* page 474 Table 8.7 Reduction & Oxidation Reactions That may be combined To result in Biologically mediated exergonic processes (pH=7) *

Example	a. REDUCTION Reaction b. OXIDATION Reaction	$\Delta G^\circ(w)$ pH=7 (KJ eq^{-1})	ΔG° pH=7 (Kcal / equiv.)
Aerobic Respiration	a. $\frac{1}{4} O_2(g) + H^+(w) + e^- = \frac{1}{2} H_2O$ b. $\frac{1}{4} CH_2O + \frac{1}{4} H_2O = \frac{1}{4} CO_2(g) + H^+(w) + e^-$	-125	-29.9
Denitrification	a. $\frac{1}{5} NO_3^- + \frac{6}{5} H^+(w) + e^- = \frac{1}{10} N_2(g) + \frac{3}{5} H_2O$ b. $\frac{1}{4} CH_2O + \frac{1}{4} H_2O = \frac{1}{4} CO_2(g) + H^+(w) + e^-$	-119	-28.4
Nitrate Reduction	a. $\frac{1}{8} NO_3^- + \frac{5}{4} H^+(w) + e^- = \frac{1}{8} NH_4^+ + \frac{3}{8} H_2O$ b. $\frac{1}{4} CH_2O + \frac{1}{4} H_2O = \frac{1}{4} CO_2(g) + H^+(w) + e^-$	-82	-19.6
N Fixation	a. $\frac{1}{6} N_2 + \frac{4}{3} H^+(w) + e^- = \frac{1}{3} NH_4^+$ b. $\frac{1}{4} CH_2O + \frac{1}{4} H_2O = \frac{1}{4} CO_2(g) + H^+(w) + e^-$	-20	-4.8
Nitrification	a. $\frac{1}{4} O_2(g) + H^+(w) + e^- = \frac{1}{2} H_2O$ b. $\frac{1}{8} NH_4^+ + \frac{3}{8} H_2O = \frac{1}{8} NO_3^- + \frac{5}{4} H^+(w) + e^-$	-43	-10.3

↙ Figure 8.4 pg 477

Denitrification

unBalanced Reaction: $\frac{1}{5}NO_3^- + \frac{5}{4}H^+(w) + e^- = \frac{1}{10}N_2(g) + \frac{3}{5}H_2O$

Balanced Reaction: $2\,NO_3^- + \frac{50}{4}H^+(w) + 10e^- = N_2(g) + 6H_2O$

$$\text{denit Rate}\left[\frac{mg\cdot N}{m^2\cdot hR}\right] \cdot \underset{PH=7}{\Delta G^\circ}\left[\frac{-119\ KJ}{equiv.\ e^-}\right] \cdot \frac{10e^-}{FULL\ RXN} \cdot \frac{1\ g\cdot N}{1000\ mg\cdot N} \cdot \frac{1\ mol N}{14\ g\ N} \cdot \frac{1\ ^{FULL\ RXN}}{2\ mol N}$$

$$= \frac{KJ\ PRODUCED}{m^2\cdot hR}$$

RATE OF ENERGY PRODUCTION FROM DENITRIFICATION

↑ CONVERT UNITS OF RATE

ALTERNATIVELY, CAN USE:

$$\underset{PH=7}{\Delta G^\circ}\left[-28.4\ \frac{KCal}{equiv.\ e^-}\right]$$

AEROBIC RESPIRATION

ER RATE $\left[\frac{g\text{-}O_2}{m^2 \cdot day}\right]$

UNBALANCED REACTION: $\frac{1}{4} O_2(g) + H^+(w) + e^- = \frac{1}{2} H_2O$

BALANCED REACTION: $O_2(g) + 4H^+(w) + 4e^- = 2H_2O$

$$\hookrightarrow \cdot \underbrace{\Delta G^\circ_{PH=7}\left[\frac{-125\ KJ}{equiv.\ e^-}\right]}_{\text{alternatively, } \Delta G_{PH=7}\left[\frac{-29.9\ Kcal}{equiv.\ e^-}\right]} \cdot \frac{4\ e^-}{FULL\ RXN} \cdot \frac{2\ mol\ O_2}{32\ g\ O_2} \cdot \frac{1\ FULL\ RXN}{1\ mol\ O_2} = \underbrace{\frac{KJ\ PROD.}{m^2 \cdot day}}_{\text{RATE OF ENERGY PROD. FROM AEROBIC RESPIR.}}$$

$$\underbrace{\frac{KJ\ PROD}{m^2 \cdot day} \cdot \frac{1\ day}{24\ hRS}}_{\text{not SURE IF this scaling is Reasonable.}} = \frac{KJ\ PROD}{m^2 \cdot hR}$$

NITRIFICATION

UNBALANCED RXN: $\frac{1}{8}NH_4^+ + \frac{3}{8}H_2O = \frac{1}{8}NO_3^- + \frac{5}{4}H^+(w) + e^-$

BALANCED RXN: $NH_4^+ + 3H_2O = NO_3^- + 10H^+(w) + 8e^-$

$$\text{nitrif RATE}\left[\frac{mg\ N}{m^2 \cdot hR}\right] : \underset{pH=7}{\Delta G^\circ}\left[\frac{-43\ KJ}{equiv\ e^-}\right] \cdot \frac{8\ e^-}{FULL\ RXN} \cdot \frac{1\ gN}{1000\ mgN} \cdot \frac{1\ molN}{14\ gN} \cdot \frac{1\ \overset{FULL}{RXN}}{1\ mol\ N}$$

OR $\underset{pH7}{\Delta G^\circ}\left[\frac{-10.3\ kcal}{equiv\ e^-}\right]$

NITROGEN FIXATION

UNBALANCED REACTION: $\frac{1}{6}N_2 + \frac{4}{3}H^+(w) + e^- = \frac{1}{3}NH_4^+$

BALANCED REACTION: $N_2 + 8H^+(w) + 6e^- = 2NH_4^+$

$$N_2 \text{ Fix Rate}\left[\frac{mg\text{-}N}{m^2 \cdot hR}\right] = \underset{pH=7}{\Delta G^\circ}\left[\frac{-20\ KJ}{equiv\ e^-}\right] \cdot \frac{6\ e^-}{FULL\ RXN} \cdot \frac{1\ gN}{1000\ mg\text{-}N} \cdot \frac{1\ mol N}{14\ g\ N} \cdot \frac{1\ FULL\ RXN}{2\ mol\ N} = \frac{KJ\ PROD.}{m^2 \cdot hR}$$

OR

$$\underset{pH=7}{\Delta G^\circ}\left[\frac{-4.8\ Kcal}{equiv.\ e^-}\right]$$

Table 8.7. Reduction and Oxidation Reactions that May Be Combined to Result in Biologically Mediated Exergonic Processes (pH = 7)

Reduction	$p\varepsilon^\circ(W) = \log K(W)$	Oxidation	$p\varepsilon^\circ(W) = -\log K(W)$
(A) $\frac{1}{4}O_2(g) + H^+(W) + e^- = \frac{1}{2}H_2O$	+13.75	(L) $\frac{1}{4}CH_2O + \frac{1}{4}H_2O = \frac{1}{4}CO_2(g) + H^+(W) + e^-$	−8.20[a]
(B) $\frac{1}{5}NO_3^- + \frac{6}{5}H^+(W) + e^- = \frac{1}{10}N_2(g) + \frac{3}{5}H_2O$	+12.65	(L-1) $\frac{1}{2}HCOO^- = \frac{1}{2}CO_2(g) + \frac{1}{2}H^+(W) + e^-$	−8.73
(C) $\frac{1}{2}MnO_2(s) + \frac{1}{2}HCO_3^-\ (10^{-3}) + \frac{3}{2}H^+(W) + e^- = \frac{1}{2}MnCO_3(s) + H_2O$	+8.9	(L-2) $\frac{1}{2}CH_2O + \frac{1}{2}H_2O = \frac{1}{2}HCOO^- + \frac{3}{2}H^+(W) + e^-$	−7.68
(D) $\frac{1}{8}NO_3^- + \frac{5}{4}H^+(W) + e^- = \frac{1}{8}NH_4^+ + \frac{3}{8}H_2O$	+6.15	(L-3) $\frac{1}{2}CH_3OH = \frac{1}{2}CH_2O + H^+(W) + e^-$	−3.01
(E) $FeOOH(s) + HCO_3^-\ (10^{-3}) + 2H^+(W) + e^- = FeCO_3(s) + 2H_2O$	−0.8	(L-4) $\frac{1}{2}CH_4(g) + \frac{1}{2}H_2O = \frac{1}{2}CH_3OH + H^+(W) + e^-$	+2.88
(F) $\frac{1}{2}CH_2O + H^+(W) + e^- = \frac{1}{2}CH_3OH$	−3.01	(M) $\frac{1}{8}HS^- + \frac{1}{2}H_2O = \frac{1}{8}SO_4^{2-} + \frac{9}{8}H^+(W) + e^-$	−3.75
(G) $\frac{1}{8}SO_4^{2-} + \frac{9}{8}H^+(W) + e^- = \frac{1}{8}HS^- + \frac{1}{2}H_2O$	−3.75	(N) $FeCO_3(s) + 2H_2O = FeOOH(s) + HCO_3^-\ (10^{-3}) + 2H^+(W) + e^-$	−0.8
(H) $\frac{1}{8}CO_2(g) + H^+(W) + e^- = \frac{1}{8}CH_4(g) + \frac{1}{4}H_2O$	−4.13	(O) $\frac{1}{8}NH_4^+ + \frac{3}{8}H_2O = \frac{1}{8}NO_3^- + \frac{5}{4}H^+(W) + e^-$	+6.15
(J) $\frac{1}{6}N_2 + \frac{4}{3}H^+(W) + e^- = \frac{1}{3}NH_4^+$	−4.68	(P) $\frac{1}{2}MnCO_3(s) + H_2O = \frac{1}{2}MnO_2(s) + \frac{1}{2}HCO_3^-\ (10^{-3}) + \frac{3}{2}H^+(W) + e^-$	8.9

Examples	*Combinations*	$\Delta G^\circ(W)$ pH = 7 (kJ eq^{-1})
Aerobic respiration	A + L	−125
Denitrification	B + L	−119
Nitrate reduction	D + L	−82
Fermentation	F + L	−27
Sulfate reduction	G + L	−25
Methane fermentation	H + L	−23
N fixation	J + L	−20
Sulfide oxidation	A + M	−100
Nitrification	A + O	−43
Ferrous oxidation	A + N	−88
Mn(II) oxidation	A + P	−30

[a] CH_2O is used as a formula for an "average" organic substance. The free energy change involved with different specific organic substances may differ from that given for CH_2O. The difference may be large, especially in anoxic processes with substrates whose carbon has a different oxidation state than that in CH_2O.

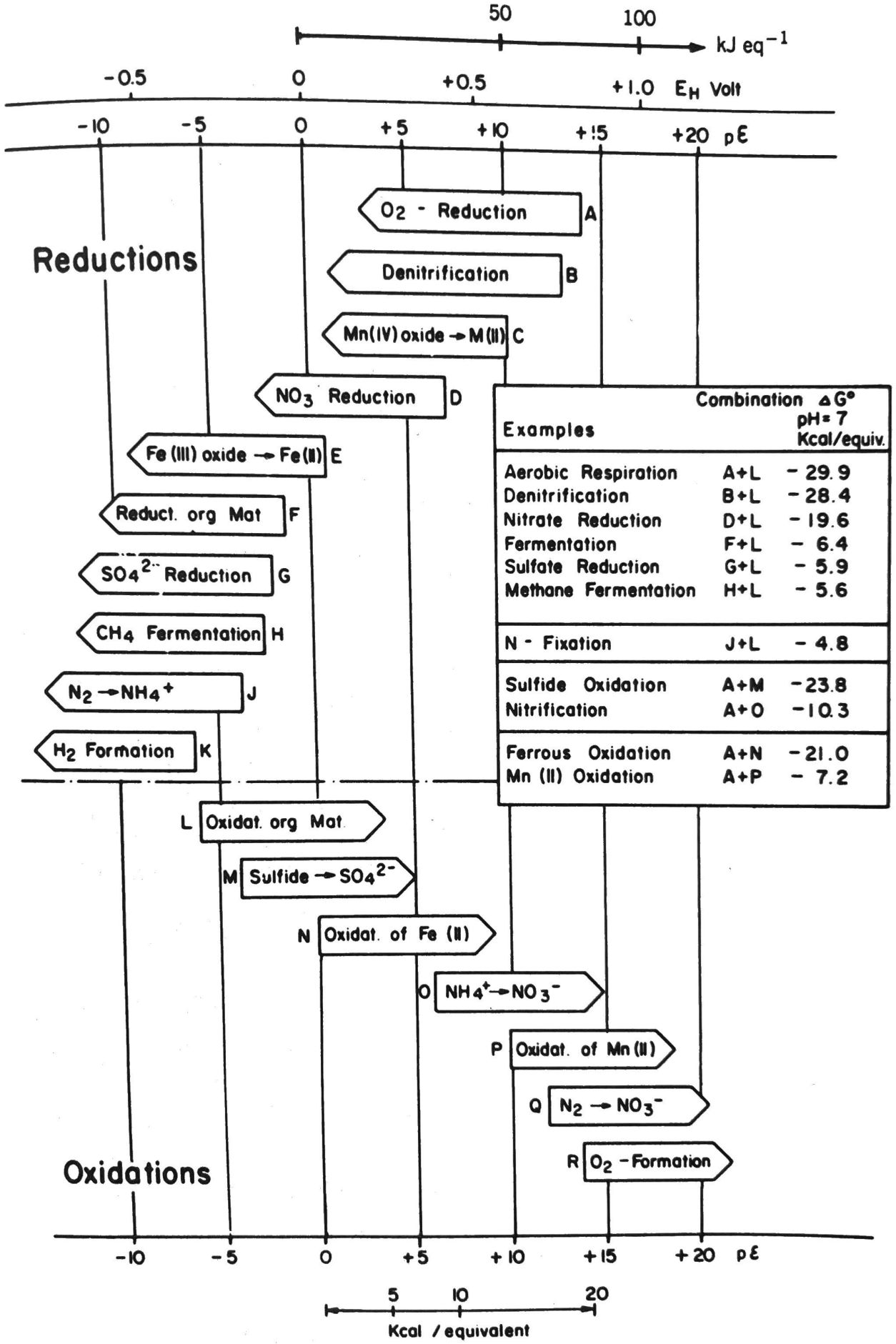

Figure 8.14. Sequence of microbially mediated redox processes. The letters refer to the reactions given in Table 8.7.