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Multiannual programme of the Joint Research Centre 1980-83

1983 Annual Status Report

Nuclear measurements

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PROJECTS

- project Measurements of Nuclear Data:
  - neutron data
  - non neutron nuclear data
- project Nuclear Reference Materials and Techniques:
  - nuclear reference materials
  - samples and targets for nuclear measurements
  - study for the production of enriched actinide isotopes for research purposes

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1. INTRODUCTION

The JRC programme "Nuclear Measurements" is carried out exclusively by the Geel Establishment (the Central Bureau for Nuclear Measurements, CBNM), and forms by far the largest fraction of the work commitment of that Establishment. It conforms closely with the aim of the Establishment as envisaged in the Treaty establishing the European Atomic Energy Community. In addition it is designed to extend the exploitation of the CBNM's major nuclear-measurement facilities, the performances of which have been increased and improved in recent years. These include the two large accelerator installations (the electron linear accelerator and the Van de Graaff generator) and the mass spectrometers.
The Nuclear Measurements programme is divided into two main projects, Nuclear Data on the one hand and Nuclear Reference Materials and Techniques on the other.
In the former the JRC action forms part of world-wide sets of actions to establish reliable, and in many cases very precise, figures for important nuclear parameters - e.g. neutron interaction cross-sections, radionuclide half lives - needed for the development and exploitation of nuclear energy for peaceful purposes. In this work the CBNM pays particular attention to the specific needs of the Community and to complement similar actions undertaken in the laboratories belonging to the Member States.
Concerning Nuclear Reference Materials and Techniques the actions are to provide materials to which analytical and other measurements carried out in the nuclear industry

or by the nuclear community can be referred. One or more of the properties of the materials must therefore be well characterized and eventually certified and in order to carry this out effectively the important techniques used for characterization must be continuously examined and if possible improved. The basic aim of the Nuclear Measurement programme is therefore to develop nuclear metrology with special orientation towards satisfying the demands for basic nuclear data and for materials and methods of reference.

2. RESULTS

Measurements of Nuclear Data

This project is divided into two parts, one concerned with data pertinent for neutron-induced reactions and the other with so-called non-neutron nuclear data, i.e. mainly data on radionuclide decay.

Neutron Data

The main objective is to measure accurate differential cross-section data needed for fast reactor design and safety, long-term irradiation effects on fuel and structural materials, shielding, nuclear waste treatment and storage, safeguards and also for fusion reactors and technology. A prime objective for CBNM remains the improvement of the knowledge of standard cross sections required for these research areas. Also the understanding of underlying physics mainly concerning neutron-induced reactions necessary for current and future nuclear power technology is an important objective.

During 1983 data measurements have continued using both accelerators. A measurement of the ^{242}Pu fission cross-section has been completed, covering the neutron energy range from a few eV to 10 MeV. Many resonances have been observed below 100 keV and these are being interpreted in terms of current fission theory.
Also concerning fission some interesting experiments have been completed in which the fission-fragment mass and energy distributions from the same fissioning nuclear species but in two different energy states have been compared, one the ground state by studying spontaneous fission and the other at neutron separation energy by studying the thermal neutron-induced fission of the nucleus with one neutron number less. The experiments have been performed for the fissioning-nuclei ^{238}Pu, ^{240}Pu and ^{242}Pu, with similar results from each.
The measurement of the capture cross-sections of materials used in the structure of reactors has continued, with much effort put into the analysis of the data.
A gridded ionization chamber has been developed for the assay of thin layers of fissile material as used for neutron detection and studying the fission process. The method is based on the determination of the energies and angles of emission of α-particles or fission fragments and it exploits the use of fast and stable electronic circuitry in conjunction with multiparameter data processing equipment. Compared with previous methods the new method has the advantage of being faster and much less sensitive to the exact shape of the layer and inhomogeneities in its thickness.
Considerable attention has also been given to preparing for the programme period 1984-87, particularly with regard to improving facilities and techniques to meet the demands of higher quality data for fission technology and also the possible new demands to support fusion technology.
The pulse compression system for the Linac has now been brought

into full operation and experiments using the increased resolving power are in progress. The achieved compression has exceeded expectations; from a measurement of the γ flash, a width of 0.6ns with a peak amplitude of 100 A has been observed which corresponds to a compression factor of at least 15. In the case of the Van de Graaff the external pulse compression system has been demonstrated but a satisfactory way of synchronising it with the klystron compression in the terminal has yet to be found.
It has recently become apparent that a few neutron data in the very low energy, thermal, region still need attention in relation to thermal reactor safety, but all European facilities dedicated to this type of measurement have long since been taken out of service. In order to close this gap a new cold source facility has been designed and ordered for use on the CBNM Linac.

Non Neutron Nuclear Data

In this section the objective is to meet the needs for information on the decay properties of radionuclides by experimental determination of the relevant data (including the development of techniques to improve accuracy) and by detailed evaluations of information already available.
An important highlight of 1983 in relation to this activity was the meeting of the International Committee for Radionuclide Metrology, held at Geel in May. This included a seminar on Applied Radionuclide Metrology to which CBNM contributed 8 papers. One of these papers described very accurate (about + 1 %) measurements of the half lives of excited nuclear levels for nuclei applicable to Mössbauer spectroscopy. All of these half-lives were in the range 3ns to 20 μs.

We have continued to participate in international comparisons of radioactivity measurements; during 1983 with those concerning the radionuclides ^{123}I and ^{47}Sc. An International Directory of Certified Radioactive Sources has been compiled and published in Physics Data 27.1. This will be the last year in which an activity under the title "Non-Neutron Nuclear Data" is reported. In the following programme for the period 1984-87 the activity will be featured partly under the heading "Nuclear Data for Standards" but more predominantly under the heading "Radionuclide Metrology". From now on the measurement and evaluation of important precision decay data, and also the development and application of the metrology of radionuclide decay will be emphazised.

Nuclear Reference Materials and Techniques

Nuclear Reference Materials

There exists a need for certain actinide reference materials within the European Community. This need, and the priorities for the various materials, were established a few years ago and CBNM is now engaged in trying to satisfy the need.
Three types of such material, necessary for the calibration of analytical methods, can be identified: those for destructive chemical analysis, those for destructive isotope analysis by mass spectrometry and those for non-destructive isotope analysis by measuring the emitted γ radiations.
A Uranium Oxide reference material for chemical analyses has recently been certified with the number EC110, making a total of 3 materials, U metal, UO_2, Pu metal, having European Certificates. The sales of these materials as a

function of time show no obvious trends; the stock of Pu metal is however depleting sufficiently fast for serious consideration to be given to prepare a new stock. The certification of a PuO_2 reference material has now been abandoned. Instead, thought is being given to prepare a plutonium sulphate reference material which will be easier to use than the oxide because of its better characterization. A task to prepare reference materials for the determination of uranium in minerals and ores has been planned and has started. The certification report for the sets of canned U_3O_8 to be used as reference materials for non-destructive analyses by γ spectrometry is under preparation. Each set consists of 5 samples with $^{235}U/U$ percentages of 0.3, 0.7, 1.9, 2.9 and 4.5, respectively. The dominant certified quantity - the $^{235}U/U$ abundance - is established to better than 0.2 % by calibration with synthetic mixtures of almost pure uranium isotopes, and hence with isotope ratios measured by weighing, prepared at CBNM. Some progress has been made towards the preparation and characterization (also with the aid of synthetically mixed isotopes) of plutonium isotopic reference materials. This task will receive focussed attention in the forthcoming programme period.
Some new measurements on the $^6Li/^7Li$ ratio of natural lithium have been performed and an isotopic reference material, based on the measurements, with a ratio quoted as 0.08215 ± 0.00006 is available. It has been shown that discrepancies in recently reported values of the $^6Li/^7Li$ ratio are not due to variations in the isotopic composition of the natural samples used.
A task to intercompare analytical data, on both main and impurity elements in manganese sulphate solutions used by various laboratories for calibration of neutron sources, has been finished. The implication of these results to the source calibration problem has yet to be evaluated.
Work has started on the preparation and characterization of reference materials for in-pile neutron dosimetry. In cooperation with the European Working Group on Reactor Dosimetry, specifications for 8 materials have been established; work has started on the preparation of 2 of these, viz Al and $^{238}UO_2$.

Samples and Targets for Nuclear Measurements

During 1983 a total of 1135 special samples and targets have been delivered to clients, mainly in the Community. These are mainly in the form of thin films, used as nuclear targets in accelerating machines, or alloys for in-pile dosimeters. Complete reactor dosimetry assemblies including activation, fission and temperature monitors have also been prepared.

Study of the Production of Enriched Actinide Isotopes for Research Purposes

This project is now finished and a full report has been prepared. In this report the conditions for the installation of an electromagnetic separation facility of appropriate size in the EC are examined. A consideration of separation methods other than the electromagnetic one revealed that none of these methods may be regarded today as an alternative for small-scale actinide isotope separation. Information about production, chemical purification and isotopic enrichment is compiled for all needed actinide nuclides and is used for the assessment of those needs which can be satisfied by electromagnetic isotope separation, only. The production and

electromagnetic enrichment of ^{244}Pu in the EC for use as a spike material in mass spectrometric Pu determinations is discussed in detail and is shown to be uneconomic. A design of an electromagnetic separator adapted in size to the EC needs is proposed which is equipped with special containments and handling facilities for the radioactive actinide elements. From the cost price of this separator and operational experience of a few EC laboratories the running and specific product costs are calculated and compared with present USA prices. On the basis of this comparison the decision not to proceed with the construction of a separator was taken.

3. CONCLUSIONS

This year sees the end of a programme period and with it some changes in orientation. Concerning nuclear data considerable effort has gone into the measurement of neutron-induced fission cross-sections from low to high energies. Any future measurements on these cross-sections must be addressed to the very challenging task of improving the accuracy for one or two of the important nuclei. It is doubtful if this can be done via a breakthrough in measurement technique; rather, further progress is likely to be achieved by in depth studies to improve the accuracies of the contributing parts to the measurements. The difficult measurements on the neutron resonance parameters of the isotopes present in structural parts of reactors have absorbed a lot of effort; much data have been obtained but we are still left with some doubts which require further attention. Some effort will be put into neutron data required for fusion technology and a little to evaluation of standard neutron data. Less emphasis will be put on to non-neutron nuclear data but effort to develop and apply the metrology of radionuclide decay will be maintained and work on the metrology of neutron dose introduced.
The work on the preparation, characterization and certification of nuclear reference materials, especially the actinides relating to the nuclear fuel cycle, has reached maturity. Three actinide materials have now been given European Certificates and are on sale, and other actinides are in preparation. New work on reference materials for neutron dosimetry has been started and other nuclear materials which are not actinides will be included in future work.
The feasibility study on actinide isotope separation has shown that there is presently no justification for starting a new European production of these isotopes for research purposes.
The mutual collaboration with external organizations has continued. Such collaborations are essential to ensure the full exploitation of the Linac accelerator in the area of nuclear data measurements and also in the characterization and verification work for nuclear reference materials.

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