

Lawrence Berkeley National Laboratory

Recent Work

Title

LOW-TEMPERATURE HEAT CAPACITY OF Ni_{0.62}Rh_{0.38}

Permalink

<https://escholarship.org/uc/item/3n3749hg>

Author

Triplett, B.B.

Publication Date

1971-11-01

C.2

LOW-TEMPERATURE HEAT CAPACITY OF $\text{Ni}_{0.62}\text{Rh}_{0.38}$

B. B. Triplett and Norman E. Phillips

November 1971

AEC Contract No. W-7405-eng-48

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*



35

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Low-Temperature Heat Capacity of $\text{Ni}_{0.62}\text{Rh}_{0.38}^*$

B. B. Triplett and Norman E. Phillips

Inorganic Materials Research Division, Lawrence Berkeley Laboratory,
and Department of Chemistry; University of California
Berkeley, California 94720

ABSTRACT

The magnetic field dependence of the anomalous heat capacity of $\text{Ni}_{0.62}\text{Rh}_{0.38}$ at low temperatures is consistent with superparamagnetic behavior of ferromagnetic clusters, but not with spin fluctuation effects.

Heat capacity anomalies have been observed for a number of transition metal alloys at concentrations near the critical concentration for the appearance of ordered magnetic moments. These anomalies have usually been interpreted as arising from the splitting of the energy levels of superparamagnetic clusters^{1,2} by an anisotropy field. For the Ni-Rh system the anomalous heat capacity above 1 K has been shown³ to have a temperature dependence consistent with theoretical predictions⁴ for spin fluctuation effects. However, it has also been suggested⁵ that the Ni-Rh data are equally consistent with the heat capacity expected for superparamagnetic clusters. The measurements reported here were undertaken to obtain heat capacity data for a Ni-Rh sample at lower temperatures, and to study the dependence of the anomalous heat capacity on magnetic fields to 38 kOe. The field dependence was expected to provide an additional basis for distinguishing between superparamagnetism and spin fluctuations. A field of 30 kOe should increase the splitting of the energy levels of a cluster to 4 K and reduce the below-1 K heat capacity of clusters considerably, but should have only a small effect on the anomalous heat capacity if it is associated with spin fluctuations.

A $\text{Ni}_{0.62}\text{Rh}_{0.38}$ sample was prepared as described in Ref. 3, including the 3-day anneal at 1100°C. The heat capacity was measured between 0.05 and 4 K in zero field and between 0.1 and 0.6 K in 3 kOe. The heat capacity was later measured between 0.3 and 25 K in 0, 9, 18, and 38 kOe, but in the meantime the sample had been annealed for an additional 30 days at 1100°C. The anneal increased the heat capacity by between 1 and 3% in the 0.3 to 4 K region. Figure 1 shows the results except that

the zero field data taken before the 30 day anneal are omitted above 0.6 K for clarity.

It is evident that the anomalous contribution to the heat capacity is strongly dependent on magnetic field. It has been shown that a field equivalent to the spin fluctuation temperature T_s should be required to suppress the heat capacity contribution associated with spin fluctuations.⁴ For $\text{Ni}_{0.63}\text{Rh}_{0.37}$, $T_s \approx 250$ K has been estimated,³ and T_s should be similar for $\text{Ni}_{0.62}\text{Rh}_{0.38}$ since the heat capacities are similar. The observed field dependence is therefore an order of magnitude greater than would be expected on the spin fluctuation model. The behavior shown in Fig. 1 is, however, consistent with that expected for superparamagnetic clusters. (A similar field dependence has been observed in the Fe-V system and interpreted on the basis of clusters.⁶) In zero field the heat capacity of the clusters is expected to be approximately constant over a limited range of temperature, and to drop exponentially to zero below a characteristic temperature that is determined by the anisotropy field.^{1,2} In the presence of an external field larger than the anisotropy field the characteristic temperature would be determined by the external field, and, if the free-electron gyromagnetic ratio is assumed for the clusters, should be of the order of 5 K in 38 kOe. Below 10 K, the 38 kOe data are approximately fitted by the expression

$$C = 13.3 T + 0.067 T^3 \text{ mJ/mole K}, \quad (1)$$

which suggests that the anomalous heat capacity has been largely shifted to higher temperatures. (The T^3 term and the small positive

deviations from Eq. 1 near 2 K probably include some heat capacity of magnetic origin.) We conclude that the field dependence of the anomalous heat capacity is consistent with the superparamagnetism model and not with the spin fluctuation model.

If it is assumed that Eq. 1 is an approximation to the sum of the lattice and electronic heat capacities, the low-temperature low-field magnetic heat capacity can be found by subtracting Eq. 1 from the experimental data. The magnetic heat capacity calculated in this way shows the temperature dependence expected for clusters on the basis of general qualitative considerations^{1,2} — a region of approximate independence of temperature, and a sharp drop at lower temperatures. There is also some indication of the expected drop at higher temperatures but this is obscured by the increasing lattice heat capacity.

We wish to thank Dr. E. Bucher for supplying the sample and suggesting the measurements.

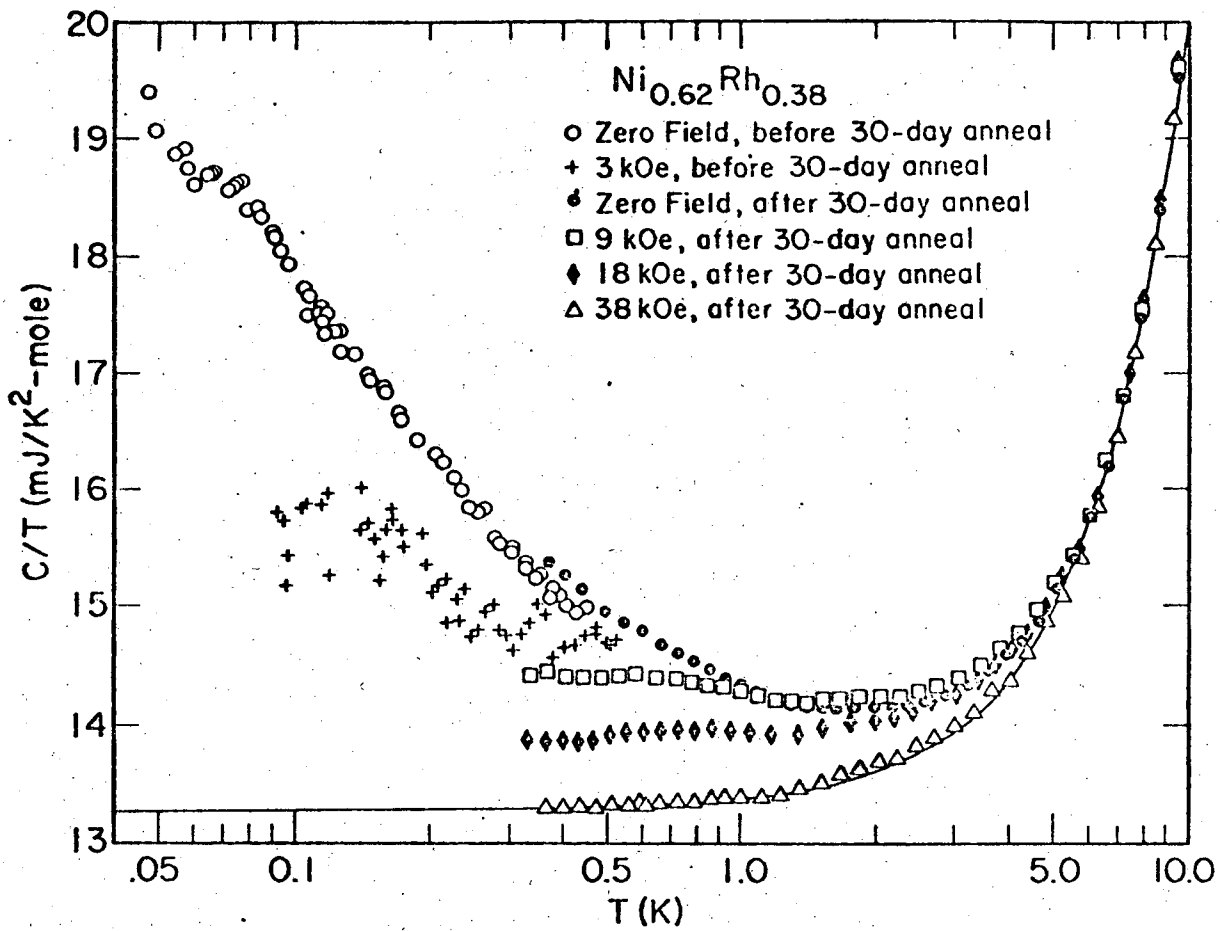
References

* Work supported in part by the U.S. Atomic Energy Commission

1. K. Schröder, and C. H. Cheng, J. Appl. Phys. 31, 2154 (1960);
K. Schröder, J. Appl. Phys. 32, 880 (1961).
2. J. D. Livingston, and C. P. Bean, J. Appl. Phys. 32, 1964 (1961).
3. E. Bucher, W. F. Brinkman, J. P. Maita, and H. J. Williams,
Phys. Rev. Letters 18, 1125 (1967).
4. W. F. Brinkman, and S. Engelsberg, Phys. Rev. 169, 417 (1968).
5. A. Hahn and E. P. Wohlfarth, Helv. Phys. Acta 41, 857 (1968).
6. W. Proctor and R. G. Scurlock, Proceedings of the Eleventh
International Conference on Low Temperature Physics, St. Andrews,
1968, J. F. Allen, D. M. Finlayson, and D. M. McCall, Eds.,
University of St. Andrews Printing Department, 1968, p. 1320.

Figure Caption

Fig. 1 The heat capacity of $\text{Ni}_{0.62}\text{Rh}_{0.38}$.



XBL 7110-1504

Fig. 1

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720