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Short Communications

The Magnetic Properties of the Elements Molybdenum and Tungsten

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R. W. ASMUSSEN and J. POTTS JENSEN

The Chemical Laboratory B, Technical University of Denmark, Copenhagen, Denmark

The first magnetic measurements concerning molybdenum and tungsten were published by Koenigsberger [1] in 1898. The author reports the χ_g-value 1.80×10^{-6} for molybdenum and 0.70×10^{-6} for tungsten. The susceptibility was dependent on the field strength. In 1899 Meyer [2] gave the χ_g-values 0.25×10^{-6} and 0.55×10^{-6}, respectively. The metal samples cannot be considered chemically and magnetically pure.

Magnetic measurements at different temperatures (room-temperature to 1 200°C) were published in 1910 by Honda [3]. For *molybdenum* a slight increase of χ_g with increasing temperature was observed; χ_g for *tungsten* was temperature independent. Mo: Metal lump (regulus) from Kahlbaum (nach Moissan), specific gravity 8.6 g/cm³. $\chi_g = 0.039 \times 10^{-6}$ is given as an average value. W: A metal lump and a powder sample both with a specific gravity 19.1 g/cm³ (from prof. Tammann); $\chi_g = 0.334 \times 10^{-6}$ and 0.336×10^{-6}, respectively.

In 1912 Owen [4] published the following results. *Molybdenum:* Powder specimen from Merck, the specific gravity 8.6 g/cm³ and $\chi_g = 0.603 \times 10^{-6}$ (0.558×10^{-6} for $H \rightarrow \infty$) at room-temperature and decreasing slightly with increasing temperature in the temperature range — 180°C to 20°C. *Tungsten:* Several samples with different (temperature independent but field strength dependent) χ_g-values. The author assumed the best value $\chi_g = 0.22 \times 10^{-6}$.

In 1933 de Haas and Alphen [5] published measurements on *molybdenum*, in which no impurities could be detected by chemical methods; spectroscopically, however, the presence of traces of certain metals were proved. Iron did not occur. The authors report $\chi_g = 0.949 \times 10^{-6}$ at 289°K. The susceptibility increases strongly with decreasing temperature. At 14.2°K, χ_g is 1.819×10^{-6}. For *tungsten* the following χ_g-values were found: 0.284×10^{-6}, 0.287×10^{-6} and 0.292×10^{-6} at the temperatures 289°K, 20.4°K and 14.2°K, respectively.

Finally Kriessman [6] in 1953 has published results of susceptibility measurements on molybdenum and tungsten. For *molybdenum:* $\chi_g = 0.93 \times 10^{-6}$ at 25°C increasing with increasing temperature being 1.11×10^{-6} at 1 825°C, (estimated from the χ_g, T-curve, no tables are published). The measurements on *tungsten* gave $\chi_g = 0.32 \times 10^{-6}$ at room-temperature; a slight increase in χ_g with increasing temperature was observed. The χ_g-value is 0.37×10^{-6} at 1 850°C. The samples used were spectroscopically pure metal-rods prepared by Johnson, Matthew and Co., London.

In this laboratory we have measured the magnetic susceptibility of molybdenum and tungsten at varying temperatures (80°K to 530°K) and at different values of the magnetic field strength.

The metal samples used for the measurements were spectroscopic standards prepared by Johnson, Matthew and Co., London. For *molybdenum* the specific gravity was determined to 10.3 g/cm³ (Landolt-Börnstein's tables give 10.2 g/cm³). The cylindrical rod had the dimensions: Diameter 4.98 mm and length 10.10 cm. In the spectra the sensitive

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Table 1. Magnetic susceptibilities $\chi_g \times 10^6$ at different temperatures and field strengths.

	W			Mo		
Temp. °K / H Ørsteds	80	195	294	80	198	372
2 138	0.278	0.292	0.294	0.838	0.868	
2 657	0.278	0.292	0.294	0.839	0.875	0.875
3 040	0.278	0.293	0.296	0.839	0.874	0.874
3 346	0.281	0.293	0.296	0.839	0.837	0.872

lines of the elements Fe and Cu were barely visible and those of Ag, Al, As, Ca, Cd, Co, Cr, K, Li, Mn, Na, Nb, Ni, Pb, Rb, Sb, Sn, Si, Ta, Ti, V, W, Zn and Zr were not observed. The specific gravity of *tungsten* was determined to 19.1 g/cm³ (Landolt-Börnstein's tables give 19.1 g/cm³). The shape of the specimen was cylindrical (diameter 4.01 mm and length 10.10 cm). In the spectra the sensitive lines of the elements Fe and Si were very faint. No lines of the elements Ag, Al, Ca, Co, Cr, K, Li, Mg, Mn, Na, Ni, Pb, Sn, Ti, V, Zn, and Zr were observed.

The magnetic measurements were carried out as previously described [7].

The susceptibilities for both metals were measured at 2 138, 2 657, 3 040 and 3 346 Ørsteds at the temperatures 291, 198 and 80°K for molybdenum and at 294, 195 and 80°K for tungsten. The high-temperature measurements were carried out at 2 657, 3 040 and 3 346 Ørsteds, while in the temperature intervals: CO_2-temperature to liquid air temperature and CO_2-temperature to room-temperature, the susceptibilities were measured at 3 346 Ørsteds.

Our measurements of the gram susceptibilities are plotted against the temperature (°K) in Fig. 1. The straight lines have been determined by means of the method of least squares and have the equations:

$$\text{Mo: } \chi_g \times 10^6 = 0.8544 + 0.000053\ T$$
$$\text{W: } \chi_g \times 10^6 = 0.2798 + 0.000037\ T$$

For both metals there seems to be, at the lowest temperatures, a more rapid

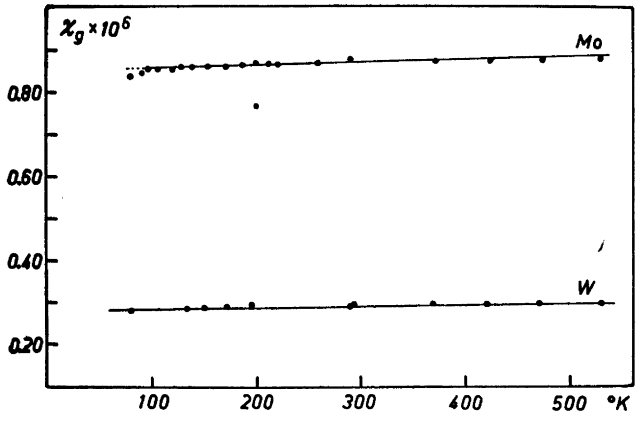

Fig. 1. Temperature dependence of the magnetic gram susceptibilities of molybdenum and tungsten.