sisting of a small number of neutrons collapse may indeed be possible, but the height of the barrier is many times larger than the initial rest energy of the system. Since the barrier $\sim N^{2/3}$, its absolute value decreases (although the required density increases) when part of the body in question is compressed. All of the conclusions remain qualitatively unchanged when one takes interaction between the neutrons into account, and in particular even for the equation of state $\epsilon \sim n^2$, which is the most rigid relation consistent with the theory of relativity. [4]

In the use of the expressions (1)—(4) it is not assumed that $n(r)$ and $\epsilon(r)$ with zero velocity, $v = 0$, correspond to the static solution; the field equations give nonvanishing values of $\dot{\lambda}$, $\dot{\nu}$, $\dot{v}$, where the dot means differentiation with respect to time. Outside the body $(r > R)$ we have $\dot{\lambda} = 0$, so that the mass M measured from the external gravitational field remains unchanged during the process of evolution which ensues for a prescribed initial distribution which does not satisfy the conditions for equilibrium.

The distribution (8) used for the proof has singularities: $\epsilon \to \infty$ for $r = 0$; ϵ has a discontinuous change from a/R^2 to 0 at $r = R$. It is easy to verify, however, that the result is not changed when one smooths out these singularities, for example by replacing Eq. (5) by

$$\varepsilon = a/\alpha^2 R^2 \text{ for } r < \alpha R; \quad \alpha \ll 1,$$
$$\varepsilon = \frac{a}{r^2}\frac{R(1+\beta)-r}{2\beta R}, \quad R(1-\beta) < r < R(1+\beta); \quad \beta \ll 1,$$
$$\varepsilon = a/r^2, \quad \alpha R < r < R(1-\beta). \quad (11)$$

In the initial distribution (5) used in our argument, and also in the smoothed distribution (11) we have everywhere $e^{-\lambda} > 0$, $e^{\nu} > 0$, i.e., the metric is not singular and there are no difficulties of the sort associated with the Schwarzschild singularity $(e^{\lambda} \to \infty, e^{\nu} = 0)$.

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*For small a one must not use the ultrarelativistic equation (8). For $a \to 0$, the mass $M \to Nm$.

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FERROELECTRIC ANTIFERROMAGNETICS

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THE discovery of complex ferroelectrics with perovskite structure and with a considerable number of Fe^{3+} ions at octahedral sites prompted the suggestion that some of these ferroelectrics have antiferromagnetic properties. [1]

This suggestion was studied in the case of $Pb(Fe_{2/3}W_{1/3})O_3$ and $Pb(Fe_{1/2}Nb_{1/2})O_3$; the bracketed ions were at the octahedral positions. X-ray diffraction at room temperature showed no ordering of the ions at the octahedral sites, i.e., these compounds were disordered solid solutions based on orthoferrites.

We investigated the electrical and magnetic properties of monocrystals of these compounds. The monocrystals were grown from a solution in molten lead oxide by spontaneous crystallization on cooling. Chemical analysis showed that the compositions of the two compounds corresponded to the specified chemical formulas.

Electrical properties were measured on thin monocrystals and magnetic properties on powders of fine monocrystals, because large crystals were not obtained. The results are shown in the figure. Magnetization of both compounds was a linear function of the magnetic field intensity ($H_{max} = 8000$ Oe). No residual magnetic moments were found throughout the temperature interval used in the tests.

The ferroelectric phase-transition temperatures, Θ_c, were determined approximately from the maxima of ϵ: they were 178°K for $PbFe_{2/3}W_{1/3}O_3$ and 387°K for $PbFe_{1/2}Nb_{1/2}O_3$. In these two compounds, as in the majority of solid solutions, phase transitions from the paraelectric into the ferroelectric state occurred over a range of temperatures. The paramagnetic-antiferromagnetic phase transitions also occurred over a range of temperatures. The curves representing $\chi(T)$ and $\chi^{-1}(T)$ had kinks at 363°K for $PbFe_{2/3}W_{1/3}O_3$ and at 143°K for $PbFe_{1/2}Nb_{1/2}O_3$; these kinks were assumed to represent the antiferromagnetic transitions. Similar dependences have been reported for antiferromagnetic crystals of $CrSe$ [2] and for the antiferromagnetic solid solutions $Mn_{1-x}Mg_xO$, [3] in which
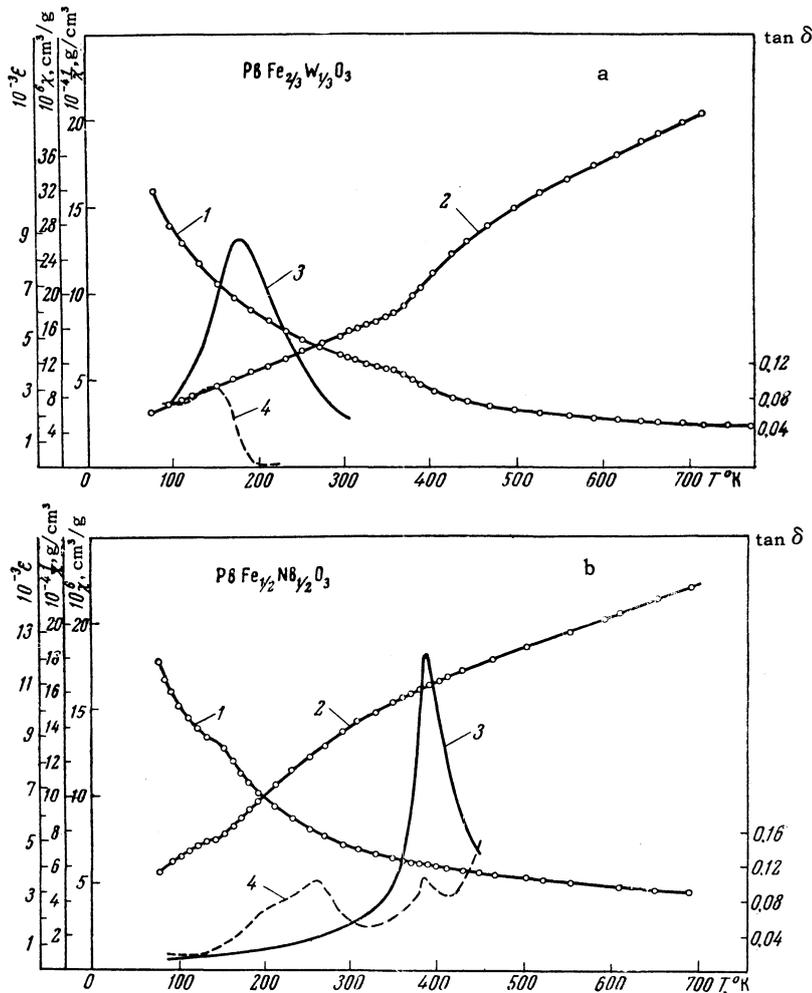
Temperature dependence of χ (1), $1/\chi$ (2), ε (3), and $\tan \delta$ (4). Electrical measurements were carried out at 10 kc.

the Néel temperatures decreased and the phase transitions became more diffuse on increase of x.

In both compounds there were considerable numbers of nonmagnetic ions at the octahedral sites. Consequently their Néel temperatures should be much lower than those of orthoferrites. Moreover, in the antiferromagnetic regions the magnetic moments of some Fe^{3+} ions are not ordered and these ions can be considered, in the first approximation, to be paramagnetic. This explains the rise of permeability on cooling below the transition points. Gilleo[4] showed that in ferromagnetic garnets the Fe^{3+} ions take part in magnetic ordering only when they have at least two magnetic ions as nearest neighbors in the second magnetic sublattice. Following this assumption, Gilleo calculated magnetic moments and Curie temperatures of several garnets containing some randomly distributed nonmagnetic ions. Similar calculations were carried out by Smolenskii, Isupov, Kraĭnik, and Agranovskaya[5] for perovskites. The formulas derived by Smolenskii et al were used to determine the Néel tem-

peratures of ferromagnets. The calculated results are given in the adjoining table. $ErFeO_3$ with $\Theta_N = 620°K$ was used as the "initial" ferromagnet with only Fe^{3+} ions at its octahedral sites. The agreement between the calculated and experimental Néel temperatures was satisfactory for $PbFe_{2/3}W_{1/3}O_3$, but not for $PbFe_{1/2}Nb_{1/2}O_3$. The reason for the discrepancy between theory and experiment in the latter case may lie in segregation of ions of one type in a sublattice at high dilutions. Moreover, with an indefinite phase transition one can hardly fix a transition temperature and therefore the comparison between experiment and theory is only approximate.

In the paramagnetic region considerably above the temperatures of the kinks in the $\chi(T)$ curves, the Curie-Weiss law, $\chi = C/(T - \Theta)$, was satisfied. The $\chi^{-1}(T)$ curves were used to find the effective magnetic moment of the Fe ion, μ_{eff}, and the Curie-Weiss constant, Θ (cf. the adjoining table).

The effective magnetic moment of the Fe ion in $PbFe_{2/3}W_{1/3}O_3$ was considerably smaller than the theoretical value $\mu_{eff} = 5.92\,\mu_B$; in addition,

	Θ_N, °K		μ_{eff}/μ_B	Θ, °K	$\left|\dfrac{\Theta_N}{\Theta}\right|$	Θ_c, °K
	calc.	exp.				
$PbFe_{1/3}W_{1/3}O_3$	406	363	4.2	—132	0.37	178
$PbFe_{1/2}Nb_{1/2}O_3$	276	143	5.4	—520	3.64	387

$|\Theta_N/\Theta| < 1$, in contrast to the majority of anti-ferromagnets which have $|\Theta_N/\Theta| > 1$. The small values of μ_{eff} and Θ of $PbFe_{2/3}W_{1/3}O_3$ may be due to inaccurate extrapolation of the linear part of $\chi^{-1}(T)$, which was obtained in a relatively narrow range of temperatures. Measurements could not be carried out at higher temperatures because of thermal dissociation of the crystals.

The $\chi(T)$ curves of both compounds did not obey the Curie-Weiss law at temperatures immediately above the transition points; this behavior was similar to that found for weak ferromagnets. The deviation from the Curie-Weiss law was due neither to the presence of nonmagnetic ions at octahedral sites nor to the broad phase transition regions, since the solid solutions $Mn_{1-x}Mg_xO$,[3] as well as CrSe crystals,[2] had the same properties but exhibited a $\chi(T)$ dependence typical of antiferromagnetics. It was therefore possible that the two lead compounds were weak ferromagnets which did not exhibit a residual magnetic moment because of a very large coercive force. To test this hypothesis some samples were cooled from a temperature well above the Néel point in a field of 8000 Oe. Even then no residual magnetic moment was found.

In crystals with ferroelectric and ferro- or antiferromagnetic ordering one can expect changes of magnetic or electric properties on spontaneous polarization or magnetization. For example, a transition to the ferroelectric state and a consequent change of the lattice symmetry in an antiferromagnetic may produce weak ferromagnetism, i.e., a ferroelectric phase transition may induce magnetic moment. Changes of the ferroelectric or ferromagnetic domain structure may also occur in magnetic or ferroelectric transitions. Unfortunately in both compounds the phase transitions were broad and these effects were small and spread over a range of temperatures. However, a maximum of tan δ was observed at 261°K in $PbFe_{1/2}Nb_{1/2}O_3$; this maximum was displaced when the frequency was varied. More work is necessary on this feature of tan δ.

The main conclusion of this work is that ferroelectric and antiferromagnetic properties may coexist in crystals.

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ELECTRONIC ACTIVATION OF MESIC ATOMS

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IT is known that the formation and filling of a "hole" in the inner electronic shells of atoms leads to multiple ionization, to the breaking of chemical bonds, and to release of the atom as a free ion.[1] Investigations of the charge distribution of atoms during radioactive transformations show that when one "hole" is filled, atoms lose, on the average, about seven outer electrons. Borde[2] showed that cascade transitions of muons in mesic atoms lead predominantly to ionization of the inner atomic shells. Thus, for example, about five electrons may be emitted in the bromine mesic atom as the muons go from a shell with principal quantum number n = 14 to the ground state. Consequently, in the case of mesic atoms, the average ion charge may be very large.

The existence of this phenomenon, called electronic activation of mesic atoms, may cause, for