Vanadium (V) — CRYSTAL

$A_r = 50.9415$

$S°(298.15\ \text{K}) = 28.936 \pm 0.42\ \text{J·K}^{-1}\text{·mol}^{-1}$
$T_{fus} = 2190 \pm 20\ \text{K}$

$\Delta_f H° = 0\ \text{kJ·mol}^{-1}$
$\Delta_f H°(298.15\ \text{K}) = 0\ \text{kJ·mol}^{-1}$
$\Delta_{fus} H° = 22.84 \pm 6.28\ \text{kJ·mol}^{-1}$

Enthalpy of Formation
Zero by definition.

Heat Capacity and Entropy
The heat capacity values for temperatures below 10 K are those chosen by Hultgren et al.[1]. A graphical integration yields $S°(10\ \text{K}) = 0.0253$ cal·K⁻¹·mol⁻¹ and $H°(10\ \text{K})-H°(0\ \text{K}) = 0.147$ cal·mol⁻¹. The adopted heat capacity values for $10 \leq T \leq 320$ K are obtained graphically, based on the following three works.

Source	Year	T/K	Purity of Vanadium
2	1936	54-297	reported ≥ 99.5%
3	1960	10-274	99.5%; remainder oxygen
4	1961	25-340	99.8%; metallic impurities <0.08%

The low temperature ($T < 50$ K) results of Clusius et al.[3] do not join smoothly with the values adopted for $T < 10$ K. This mismatch is in part due to the oxygen impurity in the vanadium sample used by Clusius et al.[3] In order to effect a smooth joining of the C_{p^v} values, a graphical representation of $C_p(\text{lattice})/T^3$ versus T for the Hultgren et al.[1] data and the Clusius et al.[3] data was used to derive adjusted $C_p°$ values. The three data sets[2-4] are in reasonably good agreement; two sets[2,4] lie predominantly above the adopted values while the remaining set[3] lies below. Above 100 K, the three data sets differ from the adopted $C_p°$ values by roughly 1%, with the difference decreasing as T increases. For the region $320 \leq T \leq 2190$, there are four works upon which the adopted $C_p°$ values are based.

Source	Year	Method	T/K	Purity of Vanadium
5	1965	$C_p°$	320-1800	99.74%
6	1934	drop	565-1928	reported as "purest"
7	1962	drop	488-1486	0.1%C, 0.07, 0.03%N
8	1971	levitation	1989-2284	0.06% total impurities

The heat capacity values reported by Kohlhaas et al.[5] are 1-2% lower than the adopted values below 950 K; 0.3% higher in the region 950-1300 K; and 7% lower above 1600 K. The results of Golutvin and Kozlowskaya[7] show considerable scatter and lie roughly 2-10% above the tabulated enthalpy values. The enthalpy data of Jaeger and Veenstra[6] do not join smoothly with that of Berezin et al.[8]. In the region 1500-2000 K the adopted enthalpy values are a compromise between the latter two sets of data. Below roughly 1100 K the adopted enthalpy and that reported by Jaeger and Veenstra[6] differ at most by ±15 cal·mol⁻¹. From 1300-1800 K the difference increases from 70 cal·mol⁻¹ to 308 cal·mol⁻¹ or from 1.0% to 2.6%. The enthalpy at 2190 K (T_{fus}) is very close to that which is obtained from a linear fit of the Berezin et al.[8] data. Whereas the two sets of data[6,8] separately indicate a $C_p°$ value near T_{fus} to be at least 11 cal·K⁻¹·mol⁻¹, the compromise yields 10.5 cal·K⁻¹·mol⁻¹.

Fusion Data
Refer to the liquid for details.

Transition Data
The literature indicates differences in opinion as to the possibility of a transition in the region 175-325 K and near 1825 K. Although there are no detailed enthalpy measurements in the 1825 K region, Barnes[9] used field-electron emission techniques to show that an allotropic trnsformation does not occur in vanadium in this region if the samples are of high purity. Earlier work concerning a possible transition in this region was referenced by Barnes.[9]

Documentation exists in the literature as to the observation of anomalies in the temperature dependence of some physical properties of vanadium in the range 175-325 K. Although the anomaly was attributed by different workers to an antiferromagnetic transition, a small distortion of the body-centered cubic crystal structure, and impurities, Kinkel' et al.[10] recently ascribed the anomaly to a second order phase transition at 230 K. Using low temperature x-ray diffraction techniques in the study of a single crystal of vanadium, Kinkel' et al.[10] observed a decrease in crystal lattice symmetry form body-centered cubic ($T > 230$ K) to tetragonal ($T < 230$ K). Nevertheless, Crangle and Smith[11] measured the specific heat of polycrystalline vanadium and confirmed the results of Clusius et al.[3] that no appreciable anomaly in $C_p°$ exists in vanadium between 175 and 265 K. We do not adopt a ΔC_p or ΔH value in the two previously mentioned regions.

Vanadium (V) — $V_1(cr)$

Enthalpy Reference Temperature = T_r = 298.15 K   Standard State Pressure = $p°$ = 0.1 MPa

T/K	$C_p°$	$S°$	$-(G°-H°(T_r))/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	$\log K_f$
	(J·K⁻¹·mol⁻¹)			(kJ·mol⁻¹)			
0	0	0	INFINITE	-4.640	0	0	0
100	13.119	7.185	48.695	-4.151	0	0	0
200	21.876	19.558	31.133	-2.315	0	0	0
250	23.703	24.655	29.340	-1.171	0	0	0
298.15	24.896	28.936	28.936	0.	0	0	0
300	24.928	29.090	28.936	0.046	0	0	0
350	25.681	32.992	29.243	1.312	0	0	0
400	26.234	36.459	29.932	2.611	0	0	0
450	26.610	39.571	30.833	3.932	0	0	0
500	26.945	42.392	31.850	5.271	0	0	0
600	27.489	47.353	34.032	7.993	0	0	0
700	28.033	51.630	35.247	10.768	0	0	0
800	28.660	55.413	38.411	13.602	0	0	0
900	29.372	58.830	40.493	16.504	0	0	0
1000	30.083	61.961	42.485	19.476	0	0	0
1100	30.878	64.864	44.389	22.523	0	0	0
1200	31.798	67.590	46.210	25.656	0	0	0
1300	32.740	70.172	47.955	28.882	0	0	0
1400	33.807	72.638	49.630	32.210	0	0	0
1500	34.811	75.004	51.244	35.640	0	0	0
1600	35.857	77.283	52.800	39.173	0	0	0
1700	37.028	79.492	54.306	42.817	0	0	0
1800	38.200	81.641	55.765	46.577	0	0	0
1900	39.539	83.742	57.182	50.464	0	0	0
2000	40.920	85.805	58.562	54.485	0	0	0
2100	42.468	87.837	59.908	58.652	0	0	0
2190.000	44.141	89.653	61.093	62.547	0	0	0
					CRYSTAL <--> LIQUID		
2200	44.329	89.856	61.223	62.991	-22.863	0.104	-0.002
2300	46.254	91.869	62.512	67.520	-22.954	1.151	-0.026
2400	48.179	93.878	63.777	72.242	-22.853	2.198	-0.048
2500	50.103	95.884	65.021	77.156	-22.559	3.236	-0.068
2600	52.028	97.886	66.247	82.263	-22.073	4.259	-0.086
2700	53.932	99.886	67.456	87.561	-21.395	5.259	-0.102

Vanadium (V) $V_1(cr)$

Vanadium (V) **LIQUID** $V_1(l)$

$A_r = 50.9415$ Vanadium (V)

$S^\circ(298.15\ \text{K}) = [36.136]\ \text{J·K}^{-1}\text{·mol}^{-1}$
$T_{fus} = 2190 \pm 20\ \text{K}$

$\Delta_f H^\circ(298.15\ \text{K}) = [17.288]\ \text{kJ·mol}^{-1}$
$\Delta_{fus} H^\circ = 22.84 \pm 6.28\ \text{kJ·mol}^{-1}$

T/K	C_p°	S°	$-(G^\circ-H^\circ(T_r))/T$	$H^\circ-H^\circ(T_r)$	$\Delta_f H^\circ$	$\Delta_f G^\circ$	$\log K_f$
	(J·K⁻¹·mol⁻¹)			(kJ·mol⁻¹)			
0							
100							
200							
250							
298.15	24.896	36.136	36.136	0.	17.288	15.141	-2.653
300	24.928	36.290	36.137	0.046	17.288	15.128	-2.634
350	25.681	40.192	36.443	1.312	17.288	14.768	-2.204
400	26.234	43.659	37.132	2.611	17.288	14.408	-1.881
450	26.610	46.771	38.033	3.932	17.288	14.048	-1.631
500	26.945	49.592	39.050	5.271	17.288	13.688	-1.430
600	27.489	54.553	41.232	7.993	17.288	12.958	-1.129
700	28.033	58.830	43.447	10.768	17.288	12.243	-0.914
800	28.660	62.613	45.611	13.602	17.288	11.528	-0.753
900	29.372	66.030	47.693	16.504	17.288	10.808	-0.627
1000	30.083	69.161	49.685	19.476	17.288	10.088	-0.527
1100	30.878	72.064	51.589	22.523	17.288	9.368	-0.445
1200	31.798	74.790	53.410	25.656	17.288	8.648	-0.376
1300	32.740	77.372	55.155	28.882	17.288	7.928	-0.319
1400	33.807	79.838	56.831	32.210	17.288	7.208	-0.269
1450.000	34.304	81.033	57.645	33.913	17.288		
					GLASS <--> LIQUID TRANSITION		
1450.000	46.204	81.033	57.645	33.913			
1500	46.204	82.599	58.451	36.223	17.871	6.478	-0.226
1600	46.204	85.581	60.054	40.844	18.959	5.682	-0.185
1700	46.204	88.382	61.639	45.464	19.935	4.822	-0.148
1800	46.204	91.023	63.199	50.084	20.795	3.907	-0.113
1900	46.204	93.521	64.729	54.705	21.529	2.948	-0.081
2000	46.204	95.891	66.229	59.325	22.128	1.954	-0.051
2100	46.204	98.146	67.695	63.946	22.582	0.934	-0.023
2190.000	46.204	100.085	68.987	68.104	CRYSTAL <--> LIQUID		
2200	46.204	100.295	69.129	68.566	0.	0.	0.
2300	46.204	102.349	70.529	73.186	0.	0.	0.
2400	46.204	104.315	71.896	77.807	0.	0.	0.
2500	46.204	106.202	73.231	82.427	0.	0.	0.
2600	46.204	108.014	74.534	87.048	0.	0.	0.
2700	46.204	109.757	75.806	91.668	0.	0.	0.
2800	46.204	111.438	77.049	96.288	0.	0.	0.
2900	46.204	113.059	78.263	100.909	0.	0.	0.
3000	46.204	114.626	79.449	105.529	0.	0.	0.
3100	46.204	116.141	80.608	110.150	0.	0.	0.
3200	46.204	117.607	81.742	114.770	0.	0.	0.
3300	46.204	119.029	82.850	119.390	0.	0.	0.
3400	46.204	120.409	83.935	124.011	0.	0.	0.
3500	46.204	121.748	84.996	128.631	0.	0.	0.
3600	46.204	123.049	86.035	133.251	0.	0.	0.
3690.080	46.204	124.191	86.953	137.414	FUGACITY = 1 bar		
3700	46.204	124.315	87.053	137.872	-446.807	1.201	-0.017
3800	46.204	125.548	88.050	142.492	-445.120	13.286	-0.183
3900	46.204	126.748	89.027	147.113	-443.485	25.328	-0.339
4000	46.204	127.918	89.984	151.733	-441.901	37.329	-0.487
4100	46.204	129.058	90.923	156.353	-440.370	49.290	-0.628
4200	46.204	130.172	91.845	160.974	-438.894	61.216	-0.761
4300	46.204	131.259	92.749	165.594	-437.472	73.106	-0.888
4400	46.204	132.321	93.636	170.215	-436.105	84.964	-1.009
4500	46.204	133.360	94.507	174.835	-434.795	96.792	-1.124

Standard State Pressure = p° = 0.1 MPa   Enthalpy Reference Temperature = T_r = 298.15 K   CURRENT June 1973

Enthalpy of Formation

The enthalpy of formation of V(l) at 298.15 K is calculated from that of the crystal by adding $\Delta_{fus} H^\circ$ and the difference in enthalpy $H^\circ(2190)-H^\circ(298.15\ \text{K})$, between the crystal and liquid. Refer to V(g) table for an additional $\Delta_f H^\circ(298.15\ \text{K})$ value as derived from effusion–mass spectrometric work.[10]

Heat Capacity and Entropy

Enthalpy data in the liquid phase have been reported by Treverton and Margrave[1] and Berezin et al.[2] Using levitation calorimetry, Treverton and Margrave[1] determined the enthalpy of V(l) in the range 2205-2638 K. They reported a least squares analysis of the enthalpy data in the form $H^\circ(T)-H^\circ(298.15\ \text{K}) = 11.6527T - 5837.7$ where T is in Kelvins and the enthalpy difference is in cal mol⁻¹ The standard deviation of the experimental points from the calculated values was ± 167 cal mol⁻¹ Berezin et al.[2] also used a form of levitation calorimetry and measured enthalpies in the region 1990-2325 K. For the liquid region their data were represented by $H^\circ(T)-H^\circ(298.15\ \text{K}) = 11.043T - 3776$, with a standard deviation of ±90 cal·mol⁻¹. These two works agree remarkably well for the C_p° value of V(l) In the measured enthalpy region, the Treverton and Margrave data[1] lie lower than the Berezin et al data[2] by roughly 600-700 cal·mol⁻¹ The two linear representations of the data intersect at 3380 K. We adopt the enthalpy values of Berezin et al.[2] since this work contains enthalpy data surrounding the melting point and a T_{fus} value which is our adopted value.

Fusion Data

The adopted value of the enthalpy of fusion, $\Delta_{fus} H^\circ = 5.46 \pm 1.50$ kcal·mol⁻¹ is based on the work by Berezin et al.[2] The actual value is calculated by taking the difference in the adopted value of $H^\circ(2190)-H^\circ(298\ 15\ \text{K})$ for V(l) and V(cr). Refer to the heat capacity discussion in the tables for V(cr) and V(l).

Preliminary results of experiments by Berezin et al.[2] indicated that T_{fus} for 99 96% pure vanadium was close to 2190 K. Representative values of T_{fus} reported in the literature are tabulated below.

Source	Purity of V	T_{fus}, K
3	0.33% O, 0.078% N	2161 ± 10
	0.15% of 7 other impurities	
4	99.8-99.9%	2192 ± 2
5	purity not given	2223
	purified by electron zone fusion	
6	99.8%	2173 ± 25
7	purity not given	2193

We adopt $T_{fus} = 2190 \pm 20$ K principally since it is consistent with the work upon which $\Delta_{fus} H^\circ$ is based. The adopted T_{fus} value is also suggested by Charlesworth[8] in his compilation of elemental melting points.

Vaporization Data

The vaporization of V(l) was studied by Farber and Srivastava.[10] Refer to V(g) table for details. Kant and Lin,[9] using a combination of effusion and mass-spectrometric techniques, reported the ratio of observed ion intensities relating to $V_2(g)$ and V(g) and corresponding to the vaporization of vanadium in the range 2060-2316 K. This ratio is of the order of 10⁻⁶ which suggests that at least in this region the contribution of $V_2(g)$ in the vapor phase may be neglected. Linearly extrapolating these data to T_{vap}, the V_2 partial pressure is of the order of 10³ smaller than the V partial pressure.

T_{vap} is calculated as the temperature at which the Gibbs energy change for the reaction V(l) → V(g) is zero. The difference between $\Delta_f H^\circ$(V, g) and $\Delta_f H^\circ$(V, l) at T_{vap} is $\Delta_{vap} H^\circ$. The uncertainty in T_{vap} is probably of the order of ±50 K.

References

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PREVIOUS: Vanadium (V) $V_1(l)$

Vanadium (V) $A_r = 50.9415$ Vanadium (V) $V_1(cr,l)$

| T/K | Enthalpy Reference Temperature = T_r = 298.15 K | | | | Standard State Pressure = $p°$ = 0.1 MPa | | |
| | J·K⁻¹·mol⁻¹ | | | | kJ·mol⁻¹ | | |
	$C_p°$	$S°$	$-(G°-H°(T_r))/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	log K_f
0	0.	0.	INFINITE	-4.640	0.	0.	0.
100	13.119	7.185	48.695	-4.151	0.	0.	0.
200	21.876	19.258	31.133	-2.315	0.	0.	0.
250	23.703	24.655	29.340	-1.171	0.	0.	0.
298.15	24.896	28.936	28.936	0.	0.	0.	0.
300	24.928	29.090	28.936	0.046	0.	0.	0.
350	25.681	32.992	29.243	1.312	0.	0.	0.
400	26.234	36.459	29.932	2.611	0.	0.	0.
450	26.610	39.571	30.833	3.932	0.	0.	0.
500	26.945	42.392	31.850	5.271	0.	0.	0.
600	27.489	47.353	34.032	7.993	0.	0.	0.
700	28.033	51.630	36.247	10.768	0.	0.	0.
800	28.660	55.413	38.411	13.602	0.	0.	0.
900	29.372	58.830	40.493	16.504	0.	0.	0.
1000	30.083	61.961	42.485	19.476	0.	0.	0.
1100	30.878	64.864	44.389	22.523	0.	0.	0.
1200	31.798	67.590	46.210	25.656	0.	0.	0.
1300	32.740	70.172	47.955	28.882	0.	0.	0.
1400	33.807	72.638	49.630	32.210	0.	0.	0.
1500	34.811	75.004	51.244	35.640	0.	0.	0.
1600	35.857	77.283	52.800	39.173	0.	0.	0.
1700	37.028	79.492	54.306	42.817	0.	0.	0.
1800	38.200	81.641	55.765	46.577	0.	0.	0.
1900	39.539	83.742	57.182	50.464	0.	0.	0.
2000	40.920	85.805	58.562	54.485	0.	0.	0.
2100	42.468	87.837	59.908	58.652	0.	0.	0.
2190.000	44.141	89.653	61.093	62.547	0.	0.	0.
2190.000	46.204	100.085	61.093	85.392	0.	0.	0.
				CRYSTAL <--> LIQUID TRANSITION			
2200	46.204	100.295	61.271	85.854	0.	0.	0.
2300	46.204	102.349	63.012	90.474	0.	0.	0.
2400	46.204	104.315	64.693	95.095	0.	0.	0.
2500	46.204	106.202	66.316	99.715	0.	0.	0.
2600	46.204	108.014	67.885	104.335	0.	0.	0.
2700	46.204	109.757	69.403	108.956	0.	0.	0.
2800	46.204	111.438	70.875	113.576	0.	0.	0.
2900	46.204	113.059	72.302	118.197	0.	0.	0.
3000	46.204	114.626	73.687	122.817	0.	0.	0.
3100	46.204	116.141	75.032	127.437	0.	0.	0.
3200	46.204	117.607	76.339	132.058	0.	0.	0.
3300	46.204	119.029	77.612	136.678	0.	0.	0.
3400	46.204	120.409	78.850	141.299	0.	0.	0.
3500	46.204	121.748	80.057	145.919	0.	0.	0.
3600	46.204	123.049	81.233	150.539	0.	0.	0.
3690.080	46.204	124.191	82.268	154.701	0.	0.	0.
				FUGACITY - 1 bar			
3700	46.204	124.315	82.380	155.160	-446.807	1.201	-0.017
3800	46.204	125.548	83.500	159.780	-445.120	13.286	-0.183
3900	46.204	126.748	84.594	164.401	-443.485	25.328	-0.339
4000	46.204	127.918	85.662	169.021	-441.901	37.329	-0.487
4100	46.204	129.058	86.707	173.641	-440.370	49.291	-0.628
4200	46.204	130.172	87.729	178.262	-438.894	61.216	-0.761
4300	46.204	131.259	88.728	182.882	-437.472	73.106	-0.888
4400	46.204	132.321	89.707	187.503	-436.105	84.964	-1.009
4500	46.204	133.360	90.666	192.123	-434.795	96.792	-1.124

PREVIOUS: CURRENT June 1973

Vanadium (V) $V_1(cr,l)$

CRYSTAL-LIQUID

0 to 2190 K crystal
above 2190 K liquid

Refer to the individual tables for details.

Vanadium (V)

Vanadium (V) IDEAL GAS $A_r = 50.9414$ Vanadium (V) $V_1(g)$

$IP(V, g) = 54360 \pm 16$ cm^{-1}
$S°(298.15 \text{ K}) = 182.30 \pm 0.8$ J·K^{-1}·mol^{-1}

$\Delta_f H°(0 \text{ K}) = 512.2 \pm 8$ kJ·mol^{-1}
$\Delta_f H°(298.15 \text{ K}) = 515.5 \pm 8$ kJ·mol^{-1}

Electronic Levels and Quantum Weights

State	ϵ_i, cm^{-1}	g_i
$^4F_{3/2}$	0	4
$^4F_{5/2}$	137.38	6
$^4F_{7/2}$	323.42	8
$^4F_{9/2}$	553.02	10
.	.	.
$^2H_{11/2}$	5425126	12
IP	54360	

T/K	$C_p°$	$S°$	$-(G°-H°(T_r))/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	log K_f
		J·K^{-1}·mol^{-1}			kJ·mol^{-1}		
0	0.	0.	INFINITE	-7.907	512.201	512.201	INFINITE
100	28.040	151.831	206.684	-5.485	514.134	499.670	-261.001
200	27.960	171.498	184.740	-2.649	515.135	484.747	-126.603
250	26.963	177.633	182.732	-1.275	515.365	477.121	-99.689
298.15	26.012	182.298	182.298	0.	515.469	469.744	-82.297
300	25.978	182.459	182.299	0.048	515.471	469.460	-81.740
350	25.191	186.402	182.612	1.326	515.483	461.790	-68.918
400	24.647	189.727	183.299	2.571	515.430	454.122	-59.302
450	24.330	192.610	184.177	3.795	515.332	446.464	-51.824
500	24.196	195.165	185.150	5.007	515.205	438.819	-45.843
600	24.283	199.579	187.198	7.428	514.905	423.569	-36.875
700	24.582	203.343	189.242	9.871	514.572	408.372	-30.473
800	24.890	206.647	191.215	12.345	514.212	393.225	-25.675
900	25.117	209.592	193.097	14.846	513.811	378.125	-21.946
1000	25.237	212.246	194.881	17.365	513.358	363.073	-18.965
1100	25.262	214.653	196.571	19.890	512.837	348.069	-16.528
1200	25.214	216.849	198.171	22.415	512.227	333.116	-14.500
1300	25.117	218.864	199.686	24.931	511.518	318.218	-12.786
1400	24.994	220.721	201.123	27.437	510.696	303.379	-11.319
1500	24.864	222.441	202.488	29.930	509.758	288.603	-10.050
1600	24.739	224.042	203.785	32.410	508.706	273.893	-8.942
1700	24.630	225.538	205.021	34.878	507.530	259.252	-7.966
1800	24.545	226.943	206.201	37.337	506.229	244.685	-7.101
1900	24.487	228.269	207.327	39.788	504.793	230.193	-6.328
2000	24.460	229.524	208.406	42.235	503.219	215.781	-5.636
2100	24.467	230.717	209.440	44.682	501.498	201.450	-5.011
2200	24.510	231.856	210.434	47.130	476.745	187.310	-4.447
2300	24.588	232.948	211.389	49.585	474.579	174.203	-3.956
2400	24.702	233.996	212.309	52.049	472.423	161.189	-3.508
2500	24.853	235.008	213.197	54.526	470.280	148.265	-3.098
2600	25.040	235.986	214.055	57.021	468.154	135.426	-2.721
2700	25.261	236.935	214.885	59.535	466.048	122.669	-2.373
2800	25.517	237.858	215.689	62.074	463.967	109.990	-2.052
2900	25.806	238.758	216.469	64.640	461.912	97.384	-1.754
3000	26.127	239.639	217.227	67.236	459.888	84.849	-1.477
3100	26.477	240.501	217.963	69.866	457.898	72.380	-1.220
3200	26.855	241.348	218.681	72.533	455.944	59.975	-0.979
3300	27.259	242.180	219.381	75.238	454.029	47.631	-0.754
3400	27.687	243.000	220.063	77.985	452.156	35.344	-0.543
3500	28.136	243.809	220.730	80.776	450.326	23.112	-0.345
3600	28.605	244.608	221.382	83.613	448.543	10.931	-0.159
3690.080	29.042	245.321	221.958	86.210			
3700	29.090	245.399	222.021	86.498	0.	0.	0.
3800	29.591	246.181	222.646	89.432	0.	0.	0.
3900	30.105	246.956	223.260	92.417	0.	0.	0.
4000	30.631	247.725	223.862	95.453	0.	0.	0.
4100	31.166	248.488	224.453	98.543	0.	0.	0.
4200	31.710	249.246	225.034	101.687	0.	0.	0.
4300	32.260	249.998	225.606	104.885	0.	0.	0.
4400	32.817	250.746	226.169	108.139	0.	0.	0.
4500	33.379	251.490	226.723	111.449	0.	0.	0.
4600	33.946	252.230	227.270	114.815	0.	0.	0.
4700	34.517	252.966	227.809	118.238	0.	0.	0.
4800	35.093	253.699	228.341	121.719	0.	0.	0.
4900	35.672	254.428	228.866	125.257	0.	0.	0.
5000	36.255	255.155	229.384	128.853	0.	0.	0.
5100	36.843	255.878	229.896	132.508	0.	0.	0.
5200	37.435	256.600	230.403	136.222	0.	0.	0.
5300	38.031	257.318	230.904	139.995	0.	0.	0.
5400	38.632	258.035	231.400	143.828	0.	0.	0.
5500	39.238	258.749	231.891	147.721	0.	0.	0.
5600	39.849	259.462	232.377	151.675	0.	0.	0.
5700	40.465	260.172	232.858	155.691	0.	0.	0.
5800	41.087	260.881	233.335	159.768	0.	0.	0.
5900	41.712	261.589	233.808	163.908	0.	0.	0.
6000	42.343	262.295	234.277	168.110	0.	0.	0.

Standard State Pressure = $p° = 0.1$ MPa. Between 3700–6000 K: FUGACITY — 1 bar.

PREVIOUS: June 1973 (1 atm)   CURRENT: June 1973 (1 bar)

Enthalpy of Formation

The vapor pressure over vanadium was measured by Edwards et al.[1] using the Knudsen method and by Farber and Srivastava[6] using effusion-mass spectrometric techniques. Our 2nd and 3rd law analysis is tabulated below, where reaction (A) refers to the sublimation V(cr) → V(g) and reaction (B), the vaporization V(l) → V(g).

Source	Reaction	Data Points	T/K	$\Delta_f H°$(298.15 K), kcal·mol^{-1} 2nd law	3rd law	Drift cal·K^{-1}·mol^{-1}
1	A	12+	1666–1882	121.67 ± 0.99	122.95	0.72 ± 0.55
6	A	7	1900–2155	121.60 ± 1.48	123.45	0.91 ± 0.73
6	B	6	2198–2412	113.04 ± 5.34	119.18	2.65 ± 2.30

*A statistical test discounted the 1766 K data point.

We adopt $\Delta_f H°$(298.15 K) = 123.2 kcal·mol^{-1} for V(g). This value, which is identical to $\Delta_{sub} H°$(298.15 K), is a median of the two sublimation studies. Hultgren et al.[2] reported a 3rd law value of 123.089 ± 0.250 kcal·mol^{-1} based on a Knudsen vapor pressure study in the range 1771–1880 K by Saxer.[3] This result is consistent with our adopted value. The results of Kant and Lin[5] indicated that the partial pressure of V_2(g) is negligible in the temperature ranges studied above.

Heat Capacity and Entropy

The electronic energy levels and quantum weights are obtained from Moore.[4] Only a few of the levels are listed above. All levels reported by Moore[4] are considered in the calculation. The heat capacity and entropy values are very similar to those adopted by Hultgren et al.,[2] being identical at 298.15 K and differing by 0.045 cal·K^{-1}·mol^{-1} in $C_p°$ at temperatures up to 3800 K. There are predicted levels which have not been observed and/or classified. It is not expected that $S°$(298.15 K) would be affected by the missing states, but that in the range 3000–6000 K, an error of 0.2–0.3 cal·K^{-1}·mol^{-1} might result.

References

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[4] C. E. Moore, U. S. Nat. Bur. Stand., NSRDS-NBS 35, Volume I, 1970 [Reprint of NBS Circular 467, Volume I, 1949].
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[6] M. Farber and R. D. Srivastava, J. Chem. Soc., Faraday Trans. I 69, 390 (1973).

Vanadium (V) $V_1(g)$

Vanadium, Ion (V+)   **IDEAL GAS** $M_r = 50.94095$ V+(g) Vanadium, Ion (V+)

$IP(V^+, g) = 118200 \pm 200$ cm⁻¹
$S°(298.15\ K) = 183.38 \pm 0.8$ J·K⁻¹·mol⁻¹

$\Delta_f H°(0\ K) = 1162.5 \pm 8$ kJ·mol⁻¹
$\Delta_f H°(298.15\ K) = [1171.947]$ kJ·mol⁻¹

Electronic Levels and Quantum Weights		
State	ϵ, cm⁻¹	g_i
$^5D_0$	0.00	1
$^5D_1$	36.05	3
$^5D_2$	106.83	5
$^5D_3$	208.89	7
$^5D_4$	339.21	9
$^5F_1$	2604.82	3

Enthalpy Reference Temperature = T_r = 298.15 K — Standard State Pressure = $p°$ = 0.1 MPa

T/K	$C°_p$	$S°$	$-(G°-H°(T_r))/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	$\log K_f$
	J·K⁻¹·mol⁻¹	J·K⁻¹·mol⁻¹	J·K⁻¹·mol⁻¹	kJ·mol⁻¹	kJ·mol⁻¹	kJ·mol⁻¹	
0	0.	0.	INFINITE	-7.898	1162.492		
100	28.792	154.942	205.447	-5.051	1165.7		
200	25.153	173.759	185.546	-2.357	1169.7		
250	23.935	179.232	183.761	-1.132	1171.0		
298.15	23.149	183.376	183.376	0	1171.947	1119.646	-196.157
300	23.125	183.519	183.376	0.043	1171.982	1119.321	-194.891
350	22.591	187.041	183.656	1.185	1172.898	1110.471	-165.729
400	22.253	190.033	184.271	2.305	1173.759	1101.494	-143.840
450	22.066	192.642	185.059	3.413	1174.584	1092.411	-126.804
500	22.004	194.963	185.935	4.514	1175.386	1083.238	-113.165
600	22.179	198.985	187.785	6.720	1176.949	1064.661	-92.687
700	22.631	202.435	189.637	8.959	1178.491	1045.824	-78.040
800	23.221	205.495	191.431	11.251	1180.028	1026.767	-67.041
900	23.836	208.266	193.150	13.604	1181.558	1007.517	-58.475
1000	24.400	210.807	194.790	16.016	1183.077	988.098	-51.613
1100	24.872	213.155	196.355	18.481	1184.573	968.527	-45.992
1200	25.238	215.335	197.847	20.987	1186.024	948.822	-41.301
1300	25.502	217.367	199.271	23.523	1187.415	928.998	-37.328
1400	25.677	219.264	200.632	26.085	1188.725	909.070	-33.918
1500	25.782	221.039	201.934	28.658	1189.946	889.052	-30.960
1600	25.834	222.705	203.181	31.239	1191.074	868.955	-28.358
1700	25.850	224.272	204.376	33.824	1192.093	848.791	-26.080
1800	25.846	225.749	205.523	36.409	1192.996	828.570	-24.044
1900	25.834	227.147	206.624	38.993	1193.772	808.302	-22.222
2000	25.823	228.471	207.684	41.575	1194.412	787.997	-20.580
2100	25.821	229.731	208.704	44.157	1194.906	767.663	-19.095
2200	25.833	230.933	209.687	46.740	1172.365	747.415	-17.746
2300	25.864	232.082	210.636	49.325	1172.408	728.098	-16.536
2400	25.915	233.183	211.553	51.914	1172.455	708.779	-15.426
2500	25.988	234.243	212.439	54.509	1172.508	689.458	-14.405
2600	26.084	235.264	213.298	57.112	1172.570	670.135	-13.463
2700	26.201	236.250	214.130	59.726	1172.642	650.809	-12.591
2800	26.339	237.206	214.937	62.353	1172.727	631.480	-11.780
2900	26.497	238.133	215.721	64.994	1172.827	612.148	-11.026
3000	26.672	239.034	216.483	67.653	1172.944	592.813	-10.322
3100	26.864	239.911	217.224	70.329	1173.078	573.473	-9.663
3200	27.070	240.768	217.947	73.026	1173.233	554.128	-9.045
3300	27.288	241.604	218.651	75.744	1173.409	534.779	-8.465
3400	27.516	242.422	219.338	78.484	1173.608	515.423	-7.919
3500	27.752	243.223	220.009	81.247	1173.829	496.062	-7.403
3600	27.993	244.008	220.665	84.034	1174.075	476.693	-6.917
3700	28.239	244.778	221.306	86.846	727.537	458.519	-6.473
3800	28.486	245.535	221.934	89.682	729.518	451.221	-6.202
3900	28.735	246.278	222.549	92.543	731.473	443.872	-5.945
4000	28.981	247.008	223.151	95.429	733.401	436.473	-5.700
4100	29.226	247.727	223.742	98.340	735.300	429.027	-5.466
4200	29.467	248.434	224.321	101.274	737.170	421.534	-5.243
4300	29.702	249.130	224.890	104.233	739.008	413.997	-5.029
4400	29.932	249.816	225.449	107.214	740.815	406.418	-4.825
4500	30.155	250.491	225.998	110.219	742.588	398.798	-4.629
4600	30.372	251.156	226.538	113.245	744.327	391.139	-4.442
4700	30.580	251.812	227.068	116.293	745.030	383.442	-4.261
4800	30.780	252.458	227.591	119.361	747.696	375.710	-4.089
4900	30.972	253.094	228.105	122.449	749.324	367.943	-3.922
5000	31.156	253.722	228.611	125.555	750.913	360.144	-3.762
5100	31.331	254.340	229.109	128.680	752.461	352.313	-3.608
5200	31.498	254.950	229.600	131.821	753.968	344.452	-3.460
5300	31.657	255.552	230.084	134.979	755.431	336.563	-3.317
5400	31.808	256.145	230.561	138.152	756.850	328.646	-3.179
5500	31.952	256.730	231.032	141.340	758.223	320.704	-3.046
5600	32.090	257.307	231.496	144.542	759.550	312.737	-2.917
5700	32.221	257.876	231.954	147.758	760.828	304.746	-2.793
5800	32.347	258.438	232.406	150.986	762.058	296.734	-2.672
5900	32.468	258.992	232.851	154.227	763.238	288.701	-2.556
6000	32.585	259.538	233.292	157.480	764.367	280.649	-2.443

CURRENT: March 1984 (1 bar)

PREVIOUS:

Enthalpy of Formation

$\Delta_f H°(V^+, g, 0\ K)$ is calculated from $\Delta_f H°(V, g, 0\ K)$[1] using the spectroscopic value of IP(V) = 54360 ± 16 cm⁻¹ (650.290 ± 0.19 kJ·mol⁻¹) from Sugar and Corliss.[2] The ionization limit is converted from cm⁻¹ to kJ·mol⁻¹ using the factor, 1 cm⁻¹ = 0.01196266 kJ·mol⁻¹, which is derived from the 1973 CODATA fundamental constants.[3] Rosenstock et al.[4] and Levin and Lias[5] have summarized additional ionization and appearance potential data.

$\Delta_f H°(V^+, g, 298.15\ K)$ is calculated from $\Delta_f H°(V^+, g, 0\ K)$ by using IP(V) with JANAF[1] enthalpies, $H°(0\ K) - H°(298.15\ K)$, for V(g), V⁺(g), and e⁻(ref). $\Delta_f H°(V \rightarrow V^+ + e^-, 298.15\ K)$ differs from a room temperature threshold energy due to inclusion of these enthalpies and to threshold effects discussed by Rosenstock et al.[4] $\Delta_f H°(298.15\ K)$ should be changed by -6.197 kJ·mol⁻¹ if it is to be used in the ion convention that excludes the enthalpy of the electron.

Heat Capacity and Entropy

The information on electronic energy levels and quantum weights, given by Sugar and Corliss,[2] is incomplete because many theoretically predicted levels have not been observed. Although we have listed only the ground, the first excited state, the highest observed excited state, and the ionization potential for V⁺(g), all levels listed by Sugar and Corliss[2] as well as estimated levels, are used in the calculation. The observed levels are too numerous to list completely. The calculations indicate that for V⁺(g), the thermodynamic functions are independent of the estimated missing levels (for n = 4, 5), the cut-off procedure, and the inclusion of n = 5 levels up to 6000 K, the Gibbs energy function showing variations of 0.001 J·K⁻¹·mol⁻¹ at this temperature. The reported uncertainty in S°(298.15 K) is due to uncertainties in the relative ionic mass, and the fundamental constants. Extension of these calculations above 6000 K may require consideration of the higher excited states (n>5), and use of different fill and cut-off procedures.[6]

References

[1] JANAF Thermochemical Tables: V(g), 3-30-73; e⁻(ref), 3-31-82.
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Vanadium, Ion (V⁻)   IDEAL GAS M_r = 50.94205 Vanadium, Ion (V⁻)   V₁⁻(g)

EA(V, g) = 0.525 ± 0.012 eV
$S°$(298.15 K) = 183.436 ± 0.002 J·K⁻¹·mol⁻¹

$\Delta_f H°$(0 K) = 461.547 ± 2.5 kJ·mol⁻¹
$\Delta_f H°$(298.15 K) = [458.588] kJ·mol⁻¹

State	ε, cm⁻¹	g_i
⁵D₀	0	1
⁵D₁	35	3
⁵D₂	105	5
⁵D₃	205	7
⁵D₄	330	9

Electronic Levels and Quantum Weights

T/K	$C°_p$	$S°$	$-[G°-H°(T_r)]/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	$\log K_f$
	(J·K⁻¹·mol⁻¹)			(kJ·mol⁻¹)			
0	0.	0.	INFINITE	-7.878	461.547		
100	28.791	155.101	205.411	-5.031			
200	25.030	173.865	185.596	-2.346			
250	23.821	179.311	183.819	-1.127			
298.15	23.049	183.436	183.436	0.	458.588	418.779	-73.368
300	23.025	183.579	183.436	0.043	458.546	418.532	-72.873
350	22.490	187.083	183.715	1.180	457.378	411.954	-61.481
400	22.119	190.062	184.327	2.294	456.155	405.548	-52.959
450	21.854	192.652	185.111	3.393	454.893	399.298	-46.349
500	21.659	194.943	185.982	4.481	453.603	393.190	-41.076
600	21.399	198.867	187.813	6.633	450.954	381.354	-33.200
700	21.239	202.153	189.633	8.764	448.231	369.969	-27.607
800	21.134	204.982	191.379	10.882	445.437	358.978	-23.439
900	21.061	207.467	193.031	12.992	442.566	348.342	-20.217
1000	21.009	209.683	194.588	15.095	439.619	338.030	-17.657
1100	20.970	211.683	196.052	17.194	436.593	328.017	-15.576
1200	20.941	213.507	197.432	19.290	433.476	318.283	-13.855
1300	20.918	215.182	198.734	21.382	430.264	308.814	-12.408
1400	20.900	216.731	199.965	23.473	426.949	299.595	-11.178
1500	20.885	218.173	201.131	25.562	423.529	290.617	-10.120
1600	20.873	219.520	202.239	27.650	420.006	281.871	-9.202
1700	20.863	220.785	203.293	29.737	416.370	273.348	-8.399
1800	20.855	221.978	204.298	31.823	412.617	265.043	-7.691
1900	20.848	223.105	205.259	33.908	408.737	256.949	-7.064
2000	20.842	224.174	206.178	35.993	404.721	249.064	-6.505
2100	20.836	225.191	207.059	38.076	400.560	241.382	-6.004
2200	20.832	226.160	207.906	40.160	373.362	234.008	-5.556
2300	20.828	227.086	208.720	42.243	368.746	227.777	-5.173
2400	20.825	227.972	209.503	44.325	364.130	221.747	-4.826
2500	20.822	228.822	210.259	46.408	359.513	215.909	-4.511
2600	20.819	229.639	210.989	48.490	354.896	210.256	-4.224
2700	20.816	230.425	211.694	50.572	350.279	204.780	-3.962
2800	20.814	231.182	212.377	52.653	345.662	199.476	-3.721
2900	20.811	231.912	213.038	54.734	341.044	194.337	-3.500
3000	20.811	232.618	213.679	56.816	336.426	189.356	-3.297
3100	20.809	233.300	214.301	58.897	331.808	184.530	-3.109
3200	20.808	233.961	214.905	60.977	327.190	179.853	-2.936
3300	20.806	234.601	215.492	63.058	322.572	175.320	-2.775
3400	20.805	235.222	216.063	65.139	317.953	170.927	-2.626
3500	20.804	235.825	216.620	67.219	313.335	166.670	-2.487
3600	20.803	236.411	217.161	69.300	308.716	162.545	-2.358
3700	20.802	236.981	217.689	71.380	-142.709	159.149	-2.255
3800	20.801	237.536	218.204	73.460	-145.642	167.963	-2.309
3900	20.801	238.076	218.707	75.540	-148.625	176.254	-2.361
4000	20.800	238.603	219.198	77.620	-151.660	184.623	-2.411
4100	20.799	239.116	219.677	79.700	-154.749	193.068	-2.460
4200	20.799	239.617	220.146	81.780	-157.891	201.590	-2.507
4300	20.798	240.107	220.605	83.860	-161.088	210.186	-2.553
4400	20.797	240.585	221.053	85.940	-164.341	218.858	-2.598
4500	20.797	241.052	221.493	88.019	-167.650	227.604	-2.642
4600	20.796	241.509	221.923	90.099	-171.015	236.425	-2.685
4700	20.796	241.957	222.344	92.179	-174.437	245.319	-2.726
4800	20.796	242.395	222.757	94.258	-177.917	254.287	-2.767
4900	20.795	242.823	223.163	96.338	-181.454	263.327	-2.807
5000	20.795	243.243	223.560	98.417	-185.049	272.441	-2.846
5100	20.795	243.655	223.950	100.497	-188.703	281.627	-2.884
5200	20.794	244.059	224.333	102.576	-192.416	290.885	-2.922
5300	20.794	244.455	224.709	104.655	-196.188	300.215	-2.959
5400	20.794	244.844	225.078	106.735	-200.021	309.617	-2.995
5500	20.793	245.225	225.441	108.814	-203.913	319.091	-3.030
5600	20.793	245.600	225.798	110.893	-207.867	328.636	-3.065
5700	20.793	245.968	226.148	112.973	-211.882	338.252	-3.100
5800	20.793	246.330	226.493	115.052	-215.958	347.938	-3.134
5900	20.792	246.685	226.832	117.131	-220.097	357.696	-3.167
6000	20.792	247.035	227.166	119.211	-224.299	367.525	-3.200

Enthalpy Reference Temperature = T_r = 298.15 K   Standard State Pressure = $p°$ = 0.1 MPa

CURRENT: March 1984 (1 bar)

PREVIOUS:

Enthalpy of Formation

$\Delta_f H°$(V⁻, g, 0 K) is calculated from $\Delta_f H°$(V, g 0 K)[1] using the adopted electron affinity of EA(V) = 0.525 ± 0.012 eV (50.654 ± 1.158 kJ·mol⁻¹). This value, recommended by Hotop and Lineberger,[2] is based on a laser photodetachment electron spectrometry study,[3] Additional information on V⁻(g) may be obtained in the critical discussions of Hotop and Lineberger,[2,4] Rosenstock et al.[5] and Massey.[6]

$\Delta_f H°$(V⁻, g, 298.15 K) is obtained from $\Delta_f H°$(V, g, 0 K) by using EA(V) with JANAF[1] enthalpies, $H°$(0 K)−$H°$(298.15 K), for V⁻(g), V(g), and e⁻(ref). $\Delta_f H°$(V⁻ → V + e⁻, 298.15 K) differs from a room–temperature threshold energy due to inclusion of these enthalpies and to threshold effects discussed by Rosenstock et al.[5] $\Delta_f H°$(298.15 K) should be changed by +6.197 kJ·mol⁻¹ if it is to be used in the ion convention that excludes the enthalpy of the electron.

Heat Capacity and Entropy

The ground state electronic configuration for V⁻(g) is given by Hotop and Lineberger,[2,4] Rosenstock et al.,[5] and Massey.[6] The fine structure separation has been calculated by an isoelectronic extrapolation of ratios of fine structure separations[3] and is that recommended by Hotop and Lineberger.[2]

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Continuation of discussions of selected V species

Vanadium

Continued from Page 1918

Sublimation Data
  Refer to the ideal gas table for details.

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W₁(ref)

$A_r = 183.85$ Tungsten (W)

T/K	C°p	S°	-(G°-H°(Tr))/T	H°-H°(Tr)	ΔfH°	ΔfG°	log Kf
		J·K⁻¹·mol⁻¹		kJ·mol⁻¹			
0	0.	0.	INFINITE	-4.973	0.	0.	0.
100	16.033	9.612	52.820	-4.321	0.	0.	0.
200	22.489	23.273	34.839	-2.313	0.	0.	0.
250	23.686	28.431	33.056	-1.156	0.	0.	0.
298.15	24.295	32.660	32.660	0.	0.	0.	0.
300	24.313	32.810	32.660	0.045	0.	0.	0.
350	24.644	36.583	32.957	1.269	0.	0.	0.
400	24.928	39.893	33.622	2.509	0.	0.	0.
450	25.144	42.842	34.485	3.760	0.	0.	0.
500	25.339	45.502	35.456	5.023	0.	0.	0.
600	25.790	50.163	37.529	7.580	0.	0.	0.
700	26.229	54.172	39.627	10.181	0.	0.	0.
800	26.669	57.703	41.670	12.826	0.	0.	0.
900	27.112	60.870	43.631	15.515	0.	0.	0.
1000	27.564	63.750	45.501	18.249	0.	0.	0.
1100	28.017	66.398	47.282	21.028	0.	0.	0.
1200	28.472	68.855	48.978	23.852	0.	0.	0.
1300	28.930	71.152	50.596	26.722	0.	0.	0.
1400	29.393	73.313	52.143	29.639	0.	0.	0.
1500	29.862	75.357	53.623	32.601	0.	0.	0.
1600	30.334	77.299	55.042	35.611	0.	0.	0.
1700	30.807	79.152	56.407	38.668	0.	0.	0.
1800	31.284	80.927	57.720	41.773	0.	0.	0.
1900	31.765	82.631	58.986	44.925	0.	0.	0.
2000	32.254	84.273	60.210	48.126	0.	0.	0.
2100	32.744	85.858	61.394	51.376	0.	0.	0.
2200	33.238	87.393	62.541	54.675	0.	0.	0.
2300	33.736	88.881	63.654	58.024	0.	0.	0.
2400	34.233	90.328	64.735	61.422	0.	0.	0.
2500	34.736	91.735	65.787	64.870	0.	0.	0.
2600	35.246	93.106	66.812	68.366	0.	0.	0.
2700	36.192	94.453	67.811	71.935	0.	0.	0.
2800	37.447	95.791	68.786	75.613	0.	0.	0.
2900	39.120	97.133	69.740	79.440	0.	0.	0.
3000	41.003	98.490	70.676	83.442	0.	0.	0.
3100	43.430	99.873	71.595	87.662	0.	0.	0.
3200	46.024	101.292	72.501	92.132	0.	0.	0.
3300	48.953	102.752	73.396	96.877	0.	0.	0.
3400	52.300	104.261	74.281	101.933	0.	0.	0.
3500	56.484	105.835	75.160	107.363	0.	0.	0.
3600	61.714	107.499	76.035	113.270	0.	0.	0.
3680.000	66.149	108.904	76.734	118.383	0.	0.	0.
				CRYSTAL <--> LIQUID TRANSITION			
3680.000	35.564	118.522	76.734	153.780	0.	0.	0.
3700	35.564	118.715	76.961	154.491	0.	0.	0.
3800	35.564	119.663	78.072	158.048	0.	0.	0.
3900	35.564	120.587	79.150	161.604	0.	0.	0.
4000	35.564	121.488	80.197	165.161	0.	0.	0.
4100	35.564	122.366	81.215	168.717	0.	0.	0.
4200	35.564	123.223	82.205	172.273	0.	0.	0.
4300	35.564	124.060	83.169	175.830	0.	0.	0.
4400	35.564	124.877	84.108	179.386	0.	0.	0.
4500	35.564	125.676	85.023	182.943	0.	0.	0.
4600	35.564	126.458	85.915	186.499	0.	0.	0.
4700	35.564	127.223	86.786	190.055	0.	0.	0.
4800	35.564	127.972	87.636	193.612	0.	0.	0.
4900	35.564	128.705	88.467	197.168	0.	0.	0.
5000	35.564	129.423	89.279	200.725	0.	0.	0.
5100	35.564	130.128	90.073	204.281	0.	0.	0.
5200	35.564	130.818	90.850	207.837	0.	0.	0.
5300	35.564	131.496	91.610	211.394	0.	0.	0.
5400	35.564	132.161	92.355	214.950	0.	0.	0.
5500	35.564	132.813	93.085	218.507	0.	0.	0.
5600	35.564	133.454	93.800	222.063	0.	0.	0.
5700	35.564	134.083	94.501	225.619	0.	0.	0.
5800	35.564	134.702	95.189	229.176	0.	0.	0.
5900	35.564	135.310	95.864	232.732	0.	0.	0.
6000	35.564	135.908	96.526	236.289	0.	0.	0.

Enthalpy Reference Temperature = T_r = 298.15 K   Standard State Pressure = $p°$ = 0.1 MPa

W₁(ref)

Tungsten (W)

REFERENCE STATE

0 to 3680 K crystal
3680 to 6000 K liquid

Refer to the individual tables for details.

T_{mp}(1 bar) ~ 5924 K
(not included in the reference state)

Tungsten (W)