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ENSL and CDRL:

Evaluated nuclear structure libraries

R. J. Howerton

Manuscript date: February 2, 1981

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Two files of nuclear structure data derived largely from the seventh edition of the Table of Isotopes are described. The files are computer oriented, and have been constructed to so that every decay can be traced either to an eventual ground state of to a positive flag that indicates nothing is known about further decay.

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LAWRENCE LIVERMORE LABORATORY
University of California · Livermore, California · 94550

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FOREWORD

The UCRL-50400 series, *An Integrated System for Production of Neutronics and Photonics Calculational Constants*, describes an integrated, computer-oriented system for the production and application of neutronics and photonics calculational constants.

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- Vol. 15, Part B, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Graphs of Cross Sections from the Library*, October 1978.
- Vol. 15, Part C, *The LLL Evaluated-Nuclear-Data Library (ENDL): Translation of ENDL Neutron-Induced Interaction Data into the ENDF/B Format*, April 1976.
- Vol. 15, Part D, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Descriptions of Individual Evaluations for Z= 0–98*, May 1978.
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- Vol. 15, Part F, *Experimental and Evaluated Elastic Nuclear Plus Interference Cross Sections for Light Charged Particles*, July 1980.

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ENSL and CDRL: Evaluated Nuclear Structure Libraries

ABSTRACT

Two files of nuclear structure data derived largely from the seventh edition of the *Table of Isotopes* are described. The files are computer oriented, and have been constructed so that every decay can be traced either to an eventual ground state or to a positive flag that indicates nothing is known about further decay.

INTRODUCTION

Shortly after the issuance of the seventh edition of the *Table of Isotopes*,[1] Dr. C. M. Lederer, of the Lawrence Berkeley Laboratory, gave Mr. Viktor Hampel, of the Lawrence Livermore National Laboratory (LLNL), magnetic tapes of this publication. Mr. Hampel used the programming services of Mr. Fred Banfield to convert the tapes to a format that Dr. Donald Gardner (also of LLNL) and I provided. Mr. Banfield produced two files in May 1979; one for level schemes derived from decay data, the other for level schemes derived from particle-induced reaction data. These two files, plus certain data of reference 1 that for one reason or another were not translated by Mr. Banfield, form the basis of two nuclear structure data files, ENSL and CDRL. In the following discussion, we describe the method by which these files were constructed and their format.

METHODS

The ENSL file contains level schemes derived from decay data, and the CDRL file contains the level schemes derived from particle-induced reaction data that have been merged into the ENSL file. The levels in each file are characterized by nucleus, level energy, parity, spin (if parity and spin are known), half-life, and number of decay modes. The nucleus, the level to which the state decays, the probability of occurrence, and the Q value are given for each decay mode of a level. Levels whose decay modes are unknown, for example, several of those derived from the particle-induced reaction data, are positively flagged. Thus, in the ENSL file the decay of a level can be followed to an eventual ground state, and in the CDRL file it can be followed

either to an eventual ground state or to a positive flag, indicating that nothing is known about further decay.

When using the CDRL file, it is possible to assume that a level with an unknown decay mode decays by gamma transition to the ground state of the same nucleus, with a probability of unity and a Q value equal to the level energy. Such an assumption is undoubtedly incorrect, but it can conserve the total energy of the transition and permit a decay to be followed (albeit artificially) to an eventual ground state. Most levels with unknown decay modes are associated with the relatively high energy states in nuclei, where the true decay is by gamma cascade. Thus, in most cases, this assumption preserves the proper decay mode but produces too hard a gamma-production spectrum with too low a gamma multiplicity.

Since the purpose of these files is to provide input for computer codes, the files must be complete--i.e., any level must be able to be traced to an eventual ground state or to a positive flag. It is in the sense of completeness, then, that these files are "evaluated" files. Of course, credit for the evaluated data goes to the compilers of the *Table of Isotopes*[1]; we merely extended their work to ensure completeness, and converted the data to easily manipulable files.

To remove ambiguities and to ensure that all decays could be followed to an eventual ground state or, where decay modes were unknown, to a positive termination, we manipulated the files to correspond to the following assumptions:

1. If no spin or parity data were given for a level, those fields were left blank. This did not affect the tracing of decays.
2. If more than one set of spin or parity data was given, the first set was assumed correct and entered into the file.
3. Stable ground states were given a half-life of 10^{50} s.
4. States without a given half-life were assumed to decay "instantaneously" and were assigned a half-life of 10^{-20} s.
5. If more than one decay mode was indicated for a level but no probabilities were given, equal probabilities were assigned.
6. All Q values were derived from the Wapstra-Bos tables.[2]
7. In the ENSL, or original decay data, file, a level without a decay mode was assumed to decay to the ground state by gamma transition.

Because there were relatively few such cases, we judged this assumption to be useful in ensuring the file's completeness.

8. When the particle-induced reaction data were merged into the ENSL file, there were many duplications of levels; some with identical energies and half-lives, others with slightly different energies. It was obvious that the same levels were represented. To deal with this problem, we assumed that two level energies differing in their ratios by less than .001 represented the same level and that its level energy was from the ENSL file. This required adjusting the level energies of decay modes derived from particle-induced reaction data, which, in turn, affected the Q values of those decay modes. The adjustment was made in the interest of energy conservation.
9. All energies are in mega-electron volts, and all half-lives are in seconds.
10. The files are ordered by ascending charge and mass of nuclei, ZA (1000Z +A), and level energy. We departed from the usual order of mass and charge to facilitate linking the files to other computer codes using the ZA convention.

CONVENTIONS AND FORMATS

The encoding, DM, of the various decay modes is as follows:

DM	Decay mode
1	Neutron
2	Proton
3	Deuteron
4	Triton
5	^{3}He
6	Alpha
7	Gamma
8	β^{+}
9	β^{-}
10	Electron capture
17	Internal transition ($0^{+} \rightarrow 0^{+}$)
18	Unresolved β^{+} + electron capture
19	Unknown
99	Stable

Each level is described by a set of data, the first record of which gives the nucleus, level energy, parity, spin, half-life, and number of decay modes to follow. The second and following records give the decay mode, the secondary nucleus, the level, and the probability and Q value of the decay mode. The formats of the records are as follows:

First record

Columns	Entry	Format
1-6*	ZA (1000Z + A)	I6
7-17	Level energy	E11.4
18	Unused	1X
19-21	Parity (1.0 or -1.0)	F3.0
22	Unused	1X
23-26	Spin	F4.1
27-37	Half-life	E11.4
38	Unused	1X
39-40	Number of decay modes	I2

Second and following records

Columns	Entry	Format
1-38	Unused	38X
39-40	Decay mode	I2
41	Unused	1X
42-47	ZA of product nucleus	I6
48-58	Level of product nucleus	E11.4
58-69	Probability of decay mode	E11.4
70-80	Q value of decay mode	E11.4

*The end of each file is flagged by an entry of 900000 in columns 1-6 of a first record.

Those who wish to consult a display of the data may refer to the microfiche included with this report; those who need computer-readable files may obtain ENSL and CDRL on magnetic tape upon request. On magnetic tape, ENSL and CDRL are available as one blocked file each or as four and five blocked files, respectively. In the latter case, each blocked file corresponds to the Z ranges on the microfiche and in Table 1, which shows the appropriate statistical data for each file. Requests for magnetic tape of the data may be directed to the National Nuclear Data Center, Brookhaven National Laboratory; the Radiation Shielding Information Center, Oak Ridge National Laboratory; or the Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria.

TABLE 1. Statistical data for each evaluated nuclear structure file.

	CDRL81	ENSL81
Number of isotopes	1553	1481
Number of levels	41209	15378
Maximum number of decays for a level	72	72
Maximum number of levels for an isotope	142	86

File	Z-Range	Number of records
CDRL81-1	1-19	11521
CDRL81-2	20-29	25526
CDRL81-3	40-59	32039
CDRL81-4	60-79	38615
CDRL81-5	80-105	18216
ENSL81-1	1-24	2767
ENSL81-2	25-49	17746
ENSL81-3	50-74	27429
ENSL81-4	75-105	15443
CDRL81	1-105	125913
ENSL81	1-105	63382

ACKNOWLEDGMENTS

The files described in this report are based on the work of the several compilers and two editors of reference 1. We acknowledge their work and apologize for any degradation it has suffered as a result of the assumptions that were made to ensure consistency and energy conservation. We thank Dr. C. M. Lederer for providing the magnetic tapes of reference 1 and Mr. Viktor Hampel for acting as an intermediary in obtaining the services of Mr. Fred Banfield. Special thanks go to Mr. Banfield for translating the tapes to the intermediate format. Finally, we thank Dr. Donald Gardner for helping devise the intermediate format and for assisting Mr. Banfield.

We also acknowledge and thank in advance those who will use the files and call to our attention any errors, deficiencies or omissions. With their help, we can produce new editions of the files that will better serve the needs of the community of users.

REFERENCES

1. *Table of Isotopes*, 7th ed., C. M. Lederer and V. S. Shirley, Eds. (Wiley, New York, 1978).
2. A. H. Wapstra and K. Bos, "The 1977 Atomic Mass Evaluation in Four Parts," *At. Data Nucl. Data Tables* 19, 177-214 (1977).