E
Titanium

L	Enthalpy Reference		Temperature =	. T. = 298.15 K		Standard S	Standard State Pressure = p	p* = 0.1 MPa
	ΤÆ	្រ		-H'(T,)]T	H*-H*(T,)	Α.H.	Φ.	log Kr
	0	o		INFINITE	-4.830	ó	Ö	oʻ
	<u>8</u> 8	14.334	8261 21.227	50.955 32.989	-4269 -2352	ರ ರ	<b>ರ</b> ರ	ರ ರ
-	298.15	25.238	30.759	30.759	ö	Ö	ď	ó
	88	25.276	30.915	30.760 31.772	2,660	ರ ರ	ರರ:	ರ ರ ರ
	8 8	78.13	44554	15,733	8.726	o c	o	၁ င
	88	29.135	<b>24.134</b>	38.257	11.114	io	ide	်ဝင်
	88	30.454	61.561	4 603 694	17.030	dd	်ဝင်	်ဝင်
	1100	34334	900:89	46.673	23.466	ó	ó	o'
	1166.000	36.175 29.245	70.058	47.938 47.938	25.791	AL AL	PHA <> BETA TRANSITION	
	1200	29.459	74.479	48.679	30.961	6	ö	
	86	30.15	79.131	52.702 52.702	33.941	တ် တုံ	တ်တံ	ာ် ဝ
	8 5	3115	83.404	56.776	43.405	jc	o c	<b>5</b> C
	2	34,359	85.448	57.932	46.778	ö	600	် ဝ
	88	37.74	89.422	61.039	\$3.929 \$3.929	ာ်ဝ	ಶಕ	
	1939,000	37.868	90.186	61.617	55.394	BETA	A <> LIQUID	
	2000	41237	98.944	62.734	72.421	ó	ď	0
	2100	47.237	101.249	64513	77.145	ďc	o'c	o c
	250	41237	105.546	67.897	86.592	öc	öc	6
	28	41737	109.485	11,069	96.040	ó	id	်ဝံ
	700 7100 7100	41331	111.338	74.051	100.764	o o	ರ ರ	ರ ರ
	2800 2800 2800	4137	116.496	75.477	110.211	o o	ರ ರ	00
	900	41237	118.097	78.211	119.659	o o	o o	o o
	888		121.146	00808	129.106	jo	ರರ	do
	3,50	100	124.010	83259	138.554	o o o	ddc	d o c
	3600	4	126.710	85.598	148.001	6	ď	
	3630.956 3630.956	40	127.114 240.028	85.951 85.951	149.463 559.447	aroun —	ID <> IDEAL GAS FUGACITY = 1 bar	GAS
	3800	34.613	240.676	88.832 92.840	561.823	o' o	o' o	ರರ
	3900 4000	35.721 36.254	243.439	96.667 100.324	568.857 572.456	o o	ರ ರ	ರರ
	4100	36.772	244.340	103.826	576.108	o	o'c	Ö
	<b>4 6 6</b>	37.757	246.115	110.403	583.562	90	o o	<b>.</b>
	4 8 8 8 8	38.670	246.988 247.852	113.497	587.361 591.206	ರ ರ	o	ರ ರ
	94 960 960	39.097	249.552	119.339	595.094 599.025	00	ರರ	ರ ರ
	4800 4900	39.892	250.388	124.764	602.995	o c	o' c	င် င
	2000	40.606	252.031	129,822	611.046	ď	i o	o i
	888	41.78	255.204	138,993	627.537	000	ರರ	ರರ
	888	42.686 43.029	2822 2822 2967	143.171 147.113 150.841	644.413 653.015	ಶರರ	ಶರರ	ರಿರರ
	010000		1				1	Contract the 1000 to the
	PREVIOUS: June 1979 (1 alm)	June 1717	(I aun)				CUMMAN	2 2 2 2 2

Refer to the individual tables for details

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Δ<sub>t</sub>H\*(0 K) = 0 kJ·mol<sup>-1</sup> Enthalpy Reference Δ<sub>t</sub>H\*(298.15 K) = 0 kJ·mx  $\Delta_{\rm us}H^{\circ} = 0.997 \pm 0.03 \, \text{kJ·m}$ 

and Ho agree with the experimental data of Wolcott' and of Aven et al.\* The maximum difference in the calculated values for \$7(5 K) 0.00071 cal·K<sup>-1</sup>-mol<sup>-1</sup>, with the adopted value being \$7(5 K) = 0.0049 cal·K<sup>-1</sup>-mol<sup>-1</sup>. Similarly for \$C\_p^2(5 K)\$ the maximum difference 0.000211 cal·K<sup>-1</sup>-mol<sup>-1</sup>, with the adopted value being \$C\_p^2(5 K) = 0.00049 cal·K<sup>-1</sup>-mol<sup>-1</sup>. In the region above 5 K and below 360 K, there are seven heat capacity studies. <sup>2,2,2,2,14</sup> The adopted values were based on the work Bieganski, Scott, \* Backhurst and Cezairliyan and Miiller. \* The mathematical and graphical treatment of these four studies yields a continu In the other studies, an equation (with two constants) was given to describe the entire set of experimental data. The constants given by Colli The adopted thermal functions for  $\alpha$ -Ti( $\alpha$ ) are derived from the studies of Collings and Ho,¹ Clusius and Franzosini,² Stalinski and smooth heat capacity curve.

There are ten studies 17-15 on the heat capacity of titanium in the range 1-5 K. Wolcott and Aven et al 4 reported the experimental.

There are ten studies 17-15 on the heat capacity of titanium in the range 1-5 K. Wolcott and Aven et al 4 reported the experimental. Heat Capacity and Entropy Enthalpy of Formation  $\Gamma_{\rm tr} = 1166 \pm 10 \, \text{K} \, (\alpha - B)$ Zero by definition

Clusius and Franzosini² and Stalinski and Bieganski.³ The maximum deviation of all studies from the adopted is 2.5% over this temperat range.

Above 300 K, there are eleven heat capacity studies<sup>4-6,14-25</sup> and seven enthalpy studies.<sup>26-33</sup> The heat capacity studies all have a sim temperature dependence in comparison with the adopted values. However, the studies of Holland, "9 Affortit, <sup>15</sup> Arutyunov, "4 and Rumyant et al. "2 lie roughly 9-33% higher than the adopted values. There is much scatter in all studies within 50 K of the α-β transition temperature. The adopted values were based on Scott, Backhurst, and Cezairliyan and Miller. The enthalpy studies show a large scatter within each str as well as a general lack of agreement between the studies.

#### Transition Data

Refer to the \(\theta\)-crystal table for details.

#### Sublimation Data

There are no sublimation studies involving α-Ti(cr). The enthalpy of sublimation is calculated as the difference between the enthalpy formation of the monatomic gas and the enthalpy of formation of  $\alpha$ -Ti( $\alpha$ )

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77K G 0 0 100 14334 220 22.547 220 24.074 230 25.276 330 25.276 340 26.187 350 26.187 350 26.187 350 26.187 350 26.137 350 26.	lou l-lou	Enthalpy R	eference T	emperature	Enthalpy Reference Temperature = $T_r = 298.15 \text{ K}$ 1.K <sup>-1</sup> mol <sup>-1</sup>		Standard State Pressure = p = 0.1 MP2	e Pressure = p	" = 0.1 MP2
10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	- lou	7/K	೮		-H'(T,)]T	H*-H*(T,)	Δ'H.	Φ.	log Kr
298.15 25.238 30.739 0.730 0.007 0.0 0.0 300 25.276 34.915 30.739 0.007 0.0 0.0 300 25.276 34.915 31.071 1.334 0.0 400 26.82 38.423 31.071 1.334 0.0 500 26.82 38.423 31.071 1.334 0.0 500 28.356 46.83 31.073 2.660 0.0 500 28.356 46.83 31.073 1.008 0.0 500 28.356 46.83 31.073 1.009 0.0 500 28.472 86.03 31.073 1.009 0.0 500 28.472 86.03 1.009 0.0 500 28.472 86.03 1.009 0.0 500 28.472 86.03 1.009 0.0 500 32.473 1.009 46.03 1.009 0.0 500 32.473 1.009 46.03 1.009 0.0 500 32.473 1.009 46.03 1.009 0.0 500 32.473 1.009 46.03 1.009 0.0 500 32.473 1.009 46.03 1.009 0.0 500 32.472 86.03 6.03 1.009 1.009 1.009 500 32.224 8.0560 54.030 1.009 1.009 500 55.220 8.043 55.800 45.189 1.784 0.762 500 55.220 8.043 55.800 45.189 1.784 0.762 500 55.220 8.043 55.800 45.189 0.762 500 500 500 500 500 500 500 500 500 500		200 E	0. 14.334 22.367 24.074	0. 8.261 21.227 26.414	INFINITE 50.955 32.989 31.160	-4.830 -4.269 -2.352	ರ <b>ೆ</b> ರೆರ	000	000
350 25.276 30.915 31.076 0.047 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.		298.15	25.238	30.759	30.759	0,	ာ်ဝံ	ော်ဇံ	ರ ರ
400 26.863 34.43 31.772 26.60 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	and	38 88	25.276 26.169	30.915 34.882	30.760	0.047	00	ဝင	600
600 28.5% 45.63 35.773 35.41 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	, i	\$ <b>\$</b> \$	26.862 27.418	25.42 25.620 25.620	31.772 32.692	2.660	00	600	
800 28-413 54-134 38.257 11.114 0 0 0. 800 28-472 58.039 40.450 14.039 0 0. 1000 30.444 61.561 42.659 17.039 0 0. 1100 34.34 68.006 44.697 20.151 0. 0. 1100 34.34 68.006 44.697 20.151 0. 0. 1100 37.33 71.113 48.350 25.791 ALPHA <> BETA 1300 37.213 71.113 48.350 25.791 ALPHA <> BETA 14.00 47.71 70.038 47.938 25.791 ALPHA <> BETA 1500 37.731 71.113 48.350 25.791 ALPHA <> BETA 1500 37.731 71.13 48.350 25.791 ALPHA <> BETA 1500 37.731 71.13 48.350 25.791 ALPHA <> BETA 1500 37.731 71.13 48.350 25.791 ALPHA <> BETA 1500 49.98 77.399 52.245 35.214 -1.786 06.40 0. 1500 55.220 84.043 55.800 45.189 1.784 0.762 1.700 61.314 87.570 57.564 51.010 44.232 0.625	ings	8	28.596	49.683	35.973	8.226	င် င	ာ် စံ	ာ် စံ
900 30,454 61,561 42,659 17,030 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	K) is	88	29.135	54.134 58.039	38.257 40.490	11.114	o' c	o' c	o c
1100   34,334   68,006   46,673   23,466   0   0   0   0   0   0   0   0   0	S IS	88	30.454 32.074	61.561 64.848	42.639 44.697	20.151	i d c	öc	ioc
1166.000 36,173 70.038 47,938 25,791 ALPHA <> BETA 1200 37,233 71,1113 48,539 27,039 -3,392 0,1118 1300 45,748 77,259 57,245 35,214 -1,787 0,420 1500 55,220 84,043 55,800 75,944 -3,007 0,420 1500 55,220 84,043 55,800 45,189 1,784 0,762 1700 61,314 87,570 57,564 51,010 4,232 0,625 1700 61,314 87,570 57,564 51,010 4,232 0,625	rk of	0011	34.334	68.006	46.673	23.466	Ö	်ဝံ	်ဝံ
1300 97.23 71.113 48.550 77.039 -13922 0.118 1300 44.948 77.239 50.433 30.934 -1.007 0.420 1500 44.948 77.239 52.245 33.214 -1.786 0.640 1500 67.20 84.043 55.800 45.189 1.784 0.762 1700 61.314 87.570 57.564 51.010 4.232 0.625	ature	1166.000	36.175	70.058	47.938	25.791	ALPH.		
1400 44.948 77.359 52.245 33.214 -1.786 0.640 1500 57.240 84.043 57.800 37.945 -0.205 0.750 1600 57.270 84.043 57.800 47.189 0.762 1700 61.314 87.570 57.564 51.010 4.232 0.625	-	1300	40.713	74.228	48.580 50.433	27.039 30.934	-3.922	0.118	-0.005
1600 55.220 84043 55 800 45 189 1.784 0.0525 1700 61.314 87.570 57.354 51.010 4.232 0.625	tsev	<u>5</u> 5	44.948 49.764	71.399 80.660	52,245	35.214	-1.786	0.640	-0.024
	ture.	0021 0021	55.220	84.043	55 800	45 189	1.784	0.762	-0.025
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		PREVIOUS: September 1966	eptember 1	996				CURREN	CURRENT: June 1979

Titanium, Alpha (α-Ti)

Ti<sub>1</sub>(cr)

 $S'(298.15 \text{ K}) = 30.759 \pm 0.2 \text{ J·K·mol}^{-1}$ 

Titanium, Alpha (α-Ti)

Titanium, Beta (β–Τί) S'(298.15 K) = 138.1221 J·K <sup>-1</sup> ·mol <sup>-1</sup>	CRYSTAL(B)	4L(B)	$A_r = 47.88$ Titanium, Beta ( $\beta$ -Ti) $\Delta H^{9/298.15 \text{ K}} = (6.860) \text{ k1-mol}^{-1}$ Enthalin Reference Temper	litanium, Enthalov Re	Beta (β-	-TI)	tanium, Beta (B-Ti) Entalor Reference Temperature = T. = 298.15 K		Ti,(CI	Presume	Ti <sub>1</sub> (cr)
			$\Delta_{cu}H^{\circ} = 4.172 \pm 0.13 \text{ kJ·mol}^{-1}$ $\Delta_{tu}H^{\circ} = 14.146 \pm 5.0 \text{ kJ·mol}^{-1}$	T.K	ย	J·K <sup>-1</sup> mol <sup>-1</sup> S*[G*-	mol-1 -[G*-H*(T;)]/T	H*-H*(T,)		<b>₽</b> @	log K <sub>r</sub>
Enthalpy of Formation The enthalpy of formation is calculated from that of $H^{\circ}(298.15~\mathrm{K})$ , between the $\alpha$ -crystal and the $\beta$ -crystal.	f the α-crystal by addii	tion of $\Delta_{ m tr} H^st$ and the	nthalpy of Formation  The enthalpy of formation is calculated from that of the $\alpha$ -crystal by addition of $\Delta_{\omega}H^{\circ}$ and the difference in enthalpy, $H^{\circ}(1166  \text{K})$ - (298.15 K), between the $\alpha$ -crystal and the $\beta$ -crystal.	200 250 250 250 250 250	33.884	2. 5.	£132	c	98	***	-
capacity studies ar ated in a manner s	at Capacity and Entropy For the B-crystal there are ten heat capacity studies and six enthalpy studies. The discussion on he le also applies to the B-Ti(cr). The entropy at 298.15 K is calculated in a manner similar to that for the enthalpy of formation.	The discussion on he uthalpy of formation.	eat Capacity and Entropy For the β-crystal there are ten heat capacity studies and six enthalpy studies. The discussion on heat capacity and enthalpy on the α-Τί(cr) ble also applies to the β-Τί(cr). The entropy at 298.15 K is calculated in a manner similar to that for the enthalpy of formation.	88888	24,006 24,309 24,511 24,914 25,216	38.271 41.994 45.260 48.176 50.816	38.123 38.416 39.071 40.883	2.0044 1.252 2.475 3.713 4.967	6.858 6.675 6.675 6.856	4622 4290 3.941 3.285	-0.810 -0.640 -0.515 -0.343
ists in two crystal high temperature	Phase Data Titaniun, at ambient pressures, exists in two crystal modifications. The low temperature (A3) structure isotypic with Mg. The high temperature form, B-Ti, is body centered cubic,	temperature form, on a force (	hase Data Titanium, at ambient pressures, exists in two crystal modifications. The low temperature form, α-IT, is hexagonal close packed, an hep 3) structure isotypic with Mg. The high temperature form, β-IT, is body centered cubic, a bcc (A2) structure isotypic with W.	888888	25.221 26.426 27.031 28.241 28.846	55.463 63.061 69.223 69.223	42.937 45.020 47.057 49.017 50.892 52.684	7.519 10.131 12.804 15.537 18.331	5.153 5.877 5.368 5.040 4.580	2.682 2.126 1.607 0.665	-0.159 -0.165 -0.065 -0.035
tues of transition to value of $\Delta_{\rm tr} H^{\circ}$ is	<b>Transition Data</b> The following table indicates the values of transition temperatures and enthalpies of transit of $T_{\rm tr}$ adoped is 1166 $\pm$ 10 K, and the value of $\Delta_{\rm tr}H^{\circ}$ is selected as 0.997 $\pm$ 0.03 kcal·mol <sup>-</sup>	oies of transition reposition reposition (based)	ransition Data  The following table indicates the values of transition temperatures and enthalpies of transition reported by various investigators. The value $T_{\rm ra}$ adoped is 1166 $\pm$ 10 K, and the value of $\Delta_{\rm ob}H^{\circ}$ is selected as 0.997 $\pm$ 0.03 kcal·mol <sup>-1</sup> , based on the work of Cezairliyan and Miller.	1166.000 1200 1300 1400	29.245 29.459 30.175 31.023	73.636 74.479 76.864 79.131	53.822 54.396 56.033 57.603	23.102 24.100 27.081 30.140	ALPHA 0. 0.	ţ	I,
T <sub>to</sub> /K	Δ <sub>w</sub> H°, kcal·mol <sup>-1</sup>	Purity, %	Method	8 99	33.115	83.404	59.111	33.290	ဝ ဝ	ဝံ ဝံ	ဝဝ
1158 ± 10		Iodide 99.0	electrical resistance	888	35.736 37.244	83.45 83.451 83.452	61.388 63.328 64.650	39.917 43.421 47.069	ರರರ	ರರರ	ರರರ
1155.7 ± 1	0.67	99.93	hydrogen solubility	1939,000	37.868	90.186	65.155	48.533	BETA	-	
1158 ± 2		99.93	thermoelectric power	2002	38.885	91.374	65.937	50.874	-14.687	0.454	-0.012
1155 ± 4	,	Iodide	cooling curve	2500 7700 7700 7700 7700 7700 7700 7700	42.562	95.248	67.195 68.426	59.010 59.010	-15.998	2037	-0.048
1154	0.943	95.56 56.56	drop calorimetry	2300	44.599	27.185	69.634	63.367	-16365	2866	-0.065
1158	0.814	73.80 1	rate of heating	2500	49.069	101.084	71.994	27.27	-16.455	4549	-0.095

# The following table indicates the values of transition temperatures and enthalpies of transition reported by various investigators. The value of $T_{\rm tr}$ adopted is 1166 $\pm$ 10 K, and the value of $\Delta_{\rm tr} H^0$ is selected as 0.997 $\pm$ 0.03 kcal·mol<sup>-1</sup>, based on the work of Cezairilyan and Miller.<sup>1</sup>

Source	$T_{\rm tr}/K$	Δ <sub>us</sub> H°, kcal·mol <sup>-1</sup>	Purity, %	Method
Fast <sup>2</sup>	1158 ± 10		Iodide	electrical resistance
Greiner and Ellis <sup>3</sup>	$1158 \pm 2$		666	electrical resitance
McQuillan*	1155.7 ± 1	29.0	99.93	hydrogen solubility
Worner	$1158 \pm 2$		99.93	thermoelectric power
Duwez	1155 ± 4		Iodide	cooling curve
Kothen,	1154	0.943	93.96	drop calorimetry
Edwards et al.	$1157 \pm 3.5$		88.66	cooling curve
Schofield	1158	0.814	1	rate of heating
Scott 10	$1156 \pm 2$	$0.978 \pm 0.025$	Iodide	adiabatic calorimetry
Backhurst11	1165-1179	0.88	Commercial	adiabatic calorimetry
Golutvin <sup>12</sup>	1155	$0.82 \pm .020$	Iodide	drop calorimetry
Kohlhaas et al. 13	1167	0.992	8766	adiabatic calorimetry
Gel'd and Putintsev <sup>14</sup>		0.998		
Martynyuk and Tsapkov15		1.028	99.74	pulsed heating
Harmelin and Lehr16		1.007		DTA
Etchessaltar and Debuique <sup>17</sup>	1154			dilatometric
Cezzirliyan and Miller	1166	0.997	45.66	electrical resistance

Fusion Data
Refer to the liquid table for details.

Sublimation Data

There are three sublimation studies involving  $\beta$ -Ti(cr). They are summarized on the ideal gas table. The enthalpy of sublimation for  $\beta$ -Ti(cr) is calculated as the difference in the enthalpies of formation at 298.15 K of Ti(g) and  $\beta$ -Ti(cr).

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# Continued on page 1915

Titanium, Beta (β-Ti)

PREVIOUS: September 1966

Ti,(cr)

CURRENT: June 1979

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Duwez, J. Metals 3, Trans. Annua, 100 Metals 3, Trans. Annua, 100 State University, Thesis, (1952).
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 W. Edwards, H. L. Johnston and W. E. Ditmars, J. Am. Chem. Soc. 75, 2467 (1953).

<sup>&</sup>lt;sup>1</sup>J. L. Scott, AEC Rept. ORNL—2328, (1957).

CURRENT: June 1979

A, = 47.88 Titanium (Ti)

LIQUID

F<sub>bs</sub> = 1936 ± 10 K

 $S^{\circ}(298.15 \text{ K}) = [39.181] \text{ J·K}^{-1} \cdot \text{mol}^{-1}$ 

Titanium (Ti)

Enthalpy of Formation

The enthalpy of formation is calculated from that of the  $\beta$ -crystal by addition of  $\Delta_{lm}H^{\circ}$  and the difference in enthalpy,  $H^{\circ}(1936 \, \mathrm{K})$ H°(198.15 K), between the β-crystal and the liquid.

Heat Capacity and Entropy There are two entialpy studies¹² covering the liquid region of titanium. The work of Treverton and Margrave¹ was adopted. A glax transition is assumed at 1300 K below which extrapolated β-Τi heat capacity values are used. The entropy is calculated in a manner simili

# to that used for the enthalpy of formation.

The investigators reporting melting temperatures and heats of melting are listed below. The value of  $T_{in}$  adopted is 1939  $\pm$  10 K, and th value of  $\Delta_{in}H^{\circ}$  is selected as 3.381  $\pm$  0.03 kcal·mol<sup>-1</sup>, based on the work of Berezin et al. <sup>2.13</sup> Fusion Data

Source	$T_{\rm fu}/{ m K}$	Δ <sub>fu</sub> H° kcal·mol <sup>-1</sup>
3urgess and Waltenburg3	2068	
Fast*	1993	
Adenstedt et al.5	1973	
Hansen et al.	1993	
Maykuth et al.7	1953	
Schoffeld and Bacon*	1933	
Oriani and Jones	1945	
Deardorff and Hayes <sup>10</sup>	1941	
Westrum and Feick"	1933	
Elyutin et al. 12	1941	4.1 ± 0.1
reverton and Margrave	1943	$3.161 \pm 0.12$
Berezin et al. 13	1939	3 381 + 0 115

#### Vaporization Data

The two vaporization studies are summarzed on the ideal gas table. The boiling point is calculated as that temperature for which  $\Delta G^*$  (for Ti(I) = Ti(g).  $\Delta_{vap}H^o$  is the corresponding enthalpy change.  $T_{vap}$  is the temperature at which fugacity is one bar. The normal boiling poin (p=1 bar) would be a slightly lower temperature.

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1=1-11 1-11 1-12 5 11 - (A 51 800% A A									-
$\Delta_{tra}H^{\circ} = 14.146 \pm 5.0 \text{ kJ·mol}^{-1}$	d formula	כובובוועב ו	J·K-'mol-'.	Linitally Activities temperature = Ir = 298,15 K	·	Standard State Pressure = $p^* = 0.1 \text{ MPa}$ k1.mol <sup>-1</sup>	Pressure = p	= 0.1 MPa	_
	rΆ	ប	.S{G.	-[G*-H*(T,)]/T	$H^{\bullet}-H^{\circ}(T_{i})$		δ.	log Kr	
difference in enthalpy, H°(1936 K)-	2885 <sub>0</sub>								
and Margrave <sup>1</sup> was adopted. A glass	300	27.638 27.639	39.181	39.181	0.051	13.652	11.141	-1.952	
ropy is calculated in a manner similar	¥ <b>\$</b> \$	27.667 27.694 27.77	43.614	39.518 40.266	1.434 2.818	13.752	10.696	1.39	
	800	27.750	53.496	42316	258	13.842	9,363	-0.978	
$\Gamma_{f_{1s}}$ adopted is 1939 $\pm$ 10 K, and the	888	27.805 27.860	58.560 62.851	44.614 46.921	8.368 11.151	13.794	8 468 7.587	-0.737 -0.566	
	888	28.104	69.871 72.847	51.272 51.272 53.283	16.739 16.739	13.552 13.361 13.065	6.725 5.882 5.066	-0.439 -0.341	
	1200	28.875	75.576	55.188 56.993	22.428	12.614	4.286 3.674	0.204	
	88	30.175	80.498 82.765	58.711 60.348	28.324 31.383	8.035 8.035	3311	-0.133	
	1460.000	31.595	84.078 84.078	61.297 61.297	33.261	Ġ.	S <> LIQUID	,	
	1200	47.237	85.355	61.921	35.150	8.652	2.576	-0.090	
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	006 006 006 006	47.237	93.967 96.521	66.566 68.076	49.321 54.045	12.693	0.962	0.028	
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	2000	47.237	98.944	69.560	58.769	o	0		
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is one bar. The normal boiling point	2700 2800	41237	113 120	79.107	91 835	်ဝင်	်ဝင်	ာ်ဝင	
;	200 3000 3000	41237 41237	116.496	81.571 82.762	101.283	ಪ್ರದ	de	ioc	
	3200	47.237	119.646	83.927	110.730	00	00	; oʻ	
nn 6th 363 (1073)	3300	47 237	122.600	86.182	120.178	್ ರ	jo		
op. oa, 203 (1913).	3500	47.237	125.379	88.343	129.625	್ ರ	ာ်ဝံ	ာ်ဝံ	
	3600	47.237	126.710	89.391	134.349	oʻ	ور	o.	
	2000	757.75	178 004	89.711	- 135.811	FUGACITY	Try - 1 bar		
	3888	4137	129.264	91.423	143.7%	-407.864 -406.685	7.788 19.039 30.258	-0.170 -0.262 -0.405	
	2	1077	130.061	93.370		-405.560	41.447	-0.541	
	24.4 88.8	4127	133.991	95.255 95.255	157.967	-404.488 -403.467	52.609 63.745	-0.670	
(E)(C) (C) (F 1)(F 1)	4400 0044	41237	136.189	97.066		-401.570	85.948	-0.303	
75).	}		2712	34517		-400.691	97.018	-1.126	
								-	

Titanium (Ti)

PREVIOUS: September 1966

C;         S - [G^- + [F(T_i)])T         HT-HTT, AH         AH         AH           0,         0.         INFNITE         -4350         0.           213.73         212.77         212.79         0.         0.           213.73         212.73         212.79         0.         0.           213.73         212.73         212.79         0.         0.           213.73         20.75         30.75         30.75         0.           25.26         38.23         31.77         2.66         0.           25.27         3.27         30.915         30.75         0.           25.27         3.27         31.77         2.66         0.           25.27         3.27         31.77         2.66         0.           25.27         3.27         4.018         0.         0.           25.27         3.27         4.018         0.         0.           25.27         4.02         0.         0.         0.           25.27         4.02         0.         0.         0.           25.27         4.02         0.         0.         0.           25.47         4.02         0.         0.	C, S, -1CFITT)  T    T-H TT     AHT   T    T    T    T    T		rence Te	Enthalpy Reference Temperature = T, I-K-'mol'	- 7, - 298.15 K		Standard St	Standard State Pressure = $p^*$	0.1 MPa
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47237         97.481         61.617         69.540         TRANK           47237         88.944         64.734         77.41         0           47237         101.246         66.233         81.869         0           47237         100.546         66.233         81.869         0           47237         100.546         66.233         81.869         0           47237         100.546         66.233         81.869         0           47237         113.120         74.051         10.054         0           47237         114.838         75.477         110.211         0           47237         118.097         72.111         119.659         0           47237         121.106         80.500         120.106         0           47237         121.106         80.500         120.106         0           47237         124.010         81.259         142.377         0           47237         124.010         81.259         142.377         0           47237         125.719         84.443         142.777         0           47237         125.049         81.859         142.073         0           4723	47237         97.481         61.617         69.540         TRANS           47237         88.944         64.734         77.41         0           47237         101.246         66.233         81.869         0           47237         100.546         66.233         81.869         0           47237         100.546         66.233         81.869         0           47237         100.548         71.059         86.040         0           47237         113.120         74.051         100.764         0           47237         114.838         75.477         110.211         0           47237         118.097         72.711         119.659         0           47237         118.097         72.111         119.659         0           47237         121.106         80.500         129.106         0           47237         121.106         80.500         129.106         0           47237         122.600         82.204         143.277         0           47237         122.600         82.204         143.277         0           47237         122.114         82.591         142.277         -409.098		37.868	90.186	61,617	55.394		0. > [JOIIID	j
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47.237 131.687 89.963 166.896 -405.560 4 47.237 133.891 92.005 171.620 -404.488 5 47.237 133.991 92.005 176.31 -404.488 5 47.237 135.103 92.994 181.067 -402.495 7 47.237 135.1250 94.914 180.515 -400.691 9	47.237 131.687 89.963 166.896 -405.560 4 47.237 133.891 92.005 171.620 -404.488 5 47.237 133.991 92.005 176.31 -403.475 6 47.237 135.103 92.994 181.067 -402.495 7 47.237 135.250 94.914 180.515 -400.691 9		1237	130.491	87,830		-407.864	19.039	-0.262
4727 13283 90.995 171.620 -404.488 5 47.227 133.991 92.005 176.32 -403.467 6 47.227 135.103 92.994 181.067 -402.495 7 47.237 136.189 93.964 183.791 -401.570 8 47.237 137.250 94.914 190.515 -400.691 9	4727 13283 90.995 171.620 -404.488 5 47.227 133.991 92.005 176.53 -403.467 6 47.227 135.103 92.994 181.067 -402.495 7 47.237 136.189 93.964 183.791 -401.570 8 47.237 137.250 94.914 190.515 -400.691 9		17.237	131.687	89.963		-405.560	41.447	-0.541
47.237 135.103 92.994 181.067 -402.495 7 47.237 136.189 93.964 183.791 -401.570 8 47.237 137.250 94.914 190.515 -400.691 9	47.237 135.103 92.994 181.067 -402.495 7 47.237 136.189 93.944 180.515 -400.691 9 94.914 180.515 -400.691 9		1237	132.853	90.995 92.005		-404.488	52.609	0.670
47237 137250 94,914 180,515 -400,691 9	47237 137250 94,914 190,515 -400,691 9		1737	135.103	92.994		-402.495	74.857	606.0
			1231	136.189	93.964 94.914		-401.570 -400.691	85.948 97.018	-1.020
PREVIOUS: CURRENT: June 1									
		TOUS:						CURREN	TF: June 19

 $A_r = 47.88$  Titanium (Ti)

CRYSTAL(α-β)-LIQUID

Refer to the individual tables for details.

to 1166 K crystal, alpha to 1936 K crystal, beta 1936 K liquid

Titanium (Ti)

J. Phys. Chem. Ref. Data, Monograph 9

2388 2012 -1707

426.574 424.683 422.852 421.082 419.374

-1.257 -1.259 -0.800 -0.800 -0.402 -0.402

60.528

53.709 56.238 65.238 65.403 68.479 71.616 74.813 78.071 81.387

225.208 225.361 227.5.361 227.5.361 227.5.361 237.862 237.863

204.769 205.547 205.547 207.396 207.396 209.026 209.026 210.578 211.487 216.190 216.190 216.190 216.71 216.840

31.065 31.671 32.273 32.870 33.460

-- FUGACTTY - 1 bz

88.195 91.685 95.229 98.828

140.676 141.607 242.527 243.439

34219

3630,956

34.042

410,390

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102.480 106.182 109.934 113.733

CURRENT: June 1979 (1 bar)

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121.466 125.397 129.367 133.374 137.418

48.707 149.552 150.388 251.214 252.031

34.613 35.173 35.173 35.173 36.174 37.173 37

141.495 145.604 149.742 153.909 158.101

6
Ξ
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Standard State Pressure = p = 0.1 MPa

K. Bol

deference Temperature = T, = 298.15 K

 $H^{\bullet}-H^{\bullet}(T_{\bullet})$ 

 $S^{\bullet} - [G^{\bullet} - H^{\bullet}(T_{\bullet})]H$ 

170.126 175.913 180.297

24,430

22.25 22.25 22.683 23.04 36.04 21.913

-75.167 -74.655 -62.875 -54.042 -41.684

73.627 73.541 73.383 73.169

-33.455 -23.190 -19.777 -17.052

428.768 401.297 401.394 401.384 399.000 339.000 300 300 300 300 300 300 300 30

6.8% 9.072 11.226 13.366 5.499

21.454 21.454 21.353 21.352

-14.828 -12.984 -11.437 -10.114 -8.969

472.299 471.587 470.816 468.945 467.795 467.795 461.617 460.736 459.793 458.779 456.510 456.510 456.510 456.510

7.633 9.774 9.774 1.930 6.314

209.407 211.270 212.996 214.609 216.132 217.578 218.961 220.290

-7.969 -7.089 -6.309 -5.612

28.555 30.836 33.162 35.537 37.963

199.731 200.822 201.867 202.870 203.837

233535 238438 238438

221.574 224,028

-4.455 -3.962 -3.514 -2.732

244.101 250.717 2217.399 204.149 191.423 191.426 192.699 112.699 1130.748 118.875 1107.077 1107.077 1107.077

436.927 434.740 432.610 430.538 428.526

40.443 42.979 45.573 48.225 50.937

25.080 25.648 26.228 26.819 27.416

28.019 28.626 29.235 30.456

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Titanium (	
A 47 88	

ol - i Enthalpy R	
$\Delta_t H^{\circ}(0  \mathbb{K}) = 470.92 \pm 16.7  \text{kJ} \cdot \text{mol}^{-1}$ $\Delta_t H^{\circ}(298.15 \mathbb{K}) = 473.63 \pm 16.7  \text{kJ} \cdot \text{mol}^{-1}$	
-mol-1	

 $S^{*}(298.15K) = 180.297 \pm 0.03 \text{ J} \cdot \text{K}^{-1}$ 

IP(Ti, g) =  $55010 \pm 100 \text{ cm}^{-1}$ 

Titanium (Ti)

IDEAL GAS

$\Delta_{i}H^{\circ}$				
	n Weights	2 6	 • ,	w
	Electronic Levels and Quantum Weights State	0.00 170.132 386.874	 	53663.32
	Electronic	፟ጜጜ፟ጚ ፞	 	. <mark>4</mark> A

## **Enthalpy of Formation**

The value adopted for the enthalpy of formation of Ti(g) is that recommended by CODATA. It is obtained from a 2nd and 3rd law evaluation of the vapor pressure data of Wu and Wahlbeck, Berstein and Kaufman, Koch et al., Strassmair and Stark, and Edwards et al.

			1		Wil et al., Suds	Silizin and Stark,	. NOW I COUNTY AND THE PROPERTY OF THE PROPERT
Source	Reaction	T/K	Data Points	Δ,H°(298.15K), kcal-mol <sup>-1</sup> 2nd law 3rd law	), kcal-mol <sup>-1</sup> 3rd law	Drift cal·K <sup>-1</sup> -mol <sup>-1</sup>	Δ <sub>t</sub> H*(298.15K) kcal·mol <sup>-1</sup>
Edwards et al.6	ď	1587-1764	8	112.0 ± 1.1	111.5 ± 0.2	-0.3 + 0.6	113.1
Strassmair and Stark	æ	1554-1772	<b>∞</b>	$111.4 \pm 3.5$	109.8 ± 0.8	10+01-	111.4
Wu and Wahlbeck <sup>2</sup>	a	1830-1923	91	$112.2 \pm 9.3$	111.6 ± 1.0	-03+40	113.3
Koch et al.	٩	1955-2379	21*	$110.9 \pm 2.4$	109.2 + 1.3	-08+11	37 611
Bernstein and Kaufman <sup>3</sup>	þ	2000-3000	Smooth	110.6	109.0	-0.6	1123
	*Two poi	nts deleted due	to a statistica	Two points deleted due to a statistical test Reaction. a) Ti(B) = Ti(g) b) Ti(I) = Ti(g)	a) Τί(β) = Τί(g)	b) Ti(l) - Ti(g)	

## Heat Capacity and Entropy

as estimated levels, are used in the calculation. The observed levels are too numerous to list completely. In our calculations, the missing levels for n = 4, n = 5, and n = 6 have been arbitrarily added near the ionization limit. Our calculations indicate that for Ti(g) the thermochemical functions are independent of the estimated missing levels (for n = 45.6) and the cut-off procedure up to 3000 K. The Gibbs energy function is essentially unaffected (<0.002 cal·K-1·mol-1) at 6000 K. The reported uncertainty in \$°(298.15K) is due to uncertainties in the relative atomic mass and the fundamental constants. Extension of these calculations above 6000 K may require consideration of the higher excited states (n > 6), more precise estimation of missing states (all n), and utilization of proper fill and cut-off procedures. In fact, the inclusion of some higher states (n = 4.5.6) and consideration of various cut-off procedures leads to calculational differences in the Gibbs energy function of rougly 0.1 cal·K<sup>-1</sup>·mol<sup>-1</sup>) or greater at temperatures near 10000 K. The electronic energy levels are given in the recent compilation by Corliss and Sugar. Although we have listed only the ground state, first two excited states, the highest observed excited state, and the ionization potential for Ti(g), all levels listed by Corliss and Sugar, as well

#### References

ICSU-CODATA Task Group, CODATA Special Report No. 7 (April 1978).

<sup>2</sup>H. Y. Wu and P. G. Wahlbeck, High Temp. Sci. 3, 469 (1971).

<sup>3</sup>H. Bemstein and L. Kaufman, Rept. AFML-TR66-193 (1966).

K. Koch, E. D. Clavert, C. R. Thomas, R. A. Beall, U.S. Bur. Mines RI 7271, 14 pp. (1969).
 H. Strassmair and D. Stark, Z. Angew. Phys. 23, 40 (1967).
 W. Edwards, H. L. Johnston, and W. E. Dilmars, J. Am. Chem. Soc. 75, 2467 (1953).

. Corliss and J. Sugar, J. Phys. Chem. Ref. Data 8, 1 (1979).

R. Downey, Jr., The Dow Chemical Company, Thermal Research, AFOSR-TR-78-0960, (March 1978).

Titanium (Ti)

PREVIOUS: June 1979 (1 atm)

Ti;(g)

TI;(g)
im, lon (Ti*)
M <sub>r</sub> = 47.87945 Titani
IDEAL GAS

Titanium Ion (Ti*)		IDEAL GAS	M <sub>r</sub> = 47.87945 Titanium, Ion (Ti*)	Titanium,	lon (Ti*)						Ti¦(g)
IP(TI <sup>+</sup> , g) = $109500 \pm 1000 \text{ cm}^{-1}$ S°(298.15K) = $183.594 \pm 0.04 \text{ J} \cdot \text{K}^{-1}\text{mol}^{-1}$			$\Delta_f H^{\circ}(0 \text{ K}) = 1128.985 \pm 6.3 \text{ kJ} \cdot \text{mol}^{-1}$ $\Delta_f H^{\circ}(298.15\text{K}) = 11138.2521 \text{ kJ} \cdot \text{mol}^{-1}$	Enthalpy R	eference Te	mperature	Enthalpy Reference Temperature = T, = 298.15 K J.KImol-1		Standard State Pressure = $p^* = 0.1 \text{ MPa}$ k 1-mol <sup>-1</sup>	Pressure = p	- 0.1 MPa
				τÆ	೮	S -[G	S° -[G*-H*(T,)]T	$H^{\bullet}-H^{\bullet}(T_{\bullet})$	$\Delta_t H^{\bullet}$	$\Phi_G$	log K,
	Electronic	Electronic Levels and Quantum Weights		٥٥	0.	0.	INFINITE	-7.899	1128.985		
	State	€, cm <sup>-1</sup> 8.		28	26.772	173.059	185.998	-258			
	î			গ্ন	26,305	178.974	184.025	-1.263			
	ដូវ	0.00		298.15	26.181	183,594	183.594	ó	1138,252	1086.429	- 190,338
	r. 7.	93.94		8	26.180	183.756	183.595	0.048	1138,292	1086.108	-189.108
	T.	225.47		350	26.166	187.790	183.913	1.357	1139,353	1077.326	-160.782
	f.	393.22		8	26.128	191,282	184.621	2665	1140,373	1068,395	-139.518
	1			\$	26.021	194,354	185,535	3.969	1141,359	1059,338	-122.965
	•			8	25.843	197.087	186.556	5.265	1142,312	1050.173	-109.711
	٠			8	25.356	201.758	188.714	7.826	1144.126	1031.573	-89.806
	• •			8	24.817	205.626	190.862	10.335	1145.826	1012.678	-75,567
	<sup>2</sup> Ε <sub>77</sub>	70893.00		8	24,320	208.907	192.917	12.791	1147.436	993.546	-64.872
	<u>.</u>	1005001		8	23,903	211.746	194.855	15,202	1148,934	974.218	-56.542
	3	10200		8	23.572	214.247	2098	273 71	1150 764	057 733	- 40 P.70

### **Enthalpy of Formation**

 $\Delta H^{\circ}(TT^{*}$ , g, 0K) is calaculated from  $\Delta H^{\circ}(TT, g, 0 \text{ K})^{-1}$  using the spectroscopic value of IP(TI) = 55010  $\pm$  100 cm<sup>-1</sup> (658.07  $\pm$  0.4 kJ·mol<sup>-1</sup>) from Corliss and Sugar. The ionization limit is converted from cm<sup>-1</sup> to kJ·mol<sup>-1</sup> using the factor, 1 cm<sup>-1</sup> = 0.01196266 kJ cm<sup>-1</sup>, which is derived from the 1973 CODATA fundamental constants. Rosenstock *et al.* and Levine and Lias have summarized additional

ionization and appearance potential data.  $\Delta H^*(Ti, g, 0 K)$  by using IP(Ti) with JANAF¹ enthalpies,  $H^*(0 K) + H^*(298.15K)$ , for Ti(g), Ti\*(g), and e^(g),  $\Delta H^*(Ti \rightarrow Ti^* + e^-, 298.15K)$  differs from a room temperature threshold energy due to inclusion of these enthalpies and to threshold effects discussed by Rosenstock et al.  $^4\Delta H^*(298.15 K)$  should be changed by  $^-6.197 \ kJ \cdot mol^{-1}$  if it is to be used in this ion convention that excludes the enthalpy of the electron.

## Heat Capacity and Entropy

83 well as estimated levels, are used in the calculation. The observed levels are too numerous to list completely. In our calculations the missing evels for n = 4,5 have been arbitrarily added near the ionization limit. The calculations indicate that for Ti'(g), the thermochemical functions are independent of the estimated missing levels for n = 4.5, the cut-off procedure, and the inclusion of n = 6 levels up to 6000 K. The Gibbs energy function is essentially unaffected (by less than 0.2%) up to 20000 K. The reported uncertainty in  $S^{\circ}(298.15K)$  is due to uncertainties in the relative atomic mass and the fundamental constants. Extension of these calculations above 6000 K may require consideration of the The electronic energy levels are given in the recent compilation by Corliss and Sugar. Although we have listed only the ground state, the first three excited states, the highest observed excited state, and the ionization potential for Ti'(g), all levels listed by Corliss and Sugar.? higher excited states (n>6), and use of proper fill and cut-off procedures.6

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CURRENT: March 1984 (1 bar) -49.870 -44.405 -39.853 -38.005 -36.005 -21.330 -21.133 -21.143 -21.143 -21.143 -18.381 -17.090 -17.090 -17.090 -17.090 -17.00 -2.436 -2.321 -2.210 -2554 954,732 995,123 9915,543 896,534 876,534 877,536 817,345 817,345 777,621 738,942 738,144 738,942 738,144 738,1 643.221 624.096 604.977 585.862 566.750 547.640 528.531 509.423 490.315 440.772 440.772 432.909 425.011 368.918 360.808 352.677 344.527 409.121 401.132 393.115 385.073 377.007 153.350 154.358 155.245 156.000 1141.638 1141.370 1141.124 1140.901 1140.702 140.527 1140,378 1140,254 1140,154 1140,078 139.997 139.990 140.004 140.037 732.380 733.660 734.899 736.098 737.258 738.379 739.462 746.061 746.879 747.669 748.434 140,026 17575
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1984 (1 bar)

CURRENT: March

191 <sub>(0)11</sub>	4
M, = 47.88055 Titanium, Ion (TI <sup>-</sup> )	
IDEAL GAS	
tanium, lon (Ti <sup>-</sup> )	

M; = 47.88055 Titanium, Ion (Ti")	$\Delta H^0(0 \text{ K}) = 463.3 \pm 4 \text{ kJ \cdot mol}^{-1}$ Enthalpy Reference Temperature = $T_r = 298.15 \text{ K}$ Standard State Pressure = $p^+$ $\Delta H^0(298.15 \text{ K}) = 1459.8331 \text{ kJ \cdot mol}^{-1}$	7.K C;	0. 0. INFINITE	174.264 185.851	25.533 179.634 184.094 -1.115 22.835 183.715 183.715 0. 459.813	22.813 183.856 183.715	
AL GAS			ls and Quantum Weights	€, cm <sup>-1</sup> &.	0	72 6	
DE			Electonic Levels	State	F3	Fsz	į
ilianium, ion (iii )	EA(Ti, g) = 0.079 $\pm$ 0.014 eV $S'(298.15 \text{ K}) = 183.715 \pm 0.001 \text{ J·K}^{-1} \cdot \text{mol}^{-1}$						

 $\Delta_H^{\bullet}(Ti^{-}, g, 0 \text{ K})$  is calculated from  $\Delta_H^{\bullet}(Ti, g, 0 \text{ K})^{\dagger}$  using the adopted electron affinity of EA(Ti) = 0.079  $\pm$  0.014 eV (7.622  $\pm$  1.351 [Limol-1]. This value, recommended by Hotop and Lineberger, is based on a laser photodetachment electron spectrometry study. Additional information in the rational influence in the rational discussions of Hoton and I inspector 2.4 Recentions of 1.3 and Massey 6 2 295 Ę, Enthalpy of Formation

information on TI (g) may be obtained in the critical discussions of Hotop and Lineberger,  $^{1.4}$  Rosenstock et al.  $^{3}$  and Massey,  $^{6}$   $\Delta_{H}^{2}$ (TI , g, 298.15 K) is obtained from  $\Delta_{H}^{2}$ (Ti, g, 0 K) by using EA(Ti) with JANAF entralpies,  $H^{2}$ (0 K)  $-H^{2}$ (298.15 K), for TI (g), and e (ref),  $\Delta_{H}^{2}$ (TI  $\rightarrow$  TI + e  $^{2}$ , 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.  $^{3}$   $\Delta_{H}^{2}$ (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 Ti<sup>-</sup>(g) is given by Hotop and Lineberger, <sup>2,4</sup> Rosenstock et al. <sup>5</sup> and Massey. <sup>6</sup> The fine structure has been calculated via an isoelectronic extrapolation from a logarithmic plot <sup>3</sup> and is that recommended by Hotop and Lineberger. <sup>2</sup>

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-- 0.1 MPa - 73.67 - 73.67 - 73.17 - 61.78 - 61.7 -2.903 -2.938 -2.930 -3.002 -3.034 -3.036 -3.036 -3.127 -3.157 -3216 log Kr 331,531 334,230 304,845 304,845 304,845 305,130 305,13 299.297 308.238 317.259 326.357 335.354 -115.660 -119.362 -123.112 -126.910 -130.754 -134.642 -138.571 -142.540 -146.547 -150.590 45,033 45 -175.485 -179.722 -183.981 -188.258 -192.552 2.27 3.371 4.454 6.456 6.456 8.776 10.242 11.146 11 48.432 50.514 50.514 54.675 56.757 58.838 66.0919 66.0919 67.160 67.160 67.160 67.160 67.160 67.160 77.460 90.038 92.118 94.197 96.277 100.436 102.515 104.594 106.674 108.753 202.445 204.509 204.509 205.459 206.377 207.257 208.915 209.698 211.182 211.886 212.568 213.228 213.869 214.490 215.094 215.680 216.251 216.806 217.348 217.875 218.390 218.892 219.382 219*8*62 220.330 220.788 221.237 221.676 219,693 220,598 222,150 223,177 223,131 226,531 226,531 226,531 227,531 227,531 237,531 237,13 241.679 242.126 242.564 242.993 243.413 211.955
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Vanadium (V)

= p* = 0.1 MPa	log Kr	ರರರ	Ö	ರರರ	ರರ	ರರರ	00	ಶರರ	ರರ	o o o	_	> LIQUID	ರರರ	್ ರ	ಠಠಠ	. ರರ	ರರರ		   	ರರರ	ರರ	ಶರರ	o o o		66	ರರಂ	600	ÖÖ
Standard State Pressure	Δ.G•	ರರರ	ó	ರರರ	oo	ರರರ	<b>ೆ</b>	ಠಠ೦	. ರರ	ರರರ		RYSTAL <>L TRANSITIO	dddd	်ဝင်	ood	600	ರರರ	0	UGACTY - 1	ರರರರ	dd	ರರರ	ooc	်ဝံဝံ	ರರ	o o c	်ဝင်	00
Standard S	Α.Η.Δ Α.Η.	ರರರ	ó	ರರರ	೦೦	ರರರ	ರರ	ರರಂ	ರರ	ರರರ	ا بي		ರರರ	್ ರ	ರರರ	. ರರ	ರರರ	0		ರರರರ	ರರ	ಶರರ	ರರಂ	ಶರರ	೦೦	ರರಂ	idd	00
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. T, = 298.15 K	-H'(T,))T	INFINITE 48.695 31.133	28.936	28.936 29.932 31.850	34.032 36.247	38.411 40.493 42.485	44.389	49.630 49.630	54.306 54.306	55.765 57.182 58.562	59.908	61.093 61.093	65.0171 65.0121 64.693	67.885	578.57 578.57 578.57 578.57	75.032	78.850 78.850 80.057	81.233	8278	82.705 86.997 91.088 94.995	98.729	109.017 109.017 112.175	115.211	123.668 126.290	128.824	133.646 135.943 138.160	140.329	144.461
Temperature = $T_r$	S - [G	0. 7.185 19.558		25.08 25.459 23.25	47.353 51.630	55.413 58.830 61.961	64.864	72.638	79.492	81.641 83.742 85.805	87.837	89.653 100.085	100.295 102.349 104.315	108.014	113.059	116,141	119.029 120.409 121.748	123.049	245.321	245.399 246.181 246.956 247.725	248.488	250.746 251.490	252230 252966 253,686	25.25 25.15 25.15	255.878 256.600	257.318 258.035 258.035	259.462	260.881
	្រ	0. 13.119 21.876	24.896	26.234 26.234 26.945	27.489	28.660 29.372 30.083	30.878	33.807	35.857 37.028	38200 39539 40520	42.468	46.204	4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	4 6 20 204	8 4 20 20 20 20 20 20 20 20 20	\$ 50 204 204	4 4 4 2 2 2 2 3 2 2 2 2	46.204	29.042	25.25 25 25.25 25 25 25 25 25 25 25 25 25 25 25 25 2	31.166	32.817 33.379	34.517	35.672	36.843 37.435	38.031 38.632 38.738	39.849	41.087
Enthalpy Reference	τÆ	°88	298.15	888	88	888	200	888	922	888 888	2100	2190.000 2190.000	8888 8888 8888	2,00	888 888 888 888	3200	888 888 888	3600	3690.080	3900 9900 9900 9900	<b>65</b>	3 <u>4</u> 8	94 96 96 96 96 96 96 96 96 96 96 96 96 96	<b>88</b> 8	\$200 \$200	888 888	888	2800 2800 2800

A, = 50.9415 Va

K crystal

K liquid

K ideal monatomic gas

to 2190 to 3690.080 3690.080

0 2190 above

Refer to the individual tables for details.

REFERENCE STATE

Vanadium (V)

J. Phys. Chem. Ref. Data, Monograph 9