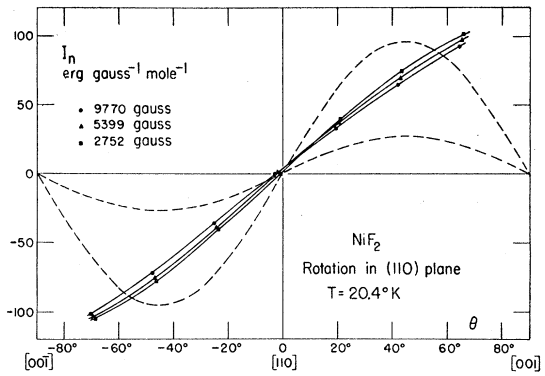

FIG. 1. Molal perpendicular magnetization of nickel fluoride *versus* angle between field and [110] direction. Rotation in (110) plane. Dashed curves indicate typical antiferromagnetic behavior.

by the torsion balance[4] is proportional to I_n, the component of the magnetization which is perpendicular both to the field direction and to the axis of the suspension. In Fig. 1 are shown values of I_n at 20.4°K and for three field strengths. The observed torques were identical at positions 180° from one another. The dashed curves in Fig. 1 illustrate the behavior expected for an antiferromagnetic substance with no permanent moment and a susceptibility independent of field strength. In this case I_n is proportional to the field strength and the two dashed curves correspond to 2752 and 9770 gauss. The magnitude of the dashed curves is calculated from the powder susceptibility data of de Haas, Schultz, and Koolhaas[5] at 20.4°K, assuming that the susceptibility parallel to the tetragonal axis is essentially zero. The observed values of I_n vary little with field strength and are suggestive of that expected from a permanent moment whose projection in the (110) plane lies preferentially in a [110] direction but which can be rotated somewhat from this position by a magnetic field.

Measurements were then made of the torques with the crystal mounted so its tetragonal axis was parallel to the axis of the suspension. In this orientation no torques are expected for a normal paramagnetic or antiferromagnetic crystal and only very small ones, amounting to 1.5 percent of the torques in the first orientation and attributable to a misorientation of a small portion of the crystal, were found above 73.2°K. Below this temperature, however, large torques were observed in this second orientation. These torques had a periodicity of 90°. Values of I_n at 20.4°K are shown in Fig. 2. These curves may be fitted by a model[6] such as is used to interpret ferromagnetic anisotropy. In the (110) plane the easy directions of magnetization are ⟨100⟩. The moment

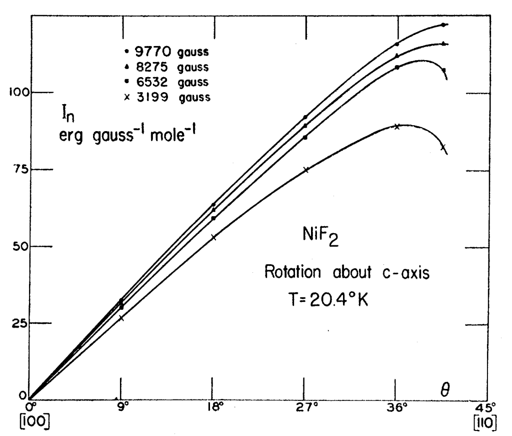

FIG. 2. Molal perpendicular magnetization of nickel fluoride *versus* angle between field and [100] direction. Rotation about tetragonal axis.

is assumed constant in magnitude and its direction is determined by the balance between the torque exerted by the magnetic field and that arising from the crystal anisotropy which will have a periodicity of 90°. The curves are consistent with a permanent moment whose magnitude is about 350 erg gauss^{-1} mole^{-1}. However, the crystalline anisotropy "constant" turns out to increase slightly more than proportionally to the field strength. The reason for this is obscure and there is therefore some question as to the applicability of the usual model for ferromagnetic anisotropy to NiF_2.

Erickson[7] has observed in neutron diffraction measurements on NiF_2 a small peak which was not found in the other antiferromagnetic fluorides of the iron group and which he interpreted as indicating that in the ordered alignment the spins, instead of being strictly parallel and antiparallel to the tetragonal axis as in MnF_2, FeF_2, and CoF_2, are in NiF_2 inclined at an angle of 10° from this axis. If one assumes that the cocking of one sublattice is in the [110] direction and that of the other sublattice at right angles in the [1$\bar{1}$0] direction, then there is a net moment in the [100] direction. The moment of 350 erg gauss^{-1} mole^{-1}, which is 3 percent of the saturation moment of the nickel ions, would on such a model correspond to a cocking of 2.5°.

The crystal used for the measurements weighed 17 mg and contained impurities of 0.02 percent Co; 0.02 percent Fe; 0.01 percent Al; 0.005 percent Cu; and 0.001 percent Mn, Mg, and Si. In order to see if the observed effects were dependent on the impurity content, some measurements were made on a large crystal containing about 1 percent Fe. The magnetizations observed below the Curie temperature with this impure crystal agreed within 0.7 percent with those found with the small purer crystal, so we do not believe that impurities are the cause of the observed phenomena.

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Radiogenic Argon Measurements

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SOME of the writers recently published the results of an experiment to determine the branching ratio of potassium by the extraction and measurement of radiogenic argon from dated potassium minerals.[1] The value of 0.06 obtained in this way is appreciably lower than the value obtained in many recent gamma-ray counting experiments. Errors in our experiment could have arisen from loss of argon during the purification process, incomplete extraction of the argon from the minerals, or incorrect dating of the minerals.

We have since carried out a number of yield runs in the purification apparatus and found that in all cases no measurable loss occurred. The argon extractions had been carried out by heating the sample to 850°C in vacuum with a sodium metal flux. To test the efficiency of this procedure we sent a second sample of Bessner microcline to G. J. Wasserburg at the University of Chicago who

TABLE I. Comparison of fluxes.

	A^{40}/K^{40}			
	Sodium flux		Sodium hydroxide flux	
Locality	Result	No. of runs	Result	No. of runs
Varala, Finland	0.119	2	0.140	6
Lee Lake, Saskatchewan	0.087	3	0.131	2
Dill Township, Ontario	0.0421	3	0.0522	6

uses an entirely different procedure for the extraction and measurement of radiogenic argon. He obtained an A^{40}/K^{40} ratio approximately 35 percent larger than our value.[2] We now find that this difference was caused by the fact that our sodium flux extracted less argon than the sodium hydroxide flux used by Wasserburg. Comparison runs have now been carried out at Toronto using both sodium metal and sodium hydroxide fluxes. The following results are typical of those obtained. In each case sodium hydroxide extracted more of the argon than metallic sodium.

The Lee Lake microcline was the same sample used for our previous measurements.[1] Using the same age of 1750 million years we obtain with the sodium hydroxide flux a branching ratio of 0.090. For our Bessner sample Wasserburg's measurements give a branching ratio of 0.088, assuming an age of 940 million years. This age we determined on a uraninite collected with the feldspar. These estimates of the branching ratio suggest that the radiogenic argon measurements as now carried out at Chicago and at Toronto are in reasonable agreement.

Both the ages quoted above were determined at Toronto by the lead ratio method applied to uraninites found in the same pegmatites as the potassium feldspars. It has been our experience that the lead ratio method generally gives the most reasonable ages for old minerals.[3]

As pointed out by Wasserburg and Hayden,[2] Nier[4] has dated a specimen identified as "Bessner Ontario uraninite" by the lead ratio method and obtained an age of only 825 million years. Through the kindness of J. P. Marble, Chairman, Committee on the Measurement of Geologic Time, we obtained some of Nier's original Bessner sample and for it found an age of 860 million years in agreement with Nier. Thus there are either uraninites of two ages at Bessner or Nier's sample was collected for him at some other locality. For this reason we have used our age for Bessner determined on the uraninite which we collected.

Additional potassium-argon measurements and a more detailed discussion are being published elsewhere.

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K-Particle Production by Protons of 2.2 and 3.0 Bev*

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STACKS of Ilford 400 μ *G*5 stripped emulsions have been exposed to radiations from a 6 mm thick copper target bombarded by the circulating proton beam of the BNL Cosmotron. No magnetic analysis was used.

Four events attributed to stopping *K* mesons have been found in area-scanning of the emulsions. Preliminary values of the masses of these mesons have been determined from range, ionization, and multiple scattering measurements. Each *K* particle was observed to enter the emulsion in the target-to-emulsion direction.

At one stack position, (a), the target-to-emulsion path, 28 cm long, made an angle of 90° with the proton beam direction; at another position, (b), the target-to-emulsion path was 50 cm long and made an angle of 45° with the proton beam. At both positions the radiations incident on the stacks from the target traversed the steel wall (1.1 cm) of the Cosmotron, and at position (b) they traversed an additional 7.5 cm of copper.

With protons of 2.2 Bev, and emulsions at (b), one stopping K^- meson (range in the emulsion 31 mm) has been found in a scanned area of 36.2 cm², in which 231 stopping π and μ mesons were observed. In these emulsions, the flux of fast particles coming from the target was about 5×10^3 cm^{-2}. The K^- meson formed a star consisting of a 50-Mev π meson (as shown by grain count and scattering) and a heavy fragment of 600 μ range. The π meson makes a two-pronged star in flight after traversing 3.1 mm of emulsion. This K^- star resembles closely the one found at the Cosmotron with magnetic selection.[1] The mass of the K^-meson has been measured as 970 ± 150 m_e. If it came from the target, as is indicated by its direction, then it is estimated that it left the target with 270-Mev kinetic energy. This kinetic energy is consistent with the production of the *K* meson either single or paired with a hyperon; it is inconsistent with production of a pair of *K* mesons of mass as low as 920 m_e in a single nucleon-nucleon collision, assuming a maximum Fermi energy of 25 Mev.[2]

With protons of 3.0 Bev, 10.8 cm² of emulsion exposed at position (a) have so far been scanned. The flux of fast particles from the target was about 3×10^3 cm^{-2}. In this area, 386 π and μ meson endings have been found and three tracks due to stopping heavy mesons (ranges in emulsion 19 mm, 40 mm, 46 mm) have been identified. In each of these events the heavy meson gave rise to a single minimum ionizing particle, with no visible recoil or electron track. The events are, then, typical of positive *K* meson decays. It is not yet known whether the decay particles are π mesons or μ mesons. The measured masses of these three *K* mesons are in the range 1050 ± 250 m_e, and their kinetic energies on leaving the copper target lie between 90 and 130 Mev.

All the *K* mesons observed lived at least 2×10^{-9} sec before coming to rest in the emulsion.

Emulsions exposed at position (b), with 3.0-Bev protons, have not yet been scanned.

We wish to thank Mrs. M. Carter and Mr. J. E. Smith for processing these emulsions, and Mrs. M. Hall, B. Cozine, A. Lea, and M. Bracker for invaluable aid in the microscopy.

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Beta-Decay Interaction*

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EXISTING arguments, presented exhaustively by Mahmoud and Konopinski[1] and since supplemented and firmly established by the electron-neutrino angular correlation experiments on helium-6[2] and neon-19,[3] indicate that the beta-decay interaction contains tensor and scalar contributions (in a ratio of the order of unity), but no vector or axial vector. Previous conclusions concerning the pseudoscalar interaction are largely invalidated by a recent re-examination of the theory[4] whose consequences are discussed below.

The new treatment gives a pseudoscalar contribution to the *l*-forbidden group ($\Delta j=\pm1$, $\Delta l=\pm2$). Direct evidence for the validity of *l* assignments comes from deuteron stripping experiments which yield the shell model *l* even when lower *l* values could compete,[5] as in phosphorus-32.[6] A mixture of single-particle states, with a $\Delta l=0$ contribution of the order of a percent or less, is possible and sometimes expected. If we ascribe the whole transition probability to pseudoscalar interaction (despite competition from the other interactions and $\Delta l=0$ admixture), we shall find an upper limit to g_P consistent with the observed *ft* values. The pseudoscalar *l*-forbidden correction factor is approximately (neglecting nuclear force corrections):

$$C_{lP}=g_P^2(4M^2)^{-1}(\alpha Z/2\rho)^2\left|\rho^{-2}\int\mathbf{r}(\boldsymbol{\sigma}\cdot\mathbf{r})\right|^2,$$

as against the allowed tensor $C_{0T}=g_T^2|\int\boldsymbol{\sigma}|^2$ and Rose and Osborn's first-forbidden pseudoscalar correction factor, which is ap-