

CRC Handbook of Chemistry and Physics

A Ready-Reference Book of Chemical and Physical Data



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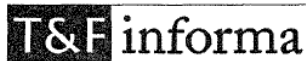
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STANDARD DENSITY OF WATER

This table gives the density ρ of water in the temperature range from 0°C to 100°C at a pressure of 101325 Pa (one standard atmosphere). From 0°C to 40°C the values are taken from the IUPAC publication in Reference 1 and refer to standard mean ocean water (SMOW), free from dissolved salts and gases. SMOW is a standard water sample of high purity and known isotopic composition. Methods of correcting for different isotopic compositions are discussed in Reference 1. The remaining values are taken from the NIST Chemistry WebBook, Reference 2.

Note that the IUPAC values refer to the IPTS-68 temperature scale, while the NIST values are based on the ITS-90 scale (where the normal boiling point is 99.974°C). The conversion between these scales can be found in Sec. 1. The difference between the scales leads to a difference in the density of water of about 20 ppm in the neighborhood of 100°C and much less at lower temperatures.

References

1. Marsh, K. N., Ed., *Recommended Reference Materials for the Realization of Physicochemical Properties*, Blackwell Scientific Publications, Oxford, 1987.
2. Lemmon, E.W., McLinden, M.O., and Friend, D.G., "Thermophysical Properties of Fluid Systems" in NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. P.J. Linstrom and W.G. Mallard, June 2005, National Institute of Standards and Technology, Gaithersburg MD, 20899 (<http://webbook.nist.gov>).
3. 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, 387-535, 2002.
4. Saul, A., and Wagner, W., "A Fundamental Equation for Water Covering the Range From the Melting Line to 1273 K at Pressures up to 25000 MPa", *J. Phys. Chem. Ref. Data* 18, 1537-1564, 1989.

$t/^\circ\text{C}$	$\rho/\text{g cm}^{-3}$	$t/^\circ\text{C}$	$\rho/\text{g cm}^{-3}$	$t/^\circ\text{C}$	$\rho/\text{g cm}^{-3}$	$t/^\circ\text{C}$	$\rho/\text{g cm}^{-3}$	$t/^\circ\text{C}$	$\rho/\text{g cm}^{-3}$
0.1	0.9998493	4.3	0.9999742	8.5	0.9998189	12.7	0.9994167	16.9	0.9987942
0.2	0.9998558	4.4	0.9999736	8.6	0.9998121	12.8	0.9994043	17.0	0.9987769
0.3	0.9998622	4.5	0.9999728	8.7	0.9998051	12.9	0.9993918	17.1	0.9987595
0.4	0.9998683	4.6	0.9999719	8.8	0.9997980	13.0	0.9993792	17.2	0.9987419
0.5	0.9998743	4.7	0.9999709	8.9	0.9997908	13.1	0.9993665	17.3	0.9987243
0.6	0.9998801	4.8	0.9999696	9.0	0.9997834	13.2	0.9993536	17.4	0.9987065
0.7	0.9998857	4.9	0.9999683	9.1	0.9997759	13.3	0.9993407	17.5	0.9986886
0.8	0.9998912	5.0	0.9999668	9.2	0.9997682	13.4	0.9993276	17.6	0.9986706
0.9	0.9998964	5.1	0.9999651	9.3	0.9997604	13.5	0.9993143	17.7	0.9986525
1.0	0.9999015	5.2	0.9999632	9.4	0.9997525	13.6	0.9993010	17.8	0.9986343
1.1	0.9999065	5.3	0.9999612	9.5	0.9997444	13.7	0.9992875	17.9	0.9986160
1.2	0.9999112	5.4	0.9999591	9.6	0.9997362	13.8	0.9992740	18.0	0.9985976
1.3	0.9999158	5.5	0.9999568	9.7	0.9997279	13.9	0.9992602	18.1	0.9985790
1.4	0.9999202	5.6	0.9999544	9.8	0.9997194	14.0	0.9992464	18.2	0.9985604
1.5	0.9999244	5.7	0.9999518	9.9	0.9997108	14.1	0.9992325	18.3	0.9985416
1.6	0.9999284	5.8	0.9999490	10.0	0.9997021	14.2	0.9992184	18.4	0.9985228
1.7	0.9999323	5.9	0.9999461	10.1	0.9996932	14.3	0.9992042	18.5	0.9985038
1.8	0.9999360	6.0	0.9999430	10.2	0.9996842	14.4	0.9991899	18.6	0.9984847
1.9	0.9999395	6.1	0.9999398	10.3	0.9996751	14.5	0.9991755	18.7	0.9984655
2.0	0.9999429	6.2	0.9999365	10.4	0.9996658	14.6	0.9991609	18.8	0.9984462
2.1	0.9999461	6.3	0.9999330	10.5	0.9996564	14.7	0.9991463	18.9	0.9984268
2.2	0.9999491	6.4	0.9999293	10.6	0.9996468	14.8	0.9991315	19.0	0.9984073
2.3	0.9999519	6.5	0.9999255	10.7	0.9996372	14.9	0.9991166	19.1	0.9983877
2.4	0.9999546	6.6	0.9999216	10.8	0.9996274	15.0	0.9991016	19.2	0.9983680
2.5	0.9999571	6.7	0.9999175	10.9	0.9996174	15.1	0.9990864	19.3	0.9983481
2.6	0.9999595	6.8	0.9999132	11.0	0.9996074	15.2	0.9990712	19.4	0.9983282
2.7	0.9999616	6.9	0.9999088	11.1	0.9995972	15.3	0.9990558	19.5	0.9983081
2.8	0.9999636	7.0	0.9999043	11.2	0.9995869	15.4	0.9990403	19.6	0.9982880
2.9	0.9999655	7.1	0.9998996	11.3	0.9995764	15.5	0.9990247	19.7	0.9982677
3.0	0.9999672	7.2	0.9998948	11.4	0.9995658	15.6	0.9990090	19.8	0.9982474
3.1	0.9999687	7.3	0.9998898	11.5	0.9995551	15.7	0.9989932	19.9	0.9982269
3.2	0.9999700	7.4	0.9998847	11.6	0.9995443	15.8	0.9989772	20.0	0.9982063
3.3	0.9999712	7.5	0.9998794	11.7	0.9995333	15.9	0.9989612	20.1	0.9981856
3.4	0.9999722	7.6	0.9998740	11.8	0.9995222	16.0	0.9989450	20.2	0.9981649
3.5	0.9999731	7.7	0.9998684	11.9	0.9995110	16.1	0.9989287	20.3	0.9981440
3.6	0.9999738	7.8	0.9998627	12.0	0.9994996	16.2	0.9989123	20.4	0.9981230
3.7	0.9999743	7.9	0.9998569	12.1	0.9994882	16.3	0.9988957	20.5	0.9981019
3.8	0.9999747	8.0	0.9998509	12.2	0.9994766	16.4	0.9988791	20.6	0.9980807
3.9	0.9999749	8.1	0.9998448	12.3	0.9994648	16.5	0.9988623	20.7	0.9980594
4.0	0.9999750	8.2	0.9998385	12.4	0.9994530	16.6	0.9988455	20.8	0.9980380
4.1	0.9999748	8.3	0.9998321	12.5	0.9994410	16.7	0.9988285	20.9	0.9980164
4.2	0.9999746	8.4	0.9998256	12.6	0.9994289	16.8	0.9988114	21.0	0.9979948

Standard Density of Water

t/°C	ρ/g cm ⁻³	t/°C	ρ/g cm ⁻³	t/°C	ρ/g cm ⁻³	t/°C	ρ/g cm ⁻³	t/°C	ρ/g cm ⁻³
21.1	0.9979731	26.1	0.9967604	31.1	0.9953139	36.1	0.9936531	51.0	0.98758
21.2	0.9979513	26.2	0.9967337	31.2	0.9952827	36.2	0.9936178	52.0	0.98712
21.3	0.9979294	26.3	0.9967069	31.3	0.9952514	36.3	0.9935825	53.0	0.98665
21.4	0.9979073	26.4	0.9966800	31.4	0.9952201	36.4	0.9935470	54.0	0.98617
21.5	0.9978852	26.5	0.9966530	31.5	0.9951887	36.5	0.9935115	55.0	0.98569
21.6	0.9978630	26.6	0.9966259	31.6	0.9951572	36.6	0.9934759	56.0	0.98521
21.7	0.9978406	26.7	0.9965987	31.7	0.9951255	36.7	0.9934403	57.0	0.98471
21.8	0.9978182	26.8	0.9965714	31.8	0.9950939	36.8	0.9934045	58.0	0.98421
21.9	0.9977957	26.9	0.9965441	31.9	0.9950621	36.9	0.9933687	59.0	0.98371
22.0	0.9977730	27.0	0.9965166	32.0	0.9950302	37.0	0.9933328	60.0	0.98320
22.1	0.9977503	27.1	0.9964891	32.1	0.9949983	37.1	0.9932968	61.0	0.98268
22.2	0.9977275	27.2	0.9964615	32.2	0.9949663	37.2	0.9932607	62.0	0.98216
22.3	0.9977045	27.3	0.9964337	32.3	0.9949342	37.3	0.9932246	63.0	0.98163
22.4	0.9976815	27.4	0.9964059	32.4	0.9949020	37.4	0.9931884	64.0	0.98109
22.5	0.9976584	27.5	0.9963780	32.5	0.9948697	37.5	0.9931521	65.0	0.98055
22.6	0.9976351	27.6	0.9963500	32.6	0.9948373	37.6	0.9931157	66.0	0.98000
22.7	0.9976118	27.7	0.9963219	32.7	0.9948049	37.7	0.9930793	67.0	0.97945
22.8	0.9975883	27.8	0.9962938	32.8	0.9947724	37.8	0.9930428	68.0	0.97890
22.9	0.9975648	27.9	0.9962655	32.9	0.9947397	37.9	0.9930062	69.0	0.97833
23.0	0.9975412	28.0	0.9962371	33.0	0.9947071	38.0	0.9929695	70.0	0.97776
23.1	0.9975174	28.1	0.9962087	33.1	0.9946743	38.1	0.9929328	71.0	0.97719
23.2	0.9974936	28.2	0.9961801	33.2	0.9946414	38.2	0.9928960	72.0	0.97661
23.3	0.9974697	28.3	0.9961515	33.3	0.9946085	38.3	0.9928591	73.0	0.97603
23.4	0.9974456	28.4	0.9961228	33.4	0.9945755	38.4	0.9928221	74.0	0.97544
23.5	0.9974215	28.5	0.9960940	33.5	0.9945423	38.5	0.9927850	75.0	0.97484
23.6	0.9973973	28.6	0.9960651	33.6	0.9945092	38.6	0.9927479	76.0	0.97424
23.7	0.9973730	28.7	0.9960361	33.7	0.9944759	38.7	0.9927107	77.0	0.97364
23.8	0.9973485	28.8	0.9960070	33.8	0.9944425	38.8	0.9926735	78.0	0.97303
23.9	0.9973240	28.9	0.9959778	33.9	0.9944091	38.9	0.9926361	79.0	0.97241
24.0	0.9972994	29.0	0.9959486	34.0	0.9943756	39.0	0.9925987	80.0	0.97179
24.1	0.9972747	29.1	0.9959192	34.1	0.9943420	39.1	0.9925612	81.0	0.97116
24.2	0.9972499	29.2	0.9958898	34.2	0.9943083	39.2	0.9925236	82.0	0.97053
24.3	0.9972250	29.3	0.9958603	34.3	0.9942745	39.3	0.9924860	83.0	0.96990
24.4	0.9972000	29.4	0.9958306	34.4	0.9942407	39.4	0.9924483	84.0	0.96926
24.5	0.9971749	29.5	0.9958009	34.5	0.9942068	39.5	0.9924105	85.0	0.96861
24.6	0.9971497	29.6	0.9957712	34.6	0.9941728	39.6	0.9923726	86.0	0.96796
24.7	0.9971244	29.7	0.9957413	34.7	0.9941387	39.7	0.9923347	87.0	0.96731
24.8	0.9970990	29.8	0.9957113	34.8	0.9941045	39.8	0.9922966	88.0	0.96664
24.9	0.9970735	29.9	0.9956813	34.9	0.9940703	39.9	0.9922586	89.0	0.96598
25.0	0.9970480	30.0	0.9956511	35.0	0.9940359	40.0	0.9922204	90.0	0.96531
25.1	0.9970223	30.1	0.9956209	35.1	0.9940015	41.0	0.99183	91.0	0.96463
25.2	0.9969965	30.2	0.9955906	35.2	0.9939671	42.0	0.99144	92.0	0.96396
25.3	0.9969707	30.3	0.9955602	35.3	0.9939325	43.0	0.99104	93.0	0.96327
25.4	0.9969447	30.4	0.9955297	35.4	0.9938978	44.0	0.99063	94.0	0.96258
25.5	0.9969186	30.5	0.9954991	35.5	0.9938631	45.0	0.99021	95.0	0.96189
25.6	0.9968925	30.6	0.9954685	35.6	0.9938283	46.0	0.98979	96.0	0.96119
25.7	0.9968663	30.7	0.9954377	35.7	0.9937934	47.0	0.98936	97.0	0.96049
25.8	0.9968399	30.8	0.9954069	35.8	0.9937585	48.0	0.98893	98.0	0.95978
25.9	0.9968135	30.9	0.9953760	35.9	0.9937234	49.0	0.98848	99.0	0.95907
26.0	0.9967870	31.0	0.9953450	36.0	0.9936883	50.0	0.98804	99.974	0.95837

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