Āris Kaksis Riga Stradin's University **2018** http://aris.gusc.lv/BioThermodynamics/CATALASE.pdf

Enzyme CATALASE radical reaction prevent non-enzymatic H_2O_2 chain reaction oxidative stress

Oxidative stress risk is proportional to oxygen or peroxide concentration $\vec{v} \sim [O_2]$ or $\vec{v} \sim [H_2O_2]$.

Peroxide accumulation risk decrease catalysts in human organism that are enzymes.

CAT increase velocity constant toxic radical **2H:-••:O-:-O:••-:H conversion** to O_{2aqua} **+2H₂O +Q**

Three H_2O_2 hydrogen peroxide sources from nature at presence of **oxygen** in **water** medium $O_{2aqua}+H_2O$, since 500 M-year's atmospheric **oxygen** concentration is 20.95% volume per cents.

1. Heavy metal compounds having high oxidation number iron(III) Fe^{3+}, cooper(II) Cu^{2+}, manganesium(IV) Mn^{4+}, as well pollutant lead(IV) Pb^{4+}.

2. Ionization radiation: ultraviolet UV, x-ray, gamma γ radiation, beta particles (${}^{0}_{1}\beta^-$ un ${}^{0}_{1}\beta^+$), alpha particles ${}^{4}_{2}\alpha^+$.

Human body 70 kg mass each second chemical elements carbon-14 ${}^{14}_{6}C$ and potasium-40 ${}^{40}_{19}K$ isotopes irradiate 7000 beta particles ${}^{0}_{1}\beta^-$ un ${}^{0}_{1}\beta^+$ and high radiation energy absorbed forming in $O_{2aqua}+H_2O$ medium of tissues 10^{13} peroxide H_2O_2 molecules per second.

3. Enzymes aldehyde oxidoreductases in **water** medium at presence of **oxygen** O_{2aqua} + H_2O gives products hydrogen peroxide H_2O_2.

Hydrogen peroxide decomposition reaction is spontaneous as is exothermic enthalpy decreases $\Delta H_r<0$ evolving the heat Q in surrounding and entropy growth $\Delta S_r>0$ as from two H_2O_2 + H_2O_2 molecules form tree molecules O_{2aqua} + H_2O + H_2O free energy decreases and its change is negative $\Delta H_r - T \bullet \Delta S_r = \Delta G_r < 0$ in thermodynamically favorable reaction.

High activation energy **Ea**=79 kJ/mol due to absence of catalyst and low geometric factor **A**=0.01 $M^{-1}s^{-1}$ make the Arrhenius velocity constant expression negligible small:

$$\vec{k} = A \bullet e^{-\frac{Ea}{RT}} = 0.01 \bullet e^{-\frac{79000}{8{,}314 \bullet 298}} = 0.01 \bullet 1.419 \bullet 10^{-14} = 1.419 \bullet 10^{-16}\ M^{-1}s^{-1}.$$ Velocity of reaction makes very small

$$\vec{v} = \vec{k} \bullet [H_2O_2]^2 = 1.419 \bullet 10^{-16} \bullet [H_2O_2]^2\ Ms^{-1};\ \text{if } [H_2O_2]=1\ M;\ \sqrt{\vec{v}} = \sqrt{\vec{k}} \bullet [H_2O_2] = 1.191 \bullet 10^{-8}$$

one molar peroxide $[H_2O_2]$=1 M solution each second converts of $1.191 \bullet 10^8$ molecules to products only one 1 peroxide molecule, that all would be converted we should wait $1.191 \bullet 10^8$ seconds, 3.78 years. One mol H_2O_2 contains Avogadro number of molecules $N_A = 6.021 \bullet 10^{23}$ particles/mol and expected time complete converting is larger as 3.78 years $6.021 \bullet 10^{23}/1.191 \bullet 10^8 = 5 \bullet 10^{15}$ times and are $3.78 \bullet 5 \bullet 10^{15} = 1.9 \bullet 10^{16}$ years. Universe age is 13.7 billion years, which is million times shorter period.

Catalyst CATALASE (**CAT**) is 1. involved into **reaction** 2. decreasing activation energy **Ea** and 3. improve geometrical factor **A** from worse value zero **A => 0** to maximally optimized one **A => 1**, that each collision is geometrically active and effective **100%** with geometric factor **A = 1** favorable conversion to products.

$$2H_2O_2 + CAT \rightarrow H_2O_2 \ldots CAT \ldots H_2O_2 \rightarrow O_{2aqua} + 2H_2O + Q_{exothermic} + CAT$$

toxic compound	transition state active complex	biological goods oxygen+water+heat + CATALASE

Biocatalyst enzyme-CATALASE according Cambridge University professor Alana Fersht shows great catalytic activity:

$$\vec{v}_{enz} = \frac{k_{cat}}{K_M} \bullet [E] \bullet [H_2O_2] = 3.6 \bullet 10^7 \bullet [E] \bullet [H_2O_2],$$

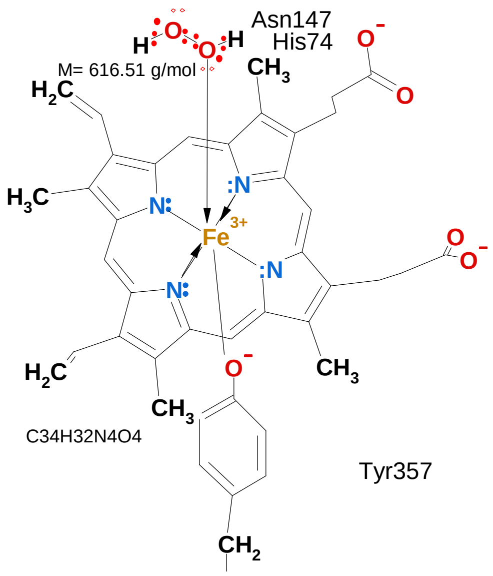
Usual catalase concentration is small $[E]=10^{-8}$M and $\vec{v}_{enz} = 0.36 \bullet [H_2O_2]\ s^{-1}$. Activation energy of catalase **Ea**=29 J/mol and geometric factor **A**=0.1311 active collision fraction is 0.988 and velocity constant value is 0.1296 $M^{-1}s^{-1}$, 98.8% of total collisions are active and converting to products O_{2aqua} + $2H_2O$ + **Q**:

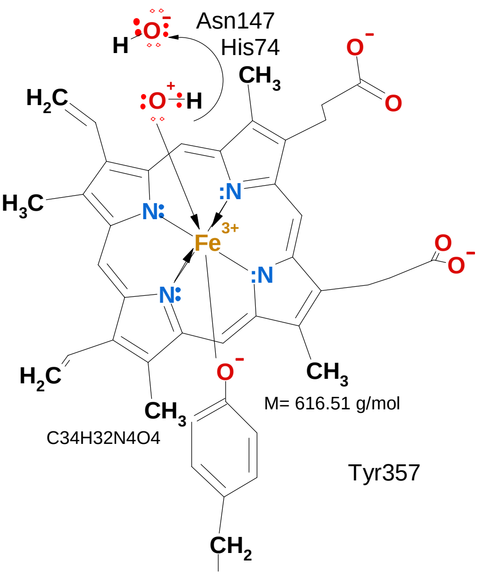
$$\vec{k} = A \bullet e^{-\frac{Ea}{RT}} = A \bullet e^{-\frac{29}{8{,}314 \bullet 298}} = A \bullet 0.988 = 0.1296\ M^{-1}s^{-1},\quad \vec{v} = \vec{k} \bullet [H_2O_2]^2 = A \bullet 0.988 \bullet [H_2O_2]^2$$

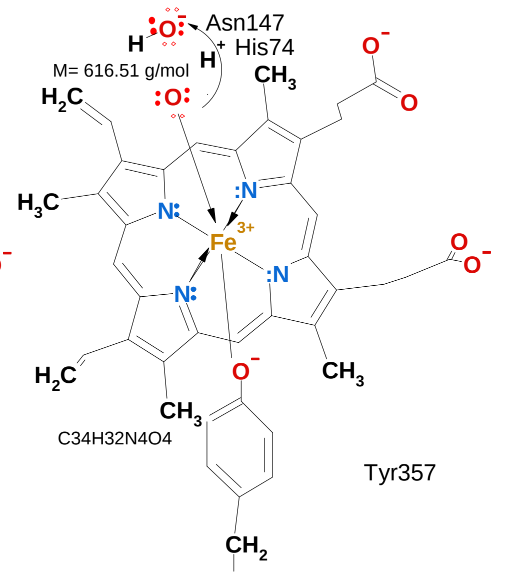
$$\sqrt{\vec{v}} = {}^{CAT}\sqrt{\vec{k}} \bullet [H_2O_2] = 0.36 \bullet [H_2O_2];\ \frac{{}^{CAT}\sqrt{\vec{k}}}{\sqrt{\vec{k}}} = \frac{0{,}36}{1{,}19 \bullet 10^{-8}} = $$ (4.) $30 \bullet 10^6$ times greater velocity constant increase

Advanced Studies of Chromo Protein CATALASE Heme pocket active site

Experimental research: http://aris.gusc.lv/06Daugavpils/Research/CATALASE.pdf

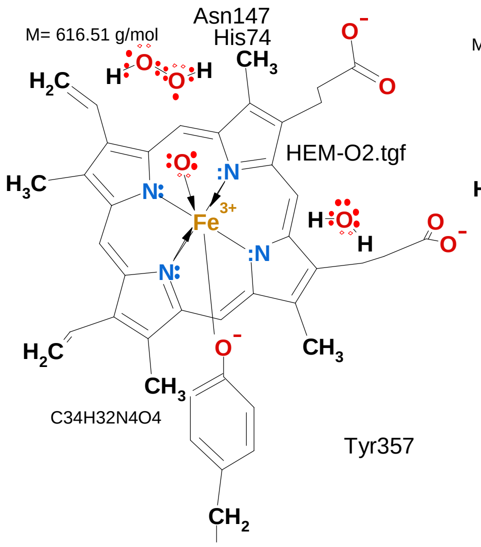


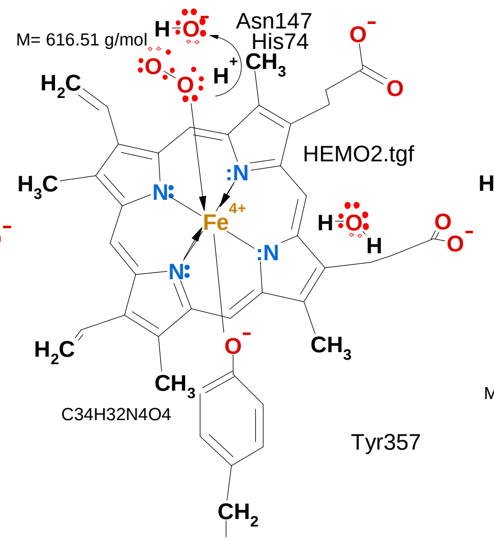


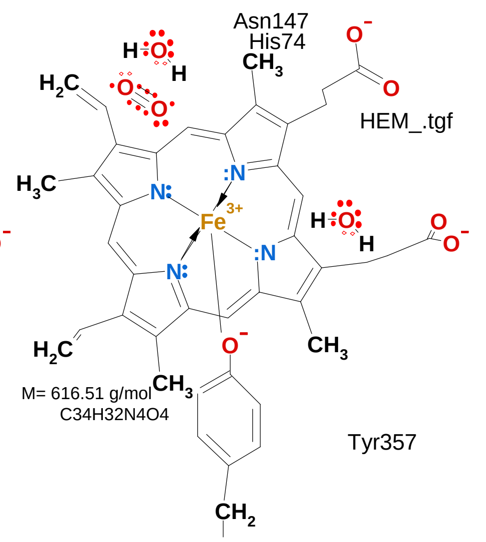


Singlet •::O-:-O::• iron(III) **Fe^{3+}** on Heme center in to water medium conversed to triplet oxygen **•:O≡:::≡O:•**
Heme pocket with 28 hydrophobic amino acids – in waterless medium oxidation-reduction reaction absent:
Val72,Val73,Ala75,Val115,Ala116,Pro128,Gly130,Val145,Gly146,Phe153,Ile154,Ala157,Leu159,Phe160,
Pro161,Phe163,Ile164,Leu198,Leu298,Ala332,Phe333,Pro335,Met349,Leu350,Gly352,Ala356,Pro358,Ala434

Singlet **•::O-:-O::•** ————→ triplet **•:O≡:::≡O:**







H_2O_2 + H_2O_2 + CAT → H_2O_2…CAT…H_2O_2 → O_{2aqua} + H_2O + H_2O + Q $_{exothermic}$+ CAT

toxic compound	transition state active complex	biological goods
		oxygen + **water** + **heat** + CATALASE

Conclusions CATALASE

1. **Catalyst** CATALASE (CAT) is involved to reaction active transition state complex formation ....

   H_2O_2…CAT…H_2O_2 and on finish released into products free unchanged CAT. ....

2. **Catalyst** (CAT) decrease activation energy **E_a** from 79000 J/mol to 29 J/mol times 2724 less. ....

3. **Catalyst** (CAT) improve geometric factor A=0.01 to A=0.13 times 13 beter. ....

4. **Catalyst** CATALASE increase reaction velocity constant $\vec{k}$ from $1.9•10^{-8}$ $M^{-1}s^{-1}$ to 0.36 $M^{-1}s^{-1}$ ....
   times $30•10^6$ thirty million more. ....

5. CATALASE peroxide accumulation risk decreases $30•10^6$ thirty million times...................................