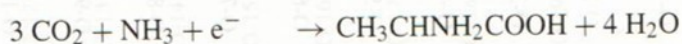


Table 2.2 Inorganic half-reactions and their Gibb's standard free energy at pH = 7.0

Reaction Number	Reduced-oxidized Compounds	Half-reaction	$\Delta G^{0'}$ kJ/e ⁻ eq
I-1	Ammonium-Nitrate:	$\frac{1}{8} \text{NO}_3^- + \frac{5}{4} \text{H}^+ + \text{e}^- = \frac{1}{8} \text{NH}_4^+ + \frac{3}{8} \text{H}_2\text{O}$	-35.11
I-2	Ammonium-Nitrite:	$\frac{1}{6} \text{NO}_2^- + \frac{4}{3} \text{H}^+ + \text{e}^- = \frac{1}{6} \text{NH}_4^+ + \frac{1}{3} \text{H}_2\text{O}$	-32.93
I-3	Ammonium-Nitrogen:	$\frac{1}{6} \text{N}_2 + \frac{4}{3} \text{H}^+ + \text{e}^- = \frac{1}{3} \text{NH}_4^+$	26.70
I-4	Ferrous-Ferric:	$\text{Fe}^{3+} + \text{e}^- = \text{Fe}^{2+}$	-74.27
I-5	Hydrogen-H ⁺ :	$\text{H}^+ + \text{e}^- = \frac{1}{2} \text{H}_2$	39.87
I-6	Nitrite-Nitrate:	$\frac{1}{2} \text{NO}_3^- + \text{H}^+ + \text{e}^- = \frac{1}{2} \text{NO}_2^- + \frac{1}{2} \text{H}_2\text{O}$	-41.65
I-7	Nitrogen-Nitrate:	$\frac{1}{5} \text{NO}_3^- + \frac{6}{5} \text{H}^+ + \text{e}^- = \frac{1}{10} \text{N}_2 + \frac{3}{5} \text{H}_2\text{O}$	-72.20
I-8	Nitrogen-Nitrite:	$\frac{1}{3} \text{NO}_2^- + \frac{4}{3} \text{H}^+ + \text{e}^- = \frac{1}{6} \text{N}_2 + \frac{2}{3} \text{H}_2\text{O}$	-92.56
I-9	Sulfide-Sulfate:	$\frac{1}{8} \text{SO}_4^{2-} + \frac{19}{16} \text{H}^+ + \text{e}^- = \frac{1}{16} \text{H}_2\text{S} + \frac{1}{16} \text{HS}^- + \frac{1}{2} \text{H}_2\text{O}$	20.85
I-10	Sulfide-Sulfite:	$\frac{1}{6} \text{SO}_3^{2-} + \frac{5}{4} \text{H}^+ + \text{e}^- = \frac{1}{12} \text{H}_2\text{S} + \frac{1}{12} \text{HS}^- + \frac{1}{2} \text{H}_2\text{O}$	11.03
I-11	Sulfite-Sulfate:	$\frac{1}{2} \text{SO}_4^{2-} + \text{H}^+ + \text{e}^- = \frac{1}{2} \text{SO}_3^{2-} + \frac{1}{2} \text{H}_2\text{O}$	50.30
I-12	Sulfur-Sulfate:	$\frac{1}{6} \text{SO}_4^{2-} + \frac{4}{3} \text{H}^+ + \text{e}^- = \frac{1}{6} \text{S} + \frac{2}{3} \text{H}_2\text{O}$	19.15
I-13	Thiosulfate-Sulfate:	$\frac{1}{4} \text{SO}_4^{2-} + \frac{5}{4} \text{H}^+ + \text{e}^- = \frac{1}{8} \text{S}_2\text{O}_3^{2-} + \frac{5}{8} \text{H}_2\text{O}$	23.58
I-14	Water-Oxygen:	$\frac{1}{4} \text{O}_2 + \text{H}^+ + \text{e}^- = \frac{1}{2} \text{H}_2\text{O}$	-78.72

→ 89 COO/e⁻ eq.

Step 4 Balance the oxygen through addition or subtraction of water. Elemental oxygen is not to be used here, as oxygen must not have its oxidation state changed.



Step 5 Balance hydrogen by introducing H⁺.



Table 2.3 Organic half-reactions and their Gibb's free energy

Reaction Number	Reduced Compounds	Half-reaction	ΔG^0 kJ/e ⁻ eq
O-1	Acetate:	$\frac{1}{8} \text{CO}_2 + \frac{1}{8} \text{HCO}_3^- + \text{H}^+ + \text{e}^-$ = $\frac{1}{8} \text{CH}_3\text{COO}^- + \frac{3}{8} \text{H}_2\text{O}$	27.40
O-2	Alanine:	$\frac{1}{6} \text{CO}_2 + \frac{1}{12} \text{HCO}_3^- + \frac{1}{12} \text{NH}_4^+ + \frac{11}{12} \text{H}^+ + \text{e}^-$ = $\frac{1}{12} \text{CH}_3\text{CHNH}_2\text{COO}^- + \frac{5}{12} \text{H}_2\text{O}$	31.37
O-3	Benzoate:	$\frac{1}{5} \text{CO}_2 + \frac{1}{30} \text{HCO}_3^- + \text{H}^+ + \text{e}^-$ = $\frac{1}{30} \text{C}_6\text{H}_5\text{COO}^- + \frac{13}{30} \text{H}_2\text{O}$	27.34
O-4	Citrate:	$\frac{1}{6} \text{CO}_2 + \frac{1}{6} \text{HCO}_3^- + \text{H}^+ + \text{e}^-$ = $\frac{1}{18} (\text{COO}^-)\text{CH}_2\text{COH}(\text{COO}^-)\text{CH}_2\text{COO}^- + \frac{4}{9} \text{H}_2\text{O}$	33.08
O-5	Ethanol:	$\frac{1}{6} \text{CO}_2 + \text{H}^+ + \text{e}^-$ = $\frac{1}{12} \text{CH}_3\text{CH}_2\text{OH} + \frac{1}{4} \text{H}_2\text{O}$	31.18
O-6	Formate:	$\frac{1}{2} \text{HCO}_3^- + \text{H}^+ + \text{e}^-$ = $\frac{1}{2} \text{HCOO}^- + \frac{1}{2} \text{H}_2\text{O}$	39.19
O-7	Glucose:	$\frac{1}{4} \text{CO}_2 + \text{H}^+ + \text{e}^-$ = $\frac{1}{24} \text{C}_6\text{H}_{12}\text{O}_6 + \frac{1}{4} \text{H}_2\text{O}$	41.35
O-8	Glutamate:	$\frac{1}{6} \text{CO}_2 + \frac{1}{9} \text{HCO}_3^- + \frac{1}{18} \text{NH}_4^+ + \text{H}^+ + \text{e}^-$ = $\frac{1}{18} \text{COOHCH}_2\text{CH}_2\text{CHNH}_2\text{COO}^- + \frac{4}{9} \text{H}_2\text{O}$	30.93
O-9	Glycerol:	$\frac{3}{14} \text{CO}_2 + \text{H}^+ + \text{e}^-$ = $\frac{1}{14} \text{CH}_2\text{OHCHOHCH}_2\text{OH} + \frac{3}{14} \text{H}_2\text{O}$	38.88
O-10	Glycine:	$\frac{1}{6} \text{CO}_2 + \frac{1}{6} \text{HCO}_3^- + \frac{1}{6} \text{NH}_4^+ + \text{H}^+ + \text{e}^-$ = $\frac{1}{6} \text{CH}_2\text{NH}_2\text{COOH} + \frac{1}{2} \text{H}_2\text{O}$	39.80

O-11	Lactate:	$\frac{1}{6} \text{CO}_2 + \frac{1}{12} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{12} \text{CH}_3\text{CHOHCOO}^- + \frac{1}{3} \text{H}_2\text{O}$	32.29
O-12	Methane:	$\frac{1}{8} \text{CO}_2 + \text{H}^+ + e^-$	$= \frac{1}{8} \text{CH}_4 + \frac{1}{4} \text{H}_2\text{O}$	23.53
O-13	Methanol:	$\frac{1}{6} \text{CO}_2 + \text{H}^+ + e^-$	$= \frac{1}{6} \text{CH}_3\text{OH} + \frac{1}{6} \text{H}_2\text{O}$	36.84
O-14	Palmitate:	$\frac{15}{19} \text{CO}_2 + \frac{1}{92} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{92} \text{CH}_3(\text{CH}_2)_{14}\text{COO}^- + \frac{31}{92} \text{H}_2\text{O}$	27.26
O-15	Propionate:	$\frac{1}{7} \text{CO}_2 + \frac{1}{14} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{14} \text{CH}_3\text{CH}_2\text{COO}^- + \frac{5}{14} \text{H}_2\text{O}$	27.63
O-16	Pyruvate:	$\frac{1}{5} \text{CO}_2 + \frac{1}{10} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{10} \text{CH}_3\text{COCO}_2^- + \frac{2}{5} \text{H}_2\text{O}$	35.09
O-17	Succinate:	$\frac{1}{7} \text{CO}_2 + \frac{1}{7} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{14} (\text{CH}_2)_2(\text{COO}^-)_2 + \frac{3}{7} \text{H}_2\text{O}$	29.09
O-18	Domestic Wastewater:	$\frac{9}{50} \text{CO}_2 + \frac{1}{50} \text{NH}_4^+ + \frac{1}{50} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{50} \text{C}_{10}\text{H}_{19}\text{O}_3\text{N} + \frac{9}{25} \text{H}_2\text{O}$	*
O-19	Custom Organic Half Reaction:	$\frac{(n-c)}{d} \text{CO}_2 + \frac{c}{d} \text{NH}_4^+ + \frac{c}{d} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{d} \text{C}_n\text{H}_a\text{O}_b\text{N}_c + \frac{2n-b+c}{d} \text{H}_2\text{O}$	*
O-20	Cell Synthesis:	$\frac{1}{5} \text{CO}_2 + \frac{1}{20} \text{NH}_4^+ + \frac{1}{20} \text{HCO}_3^- + \text{H}^+ + e^-$	$= \frac{1}{20} \text{C}_5\text{H}_7\text{O}_2\text{N} + \frac{9}{20} \text{H}_2\text{O}$	*

where, $d = (4n + a - 2b - 3c)$

* Equations O-18 to O-20 do not have ΔG^0 values because the reduced species is not chemically defined.