

Appendix B

Physical Property Tables

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Table B.1 Selected Physical Property Data^a

| Compound | Formula | Mol. Wt. | SG (20°/4°) | $T_m(^{\circ}\text{C})^b$ | $\Delta\hat{H}_m(T_m)^{c,j}$ kJ/mol | $T_b(^{\circ}\text{C})^d$ | $\Delta\hat{H}_v(T_b)^{e,j}$ kJ/mol | $T_c(\text{K})^f$ | $P_c(\text{atm})^g$ | $(\Delta\hat{H}_f^{\circ})^{h,j}$ kJ/mol | $(\Delta\hat{H}_c^{\circ})^{i,j}$ kJ/mol |
|--------------------|---|----------|----------------------|---------------------------|--|-----------------------------------|--|-------------------|---------------------|---|---|
| Acetaldehyde | CH ₃ CHO | 44.05 | 0.783 ^{18°} | −123.7 | — | 20.2 | 25.1 | 461.0 | — | −166.2(g) | −1192.4(g) |
| Acetic acid | CH ₃ COOH | 60.05 | 1.049 | 16.6 | 12.09 | 118.2 | 24.39 | 594.8 | 57.1 | −486.18(l) −438.15(g) | −871.69(l) −919.73(g) |
| Acetone | C ₃ H ₆ O | 58.08 | 0.791 | −95.0 | 5.69 | 56.0 | 30.2 | 508.0 | 47.0 | −248.2(l) −216.7(g) | −1785.7(l) −1821.4(g) |
| Acetylene | C ₂ H ₂ | 26.04 | — | — | — | −81.5 | 17.6 | 309.5 | 61.6 | +226.75(g) | −1299.6(g) |
| Ammonia | NH ₃ | 17.03 | — | −77.8 | 5.653 | −33.43 | 23.351 | 405.5 | 111.3 | −67.20(l) −46.19(g) | — −382.58(g) |
| Ammonium hydroxide | NH ₄ OH | 35.03 | — | — | — | — | — | — | — | −366.48(aq) | — |
| Ammonium nitrate | NH ₄ NO ₃ | 80.05 | 1.725 ^{25°} | 169.6 | 5.4 | Decomposes at 210°C | | | | −365.14(c) −399.36(aq) | — |
| Ammonium sulfate | (NH ₄) ₂ SO ₄ | 132.14 | 1.769 | 513 | — | Decomposes at 513°C after melting | | | | −1179.3(c) −1173.1(aq) | — |
| Aniline | C ₆ H ₇ N | 93.12 | 1.022 | −6.3 | — | 184.2 | — | 699 | 52.4 | — | — |
| Benzaldehyde | C ₆ H ₅ CHO | 106.12 | 1.046 | −26.0 | — | 179.0 | 38.40 | — | — | −88.83(l) −40.04(g) | −3520.0(l) — |
| Benzene | C ₆ H ₆ | 78.11 | 0.879 | 5.53 | 9.837 | 80.10 | 30.765 | 562.6 | 48.6 | +48.66(l) +82.93(g) | −3267.6(l) −3301.5(g) |
| Benzoic acid | C ₇ H ₆ O ₂ | 122.12 | 1.266 ^{15°} | 122.2 | — | 249.8 | — | — | — | — | −3226.7(g) |
| Benzyl alcohol | C ₇ H ₈ O | 108.13 | 1.045 | −15.4 | — | 205.2 | — | — | — | — | −3741.8(l) |
| Bromine | Br ₂ | 159.83 | 3.119 | −7.4 | 10.8 | 58.6 | 31.0 | 584 | 102 | 0(l) | — |
| 1,2-Butadiene | C ₄ H ₆ | 54.09 | — | −136.5 | — | 10.1 | — | 446 | — | — | — |
| 1,3-Butadiene | C ₄ H ₆ | 54.09 | — | −109.1 | — | −4.6 | — | 425 | 42.7 | — | — |
| <i>n</i> -Butane | C ₄ H ₁₀ | 58.12 | — | −138.3 | 4.661 | −0.6 | 22.305 | 425.17 | 37.47 | −147.0(l) −124.7(g) | −2855.6(l) −2878.5(g) |
| Isobutane | C ₄ H ₁₀ | 58.12 | — | −159.6 | 4.540 | −11.73 | 21.292 | 408.1 | 36.0 | −158.4(l) −134.5(g) | −2849.0(l) −2868.8(g) |
| 1-Butene | C ₄ H ₈ | 56.10 | — | −185.3 | 3.8480 | −6.25 | 21.916 | 419.6 | 39.7 | +1.17(g) | −2718.6(g) |
| Calcium carbide | CaC ₂ | 64.10 | 2.22 ^{18°} | 2300 | — | — | — | — | — | −62.76(c) | — |
| Calcium carbonate | CaCO ₃ | 100.09 | 2.93 | Decomposes at 825°C | | | | | | −1206.9(c) | — |
| Calcium chloride | CaCl ₂ | 110.99 | 2.152 ^{15°} | 782 | 28.37 | >1600 | — | — | — | −794.96(c) | — |

| | | | | | | | | | | | |
|--------------------------|---|--------------------|--------------------------|---------------------|-------|----------------------------------|-------|-------|------|-------------|------------|
| Calcium hydroxide | Ca(OH) ₂ | 74.10 | 2.24 | | | (−H ₂ O at 580°C) | | | | −986.59(c) | — |
| Calcium oxide | CaO | 56.08 | 3.32 | 2570 | 50 | 2850 | — | — | — | −635.6(c) | — |
| Calcium phosphate | Ca ₃ (PO ₄) ₂ | 310.19 | 3.14 | 1670 | — | — | — | — | — | −4138(c) | — |
| Calcium silicate | CaSiO ₃ | 116.17 | 2.915 | 1530 | 48.62 | — | — | — | — | −1584(c) | — |
| Calcium sulfate | CaSO ₄ | 136.15 | 2.96 | — | — | — | — | — | — | −1432.7(c) | — |
| Calcium sulfate (gypsum) | CaSO ₄ ·2H ₂ O | 172.18 | 2.32 | | | (−1.5 H ₂ O at 128°C) | — | — | — | −1450.4(aq) | — |
| | | | | | | | | | | −2021(c) | — |
| Carbon (graphite) | C | 12.010 | 2.26 | 3600 | 46.0 | 4200 | — | — | — | 0(c) | −393.51(c) |
| Carbon dioxide | CO ₂ | 44.01 | — | −56.6 at 5.2 atm | 8.33 | (Sublimes at −78°C) | 304.2 | 72.9 | | −412.9(l) | — |
| Carbon disulfide | CS ₂ | 76.14 | 1.261 ^{22°/20°} | −112.1 | 4.39 | 46.25 | 26.8 | 552.0 | 78.0 | −393.5(g) | — |
| Carbon monoxide | CO | 28.01 | — | −205.1 | 0.837 | −191.5 | 6.042 | 133.0 | 34.5 | +87.9(l) | −1075.2(l) |
| | | | | | | | | | | +115.3(g) | 1102.6(g) |
| Carbon tetrachloride | CCl ₄ | 153.84 | 1.595 | −22.9 | 2.51 | 76.7 | 30.0 | 556.4 | 45.0 | −110.52(g) | −282.99(g) |
| Chlorine | Cl ₂ | 70.91 | — | −101.00 | 6.406 | −34.06 | 20.4 | 417.0 | 76.1 | −139.5(l) | −352.2(l) |
| Chlorobenzene | C ₆ H ₅ Cl | 112.56 | 1.107 | −45 | — | 132.10 | 36.5 | 632.4 | 44.6 | −106.7(g) | −385.0(g) |
| Chloroethane | C ₂ H ₅ Cl | See ethyl chloride | | | | | | | | | |

^aAdapted in part from D. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, 3rd Edition, ©1974, Tables D.1 and F.1. Adapted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

^bMelting point at 1 atm.

^cHeat of fusion at T_m and 1 atm.

^dBoiling point at 1 atm.

^eHeat of vaporization at T_b and 1 atm.

^fCritical temperature.

^gCritical pressure.

^hHeat of formation at 25°C and 1 atm.

ⁱHeat of combustion at 25°C and 1 atm. Standard states of products are CO₂(g), H₂O(l), SO₂(g), HCl(aq), and N₂(g). To calculate $\Delta \hat{H}_c^\circ$ with H₂O(g) as a product, add 44.01 n_w to the tabulated value, where n_w = moles H₂O formed/mole fuel burned.

^jTo convert $\Delta \hat{H}$ to kcal/mol, divide given value by 4.184; to convert to Btu/lb-mole, multiply by 430.28.

(continued)

Table B.1 (Continued)

| Compound | Formula | Mol. Wt. | SG (20°/4°) | $T_m(^{\circ}\text{C})^b$ | $\Delta\hat{H}_m(T_m)^{c,j}$ kJ/mol | $T_b(^{\circ}\text{C})^d$ | $\Delta\hat{H}_v(T_b)^{e,j}$ kJ/mol | $T_c(\text{K})^f$ | $P_c(\text{atm})^g$ | $(\Delta\hat{H}_f^{\circ})^{h,j}$ kJ/mol | $(\Delta\hat{H}_c^{\circ})^{i,j}$ kJ/mol |
|-------------------------|---|----------|-----------------------|---------------------------|--|---------------------------|--|-------------------|---------------------|---|---|
| Chloroform | CHCl ₃ | 119.39 | 1.489 | −63.7 | — | 61.0 | | 536.0 | 54.0 | −131.8(l) | −373(l) |
| Copper | Cu | 63.54 | 8.92 | 1083 | 13.01 | 2595 | 304.6 | — | | 0(c) | — |
| Cupric sulfate | CuSO ₄ | 159.61 | 3.606 ^{15°} | | | Decomposes > 600°C | | | | −769.9(c) | — |
| Cyclohexane | C ₆ H ₁₂ | 84.16 | 0.779 | 6.7 | 2.677 | 80.7 | 30.1 | 553.7 | 40.4 | −843.1(aq) | |
| | | | | | | | | | | −156.2(l) | −3919.9(l) |
| | | | | | | | | | | −123.1(g) | −3953.0(g) |
| Cyclopentane | C ₅ H ₁₀ | 70.13 | 0.745 | −93.4 | 0.609 | 49.3 | 27.30 | 511.8 | 44.55 | −105.9(l) | −3290.9(l) |
| | | | | | | | | | | −77.2(g) | −3319.5(g) |
| <i>n</i> -Decane | C ₁₀ H ₂₂ | 142.28 | 0.730 | −29.9 | — | 173.8 | — | 619.0 | 20.8 | −249.7(l) | −6778.3(l) |
| | | | | | | | | | | — | −6829.7(g) |
| Diethyl ether | (C ₂ H ₅) ₂ O | 74.12 | 0.708 ^{25°} | −116.3 | 7.30 | 34.6 | 26.05 | 467 | 35.6 | −272.8(l) | −2726.7(l) |
| Ethane | C ₂ H ₆ | 30.07 | — | −183.3 | 2.859 | −88.6 | 14.72 | 305.4 | 48.2 | −84.67(g) | −1559.9(g) |
| Ethyl acetate | C ₄ H ₈ O ₂ | 88.10 | 0.901 | −83.8 | — | 77.0 | — | 523.1 | 37.8 | −463.2(l) | −2246.4(l) |
| | | | | | | | | | | −426.8(g) | — |
| Ethyl alcohol (Ethanol) | C ₂ H ₅ OH | 46.07 | 0.789 | −114.6 | 5.021 | 78.5 | 38.58 | 516.3 | 63.0 | −277.63(l) | −1366.91(l) |
| | | | | | | | | | | −235.31(g) | −1409.25(g) |
| Ethyl benzene | C ₈ H ₁₀ | 106.16 | 0.867 | −94.67 | 9.163 | 136.2 | 35.98 | 619.7 | 37.0 | −12.46(l) | −4564.9(l) |
| | | | | | | | | | | +29.79(g) | −4607.1(g) |
| Ethyl bromide | C ₂ H ₅ Br | 108.98 | 1.460 | −119.1 | — | 38.2 | — | 504 | 61.5 | −54.4(g) | — |
| Ethyl chloride | C ₂ H ₅ Cl | 64.52 | 0.903 ^{15°} | −138.3 | 4.452 | 13.1 | 24.7 | 460.4 | 52.0 | −105.0(g) | — |
| 3-Ethyl hexane | C ₈ H ₁₈ | 114.22 | 0.717 | — | — | 118.5 | 34.27 | 567.0 | 26.4 | −250.5(l) | −5407.1(l) |
| | | | | | | | | | | −210.9(g) | −5509.8(g) |
| Ethylene | C ₂ H ₄ | 28.05 | — | −169.2 | 3.350 | −103.7 | 13.54 | 283.1 | 50.5 | +52.28(g) | −1410.99(g) |
| Ethylene glycol | C ₂ H ₆ O ₂ | 62.07 | 1.113 ^{19°} | −13 | 11.23 | 197.2 | 56.9 | — | — | −451.5(l) | −1179.5(l) |
| | | | | | | | | | | −387.1(g) | — |
| Ferric oxide | Fe ₂ O ₃ | 159.70 | 5.12 | | | Decomposes at 1560°C | | | | −822.2(c) | |
| Ferrous oxide | FeO | 71.85 | 5.7 | — | — | — | — | — | — | −266.5(c) | — |
| Ferrous sulfide | FeS | 87.92 | 4.84 | 1193 | — | — | — | — | — | −95.1(c) | — |
| Formaldehyde | H ₂ CO | 30.03 | 0.815 ^{−20°} | −92 | — | −19.3 | 24.48 | — | — | −115.90(g) | −563.46(g) |
| Formic acid | CH ₂ O ₂ | 46.03 | 1.220 | 8.30 | 12.68 | 100.5 | 22.25 | — | — | −409.2(l) | −262.8(l) |
| | | | | | | | | | | −362.6(g) | — |
| Glycerol | C ₃ H ₈ O ₃ | 92.09 | 1.260 ^{50°} | 18.20 | 18.30 | 290.0 | — | — | — | −665.9(l) | −1661.1(l) |
| Helium | He | 4.00 | — | −269.7 | 0.02 | −268.9 | 0.084 | 5.26 | 2.26 | 0(g) | — |

| | | | | | | | | | | | |
|------------------------------|--|--------|---------------------------|---------------------|-------|---------|-------|--------|-------|---------------------------------|--------------------------|
| <i>n</i> -Heptane | C ₇ H ₁₆ | 100.20 | 0.684 | −90.59 | 14.03 | 98.43 | 31.69 | 540.2 | 27.0 | −224.4(l) −187.8(g) | −4816.9(l) −4853.5(g) |
| <i>n</i> -Hexane | C ₆ H ₁₄ | 86.17 | 0.659 | −95.32 | 13.03 | 68.74 | 28.85 | 507.9 | 29.9 | −198.8(l) −167.2(g) | −4163.1(l) −4194.8(g) |
| Hydrogen | H ₂ | 2.016 | — | −259.19 | 0.12 | −252.76 | 0.904 | 33.3 | 12.8 | 0(g) | −285.84(g) |
| Hydrogen bromide | HBr | 80.92 | — | −86 | — | −67 | — | — | — | −36.23(g) | — |
| Hydrogen chloride | HCl | 36.47 | — | −114.2 | 1.99 | −85.0 | 16.1 | 324.6 | 81.5 | −92.31(g) | — |
| Hydrogen cyanide | HCN | 27.03 | — | −14 | — | 26 | — | — | — | +130.54(g) | — |
| Hydrogen fluoride | HF | 20.0 | — | −83 | — | 20 | — | 503.2 | — | −268.6(g) −316.9(aq, 200) | — |
| Hydrogen sulfide | H ₂ S | 34.08 | — | −85.5 | 2.38 | −60.3 | 18.67 | 373.6 | 88.9 | −19.96(g) | −562.59(g) |
| Iodine | I ₂ | 253.8 | 4.93 | 113.3 | — | 184.2 | — | 826.0 | — | 0(c) | — |
| Iron | Fe | 55.85 | 7.7 | 1535 | 15.1 | 2800 | 354.0 | — | — | 0(c) | — |
| Lead | Pb | 207.21 | 11.337 ^{20°/20°} | 327.4 | 5.10 | 1750 | 179.9 | — | — | 0(c) | — |
| Lead oxide | PbO | 223.21 | 9.5 | 886 | 11.7 | 1472 | 213 | — | — | −219.2(c) | — |
| Magnesium | Mg | 24.32 | 1.74 | 650 | 9.2 | 1120 | 131.8 | — | — | 0(c) | — |
| Magnesium chloride | MgCl ₂ | 95.23 | 2.325 ^{25°} | 714 | 43.1 | 1418 | 136.8 | — | — | −641.8(c) | — |
| Magnesium hydroxide | Mg(OH) ₂ | 58.34 | 2.4 | Decomposes at 350°C | | | | — | — | — | — |
| Magnesium oxide | MgO | 40.32 | 3.65 | 2900 | 77.4 | 3600 | — | — | — | −601.8(c) | — |
| Mercury | Hg | 200.61 | 13.546 | −38.87 | — | −356.9 | — | — | — | 0(c) | — |
| Methane | CH ₄ | 16.04 | — | −182.5 | 0.94 | −161.5 | 8.179 | 190.70 | 45.8 | −74.85(g) | −890.36(g) |
| Methyl acetate | C ₃ H ₆ O ₂ | 74.08 | 0.933 | −98.9 | — | 57.1 | — | 506.7 | 46.30 | −409.4(l) | −1595(l) |
| Methyl alcohol (Methanol) | CH ₃ OH | 32.04 | 0.792 | −97.9 | 3.167 | 64.7 | 35.27 | 513.20 | 78.50 | −238.6(l) −201.2(g) | 726.6(l) −764.0(g) |
| Methyl amine | CH ₃ N | 31.06 | 0.699 ^{−11°} | −92.7 | — | −6.9 | — | 429.9 | 73.60 | −28.0(g) | −1071.5(l) |
| Methyl chloride | CH ₃ Cl | 50.49 | — | −97.9 | — | −24 | — | 416.1 | 65.80 | −81.92(g) | — |

(continued)

Table B.1 (Continued)

| Compound | Formula | Mol. Wt. | SG (20°/4°) | $T_m(^{\circ}\text{C})^b$ | $\Delta\hat{H}_m(T_m)^{c,j}$ kJ/mol | $T_b(^{\circ}\text{C})^d$ | $\Delta\hat{H}_v(T_b)^{e,j}$ kJ/mol | $T_c(\text{K})^f$ | $P_c(\text{atm})^g$ | $(\Delta\hat{H}_f^{\circ})^{h,j}$ kJ/mol | $(\Delta\hat{H}_c^{\circ})^{i,j}$ kJ/mol |
|---------------------|--|----------|-----------------------|---------------------------|--|-------------------------------|--|-------------------|---------------------|---|---|
| Methyl ethyl ketone | C ₄ H ₈ O | 72.10 | 0.805 | −87.1 | — | 78.2 | 32.0 | — | — | — | −2436(l) |
| Naphthalene | C ₁₀ H ₈ | 128.16 | 1.145 | 80.0 | — | 217.8 | — | — | — | — | −5157(g) |
| Nickel | Ni | 58.69 | 8.90 | 1452 | — | 2900 | — | — | — | 0(c) | — |
| Nitric acid | HNO ₃ | 63.02 | 1.502 | −41.6 | 10.47 | 86 | 30.30 | — | — | −173.23(l) −206.57(aq) | — |
| Nitrobenzene | C ₆ H ₅ O ₂ N | 123.11 | 1.203 | 5.5 | — | 210.7 | — | — | — | — | −3092.8(l) |
| Nitrogen | N ₂ | 28.02 | — | −210.0 | 0.720 | −195.8 | 5.577 | 126.20 | 33.5 | 0(g) | — |
| Nitrogen dioxide | NO ₂ | 46.01 | — | −9.3 | 7.335 | 21.3 | 14.73 | 431.0 | 100.0 | +33.8(g) | — |
| Nitric oxide | NO | 30.01 | — | −163.6 | 2.301 | −151.8 | 13.78 | 179.20 | 65.0 | +90.37(g) | — |
| Nitrogen pentoxide | N ₂ O ₅ | 108.02 | 1.63 ^{18°} | 30 | — | 47 | — | — | — | — | — |
| Nitrogen tetroxide | N ₂ O ₄ | 92.0 | 1.448 | −9.5 | — | 21.1 | — | 431.0 | 99.0 | +9.3(g) | — |
| Nitrous oxide | N ₂ O | 44.02 | 1.226 ^{−89°} | −91.1 | — | −88.8 | — | 309.5 | 71.70 | +81.5(g) | — |
| <i>n</i> -Nonane | C ₉ H ₂₀ | 128.25 | 0.718 | −53.8 | — | 150.6 | — | 595 | 23.0 | −229.0(l) — | −6124.5(l) −6171.0(g) |
| <i>n</i> -Octane | C ₈ H ₁₈ | 114.22 | 0.703 | −57.0 | — | 125.5 | — | 568.8 | 24.5 | −249.9(l) −208.4(g) | −5470.7(l) −5512.2(g) |
| Oxalic acid | C ₂ H ₂ O ₄ | 90.04 | 1.90 | — | Decomposes at 186°C | | — | — | — | −826.8(c) | −251.9(s) |
| Oxygen | O ₂ | 32.00 | — | −218.75 | 0.444 | −182.97 | 6.82 | 154.4 | 49.7 | 0(g) | — |
| <i>n</i> -Pentane | C ₅ H ₁₂ | 72.15 | 0.63 ^{18°} | −129.6 | 8.393 | 36.07 | 25.77 | 469.80 | 33.3 | −173.0(l) −146.4(g) | −3509.5(l) −3536.1(g) |
| Isopentane | C ₅ H ₁₂ | 72.15 | 0.62 ^{19°} | −160.1 | — | 27.7 | — | 461.00 | 32.9 | −179.3(l) −152.0(g) | −3507.5(l) −3529.2(g) |
| 1-Pentene | C ₅ H ₁₀ | 70.13 | 0.641 | −165.2 | 4.94 | 29.97 | — | 474 | 39.9 | −20.9(g) | −3375.8(g) |
| Phenol | C ₆ H ₅ OH | 94.11 | 1.071 ^{25°} | 42.5 | 11.43 | 181.4 | — | 692.1 | 60.5 | −158.1(l) −90.8(g) | −3063.5(s) — |
| Phosphoric acid | H ₃ PO ₄ | 98.00 | 1.834 ^{18°} | 42.3 | 10.54 | (−½H ₂ O at 213°C) | — | — | — | −1281.1(c) −1278.6(aq, 1H ₂ O) | — — |
| Phosphorus (red) | P ₄ | 123.90 | 2.20 | 590 ^{43 atm} | 81.17 | Ignites in air, 725°C | — | — | — | −17.6(c) 0(c) | — |

| | | | | | | | | | | | |
|--------------------------|----------------------------------|--------|----------------------|---------|---------------------|---------------------|-------|-------|-------|-------------------------|---------------------------|
| Phosphorus (white) | P ₄ | 123.90 | 1.82 | 44.2 | 2.51 | 280 | 49.71 | — | — | | — |
| Phosphorus pentoxide | P ₂ O ₅ | 141.95 | 2.387 | | Sublimes at 250°C | | | — | — | −1506.2(c) | — |
| Propane | C ₃ H ₈ | 44.09 | — | −187.69 | 3.52 | −42.07 | 18.77 | 369.9 | 42.0 | −119.8(l) −103.8(g) | −2204.0(l) −2220.0(g) |
| Propylene | C ₃ H ₆ | 42.08 | — | −185.2 | 3.00 | −47.70 | 18.42 | 365.1 | 45.4 | +20.41(g) | −2058.4(g) |
| <i>n</i> -Propyl alcohol | C ₃ H ₇ OH | 60.09 | 0.804 | −127 | — | 97.04 | — | 536.7 | 49.95 | −300.70(l) −255.2(g) | −2010.4(l) −2068.6(g) |
| Isopropyl alcohol | C ₃ H ₇ OH | 60.09 | 0.785 | −89.7 | — | 82.24 | — | 508.8 | 53.0 | −310.9(l) | −1986.6(l) |
| <i>n</i> -Propyl benzene | C ₉ H ₁₂ | 120.19 | 0.862 | −99.50 | 8.54 | 159.2 | 38.24 | 638.7 | 31.3 | −38.40(l) +7.82(g) | −5218.2(l) −5264.48(g) |
| Silicon dioxide | SiO ₂ | 60.09 | 2.25 | 1710 | 14.2 | 2230 | — | — | — | −851.0(c) | — |
| Sodium bicarbonate | NaHCO ₃ | 84.01 | 2.20 | | Decomposes at 270°C | | | — | — | −945.6(c) | — |
| Sodium bisulfate | NaHSO ₄ | 120.07 | 2.742 | — | — | — | — | — | — | −1126.3(c) | — |
| Sodium carbonate | Na ₂ CO ₃ | 105.99 | 2.533 | | Decomposes at 854°C | | | — | — | −1130.9(c) | — |
| Sodium chloride | NaCl | 58.45 | 2.163 | 808 | 28.5 | 1465 | 170.7 | — | — | −411.0(c) | — |
| Sodium cyanide | NaCN | 49.01 | — | 562 | 16.7 | 1497 | 155 | — | — | −89.79(c) | — |
| Sodium hydroxide | NaOH | 40.00 | 2.130 | 319 | 8.34 | 1390 | — | — | — | −426.6(c) −469.4(aq) | — — |
| Sodium nitrate | NaNO ₃ | 85.00 | 2.257 | 310 | 15.9 | Decomposes at 380°C | | | — | −466.7(c) | — |
| Sodium nitrite | NaNO ₂ | 69.00 | 2.168 ^{0°} | 271 | — | Decomposes at 320°C | | | — | −359.4(c) | — |
| Sodium sulfate | Na ₂ SO ₄ | 142.05 | 2.698 | 890 | 24.3 | — | — | — | — | −1384.5(c) | — |
| Sodium sulfide | Na ₂ S | 78.05 | 1.856 | 950 | 6.7 | — | — | — | — | −373.2(c) | — |
| Sodium sulfite | Na ₂ SO ₃ | 126.05 | 2.633 ^{15°} | | Decomposes | | | — | — | −1090.3(c) | — |

(continued)

Table B.1 (Continued)

| Compound | Formula | Mol. Wt. | SG (20°/4°) | $T_m(^{\circ}\text{C})^b$ | $\Delta\hat{H}_m(T_m)^{e,j}$ kJ/mol | $T_b(^{\circ}\text{C})^d$ | $\Delta\hat{H}_v(T_b)^{e,j}$ kJ/mol | $T_c(\text{K})^f$ | $P_c(\text{atm})^g$ | $(\Delta\hat{H}_f^{\circ})^{h,j}$ kJ/mol | $(\Delta\hat{H}_c^{\circ})^{i,j}$ kJ/mol |
|---------------------|-----------------------------------|----------|----------------------|---------------------------|--|---------------------------|--|-------------------|---------------------|---|---|
| Sodium thiosulfate | $\text{Na}_2\text{S}_2\text{O}_3$ | 158.11 | 1.667 | — | — | — | — | — | — | −1117.1(c) | — |
| Sulfur (rhombic) | S_8 | 256.53 | 2.07 | 113 | 10.04 | 444.6 | 83.7 | — | — | 0(c) | — |
| Sulfur (monoclinic) | S_8 | 256.53 | 1.96 | 119 | 14.17 | 444.6 | 83.7 | — | — | +0.30(c) | — |
| Sulfur dioxide | SO_2 | 64.07 | — | −75.48 | 7.402 | −10.02 | 24.91 | 430.7 | 77.8 | −296.90(g) | — |
| Sulfur trioxide | SO_3 | 80.07 | — | 16.84 | 25.48 | 43.3 | 41.80 | 491.4 | 83.8 | −395.18(g) | — |
| Sulfuric acid | H_2SO_4 | 98.08 | 1.834 ^{18°} | 10.35 | 9.87 | Decomposes at 340°C | | | — | −811.32(l) −907.51(aq) | — |
| Toluene | C_7H_8 | 92.13 | 0.866 | −94.99 | 6.619 | 110.62 | 33.47 | 593.9 | 40.3 | +12.00(l) +50.00(g) | −3909.9(l) −3947.9(g) |
| Water | H_2O | 18.016 | 1.00 ^{4°} | 0.00 | 6.0095 | 100.00 | 40.656 | 647.4 | 218.3 | −285.84(l) −241.83(g) | — — |
| <i>m</i> -Xylene | C_8H_{10} | 106.16 | 0.864 | −47.87 | 11.569 | 139.10 | 36.40 | 619 | 34.6 | −25.42(l) +17.24(g) | −4551.9(l) −4594.5(g) |
| <i>o</i> -Xylene | C_8H_{10} | 106.16 | 0.880 | −25.18 | 13.598 | 144.42 | 36.82 | 631.5 | 35.7 | −24.44(l) +18.99(g) | −4552.9(l) −4596.3(g) |
| <i>p</i> -Xylene | C_8H_{10} | 106.16 | 0.861 | 13.26 | 17.11 | 138.35 | 36.07 | 618 | 33.9 | −24.43(l) 17.95(g) | −4552.91(l) −4595.2(g) |
| Zinc | Zn | 65.38 | 7.140 | 419.5 | 6.674 | 907 | 114.77 | — | — | 0(c) | — |

Table B.2 Heat Capacities^a

| Form 1: $C_p[\text{kJ}/(\text{mol}\cdot^\circ\text{C})]$ or $[\text{kJ}/(\text{mol}\cdot\text{K})] = a + bT + cT^2 + dT^3$ Form 2: $C_p[\text{kJ}/(\text{mol}\cdot^\circ\text{C})]$ or $[\text{kJ}/(\text{mol}\cdot\text{K})] = a + bT + cT^{-2}$ | | | | | | | | | | |
|--|------------------------------|-------------|-------|------|------------------|-----------------|-----------------|-------------------------|--------------------|-----------------------------|
| <i>Example:</i> $(C_p)_{\text{acetone(g)}} = 0.07196 + (20.10 \times 10^{-5})T - (12.78 \times 10^{-8})T^2 + (34.76 \times 10^{-12})T^3$, where T is in $^\circ\text{C}$. | | | | | | | | | | |
| <i>Note:</i> The formulas for gases are strictly applicable at pressures low enough for the ideal gas equation of state to apply. | | | | | | | | | | |
| Compound | Formula | Mol. Wt. | State | Form | Temp. Unit | $a \times 10^3$ | $b \times 10^5$ | $c \times 10^8$ | $d \times 10^{12}$ | Range (Units of T) |
| Acetone | CH_3COCH_3 | 58.08 | l | 1 | $^\circ\text{C}$ | 123.0 | 18.6 | | | −30–60 |
| | | | g | 1 | $^\circ\text{C}$ | 71.96 | 20.10 | −12.78 | 34.76 | 0–1200 |
| Acetylene | C_2H_2 | 26.04 | g | 1 | $^\circ\text{C}$ | 42.43 | 6.053 | −5.033 | 18.20 | 0–1200 |
| Air | | 29.0 | g | 1 | $^\circ\text{C}$ | 28.94 | 0.4147 | 0.3191 | −1.965 | 0–1500 |
| | | | g | 1 | K | 28.09 | 0.1965 | 0.4799 | −1.965 | 273–1800 |
| Ammonia | NH_3 | 17.03 | g | 1 | $^\circ\text{C}$ | 35.15 | 2.954 | 0.4421 | −6.686 | 0–1200 |
| Ammonium sulfate | $(\text{NH}_4)_2\text{SO}_4$ | 132.15 | c | 1 | K | 215.9 | | | | 275–328 |
| Benzene | C_6H_6 | 78.11 | l | 1 | $^\circ\text{C}$ | 126.5 | 23.4 | | | 6–67 |
| | | | g | 1 | $^\circ\text{C}$ | 74.06 | 32.95 | −25.20 | 77.57 | 0–1200 |
| Isobutane | C_4H_{10} | 58.12 | g | 1 | $^\circ\text{C}$ | 89.46 | 30.13 | −18.91 | 49.87 | 0–1200 |
| <i>n</i> -Butane | C_4H_{10} | 58.12 | g | 1 | $^\circ\text{C}$ | 92.30 | 27.88 | −15.47 | 34.98 | 0–1200 |
| Isobutene | C_4H_8 | 56.10 | g | 1 | $^\circ\text{C}$ | 82.88 | 25.64 | −17.27 | 50.50 | 0–1200 |
| Calcium carbide | CaC_2 | 64.10 | c | 2 | K | 68.62 | 1.19 | -8.66×10^{10} | — | 298–720 |
| Calcium carbonate | CaCO_3 | 100.09 | c | 2 | K | 82.34 | 4.975 | -12.87×10^{10} | — | 273–1033 |
| Calcium hydroxide | $\text{Ca}(\text{OH})_2$ | 74.10 | c | 1 | K | 89.5 | | | | 276–373 |
| Calcium oxide | CaO | 56.08 | c | 2 | K | 41.84 | 2.03 | -4.52×10^{10} | | 273–1173 |
| Carbon | C | 12.01 | c | 2 | K | 11.18 | 1.095 | -4.891×10^{10} | | 273–1373 |
| Carbon dioxide | CO_2 | 44.01 | g | 1 | $^\circ\text{C}$ | 36.11 | 4.233 | −2.887 | 7.464 | 0–1500 |
| Carbon monoxide | CO | 28.01 | g | 1 | $^\circ\text{C}$ | 28.95 | 0.4110 | 0.3548 | −2.220 | 0–1500 |
| Carbon tetrachloride | CCl_4 | 153.84 | l | 1 | K | 93.39 | 12.98 | | | 273–343 |
| Chlorine | Cl_2 | 70.91 | g | 1 | $^\circ\text{C}$ | 33.60 | 1.367 | −1.607 | 6.473 | 0–1200 |
| Copper | Cu | 63.54 | c | 1 | K | 22.76 | 0.6117 | | | 273–1357 |

^aAdapted in part from D. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, 3rd Edition, © 1974, Table E.1. Adapted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

(continued)

Table B.2 (Continued)

| Compound | Formula | Mol. Wt. | State | Form | Temp. Unit | $a \times 10^3$ | $b \times 10^5$ | $c \times 10^8$ | $d \times 10^{12}$ | Range (Units of T) |
|-------------------------------|----------------------------------|-------------|-------|------|---------------|-----------------|-----------------|---------------------------|--------------------|-----------------------------|
| Cumene (Isopropyl benzene) | C ₉ H ₁₂ | 120.19 | g | 1 | °C | 139.2 | 53.76 | -39.79 | 120.5 | 0-1200 |
| Cyclohexane | C ₆ H ₁₂ | 84.16 | g | 1 | °C | 94.140 | 49.62 | -31.90 | 80.63 | 0-1200 |
| Cyclopentane | C ₅ H ₁₀ | 70.13 | g | 1 | °C | 73.39 | 39.28 | -25.54 | 68.66 | 0-1200 |
| Ethane | C ₂ H ₆ | 30.07 | g | 1 | °C | 49.37 | 13.92 | -5.816 | 7.280 | 0-1200 |
| Ethyl alcohol (Ethanol) | C ₂ H ₅ OH | 46.07 | l | 1 | °C | 103.1 | | | | 0 |
| | | | l | 1 | °C | 158.8 | | | | 100 |
| | | | g | 1 | °C | 61.34 | 15.72 | -8.749 | 19.83 | 0-1200 |
| Ethylene | C ₂ H ₄ | 28.05 | g | 1 | °C | +40.75 | 11.47 | -6.891 | 17.66 | 0-1200 |
| Ferric oxide | Fe ₂ O ₃ | 159.70 | c | 2 | K | 103.4 | 6.711 | -17.72 × 10 ¹⁰ | — | 273-1097 |
| Formaldehyde | CH ₂ O | 30.03 | g | 1 | °C | 34.28 | 4.268 | 0.0000 | -8.694 | 0-1200 |
| Helium | He | 4.00 | g | 1 | °C | 20.8 | | | | 0-1200 |
| <i>n</i> -Hexane | C ₆ H ₁₄ | 86.17 | l | 1 | °C | 216.3 | | | | 20-100 |
| | | | g | 1 | °C | 137.44 | 40.85 | -23.92 | 57.66 | 0-1200 |
| Hydrogen | H ₂ | 2.016 | g | 1 | °C | 28.84 | 0.00765 | 0.3288 | -0.8698 | 0-1500 |
| Hydrogen bromide | HBr | 80.92 | g | 1 | °C | 29.10 | -0.0227 | 0.9887 | -4.858 | 0-1200 |
| Hydrogen chloride | HCl | 36.47 | g | 1 | °C | 29.13 | -0.1341 | 0.9715 | -4.335 | 0-1200 |
| Hydrogen cyanide | HCN | 27.03 | g | 1 | °C | 35.3 | 2.908 | 1.092 | | 0-1200 |
| Hydrogen sulfide | H ₂ S | 34.08 | g | 1 | °C | 33.51 | 1.547 | 0.3012 | -3.292 | 0-1500 |
| Magnesium chloride | MgCl ₂ | 95.23 | c | 1 | K | 72.4 | 1.58 | | | 273-991 |
| Magnesium oxide | MgO | 40.32 | c | 2 | K | 45.44 | 0.5008 | -8.732 × 10 ¹⁰ | | 273-2073 |
| Methane | CH ₄ | 16.04 | g | 1 | °C | 34.31 | 5.469 | 0.3661 | -11.00 | 0-1200 |
| | | | g | 1 | K | 19.87 | 5.021 | 1.268 | -11.00 | 273-1500 |
| Methyl alcohol (Methanol) | CH ₃ OH | 32.04 | l | 1 | °C | 75.86 | 16.83 | | | 0-65 |
| | | | g | 1 | °C | 42.93 | 8.301 | -1.87 | -8.03 | 0-700 |
| Methyl cyclohexane | C ₇ H ₁₄ | 98.18 | g | 1 | °C | 121.3 | 56.53 | -37.72 | 100.8 | 0-1200 |
| Methyl cyclopentane | C ₆ H ₁₂ | 84.16 | g | 1 | °C | 98.83 | 45.857 | -30.44 | 83.81 | 0-1200 |
| Nitric acid | NHO ₃ | 63.02 | l | 1 | °C | 110.0 | | | | 25 |
| Nitric oxide | NO | 30.01 | g | 1 | °C | 29.50 | 0.8188 | -0.2925 | 0.3652 | 0-3500 |

| | | | | | | | | | | |
|------------------------------|--|--------------|---|---|----|--------|--------|---------|--------|---------|
| Nitrogen | N ₂ | 28.02 | g | 1 | °C | 29.00 | 0.2199 | 0.5723 | −2.871 | 0–1500 |
| Nitrogen dioxide | NO ₂ | 46.01 | g | 1 | °C | 36.07 | 3.97 | −2.88 | 7.87 | 0–1200 |
| Nitrogen tetroxide | N ₂ O ₄ | 92.02 | g | 1 | °C | 75.7 | 12.5 | −11.3 | | 0–300 |
| Nitrous oxide | N ₂ O | 44.02 | g | 1 | °C | 37.66 | 4.151 | −2.694 | 10.57 | 0–1200 |
| Oxygen | O ₂ | 32.00 | g | 1 | °C | 29.10 | 1.158 | −0.6076 | 1.311 | 0–1500 |
| <i>n</i> -Pentane | C ₅ H ₁₂ | 72.15 | l | 1 | °C | 155.4 | 43.68 | | | 0–36 |
| | | | g | 1 | °C | 114.8 | 34.09 | −18.99 | 42.26 | 0–1200 |
| Propane | C ₃ H ₈ | 44.09 | g | 1 | °C | 68.032 | 22.59 | −13.11 | 31.71 | 0–1200 |
| Propylene | C ₃ H ₆ | 42.08 | g | 1 | °C | 59.580 | 17.71 | −10.17 | 24.60 | 0–1200 |
| Sodium carbonate | Na ₂ CO ₃ | 105.99 | c | 1 | K | 121 | | | | 288–371 |
| Sodium carbonate decahydrate | Na ₂ CO ₃ · 10H ₂ O | 286.15 | c | 1 | K | 535.6 | | | | 298 |
| Sulfur | S | 32.07 | c | 1 | K | 15.2 | 2.68 | | | 273–368 |
| | | (Rhombic) | | | | | | | | |
| | | | c | 1 | K | 18.3 | 1.84 | | | 368–392 |
| | | (Monoclinic) | | | | | | | | |
| Sulfuric acid | H ₂ SO ₄ | 98.08 | l | 1 | °C | 139.1 | 15.59 | | | 10–45 |
| Sulfur dioxide | SO ₂ | 64.07 | g | 1 | °C | 38.91 | 3.904 | −3.104 | 8.606 | 0–1500 |
| Sulfur trioxide | SO ₃ | 80.07 | g | 1 | °C | 48.50 | 9.188 | −8.540 | 32.40 | 0–1000 |
| Toluene | C ₇ H ₈ | 92.13 | l | 1 | °C | 148.8 | 32.4 | | | 0–110 |
| | | | g | 1 | °C | 94.18 | 38.00 | −27.86 | 80.33 | 0–1200 |
| Water | H ₂ O | 18.016 | l | 1 | °C | 75.4 | | | | 0–100 |
| | | | g | 1 | °C | 33.46 | 0.6880 | 0.7604 | −3.593 | 0–1500 |

Table B.3 Vapor Pressure of Water^a

| | | $p_v(\text{mm Hg})$ versus $T(^{\circ}\text{C})$ | | | | | | | | | |
|----------------------|-----------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | <i>Example:</i> The vapor pressure of liquid water at 4.3°C is 6.230 mm Hg | | | | | | | | | |
| | $T(^{\circ}\text{C})$ | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| Ice ↓ | −14 | 1.361 | 1.348 | 1.336 | 1.324 | 1.312 | 1.300 | 1.288 | 1.276 | 1.264 | 1.253 |
| | −13 | 1.490 | 1.477 | 1.464 | 1.450 | 1.437 | 1.424 | 1.411 | 1.399 | 1.386 | 1.373 |
| | −12 | 1.632 | 1.617 | 1.602 | 1.588 | 1.574 | 1.559 | 1.546 | 1.532 | 1.518 | 1.504 |
| | −11 | 1.785 | 1.769 | 1.753 | 1.737 | 1.722 | 1.707 | 1.691 | 1.676 | 1.661 | 1.646 |
| | −10 | 1.950 | 1.934 | 1.916 | 1.899 | 1.883 | 1.866 | 1.849 | 1.833 | 1.817 | 1.800 |
| | −9 | 2.131 | 2.122 | 2.093 | 2.075 | 2.057 | 2.039 | 2.021 | 2.003 | 1.985 | 1.968 |
| | −8 | 2.326 | 2.306 | 2.285 | 2.266 | 2.246 | 2.226 | 2.207 | 2.187 | 2.168 | 2.149 |
| | −7 | 2.537 | 2.515 | 2.493 | 2.472 | 2.450 | 2.429 | 2.408 | 2.387 | 2.367 | 2.346 |
| | −6 | 2.765 | 2.742 | 2.718 | 2.695 | 2.672 | 2.649 | 2.626 | 2.603 | 2.581 | 2.559 |
| | −5 | 3.013 | 2.987 | 2.962 | 2.937 | 2.912 | 2.887 | 2.862 | 2.838 | 2.813 | 2.790 |
| | −4 | 3.280 | 3.252 | 3.225 | 3.198 | 3.171 | 3.144 | 3.117 | 3.091 | 3.065 | 3.039 |
| | −3 | 3.568 | 3.539 | 3.509 | 3.480 | 3.451 | 3.422 | 3.393 | 3.364 | 3.336 | 3.308 |
| | −2 | 3.880 | 3.848 | 3.816 | 3.785 | 3.753 | 3.722 | 3.691 | 3.660 | 3.630 | 3.599 |
| | −1 | 4.217 | 4.182 | 4.147 | 4.113 | 4.079 | 4.045 | 4.012 | 3.979 | 3.946 | 3.913 |
| | −0 | 4.579 | 4.542 | 4.504 | 4.467 | 4.431 | 4.395 | 4.359 | 4.323 | 4.287 | 4.252 |
| Liquid water ↓ | 0 | 4.579 | 4.613 | 4.647 | 4.681 | 4.715 | 4.750 | 4.785 | 4.820 | 4.855 | 4.890 |
| | 1 | 4.926 | 4.962 | 4.998 | 5.034 | 5.070 | 5.107 | 5.144 | 5.181 | 5.219 | 5.256 |
| | 2 | 5.294 | 5.332 | 5.370 | 5.408 | 5.447 | 5.486 | 5.525 | 5.565 | 5.605 | 5.645 |
| | 3 | 5.685 | 5.725 | 5.766 | 5.807 | 5.848 | 5.889 | 5.931 | 5.973 | 6.015 | 6.058 |
| | 4 | 6.101 | 6.144 | 6.187 | 6.230 | 6.274 | 6.318 | 6.363 | 6.408 | 6.453 | 6.498 |
| | 5 | 6.543 | 6.589 | 6.635 | 6.681 | 6.728 | 6.775 | 6.822 | 6.869 | 6.917 | 6.965 |
| | 6 | 7.013 | 7.062 | 7.111 | 7.160 | 7.209 | 7.259 | 7.309 | 7.360 | 7.411 | 7.462 |
| | 7 | 7.513 | 7.565 | 7.617 | 7.669 | 7.722 | 7.775 | 7.828 | 7.882 | 7.936 | 7.990 |
| | 8 | 8.045 | 8.100 | 8.155 | 8.211 | 8.267 | 8.323 | 8.380 | 8.437 | 8.494 | 8.551 |
| | 9 | 8.609 | 8.668 | 8.727 | 8.786 | 8.845 | 8.905 | 8.965 | 9.025 | 9.086 | 9.147 |
| | 10 | 9.209 | 9.271 | 9.333 | 9.395 | 9.458 | 9.521 | 9.585 | 9.649 | 9.714 | 9.779 |
| | 11 | 9.844 | 9.910 | 9.976 | 10.042 | 10.109 | 10.176 | 10.244 | 10.312 | 10.380 | 10.449 |
| | 12 | 10.518 | 10.588 | 10.658 | 10.728 | 10.799 | 10.870 | 10.941 | 11.013 | 11.085 | 11.158 |
| | 13 | 11.231 | 11.305 | 11.379 | 11.453 | 11.528 | 11.604 | 11.680 | 11.756 | 11.833 | 11.910 |
| | 14 | 11.987 | 12.065 | 12.144 | 12.223 | 12.302 | 12.382 | 12.462 | 12.543 | 12.624 | 12.706 |
| | 15 | 12.788 | 12.870 | 12.953 | 13.037 | 13.121 | 13.205 | 13.290 | 13.375 | 13.461 | 13.547 |
| | 16 | 13.634 | 13.721 | 13.809 | 13.898 | 13.987 | 14.076 | 14.166 | 14.256 | 14.347 | 14.438 |
| | 17 | 14.530 | 14.622 | 14.715 | 14.809 | 14.903 | 14.997 | 15.092 | 15.188 | 15.284 | 15.380 |
| | 18 | 15.477 | 15.575 | 15.673 | 15.772 | 15.871 | 15.971 | 16.071 | 16.171 | 16.272 | 16.374 |
| | 19 | 16.477 | 16.581 | 16.685 | 16.789 | 16.894 | 16.999 | 17.105 | 17.212 | 17.319 | 17.427 |
| | 20 | 17.535 | 17.644 | 17.753 | 17.863 | 17.974 | 18.085 | 18.197 | 18.309 | 18.422 | 18.536 |
| | 21 | 18.650 | 18.765 | 18.880 | 18.996 | 19.113 | 19.231 | 19.349 | 19.468 | 19.587 | 19.707 |
| | 22 | 19.827 | 19.948 | 20.070 | 20.193 | 20.316 | 20.440 | 20.565 | 20.690 | 20.815 | 20.941 |
| | 23 | 21.068 | 21.196 | 21.324 | 21.453 | 21.583 | 21.714 | 21.845 | 21.977 | 22.110 | 22.243 |
| | 24 | 22.377 | 22.512 | 22.648 | 22.785 | 22.922 | 23.060 | 23.198 | 23.337 | 23.476 | 23.616 |

^aFrom R. H. Perry and C. H. Chilton, Eds., *Chemical Engineers' Handbook*, 5th Edition, McGraw-Hill, New York, 1973, Tables 3-3 and 3-5. Reprinted by permission of McGraw-Hill Book Co.

(continued)

Table B.3 (Continued)

| $T(^{\circ}\text{C})$ | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 25 | 23.756 | 23.897 | 24.039 | 24.182 | 24.326 | 24.471 | 24.617 | 24.764 | 24.912 | 25.060 |
| 26 | 25.209 | 25.359 | 25.509 | 25.660 | 25.812 | 25.964 | 26.117 | 26.271 | 26.426 | 26.582 |
| 27 | 26.739 | 26.897 | 27.055 | 27.214 | 27.374 | 27.535 | 27.696 | 27.858 | 28.021 | 28.185 |
| 28 | 28.349 | 28.514 | 28.680 | 28.847 | 29.015 | 29.184 | 29.354 | 29.525 | 29.697 | 29.870 |
| 29 | 30.043 | 30.217 | 30.392 | 30.568 | 30.745 | 30.923 | 31.102 | 31.281 | 31.461 | 31.642 |
| 30 | 31.824 | 32.007 | 32.191 | 32.376 | 32.561 | 32.747 | 32.934 | 33.122 | 33.312 | 33.503 |
| 31 | 33.695 | 33.888 | 34.082 | 34.276 | 34.471 | 34.667 | 34.864 | 35.062 | 35.261 | 35.462 |
| 32 | 35.663 | 35.865 | 36.068 | 36.272 | 36.477 | 36.683 | 36.891 | 37.099 | 37.308 | 37.518 |
| 33 | 37.729 | 37.942 | 38.155 | 38.369 | 38.584 | 38.801 | 38.018 | 39.237 | 39.457 | 39.677 |
| 34 | 39.898 | 40.121 | 40.344 | 40.569 | 40.796 | 41.023 | 41.251 | 41.480 | 41.710 | 41.942 |
| 35 | 42.175 | 42.409 | 42.644 | 42.880 | 43.117 | 43.355 | 43.595 | 43.836 | 44.078 | 44.320 |
| 36 | 44.563 | 44.808 | 45.054 | 45.301 | 45.549 | 45.799 | 46.050 | 46.302 | 46.556 | 46.811 |
| 37 | 47.067 | 47.324 | 47.582 | 47.841 | 48.102 | 48.364 | 48.627 | 48.891 | 49.157 | 49.424 |
| 38 | 49.692 | 49.961 | 50.231 | 50.502 | 50.774 | 51.048 | 51.323 | 51.600 | 51.879 | 52.160 |
| 39 | 52.442 | 52.725 | 53.009 | 53.294 | 53.580 | 53.867 | 54.156 | 54.446 | 54.737 | 55.030 |
| 40 | 55.324 | 55.61 | 55.91 | 56.21 | 56.51 | 56.81 | 57.11 | 57.41 | 57.72 | 58.03 |
| 41 | 58.34 | 58.65 | 58.96 | 59.27 | 59.58 | 59.90 | 60.22 | 60.54 | 60.86 | 61.18 |
| 42 | 61.50 | 61.82 | 62.14 | 62.47 | 62.80 | 63.13 | 63.46 | 63.79 | 64.12 | 64.46 |
| 43 | 64.80 | 65.14 | 65.48 | 65.82 | 66.16 | 66.51 | 66.86 | 67.21 | 67.56 | 67.91 |
| 44 | 68.26 | 68.61 | 68.97 | 69.33 | 69.69 | 70.05 | 70.41 | 70.77 | 71.14 | 71.51 |
| 45 | 71.88 | 72.25 | 72.62 | 72.99 | 73.36 | 73.74 | 74.12 | 74.50 | 74.88 | 75.26 |
| 46 | 75.65 | 76.04 | 76.43 | 76.82 | 77.21 | 77.60 | 78.00 | 78.40 | 78.80 | 79.20 |
| 47 | 79.60 | 80.00 | 80.41 | 80.82 | 81.23 | 81.64 | 82.05 | 82.46 | 82.87 | 83.29 |
| 48 | 83.71 | 84.13 | 84.56 | 84.99 | 85.42 | 85.85 | 86.28 | 86.71 | 87.14 | 87.58 |
| 49 | 88.02 | 88.46 | 88.90 | 89.34 | 89.79 | 90.24 | 90.69 | 91.14 | 91.59 | 92.05 |
| $T(^{\circ}\text{C})$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 50 | 92.51 | 97.20 | 102.09 | 107.20 | 112.51 | 118.04 | 123.80 | 129.82 | 136.08 | 142.60 |
| 60 | 149.38 | 156.43 | 163.77 | 171.38 | 179.31 | 187.54 | 196.09 | 204.96 | 214.17 | 223.73 |
| 70 | 233.7 | 243.9 | 254.6 | 265.7 | 277.2 | 289.1 | 301.4 | 314.1 | 327.3 | 341.0 |
| 80 | 355.1 | 369.7 | 384.9 | 400.6 | 416.8 | 433.6 | 450.9 | 468.7 | 487.1 | 506.1 |
| $T(^{\circ}\text{C})$ | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 90 | 525.76 | 527.76 | 529.77 | 531.78 | 533.80 | 535.82 | 537.86 | 539.90 | 541.95 | 544.00 |
| 91 | 546.05 | 548.11 | 550.18 | 552.26 | 554.35 | 556.44 | 558.53 | 560.64 | 562.75 | 564.87 |
| 92 | 566.99 | 569.12 | 571.26 | 573.40 | 575.55 | 577.71 | 579.87 | 582.04 | 584.22 | 586.41 |
| 93 | 588.60 | 590.80 | 593.00 | 595.21 | 597.43 | 599.66 | 601.89 | 604.13 | 606.38 | 608.64 |
| 94 | 610.90 | 613.17 | 615.44 | 617.72 | 620.01 | 622.31 | 624.61 | 626.92 | 629.24 | 631.57 |
| 95 | 633.90 | 636.24 | 638.59 | 640.94 | 643.30 | 645.67 | 648.05 | 650.43 | 652.82 | 655.22 |
| 96 | 657.62 | 660.03 | 662.45 | 664.88 | 667.31 | 669.75 | 672.20 | 674.66 | 677.12 | 679.69 |
| 97 | 682.07 | 684.55 | 687.04 | 689.54 | 692.05 | 694.57 | 697.10 | 699.63 | 702.17 | 704.71 |
| 98 | 707.27 | 709.83 | 712.40 | 714.98 | 717.56 | 720.15 | 722.75 | 725.36 | 727.98 | 730.61 |
| 99 | 733.24 | 735.88 | 738.53 | 741.18 | 743.85 | 746.52 | 749.20 | 751.89 | 754.58 | 757.29 |
| 100 | 760.00 | 762.72 | 765.45 | 768.19 | 770.93 | 773.68 | 776.44 | 779.22 | 782.00 | 784.78 |
| 101 | 787.57 | 790.37 | 793.18 | 796.00 | 798.82 | 801.66 | 804.50 | 807.35 | 810.21 | 813.08 |

Table B.4 Antoine Equation Constants^a

| $\log_{10} p^* = A - \frac{B}{T + C} \quad p^* \text{ in mm Hg, } T \text{ in } ^\circ\text{C}$ | | | | | |
|---|---|----------------|---------|----------|---------|
| Example: The vapor pressure of acetaldehyde at 25°C is determined as follows: | | | | | |
| $\log_{10} p_{\text{C}_2\text{H}_4\text{O}}^*(25^\circ\text{C}) = 8.00552 - \frac{1600.017}{25 + 291.809} = 2.9551$ | | | | | |
| $\Rightarrow p_{\text{C}_2\text{H}_4\text{O}}^*(25^\circ\text{C}) = 10^{2.9551} = 902 \text{ mm Hg}$ | | | | | |
| Compound | Formula | Range (°C) | A | B | C |
| Acetaldehyde | C ₂ H ₄ O | −0.2 to 34.4 | 8.00552 | 1600.017 | 291.809 |
| Acetic acid | C ₂ H ₄ O ₂ | 29.8 to 126.5 | 7.38782 | 1533.313 | 222.309 |
| Acetic acid* | C ₂ H ₄ O ₂ | 0 to 36 | 7.18807 | 1416.7 | 225 |
| Acetic anhydride | C ₄ H ₆ O ₃ | 62.8 to 139.4 | 7.14948 | 1444.718 | 199.817 |
| Acetone | C ₃ H ₆ O | −12.9 to 55.3 | 7.11714 | 1210.595 | 229.664 |
| Acrylic acid | C ₃ H ₄ O ₂ | 20.0 to 70.0 | 5.65204 | 648.629 | 154.683 |
| Ammonia* | NH ₃ | −83 to 60 | 7.55466 | 1002.711 | 247.885 |
| Aniline | C ₆ H ₇ N | 102.6 to 185.2 | 7.32010 | 1731.515 | 206.049 |
| Benzene | C ₆ H ₆ | 14.5 to 80.9 | 6.89272 | 1203.531 | 219.888 |
| <i>n</i> -Butane | <i>n</i> -C ₄ H ₁₀ | −78.0 to −0.3 | 6.82485 | 943.453 | 239.711 |
| <i>i</i> -Butane | <i>i</i> -C ₄ H ₁₀ | −85.1 to −11.6 | 6.78866 | 899.617 | 241.942 |
| 1-Butanol | C ₄ H ₁₀ O | 89.2 to 125.7 | 7.36366 | 1305.198 | 173.427 |
| 2-Butanol | C ₄ H ₁₀ O | 72.4 to 107.1 | 7.20131 | 1157.000 | 168.279 |
| 1-Butene | C ₄ H ₈ | −77.5 to −3.7 | 6.53101 | 810.261 | 228.066 |
| Butyric acid | C ₄ H ₈ O ₂ | 20.0 to 150.0 | 8.71019 | 2433.014 | 255.189 |
| Carbon disulfide | CS ₂ | 3.6 to 79.9 | 6.94279 | 1169.110 | 241.593 |
| Carbon tetrachloride | CCl ₄ | 14.1 to 76.0 | 6.87926 | 1212.021 | 226.409 |
| Chlorobenzene | C ₆ H ₅ Cl | 62.0 to 131.7 | 6.97808 | 1431.053 | 217.550 |
| Chlorobenzene* | C ₆ H ₅ Cl | 0 to 42 | 7.10690 | 1500.0 | 224.0 |
| Chlorobenzene* | C ₆ H ₅ Cl | 42 to 230 | 6.94504 | 1413.12 | 216.0 |
| Chloroform | CHCl ₃ | −10.4 to 60.3 | 6.95465 | 1170.966 | 226.232 |
| Chloroform* | CHCl ₃ | −30 to 150 | 6.90328 | 1163.03 | 227.4 |
| Cyclohexane | C ₆ H ₁₂ | 19.9 to 81.6 | 6.84941 | 1206.001 | 223.148 |
| Cyclohexanol | C ₆ H ₁₂ O | 93.7 to 160.7 | 6.25530 | 912.866 | 109.126 |
| <i>n</i> -Decane | <i>n</i> -C ₁₀ H ₂₂ | 94.5 to 175.1 | 6.95707 | 1503.568 | 194.738 |
| 1-Decene | C ₁₀ H ₂₀ | 86.8 to 171.6 | 6.95433 | 1497.527 | 197.056 |
| 1,1-Dichloroethane | C ₂ H ₄ Cl ₂ | −38.8 to 17.6 | 6.97702 | 1174.022 | 229.060 |
| 1,2-Dichloroethane | C ₂ H ₄ Cl | −30.8 to 99.4 | 7.02530 | 1271.254 | 222.927 |
| Dichloromethane | CH ₂ Cl ₂ | −40.0 to 40 | 7.40916 | 1325.938 | 252.616 |
| Diethyl ether | C ₄ H ₁₀ O | −60.8 to 19.9 | 6.92032 | 1064.066 | 228.799 |
| Diethyl ketone | C ₅ H ₁₀ O | 56.5 to 111.3 | 7.02529 | 1310.281 | 214.192 |
| Diethylene glycol | C ₄ H ₁₀ O ₂ | 130.0 to 243.0 | 7.63666 | 1939.359 | 162.714 |
| Dimethyl ether | C ₂ H ₆ O | −78.2 to −24.9 | 6.97603 | 889.264 | 241.957 |
| Dimethylamine | C ₂ H ₇ N | −71.8 to 6.9 | 7.08212 | 960.242 | 221.667 |
| <i>N,N</i> -Dimethylformamide | C ₃ H ₇ NO | 30.0 to 90.0 | 6.92796 | 1400.869 | 196.434 |
| 1,4-Dioxane | C ₄ H ₈ O ₂ | 20.0 to 105.0 | 7.43155 | 1554.679 | 240.337 |
| Ethanol | C ₂ H ₆ O | 19.6 to 93.4 | 8.11220 | 1592.864 | 226.184 |
| Ethanolamine | C ₂ H ₇ NO | 65.4 to 170.9 | 7.45680 | 1577.670 | 173.368 |
| Ethyl acetate | C ₄ H ₈ O ₂ | 15.6 to 75.8 | 7.10179 | 1244.951 | 217.881 |
| Ethyl acetate* | C ₄ H ₈ O ₂ | −20 to 150 | 7.09808 | 1238.710 | 217.0 |
| Ethyl chloride | C ₂ H ₅ Cl | −55.9 to 12.5 | 6.98647 | 1030.007 | 238.612 |
| Ethylbenzene | C ₈ H ₁₀ | 56.5 to 137.1 | 6.95650 | 1423.543 | 213.091 |

^aAdapted from T. Boublik, V. Fried, and E. Hala, *The Vapour Pressures of Pure Substances*, Elsevier, Amsterdam, 1973. If marked with an asterisk (*), constants are from *Lange's Handbook of Chemistry*, 9th Edition, Handbook Publishers, Inc., Sandusky, OH, 1956.

(continued)

Table B.4 (Continued)

| Compound | Formula | Range (°C) | A | B | C |
|------------------------|---|-----------------|---------|----------|---------|
| Ethylene glycol | C ₂ H ₆ O ₂ | 50.0 to 200.0 | 8.09083 | 2088.936 | 203.454 |
| Ethylene oxide | C ₂ H ₄ O | 0.3 to 31.8 | 8.69016 | 2005.779 | 334.765 |
| 1,2-Ethylenediamine | C ₂ H ₈ N ₂ | 26.5 to 117.4 | 7.16871 | 1336.235 | 194.366 |
| Formaldehyde | HCHO | −109.4 to −22.3 | 7.19578 | 970.595 | 244.124 |
| Formic acid | CH ₂ O ₂ | 37.4 to 100.7 | 7.58178 | 1699.173 | 260.714 |
| Glycerol | C ₃ H ₈ O ₃ | 183.3 to 260.4 | 6.16501 | 1036.056 | 28.097 |
| <i>n</i> -Heptane | <i>n</i> -C ₇ H ₁₆ | 25.9 to 99.3 | 6.90253 | 1267.828 | 216.823 |
| <i>i</i> -Heptane | <i>i</i> -C ₇ H ₁₆ | 18.5 to 90.9 | 6.87689 | 1238.122 | 219.783 |
| 1-Heptene | C ₇ H ₁₄ | 21.6 to 94.5 | 6.91381 | 1265.120 | 220.051 |
| <i>n</i> -Hexane | <i>n</i> -C ₆ H ₁₄ | 13.0 to 69.5 | 6.88555 | 1175.817 | 224.867 |
| <i>i</i> -Hexane | <i>i</i> -C ₆ H ₁₄ | 12.8 to 61.1 | 6.86839 | 1151.401 | 228.477 |
| 1-Hexene | C ₆ H ₁₂ | 15.9 to 64.3 | 6.86880 | 1154.646 | 226.046 |
| Hydrogen Cyanide | HCN | −16.4 to 46.2 | 7.52823 | 1329.49 | 260.418 |
| Methanol | CH ₃ OH | 14.9 to 83.7 | 8.08097 | 1582.271 | 239.726 |
| Methanol* | CH ₃ OH | −20 to 140 | 7.87863 | 1473.11 | 230.0 |
| Methyl acetate | C ₃ H ₆ O ₂ | 1.8 to 55.8 | 7.06524 | 1157.630 | 219.726 |
| Methyl bromide | CH ₃ Br | −70.0 to 3.6 | 7.09084 | 1046.066 | 244.914 |
| Methyl chloride | CH ₃ Cl | −75.0 to 5.0 | 7.09349 | 948.582 | 249.336 |
| Methyl ethyl ketone | C ₄ H ₈ O | 42.8 to 88.4 | 7.06356 | 1261.339 | 221.969 |
| Methyl isobutyl ketone | C ₆ H ₁₂ O | 21.7 to 116.2 | 6.67272 | 1168.408 | 191.944 |
| Methyl methacrylate | C ₅ H ₈ O ₂ | 39.2 to 89.2 | 8.40919 | 2050.467 | 274.369 |
| Methylamine | CH ₅ N | −83.1 to −6.2 | 7.33690 | 1011.532 | 233.286 |
| Methylcyclohexane | C ₇ H ₁₄ | 25.6 to 101.8 | 6.82827 | 1273.673 | 221.723 |
| Naphthalene | C ₁₀ H ₈ | 80.3 to 179.5 | 7.03358 | 1756.328 | 204.842 |
| Nitrobenzene | C ₆ H ₅ NO ₂ | 134.1 to 210.6 | 7.11562 | 1746.586 | 201.783 |
| Nitromethane | CH ₃ NO ₂ | 55.7 to 136.4 | 7.28166 | 1446.937 | 227.600 |
| <i>n</i> -Nonane | <i>n</i> -C ₉ H ₂₀ | 70.3 to 151.8 | 6.93764 | 1430.459 | 201.808 |
| 1-Nonene | C ₉ H ₁₈ | 66.6 to 147.9 | 6.95777 | 1437.862 | 205.814 |
| <i>n</i> -Octane | <i>n</i> -C ₈ H ₁₈ | 52.9 to 126.6 | 6.91874 | 1351.756 | 209.100 |
| <i>i</i> -Octane | <i>i</i> -C ₈ H ₁₈ | 41.7 to 118.5 | 6.88814 | 1319.529 | 211.625 |
| 1-Octene | C ₈ H ₁₆ | 44.9 to 122.2 | 6.93637 | 1355.779 | 213.022 |
| <i>n</i> -Pentane | <i>n</i> -C ₅ H ₁₂ | 13.3 to 36.8 | 6.84471 | 1060.793 | 231.541 |
| <i>i</i> -Pentane | <i>i</i> -C ₅ H ₁₂ | 16.3 to 28.6 | 6.73457 | 992.019 | 229.564 |
| 1-Pentanol | C ₅ H ₁₂ O | 74.7 to 156.0 | 7.18246 | 1287.625 | 161.330 |
| 1-Pentene | C ₅ H ₁₀ | 12.8 to 30.7 | 6.84268 | 1043.206 | 233.344 |
| Phenol | C ₆ H ₆ O | 107.2 to 181.8 | 7.13301 | 1516.790 | 174.954 |
| 1-Propanol | C ₃ H ₈ O | 60.2 to 104.6 | 7.74416 | 1437.686 | 198.463 |
| 2-Propanol | C ₃ H ₈ O | 52.3 to 89.3 | 7.74021 | 1359.517 | 197.527 |
| Propionic acid | C ₃ H ₆ O ₂ | 72.4 to 128.3 | 7.71423 | 1733.418 | 217.724 |
| Propylene oxide | C ₃ H ₆ O | −24.2 to 34.8 | 7.01443 | 1086.369 | 228.594 |
| Pyridine | C ₅ H ₅ N | 67.3 to 152.9 | 7.04115 | 1373.799 | 214.979 |
| Styrene | C ₈ H ₈ | 29.9 to 144.8 | 7.06623 | 1507.434 | 214.985 |
| Toluene | C ₇ H ₈ | 35.3 to 111.5 | 6.95805 | 1346.773 | 219.693 |
| 1,1,1-Trichloroethane | C ₂ H ₃ Cl ₃ | −5.4 to 16.9 | 8.64344 | 2136.621 | 302.769 |
| 1,1,2-Trichloroethane | C ₂ H ₃ Cl ₃ | 50.0 to 113.7 | 6.95185 | 1314.410 | 209.197 |
| Trichloroethylene | C ₂ HCl ₃ | 17.8 to 86.5 | 6.51827 | 1018.603 | 192.731 |
| Vinyl acetate | C ₄ H ₆ O ₂ | 21.8 to 72.0 | 7.21010 | 1296.130 | 226.655 |
| Water* | H ₂ O | 0 to 60 | 8.10765 | 1750.286 | 235.000 |
| Water* | H ₂ O | 60 to 150 | 7.96681 | 1668.210 | 228.000 |
| <i>m</i> -Xylene | <i>m</i> -C ₈ H ₁₀ | 59.2 to 140.0 | 7.00646 | 1460.183 | 214.827 |
| <i>o</i> -Xylene | <i>o</i> -C ₈ H ₁₀ | 63.5 to 145.4 | 7.00154 | 1476.393 | 213.872 |
| <i>p</i> -Xylene | <i>p</i> -C ₈ H ₁₀ | 58.3 to 139.3 | 6.98820 | 1451.792 | 215.111 |

Table B.5 Properties of Saturated Steam: Temperature Table^a

| $T(^{\circ}\text{C})$ | $P(\text{bar})$ | $\hat{V}(\text{m}^3/\text{kg})$ | | $\hat{U}(\text{kJ/kg})$ | | $\hat{H}(\text{kJ/kg})$ | | |
|-----------------------|-----------------|---------------------------------|-------|-------------------------|--------|-------------------------|-------------|--------|
| | | Water | Steam | Water | Steam | Water | Evaporation | Steam |
| 0.01 | 0.00611 | 0.001000 | 206.2 | zero | 2375.6 | +0.0 | 2501.6 | 2501.6 |
| 2 | 0.00705 | 0.001000 | 179.9 | 8.4 | 2378.3 | 8.4 | 2496.8 | 2505.2 |
| 4 | 0.00813 | 0.001000 | 157.3 | 16.8 | 2381.1 | 16.8 | 2492.1 | 2508.9 |
| 6 | 0.00935 | 0.001000 | 137.8 | 25.2 | 2383.8 | 25.2 | 2487.4 | 2512.6 |
| 8 | 0.01072 | 0.001000 | 121.0 | 33.6 | 2386.6 | 33.6 | 2482.6 | 2516.2 |
| 10 | 0.01227 | 0.001000 | 106.4 | 42.0 | 2389.3 | 42.0 | 2477.9 | 2519.9 |
| 12 | 0.01401 | 0.001000 | 93.8 | 50.4 | 2392.1 | 50.4 | 2473.2 | 2523.6 |
| 14 | 0.01597 | 0.001001 | 82.9 | 58.8 | 2394.8 | 58.8 | 2468.5 | 2527.2 |
| 16 | 0.01817 | 0.001001 | 73.4 | 67.1 | 2397.6 | 67.1 | 2463.8 | 2530.9 |
| 18 | 0.02062 | 0.001001 | 65.1 | 75.5 | 2400.3 | 75.5 | 2459.0 | 2534.5 |
| 20 | 0.0234 | 0.001002 | 57.8 | 83.9 | 2403.0 | 83.9 | 2454.3 | 2538.2 |
| 22 | 0.0264 | 0.001002 | 51.5 | 92.2 | 2405.8 | 92.2 | 2449.6 | 2541.8 |
| 24 | 0.0298 | 0.001003 | 45.9 | 100.6 | 2408.5 | 100.6 | 2444.9 | 2545.5 |
| 25 | 0.0317 | 0.001003 | 43.4 | 104.8 | 2409.9 | 104.8 | 2442.5 | 2547.3 |
| 26 | 0.0336 | 0.001003 | 41.0 | 108.9 | 2411.2 | 108.9 | 2440.2 | 2549.1 |
| 28 | 0.0378 | 0.001004 | 36.7 | 117.3 | 2414.0 | 117.3 | 2435.4 | 2552.7 |
| 30 | 0.0424 | 0.001004 | 32.9 | 125.7 | 2416.7 | 125.7 | 2430.7 | 2556.4 |
| 32 | 0.0475 | 0.001005 | 29.6 | 134.0 | 2419.4 | 134.0 | 2425.9 | 2560.0 |
| 34 | 0.0532 | 0.001006 | 26.6 | 142.4 | 2422.1 | 142.4 | 2421.2 | 2563.6 |
| 36 | 0.0594 | 0.001006 | 24.0 | 150.7 | 2424.8 | 150.7 | 2416.4 | 2567.2 |
| 38 | 0.0662 | 0.001007 | 21.6 | 159.1 | 2427.5 | 159.1 | 2411.7 | 2570.8 |
| 40 | 0.0738 | 0.001008 | 19.55 | 167.4 | 2430.2 | 167.5 | 2406.9 | 2574.4 |
| 42 | 0.0820 | 0.001009 | 17.69 | 175.8 | 2432.9 | 175.8 | 2402.1 | 2577.9 |
| 44 | 0.0910 | 0.001009 | 16.04 | 184.2 | 2435.6 | 184.2 | 2397.3 | 2581.5 |
| 46 | 0.1009 | 0.001010 | 14.56 | 192.5 | 2438.3 | 192.5 | 2392.5 | 2585.1 |
| 48 | 0.1116 | 0.001011 | 13.23 | 200.9 | 2440.9 | 200.9 | 2387.7 | 2588.6 |
| 50 | 0.1234 | 0.001012 | 12.05 | 209.2 | 2443.6 | 209.3 | 2382.9 | 2592.2 |
| 52 | 0.1361 | 0.001013 | 10.98 | 217.7 | 2446 | 217.7 | 2377 | 2595 |
| 54 | 0.1500 | 0.001014 | 10.02 | 226.0 | 2449 | 226.0 | 2373 | 2599 |
| 56 | 0.1651 | 0.001015 | 9.158 | 234.4 | 2451 | 234.4 | 2368 | 2602 |
| 58 | 0.1815 | 0.001016 | 8.380 | 242.8 | 2454 | 242.8 | 2363 | 2606 |
| 60 | 0.1992 | 0.001017 | 7.678 | 251.1 | 2456 | 251.1 | 2358 | 2609 |
| 62 | 0.2184 | 0.001018 | 7.043 | 259.5 | 2459 | 259.5 | 2353 | 2613 |
| 64 | 0.2391 | 0.001019 | 6.468 | 267.9 | 2461 | 267.9 | 2348 | 2616 |
| 66 | 0.2615 | 0.001020 | 5.947 | 276.2 | 2464 | 276.2 | 2343 | 2619 |
| 68 | 0.2856 | 0.001022 | 5.475 | 284.6 | 2467 | 284.6 | 2338 | 2623 |

^aFrom R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, Cambridge University Press, London, 1968. \hat{V} = specific volume, \hat{U} = specific internal energy, and \hat{H} = specific enthalpy. Note: $\text{kJ/kg} \times 0.4303 = \text{Btu/lb}_m$.

(continued)

Table B.5 (Continued)

| $T(^{\circ}\text{C})$ | $P(\text{bar})$ | $\hat{V}(\text{m}^3/\text{kg})$ | | $\hat{U}(\text{kJ/kg})$ | | $\hat{H}(\text{kJ/kg})$ | | |
|-----------------------|-----------------|---------------------------------|-------|-------------------------|-------|-------------------------|-------------|-------|
| | | Water | Steam | Water | Steam | Water | Evaporation | Steam |
| 70 | 0.3117 | 0.001023 | 5.045 | 293.0 | 2469 | 293.0 | 2333 | 2626 |
| 72 | 0.3396 | 0.001024 | 4.655 | 301.4 | 2472 | 301.4 | 2329 | 2630 |
| 74 | 0.3696 | 0.001025 | 4.299 | 309.8 | 2474 | 309.8 | 2323 | 2633 |
| 76 | 0.4019 | 0.001026 | 3.975 | 318.2 | 2476 | 318.2 | 2318 | 2636 |
| 78 | 0.4365 | 0.001028 | 3.679 | 326.4 | 2479 | 326.4 | 2313 | 2639 |
| 80 | 0.4736 | 0.001029 | 3.408 | 334.8 | 2482 | 334.9 | 2308 | 2643 |
| 82 | 0.5133 | 0.001030 | 3.161 | 343.2 | 2484 | 343.3 | 2303 | 2646 |
| 84 | 0.5558 | 0.001032 | 2.934 | 351.6 | 2487 | 351.7 | 2298 | 2650 |
| 86 | 0.6011 | 0.001033 | 2.727 | 360.0 | 2489 | 360.1 | 2293 | 2653 |
| 88 | 0.6495 | 0.001034 | 2.536 | 368.4 | 2491 | 368.5 | 2288 | 2656 |
| 90 | 0.7011 | 0.001036 | 2.361 | 376.9 | 2493 | 377.0 | 2282 | 2659 |
| 92 | 0.7560 | 0.001037 | 2.200 | 385.3 | 2496 | 385.4 | 2277 | 2662 |
| 94 | 0.8145 | 0.001039 | 2.052 | 393.7 | 2499 | 393.8 | 2272 | 2666 |
| 96 | 0.8767 | 0.001040 | 1.915 | 402.1 | 2501 | 402.2 | 2267 | 2669 |
| 98 | 0.9429 | 0.001042 | 1.789 | 410.6 | 2504 | 410.7 | 2262 | 2673 |
| 100 | 1.0131 | 0.001044 | 1.673 | 419.0 | 2507 | 419.1 | 2257 | 2676 |
| 102 | 1.0876 | 0.001045 | 1.566 | 427.1 | 2509 | 427.5 | 2251 | 2679 |

Table B.6 Properties of Saturated Steam: Pressure Table^a

| <i>P</i> (bar) | <i>T</i> (°C) | \hat{V} (m ³ /kg) | | \hat{U} (kJ/kg) | | \hat{H} (kJ/kg) | | |
|----------------|---------------|--------------------------------|-------|-------------------|--------|-------------------|-------------|--------|
| | | Water | Steam | Water | Steam | Water | Evaporation | Steam |
| 0.00611 | 0.01 | 0.001000 | 206.2 | zero | 2375.6 | +0.0 | 2501.6 | 2501.6 |
| 0.008 | 3.8 | 0.001000 | 159.7 | 15.8 | 2380.7 | 15.8 | 2492.6 | 2508.5 |
| 0.010 | 7.0 | 0.001000 | 129.2 | 29.3 | 2385.2 | 29.3 | 2485.0 | 2514.4 |
| 0.012 | 9.7 | 0.001000 | 108.7 | 40.6 | 2388.9 | 40.6 | 2478.7 | 2519.3 |
| 0.014 | 12.0 | 0.001000 | 93.9 | 50.3 | 2392.0 | 50.3 | 2473.2 | 2523.5 |
| 0.016 | 14.0 | 0.001001 | 82.8 | 58.9 | 2394.8 | 58.9 | 2468.4 | 2527.3 |
| 0.018 | 15.9 | 0.001001 | 74.0 | 66.5 | 2397.4 | 66.5 | 2464.1 | 2530.6 |
| 0.020 | 17.5 | 0.001001 | 67.0 | 73.5 | 2399.6 | 73.5 | 2460.2 | 2533.6 |
| 0.022 | 19.0 | 0.001002 | 61.2 | 79.8 | 2401.7 | 79.8 | 2456.6 | 2536.4 |
| 0.024 | 20.4 | 0.001002 | 56.4 | 85.7 | 2403.6 | 85.7 | 2453.3 | 2539.0 |
| 0.026 | 21.7 | 0.001002 | 52.3 | 91.1 | 2405.4 | 91.1 | 2450.2 | 2541.3 |
| 0.028 | 23.0 | 0.001002 | 48.7 | 96.2 | 2407.1 | 96.2 | 2447.3 | 2543.6 |
| 0.030 | 24.1 | 0.001003 | 45.7 | 101.0 | 2408.6 | 101.0 | 2444.6 | 2545.6 |
| 0.035 | 26.7 | 0.001003 | 39.5 | 111.8 | 2412.2 | 111.8 | 2438.5 | 2550.4 |
| 0.040 | 29.0 | 0.001004 | 34.8 | 121.4 | 2415.3 | 121.4 | 2433.1 | 2554.5 |
| 0.045 | 31.0 | 0.001005 | 31.1 | 130.0 | 2418.1 | 130.0 | 2428.2 | 2558.2 |
| 0.050 | 32.9 | 0.001005 | 28.2 | 137.8 | 2420.6 | 137.8 | 2423.8 | 2561.6 |
| 0.060 | 36.2 | 0.001006 | 23.74 | 151.5 | 2425.1 | 151.5 | 2416.0 | 2567.5 |
| 0.070 | 39.0 | 0.001007 | 20.53 | 163.4 | 2428.9 | 163.4 | 2409.2 | 2572.6 |
| 0.080 | 41.5 | 0.001008 | 18.10 | 173.9 | 2432.3 | 173.9 | 2403.2 | 2577.1 |
| 0.090 | 43.8 | 0.001009 | 16.20 | 183.3 | 2435.3 | 183.3 | 2397.9 | 2581.1 |
| 0.10 | 45.8 | 0.001010 | 14.67 | 191.8 | 2438.0 | 191.8 | 2392.9 | 2584.8 |
| 0.11 | 47.7 | 0.001011 | 13.42 | 199.7 | 2440.5 | 199.7 | 2388.4 | 2588.1 |
| 0.12 | 49.4 | 0.001012 | 12.36 | 206.9 | 2442.8 | 206.9 | 2384.3 | 2591.2 |
| 0.13 | 51.1 | 0.001013 | 11.47 | 213.7 | 2445.0 | 213.7 | 2380.4 | 2594.0 |
| 0.14 | 52.6 | 0.001013 | 10.69 | 220.0 | 2447.0 | 220.0 | 2376.7 | 2596.7 |

| | | | | | | | | |
|--------------------|-------|----------|-------|-------|--------|-------|--------|--------|
| 0.15 | 54.0 | 0.001014 | 10.02 | 226.0 | 2448.9 | 226.0 | 2373.2 | 2599.2 |
| 0.16 | 55.3 | 0.001015 | 9.43 | 231.6 | 2450.6 | 231.6 | 2370.0 | 2601.6 |
| 0.17 | 56.6 | 0.001015 | 8.91 | 236.9 | 2452.3 | 236.9 | 2366.9 | 2603.8 |
| 0.18 | 57.8 | 0.001016 | 8.45 | 242.0 | 2453.9 | 242.0 | 2363.9 | 2605.9 |
| 0.19 | 59.0 | 0.001017 | 8.03 | 246.8 | 2455.4 | 246.8 | 2361.1 | 2607.9 |
| 0.20 | 60.1 | 0.001017 | 7.65 | 251.5 | 2456.9 | 251.5 | 2358.4 | 2609.9 |
| 0.22 | 62.2 | 0.001018 | 7.00 | 260.1 | 2459.6 | 260.1 | 2353.3 | 2613.5 |
| 0.24 | 64.1 | 0.001019 | 6.45 | 268.2 | 2462.1 | 268.2 | 2348.6 | 2616.8 |
| 0.26 | 65.9 | 0.001020 | 5.98 | 275.6 | 2464.4 | 275.7 | 2344.2 | 2619.9 |
| 0.28 | 67.5 | 0.001021 | 5.58 | 282.7 | 2466.5 | 282.7 | 2340.0 | 2622.7 |
| 0.30 | 69.1 | 0.001022 | 5.23 | 289.3 | 2468.6 | 289.3 | 2336.1 | 2625.4 |
| 0.35 | 72.7 | 0.001025 | 4.53 | 304.3 | 2473.1 | 304.3 | 2327.2 | 2631.5 |
| 0.40 | 75.9 | 0.001027 | 3.99 | 317.6 | 2477.1 | 317.7 | 2319.2 | 2636.9 |
| 0.45 | 78.7 | 0.001028 | 3.58 | 329.6 | 2480.7 | 329.6 | 2312.0 | 2641.7 |
| 0.50 | 81.3 | 0.001030 | 3.24 | 340.5 | 2484.0 | 340.6 | 2305.4 | 2646.0 |
| 0.55 | 83.7 | 0.001032 | 2.96 | 350.6 | 2486.9 | 350.6 | 2299.3 | 2649.9 |
| 0.60 | 86.0 | 0.001033 | 2.73 | 359.9 | 2489.7 | 359.9 | 2293.6 | 2653.6 |
| 0.65 | 88.0 | 0.001035 | 2.53 | 368.5 | 2492.2 | 368.6 | 2288.3 | 2656.9 |
| 0.70 | 90.0 | 0.001036 | 2.36 | 376.7 | 2494.5 | 376.8 | 2283.3 | 2660.1 |
| 0.75 | 91.8 | 0.001037 | 2.22 | 384.4 | 2496.7 | 384.5 | 2278.6 | 2663.0 |
| 0.80 | 93.5 | 0.001039 | 2.087 | 391.6 | 2498.8 | 391.7 | 2274.1 | 2665.8 |
| 0.85 | 95.2 | 0.001040 | 1.972 | 398.5 | 2500.8 | 398.6 | 2269.8 | 2668.4 |
| 0.90 | 96.7 | 0.001041 | 1.869 | 405.1 | 2502.6 | 405.2 | 2265.6 | 2670.9 |
| 0.95 | 98.2 | 0.001042 | 1.777 | 411.4 | 2504.4 | 411.5 | 2261.7 | 2673.2 |
| 1.00 | 99.6 | 0.001043 | 1.694 | 417.4 | 2506.1 | 417.5 | 2257.9 | 2675.4 |
| 1.01325 (1 atm) | 100.0 | 0.001044 | 1.673 | 419.0 | 2506.5 | 419.1 | 2256.9 | 2676.0 |

^aFrom R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, Cambridge University Press, London, 1968. \hat{V} = specific volume, \hat{U} = specific internal energy, and \hat{H} = specific enthalpy. Note: $\text{kJ/kg} \times 0.4303 = \text{Btu/lb}_m$.

(continued)

Table B.6 (Continued)

| $P(\text{bar})$ | $T(^{\circ}\text{C})$ | $\hat{V}(\text{m}^3/\text{kg})$ | | $\hat{U}(\text{kJ/kg})$ | | $\hat{H}(\text{kJ/kg})$ | | |
|-----------------|-----------------------|---------------------------------|-------|-------------------------|--------|-------------------------|-------------|--------|
| | | Water | Steam | Water | Steam | Water | Evaporation | Steam |
| 1.1 | 102.3 | 0.001046 | 1.549 | 428.7 | 2509.2 | 428.8 | 2250.8 | 2679.6 |
| 1.2 | 104.8 | 0.001048 | 1.428 | 439.2 | 2512.1 | 439.4 | 2244.1 | 2683.4 |
| 1.3 | 107.1 | 0.001049 | 1.325 | 449.1 | 2514.7 | 449.2 | 2237.8 | 2687.0 |
| 1.4 | 109.3 | 0.001051 | 1.236 | 458.3 | 2517.2 | 458.4 | 2231.9 | 2690.3 |
| 1.5 | 111.4 | 0.001053 | 1.159 | 467.0 | 2519.5 | 467.1 | 2226.2 | 2693.4 |
| 1.6 | 113.3 | 0.001055 | 1.091 | 475.2 | 2521.7 | 475.4 | 2220.9 | 2696.2 |
| 1.7 | 115.2 | 0.001056 | 1.031 | 483.0 | 2523.7 | 483.2 | 2215.7 | 2699.0 |
| 1.8 | 116.9 | 0.001058 | 0.977 | 490.5 | 2525.6 | 490.7 | 2210.8 | 2701.5 |
| 1.9 | 118.6 | 0.001059 | 0.929 | 497.6 | 2527.5 | 497.8 | 2206.1 | 2704.0 |
| 2.0 | 120.2 | 0.001061 | 0.885 | 504.5 | 2529.2 | 504.7 | 2201.6 | 2706.3 |
| 2.2 | 123.3 | 0.001064 | 0.810 | 517.4 | 2532.4 | 517.6 | 2193.0 | 2710.6 |
| 2.4 | 126.1 | 0.001066 | 0.746 | 529.4 | 2535.4 | 529.6 | 2184.9 | 2714.5 |
| 2.6 | 128.7 | 0.001069 | 0.693 | 540.6 | 2538.1 | 540.9 | 2177.3 | 2718.2 |
| 2.8 | 131.2 | 0.001071 | 0.646 | 551.1 | 2540.6 | 551.4 | 2170.1 | 2721.5 |
| 3.0 | 133.5 | 0.001074 | 0.606 | 561.1 | 2543.0 | 561.4 | 2163.2 | 2724.7 |
| 3.2 | 135.8 | 0.001076 | 0.570 | 570.6 | 2545.2 | 570.9 | 2156.7 | 2727.6 |
| 3.4 | 137.9 | 0.001078 | 0.538 | 579.6 | 2547.2 | 579.9 | 2150.4 | 2730.3 |
| 3.6 | 139.9 | 0.001080 | 0.510 | 588.1 | 2549.2 | 588.5 | 2144.4 | 2732.9 |
| 3.8 | 141.8 | 0.001082 | 0.485 | 596.4 | 2551.0 | 596.8 | 2138.6 | 2735.3 |
| 4.0 | 143.6 | 0.001084 | 0.462 | 604.2 | 2552.7 | 604.7 | 2133.0 | 2737.6 |
| 4.2 | 145.4 | 0.001086 | 0.442 | 611.8 | 2554.4 | 612.3 | 2127.5 | 2739.8 |
| 4.4 | 147.1 | 0.001088 | 0.423 | 619.1 | 2555.9 | 619.6 | 2122.3 | 2741.9 |
| 4.6 | 148.7 | 0.001089 | 0.405 | 626.2 | 2557.4 | 626.7 | 2117.2 | 2743.9 |
| 4.8 | 150.3 | 0.001091 | 0.389 | 633.0 | 2558.8 | 633.5 | 2112.2 | 2745.7 |
| 5.0 | 151.8 | 0.001093 | 0.375 | 639.6 | 2560.2 | 640.1 | 2107.4 | 2747.5 |
| 5.5 | 155.5 | 0.001097 | 0.342 | 655.2 | 2563.3 | 655.8 | 2095.9 | 2751.7 |
| 6.0 | 158.8 | 0.001101 | 0.315 | 669.8 | 2566.2 | 670.4 | 2085.0 | 2755.5 |
| 6.5 | 162.0 | 0.001105 | 0.292 | 683.4 | 2568.7 | 684.1 | 2074.7 | 2758.9 |
| 7.0 | 165.0 | 0.001108 | 0.273 | 696.3 | 2571.1 | 697.1 | 2064.9 | 2762.0 |

| | | | | | | | | |
|------|-------|----------|--------|--------|--------|--------|--------|--------|
| 7.5 | 167.8 | 0.001112 | 0.2554 | 708.5 | 2573.3 | 709.3 | 2055.5 | 2764.8 |
| 8.0 | 170.4 | 0.001115 | 0.2403 | 720.0 | 2575.5 | 720.9 | 2046.5 | 2767.5 |
| 8.5 | 172.9 | 0.001118 | 0.2268 | 731.1 | 2577.1 | 732.0 | 2037.9 | 2769.9 |
| 9.0 | 175.4 | 0.001121 | 0.2148 | 741.6 | 2578.8 | 742.6 | 2029.5 | 2772.1 |
| 9.5 | 177.7 | 0.001124 | 0.2040 | 751.8 | 2580.4 | 752.8 | 2021.4 | 2774.2 |
| 10.0 | 179.9 | 0.001127 | 0.1943 | 761.5 | 2581.9 | 762.6 | 2013.6 | 2776.2 |
| 10.5 | 182.0 | 0.001130 | 0.1855 | 770.8 | 2583.3 | 772.0 | 2005.9 | 2778.0 |
| 11.0 | 184.1 | 0.001133 | 0.1774 | 779.9 | 2584.5 | 781.1 | 1998.5 | 2779.7 |
| 11.5 | 186.0 | 0.001136 | 0.1700 | 788.6 | 2585.8 | 789.9 | 1991.3 | 2781.3 |
| 12.0 | 188.0 | 0.001139 | 0.1632 | 797.1 | 2586.9 | 798.4 | 1984.3 | 2782.7 |
| 12.5 | 189.8 | 0.001141 | 0.1569 | 805.3 | 2588.0 | 806.7 | 1977.4 | 2784.1 |
| 13.0 | 191.6 | 0.001144 | 0.1511 | 813.2 | 2589.0 | 814.7 | 1970.7 | 2785.4 |
| 14 | 195.0 | 0.001149 | 0.1407 | 828.5 | 2590.8 | 830.1 | 1957.7 | 2787.8 |
| 15 | 198.3 | 0.001154 | 0.1317 | 842.9 | 2592.4 | 844.7 | 1945.2 | 2789.9 |
| 16 | 201.4 | 0.001159 | 0.1237 | 856.7 | 2593.8 | 858.6 | 1933.2 | 2791.7 |
| 17 | 204.3 | 0.001163 | 0.1166 | 869.9 | 2595.1 | 871.8 | 1921.5 | 2793.4 |
| 18 | 207.1 | 0.001168 | 0.1103 | 882.5 | 2596.3 | 884.6 | 1910.3 | 2794.8 |
| 19 | 209.8 | 0.001172 | 0.1047 | 894.6 | 2597.3 | 896.8 | 1899.3 | 2796.1 |
| 20 | 212.4 | 0.001177 | 0.0995 | 906.2 | 2598.2 | 908.6 | 1888.6 | 2797.2 |
| 21 | 214.9 | 0.001181 | 0.0949 | 917.5 | 2598.9 | 920.0 | 1878.2 | 2798.2 |
| 22 | 217.2 | 0.001185 | 0.0907 | 928.3 | 2599.6 | 931.0 | 1868.1 | 2799.1 |
| 23 | 219.6 | 0.001189 | 0.0868 | 938.9 | 2600.2 | 941.6 | 1858.2 | 2799.8 |
| 24 | 221.8 | 0.001193 | 0.0832 | 949.1 | 2600.7 | 951.9 | 1848.5 | 2800.4 |
| 25 | 223.9 | 0.001197 | 0.0799 | 959.0 | 2601.2 | 962.0 | 1839.0 | 2800.9 |
| 26 | 226.0 | 0.001201 | 0.0769 | 968.6 | 2601.5 | 971.7 | 1829.6 | 2801.4 |
| 27 | 228.1 | 0.001205 | 0.0740 | 978.0 | 2601.8 | 981.2 | 1820.5 | 2801.7 |
| 28 | 230.0 | 0.001209 | 0.0714 | 987.1 | 2602.1 | 990.5 | 1811.5 | 2802.0 |
| 29 | 232.0 | 0.001213 | 0.0689 | 996.0 | 2602.3 | 999.5 | 1802.6 | 2802.2 |
| 30 | 233.8 | 0.001216 | 0.0666 | 1004.7 | 2602.4 | 1008.4 | 1793.9 | 2802.3 |
| 32 | 237.4 | 0.001224 | 0.0624 | 1021.5 | 2602.5 | 1025.4 | 1776.9 | 2802.3 |
| 34 | 240.9 | 0.001231 | 0.0587 | 1037.6 | 2602.5 | 1041.8 | 1760.3 | 2802.1 |
| 36 | 244.2 | 0.001238 | 0.0554 | 1053.1 | 2602.2 | 1057.6 | 1744.2 | 2801.7 |
| 38 | 247.3 | 0.001245 | 0.0524 | 1068.0 | 2601.9 | 1072.7 | 1728.4 | 2801.1 |

(continued)

Table B.6 (Continued)

| $P(\text{bar})$ | $T(^{\circ}\text{C})$ | $\hat{V}(\text{m}^3/\text{kg})$ | | $\hat{U}(\text{kJ/kg})$ | | $\hat{H}(\text{kJ/kg})$ | | |
|-----------------|-----------------------|---------------------------------|---------|-------------------------|--------|-------------------------|-------------|--------|
| | | Water | Steam | Water | Steam | Water | Evaporation | Steam |
| 40 | 250.3 | 0.001252 | 0.0497 | 1082.4 | 2601.3 | 1087.4 | 1712.9 | 2800.3 |
| 42 | 253.2 | 0.001259 | 0.0473 | 1096.3 | 2600.7 | 1101.6 | 1697.8 | 2799.4 |
| 44 | 256.0 | 0.001266 | 0.0451 | 1109.8 | 2599.9 | 1115.4 | 1682.9 | 2798.3 |
| 46 | 258.8 | 0.001272 | 0.0430 | 1122.9 | 2599.1 | 1128.8 | 1668.3 | 2797.1 |
| 48 | 261.4 | 0.001279 | 0.0412 | 1135.6 | 2598.1 | 1141.8 | 1653.9 | 2795.7 |
| 50 | 263.9 | 0.001286 | 0.0394 | 1148.0 | 2597.0 | 1154.5 | 1639.7 | 2794.2 |
| 52 | 266.4 | 0.001292 | 0.0378 | 1160.1 | 2595.9 | 1166.8 | 1625.7 | 2792.6 |
| 54 | 268.8 | 0.001299 | 0.0363 | 1171.9 | 2594.6 | 1178.9 | 1611.9 | 2790.8 |
| 56 | 271.1 | 0.001306 | 0.0349 | 1183.5 | 2593.3 | 1190.8 | 1598.2 | 2789.0 |
| 58 | 273.3 | 0.001312 | 0.0337 | 1194.7 | 2591.9 | 1202.3 | 1584.7 | 2787.0 |
| 60 | 275.6 | 0.001319 | 0.0324 | 1205.8 | 2590.4 | 1213.7 | 1571.3 | 2785.0 |
| 62 | 277.7 | 0.001325 | 0.0313 | 1216.6 | 2588.8 | 1224.8 | 1558.0 | 2782.9 |
| 64 | 279.8 | 0.001332 | 0.0302 | 1227.2 | 2587.2 | 1235.7 | 1544.9 | 2780.6 |
| 66 | 281.8 | 0.001338 | 0.0292 | 1237.6 | 2585.5 | 1246.5 | 1531.9 | 2778.3 |
| 68 | 283.8 | 0.001345 | 0.0283 | 1247.9 | 2583.7 | 1257.0 | 1518.9 | 2775.9 |
| 70 | 285.8 | 0.001351 | 0.0274 | 1258.0 | 2581.8 | 1267.4 | 1506.0 | 2773.5 |
| 72 | 287.7 | 0.001358 | 0.0265 | 1267.9 | 2579.9 | 1277.6 | 1493.3 | 2770.9 |
| 74 | 289.6 | 0.001364 | 0.0257 | 1277.6 | 2578.0 | 1287.7 | 1480.5 | 2768.3 |
| 76 | 291.4 | 0.001371 | 0.0249 | 1287.2 | 2575.9 | 1297.6 | 1467.9 | 2765.5 |
| 78 | 293.2 | 0.001378 | 0.0242 | 1296.7 | 2573.8 | 1307.4 | 1455.3 | 2762.8 |
| 80 | 295.0 | 0.001384 | 0.0235 | 1306.0 | 2571.7 | 1317.1 | 1442.8 | 2759.9 |
| 82 | 296.7 | 0.001391 | 0.0229 | 1315.2 | 2569.5 | 1326.6 | 1430.3 | 2757.0 |
| 84 | 298.4 | 0.001398 | 0.0222 | 1324.3 | 2567.2 | 1336.1 | 1417.9 | 2754.0 |
| 86 | 300.1 | 0.001404 | 0.0216 | 1333.3 | 2564.9 | 1345.4 | 1405.5 | 2750.9 |
| 88 | 301.7 | 0.001411 | 0.0210 | 1342.2 | 2562.6 | 1354.6 | 1393.2 | 2747.8 |
| 90 | 303.3 | 0.001418 | 0.02050 | 1351.0 | 2560.1 | 1363.7 | 1380.9 | 2744.6 |
| 92 | 304.9 | 0.001425 | 0.01996 | 1359.7 | 2557.7 | 1372.8 | 1368.6 | 2741.4 |
| 94 | 306.4 | 0.001432 | 0.01945 | 1368.2 | 2555.2 | 1381.7 | 1356.3 | 2738.0 |

| | | | | | | | | |
|------------------|--------|----------|---------|--------|--------|--------|--------|--------|
| 96 | 308.0 | 0.001439 | 0.01897 | 1376.7 | 2552.6 | 1390.6 | 1344.1 | 2734.7 |
| 98 | 309.5 | 0.001446 | 0.01849 | 1385.2 | 2550.0 | 1399.3 | 1331.9 | 2731.2 |
| 100 | 311.0 | 0.001453 | 0.01804 | 1393.5 | 2547.3 | 1408.0 | 1319.7 | 2727.7 |
| 105 | 314.6 | 0.001470 | 0.01698 | 1414.1 | 2540.4 | 1429.5 | 1289.2 | 2718.7 |
| 110 | 318.0 | 0.001489 | 0.01601 | 1434.2 | 2533.2 | 1450.6 | 1258.7 | 2709.3 |
| 115 | 321.4 | 0.001507 | 0.01511 | 1454.0 | 2525.7 | 1471.3 | 1228.2 | 2699.5 |
| 120 | 324.6 | 0.001527 | 0.01428 | 1473.4 | 2517.8 | 1491.8 | 1197.4 | 2689.2 |
| 125 | 327.8 | 0.001547 | 0.01351 | 1492.7 | 2509.4 | 1512.0 | 1166.4 | 2678.4 |
| 130 | 330.8 | 0.001567 | 0.01280 | 1511.6 | 2500.6 | 1532.0 | 1135.0 | 2667.0 |
| 135 | 333.8 | 0.001588 | 0.01213 | 1530.4 | 2491.3 | 1551.9 | 1103.1 | 2655.0 |
| 140 | 336.6 | 0.001611 | 0.01150 | 1549.1 | 2481.4 | 1571.6 | 1070.7 | 2642.4 |
| 145 | 339.4 | 0.001634 | 0.01090 | 1567.5 | 2471.0 | 1591.3 | 1037.7 | 2629.1 |
| 150 | 342.1 | 0.001658 | 0.01034 | 1586.1 | 2459.9 | 1611.0 | 1004.0 | 2615.0 |
| 155 | 344.8 | 0.001683 | 0.00981 | 1604.6 | 2448.2 | 1630.7 | 969.6 | 2600.3 |
| 160 | 347.3 | 0.001710 | 0.00931 | 1623.2 | 2436.0 | 1650.5 | 934.3 | 2584.9 |
| 165 | 349.8 | 0.001739 | 0.00883 | 1641.8 | 2423.1 | 1670.5 | 898.3 | 2568.8 |
| 170 | 352.3 | 0.001770 | 0.00837 | 1661.6 | 2409.3 | 1691.7 | 859.9 | 2551.6 |
| 175 | 354.6 | 0.001803 | 0.00793 | 1681.8 | 2394.6 | 1713.3 | 820.0 | 2533.3 |
| 180 | 357.0 | 0.001840 | 0.00750 | 1701.7 | 2378.9 | 1734.8 | 779.1 | 2513.9 |
| 185 | 359.2 | 0.001881 | 0.00708 | 1721.7 | 2362.1 | 1756.5 | 736.6 | 2493.1 |
| 190 | 361.4 | 0.001926 | 0.00668 | 1742.1 | 2343.8 | 1778.7 | 692.0 | 2470.6 |
| 195 | 363.6 | 0.001977 | 0.00628 | 1763.2 | 2323.6 | 1801.8 | 644.2 | 2446.0 |
| 200 | 365.7 | 0.00204 | 0.00588 | 1785.7 | 2300.8 | 1826.5 | 591.9 | 2418.4 |
| 205 | 367.8 | 0.00211 | 0.00546 | 1810.7 | 2274.4 | 1853.9 | 532.5 | 2386.4 |
| 210 | 369.8 | 0.00220 | 0.00502 | 1840.0 | 2242.1 | 1886.3 | 461.3 | 2347.6 |
| 215 | 371.8 | 0.00234 | 0.00451 | 1878.6 | 2198.1 | 1928.9 | 366.2 | 2295.2 |
| 220 | 373.7 | 0.00267 | 0.00373 | 1952 | 2114 | 2011 | 185 | 2196 |
| 221.2 | 374.15 | 0.00317 | 0.00317 | 2038 | 2038 | 2108 | 0 | 2108 |
| (Critical point) | | | | | | | | |

Table B.7 Properties of Superheated Steam^a

| $P(\text{bar})$ ($T_{\text{sat.}}(^{\circ}\text{C})$) | | Sat'd Water | Sat'd Steam | Temperature ($^{\circ}\text{C}$) \rightarrow | | | | | | | |
|--|-----------|----------------|----------------|--|-----------|----------|---------|---------|---------|---------|---------|
| | | | | 50 | 75 | 100 | 150 | 200 | 250 | 300 | 350 |
| 0.0 (—) | \hat{H} | — | — | 2595 | 2642 | 2689 | 2784 | 2880 | 2978 | 3077 | 3177 |
| | \hat{U} | — | — | 2446 | 2481 | 2517 | 2589 | 2662 | 2736 | 2812 | 2890 |
| | \hat{V} | — | — | — | — | — | — | — | — | — | — |
| 0.1 (45.8) | \hat{H} | 191.8 | 2584.8 | 2593 | 2640 | 2688 | 2783 | 2880 | 2977 | 3077 | 3177 |
| | \hat{U} | 191.8 | 2438.0 | 2444 | 2480 | 2516 | 2588 | 2661 | 2736 | 2812 | 2890 |
| | \hat{V} | 0.00101 | 14.7 | 14.8 | 16.0 | 17.2 | 19.5 | 21.8 | 24.2 | 26.5 | 28.7 |
| 0.5 (81.3) | \hat{H} | 340.6 | 2646.0 | 209.3 | 313.9 | 2683 | 2780 | 2878 | 2979 | 3076 | 3177 |
| | \hat{U} | 340.6 | 2484.0 | 209.2 | 313.9 | 2512 | 2586 | 2660 | 2735 | 2811 | 2889 |
| | \hat{V} | 0.00103 | 3.24 | 0.00101 | 0.00103 | 3.41 | 3.89 | 4.35 | 4.83 | 5.29 | 5.75 |
| 1.0 (99.6) | \hat{H} | 417.5 | 2675.4 | 209.3 | 314.0 | 2676 | 2776 | 2875 | 2975 | 3074 | 3176 |
| | \hat{U} | 417.5 | 2506.1 | 209.2 | 313.9 | 2507 | 2583 | 2658 | 2734 | 2811 | 2889 |
| | \hat{V} | 0.00104 | 1.69 | 0.00101 | 0.00103 | 1.69 | 1.94 | 2.17 | 2.40 | 2.64 | 2.87 |
| 5.0 (151.8) | \hat{H} | 640.1 | 2747.5 | 209.7 | 314.3 | 419.4 | 632.2 | 2855 | 2961 | 3065 | 3168 |
| | \hat{U} | 639.6 | 2560.2 | 209.2 | 313.8 | 418.8 | 631.6 | 2643 | 2724 | 2803 | 2883 |
| | \hat{V} | 0.00109 | 0.375 | 0.00101 | 0.00103 | 0.00104 | 0.00109 | 0.425 | 0.474 | 0.522 | 0.571 |
| 10 (179.9) | \hat{H} | 762.6 | 2776.2 | 210.1 | 314.7 | 419.7 | 632.5 | 2827 | 2943 | 3052 | 3159 |
| | \hat{U} | 761.5 | 2582 | 209.1 | 313.7 | 418.7 | 631.4 | 2621 | 2710 | 2794 | 2876 |
| | \hat{V} | 0.00113 | 0.194 | 0.00101 | 0.00103 | 0.00104 | 0.00109 | 0.206 | 0.233 | 0.258 | 0.282 |
| 20 (212.4) | \hat{H} | 908.6 | 2797.2 | 211.0 | 315.5 | 420.5 | 633.1 | 852.6 | 2902 | 3025 | 3139 |
| | \hat{U} | 906.2 | 2598.2 | 209.0 | 313.5 | 418.4 | 603.9 | 850.2 | 2679 | 2774 | 2862 |
| | \hat{V} | 0.00118 | 0.09950 | 0.00101 | 0.00102 | 0.00104 | 0.00109 | 0.00116 | 0.111 | 0.125 | 0.139 |
| 40 (250.3) | \hat{H} | 1087.4 | 2800.3 | 212.7 | 317.1 | 422.0 | 634.3 | 853.4 | 1085.8 | 2962 | 3095 |
| | \hat{U} | 1082.4 | 2601.3 | 208.6 | 313.0 | 417.8 | 630.0 | 848.8 | 1080.8 | 2727 | 2829 |
| | \hat{V} | 0.00125 | 0.04975 | 0.00101 | 0.00102 | 0.00104 | 0.00109 | 0.00115 | 0.00125 | 0.0588 | 0.0665 |
| 60 (275.6) | \hat{H} | 1213.7 | 2785.0 | 214.4 | 318.7 | 423.5 | 635.6 | 854.2 | 1085.8 | 2885 | 3046 |
| | \hat{U} | 1205.8 | 2590.4 | 208.3 | 312.6 | 417.3 | 629.1 | 847.3 | 1078.3 | 2668 | 2792 |
| | \hat{V} | 0.00132 | 0.0325 | 0.00101 | 0.00103 | 0.00104 | 0.00109 | 0.00115 | 0.00125 | 0.0361 | 0.0422 |
| 80 (295.0) | \hat{H} | 1317.1 | 2759.9 | 216.1 | 320.3 | 425.0 | 636.8 | 855.1 | 1085.8 | 2787 | 2990 |
| | \hat{U} | 1306.0 | 2571.7 | 208.1 | 312.3 | 416.7 | 628.2 | 845.9 | 1075.8 | 2593 | 2750 |
| | \hat{V} | 0.00139 | 0.0235 | 0.00101 | 0.00102 | 0.00104 | 0.00109 | 0.00115 | 0.00124 | 0.0243 | 0.0299 |
| 100 (311.0) | \hat{H} | 1408.0 | 2727.7 | 217.8 | 322.9 | 426.5 | 638.1 | 855.9 | 1085.8 | 1343.4 | 2926 |
| | \hat{U} | 1393.5 | 2547.3 | 207.8 | 311.7 | 416.1 | 627.3 | 844.4 | 1073.4 | 1329.4 | 2702 |
| | \hat{V} | 0.00145 | 0.0181 | 0.00101 | 0.00102 | 0.00104 | 0.00109 | 0.00115 | 0.00124 | 0.00140 | 0.0224 |
| 150 (342.1) | \hat{H} | 1611.0 | 2615.0 | 222.1 | 326.0 | 430.3 | 641.3 | 858.1 | 1086.2 | 1338.2 | 2695 |
| | \hat{U} | 1586.1 | 2459.9 | 207.0 | 310.7 | 414.7 | 625.0 | 841.0 | 1067.7 | 1317.6 | 2523 |
| | \hat{V} | 0.00166 | 0.0103 | 0.00101 | 0.00102 | 0.00104 | 0.00108 | 0.00114 | 0.00123 | 0.00138 | 0.0115 |
| 200 (365.7) | \hat{H} | 1826.5 | 2418.4 | 226.4 | 330.0 | 434.0 | 644.5 | 860.4 | 1086.7 | 1334.3 | 1647.1 |
| | \hat{U} | 1785.7 | 2300.8 | 206.3 | 309.7 | 413.2 | 622.9 | 837.7 | 1062.2 | 1307.1 | 1613.7 |
| | \hat{V} | 0.00204 | 0.005875 | 0.00100 | 0.00102 | 0.00103 | 0.00108 | 0.00114 | 0.00122 | 0.00136 | 0.00167 |
| 221.2(P_c) (374.15)(T_c) | \hat{H} | 2108 | 2108 | 228.2 | 331.7 | 435.7 | 645.8 | 861.4 | 1087.0 | 1332.8 | 1635.5 |
| | \hat{U} | 2037.8 | 2037.8 | 206.0 | 309.2 | 412.8 | 622.0 | 836.3 | 1060.0 | 1302.9 | 1600.3 |
| | \hat{V} | 0.00317 | 0.00317 | 0.00100 | 0.00102 | 0.00103 | 0.00108 | 0.00114 | 0.00122 | 0.00135 | 0.00163 |
| 250 (—) | \hat{H} | — | — | 230.7 | 334.0 | 437.8 | 647.7 | 862.8 | 1087.5 | 1331.1 | 1625.0 |
| | \hat{U} | — | — | 205.7 | 308.7 | 412.1 | 620.8 | 834.4 | 1057.0 | 1297.5 | 1585.0 |
| | \hat{V} | — | — | 0.00100 | 0.00101 | 0.00103 | 0.00108 | 0.00113 | 0.00122 | 0.00135 | 0.00160 |
| 300 (—) | \hat{H} | — | — | 235.0 | 338.1 | 441.6 | 650.9 | 865.2 | 1088.4 | 1328.7 | 1609.9 |
| | \hat{U} | — | — | 205.0 | 307.7 | 410.8 | 618.7 | 831.3 | 1052.1 | 1288.7 | 1563.3 |
| | \hat{V} | — | — | 0.0009990 | 0.00101 | 0.00103 | 0.00107 | 0.00113 | 0.00121 | 0.00133 | 0.00155 |
| 500 (—) | \hat{H} | — | — | 251.9 | 354.2 | 456.8 | 664.1 | 875.4 | 1093.6 | 1323.7 | 1576.3 |
| | \hat{U} | — | — | 202.4 | 304.0 | 405.8 | 611.0 | 819.7 | 1034.3 | 1259.3 | 1504.1 |
| | \hat{V} | — | — | 0.0009911 | 0.00100 | 0.00102 | 0.00106 | 0.00111 | 0.00119 | 0.00129 | 0.00144 |
| 1000 (—) | \hat{H} | — | — | 293.9 | 394.3 | 495.1 | 698.0 | 903.5 | 1113.0 | 1328.7 | 1550.5 |
| | \hat{U} | — | — | 196.5 | 295.7 | 395.1 | 594.4 | 795.3 | 999.0 | 1207.1 | 1419.0 |
| | \hat{V} | — | — | 0.0009737 | 0.0009852 | 0.001000 | 0.00104 | 0.00108 | 0.00114 | 0.00122 | 0.00131 |

^aAdapted from R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, Cambridge University Press, London, 1968. Water is a liquid in the enclosed region between 50°C and 350°C. \hat{H} = specific enthalpy (kJ/kg), \hat{U} = specific internal energy (kJ/kg), \hat{V} = specific volume (m³/kg). Note: kJ/kg \times 0.4303 = Btu/lb_m.

(continued)

Table B.7 (Continued)

| $P(\text{bar})$ ($T_{\text{sat}}, ^\circ\text{C}$) | | Temperature ($^\circ\text{C}$) \rightarrow | | | | | | | |
|---|-----------|--|----------|----------|----------|----------|----------|----------|----------|
| | | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 |
| 0.0 (—) | \hat{H} | 3280 | 3384 | 3497 | 3597 | 3706 | 3816 | 3929 | 4043 |
| | \hat{U} | 2969 | 3050 | 3132 | 3217 | 3303 | 3390 | 3480 | 3591 |
| | \hat{V} | — | — | — | — | — | — | — | — |
| 0.1 (45.8) | \hat{H} | 3280 | 3384 | 3489 | 3596 | 3706 | 3816 | 3929 | 4043 |
| | \hat{U} | 2969 | 3050 | 3132 | 3217 | 3303 | 3390 | 3480 | 3571 |
| | \hat{V} | 21.1 | 33.3 | 35.7 | 38.0 | 40.3 | 42.6 | 44.8 | 47.2 |
| 0.5 (81.3) | \hat{H} | 3279 | 3383 | 3489 | 3596 | 3705 | 3816 | 3929 | 4043 |
| | \hat{U} | 2969 | 3049 | 3132 | 3216 | 3302 | 3390 | 3480 | 3571 |
| | \hat{V} | 6.21 | 6.67 | 7.14 | 7.58 | 8.06 | 8.55 | 9.01 | 9.43 |
| 1.0 (99.6) | \hat{H} | 3278 | 3382 | 3488 | 3596 | 3705 | 3816 | 3928 | 4042 |
| | \hat{U} | 2968 | 3049 | 3132 | 3216 | 3302 | 3390 | 3479 | 3570 |
| | \hat{V} | 3.11 | 3.33 | 3.57 | 3.80 | 4.03 | 4.26 | 4.48 | 4.72 |
| 5.0 (151.8) | \hat{H} | 3272 | 3379 | 3484 | 3592 | 3702 | 3813 | 3926 | 4040 |
| | \hat{U} | 2964 | 3045 | 3128 | 3213 | 3300 | 3388 | 3477 | 3569 |
| | \hat{V} | 0.617 | 0.664 | 0.711 | 0.758 | 0.804 | 0.850 | 0.897 | 0.943 |
| 10 (179.9) | \hat{H} | 3264 | 3371 | 3478 | 3587 | 3697 | 3809 | 3923 | 4038 |
| | \hat{U} | 2958 | 3041 | 3124 | 3210 | 3296 | 3385 | 3475 | 3567 |
| | \hat{V} | 0.307 | 0.330 | 0.353 | 0.377 | 0.402 | 0.424 | 0.448 | 0.472 |
| 20 (212.4) | \hat{H} | 3249 | 3358 | 3467 | 3578 | 3689 | 3802 | 3916 | 4032 |
| | \hat{U} | 2946 | 3031 | 3115 | 3202 | 3290 | 3379 | 3470 | 3562 |
| | \hat{V} | 0.151 | 0.163 | 0.175 | 0.188 | 0.200 | 0.211 | 0.223 | 0.235 |
| 40 (250.3) | \hat{H} | 3216 | 3331 | 3445 | 3559 | 3673 | 3788 | 3904 | 4021 |
| | \hat{U} | 2922 | 3011 | 3100 | 3188 | 3278 | 3368 | 3460 | 3554 |
| | \hat{V} | 0.0734 | 0.0799 | 0.0864 | 0.0926 | 0.0987 | 0.105 | 0.111 | 0.117 |
| 60 (275.6) | \hat{H} | 3180 | 3303 | 3422 | 3539 | 3657 | 3774 | 3892 | 4011 |
| | \hat{U} | 2896 | 2991 | 3083 | 3174 | 3265 | 3357 | 3451 | 3545 |
| | \hat{V} | 0.0474 | 0.0521 | 0.0566 | 0.0609 | 0.0652 | 0.0693 | 0.0735 | 0.0776 |
| 80 (295.0) | \hat{H} | 3142 | 3274 | 3399 | 3520 | 3640 | 3759 | 3879 | 4000 |
| | \hat{U} | 2867 | 2969 | 3065 | 3159 | 3252 | 3346 | 3441 | 3537 |
| | \hat{V} | 0.0344 | 0.0382 | 0.0417 | 0.0450 | 0.0483 | 0.0515 | 0.0547 | 0.0578 |
| 100 (311.0) | \hat{H} | 3100 | 3244 | 3375 | 3500 | 3623 | 3745 | 3867 | 3989 |
| | \hat{U} | 2836 | 2946 | 3047 | 3144 | 3240 | 3335 | 3431 | 3528 |
| | \hat{V} | 0.0264 | 0.0298 | 0.0328 | 0.0356 | 0.0383 | 0.0410 | 0.0435 | 0.0461 |
| 150 (342.1) | \hat{H} | 2975 | 3160 | 3311 | 3448 | 3580 | 3708 | 3835 | 3962 |
| | \hat{U} | 2744 | 2883 | 2999 | 3105 | 3207 | 3307 | 3407 | 3507 |
| | \hat{V} | 0.0157 | 0.0185 | 0.0208 | 0.0229 | 0.0249 | 0.0267 | 0.0286 | 0.0304 |
| 200 (365.7) | \hat{H} | 2820 | 3064 | 3241 | 3394 | 3536 | 3671 | 3804 | 3935 |
| | \hat{U} | 2622 | 2810 | 2946 | 3063 | 3172 | 3278 | 3382 | 3485 |
| | \hat{V} | 0.009950 | 0.0127 | 0.0148 | 0.0166 | 0.0182 | 0.197 | 0.211 | 0.0225 |
| 221.2(P_c) (374.15)(T_c) | \hat{H} | 2733 | 3020 | 3210 | 3370 | 3516 | 3655 | 3790 | 3923 |
| | \hat{U} | 2553 | 2776 | 2922 | 3045 | 3157 | 3265 | 3371 | 3476 |
| | \hat{V} | 0.008157 | 0.0110 | 0.0130 | 0.0147 | 0.0162 | 0.0176 | 0.0190 | 0.0202 |
| 250 (—) | \hat{H} | 2582 | 2954 | 3166 | 3337 | 3490 | 3633 | 3772 | 3908 |
| | \hat{U} | 2432 | 2725 | 2888 | 3019 | 3137 | 3248 | 3356 | 3463 |
| | \hat{V} | 0.006013 | 0.009174 | 0.0111 | 0.0127 | 0.0141 | 0.0143 | 0.0166 | 0.0178 |
| 300 (—) | \hat{H} | 2162 | 2826 | 3085 | 3277 | 3443 | 3595 | 3740 | 3880 |
| | \hat{U} | 2077 | 2623 | 2825 | 2972 | 3100 | 3218 | 3330 | 3441 |
| | \hat{V} | 0.002830 | 0.006734 | 0.008680 | 0.0102 | 0.0114 | 0.0126 | 0.0136 | 0.0147 |
| 500 (—) | \hat{H} | 1878 | 2293 | 2723 | 3021 | 3248 | 3439 | 3610 | 3771 |
| | \hat{U} | 1791 | 2169 | 2529 | 2765 | 2946 | 3091 | 3224 | 3350 |
| | \hat{V} | 0.001726 | 0.002491 | 0.003882 | 0.005112 | 0.006112 | 0.007000 | 0.007722 | 0.008418 |
| 1000 (—) | \hat{H} | 1798 | 2051 | 2316 | 2594 | 2857 | 3105 | 3324 | 3526 |
| | \hat{U} | 1653 | 1888 | 2127 | 2369 | 2591 | 2795 | 2971 | 3131 |
| | \hat{V} | 0.001446 | 0.001628 | 0.001893 | 0.002246 | 0.002668 | 0.003106 | 0.003536 | 0.003953 |

Table B.8 Specific Enthalpies of Selected Gases: SI Units

| \hat{H} (kJ/mol) | | | | | | | |
|--|-------|----------------|----------------|----------------|-------|-----------------|------------------|
| Reference state: Gas, $P_{\text{ref}} = 1 \text{ atm}$, $T_{\text{ref}} = 25^\circ\text{C}$ | | | | | | | |
| T | Air | O ₂ | N ₂ | H ₂ | CO | CO ₂ | H ₂ O |
| 0 | −0.72 | −0.73 | −0.73 | −0.72 | −0.73 | −0.92 | −0.84 |
| 25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100 | 2.19 | 2.24 | 2.19 | 2.16 | 2.19 | 2.90 | 2.54 |
| 200 | 5.15 | 5.31 | 5.13 | 5.06 | 5.16 | 7.08 | 6.01 |
| 300 | 8.17 | 8.47 | 8.12 | 7.96 | 8.17 | 11.58 | 9.57 |
| 400 | 11.24 | 11.72 | 11.15 | 10.89 | 11.25 | 16.35 | 13.23 |
| 500 | 14.37 | 15.03 | 14.24 | 13.83 | 14.38 | 21.34 | 17.01 |
| 600 | 17.55 | 18.41 | 17.39 | 16.81 | 17.57 | 26.53 | 20.91 |
| 700 | 20.80 | 21.86 | 20.59 | 19.81 | 20.82 | 31.88 | 24.92 |
| 800 | 24.10 | 25.35 | 23.86 | 22.85 | 24.13 | 37.36 | 29.05 |
| 900 | 27.46 | 28.89 | 27.19 | 25.93 | 27.49 | 42.94 | 33.32 |
| 1000 | 30.86 | 32.47 | 30.56 | 29.04 | 30.91 | 48.60 | 37.69 |
| 1100 | 34.31 | 36.07 | 33.99 | 32.19 | 34.37 | 54.33 | 42.18 |
| 1200 | 37.81 | 39.70 | 37.46 | 35.39 | 37.87 | 60.14 | 46.78 |
| 1300 | 41.34 | 43.38 | 40.97 | 38.62 | 41.40 | 65.98 | 51.47 |
| 1400 | 44.89 | 47.07 | 44.51 | 41.90 | 44.95 | 71.89 | 56.25 |
| 1500 | 48.45 | 50.77 | 48.06 | 45.22 | 48.51 | 77.84 | 61.09 |

Table B.9 Specific Enthalpies of Selected Gases:
American Engineering Units

| \hat{H} (Btu/lb-mole) | | | | | | | |
|--|-------|----------------|----------------|----------------|-------|-----------------|------------------|
| Reference state: Gas, $P_{\text{ref}} = 1 \text{ atm}$, $T_{\text{ref}} = 77^\circ\text{F}$ | | | | | | | |
| T | Air | O ₂ | N ₂ | H ₂ | CO | CO ₂ | H ₂ O |
| 32 | −312 | −315 | −312 | −310 | −312 | −394 | −361 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 160 | 162 | 160 | 159 | 160 | 206 | 185 |
| 200 | 858 | 875 | 857 | 848 | 859 | 1132 | 996 |
| 300 | 1563 | 1602 | 1558 | 1539 | 1564 | 2108 | 1818 |
| 400 | 2275 | 2342 | 2265 | 2231 | 2276 | 3129 | 2652 |
| 500 | 2993 | 3094 | 2976 | 2925 | 2994 | 4192 | 3499 |
| 600 | 3719 | 3858 | 3694 | 3621 | 3720 | 5293 | 4359 |
| 700 | 4451 | 4633 | 4418 | 4319 | 4454 | 6429 | 5233 |
| 800 | 5192 | 5418 | 5150 | 5021 | 5195 | 7599 | 6122 |
| 900 | 5940 | 6212 | 5889 | 5725 | 5945 | 8790 | 7025 |
| 1000 | 6695 | 7015 | 6635 | 6433 | 6702 | 10015 | 7944 |
| 1100 | 7459 | 7826 | 7399 | 7145 | 7467 | 11263 | 8880 |
| 1200 | 8230 | 8645 | 8151 | 7861 | 8239 | 12533 | 9831 |
| 1300 | 9010 | 9471 | 8922 | 8581 | 9021 | 13820 | 10799 |
| 1400 | 9797 | 10304 | 9699 | 9306 | 9809 | 15122 | 11783 |
| 1500 | 10590 | 11142 | 10485 | 10035 | 10606 | 16436 | 12783 |
| 1600 | 11392 | 11988 | 11278 | 10769 | 11409 | 17773 | 13798 |
| 1700 | 12200 | 12836 | 12080 | 11509 | 12220 | 19119 | 14831 |
| 1800 | 13016 | 13691 | 12888 | 12254 | 13036 | 20469 | 15877 |
| 1900 | 13837 | 14551 | 13702 | 13003 | 13858 | 21840 | 16941 |
| 2000 | 14663 | 15415 | 14524 | 13759 | 14688 | 23211 | 18019 |

Table B.10 Atomic Heat Capacities for Kopp's Rule^a

| Element | $C_{pa}[\text{J}/(\text{g}\cdot\text{atom}\cdot^\circ\text{C})]$ | |
|------------|--|---------|
| | Solids | Liquids |
| C | 7.5 | 12 |
| H | 9.6 | 18 |
| B | 11 | 20 |
| Si | 16 | 24 |
| O | 17 | 25 |
| F | 21 | 29 |
| P | 23 | 31 |
| S | 26 | 31 |
| All Others | 26 | 33 |

^aD. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, 3rd Edition, Prentice-Hall, Englewood Cliffs, NJ, 1974, p. 270.

Table B.11 Integral Heats of Solution and Mixing at 25°C

| $r(\text{mol H}_2\text{O/mol solute})$ | $(\Delta\hat{H}_s)_{\text{HCl(g)}}$ kJ/mol HCl | $(\Delta\hat{H}_s)_{\text{NaOH(s)}}$ kJ/mol NaOH | $(\Delta\hat{H}_m)_{\text{H}_2\text{SO}_4}$ kJ/mol H ₂ SO ₄ |
|--|---|---|--|
| 0.5 | — | — | −15.73 |
| 1 | −26.22 | — | −28.07 |
| 1.5 | — | — | −36.90 |
| 2 | −48.82 | — | −41.92 |
| 3 | −56.85 | −28.87 | −48.99 |
| 4 | −61.20 | −34.43 | −54.06 |
| 5 | −64.05 | −37.74 | −58.03 |
| 10 | −69.49 | −42.51 | −67.03 |
| 20 | −71.78 | −42.84 | — |
| 25 | — | — | −72.30 |
| 30 | −72.59 | −42.72 | — |
| 40 | −73.00 | −42.59 | — |
| 50 | −73.26 | −42.51 | −73.34 |
| 100 | −73.85 | −42.34 | −73.97 |
| 200 | −74.20 | −42.26 | — |
| 500 | −74.52 | −42.38 | −76.73 |
| 1 000 | −74.68 | −42.47 | −78.57 |
| 2 000 | −74.82 | −42.55 | — |
| 5 000 | −74.93 | −42.68 | −84.43 |
| 10 000 | −74.99 | −42.72 | −87.07 |
| 50 000 | −75.08 | −42.80 | — |
| 100 000 | −75.10 | — | −93.64 |
| 500 000 | — | — | −95.31 |
| ∞ | −75.14 | −42.89 | −96.19 |

^aFrom J. C. Whitwell and R. K. Toner, *Conservation of Mass and Energy*, pp. 344–346. Copyright © 1969 by McGraw-Hill, Inc. Used with permission of McGraw-Hill.

