	Discharge conditions: I_{max} = 13.5 kiloamp, H = 7300 oe, p = 1 – 2 × 10^{-2} mm Hg	Discharge conditions: I_{max} = 34 kiloamp, H = 7300 oe, p = 1 – 2 × 10^{-2} mm Hg	Ratio
Total electric energy delivered to the plasma, kilojoules	2.8	11.9	4.3
Value of $\sum_{300\,\text{Å}}^{1900\,\text{Å}} E_\lambda$, arbitrary units	0.7	3.3	4.8
Fraction of light energy taken by the Lyman lines	1/180	1/580	
Fraction of the total energy (%) lost by radiation, based on measurements with thermoluminophor in three positions	65; 105; 65	80; –; 70	

scura at several distances from the small aperture (0.14 mm in diameter) so that various sections of the image of the plasma column were projected† on it. The total energy losses were calculated with allowance for the energy distribution of the radiation and the spectral sensitivity of the thermoluminophor, known only up to λ = 800 A. The data were extrapolated to the shorter wavelengths. The estimated possible error in the determination of the absolute value of the light losses does not exceed 50%. The results of the measurements with the thermoluminophor are listed in the table. The results of all the measurements show that the greater part of the energy delivered to the plasma is lost by radiation from the impurities. In view of this, it is difficult to count on success in heating a deuterium plasma by Joule heat without eliminating the sources of contamination.

The author thanks L. A. Artsimovich and N. A. Yavlinskiĭ for help in the work.

*The construction of the ionization chamber was developed by V. S. Mukhovatov in his diploma project.

†The thermoluminophor, calibrated in absolute energy units, was graciously furnished us by V. A. Arkhangel'skaya and T. K. Razumova, to whom the author expresses his gratitude.

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ANTIFERROMAGNETISM IN NiF_2

R. A. ALIKHANOV

Institute of Physical Problems, Academy of Sciences, U.S.S.R.

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THE fluorides of the elements of the iron group (Mn, Fe, Co, and Ni) form an isomorphic series of compounds with a tetragonal lattice. Neutronographic studies of these compounds, conducted by Erickson,[1] show that they all have an antiferromagnetic structure at hydrogen temperatures. In the diffraction picture, at the locations of the reflections having indices (100), (111), (210), and (201), an increase of intensity over that of room temperature was observed. The absence of a (001) reflection for MnF_2, FeF_2, and CoF_2 indicates that the direction of the antiferromagnetic vector coincides with the tetragonal axis of the crystal. For nickel fluoride at 25°K some change of intensity in the region of the (001) reflection is noted. This is manifest by a small increase in the right arm of the (110) peak. On this basis, Erickson proposed a magnetic structure for NiF_2 somewhat different from that of the other fluorides. According to his data the spins are inclined at an angle of 10° from the tetragonal axis. The magnetic structure proposed by Erickson is shown dashed in Fig. 1. Angle α, obtained from x-ray data,[2] is equal to 8° and was apparently taken as the direction of the spins. The angular half-width of the (110) diffraction maximum on the NiF_2 neutron-diffraction pattern is 1.5°, a fairly large value. The (110) nuclear reflection thus overlaps the (001) magnetic reflection and the precision with which a prediction regarding the magnetic structure can be made is limited.

Our neutron-diffraction studies of NiF_2 were made from patterns with diffraction maxima that had an angular half-width of 0.65°.[3] Our NiF_2 sample was prepared by the Technology Division of the Institute of Physical Problems, U.S.S.R. Academy of Sciences, by heating the aqueous salt for several hours in a current of hydrogen fluoride. This procedure produced a yellowish-green fine crystalline powder. The neutron-diffraction pattern of the sample at hydrogen temperature is shown in Fig. 2. Owing to good resolving power, the (001) and (100) reflections are separated.

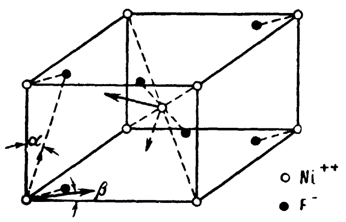

FIG. 1

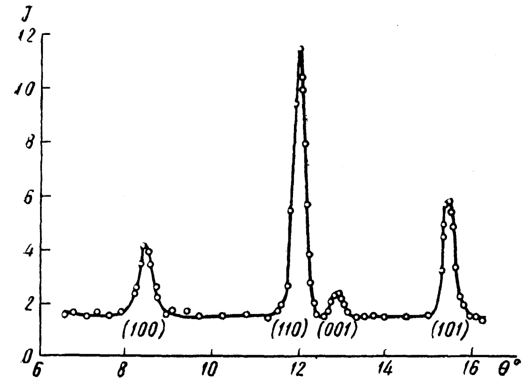

FIG. 2

The direction of the antiferromagnetism with respect to the crystallographic axes was determined from data on the ratio of the magnetic intensities J_{100}/J_{001}. Calculation shows that the antiferromagnetic moments lie in the (001) plane, perpendicular to the tetragonal axis (see Fig. 1). The possibility of such a structure was investigated earlier by Dzyaloshinskiĭ[4] on the basis of Landau's theory of phase transitions. This theory admits of three possible magnetic states. In the first state, the equal but oppositely oriented spins of the two metallic ions of the lattice are directed along the tetragonal axis. In the second state, II_1. the spins are directed along one of the equivalent [100] directions, which are rotated slightly toward one another about the crystal axis in the (001) plane, so that there results a spontaneous magnetic moment $\overline{m}$ directed along [100]. In the third possible state, II_2, the magnetic moments are directed along one of the [110] axes, but they are of different magnitudes. Moreover, within a very narrow temperature range, where mutual changes are possible between the above-mentioned magnetic states, the theory admits of the existence of two additional magnetic states. In the first of these, III_1, the spins lie in the (001) plane inclined at a small angle to the crystal axis, so that a spontaneous magnetic moment appears in the [100] direction. In state III_2, the spins and the moment $\overline{m}$ lie in the (110) plane. According to Erickson's data, the first magnetic state is found in MnF_2, FeF_2, and CoF_2. As present measurements have proved, the magnetic structure of NiF_2 corresponds to that of the second state. The weak ferromagnetism (presence of moment $\overline{m}$), characteristic of this state, should have made a magnetic contribution to the reflections with indices of even sum, particularly to the (110) reflection. A very small increase in the intensity of this reflection is actually observed upon changing from nitrogen temperature to that of hydrogen. In our experiments a change of intensity in the (110) maximum was constantly recorded upon cooling the sample from nitrogen to hydrogen temperature and upon heating the sample after vaporization of the hydrogen. A small change of intensity was observed in both cases: an increase in the former and a decrease in the latter. In the latter case, the intensity of the neutron beam was increased in order to increase the effect. Calculation shows that the observed effect, including the change of intensity with temperature, may be explained by a deflection of the moments of the sublattices from the (100) plane by an angle β not greater than 13° (see Fig. 1).

Matarresse and Stout,[5] in studying the twisting moment of a single crystal of NiF_2, discovered a weak ferromagnetism of this compound in the [100] direction. Its absolute value, equal to 350 ergs per gauss-mole, constitutes 3 percent of the saturation moment of the nickel ion, corresponding to an angle β of 2.5°. The experimental data obtained in this manner quite definitely establish a magnetic state II_1 for NiF_2. The possibility of the existence of type III states was studied by measuring the temperature dependence of the intensity J of the (100) and (001) magnetic reflections (Fig. 3). The transition point, determined by extrapolating the curves, is at 78.5°K. According to specific-heat data, the transition point is at 73.2°K.[6] The curves are in general smooth. The difference $J_{He} - J_T$ varies approximately as T^2. The crystal does not change in magnetic structure as the temperature is reduced from T_N down to helium temperature. Had there been a change in magnetic structure, the temperature-dependence curve of J_{001} would have had a maximum.

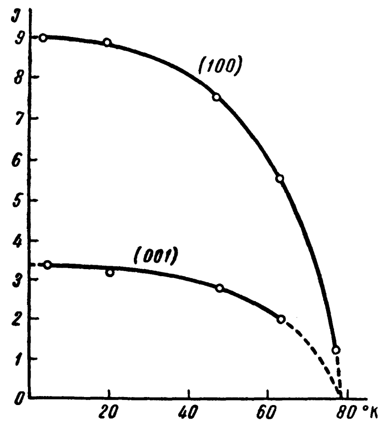

FIG. 3

I wish to thank Academician P. L. Kapitza for continuous interest in this work. I am grateful to A. S. Borovik-Romanov for much advice and to I. E. Dzyaloshinskiĭ for valuable discussion. I am indebted to Yu. G. Abov for his constant cooperation in the work. I also thank N. N. Mikhaĭlov for furnishing the sample.

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ON CERTAIN SINGULARITIES IN THE INTERACTION WITH LIGHT NUCLEI OF PARTICLES WITH ENERGIES $E \geq 2 \times 10^{12}$ ev

N. L. GRIGOROV and V. Ya. SHESTOPEROV

Nuclear Physics Institute, Moscow State University

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IN a previous paper[1] we have shown, by assuming the existence of large fluctuations in the fraction of energy transferred to π mesons when a high-energy nucleon interacts with a light nucleus, that all the observed basic characteristics of extensive atmospheric showers can be easily explained without resorting to the hypothesis that the shower development is influenced by the nuclear cascade.[2] This paper presents experimental data demonstrating the existence of interactions in which the primary particle loses almost all its energy (to the production of π^0 mesons), and estimates the probability of this process.

The experimental array, shown schematically in Fig. 1, consisted of four mutually perpendicular rows of pulse ionization chambers. Each row contained 33 chambers 330 cm long and 10 cm in diameter. The effective area of the array was 10 m^2. Each of the 132 chambers was connected to its own amplifier, which measured the pulses with 300 to 400-fold range of amplitudes. Pulse registration occurred whenever the ionization in any two or more chamber rows exceeded a given value. Part of the time the array operated with a hodoscope of 250 counters located at various distances from the array. This work was performed in Moscow during 1959. E. S. Loskevich and A. A. Oles' took part in the task.

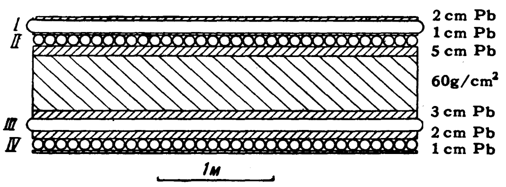

FIG. 1. Schematic array

During the operation of the array, there were observed in chamber rows I and II impulses for which almost all the ionization was confined to a circle of ~ 20 cm radius. In subsequent data processing, those events were selected in which more than 70% of all ionization was concentrated in not