



Standard Specification for Normal Butane Thermophysical Property Tables¹

This standard is issued under the fixed designation D4650; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The thermophysical property tables for normal butane are for use in the calculation of the pressure-volume-temperature (PVT), thermodynamic, and transport properties of normal butane for process design and operations. Tables are provided for gaseous and liquid normal butane at temperatures between 136 and 560 K at pressures to 20 MPa. One table provides properties at the conditions of liquid-vapor equilibrium (saturation properties). The other table provides properties at selected T , p points for the equilibrium phase at those conditions. The tables were developed by the National Institute of Standards and Technology from a Standard Reference Database product REFPROP, version 8.0.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Applicability

2.1 These tables apply directly only to pure gaseous normal butane. However, it is expected that they may find substantial use in mathematical models and tables for the thermophysical properties of mixtures containing normal butane.

3. Tables

3.1 These thermophysical property tables are:

3.1.1 *Thermophysical Properties of Coexisting Gaseous and Liquid Normal Butane*, in SI units. See [Table 1](#).

3.1.2 *Thermophysical Properties of Normal Butane Along Isobars*, in SI units. See [Table 2](#).

3.2 The tabulated thermophysical properties are:

ρ , molar density ($\text{mol}\cdot\text{l}^{-1}$)

H , molar enthalpy ($\text{J}\cdot\text{mol}^{-1}$)

S , molar entropy ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

C_v , constant volume molar heat capacity ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

C_p , constant pressure molar heat capacity ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

c , speed of sound ($\text{m}\cdot\text{s}^{-1}$)

η , viscosity ($\mu\text{Pa}\cdot\text{s}$)

λ , thermal conductivity ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$)

3.3 These tables were produced by equations from a computer package, “NIST Standard Reference Database 23; Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version =8.0” A wide selection of units (SI units, engineering units, chemical units) is available with this program.²

4. Additional Information

4.1 Reference state properties are required to calculate certain of the thermodynamic properties (enthalpy, entropy, etc.) from an equation of state formulation. The reference state properties used to generate the tables in this specification are: enthalpy, H , and entropy, S , at 298.15 K and 0.101325 MPa ($H = 19275.7 \text{ J/mol}$ and $S = 309.909 \text{ J/(mol K)}$). The molar mass of normal butane is 58.122 g/mol.

5. Keywords

5.1 natural gas; normal butane gas tables; thermodynamic properties of normal butane; transport properties of normal butane

¹ This specification is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.08 on Thermophysical Properties.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1987. Last previous edition approved in 2003 as D4650 – 93 (2003). DOI: 10.1520/D4650-08.

² Available from Standard Reference Data, National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 3460, Gaithersburg, MD 20899.

TABLE 1 Thermophysical Properties of Coexisting Gaseous and Liquid Normal Butane

T K	p MPa	ρ mol·l ⁻¹	H J·mol ⁻¹	S J·mol ⁻¹ ·K ⁻¹	C_v J·mol ⁻¹ ·K ⁻¹	C_p J·mol ⁻¹ ·K ⁻¹	c m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
136	8.201E-07	12.627	-22292	134.96	83.79	114.72	1819.4	2201	176.2
136	8.201E-07	7.252E-07	6477.2	346.50	56.23	64.54	149.44	3.349	4.905
140	1.692E-06	12.563	-21832	138.29	83.80	114.92	1793.1	1887	174.8
140	1.692E-06	1.454E-06	6737.0	342.36	57.05	65.36	151.48	3.452	5.091
144	3.338E-06	12.499	-21372	141.53	83.81	115.12	1767.4	1645	173.4
144	3.338E-06	2.788E-06	7000.1	338.56	57.85	66.16	153.49	3.555	5.283
148	6.32E-06	12.435	-20911	144.69	83.82	115.33	1742.2	1452	172.0
148	6.32E-06	5.136E-06	7266.2	335.08	58.62	66.94	155.48	3.658	5.479
152	1.152E-05	12.371	-20450	147.76	83.84	115.55	1717.5	1295	170.4
152	1.152E-05	9.118E-06	7535.4	331.88	59.38	67.70	157.44	3.760	5.681
156	2.029E-05	12.307	-19987	150.77	83.87	115.79	1693.2	1165	168.8
156	2.029E-05	1.565E-05	7807.5	328.94	60.13	68.44	159.37	3.863	5.888
160	3.461E-05	12.243	-19523	153.70	83.92	116.05	1669.2	1055	167.2
160	3.461E-05	2.602E-05	8082.6	326.24	60.86	69.18	161.28	3.965	6.099
164	5.732E-05	12.178	-19059	156.57	83.98	116.32	1645.4	961.7	165.6
164	5.732E-05	4.205E-05	8360.5	323.76	61.59	69.91	163.17	4.067	6.316
168	9.238E-05	12.114	-18593	159.38	84.07	116.62	1621.8	881.0	163.9
168	9.238E-05	6.615E-05	8641.1	321.49	62.31	70.63	165.02	4.170	6.538
172	0.0001452	12.050	-18126	162.13	84.17	116.93	1598.4	810.7	162.1
172	0.0001452	0.0001016	8924.5	319.40	63.03	71.36	166.85	4.271	6.766
176	0.0002229	11.986	-17657	164.82	84.30	117.27	1575.2	749.1	160.4
176	0.0002229	0.0001524	9210.6	317.48	63.75	72.09	168.66	4.373	6.998
180	0.0003348	11.921	-17187	167.46	84.46	117.64	1552.1	694.6	158.6
180	0.0003348	0.0002238	9499.3	315.72	64.48	72.82	170.43	4.475	7.235
184	0.0004928	11.856	-16716	170.05	84.64	118.03	1529.2	646.1	156.8
184	0.0004928	0.0003223	9790.6	314.11	65.21	73.56	172.18	4.576	7.478
188	0.0007118	11.792	-16243	172.59	84.85	118.44	1506.3	602.7	154.9
188	0.0007118	0.0004558	10084	312.63	65.95	74.31	173.90	4.677	7.725
192	0.0010102	11.727	-15768	175.09	85.08	118.89	1483.5	563.7	153.1
192	0.0010102	0.0006337	10381	311.28	66.70	75.07	175.59	4.778	7.977
196	0.0014104	11.661	-15292	177.55	85.34	119.36	1460.8	528.5	151.2
196	0.0014104	0.000867	10680	310.05	67.46	75.85	177.25	4.879	8.235
200	0.001939	11.596	-14814	179.96	85.63	119.86	1438.2	496.5	149.4
200	0.001939	0.0011686	10981	308.93	68.23	76.64	178.87	4.979	8.497
204	0.0026276	11.531	-14333	182.34	85.94	120.38	1415.7	467.4	147.5
204	0.0026276	0.0015535	11284	307.92	69.01	77.45	180.46	5.079	8.765
208	0.003513	11.465	-13850	184.68	86.29	120.94	1393.2	440.8	145.6
208	0.003513	0.0020385	11590	306.99	69.81	78.28	182.01	5.179	9.037
212	0.0046377	11.399	-13365	186.99	86.65	121.53	1370.8	416.5	143.7
212	0.0046377	0.0026425	11898	306.16	70.63	79.13	183.53	5.279	9.315
216	0.00605	11.332	-12878	189.27	87.05	122.15	1348.5	394.1	141.8
216	0.00605	0.0033866	12208	305.41	71.46	80.01	185.00	5.378	9.597
220	0.0078045	11.265	-12388	191.52	87.47	122.80	1326.2	373.4	139.9
220	0.0078045	0.0042942	12520	304.74	72.32	80.91	186.44	5.477	9.884
224	0.0099624	11.198	-11895	193.73	87.92	123.48	1304.0	354.4	138.0
224	0.0099624	0.0053905	12835	304.14	73.18	81.83	187.82	5.575	10.176
228	0.012592	11.131	-11400	195.93	88.40	124.19	1281.8	336.7	136.1
228	0.012592	0.0067034	13151	303.60	74.07	82.78	189.16	5.674	10.47

TABLE 1 *Continued*

T K	p MPa	ρ mol·l ⁻¹	H J·mol ⁻¹	S J·mol ⁻¹ ·K ⁻¹	C_V J·mol ⁻¹ ·K ⁻¹	C_P J·mol ⁻¹ ·K ⁻¹	c m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
232	0.015766	11.063	-10901	198.09	88.89	124.93	1259.7	320.3	134.2
232	0.015766	0.0082627	13469	303.13	74.98	83.75	190.45	5.772	10.78
236	0.019568	10.995	-10400	200.23	89.42	125.70	1237.6	305.1	132.3
236	0.019568	0.0101	13788	302.73	75.90	84.76	191.69	5.869	11.08
240	0.024086	10.926	-9895.3	202.35	89.96	126.50	1215.6	290.9	130.4
240	0.024086	0.012251	14109	302.37	76.84	85.79	192.87	5.966	11.40
244	0.029415	10.857	-9387.3	204.45	90.53	127.33	1193.7	277.6	128.6
244	0.029415	0.01475	14432	302.07	77.80	86.85	194.00	6.064	11.71
248	0.035656	10.787	-8875.9	206.53	91.13	128.20	1171.8	265.2	126.7
248	0.035656	0.017637	14756	301.82	78.78	87.94	195.06	6.160	12.03
252	0.042919	10.717	-8360.9	208.58	91.74	129.10	1149.9	253.5	124.8
252	0.042919	0.020952	15082	301.61	79.78	89.06	196.06	6.257	12.36
256	0.051319	10.646	-7842.3	210.62	92.37	130.02	1128.1	242.6	123.0
256	0.051319	0.024739	15408	301.44	80.80	90.22	197.00	6.354	12.70
260	0.060978	10.575	-7319.7	212.64	93.03	130.98	1106.4	232.3	121.19
260	0.060978	0.029042	15736	301.32	81.84	91.40	197.86	6.450	13.03
264	0.072022	10.503	-6793.2	214.65	93.70	131.98	1084.7	222.6	119.4
264	0.072022	0.033908	16065	301.23	82.89	92.62	198.66	6.547	13.38
268	0.084586	10.430	-6262.7	216.64	94.39	133.00	1063.0	213.5	117.6
268	0.084586	0.039388	16394	301.18	83.96	93.88	199.38	6.644	13.73
272	0.098809	10.357	-5727.8	218.62	95.10	134.06	1041.4	204.9	115.8
272	0.098809	0.045533	16725	301.16	85.05	95.16	200.03	6.740	14.08
276	0.11484	10.283	-5188.6	220.58	95.83	135.15	1019.8	196.7	114.1
276	0.11484	0.052397	17055	301.17	86.15	96.49	200.59	6.838	14.45
280	0.13282	10.208	-4644.9	222.53	96.57	136.28	998.26	189.0	112.3
280	0.13282	0.060039	17387	301.21	87.27	97.85	201.08	6.935	14.82
284	0.15291	10.132	-4096.6	224.46	97.33	137.44	976.74	181.6	110.6
284	0.15291	0.068517	17719	301.28	88.41	99.25	201.47	7.034	15.20
288	0.17526	10.055	-3543.4	226.39	98.10	138.64	955.24	174.6	108.9
288	0.17526	0.077896	18051	301.37	89.56	100.69	201.78	7.133	15.58
292	0.20005	9.9773	-2985.3	228.31	98.89	139.88	933.77	168.0	107.2
292	0.20005	0.088241	18383	301.48	90.72	102.17	202.00	7.233	15.97
296	0.22744	9.8985	-2422.1	230.21	99.70	141.15	912.32	161.7	105.6
296	0.22744	0.099622	18714	301.62	91.90	103.70	202.13	7.334	16.37
300	0.2576	9.8186	-1853.7	232.11	100.51	142.47	890.88	155.6	103.9
300	0.2576	0.11212	19046	301.78	93.10	105.27	202.15	7.436	16.78
304	0.2907	9.7376	-1279.9	234.00	101.34	143.83	869.44	149.9	102.3
304	0.2907	0.12580	19377	301.95	94.31	106.89	202.08	7.540	17.20
308	0.32694	9.6553	-700.5	235.88	102.18	145.24	848.01	144.3	100.7
308	0.32694	0.14075	19707	302.14	95.53	108.56	201.89	7.646	17.64
312	0.36648	9.5717	-115.4	237.75	103.03	146.69	826.57	139.0	99.16
312	0.36648	0.15707	20037	302.35	96.76	110.29	201.61	7.754	18.08
316	0.40952	9.4867	475.7	239.62	103.90	148.20	805.11	134.0	97.62
316	0.40952	0.17485	20365	302.56	98.01	112.08	201.2	7.865	18.53
320	0.45624	9.4002	1072.8	241.48	104.78	149.76	783.62	129.1	96.10
320	0.45624	0.19420	20693	302.80	99.27	113.94	200.69	7.978	18.90
324	0.50684	9.3122	1676.3	243.34	105.66	151.38	762.10	124.4	94.61
324	0.50684	0.21521	21018	303.04	100.55	115.87	200.05	8.095	19.48
328	0.56152	9.2224	2286.3	245.20	106.56	153.07	740.53	119.9	93.14

TABLE 1 *Continued*

<i>T</i> K	<i>p</i> MPa	ρ mol·l ⁻¹	<i>H</i> J·mol ⁻¹	<i>S</i> J·mol ⁻¹ ·K ⁻¹	<i>C_v</i> J·mol ⁻¹ ·K ⁻¹	<i>C_p</i> J·mol ⁻¹ ·K ⁻¹	<i>c</i> m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
328	0.56152	0.23803	21342	303.29	101.84	117.87	199.28	8.215	19.98
332	0.62047	9.1307	2903.0	247.04	107.47	154.83	718.90	115.5	91.69
332	0.62047	0.26278	21663	303.55	103.13	119.97	198.38	8.339	20.49
336	0.6839	9.0371	3526.8	248.89	108.40	156.67	697.19	111.3	90.27
336	0.6839	0.28961	21982	303.82	104.45	122.17	197.35	8.467	21.02
340	0.75201	8.9414	4157.8	250.74	109.33	158.60	675.39	107.2	88.88
340	0.75201	0.31868	22298	304.09	105.77	124.47	196.17	8.601	21.58
344	0.82501	8.8434	4796.3	252.58	110.28	160.62	653.49	103.3	87.51
344	0.82501	0.35017	22611	304.36	107.10	126.90	194.83	8.740	22.15
348	0.90313	8.7429	5442.7	254.42	111.24	162.77	631.45	99.44	86.16
348	0.90313	0.38429	22919	304.64	108.43	129.46	193.35	8.886	22.75
352	0.98658	8.6397	6097.4	256.26	112.22	165.04	609.25	95.71	84.84
352	0.98658	0.42128	23223	304.92	109.77	132.19	191.69	9.038	23.37
356	1.0756	8.5335	6760.7	258.11	113.21	167.46	586.88	92.08	83.54
356	1.0756	0.46139	23523	305.19	111.11	135.10	189.86	9.199	24.03
360	1.1704	8.4241	7433.0	259.96	114.22	170.06	564.31	88.54	82.27
360	1.1704	0.50492	23816	305.46	112.46	138.25	187.85	9.369	24.72
364	1.2712	8.3111	8115.0	261.81	115.26	172.86	541.49	85.07	81.02
364	1.2712	0.55224	24102	305.73	113.82	141.68	185.65	9.550	25.44
368	1.3783	8.1941	8807.2	263.66	116.31	175.92	518.41	81.68	79.79
368	1.3783	0.60376	24380	305.98	115.21	145.48	183.24	9.742	26.20
372	1.492	8.0727	9510.3	265.52	117.39	179.27	495.02	78.36	78.58
372	1.492	0.65996	24650	306.22	116.63	149.72	180.62	9.947	27.02
376	1.6124	7.9462	10225	267.40	118.51	183.00	471.27	75.09	77.39
376	1.6124	0.72142	24909	306.45	118.10	154.54	177.76	10.17	27.88
380	1.7399	7.8141	10953	269.28	119.66	187.19	447.13	71.86	76.22
380	1.7399	0.78888	25155	306.65	119.62	160.09	174.66	10.41	28.81
384	1.8749	7.6755	11694	271.17	120.86	191.99	422.54	68.67	75.07
384	1.8749	0.86320	25388	306.83	121.21	166.57	171.29	10.67	29.82
388	2.0175	7.5292	12451	273.09	122.10	197.59	397.44	65.49	73.93
388	2.0175	0.94551	25604	306.98	122.88	174.29	167.64	10.95	30.92
392	2.1682	7.3739	13226	275.02	123.41	204.28	371.76	62.33	72.81
392	2.1682	1.0372	25801	307.10	124.63	183.68	163.69	11.27	32.13
396	2.3274	7.2077	14021	276.98	124.80	212.51	345.43	59.16	71.70
396	2.3274	1.1403	25973	307.16	126.47	195.40	159.41	11.62	33.48
400	2.4954	7.0280	14841	278.98	126.28	223.05	318.35	55.96	70.60
400	2.4954	1.2573	26116	307.17	128.42	210.57	154.77	12.03	35.03
404	2.6729	6.8308	15690	281.03	127.89	237.22	290.40	52.70	69.53
404	2.6729	1.3920	26220	307.10	130.51	231.11	149.74	12.50	36.85
408	2.8602	6.6104	16577	283.15	129.65	257.67	261.43	49.34	68.48
408	2.8602	1.5502	26275	306.92	132.78	260.79	144.27	13.05	39.07
412	3.0582	6.3565	17518	285.37	131.63	290.35	231.23	45.79	67.51
412	3.0582	1.7415	26259	306.58	135.31	308.00	138.31	13.74	41.93
416	3.2676	6.0492	18541	287.76	133.97	352.04	199.49	41.93	66.79
416	3.2676	1.9840	26134	306.01	138.28	396.04	131.77	14.64	46.01
420	3.4897	5.6393	19721	290.49	136.99	514.51	165.59	37.39	67.19
420	3.4897	2.3227	25806	304.98	142.07	623.01	124.46	15.96	53.10
424	3.7262	4.8868	21424	294.42	142.65	2001.10	127.24	30.58	79.51
424	3.7262	2.9801	24823	302.43	148.13	2609.40	115.73	18.84	77.92

TABLE 2 Thermophysical Properties of Normal Butane Along Isobars

T K	ρ mol·l ⁻¹	H J·mol ⁻¹	S J·mol ⁻¹ ·K ⁻¹	C_v J·mol ⁻¹ ·K ⁻¹	C_p J·mol ⁻¹ ·K ⁻¹	c m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
Pressure = 0.1 MPa								
140	12.564	-21826	138.28	83.81	114.91	1793.4	1889	174.9
150	12.404	-20674	146.22	83.84	115.44	1730.2	1371	171.2
160	12.243	-19517	153.69	83.92	116.04	1669.6	1056	167.3
170	12.083	-18353	160.75	84.12	116.77	1610.6	845.4	163.0
180	11.922	-17181	167.45	84.46	117.63	1552.6	695.1	158.6
190	11.760	-16000	173.83	84.96	118.65	1495.4	583.2	154.1
200	11.597	-14807	179.95	85.63	119.85	1438.8	496.9	149.4
210	11.433	-13602	185.83	86.47	121.22	1382.6	428.7	144.7
220	11.267	-12382	191.50	87.48	122.79	1326.8	373.8	139.9
230	11.098	-11146	197.00	88.65	124.54	1271.4	328.6	135.2
240	10.927	-9891.0	202.34	89.97	126.49	1216.2	291.1	130.5
250	10.753	-8615.5	207.55	91.43	128.63	1161.4	259.4	125.8
260	10.576	-7317.7	212.64	93.03	130.97	1106.7	232.4	121.2
270	10.394	-5995.4	217.63	94.74	133.52	1052.3	209.2	116.7
272.31	10.351	-5685.7	218.77	95.16	134.15	1039.7	204.2	115.7
272.31	0.046045	16750	301.16	85.13	95.27	200.07	6.748	14.11
280	0.044602	17488	303.83	86.83	96.77	203.31	6.945	14.82
290	0.042873	18466	307.26	89.13	98.84	207.36	7.200	15.77
300	0.041289	19466	310.65	91.50	101.03	211.28	7.452	16.75
320	0.038480	21532	317.32	96.40	105.67	218.74	7.952	18.80
340	0.036056	23694	323.87	101.45	110.52	225.80	8.446	20.98
360	0.033938	25954	330.33	106.54	115.48	232.55	8.934	23.28
380	0.032067	28313	336.70	111.64	120.48	239.03	9.419	25.72
400	0.030400	30773	343.01	116.69	125.45	245.29	9.899	28.27
420	0.028904	33331	349.25	121.67	130.36	251.36	10.38	30.96
440	0.027552	35986	355.43	126.54	135.18	257.25	10.85	33.78
460	0.026324	38737	361.54	131.30	139.90	262.99	11.32	36.72
480	0.025203	41581	367.59	135.93	144.49	268.59	11.78	39.79
500	0.024176	44516	373.58	140.43	148.97	274.06	12.25	42.98
520	0.023230	47539	379.51	144.80	153.32	279.42	12.71	46.31
540	0.022357	50648	385.37	149.05	157.54	284.66	13.17	49.76
560	0.021548	53840	391.18	153.16	161.64	289.80	13.62	53.34
Pressure = 1 MPa								
140	12.570	-21767	138.19	83.86	114.88	1796.8	1905	175.1
150	12.411	-20616	146.13	83.89	115.40	1733.9	1381	171.5
160	12.251	-19459	153.60	83.97	116.00	1673.5	1064	167.4
170	12.091	-18295	160.65	84.17	116.72	1614.8	851.3	163.4
180	11.931	-17124	167.35	84.51	117.57	1557.2	700.1	159.0
190	11.770	-15943	173.73	85.01	118.58	1500.3	587.4	154.4
200	11.608	-14752	179.84	85.68	119.77	1443.9	500.6	149.8
210	11.444	-13547	185.72	86.52	121.13	1388.1	432.0	145.1
220	11.279	-12329	191.39	87.52	122.68	1332.7	376.7	140.4
230	11.112	-11093	196.88	88.69	124.41	1277.6	331.4	135.6
240	10.942	-9839.7	202.21	90.01	126.34	1222.9	293.6	131.0
250	10.770	-8565.9	207.41	91.48	128.45	1168.5	261.8	126.3
260	10.594	-7270.0	212.49	93.07	130.76	1114.4	234.7	121.8
270	10.413	-5950.0	217.48	94.79	133.27	1060.6	211.3	117.3
280	10.229	-4603.9	222.37	96.61	135.98	1006.9	191.0	112.9
290	10.038	-3229.6	227.19	98.54	138.92	953.24	173.1	108.7
300	9.8412	-1824.8	231.95	100.54	142.09	899.57	157.3	104.5
320	9.4218	1087.1	241.35	104.79	149.32	791.34	130.3	96.58
340	8.9549	4159.1	250.66	109.33	158.25	679.85	107.8	89.13
352.62	8.6234	6199.6	256.55	112.37	165.40	605.80	95.14	84.64
352.62	0.42728	23270	304.96	109.97	132.62	191.42	9.064	23.47
360	0.40955	24245	307.70	111.18	131.74	197.12	9.229	24.30
380	0.37116	26878	314.81	115.04	131.97	210.36	9.690	26.68
400	0.34181	29536	321.63	119.28	134.10	221.49	10.16	29.23
420	0.31812	32248	328.25	123.67	137.13	231.27	10.62	31.93
440	0.29835	35025	334.70	128.13	140.64	240.10	11.09	34.77
460	0.28143	37875	341.04	132.59	144.41	248.23	11.55	37.74
480	0.26670	40802	347.27	136.99	148.29	255.80	12.02	40.84
500	0.25369	43807	353.40	141.32	152.21	262.94	12.48	44.07
520	0.24209	46890	359.45	145.55	156.11	269.71	12.93	47.42
540	0.23164	50051	365.41	149.68	159.98	276.17	13.38	50.91
560	0.22217	53289	371.30	153.71	163.79	282.37	13.84	54.52
Pressure = 2 MPa								
140	12.578	-21702	138.09	83.92	114.85	1800.5	1923	175.4
150	12.419	-20551	146.03	83.94	115.36	1737.9	1393	171.8
160	12.260	-19394	153.49	84.03	115.95	1677.9	1072	167.9

TABLE 2 *Continued*

<i>T</i> K	ρ mol·l ⁻¹	<i>H</i> J·mol ⁻¹	<i>S</i> J·mol ⁻¹ ·K ⁻¹	<i>C_v</i> J·mol ⁻¹ ·K ⁻¹	<i>C_p</i> J·mol ⁻¹ ·K ⁻¹	<i>c</i> m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
170	12.100	-18231	160.54	84.22	116.66	1619.5	858.0	163.7
180	11.941	-17060	167.23	84.56	117.51	1562.2	705.6	159.3
190	11.780	-15880	173.61	85.06	118.51	1505.6	592.0	154.8
200	11.619	-14690	179.72	85.73	119.68	1449.6	504.7	150.2
210	11.457	-13486	185.59	86.57	121.03	1394.2	435.6	145.6
220	11.293	-12269	191.26	87.57	122.56	1339.1	380.0	140.9
230	11.126	-11035	196.74	88.74	124.27	1284.5	334.4	136.2
240	10.958	-9782.4	202.07	90.06	126.17	1230.3	296.4	131.5
250	10.787	-8510.4	207.26	91.53	128.26	1176.4	264.4	126.9
260	10.613	-7216.6	212.34	93.12	130.54	1122.8	237.2	122.4
270	10.435	-5899.1	217.31	94.84	133.00	1069.6	213.7	118.0
280	10.252	-4556.0	222.19	96.66	135.66	1016.6	193.3	113.6
290	10.065	-3185.2	227.00	98.58	138.52	963.76	175.4	109.4
300	9.8708	-1784.7	231.75	100.59	141.61	911.00	159.5	105.3
320	9.4601	1115.7	241.11	104.83	148.56	805.11	132.5	97.44
340	9.0072	4167.9	250.35	109.34	156.96	697.16	110.1	90.12
360	8.4882	7410.6	259.62	114.16	167.92	583.69	90.65	83.25
380	7.8483	10925	269.12	119.56	185.44	456.34	72.69	76.62
387.52	7.5472	12360	272.86	121.95	196.87	400.48	65.88	74.07
387.52	0.93517	25579	306.97	122.68	173.29	168.10	10.92	30.78
400	0.83711	27639	312.2	123.85	159.11	184.18	10.98	31.66
420	0.73671	30732	319.75	126.72	151.92	202.90	11.24	33.83
440	0.66788	33754	326.78	130.34	150.78	217.41	11.59	36.40
460	0.61565	36778	333.50	134.27	151.92	229.57	11.98	39.22
480	0.57375	39838	340.01	138.32	154.13	240.18	12.38	42.23
500	0.53891	42947	346.36	142.39	156.91	249.70	12.80	45.40
520	0.50919	46116	352.57	146.43	160.00	258.40	13.23	48.72
540	0.48337	49348	358.67	150.42	163.26	266.46	13.66	52.19
560	0.46062	52647	364.67	154.34	166.60	274.00	14.09	55.79
Pressure = 3 MPa								
140	12.585	-21636	137.99	83.98	114.82	1804.1	1941	175.6
150	12.426	-20486	145.92	84.00	115.32	1741.9	1405	172.1
160	12.268	-19330	153.39	84.08	115.91	1682.2	1081	168.2
170	12.109	-18167	160.43	84.27	116.61	1624.1	864.7	164.0
180	11.951	-16997	167.12	84.61	117.45	1567.1	711.0	159.7
190	11.791	-15818	173.50	85.11	118.44	1510.9	596.7	155.2
200	11.631	-14628	179.60	85.78	119.60	1455.3	508.7	150.7
210	11.469	-13425	185.47	86.61	120.93	1400.2	439.3	146.0
220	11.306	-12208	191.13	87.62	122.44	1345.5	383.3	141.4
230	11.141	-10976	196.61	88.79	124.14	1291.3	337.4	136.7
240	10.974	-9725.0	201.93	90.11	126.02	1237.5	299.2	132.1
250	10.804	-8454.7	207.11	91.58	128.08	1184.1	267.1	127.5
260	10.632	-7162.8	212.18	93.17	130.32	1131.1	239.7	123.0
270	10.456	-5847.7	217.14	94.89	132.74	1078.5	216.1	118.6
280	10.275	-4507.4	222.02	96.71	135.35	1026.1	195.6	114.3
290	10.090	-3140.0	226.82	98.63	138.15	974.03	177.6	110.1
300	9.8996	-1743.6	231.55	100.63	141.16	922.12	161.7	106.0
320	9.4970	1145.1	240.87	104.86	147.88	818.38	134.6	98.29
340	9.0566	4179.5	250.07	109.35	155.82	713.55	112.3	91.08
360	8.5593	7391.1	259.24	114.10	165.79	605.20	93.08	84.37
380	7.9662	10839	268.56	119.28	180.13	488.16	75.67	78.04
400	7.1622	14691	278.43	125.62	210.58	348.01	58.34	71.67
410.85	6.4340	17240	284.72	131.03	279.05	240.08	46.84	67.78
410.85	1.6821	26273	306.70	134.55	291.72	140.09	13.52	41.02
420	1.4245	28427	311.89	132.14	205.30	161.75	12.86	38.57
440	1.1738	32114	320.47	133.32	172.40	189.36	12.57	39.23
460	1.0348	35469	327.93	136.31	164.69	208.23	12.68	41.35
480	0.93874	38738	334.89	139.83	162.84	223.17	12.93	43.99
500	0.86587	41998	341.54	143.56	163.34	235.76	13.24	46.94
520	0.80748	45280	347.97	147.37	164.99	246.79	13.59	50.12
540	0.75899	48601	354.24	151.19	167.28	256.68	13.97	53.49
560	0.71770	51973	360.37	154.98	169.92	265.71	14.36	57.02
Pressure = 5 MPa								
140	12.599	-21505	137.79	84.10	114.76	1811.4	1977	176.1
150	12.442	-20355	145.72	84.11	115.25	1749.9	1428	172.6
160	12.285	-19200	153.18	84.18	115.82	1690.8	1098	168.8
170	12.127	-18039	160.22	84.37	116.51	1633.3	878.1	164.7
180	11.970	-16870	166.90	84.71	117.33	1576.9	722.1	160.5
190	11.812	-15692	173.27	85.21	118.30	1521.3	606.1	156.0
200	11.653	-14503	179.36	85.87	119.43	1466.4	516.9	151.5
210	11.493	-13302	185.22	86.71	120.74	1412.0	446.6	146.9

TABLE 2 *Continued*

<i>T</i> K	ρ mol·l ⁻¹	<i>H</i> J·mol ⁻¹	<i>S</i> J·mol ⁻¹ ·K ⁻¹	<i>C_v</i> J·mol ⁻¹ ·K ⁻¹	<i>C_p</i> J·mol ⁻¹ ·K ⁻¹	<i>c</i> m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
220	11.332	-12088	190.87	87.72	122.22	1358.1	389.9	142.3
230	11.170	-10857	196.34	88.89	123.88	1304.7	343.4	137.7
240	11.005	-9609.3	201.65	90.21	125.72	1251.7	304.8	133.2
250	10.838	-8342.2	206.83	91.67	127.73	1199.3	272.3	128.6
260	10.669	-7054.2	211.88	93.27	129.91	1147.3	244.6	124.2
270	10.496	-5743.4	216.82	94.99	132.26	1095.7	220.8	119.9
280	10.320	-4408.4	221.68	96.81	134.78	1044.6	200.1	115.6
290	10.140	-3047.2	226.45	98.72	137.48	993.90	182.0	111.5
300	9.9548	-1658.3	231.16	100.72	140.34	943.54	166.0	107.5
320	9.5670	1210.4	240.42	104.94	146.66	843.60	138.8	99.92
340	9.1483	4214.3	249.52	109.39	153.90	744.04	116.6	92.91
360	8.6862	7375.2	258.55	114.06	162.47	643.65	97.64	86.47
380	8.1588	10728	267.61	118.98	173.30	540.35	80.92	80.56
400	7.5216	14340	276.87	124.35	189.21	430.26	65.43	75.04
420	6.6460	18405	286.78	130.86	223.30	304.64	49.76	69.55
440	4.6563	24326	300.52	141.61	450.47	155.71	28.47	63.93
460	2.5025	31574	316.67	141.80	250.79	162.44	16.76	51.25
480	1.9754	35948	325.99	143.37	199.26	188.80	15.20	49.80
500	1.7051	39764	333.78	146.11	184.83	208.77	14.78	51.14
520	1.5278	43400	340.91	149.32	179.63	224.97	14.72	53.45
540	1.3979	46973	347.65	152.73	178.08	238.73	14.83	56.29
560	1.2963	50535	354.13	156.24	178.32	250.78	15.04	59.46
Pressure = 7.5 MPa								
140	12.617	-21342	137.54	84.25	114.69	1820.5	2023	176.8
150	12.461	-20192	145.47	84.24	115.16	1759.7	1458	173.3
160	12.305	-19038	152.92	84.31	115.72	1701.4	1120	169.6
170	12.149	-17878	159.95	84.50	116.38	1644.6	895.0	165.6
180	11.994	-16710	166.63	84.83	117.18	1589.0	735.9	161.4
190	11.837	-15534	172.99	85.33	118.13	1534.2	617.8	157.0
200	11.681	-14347	179.07	85.99	119.24	1480.0	527.1	152.6
210	11.523	-13148	184.92	86.83	120.52	1426.5	455.6	148.1
220	11.364	-11936	190.56	87.84	121.97	1373.4	398.0	143.5
230	11.204	-10708	196.02	89.01	123.59	1321.0	350.9	139.0
240	11.043	-9463.5	201.32	90.33	125.38	1269.0	311.7	134.5
250	10.879	-8200.1	206.47	91.80	127.33	1217.6	278.8	130.0
260	10.713	-6916.4	211.51	93.39	129.45	1166.8	250.7	125.7
270	10.545	-5610.7	216.43	95.11	131.72	1116.5	226.6	121.4
280	10.374	-4281.5	221.27	96.93	134.15	1066.8	205.7	117.2
290	10.199	-2927.3	226.02	98.84	136.72	1017.6	187.4	113.2
300	10.020	-1546.5	230.70	100.84	139.45	968.94	171.2	109.3
320	9.6482	1300.8	239.89	105.04	145.38	873.03	143.9	101.9
340	9.2520	4273.2	248.90	109.47	151.99	778.73	121.6	95.06
360	8.8235	7386.1	257.79	114.06	159.45	685.58	102.9	88.88
380	8.3508	10659	266.63	118.82	168.08	592.97	86.66	83.31
400	7.8150	14122	275.51	123.79	178.64	500.14	72.13	78.31
420	7.1824	17829	284.55	129.06	192.92	406.27	58.71	73.80
440	6.3836	21895	294.01	134.82	215.85	311.63	45.82	69.61
460	5.2865	26569	304.39	140.91	252.63	228.45	33.22	65.53
480	4.0503	31735	315.38	145.41	253.10	195.26	23.78	61.51
500	3.2073	36502	325.12	148.38	224.13	199.23	19.42	59.19
520	2.7037	40777	333.50	151.26	205.30	212.67	17.58	59.12
540	2.3765	44777	341.05	154.33	195.82	227.03	16.76	60.49
560	2.1438	48642	348.08	157.57	191.36	240.47	16.42	62.73
Pressure = 10 MPa								
140	12.635	-21178	137.30	84.39	114.62	1829.4	2070.6	177.4
150	12.480	-20029	145.22	84.37	115.08	1769.4	1488.3	174.0
160	12.325	-18876	152.66	84.43	115.62	1711.8	1141.4	170.4
170	12.171	-17717	159.69	84.62	116.27	1655.8	912.0	166.4
180	12.017	-16550	166.36	84.95	117.05	1600.9	749.8	162.3
190	11.862	-15375	172.71	85.45	117.98	1546.8	629.5	158.0
200	11.707	-14190	178.79	86.11	119.06	1493.4	537.3	153.6
210	11.552	-12993	184.63	86.95	120.31	1440.6	464.6	149.2
220	11.396	-11783	190.26	87.96	121.73	1388.4	406.2	144.7
230	11.238	-10558	195.70	89.13	123.31	1336.8	358.4	140.2
240	11.079	-9316.5	200.99	90.45	125.06	1285.8	318.6	135.8
250	10.919	-8056.5	206.13	91.92	126.97	1235.4	285.2	131.4
260	10.756	-6776.6	211.15	93.51	129.02	1185.7	256.8	127.1
270	10.592	-5475.5	216.06	95.23	131.23	1136.5	232.4	122.9
280	10.425	-4151.6	220.87	97.05	133.58	1088.1	211.2	118.8
290	10.255	-2803.5	225.60	98.96	136.06	1040.2	192.7	114.8
300	10.082	-1429.9	230.26	100.96	138.68	993.02	176.3	111.0

TABLE 2 *Continued*

<i>T</i> K	ρ mol·l ⁻¹	<i>H</i> J·mol ⁻¹	<i>S</i> J·mol ⁻¹ ·K ⁻¹	<i>C_v</i> J·mol ⁻¹ ·K ⁻¹	<i>C_p</i> J·mol ⁻¹ ·K ⁻¹	<i>c</i> m·s ⁻¹	η μPa·s	λ mW·m ⁻¹ ·K ⁻¹
320	9.7235	1399.1	239.39	105.15	144.30	900.52	148.8	103.7
340	9.3461	4345.8	248.32	109.56	150.46	810.46	126.5	97.10
360	8.9438	7421.2	257.11	114.11	157.19	722.73	107.8	91.10
380	8.5098	10638	265.8	118.79	164.61	637.27	91.84	85.77
400	8.0346	14011	274.45	123.57	172.93	554.16	77.78	81.08
420	7.5052	17563	283.11	128.48	182.54	473.76	65.18	77.00
440	6.9034	21326	291.86	133.51	194.14	397.04	53.70	73.48
460	6.2060	25347	300.8	138.61	208.29	326.99	43.21	70.44
480	5.4101	29654	309.96	143.52	221.41	272.28	34.02	67.87
500	4.6089	34125	319.09	147.84	223.43	243.50	27.08	65.91
520	3.9401	38529	327.72	151.55	216.25	236.05	22.71	64.94
540	3.4352	42770	335.73	154.96	208.15	239.33	20.20	65.13
560	3.0595	46870	343.18	158.28	202.21	247.22	18.78	66.32
Pressure = 20 MPa								
140	12.703	-20522	136.34	84.93	114.37	1864.1	2271	179.8
150	12.553	-19376	144.25	84.88	114.78	1807.0	1614	176.7
160	12.404	-18226	151.67	84.91	115.27	1752.1	1231	173.3
170	12.255	-17070	158.68	85.08	115.86	1698.7	981.1	169.6
180	12.106	-15908	165.32	85.41	116.58	1646.4	805.9	165.8
190	11.958	-14738	171.64	85.90	117.44	1595.0	676.8	161.7
200	11.810	-13559	177.69	86.57	118.45	1544.3	578.2	157.6
210	11.662	-12369	183.50	87.41	119.61	1494.3	500.7	153.4
220	11.513	-11166	189.09	88.42	120.93	1445.0	438.6	149.2
230	11.365	-9949.7	194.5	89.59	122.40	1396.5	387.8	144.9
240	11.215	-8717.7	199.74	90.91	124.02	1348.7	345.7	140.8
250	11.065	-7468.8	204.84	92.38	125.78	1301.6	310.4	136.6
260	10.914	-6201.6	209.81	93.98	127.67	1255.4	280.4	132.5
270	10.763	-4914.9	214.67	95.70	129.69	1210.0	254.7	128.6
280	10.610	-3607.5	219.42	97.52	131.82	1165.5	232.4	124.7
290	10.455	-2278.2	224.09	99.43	134.05	1121.8	213.0	121.0
300	10.299	-926.2	228.67	101.42	136.38	1079.1	195.9	117.3
320	9.9823	1849.8	237.63	105.60	141.27	996.50	167.4	110.6
340	9.6571	4726.5	246.34	109.98	146.44	917.76	144.4	104.4
360	9.3222	7708.6	254.87	114.48	151.80	843.08	125.5	98.88
380	8.9765	10799	263.22	119.04	157.30	772.69	109.6	94.05
400	8.6189	14001	271.43	123.62	162.88	706.89	95.94	89.92
420	8.2491	17314	279.51	128.20	168.46	646.04	84.11	86.45
440	7.8672	20739	287.48	132.73	173.99	590.48	73.73	83.64
460	7.4747	24273	295.33	137.20	179.38	540.54	64.57	81.44
480	7.0739	27913	303.07	141.58	184.53	496.45	56.49	79.80
500	6.6690	31652	310.71	145.85	189.28	458.47	49.41	78.67
520	6.2660	35480	318.21	149.99	193.44	426.95	43.28	78.03
540	5.8726	39384	325.58	154.00	196.81	402.13	38.08	77.84
560	5.4975	43347	332.78	157.88	199.34	383.87	33.76	78.08

The symbols are:

T , temperature (K)

ρ , molar density ($\text{mol}\cdot\text{l}^{-1}$)

H , molar enthalpy ($\text{J}\cdot\text{mol}^{-1}$)

S , molar entropy ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

C_v , constant volume molar heat capacity ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

C_p , constant pressure molar heat capacity ($\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$)

c , speed of sound ($\text{m}\cdot\text{s}^{-1}$)

η , viscosity ($\mu\text{Pa}\cdot\text{s}$)

λ , thermal conductivity ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$)

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).