Nuclear Science

Objective

To increase Member State capabilities in the development and application of nuclear science as a tool for their technological and economic development.

Atomic and Nuclear Data

The Agency maintains a wide range of databases of nuclear, atomic and molecular data that are available to Member States, primarily through on-line services. During 2010, there were approximately 150 000 retrievals, an increase of about 15% over the previous year. In addition, more than 7000 reports, manuals and technical documents were downloaded.

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An important related activity is to provide on-line tools to aid searches and enhance the visual display and ease of use of databases. The Experimental Nuclear Reaction Data (EXFOR) collection of experimental reaction measurements, for example, covers measurements from 1935 to the present day and contains data from almost 19 000 experiments (approximately 11 500 000 data points). An on-line tool which enables a user to upload and compare data against other data in EXFOR and to include uncertainties/variables in calculations was developed for use by partners and mirror sites.

The Evaluated Nuclear Structure Data File (ENSDF) graphical interface and retrieval tool, released in 2009, was significantly extended to show diagrams of energy levels and a wider range of properties, such as magnetic dipole moments and nuclear radii (Fig. 1). This tool can be accessed at *http://www-nds.iaea.org/livechart/*.

The creation of the Agency's Reference Input Parameter Library (RIPL) has made the collection

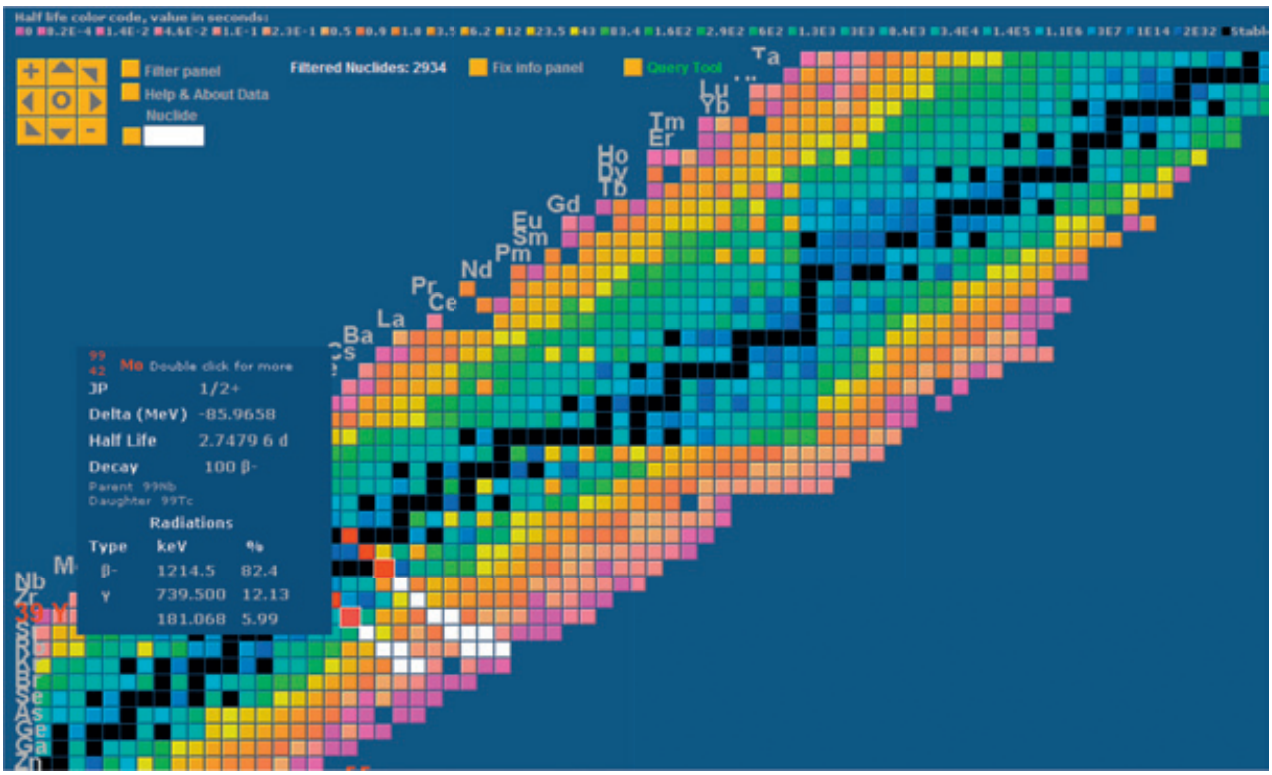

FIG. 1. The ENSDF LiveChart of Nuclides, an on-line interactive tool which enables users to easily select a nuclide, in this case molybdenum-99, and display basic properties. More detail on the nuclide is available by double clicking on the nuclide square.

FIG. 2. Hall of small angle neutron scattering beam lines of CARR (source: CIAE).

of parameters required as input to model codes for theoretical calculations less difficult and time consuming. A wide range of data is now interactively available on-line (*http://www-nds.iaea.org/RIPL-3/*), greatly simplifying the work of theoreticians.

In supporting fusion technology, the Agency continued its coordination of the development of the XML Schema for Atoms, Molecules and Solids (XSAMS) standard for the exchange of atomic, molecular and plasma–material interaction data. Another activity in 2010 included the development of a new knowledge base for atomic, molecular and plasma–material interaction data for fusion (*http://www-amdis.iaea.org/w*).

A CRP was initiated in 2010 to generate data for spectroscopic and collisional properties of tungsten as an impurity in fusion plasma. Tungsten is foreseen as the main wall material for a fusion power plant.

The Agency organized three training workshops in 2010 in cooperation with the Abdus Salam ICTP entitled 'Nuclear Reaction Data for Advanced Reactor Technologies', 'Nuclear Structure and Decay Data: Theory and Evaluation' and 'Nuclear Science and Technology: Analytical Applications'. A workshop to train new EXFOR compilers was also organized in Vienna. In all, about 90 participants were trained at these events.

Research Reactors

Improving Utilization

Collaborative efforts between Member States (both with and without research reactors) were further enhanced in 2010 with the creation in September of the Mediterranean Research Reactor Network (MRRN) and the initiation of a research reactor network in the Asia–Pacific region under AONSA (Asia–Oceania Neutron Scattering Association). In addition, the Australian Nuclear Science and Technology Organisation, with its state of the art neutron beam facilities at the OPAL research reactor, was redesignated as an IAEA Collaborating Centre (IAEA-CC) for Neutron Scattering Applications. The Agency contributed equipment, staff training and expertise for one of the neutron scattering beam lines of the China Advanced Research Reactor (CARR) (Fig. 2) that attained first criticality on 13 May 2010.

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A technical meeting on the 'Assessment of Core Structural Materials and Surveillance Programme of Research Reactors' helped establish an information exchange platform for implementation of surveillance programmes to predict age related degradation mechanisms that may cause unplanned research reactor outages.

An improved version of the IAEA Research Reactor Database (RRDB) featuring updated information for 115 of the 237 facilities in operation was released through the NUCLEUS web portal (*http://nucleus.iaea.org/RRDB/*).

Addressing the Shortage of Molybdenum-99 Supplies

Interruptions in the production of molybdenum-99 (Mo-99) resulted in worldwide delays to patient care from August 2008 until September 2010. This was particularly the case in the last six months of that period, when the facilities of the two largest producers were shut down. As part of ongoing efforts to counteract the shortage of Mo-99 supplies from research reactors using HEU, the Agency organized a meeting in August to assess opportunities for international collaboration to support the transition to Mo-99 production based on LEU. The meeting focused on the specific challenges confronting major HEU based producers and identified opportunities for potential multilateral cooperation on high density LEU target development, front end adaptive processing and back end waste management. Furthermore, the meeting proposed the formation of an international expert group, under Agency auspices, to coordinate further actions.

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The Agency also began a comparative assessment of non-HEU technologies for Mo-99 production, due for completion in 2011, which will supplement the OECD/NEA High-level Group's report on economic comparison, one of two OECD/NEA reports on this topic to which the Agency has contributed. And under an ongoing CRP related to the production of Mo-99 using LEU targets, a workshop was held in November in Santiago, Chile, where participants shared experience and quality assurance aspects of waste management in the LEU production of Mo-99.

Research Reactors in Education and Training

The Agency assisted the Jordan University of Science and Technology (JUST) and North Carolina State University (NCSU) in the USA in implementing the first international 'remote reactor' programme, funded through an extrabudgetary contribution from the USA. Signals from NCSU's PULSTAR research reactor are sent to JUST and the displays at PULSTAR are replicated in the classroom in Jordan. Video conferencing permits real time interaction with instructors in the USA.

In 2010, a second Research Reactor Group Fellowship Training Course to assist Member States interested in initiating research reactor projects was organized by the Eastern European Research Reactor Initiative (EERRI), supported by the Agency. The six week course included theoretical classes, technical visits and hands-on experiments.

Research Reactor Fuel

The Agency published *Corrosion of Research Reactor Aluminium Clad Spent Fuel in Water* (IAEA-TECDOC-1637), which presents work performed as part of both a CRP and a technical cooperation regional project on 'Management of Spent Fuel from Research Reactors' in Latin America. The publication is also intended to support the efforts of research reactor operators to improve practices used for interim wet storage of spent fuel.

The Agency also published *Cost Aspects of the Research Reactor Fuel Cycle* (IAEA Nuclear Energy Series No. NG-T-4.3). This report provides methodologies for the economic analysis of research reactor operations as well as related case studies.

Support continued to Member States and international programmes to return research reactor fuel to its country of origin. As part of the Russian Research Reactor Fuel Return (RRRFR) programme, five shipments amounting to approximately 109 kg of fresh HEU fuel were repatriated from Belarus, the Czech Republic and Ukraine under contracts arranged by the Agency. The Agency also assisted in the repatriation of around 376 kg of spent HEU fuel from Belarus, Poland, Ukraine and Serbia (13.2 kg from Vinča, Serbia, as reported below).

A technical cooperation project to repatriate spent fuel from the Vinča Institute in Serbia to the Russian Federation was successfully completed in 2010. The return of 2.5 tonnes of spent fuel, including approximately 13 kg of HEU, to the Russian

FIG. 3. Aerial view of the Elettra facility, Trieste, Italy.

Federation signified the elimination of all HEU from Serbia.

Accelerators for Materials Science and Analytical Applications

In cooperation with the Abdus Salam ICTP, the Agency organized several workshops and training courses in 2010. One course, in particular, focused on 'Synchrotron and Free-Electron-Laser Sources and their Multidisciplinary Applications', which was hosted by Elettra, an IAEA Collaborating Centre (Fig. 3).

In addition, a series of technical meetings on a broad range of accelerator related subjects was held to support Member States in the areas of capacity building, knowledge transfer and networking.

A CRP that ended in 2010 facilitated the creation of a broad network of low–medium energy facilities which will assist users in neutron based research where new techniques require access to spallation neutron sources with a neutron intensity enhanced by two further orders of magnitude. In addition, the network will provide a source of information on new techniques and training opportunities for users and operators of small neutron facilities. It will also give major neutron facilities access to smaller facilities to test new techniques and designs.

A technical meeting on the 'Role of Nuclear based Techniques in Development and Characterization of Materials for Hydrogen Storage and Fuel Cells' was held in August in Quebec, Canada. Such techniques are expected to play a role in global energy security in the future.

Nuclear Instrumentation and Spectrometry

The development of X ray fluorescence (XRF) techniques for the analysis of materials remained a major focus of the Agency's Laboratories, Seibersdorf.

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A number of methodological improvements in the energy dispersive XRF technique were made, including optimization of the method for determining major, minor and trace elements in soil samples. A principal component analysis was applied for the interpretation of a large set of XRF data in support of soil erosion studies. For the characterization of the depth profile of thin film solar cells, synchrotron radiation based XRF techniques were developed in cooperation with a facility in Germany. Computer based modules for learning and teaching in the field of total reflection XRF were developed, and quality management tools were revised and upgraded

FIG. 4. Laboratory based teaching at the Agency's Laboratories, Seibersdorf.

to comply with the latest developments in ISO guidelines.

Under technical cooperation projects, 60 scientists attended training courses and workshops on the application of XRF techniques for cultural heritage and environmental pollution monitoring. Another 250 were trained, through 11 regional and 9 national training courses at Member State laboratories and at the Agency's Laboratories, Seibersdorf, in the effective utilization of nuclear instrumentation and in the development and utilization of information and communication technology based teaching materials for nuclear sciences and applications (Fig. 4). In addition, new guidelines for the establishment of a network of laboratories for environmental monitoring and other applications were prepared.

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Nuclear Fusion

The 23rd IAEA Fusion Energy Conference, held in October in Daejeon, the Republic of Korea, attracted over 1000 participants (Fig. 5) from 38 Member States and four international organizations. Approximately 600 papers were

FIG. 5. An exhibition at the Agency's Fusion Energy Conference in Daejeon, the Republic of Korea.

presented. The conference summary highlighted materials development for ITER and fusion power plants, and the development of steady state physics and technology for nuclear fusion systems as key areas for urgent R&D efforts.

Under the IAEA–ITER cooperation agreement, the first joint technical meeting on the 'Analysis of ITER Materials and Technologies' was held in November in Monaco to develop a knowledge base of materials and technologies specific to ITER. The meeting was instrumental in articulating detailed ITER needs and requirements to a relevant community of materials scientists and engineers and highlighted areas of urgent R&D efforts.