

# THERMOPHYSICAL PROPERTIES OF WATER AND STEAM

Eric W. Lemmon and Allan H. Harvey

These tables summarize the thermophysical properties of water and steam at equilibrium as accepted by the International Association for the Properties of Water and Steam (<http://www.iapws.org>) for general and scientific use. The thermodynamic properties are calculated from the equation of state of Wagner and Pruß (Ref. 6). The reference state for these tables is the liquid at the triple point, at which the internal energy and entropy are taken as zero. These tables refer to states at 1 bar (100 KPa) pressure with temperatures in °C in the first section; liquid and gaseous states at equilibrium as a function of temperature in the second section; and properties along isobars in the third section. The tabulated properties are pressure ( $P$ ), density ( $\rho$ ), enthalpy ( $H$ ), entropy ( $S$ ), isochoric heat capacity ( $C_v$ ), isobaric heat capacity ( $C_p$ ), speed of sound ( $u$ ), viscosity ( $\eta$ ), thermal conductivity ( $\lambda$ ), and static dielectric constant ( $D$ ). In the saturation tables, the first line of identical temperatures is for the liquid state and the second line is for the vapor state. A duplicate entry in the isobar section indicates a phase transition (liquid-vapor) at that temperature; property values are then given for both phases. These are identified by the high densities in the liquid and the low densities in the vapor. The temperature scale is ITS-90. Additional calculations at state points not listed below can be obtained by using the NIST Standard Reference Data program REFPROP (Ref. 5) or the water-specific program steam (Ref. 2).

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 the 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.

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 the 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.

## References

1. Fernández, D.P., Goodwin, A.R.H., Lemmon, E.W., Levelt Sengers, J.M.H., and Williams, R.C., A Formulation for the Static Permittivity of Water and Steam at Temperatures from 238 K to 873 K at Pressures up to 1200 MPa, Including Derivatives and Debye-Hückel Coefficients, *J. Phys. Chem. Ref. Data* 26, 1125, 1997.
2. Harvey, A.H., and Lemmon, E.W., NIST Standard Reference Database 10: NIST/ASME Steam Properties, Version 3.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Maryland, 20013 (<http://www.nist.gov/srd/nist10.cfm>).
3. Huber, M.L., Perkins, R.A., Laesecke, A., Friend, D.G., Sengers, J.V., Assael, M.J., Metaxa, I.M., Vogel, E., Mareš, R., and Miyagawa, K., New International Formulation for the Viscosity of Water, *J. Phys. Chem. Ref. Data* 38, 101, 2009.
4. Huber, M.L., Perkins, R.A., Friend, D.G., Sengers, J.V., Assael, M.J., Metaxa, I.N., Miyagawa, K., Hellmann, R., and Vogel, E., New International Formulation for the Thermal Conductivity of H<sub>2</sub>O, *J. Phys. Chem. Ref. Data* 41, 033102, 2012.
5. Lemmon, E.W., Huber, M.L., and McLinden, M.O., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 9.1, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Maryland, 2013 (<http://www.nist.gov/srd/nist23.cfm>).
6. 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, 387, 2002.

## Thermophysical Properties of H<sub>2</sub>O from the Triple Point to the Critical Point

$t/^{\circ}\text{C}$	$P/\text{MPa}$	$\rho/\text{kg m}^{-3}$	$H/\text{kJ kg}^{-1}$	$S/\text{kJ kg}^{-1}\text{ K}^{-1}$	$C_v/\text{kJ kg}^{-1}\text{ K}^{-1}$	$C_p/\text{kJ kg}^{-1}\text{ K}^{-1}$	$u/\text{m s}^{-1}$	$D$	$\eta/\mu\text{Pa s}$	$\lambda/\text{mW m}^{-1}\text{ K}^{-1}$
<b><math>P = 0.1 \text{ MPa (1 bar)}</math></b>										
0.01	0.1	999.84	0.10186	0.000007	4.2170	4.2194	1402.4	87.899	1791.1	555.67
10	0.1	999.70	42.118	0.15108	4.1906	4.1952	1447.3	83.974	1305.9	578.78
20	0.1	998.21	84.006	0.29646	4.1567	4.1841	1482.3	80.223	1001.6	598.01
25	0.1	997.05	104.92	0.36720	4.1376	4.1813	1496.7	78.408	890.02	606.52
30	0.1	995.65	125.82	0.43673	4.1172	4.1798	1509.2	76.634	797.22	614.39
40	0.1	992.22	167.62	0.57237	4.0734	4.1794	1528.9	73.201	652.73	628.48
50	0.1	988.03	209.42	0.70377	4.0262	4.1813	1542.6	69.916	546.52	640.62
60	0.1	983.20	251.25	0.83125	3.9765	4.1850	1551.0	66.774	466.03	651.00

$t/^{\circ}\text{C}$	$P/\text{MPa}$	$\rho/\text{kg m}^{-3}$	$H/\text{kJ kg}^{-1}$	$S/\text{kJ kg}^{-1}\text{K}^{-1}$	$C_v/\text{kJ kg}^{-1}\text{K}^{-1}$	$C_p/\text{kJ kg}^{-1}\text{K}^{-1}$	$u/\text{m s}^{-1}$	$D$	$\eta/\mu\text{Pa s}$	$\lambda/\text{mW m}^{-1}\text{K}^{-1}$
70	0.1	977.76	293.12	0.95509	3.9251	4.1901	1554.7	63.770	403.55	659.76
80	0.1	971.79	335.05	1.0755	3.8728	4.1968	1554.4	60.898	354.05	666.99
90	0.1	965.31	377.06	1.1928	3.8204	4.2052	1550.4	58.152	314.17	672.79
99.606	0.1	958.63	417.50	1.3028	3.7702	4.2152	1543.5	55.628	282.75	677.06
99.606	0.1	0.59034	2674.9	7.3588	1.5548	2.0784	471.99	1.0058	12.218	24.532
100	0.1	0.58967	2675.8	7.3610	1.5535	2.0766	472.28	1.0058	12.234	24.564
<b>Saturation</b>										
0.01	0.000612	999.79	0.000612	0.0	4.2174	4.2199	1402.3	87.895	1791.4	555.60
0.01	0.000612	0.0048546	2500.9	9.1555	1.4184	1.8844	409.00	1.00006	8.9458	16.761
10	0.0012282	999.65	42.021	0.15109	4.1910	4.1955	1447.1	83.971	1306.0	578.71
10	0.0012282	0.0094071	2519.2	8.8998	1.4269	1.8947	416.17	1.00012	9.2384	17.412
20	0.0023393	998.16	83.914	0.29648	4.1570	4.1844	1482.2	80.219	1001.6	597.95
20	0.0023393	0.017314	2537.4	8.6660	1.4359	1.9059	423.18	1.00021	9.5441	18.087
25	0.0031699	997.00	104.83	0.36722	4.1379	4.1816	1496.5	78.405	890.04	606.46
25	0.0031699	0.023075	2546.5	8.5566	1.4405	1.9118	426.63	1.00028	9.7009	18.433
30	0.0042470	995.61	125.73	0.43675	4.1175	4.1801	1509.0	76.630	797.22	614.34
30	0.0042470	0.030415	2555.5	8.4520	1.4452	1.9180	430.03	1.00036	9.8602	18.786
40	0.0073849	992.18	167.53	0.57240	4.0737	4.1796	1528.7	73.197	652.72	628.44
40	0.0073849	0.051242	2573.5	8.2555	1.4552	1.9314	436.71	1.00059	10.185	19.509
50	0.012352	988.00	209.34	0.70381	4.0264	4.1815	1542.4	69.913	546.50	640.57
50	0.012352	0.083147	2591.3	8.0748	1.4663	1.9468	443.21	1.00094	10.516	20.261
60	0.019946	983.16	251.18	0.83129	3.9767	4.1851	1550.8	66.772	466.02	650.96
60	0.019946	0.13043	2608.8	7.9081	1.4789	1.9648	449.50	1.0014	10.854	21.043
70	0.031201	977.73	293.07	0.95513	3.9252	4.1902	1554.6	63.768	403.53	659.72
70	0.031201	0.19843	2626.1	7.7540	1.4937	1.9862	455.57	1.0021	11.195	21.860
80	0.047414	971.77	335.01	1.0756	3.8729	4.1969	1554.3	60.896	354.04	666.97
80	0.047414	0.29367	2643.0	7.6111	1.5111	2.0120	461.39	1.0030	11.539	22.717
90	0.070182	965.30	377.04	1.1929	3.8204	4.2053	1550.4	58.151	314.17	672.77
90	0.070182	0.42390	2659.5	7.4781	1.5316	2.0429	466.94	1.0043	11.885	23.618
100	0.10142	958.35	419.17	1.3072	3.7682	4.2157	1543.2	55.527	281.58	677.21
100	0.10142	0.59817	2675.6	7.3541	1.5558	2.0800	472.20	1.0059	12.232	24.570
110	0.14338	950.95	461.42	1.4188	3.7167	4.2283	1532.9	53.018	254.61	680.35
110	0.14338	0.82693	2691.1	7.2381	1.5843	2.1244	477.13	1.0080	12.580	25.579
120	0.19867	943.11	503.81	1.5279	3.6662	4.2435	1519.9	50.620	232.03	682.24
120	0.19867	1.1221	2705.9	7.1291	1.6177	2.1770	481.73	1.0105	12.927	26.652
140	0.36154	926.13	589.16	1.7392	3.5694	4.2826	1486.2	46.131	196.64	682.53
140	0.36154	1.9667	2733.4	6.9293	1.7002	2.3109	489.82	1.0177	13.618	29.016
160	0.61823	907.45	675.47	1.9426	3.4788	4.3354	1443.2	42.018	170.43	678.73
160	0.61823	3.2596	2757.4	6.7491	1.8044	2.4883	496.29	1.0282	14.304	31.721
180	1.0028	887.00	763.05	2.1392	3.3949	4.4050	1391.7	38.235	150.38	671.28
180	1.0028	5.1588	2777.2	6.5840	1.9279	2.7129	501.04	1.0431	14.985	34.832
200	1.5549	864.66	852.27	2.3305	3.3179	4.4958	1332.1	34.742	134.58	660.01
200	1.5549	7.8610	2792.0	6.4302	2.0666	2.9895	503.92	1.0636	15.666	38.426
220	2.3196	840.22	943.58	2.5177	3.2479	4.6146	1264.5	31.495	121.77	645.26
220	2.3196	11.615	2800.9	6.2840	2.2172	3.3289	504.77	1.0915	16.354	42.606
240	3.3469	813.37	1037.6	2.7020	3.1850	4.7719	1189.0	28.455	111.06	627.17
240	3.3469	16.749	2803.0	6.1423	2.3794	3.7537	503.32	1.1292	17.062	47.525
260	4.6923	783.63	1135.0	2.8849	3.1301	4.9856	1105.3	25.580	101.81	605.78
260	4.6923	23.712	2796.6	6.0016	2.5555	4.3075	499.21	1.1802	17.810	53.446
280	6.4166	750.28	1236.9	3.0685	3.0849	5.2889	1012.6	22.824	93.550	581.03
280	6.4166	33.165	2779.9	5.8579	2.7503	5.0731	491.93	1.2505	18.630	60.878
300	8.5879	712.14	1345.0	3.2552	3.0530	5.7504	909.40	20.135	85.855	552.65
300	8.5879	46.168	2749.6	5.7059	2.9708	6.2197	480.73	1.3504	19.580	70.900
320	11.284	667.09	1462.2	3.4494	3.0428	6.5373	793.16	17.440	78.310	520.02
320	11.284	64.638	2700.6	5.5372	3.2276	8.1589	464.43	1.5012	20.773	86.156
340	14.601	610.67	1594.5	3.6601	3.0781	8.2080	658.27	14.606	70.331	481.93
340	14.601	92.759	2621.8	5.3356	3.5430	12.236	440.72	1.7555	22.477	114.52
360	18.666	527.59	1761.7	3.9167	3.2972	15.004	479.74	11.225	60.306	439.16
360	18.666	143.90	2481.5	5.0536	4.0068	27.356	402.37	2.3096	25.638	191.44
373.946	22.064	322.00	2084.3	4.4070				5.3606		

Thermophysical Properties of H<sub>2</sub>O along Isobars from 0.1 MPa to 100 MPa

$T/K$	$P/\text{MPa}$	$\rho/\text{kg m}^{-3}$	$H/\text{kJ kg}^{-1}$	$S/\text{kJ kg}^{-1} \text{K}^{-1}$	$C_v/\text{kJ kg}^{-1} \text{K}^{-1}$	$C_p/\text{kJ kg}^{-1} \text{K}^{-1}$	$u/\text{m s}^{-1}$	$D$	$\eta/\mu\text{Pa s}$	$\lambda/\text{mW m}^{-1} \text{K}^{-1}$
<b><math>P = 0.1 \text{ MPa (1 bar)}</math></b>										
273.16	0.1	999.84	0.10186	0.000007	4.2170	4.2194	1402.4	87.899	1791.1	555.67
280	0.1	999.91	28.894	0.10411	4.1998	4.2009	1434.3	85.192	1433.6	571.98
300	0.1	996.56	112.65	0.39306	4.1302	4.1806	1501.5	77.747	853.74	609.50
320	0.1	989.43	196.25	0.66281	4.0414	4.1805	1538.9	70.935	576.73	637.00
340	0.1	979.54	279.93	0.91646	3.9414	4.1883	1554.0	64.702	421.63	657.17
360	0.1	967.40	363.82	1.1562	3.8369	4.2023	1552.1	59.004	325.86	671.11
372.756	0.1	958.63	417.50	1.3028	3.7702	4.2152	1543.5	55.628	282.75	677.06
372.756	0.1	0.59034	2674.9	7.3588	1.5548	2.0784	471.99	1.0058	12.218	24.532
380	0.1	0.57824	2689.9	7.3986	1.5356	2.0507	477.08	1.0056	12.498	25.134
400	0.1	0.54761	2730.4	7.5025	1.5082	2.0078	490.31	1.0051	13.278	26.825
450	0.1	0.48458	2829.7	7.7365	1.4943	1.9752	520.60	1.0040	15.267	31.269
500	0.1	0.43514	2928.6	7.9447	1.5082	1.9813	548.31	1.0033	17.299	36.032
550	0.1	0.39507	3028.1	8.1344	1.5319	2.0010	574.19	1.0027	19.356	41.093
600	0.1	0.36185	3128.8	8.3096	1.5600	2.0268	598.61	1.0023	21.425	46.424
650	0.1	0.33384	3230.8	8.4730	1.5903	2.0557	621.79	1.0020	23.496	51.996
700	0.1	0.30988	3334.4	8.6264	1.6222	2.0867	643.92	1.0017	25.562	57.782
750	0.1	0.28915	3439.5	8.7715	1.6553	2.1191	665.11	1.0015	27.617	63.759
800	0.1	0.27102	3546.3	8.9093	1.6892	2.1525	685.47	1.0013	29.657	69.908
900	0.1	0.24085	3765.0	9.1668	1.7589	2.2216	724.03	1.0011	33.680	82.647
1000	0.1	0.21673	3990.7	9.4045	1.8297	2.2921	760.17	1.00088	37.615	95.877
1100	0.1	0.19701	4223.4	9.6263	1.9000	2.3621	794.33	1.00074	41.453	109.50
1200	0.1	0.18058	4463.0	9.8348	1.9682	2.4302	826.85	1.00063	45.192	123.44
<b><math>P = 1 \text{ MPa (10 bar)}</math></b>										
273.16	1.0	1000.3	1.0180	0.000066	4.2127	4.2150	1403.9	87.937	1789.1	556.36
280	1.0	1000.3	29.783	0.10407	4.1960	4.1973	1435.7	85.228	1432.5	572.59
300	1.0	996.96	113.48	0.39281	4.1272	4.1781	1503.0	77.781	853.66	610.00
320	1.0	989.82	197.03	0.66242	4.0390	4.1784	1540.5	70.967	576.89	637.47
340	1.0	979.93	280.67	0.91594	3.9395	4.1863	1555.7	64.734	421.86	657.64
360	1.0	967.81	364.52	1.1556	3.8353	4.2004	1553.9	59.035	326.10	671.61
380	1.0	953.74	448.73	1.3832	3.7315	4.2220	1538.4	53.827	262.82	680.00
400	1.0	937.87	533.47	1.6005	3.6315	4.2535	1511.3	49.065	218.82	683.32
450	1.0	890.39	749.20	2.1086	3.4076	4.3924	1400.6	38.814	153.23	672.77
453.028	1.0	887.13	762.52	2.1381	3.3954	4.4045	1392.0	38.258	150.49	671.33
453.028	1.0	5.1450	2777.1	6.5850	1.9271	2.7114	501.02	1.0430	14.981	34.812
500	1.0	4.5323	2891.2	6.8250	1.6699	2.2795	535.74	1.0344	17.054	38.473
550	1.0	4.0581	3001.8	7.0359	1.6159	2.1647	565.75	1.0282	19.215	42.908
600	1.0	3.6871	3109.0	7.2224	1.6098	2.1292	592.58	1.0236	21.349	47.802
650	1.0	3.3843	3215.2	7.3925	1.6227	2.1254	617.34	1.0202	23.462	53.075
700	1.0	3.1305	3321.7	7.5504	1.6447	2.1368	640.55	1.0174	25.555	58.664
750	1.0	2.9140	3429.0	7.6984	1.6715	2.1566	662.53	1.0153	27.628	64.516
800	1.0	2.7265	3537.5	7.8384	1.7014	2.1816	683.48	1.0135	29.680	70.591
900	1.0	2.4174	3758.5	8.0986	1.7663	2.2402	722.85	1.0108	33.716	83.281
1000	1.0	2.1723	3985.7	8.3380	1.8346	2.3048	759.50	1.0088	37.655	96.534
1100	1.0	1.9729	4219.5	8.5608	1.9034	2.3713	794.01	1.0074	41.494	110.21
1200	1.0	1.8074	4460.0	8.7699	1.9708	2.4371	826.77	1.0063	45.231	124.21
<b><math>P = 10 \text{ MPa (100 bar)}</math></b>										
273.16	10.0	1004.8	10.111	0.00049	4.1721	4.1726	1418.4	88.311	1770.0	563.05
280	10.0	1004.7	38.613	0.10355	4.1593	4.1622	1450.3	85.588	1422.2	578.60
300	10.0	1001.0	121.73	0.39029	4.0984	4.1536	1518.2	78.113	852.99	614.97
320	10.0	993.70	204.84	0.65846	4.0157	4.1580	1556.4	71.284	578.57	642.13
340	10.0	983.84	288.08	0.91079	3.9205	4.1672	1572.6	65.044	424.17	662.33
360	10.0	971.85	371.56	1.1493	3.8198	4.1810	1572.0	59.345	328.53	676.49
380	10.0	957.99	455.37	1.3759	3.7188	4.2013	1558.0	54.140	265.22	685.19
400	10.0	942.42	539.67	1.5921	3.6210	4.2302	1532.7	49.385	221.17	688.88
450	10.0	896.16	753.94	2.0967	3.4010	4.3553	1428.4	39.172	155.48	679.41
500	10.0	838.02	977.18	2.5669	3.2211	4.6022	1271.3	30.794	119.83	646.41

<i>T</i> /K	<i>P</i> /MPa	$\rho$ /kg m <sup>-3</sup>	<i>H</i> /kJ kg <sup>-1</sup>	<i>S</i> /kJ kg <sup>-1</sup> K <sup>-1</sup>	<i>C<sub>v</sub></i> /kJ kg <sup>-1</sup> K <sup>-1</sup>	<i>C<sub>p</sub></i> /kJ kg <sup>-1</sup> K <sup>-1</sup>	<i>u</i> /m s <sup>-1</sup>	<i>D</i>	$\eta$ /μPa s	$\lambda$ /mW m <sup>-1</sup> K <sup>-1</sup>
550	10.0	761.82	1218.8	3.0270	3.0865	5.1407	1054.6	23.531	96.080	590.37
584.147	10.0	688.42	1408.1	3.3606	3.0438	6.1237	847.33	18.660	81.718	535.29
584.147	10.0	55.463	2725.5	5.6160	3.1065	7.1408	472.51	1.4248	20.194	78.344
600	10.0	49.773	2820.0	5.7756	2.6239	5.1365	503.34	1.3649	21.017	72.247
650	10.0	40.479	3022.6	6.1009	2.1103	3.3968	562.10	1.2672	23.472	68.284
700	10.0	35.355	3177.4	6.3305	1.9338	2.8741	602.20	1.2145	25.773	69.997
750	10.0	31.810	3314.6	6.5200	1.8625	2.6452	634.58	1.1793	27.973	73.764
800	10.0	29.107	3443.7	6.6867	1.8367	2.5313	662.61	1.1536	30.101	78.664
900	10.0	25.123	3691.6	6.9787	1.8439	2.4458	710.98	1.1182	34.201	90.420
1000	10.0	22.241	3935.5	7.2357	1.8843	2.4397	753.03	1.0948	38.144	103.67
1100	10.0	20.017	4180.6	7.4693	1.9377	2.4661	791.02	1.0782	41.960	117.74
1200	10.0	18.230	4429.2	7.6855	1.9957	2.5070	826.16	1.0659	45.663	132.27
<i>P</i> = 100 MPa (1000 bar)										
273.16	100.0	1045.3	95.444	-0.0083717	3.8761	3.9053	1575.5	91.834	1660.1	616.62
280	100.0	1043.6	122.26	0.088571	3.8869	3.9328	1603.8	88.976	1367.4	627.72
300	100.0	1037.2	201.44	0.36171	3.8751	3.9798	1667.9	81.216	859.19	657.72
320	100.0	1028.9	281.30	0.61941	3.8289	4.0043	1707.7	74.222	599.18	683.70
340	100.0	1019.0	361.55	0.86265	3.7637	4.0194	1728.7	67.891	448.03	705.08
360	100.0	1007.8	442.05	1.0927	3.6883	4.0309	1735.4	62.150	352.49	721.60
380	100.0	995.37	522.79	1.3110	3.6089	4.0427	1730.9	56.937	288.37	733.29
400	100.0	981.82	603.78	1.5187	3.5293	4.0569	1717.3	52.201	243.33	740.39
450	100.0	943.51	807.84	1.9993	3.3430	4.1105	1652.8	42.149	175.71	740.46
500	100.0	899.21	1015.4	2.4366	3.1820	4.1968	1555.7	34.149	139.57	720.25
550	100.0	848.78	1228.2	2.8421	3.0452	4.3234	1435.5	27.667	117.36	684.16
600	100.0	791.49	1448.6	3.2256	2.9295	4.5019	1300.4	22.290	101.85	634.92
650	100.0	726.21	1679.5	3.5952	2.8329	4.7503	1158.6	17.717	89.647	575.50
700	100.0	651.77	1925.0	3.9589	2.7538	5.0832	1020.0	13.754	79.123	508.87
750	100.0	568.52	2188.5	4.3223	2.6866	5.4492	898.84	10.336	69.732	438.73
800	100.0	482.23	2466.5	4.6811	2.6169	5.6108	813.97	7.5622	61.842	371.17
900	100.0	343.61	3000.1	5.3104	2.4386	4.8879	765.30	4.2835	52.771	275.39
1000	100.0	265.45	3440.1	5.7749	2.2950	3.9788	792.50	2.9559	50.506	237.77
1100	100.0	220.62	3809.8	6.1276	2.2276	3.4715	832.67	2.3472	51.089	232.34
1200	100.0	191.53	4142.5	6.4172	2.2098	3.2098	872.28	2.0111	52.802	238.54

# VAPOR PRESSURE AND OTHER SATURATION PROPERTIES OF WATER

Eric W. Lemmon

This table summarizes the vapor pressure, enthalpy (heat) of vaporization, and surface tension  $\gamma$  of water as accepted by the International Association for the Properties of Water and Steam ([www.iapws.org](http://www.iapws.org)) for general and scientific use. The vapor pressure and heat of vaporization are calculated from the equation of state of Wagner and Pruss (Ref. 1). The temperature scale is ITS-90. Additional calculations at state points not listed below can be obtained by using the NIST Standard Reference Data program REFPROP ([www.nist.gov/srd/nist23.cfm](http://www.nist.gov/srd/nist23.cfm)) or the water-specific program Steam Properties ([www.nist.gov/srd/nist10.cfm](http://www.nist.gov/srd/nist10.cfm)).

## References

1. 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, 387, 2002.
2. International Association for the Properties of Water and Steam, Release on the surface tension of ordinary water substance, *Physical Chemistry of Aqueous Systems: Proceedings of the 12th International Conference on the Properties of Water and Steam*, Orlando, Florida, September 11–16, 1994, pp. A139–A142.

## Vapor Pressure, Enthalpy of Vaporization, and Surface Tension of Water

$t/^{\circ}\text{C}$	$P/\text{kPa}$	$\Delta_{\text{vap}}H/\text{kJ kg}^{-1}$	$\gamma/\text{mN m}^{-1}$
0.01	0.61165	2500.9	75.65
2	0.70599	2496.2	75.37
4	0.81355	2491.4	75.08
6	0.93536	2486.7	74.80
8	1.0730	2481.9	74.51
10	1.2282	2477.2	74.22
12	1.4028	2472.5	73.93
14	1.5990	2467.7	73.63
16	1.8188	2463.0	73.34
18	2.0647	2458.3	73.04
20	2.3393	2453.5	72.74
22	2.6453	2448.8	72.43
24	2.9858	2444.0	72.13
25	3.1699	2441.7	71.97
26	3.3639	2439.3	71.82
28	3.7831	2434.6	71.51
30	4.2470	2429.8	71.19
32	4.7596	2425.1	70.88
34	5.3251	2420.3	70.56
36	5.9479	2415.5	70.24
38	6.6328	2410.8	69.92
40	7.3849	2406.0	69.60
42	8.2096	2401.2	69.27
44	9.1124	2396.4	68.94
46	10.099	2391.6	68.61
48	11.177	2386.8	68.28
50	12.352	2381.9	67.94
52	13.631	2377.1	67.61
54	15.022	2372.3	67.27
56	16.533	2367.4	66.93
58	18.171	2362.5	66.58
60	19.946	2357.7	66.24

$t/^{\circ}\text{C}$	$P/\text{kPa}$	$\Delta_{\text{vap}}H/\text{kJ kg}^{-1}$	$\gamma/\text{mN m}^{-1}$
62	21.867	2352.8	65.89
64	23.943	2347.8	65.54
66	26.183	2342.9	65.19
68	28.599	2338.0	64.84
70	31.201	2333.0	64.48
72	34.000	2328.1	64.12
74	37.009	2323.1	63.76
76	40.239	2318.1	63.40
78	43.703	2313.0	63.04
80	47.414	2308.0	62.67
82	51.387	2302.9	62.31
84	55.635	2297.9	61.94
86	60.173	2292.8	61.56
88	65.017	2287.6	61.19
90	70.182	2282.5	60.82
92	75.684	2277.3	60.44
94	81.541	2272.1	60.06
96	87.771	2266.9	59.68
98	94.390	2261.7	59.30
100	101.42	2256.4	58.91
102	108.87	2251.1	58.53
104	116.78	2245.8	58.14
106	125.15	2240.4	57.75
108	134.01	2235.1	57.36
110	143.38	2229.6	56.96
112	153.28	2224.2	56.57
114	163.74	2218.7	56.17
116	174.77	2213.2	55.77
118	186.41	2207.7	55.37
120	198.67	2202.1	54.97
122	211.59	2196.5	54.56
124	225.18	2190.9	54.16
126	239.47	2185.2	53.75
128	254.50	2179.5	53.34
130	270.28	2173.7	52.93
132	286.85	2167.9	52.52
134	304.23	2162.1	52.11
136	322.45	2156.2	51.69
138	341.54	2150.3	51.27
140	361.54	2144.3	50.86
142	382.47	2138.3	50.44
144	404.37	2132.2	50.01
146	427.26	2126.1	49.59
148	451.18	2119.9	49.17
150	476.16	2113.7	48.74
152	502.25	2107.5	48.31
154	529.46	2101.2	47.89
156	557.84	2094.8	47.46
158	587.42	2088.4	47.02
160	618.23	2082.0	46.59
162	650.33	2075.5	46.16
164	683.73	2068.9	45.72
166	718.48	2062.3	45.28
168	754.62	2055.6	44.85
170	792.19	2048.8	44.41