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EVALUATED NUCLEAR STRUCTURE DATA FILE (ENSDF)

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Abstract: The Evaluated Nuclear Structure Data File (ENSDF), is maintained by the National Nuclear Data Center (NNDC) on behalf of the international Nuclear Structure and Decay Data (NSDD) network organized under the auspices of the International Atomic Energy Agency. ENSDF provides evaluated experimental nuclear structure and decay data for basic and applied research. The activities of the NSDD network, the publication of the evaluations, and their use in different applications are described. Since 1986, the ENSDF and related numeric and bibliographic data bases have been made available for on-line access. The current status of these data bases, and future plans to improve the on-line access to their contents are discussed.

(evaluated nuclear structure data, nuclear structure references, evaluated nuclear reaction data, on-line access)

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Introduction

The data on discrete bound states of nuclei are of interest to basic and applied research. This paper describes the international effort organized to evaluate these data, the status of this work and the availability of the evaluations for various applications.

Nuclear Structure & Decay Data (NSDD) Network

The international Nuclear Structure & Decay Data (NSDD) network is organized under the auspices of the International Atomic Energy Agency, and co-ordinated by the National Nuclear Data Center (NNDC) at the Brookhaven National Laboratory. The NSDD network is made up of evaluators in 10 countries and 15 institutions shown in Table 1. The activities of the Chinese Nuclear Data Center, Beijing, include evaluations done at Jilin University, Changchun, and the Institute of Nuclear Research, Shanghai. Evaluations are also performed at the National Tsing Hua University, Taiwan. The network is responsible for the evaluation of all the mass-chains on a continual basis. A mass-chain is formed by all the nuclides of the same mass and different chemical elements. Each of the members of the network has a permanent assignment of mass-chains depending on the number of evaluators, their research interests, or special expertise in a particular mass-region. Temporary assignments of

mass-chains are also possible depending on the current interests of the evaluators and also to help out other members of the network in updating the mass-chains that are old.

Table 1
The NSDD Network

Country	Institution
Belgium	Ghent University
Canada	McMaster University
France	Centre d'Etudes Nucleaires de Grenoble
Japan	Japan Atomic Energy Research Institute
Kuwait	Kuwait Institute for Scientific Research
The Netherlands	University of Utrecht
Peoples' Republic of China	Chinese Nuclear Data Center
Sweden	University of Lund
Union of Soviet Socialist Republics	Institut Atomnoi Energii I.V.Kurchatova Data Center, Leningrad Nuclear Physics Institute
United States of America	Brookhaven National Laboratory Idaho National Engineering Lab Lawrence Berkeley Laboratory Oak Ridge National Laboratory Triangle Universities Nuclear Lab

Evaluated Nuclear Structure Data File (ENSDF)

The Evaluated Nuclear Structure Data File[1] (ENSDF), is made up of evaluated experimental data for $A=1-266$. ENSDF is maintained by the NNDC on behalf of the international NSDD network. For $A>44$, the evaluations are coded in the ENSDF format for entry into the data file and are published in the Nuclear Data Sheets. For $3<A<45$, the evaluations are published in the journal Nuclear Physics and a subset of the published data is extracted and entered into the ENSDF. It is expected that future evaluations of $A=3-20$ by the Triangle Universities group will be coded into the ENSDF. The publication status of the evaluations for the light nuclei $A<45$ is shown in Table 2. For the remaining nuclei in the ENSDF, the status is shown in Fig. 1. The ENSDF is updated when new evaluations are published in the Nuclear Data Sheets.

A-Chain Status in ENSDF (A>44)

Center - ALL
25-APR-91

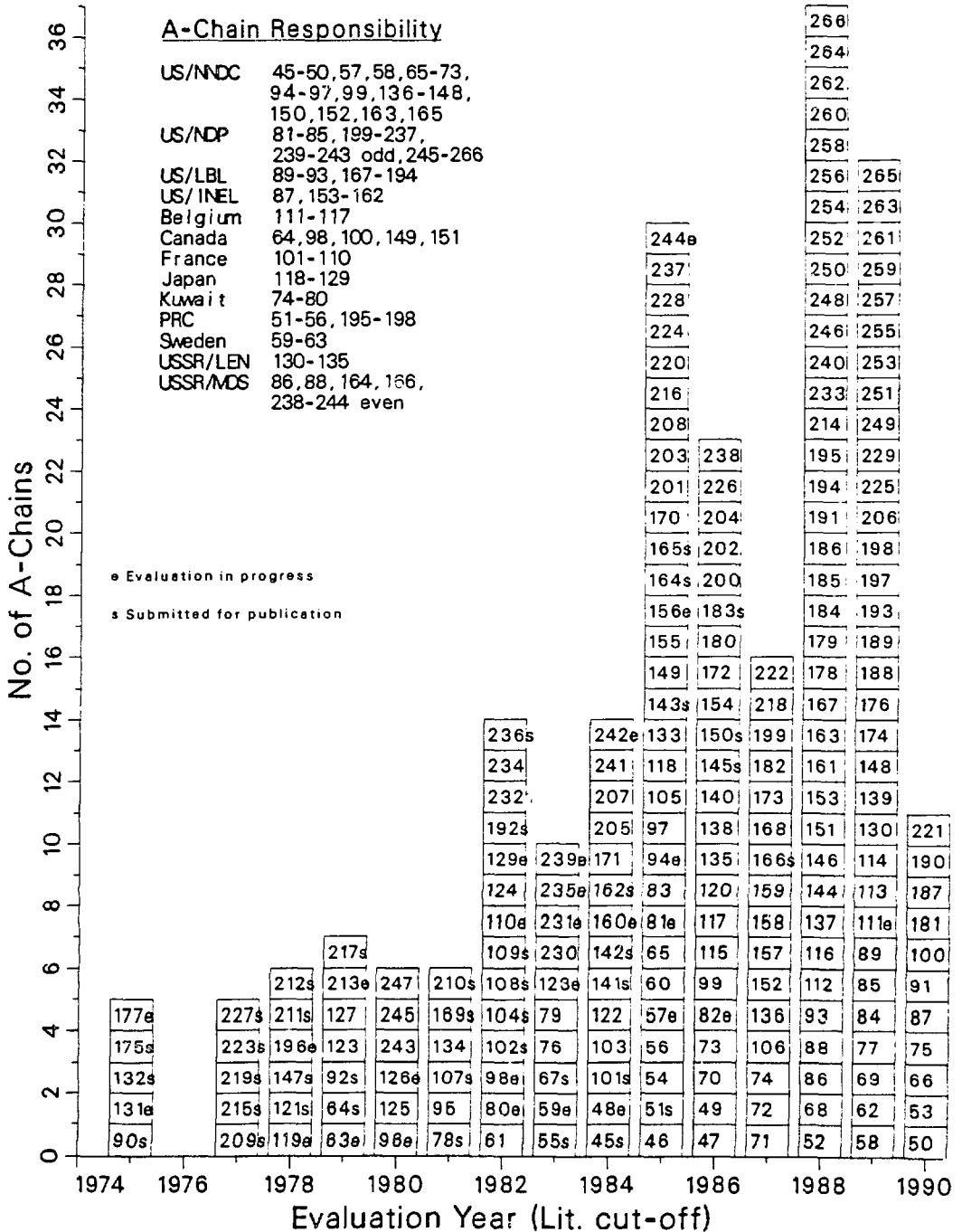


Table 2		
Publication Status of Evaluations for A=1-44		
A-range	Date*	Reference
1-2		@
3	6/87	Nuc. Phys. A474 , 1 (1987)@
4#	12/72	Nuc. Phys. A206 , 1 (1973)@
5-10	6/88	Nuc. Phys. A490 , 1 (1988)
11-12	6/89	Nuc. Phys. A506 , 1 (1990)
13-15	7/90	Nuc. Phys. A523 , 1 (1991)
16-17	6/86	Nuc. Phys. A460 , 1 (1986)
18-20	6/87	Nuc. Phys. A475 , 1 (1987)
21-44	6/90	Nuc. Phys. A521 , 1 (1990)

* Literature cut-off dates for published evaluations
 @ Unpublished partial evaluations are included in ENSDF
 # A new evaluation by the Triangle Universities group is in progress

The Contents of ENSDF

ENSDF contains evaluated experimental data summarizing the present knowledge on the structure and decay of nuclei. If there are gaps in experimental data, they are not filled in with theoretical or nuclear model calculations. While the emphasis is on experimental data, the evaluations do use well-founded systematics or theory. Thus the ENSDF can serve as a guide for planning future experimental work, and to test or develop new theories. It can also be used as input for nuclear model code cal-

culations of reaction data or other applications such as decay heat calculations in reactors or nuclear medicine.

The ENSDF is organized as a collection of data sets for each nuclear species. The data sets are of the following types: adopted properties of the nucleus, and source data sets each of which gives the evaluated data of a single type of measurement such as radioactive decay or reaction experiments. The contents of the source data are combined together by an evaluator to arrive at the adopted properties which may be considered as the "best" or the recommended properties of the nuclear levels or radiations.

In the adopted data sets, β^- and α decay energies of the ground state, and neutron and proton separation energies are given for each nuclide. For each level the following information is given: its excitation energy, J^π with arguments supporting the assignment, half-life or total width, decay branching for ground state and isomers, static electric and magnetic moments, flags indicating in which decay and reaction data sets the level is seen, the configuration assignments (Nilsson orbitals or shell model), band parameters, isomer and isotope shifts, references to data on charge distribution of ground states, deformation parameters and electric and magnetic excitation probabilities. For the γ -rays, their placement in the level scheme, measured γ -ray or $E0$ transition energy, relative photon intensity from each level, electric or magnetic multipole character, the mixing ratio, and nuclear penetration parameter, total internal-conversion

coefficient when appreciable and reduced transition probabilities are given. In the decay or reaction data sets, nuclear structure data extracted from β decay, α decay, isomeric decay, Coulomb excitation, particle transfer reactions such as (d,p), (t,p) etc., heavy ion reactions, or mesic atom studies are presented. The contents of the ENSDF at this time are shown in Table 3.

Card Images:	$\approx 990,000$
Data Sets:	11,002
Nuclides:	2,325
<u>Data Sets:</u>	
Adopted Levels, Gammas*	2,321
Decay Data (including spontaneous fission)	2,917
Reactions	5,390
Muonic Atom	28
Mossbauer	18
Comments	223
References	252
*Includes decay and reaction data sets for nuclei which have no adopted data sets	

The evaluations for $A > 44$ are sent as a computer file by the evaluator to the NNDC for further processing. The NNDC maintains and distributes to the network members a number of format and physics checking codes to aid in evaluating the data and in assembling the data files. These data files are processed and checked at the

NNDC to prepare a pre-review copy which is sent back to the evaluator. The evaluator proofreads this copy, checks the evaluation and sends it back with any corrections. These corrections are implemented, and a review copy prepared and sent for refereeing which checks the evaluation for completeness and correctness of data, physics content, documentation and style of presentation. The referee's comments are sent to the evaluator along with any corrections or suggestions from the Editor-in-chief. These corrections, changes and any updates to the data files by the evaluator are included in the post-review copy which is sent to the reviewer for approval of changes. If there are no problems, the manuscript is then prepared in publication format. This involves suppressing several computer-generated numbers, tables and drawings and generating a new lay-out without in any way sacrificing the essential physics contents of the publication. The final camera-ready publication copy is then sent to the publisher and after an evaluation has been published in the Nuclear Data Sheets, it is merged into the ENSDF.

New mass-chain evaluations are published in 9 issues of the Nuclear Data Sheets per year. In this publication, the format is designed to convey to the user the necessary physics information in the evaluation in a direct transparent manner. Drawings of radioactive decays and reactions with gammas are given showing band structure where needed. Detailed results that could not be adequately shown in the drawings are given in Tables. An Index to the Drawings and Tables precedes these; a list of References to the literature used in the evaluation is

also given.

Applied Uses of ENSDF

The data in the ENSDF can be selectively extracted, processed and re-formatted to suit special applications. A program MEDLIST [2,3] was written in 1975 to use ENSDF data for nuclear medicine. RADLST [4] is a much enhanced and improved version of this program. It is designed to calculate the nuclear and atomic radiations associated with radioactive decay of nuclei for a variety of applications such as nuclear medicine, health physics, industry, nuclear power, geophysics, and environmental studies.

The ENSDF is also a source from which a number of publications such as the Nuclear Wallet Cards[5] published by the NNDC are derived. It is also planned to extract data for the projected new 8th edition of the Table of Isotopes from the ENSDF.

Nuclear Structure References (NSR) File

The NNDC maintains the Nuclear Structure References (NSR) file which is a computer file of indexed references to low and intermediate energy nuclear physics. This file was initially begun in support of the nuclear structure data evaluations for the ENSDF. However, this bibliographic file has found a much larger class of basic and applied physics users in addition to the network

evaluators. The scope of literature coverage in the NSR has also expanded over the years to include new areas of active research published in the leading publications in the field such as Physical Review C or Nuclear Physics A.

The updates to the NSR are published every four months in three issues of the Nuclear Data Sheets as Recent References; the file however, is updated weekly. This publication is divided into four sections: (i) key numbers and keywords: each key number is a unique index for each entry followed by a keyword abstract containing information on specific nuclei; (ii) reaction index: an index to experimental papers on nuclear reactions; (iii) references: a bibliography of experimental nuclear reaction and structure articles ordered by year of publication and last name of the first author and (iv) secondary sources: contain an index to non-journal literature. Though the emphasis is on experimental papers in literature coverage, theoretical papers dealing with specific nuclei and reactions are also scanned and assigned keywords. The NNDC regularly scans 80 journals; these are listed in the introductory section of the Recent References. In addition to these primary references, conference proceedings published in Nuclear Physics A, Nuclear Instruments & Methods in Physics Research and other journals are also coded as primary references. Secondary references published in progress reports of leading laboratories around the world and important conference proceedings are scanned regularly. Other secondary sources are covered on a time available basis or on request from the network evalua-

tors for mass-chain evaluations. Over the past few years, the NNDC has received continued cooperation from the compilers at the Gatchina data center in the USSR in coding for the NSR conference proceedings and obscure sources from the USSR. Periodically, the NNDC has also received entries prepared from Japanese laboratory reports by the compilers at the RIKEN data center in Japan. At present, there are $\approx 120,000$ references in the NSR file; and $\approx 2,600$ primary references and $\approx 1,100$ secondary references are added every year.

In the NSR, each reference is uniquely identified by a keynumber; this is used in identifying the reference in the ENSDF. Most NSR entries made since 1968 have a keyword abstract describing the contents of the article. This abstract consists of a complete list of nuclides, reactions, decays and nuclear properties measured or deduced in it. It is possible to make retrievals from NSR using a group of "selectors" which form a subset of keywords; further narrowing down of selected references is possible by imposing boolean restrictions on the selected groups.

The On-line Access System

The data in the ENSDF may also be accessed by electronic means using computer networks as an alternative to the hard copy publication. The advantages of such access are many: most recent data are obtained from one source, quick computer search and retrievals of data are possible, users can tailor retrievals for special applications and the retrieved data can be transferred to the

user's computer for further processing or printed out to obtain a hard copy. Since 1986, on-line access has been provided for the computerized numeric and bibliographic nuclear physics information available at the NNDC to users in the United States and Canada. Similar services may also be available from other members of the NSDD network. The service is available on the NNDC VAX cluster and may be accessed by computer networks such as INTERNET or ESNET or by telephone. No special authorization is required to access the NNDC on-line newsletter, mail facility, and HELP files to become acquainted with the system. Users have to contact the NNDC for authorization to access other data bases such as the ENSDF and the NSR discussed earlier and the following.

NUDAT-NUclear DAta-evaluated numeric data extracted or derived from the ENSDF for nuclear level properties and radiations, from the Nuclear Wallet Cards[5] for nuclear ground and metastable state properties and evaluated thermal neutron cross sections and resonance integrals from Neutron Cross Sections, Vol. 1[6,7]

CINDA - Computer Index of Neutron Data - bibliographic references to neutron reaction data.

CSISRS - Cross Section Information Storage and Retrieval System - experimental data on neutron, photon, and charged particle reactions.

ENDF - Evaluated Nuclear Data File - evaluated neutron-induced reaction and decay data. Currently the data base contains the US evaluated file, ENDF/B-VI.

MIRD—Medical Internal Radiation Dose—plots and tables of nuclide decay radiations derived from the ENSDF and in the format of the ICRP Publication 38[8].

PHYSICO—PHYSICS CODES—codes to calculate physics quantities e.g., internal conversion coefficients, logft values and related quantities.

XRAY—Photo Atomic Data—evaluated photo-atomic cross sections and attenuation coefficients for elements, compounds and mixtures and polarized scattering cross sections including Compton and Rayleigh scattering and Rayleigh scattering with anomalous corrections.

In the above data bases, at the present time, there is a terminal plotting capability for ENSDF, CSISRS, ENDF and XRAY and the disk output may be used in a PLOT utility program to generate a graphics file for ENSDF and CSISRS.

S.

The use of the NNDC on-line system has grown over the past few years and the user statistics for 1986–1991 are shown in Table 4.

The NNDC assisted in installing in 1987 its nuclear structure related data bases in the on-line system of the Nuclear Energy Agency Data Bank, Saclay, which provides similar services locally in Europe. A data base system for radioactivity gamma rays and nuclear structure references from the NSR file have been made available by the evaluation group at Lund University. These are available for on-line access via the NORDic University NETWORK (NORDUNET) and the Swedish Univer-

Table 4
On-line Access Statistics

Year	Runs	Retrievals*	NSR	ENSDF	NUDAT	CINDA	CSISRS	ENDF	MIRD	PLOT	PHYSICO	XRAY
1986	648	1621	814	142	536	129						
1987	1275	4263	2521	863	815	60						
1988	2264	8748	5022	1303	1492	285	459	187				
1989	3374	8406	3253	850	1841	522	1649	150	121	11	9	
1990	5436	12067	5613	1256	2204	187	1623	1019	53	39	65	8
1991@	3185	6452	2983	690	1806	78	278	395	5	23	107	87

@ January to April

* The number of pieces of information in each retrieval depends on the complexity of the retrieval

sity computer NETwork (SUNET). The Fachinfor-
mationszentrum (FIZ), Karlsruhe, a former member of the
NSDD network, offers ENSDF, NSR and MEDLIST data
bases for on-line access via telecommunication networks.
MEDLIST is a nuclear medicine data base derived from
ENSDF using the program MEDLIST [2,3].

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