KDK-2
EANDC(OR)-135/L
INDC(SWD)-5/G

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN SWEDEN, SEPTEMBER 1973

SWEDISH NUCLEAR DATA COMMITTEE
STOCKHOLM, SWEDEN

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PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN SWEDEN, SEPTEMBER 1973

Compiled by

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National Defence, Stockholm
Sweden

CONTENTS

Preface

This report gives information about the Swedish Nuclear Data Committee formed in 1972 and about other nuclear data activities in progress at different laboratories in Sweden.

The neutron data measurements are described as in earlier progress reports in some detail while only an orientation is given about nuclear structure and reaction measurements in progress at different laboratories. The report gives also short information about new experimental facilities and about compilation and evaluation works.

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Laboratories submitting contributions to this compilation

1. ORIENTATION CONCERNING THE SWEDISH NUCLEAR DATA COMMITTEE

The need of nuclear data information in different applied nuclear physics fields in Sweden was investigated in 1971. As a result of this investigation a Swedish Nuclear Data Committee (KDK) was formed. The Committee had its first meeting in December 1972. It consists at present of ten members representing on one hand users of nuclear data within the reactor, shielding, fusion, medical and biological fields from reactor industries, national institutions and universities and on the other hand producers from national institutions and universities.

The Committee meets twice a year handling questions concerning information, coordination and consultation of works in the nuclear data field.

The Committee will annually publish reports about nuclear data activities in Sweden and compile request lists of nuclear data needs in different applied areas.

The present members of the Committee are listed below where also is marked the introducers of items in different applied areas.

Mr G Apelqvist (Thermal reactors)
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Dr L G Strömberg (Compilation and evaluation)
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2. NEUTRON AND FISSION DATA MEASUREMENTS

2.1 NEUTRON PHYSICS

2.1.1 Elastic and Inelastic Neutron Scattering

2.1.1.1 Fast neutron elastic scattering measurements

M.A. Etemad, B. Holmqvist and T. Wiedling
Neutron Physics Laboratory, Studsvik

In the present work neutron elastic scattering angular distributions have been measured at 7.0 MeV neutron energy for the elements As, Nb, Cd, Sb, Hf, Pb and Pb_r (radiogenic lead).

The measurements were performed with a time-of-flight spectrometer, employing a NE213 proton recoil liquid scintillator thus allowing pulse shape analyses to discriminate against γ-rays. The neutron elastic cross sections were determined relative to the well known n-p cross sections by the use of a polythene reference sample. The angular distributions were measured in the interval 20^o to 70^o in steps of 5^o and in the interval 70^o to 160^o at each 10^o. The measured angular distributions have been corrected for the effects of the finite geometry of the target-scatterer-detector assembly, the neutron flux attenuation in the scattering sample, the intensity distribution of the target neutrons from $H^2(d,n)$ reaction as well as multiple scattering of neutrons. These corrections have been performed by a Monte Carlo program. The corrected experimental angular distributions are expressed in terms of the Legendre polynomial functions.

The measured angular distributions have been compared with distributions calculated with a local nuclear potential discussed in the earlier reports [1, 2]. Five of the potential parameters, i.e. U, W, r_{oU}, r_{oW} and a, have been adjusted to obtain the best agreement with the measured and the calculated angular distributions. The spin-orbit potential depth and the diffuseness parameter of the imaginary potential were kept constant, in the parameter search procedure, since it has been shown [1] that the angular distributions are comparatively insensitive to variations in these parameters. Their values were chosen to be 8.0 MeV and 0.48 fm, respectively.

The optical model parameters obtained for the studied elements by the five parameter search procedure are given in Table 1. Also shown in this table are the values of the measured total elastic cross sections (σ_{el}^{exp}) as well as those calculated by the optical model using the search parameter data (σ_{el}) and the generalized parameters (σ_{el}^{gen}). The measured and calculated angular distributions for elements As, Au, Sb and Pb_r are plotted in Fig. 1. The solid lines represent the optical model predicted cross sections by using the five parameter search procedure data while the dashed lines demonstrate the distributions calculated according to the generalized parameters. In the case of the Pb_r two scattering samples with different sizes were used in the measurements. The experimental results obtained by using the larger sample are shown in Fig. 1 and 2 by filled circles.

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[1] Holmqvist, B., A Systematic study of fast neutron scattering in the energy region 1.5 to 8.1 MeV, Arkiv Fysik 38 (1968) 403

[2] Holmqvist, B. and Wiedling, T., Optical model analyses of neutron scattering at 8 MeV, Nucl. Phys. A188 (1972) 24

[3] Holmqvist, B. and Wiedling, T., Optical model analyses of experimental fast neutron elastic scattering data, 1971 (AE-430) and Journ. Nucl. Energy (in press)

Table 1

Elements	As	Nb	Cd	Sb	Hf	Au	Pb	Pb_r
U(MeV)	49.5	46.4	51.4	48.8	46.7	48.09	45.5	45.3
W(MeV)	9.36	9.38	10.81	9.43	7.09	7.53	7.81	6.33
r_{oU}(fm)	1.18	1.24	1.17	1.20	1.20	1.18	1.23	1.24
r_{oW}(fm)	1.20	1.22	1.25	1.24	1.23	1.25	1.30	1.30
a(fm)	0.67	0.65	0.69	0.68	0.66	0.68	0.66	0.63
σ_{el}(b)	2.12	2.14	1.74	1.81	2.33	2.71	3.14	3.27
σ_{el}^{gen}(b)	2.05	1.93	1.82	1.81	2.46	2.86	3.13	3.10
σ_{el}^{exp}(b)	2.40	2.10	1.73	1.65	2.39	2.51	2.72	2.78

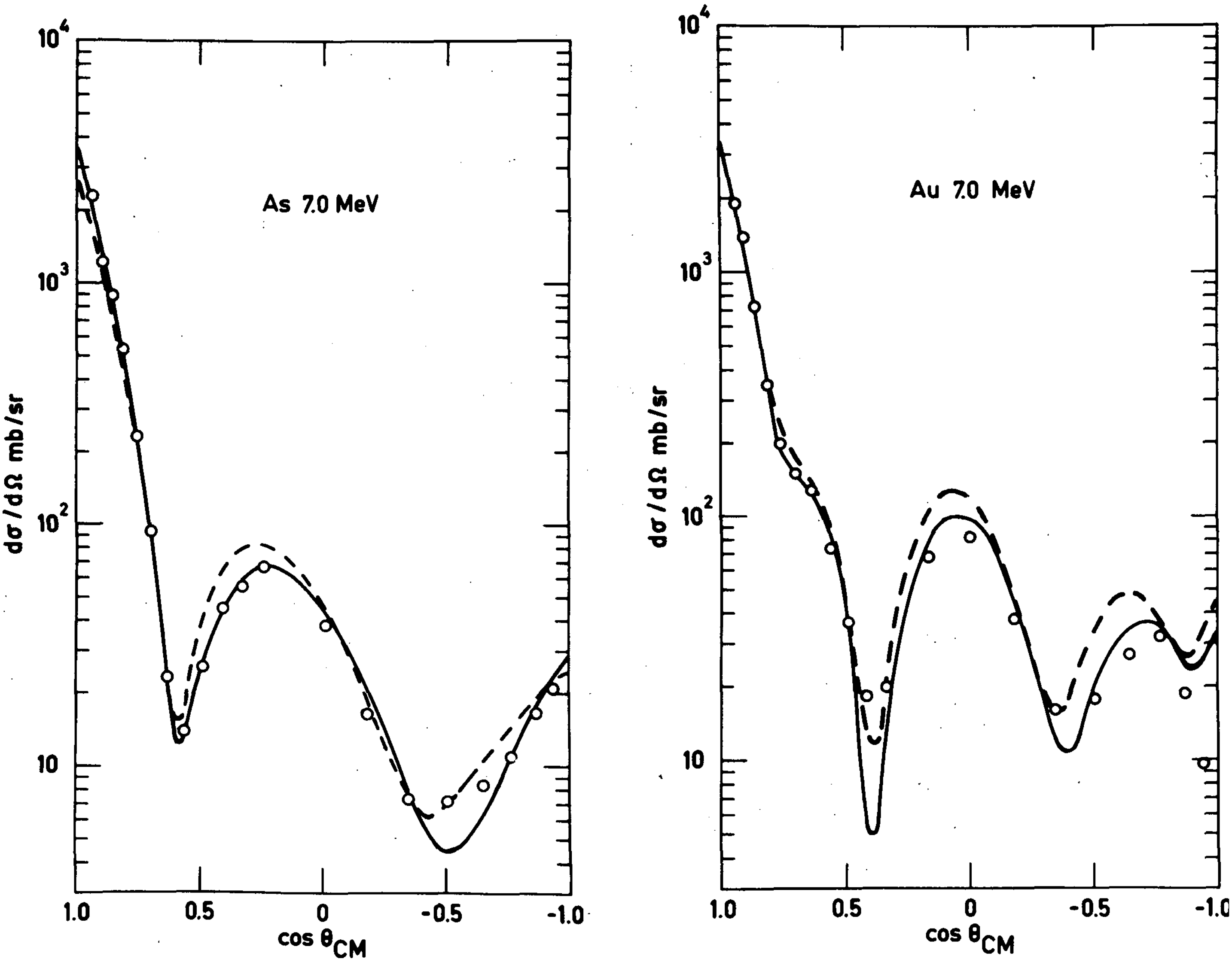

Fig. 1

Measured and calculated angular distributions for elements As and Au. The solid lines represent the optical model predicted cross sections by using the five parameter search procedure data while the dashed lines demonstrate the distributions calculated according to the generalized parameters.

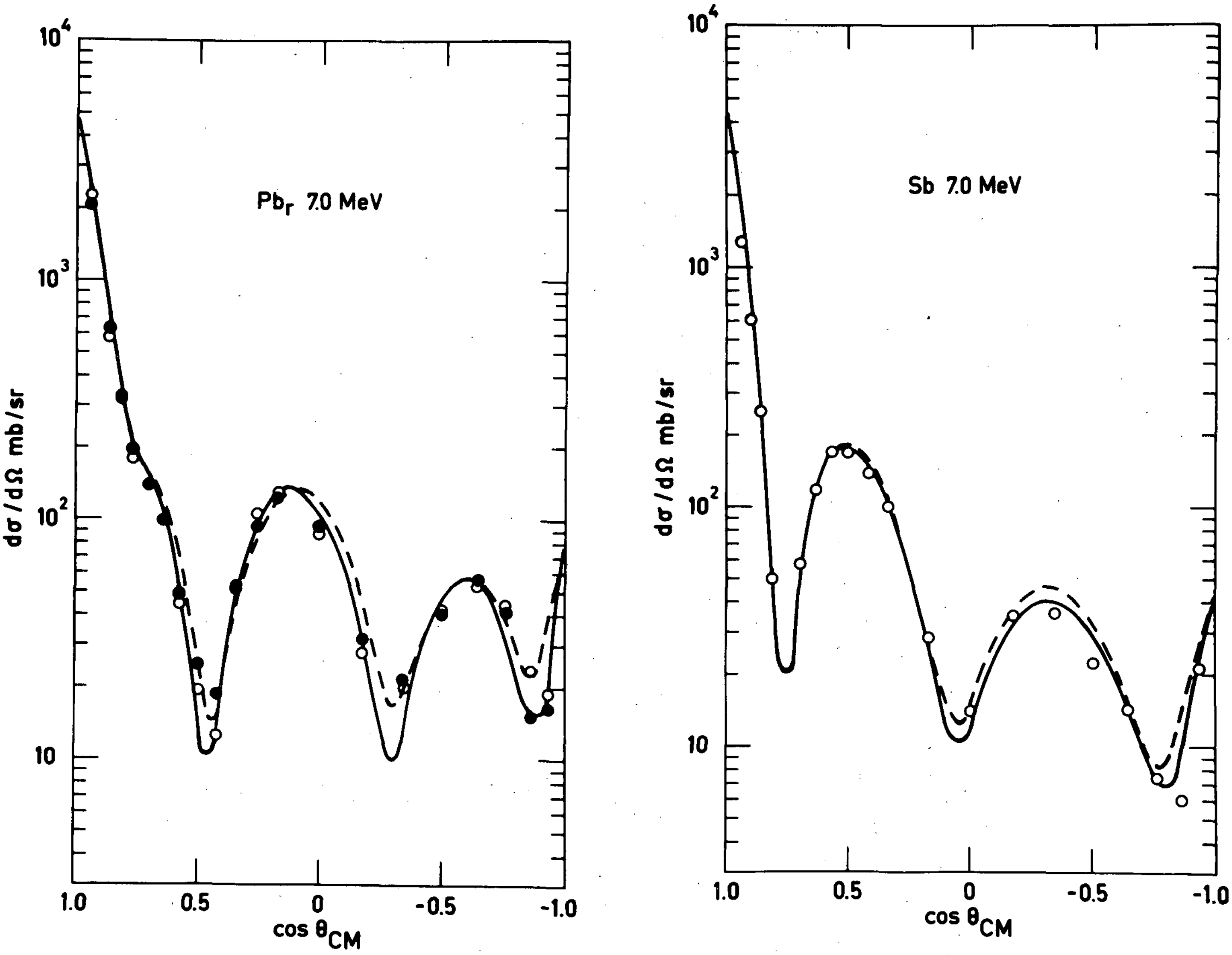

Fig. 2

Measured and calculated angular distributions for elements Sb and Pb_r. The solid lines represent the optical model predicted cross sections by using the five parameter search procedure data while the dashed lines demonstrate the distributions calculated according to the generalized parameters.

2.1.1.2 Neutron elastic scattering at forward angles

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The purpose of the present experiment was to measure neutron elastic scattering in the MeV range from elements of different mass number at angles between 10° and 40° and in steps of 2.5°. The measurements have been made with the standard time-of-flight spectrometer. However, without special experimental arrangements, the errors of the cross section measurements at small angles made with this instrument are larger than those at other scattering angles because of the increase of the background due to source neutrons hitting the detector and to neutrons being scattered by the material of the collimator shielding. Therefore the signal-to-background ratio was essentially improved by increasing the distance between the neutron target and the scattering sample. The angular spread introduced by the finite dimensions of the target-scatterer-detector system was 1.5°. This figure is considered sufficiently small for the purpose of the present measurements.

The forward angle differential cross sections measured for Fe, Co, Ni, Pb and Bi have been combined with the differential cross sections previously measured at the Neutron Physics Laboratory for the same elements at angles larger than 20° in an optical model study. A standard spherical optical potential with a spin orbit term and with Saxon-Woods and derivative Saxon-Woods form factors for the real and imaginary potential parts has been used for that purpose. The real and imaginary potential depths and the real diffuseness parameter as well as the radii parameters have been varied to obtain the best agreement between experimental and calculated angular distributions. The results of these calculations are shown as solid lines in Fig. 1. They correspond both to the results obtained with the new and old cross section data combined as well as optical model calculations based only upon the old data since these results are indistinguishable from each other within the scale of the figure. The optical model parameters extracted

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from these investigations are given in Table 1 and 2 from which it is clear that except for minor discrepancies the same set of potential parameters are obtained with and without the forward angle scattering results. Only in the case of iron we see that the U values differ somewhat but this is compensated for by a lower value of r_{oU} in accordance with the well known ambiguity relationship between these parameters. Finally it is also clear that the experimental total elastic cross sections calculated with and without the forward scattering data agree within the accuracy of the measurements.

The results of the small angle scattering measurements show that when the angular range above about 20^{o} has been carefully measured, it is not necessary to extend the cross section measurements for angles below 20^{o}.

Table 1

Optical model parameters from five parameter search calculations made on the basis of measured forward angle differential elastic cross sections together with previous Studsvik cross section data for angles larger than 20°. Also included are integrated calculated and measured cross sections.

Element	Fe	Co	Ni	Pb	Bi
U	49.6	50.1	51.9	46.0	45.1
W	11.04	10.00	11.27	7.60	6.26
r_{oU}	1.21	1.20	1.17	1.24	1.24
r_{oW}	1.15	1.10	1.16	1.27	1.30
a	0.66	0.66	0.71	0.57	0.67
σ_{SE}*	1.84	2.02	1.86	3.20	3.37
σ_{CE}	0	0	0	0	0
σ_{EL}	1.84	2.02	1.86	3.20	3.37
σ_{A}	1.49	1.50	1.58	2.48	2.53
σ_{T}	3.33	3.52	3.44	5.68	5.90
σ_{EL}^{exp}	1.73±0.09	1.87±0.09	1.75±0.09	2.74±0.11	3.34±0.15

* All the cross sections are expressed in barns

Table 2

Optical model parameters from five parameter search calculations made on the basis of previously measured differential cross section data in the angular interval 20° to 160°. Also included are integrated calculated and measured cross sections.

Element	Fe	Co	Ni	Pb	Bi
U	46.7	49.1	51.5	45.8	44.9
W	10.45	10.22	11.30	7.67	6.22
r_{oU}	1.24	1.22	1.18	1.24	1.24
r_{oW}	1.24	1.11	1.18	1.27	1.26
a	0.66	0.66	0.71	0.57	0.68
σ_{SE}*	1.85	2.02	1.86	3.15	3.34
σ_{CE}	0	0	0	0	0
σ_{EL}	1.85	2.02	1.86	3.15	3.34
σ_A	1.51	1.52	1.59	2.49	2.44
σ_T	3.36	3.54	3.45	5.64	5.78
σ_{EL}^{exp}	1.80±0.09	1.81±0.09	1.79±0.09	2.72±0.11	2.99±0.15

* All the cross sections are expressed in barns

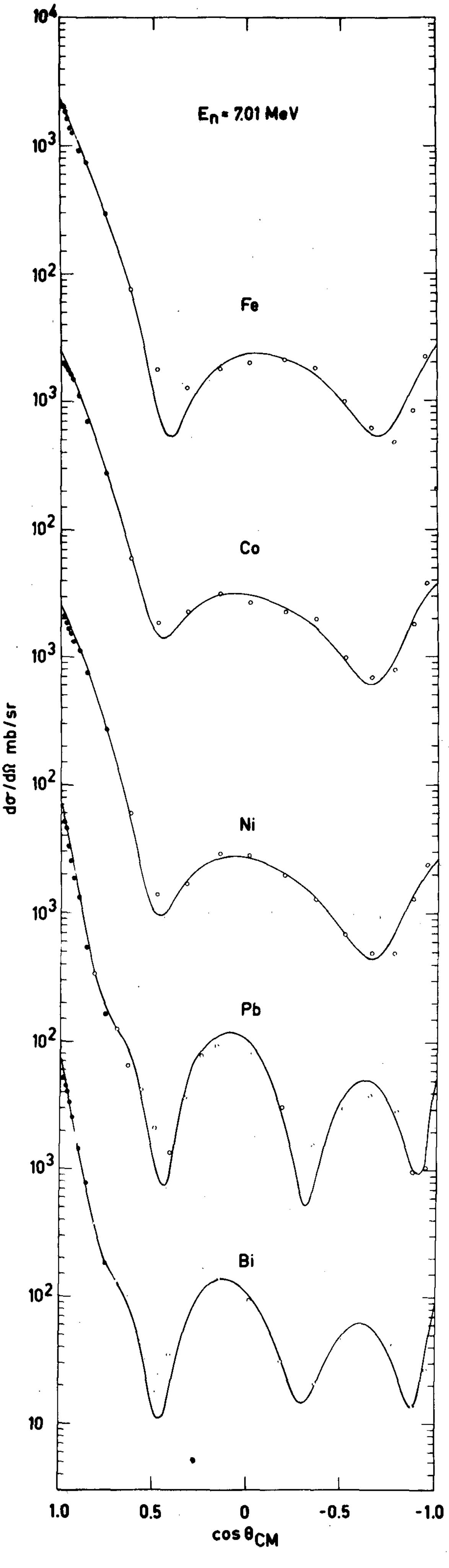

Fig. 1

The elastic angular distributions on Fe, Co, Ni, Pb and Bi at 7.01 MeV incident neutron energy. The filled circles are data from the present measurements and opened circles are data from previous measurements.

2.1.1.3 Fast neutron inelastic scattering measurements in several elements

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The present investigation was undertaken to perform a systematic study of neutron inelastic scattering cross sections for a number of elements between Al and Bi over a wide energy range. Neutron inelastic scattering processes have been observed in the elements: Al, Ti, V, Mn, Fe, Ni, Nb, Pb, Pb_r (radiogenic lead) and Bi in the energy region from 2 to 4.5 MeV at energy steps of 250 keV.

The experimental excitation functions obtained in this work have been compared with those calculated using the Hauser-Feshbach [1] formalism corrected for the level width fluctuation and resonance interference effects according to Moldauer [2]. Furthermore, the results of this work are compared with the available experimental data reported in the literature as well as the excitation functions according to the Evaulated Neutron Data File (ENDF/B).

An overall comparison of the experimental and theoretical results obtained in this work indicates that the calculation of neutron inelastic scattering cross sections based on Hauser-Feshbach formalism together with the Moldauer corrections will in general give a good description of those cross sections. At low energies where there are few channels open for the decay of the compound nucleus the corrections according to the Moldauer theory are more important and cannot be neglected. At higher energies where inelastic transitions to many states of the target nucleus will be energetically possible these corrections are small and pure H-F calculations seem to be adequate.

This type of calculations is very sensitive to the level properties of the target nucleus. Accordingly, proper knowledge of the level energies and their spins and parities are necessary for realistic calculations.

A detailed paper giving all the results of the present work is prepared and will be published shortly as an AE-report.

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[1] Hauser, W. and Feshbach, H., Phys. Rev. 87(1952)366

[2] Moldauer, P.A., Phys. Rev. 135B(1964)642

2.1.1.4 A systematic study of fast neutron inelastic scattering in the energy range 2.0 to 4.5 MeV

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During the last four years fast neutron inelastic scattering from twenty elements in the atomic mass region 24 to 209 has been measured with high resolution time-of-flight technique in the energy range 2.0 to 4.5 MeV in steps of 0.25 MeV. The experimental results have been interpreted in terms of the Hauser-Feshbach statistical model corrected according to Moldauer for level width fluctuations and resonance-interference effects. For most of the investigated elements the general conclusion is that the experimental neutron inelastic scattering cross sections as a rule can be adequately described in terms of the H.F.-model properly corrected according to Moldauer.

However, for excitation energies higher than about 2.5 MeV there are groups of levels in the target nucleus which cannot be separated in a neutron time-of-flight experiment with the present state of art. These data have been compared with the corresponding calculated cross sections by adding the partial cross sections of the group. For Mn as well as for some other elements the calculated cross sections are in these cases systematically higher than the experimental ones (Fig. 1). Since the cross sections for inelastic scattering are sensitive to the parity and spin of individual levels, these parameters have been varied in order to improve the fit between experimental and calculated cross sections but without success. One possible explanation for these discrepancies could be that some of the given levels have not single particle character which are the only levels which can be taken into account in a Hauser-Feshbach calculation.

At higher incident neutron energies only the lowest excited states are resolved in the time-of-flight spectra for some elements, e.g. Nb, In and Ta. The shape of the continuous spectrum obtained in these cases can be used to test statistical models describing the level density in the nucleus. Calculations have been made based on a level density derived from the Fermi gas model.

The continuous spectra observed for the above mentioned elements and energies have also been studied in terms of the expression

$$N(E) = \text{const } E \exp(-E/T)$$

and values for the parameter T have been extracted. The experimental values of the parameter T obtained for Nb, In and Ta are shown in Table 1. These values are in good agreement with those reported by Thomson [1].

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[1] D.B. Thomson, Phys. Rev. 129 (1963) 1649

Table 1

Element	Primary neutron energy MeV	T MeV
Nb	4.50	0.48±0.05
In	4.26	0.41±0.04
	4.50	0.43±0.04
Ta	3.78	0.44±0.04
	4.02	0.47±0.04
	4.26	0.47±0.04
	4.50	0.49±0.04

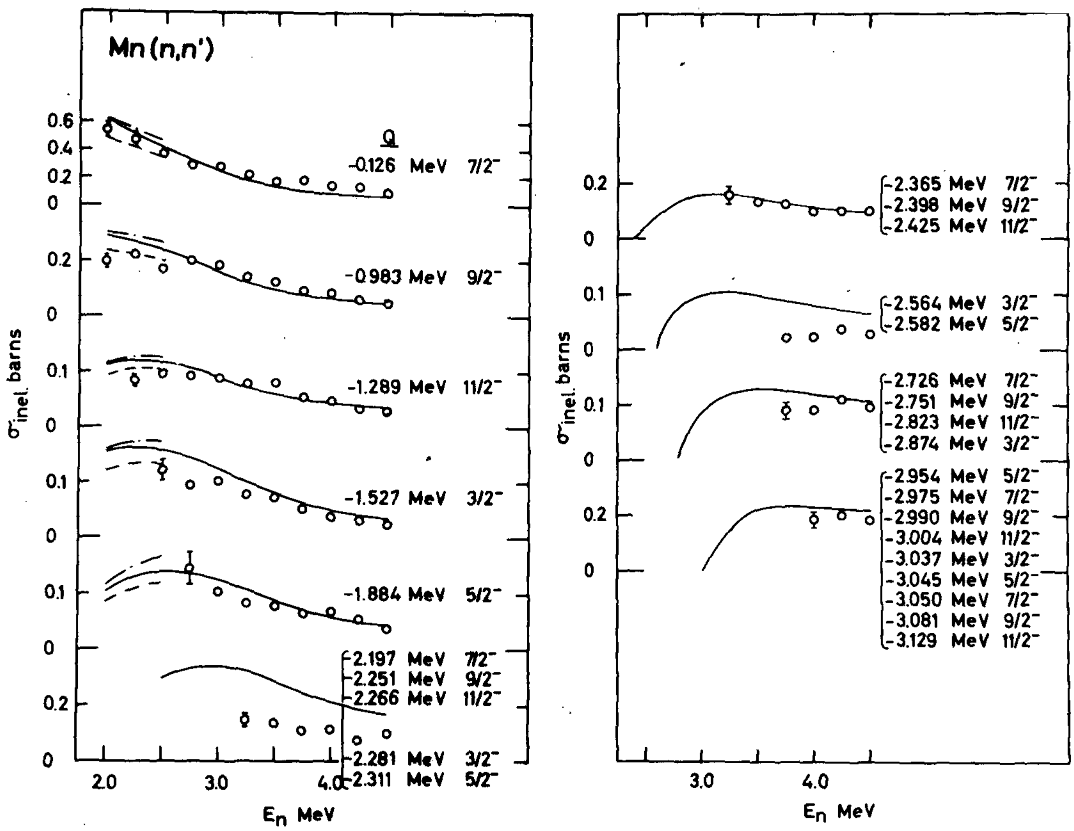

Fig. 1

Excitation functions for inelastic scattering from Mn. The experimental results (circles) are compared to cross sections calculated by use of the Hauser-Feshbach formalism (solid lines) as well as to cross sections calculated according to Moldauer with $Q_\alpha = 0$ (dashed lines) and $Q_\alpha = 1$ (the third line).

2.1.1.5 Energy distribution of neutrons from (n,n') and (n,2n) reactions

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An experiment was performed to determine the energy distribution of neutrons from (n,n') and (n,2n) reactions on Fe, Nb, Mo, Pd, Cd, Nd, Sm, Hf, Ta, Au, Pb and Bi samples at 8 MeV bombarding neutron energy. Samples of natural isotopic composition were chosen to cover a broad region of mass numbers. Some of the samples consist of a single isotope with (n,2n) threshold below the bombarding energy (Ta) or with (n,2n) threshold above 8 MeV (Nb, Au).

8 MeV neutrons were produced by the D(d,n) reaction with a pulsed ion beam of 1.5 nsec width. The neutron detector consisting of a liquid scintillator with pulse shape discrimination properties was placed at a distance of 300 cm from the sample. The relative efficiency of the detector was determined by observing the angular distribution of neutrons scattered on hydrogen as well as detecting neutrons from the $T(p,n)^3He$ reaction. Two BF_3 long counters were used to monitor the neutron flux. The measurements were performed using time-of-flight technique. The energy calibration of the spectrometer was determined by measuring elastic and inelastic neutron scattering on different elements having well established level scheme.

The neutron spectrum measurements were done at 120^o degree relative to the direction of the incident beam. The angular distribution of neutrons from Mo(n,n') and Mo(n,2n) reactions has been determined between 30^o and 150^o degrees in 30 degree steps.

The experimental result will be compared with a recently developed theory [1, 2]. This calculation method, based on the original Weisskopf model of the compound nucleus, avoids the usual rough and ambiguous approximations and for most nuclei gave predictions in

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good agreement with the experimental data at 14 MeV bombarding neutron energy [1]. A comparison between the experimental and theoretical results is given in Fig. 1 for the Nb(n,n') reaction, the theoretical curve is taken from reference [2]. The data analysis is still in progress so the results should be considered as tentative.

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[1] Gy. Kluge and L. Jéki, Report KFKl-72-17 (1972)

[2] L. Jéki and Gy. Kluge, J. of Nucl. Energy 27 (1973) 115

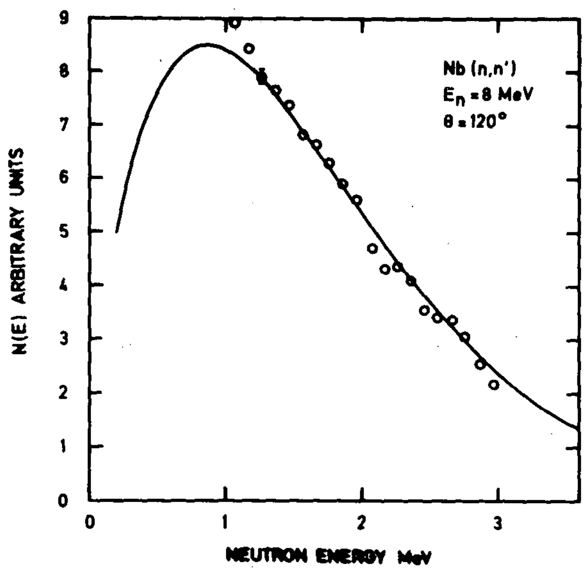

Fig. 1

A comparison between the experimental and theoretical results for the Nb(n,n') reaction.

2.1.1.6 Study of the gamma-ray production in neutron scattering on light nuclei

Henri Condé, Lars-Göran Strömberg, Research Institute of National Defence, Stockholm, Claes Nordborg and Leif Nilsson, Tandem Accelerator Laboratory, Uppsala

Measurements of the gamma-ray production cross section of ^{16}O have been made at the Tandem accelerator at Uppsala. Neutrons in the energy region 7.0 - 10.5 MeV were produced through the $D(d,n)^3He$ and $T(p,n)^3He$ reactions in gas targets.

A large NaI crystal has been used as the gamma detector. The neutron flux was measured with a proton recoil telescope. Data handling is in progress.

Simultaneous measurements of inelastic gamma-rays and elastic neutron scattering is planned for ^{14}N in the same energy region with a Ge(Li) gamma-ray spectrometer and a liquid scintillator as neutron detector.

2.1.1.7 A study of the (n,2nγ)-reaction in the energy interval 16 - 20 MeV

V. Corcalciuc*, B. Holmqvist and G.A. Prokopets**
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The (n,2n) and (n,n') reactions are very interesting to study since they are dominating for middle weight nuclei when the incident neutron energy is in the interval from about 12 MeV to 23 MeV. Because of experimental difficulties the data information available in this energy interval is very scarce. In our experiments the energy dependence of the cross sections for the production of discrete γ-ray lines have been measured in the neutron energy interval from 16 MeV to 22 MeV and for the elements F, Fe and Co. For that purpose samples (diameter 8.5, height 1.0 cm) were irradiated with 2 ns bursts of neutrons produced by the $T(d,n)^3He$ reaction. The γ-rays following (n,2n) processes were observed with a well shielded 100 cm^3 Ge(Li)-detector. Neutrons were separated from γ-rays by time of flight technique. The γ-ray interval of interest in the measurements was from 0.2 MeV to 3 MeV. The primary neutron flux was monitored with a BF_3 - long counter as well as with a time-of-flight monitor. Contribution of γ-rays from neutron inelastic scattering of D(d,n) neutrons were corrected for by making a separate scattering experiment with such a neutron source using the time-of-flight monitor for normalization purposes. The background was observed with a plexiglass sample. The cross sections were related to the known cross section of the $^{63}Cu(n,2n)^{62}Cu$ reaction taken from the evaluation of Nakasima [1]. Data analyses are in progress and here only the results for iron will be given. These are considered as being characteristic for the entire experimental material.

A typical γ-ray spectrum observed for Fe at a primary neutron energy of 16.2 MeV is shown in Fig. 1. The upper spectrum has been taken with the iron sample. The lower spectrum has been collected with a plexiglass sample. The last spectrum shows the same γ-ray

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lines and intensities as the one observed without any scatterer in position. Peaks corresponding to neutron inelastic scattering and (n,2nγ)-reactions in ^{56}Fe were indentified on the basis of the known level schemes of ^{55}Fe and ^{56}Fe. The weak lines shown contains more than a thousand counts.

Excitation functions of the $^{56}Fe(n,2n)^{55}Fe$ reaction corresponding to the excited states in ^{55}Fe have been plotted as a function of the incident neutron energy in Fig. 2.

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[1] K. Nakasima, Progr. Theoret. Phys. (Kyoto) 14 (1957) 126

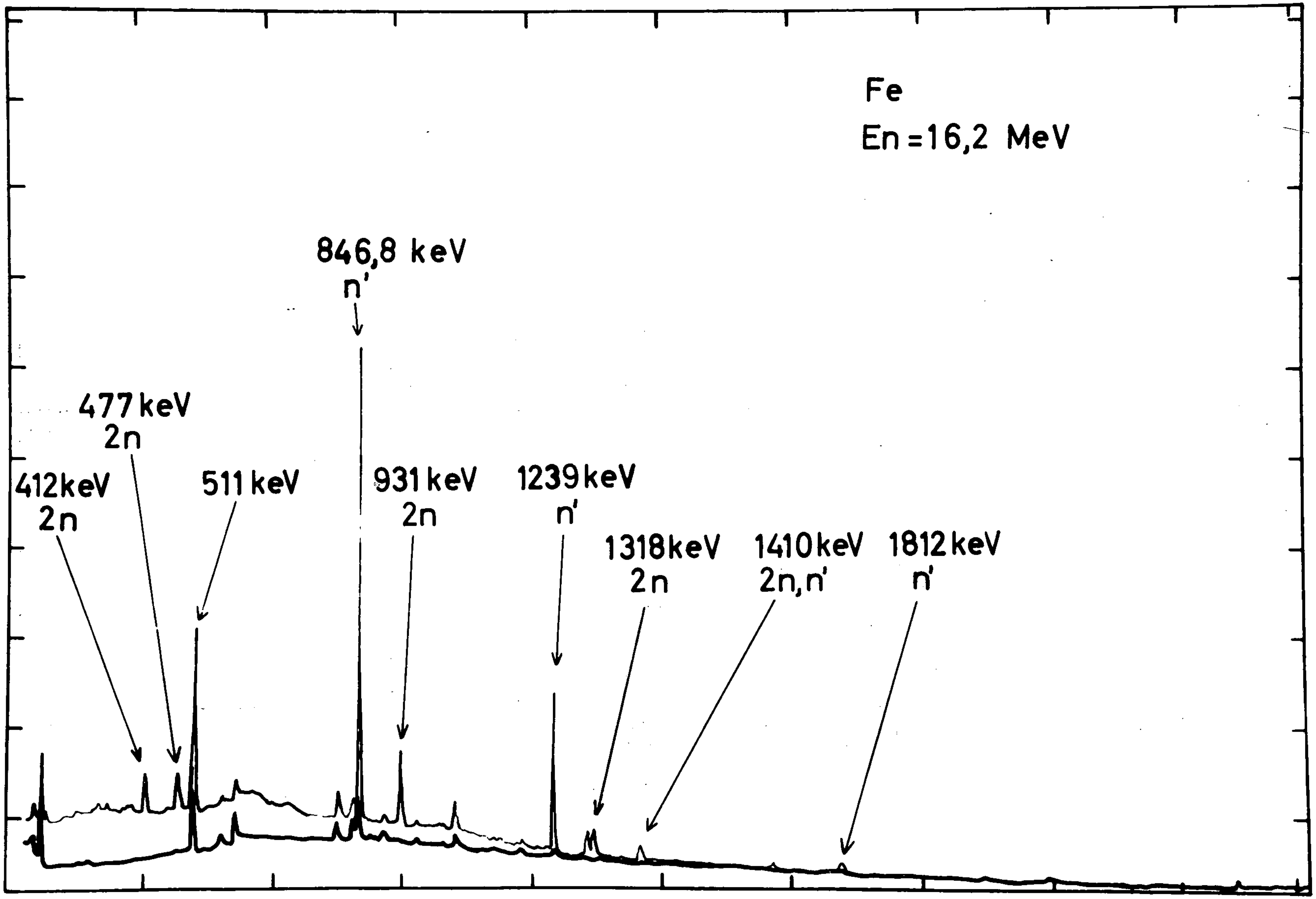

Fig. 1

A study of the $(n,2n\gamma)$-reaction in the energy interval 16 - 20 MeV.

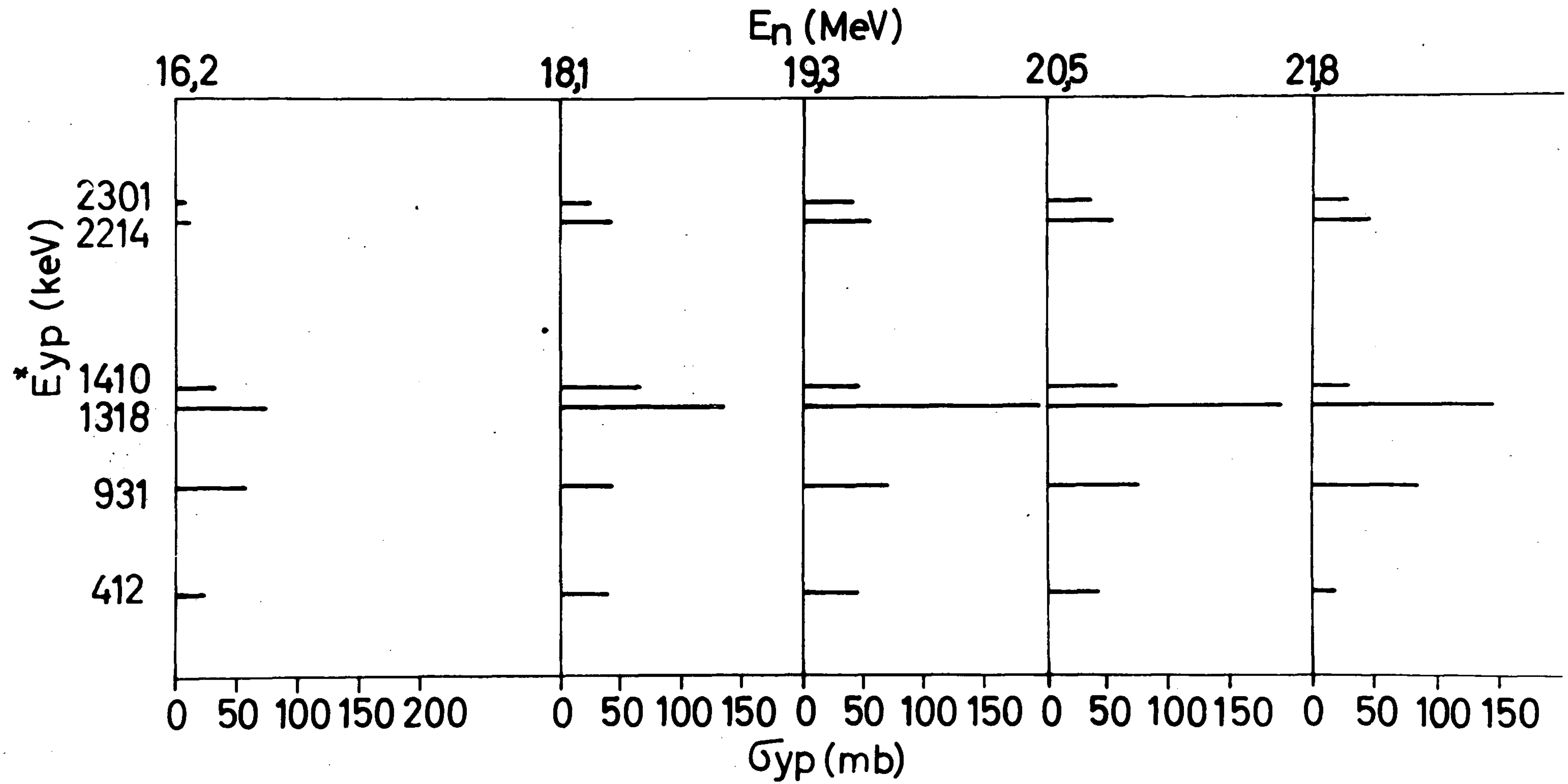

Fig. 2

A study of the (n,2nγ)-reaction in the energy interval 16 - 20 MeV

2.1.1.8 Fast neutron interaction with the ^{9}Be-nucleus

V. Corcalciuc*, B. Holmqvist, G.A. Prokopets** and
T. Wiedling
Neutron Physics Laboratory, Studsvik

The aim of the present work was to measure elastic and inelastic scattering from ^{9}Be and also to study the continuum spectrum due to the (n,2n) process in that nucleus. The measurements were carried out at 3.52, 4.20, 5.57, 6.08 and 7.01 MeV incident neutron energies using the T(p,n) and the D(d,n) reactions as neutron sources. Angular distribution measurements of elastic and inelastic neutron scattering were performed in the angular range 20° to 160° in steps of 10°. Measurements were also made at 2.98 and 7.60 MeV incident energies at 30° and 90° in order to study the continuum spectrum. The spectra were recorded with standard time-of-flight technique together with a neutron detector with gamma discrimination properties. The flight path was 300 cm. The total energy spread was ± 100 keV.

A typical time-of-flight spectrum taken at 5.57 MeV energy and at 90° is shown in Fig. 1. It is clear that the level at 2.43 MeV is strongly excited by neutron inelastic scattering. On the other hand there does not seem to be any evidence for the excitation of the 1.70 and 2.78 MeV levels in ^{9}Be. The excitation of these states is probably not observed because the reaction ^{9}Be(n,n'n)^{8}Be takes place with a much larger probability than the ^{9}Be(n,n')^{9}Be reaction.

The neutron elastic angular distributions have been analysed in terms of a standard spherical optical potential including a spin-orbit potential. The real and imaginary potential parts consisted of Saxon-Wood and derivate Saxon-Woods form factors, respectively. The real and imaginary potential depths as well as the corresponding radii parameters and the real diffuseness parameter were varied to obtain the best agreement between measured and calculated cross sections. The spin-orbit potential depth and the diffuseness parameter of the imaginary part were kept constant throughout the

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calculations. Their values were 8.0 MeV and 0.48 fm, respectively. The results of these calculations are shown in Fig. 2 where the solid lines are the sum of the differential shape elastic cross sections and the differential compound elastic cross sections. The latter have been calculated on the basis of the Hauser-Feshbach formalism. The distributions at the two lowest energies are less well described by the model probably because of the broad resonance in the excitation function of elastic scattering from ^{9}Be in that energy region. The values of the parameters obtained in the optical model calculations are shown in Table 1 together with measured and calculated total cross sections. It is clear that a consistent set of parameters have been obtained at the three highest energies. The deviation from the general trend at the lowest energies is obvious.

The elastic and inelastic angular distributions are at present investigated in terms of an optical model in which collectiv effects are taken into account. The experimental angular distributions will also be analysed by using the DWBA approach by taking deformation into account.

The continuous evaporation spectrum observed for ^{9}Be is analysed in terms of a nuclear temperature.

Table 1.

Spherical optical model parameters derived from five parameter search calculations by using the experimental fast neutron elastic angular distributions of ^{9}Be

E_n(MeV)	3.50	4.20	5.57	6.08	7.01
U(MeV)	19.06	22.09	32.51	28.25	34.84
W(MeV)	7.82	7.87	5.98	5.47	5.73
a(fm)	0.52	0.46	0.43	0.51	0.50
r_{oU}(fm)	1.10	1.45	1.52	1.56	1.49
r_{oW}(fm)	1.23	1.28	1.42	1.24	1.21
σ_{se}(b)	0.70	1.03	0.96	1.24	0.94
σ_{ce}(b)	0.38	0.33	0.29	0.24	0.16
σ_{el}(b)	1.08	1.36	1.25	1.48	1.10
σ_T(b)	1.40	1.83	2.05	2.26	1.76
σ_{el}^{exp}(b)	1.48±0.06	1.30±0.05	1.21±0.05	1.43±0.06	1.12±0.05
σ_T^{exp}(b)*	2.30	1.90	1.95	1.90	1.80

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* From BNL 325

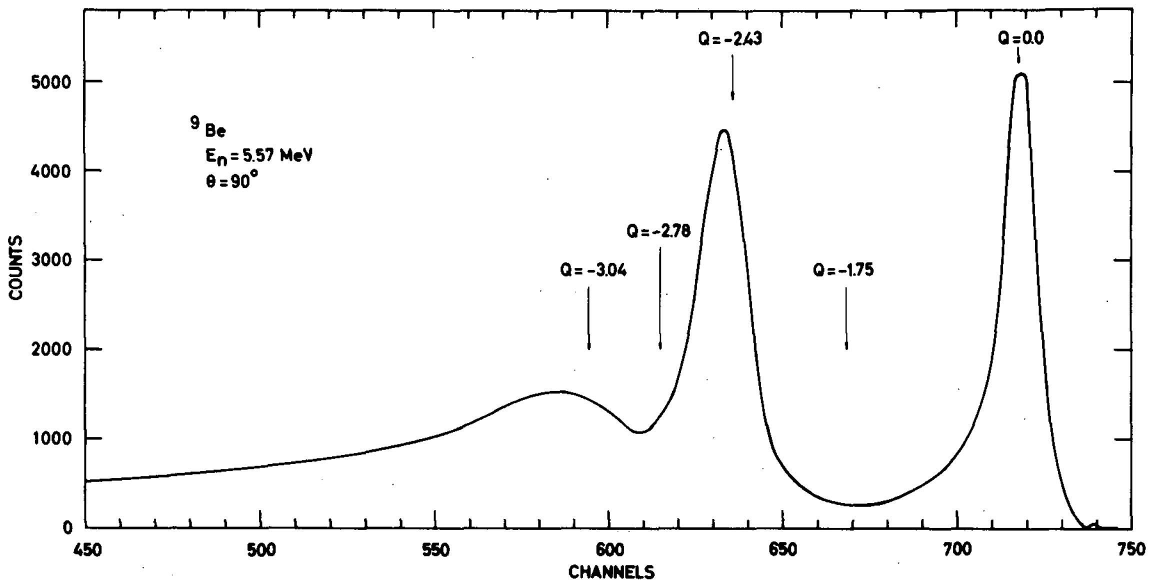

Fig. 1

A typical time-of-flight spectrum at E_n = 5.57 MeV at 90°.
The arrows show the exspected position of the levels in ^{9}Be.

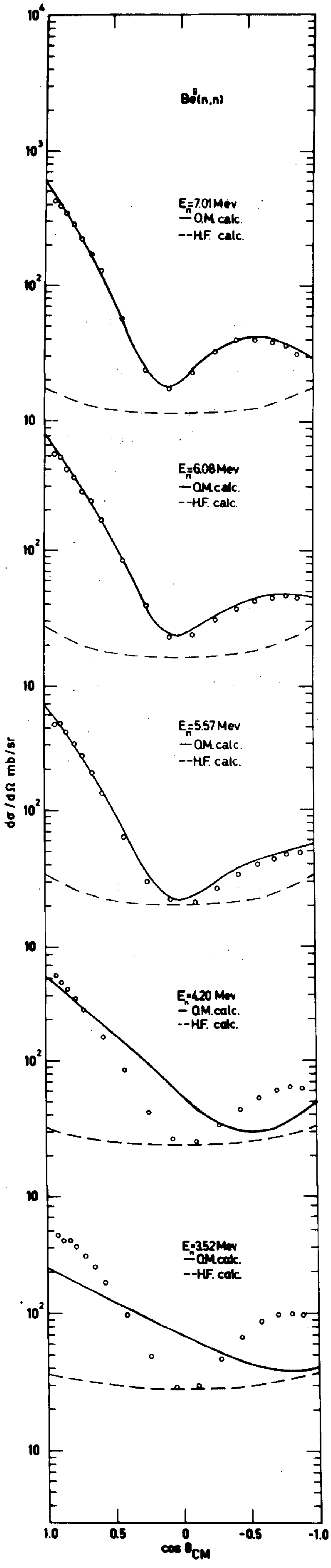

Fig. 2

Fast neutron interaction with the ^{9}Be-nucleus.

2.1.2 Neutron Capture

2.1.2.1 The large liquid scintillator tank for (n,γ) cross-section measurements

J McDonald
Neutron Physics Laboratory, Studsvik

This facility is at present being prepared for measurements of (n,γ) cross-sections in various materials - in particular an attempt will be made to observe a possible structure in the $^{89}Y(n,\gamma)$ cross-section for neutron energies around 1 MeV. Such a structure is suggested by recent theoretical work [1], and capture cross-section measurements can provide a useful complement to studies of the $^{89}Y(n,\gamma)$ capture gamma spectrum which are also under way at present [2].

The electronic system for the detector is being overhauled and optimized, and some preliminary calibration tests using "standard" neutron capture samples (In and Au) are planned before the ^{89}Y studies commence.

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[1] S. Ramavataran et al., Preprint (1973), Laval University, Quebec

[2] D. Earle et al., Private communication

2.1.2.2 Gamma-ray spectra from fast neutron capture in ^{197}Au

E.D. Earle*, Swedish Research Councils' Laboratory,
Studsvik, L. Nilsson, Tandem Accelerator Laboratory,
Uppsala and I. Bergqvist, Department of Physics,
University of Lund, Lund

An anomalous intensity around 5.5 MeV in the γ-ray spectra following neutron capture in nuclei with mass number between 180 and 208 has previously been observed in experiments with thermal and fast neutrons. The effect has been analysed in terms of level density and γ-ray strength function. In particular, two experiments have been performed for the $^{197}Au(n,\gamma)^{198}Au$ reaction with neutrons in the MeV region with different results. The first experiment [1] indicated that the shape of the γ-ray spectrum is almost independent of incident neutron energy, i.e. that the relative intensity of the anomalous bump is nearly constant with neutron energy and that the intensity of γ-rays at energies above the bump is relatively insignificant even at 3-4 MeV neutron energy. On the other hand, the results of a recent experiment [2] at E_n = 2.6 MeV showed a significant stronger neutron energy dependence of the γ-ray spectrum shape with significant intensity in the γ-ray region above the bump. These differences in the spectrum shape affect the derived γ-ray strength functions. The first experiment requires a pygmy resonance while the later experiment requires only a dip below 5.5 MeV in the strength function in order to reproduce the observed spectra.

It seems probable that the difference in the experimental results is due to uncertainties in the background correction of the γ-ray spectra. Both experiments were performed in an open geometry with only a shadow bar for shielding. It was found that the signal-to-background ratio could be significantly improved by an appropriate shielding around the γ-ray detector thereby enabling the background correction to be more accurately determined.

The present experiment was performed with the 2 ns pulsed proton beam of the 6 MV Van de Graaff accelerator at Studsvik. Measurements at E_n = 35 ± 20 keV and 560 ± 120 keV were made utilizing

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* On leave of absence from Chalk River Nuclear Laboratories, Chalk River Canada

the neutrons from the $^{7}Li(p,n)^{7}Be$ reaction and at E_n = 1200 and 1500 ± 125 keV utilizing the $^{3}H(p,n)^{3}He$ reaction. The gold sample, 0.5 cm thick and 8 cm in diameter, was placed at 0° with respect to the proton beam and 15.5 cm from the neutron producing target. The γ-ray detector was a 12.5 cm by 15 cm NaI(Tl) scintillator placed at 90° relative to the proton beam at a distance of 87.5 cm from the sample. The detector was shielded by 10 cm lead immediately around the detector and 40 cm of borated paraffin except for 10 cm diameter aperture between sample and detector. Furthermore, the detector was shielded from neutrons and γ-rays from the target by a shadow bar consisting of 10 cm of tungsten (next to the target), 10 cm of lead and 10 cm of paraffin. The time-of-flight technique was used to further improve the signal-to-background ratio. The time resolution (FWHM) was typically 5 ns. and the signal-to-background ratio for γ-ray energies above 2 MeV about 5:1. The neutron flux was monitored by a long counter placed at 0° with respect to the proton beam and 237 cm from the target.

The γ-ray pulses were recorded in a Nuclear Data 4096 channel analyser used in two-parameter mode, 16 x 256, with 16 channels for the time spectra and 256 channels for the γ-ray spectra. For each neutron energy the spectra were measured with and without the gold sample in the beam. The results from the runs with no sample in the beam showed that the background was independent of the sample. Further tests on the significance of the background due to neutrons scattered by the sample were made with a bismuth sample and it was found that this background was negligible.

It is important that the energy calibration of the γ-ray detector be known if the neutron energy dependence of the γ-ray spectrum is to be determined. All γ-ray spectra contained the 2.22 MeV line from thermal neutron capture in hydrogen. Between each run a calibration spectrum was recorded with beam on and a PuBe source placed in front of the NaI detector giving both 2.22 MeV and 4.44 MeV calibration lines.

Analysis of the data is in progress.

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[1] B. Lundberg and N. Starfelt, Nuclear Physics 67 (1965) 321

[2] E.D. Earle, M.A. Lone, G.A. Bartholomew, W.J. McDonald, K.H. Bray, G.A. Moss and G.C. Nielson, Contribution to Conference on Nuclear Structure Study with Neutrons, Budapest 1972, p. 262

2.1.2.3 Neutron capture reactions in the giant resonance region

I. Bergqvist, B. Pålsson, Department of Physics, University of Lund, J. Eriksson, AB Atomenergi, Studsvik, A. Lindholm and L. Nilsson, Tandem Accelerator Laboratory, Uppsala

Neutron capture in the giant resonance region has been studied for several years at the van de Graaff Laboratory at Studsvik. These investigations were limited to neutron energies below 8.5 MeV, which implied that in most heavy and medium-weight nuclei it was not possible to reach the peak of the giant resonance. The tandem accelerator at Uppsala offers the possibility to produce mono-energetic neutrons of energies up to 11 MeV using the $^{3}H(p,n)^{3}He$ reaction. The tandem accelerator is also equipped with a pulsed ion source and is thus well suited for capture studies of this type.

The main features of radiative capture of nucleons in the giant resonance region have been described with considerable success by a semi-direct capture model. For example, the model accounts well for both the spectrum shapes and the cross sections for 14 MeV neutron capture in a number of nuclei. Also the spectruum shapes and the cross sections of the $^{208}Pb(n,\gamma)$ reaction over the entire range of the giant resonance are well described. There are cases, however, where the model is not as successful, motivating further experimental and theoretical investigations. Our present program within this field concerns studies of the neutron capture process in light nuclei (Si and S) and in nuclei with closed neutron shells (Y and Ce).

For Si and S, measurements have been performed at three neutron energies between 6.5 and 8.5 MeV and at 14.7 MeV. Cross sections for transitions to various single-particle states have been evaluated and a preliminary report on these results have been given at a conference in Budapest. Comparisons between the experiment and predictions of the semi-direct capture model show that the model is not capable of reproducing the shapes of the spectra at energies far below the peak of the giant resonance. At 14.7 MeV, on the other hand the shapes of the experiment and theoretical spectra are quite similar. The quantitative comparison of the cross sections also shows that at 14.7 MeV the theoretical description is satisfactory. At the lower energies the experimental cross sections are much larger than the theoretical ones. The reason for this discrepancy is not understood at present.

Measurements in the 6 to 11 MeV neutron energy range have been performed for Y (N=50) and Ce (N=82). In parallel with the experiments cross sections based on the semi-direct capture model have been calculated. From the preliminary analysis, the model accounts for both the shapes of the gamma-ray spectra and the energy dependence of the cross section. A report on the results of the preliminary data analysis for Y and Ce was given at a recent conference at Asilomar [2]. Further data analysis is in progress.

Some efforts have been devoted to modifications of the code used to calculate semi-direct capture cross sections. In particular, interference between direct and collective capture has been included. The interference is destructive below the peak of the giant resonance and constructive at and above it. An investigation of the possibility of significant changes in the calculated cross sections due to different reasonable choices of the parameter values of the model has also been made. Finally, the radial shape of the particle-vibration coupling potential has been changed from the original surface form to a volume form in accordance with a prescription by Lane. The results of these calculations are being summarized in a report and will be published shortly.

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[1] L. Nilsson, A. Lindholm, I. Bergqvist and B. Lundberg, contribution to the Conference on Nuclear Structure Study with Neutrons, Budapest, July 31 - August 5, 1972

[2] L. Nilsson, A. Lindholm, I. Bergqvist, B. Pålsson and J. Eriksson, contribution to the International Conference on Photonuclear Reactions and Applications, Asitomar, March 26-30, 1973

[3] A.M. Lane, private communication

2.1.2.4 Studies of (d,pγ) reactions in nuclei with mass numbers around A = 50

I. Bergqvist, L. Carlén, Department of Physics, University of Lund, and L. Nilsson, Tandem Accelerator Laboratory, Uppsala

The main purpose of these (d,pγ) experiments is to obtain a better understanding of the neutron capture process in nuclei near the closed neutron shell at N = 28. It is believed, that a comparison between the shapes of the gamma-ray spectra from keV-neutron capture and from weakly bound levels, populated by the neutron transfer in the (d,p) reaction, will tell whether or not the neutron capture processes are similar. Another purpose of the experiment is to use the (d,pγ) reaction as a spectroscopic tool to gain information concerning the structure of bound levels in the residual nucleus.

Until now gamma-rays in coincidence with protons from the bombardment of a ^{56}Fe target with 5.0 MeV deuterons have been recorded both with a big NaI(Tl) detector and with a Ge(Li) detector. The importance of the NaI(Tl) detector in connection with the observation of high-energy transitions is clearly illustrated. The analysis and interpretation of the data are in progress.

2.1.2.5 Neutron capture cross section activation measurements at 14 MeV

I. Bergqvist, B. Pålsson, Department of Physics, University of Lund, J. Eriksson, AB Atomenergi, Studsvik, A. Lindholm and L. Nilsson, Tandem Accelerator Laboratory, Uppsala

An attempt is being made to resolve the discrepancy between 14 MeV neutron capture cross sections for deformed nuclei measured by different methods. The cross sections derived from gamma-ray spectrum measurements are found to be about 1 mb whereas activation measurements give cross sections scattered between 7 and 10 mb. It has been suggested that the discrepancy is due to an experimental error in the activation measurements; in particular the influence of low-energy neutrons is difficult to correct for.

The proton and neutron capture reactions should proceed through the same reaction mechanism. Activation measurements on proton capture in deformed nuclei are rather insensitive to the presence of low-energy incident particles and thus it appears that the (p,γ) reaction offers a better possibility to study nucleon capture in deformed nuclei than the (n,γ) reaction.

Activation measurements to determine the proton capture cross sections have been performed on ^{176}Yb and ^{209}Bi at incident energies 11.2 and 12.0 MeV.

In the measurements of the produced activities a major problem is to distinguish between activities produced through (p,γ), (p,n) and $(p,2n)$. The cross sections for the latter two reactions are at these energies of the order of 1 b.

The β^- activity produced by the $^{176}Yb(p,\gamma)^{177}Lu$ reaction in a target containing 96.43% ^{176}Yb and 0.52% ^{172}Yb, is strongly disturbed by conversion electrons from ^{172}Lu produced by the $^{172}Yb(p,n)^{172}Lu$ reaction. This problem will probably be solved with the use of higher-enriched material. In the case of ^{209}Bi, $^{208, 209, 210}Po$ activities are produced. These are decaying by α emission. Preliminary cross sections estimates give values well below 1 mb in agreement with previous activation work.

2.1.2.6 Experimental investigation of the role of target geometry in 15 MeV neutron capture cross section activation measurements

K. Ponnert and I. Bergqvist, Department of Physics, University of Lund, Lund

Many of the previous results on 14 - 15 MeV neutron capture cross sections obtained by the activation method are found to be both inconsistent and significantly different from those determined by directly observing the capture γ-rays. The numerous discrepancies between different activation results on the same cross sections clearly imply great experimental uncertainties in many of the reported measurements.

In the present work the effect of secondary neutrons on the observed capture cross section for the ^{115}In (n,γ)^{116}In reaction is studied by the activation method. This is performed by systematically varying the target geometry, the sample dimension and the distance target-sample.

The 15 MeV neutrons are produced through the T(d,n)^{4}He reaction, where the deuterons, accelerated to 575 keV, are obtained from the 3 MeV Van de Graaff accelerator. The γ-ray spectra from the irradiated In samples are measured by a 43 cm^3 Ge(Li)-detector and the cross sections are determined relative to the known cross sections of the ^{27}Al(n,α) reaction leading to the 15-hour ^{24}Na.

The preliminary results to date give a 15 MeV neutron capture cross section for In of about 1 mb.

2.1.3 (n,α)-reactions

2.1.3.1 Measurement of the $^{59}Ni(n,\alpha)$ cross section

J. McDonald and N.G. Sjöstrand, Department of Reactor Physics, Chalmers University of Technology, Gothenburg

There is theoretical and indirect experimental evidence that Ni-59 has a thermal (n,α) cross section of the order of 10 berns. A direct determination is under way using a monochromatic beam of thermal neutrons. Two samples are prepared from enriched Ni-58; in one of them a substantial amount of Ni-59 is obtained by irradiation for several months in a reactor. The samples are mounted in a vacuum chamber, and the alpha particles are detected by a silicon surface barrier charged-particle detector.

2.2 FISSION PHYSICS

2.2.1 Studies of the fission threshold structure for ^{232}Th and ^{231}Pa

M. Holmberg and L-E Persson, The Research Institute of
National Defence, Stockholm

Measurements of the fission cross section and of the angular distributions of the fission fragments have been made for ^{232}Th and ^{231}Pa in the fission threshold region. The measurements have been made at the 5.5 MeV Van de Graaff at Studsvik. The "Macrofol" technique was used in the measurements of the angular distributions. The results are to be published.

2.2.2 Measurements of fission cross-section ratios for various fissile nuclei

H. Condé, L.G. Strömberg, Research Institute of National Defence, Stockholm and C. Nordborg, Tandem Accelerator Laboratory, Uppsala

Measurements of fission cross-section ratios, $\sigma_f(X)/\sigma_f(^{235}U)$ for various fissile nuclei are in progress at the 12 MeV Tandem Accelerator at Uppsala. In a test measurement a back-to-back fission chamber with four separate outputs has been used for measuring the $^{238}U/^{235}U$ fission cross section ratio from 5 to 9 MeV neutron energy in steps of 0.3 MeV. The neutrons are produced by the T(p,n) and D(d,n)-reactions in gas-targets. The fission ionization chamber is run in a time-of-flight arrangement with a time resolution of about 5 ns. The fast neutron flux is measured with a proton recoil detector. The total amount of fissile material is about 45 mg, the isotopes being deposited on 0.1 mm Al. (The ^{235}U foils have been supplied by BCMN, Geel and the $^{236,238}U$ and ^{232}Th foils by AB Atomenergi, Studsvik), The experiment is planned to be extended over a wider energy range and to include the nuclei mentioned above.

A measurement is also in progress of the fission fragment angular distributions in the neutron energy range 5 - 10 MeV for the same nuclei. The fragment angular distributions are measured with a scattering chamber containing "macrofol" detectors.

2.2.3 The prompt fission neutron spectrum of ^{235}U and ^{238}U induced by 2.1 MeV neutrons

P.I. Johansson, L. Jéki*, B. Holmqvist and T Wiedling
Neutron Physics Laboratory, Studsvik

The dependence of the shape of the fission neutron spectrum of ^{235}U on the incident neutron energy has been studied. The fissions were induced by 2.1 MeV neutrons with a pulse burst of 1.5 ns duration. The sample consisted of hollow cylinders weighing about 100 g. The proton-recoil scintillation detector was placed 300 cm from the sample at an angle of 90^{o} relative to the incident neutrons. The relative efficiency of the neutron detector was determined by observing the angular distribution of neutrons scattered from hydrogen as well as detecting neutrons from the reactions $T(p,n)^{3}He$ and $T(d,n)^{4}He$. The energy scale of the time-of-flight spectrometer was determined observing neutrons of known incident energy elastically and inelastically scattered from different elements. Prompt and delayed gamma rays were electronically suppressed by a factor of 100 using a time-of-flight spectrometer.

The ratio of the number of ^{235}U fission neutrons induced by 1.2 MeV neutrons to those induced by 0.53 MeV neutrons was studied as a function of fission neutron energy (Fig. 1). The error bars indicate the statistical uncertainties. It is observed that the 1.5 MeV difference in incident energy does not change the shape of the ^{235}U spectrum in the energy range investigated.

The fission neutron spectrum obtained at 0.53 MeV incident neutron energy has been interpreted in terms of a distribution function of the form

$$N(E) \sim \exp(-EA)\sinh(BE)^{\frac{1}{2}}$$

over the energy range 0.6 to 14 MeV.

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* On leave from Central Research Institute for Physics, Budapest, Hungary

The best fit parameters are A = 1.03±0.03 MeV^{-1} and B = 2.43±0.26 MeV^{-1}. The average fission neutron energy calculated with the given distribution and parameters is 2.04±0.09 MeV.

The spectrum from a ^{235}U measurement at 2.1 MeV has been used as a standard to measure the prompt fission neutron spectrum of ^{238}U at the same incident neutron energy. Fig. 2 shows the quotient of the yields of fission neutrons from ^{238}U and ^{235}U. The quotient has been normalized to one. The error bars indicate the statistical uncertainty. It is seen that the fission neutron spectrum shapes for the two isotopes agree within the counting statistics. However the energy range below 2 MeV has not been analyzed for ^{238}U. Thus a mean fission neutron energy for ^{238}U can only be found under the assumption that the spectrum shape for ^{238}U and ^{235}U are equal also below 2 MeV.

The data analysis is still in progress and the results are to be considered as tentative.

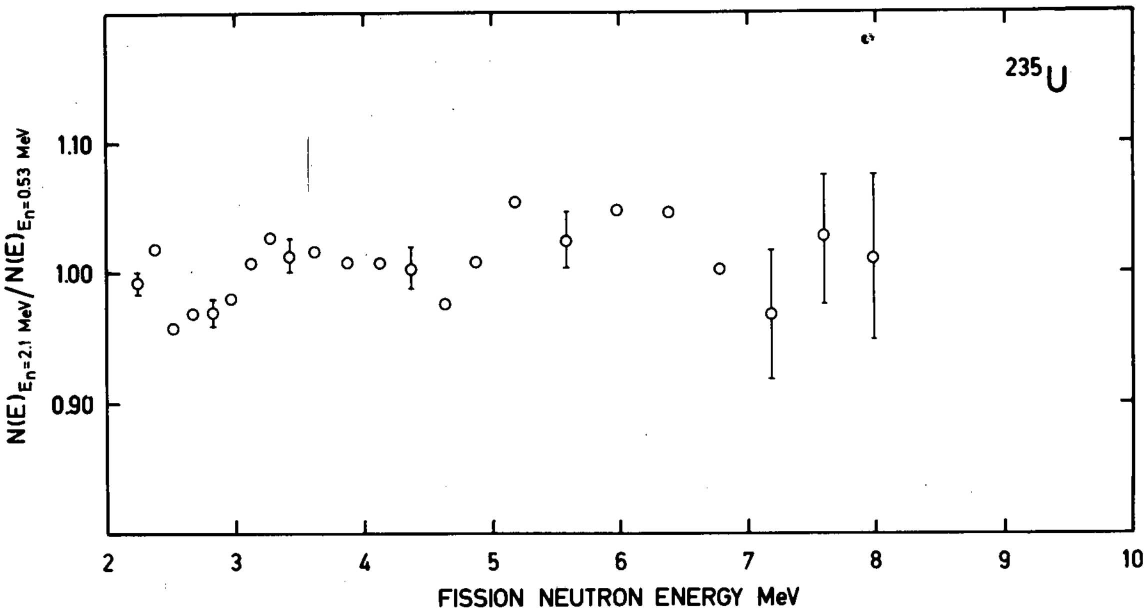

Fig. 1

The quotient of the yields of fission neutrons from ^{235}U at the incident neutron energies 2.1 MeV and 0.53 MeV.

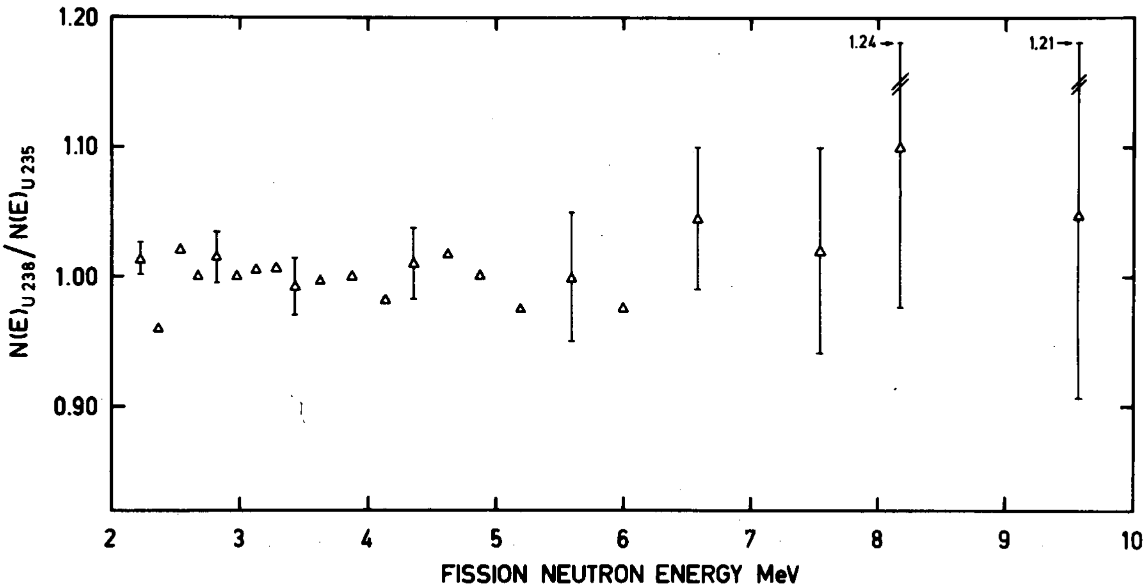

Fig. 2

The quotient of the yields at 90^{o} of fission neutrons from ^{238}U and ^{235}U at an incident energy of 2.1 MeV.

2.2.4 Angular measurements of fission neutrons from ^{235}U and ^{238}U

P.I. Johansson, L. Jéki*, B. Holmqvist and T. Wiedling

Neutron Physics Laboratory, Studsvik

A measurement of prompt fission neutron spectra from ^{235}U and ^{238}U have been performed to determine the angular distribution relative to the direction of the incident primary neutrons. The measurements were also made in order to investigate if there are any systematic errors introduced when the shape of the prompt fission neutron spectrum is observed at only one angle.

The experiments were performed by using time-of-flight technique at an incident neutron energy of (2.07±0.1) MeV. Neutrons were produced by the $T(p,n)^3He$ reaction with a pulsed ion beam of 1.5 ns width. The neutron detector consisting of a liquid scintillator with pulse shape discrimination properties was placed at a distance of 300 cm from the sample. Two BF_3-long counters placed at fixed angles was used to monitor the relative neutron flux. By observing neutrons of known incident energies scattered elastically and inelastically from different nuclei and at different energies the energy scale of the time-of-flight spectra was determined. The ^{235}U and ^{238}U scatterers consisted of hollow cylinders weighing about 100 g.

The angular distribution measurements were performed in angular range from 20^o to 150^o in steps of 15^o. The measurements were made alternatively with the ^{235}U and ^{238}U sample as well as without a sample in position. The measurements at some angles were also repeated.

For evaluation of the angular distribution of fission neutrons $N(E,\theta)$ the number of counts was summed up in the energy range 3 MeV to 11 MeV in steps of 1 MeV. In Figs. 1 and 2 is shown $N(E,\theta)/N(E,90)$ for ^{235}U and ^{238}U respectively, where E is the gravity centre in the energy interval at the angle θ. The quotient $N(\theta)/N(90)$ for ^{235}U and ^{238}U is shown in Figs. 1 and 2 where $N(\theta)$ is the number of counts in the energy range 2.5 to 11 MeV.

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* On leave from Central Research Institute for Physics, Budapest, Hungary

The error bars include counting statistics and uncertainties in the energy scale. The dashed curves in Fig 1 and 2 are the results of fits assuming second order angular dependence described by a Legendre polynomial of the form

$$N(\theta) = A_o P_o + A_1 P_1 (\cos\theta) + A_2 P_2 (\cos\theta)$$

The coefficients A_o, A_1 and A_2 was found to be 1.017, 0.024 and 0.024 for ^{235}U and 1.052, 0.003 and 0.041 for ^{238}U, respectively.

The quotient between the fission neutron spectrum for ^{238}U and ^{235}U was determined for the sum of the spectra of individual angles. The result is shown in fig. 3 and is in good agreement with the quotient between the spectra measured at 90^o (see 2.2.3).

The data analysis is still in progress why the result given is to be considered as tentative.

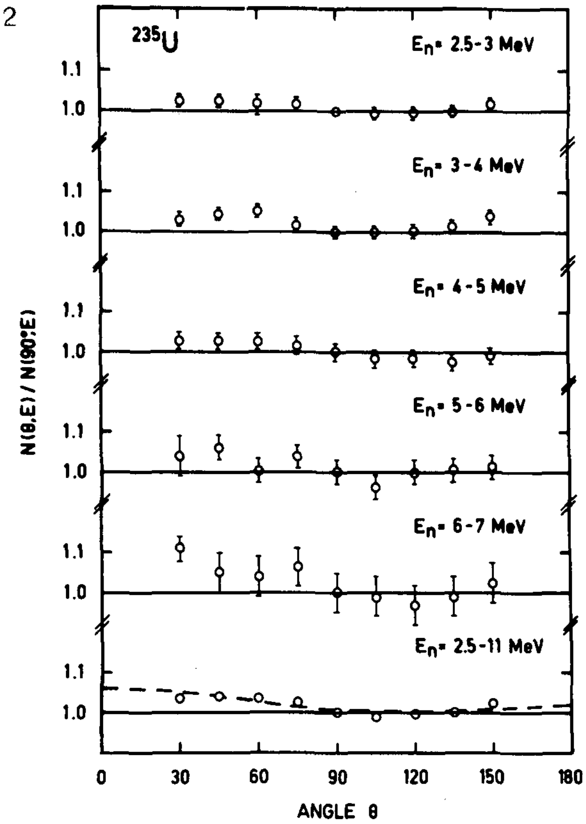

Fig. 1

The relative fission neutron anuglar distribution for ^{235}U plotted as N(θ,E)/N(90,E) were E is the fission neutron energy and θ the angle of the incident and the emitted neutron.

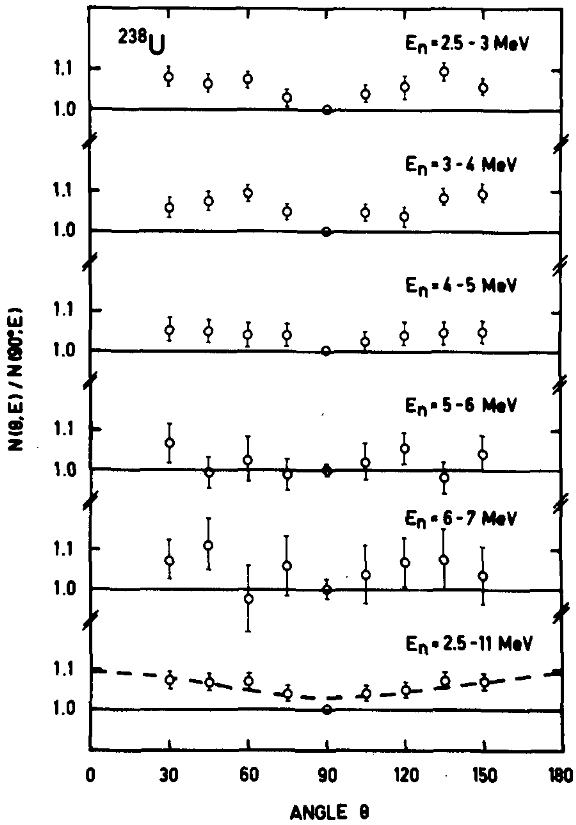

Fig. 2

The relative fission neutron angular distribution for ^{238}U plotted as N(θ,E)/N(90,E) were E is the fission neutron energy and θ the angle of the incident and the emitted neutron.

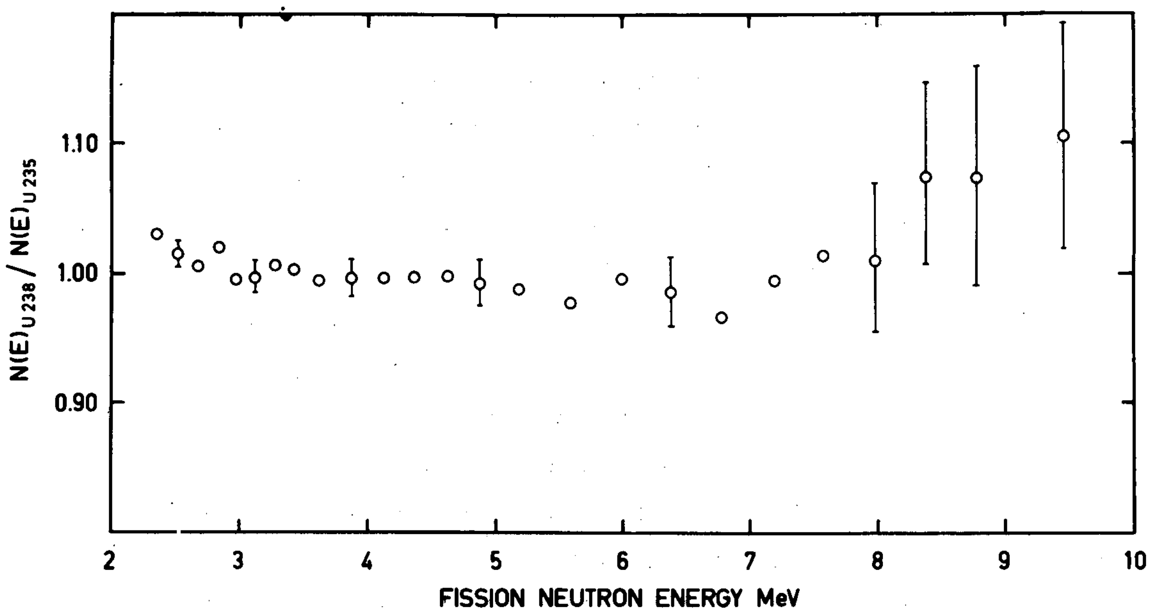

Fig. 3

The quotient of the yields of fission neutrons from ^{238}U and ^{235}U at an incident energy of 2.1 MeV measured at 9 angles between 30° and 150°.

3. NUCLEAR STRUCTURE AND REACTION MEASUREMENTS

3.1 RESEARCH INSTITUTE FOR PHYSICS, 104 05 STOCKHOLM

C J Herrlander

The nuclear research programme at the Research Institute for Physics (AFI) is centred around the two cyclotrons. Alpha-particle beams of up to 14 MeV and 50 MeV, respectively, are mainly used for producing high-spin states in neutron-deficient nuclei. The γ-ray decay of these states is studied in-beam with the help of Ge(Li) high-resolution spectrometers and suitable auxiliary arrangements. Information is thus primarily obtained on the energy, spin and decay properties of such levels, but also quantities like life-times and magnetic moments are studied. The large cyclotron has recently been significantly improved in order to permit the exploitation of heavy ion (carbon, nitrogen, etc.) beams to reach still more neutron-deficient nuclei and states of still higher spins. - An isotope-separator on-line makes it possible to study the decay of very short-lived activities, both neutron-deficient (produced in (HI,xn) reactions) and neutron-rich (produced in particle-induced fission) radio nuclei.

3.2 SWEDISH RESEARCH COUNCIL'S LABORATORY, STUDSVIK, NYKÖPING

3.2.1 Spectroscopy on short-lived fission products (OSIRIS)

G Rudstam

A very extensive research programme on microscopic fission product data is performed using an isotope-separator on line reactor R20 at Studsvik [1]. By this technique it is possible to study a large range of fission products in the half-life range down to a fraction of a second. Measurements are in progress to study one or several of the following parameters for a large number of fission products: $T_{1/2}$, β^- (Q-value), β (strength), e^-, γ and delayed neutrons.

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[1] S. Borg et al., Nucl. Instr. & Methods 91, 109 (1971)

3.2.2 Spectroscopy on (n_{th},γ) reactions

B. Fogelberg, A. Bäcklin and J. McDonald

Beam facility

An external neutron beam from the R2 reactor has been arranged. A flux density of about $4 \cdot 10^6\ n_{th}/cm^2$, s, essentially free from fast neutrons and gamma-rays is obtained from diffraction in a graphite crystal.

$^{113}Cd(n,\gamma)^{114}Cd$

The half-life of the second excited 0^+ level in ^{114}Cd has been measured using delayed γ-γ coincidences.

$^{235}U(n,\gamma)^{236}U$

The conversion electron and γ-ray data obtained for this reaction have now been analyzed and a report has been written [1]. Of special interest are the low-lying negative parity levels at 688, 744 and 848 keV. The first of these levels has been suggested [2] as a $KI^{\pi} = 22^-$ state, which is strongly supported by our data. No indication was found for the low-lying K = 0 band suggest at energies close to the above mentioned level-energies [3, 4]. A definite E0 admixture to some transitions in ^{236}U made possible an identification of the first three members of the β-vibrational band, but no transitions from the suggested [5] γ-band were observed.

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[1] B. Fogelberg and A. Bäcklin, Conversion electrons from the reaction $^{235}U(n,\gamma)^{236}U$, The Swedish Research Council's Laboratory, Studsvik

[2] C. M. Lerer, J.M. Jaklevic and S. G Prussin, Nucl. Phys. A 135 (1969) 36

[3] H. F. Brinkmann, preprint

[4] I. R. Huizenga, private communication

[5] W. R. Kane, Phys. Rev. Lett. 25 (1969) 953

3.3 TANDEM ACCELERATOR LABORATORY, UPPSALA

A. Johansson

The national Tandem Accelerator Laboratory has as its basic research facility an EN van de Graaff tandem machine. It has been operated with terminal voltages up to 6 MV with continuous beams of protons, deuterons, ^{3}He, ^{4}He, ^{16}O and Cl particles with pulsed beams of protons and deuterons. An on-line computer, a PDP-15/40, with 40 k core memory is available for all accelerator users as are also several detectors and electronic units.

To a large extent, the research at the laboratory is being done by groups from research departments and institutes outside the laboratory itself and the research in nuclear physics is, consequently, quite diversified. Investigations are presently being persued in the following fields:

a) Three-nucleon problem, particularly the deuteron breakup by proton bombardment.
b) Nuclear spectroscopy in the region Z = 42 - 49, with the use of particle-gamma correlation techniques and also a double focussing spectrometer for precision measurements on conversion electrons.
c) Nuclear lifetimes both with electron-electron coincidence measurements and with Doppler shift techniques
d) Coulomb excitation studies.
e) Nuclear quadrupole moments through the reorientation precession technique
f) Nuclear magnetic dipole moments using ion implantation perturbed angular correlations
g) Structure of the Ne isotopes through particle-gamma correlations
h) Various uses of pulsed proton and deuteron beams for time-of-flight measurements.

The accelerator facility is also used quite extensively for studies in atomic and solid state physics.

3.4 UNIVERSITY OF GOTHENBURG AND CHALMERS UNIVERSITY OF TECHNOLOGY, DEPARTMENT OF NUCLEAR PHYSICS, GOTHENBURG

J. Dubois

At the 3 MeV Van de Graaff accelerator, recently equipped with a PDP 11/20 DOS computer system on line, level structure studies including life time measurements have been made on medium weight nuclei by use of (p,γ)-reactions.

Nuclear spectroscopy studies to investigate high spin configurations in light and medium mass nuclei have been made at the 80 cm and 225 cm cyclotrons at the Research Institute for Physics. Nuclear structure studies by means of (p,n)-reactions have been made at the Van de Graaff accelerator at Studsvik and by means of $(d,p\gamma)$-reactions, involving particle-gamma coincidence techniques, at the Uppsala Tandem-accelerator. A double focusing heavy particle spectrometer is being installed at the Uppsala Tandem for future nuclear structure studies.

3.5 UNIVERSITY OF LUND AND LUND INSTITUTE OF TECHNOLOGY, DEPARTMENT OF NUCLEAR PHYSICS, LUND

I. Bergqvist

Nuclear structure and reaction studies are made at the 1.2 GeV synchrotrone, the 12 MeV microtron and at the 3 MeV and 500 keV Van de Graaff accelerators.

The main emphasis is put on studies of photoinduced reactions and of proton and neutron capture.

Photoinduced reactions involving the emission of photons, neutrons and charged particles are studied. Measurements are also made on high-energy photofission and subbarrier photo-fission on uranium isotopes.

Nuclear structure studies are made by the use of (p,γ) reactions. Measurements on medium weight nuclei are in progress.

The reaction mechanism in fast neutron capture are studied by measurements on (n,γ) and (d,pγ)-reactions (See also 2.1.2.2, 2.1.2.3 and 2.1.2.4).

4. EXPERIMENTAL FACILITIES

Information are given below of improvments and changes of experimental facilities for nuclear physics.

4.1 RESEARCH INSTITUTE FOR PHYSICS, STOCKHOLM

C J Herrlander

The 225 cm cyclotron was shut down in spring 1971 for the final phase of an extensive improvement program to permit the exploitation of heavy ions (p, d, α, $^{12}C^{4+}$, $^{14}N^{5+}$, $^{16}O^{5+}$, $^{20}Ne^{4+}$ (3rd harmonic), $^{40}Ar^{8+}$ (3rd harmonic). The radio frequency system, the D-circuit and the power system for the ion source have been rebuilt. The machine is now running and alpha-particle beams of 56 MeV have been obtained.

A fast pulsing system has also been built which allows one pulse out of three, four or five to pass through a slit. The system is dimensioned to handle beams of particles with mass-to-charge ratios ≤ 3.3 and energies ≤ 12.5 MeV/nucleon.

4.2 SWEDISH RESEARCH COUNCIL'S LABORATORY, STUDSVIK, NYKÖPING

G. Rudstam

A new targetsystem has been installed at OSIRIS, the isotope separator on-line system at the R20 reactor. The source intensity has been increased by a factor of about 10 with the new system.

4.3 TANDEM ACCELERATOR LABORATORY, UPPSALA

A. Johansson

A foil-stripper is under construction to be used as an alternative to the existing gas-stripper. The accelerator tube has been run for almost 15 000 hours and is beginning to show sign of wear. It will be replaced in the end of 1973.

4.4 UNIVERSITY OF LUND AND LUND INSTITUTE OF TECHNOLGY, DEPARTMENT OF NUCLEAR PHYSICS

R. Hellborg

The budget has been allocated for a 6 MeV tandem-pelletrone to be installed in late 1974. The machine will be equipped with a duo-plasmatron-ion-source for the acceleration of p,d and He-ions. The machine will replace the old 3 MeV van de Graaff accelerator. The research program will include nuclear structure and reaction studies and also neutron physics.

5. COMPILATION AND EVALUATION

5.1 STATUS REPORT OF THE EVALUATED NEUTRON DATA LIBRARIES AT THE AB ATOMENERGI

H. Häggblom

There are two different libraries of neutron cross sections at AB Atomenergi of which one is used for thermal and the other for fast reactors.

The BUXY-library for the thermal reactors includes data of 75 nuclides in 69 energy-groups. Most of the data are from the WIMS-library, which in turn is based on UKNDL. During the last year data have been included for Gd-154, Gd-156, Np-237, Pu-238, Am-241, Am-242, Am-243, Cm-242 and Cm-244.

The SPENG-library includes cross sections mainly for fast reactors. The data to this library was originally evaluated in Sweden, but has been replaced to a large extent of data taken from ENDF/B-III.

The codes ETOS and DORIX have been used to process the data. ETOS produces point-by-point cross sections while DORIX produces group cross sections in the resonance region. Both types of cross sections exist in the SPENG library. Data from the library are then used as an input to the SPENG-programme to produce group cross sections.

The fission products have in the calculations been replaced with a pseudo-fission product. The cross sections for this product was calculated in 1967 and a revision of these data will be made.

5.2 EXCITATION FUNCTIONS FOR CHARGED PARTICLE INDUCED REACTIONS IN LIGHT ELEMENTS AT LOW PROJECTILE ENERGIES

J. Lorenzen and D. Brune, AB Atomenergi, Studsvik

A compilation of excitation functions for charged particle induced reactions in light elements at low projectile energies has been made with the aim of making it useful in various fields of nuclear applications with emphasis on charged particle activation analysis [1].

Activation analysis of light elements using charged particles has proved to be an important tool in solving various problems in analytical chemistry, e.g. those associated with metal surfaces. Scientists desiring to evaluate the distribution of light elements in the surface of various matrices using charged particle reactions require accurate data on cross sections in the MeV-region.

A knowledge of cross section data and yield-functions is of great interest in many applied fields involving work with charged particles, such as radiological protection and health physics, material research, semiconductor material investigations and corrosion chemistry. The authors therefore decided to collect a limited number of data which find use in these fields. Although the compilation is far from being complete, it is expected to be of assistance in devising measurements of charged particle reactions in Van de Graaff or other low energy accelerators.

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[1] To be included in a handbook of cross section data for activation analysis purposes published by IAEA.

5.3 COMPILATION OF PHOTONUCLEAR CROSS SECTIONS

B. Forkman and B. Bülow, Department of Nuclear Physics,
University of Lund, Lund

A compilation of photnuclear cross sections have been made for the planned IAEA handbook of cross sections for activation analysis. The compilation includes about sixty (γ,n) cross section in the giant resonance region sometimes complemented with cross sections for other types of reactions. Special reference is taken to needs in activation analysis.

5.4 MEETING ON THE APPLICATION OF NUCLEAR DATA IN THE PREPARATION OF RADIONUCLIDES FOR USE IN MEDICINE AND BIOLOGY, STUDSVIK, DECEMBER 11, 1972

In preparation for the IAEA Symposium on Applications of Nuclear Data in Science and Technology, held in Paris 12 - 16 March, 1973, a preparatory meeting was held on the 11th of December, 1972, at Studsvik, Sweden [1].

The object for this meeting was to enable the exchange of information about the applications of nuclear data in the preparation of radionuclides for use in medicine and biology.

Nine experts in various fields of experience participated in the meeting. The following subjects were discussed.

Reactor-produced radionuclides
Generator-produced radionuclides
Accelerator-produced radionuclides
Radionuclide-production with fast neutrons
Use of medical betatrons for photon-activation
Other data important for the preparation and use of radionuclides in medicine and biology
Summary, conclusion and requests

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[1] B. Persson, Report to the IAEA Symposium on Applications of Nuclear Data in Science and Technology, Paris, 12 - 16 March, 1973, IAEA-SM-170/92