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THE ELECTRICAL RESISTANCE OF BISMUTH FROM 25 TO 90 KILOBARS

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When Bridgman[1] determined the volume-pressure relationships of bismuth to 100 kg cm^{-2}, he found two small volume discontinuities at 45 and 64 kg cm^{-2}. Probably every investigator in high pressures has determined the electrical resistivity of bismuth in this pressure range. Until Zeitlin and Brayman[2] reported discontinuities in the resistance of bismuth at these pressures, no one had found resistance discontinuities that corresponded to the volume discontinuities at 45 and 64 kbars. Because of this report, we undertook a more careful determination of the resistance of bismuth as a function of pressure. Our results indicate that there is no discontinuity in the resistance that is greater than 0.1%. This is much smaller than the discontinuity reported by Zeitlin and Brayman.

The Bridgman anvils, bismuth wire sample, and method of sample mounting used here have been described elsewhere.[3] The resistance of the sample, which was about 2 ohms, was measured with a Leeds and Northrup Mueller bridge. The room was air conditioned, and the maximum variation in room temperature (about 3°C) was so small that it was not necessary to consider the resistance change in the bridge leads. The anvils were kept in an oil bath which was thermostated to 28.0 ± 0.1°C. The press has a large diameter

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ram and low pressure oil system. A strain gauge in conjunction with a Baldwin-Lima-Hamilton SR-4 bridge was used for the determination of the load. The sensitivity of the load measurement was 25 bars. The stability of the press is such that in a period of 12 hours the load would decrease by no more than 0.5%. During the day, the load was monitored and kept within 0.1% of the assigned value.

The resistance of the sample through Phase II and in Phase "VIII" were determined in the usual fashion, about two minutes after each pressure increment. In the intermediate region, the region of interest, the sample was permitted to stand until a resistance reading was obtained that was constant in the fourth decimal, a part in 20,000. This took several hours after a compression of 2 kbars. The resistance came to within 0.2% in about two minutes and then drifted downward at a very slow rate for two or three hours afterwards. When all factors are considered, the relative accuracy of the various resistances in a given experiment should be less than 0.1%.

Three complete experiments were performed. In each case the behavior before and after the region of interest agreed closely with our previous work and that of other investigators. We found no indication of a resistance discontinuity in the 40 or 60 kbar region. We can only conclude that Zeitlin and Brayman obtained spurious results for some reason that we are not in a position to determine.

We found that the most satisfactory method of showing our results was to fit a least squares quadratic expression to our data, and then show the deviation from this fit. This is shown in Fig. 1. This representation is purely empirical and is not meant to imply that this is the correct

representation of the resistance of bismuth as a function of pressure. The average deviation of a single and all three determinations is 0.06%, a figure that is reasonable with our expected error. What is more important, there appears to be no systematic deviation.

The lack of discontinuity in the resistance cannot be taken as absolute proof that the phases reported by Bridgman do not exist. There are systems which do not exhibit a discontinuity in the resistance accompanying a phase change. Lanthanum is such a case.[4]

This work was performed under the auspices of the United States Atomic Energy Commission.

Footnotes

(1) P. W. Bridgman, Proc. Am. Acad. Arts and Sci. 74, 425 (1942).

(2) A. Zeitlin and J. Brayman, High-Pressure Measurement, A. A. Giardini and E. C. Lloyd, eds. (Butterworths, Washington, 1963), pp. 301-320.

(3) P. W. Montgomery, H. D. Stromberg, G. H. Jura, and G. Jura, High-Pressure Measurement, A. A. Giardini and E. C. Lloyd, eds. (Butterworths, Washington, 1963), pp. 1-16.

(4) D. McWhan, P. W. Montgomery, H. D. Stromberg, and G. Jura, J. Phys. Chem. 67, 2308 (1963).

Figure Caption

Fig. 1. Deviation of experimental points from an assumed quadratic curve fitted through the experimental points between 32 and 90 kbars. The results of three independent determinations are shown. Three points in which the deviation was greater than 0.25% are not shown. There is no indication of any transitions in the regions at 45 and 60 kbars.

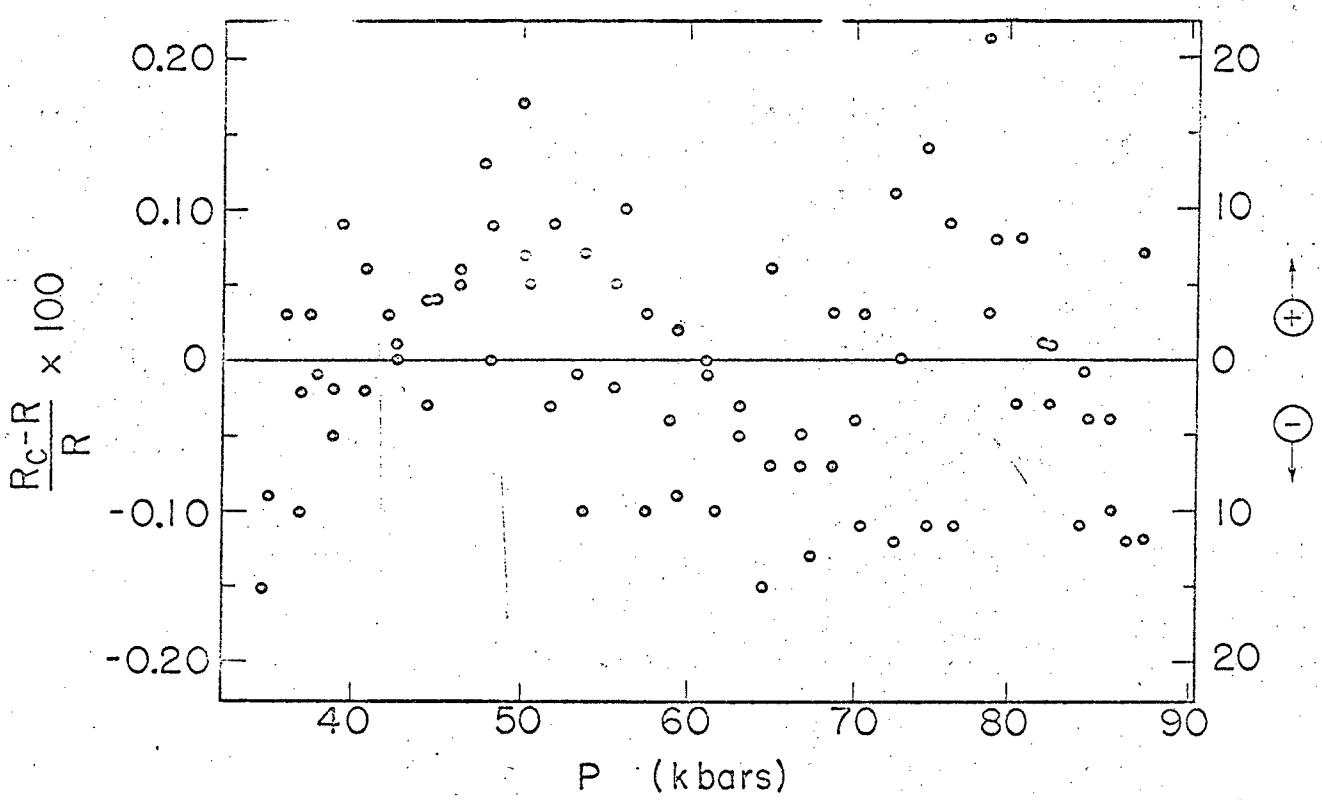
0.20
0.10
0
-0.10
-0.20
20
10
0
10
20
40
50
60
70
80
90
P (kbars)
$\frac{R_c-R}{R} \times 100$
+
−
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Fig. 1