International Atomic Energy Agency

INDC(CCP)-9/U
DEC 1970

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

USSR STATE COMMITEE ON THE UTILIZATION OF ATOMIC ENERGY NUCLEAR DATA INFORMATION CENTRE

(Collected Abstracts)

No. 9

English translation of an original in Russian
published by Atomizdat, 1969

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, P.O. BOX 590, A-1011 VIENNA

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English Translation of:

ЯДЕРНО-ФИЗИЧЕСКИЕ ИССЛЕДОВАНИЯ в СССР

СБОРНИК АННОТАЦИЙ

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, P.O. BOX 590, A-1011 VIENNA

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Institute of Physics and Power Engineering

ROTATIONAL STATES OF A TWO-PARTICLE SYSTEM

E.V. Gai

(Submitted to Jadernaja Fizika)

The author investigates the principles of splitting of rotational states in a two-particle system with central interaction, in classical and quantum mechanics. It is shown that pure rotation of the system corresponds to rigid fixation of the particles, i.e. to the loss of one degree of freedom, and is described by degenerate equations. The possibility of a zero-rotation energy for the system is discussed. The sufficient conditions are obtained for the splitting of rotational states whose spectrum does not necessarily coincide with the spectrum of the rigid rotator.

THERMODYNAMIC DESCRIPTION OF THE ENERGY SPECTRA OF ATOMIC NUCLEI

Yu.B. Sokolov, V.S. Stavinsky,
(Published in Jadernaja Fizika 11, 1969)

Using the available spectroscopic data the authors calculate the statistical sum and various thermodynamic functions for the nuclei ^{41}Ca, ^{51}Cr, ^{55,58}Fe and ^{59,61}Ni. They also estimate the influence of a break in the spectrum, missing levels and the degree of level degeneracy.

OPTIMUM PARAMETERS OF A NEUTRON OPTICAL POTENTIAL FOR THE ^{238}U NUCLEUS

G.V. Anikin, A.G. Dovbenko, L.Ya. Kazakova,
V.E. Kolesov, V.I. Popov, G.N. Smirenkin
A.S. Tishin

This paper presents the results of attempts to find a single optical potential giving a satisfactory description of the experimental data on the scattering of neutrons by ^{238}U nuclei in the energy range 0.075-15.2 MeV.

An automatic search programme is used to fit the parameters for potentials with surface, volume and combined absorption. The optical potential is:

$$-V = V_0 \cdot f(r) + i\left(W_1 \cdot f(r) + W_2 \cdot g(r)\right) + V_{co} \cdot h(r) \cdot \vec{l}\vec{\sigma} ,$$

where

$$f(r) = \frac{1}{1 + exp\left(\frac{r - R_1}{a}\right)} ,$$

$$h(r) = \left(\frac{\hbar}{m_\pi c}\right)^2 \cdot \frac{1}{r} \left| \frac{df(r)}{dr} \right| ,$$

$$g(r) = \frac{4 exp\left(\frac{r - R_2}{b}\right)}{\left(1 + exp\left(\frac{r - R_2}{b}\right)\right)^2} ,$$

$$R_1 = r_1 A^{1/3} , \qquad R_2 = r_2 A^{1/3} . \tag{1}$$

The fit of the parameters was obtained from the angular distributions of elastically scattered neutrons and the total cross-sections for 14 neutron energies. The value was minimized as follows:

$$H^2 = H_1^2 + H_2^2 = \frac{1}{14N} \sum_n^{14} \sum_i^{N} \left(\frac{\sigma^{эксп.}(\theta_i, E_n) - \sigma^{расч.}(\theta_i, E_n)}{\sigma^{эксп.}(\theta_i, E_n)} \right) + \frac{B}{14} \sum_n^{14} \left(\frac{\sigma_t^{эксп.}(E_n) - \sigma^{расч.}(E_n)}{\sigma_t^{эксп.}(E_n)} \right)^2 \tag{2}$$

The parameters of the potentials obtained are given in Table 1.

<u>Table 1</u>

Type of absorption	Surface				Volume				Combined	
No. of group	I	II	III	IV	I	II	III	IV	II	III
B	IO^6	9	9	0	IO^6	9	9	0	9	9
V_o (MeV)	4I,5	43,2	4I,9	43,3	44,3	43	39,I	42,2	40,9	38,9
r_1 (F)	I,3I	I,28	I,3	I,29	I,25	I,26	I,35	I,3I	I,3I	I,35
a (F)	0,36	0,29	0,25	0,27	0,6	0,56	0,36	0,3	0,46	0,3I
W_1 (MeV)	-	-	-	-	3,6	4,5	4,2	5	2,I	I,5
W_2 (MeV)	4	4,7	5,6	IO	-	-	-	-	5	5
r_2 (F)	I,I7	I,I7	I,05	I,I	-	-	-	-	I,06	I,26
b (F)	0,95	I,0	0,95	0,72	-	-	-	-	0,72	0,64
V_{so} (MeV)	4,9	3,3	I7,8	I8,5	0	3,I	I4,9	I7	0	I6,4
H_1^2	0,I37	0,077	0,054	0,037	0,I	0,057	0,058	0,04	0,06I	0,054
H_2^2	I,7.IO^{-4}	I,2.IO^{-3}	3,6.IO^{-3}	7.IO^{-3}	7,9.IO^{-4}	I,2.IO^{-3}	2,2.IO^{-3}	9,7.IO^{-3}	6,4.IO^{-4}	I,4.IO^{-3}

RADIATIVE CAPTURE OF NEUTRONS BY THE ^{241}Am NUCLEUS

A.G. Dovbenko, V.I. Ivanov, V.E. Kolesov,
V.A. Tolstikov

(Submitted to the Nuclear Data Centre Bulletin)

The authors give the results of experimental studies on cross-sections for the radiative capture, by the ^{241}Am nucleus, of thermal neutrons and fission spectrum neutrons for the core of the BR-5 reactor. The following cross-sections were obtained for the reactions ^{241}Am$(n,\gamma)^{242}$Am, ^{241}Am$(n,\gamma)^{242}$Am, ^{241}Am$(n,\gamma)^{242g}$Am respectively: 940 ± 90 mb, 150 ± 14 mb, 790 ± 92 mb. The isomeric ratio σ_m/σ_g was obtained for thermal and fast neutron capture: 0.128 ± 0.034 and 0.189 ± 0.022.

Measurements of the ^{241}Am$(n,\gamma)^{242}$Am reaction cross-section for fast neutrons and of the isomeric ratio σ_m/σ_g for thermal and fast neutrons are compared with calculations based on the statistical theory of nuclear reactions.

ANGULAR ANISOTROPY OF THE NEUTRON FISSION OF ^{237}Np AND ^{241}Am

D.L. Shpak, V.I. Fursov,
G.N. Smirenkin

Glass detectors were used for detailed measurements of the angular distributions of fragments in the fission of ^{237}Np and ^{241}Am by neutrons in the energy range 0.3-7.2 MeV. The energy dependence of the parameter in the fissionable odd-odd nuclei studied is stepped. The authors discuss the possibility of explaining this dependence as the effect of a discrete change in the number of excited quasi-particles.

Table 1 shows the coefficient of angular anisotropy $A = \frac{W(0^\circ)}{W(90^\circ)}$ as a function of the neutron energy E_n.

Table 1

ANGULAR ANISOTROPY OF FISSION FRAGMENTS FOR Np^{237} and Am^{241}

E (MeV)	^{237}Np	^{241}Am
0,30 ± 0,02	-0,025 ± 0,050	0,0II ± 0,040
0,34 ± 0,02	0,037 ± 0,025	0,000 ± 0,020
0,38 ± 0,02	- 0,026 ± 0,030	0,0I3 ± 0,040
0,42 ± 0,02	- 0,022 ± 0,025	0,000 ± 0,040
0,46 ± 0,02	0,002 ± 0,030	0,002 ± 0,050
0,50 ± 0,02	- 0,020 ± 0,020	0,0I6 ± 0,040
0,54 ± 0,02	- 0,055 ± 0,030	0,045 ± 0,040
0,58 ± 0,02	- 0,030 ± 0,025	0,036 ± 0,020
0,62 ± 0,02	0,035 ± 0,025	0,022 ± 0,0I4
0,66 ± 0,02	0,0I3 ± 0,02I	0,04I ± 0,026
0,70 ± 0,02	0,063 ± 0,0I5	0,044 ± 0,020
0,74 ± 0,02	0,06I ± 0,025	0,049 ± 0,0I9
0,80 ± 0,04	0,073 ± 0,0I5	0,053 ± 0,0I8
0,90 ± 0,04	0,I07 ± 0,020	0,074 ± 0,025
I,00 ± 0,04	0,I00 ± 0,0I9	0,076 ± 0,0I4
I,I0 ± 0,04	0,I23 ± 0,02I	0,096 ± 0,0I3
I,20 ± 0,04	0,I24 ± 0,0II	0,090 ± 0,0I5
I,35 ± 0,05	0,I37 ± 0,0I6	0,I02 ± 0,008
I,50 ± 0,05	0,I43 ± 0,020	0,I09 ± 0,0II
I,65 ± 0,05	0,I36 ± 0,033	0,I02 ± 0,0I3
I,80 ± 0,05	0,I60 ± 0,0I9	0,098 ± 0,008
I,95 ± 0,05	0,I45 ± 0,0I8	0,I0I ± 0,0I0

I	2	3
2,I0 ± 0,05	0,I67 ± 0,0I2	0,09I ± 0,0I3
2,25 ± 0,05	0,I75 ± 0,020	0,I0I ± 0,0I5
2,40 ± 0,05	0,I78 ± 0,0I0	0,I29 ± 0,0I2
2,55 ± 0,05	0,I79 ± 0,0I4	0,085 ± 0,0I0
2,70 ± 0,05	0,I66 ± 0,024	0,II3 ± 0,009
2,85 ± 0,05	0,I45 ± 0,0I9	0,092 ± 0,0I8
3,00 ± 0,05	0,II5 ± 0,0I4	0,I09 ± 0,0I2
3,I5 ± 0,05	0,I34 ± 0,023	0,I03 ± 0,0I4
3,30 ± 0,05	0,I76 ± 0,020	0,I0I ± 0,0I5
3,75 ± 0,05	0,I35 ± 0,025	0,I29 ± 0,006
3,90 ± 0,05	0,I22 ± 0,0I6	
4,05 ± 0,05	0,I83 ± 0,020	0,I0I ± 0,020
4,20 ± 0,05	0,I72 ± 0,0I2	
4,35 ± 0,05	0,I84 ± 0,009	0,084 ± 0,0I2
4,50 ± 0,05	0,I62 ± 0,0I2	0,092 ± 0,0I8
4,65 ± 0,05	0,I56 ± 0,0I4	0,088 ± 0,009
4,80 ± 0,05	0,I44 ± 0,0I6	0,095 ± 0,007
4,95 ± 0,05	0,I67 ± 0,0II	0,II0 ± 0,008
5,I0 ± 0,05	0,I29 ± 0,020	0,I29 ± 0,008
5,25 ± 0,05	0,I87 ± 0,0I5	0,I39 ± 0,023
5,40 ± 0,05	0,I77 ± 0,0I0	0,I24 ± 0,0I0
5,55 ± 0,05	0,I48 ± 0,0I5	0,I0I ± 0,0II
5,70 ± 0,05	0,I54 ± 0,02I	0,I29 ± 0,0I2
5,85 ± 0,05	0,I68 ± 0,02I	0,I2I ± 0,009
6,00 ± 0,05	0,I72 ± 0,0I4	0,I09 ± 0,0I4
6,I5 ± 0,05	0,242 ± 0,020	0,I25 ± 0,0I2
6,30 ± 0,05	0,205 ± 0,024	0,II5 ± 0,0I0
6,45 ± 0,05	0,224 ± 0,028	0,I64 ± 0,0I2
6,60 ± 0,05	0,246 ± 0,0I4	0,I50 ± 0,0I9
6,75 ± 0,05	0,278 ± 0,02I	0,I46 ± 0,006
6,90 ± 0,05	0,22I ± 0,02I	0,I66 ± 0,0I0
7,05 ± 0,05	0,206 ± 0,024	0,20I ± 0,0I4
7,20 ± 0,05	0,248 ± 0,0I6	0,I55 ± 0,0II

EXPERIMENTAL DATA ON THE YIELDS OF THE ISOTOPES ^{11}C, ^{13}N AND ^{18}F, USED TO DETERMINE IMPURITIES OF CARBON, NITROGEN, OXYGEN AND OTHER LIGHT ELEMENTS BY ACTIVATION ANALYSIS WITH VARIOUS CHARGED PARTICLES

N.N. Krasnov, P.P. Dmitriev, Z.P. Dmitrieva
I.O. Konstantinov and G.A. Molin

The authors measured the yield of ^{11}C, ^{13}N and ^{18}F as a function of the incident particle energy in the irradiation of thick targets of the following light elements: Be, B, C, N, O, F, Na, Mg and Al. The work was performed on the cyclotron of the Institute of Physics and Power Engineering with maximum particle energies of 22 MeV (protons), 22 MeV (deuterons), 44 MeV (alpha particles) and 30 MeV (^{3}He ions). The energy of the particles was varied by copper retarding foils.

The yield data obtained, shown in Figs 1-8, afford a means of (i) selecting the optimum sample-irradiation conditions for determining light-element impurities by activation analysis with charged particles, (ii) estimating without difficulty the sensitivity of the analysis and (iii) using an absolute method for the activation analysis.

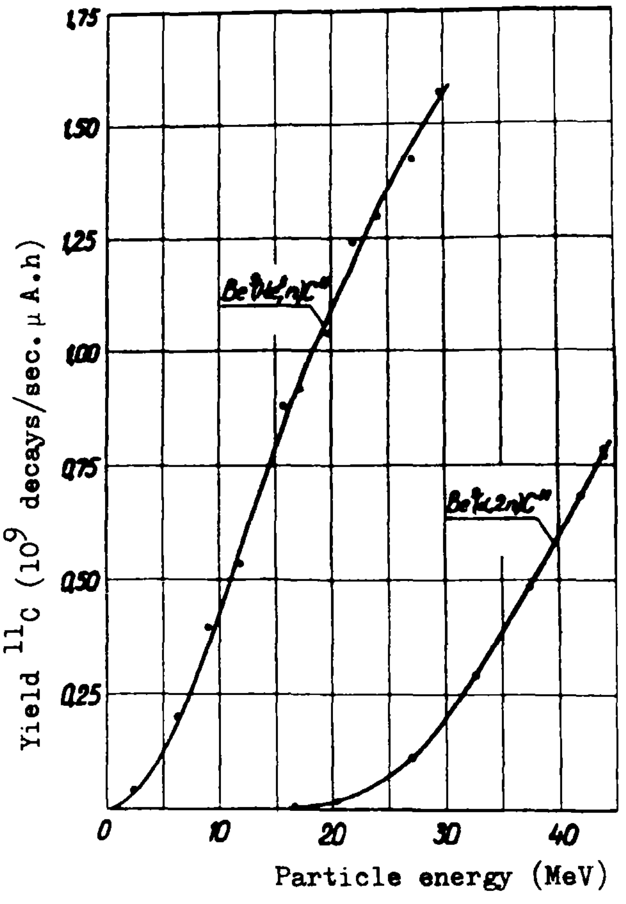
Yield ^{11}C (10^9 decays/sec. µ A.h)
1,75
1,50
1,25
1,00
0,75
0,50
0,25
0
10
20
30
40
Particle energy (MeV)
$Be^9(He^3,n)C^{11}$
$Be^9(\alpha,2n)C^{11}$

Fig. 1

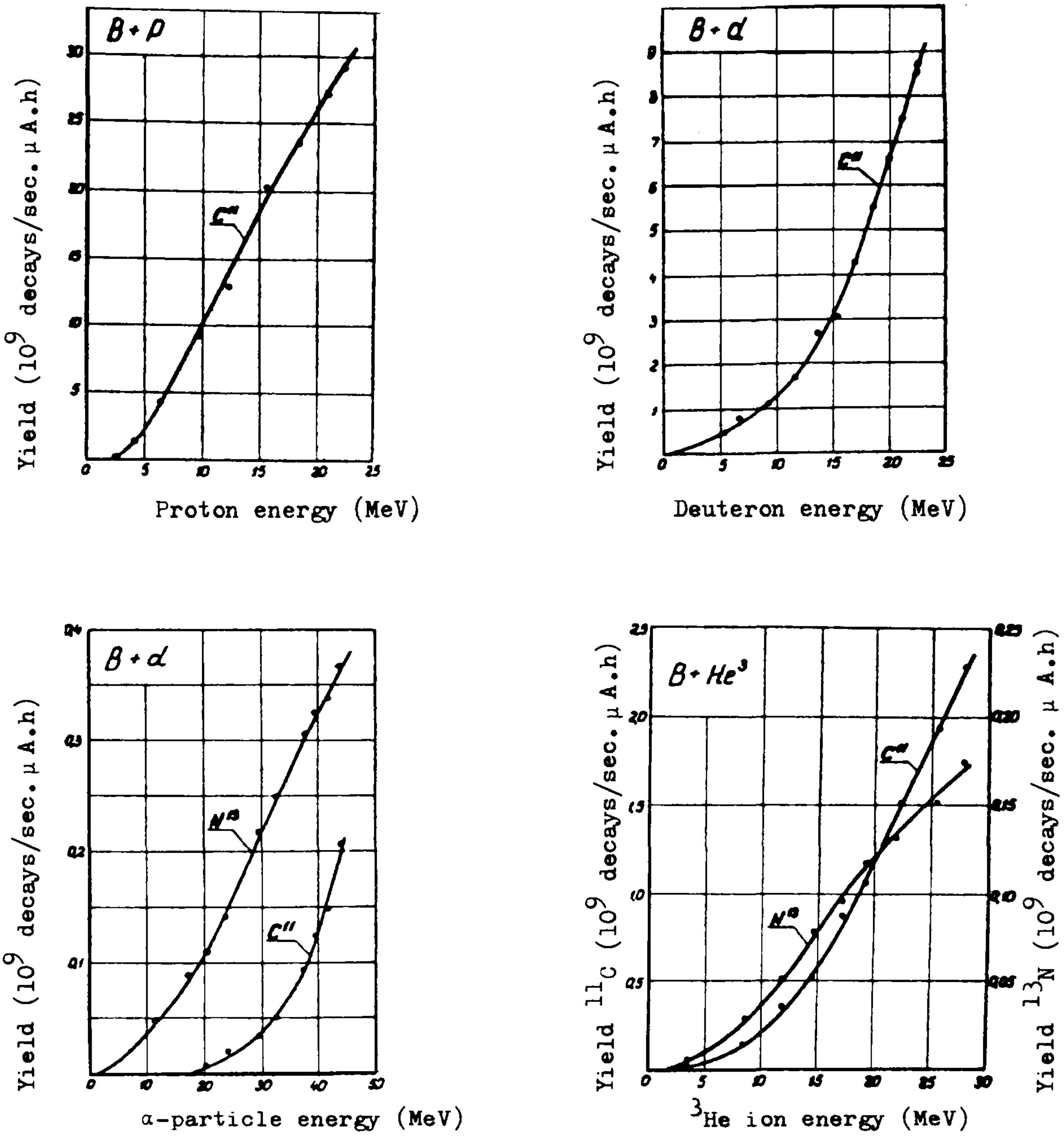
B+p
C11
Yield (10^9 decays/sec. μ A.h)
5
10
15
20
25
30
0
5
10
15
20
25
Proton energy (MeV)
B+d
C11
Yield (10^9 decays/sec. μ A.h)
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25
Deuteron energy (MeV)
B+α
N13
C11
Yield (10^9 decays/sec. μ A.h)
0.1
0.2
0.3
0.4
0
10
20
30
40
50
α-particle energy (MeV)
B+He3
C11
N13
Yield 11C (10^9 decays/sec. μ A.h)
0.5
10
15
20
25
Yield 13N (10^9 decays/sec. μ A.h)
0.05
0.10
0.15
0.20
0.25
0
5
10
15
20
25
30
3He ion energy (MeV)

Fig. 2

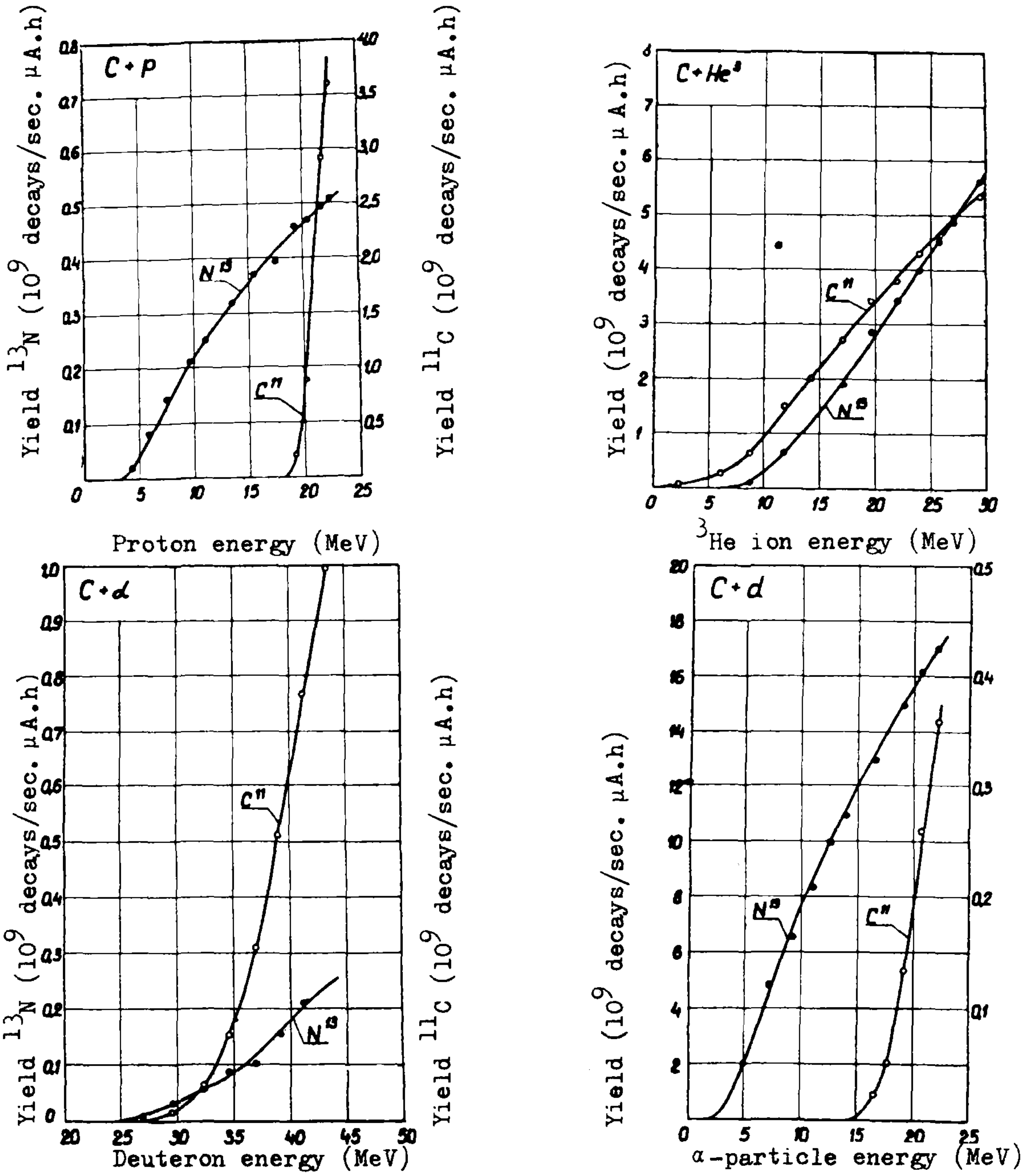
C+p
Yield ^{13}N (10^9 decays/sec. µA.h)
Yield ^{11}C (10^9 decays/sec. µA.h)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
N^{13}
C^{11}
0
5
10
15
20
25
Proton energy (MeV)
C+He^3
Yield (10^9 decays/sec. µ A.h)
8
7
6
5
4
3
2
1
C^{11}
N^{13}
0
5
10
15
20
25
30
^{3}He ion energy (MeV)
C+d
Yield ^{13}N (10^9 decays/sec. µA.h)
Yield ^{11}C (10^9 decays/sec. µA.h)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
C^{11}
N^{13}
20
25
30
35
40
45
50
Deuteron energy (MeV)
C+d
Yield (10^9 decays/sec. µA.h)
20
18
16
14
12
10
8
6
4
2
0.5
0.4
0.3
0.2
0.1
N^{13}
C^{11}
0
5
10
15
20
25
α-particle energy (MeV)

Fig. 3

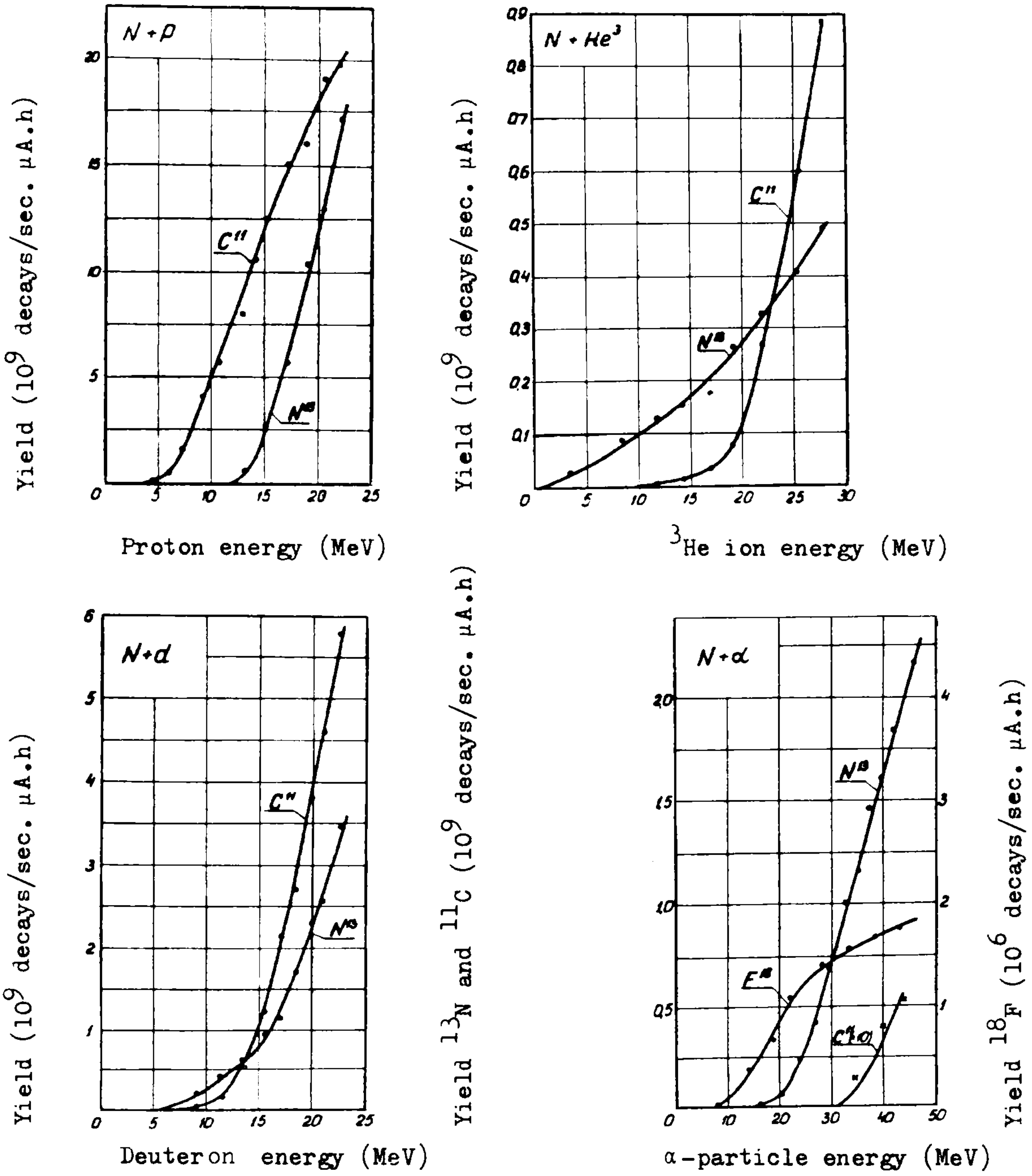
N + p
C^{11}
N^{13}
Yield (10^9 decays/sec. µA.h)
0
5
10
15
20
25
Proton energy (MeV)
N + He^3
C^{11}
N^{13}
Yield (10^9 decays/sec. µA.h)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
5
10
15
20
25
30
^{3}He ion energy (MeV)
N + d
C^{11}
N^{13}
Yield (10^9 decays/sec. µA.h)
1
2
3
4
5
6
0
5
10
15
20
25
Deuteron energy (MeV)
N + α
N^{13}
F^{18}
C^{11}α
Yield ^{13}N and ^{11}C (10^9 decays/sec. µA.h)
0.5
1.0
1.5
2.0
Yield ^{18}F (10^6 decays/sec. µA.h)
1
2
3
4
0
10
20
30
40
50
α-particle energy (MeV)

Fig. 4

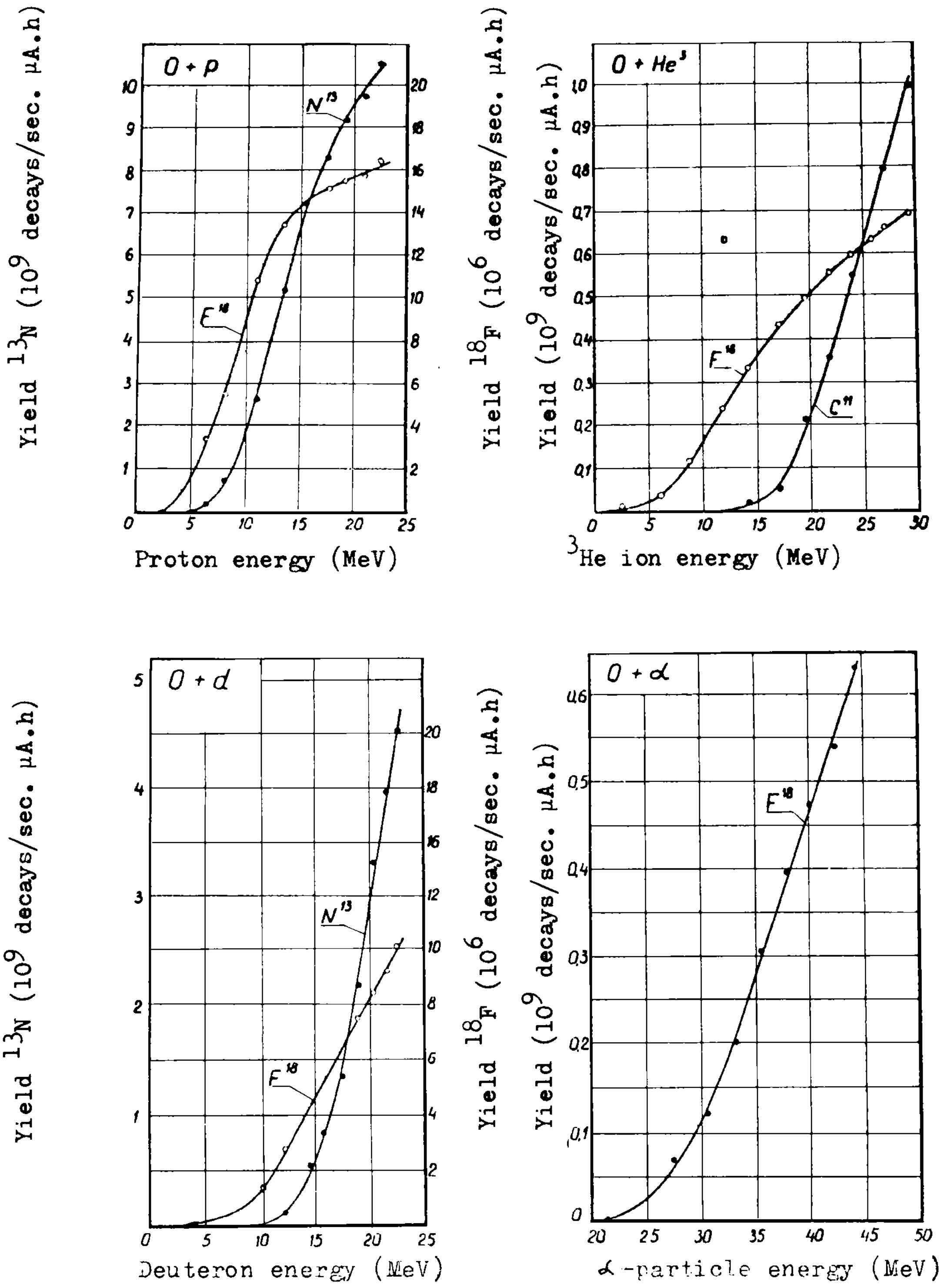
O + p
N^{13}
F^{18}
Yield ^{13}N (10^9 decays/sec. μA.h)
Yield ^{18}F (10^6 decays/sec. μA.h)
Proton energy (MeV)
0
5
10
15
20
25
O + He³
F^{18}
C^{11}
Yield (10^9 decays/sec. μA.h)
^{3}He ion energy (MeV)
0
5
10
15
20
25
30
O + d
N^{13}
F^{18}
Yield ^{13}N (10^9 decays/sec. μA.h)
Yield ^{18}F (10^6 decays/sec. μA.h)
Deuteron energy (MeV)
0
5
10
15
20
25
O + α
F^{18}
Yield (10^9 decays/sec. μA.h)
α-particle energy (MeV)
20
25
30
35
40
45
50

Fig. 5

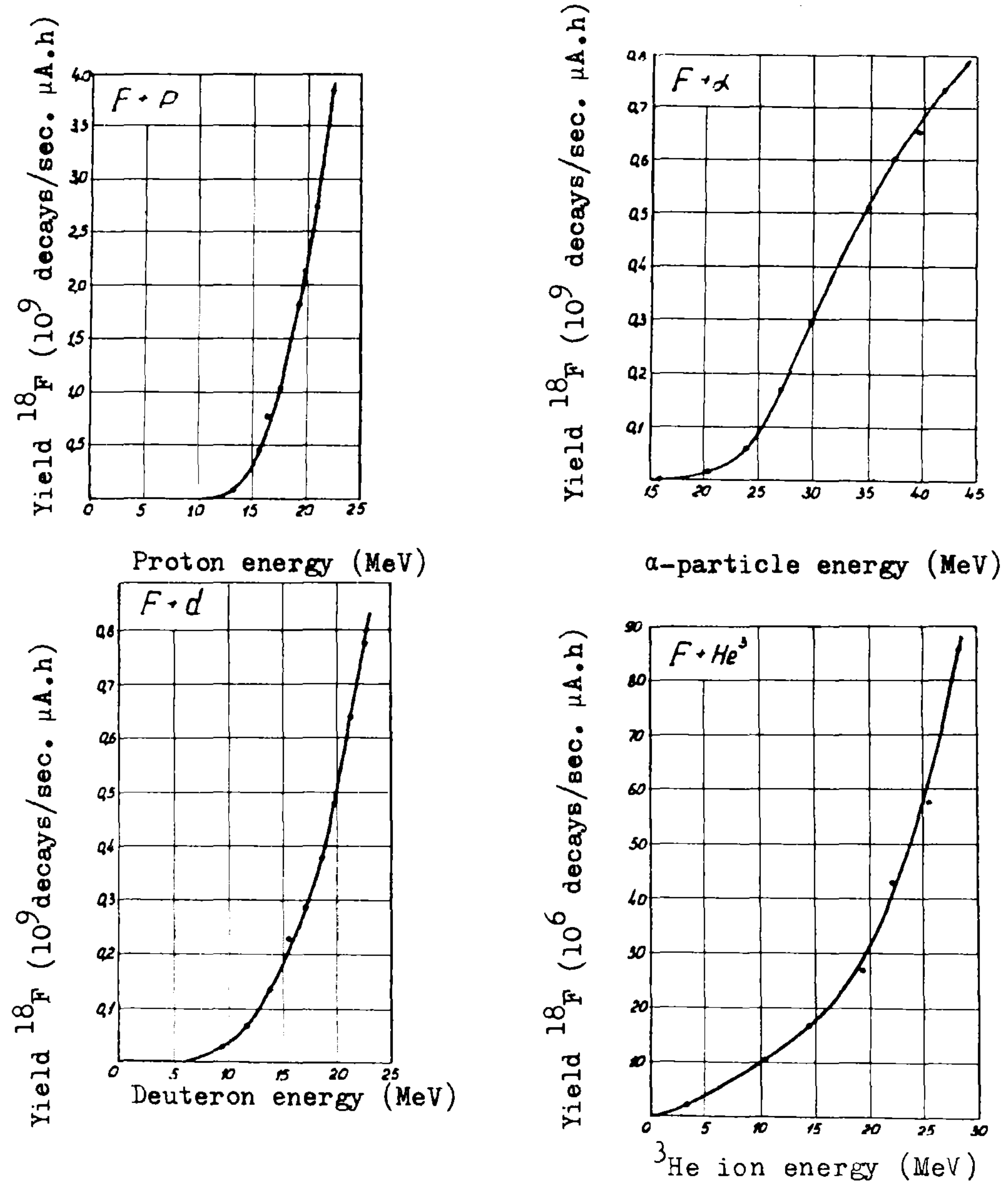
F + p
Yield ^{18}F (10^9 decays/sec. μA.h)
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
0
5
10
15
20
25
Proton energy (MeV)
F + α
Yield ^{18}F (10^9 decays/sec. μA.h)
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
15
20
25
30
35
40
45
α-particle energy (MeV)
F + d
Yield ^{18}F (10^9decays/sec. μA.h)
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0
5
10
15
20
25
Deuteron energy (MeV)
F + He^3
Yield ^{18}F (10^6 decays/sec. μA.h)
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
^{3}He ion energy (MeV)

Fig. 6

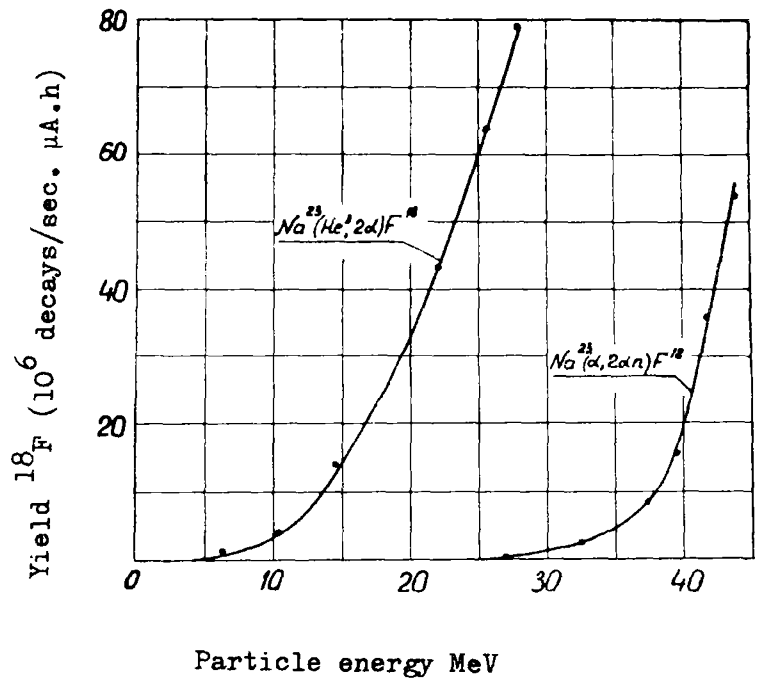
80
60
40
20
0
10
20
30
40
Yield ^{18}F (10^6 decays/sec. µA.h)
Particle energy MeV
$Na^{23}(He^3,2\alpha)F^{18}$
$Na^{23}(\alpha,2\alpha n)F^{18}$

Fig. 7

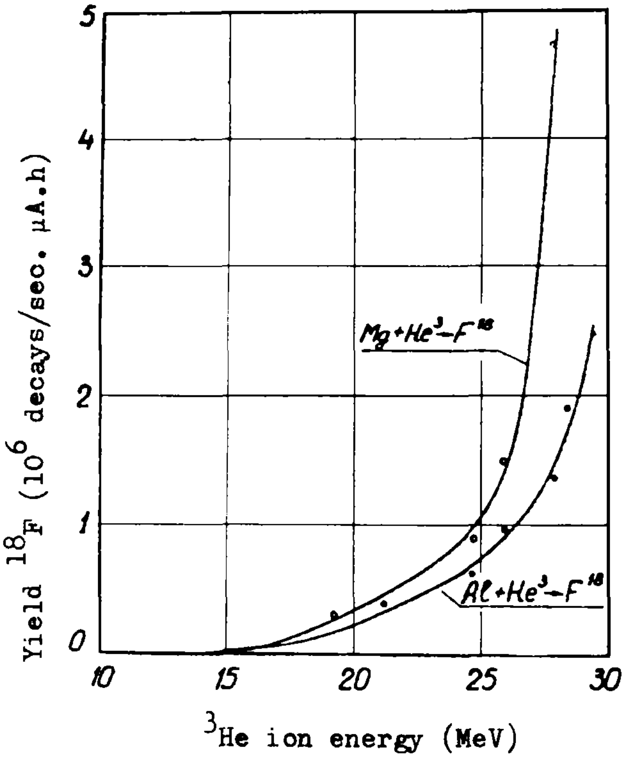
Yield ^{18}F (10^6 decays/sec. μA.h)
5
4
3
2
1
0
10
15
20
25
30
^{3}He ion energy (MeV)
Mg+He^3→F^{18}
Al+He^3→F^{18}

Fig. 8

A METHOD OF MEASURING CONCENTRATIONS OF FISSIONABLE SUBSTANCES USING NEUTRON BIAS LIGHTING

V.K. Bogatyrev, B.G. Dubovsky and
V.V. Frolov
(submitted to Atomnaja Energija)

The authors describe a method of measuring uranium-235 concentrations by means of bias lighting by neutrons from an Sb-Be source and recording of fission neutrons. The source background is eliminated by moving a cadmium-coated neutron counter with a polyethylene spacer to a distance of 15-18 cm from the source. A source intensity of 100 Ci gives a sensitivity of 1 mg/l and higher. The method is suitable for analysing irradiated solids and solutions.

GAMMA BACKGROUND PULSE-COMPENSATION EFFECT IN NEUTRON DETECTORS

V.K. Bogatyrev, Yu.V. Volkov, V.V. Charychansky
(submitted to Atomnaja Energija)

The authors discuss the theoretical aspects of increasing the insensitivity of neutron detectors to gamma background by making use of the pulse compensation effect. This effect is little used in ionization and scintillation detectors. The influence of long electron ranges and multiple electron scattering on the probability of occurrence of a spurious neutron pulse is discussed. By using pulse compensation it is possible, with a properly designed detector, to increase the permissible gamma background by almost two orders of magnitude.

SECONDARY GAMMA-RADIATION DOSES FORMED IN RADIATION SHIELDING AGAINST HEAVY CHARGED PARTICLES

E.S. Matusevich

The author discusses the results of measuring the gamma-radiation doses produced in targets irradiated by protons of energy 10.5, 22 and 660 MeV, and by particles of 42 MeV energy. The measurements were made at angles of 0°, 45° and 90° to the direction of the beam of primary particles. The targets were made of the following elements: Li, C, Al, Ti, Ni, Cu, Nb, Cd, Ta and Pb. It is shown that the mean energy carried off by all the gamma rays in the inelastic interaction of a heavy charged particle with the nuclei is about 3 MeV. A method is proposed for approximately estimating the secondary gamma-radiation doses behind shielding of thickness 10-50 g/cm^2.

Institute of Theoretical and Experimental Physics

MEASUREMENT OF MEAN CROSS-SECTIONS AND ALPHA FOR PLUTONIUM-239

F.N. Belyaev, K.G. Ignatev, S.I. Sukhoruchkin, S.P. Borovlev,
V.V. Pavlov, M.V. Polozov, A.N. Soldatov

Because of the discrepancies in the mean capture and fission cross-sections and in alpha for plutonium-239 in the neutron energy range of a few keV [1, 2] we measured these values with a neutron spectrometer on the cyclotron of the Institute of Theoretical and Experimental Physics.

The variation in the fission cross-section is measured from the yield of fast neutrons using two counters which are practically insensitive to gamma rays: (1) a ZnS detector with paraffin wax and (2) a stilbene detector with component separation. The stilbene detector was used together with a detector consisting of six NaI(Tl) crystals of dimensions 80 x 80 mm^2 to record the capture and fission gamma rays. To decrease the background the NaI counters are connected in pairs in coincidence. These cross-sections have already been measured by a similar method [3] for neutron energies up to 200 eV. The measurements are performed on a 15-m cyclotron base with a resolution of 0.2 μsec/m with a metallic sample of ^{239}Pu of thickness 2.2×10^{-3} atoms/barn.

In the course of the measurements preliminary values of alpha were obtained in the neutron energy range 0.3 eV-10 keV.

At the moment, work is being carried out to improve the values obtained.

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KINETIC ENERGY OF FRAGMENTS IN THE SPONTANEOUS FISSION OF ^{244}Cm

I.D. Alkhasov, O.I. Kostochkin, L.Z. Malkin, K.A. Petrzhak
and V.I. Shpakov

Semiconductor detectors were used for measuring the kinetic energies of both fragments in the spontaneous fission of ^{244}Cm. Absolute energy calibration was performed using the Schmitt method [1], which takes into account the mass dependence of the pulse amplitude defect in semiconductor detectors. The calibration constants characterizing the detectors were determined from the energy spectra of single fragments in the thermal-neutron fission of ^{235}U. Corrections for the emission of neutrons from the fragments were introduced into the experimental data; the total number of prompt neutrons was determined using a liquid scintillation counter, and the share attributable to each fragment was calculated from Terrell's [2] "universal" curve. During the measurements 64 700 spontaneous ^{244}Cm fission events were recorded.

The data were processed on the Minsk-22 computer. A graph was obtained for fragment mass versus total kinetic energy before neutron emission. The graph is used to determine the mean total kinetic energy ($\bar{E}_k$ = 188.6 ± 2.2 MeV), the mean energies of light and heavy fragments ($\bar{E}_l$ = 107.5 ± 1.8 MeV and $\bar{E}_h$ = 81.1 ± 1.3 MeV, respectively), the mean masses of light and heavy fragments ($\bar{M}_l$ = 104.6 ± 1.7 absolute units of mass and $\bar{M}_h$ = 139.0 ± 2.2 amv; respectively).

The errors indicated are mean square values and are made up of errors in determining the average values from the graph, error in determining the calibration constants from the single fragment ^{235}U spectra, error in measuring the pulse amplitude and error in the value of the calibration coefficients in the Schmitt formula.

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FRAGMENT-YIELD FINE STRUCTURE IN THE FISSION OF HEAVY NUCLEI

I.A. Baranov, A.N. Protopopov, B.M. Shiryaev
(submitted to Jadernaya Fizika)

The authors measured the fragment-yield distribution in the thermal-neutron fission of ^{235}U for various fixed kinetic energies of fragment pairs. The measurements were performed using silicon semiconductor counters and their purpose was to compare the experimental yield distributions with distributions obtained by calculating the yields from the statistical model, and to check the results given in reference /‾1_7, which report a yield structure for cases of fragments of low kinetic energy.

From the measurements carried out it follows that the yield fine structure appears only for pair fragments with high fixed kinetic energy ($>$ 100 Mev). The figure gives the spectra measured in this work for pair fragments with kinetic energy $E_k = 60.7, 68.2$ and 79.0 ± 0.5 MeV (converted to the mass numbers of the fragments) together with the distribution for $E_k = 70$ MeV taken from reference /‾1_7.

Comparison shows a divergence between the experimentally obtained distributions and the distributions calculated from the statistical model, and this may be due to the inaccuracy of the parameters used in the calculations.

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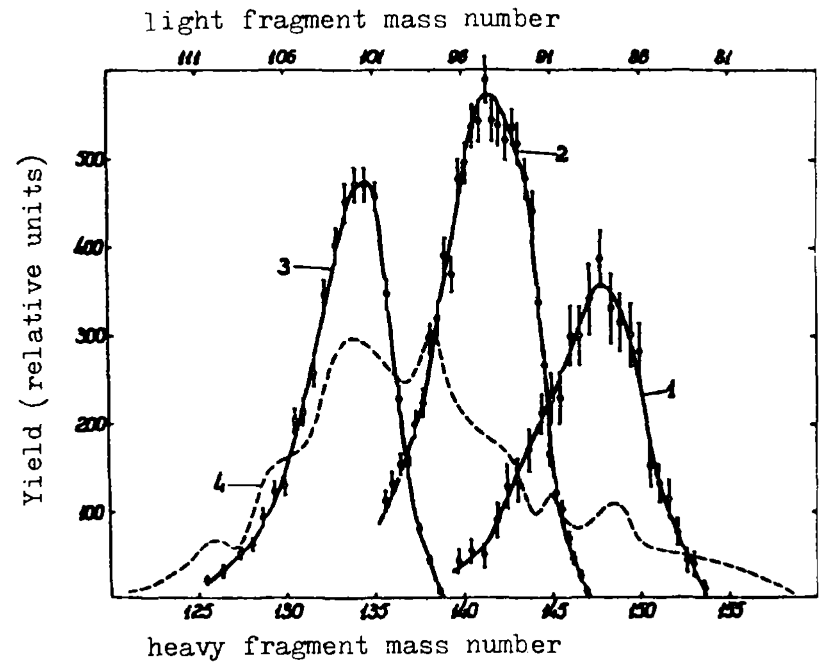

Fig. 1 Fragment yields (measured) versus mass number for pair fragments of fixed kinetic energy E_k = 60.7, 68.2 and 79.0 MeV (curves 1, 2 and 3 respectively), and yields for E_k = 70 MeV (curve 4) from reference [1].

Joint Institute of Nuclear Research

NEUTRON RESONANCE PARAMETERS FOR THE ISOTOPES ^{85}Rb AND ^{87}Rb

M.K. Grebenyuk, P.Sh. Kovach, Kh. Maletski, I.M. Salamatin
(JINR Report R3-4357, Dubna, 1969)

The time-of-flight method was used with flight paths of 1000 and 242 m respectively, for neutron transmission and radiative capture measurements on separated isotopes of rubidium on the IBR pulsed reactor with microtron.

In the neutron energy range up to about 20 keV the parameters of 54 levels were obtained using the areas method (Table 1). The spins were obtained for a number or resonances using the "shape" method. Various mean nuclear parameters were calculated for the isolated level parameters found (Table 2).

Table 1

Neutron resonance parameters for rubidium isotopes

Target nucleus	Eo (eV)	Eo (eV)	J	$g\Gamma_n$ (eV)	$\Delta g\Gamma_n$ (eV)	$g\Gamma_n$ (eV)	$\Delta g\Gamma_\gamma$ (eV)
Rb^{85}	I76,6*	0,3		0,0004	0,00006		
	224,7*	0,3		0,00057	0,00008		
	236,6*	0.4		(0,0054)	(0,0005)		
	429*	I		0,00I4	0,0002		
	466*	I,2		0,0008	0,0002		
	477	I,2		0,02I	0,003		
	530	I,4	2	0,77	0,I0	0,094	0,0I4
	546*	I,4		0,003	0,00I		
	598*	I,6		0,0032	0,0004		
	658	2		0,I7	0,05		
	807*	3		0,008	0,00I		
	I0I2	4		0,07	0,02		
	I046	4		0,46	0,07	0,094	0,0I4
	I2I0	5		0,84	0,I3	0,II0	0,0I6
	I4I4	6		3,2	0,3	0,I00	0,0I5
	I5I4	7		0,07	0,02		
	I686	I0		0,34	0,I0	0,I02	0,0I5
	I943*	I0		0.0I0	0,005		

* presumed P-wave resonances

Table 1 (Cont'd)

I	2	3	4	5	6	7	8
	I996	I5		0,26	0,09	0,I00	0,0I5
	2II0	I5		0,25	0,I0		
	2I90*	20		0,0I0	0,005		
	23I0*	20		0,020	0,006		
	2420	I5		3,8	0,6		
	2550*	20		0,033	0,0I0		
	26I0	20		0,05	0,02		
	2800*	25		0,020	0,007		
	3020	I5		2,6	0,6		
	3235	I5		I,4	0,35		
	3360	I5		0,3	0,I		
	4060	20		I,8	0,4		
	4250	I5		4,2	0,8		
	4930	30		6	I		
	5I80	30		2,3	0,8		
	5660	25		3,0	0,8		
	7250	35		6	I,5		
	8430	70		I6	3		
	93I0	70		I0	3		
	II030	I00		8	3		
	I2880	I20		I3	4		
	I5030	I00		2I	5		
	I5560	II0		8	3		
	I6690	I20		9	3		
	I7I70	I20		II	4		
Rb^{87}	269,5*	I		(0,007)	(0,00I)		
	378	I,6	2	0,44	0,04	0,088	0,0I3
	3840	I5		II,6	I,5		
	5I20	30		2I,6	3		
	7580	35	I	5I	7		
	8370	40		5	I		
	8790	45	2	I37	I6		
	III60	60		23	5		
	I4980	I00		20	6		
	23470	400		I20	30		

* presumed P-wave resonances

Table 2

Averaged parameters for rubidium isotopes

Target nucleus	So, 10^{-4}	$\bar{D}$ of observed s - levels (eV)	a (MeV^{-1})	$\Gamma\gamma$ (eV)
85	$I,I \pm^{0,5}_{0,3}$	I80 ± 30	I0,I5 ± 0,20	0,225 ± 0,035
87	$I,6 \pm^{I,4}_{0,5}$	I600 ± 420	I0,78 ± 0,42	0,I40 ± 0,025

The values of $\Gamma\gamma$ given in the table are taken for resonances 530 eV (^{85}Rb) and 378 eV ^{87}Rb).

SLOW-NEUTRON FISSION CROSS-SECTION FOR ^{237}Np

K.A. Gavrilov, K.K. Koshaeva, S.N. Kraitor
and L.B. Pikelner

The IBR pulsed reactor was used to measure the ^{237}Np fission cross-section for neutrons of energy 10^{-2}-10^{-3} eV by the time-of-flight method with a resolution of 0.25 µsec/m. Values of $\sigma_0\Gamma_f$ and Γ_f were obtained in the region below 10 eV for a number of resolved levels (see Table 1). The parameters from the work of Paya et al. [1] are given. In the range of unresolved resonances an intermediate structure is observed.

The authors consider the influence of sub-barrier fission in relation to the use of ^{237}Np as threshold detector. It is shown that the error in measuring the neutron flux may be as large as 50% in measurements in soft neutron spectra.

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Table 1

E_o (eV)	$\sigma_o \Gamma_f$ (b.eV)	Γ_f (μeV)	$g\Gamma_n$ (MeV) (from Ref. 1)	$\sigma_o \Gamma_f$ b.eV (Ref. 1)
0,49	$(2,9 \pm 0,7).\mathrm{IO}^{-3}$	I,3	0,0I6	
I,32	$(3,8 \pm \mathrm{I},0).\mathrm{IO}^{-3}$	4,I	0,0I87	$(2,5 \pm 0,6).\mathrm{IO}^{-3}$
I,48	$(3,5 \pm \mathrm{I},0).\mathrm{IO}^{-3}$	I,I	0,0725	$(2 \pm 0,5).\mathrm{IO}^{-3}$
I,97	$(\mathrm{I},9 \pm \mathrm{I},0).\mathrm{IO}^{-3}$	8,4	0,0083	-
3,88	$(\mathrm{I}6 \pm 4).\mathrm{IO}^{-3}$	7,8	0,I22	$(8,9 \pm \mathrm{I},2).\mathrm{IO}^{-3}$
5,80	$(46 \pm 9).\mathrm{IO}^{-3}$	I3	0,3II	$(\mathrm{I}9 \pm 3).\mathrm{IO}^{-3}$
7,5	$(\mathrm{I}2 \pm 6).\mathrm{IO}^{-3}$	I9	0,073	-

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STUDIES ON THE ELASTIC SCATTERING OF NEUTRONS OF ENERGY 0.3-4.1 MeV ON TITANIUM AND CHROMIUM NUCLEI, USING THE OPTICAL MODEL OF THE NUCLEUS

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M.V. Pasechnik, N.M. Pravdivy
and I.E. Sanzhur

In this work we obtained experimental data on the angular distributions of neutrons elastically scattered on nuclei of titanium and chromium and data on the polarizing power of these nuclei for neutrons of medium energy. The angular distributions of elastically scattered neutrons were measured in the range of angles 20-145° for neutron energies 2, 2.5 and 3 MeV. Data on the polarizing power of these nuclei were obtained for neutron energies 1.5 and 2 MeV. The experimental data in the present work supplement the existing data in the literature, both our own data and those of other authors, on the angular distributions of neutrons elastically scattered in titanium and chromium nuclei in the energy range 0.3-4.1 MeV and on the polarizing power of these nuclei.

In addition, an optical model analysis is made of experimental data on the angular distributions of neutrons elastically scattered on titanium and chromium nuclei [1-5] and on the polarizing power of these nuclei for eight neutron energies. The theoretical calculations were based on a potential of the form:

$$V(r) = -V_c f(r) - iW_c g(r) + V_{so} \left(\frac{\hbar}{\mu c}\right)^2 \frac{1}{r} \frac{d}{dr} f(r) \vec{\sigma} \cdot \vec{l}$$

where $f(r)$ and $g(r)$ are taken in the Woods-Saxon and Gauss forms, respectively. In the calculations the optical potential parameters were automatically varied to obtain a minimum value of χ^2:

$$\chi^2 = \chi_1^2 + \chi_2^2$$

where

$$\chi_1^2 = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{\sigma^{calc.}(\theta_i)-\sigma^{exp.}(\theta_i)}{\Delta\sigma^{exp.}(\theta_i)}\right]^2 ; \quad \chi_2^2 = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{P^{calc.}(\theta_i)-P^{exp.}(\theta_i)}{\Delta P^{exp.}(\theta_i)}\right]^2 .$$

The paper discusses the change in the optical potential parameters with energy.

The results of measuring the differential cross-sections of non-polarized neutrons are given in the form of an expansion in Legendre polynomials:

$$\frac{d\sigma el}{d\Omega} = \sum_{i=0}^{N} A_i P_i(\mathrm{Cos}\theta)$$

The values of the coefficients A_i and of the calculation constants (σ_{el}, σ_{tre} and Cosθ) are given in Table I. Table II gives right-left asymmetry and polarizing power of the nuclei in relation to the scattering angle. The optimal parameters of optical potential, obtained from a four-parameters' fit, are given in Table III (r_0 = 1.25fm, b = 0.98fm). In addition to the four-parameter analysis, two-parameter and three-parameter analyses were carried out for titanium. In the calculations with variation of two parameters the following non-varying parameters were used: V_{so} = 10 MeV, a = 0.65fm, b = 0.98fm and r_0 = 1.25.

The values of the optimum parameters for the optical model, obtained from two-parameter and three-parameter analyses are given in Tables IV and V, respectively.

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Table I

Numerical values of coefficients in the Legendre polynomial expansion of differential cross-sections; total elastic scattering cross-sections; transport cross-sections; mean value of elastic scattering angle cosine

	Titanium			Chromium		
E_n (MeV) / Ai (barn/ster)	2.0	2.5	3.0	2.0	2.5	3.0
A_0	0,2I6	0,204	0,I84	0,2I7	0,202	0,I87
A_1	0,228	0,25I	0,3I3	0,200	0,230	0,280
A_2	0,350	0,372	0,386	0,332	0,349	0,363
A_3	0,I40	0,234	0,288	0,I66	0,222	0,279
A_4	0,052	0,I33	0,II3	0,070	0,092	0,093
A_5	- 0,003	0,040	0,0I3	0,0I4	0,0I6	0,004
A_6	- 0,0I9	0,0II	- 0,0I5	-	0,002	-0,007
A_7	- 0,0I4	0,002	- 0,029	-	- 0,0I0	-0,024
σ_{el}, барн	2,7I3 ± 0,052	2,562 ± 0,230	2,3II ± 0,I70	2,726 ± 0,049	2,537 ± 0,200	2,349 ± 0,I30
σ_{tr}, барн	I,758	I,5I2	I,00I	I,889	I,573	I,I84
$\overline{Cos\,\theta}$	0,352	0,4I0	0,567	0,307	0,380	0,496

Table II

Asymmetry and polarizing power of titanium and chromium nuclei

Titanium

	1.5 MeV		2.0 MeV	
$Cos\,\theta$	τ	$P_2(\theta)$	τ	$P_2(\theta)$
0,939	I,026 ± 0,025	-(0,035±0,034)	I,023 ± 0,0I7	-(0,052±0,038)
0,866	I,030 ± 0,023	-(0,042±0,03I)	I,0I9 ± 0,0I9	-(0,043±0,04I)
0,766	I,057 ± 0,026	-(0,077±0,034)	I,0I9 ± 0,0I5	-(0,042±0,034)
0,574	I,026 ± 0,032	-(0,036±0,043)	I,0004±0,022	-(0,00I±0,050)
0,342	I,033 ± 0,030	-(0,045±0,04I)	0,989 ± 0,030	+(0,024±0,070)
0,087	0,999 ± 0,038	+(0,00I±0,053)	0,965 ± 0,026	+(0,082±0,06I)
-0,I74	0,899 ± 0,04I	+(0,I48±0,063)	0,977 ± 0,030	+(0,058±0,070)
-0,423	0,86I ± 0,039	+(0,207±0,062)	0,978 ± 0,026	+(0,049±0,060)
-0,643	0,870 ± 0,025	+(0,I93±0,039)	I,02I ± 0,025	-(0,050±0,055)
-0,8I9	0,9II ± 0,03I	+(0,I30±0,048)	0,995 ± 0,027	+(0,0I3±0,063)

Table II (cont'd)

Chromium

	1.5 MeV		2.0 MeV	
Cosθ	τ	$P_2(\theta)$	τ	$P_2(\theta)$
0,939	I,022 ± 0,0I4	-(0,029±0,0I9)	I,035 ± 0,022	-(0,078±0,047)
0,866	I,028 ± 0,0I9	-(0,039±0,025)	I,063 ± 0,023	-(0,I39±0,050)
0,766	I,040 ± 0,0I8	-(0,055±0,024)	I,090 ± 0,0I9	-(0,I94±0,040)
0,574	I,039 ± 0,025	-(0,054±0,033)	I,073 ± 0,025	-(0,I59±0,054)
0,342	I,055 ± 0,024	-(0,074±0,032)	0,99I ± 0,026	+(0,02I±0,060)
0,087	I,006 ± 0,023	-(0,008±0,032)	0,974 ± 0,025	+(0,060±0,058)
-0,I74	0,949 ± 0,025	+(0,073±0,036)	I,035 ± 0,028	-(0,078±0,05I)
-0,423	0,964 ± 0,023	+(0,05I±0,034)	I,0I9 ± 0,024	-(0,043±0,054)
-0,643	0,939 ± 0,02I	+(0,088±0,03I)	I,0I0 ± 0,03I	-(0,022±0,069)
-0,8I9	0,963 ± 0,023	+(0,053±0,033)	0,989 ± 0,03I	+(0,024 ±0,070)

Table III

Optimal values of optical potential parameters for titanium and chromium, obtained from 4-parameter analysis. Comparison of calculated and experimental total cross-sections (σ).

E_n(MeV)	χ_1^2	V_c(MeV)	W_c(MeV)	V_{so}(MeV)	a(fm)	σ_t calc. (barns)	σ_t exp. (barns)
0,3	2,67	47	6,5	II,5	0,6I	2,728	2,79
0,5	I,44	47	7	I0,5	0,63	2,684	2,42
I,0	0,43	47	5	8,5	0,6I	2,684	2,80
I,5	I,54	50	5,5	I6	0,5I	3,2I6	3,20
I,5*	0,34	53,5	II,5	I5	0,4I	2,700	-"-
I,5**	,28	49	9	I7,5	0,57	3,227	-"-
2,0	.3,93	49	6	I0,0	0,55	3,546	3,60
2,0*	0,60	53	I2,5	2,5	0,69	3,406	-"-
2,0**	32,0I	48,5	8	I0,5	0,59	3,535	-"-
2,5	3,I7	49	8,5	8,5	0,65	3,702	3,70
3,0	3,06	48	9	I0	0,65	3,688	3,68
3,0*	3,38	49	I3	6	0,63	3,440	-"-
3,0**	8,I7	47,5	I2	7,5	0,67	3,630	-"-
4,I	0,24	47,5	8	I2	0,69	3,668	3,65

* $-x^2 = x_2^2$

** $-x^2 = x_I^2 + x_2^2$

Table III (cont'd)

I	2	3	4	5	6	7	8
			Cr				
0,3	0,89	46	5	7	0,57	2,395	2,26
0,5	5,62	44,5	8,0	II	0,53	3,02I	3,25
0,8	0,85	46	7	9,5	0,59	2,87I	2,76
I,5	I,72	49	4	I6	0,4I	3,062	3,I0
I,5*	0,36	51,5	II	6,5	0,55	3,I56	-"-
I,5**	I4,07	48,5	I3	9,5	0,4I	3,025	-"-
2,0	I6,96	49	6,5	8	0,55	3,462	3,5
2,0*	I,II	49,5	9	5,5	0,79	3,906	-"-
2,0**	20,77	49	7	7	0,55	3,485	-"-
2,5	3,I2	48,5	8	I0,5	0,57	3,422	3,47
3,0	4,90	47,5	7,5	I5,5	0,7I	3,53I	3,52
3,0*	2,7I	49	I2,5	5	0,65	3,435	-"-
3,0**	33,99	48,5	I0,5	7	0,65	3,545	-"-
4,I	I,88	49,5	9,5	I2	0,67	3,446	3,73

Table IV

Optimum values of optical potential parameters for titanium, obtained from 2-parameter analysis. Comparison of calculated and experimental total cross-sections (σ).

E_n(MeV)	χ_1^2	V_c(MeV)	W_c(MeV)	σ_t calc. (barns)	σ_t exp. (barns)
0,3	2,67	46,5	6	2,663	2,79
0,5	I,43	46,5	7	2,709	2,42
I,0	0,43	46	4	2,750	2,80
I,5	8,50	48	II	3,44I	3,20
2,0	5I,I3	47,5	II	3,59I	3,60
2,5	3,43	49	8	3,669	3,70
3,0	3,06	48	9	3,688	3,68
4,I	0,86	48	9	3,556	3,65

* $-x^2 = x_2^2$

** $-x^2 = x_I^2 + x_2^2$

Table V

Optimum values of optical potential parameters for titanium obtained from 3-parameter analysis. Comparison of calculated and experimental total cross-sections.

E_n(MeV)	χ_1^2	V_c(MeV)	W_c(MeV)	a(fm)	σ_t calc. (barns)	σ_t exp. (barns)
0,3	2,69	47	6,5	0,61	2,703	2,79
0,5	1,35	47	7	0,63	2,673	2,42
1,0	0,43	47,5	4,5	0,59	2,651	2,80
1,5	6,00	48,5	7,5	0,57	3,284	3,20
2,0	13,93	49	6	0,55	3,546	3,60
2,5	3,30	48,5	9	0,67	3,702	3,70
3,0	3,06	48	9	0,65	3,688	3,68
4,1	0,58	48	9,5	0,67	3,568	3,65

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