# Appendix 3: Data Section

Table 7.5.1: Van der Waals coefficients

| Molecule | a (bar $L^2$ $mol^{-2}$) | a (atm $L^2$ $mol^{-2}$) | b (L $mol^{-1}$) |
|---|---|---|---|
| Helium | 0.03460 | 0.03415 | 0.02373 |
| Hydrogen | 0.02465 | 0.2432 | 0.02667 |
| Nitrogen | 1.3661 | 1.3483 | 0.03858 |
| Oxygen | 1.3820 | 1.3639 | 0.03186 |
| Carbon monoxide | 1.4734 | 1.4541 | 0.039523 |
| Carbon dioxide | 3.6551 | 3.6073 | 0.042816 |
| Ammonia | 4.3044 | 4.2481 | 0.037847 |
| Water | 5.536 | 5.464 | 0.03049 |
| Ethylene | 4.6112 | 4.5509 | 0.05820 |
| Ethane | 5.5818 | 5.5088 | 0.06514 |
| Propane | 9.3919 | 9.2691 | 0.09049 |
| Pentane | 19.124 | 18.874 | 0.14510 |
| Benzene | 18.876 | 18.629 | 0.11974 |

D. A. McQuarrie, J. D. Simon, "Physical Chemistry: A Molecular Approach," University Science Books, Sausalito, CA, 1997. p. 644.

Table 7.5.3: Redlich-Kwong coefficients

| Molecule | A (bar $L^2$ $mol^{-2}$) | A (atm $L^2$ $mol^{-2}$) | B (L $mol^{-1}$) |
|---|---|---|---|
| Helium | 0.07991 | 0.07886 | 0.016450 |
| Hydrogen | 1.4333 | 1.4145 | 0.018482 |
| Nitrogen | 15.551 | 15.348 | 0.026738 |
| Oxygen | 17.411 | 17.183 | 0.022082 |
| Carbon monoxide | 17.208 | 16.983 | 0.027394 |
| Carbon dioxide | 64.597 | 63.752 | 0.029677 |
| Ammonia | 87.808 | 86.660 | 0.026232 |
| Ethylene | 78.512 | 77.486 | 0.040339 |
| Ethane | 98.831 | 97.539 | 0.045153 |
| Propane | 183.02 | 180.63 | 0.062723 |
| Pentane | 419.97 | 414.48 | 0.10057 |
| Benzene | 453.32 | 447.39 | 0.082996 |

D. A. McQuarrie, J. D. Simon, "Physical Chemistry: A Molecular Approach," University Science Books, Sausalito, CA, 1997. p. 646.

Table 7.6.1: The coefficient of thermal expansion and isothermal compressibility at 25°C.

| Substance | $\alpha$ ($K^{-1}$)/$10^{-4}$ | $\kappa_T$ ($bar^{-1}$)/$10^{-6}$ | Substance | $\alpha$ ($K^{-1}$)/$10^{-4}$ | $\kappa_T$ ($bar^{-1}$)/$10^{-6}$ |
|---|---|---|---|---|---|
| Al | 0.693 | 1.385 | Benzene | 12.4 | 95.4 |
| Cu | 0.500 | 0.775 | Carbon tetrachloride | 11.6 | 105.3 |
| Diamond | 0.030 | 0.185 | Chloroform | 12.3 | 96.1 |
| Au | 0.426 | 0.577 | Cyclohexane | 11.7 | 109.6 |
| Hg | 1.81 | 4.01 | *n*-Decane | 10.2 | 109.4 |
| Pt | 0.27 | 0.359 | Dichloromethane | 13.9 | 103. |
| Ag | 0.57 | 0.993 | Ethanol | 11.2 | 114.0 |
| W | 0.13 | 0.309 | Ethyl acetate | 13.7 | 116.8 |
| Water (0°C) | -0.677 | 49.4 | *n*-Hexane | 14.1 | 158.5 |
| Water (20°C) | 2.067 | 45.2 | Hexanol | 10.3 | 82.4 |
| Water (25°C) | 2.569 | 45.24 | Methanol | 11.4 | 123.5 |
| Water (100°C) | 7.066 | 47.4 | *n*-Octane | 11.6 | 118.2 |
| Acetone | 14.9 | 122.3 | *n*-Pentane | 16.4 | 218.0 |
| Acetic acid | 11.1 | 95.4 | Toluene | 10.6 | 91.5 |

D. R. Lide, Ed., *Handbook of Chemistry and Physics, 88th Ed.*, Taylor & Francis CRC Press, Boca Raton, FL, 2007 and *48th Ed.*, 1968. [Some $\alpha$ values extrapolated linearly to 25°C]

Table 8.1.1: Thermodynamic Properties of Phase Transitions at 1 atm.[1-3]

| Substance | | $T_b$ (°C) | $\Delta_{vap}H°$ @ $T_b$ (kJ mol$^{-1}$) | $\Delta_{vap}H°$ @ 298 K (kJ mol$^{-1}$) | $T_m$ (°C) | $\Delta_{fus}H°$ @ $T_m$ (kJ mol$^{-1}$) | $\Delta_{sub}H°$@ 298 K (kJ mol$^{-1}$) |
|---|---|---|---|---|---|---|---|
| *Inorganic* | | | | | | | |
| Ammonia | $NH_3$ | -33.33 | 23.33 | 19.86 | -77.73 | 5.66 | |
| Argon | Ar | -185.85 | 6.43 | | -189.34 | 1.18 | |
| Bromine | $Br_2$ | 58.8 | 29.96 | 30.91 | -7.2 | 10.57 | |
| Chlorine | $Cl_2$ | -34.04 | 20.41 | 17.65 | -101.5 | 6.40 | |
| Fluorine | $F_2$ | -188.11 | 6.62 | | -219.67 | 0.51 | |
| Helium | He | -268.93 | 0.08 | | | | |
| Hydrogen | $H_2$ | -252.76 | .090 | | -259.16 | 0.12 | |
| Hydrobromic acid | HBr | -66.38 | 17.61 | 12.69 | -86.80 | 2.906 | |
| Hydrochloric acid | HCl | -85. | 16.15 | 9.08 | -114.17 | 2.00 | |
| Hydroiodic acid | HI | -35.55 | 19.76 | 17.36 | -50.76 | 2.87 | |
| Hydrosulfuric acid | $H_2S$ | -59.55 | 18.67 | 14.08 | -85.5 | 2.38 | |
| Hydrazine | $H_4N_2$ | 113.55 | 41.8 | 44.7 | 1.54 | 12.66 | |
| Iodine | $I_2$ | 184.4 | 41.57 | | 113.7 | 15.52 | 62.4 |
| Nitrogen | $N_2$ | -195.79 | 5.577 | | -210.0 | 0.71 | |
| Nitric oxide | NO | -151.74 | 13.83 | | -163.6 | 2.30 | |
| Nitrous oxide | $N_2O$ | -88.48 | 16.53 | | -90.8 | 6.54 | |
| Oxygen | $O_2$ | -182.95 | 6.820 | 8.204 | -218.79 | 0.44 | |
| Phosphine | $PH_3$ | -87.75 | 14.6 | | | | |
| Phosphorous trichloride | $PCl_3$ | 76. | 30.5 | 32.1 | -93. | 7.10 | |
| Sulfur | S | 444.61 | 45. | | 115.2 | 1.721 | 62.2 |
| Sulfur dioxide | $SO_2$ | -10.05 | 24.94 | 22.92 | | | |
| Sulfur trioxide | $SO_3$ | 44.5 | 40.69 | 43.14 | 16.8 | 8.60 | |
| Water | $H_2O$ | 99.97 | 40.65 | 43.98 | 0.00 | 6.01 | |
| *Organic* | | | | | | | |
| Acetaldehyde | $C_2H_4O$ | 20.1 | 25.76 | 25.47 | -123.37 | 2.31 | |
| Acetic acid | $C_2H_4O_2$ | 117.9 | 23.70 | 23.36 | 16.64 | 11.73 | |
| Acetic anhydride | $C_4H_7O_3$ | 139.5 | 38.2 | | -74.1 | 10.5 | |
| Acetone | $C_2H_6O$ | 56.05 | 29.10 | 30.99 | -94.7 | 5.77 | |
| Acetonitrile ($CH_3CN$) | $C_2H_3N$ | 81.65 | 29.75 | 32.94 | -43.82 | 8.16 | |
| Acetophenone | $C_7H_6O$ | 202. | 43.98 | 55.40 | 19.9 | | |
| Adenine | $C_5H_5N_5$ | | | | | | 109.2 |
| Anthracene | $C_{14}H_{10}$ | | | | 215.76 | 29.4 | 56.5 |
| Azulene | $C_{10}H_8$ | 242.0 | | 63.8 | 100. | | 82.8 |
| Benzaldehyde | $C_7H_6O$ | 178.8 | 42.5 | 50.3 | -57.1 | 9.32 | |
| Benzene | $C_6H_6$ | 80.09 | 30.72 | 33.83 | 5.49 | 9.87 | |
| Benzoic acid | $C_7H_6O_2$ | | | | 122.35 | 18.02 | 89.230 |
| Benzonitrile | $C_7H_5N$ | 191.1 | 45.9 | 52.5 | -13.99 | 9.1 | |
| Benzophenone | $C_{13}H_{10}O$ | | | | 47.9 | 18.19 | 94.1 |
| Benzyl alcohol | $C_6H_6O$ | 205.31 | 50.48 | 60.3 | -15.4 | 8.97 | |
| Biphenyl | $C_{12}H_{10}$ | | | | 68.93 | 18.57 | 81.520 |
| Bromobenzene | $C_6H_5Br$ | 156.06 | | 44.54 | -30.72 | 10.70 | |
| 1-Bromobutane | $C_4H_9Br$ | 101.6 | 32.51 | 36.64 | -112.6 | 9.23 | |
| 2-Bromobutane | $C_4H_9Br$ | 91.3 | 30.77 | 34.41 | -112.65 | 6.89 | |
| Bromoethane | $C_2H_5Br$ | 38.5 | 27.04 | 28.03 | -118.6 | 7.47 | |
| Bromoethylene | $C_2H_3Br$ | 15.8 | 23.4 | 18.2 | -139.54 | 5.12 | |
| Bromomethane | $CH_4Br$ | 3.5 | 23.91 | 22.81 | -93.68 | 5.98 | |
| 1-Bromopentane | $C_5H_{11}Br$ | 129.8 | 35.01 | 41.28 | -88.0 | 14.37 | |
| 1-Bromopropane | $C_3H_7Br$ | 71.1 | 29.84 | 32.01 | -110.3 | 6.44 | |
| 2-Bromopropane | $C_3H_7Br$ | 59.5 | 28.33 | 30.17 | -89.0 | 6.53 | |
| 1,3-Butadiene | $C_4H_6$ | -4.41 | 22.47 | 20.86 | -108.91 | 7.98 | |

| Substance | | $T_b$ (°C) | $\Delta_{vap}H°(T_b)$ | $\Delta_{vap}H°$(T) | $T_m$ (°C) | $\Delta_{fus}H°(T_m)$ | $\Delta_{sub}H°$(T) |
|---|---|---|---|---|---|---|---|
| Butane | $C_4H_{10}$ | -0.5 | 22.44 | 21.02 | -138.3 | 4.66 | |
| Butanenitrile | $C_5H_8N$ | 117.6 | 33.68 | 39.33 | | | |
| Butanoic acid | $C_4H_8O_2$ | 163.75 | 41.8 | 40.45 | -5.1 | 11.59 | |
| 1-Butanol | $C_4H_{10}O$ | 117.73 | 43.29 | 52.35 | -88.6 | 9.37 | |
| 1-Butene | $C_4H_8$ | -6.26 | 22.07 | 20.22 | -185.34 | 3.96 | |
| *cis*-2-Butene | $C_4H_8$ | 3.71 | 23.34 | 22.16 | -138.88 | 7.31 | |
| *trans*-2-Butene | $C_4H_8$ | 0.88 | 22.72 | 21.40 | -105.52 | 9.76 | |
| 1-Butyne | $C_4H_6$ | 8.08 | 24.52 | 23.35 | -125.7 | 6.03 | |
| 2-Butyne | $C_4H_6$ | | | | -32.2 | 9.23 | |
| Camphene | $C_{10}H_{16}$ | 106.9 | | 43.5 | 49. | | 46.86 |
| Camphor | $C_{10}H_{16}O$ | 209.2 | 59.5 | | 178.4 | 6.820 | 51.9(0.8) |
| Carbon tetrachloride | $CCl_4$ | 76.8 | 29.82 | 32.43 | -22.62 | 2.56 | |
| Chlorobenzene | $C_6H_5Cl$ | 131.72 | 35.19 | 40.97 | -45.31 | 9.6 | |
| 1-Chlorobutane | $C_3H_7Cl$ | 78.4 | 30.39 | 33.51 | | | |
| (±)-2-Chlorobutane | $C_3H_7Cl$ | 68.2 | 29.17 | 31.53 | | | |
| Chloroethane | $C_2H_5Cl$ | 12.3 | 24.65 | 28. | -138.4 | 4.45 | |
| Chloroethylene | $C_2H_3Cl$ | -13.8 | 20.8 | | -153.84 | 4.92 | |
| Chloroform | $CHCl_3$ | 61.17 | 29.24 | 31.28 | -63.41 | 9.5 | |
| Chloromethane | $CH_3Cl$ | -24.09 | 21.40 | 18.92 | -97.7 | 6.43 | |
| Cyclobutane | $C_4H_8$ | 12.6 | 24.19 | 23.51 | -90.7 | 1.09 | |
| Cyclohexane | $C_6H_{12}$ | 80.73 | 29.97 | 33.01 | 6.59 | 2.68 | |
| Cyclohexanol | $C_6H_{12}O$ | 160.84 | | 62.01 | 25.93 | 1.78 | |
| Cyclohexene | $C_6H_{10}$ | 82.98 | 30.46 | 33.47 | -103.5 | 3.29 | |
| Cyclopentane | $C_5H_{10}$ | 49.3 | 27.30 | 28.52 | -93.4 | 0.61 | |
| Cyclopropane | $C_3H_6$ | -32.81 | 20.05 | 16.93 | -127.58 | 5.44 | |
| Cytosine | $C_4H_5N_3O$ | | | | | | 162.3 |
| Decane | $C_{10}H_{22}$ | 174.15 | 39.58 | 51.42 | -29.6 | 28.72 | |
| 1,1-Dichloroethane | $C_2H_4Cl_2$ | 57.3 | 28.85 | 30.62 | -96.9 | 7.87 | |
| 1,2-Dichloroethane | $C_2H_4Cl_2$ | 83.5 | 31.98 | 35.16 | -35.7 | 8.84 | |
| *cis*-Dichloroethylene | $C_2H_2Cl_2$ | 60.1 | 30.2 | | -80.0 | 7.2 | |
| *trans*- Dichloroethylene | $C_2H_2Cl_2$ | 48.7 | 28.9 | | | | |
| Dichloromethane | $CH_2Cl_2$ | 40. | 28.06 | 28.82 | -97.2 | 4.60 | |
| Diethylether | $C_2H_6O$ | 34.5 | 26.52 | 27.10 | -116.2 | 7.19 | |
| Diisopropylether | $C_6H_{14}O$ | 68.4 | 29.10 | 32.12 | -85.4 | 12.04 | |
| Dimethylether | $C_2H_6O$ | -24.8 | 21.51 | 18.51 | -141.5 | 4.94 | |
| Dimethylsulfoxide | $C_2H_6OS$ | 189. | 43.1 | | 17.89 | 14.37 | |
| 1,4-Dioxane | $C_4H_8O_2$ | 101.5 | 34.16 | 38.60 | 11.85 | 12.84 | |
| Dipropylether | $C_6H_{14}O$ | 90.08 | 31.31 | 35.69 | -114.8 | 10.8 | |
| Ethane | $C_6H_6$ | -88.6 | 14.69 | 5.16 | -182.79 | 2.72 | |
| 1,2-Ethanediol | $C_6H_6O_2$ | 197.3 | 50.5 | 63.9 | -12.69 | 9.96 | |
| Ethanol | $C_2H_6O$ | 78.29 | 38.56 | 42.32 | -114.14 | 4.931 | |
| Ethyl acetate | $C_4H_8O_2$ | 77.11 | 31.94 | 35.60 | -83.8 | 10.48 | |
| Ethylbenzene | $C_8H_{10}$ | 136.16 | 35.57 | 42.24 | -94.96 | 9.18 | |
| 2-Ethyl-1-butene | $C_6H_{12}$ | 64.7 | | 31.13 | -132.0 | | |
| Ethylcyclohexane | $C_8H_{16}$ | 131.9 | 34.04 | 40.56 | -111.3 | 8.33 | |
| Ethylene | $C_2H_4$ | -103.77 | 13.53 | | -169.15 | 3.35 | |
| Fluorobenzene | $C_6H_5F$ | 84.73 | 31.19 | 34.58 | -42.18 | 11.31 | |
| Formaldehyde | $CH_2O$ | -19.1 | 23.3 | | -117.0 | | |
| Formamide | $CH_3NO$ | 220 | | 60.15 | 2.49 | 8.44 | |
| Formic acid | $CH_2O_2$ | 101. | 22.69 | 20.10 | 8.3 | 12.68 | |
| Furan | $C_4H_4O$ | 31.5 | 27.10 | 27.45 | -85.61 | 3.80 | |
| Glycerol | $C_3H_8O_3$ | 290 | 61.0 | 91.7(0.9) | 18.1 | 18.3 | |
| Guanine | $C_5H_5N_5O$ | | | | | | 186.2 |
| Heptane | $C_7H_{16}$ | 98.4 | 31.77 | 36.57 | -90.55 | 14.03 | |
| Hexane | $C_6H_{14}$ | 68.73 | 28.85 | 31.56 | -95.35 | 13.08 | |

| Substance | | $T_b$ (°C) | $\Delta_{vap}H°(T_b)$ | $\Delta_{vap}H°$(Ŧ) | $T_m$ (°C) | $\Delta_{fus}H°(T_m)$ | $\Delta_{sub}H°$(Ŧ) |
|---|---|---|---|---|---|---|---|
| 1-Hexanol | $C_6H_{14}O$ | 157.6 | 44.50 | 61.61 | -47.4 | 15.38 | |
| 1-Hexene | $C_6H_{12}$ | 63.48 | 28.3 | 30.61 | -139.76 | 9.35 | |
| Limonene | $C_{10}H_{16}$ | | | 43.9 | | | 48.1 |
| Menthol | $C_{10}H_{20}O$ | 216.5 | | 56.5 | 40.8 | 11.88 | 79. |
| Methane | $CH_4$ | -161.48 | 8.19 | | -182.47 | 0.94 | |
| Methanol | $CH_4O$ | 64.6 | 35.21 | 37.43 | -97.53 | 3.215 | |
| Methyl acetate | $C_3H_6O_2$ | 56.87 | 30.32 | 32.29 | -98.25 | 7.49 | |
| Methylamine | $CH_5N$ | -6.32 | 25.60 | 23.37 | -93.5 | 6.13 | |
| 4-Methylaniline | $C_7H_9N$ | 200.4 | 44.3 | 43.18 | 43.9 | 17.3 | |
| 2-methyl-1,3-butadiene | $C_5H_8$ | 34.1 | 25.8 | 26.8 | -145.9 | 4.9246 | |
| 3-methyl-1,2-butadiene | $C_5H_8$ | 39. | 27.2 | 27.9 | -113.6 | 7.956 | |
| β-Myrcene (l) | $C_{10}H_{16}$ | 167.1 | | 44.6 | | | |
| Naphthalene | $C_{10}H_8$ | 216.9 | 43.2 | | 80.05 | 18.8 | 72.1 |
| Nitromethane | $CH_3NO_2$ | 101.19 | 33.99 | 38.27 | -28.38 | 9.70 | |
| Octane | $C_8H_{18}$ | 125.67 | 34.41 | 41.49 | -56.82 | 20.73 | |
| Oxalic acid | $C_2H_2O_4$ | | | | | | 98.5 |
| *cis*-1,3-Pentadiene | $C_5H_8$ | 44.2 | | | -140.8 | 5.64 | |
| *trans*-1,3-Pentadiene | $C_5H_8$ | 42.0 | | | -87.4 | 7.14 | |
| 1,4-Pentadiene | $C_5H_8$ | 26. | 25.2 | | -148.2 | 6.12 | |
| Pentane | $C_5H_{12}$ | 36.06 | 25.79 | 26.43 | -129.67 | 8.40 | |
| 1-Pentanol | $C_5H_{12}O$ | 137.98 | 44.36 | 57.02 | -77.6 | 10.50 | |
| Phenanthrene | $C_{14}H_{10}$ | 336.1 | 55.7 | 75.50 | 373.81 | 15.720 | 90.900 |
| Phenol | $C_6H_6O$ | 181.87 | 45.69 | 57.82 | 40.89 | 11.51 | 68.6 |
| α-Pinene | $C_{10}H_{16}$ | | | 44.7 | | | |
| β-Pinene | $C_{10}H_{16}$ | | | 46.4 | | | |
| Propane | $C_3H_8$ | -42.1 | 19.04 | 14.79 | -187.63 | 3.50 | |
| 1-Propanol | $C_3H_8O$ | 97.2 | 41.44 | 47.45 | -124.39 | 5.37 | |
| 2-Propanol | $C_3H_8O$ | 82.3 | 39.85 | 45.39 | -87.9 | 5.41 | |
| Propene | $C_3H_6$ | -47.69 | 18.42 | 14.24 | -185.24 | 3.003 | |
| Pyrrole | $C_4H_5N$ | 129.79 | 38.75 | 45.09 | -23.39 | 7.91 | |
| Pyrrolidine | $C_4H_9N$ | 86.56 | 33.01 | 37.52 | -57.79 | 8.58 | |
| Styrene | $C_8H_8$ | 145. | 38.7 | | -30.65 | 10.9 | |
| Toluene | $C_7H_8$ | 110.63 | 33.18 | 38.01 | -94.95 | 6.64 | |
| α-Terpinene | $C_{10}H_{16}$ | 174. | 14.5 | 16.3 | | | |
| α-Terpineol | $C_{10}H_{18}O$ | 217.6 | 48.3 | 52.3 | 35.0 | | 80.1 |
| Tetrafluoromethane | $CF_4$ | -128.1 | 11.814 | | -183.60 | 0.704 | |
| Tetrafluoroethylene | $C_2F_4$ | -76.4 | 16.821 | | -131.15 | 7.72 | |
| Tetrahydrofuran | $C_4H_8O$ | 66. | 29.81 | 31.99 | -108.44 | 8.54 | |
| Thymine | $C_5H_6N_2O_2$ | | | 134.1(4.2) | 48.2 | | 131.3 |
| 2,2,4-Trimethylpentane | $C_8H_{18}$ | 99.22 | 30.79 | 35.14 | -107.3 | 9.20 | |
| 2,4,6-Trinitrotoluene | $C_7H_5N_3O_6$ | | | | 80.5 | 22.9 | 104.7 |
| Uracil | $C_4H_4N_2O_2$ | | | | | | 126.5 |
| Urea | $C_2H_5N$ | | | | 133.3 | 13.9 | 98.6 |
| *o*-Xylene | $C_8H_{10}$ | 144.5 | 36.24 | 43.43 | -25.2 | 13.6 | |
| *m*-Xylene | $C_8H_{10}$ | 139.07 | 35.66 | 42.65 | -47.8 | 11.6 | |
| *p*-Xylene | $C_8H_{10}$ | 138.23 | 35.67 | 42.40 | 13.25 | 17.12 | |

1. J. G. Speight, *Lange's Handbook of Chemistry, 16th Ed.*, McGraw-Hill, New York, NY, 2005.
2. W. M. Haynes, D. R. Lide, Eds., *Handbook of Chemistry and Physics, 92nd Ed.*, CRC Press, Taylor & Francis, Boca Raton, FL.
3. NIST Chemistry Webbook, "webbook.nist.gov/chemistry"

Table 8.4.1: Thermodynamic Properties of Inorganic Substances and Aqueous Inorganic and Organic Solutions at 298.15 K. The standard state is 1 bar or unit activity.[1-14] (*Refs. listed after Table 8.4.3*)

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| *Aluminum* | | | | |
| Al (s) | 0.0 | 0.0 | 28.30 | 24.2 |
| $Al_2O_3$ (α-solid) | -1675.7 | -1582.4 | 50.92 | 79.04 |
| $AlF_3$ (s) | -1510.4 | -1425.1 | 66.5 | 75.10 |
| $AlCl_3$ (s) | -704.2 | -628.8 | 109.3 | 91.1 |
| $Al_2Cl_6$ (g) | -1290.8 | -1220.4 | 490.0 | |
| $Al_2(SO_4)_3$ (s) | -3440.84 | -3100.13 | 239.3 | 259.41 |
| *Antimony* | | | | |
| Sb (solid III) | 0.0 | 0.0 | 45.69 | 25.23 |
| Sb (g) | 262.3 | 222.2 | 180.16 | 20.79 |
| $Sb_4O_6$ (solid II) | -1440.6 | -1268.2 | 220.9 | |
| $Sb_4O_6$ (solid I) | -1417.1 | -1253.1 | 246.0 | 202.76 |
| $Sb_2O_5$(s) | -971.9 | -829.3 | 125.1 | |
| $SbCl_5$ (l) | -440.2 | -350.2 | 301 | |
| $SbCl_3$ (s) | -382.17 | -323.72 | 184.1 | 107.9 |
| SbOCl (s) | -374.0 | | | |
| *Argon* | | | | |
| Ar (g) | 0.0 | 0.0 | 154.7335 | 20.7857 |
| *Arsenic* | | | | |
| As (α-solid, grey) | 0.0 | 0.0 | 35.1 | 24.64 |
| As (g) | 302.5 | 261.0 | 174.2 | 20.786 |
| $As_2$ (g) | 222.2 | 171.9 | 239.4 | 35.0 |
| $As_4$ (g) | 143.9 | 92.5 | 314 | |
| $H_3As$ (g) | 66.44 | 68.91 | 222.8 | 38.07 |
| $As_2O_5$ (s) | -924.9 | -782.3 | 105.4 | 116.52 |
| $As_4O_6$ (monoclinic) | -1309.6 | -1154.03 | 234. | |
| $AsO_3^{2-}$ (ao) | -888.1 | -648.4 | -162.8 | |
| $H_3AsO_3$ (ao) | -742.2 | -639.80 | 195.0 | |
| $H_3AsO_4$ (ao) | -902.5 | -766.0 | 184.0 | |
| $AsCl_3$ (l) | -305.0 | -259.4 | 216.3 | |
| *Barium* | | | | |
| Ba (s) | 0.0 | 0.0 | 62.5 | 28.1 |
| Ba (g) | 180.0 | 146.0 | 170.2 | 20.7861 |
| $Ba^{2+}$ (ao) | -537.64 | -560.77 | 9.6 | |
| BaO (s) | -548.0 | -520.3 | 70.1 | 47.3 |
| $Ba(OH)_2$ (s) | -944.7 | | | |
| $Ba(OH)_2$ (ao) | -998.22 | -875.38 | -8. | |
| $BaCl_2$ (s) | -855.0 | -806.7 | 123.7 | 75.1 |
| $BaCO_3$ (s) | -1213.0 | -1134.4 | 112.1 | 86.0 |
| $Ba(NO_3)_2$ (s) | -988.0 | -792.6 | 214.0 | 151.4 |
| $BaSO_4$ (s) | -1473.2 | -1362.2 | 132.2 | 101.8 |
| $BaCrO_4$ (s) | 1428.0 | | | |
| *Beryllium* | | | | |
| Be (s) | 0.0 | 0.0 | 9.54 | 16.4 |
| Be (g) | 324.0 | 286.6 | 136.3 | 20.79 |
| $Be^{2+}$ (ao) | -382.8 | -379.7 | -129.7 | |
| $BeCl_2$ (s) | -490.4 | -445.6 | 75.8 | 62.4 |
| *Bismuth* | | | | |
| Bi (s) | 0.0 | 0.0 | 56.74 | 25.52 |
| Bi (g) | 207.1 | 168.2 | 187.00 | 20.79 |
| $Bi_2O_3$ (s) | -573.88 | -493.7 | 151.5 | 113.51 |
| $BiCl_3$ (s) | -379.1 | -315.0 | 177.0 | 105.0 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| BiOCl (s) | -366.9 | -322.1 | 120.5 | |
| *Boron* | | | | |
| B (β-solid) | 0.0 | 0.0 | 5.86 | 11.09 |
| B (g) | 565.0 | 521.0 | 153.4 | 20.799 |
| $B_2H_6$ (g) | 36.4 | 87.6 | 232.1 | 56.7 |
| $B_2O_3$ (s) | -1273.5 | -1194.3 | 54.0 | 62.8 |
| $H_3BO_3$ (s) | -1094.33 | -968.9 | 90.0 | 86.1 |
| $[B(OH)_4]^-$ (ao) | -1344.03 | -1153.32 | 102.5 | |
| BN (s) | -254.4 | -228.4 | 14.81 | 19.71 |
| $BF_3$ (g) | -1136.00 | -1119.4 | 254.4 | 50.46 |
| $BCl_3$ (l) | -427.2 | -387.4 | 206.3 | 106.7 |
| $NaBH_4$ (s) | -188.6 | -123.9 | 101.3 | 86.8 |
| *Bromine* | | | | |
| Br (g) | 111.884 | 82.429 | 174.912 | 20.786 |
| $Br_2$ (l) | 0.0 | 0.0 | 152.231 | 75.689 |
| $Br_2$ (g) | 30.9 | 3.1 | 245.5 | 36.0 |
| $Br^-$ (ao) | -121.55 | -103.96 | 82.4 | -141.8 |
| HBr (g) | -36.3 | -53.43 | 198.7 | 29.142 |
| HBrO (ao) | -113.0 | -82.4 | 142.3 | |
| $BrO^-$ (ao) | -94.1 | -33.4 | 42.0 | |
| $BrO_3^-$ (ao) | -67.07 | 18.54 | 161.7 | |
| $BrO_4^-$ (ao) | 13.0 | 118.1 | 199.6 | |
| BrF (g) | -93.85 | -109.16 | 228.86 | 32.97 |
| BrCl (g) | 14.64 | -0.96 | 240.1 | 34.98 |
| *Cadmium* | | | | |
| Cd (γ-solid) | 0.0 | 0.0 | 51.80 | 25.98 |
| Cd (g) | 111.8 | 77.2 | 167.749 | 20.786 |
| $Cd^{2+}$ (ao) | -75.92 | -77.6 | -73.2 | |
| CdO (s) | -258.35 | -228.7 | 54.8 | 43.43 |
| CdS (s) | -161.9 | -156.5 | 64.9 | |
| *Calcium* | | | | |
| Ca (s) | 0.0 | 0.0 | 41.63 | 25.9 |
| Ca (g) | 177.8 | 144.0 | 154. 9 | 20.786 |
| $Ca^{2+}$ (ao) | -542.83 | -553.58 | -53.1 | |
| CaO (s) | -634.9 | -603.3 | 38.1 | 42.0 |
| $Ca(OH)_2$ (s) | -985.2 | -897.5 | 83.4 | 87.5 |
| $CaC_2$ (s) | -62.8 | -67.8 | 70.3 | 62.34 |
| $CaCO_3$ (calcite) | -1207.6 | -1129.1 | 91.7 | 83.5 |
| $CaCO_3$ (aragonite) | -1207.8 | -1128.2 | 88.0 | 82.3 |
| $Ca(NO_3)_2$ (s) | -938.2 | -742.8 | 193.2 | 149.4 |
| $CaSO_4$ (s) | -1434.5 | -1322.0 | 106.5 | 99.7 |
| $CaCl_2$ (s) | -795.4 | -748.8 | 108.4 | 72.9 |
| $CaCl_2 \cdot 6H_20$ (s) | -2607.26 | | | |
| $Ca(NO_3)_2$ (s) | -938.2 | -742.8 | 193.2 | 149.4 |
| $Ca_3(PO_4)_2$ (s) | -4120.79 | -3884.7 | 236.0 | 227.82 |
| *Carbon* | | | | |
| C (graphite) | 0.0 | 0.0 | 5.740 | 8.527 |
| C (diamond) | 1.8966 | 2.8995 | 2.377 | 6.1149 |
| C (g) | 716.68 | 671.3 | 158.100 | 20.79 |
| $CH_4$ (g) | -74.6 | -50.5 | 186.3 | 35.7 |
| $C_2H_2$ (g) | 227.4 | 209.9 | 200.9 | 44.0 |
| CO (g) | -110.525 | -137.152 | 197.7 | 29.117 |
| $CO_2$ (g) | -393.509 | -394.359 | 213.74 | 37.11 |
| $CO_2$ (ao) | -413.26 | -385.97 | 119.36 | |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $CH_3COOH$ (ao) | -485.76 | -396.46 | 178.7 | |
| $CH_3COO^-$ (ao) | -486.01 | -369.31 | 86.6 | -6.3 |
| $H_2CO_3$ (ao) | -699.65 | -623.08 | 187.4 | |
| $HCO_3^-$ (ao) | -691.90 | -586.77 | 91.2 | |
| $CO_3^{2-}$ (ao) | -677.14 | -527.81 | -56.9 | |
| HCOOH (l) | -425.1 | -361.4 | 129.0 | 99.0 |
| HCOOH (ao) | -425.43 | -372.3 | 163.. | -87.9 |
| $HCOO^-$ (ao) | -425.55 | -351.0 | 92.0 | -87.9 |
| $H_2C_2O_4$ (s) | -829.9 | -697.9 | 109.8 | 91.0 |
| $HC_2O_4^-$ (ao) | -818.4 | -698.3 | 149.4 | |
| $C_2O_4^{2-}$ (ao) | -825.1 | -673.9 | 45.6 | |
| HCN (g) | 135.1 | 124.7 | 201.78 | 35.86 |
| HCN (l) | 108.87 | 124.97 | 112.84 | |
| HCN (ao) | 107.11 | 119.66 | 124.7 | |
| $CN^-$ (ao) | 150.6 | 172.4 | 94.1 | |
| $OCN^-$ (ao) | -146.6 | -97.4 | 106.7 | |
| Glycine (s) $C_2H_5NO_2$ | -528.5(5) | -368.6 | 103.5 | 99.2 |
| $^+H_3NCH_2COOH$ (ao) | -517.912 | -384.061 | 190.20 | |
| $^+H_3NCH_2COO^-$ (ao) | -513.988 | -370.647 | 158.32 | |
| $H_2NCH_2COO^-$ (ao) | -469.780 | -314.833 | 119.41 | |
| $CS_2$ (l) | 89.0 | 64.6 | 151.34 | 76.4 |
| $CF_4$ (g) | -933.6 | -889.0 | 261.6 | 61.1 |
| $CCl_4$ (l) | -128.1 | -57.27 | 214.39 | 131.75 |
| *Chlorine* | | | | |
| Cl (g) | 121.679 | 105.696 | 165.088 | 21.841 |
| $Cl_2$ (g) | 0.0 | 0.0 | 222.957 | 33.907 |
| $Cl^-$ (ao) | -167.159 | -131.260 | 56.5 | -136.4 |
| HCl (g) | -92.307 | -95.299 | 186.799 | 29.12 |
| HClO (ao) | -120.9 | -79.9 | 142. | |
| $ClO^-$ (ao) | -107.1 | -36.8 | 42.0 | |
| $HClO_2$ (ao) | -51.9 | 5.9 | 188.3 | |
| $ClO_2^-$ (ao) | -66.5 | 17.2 | 101.3 | |
| $ClO_3^-$ (ao) | -103.97 | -8.03 | 162.3 | |
| $ClO_4^-$ (ao) | -129.33 | -8.62 | 182.0 | |
| ClF (g) | -54.48 | -55.94 | 217.78 | 32.05 |
| $ClF_3$ (g) | -163.2 | -123.0 | 281.50 | 63.85 |
| *Chromium* | | | | |
| Cr (s) | 0.0 | 0.0 | 23.77 | 23.35 |
| Cr (g) | 396.6 | 351.8 | 174.5 | 20.79 |
| $Cr^{2+}$ (ao) | -143.5 | | | |
| $CrO_4^{2-}$ (ao) | -881.15 | -727.75 | 50.21 | |
| $Cr_2O_7^{2-}$ (ao) | -1490.3 | -1301.1 | 261.9 | |
| $CrO_3$ (s) | -589.5 | | | |
| $Cr(OH)_3$ (s) | -1064.0 | | | |
| $[Cr(H_2O)_6]_3^+$ (ao) | -1999.1 | | | |
| *Cobalt* | | | | |
| Co (hexagonal) | 0.0 | 0.0 | 30.04 | 24.81 |
| Co (g) | 424.7 | 380.3 | 179.5 | 23.0 |
| $Co^{3+}$ (ao) | 92.0 | 134.0 | -305.0 | |
| CoO (s) | -237.94 | -214.22 | 52.97 | 55.23 |
| $Co_3O_4$ (s) | -891. | -774. | 102.5 | 123.4 |
| $CoCl_2$ (s) | -312.5 | -269.9 | 109.16 | 78.49 |
| *Copper* | | | | |
| Cu (s) | 0.0 | 0.0 | 33.150 | 24.435 |
| Cu (g) | 338.32 | 298.58 | 166.38 | 20.79 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $Cu^+$ (ao) | 71.67 | 49.98 | 40.6 | |
| $Cu^{2+}$ (ao) | 64.77 | 65.49 | -99.6 | |
| CuO (s) | -157.3 | -129.7 | 42.64 | 42.30 |
| $Cu_2O$ (s) | -168.6 | -146.0 | 93.14 | 63.64 |
| CuS (s) | -53.1 | -53.6 | 66.5 | 47.82 |
| $Cu_2S$ (s) | -79.5 | -86.2 | 120.9 | 76.32 |
| $CuCl_2$ (s) | -220.1 | -175.7 | 108.07 | 71.88 |
| CuCl (s) | -137.2 | -119.87 | 86.2 | 48.5 |
| $Cu(NO_3)_2$ (s) | -302.9 | | | |
| $CuSO_4$ (s) | -771.36 | -661.9 | 109. | 100.0 |
| $CuSO_4 \cdot 5H_2O$ (s) | -2279.65 | -1880.04 | 300.4 | 280. |
| $Cu(NH_3)_4^{2+}$ (ao) | -348.5 | -111.3 | 273.6 | |
| *Deuterium, $^2H$* | | | | |
| $^2H_2$ (g) ($D_2$) | 0 | 0 | 144.96 | 29.19 |
| $^2HH$ (g) (DH) | 0.321 | -1.463 | 143.80 | 29.20 |
| $^2H_2O$ (l) ($D_2O$) | -294.60 | -243.44 | 75.94 | 84.35 |
| $^2H_2O$ (g) ($D_2O$) | -249.20 | -234.54 | 198.33 | 34.25 |
| $^2HHO$ (g) (DHO) | -245.37 | -233.18 | 199.51 | 33.79 |
| $^2HCl$ (g) | -93.35 | -95.94 | 192.63 | 29.17 |
| $^2HF$ (g) | -275.5 | -277.27 | 179.70 | 29.14 |
| *Fluorine* | | | | |
| F (g) | 78.99 | 61.92 | 158.645 | 22.744 |
| $F_2$ (g) | 0.0 | 0.0 | 202.67 | 31.30 |
| $F^-$ (ao) | -332.63 | -278.79 | -13.8 | -106.7 |
| HF (g) | -271.1 | -273.2 | 173.669 | 29.133 |
| HF (ao) | -320.08 | -296.85 | 88.7 | |
| $[FHF]^-$ (ao) | -649.9 | -578.1 | 92.5 | |
| *Helium* | | | | |
| He (g) | 0.0 | 0.0 | 126.0405 | 20.7857 |
| *Hydrogen* | | | | |
| H (g) | 217.965 | 203.263 | 114.604 | 20.7857 |
| $H_2$ (g) | 0.0 | 0.0 | 130.574 | 28.824 |
| *Iodine* | | | | |
| I (g) | 106.838 | 70.283 | 180.682 | 20.786 |
| $I_2$ (s) | 0.0 | 0.0 | 116.135 | 54.438 |
| $I^-$ (ao) | -55.19 | -51.57 | 111.3 | -142.3 |
| $[I_3]^-$ (ao) | -51.5 | -51.5 | 239.3 | |
| HI (g) | 26.48 | 1.72 | 206.485 | 29.158 |
| HIO (ao) | -138.1 | -99.2 | 95.4 | |
| $IO^-$ (ao) | -107.5 | -38.5 | -5.4 | |
| $IO_3^-$ (ao) | -221.3 | -128.0 | 118.4 | |
| $IF_5$ (l) | -864.8 | | | |
| $IF_5$ (g) | -822.5 | -751.7 | 327.7 | 99.2 |
| $ICl_3$ (s) | -89.5 | -22.34 | 167.4 | |
| IBr (s) | -10.5 | | | |
| *Iron* | | | | |
| Fe ($\alpha$-solid) | 0.0 | 0.0 | 27.28 | 25.10 |
| Fe (g) | 416.3 | 370.7 | 180.49 | 25.68 |
| $Fe^{2+}$ (ao) | -89.1 | -78.90 | -137.7 | |
| $Fe^{3+}$ (ao) | -48.5 | -4.7 | -315.9 | |
| FeO (s) | -272.0 | | | 48.12 |
| $Fe_2O_3$ (s,hematite) | -824.2 | -742.2 | 87.40 | 103.85 |
| $Fe_3O_4$ (s,magnetite) | -1118.4 | -1015.5 | 146.4 | 143.43 |
| $Fe(OH)^+$ (ao) | -324.7 | -277.4 | -29.0 | |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | S° (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $Fe(OH)^{2+}$ (ao) | -290.8 | -229.4 | -142. | |
| $Fe(OH)_2$ (s) | -569.0 | -486.6 | 88. | |
| $Fe(OH)_3$ (s) | -823.0 | -696.6 | 106.7 | |
| $FeCl_2$ (s) | -341.79 | -302.34 | 117.95 | 76.65 |
| $FeCl_3$ (s) | -399.49 | -334.05 | 142.3 | 96.65 |
| $FeSO_4$ (s) | -928.4 | -820.9 | 107.5 | 100.58 |
| $FeSO_4 \cdot 7H_2O$ (s) | -3014.57 | -2510.27 | 409.2 | 394.47 |
| $Fe_2(SO_4)_3$ (s) | -2581.5 | | | |
| $K_3[Fe(CN)_6]$ (s) | -173.2 | | | |
| $[Fe(CN)_6]^{3-}$ (ao) | 561.9 | 729.4 | 270.3 | |
| $K_4[Fe(CN)_6]$ (s) | -523.4 | | | |
| $[Fe(CN)_6]^{4-}$ (ao) | 455.6 | 695.1 | 95.0 | |
| $Fe(CNS)^{2+}$ (ao) | 23.4 | 71.1 | -130. | |
| *Lead* | | | | |
| Pb (s) | 0.0 | 0.0 | 64.81 | 26.44 |
| Pb (g) | 195.0 | 161.9 | 175.37 | 20.79 |
| $Pb^{2+}$ (ao) | -1.7 | -24.43 | 10.5 | |
| PbO (yellow) | -217.32 | -187.90 | 68.70 | 45.77 |
| PbO (red) | -218.99 | -188.95 | 66.5 | 45.81 |
| $PbO_2$ (s) | -277.4 | -217.36 | 68.6 | 64.64 |
| $Pb_3O_4$ (s) | -718.4 | -601.2 | 211.3 | 146.9 |
| PbS(s) | -100.4 | -98.7 | 91.2 | 49.50 |
| $PbCl_2$ (s) | -359.41 | -314.13 | 136.0 | |
| $Pb(NO_3)_2$ (s) | -451.97 | | | |
| $PbSO_4$ (s) | -919.94 | -813.20 | 148.57 | 103.207 |
| *Lithium* | | | | |
| Li (s) | 0.0 | 00 | 28.03 | 23.64 |
| Li (g) | 155.10 | 122.13 | 138.633 | 20.7861 |
| $Li^+$ (ao) | -278.49 | -293.31 | 13.4 | 68.6 |
| LiH (s) | -90.5 | -68.3 | 20.0 | 27.9 |
| LiOH (s) | -487.5 | -441.5 | 42.8 | 49.6 |
| LiF (s) | -616.0 | -587.7 | 35.7 | 41.6 |
| LiCl (s) | -408.6 | -384.4 | 59.3 | 48.0 |
| $LiAlH_4$ (s) | -116.3 | -44.7 | 78.7 | 83.2 |
| *Magnesium* | | | | |
| Mg (s) | 0.0 | 0.0 | 32.7 | 24.9 |
| Mg (g) | 147.1 | 112.5 | 148.65 | 20.786 |
| $Mg^{2+}$ (ao) | -466.85 | -454.8 | -138.1 | |
| MgO (s) | -601.6 | -569.3 | 27.0 | 37.2 |
| $Mg(OH)_2$ (s) | -924.66 | -833.75 | 63.14 | 77.03 |
| $Mg_3N_2$ (s) | -461.24 | -406.07 | 104.56 | |
| $MgCl_2$ (s) | -641.83 | -592.33 | 89.5 | 71.30 |
| $MgBr_2$ (s) | -517.6 | | | |
| $MgI_2$ (s) | -359.8 | | | |
| $MgCO_3$ (s) | -1113. | -1029. | 65.7 | 75.52 |
| $Mg(NO_3)_2$ (s) | -789.60 | -588.40 | 164.01 | 142.00 |
| $Mg_3(PO_4)_2$ (s) | -4022.9 | | | |
| $MgSO_4$ (s) | -1284.9 | -1170.6 | 91.6 | 96.5 |
| *Manganese* | | | | |
| Mn ($\alpha$-solid) | 0.0 | 0.0 | 32.01 | 26.32 |
| Mn (g) | 280.7 | 238.5 | 173.7 | 20.8 |
| MnO (s) | -385.22 | -362.92 | 59.71 | 45.44 |
| $MnO_2$ (s) | -520.03 | -465.18 | 53.05 | 54.14 |
| $Mn_2O_3$ (s) | -959.0 | -881.2 | 110.5 | 107.65 |
| $Mn_3O_4$ (s) | -1387.8 | -1283.2 | 155.6 | 139.66 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $Mn(OH)^+$ (ao) | -450.6 | -405.6 | -17.0 | |
| $KMnO_4$ (s) | -837.2 | -737.6 | 171.7 | 117.6 |
| $MnO_4^-$ (ao) | -541.4 | -447.3 | 191.2 | -82.0 |
| $MnO_4^{2-}$ (ao) | -653.0 | -500.7 | 59.0 | |
| *Mercury* | | | | |
| Hg (l) | 0.0 | 0.0 | 76.02 | 27.983 |
| $Hg^{2+}$ (ao) | 171.1 | 164.43 | -32.2 | |
| $Hg_2^{2+}$ (ao) | 172.4 | 153.55 | 84.5 | |
| HgO (red) | -90.84 | -58.555 | 70.29 | 44.06 |
| HgO (yellow) | -90.46 | -58.425 | 71.1 | |
| $HgCl_2$ (s) | -224.3 | -178.7 | 146.0 | |
| $Hg_2Cl_2$ (s) | -265.22 | -210.777 | 192.5 | |
| HgS (red) | -58.2 | -50.6 | 82.4 | 48.41 |
| HgS (black) | -53.6 | -47.7 | 88.3 | |
| *Neon* | | | | |
| Ne (g) | 0.0 | 0.0 | 146.2187 | 20.7857 |
| *Nickel* | | | | |
| Ni (s) | 0.0 | 0.0 | 29.81 | 26.07 |
| Ni (g) | 429.7 | 384.5 | 182.2 | 23.4 |
| $Ni^{2+}$ (ao) | -54.0 | -45.6 | -128.9 | |
| NiO (s) | -239.74 | -211.71 | 37.99 | 44.31 |
| $Ni(OH)^+$ (ao) | -287.9 | -227.6 | -71.0 | |
| NiS (s) | -82.0 | -79.5 | 53.0 | 47.11 |
| $NiCl_2$ (s) | -305.332 | -259.065 | 97.66 | 71.67 |
| $[Ni(NH_3)_6]^{2+}$ (ao) | -630.1 | -256.1 | 394.6 | |
| *Nitrogen* | | | | |
| N (g) | 472.70 | 455.56 | 153.30 | 20.786 |
| $N_2$ (g) | 0.0 | 0.0 | 191.50 | 29.125 |
| $N_3^-$ (ao) | -287.9 | -227.6 | -71.0 | |
| $NH_3$ (g) | -46.11 | -16.49 | 192.34 | 35.06 |
| $NH_3$ (ao) | -80.29 | -26.57 | 111.294 | |
| $NH_4^+$ (ao) | -132.51 | -79.37 | 113.4 | 79.9 |
| $N_2H_4$ (l) | 50.63 | 149.24 | 121.21 | 98.87 |
| $N_2H_5^+$ (ao) | -7.5 | 82.5 | 151.0 | 70.3 |
| NO (g) | 90.25 | 86.57 | 210.652 | 29.844 |
| $NO_2$ (g) | 33.18 | 51.30 | 239.95 | 37.20 |
| $N_2O$ (g) | 82.05 | 104.18 | 219.74 | 38.45 |
| $N_2O_3$ (g) | 83.72 | 139.41 | 312.17 | 65.61 |
| $N_2O_4$ (g) | 9.16 | 97.82 | 304.18 | 77.28 |
| $N_2O_5$ (s) | -43.1 | 113.8 | 178.2 | 143.1 |
| $N_2O_5$ (g) | 11.3 | 115.1 | 355.6 | 84.5 |
| $HNO_3$ (l) | -174.10 | -80.79 | 155.60 | 109.87 |
| $NO_3^-$ (ao) | -207.36 | -111.34 | 146.4 | -86.6 |
| $HNO_2$ (l) | -79.5 | -46.0 | 254.1 | 45.6 |
| $NO_2^-$ (ao) | -104.6 | -32.2 | 123.0 | -97.5 |
| $NH_4NO_3$ (s) | -365.56 | -184.01 | 151.08 | 139.3 |
| $NH_4NO_2$ (s) | -256.5 | | | |
| $NH_4Cl$ (s) | -314.43 | -202.87 | 94.6 | 84.1 |
| $(NH_4)_2SO_4$ (s) | -1180.85 | -901.90 | 220.08 | 187.49 |
| NOCl (g) | 51.71 | 66.07 | 26.58 | 44.69 |
| NOBr (g) | 82.17 | 82.42 | 273.55 | 45.48 |
| $NH_4(CH_3COO)$ (s) | -616.14 | | | |
| *Oxygen* | | | | |
| O (g) | 249.170 | 231.785 | 160.946 | 21.912 |
| $O_2$ (g) | 0.0 | 0.0 | 205.029 | 29.355 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $O_3$ (g) | 142.7 | 163.2 | 238.82 | 39.20 |
| OH (g) | 39.0 | 34.2 | 183.7 | 29.9 |
| $OH^-$ (ao) | -229.994 | -157.293 | -10.75 | -148.5 |
| $HO_2^-$ (ao) | -160.33 | 67.4 | 23.9 | |
| $H_2O$ (l) | -285.830 | -237.178 | 69.92 | 75.291 |
| $H_2O$ (g) | -241.818 | -228.589 | 188.715 | 33.577 |
| $H_2O_2$ (l) | -187.78 | -120.42 | 109.6 | 89.1 |
| $H_2O_2$ (ao) | -191.7 | -134.10 | 143.9 | |
| *Phosphorus* | | | | |
| P (white) | 0.0 | 0.0 | 41.09 | 23.840 |
| P (red) | -17.6 | -12.1 | 22.80 | 21.21 |
| P (black) | -39.3 | | | |
| P (g) | 314.64 | 278.28 | 167.268 | 20.786 |
| $P_4$ (g) | 58.91 | 24.48 | 279.87 | 67.15 |
| $PH_3$ (g) | 5.4 | 13.4 | 210.12 | 37.11 |
| $P_4O_6$ (s) | -1640.1 | | | |
| $P_4O_{10}$ (s) | -2984.0 | -2697.8 | 228.86 | 211.71 |
| $HPO_3$ (s) | -948.5 | | | |
| $H_3PO_2$ (s) | -604.6 | | | |
| $H_3PO_3$ (s) | -964.4 | | | |
| $H_3PO_4$ (s) | -1279.1 | -1119.22 | 110.50 | 106.06 |
| $H_3PO_4$ (l) | -1266.9 | | | |
| $H_3PO_4$ (ao) | -1288.34 | -1142.65 | 158.2 | |
| $H_2PO_4^-$ (ao) | -1302.6 | -1130.39 | 92.5 | |
| $HPO_4^{2-}$ (ao) | -1299.0 | -1089.26 | -33.5 | |
| $PO_4^{3-}$ (ao) | -1277.4 | -1018.8 | -220.5 | |
| $H_4P_2O_7$ (s) | -2241.0 | | | |
| $PF_5$ (g) | -1595.8 | | | |
| $PF_3$ (g) | -918.8 | -897.5 | 273.13 | 58.70 |
| $PCl_5$ (g) | -374.9 | -305.0 | 364.47 | 112.80 |
| $PCl_5$ (s) | -443.5 | | | |
| $PCl_3$ (l) | -319.7 | -272.4 | 217.2 | |
| $PCl_3$ (g) | -287.0 | -267.8 | 311.67 | 71.84 |
| *Potassium* | | | | |
| K (s) | 0.0 | 0.0 | 63.6 | 29.16 |
| K (g) | 90.00 | 61.17 | 160.230 | 20.786 |
| $K^+$ (ao) | -252.38 | -283.27 | 102.5 | 21.8 |
| $KO_2$ (s) | -284.9 | -239.4 | 116.7 | 77.5 |
| $K_2O_2$ (s) | -494.1 | -425.1 | 102.1 | |
| KOH (s) | -424.76 | -379.08 | 78.9 | 64.9 |
| KCl (s) | -576.27 | -537.75 | 66.57 | 49.04 |
| KCl (s) | -435.868 | -408.325 | 82.68 | 51.51 |
| KBr (s) | -392.17 | -379.20 | 96.44 | 53.85 |
| KI (s) | -327.65 | -322.29 | 104.35 | 55.06 |
| $K_2CO_3$ (s) | -1146.12 | | | |
| $KNO_3$ (s) | -494.6 | -394.9 | 133.1 | 96.4 |
| $KNO_2$ (s) | -369.8 | -306.6 | 152.1 | 107.4 |
| $KH_2PO_4$ (s) | -1568.3 | -1415.9 | 134.9 | 116.6 |
| $K_2SO_4$ (s) | -1437.8 | -1321.4 | 175.6 | 131.5 |
| $KMnO_4$ (s) | -837.2 | -737.6 | 171.71 | 117.6 |
| $K_2Cr_2O_7$ (s) | -2061.5 | -1881.8 | 291.2 | 219.24 |
| *Selenium* | | | | |
| Se (black) | 0.0 | 0.0 | 42.442 | 25.363 |
| Se (red) | 6.7 | | | |
| Se (g) | 227.07 | 187.07 | 176.61 | 20.7928 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $H_2Se$ (g) | 29.7 | 15.9 | 218.91 | 34.73 |
| $SeO_2$ (s) | -225.35 | | | |
| $SeO_3$ (s) | -166.9 | | | |
| $H_2SeO_4$ (s) | -530.1 | | | |
| $SeF_6$ (g) | -1117. | -1017. | 313.76 | 110.5 |
| $SeCl_4$ (s) | -183.3 | | | |
| *Silicon* | | | | |
| Si (s) | 0.0 | 0.0 | 18.81 | 20.00 |
| Si (g) | 455.6 | 411.3 | 167.981 | 22.251 |
| $SiH_4$ (g) | 34.3 | 56.9 | 204.6 | 42.84 |
| $SiO_2$ ($\alpha$-quartz) | -910.7 | -856.29 | 41.46 | 44.43 |
| $H_2SiO_4$ (s) | -1481.1 | -1333.0 | 193. | |
| $H_2SiO_3$ (s) | -1188.7 | -1092.4 | 134. | |
| $SiF_4$ (g) | -1614.94 | -1572.68 | 282.38 | 73.64 |
| $SiCl_4$ (l) | -687.0 | -619.90 | 239.7 | 145.31 |
| $SiBr_4$ (l) | -457.3 | -443.9 | 277.8 | |
| SiC (cubic) | -65.3 | -62.8 | 16.61 | 26.86 |
| *Silver* | | | | |
| Ag (s) | 0.0 | 0.0 | 42.55 | 25.351 |
| Ag (g) | 284.9 | 246.01 | 172.997 | 20.79 |
| $Ag^+$ (ao) | 105.6 | 77.1 | 72.7 | 21.8 |
| $Ag_2O$ (s) | -31.05 | -11.21 | 121.3 | 65.86 |
| $Ag_2S$ (orthorhomb) | -32.6 | -40.67 | 140.01 | 76.53 |
| AgCl (s) | -127.068 | -109.805 | 96.2 | 50.80 |
| $[AgCl_2]^-$ (ao) | -245.2 | -215.5 | 231.4 | |
| AgI (s) | -61.84 | -66.19 | 115.5 | 56.82 |
| $AgBrO_3$ (s) | -10.46 | 71.30 | 151.9 | |
| $AgNO_3$ (s) | -129.39 | -33.41 | 140.92 | 93.05 |
| $[Ag(NH_3)_2]^+$ (ao) | -111.29 | -17.24 | 245.2 | |
| *Sodium* | | | | |
| Na (s) | 0.0 | 0.0 | 51.30 | 28.41 |
| Na (g) | 107.5 | 77.0 | 153.718 | 20.7861 |
| $Na^+$ (ao) | -240.12 | -261.905 | 59.0 | 46.4 |
| NaOH (s) | -425.8 | -379.7 | 64.4 | 59.54 |
| $Na_2S$ (s) | -364.8 | -349.8 | 83.7 | |
| NaCl(s) | -411.003 | -384.028 | 72.4 | 50.5 |
| $Na_2CO_3$ (s) | -1130.7 | -1044.4 | 135.0 | 112.3 |
| $NaHCO_3$ (s) | -950.8 | -851.0 | 101.7 | 87.61 |
| $Na_2SO_4$ (s) | -1387.1 | -1270.2 | 149.6 | 128.2 |
| $Na_2S_2O_3$ (s) | -1123.0 | -1028.0 | 155. | 155. |
| $NaClO_4$ (s) | -383.3 | -254.9 | 142.3 | 100.8 |
| $NaCH_3COO$ (s) | -708.8 | -607.2 | 123.0 | 79.9 |
| *Strontium* | | | | |
| Sr (s) | 0.0 | 0.0 | 55.0 | 26.8 |
| Sr (g) | 164.4 | 130.9 | 164.6 | 20.79 |
| $Sr^{2+}$ (ao) | -545.8 | -559.5 | -32.6 | |
| SrO (s) | -592.0 | -561.9 | 54.4 | 45.02 |
| $SrCO_3$ (s) | -1220.1 | -1140.1 | 97.1 | 81.42 |
| $SrCl_2$ (s) | -828.9 | -781.1 | 114.9 | 75.6 |
| *Sulfur* | | | | |
| $S_8$ (rhombic) | 0.0 | 0.0 | 32.054 | 22.64 |
| $S_8$ (monoclinic) | 0.33 | 0.1 | 32.6 | 23.6 |
| S (g) | 277.17 | 236.7 | 167.829 | 23.673 |
| $S_8$ (g) | 102.30 | 49.66 | 430.87 | 156.44 |
| $H_2S$ (g) | -20.63 | -33.4 | 205.8 | 34.23 |

| Substance | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|
| $H_2S$ (ao) | -39.7 | -27.83 | 121. | |
| $HS^-$ (ao) | -17.6 | 12.08 | 62.08 | |
| $S^{2-}$ (ao) | 33.1 | 85.8 | -14.6 | |
| $S_2^{2-}$ (ao) | 30.1 | 79.5 | 28.5 | |
| $SCN^-$ (ao) | 76.4 | 92.7 | 144.3 | -40.2 |
| $SO_2$ (g) | -296.830 | -300.194 | 248.223 | 39.87 |
| $SO_3$ (s) | -454.51 | -374.2 | 70.7 | |
| $SO_3$ (g) | -395.72 | -371.08 | 256.76 | 50.67 |
| $H_2SO_4$ (l) | -813.989 | -690.101 | 156.904 | 138.91 |
| $HSO_4^-$ (ao) | -887.34 | -755.91 | 131.8 | -84.0 |
| $SO_4^{2-}$ (ao) | -909.34 | -744.5 | 20.1 | -293.0 |
| $SO_3^{2-}$ (ao) | -635.5 | -486.5 | -29.0 | |
| $S_2O_3^{2-}$ (ao) | -652.3 | -522.5 | 67.0 | |
| $S_2O_4^{2-}$ (ao) | -753.5 | -600.3 | 92.0 | |
| $S_2O_8^{2-}$ (ao) | -1344.7 | -1114.9 | 244.3 | |
| $SF_6$ (g) | -1220.5 | -1116.5 | 291.5 | 97.0 |
| $SF_4$ (g) | -763.2 | -722.0 | 299.6 | 77.6 |
| $SCl_2$ (l) | -50.21 | | | |
| $S_2Cl_2$ (l) | -59.41 | | | |
| *Tellurium* | | | | |
| Te (s) | 0.0 | 0.0 | 49.71 | 25.73 |
| Te (g) | 196.7 | 157.1 | 182.7 | 20.79 |
| $H_2Te$ (g) | 99.6 | | | |
| $TeO_2$ (s) | -322.6 | -270.3 | 79.5 | |
| *Tin* | | | | |
| Sn (white) | 0.0 | 0.0 | 51.18 | 26.99 |
| Sn (gray) | -2.09 | 0.13 | 44.14 | 25.77 |
| Sn (g) | 301.2 | 266.2 | 168.492 | 21.3 |
| $Sn^{2+}$ (ao) | -8.8 | -27.2 | -16.7 | |
| SnO (tetragonal) | -280.71 | -251.91 | 57.17 | 44.31 |
| $SnO_2$ (tetragonal) | -577.63 | -515.83 | 49.04 | 52.59 |
| $SnCl_4$ (l) | -511.3 | -440.1 | 258.6 | 165.3 |
| *Uranium* | | | | |
| U (s) | 0.0 | 0.0 | 50.20 | 27.49 |
| U (g) | 533. | 488. | 199.79 | |
| $U^{3+}$ (ao) | -489.1 | -476.2 | -188.0 | |
| $UO_2$ (s) | -1085. | -1031.8 | 77.03 | |
| $UO_3$ (s,gamma) | -1223.8. | -1145.7 | 96.11 | |
| $UF_6$ (g) | -2147.4. | -2063.7 | 377.9 | 129.6 |
| *Xenon* | | | | |
| Xe (g) | 0.0 | 0.0 | 169.685 | 20.7857 |
| $XeF_4$ (s) | -261.5 | | | |
| *Zinc* | | | | |
| Zn (s) | 0.0 | 0.0 | 41.63 | 25.40 |
| Zn (g) | 130.73 | 95.14 | 160.98 | 20.79 |
| $Zn^{2+}$ (ao) | -153.89 | -147.06 | -112.1 | 46. |
| ZnO (s) | -350.46 | -320.45 | 43.5 | 40.25 |
| $Zn(OH)_2$ (s) | -641.9 | -553.5 | 81.2 | |
| ZnS (s,wurtzite) | -192.63 | | | |
| ZnS (s,sphalerite) | -205.98 | -201.29 | 57.7 | 46.0 |
| $ZnCl_2$ (s) | -415.05 | -369.430 | 111.46 | 71.34 |
| $ZnCO_3$ (s) | -812.8 | -731.5 | 82.4 | 79.4 |
| $ZnSO_4$ (s) | -982.822 | -871.5 | 110.5 | 99.2 |

(ai) = aqueous standard state, completely dissociated. (ao) = aqueous standard state, undissociated

For example: $\Delta_f H°(CH3COOH)$ (ai) = $\Delta_f H°(CH3COO^-)$ (ao) and $\Delta_f H°(C_2O_2H_2)$ (ai) = $\Delta_f H°(C_2O_2^{2-})$ (ao)

Table 8.4.2: Thermodynamic Properties of Organic Substances at 298.15 K. The standard state is 1 bar and unit activity.

| Substance | Formula | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | $S°$ (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|---|
| Acetaldehyde (l) | $C_2H_4O$ | -191.8(5) | -128.3 | 160.4 | 274.7 |
| Acetaldehyde (g) | $C_2H_4O$ | -166.19 | -128.86 | 250.3 | 57.3 |
| Acetic acid (l) | $C_2H_4O_2$ | -484.4(3) | -390.2 | 159.9 | 124.4 |
| Acetic acid (ai) (aq) | $C_2H_4O_2$ | -486.34 | -369.65 | 86.7 | -6.3 |
| Acetic anhydride (l) | $C_4H_7O_3$ | -624.4(9) | -489.14 | 268.8 | |
| Acetone (l) | $C_2H_6O$ | -242.1(17) | -155.8 | 200.6 | 126.5 |
| Acetonitrile (l) ($CH_3CN$) | $C_2H_3N$ | 31.4(72) | 99.2 | 149.7 | 91.5 |
| Acetonitrile (g) | $C_2H_3N$ | 65.23 | 82.58 | 245.12 | 52.22 |
| Acetophenone (l) | $C_7H_6O$ | -142.5(10) | -17.0 | 249.6 | |
| Acetyl chloride (l) | $C_2H_3OCl$ | -272.9(7) | -208.2 | 201.0 | 117. |
| Acetylene (g) | $C_2H_2$ | 226.73 | 209.20 | 200.94 | 43.93 |
| Adenine (s) | $C_5H_5N_5$ | 96.0(9) | 299.6 | 151.1 | 147.0 |
| *L*-Alanine (s) | $C_3H_7NO_2$ | -560. | -367. | 129.21 | |
| Anthracene (s) | $C_{14}H_{10}$ | 129.2(18) | 286.0 | 207.6 | 208.1 |
| *D*-Arginine (s) | $C_6H_8N_4O_2$ | -623.5(13) | -240.5 | 250.8 | |
| *L*-(+)-Ascorbic acid (s) | $C_6H_8O_6$ | -1164.6(10) | | | |
| *L*-(+)-Asparagine (s) | $C_4H_8N_2O_3$ | -789.4(8) | -530.6 | 174.6 | |
| *L*-(+)-Aspartic acid (s) | $C_4H_7NO_4$ | -973.3(8) | -730.7 | 170.2 | |
| Azulene (g) | $C_{10}H_8$ | 289.1(34) | 353.4 | 338.1 | 128.5 |
| Benzaldehyde (l) | $C_7H_6O$ | -87.0 | 6.5 | 221.2 | 172.0 |
| Benzene (l) | $C_6H_6$ | 49.0(6) | 124.4 | 173.4 | 81.7 |
| Benzene (g) | $C_6H_6$ | 82.6(7) | 129.7 | 269.2 | |
| Benzoic acid (s) | $C_7H_6O_2$ | -385.2(5) | -245.3 | 167.6 | 146.3 |
| Benzonitrile (g) | $C_7H_5N$ | 45.8(21) | 260.8 | 321.0 | 109.1 |
| Benzophenone (s) | $C_{13}H_{10}O$ | -34.5(21) | 140.2 | 245.2 | |
| Benzyl alcohol (l) | $C_6H_6O$ | -160.7(12) | -27.5 | 216.7 | 218.0 |
| Biphenyl (s) | $C_{12}H_{10}$ | 99.4(18) | 254.2 | 205.9 | 162.3 |
| Bromobenzene (l) | $C_6H_5Br$ | 60.9(41) | 126.6 | 217.6 | 155.5 |
| 1-Bromobutane (g) | $C_4H_9Br$ | -107.1(13) | -12.9 | 369.8 | 109.3 |
| 2-Bromobutane (g) | $C_4H_9Br$ | -120.3(12) | -25.8 | 370.3 | 110.8 |
| Bromoethane (l) | $C_2H_5Br$ | -90.1(28) | -27.8 | 198.7 | 100.8 |
| Bromoethylene (g) | $C_2H_3Br$ | 79.2(91) | 80.75 | 275.4 | 55.4 |
| Bromomethane (g) | $CH_4Br$ | -35.5(11) | -28.24 | 245.8 | 42.5 |
| 1-Bromopentane (g) | $C_5H_{11}Br$ | -129.0(15) | -5.7 | 408.8 | 132.2 |
| 1-Bromopropane (g) | $C_3H_7Br$ | -87.0(33) | -22.5 | 330.9 | 86.4 |
| 2-Bromopropane (g) | $C_3H_7Br$ | -99.4 | -27.2 | 316.2 | 89.4 |
| Bromotrifluoromethane (g) | $CBrF_3$ | -648.9(29) | -622.6 | 297.8(5) | 69.3 |
| 1,3-Butadiene (g) | $C_4H_6$ | 108.8(11) | 150.7 | 278.7 | 79.5 |
| Butane (g) | $C_4H_{10}$ | -125.6(7) | -17.2 | 310.1 | 97.5 |
| Butanenitrile (g) | $C_5H_8N$ | 33.6(10) | 108.7 | 325.4 | 97.0 |
| Butanoic acid (l) | $C_4H_8O_2$ | -533.8(6) | -377.7 | 226.4 | 176.2 |
| 1-Butanol (l) | $C_4H_{10}O$ | -327.3(4) | -162.5 | 226.4 | 177.0 |
| 1-Butanol (g) | $C_4H_{10}O$ | -275.0(4) | -150.8 | 362.8 | 122.6 |
| 1-Butene (g) | $C_4H_8$ | 0.1(10) | 71.3 | 305.6 | 85.7 |
| *cis*-2-Butene (g) | $C_4H_8$ | -7.1(10) | 65.9 | 300.8 | 78.9 |
| *trans*-2-Butene (g) | $C_4H_8$ | -11.4(10) | 63.0 | 296.5 | 87.8 |
| 1-Butyne (g) | $C_4H_6$ | 165.2(9) | 202.1 | 290.8 | 81.4 |
| 2-Butyne (g) | $C_4H_6$ | 145.7(12) | 185.4 | 283.3 | 78.0 |
| Camphene (s) | $C_{10}H_{16}$ | -76.23 | | | |
| Camphor (s) | $C_{10}H_{16}O$ | -319.4 | | | 271.2 |
| Carbon tetrachloride (l) | $CCl_4$ | -135.44 | -65.56 | 216.40 | 131.75 |
| Chlorobenzene (l) | $C_6H_5Cl$ | 11.0(13) | 89.2 | 209.2 | 150.2 |

| Substance | Formula | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | S° (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|---|
| 1-Chlorobutane (g) | $C_3H_7Cl$ | -154.6(12) | -38.8 | 358.1 | 107.6 |
| (±)-2-Chlorobutane (g) | $C_3H_7Cl$ | -161.2(84) | -53.5 | 359.6 | 108.5 |
| Chlorofluoromethane (g) | $CH_2ClF$ | -482.6(32) | -450.0 | 281.0(8) | 57.1 |
| Chloroethylene (g) | $C_2H_3Cl$ | 37.2 | 53.6 | 264.0 | 53.7 |
| Chloroethyne (g) | $C_2HCl$ | 213.0 | 197.0 | 241.9 | 54.3 |
| Chloroform (l) | $CHCl_3$ | -134.47 | -73.72 | 201.7 | 113.8 |
| Chloromethane (g) | $CH_3Cl$ | -80.83 | -57.40 | 234.47 | 40.75 |
| Cyclobutane (g) | $C_4H_8$ | 27.7 | 110.0 | 265.4 | 72.2 |
| Cyclobutene (g) | $C_4H_6$ | 156.7 | 174.7 | 263.5 | 67.1 |
| Cyclohexane (l) | $C_6H_{12}$ | -156.4 | 26.7 | 204.4 | 154.9 |
| Cyclohexanol (l) | $C_6H_{12}O$ | -348.1 | -133.3 | 199.6 | 208.2 |
| Cyclohexene (l) | $C_6H_{10}$ | -38.5 | 101.6 | 214.6 | 148.3 |
| Cyclopentane (l) | $C_5H_{10}$ | -105.1(13) | 36.4 | 204.3 | 128.9 |
| Cyclopentane (g) | $C_5H_{10}$ | -76.4(8) | 38.6 | 292.9 | 83.0 |
| Cyclopentene (l) | $C_5H_8$ | 4.2(8) | 108.5 | 201.3 | 122.3 |
| Cyclopentene (g) | $C_5H_8$ | 34.3(32) | 110.8 | 291.8 | 75.1 |
| Cyclopropane (g) | $C_3H_6$ | 53.3(6) | 104.4 | 237.4 | 55.9 |
| Cyclopropene (g) | $C_3H_4$ | 277.1(25) | 286.3 | 223.5 | |
| *L*-Cysteine (s) | $C_3H_7NO_2S$ | -534.1 | | | |
| (-)-Cystine (s) | $C_6H_{12}N_2O_4S_2$ | -1032.7(38) | | | |
| Cytosine (s) | $C_4H_5N_3O$ | -221.3 | | | 132.6 |
| Decane (l) | $C_{10}H_{22}$ | -300.9 | 17.5 | 425.5 | 314.4 |
| 1,1-Dichloroethane (g) | $C_2H_4Cl_2$ | -127.7 | -70.8 | 305.1 | 76.2 |
| 1,2-Dichloroethane (g) | $C_2H_4Cl_2$ | -126.4 | -70.5 | 308.4 | 78.7 |
| *cis*-Dichloroethylene (l) | $C_2H_2Cl_2$ | -27.6 | 22.05 | 198.41 | 113. |
| *trans*- Dichloroethylene (l) | $C_2H_2Cl_2$ | -23.14 | 27.28 | 195.85 | 113. |
| Dichloromethane (l) | $CH_2Cl_2$ | -121.46 | -67.32 | 177.8 | 100.0 |
| Diethylether (l) | $C_2H_6O$ | -279.3(8) | -116.7 | 253.1 | 170.7 |
| Diethylether (g) | $C_2H_6O$ | -252.1(18) | -122.3 | 342.7 | 112.5 |
| Diisopropylether (g) | $C_6H_{14}O$ | -319.2(16) | -121.9 | 390.2 | 158.3 |
| Dimethylether (g) | $C_2H_6O$ | -184.1(14) | -112.9 | 267.1 | 65.8 |
| Dimethylsulfoxide (l) | $C_2H_6OS$ | -204.2(7) | -99.2 | 188.3 | 147.3 |
| 1,4-Dioxane (l) | $C_4H_8O_2$ | -353.9 | -188.1 | 270.2 | 152.1 |
| 1,4-Dioxane (g) | $C_4H_8O_2$ | -315.8(8) | -180.8 | 299.8 | 94.1 |
| Dipropylether (g) | $C_6H_{14}O$ | -292.9(11) | -105.6 | 422.5 | 158.3 |
| Ethane (g) | $C_2H_6$ | -84.68 | -32.89 | 229.49 | 52.63 |
| 1,2-Ethanediol (l) | $C_2H_6O_2$ | -455.3(7) | -323.2 | 166.9 | 149.8 |
| 1,2-Ethanediol (g) | $C_2H_6O_2$ | -387.5(18) | -304.5 | 323.6 | 97.1 |
| Ethanol (l) | $C_2H_6O$ | -277.0 | -174.2 | 161.0 | 112.0 |
| Ethanol (g) | $C_2H_6O$ | -235.2(4) | -167.9 | 282.6 | 65.4 |
| Ethyl acetate (l) | $C_4H_8O_2$ | -473.3(5) | -332.7 | 259.4 | 169.9 |
| Ethyl acetate (g) | $C_4H_8O_2$ | -444.1(6) | -327.4 | 362.8 | 113.6 |
| Ethylbenzene (g) | $C_8H_{10}$ | 29.9(11) | 130.6 | 360.5 | 128.4 |
| 2-Ethyl-1-butene (g) | $C_6H_{12}$ | -56.0(15) | 80.0 | 376.6 | 133.6 |
| Ethylcyclohexane (l) | $C_8H_{16}$ | -211.9(16) | 29.1 | 280.9 | 209.2 |
| Ethylcyclohexane (g) | $C_8H_{16}$ | -171.7(16) | 39.3 | 382.6 | 158.8 |
| Ethylene (g) | $C_2H_4$ | 52.26 | 68.15 | 219.56 | 43.56 |
| Ethylene oxide (g) | $C_2H_4O$ | -52.6(6) | -13.1 | 242.4 | 48.3 |
| Ethylmethylether (g) | $C_3H_8O$ | -216.4(7) | -117.7 | 310.6 | 89.8 |
| Ethynylbenzene (g) | $C_8H_6$ | 327.3 | 361.8 | 321.7 | 114.9 |
| Fluorobenzene (g) | $C_6H_5F$ | -116.0(14) | -69.0 | 302.6 | 94.4 |
| Fluoroethane (g) | $C_2H_5F$ | -263.2 | -211.0 | 265.0 | 59.5 |
| Fluoromethane (g) | $CH_3F$ | -237.8 | -213.8 | 222.8 | 37.5 |
| 1-Fluoropropane (g) | $C_3H_7F$ | -285.9(23) | -200.3 | 304.2 | 82.6 |
| 2-Fluoropropane (g) | $C_3H_7F$ | -293.5(15) | -204.2 | 292.1 | 82.0 |

| Substance | Formula | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | S° (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|---|
| Formaldehyde (g) | $CH_2O$ | -108.6(5) | -109.9 | 218.8 | 35.4 |
| Formamide (g) | $CH_3NO$ | -193.9 | -141.0 | 248.6 | 45.4 |
| Formic acid (l) | $CH_2O_2$ | -425.1(4) | -361.4 | 129.0 | 99.0 |
| Formic acid (g) | $CH_2O_2$ | -378.7(6) | -351.0 | 248.7 | 45.2 |
| *D*-(-)-Fructose (s) | $C_6H_{12}O_6$ | -1265.6(5) | | | |
| *D*-(+)-Fucose (s) | $C_6H_{12}O_5$ | -1099.1 | | | |
| Fumaric acid (s) | $C_4H_4O_4$ | -811.7(8) | -655.6 | 166.1 | |
| Furan (g) | $C_4H_4O$ | -34.9(7) | 0.88 | 267.2 | 65.4 |
| 2-Furanmethanol (l) | $C_5H_6O_2$ | -276.2(13) | -154.2 | 215.5 | 206.1 |
| *D*-(+)-Galactose (s) | $C_6H_{12}O_6$ | -1286.3(5) | -918.8 | 205.4 | |
| *D*-gluconic acid (s) | $C_6H_{12}O_7$ | -1587.0 | | | |
| *D*-(+)-Glucose (s) | $C_6H_{12}O_6$ | -1273.3(11) | -910.4 | 212.1 | |
| *D*-(-)-Glucose (s) | $C_6H_{12}O_6$ | -1268. | -910. | 212. | |
| *D*-(-)-Glutamic acid (s) | $C_5H_9NO_4$ | -1009.7(8) | -727.5 | 191.2 | |
| *L*-(+)-Glutamic acid (s) | $C_5H_9NO_4$ | -1005.2(12) | -731.3 | 188.2 | |
| *L*-Glutamine (s) | $C_5H_{10}N_2O_3$ | -826.4(7) | | | |
| Glycerol (l) | $C_3H_8O_3$ | -669.6 | -478.4 | 206.3 | 218.9 |
| Glycine (s) | $C_2H_5NO_2$ | -528.5(5) | -368.6 | 103.5 | 99.2 |
| $^{+}H_3NCH_2COOH$ (ao) | $C_2H_6NO_2^{+}$ | -517.912 | -384.061 | 190.20 | |
| $^{+}H_3NCH_2COO^{-}$ (ao) | $C_2H_5NO_2$ | -513.988 | -370.647 | 158.32 | |
| $H_2NCH_2COO^{-}$ (ao) | $C_2H_4NO_2^{-}$ | -469.780 | -314.833 | 119.41 | |
| Glycylglycine (s) | $C_6H_{14}O_5$ | -747.7(6) | -490.6 | 190.0 | |
| Guanidine (s) | $CH_5N_3$ | -56.0 | | | |
| Guanine (s) | $C_5H_5N_5O$ | -182.9 | 47.4 | 160.3 | |
| Heptane (l) | $C_7H_{16}$ | -224.2 | 1.0 | 328.6 | 224.7 |
| Heptane (g) | $C_7H_{16}$ | -187.7 | 8.0 | 427.9 | 166.0 |
| Hexane (l) | $C_6H_{14}$ | -198.8 | -3.8 | 296.1 | 189.1 |
| Hexane (g) | $C_6H_{14}$ | -167.1(8) | -0.25 | 388.4 | 143.1 |
| 1-Hexanol (l) | $C_6H_{14}O$ | -377.5(5) | -152.3 | 28.5 | 236.8 |
| 1-Hexanol (g) | $C_6H_{14}O$ | -317.6 | -135.6 | 441.1 | 155.6 |
| 1-Hexene (l) | $C_6H_{12}$ | -74.1(16) | 83.6 | 295.1 | 183.3 |
| 1-Hexene (g) | $C_6H_{12}$ | -43.5(16) | 84.45 | 384.6 | 132.2 |
| *L*-Histidine (s) | $C_6H_9N_3O_2$ | -466.7 | | | |
| Hydrazine (l) | $N_2H_4$ | 50.6 | 149.2 | 121.2 | 98.9 |
| *L*-Isoleucine (s) | $C_6H_{13}NO_2$ | -637.9(9) | -347.2 | 208.0 | 188.3 |
| Ketene (g) | $C_2H_2O$ | -47.5(16) | -60.3 | 241.8 | 51.8 |
| (+)-Lactic acid (s) | $C_3H_6O_3$ | -694.1 | -522.9 | 142.3 | |
| (β)-Lactose (s) | $C_{12}H_{22}O_{11}$ | -2236.7(8) | -1567.0 | 386.2 | |
| L-Leucine (s) | $C_6H_{13}NO_2$ | -646.8 | -356.7 | 211.79 | 190.6 |
| Limonene (l) | $C_{10}H_{16}$ | -54.5 | | | 249.0 |
| (*DL*)-Lysine (s) | $C_6H_{14}N_2O_2$ | -678.7 | | | |
| Menthol (s) | $C_{10}H_{20}O$ | -480.57 | | | |
| Methane (g) | $CH_4$ | -74.81 | -50.75 | 186.155 | 35.309 |
| Methanol (l) | $CH_4O$ | -238.66 | -166.36 | 126.8 | 81.6 |
| Methanol (g) | $CH_4O$ | -201.0 | -162.3 | 239.9 | 44.1 |
| *L*-Methionine (s) | $C_5H_{11}NO_2S$ | -577.5 | | | |
| Methyl acetate (g) | $C_3H_6O_2$ | -413.3 | -326.8 | 324.4 | 86.0 |
| Methylamine (l) | $CH_5N$ | -47.3 | 35.6 | 150.21 | |
| Methylamine (g) | $CH_5N$ | -22.97 | 32.16 | 243.41 | 53.1 |
| 4-Methylaniline (g) | $C_7H_9N$ | 55.3 | 167.7 | 347.0 | 126.2 |
| 2-methyl-1,3-butadiene (l) | $C_5H_8$ | 48.2 | 144.2 | 229.3 | 156.7 |
| 2-methyl-1,3-butadiene (g) | $C_5H_8$ | 75.5 | 145.9 | 315.6 | 104.6 |
| 3-methyl-1,2-butadiene (g) | $C_5H_8$ | 129.7 | 198.6 | 319.7 | 105.4 |
| methylisocyanate (l) | $C_2H_3N$ | 117.2 | 159.5 | 159. | |
| methylisocyanate (g) | $C_2H_3N$ | 149.0 | 165.7 | 246.92 | 52.93 |

| Substance | Formula | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | S° (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|---|
| β-Myrcene (l) | $C_{10}H_{16}$ | 14.5 | | | |
| Naphthalene (s) | $C_{10}H_8$ | 78.5 | 201.6 | 167.4 | 165.7 |
| Naphthalene (g) | $C_{10}H_8$ | 150.6 | 224.1 | 333.1 | 131.9 |
| Nitroethane (g) | $C_2H_5NO_2$ | -102.3 | -4.9 | 315.4 | 78.2 |
| Nitromethane (l) | $CH_3NO_2$ | -112.6 | -14.4 | 171.8 | 106.6 |
| Nitromethane (g) | $CH_3NO_2$ | -80.8 | -15.3 | 282.9 | 55.5 |
| Octane (l) | $C_8H_{18}$ | -250.1 | 6.2 | 361.1 | |
| Octane (g) | $C_8H_{18}$ | -208.6 | 16.4 | 466.7 | 188.9 |
| Oxalic acid (s) | $C_2H_2O_4$ | -829.9 | -697.9 | 109.8 | 91.0 |
| Oxalic acid (g) | $C_2H_2O_4$ | -731.8 | -662.7 | 320.6 | 86.2 |
| *cis*-1,3-Pentadiene (g) | $C_5H_8$ | 81.5 | 145.8 | 324.3 | 94.6 |
| *trans*-1,3-Pentadiene (g) | $C_5H_8$ | 76.5 | 146.73 | 319.7 | 103.3 |
| 1,4-Pentadiene (g) | $C_5H_8$ | 105.7 | 170.3 | 333.5 | 105.0 |
| Pentane (l) | $C_5H_{12}$ | -173.5 | -9.3 | 260.4 | 164.8 |
| Pentane (g) | $C_5H_{12}$ | -146.9 | -8.4 | 349.0 | 120.2 |
| 1-Pentanol (g) | $C_5H_{12}O$ | -294.7 | -146.0 | 402.5 | 133.1 |
| Phenanthrene (s) | $C_{14}H_{10}$ | 110.1 | 264.8 | 215.1 | 220.6 |
| Phenol (s) | $C_6H_6O$ | -165.0 | -50.9 | 146.0 | |
| *L*-Phenylalanine (s) | $C_9H_{11}NO_2$ | -466.9 | -211.2 | 213.6 | 203.0 |
| α-Pinene (l) | $C_{10}H_{16}$ | -16.4 | | | |
| α-Pinene (g) | $C_{10}H_{16}$ | 28.3 | | | |
| β-Pinene (l) | $C_{10}H_{16}$ | -7.70 | | | |
| β-Pinene (g) | $C_{10}H_{16}$ | 38.7 | | | |
| *L*-Proline (s) | $C_5H_9NO_2$ | -515.2 | | | |
| Propane (g) | $C_3H_8$ | -103.8 | -23.4 | 270.3 | 73.6 |
| 1-Propanol (g) | $C_3H_8O$ | -255.1 | -161.8 | 322.6 | 85.6 |
| 2-Propanol (l) | $C_3H_8O$ | -318.1 | -180.3 | 181.1 | 155.0 |
| 2-Propanol (g) | $C_3H_8O$ | -272.6 | -173.4 | 309.2 | 89.3 |
| Propyne (g) | $C_3H_4$ | 184.9 | 194.4 | 248.1 | 60.7 |
| Pyrrole (l) | $C_4H_5N$ | 63.1 | 149.3 | 156.4 | 127.7 |
| Pyrrolidine (l) | $C_4H_9N$ | -41.0 | 108.9 | 204.1 | 156.6 |
| Pyrrolidine (g) | $C_4H_9N$ | -3.6 | 114.7 | 309.5 | 81.1 |
| *L*-serine (s) | $C_3H_7NO_3$ | -732.7 | | | |
| Styrene (l) | $C_8H_8$ | 103.8 | 202.4 | 237.6 | 182.0 |
| Styrene (g) | $C_8H_8$ | 147.9 | 213.8 | 345.1 | |
| Sucrose (s) | $C_{12}H_{22}O_{11}$ | -2222. | -1543. | 360.2 | |
| Toluene (l) | $C_7H_8$ | 50.0 | 122.0 | 320.7 | 103.6 |
| α-Terpinene (g) | $C_{10}H_{16}$ | -20.6 | | | |
| α-Terpineol (l) | $C_{10}H_{18}O$ | -359.2 | | | |
| Tetrafluoromethane (g) | $CF_4$ | -925. | -879. | 261.50 | 61.1 |
| Tetrafluoroethylene (l) | $C_2F_4$ | -658.9 | -623.7 | 300.1 | 80.5 |
| Tetrahydrofuran (l) | $C_4H_8O$ | -216.2 | -83.8 | 204.3 | 124.0 |
| Tetrahydrofuran (g) | $C_4H_8O$ | -184.2 | -81.1 | 302.4 | 76.3 |
| *L*-Threonine (s) | $C_4H_9NO_3$ | -807.2 | | | |
| Thymine (l) | $C_5H_6N_2O_2$ | -462.8 | | | 150.8 |
| 2,2,4-Trimethylpentane (l) | $C_8H_{18}$ | -259.2 | 6.9 | 328.0 | 239.1 |
| 2,2,4-Trimethylpentane (g) | $C_8H_{18}$ | -224.0 | 13.7 | 423.2 | |
| 2,4,6-Trinitrotoluene (s) | $C_7H_5N_3O_6$ | -63.2 | | | 243.3 |
| *L*-Tryptophan (s) | $C_{11}H_{12}N_2O_2$ | -415.2 | -119.4 | 251.0 | 238.2 |
| *L*-Tyrosine (s) | $C_9H_{11}NO_3$ | -685.1 | -398.9 | 214.0 | 216.4 |
| Uracil (s) | $C_4H_4N_2O_2$ | -429.4 | | | 120.5 |
| Urea (s) | $CH_4N_2O$ | -333.1 | -196.8 | 104.6 | 93.1 |
| Uric acid (s) | $C_5H_4N_4O_3$ | -618.8 | -358.8 | 173.2 | 166.1 |
| (*DL*)-Valine (s) | $C_5H_{11}NO_2$ | -628.9 | -359.0 | 178.9 | 168.8 |

| Substance | Formula | $\Delta_f H°$ (kJ mol$^{-1}$) | $\Delta_f G°$ (kJ mol$^{-1}$) | S° (J K$^{-1}$ mol$^{-1}$) | $C_p°$ (J K$^{-1}$ mol$^{-1}$) |
|---|---|---|---|---|---|
| *L*-valine (s) | $C_5H_{11}NO_2$ | -617.9 | | | |
| *o*-Xylene (g) | $C_8H_{10}$ | 19.1 | 122.1 | 352.8 | 133.3 |
| *m*-Xylene (g) | $C_8H_{10}$ | 17.3 | 118.9 | 357.7 | 127.6 |
| *p*-Xylene (g) | $C_8H_{10}$ | 18.0 | 121.1 | 352.4 | 126.9 |

Table 8.4.3: Enthalpies of Combustion at 298.15 K. The standard state is 1 bar and unit activity.[*13-18]

| Substance | Formula | $\Delta_{comb}H°$ (kJ mol$^{-1}$) |
|---|---|---|
| Ammonia (g) | $NH_3$ | -382.8 |
| Carbon (graph) | C | -393.509 |
| Carbon monoxide (g) | CO | -283.0 |
| Acetaldehyde (l) | $C_2H_4O$ | -1166.9 |
| Acetic acid (l) | $C_2H_4O_2$ | -874.2 |
| Acetone (l) | $C_2H_6O$ | -1789.9 |
| Acetonitrile (l) | $C_2H_3N$ | -1247.2 |
| Acetophenone (l) | $C_7H_6O$ | -4148.9 ± 0.88 |
| Acetylene (g) | $C_2H_2$ | -1301.1 |
| Adenine (s) | $C_5H_5N_5$ | -2779.0 ± 1.3 |
| *L*-Alanine (s) | $C_3H_7NO_2$ | -1621. ± 1.7 |
| Anthracene (s) | $C_{14}H_{10}$ | -7061. ± 10. |
| *D*-Arginine | $C_6H_{14}N_4O_2$ | -3738.3 ± 1.3 |
| *L*-(+)-Ascorbic acid (s) | $C_6H_8O_6$ | -2344.1 ± 0.9 |
| *L*-(+)-Asparagine (s) | $C_4H_8N_2O_3$ | -1928.5 ± 0.71 |
| *L*-(+)-Aspartic acid (s) | $C_4H_7NO_4$ | -1601.1 ± 0.79 |
| Azulene (l) | $C_{10}H_8$ | -5293. ± 3. |
| Benzene (l) | $C_6H_6$ | -3267.6 |
| Benzoic acid (s) | $C_7H_6O_2$ | -3228.2 |
| Benzophenone (s) | $C_{13}H_{10}O$ | -6508. ± 10. |
| Benzyl alcohol (l) | $C_6H_6O$ | -3743.0 ± 2.8 |
| Biphenyl (s) | $C_{12}H_{10}$ | -6250. ± 20. |
| Borneol (s) | $C_{10}H_{18}O$ | -6231.2 |
| 1,3-Butadiene (g) | $C_4H_6$ | -2541.5 |
| Butane (g) | $C_4H_{10}$ | -2877.6 |
| Butanoic acid (l) | $C_4H_8O_2$ | -2183.5 ± 0.59 |
| 1-Butanol (l) | $C_4H_{10}O$ | -2670. ± 20. |
| 1-Butene (g) | $C_4H_8$ | -2717. |
| *cis*-2-Butene (g) | $C_4H_8$ | -2710. |
| *trans*-2-Butene (g) | $C_4H_8$ | -2707. |
| Camphene (s) | $C_{10}H_{16}$ | -6146. ± 2. |
| Camphor (s) | $C_{10}H_{16}O$ | -5902. ± 3. |
| Cyclobutane (g) | $C_4H_8$ | -2720.4 ± 0.5 |
| Cyclobutene (g) | $C_4H_6$ | -2588.2 ± 1.5 |
| Cyclohexane (l) | $C_6H_{12}$ | -3919.6 |
| Cyclopentane (l) | $C_5H_{10}$ | -3291.4 ± 0.6 |
| Cyclopropane (g) | $C_3H_6$ | -2091.3 |
| *L*-Cysteine (s) | $C_3H_7NO_2S$ | -2248.84 ± 0.55 |
| (-)-Cystine (s) | $C_6H_{12}N_2O_4S_2$ | -4248.0 ± 3.8 |
| Cytosine (s) | $C_4H_5N_3O$ | -2067.3 ± 2.0 |
| Decane (l) | $C_{10}H_{22}$ | -6778.33 ± 0.88 |
| Diethylether (l) | $C_2H_6O$ | -2723.9 |
| Dimethylether (g) | $C_2H_6O$ | -1460.4 |
| Dimethylsulfoxide (l) | $C_2H_6OS$ | -2037.3 ± 1.3 |

| Substance | Formula | $\Delta_{comb}H°$ (kJ mol$^{-1}$) |
|---|---|---|
| 1,4-Dioxane (l) | $C_4H_8O_2$ | -2362.23 ± 0.99 |
| Ethane (g) | $C_6H_6$ | -1560.7 |
| Ethanol (l) | $C_2H_6O$ | -1366.8 |
| Ethyl acetate (l) | $C_4H_8O_2$ | -2238.1 |
| Ethylene (g) | $C_2H_4$ | -1411.2 |
| Ethylene oxide (l) | $C_2H_4O$ | -1280.9 |
| Ethylmethylether (g) | $C_3H_8O$ | -2107.4 ± 0.63 |
| Ethynylbenzene (l) | $C_8H_6$ | -4289.9 |
| Fenchane (l) | $C_{10}H_{18}$ | -1502.6 |
| Formaldehyde (g) | $CH_2O$ | -570.78 ± 0.42 |
| Formamide (l) | $CH_3NO$ | -568.3 |
| Formic acid (l) | $CH_2O_2$ | -254.6 |
| *D*-(-)-Fructose (s) | $C_6H_{12}O_6$ | -2810.4 ± 0.3 |
| Fumaric acid (s) | $C_4H_4O_4$ | -1334.7 ± 0.8 |
| Furan (l) | $C_4H_4O$ | -2083.4 |
| *D*-(+)-Galactose (s) | $C_6H_{12}O_6$ | -2804. |
| *D*-gluconic acid (s) | $C_6H_{12}O_7$ | -2465.9 ± 2.8 |
| *D*-(+)-Glucose (s) | $C_6H_{12}O_6$ | -2805. |
| *D*-(-)-Glutamic acid (s) | $C_5H_9NO_4$ | -2251.32 ± 0.68 |
| *L*-(+)-Glutamic acid (s) | $C_5H_9NO_4$ | -2250.47 ± 0.93 |
| *L*-Glutamine (s) | $C_5H_{10}N_2O_3$ | -2570.3 ± 0.63 |
| Glycerol (l) | $C_3H_8O_3$ | -1655.4 |
| Glycine (s) | $C_2H_5NO_2$ | -975. ± 8. |
| Guanidine (s) | $CH_5N_3$ | -1052.1 ± 1.0 |
| Guanine (s) | $C_5H_5N_5O$ | -2498.2 ± 0.79 |
| Heptane (l) | $C_7H_{16}$ | -4817.0 |
| Hexane (l) | $C_6H_{14}$ | -4163.2 |
| Hexene (l) | $C_6H_{12}$ | -4001.8 |
| 1-Hexanol (l) | $C_6H_{14}O$ | -3984.37 ± 0.44 |
| *L*-Histidine (s) | $C_6H_9N_3O_2$ | -3205.5 ± 2.5 |
| Hydrazine (g) | $N_2H_4$ | -622.08 |
| *L*-Isoleucine (s) | $C_6H_{13}NO_2$ | -3578.3 ± 1.4 |
| Ketene (g) | $C_2H_2O$ | -1025.4 |
| *L*-(+)-Lactic acid (s) | $C_3H_6O_3$ | -1343.98 ± 0.46 |
| (β)-Lactose (s) | $C_{12}H_{22}O_{11}$ | -5629.45 ± 0.50 |
| *L*-Leucine (s) | $C_6H_{13}NO_2$ | -3572.0 ± 0.3 |
| *D*-Limonene (l) | $C_{10}H_{16}$ | -6167.2 ± 2.1 |
| *L*-Lysine (s) | $C_6H_{14}N_2O_2$ | -3683.2 ± 1.5 |
| Menthol (s) | $C_{10}H_{20}O$ | -6313. |
| Methane (g) | $CH_4$ | -890.7 ± 0.4 |
| Methanol (l) | $CH_4O$ | -725.7 ± 0.1 |
| *L*-Methionine (s) | $C_5H_{11}NO_2S$ | -3564.11 ± 0.61 |
| Methylacetate (l) | $C_3H_6O_2$ | -1592.2 ± 0.67 |
| Methylamine (l) | $CH_5N$ | -1060.8 ± 0.4 |
| 2-methyl-1,3-butadiene (l) | $C_5H_8$ | -3158.2 ± 1.6 |
| 3-methyl-1,2-butadiene (l) | $C_5H_8$ | -3212.1 ± 0.42 |
| methylisocyanate (l) | $C_2H_3N$ | -1123.8 |
| β-Myrcene (l) | $C_{10}H_{16}$ | -6236.3 ± 2.1 |
| Naphthalene (s) | $C_{10}H_8$ | -5156.3 |
| Nitroethane (l) | $C_2H_5NO_2$ | -1357.7 |
| Nitromethane (l) | $CH_3NO_2$ | -709.2 |
| Octane (l) | $C_8H_{18}$ | -5470.5 |
| Oxalic acid (s) | $C_2H_2O_4$ | -251.1 |
| *cis*-1,3-Pentadiene (g) | $C_5H_8$ | -3193.6 ± 0.88 |

| Substance | Formula | $\Delta_{comb}H°$ (kJ mol$^{-1}$) |
|---|---|---|
| *trans*-1,3-Pentadiene (g) | $C_5H_8$ | -3186.7 ± 0.63 |
| 1,4-Pentadiene (g) | $C_5H_8$ | -3217.2 ± 1.3 |
| Pentane (l) | $C_5H_{12}$ | -3509.0 |
| 1-Pentanol (l) | $C_5H_{12}O$ | -3330.9 |
| Phenanthrene (s) | $C_{14}H_{10}$ | -7040. ± 30. |
| Phenol (s) | $C_6H_6O$ | -3053.5 |
| *L*-Phenylalanine (s) | $C_9H_{11}NO_2$ | -4646.3 ± 0.8 |
| α-Pinene (l) | $C_{10}H_{16}$ | -6205.3 ± 2.9 |
| β-Pinene (l) | $C_{10}H_{16}$ | 6214.1 ± 2.9 |
| *L*-Proline (s) | $C_5H_9NO_2$ | -2746.2 ± 2.5 |
| Propane (g) | $C_3H_8$ | -2219.2 |
| Propanal (l) | $C_3H_6O$ | -1822.7 |
| 1-Propanol (g) | $C_3H_8O$ | -2021.31 ± 0.25 |
| 2-Propanol (l) | $C_3H_8O$ | -2006.9 ± 0.2 |
| Pyridine (l) | $C_5H_5N$ | -2782.3 |
| Pyrrole (l) | $C_4H_5N$ | -2351.7 |
| Pyrrolidine (l) | $C_4H_9N$ | -2819.3 |
| *L*-serine (s) | $C_3H_7NO_3$ | -1448.21 ± 0.18 |
| Sucrose (s) | $C_{12}H_{22}O_{11}$ | -5643.4 ± 1.8 |
| Toluene (l) | $C_7H_8$ | -3910.3 |
| α-Terpinene (l) | $C_{10}H_{16}$ | -6152.2 |
| α-Terpineol (s) | $C_{10}H_{18}O$ | -6148.4 |
| Tetrahydrofuran (l) | $C_4H_8O$ | -2501.2 ± 0.84 |
| *L*-Threonine (s) | $C_4H_9NO_3$ | -2084.6 ± 1.1 |
| Thymine (l) | $C_5H_6N_2O_2$ | -2362.23 ± 0.84 |
| 2,2,4-Trimethylpentane (l) | $C_8H_{18}$ | -5461.3 ± 1.3 |
| 2,4,6-Trinitrotoluene (s) | $C_7H_5N_3O_6$ | -3410. ± 20. |
| *L*-Tryptophan (s) | $C_{11}H_{12}N_2O_2$ | -5628.32 ± 0.84 |
| *L*-Tyrosine (s) | $C_9H_{11}NO_3$ | -4428.1 ± 1.5 |
| Uracil (s) | $C_4H_4N_2O_2$ | -1721.3 ± 2.2 |
| Urea (s) | $C_2H_5N$ | -635. ± 8. |
| Uric acid (s) | $C_5H_4N_4O_3$ | -1920.4 ± 0.84 |
| *L*-valine (s) | $C_5H_{11}NO_2$ | -2910.7 ± 1.9 |

* Some values are at 1 atm, however, the difference in standard states is less than the experimental uncertainty.


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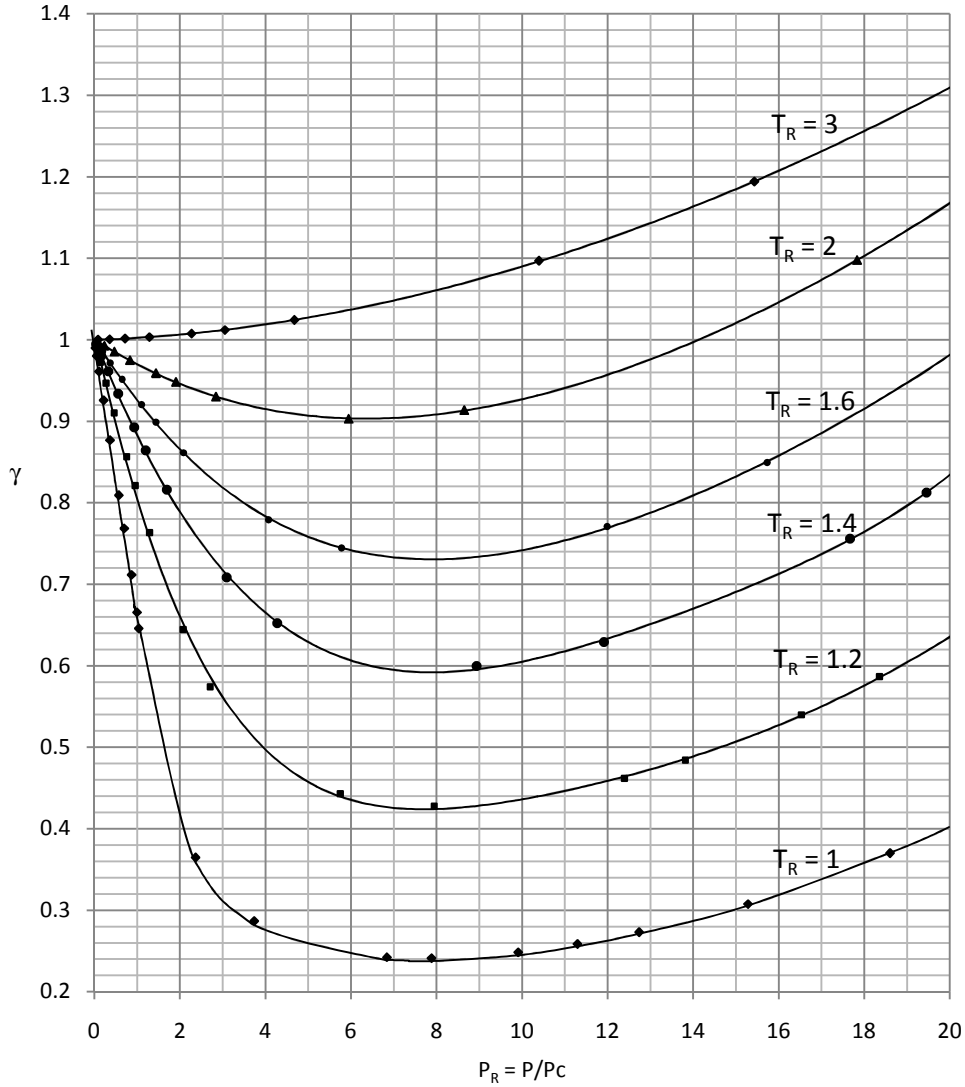


Figure 16.7.1: (c). The Law of Corresponding States allows the estimation of the fugacity coefficient from the reduced temperature and pressure.

Table 18.3.1: Henry's Law constants and Gibbs energies of desolvation. The number in parenthesis is the literature source for that substance and following substances. The literature value is shown in bold.*

| substance | $k_H$ bar | $k_{cc}$ unitless | $k_{pc}$ bar L mol$^{-1}$ | $\Delta_{desol}G°$ kJ mol$^{-1}$ | $\Delta_{desol}G°_{cc}$ kJ mol$^{-1}$ | $\Delta_{desol}G°_{pc}$ kJ mol$^{-1}$ |
|---|---|---|---|---|---|---|
| benzene (1) | 296. | **0.216** | 5.35 | -14.11 | 3.80 | -4.16 |
| toluene | 361. | **0.263** | 6.52 | -14.60 | 3.31 | -4.65 |
| ethylbenzene | 436. | **0.318** | 7.88 | -15.07 | 2.84 | -5.12 |
| *m*,*p*-xylene | 409. | **0.298** | 7.39 | -14.91 | 3.00 | -4.96 |
| o-xylene | 280. | **0.204** | 5.06 | -13.97 | 3.94 | -4.02 |
| 1,1,1-trichloroethane | 985. | **0.718** | 17.80 | -17.09 | 0.82 | -7.14 |
| trichloroethylene | 576. | **0.420** | 10.41 | -15.76 | 2.15 | -5.81 |
| tetrachloroethylene | 956. | **0.697** | 17.28 | -17.01 | 0.89 | -7.06 |
| methyl-*t*-butyl ether | 29.6 | **0.0216** | 0.54 | -8.40 | 9.51 | 1.55 |
| trichloroethylene (2) | 538. | **0.392** | 9.72 | -15.59 | 2.32 | -5.64 |
| 1,1-dichloroethylene | 1.47 x10$^3$ | **1.069** | 26.50 | -18.07 | -0.17 | -8.12 |
| *cis*-1,2-dichlororethylene | 229. | **0.167** | 4.14 | -13.47 | 4.44 | -3.52 |
| *trans*-1,2-dichloroethylene | 527. | **0.384** | 9.52 | -15.54 | 2.37 | -5.59 |
| vinylchloride | 1.56x10$^3$ | **1.137** | 28.19 | -18.23 | -0.32 | -8.28 |
| 1,1-dichloroethane | 316. | **0.230** | 5.70 | -14.26 | 3.64 | -4.32 |
| chloroethane | 626. | **0.456** | 11.30 | -15.96 | 1.95 | -6.01 |
| carbon tetrachloride | 1.71x10$^3$ | **1.244** | 30.84 | -18.45 | -0.54 | -8.50 |
| chloroform | 2.1x10$^2$ | **0.150** | 3.72 | -13.21 | 4.70 | -3.26 |
| dichloromethane | 123. | **0.0895** | 2.22 | -11.92 | 5.98 | -1.98 |
| chloromethane | 495. | **0.361** | 8.95 | -15.38 | 2.53 | -5.43 |
| methane (3) | **4.19x10$^4$** | 30.5 | 757. | -26.38 | -8.48 | -16.43 |
| $O_2$ | **4.40x10$^4$** | 32.1 | 795. | -26.50 | -8.60 | -16.56 |
| $CO_2$+$H_2CO_3$ (pure $H_2O$) | **1.67x10$^3$** | 1.20 | 30.2 | -18.40 | -0.49 | -8.45 |
| $CO_2$+$H_2CO_3$ (sea $H_2O$,4) | 1.9x10$^3$ | 1.38 | **34.3** | -18.72 | -0.81 | -8.77 |

*The SI units are Pa m$^3$ mol$^{-1}$; example: for benzene $k_{pc}$ = 5.35 bar L mol$^{-1}$(100 Pa bar$^{-1}$ m$^3$ L$^{-1}$) = 535. Pa m$^3$ mol$^{-1}$.


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Table 21.1.1: Standard Reduction Potentials at 25°C.[1,2]*

| Acidic Solution | $E^\circ_{red}$ (V) | $dE^\circ_{red}/dT$ (mV $K^{-1}$) | $d^2E^\circ_{red}/dT^2$ (μV $K^{-1}$) |
|---|---|---|---|
| $F_2$ (g) + 2e$^-$ → 2F$^-$ | 2.890 | -1.870 | -4.75 |
| $Co^{3+}$ + e$^-$ → $Co^{2+}$ | 1.92 | 1.23 | |
| $N_2O$ (g) + 2H$^+$ + 2e$^-$ → $N_2$ (g) + $H_2O$ | 1.769 | -0.461 | |
| $H_2O_2$ + 2H$^+$ + 2e$^-$ → 2 $H_2O$ | 1.763 | -0.698 | |
| $PbO_2$ (s) + 4H$^+$ + $SO_4^{2-}$ + 2e$^-$ → $PbSO_4$(s) + 2 $H_2O$ | 1.685 | 0.326 | 2.516 |
| 2 NO (g) + 2H$^+$ + 2e$^-$ → $N_2O$ (g) + $H_2O$ | 1.587 | -1.359 | |
| $BrO_3^-$ + 6H$^+$ + 5e$^-$ → ½ $Br_2$ (l) + 3 $H_2O$ | 1.513 | -0.419 | |
| $MnO_4^-$ + 8H$^+$ + 5e$^-$ → $Mn^{2+}$ + 4 $H_2O$ | 1.507 | -0.646 | 2.5 |
| $PbO_2$ (s) + 4H$^+$ + 2e$^-$ → $Pb^{2+}$ + 2 $H_2O$ | 1.458 | -0.253 | |
| $ClO_3^-$ + 6H$^+$ + 5e$^-$ → ½ $Cl_2$ (g) + 3 $H_2O$ | 1.458 | -0.347 | |
| 2 $NH_3OH^+$ + H$^+$ + 2e$^-$ → $N_2H_5^+$ + 2 $H_2O$ | 1.40 | -0.60 | |
| $Cl_2$ (g) + 2e$^-$ → 2Cl$^-$ | 1.3604 | -1.248 | -5.83 |
| $Cr_2O_7^{2-}$ + 14H$^+$ + 6e$^-$ → 2$Cr^{3+}$ + 7 $H_2O$ | 1.36 | -1.32 | |
| $N_2H_5^+$ + 3H$^+$ + 2e$^-$ → 2 $NH_4^+$ | 1.250 | -0.28 | |
| $MnO_2$ (s) + 4 H$^+$ + 2e$^-$ → $Mn^{2+}$ + 2 $H_2O$ | 1.230 | -0.609 | |
| $ClO_4^-$ + 2H$^+$ + 2e$^-$ → $ClO_3^-$ + $H_2O$ | 1.226 | -0.416 | |
| $O_2$ (g) + 4H$^+$ + 4e$^-$ → 2 $H_2O$ | 1.2291 | -0.8456 | 0.5525 |
| $IO_3^-$ + 6H$^+$ + 5e$^-$ → ½ $I_2$ + 3 $H_2O$ | 1.210 | -0.367 | |
| $ClO_3^-$ + 3H$^+$ + 2e$^-$ → $HClO_2$ + $H_2O$ | 1.157 | -0.180 | |
| $IO_3^-$ + 5H$^+$ + 4e$^-$ → HOI+ 2 $H_2O$ | 1.154 | -0.374 | |
| $Br_2$ (l) + 2e$^-$ → 2Br$^-$ | 1.078 | -0.611 | -6.06 |
| $HNO_2$ + H$^+$ + e$^-$ → NO (g) + $H_2O$ | 0.984 | 0.649 | |
| $NO_3^-$ + 4H$^+$ + 3e$^-$ → NO (g) + 2 $H_2O$ | 0.955 | 0.028 | |
| 2 $Hg^{2+}$ + 2e$^-$ → $Hg_2^{2+}$ | 0.908 | 0.095 | |
| $Hg^{2+}$ + 2e$^-$ → Hg (l) | 0.852 | -0.116 | |
| $Ag^+$ + e$^-$ → Ag (s) | 0.7993 | -0.989 | -0.38 |
| $Hg_2^{2+}$ + 2e$^-$ → Hg (l) | 0.796 | -0.327 | |
| $NO_3^-$ + 2H$^+$ + 2e$^-$ → $NO_2$ (g) + $H_2O$ | 0.773 | 1.018 | |
| $Fe^{3+}$ + e$^-$ → $Fe^{2+}$ | 0.771 | 1.175 | |
| $O_2$ (g) + 2 H$^+$ + 2e$^-$ → $H_2O_2$ | 0.695 | -0.993 | |
| $I_2$ (s) + 2e$^-$ → 2I$^-$ | 0.620 | -0.234 | -6.39 |
| $Cu^+$ + e$^-$ → Cu (s) | 0.518 | -0.754 | |
| $Fe(CN)_6^{3-}$ + e$^-$ → $Fe(CN)_6^{4-}$ | 0.356 | | |
| $Cu^{2+}$ + 2e$^-$ → Cu (s) | 0.339 | 0.011 | |
| $N_2$ (g) + 8H$^+$ + 6e$^-$ → 2 $NH_4^+$ | 0.274 | -0.616 | 0.26 |
| $Hg_2Cl_2$ (s) + 2e$^-$ → 2 Hg (l) + 2 Cl$^-$ | 0.2676 | -0.317 | -5.664 |
| AgCl (s) + 1 e$^-$ → Ag (s) + Cl$^-$ | 0.2223 | -0.658 | -5.744 |
| $Cu^{2+}$ + e$^-$ → $Cu^+$ | 0.161 | 0.776 | |
| 2H$^+$ + 2e$^-$ → $H_2$ (g) | **0.00** | **0.00** | **0.00** |
| $Fe^{3+}$ + 3e$^-$ → Fe (s) | -0.036 | | |
| $Pb^{2+}$ + 2e$^-$ → Pb (s) | -0.126 | -0.395 | |
| $Sn^{2+}$ + 2e$^-$ → Sn (s) | -0.141 | -0.32 | |
| $Ni^{2+}$ + 2e$^-$ → Ni (s) | -0.236 | 0.146 | |
| $Co^{2+}$ + 2e$^-$ → Co (s) | -0.282 | 0.065 | |
| $PbSO_4$ (s) + 2e$^-$ → Pb (s) + $HSO_4^-$ | -0.3588 | -1.015 | -1.555 |
| $PbI_2$ + 2e$^-$ → Pb (s) + 2I$^-$ | -0.365 | | |
| $Cd^{2+}$ + 2e$^-$ → Cd (s) | -0.402 | -0.029 | |
| $Cr^{3+}$ + e$^-$ → $Cr^{2+}$ | -0.42 | 1.4 | |
| $Fe^{2+}$ + 2e$^-$ → Fe (s) | -0.44 | 0.07 | |
| $Cr^{3+}$ + 3e$^-$ → Cr (s) | -0.74 | 0.44 | |

| Acidic Solution | $E^\circ_{red}$ (V) | $dE^\circ_{red}/dT$ (mV $K^{-1}$) | $d^2E^\circ_{red}/dT^2$ (μV $K^{-1}$) |
|---|---|---|---|
| $Zn^{2+} + 2e^- \rightarrow Zn$ (s) | -0.762 | 0.119 | |
| $Ti^{3+} + e^- \rightarrow Ti^{2+}$ | -0.9 | 1.5 | |
| $TiO_2$ (s,rutile) + 4 $H^+$ + 4$e^-$ → Ti (s) + 2 $H_2O$ | -1.076 | 0.365 | |
| $Mn^{2+} + 2e^- \rightarrow Mn$ (s) | -1.182 | -1.129 | -0.9 |
| $Ti^{2+} + 2e^- \rightarrow Ti$ (s) | -1.60 | -0.16 | |
| $Al^{3+} + 3e^- \rightarrow Al$ (s) | -1.667 | 0.533 | |
| $N_2$ (g) + 2 $H_2O$ + 4$H^+$ + 2$e^-$ → 2 $NH_3OH^+$ | -1.83 | -0.96 | |
| $Mg^{2+} + 2e^- \rightarrow Mg$ (s) | -2.360 | 0.199 | |
| $Na^+ + e^- \rightarrow Na$ (s) | -2.7143 | -0.757 | -1.13 |
| $Ca^{2+} + 2e^- \rightarrow Ca$ (s) | -2.868 | -0.186 | |
| $K^+ + e^- \rightarrow K$ (s) | -2.936 | -1.074 | -0.23 |
| $Li^+ + e^- \rightarrow Li$ (s) | -3.040 | -0.514 | -2.02 |
| **Basic Solution** | $E^\circ_{red}$ (V) | $dE^\circ_{red}/dT$ (mV $K^{-1}$) | $d^2E^\circ_{red}/dT^2$ (μV $K^{-1}$) |
| $BrO_4^-$ + $H_2O$ + 2$e^-$ → $BrO_3^-$ + 2 $OH^-$ | 0.917 | -1.347 | |
| $ClO^-$ + $H_2O$ + 2$e^-$ → $Cl^-$ + 2 $OH^-$ | 0.890 | -1.079 | |
| $HO_2^-$ + $H_2O$ + 2$e^-$ → 3 $OH^-$ | 0.867 | -1.330 | |
| $BrO^-$ + $H_2O$ + 2$e^-$ → $Br^-$ + 2 $OH^-$ | 0.766 | -0.94 | |
| $IO_4^{--}$ + $H_2O$ + 2$e^-$ → $IO_3^{--}$ + 2 $OH^-$ | 0.761 | -1.69 | |
| $BrO_3^-$ + 3 $H_2O$ + 6$e^-$ → $Br^-$ + 6 $OH^-$ | 0.613 | -1.287 | |
| $MnO_4^-$ + 2 $H_2O$ + 3$e^-$ → $MnO_2$ (s) + 4 $OH^-$ | 0.588 | -1.785 | |
| $BrO_3^-$ + 3 $H_2O$ + 5$e^-$ → ½ $Br_2$ (l) + 6 $OH^-$ | 0.520 | -1.422 | |
| $ClO_3^-$ + 3 $H_2O$ + 5$e^-$ → ½ $Cl_2$ (g) + 6 $OH^-$ | 0.465 | -1.350 | |
| $O_2$ (g) + 2 $H_2O$ + 4$e^-$ → 4 $OH^-$ | 0.4011 | -1.6816 | 7.23 |
| $ClO_4^-$ + $H_2O$ + 2$e^-$ → $ClO_3^-$ + 2 $OH^-$ | 0.398 | -1.252 | |
| $ClO_3^-$ + $H_2O$ + 2$e^-$ → $ClO_2^-$ + 2 $OH^-$ | 0.271 | -1.466 | |
| $IO_3^-$ + 3 $H_2O$ + 6$e^-$ → $I^-$ + 6 $OH^-$ | 0.269 | -1.163 | |
| $PbO_2$ (s) + $H_2O$ + 2$e^-$ → PbO (s,red) + 2 $OH^-$ | 0.254 | -1.161 | |
| $O_2$ (g) + $H_2O$ + 2 $e^-$ → $HO_2^-$ + OH | -0.065 | -2.033 | |
| $CrO_4^{2-}$ + 4 $H_2O$ + 3$e^-$ → $Cr(OH)_3$ (s) + 5 $OH^-$ | -0.12 | -1.62 | |
| $Mn_2O_3$ (s) + 3 $H_2O$ + 2$e^-$ → 2 $Mn(OH)_2$ (s) + 2 $OH^-$ | -0.234 | -1.49 | |
| $SO_3^{2-}$ + 3 $H_2O$ + 4$e^-$ → $S_2O_3^{2-}$ + 6 $OH^-$ | -0.566 | -1.06 | |
| PbO (s,red) + $H_2O$ + 2$e^-$ → Pb (s) + 2 $OH^-$ | -0.578 | -1.159 | |
| $Co(OH)_2$ (s) + 2$e^-$ → Co (s) + 2 $OH^-$ | -0.746 | -1.02 | |
| $SO_4^{2-}$ + 4 $H_2O$ + 6$e^-$ → S (s) + 8 $OH^-$ | -0.751 | -1.288 | |
| $S_2O_3^{2-}$ + 3 $H_2O$ + 4$e^-$ → 2 S (s) + 6 $OH^-$ | -0.752 | -1.40 | |
| 2$H_2O$ + 2$e^-$ → $H_2$ (g) + 2 $OH^-$ | -0.8280 | -0.8360 | -7.78 |
| $Fe_2O_3$ (s) +3 $H_2O$ + 2$e^-$ → 2 $Fe(OH)_2$ (s) + 2 $OH^-$ | -0.86 | -1.43 | |
| 4 $SO_4^{2-}$ + 10 $H_2O$ + 14$e^-$ → $S_4O_6^{2-}$ + 20 $OH^-$ | -0.862 | -1.22 | |
| $Fe(OH)_2$ (s) + 2$e^-$ → Fe (s) + 2 $OH^-$ | -0.89 | -1.09 | |
| SnO (s) + $H_2O$ + 2$e^-$ → Sn (s) + 2 $OH^-$ | -0.930 | -1.176 | |
| $SO_4^{2-}$ + $H_2O$ + 2$e^-$ → $SO_3^{2-}$ + 2 $OH^-$ | -0.936 | -1.41 | |
| $SnO_2$ (s) + 2 $H_2O$ + 4$e^-$ → Sn (s) + 4 $OH^-$ | -0.945 | -1.152 | |
| $Zn(OH)_4^{2-}$ + 2$e^-$ → Zn (s) + 4 $OH^-$ | -1.199 | | |
| $Mn(OH)_2$ (s) + 2$e^-$ → Mn (s) + 2 $OH^-$ | -1.565 | -1.10 | |
| $Al(OH)_4^-$ + 3$e^-$ → Al (s) + 4 $OH^-$ | -2.328 | -1.13 | |
| $Mg(OH)_2$ (s) + 2$e^-$ → Mg (s) + 2 $OH^-$ | -2.690 | -0.946 | |

1. S. G. Bratsch, "Standard Electrode Potentials and Temperature Coefficients in Water at 298 K," *J. Phys. Chem. Ref. Data*, **1989**, *18(1)*, 1-20. 2. D. C. Harris, *Quantitative Chemical Analysis 7th Ed.*, W. H. Freeman, New York, NY, 2007. Appendix H.

*The temperature derivatives assume $E^\circ_{red}$ for the standard hydrogen electrode is independent of T. The actual value for the standard hydrogen electrode is $dE^\circ_{red}/dT$ = 0.871 mV $K^{-1}$, which must be included in entropy calculations for individual species.