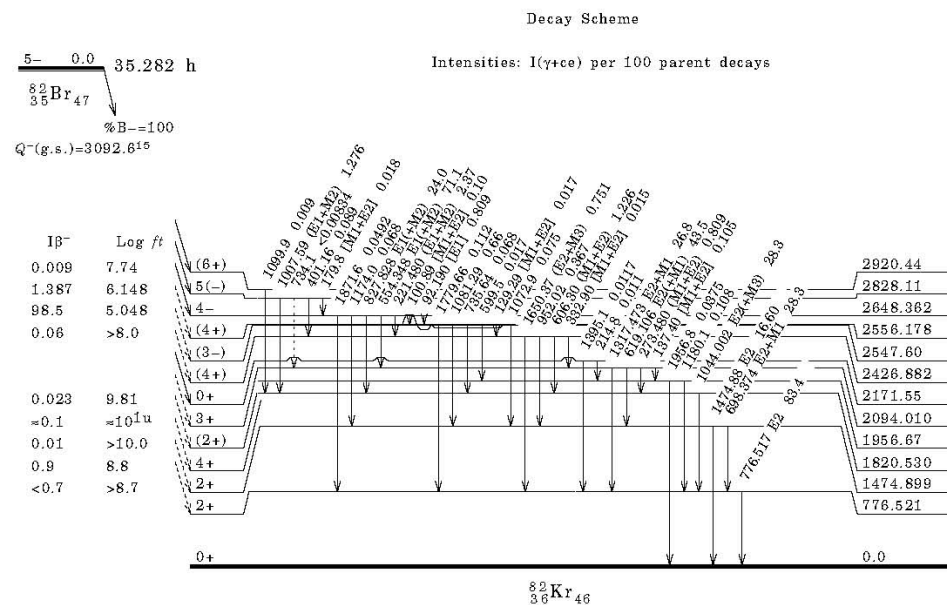


ENSDF Plot (^{82}Br β -decay)

$^{82}\text{Kr}_{46}$

$^{82}\text{Kr}_{46}$

^{82}Br β - Decay (35.282 h) 1994Go12,1983Me08





NSR (Nuclear Science References)

- **NSR** (*Nuclear Science References*, previously called *Nuclear Structure 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
 - Closely linked to ENSDF
 - Retrieval by nuclide, reaction, quantity, keywords, authors,...
 - Access by WWW



NSR retrieval (on author)

NSR Query Results - Microsoft Internet Explorer provided by IAEA

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Reload Print Mail News RSS Feeds

Address http://www.nndc.bnl.gov/nsr/fastsrch_act.jsp Go Links

NSR Query Results

Publication year range : 1910 to 2007
Primary references only.

Output year order : Descending
Format : Normal

NSR database version of November 9, 2007.

Search: Author = capote

Found 15 matches.

[Back to query form](#)

2007OK01

Phys.Rev. C 75, 034616 (2007)

N.T.Okumusoglu, F.Korkmaz Gorur, J.Birchall, E.Sh.Soukhovitskii, R.Capote, J.M.Quesada, S.Chiba

Angular distributions of protons scattered by ^{40}Ar nuclei with excitation of the 2^+ (1.46 MeV) and 3^- (3.68 MeV) collective levels for incident energies of 25.1, 32.5, and 40.7 MeV

NUCLEAR REACTIONS $^{40}\text{Ar}(p, p)$, (p, p') , $E=25.1, 32.5, 40.7$ MeV; measured $\sigma(E, \theta)$, $A_y(\theta)$. ^{40}Ar deduced deformation parameters. Isospin dependent soft-rotator coupled-channels optical model analysis.

doi: [10.1103/PhysRevC.75.034616](https://doi.org/10.1103/PhysRevC.75.034616)

2006SI23

Phys.Rev. C 74, 014608 (2006)



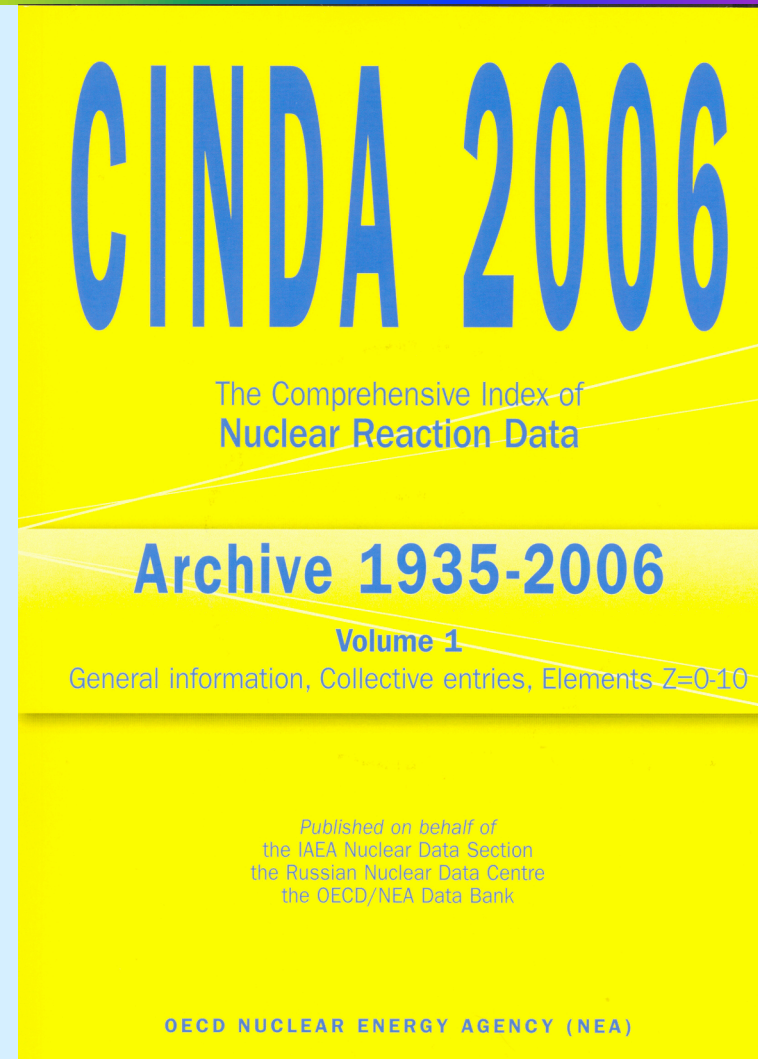
CINDA (Computer Index of Nuclear Reaction Data)

- Bibliography and index of nuclear reaction data
- 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”)
- Started in the 1950s as index of neutron data; only recently extended to charged-particle and photonuclear data



CINDA products and retrievals

- **CINDA book**
 - **Latest version:**
 - **Archive 1935-2006 (7 volumes)**
 - **Book comes with DVD (Data display program JANIS)**
- **Selective online retrievals**
- **WWW output with hyperlinks to EXFOR and electronic journals**





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

C4/Servlet Select - Microsoft Internet Explorer provided by IAEA

File Edit View Favorites Tools Help



Address <http://www-nds.iaea.org/exfor/servlet/C4sSearch5>

Request #27

CINDA Data Search Results: Reactions: 5; Lines: 79; Full Blocks:48

Go to Reaction:

- 1) 25-MN-55(N,P)24-CR-55, 3) 25-MN-55(N,P)24-CR-55,DA 5) 25-MN-55(N,P)24-CR-55,DAP
2) 25-MN-55(N,P)24-CR-55,CS 4) 25-MN-55(N,P)24-CR-55,DAE

Data Selection

Data for Output: ☐ Selected ☐ Unselected ☒ All

Output Formats: ☒ CINDA ☒ Bibliography ☐ EXFOR ☒ Show full CINDA-blocks

n Lab	iLn	Energy range,eV	Work Type	Reference	Date	[Author]	Comment	Display [NSR-Key]
<input checked="" type="radio"/> 1)	25-MN-55(N,P)24-CR-55,	OldQuantity=[NP]						
<input type="checkbox"/> 1	3ALGALG	1 1.5+07	Theo Jour	J,ARI,49,1497	199807	Belgaid+	SEMI-EMPIR SYSTEMAT.TBL SIG	L B .
<input type="checkbox"/> 2	3HUNKOS	1 1.5+07	Eval Rept	R,INDC(HUN)-032	199710	Doczi+	EVAL OF EXPTS.TBL RECOMM SIG	L B .
<input type="checkbox"/> 3	4RUSFEI	1 5.0+06 2.0+07	Theo Jour	J,YK,1995,(2),41	199604	Shubin+	OPTMOD CALC,CFD, GRPH	L B .
<input type="checkbox"/> 4	3VN IPH	1 1.4+07 1.5+07	Theo Jour	J,JRN/L,212,197	199602	Khien+	EMPIR FORMULA.TBL CFD EXP+OTH	L B . 1996KH06
<input type="checkbox"/> 5	3INDKUK	1 1.4+07	Theo Jour	J,IPA,33,256	199505	Bansal+	CALC SIG.TBL MODLS+EXPTS CFD	L B .
<input type="checkbox"/> 6	4RUSOIE	1 1.5+07	Theo Jour	J,NIM/B,103,15	1995	Konobeyev+	MDL CALC, CFD EXP, TBL	L B .
<input type="checkbox"/> 7	3INDKUK	1 3.0+06 2.0+07	Theo Jour	J,IJP/A,68,473	199409	Bansal+	SIG(E) ANAL.GRPH CALC CFD	L B .
<input type="checkbox"/> 8	2JPNTOK	1 2.2+07 3.9+07	Expt Jour	J,NSE,111,391	199208	Uwamino+	(N,P+ALF).GRPH EXCIT FUNCT	L B . 1992UW01
<input type="checkbox"/> 9		2 2.2+07 3.9+07	Expt Data	4,EXFOR22703.012	200110	.18 PTS	SIG N,P+A	L . X4
<input type="checkbox"/> 10	2GERDRE	1 Tr 2.5+07	Theo Prog	P,KFK-5079,44	199207	Eckstein+	EXCIFON CALC CFD OTHER EVAL	L B .
<input type="checkbox"/> 11	2JPNJAE	1 Tr 2.0+07	Eval Jour	J,NST,26,955	1989	Shibata.	H-F AND PREEQ CAL.NDG	L B . 1989SH31
<input type="checkbox"/> 12	2JPNKYU	1 Tr 2.0+07	Eval Conf	C,88MITO,,481	198805	Uenohara+	BAYESIAN METH+STAT CAL	L B .
<input type="checkbox"/> 13	3HUNKOS	1 1.3+07 1.5+07	Revw Book	B,OKAMOTO,261	198704	Boedy+	TBL:RECOMM SIG FOR ACT ANALYS	L B .
<input type="checkbox"/> 14	4CCPFEI	1 5.3+06 2.0+07	Eval Book	B,OKAMOTO,305	198704	Manokhin+	TBL+GRPH:SIG(E),ENDL/A-LIB	L B .
<input type="checkbox"/> 15	3INDTRM	1 1.0+07 5.0+07	Theo Prog	P,BARC-1297,3	1986	Garg.	ALICE CALC.NO DATA	L B .
<input type="checkbox"/> 16	1USALRL	1 Tr 2.0+07	Eval Data	3,INDL/V-2535	198506	.ENDF	FORMAT,ACTL-82 RENORMALIZED	L B .
<input type="checkbox"/> 17	2AUSIRK	1 0.0+00 3.0+07	Theo Conf	C,82ANTWER,,552	198209	Strohmaier+	OPT,CMFD NUCL,EXCITON MDL	L B .
<input type="checkbox"/> 18	3INDTRM	1 Tr 2.0+07	Eval Prog	P,BARC-1183,27	1982	Garg+	H-F+PRE-EQUIL EXCITON MDL.NDG	L B .
<input type="checkbox"/> 19	2NEDRCN	1 Tr 2.0+07	Comp Rept	R,ECN-104	198111	Zijp+	TOT GAS PROD. ENDFB4,620 GRPS	L B .
<input type="checkbox"/> 20	2GERJUL	1 3.0+07	Expt Conf	C,80BNL,,539	198007	Qaim+	ACT.CS VS ASSYM PAR GRPH.	L B .
<input type="checkbox"/> 21	3HUNKOS	1 1.4+07	Revw Conf	S,IAEA-223-199	197912	Csikai.	GRPH RANGE OF ACTIV-XPT DATA	L B .
<input type="checkbox"/> 22	3HUNKOS	1 1.3+07 1.6+07	Theo Jour	J,NP/A,319,(1),157	197904	Sudar+	H-F STATMDL COMPARED TO EXP	L B .
<input type="checkbox"/> 23		2 1.3+07 1.6+07	Theo Conf	C,78HARWELL,,755	197809	Sudar+	H-F CALCULATION CFD EXP.GRAPH	L . .
<input type="checkbox"/> 24	4CCPRI	1 +07	Theo Rept	R,YK-2(33)-47	1979	Trofimov+	E OF SIG-MAX,CFD EXPT.TABL	L B .
<input type="checkbox"/> 25	4CCPFEI	1 1.5+07	Eval Rept	R,YK-1(32),55	1979	Bychkov+	COMP+EVAL SIG(14.5MEV),TABL	L B .
<input type="checkbox"/> 26		2 1.4+07 1.5+07	Eval Rept	R,INDC(CCP)-146	198007	.PAGE 54.	ENGLISH OF YK-32,55	L . .
<input type="checkbox"/> 27	1USABNL	1 Tr 2.0+07	Theo Abst	A,BAP,21,536	197604	Mughabghab+	UHLE NUCLMDL CODE.CFD.NDG	L B .
<input type="checkbox"/> 28	4CCPKAZ	1 1.4+07 1.5+07	Theo Jour	J,YF,18,705	197310	Levkovskij.	AVERAGED SIG,CALC,TBL	L B . 1973LE31



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



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
- ~17000 experimental works, ~120 000 data tables



More on EXFOR

- Library contains numerical tables and structured abstract with experimental and bibliographic information
- Direct bibliographic link to CINDA
- 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
- Web retrieval interface improved continuously
- Two CD-ROM versions (same database, different retrieval software), developed by NDS
- Various output formats:
 - Standard format (EXchange FORmat)
 - Interpreted EXFOR
 - Bibliographic output
 - Computational (Table) formats for plotting etc.
 - Various plotting options



EXFOR “Standard” format

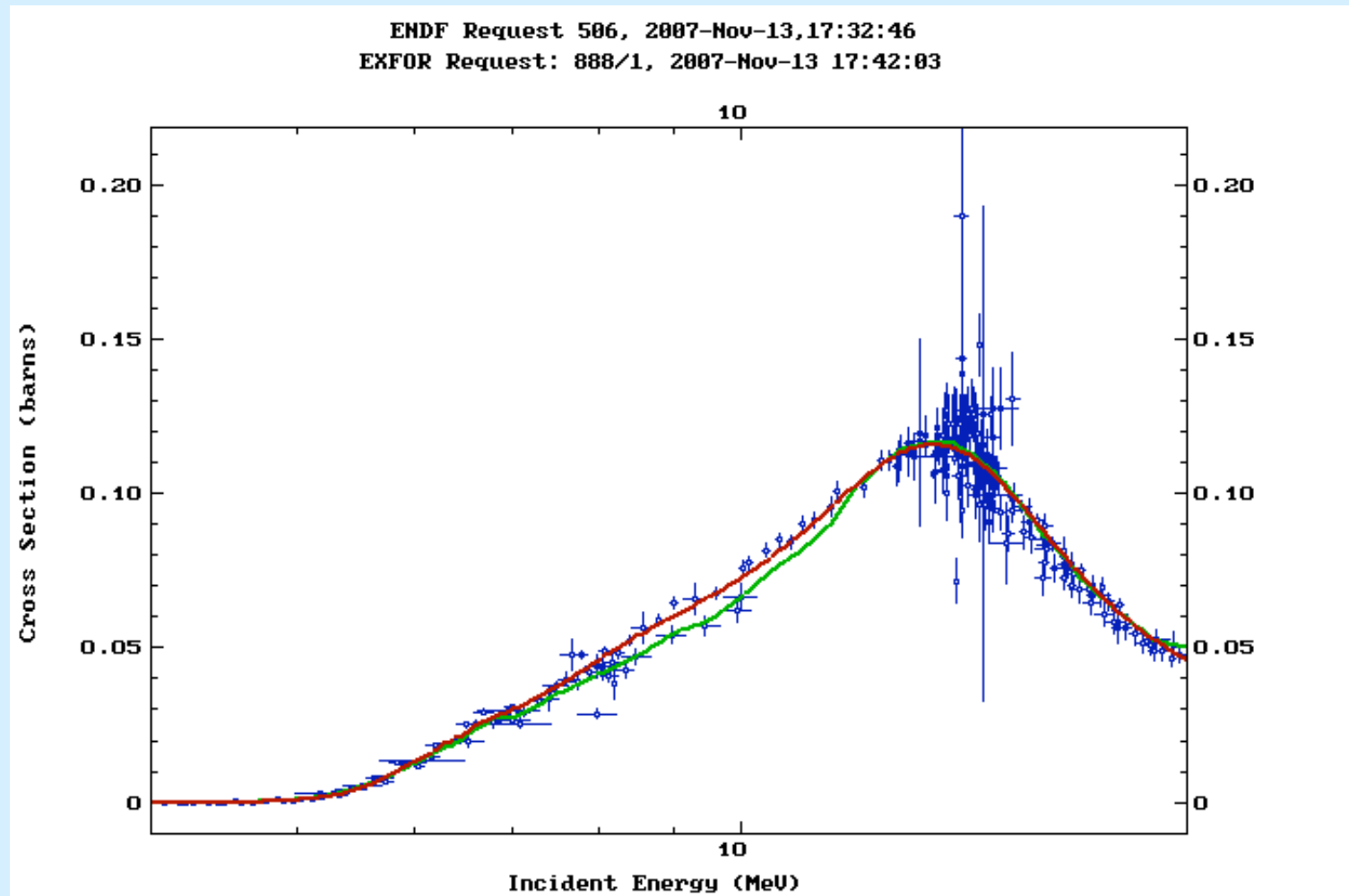
Same data in
computational
 (“table”) format

e30670.txt - WordPad									
File Edit View Insert Format Help									
SUBENT	30670002	840912					30670002	1	
BIB	2	4					30670002	2	
REACTION	(94-PU-239(N,F),,SIG)						30670002	3	
STATUS	DATA FROM YUAN HAN-RONG AS PRIV.COMM.,83/12/07, WHICH						30670002	4	
	CORRESPOND TO THE CURVE (FIG 4) OF CHINESE J.OF NUCL.						30670002	5	
	PHYS.,4,(2) (1982)131.						30670002	6	
ENDBIB	4						30670002	7	
NOCOMMON	0	0					30670002	8	
DATA	3	16					30670002	9	
EN	DATA	DATA-ERR					30670002	10	
MEV	B	B					30670002	11	
1.0000E+00	1.8600E+00	5.2000E-02					30670002	12	
1.2000E+00	1.8760E+00	5.3000E-02					30670002	13	
1.4000E+00	1.9840E+00	5.6000E-02					30670002	14	
1.6000E+00	1.9580E+00	5.5000E-02					30670002	15	
3.4000E+00	1.8520E+00	5.1000E-02					30670002	16	
3.6000E+00	1.8240E+00	5.1000E-02					30670002	17	
3.8000E+00	1.8250E+00	5.1000E-02					30670002	18	
4.0000E+00	1.7960E+00	5.0000E-02					30670002	19	
4.2000E+00	1.7810E+00	5.0000E-02					30670002	20	
4.4000E+00	1.7670E+00	4.0000E-02					30670002	21	
4.6000E+00	1.7560E+00	4.0000E-02					30670002	22	
4.8000E+00	1.6980E+00	4.7000E-02					30670002	23	
5.0000E+00	1.6960E+00	4.7000E-02					30670002	24	
5.2000E+00	1.6640E+00	4.6000E-02					30670002	25	
5.4000E+00	1.6600E+00	4.6000E-02					30670002	26	
5.6000E+00	1.6830E+00	4.7000E-02					30670002	27	
ENDDATA	18						30670002	28	
ENDSUBENT	3						3067000299999		
PHYSNT	1	0	16	1.0000E+06	5.6000E+06	1	0	0	
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1	1	0	
1.0000E+06	0.0000E+00	0.0000E+00	1.8600E+00	5.2000E-02	5.2000E-02	1	1	1	
1.2000E+06	0.0000E+00	0.0000E+00	1.8760E+00	5.3000E-02	5.3000E-02	1	1	1	
1.4000E+06	0.0000E+00	0.0000E+00	1.9840E+00	5.6000E-02	5.6000E-02	1	1	1	
1.6000E+06	0.0000E+00	0.0000E+00	1.9580E+00	5.5000E-02	5.5000E-02	1	1	1	
3.4000E+06	0.0000E+00	0.0000E+00	1.8520E+00	5.1000E-02	5.1000E-02	1	1	1	
3.6000E+06	0.0000E+00	0.0000E+00	1.8240E+00	5.1000E-02	5.1000E-02	1	1	1	
3.8000E+06	0.0000E+00	0.0000E+00	1.8250E+00	5.1000E-02	5.1000E-02	1	1	1	
4.0000E+06	0.0000E+00	0.0000E+00	1.7960E+00	5.0000E-02	5.0000E-02	1	1	1	
4.2000E+06	0.0000E+00	0.0000E+00	1.7810E+00	5.0000E-02	5.0000E-02	1	1	1	
4.4000E+06	0.0000E+00	0.0000E+00	1.7670E+00	4.0000E-02	4.0000E-02	1	1	1	
4.6000E+06	0.0000E+00	0.0000E+00	1.7560E+00	4.0000E-02	4.0000E-02	1	1	1	
4.8000E+06	0.0000E+00	0.0000E+00	1.6980E+00	4.7000E-02	4.7000E-02	1	1	1	
5.0000E+06	0.0000E+00	0.0000E+00	1.6960E+00	4.7000E-02	4.7000E-02	1	1	1	
5.2000E+06	0.0000E+00	0.0000E+00	1.6640E+00	4.6000E-02	4.6000E-02	1	1	1	
5.4000E+06	0.0000E+00	0.0000E+00	1.6600E+00	4.6000E-02	4.6000E-02	1	1	1	
5.6000E+06	0.0000E+00	0.0000E+00	1.6830E+00	4.7000E-02	4.7000E-02	1	1	1	



EXFOR retrieval (plot with ENDF data)

$^{56}\text{Fe}(n,p)$ cs
Exp. data
with
ENDF/B-VII
and IRDF-2002
evaluation





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-VII, JEF, BROND, JENDL, CENDL, and others
- ENDF/B-VII: Version 7 of the U.S. nuclear data library, released in Dec.2006 by US-NNDC
 - Format Manual: BNL-NCS-44945-05(=ENDF-102), Rev. June 2005
 - Summary documentation of evaluations:
Nucl.Data Sheets, Vol.107, No.12 (December 2006)



Contents of ENDF/B-VII

- **ENDF/B-VII Neutron Sublibrary** (393 materials from ^1H to ^{255}Fm . Neutron data, mostly 0-20 MeV, some materials extended to 150 MeV)
 - Basic file
 - 300 K point data file (Resonance parameters converted to cross sections)
- Other **sublibraries** for:
 - Incident charged particles (p, d, t, ^3He)
 - Neutron cross section standards
 - Decay data
 - Photo-atomic interaction
 - Thermal scattering law data
 - Fission product yields (neutron-induced and spontaneous)
 - Photonuclear data



ENDF File Structure

- “Sublibrary” determines incident particle and basic data type (neutron data, proton data, decay data,...)
- Hierarchical file organization:
 - Sublibrary
 - 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.



Access to major ENDF libraries

- **Major libraries** ENDF/B-VII, JEFF, BROND, JENDL, CENDL and others available online (interactive, retrieval by material, reaction and data type, energy): database “**ENDF**”
- Various **utilities** for file handling, plotting, pre-processing: ENDF *Pre-Processing Codes* and *Utility Codes*, available for downloading
- **CD-ROM** or DVD (libraries and codes)
Separate: “POINT2007” (Point data from ENDF/B-VII at 8 temperatures)
- **Output:**
 - ENDF-format (all definitions coded with numerical flags)
 - Table format and plots available online



2.2 Selected Specialized Libraries (including many IAEA products)

- FENDL-2.1
- IAEA Photonuclear Data Library
- Medical Radiosotope Prod. Cs Library
- RNAL
- RIPL-2
-



FENDL-2.1 (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/2.1: **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** calculations
 - 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 website and on CD-ROM (47 directories, 810 files, 1 Gbyte data)



IAEA Photonuclear Data Library

- Evaluated photonuclear data for 164 nuclides mostly up to 140 MeV
- Cross sections and emission spectra
- Result of IAEA CRP
- Available from IAEA website
- Handbook IAEA-TECDOC-1178 (October 2000)
- Various applications: radiation shielding, radiotherapy, waste transmutation and others
- Recently included in ENDF/B-VII



Charged-particle cross section database for medical radioisotope production

- Evaluated cross sections for 48 reactions induced by light charged particles with incident energies of several tens of MeV (max.100)
 - Production cross sections for diagnostic radioisotopes
 - Cross sections for beam monitor reactions
- Result of IAEA CRP
- Data and documentation available from NDS website
- Handbook IAEA-TECDOC-1211 (May 2001)



RNAL (Reference Neutron Activation Library)

- Evaluated cross sections for 255 neutron-induced reactions leading to radioactive products
- For activation analysis and various other applications
- Product of IAEA CRP. Evaluations extracted from various projects
- Data, plots, and documentation available from NDS website and on CD-ROM



RIPL-2 (Reference Input Parameter Library for Nuclear Model Calculations)

- Result of IAEA coordinated project, released 2003
- Input parameters for theoretical calculations of nuclear reaction cross sections involving light particles up to about 100 MeV
- Contents:
 - Atomic masses and deformations
 - Discrete level and decay schemes
 - Spacings of neutron resonances
 - Optical model parameters
 - Level densities
 - Gamma-ray strength functions and giant resonance parameters
 - Fission barriers
- Available from IAEA web pages and on CD-ROM.
Handbook: IAEA-TECDOC-1506 (2006)



PADF-2007 (Proton Activation File)

- Authors: Konobeyev et al., Karlsruhe, Germany
- 418 575 excitation functions for incident protons up to 150 MeV for targets from Mg to Ra
- 2355 target nuclei including isomeric states with half-lives > 1 second
- Based on model calculations (using TALYS and ALICE/ASH) and available experimental data
- Available from NDS website



Examples of other recent IAEA products

- PGAA - Database for prompt gamma-ray neutron activation analysis
- X-ray and gamma-ray standards
- IBANDL - Ion Beam Analysis Nuclear Data Library
- Nuclear Data for Safeguards 2007
- ADS-Lib - Application Library for Accelerator Driven Systems
- INDL/TSL – IAEA Thermal Scattering Law Library
- Neutron Cross Section Standards 2006



And there is much more....

- Many additional data libraries available from NDS can be found in IAEA-NDS-7
(<http://www-nds.iaea.org/reports/nds-7.pdf>)
- Direct links to some minor databases, and index of IAEA-NDS-documentation series:
IAEA-NDS-0
(<http://www-nds.iaea.org/nds-0.html>)



3. Data Access and Services

- Web
- CD, DVD
- Mail and hardcopy
- Computer codes
- Alternative entry points
- How to reference the data
- Trends



Web services

- **IAEA Nuclear Data Services** homepage:
<http://www-nds.iaea.org>
- Brazil mirror server:
<http://www-nds.ipen.br>
- Indian mirror server:
<http://www-nds.indcentre.org.in>
- General IAEA homepage:
<http://www.iaea.org> “Worldatom”



Mail and hardcopy services by NDS

- Data by mail
 - CD-ROM or DVD
- Hardcopy documents
 - Manuals and data library documentation
 - Handbooks
 - Meeting reports
 - Research reports
 - Nuclear Data Newsletter

Most documents (almost all of those published by NDS) are made available also on the web in PDF format.



How to request mail services

- e-mail:
services@iaeand.iaea.org for data requests,
online@iaeand.iaea.org for questions on online services, or
Fax: +43-1-26007
- Mail:
Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100
A-1400 Vienna, Austria



Want to be kept informed?

Available as hardcopy
and from WWW in PDF
format

 IAEA International Atomic Energy Agency 	<h2>Nuclear Data Newsletter</h2> <p>A newsletter of the Nuclear Data Section (NDS) Issue No. 43, May 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.7• Karlsruhe Chart of Nuclides, p.11 <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@iaeaand.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 is on-going and can be accessed on: http://www-nds.iaea.org/reports-new/</p> <h4>Staff Items</h4> <p>The Nuclear Data Section extends a warm welcome to Dr. Daniel Abriola. A nuclear physicist, Daniel has taken the position of Deputy Head of the Nuclear Data Section. As well as being directly responsible for the availability and provision of nuclear data to all Member States, Daniel is involved in the organization of workshops and CRPs related to a wide range of nuclear data development initiatives. Telephone: +41-1-2600-21717; email: d.abriola@iaea.org</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>



Computer codes

- Most computer codes for nuclear data processing have to be requested from the *OECD-NEA Data Bank* at Issy-les-Moulineaux near Paris, France (or sometimes from *Radiation Shielding Information Computational Center (RSICC)*, Oak Ridge, for codes originating from USA)
- The following codes are available from NDS (mostly also on CD-ROM):
 - EMPIRE-II: System of codes for nuclear reaction calculations
 - ENDF Utility codes and ENDF Preprocessing codes
 - ENDVER: ENDF verification support package
 - ENSDF analysis and utility programs
 - ZVVIEW package for interactive plotting



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



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) with date of retrieval
- 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.org/ndspub/documents/online/>



IAEA Nuclear data services: Trends

- Continuous improvements of retrieval interfaces
- Various output formats for different user groups
- Increased integration of databases of different format and origin
- Distribution through web and CD/DVD



4. Conclusion

- Starting point for nuclear data searches:
IAEA Nuclear Data Services
<http://www-nds.iaea.org>
 - Most complete collection of nuclear data libraries with documentations published in *IAEA-NDS-* report series
 - Online and off-line data service available cost-free
- What are the most important databases for your field of application? Send your feedback to IAEA-NDS
- Data requests and feedback: e-mail to *services@iaeand.iaea.org*



IAEA headquarters (Vienna International Centre)

