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## PROPERTIES OF LIQUIDS

Function values at 100 kPa and 288 K for room-temperature liquids, or at 100 kPa and the normal boiling point for room-temperature gases, or the normal melting point for room-temperature solids, or the triple point for sublimating substances (C<sub>2</sub>H<sub>2</sub>, CO<sub>2</sub>, SF<sub>8</sub> and UF<sub>8</sub>).

Substance	Formula	Melting temp. $T_f$ K	Boiling temp. $T_b$ K	Melting enthalpy $h_{sl}$ kJ/kg	Boiling enthalpy $h_{lv}$ kJ/kg	Density (mass) $\rho$ kg/m <sup>3</sup>	<a href="#">Thermal expansion</a> $\alpha \cdot 10^6$ K <sup>-1</sup>	Compressibility <sup>a</sup> $\kappa \cdot 10^9$ Pa <sup>-1</sup>	Surface tension <sup>b</sup> $\sigma$ N/m	Thermal capacity $c_p$ J/(kg·K)	Thermal conductivity $k$ W/(m·K)	Dynamic viscosity $\mu \cdot 10^6$ Pa·s
Acetylene	C <sub>2</sub> H <sub>2</sub>	193 <sup>c</sup>	193 <sup>c</sup>	115 <sup>c</sup>	700 <sup>c</sup>	615 <sup>c</sup>	2500		0.001	3000	0.50	160
Acetone	C <sub>3</sub> H <sub>6</sub> O	178	329	98	532	749	1400	1.2	0.024	2150	0.18	330
Ammonia	NH <sub>3</sub>	195	240	332	1357	697	1800	0.7	0.022	4600	0.50	266
Aniline	C <sub>6</sub> H <sub>7</sub> N	276	457	114	434	1021	840	0.36	0.042	2140	0.17	4467
Argon	Ar	84	87	30	163	1395	4500	2.1	0.014	625	0.13	240
1,3-Butadiene	C <sub>4</sub> H <sub>6</sub>	164	269	148		621	1800	1.9	0.013	2260	0.13	
Benzene	C <sub>6</sub> H <sub>6</sub>	279	353	126	394	884	1400	1.6	0.029	1720	0.15	653
n-Butane	C <sub>4</sub> H <sub>10</sub>	135	273	80	365	602 <sup>d</sup>	1800	2.2	0.012	2400	0.12	282
iso-Butane	C <sub>4</sub> H <sub>10</sub>	114	261	78	366	594 <sup>e</sup>	1900	2.3	0.012	2300	0.12	150
Carbon dioxide	CO <sub>2</sub>	217 <sup>f</sup>	217 <sup>f</sup>	185 <sup>f</sup>	350 <sup>f</sup>	1180 <sup>f</sup>	3200 <sup>f</sup>	1.9 <sup>f</sup>	0.017 <sup>f</sup>	1950 <sup>f</sup>	0.18 <sup>f</sup>	260 <sup>f</sup>
Carbon tetrachloride	CCl <sub>4</sub>	250	350	30	195	1590	1240	1.0	0.027	840	0.11	967
Cyclohexane	C <sub>6</sub> H <sub>12</sub>	280	354	31	360	778	1400	1.9	0.025	1860	0.13	411
Chloroform	CHCl <sub>3</sub>	210	335	74	247	1489	1200	0.69	0.027	980	0.13	562
n-Decane	C <sub>10</sub> H <sub>22</sub>	243	447	202	276	730	1010	0.84	0.024	2000	0.15	920
Diesel	(C <sub>12</sub> H <sub>26</sub> )	235 <sup>g</sup>	470 <sup>g</sup>		250	840	830		0.028	1900	0.15	2400
1-Dodecene	C <sub>12</sub> H <sub>24</sub>	238	586	122	373	761	980			2150	0.14	1360
n-Dodecane	C <sub>12</sub> H <sub>26</sub>	263	489	216	257	780	920	0.77	0.025	2220	0.14	1340
<a href="#">DME</a> (dimethyl ether)	C <sub>2</sub> H <sub>6</sub> O	132	250	107	460	736	1900	1.6	0.011	2540	0.14	100

<a href="#">ETBE</a> (ethyl tert-butyl ether)	C <sub>6</sub> H <sub>14</sub> O	179	340			770						400
Ethane	C <sub>2</sub> H <sub>6</sub>	90	185	95	520	544 <sup>h</sup>	2300 <sup>h</sup>	1.8 <sup>h</sup>	0.016 <sup>h</sup>	2440 <sup>h</sup>	0.17 <sup>h</sup>	169 <sup>h</sup>
Ethanol	C <sub>2</sub> H <sub>6</sub> O	156	351	108	860	790	1100	1.1	0.023	2440	0.18	1194
Ether (diethyl ether)	C <sub>4</sub> H <sub>10</sub> O	157	308	99	351	715	1630		0.016	2260	0.14	230
Ethylene glycol	C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	262	471	181	800	1110	650	0.33	0.048	2400	0.26	16·10 <sup>3</sup>
Ethylene	C <sub>2</sub> H <sub>4</sub>	104	169	120	483	568 <sup>i</sup>	2500	1.8	0.016	2420	0.19	176
Gasoline	(C <sub>8</sub> H <sub>18</sub> )	217 <sup>g</sup>	360 <sup>g</sup>		340	750	900		0.025	2100	0.15	380
Glycerol (glycerine)	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>	291	560	199	663	1260	500	0.21	0.064	2430	0.30	1400·10 <sup>3</sup>
Helium ( <sup>4</sup> He)	He	0.95	4.2	3.5	20.7	125	205 000	520	0.0001	5000	0.02	3.2
Helium-3 ( <sup>3</sup> He)	He	NA	3.2	NA	8.7	59	50 000	300		1500		
n-Heptane	C <sub>7</sub> H <sub>16</sub>	182	372	140	321	684	1600	2.9	0.020	2220	0.13	409
n-Hexane	C <sub>6</sub> H <sub>14</sub>	178	342	150	337	658	1600	2.7	0.019	2260	0.12	320
n-Hexadecane (cetane)	C <sub>16</sub> H <sub>34</sub>	291	550	230	358	773			0.028	2210	0.15	3030
Hydrazine	N <sub>2</sub> H <sub>4</sub>	275	387	395	1400	1010	2090	0.22	0.067	3080	0.57	900
Hydrogen <sup>i</sup>	H <sub>2</sub>	14	20	59	448	71	16 600	19	0.002	8700	0.12	10
(Hydrogen) Deuterium	D <sub>2</sub>	19	23	49	304	163	16 700	13		8000	0.14	
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	273	423	368	1519	1450	790	0.21	0.080	2620	0.55	1200
Kerosene, Jet A-1, RP1	(C <sub>12</sub> H <sub>24</sub> )	230 <sup>g</sup>	450 <sup>g</sup>		250	820	830	0.70	0.028	2000	0.13	2400
Mercury	Hg	234	630	12	301	13546	180	0.038	0.490	139	9.3	1550
Methane	CH <sub>4</sub>	91	112	58	511	423	3500	2.2	0.012	3420	0.18	110
Methanol	CH <sub>4</sub> O	175	338	99	1100	791	1490	1.05	0.023	2510	0.21	593
<a href="#">MMH</a> (monomethyl hydrazine)	CH <sub>6</sub> N <sub>2</sub>	221	364			875				2950	0.25	
<a href="#">MTBE</a> (methyl tert-butyl ether)	C <sub>5</sub> H <sub>12</sub> O	164	328	88		740				2090	0.12	350
Nitric acid	HNO <sub>3</sub>	231	394	167	615	1510		0.32	0.042	2000	0.29	800
Nitrogen	N <sub>2</sub>	63	77	26	199	807	5700	3.2	0.012	2040	0.145	161
di-Nitrogen oxide	N <sub>2</sub> O	182	185	149	376	1230	2400	1.1	0.024	1720	0.20	325
di-Nitrogen tetroxide <sup>k</sup>	N <sub>2</sub> O <sub>4</sub>	262	294	160	330	1440				1550	0.29	

n-Octane	C <sub>8</sub> H <sub>18</sub>	217	399	181	306	703	2000	4	0.022	2100	0.15	562
iso-Octane	C <sub>8</sub> H <sub>18</sub>	166	372	180	308	692			0.018	2100	0.10	350
Oil (mineral, vegetable...) <sup>l</sup>	C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>					900	900	0.5		2000	0.15	10 <sup>3</sup> ..10 <sup>7</sup>
Oxygen	O <sub>2</sub>	54	90	14	213	1142	4 400	2.0	0.020	1700	0.15	
n-Pentane	C <sub>5</sub> H <sub>12</sub>	143	309	116	356	626	1700	2.4	0.016	2180	0.14	229
Propane <sup>m</sup>	C <sub>3</sub> H <sub>8</sub>	85	231	95	430	581	2000	2.0	0.016	2140	0.13	198 <sup>j</sup>
Propylene (propene)	C <sub>3</sub> H <sub>6</sub>	88	225	71	437	612	2000	2.0	0.008	2200	0.11	190
Propylene glycol	C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	214	461	99	800	1036	730		0.040	2790	0.20	42·10 <sup>3</sup>
<a href="#">R12</a> <sup>n</sup>	CCl <sub>2</sub> F <sub>2</sub>	115	243		165	1488	2000	2.0	0.016	966	0.07	200
<a href="#">R134a</a> (tetrafluoroethane) <sup>o</sup>	CF <sub>3</sub> CH <sub>2</sub> F	170	247	1300	215	1380	2200	2.0	0.015	1280	0.10	380
<a href="#">R410A</a> <sup>p</sup>	n.a.	120	222		190	1350	2300	1.7	0.018	1368	0.17	
Silicone oil DMS-10	-[Si(CH <sub>3</sub> ) <sub>2</sub> O]-			1050		950	900	0.6	0.021	1800	0.11	9500
Sodium <sup>q</sup>	Na	371	1160	115	1020	780 <sup>q</sup>	70	0.2	0.200	1250	60	200
Sulfur dioxide	SO <sub>2</sub>	198	263	135	389	1455	1700	1.0			0.20	550
Sulfur hexafluoride <sup>r</sup>	SF <sub>6</sub>	223	223	40	162	1845	2800	3.2	0.011	837		
Sulfuric acid	H <sub>2</sub> SO <sub>4</sub>	283	561		745	1840		0.3		1400		23000
Tetradecafluorohexane <sup>s</sup> (FC-72)	C <sub>6</sub> F <sub>14</sub>	183	329		88	1680	1560		0.010	1100	0.057	640
<a href="#">UDMH</a> (unsym.dim.hydrazine)	C <sub>2</sub> H <sub>8</sub> N <sub>2</sub>	216	337			790				2650	0.16	
Uranium hexafluoride <sup>t</sup>	UF <sub>6</sub>	337	337	54	82	3670	6000		0.018	620	1.9	900
Water <sup>u</sup>	H <sub>2</sub> O	273	373	334	2257	999	150	0.45	0.073 <sup>t</sup>	4180	0.60	1000 <sup>t</sup>
Water, Heavy <sup>v</sup>	D <sub>2</sub> O	277	374	319	2090	1105	100	0.47	0.073	4210	0.60	
Xenon	Xe	161	165	17	96	2990	2300	1.7	0.018	350	0.07	450

- a) The compressibility coefficient,  $\kappa$ , is related to the speed of sound,  $c$ , and the density by  $c=(\rho\kappa)^{-1/2}$  (e.g. for pure water  $c=(\rho\kappa)^{-1/2}=(998\cdot 0.46\cdot 10^{-9})^{-1/2}=1480$  m/s; and roughly the same for sea water). For liquid-vapour equilibrium,  $\kappa$  and  $\alpha$  increase a lot with  $T$  and  $p$  diverging at the critical point.
- b) Surface tension for liquid in air. For liquid in water (if immiscible, of course), values may differ (e.g. for benzene in air  $\sigma=0.029$  N/m but  $\sigma=0.035$  N/m for benzene in water).
- c) Acetylene has no normal points for melting and boiling because at the normal pressure of 100 kPa the only phase change is the solid-gas transition at 189 K (normal sublimation point). Data in this table refers to the triple point:  $p_{tr}=128$  kPa,  $T_{tr}=193$  K= $-80$  °C; i.e.,  $\rho_{l,tr}=615$  kg/m<sup>3</sup>,  $h_{sv}=h_{sl}+h_{lv}=115+700=815$  kJ/kg. Sublimation point data:  $T=189$  K= $-84$  °C,  $\rho_s=729$  kg/m<sup>3</sup>,  $h_{sv}=820$  kJ/kg. See additional comments in f).

- d) n-Butane liquid density at 288 K and its equilibrium pressure (175 kPa):  $\rho_l=584 \text{ kg/m}^3$ .
- e) iso-Butane liquid density at 288 K and its equilibrium pressure (258 kPa):  $\rho_l=563 \text{ kg/m}^3$ .
- f) Carbon dioxide has no normal points for melting and boiling because at the normal pressure of 100 kPa the only phase change is the solid-gas transition at 195 K (normal sublimation point). Data in this table refers to the triple point:  $p_{tr}=518 \text{ kPa}$ ,  $T_{tr}=217 \text{ K}=-56.3 \text{ }^\circ\text{C}$ ; i.e.,  $\rho_{l,tr}=615 \text{ kg/m}^3$ ,  $h_{sv}=h_{sl}+h_{lv}=185+350=535 \text{ kJ/kg}$ . Sublimation point data:  $T=195 \text{ K}=-78.5 \text{ }^\circ\text{C}$ ,  $\rho_s=1560 \text{ kg/m}^3$  (if well compacted),  $h_{sv}=575 \text{ kJ/kg}$ . Notice that most liquid properties vary a lot near the critical point, which is the case at room temperature for  $\text{CO}_2$ ,  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_6$ ,  $\text{N}_2\text{O}$ ,  $\text{SF}_6$ , and  $\text{UF}_6$ . For liquid  $\text{CO}_2$  at 288 K and its equilibrium pressure (5.1 MPa):  $\rho=823 \text{ kg/m}^3$ ,  $\alpha=3200 \cdot 10^{-6} \text{ K}^{-1}$ ,  $\kappa=7.8 \cdot 10^{-9} \text{ Pa}^{-1}$ ,  $\sigma=0.002 \text{ N/m}$ ,  $k=0.09 \text{ W/(m}\cdot\text{K)}$ , and  $\mu=70 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ , and  $c_p=3420 \text{ J/(kg}\cdot\text{K)}$ , growing from  $c_p=1950 \text{ J/(kg}\cdot\text{K)}$  at the triple point, to infinity at the critical point (the difference between  $c_p$  and  $c_v$  of the saturated liquid is important in this case: the thermal capacity at constant volume at 288 K and 5.1 MPa is  $c_v=990 \text{ J/(kg}\cdot\text{K)}$ ).
- g) Diesel, gasoline and kerosene are mixtures of various compositions and have not precise boiling or melting points (e.g. at 300 K 10%wt of gasoline is in the vapour state, and at 440 K 90%). Surface tension may vary in the range  $\sigma=0.022..0.035 \text{ N/m}$ . [Jet A-1](#) is a kerosene fuel with additives to freeze at  $-50 \text{ }^\circ\text{C}$  and  $\rho=800..820 \text{ kg/m}^3$ ,  $c=2000..2100 \text{ J/(kg}\cdot\text{K)}$ ,  $k=0.10..0.14 \text{ W/(m}\cdot\text{K)}$ ). Rocket propellant [RP1](#) is similar to Jet A-1. Surrogate pure components are often used for theoretical studies, but only a few properties can be properly matched: octane (normal or iso) is used as surrogate of gasoline, and dodecane or dodecene for diesel, kerosene, Jet A-1 and RP1.
- h) Liquid ethane at 288 K and its equilibrium pressure (3.36 MPa) has  $\rho_l=358 \text{ kg/m}^3$ ,  $\alpha=0.013 \text{ K}^{-1}$ ,  $c=430 \text{ m/s}$ ,  $c_p=4750 \text{ J/(kg}\cdot\text{K)}$ ,  $k=0.079 \text{ W/(m}\cdot\text{K)}$ , and  $\mu=45 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ .
- i) There are two [spin-isomers of  \$\text{H}\_2\$](#) : ortho and para. Gas at room temperature is mostly orthohydrogen, but, when liquefied, it is important to convert it to almost pure parahydrogen because otherwise there is a slow natural conversion of ortho to para with a release of 516 kJ/kg that contributes to boil-off.
- j) Data for [H<sub>2</sub>O<sub>2</sub>](#) pure.  $\text{H}_2\text{O}_2$  is most used in aqueous solutions, with >80 % mass fraction in propulsion (named [HTP](#), high test peroxide), with around 30 % as a chemical in industry for bleaching (its main application), and with around 3 % in medicine as antiseptic. The peroxide bond (a single bond HO–OH) is unstable and slowly decomposes, so that storage tanks should be vented, and kept cool and in the dark. It decomposes violently at high temperature (its boiling point is extrapolated, but solutions may be safely distilled under reduced pressure), or at room temperature in contact with catalysts like silver. Density of solid at melting point is  $1700 \text{ kg/m}^3$ , and that of pure liquid at  $100 \text{ }^\circ\text{C}$  is  $1350 \text{ kg/m}^3$ .  $\text{H}_2\text{O}_2/\text{H}_2\text{O}$  solutions are eutectic, i.e. although both pure substances melt at around  $0 \text{ }^\circ\text{C}$ , a 50 %wt mix melts at  $-52 \text{ }^\circ\text{C}$ .
- k) At equilibrium, there is always a mixture of dinitrogen tetroxide ( $\text{N}_2\text{O}_4$ ) and nitrogen dioxide ( $\text{NO}_2$ ). The  $\text{NO}_2/\text{N}_2\text{O}_4$  equilibrium depends on temperature,  $\text{NO}_2$  being favoured in the gas phase at high temperatures, whereas  $\text{N}_2\text{O}_4$  is preponderant in the gas phase at low temperature, and in condensed phases. When condensing, at  $21.3 \text{ }^\circ\text{C}$  at 100 kPa, most of the liquid is  $\text{N}_2\text{O}_4$  which is colourless or pale brownish; when solidified (at  $-11.2 \text{ }^\circ\text{C}$ ) a white solid appears.  $\text{N}_2\text{O}_4$  is a hypergolic propellant that spontaneously reacts upon contact with various forms of hydrazine, all of them liquid at normal pressure; this fact, and the ease of liquefying the  $\text{N}_2\text{O}_4$  (liquid at 100 kPa for  $T < 21 \text{ }^\circ\text{C}$ ), makes them popular bipropellants for spacecraft rockets.
- l) Formula of oleic acid ( $\text{CH}_3-(\text{CH}_2)_7-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$ ,  $T_m=268 \text{ K}$ ,  $h_{sl}=75 \text{ kJ/kg}$ ), the major component in olive oil. Oils are thick liquids (non-volatile and viscous) made directly (natural oils) or indirectly (synthetic oils) from fossil matter, living matter, or minerals. Mineral oils are high hydrocarbons obtained from petroleum distillation and used either as fuels (diesel oil and heavy fuel oil) or as lubricants (lube oils). Fat oils are triglycerides-esters from plants or animals (olive, soybean, peanut sunflower, coconut, corn linseed, palm, essential oils, whale, castor). They are organic (carbon) or inorganic (silicon) polymers with a range of molar mass values, and do not show sharp phase transitions. Density: they are usually less dense than water (but sulphuric oleum nearly reaches a density double than water): e.g. olive and vegetable oils have some  $\rho=915..925 \text{ kg/m}^3$ , whereas lubricant, combustible and hydraulic oils may have  $\rho=800..1000 \text{ kg/m}^3$ . Thermal capacity: values are near  $c_p=2000 \text{ J/kg}\cdot\text{K}$  in most cases; lube oils have about  $1800 \text{ J/kg}\cdot\text{K}$  at 250 K, linearly increasing to about  $3000 \text{ J/kg}\cdot\text{K}$  at 600 K; oils use for heat transfer may have values some  $200 \text{ J/kg}\cdot\text{K}$  lower. Thermal conductivity: all of them are poor conductors, with  $k=0.10..0.15 \text{ W/m}\cdot\text{K}$ , slightly decreasing with temperature, even for thermal oils, which are just more resistant to high temperatures (up to 600 K). Viscosity: oil viscosity may vary orders of magnitude from one oil to the other, and decreases exponentially with temperature; e.g. at  $15 \text{ }^\circ\text{C}$ ,  $\mu=3 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  for light silicone oils, gas oil and diesel oil,  $\mu=80 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  for olive oil and light mineral oils,  $\mu > 1000 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  for fuel oil and thick silicone oils).
- m) Liquid propane at 288 K and its equilibrium pressure (729 kPa) has  $\rho_l=508 \text{ kg/m}^3$ ,  $\alpha=2990 \cdot 10^{-6} \text{ K}^{-1}$ ,  $c=780 \text{ m/s}$ ,  $c_p=2620 \text{ J/(kg}\cdot\text{K)}$ ,  $k=0.099 \text{ W/(m}\cdot\text{K)}$ , and  $\mu=108 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ .

- n) R12, dichlorodifluoromethane (also named freon), was the most used refrigerant in the 20<sup>th</sup> c. since its first synthesis in 1929 to its production banning in 1995. Liquid R12 at 288 K and its equilibrium pressure (488 kPa) has  $\rho_l=1350 \text{ kg/m}^3$ ,  $\alpha=2600 \cdot 10^{-6} \text{ K}^{-1}$ ,  $c=553 \text{ m/s}$ ,  $\sigma=0.010 \text{ N/m}$ ,  $c_p=964 \text{ J/(kg}\cdot\text{K)}$ ,  $k=0.087 \text{ W/(m}\cdot\text{K)}$ , and  $\mu=343 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ .
- o) Liquid R134a at 288 K and its equilibrium pressure (486 kPa) has  $\rho_l=1244 \text{ kg/m}^3$ ,  $\alpha=2920 \cdot 10^{-6} \text{ K}^{-1}$ ,  $c=553 \text{ m/s}$ ,  $\sigma=0.010 \text{ N/m}$ ,  $c_p=1390 \text{ J/(kg}\cdot\text{K)}$ ,  $k=0.085 \text{ W/(m}\cdot\text{K)}$ , and  $\mu=221 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ .
- p) R410A is a near-azeotropic mixture of R32 (difluoromethane,  $\text{CH}_2\text{F}_2$ ) and R125 (pentafluoroethane,  $\text{CHF}_2\text{CF}_3$ ), 50/50 by weight (70/30 molar), which can be approximated as a pure substance. Liquid R410A at 288 K and its equilibrium pressure (1253 kPa) has  $\rho_l=1107 \text{ kg/m}^3$ ,  $\alpha=4220 \cdot 10^{-6} \text{ K}^{-1}$ ,  $c=485 \text{ m/s}$ ,  $\sigma=0.007 \text{ N/m}$ ,  $c_p=1610 \text{ J/(kg}\cdot\text{K)}$ .
- q) Sodium,  $M=0.023 \text{ kg/mol}$ ,  $\rho_L=780 \text{ kg/m}^3$ ,  $\rho_S=970 \text{ kg/m}^3$ . The Na-K eutectic alloy, with 22% Na by mass, is a room-temperature liquid,  $T_m=-12.6 \text{ }^\circ\text{C}$ ,  $T_b=785 \text{ }^\circ\text{C}$ , used in high-temperature high-heat-transfer applications; at 100  $^\circ\text{C}$ ,  $\rho=855 \text{ kg/m}^3$ ,  $\alpha=340 \cdot 10^{-6} \text{ 1/K}$ ,  $c=936 \text{ J/(kg}\cdot\text{K)}$ ,  $k=23 \text{ W/(m}\cdot\text{K)}$ ,  $\mu=505 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$ ,  $\sigma=115 \cdot 10^{-3} \text{ N/m}$  and  $\sigma_{\text{elec}}=2.5 \cdot 10^6 \text{ S/m}$ , i.e. 4% that of Cu.
- r) Sulfur hexafluoride has no normal points for melting and boiling because at the normal pressure of 100 kPa the only phase change is the solid-gas transition at 209 K (normal sublimation point). Data in this table refers to the triple point:  $p_{tr}=226 \text{ kPa}$ ,  $T_{tr}=224 \text{ K}=-49.4 \text{ }^\circ\text{C}$ ; i.e.,  $\rho_{l,tr}=1845 \text{ kg/m}^3$ ,  $h_{sv}=h_{sl}+h_{lv}=40+162=202 \text{ kJ/kg}$ . Sublimation point data:  $T=209 \text{ K}=-63.9 \text{ }^\circ\text{C}$ ,  $\rho_s=2770 \text{ kg/m}^3$ ,  $h_{sv}=202 \text{ kJ/kg}$ . Liquid at 288 K and its equilibrium pressure (1.85 MPa) has  $\rho_l=1440 \text{ kg/m}^3$ ,  $\alpha=7070 \cdot 10^{-6} \text{ K}^{-1}$ ,  $c=252 \text{ m/s}$ ,  $\sigma=0.003 \text{ N/m}$ , and  $c_p=1165 \text{ J/(kg}\cdot\text{K)}$ . See further data under [Gas properties](#). See additional comments in f).
- s) Tetradecafluorohexane or perfluorohexane (traded as Fluorinert FC-72, or as Flutec PP1), is a liquid coolant commonly used in electronics cooling because of its electrical insulation properties and stability (thermal, chemical, and biological). Its vapour pressure at 25  $^\circ\text{C}$  is 30 kPa. Its refractive index is  $n=1.251$ . It has zero ozone depletion potential (ODP=0), but a high global warming potential (GWP>5000).
- t) Uranium hexafluoride has no normal points for melting and boiling because at the normal pressure of 100 kPa the only phase change is the solid-gas transition at 329 K (normal sublimation point). Data in this table refers to the triple point:  $p_{tr}=152 \text{ kPa}$ ,  $T_{tr}=337 \text{ K}=-64 \text{ }^\circ\text{C}$ ; i.e.,  $\rho_{l,tr}=3700 \text{ kg/m}^3$ ,  $h_{sv}=h_{sl}+h_{lv}=54+82=136 \text{ kJ/kg}$ . Sublimation point data:  $T=329 \text{ K}=56.4 \text{ }^\circ\text{C}$ ,  $\rho_s=4850 \text{ kg/m}^3$ ,  $h_{sv}=136 \text{ kJ/kg}$ . See further data under [Gas properties](#). See additional comments in f).
- u) Water properties may be used as a first approximation for many natural aqueous solutions (milk, wine, beer, vinegar, seawater, urine, fruit juices, etc.). Their densities are typically  $\rho=1020..1030 \text{ kg/m}^3$ , their melting points 1..2 K below that of water, their boiling points 0.5..1.5 K above that of water, their thermal capacities some 80% of water. Pure water has anomalous dilatation in the 0..4  $^\circ\text{C}$  range, with maximum density  $\rho=1000 \text{ kg/m}^3$  at  $T_4=3.98 \text{ }^\circ\text{C}=277.13 \text{ K}$  decreasing with temperature to  $958 \text{ kg/m}^3$  at 100  $^\circ\text{C}$  (with a minimum of  $322 \text{ kg/m}^3$  at the critical point); a good approximation in the 0..200  $^\circ\text{C}$  range may be  $\rho=1000-0.1\cdot(T-T_4)-0.0033\cdot(T-T_4)^2 \text{ kg/m}^3$ , with  $T_4$  as above. Interface tension of water/air or water/vapour is 0.073 N/m, but for water/mercury 0.390 N/m, water/octane 0.052 N/m, water/benzene 0.035 N/m. Contact angle water/glass in air 0 $^\circ$  if pure, some 30 $^\circ$  typical; mercury/glass in air 140 $^\circ$  if pure, some 120 $^\circ$  typical. Liquid viscosity varies a lot with temperature; e.g. for water,  $\mu=1.8 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  at 0  $^\circ\text{C}$ ,  $0.5 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  at 50  $^\circ\text{C}$  and  $0.35 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$  at 100  $^\circ\text{C}$ . The boiling point of water at 100 kPa is  $T_b=372.75 \pm 0.02 \text{ K}$  ( $99.60 \pm 0.02 \text{ }^\circ\text{C}$ ), whereas at 101.325 kPa (1 atm) it is  $373.12 \pm 0.02 \text{ K}$  ( $99.97 \pm 0.02 \text{ }^\circ\text{C}$ ).
- v) Heavy water usually means water that has been enriched in the deuterium isotope, D, which is not radioactive (without changing oxygen isotope composition), in the form HDO or D<sub>2</sub>O; data here only apply to D<sub>2</sub>O. Heavy water, contrary to normal (or light) water, does not quench thirst; seeds do not germinate. Additional data: for H<sub>2</sub>O (i.e. hydrogen oxide),  $\rho_{\text{max}}=1000 \text{ kg/m}^3$  at 3.98  $^\circ\text{C}$  ( $\rho_{\text{sol}}=917 \text{ kg/m}^3$  at  $T_f=0 \text{ }^\circ\text{C}$ ); for D<sub>2</sub>O (i.e. deuterium oxide):  $\rho_{\text{max}}=1106 \text{ kg/m}^3$  at 11.2  $^\circ\text{C}$ ,  $\rho_{\text{sol}}=1018 \text{ kg/m}^3$  at  $T_f=3.82 \text{ }^\circ\text{C}$  (thus, a heavy-water ice-cube sinks in normal water); for T<sub>2</sub>O (i.e. tritium oxide):  $\rho_{\text{max}}=1215 \text{ kg/m}^3$  at 13.4  $^\circ\text{C}$ ,  $\rho_{\text{sol}}=? \text{ kg/m}^3$  at  $T_f=4.49 \text{ }^\circ\text{C}$ .