Strontium (α–Sr)

$A_r = 87.62$

Pearson Notation: CF4
$S°(298.15 \text{ K}) = 55.69 \pm 0.1 \text{ J·K}^{-1}\text{·mol}^{-1}$
$T_m(\alpha \to \beta) = 820 \pm 8 \text{ K}$

$\Delta_f H°(0 \text{ K}) = 0 \text{ kJ·mol}^{-1}$
$\Delta_f H°(298.15 \text{ K}) = 0 \text{ kJ·mol}^{-1}$
$\Delta_m H°(820 \text{ K}) = 0.8368 \pm 0.17 \text{ kJ·mol}^{-1}$

CRYSTAL(α)

Strontium, Alpha (Sr) — Sr₁(cr)

Standard State Pressure = $p° = 0.1$ MPa

Enthalpy Reference Temperature = $T_r = 298.15$ K

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	-6.568	0.	0.	0.
100	23.481	28.050	78.738	-5.069	0.	0.	0.
200	25.757	45.209	58.112	-2.581	0.	0.	0.
298.15	26.791	55.694	55.694	0.	0.	0.	0.
300	26.809	55.859	55.694	0.050	0.	0.	0.
350	27.298	60.029	56.022	1.402	0.	0.	0.
400	27.777	63.704	56.757	2.779	0.	0.	0.
450	28.278	67.005	57.716	4.180	0.	0.	0.
500	28.785	70.010	58.797	5.607	0.	0.	0.
600	29.814	75.349	61.122	8.536	0.	0.	0.
700	30.864	80.023	63.495	11.570	0.	0.	0.
800	31.935	84.214	65.827	14.710	0.	0.	0.
820 000	32.151	85.005	66.285	15.351	--- ALPHA <--> BETA ---		
900	33.027	88.038	68.085	17.958	-0.626	0.072	-0.004
1000	34.139	91.576	70.260	21.316	-0.302	0.133	-0.007
1100	35.273	94.882	72.349	24.786	-7.768	0.522	-0.025
1200	36.428	98.001	74.358	28.371	-8.129	1.292	-0.056
1300	37.604	100.963	76.292	32.073	-8.374	2.088	-0.084
1400	38.801	103.794	78.156	35.893	-8.500	2.898	-0.108
1500	40.019	106.512	79.956	39.834	-8.505	3.713	-0.129

Enthalpy of Formation

Zero by definition.

Heat Capacity and Entropy

The adopted heat capacities are derived from the heat capacity[1,2] and enthalpy[2] data by fitting the experimental data with orthogonal polynomials over selected overlapping temperature intervals. The temperature region of 1–9 K is described by the equation: $C_p° = 3.281 \times 10^{-3} T + 189 \times 10^{-4} T^3$ cal·K⁻¹·mol⁻¹. The $S°(298.15$ K) value calculated from the polynomials agrees to within 0.002 cal·K⁻¹·mol⁻¹ with that given by Boerio and Westrum[1] and adopted by Gurvich et al.[3]

Boerio and Westrum[1] used adiabatic-shield calorimetry to measure the low temperature heat capacity, 83 data points in the range 6.28 to 346.42 K. Two other studies have also been made: Kreplovich and Paukov (5–300 K)[4,5] and Roberts (1–20 K).[6] In the temperature region below 20 K, both these studies deviate from the adopted values similarly, from ~44% low at 5 K to ~15% low at 20 K. Since the sample used by Kreplovich and Paukov[4,5] was shown to contain a substantial oxygen impurity, of the order of 6 ± 3 mole %,[1] the sample used by Roberts[6] probably had similar impurities. Roberts reported a purity of 98.25% but only metallic impurities were analyzed.

Stephens and Roth[3] measured enthalpy (350–1191 K) by drop calorimetry and heat capacity (298–785 K) by differential scanning calorimetry. We fit the 14 enthalpy points at 400–812 K with a polynomial, using the adiabatic[1] and DSC[2] data as a guide to the shape of the heat capacity curve. We adopt this fit only above 350 K, although the derived $C_p°$ values agree closely (± 0.3%) with the adiabatic data[1] at 250 to 320 K. Between 320 and 400 K the adopted $C_p°$ values are a compromise between those of Boerio and Westrum and those of Stephens and Roth. This compromise yields an upward inflection point in $C_p°$ versus T near 330 K. The largest deviation of Boerio and Westrum[1] above 320 K is ~0.7% at 343.42 K. The DSC data[2] deviate by -0.8 to +2.0% except for +3 8% at 785 K. The enthalpy data[2] deviate by -1.6 to +1.8% (400–812 K) with larger deviations at 350 and 550 K.

Phase Data

According to Pearson,[7] α–strontium has the face-centered-cubic structure, isotypic with Cu, designated as CF4 In the alkaline earth metal series, only α–calcium has the same structure.

Transition Data

Refer to the β–crystal table for details.

Sublimation Data

The enthalpy of sublimation of α–strontium is the enthalpy of formation of the gas The experimental studies are discussed in the ideal gas table.

References

[1] J. Boerio and E. F. Westrum, J. Chem. Thermodyn. 10, 1 (1978).
[2] H. J. Stephens and E. P. Roth, Sandia National Laboratories, Albuquerque, New Mexico, personal communication, (May 3, 1982).
[3] L. V. Gurvich, I. V. Veits et al., "Thermodynamic Properties of Individual Substances," 3rd ed., Vol. III, Nauka, Moscow, (1981).
[4] L. M. Khriplovich and I. E. Paukov, Zh. Fiz. Khim. 50, 567 (1976).
[5] L. M. Khriplovich and I. E. Paukov, VINITI Documentary Deposit No. 3190–75, (November, 11, 1975).
[6] L. M. Roberts, Proc. Phys. Soc. (London) B70, 733 (1957).
[7] W. B. Pearson, "A Handbook of Lattice Spacing and Structures of Metals and Alloys," Pergamon Press, London, 1958, (1967).

Sr₁(cr)

Strontium (β–Sr) CRYSTAL(β) $A_r = 87.62$ Strontium, Beta (Sr)

Standard State Pressure = $p° = 0.1$ MPa

Enthalpy Reference Temperature = T_r = 298.15 K

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							
100							
200							
250							
298.15	27.607	57.175	57.175	0	1.211	0.770	-0.135
300	27.614	57.346	57.175	0.051	1.213	0.767	-0.134
400	28.033	65.347	58.263	2.833	1.266	0.609	-0.080
500	28.451	71.647	60.332	5.658	1.262	0.444	-0.046
600	28.870	76.872	62.665	8.524	1.199	0.285	-0.025
700	29.288	81.353	65.022	11.432	1.073	0.142	-0.011
800	29.706	85.291	67.315	14.381	0.883	0.021	-0.001
820.000	29.790	86.026	67.762	14.976	---- ALPHA <--> BETA ----		
900	30.125	88.814	69.511	17.373	0.	0.	0.
1000	30.543	92.010	71.604	20.406	0.	0.	0.
1050.000	30.752	93.505	72.611	21.939	---- BETA <--> LIQUID ----		
1100	30.962	94.941	73.594	23.481	-7.861	0.364	-0.017
1200	31.380	97.653	75.487	26.599	-8.690	1.149	-0.050
1300	31.798	100.181	77.291	29.757	-9.478	2.001	-0.080
1400	32.217	102.553	79.011	32.958	-10.223	2.912	-0.109
1500	32.635	104.790	80.656	36.201	-10.927	3.875	-0.135

Strontium (β–Sr)

Pearson Notation: cI2
$S°$(298.15 K) = [57.175] J·K⁻¹·mol⁻¹
T_{trs}(α→β) = 820 ± 8 K
T_m(β→l) = 1050 ± 10 K

$\Delta_f H°$(298.15 K) = [1.211] kJ·mol⁻¹
$\Delta_{trs} H°$(820 K) = 0.8368 ± 0.17 kJ·mol⁻¹
$\Delta_{fus} H°$(1050 K) = 7.4308 ± 0.8 kJ·mol⁻¹

Enthalpy of Formation

$\Delta_f H°$(Sr, cr, β, 298.15 K) is calculated from $\Delta_f H°$(Sr, α, cr, 298.15 K) by adding the enthalpy of transition, $\Delta_{trs} H°$, and the difference in enthalpy, $H°$(820 K)–$H°$(298.15 K), between α-Sr and β-Sr.

Heat Capacity and Entropy

The drop-calorimetry data of Stephens and Roth[1] contain 9 points (819.6-1048 8 K) that appear to be in the region of stability of β-strontium. Their values of $[H°(T)-H°(298.15 K)]/(T-298.15 K)$ show systematic curvature suggestive of the effects of incomplete transition or premelting near the extreme temperatures. Constant $C_p°$ values ranging from ~6.3 to 9.3 cal·K⁻¹·mol⁻¹ can be derived by various selections and weightings of the points. We arbitrarily select a $C_p°$ near 7.3 cal·K⁻¹·mol⁻¹ with a linear temperature dependence that maintains the proper stability relationships when extrapolated below T_{trs} and above T_m. This curve reproduces the enthalpy data within ±1.2% (819.6-990.5 K) and corresponds to premelting effects of ~140 to 450 cal·mol⁻¹ in the region from 1029 to 1049 K. $S°$(298.15 K) is calculated from that of α-strontium using entropy increments analogous to the enthalpy increments used to calculate $\Delta_f H°$(298.15 K).

Phase Data

According to Pearson,[2] β-strontium has the body-centered-cubic structure, isotypic with W, designated as cI2. In the alkaline earth metal series, β-calcium, β-beryllium, and barium have the same structure. Note that we now use the name beta[3] for the phase of Sr stable near T_{trs}, unlike Pearson who retains the historical name gamma. The change arose when Peterson and Colburn[3] found that an intermediate hexagonal-close-packed phase does not occur in Sr containing a smaller amount of H₂ impurity.

Transition Data

We select T_{trs} = 820 ± 8 K based on enthalpy data of Stephens and Roth[1] and DTA data of Peterson and Colburn.[3] DTA gave ~813 K on cooling and 828 K (after correction for H impurity) on heating. We adopt an enthalpy of transition of 200 ± 40 cal·mol⁻¹ derived from our fits of the enthalpy data[1] for β and α phases; Stephens and Roth selected the same value. Almost 170 out of the 200 cal/mol appeared between 812 and 819.6 K. Another 30 cal·mol⁻¹ appeared between 819.6 and 824.9 K, while possibly 40 cal·mol⁻¹ appeared between 824.9 and 835.6 K. The latter enthalpy increments are uncertain because of almost equal-sized scatter in the data and because of uncertainty in $C_p°$(β). Our adopted value of T_{trs} = 820 K is in the middle of the DTA hysteresis range. The temperature range up to T_m includes most of the transition enthalpy seen in the sample of Stephens and Roth. Their sample was identical with that used by Boerio and Westrum[4] to measure the low temperature $C_p°$ and $S°$ of α phase.

Peterson and Colburn[3] found that T_{trs} increased rapidly with increasing hydrogen content. They also observed the intermediate hexagonal-close-packed phase at hydrogen contents of >3 mole % but not at 0.4 mole %, suggesting that this phase does not occur in pure strontium. The enthalpy and heat capacity data[1] are consistent with this interpretation.

Sublimation Data

The enthalpy of sublimation of β-strontium is calculated as the difference in the enthalpies of formation of the gas and β-strontium. The experimental studies are discussed in the Sr(g) table.

References

[1]H. J. Stephens and E. P. Roth, Sandia National Laboratories, Albuquerque, New Mexico, personal communication, (May 3, 1982).
[2]W. B. Pearson, "A Handbook of Lattice Spacing and Structures of Metals and Alloys," Pergamon Press, London, 1958, (1967).
[3]D. T. Peterson and R. P. Colburn, J. Phys. Chem. 70, 463 (1966).
[4]J. Boerio and E. F. Westrum, J. Chem. Thermodyn. 10, 1 (1978).

PREVIOUS:

Strontium, Beta (Sr)

Strontium (Sr)   LIQUID $A_r = 87.62$

$S°(298.15\ \text{K}) = [50.901]\ \text{J·K}^{-1}\text{·mol}^{-1}$
$T_{fus}(\beta\rightarrow l) = 1050 \pm 10\ \text{K}$

$\Delta_f H°(298.15\ \text{K}) = [0.911]\ \text{kJ·mol}^{-1}$
$\Delta_{fus}H°(1050\ \text{K}) = 7.4308 \pm 0.8\ \text{kJ·mol}^{-1}$

Enthalpy of Formation

$\Delta_f H°(\text{Sr, l}, 298.15\ \text{K})$ is calculated from $\Delta_f H°(\text{Sr, cr}, \beta, 298.15\ \text{K})$ by adding the enthalpy of fusion, $\Delta_{fus}H°$, and the difference in enthalpy, $H°(1050\ \text{K})-H°(298.15\ \text{K})$, between β-Sr and the liquid.

Heat Capacity and Entropy

$C°_p$ is the constant value derived from three enthalpy points (1059–1191 K) measured by Stephens and Roth.[1] Their points deviate from the adopted enthalpies by −0.8 to +0.5%. We assume a glass transition with zero enthalpy at 650 K; below 650 K we assume that $C°_p$ (glass) is equal to the $C°_p$ (α) curve derived from the enthalpy data for α strontium (refer to that table). These or similar assumptions are necessary to ensure that $S°(298.15\ \text{K})$ of the supercooled liquid is larger than that of α-strontium. $S°(298.15\ \text{K})$ is calculated from that of β-strontium using entropy increments analogous to the enthalpy increments used to calculate $\Delta_f H°(298.15\ \text{K})$.

Fusion Data

$T_{fus} = 1050 \pm 10$ K is the value selected by Stephens and Roth[1] based on their enthalpy study. Previous studies by thermal analysis[2-3] gave 1042 ± 2 K (IPTS–68) for high-purity strontium. The reason for the difference is not clear, although it probably arises from differences in sample purity or measurement method. The observed enthalpies[1] showed that melting of the sample was complete at 1059.1 K but only ~20 to 30% complete at 1048.8 K. This suggests either that the sample needed a much longer equilibration time at 1048.8 K or that it actually melted at least 7 degrees higher than 1042 K. The enthalpy at 1035.1 K showed a small premelting effect. A melting point of 1048 K (IPTS–68) was found by Kanda and coworkers[4-6] for three samples that, based on their transition behavior, probably contained over 3 mole % of hydrogen. Although hydrogen increases both T_{fus} and T_{trs}, the changes are greatest in the transition region.[2] The sample in the enthalpy study had normal transition behavior without the changes typical of hydrogen impurity. This sample was identical to that used in measurement of $C°_p$ and $S°$ at low temperature; analytical data[7] showed it to be of high purity. We choose to base all properties, including melting point, on the data for this same sample.

The enthalpy of fusion is derived from our fits of the enthalpy data[1] in the liquid and beta regions. Stephens and Roth[1] selected the value 1871 ± 55 cal·mol⁻¹ based on a somewhat different fit in the β region.

Vaporization Data

T_{vap} is calculated as the temperature for which $\Delta_{vap}G° = 0$ for the liquid vaporizing to the ideal monatomic gas. T_{vap} corresponds to a fugacity of one bar. The enthalpy of vaporization is calculated from the enthalpy of formation of the liquid and the gas at T_{vap}. Vaporization studies are discussed in the ideal gas table.[8]

Strontium (Sr)

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							
100							
200							
250							
298.15	39.463	50.901	50.901	0.	0.911	2.340	−0.410
300	39.463	51.145	50.902	0.073	0.934	2.348	−0.409
400	39.463	62.498	52.450	4.019	2.151	2.634	−0.344
500	39.463	71.304	55.373	7.966	3.270	2.623	−0.274
600	39.463	78.498	58.645	11.912	4.286	2.396	−0.209
700	39.463	84.582	61.927	15.858	5.199	2.008	−0.150
800	39.463	89.851	65.096	19.804	6.005	1.496	−0.098
900	39.463	94.499	68.110	23.751	6.077	0.961	−0.056
1000	39.463	98.657	70.960	27.697	6.990	0.343	−0.018
1050.000	39.463	100.582	72.325	29.670	— BETA <--> LIQUID —		
1100	39.463	102.418	73.652	31.643	0.	0.	0.
1200	39.463	105.852	76.194	35.589	0.	0.	0.
1300	39.463	109.010	78.598	39.536	0.	0.	0.
1400	39.463	111.935	80.877	43.482	0.	0.	0.
1500	39.463	114.658	83.039	47.428	0.	0.	0.
1600	39.463	117.204	85.095	51.374	0.	0.	0.
1685.492	39.463	119.259	86.777	54.748	— FUGACITY = 1 bar —		
1700	39.463	119.597	87.055	55.321	−136.914	1.180	−0.036
1800	39.463	121.853	88.926	59.267	−135.054	9.249	−0.268
1900	39.463	123.986	90.716	63.213	−133.199	17.215	−0.473
2000	39.463	126.010	92.431	67.159	−131.352	25.084	−0.655
2100	39.463	127.936	94.076	71.106	−129.518	32.861	−0.817
2200	39.463	129.771	95.657	75.052	−127.700	40.550	−0.963
2300	39.463	131.526	97.179	78.998	−125.904	48.158	−1.094
2400	39.463	133.205	98.645	82.944	−124.137	55.688	−1.212
2500	39.463	134.816	100.060	86.891	−122.406	63.145	−1.319
2600	39.463	136.364	101.427	90.837	−120.720	70.533	−1.417
2700	39.463	137.853	102.748	94.783	−119.086	77.858	−1.506
2800	39.463	139.288	104.028	98.729	−117.516	85.123	−1.588
2900	39.463	140.673	105.268	102.676	−116.019	92.334	−1.663
3000	39.463	142.011	106.470	106.622	−114.605	99.494	−1.732

Strontium (Sr)   Sr₁(l)

References

[1] H. J. Stephens and E. P. Roth, Sandia National Laboratories, Albuqurque, New Mexico, personal communication, (May 3, 1982).
[2] D. T. Peterson and R. P. Colburn, J. Phys. Chem. 70, 468 (1966).
[3] A. S. Dworkin, H. R. Bronstein and M. A. Bredig, J. Phys. Chem. 72, 1892 (1968).
[4] W. O. Roberts, Ph.D. Dissertation, Syracuse Univ., 1964; Diss. Abstr. 25, 6218 (1965).
[5] F. E. Wang, F. A. Kanda and A. J. King, J. Phys. Chem. 66, 2138 (1962).
[6] J. C. Schottmiller, A. J. King and F. A. Kanda, J. Phys. Chem. 62, 1446 (1958).
[7] J. Boerio and E. F. Westrum, Jr., J. Chem. Thermodyn. 10, 1 (1978).
[8] JANAF Thermochemical Tables: Sr(g), 9-30-83.

Strontium (Sr)

A_r = 87.62 Strontium (Sr)

Sr(cr,l)

CRYSTAL(α-β)-LIQUID

0	to	820	K crystal, alpha
820	to	1050	K crystal, beta
above		1050	K liquid

Refer to the individual tables for details.

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	-6.568	0	0	0
100	23.481	28.050	78.738	-5.069	0	0	0
200	25.757	45.209	58.112	-2.581	0	0	0
298.15	26.791	55.694	55.694	0.	0	0	0
300	26.809	55.859	55.694	0.050	0	0	0
350	27.298	60.029	56.022	1.402	0	0	0
400	27.777	63.704	56.757	2.779	0	0	0
450	28.278	67.005	57.716	4.180	0	0	0
500	28.783	70.010	58.797	5.607	0	0	0
600	29.814	75.349	61.122	8.536	0	0	0
700	30.864	80.023	63.495	11.570	0	0	0
800	31.935	84.214	65.827	14.710	0	0	0
820.000	32.151	85.005	66.285	15.351	ALPHA <--> BETA TRANSITION		
820.000	29.790	86.026	66.285	16.188			
900	30.125	88.814	68.165	18.584	0	0	0
1000	30.543	92.010	70.393	21.618	0	0	0
1050.000	30.752	93.505	71.458	23.150	BETA <--> LIQUID TRANSITION		
1050.000	39.463	100.582	71.458	30.581			
1100	39.463	102.418	72.824	32.554	0	0	0
1200	39.463	105.852	75.435	36.500	0	0	0
1300	39.463	109.010	77.898	40.446	0	0	0
1400	39.463	111.935	80.226	44.393	0	0	0
1500	39.463	114.658	82.432	48.339	0	0	0
1600	39.463	117.204	84.526	52.285	0	0	0
1685.492	39.463	119.259	86.236	55.659	FUGACITY = 1 bar		
1700	39.463	119.597	86.520	56.231	-136.914	1.180	-0.036
1800	39.463	121.853	88.421	60.178	-135.054	9.249	-0.268
1900	39.463	123.986	90.237	64.124	-133.199	17.215	-0.473
2000	39.463	126.010	91.975	68.070	-131.352	25.084	-0.655
2100	39.463	127.936	93.642	72.016	-129.518	32.861	-0.817
2200	39.463	129.771	95.243	75.963	-127.700	40.550	-0.963
2300	39.463	131.526	96.783	79.909	-125.904	48.158	-1.094
2400	39.463	133.205	98.266	83.855	-124.137	55.688	-1.212
2500	39.463	134.816	99.696	87.801	-122.406	63.145	-1.319
2600	39.463	136.364	101.076	91.748	-120.720	70.533	-1.417
2700	39.463	137.853	102.411	95.694	-119.086	77.858	-1.506
2800	39.463	139.288	103.703	99.640	-117.516	85.123	-1.588
2900	39.463	140.673	104.954	103.586	-116.019	92.334	-1.663
3000	39.463	142.011	106.167	107.533	-114.605	99.494	-1.732

PREVIOUS: CURRENT: September 1983

Strontium (Sr)   Sr(cr,l)

Strontium (Sr) — IDEAL GAS $A_r = 87.62$

Sr₁(g)

$IP(Sr, g) = 45932.0 \pm 0.2 \ cm^{-1}$
$S^\circ(298.15\ K) = 164.64 \pm 0.02 \ J \cdot K^{-1} \cdot mol^{-1}$

$\Delta_f H^\circ(0\ K) = 164.4 \pm 1.7 \ kJ \cdot mol^{-1}$
$\Delta_f H^\circ(298.15\ K) = 164.0 \pm 1.7 \ kJ \cdot mol^{-1}$

Electronic Levels and Quantum Weights

State	ϵ, cm⁻¹	g_i
$^1S_0$	0.00	1
$^3P_0$	14317.520	1
$^3P_1$	14504.351	3
$^3P_2$	14898.563	5
$^3D_1$	18159.056	3
$^3D_2$	18218.795	5
$^3D_3$	18319.267	7

Strontium (Sr)   Sr₁(g)

Standard State Pressure = p° = 0.1 MPa

Enthalpy Reference Temperature = T_r = 298.15 K

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	0.	0.	INFINITE	-6.197	164.371	164.371	INFINITE
100	20.786	141.933	183.121	-4.119	164.950	153.562	-80.212
200	20.786	156.341	166.542	-2.040	164.540	142.314	-37.169
250	20.786	160.979	164.982	-1.001	164.277	136.782	-28.579
298.15	20.786	164.640	164.640	0.	164.000	131.518	-23.041
300	20.786	164.769	164.641	0.038	163.989	131.316	-22.864
350	20.786	167.973	164.894	1.078	163.675	125.895	-18.789
400	20.786	170.749	165.456	2.117	163.338	120.521	-15.738
450	20.786	173.197	166.183	3.156	162.976	115.190	-13.371
500	20.786	175.387	166.996	4.196	162.589	109.901	-11.481
600	20.786	179.177	168.719	6.274	161.738	99.441	-8.657
700	20.786	182.381	170.448	8.353	160.783	89.133	-6.651
800	20.786	185.156	172.117	10.431	159.722	78.968	-5.156
900	20.786	187.605	173.705	12.510	157.926	69.015	-4.006
1000	20.786	189.795	175.206	14.589	156.971	59.187	-3.092
1100	20.787	191.776	176.624	16.667	148.113	49.820	-2.366
1200	20.787	193.584	177.963	18.746	146.246	40.967	-1.783
1300	20.788	195.248	179.229	20.825	144.378	32.269	-1.297
1400	20.791	196.789	180.429	22.904	142.511	23.715	-0.885
1500	20.798	198.224	181.568	24.983	140.644	15.295	-0.533
1600	20.813	199.566	182.652	27.063	138.778	6.999	-0.229
1685.492	20.834	200.650	183.537	28.844	0.	0.	0.
1700	20.839	200.829	183.684	29.146	0.	0.	0.
1800	20.882	202.021	184.670	31.232	0.	0.	0.
1900	20.949	203.152	185.613	33.333	0.	0.	0.
2000	21.049	204.229	186.517	35.423	0.	0.	0.
2100	21.191	205.259	187.385	37.534	0.	0.	0.
2200	21.383	206.249	188.220	39.663	0.	0.	0.
2300	21.636	207.205	189.025	41.813	0.	0.	0.
2400	21.939	208.132	189.802	43.992	0.	0.	0.
2500	22.361	209.036	190.553	46.207	0.	0.	0.
2600	22.849	209.923	191.281	48.467	0.	0.	0.
2700	23.430	210.796	191.988	50.780	0.	0.	0.
2800	24.109	211.660	192.675	53.157	0.	0.	0.
2900	24.889	212.519	193.345	55.606	0.	0.	0.
3000	25.770	213.377	193.998	58.138	0.	0.	0.
3100	26.753	214.238	194.637	60.763	0.	0.	0.
3200	27.834	215.104	195.263	63.492	0.	0.	0.
3300	29.008	215.978	195.878	66.333	0.	0.	0.
3400	30.270	216.863	196.482	69.296	0.	0.	0.
3500	31.611	217.759	197.077	72.389	0.	0.	0.
3600	33.022	218.670	197.664	75.620	0.	0.	0.
3700	34.493	219.594	198.244	78.996	0.	0.	0.
3800	36.011	220.534	198.818	82.520	0.	0.	0.
3900	37.565	221.490	199.387	86.199	0.	0.	0.
4000	39.142	222.461	199.952	90.034	0.	0.	0.
4100	40.730	223.447	200.513	94.028	0.	0.	0.
4200	42.304	224.446	201.071	98.176	0.	0.	0.
4300	43.874	225.460	201.626	102.485	0.	0.	0.
4400	45.418	226.486	202.180	106.950	0.	0.	0.
4500	46.927	227.524	202.731	111.568	0.	0.	0.
4600	48.214	228.556	203.280	116.269	0.	0.	0.
4700	49.584	229.608	203.829	121.159	0.	0.	0.
4800	50.884	230.665	204.377	126.182	0.	0.	0.
4900	52.114	231.727	204.925	131.333	0.	0.	0.
5000	53.254	232.791	205.471	136.597	0.	0.	0.
5100	54.274	233.851	206.017	141.953	0.	0.	0.
5200	55.250	234.914	206.563	147.429	0.	0.	0.
5300	56.141	235.975	207.108	153.000	0.	0.	0.
5400	56.945	237.032	207.652	158.655	0.	0.	0.
5500	57.662	238.084	208.196	164.386	0.	0.	0.
5600	58.296	239.129	208.739	170.184	0.	0.	0.
5700	58.846	240.166	209.281	176.042	0.	0.	0.
5800	59.317	241.193	209.822	181.951	0.	0.	0.
5900	59.417	242.171	210.359	187.693	0.	0.	0.
6000	59.709	243.172	210.897	193.650	0.	0.	0.

(A dashed line labelled "— FUGACITY ~ 1 bar" crosses the $\Delta_f H^\circ$, $\Delta_f G^\circ$ and $\log K_f$ columns beginning at 1685.492 K.)

Enthalpy of Formation

The enthalpy of formation is the enthalpy of sublimation, $164.0 \pm 1.7 \ kJ \cdot mol^{-1}$. The adopted value is derived mainly from the boiling point study of Bohdansky and Schins.[1] It is confirmed by the early data of Hartmann and Schneider[2] and by the Knudsen effusion–mass–spectrometric study of Boerboom et al.[4] Data of Ruff and Hartmann[3] are readily dismissed due to the large entropy discrepancy.
A complete reanalysis of all the alkaline earth metals is in progress.

Source	Method	T/K	$\Delta_f H^\circ$(298.15 K), kcal·mol⁻¹ 2nd law	3rd law	δS cal·K⁻¹·mol⁻¹
1	Boiling Point	1218–1982	40.1 ± 0.4	39.16 ± 0.46	0.6 ± 0.3
2	Boiling Point	1200–1380	40.0 ± 0.6	39.46 ± 0.14	0.4 ± 0.4
3	Boiling Point	1218–1412	77 ± 4	38.0 ± 5	29 ± 3
4	Effusion–Mass Spec.	772–923	36.4	39.04 ± 0.39	-3.1
5	Effusion	673–873	35.7 ± 0.5	38.65 ± 0.57	-3.8 ± 0.6

*Temperatures are adjusted to IPTS–68 by assuming published values to be IPTS–48.

Heat Capacity and Entropy

Observed energy levels and quantum weights are from Moore[6] as modified by Garton et al.[7,8] Energies of unobserved but predicted terms[6] are estimated by comparison of Ca I, Sr I, Ba I and their isoelectronic ions. The most important energies are for terms of the 4d5s' configuration which are estimated at 25000 ± 10000 cm⁻¹. We adopt an energy-level cutoff which is about kT_{max} (T_{max}~6000 K) below each series limit. For Sr I this corresponds to omitting levels above 4s, 7p, 6d and 5f. Levels above 30000 cm⁻¹ are averaged. The adopted functions are essentially identical with earlier tables up to 3000 K; however, the entropies at 6000 K differ as follows: Hilsenrath et al.,[9] 57.49; Gurvich et al.,[10] 58.80 cal·K⁻¹·mol⁻¹. These differences arise from different methods of cutoff and different degrees of accounting for the unobserved terms.

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Strontium, Ion (Sr⁺) IDEAL GAS Sr⁺(g)

$M_r = 87.61945$ Strontium, Ion (Sr⁺) Sr⁺(g)

$IP(Sr^+, g) = 88964.0 \pm 0.5 \ cm^{-1}$
$S°(298.15 K) = 170.403 \pm 0.02 \ J \cdot K^{-1} \cdot mol^{-1}$

$\Delta_f H°(0 K) = 713.840 \ kJ \cdot mol^{-1}$
$\Delta_f H°(298.15 K) = [719.666] \ kJ \cdot mol^{-1}$

		Enthalpy Reference Temperature — T_r = 298.15 K				Standard State Pressure — $p° = 0.1$ MPa		
			J·K⁻¹·mol⁻¹			kJ·mol⁻¹		
T/K	$C_p°$	$S°$	$-(G°-H°(T_r))/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	log K_f
0	0.	0.	INFINITE	-6.197	713.840		
100	20.786	147.696	188.884	-4.119			-118.995
200	20.786	162.104	172.305	-2.040			-118.217
250	20.786	166.742	170.745	-1.001			-100.307
298.15	20.786	170.403	170.403	0.	719.666	679.211	-118.995
300	20.786	170.532	170.404	0.038	719.694	678.960	-118.217
350	20.786	173.736	170.657	1.078	720.419	672.113	-100.307
400	20.786	176.512	171.219	2.117	721.122	665.164	-86.861
450	20.786	178.960	171.946	3.156	721.799	658.128	-76.394
500	20.786	181.150	172.759	4.196	722.451	651.018	-68.011
600	20.786	184.940	174.483	6.274	723.678	636.615	-55.422
700	20.786	188.144	176.211	8.353	724.802	622.014	-46.415
800	20.786	190.919	177.880	10.431	725.819	607.259	-39.650
900	20.786	193.368	179.468	12.510	726.102	592.456	-34.385
1000	20.786	195.558	180.969	14.589	727.226	577.546	-30.168
1100	20.786	197.539	182.387	16.667	720.447	562.889	-26.729
1200	20.786	199.347	183.726	18.746	720.658	548.556	-23.878
1300	20.787	201.011	184.992	20.825	720.869	534.206	-21.465
1400	20.789	202.552	186.192	22.903	721.080	519.839	-19.395
1500	20.792	203.986	187.331	24.982	721.291	505.457	-17.602
1600	20.799	205.328	188.415	27.062	721.503	491.061	-16.032
1700	20.811	206.589	189.447	29.142	584.802	477.832	-14.682
1800	20.831	207.780	190.433	31.224	586.876	471.480	-13.682
1900	20.861	208.907	191.376	33.309	588.948	465.012	-12.784
2000	20.904	209.978	192.279	35.397	591.015	458.436	-11.973
2100	20.963	210.999	193.146	37.490	593.075	451.756	-11.237
2200	21.041	211.976	193.980	39.590	595.125	444.978	-10.563
2300	21.140	212.913	194.783	41.699	597.163	438.108	-9.950
2400	21.264	213.815	195.557	43.819	599.182	431.149	-9.384
2500	21.414	214.686	196.305	45.953	601.179	424.107	-8.861
2600	21.590	215.530	197.029	48.103	603.148	416.985	-8.377
2700	21.795	216.348	197.729	50.272	605.082	409.788	-7.928
2800	22.028	217.145	198.408	52.463	606.976	402.520	-7.509
2900	22.290	217.922	199.068	54.678	608.821	395.185	-7.118
3000	22.580	218.683	199.709	56.922	610.611	387.788	-6.752
3100	22.897	219.428	200.333	59.195	612.338	380.332	-6.409
3200	23.239	220.161	200.941	61.502	613.994	372.821	-6.086
3300	23.605	220.881	201.535	63.844	615.574	365.260	-5.782
3400	23.993	221.592	202.114	66.223	617.069	357.652	-5.495
3500	24.400	222.293	202.681	68.643	618.474	350.001	-5.223
3600	24.824	222.986	203.235	71.104	619.782	342.312	-4.967
3700	25.263	223.672	203.778	73.608	620.990	334.587	-4.724
3800	25.714	224.352	204.311	76.157	622.093	326.632	-4.493
3900	26.174	225.026	204.833	78.751	623.087	319.048	-4.273
4000	26.640	225.694	205.346	81.392	623.971	311.241	-4.064
4100	27.110	226.358	205.851	84.079	624.744	303.413	-3.866
4200	27.581	227.017	206.347	86.814	625.408	295.567	-3.676
4300	28.051	227.672	206.835	89.596	625.959	287.707	-3.495
4400	28.517	228.322	207.316	92.424	626.401	279.835	-3.322
4500	28.976	228.968	207.790	95.299	626.737	271.955	-3.157
4600	29.428	229.610	208.258	98.219	627.035	264.063	-2.999
4700	29.869	230.247	208.719	101.184	627.188	256.171	-2.847
4800	30.299	230.881	209.174	104.193	627.252	248.276	-2.702
4900	30.715	231.510	209.623	107.243	627.231	240.380	-2.562
5000	31.115	232.134	210.067	110.335	627.137	232.486	-2.429
5100	31.500	232.754	210.506	113.466	626.991	224.592	-2.300
5200	31.868	233.369	210.940	116.634	626.761	216.704	-2.177
5300	32.217	233.980	211.369	119.839	626.474	208.821	-2.058
5400	32.548	234.585	211.793	123.077	626.136	200.944	-1.944
5500	32.859	235.185	212.213	126.348	625.754	193.074	-1.834
5600	33.151	235.780	212.628	129.648	625.335	185.210	-1.728
5700	33.423	236.369	213.040	132.977	624.884	177.355	-1.625
5800	33.675	236.953	213.447	136.332	624.409	169.508	-1.527
5900	33.908	237.530	213.850	139.712	624.125	161.645	-1.431
6000	34.121	238.102	214.250	143.113	623.649	153.810	-1.339

CURRENT. September 1983 (1 bar)

Electronic Levels and Quantum Weights

State	ϵ_i, cm⁻¹	g_i
$^2S_{1/2}$	0.00	2
$^2D_{3/2}$	14555.90	4
$^2D_{5/2}$	14836.24	6
$^2P_{1/2}$	23715.19	2
$^2P_{3/2}$	24516.65	4
$^2S_{1/2}$	47736.53	2

Enthalpy of Formation

$\Delta_f H°(Sr^+, g, 0 K)$ is calculated from $\Delta_f H°(Sr, g, 0 K)[1]$ using the spectroscopic value of $IP(Sr) = 45932.0 \pm 0.2 \ cm^{-1}$ $(549.469 \pm 0.002 \ kJ \cdot mol^{-1})$ from Moore.[2] The ionization limit is converted from cm⁻¹ to kJ·mol⁻¹ using the factor, $1 \ cm^{-1} = 0.01196266 \ kJ \cdot mol^{-1}$, 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.

$\Delta_f H°(Sr^+, g, 298.15 K)$ is calculated from $\Delta_f H°(Sr, g, 0 K)$ by using $IP(Sr)$ with JANAF[1] enthalpies, $H°(0 K)-H°(298.15 K)$, for Sr(g), Sr⁺(g), and e⁻(ref). $\Delta_f H°(Sr \rightarrow Sr^+ + e^-, 298.15 K)$ 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 $-6.197 \ kJ \cdot mol^{-1}$ 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 Moore,[2] is incomplete because many theoretically predicted levels have not been observed. Our calculations indicate that any reasonable method of filling in these missing levels and cutting off the summation in the partition function[7] has as no effect on the thermodynamic functions to 6000 K. This is a result of the high energy of all levels other than the ground state and the levels listed above; the next excited state is approximately 53286 cm⁻¹ above the ground state. Since inclusion of these higher excited states have little effect on the thermodynamic functions (to 6000 K), we list only the ground state and the first four excited states. 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 excited states and use of different fill and cutoff procedures.[7]

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