

The Thermal Diffusion Factor of Helium

F. van der Valk and A. E. de Vries

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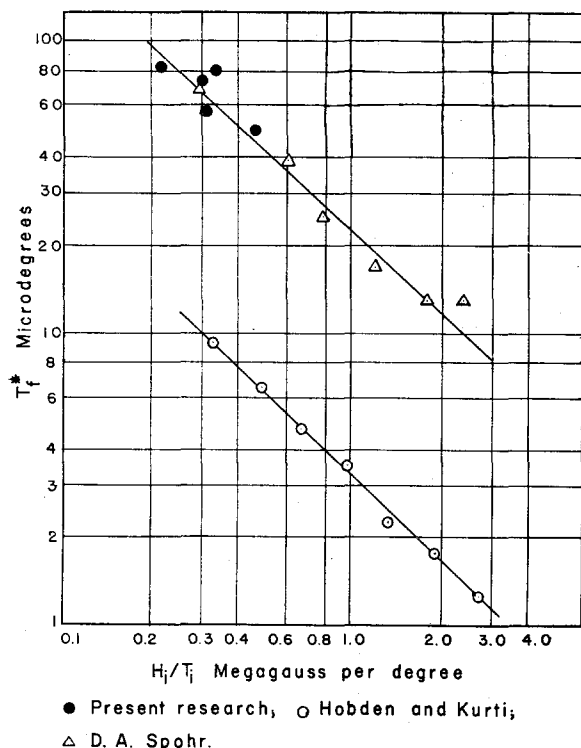


FIG. 1. Cooling of metallic copper.

Shielding of the first stage from the magnetic field during magnetization of the second stage was accomplished by the insertion about the apparatus of two closely fitting pieces of soft iron, forming a hollow block of iron $4\frac{1}{2} \times 6\frac{1}{2}$ in. \times 4 in. (high), each piece supported by a hinged and pinned framework of aluminum alloy. The amount of iron required for this purpose was determined experimentally. The force on the supports at full field was estimated to be about a ton.

The temperature scale used for the first stage was taken from that of Daniels and Kurti,⁴ using a small correction to our T^* values based on isentropes and warming curves.

The five experiments reported here starting temperatures (T_i) from 0.023° to 0.037° and magnetic fields (H_i) from 4.9 to 15.0 kgauss, and overlap the lower end of the (H_i/T_i) region covered by Spohr.¹ The results are shown in Fig. 1, along with the six demagnetizations reported by Spohr¹ and the seven reported by Hobden and Kurti.²

In Fig. 1 the observed magnetic temperature T_f^* is plotted on log-log scale against H_i/T_i . The straight lines through the data are arbitrary. The spread of about 5% in the observed final temperatures is consistent with susceptibility. Our final temperatures agree with those of Spohr,² which were also measured ballistically with about the same apparatus geometry and a (dc) primary field of about 9 gauss, but both sets are about 8 times higher than those of Hobden and Kurti,³

which were measured with a different apparatus geometry and a much smaller (ac) primary field.

The observed nuclear susceptibility decayed with time in a strict exponential fashion. The decay constant, τ was given by $\tau T_i = 0.45 \text{ sec}^\circ\text{K}$, within several percent. Hobden and Kurti³ observed τT_i of 0.30 with a field of 0.05 gauss and comment that this product doubled when the field was increased to 5 gauss. (Spohr² did not succeed in observing exponential decay.)

We are pleased to report our repetition of the original results of Spohr,² and to have observed essentially the same relaxation times as did Hobden and Kurti³ in their lower (nuclear) temperature range. We see no reason at present to quarrel with their interpretation of τ as the relaxation time for energy transfer between nuclear spin and the electronic system. The eightfold difference in final temperature appears to be related to the measuring fields used and to the difficulty of removing heat of (nuclear) magnetization, but the exact reasons for it are not clear to us.

We wish to express our thanks to Professor J. M. Daniels for invaluable advice in the construction of the apparatus and for assistance during the construction of most of it.

¹ N. Kurti, F. N. H. Robinson, F. E. Simon, and D. A. Spohr, *Nature* **178**, 450 (1956).

² D. A. Spohr, thesis, Oxford University (1958).

³ M. V. Hobden and N. Kurti, *Phil. Mag.* [8] **4**, 1092 (1959).

⁴ J. M. Daniels and N. Kurti, *Proc. Roy. Soc. (London)* **A221**, 243 (1954).

The Thermal Diffusion Factor of Helium

F. VAN DER VALK AND A. E. DE VRIES

*F.O.M.-Laboratorium voor Massaspectrografie,
Amsterdam, Holland*

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WE measured the thermal diffusion factor of helium in a 9-tube swing separator with a constant lower temperature of 295°K and higher temperatures varying from 370°K to 700°K . The gas used contained 10%³ He; the tubes of the swing separator were 10 cm long with i.d. of 1 cm; the swinging time was 13.5 sec; the pressure was always near 1 atm. Samples were drawn after two days and analyzed with a mass spectrometer; the resulting values of $\ln Q$ were plotted against $\ln T_{\text{high}}/T_{\text{low}}$. In this plot we obtained within experimental error a straight line with slope 0.555 ± 0.017 , giving a constant value of 0.0617 ± 0.0019 for α in this range (Fig. 1).

This obviously is in contradiction with the measurements of Moran and Watson¹ who found a marked

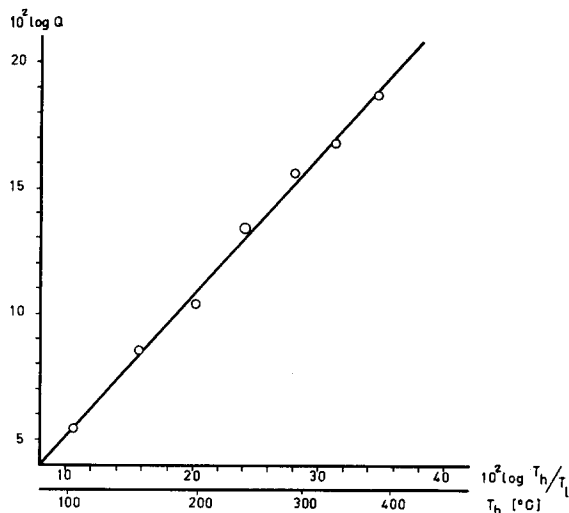


FIG. 1. \log_{10} (separation factor) vs \log_{10} (temperature ratio).

decrease of α towards higher temperatures in this region. However, our value fits excellently with theoretical values for the exp-6-model, using the parameters of Mason and Rice,² which indicate a slight decrease of α from 0.0620 at 400°K to 0.0605 at 700°K.

¹ T. I. Moran and W. W. Watson, *Phys. Rev.* **109**, 1184-90 (1958). Measurements on ²⁰Ne-²²Ne were in reasonable good agreement with those of Moran and Watson.

² E. A. Mason and W. E. Rice, *J. Chem. Phys.* **22**, 522-35 (1954).

Phase Transition in Ammonium Fluoride*

RICHARD STEVENSON

*Eaton Electronics Research Laboratory, McGill University,
Montreal, Canada*

(Received September 12, 1960)

HIGH-pressure experiments using the piston-displacement method¹ show that a phase transition with an exceptionally large change in volume appears under pressure in ammonium fluoride. A typical p - V isotherm obtained from these experiments is shown in Fig. 1. At room temperature the transition occurs at 3800 atm, with a volume change of approximately 28%. The phase diagram for the substance is given in Fig. 2; the bars represent the range between which the change occurred with pressure increasing and pressure decreasing. At room temperature this "region of indifference" was small, but at liquid nitrogen temperature the transition came about only at the highest pressure available with the apparatus, and recovery

started only when the pressure was completely removed. At all temperatures several minutes were required for the transition to go to completion. The change in volume appeared to decrease as the temperature decreased, but no accurate values were obtained at the lower temperatures.

There has been one report² of a sharp rise in the dielectric constant of NH_4F at 246°K. This was assumed to represent a phase transition, since the transition at 243°K in NH_4Cl shows a similar change in the dielectric constant. This temperature region was closely studied in the present experiments, but no evidence of a phase change was seen.

At atmospheric pressure ammonium fluoride has a wurtzite structure, and is different from the other ammonium halides which are cubic. Pauling³ suggests that this difference is due to hydrogen bond formation in the fluoride, with resultant $\text{N}-\text{H}\cdots\text{F}$ coordination. It would appear that the phase change in the fluoride is a collapse of the wurtzite structure into a cubic configuration similar to those found in the other halides. A short calculation (suggested by W. H. Stockmayer) indicates that the size of the volume change is what might be expected for a transition to a cubic structure. The cube root of the molecular volumes for ammonium iodide, bromide, and chloride can be plotted against the sum of the ionic radii for each particular substance. By extrapolating the curve, an estimate of the molecular volume of a hypothetical cubic ammonium fluoride is obtained. This volume is 26% smaller than the actual molecular volume, which

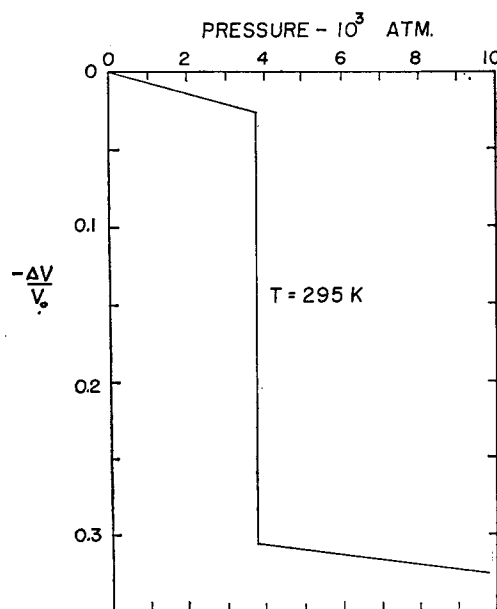


FIG. 1. Pressure-volume isotherm (reduced from the experimental data) at room temperature of NH_4F . The zero pressure phase has a wurtzite structure. Hysteresis associated with the transition is shown in Fig. 2.