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SERVING BASIC NEEDS OF SCIENCE AND TECHNOLOGY

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Nuclear data: Serving basic needs of science and technology

An overview of the IAEA's international nuclear data centre

by Alex Lorenz and Joseph J. Schmidt

In today's world, the transfer and spread of information implies the systematic collection, classification, storage, retrieval, and dissemination of knowledge with the essential use of computers.

To be able to take best advantage of information technology that has been developing over the last decades, scientific knowledge has to be reduced to concentrated factual statements or data. Today, the volume of information published prevents anyone from being fully informed in his or her own field, not to speak of keeping up with developments in other fields. Consequently, it has become necessary to supplement conventionally published information (such as books, journals, and reports) kept in libraries with condensed information, amenable to computer processing and presented to users in easily accessible and conveniently utilized form.

Condensed information takes a variety of forms:

- Bibliographic abstract collections, such as the International Nuclear Information Service (INIS)
- Bulletins and newsletters of extracted information
- Indexes to specific information, such as CINDA (an index to the literature on microscopic neutron data)
- Collections of factual information in numerical form.

Demands for more data

Most important for scientists and engineers by far are numerical data that form the basic input data for all problems solved by computation. In the field of nuclear technology, the last 30 years have seen a growing demand for an organized and easily accessible body of numerical nuclear information. Trends in nuclear power technology — such as the current development of more efficient and safe nuclear fission reactors, the long-term planning of nuclear fusion reactors, and the increased use of nuclear methods and techniques in practically all fields of science and technology — continuously demand more and better numerical information, commonly referred to as nuclear data.

During the last 5 to 10 years, more and more developing countries are requiring nuclear data, and the number and sophistication of requests for information have increased considerably. As of now, scientists in more than 70 Member States have received IAEA nuclear data services. The number of requests received annually by the IAEA Nuclear Data Section has doubled over the last 5 years. Several developing Member States in the last few years have started development of nuclear power and fuel cycle technologies. Many more have become increasingly motivated to introduce nuclear techniques entailing the use of nuclear radiations and isotopes in science and industry.

These developments have put an ever-increasing demand on the IAEA to provide a growing number of users with an extensive amount of up-to-date nuclear data, and the required computer codes for processing them. Through the service, the Agency is contributing to

Agriculture is one of many fields that need nuclear data to support research and development. Shown here are scientists at the IAEA's agricultural laboratory in Seibersdorf, Austria. (Credit: Katholitzky)

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the creation of a nuclear infrastructure in these countries.

The principal objective of the Agency's nuclear data programme is to provide needed nuclear and atomic numerical data to scientific communities in all Member States. This is accomplished through activities of three programme components:

- ***Data assessment and research co-ordination***
- ***Data processing and exchange***
- ***Data centre services and technology transfer***

To ensure the proper planning and execution of tasks, the IAEA Nuclear Data Programme is guided by the International Nuclear Data Committee, an external permanent advisory committee of the Agency composed of high-level experts appointed by the Director General. This committee reviews the programme regularly and directs its future activities on the basis of the needs and priorities of developed and developing Member States.

Nuclear data centre activities

The IAEA nuclear data centre maintains the following activities:

- As a centre of research co-ordination, it assesses the needs for nuclear data in various fields of science and technology. It does this by maintaining contact through meetings and laboratory visits with more than 200 research laboratories in 60 Member States (including 55 research laboratories in 33 developing countries) active in the measurement or processing of nuclear data. To promote the generation and improvement of needed nuclear and atomic data, it maintains several co-ordinated research programmes encompassing some 50 groups at research institutes. From these efforts, the centre is able to produce compilations of standard reference nuclear data, and to generate specialized files for important fields of technology. These include nuclear safety, nuclear materials safeguards, and nuclear fusion.

- As a centre for data compilation, validation, and exchange, it co-ordinates worldwide networks of more than 30 national and regional data centres and groups for the systematic collection, evaluation, and dissemination of nuclear and atomic data. As the most important part of this effort, all nuclear data generated in the world are compiled by four co-operating nuclear data centres. This four-centre network is between the USA, USSR, IAEA, and the Nuclear Energy Agency of the Organisation for Co-operation and Development (OECD/NEA); it operates through a common data base called EXFOR. Since 1970, these data have been systematically exchanged at a rate of about 40 magnetic tapes per year. The total volume of EXFOR data (consisting of approximately 300 megabytes of numerical data) constitutes data from 51 countries. Of the total data, 35% are from the USA, 11% from the USSR, 43% from the OECD Member States (except USA), and 11% from all other IAEA Member States, including 29 developing countries. In addition to the comprehensive EXFOR database, 80 special-purpose nuclear data libraries (containing an additional 600 megabytes of numerical and bibliographic data) are maintained at the IAEA nuclear data centre. A considerable effort is being devoted to data analysis, checking, and validation to guarantee their accuracy and reliability.

- As an international data centre, it offers extensive services primarily to developing Member States. It provides nuclear data and associated data processing computer codes and documentation. It also supports and co-ordinates the East-West and North-South transfer and exchange of nuclear data information. In 1985, the centre received 881 requests from 73 Member States (53 developing and 20 industrialized countries), including 269 for numerical nuclear data, 13 for data processing codes, and 591 for technical reports. In response to these requests, the Nuclear Data Section distributed in 1985 some 1900 documents and more than 45 000 individual data sets of nuclear data having a total volume of approximately 1600 megabytes. At the same time, extensive guidance to scientists in developing countries in the use and computer processing of these data has been given.

- As a principal international centre for the production and dissemination of nuclear data publications, it periodically publishes two major bibliographic data indexes for sale (CINDA for nuclear data and CIAMDA for atomic data) and distributes each of them to more than 1200 libraries, research groups, and individuals. Also periodically produced is the world request list WRENDA, which contains over 1000 requests for nuclear data measurements. This is distributed to some 800 research scientists and programme directors who use it as guidance for research. Annually, the centre also produces an average of 20 nuclear data reports, distributes some 40 nuclear data reports generated in Member States, and translates about 10 nuclear data reports from Russian into English; each individual report is distributed on average to about 300 to 500 scientists.

- As a centre of data technology transfer to developing Member States, it serves as a focal point for the transfer of nuclear methods and techniques. More than 20 developing and 10 industrialized countries participate in the Interregional Technical Co-operation Project on Nuclear Data Techniques and Instrumentation. Through this project, the centre provides technical assistance in the form of equipment, fellowships, expert missions, and research contracts. The aim is to train nuclear scientists and technicians in developing Member States in the use of nuclear methods and techniques. Jointly with the International Centre for Theoretical Physics at Trieste, the centre also organizes activities. These include biennial courses on nuclear data computation for nuclear technology, at which some 70 to 90 scientists from about 30 developing countries participate, and annual interregional technical co-operation training courses typically involving 20 scientists from 20 developing countries.

Trends influencing development

As illustrated in an accompanying table, nuclear data have a wide range of applications in activity areas that are continuously subject to growth and development. Consequently, new requirements for improved nuclear data or for data that currently do not exist are created. In addition, the growth of nuclear science and technology in developing countries brings with it the need for a continuing programme for the transfer of nuclear data technology to scientists in those countries. Several developments now are determining the trends in the nuclear data field:

- Improvement of data files, with a special emphasis on the accuracy and reliability of the data required
- Generation of comprehensive compilations of nuclear and atomic data, in the form of handbooks supplemented by computer-based data files for specific fields of application (nuclear safety, safeguards, nuclear fusion, nuclear geophysics, and medical radiotherapy, for instance)
- Maintenance of an intensive technical assistance and training programme for the benefit of developing countries.

Nuclear data needs in various fields

In various fields, nuclear and atomic data are a basic information component for the design, implementation, and interpretation of nuclear methods and techniques extending far beyond the primary considerations of nuclear power. (See the accompanying box for a report on nuclear data and nuclear safety). Some examples of trends in nuclear data requirements in other fields include:

- ***Radiotherapy.*** Recent developments in high-energy neutron and proton radiotherapy have created new requirements for nuclear and atomic data in energy ranges and for nuclides. To be able to understand radiobiological mechanisms in radiotherapy, accurate radiation transport calculations are performed to simulate the interaction of various high-energy radiation fields (e.g., neutrons, protons, electrons, X-rays and gamma rays) with cell tissue. Also, with the development of high-energy neutron and proton therapy, data are required for the design of the necessary shielding and beam-shaping devices and for the understanding of the effects of radiation interaction with living tissue. A series of meetings is planned by the Agency's nuclear data centre to assess the existing data for these applications and to stimulate new experimental and theoretical work to fill existing gaps.

- ***Fusion.*** The development of fusion power and its associated technology is based to a large extent on extensive calculations. These require both atomic data to describe processes in the fusion plasma and neutron nuclear data to simulate the transport of neutrons and their absorption in tritium-generating blankets and in surrounding shielding. In both areas, the data are marginally adequate to satisfy the requirements. The Agency's nuclear data centre has maintained a separate activity on atomic data directed specifically to the needs of atomic physicists and fusion plasma modellers working toward the realization of nuclear fusion. This work is in addition to activities that assess nuclear data requirements in the development of fusion reactors and establish a nuclear data file for fusion reactor calculations.

Nuclear data applications in IAEA programme areas

Nuclear power	• Physics design of fission and fusion reactors (core calculations, plasma transport) • Engineering design of fission and fusion reactors (structural integrity, radiation damage, shielding)
Nuclear fuel cycle	• Inside and outside reactor fuel management • Chemical reprocessing • Handling, treatment and disposal of waste
Nuclear safety	• Radiological safety (handling and monitoring of radiation, radiation effects, and dose calculations) • Nuclear accident assessment (nuclear safety and criticality calculations)
Safeguards	• Development of instruments, methods, and techniques (non-destructive assay and calculational methods, for example)
Physical sciences	• Nuclear physics (design and utilization of accelerators, research reactors and radiation detectors, application and analysis of nuclear techniques) • Plasma physics and controlled fusion research
Industry and chemistry	• Material analysis (nuclear techniques in mineral exploration, application of analytical techniques) • Production of radiation sources and radioisotopes for medical and pharmaceutical applications
Isotope hydrology	• Application of nuclear techniques using environmental isotopes, artificial isotope tracers, and sealed radioactive sources
Marine sciences	• Evaluation of environmental impacts of radionuclide releases in the oceans • Assessment of waste disposal in the oceans and marine pollution
Life sciences	• Medical applications (use of radioisotopes and radiations in clinical medicine, nuclear particle therapy) • Radiation dosimetry (interaction of radiation with matter) • Environmental research (activation analysis, trace analysis, effect of low-level radiation)
Food and agriculture	• Animal and plant production (use of radioisotope tracers) • Food irradiation

● *Nuclear geophysics.* This field employs techniques designed to identify the nature, and measure the composition of, minerals and fluids contained in subsurface formations by performing gamma ray spectroscopy in wells or boreholes. Exact quantitative analysis is required of the measured data, which are designed to determine concentrations of trace elements and major mineral components. This requirement places severe demands on the quality of spectroscopic measurements. Consequently, it entails demands on the accuracy of gamma-spectroscopic and nuclear-reaction data used in radiation transport calculations that simulate conditions in geological bulk materials, and in the actual analysis and interpretation of geophysical measurements. Existing evaluated nuclear data produced for applications in nuclear reactor technology do not satisfactorily meet these requirements. They are not adequate to cover the full scope of nuclides present in geological materials, or to include the type of nuclear reaction and gamma-ray production cross-sections that occur in such measurements. Currently, a significant effort is being devoted to review the status and availability of required data. In the coming years, the Agency's nuclear data centre plans to produce a comprehensive handbook and associated computer file of nuclear data for nuclear geophysics applications.

● *Safeguards.* A main objective of the Agency's nuclear materials safeguards programme is the control of the flow of fissile and fertile nuclear material. Nuclear material accountancy is based on information supplied by plant operators and the verification of this information by control checks performed by IAEA safeguards inspectors. Analytical techniques used to perform these verification checks consist of destructive (DT) and non-destructive (NDT) techniques that rely on the measurement of the energies and intensities of radiation emitted by the analysed materials. Understanding and interpreting the results of these measurements require extensive knowledge of the pertinent nuclear data to a high degree of accuracy. Nuclear data also are needed in calculations performed to support these measurements, and for the improvement and the development of new analytical techniques and instrumentation. Currently, the Agency's nuclear data centre is working with staff of the Agency's Safeguards Department to compile required data and prepare a handbook of nuclear data for safeguards applications. It is planned to complement this handbook with a data file for direct computer input.

Nuclear data and nuclear safety

Among all areas of nuclear data applications, nuclear safety is one that has had prominent international coverage during the last few years. This is probably one of the principal underlying motives for the improvement of the accuracy and reliability of nuclear data.

Nuclear safety covers diverse issues. These range from inherent reactor safety (including nuclear radiation damage to reactor structural materials, the build-up of actinides and fission products, and criticality safety) to environmental protection against nuclear radiations emanating from reactors and the transport and processing of spent nuclear fuel and waste material.

The quantitative assessment of these issues, and the calculation of tolerance doses for radiation exposure to man, presupposes a detailed knowledge of properties of emitted nuclear radiations and of nuclear processes from which these radiations originate. The accuracy and reliability of these data are of utmost importance: They have a direct bearing on the accuracy and reliability of nuclear safety calculations.

An example of such considerations is the requirement for nuclear and atomic data for determining radiation damage to structural materials used in fission and fusion reactors. Damage to component materials due to neutron or charged particle radiation has a direct bearing on the safety, economy, and design of nuclear reactors. (Radiation damage to materials arises after a prolonged exposure of reactor components to high radiation fields, encountered within the confines of nuclear reactors.) To understand damage-producing mechanisms, it is necessary to correlate the type and extent of damage with the nature and intensity of the radiation environment. The information needed to interpret and understand this correlation consists of nuclear as well as atomic data. As of now, the database to fully understand and predict all aspects of radiation damage still does not exist.

One type of nuclear data required is represented by neutron cross-sections that quantify the interaction of fast neutrons with reactor structural materials used in fission and fusion reactors. This data is required for the assessment of nuclear safety and radiation damage as well as for neutron economy and shielding calculations. For the component nuclides of structural materials (namely, iron, nickel, and chromium — the three main constituents of stainless steel), neutron reaction data used in fission and fusion neutronics calculations are quite old and generally no longer reflect the present state of knowledge. In recent years a considerable amount of neutron-induced reaction data for structural materials has been measured. Significant improvements in nuclear models and computer codes, which predict and interpret fast neutron-nucleus reactions, have been made. International efforts are currently being co-ordinated by the Agency's nuclear data centre to improve existing evaluated nuclear data, taking into account more recent experimental data and nuclear model descriptions.

Another issue of significance to nuclear safety is the build-up of actinide and fission product radionuclides during reactor operation. Both result from the processes of neutron capture and fission in nuclear reactor fuel. Both also figure prominently in the consideration of nuclear reactor safety, the nuclear fuel cycle, spent fuel management, and nuclear materials safeguards. For the actinides, continuous review and international standardization is required to guarantee the accuracy and availability of a wide variety of nuclear data. (These include the neutron-induced fission and capture cross-sections, the resonance parameters, the average number of prompt neutrons released per fission, and the nuclear decay properties for a number of transuranium nuclides produced in irradiated fuel.)

Recently, the Agency has published a compilation of decay data of the transactinium nuclides, which represents the culmination of a 7-year effort involving the participation of major laboratories. For the fission products, both fission yields and half-lives are often still not known to the degree of accuracy required, and a similar effort to update this database is envisioned. In the coming years, the Agency's nuclear data centre plans to convene several meetings and co-ordinate research to close gaps and improve the accuracy of the required data.