

2.14. THERMODYNAMIC PROPERTIES

Explanation of Tables The following subsection presents thermodynamic properties of a number of fluids. In some cases, transport properties are also included.

Property tables generated from the NIST database (Lemmon, E. W., M. O. McLinden, and M. L. Huber, NIST Standard Reference Database 23) are listed in [Table 2-109](#). The number of digits provided in these tables was chosen for uniformity of appearance and formatting and does not represent the uncertainties of the physical quantities: They are the result of calculations from the standard thermophysical property formulations within a fixed format. They were generated using REFPROP software (Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). Megan Friend helped produce these tables initially for Perry's 8th edition.

Because properties for many compounds also can be generated by the user at the NIST website, only more commonly used compounds' properties are given here. For other compounds, go to <http://webbook.nist.gov> and select NIST Chemistry WebBook > Thermophysical Properties of Fluid Systems High Accuracy Data. After selecting the desired unit system and temperature and/or pressure increments for which properties are to be generated, the resulting table can be copied into a spreadsheet.

Notation

c_p = isobaric specific heat

c_v = isochoric specific heat

e = specific internal energy

h = enthalpy

k = thermal conductivity

p = pressure

s = specific entropy

t = temperature

T = absolute temperature

u = specific internal energy

μ = viscosity

v = specific volume

f = subscript denoting saturated liquid

g = subscript denoting saturated vapor

Unit Conversions For this subsection, the following unit conversions are applicable:

c_p , specific heat: To convert kilojoules per kilogram-kelvin to British thermal units (Btu) per pound-degree Fahrenheit, multiply by 0.23885.

e , internal energy: To convert kilojoules per kilogram to Btu per pound, multiply by 0.42992.

g , gravity acceleration: To convert meters per second squared to feet per second squared, multiply by 3.2808.

h, enthalpy: To convert kilojoules per kilogram to Btu per pound, multiply by 0.42992.

k, thermal conductivity: To convert watts per meter-kelvin to Btu-feet per hour-square foot-degree Fahrenheit, multiply by 0.57779.

p, pressure: To convert bars to kilopascals, multiply by 100; to convert bars to pounds-force per square inch, multiply by 14.504; and to convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

s, entropy: To convert kilojoules per kilogram-kelvin to Btu per pound-degree Rankine, multiply by 0.23885.

t, temperature: $^{\circ}\text{F} = 9/5^{\circ}\text{C} + 32$.

T, absolute temperature: $^{\circ}\text{R} = 9/5 \text{ K}$.

u, internal energy: To convert kilojoules per kilogram to Btu per pound, multiply by 0.42992.

μ , viscosity: To convert pascal-seconds to pound-force-seconds per square foot, multiply by 0.020885; to convert pascal-seconds to c_p , multiply by 1000.

v, specific volume: To convert cubic meters per kilogram to cubic feet per pound, multiply by 16.018.

ρ , density: To convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.062428.

Additional References Bretsznajder, *Prediction of Transport and Other Physical Properties of Fluids*, Pergamon, New York, 1971. D'Ans and Lax, *Handbook for Chemists and Physicists* (in German), 3 vols., Springer-Verlag, Berlin. *Engineering Data Book*, 12th ed., 2004, Natural Gas Processors Suppliers Association, Tulsa, Okla. Ganick, Hartnett, and Rohsenow, *Handbook of Heat Transfer*, 2nd ed., McGraw-Hill, New York, 1984. Gray, *American Institute of Physics Handbook*, 3d ed., McGraw-Hill, New York, 1972. Kay and Laby, *Tables of Physical and Chemical Constants*, Longman, London, various editions and dates. *Landolt-Börnstein Tables*, many volumes and dates, Springer-Verlag, Berlin. Partington, *Advanced Treatise on Physical Chemistry*, Longman, London, 1950. Raznjevic, *Handbook of Thermodynamic Tables and Charts*, McGraw-Hill, New York, 1976 and other editions. Reynolds, *Thermodynamic Properties in SI*, Department of Mechanical Engineering, Stanford University, 1979. Stephan and Lucas, *Viscosity of Dense Fluids*, Plenum, New York and London, 1979. Vargaftik, *Tables of the Thermophysical Properties of Gases and Liquids*, Wiley, New York, 1975. Vargaftik, Filippov, Tarzimanov, and Totskiy, *Thermal Conductivity of Liquids and Gases* (in Russian), Standartov, Moscow, 1978. Weast, *Handbook of Chemistry and Physics*, Chemical Rubber Co., Boca Raton, FL, 97th print edition (2016) and online.

Table 2-109 Thermodynamic Properties of Acetone

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
178.50	2.3265E-06	15.723	0.063601	0.47366	0.47366	0.0080825	0.082500	0.11544	1765.7	-0.43351
180.00	2.8743E-06	15.695	0.063715	0.64687	0.64687	0.0090488	0.082598	0.11550	1757.0	-0.43308
195.00	1.9454E-05	15.416	0.064868	2.3835	2.3835	0.018316	0.083407	0.11604	1672.3	-0.42849
210.00	9.6588E-05	15.141	0.066048	4.1282	4.1282	0.026935	0.084076	0.11660	1591.8	-0.42274

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
225.00	0.00037556	14.867	0.067264	5.8823	5.8823	0.035003	0.084758	0.11731	1514.4	-0.41520
240.00	0.0012008	14.593	0.068525	7.6487	7.6488	0.042602	0.085541	0.11825	1439.4	-0.40545
255.00	0.0032765	14.319	0.069840	9.4311	9.4314	0.049806	0.086468	0.11946	1366.3	-0.39322
270.00	0.0078514	14.041	0.071218	11.234	11.234	0.056674	0.087553	0.12094	1294.8	-0.37827
285.00	0.016899	13.760	0.072673	13.060	13.062	0.063259	0.088794	0.12270	1224.5	-0.36033
300.00	0.033259	13.474	0.074217	14.915	14.918	0.069601	0.090180	0.12474	1155.2	-0.33907
315.00	0.060720	13.181	0.075867	16.802	16.807	0.075739	0.091697	0.12704	1086.7	-0.31399
330.00	0.10404	12.880	0.077643	18.725	18.733	0.081702	0.093329	0.12962	1018.8	-0.28437
345.00	0.16891	12.568	0.079569	20.687	20.701	0.087517	0.095063	0.13249	951.24	-0.24915
360.00	0.26188	12.243	0.081677	22.693	22.714	0.093209	0.096886	0.13568	883.84	-0.20678
375.00	0.39033	11.904	0.084008	24.746	24.779	0.098798	0.098794	0.13924	816.36	-0.15495
390.00	0.56235	11.545	0.086616	26.852	26.900	0.10431	0.10078	0.14328	748.57	-0.090162
405.00	0.78681	11.163	0.089578	29.015	29.085	0.10975	0.10286	0.14794	680.21	-0.0069455
420.00	1.0733	10.753	0.093001	31.243	31.343	0.11516	0.10504	0.15350	610.99	0.10371
435.00	1.4324	10.304	0.097051	33.546	33.685	0.12056	0.10736	0.16042	540.51	0.25760
450.00	1.8759	9.8043	0.10200	35.938	36.130	0.12599	0.10986	0.16967	468.19	0.48516
465.00	2.4172	9.2319	0.10832	38.445	38.707	0.13150	0.11265	0.18350	392.99	0.85357
480.00	3.0725	8.5423	0.11706	41.117	41.476	0.13720	0.11600	0.20893	312.66	1.5474
495.00	3.8632	7.6072	0.13145	44.096	44.604	0.14341	0.12077	0.28551	221.66	3.3240
508.10	4.6924	4.7000	0.21277	49.249	50.247	0.15437			0	14.310
178.50	2.3265E-06	1.5677E-06	637,900.	36.689	38.173	0.21928	0.050120	0.058440	172.60	3845.4
180.00	2.8743E-06	1.9207E-06	520,660.	36.764	38.260	0.21801	0.050280	0.058600	173.29	3637.4

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
195.00	1.9454E-05	1.2001E-05	83,324.	37.528	39.149	0.20686	0.051928	0.060265	179.95	2139.7
210.00	9.6588E-05	5.5355E-05	18,065.	38.314	40.059	0.19803	0.053740	0.062119	186.29	1312.0
225.00	0.00037556	0.00020108	4,973.1	39.121	40.989	0.19103	0.055800	0.064267	192.29	834.10
240.00	0.0012008	0.00060385	1,656.0	39.947	41.936	0.18546	0.058169	0.066795	197.94	547.82
255.00	0.0032765	0.0015555	642.89	40.790	42.897	0.18104	0.060883	0.069763	203.19	370.79
270.00	0.0078514	0.0035368	282.74	41.649	43.869	0.17754	0.063945	0.073198	207.99	258.27
285.00	0.016899	0.0072603	137.74	42.522	44.849	0.17479	0.067329	0.077094	212.26	184.97
300.00	0.033259	0.013699	72.996	43.406	45.834	0.17266	0.070988	0.081429	215.93	136.14
315.00	0.060720	0.024107	41.482	44.302	46.821	0.17102	0.074863	0.086172	218.90	102.93
330.00	0.10404	0.040034	24.979	45.207	47.806	0.16980	0.078895	0.091302	221.08	79.878
345.00	0.16891	0.063362	15.782	46.119	48.784	0.16892	0.083030	0.096822	222.35	63.590
360.00	0.26188	0.096367	10.377	47.033	49.751	0.16831	0.087227	0.10277	222.60	51.884
375.00	0.39033	0.14184	7.0503	47.946	50.698	0.16791	0.091459	0.10927	221.70	43.343
390.00	0.56235	0.20329	4.9192	48.849	51.615	0.16768	0.095718	0.11649	219.53	37.032
405.00	0.78681	0.28530	3.5050	49.733	52.490	0.16754	0.10001	0.12481	215.94	32.325
420.00	1.0733	0.39420	2.5368	50.582	53.305	0.16745	0.10438	0.13483	210.76	28.797
435.00	1.4324	0.53918	1.8547	51.376	54.033	0.16734	0.10887	0.14772	203.80	26.154
450.00	1.8759	0.73472	1.3611	52.083	54.636	0.16711	0.11357	0.16583	194.82	24.184
465.00	2.4172	1.0061	0.99393	52.648	55.050	0.16664	0.11865	0.19480	183.50	22.717
480.00	3.0725	1.4051	0.71168	52.968	55.154	0.16569	0.12436	0.25197	169.39	21.551
495.00	3.8632	2.0767	0.48154	52.771	54.631	0.16367	0.13126	0.42947	151.36	20.240
508.10	4.6924	4.7000	0.21277	49.249	50.247	0.15437			0	14.310

Single-Phase Properties

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
200.00	0.10000	15.325	0.065254	2.9626	2.9691	0.021248	0.083638	0.11621	1645.6	-0.42678
250.00	0.10000	14.411	0.069389	8.8328	8.8397	0.047436	0.086143	0.11902	1391.1	-0.39768
300.00	0.10000	13.475	0.074210	14.913	14.921	0.069594	0.090180	0.12473	1155.7	-0.33922
328.84	0.10000	12.903	0.077500	18.575	18.583	0.081247	0.093199	0.12941	1024.0	-0.28685
328.84	0.10000	0.038565	25.930	45.137	47.730	0.16988	0.078579	0.090892	220.94	81.384
350.00	0.10000	0.035712	28.002	46.843	49.643	0.17552	0.079533	0.090386	229.44	58.339
400.00	0.10000	0.030709	32.563	50.998	54.255	0.18783	0.085418	0.094849	246.85	30.192
450.00	0.10000	0.027083	36.923	55.474	59.166	0.19939	0.092823	0.10175	262.23	18.173
500.00	0.10000	0.024272	41.200	60.316	64.436	0.21049	0.10033	0.10903	276.40	12.201
550.00	0.10000	0.022008	45.437	65.522	70.066	0.22122	0.10753	0.11612	289.72	8.8355
200.00	1.0000	15.333	0.065220	2.9486	3.0138	0.021178	0.083649	0.11619	1649.7	-0.42708
250.00	1.0000	14.423	0.069336	8.8130	8.8824	0.047357	0.086152	0.11896	1396.0	-0.39848
300.00	1.0000	13.491	0.074123	14.885	14.959	0.069499	0.090182	0.12460	1162.0	-0.34115
350.00	1.0000	12.483	0.080107	21.312	21.392	0.089316	0.095644	0.13326	936.35	-0.24033
400.00	1.0000	11.308	0.088431	28.263	28.351	0.10788	0.10213	0.14605	707.25	-0.042437
416.48	1.0000	10.852	0.092149	30.714	30.806	0.11389	0.10452	0.15210	627.32	0.074613
416.48	1.0000	0.36582	2.7336	50.387	53.120	0.16747	0.10335	0.13228	212.13	29.536
450.00	1.0000	0.31254	3.1996	54.081	57.281	0.17709	0.10087	0.11921	233.76	20.211
500.00	1.0000	0.26538	3.7681	59.388	63.156	0.18947	0.10402	0.11743	256.99	12.984
550.00	1.0000	0.23391	4.2751	64.832	69.107	0.20081	0.10950	0.12100	275.55	9.1542
200.00	5.0000	15.367	0.065073	2.8871	3.2125	0.020868	0.083704	0.11609	1667.9	-0.42837
250.00	5.0000	14.471	0.069106	8.7271	9.0726	0.047011	0.086197	0.11871	1417.7	-0.40187
300.00	5.0000	13.560	0.073747	14.762	15.130	0.069085	0.090197	0.12408	1189.0	-0.34909
350.00	5.0000	12.588	0.079439	21.128	21.525	0.088784	0.095584	0.13214	972.15	-0.25988
400.00	5.0000	11.490	0.087035	27.958	28.393	0.10711	0.10186	0.14320	759.27	-0.10136

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
450.00	5.0000	10.123	0.098782	35.450	35.944	0.12488	0.10898	0.16059	538.79	0.26123
500.00	5.0000	7.8139	0.12798	44.435	45.075	0.14406	0.11961	0.23343	262.33	2.3418
550.00	5.0000	1.7344	0.57657	60.563	63.446	0.17943	0.12191	0.17820	205.69	10.650
200.00	10.000	15.410	0.064894	2.8125	3.4614	0.020488	0.083781	0.11598	1689.9	-0.42983
250.00	10.000	14.528	0.068831	8.6237	9.3120	0.046589	0.086264	0.11843	1443.6	-0.40569
300.00	10.000	13.641	0.073307	14.616	15.349	0.068589	0.090234	0.12351	1220.9	-0.35775
350.00	10.000	12.709	0.078687	20.916	21.703	0.088163	0.095554	0.13100	1013.1	-0.27983
400.00	10.000	11.683	0.085592	27.629	28.485	0.10626	0.10166	0.14066	815.03	-0.15336
450.00	10.000	10.491	0.095320	34.864	35.818	0.12352	0.10827	0.15332	622.74	0.080235
500.00	10.000	8.9733	0.11144	42.815	43.930	0.14060	0.11552	0.17314	433.48	0.63674
550.00	10.000	6.6600	0.15015	52.079	53.581	0.15896	0.12442	0.22174	255.34	2.7218
250.00	100.00	15.320	0.065276	7.2620	13.790	0.040421	0.088285	0.11631	1791.8	-0.43634
300.00	100.00	14.657	0.068228	12.852	19.675	0.061873	0.092127	0.11946	1616.6	-0.42000
350.00	100.00	14.023	0.071312	18.631	25.763	0.080632	0.097243	0.12424	1466.4	-0.39555
400.00	100.00	13.409	0.074574	24.654	32.112	0.097579	0.10299	0.12980	1337.4	-0.36734
450.00	100.00	12.813	0.078044	30.941	38.745	0.11320	0.10892	0.13553	1226.9	-0.33807
500.00	100.00	12.234	0.081739	37.489	45.663	0.12777	0.11478	0.14112	1133.0	-0.30922
550.00	100.00	11.674	0.085664	44.286	52.852	0.14147	0.12045	0.14639	1053.8	-0.28171
450.00	500.00	15.616	0.064037	27.237	59.256	0.097266	0.11562	0.13393	2201.1	-0.39010
500.00	500.00	15.306	0.065335	33.413	66.081	0.11164	0.12123	0.13909	2129.8	-0.37710
550.00	500.00	15.012	0.066615	39.856	73.163	0.12514	0.12669	0.14416	2067.5	-0.36510

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
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The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.1% in the saturated liquid density between 280 and 310 K, 0.5% in density in the liquid phase below 380 K, and 1% in density elsewhere, including all states at pressures above 100 MPa. The uncertainties in vapor pressure are 0.5% above 270 K (0.25% between 290 and 390 K), and the uncertainties in heat capacities and speeds of sound are 1%. These uncertainties (in caloric properties and sound speeds) may be higher at pressures above the saturation pressure and at temperatures above 320 K in the liquid phase and at supercritical conditions.

Table 2-110 Thermodynamic Properties of Air

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
Saturated Properties												
59.75	0.005265	33.067	0.030242	-1.0619	-1.0617	-0.01536	0.034011	0.055064	1030.3	-0.40785	171.43	376.64
60	0.005546	33.031	0.030275	-1.0481	-1.0480	-0.01513	0.033955	0.055062	1028.3	-0.40743	171.02	371.92
61	0.006797	32.888	0.030406	-0.99308	-0.99287	-0.01422	0.033731	0.055060	1020.3	-0.40565	169.40	353.83
62	0.008270	32.745	0.030539	-0.93803	-0.93778	-0.01333	0.033512	0.055062	1012.2	-0.40375	167.78	336.91
63	0.009994	32.601	0.030674	-0.88298	-0.88267	-0.01245	0.033298	0.055069	1004.0	-0.40173	166.16	321.09
64	0.012000	32.457	0.030810	-0.82792	-0.82755	-0.01158	0.033089	0.055081	995.77	-0.39958	164.53	306.27
65	0.014320	32.312	0.030949	-0.77286	-0.77241	-0.01073	0.032884	0.055098	987.48	-0.39729	162.91	292.39
66	0.016988	32.166	0.031089	-0.71777	-0.71725	-0.00989	0.032683	0.055120	979.13	-0.39485	161.28	279.38
67	0.020042	32.020	0.031231	-0.66267	-0.66205	-0.00906	0.032486	0.055148	970.72	-0.39227	159.65	267.17

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
68	0.023520	31.873	0.031375	-0.60755	-0.60681	-0.00824	0.032294	0.055181	962.24	-0.38952	158.01	255.71
69	0.027461	31.725	0.031521	-0.55239	-0.55152	-0.00744	0.032105	0.055220	953.70	-0.38660	156.37	244.94
70	0.031908	31.576	0.031669	-0.49720	-0.49619	-0.00664	0.031920	0.055266	945.10	-0.38352	154.73	234.81
71	0.036905	31.427	0.031820	-0.44196	-0.44079	-0.00586	0.031739	0.055317	936.43	-0.38024	153.09	225.28
72	0.042498	31.277	0.031972	-0.38669	-0.38533	-0.00508	0.031562	0.055376	927.70	-0.37677	151.44	216.31
73	0.048733	31.126	0.032127	-0.33135	-0.32979	-0.00432	0.031388	0.055441	918.90	-0.37310	149.79	207.85
74	0.055659	30.974	0.032285	-0.27597	-0.27417	-0.00357	0.031217	0.055514	910.04	-0.36922	148.14	199.88
75	0.063326	30.821	0.032445	-0.22051	-0.21846	-0.00282	0.031050	0.055594	901.11	-0.36511	146.49	192.35
76	0.071786	30.668	0.032608	-0.16499	-0.16265	-0.00209	0.030886	0.055682	892.11	-0.36076	144.83	185.23
77	0.081091	30.513	0.032773	-0.10939	-0.10673	-0.00136	0.030725	0.055779	883.05	-0.35616	143.16	178.51
78	0.091294	30.357	0.032941	-0.05371	-0.05070	-0.00064	0.030568	0.055884	873.91	-0.35130	141.50	172.14
79	0.10245	30.200	0.033112	0.002063	0.005456	6.86E-05	0.030413	0.055998	864.71	-0.34616	139.83	166.11
80	0.11462	30.042	0.033287	0.057934	0.061749	0.000772	0.030262	0.056122	855.44	-0.34074	138.15	160.39
81	0.12785	29.883	0.033464	0.11391	0.11819	0.001467	0.030113	0.056256	846.09	-0.33500	136.48	154.96
82	0.14221	29.722	0.033645	0.17000	0.17478	0.002156	0.029968	0.056400	836.67	-0.32894	134.80	149.80
83	0.15775	29.560	0.033829	0.22621	0.23155	0.002838	0.029826	0.056556	827.18	-0.32254	133.11	144.90
84	0.17453	29.397	0.034017	0.28255	0.28849	0.003513	0.029686	0.056723	817.61	-0.31577	131.42	140.23
85	0.19262	29.232	0.034209	0.33903	0.34562	0.004181	0.029550	0.056902	807.96	-0.30862	129.78	135.78

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
86	0.21207	29.066	0.034404	0.39566	0.40296	0.004844	0.029417	0.057094	798.24	-0.30107	128.11	131.54
87	0.23295	28.898	0.034604	0.45245	0.46051	0.005501	0.029286	0.057300	788.44	-0.29308	126.44	127.50
88	0.25531	28.729	0.034808	0.50940	0.51829	0.006153	0.029158	0.057521	778.56	-0.28464	124.76	123.63
89	0.27922	28.558	0.035017	0.56653	0.57631	0.006799	0.029033	0.057757	768.59	-0.27572	123.07	119.93
90	0.30475	28.385	0.035230	0.62386	0.63459	0.007440	0.028911	0.058009	758.55	-0.26628	121.38	116.38
91	0.33196	28.210	0.035449	0.68138	0.69315	0.008077	0.028792	0.058278	748.42	-0.25629	119.69	112.98
92	0.36091	28.033	0.035672	0.73912	0.75199	0.008708	0.028676	0.058566	738.20	-0.24573	118.00	109.72
93	0.39166	27.854	0.035901	0.79709	0.81115	0.009336	0.028563	0.058874	727.90	-0.23455	116.30	106.59
94	0.42429	27.673	0.036137	0.85529	0.87062	0.009960	0.028453	0.059202	717.51	-0.22270	114.61	103.58
95	0.45886	27.489	0.036378	0.91375	0.93044	0.010579	0.028346	0.059553	707.03	-0.21016	112.91	100.68
96	0.49543	27.304	0.036625	0.97248	0.99063	0.011195	0.028241	0.059928	696.46	-0.19686	111.21	97.879
97	0.53408	27.115	0.036880	1.0315	1.0512	0.011808	0.028140	0.060329	685.80	-0.18275	109.51	95.179
98	0.57486	26.924	0.037142	1.0908	1.1122	0.012418	0.028042	0.060757	675.05	-0.16779	107.81	92.571
99	0.61786	26.730	0.037411	1.1505	1.1736	0.013025	0.027948	0.061216	664.20	-0.15189	106.11	90.048
100	0.66313	26.533	0.037688	1.2104	1.2354	0.013630	0.027856	0.061707	653.26	-0.13501	104.41	87.605
101	0.71074	26.333	0.037975	1.2708	1.2978	0.014232	0.027768	0.062232	642.22	-0.11705	102.71	85.236
102	0.76077	26.130	0.038270	1.3315	1.3606	0.014833	0.027684	0.062796	631.08	-0.09794	101.01	82.937
103	0.81329	25.923	0.038575	1.3926	1.4240	0.015431	0.027603	0.063401	619.84	-0.07758	99.316	80.703

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
104	0.86836	25.713	0.038891	1.4542	1.4880	0.016029	0.027525	0.064052	608.50	-0.05588	97.623	78.529
105	0.92606	25.499	0.039217	1.5162	1.5525	0.016625	0.027452	0.064753	597.06	-0.03271	95.933	76.412
106	0.98645	25.281	0.039556	1.5787	1.6177	0.017221	0.027383	0.065508	585.51	-0.00795	94.247	74.347
107	1.0496	25.058	0.039908	1.6417	1.6836	0.017816	0.027317	0.066323	573.85	0.018543	92.565	72.331
108	1.1156	24.831	0.040273	1.7053	1.7502	0.018411	0.027256	0.067206	562.09	0.046927	90.888	70.361
109	1.1845	24.598	0.040653	1.7695	1.8176	0.019006	0.027200	0.068163	550.21	0.077386	89.216	68.432
110	1.2564	24.361	0.041050	1.8343	1.8858	0.019602	0.027149	0.069205	538.21	0.11012	87.551	66.542
111	1.3314	24.118	0.041464	1.8997	1.9549	0.020200	0.027103	0.070341	526.10	0.14538	85.893	64.688
112	1.4095	23.868	0.041896	1.9659	2.0250	0.020799	0.027062	0.071585	513.86	0.18342	84.242	62.867
113	1.4908	23.613	0.042350	2.0329	2.0960	0.021400	0.027028	0.072951	501.48	0.22456	82.599	61.075
114	1.5753	23.350	0.042826	2.1007	2.1682	0.022004	0.027000	0.074459	488.97	0.26917	80.965	59.311
115	1.6633	23.080	0.043328	2.1695	2.2415	0.022611	0.026979	0.076131	476.31	0.31767	79.340	57.571
116	1.7546	22.801	0.043857	2.2392	2.3161	0.023223	0.026965	0.077996	463.48	0.37057	77.724	55.852
117	1.8495	22.514	0.044417	2.3100	2.3922	0.023840	0.026961	0.080090	450.49	0.42848	76.119	54.152
118	1.9479	22.217	0.045011	2.3821	2.4697	0.024462	0.026966	0.082459	437.29	0.49214	74.523	52.467
119	2.0499	21.908	0.045645	2.4554	2.5490	0.025092	0.026982	0.085163	423.88	0.56243	72.938	50.794
120	2.1557	21.588	0.046323	2.5303	2.6302	0.025731	0.027010	0.088280	410.23	0.64047	71.363	49.130
121	2.2653	21.253	0.047052	2.6069	2.7135	0.026380	0.027053	0.091919	396.30	0.72765	69.798	47.469

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
122	2.3787	20.903	0.047841	2.6854	2.7992	0.027041	0.027113	0.096227	382.04	0.82574	68.243	45.809
123	2.4960	20.534	0.048700	2.7662	2.8878	0.027717	0.027194	0.10142	367.40	0.93703	66.700	44.141
124	2.6173	20.144	0.049643	2.8496	2.9796	0.028412	0.027300	0.10781	352.31	1.0646	65.170	42.460
125	2.7427	19.727	0.050691	2.9363	3.0753	0.029131	0.027438	0.11589	336.67	1.2125	63.658	40.755
126	2.8721	19.278	0.051871	3.0269	3.1759	0.029880	0.027618	0.12645	320.36	1.3865	62.176	39.013
127	3.0055	18.788	0.053225	3.1227	3.2827	0.030668	0.027855	0.14089	303.21	1.5951	60.751	37.215
128	3.1431	18.242	0.054818	3.2253	3.3976	0.031512	0.028171	0.16186	285.00	1.8510	59.445	35.332
129	3.2845	17.616	0.056765	3.3379	3.5243	0.032436	0.028607	0.19519	265.37	2.1752	58.409	33.316
130	3.4295	16.863	0.059300	3.4661	3.6695	0.033492	0.029242	0.25624	243.75	2.6058	58.054	31.072
131	3.5770	15.869	0.063015	3.6243	3.8497	0.034804	0.030266	0.40151	219.07	3.2246	59.591	28.384
132	3.7228	14.198	0.070432	3.8680	4.1302	0.036863	0.032343	1.0148	189.12	4.2808	67.802	24.467
132.63	3.7858	10.448	0.095715	4.4004	4.7627	0.041603			0	6.3978		
59.75	0.002432	0.004907	203.80	4.8774	5.3730	0.096708	0.020805	0.029217	154.83	58.283	5.2938	4.2197
60	0.002584	0.005192	192.59	4.8825	5.3800	0.096323	0.020809	0.029225	155.14	57.634	5.3199	4.2382
61	0.003274	0.006475	154.45	4.9025	5.4081	0.094825	0.020825	0.029261	156.38	55.151	5.4244	4.3119
62	0.004111	0.008005	124.93	4.9225	5.4361	0.093392	0.020843	0.029302	157.60	52.832	5.5291	4.3855
63	0.005120	0.009817	101.86	4.9424	5.4639	0.092020	0.020864	0.029348	158.81	50.666	5.6340	4.4590
64	0.006325	0.011948	83.693	4.9621	5.4915	0.090705	0.020886	0.029399	159.99	48.640	5.7391	4.5324

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
65	0.007756	0.014438	69.263	4.9817	5.5189	0.089445	0.020911	0.029455	161.16	46.742	5.8444	4.6057
66	0.009442	0.017326	57.715	5.0012	5.5461	0.088235	0.020938	0.029518	162.30	44.963	5.9500	4.6788
67	0.011416	0.020659	48.406	5.0205	5.5731	0.087074	0.020968	0.029587	163.42	43.293	6.0559	4.7519
68	0.013713	0.024481	40.849	5.0397	5.5998	0.085959	0.021000	0.029663	164.53	41.724	6.1621	4.8248
69	0.016372	0.028841	34.673	5.0587	5.6263	0.084887	0.021035	0.029746	165.60	40.248	6.2688	4.8976
70	0.019431	0.033789	29.595	5.0774	5.6525	0.083855	0.021072	0.029836	166.66	38.858	6.3759	4.9703
71	0.022933	0.039379	25.394	5.0960	5.6784	0.082862	0.021113	0.029934	167.69	37.548	6.4835	5.0429
72	0.026921	0.045664	21.899	5.1144	5.7040	0.081906	0.021156	0.030040	168.70	36.313	6.5917	5.1154
73	0.031443	0.052702	18.975	5.1326	5.7292	0.080983	0.021201	0.030155	169.69	35.146	6.7005	5.1878
74	0.036547	0.060550	16.515	5.1505	5.7541	0.080094	0.021250	0.030278	170.65	34.043	6.8099	5.2602
75	0.042282	0.069268	14.437	5.1682	5.7786	0.079235	0.021302	0.030410	171.58	32.999	6.9202	5.3325
76	0.048702	0.078918	12.671	5.1856	5.8027	0.078406	0.021356	0.030552	172.49	32.010	7.0312	5.4048
77	0.055859	0.089564	11.165	5.2028	5.8264	0.077604	0.021414	0.030703	173.37	31.072	7.1431	5.4771
78	0.063810	0.10127	9.8746	5.2196	5.8497	0.076828	0.021474	0.030865	174.23	30.183	7.2560	5.5494
79	0.072611	0.11410	8.7639	5.2362	5.8726	0.076076	0.021538	0.031037	175.05	29.337	7.3700	5.6217
80	0.082321	0.12813	7.8043	5.2525	5.8949	0.075348	0.021605	0.031220	175.85	28.534	7.4851	5.6940
81	0.093001	0.14343	6.9721	5.2684	5.9169	0.074643	0.021674	0.031415	176.62	27.769	7.6014	5.7664
82	0.10471	0.16006	6.2475	5.2841	5.9383	0.073957	0.021747	0.031621	177.36	27.041	7.7192	5.8389

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m ² ·K)	Viscosity µPa·s
83	0.11751	0.17811	5.6145	5.2994	5.9591	0.073292	0.021822	0.031840	178.07	26.346	7.8384	5.9116
84	0.13147	0.19765	5.0595	5.3143	5.9795	0.072645	0.021901	0.032072	178.75	25.684	7.9591	5.9844
85	0.14665	0.21875	4.5715	5.3289	5.9993	0.072016	0.021983	0.032317	179.40	25.051	8.0817	6.0574
86	0.16312	0.24150	4.1408	5.3431	6.0185	0.071403	0.022068	0.032577	180.02	24.447	8.2060	6.1307
87	0.18094	0.26598	3.7597	5.3569	6.0372	0.070806	0.022155	0.032851	180.61	23.869	8.3324	6.2043
88	0.20018	0.29228	3.4214	5.3703	6.0552	0.070224	0.022246	0.033141	181.17	23.316	8.4610	6.2781
89	0.22091	0.32048	3.1203	5.3832	6.0726	0.069655	0.022340	0.033447	181.69	22.786	8.5919	6.3524
90	0.24320	0.35068	2.8516	5.3958	6.0893	0.069099	0.022436	0.033770	182.19	22.278	8.7254	6.4272
91	0.26712	0.38298	2.6111	5.4079	6.1054	0.068556	0.022536	0.034111	182.65	21.791	8.8616	6.5024
92	0.29273	0.41747	2.3954	5.4195	6.1207	0.068024	0.022638	0.034472	183.08	21.324	9.0008	6.5782
93	0.32011	0.45426	2.2014	5.4307	6.1354	0.067503	0.022744	0.034853	183.47	20.876	9.1433	6.6547
94	0.34934	0.49345	2.0265	5.4413	6.1492	0.066991	0.022852	0.035256	183.84	20.445	9.2893	6.7318
95	0.38047	0.53517	1.8686	5.4514	6.1624	0.066489	0.022964	0.035681	184.17	20.031	9.4390	6.8098
96	0.41359	0.57953	1.7255	5.4610	6.1747	0.065995	0.023078	0.036132	184.46	19.632	9.5929	6.8887
97	0.44878	0.62667	1.5957	5.4701	6.1862	0.065510	0.023196	0.036610	184.72	19.249	9.7513	6.9686
98	0.48609	0.67671	1.4777	5.4785	6.1968	0.065031	0.023317	0.037116	184.95	18.879	9.9145	7.0495
99	0.52562	0.72980	1.3702	5.4864	6.2066	0.064560	0.023441	0.037654	185.14	18.523	10.083	7.1317
100	0.56742	0.78609	1.2721	5.4936	6.2154	0.064094	0.023568	0.038225	185.30	18.180	10.257	7.2153

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
101	0.61159	0.84575	1.1824	5.5002	6.2233	0.063633	0.023698	0.038834	185.42	17.848	10.438	7.3003
102	0.65820	0.90895	1.1002	5.5060	6.2302	0.063177	0.023833	0.039483	185.51	17.528	10.626	7.3870
103	0.70732	0.97587	1.0247	5.5112	6.2360	0.062726	0.023970	0.040176	185.55	17.218	10.821	7.4755
104	0.75903	1.0467	0.95535	5.5156	6.2408	0.062277	0.024112	0.040918	185.57	16.918	11.024	7.5659
105	0.81341	1.1217	0.89147	5.5193	6.2444	0.061832	0.024258	0.041714	185.54	16.628	11.237	7.6586
106	0.87055	1.2011	0.83254	5.5221	6.2469	0.061389	0.024408	0.042570	185.48	16.346	11.459	7.7537
107	0.93052	1.2852	0.77810	5.5240	6.2481	0.060947	0.024563	0.043492	185.38	16.072	11.693	7.8514
108	0.9934	1.3742	0.72772	5.5250	6.2480	0.060506	0.024722	0.044490	185.24	15.805	11.939	7.9521
109	1.0593	1.4684	0.68102	5.5251	6.2465	0.060065	0.024887	0.045573	185.07	15.546	12.198	8.0560
110	1.1282	1.5682	0.63767	5.5241	6.2436	0.059623	0.025058	0.046751	184.85	15.292	12.473	8.1634
111	1.2004	1.6740	0.59737	5.5221	6.2391	0.059180	0.025234	0.048038	184.60	15.044	12.764	8.2749
112	1.2757	1.7862	0.55985	5.5188	6.2330	0.058735	0.025418	0.049450	184.30	14.800	13.074	8.3907
113	1.3545	1.9053	0.52486	5.5143	6.2252	0.058286	0.025608	0.051005	183.97	14.561	13.406	8.5114
114	1.4366	2.0318	0.49217	5.5085	6.2156	0.057833	0.025807	0.052727	183.59	14.324	13.762	8.6375
115	1.5223	2.1664	0.46160	5.5012	6.2039	0.057375	0.026015	0.054644	183.17	14.090	14.145	8.7696
116	1.6115	2.3097	0.43296	5.4924	6.1901	0.056910	0.026232	0.056790	182.71	13.856	14.559	8.9086
117	1.7045	2.4625	0.40608	5.4819	6.1740	0.056437	0.026461	0.059209	182.21	13.623	15.008	9.0552
118	1.8013	2.6259	0.38082	5.4695	6.1554	0.055955	0.026701	0.061956	181.66	13.388	15.499	9.2104

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
119	1.9020	2.8009	0.35702	5.4550	6.1341	0.055461	0.026956	0.065102	181.08	13.151	16.039	9.3755
120	2.0067	2.9889	0.33457	5.4383	6.1097	0.054954	0.027226	0.068738	180.45	12.909	16.635	9.5518
121	2.1156	3.1913	0.31335	5.4190	6.0819	0.054432	0.027514	0.072988	179.78	12.661	17.298	9.7412
122	2.2287	3.4103	0.29323	5.3969	6.0504	0.053890	0.027823	0.078015	179.06	12.405	18.042	9.9456
123	2.3462	3.6481	0.27412	5.3715	6.0147	0.053326	0.028155	0.084052	178.31	12.137	18.884	10.168
124	2.4682	3.9078	0.25590	5.3424	5.9740	0.052735	0.028516	0.091426	177.51	11.854	19.849	10.411
125	2.5949	4.1934	0.23847	5.3089	5.9277	0.052112	0.028910	0.10063	176.68	11.553	20.968	10.681
126	2.7266	4.5101	0.22173	5.2701	5.8746	0.051448	0.029344	0.11241	175.81	11.229	22.288	10.982
127	2.8633	4.8653	0.20554	5.2248	5.8133	0.050732	0.029827	0.12801	174.91	10.874	23.877	11.324
128	3.0055	5.2697	0.18976	5.1713	5.7417	0.049950	0.030371	0.14959	173.96	10.480	25.841	11.720
129	3.1536	5.7405	0.17420	5.1069	5.6563	0.049076	0.030994	0.18134	172.98	10.033	28.367	12.191
130	3.3084	6.3074	0.15854	5.0268	5.5513	0.048067	0.031726	0.23261	171.93	9.5119	31.807	12.775
131	3.4712	7.0343	0.14216	4.9209	5.4143	0.046830	0.032619	0.32992	170.79	8.8740	37.001	13.553
132	3.6462	8.1273	0.12304	4.7566	5.2053	0.045064	0.033814	0.59804	169.40	7.9854	46.996	14.798
132.63	3.7858	10.448	0.095715	4.4004	4.7627	0.041603			0	6.3978		

Single-Phase Properties

100	0.1	0.12283	8.1414	5.6800	6.4941	0.080463	0.021087	0.030116	198.24	17.423	9.4692	7.1068
300	0.1	0.040103	24.936	9.8544	12.348	0.11269	0.020796	0.029149	347.36	2.2510	26.384	18.537

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
500	0.1	0.024046	41.586	14.072	18.231	0.12770	0.021504	0.029830	446.40	0.50305	39.944	27.090
700	0.1	0.017175	58.223	18.500	24.323	0.13794	0.022817	0.031137	523.89	-0.12430	51.755	34.176
900	0.1	0.013359	74.855	23.201	30.686	0.14593	0.024150	0.032467	589.60	-0.41124	62.543	40.394
1100	0.1	0.010931	91.486	28.145	37.293	0.15255	0.025246	0.033562	648.15	-0.56194	72.680	46.051
1300	0.1	0.009249	108.12	33.282	44.094	0.15823	0.026091	0.034406	701.76	-0.64963	82.381	51.325
1500	0.1	0.008016	124.75	38.568	51.042	0.16320	0.026734	0.035049	751.59	-0.70457	91.781	56.325
1700	0.1	0.007073	141.38	43.966	58.104	0.16762	0.027229	0.035544	798.38	-0.74078	100.97	61.127
1900	0.1	0.006329	158.00	49.453	65.253	0.17160	0.027619	0.035934	842.62	-0.76547	110.01	65.783
100	1	26.593	0.037604	1.2007	1.2383	0.013532	0.027868	0.061355	658.25	-0.14308	104.97	88.326
106.22	1	25.232	0.039632	1.5924	1.6321	0.017351	0.027368	0.065680	582.97	-0.00232	93.879	73.903
108.1	1	1.3836	0.72278	5.5251	6.2479	0.060461	0.024739	0.044597	185.23	15.779	11.965	7.9625
300	1	0.40205	2.4873	9.8022	12.289	0.093372	0.020859	0.029563	348.45	2.1789	26.684	18.672
500	1	0.23974	4.1711	14.046	18.218	0.10851	0.021526	0.029954	448.46	0.47425	40.110	27.179
700	1	0.17119	5.8415	18.485	24.326	0.11877	0.022830	0.031194	525.96	-0.13809	51.868	34.242
900	1	0.13319	7.5079	23.190	30.698	0.12677	0.024159	0.032498	591.54	-0.41899	62.628	40.446
1100	1	0.10902	9.1727	28.138	37.311	0.13340	0.025253	0.033582	649.96	-0.56686	72.748	46.094
1300	1	0.092279	10.837	33.278	44.114	0.13908	0.026096	0.034419	703.44	-0.65304	82.438	51.361
1500	1	0.079999	12.500	38.565	51.065	0.14405	0.026738	0.035057	753.17	-0.70711	91.830	56.357

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
1700	1	0.070604	14.163	43.964	58.128	0.14847	0.027233	0.035550	799.86	-0.74278	101.01	61.155
1900	1	0.063185	15.827	49.451	65.278	0.15245	0.027622	0.035939	844.02	-0.76711	110.05	65.808
100	5	27.222	0.036735	1.0983	1.2820	0.012483	0.028034	0.058181	710.56	-0.21837	111.13	96.436
300	5	2.0232	0.49426	9.5710	12.042	0.079244	0.021131	0.031423	355.63	1.8817	28.389	19.420
500	5	1.1814	0.84642	13.935	18.167	0.094907	0.021621	0.030478	458.30	0.36370	40.969	27.606
700	5	0.84321	1.1859	18.417	24.347	0.10529	0.022885	0.031434	535.45	-0.19118	52.433	34.545
900	5	0.65711	1.5218	23.146	30.755	0.11334	0.024197	0.032632	600.34	-0.44905	63.045	40.682
1100	5	0.53874	1.8562	28.107	37.388	0.11999	0.025282	0.033664	658.10	-0.58606	73.076	46.287
1300	5	0.45667	2.1898	33.256	44.205	0.12568	0.026119	0.034473	711.01	-0.66646	82.707	51.523
1500	5	0.39636	2.5229	38.550	51.165	0.13066	0.026757	0.035095	760.23	-0.71716	92.057	56.497
1700	5	0.35015	2.8559	43.954	58.234	0.13509	0.027249	0.035577	806.49	-0.75073	101.21	61.278
1900	5	0.31361	3.1887	49.445	65.389	0.13907	0.027636	0.035958	850.28	-0.77366	110.22	65.917
100	10	27.863	0.035889	0.99444	1.3533	0.011382	0.028284	0.055716	763.47	-0.27969	117.77	105.78
300	10	4.0370	0.24771	9.2885	11.766	0.072612	0.021441	0.033664	369.50	1.5212	31.116	20.637
500	10	2.3157	0.43183	13.802	18.120	0.088894	0.021733	0.031078	471.81	0.25100	42.260	28.194
700	10	1.6542	0.60452	18.336	24.382	0.099422	0.022952	0.031710	547.83	-0.24405	53.257	34.944
900	10	1.2922	0.77388	23.092	30.831	0.10752	0.024243	0.032786	611.64	-0.47890	63.641	40.985
1100	10	1.0618	0.94184	28.070	37.489	0.11420	0.025317	0.033760	668.47	-0.60517	73.538	46.531

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
1300	10	0.90165	1.1091	33.231	44.321	0.11990	0.026146	0.034537	720.60	-0.67990	83.082	51.728
1500	10	0.78374	1.2759	38.532	51.292	0.12489	0.026780	0.035139	769.17	-0.72730	92.372	56.673
1700	10	0.69321	1.4426	43.943	58.368	0.12932	0.027268	0.035608	814.87	-0.75881	101.48	61.432
1900	10	0.62149	1.6090	49.438	65.528	0.13330	0.027653	0.035981	858.18	-0.78039	110.45	66.054
100	100	33.161	0.030156	0.24746	3.2631	0.001378	0.031980	0.048218	1192.4	-0.47290	179.20	252.46
300	100	21.138	0.047309	7.0356	11.767	0.049067	0.023981	0.038366	818.47	-0.49747	86.312	53.642
500	100	15.089	0.066273	12.371	18.999	0.067619	0.023117	0.034686	772.41	-0.55640	71.549	42.159
700	100	11.803	0.084722	17.367	25.840	0.079134	0.023855	0.034011	790.14	-0.62591	73.572	43.339
900	100	9.7481	0.10258	22.408	32.667	0.087711	0.024903	0.034331	821.78	-0.67702	79.057	46.948
1100	100	8.3307	0.12004	27.580	39.584	0.09465	0.025831	0.034845	857.40	-0.71435	85.797	51.158
1300	100	7.2877	0.13722	32.880	46.602	0.10051	0.026565	0.035323	894.00	-0.74281	93.151	55.511
1500	100	6.4847	0.15421	38.287	53.708	0.10559	0.027131	0.035723	930.40	-0.76506	100.84	59.875
1700	100	5.8456	0.17107	43.779	60.886	0.11009	0.027569	0.036049	966.13	-0.78264	108.75	64.208
1900	100	5.3239	0.18783	49.340	68.123	0.11411	0.027915	0.036317	1001.0	-0.79653	116.78	68.504
300	500	34.106	0.029320	6.2145	20.875	0.033155	0.028875	0.039265	1678.8	-0.57656	208.23	181.12
500	500	29.826	0.033528	11.583	28.348	0.052311	0.026614	0.036111	1573.6	-0.65015	178.50	120.62
700	500	26.714	0.037433	16.768	35.484	0.064323	0.026496	0.035494	1514.8	-0.67879	161.67	97.470
900	500	24.283	0.041180	22.008	42.598	0.073261	0.026991	0.035702	1482.8	-0.68796	151.95	86.531

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
1100	500	22.305	0.044833	27.358	49.775	0.080460	0.027539	0.036073	1468.3	-0.69130	146.88	81.387
1300	500	20.651	0.048423	32.814	57.025	0.086515	0.028000	0.036415	1465.1	-0.69354	144.95	79.411
1500	500	19.243	0.051966	38.354	64.337	0.091746	0.02836	0.036693	1469.3	-0.69594	145.84	79.312
1700	500	18.027	0.055473	43.961	71.698	0.096353	0.02864	0.036911	1478.5	-0.69875	148.48	80.393
1900	500	16.963	0.058952	49.623	79.098	0.10047	0.02886	0.037085	1491.1	-0.70188	152.39	82.251
300	1000	40.130	0.024919	6.8286	31.747	0.024761	0.032271	0.041510	2208.5	-0.50493	274.96	337.76
500	1000	36.567	0.027347	12.271	39.618	0.044944	0.029334	0.037843	2104.7	-0.57316	247.30	219.41
700	1000	33.895	0.029503	17.554	47.057	0.057468	0.028754	0.036801	2033.9	-0.60504	230.60	174.51
900	1000	31.736	0.031510	22.890	54.399	0.066695	0.028917	0.036702	1984.7	-0.61882	219.72	149.43
1100	1000	29.916	0.033427	28.327	61.754	0.074073	0.029215	0.036858	1951.3	-0.62560	212.46	133.76
1300	1000	28.338	0.035288	33.857	69.145	0.080246	0.029476	0.037051	1929.3	-0.62968	207.70	123.58
1500	1000	26.946	0.037111	39.461	76.573	0.085561	0.029675	0.037224	1915.7	-0.63251	204.81	116.94
1700	1000	25.701	0.038909	45.123	84.032	0.090229	0.029821	0.037369	1908.3	-0.63465	203.41	112.74
1900	1000	24.577	0.040688	50.830	91.519	0.094392	0.029928	0.037491	1905.8	-0.63632	203.25	110.27

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
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This table was generated for a standard three-component dry air containing mole fractions 0.7812 nitrogen, 0.2096 oxygen, and 0.0092 argon. The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., Jacobsen, R. T., Penoncello, S. G., and Friend, D. G., "Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa," *J. Phys. Chem. Ref. Data* **29**(3):331–385, 2000. The source for viscosity and thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25**:21–69, 2004.

Properties at the freezing point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

In the range from the solidification point to 873 K at pressures to 70 MPa, the estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated speed of sound values is 0.2% and that for calculated heat capacities is 1%. At temperatures above 873 K and 70 MPa, the estimated uncertainty of calculated density values is 0.5%, increasing to 1.0% at 2000 K and 2000 MPa. For viscosity, the uncertainty is 1% in the dilute gas. The uncertainty is around 2% between 270 and 300 K and increases to 5% outside of this region. There are very few measurements between 130 and 270 K for air to validate this claim, and the uncertainties may be even higher in this supercritical region. For thermal conductivity, the uncertainty for the dilute gas is 2% with increasing uncertainties near the triple points. The uncertainties range from 3% between 140 and 300 K to 5% at the triple point and at high temperatures. The uncertainties above 100 MPa are not known due to a lack of experimental data.

Figure 2-3 Pressure-enthalpy diagram for dry air. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of E. W. Lemmon, R. T. Jacobsen,, S. G. Penoncello, and D. G. Friend.

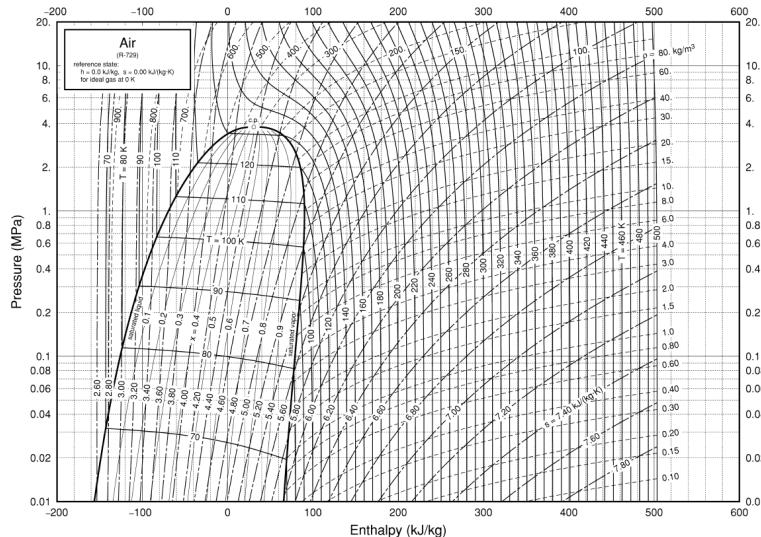


Table 2-111 Air

Other tables include Stewart, R. B., S. G. Penoncello, et al., University of Idaho CATS report, 85-5, 1985 (0.1-700 bar, 85-750 K), and Lemmon, E. W., Jacobsen, R. T., Penoncello, S. G., and Friend, D. G., Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa, *J. Phys. Chem. Ref. Data*, **29**(3): 331-385, 2000. Tables including reactions with hydrocarbons include Gordon, S., NASA Techn. Paper 1907, 4 vols., 1982. See also Gupta, R. N., K-P. Lee, et al., NASA RP 1232, 1990 (89 pp.) and RP 1260, 1991 (75 pp.). Analytic expressions for high temperatures were given by Matsuzaki, R., *Jap. J. Appl. Phys.*, **21**, 7 (1982): 1009-1013 and Japanese National Aerospace Laboratory report NAL TR 671, 1981 (45 pp.). Functions from 1500 to 15,000 K were tabulated by Hilsenrath, J. and M. Klein, AEDC-TR-65-58 = AD 612 301, 1965 (333 pp.). Tables from 10000 to 10,000,000 K were authored by Gilmore, F. R., Lockheed rept. 3-27-67-1, vol 1., 1967 (340 pp.), also published as *Radiative Properties of Air*, IFI/Plenum, New York, 1969 (648 pp.). Saturation and superheat tables and a chart to 7000 psia, 660°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, Ga, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

Air, Moist

For other data in this handbook, please see [Figure 2-2](#) and the psychrometric tables, figures and descriptions in [Section 12](#).

An ASHRAE publication, *Thermodynamic Properties of Dry Air and Water and S. I. Psychrometric Charts*, 1983 (360 pp.), extensively reviews moist air properties. Gandiduson, P., *Chem. Eng.*, Oct. 29, 1984 gives on page 118 a nomograph from 50 to 120°F, while equations in SI units were given by Nelson, B., *Chem. Eng. Progr.* **76**, 5 (May 1980): 83-85. Liley, P. E., *2000 Solved Problems in M.E. Thermodynamics*, McGraw-Hill, New York, 1989, gives four simple equations with which most calculations can be made. Devres, Y.O., *Appl. Energy* **48** (1994): 1-18 gives equations with which three known properties can be used to determine four others. Klappert, M. T. and G. F. Schilling, Rand RM-4244-PR = AD 604 856, 1984 (40 pp.) gives tables from 100 to 270 K, while programs from -60 to 2°F are given by Sando, F. A., *ASHRAE Trans.*, **96**, 2 (1990): 299-308.

Viscosity references include Kestin, J. and J. H. Whitelaw, *Int. J. Ht. Mass Transf.* **7**, 11 (1964): 1245-1255; Studnokov, E. L., *Inz.-Fiz. Zhur.* **19**, 2 (1970): 338-340; Hochramer, D. and F. Munczak, *Setzb. Ost. Acad. Wiss II* **175**, 10 (1966): 540-550. For thermal conductivity see, for instance, Mason, E. A. and L. Monchick, *Humidity and Moisture Control in Science and Industry*, Reinhold, New York, 1965 (257-272).

Table 2-112 Thermodynamic Properties of Ammonia

Tempe rature K	Pressu re MPa	Densit y mol/d m ³	Volum e dm ³ /m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l·K)	C_v kJ/(mo l·K)	C_p kJ/(mo l·K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
195.50	0.0060 912	43.035	0.0232 37	0.0000 0	0.0001 4154	0.0000 0	0.0499 72	0.0715 65	2124.2	-0.233 62	818.99	559.57
200.00	0.0086 509	42.754	0.0233 89	0.3233 3	0.3235 3	0.0016 351	0.0498 37	0.0719 88	2080.2	-0.229 17	803.14	507.28
210.00	0.0177 39	42.111	0.0237 47	1.0480	1.0484	0.0051 707	0.0495 21	0.0729 71	1992.7	-0.218 83	768.02	414.98
220.00	0.0337 90	41.442	0.0241 30	1.7825	1.7833	0.0085 874	0.0492 07	0.0739 50	1913.7	-0.208 13	733.17	346.68
230.00	0.0604 07	40.748	0.0245 41	2.5265	2.5279	0.0118 94	0.0489 06	0.0748 83	1839.2	-0.197 12	698.80	294.94
240.00	0.1022 3	40.032	0.0249 80	3.2793	3.2818	0.0150 98	0.0486 13	0.0757 64	1766.9	-0.185 61	665.09	254.85
250.00	0.1649 4	39.293	0.0254 50	4.0403	4.0445	0.0182 05	0.0483 27	0.0766 08	1695.6	-0.173 27	632.16	223.08
260.00	0.2553 1	38.533	0.0259 52	4.8093	4.8160	0.0212 22	0.0480 47	0.0774 48	1624.5	-0.159 63	600.07	197.34

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
270.00	0.38107	37.748	0.026491	5.5862	5.5963	0.024154	0.047774	0.078328	1553.1	-0.14414	568.85	176.06
280.00	0.55092	36.939	0.027072	6.3712	6.3861	0.027010	0.047511	0.079296	1481.0	-0.12612	538.50	158.12
290.00	0.77436	36.101	0.027700	7.1651	7.1866	0.029797	0.047266	0.080412	1407.8	-0.10470	508.99	142.74
300.00	1.0617	35.230	0.028385	7.9691	7.9993	0.032525	0.047044	0.081747	1333.2	-0.078790	480.25	129.33
310.00	1.4240	34.320	0.029138	8.7850	8.8265	0.035203	0.046856	0.083390	1256.7	-0.046923	452.23	117.49
320.00	1.8728	33.363	0.029973	9.6153	9.6714	0.037843	0.046715	0.085465	1177.9	-0.0070718	424.83	106.91
330.00	2.4205	32.350	0.030912	10.463	10.538	0.040458	0.046636	0.088145	1096.5	0.043673	397.96	97.325
340.00	3.0802	31.264	0.031986	11.333	11.432	0.043065	0.046642	0.091701	1011.8	0.10967	371.51	88.555
350.00	3.8660	30.087	0.033237	12.232	12.361	0.045682	0.046767	0.096576	923.38	0.19774	345.32	80.430
360.00	4.7929	28.788	0.034737	13.169	13.335	0.048339	0.047064	0.10357	830.62	0.31928	319.25	72.796
370.00	5.8778	27.321	0.036602	14.158	14.373	0.051075	0.047619	0.11435	732.78	0.49497	293.07	65.493
380.00	7.1402	25.606	0.039054	15.224	15.503	0.053961	0.048589	0.13314	628.75	0.76738	266.57	58.315
390.00	8.6045	23.465	0.042616	16.424	16.790	0.057149	0.050319	0.17550	515.88	1.2455	239.65	50.877
400.00	10.305	20.232	0.049426	17.969	18.478	0.061223	0.054109	0.38707	384.58	2.3557	216.00	41.802
405.40	11.339	13.212	0.075690	20.640	21.499	0.068559			0	5.0513		
195.50	0.0060912	0.0037635	265.71	23.661	25.279	0.12931	0.026510	0.035130	354.12	171.13	19.636	6.8396
200.00	0.0086509	0.0052305	191.19	23.770	25.424	0.12714	0.026650	0.035345	357.91	152.55	19.684	6.9515
210.00	0.017739	0.010249	97.573	24.006	25.737	0.12273	0.027053	0.035961	365.94	120.01	19.860	7.2115

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
220.00	0.033790	0.018721	53.415	24.233	26.038	0.11884	0.027583	0.036783	373.38	96.215	20.132	7.4846
230.00	0.060407	0.032214	31.043	24.450	26.325	0.11536	0.028245	0.037836	380.19	78.430	20.503	7.7679
240.00	0.10223	0.052667	18.987	24.655	26.596	0.11224	0.029043	0.039142	386.30	64.852	20.978	8.0587
250.00	0.16494	0.082417	12.133	24.846	26.847	0.10942	0.029978	0.040728	391.66	54.280	21.560	8.3552
260.00	0.25531	0.12421	8.0506	25.021	27.077	0.10684	0.031050	0.042623	396.20	45.905	22.258	8.6558
270.00	0.38107	0.18126	5.5168	25.179	27.281	0.10447	0.032253	0.044859	399.86	39.175	23.079	8.9595
280.00	0.55092	0.25729	3.8867	25.317	27.459	0.10227	0.033581	0.047476	402.59	33.701	24.034	9.2664
290.00	0.77436	0.35664	2.8040	25.435	27.606	0.10021	0.035028	0.050530	404.30	29.207	25.138	9.5771
300.00	1.06178	0.48448	2.0641	25.528	27.720	0.098259	0.036584	0.054099	404.95	25.489	26.408	9.8938
310.00	1.42402	0.64702	1.5455	25.595	27.796	0.096395	0.038244	0.058302	404.45	22.391	27.872	10.220
320.00	1.87282	0.85202	1.1737	25.632	27.830	0.094589	0.040004	0.063320	402.70	19.794	29.568	10.561
330.00	2.4205	1.1094	0.90139	25.634	27.816	0.092817	0.041868	0.069443	399.61	17.599	31.559	10.927
340.00	3.0802	1.4325	0.69810	25.595	27.746	0.091046	0.043844	0.077150	395.05	15.728	33.945	11.330
350.00	3.8660	1.8399	0.54350	25.505	27.606	0.089242	0.045954	0.087280	388.86	14.112	36.900	11.792
360.00	4.7929	2.3598	0.42377	25.350	27.381	0.087355	0.048233	0.10141	380.83	12.690	40.752	12.346
370.00	5.8778	3.0375	0.32922	25.107	27.042	0.085316	0.050744	0.12286	370.69	11.400	46.149	13.053
380.00	7.1402	3.9558	0.25279	24.734	26.539	0.083003	0.053589	0.16000	357.96	10.172	54.556	14.025
390.00	8.6045	5.2979	0.18875	24.144	25.768	0.080169	0.056957	0.24170	341.67	8.9038	70.114	15.527

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
400.00	10.305	7.6973	0.12992	23.047	24.386	0.075992	0.061281	0.59477	318.22	7.3513	113.54	18.529
405.40	11.339	13.212	0.075690	20.640	21.499	0.068559			0	5.0513		
Single-Phase Properties												
200.00	0.10000	42.756	0.023388	0.32270	0.32504	0.0016320	0.049842	0.071983	2080.3	-0.22921	803.24	507.47
239.56	0.10000	40.064	0.024960	3.2461	3.2486	0.014960	0.048626	0.075726	1770.0	-0.18613	666.56	256.42
239.56	0.10000	0.051595	19.382	24.646	26.584	0.11237	0.029005	0.039079	386.05	65.377	20.955	8.0459
300.00	0.10000	0.040502	24.690	26.378	28.847	0.12080	0.028021	0.036849	434.39	27.493	25.100	10.161
400.00	0.10000	0.030171	33.144	29.297	32.612	0.13162	0.030417	0.038883	497.93	10.681	37.215	13.971
500.00	0.10000	0.024091	41.509	32.514	36.665	0.14065	0.033897	0.042280	550.96	5.5276	53.119	17.863
600.00	0.10000	0.020060	49.849	36.096	41.081	0.14869	0.037731	0.046083	597.69	3.2702	68.607	21.682
700.00	0.10000	0.017188	58.179	40.068	45.885	0.15609	0.041678	0.050015	640.16	2.0841	78.312	25.391
200.00	1.00000	42.774	0.023379	0.31651	0.33989	0.0016010	0.049890	0.071938	2081.5	-0.22959	804.23	509.28
298.05	1.00000	35.403	0.028246	7.8111	7.8393	0.031996	0.047085	0.081465	1347.9	-0.084271	485.81	131.82
298.05	1.00000	0.45697	2.1883	25.512	27.700	0.098633	0.036271	0.053356	404.91	26.163	26.145	9.8313
300.00	1.00000	0.45215	2.2117	25.592	27.804	0.098979	0.035866	0.052493	407.16	25.620	26.308	9.9115
400.00	1.00000	0.31157	3.2095	29.019	32.229	0.11177	0.031641	0.041627	488.94	10.494	38.087	13.927
500.00	1.00000	0.24426	4.0940	32.359	36.453	0.12119	0.034312	0.043338	546.79	5.4884	53.750	17.877
600.00	1.00000	0.20197	4.9513	35.994	40.945	0.12937	0.037928	0.046628	595.60	3.2544	69.123	21.717

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
700.00	1.0000	0.17248	5.7977	39.994	45.792	0.13684	0.041791	0.050341	639.15	2.0746	78.751	25.434
200.00	5.0000	42.852	0.023336	0.28942	0.40611	0.0014649	0.050097	0.071739	2086.8	-0.23126	808.60	517.30
300.00	5.0000	35.450	0.028209	7.8852	8.0263	0.032243	0.047090	0.080899	1361.2	-0.089577	487.57	132.49
362.03	5.0000	28.505	0.035081	13.365	13.540	0.048887	0.047152	0.10538	811.17	0.34968	313.94	71.291
362.03	5.0000	2.4828	0.40277	25.309	27.323	0.086956	0.048722	0.10501	378.95	12.419	41.693	12.475
400.00	5.0000	1.8706	0.53459	27.540	30.213	0.094581	0.038466	0.061581	441.81	9.6373	45.730	14.036
500.00	5.0000	1.3046	0.76650	31.630	35.462	0.10634	0.036193	0.048779	528.14	5.2830	57.294	18.073
600.00	5.0000	1.0412	0.96040	35.527	40.329	0.11521	0.038798	0.049210	586.79	3.1693	71.791	21.941
700.00	5.0000	0.87563	1.1420	39.662	45.373	0.12298	0.042289	0.051836	635.17	2.0254	80.941	25.662
200.00	10.000	42.947	0.023284	0.25644	0.48928	0.0012980	0.050342	0.071495	2093.5	-0.23328	814.02	527.29
300.00	10.000	35.714	0.028000	7.7848	8.0648	0.031903	0.047164	0.079960	1394.2	-0.10159	496.50	136.36
398.32	10.000	20.945	0.047744	17.655	18.132	0.060394	0.053149	0.30653	409.04	2.0704	218.73	43.632
398.32	10.000	7.1390	0.14008	23.303	24.704	0.076892	0.060447	0.46915	323.12	7.6606	101.04	17.793
400.00	10.000	6.5455	0.15278	23.801	25.329	0.078458	0.057611	0.30552	336.28	7.7633	95.455	17.230
500.00	10.000	2.8656	0.34897	30.616	34.106	0.098525	0.038603	0.057806	505.64	4.9335	63.922	18.722
600.00	10.000	2.1650	0.46190	34.920	39.539	0.10844	0.039862	0.052806	577.38	3.0278	76.053	22.393
700.00	10.000	1.7835	0.56069	39.241	44.848	0.11663	0.042896	0.053796	631.50	1.9491	84.235	26.035
300.00	100.00	38.995	0.025644	6.5830	9.1474	0.027511	0.048894	0.072740	1774.7	-0.19551	622.86	193.71

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
400.00	100.00	33.105	0.030207	13.432	16.453	0.048523	0.046636	0.073557	1378.2	-0.11309	431.98	96.237
500.00	100.00	27.067	0.036945	20.212	23.907	0.065147	0.045999	0.075495	1081.8	0.049919	305.65	60.386
600.00	100.00	21.518	0.046473	26.825	31.472	0.078942	0.046723	0.075193	918.11	0.23722	234.79	46.188
700.00	100.00	17.303	0.057794	33.074	38.854	0.090326	0.048331	0.072317	861.52	0.32753	196.04	41.237
300.00	500.00	45.670	0.021896	4.7114	15.660	0.018023	0.052877	0.067831	2597.1	-0.25055	989.00	376.31
400.00	500.00	42.416	0.023576	10.633	22.421	0.037482	0.051527	0.066802	2353.2	-0.25064	804.05	188.46
500.00	500.00	39.515	0.025307	16.367	29.021	0.052215	0.050431	0.065418	2176.9	-0.25260	674.00	120.77
600.00	500.00	36.909	0.027094	22.007	35.554	0.064127	0.050614	0.065476	2044.6	-0.24722	582.63	91.251
700.00	500.00	34.550	0.028943	27.680	42.152	0.074295	0.051816	0.066615	1943.8	-0.23682	511.57	77.538
300.00	1000.0	49.944	0.020022	4.1818	24.204	0.011750	0.055176	0.065784	3230.2	-0.25989	1324.0	554.62
400.00	1000.0	47.551	0.021030	9.8612	30.891	0.030984	0.054864	0.066677	2997.6	-0.25431	1138.9	274.91
500.00	1000.0	45.362	0.022045	15.432	37.477	0.045686	0.053323	0.065150	2842.8	-0.26084	996.49	174.11
600.00	1000.0	43.378	0.023053	20.911	43.964	0.057514	0.052940	0.064819	2728.6	-0.26235	887.73	129.02
700.00	1000.0	41.556	0.024064	26.418	50.481	0.067559	0.053649	0.065697	2639.0	-0.25820	797.25	107.14

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., Harms-Watzenberg, F., and Baehr, H. D., "Eine neue Fundamentalgleichung fuer Ammoniak," *DKV-Tagungsbericht*, 20:167–181, 1993. The source for viscosity is Fenghour, A., Wakeham, W. A., Vesovic, V., Watson, J. T. R., Millat, J., and Vogel, E., "The Viscosity of Ammonia," *J. Phys. Chem. Ref. Data* 24:1649–1667, 1995. The source for thermal conductivity is Tufeu, R., Ivanov, D. Y., Garrabos, Y., and Le Neindre, B., "Thermal Conductivity of Ammonia in a Large Temperature and Pressure Range Including the Critical Region," *Ber. Bunsenges. Phys. Chem.* 88:422–427, 1984.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.2% in density, 2% in heat capacity, and 2% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%. The uncertainty varies from 0.5% for the viscosity of the dilute gas phase at moderate temperatures to about 5% for the viscosity at high pressures and temperatures. The uncertainty in thermal conductivity is 2%.

Table 2-113 Thermodynamic Properties of Carbon Dioxide

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
Saturated Properties												
216.59	0.51796	26.777	0.037345	3.5030	3.5223	0.022943	0.042895	0.085960	975.85	-0.14430	180.63	256.70
220.00	0.59913	26.497	0.037740	3.7943	3.8169	0.024279	0.042682	0.086338	951.21	-0.13180	176.15	242.01
225.00	0.73509	26.078	0.038347	4.2235	4.2517	0.026209	0.042383	0.087024	915.16	-0.11104	169.67	222.19
230.00	0.89291	25.646	0.038992	4.6554	4.6902	0.028110	0.042103	0.087886	879.09	-0.086994	163.28	204.23
235.00	1.0747	25.201	0.039680	5.0908	5.1334	0.029986	0.041843	0.088954	842.88	-0.059053	156.98	187.88
240.00	1.2825	24.742	0.040418	5.5303	5.5821	0.031840	0.041605	0.090263	806.38	-0.026454	150.75	172.96
245.00	1.5185	24.264	0.041213	5.9749	6.0375	0.033678	0.041393	0.091866	769.44	0.011808	144.58	159.30
250.00	1.7850	23.767	0.042075	6.4256	6.5007	0.035505	0.041212	0.093831	731.78	0.057087	138.47	146.74
255.00	2.0843	23.246	0.043018	6.8836	6.9733	0.037326	0.041079	0.096251	693.01	0.11121	132.40	135.14

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
260.00	2.4188	22.697	0.044059	7.3505	7.4571	0.039148	0.041029	0.099258	652.58	0.17663	126.35	124.40
265.00	2.7909	22.114	0.045219	7.8282	7.9544	0.040979	0.041109	0.10306	610.07	0.25672	120.31	114.40
270.00	3.2033	21.491	0.046531	8.3190	8.4681	0.042829	0.041351	0.10798	565.46	0.35639	114.25	105.02
275.00	3.6589	20.817	0.048037	8.8266	9.0024	0.044711	0.041750	0.11457	519.14	0.48324	108.17	96.174
280.00	4.1607	20.077	0.049808	9.3560	9.5633	0.046643	0.042270	0.12385	471.54	0.64959	102.03	87.731
285.00	4.7123	19.247	0.051957	9.9154	10.160	0.048657	0.042900	0.13790	422.75	0.87650	95.810	79.548
290.00	5.3177	18.284	0.054693	10.519	10.810	0.050805	0.043734	0.16176	371.95	1.2037	89.546	71.409
295.00	5.9822	17.100	0.058480	11.197	11.547	0.053196	0.045175	0.21098	315.91	1.7218	83.558	62.936
300.00	6.7131	15.434	0.064793	12.036	12.471	0.056151	0.049288	0.38279	245.67	2.7258	80.593	53.107
304.13	7.3773	10.625	0.094118	13.928	14.622	0.063094			0	5.8665		
216.59	0.51796	0.31268	3.1982	17.286	18.943	0.094138	0.027691	0.039992	222.78	26.174	11.014	10.951
220.00	0.59913	0.35941	2.7824	17.329	18.996	0.093276	0.028120	0.040943	223.15	25.084	11.301	11.135
225.00	0.73509	0.43766	2.2849	17.387	19.067	0.092055	0.028782	0.042489	223.49	23.617	11.745	11.409
230.00	0.89291	0.52878	1.8912	17.438	19.127	0.090878	0.029488	0.044244	223.57	22.288	12.221	11.689
235.00	1.0747	0.63442	1.5762	17.481	19.175	0.089736	0.030241	0.046248	223.40	21.077	12.736	11.976
240.00	1.2825	0.75654	1.3218	17.515	19.210	0.088622	0.031042	0.048555	222.96	19.969	13.297	12.272
245.00	1.5185	0.89743	1.1143	17.538	19.230	0.087526	0.031899	0.051242	222.24	18.950	13.917	12.579
250.00	1.7850	1.0599	0.94353	17.550	19.234	0.086439	0.032827	0.054421	221.22	18.005	14.610	12.902

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
255.00	2.0843	1.2472	0.80180	17.549	19.220	0.085352	0.033844	0.058244	219.87	17.117	15.396	13.245
260.00	2.4188	1.4637	0.68320	17.532	19.185	0.084254	0.034955	0.062912	218.19	16.277	16.306	13.614
265.00	2.7909	1.7149	0.58314	17.498	19.125	0.083133	0.036164	0.068721	216.15	15.476	17.381	14.017
270.00	3.2033	2.0080	0.49800	17.441	19.037	0.081972	0.037482	0.076168	213.75	14.704	18.687	14.469
275.00	3.6589	2.3535	0.42490	17.359	18.913	0.080750	0.038949	0.086123	210.96	13.947	20.325	14.987
280.00	4.1607	2.7663	0.36150	17.241	18.746	0.079437	0.040628	0.10020	207.72	13.185	22.468	15.601
285.00	4.7123	3.2702	0.30579	17.078	18.519	0.077987	0.042629	0.12177	203.94	12.387	25.424	16.361
290.00	5.3177	3.9074	0.25593	16.848	18.209	0.076319	0.045155	0.15906	199.45	11.509	29.821	17.357
295.00	5.9822	4.7654	0.20985	16.509	17.764	0.074270	0.048677	0.23904	193.84	10.459	37.215	18.792
300.00	6.7131	6.1028	0.16386	15.935	17.035	0.071364	0.054908	0.52463	185.33	9.0093	53.689	21.306
304.13	7.3773	10.625	0.094118	13.928	14.622	0.063094			0	5.8665		
Single-Phase Properties												
250.00	0.10000	0.048542	20.601	18.448	20.509	0.11415	0.026766	0.035428	247.79	17.399	12.950	12.565
450.00	0.10000	0.026758	37.372	24.664	28.401	0.13712	0.034775	0.043148	324.41	4.0212	29.346	21.901
650.00	0.10000	0.018506	54.037	32.199	37.602	0.15397	0.040192	0.048529	385.01	1.6551	45.466	29.873
850.00	0.10000	0.014148	70.683	40.636	47.705	0.16750	0.043944	0.052271	437.11	0.78058	60.295	36.707
1050.0	0.10000	0.011452	87.321	49.704	58.436	0.17883	0.046573	0.054895	483.65	0.34646	73.843	42.692
250.00	1.0000	0.53250	1.8779	18.023	19.901	0.093263	0.029361	0.042504	235.08	17.606	13.584	12.691
450.00	1.0000	0.27038	3.6985	24.546	28.244	0.11771	0.034954	0.043866	322.89	3.9880	29.620	21.954

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
650.00	1.0000	0.18527	5.3976	32.133	37.530	0.13473	0.040239	0.048779	385.36	1.6311	45.651	29.907
850.00	1.0000	0.14131	7.0767	40.591	47.668	0.14830	0.043965	0.052397	438.06	0.76632	60.435	36.732
1050.0	1.0000	0.11430	8.7487	49.671	58.419	0.15965	0.046585	0.054970	484.84	0.33777	73.956	42.712
250.00	5.0000	24.060	0.041563	6.2824	6.4902	0.034925	0.041321	0.090937	762.21	0.015208	142.22	153.15
287.43	5.0000	18.798	0.053196	10.202	10.468	0.049681	0.043268	0.14775	398.39	1.0195	92.760	75.598
287.43	5.0000	3.5600	0.28090	16.977	18.381	0.077209	0.043774	0.13705	201.86	11.974	27.323	16.808
450.00	5.0000	1.4155	0.70647	24.000	27.533	0.10313	0.035769	0.047478	317.50	3.8034	31.164	22.429
650.00	5.0000	0.92982	1.0755	31.842	37.219	0.12091	0.040445	0.049898	387.59	1.5263	46.589	30.157
850.00	5.0000	0.70241	1.4237	40.395	47.513	0.13469	0.044055	0.052945	442.64	0.70611	61.117	36.899
1050.0	5.0000	0.56658	1.7650	49.524	58.349	0.14613	0.046637	0.055297	490.31	0.30129	74.494	42.836
250.00	10.000	24.459	0.040885	6.0862	6.4950	0.034120	0.041488	0.087624	804.05	-0.034849	147.52	162.47
450.00	10.000	2.9910	0.33433	23.276	26.619	0.095787	0.036785	0.052935	314.60	3.4705	33.917	23.679
650.00	10.000	1.8632	0.53671	31.482	36.849	0.11461	0.040693	0.051293	391.91	1.3965	48.005	30.687
850.00	10.000	1.3930	0.71790	40.155	47.334	0.12866	0.044164	0.053603	449.04	0.63635	62.093	37.224
1050.0	10.000	1.1205	0.89248	49.347	58.271	0.14021	0.046701	0.055685	497.48	0.25964	75.242	43.066
250.00	100.00	28.075	0.035619	4.3002	7.8621	0.026023	0.043569	0.073521	1227.6	-0.27302	206.28	287.05
450.00	100.00	19.246	0.051959	16.560	21.756	0.067062	0.040841	0.066107	753.30	-0.11128	106.65	83.996
650.00	100.00	13.677	0.073117	27.132	34.444	0.090445	0.043108	0.061252	646.36	-0.054084	86.093	58.868

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
850.00	100.00	10.636	0.094022	37.076	46.478	0.10660	0.045620	0.059534	646.61	-0.13292	87.259	54.445
1050.0	100.00	8.7929	0.11373	46.995	58.368	0.11916	0.047676	0.059512	668.90	-0.21482	94.022	55.058
450.00	500.00	28.922	0.034576	13.014	30.302	0.050604	0.047702	0.063434	1576.4	-0.38514	239.59	303.64
650.00	500.00	25.661	0.038969	23.302	42.786	0.073576	0.048419	0.061885	1404.7	-0.40369	197.25	191.14
850.00	500.00	23.144	0.043208	33.551	55.155	0.090166	0.049676	0.061912	1320.1	-0.41098	177.31	145.07
1050.0	500.00	21.126	0.047334	43.903	67.570	0.10328	0.050818	0.062247	1278.7	-0.41674	168.50	123.33

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple-Point Temperature to 1100 K at Pressures up to 800 MPa," *J. Phys. Chem. Ref. Data* 25(6):1509–1596, 1996. The source for viscosity is Fenghour, A., Wakeham, W. A., and Vesovic, V., "The Viscosity of Carbon Dioxide," *J. Phys. Chem. Ref. Data* 27:31–44, 1998. The source for thermal conductivity is Vesovic, V., Wakeham, W. A., Olchowy, G. A., Sengers, J. V., Watson, J. T. R., and Millat, J., "The Transport Properties of Carbon Dioxide," *J. Phys. Chem. Ref. Data* 19:763–808, 1990.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

At pressures up to 30 MPa and temperatures up to 523 K, the estimated uncertainty ranges from 0.03% to 0.05% in density, 0.03% (in the vapor) to 1% in the speed of sound (0.5% in the liquid), and 0.15% (in the vapor) to 1.5% (in the liquid) in heat capacity. Special interest has been focused on the description of the critical region and the extrapolation behavior of the formulation (to the limits of chemical stability). The uncertainty in viscosity ranges from 0.3% in the dilute gas near room temperature to 5% at the highest pressures. The uncertainty in thermal conductivity is less than 5%.

Table 2-114 Thermodynamic Properties of Carbon Monoxide

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
68.160	0.015537	30.330	0.032971	-0.81158	-0.81106	-0.010820	0.035351	0.060430	998.20	-0.36906	180.28	274.18
70.000	0.021053	30.064	0.033262	-0.70065	-0.69995	-0.0092140	0.034805	0.060226	980.50	-0.36553	175.49	252.15

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
72.000	0.028718	29.773	0.033588	-0.58046	-0.57950	-0.0075210	0.034248	0.060064	961.22	-0.36074	170.45	232.14
74.000	0.038447	29.478	0.033924	-0.46058	-0.45927	-0.0058785	0.033724	0.059961	941.89	-0.35489	165.55	215.32
76.000	0.050599	29.180	0.034270	-0.34088	-0.33915	-0.0042823	0.033232	0.059917	922.49	-0.34794	160.76	201.01
78.000	0.065559	28.878	0.034628	-0.22127	-0.21900	-0.0027285	0.032768	0.059930	903.01	-0.33981	156.06	188.69
80.000	0.083738	28.573	0.034999	-0.10165	-0.098716	-0.0012138	0.032329	0.060002	883.44	-0.33041	151.45	177.96
82.000	0.10556	28.262	0.035383	0.018099	0.021834	0.00026503	0.031915	0.060132	863.76	-0.31966	146.89	168.52
84.000	0.13148	27.947	0.035782	0.13806	0.14277	0.0017110	0.031522	0.060324	843.95	-0.30742	142.40	160.13
86.000	0.16196	27.626	0.036197	0.25835	0.26421	0.0031269	0.031150	0.060578	824.00	-0.29356	137.96	152.60
88.000	0.19748	27.300	0.036630	0.37906	0.38629	0.0045153	0.030798	0.060899	803.89	-0.27794	133.57	145.77
90.000	0.23852	26.967	0.037082	0.50030	0.50915	0.0058787	0.030463	0.061291	783.60	-0.26034	129.23	139.52
92.000	0.28559	26.627	0.037556	0.62218	0.63291	0.0072195	0.030146	0.061760	763.12	-0.24056	124.94	133.75
94.000	0.33919	26.280	0.038052	0.74482	0.75773	0.0085399	0.029846	0.062314	742.41	-0.21834	120.69	128.38
96.000	0.39983	25.924	0.038574	0.86835	0.88377	0.0098422	0.029562	0.062962	721.45	-0.19335	116.51	123.34
98.000	0.46805	25.559	0.039125	0.99289	1.0112	0.011129	0.029294	0.063716	700.22	-0.16523	112.38	118.57
100.00	0.54438	25.184	0.039708	1.1186	1.1402	0.012402	0.029043	0.064590	678.68	-0.13353	108.31	114.02
102.00	0.62934	24.798	0.040326	1.2457	1.2710	0.013663	0.028809	0.065604	656.78	-0.097704	104.30	109.66
104.00	0.72348	24.399	0.040985	1.3742	1.4039	0.014916	0.028592	0.066781	634.50	-0.057078	100.36	105.45
106.00	0.82736	23.987	0.041689	1.5045	1.5390	0.016162	0.028395	0.068153	611.77	-0.010824	96.482	101.35

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
108.00	0.94154	23.560	0.042446	1.6368	1.6768	0.017404	0.028218	0.069759	588.54	0.042104	92.679	97.342
110.00	1.0666	23.114	0.043263	1.7713	1.8175	0.018646	0.028066	0.071656	564.73	0.10304	88.948	93.404
112.00	1.2031	22.649	0.044151	1.9085	1.9616	0.019891	0.027941	0.073916	540.25	0.17371	85.290	89.510
114.00	1.3517	22.161	0.045124	2.0487	2.1097	0.021142	0.027850	0.076648	515.01	0.25641	81.702	85.641
116.00	1.5130	21.646	0.046197	2.1925	2.2624	0.022406	0.027800	0.080005	488.86	0.35427	78.180	81.774
118.00	1.6877	21.099	0.047395	2.3405	2.4205	0.023688	0.027803	0.084225	461.63	0.47167	74.716	77.888
120.00	1.8765	20.513	0.048749	2.4938	2.5853	0.024996	0.027874	0.089692	433.11	0.61495	71.296	73.954
122.00	2.0802	19.878	0.050307	2.6536	2.7583	0.026343	0.028038	0.097070	403.00	0.79382	67.896	69.940
124.00	2.2997	19.179	0.052141	2.8221	2.9420	0.027744	0.028333	0.10762	370.88	1.0239	64.476	65.797
126.00	2.5360	18.390	0.054377	3.0024	3.1403	0.029230	0.028826	0.12411	336.15	1.3325	60.972	61.448
128.00	2.7904	17.464	0.057259	3.2010	3.3608	0.030854	0.029646	0.15392	297.82	1.7728	57.261	56.748
130.00	3.0647	16.288	0.061393	3.4328	3.6210	0.032745	0.031097	0.22603	254.03	2.4703	53.107	51.348
132.86	3.4982	10.850	0.092166	4.2912	4.6137	0.040039			0	6.1475		
68.160	0.015537	0.027707	36.091	5.1252	5.6859	0.084499	0.021089	0.029785	167.25	40.804	6.6865	4.6366
70.000	0.021053	0.036656	27.281	5.1600	5.7343	0.082704	0.021155	0.029947	169.22	38.426	6.8845	4.7768
72.000	0.028718	0.048780	20.500	5.1971	5.7859	0.080887	0.021238	0.030153	171.27	36.126	7.1009	4.9329
74.000	0.038447	0.063796	15.675	5.2334	5.8361	0.079194	0.021333	0.030394	173.22	34.080	7.3188	5.0934
76.000	0.050599	0.082130	12.176	5.2688	5.8849	0.077613	0.021441	0.030672	175.07	32.250	7.5382	5.2589

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
78.000	0.065559	0.10424	9.5935	5.3031	5.9320	0.076131	0.021563	0.030993	176.80	30.604	7.7592	5.4300
80.000	0.083738	0.13059	7.6573	5.3363	5.9775	0.074739	0.021699	0.031360	178.42	29.116	7.9820	5.6076
82.000	0.10556	0.16171	6.1841	5.3682	6.0210	0.073426	0.021850	0.031777	179.92	27.763	8.2067	5.7922
84.000	0.13148	0.19810	5.0478	5.3988	6.0625	0.072185	0.022017	0.032250	181.29	26.527	8.4335	5.9847
86.000	0.16196	0.24036	4.1605	5.4280	6.1019	0.071007	0.022199	0.032783	182.54	25.392	8.6627	6.1860
88.000	0.19748	0.28906	3.4595	5.4556	6.1388	0.069885	0.022397	0.033383	183.66	24.345	8.8944	6.3968
90.000	0.23852	0.34486	2.8997	5.4816	6.1733	0.068813	0.022611	0.034057	184.65	23.377	9.1291	6.6182
92.000	0.28559	0.40845	2.4483	5.5058	6.2050	0.067785	0.022842	0.034813	185.51	22.477	9.3672	6.8512
94.000	0.33919	0.48058	2.0808	5.5280	6.2338	0.066796	0.023089	0.035661	186.22	21.638	9.6091	7.0969
96.000	0.39983	0.56209	1.7791	5.5482	6.2595	0.065840	0.023352	0.036615	186.80	20.853	9.8555	7.3566
98.000	0.46805	0.65388	1.5293	5.5661	6.2819	0.064912	0.023633	0.037690	187.23	20.118	10.107	7.6317
100.00	0.54438	0.75700	1.3210	5.5816	6.3007	0.064007	0.023931	0.038906	187.52	19.426	10.366	7.9239
102.00	0.62934	0.87260	1.1460	5.5945	6.3157	0.063120	0.024248	0.040288	187.67	18.773	10.632	8.2350
104.00	0.72348	1.0020	0.99799	5.6044	6.3265	0.062248	0.024586	0.041869	187.66	18.154	10.909	8.5675
106.00	0.82736	1.1468	0.87198	5.6112	6.3327	0.061385	0.024945	0.043694	187.51	17.565	11.198	8.9238
108.00	0.94154	1.3088	0.76404	5.6145	6.3339	0.060526	0.025329	0.045820	187.20	17.001	11.502	9.3073
110.00	1.0666	1.4903	0.67102	5.6138	6.3295	0.059665	0.025741	0.048326	186.73	16.458	11.828	9.7221
112.00	1.2031	1.6938	0.59039	5.6088	6.3191	0.058797	0.026186	0.051322	186.11	15.930	12.181	10.173

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
114.00	1.3517	1.9228	0.52008	5.5986	6.3016	0.057914	0.026671	0.054966	185.33	15.411	12.569	10.667
116.00	1.5130	2.1815	0.45841	5.5827	6.2762	0.057008	0.027203	0.059493	184.38	14.894	13.005	11.213
118.00	1.6877	2.4754	0.40397	5.5598	6.2416	0.056070	0.027794	0.065263	183.27	14.372	13.507	11.821
120.00	1.8765	2.8123	0.35558	5.5286	6.1959	0.055084	0.028462	0.072864	181.99	13.833	14.101	12.509
122.00	2.0802	3.2027	0.31224	5.4872	6.1367	0.054034	0.029229	0.083320	180.52	13.265	14.826	13.301
124.00	2.2997	3.6629	0.27301	5.4324	6.0602	0.052892	0.030133	0.098585	178.84	12.648	15.747	14.234
126.00	2.5360	4.2194	0.23700	5.3595	5.9605	0.051613	0.031233	0.12291	176.93	11.956	16.981	15.373
128.00	2.7904	4.9212	0.20320	5.2594	5.8264	0.050117	0.032636	0.16759	174.68	11.140	18.777	16.840
130.00	3.0647	5.8832	0.16998	5.1113	5.6322	0.048216	0.034579	0.27599	171.86	10.100	21.845	18.936
132.86	3.4982	10.850	0.092166	4.2912	4.6137	0.040039			0	6.1475		
Single-Phase Properties												
100.00	0.10000	0.12298	8.1315	5.7653	6.5785	0.080014	0.021118	0.030153	201.29	17.820	10.075	6.9147
200.00	0.10000	0.060293	16.586	7.8674	9.5259	0.10048	0.020812	0.029239	288.05	5.3111	19.227	12.897
300.00	0.10000	0.040104	24.935	9.9522	12.446	0.11231	0.020833	0.029191	353.12	2.5186	26.605	17.731
400.00	0.10000	0.030062	33.265	12.045	15.371	0.12073	0.021028	0.029364	407.29	1.2653	33.106	21.870
500.00	0.10000	0.024045	41.588	14.169	18.328	0.12733	0.021479	0.029807	454.00	0.56244	39.272	25.540
100.00	1.0000	25.261	0.039586	1.1047	1.1443	0.012262	0.029062	0.064114	685.44	-0.14414	112.87	113.83
108.96	1.0000	23.349	0.042829	1.7009	1.7437	0.017998	0.028142	0.070627	577.22	0.070176	90.884	95.450
108.96	1.0000	1.3931	0.71782	5.6147	6.3325	0.060114	0.025522	0.046966	186.99	16.739	11.655	9.5017

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
200.00	1.0000	0.61727	1.6200	7.7647	9.3847	0.080819	0.020996	0.030510	286.20	5.1924	19.474	13.192
300.00	1.0000	0.40214	2.4867	9.8936	12.380	0.092976	0.020895	0.029646	354.42	2.4256	26.760	17.918
400.00	1.0000	0.29999	3.3334	12.005	15.338	0.10149	0.021064	0.029598	409.43	1.2088	33.222	22.024
500.00	1.0000	0.23962	4.1732	14.140	18.313	0.10812	0.021505	0.029948	456.39	0.52786	39.364	25.676
100.00	5.0000	25.864	0.038663	0.99666	1.1900	0.011154	0.029263	0.060925	737.92	-0.21740	152.30	112.19
200.00	5.0000	3.4130	0.29299	7.2656	8.7305	0.064994	0.021878	0.038000	285.27	4.3757	22.190	15.094
300.00	5.0000	2.0232	0.49426	9.6364	12.108	0.078767	0.021174	0.031673	362.95	2.0288	27.812	18.716
400.00	5.0000	1.4824	0.67458	11.834	15.207	0.087691	0.021224	0.030585	420.15	0.98413	33.871	22.588
500.00	5.0000	1.1786	0.84845	14.015	18.258	0.094498	0.021618	0.030535	467.56	0.39254	39.837	26.139
100.00	10.000	26.482	0.037761	0.88669	1.2643	0.0099878	0.029539	0.058409	792.04	-0.27800	200.46	110.33
200.00	10.000	7.4298	0.13459	6.5960	7.9419	0.056188	0.022832	0.048831	307.84	2.8854	34.772	19.114
300.00	10.000	4.0263	0.24837	9.3290	11.813	0.072068	0.021511	0.034036	379.01	1.5731	30.972	19.862
400.00	10.000	2.9079	0.34389	11.634	15.073	0.081462	0.021420	0.031689	435.68	0.74980	35.414	23.298
500.00	10.000	2.3052	0.43381	13.870	18.208	0.088461	0.021755	0.031188	482.48	0.25486	40.797	26.682
100.00	50.000	29.422	0.033988	0.39153	2.0910	0.0040257	0.031398	0.052094	1066.8	-0.43831	567.46	99.463
200.00	50.000	20.591	0.048566	4.5424	6.9707	0.038097	0.025036	0.045541	706.01	-0.28689	256.88	50.929
300.00	50.000	14.766	0.067725	7.7949	11.181	0.055259	0.023212	0.039083	609.73	-0.21242	139.18	34.086
400.00	50.000	11.439	0.087418	10.518	14.889	0.065951	0.022620	0.035519	604.51	-0.27153	94.476	31.319

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
500.00	50.000	9.3865	0.10654	13.024	18.350	0.073681	0.022659	0.033937	622.30	-0.36911	76.899	32.167
100.00	100.00	31.474	0.031772	0.095937	3.2732	-0.00053857	0.033037	0.050530	1282.4	-0.47725	1005.7	90.560
200.00	100.00	24.888	0.040181	3.9022	7.9203	0.031951	0.026437	0.043352	987.69	-0.50923	536.84	73.380
300.00	100.00	20.200	0.049505	7.0625	12.013	0.048608	0.024358	0.038799	866.60	-0.54516	331.69	54.648
400.00	100.00	16.970	0.058928	9.8487	15.741	0.059353	0.023555	0.036051	822.33	-0.59581	229.18	45.748
500.00	100.00	14.662	0.068206	12.449	19.269	0.067230	0.023434	0.034683	808.91	-0.64123	173.58	42.504

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. The source for viscosity and thermal conductivity is Version 9.08 of the NIST14 database.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The equation of state is valid from the triple point to 500 K with pressures to 100 MPa. At higher pressures, the deviations from the equation increase rapidly, and it is not recommended to use the equation above 100 MPa. The uncertainties in the equation are 0.3% in density (approaching 1% near the critical point), 0.2% in vapor pressure, and 2% in heat capacities. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

Figure 2-4 Temperature-entropy diagram for carbon monoxide. Pressure P , in atmospheres; density ρ , in grams per cubic centimeter; enthalpy H , in joules per gram. (From J.G. Hust and R.B. Stewart, NBS Tech. Note 202, 1963.)

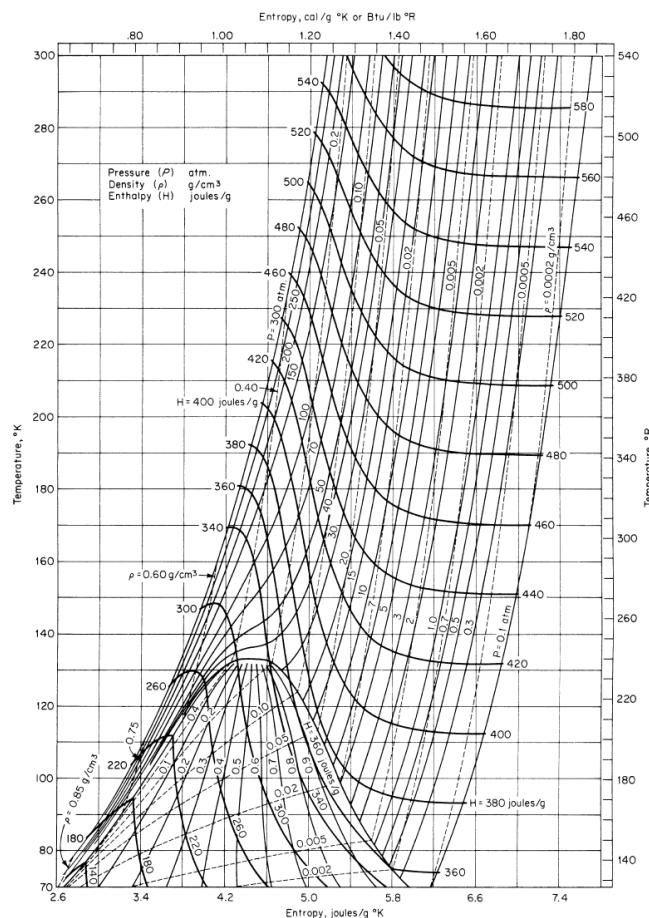


Table 2-115 Thermodynamic Properties of Ethanol

Tempera ture K	Pressu re MPa	Densit y mol/d m ³	Volum e dm ³ /m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l·K)	C_v kJ/(mo l·K)	C_p kJ/(mo l·K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
250.00	0.0002 7007	17.911	0.0558 31	6.9274	6.9275	0.0373 30	0.0766 57	0.0936 12	1325.0	-0.445 53	178.12	3140.9
265.00	0.0008 9527	17.642	0.0566 81	8.3792	8.3793	0.0429 68	0.0837 98	0.1002 8	1260.8	-0.414 23	173.58	2182.0
280.00	0.0025 823	17.376	0.0575 51	9.9424	9.9426	0.0487 04	0.0916 53	0.1082 9	1202.8	-0.378 72	169.56	1564.4
295.00	0.0066 146	17.106	0.0584 60	11.630	11.631	0.0545 74	0.0994 33	0.1167 8	1149.2	-0.343 23	165.87	1152.5
310.00	0.0152 98	16.828	0.0594 26	13.445	13.446	0.0605 74	0.1067 0	0.1252 4	1098.1	-0.309 10	162.38	869.40

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
325.00	0.032394	16.537	0.060469	15.385	15.387	0.066684	0.11322	0.13340	1048.0	-0.27615	159.01	669.49
340.00	0.063544	16.231	0.061610	17.444	17.448	0.072875	0.11893	0.14115	997.94	-0.24356	155.69	524.87
355.00	0.11663	15.905	0.062872	19.615	19.622	0.079123	0.12381	0.14847	947.31	-0.21011	152.39	417.88
370.00	0.20205	15.557	0.064281	21.892	21.905	0.085403	0.12792	0.15543	895.56	-0.17428	149.09	337.04
385.00	0.33279	15.181	0.065871	24.268	24.290	0.091699	0.13130	0.16215	842.31	-0.13410	145.78	274.76
400.00	0.52446	14.774	0.067684	26.740	26.775	0.098000	0.13405	0.16883	787.16	-0.086812	142.47	225.91
415.00	0.79509	14.331	0.069779	29.307	29.362	0.10430	0.13625	0.17576	729.67	-0.028333	139.18	186.93
430.00	1.1649	13.843	0.072241	31.970	32.054	0.11061	0.13798	0.18341	669.25	0.047976	135.93	155.35
445.00	1.6559	13.298	0.075202	34.737	34.862	0.11695	0.13934	0.19262	605.07	0.15384	132.78	129.37
460.00	2.2916	12.676	0.078889	37.629	37.810	0.12335	0.14041	0.20504	535.80	0.31228	129.85	107.62
475.00	3.0963	11.941	0.083745	40.684	40.943	0.12991	0.14134	0.22469	459.19	0.57597	127.41	88.972
490.00	4.0954	11.007	0.090848	44.002	44.374	0.13684	0.14234	0.26508	371.03	1.0976	126.33	72.213
505.00	5.3159	9.5842	0.10434	47.926	48.480	0.14485	0.14382	0.41790	264.74	2.5369	129.43	55.104
513.90	6.1480	5.9910	0.16692	53.880	54.906	0.15723			0	8.6373		
250.00	0.00027007	0.00012998	7693.7	49.039	51.116	0.21409	0.058885	0.067215	226.86	149.30	14.936	7.2715
265.00	0.00089527	0.00040670	2458.8	49.932	52.134	0.20808	0.060795	0.069146	233.03	111.11	15.737	7.7433
280.00	0.0025823	0.0011115	899.69	50.851	53.174	0.20310	0.062753	0.071149	238.89	87.283	16.612	8.2114
295.00	0.0066146	0.0027080	369.28	51.792	54.234	0.19899	0.064753	0.073238	244.41	71.858	17.566	8.6756

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
310.00	0.015298	0.0059814	167.18	52.749	55.307	0.19561	0.066816	0.075464	249.49	61.180	18.602	9.1353
325.00	0.032394	0.012150	82.305	53.717	56.383	0.19282	0.068988	0.077921	254.02	53.164	19.731	9.5902
340.00	0.063544	0.022975	43.525	54.684	57.450	0.19053	0.071336	0.080736	257.88	46.697	20.969	10.040
355.00	0.11663	0.040873	24.466	55.640	58.494	0.18862	0.073932	0.084059	260.92	41.226	22.341	10.486
370.00	0.20205	0.069039	14.485	56.573	59.500	0.18701	0.076838	0.088058	263.02	36.486	23.886	10.929
385.00	0.33279	0.11160	8.9606	57.469	60.451	0.18562	0.080106	0.092930	264.03	32.353	25.659	11.372
400.00	0.52446	0.17385	5.7521	58.312	61.329	0.18438	0.083774	0.098936	263.82	28.756	27.741	11.820
415.00	0.79509	0.26261	3.8080	59.087	62.115	0.18322	0.087876	0.10646	262.27	25.644	30.251	12.283
430.00	1.1649	0.38683	2.5851	59.774	62.785	0.18208	0.092450	0.11610	259.21	22.967	33.369	12.774
445.00	1.6559	0.55876	1.7897	60.348	63.312	0.18088	0.097544	0.12898	254.44	20.681	37.377	13.318
460.00	2.2916	0.79629	1.2558	60.777	63.654	0.17954	0.10323	0.14727	247.61	18.747	42.735	13.961
475.00	3.0963	1.1286	0.88602	61.004	63.747	0.17792	0.10966	0.17612	238.10	17.136	50.248	14.786
490.00	4.0954	1.6143	0.61945	60.916	63.453	0.17578	0.11709	0.23200	224.59	15.831	61.578	15.982
505.00	5.3159	2.4339	0.41086	60.144	62.328	0.17228	0.12644	0.42053	203.70	14.728	82.512	18.148
513.90	6.1480	5.9910	0.16692	53.880	54.906	0.15723			0	8.6373		

Single-Phase Properties

300.00	0.10000	17.016	0.058768	12.219	12.225	0.056554	0.10193	0.11962	1132.5	-0.33179	164.74	1047.2
351.05	0.10000	15.993	0.062527	19.033	19.040	0.077475	0.12261	0.14658	960.72	-0.21908	153.26	443.11

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
351.05	0.10000	0.035314	28.317	55.390	58.222	0.18909	0.073221	0.083127	260.21	42.587	21.965	10.369
400.00	0.10000	0.030577	32.704	59.207	62.477	0.20043	0.080640	0.089997	279.09	28.685	26.374	11.853
500.00	0.10000	0.024191	41.338	67.925	72.058	0.22176	0.092910	0.10162	312.39	11.830	37.865	14.768
600.00	0.10000	0.020086	49.786	77.796	82.775	0.24127	0.10403	0.11252	341.55	5.6356	52.622	17.543
300.00	1.0000	17.034	0.058707	12.202	12.261	0.056497	0.10191	0.11954	1137.9	-0.33273	165.24	1053.2
400.00	1.0000	14.795	0.067589	26.715	26.783	0.097937	0.13400	0.16857	791.85	-0.089821	142.87	227.32
423.85	1.0000	14.049	0.071181	30.866	30.938	0.10802	0.13732	0.18015	694.41	0.013963	137.25	167.52
423.85	1.0000	0.33095	3.0216	59.504	62.526	0.18255	0.090516	0.11184	260.65	24.014	32.003	12.568
500.00	1.0000	0.25567	3.9114	67.014	70.925	0.20078	0.096953	0.11008	300.64	12.007	39.539	14.859
600.00	1.0000	0.20473	4.8846	77.311	82.195	0.22131	0.10581	0.11605	337.33	5.6301	53.583	17.678
300.00	5.0000	17.111	0.058443	12.129	12.421	0.056249	0.10185	0.11922	1161.4	-0.33665	167.43	1079.6
400.00	5.0000	14.961	0.066842	26.516	26.851	0.097435	0.13359	0.16658	829.44	-0.11211	146.07	238.82
500.00	5.0000	10.220	0.097846	46.419	46.908	0.14179	0.14311	0.32410	308.88	1.7596	127.42	61.882
501.39	5.0000	10.013	0.099875	46.876	47.375	0.14272	0.14340	0.35152	292.31	2.0063	128.00	59.510
501.39	5.0000	2.1809	0.45852	60.445	62.737	0.17336	0.12389	0.34099	209.80	15.000	75.676	17.454
600.00	5.0000	1.1372	0.87939	74.966	79.363	0.20395	0.11419	0.13659	314.06	5.6703	61.725	18.972
300.00	10.000	17.203	0.058131	12.041	12.623	0.055950	0.10179	0.11885	1189.5	-0.34096	170.07	1111.8
400.00	10.000	15.147	0.066020	26.293	26.953	0.096860	0.13313	0.16456	872.36	-0.13414	149.80	252.40

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
500.00	10.000	11.521	0.086800	44.752	45.620	0.13830	0.14031	0.22204	464.50	0.60618	130.15	80.680
600.00	10.000	2.8001	0.35713	71.266	74.837	0.19172	0.12599	0.18744	273.66	5.6926	84.190	23.411
300.00	100.00	18.389	0.054380	10.984	16.422	0.051802	0.10149	0.11571	1558.1	-0.37198	207.54	1611.3
400.00	100.00	17.030	0.058722	24.075	29.947	0.090466	0.12901	0.15081	1348.2	-0.25352	195.29	435.09
500.00	100.00	15.408	0.064899	39.356	45.846	0.12589	0.13221	0.16433	1166.1	-0.17199	188.35	192.15
600.00	100.00	13.601	0.073523	55.055	62.407	0.15608	0.12575	0.16553	1015.1	-0.082822	187.31	109.49
300.00	200.00	19.244	0.051963	10.349	20.742	0.048505	0.10196	0.11495	1830.4	-0.37578	238.67	2085.4
400.00	200.00	18.138	0.055134	22.905	33.931	0.086238	0.12678	0.14539	1660.3	-0.28090	228.57	591.02
500.00	200.00	16.878	0.059250	37.295	49.145	0.12014	0.12868	0.15623	1525.6	-0.22946	224.49	269.30
600.00	200.00	15.505	0.064494	51.902	64.801	0.14869	0.12066	0.15566	1422.7	-0.19099	226.40	148.43

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Dillon, H.E., and Penoncello, S.G., "A Fundamental Equation for Calculation of the Thermodynamic Properties of Ethanol," *Int. J. Thermophys.*, **25**(2):321–335, 2004. The source for viscosity is Kiselev, S. B., Ely, J. F., Abdulagatov, I. M., and Huber, M. L., "Generalized SAFT-DFT/DMT Model for the Thermodynamic, Interfacial, and Transport Properties of Associating Fluids: Application for *n*-Alkanols," *Ind. Eng. Chem. Res.*, **44**:6916–6927, 2005. The source for thermal conductivity is unpublished, 2004; however, the fit uses functional form found in Marsh, K., Perkins, R., and Ramires, M.L.V., "Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data*, **47**(4):932–940, 2002.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.2% in density, 3% in heat capacities, 1% in speed of sound, and 0.5% in vapor pressure and saturation densities. The estimated uncertainty in the liquid phase along the saturation boundary is approximately 3%, increasing to 10% at pressures to 100 MPa, and is estimated at 10% in the vapor phase. The estimated uncertainty in the liquid phase is approximately 5% and is estimated as 10% in the vapor phase.

Figure 2-5 Enthalpy-concentration diagram for aqueous ethyl alcohol. Reference states: Enthalpies of liquid water and ethyl alcohol at 0°C are zero. Note: In order to interpolate equilibrium compositions, a vertical may be erected from any liquid composition on the boiling line and its intersection with the auxiliary line determined. A horizontal from this intersection will establish the equilibrium vapor composition on the dew line. (F. Bosnjakovic, Technische Thermodynamik, T. Steinkopff, Leipzig, 1935.)

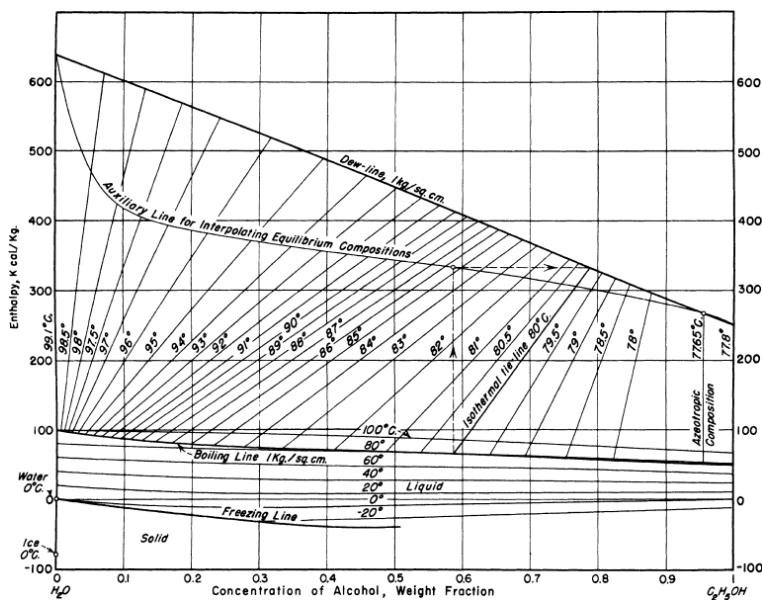


Table 2-116 Thermodynamic Properties of Normal Hydrogen

Tempera ture K	Pressu re MPa	Densit y mol/d m³	Volum e dm³/m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l·K)	C_v kJ/(mo l·K)	C_p kJ/(mo l·K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
13.957	0.0077 031	38.148	0.0262 14	-0.104 34	-0.104 14	-0.005 9480	0.0110 64	0.0156 54	1361.1	-1.413 7	76.293	25.463
14.000	0.0078 936	38.129	0.0262 26	-0.103 67	-0.103 46	-0.005 9000	0.0109 57	0.0155 47	1359.6	-1.423 0	76.650	25.310
15.000	0.0134 36	37.701	0.0265 24	-0.088 896	-0.088 539	-0.004 8799	0.0096 961	0.0144 20	1318.5	-1.520 4	84.106	22.215
16.000	0.0215 34	37.261	0.0268 38	-0.074 446	-0.073 868	-0.003 9471	0.0096 482	0.0147 09	1271.6	-1.469 5	90.079	19.784
17.000	0.0328 48	36.802	0.0271 72	-0.059 414	-0.058 521	-0.003 0355	0.0100 03	0.0155 57	1226.6	-1.362 3	94.784	17.815
18.000	0.0480 78	36.321	0.0275 33	-0.043 440	-0.042 116	-0.002 1219	0.0104 62	0.0166 42	1185.5	-1.240 9	98.405	16.182
19.000	0.0679 60	35.812	0.0279 23	-0.026 375	-0.024 477	-0.001 1983	0.0109 15	0.0178 42	1147.3	-1.119 4	101.10	14.799

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
20.000	0.093249	35.274	0.028350	-0.0081516	-0.0055080	-0.00026211	0.011323	0.019120	1110.7	-1.0003	103.01	13.607
21.000	0.12472	34.702	0.028817	0.011274	0.014868	0.00068790	0.011677	0.020476	1074.7	-0.88232	104.24	12.565
22.000	0.16314	34.092	0.029333	0.031947	0.036732	0.0016528	0.011978	0.021935	1038.2	-0.76268	104.87	11.641
23.000	0.20932	33.439	0.029905	0.053929	0.060188	0.0026344	0.012235	0.023539	1000.5	-0.63795	104.98	10.811
24.000	0.26406	32.738	0.030546	0.077308	0.085375	0.0036357	0.012457	0.025351	960.99	-0.50414	104.60	10.057
25.000	0.32818	31.979	0.031271	0.10222	0.11248	0.0046610	0.012655	0.027465	919.10	-0.35648	103.79	9.3625
26.000	0.40250	31.152	0.032101	0.12884	0.14176	0.0057167	0.012840	0.030024	874.29	-0.18882	102.53	8.7151
27.000	0.48788	30.242	0.033067	0.15744	0.17357	0.0068122	0.013025	0.033265	826.00	0.0073109	100.83	8.1034
28.000	0.58524	29.225	0.034217	0.18843	0.20846	0.0079614	0.013224	0.037610	773.58	0.24446	98.654	7.5160
29.000	0.69554	28.067	0.035629	0.22245	0.24723	0.0091865	0.013460	0.043909	716.22	0.54283	95.935	6.9409
30.000	0.81989	26.706	0.037444	0.26061	0.29132	0.010527	0.013764	0.054194	652.73	0.93827	92.547	6.3620
31.000	0.95964	25.017	0.039973	0.30524	0.34360	0.012063	0.014198	0.074872	581.16	1.5038	88.221	5.7518
32.000	1.1168	22.637	0.044175	0.36302	0.41236	0.014035	0.014926	0.14185	497.24	2.4292	82.176	5.0391
33.190	1.3301	14.940	0.066934	0.53004	0.61907	0.020012			0	5.3208		
13.957	0.0077031	0.067540	14.806	0.68715	0.80120	0.058918	0.013157	0.021964	304.61	31.943	10.375	0.66345
14.000	0.0078936	0.069018	14.489	0.68764	0.80201	0.058777	0.013129	0.021944	305.17	31.808	10.431	0.66695
15.000	0.013436	0.11050	9.0494	0.69864	0.82024	0.055705	0.012872	0.021898	316.15	28.572	11.624	0.74268
16.000	0.021534	0.16764	5.9651	0.70899	0.83745	0.053010	0.012907	0.022199	325.05	25.724	12.681	0.81064

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
17.000	0.032848	0.24349	4.10695	0.71875	0.85365	0.050622	0.012992	0.022618	333.00	23.407	13.681	0.87421
18.000	0.048078	0.34126	2.93033	0.72783	0.86871	0.048480	0.013083	0.023121	340.22	21.522	14.669	0.93555
19.000	0.067960	0.46437	2.15354	0.73614	0.88249	0.046537	0.013178	0.023724	346.75	19.961	15.675	0.99611
20.000	0.093249	0.61652	1.62209	0.74359	0.89484	0.044755	0.013280	0.024449	352.59	18.642	16.716	1.0569
21.000	0.12472	0.80187	1.24715	0.75005	0.90558	0.043103	0.013392	0.025329	357.75	17.507	17.806	1.1186
22.000	0.16314	1.0251	0.97549	0.75541	0.91455	0.041554	0.013514	0.026401	362.25	16.513	18.956	1.1819
23.000	0.20932	1.2919	0.77406	0.75951	0.92154	0.040085	0.013650	0.027724	366.11	15.629	20.180	1.2472
24.000	0.26406	1.6089	0.62153	0.76218	0.92630	0.038674	0.013802	0.029376	369.34	14.829	21.493	1.3151
25.000	0.32818	1.9848	0.50383	0.76318	0.92853	0.037303	0.013973	0.031482	371.95	14.091	22.916	1.3863
26.000	0.40250	2.4307	0.41141	0.76224	0.92783	0.035950	0.014167	0.034234	373.96	13.396	24.477	1.4619
27.000	0.48788	2.9618	0.33763	0.75895	0.92368	0.034594	0.014392	0.037960	375.38	12.726	26.218	1.5433
28.000	0.58524	3.6003	0.27775	0.75276	0.91531	0.033206	0.014655	0.043253	376.19	12.061	28.202	1.6331
29.000	0.69554	4.3810	0.22826	0.74277	0.90154	0.031749	0.014971	0.051322	376.39	11.374	30.535	1.7362
30.000	0.81989	5.3643	0.18642	0.72747	0.88031	0.030160	0.015358	0.065054	375.97	10.624	33.407	1.8628
31.000	0.95964	6.6763	0.14978	0.70374	0.84748	0.028317	0.015854	0.093486	374.91	9.7362	37.226	2.0375
32.000	1.1168	8.6823	0.11518	0.66274	0.79136	0.025879	0.016535	0.18606	373.31	8.5059	43.200	2.3378
33.190	1.3301	14.940	0.066934	0.53004	0.61907	0.020012			0	5.3208		
Single-Phase Properties												

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
25.000	0.10000	0.50823	1.96767	0.81207	1.0088	0.049309	0.012734	0.022519	403.66	12.894	20.761	1.3142
100.00	0.10000	0.12030	8.3127	1.7949	2.6261	0.079163	0.014263	0.022637	808.92	1.4058	68.334	4.1896
175.00	0.10000	0.068680	14.560	3.0224	4.4785	0.092882	0.018150	0.026480	1026.9	0.13575	117.11	6.1845
250.00	0.10000	0.048077	20.800	4.4642	6.5442	0.10269	0.020003	0.028323	1209.1	-0.22980	160.59	7.9025
325.00	0.10000	0.036986	27.037	5.9947	8.6984	0.11022	0.020681	0.028998	1371.7	-0.38965	197.72	9.4561
400.00	0.10000	0.030054	33.273	7.5545	10.882	0.11626	0.020865	0.029180	1519.7	-0.47650	234.06	10.892
25.000	1.0000	32.746	0.030538	0.089693	0.12023	0.0041410	0.012580	0.025394	985.14	-0.51115	106.80	9.9923
31.268	1.0000	24.474	0.040861	0.31894	0.35980	0.012531	0.014353	0.084709	560.14	1.7031	86.829	5.5759
31.268	1.0000	7.1182	0.14049	0.69511	0.83559	0.027747	0.016014	0.10713	374.52	9.4548	38.524	2.0997
100.00	1.0000	1.2044	0.83027	1.7679	2.5982	0.059751	0.014331	0.023244	817.03	1.3036	70.413	4.2550
175.00	1.0000	0.68243	1.4653	3.0101	4.4754	0.073667	0.018190	0.026659	1035.8	0.11718	118.31	6.2213
250.00	1.0000	0.47788	2.0926	4.4576	6.5501	0.083515	0.020028	0.028401	1217.3	-0.23428	161.46	7.9283
325.00	1.0000	0.36797	2.7176	5.9910	8.7086	0.091062	0.020699	0.029039	1379.1	-0.39039	198.43	9.4759
400.00	1.0000	0.29924	3.3418	7.5525	10.894	0.097113	0.020878	0.029204	1526.4	-0.47605	234.65	10.908
25.000	5.0000	35.661	0.028042	0.046611	0.18682	0.0021443	0.012376	0.020610	1223.4	-0.90198	119.36	13.101
100.00	5.0000	5.9683	0.16755	1.6549	2.4927	0.045314	0.014583	0.025613	865.94	0.86369	80.395	4.5875
175.00	5.0000	3.3132	0.30183	2.9582	4.4673	0.059998	0.018352	0.027370	1077.3	0.032971	123.58	6.3871
250.00	5.0000	2.3268	0.42978	4.4292	6.5781	0.070022	0.020136	0.028723	1254.0	-0.25678	165.19	8.0420

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
325.00	5.0000	1.7990	0.55587	5.9750	8.7543	0.077631	0.020776	0.029211	1412.0	-0.39563	201.36	9.5631
400.00	5.0000	1.4680	0.68120	7.5440	10.950	0.083710	0.020937	0.029304	1556.2	-0.47537	237.09	10.979
25.000	10.000	37.930	0.026364	0.020221	0.28386	0.00059913	0.012222	0.018499	1402.1	-1.0762	131.12	16.625
100.00	10.000	11.417	0.087588	1.5346	2.4105	0.038585	0.014838	0.027423	955.43	0.39679	94.196	5.1692
175.00	10.000	6.3697	0.15699	2.9000	4.4699	0.053931	0.018532	0.028063	1133.3	-0.068718	130.39	6.6199
250.00	10.000	4.5028	0.22209	4.3966	6.6175	0.064133	0.020260	0.029065	1300.6	-0.28786	169.92	8.1898
325.00	10.000	3.5006	0.28567	5.9563	8.8130	0.071811	0.020867	0.029402	1453.0	-0.40519	205.05	9.6733
400.00	10.000	2.8687	0.34859	7.5339	11.020	0.077921	0.021006	0.029419	1593.1	-0.47687	240.15	11.067
100.00	50.000	31.993	0.031257	1.1768	2.7397	0.023964	0.016349	0.026254	1710.1	-0.57213	192.47	10.534
175.00	50.000	22.700	0.044053	2.6415	4.8442	0.039587	0.019545	0.029321	1632.6	-0.46415	189.52	9.1377
250.00	50.000	17.524	0.057066	4.2297	7.0830	0.050225	0.020999	0.030163	1690.7	-0.46214	211.67	9.7772
325.00	50.000	14.304	0.069911	5.8539	9.3494	0.058153	0.021434	0.030202	1784.8	-0.48443	237.63	10.827
400.00	50.000	12.107	0.082595	7.4773	11.607	0.064404	0.021458	0.029985	1887.2	-0.51016	267.11	11.965
175.00	100.00	33.019	0.030286	2.5589	5.5875	0.033643	0.020316	0.029140	2128.4	-0.52750	282.17	13.079
250.00	100.00	27.257	0.036688	4.1604	7.8292	0.044291	0.021603	0.030346	2125.4	-0.50698	303.19	12.218
325.00	100.00	23.228	0.043051	5.8083	10.113	0.052281	0.021923	0.030469	2170.6	-0.51215	327.83	12.546
400.00	100.00	20.261	0.049356	7.4555	12.391	0.058588	0.021864	0.030246	2235.8	-0.52481	356.83	13.289

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Younglove, B. A., "Thermophysical Properties of Fluids. I. Argon, Ethylene, Parahydrogen, Nitrogen, Nitrogen Trifluoride, and Oxygen," *J. Phys. Chem. Ref. Data, Suppl.* 1, 11: 1–11, 1982. The source for viscosity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note* 617, 1972. The source for thermal conductivity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note* 617, 1972.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.1% in the liquid phase, 0.25% in the vapor phase, and 0.2% in the supercritical region. The uncertainty in heat capacity is 3%, and the uncertainty in speed of sound is 2% in the liquid phase and 1% elsewhere. The uncertainty in viscosity ranges from 4% to 15%. The uncertainty in thermal conductivity below 100 K is estimated to be 3% below 150 atm and up to 10% below 700 atm. For temperatures around 100 K at low densities, the uncertainty is about 1%. Above 100 K, the uncertainty is estimated to be on the order of 10%.

Table 2-117 Saturated Hydrogen Peroxide*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
273	0.0004	0.00068	1672	-5577	-4027	2.990	8.662	1.45	18.0	0.483
300	0.0031	0.00069	235	-5510	-3995	3.224	8.269	1.48	11.3	0.481
350	0.0564	0.00072	15.1	-5376	-3933	3.631	7.758	1.54	4.3	0.474
400	0.4521	0.00076	2.12	-5238	-3878	4.032	7.440	1.61	2.2	0.464
450	2.143	0.00081	0.487	-5091	-3820	4.346	7.172	1.68	1.3	0.453
500	7.126	0.00088	0.155	-4945	-3777	4.656	6.992	1.75	0.89	0.443
550	18.56	0.00095	0.0605	-4794	-3745	4.941	6.846	1.82	0.65	0.431
600	40.75	0.00107	0.0268	-4635	-3731	5.209	6.720	1.90	0.50	0.416
650	79.27	0.00125	0.0125	-4463	-3746	5.485	6.582			
700	141.7	0.00171	0.0048	-4195	-3860	5.682	6.339			
708.5 ^c	155.3	0.00284	0.0028	-4012	-4012	5.732	5.732			

*Values reproduced or converted from a tabulation by Tsykalo and Tabachnikov in V. A. Rabinovich (ed.), *Thermophysical Properties of Gases and Liquids*, Standartov, Moscow, 1968; NBS-NSF transl. TT 69-55091, 1970. The reader may be reminded that very pure hydrogen peroxide is very difficult to obtain owing to its decomposition or instability. c = critical point. The FMC Corp., Philadelphia, PA tech. bull. 67, 1969 (100 pp.) contains an enthalpy-pressure diagram to 3000 psia, 1100 K.

Table 2-118 Thermodynamic Properties of Hydrogen Sulfide

Tempera ture K	Pressu re MPa	Densit y mol/d m ³	Volum e dm ³ /m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l·K)	C_v kJ/(mo l·K)	C_p kJ/(mo l·K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
187.70	0.0232 59	29.116	0.0343 45	-1.721 0	-1.720 2	-0.008 5877	0.0443 90	0.0688 35	1437.8	-0.340 39	254.24	439.13
190.00	0.0271 06	29.003	0.0344 79	-1.562 8	-1.561 9	-0.007 7504	0.0441 24	0.0687 07	1425.8	-0.339 23	251.74	428.67
200.00	0.0503 40	28.505	0.0350 82	-0.878 41	-0.876 64	-0.004 2394	0.0430 42	0.0682 73	1373.4	-0.332 53	240.93	385.68
210.00	0.0874 74	27.998	0.0357 17	-0.197 59	-0.194 46	-0.000 91743	0.0420 67	0.0680 29	1321.0	-0.322 87	230.26	346.75
220.00	0.1436 6	27.480	0.0363 90	0.4813 8	0.4866 1	0.0022 415	0.0411 88	0.0679 75	1268.4	-0.309 88	219.81	311.74
230.00	0.2248 5	26.949	0.0371 07	1.1602	1.1686	0.0052 596	0.0403 93	0.0681 15	1215.6	-0.293 05	209.52	280.37
240.00	0.3376 7	26.403	0.0378 75	1.8406	1.8534	0.0081 564	0.0396 77	0.0684 61	1162.3	-0.271 74	199.43	252.29
250.00	0.4893 4	25.838	0.0387 02	2.5245	2.5434	0.0109 49	0.0390 30	0.0690 32	1108.5	-0.245 09	189.56	227.14
260.00	0.6875 1	25.253	0.0395 99	3.2135	3.2408	0.0136 54	0.0384 49	0.0698 59	1053.9	-0.211 97	179.91	204.60
270.00	0.9402 2	24.642	0.0405 80	3.9100	3.9481	0.0162 85	0.0379 30	0.0709 89	998.54	-0.170 84	170.48	184.32
280.00	1.2558	24.002	0.0416 62	4.6161	4.6685	0.0188 57	0.0374 70	0.0724 90	942.08	-0.119 59	161.26	166.02
290.00	1.6429	23.327	0.0428 68	5.3348	5.4053	0.0213 85	0.0370 70	0.0744 66	884.34	-0.055 218	152.24	149.44
300.00	2.1103	22.609	0.0442 30	6.0696	6.1629	0.0238 85	0.0367 32	0.0770 82	825.04	0.0266 36	143.40	134.32
310.00	2.6672	21.838	0.0457 91	6.8248	6.9469	0.0263 73	0.0364 62	0.0806 03	763.84	0.1326 0	134.71	120.43
320.00	3.3233	21.000	0.0476 18	7.6068	7.7650	0.0288 73	0.0362 73	0.0854 98	700.23	0.2732 4	126.16	107.58
330.00	4.0889	20.073	0.0498 18	8.4246	8.6283	0.0314 14	0.0361 91	0.0926 66	633.51	0.4665 5	117.71	95.533
340.00	4.9755	19.021	0.0525 73	9.2932	9.5548	0.0340 44	0.0362 65	0.1041 0	562.59	0.7461 8	109.36	84.050

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
350.00	5.9969	17.776	0.056256	10.241	10.578	0.036848	0.036600	0.12534	485.59	1.1841	101.19	72.784
360.00	7.1713	16.172	0.061837	11.335	11.779	0.040035	0.037471	0.17963	398.86	1.9714	93.864	61.060
370.00	8.5294	13.436	0.074429	12.903	13.538	0.044599	0.040079	0.63367	292.76	3.9324	92.754	46.102
373.10	8.9987	10.190	0.098135	14.470	15.353	0.049374			0	6.3885		
187.70	0.023259	0.015024	66.559	16.328	17.876	0.095815	0.025347	0.034000	245.84	55.730	10.628	8.0025
190.00	0.027106	0.017314	57.758	16.382	17.947	0.094930	0.025386	0.034078	247.20	53.868	10.775	8.1053
200.00	0.050340	0.030704	32.569	16.611	18.250	0.091395	0.025586	0.034487	252.82	46.796	11.429	8.5566
210.00	0.087474	0.051165	19.545	16.832	18.541	0.088301	0.025837	0.035021	257.96	41.090	12.107	9.0159
220.00	0.14366	0.080932	12.356	17.043	18.818	0.085567	0.026142	0.035698	262.58	36.435	12.816	9.4844
230.00	0.22485	0.12253	8.1613	17.244	19.079	0.083129	0.026502	0.036537	266.64	32.601	13.566	9.9634
240.00	0.33767	0.17879	5.5933	17.431	19.320	0.080933	0.026917	0.037563	270.10	29.412	14.365	10.455
250.00	0.48934	0.25286	3.9547	17.604	19.539	0.078934	0.027388	0.038807	272.91	26.737	15.227	10.961
260.00	0.68751	0.34834	2.8707	17.761	19.735	0.077092	0.027914	0.040312	275.05	24.476	16.166	11.485
270.00	0.94022	0.46937	2.1305	17.899	19.902	0.075375	0.028496	0.042139	276.47	22.550	17.202	12.031
280.00	1.2558	0.62086	1.6107	18.016	20.039	0.073752	0.029136	0.044378	277.15	20.897	18.360	12.604
290.00	1.6429	0.80887	1.2363	18.108	20.139	0.072193	0.029838	0.047166	277.05	19.466	19.675	13.213
300.00	2.1103	1.0411	0.96050	18.171	20.198	0.070669	0.030608	0.050723	276.12	18.212	21.197	13.867
310.00	2.6672	1.3280	0.75300	18.199	20.207	0.069149	0.031458	0.055410	274.34	17.097	22.997	14.582

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
320.00	3.3233	1.6843	0.59373	18.183	20.156	0.067594	0.032407	0.061879	271.64	16.081	25.187	15.380
330.00	4.0889	2.1323	0.46898	18.109	20.027	0.065956	0.033485	0.071400	268.00	15.116	27.946	16.300
340.00	4.9755	2.7096	0.36906	17.957	19.793	0.064157	0.034746	0.086837	263.35	14.142	31.600	17.405
350.00	5.9969	3.4881	0.28669	17.684	19.403	0.062064	0.036293	0.11617	257.65	13.053	36.820	18.833
360.00	7.1713	4.6442	0.21532	17.192	18.736	0.059360	0.038364	0.19265	250.84	11.629	45.513	20.940
370.00	8.5294	6.9933	0.14299	16.046	17.266	0.054674	0.041755	0.80649	242.80	9.0701	70.939	25.604
373.10	8.9987	10.190	0.098135	14.470	15.353	0.049374			0	6.3885		

Single-Phase Properties

200.00	0.10000	28.506	0.035080	-0.87902	-0.87551	-0.0042425	0.043042	0.068269	1373.6	-0.33258	240.95	385.79
212.60	0.10000	27.865	0.035888	-0.021243	-0.017654	-0.00082766	0.041830	0.067997	1307.4	-0.31984	227.54	337.30
212.60	0.10000	0.057900	17.271	16.888	18.615	0.087559	0.025911	0.035183	259.21	39.791	12.288	9.1366
300.00	0.10000	0.040389	24.759	19.164	21.640	0.099486	0.025979	0.034563	309.73	16.968	17.999	12.954
400.00	0.10000	0.030157	33.160	21.830	25.146	0.10956	0.027268	0.035693	356.35	8.9467	24.990	17.172
500.00	0.10000	0.024088	41.515	24.642	28.794	0.11770	0.028923	0.037297	396.06	5.5432	32.218	21.094
600.00	0.10000	0.020059	49.853	27.626	32.611	0.12465	0.030708	0.039059	431.20	3.7250	39.592	24.714
700.00	0.10000	0.017187	58.182	30.789	36.607	0.13081	0.032534	0.040873	463.05	2.6185	47.091	28.082
200.00	1.00000	28.528	0.035053	-0.89011	-0.85506	-0.0042980	0.043058	0.068210	1377.6	-0.33351	241.31	387.91
272.07	1.00000	24.513	0.040795	4.0550	4.0958	0.016821	0.037830	0.071266	986.97	-0.16116	168.56	180.39

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
272.07	1.0000	0.49800	2.0080	17.925	19.933	0.075033	0.028623	0.042564	276.67	22.188	17.430	12.147
300.00	1.0000	0.43539	2.2968	18.775	21.072	0.079019	0.027626	0.039427	296.60	17.369	19.015	13.337
400.00	1.0000	0.31003	3.2255	21.626	24.852	0.089907	0.027708	0.037234	351.09	9.0111	25.609	17.465
500.00	1.0000	0.24394	4.0993	24.507	28.606	0.098281	0.029100	0.038036	393.73	5.5366	32.691	21.319
600.00	1.0000	0.20183	4.9547	27.525	32.480	0.10534	0.030799	0.039492	430.30	3.7023	39.980	24.893
700.00	1.0000	0.17237	5.8015	30.710	36.511	0.11155	0.032589	0.041157	462.94	2.5947	47.423	28.227
200.00	5.0000	28.625	0.034935	-0.93837	-0.76369	-0.0045411	0.043127	0.067957	1394.7	-0.33745	242.90	397.26
300.00	5.0000	22.858	0.043749	5.9433	6.1620	0.023458	0.036740	0.075047	855.61	-0.017492	146.15	139.57
340.26	5.0000	18.992	0.052654	9.3164	9.5797	0.034113	0.036269	0.10449	560.70	0.75500	109.14	83.760
340.26	5.0000	2.7266	0.36675	17.952	19.786	0.064108	0.034782	0.087361	263.22	14.116	31.710	17.437
400.00	5.0000	1.8047	0.55412	20.549	23.319	0.073747	0.030043	0.048271	325.86	9.1749	29.786	19.070
500.00	5.0000	1.2939	0.77288	23.863	27.728	0.083609	0.029940	0.041996	384.33	5.4471	35.063	22.459
600.00	5.0000	1.0365	0.96476	27.065	31.889	0.091196	0.031216	0.041590	427.30	3.5816	41.773	25.773
700.00	5.0000	0.87211	1.1466	30.353	36.086	0.097665	0.032838	0.042472	463.26	2.4840	48.924	28.935
200.00	10.000	28.741	0.034793	-0.99643	-0.64850	-0.0048367	0.043212	0.067668	1415.5	-0.34197	244.82	408.90
300.00	10.000	23.238	0.043033	5.7496	6.1800	0.022795	0.036779	0.072377	902.78	-0.077399	150.49	148.08
400.00	10.000	5.0473	0.19812	18.370	20.351	0.062081	0.034651	0.10189	291.29	8.2243	44.719	23.639
500.00	10.000	2.8037	0.35667	22.959	26.526	0.076030	0.031080	0.048875	375.68	5.1487	38.963	24.438

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
600.00	10.000	2.1399	0.46730	26.466	31.139	0.084452	0.031755	0.044597	426.01	3.3812	44.210	27.165
700.00	10.000	1.7663	0.56617	29.903	35.564	0.091275	0.033155	0.044212	465.45	2.3347	50.878	30.013
300.00	75.000	26.050	0.038388	4.3332	7.2123	0.017506	0.037754	0.061705	1276.9	-0.33612	187.18	232.59
400.00	75.000	21.973	0.045510	9.9713	13.384	0.035260	0.035381	0.061962	983.51	-0.18247	134.39	124.22
500.00	75.000	17.947	0.055720	15.404	19.583	0.049092	0.034762	0.061649	786.35	0.057516	103.90	81.074
600.00	75.000	14.519	0.068874	20.474	25.640	0.060142	0.034994	0.059227	688.11	0.27314	87.712	62.531
700.00	75.000	11.974	0.083511	25.148	31.412	0.069045	0.035721	0.056291	654.55	0.36585	82.684	54.563
300.00	150.00	27.794	0.035979	3.5100	8.9069	0.013888	0.038777	0.058983	1538.4	-0.40376	214.24	311.25
400.00	150.00	24.751	0.040403	8.6429	14.703	0.030575	0.036402	0.057226	1302.6	-0.37006	165.64	174.85
500.00	150.00	21.937	0.045585	13.539	20.377	0.043238	0.035779	0.056273	1132.1	-0.31802	135.75	119.57
600.00	150.00	19.449	0.051416	18.248	25.960	0.053420	0.036044	0.055409	1019.1	-0.26874	118.38	93.323
700.00	150.00	17.335	0.057687	22.811	31.464	0.061906	0.036804	0.054711	949.06	-0.23292	110.03	79.581

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E.W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* 51(3): 785–850, 2006. The source for viscosity and thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.1% in the liquid phase below the critical temperature, 0.4% in the vapor phase, 1% at supercritical temperatures up to 500 K, and 2.5% at higher temperatures. Uncertainties will be higher near the critical point, and may be lower than 0.5% between 400 and 500 K. The uncertainty in vapor pressure is 0.25%, and the uncertainty in heat capacities is estimated to be 1%. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

Figure 2-6 Enthalpy-concentration diagram for aqueous hydrogen chloride at 1 atm. Reference states: enthalpy of liquid water at 0°C is zero; enthalpy of pure saturated HCl vapor at 1 atm (-85.03°C) is 8000 kcal/mol. Note: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. Saturation values may be read at the ends of the tie lines [C.C. Van Nuys, Trans. Am. Inst. Chem. Eng 39: 663 (1943)].

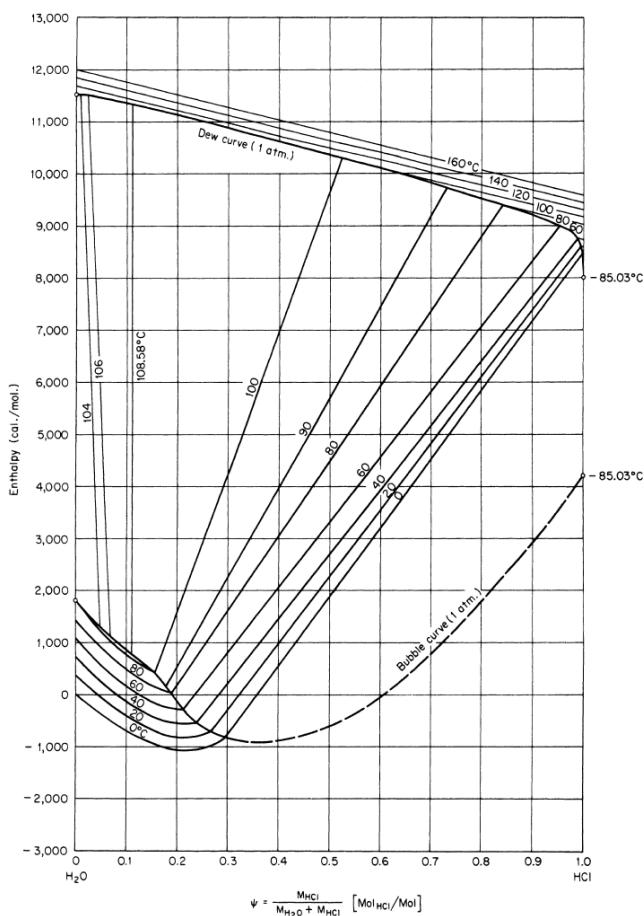


Table 2-119 Thermodynamic Properties of Methane

Tempera ture K	Pressu re MPa	Densit y mol/d m ³	Volum e dm ³ /m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l·K)	C_v kJ/(mo l·K)	C_p kJ/(mo l·K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
90.694 96	0.0116 96	28.142	0.0355 34	-1.152 6	-1.152 2	-0.011 389	0.0347 76	0.0540 29	1538.6	-0.481 91	211.24	204.52
100.00 76	0.0343 76	27.357	0.0365 54	-0.647 28	-0.646 02	-0.006 0856	0.0339 08	0.0546 81	1452.0	-0.458 12	199.67	155.78
105.00 77	0.0563 77	26.923	0.0371 43	-0.373 06	-0.370 97	-0.003 4096	0.0335 00	0.0551 35	1403.9	-0.442 02	193.03	136.86
110.00 30	0.0881 30	26.478	0.0377 68	-0.096 585	-0.093 257	-0.000 83691	0.0331 15	0.0556 56	1354.7	-0.423 28	186.18	121.34

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
115.00	0.13221	26.021	0.038431	0.18242	0.18750	0.0016441	0.032749	0.056253	1304.6	-0.40145	179.21	108.39
120.00	0.19143	25.551	0.039138	0.46425	0.47174	0.0040439	0.032400	0.056941	1253.5	-0.37589	172.15	97.432
125.00	0.26876	25.065	0.039896	0.74927	0.75999	0.0063722	0.032069	0.057741	1201.3	-0.34578	165.04	88.031
130.00	0.36732	24.562	0.040714	1.0379	1.0529	0.0086383	0.031757	0.058684	1148.1	-0.31006	157.91	79.868
135.00	0.49035	24.038	0.041600	1.3307	1.3511	0.010851	0.031469	0.059809	1093.6	-0.26735	150.78	72.699
140.00	0.64118	23.491	0.042569	1.6284	1.6557	0.013020	0.031206	0.061169	1037.7	-0.21579	143.65	66.333
145.00	0.82322	22.917	0.043636	1.9317	1.9676	0.015154	0.030974	0.062840	980.17	-0.15286	136.54	60.620
150.00	1.0400	22.309	0.044825	2.2418	2.2884	0.017264	0.030780	0.064932	920.85	-0.075032	129.43	55.437
155.00	1.2950	21.661	0.046165	2.5602	2.6199	0.019362	0.030631	0.067613	859.39	0.022798	122.32	50.682
160.00	1.5921	20.964	0.047702	2.8887	2.9647	0.021462	0.030541	0.071156	795.43	0.14836	115.19	46.266
165.00	1.9351	20.202	0.049500	3.2304	3.3262	0.023584	0.030531	0.076044	728.42	0.31398	108.01	42.105
170.00	2.3283	19.355	0.051667	3.5895	3.7098	0.025755	0.030634	0.083218	657.52	0.54087	100.73	38.115
175.00	2.7765	18.384	0.054394	3.9734	4.1244	0.028021	0.030920	0.094816	581.27	0.86918	93.324	34.196
180.00	3.2852	17.218	0.058078	4.3965	4.5873	0.030467	0.031554	0.11699	497.01	1.3866	85.799	30.193
185.00	3.8617	15.668	0.063825	4.8955	5.1420	0.033313	0.033085	0.17822	398.59	2.3397	78.733	25.773
190.00	4.5186	12.515	0.079902	5.7074	6.0685	0.038000	0.041746	1.5082	250.31	5.2488	96.970	18.982
190.56	4.5992	10.139	0.098628	6.2136	6.6672	0.041109			0	6.8877		
90.694	0.011696	0.015630	63.981	6.8310	7.5793	0.084885	0.025243	0.033851	249.13	47.921	8.8517	3.6388

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
100.00	0.034376	0.042048	23.782	7.0469	7.8644	0.079019	0.025487	0.034425	260.09	37.826	10.015	3.9976
105.00	0.056377	0.066154	15.116	7.1582	8.0104	0.076413	0.025652	0.034853	265.31	33.883	10.669	4.1951
110.00	0.088130	0.099622	10.038	7.2654	8.1501	0.074103	0.025842	0.035378	270.01	30.662	11.350	4.3964
115.00	0.13221	0.14457	6.9171	7.3680	8.2825	0.072036	0.026056	0.036016	274.17	28.004	12.062	4.6019
120.00	0.19143	0.20332	4.9183	7.4652	8.4067	0.070168	0.026295	0.036786	277.76	25.790	12.811	4.8123
125.00	0.26876	0.27844	3.5915	7.5562	8.5215	0.068464	0.026560	0.037714	280.76	23.928	13.604	5.0285
130.00	0.36732	0.37278	2.6825	7.6403	8.6257	0.066891	0.026854	0.038836	283.13	22.347	14.449	5.2517
135.00	0.49035	0.48962	2.0424	7.7165	8.7180	0.065421	0.027182	0.040203	284.86	20.993	15.355	5.4833
140.00	0.64118	0.63279	1.5803	7.7837	8.7970	0.064029	0.027549	0.041885	285.93	19.819	16.334	5.7254
145.00	0.82322	0.80691	1.2393	7.8406	8.8608	0.062694	0.027965	0.043985	286.31	18.789	17.402	5.9806
150.00	1.0400	1.0177	0.98256	7.8856	8.9074	0.061391	0.028439	0.046657	285.97	17.870	18.581	6.2526
155.00	1.2950	1.2728	0.78568	7.9166	8.9340	0.060098	0.028989	0.050144	284.88	17.035	19.904	6.5462
160.00	1.5921	1.5821	0.63206	7.9306	8.9369	0.058789	0.029636	0.054849	283.01	16.255	21.423	6.8688
165.00	1.9351	1.9603	0.51014	7.9238	8.9109	0.057431	0.030412	0.061496	280.30	15.500	23.225	7.2313
170.00	2.3283	2.4294	0.41163	7.8898	8.8482	0.055982	0.031374	0.071527	276.66	14.732	25.477	7.6515
175.00	2.7765	3.0268	0.33038	7.8184	8.7357	0.054371	0.032615	0.088273	271.99	13.896	28.545	8.1609
180.00	3.2852	3.8257	0.26139	7.6893	8.5480	0.052471	0.034338	0.12151	266.04	12.892	33.392	8.8251
185.00	3.8617	5.0137	0.19945	7.4515	8.2217	0.049961	0.037087	0.21701	258.03	11.492	43.706	9.8238

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	Cp kJ/(mol·K)	Cv kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
190.00	4.5186	7.8027	0.12816	6.7850	7.3641	0.044819	0.045796	2.2590	238.55	8.4951	119.40	12.455
190.56	4.5992	10.139	0.098628	6.2136	6.6672	0.041109			0	6.8877		
Single-Phase Properties												
100.00	0.10000	27.360	0.036549	-0.64803	-0.64438	-0.0060931	0.033911	0.054672	1452.6	-0.45829	199.74	155.91
111.51	0.10000	26.341	0.037963	-0.012738	-0.0089413	-0.000079677	0.033003	0.055828	1339.7	-0.41705	184.09	117.20
111.51	0.10000	0.11186	8.9395	7.2969	8.1908	0.073456	0.025904	0.035558	271.33	29.808	11.561	4.4579
200.00	0.10000	0.060518	16.524	9.5570	11.209	0.093427	0.025259	0.033784	369.98	9.2893	21.941	7.8096
300.00	0.10000	0.040158	24.901	12.175	14.665	0.10741	0.027479	0.035869	449.74	4.3216	34.552	11.245
400.00	0.10000	0.030082	33.243	15.151	18.475	0.11834	0.032300	0.040652	510.56	2.2395	50.127	14.272
500.00	0.10000	0.024055	41.572	18.673	22.831	0.12803	0.038196	0.046533	561.86	1.2245	68.564	16.976
600.00	0.10000	0.020042	49.895	22.795	27.784	0.13705	0.044179	0.052509	608.04	0.68722	88.921	19.431
100.00	1.0000	27.403	0.036493	-0.65829	-0.62179	-0.0061960	0.033950	0.054562	1459.6	-0.46060	200.62	157.63
149.14	1.0000	22.416	0.044610	2.1878	2.2325	0.016902	0.030810	0.064535	931.21	-0.089695	130.66	56.297
149.14	1.0000	0.97852	1.0220	7.8788	8.9007	0.061614	0.028353	0.046147	286.08	18.022	18.368	6.2043
200.00	1.0000	0.64363	1.5537	9.3582	10.912	0.073276	0.025879	0.036730	357.81	9.5001	23.028	8.0145
300.00	1.0000	0.40776	2.4524	12.072	14.524	0.087922	0.027621	0.036721	447.04	4.2699	35.152	11.367
400.00	1.0000	0.30205	3.3108	15.083	18.393	0.099023	0.032360	0.041056	510.57	2.2001	50.558	14.357
500.00	1.0000	0.24058	4.1567	18.623	22.780	0.10879	0.038227	0.046766	562.99	1.1998	68.902	17.040

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
600.00	1.0000	0.20012	4.9971	22.755	27.752	0.11784	0.044198	0.052659	609.73	0.67124	89.200	19.483
100.00	5.0000	27.586	0.036250	-0.70190	-0.52065	-0.0066393	0.034116	0.054117	1490.0	-0.46993	204.45	165.28
200.00	5.0000	5.4706	0.18279	7.8197	8.7337	0.051495	0.032029	0.11667	291.29	8.9784	40.612	10.828
300.00	5.0000	2.1799	0.45874	11.590	13.884	0.072954	0.028262	0.041234	439.25	3.9428	38.480	12.194
400.00	5.0000	1.5333	0.65221	14.779	18.040	0.084897	0.032614	0.042903	513.11	2.0089	52.693	14.872
500.00	5.0000	1.2013	0.83240	18.401	22.563	0.094971	0.038361	0.047789	569.49	1.0870	70.509	17.410
600.00	5.0000	0.99281	1.0072	22.581	27.617	0.10417	0.044277	0.053309	618.13	0.60013	90.498	19.768
100.00	10.000	27.802	0.035969	-0.75239	-0.39270	-0.0071652	0.034314	0.053642	1525.7	-0.47979	209.07	174.83
200.00	10.000	16.593	0.060268	5.1551	5.7578	0.034542	0.030129	0.085085	567.92	1.0266	84.234	29.399
300.00	10.000	4.6859	0.21340	10.942	13.077	0.065137	0.028995	0.048165	444.53	3.2606	44.730	13.896
400.00	10.000	3.1002	0.32256	14.401	17.627	0.078246	0.032902	0.045220	522.58	1.7355	55.941	15.766
500.00	10.000	2.3887	0.41863	18.132	22.318	0.088698	0.038516	0.049007	580.99	0.94125	72.781	18.011
600.00	10.000	1.9619	0.50971	22.371	27.468	0.098073	0.044371	0.054070	630.63	0.51200	92.268	20.217
200.00	100.00	25.496	0.039222	3.0510	6.9732	0.020596	0.032058	0.048512	1541.0	-0.51619	188.05	80.392
300.00	100.00	21.266	0.047024	7.0865	11.789	0.040126	0.031823	0.048281	1267.5	-0.44889	137.68	47.835
400.00	100.00	17.881	0.055926	11.121	16.713	0.054276	0.035273	0.050523	1115.8	-0.37484	120.38	37.584
500.00	100.00	15.305	0.065340	15.405	21.939	0.065922	0.040312	0.054139	1044.8	-0.32811	120.87	33.590
600.00	100.00	13.357	0.074869	20.074	27.561	0.076160	0.045724	0.058364	1018.4	-0.30439	130.36	32.111

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
200.00	500.00	33.003	0.030301	2.3322	17.482	0.0061671	0.037832	0.047821	2664.2	-0.53926	429.60	205.24
300.00	500.00	30.786	0.032482	5.9505	22.192	0.025271	0.037006	0.047114	2500.0	-0.55416	358.93	106.90
400.00	500.00	28.929	0.034567	9.7401	27.024	0.039152	0.039890	0.049933	2360.3	-0.52806	312.36	78.768
500.00	500.00	27.331	0.036588	13.934	32.228	0.050747	0.044407	0.054280	2250.3	-0.49035	285.41	66.669
600.00	500.00	25.934	0.038559	18.612	37.892	0.061061	0.049344	0.059017	2168.1	-0.45514	272.14	60.413

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Setzmann, U., and Wagner, W., "A New Equation of State and Tables of Thermodynamic Properties for Methane Covering the Range from the Melting Line to 625 K at Pressures up to 1000 MPa," *J. Phys. Chem. Ref. Data* **20**(6):1061–1151, 1991. The source for viscosity is Younglove, B. A., and Ely, J. F., "Thermophysical Properties of Fluids. II. Methane, Ethane, Propane, Isobutane and Normal Butane," *J. Phys. Chem. Ref. Data* **16**:577–798, 1987. The source for thermal conductivity is Friend, D. G., Ely, J. F., and Ingham, H., "Tables for the Thermophysical Properties of Methane," *NIST Tech. Note* 1325, 1989.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.03% for pressures below 12 MPa and temperatures below 350 K and up to 0.07% for pressures less than 50 MPa. For the speed of sound, the uncertainty ranges from 0.03% (in the vapor phase) to 0.3% depending on temperature and pressure. Heat capacities may be generally calculated within an uncertainty of 1%. The uncertainty in viscosity is 2%, except in the critical region which is 5%. The uncertainty in thermal conductivity of the dilute gas between 130 and 625 K is 2.5%. For temperatures below 130 K, the uncertainty is less than 10%. Excluding the dilute gas, the uncertainty is 2% between 110 and 725 K at pressures up to 70 MPa, except near the critical point which has an uncertainty of 5% or greater. For the vapor at lower temperatures and the dense liquid near the triple point, an uncertainty of 10% is possible.

Table 2-120 Thermodynamic Properties of Methanol

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
175.61	1.8635E-07	28.230	0.035423	-12.440	-12.440	-0.049524	0.056728	0.070390	1625.1	-0.40884
180.00	3.7619E-07	28.096	0.035592	-12.130	-12.130	-0.047781	0.056689	0.070750	1590.2	-0.40373
195.00	3.2175E-06	27.629	0.036194	-11.067	-11.067	-0.042108	0.056604	0.070897	1496.4	-0.39791

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
210.00	1.9841E-05	27.163	0.036815	-10.001	-10.001	-0.036846	0.057072	0.071215	1425.3	-0.39361
225.00	9.4330E-05	26.703	0.037449	-8.9277	-8.9277	-0.031908	0.057992	0.072004	1363.2	-0.38674
240.00	0.00036348	26.250	0.038096	-7.8395	-7.8395	-0.027226	0.059275	0.073141	1304.6	-0.37793
255.00	0.0011791	25.802	0.038756	-6.7318	-6.7318	-0.022750	0.060916	0.074617	1248.2	-0.36733
270.00	0.0033166	25.360	0.039432	-5.5991	-5.5990	-0.018434	0.062917	0.076487	1194.1	-0.35457
285.00	0.0082787	24.922	0.040125	-4.4351	-4.4347	-0.014239	0.065250	0.078803	1142.6	-0.33915
300.00	0.018682	24.484	0.040844	-3.2329	-3.2322	-0.010129	0.067864	0.081584	1093.5	-0.32073
315.00	0.038692	24.041	0.041595	-1.9858	-1.9842	-0.0060725	0.070693	0.084823	1046.3	-0.29904
330.00	0.074453	23.590	0.042390	-0.68700	-0.68385	-0.0020451	0.073674	0.088505	1000.2	-0.27385
345.00	0.13447	23.124	0.043244	0.66961	0.67543	0.0019747	0.076752	0.092616	954.32	-0.24479
360.00	0.22992	22.638	0.044174	2.0901	2.1003	0.0060049	0.079881	0.097164	907.64	-0.21121
375.00	0.37483	22.123	0.045203	3.5806	3.5975	0.010061	0.083033	0.10219	859.31	-0.17199
390.00	0.58617	21.571	0.046358	5.1475	5.1746	0.014159	0.086189	0.10776	808.48	-0.12529
405.00	0.88399	20.973	0.047681	6.7983	6.8404	0.018314	0.089346	0.11405	754.41	-0.068163
420.00	1.2914	20.315	0.049226	8.5423	8.6058	0.022546	0.092514	0.12133	696.47	0.0042669
435.00	1.8349	19.579	0.051075	10.392	10.485	0.026879	0.095722	0.13007	634.17	0.10021
450.00	2.5433	18.741	0.053360	12.364	12.500	0.031347	0.099032	0.14120	567.09	0.23444
465.00	3.4456	17.759	0.056310	14.488	14.682	0.036009	0.10257	0.15679	494.36	0.43762
480.00	4.5713	16.553	0.060411	16.820	17.096	0.040977	0.10666	0.18345	412.12	0.79465
495.00	5.9794	14.880	0.067203	19.521	19.923	0.046590	0.11250	0.25717	308.94	1.6506
510.00	7.7496	11.689	0.085547	23.297	23.960	0.054351	0.12653	1.1088	192.83	4.6061

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
513.38	8.2159	8.7852	0.11383	25.917	26.852	0.059911			0	6.7425
175.61	1.8635E-07	1.2764E-07	7,834,400.	28.219	29.679	0.19032	0.031874	0.040287	239.95	1187400.
180.00	3.7619E-07	2.5140E-07	3,977,700.	28.353	29.850	0.18544	0.032397	0.040854	242.62	857090.
195.00	3.2175E-06	1.9855E-06	503,660.	28.810	30.430	0.17069	0.035224	0.043954	251.06	293110.
210.00	1.9841E-05	1.1378E-05	87,892.	29.259	31.003	0.15841	0.040104	0.049389	258.49	105090.
225.00	9.4330E-05	5.0556E-05	19,780.	29.698	31.564	0.14806	0.047248	0.057480	265.30	39363.
240.00	0.00036348	0.00018304	5,463.4	30.123	32.109	0.13923	0.056324	0.067973	271.89	15552.
255.00	0.0011791	0.00056065	1,783.7	30.534	32.637	0.13164	0.066572	0.080135	278.43	6557.5
270.00	0.0033166	0.0014959	668.48	30.932	33.149	0.12508	0.077055	0.093000	284.90	2971.8
285.00	0.0082787	0.0035581	281.05	31.321	33.648	0.11938	0.086920	0.10564	291.19	1449.9
300.00	0.018682	0.0076845	130.13	31.703	34.134	0.11442	0.095581	0.11740	297.15	759.96
315.00	0.038692	0.015300	65.359	32.077	34.606	0.11009	0.10279	0.12798	302.63	426.34
330.00	0.074453	0.028438	35.164	32.442	35.060	0.10627	0.10860	0.13749	307.47	254.84
345.00	0.13447	0.049870	20.052	32.789	35.485	0.10287	0.11331	0.14644	311.48	161.53
360.00	0.22992	0.083267	12.009	33.108	35.869	0.099808	0.11736	0.15559	314.48	108.02
375.00	0.37483	0.13344	7.4940	33.385	36.194	0.096984	0.12125	0.16605	316.20	75.802
390.00	0.58617	0.20674	4.8370	33.601	36.436	0.094317	0.12546	0.17917	316.34	55.467
405.00	0.88399	0.31179	3.2073	33.736	36.571	0.091723	0.13033	0.19663	314.53	42.002
420.00	1.2914	0.46071	2.1706	33.767	36.570	0.089128	0.13587	0.21986	310.36	32.587
435.00	1.8349	0.67055	1.4913	33.687	36.423	0.086505	0.14101	0.24709	303.71	25.532
450.00	2.5433	0.96219	1.0393	33.541	36.184	0.083978	0.14238	0.26502	295.26	19.860
465.00	3.4456	1.3555	0.73775	33.439	35.981	0.081813	0.13589	0.25879	285.25	15.568

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
480.00	4.5713	1.9102	0.52352	33.258	35.652	0.079634	0.12618	0.27959	267.83	13.904
495.00	5.9794	2.9050	0.34423	32.267	34.325	0.075685	0.12608	0.42448	247.46	12.099
510.00	7.7496	5.1706	0.19340	29.688	31.187	0.068520	0.13259	1.9096	212.65	9.5115
513.38	8.2159	8.7852	0.11383	25.917	26.852	0.059911			0	6.7425
Single-Phase Properties										
200.00	0.10000	27.474	0.036398	-10.713	-10.709	-0.040317	0.056702	0.070943	1471.5	-0.39677
300.00	0.10000	24.486	0.040839	-3.2341	-3.2300	-0.010133	0.067862	0.081580	1094.1	-0.32081
337.30	0.10000	23.366	0.042798	-0.034546	-0.030266	-0.000089518	0.075163	0.090451	977.93	-0.26023
337.30	0.10000	0.037626	26.577	32.613	35.271	0.10457	0.11100	0.14187	309.54	202.71
400.00	0.10000	0.030452	32.839	36.075	39.359	0.11581	0.044972	0.054208	349.19	40.941
500.00	0.10000	0.024157	41.396	40.921	45.060	0.12851	0.051823	0.060380	387.15	12.933
600.00	0.10000	0.020089	49.779	46.476	51.454	0.14014	0.059065	0.067441	420.71	4.3382
200.00	1.0000	27.491	0.036376	-10.720	-10.684	-0.040354	0.056724	0.070932	1475.1	-0.39705
300.00	1.0000	24.514	0.040793	-3.2472	-3.2064	-0.010176	0.067848	0.081541	1100.0	-0.32177
400.00	1.0000	21.193	0.047185	6.2298	6.2770	0.016901	0.088257	0.11177	775.46	-0.090229
409.75	1.0000	20.772	0.048143	7.3401	7.3883	0.019645	0.090347	0.11623	736.51	-0.047179
409.75	1.0000	0.35352	2.8287	33.758	36.586	0.090904	0.13203	0.20333	313.48	38.678
500.00	1.0000	0.25202	3.9680	40.335	44.303	0.10818	0.056676	0.068069	376.08	13.330
600.00	1.0000	0.20501	4.8778	46.300	51.178	0.12070	0.061344	0.070369	413.09	4.5635
200.00	5.0000	27.561	0.036283	-10.752	-10.571	-0.040517	0.056820	0.070883	1490.9	-0.39825
300.00	5.0000	24.635	0.040592	-3.3039	-3.1010	-0.010367	0.067795	0.081377	1125.5	-0.32568
400.00	5.0000	21.441	0.046640	6.0896	6.3228	0.016546	0.087676	0.11029	818.58	-0.11504

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
484.95	5.0000	16.076	0.062203	17.655	17.966	0.042725	0.10826	0.19836	381.15	0.98684
484.95	5.0000	2.1711	0.46060	33.047	35.350	0.078574	0.12499	0.32263	260.06	13.826
500.00	5.0000	1.7679	0.56566	35.907	38.735	0.085457	0.098975	0.17315	301.43	12.155
600.00	5.0000	1.1389	0.87808	45.247	49.638	0.10553	0.072927	0.087489	379.21	5.1009
200.00	10.000	27.648	0.036169	-10.791	-10.430	-0.040716	0.056935	0.070820	1509.9	-0.39966
300.00	10.000	24.779	0.040357	-3.3713	-2.9677	-0.010598	0.067746	0.081196	1155.3	-0.32990
400.00	10.000	21.717	0.046048	5.9321	6.3925	0.016141	0.087087	0.10880	865.91	-0.13884
500.00	10.000	15.932	0.062765	19.374	20.002	0.046226	0.10760	0.18959	424.68	0.83939
600.00	10.000	2.6640	0.37537	43.262	47.015	0.096406	0.088868	0.12122	343.60	5.0965
200.00	100.00	28.911	0.034588	-11.305	-7.8460	-0.043691	0.057827	0.068992	1772.1	-0.41976
300.00	100.00	26.630	0.037552	-4.2043	-0.44914	-0.013840	0.067889	0.079818	1515.8	-0.35799
400.00	100.00	24.493	0.040827	4.3449	8.4277	0.011565	0.082823	0.098951	1334.7	-0.26099
500.00	100.00	22.020	0.045413	14.917	19.458	0.036085	0.095694	0.12152	1164.1	-0.14407
600.00	100.00	19.139	0.052250	27.300	32.525	0.059862	0.10406	0.13787	977.50	-0.023905
300.00	500.00	30.547	0.032736	-5.4195	10.949	-0.022106	0.070293	0.080627	2316.0	-0.34762
400.00	500.00	29.154	0.034300	2.2795	19.430	0.0022308	0.077541	0.089761	2194.8	-0.30897
500.00	500.00	27.670	0.036140	11.020	29.089	0.023726	0.084883	0.10419	2123.2	-0.24751
600.00	500.00	26.003	0.038457	21.094	40.322	0.044161	0.092281	0.12017	2074.1	-0.19279

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is de Reuck, K. M., and Craven, R. J. B., "Methanol, International Thermodynamic Tables of the Fluid State –12," IUPAC, Blackwell Scientific Publications, London, 1993. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are generally 0.1% in density and 2% in the speed of sound, except in the critical region and high pressures.

Table 2-121 Thermodynamic Properties of Nitrogen

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
Saturated Properties												
63.15120	0.012520	30.957	0.032303	-4.2230	-4.2226	0.067951	0.032951	0.056033	995.28	-0.40419	173.24	311.59
65.00004	0.017404	30.685	0.032589	-4.1194	-4.1188	0.069569	0.032591	0.056121	976.36	-0.39833	169.51	282.07
67.00000	0.024300	30.387	0.032909	-4.0071	-4.0063	0.071270	0.032207	0.056231	956.04	-0.39135	165.49	254.55
69.00013	0.033213	30.085	0.033239	-3.8946	-3.8935	0.072924	0.031831	0.056360	935.83	-0.38364	161.47	230.85
71.00027	0.044527	29.779	0.033581	-3.7819	-3.7804	0.074535	0.031463	0.056512	915.66	-0.37508	157.47	210.32
73.00056	0.058656	29.468	0.033935	-3.6689	-3.6669	0.076105	0.031106	0.056690	895.49	-0.36560	153.46	192.43
75.00043	0.076043	29.153	0.034302	-3.5556	-3.5530	0.077637	0.030760	0.056899	875.28	-0.35506	149.47	176.75
77.00052	0.097152	28.832	0.034683	-3.4419	-3.4385	0.079133	0.030427	0.057142	855.00	-0.34334	145.48	162.94
79.0007	0.12247	28.506	0.035080	-3.3278	-3.3235	0.080597	0.030105	0.057425	834.61	-0.33029	141.50	150.71
81.0001	0.15251	28.175	0.035493	-3.2132	-3.2078	0.082030	0.029795	0.057752	814.07	-0.31574	137.55	139.82

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
83.000	0.18780	27.837	0.035924	-3.0980	-3.0913	0.083436	0.029499	0.058130	793.36	-0.29951	133.61	130.07
85.000	0.22886	27.492	0.036375	-2.9822	-2.9739	0.084815	0.029215	0.058566	772.44	-0.28135	129.66	121.31
87.000	0.27626	27.139	0.036847	-2.8657	-2.8555	0.086172	0.028944	0.059068	751.28	-0.26099	125.72	113.38
89.000	0.33055	26.779	0.037343	-2.7483	-2.7360	0.087507	0.028687	0.059647	729.84	-0.23813	121.77	106.18
91.000	0.39230	26.409	0.037865	-2.6301	-2.6152	0.088823	0.028444	0.060315	708.09	-0.21237	117.83	99.602
93.000	0.46210	26.030	0.038417	-2.5107	-2.4930	0.090123	0.028215	0.061088	685.99	-0.18326	113.89	93.568
95.000	0.54052	25.640	0.039002	-2.3902	-2.3691	0.091408	0.028001	0.061983	663.50	-0.15025	109.95	88.004
97.000	0.62817	25.238	0.039623	-2.2683	-2.2434	0.092682	0.027804	0.063026	640.57	-0.11264	106.02	82.847
99.000	0.72566	24.822	0.040288	-2.1449	-2.1156	0.093946	0.027624	0.064246	617.14	-0.069613	102.08	78.042
101.00	0.83358	24.390	0.041000	-2.0196	-1.9854	0.095204	0.027464	0.065684	593.17	-0.020100	98.144	73.543
103.00	0.95259	23.941	0.041769	-1.8923	-1.8525	0.096459	0.027327	0.067392	568.58	0.037239	94.208	69.306
105.00	1.0833	23.471	0.042605	-1.7625	-1.7163	0.097715	0.027214	0.069443	543.30	0.10414	90.272	65.292
107.00	1.2264	22.978	0.043520	-1.6298	-1.5765	0.098977	0.027133	0.071937	517.24	0.18288	86.337	61.464
109.00	1.3826	22.457	0.044530	-1.4938	-1.4323	0.10025	0.027088	0.075021	490.29	0.27654	82.404	57.786
111.00	1.5526	21.902	0.045658	-1.3537	-1.2828	0.10154	0.027089	0.078914	462.32	0.38936	78.472	54.224
113.00	1.7371	21.306	0.046935	-1.2086	-1.1271	0.10285	0.027149	0.083966	433.19	0.52741	74.544	50.740
115.00	1.9370	20.658	0.048407	-1.0571	-0.96336	0.10420	0.027290	0.090771	402.67	0.69974	70.626	47.290
117.00	2.1533	19.943	0.050144	-0.89741	-0.78944	0.10561	0.027545	0.10044	370.43	0.92076	66.728	43.824

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
119.00	2.3869	19.134	0.052262	-0.72635	-0.60161	0.10710	0.027981	0.11531	335.85	1.2154	62.883	40.270
121.00	2.6391	18.187	0.054985	-0.53833	-0.39322	0.10873	0.028755	0.14140	297.68	1.6317	59.196	36.509
123.00	2.9116	16.997	0.058834	-0.32093	-0.14962	0.11059	0.030317	0.20028	253.32	2.2811	56.121	32.310
125.00	3.2069	15.210	0.065747	-0.031475	0.17937	0.11310	0.034680	0.46831	195.48	3.5308	56.435	26.935
126.19	3.3958	11.184	0.089414	0.51527	0.81891	0.11807			0	6.0831		
63.151	0.012520	0.024070	41.546	1.2945	1.8147	0.16355	0.021007	0.029647	161.11	40.718	5.6209	4.3763
65.000	0.017404	0.032594	30.680	1.3299	1.8639	0.16161	0.021059	0.029788	163.20	38.268	5.8164	4.5123
67.000	0.024300	0.044300	22.573	1.3675	1.9160	0.15966	0.021123	0.029969	165.37	35.907	6.0298	4.6601
69.000	0.033213	0.059031	16.940	1.4042	1.9668	0.15786	0.021196	0.030180	167.43	33.803	6.2457	4.8088
71.000	0.044527	0.077273	12.941	1.4400	2.0162	0.15618	0.021278	0.030427	169.39	31.922	6.4645	4.9585
73.000	0.058656	0.099542	10.046	1.4747	2.0639	0.15461	0.021370	0.030712	171.23	30.231	6.6870	5.1096
75.000	0.076043	0.12638	7.9124	1.5082	2.1099	0.15314	0.021472	0.031039	172.95	28.707	6.9138	5.2621
77.000	0.097152	0.15838	6.3140	1.5404	2.1539	0.15176	0.021585	0.031413	174.55	27.328	7.1458	5.4164
79.000	0.12247	0.19613	5.0986	1.5713	2.1957	0.15046	0.021709	0.031839	176.03	26.074	7.3839	5.5727
81.000	0.15251	0.24030	4.1614	1.6007	2.2353	0.14923	0.021845	0.032323	177.38	24.931	7.6295	5.7313
83.000	0.18780	0.29157	3.4297	1.6284	2.2725	0.14806	0.021994	0.032873	178.60	23.884	7.8837	5.8924
85.000	0.22886	0.35069	2.8515	1.6544	2.3070	0.14694	0.022157	0.033496	179.68	22.923	8.1483	6.0565
87.000	0.27626	0.41846	2.3897	1.6784	2.3386	0.14587	0.022334	0.034204	180.63	22.035	8.4251	6.2238

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
89.000	0.33055	0.49576	2.0171	1.7005	2.3672	0.14485	0.022528	0.035008	181.43	21.212	8.7163	6.3948
91.000	0.39230	0.58355	1.7137	1.7203	2.3925	0.14385	0.022738	0.035925	182.10	20.446	9.0247	6.5700
93.000	0.46210	0.68291	1.4643	1.7377	2.4143	0.14289	0.022967	0.036973	182.62	19.730	9.3533	6.7499
95.000	0.54052	0.79504	1.2578	1.7525	2.4324	0.14195	0.023217	0.038177	182.99	19.057	9.7060	6.9353
97.000	0.62817	0.92134	1.0854	1.7645	2.4463	0.14103	0.023489	0.039568	183.21	18.421	10.087	7.1270
99.000	0.72566	1.0634	0.94038	1.7733	2.4557	0.14012	0.023787	0.041185	183.28	17.815	10.503	7.3260
101.00	0.83358	1.2231	0.81759	1.7788	2.4603	0.13922	0.024113	0.043081	183.18	17.236	10.960	7.5334
103.00	0.95259	1.4027	0.71291	1.7804	2.4595	0.13832	0.024471	0.045326	182.93	16.676	11.467	7.7509
105.00	1.0833	1.6049	0.62309	1.7778	2.4528	0.13742	0.024860	0.048012	182.51	16.132	12.035	7.9804
107.00	1.2264	1.8331	0.54553	1.7703	2.4394	0.13651	0.025284	0.051276	181.93	15.600	12.679	8.2245
109.00	1.3826	2.0916	0.47811	1.7573	2.4183	0.13557	0.025750	0.055332	181.19	15.075	13.419	8.4867
111.00	1.5526	2.3860	0.41911	1.7377	2.3884	0.13461	0.026284	0.060528	180.28	14.546	14.284	8.7716
113.00	1.7371	2.7240	0.36711	1.7102	2.3479	0.13360	0.026924	0.067435	179.15	13.996	15.315	9.0860
115.00	1.9370	3.1162	0.32091	1.6730	2.2946	0.13253	0.027721	0.077010	177.75	13.409	16.580	9.4395
117.00	2.1533	3.5786	0.27944	1.6234	2.2251	0.13138	0.028723	0.091003	176.01	12.767	18.186	9.8474
119.00	2.3869	4.1370	0.24172	1.5572	2.1341	0.13009	0.029997	0.11312	173.87	12.045	20.329	10.336
121.00	2.6391	4.8380	0.20670	1.4665	2.0119	0.12860	0.031683	0.15295	171.17	11.203	23.424	10.953
123.00	2.9116	5.7846	0.17287	1.3343	1.8376	0.12675	0.034185	0.24490	167.43	10.148	28.604	11.813

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
125.00	3.2069	7.3244	0.13653	1.1039	1.5417	0.12400	0.039278	0.66512	160.26	8.6030	41.535	13.326
126.19	3.3958	11.184	0.089414	0.51527	0.81891	0.11807			0	6.0831		
Single-Phase Properties												
100.00	0.10000	0.12268	8.1514	2.0396	2.8547	0.15950	0.021049	0.030012	201.64	16.082	9.3806	6.9581
600.00	0.10000	0.020037	49.908	12.573	17.564	0.21217	0.021796	0.030118	496.27	0.021483	44.840	29.577
1100.0	0.10000	0.010930	91.489	24.284	33.433	0.23131	0.024932	0.033248	660.05	-0.65654	70.075	44.199
1600.0	0.10000	0.0075152	133.06	37.272	50.579	0.24414	0.026815	0.035130	788.94	-0.81543	92.344	56.398
100.00	1.0000	24.658	0.040554	-2.0907	-2.0501	0.094493	0.027546	0.064564	609.42	-0.054514	100.58	76.255
103.75	1.0000	23.768	0.042073	-1.8441	-1.8020	0.096928	0.027281	0.068113	559.22	0.060996	92.738	67.783
103.75	1.0000	1.4754	0.67778	1.7800	2.4577	0.13799	0.024612	0.046272	182.79	16.471	11.671	7.8351
600.00	1.0000	0.19960	5.0099	12.554	17.564	0.19300	0.021812	0.030198	498.66	0.0061465	44.992	29.626
1100.0	1.0000	0.10899	9.1755	24.277	33.452	0.21216	0.024938	0.033267	662.07	-0.65940	70.155	44.221
1600.0	1.0000	0.074993	13.335	37.270	50.605	0.22499	0.026820	0.035138	790.64	-0.81612	92.399	56.411
100.00	5.0000	25.436	0.039314	-2.2176	-2.0210	0.093188	0.027713	0.059868	673.24	-0.17096	108.13	84.510
600.00	5.0000	0.98084	1.0195	12.469	17.567	0.17948	0.021881	0.030539	509.60	-0.057679	45.797	29.882
1100.0	5.0000	0.53797	1.8588	24.247	33.541	0.19875	0.024969	0.033350	671.08	-0.67112	70.555	44.330
1600.0	5.0000	0.37146	2.6921	37.259	50.720	0.21161	0.026839	0.035170	798.18	-0.81886	92.663	56.476
100.00	10.000	26.188	0.038186	-2.3398	-1.9580	0.091882	0.028004	0.056646	734.22	-0.25658	115.90	93.648
600.00	10.000	1.9183	0.52130	12.368	17.581	0.17355	0.021965	0.030926	523.87	-0.12928	46.995	30.284

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
1100.0	10.000	1.0590	0.94433	24.211	33.654	0.19296	0.02506	0.033447	682.37	-0.68394	71.130	44.493
1600.0	10.000	0.73435	1.3618	37.246	50.864	0.20583	0.026863	0.035209	807.57	-0.82170	93.033	56.570
600.00	500.00	27.434	0.036451	10.778	29.003	0.13791	0.026493	0.035336	1574.4	-0.70223	177.40	103.10
1100.0	500.00	21.868	0.045729	23.840	46.705	0.15935	0.027586	0.035848	1501.4	-0.72394	149.37	79.801
1600.0	500.00	18.335	0.054541	37.584	64.855	0.17295	0.028647	0.036665	1506.6	-0.73166	147.47	79.226
600.00	1000.0	34.270	0.029180	11.714	40.894	0.13093	0.029169	0.036905	2107.2	-0.61888	278.97	208.00
1100.0	1000.0	29.362	0.034057	25.065	59.122	0.15303	0.029373	0.036577	1985.1	-0.65271	232.49	129.86
1600.0	1000.0	25.920	0.038580	38.999	77.579	0.16685	0.029977	0.037212	1942.0	-0.65439	214.36	110.35

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson on K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., Lemmon, E. W., Jacobsen, R. T., Wagner, W., and Yokozeki, A., "A Reference Quality Thermodynamic Property Formulation for Nitrogen," *J. Phys. Chem. Ref. Data* **29**(6):1361–1433, 2000. See also *Int. J. Thermophys.* **14**(4):1121–1132, 1998. The source for viscosity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25**:21–69, 2004. The source for thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25**:21–69, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density of the equation of state is 0.02% from the triple point up to temperatures of 523 K and pressures up to 12 MPa and from temperatures of 240 to 523 K at pressures less than 30 MPa. In the range from 270 to 350 K at pressures less than 12 MPa, the uncertainty in density is 0.01%. The uncertainty at very high pressures (>1 GPa) is 0.6% in density. The uncertainty in pressure in the critical region is estimated to be 0.02%. In the gaseous and supercritical region, the speed of sound can be calculated with a typical uncertainty of 0.005% to 0.1%. At liquid states and at high pressures, the uncertainty increases to 0.5% to 1.5%. For pressures up to 30 MPa, the estimated uncertainty for heat capacities ranges from 0.3% at gaseous and gaslike supercritical states up to 0.8% at liquid states and at certain gaseous and supercritical states at low temperatures. The uncertainty is 2% for pressures up to 200 MPa and larger at higher pressures. The estimated uncertainties of vapor pressure, saturated-liquid density, and saturated-vapor density are in general 0.02% for each property. The formulation yields a reasonable extrapolation behavior up to the limits of chemical stability of nitrogen.

For viscosity, the uncertainty is 0.5% in dilute gas. Away from the dilute gas (pressures greater than 1 MPa and in the liquid), the uncertainties are as low as 1% between 270 and 300 K at pressures less than 100 MPa, and increase outside that range. The uncertainties are around 2% at temperatures of 180 K and higher. Below this and away from the critical region, the uncertainties steadily increase to around 5% at the triple points of the fluids. The uncertainties in the critical region are higher.

For thermal conductivity, the uncertainty for the dilute gas is 2% with increasing uncertainties near the triple point. For the nondilute gas, the uncertainty is 2% for temperatures greater than 150 K. The uncertainty is 3% at temperatures less than the critical point and 5% in the critical region, except for states very near the critical point.

Figure 2-7 Pressure-enthalpy diagram for nitrogen. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Span, R., E. W. Lemmon, R. T. Jacobsen, W. Wagner, and A. Yokozeki, "A Reference Equation of State for the Thermodynamic Properties of Nitrogen for Temperatures from 63.151 to 1000 K and Pressures to 2200 MPa," J. Phys. Chem. Ref. Data 29:1361–1433, 2000.

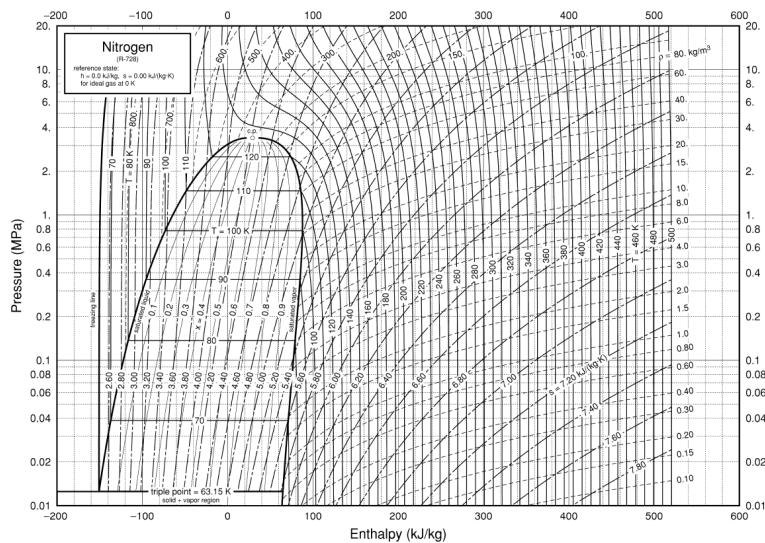


Table 2-122 Thermodynamic Properties of Oxygen

Tempera ture K	Pressu re MPa	Densit y mol/d m ³	Volum e dm ³ /m ol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mo l-K)	C_v kJ/(mo l-K)	C_p kJ/(mo l-K)	Sound speed m/s	Joule- Thoms on K/MPa	Therm. cond. mW/(m ·K)	Viscosi ty μPa·s
Saturated Properties												
54.361	0.0001 4628	40.816	0.0245 00	-6.195 4	-6.195 4	0.0669 46	0.0382 52	0.0535 41	1123.4	-0.379 92	201.92	773.62
55.000	0.0001 7857	40.734	0.0245 49	-6.161 3	-6.161 2	0.0675 71	0.0376 51	0.0534 89	1126.9	-0.378 86	201.02	747.53
60.000	0.0007 2582	40.064	0.0249 60	-5.893 8	-5.893 8	0.0722 25	0.0348 35	0.0535 48	1127.4	-0.370 11	193.94	578.07
65.000	0.0023 349	39.367	0.0254 02	-5.625 8	-5.625 7	0.0765 16	0.0334 69	0.0536 68	1101.7	-0.363 12	186.82	457.94
70.000	0.0062 623	38.656	0.0258 69	-5.357 3	-5.357 2	0.0804 95	0.0325 32	0.0536 97	1066.3	-0.356 86	179.70	371.79
75.000	0.0145 47	37.936	0.0263 60	-5.088 9	-5.088 5	0.0841 99	0.0317 45	0.0537 19	1027.5	-0.349 72	172.58	308.66
80.000	0.0301 23	37.203	0.0268 79	-4.820 2	-4.819 4	0.0876 67	0.0310 30	0.0538 08	987.43	-0.340 56	165.44	261.22

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
85.000	0.056831	36.457	0.027430	-4.5510	-4.5495	0.090931	0.030365	0.054012	946.87	-0.32856	158.27	224.62
90.000	0.099350	35.692	0.028017	-4.2806	-4.2778	0.094023	0.029745	0.054361	905.90	-0.31302	151.05	195.64
95.000	0.16308	34.905	0.028649	-4.0084	-4.0038	0.096967	0.029169	0.054880	864.40	-0.29316	143.81	172.12
100.00	0.25400	34.092	0.029333	-3.7337	-3.7263	0.099787	0.028636	0.055599	822.19	-0.26804	136.55	152.56
105.00	0.37853	33.245	0.030079	-3.4556	-3.4442	0.10250	0.028146	0.056557	779.06	-0.23637	129.25	135.93
110.00	0.54340	32.360	0.030903	-3.1732	-3.1564	0.10513	0.027703	0.057816	734.77	-0.19639	121.92	121.52
115.00	0.75559	31.426	0.031820	-2.8853	-2.8612	0.10770	0.027311	0.059469	689.03	-0.14551	114.57	108.81
120.00	1.0223	30.434	0.032858	-2.5904	-2.5568	0.11022	0.026976	0.061666	641.52	-0.079899	107.23	97.426
125.00	1.3509	29.367	0.034051	-2.2867	-2.2407	0.11271	0.026712	0.064659	591.86	0.0063780	99.912	87.086
130.00	1.7491	28.203	0.035457	-1.9711	-1.9091	0.11520	0.026536	0.068905	539.50	0.12309	92.634	77.571
135.00	2.2250	26.907	0.037165	-1.6394	-1.5567	0.11773	0.026485	0.075327	483.69	0.28750	85.404	68.687
140.00	2.7878	25.415	0.039347	-1.2839	-1.1742	0.12035	0.026634	0.086099	423.10	0.53357	78.217	60.223
145.00	3.4477	23.599	0.042375	-0.88908	-0.74298	0.12319	0.027189	0.10778	355.20	0.93865	71.056	51.869
150.00	4.2186	21.110	0.047372	-0.41330	-0.21346	0.12654	0.028982	0.17484	273.80	1.7389	64.190	42.900
154.58	5.0428	13.630	0.073368	0.66752	1.0375	0.13442			0	5.0628		
54.361	0.00014628	0.00032370	3089.2	1.1195	1.5714	0.20982	0.021241	0.029631	140.32	507.90	4.4204	4.0962
55.000	0.00017857	0.00039060	2560.2	1.1327	1.5898	0.20850	0.021297	0.029698	141.11	480.26	4.4842	4.1481
60.000	0.00072582	0.0014561	686.75	1.2355	1.7339	0.19935	0.021815	0.030320	147.03	284.62	4.9840	4.5528

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
65.000	0.0023349	0.0043291	230.99	1.3377	1.8770	0.19194	0.022310	0.030934	152.65	156.71	5.4863	4.9555
70.000	0.0062623	0.010804	92.556	1.4393	2.0189	0.18587	0.022565	0.031294	158.07	87.254	5.9925	5.3557
75.000	0.014547	0.023509	42.536	1.5397	2.1584	0.18083	0.022513	0.031336	163.33	52.570	6.5051	5.7533
80.000	0.030123	0.045891	21.791	1.6377	2.2941	0.17659	0.022239	0.031177	168.36	35.817	7.0277	6.1486
85.000	0.056831	0.082138	12.175	1.7320	2.4239	0.17297	0.021896	0.031019	173.06	27.728	7.5654	6.5423
90.000	0.099350	0.13710	7.2938	1.8209	2.5455	0.16984	0.021624	0.031053	177.30	23.649	8.1241	6.9355
95.000	0.16308	0.21627	4.6239	1.9031	2.6571	0.16708	0.021515	0.031420	180.99	21.338	8.7113	7.3301
100.00	0.25400	0.32579	3.0695	1.9772	2.7569	0.16462	0.021605	0.032204	184.06	19.753	9.3362	7.7281
105.00	0.37853	0.47267	2.1156	2.0421	2.8430	0.16238	0.021894	0.033461	186.44	18.446	10.010	8.1324
110.00	0.54340	0.66506	1.5036	2.0966	2.9136	0.16032	0.022361	0.035245	188.14	17.250	10.748	8.5467
115.00	0.75559	0.91283	1.0955	2.1391	2.9668	0.15838	0.022978	0.037647	189.13	16.118	11.571	8.9760
120.00	1.0223	1.2284	0.81405	2.1678	3.0000	0.15652	0.023726	0.040839	189.41	15.045	12.509	9.4273
125.00	1.3509	1.6285	0.61407	2.1801	3.0097	0.15471	0.024597	0.045146	188.96	14.029	13.607	9.9112
130.00	1.7491	2.1366	0.46803	2.1722	2.9908	0.15289	0.025604	0.051204	187.75	13.062	14.940	10.445
135.00	2.2250	2.7893	0.35852	2.1380	2.9357	0.15100	0.026794	0.060349	185.74	12.120	16.641	11.061
140.00	2.7878	3.6487	0.27407	2.0670	2.8311	0.14896	0.028269	0.075824	182.82	11.155	18.977	11.823
145.00	3.4477	4.8412	0.20656	1.9383	2.6505	0.14659	0.030276	0.10781	178.78	10.071	22.582	12.881
150.00	4.2186	6.7170	0.14888	1.6938	2.3219	0.14345	0.033574	0.21201	172.82	8.6358	29.666	14.721

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
154.58	5.0428	13.630	0.073368	0.66752	1.0375	0.13442			0	5.0628		
Single-Phase Properties												
100.00	0.10000	0.12316	8.1192	2.0355	2.8474	0.17297	0.020885	0.029925	188.37	18.479	9.0852	7.7121
300.00	0.10000	0.040116	24.928	6.2338	8.7265	0.20531	0.021078	0.029435	329.72	2.6530	26.485	20.652
500.00	0.10000	0.024050	41.579	10.604	14.762	0.22069	0.022781	0.031108	421.27	0.75388	41.046	30.486
700.00	0.10000	0.017177	58.216	15.357	21.179	0.23147	0.024672	0.032992	493.31	0.10517	53.966	38.653
900.00	0.10000	0.013360	74.849	20.438	27.923	0.23994	0.026045	0.034363	555.60	-0.18735	65.867	45.806
100.00	1.0000	34.158	0.029276	-3.7444	-3.7151	0.099680	0.028683	0.055399	826.85	-0.27181	137.23	153.89
119.62	1.0000	30.512	0.032774	-2.6131	-2.5803	0.11003	0.027000	0.061476	645.19	-0.085501	107.79	98.249
119.62	1.0000	1.2018	0.83209	2.1662	2.9983	0.15666	0.023665	0.040564	189.41	15.124	12.433	9.3921
300.00	1.0000	0.40337	2.4791	6.1772	8.6563	0.18598	0.021148	0.029887	329.90	2.6066	26.894	20.846
500.00	1.0000	0.24010	4.1649	10.576	14.741	0.20149	0.022802	0.031240	422.68	0.73726	41.288	30.630
700.00	1.0000	0.17135	5.8360	15.340	21.176	0.21230	0.024682	0.033052	494.87	0.098376	54.139	38.766
900.00	1.0000	0.13328	7.5029	20.426	27.929	0.22078	0.026051	0.034395	557.14	-0.19062	66.001	45.899
100.00	5.0000	34.497	0.028988	-3.7983	-3.6533	0.099132	0.028935	0.054458	850.39	-0.28978	140.71	160.92
154.36	5.0000	16.011	0.062457	0.35374	0.66602	0.13204	0.038878	3.5718	163.89	4.2044	75.954	29.668
154.36	5.0000	11.160	0.089610	1.0294	1.4774	0.13729	0.041906	4.2513	158.85	6.0016	72.313	20.574
300.00	5.0000	2.0616	0.48505	5.9227	8.3480	0.17177	0.021448	0.032003	332.25	2.3730	28.797	21.766
500.00	5.0000	1.1908	0.83975	10.454	14.653	0.18787	0.022894	0.031815	429.36	0.66261	42.362	31.267

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
700.00	5.0000	0.84728	1.1802	15.264	21.165	0.19881	0.024726	0.033309	501.98	0.068114	54.901	39.261
900.00	5.0000	0.65931	1.5167	20.373	27.956	0.20734	0.026076	0.034537	564.07	-0.20519	66.593	46.305
100.00	10.000	34.885	0.028665	-3.8593	-3.5726	0.098498	0.029235	0.053516	877.07	-0.30803	144.82	169.49
300.00	10.000	4.2056	0.23778	5.6024	7.9802	0.16499	0.021790	0.034749	339.35	2.0332	31.466	23.153
500.00	10.000	2.3538	0.42484	10.306	14.554	0.18182	0.022999	0.032491	438.67	0.56900	43.708	32.074
700.00	10.000	1.6705	0.59861	15.171	21.157	0.19292	0.024776	0.033613	511.24	0.030534	55.839	39.873
900.00	10.000	1.3010	0.76866	20.307	27.993	0.20150	0.026104	0.034706	572.92	-0.22339	67.321	46.804
100.00	25.000	35.884	0.027867	-4.0109	-3.3142	0.096845	0.030037	0.051627	945.24	-0.34532	155.97	194.38
300.00	25.000	10.393	0.096215	4.7194	7.1247	0.15490	0.022521	0.040917	390.80	1.0167	41.851	29.605
500.00	25.000	5.6243	0.17780	9.8920	14.337	0.17346	0.023256	0.034167	472.62	0.30658	47.943	34.705
700.00	25.000	3.9923	0.25048	14.907	21.169	0.18495	0.024901	0.034397	541.32	-0.076019	58.651	41.714
900.00	25.000	3.1222	0.32028	20.117	28.124	0.19369	0.026174	0.035155	600.66	-0.27597	69.464	48.271
100.00	75.000	38.263	0.026135	-4.3340	-2.3739	0.092788	0.031906	0.049123	1115.1	-0.39472	184.96	274.96
300.00	75.000	21.603	0.046289	3.1884	6.6601	0.14315	0.023601	0.041272	645.54	-0.18640	75.261	53.378
500.00	75.000	13.760	0.072675	8.8798	14.330	0.16284	0.023725	0.036534	619.75	-0.20732	64.149	45.084
700.00	75.000	10.201	0.098029	14.192	21.544	0.17498	0.025126	0.035903	657.04	-0.31840	68.835	48.269
900.00	75.000	8.1749	0.12233	19.571	28.745	0.18403	0.026293	0.036153	701.72	-0.40609	76.863	53.163

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Schmidt, R., and Wagner, W., "A New Form of the Equation of State for Pure Substances and Its Application to Oxygen," *Fluid Phase Equilibria*, **19**:175–200, 1985. The source for viscosity and thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25**:21–69, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 1% in the speed of sound, except in the critical region. For viscosity, the uncertainty is 1% in the dilute gas at temperatures above 200 K, and 5% in the dilute gas at lower temperatures. The uncertainty is around 2% between 270 and 300 K, and increases to 5% outside of this region. The uncertainty may be higher in the liquid near the triple point. The uncertainty for the dilute gas is 2% with increasing uncertainties near the triple point. For thermal conductivity, the uncertainties range from 3% between 270 and 300 K to 5% elsewhere. The uncertainties above 100 MPa are not known due to a lack of experimental data.

Figure 2-8 Pressure-enthalpy diagram for oxygen. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Schmidt, R., and W. Wagner, "A New Form of the Equation of State for Pure Substances and Its Application to Oxygen," *Fluid Phase Equilibria* **19**: 175–200, 1985.

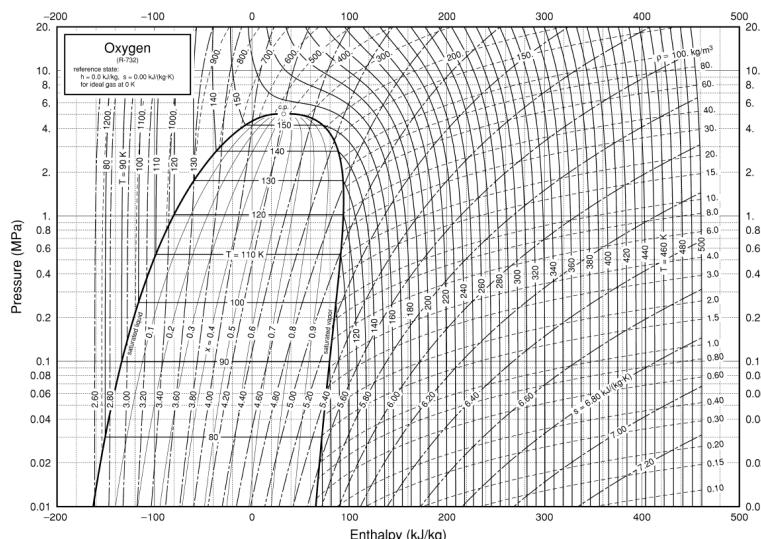


Figure 2-9 Enthalpy-concentration diagram for oxygen-nitrogen mixture at 1 atm. Reference states: Enthalpies of liquid oxygen and liquid nitrogen at the normal boiling point of nitrogen are zero. (Dodge, B.F. *Chemical Engineering Thermodynamics*, McGraw-Hill, New York, 1944.) Wilson, G.M., P.M. Silverberg, and M.G. Zellner, AFAPL TDR 64-64 (AD 603151), 1964, p. 314, present extensive vapor-liquid equilibrium data for the three-component system argon-nitrogen-oxygen as well as for binary systems including oxygen-nitrogen. Calculations for this mixture are also available with the NIST REFPROP software.

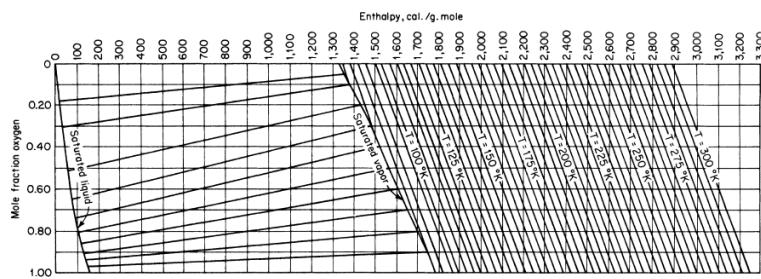
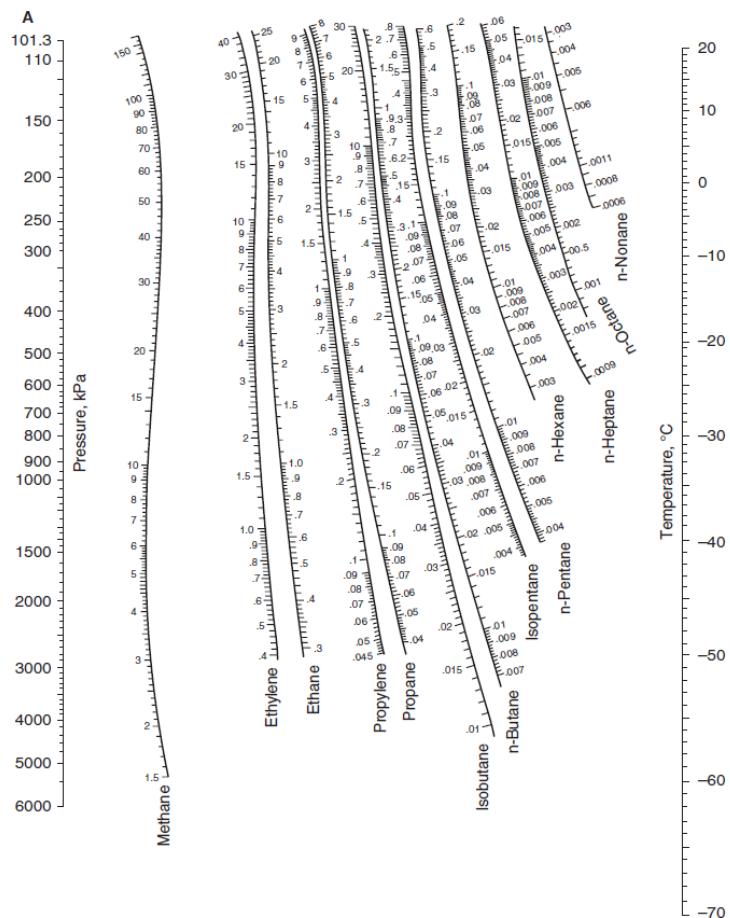


Figure 2-10 K values ($K = y/x$) in light-hydrocarbon systems. (a) Low-temperature range. (b) High-temperature range. [C.L. DePriester, *Chem. Eng. Prog. Symp.*, Ser. 7, **49**: 1 (1953); converted to SI units by D.B. Dadyburjor, *Chem. Eng. Prog.* **74**: 4 (1978).]



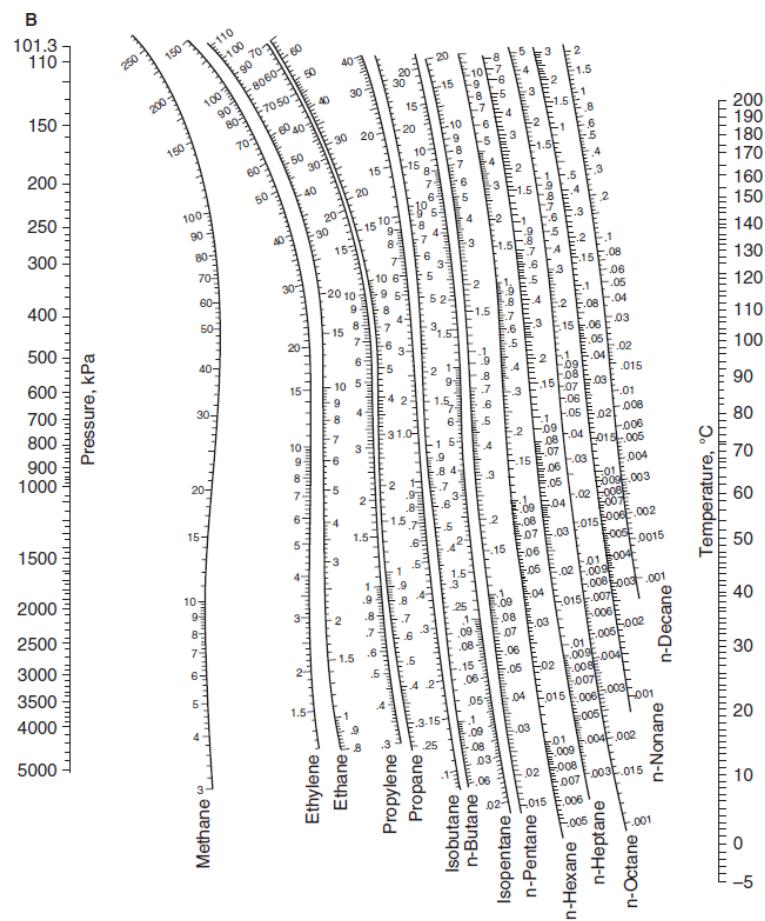


Table 2-123 Composition of Selected Refrigerant Mixtures*, Composition, mass%

Mixed Product Name	Property Table/Figure	R-32	R-125	R-134a	R-143a	Ozone Depletion Potential (ODP) [†]	Global Warming Potential (GWP) [‡] (100 year)
R-32	2-126, Fig. 2-12	100				0	650
R-125	2-127, Fig. 2-13		100			0	3400
R-134a	2-128, Fig. 2-14			100		0	1300
R-143a	2-129				100	0	4300
R-404A	2-130		44	4	52	0	3300
R-407C	2-131, Fig. 2-15	23	25	52		0	1600
R-410A	2-132	50	50			0	2088

*All products listed here are HFCs (hydrofluorocarbons), the primary replacement for hydrochlorofluorocarbons (HCFCs) like R-22.

[†]The ODP of the old CFC refrigerants R-11 and R-12 is 1.

[‡]CO₂ is the GWP reference: GWP of CO₂ = 1.

Table 2-124 Thermodynamic Properties of R-22, Chlorodifluoromethane

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _v kJ/(mol·K)	C _p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
115.73	3.7947E-07	19.907	0.050235	2.5595	2.5595	0.0065813	0.061918	0.092976	1410.9	-0.44463
120.00	9.9588E-07	19.777	0.050564	2.9559	2.9559	0.0099451	0.061567	0.092700	1388.4	-0.44526
135.00	1.7187E-05	19.325	0.051747	4.3400	4.3400	0.020814	0.060123	0.091960	1312.3	-0.44448
150.00	0.00015627	18.873	0.052985	5.7179	5.7179	0.030493	0.059099	0.091824	1239.0	-0.43872
165.00	0.00089946	18.420	0.054289	7.0951	7.0951	0.039243	0.058356	0.091789	1166.5	-0.43084
180.00	0.0037009	17.963	0.055670	8.4715	8.4717	0.047227	0.057679	0.091751	1095.0	-0.42063
195.00	0.011835	17.500	0.057141	9.8483	9.8490	0.054574	0.057097	0.091898	1024.5	-0.40608
210.00	0.031218	17.028	0.058726	11.230	11.232	0.061399	0.056707	0.092431	954.55	-0.38505
225.00	0.070909	16.542	0.060453	12.622	12.627	0.067804	0.056579	0.093482	884.79	-0.35555
240.00	0.14319	16.036	0.062359	14.034	14.043	0.073877	0.056737	0.095120	814.96	-0.31561
255.00	0.26329	15.506	0.064493	15.472	15.489	0.079692	0.057171	0.097391	744.97	-0.26263
270.00	0.44888	14.944	0.066919	16.945	16.975	0.085308	0.057856	0.10037	674.69	-0.19248
285.00	0.71966	14.341	0.069730	18.462	18.513	0.090782	0.058767	0.10424	603.91	-0.097827
300.00	1.0970	13.686	0.073070	20.034	20.114	0.096166	0.059887	0.10941	532.11	0.035333
315.00	1.6039	12.956	0.077181	21.676	21.800	0.10152	0.061218	0.11688	458.37	0.23608
330.00	2.2661	12.114	0.082547	23.418	23.605	0.10696	0.062814	0.12929	381.15	0.57205
345.00	3.1130	11.069	0.090340	25.325	25.606	0.11267	0.064858	0.15550	298.16	1.2334
360.00	4.1837	9.5229	0.10501	27.613	28.053	0.11931	0.068488	0.25950	201.90	3.0745
369.30	4.9900	6.0582	0.16506	30.901	31.725	0.12907			0	10.366
115.73	3.7947E-07	3.9436E-07	2,535,700.	27.807	28.769	0.23305	0.028465	0.036779	119.91	398.80
120.00	9.9588E-07	9.9813E-07	1,001,900.	27.929	28.927	0.22637	0.028872	0.037186	121.91	367.18

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
135.00	1.7187E-05	1.5313E-05	65.305.	28.373	29.495	0.20715	0.030386	0.038703	128.58	269.83
150.00	0.00015627	0.00012533	7.979.0	28.840	30.087	0.19295	0.031990	0.040316	134.79	197.57
165.00	0.00089946	0.00065634	1.523.6	29.329	30.699	0.18230	0.033655	0.042018	140.59	146.30
180.00	0.0037009	0.0024808	403.09	29.836	31.328	0.17421	0.035388	0.043849	145.98	110.28
195.00	0.011835	0.0073561	135.94	30.357	31.966	0.16800	0.037218	0.045881	150.87	84.902
210.00	0.031218	0.018161	55.062	30.885	32.603	0.16317	0.039177	0.048204	155.15	66.865
225.00	0.070909	0.038991	25.647	31.411	33.229	0.15937	0.041300	0.050920	158.70	53.872
240.00	0.14319	0.075182	13.301	31.928	33.833	0.15634	0.043615	0.054144	161.35	44.348
255.00	0.26329	0.13342	7.4950	32.428	34.401	0.15386	0.046138	0.058023	162.96	37.240
270.00	0.44888	0.22208	4.5029	32.900	34.922	0.15178	0.048881	0.062763	163.38	31.852
285.00	0.71966	0.35201	2.8409	33.335	35.380	0.14996	0.051851	0.068713	162.45	27.725
300.00	1.0970	0.53822	1.8580	33.717	35.755	0.14830	0.055064	0.076534	159.98	24.549
315.00	1.6039	0.80363	1.2443	34.021	36.017	0.14666	0.058574	0.087659	155.73	22.102
330.00	2.2661	1.1882	0.84159	34.207	36.114	0.14486	0.062516	0.10579	149.36	20.201
345.00	3.1130	1.7777	0.56253	34.184	35.935	0.14261	0.067254	0.14389	140.39	18.613
360.00	4.1837	2.8529	0.35052	33.661	35.127	0.13896	0.074178	0.29995	127.92	16.641
369.30	4.9900	6.0582	0.16506	30.901	31.725	0.12907			0	10.366

Single-Phase Properties

150.00	0.10000	18.874	0.052982	5.7167	5.7220	0.030484	0.059102	0.091820	1239.3	-0.43876
232.06	0.10000	16.306	0.061325	13.284	13.290	0.070699	0.056618	0.094177	851.94	-0.33819
232.06	0.10000	0.053734	18.610	31.656	33.517	0.15786	0.042364	0.052366	160.06	49.032
250.00	0.10000	0.049441	20.226	32.442	34.465	0.16180	0.043860	0.053391	166.39	38.154
350.00	0.10000	0.034652	28.859	37.325	40.211	0.18105	0.053191	0.061845	196.16	13.439
450.00	0.10000	0.026819	37.287	43.093	46.822	0.19762	0.061672	0.070141	221.08	6.7638

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
550.00	0.10000	0.021901	45.660	49.620	54.186	0.21238	0.068475	0.076877	243.30	4.0604
150.00	1.0000	18.885	0.052952	5.7053	5.7582	0.030408	0.059134	0.091780	1241.8	-0.43921
250.00	1.0000	15.711	0.063648	14.961	15.024	0.077665	0.057020	0.096318	773.25	-0.28642
296.57	1.0000	13.841	0.072248	19.669	19.741	0.094938	0.059612	0.10807	548.68	0.00029448
296.57	1.0000	0.48960	2.0425	33.635	35.677	0.14867	0.054305	0.074523	160.70	25.205
350.00	1.0000	0.37703	2.6523	36.754	39.407	0.16025	0.055369	0.068138	184.85	14.183
450.00	1.0000	0.27693	3.6110	42.774	46.385	0.17776	0.062289	0.072300	216.22	6.8582
550.00	1.0000	0.22209	4.5027	49.400	53.903	0.19283	0.068737	0.077971	241.16	4.0624
150.00	5.0000	18.931	0.052823	5.6555	5.9197	0.030074	0.059277	0.091614	1253.0	-0.44109
250.00	5.0000	15.837	0.063142	14.822	15.138	0.077105	0.057135	0.095206	797.37	-0.30700
350.00	5.0000	11.141	0.089759	25.585	26.034	0.11341	0.064765	0.14356	317.33	1.0314
450.00	5.0000	1.6422	0.60893	41.131	44.175	0.16067	0.065284	0.087278	194.56	7.0507
550.00	5.0000	1.1832	0.84520	48.377	52.603	0.17760	0.069855	0.083655	232.93	3.9600
150.00	10.000	18.987	0.052667	5.5953	6.1220	0.029665	0.059460	0.091420	1266.7	-0.44331
250.00	10.000	15.982	0.062569	14.663	15.289	0.076450	0.057274	0.094054	825.41	-0.32844
350.00	10.000	12.008	0.083275	24.782	25.615	0.11098	0.063647	0.11843	412.24	0.39255
450.00	10.000	4.2433	0.23566	38.423	40.780	0.14893	0.068870	0.12461	184.82	5.5220
550.00	10.000	2.5432	0.39321	47.019	50.951	0.16944	0.071068	0.092204	229.21	3.5059
150.00	30.000	19.198	0.052089	5.3741	6.9367	0.028113	0.060251	0.090769	1318.0	-0.45090
250.00	30.000	16.469	0.060719	14.132	15.953	0.074181	0.057799	0.091018	921.00	-0.38542
350.00	30.000	13.518	0.073976	23.279	25.499	0.10621	0.063170	0.10053	603.47	-0.13764
450.00	30.000	10.241	0.097648	33.086	36.016	0.13259	0.069234	0.10864	392.35	0.40072
550.00	30.000	7.3810	0.13548	42.738	46.802	0.15425	0.073417	0.10533	317.51	0.89994
150.00	60.000	19.480	0.051336	5.0916	8.1717	0.026007	0.061560	0.089983	1384.9	-0.45992
250.00	60.000	17.029	0.058724	13.533	17.056	0.071434	0.058519	0.088686	1034.6	-0.42947

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
350.00	60.000	14.650	0.068258	22.111	26.206	0.10216	0.063912	0.094730	764.59	-0.31532
450.00	60.000	12.381	0.080770	31.083	35.929	0.12657	0.070220	0.099099	589.21	-0.17799
550.00	60.000	10.405	0.096108	40.152	45.919	0.14662	0.075020	0.10030	492.11	-0.055349

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Kamei, A., Beyerlein, S. W., and Jacobsen, R. T., "Application of Nonlinear Regression in the Development of a Wide Range Formulation for HCFC-22," *Int. J. Thermophys.* **16**:1155–1164, 1995. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 1% in heat capacity, and 0.3% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%.

Figure 2-11 Pressure-enthalpy diagram for Refrigerant 22. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Kamei, A., S. W. Beyerlein, and R. T. Jacobsen, "Application of Nonlinear Regression in the Development of a Wide Range Formulation for HCFC-22," *Int. J. Thermophysics* **16**:1155–1164, 1995.

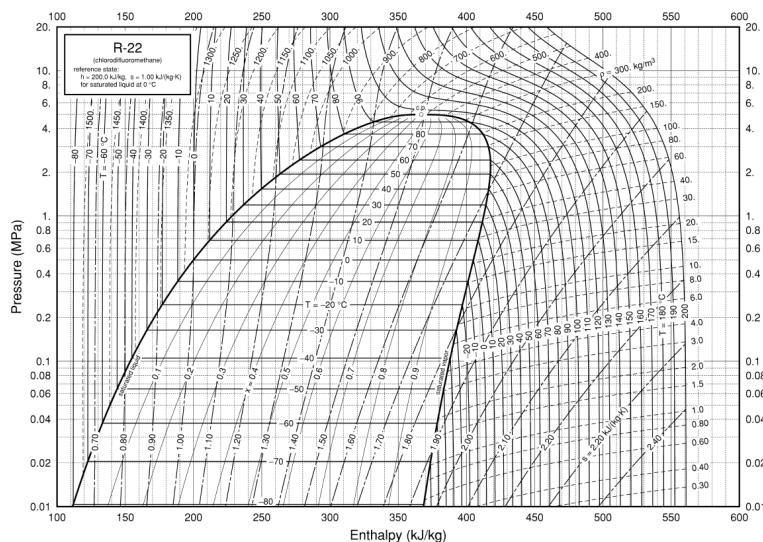


Table 2-125 Thermodynamic Properties of R-32, Difluoromethane

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
Saturated Properties											
136.34	4.8000E-05	27.473	0.036399	-0.99220	-0.99220	-0.0054608	0.055447	0.082847	1414.4	-0.33760	242.91
140.00	8.3535E-05	27.302	0.036627	-0.68946	-0.68946	-0.0032696	0.054980	0.082588	1395.1	-0.33728	241.74
150.00	0.00032474	26.835	0.037265	0.13324	0.13325	0.0024067	0.053793	0.081975	1342.3	-0.33542	237.64
160.00	0.0010410	26.364	0.037930	0.95053	0.95057	0.0076815	0.052740	0.081513	1289.9	-0.33191	232.45
170.00	0.0028536	25.889	0.038626	1.7640	1.7641	0.012613	0.051818	0.081215	1237.6	-0.32650	226.39
180.00	0.0068782	25.409	0.039357	2.5753	2.5756	0.017251	0.051021	0.081087	1185.7	-0.31891	219.64
190.00	0.014904	24.921	0.040127	3.3862	3.3868	0.021635	0.050345	0.081137	1133.8	-0.30886	212.37
200.00	0.029545	24.424	0.040944	4.1983	4.1995	0.025800	0.049783	0.081373	1082.1	-0.29600	204.70
210.00	0.054344	23.916	0.041814	5.0135	5.0158	0.029778	0.049333	0.081803	1030.4	-0.27988	196.75
220.00	0.093819	23.394	0.042745	5.8337	5.8377	0.033594	0.048988	0.082443	978.59	-0.25996	188.62
230.00	0.15345	22.858	0.043749	6.6608	6.6675	0.037271	0.048747	0.083313	926.62	-0.23550	180.39
240.00	0.23965	22.303	0.044838	7.4969	7.5077	0.040830	0.048604	0.084442	874.35	-0.20551	172.14
250.00	0.35967	21.726	0.046028	8.3443	8.3609	0.044291	0.048559	0.085874	821.65	-0.16864	163.92
260.00	0.52157	21.124	0.047340	9.2056	9.2303	0.047671	0.048610	0.087676	768.33	-0.12292	155.78
270.00	0.73415	20.491	0.048802	10.084	10.120	0.050989	0.048761	0.089947	714.18	-0.065518	147.75
280.00	1.0069	19.820	0.050454	10.983	11.034	0.054264	0.049019	0.092852	658.88	0.0079177	139.86
290.00	1.3501	19.102	0.052350	11.908	11.979	0.057517	0.049399	0.096659	602.05	0.10428	132.11

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
300.00	1.7749	18.323	0.054577	12.866	12.963	0.060775	0.049934	0.10185	543.11	0.23517	124.48
310.00	2.2934	17.460	0.057273	13.867	13.998	0.064076	0.050685	0.10938	481.27	0.42163	116.94
320.00	2.9194	16.477	0.060691	14.930	15.107	0.067477	0.051776	0.12140	415.41	0.70602	109.42
330.00	3.6686	15.299	0.065364	16.088	16.328	0.071088	0.053487	0.14404	343.84	1.1876	101.80
340.00	4.5614	13.740	0.072779	17.428	17.760	0.075179	0.056594	0.20457	263.77	2.1660	94.166
350.00	5.6311	10.732	0.093180	19.453	19.977	0.081343	0.066340	1.2085	163.70	5.4955	97.067
351.26	5.7826	8.1501	0.12270	20.836	21.546	0.085769			0	8.0731	
136.34	4.8000E-05	4.2353E-05	23,611.	21.981	23.115	0.17135	0.025987	0.034319	169.60	881.12	6.9492
140.00	8.3535E-05	7.1788E-05	13,930.	22.076	23.239	0.16765	0.026110	0.034451	171.76	769.01	6.9554
150.00	0.00032474	0.00026061	3,837.2	22.335	23.581	0.15872	0.026507	0.034889	177.47	541.12	7.0006
160.00	0.0010410	0.00078411	1,275.3	22.593	23.921	0.15125	0.027014	0.035477	182.88	391.73	7.0875
170.00	0.0028536	0.0020270	493.35	22.850	24.258	0.14493	0.027667	0.036272	187.97	291.02	7.2166
180.00	0.0068782	0.0046295	216.01	23.103	24.589	0.13955	0.028505	0.037336	192.69	221.02	7.3887
190.00	0.014904	0.0095503	104.71	23.350	24.910	0.13492	0.029560	0.038728	197.00	170.81	7.6049
200.00	0.029545	0.018112	55.213	23.588	25.219	0.13090	0.030843	0.040483	200.85	133.79	7.8668
210.00	0.054344	0.032028	31.223	23.816	25.513	0.12738	0.032341	0.042613	204.20	106.00	8.1765
220.00	0.093819	0.053428	18.717	24.032	25.788	0.12428	0.034016	0.045105	206.99	84.924	8.5374
230.00	0.15345	0.084890	11.780	24.234	26.042	0.12151	0.035821	0.047943	209.19	68.870	8.9546

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
240.00	0.23965	0.12949	7.7224	24.421	26.272	0.11901	0.037709	0.051127	210.73	56.605	9.4365
250.00	0.35967	0.19093	5.2375	24.590	26.474	0.11674	0.039648	0.054696	211.57	47.194	9.9965
260.00	0.52157	0.27370	3.6537	24.738	26.643	0.11464	0.041621	0.058741	211.65	39.922	10.656
270.00	0.73415	0.38340	2.6083	24.860	26.775	0.11268	0.043631	0.063434	210.90	34.246	11.449
280.00	1.0069	0.52726	1.8966	24.952	26.862	0.11079	0.045693	0.069063	209.26	29.758	12.431
290.00	1.3501	0.71503	1.3985	25.006	26.894	0.10895	0.047840	0.076110	206.64	26.148	13.691
300.00	1.7749	0.96054	1.0411	25.011	26.858	0.10709	0.050119	0.085424	202.95	23.187	15.376
310.00	2.2934	1.2848	0.77830	24.950	26.735	0.10516	0.052598	0.098649	198.02	20.693	17.748
320.00	2.9194	1.7233	0.58029	24.797	26.491	0.10305	0.055390	0.11948	191.66	18.510	21.309
330.00	3.6686	2.3442	0.42658	24.503	26.068	0.10060	0.058707	0.15836	183.49	16.477	27.173
340.00	4.5614	3.3211	0.30111	23.943	25.316	0.097403	0.063103	0.26199	172.68	14.312	38.601
350.00	5.6311	5.7166	0.17493	22.380	23.365	0.091024	0.071998	1.9028	154.59	10.637	87.141
351.26	5.7826	8.1501	0.12270	20.836	21.546	0.085769			0	8.0731	
Single-Phase Properties											
150.00	0.10000	26.836	0.037263	0.13226	0.13599	0.002402	0.053795	0.081971	1342.7	-0.33547	237.67
221.24	0.10000	23.329	0.042866	5.9359	5.9402	0.034057	0.048953	0.082538	972.15	-0.25719	187.60
221.24	0.10000	0.056727	17.628	24.058	25.821	0.12392	0.034234	0.045439	207.30	82.688	8.5859
225.00	0.10000	0.055592	17.988	24.191	25.989	0.12467	0.033681	0.044513	209.39	76.114	8.7199

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
300.00	0.10000	0.040576	24.645	26.760	29.224	0.13708	0.035327	0.044188	241.95	25.024	12.643
375.00	0.10000	0.032244	31.013	29.631	32.733	0.14749	0.041082	0.049630	267.64	12.117	18.907
150.00	1.00000	26.851	0.037243	0.12350	0.16075	0.0023417	0.053807	0.081935	1345.7	-0.33584	237.89
225.00	1.00000	23.159	0.043179	6.2265	6.2697	0.035360	0.048867	0.082690	957.47	-0.25084	185.10
279.77	1.00000	19.836	0.050414	10.962	11.013	0.054190	0.049012	0.092777	660.15	0.0060372	140.04
279.77	1.00000	0.52357	1.9100	24.951	26.861	0.11084	0.045646	0.068922	209.31	29.848	12.406
300.00	1.00000	0.46100	2.1692	25.950	28.120	0.11518	0.041298	0.057916	223.83	23.889	13.334
375.00	1.00000	0.33917	2.9484	29.227	32.175	0.12727	0.042549	0.053538	259.50	11.929	19.059
150.00	5.00000	26.915	0.037154	0.085198	0.27097	0.0020846	0.053863	0.081784	1358.9	-0.33741	238.83
225.00	5.00000	23.298	0.042923	6.1394	6.3541	0.034970	0.048922	0.082027	978.81	-0.26135	187.71
300.00	5.00000	18.710	0.053448	12.637	12.905	0.060001	0.049679	0.096911	586.17	0.13431	128.72
344.33	5.00000	12.808	0.078078	18.130	18.520	0.077304	0.059015	0.28240	224.84	2.9944	91.412
344.33	5.00000	3.9887	0.25071	23.524	24.777	0.095475	0.065786	0.39574	166.61	13.148	48.235
375.00	5.00000	2.3228	0.43051	26.928	29.080	0.10755	0.050835	0.090625	218.44	10.800	26.239
150.00	10.000	26.993	0.037047	0.038702	0.40917	0.0017692	0.053932	0.081608	1375.0	-0.33924	239.97
225.00	10.000	23.461	0.042625	6.0369	6.4632	0.034504	0.048996	0.081303	1004.1	-0.27287	190.81
300.00	10.000	19.196	0.052094	12.346	12.867	0.058997	0.049538	0.092105	639.69	0.031716	134.49

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
375.00	10.000	10.448	0.095714	21.112	22.069	0.085980	0.057265	0.21222	231.14	3.5190	77.284
150.00	30.000	27.285	0.036650	-0.13357	0.96593	0.00056834	0.054209	0.081027	1436.1	-0.34524	244.02
225.00	30.000	24.030	0.041614	5.6813	6.9297	0.032836	0.049307	0.079197	1094.1	-0.30661	201.89
300.00	30.000	20.517	0.048739	11.542	13.004	0.056105	0.049670	0.083697	789.57	-0.15824	152.78
375.00	30.000	16.472	0.060708	17.786	19.607	0.075712	0.052941	0.093069	536.98	0.21392	112.94
225.00	70.000	24.916	0.040135	5.1400	7.9495	0.030109	0.049916	0.076915	1240.7	-0.34341	219.54
300.00	70.000	22.090	0.045270	10.583	13.752	0.052355	0.050281	0.078370	986.17	-0.28333	179.29
375.00	70.000	19.309	0.051788	16.127	19.752	0.070195	0.053544	0.081767	788.81	-0.18583	147.00

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., and Yokozeki, A., "An International Standard Equation of State for Difluoromethane (R-32) for Temperatures from the Triple Point at 136.34 K to 435 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* **26**(6):1273–1328, 1997. Validated equations for the viscosity are not currently available for this fluid. The source for thermal conductivity is unpublished; however, the fit uses the functional form found in Marsh, K., Perkins, R., and Ramires, M. L. V., "Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **47**(4):932–940, 2002.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

For the equation of state, typical uncertainties are 0.05% for density, 0.02% for the vapor pressure, and 0.5% to 1% for the heat capacity and speed of sound in the liquid phase. In the vapor phase, the uncertainty in the speed of sound is 0.02%. For thermal conductivity, the estimated uncertainty of the correlation is 5%, except for the dilute gas and points approaching critical where the uncertainty rises to 10%.

Figure 2-12 Pressure-enthalpy diagram for Refrigerant 32. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Tillner-Roth, R., and A. Yokozeki, "An International Standard Equation of State for Difluoromethane (R-32) for Temperatures from the Triple Point at 136.34 K to 435 K and Pressures up to 70 MPa," J. Phys. Chem. Ref. Data 26(6): 1273–1328, 1997.

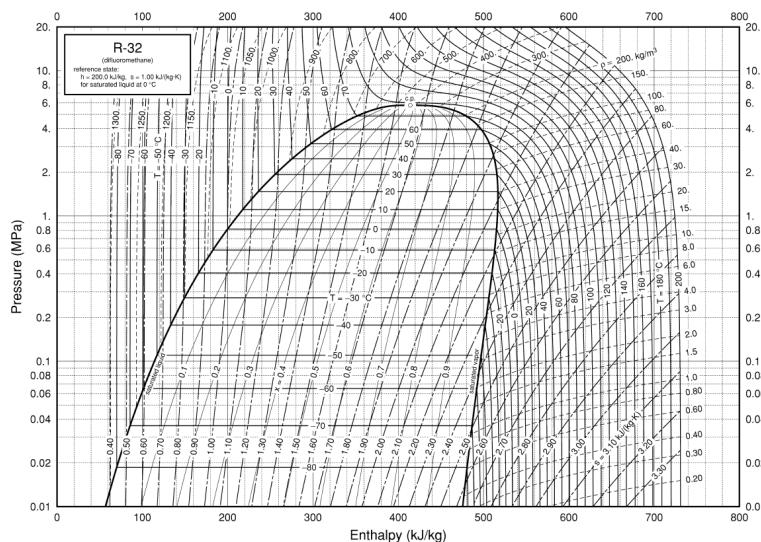


Table 2-126 Thermodynamic Properties of R-125, Pentafluoroethane

Temperature K	Pressure MPa	Density mol/dm ³ /mol	Volum e dm ³ /mol	Int. energy kJ/mol	Enthal py kJ/mol	Entrop y kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thoms on K/MPa	Therm. cond. mW/(m·K)	Viscosi ty μPa·s
Saturated Properties												
172.52	0.0029140	14.086	0.070990	10.457	10.457	0.058837	0.081329	0.12417	932.57	-0.38374	116.02	1152.4
180.00	0.0056285	13.885	0.072020	11.389	11.389	0.064124	0.082012	0.12500	893.63	-0.37406	112.52	957.54
190.00	0.012328	13.613	0.073461	12.646	12.647	0.070919	0.083102	0.12647	843.11	-0.35818	107.79	768.40
200.00	0.024602	13.336	0.074988	13.919	13.921	0.077448	0.084327	0.12825	793.91	-0.33901	103.06	631.00
210.00	0.045417	13.052	0.076615	15.210	15.214	0.083750	0.085644	0.13028	745.67	-0.31627	98.331	527.00
220.00	0.078505	12.762	0.078360	16.523	16.529	0.089856	0.087029	0.13254	698.07	-0.28935	93.653	445.76
230.00	0.12833	12.461	0.080247	17.858	17.869	0.095792	0.088472	0.13505	650.89	-0.25723	89.019	380.67
240.00	0.20004	12.150	0.082305	19.219	19.235	0.10158	0.089971	0.13785	603.92	-0.21839	84.443	327.41

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
250.00	0.29934	11.824	0.084572	20.607	20.632	0.10725	0.091529	0.14102	556.99	-0.17062	79.940	283.01
260.00	0.43250	11.481	0.087098	22.025	22.063	0.11282	0.093153	0.14468	510.02	-0.11056	75.520	245.39
270.00	0.60624	11.117	0.089954	23.478	23.532	0.11830	0.094843	0.14903	462.91	-0.032921	71.187	213.02
280.00	0.82782	10.724	0.093245	24.971	25.048	0.12374	0.096594	0.15440	415.46	0.070972	66.940	184.73
290.00	1.1050	10.295	0.097130	26.511	26.619	0.12916	0.098430	0.16135	367.36	0.21606	62.772	159.60
300.00	1.4463	9.8162	0.10187	28.112	28.259	0.13461	0.10043	0.17099	318.17	0.43036	58.667	136.86
310.00	1.8610	9.2637	0.10795	29.793	29.994	0.14015	0.10274	0.18593	267.31	0.77370	54.597	115.81
320.00	2.3600	8.5923	0.11638	31.595	31.869	0.14593	0.10571	0.21395	213.55	1.4029	50.534	95.602
330.00	2.9579	7.6744	0.13030	33.632	34.017	0.15231	0.11043	0.29625	153.34	2.9184	46.661	74.602
339.17	3.6179	4.7790	0.20925	37.417	38.174	0.16438			0	12.361		
172.52	0.0029140	0.0020381	490.65	31.863	33.293	0.19120	0.059815	0.068285	116.43	90.257	5.2349	7.4339
180.00	0.0056285	0.0037809	264.49	32.307	33.795	0.18860	0.061648	0.070217	118.54	77.516	5.7185	7.7624
190.00	0.012328	0.0078784	126.93	32.913	34.477	0.18582	0.064126	0.072893	121.15	64.018	6.3724	8.1999
200.00	0.024602	0.015031	66.529	33.530	35.167	0.18368	0.066646	0.075712	123.47	53.589	7.0353	8.6344
210.00	0.045417	0.026661	37.508	34.157	35.860	0.18207	0.069223	0.078713	125.44	45.456	7.7081	9.0657
220.00	0.078505	0.044514	22.465	34.788	36.552	0.18087	0.071864	0.081939	127.01	39.066	8.3929	9.4944
230.00	0.12833	0.070679	14.148	35.421	37.237	0.18000	0.074575	0.085437	128.11	34.014	9.0929	9.9221
240.00	0.20004	0.10763	9.2907	36.052	37.911	0.17940	0.077362	0.089271	128.68	29.998	9.8136	10.353

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
250.00	0.29934	0.15835	6.3153	36.678	38.568	0.17900	0.080230	0.093526	128.64	26.787	10.563	10.791
260.00	0.43250	0.22645	4.4159	37.292	39.202	0.17874	0.083141	0.098283	127.93	24.232	11.356	11.246
270.00	0.60624	0.31661	3.1585	37.890	39.805	0.17857	0.086003	0.10368	126.44	22.293	12.213	11.732
280.00	0.82782	0.43510	2.2983	38.460	40.363	0.17844	0.088869	0.11025	124.10	20.938	13.169	12.266
290.00	1.1050	0.59084	1.6925	38.988	40.858	0.17826	0.092050	0.11918	120.81	20.043	14.286	12.884
300.00	1.4463	0.79742	1.2540	39.453	41.267	0.17797	0.095933	0.13255	116.42	19.438	15.680	13.638
310.00	1.8610	1.0777	0.92787	39.828	41.554	0.17744	0.10077	0.15449	110.71	19.016	17.586	14.635
320.00	2.3600	1.4778	0.67670	40.054	41.651	0.17649	0.10679	0.19725	103.29	18.738	20.574	16.104
330.00	2.9579	2.1269	0.47016	39.964	41.355	0.17454	0.11481	0.32843	93.550	18.404	26.607	18.766
339.17	3.6179	4.7790	0.20925	37.417	38.174	0.16438			0	12.361		
Single-Phase Properties												
200.00	0.10000	13.337	0.074979	13.916	13.924	0.077436	0.084327	0.12823	794.34	-0.33920	103.09	631.60
224.79	0.10000	12.619	0.079245	17.160	17.168	0.092721	0.087714	0.13371	675.42	-0.27468	91.425	412.85
224.79	0.10000	0.055877	17.897	35.092	36.881	0.18042	0.073155	0.083578	127.60	36.498	8.7263	9.6994
300.00	0.10000	0.040689	24.576	41.155	43.613	0.20616	0.086960	0.095910	149.16	13.603	14.156	13.041
400.00	0.10000	0.030228	33.082	50.746	54.054	0.23608	0.10398	0.11252	172.25	5.6807	22.115	17.070
500.00	0.10000	0.024108	41.479	61.864	66.012	0.26271	0.11764	0.12607	192.24	3.1093	30.917	20.691
200.00	1.0000	13.355	0.074878	13.888	13.963	0.077295	0.084329	0.12805	799.42	-0.34145	103.50	638.78
286.46	1.0000	10.452	0.095673	25.960	26.055	0.12724	0.097767	0.15865	384.49	0.15862	64.240	168.19

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
286.46	1.0000	0.53072	1.8842	38.807	40.691	0.17833	0.090862	0.11564	122.09	20.318	13.866	12.653
300.00	1.0000	0.48261	2.0720	40.159	42.231	0.18359	0.092286	0.11224	129.90	16.539	14.732	13.270
400.00	1.0000	0.31780	3.1466	50.310	53.456	0.21585	0.10520	0.11626	165.47	5.9354	22.513	17.404
500.00	1.0000	0.24593	4.0661	61.591	65.657	0.24302	0.11806	0.12764	189.33	3.1109	31.336	21.014
200.00	5.0000	13.432	0.074450	13.768	14.140	0.076686	0.084364	0.12732	820.94	-0.35061	105.29	671.00
300.00	5.0000	10.214	0.097901	27.606	28.095	0.13288	0.099404	0.15790	379.39	0.16755	62.727	155.81
400.00	5.0000	2.1222	0.47120	47.739	50.095	0.19593	0.11164	0.15240	136.55	6.6581	27.340	22.244
500.00	5.0000	1.3333	0.75004	60.288	64.038	0.22710	0.12001	0.13643	180.53	2.9952	33.551	23.530
200.00	10.000	13.522	0.073953	13.626	14.366	0.075959	0.084459	0.12655	845.71	-0.36040	107.42	712.07
300.00	10.000	10.597	0.094369	27.096	28.039	0.13109	0.098728	0.14971	441.85	-0.0032571	67.164	177.37
400.00	10.000	5.5436	0.18039	43.724	45.528	0.18103	0.11417	0.19389	165.42	2.8474	40.583	46.568
500.00	10.000	2.8438	0.35165	58.555	62.072	0.21813	0.12198	0.14925	183.47	2.4316	37.529	29.745
200.00	30.000	13.835	0.072281	13.138	15.306	0.073355	0.085197	0.12439	927.73	-0.38765	115.19	889.29
300.00	30.000	11.489	0.087039	25.838	28.449	0.12645	0.098551	0.13883	597.35	-0.23171	79.855	245.90
400.00	30.000	9.0272	0.11078	39.705	43.028	0.16830	0.11217	0.15193	391.05	0.060756	59.824	112.78
500.00	30.000	6.8239	0.14654	54.141	58.538	0.20288	0.12339	0.15662	307.14	0.34144	53.649	67.694
300.00	60.000	12.259	0.081575	24.732	29.626	0.12196	0.10001	0.13426	735.32	-0.32748	93.938	338.04
400.00	60.000	10.465	0.095559	37.854	43.587	0.16206	0.11339	0.14453	563.68	-0.23451	75.022	173.26

Temperature K	Pressure MPa	Density mol/dm ³	Volumne dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
500.00	60.000	8.9121	0.11221	51.703	58.436	0.19516	0.12470	0.15193	471.23	-0.15582	67.810	113.08

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Jacobsen, R. T., "A New Functional Form and New Fitting Techniques for Equations of State with Application to Pentafluoroethane (HFC-125)," *J. Phys. Chem. Ref. Data* 34(1):69–108, 2005. The source for viscosity is Huber, M. L., and Laesecke, A., "Correlation for the Viscosity of Pentafluoroethane (R125) from the Triple Point to 500 K at Pressures up to 60 MPa," *Ind. Eng. Chem. Res.*, 45(12):4447–4453, 2006. The source for thermal conductivity is Perkins, R., and Huber, M. L., "Measurement and Correlation of the Thermal Conductivity of Pentafluoroethane (R125) from 190 K to 512 K at Pressures to 70 MPa," *J. Chem. Eng. Data* 51(3):898–904, 2006.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density is 0.1% at temperatures from the triple point to 400 K at pressures up to 60 MPa, except in the critical region, where an uncertainty of 0.2% in pressure is generally attained. In the limited region between 340 and 400 K and at pressures from 4 to 10 MPa, as well as for all states above 400 K, the uncertainty in density increases to 0.5%. At temperatures below 330 K and pressures below 30 MPa, the uncertainty in density in the liquid phase may be as low as 0.04%. In the vapor and supercritical region, speed of sound data are represented within 0.05% at pressures below 1 MPa. The estimated uncertainty for heat capacities is 0.5%, and the estimated uncertainty for the speed of sound in the liquid phase is 0.5% for $T > 250$ K. The estimated uncertainties of vapor pressures and saturated liquid densities calculated using the Maxwell criterion are 0.1% for each property, and the estimated uncertainty for saturated vapor densities is 0.2%. The uncertainty in density increases as the critical point is approached, while the accompanying uncertainty in calculated pressures is 0.2%. The viscosity correlation has an estimated uncertainty of 3.0% along the saturation boundary in the liquid phase, and 0.8% in the vapor. For thermal conductivity, the estimated uncertainty of the correlation is 3%, except for the dilute gas and points approaching critical, where the uncertainty rises to 5%.

Figure 2-13 Pressure-enthalpy diagram for Refrigerant 125.

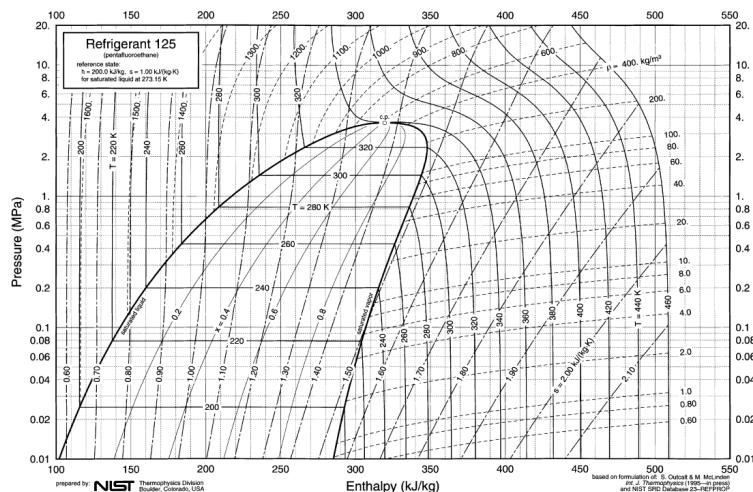


Table 2-127 Thermodynamic Properties of R-134a, 1,1,1,2-Tetrafluoroethane

Temperature K	Pressure MPa	Density mol/dm ³ /mol	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
Saturated Properties												
169.85	0.00038956	15.594	0.064126	7.2907	7.2907	0.042100	0.080831	0.12079	1120.0	-0.38145	145.24	2153.6
170.00	0.00039617	15.590	0.064142	7.3088	7.3088	0.042207	0.080824	0.12079	1119.2	-0.38136	145.15	2139.7
180.00	0.0011275	15.331	0.065228	8.5179	8.5179	0.049117	0.080732	0.12112	1068.3	-0.37370	139.12	1479.1
190.00	0.0028170	15.069	0.066362	9.7328	9.7330	0.055686	0.081114	0.12193	1017.7	-0.36352	133.32	1106.2
200.00	0.0063130	14.804	0.067550	10.957	10.958	0.061966	0.081784	0.12303	967.61	-0.35119	127.74	867.31
210.00	0.012910	14.535	0.068798	12.194	12.195	0.067999	0.082633	0.12434	918.33	-0.33678	122.36	702.27
220.00	0.024433	14.262	0.070116	13.444	13.446	0.073815	0.083595	0.12582	869.85	-0.32011	117.17	582.15
230.00	0.043287	13.984	0.071512	14.710	14.713	0.079441	0.084636	0.12746	822.11	-0.30082	112.14	491.22
240.00	0.072481	13.699	0.072999	15.992	15.997	0.084899	0.085734	0.12927	775.00	-0.27839	107.27	420.20
250.00	0.11561	13.406	0.074593	17.293	17.301	0.090209	0.086879	0.13126	728.39	-0.25204	102.53	363.25
260.00	0.17684	13.104	0.076311	18.613	18.627	0.095389	0.088067	0.13348	682.14	-0.22073	97.922	316.57
270.00	0.26082	12.791	0.078179	19.956	19.976	0.10046	0.089298	0.13597	636.12	-0.18299	93.414	277.54
280.00	0.37271	12.465	0.080227	21.322	21.352	0.10543	0.090576	0.13883	590.17	-0.13675	88.995	244.34
290.00	0.51805	12.121	0.082499	22.716	22.759	0.11032	0.091908	0.14216	544.15	-0.079015	84.644	215.64
300.00	0.70282	11.758	0.085050	24.141	24.201	0.11516	0.093303	0.14615	497.89	-0.0052732	80.341	190.46
310.00	0.93340	11.368	0.087965	25.603	25.685	0.11996	0.094777	0.15108	451.23	0.091533	76.063	168.04
320.00	1.2166	10.945	0.091364	27.108	27.219	0.12475	0.096352	0.15740	404.00	0.22306	71.781	147.78
330.00	1.5599	10.478	0.095439	28.667	28.816	0.12956	0.098067	0.16598	355.90	0.41006	67.464	129.20

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
340.00	1.9715	9.9483	0.10052	30.297	30.495	0.13446	0.10001	0.17863	306.37	0.69376	63.075	111.81
350.00	2.4611	9.3237	0.10725	32.029	32.293	0.13952	0.10241	0.20012	254.06	1.1714	58.581	95.095
360.00	3.0405	8.5279	0.11726	33.932	34.289	0.14496	0.10601	0.24863	196.05	2.1419	54.062	78.146
370.00	3.7278	7.2558	0.13782	36.283	36.797	0.15159	0.11372	0.52085	127.23	5.1434	51.767	57.956
374.21	4.0591	5.0171	0.19932	38.947	39.756	0.15938			0	11.931		
169.85	0.00038956	0.00027611	3621.7	32.764	34.175	0.20038	0.051318	0.059719	126.79	373.57	3.0801	6.8294
170.00	0.00039617	0.00028055	3564.4	32.772	34.184	0.20029	0.051354	0.059756	126.84	370.78	3.0921	6.8353
180.00	0.0011275	0.00075481	1324.8	33.287	34.781	0.19502	0.053742	0.062208	130.05	234.43	3.8934	7.2319
190.00	0.0028170	0.0017896	558.79	33.821	35.395	0.19075	0.056118	0.064682	133.11	160.10	4.6952	7.6253
200.00	0.0063130	0.0038201	261.77	34.371	36.023	0.18729	0.058489	0.067201	135.98	116.94	5.4978	8.0147
210.00	0.012910	0.0074704	133.86	34.934	36.662	0.18451	0.060874	0.069802	138.63	90.215	6.3018	8.3993
220.00	0.024433	0.013574	73.669	35.508	37.308	0.18228	0.063296	0.072534	141.01	72.584	7.1080	8.7786
230.00	0.043287	0.023188	43.125	36.090	37.956	0.18050	0.065783	0.075455	143.06	60.236	7.9176	9.1524
240.00	0.072481	0.037603	26.593	36.675	38.602	0.17909	0.068357	0.078618	144.73	51.130	8.7324	9.5209
250.00	0.11561	0.058360	17.135	37.261	39.242	0.17797	0.071031	0.082078	145.98	44.137	9.5551	9.8853
260.00	0.17684	0.087278	11.458	37.844	39.870	0.17709	0.073812	0.085888	146.75	38.613	10.389	10.247
270.00	0.26082	0.12651	7.9043	38.420	40.482	0.17640	0.076698	0.090115	146.99	34.169	11.241	10.611
280.00	0.37271	0.17865	5.5976	38.986	41.073	0.17586	0.079686	0.094850	146.63	30.561	12.118	10.980

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
290.00	0.51805	0.24685	4.0511	39.538	41.636	0.17542	0.082776	0.10023	145.61	27.621	13.035	11.363
300.00	0.70282	0.33512	2.9840	40.069	42.166	0.17504	0.085974	0.10650	143.88	25.230	14.011	11.771
310.00	0.93340	0.44874	2.2285	40.573	42.653	0.17469	0.089297	0.11404	141.33	23.301	15.081	12.219
320.00	1.2166	0.59505	1.6805	41.038	43.083	0.17432	0.092780	0.12355	137.86	21.768	16.303	12.735
330.00	1.5599	0.78498	1.2739	41.451	43.438	0.17387	0.096484	0.13638	133.33	20.578	17.780	13.358
340.00	1.9715	1.0363	0.96498	41.785	43.687	0.17326	0.10052	0.15548	127.57	19.687	19.711	14.164
350.00	2.4611	1.3818	0.72368	41.994	43.775	0.17232	0.10510	0.18870	120.33	19.033	22.525	15.300
360.00	3.0405	1.8973	0.52707	41.973	43.576	0.17075	0.11074	0.26594	111.25	18.448	27.365	17.140
370.00	3.7278	2.8805	0.34717	41.323	42.617	0.16731	0.11928	0.70016	99.370	17.050	40.137	21.336
374.21	4.0591	5.0171	0.19932	38.947	39.756	0.15938			0	11.931		

Single-Phase Properties

200.00	0.10000	14.805	0.067543	10.955	10.962	0.061955	0.081787	0.12301	968.03	-0.35132	127.78	868.18
246.79	0.10000	13.501	0.074068	16.873	16.880	0.088519	0.086506	0.13060	743.31	-0.26099	104.04	380.27
246.79	0.10000	0.050898	19.647	37.073	39.037	0.17830	0.070161	0.080931	145.63	46.198	9.2899	9.7687
275.00	0.10000	0.044972	22.236	39.124	41.348	0.18716	0.073781	0.083445	154.76	29.047	11.540	10.906
350.00	0.10000	0.034753	28.775	45.154	48.032	0.20860	0.086248	0.095065	175.31	12.552	17.537	13.823
425.00	0.10000	0.028455	35.143	52.096	55.610	0.22818	0.098386	0.10695	192.97	6.7852	23.539	16.650
200.00	1.0000	14.819	0.067479	10.933	11.001	0.061846	0.081812	0.12291	972.08	-0.35256	128.11	876.60

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
275.00	1.0000	12.657	0.07909	20.597	20.676	0.10281	0.089915	0.13695	619.10	-0.16746	91.627	262.84
312.54	1.0000	11.264	0.088775	25.980	26.069	0.12117	0.095165	0.15252	439.31	0.12101	74.978	162.71
312.54	1.0000	0.48242	2.0729	40.695	42.768	0.17460	0.090164	0.11623	140.54	22.877	15.374	12.343
350.00	1.0000	0.39132	2.5555	44.290	46.846	0.18694	0.090315	0.10603	159.63	13.885	17.989	13.936
425.00	1.0000	0.29983	3.3352	51.597	54.933	0.20785	0.099891	0.11116	185.14	7.0297	23.806	16.917
200.00	5.0000	14.880	0.067202	10.839	11.175	0.061371	0.081929	0.12246	989.55	-0.35768	129.56	915.11
275.00	5.0000	12.804	0.078103	20.385	20.776	0.10203	0.089864	0.13495	651.41	-0.19924	94.015	277.35
350.00	5.0000	9.8674	0.10134	31.397	31.904	0.13765	0.10066	0.17178	320.01	0.59952	63.012	109.32
425.00	5.0000	2.0736	0.48225	48.647	51.058	0.18734	0.10791	0.15381	148.25	7.9048	28.574	20.974
200.00	10.000	14.954	0.066874	10.727	11.395	0.060796	0.082085	0.12196	1010.3	-0.36339	131.31	966.05
275.00	10.000	12.967	0.077121	20.149	20.920	0.10115	0.089868	0.13304	687.36	-0.22964	96.744	295.02
350.00	10.000	10.478	0.095440	30.642	31.597	0.13537	0.099573	0.15486	400.60	0.21924	68.919	128.79
425.00	10.000	6.1370	0.16295	43.563	45.193	0.17038	0.11141	0.20870	177.89	3.0434	44.888	46.711
200.00	30.000	15.216	0.065720	10.326	12.298	0.058683	0.082769	0.12047	1084.1	-0.38053	137.79	1211.0
275.00	30.000	13.479	0.074190	19.398	21.624	0.098210	0.090220	0.12865	801.47	-0.30014	105.87	364.87
350.00	30.000	11.662	0.085750	29.071	31.644	0.13038	0.098885	0.13885	582.52	-0.15240	82.955	183.26
425.00	30.000	9.7202	0.10288	39.385	42.471	0.15838	0.10808	0.14967	425.63	0.10364	67.154	107.03
275.00	70.000	14.181	0.070517	18.373	23.310	0.093839	0.091314	0.12519	962.41	-0.35619	119.84	521.91

Temperature K	Pressure MPa	Density mol/dm ³	Volumne dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
350.00	70.000	12.797	0.078141	27.492	32.961	0.12484	0.099542	0.13226	787.10	-0.30093	99.868	277.09
425.00	70.000	11.494	0.087004	37.066	43.157	0.15121	0.10829	0.13963	661.39	-0.23655	86.640	181.77

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., and Baehr, H. D., "An International Standard Formulation of the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for Temperatures from 170 K to 455 K at Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* 23:657–729, 1994. The source for viscosity is Huber, M. L., Laesecke, A., and Perkins, R. A., "Model for the Viscosity and Thermal Conductivity of Refrigerants, Including a New Correlation for the Viscosity of R134a," *Ind. Eng. Chem. Res.* 42:3163–3178, 2003. The source for thermal conductivity is Perkins, R. A., Laesecke, A., Howley, J., Ramires, M. L. V., Gurova, A. N., and Cusco, L., "Experimental Thermal Conductivity Values for the IUPAC Round-Robin Sample of 1,1,1,2-Tetrafluoroethane (R134a)," NISTIR, 2000.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

Typical uncertainties are 0.05% for density, 0.02% for vapor pressure, 0.5% to 1% for heat capacity, 0.05% for vapor speed of sound, and 1% for liquid speed of sound, except in the critical region. The uncertainty in viscosity is 1.5% along the saturated-liquid line, 3% in the liquid phase, 0.5% in the dilute gas, 3% to 5% in the vapor phase, and 5% in the supercritical region, rising to 8% at pressures above 40 MPa. Below 200 K, the uncertainty is 8%. The uncertainty in thermal conductivity is 5%.

Figure 2-14 Pressure-enthalpy diagram for Refrigerant 134a. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Tillner-Roth, R., and H. D. Baehr, "An International Standard Formulation of the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) Covering Temperatures from 170 K to 455 K at Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* 23(5): 657–729, 1994.

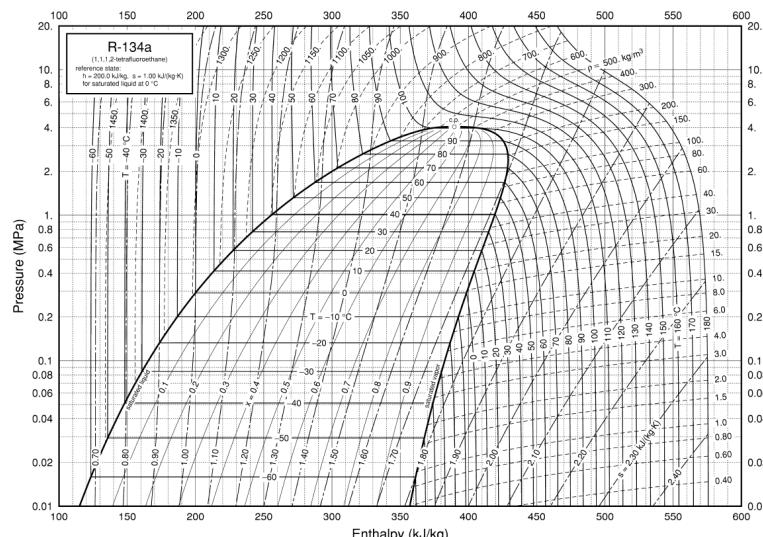


Table 2-128 Thermodynamic Properties of R-143a, 1,1,1-Trifluoroethane

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _v kJ/(mol·K)	C _p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
161.34	0.0010749	15.832	0.063163	4.4138	4.4138	0.026403	0.068393	0.10179	1058.1	-0.43936
170.00	0.0025084	15.583	0.064174	5.2969	5.2971	0.031735	0.068179	0.10225	1016.7	-0.42914
180.00	0.0059324	15.291	0.065399	6.3240	6.3244	0.037606	0.068405	0.10325	969.14	-0.41402
190.00	0.012629	14.994	0.066693	7.3629	7.3637	0.043223	0.068990	0.10460	921.61	-0.39585
200.00	0.024624	14.692	0.068062	8.4164	8.4181	0.048626	0.069825	0.10621	874.04	-0.37472
210.00	0.044602	14.384	0.069519	9.4869	9.4900	0.053849	0.070836	0.10803	826.46	-0.35034
220.00	0.075908	14.069	0.071077	10.576	10.581	0.058915	0.071969	0.11005	778.88	-0.32211
230.00	0.12252	13.745	0.072753	11.685	11.694	0.063848	0.073190	0.11227	731.28	-0.28906
240.00	0.18902	13.410	0.074570	12.817	12.831	0.068665	0.074475	0.11474	683.65	-0.24979
250.00	0.28049	13.062	0.076556	13.973	13.995	0.073385	0.075809	0.11750	635.90	-0.20231
260.00	0.40251	12.698	0.078751	15.156	15.188	0.078027	0.077186	0.12066	587.94	-0.14368
270.00	0.56112	12.314	0.081208	16.368	16.414	0.082607	0.078605	0.12435	539.61	-0.069548
280.00	0.76276	11.904	0.084004	17.615	17.680	0.087149	0.080078	0.12879	490.70	0.026895
290.00	1.0144	11.461	0.087249	18.903	18.991	0.091675	0.081625	0.13438	440.95	0.15683
300.00	1.3234	10.975	0.091119	20.239	20.360	0.096221	0.083293	0.14180	389.93	0.34002
310.00	1.6983	10.426	0.095914	21.638	21.801	0.10083	0.085172	0.15244	337.04	0.61491
320.00	2.1483	9.7846	0.10220	23.125	23.344	0.10559	0.087455	0.16980	281.21	1.0681
330.00	2.6850	8.9829	0.11132	24.750	25.048	0.11065	0.090641	0.20591	220.39	1.9469
340.00	3.3250	7.7913	0.12835	26.688	27.114	0.11659	0.096654	0.35704	149.32	4.3897
345.86	3.7618	5.1285	0.19499	29.429	30.163	0.12527			0	12.397
161.34	0.0010749	0.00080362	1244.4	25.521	26.859	0.16552	0.044397	0.052938	137.57	385.09
170.00	0.0025084	0.0017832	560.78	25.895	27.302	0.16118	0.046371	0.055037	140.62	262.77

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
180.00	0.0059324	0.0039967	250.20	26.340	27.824	0.15705	0.048691	0.057550	143.91	176.43
190.00	0.012629	0.0081006	123.45	26.796	28.355	0.15370	0.051040	0.060156	146.92	124.70
200.00	0.024624	0.015110	66.180	27.262	28.892	0.15100	0.053424	0.062886	149.60	92.835
210.00	0.044602	0.026311	38.007	27.736	29.431	0.14881	0.055867	0.065796	151.89	72.442
220.00	0.075908	0.043269	23.111	28.213	29.968	0.14704	0.058395	0.068954	153.71	58.764
230.00	0.12252	0.067850	14.738	28.693	30.498	0.14560	0.061026	0.072428	155.02	49.133
240.00	0.18902	0.10227	9.7783	29.170	31.018	0.14444	0.063766	0.076287	155.74	42.049
250.00	0.28049	0.14916	6.7041	29.641	31.521	0.14349	0.066612	0.080611	155.81	36.657
260.00	0.40251	0.21175	4.7225	30.102	32.003	0.14270	0.069560	0.085515	155.15	32.456
270.00	0.56112	0.29409	3.4004	30.548	32.456	0.14202	0.072606	0.091184	153.70	29.136
280.00	0.76276	0.40144	2.4910	30.972	32.872	0.14141	0.075756	0.097932	151.36	26.498
290.00	1.0144	0.54109	1.8481	31.366	33.240	0.14081	0.079035	0.10632	148.04	24.406
300.00	1.3234	0.72367	1.3818	31.715	33.544	0.14017	0.082489	0.11743	143.59	22.765
310.00	1.6983	0.96617	1.0350	32.000	33.758	0.13940	0.086214	0.13359	137.85	21.499
320.00	2.1483	1.2991	0.76974	32.183	33.837	0.13838	0.090400	0.16076	130.56	20.526
330.00	2.6850	1.7898	0.55871	32.184	33.684	0.13682	0.095488	0.22018	121.34	19.682
340.00	3.3250	2.6696	0.37458	31.732	32.977	0.13384	0.10298	0.47999	109.29	18.259
345.86	3.7618	5.1285	0.19499	29.429	30.163	0.12527			0	12.397

Single-Phase Properties

200.00	0.10000	14.694	0.068054	8.4143	8.4211	0.048616	0.069829	0.10620	874.45	-0.37493
225.63	0.10000	13.888	0.072006	11.198	11.205	0.061709	0.072648	0.11128	752.07	-0.30416
225.63	0.10000	0.056043	17.843	28.483	30.268	0.14619	0.059863	0.070868	154.52	52.958
300.00	0.10000	0.040759	24.534	33.380	35.833	0.16745	0.070758	0.079793	179.93	18.414
400.00	0.10000	0.030247	33.061	41.260	44.566	0.19247	0.086121	0.094695	207.36	7.5341
500.00	0.10000	0.024114	41.469	50.551	54.698	0.21503	0.099065	0.10751	231.13	4.1010

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
600.00	0.10000	0.020066	49.836	61.004	65.987	0.23558	0.10950	0.11790	252.55	2.5191
200.00	1.0000	14.715	0.067956	8.3891	8.4570	0.048489	0.069866	0.10604	879.27	-0.37736
289.48	1.0000	11.485	0.087067	18.835	18.922	0.091441	0.081543	0.13406	443.55	0.14902
289.48	1.0000	0.53292	1.8765	31.346	33.223	0.14084	0.078861	0.10583	148.24	24.503
300.00	1.0000	0.49298	2.0285	32.269	34.298	0.14449	0.077834	0.099455	155.53	20.787
400.00	1.0000	0.32001	3.1249	40.778	43.903	0.17212	0.087343	0.098681	198.53	7.7199
500.00	1.0000	0.24665	4.0544	50.244	54.298	0.19527	0.099519	0.10927	227.30	4.0976
600.00	1.0000	0.20246	4.9391	60.781	65.720	0.21607	0.10975	0.11891	251.11	2.4913
200.00	5.0000	14.806	0.067539	8.2811	8.6188	0.047943	0.070021	0.10541	900.01	-0.38724
300.00	5.0000	11.380	0.087876	19.812	20.251	0.094764	0.082741	0.13222	452.11	0.11636
400.00	5.0000	2.2504	0.44436	38.004	40.225	0.15165	0.093496	0.13815	159.25	8.1026
500.00	5.0000	1.3639	0.73318	48.802	52.468	0.17903	0.10135	0.11872	213.49	3.8903
600.00	5.0000	1.0491	0.95318	59.789	64.554	0.20106	0.11075	0.12364	246.86	2.2996
200.00	10.000	14.913	0.067054	8.1545	8.8250	0.047292	0.070195	0.10473	924.61	-0.39776
300.00	10.000	11.776	0.084916	19.382	20.231	0.093258	0.082583	0.12585	514.06	-0.037998
400.00	10.000	6.3531	0.15740	33.679	35.253	0.13608	0.095653	0.17697	196.98	2.9315
500.00	10.000	3.0122	0.33199	46.933	50.252	0.16976	0.10303	0.13206	211.16	3.0876
600.00	10.000	2.1596	0.46305	58.580	63.211	0.19339	0.11178	0.12945	248.28	1.9304
200.00	50.000	15.598	0.064113	7.3673	10.573	0.042937	0.070934	0.10170	1089.7	-0.44295
300.00	50.000	13.358	0.074862	17.612	21.355	0.086486	0.083360	0.11389	794.12	-0.33796
400.00	50.000	11.268	0.088747	28.859	33.296	0.12077	0.096003	0.12454	590.09	-0.20571
500.00	50.000	9.4018	0.10636	40.839	46.157	0.14943	0.10668	0.13213	478.93	-0.077157
600.00	50.000	7.8978	0.12662	53.306	59.637	0.17399	0.11548	0.13720	431.69	-0.0052131
300.00	100.00	14.343	0.069721	16.500	23.472	0.081539	0.084059	0.11166	1008.9	-0.40055

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
400.00	100.00	12.767	0.078330	27.298	35.131	0.11502	0.097186	0.12126	833.69	-0.35302
500.00	100.00	11.435	0.087453	38.923	47.668	0.14296	0.10821	0.12921	723.22	-0.31534
600.00	100.00	10.314	0.096952	51.227	60.923	0.16711	0.11716	0.13566	656.57	-0.28902

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Jacobsen, R. T., "An International Standard Formulation for the Thermodynamic Properties of 1,1,1-Trifluoroethane (HFC-143a) for Temperatures from 161 to 450 K and Pressures to 50 MPa," *J. Phys. Chem. Ref. Data* **29**(4):521–552, 2000. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainties of properties calculated using the equation of state are 0.1% in density, 0.5% in heat capacities, 0.02% in the speed of sound for the vapor at pressures less than 1 MPa, 0.5% in speed of sound elsewhere, and 0.1% in vapor pressure, except in the critical region.

Table 2-129 Thermodynamic Properties of R-404A

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.022649	14.209	0.070377	10.353	10.355	0.058867	0.076939	0.11881	859.89	-0.34161
205.00	0.030989	14.059	0.071131	10.948	10.950	0.061803	0.077522	0.11915	831.56	-0.33384
210.00	0.041658	13.907	0.071905	11.544	11.547	0.064678	0.078116	0.11965	804.42	-0.32460
215.00	0.055101	13.755	0.072703	12.144	12.148	0.067498	0.078719	0.12028	778.20	-0.31394
220.00	0.071804	13.600	0.073527	12.746	12.751	0.070269	0.079326	0.12103	752.69	-0.30185
225.00	0.092293	13.444	0.074380	13.353	13.359	0.072995	0.079940	0.12188	727.72	-0.28830
230.00	0.11713	13.286	0.075265	13.963	13.972	0.075679	0.080558	0.12282	703.16	-0.27318
235.00	0.14693	13.126	0.076185	14.578	14.590	0.078326	0.081183	0.12386	678.91	-0.25636
240.00	0.18232	12.963	0.077145	15.199	15.213	0.080939	0.081815	0.12499	654.88	-0.23766
245.00	0.22397	12.796	0.078147	15.824	15.842	0.083520	0.082456	0.12621	631.01	-0.21683
250.00	0.27258	12.627	0.079197	16.456	16.478	0.086073	0.083107	0.12754	607.23	-0.19356

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
255.00	0.32888	12.453	0.080301	17.094	17.120	0.088600	0.083770	0.12899	583.50	-0.16749
260.00	0.39363	12.275	0.081465	17.738	17.770	0.091104	0.084446	0.13057	559.77	-0.13814
265.00	0.46763	12.092	0.082697	18.390	18.429	0.093589	0.085137	0.13229	535.99	-0.10493
270.00	0.55168	11.904	0.084006	19.049	19.096	0.096056	0.085846	0.13419	512.13	-0.067104
275.00	0.64664	11.709	0.085402	19.717	19.772	0.098510	0.086574	0.13630	488.15	-0.023728
280.00	0.75338	11.508	0.086899	20.394	20.460	0.10095	0.087326	0.13866	464.02	0.026418
285.00	0.87280	11.298	0.088513	21.081	21.159	0.10339	0.088104	0.14133	439.69	0.084928
290.00	1.0059	11.078	0.090266	21.780	21.870	0.10583	0.088914	0.14438	415.13	0.15392
295.00	1.1536	10.848	0.092182	22.490	22.597	0.10826	0.089761	0.14793	390.28	0.23626
300.00	1.3169	10.605	0.094295	23.215	23.339	0.11071	0.090653	0.15211	365.11	0.33594
305.00	1.4970	10.346	0.096652	23.956	24.101	0.11317	0.091603	0.15715	339.56	0.45865
310.00	1.6950	10.069	0.099314	24.717	24.885	0.11566	0.092625	0.16339	313.56	0.61280
315.00	1.9122	9.7686	0.10237	25.500	25.695	0.11818	0.093744	0.17139	287.00	0.81141
320.00	2.1499	9.4384	0.10595	26.310	26.538	0.12075	0.094998	0.18212	259.73	1.0757
325.00	2.4096	9.0688	0.11027	27.157	27.423	0.12341	0.096455	0.19751	231.53	1.4433
330.00	2.6932	8.6431	0.11570	28.054	28.365	0.12619	0.098241	0.22197	201.95	1.9881
335.00	3.0027	8.1285	0.12302	29.026	29.396	0.12918	0.10064	0.26871	170.20	2.8807
340.00	3.3414	7.4362	0.13448	30.147	30.597	0.13261	0.10445	0.40392	134.59	4.6353
345.00	3.7150	5.7429	0.17413	32.108	32.755	0.13874	0.11650	8.2559	89.976	10.564
345.27	3.7348	4.9400	0.20243	32.875	33.631	0.14126			0	12.409
200.00	0.021264	0.013010	76.866	29.920	31.555	0.16521	0.058696	0.068032	138.13	88.073
205.00	0.029285	0.017550	56.979	30.185	31.853	0.16408	0.059968	0.069509	139.28	77.215
210.00	0.039592	0.023271	42.971	30.451	32.152	0.16307	0.061245	0.071021	140.34	68.305
215.00	0.052629	0.030378	32.919	30.718	32.451	0.16217	0.062526	0.072573	141.29	60.948
220.00	0.068883	0.039095	25.579	30.987	32.749	0.16138	0.063815	0.074172	142.12	54.835

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
225.00	0.088879	0.049667	20.134	31.256	33.046	0.16068	0.065113	0.075826	142.84	49.721
230.00	0.113118	0.062359	16.036	31.525	33.340	0.16006	0.066424	0.077546	143.43	45.413
235.00	0.14240	0.077463	12.909	31.795	33.633	0.15952	0.067750	0.079344	143.88	41.761
240.00	0.17718	0.095292	10.494	32.063	33.922	0.15903	0.069095	0.081232	144.18	38.642
245.00	0.21817	0.116119	8.6063	32.330	34.208	0.15861	0.070463	0.083226	144.33	35.962
250.00	0.26610	0.14055	7.1149	32.596	34.489	0.15823	0.071855	0.085343	144.32	33.645
255.00	0.32169	0.16879	5.9247	32.859	34.765	0.15789	0.073276	0.087604	144.14	31.630
260.00	0.38571	0.20137	4.9659	33.119	35.034	0.15759	0.074728	0.090033	143.77	29.871
265.00	0.45896	0.23885	4.1867	33.375	35.296	0.15732	0.076214	0.092660	143.22	28.327
270.00	0.54225	0.28183	3.5483	33.626	35.550	0.15707	0.077737	0.095524	142.46	26.970
275.00	0.63645	0.33102	3.0210	33.872	35.794	0.15684	0.079300	0.098671	141.49	25.773
280.00	0.74245	0.38725	2.5823	34.111	36.028	0.15661	0.080909	0.10217	140.29	24.718
285.00	0.86115	0.45152	2.2148	34.342	36.249	0.15639	0.082567	0.10609	138.85	23.789
290.00	0.99353	0.52501	1.9047	34.563	36.455	0.15616	0.084282	0.11056	137.16	22.972
295.00	1.1406	0.60922	1.6414	34.773	36.645	0.15592	0.086062	0.11574	135.19	22.256
300.00	1.3034	0.70599	1.4165	34.968	36.814	0.15566	0.087917	0.12186	132.92	21.633
305.00	1.4830	0.81772	1.2229	35.147	36.960	0.15536	0.089863	0.12929	130.34	21.094
310.00	1.6806	0.94761	1.0553	35.304	37.078	0.15501	0.091922	0.13856	127.41	20.630
315.00	1.8975	1.1001	0.90903	35.435	37.159	0.15459	0.094123	0.15062	124.10	20.234
320.00	2.1351	1.2815	0.78032	35.530	37.196	0.15408	0.096513	0.16713	120.38	19.889
325.00	2.3950	1.5019	0.66583	35.578	37.173	0.15343	0.099162	0.19141	116.21	19.571
330.00	2.6789	1.7781	0.56239	35.558	37.065	0.15257	0.10220	0.23111	111.51	19.233
335.00	2.9893	2.1438	0.46645	35.429	36.824	0.15136	0.10585	0.30867	106.19	18.763
340.00	3.3299	2.6882	0.37199	35.084	36.323	0.14946	0.11074	0.53035	100.03	17.851
345.00	3.7109	4.2113	0.23746	33.615	34.496	0.14379	0.12022	8.6291	90.307	14.130
345.27	3.7348	4.9400	0.20243	32.875	33.631	0.14126			0	12.409

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
226.65	0.10000	13.392	0.074669	13.554	13.561	0.073887	0.080143	0.12218	719.55	-0.28348
227.41	0.10000	0.055492	18.021	31.386	33.188	0.16038	0.065742	0.076645	143.14	47.558
300.00	0.10000	0.040750	24.540	36.596	39.050	0.18269	0.076875	0.085907	166.24	16.998
400.00	0.10000	0.030243	33.066	45.121	48.428	0.20956	0.092844	0.10141	191.81	6.9229
500.00	0.10000	0.024113	41.471	55.103	59.250	0.23365	0.10612	0.11456	213.92	3.7455
289.79	1.0000	11.088	0.090189	21.750	21.840	0.10572	0.088879	0.14425	416.16	0.15078
290.23	1.0000	0.52866	1.8916	34.573	36.464	0.15615	0.084363	0.11078	137.07	22.936
300.00	1.0000	0.49205	2.0323	35.486	37.518	0.15972	0.083854	0.10554	143.42	19.634
400.00	1.0000	0.31957	3.1292	44.644	47.773	0.18922	0.094142	0.10545	183.69	7.1401
500.00	1.0000	0.24648	4.0571	54.804	58.861	0.21391	0.10659	0.11631	210.41	3.7496
300.00	5.0000	10.994	0.090955	22.770	23.225	0.10919	0.089725	0.14193	427.56	0.11428
400.00	5.0000	2.2256	0.44932	41.867	44.113	0.16875	0.10069	0.14547	148.00	7.6582
500.00	5.0000	1.3561	0.73741	53.389	57.076	0.19774	0.10859	0.12579	198.35	3.5826
300.00	10.000	11.371	0.087944	22.323	23.203	0.10763	0.089307	0.13525	489.01	-0.035312
400.00	10.000	6.1241	0.16329	37.557	39.190	0.15323	0.10301	0.18569	184.17	2.8522
500.00	10.000	2.9622	0.33758	51.539	54.915	0.18852	0.11046	0.13925	198.11	2.8527
300.00	25.000	12.107	0.082594	21.419	23.484	0.10432	0.089393	0.12713	614.12	-0.22002
400.00	25.000	9.2730	0.10784	34.286	36.982	0.14304	0.10166	0.14227	381.56	0.20064
500.00	25.000	6.6326	0.15077	47.758	51.527	0.17548	0.11215	0.14633	292.53	0.65319
300.00	50.000	12.867	0.077719	20.472	24.358	0.10057	0.090168	0.12262	753.19	-0.32391
400.00	50.000	10.834	0.092300	32.538	37.153	0.13731	0.10251	0.13302	559.24	-0.19415
500.00	50.000	9.0225	0.11083	45.317	50.859	0.16786	0.11339	0.14051	455.37	-0.070101

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

Table 2-130 Thermodynamic Properties of R-407C

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.019158	17.036	0.058698	8.8272	8.8283	0.050593	0.070988	0.11073	956.60	-0.31996
210.00	0.035795	16.697	0.059892	9.9359	9.9380	0.056002	0.071320	0.11118	903.06	-0.30662
220.00	0.062640	16.352	0.061156	11.051	11.055	0.061189	0.071817	0.11203	851.40	-0.28934
230.00	0.10366	15.999	0.062503	12.175	12.182	0.066188	0.072410	0.11319	801.12	-0.26790
240.00	0.16353	15.637	0.063949	13.312	13.323	0.071026	0.073074	0.11465	751.77	-0.24161
250.00	0.24755	15.264	0.065512	14.464	14.480	0.075728	0.073803	0.11641	703.01	-0.20937
260.00	0.36157	14.877	0.067218	15.632	15.657	0.080314	0.074597	0.11853	654.53	-0.16951
270.00	0.51193	14.472	0.069099	16.822	16.857	0.084805	0.075463	0.12111	606.09	-0.11964
280.00	0.70540	14.045	0.071198	18.035	18.085	0.089223	0.076412	0.12427	557.44	-0.056172
290.00	0.94916	13.591	0.073576	19.278	19.348	0.093590	0.077458	0.12822	508.32	0.026372
300.00	1.2507	13.102	0.076322	20.555	20.651	0.097931	0.078624	0.13331	458.46	0.13683
310.00	1.6182	12.567	0.079573	21.877	22.006	0.10228	0.079950	0.14013	407.51	0.29038
320.00	2.0599	11.969	0.083552	23.255	23.427	0.10668	0.081509	0.14989	354.98	0.51547
330.00	2.5851	11.278	0.088671	24.711	24.940	0.11119	0.083453	0.16541	300.07	0.87274

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
340.00	3.2038	10.435	0.095832	26.287	26.594	0.11596	0.086157	0.19551	241.20	1.5203
350.00	3.9255	9.2661	0.10792	28.110	28.534	0.12137	0.090943	0.28993	174.57	3.0499
359.35	4.6317	5.2600	0.19011	32.145	33.025	0.13372			0	10.947
200.00	0.011312	0.0068643	145.68	30.051	31.699	0.16726	0.048920	0.057805	149.59	109.12
210.00	0.022624	0.013151	76.041	30.504	32.224	0.16412	0.050967	0.060200	152.36	88.122
220.00	0.041929	0.023450	42.644	30.957	32.745	0.16151	0.053143	0.062854	154.78	72.006
230.00	0.072846	0.039384	25.391	31.409	33.259	0.15933	0.055439	0.065784	156.79	59.560
240.00	0.11979	0.062913	15.895	31.857	33.761	0.15749	0.057839	0.069010	158.33	49.904
250.00	0.18793	0.096374	10.376	32.298	34.248	0.15593	0.060328	0.072563	159.36	42.378
260.00	0.28317	0.14256	7.0147	32.728	34.715	0.15460	0.062897	0.076500	159.80	36.483
270.00	0.41203	0.20484	4.8820	33.145	35.157	0.15343	0.065542	0.080917	159.60	31.840
280.00	0.58173	0.28739	3.4796	33.544	35.568	0.15240	0.068266	0.085971	158.69	28.163
290.00	0.80008	0.39560	2.5278	33.918	35.940	0.15144	0.071085	0.091920	156.99	25.236
300.00	1.0757	0.53670	1.8632	34.259	36.263	0.15051	0.074027	0.099203	154.41	22.898
310.00	1.4179	0.72101	1.3869	34.556	36.523	0.14956	0.077140	0.10861	150.83	21.024
320.00	1.8375	0.96439	1.0369	34.790	36.696	0.14852	0.080507	0.12170	146.11	19.516
330.00	2.3470	1.2939	0.77283	34.931	36.745	0.14727	0.084283	0.14208	140.03	18.284
340.00	2.9627	1.7642	0.56682	34.916	36.595	0.14560	0.088801	0.18030	132.24	17.206
350.00	3.7100	2.5260	0.39588	34.578	36.047	0.14299	0.095065	0.28700	122.09	15.951
359.35	4.6317	5.2600	0.19011	32.145	33.025	0.13372			0	10.947

Single-Phase Properties

200.00	0.10000	17.038	0.058692	8.8253	8.8312	0.050583	0.070990	0.11072	956.99	-0.32010
229.25	0.10000	16.026	0.062399	12.091	12.097	0.065819	0.072363	0.11310	804.85	-0.26966
236.25	0.10000	0.053062	18.846	31.690	33.574	0.15814	0.056928	0.067764	157.81	53.242
300.00	0.10000	0.040722	24.557	35.535	37.991	0.17467	0.063341	0.072378	179.00	20.041

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
400.00	0.10000	0.030231	33.079	42.554	45.862	0.19722	0.076588	0.085147	205.99	7.7925
500.00	0.10000	0.024109	41.479	50.849	54.997	0.21756	0.088895	0.097330	229.27	4.0471
291.84	1.0000	13.504	0.074050	19.510	19.584	0.094388	0.077662	0.12906	499.23	0.044233
297.47	1.0000	0.49738	2.0105	34.177	36.187	0.15075	0.073268	0.097199	155.15	23.442
300.00	1.0000	0.48865	2.0465	34.384	36.431	0.15156	0.072744	0.095419	156.77	22.566
400.00	1.0000	0.31821	3.1425	42.101	45.244	0.17694	0.078067	0.089213	198.26	7.9701
500.00	1.0000	0.24608	4.0637	50.576	54.639	0.19786	0.089416	0.099001	225.88	4.0390
300.00	5.0000	13.412	0.074559	20.240	20.613	0.096862	0.078093	0.12762	507.10	0.027202
400.00	5.0000	2.1880	0.45703	39.458	41.743	0.15675	0.086188	0.12964	161.10	8.5257
500.00	5.0000	1.3504	0.74050	49.289	52.992	0.18193	0.091753	0.10811	213.00	3.9036
300.00	10.000	13.740	0.072780	19.898	20.626	0.095679	0.077756	0.12301	558.94	-0.063246
400.00	10.000	7.1029	0.14079	34.426	35.834	0.13888	0.090433	0.20031	184.71	3.3408
500.00	10.000	2.9957	0.33381	47.547	50.885	0.17282	0.094263	0.12254	207.67	3.3327
300.00	25.000	14.443	0.069238	19.146	20.877	0.092972	0.077634	0.11624	672.43	-0.19834
400.00	25.000	10.899	0.091752	30.990	33.284	0.12855	0.087056	0.13223	399.92	0.28513
500.00	25.000	7.3363	0.13631	43.479	46.886	0.15889	0.096319	0.13592	289.22	0.97116
300.00	50.000	15.220	0.065703	18.302	21.587	0.089730	0.078160	0.11176	802.78	-0.28843
400.00	50.000	12.648	0.079064	29.255	33.209	0.12310	0.087179	0.12077	579.57	-0.12975
500.00	50.000	10.260	0.097468	40.787	45.660	0.15086	0.096753	0.12761	457.54	0.047330

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

Figure 2-15 Pressure-enthalpy diagram for Refrigerant 407C. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M. O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the mixture model of Lemmon, E. W., and R. T. Jacobsen, "Equations of State for Mixtures of R-32, R-125, R-134a, R-143a, and R-152a," *J. Phys. Chem. Ref. Data* **33**: 593–620, 2004.

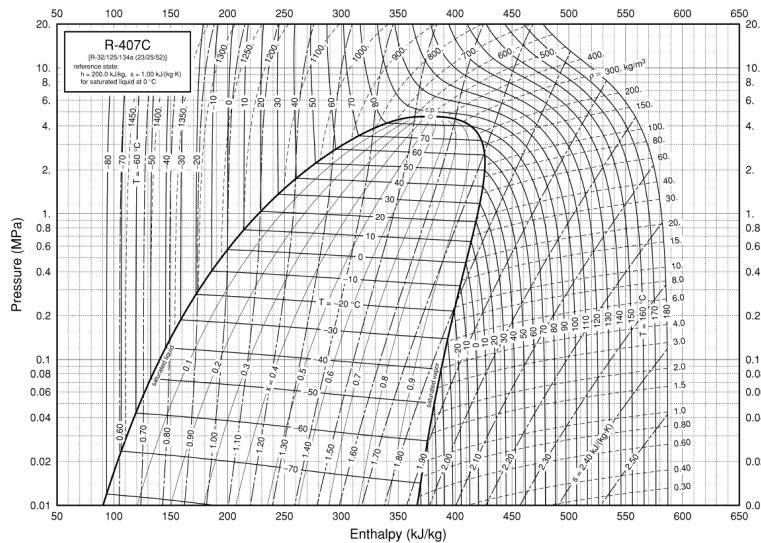


Table 2-131 Thermodynamic Properties of R-410A

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.029160	19.510	0.051256	7.0380	7.0395	0.040995	0.062260	0.097942	929.01	-0.30179
210.00	0.053727	19.093	0.052375	8.0188	8.0217	0.045781	0.062050	0.098396	879.84	-0.28524

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
215.00	0.071143	18.881	0.052962	8.5112	8.5149	0.048098	0.062014	0.098729	855.20	-0.27544
220.00	0.092819	18.667	0.053571	9.0052	9.0101	0.050370	0.062020	0.099138	830.52	-0.26446
225.00	0.11946	18.449	0.054202	9.5012	9.5077	0.052600	0.062066	0.099628	805.81	-0.25217
230.00	0.15182	18.229	0.054858	9.9997	10.008	0.054791	0.062151	0.10020	781.06	-0.23841
235.00	0.19070	18.005	0.055542	10.501	10.512	0.056948	0.062271	0.10088	756.26	-0.22300
240.00	0.23697	17.776	0.056255	11.006	11.019	0.059073	0.062426	0.10165	731.41	-0.20574
245.00	0.29152	17.543	0.057002	11.514	11.530	0.061169	0.062615	0.10253	706.48	-0.18637
250.00	0.35531	17.305	0.057786	12.026	12.047	0.063240	0.062837	0.10353	681.45	-0.16459
255.00	0.42933	17.062	0.058611	12.543	12.568	0.065289	0.063092	0.10466	656.31	-0.14006
260.00	0.51461	16.812	0.059482	13.065	13.096	0.067318	0.063380	0.10594	631.02	-0.11232
265.00	0.61223	16.555	0.060406	13.593	13.630	0.069331	0.063701	0.10738	605.55	-0.080861
270.00	0.72330	16.290	0.061388	14.127	14.172	0.071331	0.064057	0.10902	579.88	-0.045000
275.00	0.84899	16.016	0.062439	14.669	14.722	0.073321	0.064451	0.11088	553.95	-0.003906
280.00	0.99048	15.732	0.063567	15.218	15.281	0.075304	0.064884	0.11300	527.72	0.043515
285.00	1.1490	15.436	0.064785	15.776	15.851	0.077284	0.065363	0.11543	501.14	0.098651
290.00	1.3260	15.127	0.066109	16.344	16.432	0.079266	0.065893	0.11825	474.14	0.16337
295.00	1.5226	14.802	0.067559	16.924	17.026	0.081254	0.066483	0.12156	446.66	0.24022
300.00	1.7404	14.459	0.069160	17.516	17.636	0.083253	0.067147	0.12550	418.60	0.33275
305.00	1.9809	14.095	0.070948	18.123	18.263	0.085270	0.067901	0.13029	389.87	0.44607
310.00	2.2456	13.704	0.072969	18.747	18.911	0.087314	0.068773	0.13630	360.33	0.58788
315.00	2.5364	13.282	0.075293	19.392	19.583	0.089398	0.069800	0.14413	329.82	0.77028
320.00	2.8550	12.816	0.078025	20.064	20.287	0.091537	0.071046	0.15493	298.10	1.0135
325.00	3.2037	12.294	0.081343	20.772	21.032	0.093762	0.072616	0.17109	264.83	1.3544
330.00	3.5848	11.685	0.085578	21.531	21.837	0.096123	0.074717	0.19853	229.46	1.8665
335.00	4.0009	10.930	0.091491	22.376	22.742	0.098732	0.077843	0.25685	190.98	2.7232

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
340.00	4.4556	9.8413	0.10161	23.414	23.867	0.10194	0.083650	0.46832	147.49	4.4554
344.49	4.9012	6.3240	0.15813	25.988	26.763	0.11022			0	9.7623
200.00	0.029010	0.017797	56.190	26.495	28.125	0.14644	0.042482	0.052236	164.41	113.67
210.00	0.053489	0.031567	31.678	26.835	28.530	0.14345	0.044604	0.055055	167.03	90.100
215.00	0.070844	0.041089	24.338	27.002	28.726	0.14212	0.045719	0.056590	168.16	80.508
220.00	0.092447	0.052763	18.953	27.167	28.919	0.14087	0.046862	0.058205	169.16	72.155
225.00	0.11900	0.066925	14.942	27.329	29.107	0.13972	0.048026	0.059899	170.03	64.889
230.00	0.15125	0.083936	11.914	27.488	29.290	0.13864	0.049206	0.061674	170.75	58.571
235.00	0.19000	0.10420	9.5972	27.645	29.468	0.13762	0.050400	0.063533	171.32	53.077
240.00	0.23611	0.12814	7.8039	27.798	29.640	0.13667	0.051603	0.065483	171.73	48.299
245.00	0.29049	0.15625	6.4000	27.947	29.806	0.13577	0.052814	0.067535	171.97	44.137
250.00	0.35407	0.18905	5.2895	28.092	29.965	0.13492	0.054033	0.069705	172.04	40.508
255.00	0.42786	0.22714	4.4026	28.232	30.116	0.13411	0.055260	0.072011	171.93	37.336
260.00	0.51287	0.27117	3.6877	28.367	30.258	0.13333	0.056497	0.074481	171.62	34.560
265.00	0.61019	0.32190	3.1066	28.496	30.392	0.13259	0.057747	0.077148	171.11	32.123
270.00	0.72092	0.38018	2.6303	28.619	30.515	0.13187	0.059014	0.080057	170.39	29.979
275.00	0.84622	0.44702	2.2371	28.733	30.626	0.13116	0.060302	0.083265	169.45	28.087
280.00	0.98729	0.52357	1.9100	28.839	30.725	0.13047	0.061618	0.086846	168.27	26.412
285.00	1.1454	0.61123	1.6360	28.935	30.809	0.12978	0.062969	0.090901	166.84	24.924
290.00	1.3218	0.71170	1.4051	29.019	30.876	0.12908	0.064364	0.095568	165.16	23.598
295.00	1.5179	0.82707	1.2091	29.090	30.925	0.12837	0.065814	0.10104	163.20	22.410
300.00	1.7351	0.95997	1.0417	29.144	30.951	0.12764	0.067335	0.10760	160.94	21.338
305.00	1.9749	1.1138	0.89779	29.178	30.951	0.12688	0.068945	0.11566	158.36	20.365
310.00	2.2390	1.2933	0.77322	29.189	30.920	0.12606	0.070671	0.12589	155.44	19.470
315.00	2.5291	1.5048	0.66456	29.170	30.850	0.12517	0.072551	0.13943	152.13	18.632
320.00	2.8472	1.7576	0.56894	29.112	30.732	0.12418	0.074643	0.15831	148.40	17.826

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_p kJ/(mol·K)	C_v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
325.00	3.1955	2.0668	0.48384	29.002	30.548	0.12305	0.077041	0.18670	144.16	17.018
330.00	3.5766	2.4582	0.40681	28.817	30.272	0.12169	0.079915	0.23464	139.30	16.153
335.00	3.9935	2.9848	0.33503	28.510	29.848	0.11995	0.083629	0.33370	133.59	15.123
340.00	4.4504	3.7974	0.26334	27.951	29.123	0.11740	0.089197	0.65947	126.39	13.641
344.49	4.9012	6.3240	0.15813	25.988	26.763	0.11022			0	9.7623
Single-Phase Properties										
221.45	0.10000	18.604	0.053751	9.1488	9.1541	0.051020	0.062030	0.099271	823.36	-0.26104
221.53	0.10000	0.056810	17.603	27.217	28.977	0.14051	0.047215	0.058714	169.44	69.827
300.00	0.10000	0.040605	24.628	31.028	33.491	0.15794	0.050980	0.059877	198.35	19.643
400.00	0.10000	0.030202	33.111	36.670	39.981	0.17654	0.061554	0.070067	227.37	7.7467
500.00	0.10000	0.024099	41.495	43.331	47.480	0.19323	0.071249	0.079663	252.59	4.0758
280.32	1.0000	15.713	0.063641	15.253	15.317	0.075429	0.064913	0.11314	526.05	0.046760
280.42	1.0000	0.53054	1.8849	28.848	30.733	0.13041	0.061731	0.087169	168.16	26.279
300.00	1.0000	0.46599	2.1460	30.151	32.297	0.13580	0.057548	0.075210	180.65	20.254
400.00	1.0000	0.31478	3.1769	36.304	39.481	0.15648	0.062713	0.073258	220.92	7.7768
500.00	1.0000	0.24505	4.0808	43.106	47.187	0.17364	0.071665	0.081012	249.79	4.0343
300.00	5.0000	14.870	0.067248	17.202	17.539	0.082188	0.066139	0.11773	472.56	0.17344
400.00	5.0000	1.9755	0.50621	34.349	36.880	0.13813	0.068570	0.097588	192.34	7.6786
500.00	5.0000	1.3185	0.75845	42.072	45.864	0.15821	0.073521	0.087959	239.51	3.7957
300.00	10.000	15.342	0.065180	16.830	17.482	0.080897	0.065435	0.11125	533.86	0.036775
400.00	10.000	5.7949	0.17257	30.845	32.570	0.12363	0.074099	0.16518	182.45	5.0121
500.00	10.000	2.8642	0.34914	40.710	44.202	0.14982	0.075667	0.098492	233.93	3.3106
300.00	25.000	16.289	0.061392	16.058	17.592	0.078110	0.065000	0.10273	658.09	-0.14678
400.00	25.000	11.685	0.085582	26.530	28.670	0.10987	0.072157	0.11830	379.59	0.50709
500.00	25.000	7.4115	0.13493	37.197	40.570	0.13644	0.078574	0.11515	291.31	1.2724
300.00	50.000	17.287	0.057845	15.231	18.123	0.074923	0.065499	0.097459	792.80	-0.26163

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C kJ/(mol·K)	C kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
400.00	50.000	14.049	0.071182	24.722	28.281	0.10409	0.072480	0.10533	566.13	-0.063564
500.00	50.000	11.128	0.089864	34.526	39.019	0.12804	0.079657	0.10880	449.76	0.13566

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

Table 2-132 Opteon™ YF (R-1234yf)

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]	Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]	
		Liquid v _f	Vapor v _g	Liquid d _f	Vapor d _g	Liquid h _f	Latent h _{fg}	Vapor h _g	Liquid s _f	Vapor s _g	
-40	62.367	0.000 774	0.263 5	1291. 9	3.795	151.1	185.5	336.6	0.807	1.603	-40
-39	65.454	0.000 776	0.251 9	1289. 2	3.970	152.2	185.0	337.3	0.812	1.603	-39
-38	68.661	0.000 777	0.240 9	1286. 5	4.152	153.4	184.5	337.9	0.817	1.602	-38
-37	71.992	0.000 779	0.230 4	1283. 8	4.340	154.6	184.0	338.6	0.822	1.602	-37
-36	75.450	0.000 781	0.220 5	1281. 0	4.535	155.7	183.5	339.3	0.827	1.601	-36
-35	79.039	0.000 782	0.211 1	1278. 3	4.737	156.9	183.0	339.9	0.832	1.601	-35
-34	82.761	0.000 784	0.202 2	1275. 6	4.946	158.1	182.5	340.6	0.837	1.600	-34
-33	86.620	0.000 786	0.193 7	1272. 8	5.162	159.3	182.0	341.3	0.842	1.600	-33

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]		Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	
-32	90.620	0.000787	0.1857	1270.1	5.386	160.4	181.5	342.0	0.847	1.600
-31	94.764	0.000789	0.1780	1267.3	5.617	161.6	181.0	342.6	0.852	1.599
-30	99.056	0.000791	0.1708	1264.5	5.855	162.8	180.5	343.3	0.857	1.599
-29	103.500	0.000793	0.1639	1261.8	6.102	164.0	180.0	344.0	0.861	1.599
-28	108.098	0.000794	0.1573	1259.0	6.357	165.2	179.5	344.7	0.866	1.598
-27	112.856	0.000796	0.1511	1256.2	6.620	166.4	178.9	345.3	0.871	1.598
-26	117.775	0.000798	0.1451	1253.4	6.891	167.6	178.4	346.0	0.876	1.598
-25	122.861	0.000800	0.1394	1250.5	7.171	168.8	177.9	346.7	0.881	1.598
-24	128.117	0.000801	0.1340	1247.7	7.460	170.0	177.4	347.4	0.886	1.598
-23	133.548	0.000803	0.1289	1244.9	7.758	171.2	176.8	348.0	0.891	1.597
-22	139.155	0.000805	0.1240	1242.0	8.066	172.4	176.3	348.7	0.895	1.597
-21	144.945	0.000807	0.1193	1239.2	8.383	173.7	175.7	349.4	0.900	1.597
-20	150.921	0.000809	0.1148	1236.3	8.709	174.9	175.2	350.1	0.905	1.597
-19	157.086	0.000811	0.1105	1233.4	9.046	176.1	174.6	350.7	0.910	1.597
-18	163.444	0.000813	0.1065	1230.5	9.392	177.3	174.1	351.4	0.915	1.597
-17	170.001	0.000815	0.1026	1227.6	9.750	178.6	173.5	352.1	0.919	1.597
-16	176.759	0.000817	0.0988	1224.7	10.117	179.8	172.9	352.7	0.924	1.597

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	Temp [°C]
-15	183.7 24	0.000 818	0.095 3	1221. 8	10.49 6	181.0	172.4	353.4	0.929	1.597	-15
-14	190.8 98	0.000 820	0.091 9	1218. 8	10.88 5	182.3	171.8	354.1	0.934	1.597	-14
-13	198.2 87	0.000 822	0.088 6	1215. 9	11.28 6	183.5	171.2	354.7	0.939	1.597	-13
-12	205.8 95	0.000 824	0.085 5	1212. 9	11.69 9	184.8	170.6	355.4	0.943	1.597	-12
-11	213.7 26	0.000 826	0.082 5	1209. 9	12.12 3	186.0	170.0	356.1	0.948	1.597	-11
-10	221.7 83	0.000 829	0.079 6	1207. 0	12.55 9	187.3	169.5	356.7	0.953	1.597	-10
-9	230.0 72	0.000 831	0.076 9	1203. 9	13.00 8	188.5	168.9	357.4	0.958	1.597	-9
-8	238.5 97	0.000 833	0.074 2	1200. 9	13.46 9	189.8	168.3	358.0	0.962	1.597	-8
-7	247.3 63	0.000 835	0.071 7	1197. 9	13.94 3	191.0	167.7	358.7	0.967	1.597	-7
-6	256.3 73	0.000 837	0.069 3	1194. 9	14.43 1	192.3	167.0	359.4	0.972	1.597	-6
-5	265.6 32	0.000 839	0.067 0	1191. 8	14.93 1	193.6	166.4	360.0	0.976	1.597	-5
-4	275.1 44	0.000 841	0.064 7	1188. 7	15.44 6	194.9	165.8	360.7	0.981	1.597	-4
-3	284.9 15	0.000 843	0.062 6	1185. 6	15.97 4	196.1	165.2	361.3	0.986	1.597	-3
-2	294.9 48	0.000 846	0.060 5	1182. 5	16.51 7	197.4	164.6	362.0	0.991	1.598	-2
-1	305.2 49	0.000 848	0.058 6	1179. 4	17.07 4	198.7	163.9	362.6	0.995	1.598	-1
0	315.8 21	0.000 850	0.056 7	1176. 3	17.64 7	200.0	163.3	363.3	1.000	1.598	0
1	326.6 70	0.000 852	0.054 8	1173. 1	18.23 4	201.3	162.6	363.9	1.005	1.598	1

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
2	337.800	0.000855	0.0531	1170.0	18.837	202.6	162.0	364.6	1.009	1.598	2
3	349.216	0.000857	0.0514	1166.8	19.457	203.9	161.3	365.2	1.014	1.598	3
4	360.923	0.000859	0.0498	1163.6	20.092	205.2	160.7	365.9	1.019	1.599	4
5	372.925	0.000862	0.0482	1160.4	20.744	206.5	160.0	366.5	1.023	1.599	5
6	385.227	0.000864	0.0467	1157.2	21.413	207.8	159.3	367.2	1.028	1.599	6
7	397.833	0.000867	0.0452	1153.9	22.100	209.1	158.7	367.8	1.033	1.599	7
8	410.750	0.000869	0.0439	1150.6	22.804	210.5	158.0	368.4	1.037	1.599	8
9	423.981	0.000872	0.0425	1147.3	23.526	211.8	157.3	369.1	1.042	1.600	9
10	437.532	0.000874	0.0412	1144.0	24.267	213.1	156.6	369.7	1.047	1.600	10
11	451.408	0.000877	0.0400	1140.7	25.027	214.4	155.9	370.3	1.051	1.600	11
12	465.613	0.000879	0.0387	1137.4	25.807	215.8	155.2	371.0	1.056	1.600	12
13	480.152	0.000882	0.0376	1134.0	26.606	217.1	154.5	371.6	1.061	1.601	13
14	495.031	0.000884	0.0365	1130.6	27.425	218.5	153.8	372.2	1.065	1.601	14
15	510.255	0.000887	0.0354	1127.2	28.266	219.8	153.0	372.8	1.070	1.601	15
16	525.828	0.000890	0.0343	1123.8	29.127	221.2	152.3	373.4	1.075	1.601	16
17	541.756	0.000893	0.0333	1120.3	30.011	222.5	151.6	374.1	1.079	1.602	17
18	558.044	0.000895	0.0323	1116.9	30.916	223.9	150.8	374.7	1.084	1.602	18

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
19	574.6 97	0.000 898	0.031 4	1113. 4	31.84 5	225.2	150.1	375.3	1.088	1.602	19
20	591.7 21	0.000 901	0.030 5	1109. 9	32.79 6	226.6	149.3	375.9	1.093	1.602	20
21	609.1 20	0.000 904	0.029 6	1106. 3	33.77 2	228.0	148.5	376.5	1.098	1.603	21
22	626.9 01	0.000 907	0.028 8	1102. 8	34.77 2	229.3	147.7	377.1	1.102	1.603	22
23	645.0 68	0.000 910	0.027 9	1099. 2	35.79 7	230.7	147.0	377.7	1.107	1.603	23
24	663.6 26	0.000 913	0.027 1	1095. 5	36.84 8	232.1	146.2	378.3	1.112	1.603	24
25	682.5 82	0.000 916	0.026 4	1091. 9	37.92 5	233.5	145.4	378.9	1.116	1.604	25
26	701.9 40	0.000 919	0.025 6	1088. 2	39.02 9	234.9	144.6	379.5	1.121	1.604	26
27	721.7 07	0.000 922	0.024 9	1084. 5	40.16 1	236.3	143.7	380.0	1.125	1.604	27
28	741.8 87	0.000 925	0.024 2	1080. 8	41.32 1	237.7	142.9	380.6	1.130	1.605	28
29	762.4 87	0.000 928	0.023 5	1077. 1	42.51 0	239.1	142.1	381.2	1.135	1.605	29
30	783.5 11	0.000 932	0.022 9	1073. 3	43.72 9	240.5	141.2	381.8	1.139	1.605	30
31	804.9 66	0.000 935	0.022 2	1069. 5	44.97 9	241.9	140.4	382.3	1.144	1.605	31
32	826.8 57	0.000 938	0.021 6	1065. 7	46.26 0	243.4	139.5	382.9	1.148	1.606	32
33	849.1 90	0.000 942	0.021 0	1061. 8	47.57 3	244.8	138.7	383.4	1.153	1.606	33
34	871.9 71	0.000 945	0.020 4	1057. 9	48.92 0	246.2	137.8	384.0	1.158	1.606	34
35	895.2 06	0.000 949	0.019 9	1054. 0	50.30 1	247.6	136.9	384.5	1.162	1.606	35

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]	Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]	
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
36	918.900	0.000952	0.0193	1050.0	51.717	249.1	136.0	385.1	1.167	1.607	36
37	943.060	0.000956	0.0188	1046.0	53.169	250.5	135.1	385.6	1.171	1.607	37
38	967.691	0.000960	0.0183	1042.0	54.658	252.0	134.1	386.1	1.176	1.607	38
39	992.800	0.000963	0.0178	1037.9	56.186	253.4	133.2	386.7	1.181	1.607	39
40	1018.393	0.000967	0.0173	1033.8	57.753	254.9	132.3	387.2	1.185	1.608	40
41	1044.476	0.000971	0.0168	1029.6	59.360	256.4	131.3	387.7	1.190	1.608	41
42	1071.055	0.000975	0.0164	1025.5	61.010	257.8	130.3	388.2	1.194	1.608	42
43	1098.137	0.000979	0.0159	1021.2	62.702	259.3	129.4	388.7	1.199	1.608	43
44	1125.728	0.000983	0.0155	1017.0	64.440	260.8	128.4	389.2	1.204	1.608	44
45	1153.834	0.000988	0.0151	1012.6	66.223	262.3	127.4	389.7	1.208	1.608	45
46	1182.462	0.000992	0.0147	1008.3	68.053	263.8	126.3	390.1	1.213	1.609	46
47	1211.618	0.000996	0.0143	1003.9	69.933	265.3	125.3	390.6	1.217	1.609	47
48	1241.310	0.001001	0.0139	999.4	71.863	266.8	124.3	391.1	1.222	1.609	48
49	1271.543	0.001005	0.0135	994.9	73.846	268.3	123.2	391.5	1.227	1.609	49
50	1302.325	0.001010	0.0132	990.4	75.884	269.9	122.1	392.0	1.231	1.609	50
51	1333.663	0.001014	0.0128	985.8	77.978	271.4	121.0	392.4	1.236	1.609	51
52	1365.563	0.001019	0.0125	981.1	80.130	272.9	119.9	392.8	1.241	1.609	52

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]	Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]	
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
53	1398.032	0.001024	0.0121	976.4	82.343	274.5	118.8	393.3	1.245	1.609	53
54	1431.079	0.001029	0.0118	971.6	84.619	276.0	117.7	393.7	1.250	1.609	54
55	1464.709	0.001034	0.0115	966.7	86.961	277.6	116.5	394.1	1.254	1.610	55
56	1498.931	0.001040	0.0112	961.8	89.371	279.2	115.3	394.5	1.259	1.610	56
57	1533.751	0.001045	0.0109	956.8	91.852	280.7	114.1	394.9	1.264	1.610	57
58	1569.178	0.001051	0.0106	951.7	94.407	282.3	112.9	395.2	1.269	1.609	58
59	1605.219	0.001056	0.0103	946.6	97.040	283.9	111.7	395.6	1.273	1.609	59
60	1641.882	0.001062	0.0100	941.3	99.754	285.5	110.4	395.9	1.278	1.609	60
61	1679.174	0.001068	0.0098	936.0	102.552	287.1	109.1	396.3	1.283	1.609	61
62	1717.104	0.001075	0.0095	930.6	105.438	288.8	107.8	396.6	1.287	1.609	62
63	1755.680	0.001081	0.0092	925.1	108.418	290.4	106.5	396.9	1.292	1.609	63
64	1794.911	0.001088	0.0090	919.5	111.496	292.1	105.1	397.2	1.297	1.609	64
65	1834.805	0.001094	0.0087	913.7	114.676	293.7	103.7	397.5	1.302	1.609	65
66	1875.370	0.001101	0.0085	907.9	117.964	295.4	102.3	397.7	1.307	1.608	66
67	1916.617	0.001109	0.0082	901.9	121.367	297.1	100.9	398.0	1.311	1.608	67
68	1958.553	0.001116	0.0080	895.8	124.891	298.8	99.4	398.2	1.316	1.608	68
69	2001.189	0.001124	0.0078	889.6	128.544	300.5	97.9	398.4	1.321	1.607	69

Saturation Properties—Temperature Table											
Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s	
70	2044. 535	0.001 132	0.007 6	883.2	132.3 32	302.2	96.3	398.6	1.326	1.607	70
71	2088. 600	0.001 141	0.007 3	876.7	136.2 66	304.0	94.8	398.7	1.331	1.606	71
72	2133. 395	0.001 149	0.007 1	870.0	140.3 55	305.7	93.1	398.9	1.336	1.606	72
73	2178. 931	0.001 159	0.006 9	863.1	144.6 11	307.5	91.5	399.0	1.341	1.605	73
74	2225. 219	0.001 168	0.006 7	856.1	149.0 44	309.3	89.8	399.1	1.346	1.605	74
75	2272. 271	0.001 178	0.006 5	848.8	153.6 71	311.1	88.0	399.1	1.351	1.604	75
76	2320. 100	0.001 189	0.006 3	841.4	158.5 05	313.0	86.2	399.2	1.356	1.603	76
77	2368. 717	0.001 199	0.006 1	833.7	163.5 66	314.8	84.3	399.2	1.361	1.602	77
78	2418. 137	0.001 211	0.005 9	825.7	168.8 74	316.7	82.4	399.1	1.366	1.601	78
79	2468. 375	0.001 223	0.005 7	817.5	174.4 54	318.6	80.4	399.0	1.372	1.600	79
80	2519. 445	0.001 236	0.005 5	809.0	180.3 33	320.5	78.4	398.9	1.377	1.599	80

Superheated Vapor—Constant Pressure Tables												
V = Volume in m ³ /kg			H = Enthalpy in kJ/kg			S = Entropy in kJ/kg·K			Saturation Properties in Light Gray			
Absolute Pressure, kPa												
90			100			101.325			110			
-32.15°C			-29.78°C			-29.49°C			-27.60°C			
V	H	S	V	H	S	V	H	S	V	H	S	
Temp [°C]	0.186 9	341.9	1.600	0.169 3	343.5	1.599	0.167 2	343.7	1.599	0.1548	344.9	1.598

-30	0.188 8	343.6	1.607									-30	
-25	0.193 3	347.7	1.623	0.173 2	347.4	1.615	0.170 8	347.3	1.614	0.156 7	347.1	1.607	-25

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
-20	0.1978	351.8	1.640	0.1773	351.5	1.631	0.1748	351.5	1.630	0.1604	351.2
-15	0.2022	355.9	1.656	0.1813	355.6	1.647	0.1788	355.6	1.646	0.1642	355.4
-10	0.2066	360.1	1.672	0.1853	359.9	1.664	0.1828	359.8	1.663	0.1678	359.6
-5	0.2110	364.3	1.688	0.1893	364.1	1.680	0.1867	364.1	1.679	0.1715	363.9
0	0.2153	368.6	1.704	0.1932	368.4	1.695	0.1906	368.4	1.694	0.1751	368.2
5	0.2197	372.9	1.719	0.1971	372.7	1.711	0.1945	372.7	1.710	0.1787	372.5
10	0.2240	377.3	1.735	0.2010	377.1	1.727	0.1983	377.1	1.726	0.1822	376.9
15	0.2283	381.7	1.750	0.2049	381.5	1.742	0.2022	381.5	1.741	0.1858	381.3
20	0.2325	386.1	1.766	0.2088	386.0	1.758	0.2060	385.9	1.757	0.1893	385.8
25	0.2368	390.6	1.781	0.2126	390.5	1.773	0.2098	390.4	1.772	0.1929	390.3
30	0.2410	395.2	1.796	0.2165	395.0	1.788	0.2136	395.0	1.787	0.1964	394.9
35	0.2453	399.8	1.811	0.2203	399.6	1.803	0.2174	399.6	1.802	0.1999	399.5
40	0.2495	404.4	1.826	0.2241	404.2	1.818	0.2211	404.2	1.817	0.2034	404.1
45	0.2537	409.1	1.841	0.2279	408.9	1.833	0.2249	408.9	1.832	0.2068	408.8
50	0.2579	413.8	1.855	0.2317	413.6	1.847	0.2286	413.6	1.846	0.2103	413.5
55	0.2621	418.5	1.870	0.2355	418.4	1.862	0.2324	418.4	1.861	0.2138	418.3
60	0.2663	423.3	1.884	0.2393	423.2	1.877	0.2361	423.2	1.876	0.2172	423.1

Saturation Properties—Temperature Table													
Temp [°C]	Pressure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]		
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s			
65	0.2705	428.2	1.899	0.2431	428.0	1.891	0.2399	428.0	1.890	0.2207	427.9	1.884	65
70	0.2746	433.0	1.913	0.2468	432.9	1.905	0.2436	432.9	1.904	0.2241	432.8	1.898	70
75	0.2788	438.0	1.927	0.2506	437.9	1.920	0.2473	437.8	1.919	0.2275	437.8	1.912	75
80	0.2830	442.9	1.942	0.2544	442.8	1.934	0.2510	442.8	1.933	0.2310	442.7	1.927	80
85	0.2871	447.9	1.956	0.2581	447.8	1.948	0.2547	447.8	1.947	0.2344	447.7	1.941	85
90	0.2913	453.0	1.970	0.2619	452.9	1.962	0.2584	452.9	1.961	0.2378	452.8	1.955	90
95	0.2954	458.1	1.984	0.2656	458.0	1.976	0.2621	458.0	1.975	0.2412	457.9	1.969	95
100	0.2996	463.2	1.997	0.2693	463.1	1.990	0.2658	463.1	1.989	0.2446	463.0	1.982	100
105	0.3037	468.4	2.011	0.2731	468.3	2.003	0.2695	468.3	2.002	0.2480	468.2	1.996	105
110	0.3078	473.6	2.025	0.2768	473.5	2.017	0.2731	473.5	2.016	0.2514	473.4	2.010	110
115	0.3120	478.8	2.038	0.2805	478.7	2.031	0.2768	478.7	2.030	0.2548	478.7	2.024	115
Absolute Pressure, kPa													
120				130				140				150	
-25.56°C				-23.65°C				-21.85°C				-20.15°C	
V		H		S		V		H		S		V	
Temp [°C]	0.1426	346.3	1.598	0.1322	347.6	1.598	0.1233	348.8	1.597	0.1155	349.9	1.597	Temp [°C]
-25	0.1430	346.8	1.600										-25
-20	0.1464	350.9	1.616	0.1346	350.7	1.610	0.1244	350.4	1.603	0.1156	350.1	1.598	-20
-15	0.1499	355.1	1.633	0.1378	354.9	1.626	0.1274	354.6	1.620	0.1184	354.3	1.614	-15

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]		Entropy [kJ/kg·K]		Temp [°C]			
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>			
-10	0.153 3	359.4	1.649	0.140 9	359.1	1.642	0.130 4	358.9	1.636	0.121 2	358.6	1.631	-10
-5	0.156 6	363.6	1.665	0.144 1	363.4	1.659	0.133 3	363.2	1.653	0.124 0	362.9	1.647	-5
0	0.160 0	367.9	1.681	0.147 2	367.7	1.675	0.136 2	367.5	1.669	0.126 7	367.3	1.663	0
5	0.163 3	372.3	1.697	0.150 3	372.1	1.690	0.139 1	371.9	1.684	0.129 4	371.7	1.679	5
10	0.166 6	376.7	1.712	0.153 3	376.5	1.706	0.142 0	376.3	1.700	0.132 1	376.1	1.695	10
15	0.169 9	381.1	1.728	0.156 4	380.9	1.722	0.144 8	380.8	1.716	0.134 8	380.6	1.710	15
20	0.173 1	385.6	1.743	0.159 4	385.4	1.737	0.147 7	385.3	1.731	0.137 5	385.1	1.726	20
25	0.176 4	390.1	1.759	0.162 4	390.0	1.752	0.150 5	389.8	1.747	0.140 1	389.6	1.741	25
30	0.179 6	394.7	1.774	0.165 5	394.5	1.768	0.153 3	394.4	1.762	0.142 8	394.2	1.756	30
35	0.182 8	399.3	1.789	0.168 4	399.1	1.783	0.156 1	399.0	1.777	0.145 4	398.8	1.772	35
40	0.186 1	403.9	1.804	0.171 4	403.8	1.798	0.158 9	403.6	1.792	0.148 0	403.5	1.787	40
45	0.189 3	408.6	1.819	0.174 4	408.5	1.813	0.161 6	408.3	1.807	0.150 6	408.2	1.801	45
50	0.192 5	413.4	1.833	0.177 3	413.2	1.827	0.164 4	413.1	1.822	0.153 2	413.0	1.816	50
55	0.195 6	418.1	1.848	0.180 3	418.0	1.842	0.167 1	417.9	1.836	0.155 7	417.7	1.831	55
60	0.198 8	422.9	1.863	0.183 2	422.8	1.857	0.169 9	422.7	1.851	0.158 3	422.6	1.846	60
65	0.202 0	427.8	1.877	0.186 2	427.7	1.871	0.172 6	427.6	1.865	0.160 9	427.4	1.860	65
70	0.205 1	432.7	1.892	0.189 1	432.6	1.885	0.175 3	432.5	1.880	0.163 4	432.4	1.875	70

Saturation Properties—Temperature Table													
Temp [°C]	Pressure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]		
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s			
75	0.2083	437.6	1.906	0.1920	437.5	1.900	0.1781	437.4	1.894	0.1660	437.3	1.889	75
80	0.2114	442.6	1.920	0.1949	442.5	1.914	0.1808	442.4	1.908	0.1685	442.3	1.903	80
85	0.2146	447.6	1.934	0.1978	447.5	1.928	0.1835	447.4	1.922	0.1711	447.3	1.917	85
90	0.2177	452.7	1.948	0.2007	452.6	1.942	0.1862	452.5	1.937	0.1736	452.4	1.931	90
95	0.2209	457.8	1.962	0.2037	457.7	1.956	0.1889	457.6	1.950	0.1761	457.5	1.945	95
100	0.2240	462.9	1.976	0.2065	462.8	1.970	0.1916	462.7	1.964	0.1786	462.6	1.959	100
105	0.2271	468.1	1.990	0.2094	468.0	1.984	0.1943	467.9	1.978	0.1812	467.8	1.973	105
110	0.2302	473.3	2.003	0.2123	473.2	1.997	0.1970	473.1	1.992	0.1837	473.1	1.987	110
115	0.2334	478.6	2.017	0.2152	478.5	2.011	0.1997	478.4	2.005	0.1862	478.3	2.000	115
120	0.2365	483.9	2.031	0.2181	483.8	2.025	0.2023	483.7	2.019	0.1887	483.6	2.014	120
Superheated Vapor—Constant Pressure Tables													
<i>V</i> = Volume in m ³ /kg				<i>H</i> = Enthalpy in kJ/kg				<i>S</i> = Entropy in kJ/kg·K			Saturation Properties in Light Gray		
Absolute Pressure, kPa													
160				170				180			190		
-18.54°C				-17.00°C				-15.53°C			-14.12°C		
<i>V</i>		<i>H</i>		<i>S</i>		<i>V</i>		<i>H</i>		<i>S</i>		<i>V</i>	
Temp [°C]	0.1086	351.0	1.597	0.1026	352.1	1.597	0.0972	353.0	1.597	0.0923	354.0	1.597	Temp [°C]
-15	0.1105	354.1	1.609	0.1036	353.8	1.603	0.0974	353.5	1.598				-15
-10	0.1132	358.4	1.625	0.1061	358.1	1.620	0.0998	357.8	1.615	0.0942	357.6	1.610	-10
-5	0.1158	362.7	1.641	0.1086	362.4	1.636	0.1022	362.2	1.632	0.0965	362.0	1.627	-5

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table										
		Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]	
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>		
0	0.1184	367.1	1.658	0.1111	366.8	1.653	0.1045	366.6	1.648	0.0987	366.4	1.643
5	0.1210	371.5	1.674	0.1135	371.2	1.669	0.1069	371.0	1.664	0.1009	370.8	1.659
10	0.1235	375.9	1.689	0.1159	375.7	1.684	0.1092	375.5	1.680	0.1031	375.3	1.675
15	0.1261	380.4	1.705	0.1183	380.2	1.700	0.1114	380.0	1.696	0.1053	379.8	1.691
20	0.1286	384.9	1.721	0.1207	384.7	1.716	0.1137	384.5	1.711	0.1074	384.3	1.707
25	0.1311	389.4	1.736	0.1231	389.3	1.731	0.1160	389.1	1.727	0.1096	388.9	1.722
30	0.1335	394.0	1.751	0.1254	393.9	1.747	0.1182	393.7	1.742	0.1117	393.5	1.738
35	0.1360	398.7	1.766	0.1277	398.5	1.762	0.1204	398.4	1.757	0.1138	398.2	1.753
40	0.1385	403.3	1.782	0.1301	403.2	1.777	0.1226	403.0	1.772	0.1159	402.9	1.768
45	0.1409	408.1	1.796	0.1324	407.9	1.792	0.1248	407.8	1.787	0.1180	407.6	1.783
50	0.1433	412.8	1.811	0.1347	412.7	1.807	0.1270	412.5	1.802	0.1201	412.4	1.798
55	0.1458	417.6	1.826	0.1370	417.5	1.821	0.1292	417.3	1.817	0.1222	417.2	1.813
60	0.1482	422.4	1.841	0.1393	422.3	1.836	0.1313	422.2	1.832	0.1242	422.1	1.827
65	0.1506	427.3	1.855	0.1415	427.2	1.850	0.1335	427.1	1.846	0.1263	427.0	1.842
70	0.1530	432.2	1.870	0.1438	432.1	1.865	0.1356	432.0	1.861	0.1283	431.9	1.856
75	0.1554	437.2	1.884	0.1461	437.1	1.879	0.1378	437.0	1.875	0.1303	436.9	1.871
80	0.1578	442.2	1.898	0.1483	442.1	1.894	0.1399	442.0	1.889	0.1324	441.9	1.885

Saturation Properties—Temperature Table													
Temp [°C]	Pressure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]	1.899	85
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s			
85	0.1602	447.2	1.912	0.1506	447.1	1.908	0.1420	447.0	1.903	0.1344	446.9	1.899	85
90	0.1626	452.3	1.926	0.1528	452.2	1.922	0.1442	452.1	1.917	0.1364	452.0	1.913	90
95	0.1649	457.4	1.940	0.1551	457.3	1.936	0.1463	457.2	1.931	0.1384	457.1	1.927	95
100	0.1673	462.6	1.954	0.1573	462.5	1.950	0.1484	462.4	1.945	0.1405	462.3	1.941	100
105	0.1697	467.7	1.968	0.1595	467.6	1.963	0.1505	467.6	1.959	0.1425	467.5	1.955	105
110	0.1720	473.0	1.982	0.1618	472.9	1.977	0.1526	472.8	1.973	0.1445	472.7	1.969	110
115	0.1744	478.2	1.995	0.1640	478.1	1.991	0.1547	478.1	1.987	0.1465	478.0	1.982	115
120	0.1767	483.5	2.009	0.1662	483.4	2.004	0.1568	483.4	2.000	0.1485	483.3	1.996	120
125	0.1791	488.9	2.023	0.1684	488.8	2.018	0.1589	488.7	2.014	0.1505	488.6	2.010	125
130	0.1815	494.2	2.036	0.1706	494.2	2.031	0.1610	494.1	2.027	0.1524	494.0	2.023	130
Absolute Pressure, kPa													
200				210				220				230	
-12.77°C				-11.47°C				-10.22°C				-9.01°C	
V	H	S	V	H	S	V	H	S	V	H	S		
Temp [°C]	0.0879	354.9	1.597	0.0839	355.7	1.597	0.0802	356.6	1.597	0.0769	357.4	1.597	Temp [°C]
-10	0.0891	357.3	1.606	0.0845	357.0	1.602	0.0803	356.8	1.597				-10
-5	0.0913	361.7	1.623	0.0866	361.5	1.618	0.0824	361.2	1.614	0.0785	360.9	1.610	-5
0	0.0934	366.1	1.639	0.0887	365.9	1.635	0.0843	365.7	1.631	0.0804	365.4	1.627	0
5	0.0956	370.6	1.655	0.0907	370.4	1.651	0.0863	370.1	1.647	0.0823	369.9	1.643	5

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
10	0.0977	375.1	1.671	0.0927	374.9	1.667	0.0883	374.7	1.663	0.0842	374.4
15	0.0997	379.6	1.687	0.0947	379.4	1.683	0.0902	379.2	1.679	0.0860	379.0
20	0.1018	384.2	1.703	0.0967	384.0	1.699	0.0921	383.8	1.695	0.0878	383.6
25	0.1039	388.7	1.718	0.0987	388.6	1.714	0.0940	388.4	1.710	0.0896	388.2
30	0.1059	393.4	1.733	0.1006	393.2	1.730	0.0958	393.0	1.726	0.0914	392.9
35	0.1079	398.0	1.749	0.1025	397.9	1.745	0.0977	397.7	1.741	0.0932	397.6
40	0.1099	402.7	1.764	0.1045	402.6	1.760	0.0995	402.4	1.756	0.0950	402.3
45	0.1119	407.5	1.779	0.1064	407.3	1.775	0.1013	407.2	1.771	0.0967	407.0
50	0.1139	412.3	1.794	0.1083	412.1	1.790	0.1032	412.0	1.786	0.0985	411.8
55	0.1159	417.1	1.809	0.1101	417.0	1.805	0.1050	416.8	1.801	0.1002	416.7
60	0.1178	421.9	1.823	0.1120	421.8	1.819	0.1068	421.7	1.816	0.1020	421.6
65	0.1198	426.8	1.838	0.1139	426.7	1.834	0.1086	426.6	1.830	0.1037	426.5
70	0.1217	431.8	1.852	0.1158	431.6	1.849	0.1103	431.5	1.845	0.1054	431.4
75	0.1237	436.7	1.867	0.1176	436.6	1.863	0.1121	436.5	1.859	0.1071	436.4
80	0.1256	441.7	1.881	0.1195	441.6	1.877	0.1139	441.5	1.874	0.1088	441.4
85	0.1275	446.8	1.895	0.1213	446.7	1.891	0.1157	446.6	1.888	0.1105	446.5
90	0.1295	451.9	1.909	0.1231	451.8	1.906	0.1174	451.7	1.902	0.1122	451.6

Saturation Properties—Temperature Table														
Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]			
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s				
95	0.1314	457.0	1.923	0.1250	456.9	1.920	0.1192	456.8	1.916	0.1139	456.7	1.913	95	
100	0.1333	462.2	1.937	0.1268	462.1	1.934	0.1209	462.0	1.930	0.1155	461.9	1.927	100	
105	0.1352	467.4	1.951	0.1286	467.3	1.947	0.1227	467.2	1.944	0.1172	467.1	1.940	105	
110	0.1371	472.6	1.965	0.1305	472.5	1.961	0.1244	472.4	1.958	0.1189	472.3	1.954	110	
115	0.1390	477.9	1.979	0.1323	477.8	1.975	0.1261	477.7	1.971	0.1206	477.6	1.968	115	
120	0.1409	483.2	1.992	0.1341	483.1	1.988	0.1279	483.0	1.985	0.1222	482.9	1.981	120	
125	0.1428	488.5	2.006	0.1359	488.5	2.002	0.1296	488.4	1.998	0.1239	488.3	1.995	125	
130	0.1447	493.9	2.019	0.1377	493.8	2.015	0.1313	493.8	2.012	0.1255	493.7	2.008	130	
135	0.1466	499.3	2.032	0.1395	499.3	2.029	0.1331	499.2	2.025	0.1272	499.1	2.022	135	
Superheated Vapor—Constant Pressure Tables														
$V = \text{Volume in m}^3/\text{kg}$				$H = \text{Enthalpy in kJ/kg}$			$S = \text{Entropy in kJ/kg·K}$			Saturation Properties in Light Gray				
Absolute Pressure, kPa														
240				250			260			270				
-7.84°C				-6.70°C			-5.60°C			-4.54°C				
V		H		S		V		H		S		V		
Temp [°C]	0.0738	358.2	1.597	0.0710	358.9	1.597	0.0684	359.6	1.597	0.0659	360.3	1.597	Temp [°C]	
-5	0.0749	360.7	1.606	0.0716	360.4	1.603	0.0686	360.2	1.599					-5
0	0.0768	365.2	1.623	0.0734	364.9	1.619	0.0703	364.7	1.616	0.0675	364.4	1.612	0	
5	0.0786	369.7	1.639	0.0752	369.5	1.636	0.0721	369.2	1.632	0.0691	369.0	1.629	5	
10	0.0804	374.2	1.656	0.0769	374.0	1.652	0.0738	373.8	1.649	0.0708	373.6	1.645	10	

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
15	0.0822	378.8	1.672	0.0787	378.6	1.668	0.0754	378.4	1.665	0.0724	378.2 1.661 15
20	0.0840	383.4	1.687	0.0804	383.2	1.684	0.0771	383.0	1.681	0.0740	382.8 1.677 20
25	0.0857	388.0	1.703	0.0821	387.9	1.700	0.0787	387.7	1.696	0.0756	387.5 1.693 25
30	0.0874	392.7	1.719	0.0837	392.5	1.715	0.0803	392.4	1.712	0.0772	392.2 1.709 30
35	0.0891	397.4	1.734	0.0854	397.2	1.731	0.0819	397.1	1.727	0.0787	396.9 1.724 35
40	0.0908	402.1	1.749	0.0870	402.0	1.746	0.0835	401.8	1.743	0.0803	401.7 1.739 40
45	0.0925	406.9	1.764	0.0887	406.8	1.761	0.0851	406.6	1.758	0.0818	406.5 1.755 45
50	0.0942	411.7	1.779	0.0903	411.6	1.776	0.0867	411.4	1.773	0.0833	411.3 1.770 50
55	0.0959	416.5	1.794	0.0919	416.4	1.791	0.0882	416.3	1.788	0.0848	416.1 1.785 55
60	0.0976	421.4	1.809	0.0935	421.3	1.806	0.0898	421.2	1.802	0.0863	421.0 1.799 60
65	0.0992	426.3	1.824	0.0951	426.2	1.820	0.0913	426.1	1.817	0.0878	426.0 1.814 65
70	0.1009	431.3	1.838	0.0967	431.2	1.835	0.0928	431.1	1.832	0.0893	430.9 1.829 70
75	0.1025	436.3	1.852	0.0983	436.2	1.849	0.0944	436.1	1.846	0.0907	435.9 1.843 75
80	0.1041	441.3	1.867	0.0998	441.2	1.864	0.0959	441.1	1.861	0.0922	441.0 1.858 80
85	0.1058	446.4	1.881	0.1014	446.3	1.878	0.0974	446.2	1.875	0.0937	446.1 1.872 85
90	0.1074	451.5	1.895	0.1030	451.4	1.892	0.0989	451.3	1.889	0.0951	451.2 1.886 90
95	0.1090	456.6	1.909	0.1045	456.5	1.906	0.1004	456.4	1.903	0.0966	456.3 1.900 95

Saturation Properties—Temperature Table													
Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]		
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s			
100	0.1106	461.8	1.923	0.1061	461.7	1.920	0.1019	461.6	1.917	0.0980	461.5	1.914	100
105	0.1122	467.0	1.937	0.1076	466.9	1.934	0.1034	466.8	1.931	0.0995	466.7	1.928	105
110	0.1138	472.3	1.951	0.1092	472.2	1.948	0.1049	472.1	1.945	0.1009	472.0	1.942	110
115	0.1154	477.5	1.965	0.1107	477.4	1.961	0.1064	477.4	1.958	0.1023	477.3	1.956	115
120	0.1170	482.9	1.978	0.1122	482.8	1.975	0.1078	482.7	1.972	0.1038	482.6	1.969	120
125	0.1186	488.2	1.992	0.1138	488.1	1.989	0.1093	488.0	1.986	0.1052	488.0	1.983	125
130	0.1202	493.6	2.005	0.1153	493.5	2.002	0.1108	493.4	1.999	0.1066	493.4	1.996	130
135	0.1218	499.0	2.019	0.1168	499.0	2.015	0.1123	498.9	2.012	0.1080	498.8	2.010	135
140	0.1234	504.5	2.032	0.1184	504.4	2.029	0.1137	504.3	2.026	0.1094	504.3	2.023	140
Absolute Pressure, kPa													
280				290				300				310	
-3.50°C				-2.49°C				-1.51°C				-0.55°C	
V		H		S		V		H		S		V	
Temp [°C]	0.0637	361.0	1.597	0.0615	361.7	1.597	0.0596	362.3	1.598	0.0577	362.9	1.598	Temp [°C]
0	0.0648	364.2	1.609	0.0623	363.9	1.606	0.0600	363.7	1.603	0.0579	363.4	1.600	0
5	0.0664	368.8	1.626	0.0639	368.5	1.622	0.0616	368.3	1.619	0.0594	368.1	1.616	5
10	0.0680	373.4	1.642	0.0655	373.2	1.639	0.0631	372.9	1.636	0.0609	372.7	1.633	10
15	0.0696	378.0	1.658	0.0670	377.8	1.655	0.0646	377.6	1.652	0.0623	377.4	1.649	15
20	0.0712	382.6	1.674	0.0685	382.4	1.671	0.0661	382.2	1.668	0.0638	382.0	1.665	20

Temp [°C]	Press ure [kPa]	Saturation Properties—Temperature Table									
		Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid <i>v</i>	Vapor <i>v</i>	Liquid <i>d</i>	Vapor <i>d</i>	Liquid <i>h</i>	Latent <i>h</i>	Vapor <i>h</i>	Liquid <i>s</i>	Vapor <i>s</i>	
25	0.0727	387.3	1.690	0.0700	387.1	1.687	0.0675	386.9	1.684	0.0652	386.8
30	0.0742	392.0	1.706	0.0715	391.8	1.703	0.0690	391.7	1.700	0.0666	391.5
35	0.0757	396.7	1.721	0.0730	396.6	1.718	0.0704	396.4	1.715	0.0680	396.2
40	0.0772	401.5	1.736	0.0744	401.4	1.734	0.0718	401.2	1.731	0.0693	401.0
45	0.0787	406.3	1.752	0.0758	406.2	1.749	0.0732	406.0	1.746	0.0707	405.9
50	0.0802	411.1	1.767	0.0773	411.0	1.764	0.0746	410.9	1.761	0.0720	410.7
55	0.0816	416.0	1.782	0.0787	415.9	1.779	0.0759	415.7	1.776	0.0733	415.6
60	0.0831	420.9	1.797	0.0801	420.8	1.794	0.0773	420.6	1.791	0.0747	420.5
65	0.0845	425.8	1.811	0.0815	425.7	1.808	0.0786	425.6	1.806	0.0760	425.5
70	0.0860	430.8	1.826	0.0829	430.7	1.823	0.0800	430.6	1.820	0.0773	430.5
75	0.0874	435.8	1.840	0.0842	435.7	1.838	0.0813	435.6	1.835	0.0786	435.5
80	0.0888	440.9	1.855	0.0856	440.8	1.852	0.0827	440.6	1.849	0.0799	440.5
85	0.0902	445.9	1.869	0.0870	445.8	1.866	0.0840	445.7	1.864	0.0812	445.6
90	0.0916	451.1	1.883	0.0884	451.0	1.880	0.0853	450.9	1.878	0.0825	450.7
95	0.0930	456.2	1.897	0.0897	456.1	1.894	0.0866	456.0	1.892	0.0837	455.9
100	0.0944	461.4	1.911	0.0911	461.3	1.909	0.0879	461.2	1.906	0.0850	461.1
105	0.0958	466.6	1.925	0.0924	466.5	1.922	0.0892	466.4	1.920	0.0863	466.3

Temp [°C]	Press ure [kPa]	Volume [m ³ /kg]		Density [kg/m ³]		Enthalpy [kJ/kg]			Entropy [kJ/kg·K]		Temp [°C]
		Liquid v	Vapor v	Liquid d	Vapor d	Liquid h	Latent h	Vapor h	Liquid s	Vapor s	
110	0.0972	471.9	1.939	0.0938	471.8	1.936	0.0905	471.7	1.934	0.0875	471.6
115	0.0986	477.2	1.953	0.0951	477.1	1.950	0.0918	477.0	1.947	0.0888	476.9
120	0.1000	482.5	1.966	0.0964	482.4	1.964	0.0931	482.3	1.961	0.0901	482.3
125	0.1013	487.9	1.980	0.0978	487.8	1.977	0.0944	487.7	1.975	0.0913	487.6
130	0.1027	493.3	1.993	0.0991	493.2	1.991	0.0957	493.1	1.988	0.0926	493.0
135	0.1041	498.7	2.007	0.1004	498.6	2.004	0.0970	498.6	2.002	0.0938	498.5
140	0.1055	504.2	2.020	0.1017	504.1	2.017	0.0983	504.0	2.015	0.0950	504.0
145	0.1068	509.7	2.033	0.1031	509.6	2.031	0.0996	509.6	2.028	0.0963	509.5

Figure 2-16 Pressure-enthalpy diagram for Refrigerant 1234yf. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., M.O. McLinden, and M. L. Huber, 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology). Provided by Chemours.

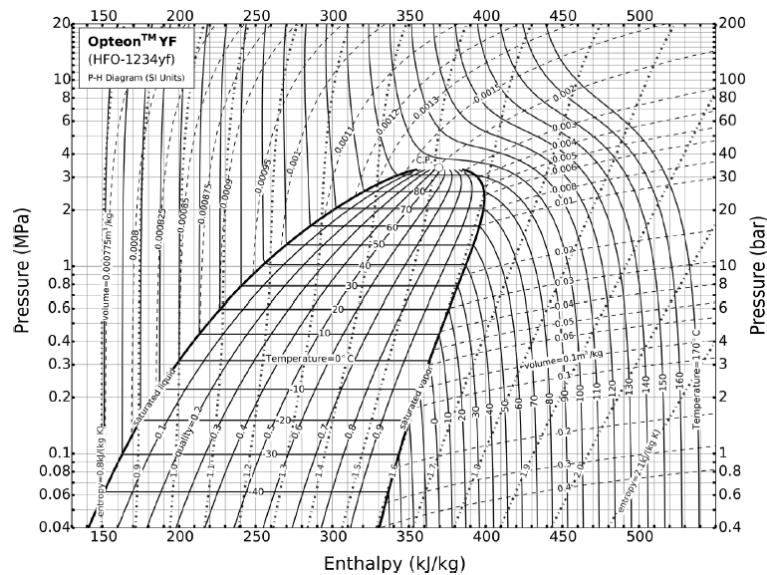


Table 2-133 Thermophysical Properties of Saturated Seawater

Temp., °C	Pressure, bar	$v, (\text{m}^3/\text{kg}) \times 10^3$	$c_p, \text{kJ}/(\text{kg}\cdot\text{K})$	$\mu, \text{Ns/m}^2$	$k, \text{W}/(\text{m}\cdot\text{K})$	N_{Pr}	$10^5 k, 1/\text{bar}$
0	0.005993	1.000158	4.000	0.001884	0.560	13.46	5.06
1	0.006438	1.000099	4.000	0.001827	0.563	12.98	5.02
2	0.006916	1.000057	4.000	0.001772	0.565	12.55	4.98
3	0.007427	1.000033	4.000	0.001720	0.567	12.13	4.95
4	0.007970	1.000025	4.001	0.001669	0.569	11.74	4.92
5	0.008548	1.000033	4.001	0.001620	0.571	11.35	4.89
6	0.009163	1.000057	4.001	0.001574	0.574	10.97	4.86
7	0.009816	1.000096	4.002	0.001529	0.576	10.62	4.83
8	0.010511	1.000149	4.002	0.001486	0.578	10.29	4.80
9	0.011248	1.000261	4.002	0.001445	0.580	9.97	4.78
10	0.01203	1.000298	4.003	0.001405	0.582	9.70	4.76
11	0.01286	1.000392	4.003	0.001367	0.584	9.37	4.74
12	0.01374	1.000500	4.003	0.001330	0.586	9.09	4.72
13	0.01467	1.000620	4.004	0.001294	0.588	8.81	4.70
14	0.01566	1.000727	4.004	0.001259	0.590	8.54	4.68
15	0.01671	1.000899	4.005	0.001226	0.592	8.29	4.66
16	0.01781	1.001055	4.005	0.001195	0.594	8.06	4.65
17	0.01898	1.001224	4.006	0.001165	0.595	7.82	4.63
18	0.02022	1.001404	4.006	0.001136	0.597	7.62	4.62
19	0.02153	1.001595	4.007	0.001107	0.599	7.41	4.60
20	0.02291	1.001796	4.007	0.001080	0.600	7.21	4.59
21	0.02437	1.002009	4.007	0.001054	0.602	7.02	4.57
22	0.02591	1.002232	4.008	0.001029	0.604	6.82	4.56
23	0.02753	1.002465	4.008	0.001005	0.605	6.66	4.55
24	0.02924	1.002708	4.009	0.000981	0.607	6.48	4.54
25	0.03104	1.002961	4.009	0.000958	0.608	6.31	4.53
26	0.03294	1.003224	4.009	0.000936	0.609	6.16	4.52

Temp., °C	Pressure, bar	$v, (\text{m}^3/\text{kg}) \cdot 10^3$	$c, \text{kJ}/(\text{kg}\cdot\text{K})$	$\mu, \text{Ns/m}$	$k, \text{W}/(\text{m}\cdot\text{K})$	N	$10^3 \kappa, 1/\text{bar}$
27	0.03494	1.003496	4.010	0.000915	0.611	6.01	4.51
28	0.03705	1.003778	4.010	0.000895	0.612	5.86	4.50
29	0.03926	1.004069	4.011	0.000875	0.614	5.72	4.49
30	0.04159	1.004369	4.011	0.000855	0.615	5.58	4.48

$\kappa = (-1/V)(\partial v/\partial p)_T \cdot 10^5$. Thus, at 0°C, the compressibility is $5.06 \times 10^{-5}/\text{bar}$.

For further information see, for instance, Bromley, LeR. A., *J. Chem. Eng. Data*, **12**, 2 (1967): 202–206; **13**, 1 (1968): 60–62 and **13**, 3: 399–402; **15**, 2 (1970): 246–253; and *A.I.Ch.E.J.*, **20**, 2 (1974): 326–335.

Thermal conductivity data sources include Castelli, V. J., E. M. Stanley, et al., *Deep Sea Res.*, **211** (1974): 311–318; Levy, F. L., *Int. J. Refrig.*, **5**, 3 (1982): 155–159.

For velocity of sound, see, for instance, U.S. Naval Oceanographic Office SP 58, 1962 (50 pp.). More recent information is contained in UNESCO technical papers. See *Marine Science No. 38*, 1981 (6 pp.) and No. 44, 1983 (53 pp.).

For sea ice properties, see Fukusako, S., *Int. J. Thermophys.*, **11**, 2 (1990): 353–372.

Figure 2-17 Enthalpy-concentration diagram for aqueous sodium hydroxide at 1 atm. Reference states: enthalpy of liquid water at 32°F and vapor pressure is zero; partial molal enthalpy of infinitely dilute NaOH solution at 64°F and 1 atm is zero. [W.L. McCabe, *Trans. Am. Inst. Chem. Eng.*, **31**: 129 (1935).]

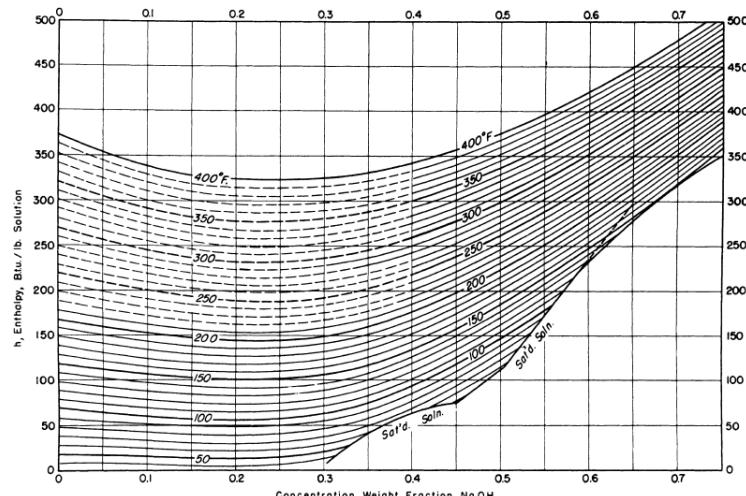


Figure 2-18 Enthalpy-concentration diagram for aqueous sulfuric acid at 1 atm. Reference states: enthalpies of pure-liquid components at 32°F and vapor pressures are zero. Note: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. The upper ends of the tie lines in this region are assumed to be pure water. (O.A. Hougen and K.M. Watson, *Chemical Process Principles, part I*, Wiley, New York, 1943.)

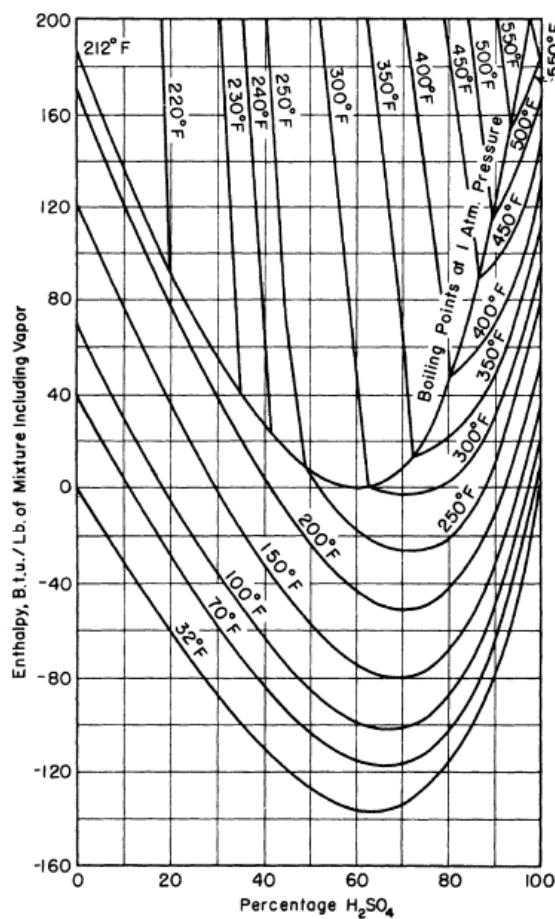


Table 2-134 Saturated Solid/Vapor Water*

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Solid	Vapor	Solid	Vapor	Solid	Vapor
-160	4.949.-8	0.01722	3.607.+9	-222.05	990.38	-0.4907	3.5549
-150	1.620.-7	0.01723	1.139.+9	-218.82	994.80	-0.4801	3.4387
-140	4.928.-7	0.01724	3.864.+8	-215.49	999.21	-0.4695	3.3301
-130	1.403.-6	0.01725	1.400.+8	-212.08	1003.63	-0.4590	3.2284
-120	3.757.-6	0.01726	5.386.+7	-208.58	1008.05	-0.4485	3.1330
-110	9.517.-6	0.01728	2.189.+7	-204.98	1012.47	-0.4381	3.0434
-100	2.291.-5	0.01729	9.352.+6	-201.28	1016.89	-0.4277	2.9591
-90	5.260.-5	0.01730	4.186.+6	-197.49	1021.31	-0.4173	2.8796

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Solid	Vapor	Solid	Vapor	Solid	Vapor
-80	1.157.-4	0.01731	1.955.+6	-193.60	1025.73	-0.4069	2.8045
-70	2.443.-4	0.01732	9.501.+5	-189.61	1030.15	-0.3965	2.7336
-60	4.972.-4	0.01734	4.788.+5	-185.52	1034.58	-0.3862	2.6664
-50	9.776.-4	0.01735	2.496.+5	-181.34	1039.00	-0.3758	2.6028
-45	1.354.-3	0.01736	1.824.+5	-179.21	1041.21	-0.3707	2.5723
-40	1.861.-3	0.01737	1.343.+5	-177.06	1043.42	-0.3655	2.5425
-35	2.540.-3	0.01737	9.961.+4	-174.88	1045.63	-0.3604	2.5135
-30	3.440.-3	0.01738	7.441.+4	-172.68	1047.84	-0.3552	2.4853
-25	4.627.-3	0.01739	5.596.+4	-170.46	1050.05	-0.3501	2.4577
-20	6.181.-3	0.01739	4.237.+4	-168.21	1052.26	-0.3449	2.4308
-15	8.204.-3	0.01740	3.228.+4	-165.94	1054.47	-0.3398	2.4046
-10	1.082.-2	0.01741	2.475.+4	-163.65	1056.67	-0.3347	2.3791
-5	1.419.-2	0.01741	1.909.+4	-161.33	1058.88	-0.3295	2.3541
0	1.849.-2	0.01742	1.481.+4	-158.98	1061.09	-0.3244	2.3297
5	2.396.-2	0.01743	1.155.+4	-156.61	1063.29	-0.3193	2.3039
10	3.087.-2	0.01744	9.060.+3	-154.22	1065.50	-0.3142	2.2827
15	3.957.-2	0.01744	7.144.+3	-151.80	1067.70	-0.3090	2.2600
16	4.156.-2	0.01745	6.817.+3	-151.32	1068.14	-0.3080	2.2555
18	4.581.-2	0.01745	6.210.+3	-150.34	1069.02	-0.3060	2.2466
20	5.045.-2	0.01745	5.662.+3	-149.36	1069.90	-0.3039	2.2378
22	5.552.-2	0.01746	5.166.+3	-148.38	1070.38	-0.3019	2.2291
24	6.105.-2	0.01746	4.717.+3	-147.39	1071.66	-0.2998	2.2205
26	6.708.-2	0.01746	4.311.+3	-146.40	1072.53	-0.2978	2.2119
28	7.365.-2	0.01746	3.943.+3	-145.40	1073.41	-0.2957	2.2034
30	8.080.-2	0.01747	3.608.+3	-144.40	1074.29	-0.2937	2.1950
31	8.461.-2	0.01747	3.453.+3	-143.90	1074.73	-0.2927	2.1908

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Solid	Vapor	Solid	Vapor	Solid	Vapor
32	8.858.-2	0.01747	3.305.+3	-143.40	1075.16	-0.2916	2.1867

*Condensed from *Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1967 and 1972. Reproduced by permission. The validity of many standard reference tables has been critically reviewed by Jancso, Pupezin, and van Hook, *J. Phys. Chem.*, 74 (1970):2984. Current information on the properties of solid, vapor, and liquid water properties can be found at <http://www.iapws.org>. The notation 4.949.-8, 3.607.+9, etc., means 4.949×10^{-8} , 3.607×10^9 , etc.

Table 2-135 Thermodynamic Properties of Water

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity $\mu\text{Pa}\cdot\text{s}$
Saturated Properties												
273.16	0.000612	55.497	0.018019	0	1.1E-05	0	0.075978	0.076023	1402.3	-0.24142	561.04	1791.2
280	0.000992	55.501	0.018018	0.51875	0.51877	0.001876	0.075669	0.075688	1434.1	-0.23515	574.04	1433.7
290	0.001920	55.440	0.018038	1.2742	1.2742	0.004527	0.075095	0.075429	1472.1	-0.22720	592.73	1084.0
300	0.003537	55.315	0.018078	2.0278	2.0279	0.007082	0.074412	0.075320	1501.4	-0.22024	610.28	853.84
310	0.006231	55.139	0.018136	2.7808	2.7810	0.009551	0.073645	0.075294	1523.2	-0.21393	626.05	693.54
320	0.010546	54.919	0.018209	3.5339	3.5340	0.011941	0.072811	0.075317	1538.7	-0.20804	639.71	577.02
330	0.017213	54.662	0.018294	4.2873	4.2876	0.014260	0.071927	0.075373	1548.7	-0.20241	651.18	489.49
340	0.027188	54.371	0.018392	5.0414	5.0419	0.016511	0.071008	0.075456	1553.9	-0.19690	660.55	421.97
350	0.041682	54.049	0.018502	5.7964	5.7972	0.018700	0.070070	0.075567	1554.8	-0.19140	668.00	368.77
360	0.062194	53.698	0.018623	6.5526	6.5538	0.020830	0.069124	0.075708	1552.0	-0.18581	673.76	326.10
370	0.090535	53.321	0.018754	7.3104	7.3121	0.022906	0.068180	0.075883	1545.8	-0.18005	678.02	291.36
380	0.12885	52.918	0.018897	8.0701	8.0725	0.024932	0.067247	0.076098	1536.5	-0.17404	681.00	262.69
390	0.17964	52.490	0.019051	8.8320	8.8354	0.026911	0.066331	0.076357	1524.3	-0.16769	682.83	238.77

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
400	0.24577	52.038	0.019217	9.5966	9.6013	0.028847	0.065438	0.076664	1509.5	-0.16092	683.64	218.60
410	0.33045	51.563	0.019394	10.364	10.371	0.030743	0.064570	0.077026	1492.2	-0.15366	683.52	201.43
420	0.43730	51.064	0.019583	11.136	11.144	0.032602	0.063731	0.077447	1472.5	-0.14581	682.53	186.68
430	0.57026	50.541	0.019786	11.911	11.923	0.034427	0.062920	0.077934	1450.6	-0.13728	680.70	173.91
440	0.73367	49.994	0.020003	12.692	12.706	0.036222	0.062140	0.078495	1426.5	-0.12794	678.05	162.77
450	0.9322	49.421	0.020234	13.477	13.496	0.037988	0.061390	0.079136	1400.4	-0.11767	674.59	152.98
460	1.1709	48.824	0.020482	14.269	14.293	0.039729	0.060671	0.079869	1372.2	-0.10631	670.28	144.31
470	1.4551	48.199	0.020748	15.068	15.098	0.041448	0.059984	0.080706	1342.0	-0.09369	665.12	136.58
480	1.7905	47.545	0.021033	15.875	15.913	0.043147	0.059327	0.081662	1309.8	-0.07959	659.07	129.64
490	2.1831	46.861	0.021340	16.690	16.737	0.044830	0.058702	0.082757	1275.7	-0.06372	652.06	123.37
500	2.6392	46.145	0.021671	17.515	17.573	0.046498	0.058109	0.084013	1239.6	-0.04578	644.05	117.66
510	3.1655	45.393	0.022030	18.352	18.421	0.048156	0.057548	0.085464	1201.5	-0.02534	634.95	112.42
520	3.7690	44.603	0.022420	19.200	19.285	0.049807	0.057023	0.087149	1161.3	-0.00189	624.68	107.57
530	4.4569	43.770	0.022847	20.064	20.165	0.051454	0.056536	0.089124	1119.1	0.025264	613.15	103.05
540	5.2369	42.889	0.023316	20.943	21.065	0.053102	0.056089	0.091464	1074.6	0.057002	600.26	98.792
550	6.1172	41.954	0.023836	21.841	21.987	0.054756	0.055690	0.094275	1027.9	0.094527	585.95	94.746
560	7.1062	40.956	0.024417	22.762	22.935	0.056422	0.055347	0.097713	978.54	0.13949	570.21	90.857
570	8.2132	39.885	0.025072	23.709	23.915	0.058106	0.055071	0.10201	926.44	0.19425	553.08	87.074

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
580	9.448	38.725	0.025823	24.688	24.932	0.059821	0.054881	0.10754	871.23	0.26220	534.74	83.342
590	10.821	37.456	0.026698	25.707	25.996	0.061577	0.054808	0.11491	812.49	0.34857	515.43	79.600
600	12.345	36.048	0.027741	26.777	27.119	0.063396	0.054902	0.12526	749.57	0.46172	495.46	75.773
610	14.033	34.451	0.029026	27.917	28.324	0.065309	0.055258	0.14100	681.27	0.61660	475.03	71.759
620	15.901	32.577	0.030697	29.160	29.648	0.067371	0.056100	0.16852	604.73	0.84473	454.10	67.382
630	17.969	30.210	0.033101	30.585	31.180	0.069715	0.058152	0.23108	513.19	1.2251	432.51	62.244
640	20.265	26.729	0.037413	32.422	33.180	0.072737	0.064521	0.46736	400.66	1.9542	414.93	55.247
647.1	22.064	17.874	0.055948	36.314	37.548	0.079393			0	3.7410		
273.16	0.000612	0.000269	3711.0	42.785	45.055	0.16494	0.025553	0.033947	409.00	592.65	17.071	9.2163
280	0.000992	0.000426	2345.4	42.954	45.280	0.16174	0.025657	0.034073	413.92	477.26	17.442	9.3815
290	0.001920	0.000797	1254.3	43.201	45.609	0.15741	0.025816	0.034270	420.99	351.65	18.031	9.6414
300	0.003537	0.001420	704.01	43.446	45.936	0.15344	0.025982	0.034483	427.89	264.35	18.673	9.9195
310	0.006231	0.002424	412.60	43.690	46.261	0.14981	0.026158	0.034716	434.63	203.74	19.369	10.213
320	0.010546	0.003978	251.39	43.931	46.582	0.14647	0.026350	0.034980	441.18	161.25	20.117	10.518
330	0.017213	0.006304	158.62	44.169	46.900	0.14339	0.026568	0.035287	447.54	130.92	20.922	10.833
340	0.027188	0.009681	103.30	44.404	47.212	0.14054	0.026821	0.035653	453.68	108.77	21.784	11.157
350	0.041682	0.014448	69.213	44.634	47.519	0.13791	0.027118	0.036091	459.58	92.178	22.707	11.487
360	0.062194	0.021014	47.586	44.860	47.819	0.13546	0.027469	0.036617	465.22	79.440	23.695	11.823

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
370	0.090535	0.029859	33.491	45.079	48.111	0.13317	0.027883	0.037249	470.57	69.427	24.750	12.162
380	0.12885	0.041537	24.075	45.291	48.393	0.13104	0.028372	0.038004	475.61	61.373	25.875	12.504
390	0.17964	0.056683	17.642	45.496	48.665	0.12904	0.028944	0.038903	480.32	54.749	27.074	12.848
400	0.24577	0.076014	13.156	45.691	48.924	0.12715	0.029608	0.039963	484.67	49.181	28.347	13.192
410	0.33045	0.10034	9.9666	45.876	49.170	0.12537	0.030369	0.041203	488.65	44.405	29.699	13.538
420	0.43730	0.13055	7.6601	46.050	49.400	0.12369	0.031230	0.042634	492.22	40.237	31.128	13.883
430	0.57026	0.16765	5.9649	46.211	49.613	0.12208	0.032187	0.044269	495.39	36.550	32.638	14.228
440	0.73367	0.21276	4.7002	46.359	49.807	0.12054	0.033234	0.046114	498.12	33.259	34.230	14.573
450	0.93220	0.26711	3.7438	46.492	49.982	0.11907	0.034362	0.048177	500.41	30.307	35.904	14.917
460	1.1709	0.33209	3.0113	46.609	50.134	0.11764	0.035561	0.050469	502.24	27.653	37.663	15.261
470	1.4551	0.40925	2.4435	46.708	50.263	0.11627	0.036821	0.053005	503.60	25.265	39.512	15.606
480	1.7905	0.50035	1.9986	46.788	50.367	0.11493	0.038137	0.055809	504.45	23.118	41.455	15.952
490	2.1831	0.60738	1.6464	46.848	50.442	0.11362	0.039503	0.058919	504.78	21.187	43.502	16.300
500	2.6392	0.73265	1.3649	46.885	50.487	0.11233	0.040920	0.062388	504.55	19.450	45.666	16.653
510	3.1655	0.87884	1.1379	46.898	50.500	0.11105	0.042391	0.066289	503.71	17.886	47.969	17.011
520	3.7690	1.04918	0.95318	46.883	50.475	0.10979	0.043920	0.070723	502.23	16.475	50.442	17.377
530	4.4569	1.24734	0.80174	46.838	50.411	0.10852	0.045519	0.075827	500.05	15.197	53.130	17.755
540	5.2369	1.47809	0.67659	46.758	50.302	0.10724	0.047197	0.081789	497.10	14.035	56.102	18.149

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
550	6.1172	1.7471	0.57238	46.641	50.142	0.10595	0.048968	0.088873	493.31	12.973	59.456	18.563
560	7.1062	2.0620	0.48497	46.478	49.925	0.10462	0.050848	0.097461	488.58	11.997	63.341	19.007
570	8.2132	2.4325	0.41110	46.264	49.641	0.10324	0.052856	0.10813	482.79	11.093	67.981	19.489
580	9.4480	2.8720	0.34819	45.988	49.278	0.10180	0.055017	0.12178	475.80	10.248	73.721	20.024
590	10.821	3.3994	0.29417	45.636	48.819	0.10026	0.057361	0.13994	467.41	9.4499	81.108	20.634
600	12.345	4.0434	0.24732	45.188	48.242	0.098600	0.059939	0.16540	457.33	8.6837	91.052	21.350
610	14.033	4.8497	0.20620	44.613	47.506	0.096755	0.062831	0.20384	445.11	7.9329	105.17	22.229
620	15.901	5.9009	0.16946	43.855	46.550	0.094631	0.066197	0.26923	429.99	7.1743	126.66	23.374
630	17.969	7.3737	0.13562	42.801	45.238	0.092029	0.070465	0.40819	410.21	6.3669	163.44	25.018
640	20.265	9.8331	0.10170	41.095	43.156	0.088324	0.077576	0.94736	379.64	5.3854	250.01	27.938
647.1	22.064	17.874	0.055948	36.314	37.548	0.079393			0	3.7410		

Single-Phase Properties

300	0.1	55.317	0.018078	2.0277	2.0295	0.007081	0.074406	0.075315	1501.5	-0.22024	610.32	853.83
372.76	0.1	53.212	0.018793	7.5196	7.5214	0.02347	0.067921	0.075938	1543.5	-0.17843	678.97	282.91
372.76	0.1	0.032769	30.517	45.138	48.190	0.13257	0.02801	0.037444	471.99	67.038	25.053	12.256
400	0.1	0.030397	32.898	45.900	49.189	0.13516	0.02717	0.036170	490.31	47.254	27.008	13.285
500	0.1	0.024154	41.401	48.619	52.759	0.14313	0.02717	0.035693	548.31	19.298	35.861	17.270
600	0.1	0.020086	49.786	51.387	56.365	0.14970	0.028103	0.036513	598.61	10.567	46.367	21.407
700	0.1	0.017201	58.136	54.256	60.069	0.15541	0.029225	0.037592	643.92	6.6444	57.964	25.564

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
800	0.1	0.015044	66.471	57.240	63.887	0.16050	0.030431	0.038778	685.47	4.5167	70.385	29.669
900	0.1	0.013369	74.799	60.347	67.827	0.16514	0.031687	0.040024	724.03	3.2280	83.466	33.685
1000	0.1	0.012030	83.123	63.581	71.893	0.16943	0.032963	0.041293	760.17	2.3885	97.085	37.592
1100	0.1	0.010936	91.444	66.941	76.085	0.17342	0.034228	0.042554	794.33	1.8122	111.15	41.382
1200	0.1	0.010024	99.763	70.426	80.402	0.17718	0.035458	0.043781	826.85	1.4006	125.58	45.054
300	1	55.340	0.018070	2.0263	2.0444	0.007077	0.074353	0.075270	1503.0	-0.22022	610.73	853.67
400	1	52.060	0.019209	9.5914	9.6106	0.028834	0.065422	0.076628	1511.3	-0.16113	684.10	218.80
453.03	1	49.243	0.020307	13.717	13.737	0.038518	0.061169	0.079348	1392.0	-0.11435	673.37	150.24
453.03	1	0.28559	3.5015	46.529	50.030	0.11863	0.034718	0.048846	501.02	29.473	36.427	15.021
500	1	0.25158	3.9749	48.111	52.086	0.12295	0.030084	0.041065	535.74	19.741	38.799	17.051
600	1	0.20466	4.8861	51.123	56.009	0.13011	0.029002	0.038358	592.58	10.615	47.636	21.329
700	1	0.17377	5.7547	54.087	59.842	0.13602	0.029629	0.038495	640.55	6.6387	58.735	25.550
800	1	0.15134	6.6074	57.121	63.729	0.14121	0.030651	0.039301	683.48	4.5077	70.983	29.687
900	1	0.13418	7.4524	60.258	67.710	0.14590	0.031821	0.040358	722.85	3.2212	84.000	33.718
1000	1	0.12058	8.2932	63.511	71.804	0.15021	0.033051	0.041522	759.50	2.3837	97.573	37.630
1100	1	0.10951	9.1313	66.885	76.016	0.15422	0.034290	0.042719	794.01	1.8089	111.57	41.420
1200	1	0.10032	9.9677	70.380	80.347	0.15799	0.035504	0.043905	826.77	1.3982	125.89	45.088
300	5	55.439	0.018038	2.0204	2.1106	0.007057	0.074119	0.075070	1509.8	-0.22012	612.54	853.00

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
400	5	52.173	0.019167	9.5643	9.6601	0.028766	0.065337	0.076438	1520.9	-0.16222	686.54	219.84
500	5	46.267	0.021614	17.474	17.582	0.046415	0.058082	0.083643	1250.0	-0.04945	646.52	118.27
537.09	5	43.151	0.023175	20.685	20.801	0.052622	0.056215	0.090740	1087.8	0.047232	604.15	100.01
537.09	5	1.4072	0.71063	46.785	50.338	0.10762	0.046699	0.079952	498.04	14.362	55.203	18.032
600	5	1.1320	0.88340	49.734	54.151	0.11436	0.034611	0.051045	561.07	10.407	54.653	21.062
700	5	0.91269	1.0957	53.286	58.765	0.12148	0.031678	0.043318	624.59	6.5536	62.680	25.547
800	5	0.77805	1.2853	56.576	63.002	0.12714	0.031683	0.041848	674.39	4.4532	73.950	29.806
900	5	0.68224	1.4658	59.855	67.183	0.13207	0.032430	0.041922	717.57	3.1856	86.626	33.891
1000	5	0.60918	1.6416	63.197	71.405	0.13652	0.033447	0.042571	756.57	2.3599	99.971	37.821
1100	5	0.55109	1.8146	66.632	75.705	0.14061	0.034565	0.043465	792.63	1.7924	113.64	41.606
1200	5	0.50355	1.9859	70.172	80.101	0.14444	0.035704	0.044458	826.45	1.3865	127.51	45.257
300	10	55.561	0.017998	2.0131	2.1931	0.007031	0.073834	0.074829	1518.2	-0.21999	614.81	852.28
400	10	52.312	0.019116	9.5311	9.7222	0.028682	0.065233	0.076208	1532.7	-0.16351	689.57	221.13
500	10	46.517	0.021497	17.389	17.604	0.046244	0.058028	0.082910	1271.3	-0.05669	651.64	119.55
584.15	10	38.213	0.026169	25.105	25.367	0.060543	0.054835	0.11032	847.33	0.29540	526.83	81.795
584.15	10	3.0787	0.32482	45.852	49.100	0.10117	0.055964	0.128640	472.51	9.9124	76.543	20.267
600	10	2.7628	0.36195	47.183	50.802	0.10405	0.047271	0.092535	503.34	9.4382	71.110	21.036
700	10	1.9625	0.50956	52.145	57.241	0.11405	0.034838	0.051779	602.20	6.3228	69.301	25.704

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
800	10	1.6157	0.61893	55.851	62.040	0.12046	0.033089	0.045603	662.61	4.3529	78.476	30.054
900	10	1.3945	0.71709	59.334	66.505	0.12572	0.033219	0.044062	710.98	3.1289	90.516	34.176
1000	10	1.2345	0.81002	62.798	70.898	0.13035	0.033947	0.043952	753.03	2.3241	103.50	38.111
1100	10	1.1111	0.90002	66.314	75.314	0.13456	0.034908	0.044427	791.02	1.7683	116.73	41.882
1200	10	1.0119	0.98820	69.910	79.792	0.13846	0.035954	0.045164	826.16	1.3695	130.00	45.506
300	100	57.573	0.017369	1.8921	3.6290	0.006516	0.069812	0.071696	1667.9	-0.21618	654.50	856.88
400	100	54.500	0.018349	9.0423	10.877	0.027360	0.063582	0.073086	1717.3	-0.17905	741.80	243.50
500	100	49.914	0.020034	16.289	18.292	0.043895	0.057324	0.075607	1555.7	-0.12564	730.42	138.92
600	100	43.935	0.022761	23.820	26.097	0.058109	0.052776	0.081104	1300.4	-0.02079	645.83	101.51
700	100	36.179	0.027640	31.916	34.680	0.071320	0.049610	0.091576	1020.0	0.21155	510.14	79.363
800	100	26.768	0.037359	40.700	44.435	0.084331	0.047143	0.10108	813.97	0.65939	351.46	62.042
900	100	19.073	0.052429	48.805	54.048	0.095669	0.043932	0.088057	765.30	1.0399	257.03	53.250
1000	100	14.734	0.067868	55.188	61.975	0.10404	0.041345	0.071678	792.50	1.0944	232.07	51.518
1100	100	12.246	0.081656	60.470	68.635	0.11039	0.040131	0.062539	832.67	0.98401	223.70	52.497
1200	100	10.631	0.094062	65.222	74.628	0.11561	0.039810	0.057826	872.28	0.83544	219.07	54.415
300	500	63.750	0.015686	1.5247	9.3678	0.003746	0.063403	0.068296	2228.6	-0.19915	763.82	1089.4
400	500	60.862	0.016431	7.9635	16.179	0.023347	0.059634	0.067603	2258.7	-0.19486	929.09	320.18
500	500	57.695	0.017332	14.264	22.930	0.038412	0.055769	0.067522	2200.7	-0.18339	1096.6	189.08

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
600	500	54.316	0.018411	20.481	29.687	0.050731	0.052734	0.067584	2093.8	-0.16883	1097.9	141.83
700	500	50.847	0.019667	26.606	36.439	0.061141	0.050315	0.067436	1970.5	-0.15188	935.15	118.47
800	500	47.385	0.021104	32.615	43.167	0.070124	0.048442	0.067080	1850.1	-0.13256	738.72	104.70
900	500	44.018	0.022718	38.492	49.851	0.077998	0.047068	0.066596	1743.4	-0.11124	572.49	95.388
1000	500	40.814	0.024501	44.233	56.484	0.084987	0.046126	0.066041	1655.7	-0.08910	445.17	88.418
1100	500	37.834	0.026432	49.839	63.055	0.091251	0.045537	0.065356	1589.3	-0.06907	350.97	83.021
1200	500	35.124	0.028470	55.312	69.547	0.096900	0.045218	0.064451	1543.9	-0.05511	282.78	78.952
400	1000	65.942	0.015165	7.4792	22.644	0.019833	0.057934	0.065743	2718.6	-0.19303	1172.7	329.93
500	1000	63.253	0.015810	13.357	29.167	0.034391	0.055063	0.064967	2677.2	-0.19158	2199.5	190.55
600	1000	60.572	0.016509	19.141	35.650	0.046212	0.053055	0.064676	2602.3	-0.18789	3250.5	137.73
700	1000	57.937	0.017260	24.836	42.096	0.056150	0.051393	0.064219	2513.7	-0.18439	3202.2	108.98
800	1000	55.384	0.018056	30.435	48.491	0.064689	0.050059	0.063663	2423.7	-0.18105	2408.7	91.430
900	1000	52.937	0.018890	35.938	54.828	0.072155	0.049062	0.063101	2338.7	-0.17779	1610.7	80.198
1000	1000	50.611	0.019759	41.354	61.113	0.078776	0.048373	0.062594	2261.5	-0.17459	1052.9	72.716
1100	1000	48.415	0.020655	46.695	67.350	0.084722	0.047942	0.062176	2193.2	-0.17139	703.41	67.520
1200	1000	46.349	0.021575	51.976	73.551	0.090117	0.047713	0.061861	2133.6	-0.16808	487.61	63.774

Temperature K	Pressure MPa	Density mol/dm ³	Volume dm ³ /mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C _p kJ/(mol·K)	C _v kJ/(mol·K)	Sound speed m/s	Joule-Thomson on K/MPa	Therm. cond. mW/(m·K)	Viscosity µPa·s
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The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Wagner, W., and Pruss, A., "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use," *J. Phys. Chem. Ref. Data* 31(2):387–535, 2002. The source for viscosity is International Association for the Properties of Water and Steam, *Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance*, IAPWS, 1997. The source for thermal conductivity is the International Association for the Properties of Water and Steam, *Revised Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance*, IAPWS, 1998.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density of the equation of state is 0.0001% at 1 atm in the liquid phase, and 0.001% at other liquid states at pressures up to 10 MPa and temperatures to 423 K. In the vapor phase, the uncertainty is 0.05% or less. The uncertainties rise at higher temperatures and/or pressures, but are generally less than 0.1% in density except at extreme conditions. The uncertainty in pressure in the critical region is 0.1%. The uncertainty of the speed of sound is 0.15% in the vapor and 0.1% or less in the liquid, and increases near the critical region and at high temperatures and pressures. The uncertainty in isobaric heat capacity is 0.2% in the vapor and 0.1% in the liquid, with increasing values in the critical region and at high pressures. The uncertainties of saturation conditions are 0.025% in vapor pressure, 0.0025% in saturated-liquid density, and 0.1% in saturated-vapor density. The uncertainties in the saturated densities increase substantially as the critical region is approached. For the uncertainties in the viscosity and thermal conductivity, see the IAPWS Release.

Table 2-136 Thermodynamic Properties of Water Substance along the Melting Line

P , bar	T , °C	$10^3 v_f$, m ³ /kg	h_f , kJ/kg	s_f , kJ/kg·K	c_{pf} , kJ/kg·K	c_{melt} , kJ/kg·K	$10^6 \alpha_f$, K ⁻¹	$10^6 K_{f,T}$ bar ⁻¹
$6.117 \times 10^{-3} t$	0.0100	1.00021	0	0	4.219	3.969	-67.42	50.90
1.01325	0.0026	1.00016	0.0719	-0.0001	4.218	3.970	-67.17	50.88
50	-0.3618	0.99770	3.5140	-0.0054	4.196	3.997	-54.92	50.30
100	-0.7410	0.99523	6.9794	-0.0110	4.174	4.023	-42.52	49.73
150	-1.1249	0.99278	10.3964	-0.0167	4.152	4.047	-30.24	49.17
200	-1.5166	0.99037	13.7648	-0.0225	4.132	4.070	-18.05	48.63
250	-1.9151	0.98798	17.0843	-0.0285	4.112	4.092	-5.93	48.11
300	-2.3206	0.98562	20.3547	-0.0347	4.092	4.113	6.12	47.59
400	-3.1532	0.98098	26.7472	-0.0474	4.056	4.150	30.09	46.61
500	-4.0156	0.97643	32.9403	-0.0607	4.022	4.184	53.97	45.68
600	-4.909	0.97196	38.932	-0.0747	3.992	4.215	77.87	44.80
800	-6.790	0.96326	50.300	-0.1046	3.937	4.270	126.18	43.19
1000	-8.803	0.95493	60.836	-0.1371	3.893	4.320	175.98	41.74

Condensed from U. Grigull, Private communication, January 18, 1995.

Materials prepared at Technical University München, Germany by U. Grigull and S. Marek. For a table as a function of temperature, see Grigull, U. and S. Marek, *Warme u. Stoff.*, **30** (1994): 1–8.

t = the triple point (at 6.117×10^{-3} bar, 0.01°C); $v_f = 0.0010021$ m³/kg; $\alpha_f = -67.42 \times 10^{-6}/\text{K}$.

Other equations for properties are given by Jones, F. E. and G. L. Harris, *J. Res. N.I.S.T.*, **97**, 3 (1992): 335–340, and by Wagner, W. and A. Pruss, *J. Phys. Chem. Ref. Data*, **22**, 3 (1993): 783–787. Steam tables include Walker, W. A., U.S. Naval Ordn. Lab. rept. NOLTR NOLTR-66-217 = AD 651105 (0–1000 bar, 0–150°C), 1967 (72 pp.); Grigull, U., J. Straub, et al., *Steam Tables in S.I. Units* (0.01–1000 bar, 0–1000°C), Springer-Verlag, Berlin, 1990 (133 pp.); Tseng, C. M., T. A. Hamp, et al., *Atomic Energy of Canada* rept. (30 props, sat liq & vap., 1–220 bar), AECL-5910 1977 (90 pp.). For dissociation, see e.g., Klonicek, V., *Rozpr. Cesko Acad Ved., Rada techn ved* (0.01–100 bar, 1000–5000 K), **77**, 1 (1967). The proceedings of the 10th international conference on the properties of steam were edited by Sytchev, V. V. and A. A. Aleksandrov, Plenum, NY, 1984; and for the 11th conference by Pichal, M. and O. Sifner, Hemisphere, 1989 (550 pp.). Current information on the properties of solid, vapor, and liquid water properties can be found at <http://www.iapws.org>.

For electrical conductivity, see e.g., Marshall, W. L., *J. Chem. Eng. Data*, **32** (1987): 221–226.