LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Christiansen Filters as Polarizers

The Christiansen effect has been used for filters not only in the visible but also in the ultraviolet and infrared. Yet it apparently has not been used with doubly refracting material, as such. Wood has used quartz particles in making filters, but on account of convenience rather than for birefringence.

The dispersion curves for the material of the particles and for the immersion liquid are of course familiar. Suppose however that a doubly refracting material is used. Then the dispersion curves will be as shown in Fig. 1, where the upper solid curve is the dispersion curve for one direction of vibration in the solid, the other is that for the perpendicular direction, T_1 is the dispersion curve for the liquid at a temperature T_1, and T_2 the corresponding curve at a somewhat higher temperature T_2.

Obviously there are two Christiansen wave-lengths, and the beams thus transmitted are polarized at right angles to each other. If the wave-length $\lambda_\perp$ is just below the range of the visible spectrum, the observed transmitted beam is monochromatic and plane polarized. On changing the index of refraction either by changing the composition of the liquid or by changing the temperature, the changes in the transmitted wave-lengths should proceed with each of the two components exactly as in the case of the experiments in which isotropic solids have been used.

The only difficulty then is to obtain doubly refracting material which is sufficiently small in particle size and still remains oriented. The birefringence of Cellophane suggested that fibers of cellulose, such as rayon, might serve the purpose. Accordingly a frame carefully wound with such a material, viscose happened to be available, was immersed in a mixture of carbon disulphide and benzene. In due time the effect was quite clear. The transmitted light was considerably spread out in the direction perpendicular to the fibers, perhaps a diffraction effect due to lack of homogeneity in the fibers, but the light was very nearly plane polarized and of a quite limited spectral region.

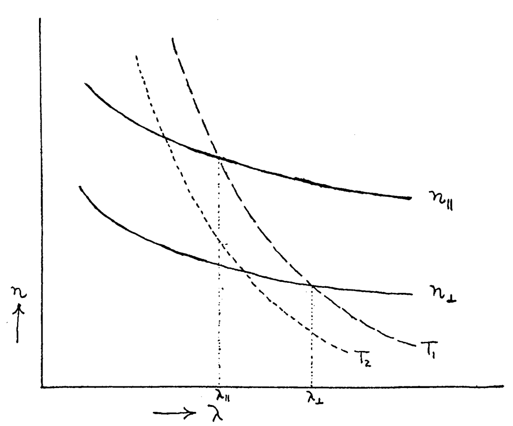

FIG. 1. Dispersion curves for the solid (solid lines) and for the liquid at different temperatures (dotted lines).

The birefringence in this case is such that it is possible, for example, to adjust the filter to transmit green polarized horizontally and blue polarized vertically. The fact that the transmitted light for one direction of polarization follows so definitely the behavior of the light transmitted by the Christiansen cells described by Wood and others[1] indicates that this is a true Christiansen effect.

In the case of the viscose fibers used in the experiments the two indices of refraction were not measured with any accuracy, but it was clearly shown that the index of refraction is greater for a vibration direction along the fiber than for the direction across the fiber. The same result was obtained with silk, the frame being wound with white silk thread.

As is well known, x-ray studies have shown that both rayon and silk possess structure, but it has not been the practice to consider their fibers as doubly refracting crystals for optical work.

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Columbia University,
August 10, 1936.

[1] Wood, *Physical Optics;* Denmark and Cady, J. Opt. Soc. Am. **25**, 330 (1935); Barnes and Bonner, Phys. Rev. **49**, 732 (1936).

Bragg Reflection of Slow Neutrons

The peak of the velocity distribution of thermal neutrons[1] indicates a momentum for which the de Broglie wave-length, h/mv, is approximately 1.6A. If such neutrons suffer Bragg reflection, they will be regularly reflected from a magnesium oxide (MgO) crystal ($2d=4.0$A) when the Bragg angle is about $22°(\eta\lambda=2d\sin\theta_\eta)$.

Sixteen well-formed single crystals of MgO, about $8\times25\times44$ mm, were mounted in a ring with the source and detector placed on the axis for a grazing angle of 22°, as shown in Fig. 1.

BACKGROUND, N_{Cd}, OF HIGH SPEED NEUTRONS

The detectors were (1), an ionization chamber filled with BF_3 in the first run, and (2), one lined with B_4C in the second and third runs. The sensitivity of both of these chambers[2] extends to neutrons of such high velocity that it was quite impossible to absorb all detectable neutrons

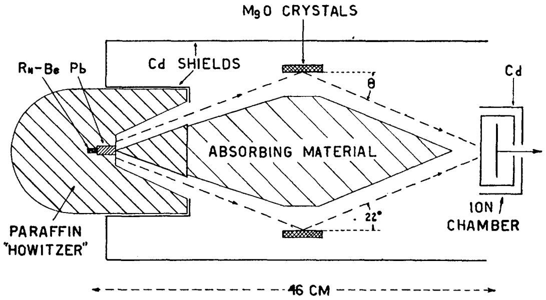

FIG. 1.

emerging in the direction of the chamber. These together with those scattered from the general surroundings account for the number (N_{Cd}) of neutrons counted when the cadmium screening of the chamber is completed by a sheet of Cd across its front.

The entire removal of the crystals made practically no change in the count of these high speed (Cd penetrating) neutrons, and further, the subsequent removal of the Cd from the front of the chamber made no appreciable increase in the count.

NEUTRONS SCATTERED BY SINGLE CRYSTALS

It thus appears (1), that the crystals do not significantly affect the amount, N_{Cd}, of high speed neutrons counted, and (2), that the slow speed neutrons counted were scattered from the crystals.

When the crystals are in the Bragg positions, the total number N_B of neutrons counted will be the background N_{Cd} plus both those regularly reflected and incoherently scattered by the crystals. The amount of incoherent scattering should be practically independent of crystal orientation, so to observe this without regular reflection the crystals were tilted, alternately clockwise and counterclockwise, about 25° from the Bragg position. In this case of crossed crystals the total count N_X will be N_{Cd} plus the incoherent scattering. Hence N_B-N_X should be a measure of the number of slow neutrons that are regularly reflected. In the first run, N_B-N_X was eight times that accountable on the basis of statistical fluctuations and in the second run, six times. These results at once indicated the Bragg reflection of slow neutrons. As a check, it seemed necessary to determine by actual test whether or not polycrystalline blocks of about the same size and scattering power would, due to the change in geometric disposition, scatter more slow neutrons in the "Bragg" position than in the crossed position.

SCATTERING BY POLYCRYSTALLINE BLOCKS

In this, the third run, aluminum metal blocks of rectangular size and thickness equal to the rectangular boundary of the somewhat irregular single crystals, used in the first two runs, were mounted in place of the crystals. Aluminum was used since it has approximately the same effective scattering power per unit volume as MgO. The result

TABLE I. *Observed Numbers.*

	Bragg		Crossed		Background	
Run	Counts $\times 10^{-3}$	Rate N_B/min.	Counts $\times 10^{-3}$	Rate N_X/min.	Counts $\times 10^{-3}$	Rate N_{Cd}/min.
1st	23	$60.5\pm.4$ $N_B-N_X=4.9\pm.6$	21	$55.6\pm.4$	3.8	$43.3\pm.7$
2nd	11	$28.8\pm.3$ $N_B-N_X=2.3\pm.4$	8.6	$26.5\pm.3$	3	$20.9\pm.4$
3rd	12	$37.6\pm.3$ $N_B-N_X=.1\pm.4$	12	$37.7\pm.3$	6	$28.0\pm.4$

TABLE II. *Relative Numbers.*

Run	$\frac{N_B-N_X}{N_B-N_{Cd}}$	$\frac{N_X}{N_{Cd}}$	$\frac{N_B}{N_{Cd}}$
		With MgO Crystals	
1st	0.40 ± 0.06	1.28 ± 0.02	1.40 ± 0.02
2nd	$.41\pm.09$	$1.27\pm.03$	$1.38\pm.03$
		With Al Blocks	
3rd	0.01 ± 0.04	1.34 ± 0.02	1.34 ± 0.02
	corrected	1.22	1.22

$$N_B-N_X=0.1\pm0.4$$

indicates that the change in geometry could not have changed the incoherent scattering much more than the statistical fluctuations.

SUMMARY OF RESULTS

The greatest statistical precision was obtained for N_B and N_X, and hence these two values in Table I are the best evidence for the Bragg type of reflection of neutrons. It is also interesting to note the relative amount of reflection and scattering as shown in Table II.

The correction shown takes account of the fact that the total volume of the aluminum blocks used in the third run was 1.63 times that of the crystals (due to the irregular outline of the crystals, as mentioned above).

On the basis of this evidence it seems reasonable to conclude that we have in these experiments observed the reflection of slow neutrons in accord with the Bragg relation between the de Broglie wave-length of these neutrons and the grating space of these crystals.

It should be noted that the experimental arrangement (see Fig. 1) permits a sufficiently large angular divergence so that the Bragg conditions are satisfied for a large portion of the velocity range in the Maxwellian distribution[1] of the thermal neutrons.

Grateful acknowledgment is made to Mr. Raymond Ridgeway for supplying us with the unusually large single crystals of MgO used in this work.

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August 17, 1936.

[1] J. R. Dunning, G. B. Pegram, G. A. Fink, D. P. Whitehall and E. Segrè, Phys. Rev. **48**, 704 (1935).
[2] Dana P. Mitchell, Phys. Rev. **49**, 453 (1936).