

THERMODYNAMIC VALUES FOR SUBSTANCES AT 298.15 K (25°C)

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol-K) |
|-----------------------------------|--------------------------------|--------------------------------|------------------------|
| Aluminum | | | |
| Al _(s) | 0 | 0 | 28.3 |
| AlCl _{3(s)} | -705.6 | -630.0 | 109.3 |
| Al ₂ O _{3(s)} | -1669.8 | -1576.5 | 51.0 |
| Barium | | | |
| Ba _(s) | 0 | 0 | 63.2 |
| BaCO _{3(s)} | -1216.3 | -1137.6 | 112.1 |
| BaO _(s) | -553.5 | -525.1 | 70.4 |
| Beryllium | | | |
| Be _(s) | 0 | 0 | 9.44 |
| BeO _(s) | -608.4 | -579.1 | 13.8 |
| Be(OH) _{2(s)} | -905.8 | -817.9 | 50.2 |
| Bromine | | | |
| Br _(g) | 111.8 | 82.4 | 174.9 |
| Br ⁻ _(aq) | -120.9 | -102.8 | 80.7 |
| Br _{2(g)} | 30.7 | 3.14 | 245.3 |
| Br _{2(l)} | 0 | 0 | 152.3 |
| HBr _(g) | -36.2 | -53.2 | 198.5 |
| Calcium | | | |
| Ca _(g) | 179.3 | 145.5 | 154.8 |
| Ca _(s) | 0 | 0 | 41.4 |
| CaCO _{3(s, calcite)} | -1207.1 | 1128.8 | 92.9 |
| CaCl _{2(s)} | -795.8 | -748.1 | 104.6 |
| CaF _{2(s)} | -1219.6 | -1167.3 | 68.9 |
| CaO _(s) | -635.5 | -604.2 | 39.8 |
| Ca(OH) _{2(s)} | -986.2 | -898.5 | 83.4 |
| CaSO _{4(s)} | -1434.0 | -1321.8 | 106.7 |
| Carbon | | | |
| C _(g) | 718.4 | 672.9 | 158.0 |

| | | | |
|----------------------------|---------|--------|-------|
| $C_{(s, \text{diamond})}$ | 1.88 | 2.84 | 2.43 |
| $C_{(s, \text{graphite})}$ | 0 | 0 | 5.69 |
| $CCl_{4(g)}$ | -106.7 | -64.0 | 309.4 |
| $CCl_{4(l)}$ | -139.3 | -68.6 | 214.4 |
| $CF_{4(g)}$ | -679.9 | -635.1 | 262.3 |
| $CH_{4(g)}$ | -74.8 | -50.8 | 186.3 |
| $C_2H_2(g)$ | 226.7 | 209.2 | 200.8 |
| $C_2H_4(g)$ | 52.3 | 68.1 | 219.4 |
| $C_2H_6(g)$ | -84.7 | -32.9 | 229.5 |
| $C_3H_8(g)$ | -103.9 | -23.5 | 269.9 |
| $C_4H_{10(g)}$ | -124.7 | -15.7 | 310.0 |
| $C_4H_{10(l)}$ | -147.6 | -15.0 | 231.0 |
| $C_6H_6(g)$ | 82.9 | 129.7 | 269.2 |
| $C_6H_6(l)$ | 49.0 | 124.5 | 172.8 |
| $CH_3OH(g)$ | -201.2 | -161.9 | 237.6 |
| $CH_3OH(l)$ | -238.6 | -166.2 | 126.8 |
| $C_2H_5OH(g)$ | -235.1 | -168.5 | 282.7 |
| $C_2H_5OH(l)$ | -277.7 | -174.8 | 160.7 |
| $C_6H_{12}O_6(s)$ | -1273.0 | -910.4 | 212.1 |
| $CO(g)$ | -110.5 | -137.2 | 197.9 |
| $CO_2(g)$ | -393.5 | -394.4 | 213.6 |
| $HC_2H_3O_2(l)$ | -487.0 | -392.4 | 159.8 |
| Cesium | | | |
| $Cs(g)$ | 76.5 | 49.5 | 175.6 |
| $Cs(l)$ | 2.09 | 0.03 | 92.1 |
| $Cs(s)$ | 0 | 0 | 85.2 |
| $CsCl(s)$ | -442.8 | -414.4 | 101.2 |
| Chlorine | | | |
| $Cl(g)$ | 121.7 | 105.7 | 165.2 |
| $Cl_{(aq)}^-$ | -167.2 | -131.2 | 56.5 |
| $Cl_{2(g)}$ | 0 | 0 | 223.0 |
| $HCl_{(aq)}$ | -167.2 | -131.2 | 56.5 |
| $HCl(g)$ | -92.3 | -95.3 | 186.7 |

| | | | |
|------------------------------|---------|---------|-------|
| Chromium | | | |
| $\text{Cr}_{(g)}$ | 397.5 | 352.6 | 174.2 |
| $\text{Cr}_{(s)}$ | 0 | 0 | 23.6 |
| $\text{Cr}_2\text{O}_{3(s)}$ | -1139.7 | -1058.1 | 81.2 |
| Cobalt | | | |
| $\text{Co}_{(g)}$ | 439 | 393 | 179 |
| $\text{Co}_{(s)}$ | 0 | 0 | 28.4 |
| Copper | | | |
| $\text{Cu}_{(g)}$ | 338.4 | 298.6 | 166.3 |
| $\text{Cu}_{(s)}$ | 0 | 0 | 33.3 |
| $\text{CuCl}_{2(s)}$ | -205.9 | -161.7 | 108.1 |
| $\text{CuO}_{(s)}$ | -156.1 | -128.3 | 42.6 |
| $\text{Cu}_2\text{O}_{(s)}$ | -170.7 | -147.9 | 92.4 |
| Fluorine | | | |
| $\text{F}_{(g)}$ | 80.0 | 61.9 | 158.7 |
| $\text{F}_{(aq)}^-$ | -332.6 | -278.8 | -13.8 |
| $\text{F}_{2(g)}$ | 0 | 0 | 202.7 |
| $\text{HF}_{(g)}$ | -268.6 | -270.7 | 173.5 |
| Hydrogen | | | |
| $\text{H}_{(g)}$ | 217.9 | 203.3 | 114.6 |
| $\text{H}_{(aq)}^+$ | 0 | 0 | 0 |
| $\text{H}_{(g)}^+$ | 1536.2 | 1517.0 | 108.9 |
| $\text{H}_{2(g)}$ | 0 | 0 | 130.6 |
| Iodine | | | |
| $\text{I}_{(g)}$ | 106.6 | 70.2 | 180.7 |
| $\text{I}_{(aq)}^-$ | -55.2 | -51.6 | 111.3 |
| $\text{I}_{2(g)}$ | 62.3 | 19.4 | 260.6 |
| $\text{I}_{2(s)}$ | 0 | 0 | 116.7 |
| $\text{HI}_{(g)}$ | 25.9 | 1.30 | 206.3 |
| Iron | | | |
| $\text{Fe}_{(g)}$ | 415.5 | 369.8 | 180.5 |
| $\text{Fe}_{(s)}$ | 0 | 0 | 27.2 |
| $\text{Fe}_{(aq)}^{2+}$ | -87.9 | -84.9 | 113.4 |

| | | | |
|-------------------------------------|---------|---------|-------|
| $\text{Fe}^{3+}_{(\text{aq})}$ | -47.7 | -10.5 | 293.3 |
| $\text{FeCl}_{2(\text{s})}$ | -341.8 | -302.3 | 117.9 |
| $\text{FeCl}_{3(\text{s})}$ | -400 | -334 | 142.3 |
| $\text{FeO}_{(\text{s})}$ | -271.9 | -255.2 | 60.8 |
| $\text{Fe}_2\text{O}_{3(\text{s})}$ | -822.2 | -741.0 | 90.0 |
| $\text{Fe}_3\text{O}_{4(\text{s})}$ | -1117.1 | -1014.2 | 146.4 |
| $\text{FeS}_{2(\text{s})}$ | -171.5 | -160.1 | 52.9 |

Lead

| | | | |
|---|--------|--------|-------|
| $\text{Pb}_{(\text{s})}$ | 0 | 0 | 68.9 |
| $\text{PbBr}_{2(\text{s})}$ | -277.4 | -260.7 | 161 |
| $\text{PbCO}_{3(\text{s})}$ | -699.1 | -625.5 | 131.0 |
| $\text{Pb}(\text{NO}_3)_{2(\text{aq})}$ | -421.3 | -246.9 | 303.3 |
| $\text{Pb}(\text{NO}_3)_{2(\text{s})}$ | -451.9 | — | — |
| $\text{PbO}_{(\text{s})}$ | -217.3 | -187.9 | 68.7 |

Lithium

| | | | |
|-------------------------------|--------|--------|-------|
| $\text{Li}_{(\text{g})}$ | 159.3 | 126.6 | 138.8 |
| $\text{Li}_{(\text{s})}$ | 0 | 0 | 29.1 |
| $\text{Li}^{+}_{(\text{aq})}$ | -278.5 | -273.4 | 12.2 |
| $\text{Li}^{+}_{(\text{g})}$ | 685.7 | 648.5 | 133.0 |
| $\text{LiCl}_{(\text{s})}$ | -408.3 | -384.0 | 59.3 |

Magnesium

| | | | |
|--------------------------------------|--------|--------|-------|
| $\text{Mg}_{(\text{g})}$ | 147.1 | 112.5 | 148.6 |
| $\text{Mg}_{(\text{s})}$ | 0 | 0 | 32.5 |
| $\text{MgCl}_{2(\text{s})}$ | -641.6 | -592.1 | 89.6 |
| $\text{MgO}_{(\text{s})}$ | -601.8 | -569.6 | 26.8 |
| $\text{Mg}(\text{OH})_{2(\text{s})}$ | -924.7 | -833.7 | 63.2 |

Manganese

| | | | |
|----------------------------------|--------|--------|-------|
| $\text{Mn}_{(\text{g})}$ | 280.7 | 238.5 | 173.6 |
| $\text{Mn}_{(\text{s})}$ | 0 | 0 | 32.0 |
| $\text{MnO}_{(\text{s})}$ | -385.2 | -362.9 | 59.7 |
| $\text{MnO}_{2(\text{s})}$ | -519.6 | -464.8 | 53.1 |
| $\text{MnO}_4^{-}_{(\text{aq})}$ | -541.4 | -447.2 | 191.2 |

Mercury

| | | | |
|--------------------------|------|------|-------|
| $\text{Hg}_{(\text{g})}$ | 60.8 | 31.8 | 174.9 |
|--------------------------|------|------|-------|

| | | | |
|------------------------------------|--------|--------|-------|
| Hg(l) | 0 | 0 | 77.4 |
| HgCl _{2(s)} | -230.1 | -184.0 | 144.5 |
| Hg ₂ Cl _{2(s)} | -264.9 | -210.5 | 192.5 |
| Nickel | | | |
| Ni(g) | 429.7 | 384.5 | 182.1 |
| Ni(s) | 0 | 0 | 29.9 |
| NiCl _{2(s)} | -305.3 | -259.0 | 97.65 |
| NiO(s) | -239.7 | -211.7 | 38.0 |
| Nitrogen | | | |
| N(g) | 472.7 | 455.5 | 153.3 |
| N _{2(g)} | 0 | 0 | 191.5 |
| NH _{3(aq)} | -80.3 | -26.5 | 111.3 |
| NH _{3(g)} | -46.2 | -16.7 | 192.5 |
| NH ₄ ⁺ (aq) | -132.5 | -79.3 | 113.4 |
| N ₂ H _{4(g)} | 95.4 | 159.4 | 238.5 |
| NH ₄ CN(s) | 0.0 | — | — |
| NH ₄ Cl(s) | -314.4 | -203.0 | 94.6 |
| NH ₄ NO _{3(s)} | -365.6 | -184.0 | 151 |
| NO(g) | 90.4 | 86.7 | 210.6 |
| NO _{2(g)} | 33.8 | 51.8 | 240.5 |
| N ₂ O(g) | 81.6 | 103.6 | 220.0 |
| N ₂ O _{4(g)} | 9.66 | 98.3 | 304.3 |
| NOCl(g) | 52.6 | 66.3 | 264 |
| HNO _{3(aq)} | -206.6 | -110.5 | 146 |
| HNO _{3(g)} | -134.3 | -73.9 | 266.4 |
| Oxygen | | | |
| O(g) | 247.5 | 230.1 | 161.0 |
| O _{2(g)} | 0 | 0 | 205.0 |
| O _{3(g)} | 142.3 | 163.4 | 237.6 |
| OH ⁻ (aq) | -230.0 | -157.3 | -10.7 |
| H ₂ O(g) | -241.8 | -228.6 | 188.8 |
| H ₂ O(l) | -285.8 | -237.1 | 69.9 |
| H ₂ O _{2(g)} | -136.1 | -105.5 | 232.9 |
| H ₂ O _{2(l)} | -187.8 | -120.4 | 109.6 |

Phosphorus

| | | | |
|--------------------------|---------|---------|-------|
| $P_{(g)}$ | 316.4 | 280.0 | 163.2 |
| $P_{2(g)}$ | 144.3 | 103.7 | 218.1 |
| $P_{4(g)}$ | 58.9 | 24.4 | 280 |
| $P_{4(s, \text{red})}$ | -17.5 | -12.0 | 22.9 |
| $P_{4(s, \text{white})}$ | 0 | 0 | 41.1 |
| $PCl_{3(g)}$ | -288.1 | -269.6 | 311.7 |
| $PCl_{3(l)}$ | -319.6 | -272.4 | 217 |
| $PF_{5(g)}$ | -1594.4 | -1520.7 | 300.8 |
| $PH_{3(g)}$ | 5.4 | 13.4 | 210.2 |
| $P_4O_{6(s)}$ | -1640.1 | — | — |
| $P_4O_{10(s)}$ | -2940.1 | -2675.2 | 228.9 |
| $POCl_{3(g)}$ | 542.2 | -502.5 | 325 |
| $POCl_{3(l)}$ | -597.0 | -520.9 | 222 |
| $H_3PO_{4(aq)}$ | -1288.3 | -1142.6 | 158.2 |

Potassium

| | | | |
|----------------|---------|---------|-------|
| $K_{(g)}$ | 90.0 | 61.17 | 160.2 |
| $K_{(s)}$ | 0 | 0 | 64.7 |
| $KCl_{(s)}$ | -435.9 | -408.3 | 82.7 |
| $KClO_{3(s)}$ | -391.2 | -289.9 | 143.0 |
| $KClO_{3(aq)}$ | -349.5 | -284.9 | 265.7 |
| $K_2CO_{3(s)}$ | -1150.2 | -1064.6 | 155.4 |
| $KNO_{3(s)}$ | -492.7 | -393.1 | 288.1 |
| $K_2O_{(s)}$ | -363.2 | -322.1 | 94.1 |
| $KO_{2(s)}$ | -284.5 | -240.6 | 122.5 |
| $K_2O_{2(s)}$ | -495.8 | -429.8 | 113.0 |
| $KOH_{(s)}$ | -424.7 | -378.9 | 78.91 |
| $KOH_{(aq)}$ | -482.4 | -440.5 | 91.6 |

Rubidium

| | | | |
|----------------|--------|--------|-------|
| $Rb_{(g)}$ | 85.8 | 55.8 | 170.0 |
| $Rb_{(s)}$ | 0 | 0 | 76.8 |
| $RbCl_{(s)}$ | -430.5 | -412.0 | 92 |
| $RbClO_{3(s)}$ | -392.4 | -292.0 | 152 |

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|------------------------------------|---------|---------|-------|
| Scandium | | | |
| $\text{Sc}_{(g)}$ | 377.8 | 336.1 | 174.7 |
| $\text{Sc}_{(s)}$ | 0 | 0 | 34.6 |
| Selenium | | | |
| $\text{H}_2\text{Se}_{(g)}$ | 29.7 | 15.9 | 219.0 |
| Silicon | | | |
| $\text{Si}_{(g)}$ | 368.2 | 323.9 | 167.8 |
| $\text{Si}_{(s)}$ | 0 | 0 | 18.7 |
| $\text{SiC}_{(s)}$ | -73.2 | -70.9 | 16.6 |
| $\text{SiCl}_{4(l)}$ | -640.1 | -572.8 | 239.3 |
| $\text{SiO}_{2(s, \text{quartz})}$ | -910.9 | -856.5 | 41.8 |
| Silver | | | |
| $\text{Ag}_{(s)}$ | 0 | 0 | 42.6 |
| $\text{Ag}^+_{(aq)}$ | 105.9 | 77.11 | 73.9 |
| $\text{AgCl}_{(s)}$ | -127.0 | -109.7 | 96.1 |
| $\text{Ag}_2\text{O}_{(s)}$ | -31.1 | -11.2 | 121.3 |
| $\text{AgNO}_{3(s)}$ | -124.4 | -33.4 | 140.9 |
| Sodium | | | |
| $\text{Na}_{(g)}$ | 107.7 | 77.3 | 153.7 |
| $\text{Na}_{(s)}$ | 0 | 0 | 51.5 |
| $\text{Na}^+_{(aq)}$ | -240.1 | -261.9 | 59.0 |
| $\text{Na}^+_{(g)}$ | 609.3 | 574.3 | 148.0 |
| $\text{NaBr}_{(aq)}$ | -360.6 | -364.7 | 141.0 |
| $\text{NaBr}_{(s)}$ | -361.4 | -349.3 | 86.8 |
| $\text{Na}_2\text{CO}_{3(s)}$ | -1130.9 | -1047.7 | 136.0 |
| $\text{NaCl}_{(aq)}$ | -407.1 | -393.0 | 115.5 |
| $\text{NaCl}_{(g)}$ | -181.4 | -201.3 | 229.8 |
| $\text{NaCl}_{(s)}$ | -410.9 | -384.0 | 72.3 |
| $\text{NaHCO}_{3(s)}$ | -947.7 | -851.8 | 102.1 |
| $\text{NaNO}_{3(aq)}$ | -446.2 | -372.4 | 207 |
| $\text{NaNO}_{3(s)}$ | -467.9 | -367.0 | 116.5 |
| $\text{NaOH}_{(aq)}$ | -469.6 | -419.2 | 49.8 |

| | | | |
|------------------------------------|--------|--------|-------|
| NaOH _(s) | -425.6 | -379.5 | 64.5 |
| Strontium | | | |
| SrO _(s) | -592.0 | -561.9 | 54.9 |
| Sr _(g) | 164.4 | 110.0 | 164.6 |
| Sulfur | | | |
| S _(s, rhombic) | 0 | 0 | 31.88 |
| S _{8(g)} | 102.3 | 49.7 | 430.9 |
| SO _{2(g)} | -296.9 | -300.4 | 248.5 |
| SO _{3(g)} | -395.2 | -370.4 | 256.2 |
| SO _{4²⁻(aq)} | -909.3 | -744.5 | 20.1 |
| SOCl _{2(l)} | -245.6 | — | — |
| H ₂ S _(g) | -20.2 | -33.0 | 205.6 |
| H ₂ SO _{4(aq)} | -909.3 | -744.5 | 20.1 |
| H ₂ SO _{4(l)} | -814.0 | -689.9 | 156.1 |
| Titanium | | | |
| Ti _(g) | 468 | 422 | 180.3 |
| Ti _(s) | 0 | 0 | 30.76 |
| TiCl _{4(g)} | -763.2 | -726.8 | 354.9 |
| TiCl _{4(l)} | -804.2 | -728.1 | 221.9 |
| TiO _{2(s)} | -944.7 | -889.4 | 50.29 |
| Vanadium | | | |
| V _(g) | 514.2 | 453.1 | 182.2 |
| V _(s) | 0 | 0 | 28.9 |
| Zinc | | | |
| Zn _(g) | 130.7 | 95.2 | 160.9 |
| Zn _(s) | 0 | 0 | 41.63 |
| ZnCl _{2(s)} | -415.1 | -369.4 | 111.5 |
| ZnO _(s) | -348.0 | -318.2 | 43.9 |