Nuclear data for science & technology: Centres for development

An update on the IAEA's nuclear data centre, its services, and the contributions to the global network from developing countries

by
Hans Lemmel

A typical example of a modern nuclear physics application is the mineral analysis of geological samples by neutron activation. The sample to be investigated is exposed to a neutron radiation, and the resulting gamma-ray spectrum is analyzed with respect to the intensities and energies of the gamma lines to determine the nuclear composition of the sample and its mineral content. This method, which is used in industrialized countries and increasingly in developing ones as well, requires comprehensive files of nuclear data: the neutron activation cross-sections for the elements occurring in the sample, nuclear half-lives, and the radioactive decay data of the activated nuclides under investigation.

Radiotherapy is another example illustrating the importance of nuclear data applications. Under certain conditions cancer may be treated with nuclear radiations of various types: heavy ions, ionizing charged particles, electrons, photons, or neutrons. To select the most suitable radiation, and to estimate the impact on the tumor and the undesirable effects on the surrounding healthy tissue, computer calculations depend upon a variety of databases, including ionization and scattering cross-sections.

Such data files are available to scientists in all IAEA Member States through the Agency's nuclear data services. Required data files can be obtained on a magnetic tape or on computer diskettes, together with documentation on the format and origin of the data. More recently, the world's major data libraries have also become accessible on-line through NDIS, the Nuclear Data Information System, via the Internet or World Wide Web. Also available are a number of nuclear data handbooks which continue to be convenient to many users, in parallel to the fast development of electronic services.

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The IAEA Nuclear Data Section operates a centre which maintains the world's most comprehensive collection of nuclear and atomic data libraries that are needed for nuclear and radiation technologies in Member States. This article reviews these services, and the particular role of developing countries in this global data network.

Energy and non-energy applications

While nuclear data are now increasingly needed for all types of nuclear technologies, the primary needs for such comprehensive data files came, originally, from nuclear power research and development, which depends upon a large variety of nuclear data. *(See box, next page.)* A large fraction of these data are also needed for non-energy applications. The basic data libraries are, therefore, "general purpose" libraries and not meant for specific applications. *(See box, page 36.)* These data libraries are rather voluminous; each of them has a typical size in the order of 100 megabytes. They are presented in internationally agreed formats for which a variety of data processing computer codes is available.

In addition, a large number of "special purpose" nuclear data libraries have been established for specific applications. They include those specializing in standard reference data for the standardization of nuclear measurements, for detector calibration and neutron dosimetry, and many others. These data libraries use different formats and are smaller in size so that they are most suitable for use on personal computers. There are also nuclear data handbooks, which contain not only tabulations and curves of nuclear data but also detailed instructions on measurement techniques for specific applications. *(See box, page 36.)*

Apart from nuclear power applications, nuclear data files are used for university education;

nuclear physics research; national centres or institutes; research and development; material analysis by neutron activation; industrial processes; dosimetry, detector calibration; production of medical radioisotopes; and applications in radiotherapy.

Nuclear data measurements

Whereas the first nuclear power reactors started with a rather crude knowledge of nuclear data, it soon became evident that their efficiency, economy, and safety require not only detailed and accurate knowledge of all relevant nuclear data but also a careful analysis of the data uncertainties and of their consequences. More accurate nuclear data, permitting predictions of reactor behaviour in unusual operating conditions, increase reactor safety. They also increase the economic operation, providing, for example, more accurate radiation damage cross-sections that enable more reliable prediction of the lifetime of a reactor vessel. Hence, even a small increase in nuclear data accuracy in nuclear metrology can translate into many millions of dollars of savings in power reactor operations worldwide.

Consequently, a comprehensive nuclear data measurement programme was carried out, primarily in the United States, Western Europe, the former Soviet Union, and Japan, starting in the 1950s and culminating in the 1970s and early 1980s. It still continues, though on a lower level. The programme also included various measurements contributed by the more advanced developing countries.

Evaluation of nuclear data

The first nuclear data measurements had rather large uncertainties, and different measurements of the same quantity often showed discrepancies. Considerable efforts were invested to change this picture. They included the development of new methods, measurement facilities, radiation detectors, electronic analyzers, and the preparation of isotopic pure samples until the nuclear data could be determined with the high precision that is required to make accurate nuclear technologies possible.

A new science evolved: the evaluation of nuclear data. Evaluators start from the available experimental data, supplement them with theoretical estimates for energy regions and data types that have not been covered by experiments, and bring the resulting recommended data into file formats required for computer codes in specific applications.

Examples of nuclear data categories

Nuclear Structure and Decay Data

- Isotopic masses; nuclear levels and their properties
- Half-lives of radionuclides and isomers
- Energies and intensities of gamma-rays and emitted particles

Nuclear Reaction Data

- Cross-sections for nuclear reactions induced by neutrons, photons, protons, and other charged particles including heavy ions
- Reactions leading to activation, radiation damage, radioisotope production, fission, spallation, transmutation, etc.
- Yields and energies of gamma-rays and secondary particles
- Nuclear fission: yields of fission-neutrons and fission products, related energy release, etc.

Atomic Data

- Electron interactions
- Fusion plasma interactions
- Atomic processes in medical irradiations

The nuclear data libraries that resulted from these efforts represent an enormous benefit, and the free exchange of nuclear data files among industrialized and developing countries reflects a significant degree of successful technology transfer.

Contributions from developing countries

What role have developing countries played in the development of nuclear data? In the period 1970-90, about 44,000 measurements of neutron reaction data have been performed worldwide, of which 4000 (or 9%) were done in 32 developing countries. To improve the transfer of technology in this field, which can strengthen the capability of developing countries to utilize nuclear techniques in many applications, the IAEA implemented an interregional technical co-operation project on nuclear data techniques and instrumentation in the 1980s. Subsequently, developing countries participated in the Agency's Co-ordinated Research Programme for establishing or improving nuclear databases for specific applications. These included 14-MeV neutron activation cross-sections, nuclear data for medical applications, actinide nuclear data in fission reactors, and nuclear and atomic data for fusion reactor design.

Nuclear data libraries

(acronym, orginator, contents)

Major comprehensive libraries

- EXPOR; International Nuclear Data Centres Network; contains experimental nuclear reaction data
- ENSDF; United States and International Network; contains nuclear structure data and radiation data of radionuclides
- *Libraries containing evaluated nuclear reaction data in uniform "ENDF" format:* ENDF/B-6, United States; JEF-2, Nuclear Energy Agency of the OECD; JENDL-3.2, Japan; BROND-2, Russian Federation; CENDL-2, China
- FENDL; IAEA and International Network; contains nuclear data for fusion reactor design, and for other applications as well

Special purpose libraries

- N.D. Standards; IAEA International Nuclear Data Committee; standards for nuclear measurements
- XG Standards; IAEA Co-ordinated Research Programme; calibration of detectors for gamma rays and X-rays
- IRDF; IAEA in co-operation with other centres; international reactor dosimetry file, neutron dosimetry by foil activation
- IDGAM; Japan-Brazil; identification of radionuclides by their gamma rays
- ALADDIN; IAEA and Data Centres Network; atomic and molecular collision data for nuclear fusion applications
- SGNucDat; IAEA Nuclear Data Section; nuclear data for safeguards
- GANAAS; IAEA Physics Section; neutron activation analysis
- CENPL; China; various evaluated nuclear parameters
- MENDL-2; Russian Federation; nuclear transmutation

Network of nuclear data centres

- National Nuclear Data Center, Brookhaven, United States; services to United States and Canada
- Nuclear Energy Agency (NEA) Data Bank, Organization for Economic Co-operation and Development (OECD), Paris, France; services to European OECD countries and Japan
- IAEA Nuclear Data Section, Vienna, Austria; services primarily to developing countries and co-ordination of the global network
- Russian Nuclear Data Centers, Obninsk and Moscow, Russia; services to States emerging from the former USSR

In addition to these core centres, the Network includes national nuclear data centres in Japan, China, and Hungary. Other countries co-operate without formal participation in the Network.

Nuclear data handbooks

Atomic and Molecular Data for Radiotherapy and Radiation Research (IAEA TECDOC-799, issued 1995)

The Index to the Literature and Computer Files on Microscopic Neutron Data (CINDA, published annually)

International Bulletin on Atomic and Molecular Data for Fusion (IBAMD-49, published twice per year)

Handbook on Nuclear Activation Data (IAEA Technical Reports Series No. 273, issued in 1987 and reprinted in 1995)

Decay Data of the Transactinium Nuclides (IAEA Technical Reports Series No. 261, issued in 1986 and reprinted in 1995)

X-ray and Gamma Ray Standards for Detector Calibration (IAEA TECDOC-619, issued in 1991 and reprinted in 1994)

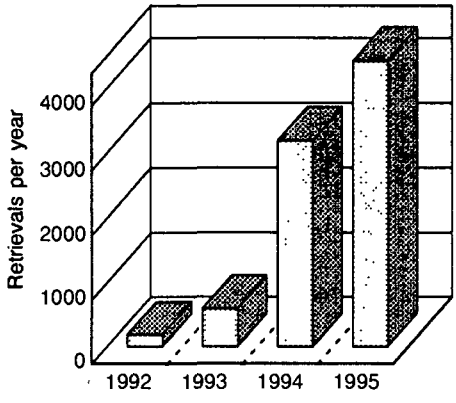
Handbook on Nuclear Data for Borehole Logging and Mineral Analysis (IAEA Technical Reports Series No. 357, issued 1993)

The present situation is not uniform. A number of developing countries — for example, Argentina, Bangladesh, Brazil, Egypt, Israel, Morocco, Pakistan, Thailand, Turkey, Viet Nam, and many Eastern European countries, among others — had and continue to have nuclear data measurement programmes. Some countries — for example, Algeria, Malaysia, Mexico, Myanmar, Saudi Arabia, and various others — reported occasional nuclear data measurements. India, after a very strong nuclear data programme in the 1970s, has reduced these activities noticeably, whereas China started around 1980 with a strong nuclear data programme, and continues to give it strong support.

An interesting example is the Republic of Korea: Although the country has a nuclear power programme, there were, in the past, almost no nuclear data measurements performed there. However, in recent years it was realized that an adequate nuclear physics infrastructure, including data measurements, is a necessity for a country with strong nuclear applications in energy and industry. Consequently, a strong increase in

The Nuclear Data Information System (NDIS)

Development of nuclear data on-line services, presently used by 41 countries



Nuclear data services in 1990-95, by geographical region

	Services by mail		On-line services	
Region	Number of countries	% of request	Number of countries	% of requests
OECD countries	22	24%	17	36%
Former USSR	6	7%	2	17%
Eastern Europe	9	18%	8	40%
Asia, Australia	15	24%	6	1%
Africa and Near East	26	13%	2	3%
Latin America	15	14%	6	3%
	93	**100%**	**41**	**100%**

nuclear data activities there is expected in the near future.

For nuclear power applications, a special effort is needed to process nuclear data libraries into special formats ("multigroup data") required for computer codes. Among the developing countries, it is primarily Algeria, India, Indonesia, the Republic of Korea, and Slovenia which are involved in such activities that are co-ordinated by the IAEA and supported by training courses.

Another co-operative project concerns the maintenance of the international database for nuclear structure and decay data. China, Kuwait, and Russia have joined seven countries of the Organization for Economic Co-operation and Development (OECD) in the project, which is guided by the IAEA and the US National Nuclear Data Centre.

Nuclear data needs in industrialized countries

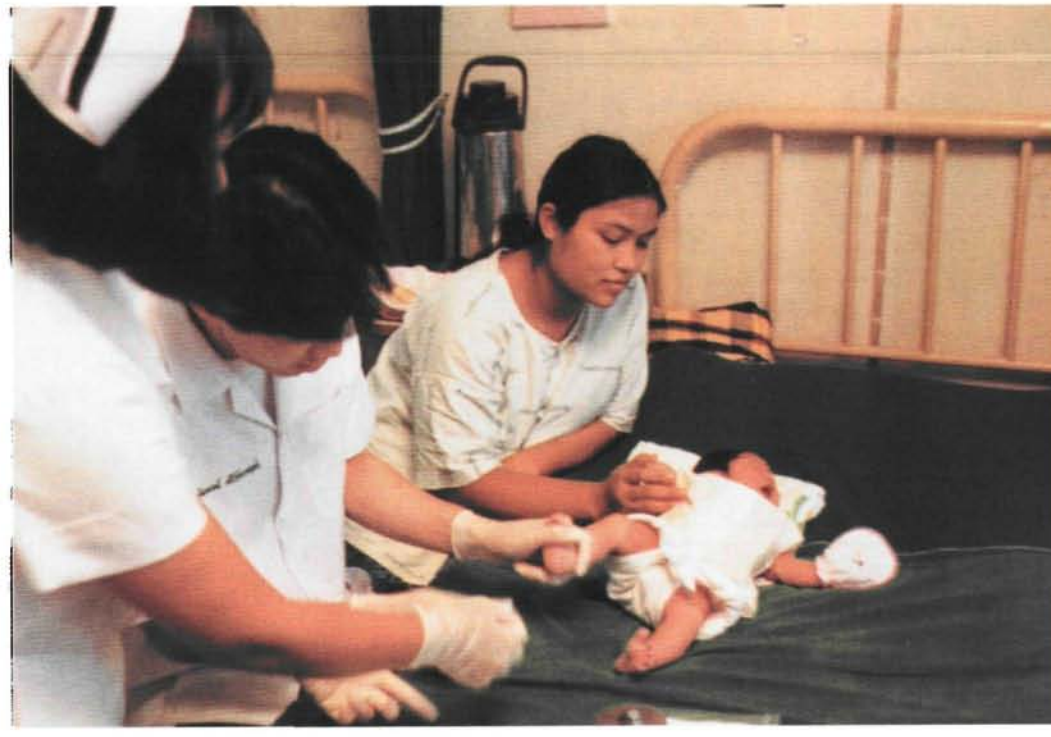
In the field of nuclear data, industrialized countries are presently in a transition phase. Having solved the main nuclear data needs for thermal and fast power reactors, many of the measurement facilities have been closed down. At the same time, many experienced nuclear physicists have retired. Suddenly it was realized that there may be a shortage of young nuclear physicists, and the continuing use of nuclear energy may be endangered unless the know-how of nuclear data measurement techniques is preserved. This concern has been expressed in several expert studies in France, the United States, Japan, Russia, and at the OECD Nuclear Energy Agency (NEA). Furthermore, a group of leading experts convened by the IAEA in 1995 concluded that the Agency's nuclear data programme is of continuing relevance and high priority to all Member States.

At present, the activities of industrialized countries concentrate on nuclear data needs for fusion reactor development and on higher energy nuclear data required to study the transmutation of unwanted actinides produced in power reactors. This research requires expensive facilities that are not available in developing countries.

Besides this advanced nuclear data research, the work to improve nuclear data for fission power reactors continues. Under the auspices of the International Nuclear Data Committee, the data centres compiled a list of nuclear data for which an increased accuracy is required for specific applications in power reactors and nuclear material safeguards. This list includes 290 top priority requests and 430 requests with lower priority. It is intended to serve as a guide to scientists and administrators when planning nuclear research programmes. A similar "high-priority list" for requests about nuclear data measurements was recently established by the NEA. Within the network of Nuclear Data Centres, the NEA plays a leading role in nuclear data evaluation co-operative efforts.

International co-ordination

Already in the 1950s, nuclear data measurements became so numerous that a national Nuclear Data Centre was formed in the United States at the Brookhaven National Laboratory.



Nuclear data are required in a range of fields including health care.
(Credit: H.F. Meyer/IAEA)

In 1964 three more centres were founded at the NEA, the IAEA, and in Obninsk, Russia. These four centres are the core of the Nuclear Data Centres Network co-ordinated by the IAEA. *(See box, page 36.)* They provide the essential link between the producers and the users of nuclear data. The task of collecting the large amounts of data, to compile and evaluate them, and to make them available in formats needed by the users, can be done only by a well co-ordinated international effort. This approach avoids duplication, and maximizes the use of specialized experts in the co-operating centres and countries.

The achievements of this network have been impressive. By a systematic exchange between the centres, a scientist in any Member State has access to all nuclear data information, regardless in which country the data have been generated. Furthermore, the data (at least the main categories of nuclear data) are presented in worldwide uniform formats so that the same set of data processing computer codes can be applied when using evaluated data libraries coming from the United States, Europe, Russia, China, or Japan.

Within the data network, the IAEA Nuclear Data Section concentrates on services to developing countries, whereas the services to industrialized countries are primarily through their national data centres or the NEA Data Bank. In addition to databases received from the co-operating centres for free distribution to all Member States, the products of the IAEA's Nuclear Data Centre result primarily from Co-ordinated Research Programmes and informal co-operative mechanisms. The priorities of the IAEA programme on nuclear and atomic data for applications are determined by the International Nuclear Data Committee, a standing advisory body with members from Brazil, China, Hungary, India, Russia, and eight OECD countries.

Requests for services

Over the past years, the Agency's Nuclear Data Centre has received about 800 requests per year from scientists in 93 Member States. Annually, about 300 data files on magnetic tapes and diskettes, 100 related data processing computer codes, and 2000 copies of printed materials have been shipped. In addition to these conventional request services, more than 4000 electronic retrievals were made in 1995 through the on-line Nuclear Data Information System via the Internet. *(See graph and table, previous page.)*

In the future, it is expected that the demand for on-line services will grow fast, and significant efforts will be made by the IAEA Nuclear Data Section to further widen and improve the services. The number of requests demonstrate that the on-line services are presently used primarily by scientists in European countries. Such electronic access to nuclear data will supplement conventional mail shipments, which for most developing countries remain, for the time being, the main avenue for receiving the information they need in support of their development in nuclear science and technology. ❐