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Volume Measurements on Chromium to Pressure of 30 Kilobars

Abstract. *The unit cell volume of chromium was measured as a function of pressure from 1 bar to 30 kilobars by x-ray diffraction techniques. The antiferromagnetic transition occurred at 1.5 kilobars at 29°C, where there is a discontinuity in the slope of the curve for lattice parameter vs. pressure. By electrical resistance measurements the value of* $-\Delta T_N/\Delta P$ *was determined to be 5.9° ± 0.3° per kilobar. At room temperature chromium remains in the body-centered cubic crystal structure from 0 to 55 kilobars.*

A transition in Cr from the antiferromagnetic state to the paramagnetic state (the Neel point, T_N) has long been known and has been of interest to investigators. Bridgman noticed anomalies in certain properties of Cr as a function of pressure, notably in the electrical resistance and compressibility (*1, 2*). However, much of his data are inconsistent with the findings of recent workers, and it has been suggested that the inconsistency is due to the impurity content of his samples and to strains introduced into his pressure system (*3*). Since the time when our work commenced, several notes and articles have been published about Cr under pressure, investigations being made by means of electrical resistance (*3*), neutron diffraction (*4*), and ultrasonic vibrations (*5*). Our work concerns the volume anomaly in Cr at the Neel point.

We measured volume changes by x-ray diffraction techniques. Chromium powder was mixed with polyethylene powder, and the mixture was pressed together to give a sample (about 0.3 mm thick) containing about one absorption length (the thickness of chromium required to reduce the incident beam intensity by $1/e$) of Cr (0.05 mm). Besides providing a sample of workable thickness, addition of polyethylene served to improve the approximation to hydrostatic conditions in the solid pressure-system. This sample was then centered in either a boron-filled plastic tetrahedron or a lithium hydride tetrahedron and placed in the tetrahedral x-ray diffraction press (*6*). Molybdenum $K\alpha$ radiation was used, and the five most intense lines of the Cr powder pattern, (110), (200), (211), (220), and (310), were monitored. Pressure was determined by means of the bismuth I-II transition at 25.2 kb in conjunction with continuous resistance measurements of Yb which were related to NaCl compressibility as determined by x-ray diffraction (*7*).

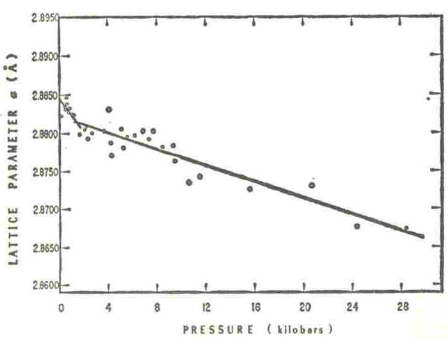

Fig. 1. Lattice parameters of chromium vs. pressure.

For the determination of the lattice parameter as a function of pressure, the lattice parameters computed from the spacings (measured in two independent runs) of each of the five major Cr lines were averaged at each pressure setting. Thus each point in the curve of Fig. 1 is the average of ten measurements. The uncertainty in lattice parameter is of the order of 0.05 percent in the antiferromagnetic region and 0.10 percent the paramagnetic region. The extremely low compressibility of Cr makes measurement difficult. However, least-square fits of the points from 0 to 2 and from 28 kb show a clear break at 1.5 kb. Our electrical resistance measurements on Cr also indicate a transition (resistance discontinuity) at 1.5 kb. The temperature during these experiments was 29.0° ± 0.5°C. Litvin and Ponyatovskii (*4*), by studies of neutron diffraction and electrical resistance, found the transition at 38°C at atmospheric pressure and found $-\Delta T_N/\Delta P$ to be 5.9°/kb. This would put the transition at about 1.5 kb at 29°C, which is consistent with our data.

In the electrical resistance measurements on Cr we have found the atmospheric pressure Neel temperature to be 38.0° ± 0.5°C, in excellent agreement with the findings of other workers (*3, 4*). From these same measurements we determined $\Delta T_N/\Delta P$ to be 5.9° ± 0.3°/kb, again in agreement with the value of Litvin and Ponyatovskii (*4*) but slightly higher than that of Mitsui and Tomizuka (see *3*), who found 5.1° ± 0.2°/kb.

From the data of Fig. 1 we calculate a bulk compressibility in the antiferromagnetic region of $\beta_0 = 21.8 \times 10^{-13}$ (dyne/cm^2)$^{-1}$. In the paramagnetic region $\beta = 5.60 \times 10^{-13}$ (dyne/cm^2)$^{-1}$. The initial compressibility is larger than obtained by Bridgman (*1*), who found $\beta_0 = 6.1 \times 10^{-13}$ (dyne/cm^2)$^{-1}$. However, it should be noted that the scatter of points in Bridgman's compressibility measurements (*2*) is approximately 3 times that of ours and that Bridgman did not detect a break in the compressibility curve. A plot of $\Delta V/V$ against P at 30°C as given by Bridgman (*1*) (he gave smoothed data at 1-kb intervals) indicates that the initial compressibility was probably considerably higher than 5×10^{-13} which is the slope of his line between 1 and 12 kb.

In an extended x-ray run in which the diffraction pattern was scanned every 5 kb, we found that Cr remains in a body-centered cubic crystal structure from 0 to 55 kb at 28°C.

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References and Notes

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