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REVIEW OF PANEL ON REFERENCE NUCLEAR DATA SURVEYS AND DISCUSSIONS ON REFERENCE NUCLEAR DATA NEEDS

T.W. Burrows

October 1982

INFORMATION ANALYSIS CENTER REPORT

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, NEW YORK 11973

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Abstract

The results of the six meetings in the years 1976 through 1981 of the Panel on Reference Nuclear Data is reviewed, as well as the results of other studies and workshops. A brief review of how current programs are meeting the expressed nuclear data needs of professional groups is also presented. The types of data included in the review are reaction cross sections, isotopic abundances, atomic masses, nuclear structure, radioactive decay, and fission.

I. INTRODUCTION AND BACKGROUND

In 1976 the Panel on Reference Nuclear Data was organized at the suggestion of the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. The Panel, composed of representatives from most of the US professional societies containing users of nuclear data, has met six times to discuss the nuclear data needs of their memberships and to provide advice to information centers on the types of nuclear data needed and the preferred forms of these data. Table 1 lists the societies represented and Table 2 summarizes the meetings.

Since most of the societies represented on the Panel have now been surveyed and there have been extensive discussions of the needs at the meetings, it is appropriate to review the results of the six meetings of the Panel. In addition to the results obtained by the Panel, there have been many other surveys and recommendations made by various specialist's workshops, study groups, and other panels. Since the interests of these other groups often overlap or complement the interests of the Panel, a brief review of some of these results would also be useful.

It also seems useful at this time to discuss how various on-going programs are meeting the various needs of the users.

II. REVIEW OF OTHER SURVEYS AND STUDIES

In 1980 there were two specialists meetings convened by the International Atomic Energy Agency on behalf of the International Nuclear Data Committee. These meetings were on neutron-source reactions¹ and medical radioisotope production,² respectively. The recommendation to compile relevant monoenergetic neutron-source reaction data¹ echoes the need expressed by AAPM at the Panel.³ This need is also reflected by the recommendations of the workshop on Intense High-Energy Neutron Sources and their Characteristics⁴ for additional measurements of the angular distribution and neutron energy spectra for such reactions as protons on lithium or beryllium.

The recommendations by the medical radioisotope production workshop², although more selective, closely follow the needs expressed by the Panel members interested in biomedical applications of nuclear data.⁵ These recommendations included additional half-life, branching ratios, and radiation data for specific isotopes, selected cross section evaluations for common positron emitters and beam monitors, compilation of experimental data for commonly used radioisotopes, and measurements of cross sections for potentially useful reactions, (e.g. $^{19}\text{F}(p,n)^{19}\text{Ne}$).

Since 1975 there has also been a Panel on Basic Nuclear Data Compilations. The primary emphasis of this Panel has been the quality and timeliness of nuclear structure and decay data evaluations, particularly those appearing in the Nuclear Data Sheets. This has included an evaluation of the BNL Study⁶ and a review of the transfer of maintenance and publication responsibilities from the Nuclear Data Project to the National Nuclear Data Center. They have also addressed themselves to other concerns (e.g. the preservation of tabular differential charged-particle cross section data) and suggested various areas of compilation activities, including radioisotope production, reactions related to fusion, and other, such as medium energy physics.

Historically, there have been many other studies and surveys on reference nuclear data needs. These are too numerous to discuss in detail and a list of some of these reports is included as Table 3. Excluding the differing biases in these earlier works, the expressed needs are very similar to those expressed by this Panel. For example, the BNL Study Group⁶ found, as a result of their own survey and of the previous studies, a need for bibliographies of nuclear structure and reaction data, for evaluations of nuclear structure and decay data and reaction data relevant to fusion, medical, and isotope production applications,* and for compilations of experimental data on nuclear structure and decay, Coulomb excitation, reaction cross sections, excitation functions, isobaric analogs, and L-transfers.†

A survey by G. H. Miley⁷ on charged-particle cross-sections required for fusion was also presented at the Fifth Meeting of the Panel on Reference Nuclear Data. This review noted that the data for the basic D-T fuel cycle are adequate, but could be refined, and that the data required for other possible fuel cycles are generally not complete and recommended the development of a national data bank and common computerized exchange format for fusion applications.

Many of the needs expressed in these studies and in the results of the various Panel Meetings are also reflected, in more detail, in the most recent DOE request list,⁸ reflecting the programmatic needs of various agencies.

Many of the earlier studies also found that the community was worried about the time interval between evaluations, particularly for nuclear structure. This concern has been addressed by the establishment of the US Nuclear Data Network and the IAEA-sponsored Nuclear Structure and Decay Data Network.

III. REVIEW OF PANEL SURVEYS AND DISCUSSIONS

The various surveys presented and discussions at the six Panel Meetings have shown the applied community's need for many types of reference nuclear data as summarized in Figure 1 and Table 4. These include decay data primarily electromagnetic radiations, half-life and decay modes, isotopic abundance, and neutron cross sections. This is reflected by the heavy use of

*Some desire was also expressed for evaluations of Coulomb excitation, coincident radiation, polarization, and fission product and prompt neutron yield data.

†This desire for experimental data compilation was often qualified by the opinion that such an effort should not be made at the expense of bibliographic or evaluation activities. Other areas of some interest were coincidence, fission product and prompt neutron yields, and polarization data.

the various wall charts, the Table of Isotopes, and BNL-325, ENDF,* or ENDL.† Photonuclear and charged-particle reaction data were also important to some of the groups.

While there was considerable overlap between the various groups of users as to the general areas of nuclear data needs, there were differences as to the reactions, energy ranges, or decay data needed and the preferred form of the data. For example, reactor physics generally required cross section data on materials covering the periodic table to ≈ 20 MeV, while fusion and biomedical needs are for a more restricted set of materials, but to energies up to 50 or 100 MeV. Charged-particle-induced reaction cross-section needs also differ among the groups but may be divided into three areas: 1) neutron-source reactions, 2) light-ion reactions relevant to fusion, and 3) radioisotope production. In general, the basic nuclear data are required in the form of tables, drawings, or computerized files. However, there is also the need for more applied data, e.g. reaction rates for fusion reactions or listings of the atomic and nuclear radiations from the decay of nuclei.

Finally, it is interesting to note the similarities between the results of the "Radioactivity Handbook" survey which had a heavy response from the "basic" community and the other survey results in the areas where survey questions overlapped.

IV. REVIEW OF CURRENT PROGRAMS

A. Nuclear Structure and Decay Data

1. Compilation and Evaluation

It was in the area of nuclear structure and decay data that the first organized compilation and evaluation effort began with the work of G. T. Seaborg, T. Laurentsén, K. Way, C. Van der Leun and P. Endt, and others. However, as the volume of data geometrically increased, there developed a serious time lag in the evaluations. The time interval between the Sixth and Seventh Editions of the Table of Isotopes was ≈ 10 years and there developed a similar problem in the evaluations presented in the Nuclear Data Sheets. In response to this problem the US Nuclear Data Network and the IAEA-sponsored Nuclear Structure and Decay Data Network were formed to reduce the redundancy in evaluations and to involve more evaluators in the process.

While the nominal time interval between evaluations of four years has not been reached, the time interval has been reduced. With the exception of the time interval problems, the needs of the community for nuclear structure and decay data seem to be satisfied. Efforts are also being made within the networks to present the data in a form more useful to specific applications, e.g. the "Radioactivity Handbook".

*Evaluated Nuclear Data File, maintained by the National Nuclear Data Center, Brookhaven National Laboratory on behalf of the Cross Section Evaluation Working Group.

†Evaluated Nuclear Data Library, produced by R. Howerton, et al., Lawrence Livermore National Laboratory.

There has also been work done by other groups, based on ENSDF,* to produce data for specific applications. An example, of this would be the decay data files found in ENDF.

2. Bibliographic

The bibliographic activities begun by the Nuclear Data Project, Oak Ridge National Laboratory, in the form of "Recent References" and the Nuclear Structure Reference file are being continued by the NNDC on behalf of the networks. This effort seems to satisfy the "basic" community's needs and part of the "applied" community's needs.

B. Neutron Data

1. Compilation and Bibliographic

The compilation work begun by D. Hughes and the bibliographic effort begun by H. Goldstein and others continues with the cooperation of four centers.† This cooperation results in an experimental data exchange format, EXFOR, and a bibliographic file, CINDA,‡ and annual publications of the bibliography. Although current manpower commitments are low, the general needs of the community seem to be satisfied.

2. Evaluation

Many countries maintain an evaluation effort. In this country the effort is maintained by various groups working in the Cross Section Evaluation Working Group (CSWEG), resulting in ENDF maintained by NNDC on behalf of the Group. This work has resulted in a reference data base which appears to be quite satisfactory for the current fission reactors in operation, although improvements should be made as problems are recognized or new information is available. Attempts have been made to address the needs of fusion and biomedical users; however, manpower limitations have restricted the usefulness of ENDF for these users.

C. Charged-Particle

At present, with the exceptions of groups at several laboratories interested in light-ion reactions relevant to fusion and astrophysics, there

* Evaluated Nuclear Structure Data File, maintained the National Nuclear Data Center, Brookhaven National Laboratory, on behalf of the US Nuclear Data Network and the IAEA-sponsored Nuclear Structure and Decay Data Network.

† The four centers are the National Nuclear Data Center, Brookhaven National Laboratory (NNDC); the Nuclear Data Centre, Fiziko-Energeticheskij, Obninsk, USSR; the NEA Data Bank, Saclay, France; and the IAEA Nuclear Data Section, Vienna, Austria (NDS).

‡ Computer Index of Neutron Data.

is no major effort to compile or evaluate charged-particle reaction data. Even among these groups there is no standard data base or exchange format.

There have been several attempts in the past to compile and evaluate such data in a systematic way, but these have met with limited success, perhaps due to the volume of data available and the diffuseness of the user community. The most recent attempt was through the International Nuclear Reaction Data Network.* This network agreed to the exchange of experimental data using the exchange format, EXFOR, and to the need for a bibliography of integral charged-particle nuclear data. There have been four active members of the network in the charged-particle area: 1) KACHAPAG, compiling radioisotope production data; 2) NNDC, maintaining the bibliography and compiling neutron-source reaction and organic radioisotope production data; 3) CAJAD, compiling some charged-particle data produced in the USSR; and 4) NSD, compiling some neutron-source reaction data. The activities of KACHAPAG ceased in December, 1981, and the charged-particle activities at the NNDC, except for retrievals from the data bases, was terminated in March, 1982. It is hoped that the Nuclear Structure References file will prove to be an adequate bibliographic source to the community requiring information on radioisotope production and neutron-source reactions.

An exchange format for evaluated charged-particle nuclear data was developed and proposed by a subcommittee of CSWEG. However, it does not appear to have been used to date.

D. Photonuclear Data

Two groups in the United States have been active in the compilation of photonuclear data for many years. These are the group headed by B. L. Berman at Lawrence Livermore National Laboratory and the Photonuclear Data Center headed by E. Fuller at the National Bureau of Standards. These have recently been joined by the Photonuclear Data Center, Moscow, which produces periodic indices and has compiled some data in EXFOR.

The Photonuclear Data Center no longer exists as a separate, well-defined entity within the Bureau. A small Photonuclear Data Group is, however, trying to maintain minimum services for the user community, publishing a second supplement to their photonuclear reaction index, and finishing compiling and evaluating photonuclear reaction data for ^{12}C , ^{14}N , and ^{16}O .

* In addition to the four centers listed above, the members of the network are:

Center for Nuclear Structure and Reaction Data of the USSR State Committee on the Utilization of Atomic Energy, Moscow, USSR (CAJAD)
Charged-Particle Data Group, Institut für Radiochemie, Kernforschungszentrum Karlsruhe, Federal Republic of Germany (KACHAPAG)
Department of Physics, Hokkaido University, Sapporo, Hokkaido, Japan
Nuclear Physics Division, Atomic Energy Research Establishment, Harwell, UK
Fachinformationzentrum, Karlsruhe, Federal Republic of Germany
Nuclear Data Group, Institute Baden Jadrowyeh, Warsaw, Poland.

V. CONCLUSIONS

In reviewing some of the earlier studies and the results of the various Panel meetings, it appears that the basic requirements of the community for reference nuclear data have remained consistent over many years. Regions of interest, energy ranges, and accuracy requirements may have changed but the need for nuclear structure and decay and for nuclear reaction data has been consistently expressed. In the areas of nuclear structure and decay data and neutron reaction data many of the needs seem to be satisfied by current programs, although additional effort may be justified. In the areas of charged-particle- and photon-induced reaction data, it appears that most of the needs are not currently being met in any organized program.

It would be very useful for the members of the Panel to review the current programs providing reference nuclear data in light of the needs of their societies and through their societies to make definite recommendations on how these programs could be improved.

REFERENCES

1. K. Okamoto, editor, International Nuclear Data Committee Report INDC (NDS)-114, 1980.
2. K. Okamoto, editor, International Nuclear Data Committee Report INDC (NDS)-123, 1980.
3. T.W. Burrows and J.E. Cline. Minutes of the Second Annual Meeting of the Panel on Reference Nuclear Data. Unpublished, 1978.
4. C.D. Bowman, chairman, "Intense High Energy Neutron Sources and Their Characteristics," in Symposium on Neutron Cross Sections from 10 to 50 MeV, p. 7. Brookhaven National Laboratory Report BNL-NCS-51245, 1980.
5. T.W. Burrows, L. Stewart, and J.J. Coyne, Brookhaven National Laboratory Report BNL-NCS-51023, 1979.
6. S. Pearlstein, N. Holden, C. Dunford, T. Burrows, and M. Bhat, Brookhaven National Laboratory Report BNL-NCS-20573, 1975.
7. G.H. Miley, "Charged-Particle Cross Section Data for Fusion Plasma Applications," in Proceedings of the Conference on Nuclear Data Evaluation Methods and Procedures, p. 935, Brookhaven National Laboratory Report BNL-NCS-51363, 1981.
8. National Nuclear Data Center (compiled and edited for the DOE Nuclear Data Committee), Brookhaven National Laboratory Report BNL-NCS-51354, 1981.

Table 1

Professional Societies Represented on the Panel
on Reference Nuclear Data

American Association of Physics in Medicine

American Chemical Society

Division of Nuclear Chemistry and Technology

American Nuclear Society

Division of Controlled Nuclear Fusion

Division of Isotopes and Radiation

Division of Radiation Protection and Shielding

Division of Reactor Physics

American Society for the Testing of Materials

E-10 Committee, Nuclear Applications and Measurements of
Radiation Effects

Health Physics Society

Institute of Electrical and Electronic Engineers

National Council on Radiation Protection and Measurements

Radiation Research Society

Radiopharmaceutical Research Council, Society of Nuclear
Medicine

Society of Nuclear Medicine

Table 2

Panel on Reference Nuclear Data Meetings

All meetings of the Panel on Reference Nuclear Data were held at Brookhaven National Laboratory.

<u>Date</u>	<u>Documentation</u>
October 19, 1976	Panel on Reference Nuclear Data and Surveys of Reference Data Requirements. T. W. Burrows and S. Pearlstein. Brookhaven National Laboratory Report BNL-NCS-50717 (1977).
October 25, 1977	Panel on Reference Nuclear Data. J. E. Cline and T. W. Burrows. Unpublished.
October 5, 1978	Minutes of the Third Annual Meeting of the Panel on Reference Nuclear Data. T. W. Burrows, L. Stewart, and J. J. Coyne. Brookhaven National Laboratory Report BNL-NCS-51023 (1979).
November 1-2, 1979	Minutes of the Fourth Annual Meeting of the Panel on Reference Nuclear Data. T. W. Burrows, L. Stewart, and J. J. Coyne. Brookhaven National Laboratory Report BNL-NCS-51250 (1980).
October 23-24, 1980	Minutes of the Fifth Annual Meeting of the Panel on Reference Nuclear Data. T. W. Burrows, J. J. Coyne, and D. S. Brenner. Brookhaven National Laboratory Report BNL-NCS-51364 (1981).
October 15-16, 1981	Minutes of the Sixth Annual Meeting of the Panel on Reference Nuclear Data. T. W. Burrows, and D. S. Brenner (to be published).

Table 3

Some Previous Studies on Reference Nuclear Data

1. S. Pearlstein, N. Holden, C. Dunford, T. Burrows, and M. Bhat. Study on the Compilation and Evaluation of Nuclear Structure and Charged Particle Reaction Data. Brookhaven National Laboratory Report BNL-NCS-20573.
2. A. Calamand. Survey of Current and Future Needs for Charged Particle and Photonuclear Reaction Data. International Nuclear Data Committee Report INDC (NDS)-62/W.
3. C. M. Lederer and J. M. Hollander. A Survey of Nuclear Data Use in Applied Fields, in Proc. Symp. Nuclear Data in Science and Technology, Paris, March 12-16, 1973, Vol. 2, pp. 449-56, IAEA, Vienna, 1973.
4. H. Munzel and W. Michaelis. Survey of Nuclear Data Needs in Activation Analysis. Kernforschungszentrum Karlsruhe Report KFK-1812, 1973 [INDC (GER)-12].
5. Dissemination and Use of Information in Physics, in Physics in Perspective, Vol. 2, Chap. 14, National Academy of Sciences, Washington, DC, 1973.
6. Ad Hoc Panel on Nuclear Data Compilations, Committee on Nuclear Science, National Research Council, National Academy of Sciences. Nuclear Data Compilations, the Lifeblood of the Nuclear Sciences and Their Applications. 1971.
7. Science, Government, and Information, a Report of the President's Science Advisory Committee, Panel on Science Information, A. Weinberg, Chairman, The White House, Jan. 10, 1963.

TABLE 4

SUMMARY OF RESULTS

(Percent of responses, except as noted)

Type of Data Required	Survey Results (See end of table for explanation)											
	1	2					3				4*	5
		a	b*	c	d	e	a*	b	c*	d*		
Neutron Cross Sections	69	S	S	40	42				S		S	50
Capture					91			27				59
Fission		58		72	84			19				58
Scattering					73			20				46
Capture- γ Spectra				49	73							61
Activation						58						58
Prompt γ -production						68				S		68
Isotopic Abundances	84	84	S	73	71			87				80
Atomic Masses	66	53			67	32						54
Nuclear Structure and Decay Data											S	
$T_{1/2}$'s	95	89		87	81	78	S	91		S		87
J^π 's	46	16		7	33	8						22
Decay Modes	93	79		76		71		96				83
Radiations	98								S	S		98
γ -rays	97	89		90	73	81		100				88
X-rays	74	74		69	47	63		82				68
α -particles	75	47		60	52	48		59				57
Auger electrons	38			2								20
protons	38	11										24
$\beta^\pm$ -particles	82	58		66	44			83				67
Conversion electrons	53	37		45								45
Delayed particles	46	17			73							45
$<\beta^->$ energy	38											38
$<\beta^+>$ energy	34											34
Average photon energy	41											41
Level Schemes	85	47		47	55	18						50
Radioisotope Production Methods	55	47					S			S		51

TABLE 4 (continued)

Type of Data Required	Survey Results (See end of table for explanation)											
	1	2					3				4*	5
		a	b*	c	d	e	a*	b	c*	d*		
Fission	†											
n yields/distributions					83			20			52	
γ-yields/distributions					75						75	
product yields/distributions					88			65			76	
Charged-particle and photon cross sections		53		23		13					30	
Photonuclear												
Photoneutron					66						66	
Photoproton					28						28	
Charged-particle	†								S	S		
Reaction cross sections					44						44	
Product distributions					31						31	
Nuclear elastic					23						23	
Cross sections for specific levels				10		18					14	
Angular distributions				12		16					14	
γ-ray spectra				30		38					34	

1. Radioactivity Handbook Survey (Fifth Meeting)

2. Reactor Physics

- Nuclear Science and Plasma Society (First Meeting)
- E-10 Committee, ASTM (Second Meeting)
- Isotopes and Radiation Division, ANS (Second Meeting)
- Reactor Physics, ANS (Third Meeting)
- Radiation Protection and Shielding, ANS (First Meeting)

3. Medicine and Biology

- Society of Nuclear Medicine (no formal survey)
- Radiopharmaceutical Council (Sixth Meeting)
- American Association of Physics in Medicine (Second Meeting)
- Nuclear Chemistry and Technology, ACS (no formal survey)

4. Fusion

From presentations and discussions of members representing the Controlled Fusion Division, ANS, and the Nuclear Science and Plasma Society, IEEE.

5. Unweighted average of the numerical results of the surveys listed above.

* S=Strong need expressed

† Not asked on survey, but 2% of the respondents requested fission yields and 1% charged-particle cross sections under the category of "other types of data."

SURVEY RESULTS

Figure 1.
Summary of Survey Results

Only the major categories surveyed are shown here. See Table 3 for details. The largest response for any sub-category is shown in the plot. In addition, the responses from the various Divisions have been combined as an unweighted average of the individual Division responses. Where no bar is shown, the question was not asked in the surveys.

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