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NUCLEAR STRUCTURE DATABASE

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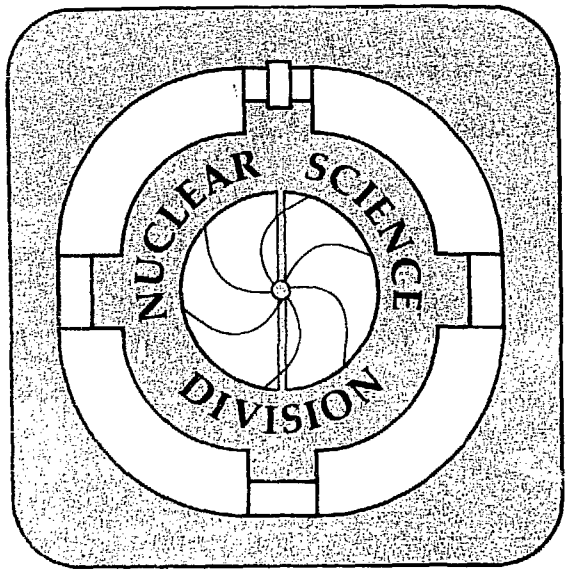
June 1980



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by

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Summary

A nuclear structure database has been created from the *Table of Isotopes*[1] level-scheme file. This database contains evaluated data (through 1977) on level and deexcitation properties for all known isotopes from radioactive decay and nuclear reaction studies. The data are organized in simple array formats to enable rapid searches for specific level or decay information. Examples of the use of this database to study the properties of first excited $J^{\pi}=2^{+}$ states in even-even nuclei and Weisskopf enhancements of delayed γ-ray transitions are shown.

I. Introduction

The evaluated radioactive decay and nuclear reaction data for all known nuclides (through 1977), which were published in the seventh edition of the *Table of Isotopes*[1], exist on a computer file at LBL. This original file, from which the level scheme figures for the table were produced, contains data on the parent nuclei (levelenergies, spins, half-lives, modes of decay and Q-values) and also information about the daughter nuclei (level energies, spins, half-lives, feeding intensities from the parents, rotational and single particle information; as well as γ-ray energies, intensities, multipolarities, and particle decay modes). The file also contains original references and plotting instructions.

This evaluated data file was designed to produce level-scheme plots and is not suitable as a database for horizontal compilations and systematic studies of nuclear properties. We have restructured the data file in order to make it possible to manipulate the data efficiently. References, plotting instructions, and all non-data contents were purged from the file, which was then reorganized into a database containing bidimensional arrays of no more than 5000 elements each. Two kinds of arrays were created: L (level)-arrays containing parent and daughter level information, and D (deexcitation)-arrays with γ-ray and particle decay properties. In general there are two L-arrays and two D-arrays for each nucleus, the first containing radioactive decay data and the second containing nuclear reaction data. These arrays are on files stored separately on magnetic tape for all evaluated mass chains, ordered by ascending A and within each A by ascending Z. A-chains are separated by end-of-file (EOF) marks and isotope records by end-of-record (EOR) marks. By use of LBL system routines to skip files and/or records, selected pieces of the database can be returned for further analysis. An array INDEX(A,Z) has

been created containing the address of each isotope array in the file, so that these smaller arrays can be selectively retrieved. This makes the database suitable for use even in small computer systems.

The level arrays L(K,I) for radioactive decay contain level information for the levels of the parent(s)-daughter system, and for each level (K) its associated properties (I) including energy, spin, half-life, etc. The initial elements of the array (L(1,I),I=1,4) are A,Z, number of levels, and number of parents respectively. This allows rapid manipulation of each array without reading every element. Reaction level arrays are very similar except here reaction identification replaces the parent information discussed above. The deexcitation arrays D(K,I) have the same structure for decay and reaction data. The initial 3 elements (D(1,I),I=1,3) contain A,Z, number of transitions, and for each transition (K) its various associated properties (I) are recorded. These properties (I) include energy, intensity, multipolarity and a level identifier which provides a direct link to the L-array. Thus one can find transitions associated with particular level properties or connect levels to selected transitions. The aim of this format is to facilitate selective searches on nuclear information, i.e., a particular level property without reading the entire database.

The various properties stored in this database are in alphanumeric formats. This is somewhat cumbersome in terms of pure numeric analysis, however the subjective analysis of the compilers is retained. Thus, for example, uncertain numbers can be retained or discarded at the discretion of the programmer. A full explication of the non-numeric data is included below, taken largely intact from reference 2. Finally, we must

mention that this database is the most up-to-date nuclear structure data file now available. The Evaluated Nuclear Structure Data File (ENSDF) stored at Brookhaven National Laboratory is somewhat broader in scope, but will not be generally as current as this file until at least 1982. It is anticipated that the ENSDF file will eventually be incorporated into this database.

II. Structure of the *Table of Isotopes* File

The *Table of Isotopes* computer file was created primarily to generate level-scheme drawings. It is an 80-character record file (card image) with 146,200 cards ordered by mass number (A), and within a given A, by increasing atomic number (Z). The file is comprised of eight types of cards containing isotope (I), reference (R), parent nuclei (P), level energy (L), decay (D) information, particle decay (Q), comments (C), and plot-control (X) information. The structure of these cards is shown in figure 1a. For each isotope there may be a level scheme with levels populated from radioactive decay and/or a level scheme populated by one or more nuclear reactions. For radioactive decay level schemes there is one I-card per scheme, one P-card for each parent (e.g., β^+ and α-decay), one L-card for each level, and a D-card for each mode of deexcitation of every level (i.e., multiple γ-rays). For reaction level schemes there is one I-card for each reaction, no P-cards, and L- and D-cards as in radioactive decay schemes. A Q-card is used to plot on the same scheme levels of the daughter populated by particle decay from excited states of the parent, and contains essentially redundant information. A more detailed description of this file is given in reference 2.

III. Database Structure

Although the *Table of Isotopes* data file contains the most current broad-based collection of nuclear level-scheme data, it is not in a form suitable for complex searching on specific subsets of information. This is because it is generally impossible, when searching the file for specific information, to also retrieve related information without reading virtually all records at least once. Thus, in order to find the energy of the lowest 2^+ state in each even-even nucleus, it would be necessary to search every card to find the I-cards, interpret that card to determine if it refers to an even-even nucleus, and then search the L-cards until the first 2^+ spin is found. We have restructured the *Table of Isotopes* file by removing all non-data information (references and plotting instructions) and creating two arrays of data for levels (L) and decay (D) organized by A and Z. These arrays are structured for ease of retrieval of specific level or decay information without requiring the reading of large amounts of extraneous information. An index to the arrays was also created to aid in finding information on specific isotopes. For the example above, the addresses of the desired even-even nuclei could be obtained through a search of the index array, after which it would be necessary only to search the spin elements of the L-array for the first 2^+. The desired energy is then found because it exists as an element explicitly associated with that particular spin. A more detailed discussion of these arrays and their contents is continued below. The level and decay properties retain their definitions from reference 2. Some of the discussion of these properties is taken *verbatim* from reference 2 and exists here only for the convenience of the reader. The authors strongly suggest that the reader consult reference 2 for more detailed descriptions.

A. Index (A,Z) Array

Two L- and two D-files were created for radioactive decay and nuclear reactions respectively. Each file is ordered by mass number (A) and within each A by atomic number (Z) in ascending order beginning with the lightest known element of that A. At least one pair of L- and D- arrays exists for each known isotope. The arrays for each A are stored on magnetic tape and separated by end-of-file (EOF) marks; arrays for each Z are separated by end-of-record (EOR) marks. For missing A files where no data are present, the EOF marks are included to retain the consecutive order of the file.

For each L- and D- file a separate, bidimensional array INDEX(A,Z) was created containing the addresses of the L- and D-arrays for the different A and Z values. If one wishes to locate an array for a given A and Z, he must skip A-1 EOF marks to retrieve the file for A and then INDEX(A,Z)-1 EOR marks to obtain the array for the desired Z. In Table I we have listed a directory of all the arrays contained in the database file. In order to obtain the array INDEX(256,100) for either radioactive decay or reaction data from the LBL Computer Center Tape Library (GSS), one of the following files should be called (format 6612):

Radioactive array index	INDEX/RDECAY,24229.
Reaction array index	INDEX/REACTIONS,24229.

B. Structure and Nuclear Property Information on L-Arrays for Radioactive Decay,L(K,I)

The L-arrays are integer with dimension (300,14). Subscript I labels the various nuclear properties associated with the K element of the array. The structure of this array is shown in figure 2a. When a property stored in the array requires more than one CDC word (10 characters), two or more

elements of the array are used to store it. All numerical values in the data consist of a "generalized number", which is defined as either a decimal or exponent number which may be preceded by one of the following symbols:

$>$, $<$

$\leqslant$, $\geqslant$

$\neq$ (interpreted as $\approx$)

$\lessapprox$ (interpreted as $\lesssim$)

$\gtrapprox$ (interpreted as $\gtrsim$)

Additional alphanumeric data appear in various formats described later.

1. The first element (K=1) of the array contains the following information necessary to determine the array contents:

L(1,1)=A (mass number)

L(1,2)=Z (atomic number)

L(1,3)=NLEV (number of levels in the scheme)

L(1,4)=NPAR (number of parent nuclei in the scheme)

L(1,5-14)= not used

2. All of the information about the parent nuclei is contained in the elements $2 \leqslant K \leqslant$ NPAR+1. The specific parent nuclear properties (I) are:

2.1 L(K,1)= } PARENT NUCLEI (2 elements)
L(K,2)= }

where allowable names for the parent nuclei can be:

Format	Example	Interpretation
A-Element	22-NA	^{22}Na
AM-Element	110M-AG	^{110m}Ag
AM_i-Element (i is an integer)	192M2-IR	$^{192m_2}Ir$
A-Element($T_{1/2}$)	180RE(20 H)	$^{180}Re(20h)$

2.2 L(K,3)=DECAY MODE

The following are possible decay modes.

Mode	Interpretation
SF	Spontaneous fission
N	n
P	p
A	α
B-	β^-
EC+B+	EC+β^+
B++EC	β^++EC
EC,B+	EC,β^+
B+,EC	β^+,EC
B+	β^+
EC	EC

2.3 L(K,4)=HALF-LIFE

The half-life consists of a generalized number plus one of the following units:

AS	M
FS	H
PS	D
NS	Y
US (microsecond)	
MS	
S	

It may also have a blank between the number and the unit.

Numbers preceded by a W are "level widths" expressed in MeV.

2.4 L(K,5)= } SPIN (two elements)
L(K,6)= }

"Spin" refers generally to level quantum numbers including J,¶,K, Nilsson numbers [N,$n_z\Lambda$], T(isospin), and ℓ-transfer value (direct reaction). Different quantum numbers are preceded by a letter denoting type(s) and

are separated by blanks. Type designation is as follows:

S Spin and parity (optional, see below)

K K(Nilsson assignment)(optional, see below)

T Isospin

L ℓ-transfer value

For example S5/2+ K5/2[642]

indicates $J^{\pi}=5/2^{+}$ and the Nilsson assignment is 5/2[642]. If no character precedes the first value it is assumed to be J^{π} and if no character precedes the second value it is assumed to be K or the Nilsson assignment. Uncertain assignments are given in parenthesis. Band structure may be indicated by appending a letter to K to indicate two or more different bands with the same K. This is not necessary if bands (odd-A) are assigned different Nilsson quantum numbers.

Examples are:

0+ K0
2+ K0 } ground state band

0+ K0A
2+ K0A } first excited state K=0 band

0+ K0B
2+ K0B } second excited state K=0 band

A complete list of the valid spin formats is given in reference 2.

2.5 L(K,7)=
L(K,8)= } Q-VALUE (two elements)

The Q-value for the decay may be either a generalized number or a number with an uncertainty.

Examples:

≠3.02 (approximately 3.02 MeV)

4.051+-10 (4.051±0.010 MeV)

2.6 L(K,9)=ID (Parent)

An identifier is a single character or a blank. This identifier is used on corresponding levels to indicate the parent which feeds that level (if there is more than one parent).

3. Level information is found in the array elements with K≥NPAR+2. The specific properties are:

3.1 L(K,1)=LEVEL ENERGY

The energy is a generalized number ordered in K by ascending value which may be followed by one or more of the following modifiers:

Modifier	Interpretation
I	Isomer
?	Uncertain level
C	Complex level
(C)	Probably complex level

Energies are generally given in MeV; however, in some cases keV are used. It is not possible, *a priori*, to determine the units used here.

3.2 L(K,2)=, L(K,3)=, L(K,4)= } SPIN (three elements)

The usage discussed in "parent nuclei" above applies here.

3.3 L(K,5)=HALF-LIFE

The usage discussed in "parent nuclei" above applies here.

3.4 L(K,I=6,8,10,12)=PARENT IDENTIFICATION/DECAY MODE

L(K,I=7,9,11,13)=FEEDING INTENSITY

These pairs of elements contain the various decay identifiers and their associated intensities. The first character of the even-numbered elements contains the parent identifier (described above), and the remaining characters describe the decay mode (see above). For example, AEC signifies an electron-capture-fed level from parent A. If the decay mode is blank, the parent nucleus data must be consulted. When the parent decays by EC+β^+ decay, but the feeding intensity refers only to EC, the mode is specified. Grouped feeding to more than one level is indicated by Sn (possibly preceded by a blank) following the mode specification, where n is the number of levels fed by that transition. The feeding applies to the previous n levels including the present one. The feeding intensity given in the odd-elements is a generalized number representing the feeding in % or, if it is preceded by an R, it is a relative intensity.

3.5 L(K,14)=TRANSITION IDENTIFIER

This element links the L-arrays and the D-arrays. It contains the value of the subscript K of the D-array element corresponding to the last transition which deexcites the level (see Section D). If no transitions deexcite the level, L(K,14)=0 except for the array element for the ground state L(NPAR+2,14)=1. To determine the number of transitions deexciting a given level use the relationship

$$N(\text{transitions})=L(K,14)-L(K',14)$$

where K' corresponds to the first preceding level with decaying transitions.

C. Structure and Nuclear Property Information on L-Arrays for Nuclear Reactions, L(K,I).

The L-arrays are integer with dimension (300,12). As in radioactive decay, K labels the different levels of the scheme and I the associated

nuclear properties. Figure 2b shows the structure of this array. Many of these properties are identical to those discussed for the radioactive decay arrays. Only the different properties will be discussed in detail here.

1. The first element (K=1) of the array contains the following information necessary to determine the array contents.

L(1,1)=A (mass number)

L(1,2)=Z (atomic number)

L(1,3)=NLEV (number of levels in the scheme)

L(1,4)=NREACT (number of reactions)

L(1,5-12)=not used

2. The information about the reactions feeding levels in this array is contained in the elements $2 \leq K \leq NREACT+1$. The specific properties are:

2.1 L(K,1)=, L(K,2)=, L(K,3)=, L(K,4)= } REACTION LIST (4 elements)

Typical reaction names may be

FISSION

COULOMB EXCITATION

56-FE(P,NG)

20-NE(16-O,12-C)

IN-BEAM G SPECT

Proper particle names are:

Symbol	Interpretation
P	p
N	n
D	d
T	t
A	α
G	γ
E	e
PI+	π^+
PI-	π^-
PIO	π^o
MU+	μ^+
MU-	μ^-
MUO	μ^o
KA+	K^+
KA-	K^-
KAO	K^o
KAOA	$\tilde{K}^o$

The final nucleus is not listed.

2.2 L(K,5)=REACTION IDENTIFIER

As in radioactive decay this is a single character (or blank) identifying the reaction in the level list below.

3. The level information is contained in array elements with K $\geq$ NREACT+2. The information is identical to that for radioactive decay with the following exceptions:

3.1 L(K,I=6,7,8,9,10,11)=FEEDING REACTION IDENTIFICATION

Each element may contain up to 10 one character reaction identifiers described above. Grouped feeding is defined as in radioactive decay.

3.2 L(K,12)=TRANSITION IDENTIFIER

Identical to element L(K,14) in radioactive decay.

D. Structure and Nuclear Property Information on D-Arrays, D(K,I).

D-arrays are structured identically for both radioactive decay and nuclear reactions. The D-arrays are integer with dimension (500,10). Subscript I labels the various nuclear properties associated with the K element of the array. The structure of this array is described in figure 2c.

1. The first element (K=1) of the array contains the following information necessary to determine the array contents.

D(1,1)=A (mass number)

D(1,2)=Z (atomic number)

D(1,3)=NTRANS (number of transitions in the scheme)

D(1,4-10)=not used

2. All of the information on the transitions is contained in the array elements with K≥2. Transitions may be γ-rays or particles (including electron capture). If no transitions have been observed D(1,3)=0. The specific properties are:

2.1 D(K,1)=TRANSITION ENERGY

For γ-rays the energy is a generalized number with the following possible additions:

Modifier	Interpretation
*	Same transition used more than once in the scheme
?	Uncertain transition

If the transition energy is blank or ? only, it was not originally intended to be plotted and is extremely uncertain or not measured. For particle decays no energy is given. Only the decay mode (see parent nuclei, decay mode) is given in D(K,1). The modifier ? may also be

present indicating an uncertain transition.

Grouped decay may be indicated for either gamma or particle decay by Sn (possibly preceded by a blank) appended to the γ-ray energy or decay mode. The transition originates at one of the last n levels.

Examples of a grouped format are

≠0.28S3	(≈0.28 γ-ray originates from the 3 last-named levels)
≠0.28*?S2	(0.28 multiply used uncertain γ-ray originates from one of the last 2 levels)
PS2	(proton group from the last two levels)
P?S2	(uncertain proton group from the last two levels)
?S2	(unlabeled, uncertain γ-ray from the last two levels)

2.2 D(K,2)= } ABSOLUTE INTENSITY (two elements)
D(K,3)= }

Absolute intensities are generalized numbers, numbers with uncertainties (e.g., 23.8+-5), or W(weak). For γ-rays the intensities refer to photons; for the conversion electron intensity in a specific shell the following symbols are appended (sometimes enclosed in parenthesis):

Symbol	Interpretation
E	e^- total
K	K shell
L	L "
M	M "
N	N "
O	O "
P	P "

2.3 D(K,4)= } RELATIVE INTENSITY (two elements)
D(K,5)= }

This is identical in format to absolute intensity (2.2).

2.4 D(K,6)= }
D(K,7)= } MULTIPOLARITY(three elements)
D(K,8)= }

Multipolarities may be single values, admixtures or choices. An admixture is separated from the first multipolarity by a blank. The symbol % is not in the file but is implicitly assumed. Examples of these are:

Form	Interpretation
M1	M1
(M1)	Probably M1
M1+E2	M1+E2
M1,E2	M1 or E2
(M1,E2)	Probably M1 or E2
M1(+E2)	M1, probably an E2 admixture
M1+0.5 E2	M1+0.5%E2
M1(+≠0.5 E2)	M1 + probably ≈0.5%E2
NOT E1	not E1

2.5 D(K,9)=FINAL LEVEL ENERGY

This generalized number identifies the level where the γ-ray or particle terminates. For γ-rays this corresponds exactly to the energy of a previously named level including modifiers such as ≠ or>, but excluding ?,I,C, or (C). For particle decay the final level energy may be absent or correspond to a daughter level of a different nucleus. Grouped final levels may be indicated by Sn (blank Sn) appended to the final level energy for either γ-ray or particle transitions.

2.7 D(K,10)=LEVEL IDENTIFIER

This important array element provides a link between the D- and L-arrays. The level identifier is the subscript K of the L-array corresponding to the initial level of the transition.

E. Retrieval of D- and L- Arrays from GSS Magnetic Tape.

D- and L-arrays are stored on magnetic tape at the LBL Computer Center Tape Library (GSS). The radioactive decay arrays are stored as follows:

LEVEL ARRAYS L(K,I): ARRAYS/LEVELS/RDECAY,24229.

DECAY ARRAYS D(K,I): ARRAYS/GAMMAS/RDECAY,24229.

For reaction data substitute REACTIONS for RDECAY in the pathname.

Formats for L- and D- arrays are shown in figure 2.

A typical search consists of the following steps:

1. Retrieve the data base file from magnetic tape (GSS) and store it into an input(disk) file (TAPE1). This is done with the GETTAPE command:

```
GETTAPE,TAPE1=ARRAYS/LEVELS/RDECAY,24229.
```

2. Read the initial four(three) elements of the L(D)-array from the input file. The identification and content of the array are stored in these elements(see Sections C1 and D1). This information is necessary to store the complete array into core memory (see Section E3 below).

Level array

```
READ(1,10) (L(1,I),I=1,4)
10 FORMAT(3I3,I2)
```

Decay array

```
READ(1,10)(D(1,I),I=1,3)
10 FORMAT(3I3)
```

3. Store the rest of the array into core memory. This is done by calling one of the LOAD subroutines shown below.

a) L-array for radioactive decay.

```
      SUBROUTINE LOADLD
      DIMENSION L(300,14)
      COMMON/LARRAY/L
C.....L(1,4)= NUMBER OF PARENT NUCLEI
      KMAXP= L(1,4) + 1
      KMAXP1= KMAXP + 1
C.....L(1,3)= NUMBER OF LEVELS
C.....KMAX= MAXIMUM VALUE OF SUBSCRIPT K OF ARRAY L(K,I)
      KMAX= KMAXP + L(1,3)
      READ(1,10) ((L(K,I),I=1,9),K=2,KMAXP)
      READ(1,20) ((L(K,I),I=1,14),K=KMAXP1,KMAX)
   10 FORMAT(7A10,A8,A1)
   20 FORMAT(5A10,8A8,I3)
      RETURN
      END
```

b) L-array for nuclear reactions.

```
      SUBROUTINE LOADLR
      DIMENSION L(300,12)
      COMMON/LARRAY/L
C.....L(1,4)= NUMBER OF PARENT NUCLEI
      KMAXR= L(1,4) + 1
      KMAXR1= KMAXR + 1
C.....L(1,3)= NUMBER OF LEVELS
C.....KMAX= MAXIMUM VALUE OF SUBSCRIPT K OF ARRAY L(K,I)
      KMAX= KMAXR + L(1,3)
      READ(1,10) ((L(K,I),I=1,5),K=2,KMAXR)
      READ(1,20) ((L(K,I),I=1,12),K=KMAXR1,KMAX)
   10 FORMAT(4A10,A1)
   20 FORMAT(11A10,I3)
      RETURN
      END
```

c) D-array for either radioactive decay or nuclear reaction.

```
      SUBROUTINE LOADD
      INTEGER D(500,10)
      COMMON/DARRAY/D
C.....D(1,3)= NUMBER OF TRANSITIONS
C.....KMAX= MAXIMUM VALUE OF SUBSCRIPT K OF ARRAY D(K,I)
      KMAX= D(1,3) + 1
      READ(1,10) ((D(K,I),I=1,10),K=2,KMAX)
   10 FORMAT(A10,2(A8,A7),2A10,A9,A10,I3)
      RETURN
      END
```

4. Perform the search. Now the search for a specific nuclear property(ies) can be done using the L-and/or D-arrays. See Section IV for examples.

IV. Examples of Use of the Database.

A. Energy of the Lowest 2^+ States and Weisskopf Enhancement for the $2_1^+ \rightarrow 0_1^+$ Transitions in Even-Even Nuclei.

The available information about the lowest lying 2^+ states of even-even nuclei was retrieved from the database in the following manner. First, the index arrays for decay and reaction level information were searched to find those which contained even A and Z values. The spin array elements L(K,5) and L(K,6), K$\geqslant$ NPAR+3 were scanned for the first 2^+ or (2^+) assignment (the L-arrays are ordered by increasing energy). After this successful search, the energy L(K,1) and half-life (L,4) were retrieved. The computer code utilized in this search is shown in figure 3, and a part of the output file is shown in figure 4. From this output an array of 2^+ energies (in keV) was obtained which is displayed in Table II. The collected half-lives were then utilized to calculate the Weisskopf enhancements (without the statistical factor) for the E2 transitions to the ground state, which are displayed in Table III.

B. Compilation of γ-ray B(M,L$\leqslant$ 5) and B(E,L$\leqslant$ 6) Experimental Reduced Transition Probabilities.

All mass chains were searched to identify γ-ray transitions with known half-lives and multipolarities. For each A,Z the L-array was searched to select all levels with measured half-lives (L(K,5)$\neq$ blank). The γ-ray properties for these levels reside in the array element D(J,I), where J is determined through L(K,14) (the link between D- and L- arrays). The multipolarities D(J,6) were searched for non-blank values. Whenever a measured half-life and transition multipolarity were found, the transition intensity, multipolarity, and level half-life were recorded along with those of all

associated deexcitations from the same level (to obtain branching ratios) to a file containing all similar multipolarities. Figure 5 shows the data extracted for E5 transitions, and figure 6 shows the distribution of M4 reduced transition probabilities in Weisskopf units (omitting statistical factors). The entire sort for all multipolarities ($0 \leq \ell \leq 6$) took 18.6 s execution time on the LBL CDC-7600 computer.

References

1. *Table of Isotopes*, 7th edition: C.M. Lederer and V.S. Shirley, editors; E. Browne, J.M. Dairiki, and R.E. Doebler, principal authors; A.A. Shihab-Eldin, L.J. Jardine, J.K. Tuli, and A.B. Buyrn, authors, John Wiley and Sons, Inc., New York (1978).

2. "Level Scheme Analysis and Graphics", C.M. Lederer, LBL-1996 (1973).

Table I. Index of the Arrays Contained in the Database

a. Radioactive decay.

A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z
1	1		18		28		34		39		45	117	49		55		55		64	163	66		71		80		83		88	241	94
3	2		19		29		35		40		46		50		56		56		65		67		72	191	76		84	218	84		95
6	3	39	18	61	27		36		42		47		51	129	50		58	149	60		68		73		77	205	81		86		96
7	3		19		28	80	34		43	104	42		52		51		59		61		69		74		78		82		87	242	94
8	3	40	18		29		35	93	37		44		53		52		60		62	164	68		78		79		83	219	86		95
	4		20	62	27		36		38		45	118	47		53	139	55		63		67	178	71	192	76		84		87		96
9	4	41	18		28		37		39		46		48		54		56		64		68		72		77		85	220	86	243	94
	5		19		29	81	33		40		47		49		55		57	150	60		69		74		78	206	81		87		95
10	5		20	63	28		34		41		48		50		56		58		62		70		76		79		82		88		96
11	4		21		29		35		42	105	44		51		57		59		64	165	66		78		80		83	221	87	244	94
	5	42	19		30		36		43		45		52	130	50		60		65		67	179	72	193	77		84		88		96
12	6		20	64	28		37		44		46		53		51		61		66		68		73		78	207	81		89		98
13	6		21		30	82	34	94	38		47	119	48		52		62	151	61		69		74		79		82	222	86	245	95
	7	43	19		31		35		39		48		49		53	140	55		62	166	67		75		80		83		88		96
14	6		20	65	29		36		40	106	44		50		54		56		63		68	180	72		81		84		89	246	95
	7		21		30		37		41		45		51		56		57		64		69		74	194	77		85	223	87		96
15	7	44	19		31	83	34		42		46		52		57		58	152	61		70		75		78		86		88	247	96
16	7		20	66	29		35		43		48	120	47	131	50		59		62		71		76		79	208	81		89		97
	8		21		30		36	95	38	107	45		48		52		60		63		72		77		80		82		90		98
17	8		22		31		37		39		46		49		53		62		64	167	67		78		81		83	224	88	248	96
	9	45	20	67	30		38		40		47		50	141	55		65		68	181	73		82		84		89		97
18	8		21		31	84	34		41		48		52		55		57		66		69		74	195	78		85		90		98
	9		23	68	29		35		42		49		53		56	153	62		70		75		79	209	81	225	88		100
19	9	46	20		30		36		43	108	44		54		57		59		63		71		79		80		82		89	249	96
20	9		21		31		37		44		45	121	49	132	50		60		64	168	68	182	72		81		83		90		97
	10		22		32		38		45		46		50		51		61		65		70		73	196	78		84	226	88		98
21	10		23	69	30	85	34	96	38		47		51		52		62	154	62		72		74		79		85		89	250	96
	11	47	20		31		35		39		48		52		53		63		63	169	68		75		80		86		90		97
22	10		21		32		36		40		49		53		54	142	55		64		69		76		81		87	227	89		98
	11		22		33		37		42		50	122	48		56		56		66		70		78		82	210	81		90	251	97
23	10	48	20	70	30		38		43	109	46		49		57		57	155	63		71	183	73	197	78		82	228	88		98
	11		22		32		39		44		47		50		58		58		64		72		74		79		83		89		99
24	11		23		33		40		45		48		51	133	51		60		65	170	68		75		80		84		90		100
	12	49	21	71	31	86	34	97	39		49		52		52		62		66		70		76		81		85		92	252	98
	13		22		32		36		40	110	47		53		53	143	58	156	63		71	184	73		82		86	229	90	253	98
25	11		23		33		37		41		[illegible]		54		54		59		64		72		74	198	78	211	82	230	90		99
	12		25	72	31		38		42		47	123	50		55		60		65		74		75		79		83		92		100
	13	50	21		32		39		43		48		51		56		61		66	171	69		76		80		84	231	90	254	100
26	12		22		33	87	36		44		49		52		57		62		67		70		78		81		85		91	255	100
	13		24		34		37		45		50		53		58		63		68		71		79		82		86		92	256	100
27	12	51	22		35		38	98	39	111	46		54	134	52	144	56	157	63		72		80		83		88	232	90		
	13		23	73	32		39		40		47		55		53		58		64	172	69	185	74	199	78	212	82		92		
28	12		24		33		40		41		48	124	49		54		59		65		70		75		79		83	233	91		
	13	52	23		34	88	36		42		49		50		55		60		66		71		76		80		84		92		
	14		24		35		37		44		50		51		56		62		68		72		81		81		85		93		
29	13		25	74	31		38		45	112	46		52		57		63	158	64		73	186	74		82		86	234	90		
	14		26		32		39	99	40		47		54		58	145	59		65		74		75		83		87		91		
	15	53	23		34		40		41		48		55	135	52		60		66		76		76	200	79	213	83		92		
30	14		24		35	89	36		42		49	125	50		53		61		67	173	69		78		80		84	235	92		
	15		25		36		37		43		50		51		54		62		68		70		80		81		85		93		
31	14		26	75	32		38		44	113	48		52		55		63	159	64		71	187	75		82		87	236	91		
	15		27		33		39		45		49		53		56		64		65		72		76		85		88		92		
32	15	54	24		34		40	100	40		50		54		57	146	58		66		76		77	201	80	214	82		93		
	16		26		35	90	36		41		51		55		58		59		67	174	70		81		81		83		94		
33	15	55	25	76	32		37		42	114	48	126	51		59		60		68		71	188	75		82		84	237	92		
	16		26		34		38		44		49		52		60		62	160	64		72		76		83		85		93		
	17	56	25		35		39		45		50		54	136	54		63		66		74		77		84		87		94		
34	15		26		36		40		46	115	48		55		56		64		67		76		78	202	80	215	84	238	92		
	16		27	77	32		41	101	43		49		56		58	147	60		68	175	70		80		81		85		93		
	17	57	26		33		42		44		50	127	50		59		61	161	65		71	189	76		82		86		94		
35	16		27		34	91	37		45		51		51		60		62		66		72		77		83		87		96		
	17		29		35		38		46		53		52	137	55		63		67		73		78		84	216	84	239	93		
36	16	58	26		36		39		47	116	47		53		56		64		68	176	70		79	203	81		85		94		
	18		27	78	33		40	102	42		48		54		57		66	162	65		72	190	75		82		86		95		
37	17		28		34		41		44		49		55		58	148	58		66		73		76		83		87	240	92		
	18	59	27		36		42		46		50	128	51		59		60		67		74		77		84	217	85		93		
	19		28		37	92	37		47		51		52		60		61		68		75		78	204	80		86		94		
38	17	60	27	79	33		38	103	44		52		54	138	54		62		69	177	70		79		82		87		96		

Table I. (continued)

b. Reaction data.

A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z	A	Z
4	1	23	10		19		24		32	83	34		42	108	44		51		57		64		65	172	70		78		80	229	89
	2		11		20		25	67	29		35		43		46		52		58	145	60		66		71		80		81	230	90
	3		12	40	18		26		30		36		44		47		54	134	52		61		67		72	187	74		82	231	89
5	2	24	10		19	53	23		31		38	97	40		48		56		55		62		68		74		75	200	80		90
	3		11		20		24		32	84	34		41		50	121	49		56		63		70		76		76		81		91
6	2		12		21		25	68	30		36		42	109	43		50		58		64	159	64	173	70		77		82	232	90
	3		13	41	18		26		31		37		43		46		51		60	146	56		65		71		78		83		92
	4	25	10		19	54	23		32		38		44		47	122	50	135	53		58		66		72		79		84	233	90
7	3		11		20		24	69	29	85	35	98	40		48		51		54		60		67	174	70	188	74	201	80		91
	4		12		21		25		30		36		41		49		52		55		62		68		71		75		81		92
8	3		13	42	18		26		31		37		42		50		54		56		63		70		72		76		82	234	90
	4		14		19		27		32		38		43	110	44		56		57		64	160	64		74		78	202	80		92
	5	26	11		20	55	24		33		39		44		46	123	49		58	147	60		65	175	70		80		81	235	91
9	3		12		21		25	70	30	86	36		45		47		50		59		62		66		71	189	75		82		92
	4		13		22		26		31		37		46		48		51		60		64		67		72		76		84		93
	5		14	43	18		27		32		38	99	41		49		52	136	54	148	58		68		73		77	203	80	236	92
	6	27	12		19	56	24	71	30	87	35		42		50		54		56		60		70		74		78		81	237	91
10	4		13		20		25		31		37		43	111	44	124	50		58		62	161	64	176	70		79		82		92
	5		14		21		26		32		38		44		46		51		60		64		65		71	190	76	204	80		93
	6	28	12		22		27		33		39		45		48		52	137	54	149	59		66		72		78		81		94
11	4		13	44	18		28	72	30	88	36		46		49		54		55		60		67		74		80		82	238	92
	5		14		19	57	25		31		37	100	40		50		56		56		61		68		76	191	75		83		93
	6		15		20		26		32		38		42	112	44	125	50		57		62	162	66	177	70		76		84		94
12	4	29	13		21		27		33		39		43		46		51		58		63		67		71		77	205	80	239	92
	5		14		22		28		34		40		44		48		52		59		66		68		72		78		81		93
	6		15	45	18	58	25	73	32	89	38		46		49		54		60	150	58		70		73		79		82		94
	7	30	13		19		26		33		39	101	42		50		57	138	54		60	163	66		74		80		83	240	92
13	5		14		20		27		34		40		43		52	126	50		56		62		67		75		81		84		94
	6		15		21		28	74	32	90	36		44	113	48		52		57		64		68	178	72	192	76		85		95
	7		16		22		29		33		38		45		49		54		58	151	60	164	66		74		77	206	80	241	94
14	5	31	14	46	19	59	26		34		39		46		50		56		60		61		67		76		78		81		95
	6		15		20		27		36		40	102	40		51	127	51	139	56		62		68	179	72		79		82	242	94
	7		16		21		28	75	32		41		42	114	46		52		57		63		70		73		80		83		95
	8	32	14		22		29		33		42		44		48		53		58		64	165	66		74	193	77		84	243	94
15	6		15		23	60	26		34	91	39		45		49		54		59	152	60		67		75		78		86		95
	7		16	47	19		27	76	32		40		46		50		55		60		62		68	180	72		79	207	81		96
	8		17		20		28		33		41		48		51		57	140	54		63		69		74		80		82	244	94
16	6	33	15		21		29		34		42		50		52	128	52		55		64		70		76		81		83		95
	7		16		22		30		35	92	39	103	44	115	48		53		57	153	62	166	67	181	72	194	77		84		96
	8		17		23	61	27		36		40		45		49		54		58		63		68		73		78		86	245	94
	9		18	48	20		28	77	32		41		46		50		56		59		64		70		74		79	208	82		96
17	7	34	15		21		29		33		42		47		51		58		60		65		72		75		80		83	246	96
	8		16		22	62	26		34		43	104	42		52		60		62	154	60	167	68		76		82		84	247	96
	9		17		23		27		35	93	39		44	116	46	129	51	141	58		62		69	182	73	195	78	209	81		97
	10		18		24		28		36		40		45		48		52		59		63		70		74		79		82	248	96
18	7	35	16	49	20		29	78	34		41		46		49		53		60		64		71		76		80		83		98
	8		17		21		30		35		42		47		50		54	142	56		66	168	68		78		81		84	249	96
	9		18		22	63	27		36		43		48		51		56		58	155	62		69	183	74		82		85		97
	10		19		23		28		38		44		50		52		57		59		63		70		75	196	78	210	82		98
19	8	36	16		24		29	79	34	94	38	105	44		54	130	52		60		64		72		76		79		83	250	96
	9		17	50	20		30		35		39		45	117	48		54		61		65	169	68		77		80		84		98
	10		18		21	64	27		36		40		46		49		56		62		66		69	184	74		82		85	251	99
20	8		19		22		28	80	34		41		47		50		58		64		68		70		75	197	78	211	82		
	9	37	16		23		29		35		42		48		51	131	52	143	58	156	62		71		76		79		83		
	10		17		24		30		36		43	106	42		52		53		60		64		72		78		80		84		
	11		18		25		31		38		44		44	118	48		54		61		66	170	68		80		81		85		
21	9		19	51	21	65	28	81	34	95	39		46		50		56		62		68		69	185	74		82	212	82		
	10		20		22		29		35		40		47		51		57		63	157	64		70		75	198	78		84		
	11	38	17		23		30		36		41		48		52	132	54	144	56		65		72		76		79		86		
	12		18		24		31		37		42		50		54		56		58		66	171	68		77		80	213	87		
22	9		19		25	66	28	82	34		43	107	46	119	49		58		60		67		69		78		81	214	88		
	10		20		26		29		35		44		47		50	133	54		61		68		70	186	74		82	216	88		
	11	39	17	52	22		30		36	96	40		48		51		55		62	158	62		71		75	199	78	224	88		
	12		18		23		31		38		41		49	120	50		56		63		64		72		76		79	228	90		

TABLE II. ENERGY OF FIRST EXCITED 2+ STATES IN EVEN-EVEN NUCLEI (Z=2-50). CLOSED SHELLS ARE INDICATED BY ***

Z / N	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	Z / N
2	33000	1670	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	2
4	1800	2940	3353	*						*				*											*	4
6	*	3368	4439	6590						*				*											*	6
8	***	***	7012	6919	1887	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	8
10	*		1750	1982	1634	1247				*				*											*	10
12	*			1674	1275	1369	1796			*				*											*	12
14	*			*	1981	1809	1779	2211		*				*											*	14
16	*			*		1473	2235	2230	2091	*				*											*	16
18	*			*			1941	2127	1970	2206				*											*	18
20	***	***	***	***	***	***	***	***	3291	2168	3904	1555	***	***	***	***	***	***	***	***	***	***	***	***	***	20
22	*			*					1461	1525	1083			*											*	22
24	*			*					1208	1157	889	752		*											*	24
26	*			*						1347	984	783	840	*											*	26
28	***	***	***	***	***	***	***	***	***	3832	1554	1434	1408	2701	***	***	***	***	***	***	***	***	***	***	***	28
30	*			*						1030	1047	835	847	1454	1004										*	30
32	*			*						*		1008	811	1332	954										*	32
34	*			*						*				1173	991	957									*	34
36	*			*						*			1630	1346	1039	1016									*	36
38	*			*						*				1420	1077	1040	862	456							*	38
40	*			*						*				*	885	834	635	424	505						*	40
42	*			*						*				*	650	596	559	455	385						*	42
44	*			*						*				*		563	614	616	573						*	44
46	*			*						*				*			666	776	793						*	46
48	*			*						*				*			654	882	1077	1057	948				*	48
50	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	1455	1565	1836	2186	1509	1428	***	***	***	50
52	*			*						*				*			704	775	832	934	871	833	841		1354	52
54	*			*						*				*				707	815	919	778	652	666	719	1216	54
56	*			*						*				*					837	1751	787	540	557	658	1210	56
58	*			*						*				*					815	1223	535	475	556	633	1206	58
60	*			*						*				*						212	296	358	512	633	1212	60
62	*			*						*				*						152	192	270	434	658	1257	62
64	*			*						*				*							172	242	374	617	1300	64
66	*			*						*				*								241	349	558	1294	66
68	*			*						*				*								237	333	513	1230	68
70	*			*						*				*									341	488	1172	70
72	*			*						*				*										506	1141	72
74	*			*						*				*										570	1132	74
76	*			*						*				*											1145	76
78	*			*						*				*											*	78
80	*			*						*				*											1217	80
82	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	82
N / Z	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	N / Z

TABLE II. (CONTINUED, Z=52-100).

Z / N	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	Z / N
60	720															*										60
62	709	337														*										62
64	679	337	183													*										64
66	605	322	197													*										66
68	560	331	230		144											*										68
70	564	354	256	207												*										70
72	603	389	283	254												*										72
74	666	443	357	325	294											*										74
76	743	536	465	409	373											*										76
78	839	668	605	552	520	531	526									*										78
80	974	847	818	789	774	768	743									*										80
82	1279	1313	1436	1596	1576	1660	**********									**********										82
84		589	602	641	696	747	784	804								*										84
86		377	360	397	454	550	638	614								*										86
88			199	258	302	334	344	334	345	358						*										88
90			181	158	130	122	123	138	192	243						*										90
92				98	76	82	89	99	126	166						*										92
94					73	76	80	87	102	124	159					*										94
96						73	75	81	91	102	124	156	228			*										96
98								73	81	88	101	123	152			*										98
100									80	84	95	112	135			*										100
102									79	79	91	109	132	160		*										102
104										76	88	106	132	155	367	*										104
106										82	93	104	127	163	405	*										106
108											93	100	120	192	413	*										108
110											98	111	137	266	416	*										110
112												123	155	296	423	965										112
114													187	317	428	1049										114
116													206	328	426	1063	668									116
118														356	412	1026	675									118
120														407	368	961	683	632								120
122															440	899	701									122
124															437	803	686	644								124
126	**********														1068	4086	1181	1272	1381	**********						126
128																800	727		688							128
130																805	609	465								130
132																837	550	324	177							132
134																*	512	241	111	93						134
136																*		186	84	72	59					136
138																*			68	58	52					138
140																*			59	53	48					140
142																*				49	43	45	35			142
144																*				49	45	44	40			144
146																*					45	43	42	40		146
148																*					45	45	43		44	148
150																*						45	43	42		150
152																*							43	43		152
154																*							43	46	45	154
156																*									48	156
N / Z	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	N / Z

TABLE III. E2 WEISSKOPF ENHANCEMENTS FOR THE $2_1^+ \rightarrow 0_1^+$ TRANSITIONS IN EVEN-EVEN NUCLEI, Z=2-50. CLOSED SHELLS ARE INDICATED BY ***.

Z / N	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	Z / N
2	***																									2
4	*		9	*						*				*											*	4
6	*	8	5	*						*				*											*	6
8	***			4	18	***																				8
10	*			3	22	17				*				*											*	10
12	*			1	12	20	7			*				*											*	12
14	*			*	6	13	13	16		*				*											*	14
16	*			*		13	8	9	15	*				*											*	16
18	*			*			8	7	10	*				*											*	18
20	***							3	4	2	18	***														20
22	*			*					10	10	14			*											*	22
24	*			*					8	10	23	25		*											*	24
26	*			*						3	14	19		*											*	26
28	***									2	6	11	8	6	***											28
30	*			*						*	13	14	16	10											*	30
32	*			*						*			13	13											*	32
34	*			*						*				12	22										*	34
36	*			*						*				8	18										*	36
38	*			*						*				*	15	21	19								*	38
40	*			*						*				*	19	25	40	58							*	40
42	*			*						*				*		34	44	58	81						*	42
44	*			*						*				*		27	33	39							*	44
46	*			*						*				*			24	19	27						*	46
48	*			*						*				*			17	15	10						*	48
50	***																		7	5	7	***				50
52	*			*						*				*						6	15	21			*	52
54	*			*						*				*						4	20	30			*	54
56	*			*						*				*						4	21	41			*	56
58	*			*						*				*							37	51	37	26	*	58
60	*			*						*				*						62	78	60	49	27	*	60
62	*			*						*				*						90	73		50	27	16	62
64	*			*						*				*							90	62	57	33	15	64
66	*			*						*				*								62		32	13	66
68	*			*						*				*								70	21	31	13	68
70	*			*						*				*									33		12	70
72	*			*						*				*											11	72
74	*			*						*				*											9	74
76	*			*						*				*											*	76
78	*			*						*				*											*	78
80	*			*						*				*											*	80
82	***																									82
Z / N	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	Z / N

TABLE III. (CONTINUED, Z=52-100).

Z	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	Z
N																										N
60																*										60
62																*										62
64																*										64
66		50														*										66
68	29	62														*										68
70	37	48	67													*										70
72	31	41	77	84												*										72
74	25	36	60	75												*										74
76	20	46	36	52												*										76
78	15	22	33													*										78
80			19													*										80
82	*********		10	13	19	11	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	82
84				21	23											*										84
86			30		32	33										*										86
88			49	38	56	57	80		68	73						*										88
90			57	79	116	140	159	149	110	90						*										90
92				102		175	186	179	167	140						*										92
94					87		197	193	200	169	126					*										94
96							199	199	213	195	153					*										96
98								208	209	205	181					*										98
100									210	202	148					*										100
102									207	207	149					*										102
104										201	187				62	*										104
106										178	157	147	126	126	44	*										106
108											154	134	99	94		*										108
110												118	97	83		*										110
112												111	76	70		*										112
114													73	62		*										114
116													62	46	41	*										116
118														45	30	*										118
120														29	27	*										120
122															19	4										122
124															13	3										124
126	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	**********	126
128																*										128
130																*										130
132																*										132
134																*		46	111							134
136																*		59	98	162						136
138																*			123	169	223					138
140																*			144	194	234					140
142																*				201	234					142
144																*				182	250	285				144
146																*					271	294				146
148																*						296	333			148
150																*						292	324			150
152																*							323			152
154																*								357		154
156																*										156
N																										N
Z	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	Z

a.

I	ISOTOPE		REACTION				ID
R	REFERENCES						
P	PARENT		MODE	HALF-LIFE	SPIN	Q-VALUE	ID
L	ENERGY	SPIN		HALF-LIFE	FEEDING	INTENSITY	LOG FT, HF
D	ENERGY	ABS. INTENSITY	REL. INTENSITY	MULTIPOLARITY			FINAL LEVEL
Q	DAUGHTER		MODE	Q-VALUE	LEVELS [ENERGY Iπ]		
C	COMMENT						
X	PLOT CONTROL						

b.

```
I14-N                  DECAY
R*P*R 148 1024//66, *N*P *A129 172//69,
RC*N*P *A268 1//76
MEV
P14-C                  B-        5730Y     0+                  0.156478+-9        A
P14-O                  B+        70.60S    0+                  5.1449+-5          B
L0          1+                                          A      100       9.02
L                                                       B      0.61      7.3
L2.3129     0+                                0.96PS    B      99.33     3.49
D2.3127                                       M1                         0
L3.9478     1+                                3.1FS     B      0.06       3.0
D?                             96.1+-3        M1                         2.3129
D?                             3.9+-3         E2+11 M1                   0
X RENORM OPTION=5A
```

Fig. 1

a. *Table of Isotopes* structure of card-image-level-scheme file.

b. A typical example: ^{14}N level scheme.

a. Radioactive Decay Array L(300,14)

Format	Elements
3I3,I2	L(1,1)=A, L(1,2)=Z, L(1,3)=NLEV, L(1,4)=NPAR
7A10,A8,A1	L(K,I), K=2,NPAR+1; I=1,9
5A10,8A8,I3	L(K,I), K=NPAR+2,NPAR+NLEV+1; I=1,12

b. Reaction Data Array L(300,12)

Format	Elements
3I3,I2	L(1,1)=A, L(1,2)=Z, L(1,3)=NLEV, L(1,4)=NREACT
4A10,A1	L(K,I), K=2, NREACT+1; I=1,5
11A10,I3	L(K,I), K=NREACT+2, NREACT+NLEV+1; I=1,12

c. Radioactive Decay and Reaction Data Array D(500,10)

Format	Elements
3I3	L(1,1)=A, L(1,2)=Z, L(1,3)=NTRANS
A10,2(A8,A7),2A10, A9, A10,I3	L(K,I), K=2,NTRANS+1; I=1,10

Fig. 2. Formats of decay and reaction arrays (as written to GSS). See text for a definition of the variables.

```
BANDR,7,63.462001,BROWNE
FTN4,OPT=2.
GETTAPE,TAPE1=ARRAYS/LEVELS/REACTIONS,24229.
GETTAPE,TAPE2=INDEX/REACTIONS,24229.
REWIND,TAPE1,TAPE2.
LINK,X.
REWIND,TAPE4.
COPYSBF,TAPE4,OUTPUT.
EXIT.
DUMP,0.
CRUMP.
FIN.
C.....
C     END OF CONTROL CARDS
C*****************************************************************************
C.....
C     PROGRAM BAND RETRIEVES ENERGIES, SPINS, AND HALF-LIVES OF FIRST 2+
C     STATES IN EVEN-EVEN NUCLEI. IT CONSISTS OF A MAIN ROUTINE BAND
C     AND A SUBROUTINE TWOPLUS. BAND SEARCHES THE DATA BASE FOR
C     L-ARRAYS OF EVEN-EVEN NUCLEI. TWOPLUS SEARCHES EACH PARTICULAR
C     ARRAY FOR 2+ STATES AND EXTRACTS THE CORRESPONDING INFORMATION.
C     INPUT FILES ARE TAPE1= LEVEL-ARRAYS, TAPE2= INDEX ARRAY. OUTPUT
C     FILE IS TAPE4=ARRAYS ILEV(ENERGIES), ISPIN(SPINS), AND IHALF(HALF-
C     LIVES).
C.....
      PROGRAM BAND(TAPE1,TAPE2,TAPE4)
      DIMENSION L(300,12),INDEX(256,100),ILEV(250,100),ISPIN(250,100),IH
     *ALF(250,100)
      COMMON/LARRAY/L
      COMMON/LCM/INDEX,ILEV,ISPIN,IHALF
      LEVEL 2,INDEX,ILEV,ISPIN,IHALF
      DATA ILEV/25000*10H          /
      DATA ISPIN/25000*10H          /
      DATA IHALF/25000*10H          /
      WRITE(4,1385)
 1385 FORMAT(7X,*A*,8X,*Z*,7X,*ENERGY*,7X,*SPIN*,4X,*HALF-LIFE*/7X,*----
     *----------*)
C.....
C     LOAD ARRAY INDEX INTO MEMORY
C.....
      READ(2,1020) ((INDEX(IA,IZ),IZ=1,100),IA=1,256)
 1020 FORMAT(6612)
      I=2
      KFLAG=0
C.....
C     REACTION DATA STARTS AT MASS NUMBER A=4. SKIP 3 FILES.
C.....
      CALL Q9SKPFF(1,3)
    5 I = I + 2
      IF(I.GT.90) GO TO 3000
C.....
C     READ MASS NUMBER, ATOMIC NUMBER, NUMBER OF LEVELS, NUMBER OF
C     REACTIONS.
C.....
    6 READ(1,1000) L(1,1),L(1,2),L(1,3),L(1,4)
      IF(EOI(1).NE.0) GO TO 3000
```

Fig. 3. Computer code for searching $J^{\pi}=2^{+}$ states in even-even nuclei.

```
C.....
C     CHECK FOR EOF-MARK. IF NO EOF IS FOUND START PROCESSING DATA,
C     OTHERWISE SKIP 2 FILES TO NEXT EVEN-A ARRAY.
C.....
      IF(EOF(1).EQ.0) GO TO 10
      IF(KFLAG.EQ.1) GO TO 8
C.....
C     SKIP 2 FILES
C.....
    7 CALL Q9SKPFF(1,2)
      GO TO 5
C.....
C     SKIP 1 FILE
C.....
    8 CALL Q9SKPFF(1,1)
      GO TO 5
 1000 FORMAT(3I3,I2)
   10 KFLAG=0
      IF(L(1,1).EQ.I) GO TO 20
      STOP
   20 IMASS = I
      IZMIN = L(1,2)
C.....
C     DETERMINE WHETHER L(1,2)=Z IS EVEN OR ODD. IF EVEN CALL SUBROUTINE
C     TWOPLUS. IF ODD SKIP 1 RECORD.
C.....
      RZMIN = IZMIN/2.0
      INZMIN= IZMIN / 2
      DIFF= RZMIN - INZMIN
      IDIFF= DIFF * 10
      IF(IDIFF.EQ.0) GO TO 30
      KFLAG=1
C.....
C     SKIP 1 RECORD.
C.....
      CALL Q9SKIP(1)
      GO TO 6
C.....
C     SUBROUTINE TWOPLUS RETURNS THE ENERGY(ILEV), SPIN(ISPIN), AND
C     HALF-LIFE(IHALF) OF FIRST 2+ STATES.
C.....
   30 CALL TWOPLUS
C.....
C     SEARCH FOR NEXT EVEN-EVEN ISOBARS.
C.....
      NINDEX=INDEX(IMASS,IZMIN)
      IZMIN = IZMIN + 2
      IZMIN2=IZMIN + 20
      IF(IZMIN2.GT.100) IZMIN2=100
      DO 40 KZ= IZMIN,IZMIN2,2
      KINDEX= INDEX(IMASS,KZ)
      IF(KINDEX.NE.0) GO TO 50
   40 CONTINUE
      KFLAG=1
      GO TO 7
```

Continuation of Fig. 3

```
   50 KKNDEX = KINDEX - NINDEX
      IF(KKNDEX.GE.1) GO TO 55
      STOP
   55 KHNDEX = KKNDEX - 1
      IF(KHNDEX.EQ.0) GO TO 6
C.....
C     SKIP KINDEX RECORDS.
C.....
      CALL Q9SKPRF(1,KHNDEX)
      GO TO 6
 3000 STOP
      END
C*******************************************************************************
      SUBROUTINE TWOPLUS
      DIMENSION L(300,12),IALPHA(10),ILEV(250,100),ISPIN(250,100),IHALF(
     *250,100), INDEX(256,100)
      COMMON/LARRAY/L
      COMMON/LCM/INDEX,ILEV,ISPIN,IHALF
      LEVEL 2,INDEX,ILEV,ISPIN,IHALF
C.....
C     LOAD L-ARRAY INTO MEMORY.
C.....
      CALL LOADLR
      KMAXR= L(1,4) + 1
      KMAX= KMAXR + L(1,3)
      K = KMAXR + 1
C.....
C     STORE SPIN OF FIRST LEVEL INTO VARIABLE KSPIN.
C.....
    5 KSPIN= L(K,2)
C.....
C     DECODE SPIN INFORMATION INTO A 10-CHARACTER ARRAY IALPHA AND
C     SEARCH FOR 2+, (2+), (2)+, OR 2(+).
C.....
      DECODE(10,400,KSPIN) IALPHA
  400 FORMAT(10A1)
      DO 10 I=1,10
      IF(IALPHA(I).NE.1H ) GO TO 20
   10 CONTINUE
      IF(K.EQ.KMAX) GO TO 90
      K=K+1
      GO TO 5
   20 IMIN=I
      DO 30 J=IMIN,10
      IF(IALPHA(J).EQ.1H ) GO TO 40
   30 CONTINUE
      STOP
   40 IMAX=J
      IDIG=IMAX - IMIN
      IF(IDIG.EQ.2.OR.IDIG.EQ.4) GO TO 45
      IF(K.EQ.KMAX) GO TO 90
      K=K+1
      GO TO 5
```

Continuation of Fig. 3

```
   45 IMAX1= IMIN + IDIG - 1
      DO 50 LL=IMIN,IMAX1
      IF(IALPHA(LL).EQ.1H+) GO TO 60
   50 CONTINUE
   55 IF(K.EQ.KMAX) GO TO 90
      K=K+1
      GO TO 5
   60 DO 70 KL=IMIN,IMAX1
      IF(IALPHA(KL).EQ.1H,) GO TO 55
   70 CONTINUE
      KP=IMIN
      IF(IALPHA(IMIN).EQ.1H(.OR.IALPHA(IMIN).EQ.1H[) GO TO 80
   75 IF(IALPHA(KP).EQ.1H2) GO TO 100
      IF(K.EQ.KMAX) GO TO 90
      K=K+1
      GO TO 5
   80 KP = KP + 1
      GO TO 75
C.....
C    STORE ENERGY INTO ILEV, SPIN INTO ISPIN, HALF-LIFE INTO IHALF.
C.....
  100 IMASS=L(1,1)
      IELEM=L(1,2)
      ILEV(IMASS,IELEM)=L(K,1)
      ISPIN(IMASS,IELEM)=L(K,2)
      IHALF(IMASS,IELEM)= L(K,5)
C.....
C     WRITE INFORMATION ON 2+ LEVEL.
C.....
      WRITE(4,388) IMASS,IELEM,ILEV(IMASS,IELEM),ISPIN(IMASS,IELEM),IHAL
     *F(IMASS,IELEM)
  388 FORMAT(2(6X,I3),3(6X,A10))
   90 RETURN
      END
C*****
      SUBROUTINE LOADLR
      DIMENSION L(300,12)
      COMMON/LARRAY/L
C.....
C     L(1,4)= NUMBER OF REACTIONS
C.....
      KMAXR= L(1,4) + 1
      KMAXR1= KMAXR + 1
C.....
C     L(1,3)= NUMBER OF LEVELS
C.....
C.....
C     KMAX= MAXIMUM VALUE OF SUBSCRIPT K OF ARRAY L(K,II).
C.....
      KMAX= KMAXR + L(1,3)
      READ(1,10) ((L(K,I),I=1,5),K=2,KMAXR)
      READ(1,20) ((L(K,I),I=1,12),K=KMAXR1,KMAX)
   10 FORMAT(4A1 ,A1)
   20 FORMAT(11A10,I3)
      RETURN
      END
```

Continuation of Fig. 3

A	Z	ENERGY	SPIN	HALF-LIFE
4	2	33.0	(2+) T(0)	
6	2	1.80	(2)+	W0.11
6	4	1.67	(2+)	W1.2
8	4	2.94	2+	W1.56
10	4	3.3680	2+	0.12PS
10	6	3.353	2+	0.11PS
12	6	4.4391	2+	42FS
14	6	7.012	2+	
14	8	6.59	2+	
16	6	1.75	(2+)	
16	8	6.919	2+ 0	4.2FS
18	8	1.9822	2+	2.0PS
18	10	1.8873	2+	0.46PS
20	8	1.6737	2+	10PS
20	10	1.6338	2+ 0	0.7PS
22	10	1.27458	2+ K0	3.7PS
22	12	1.2470	2+	3PS
24	10	1.981	2+	0.7PS
24	12	1.36859	2+ K0A	1.44PS
26	12	1.8087	2+ K0	0.49PS
26	14	1.7959	2+	1.0PS
28	12	1.4735	2+	1.2PS
28	14	1.7789	2+	0.50PS
30	14	2.2355	2+	0.24PS
30	16	2.2107	2+	0.12PS
32	14	1.9414	2+	0.4PS
32	16	2.2302	2+	0.18PS
34	16	2.1274	2+	0.28PS
34	18	2.0911	2+	0.14PS
36	16	3.291	2+	0.08 PS
36	18	1.97039	2+	0.28PS
38	18	2.16760	2+	0.4PS
38	20	2.206	2+	
40	18	1.46081	2+	1.1PS
40	20	3.9041	2+	0.04PS
42	18	1.2082	2+	3PS
42	20	1.5246	2+	0.82PS
42	22	1.555	2+	0.4PS
44	20	1.1570	2+	2.9PS
44	22	1.0830	2+ 0	3PS
46	20	1.346	2+	3.9PS
46	22	0.8892	2+	4.6PS
48	20	3.8323	2+	0.04PS
48	22	0.9834	2+	4.3PS
48	24	0.7524	2+	9PS
50	20	1.03	2+ L2	
50	22	1.555	2+ LA1+3	1.0PS
50	24	0.7833	2+	9PS
52	22	1.0471	2+	3PS
52	24	1.4343	2+	0.71PS
52	26	0.84	2+	
54	24	0.83486	2+	8.2PS
54	26	1.4084	2+	1.0PS

Fig. 4. Properties of first $J^{\P}=2^{+}$ states in even-even nuclei. This is part of the output file from the code shown in figure 3.

E5 TRANSITIONS

		A= 90	Z= 39	
L0.68204I	7+		3.19H	
G0.47953	91+-4	100	M4	0.20251
G0.6820		0.34+-5	(E5)	0
GB-	0.0021+-2			
		A= 90	Z= 40	
L2.31893I	5-		809MS	
G0.13260		5.04+-5	E3	2.18622
G2.31890		100.0+-2	E5	0
		A= 113	Z= 48	
L0.2637I	11/2-		14 Y	
G0.2637			E5	0
GB-	99.9			
		A= 123	Z= 52	
L0.2475I	11/2-		119.7D	
G0.08846		0.11	M4	0.15900
G0.2475		4.1E-4	E5	0
		A= 192	Z= 77	
L0.161I	9(+)		241Y	
G0.161			(E5)	0
		A= 202	Z= 82	
L2.1698I	9-		3.62H	
G0.7870		100+-5	E5	1.3828
G0.5476		0.25+-8	E5	1.6231
G0.1293		0.08+-3	E4	2.0403
GEC	9.5			
		A= 204	Z= 82	
L2.1855I	9-		66.9M	
G0.6222		W	E5	1.5628
G0.9117		13.4+-14	E5	1.2739
		A= 206	Z= 81	
L2.643I	(12-)		3.6M	
G0.565?		13+-4		2.078
G1.0214		76+-7	(E5)	1.621

Fig. 5. Data on all E5 transitions observed in radioactive decay extracted from the *Table of Isotopes* level-scheme file.

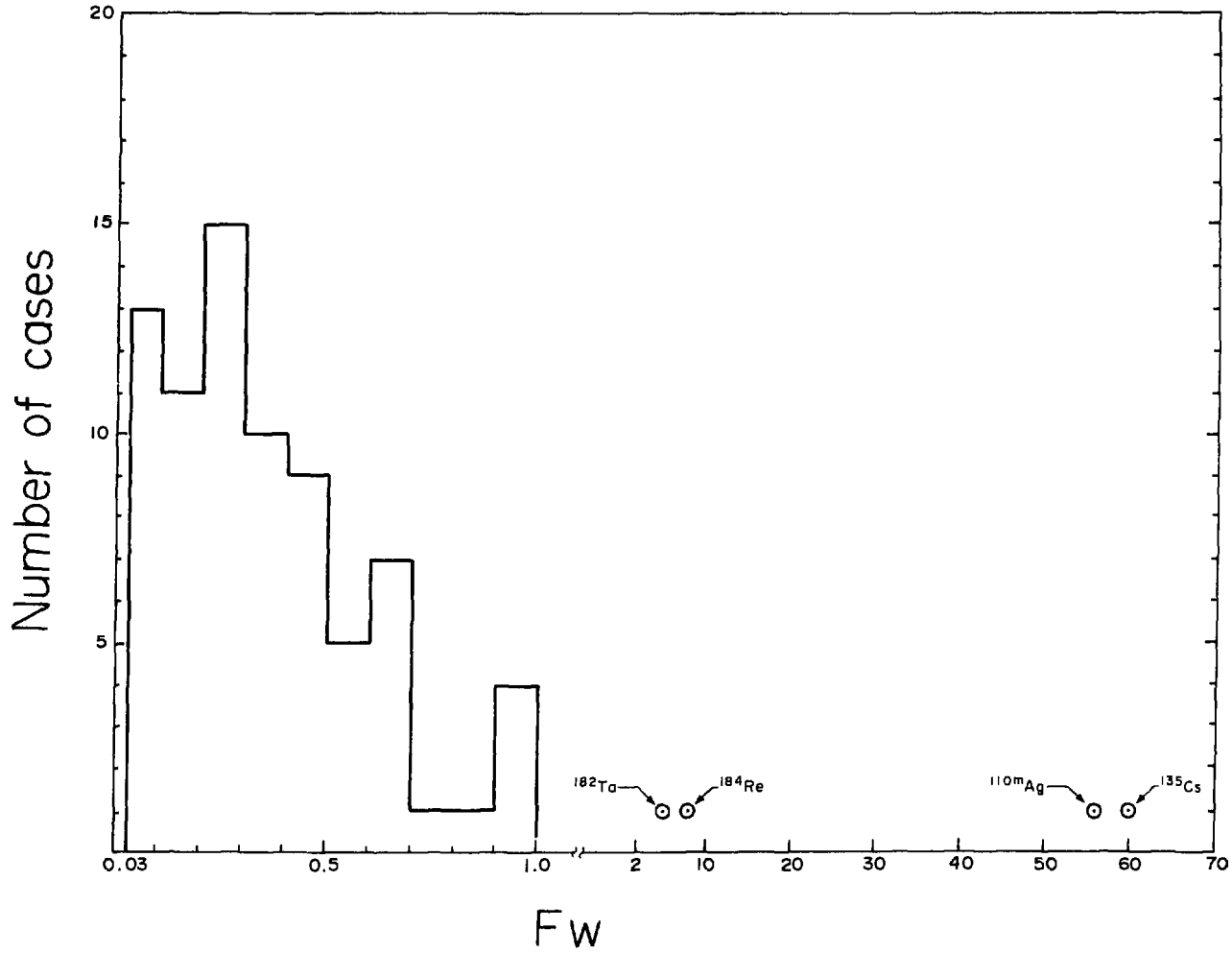

Fig. 6. Distribution of M4 reduced transition probabilities in Weisskopf units. For those transitions where FW>1 the individual nuclei are identified.