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Revised Release on Surface Tension of Ordinary Water Substance

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This revised release contains 6 pages, including this cover page.

This revised release has been authorized by the International Association for the Properties of Water and Steam (IAPWS) at its meeting in Moscow, Russia, 23-27 June, 2014, for issue by its Secretariat. The members of IAPWS are: Britain and Ireland, Canada, the Czech Republic, Germany, Japan, Russia, Scandinavia (Denmark, Finland, Norway and Sweden), and the United States of America, and Associate Members Argentina and Brazil, Australia, France, Greece, Italy, New Zealand and Switzerland.

This release is a minor revision of the IAPWS release of 1994, to add information about the extrapolation of the formulation to temperatures below the triple point of water. The formulation itself is unchanged from the 1994 document.

Further information about this release and other documents issued by IAPWS can be obtained from the Executive Secretary of IAPWS or from http://www.iapws.org.

Background

In 1975, Working Group III (on Special Properties) of IAPS had critically examined the experimental results of the surface tension of the interface between the liquid and vapor phases of ordinary water and recommended a set of surface tension values and uncertainties associated with each value of the surface tension.

IAPS issued a Release on the Surface Tension of Ordinary Water Substance in 1976, based on these recommended values and with temperatures expressed on the International Practical Temperature Scale of 1968 (IPTS-68). A mathematical formulation was adopted that reproduced the recommended tabulated values within their uncertainties. The technical details of this work are documented in [1]. A minor revision of this release was adopted in 1994 to provide adjusted values corresponding to temperatures on the International Temperature Scale of 1990 (ITS-90) and to use the critical temperature for water corresponding to that from the 1992 IAPWS Release on the Values of Temperature, Pressure and Density of Ordinary and Heavy Water Substances at their Respective Critical Points [2].

Recent experimental work in two laboratories on the surface tension of supercooled water [3,4] has shown that the previously recommended surface tension formulation is also accurate in the supercooled region, down to at least –25 °C. This 2014 revision has been issued to state that the formulation may be extrapolated in that region.

Representation of the Surface Tension of Ordinary Water Substance

Experimental values of surface tension of ordinary water substance

In Table 1, recommended values of the surface tension (σ) are given in column 2. The corresponding uncertainty values ($\Delta\sigma$) are given in column 3 of Table 1.

Equation for the surface tension of ordinary water substance

The following recommended interpolating equation gives values of surface tension within the stated uncertainty:

$$\sigma = B\tau^{\mu}(1+b\tau)$$

where
σ = surface tension
τ = $1 - T / T_c$
T = absolute temperature
T_c = 647.096 K
B = 235.8 mN/m
b = –0.625
μ = 1.256

This equation is valid between the triple point (0.01 °C) and reference temperature, T_c. It also provides reasonably accurate values when extrapolated into the supercooled region, to temperatures as low as –25 °C.

Values of surface tension calculated from this equation are given in column 4 of Table 1.

Notes: (i) T denotes absolute temperature, ITS-90.

(ii) The reference temperature is the critical point temperature given in the IAPWS Release on the Values of Temperature, Pressure and Density of Ordinary and Heavy Water Substances at their Respective Critical Points [2].

(iii) The values of the constants B, b, and μ are those presented in the release of 1976. Adjustment of the reference temperature produces values of surface tension from the equation for ITS-90 temperatures with improved root-mean-square deviation compared with the original equation and the surface tension values for the IPTS-68 temperatures in the release of 1976.

Table 1 Surface Tension of Ordinary Water Substance

(1) Temp. t, °C	(2) Surf. Tension experimental σ mN/m	(3) Uncertainty $\Delta\sigma$ mN/m	(4) Surf. Tension calculated σ_{calc} mN/m	(5) difference $\sigma_{calc}-\sigma$ mN/m
0.01	75.64	0.38	75.65	0.01
5	74.94	0.37	74.94	0.00
10	74.23	0.37	74.22	–0.01
15	73.49	0.37	73.49	–0.00
20	72.74	0.36	72.74	–0.00
25	71.98	0.36	71.97	–0.01
30	71.19	0.36	71.19	0.00
35	70.41	0.35	70.40	–0.01
40	69.59	0.35	69.60	0.01
45	68.78	0.34	68.78	–0.00
50	67.93	0.34	67.94	0.01
55	67.09	0.34	67.10	0.01
60	66.24	0.33	66.24	–0.00
65	65.36	0.33	65.37	0.01
70	64.47	0.32	64.48	0.01
75	63.57	0.32	63.58	0.01
80	62.68	0.31	62.67	–0.01
85	61.76	0.31	61.75	–0.01
90	60.82	0.30	60.82	–0.00
95	59.88	0.30	59.87	–0.01
100	58.92	0.29	58.91	–0.01
105	57.95	0.29	57.94	–0.01
110	56.97	0.28	56.96	–0.01
115	55.98	0.28	55.97	–0.01
120	54.97	0.27	54.97	–0.00
125	53.96	0.27	53.96	–0.00
130	52.94	0.26	52.93	–0.01
135	51.90	0.26	51.90	–0.00
140	50.86	0.25	50.86	–0.00
145	49.81	0.25	49.80	–0.01
150	48.75	0.24	48.74	–0.01
155	47.67	0.24	47.67	0.00
160	46.58	0.23	46.59	0.01
165	45.49	0.23	45.50	0.01
170	44.40	0.22	44.41	0.01
175	43.30	0.22	43.30	0.00
180	42.19	0.22	42.19	0.00
185	41.07	0.22	41.07	0.00
190	39.95	0.22	39.95	–0.00
195	38.82	0.22	38.81	–0.01
200	37.68	0.22	37.67	–0.01

Table 1 continued

(1) Temperature t, °C	(2) Surf. Tension experimental σ mN/m	(3) Uncertainty $\Delta\sigma$ mN/m	(4) Surf. Tension calculated σ_{calc} mN/m	(5) difference $\sigma_{calc}-\sigma$ mN/m
205	36.54	0.22	36.53	–0.01
210	35.40	0.22	35.38	–0.02
215	34.24	0.22	34.23	–0.01
220	33.09	0.22	33.07	–0.02
225	31.92	0.22	31.90	–0.02
230	30.76	0.22	30.74	–0.02
235	29.58	0.22	29.57	–0.01
240	28.40	0.22	28.39	–0.01
245	27.22	0.22	27.22	–0.00
250	26.05	0.22	26.04	–0.01
255	24.86	0.21	24.87	0.01
260	23.66	0.21	23.69	0.03
265	22.46	0.21	22.51	0.05
270	21.29	0.20	21.34	0.05
275	20.14	0.20	20.16	0.02
280	18.93	0.20	18.99	0.06
285	17.76	0.19	17.83	0.07
290	16.60	0.19	16.66	0.06
295	15.45	0.19	15.51	0.06
300	14.30	0.18	14.36	0.06
305	13.18	0.18	13.22	0.04
310	12.04	0.17	12.09	0.05
315	10.92	0.16	10.97	0.05
320	9.81	0.16	9.86	0.05
325	8.73	0.15	8.77	0.04
330	7.66	0.14	7.70	0.04
335	6.61	0.13	6.65	0.04
340	5.59	0.12	5.63	0.04
345	4.60	0.11	4.63	0.03
350	3.64	0.10	3.67	0.03
355	2.74	0.10	2.74	0.00
360	1.89	0.10	1.88	–0.01
365	1.12	0.10	1.08	–0.04
370	0.45	0.10	0.39	–0.06

References

[1] Vargaftik, N.B., Volkov, B.N., and Voljak, L.D., International Tables of the Surface Tension of Water, *J. Phys. Chem. Ref. Data* **12**, 817 (1983).

[2] IAPWS, *Release: Values of Temperature, Pressure, and Density of Ordinary and Heavy Water Substance at their Respective Critical Points*, available from http://www.iapws.org (1992).

[3] Hrubý, J., Vinš, V., Mareš, R., Hykl, J., and Kalová, J., Surface Tension of Supercooled Water: No Inflection Point down to –25 °C, *J. Phys. Chem. Lett.* **5**, 425 (2014).

[4] Vinš, V., Fransen, M., Hykl, J., and Hrubý, J., Surface Tension of Supercooled Water Determined by Using a Counterpressure Capillary Rise Method, *J. Phys. Chem. B* **119**, 5567-5575 (2015).