Temperature	α_s/α_n	ε_0/kT_k	α_s/α_n	ε_0/kT_k	Temperature	α_s/α_n	ε_0/kT_k	α_s/α_n	ε_0/kT_k
	Along C_4		Along C_2			Along C_4		Along C_2	
3.73	1.00	0.00	1.00	0.00	3.30	0.51	0.96	0.42	1.18
3.72	0.97	0.06	0.94	0.12	3.20	0.46	1.03	0.37	1.26
3.70	0.91	0.17	0.83	0.33	3.10	0.41	1.12	0.34	1.32
3.66	0.82	0.35	0.74	0.52	3.00	0.37	1.19	0.30	1.39
3.60	0.74	0.51	0.65	0.71	2.80	0.29	1.34	0.25	1.46
3.55	0.68	0.62	0.59	0.82	2.50	0.20	1.48	0.18	1.54
3.50	0.64	0.70	0.55	0.91	2.10	0.12	1.54	0.11	1.60
3.40	0.57	0.84	0.48	1.06					

with the isotropic theory of superconductivity is obtained for the case of sound propagation along the fourfold axis.

[1] R. W. Morse and H. V. Bohm, Phys. Rev. **108**, 1094 (1957).

[2] Lock, Pippard, and Shoenberg, Proc. Camb. Phil. Soc. **47**, 811 (1951), Reynolds, Serin, Wright and Nesbitt, Phys. Rev. **78**, 487 (1950).

[3] B. G. Lazarev and L. S. Kan, J. Exptl. Theoret. Phys. (U.S.S.R.) **14**, 463 (1944).

[4] Bardeen, Cooper and Schrieffer, Phys. Rev. **108**, 1175 (1957).

Translated by R. Berman
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STORAGE OF COLD NEUTRONS

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Submitted to JETP editor April 3, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 1952-1953 (June, 1959)

THE idea of retaining slow neutrons has been mentioned many times, but the corresponding experiments have not yet been performed, and the literature does not contain even rough estimates pertaining to this problem.

It is known that slow neutrons experience total internal reflection in glancing incidence on the surface of most substances. At sufficiently low velocities, the neutrons cannot penetrate in such a substance even under normal incidence. Thus, for carbon with a density $\sim 2 g/cm^3$ the critical neutron velocity is close to 5 m/sec, for beryllium it is approximately 7 m/sec. Let us place neutrons in a cavity surrounded on all sides by graphite. The neutrons of speed higher than critical will rapidly leave the cavity, but neutrons of less than critical speed are blocked in the cavity and vanish only as they decay, with a half-life of approximately 12 minutes. Such slow neutrons will penetrate into the wall only a depth on the order of their wavelength; taking into account dimensionless factors, the depth is $\sim 10^{-6}$ cm. Therefore if the cavity has a considerable volume, the fraction of the time that the neutrons stay in the material of the shell is quite small; for a one-cubic-meter cavity this fraction is $\sim 10^{-7}$.

The capture cross section of carbon (4.5×10^{-27} cm^2 at $v = 2.2 \times 10^5$ cm/sec) obeys the 1/v law and corresponds to a neutron lifetime in carbon of ~ 0.01 sec regardless of its velocity. For neutrons in a cavity we obtain an absorption time of $0.01/10^{-7} = 10^5$ sec 1 day. Slow neutrons will also be lost, as they acquire energy by collision; obviously, however, this process is greatly suppressed, because the neutrons are for the most time in the cavity and not in the material of the shell.

The most difficult feat is to obtain a sufficient number of such neutrons. For a Maxwellian distribution at room temperature, the fraction of such neutrons is on the order of 10^{-8}.

It is advisable first to cool the neutrons in a volume filled with liquid helium, and then the fraction of the necessary neutrons increases to 10^{-5}. As a result of the long life of the slow neutrons in the cavity, their concentration after a few seconds becomes equal to the Maxwellian equilibrium concentration. The principal difficulty is connected with the need for having a large volume of liquid helium, because of the long range of the neutrons in helium (50 cm).

With a fully moderated neutron flux of 10^{12} cm^{-2} sec^{-1} from a reactor, the flux of neutrons emitted with a temperature of 3° K can amount to 10^{11} cm^{-2} sec^{-1}, which corresponds at an average velocity on the order of 2×10^4 cm/sec to a density of 5×10^6 cm^{-3} of thermal neutrons, in-

cluding 50 cm^{-3} slow ones (with velocity less than 500 cm/sec). Thus, under the most favorable assumptions, it is possible to accumulate up to 5×10^7 slow neutrons in a cavity 1 m^3 in volume.

By placing a graphite partition over the opening that joins the cavity with the liquid helium it is possible to remove the cavity with slow neutrons from the reactor and make the measurements at a small background.

It may prove advantageous to use a palliative variant without helium, by cooling the neutron say to 70°K and accumulating up to 10^5 neutrons. We note that the index of refraction of the moderator should be less than the index of refraction of the cavity material, or else the moderator will not admit necessary neutrons in from the vacuum, and consequently will not let any out. An experi- of this type is quite difficult, but it seems that it can give the experimentators a valuable method of investigating the interaction of slow neutrons with substances introduced into the cavity. By introducing an (n, γ) absorber of neutrons into the cavity, it is easy to measure the number of neutrons left intact at the instant of observation.

We note that the neutrons in the cavity can be effectively heated to a speed above critical by mechanical displacement of the graphite surfaces at a speed of several meters per second.

The theory of the coefficient of refraction and the total internal reflection of neutrons is well known; we note only that it remains valid also at those small energies, at which the absorption cross section, following the 1/v law, becomes equal to or greater than the scattering cross section. It is easy to verify that the imaginary part of the pseudo-potential, the part describing the absorption, is small compared with the real part, which describes the scattering. Their ratio is equal to $\sqrt{\pi\sigma_s}/\lambda_1$, where λ_1 is the wavelength of the neutron for which $\sigma_s = \sigma_a$. Consequently, in the case of total internal reflection, absorption does not change the exponential law of damping of the wave function of the neutron in the medium.

[1] D. J. Hughes, Pile Neutron Research, Addison-Wesley, Cambridge, Mass., 1953. Russ. Transl. IIL, M., 1954.

[2] N. V. Vlasov, Нейтроны, (Neutrons), GTTI, 1955.

Translated by J. G. Adashko
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PIEZOMAGNETISM IN THE ANTIFERROMAGNETIC FLUORIDES OF COBALT AND MANGANESE

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Submitted to JETP editor April 1, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 1954-1955 (June, 1959)

THE magnetic symmetry of some antiferromagnetic crystals permits the existence of a piezomagnetic effect,[1,2] i.e., the appearance of a spontaneous moment on applying pressure. For a group of transition element fluorides in which the antiferromagnetic vector is directed along the four-fold axis (z) of the tetragonal cell,[4] Dzyaloshinskiĭ[3] has shown that, on applying a shear stress σ_{xz}, a ferromagnetic moment $m_y = \lambda\sigma_{xz}$ should be observed. No piezomagnetic effect has been experimentally observed to date.

To detect piezomagnetism we used a specially constructed magnetic torsion balance, in which a press containing the specimen was suspended on vertical wires. Following a proposal made by P. L. Kapitza, the press was controlled with the aid of evacuated sealed bellows. When the pressure of helium gas in the space surrounding the press was reduced, the compressed bellows tried to expand and by way of a lever applied a magnified pressure to the specimen. For a specimen of 1 mm^2 cross section, the maximum pressure was ~ 500 kg/cm^2.

Single crystals of CoF_2 and MnF_2 were studied, out of which parallelipipeds were sawed—the crystallographic axes being disposed as shown in the figure. On applying a pressure, p, to such a specimen, shear stresses $\sigma_{xz} = p/2$ arise in it. The specimen was situated in an inhomogeneous magnetic field directed along the y axis, and the magnetic moment m_y was measured for several values of the field. The measurements were made at liquid hydrogen temperature (20.4°K), where the antiferromagnetic ordering of the fluorides considered is almost at saturation. The relative accuracy of the measurements was $\pm 0.3\%$; the error in the absolute values of the moment could amount to 10%.

The results of the measurements obtained on the CoF_2 specimen are given in the figure, where the dependence of molar magnetic moment on field is shown. With no pressure (line 1) we have m =