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 (C₂H₂, CO₂, SF₆ and UF₆).

<table>
<thead>
<tr>
<th>Substance</th>
<th>Formula</th>
<th>Melting temp.  $T_f$ K</th>
<th>Boiling temp. $T_b$ K</th>
<th>Melting enthalpy $h_{sl}$ kJ/kg</th>
<th>Boiling enthalpy $h_{lv}$ kJ/kg</th>
<th>Density (mass) $\rho$ kg/m$^3$</th>
<th>Thermal expansion $\alpha \times 10^6$ K$^{-1}$</th>
<th>Compressibility $\kappa \times 10^9$ Pa$^{-1}$</th>
<th>Surface tension $\sigma$ N/m</th>
<th>Thermal capacity $c_p$ J/(kg·K)</th>
<th>Thermal conductivity $k$ W/(m·K)</th>
<th>Dynamic viscosity $\mu \times 10^6$ Pa·s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene</td>
<td>C₂H₂</td>
<td>193$^c$</td>
<td>193$^c$</td>
<td>115$^c$</td>
<td>700$^c$</td>
<td>615$^c$</td>
<td>2500</td>
<td>0.001</td>
<td>3000</td>
<td>0.50</td>
<td>160</td>
<td>1.0</td>
</tr>
<tr>
<td>Acetone</td>
<td>C₃H₆O</td>
<td>178</td>
<td>329</td>
<td>98</td>
<td>532</td>
<td>749</td>
<td>1400</td>
<td>1.2</td>
<td>0.024</td>
<td>2150</td>
<td>0.18</td>
<td>330</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>195</td>
<td>240</td>
<td>332</td>
<td>1357</td>
<td>697</td>
<td>1800</td>
<td>0.7</td>
<td>0.022</td>
<td>4600</td>
<td>0.50</td>
<td>266</td>
</tr>
<tr>
<td>Aniline</td>
<td>C₆H₇N</td>
<td>276</td>
<td>457</td>
<td>114</td>
<td>434</td>
<td>1021</td>
<td>840</td>
<td>0.36</td>
<td>0.042</td>
<td>2140</td>
<td>0.17</td>
<td>4467</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>84</td>
<td>87</td>
<td>30</td>
<td>163</td>
<td>1395</td>
<td>4500</td>
<td>2.1</td>
<td>0.014</td>
<td>625</td>
<td>0.13</td>
<td>240</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>C₆H₆</td>
<td>164</td>
<td>269</td>
<td>148</td>
<td>621</td>
<td>1800</td>
<td>1.9</td>
<td>0.013</td>
<td>2260</td>
<td>0.13</td>
<td>13</td>
<td>0.13</td>
</tr>
<tr>
<td>Benzene</td>
<td>C₆H₆</td>
<td>279</td>
<td>353</td>
<td>126</td>
<td>394</td>
<td>884</td>
<td>1400</td>
<td>1.6</td>
<td>0.029</td>
<td>1720</td>
<td>0.15</td>
<td>653</td>
</tr>
<tr>
<td>n-Butane</td>
<td>C₄H₁₀</td>
<td>135</td>
<td>273</td>
<td>80</td>
<td>365</td>
<td>602$^d$</td>
<td>1800</td>
<td>2.2</td>
<td>0.012</td>
<td>2400</td>
<td>0.12</td>
<td>282</td>
</tr>
<tr>
<td>iso-Butane</td>
<td>C₄H₁₀</td>
<td>114</td>
<td>261</td>
<td>78</td>
<td>366</td>
<td>594$^e$</td>
<td>1900</td>
<td>2.3</td>
<td>0.012</td>
<td>2300</td>
<td>0.12</td>
<td>150</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>217$^f$</td>
<td>217$^f$</td>
<td>185$^f$</td>
<td>350$^f$</td>
<td>1180$^f$</td>
<td>3200$^f$</td>
<td>1.9$^f$</td>
<td>0.017$^f$</td>
<td>1950$^f$</td>
<td>0.18$^f$</td>
<td>260$^f$</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>CCl₄</td>
<td>250</td>
<td>350</td>
<td>30</td>
<td>195</td>
<td>1590</td>
<td>1240</td>
<td>1.0</td>
<td>0.027</td>
<td>840</td>
<td>0.11</td>
<td>967</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>C₆H₁₂</td>
<td>280</td>
<td>354</td>
<td>31</td>
<td>360</td>
<td>778</td>
<td>1400</td>
<td>1.9</td>
<td>0.025</td>
<td>1860</td>
<td>0.13</td>
<td>411</td>
</tr>
<tr>
<td>Chloroform</td>
<td>CHCl₃</td>
<td>210</td>
<td>335</td>
<td>74</td>
<td>247</td>
<td>1489</td>
<td>1200</td>
<td>0.69</td>
<td>0.027</td>
<td>980</td>
<td>0.13</td>
<td>562</td>
</tr>
<tr>
<td>n_Decane</td>
<td>C₁₀H₂₂</td>
<td>243</td>
<td>447</td>
<td>202</td>
<td>276</td>
<td>730</td>
<td>1010</td>
<td>0.84</td>
<td>0.024</td>
<td>2000</td>
<td>0.15</td>
<td>920</td>
</tr>
<tr>
<td>Diesel</td>
<td>(C₁₂H₂₆)</td>
<td>235$^g$</td>
<td>470$^g$</td>
<td>250</td>
<td>840</td>
<td>830</td>
<td>0.028</td>
<td>1900</td>
<td>0.15</td>
<td>2400</td>
<td>1.0</td>
<td>1360</td>
</tr>
<tr>
<td>1-Dodecene</td>
<td>C₁₂H₂₄</td>
<td>238</td>
<td>586</td>
<td>122</td>
<td>373</td>
<td>761</td>
<td>980</td>
<td>0.77</td>
<td>0.025</td>
<td>2220</td>
<td>0.14</td>
<td>1340</td>
</tr>
<tr>
<td>n-Dodecane</td>
<td>C₁₂H₂₆</td>
<td>263</td>
<td>489</td>
<td>216</td>
<td>257</td>
<td>780</td>
<td>920</td>
<td>0.77</td>
<td>0.025</td>
<td>2220</td>
<td>0.14</td>
<td>1340</td>
</tr>
<tr>
<td>DME (dimethyl ether)</td>
<td>C₂H₆O</td>
<td>132</td>
<td>250</td>
<td>107</td>
<td>460</td>
<td>736</td>
<td>1900</td>
<td>1.6</td>
<td>0.011</td>
<td>2540</td>
<td>0.14</td>
<td>100</td>
</tr>
<tr>
<td>Substance</td>
<td>Molecular Formula</td>
<td>Molecular Weight</td>
<td>Density @0°C (g/cm³)</td>
<td>Melting Point (°C)</td>
<td>Boiling Point (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETBE (ethyl tert-butyl ether)</td>
<td>C₆H₁₄O</td>
<td>179</td>
<td>340</td>
<td>770</td>
<td>1.8⁷ 0.016⁷ 2440⁹ 0.17⁹ 169⁹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>C₂H₆</td>
<td>90</td>
<td>185</td>
<td>95</td>
<td>352</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol</td>
<td>C₂H₆O</td>
<td>156</td>
<td>351</td>
<td>108</td>
<td>860</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ether (diethyl ether)</td>
<td>C₄H₁₀O₂</td>
<td>262</td>
<td>471</td>
<td>181</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene glycol</td>
<td>C₂H₄O₂</td>
<td>104</td>
<td>169</td>
<td>120</td>
<td>483</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene</td>
<td>C₂H₄</td>
<td>104</td>
<td>169</td>
<td>120</td>
<td>483</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>(C₈H₁₈)</td>
<td>217</td>
<td>360</td>
<td>340</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycerol (glycerine)</td>
<td>C₃H₈O₃</td>
<td>291</td>
<td>560</td>
<td>199</td>
<td>663</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helium (⁴He)</td>
<td>He</td>
<td>9.5</td>
<td>4.2</td>
<td>3.5</td>
<td>20.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helium-3 (³He)</td>
<td>He</td>
<td>NA</td>
<td>3.2</td>
<td>NA</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-Heptane</td>
<td>C₇H₁₆</td>
<td>182</td>
<td>372</td>
<td>140</td>
<td>321</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-Hexane</td>
<td>C₆H₁₄</td>
<td>178</td>
<td>342</td>
<td>150</td>
<td>337</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-Hexadecane (cetane)</td>
<td>C₁₆H₃₄</td>
<td>291</td>
<td>550</td>
<td>230</td>
<td>358</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrazine</td>
<td>N₂H₄</td>
<td>275</td>
<td>387</td>
<td>395</td>
<td>1400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>14</td>
<td>20</td>
<td>59</td>
<td>448</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hydrogen) Deuterium</td>
<td>D₂</td>
<td>19</td>
<td>23</td>
<td>49</td>
<td>304</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene, Jet A-1, RP1</td>
<td>(C₁₂H₂₄)</td>
<td>230</td>
<td>450</td>
<td>250</td>
<td>820</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
<td>234</td>
<td>630</td>
<td>12</td>
<td>301</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>91</td>
<td>112</td>
<td>58</td>
<td>511</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>CH₄O</td>
<td>175</td>
<td>338</td>
<td>99</td>
<td>1100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMH (monomethyl hydrazine)</td>
<td>CH₃N₂</td>
<td>221</td>
<td>364</td>
<td>875</td>
<td>875</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTBE (methyl tert-butyl ether)</td>
<td>C₃H₁₂O</td>
<td>164</td>
<td>328</td>
<td>88</td>
<td>740</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitric acid</td>
<td>HNO₃</td>
<td>231</td>
<td>394</td>
<td>167</td>
<td>615</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>63</td>
<td>77</td>
<td>26</td>
<td>199</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>di-Nitrogen oxide</td>
<td>N₂O</td>
<td>182</td>
<td>185</td>
<td>149</td>
<td>376</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>di-Nitrogen tetroxide</td>
<td>N₂O₄</td>
<td>262</td>
<td>294</td>
<td>160</td>
<td>330</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-Octane</td>
<td>C₈H₁₈</td>
<td>217</td>
<td>399</td>
<td>181</td>
<td>306</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

‡ Values are approximate.
<table>
<thead>
<tr>
<th>Substance</th>
<th>Chemical Formula</th>
<th>Sublimation point</th>
<th>Density</th>
<th>Equilibrium pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>iso-Octane</td>
<td>C₈H₁₈</td>
<td>-</td>
<td>166</td>
<td>372</td>
</tr>
<tr>
<td>Oil (mineral, vegetable)²</td>
<td>C₁₈H₃₆O₂</td>
<td>-</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>-</td>
<td>54</td>
<td>90</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>C₅H₁₂</td>
<td>-</td>
<td>143</td>
<td>309</td>
</tr>
<tr>
<td>Propane</td>
<td>C₃H₈</td>
<td>-</td>
<td>85</td>
<td>231</td>
</tr>
<tr>
<td>Propylene (propene)</td>
<td>C₃H₆</td>
<td>-</td>
<td>88</td>
<td>225</td>
</tr>
<tr>
<td>Propylene glycol</td>
<td>C₆H₁₂O₂</td>
<td>-</td>
<td>214</td>
<td>461</td>
</tr>
<tr>
<td>R₁₂</td>
<td>CCl₂F₂</td>
<td>-</td>
<td>115</td>
<td>243</td>
</tr>
<tr>
<td>R₁₃₄a (tetrafluoroethane)³</td>
<td>CF₃CH₂F</td>
<td>-</td>
<td>170</td>
<td>247</td>
</tr>
<tr>
<td>Silicone oil DMS-10</td>
<td>n.a.</td>
<td>-</td>
<td>120</td>
<td>222</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>-</td>
<td>371</td>
<td>1160</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>SO₂</td>
<td>-</td>
<td>198</td>
<td>263</td>
</tr>
<tr>
<td>Sulfur hexafluoride⁴</td>
<td>SF₆</td>
<td>-</td>
<td>223</td>
<td>223</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>H₂SO₄</td>
<td>-</td>
<td>283</td>
<td>561</td>
</tr>
<tr>
<td>Tetradecafluorohexane⁵ (FC-72)</td>
<td>C₆F₁₄</td>
<td>-</td>
<td>183</td>
<td>329</td>
</tr>
<tr>
<td>UDMH (unsym.dim.hydrazine)</td>
<td>C₂H₆N₂</td>
<td>-</td>
<td>216</td>
<td>337</td>
</tr>
<tr>
<td>Uranium hexafluoride⁶</td>
<td>UF₆</td>
<td>-</td>
<td>337</td>
<td>337</td>
</tr>
<tr>
<td>Water</td>
<td>H₂O</td>
<td>-</td>
<td>273</td>
<td>373</td>
</tr>
<tr>
<td>Water, Heavy⁷</td>
<td>D₂O</td>
<td>-</td>
<td>277</td>
<td>374</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
<td>-</td>
<td>161</td>
<td>165</td>
</tr>
</tbody>
</table>

a) The compressibility coefficient, κ, is related to the speed of sound, c, and the density by \(c=(\rho\kappa)^{-1/2}\) (e.g. for pure water \(c=(\rho\kappa)^{-1/2}=(998\cdot0.46\cdot10^{-9})^{-1/2}=1480\) m/s; and roughly the same for sea water). For liquid-vapour equilibrium, κ 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., \(\rho_{tr}=615\) kg/m³, \(h_{sv}=h_{st}+h_{l}=115+700=815\) kJ/kg. Sublimation point data: \(T=189\) K=−84 °C, \(\rho_{s}=729\) kg/m³, \(h_{sv}=820\) kJ/kg. See additional comments in f).
d) n-Butane liquid density at 288 K and its equilibrium pressure (175 kPa): \(\rho=584\) kg/m³.
e) Iso-Butane liquid density at 288 K and its equilibrium pressure (258 kPa): \( \rho = 563 \text{ kg/m}^3 \).

f) Liquid R134a at 288 K and its equilibrium pressure (486 kPa) has \( \rho = 615 \text{ kg/m}^3 \), \( \alpha = 2600 \cdot 10^{-6} \text{ K}^{-1} \), \( c = 553 \text{ m/s} \), \( \sigma = 0.010 \text{ N/m} \), \( k = 0.099 \text{ W/(m·K)} \), and \( \mu = 221 \cdot 10^{-6} \text{ Pa·s} \).

g) Diesel, gasoline and kerosene are mixtures of various compositions and have not precise boiling or melting points (e.g. at 300 K 10\(^{\circ}\)wt of gasoline is in the vapor state, and at 440 K 90\(^{\circ}\)). Surface tension may vary in the range \( \sigma = 0.022 \ldots 0.035 \text{ N/m} \). Jet A-1 is a kerosene fuel with additives to freeze at \( -50 \text{°C} \) and \( \rho = 800 \ldots 820 \text{ kg/m}^3 \), \( c = 2000 \ldots 2100 \text{ J/(kg·K)} \), \( k = 0.10 \ldots 0.14 \text{ W/(m·K)} \). 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 \( \rho = 358 \text{ kg/m}^3 \), \( \alpha = 0.013 \text{ K}^{-1} \), \( c = 430 \text{ m/s} \), \( c_p = 4750 \text{ J/(kg·K)} \), \( k = 0.079 \text{ W/(m·K)} \), and \( \mu = 45 \cdot 10^{-6} \text{ Pa·s} \).

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) 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 213 °C at 100 kPa, most of the liquid is \( \text{N}_2\text{O}_4 \) which is colourless or pale brownish; when solidified (at \( -11.2 \) °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 \( T=21 \) °C), makes them popular bipropellants for spacecraft rockets.

k) Formula of oleic acid (\( \text{CH}_3-(\text{CH}_2)_{7}-\text{CH}=\text{CH}-(\text{CH}_2)_{7}-\text{COOH} \), \( T_m=268 \text{ K}, \rho_l=75 \text{ kg/kg}_j \)), 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 \( \rho = 915 \ldots 925 \text{ kg/m}^3 \), whereas lubricant, combustible and hydraulic oils may have \( \rho = 800 \ldots 1000 \text{ kg/m}^3 \). Thermal capacity: values are near \( c_p = 2000 \text{ J/(kg·K)} \) in most cases; lube oils have about 1800 J/(kg·K) at 250 K, linearly increasing to about 3000 J/(kg·K) at 600 K; oils use for heat transfer may have values some 200 J/kg·K) lower. Thermal conductivity: all of them are poor conductors, with \( k = 0.10 \ldots 0.15 \text{ W/m·K} \), 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 °C, \( \mu = 3 \cdot 10^{-3} \text{ Pa·s} \) for light silicone oils, gas oil and diesel oil, \( \mu = 80 \cdot 10^{-3} \text{ Pa·s} \) for olive oil and light mineral oils, \( \mu = 1000 \cdot 10^{-3} \text{ Pa·s} \) for fuel oil and thick silicone oils.

l) Liquid propane at 288 K and its equilibrium pressure (729 kPa) has \( \rho = 508 \text{ kg/m}^3 \), \( \alpha = 2990 \cdot 10^{-6} \text{ K}^{-1} \), \( c = 780 \text{ m/s} \), \( c_p = 2620 \text{ J/(kg·K)} \), \( k = 0.099 \text{ W/(m·K)} \), and \( \mu = 108 \cdot 10^{-6} \text{ Pa·s} \).

m) R12, dichlorodifluoromethane (also named freon), was the most used refrigerant in the 20th 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 \( \rho = 1350 \text{ kg/m}^3 \), \( \alpha = 2600 \cdot 10^{-6} \text{ K}^{-1} \), \( c = 553 \text{ m/s} \), \( \sigma = 0.010 \text{ N/m} \), \( c_p = 964 \text{ J/(kg·K)} \), \( k = 0.087 \text{ W/(m·K)} \), and \( \mu = 343 \cdot 10^{-6} \text{ Pa·s} \).

n) Liquid R134a at 288 K and its equilibrium pressure (486 kPa) has \( \rho = 1244 \text{ kg/m}^3 \), \( \alpha = 2920 \cdot 10^{-6} \text{ K}^{-1} \), \( c = 553 \text{ m/s} \), \( \sigma = 0.010 \text{ N/m} \), \( c_p = 1390 \text{ J/(kg·K)} \), \( k = 0.085 \text{ W/(m·K)} \), and \( \mu = 221 \cdot 10^{-6} \text{ Pa·s} \).
o) R410A is a near-azeotropic mixture of R32 (difluoromethane, CH₂F₂) and R125 (pentafluoroethane, CHF₂CF₃), 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 \( \rho = 1107 \text{ kg/m}^3 \), \( \alpha = 340 \times 10^{-6} \text{ K}^{-1} \), \( c = 936 \text{ J/(kg·K)} \), \( \sigma = 0.007 \text{ N/m} \), \( c_p = 1610 \text{ J/(kg·K)} \).

p) Sodium, \( M = 0.023 \text{ kg/mol} \), \( \rho_\text{L} = 780 \text{ kg/m}^3 \), \( \rho_\text{S} = 970 \text{ kg/m}^3 \). The Na-K eutectic alloy, with 22% Na by mass, is a room-temperature liquid, \( T_\text{m} = -1.2 \text{ ºC} \), \( T_\text{b} = 785 \text{ ºC} \), used in high-temperature high-heat-transfer applications; at 100 ºC, \( \rho = 855 \text{ kg/m}^3 \), \( \alpha = 340 \times 10^{-6} \text{ K}^{-1} \), \( c = 936 \text{ J/(kg·K)} \), \( k = 23 \text{ W/(m·K)} \), \( \mu = 505 \times 10^{-6} \text{ Pa·s} \), \( \sigma = 115 \times 10^{-3} \text{ N/m} \), \( \sigma_\text{elec} = 2.5 \times 10^6 \text{ S/m} \), i.e. 4% that of Cu.

q) 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: \( p_\text{tr} = 226 \text{ kPa} \), \( T_\text{tr} = 224 \text{ K} \), \( T_\text{tr} = -49.4 \text{ ºC} \). Sublimation point data: \( T = 209 \text{ K} = -63.9 \text{ ºC} \), \( \rho = 2770 \text{ kg/m}^3 \), \( h_\text{boil} = 202 \text{ kJ/kg} \). Liquid at 288 K and its equilibrium pressure (1.85 MPa) has \( \rho = 1440 \text{ kg/m}^3 \), \( \alpha = 7070 \times 10^{-6} \text{ K}^{-1} \), \( c = 252 \text{ m/s} \), \( \sigma = 0.003 \text{ N/m} \), and \( c_p = 1165 \text{ J/(kg·K)} \). See further data under Gas properties. See additional comments in f).

r) 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 ºC 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).

s) 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: \( p_\text{tr} = 152 \text{ kPa} \), \( T_\text{tr} = 337 \text{ K} = -64 \text{ ºC} \), \( h_\text{tr} = 54+82+136 \text{ kJ/kg} \). Sublimation point data: \( T = 329 \text{ K} = 56.4 \text{ ºC} \), \( \rho_\text{S} = 4850 \text{ kg/m}^3 \), \( h_\text{S} = 136 \text{ kJ/kg} \). See further data under Gas properties. See additional comments in f).

t) 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 ºC range, with maximum density \( \rho = 1000 \text{ kg/m}^3 \) at \( T = 3.98 \text{ ºC} \). A good approximation in the 0..200 ºC range may be \( \rho = 1000 - 0.1 \times (T - T_4) - 0.0033 \times (T - T_4)^2 \text{ kg/m}^3 \), 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 0º if pure, some 30º typical; mercury/glass in air 140º if pure, some 120º typical. Liquid viscosity varies a lot with temperature; e.g. for water, \( \mu = 1.8 \times 10^{-3} \text{ Pa·s} \) at 0 ºC, \( 0.5 \times 10^{-3} \text{ Pa·s} \) at 50 ºC and \( 0.35 \times 10^{-3} \text{ Pa·s} \) at 100 ºC. The boiling point of water at 100 kPa is \( T_\text{b} = 372.75 \pm 0.02 \text{ K} \) (99.60 ± 0.02 ºC), whereas at 101.325 kPa (1 atm) it is 373.12 ± 0.02 K (99.97 ± 0.02 ºC).

u) Heavy water usually means water that has been enriched in the deuterium isotope (without changing oxygen isotope composition), in the form HDO or D₂O; data here only apply to D₂O. Heavy water, contrary to normal (or light) water, does not quench thirst; seeds do not germinate. Additional data: for H₂O (i.e. hydrogen oxide), \( \rho_{\text{max}} = 1000 \text{ kg/m}^3 \) at 3.98 ºC (\( \rho_{\text{sol}} = 917 \text{ kg/m}^3 \) at \( T = 0 \text{ ºC} \)); for D₂O (i.e. deuterium oxide): \( \rho_{\text{max}} = 1106 \text{ kg/m}^3 \) at 11.2 ºC, \( \rho_{\text{sol}} = 1018 \text{ kg/m}^3 \) at \( T = 3.82 \text{ ºC} \) (thus, a heavy-water ice-cube sinks in normal water); for T₂O (i.e. tritium oxide): \( \rho_{\text{max}} = 1215 \text{ kg/m}^3 \) at 13.4 ºC, \( \rho_{\text{sol}} = ? \text{ kg/m}^3 \) at \( T = 4.49 \text{ ºC} \).