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NUCLEAR STRUCTURE DATABASE

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NUCLEAR STRUCTURE DATABASE

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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 (level energies, 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 66I2):

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:

$$\begin{aligned}
 &>, < \\
 &\leq, \geq \\
 &\neq \quad (\text{interpreted as } \approx) \\
 &\left. \begin{array}{l} \leqneq \\ \gtrless \end{array} \right\} \quad (\text{interpreted as } \approx) \\
 &\left. \begin{array}{l} \gtneq \\ \lessgtr \end{array} \right\} \quad (\text{interpreted as } \approx)
 \end{aligned}$$

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 $2 \leq K \leq NPAR+1$. The specific parent nuclear properties (I) are:

2.1 $\left. \begin{array}{l} L(K,1)= \\ L(K,2)= \end{array} \right\} \text{ PARENT NUCLEI (2 elements)}$

where allowable names for the parent nuclei can be:

<u>Format</u>	<u>Example</u>	<u>Interpretation</u>
A-Element	22-NA	$^{22}_{\text{Na}}$
AM-Element	110M-AG	$^{110\text{m}}_{\text{Ag}}$
AM _i -Element (i is an integer)	192M2-IR	$^{192\text{m}}_2\text{Ir}$
A-Element($T_{1/2}$)	180RE(20 H)	$^{180}_{\text{Re}}(20\text{h})$

2.2 L(K,3)=DECAY MODE

The following are possible decay modes.

<u>Mode</u>	<u>Interpretation</u>
SF	Spontaneous fission
N	n
P	p
A	α
B-	β^-
EC+B+	$EC+\beta^+$
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 $$\begin{matrix} L(K,5)= \\ L(K,6)= \end{matrix} \left. \vphantom{\begin{matrix} L(K,5)= \\ L(K,6)= \end{matrix}} \right\} \text{SPIN (two elements)}$$

"Spin" refers generally to level quantum numbers including J, π ,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 } ground state band
 2+ K0 }
 0+ KOA } first excited state K=0 band
 2+ KOA }
 0+ KOB } second excited state K=0 band
 2+ KOB }

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

2.5 $\left. \begin{array}{l} L(K,7)= \\ L(K,8)= \end{array} \right\} \text{Q-VALUE (two elements)}$

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

Examples:

$\neq 3.02$ (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 $K \geq NPAR+2$. 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:

<u>Modifier</u>	<u>Interpretation</u>
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 $$\left. \begin{array}{l} L(K,2)= \\ L(K,3)= \\ L(K,4)= \end{array} \right\} \text{SPIN (three elements)}$$

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 $EC+\beta^+$ 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
$$\left. \begin{array}{l} L(K,1)= \\ L(K,2)= \\ L(K,3)= \\ L(K,4)= \end{array} \right\} \text{REACTION LIST (4 elements)}$$

Typical reaction names may be

FISSION

COULOMB EXCITATION

56-FE(P,NG)

20-NE(16-0,12-C)

IN-BEAM G SPECT

Proper particle names are:

<u>Symbol</u>	<u>Interpretation</u>
P	p
N	n
D	d
T	t
A	α
G	γ
E	e
PI+	π^+
PI-	π^-
PIO	π^0
MU+	μ^+
MU-	μ^-
MUO	μ^0
KA+	K+
KA-	K-
KAO	K^0
KAOA	K^0

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)

$D(1,4-10)=\text{not used}$

2. All of the information on the transitions is contained in the array elements with $K \geq 2$. 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 $D(K,1)=\text{TRANSITION ENERGY}$

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

<u>Modifier</u>	<u>Interpretation</u>
*	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 $\left. \begin{matrix} D(K,2)= \\ D(K,3)= \end{matrix} \right\}$ ABSOLUTE INTENSITY (two elements)

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):

<u>Symbol</u>	<u>Interpretation</u>
E	e ⁻ total
K	K shell
L	L "
M	M "
N	N "
O	O "
P	P "

2.3 $\left. \begin{matrix} D(K,4)= \\ D(K,5)= \end{matrix} \right\}$ RELATIVE INTENSITY (two elements)

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

2.4
$$\left. \begin{array}{l} D(K,6)= \\ D(K,7)= \\ D(K,8)= \end{array} \right\} \text{MULTIPOLARITY(three elements)}$$

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:

<u>Form</u>	<u>Interpretation</u>
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 $D(K,9)=\text{FINAL LEVEL ENERGY}$

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 $\neq$ 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 $D(K,10)=\text{LEVEL IDENTIFIER}$

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	Decay array
READ(1,10) (L(1,I),I=1,4)	READ(1,10)(D(1,I),I=1,3)
10 FORMAT(3I3,I2)	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), $K \geq \text{NPAR}+3$ 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 $B(M, L \leq 5)$ and $B(E, L \leq 6)$ 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.

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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.

[illegible]

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	A	Z				
4	1	2	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	200	80	90				
	3		11		20		25		32		84	34		41		50		58		63		62		70		76		75	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		47		44		51	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		80		93			
	4		12		21		25		30		36		42		49		52		55		62		68		71		75		81		92				
8	3		13		42	18		26		31		37		43		46		50		56		63		70		72		76		82		94	234	90	
	4		14		19		27		32		38		43		44		50		56		60	160		64		74		78		80	202	80	92		
9	3		12		21		25		70	30		86	36		45		47		50		59	147		62		66		72		80		235	91		
	4		13		22		26		31		37		46		48		51		60		64		67		72		76		82		93				
	5		14		43	18		27		32		38		99	41		49		52		136	54		68		73		77		83		94	236	92	
10	4		5		27	12		56	24		71	30		87	35		42		50		54		60		70		74		78		81	237	91		
	5		14		13		20		31		37		43		44		50		58		62		65		71		79		82		92				
	6		28	12		22		27		33		39		45		48		51		60		64		65		71		190	76		204		93		
11	5		14		44	18		28		72	30		88	36		46		49		54		55		61		67		74		80		82	238	92	
	6		15		57	25		31		37		43		49		50		56		56		60		67		74		80		83		93			
12	4		29	13		21		27		33		39		42		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		84		94		
	6		15		45	18		58	25		73	32		89	38		46		49		54		60	150	58	70		73		79		82	94		
13	5		30	13		19		26		33		39		41		42		50		57		64		63		67		74		80		83	240	92	
	6		15		20		27		34		40		43		52		126		50		56		62		67		75		81		84		94		
	7		16		21		28		74	32		90	36		44		113		52		57		64		68		78		82		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		42		102		40		51		127	51		139	56		62		68		72		242	94	
	7		16		21		28		75	32		41		42		114		46		52		57		63		70		73		80		83	95		
15	6		15		23		60	26		34		91	39		45		49		54		59	152		60		67		75		78		86			
	7		16		24		29		33		42		44		50		52		55		64		63		69		74		80		82		244	94	
	8		17		25		20		28		33		41		48		51		57		140	54		63		70		73		80		83	95		
16	6		33	15		21		29		34		42		50		52		128		52		55		64		70		76		81		83			
	7		16		22		30		15		92	39		103	44		115		48		53		57	153		62		181		194		77			
	8		17		23		61	27		36		40		45		49		54		58		63		68		73		78		86		245	94		
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		167		76		82		84		247	96	
	9		17		23		27		35		93	39		44		116		46		53		58		62		69		74		79		82		248	96
18	7		35	16		49	20		78	34		41		46		49		53		60		64		71		76		80		83		249	96		
	8		17		21		30		35		42		47		50		54		142		56		66		168		78		81		84		249	96	
	9		18		22		63	27		36		43		48		51		56		158		155		62		69		83		82		85		97	
19	8		19		23		28		38		44		50		52		57		59		63		70		75		76		75		156	78	210	82	
	9		17		50	20		30		35		39		45		117		48		54		61		65		169		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		143		156		62		71		76		79		83			
	10		17		24		30		36		43		49		52		53		60		64		66		72		78		80		84				
	11		18		25		31		38		44		50		54		118		48		54		61		66		170		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		144		156		65		72		76		79		86			
	12		18		24		31		37		42		50		54		56		58		65		66		71		77		80		213	87			
22	9		19		25		66	28		82	34		93		47		119		49		58		60		67		69		78		81		214	88	
	10		20		26		29		35		43		44		47		50		133		141		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 11. ENERGY OF FIRST EXCITED 2+ STATES IN EVEN-EVEN NUCLEI (Z=2-50). CLOSED SHELLS ARE INDICATED BY ***

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	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	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	*****																		*	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		*****																		*	78																		
80	*	*			*****																		*	1217		*****																		*	80																		
82	*****																								82																																						
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	N																																					

TABLE II. (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	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																										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

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	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	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					
2	*****																											2			
4	*			9	*	*****										*		*****										*			
6	*		8	5	*	*****										*		*****										*			
8	*****					4	18	*****											*****										*		
10	*				3	22	17			*				*												*					
12	*				1	12	20	7		*				*												*					
14	*				*	6	13	13	16	*				*												*					
16	*				*		13	8	9	15	*			*												*					
18	*				*			8	7	10	*			*												*					
20	*****									3	4	2	18	*****											20						
22	*				*				10	10	14			*												*					
24	*				*				8	10	23	25		*												*					
26	*				*					3	14	19		*												*					
28	*****											2	6	11	8	6	*****											28			
30	*				*					*	13	14	16	10												*					
32	*				*					*			13	13												*					
34	*				*					*				12	22											*					
36	*				*					*				8	18											*					
38	*				*					*				15	21	19										*					
40	*				*					*				19	25	40	58									*					
42	*				*					*				*		34	44	58	81							*					
44	*				*					*				*		27	33	39								*					
46	*				*					*				*			24	19	27							*					
48	*				*					*				*			17	15	10							*					
50	*****																			7	5	7	*****								50
52	*				*					*				*						6	15	21				*					
54	*				*					*				*						4	20	30				*					
56	*				*					*				*						4	21	41				*					
58	*				*					*				*							37	51	37	26		*					
60	*				*					*				*							62	78	60	49	27	*					
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			
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					

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
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																*										134
136																*	46	111								136
138																*	59	98	162							138
140																*		123	169	223						140
142																*		144	194	234						142
144																*			201	234						144
146																*			182	250	285					146
148																*				271	294					148
150																*					296	333				150
152																*					292	324				152
154																*						323				154
156																*							357			156
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 I π]			
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+                      B      99.33    3.49
D2.3127         M1      0
L3.9478        1+                      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)

<u>Format</u>	<u>Elements</u>
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)

<u>Format</u>	<u>Elements</u>
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)

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

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.
GRUMP.
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.....
C   PROGRAM BAND(TAPE1,TAPE2,TAPE4)
C   DIMENSION L(300,12),INDEX(256,100),ILEV(250,100),ISPIN(250,100),IH
C   *ALF(250,100)
C   COMMON/LARRAY/L
C   COMMON/LCM/INDEX,ILEV,ISPIN,IHALF
C   LEVEL 2,INDEX,ILEV,ISPIN,IHALF
C   DATA ILEV/25000*10H      /
C   DATA ISPIN/25000*10H    /
C   DATA IHALF/25000*10H    /
C   WRITE(4,1385)
C 1385 FORMAT(7X,*A*,8X,*Z*,7X,*ENERGY*,7X,*SPIN*,4X,*HALF-LIFE*/7X,*---
C   *-----*)
C.....
C   LOAD ARRAY INDEX INTO MEMORY
C.....
C   READ(2,1020) ((INDEX(IA,IZ),IZ=1,100),IA=1,256)
C 1020 FORMAT(66I2)
C   I=2
C   KFLAG=0
C.....
C   REACTION DATA STARTS AT MASS NUMBER A=4. SKIP 3 FILES.
C.....
C   CALL Q9SKPFF(1,3)
C   5 I = I + 2
C   IF(I.GT.90) GO TO 3000
C.....
C   READ MASS NUMBER, ATOMIC NUMBER, NUMBER OF LEVELS, NUMBER OF
C   REACTIONS.
C.....
C   6 READ(1,1000) L(1,1),L(1,2),L(1,3),L(1,4)
C   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.....
C   IF(EOF(1).EQ.0) GO TO 10
C   IF(KFLAG.EQ.1) GO TO 8
C.....
C   SKIP 2 FILES
C.....
C   7 CALL Q9SKPFF(1,2)
C   GO TO 5
C.....
C   SKIP 1 FILE
C.....
C   8 CALL Q9SKPFF(1,1)
C   GO TO 5
1000 FORMAT(3I3,I2)
C   10 KFLAG=0
C   IF(L(1,1).EQ.I) GO TO 20
C   STOP
C   20 IMASS = I
C   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.....
C   RZMIN = IZMIN/2.0
C   INZMIN= IZMIN / 2
C   DIFF= RZMIN - INZMIN
C   IDIFF= DIFF * 10
C   IF(IDIFF.EQ.0) GO TO 30
C   KFLAG=1
C.....
C   SKIP 1 RECORD.
C.....
C   CALL Q9SKIP(1)
C   GO TO 6
C.....
C   SUBROUTINE TWOPLUS RETURNS THE ENERGY(ILEV), SPIN(ISPIN), AND
C   HALF-LIFE(IHALF) OF FIRST 2+ STATES.
C.....
C   30 CALL TWOPLUS
C.....
C   SEARCH FOR NEXT EVEN-EVEN ISOBARS.
C.....
C   NINDEX=INDEX(IMASS,IZMIN)
C   IZMIN = IZMIN + 2
C   IZMIN2=IZMIN + 20
C   IF(IZMIN2.GT.100) IZMIN2=100
C   DO 40 KZ= IZMIN,IZMIN2,2
C   KINDEX= INDEX(IMASS,KZ)
C   IF(KINDEX.NE.0) GO TO 50
40 CONTINUE
C   KFLAG=1
C   GO TO 7

```

```

50 KKINDEX = KINDEX - NINDEX
   IF(KKINDEX.GE.1) GO TO 55
   STOP
55 KHINDEX = KKINDEX - 1
   IF(KHINDEX.EQ.0) GO TO 6
C.....
C   SKIP KINDEX RECORDS.
C.....
   CALL Q9SKPRF(1,KHINDEX)
   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

```

```

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

```

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+ KO	3.7PS
22	12	1.2470	2+	3PS
24	10	1.981	2+	0.7PS
24	12	1.36859	2+ KOA	1.44PS
26	12	1.8087	2+ KO	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 $J^\pi=2^+$ 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.

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