KDK-37

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NEANDC(OR)-154/L
INDC(SWD)-14/L

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN SWEDEN FOR 1979.

SWEDISH NUCLEAR DATA COMMITTEE
STOCKHOLM, SWEDEN

APRIL 1980

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Compiled by
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National Defense Research Institute
Stockholm, Sweden
April 1980

CONTENTS

PREFACE

This report contains information from laboratories in Sweden about measurements, and compilations which are relevant to obtain nuclear data for research and development in different applied fields of nuclear physics.

Reports relevant to the nuclear energy field are given of neutron cross section measurements and studies of the fission process. Reports are also given of nuclear structure and decay data measurements especially fission product nuclear data measurements of importance for the research on reactor safety and nuclear waste handling. Charged particle and photonuclear cross section measurements with applications in e.g. activation analysis and the production of radioisotopes for medical use are reported as well.

In some cases reports are also given of measurements aiming to test nuclear models which are commonly used for the calculation of the above type of data.

In general basic nuclear physics research is not included in this report. However, the limitation between pure and applied nuclear physics is not strict why reports micht be missing or added as a matter of subjective judgements.

The report also contains short information about changes of existing experimental facilities.

The document contains information of a preliminary or private nature and should be used with discretion. Its contents may not be quoted without the explicit permission of the originator.

1. THE SWEDISH NUCLEAR DATA COMMITTEE (KDK)

1.1 Status report, Dec 77 - Dec 78

The Swedish Nuclear Data Committee has been supported for the present time period as a research project under the Board for Energy Source Development. The Committee including the "Coordination Group on Measurements" has had the same members as listed in the Progress Report from 1977 (KDK-15).

The Committee has discussed nuclear compilation and measurement program in progress, which are related to nuclear data. In special, the work to compile selected neutron data for a number of actinides initiated by KDK in 1978 and sponsored by the Swedish Nuclear Power Inspectorate (see 1.2) has been completed (KDK-35).

International nuclear data activities at IAEA and OECD-NEA referred to national nuclear data groups for considerations have been discussed. Recommendations have been given concerning Swedish representation in international nuclear data meetings.

Publications

KDK-32 Progress report on Nuclear Data Activities in Sweden (Dec 77 - Dec 78) April 1979.

KDK-33 Report from "IAEA Research Coordination Meeting on the Intercomparison of Evaluations of Actinide Neutron Nuclear Data", Aix-en-Provance, Apr 30 - May 1, 1979 and the "Second Advisory Group Meeting on Transactinium Isotope Nuclear Data", Cadarache May 2-5, 1979 (June 1979)(In Swedish).

KDK-34 KDK Annual Report 1978/79 (Sept 1979)(In Swedish).

KDK-35 Compilation of Actinide Neutron Nuclear Data.

KDK-36 Report from the 21st NEANDC Meeting, Sept 24-28, 1979, CBMN, Geel, Belgium (Oct 1979)(In Swedish).

1.2 Compilation of neutron data for selected actinides

P Andersson, Lund Inst. of Techn.
J-E Christiansson, Univ. of Gothenburg,
H Condé, Nat. Defense Research Inst.,
H Häggblom, Studsvik Energiteknik AB,
C Nordborg*, Tandem Accelerator Lab.,
H Sandberg, Chalmers Univ. of Techn. and
B Trostell, The Studsvik Science Lab.

The Swedish Nuclear Data Committee has initiated a compilation of evaluated and experimental neutron data for 16 different isotopes from ^{232}Th to ^{248}Cm. The compilation has been published as a KDK-report (KDK-35).

The data are primarily requested for calculations in reactor physics and of actinide build-up and for inciniration studies of nuclear waste by neutron irradiation.

The compilation includes evaluated data from the following libraries: ENDF/B, ENDL, UKNDL, KEDAK and JENDL. A selection of experimental data was also compiled from the NEUDADA library and recent publications.

The compiled data are presented in graphs covering for each isotope and cross section two energy regions: one from thermal energy to about 1 eV and the other from about 10 keV to 20 MeV. The thermal values and resonance integrals (0.5 eV-50 keV) are given in tables.

*Present address: NEA Nuclear Data Bank, 911 90 Gif-sur-Yvette, France

2. CHALMERS UNIVERSITY OF TECHNOLOGY, S-402 20 GOTHENBURG

2.1 Department of Physics

2.1.1 High spin states of neutron deficient odd nuclei in the $80 < A < 90$ region

S.E. Arnell, Ö. Skeppstedt and E. Wallander

A. Nilsson, Research Institute of Physics, Stockholm

In our current program for investigating neutron deficient nuclei in the $80 < A < 90$ region we have obtained information on ^{85}Y and ^{87}Y. The two nucleides were produced by the $^{84,86}Sr(\alpha,p2n)^{85,87}Y$ reactions at $E_\alpha = 51$ MeV. In the spin region ($11/2 < J < 25/2$) the structure of these nuclei is dominated by the generelized seniority-three states of the configuration $\pi g_{9/2}\nu g_{9/2}^{-4}$ and $\pi g_{9/2}\nu g_{9/2}^{-2}$, respectively, which makes it amenable to relatively simple shell-model calculations.

2.1.2 On-line studies of very unstable nuclei

G. Andersson, B. Jonson, S. Mattsson and G. Nyman

The first observation of beta-delayed two-neutron emission has been made at ISOLDE in a neutron-neutron time correlation measurement of 8.5 ms ^{11}Li. The branching ratio for this new decay mode was determined as 9±3%.

By means of delayed coincidences between β-particles and conversion electrons the life-time of the 2^+-state (129.2 keV) in ^{100}Sr was determined as 5.15±0.20 ns. The derived deformation parameter ε = 0.29 indicates a well-developed axial rotor. Total beta-decay energies have been measured for ^{96,98}Rb, ^{96,98}Sr and ^{98g}Y at Inst. für Kernchemie, Mainz.

In a joint ISOLDE-KFA Jülich experiment all known states in ^{132}Sn are assigned to have positive parity.

At GSI measurements of alpha energies, alpha-branching ratios, half-lives, and reduced alpha-widths have been performed in the Te-Cs region.

2.2 Department of Nuclear Chemistry

2.2.1 Nuclear spectroscopic studies of short-lived radionuclides

K. Brodén and G. Skarnemark

The decay properties of short-lived radionuclides are studied by means of γ-ray, β- and delayed neutron spectroscopy. The sources are prepared using the continuous chemical separation system SISAK. During 1979, we have investigated the decay of $^{106-108}Tc$ and ^{133m}I. Studies of Br, Zr and As are in progress.

3. THE GUSTAF WERNER INSTITUTE, UNIVERSITY OF UPPSALA, BOX 531, S-751 21 UPPSALA

3.1 Physical biology

3.1.1 Production of radionuclides for biological and medical applications

H Lundqvist, P Malmborg and C-G Stålnacke, B Långström and S Sjöberg, Department of Organic Chemistry, University of Uppsala

Routine production of radionuclides (mainly ^{11}C) has continued during 1979 using about 8 h of beam time per week. Reliable and handy performance has been obtained with the third generation gas target system (features and production parameters see Annual Report 1978). An on-line radiogas-chromatographic system has been constructed and used for the analysis of target gases and reaction products. The synthesis and labelling of biomolecules now also include a tripeptide Gly-(^{11}C)Met-Gly and some ^{11}C-labelled aliphatic and aromatic hydrocarbons.

In the nutritional studies on the availability of amino acids in fodder ^{11}C-Methionine, synthesized with a manual prototype "$^{11}CH_3I$-factory", has been used in a series of experiments on pigs (the University of Agriculture, Uppsala). In a collaboration with the Stockholm hospital Karolinska Sjukhuset, $^{11}CO_2$ was trapped in KOH, transported 70 km, photosynthetically labelled into ^{11}C-glucose with green algae and used in dog brain studies with the positron camera.

Preliminary test irradiations for the production of ^{18}F have been performed with deuterons on a neon gas target.

4. LUND UNIVERSITY AND LUND INSTITUTE OF TECHNOLOGY, S-223 62 LUND

4.1. Department of nuclear physics - Pelletron group

4.1.1. Neutron capture measurements with activation technique

P. Andersson, I. Bergqvist, G. Magnusson and R. Zorro

The results from activation measurements of 14-15 MeV neutron capture cross sections indicate that previous measurements at other neutron energies are influenced by secondary low energy neutrons (1,2). These neutrons are produced in the sample itself and in surrounding materials by nuclear reactions like (n,2n), (n,np) and (n,n').

The corrections due to secondary neutrons can be determined by observing the dependence of sample thickness and source-to-sample distance on the activation yield.

Measurements of capture cross sections at the neutron energy 14.7 MeV have been concluded for the nuclei ^{23}Na, ^{55}Mn, ^{89}Y, ^{115}In, ^{127}I, ^{138}Ba, ^{186}W and ^{197}Au (2). An experiment has been initiated to determine the capture cross section of ^{238}U.

Further measurements in the neutron energy range 1-10 MeV for ^{115}In and ^{197}Au are in progress. The irradiations are performed with neutrons from the T(p,n)^{3}He-reaction. The protons are accelerated by the Pelletron-accelerator and a tritiated titanium target on tantalum backing is used as neutron source. The induced activity is measured with a Ge(Li) spectrometer and corrections for γ-ray attenuation in the sample is made. The activation yield for the different irradiation-geometries are calculated with a computer-code which take into consideration the geometry of the source, the neutron energy spread (3) and the variation of the neutron flux with emission angle. The integrated neutron flux is determined from the ^{115}In(n,n')^{115m}In reaction (4).

The results show good agreement with earlier activation experiments for neutron energies below about 2 MeV but diverge at higher energies indicating an influence of secondary neutrons. The contribution of these neutrons increases with neutron energy.

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1) G. Magnusson and I. Bergqvist, Nucl. Technol., 34, 114 (1977)

2) G. Magnusson, P. Andersson and I. Bergqvist, Physica Scripta 21 (1980) 21

3) G. Magnusson and P. Andersson, Nuclear Physics Report, LUNFD6/(NFFR-3030) /1-37/1979

4) P. Andersson, S. Lundberg and G. Magnusson, Nuclear Physics Report, LUNFD6/(NFFR-3021)/1-22/1978

4.1.2. Proton capture by ^{176}Yb in the giant dipole resonance region

B. Pålsson, J. Krumlinde, I. Bergqvist, L. Nilsson, A. Lindholm, D.S. Santry, E.D. Earle

This work has been completed and a report has been submitted for publication. The abstract of the paper is the following:

The proton capture cross section for the reaction ^{176}Yb(p,γ)^{177}Lu has been measured for incident proton energies between 6 and 24 MeV. The excitation function for this deformed nucleus agrees remarkably well with the results of previous studies on spherical nuclei, e.g. ^{142}Ce(p,γ)^{143}Pr. The results indicate that the giant dipole resonance (GDR) is strongly excited as predicted by the direct-semidirect (DSD) model. It is found that the model describes reasonably well the excitation function. In the low-energy proton range, where the excitation function increases rapidly with proton energy, the observed cross section is significantly higher than the DSD predictions. The difference can only partly be explained by compound nucleus contributions. In the high-energy end, the predicted cross section tends to be too high primarily due to an increasing contribution of direct capture to orbitals with large angular momenta.

4.1.3. Nucleon Capture reactions in and below the giant resonance region

I. Bergqvist, R. Zorro, N. Olsson, T. Andersson, A. Lindholm, L. Nilsson and A. Waheed

(see also 8.1)

The study of nucleon capture reactions is performed as an Uppsala-Lund collaboration. Several investigations are in progress in collaboration with scientists at Los Alamos Scientific laboratory, USA, University of Oregon, USA, Jozef

Stefan Institute, Ljubljana, Yogoslavia and Centre d'Etudes de Bruyéres-le-Chatel, France.

Recent measurements involve the study of neutron capture processes in silicon and sulphur via single-particle type resonances. Such resonances were observed in a previous experiment (1). The new measurements extend the neutron range to higher energies.

It has previously been pointed out that fast neutron capture might be a promising tool to localize E2 giant resonance strength in nuclei. The method has been utilized in an effort to look for E2 strength in ^{209}Pb. The study is a collaboration with Los Alamos. Measurements in the neutron energy range 5.5 - 8 MeV have recently been concluded in Uppsala in search for the iso-scalar E2 strength. Analysis of the data is in progress.

The work to supply the large NaI(Tl) scintillation detector with an anti-compton annulus detector has been initiated. The photo tubes of the detector will also be replaced. The aim is to improve the energy resolution, the single-to-background ratio and the timing resolution of the detector in order to make measurements at higher neutron energies, $E_n \simeq 20$ MeV feasible.

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1) A. Lindholm, L. Nilsson, I. Bergqvist and N. Olsson, Z. Physik A289 (1979) 229

4.1.4. Investigation of the Gamma Ray Strength Function in ^{64,66}Zn by Means of the Average Resonance Method

B. Erlandsson, K. Nilson and A. Marcinkowski

The reactions ^{63}Cu(p,γ)^{64}Zn and ^{65}Cu(p,γ)^{66}Zn have been used to study the average intensities of primary gamma rays from compound nuclear states in a broad energy region just below the neutron binding energy in ^{64}Zn and ^{66}Zn. The gamma rays were detected with a three-crystal pair-spectrometer for differences in the proton energies of 16-20 keV. Spectra obtained in this way were added to get only one averaged spectrum for each of the two nuclei. Comparison of the relative intensities of the primary gamma-ray transitions were made with the predictions of the compound nucleus statistical model. The E1 gamma-ray strength functions for energies below 11 MeV have been

deduced from the experiment.

4.1.5. Low Spin States in ^{64}Zn and ^{66}Zn

B. Erlandsson, J. Lyttkens, K. Nilson, A. Marcinkowski

The gamma decays following the $^{63}Cu(p,\gamma)^{64}Zn$ and $^{65}Cu(p,\gamma)^{66}Zn$ reactions have been studied with a single Ge(Li) detector and with the Ge(Li) detector incorporated in a three-crystal pair spectrometer. Proton energies of about 2 MeV have been used. Level schemes up to about 4 MeV for ^{64}Zn and ^{66}Zn have been constructed from the data.

4.1.6. The Average Resonance Spectroscopy Method Applied to a Target of ^{64}Ni

B. Erlandsson, K. Nilson, A. Marcinkowski and J. Piotrowski

The $^{64}Ni(p,\gamma)^{65}Cu$ reaction has been studied in the proton energy range E_p = 2.05-2.55 MeV. The gamma-ray spectra were recorded with a three-crystal pair spectrometer at proton energy differences of 19 keV covering the proton energy range. An average gamma-ray spectrum was formed by adding all the individual spectra after proper adjustment as a result of the alterations in proton energy. The intensities of the gamma rays to final states with known J^{π}-values were tested against theoretical calculations based on the Hauser-Feshbach theory with good results. These calculations and earlier reports on the possible J^{π} assignments enabled us to suggest the following spins and parities: 2094.3 ($7/2^-$), 2107.4 ($5/2^-$), 2212.8 ($1/2^-$), 2286.6 ($7/2^-$), 2594 ($1/2^-$, $5/2^-$), 2753 ($7/2^+$, $9/2^+$), 2839 ($7/2^+$, $9/2^+$) and 3632 keV ($1/2^+$, $3/2^+$).

4.1.7. Investigation of the Gamma Ray Strength Function in ^{51}V by Means of the Average Resonance Method

B. Erlandsson, K. Nilson and A. Marcinkowski

A three-crystal pair spectrometer has been used to study the $^{50}Ti(p,\gamma)^{51}V$ reaction for E_p = 2.1-2.5 and 2.6-3.1 MeV. The gamma-ray spectra were measured throughout the proton energy interval in steps of about 15 keV. These spectra were added to get only one averaged spectrum. The intensities of high-energy gamma transitions populating the low-excited states of ^{51}V have been determined. The intensities of the gamma rays to final states with known J^{π}-values were tested against theoretical calculations based on the Hauser-Feshbach theory with good results. The gamma-ray strenght function for energies lower than 11 MeV has been evaluated from the measured average intensities of primary

gamma rays. It was found in the present experiment that the measured strength function supports the hypothesis that the E1 strength function supports the hypothesis that the E1 strength function at low energies can be derived from the giant dipole resonance and that a giant resonance is built on each excited state.

This work has been published in Nucl. Phys. A239, 1 (1979)

4.1.8. Beta Strength Function for ^{71}Ga

L. Spanier, C-O Wene, B. Erlandsson and K. Nilson

We have studied the isobaric-analogue states (IAS) in ^{71}Ga with the reaction ^{70}Zn(p,γ)^{71}Ga of a proton energy of about 4 MeV. The gamma rays from the IAS have been measured with a pair-spectrometer. The Gamow-Teller (GT) operator is approximately proportional to the isovector part of the M1 gamma transition operator. This makes it possible to deduce the GT β-strength function for ^{71}Ga which are also fed by β-transitions from the ground state and the low-lying $9/2^+$ state in ^{71}Zn. There are only preliminary results at this moment.

4.1.9. A Study of the Structure of the ^{63}Cu nucleus by the Average Resonance Spectroscopy Method

B. Erlandsson, J. Lyttkens, K. Nilson and A. Marcinkowski

The (p,γ) reaction on ^{62}Ni was studied in the energy range 1.9-2.4 MeV using a new three-crystal pair spectrometer, consisting of a 80 cm^3 Ge(Li) detector (ΔE_γ = 1.92 keV at E_γ = 1332 keV) and a Harshaw annular detector with a 25 cm x 30 cm NaI crystal with an axial true hole. The crystal is optically separated in two equal hemicylinders.

As a 3-4 keV thick target was used in order to get a good resolution the energy range had to be covered with about 150 spectra. Only preliminary results are available at the moment.

4.1.10. Evaluation of Nuclear Structure and Decay Data

B. Erlandsson, J. Lyttkens and K. Nilson

In the last few years IAEA has held international meetings in order to organize the evaluation of nuclear strucutre and decay data. The Department of Nuclear Physics at the University of Lund and Lund Institute of Technology was invited to join in the evaluation work and has taken part on a trial basis in this

work. The department has been assigned the evaluation of nuclei with A-113. This mass chain belongs to a mass region for which Oak Ridge National Laboratory in the United States is responsible. In november 1978 a member of the group participated in a "New Evaluators Orientation" program at Oak Ridge. During 1979 all the relevant articles has been collected and studied. The evaluation of A=113 will be completed in 1980.

4.1.11. The beta-strength function: shape and consequences

C-O. Wene

(In collaboration with Max Planck Institut für Kernphysik, Heidelberg and Institute of Physics, University of Leningrad)

The objectives of the collaboration is to systemize our theoretical and experimental knowledge of the low-lying structures in the beta strength function and to investigate the effect to these structures in areas where high energy beta-decays play a dominant role, e.g. astrophysics.

A systematic investigation (1) of the low-lying structures indicate that there are two strong candidates for a resonant structure in neutronrich actinides resulting in the large β-delayed fission (βDF) branching ratios. The investigation also points (1,2,3) to large effects on the synthesis of the heavy elements through the r- or u-process. The low-lying structures will also be of large importance in understanding the electron captures in the degenerate cores of evolved stars. The A=56 isobaric chain is here of special interest. Fig. 11 shows the positions of the low-lying structures (SFS9) in the first $T_3>0$ nuclei in this isobar. The influence of the SFS on the decay of ^{56}Ni and ^{56}Fe and on the neutrino losses will be large already at moderate core densities. This will be important both for the carbon detonation model and for the gravitational collapse of very massive stars.

β-delayed fission gives a possibility to investigate the fission barrier in nuclides so far off stability e.g. by measuring the βDF branching ratios. However, before any information on the fission barrier can be extracted, the effect of the low-lying structures on the branching ratios has to be considered. Thus, as discussed in (4), the analysis of recent measurements in ^{232}Pu assuming a constant strength function indicate large systematic errors in the Strutinsky procedure for calculating fission barriers, however, if the low-lying structures are included, the measured branching ratio is constant with the calculated barriers within the errors quoted for the calculation.

The collaboration is also generating an experimental programme. The (p,γ)-experiment to detect M1 γ-decay from the isobaric analogue state is an example of this.

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1) H.V. Klapdor, C-O. Wene, to be published in Isvest. Akad. Nauk USSR, 1979

2) C-O. Wene, H.V. Klapdor, Proc. Int. Conf. on Nucl. Structure Tokyo 1977, p. 797

3) H.V. Klapdor, C-O. Wene, Astrophys. J. Lett. 230, (1979) 113

4) H.V. Klapdor, C-O. Wene, I.N. Isosimow, Yu.W. Naumow, Proc. Int. Symp. Phys. Chemistry of Fission, Jülich 1979
H.V. Klapdor, C-O. Wene, I.N. Isosimow, Yu.W. Naumow, Z. Phys. A292 249

4.2. Department of Physics - Photonuclear Group

4.2.1. $^{28}Si(\gamma,p)^{27}Al$ and $^{28}Si(\gamma,\alpha)^{24}Mg$ reactions in the giant resonance region

L. Cardman[1], A. Doran[2], A. Erell[2], R. Gulbranson[1], K. Lindgren and A. Yavin

1) University of Illinois, URBANA, Ill. USA

2) Tel-Aviv University, RAMAT-AVIV, Israel

The emission of protons and alphas after excitation of silicon with monoenergetic photons from the tagged photon facility at the University of Illinois is studied. Si(Li) detectors of different thickness (1, 3 and 5 mm) were used as both targets and detectors giving a 4 π solid angle. Data have been taken in the energy region $13.5 < E_\gamma < 25.5$ MeV, with an overall resolution of about 150 keV. Several decay channels were observed and excitation functions for the channels $p_p - p_{10}$, α_0 and α_1 have been determined. A pronounced structure is observed in all decay channels studied. The experimental results are at present being analysed.

4.2.2. Cluster emission from complex nuclei irradiated by 500 MeV bremsstrahlung

J-O. Adler, G. Andersson, H-Å. Gustafsson and K. Hansen

During 1979 we have finished the experimental part of a systematic investigation of the emission of light charged particles from complex nuclei irradiated by

high energy photons (i.e. 500 MeV bremsstrahlung). The investigation cover the nuclei Au, Ta, Tb, Ag, Cu, Al, C and Li of which Ta, Tb and Li were measured during 1979.

The emitted particles were detected in a counter telescope with surface barrier detectors which allowed separation of the different hydrogen and helium isotopes[1]. Energy and angular distributions have here measured except for Ta and Tb, where only energy distributions at 90° were measured, and the results have been compared with cascade-evaporation calculations. For the ^{4}He-distributions the calculations were extended to include the contribution from knock-out of surface α-particles by the cascade nucleons.

Analysis of the results from measurements on Au, Ag and Cu[1,2] shows that the main contribution to the emission comes from evaporation, but that there also is a direct contribution of the order of 10 % for protons and α-particles.

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1) J-O. Adler et al, Nucl. Phys. A223 (1974) 145

2) J-O. Adler et al, Emission of hydrogen and helium nuclei from Au, Ag and Cu irradiated by 500 MeV bremsstrahlung.
Z, Physik, accepted for publication.

4.2.3. Photofission of ^{234}U

Yu. Tsipenyuk*, A.S. Soldatov*, L.J. Lindgren
* The Institute of Physical Problems, Moscow

An experiment on low energy photofission of ^{234}U has been performed at the Institute of Physical Problems (Moscow). The aim of this mutual experiment was to measure the photofission yield at very low excitation energies.

In an earlier study it was found that photofission data for ^{234}U showed more peculiarities when compared to data on ^{236}U and ^{238}U[1]. These deviations were interpreted as a result of a different and more complex barrier shape for ^{234}U.

The present total yield measurements show that at low energy the energy dependence is approximately the same as for ^{238}U but at energies above 5.2 MeV the shape of the yield is much more gentle than for ^{238}U.

Angular distribution measurements also made in Moscow show that c/b, quadrupole to dipole ratio, is quickly rising for energies below 5.2 MeV.

The present measurements have given further support to the earlier interpretation that the barrier shape for ^{234}U is more complex than the fission barrier for ^{236}U and ^{238}U. To be complete the excitation energy region 6.5-7 MeV ought to be studied in future.

The results from the present experiment on ^{234}U will be published in Sov. Journal of Nucl. Phys.

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1) L.J. Lindgren, A. Alm and A. Sandell
Nucl. Phys. A298 (1978) 43

4.2.4. Fission of light and medium-heavy nuclei induced by 600 MeV protons

G. Andersson, M. Areskoug[1], H-Å. Gustafsson[2], G. Hyltén, B. Schrøder, E. Habebø[3]

[1] present address: The Swedish University of Agriculture Science, Lund

[2] present address: EP-Division, CERN, Geneva, Switzerland

[3] Department of Chemistry, University of Oslo, Oslo, Norway

The experimental part of a systematic investigation of the fission properties of light and medium-heavy nuclei was completed during 1979. Eleven elements ranging from Se to U has been studied with 600 MeV protons from the synchrocyclotron at CERN. In coincidence experiments the binary character of the reaction was established by means of inplane angular correlations. The total kinetic energy release was found to follow closely the semiempirical formulae of Viola /1/, i.e. to be some 10 MeV higher than predicted /2/. Mass distributions were determined from the measured kinetic energies of complementary products. Apart from a narrow region around La the mass distributions are symmetric.

Another discrepancy between experimental data and macroscopic theories is obtained in connection with the height of the fission barriers. An analysis of cross sections and in-plane angular correlations /4/ yield fission barrier heights for Ag, La and Tb which are 20-40 per cent below those predicted. The mass asymmetry observed for La /5/ and Ce is probably caused by shell

effects, i.e. we obtain a situation similar to the one observed in the actinied region. In the case of La and Ce the crucial neutron number for strong octupole deformations seem to be around 80 /6/.

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1) V.E. Viola Jr., Nucl. Data 1 (1966) 391

2) J.R. Nix, Nucl. Phys. A130 (1969) 241

3) A.A. Kotov et al., Sov. J. Nucl. Phys. 20 (1975) 251

4) G. Andersson et.al., Z. Physik A293 (1979) 241

5) G. Andersson et.al., IAEA-AM-241/F17, in press.

6) S.A.E. Johansson, private communication
I. Ragnarsson, TH. 2765-CERN, unpublished

5. NATIONAL INSTITUTE OF RADIATION PROTECTION, BOX 60204, S-104 01 STOCKHOLM*

5.1 Angular distributions of the fission fragments of ^{232}Th for neutron induced fission in the energy region 1.6-1.8 MeV

M. Holmberg

The angular distributions of the fission fragments in neutron induced fission of ^{232}Th were measured in the energy interval 1.6-1.8 MeV, where a structure in the fission cross section occurs. The energy resolution used permitted the measurements to be made for individual peaks in the cross section. The results agree with previous assignments of a K = 3/2 band for the 1.60 MeV peak. The results indicate a $K \geq 3/2$ rotational band for the peak at 1.72 MeV, which does not agree with a previous assignment of a K = 1/2 band.

(submitted for publ. in Nucl. Phys.)

5.2 The fission cross section and some angular distributions of the fission fragments of ^{231}Pa for neutron induced fission in the energy region 0.1-4.0 MeV

M. Holmberg and L.-E. Persson

The fission cross section for the neutron induced fission of ^{231}Pa was measured in the energy region 0.1-4.0 MeV. The fission fragment angular distributions were measured at four energies around 700 keV. The results show that the rise in the fission cross section occurs at 500 keV and the cross section reaches a plateau value of the order of 1.2-1.4 b in the energy region 2-4 MeV. Peaks in the cross section were observed at 156 keV, 200 keV, 320 keV and 580 keV. The measurements indicate an unresolved structure in the cross section at 540 keV, 690 keV and 950 keV. The fission fragment angular distributions demonstrate a sharp forward peaked distribution at 685 keV in comparison with the distributions measured in the vicinity of that energy.

(submitted for publ. in Nucl. Sci. Engn.)

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*The experimental work was done at the National Defense Research Institute (see KDK-6, Sept. 1974 p. 26).

6. RESEARCH INSTITUTE OF PHYSICS, S-104 05 STOCKHOLM

A. Nilsson

As in earlier years, the research at the 225-cm cyclotron has been concentrated on nuclear states of very high spin, excited by α- or ^{12}C-induced reactions.

However, a considerable part of the available beam-time was used for production of ^{81m}Rb for the Danderyd Hospital and ^{11}C for the Karolinska Hospital. The latter isotope was used for making glukose for brain studies with the positron camera.

The surface physics group has continued their work on phenomena relevant to fusion reactor wall technology. Thus, e.g. they have studied the recombination of deuterium atoms diffusing through a stainless steel plate to form molecules at the surface, as well as the interdiffusion of stainless steel components and palladium in a palladium-coated plate at elevated temperatures.

7. THE STUDSVIK SCIENCE RESEARCH LABORATORY
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7.1 Nuclear Chemistry Group

P Aagaard, K Aleklett, P Hoff, L Jacobsson, B Johansson, O Johansson, E Lund, G Rudstam, M af Ugglas (part-time) and H-U Zwicky

7.1.1 Development of the target system of OSIRIS

The integrated target and ion source of OSIRIS has up to now been used for production of all fission product elements which are volatile at about 1500°C. During the year a method has been developed in which a fluorine compound is fed into the ion source, which leads to a release also of non volatile elements in particular the alkaline and rare earths. The method makes it possible to obtain strong samples of hitherto little known or unknown fission products and holds thus great promises for future projects.

Improved studies of Br and I fission products has also been made during the year by collecting the samples as $AlBr^+$ or AlI^+ ions, which shifts the Br and I activities by 27 mass units to regions where other isobars cause only little disturbance.

7.1.2 Total β-decay energies

Measurements of total β-decay energies have hitherto been performed for about 50 fission products. The results have been compiled in a conference report [1)] and compared with mass formulas. This comparison shows that almost all the mass formulas predict too low binding energies, especially for nuclides far from stability. It should also be mentioned that a report on total decay energies of the bromine isotopes $^{85-89}Br$ has been published during 1979 [2)].

Using the aluminium-containing target it has been possible to measure the Q_β-values of ^{89}Br, ^{90}Br, ^{139}I and ^{140}I under very favourable conditions. These measurements are very difficult with the regular target - ion source because of highly disturbing activities from isobaric noble gas and alkali isotopes.

7.1.3 Delayed neutron branching ratios

A report on delayed neutron branching ratios containing data for 30 precursors will soon appear in the literature [3]. The existence of great discrepancies between P_n-value determinations from different laboratories has prompted us to pay special attention to the calubration of the beta and neutron detectors used in the experiment. The efficiency of the β-detector was determined with the ordinary β-γ coincidence method. In order to determine the efficiency function of the neutron counter the (p,n)-reactions in ^{51}V and ^{57}Fe were used for the production of monoenergetic neutrons. The energy dependence was found to be strong.

Recently, the aluminium vapour method was used to determine the P_n-values of $^{89-91}Br$ and $^{139-141}I$. The results of the measurements are given in Table 1. A manuscript has been submitted to Z. Phys. A. [4]. A survey of branching ratios has been prepared for a Consultants' Meeting arranged by IAEA [5].

7.1.4 Population of excited states via delayed neutrons

The branching of the delayed neutrons to various excited states in the final nucleus has been studied experimentally for ^{81}Ga, $^{88,89}Br$, $^{93-96}Rb$, ^{135}Sb, and ^{139}I. A report [6] has been prepared. Theoretical calculations of the delayed neutron feeding of excited states in the residual nuclei via delayed neutrons have also been performed. The model used is a simple statistical description assuming a Fermi-gas level density formula and with neutron widths calculated from the optical model. The β-strength function was taken to be proportional to the level density and the Porter-Thomas fluctuations in the beta-intensity and in the neutron-widths has been taken into account.

The reproduction of the experimental results is not quite satisfactory, and there seems to be a need for a more refined model for the process, with more exact level density calculations and using a more realistic β-strength function.

7.1.5 The decay of neutron-rich gallium and germanium isotopes

During 1979, decay studies of $^{79-82}Ga$ and $^{79-82}Ge$ have been performed, involving measurements of single γ-rays, conversion electrons, and $\gamma\gamma$-coincidences. These nuclei are in the vicinity of the doubly-closed shell nucleus ^{78}Ni, and at present OSIRIS is the only facility where they are available for investigation.

Detailed decay schemes have been obtained for most of the nuclides listed above, and the analysis will be completed in the near future.

7.1.6 Energy spectrum of antineutrinos around a nuclear reactor

The study of the energy spectrum of antineutrinos around a nuclear reactor has been completed, and the results have been published [7]. Such spectra are necessary for the interpretation of experimental data obtained using a reactor as the source of antineutrinos. The spectrum, which have deduced mainly from beta-decay experiments carried out at OSIRIS, is weaker at high energies (above 8 MeV) than earlier published spectra. It agrees well with another study using different techniques, which was also published in 1979 [8].

7.1.7 Theoretical study of the evaporation step in nuclear reactions

Using ISOL-techniques it is possible to measure nuclear reaction yields covering a very wide yield range. An example is the yield pattern of cesium isotopes from mass 114 to mass 137, formed by spallation of lanthanum with 600 MeV protons. In this case the yields vary by a factor of more than 10^{10}, and it is very interesting to see whether the present two-step model, a nucleonic cascade followed by an evaporation step, for spallation reactions can explain the experimental results. A theoretical study based on this model is being carried out in coolaboration with Dr E Hagebö from the nuclear chemistry department of the University of Oslo. The evaporation part

of the reaction is handled using the method described in a report which has recently been published [9]. The study is not yet finished, but the calculations carried out so far show that the reaction model offers a useful description of spallation reactions.

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TABLE I

P_n-values of Bromine and Iodine Precursors

Precursor	Half-life (s)	P_n (%)
^{89}Br	4.37	12.9 ± 0.8
^{90}Br	1.92 ± 0.02[a]	23.1 ± 1.7
^{91}Br	0.541	18.2 ± 1.3
^{139}I	2.29 ± 0.02[a]	9.0 ± 0.6
^{140}I	0.59	8.6 ± 0.6
^{141}I	0.43 ± 0.02[a]	25.3 ± 3.0

a) Improved half-life determination.

7.2 Nuclear Spectroscopy Group

B Fogelberg

7.2.1 Studies of the heavy even Sn isotopes

The levels of even mass Sn nuclei populated in the decays of In isotopes have been studied. A report comprising level scheme studies of $^{120-128}Sn$ has recently been published [1]. During 1979 the work has continued with studies of γ-rays, conversion electrons and γγ-delay for the decay $^{130}In \rightarrow {}^{130}Sn$. Measurements of level half lives in ^{116}Sn and ^{128}Sn have also been made. An interesting feature in $^{128,130}Sn$ is a low energy cascade of an E2 and an E1 transition, most probably between

levels with the spin sequence $10^+ \rightarrow 8^+ \rightarrow 7^-$. The half lives of the presumed 10^+ levels in $^{128,130}Sn$ has been measured and since the 10^+ and 8^+ levels can be assumed to be pure $(h_{11/2})^2$ states one is able to deduce the effective charge of the $h_{11/2}$ subshell.

7.2.2 The decay of ^{137}I to ^{137}Xe

The study of this very complicated decay has continued during 1979 and can now be said to be completed. The level scheme shows 100 γ-decaying levels, of which 22 are situated above the neutron binding energy. A report is near comoletion.

7.2.3 Studies of odd mass Sn isotopes

The presence of β-populated isomeric levels in $^{127,129}Sn$ with lifetimes in the μs region have been revealed in a previous study[2)] of these nuclei at OSIRIS. The delayed γ-rays in ^{129}Sn have also been observed[3)] to follow the decay of isomeric levels populated directly in fission, but was then interpreted as transitions in ^{129}Sb.

In a recent preliminary study of these isomers at OSIRIS, we were able to determine the halflife of the isomer in ^{127}Sn to (3.1 ± 0.9) μs. Further measurements are needed to establish the nature of these isomers.

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7.3 Neutron Physics Laboratory

7.3.1 Compilation of Neutron Data for Selected Actinides

B Trostell

The Swedish Nuclear Data Committee has initiated a compilation of a selected set of neutron cross section data for the 16 most important actinide isotopes. The compilation work has been done by a working group consisting of experts in experimental nuclear physics. The work has been spnsored by the Swedish Board for Energy Source Development and the Swedish Nuclear Power Inspectorate.

The main part of the data information has been obtained from the OECD/NEA Nuclear Data Bank at Saclay, France. It consists of 5 evaluated neutron data libraries used in USA, Japan and Western Europe (including Sweden) and of a file (NEUDADA) of experimental neutron data. Besides, recent experimental data have been obtained from laboratory and conference reports.

The aim of the work is to present available data in such a way as to allow a comparison between different evaluated libraries and to judge about the reliablility of these libraries from the experimental data.

The report will be published in the beginning of 1980.

7.3.2 A routine method for accurate neutron energy determination with time-of-flight technique

N Olsson and B Trostell

In a recently started program for precision measurements of elastic scattering cross sections for carbon, efforts have been made to develop a routine method for accurate determination of the incident neutron energy.

The method is based on a direct measurement of the time-of-flight difference between neutrons and γ-rays from the target over a known flitht path. From this information the neutron energy can be determined with high accuracy.

The method has been tested by making transmission measurements over the 2.078 MeV resonance in carbon in steps of 10 keV. Since the resonance is narrow (≈ 8 keV) compared to the neutron energy spread (≈ 50 keV), the measurements also gave information of this energy spread. The $T(p,n)^3He$ reaction with a 1.5 cm long gas target was used to produce the neutrons. The flight path was 6 meters.

7.3.3 Measurements of the inelastic neutron scattering cross sections of ^{141}Pr and ^{89}Y

B Trostell

The prompt γ-rays from the scattering process has been measured down to the reaction threshold with a high resolution Ge(Li)-detector.

The measurements were performed with neutrons, produced by the T(p,n)-reaction with 2 ns ion pulses. The neutron energy steps were 0.1 MeV and the energy range covered was from 1.1 to 2.5 MeV for ^{141}Pr and from 2.2 to 3.5 MeV for ^{89}Y. The total energy spread of the neutrons hitting the scatterers was less than ± 50 keV. The Ge(Li)-detector was positioned in a massive shield, wiewing the scatterer through a narrow collimator. An analysis is in progress, including construction of level schemes using the γ-ray and neutron energies.

7.3.4 Neutron elastic scattering from Pb_r and Bi

N Olsson, B Holmqvist and T Wiedling

A comparison of the neutron elastic scattering cross sections of Pb_r (radiogenic lead; 88.2 % ^{206}Pb) and ^{209}Bi in the energy region 1 - 10 MeV shows some interesting differences. A broad maximum at about 3 MeV in the cross section for ^{209}Bi and natural Pb is absent for ^{206}Pb. In order to investigate the situation, experiments have been started to measure the cross sections of Pb_r and ^{209}Bi with high accuracy in the energy range 1 - 8 MeV.

As a part of this project the differential elastic scattering cross sections of ^{209}Bi and Pb_r have been measured at nine incident energies in the range 2 - 4 MeV, with an energy spread of ± 0.025 MeV. The experimental arrangements have been described elsewhere [1].

The five points close to 3 MeV, measured in steps of 70 keV, show no sign of any fine structure in this energy region within the resolution of the experiment. For ^{209}Bi the data points around 3 MeV and at 3.5 and 4 MeV clearly confirm the existence of a giant resonance at about 3 MeV. The results for ^{206}Pb may indicate the presence of a giant resonance also in this case. However, more data are necessary to confirm that.

7.3.5 The Prompt Fission Neutron Spectrum of ^{239}Pu

P I Johansson and T Wiedling

There is a current interest in ever increased accuracy of experimental neutron data. There are some standard reference data and a number of other important data which are under continous review byINDC and NEANDC. The energy spectra of fission neutrons of ^{235}U, ^{238}U and ^{239}Pu belong to this category. The neutron spectra of these isotopes have been studied for a number of years at this laboratory. Preliminary results from the ^{239}Pu measurements have been reported recently and a detailed report is in preparation.

7.3.6 Neutron capture in and below the giant resonance region (see also 4.1.3)

N Olsson

I Bergqvist and R Zorro, Department of Physics, University of Lund

T Andersson, A Lindholm, L Nilsson and A Waheed, Tandem Accelerator Laboratory, Uppsala.

(This work has been performed at the Tandem Accelerator Laboratory, Uppsala).

Previous work on neutron capture in selected nuclei over the entire mass region has shown the importance of direct

and semidirect processes in the giant resonance region.

Hitherto, most of the experiments have been concentrated on studies of the E1 giant resonance, but it is also interesting to study giant multipole resonances other than the giant dipole. The neutron radiative capture method has thus been utilized in an attempt to look for the E2 strength in ^{209}Pb. Recent measurements in the neutron energy range 5.5 - 8 MeV were performed to study this isoscalar E2 strength and the analysis of the data is at present in progress.

Measurements have also been performed to obtain the contributions to the capture cross sections from compoung reactions and from capture through single particle states. One part of this work has been to study neutron radiative capture through single particle states in the light nuclei ^{28}Si [2] and ^{32}S.

7.3.7 Precision Recording and Analysis of Experimental Fast Neutron Elastic Scattering Angular Distributions

T Wiedling

A study [3] has been made of a few factors influencing the fitting of a Legendre polynomial expansion to a neutron angular distribution and the accuracy with which total integrated elastic scattering cross sections can be estimated. The fitting procedure has to be considered in detail before an estimate can be made of the integrated cross sections. However, regardless of whether the experiments are to be performed mainly because of pure physics interests or following a request for data for applied purposes, the measurements are usually done using the same techniques; there will probably only be minor differences in the data collection, for instance with regard to the choice of primary neutron energy or angular range. The fitting procedure is most important when analyzing precision angular distributions of all types of neutron scattering measurements.

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7.4 Facility for monoenergetic neutrons

N Ryde and W Klamra, Chalmers University of Technology, Gothenburg
R Bergman, Studsvik Energiteknik AB

The facility for extracting monoenergetic neutron beams of 24 keV energy from the R2 reactor, has been used for development of a method to detect and measure the cadmium content in different human organs as kidney and liver and for radiobiological investigations for studies of the influence of neutron radiation on cromosomes of plants.

For the purpose first mentioned "phantoms" were irradiated with the 24 keV neutrons. It was found that the uncertainties in the estimated cadmium content was less than 20 %.

With the present arrangement 15 mg cadmium in the kidneys may be estimated with a precision of ± 10 mg at 2 minutes exposure. By exchanging the Ge(Li)-detector used for one with about 5 times higher efficiency a cadmium content of 4 mg in the kidneys may be measured with a precision of ± 3 mg in one minute, giving a dose as low as 35 mrad in the most exposed tissue.

8. TANDEM ACCELERATOR LABORATORY, BOX 533, S-751 21 UPPSALA

8.1 Nucleon capture reactions in and below the giant resonance region

I Bergqvist and R Zorro, Department of Physics, University of Lund, N Olsson, Studsvik Science Research Laboratory, ~~and~~ T Andersson, A Lindholm, L Nilsson and A Waheed

(see also 4.1.3)

Parts of this work are performed in collaboration with scientists from Jozef Stefan Institute, Ljubljana, Yugoslavia, Chalk River Nuclear Laboratories, Canada, Centre d'Etudes de Bruyéres-le-Chatel, France, Los Alamos Scientific Laboratory, USA and University of Oregon, USA.

Experiments designed to study the effects of compound nucleus processes in radiative neutron capture in calcium, nickel, yttrium and radiogenic lead have been completed and a report has been accepted for publication (1).

The work aiming at investigating neutron capture in silicon and sulphur via single-particle type resonances (2) has been continued to higher energies. Further experiments are planned for the spring of 1980.

The experiment on proton capture in ^{176}Yb was summarized in an internal report about a year ago (3). Since then more elaborate direct-semidirect model calculations according to the prescription of Boisson and Jang (4) have been performed (in collaboration with J Krumlinde, Department of Mathematical Physics, Lund University of Technology).

The method to measure neutron capture cross sections developed in collaboration with Centre d'Etudes de Bruyères-le-Chatel (CEBC) and Los Alamos Scientific Laboratory (LASL) has been exploited in two recent reports (5,6).

The investigation of the isospin structure of the giant dipole resonance in ^{41}Ca performed in collaboration with LASL has been completed and a report will appear shortly in the Physical Review (7).

As was pointed out in the preceeding annual report fast neutron radiative capture is a promising tool to localize E2 strength in nuclei. The method has been utilized in an effort to look for E2 strength in ^{209}Pb in a collaboration between TLU and LASL. Recently measurements in the neutron energy range 5.5-8 MeV were performed at Uppsala to look for isoscalar E2 strength. The analysis of the data is being performed. Measurements designed to investigate isovector E2 strength in ^{209}Pb are planned for the spring of 1980 at LASL.

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8.2 Measurements of the $^{6}Li(n,t)^{4}He$ cross section

T Andersson, C Nordborg* and L Nilsson, and H Condé,
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The cross section for the $T(\alpha,{}^{6}Li)n$ reaction is being measured over a wide excitation energy range of ^{7}Li.

The differential cross section at 3° in the laboratory system has been measured at alpha energies from 11.5 to 16.7 MeV corresponding to neutron energies from about 200 keV to 2.8 MeV for the $^{6}Li(n,t)^{4}He$ reaction. Measurements of the angular distributions of the ^{6}Li ions are in progress at a number of alpha bombarding energies between 13 and 18 MeV.

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9. UNIVERSITY OF STOCKHOLM

9.1 Department of Physics, Low Energy Division

C. Bargholz

During 1979 the Low Energy Division at the University of Stockholm has directed its research effort primarily to other fields than nuclear structure physics. Only one project have been finished during the year in that particular area.

Gamma-ray multipolarities in ^{206}Pb studied by gamma-gamma directional correlations.

Gamma-gamma directional correlations have been measured in the decay of ^{206}Bi. Using a multichannel goniometer with 2 Ge- and 6 Na I-detectors the directional correlations have been measured for 17 cascades in ^{206}Pb. From the results, electromagnetic multipole mixing ratios are deduced.

Transition energy (keV)	Multipolarity	Mixing ratio[x] (δ ($\lambda/\lambda + 1$))
184	M1 + E2	- 0.013(25)
344	M1 + E2	0.085(63)
398	M1 + E2	0.028(42)
497	M1 + E2	- 0.02(11)
516	E3 + M4	0.014(23)
537	M1 + E3	- 0.05(10)
620	M1 + E2	- 0.33(29)
632	M1 + E2	- 0.12(3)

x) The sign of the mixing ratio is defined according to the use of emission matric elements.

CINDA Type Index of Neutron Cross Section Measurements

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Element S	A	Quantity	Type	Energy Min	Max	KDK-37 Page	Lab	Comments
Li	6	(n,t)	EXPT PROG	2.0+5	2.8+6	32	TLU	ANDERSSON+. MEAS. ON INVERSE REACTION
NA	23	(n,γ)	EXPT PROG	1.5+7	-	8	LND	ANDERSSON+. ACT. TECHNIQUE
SI	28	(n,γ)	EXPT PROG	3.2+6	1.5+7	9	LND	BERGQVIST+. RESULTS COMP. TO DSD CALC.
S	32	(n,γ)	EXPT PROG	3.2+6	1.5+7	9	LND	BERGQVIST+. RESULTS COMP. TO DSD AND CN CALC.
MN	55	(n,γ)	EXPT PROG	1.5+7	-	8	LND	ANDERSSON+. ACT. TECHNIQUE
GA	79	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GA	80	FISS PROD γ	EXPT PROG			22	SVR	ALEKLETT+.
GA	81	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GA	81	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
GA	82	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GE	79	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GE	80	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GE	81	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
GE	82	FISS PROD γ	EXPT PROG			22	SWR	ALEKLETT+.
BR	85	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
BR	86	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
BR	87	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
BR	88	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
BR	88	FISS PROD β	EXPT PROG			21	SWR	ALEKLETT+.
BR	89	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
BR	89	DELAYED NEUTS	EXPT PROG			20	SWR	ALEKLETT+.
BR	90	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+
BR	91	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+

Element S	A	Quantity	Type	Energy Min	Max	KDK-37 Page	Lab	Comments
RB	93	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
RB	94	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
RB	95	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
RB	96	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
Y	89	INELASTIC γ	EXPT PROG	2.2+6	3.5+6	27	SWR	TROSTELL.
Y	89	(n,γ)	EXPT PROG	1.5+7		8	LND	ANDERSSON+. ACT. TECHNIQUE
IN	115	(n,γ)	EXPT PROG	1.0+6	1.5+7	8	LND	ANDERSSON+. ACT. TECHNIQUE
SN	116	FISS PROD γ	EXPT PROG			24	SWR	FOGELBERG+.
SN	127	FISS PROD γ	EXPT PROG			25	SWR	FOGELBERG+.
SN	128	FISS PROD γ	EXPT PROG			24	SWR	FOGELBERG+.
SN	129	FISS PROD γ	EXPT PROG			25	SWR	FOGELBERG+.
SN	130	FISS PROD γ	EXPT PROG			24	SWR	FOGELBERG+.
SB	135	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
I	127	(n,γ)	EXPT PROG	1.5+7		8	LND	ANDERSSON+. ACT. TECHNIQUE
I	137	FISS PROD γ	EXPT PROG			25	SWR	FOGELBERG.
I	139	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
I	139	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
I	140	FISS PROD β	EXPT PROG			20	SWR	ALEKLETT+.
I	140	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
I	141	DELAYED NEUTS	EXPT PROG			21	SWR	ALEKLETT+.
XE	137	FISS PROD γ	EXPT PROG			25	SWR	FOGELBERG+.
BA	138	(n,γ)	EXPT PROG	1.5+7		8	LND	ANDERSSON+. ACT. TECHNIQUE
PR	141	INELASTIC γ	EXPT PROG	1.1+6	2.5+6	27	SWR	TROSTELL.
W	186	(n,γ)	EXPT PROG	1.5+7		8	LND	ANDERSSON+. ACT. TECHNIQUE
AU	197	(n,γ)	EXPT PROG	1.0+6	1.5+7	8	LND	ANDERSSON+. ACT. TECHNIQUE
PB	206	DIFF ELASTIC	EXPT PROG	2.0+6	4.0+6	27	SWR	OLSSON+. TOF 15° TO 160°
PB	209	(n,γ)	EXPT PROG	5.5+6	8.0+6	31	TLU	BERGQVIST+. REACTION MECHANISM STUDIES

Element S	A	Quantity	Type	Energy Min	Max	KDK-37 Page	Lab	Comments
BI		DIFF ELASTIC	EXPT PROG	2.0+6	4.0+6	27	SWR	OLSON+. TOF 15° TO 160°
PA	231	FISSION	EXPT PROG	1.0+5	4.0+6	18	FOA	HOLMBERG+.
TH	232	FISSION	EXPT PROG	1.6+6	1.8+6	18	FOA	HOLMBERG+.
TH	232	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
		$\bar{\nu}$					FOA	CONDÉ.
U	233	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
		$\bar{\nu}$					FOA	CONDÉ.
U	234	PHOTO-FISSION	EXPT PROG			15	LND	LINDGREN+.
U	235	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		ELASTIC					SWR	TROSTELL.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM
		RES INT CAP						
		$\bar{\nu}$					FOA	CONDÉ.
U	238	(n,γ)	EXPT PROG	1.5+7	-	8	LND	ANDERSSON+. ACT. TECHNIQUE
U	238	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		INELASTIC					SWR	TROSTELL.
		(n,γ)					SWR	TROSTELL.
		(n,2n)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
		$\bar{\nu}$					FOA	CONDÉ.
NP	237	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON
PU	239	SPECT FISS N	EXPT PROG			28	SWR	JOHANSSON+.
PU	239	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		ELASTIC					SWR	TROSTELL.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
		$\bar{\nu}$					FOA	CONDÉ.

Element S	A	Quantity	Type	Energy Min	Max	KDK-37 Page	Lab	Comments
PU	240	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
PU	241	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
PU	242	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					AE	HÄGGBLOM.
AM	241	TOTAL	COMP PROG	THR	2.0+7	3	CTH	CHRISTIANSSON.
		FISSION					CTH	-"-
		(n,γ)					CTH	-"-
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
AM	243	TOTAL	COMP PROG	THR	2.0+7	3	CTH	SANDBERG.
		FISSION					CTH	-"-
		(n,γ)					CTH	-"-
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
CM	244	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
CM	245	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
CM	246	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
CM	247	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						
CM	248	TOTAL	COMP PROG	THR	2.0+7	3	FOA	CONDÉ.
		FISSION					TLU	NORDBORG.
		(n,γ)					LND	ANDERSSON.
		RES INT FISS					AE	HÄGGBLOM.
		RES INT CAP						