

Aris Kaksis , dep. Human Physiology and Biochemistry , [aris.kaksis@rsu.lv](mailto:aris.kaksis@rsu.lv), Riga Stradin's University, Functionally activate oxygen and carbon dioxide molecules with high rate protolysis equilibria as Biosphere Self-Organization Attractors create perfect order homeostasis reactions to link bioenergetic.

**Abstract.** The quantitative studies for oxygen and carbon dioxide functional activity reveal multiply generated Self-Organization Attractors: pH=7.36, enzyme Carbonic Anhydrase reactivity, water concentration  $[H_2O]=55.3 \text{ mol/Liter}$ , air oxygen level 20.95 %, osmolar concentration 0.305 M, ionic strength 0.25 M, temperature 310.15 K degree etc.. [1] High rate protolysis with water make oxygen fire safe and  $CO_{2\text{aqua}}$  functional active for Life Biochemistry. In 2023 are hundred Years of Brønsted - Lowry protolysis with water, which high rate protonation stay at equilibria while homeostasis continues. Dissolute oxygen forms [arterial concentration](#)  $[O_{2\text{aqua}}]=6 \cdot 10^{-5} \text{ M}$  as safe Bioenergetic sustaining isooxia with Attractors of Self-Organization. [3]

Thermodynamic indicate Biosphere indispensability to reach Self-Organization Attractor values. Destiny is trend to minimum of free energy change in homeostasis. Attractors made functionally active molecules Self-Organize the perfect reactions order in homeostasis. [2,3,4] Deviation from Attractor values disorder the homeostasis. The Chaos stops the homeostasis which disappears as extinct from Biosphere.

**Keywords:** Biosphere, Thermodynamics, Self-Organization, Attractors, Bioenergetics.

**Introduction.** Ilya Prigogine in 1954 demonstrates the isolate mixture of compounds in reactions trend reach Free energy change minimum at equilibrium state. [2] Prigogine in 1977 declares: equilibrium state is Attractor for non-equilibrium state in reactions mixture of compounds. [3,4] Prigogine explains perfect order formation as Self-Organization Attractors for Universe and Sciences.

About Universe creation in perfect order Maria Kuman: „The nonlinear no equilibrium theory of Prigogine is also called The Chaos Theory because it claims that our Universe was created in perfect order out of the chaos.”.

[5] Chaos is just apparent disorder. The Biosphere belongs to our human civilization as part of perfect Universe.

Attractors create perfect order with functionally active molecules. Self-Organization with Attractors in dissipative structures makes the homeostasis order. Biochemistry Thermodynamic studies indicate Attractor vales of two types: the primary Attractors are common for Life Biosphere (air oxygen level 20.95 %  $O_2$ , Carbonic Anhydrase CA reactivity), the secondary Attractors are for individual organisms (generate concentration gradients, isooxia-homeostasis Norma) and multipurpose Attractor values (pH=7.36, water, concentration).

Free energy content for protolysis products  $H_3O^++OH^-$  increases to  $99.8 \text{ kJ/mol}$  from  $H_2O+H_2O$  zero 0: to  $H_2O+H_2O \rightleftharpoons H_3O^++OH^-$ ;  $K_{H_3O^++OH^-}=[H_3O^+][OH^-]/[H_2O]^2=3.26 \cdot 10^{-18}$ ;  $\Delta G_{H_3O^++OH^-}=-R \cdot T \cdot \ln(K_{H_3O^++OH^-})=99.8 \text{ kJ/mol}$ .

### Thermodynamic methods

**Four Attractors and decreased Oxygen power for functional activity isooxia.** Water triplet state of oxygen, its concentration  $[H_2O]=55.3 \text{ mol/Liter}$ , air oxygen level 20.95 % for five hundred million Years, pH=7.36 for the concentration  $[H_3O^+]=10^{-7.36} \text{ M}$ .

Water solution oxygen keeps triplet state for temperatures from  $0^\circ \text{ C}$  to  $100^\circ \text{ C}$ . Oxygen no reaction with water, prevent singlet formation and is inactive. **Triplet** oxygen atoms in molecule bound with three covalent bonds  $\cdot\text{O}=\text{O}:\cdot$ , however degenerate electron pair loosen another covalent orbital as radical, therefore in total **triplet** exhibit double bond  $:\text{O}=\text{O}:$ .

Air oxygen 20.95 % concentration as Attractor forms functional active solutions in arterial and venous blood. Blood plasma contact interface with [air dissolve](#)  $[O_{2\text{aqua}}]=9.77\cdot 10^{-5}$  M concentration, if osmolarity is  $C_{\text{osm}}=0.305$  M, ionic strength  $I=0.25$  M, air oxygen is 20.95 %. [6,1] Blood solubility constant  $K_{O_2\text{blood}}$  is:

$$K_{O_2\text{blood}}=[O_{2\text{aqua}}]/[O_{2\text{gas}}]=9.768\cdot 10^{-5}/0.2095=10^{-3.33} \text{ M}=10^{-pK_{O_2\text{blood}}}$$

Oxygen water solutions through membrane aquaporins in osmosis against concentration gradients form arterial  $[O_{2\text{aqua}}]=6\cdot 10^{-5}$  M and venous  $[O_{2\text{aqua}}]=0.426\cdot 10^{-5}$  M [concentrations](#) [6], what corresponds to isooxia (homeostasis Norma).  $O_{2\text{gas\_AIR}}+H_2O+\Delta G_{\text{Aquaporins}}\rightarrow O_{2\text{aqua-Blood}}+Q$ .

Hyperoxia, oxygen excess as oxidative stress with acidosis mechanism accumulate increasing Free energy content. The oxygen becomes fire-insecure for Biochemistry as oxidative stress hazard for Life.

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

Rotating Electrode Method and Oxygen Reduction Electro catalysts: detect oxygen solubility.

Solubility at 25° C 298.15 K divide gas mol fraction one  $[O_{2\text{gas}}]=1$ :  $[O_{2\text{aqua}}]=K_{O_2}=1.22\cdot 10^{-3}$  M/1=  $\frac{[O_{2\text{aqua}}]}{[O_{2\text{gas}}]}$ . [7]

Atmosphere oxygen 20.95 % mol fraction is 0.2095. Solubility from air 20.95 % proportional to mol fraction

$$[O_{2\text{aqua}}]=1.22\cdot 10^{-3}\cdot 0.2095=2.556\cdot 10^{-4} \text{ M. Mol fraction of water solution is ratio: } [O_{2\text{aqua}}]/[H_2O].$$

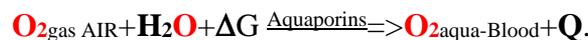
Thermodynamic solubility product is calculates in ratio:

$$K_{\text{sp}}=\frac{[O_{2\text{aqua}}]}{[O_{2\text{gas}}]\cdot [H_2O]}=K_{O_2}/[H_2O]=1.22\cdot 10^{-3}/55.3=2.205\cdot 10^{-5} \text{ and Free energy change minimum in expression:}$$

$G_{O_2\text{aqua}}=\Delta G_{\text{sp}}=-R\cdot T\cdot \ln(K_{\text{sp}})=-8.3144\cdot 298.15\cdot \ln(2.205\cdot 10^{-5})=26.58$  kJ/mol. Water solution oxygen free energy content increases about 26.58 kJ/mol, but inactive triplet oxygen is most negative benefit Attractor for homeostasis.

Table 1. Standard  $\Delta H^\circ_{\text{Hess}}$ ,  $\Delta S^\circ_{\text{Hess}}$  and  $\Delta G^\circ_{\text{Hess}}$  values of formation from elements, at ionic strength 0.25 M, at 298.15 K degree. [1] **Biochemistry thermodynamic 2006** [8] in bold are data for pH=7.36.

Substance	$\Delta H^\circ_{\text{Hess}}$ , kJ/mol	$\Delta S^\circ_{\text{Hess}}$ , J/mol/K	$\Delta G^\circ_{\text{Hess}}$ , kJ/mol	Free energy content accumulation kJ/mol
<b><math>O_{2\text{aqua}}</math></b>	<b>-11,70</b>	<b>-94,2</b>	<b>16,40</b>	
$O_{2\text{aqua}}$	-11,715	110,876	16,4	
$O_{2\text{gas}}$	0	205,152	<b>-61,166</b>	
<b><math>H_3O^+</math></b>	-285,81	-3,854	-213,275	Protolysis accumulates in ions $H_3O^++OH^-$ :
<b><math>OH^-</math></b>	-230,015	-10,9	-157,2	$G_{H_3O^++OH^-}=99.8$
<b><math>H_2O</math></b>	-285,85	69,9565	-237,191	$G_{O_2}=303.1$ kJ/mol; $G^\circ_{H_2\text{gas}}=\mathbf{85,64}$ kJ/mol; <a href="#">Alberty</a> [8]
<b><math>H_2O</math></b>	<b>-286,65</b>	<b>-453,188</b>	<b>-151,549</b>	
$CO_{2\text{aqua}}$	-413,798	117,5704	-385,98	Solubility accumulate energy $\Delta G_{\text{sp}CO_{2\text{aqua}}}=8.3845$ kJ/mol;
$CO_{2\text{gas}}$	-393,509	213,74	-394,359	
<b><math>HCO_3^-</math></b>	<b>-692,495</b>	<b>-494,768</b>	<b>-544,969</b>	Hess for: Enthalpy $\Delta H_{\text{Hess}}$ , for Entropy $\Delta S_{\text{Hess}}$ , and
<b><math>HCO_3^-</math></b>	-689,93	98,324	-586,94	for Free energy $\Delta G_{\text{Hess}}$ .



**Exothermic:**  $\Delta H_{\text{Hess}}=-11.7$  kJ/mol, **Endoergic:**  $\Delta G_{\text{Hess}}=77.6$  kJ/mol,  $\Delta S_{\text{dispersed}}=-\Delta H_{\text{Hess}}/T=39.2$  J/mol/K.

Solubility Hess Entropy  $\Delta S_{\text{Hess}}=\Delta S^\circ_{O_{2\text{aqua-Blood}}}-\Delta S^\circ_{O_{2\text{gas-AIR}}}=-299$  J/mol/K;

Solubility collect Hess Free energy in oxygen one mol  $O_{2\text{aqua-Blood}}$  is positive value:

$$\Delta G_{\text{Hess}}=\Delta H_{\text{Hess}}-T\cdot \Delta S_{\text{Hess}}=-11.7-298.15\cdot -0.299352=77.55 \text{ kJ/mol } \mathbf{\text{endoergic.}}$$

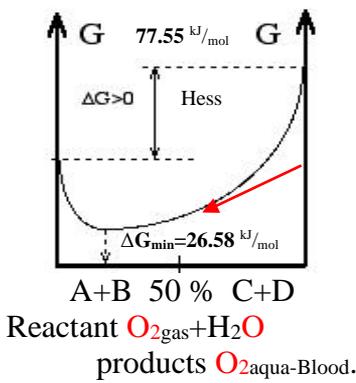


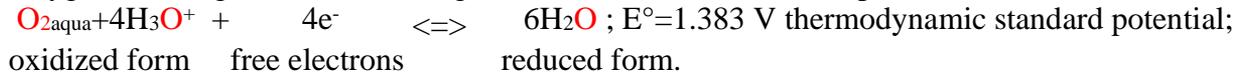
Figure 1. Exothermic and endoergic Hess oxygen solubility having Free energy change positive  $\Delta G_{\text{Hess}}=77.55 \text{ kJ/mol}$ , but minimized Free energy change  $\Delta G_{\text{min}}=\Delta G_{\text{sp}}=G_{\text{O2aqua}}=26.58 \text{ kJ/mol}$  reaching solubility product equilibrium mixture:

$$K_{\text{sp}} = \frac{[\text{O}_{2\text{aqua}}]}{[\text{O}_{2\text{gas}}] \cdot [\text{H}_2\text{O}]} = 2.205 \cdot 10^{-5}$$

Le Chatelier principle is reaching Prigogine declared Attractor for non-equilibrium state Free energy change minimum  $\Delta G_{\text{min}}$ .

Non- equilibrium mixture of compounds trends reaching equilibrium state - minimum  $\Delta G_{\text{min}}$ , but never do as homeostasis is non-equilibrium state.

Blood plasma oxygen is strong oxidant according half reaction classic standard potential  $E_0=1.229 \text{ Volts}$  [2]:



1) Two **Attractors**: air oxygen  $\text{O}_2$  20.95 % and  $\text{pH}=7.36$  minimize Free energy content in one mol of  $\text{O}_{2\text{aqua}}$ , with arterial blood concentration  $[\text{O}_{2\text{aqua}}]=6 \cdot 10^{-5} \text{ M}$  and  $\text{pH}=7.36$  concentration  $[\text{H}_3\text{O}^+]=10^{-7.36} \text{ M}$ .

$$E = E_0 + 0.01478 \cdot \lg([\text{O}_{2\text{aqua}}] \cdot [\text{H}_3\text{O}^+]^4) = 1.229 + 0.01478 \cdot \lg(6 \cdot 10^{-5} \cdot 10^{-7.36 \cdot 4}) = 0.731 \text{ Volts}.$$

Oxidative stress potential decreases about  $\Delta E_{\text{O2aqua pH}} = E - E_0 = 0.73 - 1.229 = -0.497 \text{ Volts}$  and minimizes Free energy content for oxygen about:  $\Delta G_{\text{min}} = \Delta E_{\text{O2aqua pH}} \cdot F \cdot n = -0.497 \cdot 96485 \cdot 4 / 1000 = -192 \text{ kJ/mol}$ .

2) **Attractor water** concentration decreases thermodynamic standard potential from 1.383 Volts to classic standard potential 1.229 Volts [1] about -0.154 Volts  $= \Delta E_{\text{H2O}}$ .

Water concentration  $[\text{H}_2\text{O}] = 996.23 / 18 = 55.3 \text{ M}$  value forms thermodynamic standard potential  $E^\circ = 1.383 \text{ Volts}$  which classically included in  $E_0$  classic standard potential:

$$E_0 = E^\circ + 0.0591 / 4 \cdot \lg(1 / [\text{H}_2\text{O}]^6) = 1.383 + 0.01478 \cdot \lg(1 / 55.346^6) = 1.229 \text{ Volts};$$

Attractor  $[\text{H}_2\text{O}]$  concentration oxidative stress potential decreases about:  $\Delta E_{\text{H2O}} = E^\circ - E_0 = 1.383 - 1.229 = -0.154$

Volts and minimizes Free energy content decreasing about  $\Delta G_{\text{arterial}} = \Delta E_{\text{H2O}} \cdot F \cdot n = -0.154 \cdot 96485 \cdot 4 / 1000 = -59.82 \text{ kJ/mol}$ . Total oxidative stress potential decreases about  $\Delta E = \Delta E_{\text{O2aqua pH}} + \Delta E_{\text{H2O}} = -0.497 - 0.155 = -0.652 \text{ Volts}$ . With

Attractors of air  $\text{O}_2$  20.95 %,  $\text{pH}=7.36$  and  $[\text{H}_2\text{O}]=55.3 \text{ M}$  total water solution Free energy decreases about:

$$G_{\text{O2Biochem\_arterial}} = G_{\text{O2aqua}} + \Delta G_{\text{arterial}} + G_{\text{O2sp}} = 303.1 - 251.6 + 26.58 = 78.08 \text{ kJ/mol. Poetic one says to smother the flame.}$$

Oxygen becomes fire safe–functional active Norma for Life. Strong oxidant free energy content  $G_{\text{O2}}=303.1 \text{ kJ/mol}$

becomes  $G_{\text{O2Bio}}=237,2-151.55=78.08 \text{ kJ/mol}$  times 3.88 less active therefore fire safe for Biochemistry with free

energy  $G_{\text{O2Bio}}=78.08 \text{ kJ/mol}$ . Free energy content with potential decrease prevents oxidative stress. Extra Free

energy accumulation increases oxygen power and create hyperoxia, which disorder homeostasis with chaotic

oxidation. That destroy organism with abnormal activate  $\text{O}_{2\text{aqua}}$  molecules.

NASA Apollo project closed 1972 due to hyperoxia, because astronauts had to work in pure 100 % oxygen atmosphere, which is five times greater about global Attractor value 20.95 % oxygen. Hyperoxia is hazard nor for astronauts nor for NASA technologic Apollo equipment devices.

Hypoxia is specific order of homeostasis for decreased oxygen concentration.

Hypoxia switch on the Hypoxia Induced Factors cell proteins HIF, which work on nuclear receptors induce in cells processes with decreased oxygen concentration - deficiency. The Nobel Prize 2019 in Medicine.

## Synthesis of Carbonic Anhydrase CA indispensable Attractor.

Carbonic Anhydrase reactivity and generate Physiologic buffer solutions total equilibrium value pH=7.36 as Self-Organization Attractors. In reaction  $\text{CO}_2+2\text{H}_2\text{O}$  products ( $\text{CO}_{2\text{aqua}}$ )  $\text{H}_3\text{O}^++\text{HCO}_3^-$  accumulate free energy content  $G_{\text{H}_3\text{O}^++\text{HCO}_3^-}=8.38 \text{ kJ/mol}+60 \text{ kJ/mol}$  is indispensable for functional activity of bicarbonate buffer system on the planet Earth for perfect reactions order in homeostasis complex processes.

$\text{CO}_2$  no reaction with water  $\text{H}_2\text{O}$  at absence of CA.  $\text{CO}_2$  is small soluble and slow react with  $\text{OH}^-$ . Solubility  $\text{CO}_{2\text{gas}}+\text{H}_2\text{O}+\Delta G\rightleftharpoons\text{CO}_{2\text{aqua}}+\text{Q}$  product constant:  $K_{\text{spCO}_{2\text{aqua}}}=[\text{CO}_{2\text{aqua}}]/[\text{CO}_{2\text{gas}}]/[\text{H}_2\text{O}]=0.034$  is unfavored but exothermic  $\Delta H_{\text{Hess}}=\Delta H^\circ\text{CO}_{2\text{aq}}-\Delta H^\circ\text{CO}_{2\text{gas}}=-20.3 \text{ kJ/mol}$ .

$$\Delta G_{\text{spCO}_{2\text{aqua}}}=-R\cdot T\cdot\ln(K_{\text{spCO}_{2\text{aqua}}})=-8.3144\cdot 298.15\cdot\ln(0.034045)/1000=8.379 \text{ kJ/mol minimum.}$$

Air 0.04 % mol fraction  $[\text{CO}_{2\text{gas}}]=0.0004$  dissolve concentration is:

$$[\text{CO}_{2\text{aqua}}]=K_{\text{spCO}_{2\text{aqua}}}\cdot[\text{H}_2\text{O}]\cdot[\text{CO}_{2\text{gas}}]=0.034045\cdot 55.3457\cdot 0.0004=0.000753 \text{ M.}$$

Carbon dioxide  $\text{CO}_{2\text{aqua}}$  react with  $\text{OH}^-$  times  $10^6$  slower about neutralization reaction:

$\text{H}_3\text{O}^++\text{HCO}_3^-\Rightarrow\text{CO}_{2\text{aqua}}+2\text{H}_2\text{O}+\Delta G+\text{Q}$ , because neutralization velocity constant is  $k_2=5.16885\cdot 10^{18} \text{ M}^{-2}\text{s}^{-1}$ , but  $\text{OH}^-$  ions:  $\text{CO}_{2\text{aqua}}+\text{OH}^-\Rightarrow\text{HCO}_3^-$  velocity constant  $k_{1\text{OH}}$  is from  $1.5\cdot 10^2 \text{ M}^{-2}\text{s}^{-1}$  to  $1.5 \text{ M}^{-2}\text{s}^{-1}$ . Reaction is favored  $\Delta G_{\text{HessHCO}_3^-}=G_{\text{HCO}_3^-}-(G_{\text{CO}_{2\text{aqua}}}+G_{\text{OH}^-})=46,08-(8,379+77,36)=-39,66 \text{ kJ/mol}$  with equilibrium constant:  $[\text{HCO}_3^-]/[\text{CO}_{2\text{aqua}}]/[\text{OH}^-]=K_{\text{eq\_HCO}_3^-}=\text{EXP}(-\Delta G_{\text{eq\_HCO}_3^-}/R/T)=\text{EXP}(39659/8,3144/298,15)=8871734=10^{6,948}$ , with exothermic heat production Q:  $\Delta H_{\text{Hess}}=\Delta H^\circ\text{HCO}_3-\Delta H^\circ\text{CO}_2-\Delta H^\circ\text{OH}^-=-48.68 \text{ kJ/mol}$ .  $\text{HCO}_3^-\Rightarrow\text{CO}_{2\text{aqua}}+\text{OH}^-$ :  $k_{1\text{OH}}/k_{2\text{HCO}_3^-}=K_{\text{eq\_HCO}_3^-}=1.5\cdot 10^2/k_{2\text{HCO}_3^-}=8871734$ ;  $k_{2\text{HCO}_3^-}=k_{1\text{OH}}/K_{\text{eq\_HCO}_3^-}=1.5\cdot 10^2/8871734=1.6908\cdot 10^{-5}$ . Decomposition  $\text{HCO}_3^-\Rightarrow\text{CO}_{2\text{aqua}}+\text{OH}^-$  velocity constant  $k_{2\text{HCO}_3^-}$  is from  $1.6908\cdot 10^{-5}$  to  $1.6908\cdot 10^{-7}$ . Reaction with  $\text{OH}^-$  ions is hundred billions to ten trillion  $10^{13}$  times slower about CA Carbonic Anhydrase velocity constant.

CA Carbonic Anhydrase protolytic reactivity create functional active bicarbonate buffer Self-Organization Attractor pH=7.36 with generate concentration gradients for transport  $\text{H}_3\text{O}^+$ ,  $\text{HCO}_3^-$ ,  $\text{CO}_{2\text{aqua}}$  and osmosis. [9] CA Carbonic Anhydrase high rate protolysis reaction of  $\text{CO}_{2\text{aqua}}$  with two water molecules:

$$\text{CO}_{2\text{aqua}}+2\text{H}_2\text{O}+\Delta G+\text{Q}=\nu 1^{\text{CA}}>\text{H}_3\text{O}^++\text{HCO}_3^- \text{ and velocity constant is: } k_{1\text{CO}_{2\text{aqua}}}=1.5\cdot 10^8 \text{ M}^{-1}\text{s}^{-1}. [9]$$

Neutralization  $\text{H}_3\text{O}^++\text{HCO}_3^-\rightleftharpoons\text{CO}_{2\text{aqua}}+2\text{H}_2\text{O}$  velocity constant is times  $10^{10.54}$  higher about Carbonic Anhydrase velocity constant:  $k_2/k_{1\text{CO}_{2\text{aqua}}}=5.16885\cdot 10^{18}/1.5/10^8=10^{10.54}$ .

CA protolysis equilibrium constant have calculated in the velocity constants ratio expression:

$$K_{\text{eqCAHCO}_3\text{aqua}}=k_{1\text{CO}_{2\text{aqua}}}/k_2=\frac{[\text{HCO}_3^-]_{\text{aqua}}\cdot[\text{H}_3\text{O}^+]}{[\text{CO}_2]_{\text{aqua}}\cdot[\text{H}_2\text{O}]^2}=K_{\text{a\_CO}_{2\text{aqua}}}/[\text{H}_2\text{O}]^2=10^{(-7.0512)}/55.32=2.906\cdot 10^{-11}=10^{-10.54}.$$

Bicarbonate buffer system acid protolysis constant  $\text{pK}_{\text{a\_CO}_{2\text{aqua}}}=7.0512$  is friendly to pH=7.36:

$$K_{\text{a\_CO}_{2\text{aqua}}}=K_{\text{eqCAHCO}_3\text{aqua}}\cdot[\text{H}_2\text{O}]^2=\frac{[\text{HCO}_3^-]_{\text{aqua}}\cdot[\text{H}_3\text{O}^+]}{[\text{CO}_2]_{\text{aqua}}}=10^{-7.0512}=10^{-\text{pK}_{\text{a\_CO}_{2\text{aqua}}}}$$

Original  $\text{pK}_{\text{a\_CO}_{2\text{aqua}}}=7.0512$  obtained and calculate for [BUFFER solution](#). [1]

Neutralization:  $\text{H}_3\text{O}^++\text{HCO}_3^-\rightleftharpoons\text{CO}_{2\text{aqua}}+2\text{H}_2\text{O}$  constant is inverse to protolysis and favored:

$$K_{\text{eqNeutralization}}=1/K_{\text{eqCAHCO}_3\text{aqua}}=[\text{HCO}_3^-]\cdot[\text{H}_3\text{O}^+]/[\text{CO}_{2\text{aqua}}]/[\text{H}_2\text{O}]^2=1/2.906/10^{-11}=3441200000=10^{10.54}.$$

Hess Free energy change is exoergic:  $\Delta G_{\text{Hess}}=2\Delta G^\circ\text{H}_2\text{O}+\Delta G^\circ\text{CO}_2-\Delta G^\circ\text{H}_3\text{O}-\Delta G^\circ\text{HCO}_3=-102 \text{ kJ/mol}$ ;

$$\Delta G_{\text{Hess}}=2G_{\text{H}_2\text{O}}+G_{\text{CO}_{2\text{aqua}}}-G_{\text{H}_3\text{O}}-G_{\text{HCO}_3}=2\cdot 0+8.379-22,44-46,08=-60.14 \text{ kJ/mol and}$$

$$\text{Enthalpy Hess change exothermic: } \Delta H_{\text{Hess}}=2\Delta H^\circ\text{H}_2\text{O}+\Delta H^\circ\text{CO}_2-\Delta H^\circ\text{H}_3\text{O}-\Delta H^\circ\text{HCO}_3=-7.19 \text{ kJ/mol .}$$

Neutralization is favored reaction. Free energy change minimum expression is negative:

$$\Delta G_{\text{eqNeutralization}}=-R\cdot T\cdot\ln(K_{\text{eqNeutralization}})=-8.3144\cdot 298.15\cdot\ln(3441200000)=-60.14 \text{ kJ/mol.}$$

$\text{CO}_{2\text{aqua}}$  protolysis minimum is positive:

$$\Delta G_{\text{eqCAHCO}_3\text{aqua}}=-R\cdot T\cdot\ln(K_{\text{eqCA\_HCO}_3\text{aqua}})=-8.3144\cdot 298.15\cdot\ln(1/3441200000)=60.14 \text{ kJ/mol.}$$

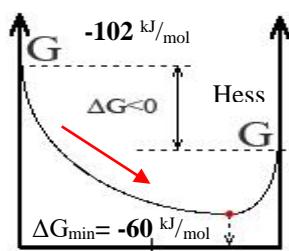


Figure 2. Exothermic and exoergic neutralization Hess Free energy change  $\Delta G_{\text{eqNeutralization}}$  negative  $-102 \text{ kJ/mol}$ , but minimizes  $\Delta G_{\text{min}}=\Delta G_{\text{eqNeutralization}}=-60.14 \text{ kJ/mol}$  reaching equilibrium mixture:  $K_{\text{eqNeutralization}}=3441200000$  at presence of CA

Carbonic Anhydrase. Carbon dioxide reaction with hydroxide anions is slow because of small factorials velocity  $k_{1\text{OH}}$  from  $1.5\cdot 10^2 \text{ M}^{-2}\text{s}^{-1}$  to  $1.5 \text{ M}^{-2}\text{s}^{-1}$  and concentrations  $[\text{CO}_{2\text{aqua}}]=0.0007512 \text{ M}$ ,  $[\text{OH}^-]=10^{-6.64} \text{ M}$ . Carbonic Anhydrase synthesis solved for bioenergetic perfect order homeostasis as Self-Organization Attractor. [3,4]

Reactants  $\text{H}_3\text{O}^++\text{HCO}_3^-$  products  $\text{CO}_{2\text{aqua}}+2\text{H}_2\text{O}$ .

**pH=7.36 multipurpose Self-Organization Attractor creates positive and negative charged groups  $\text{R-COO}^-$ ,  $\text{R-NH}_3^+$ ,  $\text{HPO}_4^{2-}$ ,  $\text{R-PO}_4^{2-}$ ,  $\text{HCO}_3^-$  as free and linked in **R** molecules: amino acids, proteins, nucleic acids, carbohydrates, coenzymes.**

Buffer systems in the Life organism trend to Self-Organization Attractor **pH** value **7.36**. Each of dominate buffer system have 7.36 friendly maximum (Figure 3. and 4.) of the buffer capacity: dihydrogen phosphate  $\text{pK}_{\text{a-H}_2\text{PO}_4}=7.199$  [1] and Carbonic Anhydrase create protolysis calculate constant:  $\text{pK}_{\text{a-CO}_2\text{aqua}}=7.0512$ . [1]

Table 2. [6] Proteins as long chain polypeptides and free amino acids with four type acid groups constitute 47 values for classic acid constants. In three forms  $\text{pK}_{\text{a-COOH}}$ ,  $\text{pK}_{\text{a-NH}_3^+}$ ,  $\text{pK}_{\text{aRgroup}}$ :  
for deprotonate carboxylate negative anion  $\text{R-COO}^-$ ,  
for protonate positive charged ammonium cation  $\text{R-NH}_3^+$ ,  
neutral phenolic acid Tyr- $\text{OH}$  and Cys- $\text{SH}$  neutral sulfhydryl groups.

Amino Acid	$\text{pK}_{\text{aCOOH}}$	$\text{pK}_{\text{aNH}_3^+}$	$\text{pK}_{\text{aRgroup}}$
Isoleucine	2.36	9.68	
Valine	2.32	9.62	
Leucine	2.36	9.60	
Phenylalanine	1.83	9.13	
Cysteine	1.96	10.28	8.18
Methionine	2.28	9.21	
Alanine	2.34	9.69	
Proline	1.99	10.96	
Glycine	2.34	9.60	
Threonine	2.11	9.62	
Serine	2.21	9.15	
Tryptophan	2.38	9.39	
Tyrosine	2.20	9.11	10.07
Histidine	1.82	9.17	6.00
Aspartate	1.88	9.60	3.65
Glutamate	2.19	9.67	4.25
Asparagine	2.02	8.80	
Glutamine	2.17	9.13	
Lysine	2.18	8.95	10.53
Arginine	2.17	9.04	12.48

20 amino acids four type protolysis groups classic 47 acids constant  $\text{pK}_{\text{a}}$  values:  
1.  $\text{R-COOH} \rightleftharpoons \text{R-COO}^- + \text{H}^+$ , 22 values of groups 47;  
2.  $\text{R-NH}_3^+ \rightleftharpoons \text{R-NH}_2 + \text{H}^+$  22+1=23 values of groups 47;  
3. Tyr-phenol- $\text{OH} \rightleftharpoons \text{Tyr-phenolate-O}^- + \text{H}^+$ ;  
4. Cysteine- $\text{SH} \rightleftharpoons \text{Cysteine-S}^- + \text{H}^+$  one group.  
Biochemical environment Self-Organization Attractor **pH=7.36** creates molecules functional activity as charged groups: carboxylate  $\text{R-COO}^-$  and ammonium  $\text{R-NH}_3^+$ .  
Maximal carboxylate  $\text{pK}_{\text{a-COOH}}$  value smaller about 7.36=**pH**:  
 $\text{pK}_{\text{a-COOH}}=4.25 <$  including fatty acids too  $4.9 < 7.36$  and  
smallest ammonium  $\text{pK}_{\text{a-NH}_3^+}$  value grater about  $7.36 < 9.04 = \text{pK}_{\text{a-NH}_3^+}$   
 $\text{NpK}_{\text{a}}$  number of parallel protolytic equilibria  
average mean  $\text{pK}_{\text{a\_mean}}$  value is calculated as:  
 $\text{pK}_{\text{a\_mean}} = (\sum \text{pK}_{\text{aRgroup}} + \sum \text{pK}_{\text{aNH}_3^+} + \sum \text{pK}_{\text{aCOOH}}) / \text{NpK}_{\text{a}}$ .  
*Ostwald's dilution law* calculates the pH of solution  
at concentration C logarithm:  
$$\text{pH} = \frac{\text{pK}_{\text{a\_mean}} - \log C}{2}$$

### Shuttle hemoglobin stabilized multipurpose Self-Organization Attractor **pH=7.36**.

Hemoglobin in tissue desorbs oxygen  $\text{O}_{2\text{aqua}}$  for exchange to  $\text{HCO}_3^-$  and  $\text{H}^+$  but in lungs releases  $\text{HCO}_3^-$  and  $\text{H}^+$  due to adsorption of oxygen  $\text{O}_{2\text{aqua}}$ . [6] Exchange equilibrium established oxygen concentration in arterial  $6 \cdot 10^{-5}$  M and venous  $0.426 \cdot 10^{-5}$  M according actual hemoglobin sensitive [oxygen concentration in blood](#):



arterial concentration  $[\text{O}_{2\text{aqua}}] = 6 \cdot 10^{-5}$  M ,

fraction  $[(\text{H}^+) \text{HbT} \dots \text{salt bridges} \dots (\text{HCO}_3^-)] = 0.04$  , fraction  $[\text{HbR}(\text{O}_2)] = 0.96$ , [6]

venous concentration  $[\text{O}_{2\text{aqua}}] = 0.426 \cdot 10^{-5}$  M ,

fraction  $[(\text{H}^+) \text{HbT} \dots \text{salt bridges} \dots (\text{HCO}_3^-)] = 0.37$ , fraction  $[\text{HbR}(\text{O}_2)] = 0.63$ . [6]

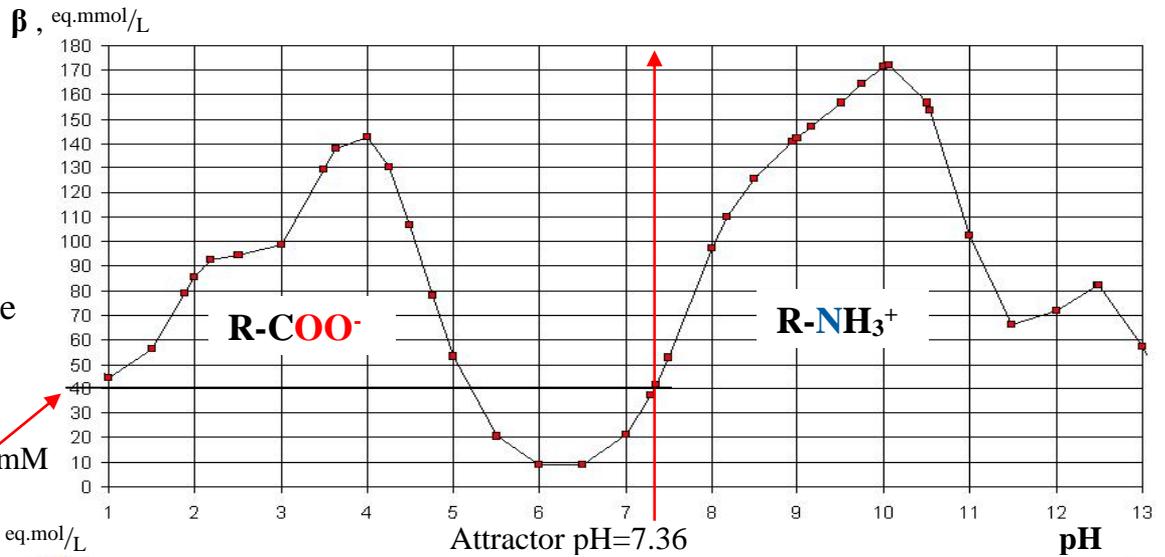
In one blood circulation organism consume  $0.96 - 0.63 = 0.33$  fraction of oxygen from arterial saturated fraction  $0.96 = [\text{HbR}(\text{O}_2)]$ . [6] Stabilized Norma concentrations  $[\text{HCO}_3^-] = 0.0154$  M,  $[\text{CO}_{2\text{aqua}}] = 0.0076$  M sustain Self-Organization Attractor **pH=7.36**.

Henderson Haselbalh expression for Brensted protolysis calculates Attractor value 7.36:

$$\text{pH} = \text{pK}_{\text{a}} + \log \frac{[\text{HCO}_3^-]}{[\text{CO}_2]_{\text{aqua}}} = 7.0512 + \log(0.0154 \text{ M} / 0.0076 \text{ M}) = 7.36.$$

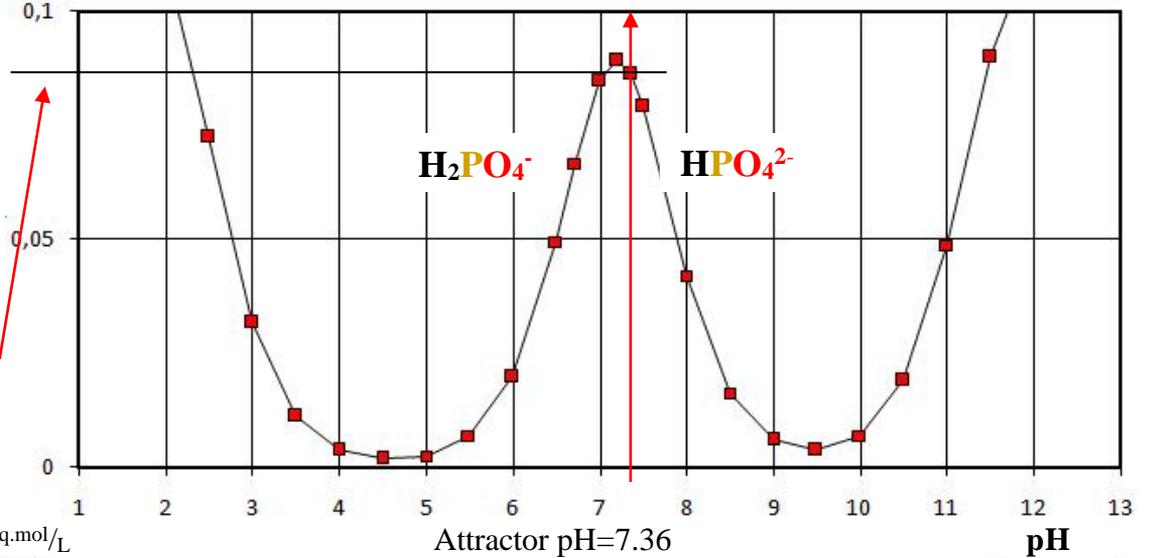
Self-Organization Attractor 7.36 creates functional activity of molecules with charged groups negative , positive:  $\text{HPO}_4^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{R-COO}^-$ ,  $\text{R-NH}_3^+$ ,  $\text{R-PO}_4^{2-}$  as free and linked in molecules **R**: amino acids, proteins, nucleic acids, carbohydrates, coenzymes. 11<sup>th</sup> and 12<sup>th</sup> pages: [BUFFER solution](#). [1]

Proteins buffer have silence region from **pH=6** to 7.36 . 23 thousand protein total buffer solution concentration is  $C_{\text{buffer}}=3 \text{ mM}$ . Muscle cytosol proteins the Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 40 \text{ mM}$  **30.3 %**  $= 40/132 * 100 \%$



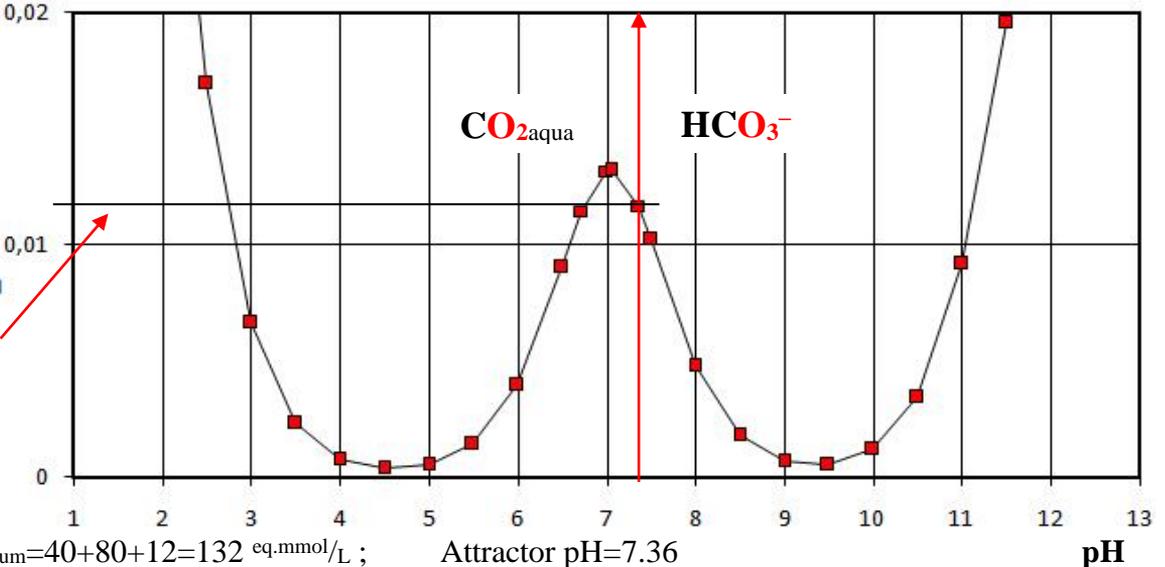
Total phosphate buffer systems concentration  $[\text{H}_2\text{PO}_4^-] + [\text{HPO}_4^{2-}]$  in muscle cells cytosol is  $C_{\text{buffer}}=0.155 \text{ M}$

The Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 80 \text{ mM}$  **66.6 %**  $= 80/132 * 100 \%$



Total bicarbonate buffer system concentration  $[\text{CO}_{2\text{aqua}}] + [\text{HCO}_3^-]$  is

$C_{\text{buffer}}=0.023 \text{ M}$ . The Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 12 \text{ mM}$  **9.1 %**  $= 12/132 * 100 \%$



Total Buffer capacity  $\beta_{\text{sum}}=40+80+12=132 \text{ eq.mmol/L}$ ; Attractor  $\text{pH}=7.36$

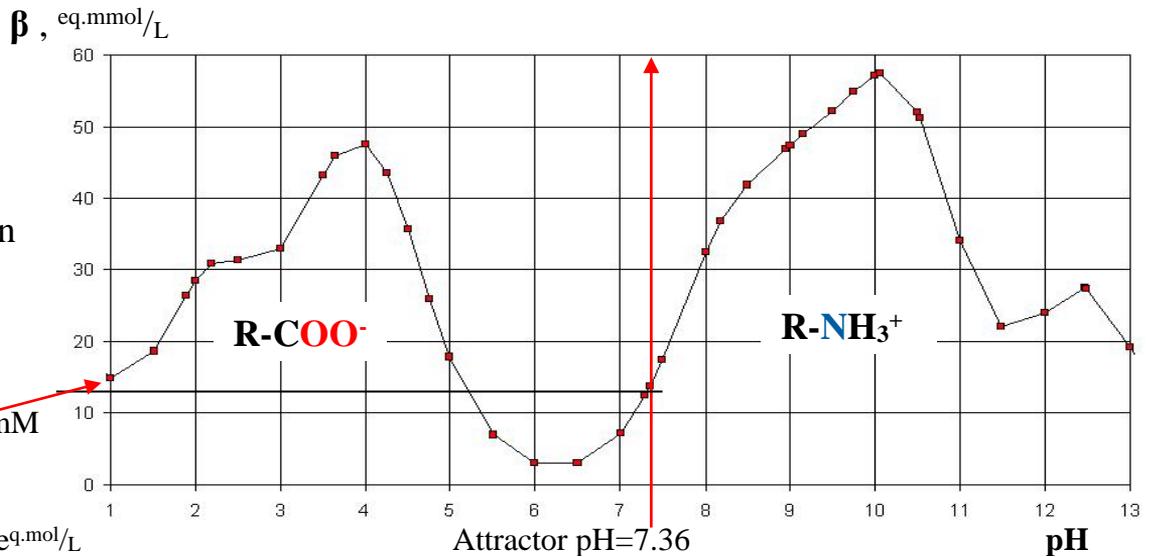
Figure 3. Cytosol muscle cells. Buffer capacities versus pH values from 1 to 13. Actual buffer capacity at Attractor  $\text{pH}=7.36$  for two dominate phosphate , bicarbonate and total protein made buffer capacity sum.

at  $\text{pH}=7.36$ : proteins + phosphate + bicarbonate ,  
 $\text{proteins} + ([\text{H}_2\text{PO}_4^-] + [\text{HPO}_4^{2-}]) + ([\text{CO}_{2\text{aqua}}] + [\text{HCO}_3^-])$ ,  
 total buffer capacity: 100 % = **30.3 %** + **66.6 %** + **9.1 %**;

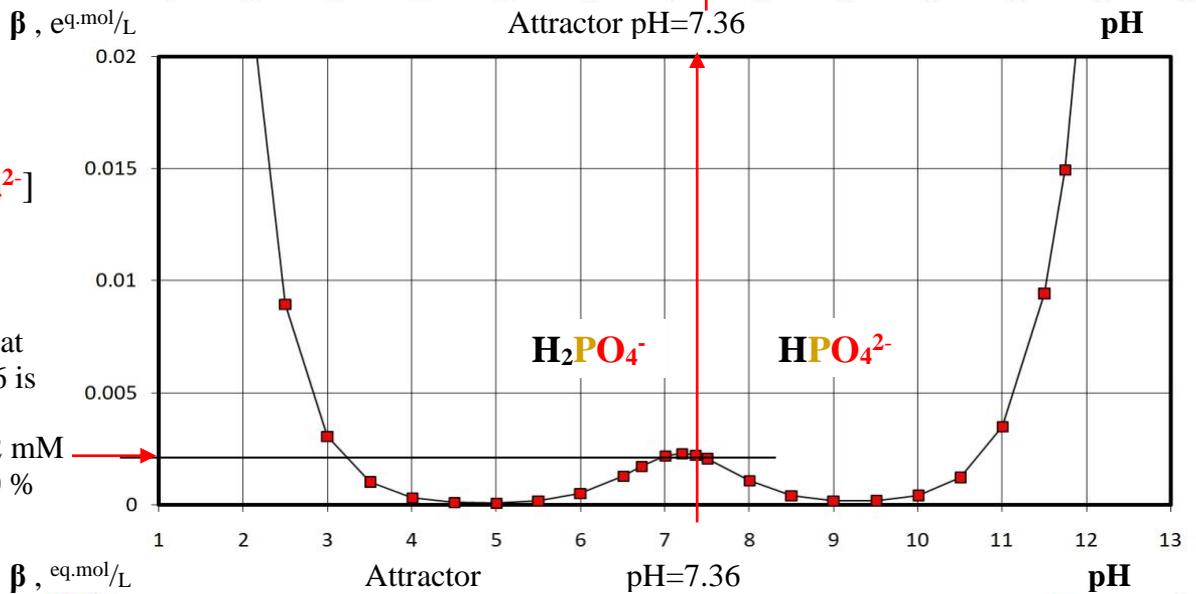
Buffer capacity is acid  $\Delta n_{\text{ac}}$  or base  $\Delta n_{\text{b}}$  equivalent\_mols/ in one Liter changing pH per one unit  $\Delta \text{pH}=\pm 1$ .

Three type buffer systems create multipurpose Self-Organized Attractor  $\text{pH}=7.36$  for perfect homeostasis order with charged groups as free and linked in molecules R.

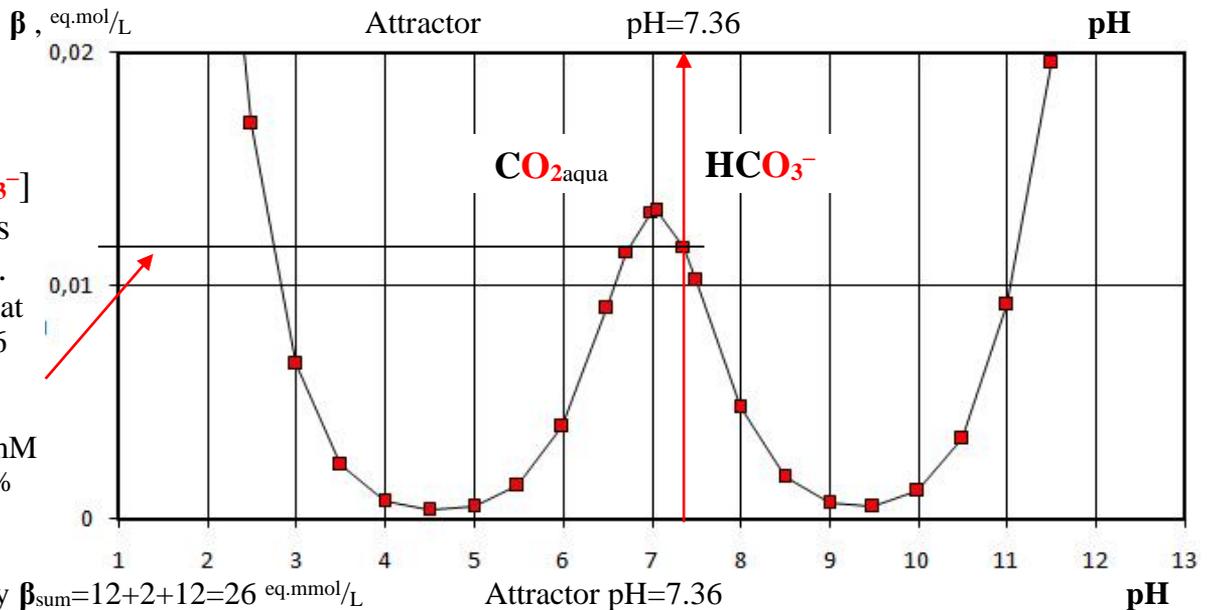
Proteins buffer have silence region from  $\text{pH}=6$  to  $7.36$ . Protein total buffer solution concentration  $C_{\text{buffer}}=1 \text{ mM}$  for albumin. The Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 12 \text{ mM}$  **46.15 %**  $= 12/26 * 100 \%$



Total phosphate buffer systems concentration  $[\text{H}_2\text{PO}_4^-] + [\text{HPO}_4^{2-}]$  in blood plasma  $C_{\text{buffer}}=0.004 \text{ M}$ . The Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 2 \text{ mM}$  **7.7 %**  $= 2/26 * 100 \%$



Total bicarbonate buffer system concentration  $[\text{CO}_{2\text{aqua}}] + [\text{HCO}_3^-]$  in blood plasma is  $C_{\text{buffer}}=0.023 \text{ M}$ . The Buffer capacity at physiologic  $\text{pH}=7.36$  is  $\beta = 12 \text{ mM}$  **46.15 %**  $= 12/26 * 100 \%$



Total Buffer capacity  $\beta_{\text{sum}}=12+2+12=26 \text{ eq.mmol/L}$

Figure 4. Extra Cellular space Blood plasma. Buffer capacities versus pH values from 1 to 13. Actual buffer capacity at Attractor  $\text{pH}=7.36$  for two dominate phosphate, bicarbonate and total protein made buffer capacity sum.

at  $\text{pH}=7.36$ : proteins + phosphate + bicarbonate, total buffer capacity: 100 % = **46.15 %** + **7.7 %** + **46.15 %**;

Buffer capacity is acid  $\Delta n_{\text{ac}}$  or base  $\Delta n_{\text{b}}$  equivalent\_mols/ in one Liter changing pH per one unit  $\Delta \text{pH}=\pm 1$ . Three type buffer systems create multipurpose Self-Organized Attractor  $\text{pH}=7.36$  for perfect homeostasis order with charged groups as free and linked in molecules R.

11<sup>th</sup> and 12<sup>th</sup> pages: [BUFFER solution](#). [1]

The primary Self-Organization Attractor air oxygen  $O_2$  20.95 %.

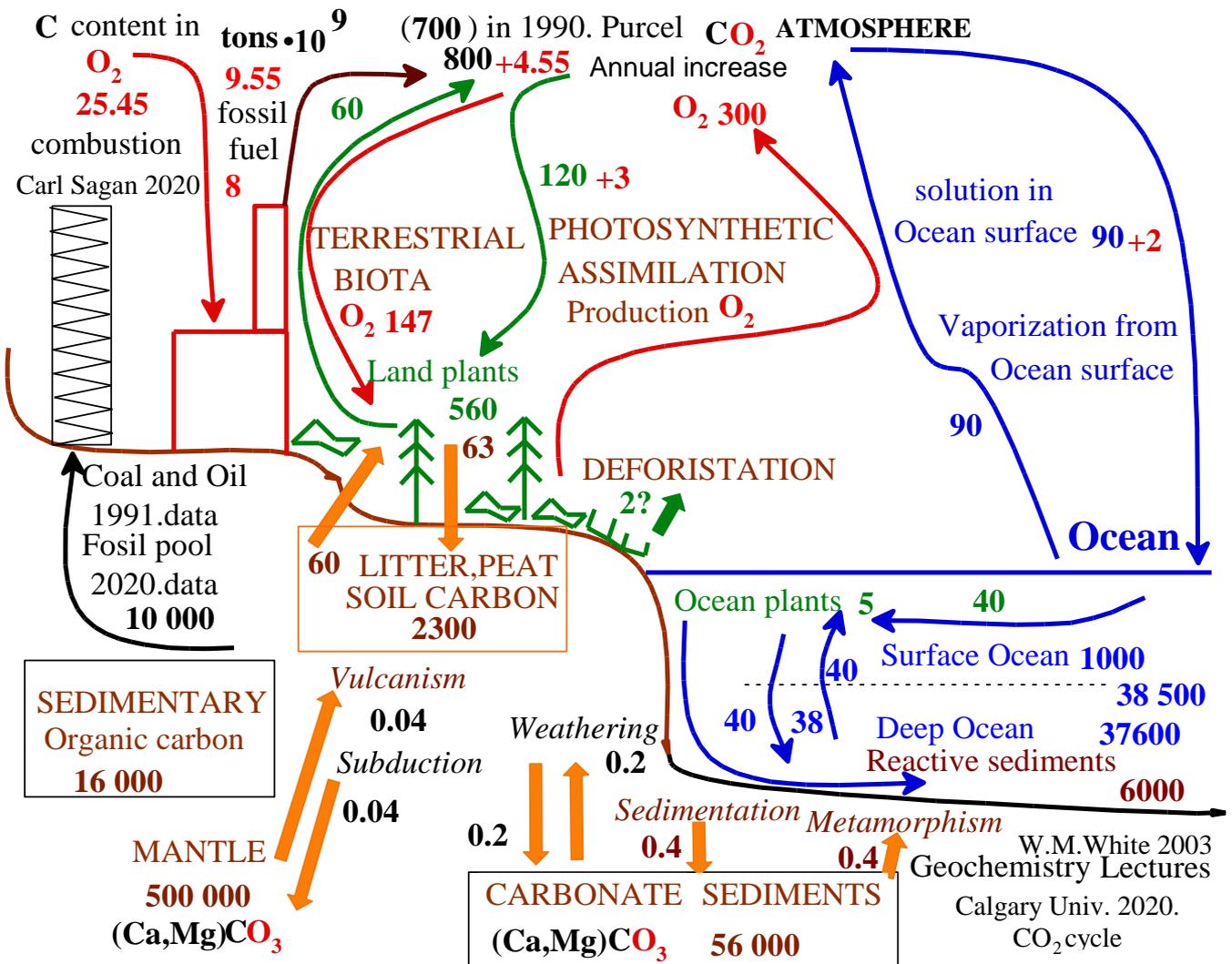


Figure 5. Dynamic growth of  $CO_2$  in atmosphere last thirty Years.  $CO_2$  and  $O_2$  cycle combined data from: 1991<sup>st</sup> Kotz JC, Purcell KF 700 Gt of  $CO_2$  in atmosphere<sup>[10]</sup>, 2003<sup>rd</sup> White VM 725 Gt of  $CO_2$ <sup>[11]</sup> and 2020<sup>th</sup> Carbon cycle University Calgary 800 Gt of  $CO_2$  in atmosphere.<sup>[12]</sup>

Civilization with regular pollutions add about 1.2 % to atmosphere annual  $4.55$  Gt to reach  $800$  Gt  $CO_2$ ↑<sub>gas</sub> in 2020<sup>th</sup> as well bulk 98.8 % irregular changed of totally global and cosmic processes oscillation see on Figure 6. for 600 million Years. Ocean and in all Earth waters dissolve 47 times greater  $CO_2$ ↑<sub>aqua</sub> amount  $38500$  as in atmosphere  $800$  Gt, but carbonate  $(Ca,Mg)CO_3$ ↑<sub>solid</sub> sediments in Earth crust contains 70 times more  $CO_2$  as in atmosphere .

The Carbonic Anhydrase and photosynthesis each Year assimilates  $CO_2$  amount 15.4 % from atmosphere  $800+4.55$  Gt producing glucose  $307.5$  Gt with carbon mass  $120+3$  Gt. Photosynthesis evolved oxygen amount in atmosphere  $300-147=153$  Gt restore and maintain primary Self-Organization Attractor oxygen  $O_2$  level 20.95 % during 500 million Years.

Combustion products  $CO_2$  as carbon amount  $2$  Gt of fossil fuel dissolve warm up the oceans in reaction with  $OH^-$  ions  $0.167 \cdot 10^{15} \cdot 69 = 11.5 \cdot 10^{15}$  kJ. Warming heat in ocean  $11.5 \cdot 10^{15}$  kJ of  $CO_2$  is more as 100 times less the Photosynthesis and Carbonic Anhydrase cooling  $-2501 \cdot 10^{15}$  kJ the Planet.<sup>[10,11,12]</sup>

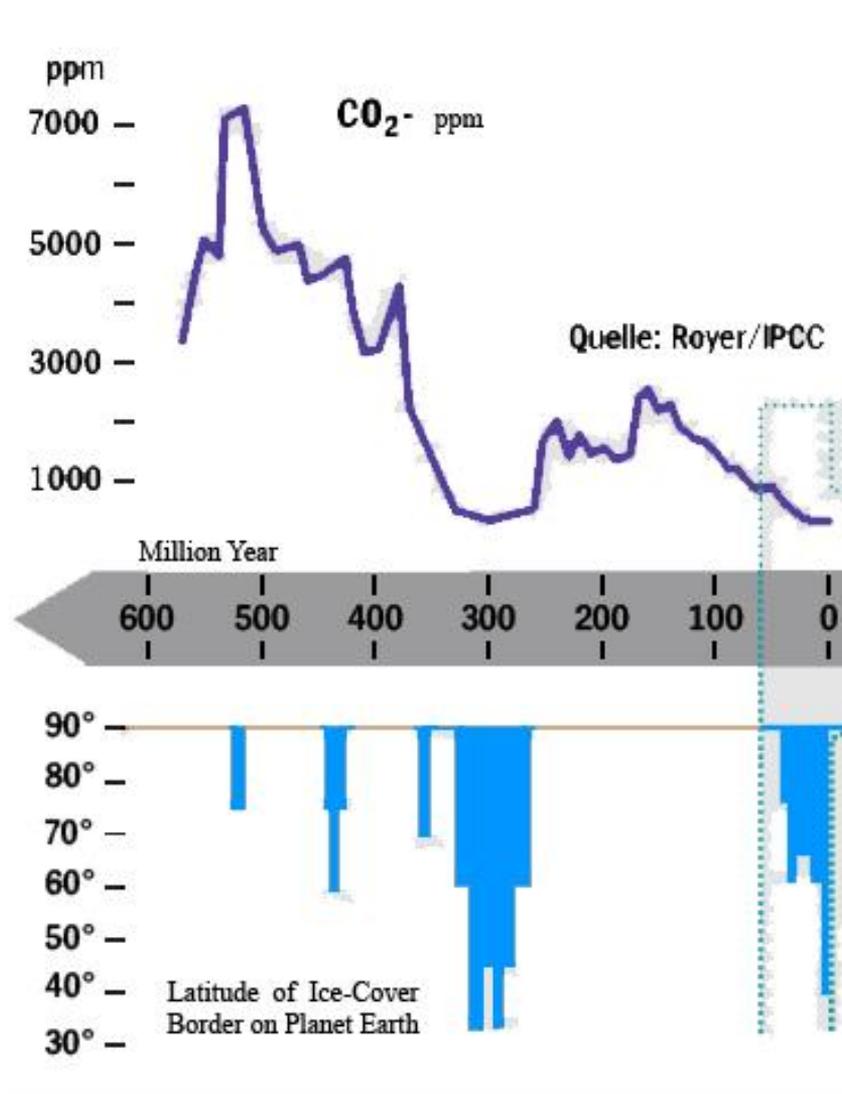


Figure 6. Climate reconstruction history since 600 Million Years ago: Atmospheric  $\text{CO}_2$  content in units' ppm, Earth ice Cover Border Latitude and temperature oscillation from  $-50^\circ$  to  $45^\circ$  degrees. <sup>[13]</sup>

Reconstruction climate history of Earth shows temperature and atmospheric content  $\text{CO}_2$  oscillation, which 600 million Years back in period 10000 Years is observing Earth warming from  $-50^\circ$  C to  $45^\circ$  C degrees and carbon(IV) oxide gas concentration in air reaches 6 %, what corresponds 60000 ppm. Climate changes are occurring with primary Self-Organization Attractor Carbonic Anhydrase CA amount insufficiency in periods at 500 MY, 200 MY. Sufficient new primary Self-Organization Attractor CA amounts restoring in interglacial periods at 300 MY and to day 0-10 MY with decrease temperature and  $\text{CO}_2$  atmospheric content below 1000 ppm. <sup>[13]</sup>

Before 600 million Years  $\text{CO}_2$  concentration in atmosphere was 0.1 %, what agree 1000 units' ppm. Atmospheric oxygen  $\text{O}_2$  concentration approximately 1 % below from today's 20.95 % volume fraction was uncomformable for bulk of present-day animal species.

Approximately 600 million Years history Earth was ice covered reminding Snowball Earth. Glacier fast melting provokes atmospheric  $\text{CO}_2$  concentration growth up to 6 % 60000 ppm. Due to greenhouse effect temperature increased from  $-50^\circ$  up to  $45^\circ$  degrees. That increase the photosynthetic reaction brought concentration of oxygen  $\text{O}_2$  fast above present-day 20.95 % up to 30 % for period in 10000 Years.

Biosphere primary Self-Organization Attractor in air oxygen  $\text{O}_2$  20.95 % is working global for 500 million Years. [Thermodynamic attractor with functionally active molecules  \$\text{O}\_{2\text{aq}}\$ ,  \$\text{CO}\_{2\text{aq}}\$](#) . <sup>[1,6,13]</sup>

# 5 complex Enzyme reactions      Versus non Enzymatic reactions

Enzyme governed complex reactions drive the LIFE in 5 ways      chaos and contamination

7<sup>th</sup> page : [Velocity KINETICS of REACTION dependence on Attractors create molecules functional Activity](#)

- |  |  |
|--|--|
| <p><b>1. GRADUAL-CONSECUTIVE</b> organized favored reaction sequence of <b>ENZYME</b> complexes for Glycolysis, Krebs cycle; Polycondensation: Replication, Polymerisation, Proteins Translation Synthesis</p>   | <div style="border: 1px solid black; padding: 2px; display: inline-block;"><b>1. Chaotic</b></div>   |
| <p><b>2. ENZYMES specificity</b> 100% efficiency of product <b>singularity</b></p>   | <p><b>2. PARALLEL</b> reaction preceeding in chemistry as side products</p>  |
| <p><b>3. JOINT-TANDEM SYNTHESIS</b><br/>Ribosomes for polypeptides, proteins<br/>Photosynthesis glucose and oxygen</p>   | <p><b>3. Thermodynamic forbidden, impossible reaction</b><br/>unfavored has positive free energy change<br/><math>\Delta G = \Delta H - \Delta S \cdot T &gt; 0</math></p> |
| <p>1<sup>st</sup> 5<sup>th</sup> page:<br/><a href="#">Thermodynamic attractor with functionally active <math>O_{2(aqua)}</math>, <math>CO_{2(aqua)}</math></a></p>  |  |
| <p><b>4. COMPETITIVE</b> regulation as <b>inhibition and allostery</b><br/>sensitive to concentration <math>O_{2(aqua)}</math>, <math>HCO_3^-</math>, <math>H^+</math> (Le Chatelier principle)<br/>His63,58 as for hemoglobin, His64 as for myoglobin as regulated back response<br/>prevent (hypo amount) deficiency and (hyper amount) overproduction<br/>so stabilises Physiologic pH=7.36, arterial <math>[O_{2(aqua)}]=6 \cdot 10^{-5}</math> M and venous <math>[O_{2(aqua)}]=0,426 \cdot 10^{-5}</math> M.<br/>Photosynthesis global stabilises oxygen concentration <math>[O_{2(AIR)}]= 20,95\%</math> in Earth Atmosphere.</p> | <div style="border: 1px solid black; padding: 2px; display: inline-block;"><b>4. Chaotic</b></div>   |
| <p><b>5. Enzyme radical driven reactivity</b> the process for maintenance of homeostasis producing resources</p>   | <p><b>5. Contamination destructive chemistry</b> with the chaotic radical chain reactions in multiple parallel products</p>  |

Figure 7. Self-Organization Attractors claim order versus non-enzymatic reactions chaos and contamination. Five type complex reactions in enzyme clusters. Self-Organization Attractors sustain the functional activity perfect order for homeostasis. Deviation from Attractor values create homeostasis disorder as Chaos.

Summary Self-Organization Attractors create perfect order homeostasis link Bioenergetic.

**Self-Organization** Attractors create functional active molecules reactivity order for homeostasis and bioenergetic. The order of functionally active molecules drives homeostasis under rule Attractors. Reaching of Attractor values create homeostasis order out of disorder. Chaos disorders the homeostasis.

The molecules functional activation of oxygen  $O_{2(aqua)}$  decreases free energy content from  $G_{O_{2(aqua)}}=303.1$  kJ/mol to  $G_{O_{2Bio}}=78.08$  kJ/mol. Carbon dioxide reaction with water  $CO_2 + 2 H_2O$  increases free energy content from zero  $G_{CO_2+2H_2O}=0$  kJ/mol to  $G_{H_3O^++HCO_3^-}=68.38$  kJ/mol. Water in protolysis increases free energy content from zero  $G_{2H_2O}=0$  kJ/mol to  $G_{H_3O^++OH^-}=99.8$  kJ/mol. Distilled water in organism medium increases free energy content from zero to  $G_{H_2O\_Biochemistry}=85.65$  kJ/mol. [1,8] Functional activation initiates Attractors. Attractors are two types and multipurpose. The primary Attractors common for Biosphere, the secondary Attractors for individual organisms and multipurpose pH=7.36, water, air oxygen.

**Oxygen**  $O_{2(aqua)}$  decreased power for functional active isooxia Norma solution in blood so in cytosol too driven with four Attractors: water triplet state of oxygen, water concentration  $[H_2O]=55.3$  mol/Liter, air oxygen level 20.95 % for five hundred million Years, pH=7.36 for the concentration  $[H_3O^+]=10^{-7.36}$  M.

**CA Carbonic Anhydrase** work as primary Attractor for Biosphere which forms dominate bicarbonate buffer of  $CO_{2(aqua)}$  acid protolysis constant  $pK_a=7.0512$ . Henderson Haselbalh expression Attractor value 7.36, which corresponds to concentration  $[H_3O^+]$ . Attractor 7.36 creates functional activity of molecules with charged groups negative and positive:  $HPO_4^{2-}$ ,  $HCO_3^-$ ,  $R-COO^-$ ,  $R-NH_3^+$ ,  $R-PO_4^{2-}$  as free and linked in amino acids, proteins, nucleic acids, carbohydrates, coenzymes, **R** molecules. Carbonic Anhydrase synthesis solve perfect order of homeostasis and bioenergetic as Self-Organization Attractor. [3,4]

**The Attractors values** in organism compartments dissipative structures drive the perfect homeostasis order with enzymes clusters on five type complex reactions. Order is key for surviving of organism. Deviation from Attractor values cause loss the homeostasis order of functional activity. Chaotic reactions waste the resources and stop the homeostasis, the non-equilibrium complex processes. The homeostasis becomes extinct from Biosphere.

Water protolysis is **indispensable** for Attractors sustaining which stay at equilibrium while homeostasis and bioenergetic continue. Water protolysis accumulate free energy in products  $H_3O^++OH^-$  99,8 kJ/mol. Attractors destiny are irreversible free energy change  $\Delta G_{Homeostasis}$  transduction between functional active molecules.

Note: Homeostasis trend to equilibrium but never reaching because it is non-equilibrium state.

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### **No Conflict of Interests.**

The author declares that there is no conflict of interests regarding the publication of this paper.

### **Authors’ Contribution**

Aris Kaksis with out financial contribution has alone study .