THERMAL PROPERTIES OF TANTALUM AT HIGH TEMPERATURES

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The high-temperature of refractory metals are of interest in connection with the possibility of studying states characterized by relatively high ratios of the absolute temperature to the Debye temperature. Particularly interesting in this connection are studies of the heat capacity, i.e., studies of the anharmonicity of lattice vibrations, the electronic heat capacity, and the effect of the vacancy contribution. In studies of the thermal conductivity it is important to clarify the role of the lattice component and the temperature dependence of the electronic component in order to determine the transfer mechanism at high temperatures. To a large extent, the experimental results available are contradictory and do not yield reliable conclusions about the basic behavior of the thermal properties. This is particularly true of tantalum. For example, of the four studies reporting data on the thermal conductivity above 25°K, two reported a negative temperature coefficient and two reported a positive coefficient. The differences between the magnitudes of the thermal conductivities reported amount to several tenths [1].

We report here measurements of the thermal properties of tantalum carried out as part of a systematic study of the properties of solid and liquid metals at high temperatures. The measurements were carried out by two methods developed in Moscow State University [1-4], each of which can be used to obtain a set of thermal properties with the same apparatus: the thermal conductivity, the temperature conductivity, the heat capacity, the electrical conductivity, and radiation properties.

We study two tantalum samples by the method of variable induction heating. The first sample (1) was a polished caste cylinder 7.3 mm in diameter and 66 mm long having the following composition: 99.61% Ta, 0.33% Nb, 0.01% Fe, Ti < 0.01%, Si < 0.01%. Its room temperature (20°C) resistivity was 13.7 μΩ · cm, and its density was 16.57 g/cm^3. The second sample (2), obtained by the metal-ceramics method, was 11.96 mm in diameter and 98 mm long, having the following composition: 99.78% Ta, 0.13% Nb, W + Mo < 0.01%, 0.003% Ti, 0.01% Si, 0.01% Fe, and 0.006% C. Its resistivity at 20°C was 13.49 μΩ · cm, and its density was 16.65 g/cm^3. A wire sample (3) 0.2 mm in diameter had the following composition: 99.9% Ta, 0.05% Mo, 0.02% Nb, 0.01% Si, 0.01% Ti, and 0.01% Al.

The accompanying table shows the resistivity ρ, the spectral likeness $\varepsilon_{\lambda T}$ and the total blackness ε_T for each of the samples.

T°K	ρ, μΩ·βω			ε_T	$\varepsilon_{\lambda, T}$
	1	2	3		
1100	49,6	46,9	—	0,140	—
1200	53,6	51,0	—	0,149	—
1300	57,3	54,6	—	0,159	0,449
1400	60,9	58,2	59,0	0,168	0,441
1500	64,4	61,8	63,0	0,178	0,435
1600	67,8	65,2	66,5	0,187	0,431
1700	71,2	68,5	70,0	0,196	0,427
1800	74,4	71,8	73,5	0,204	0,424
1900	77,6	75,2	76,5	0,213	0,421
2000	81,0	78,5	80,0	0,221	0,418
2100	84,4	81,8	83,0	0,230	0,416
2200	87,6	85,1	86,5	0,238	0,414
2300	91,0	88,4	89,2	0,246	0,412
2400	94,3	91,0	92,2	0,255	0,410
2500	97,7	95,0	95,2	0,263	0,408
2600	—	—	98,0	0,271	0,406
2700	—	—	101,0	0,280	0,404
2800	—	—	104,0	0,288	0,402
2900	—	—	107,0	0,296	0,400
2945	—	—	108,5	0,300	0,398

The measured heat capacities (Fig. 1) are essentially the same for all the samples ○) sample 1; ⊕) sample 2; △) sample 3. The mean square deviation from the experimental of the experimental points from the average curve is 1.5%. Up to temperatures on the order of 2200°K the data agree well with those recommended in /4/ as most probable; the difference is no greater than 1.5%.

An interesting point is that the increase in the heat capacity above 2400°K observed in 5, 6] and attributed to the contribution of thermal vacancies is not displayed in the results. In this connection, we note that we also found the heat capacity to have a linear behavior in the case of molybdenum and niobium [7]. Measurements above 2500°K were carried out particularly carefully: eight samples were studied, and the amplitude of the temperature fluctuations varied during the experiment. From the results we conclude that the temperature dependence of C_p at high temperatures cannot be considered finally established.

Figure 2 shows the thermal conductivity measured for the tantalum; the experimental points correspond to the results of direct measurements of thermal conductivity for sample 3. The mean square deviation of the experimental points from the smooth curve is 4.7%. For samples 1 and 2 data are shown which were found from the smoothed $C_p(T)$ and $\alpha(T)$ curves. Our results are consistent within the experimental error and approximately equal to the data of [8, 9]; up to 1900°K, they are approximately equal to the data of [10]. The data of [11, 12] are considerably below ours.

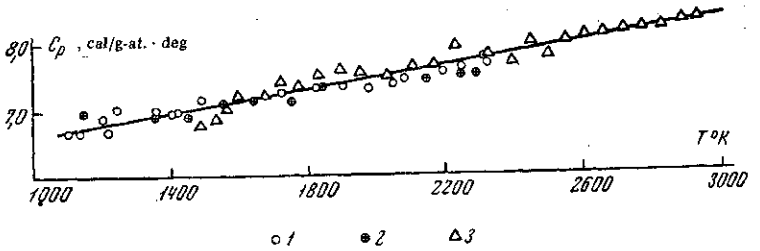

Fig. 1

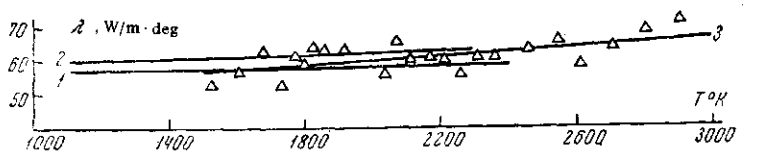

Fig. 2

All the samples are characterized by a slight increase of the thermal conductivity with increasing temperatures. Similar dependences were found for vanadium and niobium [7]. The positive temperature coefficient of the thermal conductivity should evidently be assumed a characteristic feature of V metals.

The Lorentz numbers L calculated for the various samples are approximately the same: above 1500°K, the L values do not exceed the theoretical value for the electronic thermal conductivity, so the lattice component of the thermal conductivity is apparently important only below 1500°K. Comparison of our results with those which we found for vanadium and niobium [7] implies that the role of the lattice component of the thermal conductivity decreases with increasing atomic number in the group V elements.

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