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EVALUATED DATA COLLECTIONS FROM ENSDF*

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For several years the Nuclear Data Project has been maintaining an Evaluated Nuclear Structure Data File (ENSDF), which is designed to include critically evaluated values for most nuclear spectroscopic quantities. The information in ENSDF is the same as in the *Nuclear Data Sheets*, which illustrates two particular output formats (drawings and tables). Spectroscopic information for nuclei with $A < 45$ is put into ENSDF from the evaluations of Ajzenberg-Selove and of Endt and van der Leun. An international network has been organized to provide regular revisions of the data file. Computer facilities have been developed to retrieve collections of evaluated data for special calculations or detailed examination.

[Evaluation, nuclear structure data, ENSDF, nuclear levels, radioactivity, nuclear reactions, reaction gamma rays.]

INTRODUCTION

Since 1948, the Nuclear Data Project (NDP) has been a recognized center for the systematic collection and evaluation of data from nuclear structure experiments. The Data Project has helped consolidate the rapid advance of nuclear science by identifying and publicizing conflicting results and by integrating each new measurement with those that preceded it. The organization of nuclear data for publication in *Nuclear Data Sheets*[1] has also led to the development of a natural structure for containing these data.

In 1971 NDP designed a formal structure for entering nuclear structure data into computer files.[2] This structure has been used since then to prepare, maintain, and edit a comprehensive file of Evaluated Nuclear Structure Data (ENSDF), which is used for production of drawings and tables for *Nuclear Data Sheets*.

These computer files of nuclear data are also being used as a means of making the results of basic research quickly and easily available to a broader audience. Radioactivity information, in particular, has wide application in fields such as nuclear medicine, reactor engineering, environmental impact assessment, and nuclear waste management. Often the specialists in these areas have neither the time nor the training to make effective use of the data generated by basic nuclear research. The NDP has made important progress toward providing a channel through which the results of new nuclear measurements can be transferred to any engineer or scientist who needs evaluated data to factor into his or her own work.

The value of a scientific data base is determined largely by four properties, each of which represents a compromise between what would be ideal and what is easily attainable. Ideally, the data base should be:

1. Comprehensive – All related quantities (measurable or derived from "reliable" theory) should be included, together with estimates of their uncertainties.
2. Complete – All available data of each type should be included.
3. Up-to-Date – The consequences of each reliable new measurement should appear quickly throughout the data collection.
4. Accessible – Data should be obtainable from the file according to user-defined needs and should be presentable in a user-defined format.

STATUS AND UPDATING OF ENSDF

ENSDF Current Contents

The Evaluated Nuclear Structure Data File now contains 6800 distinct sets of evaluated nuclear information. This includes:

1930	sets of adopted level properties
1850	decay schemes
3020	nuclear reaction data collections, including
230	(n,γ) reactions
225	(d,p) reactions
500	(charged-particle, $xn\gamma$) reactions

A set of adopted levels and their properties is now included for every nucleus. For nuclei with $A < 45$, ENSDF is based on the evaluations of Ajzenberg-Selove[3] and of Endt and van der Leun.[4]

Several complete collections of level properties have been assembled from ENSDF; e.g., all levels with lifetimes between 1 ps and 1 fs; odd-parity states in even nuclei. A collection of levels with spontaneous fission branching has recently been published.[5]

Most decay scheme information in ENSDF is now as complete as the measurements warrant, usually based on the most recent *Nuclear Data Sheets*. Normalization information is included wherever available, and details of electron capture and internal conversion have been added systematically, so that complete tables of atomic and nuclear radiations can be assembled for approximately 1500 decay schemes.

Regular Revision of the ENSDF Data Base

The ENSDF computer format has been adopted[6] as an international standard for the systematic storage and exchange of nuclear data. At six-month intervals, since 1977, NDP has prepared complete copies of ENSDF on magnetic tape for distribution through the (U.S.) National Nuclear Data Center at Brookhaven National Laboratory. This tape defines the current version of an International File of Evaluated Nuclear Structure and Decay Data.

At the 1977 meeting of the IAEA Advisory Group on Nuclear Structure and Decay Data[6] in Oak Ridge, the responsibility for periodic reevaluation of each mass chain was given to

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a specific evaluation center. Evaluation responsibilities were allocated with the intent of reaching and maintaining a four-year cycle. That is, every mass chain would be considered for revision at least every four years.

At present, the mechanism for updating ENSDF is by means of a complete revision of *Nuclear Data Sheets* for an entire mass chain. For older mass chains, where the evaluations were prepared by the Nuclear Data Project, the systematic addition of internal conversion coefficients, average beta energies, and detailed electron-capture ratios was recently completed for several hundred decay schemes. Newer decay data have been incorporated into ENSDF for 380 decay schemes included in the data collections of Kocher[7] and Martin.[8] In general, however, a collection of data extracted from ENSDF will be only as up-to-date as the most recent *Nuclear Data Sheets*.

There may be little justification for more frequent review of all new nuclear measurements. For some groups of radionuclides (e.g., those isotopes used in medicine) or perhaps for specific data items (such as the ^{239}Pu half-life), a more frequent consideration of newer data could be desirable. Evaluations of particular kinds of data are sometimes prepared by special working groups, and there should also be a means of including these in the ENSDF system.

A file of supporting data for ENSDF (called the "working file") has been established to include measurements or evaluations that appear between regular revisions of the data base. Data sets for the working file are prepared in standard ENSDF format and can be processed with the same analysis or publication programs. The working file can provide alternatives or supplements to the International File of evaluated data as documented in *Nuclear Data Sheets*.

Procedures for incorporating important new information into the International File between the regular cycles are being developed by the evaluation network. Documentation of differences between the International File and the published *Nuclear Data Sheets* is especially important. The evaluator or evaluation center which is responsible for the affected mass chain must also accept any changes before ENSDF can be modified. The more frequent evaluation of those data which are especially important or rapidly changing would increase the quality and usefulness of the data base.

USABLE OUTPUT FROM ENSDF

The NDSLIST Program

The standard output format from ENSDF is the same as the input. This format is convenient for making revisions or as input for a succeeding program. A number of data analysis programs have also been developed to operate on standard data sets: to identify and mark inconsistent data, to perform systematic theoretical calculations, or to reformat the data for easier use by a research worker.

Choosing a useful format for presenting the data retrieved from a data file is often as difficult as defining the retrieval. The potential user will often have special requirements (or prejudices?) about how the data should be organized and displayed. Unless the user's preferences are considered, the transfer of information from a data file to the user is seriously inhibited. He will often choose to reorganize the data again by hand, even though the recopying will surely introduce errors.

A general table-formatting program (NDSLIST) has been developed to accept standard ENSDF data sets and to prepare the separate tables of information which are needed to produce the journal *Nuclear Data Sheets*. The program will automatically separate each data set into groups of each kind of record contained in the data set. Each group of records is arranged according to increasing values of one or more data items on each record, and all accompanying information (including comments) is attached to the record in its proper place.

Although NDSLIST normally processes one data set at a time, this is not an essential restriction. A merge capability disables the isotope checking so that information from many data sets can be merged into a single table. The merge feature was used to prepare the table of SF-isomers[5] mentioned previously.

Linking of the merge facility with the ENSDF data-retrieval package makes it possible to select and display carefully tailored blocks of nuclear data. Tables of alpha and gamma radiations were prepared[9] for a recent IAEA Symposium on Transactinide Nuclear Data. The tables were limited to decay of nuclei with $A > 207$ and $T_{1/2} > 1$ s. Only radiations with an absolute intensity greater than one percent were included, and the tables were prepared in order of increasing α- or γ-ray energy, as well as by parent nucleus.

The MEDLIST Program

If a user is interested in the total physical or biological consequences of radioactive decay, it is necessary to include atomic as well as nuclear radiations. A nuclear transition can cause vacancies in the electron shells. The refilling of the electron shells is accompanied by emission of characteristic X-rays and Auger electrons. A second program (MEDLIST) has been developed to combine the basic nuclear data from ENSDF with tables of X-ray and Auger yield to prepare complete lists of radiations emitted by each radionuclide. The γ-ray intensity normalization, the page layout, and the bookkeeping (intensity of omitted weak radiations, etc.) are all performed automatically. Radiations are grouped by type: X-rays included with nuclear γ-rays; Auger lines listed with conversion-electron lines. Several special collections of radioactivity data[7,8,10] have been prepared by MEDLIST.

The MEDLIST program also prepares a computer-readable file of card images, which can be more easily used to make further calculations with the radiation data. This file of atomic and nuclear data radiations has been used[11,12] in reactor and accelerator calculations.

A third summary output from MEDLIST lists the energy emitted as each radiation type and compares the sum with the available energy; i.e. the decay Q-value. Besides giving a gross survey of radiations, the table of energy sums also indicates how completely each decay scheme has been characterized. If the sum of radiated energy is substantially larger or smaller than the branching-adjusted Q-value, then further measurements are probably needed to provide better or more complete information.

A MEDLIST survey of 1500 radioactivity data sets from ENSDF has recently been completed.[13]

SUMMARY

1. An Evaluated Nuclear Structure Data File (ENSDF) has been designed to contain most of the data of nuclear structure physics.

2. ENSDF includes adopted level information for all 1930 known nuclei. Detailed data are available for ~1500 decay schemes.

3. An international network of data evaluation centers has been organized to provide for a four-year cycle of ENSDF revisions.

4. Standard retrieval and display programs can prepare various tables of specific data which can serve as a good first approximation to a complete up-to-date compilation.

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