Mössbauer and magnetic susceptibility experiments at temperatures down to 4.2°K and in external fields up to 140 kOe show orthorhombic $\text{Al}_{x-\text{Fe}}\text{O}_3$ ($0.6<x<1.0$) to be a collinear highly anisotropic ferrimagnet; the material is also piezoelectric and has magnetic properties similar to those of the isomorphous compound $\text{GaFeO}_3$. Rhombohedral $\text{Al}_{x}\text{Fe}_x\text{O}_3$ is paramagnetic above 80°K, and at 4.2°K exhibits a Mössbauer spectrum characteristic of a nonunique hyperfine field; the application of an external magnetic field produces a spectrum with an enhanced $\Delta m=0$ line which suggests a canted spin structure similar to that in the high-temperature phase ($T>260°K$) of $\alpha\text{FeO}_3$.

We report high magnetic field Mössbauer and magnetization measurements on $\text{Al}_{x-\text{Fe}}\text{O}_3$ compounds having orthorhombic and rhombohedral crystal structures. The orthorhombic form is of interest because it is isomorphic with piezoelectric, magneto-electric and ferrimagnetic $\text{GaFeO}_3$.

The crystal structures of $\text{AlFeO}_3$ and $\text{GaFeO}_3$ have been recently reinvestigated. The orthorhombic phase is stable for an appreciable range of stoichiometric composition; i.e., $\text{Al}_{x-\text{Fe}}\text{O}_3$ and $\text{Ga}_{x-\text{Fe}}\text{O}_3$ have been prepared for values of about $0.6<x<1.0$ and $0.8<x<1.2$, respectively. Polycrystalline $\text{Al}_{x-\text{Fe}}\text{O}_3$ samples were prepared by heating the oxides at 1390°C for 48 h in oxygen. For values of $x>1.0$ we were unable to prepare an orthorhombic phase. Samples with $x<0.6$ formed an orthorhombic phase, but mixed with small amounts of $\text{Al}_2\text{O}_3$. The unit cell dimensions of orthorhombic $\text{AlFeO}_3$ with $x=1.0$ correspond very closely to those given by Dayal et al.: $a=8.60$, $b=9.25$, and $c=4.97$ Å. The orthorhombic compound with $x=0.6$ has a much smaller unit cell, the low-index lines yield the values: $a=7.55$, $b=8.20$, and $c=4.69$ Å. The rather large amount of Fe$^{3+}$ incorporated in the $\alpha\text{Al}_2\text{O}_3$ structure is explained by the thermal history
of the rhombohedral sample. This compound was grown as a single crystal from a molar mixture composed of 35% Na₂CO₃, 54% Al₂O₃, and 11% Fe₂O₃, heated to 1400°C and slowly cooled at a rate of 2°C/h to 1100°C.

As in the case of Ga₂₋ₓFeₓO₃, the orthorhombic Al₂₋ₓFeₓO₃ crystals are piezoelectric. The orthorhombic Al₂₋ₓFeₓO₃ Mössbauer spectra at 4.2°K show an ordered spin system composed of at least two magnetically nonequivalent sites with oppositely directed spins. An external field causes the middle hyperfine lines (Δm = 0) to vanish, while the outer lines (Δm = ±1) split into two well-resolved components similar to those reported previously for Ga₂₋ₓFeₓO₃.

Magnetization measurements of orthorhombic Al₂₋ₓFeₓO₃ with x = 0.6 and 1.0 polycrystalline material are not saturated at 4.2°K and 140 kOe. It should be mentioned that magnetic saturation has not been achieved on polycrystalline GaFeO₃ materials at 78°K and 140 kOe. The lack of saturation is due to the extremely high magnetic anisotropy of these compounds. This was shown earlier by Mössbauer and magnetic moment measurements on GaFeO₃ single crystals. Saturation was just achieved at about 80 kOe along principal axes at 78°K. The magnetization curves are shown in Fig. 1.

Rhombohedral Al₁.₆Fe₀.₄O₃ is paramagnetic above 80°K with a quadrupole split Mössbauer doublet, and at 4.2°K shows a poorly defined magnetic hyperfine spectrum suggesting a distribution of hyperfine fields or short-range magnetic order. Upon the application of an external magnetic field the spectrum is somewhat sharpened and the intensity of the Δm = 0 lines increases with the applied external field. This is shown in Fig. 2, where the spectra are qualitatively similar to those of a canted spin system such as αFe₂O₃ above the Morin transition. The field-dependence of the magnetic moment at 4.2°K up to 140 kOe is shown in Fig. 1.

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