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This volume presents the abstracts of work on the measurement or analysis of nuclear constants which may be of direct or indirect interest in the design and operation of nuclear reactors. It covers work carried out in certain institutes in the Soviet Union in the first half of 1965.

INSTITUTE OF PHYSICS AND ENERGETICS
(F.E.I.)

NUCLEAR FISSION

ANGULAR ANISOTROPY OF PHOTOFISSION AND PARITY OF THE GROUND STATE OF ^{239}Pu

N.S. Rabotnov, G.N. Smirenkin, A.S. Soldatov, L.N. Usacheva, S.P. Kapitsa*/ and Yu.M. Tsipenyuk*/

F.E.I. Preprint No. 12

The angular distribution of fragments from the photofission of ^{239}Pu by bremsstrahlung gamma quanta from a microtron were measured in the limiting energy range E_{max} = 5.4; 5.67-7.9 MeV. The results of the measurements were described by the ratio $w(\vartheta) = a + b \sin^2 \vartheta$. The maximum anisotropy, $\frac{b}{a} = -0.192$, corresponds to E_{max} = 5.6 MeV. The anisotropy observed was compared with the average excitation energy of fissionable nuclei E^*.

Table I

E_{max} (MeV)	$\frac{b}{a}$	E^* (MeV)
5.4	0.103 ± 0.028	5.15
5.65	-0.192 ± 0.010	5.38
5.9	-0.161 ± 0.012	5.52
6.4	-0.016 ± 0.025	5.70
6.9	-0.011 ± 0.015	(a)
7.9	0.016 ± 0.008	(a)

(a) Not calculated.

*/ Institute of Physical Problems, Moscow.

EXPERIMENTAL RESULTS OF A STUDY OF THE ANGULAR DISTRIBUTIONS OF PHOTOFISSION FRAGMENTS OF THORIUM-232, URANIUM-238, PLUTONIUM-239 AND PLUTONIUM-240

A.S. Soldatov, G.N. Smirenkin, I.E. Bocharova
and V.G. Zolotukhin

The results are given of measurements of the angular distribution of photofission fragments, carried out on the 12-MeV microtron at the Institute of Physical Problems of the USSR Academy of Sciences at a maximum bremsstrahlung energy E_{max} = 5.2-9.25 MeV. The results obtained are described well by the relationship $w(\vartheta) = a + b \sin^2 \vartheta + c \sin^2 2\vartheta$, the coefficients of which are determined by the least squares method. The dependence of the coefficients a, b and c on E_{max} is given. The results obtained make it possible to establish the dependence of the isotropic, dipole and quadrupole components of the angular distributions of the fragments on E_{max}.

ANGULAR ANISOTROPY AND MASS ASYMMETRY OF THORIUM-232 FISSION FRAGMENTS

B.D. Kuzminov and A.I. Sergachev

Paper to the Salzburg Symposium, 1965*/

The energies of paired fragments were measured using a two-compartment ionization chamber with grids. The fragments travelling at angles of 0° and 90° to the direction of the fast neutron beam from the BR-5 reactor were recorded by the two halves of a two-dimensional 128 x 128-channel analyser. The results show that, within the limits of accuracy of the experiment, the curves for the dependence of the yield and total kinetic energy of fragments on their mass are identical for angles of 0° and 90°.

MULTI-PARAMETER INVESTIGATIONS OF FAST FISSION FRAGMENTS

P.P. Dyachenko and B.D. Kuzminov

Paper to the Salzburg Symposium, 1965

The kinetic energy distributions of uranium-235 fission fragments of differing mass were investigated. Thermal neutrons and neutrons with an average energy of ~720 keV were used to induce fission. The fragments were registered by surface-barrier counters, the pulses from which were recorded

*/ Symposium on Physics and Chemistry of Fission, Salzburg, 22-26 March 1965 (IAEA).

by a two-dimensional 128 x 128-channel analyser. The average total kinetic energies of the fission fragments are the same for both types of fission. When the fission fragments have approximately the same mass this figure is 156 ± 2 MeV.

NEUTRON EMISSION IN THE ANISOTROPIC FISSION OF NUCLEI

V.I. Bolshov and G.N. Smirenkin

The effect of the angular correlation of prompt neutrons with fission fragments in the anisotropic fission of nuclei is discussed. This effect leads to an angular correlation between the fission neutrons and the direction of the bombarding neutron flux. This correlation is assessed for the simplest cases of angular distribution of fission fragments. The possibility of using the effect to measure the angular distribution of fission fragments is discussed.

$\bar{\nu}$ IN THE FISSION OF ^{235}U AND ^{232}Th BY FAST NEUTRONS

L.I. Prokhorova and G.N. Smirenkin

The average number of secondary neutrons in the fission of ^{235}U and ^{232}Th by neutrons with $E < 3$ MeV was measured. The method of measurement made use of a multi-layer fission chamber in a block of paraffin with BF_3-counters. For uranium-235, the measurements were made relative to the value of $\bar{\nu}$ at an energy of 1 MeV, which was taken to be 2.52. The data for thorium were related to the data for uranium at an energy of 2.42 MeV.

Tables II and III

^{235}U

En (MeV)	$\bar{\nu}$
0.38 ± 0.09	2.464 ± 0.059
0.59 ± 0.08	2.434 ± 0.056
0.81 ± 0.08	2.515 ± 0.064
1.00 ± 0.08	2.52
1.23 ± 0.07	2.533 ± 0.074
1.45 ± 0.06	2.553 ± 0.072
1.62 ± 0.02	2.570 ± 0.042
1.82 ± 0.08	2.584 ± 0.037
2.00 ± 0.08	2.584 ± 0.029
2.21 ± 0.08	2.647 ± 0.032
2.42 ± 0.07	2.717 ± 0.050
2.68 ± 0.07	2.795 ± 0.040
3.00 ± 0.06	2.774 ± 0.076

^{232}Th

En (MeV)	$\bar{\nu}$
1.62 ± 0.09	2.174 ± 0.085
2.00 ± 0.08	2.194 ± 0.082
2.42 ± 0.07	2.280 ± 0.080
2.84 ± 0.07	2.290 ± 0.085

PAIRING EFFECTS IN FISSION OF EVEN-EVEN COMPOUND NUCLEI NEAR THE THRESHOLD

V.M. Strutinsky*/ and V.A. Pavlinchuk

Paper to the Salzburg Symposium, 1965

The paper discusses anomalies in the energy dependence of ν connected with the existence of an energy gap at the saddle point. The results of calculations are compared with experimental data.

VARIATION OF RELATIVE YIELDS OF DELAYED NEUTRONS

B.P. Maksyutenko

Paper to the Salzburg Symposium, 1965

The paper gives the results of measurements of the relative yields of various groups of delayed neutrons from the fission of uranium-238 by neutrons with energies of 1.6-15 MeV. There is a break in the curves in the region of the thresholds of the (n,f) and (n,nf) reactions.

Table IV

T sec	Relative group yields at different E_n					
	1.6 MeV	2.3 MeV	3.8 MeV	5.75 MeV	6.5 MeV	15 MeV
55	1	1	1	1	1	1
24	9.07±0.13	8.68±0.45	7.82±0.42	6.93±0.31	12.31±0.37	4.95±0.15
15.2	2.692±0.011	5.24±0.27	4.24±0.23	3.81±0.15	0.59±0.23	3.37±0.14
5.2	8.42±0.17	9.46±0.58	10.46±0.67	9.18±0.66	13.3 ±0.6	7.0 ±0.32
2.2	23.3 ±1.0	38.6 ±2.0	33.2 ±1.8	30.69±0.78	45.7 ±3.4	22.2 ±1.3
0.5		17.2 ±2.7	16.3 ±2.6			15.2 ±1.5

*/ I.V. Kurchatov Atomic Energy Institute, Moscow.

RELATIVE YIELDS OF DELAYED NEUTRONS FROM THE FISSION OF URANIUM-235 BY 7.25 MeV NEUTRONS

B.P. Maksyutenko

The neutron source was the $D(d,n)^3He$ reaction with a target 20 mg/cm^2 in thickness. The results of the measurements are given in Table V. Comparison with earlier data shows a sharp change in the group yield ratio in comparison with the energy region below the threshold of the (n,nf) reaction.

Table V

Half-life (sec)	Relative yield
55	1
24	3.70 ± 0.04
15.5	1.94 ± 0.04
5.2	3.80 ± 0.12
2.2	6.76 ± 0.47

DELAYED NEUTRONS FROM URANIUM-233

B.P. Maksyutenko

The relative yields of delayed neutrons from uranium-233 fission by neutrons with maximum energies of 2.3 MeV, 5.6 MeV and 7.25 MeV were measured. There is a smooth change in the group yield ratios until the (n,nf) reaction begins, when there is a sharp change at a "step" in the fission cross-section.

Table VI

Half-life (sec)	Relative yields at different primary-neutron energies		
	2.3 MeV	5.6 MeV	7.25 MeV
55	1	1	1
24	1.83 ± 0.06	1.35 ± 0.05	1.50 ± 0.05
15.5	1.44 ± 0.06	1.75 ± 0.08	1.56 ± 0.07
5.2	2.38 ± 0.14	1.84 ± 0.12	2.74 ± 0.16
2.2	4.34 ± 0.17	5.66 ± 0.15	3.17 ± 0.11

NEUTRON SCATTERING

SMALL-ANGLE ELASTIC SCATTERING OF FAST NEUTRONS

G.V. Anikin, Yu.A. Aleksandrov and A.S. Soldatov

Paper to the Antwerp Conference, 1965*/

The results are reported of measurements of the differential elastic scattering cross-sections for neutrons with average energies of 0.57, 1.3, 2.45, 4.5, 5.6 and 8.4 MeV on the nuclei U, Pb and Cu for 17 angles between 2.5° and 23.8°. After taking Shwinger scattering into account, the results were compared with figures calculated on the basis of the optical model of the nucleus.

DIFFERENTIAL SCATTERING CROSS-SECTIONS FOR NEUTRONS WITH AN AVERAGE ENERGY OF ABOUT 4.5 MeV IN THE RANGE OF ANGLES 2.5°-24°

G.V. Anikin

The differential scattering cross-sections for neutrons with an average energy of about 4.5 MeV are shown graphically for ^{238}U, ^{232}Th, ^{207}Pb and ^{64}Cu.

NUCLEAR TEMPERATURES AND NUCLEAR LEVEL DENSITY PARAMETERS

V.B. Anufrienko, B.V. Devkin, G.V. Kotelnikova, G.N. Lovchikova, O.A. Salnikov, L.A. Timokhin and N.I. Fetisov

Paper to the Antwerp Conference, 1965*/

The results are given of investigations of the scattering of neutrons with an energy of 14.1 ± 0.08 MeV on nuclei with mass numbers A from 12 to 209. The spectra of neutrons scattered at an angle of 92° were measured by the time-of-flight method, with a resolution of ~4 nsec/m. From an analysis of the spectra of inelastically scattered neutrons together with neutrons from the (n,2n) reaction, the effective nuclear temperatures T_{eff} and the nuclear temperatures after evaporation of the first neutron T_1 were determined.

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*/ International Conference on the Study of Nuclear Structure with Neutrons, Antwerp, 19-23 July 1965.

Table VII

Element	T_{eff} (MeV)	T_1 (MeV)
C		
Mg	0.81 ± 0.05	
Si	0.68 ± 0.05	
Al	0.91 ± 0.05	
Ti	0.84 ± 0.05	1.48 ± 0.09
V	0.83 ± 0.05	1.18 ± 0.07
Cr	0.83 ± 0.05	1.39 ± 0.08
Mn	0.83 ± 0.04	1.15 ± 0.06
Fe	0.75 ± 0.04	1.45 ± 0.07
Co	0.77 ± 0.04	1.52 ± 0.04
Ni	0.72 ± 0.03	1.45 ± 0.06
Cu	0.66 ± 0.03	1.21 ± 0.05
Zn	0.7 ± 0.04	1.24 ± 0.06
Se	0.63 ± 0.06	0.98 ± 0.10
Zr	0.71 ± 0.04	1.17 ± 0.06
Nb	0.66 ± 0.03	1.11 ± 0.06
Mo	0.60 ± 0.04	0.91 ± 0.06
Cd	0.61 ± 0.04	0.91 ± 0.06
In	0.78 ± 0.04	1.06 ± 0.11
Sn	0.68 ± 0.04	1.02 ± 0.06
Te	0.69 ± 0.07	1.06 ± 0.11
W	0.61 ± 0.04	0.84 ± 0.05
Pb	0.93 ± 0.06	1.45 ± 0.09
Bi	0.92 ± 0.06	1.42 ± 0.09

INELASTIC SCATTERING OF NEUTRONS WITH AN INITIAL ENERGY OF 14 MeV AND DENSITY OF THE NUCLEAR LEVELS

V.B. Anufrienko, B.V. Devkin, G.V. Kotelnikova, Yu.S. Kulabukhov, G. Lovchikova, O.A. Salnikov, L.A. Timokhin, V.R. Trubnikov and N.I. Fetisov

Preprint No. 4

The spectra of secondary neutrons formed in the interaction of 14.1 MeV neutrons with the nuclei of 23 elements with mass numbers from 12 to 209 were measured in the energy range from 0.17 to 14 MeV by the time-of-flight method.

The nuclear temperatures were determined on the basis of an analysis of the spectra. It was shown that in more than 75% of the cases the neutrons interact with the nuclei through a compound nucleus. The density coefficients of the nuclear levels were determined from the temperatures found.

The table shows the effective nuclear temperatures T_{eff}, the temperatures after evaporation of the first neutron T_1 and the parameters of the formulae for density of the levels a and a" (total density of the levels $W(E^*) = const. \times \exp [2(aE^*)^{1/2}]$; the density of the levels with fixed values of the moments $W(E^*) = const. \times (E^*)^{-2} \times \exp [2(a''E^*)^{1/2}]$).

Table VIII

Element	Atomic weight	Energy range of neutrons emitted	T_{eff} $\pm 1.5\%$	T_1 $\pm 1.5\%$	a (MeV^{-1})	a" (MeV^{-1})
C	12	0.17 - 2.38	0.55		43.3	50.4
Al	27	0.61 - 2.38	0.91		15.2	19.8
Si	28	0.51 - 2.01	0.68		27.7	33.9
P	31	0.42 - 1.86	0.74		23.0	28.8
Ti	48	0.40 - 2.39	0.82	1.38	6.0	9.2
V	51	0.42 - 2.89	0.83	1.33	6.5	9.7
Cr	52	0.33 - 2.62	0.85	1.43	5.8	8.6
Mn	55	0.42 - 2.50	0.83	1.39	5.9	9.2
Fe	56	0.51 - 2.78	0.75	1.18	8.5	12.2
Co	59	0.46 - 2.89	0.77	1.20	8.1	14.2
Ni	59	0.51 - 2.28	0.72	1.12	9.5	13.3
Cu	64	0.42 - 2.50	0.66	0.99	12.4	16.8
Zn	65	0.42 - 2.18	0.69	1.10	9.8	13.9
Se	79	0.42 - 2.01	0.63	0.98	12.7	16.9
Zr	91	0.61 - 2.62	0.71	1.03	11.4	15.6
Nb	93	0.49 - 2.62	0.66	0.96	13.3	17.6
Mo	96	0.42 - 2.01	0.60	0.91	14.8	19.5
Cd	112	0.42 - 2.28	0.61	0.91	14.8	19.5
Sn	119	0.42 - 2.38	0.68	1.02	11.6	15.9
Te	128	0.42 - 2.38	0.69	1.06	10.7	14.7
W	184	0.61 - 2.75	0.61	0.84	17.5	22.6
Pb	207	0.51 - 3.56	0.93	1.45	5.3	8.5
Bi	209	0.51 - 3.56	0.92	1.42	5.6	8.7

ANGULAR DISTRIBUTION OF GAMMA QUANTA GENERATED BY THE INELASTIC SCATTERING OF NEUTRONS CN IRON

D.L. Broder, V.I. Klenov, A.I. Lashuk and I.P. Sadokhin

Submitted to the journal "Jadernaja fizika"

The angular distributions of gamma quanta with energies of 0.84, 1.28 and 1.41 MeV generated by the inelastic scattering of 1.20, 2.01 and 2.61 MeV neutrons on iron nuclei are measured. The results agree satisfactorily with calculations carried out on the basis of the optical model of the nucleus.

ENERGY DEPENDENCE OF EXCITATION OF ^{27}Al LEVELS FROM NEUTRON INELASTIC SCATTERING

D.L. Broder, A.G. Dovbenko, V.I. Klenov, V.E. Kolesov, A.I. Lashuk and I.P. Sadokhin

Paper to the Antwerp Conference, 1965

A gamma spectrometer with a 4 x 4 cm NaI(Tl) crystal was used to measure the gamma spectra in the inelastic scattering of neutrons in the energy range from 0.8 to 3.7 MeV. The measurements were carried out in annular geometry. Figures show the inelastic scattering cross-sections with excitation of the separate levels of ^{27}Al (0.842, 1.013, 2.212, 2.731 and 2.976 MeV) and the total inelastic scattering cross-section, the values obtained being compared with the curves derived from theoretical calculations.

ELASTIC SCATTERING OF NEUTRONS WITH INITIAL ENERGY 2 MeV

L.Ya. Kazakova, V.E. Kolesov, V.I. Popov, O.A. Salnikov, V.M. Sluchevskaya and V.I. Trykova

Paper to the Antwerp Conference, 1965

The paper measures the angular distributions and determines the integral elastic scattering cross-sections for neutrons with an initial ene. gy of 2 MeV on nuclei with A between 23 and 232. Results are compared with calculations made using the optical model of the nucleus.

Table IX

Element	σ_{el} (b)	Element	σ_{el} (b)	Element	σ_{el} (b)
Na	2.6	Cu	2.1	Sb	5.2
P	3.3	Zn	2.6	I	5.0
Cl	3.1	Br	2.1	Ba	6.6
Ti	3.0	Sr	4.7	Ta	4.1
Cr	2.5	Nb	3.3	W	4.4
Mn	3.2	Mo	3.5	Hg	4.1
Fe	2.3	Ag	3.2	Bi	6.3
Ni	2.5	Cd	3.9	Th	5.0

MEASUREMENT OF THE ASYMMETRY OF POLARIZED NEUTRON SCATTERING

P.S. Otstavnov

The asymmetry of elastic scattering of neutrons with an average energy of 3.4 MeV on carbon and sulphur nuclei was measured. The work was carried out with neutrons from the (d-d) reaction emitted at an angle of 49° to the axis of the deuteron beam. After scattering in the sample at an angle ϑ, the neutrons were recorded by a scintillation counter with a stilbene crystal.

The author measured the ratio of the count-rates of the detector R at angles of ϑ and $-\vartheta$ to the direction of the neutrons incident on the scatterer; this is related to the analysing capacity of the scatterer $P_2(\vartheta)$ by the equation:

$$P_1(49^{\circ}) \times P_2(\vartheta) = \frac{1 - R}{1 + R}$$

where $P_1(49^{\circ})$ is the degree of polarization of the incident neutrons equal to -0.140 ± 0.010.

Table X

ϑ (°lab.)	Carbon		Sulphur	
	R	P_2	R	P_2
30	0.891 ± 0.020	-0.439 ± 0.080	1.019 ± 0.013	0.067 ± 0.068
60	0.825 ± 0.022	-0.685 ± 0.094	0.995 ± 0.020	-0.036 ± 0.072
90	1.036 ± 0.020	0.128 ± 0.069	1.043 ± 0.025	0.150 ± 0.085
120	1.139 ± 0.040	0.464 ± 0.125	1.099 ± 0.032	0.341 ± 0.104

RADIATIVE CAPTURE OF NEUTRONS
TOTAL CROSS-SECTIONS

ABSOLUTE MEASUREMENT OF ABSORPTION CROSS-SECTIONS FOR 24 keV NEUTRONS

T.S. Belanova, A.A. Vankov, F.F. Mikhailus and Yu.Ya. Stavissky

The absolute absorption cross-sections for neutrons from a Sb-Be source were measured in spherical geometry. The measurements were carried out using two independent systems for recording the neutrons (a fission chamber in a water tank and a long counter).

Table XI

Element	σ_a (mb)	Element	σ_a (mb)
Cr	10 ± 4	Sn	128 ± 9
Cu	59 ± 8	Sb	580 ± 73
Zn	64 ± 7	W	300 ± 25
Zr	19 ± 5	Au	570 ± 30
Nb	270 ± 15	Hg	233 ± 30
Mo	192 ± 12	Pb	43 ± 7
Ag	980 ± 60	Bi	3 ± 3
Cd	384 ± 20	Th	615 ± 25
In	776 ± 66	^{238}U	412 ± 18

MEASUREMENT OF FAST-NEUTRON ABSORPTION CROSS-SECTIONS USING A RESONANCE DETECTOR IN A WATER TANK

V.P. Koroleva and Yu.Ya. Stavissky

Submitted to the journal "Jadernaja fizika"

The paper describes the method developed by the authors for measuring neutron absorption cross-sections in spherical geometry, using a water tank and a resonance detector. The results are given of measurements of the cross-sections for capture of neutrons from an Sb–Be source by nuclei of copper, indium, molbydenum, thorium and uranium.

Table XII

Material	Absorption cross-section (mb)
Cu	59 ± 6
Mo	188 ± 15
In	778 ± 79
Th	611 ± 40
^{238}U	380 ± 20

RADIATIVE CAPTURE CROSS-SECTIONS FOR 30-170 keV NEUTRONS FOR NUCLEI WITH A~180

A.G. Dovbenko, V.E. Kolesov, V.N. Kononov and Yu.Ya. Stavissky

Paper to the Antwerp Conference, 1965

The radiative neutron capture cross-sections for the nuclei Ta, W, Re and the isotopes of tungsten ^{182}W, ^{183}W, ^{184}W, and ^{186}W were measured in the energy range 30–170 keV using a liquid scintillator 0.5 x 0.5 x 0.5 m in size. The neutron energy was determined using the time-of-flight method with a resolution of 20–30 nsec/m. The data of absolute measurements in spherical geometry at a neutron energy of 24 keV were used for normalization. The results are compared with calculations made in accordance with the statistical theory of nuclear reactions.

STATISTICAL THEORY CALCULATION OF AVERAGE NEUTRON CAPTURE CROSS-SECTIONS IN THE ENERGY RANGE 0.001-14 MeV

S.M. Zakharova and A.V. Malyshev

Paper to the Antwerp Conference, 1965

The paper gives working formulae and describes a method of calculating cross-sections. The results obtained in calculating $\sigma_{n\gamma}$ for iodine are given as an example.

MEASUREMENT OF THE TOTAL NEUTRON CROSS-SECTIONS OF ^{61}Ni, ^{62}Ni, ^{64}Ni AND Sm USING A MECHANICAL NEUTRON SELECTOR

E.Ya. Doilnitsyn

The measurements were carried out using a mechanical selector with a path length of 131 m in the energy range from 0.05 eV to 0.5 MeV. It was established that the cross-sections for absorption of thermal neutrons by isotopes of nickel obey the $^1/v$-law. The total cross-sections of the nickel isotopes can be represented by the relationships

$$\sigma_t = \sigma_s + kt$$

where σ_s is the scattering cross-section, and t is the time of flight of a neutron for a distance of one metre. The values of the cross-sections and the coefficients k found from the experimental data are given in Table XIII.

Table XIII

Isotope	Absorption cross-section, adjusted to an energy of 0.025 eV	Scattering cross-section (b) σ_s	k
^{61}Ni	2.8	9.6 ± 2	$(6.1 \pm 2) \times 10^{-3}$
^{62}Ni	14	9.2 ± 0.8	$(3.0 \pm 0.3) \times 10^{-2}$
^{64}Ni	2.1	1.45 ± 0.4	$(4.65 \pm 1.2) \times 10^{-3}$

When the total cross-sections of Sm were measured in the neutron energy range from 0.4 to 0.5 eV, a resonance structure which had not previously been apparent was observed.

INSTITUTE OF THEORETICAL AND EXPERIMENTAL PHYSICS (I.T.E.F.)

DETERMINATION OF THE PARAMETERS OF NEUTRON LEVELS FOR INTERMEDIATE AND HEAVY NUCLEI

K.G. Ignatev, A.N. Soldatov and S.I. Sukhoruchkin

Work has continued with the time-of-flight neutron selector and the I.T.E.F. cyclotron to determine the neutron resonance parameters of intermediate and heavy nuclei. Nine elements have been investigated: Pd, Xe, Cu, Zn, Tl, In, Ir, Os and Mo. The positions of the levels discovered are given in the table. The inaccuracy in determining these positions was:

0.2 eV at a neutron energy of 50 eV
0.7 eV " " " " " 150 eV
1.5 eV " " " " " 250 eV
2.5 eV " " " " " 350 eV

The results obtained are compared with the results of other work.

Table XIV

Position of neutron levels

1. Palladium - 77.6; 86.7; 90.8; 104.0 (?); 113.0 (?); 126.0; 141.2; 150.0; 158.3; 177.8 (?); 182.9; 202.5; 252.8; 261.2; 274.2; 281.9; 305.3; 346.8; 355.1; 422.2; 429.5; 452.9; 466.6.

2. Xenon - 45.9; 92.7; 115.1; 126.5; 185.7; 211.2; 246.8; 280.1; 337.8.

3. Copper - 229.3; 576.7.

4. Zinc - 222.8; 438.73 (?); 500.6.

5. Thallium - 238.8.

6. Indium - 65.9; 81.1; 84.0; 95.3; 126.8; 133.9; 166.6; 188.2; 208.3; 226.2; 252.5; 269.2 (?); 292.7; 298.9; 322.2 (gr)*/; 413.0 (gr); 462.0 (gr); 587.9.

7. Iridium - 19.23; 20.16; 24.4; 25.1; 26.0; 29.9; 31.6; 36.6; 40.4; 41.5; 43.2; 45.9 (?); 50.9; 52.5; 53.9; 62.7 (?); 63.1 (gr); 65.7 (gr); 67.9; 69.2; 71.5; 77.9; 78.9 (?); 80.6; 87.3; 97.3; 100.1 (?); 103.6; 104.8; 109.9; 114.6; 116.3; 127.6 (gr); 130.1 (gr); 134.1; 143.2; 147.8 (gr); 152.8; 156.4; 163.8; 169.1 (?); 179.7; 182.8; 186.2; 195.2; 208.0; 214.9; 224.3; 247.1; 263.1; 273.1; 279.7; 289.4; 296.9 (?); 310.1; 331.8; 376.2 (gr); 416.2.

8. Osmium - 50.4; 55.0; 60.7; 63.9; 65.5; 76.3; 77.9 (?); 78.9 (?); 90.7; 104.4; 110.8; 127.9; 131.0 (?); 145.5; 149.9; 166.6; 202.7; 217.8; 317.4 (gr).

9. Molybdenum - 44.6; 70.9; 131.5; 159.8; 289.3; 362.7.

SINGLE-PARTICLE EFFECTS IN NEUTRON PHYSICS AND THE FINE STRUCTURE OF NUCLEAR MASSES (CORRELATION IN THE POSITIONS OF NEUTRON LEVELS)

S.I. Sukhoruchkin

I.T.E.F. preprint No.347

The analysis of the positions of resonances in the neutron cross-sections for all intermediate and heavy nuclei has shown the presence of grouping, which is especially apparent when levels with relatively high reduced neutron widths are selected. In the first levels of nuclei differing by two neutrons, there is a tendency towards an increase in the number of cases where they are close to each other ("coincidence of levels").

*/ Translator's note: Not understood. 'Group' has been suggested.

ANGULAR DISTRIBUTIONS AND NEUTRON SPECTRA IN (d,n) REACTIONS ON NUCLEI OF INTERMEDIATE ATOMIC WEIGHT

V.V. Okorokov, V.M. Serezhin, V.A. Smotryaev,
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I.T.E.F. preprint No.358

The paer investigates neutron spectra and angular distributions in (d,n) reactions on the isotopes ^{50}Cr, ^{52}Cr, ^{53}Cr, ^{54}Cr, ^{54}Fe, ^{56}Fe, ^{57}Fe, ^{59}Co, ^{58}Ni, ^{60}Ni, ^{62}Ni, ^{64}Ni, ^{63}Cu, ^{65}Cu, ^{64}Zn, ^{66}Zn and ^{68}Zn.

The I.T.E.F. cyclotron was used as the source for the 11.7 MeV deuterons. The measurements were made on a multi-channel fast-neutron spectrometer by the time-of-flight method. The target thickenss was 3.8-4.6 mg/cm^2.

INSTITUTE OF PHYSICS
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EFFECTIVE CROSS-SECTIONS FOR THERMAL AND RESONANCE NEUTRONS

LEVELS AND THERMAL CROSS-SECTIONS OF THE ISOTOPES ^{185}Re AND ^{187}Re

V.P. Vertebny, M.F. Vlasov, A.L. Kirilyuk, V.V. Koloty, M.V. Pasechnik, Zh.I. Pisanko and N.A. Trofimova

Submitted to the journal "Atomnaja energija"

The VVR-M (water-cooled and water-moderated) reactor of the Ukrainian Academy of Sciences' Institute of Physics, using mechanical neutron choppers, has been used to measure the neutron cross-sections of ^{185}Re and ^{187}Re in the energy range from 0.005 to 100 eV. By comparing the data for isotopically-enriched samples (resolution 0.2 μsec/m) and for natural rhenium (resolution 0.05 μsec/m), it has been determined which resonance levels belong to which isotope (Fig. 1).

The parameters of the resonance levels are given in the table.

Table XV

Isotope	Resonance energy	$2g\Gamma_n$ from the authors' measurements
^{185}Re	2.156 ± 0.019	4.3 ± 0.2
	5.93 ± 0.02	0.24 ± 0.04
	7.18 ± 0.03	1.6 ± 0.3
	11.97 ± 0.06	0.94 ± 0.12
	12.9 ± 0.07	0.9 ± 0.1
	14.74 ± 0.9 */	0.94 ± 0.15
	21.46 ± 0.15 */	10.3 ± 1.6
^{187}Re	4.41 ± 0.01	0.41 ± 0.09
	11.2 ± 0.06	3.0 ± 0.3
	16.2 ± 0.10	0.73 ± 0.10
	17.7 ± 0.10	2.3 ± 0.3
	18.5 ± 0.10	0.7 ± 0.10

*/ Levels not resolved.

The level at 32.5 eV belongs to both isotopes. Because it is so close to the level at 34 eV, the parameters of these levels could not be definitely determined. Apart from the levels given in the table, levels with the following energies were found for rhenium:

22.09 ± 0.07; 24.94 ± 0.07; 26.79 ± 0.08; 27.45 ± 0.09; 29.6 ± 0.1;
32.6 ± 0.1; 34.08 ± 0.10; 36.7 ± 0.2; 39.7 ± 0.2; 41.7 ± 0.3;
45.8 ± 0.3; 47.8 ± 0.3; 50.5 ± 0.3; 51.6 ± 0.3; 54.0 ± 0.3;
55.3 ± 0.4; 58.0 ± 0.4; 61.5 ± 0.4; 63.7 ± 0.4; 70.8 ± 0.4;
74.6 ± 0.4; 79.0 ± 0.5; 87.0 ± 0.5; 96.7 ± 0.5; 108.0 ± 0.5 eV

the level at 27.45 eV belonging to ^{185}Re and that at 39.66 eV to ^{187}Re. The most probable values of the strength functions for both isotopes are assessed.

$$\frac{\overline{\Gamma}_n^{\,o}}{D} = 1.8^{+2.0}_{-1.4} \times 10^{-4} \; (^{185}\mathrm{Re}) \text{ and } \frac{\overline{\Gamma}_n^{\,o}}{D} = 0.9^{+0.6}_{-0.2} \times 10^{-4} \; (^{187}\mathrm{Re}).$$

The cross-sections of the isotopes were measured in the thermal range with a resolution of 3.6 μsec/m and in the cold range with a resolution of 7.2 μsec/m. Fig. 2 shows the energy dependence of the cross-section of these isotopes. For ^{185}Re the contribution of the positive levels to the thermal cross-sections is ~56% of the total cross-section, and for ^{187}Re ~3%. Fig. 3 shows the neutron cross-section of ^{187}Re in the thermal range. The dots at the bottom show the contribution of the positive levels to the cross-section. Analysis of the thermal cross-sections showed that for ^{187}Re the energy of the negative level closest to zero is $5 \text{ eV} \leqslant |E_o| \leqslant 10$ eV and $\frac{g\Gamma_n^{\,o}}{E_o^{\,2}} = 0.36$. The only statement possible for ^{185}Re is that $|E_o| \geqslant 10$ eV and that $\frac{g\Gamma_n^{\,o}}{E_o^{\,2}} = 0.20$. The neutron width of these levels is at least 12-15 times more than the average reduced width for the positive levels. The total cross-section of ^{185}Re at 2200 m/sec is 118 ± 2 b, while for ^{187}Re it is 90 ± 2 b.

LEVELS AND THERMAL CROSS-SECTIONS OF THE ISOTOPES ERBIUM-162, 164, 166, 167, 168 AND 170

V.P. Vertebny, M.F. Vlasov, A.L. Kirilyuk, V.V. Koloty,
M.V. Pasechnik and N.A. Trofimova

Submitted to the Ukrainian Journal of Physics

The VVR-M (water-cooled and water-moderated) reactor of the Ukrainian Academy of Sciences' Institute of Physics, using mechanical neutron choppers, has been used to measure the neutron cross-sections of erbium-162, 164, 166, 167, 168 and 170 in the energy range from 0.005 to 100 eV.

From the data on measurements of enriched samples (resolution 0.4 μsec/m) and natural erbium (resolution 0.05 μsec/m), the resonance levels have been assigned to the respective isotopes and the parameters of some of them have been determined. The total neutron cross-sections were measured as a function of energy in the cold and thermal energy ranges with a resolution of 7.2 μsec/m and 3.6 μsec/m respectively. The results of the measurements are given in the table.

Table XVI

Isotope	Energy of level (eV)	Γ_n MeV	σ_t v=2200 m/sec (b)	Isotope	Energy of level (eV)	Γ_n MeV
^{162}Er	7.68±0.24 15.46±0.72 21 ±1	2.0 ±0.3 0.14±0.05 16 ±5	315		30.4±0.1 33.0±0.2 37.6±0.2 39.5±0.2	1.10± 0.5 1.4 ± 0.2 1.2 ± 0.2
^{164}Er	7.95±0.02	0.55±0.10	50		42.0±0.2	
^{166}Er	15.6 ±0.05	2.1 ±0.2	94± 5		49.8±0.3	
^{167}Er	0.46±0.001 0.58±0.001 5.98±0.01 9.43±0.02 20.20±0.1 26.20±0.1 27.5 ±0.1	 26. ±3 6.8 ±0.6 6 ±1 316 ±50 6 ± 2	670±30	Er_{68}	53.3±0.3 59.3±0.4 62.4±0.4 73.9±0.5 79.0±1 107 ±1	10.4± 0.6 48 ± 9 52.6
^{168}Er			35±10		130 ±1	
^{170}Er	94.5 ±1	716 ±30	45		170 ±2	353 ±100

$\bar{D}_{162}^{observed}$ ~6.5 eV	$2\bar{D}_{167}^{observed}$ ~7.4 eV

Figure 4 shows the transmission of natural erbium (resolution 0.05 μsec/m).

MEASUREMENT OF EPITHERMAL NEUTRON SCATTERING CROSS-SECTIONS FOR A NUMBER OF NUCLEI

V.P. Vertebny, V.V. Koloty, M.L. Gnidak and M.V. Pasechnik

Paper to the Ukrainian SSR Conference on the Peaceful Uses of Atomic Energy (Kharkov, 1962)

The VVR-M reactor of the Ukrainian Academy of Sciences' Institute of Physics was used in 1962 to measure total neutron scattering cross-sections in 4-π geometry as a function of neutron energy in the epithermal region. The measurements, which were carried out on the nuclei Zr, Ag, Sb, Re and Ta, were made by the time-of-flight method with a resolution of 0.24 μsec/m and a flight path of 26.7 m. The detector was a battery of boron counters. All the measurements were made relative to lead, since the scattering cross-section of lead is constant over a wide range. The samples on which the measurements were made were foils of Zr, Ag and Ta, 0.56, 0.32 and 0.5 mm thick respectively, a metal disk of Sb 5.9 mm thick and an Re powder with $n = 1.625 \times 10^{22}$ nuclei/cm^2. The results of the measurements are given in Figs. 5, 6 and 7.

The scattering cross-sections at V = 2200 m/sec are given in Table XVII.

Table XVII

Element	Cross-section	Element	Cross-section
Ag	5.5 ± 0.1	Ta	2.9 ± 0.1*/
Re	–	Zr	8.0 ± 0.1
Sb	4.1 ± 0.1		

*/ Interference minimum.

COHERENT EFFECTS IN THE INTERACTION OF COLD NEUTRONS WITH LIQUIDS

V.P. Vertebny, A.N. Maistrenko, I.P. Dzyub and M.V. Pasechnik

Submitted to the journal "Atomnaja energija"

Using a mechanical chopper and a mechanical monochromator on the VVR-M reactor, the authors measured the total cross-section of liquid oxygen and liquid nitrogen at normal pressure. There was a drop in the cross-sections after $\lambda \sim 4$-5Å. This effect is qualitatively explained by the short-range order effect. The cross-section of gaseous nitrogen was also measured at a pressure of 8.5 atm and a temperature of 20°C. It is demonstrated that in this case the energy dependence cannot be explained by the Nelkin-Krieger theory.

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NUCLEAR FISSION

ASYMMETRY AND ANGULAR ANISOTROPY OF THE MASS DISTRIBUTIONS OF FRAGMENTS OF 14 MeV NEUTRON-INDUCED FISSION OF ^{238}U

A.P. Komar, B.A. Bochagov and V.I. Fadeev

The mass distributions of the fragments have already been measured for the fission of ^{238}U by 14 MeV neutrons, for various values of the angle ϑ between the direction of flight of the fragments and the neutron beam. The total fragment yield increases with decrease in the angle ϑ, i.e. there is longitudinal anisotropy of the angular distribution of the fragments. Together with this there is an anomalous increase in the yield of fragments with mass ratios higher than the most probable, which leads to an experimental dependence of angular anisotropy on the mass asymmetry of the fragments.

Using radiochemical data on fragment yields for a number of isotopes of uranium, and also the statistical theory of angular anisotropy, the authors made calculations which showed that when ^{238}U is bombarded by 14 MeV neutrons the dependence of anisotropy on mass asymmetry is apparently caused by superposition of the mass distributions of fragments from the nuclei of ^{239}U, ^{238}U and ^{237}U, which undergo fission in the (n,f), (n,nf) and (n,2nf) reactions.

KINETIC ENERGIES OF FRAGMENTS OF ^{239}Pu FISSION INDUCED BY THERMAL AND RESONANCE NEUTRONS

G.Z. Borukhovich, D.M. Kaminker and G.A. Petrov

Two surface-barrier semi-conductor counters were used to measure the total kinetic energies of symmetrical fragments from the fission of ^{239}Pu by thermal neutrons and neutrons which had passed through a samarium filter. Within the limits of error of the measurements ($\pm$ 2 MeV) the kinetic energies were identical.

Fission by resonance neutrons reduced the yield of fission fragments in the symmetrical region by approximately 30%.

The difference between the maximum value of total kinetic energy of the fragments and total kinetic energy of the symmetrical fragments in fission by thermal neutrons is ~ 23 MeV.

GAMMA RAYS IN THE RADIATIVE CAPTURE OF NEUTRONS

DELAYED GAMMA-TRANSITIONS IN ^{186}Re AND ^{188}Re OCCURRING IN (n,γ) REACTIONS

A.M. Berestovoy, I.A. Kondurov and Yu.E. Loginov

The gamma-gamma coincidence method using scintillation counters and a time-amplitude converter was applied to investigating the delayed gamma radiation from the reactions $^{185}Re\ (n,\gamma)\ ^{186}Re$ and $^{187}Re\ (n,\gamma)\ ^{188}Re$. The table gives the lifetimes and energies of the gamma transitions discovered

Table XVIII

Nucleus	E_γ keV	$T_{1/2}$ sec.
$_{75}Re^{186}_{111}$	62 ± 3 100 ± 4 142 ± 3 210 ± 4 255 ± 6	$(11.8 \pm 1.2)\ 10^{-9}$
$_{75}Re^{188}_{113}$	62 ± 3 103 ± 6 167 ± 4	$(7.7 \pm 0.6)\ 10^{-9}$
$_{75}Re^{188}_{113}$	62 ± 3 205 ± 6	$(4.6 \pm 0.3)\ 10^{-9}$

INVESTIGATION OF THE SOFT GAMMA-RADIATION FROM THE ODD-ODD NUCLEI OF ^{46}Sc, ^{56}Mn, ^{60}Co, ^{76}As, ^{108}Ag, ^{110}Ag, ^{116}In AND ^{134}Cs OCCURRING IN (n,γ) REACTIONS, USING A SEMI-CONDUCTING Ge(Li) DETECTOR

A.M. Berestovoy, I.A. Kondurov and Yu.E. Loginov

The authors investigated the soft gamma-radiation generated in the radiative capture of neutrons by the nuclei of ^{45}Sc, ^{55}Mn, ^{59}Co, ^{75}As, ^{107}Ag, ^{109}Ag, ^{115}In and ^{133}Cs in the energy range 60–400 keV. The energies of the gamma transitions and their relative intensities are given in the table.

^{46}Sc		^{56}Mn		^{60}Co		^{76}As		^{108}Ag		^{110}Ag		^{134}Cs	
E_γ keV	I_γ o.e.	E_γ	I_γ	E_γ	I_γ	E_γ	I_γ	E_γ	I_γ	E_γ	I_γ	E_γ	I_γ
145*	100	84(1)	105	57(1)	3	73(1)	40	79(1)	100	73(2)	13	60(1)	8
216(1)	22	104(1)	56	159(1)	15	86(1)	62	100(1)	9	77(2)	14	115(1)	100
228(1)	85	186(1)	19	232(2)	100	119*	100	117*	60	95(2)	10	129(1)	32
295(1)	33	211(1)	100	257(2)	22	139(2)	23	195(1)	100	106(1)	22	176(1)	35
		270(1)	45	280(2)	95	166(1)	110	208(1)	180	117(1)	55	198(2)	22
		313(2)	80			238(2)	28	217(2)	50	196-201	170	205(2)	30
		335(2)	35			266(2)	35	241(2)	25	238(3)	100	219(2)	10
								261(2)	60	271(1)	53	235(1)	20
								298*	80	365(3)	5	261(2)	12
								330(3)	12	387(3)	3	307(1)	25
								337(3)	20				
								360(3)	10				

Notes: 1. * – complex line.

2. Accuracy of determination of relative intensities 20%.

3. In brackets – error in units of the last digit.

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NUCLEAR FISSION

DETERMINATION OF THE PROBABILITIES OF SPONTANEOUS FISSION OF URANIUM-233, URANIUM-235 AND AMERICIUM-243

B.M. Aleksandrov, A.S. Krivokhatsky, L.Z. Malkin and K.A. Petrzhak

The paper describes measurements of the probabilities of spontaneous fission of uranium-233, uranium-235 and americium-243.

Glass plates were used to detect the fission fragments; after treatment with 2.5% hydrofluoric acid, they were inspected through a microscope.

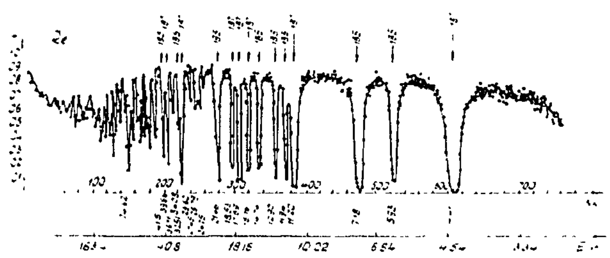
From the data of the measurements, the periods of spontaneous fission of the isotopes were obtained:

$$T_{sp}\ (^{233}U) = (1.2 \pm 0.3) \times 10^{17} \text{ years;}$$
$$T_{sp}\ (^{235}U) = (3.5 \pm 0.9) \times 10^{17} \text{ years;}$$
$$T_{sp}\ (^{243}Am) = (3.3 \pm 0.3) \times 10^{13} \text{ years.}$$

Using the data obtained and those already known for other odd-even and even-odd nuclei, an attempt was made to systematize the experimental material and to construct the probability of spontaneous fission of odd nuclei as a function of the number of neutrons, N. This relationship is shown in Figure 10. The solid points correspond to log T_{sp} for odd-odd nuclei, while the circles indicate even-odd and odd-even nuclei.

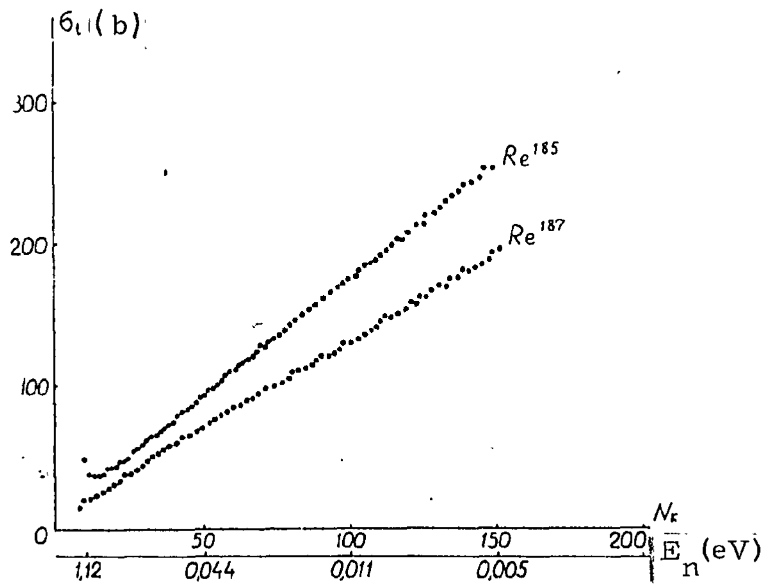
From a comparison of relationships for even and odd nuclei it follows that the average magnitude of forbiddenness is 10^{-3} to 10^4, which is in agreement with theoretical calculations.

Fig. 1



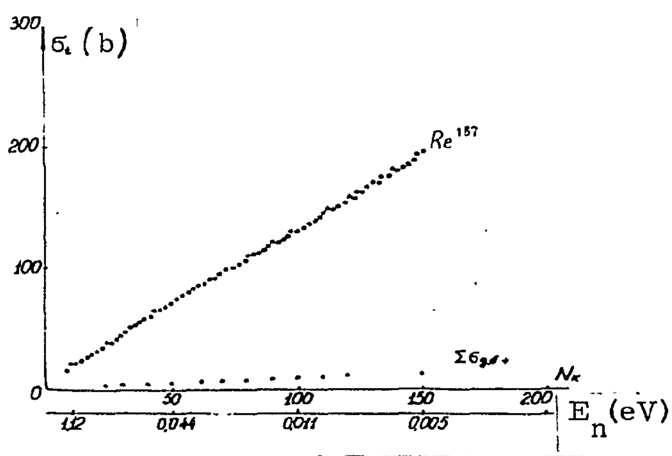
Resonance levels of ^{185}Re and ^{187}Re.

Fig. 2



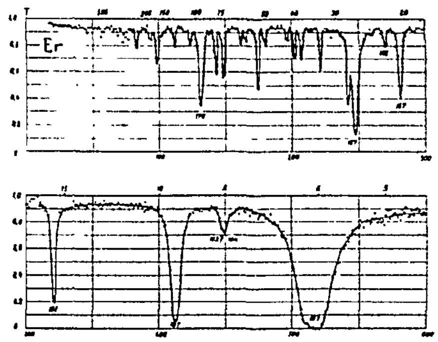
Energy dependence of the cross-sections of ^{185}Re and ^{187}Re.

Fig. 3



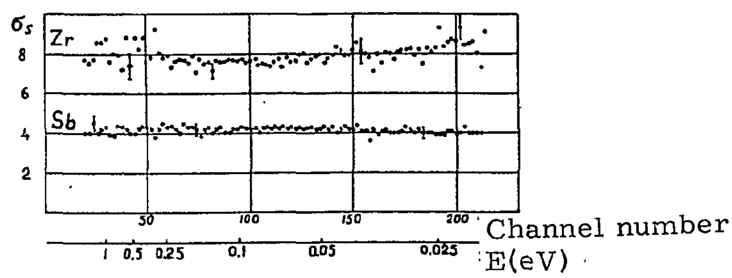
Neutron cross-section of ^{187}Re in the thermal region.

Fig. 4



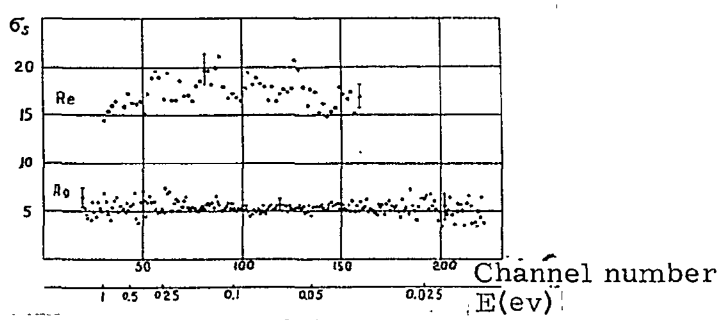
Transmission of natural erbium.

Fig. 5



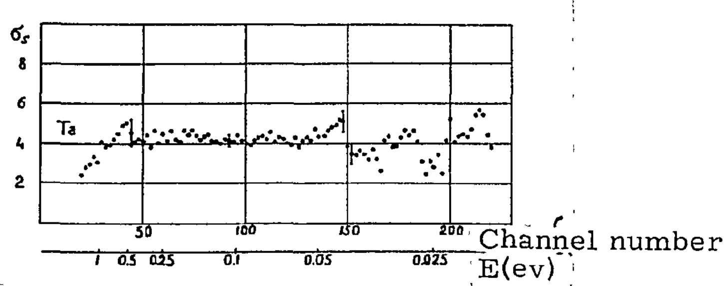
Energy dependence of the neutron scattering cross-section for Zr and Sb nuclei.

Fig. 6



Energy dependence of the neutron scattering cross-section for Re and Ag nuclei.

Fig. 7



Energy dependence of the neutron scattering cross-section for Ta nuclei.

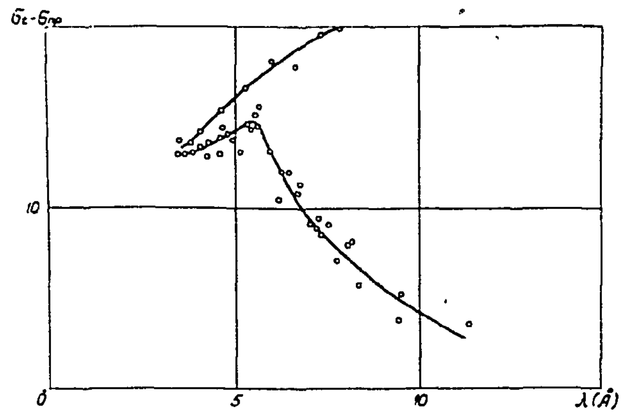


Fig. 8

Dependence of the cross-section of nitrogen (in barns) on the neutron wavelength. Upper curve - gas, lower curve - liquid.

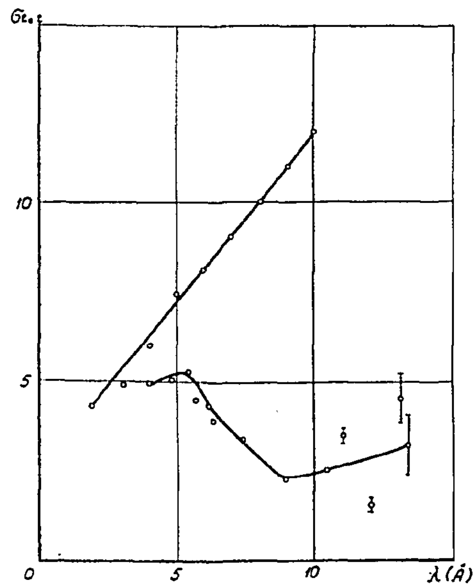


Fig. 9

Dependence of the cross-section of oxygen (in barns) on the neutron wavelength. Upper curve - gas (BNL 325), lower curve - liquid.

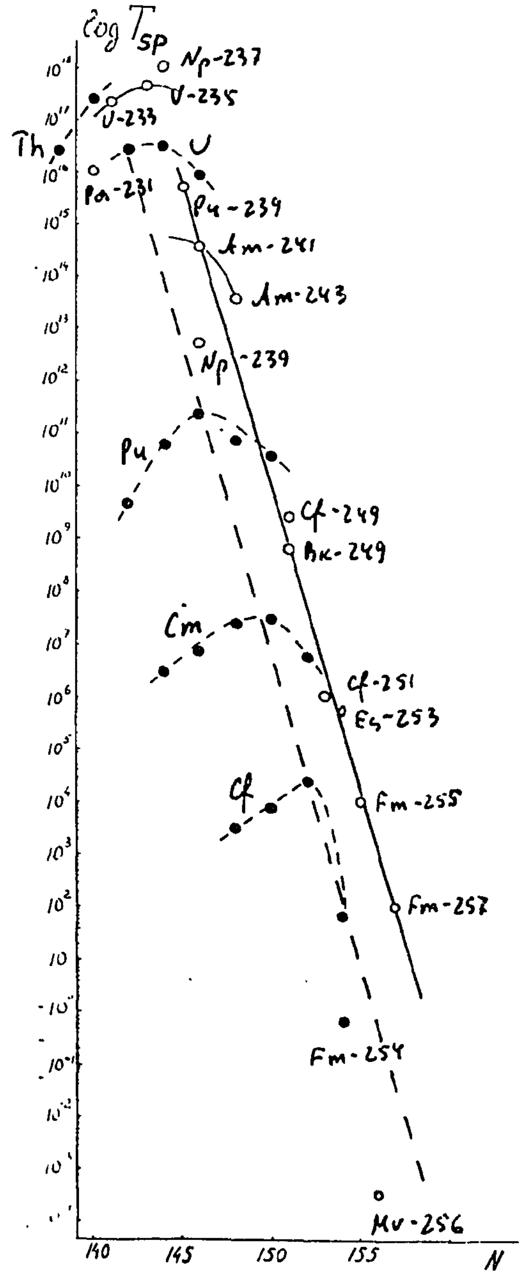


Fig. 10

Dependence of the logarithm of the spontaneous fission period ($\log T_{sp}$) on the number of neutrons in the nucleus undergoing fission.

- ● $\log T_{sp}$ for even-even nuclei.
- o $\log T_{sp}$ for odd-even nuclei.