IS-206

MASTER

ELECTRICAL RESISTIVITY OF LANTHANUM, PRASEODYMIUM, NEODYMIUM AND SAMARIUM

J. K. Alstad, R. V. Colvin,† S. Legvold and F. H. Spedding
Institute for Atomic Research and Department of Physics,
Iowa State University, Ames, Iowa

Abstract

The electrical resistivities of polycrystalline samples of La, Pr, Nd, and Sm are reported in the temperature range 1.3°K to 300°K. La exhibits a superconducting transition at 5.8°K. The curve for Pr has slope changes at 61°K and 95°K. The Nd curve shows small jumps at 5°K and 20°K. Sm shows slope changes at 14°K and 106°K.

Measurements on the resistivities of the light rare earths were reported by James et al.[1] in 1952. Improved techniques for producing metals of higher purity have led to the measurements on La, Pr, Nd, and Sm reported here. Some improvement has also been made in the experimental procedure and apparatus. The present work is an extension of the results of Colvin et al.[2] and Curry et al.[3] on the electrical resistivity of the other polycrystalline rare-earth metals, and completes the work.

The samples were prepared from arc-melted buttons of the metals. These were turned to cylinders approximately 3/16 inche in diameter by 2 inches long. The results of analyses for impurities are shown in Table I. The resistivities of the samples were measured in the cryostat described by Colvin et al.[2] The standard four-probe method was used; the potential contacts were 2.5 cm apart. Temperatures

---

Contribution No. 951. Work was performed in the Ames Laboratory of the U. S. Atomic Energy Commission.

† Now at the Edgar C. Bain Laboratory of the U. S. Steel Corporation, Monroeville, Pennsylvania.

DISCLAIMER

were measured with a copper-constantan thermocouple; any temperature in the range from 4.2°K to 300°K could be maintained by means of an automatic temperature controller. The probable error in the resistivity of a given sample varied from 1.5% at room temperature to 0.1 microohm-cm at 4.2°K. The temperature was known to within one half degree throughout the range.

The resistivity of lanthanum is shown in Fig. 1. Aside from the superconducting transition, the curve is well-behaved over the temperature region investigated. The transition temperature was found to be 5.8 ± 0.3°K., as shown in the inset. This is in agreement with Anderson et al.[4] It is likely that both the face-centered cubic structure, which is stable above 300°C, and the close-packed hexagonal structure were present in this sample. The residual resistivity (1.0×10^{-6} ohm-cm) of the present sample was significantly lower than the 10×10^{-6} ohm-cm reported by James et al.[1] for their sample.

The praseodymium data (Fig. 2) show an abrupt slope increase at 61°K. and a slope decrease at 95°K. This is in contrast with earlier work[1] which indicated no abnormal behavior in the electrical resistivity in the low-temperature region. Lock[6] reports no indication of anomalous behavior in the magnetic susceptibility. The specific heat data,[8] however, show a broad peak covering the 60°K to 100°K. temperature region. Since the more distinct slope discontinuities displayed by the present sample (together with the lower residual resistivity) are thought to be consequences of improved sample purity, it would seem advisable to investigate the magnetic susceptibility of this sample over the temperature region in question. A temperature hysteresis effect was noted in the resistivity; that is, later runs on the same sample gave lower resistivity values at the same temperatures.

Figure 3 shows the behavior of the low temperature resistivity of neodymium. The inset is a blow-up of the region from 0°K. to 30°K. showing more clearly the two jumps in the resistivity at 5°K. and 20°K. Measurements of magnetic susceptibility,[5, 6] thermoelectric power[7] and heat capacity[8] also indicate abnormal behavior near these temperatures. Lock[6] suggests that neodymium undergoes a magnetic transition near 7°K., being antiferromagnetic below this temperature.

The resistivity of samarium (Fig. 4) shows a knee at 14°K and a sharp change in slope at 106°K. Measurements of specific heat[9] and thermoelectric power[7] show abnormal behavior near the higher temperature; maxima have been reported in the specific heat[10] and magnetic susceptibility[6] curves near 14°K. The suggestion has been made[6] that samarium is also antiferromagnetic below 14°K.

From a comparison of the results reported here with those reported earlier it appears that the low temperature resistivity of a rare-earth metal is very sensitive to the presence of impurities. The rare earths are very effective "getters" for negative impurities such as oxygen, carbon, nitrogen, and hydrogen; it is believed that very small amounts of these materials in the earlier samples drastically affected their resistivities.

The authors wish to thank Mr. R. Johnson, Mr. C. Haberman and Mr. G. Wakefield for preparing the metals.

References

1. James, Legvold, and Spedding, Phys. Rev. 88, 1092 (1952).
2. Colvin, Legvold, and Spedding. To be published, Phys. Rev.
3. Curry, Legvold, and Spedding, Phys. Rev. 117, 953 (1960).
4. Anderson, Legvold, and Spedding, Phys. Rev. 109, 243 (1958).
5. Behrendt, Legvold, and Spedding, Phys. Rev. 106, 723 (1957).
6. J. M. Lock, Proc. Phys. Soc. (London) B70, 566 (1957).
7. H. J. Born, Thesis, Iowa State University, Ames, Iowa, 1960 (unpublished).
8. Parkinson, Simon, and Spedding, Proc. Roy. Soc. (London) A207, 137 (1951).
9. Jennings, Hill, and Spedding, J. Chem. Phys. 31, 1240 (1959).
10. L. M. Roberts, Proc. Phys. Soc. (London) B70, 434 (1957).

Table I

Analysis (in %)

Element	Impurities (determined from spectrographic and vacuum fusion analysis)
Lanthanum	Ce ≤ 0.03, Pr ≤ 0.03, Nd ≤ 0.02, Ca ≤ 0.01, Fe < 0.15, Si < 0.01, Mg < 0.01, Ta < 0.2. Cu, Ni, Sm, trace present.
Praseodymium	Nd ≤ 0.02, Ce ≤ 0.1, La ≤ 0.005, Ca ≤ 0.1, Fe ≤ 0.02, Mg < 0.01, Si < 0.025, T ≤ 0.2, Cr < 0.01, O ≤ 0.094, H ≤ 0.0005, N ≤ 0.0920. Ca, Cu, Mn, Ni, Ti, Y, trace present.
Neodymium	Sm ≤ 0.06, Pr ≤ 0.08, Ca < 0.05, Mg < 0.01, Fe ≤ 0.005, Si < 0.025, Ta < 0.1, Cr < 0.01 [O ≤ 0.035.] [B, Mn, Ni, trace present.]
Samarium	Ca < 0.03, Fe < 0.005, Mg < 0.01, Si < 0.01, Cu ≤ 0.05, Gd ≤ 0.02, Nd ≤ 0.02, Eu ≤ 0.005.

FIGURE CAPTIONS

Fig. 1—The electrical resistivity of La vs. temperature.

Fig. 2—The electrical resistivity of Pr vs. temperature.

Fig. 3—The electrical resistivity of Nd vs. temperature.

Fig. 4—The electrical resistivity of Sm vs. temperature.

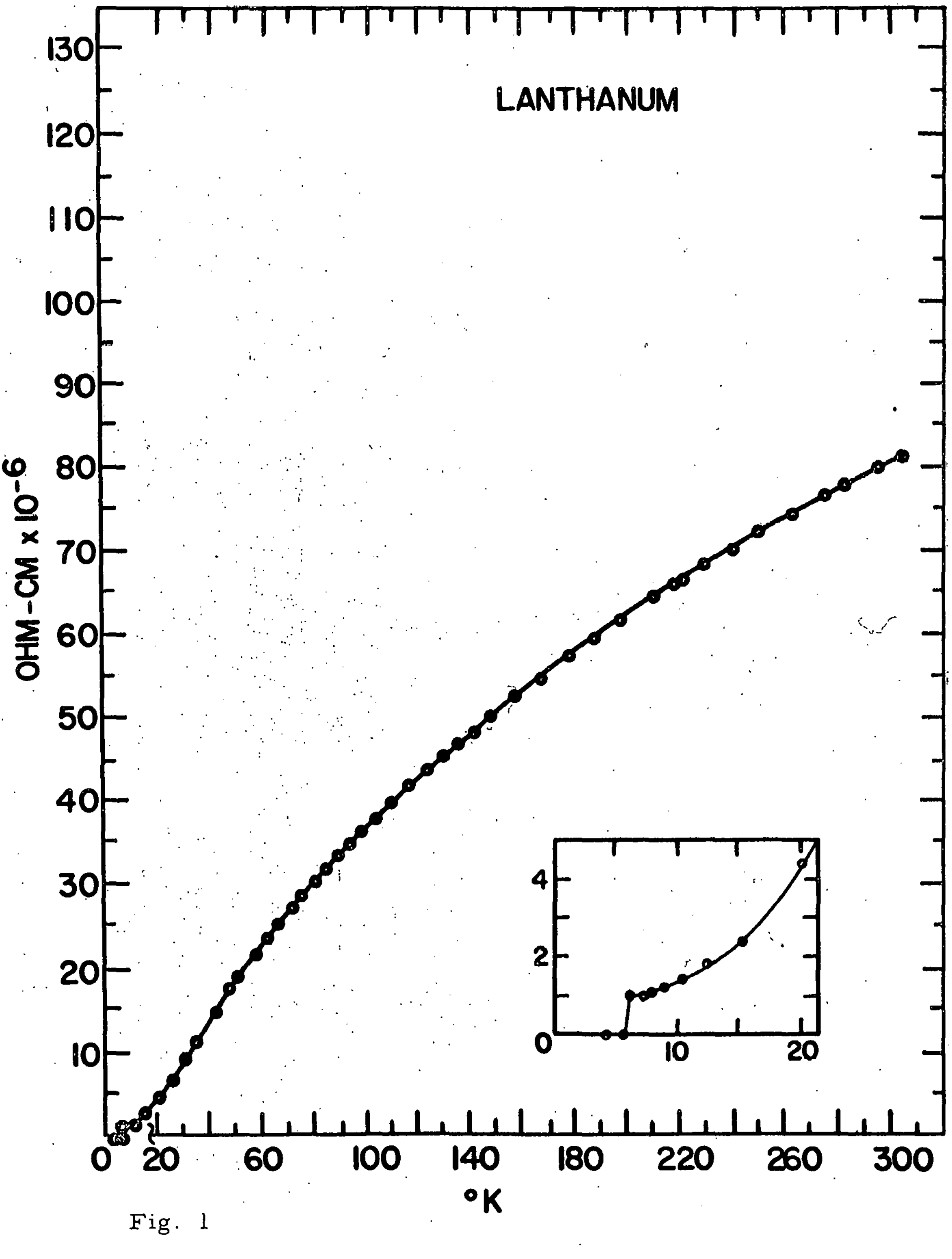
LANTHANUM
OHM-CM x 10-6
130
120
110
100
90
80
70
60
50
40
30
20
10
0
20
60
100
140
180
220
260
300
°K
4
2
0
10
20

Fig. 1

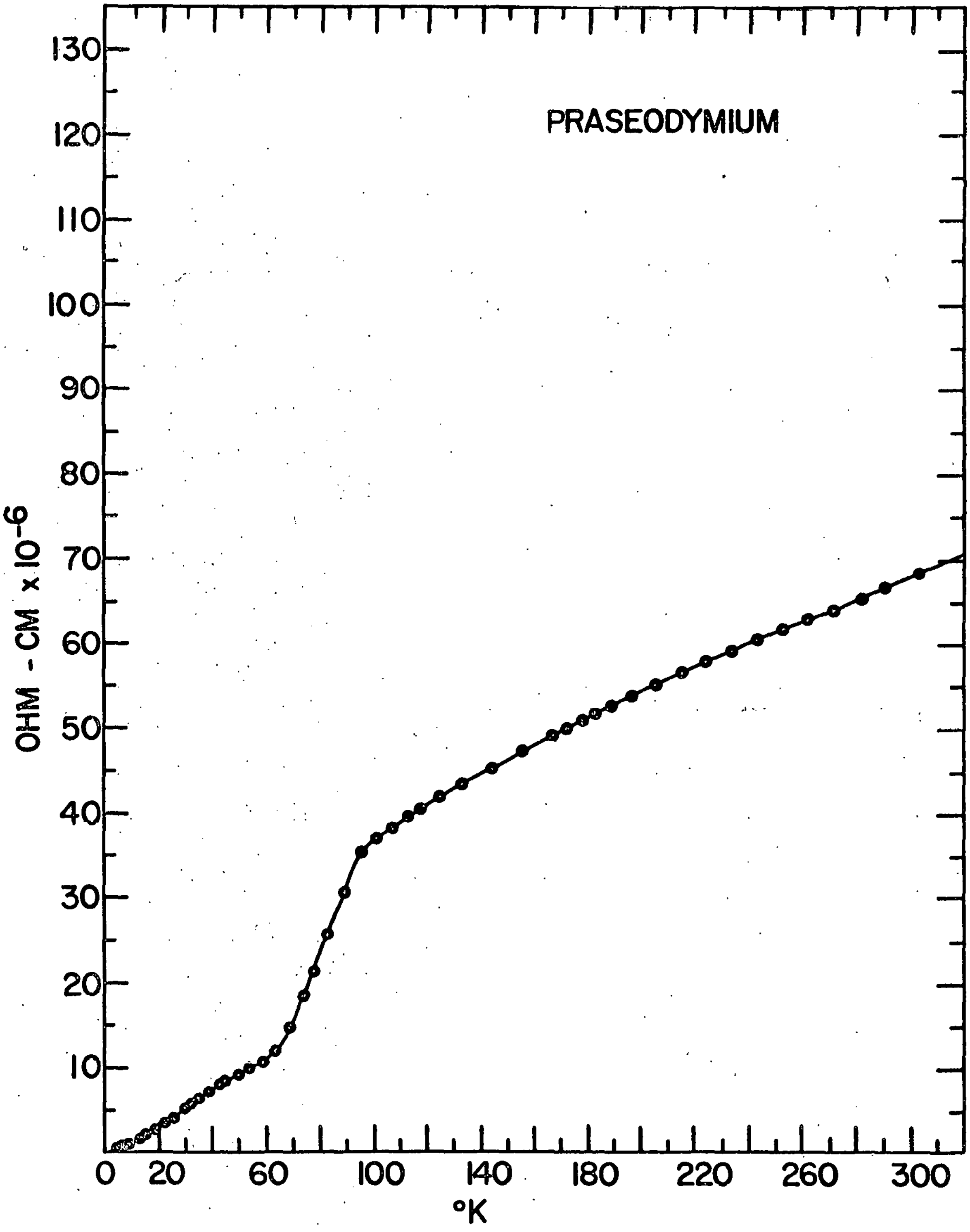
PRASEODYMIUM
OHM - CM x 10^{-6}
°K
0
20
60
100
140
180
220
260
300
10
20
30
40
50
60
70
80
90
100
110
120
130

Fig. 2

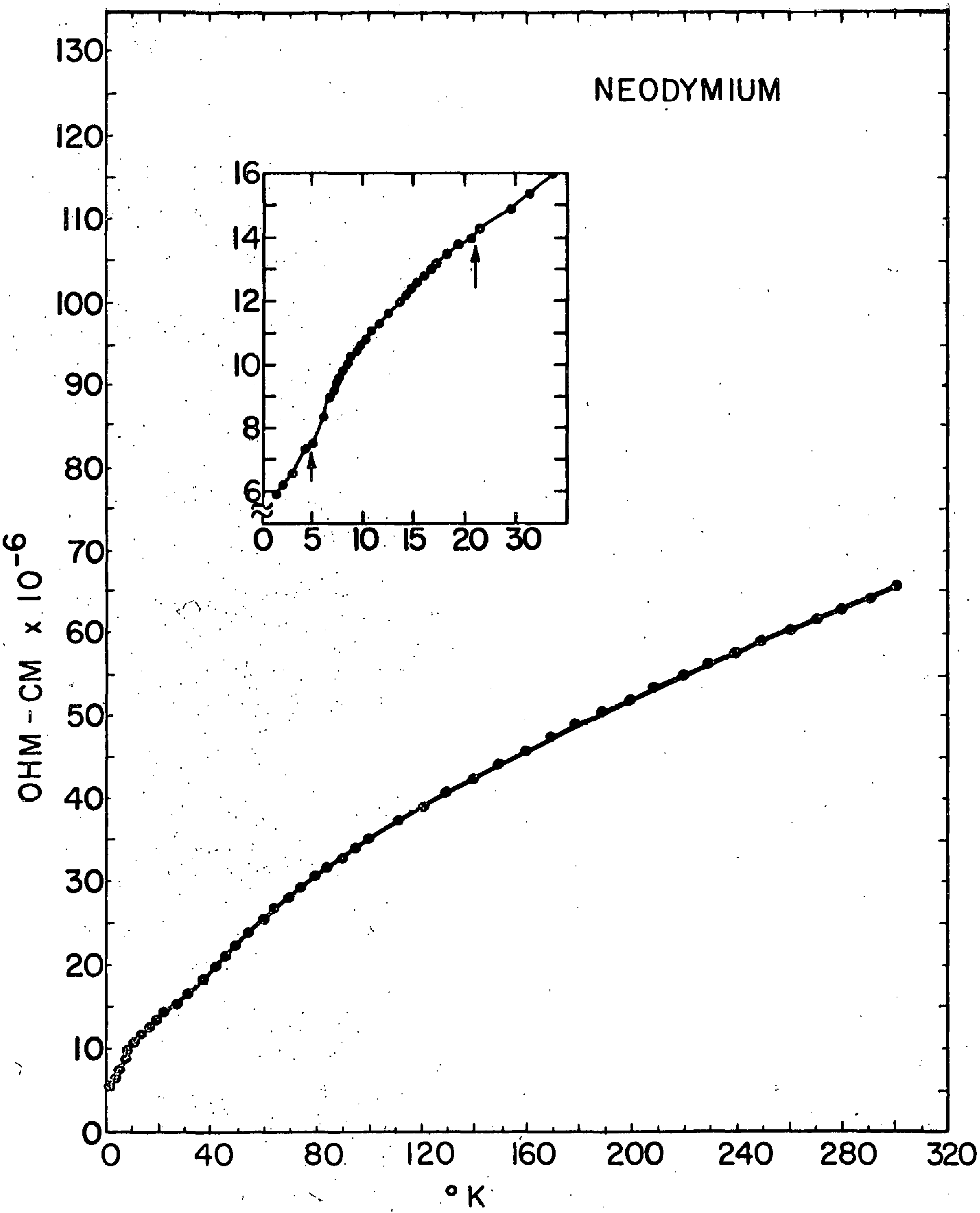
NEODYMIUM
OHM - CM x 10^-6
°K
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
40
80
120
160
200
240
280
320
6
8
10
12
14
16
0
5
10
15
20
30

Fig. 3

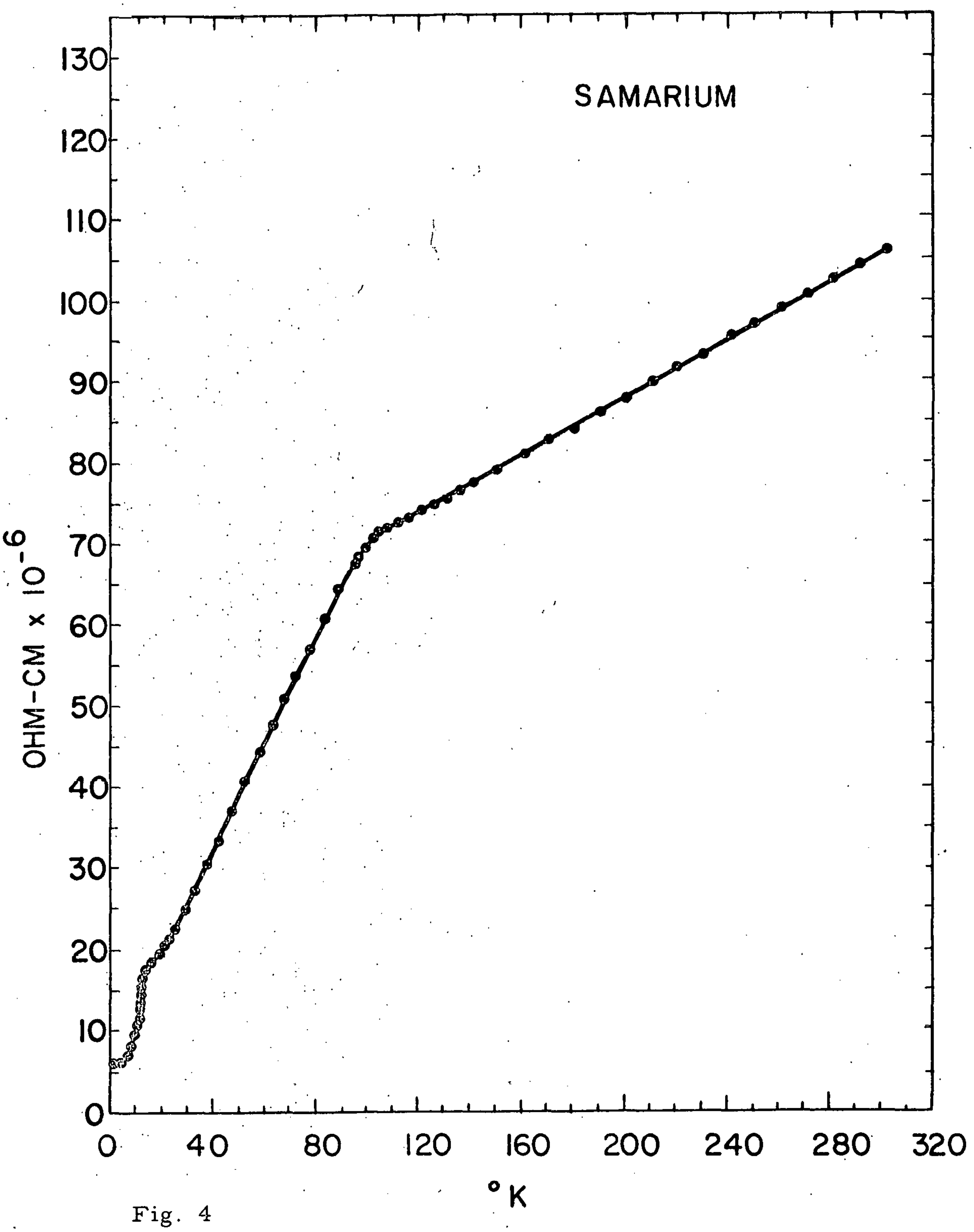
SAMARIUM
OHM-CM x 10^{-6}
°K
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
40
80
120
160
200
240
280
320

Fig. 4