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PROGRESS REPORT TO EANDC FROM AUSTRIA

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P. Weinzierl, Editor

This report contains partly preliminary data. The information given is to be considered as private communication and is not to be quoted.

A. ATOMINSTITUT DER OESTERREICHISCHEN HOCHSCHULEN, VIENNA

1. Cold Neutrons

1.1 Neutron focusing by a curved Soller collimator system

H. Rauch, M. Friedmann
(Nucl.Instr.a.Meth. (1970) in print;
IAEA Proc.Panel Instr.Inel.Scatt.Research, Vienna 1969,
in print)

The neutron focusing action of a system consisting of 45 Ni-coated totally reflecting channels with a curvature of 40 m lengths varying between 53 and 157 cm and slit widths between 0.5 and 1.4 mm is investigated. At the focal area (4.58 m behind the entrance of the channels) a marked increase of the neutron density and a high enrichment of cold neutrons is obtained.
The properties of a sandwich neutron source consisting of thin moderator sheets and open (partly totally reflecting) channels are estimated by a Monte-Carlo procedure. Such a source has a strong anisotropic emission of neutrons in direction of the open channels.

1.2 Mechanical neutron chopper and selector devices

P. Westphal, H. Rauch, C.M. Fleck, G. Breitfuss, G. Leder
(work in progress)

The new double chopper system consists of two plastic rotors with high contents of boron. It is designed for neutron wave-lengths between 4 and 20 Å and has a resolution $\Delta\lambda/\lambda \approx 1.7\%$.
The characteristic values of the chopper system are measured by test runs.
In the near future test measurements with the neutron selector are proposed. The selector is designed for neutron wavelengths between 3 and 20 Å.

1.3 Diffraction of cold neutron by the flux lines of type II superconductors

H.W.Weber, H.Rauch, E.Steinitz
(work in progress)

In order to obtain the lattice parameter and further information on the internal structure of the magnetic flux lines in superconductors the small angle Bragg diffraction is measured. In addition to very pure Nb single - and polycrystals a superconducting alloy ($\kappa \sim 3$) is investigated to facilitate a comparison of the experimental results with the theory of the mixed state.

2. Polarized Neutrons

2.1 Neutron spin-flip-chopper and spin-flip-selector

H.Rauch, H.Freisleben, R.Papp
(IAEA Proc.Symp.Neutr.Inel.Scatt., Copenhagen 1968, p.387
IAEA Proc.Panel Instr.Neutr.Inel.Scatt.Research, Vienna 1969, in print)

To obtain a further improvement of the resolution of the spin-flip-chopper shorter flipping coils are installed and a more elaborate electronic set-up is used. The high repetition rate (up to 50 kc/s) and the great duty cycle produces a remarkable gain of the peak intensity compared to mechanical devices.
The spin-flip-selector, which consists of two spin-flip-chopper devices running with a distinct electronically adjustable phase difference is a new method to measure the neutron energy without time-of-flight analysis.

2.2 Neutron depolarization measurements on Ni and Co

H.Rauch, K.Pevlik, H.Rupar
(J.Phys.Chem.Solids 30 (1969) 2175
Atomkernenergie 15 (1970) 275)

The neutron depolarization action of poly- and single crystals

of Ni near their Curie points is investigated. The measurements can be used for an exact determination of the transition point, for the investigation of effects causing a shift or a broadening of the transition and for the observation of a residue of a ferromagnetic short range order above T_c.
A Co-single crystal is investigated at room temperature at various magnetic fields. The parallel domain structure could be verified for the magnetic field direction perpendicular to the hexagonal axis.

2.3 Neutron depolarization in superconductors

H.W.Weber, K.Pfeiffer, H.Rauch
(Z.f.Phys. 219 (1969) 482)

Following earlier works on this subject several type II superconductors are investigated by the neutron depolarization technique. The ideal arrangement of the flux line lattice in a very pure Nb sample was demonstrated. Other samples of varying degree of hysteresis show distorted flux line lattices and a nonuniform propagation of the magnetic flux front with increasing magnetic field in the mixed state. The influence on the flux line lattice of the degree of hysteresis and the surface finish are under further investigation.

3. Diffraction of thermal and cold neutrons by a ruled grating

H.Rauch, A.Graf, H.Kurz
(Z.f.Phys. 220 (1969) 419)

Further investigations on the diffraction pattern of thermal and cold neutrons reflected by various ruled gratings are carried out. The results obtained allow some conclusions about the coherence properties of the neutron wave packet. The results indicate a coherence length much greater than the deBroglie wave length (> 50.000 λ). Experiments with a Laue-Fall interferometer are in preparation.

4. Calculation of spin-correlation functions

K.Binder, H.Rauch, G.Rockenbauer, V.Wildpaner
(Z.f.Phys. 219 (1969) 201
Z.f.angew.Phys. 28 (1970) 325)

The spin correlation functions are calculated by means of a Monte Carlo procedure. Heisenberg nearest neighbour interaction, classical spins, various lattices and periodical boundary conditions are used. The correlation functions are related to the magnetic neutron cross section. The results can be used for a discussion about some theoretically proposed correlation functions.

5. Neutron radiography

H.Rauch, M.Manoussakis, N.Skiadopoulos
(Neutr.Radiography Newsletter 10 (1969) 14)

In continuation of earlier work the hydrogen diffusion in deuterated organic material at various temperatures is under investigation. With this method the molecular and the jump diffusion can be separated. The experiments are done in the solid, liquid and supercooled state.

6. Determination of resonance parameters

C.M. Fleck
(Nukleonik 12 (1969) 259
Atomkernenergie 15 (1970) 271)

The self indication method combined with temperature variation or mutual indications is used for the measurement of accurate data of resonance parameters without a neutron spectrometer. The parameters of the first In resonance of 1.485 eV

$$\Gamma = (0.073 \pm 0.003)\ \text{eV}$$
$$\sigma_r = (39{,}300 \pm 400)\ \text{b}$$

and of the first Rh-resonance at 1.257 eV

$$\Gamma = (0.161 \pm 0.006)\ \text{eV}$$
$$\sigma_r = (5560 \pm 200)\ \text{b}$$

were measured.

7. Isomeric states

7.1 Investigation of isomeric states in the microsecond range

C.M.Fleck, W.Niederstätter, W.Schindler
(Atomkernenergie 15 (1970) 269)

In continuation of earlier work the low energy γ-ray spectrum of Lu following thermal neutron capture was investigated. Several new transitions could be found. The energies of all the lines were measured with an accuracy of ± 0.8 keV. Furthermore the life time of a short lived transition in Lu-177 was measured by pulse activation with thermal neutrons. The half-live was found to be 145 ± 5 µs and the energy 458.5 ± 0.8 keV.

7.2 Investigation of short-lived isomeric states

F.Grass, O.Brendstätter, F.Girsig and R.Klenk
(work in progress)

An automatic pneumatic tube system with only 15 ms transfer time using compressed helium for expelling the samples from the irradiation to the measurement position was developed. Synchronisation, with the reactor pulse is possible and converted transitions are studied in near future using a liquid scintillator. A computer program enables the automatic data processing. In pulse operation ytterbium could be determined in the nanogram range by activation analysis by means of its 68 ms Yb-175m isomeric state.

8. Photodisintegration cross-sections near the threshold energy of deuterium and beryllium

F.Bensch, F.Vesely
(to be published)

In an earlier paper (Journal Nucl.Energy 23 (1969) 537), six types of photoneutron sources have been investigated experimentally. From the neutron yield (neutrons/Curie), the photodisintegration cross-section of the target

(D_2O, Be) can be calculated with improved accuracy.

9. Cross-sections of several nuclides for neutrons of intermediate energies ($24 \leq E \leq 970$ keV)

F. Bensch, P.Ikonomou, H.Jasicek, H.Ledermann, K.Mück
(work in progress)

By means of the above-mentioned investigation on six photoneutron sources (Ref. 8), each emitting neutron within a narrow energy range, cross-sections (activation, absorption, and scattering cross-section) of several nuclides can be measured.

10. Rapid determination of radionuclide activities by a well-type gamma ionisation chamber

F.Bensch, H.Ledermann
(Nucl.Instr.a.Meth. 72 (1969) 56)

A well-type ionisation chamber has been carefully calibrated for 13 radionuclides. The interpretation of the results leads to simple relations enabling users to standardize samples of arbitrary gamma-active nuclides of activities between 100 µCi and 1 Ci and with gamma-energies between 100 keV and 2 MeV. The absoluts activity can be determined with an accuracy (8% or better) sufficient for most applications.

B INSTITUT FÜR RADIUMFORSCHUNG UND KERNPHYSIK,
AUSTRIAN ACADEMY OF SCIENCE, VIENNA

Progress in fast neutron research

1) Study of the D(n,2n)-reaction with 14 MeV-neutrons

W. Breunlich, S. Tagesen

Work is in progress on a kinemetically complete experiment to gain information on the neutron-neutron force. A deuterated liquid scintillator is irradiated with 14 MeV-neutrons. The energy of the two neutrons emitted is measured by time of flight technique. The start signal is taken from α-particles associated with the 14 MeV-neutrons.

2) Measurement of γ-spectra after 14 MeV-neutron capture

M. Uhl, H. Warhanek, P. Hoffmann

Shielding for a Ge(Li)-detector has been built and tested. It is planned to measure partial (n,γ)-cross-sections for capture γ-rays leading to ground stete and first excited state of residual nuclei.

3) Activation cross-sections of (n,p)-reactions

W. Schantl, P. Hille

28 cross reactions for almost all stable nuclei between ^{6}Li and ^{42}Ca with $(N-Z) \leq 2$ have been measured.

4) A pulsed neutron generator

C. Stengl

Work is in progress to modify the existing 14 MeV-neutron generator. High voltage will be changed from 200 kV to 400 kV. Klystron-bunching is constructed for 1 nsec pulse duration with a peak current of 20 mA. The new neutron source will be used primarily for the study of inelastic neutron scattering and (n,2n)-reactions.

5) Measurement of proton-energy spectra and angular distribution of protons emitted in (n,p)-reactions

P. Hille et al.

Work started by H. Palme, who measured energy spectra and angular distribution of protons emitted in the $^{58}Ni(n,p)$-reaction induced by 3 MeV- and 14 MeV-neutrons will be continued. The reaction chamber used by H. Palme shall be altered by adding a multiwire proportional counter to reduce background and time for measurements.

6) Predictions of the statistical model for neutron induced nuclear reactions

M. Uhl, et al.

An extensive comparison of statistical model predictions with experimental data is continued.

C. PHYSIKINSTITUT, REAKTORZENTRUM SEIBERSDORF, OESTERR. STUDIEN-GESELLSCHAFT FÜR ATOMENERGIE GmbH

1. Mass Separation and Ion Physics

1.1 Isotope Separation

F. Dydak, F. Edl, H.D. Polaschegg, T. Tortschanoff

Medium amounts of stable W-isotopes were separated upon request. For the parity admixture experiment Hg^{203}-sources with activities up to 8 mCi were separated.

1.2 Development of Duoplasmatron Ion-Sources

R.Bruckmüller, N. Klaus, P. Krempl, F.P.Viehböck, H.Winter

Sintered nickel cathodes were developed for the use in a new duoplasmatron source with slit geometry. The plasma inside the source and outside the anode aperture was investigated by single and double probes while operating the sources with different noble gases. The energy distribution of the extracted ions was measured by means of a retardation optics.
Using a new developed extraction system, argon ion currents up to 1 mA/mm^2 were obtained.

1.3 Sputtering Experiments

G. Betz, R.Dobrozemsky, F.P. Viehböck

The sputtering coefficient S for different materials was measured using medium energy ions of A^{40+}, Kr^{84+} and Xe^{132+}. The angular distributions of scattered resp. sputtered particles showed partly deviations from the results of other authors. From a careful investigation on the sputtering coefficient, which varies for different elements and energies in a wide range, the following simple relation could be established: plotting the angle of the maximum emission of sputtered material versus S, one obtains a simple curve as shown on the figure 1. This curve was obtained for 60^0 incident noble gas ions of various energies.

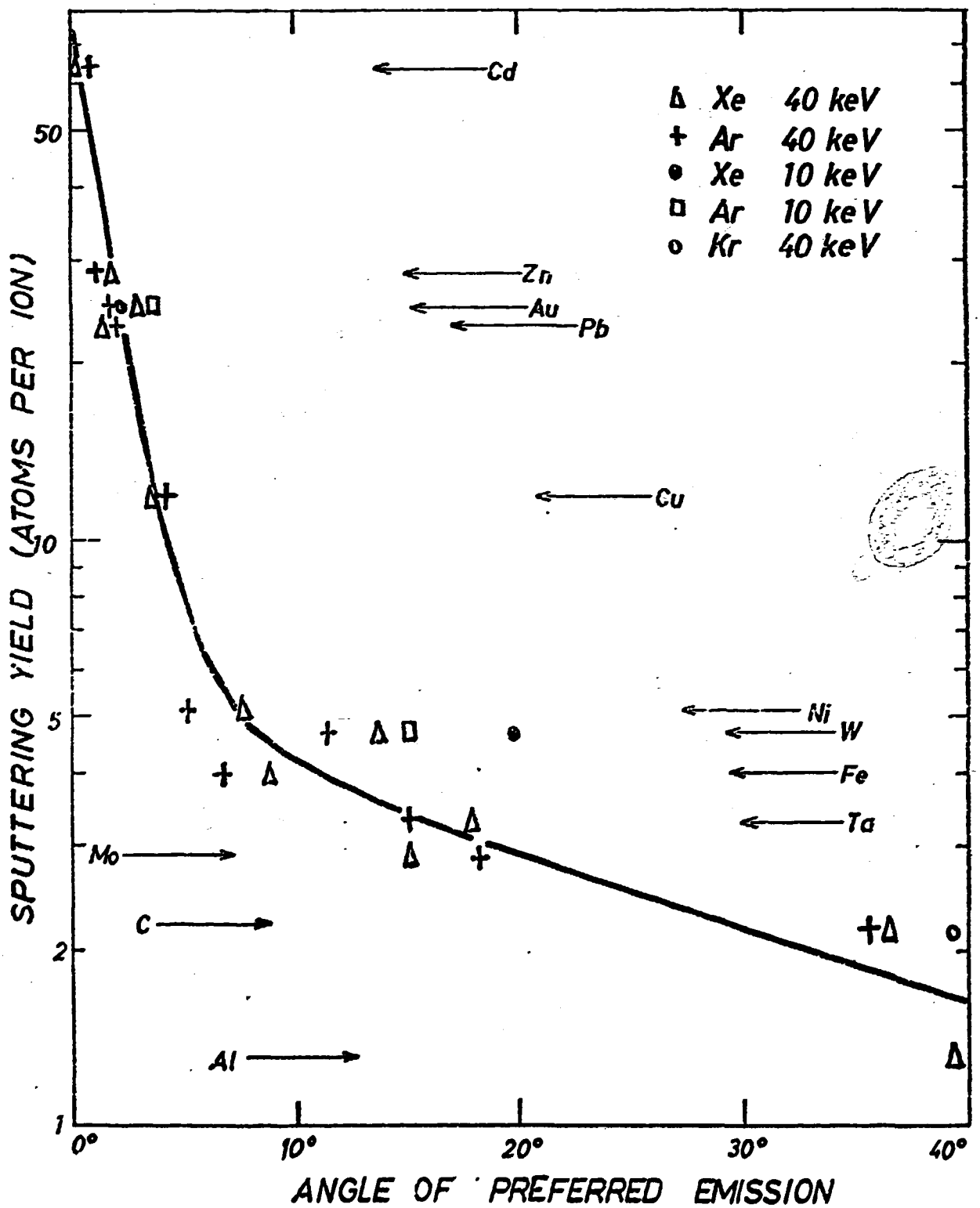
Δ Xe 40 keV
+ Ar 40 keV
• Xe 10 keV
□ Ar 10 keV
o Kr 40 keV
Cd
Zn
Au
Pb
Cu
Ni
W
Fe
Ta
Mo
C
Al
50
10
5
2
1
0°
10°
20°
30°
40°
SPUTTERING YIELD (ATOMS PER ION)
ANGLE OF PREFERRED EMISSION

FIG. 1

1.4 Penetration Depths for Medium Energy Ions in Solids

R. Dobrozemsky, G. Lammer, F.P.Viehböck, H. Wotke

A special collector system using retardation technique was developed to measure penetration depths at relatively high current densities and moderate ion energies. Measurements were carried out for Xe, Sm, W and Au-ions hitting Al, Pb and pyrolytic graphite.

2. Slow Neutron Scattering

2.1 Dependence of Phonon-energies in Na on Hydraulic Pressure

G.Ernst, G. Quittner

A series of phonons of a Na single crystal were measured with and without applying 3000 atm pressure. Measurements had to be stopped because of a failure of the pressure vessel. The data obtained are in the state of evaluation.

2.2 Structure of liquid Al by neutron scattering

O.J.Eder, E. Klikovich, B. Kunsch

An Al-furnace for neutron scattering experiments was developed using an Al_2O_3 tube as probe container. It allows temperatures up to 1000°C, which remained constant within $\pm$ 0.2°C during one measurement. The temperature gradients in the probe were smaller than 0.2°. A first series of measurements is finished.

2.3 Inelastic neutron scattering in H_2O,D_2O and mixed samples of both components

O.J.Eder, J. Lechner

Samples of H_2O, D_2O, H_2O + 5% D_2O and D_2O + 4.8% H_2O were measured at the rotating crystal spectrometer. Background was

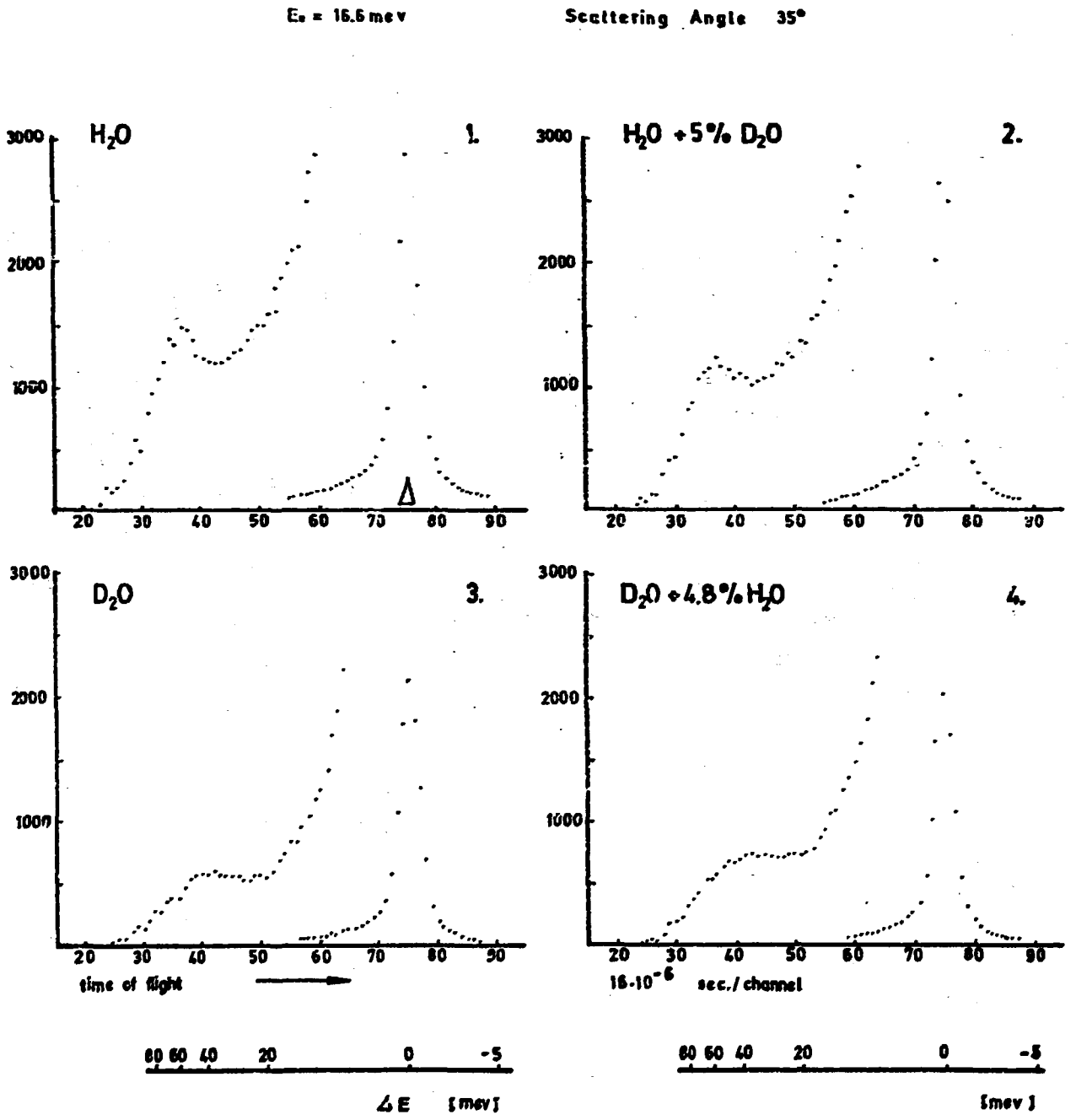
E_o = 16.6 mev
Scattering Angle 35°
H_2O
1.
H_2O + 5% D_2O
2.
D_2O
3.
D_2O + 4.8% H_2O
4.
3000
2000
1000
20 30 40 50 60 70 80 90
Δ
time of flight
$16 \cdot 10^{-6}$ sec./channel
80 60 40 20 0 -5
ΔE [mev]
[mev]

FIGURE 2

reduced by the use of a SiO_2 crystal filter and a Fermi-type chopper phased with the rotating crystal. Sample thicknesses varied between 0.3 and 1.7 mm for the different samples. The incoming neutron energy was 0.0166 eV, the scattering angles measured were 15^0, 35^0, 55^0 and 75^0. Figure 2 shows the results for the 4 samples at 35^0 scattering angle. The broad inelastic peak of the hindered rotations (60 meV in H_2O) is clearly visible. Further data evaluation is still underway.

3. Nuclear Physics

3.1 Study of angular correlation in neutron decay by measurement of the recoil proton spectrum[x)]

F.Bauer, O.Benka, R.Dobrozemsky, H.Paul, P.Ressmann, D.Semrad, P.Weinzierl

After finishing ion optical tests of the system spherical condenser - detector by photographic means satisfactorily, coincidence measurements of the secondary electrons ejected by protons from a thin Ni-foil started. These yielded first unacceptable high background rates. Geometric changes in the detector system and a repeller grid for secondary ions created in the detector region improved the situation considerably. The entire system is now in the status of assembling and preparatory vacuum tests outside the reactor.
An extremely precise proton source for simulating decay protons and calibrating purposes is also under test.

3.2 Study of parity admixture in the 279-keV state of Tl^{203}

F. Dydak, H.-D. Polaschegg

The measurements of the forward-backward asymmetry in the β-γ-angular correlation of Hg^{203}-decay is under way since January 1970. Each mass-separated source is measured during about

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x) This work was partly supported by the US Government

3 months in a continuous run in order to accumulate sufficient statistics.

3.3 Low energy γ-rays from resonance neutron capture in $Ta^{181}(n,\gamma)Ta^{182}$

H.P.Axmann, J.A. Murray (AERE Harwell), P. Riehs

In a co-operation program between the Linac group of AERE Harwell and Seibersdorf, the intensities of the gamma transitions at 134, 173, 270, 295, and 403 keV in Ta^{182} have been measured for about 20 neutron resonances of $Ta^{181}(n,\gamma)Ta^{182}$ up to 200 eV neutron energy using a Ge(Li)-detector. Relative to a measurement with a Moxon-Rae-detector no fluctuations were observed for the intensities of the 173 and 270 keV transitions within the error limits of 12%. The intensity ratio of the 173 to the 270 keV transition indicates a grouping of capture spins 3 and 4 and suggests tentative spin assignments for 9 resonances. The resonance at 166 eV shows a special high intensity for the 134 and 403 keV transition in comparison to the 270 keV transition.

3.4 Capture cross section and capture γ-rays from erbium-isotopes

H.P.Axmann, M. Moxon (AERE Harwell), P. Riehs

Using samples of Er-164, Er-166, Er-167, and Er-170 on loan from the US research pool the capture cross sections of all isotopes were measured up to about 30 keV neutron energy. The capture γ-spectrum of the isotopes 164, 167 and 168 was also measured up to 1 MeV γ-energy. Data processing is still under way.

D. INSTITUT FÜR KERNPHYSIK, TECHNISCHE HOCHSCHULE, GRAZ

1. Transport theoretical properties of cavities

L. Breitenhuber

It is shown that a theorem by DAVISSON on flux distribution in cavities holds quite generally and requires no assumption about weak absorption. The proof is extended to the adjoint fluxes. The behaviour of channels and the validity for finite systems are discussed. Numerical examples for the ARGONAUT - reactor are given.

2. A reactorkinetic method for measuring the source strength of radioactive neutron sources

L.Breitenhuber and P. Kindl

Different to LITTLER no reliance on reactortheoretical calculations was necessary. The method involves a direct gauging by U-235, concerning adjoint fluxes, which appear in the perturbation formula. An accuracy of 1.5% (relative to U-235) for sources as weak as 10^4 n/sec has been achieved and checked by an adapted bath method (H_2O, H_3BO_3-solution). Absolute flux measurements were made by fission track counting on mica and macrofol using σ_f of U-235 as primary standard.

3. Effective resonance integrals of W, Ta, Mo

L.Breitenhuber and H. Heimel

The results refer to the slab geometry of the material which may be of importance for fuel cladding. The thickness in term of S/M (cm^2/g) varied in the following ranges: tungsten 1 - 90, molybdenum 0.5 - 40, tantalum 2 - 120.

4. Shape dependence of effective resonance integrals of indium by sub-Cd-measurements

H.Heimel

Slabs and wires of various dimensions have been investigated by their reactivity effects in order to obtain information of

deviations from the basic $\sqrt{T}S/\Sigma$ -effect.

5. Experimental assessment of moderation and scattering effects in sub-Cd-measurements

L.Breitenhuber and H. Heimel

Grephite (AMT, SIGRI) and bismuth gives the possibility of measuring the pure moderation (scattering) effect due to their nearly negligible absorption. Former measurements have been confirmed as regards the dependence of the effect on atomic weight. One of us (H.H.) found a new essential effect concerning bismuth. It comprises an enhancement of effective absorption due to the fact that neutrons after scattering are more isotropic than the incident, which is overshadowed by slowing down in case of graphite. In order to deal with longer samples the z-profile of these effects (ARGONAUT central channel) have been investigated using a graphite piece of 8 cm.

6. Installation of a reactivity measurement facility

M.Pinter and H. Heimel

An additional fine regulating rod in connection with a potentiometer position indicator and digital voltmeter reading at the panel allowed a precision of $\pm$ 0.002 ¢ and has been calibrated for reactivities from 0 to 8 ¢.

7. Multigroup-transport calculations of effective resonance integrals

H.Heimel

Using 20 to 50 energy intervals the effective resonance integral of the (primarily) first resonances of cobalt, tantal and gold has been calculated. Cobalt has been used for its extreme resonance scattering and the strongly modified flux distribution due to slowing down within the relatively broad resonances. In the case of gold the following approximations have been used

a) neglection of scattering in sample,

b) allowance for scattering in sample,

c) allowance for both slowing down and scattering at gold nuclei. The final approximation gives a correction up to 4 %. In contrast to literature no assumptions have been made about narrow resonances and infinite mass, respectively.

E. REAKTORINSTITUT, TECHNISCHE HOCHSCHULE, GRAZ

1) Treatment of a cylindrical beam tube by transport theory

C. Haring

The Boltzmann equation for a cylindrical tube is solved using the method of spherical harmonics. First a method is described which allows to solve the differential equations, resulting from the P_N-approximation, if there is a mutual dependence between the coefficients in the development of the vector flux. Then the neutron flux distribution for a cylindrical tube is calculated using the P_2-approximation. The system of differential equations is solved using a special " ansatz" which consists of a linear combination of functions depending on one parameter; this leads to a system of linear equations with fixed coefficients. Finally, the solution of the Boltzmann equation is given explicitly.

2) Binary vector series in two group theory applied to multiple layer media

E.Ledinegg and M. Pinter

Binary vector series are extended here (in contrast to former applications[1,2,3]) over the entire region consisting of different zones with constant medium properties. Orthogonality relations analogous to those used in continuously variable media are applied. The convergence of binary series is investigated for special cases. The analogy between binary vectors in two group theory and vectors belonging to the Lorentz- resp. spatial rotation-group is shown by giving the transformations, with respect to which the two group-diffusion equation is invariant.

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1) F. Cap and J. Menning, Nukleonik 6, 140, 1964

2) W.H. Köhler, Nukleonik 8, 203, 1966

3) Z. Zadworski, Nukleonik 8, 169, 1966

3) Third order correlation functions in a subcritical reactor

E.Ledinegg and W. Thury

The correlation function derived earlier (Acta Physica Austr. 28, 121, 1968), where the Green functions are not related to a special reactor theory, are compared to the third order correlation functions by Borgwaldt (Diss. Karlsruhe 1966) which are valid for a space- and energy-independent model. It is shown that the above mentioned correlation functions agree with those by Borgwaldt, if the Green functions are evaluated for a point reactor model.

4) Correlation functions of 2. order taking space- and energy-dependence into account

M. Pinter

The space- and energy-dependence of correlation functions is investigated by application to a simplified Argonaut reactor. First the reactor is treated as homogeneous unreflected cylinder by means of Fermi-age theory. Then the geometry is better approximated: an internal reflector cylinder is surrounded by a ring core and the letter by an infinite outer reflector. The calculation uses two group-diffusion theory. The orthogonality relations being necessary for the solution of the inhomogeneous diffusion equation were proved to exist for a medium consisting of several layers. Finally both geometries were treated by two-group theory.

5) Theoretical and experimental contributions to the determination of correlation functions in a subcritical reactor

W. Thury

Correlation functions of 2. and 3. order were calculated for a zero-power-reactor in steady subcritical state. A third order correlation function (E.Ledinegg, Nukleonik 8, 169, 1968) was

specialized for a point reactor model. Applying these correlation functions to the ratio between the correlated and the uncorrelated part in α-Rossi-measurements, an improvement by a factor of 2 is reached. This can be used for a more precise determination of the prompt decay constant.

6) Lessons drawn from integral experiments on a set of multi-group cross sections

J.Y.Barré, M.Heindler, T.Lacapelle, J.Ravier

Two methods of using integral experiments to improve the basic neutron data of a multigroup cross section set are described. First a statistical analysis of a large number of integral parameters measured in fast critical assemblies gives us modifications in cross sections for U-235, U-238, Pu-239 and Fe leading to a new cross section set. In the second part the utility of specific critical experiments for basic neution data is demonstrated for capture cross section of Ni and high energy cross sections of fissile isotopes.

7) Interpretation of measurements of nickel reactivity coefficients in several critical assemblies

M. Heindler

The cross sections of nickel in the Cadarache multigroup cross section set are studied. For this purpose the calculated central reactivity worth of nickel are compared to experiment in 14 fast critical assemblies; the finite size of samples is taken into account. This study confirms that the nickel cross sections used so far give too positive reactivity worth. Therefore a new evaluation of nickel capture cross section was made, based on recent measurements by Spitz et al. The agreement between measured and calculated values is thus significantly improved.