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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

International cooperation in the field of nuclear data*

by

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Nuclear Data Section
Division of Research and Laboratories
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* Report presented at the XXII National Conference on Nuclear Spectroscopy and Structure of the Atomic Nucleus, Kiev, 25-28 January 1972

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Abstract

This report reviews the objectives, achievements and future developments of the international cooperation in the field of nuclear data. Particular emphasis is given to the international compilation, exchange and review of neutron data important for the development of nuclear energy as a concerted effort of the four main world neutron data centres and to the role of the IAEA in this respect. More recently in response to various demands IAEA set up a modest programme for nuclear structure and reaction data with the aim to promote and improve the international coordination of the dispersed efforts also in this field of nuclear data.

Introduction

The purpose of this report is to describe the international cooperation in the field of nuclear data, its objectives, achievements and future prospects. In accordance with its statutory objectives, i.e. "to foster the exchange of scientific and technical information on peaceful uses of atomic energy" the International Atomic Energy Agency (IAEA) already in the early sixties has taken an active interest in international coordination of the nuclear data field. This interest led to the formation of the Nuclear Data Section in 1964 with the primary objective to promote the world-wide compilation and exchange of nuclear data information, to assess the needs for nuclear data and to promote national and regional nuclear data programmes to fulfill these needs. In the formulation of its nuclear data programme the IAEA has been aided by the International Nuclear Data Scientific Working Group (INDSWG) which in 1969 was consolidated as a continuing advisory body with the name International Nuclear Data Committee (INDC). INDC is composed of members from countries with major nuclear data programmes with due consideration given to a balanced geographical representation. INDC meets annually and has the task to promote international cooperation in all phases of nuclear data activity and to advise the Director General of the IAEA in this field; NDS also serves as secretariat to the INDC.

In response to the most imminent needs for the development of nuclear reactors, especially fast power breeder reactors, NDS gave and is still giving first preference to neutron data. Under the pressure to fulfill these needs in the most efficient way a network of neutron data centres developed with the basic task to systematically compile and exchange neutron physics and data information from laboratories all over the world and to make it available to the communities of nuclear physicists and reactor designers. In addition to NDS three other centres belong to this network:

data. Compilation is always understood to include as complete material as possible.

"Evaluation" comprises the following individual steps:

- critical comparison, selection and averaging of the available experimental data,
- inter- and extrapolation of experimental data and use of nuclear theory and systematics in the case of gaps and inconsistencies in the experimental information,
- build-up of a computer library of complete, self-consistent and easily interpolable evaluated data sets from which, for example, multigroup constants and related quantities can be calculated and then be used as direct data input to reactor design calculations.

Whereas compilation generally could be conceived as the first step in the process of evaluation, it finally separated out in the case of neutron data and required an international coordination of its own because of the increasingly large amount of data measured. Neither were the experimenters in a position to supply the data to each individual requestor nor were the evaluators able to collect the data information individually from every experimenter. Nowadays neutron data compilation is predominantly done by the neutron data centres, whereas evaluation is predominantly taking place in national nuclear research centres in connection with nuclear energy projects.

I.2. CINDA

International coordination is most suitably started on the subject of compilation. For this purpose the establishment of a comprehensive and up-to-date international list of bibliographic references to experimental neutron data appears to be the first requirement. Out of various private indexing activities particularly of neutron data evaluators only the computer-based reference index CINDA (= Computer Index of Neutron DAta) which has been developed by Professor H. Goldstein and his collaborators in the USA gained world-wide recognition and has

become the primary reference source in the neutron data field. Today we have cooperation on CINDA between the Division of Technical Information Extension (DTIE) of the United States Atomic Energy Commission (USAEC), at the Oak Ridge National Laboratory in the USA; the three neutron data centres CJD, NDCC and NDS and a world-wide net of voluntary readers. The international neutron physics literature, consisting of regular publications, laboratory reports, preprints and other information sources, is systematically scanned and abstracted in the form of entries to the CINDA computer system. The content and format of these entries is exactly taylored to the needs of the users of CINDA, i.e. evaluators, reactor designers, nuclear physicists and others. They want to be informed by CINDA in a most compressed and up-to-date form upon nuclide and measured quantity, experimental energy range, reference, history of an experiment, main author and some prominent feature of the data given in a very short comment. In addition CINDA contains also references to data evaluations and to theoretical articles and reports of interest in the neutron data field.

The CINDA computer programme systems are operated by NDCC and DTIE. The content of the CINDA computer file is published annually with half-yearly supplements and distributed to more than 1500 users throughout the world. The first four international CINDA issues were published by the USAEC/DTIE and by ENEA/NDCC in alternation. The fifth issue, CINDA 71, was the first to be published by IAEA on behalf of CJD, NDCC, NDS and DTIE. Each of these four centres is responsible for compiling the CINDA entries from published literature and other information sources available from its service area, with DTIE covering the same geographical area as NNCSC. CINDA 71 contains about 70,000 entries extracted from more than 240 scientific journals, 180 report series, 110 books and conference proceedings and private communications. A particular feature of CINDA 71 is that for the first time it is produced by means of computer-controlled phototype-setting on a Linotron 505 machine. With this method the CINDA handbook turned out to be an improvement in terms of economy, handling convenience and legibility compared to former editions produced by conventional reproduction methods.

In cooperation between DTIE, NDCC and NDS, CINDA is now being developed towards an index to the experimental neutron data files of the four neutron data centres to be discussed in the next section.

I.3. EXFOR

While the four neutron data centres had developed, maintained and exchanged their own experimental neutron data files for quite some time, it was only rather recently that they met on a regular basis and agreed on a common exchange format for experimental neutron data, which is known under the name EXFOR. Instrumental for the development of EXFOR was the Panel on Neutron Data Compilation which, upon recommendation of INDC, the IAEA convened at Brookhaven National Laboratory in February 1969 and in which experts from 12 IAEA Member States and from ENEA participated [2, 3]. Following this agreement which was concluded between CJD, NDCC, NDS and NNCSC in July 1970 the four centres do not only compile and exchange neutron data and associated bibliographic information, but also the most important experimental characteristics. The centres now use the same terminology, keywords, codes and other conventions, so that the information mentioned above is coded and transmitted in an unequivocally recognizable way. The system is open-ended so that new quantities, definitions, etc., can be added when need arises and it is continuously reviewed between and at annual meetings of the four centres convened and coordinated by IAEA/NDS. As the system is still rather young, there is as yet not much response from users of EXFOR data information, although the system was originally designed in accordance with the information needs particularly of neutron data evaluators and neutron physicists. One of the main future tasks of the four centres in this respect will be to consider in detail the feedback from the changing needs of the users to the system. Finally we would like to mention a unique feature of the four-centre cooperation on EXFOR which was instrumental for its success, and this is that CJD Obninsk took it upon itself to use English language, codes and conventions and to use IBM tapes and tape units for data transmission.

I.4. Evaluated data

As a further step the neutron data centres also compile and exchange evaluated neutron data which mostly originate from evaluation work and evaluated neutron data libraries in national nuclear laboratories. The main data libraries available at present are the Evaluated Neutron Data File (ENDF/B) of the United States [4], the UK Neutron Data Library (UKNDL) [5] and the German evaluated data library KEDAK [6]. In the USSR a comprehensive system of neutron data averaged over 26 neutron energy groups has been established [7] and a computer library of evaluated energy dependent neutron data for nuclear technology use is under development. Comprehensive fission product neutron data libraries have been established by Italian and Australian evaluators, and a number of smaller, rather specialized data libraries have been produced in various countries.

Whereas nowadays experimental neutron data are freely exchanged throughout the world, the exchange of evaluated neutron data is still rather restricted, although an increasing need to obtain and use those data can be seen in many countries, particularly in developing countries. In response to this need and, again upon a recommendation of INDC, the IAEA convened a Panel on Neutron Nuclear Data Evaluation in Vienna, in September 1971 [8], in which evaluation experts from 11 IAEA Member States and from ENEA participated. This panel reviewed the methods, the quality and the present status of neutron nuclear data evaluation and examined the basic requirements and problems associated with establishing, maintaining, using and exchanging computer-based libraries of evaluated neutron data. It also reviewed still unsatisfied important needs for evaluated data in IAEA Member States, particularly in developing countries and compared in detail the main computer formats for evaluated neutron data whose knowledge is an indispensable prerequisite for an efficient international exchange of evaluated data. In spite of the restrictions mentioned above quite some exchange of evaluated neutron data is taking place already in which also NDS takes part, on a bilateral or regional basis. There is a free exchange between countries in the OECD area and even free international exchange of the whole German and of parts of the UK evaluated neutron data files.

I.5. Data reviews

A further basic activity of NDS consists in reviewing neutron data of relevance and particular importance to the development of peaceful use of

nuclear energy. As at present fast reactors play a predominant role in this development, a few items of high priority are dealt with by NDS. Hereto belong

- the α Pu-239 values in the keV range,
- the fast fission cross section of Pu-239,
- $\bar{\nu}$ standards like Cf-252 and $\bar{\nu}$ data for the heavy isotopes,
- the U-238 fast capture cross sections,
- the fast fission cross sections for the threshold isotopes Th-232, Np-237 and U-238,
- and the prompt fission neutron energy spectra of the main fissile nuclides and of the Cf-252 standard.

These reviews aim at giving a comprehensive survey of the available experimental data (available through the Four-Centre cooperation mentioned before), they assess as far as possible the systematic errors of the individual experiments, they give weighted average curves through the experimental data, they assess the pointwise confidence level of these curves, and finally they indicate gaps and inconsistencies and needs for further measurements. These reviews are done in close cooperation with the relevant experimental physicists who are the originators of the data considered. This cooperation proceeds via extensive correspondence and via specialists meetings called for discussion of specific data subjects. Those meetings were for example held twice on the subject of $\alpha(^{239}Pu)$ at Winfrith in the United Kingdom in 1969 and at Studsvik in Sweden in 1970. Other similar expert meetings were held on $\bar{\nu}$ data including the ^{252}Cf $\bar{\nu}$ standard at Studsvik in 1970, and on the status of prompt fission neutron spectrum measurements in Vienna in 1971. These meetings have proven to be a very powerful tool to understand the sources of discrepancies between different experiments and to foster measures for their explanation either by evaluation or by experiment.

I.6. Conferences and panels

In 1966 and 1970 the IAEA held two international Conferences on Nuclear Data for Reactors, in Paris and Helsinki respectively. These two conferences gave a comprehensive review of the existing neutron data needs

in various fields of peaceful nuclear technology and of the actual status of experimental and evaluation work on neutron data. The proceedings of these conferences have been published by the IAEA [9, 10]. A third IAEA Nuclear Data Conference is planned for 1974.

Aside from the two panels on neutron data compilation and evaluation, and in response to the urgent need of the neutron data community for reliable standard data the IAEA held a Panel on Nuclear Standards for Neutron Measurements in Brussels in 1967 [11] in which the most important standard cross sections in the neutron data field were reviewed and, which fostered the development of accurate methods and strengthened the importance of precision measurements. A second IAEA Panel on Neutron Standard Reference Data is planned for 1972.

I.7. RENDA

An increasing activity of NDS which is closely coupled to its data reviews mentioned above consists in the assessment of neutron data needs, particularly also in developing countries. One powerful means of getting these data needs known to the experimenters are request lists for data measurements. Those request lists for neutron data measurements have for a long time been compiled, issued, and critically reviewed by the European American Nuclear Data Committee (EANDC) with restriction to requestors in OECD countries. An individual request specifies the neutron data to be measured for a given material and energy range; it furthermore specifies the desired experimental resolution, accuracy and priority according to the needs of the requesting nuclear programme.

These lists have fulfilled an important function in the promotion of neutron data measurement programmes and have led to an increasingly detailed and accurate knowledge of neutron data as needed, e.g., for reactors. The latest OECD lists have been prepared from a computer file of the requests which allows for rapid updating and topical retrievals and which is called RENDA (= REquests for Neutron DAta Measurements) [12].

More recently NDS compiled a similar list of neutron data requests from the USSR and from a number of countries in its service area, mainly developing countries. In a cooperative effort of ENEA and IAEA it is now envisaged to combine these requests with those from the EANDC area to a first world-wide RENDA document. In the future it is envisaged to operate RENDA computer programmes at IAEA and to issue RENDA as a cooperative effort of the four neutron data centres. The role of INDC will be to review RENDA, to solicit the cooperation of national and regional neutron data committees and to promote measurement programmes to fulfill the requests.

I.8. Targets and foils

Recently NDS has initiated a survey among developing countries within its service area to ascertain the needs for accelerator targets and material foils for nuclear data measurements not necessarily restricted to neutron data. This has found an encouraging response and has led to the appropriation of some moderate funds allowing IAEA assistance in urgent cases in the purchase of targets and foils from supplying laboratories and firms in developed countries. INDC will help by screening and weighing the individual requests in the light particularly of the measurement requests as contained in RENDA.

II. Nuclear structure and reaction data

Although the subject of nuclear structure and reaction data had been raised in the early days of the IAEA in the very first discussions of the Agency's nuclear data programme, it was only in 1968 that this subject was brought up again by Dr. Hollander from Berkeley in the USA who suggested in a proposal to the IAEA that the Agency sponsor international collaboration in the field of nuclear level and radioisotope data. In 1969 Drs Grinberg and Le Gallic from Saclay, France, pointed out to the Agency that only an initiative from an international organization like the IAEA could resolve the present pressing problems in the collaboration on evaluation of radioactive decay data. In fact, together with other scientists from countries in the EURATOM area, they recently established a group with the task to review status and needs in the field of radioactive data, to start an evaluation programme on the most important of these data and to develop guidelines for their evaluation.

Recently also the need for a variety of nuclear (including neutron) data in connection with the technical development of nuclear materials safeguards has been expressed to the Agency. A first more comprehensive survey conducted by NDS revealed the need for data as diverse as

- neutron capture gamma ray spectra (not covered in the present scope of EXFOR),
- photonuclear cross section data ($\sigma_{\gamma f}$, $\sigma_{\gamma n}$),
- prompt and delayed neutron and gamma ray yields following photon irradiation,
- decay schemes and half-lives of heavy nuclides.

A similar world-wide survey is at present being carried out by NDS regarding nuclear data needs for the development of controlled thermonuclear fusion. In addition to neutron data needs for energies in the MeV range, where there is generally a gap in the existing measurements, data on a number of charged particle nuclear reactions for light nuclei are needed. Here we refer also to the first reviews of data needs for thermonuclear fusion as reported by Chernilin and Yankov [13] and by

Crocker et al. [14] at the Second IAEA Conference on Nuclear Data for Reactors in Helsinki in 1970.

Also in the field of nuclear reactors and radiation shielding the need for non-neutron nuclear data has become apparent with the increasing sophistication and detail in their design. Very recently these needs were particularly strongly expressed by the Cross Section Evaluation Working Group (CSEWG) in the United States [15]. It recommended that a unified data system be established for the computerized storage and retrieval of nuclear structure data and, that agreements be established for the free and rapid exchange of these data on an international basis, whereby the coordinating role taken by IAEA/NDS in this respect was endorsed. CSEWG refers to data such as

- nuclear level schemes and decay modes,
- branching ratios,
- multipolarity of photons,
- internal conversion coefficients,
- nuclear masses,
- reaction Q-values,
- charged particle and photonuclear cross sections

and other data for a variety of nuclides for purposes such as

- evaluation of neutron cross sections by means of optical and statistical model calculations,
- evaluation of neutron cross sections from inverse reactions,
- physics checking of the ENDF/B library of evaluated neutron data mentioned above, and
- radiation shielding calculations.

II.1. IAEA Consultants Meeting in November 1970

Starting from Dr. Hollander's proposal mentioned above, INDC discussed the matter already at its meeting in 1969 and recommended to the IAEA to sponsor a "Symposium on the Collection, Compilation, Indexing, Evaluation and Distribution of Nuclear (Including Neutron) Data" not later than 1973. At that time IAEA felt that before holding such a symposium, the status of the field of nuclear structure and reaction data should first be reviewed by convening a small Consultants Meeting.

This was done in November 1970 in Vienna, and experts from the USA, France, the Netherlands and from the Central Bureau for Nuclear Measurements, Geel/Belgium, took part in the meeting.

In summary, the status reports presented at the meeting demonstrated a severe shortage of manpower, funding and coordination in the existing dispersed activities which has contributed to a delay of data coverage of the order of five years. The principal recommendation of this consultants group was for the IAEA to take the necessary initiative steps to form an International Working Group on the Compilation, Evaluation and Dissemination of Nuclear Structure and Reaction Data (IWGNSRD). The general objectives of this group were suggested to be as follows [16]:

- to establish guidelines for the compilation, evaluation and dissemination of nuclear structure and reaction data,
- to review comprehensively the status of, and needs for, nuclear structure and reaction data and to establish guidelines for international coordination of compilation and evaluation work and to investigate means for providing dissemination of data that will adequately serve the users.

Unfortunately the meeting could be called only with fairly short notice and it was difficult for the USSR to send a representative to this meeting. Every effort was made, however, to take into account views of Soviet scientists as far as they were known to the participants. Reference was made particularly to a report by Dr. Selinov from the USSR Academy of Sciences in Moscow on "Development of Scientific Information Centres on Nuclear Data" which had been read at the CODATA Conference in St. Andrews, Scotland, in 1969. His detailed analysis of the difficulties in the nuclear structure data field was very valuable to the consultants meeting. In view of the influence which Dr. Selinov's analysis had on the formulation of the detailed guidelines for the recommended working group we quote here a few of the deficiencies and needs which he pointed out:

- deficiencies in terminology and data classification,
- frequent misprints and omissions in nuclear data manuals,
- lack of completeness in the documentation of most compilations and evaluations of nuclear data,

- need for concise and complete reference handbooks,
- need for more frequent up-dating of compilations and evaluations of nuclear data.

IAEA and INDC endorsed the proposal of the consultants meeting. Invitations to participate in the working group were sent out by IAEA to 15 Member States and four international organizations, and the first meeting of the working group will be convened at IAEA Headquarters in Vienna from 13 to 17 March 1972.

II.2. International working group on nuclear structure data

It is foreseen that, in a plenary session in the beginning of this meeting, the existing compilation and evaluation activities will be reviewed. The objective of this discussion would be to outline in detail the fields of nuclear data to be covered by the working group and to comprehensively review the actual data needs and priorities for various nuclear applications some of which were mentioned already in the previous section.

The discussions would then proceed in three subgroups with the subjects: compilation, evaluation and dissemination and application. Starting from the present status of compilation and evaluation activities, the material presented and views expressed during the first plenary session the subgroups would venture to discuss and formulate recommendations. These recommendations should be concerned with the prerequisites for international coordination and exchange of data information with a very strong emphasis on the clear definition of needs and their priorities.

For the compilation subgroup the following tasks are proposed. First on the basis of the data needs and priorities a common scope of experimental data to be compiled and exchanged on an international level will have to be defined. For this purpose an agreement on common terminology and data classification must be developed. This would be a prerequisite for the development of a common computer format (in analogy with EXFOR) for experimental data and for information on important experimental characteristics insofar as this is deemed useful.

Finally it might be useful, in order to improve the international information exchange, to consider the development of international reference handbooks such as CINDA for nuclear structure and reaction data. This would be done on the basis of existing reference indices combined with a review of requirements of existing and potential users.

Also in the field of nuclear structure and reaction data evaluation scientists are faced with an enormous increase in the volume of data to be critically compared and evaluated. As a consequence, one of the first tasks of the evaluation subgroup will be to determine, on the basis of the data needs and priorities for applications in science and technology, the scope and the depth of evaluation tasks. The subgroup will examine the present objectives and subdivision of work among the evaluation groups and discuss feasible measures to develop further the coordination of the more urgent evaluation tasks on an international level. The success of such collaboration will depend first upon a well functioning international system of compilation and exchange of experimental references and data, which makes the important experimental information rapidly available to the evaluation groups. Secondly, in order to achieve consistency between the results of different evaluations, it will be necessary to compare the various evaluation practices and procedures in use with a view to derive and agree upon certain common ground rules of evaluation. Here the determination of accuracies and confidence levels and the treatment of systematic errors in the experimental data will obviously present particularly severe problems. Thirdly, for the comparison and evaluation of different experimental works it would be valuable if an agreement on an "author guide" could be achieved which specifies minimum information standards to be required of scientific publications. The experiences in the past with such a guide in the fields of thermochemistry and thermodynamics [17] have been rather positive. This guide has also been addressed to the editors and referees of the scientific journals concerned, and they have been asked to impress upon the authors the importance of adhering to the recommendations contained in the guide. Certaintly INDC as well as IUPAP and other relevant bodies will be interested in such an author guide in the field of nuclear structure and reaction physics publications. We are sure that the cooperation also for example of the USSR Academy of Sciences will prove very fruitful. Similar considerations

apply also to published documentations of evaluation work.

For the third subgroup on dissemination and application it is proposed to start with a review of the merits and shortcomings of the presently used dissemination media for compiled and evaluated data such as standard reference data handbooks, special data tables and others. While the task of unifying notation, symbols and terminology rests particularly with the subgroup on compilation, the subgroup on dissemination will be concerned with problems such as rapid obsolescence, misprints and omissions in nuclear data manuals and other deficiencies as for example pointed out by Dr. Selinov (section II.1).

Of vital importance to data compilation and evaluation groups is the feedback from the data users. The detailed definition of the needs for nuclear structure and reaction data requires that contacts with the user communities be improved or established in order to guarantee user-oriented services by the data centres. One useful tool for such feedback would be suitably sorted request lists. Those lists would contain detailed information on data, their accuracy and priority, as specified by the user communities. RENDA [12] as well as the nuclear data request lists under development for nuclear material safeguards and thermonuclear fusion might be useful examples. It is important to understand that the matter of close contact with user communities and the subsequent establishment of data needs and their priorities for nuclear applications must be regarded as the most essential task of the working group at its first meeting.

Finally it is proposed to discuss the feasibility of an international newsletter on compilation, evaluation and dissemination of nuclear data. By such a newsletter nuclear data centres and groups could periodically inform each other and interested individuals in the scientific and technical community about work finished, published, underway and planned.

All the tasks for the subgroups of the working group meeting which have been summarized here are, so far, draft proposals. They were developed by NDS on the basis of requests for international coordination which were directed to IAEA in the past (section II), on the basis of the findings and recommendations of the November 1970 consultants meeting

(section II.1) as well as the recommendations of the last meetings of INDC and on the basis of the many comments which were made to the report of the consultants meeting. The proposed programme will be presented to the meeting for adoption. Considering the limited time available for the meeting, the great variety of participants and the massive size of the proposed programme, it is clear that most of the subjects can not be discussed to sufficient detail at this first meeting. It is therefore necessary that the work on those subjects be continued afterwards by individuals and groups to be designated and provided with definite tasks by the meeting. The results and recommendations as formulated by each one of the subgroups will be submitted to the plenary for discussion and adoption and will be widely distributed by the IAEA.

If this first meeting turns out to fulfill a vital function, a second meeting of the working group will be envisaged close to the date of the IAEA Symposium on the Collection, Compilation, Indexing, Evaluation and Dissemination of Nuclear Data for Application in Science and Technology (in the following, for the sake of brevity, referred to as Nuclear Data Symposium) scheduled for March 1973. Depending on further need, further meetings of the working group may be foreseen in annual intervals.

Whereas the working group can only convene a restricted number of experts, this symposium could fulfill the important function of bringing for the first time together the various nuclear data compilation and evaluation groups from all over the world for exchange of experiences and ideas. It will give each of these groups the opportunity to describe its programmes, objectives, services and achievements to the other groups present, and it might help to bridge the gap between neutron and non-neutron data compilation and evaluation groups.

Conclusions.

This report gives an outline of the problems and achievements in the international cooperation in the field of neutron data. It also describes some actions and plans, which the IAEA, in response to various requests from the outside and with very moderate funds, is currently undertaking towards

developing possible measures for international coordination of compilation and evaluation work in the field of nuclear structure and reaction data. The international cooperation on neutron data became organized and rather successful almost solely under the constant pressure of data needs for the development of nuclear reactors. It must be emphasized that the vital function and role of a body like the working group on nuclear structure and reaction data as being convened by the IAEA will basically depend upon the definite existence and clear determination of important data needs for nuclear applications.

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