TABLE II. g values calculated by $\nu=(\gamma/2\pi)(H_s+H_i)$.

Material	Frequency (Mc/sec)	g
$NiOFe_2O_3$	9450	2.05
	18,400	2.04
	23,500	2.06
	47,000	2.05
$MnOFe_2O_3$	9450	1.99
	18,400	1.99
	23,500	1.98
	47,000	1.99

in Kittel's formula as follows:

$$\nu=(\gamma/2\pi)(H_s+H_i), \tag{2}$$

where $\gamma=ge/2mc$, and H_i denote the internal field in the material, which must be independent of frequency.

By use of the resonance data in Table I, the most probable values of H_i were calculated by the method of least squares to be 507 oersteds for Ni ferrite and 278 oersteds for Mn ferrite. Substituting these values in Eq. (2), we obtained for both ferrites the g values shown in the last column of Table II. These g values are independent of the frequency within the limits of experimental error. It should be noted that the g factor of Mn ferrite calculated from Eq. (2) agrees with the theoretical value of 2, showing good evidence for quenching of the orbital contribution of the Mn^{++} ion.

H_i may be the internal field[3-5] caused by the magnetocrystalline anisotropic energy, and seems to be equal to the internal field discussed by Rado et al.;[4] they reported that the internal field in Ferramic A would contribute to the resonance by domain rotation in the material.

This work will be reported in detail in the near future.

[1] Vager, Meritt, and Guillaud, Phys. Rev. **81**, 477 (1951); T. Okamura and Y. Kojima, Phys. Rev. **86**, 1040 (1952). Our data which were reported in Phys. Rev. **80**, 910 (1950) cannot be used in connection with the present discussion, because they were obtained without taking into consideration the size effect.
[2] C. Kittel, Phys. Rev. **73**, 155 (1948).
[3] L. Landau and E. Lifshitz, Physik. Z. Sowjetunion **8**, 158 (1935).
[4] Rado, Wright, and Emerson, Phys. Rev. **80**, 273 (1950).
[5] J. B. Birks, Proc. Phys. Soc. (London) **B63**, 65 (1950).

Ferroelectricity in Oxides of Fluorite Structure

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(Received October 31, 1952)

A HIGH dielectric constant with a strong negative temperature coefficient recently has been reported for the new cadmium niobate composition $Cd_2Nb_2O_7$ by Bousky[1] and by Wainer and Wentworth.[2] These authors do not describe the crystal structure of this compound, but their discussion implies it to be a perovskite.

We have made powder x-ray diffraction patterns of this compound, prepared at 1150°C and found, not a perovskite structure, but a face-centered cubic structure of lattice constant 5.185 ±0.003A. The pattern is very sharp and shows no evidence of splitting in the back reflection lines, nor any indication of a superlattice. The relative intensities of the diffraction lines are very similar to those of cerium dioxide, which has the calcium fluoride structure.

This pattern can be accounted for by an arrangement of one molecule of $Cd_2Nb_2O_7$, with oxygens occupying statistically seven out of the eight anionic positions, and niobium and cadmium distributed statistically over the cationic positions of the fluorite structure. Periodic alternation of cadmium and niobium, or oxygen and vacant positions, are not compatible with the face-centered cubic structure. The O—O distance, 2.59A, is unusually small, probably because of the absence of $\frac{1}{8}$ of the oxygen atoms. The density calculated from the lattice constant is 6.24. Direct measurement on a ceramic body gave 5.89.

The high dielectric constant reported by Bousky[1] and by Wainer and Wentworth[2] was confirmed. A disk of the material fired to 1300°C shows a relative dielectric constant of 450 at room temperature. This rises to a peak of 2850 at −103°C, the Curie point. Hysteresis loops taken at −196°C show it to be ferroelectric below its Curie point.

We have also studied the analogous compound $Pb_2Nb_2O_7$, not previously described in the literature. We find a dielectric constant of 110 and a dielectric loss factor of 0.004 at 100 kc/sec, measured at room temperature. The dielectric constant rises with falling temperature from a value of 80 at 400°C to 245 at −196°C, the limit of measurement, with indications of a Curie point at somewhat lower temperatures.

The x-ray diffraction pattern of $Pb_2Nb_2O_7$ shows a distorted fluorite structure of rhombohedral symmetry. The lattice parameters are $a_0=5.285\pm0.003$A and $\alpha=89°15'$. Again there is no indication of any superstructure.

These results are significant in that they show ferroelectricity in a simple structure type where it was previously not suspected.

We thank E. J. Brajer for preparation of the samples and G. N. Cotton for the dielectric measurements which established the Curie point of $Cd_2Nb_2O_7$.

[1] S. Bousky, U. S. Patent No. 2,584,324, February 5, 1952.
[2] E. Wainer and C. Wentworth, J. Am. Ceram. Soc. **35**, 207 (1952).

The Ratio of Positive to Negative π-Meson Production from Deuterium

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(Received October 28, 1952)

THE ratio of positive to negative π-meson production from deuterium at 0° to the 340-Mev proton beam of the Berkeley cyclotron has been measured by a method which permits a direct comparison of the positive and negative production. The mesons were separated from the proton background by using a double magnet arrangement as shown in Fig. 1. Double coincidences were made between photomultiplier signals 1 and 2, and 3 and 4 in diode bridge type coincidence circuits which had resolving times of about 5×10^{-9} second. The outputs of the two bridges were combined in a slow mixer (about 10^{-6} second resolving time), and the resulting triple coincidences were taken as being due to particles that had traveled the trajectory laid out. Several checks were made to assure that this was so. Turning off either magnet reduced the triples counting rate to about one percent of the rate with the fields on. This was the same as the accidental rate measured by inserting a time delay equal to one rf cycle ($\sim6\times10^{-8}$ sec) in the signal lines from photomultipliers 1 and 3. The number of negative particles counted when the target was filled with hydrogen was the same as that from the empty target. Range curves

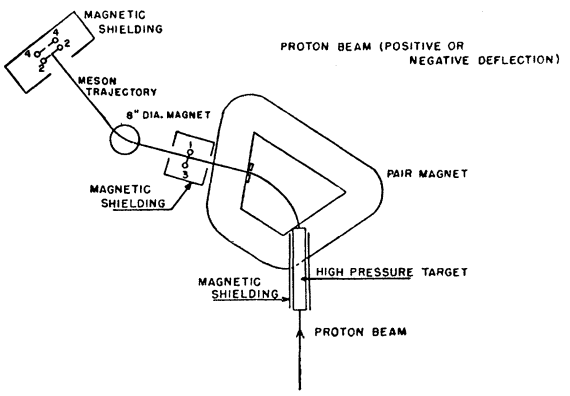

FIG. 1. Arrangement of the experimental apparatus.

TABLE I. π^+ to π^- ratio as a function of the laboratory meson energy.

E_π, Mev	π^+/π^- ratio
42	5.8 ± 2.5
51	7.4 ± 1.7
60	21.6 ± 8.9
70	22.1 ± 3.5
79	20.8 ± 7.1
88	36.5 ± 6.2
98	$34\ \pm14$
108	—
126	—

indicated a less than 5 percent contamination of particles with ranges greater than the expected meson ranges.

The target used was a high pressure gas target 24 in. long, which contained deuterium at 1400 psi at liquid nitrogen temperature. This placed 3.3 grams per square centimeter of deuterium in the beam, and since the end windows of the target contained only 1.7 grams per square centimeter of stainless steel, the production from the deuterium was greater than that from the target windows. Magnetic shielding was placed around the target to prevent the fringe fields of the first magnet from effecting the paths of the mesons produced in the far end of the target.

The ratios observed were obtained by measuring the meson production from the container plus gas at a series of energies, reversing the fields in both magnets, and measuring the mesons produced at the same energies. The gas was then removed from the container and similar measurements were made for the production from the end windows of the target. The values of the field strengths corresponding to various meson energies were obtained by using a current carrying wire to give the trajectories of the mesons of various energies. The fields were adjusted so the trajectory for each energy was the same. Use of the wire showed that reversing the magnetic fields delivered particles of the same energy but of opposite sign to the same position on the rear counters.

Checks of the counter efficiency were made using a Co^{60} source, and reversal of the magnetic fields was found to effect the counting rate in counters 1 and 3 by less than one percent. Counters 2 and 4 could not be tested in this manner, but the measured magnetic field at these counters was less than that at the position of counters 1 and 3.

The values of the π^+ to π^- ratio obtained for deuterium are given in Table I. Errors shown are standard deviations. Values are not shown for 108 and 126 Mev because no negative mesons were found at these energies. The ratios shown are those obtained by simply reversing the magnetic fields at a particular meson energy. The production curves are being corrected at the present time for the energy resolution of the apparatus, and any changes in the results will be published in a forthcoming article which will also include the results obtained for He, Be, C, and Pb.

The results that were obtained agree with the previous work on deuterium[1] in that they show a value higher than expected. Previous theoretical work[2] indicated that a ratio of about 8 might be expected. Some theoretical implication of these results are discussed in the following letter.

[1] Passman, Block, and Havens, Phys. Rev. **85**, 370 (1952).
[2] H. P. Noyes, Phys. Rev. **81**, 924 (1951).

The π^+ to π^- Ratio from Proton Bombardment of Deuterium*

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(Received October 28, 1952)

NOYES[1] has calculated the expected ratio of negative to positive π-mesons in the forward direction when deuterium is bombarded by 345-Mev protons. Most of the mesons in collisions with free target nucleons have 60-Mev to 70-Mev energy in the laboratory system. To obtain π-mesons in this energy range from $p-d$ collisions, the production must come mostly when the internal momentum of the deuteron is small. For these cases, when the proton and neutron are far apart, the uncertainties in the deuteron wave function are minimized and Noyes' assumptions are most likely to be valid. He finds a π^+ to π^- ratio of 8.2 ± 0.8 at 60 Mev if the $p+p\rightarrow\pi^+$ cross section differs from $p+n\rightarrow\pi^-$ only in a factor of two for the two protons and in the different interactions between the final nucleons. The final proton and neutron after π^+ production are taken to be in a ^3S state. Any admixture of singlet lessens the ratio. The matrix elements are assumed to be energy independent. If they vary like the square root of the meson center of mass kinetic energy, the ratio is a few percent smaller.

The experimental[2] value of the forward π^+ to π^- ratio at 60 Mev is about three times larger than predicted, implying that the $p+n\rightarrow\pi^-$ matrix element is suppressed relative to $p+p\rightarrow\pi^+$. This also seems to be true at 90°.[3]

If isotopic spin is conserved in meson production and the π^- meson is emitted predominantly into a p-state, the initial $p-n$ system is ^3S or ^3D and therefore has isotopic spin zero. Then in the final state of a π^- meson and two protons, the π^- and either proton must be in a state of isotopic spin one-half. To the extent that the interaction is strong only when leading to π^--proton states of isotopic spin $\frac{3}{2}$, the π^- production will be forbidden.[4] It is interesting to note that while isotopic spin does not contribute a selection rule for $p+p\rightarrow\pi^+$, the angular distribution indicates that the final state is one in which the π^+ and either nucleon have angular momentum $\frac{3}{2}$.[5]

* This work was performed under the auspices of the AEC.
† Now at Columbia University, New York, New York.
[1] H. P. Noyes, Phys. Rev. **81**, 924 (1951).
[2] J. Carothers and C. G. Andrè, preceding Letter [Phys. Rev. **88**, 1426 (1952)].
[3] Passman, Block and Havens, Phys. Rev. **85**, 370 (1952).
[4] This would not necessarily imply that, at these energies, the scattering of π-mesons in hydrogen should be strong only in isotopic spin 3/2 states, since the scattering could involve matrix elements which cannot contribute to single meson production, viz., a meson pair coupling [J. V. Lepore, Phys. Rev. **88**, 750 (1952); G. Wentzel, Phys. Rev. **86**, 802 (1952)].
[5] K. Brueckner and K. M. Watson, Phys. Rev. **86**, 923 (1952).

Optical and Infrared Reflectivity of Metals at Low Temperatures

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(Received November 3, 1952)

THE theory of the anomalous skin effect in metals was developed by Reuter and Sondheimer[1] to cover the case, often encountered at low temperatures, in which the electron mean free path is comparable to, or larger than the skin depth, as computed from the conventional theory.[2] Under such conditions explicit account must be taken of the motion of electrons in a spatially inhomogeneous electric field, with the result that the standard relation,[3]

$$\mathbf{j}(\mathbf{r})=\sigma(\omega)\mathbf{E}(\mathbf{r})=(ne^2\tau/m)(1+i\omega\tau)^{-1}\mathbf{E}(\mathbf{r}), \tag{1}$$

between the current density and electric field must be replaced by a more general expression of the form:

$$\mathbf{j}(\mathbf{r})=\int G(\mathbf{r},\mathbf{r}')\mathbf{E}(\mathbf{r}')dV'. \tag{2}$$

With regard to the "relaxation" region $\omega\gg1/\tau$ with which we are primarily concerned here, Reuter and Sondheimer make the plausible statement that, when the skin depth

$$\delta\gg v/\omega, \tag{3}$$

i.e., when the skin depth is large compared to the distance traversed by an electron in a period of electromagnetic oscillation, the conventional theory based upon (1) should apply. Nevertheless, their results (reference 1, Fig. 4) on metallic absorptivity in the optical and near infrared regions, in which (3) is valid, are generally in disagreement with the prediction of this theory. In the