Rubidium (Rb)

Rb₁(ref)

$A_r = 85.4678$ Rubidium (Rb)

REFERENCE STATE

0	to	312.65 K crystal
312.5	to	970.385 K liquid
above		970.385 K ideal monatomic gas

Refer to the individual tables for details.

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	-7.490	0.	0.	0.
100	25.510	47.022	101.811	-5.479	0.	0.	0.
200	27.447	65.316	79.458	-2.828	0.	0.	0.
298.15	31.062	76.778	76.778	0.	0.	0.	0.
300	31.188	76.971	76.779	0.058	0.	0.	0.
312.650	32.401	78.284	76.813	0.460			
312.650	32.307	85.300	76.813	2.653	CRYSTAL <--> LIQUID TRANSITION		
400	31.715	93.188	79.566	5.449	0.	0.	0.
500	31.197	100.207	83.020	8.593	0.	0.	0.
600	30.850	105.861	86.371	11.694	0.	0.	0.
700	30.674	110.601	89.503	14.769	0.	0.	0.
800	30.669	114.695	92.402	17.835	0.	0.	0.
900	30.835	118.315	95.084	20.908	0.	0.	0.
970.385	31.053	120.645	96.854	23.086			
970.385	20.786	194.623	96.854	94.873	LIQUID <--> IDEAL GAS FUGACITY = 1 bar		
1000	20.786	195.248	99.759	95.489	0.	0.	0.
1100	20.786	197.229	108.531	97.567	0.	0.	0.
1200	20.787	199.037	115.999	99.646	0.	0.	0.
1300	20.790	200.701	122.452	101.725	0.	0.	0.
1400	20.795	202.242	128.097	103.804	0.	0.	0.
1500	20.805	203.677	133.088	105.884	0.	0.	0.
1600	20.821	205.020	137.542	107.965	0.	0.	0.
1700	20.847	206.283	141.549	110.048	0.	0.	0.
1800	20.886	207.476	145.179	112.135	0.	0.	0.
1900	20.941	208.607	148.488	114.226	0.	0.	0.
2000	21.015	209.683	151.521	116.324	0.	0.	0.
2100	21.110	210.710	154.315	118.430	0.	0.	0.
2200	21.231	211.695	156.901	120.547	0.	0.	0.
2300	21.379	212.642	159.304	122.677	0.	0.	0.
2400	21.558	213.555	161.546	124.824	0.	0.	0.
2500	21.769	214.439	163.644	126.989	0.	0.	0.
2600	22.016	215.298	165.614	129.178	0.	0.	0.
2700	22.294	216.134	167.470	131.393	0.	0.	0.
2800	22.616	216.950	169.222	133.638	0.	0.	0.
2900	22.980	217.750	170.882	135.917	0.	0.	0.
3000	23.389	218.536	172.457	138.235	0.	0.	0.
3100	23.846	219.310	173.956	140.596	0.	0.	0.
3200	24.355	220.075	175.385	143.006	0.	0.	0.
3300	24.850	220.827	176.751	145.453	0.	0.	0.
3400	25.442	221.578	178.058	147.966	0.	0.	0.
3500	26.088	222.324	179.312	150.542	0.	0.	0.
3600	26.766	223.067	180.517	153.179	0.	0.	0.
3700	27.516	223.810	181.677	155.893	0.	0.	0.
3800	28.322	224.555	182.796	158.684	0.	0.	0.
3900	29.184	225.302	183.876	161.559	0.	0.	0.
4000	30.060	226.048	184.921	164.507	0.	0.	0.
4100	31.023	226.802	185.933	167.561	0.	0.	0.
4200	32.038	227.561	186.915	170.714	0.	0.	0.
4300	33.104	228.328	187.869	173.970	0.	0.	0.
4400	33.569	229.027	188.791	177.038	0.	0.	0.
4500	34.345	229.761	189.690	180.318	0.	0.	0.
4600	35.326	230.521	190.569	183.780	0.	0.	0.
4700	36.365	231.292	191.427	187.364	0.	0.	0.
4800	37.419	232.069	192.266	191.053	0.	0.	0.
4900	38.481	232.851	193.086	194.848	0.	0.	0.
5000	39.145	233.583	193.883	198.498	0.	0.	0.
5100	40.162	234.368	194.669	202.463	0.	0.	0.
5200	41.169	235.158	195.440	206.530	0.	0.	0.
5300	42.161	235.951	196.197	210.697	0.	0.	0.
5400	43.133	236.749	196.941	214.961	0.	0.	0.
5500	44.078	237.549	197.672	219.322	0.	0.	0.
5600	44.545	238.273	198.381	223.394	0.	0.	0.
5700	45.394	239.069	199.088	227.891	0.	0.	0.
5800	46.204	239.866	199.784	232.472	0.	0.	0.
5900	46.972	240.662	200.470	237.131	0.	0.	0.
6000	47.693	241.458	201.147	241.864	0.	0.	0.

PREVIOUS:

Standard State Pressure = p° = 0.1 MPa

CURRENT: December 1983 (1 bar)

Rb₁(ref)

Rubidium (Rb)

Rubidium (Rb)   CRYSTAL A_r = 85.4678

Rb₁(cr)

Rubidium (Rb)

$\Delta_f H°(0\text{ K}) = 0$ kJ·mol⁻¹
$\Delta_f H°(298.15\text{ K}) = 0$ kJ·mol⁻¹
$\Delta_{fus} H° = 2.19 \pm 0.09$ kJ·mol⁻¹

$S°(298.15\text{ K}) = 76.78 \pm 0.30$ J·K⁻¹·mol⁻¹
$T_{fus} = 312.65 \pm 0.1$ 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	-7.490	0.	0.	0.
100	25.510	47.022	101.811	-5.479	0.	0.	0.
200	27.447	65.316	79.458	-2.828	0.	0.	0.
250	28.690	71.560	77.272	-1.428	0.	0.	0.
298.15	31.062	76.778	76.778	0.	0.	0.	0.
300	31.188	76.971	76.779	0.058	0.	0.	0.
312.650	32.401	78.284	76.813	0.460	--- CRYSTAL <--> LIQUID ---		
350	35.848	82.132	77.176	1.735	-2.121	0.259	-0.039
400	40.465	87.220	78.114	3.642	-1.806	0.581	-0.076
450	45.082	92.253	79.406	5.781	-1.246	0.848	-0.098
500	49.699	97.242	80.940	8.151	-0.443	1.040	-0.109
600	58.932	107.119	84.482	13.582	1.888	1.134	-0.099

Standard State Pressure = $p°$ = 0.1 MPa

Enthalpy of Formation
Zero by definition.

Heat Capacity and Entropy
The thermal functions for Rb(cr) are derived following CODATA recommendations.[1] That is, these functions are based on the previous evaluation of Hultgren et al.,[2] Martin,[3,4] and Shpil'rain et al.[5] The prime sources of data are: Lien and Phillips (0.19–4.1 K),[6] Filby and Martin (0.4–1.5 K, 3–320 K),[7] McCallum and Silsbee (1.3–12 K),[8] Dauphinee et al. (25–300 K),[9] and Martin (0.4–3 K).[4]

Fusion Data
The adopted fusion temperature, $T_{fus} = 312.65 \pm 0.1$ K, is that recommended by Ohse et al.[10] based on their analysis of seven experimental studies: Rengade (312.15 ± 0.05 K),[11] Dauphine et al. (311.90 ± 0.5 K),[9] Weatherford et al. (312.45 K),[14] and Martin (312.47 K).[4] (312.65 ± 0.01 K), Basin et al. (312.31 ± 0.05 K),[13] Ott et al. (312.45 K),[14] and Martin (312.54 K).[12] Filby and Martin

The adopted enthalpy of fusion, $\Delta_{fus} H°$, 2.19 ± 0.09 kJ·mol⁻¹, is derived from the studies of Rengade,[11] Filby and Martin,[7] and Martin;[4] all three results being within 1 kcal·mol⁻¹.

Sublimation Data
Refer to the ideal gas tables for details.

References
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PREVIOUS: CURRENT: December 1983

Rubidium (Rb)   **Rb₁(cr)**

Rubidium (Rb) LIQUID $A_r = 85.4678$ Rubidium (Rb) Rb₁(l)

$S°(298.15\ K) = [83.764]\ J\cdot K^{-1}\cdot mol^{-1}$
$T_{fus} = 312.65 \pm 0.1\ K$

$\Delta_f H°(298.15\ K) = [2.184]\ kJ\cdot mol^{-1}$
$\Delta_{fus} H° = 2.19 \pm 0.09\ kJ\cdot mol^{-1}$

Enthalpy of Formation

The enthalpy of formation is calculated from that of the crystal by adding the enthalpy of fusion and difference in enthalpy, $H°(298.15\ K)$, between the crystal and liquid.

Indash $H°(298.15\ K)$, between the crystal and liquid.

Heat Capacity and Entropy

The adopted heat capacity values for Rb(l) are those recommended by Fink and Leibowitz.[1] These authors reviewed the liquid phase heat capacity and enthalpy studies for all alkali metals and recommended a $C_p°$ equation for Rb(l) based on their evaluation of four enthalpy[2-5] and three heat capacity[1-4] experimental studies. These studies provided information in the liquid region up to 1334 K.

The equation recommend by Fink and Leibowitz[1] is $C_p° = 35.494 - 0.012864\ T + 0.85409 \times 10^{-5}\ T^2$ ($J\cdot K^{-1}\cdot mol^{-1}$).

Vaporization Data

Refer to the ideal gas table for details.

References

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					Standard State Pressure = $p°$ = 0.1 MPa		
Enthalpy Reference Temperature = T_r = 298.15 K					kJ·mol⁻¹		
		J·K⁻¹·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						
100							
200							
250							
298.15	32.418	83.764	83.764	0.	2.184	0.102	-0.018
300	32.403	83.965	83.765	0.060	2.187	0.089	-0.015
312.650	32.307	85.300	83.800	0.469	CRYSTAL <--> LIQUID		
350	32.038	88.932	84.158	1.671	0.	0.	0.
400	31.715	93.188	85.027	3.264	0.	0.	0.
450	31.435	96.907	86.145	4.843	0.	0.	0.
500	31.197	100.207	87.389	6.409	0.	0.	0.
600	30.850	105.861	90.012	9.510	0.	0.	0.
700	30.674	110.601	92.624	12.584	0.	0.	0.
800	30.669	114.695	95.133	15.650	0.	0.	0.
900	30.835	118.315	97.511	18.724	----- FUGACITY - 1 bar -----		
970.385	31.053	120.645	99.105	20.901			
1000	31.171	121.580	99.757	21.823	-71.481	2.186	-0.114
1100	31.678	124.573	101.879	24.964	-70.419	9.502	-0.451
1200	32.356	127.358	103.888	28.164	-69.297	16.718	-0.728
1300	33.205	129.980	105.795	31.441	-68.100	23.838	-0.958
1400	34.225	132.477	107.612	34.811	-66.809	30.863	-1.152
1500	35.415	134.878	109.350	38.291	-65.408	37.791	-1.316
1600	36.776	137.206	111.019	41.899	-63.881	44.622	-1.457

CURRENT: December 1983

Rubidium (Rb) Rb₁(l)

Rubidium (Rb)

$A_r = 85.4678$ Rubidium (Rb)   Rb$_1$(cr,l)

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

T/K	C°	S°	−(G°−H°(T$_r$))/T	H°−H°(T$_r$)	Δ$_f$H°	Δ$_f$G°	log K$_f$
		J·K⁻¹·mol⁻¹			kJ·mol⁻¹		
0	0.	0.	INFINITE	−7.490	0.	0.	0.
100	25.510	47.022	101.811	−5.479	0.	0.	0.
200	27.447	65.316	79.458	−2.828	0.	0.	0.
250	28.690	71.560	77.272	−1.428	0.	0.	0.
298.15	31.062	76.778	76.778	0.	0.	0.	0.
300	31.188	76.971	76.779	0.058	0.	0.	0.
312.650	32.401	78.284	76.813	0.460			
312.650	32.307	85.300	76.813	2.653			
			CRYSTAL <--> LIQUID TRANSITION				
350	32.038	88.932	77.917	3.855	0.	0.	0.
400	31.715	93.188	79.566	5.449	0.	0.	0.
450	31.435	96.907	81.291	7.028	0.	0.	0.
500	31.197	100.207	83.020	8.593	0.	0.	0.
600	30.850	105.861	86.371	11.694	0.	0.	0.
700	30.674	110.601	89.503	14.769	0.	0.	0.
800	30.669	114.695	92.402	17.835	0.	0.	0.
900	30.835	118.315	95.084	20.908	0.	0.	0.
970.385	31.053	120.645	96.854	23.086			
			FUGACITY = 1 bar				
1000	31.171	121.580	97.573	24.007	−71.481	2.186	−0.114
1100	31.678	124.573	99.893	27.148	−70.419	9.502	−0.451
1200	32.356	127.358	102.067	30.349	−69.297	16.719	−0.728
1300	33.205	129.980	104.114	33.625	−68.100	23.839	−0.958
1400	34.225	132.477	106.052	36.995	−66.809	30.863	−1.152
1500	35.415	134.878	107.894	40.476	−65.408	37.791	−1.316
1600	36.776	137.206	109.653	44.084	−63.881	44.622	−1.457

PREVIOUS: CURRENT: December 1983

Rubidium (Rb)   Rb$_1$(cr,l)

CRYSTAL-LIQUID

0   to   312.65   K crystal
above   312.65   K liquid

Refer to the individual tables for details.

Rubidium (Rb)

Rubidium (Rb) IDEAL GAS $A_r = 85.4678$ Rubidium (Rb) Rb$_1$(g)

IP(Rb, g) = 33690.81 ± 0.01 cm⁻¹
S°(298.15 K) = 170.093 ± 0.025 J·K⁻¹·mol⁻¹

$\Delta_f H°$(298.15 K) = 82.2 ± 0.4 kJ·mol⁻¹
$\Delta_f H°$(298.15 K) = 80.9 ± 0.4 kJ·mol⁻¹

Electronic Levels and Quantum Weights

State	ϵ, cm⁻¹	g_i
$^2S_{1/2}$	0.00	2
$^2P_{1/2}$	12578.96	2
$^2P_{3/2}$	12816.56	4
$^2D_{5/2}$	19355.01	6
$^2D_{3/2}$	19355.45	4
·	·	·
$^2P_{3/2}$	33671.07	·
IP	33690.81	4

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	82.192	82.192	INFINITE
100	20.786	147.386	188.573	−4.119	82.260	72.224	−37.726
200	20.786	161.794	171.994	−2.040	81.688	62.393	−16.295
250	20.786	166.432	170.435	−1.001	81.327	57.609	−12.037
298.15	20.786	170.093	170.093	0.	80.900	53.078	−9.299
300	20.786	170.222	170.094	0.038	80.881	52.906	−9.212
350	20.786	173.426	170.347	1.078	78.122	48.550	−7.246
400	20.786	176.202	170.909	2.117	77.568	44.363	−5.793
450	20.786	178.650	171.636	3.156	77.029	40.245	−4.671
500	20.786	180.840	172.448	4.196	76.503	36.186	−3.780
600	20.786	184.630	174.172	6.274	75.480	28.219	−2.457
700	20.786	187.834	175.901	8.353	74.484	20.421	−1.524
800	20.786	190.609	177.570	10.431	73.497	12.766	−0.834
900	20.786	193.058	179.157	12.510	72.502	5.234	−0.304
970.385	20.786	194.623	180.223	13.973	------ FUGACITY = 1 bar ------		
1000	20.786	195.248	180.659	14.589	0.	0.	0.
1100	20.786	197.229	182.077	16.667	0.	0.	0.
1200	20.787	199.037	183.416	18.746	0.	0.	0.
1300	20.790	200.701	184.682	20.825	0.	0.	0.
1400	20.795	202.242	185.882	22.904	0.	0.	0.
1500	20.805	203.677	187.021	24.984	0.	0.	0.
1600	20.821	205.020	188.105	27.065	0.	0.	0.
1700	20.847	206.283	189.137	29.149	0.	0.	0.
1800	20.886	207.476	190.123	31.235	0.	0.	0.
1900	20.941	208.607	191.067	33.326	0.	0.	0.
2000	21.015	209.683	191.971	35.424	0.	0.	0.
2100	21.110	210.710	192.839	37.530	0.	0.	0.
2200	21.231	211.695	193.674	39.647	0.	0.	0.
2300	21.379	212.642	194.478	41.777	0.	0.	0.
2400	21.558	213.555	195.254	43.924	0.	0.	0.
2500	21.769	214.439	196.004	46.090	0.	0.	0.
2600	22.016	215.298	196.729	48.278	0.	0.	0.
2700	22.294	216.134	197.433	50.493	0.	0.	0.
2800	22.616	216.950	198.115	52.738	0.	0.	0.
2900	22.980	217.750	198.778	55.017	0.	0.	0.
3000	23.389	218.536	199.424	57.335	0.	0.	0.
3100	23.846	219.310	200.053	59.696	0.	0.	0.
3200	24.355	220.075	200.667	62.106	0.	0.	0.
3300	24.850	220.827	201.266	64.553	0.	0.	0.
3400	25.442	221.578	201.852	67.066	0.	0.	0.
3500	26.088	222.324	202.427	69.642	0.	0.	0.
3600	26.766	223.067	202.989	72.279	0.	0.	0.
3700	27.516	223.810	203.542	74.993	0.	0.	0.
3800	28.322	224.555	204.083	77.784	0.	0.	0.
3900	29.184	225.302	204.620	80.659	0.	0.	0.
4000	30.060	226.048	205.146	83.607	0.	0.	0.
4100	31.023	226.802	205.665	86.661	0.	0.	0.
4200	32.038	227.561	206.177	89.814	0.	0.	0.
4300	33.104	228.328	206.683	93.070	0.	0.	0.
4400	33.569	229.027	207.177	96.138	0.	0.	0.
4500	34.345	229.761	207.668	99.418	0.	0.	0.
4600	35.326	230.521	208.156	102.880	0.	0.	0.
4700	36.365	231.292	208.640	106.464	0.	0.	0.
4800	37.419	232.069	209.120	110.154	0.	0.	0.
4900	38.481	232.851	209.596	113.948	0.	0.	0.
5000	39.145	233.583	210.063	117.598	0.	0.	0.
5100	40.162	234.368	210.532	121.563	0.	0.	0.
5200	41.169	235.158	210.998	125.630	0.	0.	0.
5300	42.161	235.951	211.461	129.797	0.	0.	0.
5400	43.133	236.749	211.922	134.062	0.	0.	0.
5500	44.078	237.549	212.381	138.422	0.	0.	0.
5600	44.545	238.273	212.828	142.494	0.	0.	0.
5700	45.394	239.069	213.281	146.991	0.	0.	0.
5800	46.204	239.866	213.733	151.572	0.	0.	0.
5900	46.972	240.662	214.182	156.231	0.	0.	0.
6000	47.693	241.458	214.630	160.964	0.	0.	0.

PREVIOUS: CURRENT December 1983 (1 bar)

Rubidium (Rb) Rb$_1$(g)

Enthalpy of Formation

The enthalpy of formation of rubidium gas is chosen to be the value recommended by CODATA.[1] This value was obtained from 2nd and 3rd law analysis of the vapor pressure studies reported by Hultgren et al.[2] As stated by CODATA,[1] the correction for the presence of the dimer in the vapor phase was made using a virial treatment, since the dissociation energy of Rb₂(g) was not well established.

The six studies used by Hultgren et al.[1] are: Volyak et al. (594–970 K),[3] Achener (745–1260 K),[4] Tepper et al. (716–1353 K),[5] Buck and Pauly (307–363 K),[6] Killian (312–377 K),[7] and Scott (365–400 K).[8]

Heat Capacity and Entropy

The thermal functions for the five alkali metal monatomic gases are calculated by the same procedure. Observed and estimated atomic energy levels are included in the partition function calculation, using an ionization potential lowering (IP-kT) technique as the cutoff procedure in the energy level summation.[11]

The lowest lying levels for these metals [14904 cm⁻¹ (Li), 16956 cm⁻¹ (Na), 12985 cm⁻¹ (K), 12578 cm⁻¹ (Rb), and 11178 cm⁻¹ (Cs)] do not contribute to the thermal functions below ~1000 K; there is only a translational contribution below this temperature. Above this approximate temperature, the thermal functions become increasingly sensitive to the partition function cutoff procedure used, due to the combined effect of the observation of atomic energy levels of high principal quantum number and a low ionization potential. Energy levels have been observed up to n = 42 (Li), 59(Na), 79(K), 77(Rb), and 73(Cs). However, not all predicted levels have been observed for each of these principal quantum numbers. The ionization potentials vary from 43487.29 cm⁻¹ for Li to 31406.1 cm⁻¹ for Cs. In calculating the thermal functions with the inclusion of missing levels up to the high principal quantum numbers just mentioned, the Gibbs energy functions show significant differences (depending on the cutoff procedure) above 3000 K.[11]

The atomic energy levels have been taken from the compilation of Moore.[9,10] Our calculated values for the thermal functions are similar to those recommended by CODATA.[1] They do differ for two reasons, however. First, the entropy differs by 0.1094 J·K⁻¹·mol⁻¹ because this table uses a reference pressure of 1 bar, whereas the CODATA recommendations are based on 1 atm. Second, the entropies at 298.15 K for all alkali metal gases differs by ~0.004 J·K⁻¹·mol⁻¹, presumably due to the use of slightly different values for auxiliary data.

References

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Rubidium, Ion (Rb⁺)　　　　IDEAL GAS　　　　$M_r = 85.46725$　　　　Rb⁺(g)

$IP(Rb^+, g) = 220048 \pm 30$ cm⁻¹
$S°(298.15 \text{ K}) = 164.330 \pm 0.02$ J·K⁻¹·mol⁻¹

$\Delta_f H°(0 \text{ K}) = 485.224$ kJ·mol⁻¹
$\Delta_f H°(298.15 \text{ K}) = [490.129]$ kJ·mol⁻¹

Electronic Level and Quantum Weight

State	ϵ, cm⁻¹	g_i
$^1S_0$	0	1

Rubidium, Ion (Rb⁺)　　　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	485.224		
100	20.786	141.623	182.810	-4.119			
200	20.786	156.031	166.231	-2.040			
250	20.786	160.669	164.672	-1.001			
298.15	20.786	164.330	164.330	0.	490.129	457.771	-80.200
300	20.786	164.459	164.330	0.038	490.148	457.570	-79.670
350	20.786	167.663	164.583	1.078	488.429	452.364	-67.512
400	20.786	170.438	165.146	2.117	488.914	447.179	-58.396
450	20.786	172.887	165.872	3.156	489.414	441.933	-51.298
500	20.786	175.077	166.685	4.196	489.927	436.630	-45.614
600	20.786	178.866	168.409	6.274	490.983	425.871	-37.075
700	20.786	182.071	170.138	8.353	492.066	414.934	-30.963
800	20.786	184.846	171.807	10.431	493.157	403.841	-26.368
900	20.786	187.294	173.394	12.510	494.241	392.611	-22.787
1000	20.786	189.484	174.896	14.589	423.818	383.448	-20.029
1100	20.786	191.465	176.313	16.667	425.896	379.310	-18.012
1200	20.786	193.274	177.653	18.746	427.975	374.984	-16.323
1300	20.786	194.938	178.919	20.824	430.053	370.483	-14.886
1400	20.786	196.478	180.119	22.903	432.131	365.823	-13.649
1500	20.786	197.912	181.258	24.982	434.209	361.014	-12.572
1600	20.785	199.254	182.341	27.060	436.285	356.067	-11.624
1700	20.786	200.514	183.374	29.139	438.358	350.990	-10.785
1800	20.786	201.702	184.359	31.217	440.429	345.791	-10.035
1900	20.786	202.826	185.302	33.296	442.495	340.477	-9.360
2000	20.786	203.892	186.205	35.375	444.555	335.054	-8.751
2100	20.786	204.906	187.071	37.453	446.606	329.528	-8.197
2200	20.786	205.873	187.904	39.532	448.646	323.906	-7.690
2300	20.786	206.797	188.706	41.610	450.673	318.190	-7.226
2400	20.786	207.682	189.478	43.689	452.684	312.387	-6.799
2500	20.786	208.530	190.223	45.768	454.675	306.500	-6.404
2600	20.786	209.346	190.943	47.846	456.643	300.534	-6.038
2700	20.786	210.130	191.639	49.925	458.586	294.493	-5.697
2800	20.786	210.886	192.313	52.004	460.498	288.380	-5.380
2900	20.786	211.615	192.966	54.082	462.376	282.200	-5.083
3000	20.786	212.320	193.600	56.161	464.215	275.955	-4.805
3100	20.786	213.002	194.215	58.239	466.011	269.650	-4.544
3200	20.786	213.662	194.812	60.318	467.759	263.288	-4.298
3300	20.786	214.301	195.393	62.397	469.469	256.871	-4.066
3400	20.786	214.922	195.959	64.475	471.113	250.404	-3.847
3500	20.786	215.524	196.509	66.554	472.694	243.889	-3.640
3600	20.786	216.110	197.045	68.632	474.215	237.330	-3.444
3700	20.786	216.679	197.568	70.711	475.658	230.729	-3.257
3800	20.786	217.234	198.079	72.790	477.024	224.091	-3.080
3900	20.786	217.774	198.577	74.868	478.307	217.418	-2.912
4000	20.786	218.300	199.063	76.947	479.515	210.712	-2.752
4100	20.786	218.813	199.539	79.025	480.619	203.978	-2.599
4200	20.786	219.314	200.004	81.104	481.623	197.218	-2.453
4300	20.786	219.803	200.458	83.183	482.524	190.436	-2.313
4400	20.786	220.281	200.904	85.261	483.613	183.603	-2.180
4500	20.786	220.748	201.339	87.340	484.491	176.763	-2.052
4600	20.786	221.205	201.766	89.418	485.186	169.914	-1.929
4700	20.786	221.652	202.185	91.497	485.759	163.054	-1.812
4800	20.786	222.090	202.595	93.576	486.227	156.183	-1.700
4900	20.786	222.518	202.997	95.654	486.589	149.303	-1.592
5000	20.786	222.938	203.392	97.733	487.097	142.385	-1.487
5100	20.786	223.350	203.779	99.811	487.289	135.490	-1.388
5200	20.786	223.753	204.159	101.890	487.379	128.591	-1.292
5300	20.786	224.149	204.533	103.969	487.370	121.691	-1.199
5400	20.786	224.538	204.900	106.047	487.262	114.792	-1.110
5500	20.786	224.919	205.260	108.126	487.058	107.896	-1.025
5600	20.786	225.294	205.614	110.204	487.144	100.950	-0.942
5700	20.786	225.662	205.963	112.283	486.804	94.057	-0.862
5800	20.786	226.023	206.306	114.362	486.381	87.170	-0.785
5900	20.786	226.379	206.643	116.440	485.879	80.291	-0.711
6000	20.786	226.728	206.975	118.519	485.302	73.422	-0.639

PREVIOUS:　　　　CURRENT: December 1983 (1 bar)

Enthalpy of Formation

$\Delta_f H°(Rb^+, g, 0 \text{ K})$ is calculated from $\Delta_f H°(Rb, g, 0 \text{ K})$[1] using the spectroscopic value of $IP(Rb) = 33690.81 \pm 0.01$ cm⁻¹ ($403.032 \pm .0001$ kJ·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·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.

$\Delta_f H°(Rb^+, g, 298 \; 15 \text{ K})$ is calculated from $\Delta_f H°(Rb, g, 0 \text{ K})$ by using $IP(Rb)$ with JANAF enthalpies, $H°(0 \text{ K}) - H°(298.15 \text{ K})$, for Rb(g), Rb⁺(g), and e⁻ (ref). $\Delta_f H°(Rb \to Rb^+ + e^-, 298.15 \text{ K})$ differs from a room temperature threshold energy due to inclusion of these enthalpies, and to threshold effects discussed by Rosenstock et al.[4] $\Delta_f H°(298.15 \text{ K})$ should be changed by -6.197 kJ·mol⁻¹ if it is to be used in the ion convention that excludes the enthalpy of the electron.

Heat Capacity and Entropy

The information on electronic energy levels and quantum weights, given by Moore[6] 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 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; the first excited state is approximately 126454 cm⁻¹ above the ground state. Since inclusion of these excited states has no effect on the thermodynamic functions (to 6000 K), we list only the ground state. 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]

References

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Rb⁻(g)

Rubidium, Ion (Rb⁻)   **IDEAL GAS** $M_r = 85.46835$ Rubidium, Ion (Rb⁻)

EA(Rb, g) = 0.48592 ± 0.00002 eV
$S°(298.15\ K) = 164.330 \pm 0.005\ J\cdot K^{-1}\cdot mol^{-1}$

$\Delta_f H°(0\ K) = 35.308 \pm 0.4\ kJ\cdot mol^{-1}$
$\Delta_f H°(298.15\ K) = [27.819]\ kJ\cdot mol^{-1}$

Electronic Level and Quantum Weight

State	ϵ, cm⁻¹	g_i
¹S₀	0.0	1

			Enthalpy Reference Temperature = T_r = 298.15 K		Standard State Pressure = $p°$ = 0.1 MPa		
	$C_p°$	$S°$	$-[G°-H°(T_r)]/T$	$H°-H°(T_r)$	$\Delta_f H°$	$\Delta_f G°$	
T/K	J·K⁻¹·mol⁻¹	J·K⁻¹·mol⁻¹	J·K⁻¹·mol⁻¹	kJ·mol⁻¹	kJ·mol⁻¹	kJ·mol⁻¹	log K_f
0	0.	0.	INFINITE	-6.197	35.308		
100	20.786	141.623	182.810	-4.119			
200	20.786	156.031	166.231	-2.040			
250	20.786	160.669	164.672	-1.001			
298.15	20.786	164.330	164.330	0.	27.819	7.970	-1.396
300	20.786	164.459	164.331	0.038	27.761	7.847	-1.366
350	20.786	167.663	164.584	1.078	23.964	4.917	-0.734
400	20.786	170.438	165.146	2.117	22.370	2.305	-0.301
450	20.786	172.887	165.873	3.156	20.791	-0.109	0.013
500	20.786	175.077	166.685	4.196	19.226	-2.347	0.245
600	20.786	178.866	168.409	6.274	16.125	-6.369	0.555
700	20.786	182.071	170.138	8.353	13.050	-9.875	0.737
800	20.786	184.846	171.807	10.431	9.984	-12.941	0.845
900	20.786	187.295	173.394	12.510	6.910	-15.622	0.907
1000	20.786	189.485	174.896	14.589	-67.670	-15.774	0.824
1100	20.786	191.466	176.314	16.667	-69.748	-10.483	0.498
1200	20.786	193.274	177.653	18.746	-71.827	-5.004	0.218
1300	20.786	194.938	178.919	20.824	-73.906	0.649	-0.026
1400	20.786	196.478	180.119	22.903	-75.985	6.462	-0.241
1500	20.786	197.913	181.258	24.982	-78.065	12.424	-0.433
1600	20.786	199.254	182.341	27.060	-80.146	18.524	-0.605
1700	20.786	200.514	183.374	29.139	-82.230	24.755	-0.761
1800	20.786	201.702	184.359	31.217	-84.316	31.108	-0.903
1900	20.786	202.826	185.302	33.296	-86.407	37.577	-1.033
2000	20.786	203.892	186.205	35.375	-88.505	44.157	-1.153
2100	20.786	204.906	187.072	37.453	-90.611	50.842	-1.265
2200	20.786	205.873	187.904	39.532	-92.728	57.628	-1.368
2300	20.786	206.797	188.706	41.610	-94.858	64.510	-1.465
2400	20.786	207.682	189.478	43.689	-97.005	71.484	-1.556
2500	20.786	208.531	190.223	45.768	-99.171	78.549	-1.641
2600	20.786	209.346	190.943	47.846	-101.360	85.701	-1.722
2700	20.786	210.130	191.640	49.925	-103.574	92.938	-1.798
2800	20.786	210.886	192.314	52.004	-105.819	100.257	-1.870
2900	20.786	211.616	192.967	54.082	-108.098	107.657	-1.939
3000	20.786	212.320	193.600	56.161	-110.416	115.136	-2.005
3100	20.786	213.002	194.215	58.239	-112.777	122.693	-2.067
3200	20.786	213.662	194.812	60.318	-115.187	130.327	-2.127
3300	20.786	214.301	195.393	62.397	-117.634	138.037	-2.185
3400	20.786	214.922	195.959	64.475	-120.147	145.822	-2.240
3500	20.786	215.524	196.509	66.554	-122.724	153.682	-2.294
3600	20.786	216.110	197.046	68.632	-125.360	161.616	-2.345
3700	20.786	216.680	197.569	70.711	-128.074	169.624	-2.395
3800	20.786	217.234	198.079	72.790	-130.865	177.707	-2.443
3900	20.786	217.774	198.577	74.868	-133.740	185.865	-2.489
4000	20.786	218.300	199.063	76.947	-136.688	194.096	-2.535
4100	20.786	218.813	199.539	79.025	-139.742	202.403	-2.579
4200	20.786	219.314	200.004	81.104	-142.895	210.786	-2.622
4300	20.786	219.803	200.459	83.183	-146.151	219.246	-2.663
4400	20.786	220.281	200.904	85.261	-149.219	227.751	-2.704
4500	20.786	220.748	201.339	87.340	-152.499	236.343	-2.743
4600	20.786	221.205	201.766	89.418	-155.961	245.020	-2.782
4700	20.786	221.652	202.185	91.497	-159.545	253.775	-2.820
4800	20.786	222.090	202.595	93.576	-163.235	262.608	-2.858
4900	20.786	222.518	202.997	95.654	-167.029	271.519	-2.894
5000	20.786	222.938	203.392	97.733	-170.679	280.478	-2.930
5100	20.786	223.350	203.779	99.811	-174.644	289.540	-2.965
5200	20.786	223.754	204.159	101.890	-178.711	298.681	-3.000
5300	20.786	224.150	204.533	103.969	-182.878	307.901	-3.035
5400	20.786	224.538	204.900	106.047	-187.143	317.201	-3.068
5500	20.786	224.919	205.260	108.126	-191.503	326.581	-3.102
5600	20.786	225.294	205.615	110.204	-195.575	335.986	-3.134
5700	20.786	225.662	205.963	112.283	-200.072	345.518	-3.166
5800	20.786	226.023	206.306	114.362	-204.653	355.130	-3.198
5900	20.786	226.379	206.643	116.440	-209.312	364.821	-3.230
6000	20.786	226.728	206.975	118.519	-214.045	374.592	-3.261

CURRENT December 1983 (1 bar)

PREVIOUS:

Enthalpy of Formation

The enthalpy of formation, at 0 K, for Rb⁻(g) is calculated from the adopted electron affinity, EA(Rb, g) = 0.48592 ± 0.00002 eV (46.884 ± 0.002 kJ·mol⁻¹). This value, recommended by Hotop and Lineberger, was measured by a tunable laser photodetachment threshold technique.[2] Additional discussion on Rb⁻(g) may be obtained in the critical discussions of Hotop and Lineberger,[1,6] Rosenstock et al.,[3] and Massey.[4]

$\Delta_f H°$(Rb⁻, g, 298.15 K) is obtained from $\Delta_f H°$(Rb, g, 0 K) by using EA(Rb, g, 0 K) with JANAF[5] enthalpies, $H°(0\ K)- H°(298.15\ K)$, for Rb⁻(g), Rb(g), and e⁻(ref). $\Delta_f H°$(Rb⁻ → Rb + 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.[3] $\Delta_f H°$(298.15 K) should be changed by +6.197 kJ·mol⁻¹ if it is to be used in the ion convention which excludes the enthalpy of the electron.

Heat Capacity and Entropy

The ground state configuration for Rb⁻(g) is given by Hotop and Lineberger[1,6] and Rosenstock et al.[3] Lacking any experimental evidence as to the stability of any excited states, we assume that no stable excited states exist.

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Rubidium, Ion (Rb⁻)

Rubidium (Rb₂)   IDEAL GAS $M_r = 169.8234$ Rb₂(g)

$D_0^\circ = 46.91 \pm 1.9$ kJ·mol⁻¹ (natural abundance)
$S^\circ(298.15\text{ K}) = 271.07 \pm 0.08$ J·K⁻¹·mol⁻¹

$\Delta_f H^\circ(0\text{ K}) = 117.34 \pm 2.5$ kJ·mol⁻¹
$\Delta_f H^\circ(298.15\text{ K}) = 113.29 \pm 2.5$ kJ·mol⁻¹

Spectroscopic Data for ⁸⁵Rb₂ (Ground State: $^1\Sigma_g^+$) in cm⁻¹

$\omega_e = 57.747$ $\omega_e x_e = 0.1582$
$B_e = 0.02278$ $\alpha_e = 4.7 \times 10^{-5}$
$D_e = 1.5 \times 10^{-8}$ $r_e = 4.173$ Å

Heat of Formation

Using the adopted value of the dissociation energy for Rb₂(g), $D_0^\circ = 46.91$ kJ·mol⁻¹ (natural abundance Rb₂) as deduced from the ⁸⁵Rb dissociation energy from reference[4] ($D^\circ = 47.277 \pm 1.93$ kJ·mol⁻¹) and the recommended $\Delta_f H^\circ$(Rb, g, 0 K) = 82.17 kJ·mol⁻¹ from NBS,[5] we calculate $\Delta_f H^\circ$(Rb₂, g, 0 K) = 117.34 kJ·mol⁻¹. Using the NBS enthalpy value for Rb(cr) (H°(298.15 K)$-H^\circ$(0 K) = 7.489 kJ·mol⁻¹) and the current JANAF value for H°(298.15 K)$-H^\circ$(0 K) of Rb₂(g), we obtain $\Delta_f H^\circ$(Rb₂, g, 298.15 K) = 113.29 kJ·mol⁻¹. Note that in a mass spectrometric study by Piacente et al.,[6] the dissociation energy of Rb₂(g) was determined as 41.84 ± 2.1 kJ·mol⁻¹. This value appears to be too low when compared to the alkali metal group trends apparent in plots of D_0° versus r_e or D_0° versus group member.

Heat Capacity and Entropy

The heat capacity and entropy were calculated using a direct summation technique similar to the Li₂(g) species[7] using the data for the ⁸⁵Rb₂ species given above.[12] Since insufficient spectroscopic data exist for the lower lying excited electronic states, we performed the calculation on the ground state only as discussed in the K₂(g) table.[7] Separate calculations were performed on the isotopic species ⁸⁵Rb₂, ⁸⁷Rb₂, and ⁸⁵Rb⁸⁷Rb and the results combined according to the natural atomic isotopic abundances:[1] ⁸⁵Rb, 72.165%; ⁸⁷Rb, 27.835%. Spectroscopic input data for the calculation of the isotopic species were calculated from the ⁸⁵Rb₂(g) data using reduced mass scaling. The rotational levels were weighted according to the nuclear spins of the atoms (⁸⁵Rb, I = 5/2; ⁸⁷Rb, I = 3/2) as follows: ⁸⁵Rb₂, even J weight = 0.583, odd J weight = 0.471; ⁸⁷Rb₂, even J weight = 0.625, odd J weight = 0.375; ⁸⁵Rb⁸⁷Rb, equal weights of 0.5.

Based on the results for the Cs₂(g) calculation,[7] neglect of the excited states probably results in negligible uncertainties in the thermodynamic functions (except for C_p°) at temperatures below ca. 2000 K. We estimate that the entropy and Gibbs energy function at 3000 K are too low by ca. 0.4 J·K⁻¹·mol⁻¹ due to the neglect of the excited states. The adopted value of S°(298.15 K) is 0.07 J·K⁻¹·mol⁻¹ larger than that adopted by Gurvich et al.[8]

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Rubidium (Rb₂)

Rb₂(g)

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

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	-10.934	117.335	117.335	INFINITE
100	37.185	229.924	304.707	-7.478	116.769	103.181	-53.896
200	37.777	255.918	274.542	-3.725	115.222	90.165	-23.549
298.15	38.116	271.067	271.067	0.	113.290	78.254	-13.710
300	38.123	271.302	271.067	0.071	113.245	78.037	-13.587
400	38.440	282.314	272.567	3.899	106.291	67.916	-8.869
500	38.631	290.917	275.407	7.754	103.858	58.607	-6.123
600	38.475	297.953	278.597	11.614	101.515	49.777	-4.333
700	37.845	303.842	281.795	15.433	99.186	41.338	-3.085
800	36.797	308.831	284.871	19.168	96.789	33.236	-2.170
900	35.490	313.092	287.776	22.784	94.257	25.443	-1.477
1000	34.084	316.758	290.495	26.263	-51.424	22.313	-1.166
1100	32.696	319.941	293.031	29.602	-52.243	29.725	-1.412
1200	31.398	322.730	295.392	32.805	-53.196	37.218	-1.620
1300	30.221	325.196	297.592	35.885	-54.274	44.795	-1.800
1400	29.176	327.396	299.643	38.854	-55.464	52.460	-1.957
1500	28.258	329.377	301.561	41.725	-56.753	60.213	-2.097
1600	27.457	331.175	303.356	44.510	-58.131	68.055	-2.222
1700	26.760	332.818	305.042	47.220	-59.587	75.986	-2.335
1800	26.154	334.330	306.627	49.865	-61.115	84.005	-2.438
1900	25.626	335.729	308.123	52.453	-62.710	92.110	-2.532
2000	25.165	337.032	309.536	54.992	-64.366	100.301	-2.620
2100	24.762	338.250	310.874	57.488	-66.082	108.576	-2.701
2200	24.408	339.393	312.145	59.946	-67.858	116.935	-2.776
2300	24.096	340.471	313.354	62.371	-69.693	125.375	-2.847
2400	23.821	341.491	314.505	64.766	-71.591	133.897	-2.914
2500	23.577	342.458	315.604	67.136	-73.553	142.499	-2.977
2600	23.360	343.379	316.654	69.483	-75.584	151.181	-3.037
2700	23.166	344.257	317.661	71.809	-77.686	159.942	-3.094
2800	22.992	345.096	318.625	74.117	-79.869	168.783	-3.149
2900	22.836	345.900	319.552	76.408	-82.137	177.703	-3.201
3000	22.695	346.672	320.443	78.684	-84.496	186.703	-3.251
3100	22.568	347.414	321.302	80.947	-86.955	195.783	-3.299
3200	22.453	348.128	322.129	83.198	-89.524	204.945	-3.345
3300	22.348	348.818	322.927	85.438	-92.177	214.186	-3.390
3400	22.253	349.483	323.699	87.668	-94.974	223.511	-3.434
3500	22.166	350.127	324.445	89.889	-97.906	232.920	-3.476
3600	22.086	350.750	325.167	92.102	-100.966	242.415	-3.517
3700	22.013	351.354	325.866	94.307	-104.188	251.997	-3.558
3800	21.945	351.941	326.545	96.505	-107.573	261.669	-3.597
3900	21.884	352.510	327.203	98.696	-111.132	271.431	-3.635
4000	21.826	353.063	327.843	100.881	-114.843	281.285	-3.673
4100	21.773	353.601	328.465	103.061	-118.771	291.237	-3.710
4200	21.724	354.126	329.069	105.236	-122.901	301.287	-3.747
4300	21.679	354.636	329.658	107.406	-127.244	311.437	-3.783
4400	21.636	355.134	330.231	109.572	-131.214	321.630	-3.818
4500	21.597	355.620	330.790	111.734	-135.612	331.947	-3.853
4600	21.560	356.094	331.335	113.892	-140.378	342.385	-3.888
4700	21.525	356.558	331.867	116.046	-145.393	352.933	-3.922
4800	21.493	357.010	332.386	118.197	-150.620	363.590	-3.957
4900	21.463	357.453	332.893	120.344	-156.062	374.359	-3.991
5000	21.435	357.887	333.389	122.489	-161.216	385.179	-4.024
5100	21.408	358.311	333.873	124.631	-167.005	396.164	-4.058
5200	21.383	358.726	334.347	126.771	-172.999	407.266	-4.091
5300	21.360	359.133	334.811	128.908	-179.195	418.483	-4.124
5400	21.338	359.532	335.265	131.043	-185.590	429.820	-4.158
5500	21.317	359.924	335.710	133.176	-192.179	441.277	-4.191
5600	21.297	360.308	336.146	135.306	-198.192	452.746	-4.223
5700	21.278	360.684	336.573	137.435	-205.058	464.431	-4.256
5800	21.261	361.054	336.992	139.562	-212.091	476.236	-4.289
5900	21.244	361.418	337.403	141.687	-219.284	488.166	-4.322
6000	21.228	361.775	337.806	143.811	-226.628	500.217	-4.355

PREVIOUS: