ELSEVIER Thermochimica Acta 282/283 (1996) 317–322

thermochimica
acta

The heat capacity of tantalum from 80 to 1000 K[1]

Yoichi Takahashi[a,*], Jin-ichi Nakamura[b]

[a] *Department of Applied Chemistry, Chuo University, 1-13-27, Kasuga, Bunkyo-ku, Tokyo 112, Japan*
[b] *Department of Reactor Safety Research, Japan Atomic Energy Research Institute, Tokai-mura, Ibaraki 319-11, Japan*

Abstract

The heat capacity of metallic tantalum has been measured in the temperature range 80–1000 K by laser-flash calorimetry. The results are compared with available low- and high-temperature heat capacities, and the thermodynamic values are given.

Keywords: Heat capacity; Laser-flash calorimetry; Tantalum

---

1. Introduction

Tantalum is one of the metals of importance in the field of nuclear engineering. For thermodynamic calculations on those metals, it is very important to provide accurate heat capacity values which are consistent over the whole temperature range concerned. Heat capacity values, including relative enthalpy, of metallic tantalum have been reported by many authors [1–7], but there is considerable disparity among these data.

In the present study, the heat capacity of tantalum has been determined by laser-flash calorimetry at temperatures from 80 to 1000 K. The accuracy of the results and comparison with other available data are discussed.

2. Experimental

Measurements were made on a small disk of 99.9% pure tantalum, which was supplied by Shinkuyakin Co. Ltd., Tokyo. The disk pellet was 10 mm in diameter and

---

* Corresponding author.

[1] Dedicated to Takeo Ozawa on the Occasion of his 65th Birthday.

SSDI 0040-6031(95)02797-1

4 mm thick, and weighed 5.7661 g. The mass fraction $10^6 x_i$ of main reported impurities in the sample are as follows: C 20, N 20, O 90, Mo 30, Nb 60, W 100.

Details of heat capacity measurements by laser-flash calorimetry were described in a previous paper [8]. Experimental results on an alumina reference sample showed [8] that the accuracy was to within ± 0.5% over the temperature range 100–800 K, and to within ± 1% from 800 to 1100 K. A brief outline of the present measurements is as follows. First, the heat capacity of the tantalum sample at room temperature was determined by comparison with an α-alumina reference sample, for which recent reference values of the heat capacity of synthetic sapphire (SRM 720) [9] were used. The same absorbing disk made of glassy carbon (mass 0.030 g), with a small mass (less than 0.002 g) of silicone grease as an adhesive, was used in these measurements. Correction was made for these materials using available data [10, 11], and their total contributions to the gross heat capacity determined were less than 3%. The temperature-dependence of the heat capacity was then determined on the same tantalum sample. The front surface of the sample was coated with a thin layer of dry graphite film (miracle power products corp., cleveland, OH) for these measurements.

3. Results and discussion

The experimental results are listed in Table 1. A molar mass of 180.9479 g mol^{-1} was used for tantalum, and no correction for impurities was made. The imprecision (standard deviation) of the heat capacity measurements was within ± 0.5% from 80 to 1000 K.

The smoothed heat capacity and the derived thermodynamic functions were calculated by the least-squares method; the resulting values at selected temperatures are given in Table 2. In this calculation, entropy values at 100 K were taken from the JANAF Thermochemical Tables [12].

A comparison of these heat capacities with those from other investigations is shown in Fig. 1. Between 80 and 250 K, present results are in good agreement with those of Sterrett and Wallace [3], obtained by adiabatic calorimetry, whereas slight discrepancy is seen above 250 K. From 300 to 550 K, the results of Sterrett and Wallace are about 1% higher than the present data. The high-temperature heat capacity data of Oetting and Navratil [7], obtained by the drop method are about 0.5% higher than our data up to 800 K, and are in agreement with our data at about 900 K, whereas those of Taylor and Finch [5], obtained by a pulse method, are 3–4 per cent lower than ours.

The heat capacity data of tantalum have been compiled in the JANAF Thermochemical Tables [12], and the most probable thermal functions were evaluated by relying mainly on the results of Sterrett and Wallace [3] (12–550 K), Oetting and Navratil [7] (533–1384 K), and Cezairliyan [6] (1900–3200 K). Accordingly, the present results agree well with the values from the JANAF Tables, in particular up to 800 K: differences in heat capacities are within ± 0.5% from 300 to 800 K, whereas at 1000 K the present heat capacity data are about 1.8% higher than those of the JANAF tables.

Table 1
Experimental heat capacity of tantalum ($M_{(Ta)} = 180.9479\,g\,mol^{-1}$)

T/K	C_p/J K^{-1} mol^{-1}
Series I	
294.87	25.15
294.64	25.16
294.65	25.11
294.70	25.18
Series II	
82.48	17.96
86.55	18.54
89.03	18.56
91.57	19.00
94.03	19.26
96.45	19.51
98.71	19.69
100.95	19.94
103.55	20.19
105.63	20.29
107.66	20.71
109.63	20.80
111.51	21.05
113.36	20.94
115.16	21.19
116.92	21.35
118.62	21.50
120.27	21.45
121.88	21.65
123.45	21.77
125.00	21.74
126.52	21.77
128.02	21.88
129.46	22.07
130.86	22.19
132.25	22.30
133.58	22.17
136.28	22.36
138.89	22.50
141.34	22.61
143.57	22.70
145.66	22.61
147.77	23.03
153.66	23.07
156.94	23.17
160.16	23.14
165.21	23.26
166.23	23.46
168.78	23.53
171.38	23.58
174.03	23.69

Table 1 (*Continued*)

T/K	C_p/J K^{-1} mol^{-1}
176.80	23.77
179.55	23.83
182.34	23.67
187.94	23.92
190.76	24.05
193.59	24.07
196.38	24.04
199.17	24.21
204.65	24.27
207.34	24.25
209.94	24.28
212.58	24.43
215.18	24.38
217.77	24.59
220.19	24.53
222.80	24.42
225.62	24.44
228.37	24.54
232.33	24.56
235.06	24.61
237.63	24.61
240.20	24.67
242.69	24.80
245.13	24.74
250.21	24.82
253.35	24.86
256.70	24.89
260.96	25.02
262.89	24.88
266.90	25.06
268.79	25.05
272.60	25.04
277.06	25.06
279.02	25.10
282.61	25.03
285.97	25.04
289.13	25.04
290.72	25.09
292.40	25.08
297.63	25.17
300.76	25.12
303.70	25.15
309.99	25.25
Series III	
326.34	25.38
350.43	25.58
382.84	25.69
407.55	25.92
435.47	25.91
457.71	26.14

Table 1 (*Continued*)

T/K	C_p/J K^{-1} mol^{-1}
487.23	26.13
508.84	26.36
532.42	26.36
556.44	26.66
576.66	26.61
597.04	26.76
618.54	26.74
Series IV	
557.32	26.59
581.98	26.67
606.58	26.85
633.38	26.85
656.26	27.05
666.35	26.95
Series V	
651.97	26.97
680.86	27.11
707.27	27.20
735.56	27.36
765.84	27.30
793.43	27.48
823.13	27.63
851.69	27.83
879.03	27.96
908.47	28.07
936.98	28.26
964.05	28.30
997.01	28.59

Table 2
Molar thermodynamic properties of tantalum ($M_{(\mathrm{Ta})} = 180.9479\,\mathrm{g\,mol^{-1}}$)

T/K	C_p°/J K^{-1} mol^{-1}	S°/J K^{-1} mol^{-1}	$H^\circ(T) - H^\circ(298)$/ J mol^{-1}	$\dfrac{G^\circ(T) - H^\circ(298)}{T}$ J K^{-1} mol^{-1}
80	17.67	11.96	− 5070	75.33
100	19.88	16.14	− 4694	63.08
150	22.95	24.89	− 3610	48.96
200	24.16	31.68	− 2429	43.82
250	24.79	37.14	− 1204	41.96
298.15	25.19	41.54	0.0	41.54
300	25.20	41.70	46.61	41.54
400	25.79	49.03	2598	42.54
500	26.28	54.84	5202	44.44
700	27.18	63.83	10549	48.76
1000	28.46	73.74	18896	54.85

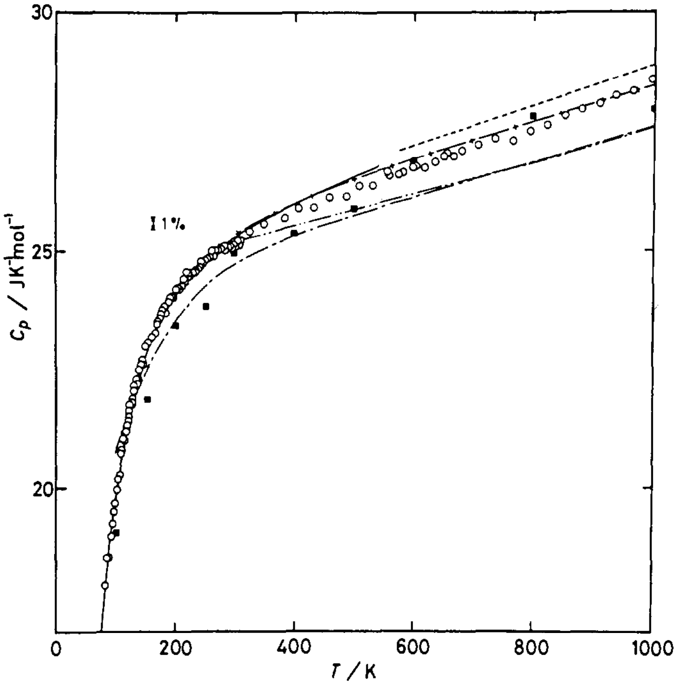

Fig. 1. Molar heat capacity of tantalum; ○, present work; ———, Sterrett and Wallace [3]; — + —, Oetting and Navratil [7]; ----, Magnus and Holzman [1]; —--—, Jaeger and Veenstra [2]; —-—, Taylor and Finch [5]; ■, Lehman [4].

References

[1] A. Magnus and H. Holzman, Ann. Phys., (Leipzig) 5 (1929) 585.
[2] F.M. Jaeger and W.A. Veenstra, Recl. Trav. Chim. Pays-Bas, 53 (1934) 677.
[3] K.F. Sterrett and W.E. Wallace, J. Amer. Chem. Soc., 80 (1958) 3176.
[4] G.W. Lehman, WADD TR 60–581, 1960.
[5] R.E. Taylor and R.A. Finch, USAEC, Report NAA-SR-6034, 1961.
[6] A. Cezairliyan, Nat. Bur. Stand. (U.S.), Report 10326, 1970.
[7] F.L. Oetting and J.D. Navratil, J. Chem. Eng. Data, 17 (1972) 230.
[8] Y. Takahashi, H. Yokokawa, H. Kadokura, Y. Sekine and T. Mukaibo, J. Chem. Thermodyn., 11 (1979) 379.
[9] D.G. Archer, J. Phys. Chem. Ref. Data, 22 (1993) 1441.
[10] Y. Takahashi and E.F. Westrum, Jr., J. Chem. Thermodyn., 2 (1979) 847.
[11] H. Kadokura, H. Yokokawa and Y. Takahashi, Netsusokutei 4 (1977) 52.
[12] N.W. Chase, Jr., C.A. Davies, J.R. Downey, Jr., D.J. Frurip, R.A. McDonald and A.N. Syverud, J. Phys. Chem. Ref. Data, 14, Suppl., 1 (1985) 1811.