

**Standard potential 0.10166 V scale with water account of metallic Hydrogen RedOx Thermodynamic. Thermodynamic water account correct Nernst's and inverse equations for electrochemistry half reactions.**

When equilibrium is established reactant and product chemical potential sum is equal  $\mu_{\text{Red}} + nF = \mu_{\text{Ox}} + n\mu_{e^-}$

but each chemical compound chemical potential is:  $\mu = \Delta G^\circ_A + RT \ln(N_A)$ , where  $N_A$  is substance A

concentration (mol fraction).  $\Delta G^\circ$  is given compound A standard free energy of formation from elements.

Free energy change Hess law of formation for pure compounds from elements  $\Delta G^\circ_{\text{Ox}}$ ,  $\Delta G^\circ_{e^-}$  and  $\Delta G^\circ_{\text{Red}}$ .

In chemical equilibrium mixture  $\Delta G^\circ_{\text{Red}} + RT \ln(N_{\text{Red}}) + nF = \Delta G^\circ_{\text{Ox}} + RT \ln(N_{\text{Ox}}) + n\Delta G^\circ_{e^-} + RT \ln(N_{e^-}^n)$

Expressing E from equilibrium conditions of the chemical potentials  $\mu$ :

$$E = \frac{\Delta G^\circ_{\text{Ox}} + n\Delta G^\circ_{e^-} - \Delta G^\circ_{\text{Red}}}{nF} + \frac{RT}{nF} \cdot \ln \left( \frac{N_{\text{Ox}} \cdot N_{e^-}^n}{N_{\text{Red}}} \right) \text{ pure compound mol fraction is } N_A = 1.$$

Free electrons in separate phase (so called electron gas) of metal is just pure compound  $N_{e^-} = 1$  therefore

$$E = \frac{\Delta G^\circ_{\text{Ox}} + n\Delta G^\circ_{e^-} - \Delta G^\circ_{\text{Red}}}{nF} + \frac{RT}{nF} \cdot \ln N_{e^-}^n + \frac{RT}{nF} \cdot \ln \left( \frac{N_{\text{Ox}}}{N_{\text{Red}}} \right). \text{ As pure compound } \ln(N_{e^-}^n) = 0.$$

So standard potential  $E^\circ = \frac{\Delta G^\circ_{\text{Ox}} + n\Delta G^\circ_{e^-} - \Delta G^\circ_{\text{Red}}}{nF}$  give Prigogine attractor the minimum of free energy

change  $\Delta G_{\text{eq}}$  at equilibrium state smaller  $|E^\circ nF = \Delta G_{\text{eq}} = \Delta G^\circ_{\text{Ox}} + n\Delta G^\circ_{e^-} - \Delta G^\circ_{\text{Red}}| < |\Delta G_{\text{Hess}}|$  as pure Hess law.

**Conversion** to decimal logarithm and thermodynamic standard  $T=298,15$  K degree we have Nernst's

$$\text{equation for reaction of reactants: Reducing form} \rightleftharpoons \text{Ox}^{\Delta n^+} + n e^- \text{ Oxidising form } E = E^\circ + \frac{0.0591}{n} \cdot \lg \left( \frac{[\text{Ox}]}{[\text{Red}]} \right).$$

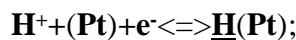
In reaction  $n e^-$  electron lose (left at metal) exert towards solution transfer  $\Delta n^+$  positively charged ions  $\text{Ox}^{\Delta n^+}$ .

Electrons  $n e^-$  leaves at metal electron gas. Such  $\Delta n^+$  positive charge entrance into solution as oxidised form

$\text{Ox}^{\Delta n^+}$  in products brings the chemical potential electrical part of negative electrons the energy  $n\Delta G^\circ_{e^-} = -nFE$ .

The water mass  $[\text{H}_2\text{O}] = 963/18 = 53.5$  M in  $[\text{H}_2\text{SO}_4] = [\text{H}_3\text{O}^+] = 1$  M disaccount solution with density 1.061 g/mL

in liter in Nernst equations for **hydrogen electrode** is classic standard potential reference zero  $E_0 = 0.0$  V:



$$E = E^\circ + 0.0591 \cdot \log K^\circ_{(\text{Pt})\text{H}} = 0.0 + 0.0591 \cdot \log [\text{H}^+] = 0.0 + 0.0591 \cdot \log(1 \text{ M}) = 0.0 \text{ Volts.}$$

Thermodynamic account Hydroxonium ions produce the water:  $\text{H}_3\text{O}^+ + (\text{Pt}) + e^- \rightleftharpoons \underline{\text{H}}(\text{Pt}) + \text{H}_2\text{O}$ .

The ratio  $[\text{H}_3\text{O}^+]/[\text{H}_2\text{O}] = 1/52,5 = X_{\text{H}_3\text{O}^+}/X_{\text{H}_2\text{O}}$  is mol fraction instead  $[\text{H}^+] = 1$  M classic zero  $E_0 = 0$  V, but with water account refers to thermodynamic standard potential  $E^\circ_{\text{H}} = 0,10166$  V.

Therefore classic measured in 1 M sulfuric acid potential is  $E = 0.0 + 0.0591 \cdot \log(1 \text{ M}) = 0$  Volts and with account the water-hydroxonium:  $E = E^\circ_{\text{H}^+} + \frac{\ln(10) \cdot R \cdot T}{F \cdot 1} \cdot \log \frac{X_{\text{H}_3\text{O}^+}}{X_{\text{H}_2\text{O}}} = E_0 + E^\circ_{\text{H}} + 0.0591 \cdot \log(1/52,5) = 0.10166 - 0.10166 = 0.0$  V.

Thermodynamic standard potential is  $E^\circ_{\text{H}} = 0.10166$  V, as ratio  $1 = K_{(\text{Pt})\text{H}} = \frac{X_{\text{H}_3\text{O}^+}}{X_{\text{H}_2\text{O}}}$  is one, than:

$$E = E^\circ_{\text{H}^+} + \frac{\ln(10) \cdot R \cdot T}{F \cdot 1} \cdot \log \frac{X_{\text{H}_3\text{O}^+}}{X_{\text{H}_2\text{O}}} = 0.10166 + 0.0591 \cdot \log(1) = 0.10166 \text{ V.}$$

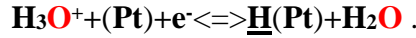
Hydroxonium reduction to metal  $\underline{\text{H}}(\text{Pt})$  hydrogen:  $\text{H}_3\text{O}^+ + (\text{Pt}) + e^- \rightleftharpoons \underline{\text{H}}(\text{Pt}) + \text{H}_2\text{O}$  free energy change is:

$\Delta G_{\text{eqRedH(Pt)}} = -E^\circ_{\text{H}} \cdot F \cdot 1 = -0.10166 \cdot 96485 \cdot 1/1000 = -9.81$  kJ/mol. Standard condition ratio one  $[\text{H}_3\text{O}^+]/[\text{H}_2\text{O}] = 1$

and standard reduction equilibrium constant is greater as one  $K_{(\text{Pt})\text{H_Red}} = [(\text{Pt})] \cdot [e^-] / [\text{H}(\text{Pt})] = 52,3$ :

$$K_{(\text{Pt})\text{H_Red}} = [\text{H}_3\text{O}^+] \cdot [(\text{Pt})] \cdot [e^-] / [\text{H}_2\text{O}] / [\text{H}(\text{Pt})] = \text{EXP}(-\Delta G_{\text{Alberty}}/R/T) = \text{EXP}(9809/8.3144/298.15) = 52.3;$$

I type electrode Metal interface  $(Pt)H$  / on its cation  $H_3O^+$  solution application.

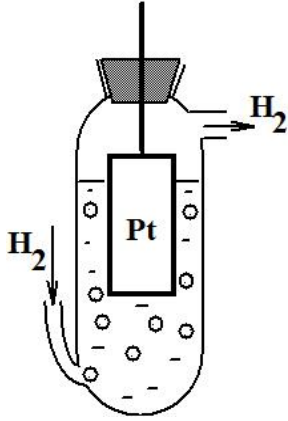


Hydroxonium reduction to metal  $\underline{H}(Pt)$   $\Delta G_{eq} = -E^{\circ}_H \cdot F \cdot 1 = -0.10166 \cdot 96485 \cdot 1 / 1000 = -9.81$  kJ/mol free energy change minimum on equilibrium referred to water and carbon dioxide gas zero scale  $G_{H_2O} = G_{CO_2(gas)} = G_{e^-} = 0$  kJ/mol.

[Alberty](#) values Hess law are close to  $H_3O^+$  reduction potential  $E^{\circ}_H = -0.10166$  V of energy  $\Delta G_{eq} = -9.81$  kJ/mol:

$$\Delta G_{Hess} = G_{H_2O} + G_{H(Pt)} - (G_{H_3O^+} + G_{(Pt)} + G_{e^-}) = 0 + 51,05 - (22,44 + 38,375 + 0) = -9,765 \text{ kJ/mol}$$

Platinum sheet immersed in hydroxonium ions  $[H^+] = [H_3O^+] = [H_2SO_4] = 1$  M sulfuric



acid solutions  $H^+ + (Pt) + e^- \rightleftharpoons \underline{H}(Pt)$ :  $E = E^{\circ} + 0.0591 \cdot \log[H^+] = 0.0 + 0.0591 \cdot \log(1 \text{ M}) = 0.0$  V is classic hydrogen reference scale zero. Account the water mass  $[H_2O] = 963/18 = 53.5$  M and ratio  $[H_3O^+]/[H_2O] = 1/52.5 = X_{H_3O^+}/X_{H_2O}$  give thermodynamic standard potential :instead

classic  $0.0$  and is  $E^{\circ}_H = E^{\circ} - 0.0591 \cdot \log([H_3O^+]/[H_2O]) = 0.0 - 0.0591 \cdot \log(1/52.5) = 0.10166$  V.

$$\text{classic } (E_{H/H^+} = -0,0591 \cdot pH \leq 0,00 \text{ V}) \quad 0,10166 \text{ V} \quad E, \text{V}$$

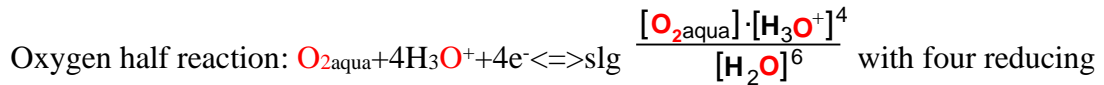
$$E_{(Pt)H/H^+} = E^{\circ}_H + 0.0591 \cdot \log\left(\frac{X_{H_3O^+}}{X_{H_2O}}\right)$$

High rate protolysis attractors  $[H_3O^+] = 10^{-7.36}$  M , pH=7.36 and water mass  $[H_2O] = 997/18 = 55.3$  M account in liter create metal hydrogen  $(Pt)H$  potential as strong reductant first **I type** electrode for electron transfer:

$$E_{pH=7,36} = 0,10166 + 0,0591 \cdot \log(10^{-7,36}/55,3) = -0,436 \text{ V}; \Delta G_{eqpH7,36} = E^{\circ}_H \cdot F \cdot 1 = -0,436 \cdot 96485 \cdot 1 / 1000 = -42,07 \text{ kJ/mol}$$

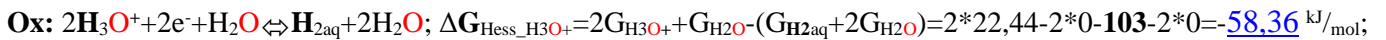
Thermodynamic standard potential  $E^{\circ}_H = 0.10166$  V is over classic zero, if hydroxonium concentration is one mol in litre  $[H_3O^+] = [H_2SO_4] = 1$  M and logarithm  $0.0591 \cdot \log(1/52.3) = -0.10166$  V instead pH=0 zero. Metall  $(Pt)H$  at pH=7,36 and  $[H_3O^+] = 10^{-7,36}$  M with potential  $E = 0,10166 + 0,0591 \cdot \log(10^{-(7,36)}/55,3) = -0,436$  V is strong reducing agent. In reaction free energy change and content in one mol (Pt)H metal are:

$$\Delta G_{eq} = E^{\circ}_H \cdot F \cdot 1 = -0,436 \cdot 96485 \cdot 1 / 1000 = -42,1 \text{ kJ/mol} \text{ and } G_{H(Pt)} = 51,05 \text{ kJ/mol} \text{ respectively. [8]}$$

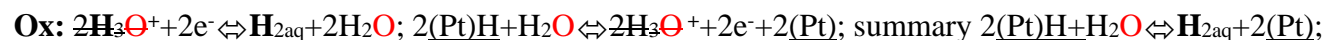
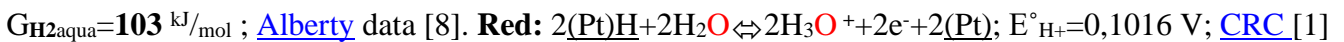


half reactions:  $4(Pt)H + 4H_2O \rightleftharpoons 4H_3O^+ + 4(Pt) + 4e^-$ ;  $E^{\circ}_H = 0.1016$  V give standard free energy change minimum  $\Delta G_{eq} = (E^{\circ}_H - E^{\circ}_{O_2}) \cdot F \cdot 1 \cdot 4 = (0.10166 - 1.485) \cdot 96485 \cdot 4 = -1.38334 \cdot 96485 \cdot 4 / 1000 = -533.9$  kJ/mol =  $2 \cdot -266.94$  kJ/mol of water formation  $O_{2(aqua)} + 4(Pt)H \Rightarrow 2H_2O$  from elements free energy content  $G_{H(Pt)} = 51$  kJ/mol ,  $G_{O_2(aq)} = 329.68$  kJ/mol:

Equilibrium value  $\Delta G_{eq2H_2O} = 2G_{H_2O} - 4G_{(Pt)H} - G_{O_2(aqua)} = 2 \cdot 0 - (4 \cdot 51,05 + 329,68) = -533,9 = 2 \cdot -266,94$  kJ/mol expresses metal free energy  $G_{H(Pt)} = (2G_{H_2O} - \Delta G_{eq2H_2O} - G_{O_2(aqua)}) / 4 = (2 \cdot 0 + 533,886 - 329,68) / 4 = 204,2 / 4 = 51,05$  kJ/mol .



Graphite electrode oxidizes hydrogen liberate (Pt) lattice  $E^{\circ}_{H_3O^+} = -58,36 \cdot 1000 / 96485 / 2 = -0,302$  V.



$$\Delta E^{\circ}_{eqH_3O^+(Pt)H} = 0,10166 + 0,302 = 0,40366 \text{ V}; \Delta G_{eqH_3O^+(Pt)H} = \Delta E^{\circ}_{eqH_3O^+(Pt)H} \cdot F \cdot 2 = 0,40366 \cdot 96485 \cdot 2 = 77,89 \text{ kJ/mol};$$

$$\Delta G_{eqH_3O^+(Pt)H} = G_{H_{2(aq)}} + 2G_{(Pt)} + G_{H_2O} - 2G_{H(Pt)} = 103 + 2 \cdot G_{(Pt)} + 0 - 2 \cdot 51,05 = 77,89 \text{ kJ/mol}$$

Platinum crystal lattice energy  $G_{(Pt)}$  is calculated using [Alberty](#) data [8] and Hess law  $\Delta G_{Hess\_sp\_Pt} = 77,89$  kJ/mol:

$$2G_{(Pt)} = \Delta G_{eqH_3O^+(Pt)H} - G_{H_{2(aq)}} + 2G_{H(Pt)} = 77,89 - 103,24 + 2 \cdot 51,05 = 76,75 = 2 \cdot 38,375 \text{ kJ/mol} \text{ for lattice } G_{(Pt)} = 38,375 \text{ kJ/mol};$$

Solubility energy  $O_{2\text{gas AIR}} + H_2O \xrightarrow{\text{Aquaporins}} O_{2\text{aq}}$  increases to products about  $G_{O_{2\text{sp}}} = 26,58 \text{ kJ/mol}$ :

$$[O_{2\text{aq}}]/[O_{2\text{gas AIR}}]/[H_2O] = K_{\text{sp}} = 2,205 \cdot 10^{-5}. G_{O_{2\text{sp}}} = -R \cdot T \cdot \ln(K_{\text{sp}}) = -8,3144 \cdot 298,15 \cdot \ln(2,205 \cdot 10^{-5}) = 26,58 \text{ kJ/mol}.$$

$$O_{2\text{aqua}} + 2H_{2\text{aqua}} \Rightarrow 2H_2O; \Delta G_{\text{Hess}H_2O\text{aqua}} = (2G_{H_2O} - (2G_{H_{2\text{aqua}}} + G_{O_{2\text{aqua}}})) / 2 = (2 \cdot 0 - (2 \cdot 103 + 330)) / 2 = -268 \text{ kJ/mol};$$

$$O_{2\text{gas}} + 2H_{2\text{gas}} \Rightarrow 2H_2O; \Delta G_{\text{Hess}H_2O\text{BioChem}} = (2G_{H_2O} - (2G_{H_{2\text{gas}}} + G_{O_{2\text{gas}}})) / 2 = (0 - (2 \cdot 85,64 + 303)) / 2 = -237.19 \text{ kJ/mol} [8]$$

$$G_{O_{2\text{gas}}}/2 = G_{H_2O} - (\Delta G_{\text{Hess}H_2O} + G_{H_{2\text{gas}}}) = 0 - (-237.19 + 85.64) = 151.55 \text{ kJ/mol}; G_{O_{2\text{gas}}} = 2 \cdot 151.55 = 303 \text{ kJ/mol}; \text{Alberty} [1,8]$$

$$H_{2\text{gas}} + H_2O \Rightarrow H_{2\text{aq}}; \text{Solubility in distilled water } \Delta G_{H_{2\text{sp}}\text{Alberty}} = G_{H_{2\text{aq}}} - G_{H_{2\text{gas}}} - G_{H_2O} = 103,24 - 85,64 - 0 = 17,6 \text{ kJ/mol} [8]:$$

$$[H_{2\text{aq}}]/[H_{2\text{gas}}]/[H_2O] = K_{\text{sp}} = \text{EXP}(-\Delta G_{H_{2\text{sp}}\text{Alberty}}/R/T) = \text{EXP}(-17600/8,3144/298,15) = 0,0008253. [8] \text{ Alberty}$$

$$[H_{2\text{aq}}] = K_{\text{sp}} \cdot [H_2O] = 0,0008253 \cdot 55,3 = 0,004564 \text{ M, if } H_{2\text{gas}} \text{ pure gas mol fraction is one } [H_{2\text{gas}}] = 1.$$

$$\text{BioChemistry medium solubility } \Delta G_{H_{2\text{sp}}\text{Biochemistry}} = G_{H_{2\text{aq}}} - G_{H_{2\text{gas}}} - G_{H_2O\text{Biochemistry}} = 103,24 - 85,64 - 85,6 = -68 \text{ kJ/mol} :$$

$$[H_{2\text{aq}}]/[H_{2\text{gas}}]/[H_2O] = K_{\text{sp}} = \text{EXP}(-\Delta G_{H_{2\text{sp}}\text{Biochemistry}}/R/T) = \text{EXP}(68000/8,3144/298,15) = 10^{11,9}. [8] \text{ Alberty}$$

$$[H_{2\text{aq}}] = K_{\text{sp}\text{Biochemistry}} \cdot [H_2O] = 10^{11,9} \cdot 55,3 = 10^{13,6} \text{ M, if } H_{2\text{gas}} \text{ pure gas mol fraction is one } [H_{2\text{gas}}] = 1.$$

Hydrogen solubility in platinum crystal lattice :  $H_{2\text{aq}} + 2(\text{Pt}) \Leftrightarrow 2(\text{Pt})\text{H} + H_2O$ ; Hess free energy change calculate from [Alberty RA.](#) [8] data of Biochemistry Thermodynamic :

$$\Delta G_{\text{Hess\_sp(Pt)H}} = 2G_{\text{H(Pt)}} + G_{H_2O} - (G_{H_{2\text{aq}}} + 2G_{(\text{Pt})}) = 2 \cdot 51,05 + 0 - (103,24 + 2 \cdot 38,375) = -77,89 \text{ kJ/mol } 54^{\text{th}} \text{ page.}'$$

Hydrogen solubility in (Pt) crystal lattice is spontaneous, because solubility constant is grate as one :

$$K_{\text{sp(Pt)H}} = [H_2O] \cdot [(\text{Pt})\text{H}]^2 / [H_{2\text{aq}}] \cdot [(\text{Pt})]^2 = \text{EXP}(-\Delta G_{(\text{Pt)H}}/R/T) = \text{EXP}(77890/8,3144/298,15) = 4,42 \cdot 10^{13}. [8]$$

$2(\text{Pt})\text{H} + H_2O \Leftrightarrow H_{2\text{aq}} + 2(\text{Pt})$ ; Metal hydrogen is weak soluble non spontaneous and constant smaller about one:

$$\Delta G_{\text{Hess\_spH2}} = G_{H_{2\text{aq}}} + 2G_{(\text{Pt})} - (2G_{\text{H(Pt)}} + G_{H_2O}) = 103,24 + 2 \cdot 38,375 - (2 \cdot 51,05 + 0) = 77,89 \text{ kJ/mol} . [8]$$

$$K_{\text{sp(Pt)H}} = [H_{2\text{aq}}] \cdot [(\text{Pt})]^2 / [H_2O] \cdot [(\text{Pt})\text{H}]^2 = \text{EXP}(-\Delta G_{(\text{Pt)H}}/R/T) = \text{EXP}(-77890/8,3144/298,15) = 2,26 \cdot 10^{-14}. [8]$$

Saturated metallic hydrogen mol fraction is  $[(\text{Pt})\text{H}]/[(\text{Pt})] = 24839$ . Metallic hydrogen (Pt)H solubility

$$2(\text{Pt})\text{H} + H_2O \Leftrightarrow H_{2\text{aq}} + 2(\text{Pt}); \text{ is small: } [H_{2\text{aq}}] = K_{\text{sp}} \cdot [H_2O] = 2,26 \cdot 10^{(-14)} \cdot 55,3 = 1,25 \cdot 10^{-12} \text{ M.}$$

$H_{2\text{gas}} + H_2O \Rightarrow H_{2\text{aq}}$ ; Solubility in 100 grams distilled water  $0,000155 \text{ g}/100\text{g}_{H_2O}$ , density  $0,996 \text{ g/L}$ , concentration is  $[H_{2\text{aq}}] = 0,000155/2/100,000155 \cdot 996 = 0,0007719 \text{ M}$ , [1] CRC

$$\text{solubility product } K_{\text{spCRC}} = [H_{2\text{aq}}]/[H_2O] = 0,0007719/55,3 = 0,000013958 ,$$

$$\text{free energy change } \Delta G_{\text{spCRC}} = -R \cdot T \cdot \ln(K_{\text{pCRC}}) = -8,3144 \cdot 298,15 \cdot \ln(0,000013958) = 27,7 \text{ kJ/mol}.$$

Platinum crystal lattes hydrogen saturated keep solubility in water  $[H_{2\text{aq}}] = 1,25 \cdot 10^{(-12)} \text{ M}$  concentration times less even  $0,0007719 \text{ M}$  and in Biochemical  $G_{H_2O\text{Biochemistry}} = 85,6 \text{ kJ/mol}$  medium. That respond to hydrogen gas mol fraction at least  $[H_{2\text{gas}}] = 0,0007719 \text{ M}/4,42/10^{(-12)} \text{ M} = 1,75 \cdot 10^8$ .

It is enough for platinum saturation with mol fraction one  $[(\text{Pt})\text{H}] = 1$ .

Classic measured potential  $E_{(\text{Pt})\text{H}} = E_{o(\text{Pt})\text{H}} + \log([H_3O^+]) = 0 - 0,0591/1 \cdot \log(1) = 0 \text{ V}$  at  $\text{pH} = -\log([H_3O^+]) = -\log(1) = 0$ ;

Thermodynamic measured  $E_{o(\text{Pt})\text{H}} = E_{oH_2O} + 0,0591/1 \cdot \log([H_3O^+]/[H_2O]) = 0,10166 + 0,0591/1 \cdot \log(1/52,5) = 0 \text{ V}$ .

Glucose thermodynamic standard potential  $E^\circ_{C_6H_{12}O_6} = 0,259 \text{ V}$  minus water  $0,0591/24 \cdot \log(1/[H_2O]^{42})$  account and minus reference scale point  $E^\circ_{(\text{Pt})\text{H}} = 0,10166 \text{ V}$  is classic standard potential  $E_{oC_6H_{12}O_6} = -0,0229 \text{ V}$  :

$$E_{oC_6H_{12}O_6} = E^\circ_{C_6H_{12}O_6} - 0,10166 + 0,0591/24 \cdot \log(1/[H_2O]^{42}) = 0,259 - 0,10166 + 0,0591/24 \cdot \log(1/55,3^{42}) = -0,0229 \text{ V.}$$

See in Table 1. and Table 2. [1-24]

Standard Electrode Potentials E<sub>o</sub> hydrogen (Pt)H zero and Thermodynamic reference 0.10166 Volts

Element	Reactants reduced form	Oxidized form products	Number + e <sup>-</sup>	Water disaccount classic zero E <sub>o</sub>	Water account + zero E <sub>oH2O</sub>	Thermodynamic scale 0.10166 V	
<b>H</b>	(Pt)H + H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup> + (Pt)+	1	classic zero <b>0</b>	0.103	<b>0.10166</b>	
	(Pt)H + OH <sup>-</sup>	H <sub>2</sub> O + (Pt)+	1	-0,828	-0,931	-0,829	
	H <sub>2aq</sub> +2H <sub>2</sub> O	2H <sub>3</sub> O <sup>+</sup> graphite	2	-0,096	-0,199	-0,301	
<b>O</b>	6H <sub>2</sub> O	O <sub>2</sub> <sup>(g)</sup> + 4 H <sub>3</sub> O <sup>+</sup>	4	1,229	1,383	1,485	
	H <sub>2</sub> O <sub>2</sub> + 2 H <sub>2</sub> O	O <sub>2</sub> <sup>2-</sup> aqua + 2 H <sub>3</sub> O <sup>+</sup>	1	1,276	1,379	1,481	
	4H <sub>2</sub> O	H <sub>2</sub> O <sub>2</sub> + 2 H <sub>3</sub> O <sup>+</sup>	2	1,776	1,982	2,084	
	H <sub>2</sub> O <sub>2</sub> + 2 H <sub>2</sub> O	O <sub>2aq</sub> + 2 H <sub>3</sub> O <sup>+</sup>	2	0,695	0,798	0,900	
<b>N</b>	NO <sub>2</sub> <sup>-</sup> + 2OH <sup>-</sup>	NO <sub>3</sub> <sup>-</sup> + H <sub>2</sub> O	2	0,010	-0,041	0,060	
	NO <sub>2</sub> + 3 H <sub>2</sub> O	NO <sub>3</sub> <sup>-</sup> + 2 H <sub>3</sub> O <sup>+</sup>	2	0,940	1,094	1,196	
	NO(g) + 2H <sub>2</sub> O	NO <sub>3</sub> <sup>-</sup> + 4H <sup>+</sup>	3	0,960	1,140	1,242	
	NH <sub>3</sub> + 9OH <sup>-</sup>	NO <sub>3</sub> <sup>-</sup> + 6H <sub>2</sub> O	8	-0,120	-0,197	-0,096	
<b>Br</b>	2Br <sup>-</sup>	Br <sub>2</sub>	2	1,087	1,087	1,189	
<b>Bi</b>	Bi <sup>3+</sup> + 9 H <sub>2</sub> O	BiO <sub>3</sub> <sup>-</sup> + 6 H <sub>3</sub> O <sup>+</sup>	2	1,800	2,263	2,365	
<b>Mn(H<sup>+</sup>)</b>	Mn <sup>2+</sup> + 12H <sub>2</sub> O	MnO <sub>4</sub> <sup>2-</sup> + 8 H <sub>3</sub> O <sup>+</sup>	5	1,510	1,760	1,860	
	(H <sub>2</sub> O) MnO <sub>2</sub> + 4OH <sup>-</sup>	MnO <sub>4</sub> <sup>-</sup> + 2H <sub>2</sub> O	3	0,600	0,531	0,633	
	(OH) MnO <sub>4</sub> <sup>2-</sup>	MnO <sub>4</sub> <sup>-</sup>	1	0,558	0,558	0,660	
<b>Pb</b>	Pb <sup>2+</sup> + 6 H <sub>2</sub> O	PbO <sub>2</sub> (s) + 4 H <sub>3</sub> O <sup>+</sup>	2	1,455	1,764	1,866	
	<b>S</b>	SO <sub>3</sub> <sup>2-</sup> + 3 H <sub>2</sub> O	SO <sub>4</sub> <sup>2-</sup> + 2 H <sub>3</sub> O <sup>+</sup>	2	0,200	0,354	0,456
		SO <sub>3</sub> <sup>2-</sup> + 2OH <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup> + H <sub>2</sub> O	2	-0,930	-0,981	-0,880
	S <sup>2-</sup>	S(s)	2	-0,480	-0,480	-0,37834	
	H <sub>2</sub> S + 2 H <sub>2</sub> O	S(s) + 2 H <sub>3</sub> O <sup>+</sup>	2	0,245	0,348	0,450	
	2S <sub>2</sub> O <sub>3</sub> <sup>2-</sup>	S <sub>4</sub> O <sub>6</sub> <sup>2-</sup>	2	0,080	0,080	0,182	
<b>Fe</b>	Fe <sup>2+</sup>	Fe <sup>3+</sup>	1	0,770	0,770	0,872	
<b>Ag</b>	Ag	Ag <sup>+</sup>	1	0,799	0,799	0,901	
<b>I</b>	2I <sup>-</sup>	I <sub>2</sub>	2	0,540	0,540	0,642	
<b>Cu</b>	Cu	Cu <sup>2+</sup>	2	0,337	0,337	0,439	
<b>F</b>	2F <sup>-</sup>	F <sub>2</sub>	2	2,870	2,870	2,972	
<b>Cl</b>	2Cl <sup>-</sup>	Cl <sub>2</sub>	2	1,360	1,360	1,462	
	3 H <sub>2</sub> O + Cl <sup>-</sup>	OCl <sup>-</sup> + 2 H <sub>3</sub> O <sup>+</sup>	2	1,490	1,644	1,746	
<b>Cr</b>	2Cr <sup>3+</sup> + 21 H <sub>2</sub> O	Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup> + 14 H <sub>3</sub> O <sup>+</sup>	6	1,330	2,051	2,153	
	Cr(OH) <sub>3</sub> (s) + 5OH <sup>-</sup>	CrO <sub>4</sub> <sup>2-</sup> + 4H <sub>2</sub> O	3	-0,130	-0,267	-0,166	
<b>C</b>	H <sub>2</sub> C <sub>2</sub> O <sub>4</sub> + 2 H <sub>2</sub> O	2CO <sub>2</sub> + 2 H <sub>3</sub> O <sup>+</sup>	2	-0,490	-0,387	-0,285	
	<b>Cr</b>	Cr <sup>3+</sup>	3	-0,744	-0,744	-0,642	
<b>Zn</b>	Zn	Zn <sup>2+</sup>	2	-0,763	-0,763	-0,661	
<b>Al</b>	Al + 4OH <sup>-</sup>	AlO <sub>2</sub> <sup>-</sup> + 2H <sub>2</sub> O	3	-2,330	-2,364	-2,263	
<b>H. C</b>	Ubiquinol+2H <sub>2</sub> O	Ubiquinone+2H <sub>3</sub> O <sup>+</sup>	2	0,459	0,562	0,664	
	Succinate <sup>2-</sup> +2H <sub>2</sub> O	Fumarate <sup>2-</sup> +2H <sub>3</sub> O <sup>+</sup>	2	0,445	0,548	0,650	
	AscorbicAcid+2H <sub>2</sub> O	C <sub>6</sub> H <sub>6</sub> O <sub>6</sub> +2H <sub>3</sub> O <sup>+</sup>	2	0,390	0,493	0,595	
	glycolate+2H <sub>2</sub> O	Glyoxylate+2H <sub>3</sub> O <sup>+</sup>	2	0,324	0,427	0,529	
	CH <sub>3</sub> CH <sub>2</sub> OH+H <sub>2</sub> O	CH <sub>3</sub> CHO+H <sub>3</sub> O <sup>+</sup> + H <sup>-</sup>	(H <sup>+</sup> +2e <sup>-</sup> )	0,190	0,241	0,343	
	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> + 42 H <sub>2</sub> O	24H <sub>3</sub> O <sup>+</sup> +6H <sub>3</sub> O <sup>+</sup> +6HCO <sub>3</sub> <sup>-</sup>	24	0,0702	0,2504	0,352	

sReaction O<sub>2</sub>aqua+2H<sub>2</sub>aqua=>2H<sub>2</sub>O is ΔG<sub>HessH2O</sub>aqua=(2G<sub>H2O</sub>-(2G<sub>H2aqua</sub>+G<sub>O2aqua</sub>))/2=(0-(2\*103+330))/2=-268 kJ/mol ;

Oxygen half reaction: O<sub>2</sub>aqua+4H<sub>3</sub>O<sup>+</sup>+4e<sup>-</sup><=>6H<sub>2</sub>O standard potential E°<sub>o2</sub>=1.485 Volts produces the water :

E<sub>o2</sub>=E°<sub>o2</sub>+0,0591/4•log([O<sub>2</sub>aqua]\*[H<sub>3</sub>O<sup>+</sup>]<sup>4</sup>/[H<sub>2</sub>O]<sup>6</sup>)=1,485 V+0,0148•log([O<sub>2</sub>aqua]\*[H<sub>3</sub>O<sup>+</sup>]<sup>4</sup>/[H<sub>2</sub>O]<sup>6</sup>) with four

reducing reverse half reactions: 4(Pt)H+4H<sub>2</sub>O<=>4H<sub>3</sub>O<sup>+</sup>+4(Pt)+4e<sup>-</sup>; E°<sub>H</sub>=0.1016 V give free energy change

ΔG<sub>eq</sub>=(E°<sub>H</sub>-E°<sub>o2</sub>)•F•1•4=(0.10166-1.485)\*96485\*4=-1.38334\*96485\*4/1000=-533.9=2\*266.94 kJ/mol of water

formation O<sub>2</sub>aqua+4(Pt)H=>2H<sub>2</sub>O from elements free energy content G<sub>H(Pt)</sub>=51 kJ/mol , G<sub>O2aq</sub>=330 kJ/mol:

ΔG<sub>eq</sub>=(E°<sub>H</sub>-E°<sub>o2</sub>)•F•1•4=(0,10166-1,485)\*96485\*4=-1,383\*96485\*4/1000=-533,9 kJ/mol .

Equilibrium value ΔG<sub>eq2H2O</sub>=2G<sub>H2O</sub>-4G<sub>(Pt)H</sub>-G<sub>O2aqua</sub>=2\*0-(4\*G<sub>(Pt)H</sub>+329.68)=-533,9=2\*-266,94 kJ/mol ,

expresses metal free energy G<sub>H(Pt)</sub>=(2G<sub>H2O</sub>-ΔG<sub>eq2H2O</sub>-G<sub>O2aqua</sub>)/4=(2\*0+533,886-329,68)/4=204,2/4=51,05 kJ/mol ;

Ox: 2H<sub>3</sub>O<sup>+</sup>+H<sub>2</sub>O+2e<sup>-</sup><=>H<sub>2aq</sub>+2H<sub>2</sub>O; ΔG<sub>Hess\_H3O+</sub>=2G<sub>H3O+</sub>+2G<sub>e-</sub>-(G<sub>H2aq</sub>+2G<sub>H2O</sub>)=2\*22,44-2\*0-103,24-2\*0=-58,36 kJ/mol;

Graphite electrode oxidizes hydrogen liberate (Pt) lattice E°<sub>H3O+</sub>=-58,36\*1000/96485/2=-0,302 V

Red: 2(Pt)H+2H<sub>2</sub>O<=>2H<sub>3</sub>O<sup>+</sup>+2e<sup>-</sup>+2(Pt); E°<sub>H+</sub>=0,1016 V; Ox+Red summary is: 2(Pt)H<=>H<sub>2aq</sub>+2(Pt);

2H<sub>3</sub>O<sup>+</sup>+H<sub>2</sub>O+2e<sup>-</sup><=>H<sub>2aq</sub>+2H<sub>2</sub>O; (Pt)H+2H<sub>2</sub>O<=>2H<sub>3</sub>O<sup>+</sup>+2e<sup>-</sup>+2(Pt); 2(Pt)H+H<sub>2</sub>O<=>H<sub>2aq</sub>+2(Pt);

ΔE°<sub>Hess\_sp\_(Pt)H</sub>=0,10166+0,302=-0,40366 V; ΔG<sub>Hess\_sp\_(Pt)H</sub>=ΔE°<sub>H3O+</sub>•F•2=0,40366\*96485\*2=77,89 kJ/mol;

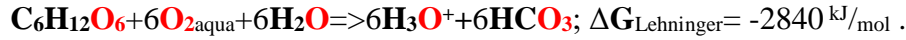
ΔG<sub>Hess\_sp\_(Pt)H</sub>=G<sub>H2aq</sub>+2G<sub>(Pt)</sub>-2G<sub>H(Pt)</sub>=103,24+2\*G<sub>(Pt)</sub>-2\*51,05=77,89 kJ/mol and platinum crystal lattice energy is:

G<sub>(Pt)</sub>=38,4 kJ/mol , because 2G<sub>(Pt)</sub>=ΔG<sub>Hess\_sp\_(Pt)H</sub>-G<sub>H2aq</sub>+2G<sub>H(Pt)</sub>=77,89-103,24+2\*51,05=76,75=2\*38,4 kJ/mol .

Red-Ox systems <b>Table 2.</b>	Standard potential E°	Classic;	Thermodynamic
Reactants reduced form=>products oxidized form+n e <sup>-</sup> Data [1-24]		Water disaccount classic zero E <sub>0</sub>	Water account + zero E <sub>0H2O</sub> Thermodynamic. scale 0.10166 V
<b>OH<sup>-</sup> = HO + e<sup>-</sup></b> CRC		2.020	2.020 2.122
<b>4 H<sub>2</sub>O = H<sub>2</sub>O<sub>2(aqua)</sub> + 2 H<sub>3</sub>O<sup>+</sup> + 2 e<sup>-</sup></b> Suchotina		1.776	1.982 2.084
<b>H<sub>2</sub>O<sub>2</sub> + 2 H<sub>2</sub>O = O<sub>2(aqua)</sub> + 2 H<sub>3</sub>O<sup>+</sup> + e<sup>-</sup></b> David Harris		1.276	1.379 1.481
<b>6 H<sub>2</sub>O = O<sub>2(aqua)</sub> + 4 H<sub>3</sub>O<sup>+</sup> + 4 e<sup>-</sup></b> Suchotina		1.229	1.383 1.485
<b>HN<sub>2</sub> + 4H<sub>2</sub>O = NO<sub>3</sub><sup>-</sup> + 3H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> University Alberta		0.928	1.133 1.235
<b>NO<sub>2</sub> + 3 H<sub>2</sub>O = NO<sub>3</sub><sup>-</sup> + 2 H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> David Harris		0.835	0.990 1.091
<b>Hydroquinone + 2H<sub>2</sub>O = p-quinone + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.699	0.802 0.904
<b>H<sub>2</sub>O<sub>2(aqua)</sub> + 2H<sub>2</sub>O = O<sub>2(aqua)</sub> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> University Alberta		0.695	0.798 0.899
<b>H<sub>2</sub>O<sub>2(aqua)</sub> + H<sub>2</sub>O = O<sub>2(aqua)</sub> + H<sub>3</sub>O<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b> University Alberta		0.695	0.746 0.848
<b>Fe<sup>2+</sup> = Fe<sup>3+</sup> + e<sup>-</sup></b> University Alberta		0.769	0.769 0.871
<b>Ubiquinol + 2H<sub>2</sub>O = Ubiquinone + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.459	0.562 0.664
<b>Succinate<sup>2-</sup> + 2H<sub>2</sub>O = Fumarate<sup>2-</sup> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.445	0.548 0.650
<b>ButyrylCoA + 2H<sub>2</sub>O = CrotonylCoA + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.399	0.502 0.604
<b>AscorbicAcid + 2H<sub>2</sub>O = C<sub>6</sub>H<sub>6</sub>O<sub>6</sub> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> DC. Harris		0.390	0.493 0.595
<b>glycolate + 2H<sub>2</sub>O = Glyoxylate + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>) + H<sub>3</sub>O<sup>+</sup></b> ; D.C.Harris 25°C		0.324	0.427 0.529
<b>Fe<sup>2+</sup> = Cytochrome F Fe<sup>3+</sup> + e<sup>-</sup></b> David Harris		0.365	0.365 0.467
<b>[Fe<sup>II</sup>(CN)<sub>6</sub>]<sup>4-</sup> = [Fe<sup>III</sup>(CN)<sub>6</sub>]<sup>3-</sup> + e<sup>-</sup></b> University Alberta		0.356	0.356 0.457
<b>Malate<sup>2-</sup> + 2H<sub>2</sub>O = Oxalo-acetate<sup>2-</sup> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.248	0.351 0.453
<b>Fe<sup>2+</sup> = Cytochrome a3 Fe<sup>3+</sup> + e<sup>-</sup></b>		0.350	0.350 0.452
<b>Lactate<sup>-</sup> + H<sub>2</sub>O = Pyruvate<sup>-</sup> + H<sub>3</sub>O<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b>		0.229	0.281 0.382
<b>FADH<sub>2</sub> + 2H<sub>2</sub>O = FADfree + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> ;		0.195	0.298 0.400
<b>CH<sub>3</sub>COO<sup>-</sup> + 2H<sub>2</sub>O = glycolate + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>) + H<sub>3</sub>O<sup>+</sup></b> ; D.C.Harris 25°C		0.161	0.263 0.365
<b>C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> + 4H<sub>2</sub>O = 2H<sub>3</sub>O<sup>+</sup> + 6H<sub>3</sub>O<sup>+</sup> + 6HCO<sub>3</sub><sup>-</sup> + 24 e<sup>-</sup></b> ; <a href="#">6<sup>th</sup> page.</a>		0,0701	0,2503 0,3521
<b>H<sub>2</sub>S<sub>aq</sub> + 2 H<sub>2</sub>O = S<sub>rombic</sub> + 2 H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> ; CRC 2010		0.142	0.245 0.347
<b>CH<sub>3</sub>CH<sub>2</sub>OH + H<sub>2</sub>O = CH<sub>3</sub>CHO + H<sub>3</sub>O<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b> ; KortlyShucha		0.190	0.241 0.343
<b>Fe<sup>2+</sup> = Cytochrome a Fe<sup>3+</sup> + e<sup>-</sup></b>		0.2900	0.2900 0.3917
<b>2GlutathSH + 2H<sub>2</sub>O = GlutaS-Sthione + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.1841	0.2871 0.3888
<b>HSH + 2H<sub>2</sub>O = S<sub>rhb</sub> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> University Alberta		0.1739	0.2769 0.3786
<b>Fe<sup>2+</sup> = Cytochrome c Fe<sup>3+</sup> + e<sup>-</sup></b>		0.2540	0.2540 0.3557
<b>LipSHSH + 2H<sub>2</sub>O = LipoicAcidS-S + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.1241	0.2271 0.3288
<b>Fe<sup>2+</sup> = Cytochrome c1 Fe<sup>3+</sup> + e<sup>-</sup></b>		0.2200	0.2200 0.3217
<b>β-OH Butyrate<sup>-</sup> + 2H<sub>2</sub>O = AcetoAcetate<sup>-</sup> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.0681	0.1711 0.2728
<b>isocitrate<sup>2-</sup> + 2H<sub>2</sub>O = α-Ketoglutarate<sup>2-</sup> + CO<sub>2</sub> + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b>		0.0341	0.1371 0.2388
<b>Nernst's H<sub>2aq</sub> + 2H<sub>2</sub>O ⇌ 2H<sub>3</sub>O<sup>+</sup> + H<sub>2</sub>O + 2e<sup>-</sup></b> ; ΔG <sub>Hess, H3O+</sub> = <a href="#">58,12</a> kJ/mol		0.0963	0.1993 0.3010
<b>Ox inverse: 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup> ⇌ H<sub>2aq</sub> + 2H<sub>2</sub>O</b> ; ΔG <sub>Hess, H2aq</sub> = <a href="#">58,12</a> kJ/mol		-0.0963	-0.1993 -0.3010
<b>H<sub>2aq</sub> + 2(Pt) ⇌ 2(Pt)H + H<sub>2</sub>O</b> ; 2(Pt)H + H <sub>2</sub> O = 2(Pt + e <sup>-</sup> + H <sup>+</sup> ) + H <sub>2</sub> O		0,0461	0,0976 0,1993
<b>H(Pt) + H<sub>2</sub>O = H<sub>3</sub>O<sup>+</sup> + (Pt) + e<sup>-</sup></b> ; [H <sub>3</sub> O <sup>+</sup> ] = 1 M pH=0 classic zero		<b>0.0</b> ; [H <sub>2</sub> SO <sub>4</sub> ] = 1 M	0.103 <b>0.10166</b>
<b>Luciferin + OH<sup>-</sup> = ?luciferin + CO<sub>2(aqua)</sub> + OH<sup>-</sup> + 3H(3H<sup>+</sup> + 3e<sup>-</sup>) + e<sup>-</sup></b> ;		0.0000	0.0000 0.1017
<b>Fe<sup>2+</sup> = Cytochrome b Fe<sup>3+</sup> + e<sup>-</sup></b>		0.0770	0.0770 0.1787
<b>CH<sub>3</sub>CHO + 3H<sub>2</sub>O = CH<sub>3</sub>COOH + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> Suchotina		-0.1180	0.0365 0.1382
<b>Glycaldeh3-P<sup>2-</sup> + H<sub>2</sub>O + HPO<sub>4</sub><sup>2-</sup> = 13PGlycerate<sup>4-</sup> + H<sub>3</sub>O<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b> ;		-0.1314	-0.0799 0.0218
<b>NADPH = NADP<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b> ;		-0.1170	-0.1170 -0.0153
<b>NADH = NAD<sup>+</sup> + H<sup>+</sup>(H<sup>+</sup> + 2e<sup>-</sup>)</b> ;	David Harris	-0.1130	-0.1130 -0.0113
<b>O<sub>2(aqua)</sub> = O<sub>2(aqua)</sub> + e<sup>-</sup></b> Suchotina		-0.2450	-0.2450 -0.1433
<b>Ferredoxin Fe<sup>2+</sup> = Ferredoxin Fe<sup>3+</sup> + e<sup>-</sup></b>		-0.4320	-0.4320 -0.3303
<b>C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> + 4H<sub>2</sub>O = 2C<sub>3</sub>H<sub>4</sub>O<sub>3</sub> + 4H<sub>3</sub>O<sup>+</sup> + 4e<sup>-</sup></b> Stryer		-0.5427	-0.4397 -0.3380
<b>S<sup>2-</sup> = S<sub>rombic</sub> + 2 e<sup>-</sup></b> ;	CRC 2010	-0.4763	-0.4763 -0.3746
<b>HS<sup>-</sup> + OH<sup>-</sup> = S<sub>rombic</sub> + H<sub>2</sub>O + 2e<sup>-</sup></b> ;	CRC 2010	-0.4780	-0.5295 -0.4278
<b>H(Pt) + OH<sup>-</sup> = H<sub>2</sub>O + (Pt) + e<sup>-</sup></b>	Suchotina	-0.8280	-0.9310 -0.8293
<b>Ubiquinol6 + 2H<sub>2</sub>O = Ubiquinone6 + 2H<sub>3</sub>O<sup>+</sup> + 2e<sup>-</sup></b> CRC 2012		-1.0500	-0.9470 -0.8453



Bio-Fuel of **Glucose C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>**, biochemical water **6H<sub>2</sub>O** and oxygen **6O<sub>2</sub><sub>aqua</sub>** energy  $\Delta G_{\text{Lehninger}} = +2840 \text{ kJ/mol}$  are used by oxidation to generating concentrations gradients of **6HCO<sub>3</sub><sup>-</sup>** and **6H<sub>3</sub>O<sup>+</sup>** ions:



Generated **6HCO<sub>3</sub><sup>-</sup>** + **6H<sub>3</sub>O<sup>+</sup>** ions drive **6O<sub>2</sub><sub>aqua</sub>** + **6H<sub>2</sub>O** through membrane aquaporins channels for osmosis against the concentration gradients but transporting ions **6HCO<sub>3</sub><sup>-</sup>** + **6H<sub>3</sub>O<sup>+</sup>** down the gradients through membrane bicarbonate and proton channels .

Quasi state equilibrium driving irreversible engine of photosynthesis accumulates free energy in products:

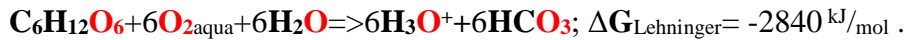


Using Hess law  $2840 \text{ kJ/mol} = G_{\text{C}_6\text{H}_{12}\text{O}_6} + 6 \cdot G_{\text{O}_2\text{Homeostasis\_arterial}} + 6 \cdot G_{\text{H}_2\text{O\_Biochem}} - (6 \cdot G_{\text{H}_3\text{O}^+} + 6 \cdot G_{\text{HCO}_3^-})$ .

Free energy content of one mol glucose is Hess law calculates referring Alberty [8] and [15] data:

$G_{\text{C}_6\text{H}_{12}\text{O}_6} = 2840 - 6 \cdot G_{\text{O}_2\text{Homeostasis\_arterial}} - 6 \cdot G_{\text{H}_2\text{O\_Biochem}} + (6 \cdot G_{\text{H}_3\text{O}^+} + 6 \cdot G_{\text{HCO}_3^-}) = 2268.8 \text{ kJ/mol}$ . So free energy of glucose is  $G_{\text{C}_6\text{H}_{12}\text{O}_6} = 2840 - 6 \cdot 78.08 - 6 \cdot 85.64 + 6 \cdot 68.52 = 2840 - 468,48 - 513,84 + 411,12 = 2268.8 \text{ kJ/mol}$ .

Free energy at quasi equilibrium calculates one using Lehninger data [6] for oxidation  $-2840 \text{ kJ/mol}$  and



$\text{O}_{2\text{aqua}} + 4\text{H}_3\text{O}^+ + 4\text{e}^- \rightleftharpoons 6\text{H}_2\text{O}$  thermodynamic standard [potential](#)  $E^\circ_{\text{O}_2} = 1.485 \text{ V}$  create arterial potential  $E_{\text{O}_2} = E^\circ_{\text{O}_2} + 0.0591/4 \cdot \log([\text{O}_{2\text{aqua}}] \cdot [\text{H}_3\text{O}^+]^4 / [\text{H}_2\text{O}]^6) = 1.485 + 0.0591/4 \cdot \log(6 \cdot 10^{-5} \cdot 10^{-(7.36 \cdot 4)} / 55.346^6) = 0.833 \text{ Volts} .$

Potential difference is  $\Delta E = \Delta G_{\text{eq}} / F / n = (E_{\text{C}_6\text{H}_{12}\text{O}_6} - E_{\text{O}_2}) = -2840000 / 96485 / 24 = (E_{\text{C}_6\text{H}_{12}\text{O}_6} - 0.833) = -1.2264 \text{ V}$ .

It let us appreciate potential for glucose oxidation:  $E_{\text{C}_6\text{H}_{12}\text{O}_6} = \Delta E + E_{\text{O}_2} = -1,226 + 0,833 = -0,393 \text{ V}$  from Lehninger data:  $-2840 \text{ kJ/mol} = \Delta G_{\text{Lehninger}} = \Delta E \cdot F \cdot n = (E_{\text{C}_6\text{H}_{12}\text{O}_6} - E_{\text{O}_2}) \cdot F \cdot n = (-0,393 - 0.833) \cdot F \cdot n = -1,2264 \cdot 96485 \cdot 24 = -2840$ .

Glucose **C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>** oxidation half reaction and six oxygen molecules reduction half reactions. Lehninger  $-2840 \text{ kJ/mol}$  energy change potential  $E_{\text{C}_6\text{H}_{12}\text{O}_6} = -0.393 \text{ Volts}$  for glucose oxidation:



Values of  $E_{\text{C}_6\text{H}_{12}\text{O}_6} = E^\circ_{\text{C}_6\text{H}_{12}\text{O}_6} + 0.0591/24 \cdot \log([\text{H}_3\text{O}^+]^{30} \cdot [\text{HCO}_3^-]^6 / [\text{C}_6\text{H}_{12}\text{O}_6] / [\text{H}_2\text{O}]^{42}) = -0.393 \text{ V} ,$

$[\text{H}_3\text{O}^+] = 10^{-(7,36)} \text{ M}$ ,  $[\text{HCO}_3^-] = 0,0154 \text{ M}$ ,  $[\text{C}_6\text{H}_{12}\text{O}_6] = 5 \cdot 10^{-(3)} \text{ M}$  and of water  $[\text{H}_2\text{O}] = 55,346 \text{ M}$ :

$-0.393 \text{ V} = E^\circ_{\text{C}_6\text{H}_{12}\text{O}_6} + 0.0591/24 \cdot \log(10^{-(7,36 \cdot 30)} \cdot 0,0154^6 / 5 / 10^{-(3)} / 55,346^{42}) .$  So standard potential is

$$E^\circ_{\text{C}_6\text{H}_{12}\text{O}_6} = -0.393 - 0.0591/24 \cdot \log(10^{-(7,36 \cdot 30)} \cdot 0,0154^6 / 5 / 10^{-(3)} / 55,346^{42}) = 352 \text{ V} .$$

Oxidation  $\text{C}_6\text{H}_{12}\text{O}_6 + 42\text{H}_2\text{O} \rightleftharpoons 24\text{H}_3\text{O}^+ + 6\text{H}_3\text{O}^+ + 6\text{HCO}_3^- + 24 \text{e}^-$ ; standard potential  $E^\circ_{\text{C}_6\text{H}_{12}\text{O}_6} = 352 \text{ Volts}$ .

The oxygen reduction:  $6 \cdot (\text{O}_{2\text{aqua}} + 4\text{H}_3\text{O}^+ + 4\text{e}^- \rightleftharpoons 6\text{H}_2\text{O})$ ; standard potential  $E^\circ_{\text{O}_2} = 1.485 \text{ Volts}$  give free energy

change  $\Delta G^\circ_{\text{eq}} = \Delta E^\circ \cdot F \cdot n = (E^\circ_{\text{C}_6\text{H}_{12}\text{O}_6} - E^\circ_{\text{O}_2}) \cdot F \cdot n = (0,352 - 1,485) \cdot F \cdot n = -1,2264 \cdot 96485 \cdot 24 = -2623,6 \text{ kJ/mol}$ .

Equilibrium  $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_{2\text{aqua}} + 6\text{H}_2\text{O} \rightleftharpoons 6\text{H}_3\text{O}^+ + 6\text{HCO}_3^-$  standard free energy change

$\Delta G_{\text{eqStandard}} = -2623,6 \text{ kJ/mol}$  constant is greater as one:

$$K_{\text{eqStandard}} = \frac{[\text{HCO}_3^-]^6 [\text{H}_3\text{O}^+]^6}{[\text{C}_6\text{H}_{12}\text{O}_6] \cdot [\text{O}_2]^6 [\text{H}_2\text{O}]^6} = \text{EXP}(-\Delta G_{\text{eqStandard}} / R / T) = \text{EXP}(2623600 / 8,3144 / 298,15) = e^{1058} = 10^{460} .$$

Homeostasis constant with values  $[\text{H}_3\text{O}^+] = 10^{-(7,36)} \text{ M}$ ,  $[\text{HCO}_3^-] = 0,0154 \text{ M}$ ,  $[\text{C}_6\text{H}_{12}\text{O}_6] = 5 \cdot 10^{-(3)} \text{ M}$ , for water  $[\text{H}_2\text{O}] = 55,3 \text{ M}$  and  $\Delta G_{\text{Lehninger}} = 2840 \text{ kJ/mol}$  is greater about standard  $K_{\text{eqHomeostasis}} = 10^{498} > 10^{460} = K_{\text{eqStandard}}$ :

$$K_{\text{eqHomeostasis}} = \frac{[\text{HCO}_3^-]^6 [\text{H}_3\text{O}^+]^6}{[\text{C}_6\text{H}_{12}\text{O}_6] \cdot [\text{O}_2]^6 [\text{H}_2\text{O}]^6} = \text{EXP}(-\Delta G_{\text{eqHomeostasis}} / R / T) = \text{EXP}(2840000 / 8,3144 / 298,15) = e^{1146} = 10^{498} .$$

**Nernst's potential** studies  $\underline{5(Pt)H} + MnO_4^-$  on hydroxonium  $H_3O^+$  and water  $H_2O$  account Oxidant reduction inverse Nernst's potential:  $MnO_4^- + 7H_3O^+ + 5e^- \leftrightarrow Mn^{2+} + 12H_2O$ ;  $E^\circ_{MnO_4} = 1.86$  V.

Reductant oxidation Nernst's potential:  $\underline{5(Pt)H} + 5H_2O \leftrightarrow 5H_3O^+ + 5e^-$ ; standart  $E^\circ_H = 0,10166$  V.

Electrones balancing  $+ne^- = 5e^- = -ne^-$  summary Red-Ox reaction:  $\underline{5(Pt)H} + MnO_4^- + 3H_3O^+ \leftrightarrow Mn^{2+} + 7H_2O$ .

$$E_{MnO_4} = -E^\circ + \frac{0.0591}{4} \cdot \lg \frac{[H_2O]^{12} \cdot [Mn^{2+}]}{[MnO_4^-] \cdot [H_3O^+]^8} = -1.86 \text{ V} + \frac{0.0591}{4} \cdot \lg \frac{[H_2O]^{12} \cdot [Mn^{2+}]}{[MnO_4^-] \cdot [H_3O^+]^8}; [H_2O] = 55.3 \text{ M} = \frac{996 \text{ g/L}}{18 \text{ g/mol}}$$

$$E_H = E^\circ_H + 0.0591 \cdot \lg \frac{[H_3O^+]}{[H_2O]} = 0.10166 \text{ V} + 0.0591 \cdot \lg \frac{[H_3O^+]}{[H_2O]};$$

Substan	$\Delta H^\circ_H, \text{kJ/mol}$	$\Delta S^\circ_H, \text{J/mol/K}$	$\Delta G^\circ_H, \text{kJ/mol}$	$\Delta G_{Hess} = \Delta G^\circ_{Mn2} + 7\Delta G^\circ_{H2O} - 3\Delta G^\circ_{H3O} - \Delta G^\circ_{MnO4} - 5\Delta G^\circ_{(Pt)H} = -1049 \text{ kJ/mol}$
$H_2O$	-285.85	69.9565	-237.191	-228.1 + 7 * -237.191 - (3 * -213.2746 - 447.2 + 5 * 99.13/2) = -1049 kJ/mol
$H_2O$	<b>-286.65</b>	<b>-453.188</b>	<b>-151.549</b>	Biochem. Thermodyn, Alberty, 2006, Massachusetts Technology Inst.
$H_3O^+$	-285.81	-3.854	-213.2746	CRC Handbook of Chemistry and Physics, 2010, D.Lide
$H_2(aq)$	23.4	-130	99.13	$\Delta G_{eq} = -800 \text{ kJ/mol}$ ; $\Delta G_{Hess} = -1049 \text{ kJ/mol}$
$MnO_4^-$	-541.4	-191.2	-447.2	for $\underline{5(Pt)H} + MnO_4^- + 8H_3O^+ \leftrightarrow Mn^{2+} + 8H_2O$ as absolute value
$Mn^{2+}$	-220.8	-73.6	-228.1	$ \Delta G_{eq} = -800 \text{ kJ/mol}  <  \Delta G_{Hess} = -1049 \text{ kJ/mol} $ ;

Concentration  $[H_2O]^{12}$  exponent 12 included in classic standard potential  $E_o = 1.51$  V as logarithm:

$$E^\circ_{MnO_4} = E_o - 0.0591/5 \cdot \log(1/[H_2O]^{12}) = 1.51 + 0.10166 - 0.0591/5 \cdot \log(1/55.3^{12}) = 1.76 + 0.10166 = 1.859 \text{ V};$$

$$\Delta G_{eqOxRed} = (E^\circ_H + E^\circ_{MnO_4}) \cdot F \cdot 1 \cdot 5 = (0.10166 - 1.86) \cdot 96485 \cdot 5 = -1.758 \cdot 96485 \cdot 5 = -848 \text{ kJ/mol}$$

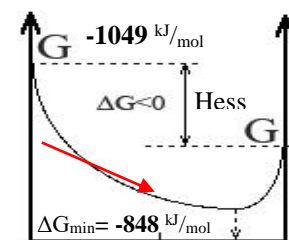
$$K_{eq} = \exp(-\Delta G_{eqOxRed}/R/T) = \exp(848.3/8.3144/298.15) = \exp(342.2) = 4.08 \cdot 10^{148};$$

Exothermic and exoergic  $MnO_4^-$  reduction by  $\underline{5(Pt)H}$  Hess free energy change negative

$\Delta G_{Hess} = \Delta G_{OxRed} = -1049 \text{ kJ/mol}$ , but minimizes  $\Delta G_{min} = \Delta G_{eq} = -848 \text{ kJ/mol}$  reaching

$$\text{equilibrium mixture } 4.08 \cdot 10^{148} = K_{eq} = \frac{[H_2O]^7 \cdot [Mn^{2+}]}{[(Pt)H]^5 [MnO_4^-] [H_3O^+]^3}; \text{ Prigogine attractor is free}$$

energy change minimum  $\Delta G_{min}$  reaching. Free energy change minimum reaching establishes equilibrium.

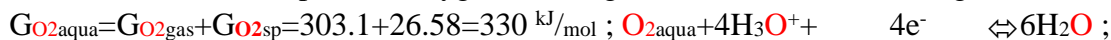


reactants  $\underline{5(Pt)H} + MnO_4^- + 3H_3O^+$   
products  $Mn^{2+} + 7H_2O$

**Nernst's potential**  $O_{2(aqua)}/H_2O$  red-ox system biochemical mechanism of acidosis and oxidative stress (forced oxidizing agent power by potential E increase)

Note: Oxidative stress causes **non enzymatic** oxidation in multiple radical chain and reactions of parallel product formations to contaminate and destroy the organism! Destructive hazard for life!

Water medium (blood plasma) oxygen is strong oxidant **1.485** V according half reaction:



oxidized form free electrons reduced form;

$$G_{H_3O^+ + OH} = G_{H_3O^+} + G_{OH} = 22.44 + 77.36 = 99.8 \text{ kJ/mol of } H_2O + H_2O \leftrightarrow H_3O^+ + OH$$

Biochemistry oxygen  $O_{2(aqua)}$  decreases free energy content  $G_{O_{2(aqua)}} = 329.7 \text{ kJ/mol}$  to  $G_{O_{2(Biochemistry)}} = 78.08 \text{ kJ/mol}$ .

Concentration arterial  $[O_{2(aqua)}] = 6 \cdot 10^{-5} \text{ M}$  and  $pH = 7.36$  concentration  $[H_3O^+] = 10^{-7.36} \text{ M}$ .

$$E_{O_2} = E^\circ + 0.0591/4 \cdot \log([O_{2(aqua)}] \cdot [H_3O^+]^4 / [H_2O]^6) = 1.485 + 0.0591/4 \cdot \log(6 \cdot 10^{-5} \cdot 10^{(-7.36 \cdot 4)} / 55.346^6) = 0.833 \text{ Volts}$$

$$\text{decrease } \Delta E_{arterial} = E^\circ - E_o = 1.485 - 0.833 = -0.652 \text{ V}; \Delta G_{arterial} = \Delta E_{H_2O} \cdot F \cdot n = -0.652 \cdot 96485 \cdot 4 / 1000 = -251.6 \text{ kJ/mol.}$$

Solubility zero value  $O_{2(gas)} \text{ AIR} + H_2O \xrightarrow{\text{Aquaporins}} O_{2(Blood)}$  increases to product level  $G_{O_{2(sp)}} = 26.58 \text{ kJ/mol}$ :

$$\frac{[O_{2(aqua)}]}{[O_{2(gas)}] \cdot [H_2O]} = K_{sp} = 2.205 \cdot 10^{-5}. G_{O_{2(sp)}} = -R \cdot T \cdot \ln(K_{sp}) = -8.3144 \cdot 298.15 \cdot \ln(2.205 \cdot 10^{-5}) = 26.58 \text{ kJ/mol.}$$

Free energy protolysis decreases  $G_{O_{2(Biochem\_arterial)}} = G_{O_{2(aqua)}} + G_{O_{2(sp)}} + \Delta G_{arterial} = 303.1 + 26.58 - 251.6 = 78.08 \text{ kJ/mol}$

and oxygen becomes fire safe biochemical oxidant, forming arterial concentration  $[O_{2(aqua)}] = 6 \cdot 10^{-5} \text{ M}$  as safe

Bioenergetic sustaining normal isooxia. [3];

Oxygen solubility Prigogine attractor free energy change Hess law solution is exothermic and endoergic



$$\Delta G_{\text{H}} = \Delta G^{\circ}_{\text{H}_2\text{O}} + \Delta G^{\circ}_{\text{O}_{2\text{aqua}}} - \Delta G^{\circ}_{\text{H}_2\text{O}} - \Delta G^{\circ}_{\text{O}_{2\text{gas}}} = 16.4 - (0 - 151.549) = 168 \text{ kJ/mol endoergic};$$

$$\Delta G_{\text{sp}} = -R \cdot T \cdot \ln(K_{\text{sp}}) = -8.3144 \cdot 298.15 \cdot \ln(2.205 \cdot 10^{-5}) = -8.3144 \cdot 298.15 \cdot 6.414 = 26.58 \text{ kJ/mol}$$

$[\text{O}_2]$  solubility Hess free energy change is positive  $\Delta G_{\text{Hess}} = \Delta G_{\text{solubility}} = 77.55 \text{ kJ/mol}$ ,

but minimized to  $\Delta G_{\text{min}} = \Delta G_{\text{sp}} = 26.58 \text{ kJ/mol}$  reaching solubility

$$\text{equilibrium mixture } K_{\text{sp}} = \frac{[\text{O}_{2\text{aqua}}]}{[\text{O}_{2\text{air}}] \cdot [\text{H}_2\text{O}]} = 2.205 \cdot 10^{-5} = 10^{-4.66}.$$

Equilibrium reaching is Prigogine attractor free energy change minimum  $\Delta G_{\text{min}}$ .

Free energy change minimum  $\Delta G_{\text{min}}$  reaching establishes equilibrium. [53rd page](#).

Zero osmolar  $C_{\text{osm}}=0 \text{ M}$  and ionic force  $I=0 \text{ M}$  in distilled water from air 20.95% solubility is:

$$[\text{O}_{2\text{water}}] = K_{\text{sp}} \cdot [\text{O}_{2\text{air}}] \cdot [\text{H}_2\text{O}] = 2.205 \cdot 10^{-5} \cdot 0.2095 \cdot 55.3 = 2.5567 \cdot 10^{-4} \text{ M}.$$

ELSEVIER, Rotating Electrode Method and Oxygen reduction Electrocatalysts, 2014, p.1-31,

1. WeiXinga, MinYinb, QingLv, YangHub, ChangpengLiub, JiujunZhangc. Pure 1atm mol fraction  $[\text{O}_{2\text{gas}}]=1$ .

Osmolar  $C_{\text{osm}}=0.305 \text{ M}$ , ionic force  $I=0.25 \text{ M}$ , air oxygen 20.95% conditions dissolve  $[\text{O}_{2\text{aqua}}]=9.768 \cdot 10^{-5} \text{ M}$ .

Therefore physiologic equilibrium constant is  $K_{\text{O}_{2\text{blood}}} = [\text{O}_{2\text{aqua}}]/[\text{O}_{2\text{air}}] = 9.768 \cdot 10^{-5}/0.2095 = 4.663 \cdot 10^{-4} = 10^{-3.3314}$ .

Arterial  $[\text{O}_{2\text{aqua}}]=6 \cdot 10^{-5} \text{ M}$  and venous  $[\text{O}_{2\text{aqua}}]=0.426 \cdot 10^{-5} \text{ M}$  concentration determines  $\text{p}K_{\text{O}_{2\text{blood}}}=3.3314$

by osmosis oxygen molecules crossing through aquaporins membranes against gradient.

Ox:  $\text{O}_{2\text{aqua}} + 4\text{H}_3\text{O}^+ + 4\text{e}^- \rightleftharpoons 6\text{H}_2\text{O}$ ;  $E^{\circ}_{\text{O}_2} = 1.485 \text{ Volts}$ ; Red:  $4(\text{Pt})\text{H} + 4\text{H}_2\text{O} \rightleftharpoons 4\text{H}_3\text{O}^+ + 4\text{e}^-$ ;  $E^{\circ}_{\text{H}} = 0.10166 \text{ V}$

$$\text{O}_{2\text{aqua}} + 4(\text{Pt})\text{H} - 2\text{H}_2\text{O}; \Delta G_{\text{eq}} = (E^{\circ}_{\text{H}} - E^{\circ}_{\text{O}_2}) \cdot F \cdot 1 \cdot 4 = (0.10166 - 1.485) \cdot 96485 \cdot 4 = -1,383 \cdot 96485 \cdot 4/1000 = -533,9 \text{ kJ/mol};$$

Equilibrium value  $\Delta G_{\text{eq}2\text{H}_2\text{O}} = 2G_{\text{H}_2\text{O}} - 4G_{(\text{Pt})\text{H}} - G_{\text{O}_{2\text{aqua}}} = 2 \cdot 0 - (4 \cdot G_{(\text{Pt})\text{H}} + 329.68) = -533,9 = 2 \cdot 266,94 \text{ kJ/mol}$  expresses metal free energy  $G_{\text{H}(\text{Pt})} = (2G_{\text{H}_2\text{O}} - \Delta G_{\text{eq}2\text{H}_2\text{O}} - G_{\text{O}_{2\text{aqua}}})/4 = (2 \cdot 0 + 533,886 - 329,68)/4 = 204,2/4 = 51,05 \text{ kJ/mol}$ .

$$\text{H}_{2\text{aq}} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{H}_3\text{O}^+ + 2\text{e}^- + \text{H}_2\text{O}; \Delta G_{\text{Hess}_{\text{H}_3\text{O}^+}} = 2G_{\text{H}_3\text{O}^+} + G_{\text{H}_2\text{O}} - (G_{\text{H}_{2\text{aq}}} + 2G_{\text{H}_2\text{O}}) = 2 \cdot 22,44 - 2 \cdot 0 - 103,24 - 2 \cdot 0 = -58,36 \text{ kJ/mol}$$

### Nernst

and graphite electrode potential  $E^{\circ}_{\text{H}_3\text{O}^+} = 58360/96485/2 = 0,302 \text{ V}$  oxidizes hydrogen and liberate (Pt) lattice.

Red:  $2(\text{Pt})\text{H} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{H}_3\text{O}^+ + 2\text{e}^- + 2(\text{Pt})$ ;  $E^{\circ}_{\text{H}} = 0,1016 \text{ V}$ ; Ox+Red summary  $2(\text{Pt})\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{H}_{2\text{aq}} + 2(\text{Pt})$ ;

$$2\text{H}_3\text{O}^+ + \text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_{2\text{aq}} + 2\text{H}_2\text{O}; (\text{Pt})\text{H} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{H}_3\text{O}^+ + 2\text{e}^- + 2(\text{Pt}); 2(\text{Pt})\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{H}_{2\text{aq}} + 2(\text{Pt});$$

$$\Delta E^{\circ}_{\text{eqH}_3\text{O}^+(\text{Pt})\text{H}} = 0,10166 - (-0,302) = 0,40366 \text{ V}; \Delta G_{\text{eqH}_3\text{O}^+(\text{Pt})\text{H}} = \Delta E^{\circ}_{\text{eqH}_3\text{O}^+(\text{Pt})\text{H}} \cdot F \cdot 2 = 0,40366 \cdot 96485 \cdot 2 = 77,9 \text{ kJ/mol};$$

$$\Delta G_{\text{eqH}_3\text{O}^+(\text{Pt})\text{H}} = G_{\text{H}_{2\text{aq}}} + 2G_{(\text{Pt})} + G_{\text{H}_2\text{O}} - 2G_{\text{H}(\text{Pt})} = 103 + 2 \cdot G_{(\text{Pt})} + 0 - 2 \cdot 51,05 = 77,894 \text{ kJ/mol}.$$

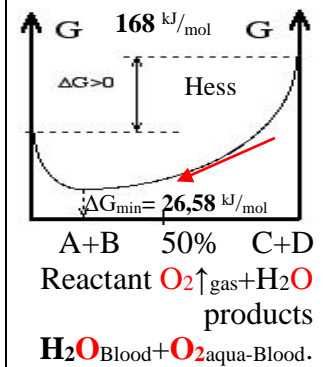
Platinum crystal lattice energy is calculated referring to zero free energy for  $G_{\text{H}_2\text{O}} = G_{\text{CO}_2\text{gas}} = G_{\text{e}^-} = 0 \text{ kJ/mol}$ ,

$$2G_{(\text{Pt})} = \Delta G_{\text{eqH}_3\text{O}^+(\text{Pt})\text{H}} - G_{\text{H}_{2\text{aq}}} + 2G_{\text{H}(\text{Pt})} = 77,894 - 103,24 + 2 \cdot 51,05 = 76,75 = 2 \cdot 38,4 \text{ kJ/mol};$$

Reduction of sulfur:  $\text{S}_{\text{rhom}} + 2\text{H}_3\text{O}^+ + 2\text{e}^- = \text{H}_2\text{S}_{\text{aq}} + 2\text{H}_2\text{O}$ ;  $E^{\circ}_{\text{S}} = 0,347 \text{ V}$ ;

$$\text{S}_{\text{rhom}} + 2(\text{Pt})\text{H} \rightleftharpoons \text{H}_2\text{S}_{\text{aq}}; \Delta G_{\text{eq}} = (E^{\circ}_{\text{H}} - E^{\circ}_{\text{S}}) \cdot F \cdot 1 \cdot 2 = (0.10166 - 0.347) \cdot 96485 \cdot 2 = -0.245 \cdot 96485 \cdot 2/1000 = -47.3 \text{ kJ/mol};$$

$$G_{\text{H}_2\text{S}_{\text{aq}}} = \Delta G_{\text{HessH}_2\text{S}} + (2G_{\text{H}(\text{Pt})} + G_{\text{S}_{\text{rhom}}}) = -47.3 + (2 \cdot -219 - 85.64) = -571 \text{ kJ/mol}.$$
 [2nd page](#).





**Nernst's potential  $O_{2\text{aqua}} / H_2O$  | (Pt)H /  $H_3O^+$  un  $H_2O_2 / H_2O$  |  $H_2O_2 / O_2$  studies**

Ox oxidizing reactant half reaction:  $O_{2\text{aqua}} + 4H_3O^+ + 4e^- \rightleftharpoons 6H_2O$ ;  $G_{H(Pt)}=204/4=51,05$  kJ/mol

Red reducing reactant half reaction:  $4(Pt)H + 4H_2O \rightleftharpoons 4H_3O^+ + 4e^-$ ; metal hydrogen  $G_{H(Pt)}=51,05$  kJ/mol

$$O_{2\text{aqua}} + 4(Pt)H \rightleftharpoons 2H_2O; \Delta G_{\text{eq}} = 2G_{H_2O} - 4G_{H(Pt)} - G_{O_{2\text{aqua}}} = (2 \cdot 0 - 4 \cdot 51,05 - 329,68) = -533,886 \text{ kJ/mol}$$

$$E_{O_2} = E^\circ_{O_2} + 0.0591/4 \cdot \lg([O_{2\text{aqua}}] \cdot [H_3O^+]^4 / [H_2O]^6) = 1.485 + 0.0591/4 \cdot \lg([O_{2\text{aqua}}] \cdot [H_3O^+]^4 / [H_2O]^6);$$

$$E_H = E^\circ + 0.0591 \cdot \lg([H_3O^+] / [H_2O]) = 0.10166 \text{ V} + 0.0591 \cdot \lg([H_3O^+] / [H_2O]);$$

Gas  $O_{2\text{gas}} + 2H_{2\text{gas}} \rightleftharpoons 2H_2O$ ;  $\Delta G_{\text{Hess}2H_2O} = 2\Delta G^\circ_{H_2O} - (2\Delta G^\circ_{H_2\text{gas}} + \Delta G^\circ_{O_{2\text{gas}}}) = 2 \cdot (-237,19) - (2 \cdot 0 + 0) = 2 \cdot (-237,19) = -474,38$  kJ/mol

$$O_{2\text{aqua}} + 2H_{2\text{aqua}} \rightleftharpoons 2H_2O; \Delta G_{\text{Alberty}2H_2O} = 2G_{H_2O} - 2G_{H_{2\text{aqua}}} - G_{O_{2\text{aqua}}} = 2 \cdot 0 - (2 \cdot 103,24 + 329,68) = -536,4 \text{ kJ/mol};$$

Hydrogen energy  $G_{H_{2\text{aqua}}} = 103$  kJ/mol of Alberty R.A. Biochemical Thermodynamic's 1-463. (2006).

Substance	$\Delta H^\circ_H$ , kJ/mol	$\Delta S^\circ_H$ , J/mol/K	$\Delta G^\circ_H$ , kJ/mol
<b>H<sub>2</sub>O</b>	-285.85	69.9565	-237.191
<b>H<sub>2</sub>O</b>	<b>-286.65</b>	<b>-453.188</b>	<b>-151.549</b>
<b>H<sub>3</sub>O<sup>+</sup></b>	-285.81	-3.854	-213.2746
<b>H<sub>2</sub>(aq)</b>	23.4	-130	99.13
<b>O<sub>2</sub>aqua</b>	<b>-11.70</b>	<b>-94.2</b>	<b>16.4</b>
<b>O<sub>2</sub>aqua</b>	-11.715	110.876	16.4

$$\Delta G_{\text{Hess}} = 2\Delta G^\circ_{H_2O} - 4\Delta G_{(Pt)H} - \Delta G^\circ_{O_{2\text{aqua}}} = -689 = 2 \cdot (-344,521) \text{ kJ/mol};$$

$$= 2 \cdot (-237,191) - (4 \cdot 51,05 + 16,4) = -689 = 2 \cdot 344,5 \text{ kJ/mol. CRC 2010}$$

$$\Delta G_{\text{eq}} = -533,886 \text{ kJ/mol}; \Delta G_{\text{Hess}} = -689 \text{ kJ/mol}$$

in reaction  $4(Pt)H + O_{2\text{aqua}} \rightleftharpoons 2H_2O$ ; absolute values

$$|\Delta G_{\text{eq}} = -533,886 \text{ kJ/mol}| < |\Delta G_{\text{Hess}} = -689 \text{ kJ/mol}|;$$

Water concentration  $[H_2O]^6$  as logarithm extracted of  $E^\circ_{\text{classic}} = 1.229 \text{ V}$   
Thermodynamic to hydrogen reference  $E^\circ = 1.383 + 0.10166 = 1.485 \text{ V}$

$$E^\circ_{O_2} = 1,485 \text{ V}; E_{O_2} = E^\circ_{O_2} + 0,0591/4 \cdot \lg(1/[H_2O]^6) - 0,10166 = 1,229 \text{ V}; [H_2O] = 996 \text{ g/L} / 18 \text{ g/mol} = 55,3 \text{ M};$$

$$\Delta G_{\text{eqOxRed}} = (E^\circ_H - E^\circ_{O_2}) \cdot F \cdot 1 \cdot 4 = (0,10166 - 1,485) \cdot 96485 \cdot 4 = -1,383 \cdot 96485 \cdot 4 = -533,886 = 2 \cdot -266,9 \text{ kJ/mol};$$

$$K_{\text{eq}2H_2O} = K_{\text{OxRed}} = \exp(-\Delta G_{\text{OxRed}}/R/T) = \exp(533886/8,3144/298,15) = \exp(215,4) = 3,42 \cdot 10^{93};$$

$$G_{H(Pt)} = (2G_{H_2O} - \Delta G_{\text{eq}2H_2O} - G_{O_{2\text{aqua}}})/4 = (2 \cdot 0 + 533,886 - 329,68)/4 = 204,2/4 = 51,05 \text{ kJ/mol}$$

Exothermic and exoergic  $O_{2\text{aqua}}$  reduction with metallic hydrogen

$4(Pt)H$  and  $H_2O_2$  dismutation Hess free energy change negative

$$\Delta G_{\text{Hess}2H_2O} = -546 \dots \text{ kJ/mol}, \Delta G_{\text{Hess}H_2O_2} = -480 \dots \text{ kJ/mol}, \text{ but minimized}$$

$$\text{reaching equilibrium } \Delta G_{\text{eq}2H_2O} = -534 \text{ kJ/mol} \text{ and } \Delta G_{\text{eqStandard}} = -228,6 \dots \text{ kJ/mol mixture}$$

$$\text{constants } K_{\text{eq}2H_2O} = 3,42 \cdot 10^{93} \dots \text{ and } K_{\text{eqStandard}} = 1,108 \cdot 10^{40} \dots$$

The minimum  $\Delta G_{\text{min}}$  is Prigogine attractor. Free energy change minimum reaching establish equilibrium state.

Red  $H_2O_2 + 2H_2O - 2e^- = O_{2\text{aqua}} + 2H_3O^+$ ;  $E^\circ_{H_2O_2} = 0.899 \text{ V}$  Alberta University;

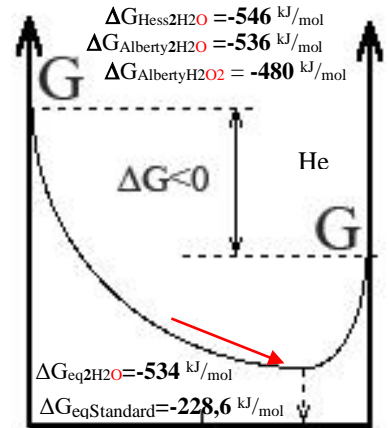
$[H_2O_2] = 1 \text{ M}$  concentration environment  $\text{pH} = 7.36$ .

Oks  $H_2O_2 + 2H_3O^+ + 2e^- = 4H_2O$ ;  $E^\circ_{Ox} = 2.084 \text{ V}$  Suhotina;

$$2H_2O_{2aq} \Rightarrow O_{2\text{aqua}} + 2H_2O + Q + \Delta G;$$

Reactants  $4(Pt)H + O_{2\text{aqua}}$  and products  $2H_2O$

Reactants  $2H_2O_{2aq}$  and products  $O_{2\text{aqua}} + 2H_2O$



4A+B 50% 2D  
2A 50% B+2C

$$\Delta G_{\text{eqStandard}} = (E_{\text{Red}} - E_{Ox}) \cdot F \cdot n = (0.7975 - 1.982) \cdot 96485 \cdot 2 = (-1.1845) \cdot 96485 \cdot 2 = -228,6 \dots \text{ kJ/mol};$$

$$K_{\text{eqStandard}} = \frac{[O_2]_{\text{aqua}} \cdot [H_2O]^2}{[H_2O_2]_{\text{aqua}}^2} = K_{H_2O_2} = \exp(-\Delta G_{\text{eq}}/R/T) = \exp(228573/8,3144/298,15) = 1,108 \cdot 10^{40} \dots$$

Red:  $E_{oH_2O_2} = E^\circ_{H_2O_2} + 0.0591/2 \cdot \lg([O_{2\text{aqua}}] \cdot [H_3O^+]^2 / [H_2O_2] / [H_2O]^2) = 0.899 + 0.0591/2 \cdot \lg(6 \cdot 10^{(-5)} \cdot 10^{(-7.36 \cdot 2)} / 1/55,3^2) = 0.2363 \text{ V}$

Ox:  $E_{oOx} = E^\circ_{H_2O_2Ox} + 0.0591/2 \cdot \lg([H_2O_2] \cdot [H_3O^+]^2 / [H_2O]^4) = 2.084 + 0.0591/2 \cdot \lg(1 \cdot 10^{(-7.36 \cdot 2)} / 55,3^4) = 1.443 \text{ V}$

$$\text{BioChem: } \Delta G_{\text{eqBioChem}} = (E_{\text{Red}} - E_{Ox}) \cdot F \cdot n = (0.2363 - 1.443) \cdot 96485 \cdot 2 = (-1.207) \cdot 96485 \cdot 2 = -232,86 \dots \text{ kJ/mol}$$

$$\Delta G_{\text{Alberty}} = G_{O_2\text{BioChem}_\text{arteriaj}} + 2 \cdot G_{H_2O\text{BioChemistry}} - 2 \cdot G_{H_2O_2} = 78,08 + 2 \cdot 85,64 - 2 \cdot 364,79 = -480,22 \text{ kJ/mol}; \text{ Alberty}$$

$$1. \Delta H_{\text{Hess}} = \Delta H^\circ_{O_2} + 2\Delta H^\circ_{H_2O} - 2\Delta H^\circ_{H_2O_2} = -11,7 - 2 \cdot 286,65 - (2 \cdot -191,99) = -201,02 \text{ kJ/mol} = -11,7 - 2 \cdot 285,85 - (2 \cdot -191,17) = -201,06 \text{ kJ/mol}$$

$$2. \Delta S_{\text{dispersed}} = -\Delta H_H/T = -(-201,02)/298,15 = 674,2 \text{ J/mol/K}; \Delta S_{\text{dispersed}} = -\Delta H_H/T = -(-201,06)/298,15 = 674,36 \text{ J/mol/K};$$

$$\Delta S_{\text{Hess}} = \Delta S^\circ_{O_2} + 2\Delta S^\circ_{H_2O} - 2\Delta S^\circ_{H_2O_2} = -94,2 + 2 \cdot -453,188 - (2 \cdot -481,688) = -37,2 \text{ J/mol/K};$$

$$\Delta S_{\text{Hess}} = \Delta S^\circ_{O_2} + 2\Delta S^\circ_{H_2O} - 2\Delta S^\circ_{H_2O_2} = 110,876 + 2 \cdot 69,9565 - (2 \cdot 143,9) = -37 \text{ J/mol/K};$$

$$2. \Delta S_{\text{total}} = \Delta S_H + \Delta S_{\text{dispersed}} = -37,2 + 674,2 = 637 \dots \text{ J/mol/K } \Delta S_{\text{total}} = -37,011 + 674,36 = 637,35 \dots \text{ J/mol/K};$$

$$4. \Delta G_{\text{Hess}} = \Delta H_H - T \cdot \Delta S_H = -201,02 - 298,15 \cdot -0,0372 = -189,9 \text{ kJ/mol exoergic spontaneous.}$$

$$\Delta G_{\text{Hess}} = \Delta H_H - T \cdot \Delta S_H = -201,06 - 298,15 \cdot -0,037 = -190 \text{ kJ/mol};$$

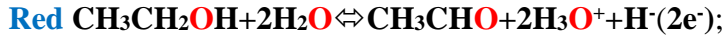
$$T \cdot \Delta S_{\text{total}} = 0,637 \cdot 298,15 = 189,9 \text{ kJ/mol}; T \cdot \Delta S_{\text{total}} = 0,63735 \cdot 298,15 = 190 \text{ kJ/mol};$$

Nernst's potential studies reducing with vitamin B<sub>3</sub> ethanal H<sub>3</sub>CCH=O and oxidising H<sub>3</sub>CCH<sub>2</sub>OH ethanol



ΔG<sub>Hess</sub>=ΔG°<sub>H<sub>3</sub>O</sub>+ΔG°<sub>CH<sub>3</sub>CHO</sub>+ΔG°<sub>NADH</sub>-ΔG°<sub>CH<sub>3</sub>CH<sub>2</sub>OH</sub>-ΔG°<sub>H<sub>2</sub>O</sub>-ΔG°<sub>NAD<sup>+</sup></sub>=159.1 kJ/mol;

ΔG<sub>Hess</sub>=32.2824+1175.5732-151.549-(75.2864+1059.11-237.191)=159.1 kJ/mol endoergic;



E°<sub>H<sub>2</sub>O</sub>=0.190+0.10166+0.0591/2\*log([H<sub>2</sub>O]<sup>2</sup>)=0.343 V;

By convention balanced n = 2 = m number of electrons 2e<sup>-</sup>ΔE° is expressed as E°<sub>H<sub>2</sub>O</sub> of the electron donor minus E°<sup>1</sup> of the electron acceptor. Because NAD<sup>+</sup> is accepting electrons from ethanol :

E°<sub>H<sub>2</sub>O</sub>=0.190-0.0591/2\*log([H<sub>2</sub>O]<sup>2</sup>)=0.190+0.02955\*log(55.3333)=0.190+0.0515=0.343 V

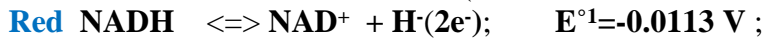
ΔE°=E°<sub>H<sub>2</sub>O</sub>-E°<sup>1</sup>=0.343-(-0.0113)=0.3545 V, n=2; ΔG<sub>eq</sub>=ΔE°•F•n=0.3545 V•2 mol•96485 C/mol=68.408 kJ/mol

ΔG<sub>eq</sub>=-R•T•ln(K<sub>eq</sub>); K<sub>eq</sub>= $\frac{[NADH] \cdot [CH_3CHO] \cdot [H_3O^+]}{[NAD^+] \cdot [CH_3CH_2OH] \cdot [H_2O]}$  = e<sup>-ΔG<sub>eq</sub>/R•T</sup> = e<sup>-68408/(8.314•298.15)}</sup> = 1.036•10<sup>-12</sup>=10<sup>-11.985</sup>



ΔG<sub>Hess</sub>=ΔG°<sub>CH<sub>3</sub>CH<sub>2</sub>OH</sub>+ΔG°<sub>H<sub>2</sub>O</sub>+ΔG°<sub>NAD<sup>+</sup></sub> -ΔG°<sub>H<sub>3</sub>O</sub>-ΔG°<sub>CH<sub>3</sub>CHO</sub>-ΔG°<sub>NADH</sub> = -159.1 kJ/mol;

ΔG<sub>Hess</sub>=75.2864+1059.11-237.191-(32.2824+1175.5732-151.549)= -159.1 kJ/mol endoergiska;



By convention balanced n=2=m number of electrons 2e<sup>-</sup>ΔE° is expressed as E°<sup>1</sup> of the electron donor minus E°<sub>H<sub>2</sub>O</sub> of the electron acceptor. Because CH<sub>3</sub>CHO is accepting electrons from NADH in our example

ΔE°=E°<sup>1</sup>-E°<sub>H<sub>2</sub>O</sub>=-0.0113-0.343=-0.3545 V, n=2; ΔG<sub>eq</sub>=ΔE°•F•n=-0.3545 V•2 mol•96485 C/mol=-68.408 kJ/mol;

ΔG<sub>eq</sub>=-R•T•ln(K<sub>eq</sub>)=- 68,408 kJ/mol; K<sub>eq</sub>= $\frac{[NAD^+] \cdot [CH_3CH_2OH] \cdot [H_2O]}{[NADH] \cdot [CH_3CHO] \cdot [H_3O^+]}$  = e<sup>ΔG<sub>eq</sub>/R•T</sup> = e<sup>-68408/(8.314•298.15)}</sup> = 9.65•10<sup>11</sup>=10<sup>11.985</sup>.

In aerobic organisms NADH oxidase with O<sub>2</sub> aqua perform ratio [NAD<sup>+</sup>]/[NADH]=10<sup>6</sup>;

ΔG<sub>Homeostasis</sub>=68.408+ R•T•ln(10<sup>6</sup>\*1/1\*10<sup>-7.36</sup>/55.3)=68.408-86.2=-17.8.....kJ/mol.

[NAD<sup>+</sup>]/[NADH]=10<sup>3</sup>; ΔG<sub>Homeostasis</sub>=68.408-69.08=-0.676.....kJ/mol.

Equilibrium is shifted far to reactants as aerobic constant K<sub>eq</sub>=10<sup>-11.985</sup> and inverse

anaerobic constant K<sub>eq</sub>=10<sup>11.985</sup>. Aerobic endothermic and endoergic vitamin B<sub>3</sub> ethanol

oxidation Hess law free energy change positive ΔG<sub>Hess</sub>=159.....kJ/mol and inverse

ethanal anaerobic reduction negative ΔG<sub>Hess</sub>=-159.....kJ/mol , but minimises reaching

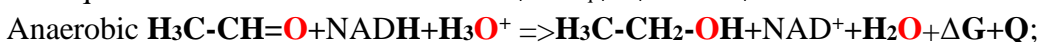
equilibrium aerobic ΔG<sub>min</sub>=ΔG<sub>eq</sub>=68.4..... kJ/mol and anaerobic

ΔG<sub>min</sub>=ΔG<sub>eq</sub>=-68.4..... kJ/mol reaching equilibrium mixture

constants 10<sup>-11.985</sup>=K<sub>eq</sub> aerobic and anaerobic 10<sup>11.985</sup>=K<sub>eq</sub>.

Prigogine attractor is free energy change absolute minimum ΔG<sub>min</sub> reaching

equilibrium ΔG<sub>min</sub>=68.4..... kJ/mol= |ΔG<sub>eq</sub>| < |ΔG<sub>Hess</sub>| = 159..... kJ/mol.



Anaerobic ΔG<sub>eq</sub>=ΔE°•F•n=-0.3545 V•2 mol•96485 C/mol=-68.408..... kJ/mol favored.

Insufficient low O<sub>2</sub> aqua concentration hypoxia to anaerobic alcohol oxidation unflavored

but ethanal reduction to ethanol favored [H<sub>3</sub>CCH<sub>2</sub>OH]/[ H<sub>3</sub>CCH=O]=1/10 homeostasis

reduction with NADH reductase enzyme as negative free energy change

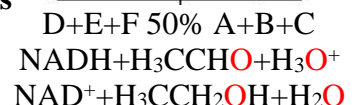
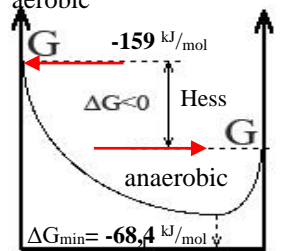
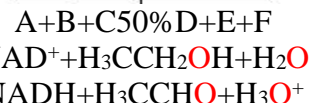
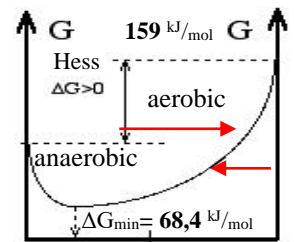
ΔG<sub>Homeostasis</sub>=-27.86.....kJ/mol

Anaerobic homeostasis ratio [NADH]/[NAD<sup>+</sup>]=10 over [NAD<sup>+</sup>] favors reduction:

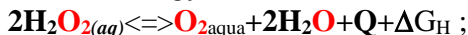
ΔG<sub>Homeostasis</sub>=-68.41+8.3144\*298.15\*ln(K<sub>Homeostasis</sub>)=-68.41+40.54 =-27.86..... kJ/mol

ΔG<sub>Homeostasis</sub>=-68.41+8.3144\*298.15\*ln( $\frac{1}{10} \frac{1}{10} \frac{55.333}{10^{-7.36}}$ )=-27.86 kJ/mol ; K<sub>Homeostasi</sub>= $\frac{[NAD^+] \cdot [CH_3CH_2OH] \cdot [H_2O]}{[NADH] \cdot [CH_3CHO] \cdot [H_3O^+]}$

[NADH]/[NAD<sup>+</sup>]=1/770; ΔG<sub>Homeostasis</sub>=68.408+8.3144\*298.15\*ln(700/1\*1/1\*55.3457/10<sup>-7.36</sup>)=0.028 kJ/mol.



High rate protolysis peroxide anions  $\text{H}^+ + \text{HOO}^- \rightleftharpoons \text{OOH} + \text{H}^+$  collision activation energy is high  $E_a = 79000 \text{ J/mol}$  oposit  $\text{HOO}^- \Rightarrow \text{Fe}^{3+}$  collision activation energy  $E_a = 29 \text{ J/mol}$  is small. Producing  $\omega=6, \omega=3$  fatty acids, oxygen, water and heat:



$$\Delta G_{\text{Hess}} = \Delta G^\circ_{\text{O}_2} + 2\Delta G^\circ_{\text{H}_2\text{O}} - 2\Delta G^\circ_{\text{H}_2\text{O}_2} = 16.40 + 2 \cdot (-237.191) - (2 \cdot -134.03) = -189.9 \dots \text{kJ/mol} \text{ exoergic}$$

$$\Delta G_{\text{HessAlberty}} = G^\circ_{\text{O}_2} + 2G^\circ_{\text{H}_2\text{O}} - 2G^\circ_{\text{H}_2\text{O}_2} = 303.1 + 2 \cdot (0) - (2 \cdot 364.79) = -426.5 / 2 \text{kJ/mol} = -213,25 \dots \text{kJ/mol} \text{ exoergic}$$

Substance	$\Delta H^\circ_{\text{H}}$ , kJ/mol	$\Delta S^\circ_{\text{H}}$ , J/mol/K	$\Delta G^\circ_{\text{H}}$ , kJ/mol
$\text{H}_3\text{O}^+$	-285.81	-3.854	-213.275
$\text{O}_2(\text{aq})$	-11.715	110.876	16.4
$\text{O}_2(\text{aq})$	<b>-11.70</b>	<b>-94.2</b>	<b>16.40</b>
$\text{H}_2\text{O}$	-285.85	69.9565	-237.191
$\text{H}_2\text{O}$	<b>-286.65</b>	<b>-453.188</b>	<b>-151.549</b>
$\text{H}_2\text{O}_2(\text{aq})$	<b>-191.99</b>	<b>-481.688</b>	<b>-48.39</b>
$\text{H}_2\text{O}_2(\text{aq})$	-191.17	143.9	-134.03
$\text{H}_2\text{O}_2(\text{l})$	-237.129	69.91	-237.129

1.  $\Delta H^\circ_{\text{Hess}} = \sum \Delta H^\circ_{\text{products}} - \sum \Delta H^\circ_{\text{reactants}}$ ; 3.  $\Delta G^\circ_{\text{Hess}} = \Delta H^\circ_{\text{H}} - T \cdot \Delta S^\circ_{\text{H}}$ ;  
 Miščenko 1968, Himia, Leningrad 2.  $\Delta S^\circ_{\text{Hess}} = \sum \Delta S^\circ_{\text{products}} - \sum \Delta S^\circ_{\text{reactants}}$   
 CRC 2010; 2.  $\Delta S^\circ_{\text{Hess}} = \sum \Delta S^\circ_{\text{products}} - \sum \Delta S^\circ_{\text{reactants}}$   
 $\Delta H_{\text{Hess}} = \Delta H^\circ_{\text{O}_2} + 2\Delta H^\circ_{\text{H}_2\text{O}} - 2\Delta H^\circ_{\text{H}_2\text{O}_2} = -201.02 \dots = -201.06 \dots \text{kJ/mol}$   
 $= -11.7 - 2 \cdot 286.65 - (2 \cdot -191.99) = -201.02 \dots \text{kJ/mol} \text{ eksotermiska..}$   
 $= -11.7 - 2 \cdot 285.85 - (2 \cdot -191.17) = -201.06 \dots \text{kJ/mol}$   
 Biochem Thermodynamic 2006 Masachusetts Technology institute  
 University Alberta 1997.

2.  $\Delta S_{\text{dispersed}} = -\Delta H_{\text{H}}/T = -(-201.02)/298.15 = 674.2 \dots \text{J/mol/K}$ ;  $\Delta S_{\text{dispersed}} = -\Delta H_{\text{H}}/T = -(201.06)/298.15 = 674.36 \dots \text{J/mol/K}$ ;  
 $\Delta S_{\text{Hess}} = \Delta S^\circ_{\text{O}_2} + 2\Delta S^\circ_{\text{H}_2\text{O}} - 2\Delta S^\circ_{\text{H}_2\text{O}_2} = -94.2 + 2 \cdot 69.9565 - (2 \cdot 143.9) = -37.2 \dots \text{J/mol/K}$ ;  
 $\Delta S_{\text{Hess}} = \Delta S^\circ_{\text{O}_2} + 2\Delta S^\circ_{\text{H}_2\text{O}} - 2\Delta S^\circ_{\text{H}_2\text{O}_2} = 110.876 + 2 \cdot 69.9565 - (2 \cdot 143.9) = -37 \dots \text{J/mol/K}$ ;  
 2.  $\Delta S_{\text{total}} = \Delta S_{\text{H}} + \Delta S_{\text{dispersed}} = -37.2 + 674.2 = 637 \dots \text{J/mol/K}$   $\Delta S_{\text{total}} = -37.011 + 674.36 = 637.35 \dots \text{J/mol/K}$ ;  
 4.  $\Delta G_{\text{Hess}} = \Delta H_{\text{H}} - T \cdot \Delta S_{\text{H}} = -201.02 - 298.15 \cdot -0.0372 = -189.9 \dots \text{kJ/mol} \text{ exoergic} \dots \text{spontaneous} \dots$   
 $\Delta G_{\text{Hess}} = \Delta H_{\text{H}} - T \cdot \Delta S_{\text{H}} = -201.06 - 298.15 \cdot -0.037 = -190 \dots \text{kJ/mol}$ ;  
 $T \cdot \Delta S_{\text{total}} = 0.637 \cdot 298.15 = 189.9 \dots \text{kJ/mol}$ ;  $T \cdot \Delta S_{\text{total}} = 0.63735 \cdot 298.15 = 190 \dots \text{kJ/mol}$ ;

Half reactions RedOx Nernst's reduction and oxidation electrons balance  $2 e^-$  at  $\text{pH}=7.36$ ,  $[\text{O}_{\text{aq}}] = 6 \cdot 10^{-5} \text{ M}$   
 $E_{\text{Red}} = E^\circ_{\text{H}_2\text{O}_2} + 0.0591/2 \cdot \lg([\text{O}_2(\text{aq})] \cdot [\text{H}_3\text{O}^+]^2 / [\text{H}_2\text{O}_2] / [\text{H}_2\text{O}]^2) = 0.899 + 0.0591/2 \cdot \lg(6 \cdot 10^{-5} \cdot 10^{-(7.36 \cdot 2)} / 1 / 55.3^2) = 0.2363 \text{ V}$   
 $E_{\text{Ox}} = E^\circ_{\text{H}_2\text{O}_2\text{Ox}} + 0.0591/2 \cdot \lg([\text{H}_2\text{O}_2] \cdot [\text{H}_3\text{O}^+]^2 / [\text{H}_2\text{O}]^4) = 2.084 + 0.0591/2 \cdot \lg(1 \cdot 10^{-(7.36 \cdot 2)} / 55.3^4) = 1.443 \text{ V}$

**Red:**  $\text{H}_2\text{O}_2 + 2 \text{H}_2\text{O} = \text{O}_2 + 2 \text{H}_3\text{O}^+ + 2 e^-$ ;  $E^\circ_{\text{Red}} = E^\circ_{\text{RedH}_2\text{O}_2} = 0.899 \text{ V}$  Alberta University classic  $E_o = 0.694 \text{ V}$ ;

**Ox:**  $\text{H}_2\text{O}_2 + 2 \text{H}_3\text{O}^+ + 2 e^- = 4 \text{H}_2\text{O}$ ;  $E^\circ_{\text{Ox}} = E^\circ_{\text{OxH}_2\text{O}_2} = 2.084 \text{ V}$  Suhotina classic  $E_o = 1.776 \text{ V}$

$2\text{H}_2\text{O}_2(\text{aq}) \Rightarrow \text{O}_2(\text{aq}) + 2\text{H}_2\text{O} + \text{Q} + \Delta G$ ; For activate homeostasis products, hydroxonium and peroxide anions:  $G_{\text{H}_2\text{O}_2} = 364.8 \text{ kJ/mol}$ ;  $G_{\text{H}_3\text{O}^+} + G_{\text{HOO}^-} = 22.44 + 418.32 = 440.76 \text{ kJ/mol}$  free energy referring to water and  $\text{CO}_2(\text{gas})$  zero  $G_{\text{H}_2\text{O}} = G_{\text{CO}_2(\text{gas})} = 0 \text{ kJ/mol}$  appreciate values :

$$\Delta G_{\text{min}} = \Delta G_{\text{eqStandart}} = (E^\circ_{\text{RedH}_2\text{O}_2} - E^\circ_{\text{OxH}_2\text{O}_2}) \cdot F \cdot n = (0.899 - 2.084) \cdot 96485 \cdot 2 = (-1.185) \cdot 96485 \cdot 2 = -228.7 \text{ kJ/mol}$$

$$K_{\text{eqStandart}} = \frac{[\text{O}_2]_{\text{aq}} \cdot [\text{H}_2\text{O}]^2}{[\text{H}_2\text{O}_2]_{\text{aq}}^2} = K_{\text{H}_2\text{O}_2} = \exp(-\Delta G_{\text{eq}} / (R \cdot T)) = \exp(228670 / (8.3144 \cdot 298.15)) = 1.15 \cdot 10^{40} \dots$$

$$\text{Homeostasis } \Delta G_{\text{eqBioChem}} = (E_{\text{Red}} - E_{\text{Ox}}) \cdot F \cdot n = (0.2363 - 1.443) \cdot 96485 \cdot 2 = (-1.206) \cdot 96485 \cdot 2 = -232.8 \dots \text{kJ/mol}$$

$$\Delta G_{\text{Alberty}} = G_{\text{O}_2(\text{BioChem}_\text{arteriaj})} + 2 \cdot G_{\text{H}_2\text{O}(\text{BioChemistry})} - 2 \cdot G_{\text{H}_2\text{O}_2} = 78.08 + 2 \cdot 85.64 - 2 \cdot 364.79 = -480.22 \text{ kJ/mol}$$
; **Alberty**

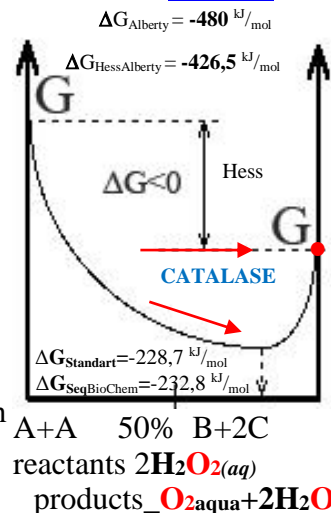
Exothermic and exoergic  $\text{H}_2\text{O}_2(\text{aq})$  dismutation Hesa free energy change  $\Delta G_{\text{Alberty}}$  and  $\Delta G_{\text{HessAlberty}}$  is negative  $-480 \dots \text{kJ/mol}$ ,  $-426.5 \dots \text{kJ/mol}$ , but minimized

$$\Delta G_{\text{eqStandart}} = -228.7 \dots \text{kJ/mol}$$
 reaching equilibrium mixture constant  $K_{\text{eq}} = 1.15 \cdot 10^{40} \dots$

Le Chatelier principle is Prigogine attractor free energy change minimum  $\Delta G_{\text{min}}$  reaching. High rate protolysis attractors  $\text{pH}=7.36$ , oxygen 20.95% in air stay at equilibrium, while homeostasis irreversibly continues, as are non equilibrium state.

Prigogine attractors Nobel Prize Chemistry 1977<sup>th</sup>. CATALASE erase peroxide molecules  $\text{H}_2\text{O}_2$  to 100%  $\omega=6, \omega=3$  fatty acids  $\text{C}_{20:4}$  efficiency elongation synthesis in peroxisomes. CATALASE reactivity is indispensable irreversible homeostasis

Brownian molecular engine for evolution and survival.



## Glass $\text{SiO}_2 \downarrow \text{SiO}_2 \downarrow \text{SiO}_2$ membrane electrode and pH detection

Glass electrodes are usually applicable to solution pH determination. As membrane electrode its potential forms on surface of silicon dioxide ( $\text{SiO}_2$ ) crystalline in protolysis of silicic acid reaction:

$\text{SiO}_2\text{-SiO}_3\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{SiO}_2\text{-SiO}_3^- + \text{H}_3\text{O}^+$ . So glass electrode potential have formed following.

On glass surface locate silicic anions functional groups  $\text{SiO}_2\text{-SiO}_3^-$ . On thin crystalline glass membrane surface in solution with  $\text{H}^+$  ions (in hydrochloric acid HCl) established protolytic equilibrium between crystalline silicic acid  $\text{SiO}_2\text{-SiO}_3\text{H}$  and anionic group of silicate  $\text{SiO}_2\text{-SiO}_3^-$ . Silicic acid is water insoluble acid and weak electrolyte:  $\text{SiO}_2\text{-SiO}_3\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{SiO}_2\text{-SiO}_3^- + \text{H}_3\text{O}^+$ .

As crystalline membrane has inner surface equilibrium and outer surface of membrane has outer equilibrium, where last depends on tested medium  $\text{H}^+$  concentration.



Product in sequence connected equilibrium constants are membrane equilibrium constant  $K_{\text{inner}} \cdot K_{\text{outer}} = K_{\text{membr}}$ :

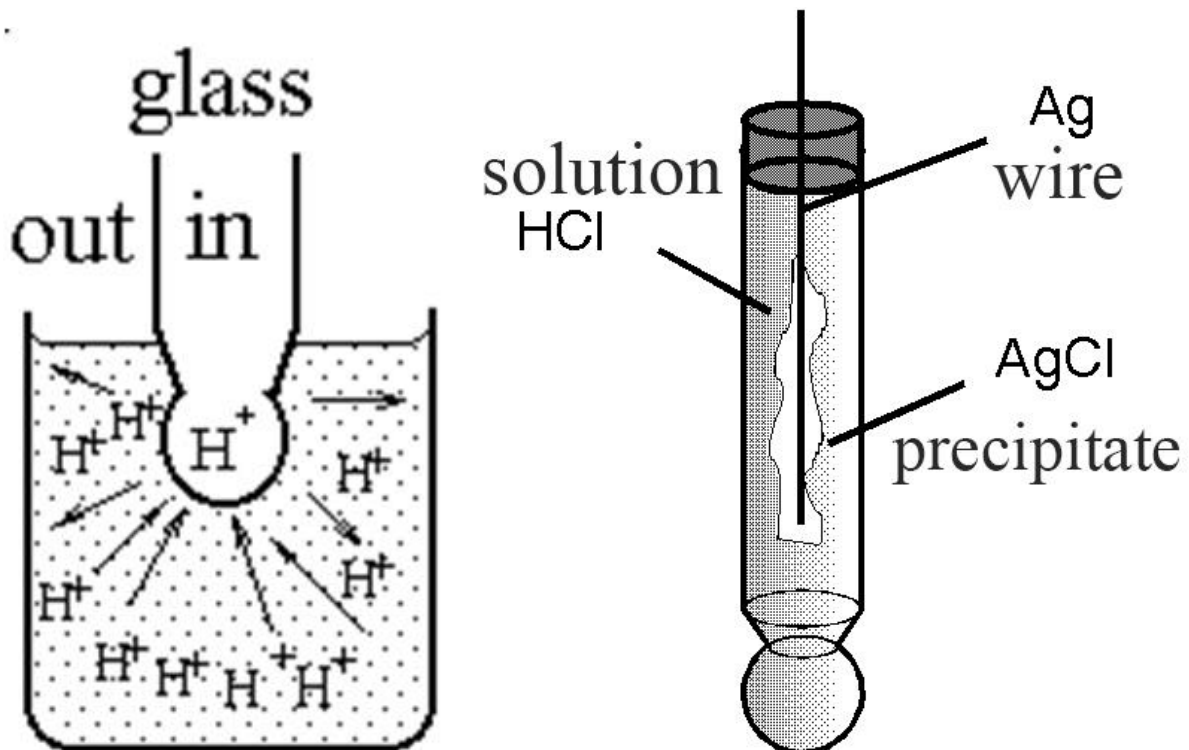
$$K_{\text{inner}} = \frac{[\text{H}_2\text{O}]}{[\text{H}_3\text{O}^+]_{\text{inner}}}; \quad K_{\text{outer}} = \frac{[\text{H}_3\text{O}^+]_{\text{outer}}}{[\text{H}_2\text{O}]}; \quad K_{\text{inner}} \cdot K_{\text{outer}} = K_{\text{membr}} = \frac{[\text{H}_3\text{O}^+]_{\text{outer}}}{[\text{H}_3\text{O}^+]_{\text{inner}}};$$

$$E_{\text{membr}} = \frac{0,0591}{n} \log \frac{[\text{H}_3\text{O}^+]_{\text{outer}}}{[\text{H}_3\text{O}^+]_{\text{inner}}} = 0,0591 (\log[\text{H}_3\text{O}^+]_{\text{outer}} - \log[\text{H}_3\text{O}^+]_{\text{inner}}) = E_{\text{const}} - 0,0591 \cdot \text{pH} \quad (24)$$

where  $n=+1$  hydrogen ion charge  $\text{H}^+$ , but logarithm of concentrations ratio is subtraction two logarithms from concentration ratio. Ions concentration inside membrane is constant  $E_{\text{const}} = -0,0591 \cdot \log[\text{H}_3\text{O}^+]_{\text{inner}}$ . Membrane potential depends only on solution  $\text{H}_3\text{O}^+_{\text{outer}}$  and  $\text{pH} = -\log[\text{H}_3\text{O}^+_{\text{outer}}]$ .

$$E_{\text{membr}} = E_{\text{const}} + 0,0591 \cdot \log[\text{H}_3\text{O}^+_{\text{outer}}] \quad (24)$$

Figure shows on end of glass tube thin bulb, that serves about glass membrane. Inside bulb HCl solution with known concentration. Outside emerge in test solution and measure the pH of solution potentiometric.





Glass membrane  $\text{HSiO}_3\text{-SiO}_2 \downarrow \text{SiO}_2 \downarrow \text{SiO}_2\text{-SiO}_3\text{H}$  and electrodes combination with silver wire.

For electric connection with glass membrane in inner solution deepes one silver wire, that forms second type electroda potential  $E_{\text{AgCl inner}}$  in sequence with membrane potential  $E_{\text{membr.}} + E_{\text{AgCl inner}}$  Potential depends only on outer pH of investigated solution, because hydrochloric acid concentration is constant. EMF (electric motion force) mesure for closed electric cycle. That acheaved in outer solution deeping reference electroda with standard potential  $E_{\text{AgCl}}$ . Electric chain closed at pH-meter contact clumps:

Total EMF potential consist of three electrodes in sequence connected as well from 3 parts:

- 1) inside glass electrode deeped AgCl electrode potential  $E_{\text{AgCl inner}}$ ;
- 2) glass membrane electrode  $E_{\text{membr.}} = E_{\text{const.}} + 0.0591 \cdot \log[\text{H}_3\text{O}^+_{\text{outer}}] = E_{\text{const.}} - 0.0591 \cdot \text{pH}$  (24);
- 3) reference electrode with standard potential  $E_{\text{AgCl}}$ .

By additive sum of constant values parts is calculated new constant:  $E'_{\text{const.}} = (E_{\text{AgCl}} + E_{\text{AgCl inner}} + E_{\text{const.}})$ .

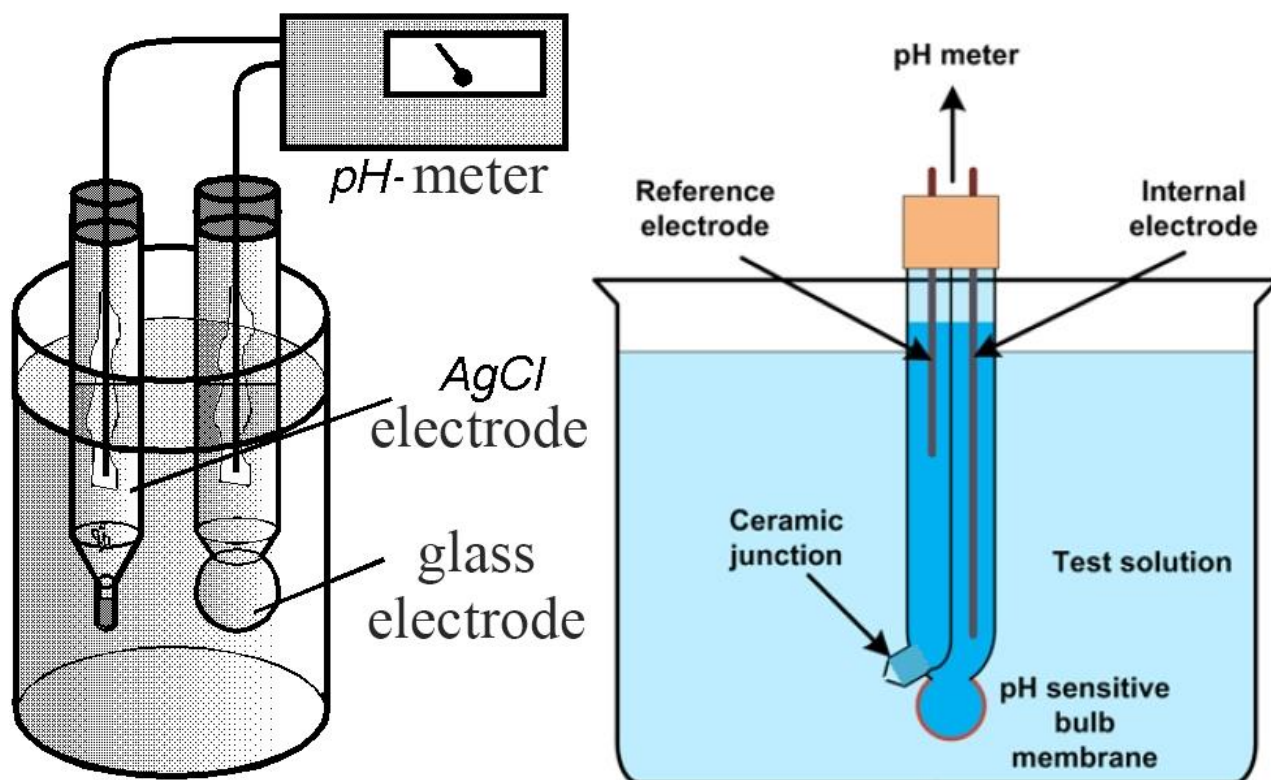
$$E_{\text{DS}} = E_{\text{AgCl}} + E_{\text{membr.}} + E_{\text{AgCl inner}} = (E_{\text{AgCl}} + E_{\text{AgCl inner}} + E_{\text{const.}}) + 0.0591 \cdot \lg [\text{H}_3\text{O}^+_{\text{inner}}] = E'_{\text{const.}} - 0.0591 \cdot \text{pH} \quad (25)$$

$$E_{\text{DS}} = E'_{\text{const.}} - 0.0591 \cdot \text{pH} \quad (26)$$

Measured electric motion force (EMF) is proportional to pH value in solution.

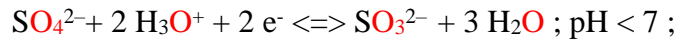
pH measurement by glass electrode has opportunities :

- 1) glass electrode is useable on complete pH interval (from pH = 0 to pH = 14);
- 2) measurement precision reaches 0.001 pH units;
- 3) measurements not depends on oxidation, reduction and proteins in solution;
- 4) permanent direct control of pH by pH-meter.



pH measurement by EMF couple with combined glass and silver chloride electrodes

**Nernst's potential  $\text{SO}_4^{2-}/\text{SO}_3^{2-}$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$  water and basic  $\text{OH}^-$  medium (forced oxidising agent power by potential E increase in acidosis)**



$$E^\circ = E_o + 0,0591/2 * \lg(1/[\text{H}_2\text{O}]^3) = +0,20 \text{ V} ; E^\circ = E_o - 0,0591/2 * \lg([\text{H}_2\text{O}]^3) = \mathbf{0,3545 \text{ V}} ;$$

$$E^\circ_{\text{SO}_4^{2-}} = E^\circ + 0,10166 + 0,0591/2 * \lg([\text{H}_2\text{O}]^3) = 0,2 + 0,10166 + 0,02955 * \lg(55,3^3) = \mathbf{0,45615 \text{ V}} ;$$

$$E_{\text{SO}_4^{2-}} = E^\circ_{\text{SO}_4^{2-}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{SO}_4^{2-}] \cdot [\text{H}_3\text{O}^+]^2}{[\text{SO}_3^{2-}] \cdot [\text{H}_2\text{O}]^3} = \mathbf{0,456 \text{ V}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{SO}_4^{2-}] \cdot [\text{H}_3\text{O}^+]^2}{[\text{SO}_3^{2-}] \cdot [\text{H}_2\text{O}]^3}$$

$$\text{At pH}=7, [\text{H}_2\text{O}]=55,3 \text{ M} ; 0,02955 * \lg([\text{H}_3\text{O}^+]^2/[\text{H}_2\text{O}]^3) = 0,02955 * \lg(10^{-7*2}/55,3^3) = \mathbf{-0,56819 \text{ V}}$$

$$E_{\text{SO}_4^{2-}} = \mathbf{0,456 - 0,5682} + 0,02955 * \lg \frac{[\text{SO}_4^{2-}]}{[\text{SO}_3^{2-}]} = \mathbf{-0,1122} + 0,02955 * \lg \frac{[\text{SO}_4^{2-}]}{[\text{SO}_3^{2-}]} ;$$



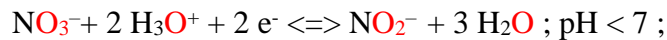
$$E^\circ_{\text{SO}_4^{2-}} = E^\circ + 0,10166 - 0,0591/2 * \lg([\text{H}_2\text{O}]) = -0,93 + 0,10166 - 0,02955 * \lg(55,3) = -0,981 + 0,10166 = \mathbf{-0,87984 \text{ V}} ;$$

$$E_{\text{SO}_4^{2-}} = E^\circ_{\text{SO}_4^{2-}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{SO}_4^{2-}] \cdot [\text{H}_2\text{O}]}{[\text{SO}_3^{2-}] \cdot [\text{OH}]^2} = \mathbf{-0,87984 \text{ V}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{SO}_4^{2-}] \cdot [\text{H}_2\text{O}]}{[\text{SO}_3^{2-}] \cdot [\text{OH}]^2}$$

$$\text{At pOH}=7, [\text{H}_2\text{O}]=55,3 \text{ M} ; 0,02955 * \lg([\text{H}_2\text{O}]/[\text{OH}]^2) = 0,02955 * \lg(55,3/10^{-7*2}) = \mathbf{+0,4651975 \text{ V}}$$

$$E_{\text{SO}_4^{2-}} = \mathbf{-0,8798} + \mathbf{0,46519763} + 0,02955 * \lg([\text{SO}_4^{2-}]/[\text{SO}_3^{2-}]) = \mathbf{-0,4146} + 0,02955 * \lg([\text{SO}_4^{2-}]/[\text{SO}_3^{2-}]);$$

**Nernst's potential  $\text{NO}_3^-/\text{NO}_2^-$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$  water and basic  $\text{OH}^-$  medium (forced oxidising agent power by potential E increase in acidosis)**



$$E^\circ = E_o + 0,0591/2 * \lg(1/[\text{H}_2\text{O}]^3) = +0,94 \text{ V} ; E_o = E^\circ - 0,0591/2 * \lg([\text{H}_2\text{O}]^3) = 0,99 \text{ V} ;$$

$$E^\circ_{\text{NO}_3^-} = E^\circ + 0,10166 + 0,0591/2 * \lg([\text{H}_2\text{O}]^3) = 0,94 + 0,10166 + 0,02955 * \lg(55,3^3) = 0,99 + 0,10166 = \mathbf{1,093 \text{ V}} ;$$

$$E_{\text{NO}_3^-} = E^\circ_{\text{NO}_3^-} + \frac{0,0591}{2} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_3\text{O}^+]^2}{[\text{NO}_2^-] \cdot [\text{H}_2\text{O}]^3} = \mathbf{1,093 \text{ V}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_3\text{O}^+]^2}{[\text{NO}_2^-] \cdot [\text{H}_2\text{O}]^3}$$

$$\text{At pH}=7, [\text{H}_2\text{O}]=55,3 \text{ M} ; 0,02955 * \lg([\text{H}_3\text{O}^+]^2/[\text{H}_2\text{O}]^3) = 0,02955 * \lg(10^{-7*2}/55,3^3) = \mathbf{-0,56819 \text{ V}}$$

$$E_{\text{NO}_3^-} = \mathbf{1,093 - 0,5682} + 0,02955 * \lg \frac{[\text{NO}_3^-]}{[\text{NO}_2^-]} = \mathbf{0,525} + 0,02955 * \lg \frac{[\text{NO}_3^-]}{[\text{NO}_2^-]} ;$$



$$E^\circ = E_o + 0,0591/2 * \lg([\text{H}_2\text{O}]) = 0,01 \text{ V} = E^\circ ; E_o = E^\circ - 0,0591/2 * \lg([\text{H}_2\text{O}]) = 0,01 + 0,02955 * \lg(55,3) = 0,0615 \text{ V} ;$$

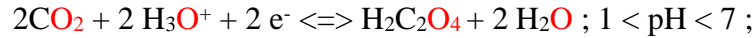
$$E^\circ_{\text{NO}_3^-} = E^\circ + 0,10166 - 0,0591/2 * \lg([\text{H}_2\text{O}]) = 0,01 + 0,10166 + 0,02955 * \lg(55,3) = 0,0615 + 0,10166 = \mathbf{0,16316 \text{ V}} ;$$

$$E_{\text{NO}_3^-} = E^\circ_{\text{NO}_3^-} + \frac{0,0591}{2} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_2\text{O}]}{[\text{NO}_2^-] \cdot [\text{OH}]^2} = \mathbf{0,16316 \text{ V}} + \frac{0,0591}{2} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_2\text{O}]}{[\text{NO}_2^-] \cdot [\text{OH}]^2}$$

$$\text{At pOH}=7, [\text{H}_2\text{O}]=55,3 \text{ M} ; 0,02955 * \lg([\text{H}_2\text{O}]/[\text{OH}]^2) = 0,02955 * \lg(55,3/10^{-7*2}) = \mathbf{+0,46519763 \text{ V}}$$

$$E_{\text{NO}_3^-} = \mathbf{0,16316} + \mathbf{0,46519763} + 0,02955 * \lg([\text{NO}_3^-]/[\text{NO}_2^-]) = \mathbf{0,527} + 0,02955 * \lg([\text{NO}_3^-]/[\text{NO}_2^-]);$$

**Nernst's potential  $2\text{CO}_2 / \text{H}_2\text{C}_2\text{O}_4$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^2) = -0.49 \text{ V}; E_o = -0.49 - 0.0591/2 * \lg(1/55.3^2) = -0.387 \text{ V};$$

$$E^\circ_{\text{H}_2\text{C}_2\text{O}_4} = E^\circ + 0.10166 + 0.0591/2 * \lg([\text{H}_2\text{O}]^2) = -0.49 + 0.10166 - 0.02955 * \lg(1/55.3^2) = \mathbf{-0.285 \text{ V}};$$

$$E_{\text{H}_2\text{C}_2\text{O}_4} = E^\circ_{\text{H}_2\text{C}_2\text{O}_4} + \frac{0.0591}{2} \cdot \lg \frac{[\text{CO}_2]^2 \cdot [\text{H}_3\text{O}^+]^2}{[\text{H}_2\text{C}_2\text{O}_4] \cdot [\text{H}_2\text{O}]^2} = \mathbf{-0.285 \text{ V}} + \frac{0.0591}{2} \cdot \lg \frac{[\text{CO}_2]^2 \cdot [\text{H}_3\text{O}^+]^2}{[\text{H}_2\text{C}_2\text{O}_4] \cdot [\text{H}_2\text{O}]^2}$$

$$\text{At pH}=7, [\text{H}_2\text{O}]=55.3 \text{ M}; 0.02955 * \lg([\text{H}_3\text{O}^+]^2 / [\text{H}_2\text{O}]^2) = 0.02955 * \lg(10^{-7*2} / 55.3^2) = \mathbf{-0.5167 \text{ V}}$$

$$E_{\text{SO}_4} = \mathbf{-0.285 - 0.5167} + 0.02955 * \lg \frac{[\text{CO}_2]^2}{[\text{H}_2\text{C}_2\text{O}_4]} = \mathbf{-0.8017} + 0.02955 * \lg \frac{[\text{CO}_2]^2}{[\text{H}_2\text{C}_2\text{O}_4]};$$

**Nernst's potential  $\text{NO}_3^- / \text{NH}_3$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/8 * \lg([\text{H}_2\text{O}]^6) = -0.12 \text{ V}; E_o = -0.12 - 0.0591/8 * \lg([\text{H}_2\text{O}]^6) = \mathbf{-0.1972 \text{ V}};$$

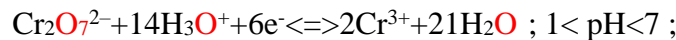
$$E^\circ_{\text{NO}_3^-/\text{NH}_3} = E^\circ + 0.10166 - 0.02955/4 * \lg(55.3^6) = -0.12 + 0.10166 - 0.0772 = -0.1972 + 0.10166 = \mathbf{-0.09554 \text{ V}};$$

$$E_{\text{NO}_3^-/\text{NH}_3} = E^\circ_{\text{NO}_3^-/\text{NH}_3} + \frac{0.0591}{8} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_2\text{O}]^6}{[\text{NH}_3] \cdot [\text{OH}^-]^9} = \mathbf{-0.0955 \text{ V}} + \frac{0.0591}{8} \cdot \lg \frac{[\text{NO}_3^-] \cdot [\text{H}_2\text{O}]^6}{[\text{NH}_3] \cdot [\text{OH}^-]^9}$$

$$\text{At pOH}=7, [\text{H}_2\text{O}]=55.3 \text{ M}; 0.02955/4 * \lg([\text{H}_2\text{O}]^6 / [\text{OH}^-]^9) = 0.02955/4 * \lg(55.3^6 / 10^{-7*9}) = \mathbf{+0.5427 \text{ V}}$$

$$E_{\text{NO}_3^-/\text{NH}_3} = \mathbf{-0.0955} + \mathbf{0.5427} + 0.02955/4 * \lg \frac{[\text{NO}_3^-]}{[\text{NH}_3]} = \mathbf{0.4427} + 0.02955/4 * \lg \frac{[\text{NO}_3^-]}{[\text{NH}_3]};$$

**Nernst's potential  $\text{Cr}_2\text{O}_7^{2-} / 2\text{Cr}^{3+}$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/6 * \lg(1/[\text{H}_2\text{O}]^{21}) = 1.33 \text{ V}; E_o = 1.33 - 0.0591/6 * \lg(1/[\text{H}_2\text{O}]^{21}) = 1.6905 \text{ V};$$

$$E^\circ_{\text{Cr}_2\text{O}_7^{2-}/2\text{Cr}^{3+}} = E^\circ + 0.10166 - 0.0591/6 * \lg(1/55.3^{21}) = 1.33 + 0.10166 + 0.3605 = 1.6905 + 0.10166 = \mathbf{1.7921 \text{ V}};$$

$$E_{\text{Cr}_2\text{O}_7^{2-}/2\text{Cr}^{3+}} = E^\circ_{\text{Cr}_2\text{O}_7^{2-}/2\text{Cr}^{3+}} + \frac{0.0591}{6} \cdot \lg \frac{[\text{Cr}_2\text{O}_7^{2-}] \cdot [\text{H}_3\text{O}^+]^{14}}{[\text{Cr}^{3+}]^2 \cdot [\text{H}_2\text{O}]^{21}} = \mathbf{1.6905 \text{ V}} + \frac{0.0591}{6} \cdot \lg \frac{[\text{Cr}_2\text{O}_7^{2-}] \cdot [\text{H}_3\text{O}^+]^{14}}{[\text{Cr}^{3+}]^2 \cdot [\text{H}_2\text{O}]^{21}}$$

$$\text{At pH}=7, [\text{H}_2\text{O}]=55.3 \text{ M}; 0.02955/3 * \lg([\text{H}_3\text{O}^+]^{14} / [\text{H}_2\text{O}]^{21}) = 0.02955/3 * \lg(10^{-7*14} / 55.3^{21}) = \mathbf{1.3258 \text{ V}}$$

$$E_{\text{Cr}_2\text{O}_7^{2-}/2\text{Cr}^{3+}} = \mathbf{1.6905} + \mathbf{1.3258} + 0.02955/3 * \lg \frac{[\text{Cr}_2\text{O}_7^{2-}]}{[\text{Cr}^{3+}]^2} = \mathbf{3.0164} + 0.02955/3 * \lg \frac{[\text{Cr}_2\text{O}_7^{2-}]}{[\text{Cr}^{3+}]^2};$$

**Nernst's potential  $\text{CrO}_4^{2-} / \text{Cr}(\text{OH})_3 \downarrow$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)

$$E^\circ = E_o + 0.0591/3 * \lg([\text{H}_2\text{O}]^4) = -0.13 \text{ V}; E_o = -0.13 - 0.0591/3 * \lg([\text{H}_2\text{O}]^4) = -0.13 - 0.0591/3 * \lg(55.3^4) = -0.2673 \text{ V};$$

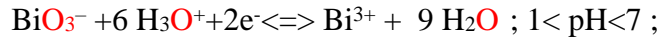
$$E^\circ_{\text{Cr}_2\text{O}_7^{2-}/2\text{Cr}^{3+}} = E^\circ + 0.10166 - 0.0591/3 * \lg(55.3^4) = -0.13 + 0.10166 - 0.1373267 = -0.2673 + 0.10166 = \mathbf{-0.1657 \text{ V}};$$

$$E_{\text{CrO}_4^{2-}/\text{Cr}(\text{OH})_3 \downarrow} = E^\circ_{\text{CrO}_4^{2-}/\text{Cr}(\text{OH})_3 \downarrow} + \frac{0.0591}{3} \cdot \lg \frac{[\text{CrO}_4^{2-}] \cdot [\text{H}_2\text{O}]^4}{[\text{Cr}(\text{OH})_3] \cdot [\text{OH}^-]^5} = \mathbf{-0.1657 \text{ V}} + \frac{0.0591}{3} \cdot \lg \frac{[\text{CrO}_4^{2-}] \cdot [\text{H}_2\text{O}]^4}{[\text{Cr}(\text{OH})_3] \cdot [\text{OH}^-]^5}$$

$$\text{At pOH}=7, [\text{H}_2\text{O}]=55.3 \text{ M}; 0.0591/3 * \lg([\text{H}_2\text{O}]^4 / [\text{OH}^-]^5) = 0.0591/3 * \lg(55.3^4 / 10^{-7*5}) = \mathbf{+0.8268 \text{ V}}$$

$$E_{\text{CrO}_4^{2-}/\text{Cr}(\text{OH})_3 \downarrow} = \mathbf{-0.1657} + \mathbf{0.8268} + 0.0591/3 * \lg \frac{[\text{CrO}_4^{2-}]}{[\text{Cr}(\text{OH})_3]} = \mathbf{+0.7483} + 0.0591/3 * \lg \frac{[\text{CrO}_4^{2-}]}{[\text{Cr}(\text{OH})_3]};$$

**Nernst's potential  $\text{BiO}_3^- / \text{Bi}^{3+}$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^9) = 1.80 \text{ V} ; E_o = 1.80 - 0.0591/2 * \lg(1/55.3^9) = 2.2635 \text{ V} ;$$

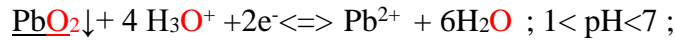
$$E^\circ_{\text{BiO}_3^-/\text{Bi}^{3+}} = E^\circ + 0.10166 + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^9) = 1.8 + 0.10166 - 0.02955 * \lg(1/55.3^9) = 2.2635 + 0.10166 = \mathbf{2.365 \text{ V}} ;$$

$$E_{\text{BiO}_3^-/\text{Bi}^{3+}} = E^\circ_{\text{BiO}_3^-/\text{Bi}^{3+}} + \frac{0.0591}{2} * \lg \frac{[\text{BiO}_3^-] \cdot [\text{H}_3\text{O}^+]^6}{[\text{Bi}^{3+}] \cdot [\text{H}_2\text{O}]^9} = \mathbf{2.365 \text{ V}} + \frac{0.0591}{2} * \lg \frac{[\text{BiO}_3^-] \cdot [\text{H}_3\text{O}^+]^6}{[\text{Bi}^{3+}] \cdot [\text{H}_2\text{O}]^9}$$

At pH=7,  $[\text{H}_2\text{O}] = 55.3 \text{ M}$  ;  $0.02955 * \lg([\text{H}_3\text{O}^+]^6/[\text{H}_2\text{O}]^9) = 0.02955 * \lg(10^{-7*6}/55.3^9) = \underline{-1.7046 \text{ V}}$

$$E_{\text{BiO}_3^-/\text{Bi}^{3+}} = \mathbf{2.365} - \underline{1.7046} + 0.02955 * \lg \frac{[\text{BiO}_3^-]}{[\text{Bi}^{3+}]} = \mathbf{0.6604} + 0.02955 * \lg \frac{[\text{BiO}_3^-]}{[\text{Bi}^{3+}]} ;$$

**Nernst's potential  $\text{PbO}_2 \downarrow / \text{Pb}^{2+}$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^6) = 1.80 \text{ V} ; E_o = 1.8 - 0.0591/2 * \lg(1/55.3^6) = 2.109 \text{ V} ;$$

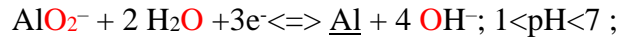
$$E^\circ_{\text{PbO}_2 \downarrow/\text{Pb}^{2+}} = E^\circ + 0.10166 - 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^6) = 1.8 + 0.10166 - 0.02955 * \lg(1/55.3^6) = 2.109 + 0.10166 = \mathbf{2.21066 \text{ V}} ;$$

$$E_{\text{PbO}_2 \downarrow/\text{Pb}^{2+}} = E^\circ_{\text{PbO}_2 \downarrow/\text{Pb}^{2+}} + \frac{0.0591}{2} * \lg \frac{[\text{PbO}_2 \downarrow] \cdot [\text{H}_3\text{O}^+]^4}{[\text{Pb}^{2+}] \cdot [\text{H}_2\text{O}]^6} = \mathbf{2.2106 \text{ V}} + \frac{0.0591}{2} * \lg \frac{[\text{PbO}_2 \downarrow] \cdot [\text{H}_3\text{O}^+]^4}{[\text{Pb}^{2+}] \cdot [\text{H}_2\text{O}]^6}$$

At pH=7,  $[\text{H}_2\text{O}] = 55.3 \text{ M}$  ;  $0.02955 * \lg([\text{H}_3\text{O}^+]^4/[\text{H}_2\text{O}]^6) = 0.02955 * \lg(10^{-7*4}/55.3^6) = \underline{-1.1364 \text{ V}}$

$$E_{\text{PbO}_2 \downarrow/\text{Pb}^{2+}} = \mathbf{2.2106} - \underline{1.1364} + 0.02955 * \lg \frac{[\text{PbO}_2 \downarrow]}{[\text{Pb}^{2+}]} = \mathbf{0.9726} + 0.02955 * \lg \frac{[\text{PbO}_2 \downarrow]}{[\text{Pb}^{2+}]} ;$$

**Nernst's potential  $\text{AlO}_2^- / \text{Al} \downarrow$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/3 * \lg([\text{H}_2\text{O}]^2) = -2.35 \text{ V} ; E_o = E^\circ - 0.0591/3 * \lg(55.3^2) = -2.4187 \text{ V} ;$$

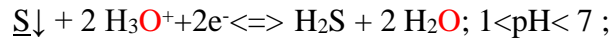
$$E^\circ_{\text{AlO}_2^-/\text{Al} \downarrow} = E^\circ + 0.10166 - 0.0591/3 * \lg([\text{H}_2\text{O}]^2) = -2.35 + 0.10166 - 0.0591/3 * \lg(55.3^2) = -2.4187 + 0.10166 = \mathbf{-2.317 \text{ V}} ;$$

$$E_{\text{AlO}_2^-/\text{Al} \downarrow} = E^\circ_{\text{AlO}_2^-/\text{Al} \downarrow} + \frac{0.0591}{3} * \lg \frac{[\text{AlO}_2^-] \cdot [\text{H}_2\text{O}]^2}{[\text{Al} \downarrow] \cdot [\text{OH}^-]^4} = \mathbf{-2.317 \text{ V}} + \frac{0.0591}{3} * \lg \frac{[\text{AlO}_2^-] \cdot [\text{H}_2\text{O}]^2}{[\text{Al} \downarrow] \cdot [\text{OH}^-]^4}$$

At pOH=7,  $[\text{H}_2\text{O}] = 55.3 \text{ M}$  ;  $0.0591/3 * \lg([\text{H}_2\text{O}]^2/[\text{OH}^-]^4) = 0.0591/3 * \lg(55.3^2/10^{-7*4}) = \underline{+0.6203 \text{ V}}$

$$E_{\text{AlO}_2^-/\text{Al} \downarrow} = \mathbf{-2.317} + \underline{0.6203} + 0.0591/3 * \lg \frac{[\text{AlO}_2^-]}{[\text{Al} \downarrow]} = \mathbf{+1.6967} + 0.0591/3 * \lg \frac{[\text{AlO}_2^-]}{[\text{Al} \downarrow]} ;$$

**Nernst's potential  $\text{S} \downarrow / \text{H}_2\text{S}$  red-ox system behaving in acidic  $\text{H}_3\text{O}^+$ , water medium**  
(forced oxidising agent power by potential E increase in acidosis)



$$E^\circ = E_o + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^2) = 0.142 \text{ V} ; E_o = 0.142 - 0.0591/2 * \lg(1/55.3^2) = 0.245 \text{ V} ;$$

$$E^\circ_{\text{S} \downarrow/\text{H}_2\text{S}} = E^\circ + 0.10166 + 0.0591/2 * \lg(1/[\text{H}_2\text{O}]^2) = 0.142 + 0.10166 - 0.02955 * \lg(1/55.3^2) = 0.245 + 0.10166 = \mathbf{0.3467 \text{ V}} ;$$

$$E_{\text{S} \downarrow/\text{H}_2\text{S}} = E^\circ_{\text{S} \downarrow/\text{H}_2\text{S}} + \frac{0.0591}{2} * \lg \frac{[\text{S}] \cdot [\text{H}_3\text{O}^+]^2}{[\text{H}_2\text{S}] \cdot [\text{H}_2\text{O}]^2} = \mathbf{0.3467 \text{ V}} + \frac{0.0591}{2} * \lg \frac{[\text{S}] \cdot [\text{H}_3\text{O}^+]^2}{[\text{H}_2\text{S}] \cdot [\text{H}_2\text{O}]^2}$$

At pH=7,  $[\text{H}_2\text{O}] = 55.3 \text{ M}$  ;  $0.02955 * \lg([\text{H}_3\text{O}^+]^2/[\text{H}_2\text{O}]^2) = 0.02955 * \lg(10^{-7*2}/55.3^2) = \underline{-0.5167 \text{ V}}$

$$E_{\text{S} \downarrow/\text{H}_2\text{S}} = \mathbf{0.3467} - \underline{0.5167} + 0.02955 * \lg \frac{[\text{S}]}{[\text{H}_2\text{S}]} = \mathbf{-0.17} + 0.02955 * \lg \frac{[\text{S}]}{[\text{H}_2\text{S}]} ;$$



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