

## Letters to the Editor

**PUBLICATION** of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length and should be submitted in duplicate.

### Ferroelectricity in Ammonium Sulfate

B. T. MATTHIAS AND J. P. REMEIKA

Bell Telephone Laboratories, Murray Hill, New Jersey

(Received May 10, 1956)

**T**HE dielectric anomalies of  $(\text{NH}_4)_2\text{SO}_4$  have been known and thoroughly investigated over a long period of time.<sup>1,2</sup> Our discovery of ferroelectricity in  $(\text{NH}_2)_3\text{Al}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$  and its isomorphs<sup>3</sup> and the subsequent discovery by Pepinsky *et al.*<sup>4</sup> of the ferroelectricity in some alums suggested a new approach to the problem. It seems that the N—H—O bond may perhaps be more important for the occurrence of ferroelectricity than had previously been anticipated.

$(\text{NH}_4)_2\text{SO}_4$  has no water of crystallization and was therefore an ultimate test to this hypothesis. We have found that  $(\text{NH}_4)_2\text{SO}_4$  becomes ferroelectric parallel to the *a*-axis below its transition point at  $-49.5^\circ\text{C}$ . The spontaneous polarization at  $-58^\circ\text{C}$  is  $2.54 \times 10^{-7}$  coulomb/cm<sup>2</sup>. The coercive field at this temperature is about 2000 v/cm and decreases with increasing temperature. The hysteresis loops are very rectangular and show no bias.

<sup>1</sup> R. Guillien, *Compt. rend.* **208**, 980 (1939).

<sup>2</sup> L. Couture *et al.*, *Compt. rend.* **243**, 1804 (1956).

<sup>3</sup> Holden, Matthias, Merz, and Remeika, *Phys. Rev.* **98**, 546 (1955).

<sup>4</sup> Pepinsky, Jona, and Shirane (to be published). We wish to thank Professor Pepinsky for the personal communication of his results.

### Phase Separation in He<sup>3</sup>—He<sup>4</sup> Solutions\*

G. K. WALTERS† AND W. M. FAIRBANK

Department of Physics, Duke University, Durham, North Carolina

(Received May 10, 1956)

**U**SING nuclear magnetic resonance techniques,<sup>1,2</sup> we have detected a separation of He<sup>3</sup>—He<sup>4</sup> solutions into two distinct liquid phases at temperatures below 0.8°K. A separation had been predicted on theoretical grounds independently by Prigogine *et al.*<sup>3</sup> and by Chester.<sup>4</sup>

For detecting the phase separation and making quantitative measurements on the He<sup>3</sup> concentrations

of the two phases, a sample container having three vertically arranged sections, connected by small holes, was constructed. When this container is placed in a magnetic field having a gradient from top to bottom, the solutions in each of the three sections come to resonance at a constant frequency for different values of the steady magnetic field. Thus, the resonance line as observed on an oscilloscope is split into three separate peaks, each corresponding to the resonance of the He<sup>3</sup> nuclei in a known section of the container. Changes in the relative amplitudes of these three peaks as a function of temperature give a measure of the concentration of He<sup>3</sup> atoms in each section of the sample container, hence a measure of the He<sup>3</sup> concentrations of the two phases.

Using this method on 40% and 60% solutions of He<sup>3</sup> in He<sup>4</sup>, we have arrived at an approximate phase diagram, shown in Fig. 1, for He<sup>3</sup>—He<sup>4</sup> solutions. In calculating this diagram from the experimental data, it was necessary to approximate the liquid mixture densities by assuming the law for perfect solutions using the known values of the molar volumes at 1.2°K of pure He<sup>4</sup> and pure He<sup>3</sup>. It was necessary also to make an assumption regarding the susceptibility per atom of He<sup>3</sup> in solutions of varying He<sup>3</sup> concentration. For both the 40% and 60% samples at temperatures above the phase separation temperature, very little deviation was observed from the Curie inverse temperature law for the susceptibility. Thus it was assumed that the susceptibility per He<sup>3</sup> atom at any temperature lies for all He<sup>3</sup> concentrations between that value predicted

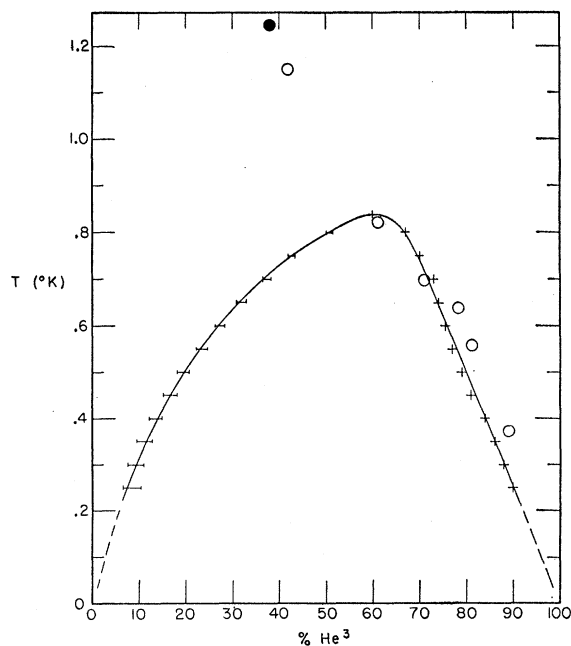


FIG. 1. Phase diagram for He<sup>3</sup>—He<sup>4</sup> solutions. The open circles represent  $T_\lambda$  measurements of Daunt and Heer. The closed circle represents a  $T_\lambda$  measurement made by us.