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February 1973

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DEVELOPMENT OF A COMPUTER-BASED NUCLEAR DATA COMPILATION -
TABLE OF ISOTOPES*

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Abstract

Based on a proposal by the authors in 1968, we are proceeding to apply computer techniques to the production of the next (7th) and future editions of the Table of Isotopes.

The use of computers is intended to accomplish several goals: (1) to reduce the probability of errors and simplify the compiler's job by improvements in the data-input procedure, by computer checks for all possible machine-detectable errors in the syntax and in the physics of the input data, and by elimination of redundant entry and proofreading of data reused in succeeding editions of the Table of Isotopes; (2) to shorten the time delay between the cut-off data for acceptance of new literature and the publication of the compilation by nearly complete automation of the production process; (3) to enable us to produce automatically sorted or inverted compilations, such as

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tables of gamma rays from all isotopes produced by neutron capture in natural targets, ordered by energy; (4) to eliminate redundant entry of abstracted data by different compilers whenever possible.

An important part of the computer automation is the development of a text input and editing system for direct keyboarding of complex text. This system is being used for input of all tabular data. Graphical data (level schemes) are input in tabular form on punched cards and plotted by computer. A major saving in effort and improvement in accuracy should thus be obtained, because level schemes can be modified easily and redrawn automatically, without the need for extensive drafting and redundant proofreading.
In 1968, shortly after the 6th edition of the Table of Isotopes was published, Lederer, Hollander, and Meissner proposed a computer-based system for data compilation [1]. Although this system was motivated by our primary goal, the production of future editions of the Table of Isotopes, the use of computers includes some new techniques that are applicable to other types of data compilations and, more generally, to multipurpose data bases.

Even though the topic of this paper was to be the computer-based system, I realize that some of you are more interested in the nuclear data than the methodology of compilation. I shall make a few remarks about the status of the Table of Isotopes project, before returning to the discussion of some aspects of the automation.

The dramatic growth of nuclear data at the close of the last decade ended a pleasant era in which one or two people could compile all the data encompassed by the Table of Isotopes. Consequently, in 1968 we envisaged an expanded project that included more compilers and the use of computers to simplify the process of updating and printing. Actual compilation work was begun in 1971 when initial funding was obtained.

We plan to maintain the traditional form and scope of the Table of Isotopes, with the following modifications:

1) Measured uncertainties will be included on all quantities.

2) Tables I and II of the 6th edition will be combined into a single table. Figure 1 shows an example of how this table will look. In place of the partial listing of "major radiations" that appeared in Table I of the 6th edition, we have included some derived
information on x-rays and absolute γ-ray intensities, where not
directly measured, in the detailed radiation data.

3) Reaction levels will be included for all nuclei. The detailed
schemes for each nucleus will be drawn separately from a skeleton
diagram for each mass chain, which shows the decay relationships
and Q-values. A sample is shown in fig. 2.

Although we believe that this is generally a very useful type of com-
pilation, we realize that many important applications require simpler tables
and more highly evaluated or reduced data - for example, best values or absolute
conversion electron intensities. We are now compiling data for the next
edition of the Table of Isotopes, with concurrent development of computer auto-
mation, as our primary goal. As a secondary goal, we intend to produce such
additional tables by use of the computer and the addition of some data to the
data files.

I turn now to the computer system. I emphasize from the outset that
the computer cannot and should not replace the intellectual aspect of compila-
tion work; rather, it enhances this by the removal of much unnecessary clerical
work that a data-evaluator must otherwise do. The major tasks we demand of
the computer are the elimination of redundant copying, proofreading, and
production work, and the detection of many types of errors that the computer
can recognize from the syntax, the context, or the physical laws and probabilities
applicable to a given kind of text or data.

At the heart of any data bank is a stored data file, mechanisms for
entry, storage, and retrieval, and printing or plotting of the data, and a
process we call "flagging" or identification. I don't want to dwell on these
teatures, which are common to all data banks, but I should mention a few
important aspects of flagging.

Flagging labels a piece of information by its type and possible use,
thus facilitating retrieval. As a simple example, one "item" in our data
file contains data on one isotope, in one data category (such as half-life),
from one reference. The isotope, data category, and reference code are flags;
in addition, the item is flagged to show method of measurement, compiler,
typist, date of entry, and "status". "Status" is actually a collection of flags;
these include intended use in the Table of Isotopes (i.e. the order of listing
for this item among all $t_{1/2}$ entries for this isotope), whether the entry is
a measured or an adopted best value, whether to use it in some other table,
etc. In complex entries, eg. a gamma-ray spectrum, the data may also contain
internal flags identifying specific quantities, such as energies, relative or
absolute intensities, conversion coefficients, and subshell ratios.

Two novel aspects of our computer development effort are (1) the use
of an improved system for entering and editing data, and (2) extensive check-
ing for errors by the computer. Both aspects are aimed primarily at improve-
ment of the accuracy of the data base. The input-editing system also simplifies
the entry process and avoids unnecessary recopying of data by the compilers.

The input-editing system is an outgrowth of earlier developmental
work in text processing at Lawrence Berkeley Laboratory, motivated by the
Table of Isotopes and the Particle Data Compilation projects. Figure 3 shows
the input console in use. The keyboard is an expanded typewriter keyboard,
and the display is a storage oscilloscope. The console is connected to a
small computer, which can drive multiple terminals. Figure 4 shows the
keyboard layout. The character set includes complete Roman and Greek alphabets in upper and lower case, numbers, and a large number of special symbols. Fonts include "normal" and combinations of superscripts or subscripts, italics and boldface.

Some useful features of this system are the following:

1) It permits easy editing, both when entering data and later, after the data have been entered and proofread. A moving cursor can be positioned anywhere in the text and insertions or deletions readily performed. (Insertions appear at the bottom of the screen, and are re-placed in the proper part of the text by striking the redisplay key.)

2) Compound symbols such as $e_{K}/\gamma$ can be entered with a single key. In fact, the typist can create such a compound symbol and assign it to a key while typing.

3) A "template", or prompting routine insures the inclusion of required data-identifiers (flags). The identifiers for each data item are entered via this routine; the upper portion of fig. 5 shows an example of one completed template. Note that the format flag, which I did not mention before, defines the number of columns and their headings for a columnar entry.

4) A true columnar format can be used to enter data directly from published tables. (Positioning is controlled by the tab and line feed keys.) An example of such a table is shown in the lower portion of fig. 5. Columnar data can be edited in the same manner as non-columnar data.
5) The system provides direct access to the stored data files via a high-speed link between the keyboard system and the main computer facility at the laboratory.

6) When not in use as a text editor, a console can be used as a standard teletype terminal connected to the main computer system.

We find that use of the keyboarding system serves not only to save time, but also to eliminate errors. It eliminates much error-prone recopying by hand, recopying that would otherwise be necessary to convert the data to a special input format. It is flexible enough to allow the data compiler to use the symbols he knows and remembers – the language of physics.

The second novel feature of our computer development is the use of the computer to perform extensive checks for errors of form or syntax, and for violations of the laws and probabilities of physics. For example, the letter 0 is similar to the digit zero, but the computer knows that the letter is not an acceptable part of a number. Of course, the computer can not always know a 2.375-MeV γ ray should have been 2.357, but it will tell us if a list of energies is out of order. It also tells us that a 23.57-MeV γ ray is highly improbable, and that 2.3 ± 0.05 is not an acceptable number. (It would be helpful if all scientists also understood this.)

The important point is that proofreading, just like data entry, is subject to human error; as any compiler knows, proofreading detects only a certain fraction of the actual mistakes. Checking by the computer is not a substitute for proofreading, but it can greatly improve the overall accuracy of the data base by warning the compiler of definite or probable errors.
One type of error readily detected by the computer is the violation of physical laws. This is especially relevant to highly correlated data, such as a nuclear level scheme. In the case of a level scheme, a misplaced transition, an incorrect level of transition energy, or an incorrect spin or multipolarity can frequently be detected because it violates energy, spin, or parity conservation.

I have not mentioned some of the interesting applications of computerized data files, because I wanted to emphasize novel features we have developed for the purpose of creating a more accurate data base with less difficulty. But inverted or sorted tables and on-line retrieval of data are obvious applications that are possible once the data are stored and properly flagged in computer-readable form.
References

Figure Captions

Fig. 1. Sample tabular listing for the Table of Isotopes, 7th edition.

Fig. 2. Sample level-scheme drawing for the Table of Isotopes, 7th edition.

Fig. 3. Keyboard-display console, Table of Isotopes text input-editing system. (The keyboard shown in this photograph is an earlier prototype version.)

Fig. 4. Schematic layout of the keyboard. Special function keys in top two rows are for
a) position control ("Tab", "Line feed", "New Page")
b) display control ("Last Page", "Next Page", "Go to" [page number] "Send", and "Redisplay")
c) editing (Cursor keys, "Delete left", "Reset cursor", "Clear data")
d) retrieval of a specified item ("Go to" [item number X] "Send")
   (X = f for identifier flags, d for data)
e) storage and retrieval of a specified block of items or mass chain
   ("Store", "Retrieve")
f) template control ("Advance Template")
g) redefinition of a key ("Create symbol" [keys] "on key" [key])
h) column number identification ("Define column")
i) fonts ("Subscript", "Superscript", "Italic", "Bold", "Greek"). Foot pedals can also be used for subscript or superscript.

Fig. 5. Sample output of part of a data item typed on the input-editing system. The upper portion contains the identifier flags, typed in response to the questions "ISOTOPE":, "DATA CATEGORY":, etc. (Identifiers labelled with superscript numbers in brackets were defined during entry of a previous
item.) The data (lower part of figure) is in columnar format, with the column headings given in the "FORMAT" identifier. \( _{-} \), \( _{T} \), and \( _{L} \) are symbols for blank, tab, and line feed.
\( ^{131}I \)

- **Energy**
  - \( \tau_{1/2} \): 8.085 d (Isso 22 715)
  - \( \tau_{5/8} \): 8.054 d (PMB 2 255)
  - \( \tau_{6/8} \): 8.067 d (PMB 2 360)
  - \( \tau_{7/8} \): 8.073 d (Isso 19 475)
  - \( \tau_{9/8} \): 8.079 d (NSeG 32 46)
  - No modification of \( \tau_{1/2} \) by chemical environment (PR 13 1699)

- **Class**
  - \( \gamma^\prime \) (PR 54 775)

- **Production**
  - Fission (PR 56 1, Nwis 27 529, PR 54 775, Nat 158 163, PR 57 363, NNES 9 984, CJR 25 371, Nat 161 520, NNES 9 1368)
  - I 7/2: \( \mu +2.738 \), q -0.40 atomic beam (PR 19 2022)

- **Beta**
  - \( \beta^- \) (PR 54 775)
    - B 0.61 (6%), 0.6065 \( \gamma \) (86%), 0.336 \( \gamma \) (13%), mag (Phca 17 637)
    - 0.807 \( \gamma \) (14%), 0.6059 \( \gamma \) (84.7%), 0.339 \( \gamma \) (13.3%), mag (PR 86 863)
    - 0.810 \( \gamma \), 0.606 \( \gamma \), 0.335, 0.9, \( \gamma \) coincidence (PR 84 585, PR 81 642)
    - 0.812 \( \gamma \) (7%), 0.6068 \( \gamma \) (6%), 0.335 \( \gamma \) (5%), 0.250 \( \gamma \) (5%), mag, \( \beta \gamma \) coincidence (PR 86 212)

- **Average \( \gamma^- \) energy**
  - 0.19, ion ch (PR 86 82)

- **Others**
  - ZP 179 62, Phil 43 648, Phil 43 221, Nat 170 916, PR 86 82, PR 83 660, PR 82 103, PR 81 482, Phca 17 658, PR 78 179, PR 76 94, PR 75 1270, PR 74 1649, PR 61 686

- **Alpha (see also \( ^{131}\text{m} \text{Xe} \))
  - 0.08164 \( \gamma \), 0.284307 \( \gamma \), 0.364467 \( \gamma \), crys (PR 91 1027)
  - 0.08165 \( \gamma \) (1.77 2.18, \( \gamma / \gamma \) 1.33 \( m \)), 0.16398 \( \gamma \) (1.83 \( m \)), 0.617 \( \gamma \) (1.7 \( m \)), 0.17723 \( \gamma \) (0.36 0.8, \( \gamma / \gamma \) 0.15 \( m \)), 0.27235 \( \gamma \) (0.8), 0.351 \( \gamma \) (0.8), 0.2907 \( \gamma \) (0.7054, \( \gamma / \gamma \) 0.41 \( m \)), 0.150 \( \gamma \) (0.113), 0.32506 \( \gamma \) (0.10 0.20), 0.32578 \( \gamma \) (0.10 0.45), \( \gamma / \gamma \) 0.03 \( m \), 0.635 \( \gamma \) (0.12), 0.325 \( \gamma \) (0.10 0.20), 0.32578 \( \gamma \) (0.10 0.45), \( \gamma / \gamma \) 0.03 \( m \), 0.635 \( \gamma \) (0.12), 0.325 \( \gamma \) (0.10 0.20), 0.32578 \( \gamma \) (0.10 0.45), \( \gamma / \gamma \) 0.03 \( m \), 0.635 \( \gamma \) (0.12)

- **\( \gamma \gamma \gamma \)**
  - ZP 244 332, PR 82 289, ArkF 23 49, PR 90 849

- **\( \beta \gamma \)**
  - PR 145 907, PR 79 728

- **Beta transverse polaris (\( \gamma \))**
  - YadF 5 1037, Nuco 25 942

- **Beta circular polaris (\( \theta \))**
  - ZP 179 62

- **Nucl align**
  - PR 120 1777

- **0.150 level of \( ^{131}I \)**
  - \( t_{1/2} \): 0.94 J ms, delay coinc (DZb n4 24)
  - 0.95 \( \gamma \) s, delay coinc (PR 140 B536)
  - 0.76 \( \gamma \) s, delay coinc (NP A161 471)

- **Others**
  - ZP 23 244, ZETP 37 314, ArkF 11 100, NP 1 280

- **\( \mu \)**
  - 2.77 50 if \( t_{1/2} = 0.95 \) \( \gamma \) s, IPAC (NP A102 203)

- **1.797 level of \( ^{131}I \)**
  - \( t_{1/2} \): 5.9 \( \gamma \) s delay coinc (PR 140 B536)
  - \( \gamma \): -0.16 \( \gamma \) if \( t_{1/2} = 5.9 \) \( \gamma \) s, IPAC (NP A102 203)

---

**Fig. 1**
Fig. 2
<table>
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<tr>
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<td>DATA CAT</td>
<td>γ(keV)</td>
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<td>NP.A143.289//70Hn01</td>
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<td>TYP IST</td>
<td>AMN[619]</td>
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<p>| | | |</p>
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<tr>
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<td>213.6±0.2</td>
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XBL 732-210

Fig. 5
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