Information Centers in

NUCLEAR PHYSICS

This commentary on the nature and uses and locations of specialized nuclear-data centers is written by a physicist who is actively engaged in the work of one such group—the Nuclear Data Project at the National Academy of Sciences—National Research Council in Washington, D. C.

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To him who, in the love of nature, finds occasion to investigate, say, the nuclear properties of europium-152, nature offers a variety of approaches. The two lowest states have half-lives of 13 years and 9.3 hours, so their decay properties can be conveniently studied. Further, these states live long enough to be subjected to atomic-beam, isotope-shift, isomer-shift, mass-spectrometer, and cross-section experiments, and some such studies have been reported. Higher levels in Eu^{152} can be studied via neutron capture gamma rays and neutron resonances. They can also be studied through reactions, such as $Eu^{151}(d,p)$, $Eu^{153}(d,t)$, or $Sm^{149}(\alpha,p)$.

At some point between the time when an experiment on Eu^{152} is first considered and the time when the results are rushed into print, the above-mentioned nature-lover will probably want to peruse the existing literature on Eu^{152}. We know of 164 papers on this subject (see references 1 to 164). He may even want to make a careful study of all such papers and to determine for himself the present state of knowledge concerning nuclear-level properties of Eu^{152}. This may take longer than the experiment. If the present rate of accumulation of papers on Eu^{152} (about two per month) continues or increases, the lab time will eventually be a small fraction of the library time. Then there are the related papers to be read—papers on similar nuclei, surveys, reviews, experimental techniques.

Eu^{152} does not hold the record for popularity. We know of 187 papers on nuclear-level properties of Si^{28}, 225 papers on Na^{23}, 121 papers on level properties of Bi^{210}, including decay properties, and 229 papers on Co^{60}, including decay properties. We think the record is held by C^{12} but have been unable to make a complete count. Finding all these papers may be difficult in itself, but the main problem is reading and analyzing them once they are found.

A small sample of the data on decay properties of Eu^{152} is shown in Table 1. The data of Hatch and of Andersson and also of Marklund (1963) are from crystal-diffraction experiments; the rest are from magnetic analysis of conversion electrons. Once such a table has been prepared, it is of interest to look for systematic patterns. For instance, Bobykin's values are consistently higher than Fowler's and lower than Cork's 1957 values.

For γ_1, 121.78 seems a reasonable "average". We note that Bobykin came very close to this "average". This gives added weight to his results for the other gammas. Confidence in Bobykin's values is reinforced by his agreement with Marklund's value for γ_{18}. Mukherjee's value of 1408 ± 2 was added in proof; the value given in his table of γ energies is 1418.9.

The values adopted in this way show a sum rela-

Table 1. Partial listing of gamma energies in the decay of 13-year Eu^{152}

	E_γ (keV)				
	γ_1	γ_3	γ_{13}	γ_{14}	γ_{18}
Shull (1948)[1]	123	442	959	1082	1403
Cork (1950)[2]	121.8	—	964	1086	—
Fowler (1956)[3]	121.4	443.8 ± 1.0	963.1 ± 1.0	1085 ± 1	1409 ± 4
Grodzins (1956)[4]	122	442	963	1085	1405
Bobykin (1957)[5]	121.77 ± 0.1	444.23 ± 0.4	964.8 ± 0.9	1086.6 ± 1.0	1409.4 ± 1.4
Cork (1957)[6]	122.2 ± 0.2	445 ± 1	969 ± 2	1092 ± 2	1416 ± 3
Nathan (1957)[7]	122	—	963 ± 10	1079 ± 11	1415 ± 14
Dzhelepov (1958)[8]	—	436	968	1086	1411
Marklund (1958)[9]	—	—	—	—	1409.1 ± 0.7
Andersson (1958)[10]	121.87 ± 0.06	—	—	—	—
Romanov (1958)[11]	121.75 ± 0.03	—	—	—	—
Hatch (1959)[12]	121.79 ± 0.03	—	—	—	—
Nathan (1959)[13]	—	444 ± 3	965 ± 9	1086 ± 10	1409 ± 14
Mukherjee (1960)[14]	122.1	448	963.3	1079.2	1408 ± 2
Marklund (1963)[15]	121.778 ± 0.006	—	—	—	—

tion: $121.78 + 964.8 = 1086.58 \approx 1086.6$; $444.23 + 964.8 = 1409 \approx 1409.1$. However, there is some evidence[14] that the 1409 γ is a doublet.

The discrepancies are not always so small. There are three measurements[4, 14, 16] of the photon-intensity ratio of the 122 keV and 1409 keV gammas. Bhattacherjee gives 0.65; Grodzins gives 2.36; Mukherjee gives 2.06. Another estimate can be obtained by using the intensities of other gammas and requiring intensity balance at the 122 keV level. This gave a ratio of about 1.2. Nathan[7] gives an upper limit of 1.7.

These are examples of some of the discrepancies which must be examined in the process of determining the present state of knowledge concerning Eu^{152}. Analyses and comparisons must be undertaken dozens of times before a "best" level scheme or decay scheme can be proposed. Each puzzle may seem petty by itself, but when all are resolved to the maximum extent possible, the results usually lead to a scheme which is better (i.e., lasts longer) than that which can be obtained by a quick scanning of the recent papers.

Reports on given topics, such as Eu^{152}, in which all the relevant experimental results are displayed, agreements and disagreements clearly pointed out, and partial resolutions attempted, are the products of information centers.

One such information center is the Nuclear Data Project, which has been under the sponsorship of the National Academy of Sciences—National Research Council since 1952. This group is concerned with the data on nuclear energy levels, their energies, spins, moments, transition probabilities, etc. Some 89 primary journals are scanned regularly, including several abstract journals. In addition, some attempt is made to analyze annually about 200 kg of progress reports, preprints, and private communications. Documents or document records are filed by nucleus. Because the document file has been maintained for more than fifteen years, it is seldom necessary to make an extensive retrospective literature search. At any time all the documents concerning a given nucleus can be compared. For a popular nucleus such as Eu^{152} this comparison takes about a month of one physicist's time. The ratio of time spent analyzing and comparing documents to the time spent looking for documents and maintaining the document file is about 5 to 1.

Some other information centers in or near nuclear physics are:

Name of Field of Interest	*Address*
Nuclear Safety Information Center	Oak Ridge National Laboratory
Reactor Physics Constants Center	Argonne National Laboratory
Radiation Shielding Information Center	ORNL
Reactor Cross Section Evaluation Group	Brookhaven National Laboratory
Neutron Cross Section Compilation Center	BNL
Fast Neutron Cross Section Center	Lawrence Radiation Laboratory
Charged Particle Cross Section Center	ORNL

Radiation Effects Information Center	Battelle Memorial Institute, Columbus, Ohio
Trilinear Chart of Nuclides	ORNL
Chart of the Nuclides	Knolls Atomic Power Laboratory, Schenectady, N. Y.
Accelerator Information Center	ORNL
Gamma Ray Spectrum Catalogue	Phillips Petroleum Co., Idaho Falls, Idaho
AEC Office of Technical Information	Oak Ridge, Tenn.
Isotopes Information Center	ORNL
nuclear masses and *Q*-values	J. H. E. Mattauch, Max-Planck-Institut, Mainz, Germany
neutron cross sections	Service des Etudes, Mathematiques et Nucléaires, Electricité de France, Clarmart, Seine-et-Oise, France
neutron interactions important for reactor design	C. H. Westcott, International Atomic Energy Agency, Vienna, Austria
Sigma Committee (neutron cross sections)	Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-Ken, Japan
nuclear facilities and equipment in Europe	European Nuclear Energy Agency, Suchet, Paris, France
Table of Isotopes	J. M. Hollander et al., UCRL
Energy Levels of Light Nuclei	F. Ajzenberg-Selove, Haverford College, Haverford, Pa., and T. Lauritsen, Institute for Theoretical Physics, Copenhagen, Denmark
Energy Levels of Light Nuclei	P. M. Endt et al., Fysisch Laboratorium der Rijkuniversiteit, Utrecht, Netherlands
Decay Schemes of Radioactive Nuclei	B. S. Dzhelepov, L. K. Peker, Leningrad State University, University Quai 7, Leningrad, USSR
beta decay energies	L. J. Lidofsky, Physics Department, Columbia University, New York, N. Y.
nuclear reactions	J. Schintlmeister, Zentralinstitut für Kernphysik, Rossendorf, Dresden, East Germany

Some of the above groups are not specifically funded as information centers but nevertheless spontaneously turn themselves into information centers at suitable intervals and produce data compilations or analyses. In addition, there are many data compilations and reviews, similar to those produced by information centers, which were prepared on a one-shot basis by people who, as far as we know, have no intention of ever doing it again. We here apologize to anyone whose favorite nuclear information center was accidently omitted and hope he will write to us and complain.

A list of information centers including those in other fields can be obtained from the National Science Foundation.[165] A survey of information centers was made by G. S. Simpson.[166] He reports that about 6000 people work in 221 science information centers in the United States. Counting information centers is not easy. Thus, the value of 221 may be considered in fairly good agreement with the value of about 400 quoted below. There is no clear way of deciding when a data center, which collects and stores data, becomes an information center which collects, stores, analyzes, and correlates data.

A list of compilations in nuclear physics put out by information centers or by individuals has been prepared.[167] Hereafter, "data tabulations" will appear as an index heading in *Nuclear Science Abstracts*. Also in the future, information concerning information centers or compiled data will be available from the National Standard Reference Data Program of the National Bureau of Standards, now in Washington, D. C. and later (perhaps by 1965) in Gaithersburg, Md. Already in operation is the National Referral Center for Science and Technology, Library of Congress, Washington, D. C. This group answers questions concerning "the information resources of the scientific and technical community".

Information centers are occasionally the subject of deliberation of responsible government bodies. The Humphrey Subcommittee (officially, the Subcommittee on Reorganization and Internal Organization of the US Senate Committee on Government Operations) has held hearings[168] and done research on the entire information transfer problem for several years.[169] One of the Subcommittee's recommendations is for a "network of information systems". The "Weinberg report" (otherwise, the report of the Panel on Science Information of the President's Science Advisory Committee)[170] stresses the need for more and better information centers. The following quotations are from that report:

> "A specialized information center makes it its business to know everything that is being published in a special field—such as nuclear spectroscopy or the thermophysical properties of chemical compounds; it collates and reviews the data, and provides its subscribers with regularly issued compilations, critical reviews, specialized bibliographies, and other such tools. Its input is the output of the central depository. There are now in the United States about 400 such centers; the net number is

growing, though some specialized information centers can and should die because the fields of science they serve cease to be active. As originally conceived, the centers compiled data as opposed to ideas or knowhow; one of the earliest data centers compiled the International Critical Tables. Many of the data centers have evolved into information centers that not only compile data but also keep abreast of all developments in a field.

"We believe that the specialized information center, backed by large central depositories, might well become a dominant means for transfer of technical information. It therefore behooves the technical community, at this early stage in the proliferation of specialized centers, to learn what makes a good specialized center, and to plan new centers accordingly."

"Science can ultimately cope with the information expansion only if enough of its most gifted practitioners will compact, review, and interpret the literature both for their own use and for the benefit of more specialized scientists. The Panel believes that such activities may eventually achieve a position in the science of the future comparable to that of theoretical physics in modern-day physics. Recognition of the importance of such scientific middlemen is discernible in the proliferation of the so-called specialized information center where information is digested and interpreted. The Panel views the specialized information center as one key to ultimate resolution of the scientific information crisis."

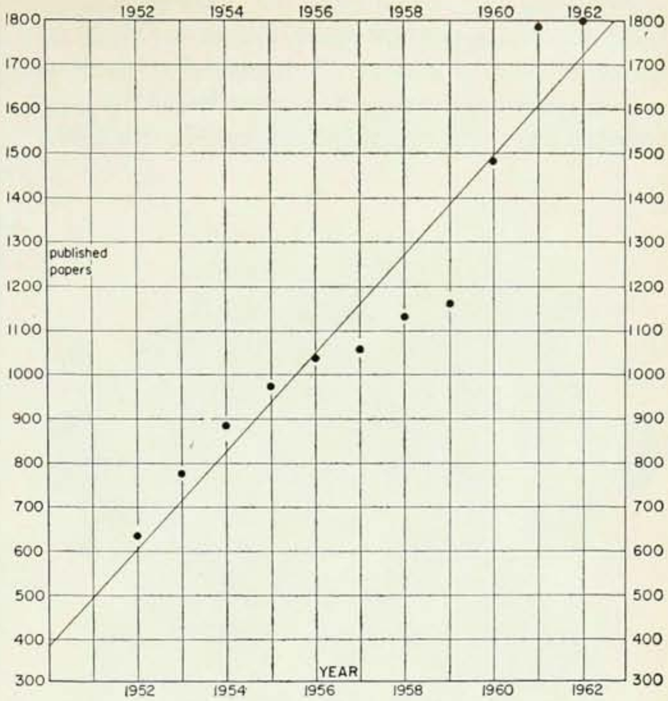

Fig. 1. Number of papers per year in experimental nuclear structure, arranged according to year of publication. The straight line has no particular significance.

We conclude our discussion of information centers in nuclear physics with this somewhat fanciful prediction: The annual number of published papers reporting experimental results in the field of nuclear structure, according to our files, is shown in Fig. 1. If the current more-or-less linear trend continues and if the average article contains one thousand words, then the nuclear-structure physicist of the year 5247 A.D. will have to spend his entire working day (18 hours), 300 days per year, reading at the rate of 1200 words per minute to cover his field—unless he uses an information center.[171]

References

1. F. B. Shull, Phys. Rev. 74, 917 (1948).
2. J. M. Cork, H. B. Keller, W. C. Rutledge, A. E. Stoddard, Phys. Rev. 77, 848 (1950).
3. C. M. Fowler, AECU—3194 (1956).
4. L. Grodzins, H. Kendall, Bull. Am. Phys. Soc. 1, No. 4, 163 B10 (1956).
5. B. V. Bobykin, K. M. Novik, Doklady Akad. Nauk SSSR 115, 263 (1957).
6. J. M. Cork, M. K. Brice, R. G. Helmer, D. E. Sarason, Phys. Rev. 107, 1621 (1957).
7. O. Nathan, M. A. Waggoner, Nuclear Phys. 2, 548 (1957).
8. B. S. Dzhelepov, N. N. Zhukovskii, Nuclear Phys. 6, 655 (1958).
9. I. Marklund, Nuclear Phys. 9, 83 (1958).
10. B. Andersson, Proc. Phys. Soc. 72, 148 (1958).
11. V. A. Romanov, Izvest. Akad. Nauk SSSR, Ser. Fiz. 22, 191; Columbia Tech. Transl. p. 188 (1958).
12. E. N. Hatch, F. Boehm, Z. Physik 155, 609 (1959).
13. O. Nathan, S. Hultberg, Nuclear Phys. 10, 118 (1959).
14. P. N. Mukherjee, I. Dutt, A. K. Sen Gupta, R. L. Bhattacharyya, Physica 26, 179 (1960).
15. I. Marklund, B. Lindstrom, Nuclear Phys. 40, 329 (1963).
16. S. K. Bhattacherjee, T. Nainan, S. Raman, B. Sahai, Nuovo Cimento 7, 501 (1958).
17. -164. References available from the author of this article on request.
165. Specialized Science Information Services in the United States, NSF 61-68, National Science Foundation, Washington, D. C. (1961).
166. G. S. Simpson, Jr., Scientific Information Centers in the United States, American Documentation 13, 43 (1962).
167. R. C. Gibbs, K. Way. A Directory to Nuclear Data Tabulations (1958) price $0.70; First Supplement appears in 1959 Nuclear Data Tables (1959) price $1.00; Second Supplement appears in 1960 Nuclear Data Tables, Part 4 (1961) price $1.50.
168. Interagency Coordination of Information (1962) price $0.80, Government Printing Office, Washington, D. C.
169. Documentation, Indexing, and Retrieval of Scientific Information, 86th Congress, 2nd Session, Senate Document 113 (1961) price $0.70; Addendum 87th Congress, 1st Session, Senate Document 15 (1961) price $0.15, U.S. Government Printing Office, Washington, D. C.
170. Science, Government, and Information (1963) price $0.25, U.S. Government Printing Office, Washington, D. C.
171. Among those who have assisted in the preparation of this paper are K. Way, director of the Nuclear Data Project, R. H. Lafferty and F. Kertesz of ORNL, A. Artna, R. Nakasima, H. Ogata, W. B. Ewbank, L. Chiao, M. Martin, G. H. Fuller, and R. Fuyat of the Nuclear Data Project.