REFERENCE STATE

0	to	980 K	crystal, alpha
980	to	1360 K	crystal, beta
1360	to	1410 K	crystal, gamma
1410	to	1517 K	crystal, delta
1517	to	2335 K	liquid
2335	to	6000 K	ideal gas, monatomic

Refer to the individual tables for details.

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°	$-[G^\circ-H^\circ(T_r)]/T$	$H^\circ-H^\circ(T_r)$	$\Delta_f H^\circ$	$\Delta_f G^\circ$	log K_f
0	0.	0.	INFINITE	−4.994	0.	0.	0.
100	14.723	8.875	52.876	−4.400	0.	0.	0.
200	23.054	22.133	34.325	−2.438	0.	0.	0.
298.15	26.299	32.010	32.010	0.	0.	0.	0.
300	26.347	32.173	32.010	0.049	0.	0.	0.
400	28.527	40.066	33.072	2.798	0.	0.	0.
500	30.292	46.696	35.152	5.772	0.	0.	0.
600	31.899	52.362	37.559	8.882	0.	0.	0.
700	33.426	57.395	40.039	12.149	0.	0.	0.
800	34.915	61.956	42.498	15.566	0.	0.	0.
900	36.384	66.153	44.896	19.131	0.	0.	0.
980.000	37.545	69.300	46.761	22.088	ALPHA <--> BETA TRANSITION		
980.000	37.572	71.572	46.761	24.314			
1000	37.698	72.332	47.265	25.067	0.	0.	0.
1100	38.116	75.945	49.710	28.858	0.	0.	0.
1200	38.535	79.279	52.037	32.690	0.	0.	0.
1300	38.953	82.380	54.253	36.565	0.	0.	0.
1361.000	39.204	84.172	55.554	38.948	BETA <--> GAMMA TRANSITION		
1361.000	43.095	85.731	55.554	41.070			
1400	43.430	86.953	56.412	42.757	0.	0.	0.
1412.000	43.514	87.324	56.673	43.279	GAMMA <--> DELTA TRANSITION		
1412.000	45.229	88.655	56.673	45.158			
1500	45.982	91.413	58.631	49.173	0.	0.	0.
1519.000	46.108	91.993	59.045	50.048	DELTA <--> LIQUID TRANSITION		
1519.000	46.024	99.931	59.045	62.106			
1600	46.024	102.322	61.176	65.834	0.	0.	0.
1700	46.024	105.112	63.679	70.436	0.	0.	0.
1800	46.024	107.743	66.055	75.039	0.	0.	0.
1900	46.024	110.231	68.315	79.641	0.	0.	0.
2000	46.024	112.592	70.470	84.244	0.	0.	0.
2100	46.024	114.837	72.530	88.846	0.	0.	0.
2200	46.024	116.978	74.502	93.448	0.	0.	0.
2300	46.024	119.024	76.393	98.051	0.	0.	0.
2334.526	46.024	119.710	77.029	99.640	LIQUID <--> IDEAL GAS FUGACITY = 1 bar		
2334.526	20.951	216.509	77.029	325.620			
2400	20.997	217.089	80.842	326.993	0.	0.	0.
2500	21.085	217.948	86.309	329.097	0.	0.	0.
2600	21.198	218.777	91.388	331.211	0.	0.	0.
2700	21.341	219.580	96.121	333.338	0.	0.	0.
2800	21.515	220.359	100.545	335.480	0.	0.	0.
2900	21.726	221.118	104.689	337.642	0.	0.	0.
3000	21.976	221.858	108.583	339.827	0.	0.	0.
3100	22.269	222.583	112.248	342.039	0.	0.	0.
3200	22.606	223.296	115.708	344.282	0.	0.	0.
3300	22.990	223.997	118.978	346.561	0.	0.	0.
3400	23.424	224.690	122.077	348.882	0.	0.	0.
3500	23.909	225.376	125.019	351.248	0.	0.	0.
3600	24.445	226.056	127.816	353.665	0.	0.	0.
3700	25.034	226.734	130.480	356.139	0.	0.	0.
3800	25.675	227.410	133.022	358.674	0.	0.	0.
3900	26.370	228.086	135.451	361.275	0.	0.	0.
4000	27.118	228.763	137.776	363.949	0.	0.	0.
4200	28.772	230.125	142.141	369.535	0.	0.	0.
4400	30.635	231.506	146.171	375.472	0.	0.	0.
4600	32.606	232.907	149.912	381.777	0.	0.	0.
4800	34.798	234.340	153.399	388.514	0.	0.	0.
5000	37.153	235.808	156.666	395.707	0.	0.	0.
5200	39.664	237.313	159.739	403.386	0.	0.	0.
5400	42.327	238.860	162.641	411.582	0.	0.	0.
5600	43.514	240.321	165.382	419.658	0.	0.	0.
5800	45.714	241.887	167.993	428.580	0.	0.	0.
6000	47.832	243.472	170.483	437.936	0.	0.	0.

PREVIOUS: CURRENT: September 1967 (1 bar)

$S°(298.15\ K) = 32.01 \pm 0.08\ J·K^{-1}·mol^{-1}$
$T_{trs}\ (\alpha \rightarrow \beta) = 980 \pm 20\ K$
$T_{trs}(\beta \rightarrow \gamma) = 1361 \pm 10\ K$
$T_{trs}(\gamma–\delta) = 1412 \pm 5\ K$
$T_{fus}(\delta–l) = 1519 \pm 5\ K$

$\Delta_f H°(0\ K) = 0\ kJ·mol^{-1}$
$\Delta_f H°(298.15\ K) = 0\ kJ·mol^{-1}$
$\Delta_{trs}H°(\alpha \rightarrow \beta) = 2.226 \pm 0.21\ kJ·mol^{-1}$
$\Delta_{trs}H°(\beta \rightarrow \gamma) = 2.122 \pm 0.33\ kJ·mol^{-1}$
$\Delta_{trs}H°(\gamma \rightarrow \delta) = 1.879 \pm 0.33\ kJ·mol^{-1}$
$\Delta_{fus}H°(\delta \rightarrow l) = 12.058 \pm 1.0\ kJ·mol^{-1}$

Enthalpy of Formation

Zero by definition.

Heat Capacity and Entropy

A thorough re examination of the manganese thermal functions is in process. Temporarily, the recommendations of Hultgren *et al.*[1] are adotped. These results are based on the heat capacity studies of Scurlock and Stevens (0.3–1 0 K),[2] Gaumer (0.64–3 K),[3] Guthrie *et al.* (1.7–4.2 K),[4] Booth *et al.* (12–20 K),[5] Kelley (52–298 K),[6] and Shomate (52–298 K),[7] and the enthalpy study of Naylor (373–1436 K).[8] As Hultgren *et al.*[1] states, the study of Naylor was chosen because it covers all forms of Mn in a self consistant manner. It is not stated why Hultgren, *et al.*[1] altered Naylor's equations,[8] which appear more appropriate than the current values.

Phase and Fusion Data

As we are temporarily adopting the analysis of Hultgren, *et al.*,[1] we rely on his analysis of the transition and fusion temperatures. Ten studies are analyzed by Hultgren *et al.*[1] The temperatures were adjusted to IPTS–68.

Sublimation Data

Refer to the ideal gas table for details.

References

[1]R. Hultgren, P. D. Desai, *et al.*, "Selected Values of the Thermodynamic Properties of the Elements," American Society for Metals," Metals Park, Ohio, (1973).
[2]R. G. Scurlock and W. N. R. Stevens, Proc. Phys. Soc. **86**, 331 (1965).
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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	−4.994	0.	0.	0.
100	14.723	8.875	52.876	−4.400	0.	0.	0.
200	23.054	22.133	34.325	−2.438	0.	0.	0.
250	24.948	27.493	32.436	−1.236	0.	0.	0.
298.15	26.299	32.010	32.010	0.	0.	0.	0.
300	26.347	32.173	32.010	0.049	0.	0.	0.
350	27.516	36.325	32.336	1.396	0.	0.	0.
400	28.527	40.066	33.072	2.798	0.	0.	0.
450	30.020	43.524	34.043	4.266	0.	0.	0.
500	30.292	46.696	35.152	5.772	0.	0.	0.
600	31.899	52.362	37.559	8.882	0.	0.	0.
700	33.426	57.395	40.039	12.149	0.	0.	0.
800	34.915	61.956	42.498	15.566	0.	0.	0.
900	36.384	66.153	44.896	19.131	0.	0.	0.
980.000	37.545	69.300	46.761	22.088	ALPHA <--> BETA TRANSITION		
980.000	37.572	71.572	46.761	24.314			
1000	37.698	72.332	47.265	25.067	0.	0.	0.
1100	38.116	75.945	49.710	28.858	0.	0.	0.
1200	38.535	79.279	52.037	32.690	0.	0.	0.
1300	38.953	82.380	54.253	36.565	0.	0.	0.
1361.000	39.204	84.172	55.554	38.948	BETA <--> GAMMA TRANSITION		
1361.000	43.095	85.731	55.554	41.070			
1400	43.430	86.953	56.412	42.757	0.	0.	0.
1412.000	43.514	87.324	56.673	43.279	GAMMA <--> DELTA TRANSITION		
1412.000	45.229	88.655	56.673	45.158			
1500	45.982	91.413	58.631	49.173	0.	0.	0.
1519.000	46.108	91.993	59.045	50.048	--- DELTA <--> LIQUID ---		
1600	46.803	94.406	60.774	53.811	−12.023	0.642	−0.021
1700	47.624	97.268	62.837	58.532	−11.904	1.431	−0.044
1800	48.446	100.013	64.827	63.336	−11.703	2.210	−0 064
1900	49.267	102.655	66.749	68.221	−11.420	2.975	−0.082

PREVIOUS: CURRENT: September 1967

$S°(298.15\ K) = [43.499]\ J·K^{-1}·mol^{-1}$
$T_{fus} = 1519 \pm 5\ K$

$\Delta_f H°(298.15\ K) = [16.289]\ kJ·mol^{-1}$
$\Delta_{fus} H° = 12.058 \pm 1.0\ kJ·mol^{-1}$

Enthalpy of Formation

The enthalpy of formation of Mn(l), $\Delta_f H°(298.15\ K)$ is calculated from that of the crystal by adding $\Delta_{fus} H°$ and the difference in enthalpy, $H°(1519\ K)–H°(298.15\ K)$, between the crystal and liquid.

Heat Capacity and Entropy

Hultgren[1] adopted $C_p°(l) = 11.0\ cal·K^{-1}·mol^{-1}$ based on the recommendation of Kelly.[2] A glass transition temperature is assumed at 1125 K, below which the heat capacity values of α–Mn(cr) are adopted. a re–examination of Mn(l) is in progress. The entropy at 298.15 K is calculated in a manner analogous to that used for the enthalpy of formation.

Vaporization Data

T_{vap}(1 bar) is calculated as the temperature at which $\Delta_r G° = 0$ for the process Mn(l) = Mn(g). $\Delta_{vap} H°$ is calculated as the difference in the enthalpies of formation of Mn(l) and Mn(g) at T_{vap}.

References

[1]R. Hultgren, P. D. Desai, *et al.*, "Selected Values of the Thermodynamic Properties of the Elements," American Society for Metals, Metals Park, Ohio, (1973).
[2]K. K. Kelley, U. S. Bur. Mines Bull. 584, 232 pp. (1960).

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							
100							
200							
250							
298.15	26.299	43.499	43.499	0.	16.289	12.863	−2.254
300	26.347	43.662	43.500	0.049	16.289	12.842	−2.236
350	27.516	47.814	43.825	1.396	16.289	12.267	−1.831
400	28.527	51.555	44.561	2.798	16.289	11.693	−1.527
450	30.020	55.013	45.533	4.266	16.289	11.118	−1.291
500	30.292	58.185	46.642	5.772	16.289	10.544	−1.102
600	31.899	63.852	49.048	8.882	16.289	9.395	−0.818
700	33.426	68.884	51.529	12.149	16.289	8.246	−0.615
800	34.915	73.445	53.988	15.566	16.289	7.097	−0.463
900	36.384	77.643	56.386	19.131	16.289	5.948	−0.345
1000	37.834	81.551	58.709	22.842	14.064	4.845	−0.253
1100	39.275	85.225	60.954	26.698	14.129	3.921	−0.186
1125.000	39.634	86.111	61.503	27.684	GLASS <--> LIQUID		
1125.000	46.024	86.111	61.503	27.684	TRANSITION		
1200	46.024	89.082	63.135	31.136	14.734	2.971	−0.129
1300	46.024	92.766	65.275	35.738	15.462	1.961	−0.079
1400	46.024	96.176	67.362	40.341	13.872	0.960	−0.036
1500	46.024	99.352	69.390	44.943	12.059	0.151	−0.005
1519.000	46.024	99.931	69.768	45.817	DELTA <--> LIQUID		
1600	46.024	102.322	71.356	49.545	0.	0.	0.
1700	46.024	105.112	73.260	54.148	0.	0.	0.
1800	46.024	107.743	75.104	58.750	0.	0.	0.
1900	46.024	110.231	76.888	63.353	0.	0.	0.
2000	46.024	112.592	78.614	67.955	0.	0.	0.
2100	46.024	114.837	80.286	72.557	0.	0.	0.
2200	46.024	116.978	81.906	77.160	0.	0.	0.
2300	46.024	119.024	83.476	81.762	0.	0.	0.
2334.526	46.024	119.710	84.006	83.351	FUGACITY = 1 bar		
2400	46.024	120.983	84.998	86.365	−224.340	6.315	−0.137
2500	46.024	122.862	86.475	90.967	−221.841	15.874	−0.332
2600	46.024	124.667	87.909	95.569	−219.353	25.334	−0.509
2700	46.024	126.404	89.303	100.172	−216.877	34.698	−0.671
2800	46.024	128.078	90.658	104.774	−214.417	43.970	−0.820
2900	46.024	129.693	91.977	109.377	−211.977	53.155	−0.957
3000	46.024	131.253	93.260	113.979	−209.559	62.256	−1.084

PREVIOUS: CURRENT: September 1967

CRYSTAL(α, β, γ, δ)–LIQUID

0	to	980 K	crystal, alpha
980	to	1361 K	crystal, beta
1361	to	1412 K	crystal, gamma
1412	to	1519 K	crystal, delta
above		1519 K	liquid

Refer to the individual tables for details.

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

	J·K⁻¹mol⁻¹			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
0	0.	0.	INFINITE	−4.994	0.	0.	0.
100	14.723	8.875	52.876	−4.400	0.	0.	0.
200	23.054	22.133	34.325	−2.438	0.	0.	0.
250	24.948	27.493	32.436	−1.236	0.	0.	0.
298.15	26.299	32.010	32.010	0.	0.	0.	0.
300	26.347	32.173	32.010	0.049	0.	0.	0.
350	27.516	36.325	32.336	1.396	0.	0.	0.
400	28.527	40.066	33.072	2.798	0.	0.	0.
450	30.020	43.524	34.043	4.266	0.	0.	0.
500	30.292	46.696	35.152	5.772	0.	0.	0.
600	31.899	52.362	37.559	8.882	0.	0.	0.
700	33.426	57.395	40.039	12.149	0.	0.	0.
800	34.915	61.956	42.498	15.566	0.	0.	0.
900	36.384	66.153	44.896	19.131	0.	0.	0.
980.000	37.545	69.300	46.761	22.088	ALPHA <--> BETA TRANSITION		
980.000	37.572	71.572	46.761	24.314			
1000	37.698	72.332	47.265	25.067	0.	0.	0.
1100	38.116	75.945	49.710	28.858	0.	0.	0.
1200	38.535	79.279	52.037	32.690	0.	0.	0.
1300	38.953	82.380	54.253	36.565	0.	0.	0.
1361.000	39.204	84.172	55.554	38.948	BETA <--> GAMMA TRANSITION		
1361.000	43 095	85.731	55.554	41.070			
1400	43.430	86.953	56.412	42.757	0.	0.	0.
1412.000	43.514	87.324	56.673	43.279	GAMMA <--> DELTA TRANSITION		
1412.000	45.229	88.655	56.673	45.158			
1500	45.982	91.413	58.631	49.173	0.	0.	0.
1519.000	46.108	91.993	59.045	50.048	DELTA <--> LIQUID TRANSITION		
1519 000	46.024	99.931	59.045	62.106			
1600	46.024	102.322	61.176	65.834	0.	0.	0.
1700	46.024	105.112	63.679	70.436	0.	0.	0.
1800	46.024	107.743	66.055	75.039	0.	0.	0.
1900	46.024	110.231	68.315	79.641	0.	0.	0.
2000	46.024	112.592	70.470	84.244	0.	0.	0.
2100	46.024	114.837	72.530	88.846	0.	0.	0.
2200	46.024	116.978	74.502	93.448	0.	0.	0.
2300	46.024	119.024	76.393	98.051	0.	0.	0.
2334.526	46.024	119.710	77.029	99.640	----- FUGACITY = 1 bar -----		
2400	46.024	120.983	78.211	102.653	−224.340	6.315	−0.137
2500	46.024	122.862	79.960	107.256	−221.841	15.874	−0.332
2600	46.024	124.667	81.645	111.858	−219.353	25.334	−0.509
2700	46.024	126.404	83.270	116.460	−216.877	34.698	−0.671
2800	46.024	128.078	84.841	121.063	−214.417	43.970	−0.820
2900	46.024	129.693	86.360	125.665	−211.977	53.155	−0.957
3000	46.024	131.253	87.830	130.268	−209.559	62.256	−1.084

PREVIOUS: CURRENT September 1967

IP (Mn, g) = 59981 ± 1 cm^{-1}
$S°(298.15\ K)$ = 173.716 $J·K^{-1}·mol^{-1}$

$\Delta_f H°(0\ K)$ = 282.1 ± 4.2 $kJ·mol^{-1}$
$\Delta_f H°$ = (298.15 K) = 283.3 ± 4.2 $kJ·mol^{-1}$

Electronic Levels and Quantum Weights		
State	ϵ_i, cm^{-1}	g_i
$^6S_{5/2}$	0.00	6
$^6D_{9/2}$	17052.29	10
$^6D_{7/2}$	17282.00	8
$^6D_{5/2}$	17451.52	6
$^6D_{3/2}$	17568.48	4
$^6D_{1/2}$	17637.15	2

Enthalpy of Formation

The value adopted for the enthalpy of formation of Mn(g), $\Delta_f H°(298.15\ K)$ = 283.3 ± 4.2 $kJ·mol^{-1}$, is that recommended by Hultgren *et al.*[1] This value is a weighted mean of sublimation and vaporization studies. The studies are Bogatyrev and Golubtsov (1043–1168 K),[2] Pratt and Spencer (1248–1620 K),[3] Wiedemeier (1269–1448 K),[4] Butler *et al.* (1075–1335 K),[5] Woolf, *et al.* (1523–1823 K),[6] McCabe and Hudson (1075–1235 K),[7] and Baur and Brunner (1587–1987 K).[8]

A reanalysis of the vapor pressure data is in progress.

Heat Capacity and Entropy

The information on electronic energy levels and quantum weights, given by Corliss and Sugar,[9] is incomplete because many theoretically predicted levels have not been observed. Although we have listed only a few of the lowest lying levels for Mn(g), all levels listed by Corliss and Sugar,[9] as well as estimated levels, are used in the calculation. The observed levels are too numerous to list completely. The calculations indicate that for Mn(g), the thermodynamic functions are independent of the estimated missing levels (for n = 4–8), the cut-off procedure, and the inclusion of n<9 levels up to 4000 K; the Gibbs energy function showing no significant variations 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>8), and use of different fill and cut-off procedures.[10]

References

[1] R. Hultgren, P. D. Desai, *et al.*, "Selected Values for Thermodynamic Properties of Metals," American Society of Metals, Metals Park, Ohio, (1973).
[2] V. L. Bogatyrev and I. V. Golubtsev, Zh. Fiz. Khim. **40**, 938 (1966).
[3] J. N. Pratt and P. J. Spencer, Q.T.S.R. No. 1, U.S. Dept. of the Army, Contract No. DA-91-591-EVC-3762, (1966).
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[5] J. F. Butler, C. L. McCabe, and H. W. Paxton, Trans. AIME **221**, 479 (1961).
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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	282.053	282.053	INFINITE
100	20.786	151.009	192.196	−4.119	283.538	269.325	−140.681
200	20.786	165.416	175.617	−2.040	283.655	254.998	−66.599
250	20.786	170.055	174.058	−1.001	283.492	247.851	−51.786
298.15	20.786	173.716	173.716	0.	283.257	241.007	−42.223
300	20.786	173.844	173.716	0.038	283.247	240.745	−41.917
350	20.786	177.049	173.969	1.078	282.938	233.685	−34.876
400	20.786	179.824	174.532	2.117	282.576	226.673	−29.600
450	20.786	182.272	175.258	3.156	282.147	219.710	−25.503
500	20.786	184.462	176.071	4.196	281.681	212.797	−22.231
600	20.786	188.252	177.795	6.274	280.649	199.115	−17.335
700	20.786	191.456	179.524	8.353	279.461	185.618	−13.851
800	20.786	194.232	181.193	10.431	278.122	172.301	−11.250
900	20.786	196.680	182.780	12.510	276.636	159.161	−9.237
1000	20.786	198.870	184.282	14.589	272.778	146.240	−7.639
1100	20.786	200.851	185.699	16.667	271.066	133.669	−6.347
1200	20.786	202.660	187.038	18.746	269.312	121.255	−5.278
1300	20.786	204.324	188.305	20.824	267.517	108.990	−4.379
1400	20.786	205.864	189.505	22.903	263.403	96.927	−3.616
1500	20.787	207.298	190.644	24.982	259.066	85.238	−2.968
1600	20.788	208.640	191.727	27.061	244.483	74.375	−2.428
1700	20.791	209.900	192.759	29.139	241.960	63.820	−1.961
1800	20.797	211.089	193.745	31.219	239.437	53.414	−1.550
1900	20.806	212.213	194.688	33.299	236.914	43.148	−1.186
2000	20.822	213.281	195.591	35.380	234.393	33.015	−0.862
2100	20.845	214.297	196.458	37.464	231.874	23.008	−0.572
2200	20.880	215.268	197.291	39.550	229.358	13.121	−0.312
2300	20.930	216.197	198.093	41.640	226.846	3.348	−0.076
2334.526	20.951	216.509	198.363	42.363	----- FUGACITY = 1 bar -----		
2400	20.997	217.089	198.866	43.736	0.	0.	0.
2500	21.085	217.948	199.612	45.840	0.	0.	0.
2600	21.198	218.777	200.333	47.954	0.	0.	0.
2700	21.341	219.580	201.031	50.081	0.	0.	0.
2800	21.515	220.359	201.708	52.223	0.	0.	0.
2900	21.726	221.118	202.364	54.385	0.	0.	0.
3000	21.976	221.858	203.002	56.570	0.	0.	0.
3100	22.269	222.583	203.622	58.782	0.	0.	0.
3200	22.606	223.296	204.225	61.025	0.	0.	0.
3300	22.990	223.997	204.814	63.305	0.	0.	0.
3400	23.424	224.690	205.388	65.625	0.	0.	0.
3500	23.909	225.376	205.950	67.991	0.	0.	0.
3600	24.445	226.056	206.499	70.408	0.	0.	0.
3700	25.034	226.734	207.036	72.882	0.	0.	0.
3800	25.675	227.410	207.564	75.417	0.	0.	0.
3900	26.370	228.086	208.081	78.019	0.	0.	0.
4000	27.118	228.763	208.590	80.693	0.	0.	0.
4100	27.919	229.442	209.090	83.444	0.	0.	0.
4200	28.772	230.125	209.583	86.278	0.	0.	0.
4300	29.678	230.813	210.068	89.200	0.	0.	0.
4400	30.635	231.506	210.548	92.216	0.	0.	0.
4500	31.574	232.201	211.021	95.311	0.	0.	0.
4600	32.606	232.907	211.489	98.520	0.	0.	0.
4700	33.681	233.619	211.952	101.834	0.	0.	0.
4800	34.798	234.340	212.411	105.258	0.	0.	0.
4900	35.956	235.069	212.866	108.795	0.	0.	0.
5000	37.153	235.808	213.318	112.450	0.	0.	0.
5100	38.389	236.556	213.766	116.227	0.	0.	0.
5200	39.664	237.313	214.211	120.129	0.	0.	0.
5300	40.976	238.081	214.655	124.161	0.	0.	0.
5400	42.327	238.860	215.096	128.325	0.	0.	0.
5500	43.716	239.649	215.535	132.627	0.	0.	0.
5600	43.514	240.321	215.964	136.401	0.	0.	0.
5700	44.624	241.101	216.398	140.808	0.	0.	0.
5800	45.714	241.887	216.831	145.324	0.	0.	0.
5900	46.784	242.677	217.262	149.948	0.	0.	0.
6000	47.832	243.472	217.692	154.679	0.	0.	0.

PREVIOUS: CURRENT: June 1984 (1 bar)

Manganese, Ion (Mn^+) IDEAL GAS M_r = 54.93745 Manganese, Ion (Mn^+) $Mn^+(g)$

$IP(Mn^+, g) = 126145.0 \pm 0.6\ cm^{-1}$
$S°(298.15\ K) = 174.997 \pm 0.05\ J\ K^{-1}\cdot mol^{-1}$

$\Delta_f H°(0\ K) = 999.6 \pm 0.5\ kJ\cdot mol^{-1}$
$\Delta_f H°(298.15\ K) = [10006.986]\ kJ\cdot mol^{-1}$

Electronic Level and Quantum Weights		
State	ϵ_i, cm^{-1}	g_i
$^7S_3$	0.00	7
$^5S_2$	9472.97	5
$^5D_4$	14325.86	9
.	.	.
.	.	.
.	.	.
$^7H_8$	120721.9	17
IP	126145.0	

Enthalpy of Formation

$\Delta_f H°(Mn^+, g, 0\ K)$ is calculated from $\Delta_f H°(Mn, g, 0\ K)$[1] using the spectroscopic value of IP(Mn) = 59981 ± 1 cm^{-1} (717.532 ± 0.012 mol^{-1}) from Corliss and Sugar.[2] The ionization limit is converted from cm^{-1} to $kJ\cdot mol^{-1}$ 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.

$\Delta_f H°(Mn^+, g, 298.15\ K)$ is calculated from $\Delta_f H°(Mn, g, 0\ K)$ by using IP(Mn) with JANAF[1] enthalpies, $H°(0\ K)-H°(298.15\ K)$, for Mn(g), $Mn^+(g)$, and e^-(ref). $\Delta_f H°(Mn \rightarrow Mn^+ + e^-, 298.15\ K)$ 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 Corliss and Sugar,[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 $Mn^+(g)$, all levels listed by Corliss and Sugar,[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 $Mn^+(g)$, the thermodynamic functions are independent of the estimated missing levels (for n = 4–7), the cut-off procedure, and the inclusion of n<8 levels up to 6000 K; the Gibbs energy function showing no significant variations 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>7), and use of different fill and cut-off procedures.[6]

References

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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	−6.197	999.586		
100	20.786	152.290	193.478	−4.119			
200	20.786	166.698	176.899	−2.040			
250	20.786	171.336	175.340	−1.001			
298.15	20.786	174.997	174.997	0.	1006.986	958.100	−167.855
300	20.786	175.126	174.998	0.038	1007.015	957.797	−166.767
350	20.786	178.330	175.251	1.078	1007.746	949.535	−141.710
400	20.786	181.106	175.813	2.117	1008.423	941.172	−122.904
450	20.786	183.554	176.540	3.156	1009.033	932.728	−108.268
500	20.786	185.744	177.353	4.196	1009.606	924.219	−96.553
600	20.786	189.534	179.077	6.274	1010.653	907.041	−78.965
700	20.786	192.738	180.805	8.353	1011.543	889.700	−66.390
800	20.786	195.514	182.474	10.431	1012.283	872.241	−56.952
900	20.786	197.962	184.062	12.510	1012.875	854.699	−49.605
1000	20.787	200.152	185.563	14.589	1011.097	837.144	−43.728
1100	20.790	202.133	186.981	16.668	1011.464	819.731	−38.926
1200	20.795	203.942	188.320	18.747	1011.789	802.286	−34.923
1300	20.805	205.607	189.587	20.827	1012.073	784.815	−31.534
1400	20.821	207.150	190.787	22.908	1010.040	767.387	−28.632
1500	20.846	208.587	191.926	24.991	1007.787	750.184	−26.124
1600	20.882	209.933	193.010	27.078	995.290	733.668	−23.952
1700	20.932	211.201	194.043	29.168	994.857	717.330	−22.041
1800	20.996	212.399	195.030	31.265	994.430	701.017	−20.343
1900	21.078	213.536	195.974	33.368	994.009	684.728	−18.824
2000	21.179	214.620	196.880	35.481	993.598	668.461	−17.458
2100	21.301	215.656	197.749	37.605	993.198	652.214	−16.223
2200	21.445	216.650	198.586	39.742	992.812	635.985	−15.100
2300	21.611	217.607	199.392	41.894	992.440	619.774	−14.076
2400	21.800	218.531	200.171	44.065	767.747	609.894	−13.274
2500	22.011	219.425	200.923	46.255	769.912	603.272	−12.605
2600	22.246	220.293	201.651	48.468	772.090	596.564	−11.985
2700	22.503	221.137	202.357	50.705	774.279	589.771	−11.410
2800	22.782	221.960	203.043	52.969	776.479	582.898	−10.874
2900	23.080	222.765	203.709	55.262	778.689	575.945	−10.374
3000	23.398	223.553	204.358	57.586	780.906	568.916	−9.906
3100	23.735	224.325	204.989	59.942	783.130	561.813	−9.466
3200	24.088	225.085	205.605	62.333	785.356	554.638	−9.054
3300	24.457	225.831	206.207	64.761	787.582	547.394	−8.665
3400	24.841	226.567	206.795	67.225	789.805	540.082	−8.297
3500	25.238	227.293	207.370	69.729	792.021	532.705	−7.950
3600	25.648	228.010	207.934	72.273	794.227	525.265	−7.621
3700	26.070	228.718	208.486	74.859	796.418	517.763	−7.310
3800	26.504	229.419	209.028	77.488	798.590	510.203	−7.013
3900	26.948	230.113	209.559	80.160	800.739	502.586	−6.731
4000	27.402	230.801	210.082	82.878	802.861	494.914	−6.463
4100	27.866	231.484	210.595	85.641	804.952	487.189	−6.207
4200	28.341	232.161	211.101	88.451	807.007	479.414	−5.962
4300	28.825	232.833	211.598	91.310	809.021	471.590	−5.729
4400	29.319	233.502	212.089	94.217	810.992	463.720	−5.505
4500	29.822	234.166	212.572	97.174	812.932	455.805	−5.291
4600	30.336	234.827	213.049	100.181	814.809	447.848	−5.085
4700	30.859	235.485	213.519	103.241	816.634	439.851	−4.888
4800	31.391	236.140	213.983	106.354	818.401	431.815	−4.699
4900	31.934	236.793	214.442	109.520	820.108	423.744	−4.517
5000	32.485	237.444	214.896	112.741	821.753	415.638	−4.342
5100	33.046	238.093	215.344	116.017	823.331	407.500	−4.174
5200	33.616	238.740	215.788	119.350	824.841	399.331	−4.011
5300	34.195	239.386	216.227	122.741	826.278	391.135	−3.855
5400	34.781	240.030	216.662	126.189	827.641	382.911	−3.704
5500	35.375	240.674	217.093	129.697	828.926	374.664	−3.558
5600	35.976	241.317	217.520	133.265	830.798	366.345	−3.417
5700	36.583	241.959	217.943	136.893	832.097	358.040	−3.281
5800	37.195	242.600	218.362	140.581	833.349	349.712	−3.149
5900	37.810	243.241	218.778	144.332	834.553	341.363	−3.022
6000	38.429	243.882	219.192	148.144	835.713	332.994	−2.899

PREVIOUS: CURRENT: June 1984 (1 bar)