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NEUTRON TOTAL CROSS-SECTION MEASUREMENT OF SOME METALS AND GASES FOR NEUTRON ENERGIES IN THE RANGE FROM $0.5 \cdot 10^{-4}$ TO $3 \cdot 10^{-4}$ EV

N.T. Kashukeev, G.A. Stanev, V.T. Surdjiisky and E.N. Stoyanova

Paper to the 7th National Conference on Physics
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ABSTRACT.

Method and facilities utilized for investigation of verycold neutrons interaction for energies $0,5.10^{-4}$ to 3.10^{-4} eV with the substance, in dependence of their velocity, are described. Neutron total cross sections of Ag, In, Cu, Fe, Ni, Mo and gases N, Ar and dry air, special camera wall samples for conservation of very-cold neutrons. It was established that in the velocity range 100 to 250 m/sec, the neutron total cross section depends of the metal velocity according 1/V law. Neutron total cross sections for investigated gases in the neutron velocity range 60-250 m/sec depend of the fraction lineal velocity. With an accuracy of 10% it was established that the neutron total cross sections of Ag, In, Cu concur with the absorption section, as for the metals Fe, Ni and Mo , besides absorption, there is also a complementary interaction, which, in these velocity ranges depends of the velocity approximately by 1/V law. Absence of superficial effects, produced by neutron incoherent elastic scattering, has been established. Metal samples with a purity of 99,95% and metals with technical purity have been investigated. Differences over experimental error in the measured cross sections have been not observed.

NEUTRON TOTAL CROSS SECTIONS MEASUREMENT OF SOME METALS AND GASES FOR NEUTRON ENERGIES IN THE RANGE FORM $0,5.10^{-4}$ to 3.10^{-4} eV.

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The present paper (chapter II) reports on data concerning verycold neutron total cross interaction for energies in the range from $0,5.10^{-4}$ to 3.10^{-4} eV with some metals. The purpose of these measurements were, from oneside, to elucidate the existence of abnormal cross section interaction of ultracold neutron with the substance, and from other side, to obtain data for the neutron velocity range from 100 to 25o m/sec. It should be noted, that the above mentioned velocity range is of real interest, as it is situated near the range of ultracold neutron and offers, simultaneously, the possibility to investigate the neutron interaction with the sample when there is an absence of coherent effect of Bragg reflexion and interaction with the surface of the sample, which, as it is shown in the estimations and the experimental investigations, are in the limits of the experimental error.

Chapter III of the paper reports on the results concerning verycold neutron total cross section with some gases in the above given velocity range. These results will be used to analyse the propagation of ultracold neutron in gases, as well as to develop gas convertors for ultracold neutrons.

I. Investigation experimental conditions of verycold neutron interaction with metals and gases.

The reported results have been obtained at the IRT-2000 Reactor of Sofia. The experiments were performed as follow: a beam of very-cold neutrons with known spectrum is passed through a metallic sheet or a gas target, whereupon the spectrum of the crossing beam is determined. The comparison of beam neutron spectra with a sample and without a sample gives us the run of the total cross section of neutron interaction with the sample in dependence of their velocity. The results of the meausurements have been proceeded by the method of least squares.

The beam of verycold neutrons is obtained by a curved mirror neutronguide, consisting of a stainless steel electropolite tube, which is sticked up to the bottom of the reactor horizontal channel. (fig. 1). The curvature radius of the neutronguide is of 22 m, and the diameter of the tube is 0,04 m; the total lenght - 7,37 m and is formed by two tubes, which, independently one of another, can be render vacuum of filled with the investigated gas.

For neutron beam spectrum analyze, a mechanical verycold neutrons time-of-flight selector was constructed, completed with a flat rotor, fitted with two apertures, which angular dimensions are $11,5^{0}$ or 4^{0}. The flight base of the selector can vary from 0,5 to 1 m. Between the rotor and the detector is put a vacuumated tube with a neutron non reflective internal cadmium surface. As detector for verycold neutrons was utilized a proportional gas counter with He^3 [1]. Time analyze of detector signals was carried out by a 400 channel analyzer, utilizing the two parts of its memory, each for 200 channels with a channel width of 102, 4 μs.

The total verycold neutron flux, falling over the sample, is 50 imp/cm^2 sec, without the detector effectivity calculation. The performed additional experiments for spectrum attenuation (maximum a 160 m/sec neutron velocity) or for acceleration of existing flux did not give any result, as the convertor (graphit, aluminium, destillated main water), situated at the bottom of the neutronguide, near the reactor active zone , was not cooled fur the purpose.

No recyclic neutrons have been observed for all measurements, as neutrons with velocity below 50 m/sec are practically absent in the obtained beam.

The bacground was determined by averaging the impluse numbers of cell channels, where statistically the impulses are uniformly distributed (not less than 100 consecutive channels) and by averaging the impulse numbers over the whole range of the analyzer and screening the rotor aperture with a cadmium foils.The results obtained by both methods are coicinding. The background was determined at each single measurement and as a rule is equal to 0,004 imp/sec for 1 channel of the analyzer, which represents 1,5% for V = 160 m/sec and 3% for V = 100 m/sec of beam spectrum. Statiscal errors, with which are given the results for neutron total cross section are determined by angular beam neutron scatterin, stipulated by the equation $\theta = 4,4 / (4,4^2 + V^2)^{1/2}$, where V is the velocity of neutrons through the neutronguide axe /in m/sec/ and indertermination in the lenght of flight path 1,5 cm, a distance at which the verycold neutrons are effectively absorbed in the detector gas.

II. Neutron total cross section investigation of verycold neutrons interaction with metals

These experiments were carried out for two configurations of the investigated metal sheets (thickness from 0,1 to 1 mm).

1. The sheet is fixed directly on the aperture of the neutronguide in front fo the selector screen. Measurements are carried out consecutively of beam spectrum without and with a sample and the results are compared for each channel.

2. A sheet of the investigated metal in a suitable form is fixed in such a way on one of the rotor apertures that, turning together with the rotor, it remains perpendicular to the falling neutron beam. In the analyzer are simultaneously recorded two spectra - of the beam, crossing the sheet, and of the beam, crossing the unscreened aperture of the rotor.

Measurements of both configurations of the sample, outside the experimental error, did not give any differences. Both method, consequently, are equally convenient for measurements as mentioned above. The second method, however, is more convenient, as we do not need to use a monitor detector for the intensity control of the falling neutron beam.

Elucidation of the role of superficial coherent effects for sample neutron scattering, a serie of measurements was performed, with a variation of the sheet numbers, disposed in sandwich, closely one to another, with a thickness corresponding to this of the sample. If the above mentioned effects are of importance, the results must depend from the sheet number, i.e. from the number of sample reflecting surfaces. Practically the results obtained with such sandwiches, composed from 1 to 4 sheets, are coinciding,

Two groups of metals were investigated:

a) Metal with absorption cross section of thermal neutrons, significantly over their cross sections for incoherent scattering (In, Ag, Cu).

b) Metals, which cross section for incoherent scattering is commensurable with their absorption cross section of thermal neutrons (Ni, Fe, Mo).

Figures 2 and 3 represent graphically the dependence of neutron interaction total cross section in the velocity range 100 to 250 m/sec with the mentioned metals , in dependence of the neutron wave lenght. It is evident, that for both metal groups this dependence is, as an example, lineal, i.e. the total cross section depends of the 1/V velocity: $\sigma(V) = a + b/V$ (1)

At extrapolation of $V \to \infty$ the interaction cross section for low absorption metals acquires negative values, which, however, as for metals with high absorption cross sections, are in the limits of statistical error. Such an extrapolation, however, is hardly recommended, taking into consideration the various interaction processes of neutron with very differentiated wave lenght.

In Table 1 are given the measured neutron interaction total cross section with a velocity of 100 m/sec, determined by the above mentioned rule (1) , as well as the total cross section determined straightly from the measurements of neutrons with a velocity of 100 m/sec. For comparison we are giving values of absorption cross section for 100 m/sec, determined by 1/V law. from the corresponding thermal neutron cross section. It is evident, that for metals of the group "a", the measured values are coinciding with literature data [2]. For metals of the group "b", the determined cross sections are significantly higher than the absorption cross section - for Ni and Fe approximately 40 barns and error percentage 10%; for Mo - 140 barns.

The investigations have been carried out with metal samples purityof 99,95%. Samples of technical cuper, nickel, ferum have been also investigated. The obtained results, however, are not significantly different from data for metal with hightened purity.

III. Investigation of verycold neutron total cross section section interaction with gases.

Investigations of gases have been carried out with two configurations of fixed gas target. With the investigated gas we filled:

a) the straight tube with non reflective walls, situated between the selector rotor and the detector. By this waw we avoid the influence of eventual changes in the reflexion coefficient of the neutronguide walls, as in the detector are falling only the straightly moving neutrons. There is, however, some deterioration in the geometry of the experimental facility, and one is obliged to resort to corrections of cross section value for inchorent scattering.

b) the second, outside tube of the neutronguide. In this case, a significant influence on the results could produce the eventual change of the neutronguide walls reflexion coefficient in the presence of the investigated gas. It is necessary to make a correction of the cross section value, taking into account the prolonged runs of the neutrons in comparison with the tube lenght, due to the wall reflexion and the running through a broken line. The reflexion number is determined by estimation of 1,5 to 2,5, in dependence of neutron velocity for a tube lenght of 3 m.

Fig. 4 gives graphically the dependence of the free neutrons run in the investigated gas (nitrogen and argon) from the neutron wave lenght. Neutron interaction total cross section in the range 60 to 250 m/sec depends from their velocity by the V fraction-lineal function:

$$\sigma(V) = (\alpha - \beta/V)^{-1} \qquad /2/$$

For lower velocities the dependence $\sigma = \sigma/V/$, is probably substantially different from the case /2/. Otherwais the total cross section interaction tends towards infinite big values for neutron velocity 40 - 50 m/sec. This fact is inadmissible, as at very low neutron velocities, their relative velocity eith respect of gas molecules, inclines toward the mean square velocity of their thermal movement.

For investigation of neutron interaction of lower energies with the substance, we are now constructing a special neutronguide.

<u>References</u>

1. Groshev L. V. - Preprint JINR P3-7282, Dubna 1973

2. Baucom H. H. - Nucleoniks 18, 198 (1960)

TEXTE EXPLICATORY TEXT OF FIGURES

Figure No 1 : Channel for investigation of verycold neutron interaction with the substance

1. Neutronguide
2. Time-of-flight mechanical selector

Figure No 2 : Dependence of verycold neutron total cross section interaction with indium and argent from the neutron wave lenght

Figure No 3 : Dependence of verycold neutron total cross section interaction with molibden, nickel, ferum and copper from the neutron wave lenght.

Figure No 4 : Dependence of verycold neutron free run in nitrogen and argon from the neutron wave.

Gas pression - 760 torrs. Temperature of gas - $290^{\circ}K$

Table No 1: 1. σ_t - total cross section of interaction for neutron velocity 100 m/sec, determined by a+b/V law, obtained after proceeding of experimental results by the method of least squares.

2. σ_{tot} - total cross section of interaction for neutron velocity 100 m/sec, determined straightly of neutron measurements with the mentioned velocity.

3. σ_a - absorption cross section for neutron velocity 100 m/sec, determined after calculation by 1/V law from the corresponding cross-section of thermal neutrons.

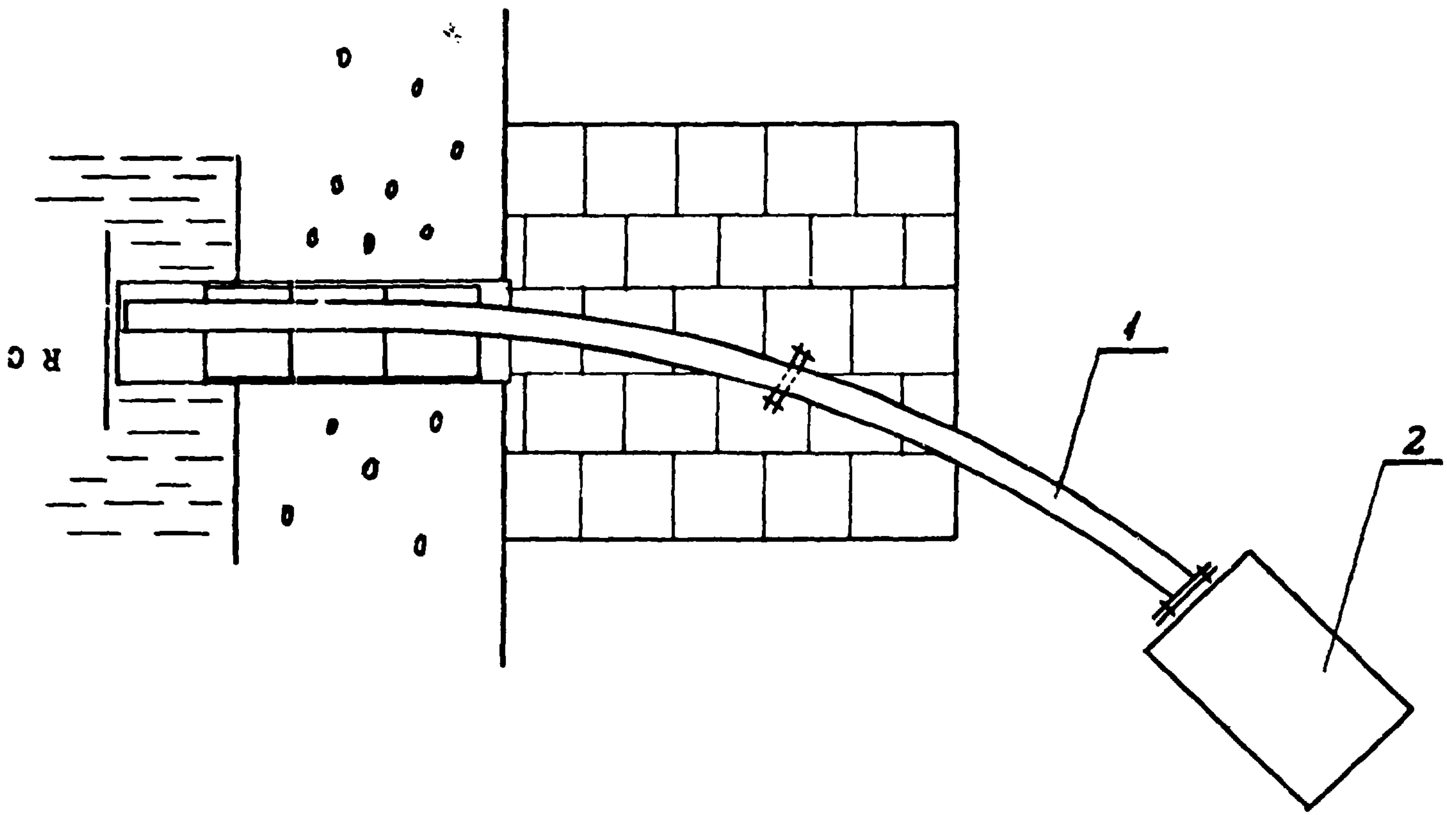
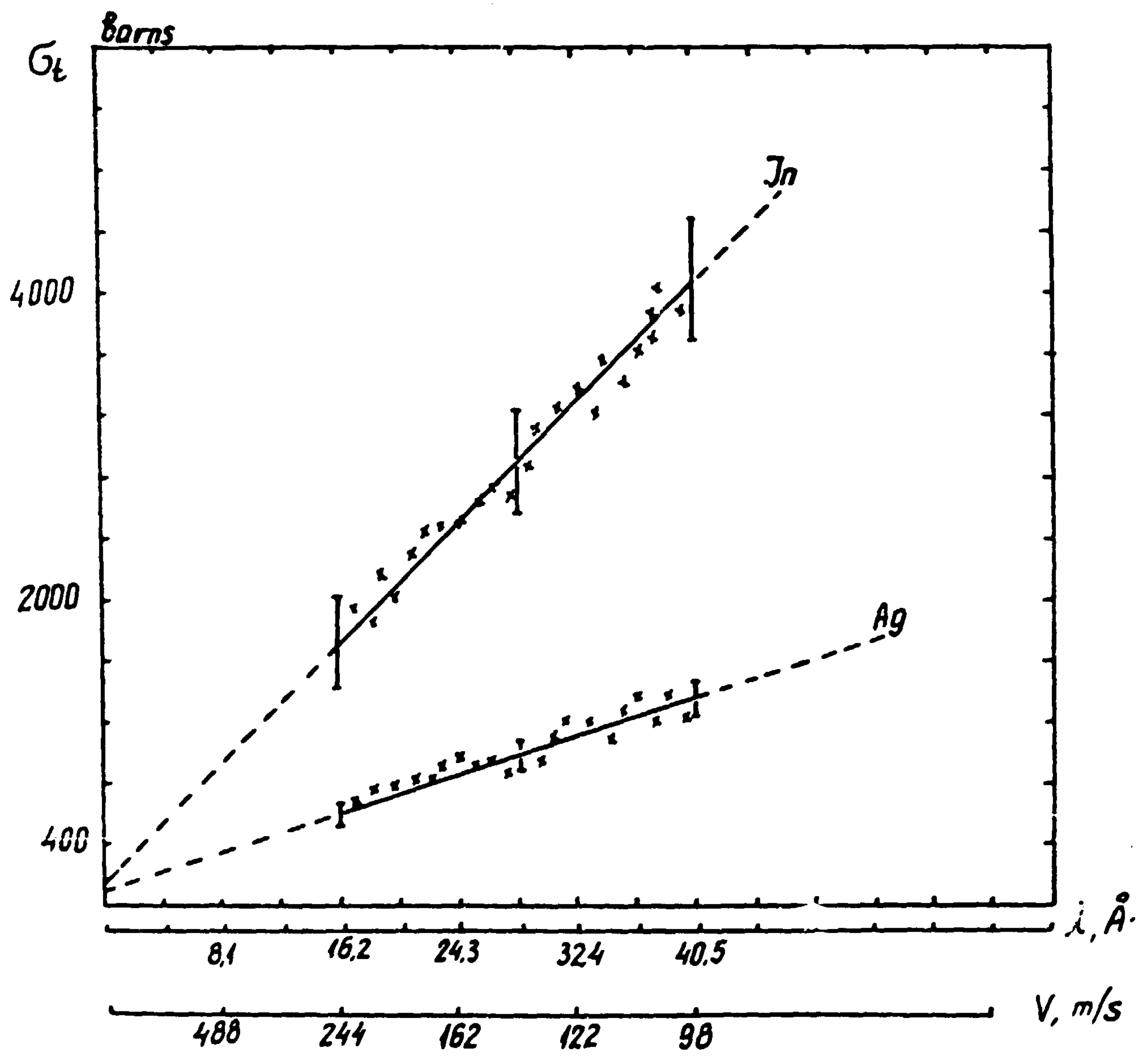
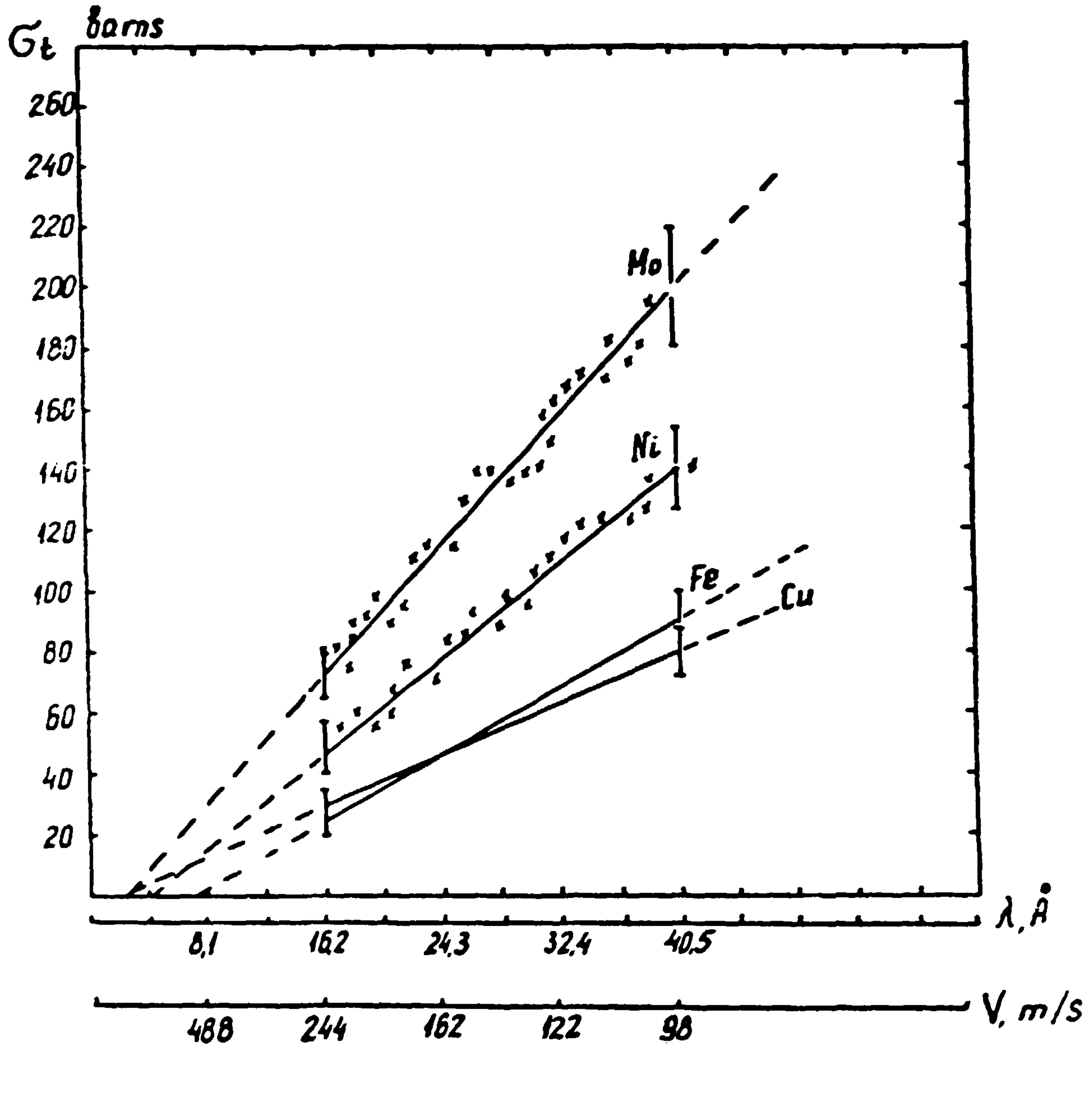


Fig. 1



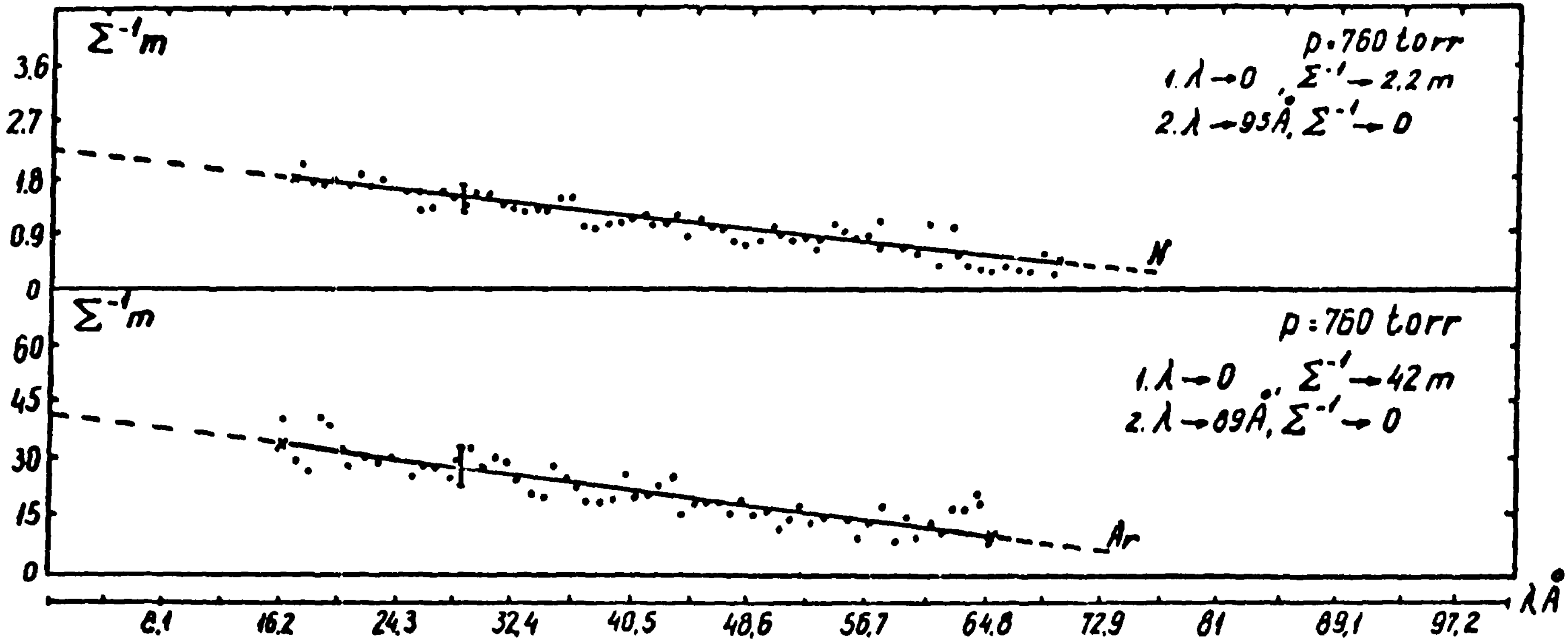
σ_t Barns
4000
2000
400
Jn
Ag
λ, Å
8,1
16,2
24,3
32,4
40,5
V, m/s
488
244
162
122
98

Fig. 2



σ_t barns
260
240
220
200
180
160
140
120
100
80
60
40
20
Mo
Ni
Fe
Cu
λ, Å
8,1
16,2
24,3
32,4
40,5
V, m/s
488
244
162
122
98

Fig. 3



Σ⁻¹m
3.6
2.7
1.8
0.9
0
p = 760 torr
1. λ → 0 , Σ⁻¹ → 2.2 m
2. λ → 95 Å, Σ⁻¹ → 0
N
Σ⁻¹m
60
45
30
15
0
p = 760 torr
1. λ → 0 , Σ⁻¹ → 42 m
2. λ → 89 Å, Σ⁻¹ → 0
Ar
8.1
16.2
24.3
32.4
40.5
48.6
56.7
64.8
72.9
81
89.1
97.2
λ Å

Fig. 4

T A B L E 1

NEUTRON TOTAL CROSS SECTION (BARNS) FOR NEUTRON VELOCITY 100 m/sec AND RELATIVE ERROR 10%

Substance	σ_t	σ_{tot}	σ_Q
Ag	1360	1330	1386
In	4100	4000	4200
Cu	85	83	84,7
Ni	140	140	101,2
Fe	92	94	57,6
Mo	195	185	59,4
N	140	135	41,4
Ar	16	16	14,5
Dry air	140	130	41,4