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PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN SWEDEN FOR 1983

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1. Neutron Data Measurements

Measurements of high energy neutron scattering are being made, at the Studsvik Science Research Laboratory (B. Holmqvist, N. Olsson, E. Ramström, and B. Trostell). The van de Graaff accelerator has been equipped with a new beam pulsing system which together with a new neutron detector give a total time resolution in scattering measurements of 700 ps. A new tritium gastarget which can take higher pressure ($\sim$4 atm) and beam currents ($\sim 3\,\mu$A) has also been developed. Measurements are in progress of the C(n,n) reference cross section at around 8 and 22 MeV. Furthermore, at 22 MeV, the present program includes the measurements of a number of neutron elastic and inelastic angular distributions with high accuracy.

Systematic investigations of sources of errors in activation capture cross section measurements are underway at the Physical Department of the Lund University (P. Andersson, I. Bergqvist and R. Zorro). Measurements of the capture cross sections for the reactions $^{115}In(n,\gamma)^{116}In$ and $^{197}Au(n,\gamma)^{198}Au$ in the neutron energy range 2 - 7.5 MeV are near completion.

Information on giant resonance structures have been obtained from studies of neutron capture gamma ray spectra including angular distributions in a collaboration between the Lund University (I. Bergqvist, P. Ekström and R. Zorro) and the Tandem Accelerator Laboratory in Uppsala. (A. Lindblom, L. Nilsson, N. Olsson (NFL) and A. Håkansson). Together with research groups at Los Alamos National Laboratory, Triangle Universities at Duke and Lawrence Livermore Laboratory the Uppsala-Lund group is participating in measurements of the $^{12}C(n,\gamma)^{13}C$ reaction. This work has prompted a careful investigation of detection efficiency for the various γ-ray scintillation detectors involved. The present status is that the Uppsala data show excellent agreement with the Los Alamos data in the overlapping region (E_n=10-14 MeV). The Duke data agree with Los Alamos results for energies above 15 MeV but depart for lower energies. In the region E_n=7-12 MeV the Duke cross sections are about twice as high as the Uppsala results.

Basic and applied neutron physics are being planned at the reconstructed cyclotron at the Gustaf Werner Institute at the Uppsala University (H. Condé, O. Jonsson, H. Lundqvist, P.U. Renberg and O. Sundberg in collaboration with groups from LU, NFL and TLU).The basic research will involve studies of nuclear structure and reactions at intermediate neutron energies (20-200 MeV). Neutron cross section measurements and reaction model studies will also be performed related to research and development in nuclear energy, biomedicine, material sciences etc. In particular, nuclear structure studies by use of the (n,p)-reaction is being planned together with measurements of total and reaction cross-sections between 20 and 200 MeV.

2. Fission Product Nuclear Data Measurements

P. Aagaard, K. Aleklett, B. Fogelberg, P.I. Johansson, E. Lund, G. Rudstam

The group for nuclear physics and chemistry at the Studsvik Science Research Laboratory has at its main tool an isotope separator ("OSIRIS") attached to the 1 MW nuclear reactor R2-0. An integrated target-ion source system is used where the target material form a cylinder consisting of uranium oxide/carbide on a matrix of graphite cloth which is placed in the discharge chamber of the ion source. The target is irradiated with thermal neutrons from the reactor with a maximum flux of 4×10^{11} n/cm^{2}s. All elements volatile in the ion source temperature of ~1500°C are released from the target and processed as elementary ions by the separator. In this way isotopes of the elements Zn, Ga, Br, Kr, Rb, Ag, Cd, In, Sb, Te, I, Xe, and Cs, and their daughter products, become available for study. By the addition of carbon tetrafluoride a further set of elements - Sr, Y, Zr, Ba, lanthanides - become volatile as fluorides and may be processed as molecular ions. This means an almost complete coverage of fission products down to half-lives about a tenth of a second.

The experimental programme is focussed on fundamental studies of short-lived fission products. This programme comprises measurements of specific

properties such as total beta decay energies, half-lives, and the emission of delayed neutron. More complete spectroscopic investigations are carried out for especially interesting nuclides. Because of the great importance of macroscopic effects of the fission products in nuclear fuel the group is also engaged in applied research with the view to measure certain quantities and to evaluate integrated effects. Examples of this is the beta part of the decay heat, the delayed-neutron energy spectrum and its time dependence, and the fission yields. The decay heat problem is also attacked by integral measurements of the beta and gamma spectra emitted from irradiated fissile nuclides using a Van de Graaff-accelerator.

A summary of the experimental programme is given below in the form of a table.

Measurements

A. Delayed neutrons
   - Branching ratios
   - Energy spectra

B. Decay data
   - Total decay energies
   - Half-lives
   - Gamma branching ratios

C. Research related to the decay heat problem
   - Measurement of the complete beta spectrum for individual fission products and determination of the average beta energy emitted per decay
   - Integral measurements of decay heat from
     ^{235}U (thermal fission; beta and gamma part)
     ^{238}U (fast fission; gamma part)

D. Fission yields
   - Yields of thermal fission of ^{235}U (many isomeric yield ratios determined for the first time)
   - Yields of fast fission of ^{238}U (new project planned)

3. Experimental facilities

A reconstruction of the cyclotron at the Gustaf Werner Institute, Uppsala is underway. The new cyclotron will be operated in two different modes namely as an isochroneous cyclotron for proton energies up to 100 MeV or as a synchrocyclotron for energies from 100 to 200 MeV. Protons, deutrons or alpha particles (10-40 μA) can be accelerated and preparations are made for later addition of heavy and polarized ion-sources. A storage ring with electron coooling (CELSIUS) is being added to the cyclotron. Options will be made to accelerate the protons in the ring up to about 1 GeV. The energy resolution will be 10^{-4} for 10^{10} particles stored and 10^{-5} for 10^{8} particles.

The first beam from the cyclotron is scheduled for summer 1985 and from CELSIUS early 1987.

A neutron spallation source for use in neutron capture therapy is proposed to be built at the Swiss Institute for Nuclear Research (SIN) by the biomedical group at GWI, Uppsala. The epithermal neutron source will be used for irradiation of Boron-10 loaded biological materials. Recent development of monoclonal antibodies, which can be loaded with very much Boron, and which will deliver the Boron to specific sites, has revived the interest in this technique.

The proposal is to utilize the 200 μA proton beam from the 72 MeV injector of the SIN-cyclotron and a heavy metal target for neutron production. The calculated intensity of the spallation source is 10^{14}-10^{15} n/s.

The possibilities to use a combined proton recoil and neutron time-of-flight spectrometer for neutron diagnostics at JET has been studied at the Department of Reactor Physics of Chalmers University of Technology. The conclusion of the study was that the derived properties (energy resolution of about 100 keV, efficiency high enough to evaluate a spectrum for each shot) can be met.

4. Compilation and evaluation

Evaluations of nuclear structure and decay data for the ENSDF library have been made by a group at the Physical Department of Lund University. Recently, evaluations have been completed for the masses A=59 and 61 and work on A=60 is in progress. The group has also published catalogues of gamma rays from radionuclides retrived from the ENSDF library.

A compilation of evaluated and experimental neutron data for the actinides has been made by the Swedish Nuclear Data Committee. The compilation includes 24 isotopes from ^{232}Th to ^{252}Cf and six of the main libraries, ENDF/B, UKNDC, JENDL, KEDAK, ENDL and SOKRATOR. Point-wise as well as group-cross sections have been compiled. A report (KDK-75) in two volumes is under publication.

Together with the experimental work on fission product nuclear data at the Studsvik Science Research Laboratory evaluations have been made of following parameters:

- Energy spectra of delayed-neutron groups and their time variation
- Decay heat in nuclear fuel
- Abundance pattern of fission products in nuclear fuel
- Antineutrino energy spectrum around a nuclear reactor.