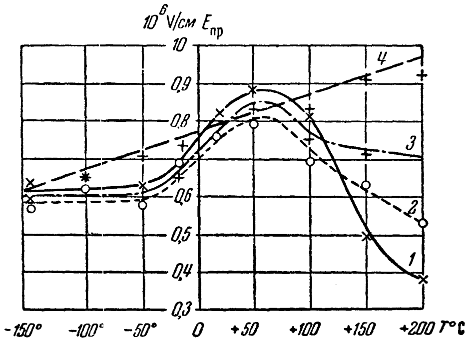

FIG. 1. Temperature dependence of E_{st} for Kbr for various durations of applied voltage: *1*—for constant voltage; *2*—for pulses of 10^2 sec. duration; *3*—for pulses 10^4 sec. durations; *4*—for pulses 10^6 sec. duration

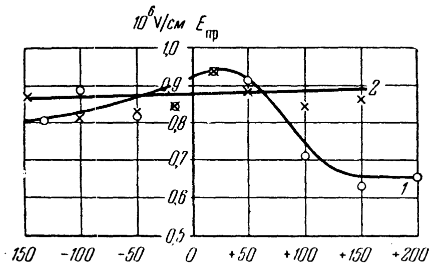

FIG. 2. Temperature dependence of E_{st} for KBr: *1*—for constant voltage, *2*—for pulses of 10^6 sec. duration.

dence of the dielectric strength E_{st} for alkali halide crystals of dielectric voltage exhibits a maximum which is smoothed out as the duration of voltage application is decreased. According to the present theories of electric puncture, which connect the electric breakdown with impact ionization by electrons, there should be observed a gradual growth at constant strength with temperature in the entire temperature range, independent of the duration of voltage application (at any rate for 10^{-6} sec pulses). In Fröhlich's "high temperature" puncture theory,[7] , an effort is made to explain the existence of a maximum in the temperature dependence of E_{st} ; however, it is impossible to explain from the point of view of this theory the fact, that the definitely exhibited maximum at constant voltage is completely absent for pulses of 10^{-6} sec duration.

2. The obtained temperature dependence indicates that the appearance of the maximum is connected with long duration processes taking place in the dielectric upon application of the field. The theory applicable to the explanation of the obtained results is that of Hipple[4] according to which reduction in puncture strength is caused by distortion of the field at the expense of volume charges: at low temperatures negative (electron) charges due to coldpossible emission, and at high temperature positive (ionic) changes due to crystal conductivity. It is cathode that at a certain temperature, both charges so compensate each other that the field is relatively undistorted and puncture strength reaches a maximum. Increase of dielectric strength with decrease of applied voltage duration at high temperatures indicates that the time required for the formation of the ionic charge is greater than 10^{-6} sec.

3. The magnitude of the electron volume change apparently depends on the emission velocity of the electrons from the cathode and, therefore, indirectly on the cathode material and condition of the contact surface as well as on the concentration of the electron traps in the crystal, i.e., on the degree of crystal contamination, preliminary heat treatment, etc.

Since it is very difficult to set up identical experimental conditions, it is quite natural to expect differences in the data obtained by different investigators (especially shift of the maximum).

Final conclusions pertaining to the causes of temperature dependence of E_{st} at puncture, it seems to us, can be made by studying the nature of the currents in the prepuncture field region.

The present work was conducted under the supervision of Prof. G. I. Skanavi, to whom the authors express their sincere thanks.

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Elastic Small Angle Scattering of Neutrons by Heavy Nuclei

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RECENT investigations of the scattering of fast electrons on hydrogen[1] substantiate the conclusions of the meson theory on the extended distribution of electrical charge in the nucleon. This distribution of charge is caused by the "cloud" of charged mesons around the central nucleus—the core. Under the action of the external electrical field the distribution of the electric charge in the nucleon will be changing. In particular, one may expect polarization of the oppositely charged mesons cloud and core in the neutron and the appearance in the neutron of an induced dipole electric moment $p = \alpha E$, which should show up in an anomalous behavior of the differential cross section of the small angle scattering of neutrons by heavy nuclei[2]. If as a first rough approximation we assume that the meson field of the neutron, located in an external electrical field $E = kV/z$, where $k = 1$, can be described by the static equation

$$[\nabla^2 + (e / c\hbar)^2 E^2 z^2]\varphi - (mc / \hbar)^2 \varphi = (4\pi / c)\, g\delta(\mathbf{r}), \quad (1)$$

then the induced dipole electric moment will be given by

$$\mathrm{p} = -\frac{e^2 g^2}{\hbar^2 c^2} E \int z^2 \frac{\exp(-2mcr/\hbar)}{r^2} d^3x + O(E^2). \quad (2)$$

From (2) it follows that

$$\alpha(\hbar c / g^2) = (e\hbar / mc^2)^2 \pi / 3m = 2{,}1 \cdot 10^{-41}. \quad (3)$$

As a result of electrical polarization the neutron undergoes additional scattering in the coulombic field of the nucleus. The effect of polarization scattering will be greatest when the parameter of collision d is limited by the conditions:

$$R < d < a, \quad (4)$$

where $R = 1{,}5 \cdot 10^{-13} A^{1/3}$

is the radius of the nucleus;

$$a = 0{,}53 \cdot 10^{-8} Z^{1/3}$$

is the radius of the electron shell. In this case, the energy of the interaction between the neutron and the nucleus has the form:

$$H(\mathrm{r}) = U(\mathrm{r}) - \mu \frac{iZ}{2r^3}\left(\frac{\hbar e}{mc}\right)^2 \sigma[\mathrm{r}\nabla] - \alpha Z^2 e^2 \frac{1}{r^4}. \quad (a)$$

Here the first term is determined by purely nuclear forces, the second term describes the interaction between the magnetic moment of the neutron $\mu\sigma$ and the coulombic field of the nucleus ("Schwinger scattering")[3].

For the evaluation of the magnitude of the polarization scattering the Born approximation was used. At distances greater than R, the nuclear forces decrease rapidly, and from the condition

$$H(\hbar / mv\,\theta) \ll 2E\theta \quad (5)$$

(m, v and E are the mass, the velocity and the energy of the neutron, scattered at the angle θ)[4] it follows that at

$$\alpha \sim 10^{-39} - 10^{-41}\,\text{см}^3,\ Z \sim 50-100,\ 0° < \theta < 15°$$

it is possible to use the Born approximation for energies $E = 10$ mev. On the assumption that the energy of the nuclear interaction U is independent of spin, we will obtain the following expression for the differential cross section of the elastic scattering (cm^2 sterad) of a beam of non-polarized neutrons on the nucleus (Z, A):

$$\sigma(\theta) = |f_0(\theta)|^2 + \frac{1}{4}\mu^2\left(\frac{\hbar}{mc}\right)^2\left(\frac{Ze^2}{\hbar c}\right)^2 \operatorname{ctg}^2\frac{\theta}{2} + f(\theta)\operatorname{Re} f_0(\theta) + \frac{1}{4} f^2(\theta), \quad (6)$$

where $f_1(\theta)$ is the amplitude of nuclear scattering:

$$f(\theta) = \frac{2m\alpha}{R}\left(\frac{Ze}{\hbar}\right)^2 KR\left(\frac{\sin KR}{K^2R^2} + \frac{\cos KR}{KR} + \operatorname{si} KR\right), \quad (b)$$

$$K = 4{,}44 \cdot 10^{12}\sqrt{E}\sin(\theta/2),$$

E is the energy of the scattered neutron in millions of electron volts.

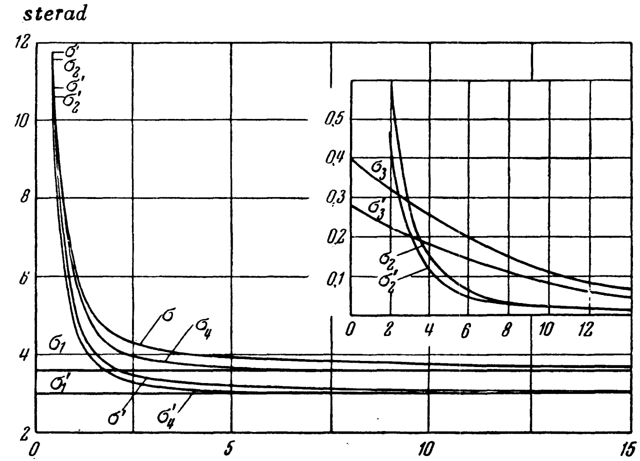
The results of the calculations by Eq. (6) are given in the graph, as well as in the Table, where the relative contribution of the polarization scattering

$$\Delta = (\sigma - \sigma_4)/\sigma$$

is expressed in its dependence on the value of the coefficient of polarizability (for $E = 4$ mev, $\theta = 3°$).* For the nuclear scattering, the solid sphere approximation was used. From the given data it is evident that the polarization scattering, as well as the Schwinger scattering, is manifest in the small angle scattering of neutrons. The range of angles

$$\theta \sim 3° \div 10°,$$

was found to be the most convenient for measurements, where the nuclear scattering is still only slightly dependent on the angle, and the Schwinger scattering is already negligible. From a comparison with Ref. 2, it follows that α is appreciably smaller than 10^{-39} cm.[3]



Differential cross section of the elastic scattering of neutrons of energy $e = 4$ mev and $\alpha = 10^{-40}$ cm^3;

$\sigma_1, \sigma_2, \sigma_3$

are the cross sections of the nuclear, Schwinger and polarization scattering on U^{238};

$\sigma_4 = \sigma_1 + \sigma_2$; $\sigma = \sigma_1 + \sigma_2 + \sigma_3$. $\sigma_1', \sigma_2', \sigma_3', \sigma_4', \sigma'$

are the corresponding cross sections of scattering on Pb^{207}

Polarization scattering introduces a considerable contribution into $\sigma(\theta)$ in the scattering of low energy neutrons and it decreases slowly with an increase in the angle θ. Thus, in the scattering

TABLE

α	nucleus		
	Cu^{64}	Pb^{207}	U^{238}
10^{-39}	54	83	88
10^{-40}	1.2	5.9	6.7

on U^{238} of neutrons of energies $E = 0.1$ mev for $\alpha = 10^{-40}$ cm^3, $\Delta = 57\%$ at $\theta = 3°$ and $\Delta = 62\%$ at $\theta = 10.°$ However, in this case for comparison with experiment it is necessary to have a good knowledge of the absolute value of the purely nuclear scattering since the slope of the curve $\sigma(\theta)$ constructed by formula (6) is small and qualitatively the curves $\sigma(\theta)$ and $\sigma_4(\theta)$ are difficult to distinguish. At a neturon energy $E \sim 3-5$ mev it is hoped that one may be able to distinguish these curves qualitatively, all the more, because for the above energies, in any case for Pb, the solid sphere approximation applies inadequately well.[5]

In conclusion we consider it a very pleasant duty to thank I. I. Bondarenko and L. N. Usachev for valuable discussion.

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*More exact calculations in the different variants of the meson theory will be published later.

*In the calculations by Eq. (6) it is necessary to take into account that the allowable range of the angles θ and of the energy E is limited not only by the requirement (5), but also by the conditions $KR \ll 1$, $k\alpha \gg 1$, which follows from (4).

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Heat Capacity of Laminar Structures at Low Temperatures

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It is well known that the heat capacities of laminar and chain structures do not obey the DeBye law $C \sim (T/\theta)^3$ at low temperatures. In the work of I. M. Lifshitz[1,2] it was shown that the deviation from the T^3 law is associated with the special role of bending waves in such structures. The anomalous form of the dispersion law (the relation between the frequency ω add the wave vector K for bending waves leads to an anomalous temperature dependence of crystal energy. In Ref. 2, the dispersion law was obtained for bending waves in strongly anisotropic media, and the corresponding heat capacity of a laminar crystal was calculated. For temperatures at which the interaction between layers may not be neglected ($T \ll \eta\Theta, \zeta\,\Theta$, where η and ζ are small elastic moduli), the formula for the heat capacity obtained in Ref. 2 may be transformed into the form*

$$Cs^2 / A = (\delta / s) + 2\,\{3K(s) - s\,dK(s)/ds\}, \quad (1)$$

$$A = Vk\eta^4\pi^2 / 16a^3\nu^3\zeta, \quad (2)$$

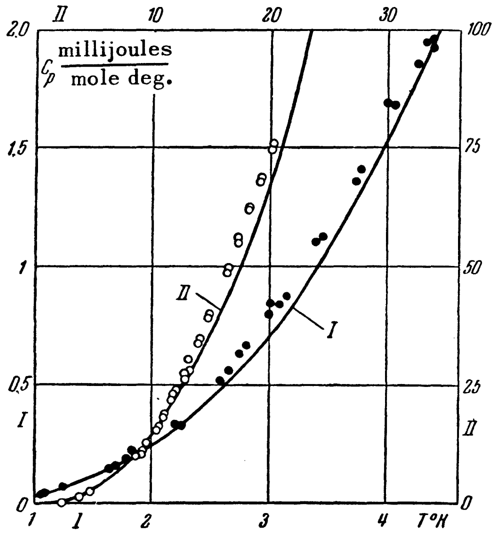
$$\delta = \zeta\eta / 15, \quad s = a'\eta^2\Theta / 4\pi\nu a T,$$

where ν is the "transverse stiffness" of the layers ($\nu \sim 1$), a' and a are the atomic distances in the layer and normal to it, and

$$K(s) = \int_0^\infty \frac{t^2 \operatorname{arctg}(t/s)\,dt}{e^{2\pi t} - 1}. \quad (3)$$

Using an integral representation for $\ln\Gamma(s)^3$, it is easy to show that

$$\frac{dK(s)}{ds} = -\frac{1}{24} - \frac{s^2}{2}\left[\frac{d}{ds}\ln\Gamma(s) - \ln s + \frac{1}{2s}\right]. \quad (4)$$



Lattice part of the heat capacity of graphite.[5] *I*—data for the region 1.0–4.4 °K. *II*—data for the region 4.0-21.0° K. Solid line—theoretical curve.

In the region of temperatures under consideration, the term

$$\delta/s \approx \zeta T/\eta\Theta \ll 1$$

and may be neglected. From Eqs. (1) and (4) we obtain the precise formula:

$$\frac{1}{A}\frac{d}{ds}(Cs^2) = s^3 \frac{d^2}{ds^2}\ln\Gamma(s) - s\,(s+1) - \frac{1}{6}, \quad (5)$$

where $d^2\ln\Gamma/ds^2$ is a tabulated function.[4] Thus, in the region of very low temperatures ($T \ll \eta\Theta, \zeta\Theta$) it is easy to tabulate the heat capacity of laminar crystals with the use of one graphical integration.

A comparison with experiment is possible in spite of the fact that the elastic constants in the region of temperatures under consideration are not known for laminar lattices. In fact, for

$$s \to 0: \; s^2C/A - 0.0914$$

(the region of quadratic dependence of heat capacity on temperature); and for

$$(T \to 0), \; s^3C/A \to 1/30$$

(the region of cubic dependence). Determining the combinations of constants required for Eq. (2) by the limiting laws, the entire curve may be constructed.

Until very recently, the necessary experimental data was not available. The data of Keesom and Pearlman[5], which appeared recently, allowed a comparison with experiment for graphite, as shown in