Name Surname :____Teacher________________________________ Group Nº __Teacher__2023

Enzyme Proteins A. Task **liver** CATALASE studies for student practical introduction helping material:

ChemScape MDLi **RasMol** MAGE FireFox application. **B.**Lunch Kenyon University: http://aris.gusc.lv/ChemFiles/catalaseKenyon/cat1.htm professor Elizabeth M. Boon '97, Aaron Downs '00, David Marcey and Aris Kaksis 2023 Riga Stradin's University prepared molecular tutorial

1. Call the cell organelles where first enzyme CATALASE found and classification number!
EC1.11.1.6...............................organelles peroxisomes..............................

2 High rate protolysis activate $G_{H_2O}+G_{HOOH}=0+365=365$ $^{kJ}/_{mol}$ to $G_{H_3O^+}+G_{HOO^-}=22.44+418.32=440.76$ $^{kJ}/_{mol}$;

1) Protolysis $\mathbf{HOOH+H_2O \Leftrightarrow H_3O^+ + HOO^-}$ $pK_a=11,75$ make possible collisions of anions $\mathbf{HOO^-}$><$\mathbf{^-OOH}$.

2) High activation energy $\mathbf{E_a}=79000$ $^{J}/_{mol}$ colliding $\mathbf{HOO^-}$><$\mathbf{^-OOH}$ with slow velocity $\vec{k}=1.416*10^{-16}$ $M^{-2}s^{-1}$ constant disproportionate $\mathbf{^-OOH}$ oxidize atoms to $\mathbf{O_{2aqua}}$ and second atoms $\mathbf{^-OOH}$ reduce about 2 $\mathbf{OH^-}$ ions,

3) which neutralizing to water: $2\mathbf{OH^-}+2\mathbf{H_3O^+}$=>$\mathbf{2H_2O+2H_2O}$. In summary produce $\mathbf{O_{2aqua}+2H_2O+2H_2O+Q}$:
$\mathbf{2H_2O_2+2H_2O \rightarrow H_3O^+ + HOO^-}$><$\mathbf{^-OOH + H_3O^+ \rightarrow O_{2aqua}+2H_2O+2H_2O+Q}$ the Life resources....................... .

2.a Collision negative to positive $\mathbf{HOO^-}$>$\mathbf{Fe^{3+}}$ have $\mathbf{E_a}=29$ $^{J}/_{mol}$ indispensible law activation energy with protonation the **His74** and Asn 147 velocity constant increases over absent **CATALASE** 30 million times as geometric factor **A** improve to **A**=>0.131: $\mathbf{H_2O_2+H_2O_2+Fe^{3+} \rightarrow}$ **His74**-$\mathbf{H^+ + HOO^-}$>$\mathbf{Fe^{3+}}$<$\mathbf{^-OOH}$+ Asn147-$\mathbf{H^+ \rightarrow O_{2aqua}+H_2O+H_2O+Q_{exothermic}+Fe^{3+}}$.

Protolysis activate transition state complex **oxygen**+ **water**+ **heat**+ CATALASE,
Negative anions collisions with positive iron $\mathbf{Fe^{3+}}$ ion produce life resources 30 million times faster.
Write disproportionation reaction first and second peroxide molecule:

1. **H-O-O-H**$_{protolysis}$+**Fe(III)**+**His74**=>**Fe(IV)-O**+(**HO**$^-_{Red}$+**H**$^+_{protonation}$-**His74**=>$\mathbf{H_2O}$).......................
2. **H-O-O-H**$_{protolysis}$+**Fe(IV)-O**$_{Ox}$+ Asn147=>**Fe(III)**+**O=O**$_{Ox}$+(**HO**$^-_{Red}$+**H**$^+_{protonation}$- Asn147=>$\mathbf{H_2O}$)..................

3. Two non enzymatic and Biochemical peroxide sources in oxygen dissolute water !
1) Heavy metal compounds iron $\mathbf{Fe^{3+}}$....., cooper $\mathbf{Cu^{2+}}$…., manganesium $\mathbf{Mn^{4+}}$...., lead $\mathbf{Pb^{4+}}$....
2) Ionization radiation: ultraviolet UV radiation..............., roentgen x-ray radiation................,
gamma **γ** radiation.............,beta (**β**$^-$un**β**$^+$)radiation..................,alpha particles $\boldsymbol{\alpha^{2+}}$ radiation.......
3) **Peroxisomal** ethylene $\mathbf{-CH_2-CH_2-}$ dehydrogenation to cis double bond $\mathbf{^{H}>C=C<^{H}}$..............

4. What **N-terminus** Asn3... and C-terminus Asn500.... amino acids have **8CAT.pdb**?
What number of amino acid has **CATALASE** polypeptide chain? 527......
What is number of amino acids on chain of **8CAT.pdb** 500-3=497; 497+1= 498.........?

4a 1-4. What **8CAT.pdb** isoelectric point IEP=pH=$pK_{a\text{-}vid}$, total charge at pH=7,36 ?
To determine water solution pH with **CATALASE** concentration $C=10^{-7,021667}$ M ($^{mol}/_{Litre}$)!

Liver Catalase (EC 1.11.1.6), present in the peroxisomes

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    SQ SEQUENCE 527 >8CAT:A|PDBID|CHAIN|SEQUENCE 67527,6 g/mol
MADNRDPASDQMKHWKEQRAAQKPDVLTTGGGNPVGDKLNSLTVGPRGPLLVQDVVFTDEMAHFDRERIPERVVHAKGAG
AFGYFEVTHDITRYSKAKVFEHIGKRTPIAVRFSTVAGESGSADTVRDPRGFAVKFYTEDGNWDLVGNNTPIFFIRDALL
FPSFIHSQKRNPQTHLKDPDMVWDFWSLRPESLHQVSFLFSDRGIPDGHRHMNGYGSHTFKLVNANGEAVYCKFHYKTDQ
GIKNLSVEDAARLAHEDPDYGLRDLFNAIATGNYPSWTLYIQVMTFSEAEIFPFNPFDLTKVWPHGDYPLIPVGKLVLNR
NPVNYFAEVEQLAFDPSNMPPGIEPSPDKMLQGRLFAYPDTHRHRLGPNYLQIPVNCPYRARVANYQRDGPMCMMDNQGG
APNYYPNSFSAPEHQPSALEHRTHFSGDVQRFNSANDDNVTQVRTFYLKVLNEEQRKRLCENIAGHLKDAQLFIQKKAVK
NFSDVHPEYGSRIQALLDKYNEEKPKNAVHTYVQHGSHLSAREKANL
        10         20         30         40         50         60         70         80
MADNRDPASD QMKHWKEQRA AQKPDVLTTG GGNPVGDKLN SLTVGPRGPL LVQDVVFTDE MAHFDRERIP ERVVHAKGAG
        90        100        110        120        130        140        150        160
AFGYFEVTHD ITRYSKAKVF EHIGKRTPIA VRFSTVAGES GSADTVRDPR GFAVKFYTED GNWDLVGNNT PIFFIRDALL
       170        180        190        200        210        220        230        240
FPSFIHSQKR NPQTHLKDPD MVWDFWSLRP ESLHQVSFLF SDRGIPDGHR HMNGYGSHTF KLVNANGEAV YCKFHYKTDQ
       250        260        270        280        290        300        310        320
GIKNLSVEDA ARLAHEDPDY GLRDLFNAIA TGNYPSWTLY IQVMTFSEAE IFPFNPFDLT KVWPHGDYPL IPVGKLVLNR
       330        340        350        360        370        380        390        400
NPVNYFAEVE QLAFDPSNMP PGIEPSPDKM LQGRLFAYPD THRHRLGPNY LQIPVNCPYR ARVANYQRDG PMCMMDNQGG
       410        420        430        440        450        460        470        480
APNYYPNSFS APEHQPSALE HRTHFSGDVQ RFNSANDDNV TQVRTFYLKV LNEEQRKRLC ENIAGHLKDA QLFIQKKAVK
       490        500        510        520       527
NFSDVHPEYG SRIQALLDKY NEEKPKNAVH TYVQHGSHLS AREKANL     CATA_BOVIN
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$pK_{mean}=pK_{sum}/ NpK$ =1339,51........../174...........=............... pKa count 172....+2....=.174..........=NpK

Val73,Val74,Ala76,Val116,Ala117,Pro129,Gly131,Val146,Gly147,Phe153,Phe154,Ile155,
Ala158,Leu159,Leu160,Phe161,Pro162,Phe164,Ile165,Phe198,Leu199,Phe200,
Leu299,Ala333,Phe334,Pro336,Met350,Leu351,Gly353,Phe356,Ala357,Pro359,Ala435
Val72,Val73,Ala75,Val115,Ala116,Pro128,Gly130,Val145,Gly146,Phe152,Phe153,Ile154,shift -1
Ala157,Leu158,Leu159,Phe160,Pro161,Phe163,Ile164,Phe197,Leu198,Phe199,
Leu298,Ala332,Phe333,Pro335,Met349,Leu350,Gly352,Phe355,Ala356,Pro358,Ala434

In account are present four Cysteine residues pK_{RR} =8.18; Sum of 174 pKa in table sum ....

AA	pKa_{COO-}	pKa_{NH3+}	pK_{RR}	Nr		AA	pKa_{COO-}	pKa_{NH3+}	pK_{RR}	Nr		AA	pKa_{COO-}	pKa_{NH3+}	pK_{RR}	Nr		AA	pKa_{COO-}	pKa_{NH3+}	pK_{RR}	Nr	
A	--	9,69		1	1	R			12,48	129	45	D			3,65	256	89	E			4,25	419	133
D	--		3,65	2	2	K			10,53	134	46	D			3,65	258	90	H			6	420	134
R	--		12,48	4	3	Y			10,07	136	47	Y			10,07	259	91	R			12,48	421	135
D	--		3,65	5	4	E			4,25	138	48	R			12,48	262	92	H			6	423	136
D	--		3,65	9	5	D			3,65	139	49	D			3,65	263	93	D			3,65	427	137
K	--		10,53	12	6	D			3,65	143	50	Y			10,07	273	94	R			12,48	430	138
H	--		6	13	7	R			12,48	155	51	Y			10,07	279	95	D			3,65	436	139
K	--		10,53	15	8	D			3,65	156	52	E			4,25	287	96	D			3,65	437	140
E	--		4,25	16	9	H			6	165	53	E			4,25	289	97	R			12,48	443	141
R	--		12,48	18	10	K			10,53	168	54	D			3,65	297	98	Y			10,07	446	142
K	--		10,53	22	11	R			12,48	169	55	K			10,53	300	99	K			10,53	448	143
D	--		3,65	24	12	H			6	174	56	H			6	304	100	E			4,25	452	144
D	--		3,65	36	13	K			10,53	176	57	D			3,65	306	101	E			4,25	453	145
K	--		10,53	37	14	D			3,65	177	58	Y			10,07	307	102	R			12,48	455	146
R	--		12,48	46	15	D			3,65	179	59	K			10,53	314	103	K			10,53	456	147
D	--		3,65	53	16	D			3,65	183	60	R			12,48	319	104	R			12,48	457	148
D	--		3,65	58	17	R			12,48	188	61	Y			10,07	324	105	C			8,18	459	149
E	--		4,25	59	18	E			4,25	190	62	E			4,25	327	106	E			4,25	460	150
H	--		6	62	19	H			6	193	63	E			4,25	329	107	H			6	465	151
D	--		3,65	64	20	D			3,65	201	64	D			3,65	334	108	K			10,53	467	152
R	--		12,48	65	21	R			12,48	202	65	E			4,25	343	109	D			3,65	468	153
E	--		4,25	66	22	D			3,65	206	66	D			3,65	347	110	K			10,53	475	154
R	--		12,48	67	23	H			6	208	67	K			10,53	348	111	K			10,53	476	155
E	--		4,25	70	24	R			12,48	209	68	R			12,48	353	112	K			10,53	479	156
R	--		12,48	71	25	H			6	210	69	Y			10,07	357	113	D			3,65	484	157
H	--		6	74	26	D			3,65	212	70	D			3,65	359	114	H			6	486	158
K	--		10,53	76	27	Y			10,07	214	71	H			6	361	115	E			4,25	488	159
Y	--		10,07	83	28	H			6	217	72	R			12,48	362	116	Y			10,07	489	160
E	--		4,25	85	29	K			10,53	220	73	H			6	363	117	R			12,48	492	161
H	--		6	88	30	D			3,65	225	74	R			12,48	364	118	D			3,65	498	162
D	--		3,65	89	31	E			4,25	227	75	Y			10,07	369	119	K			10,53	499	163
R	--		12,48	92	32	Y			10,07	230	76	C			8,18	376	120	Y			10,07	500	164
Y	--		10,07	93	33	C			8,18	231	77	Y			10,07	378	121	E			4,25	502	165
K	--		10,53	95	34	K			10,53	232	78	R			12,48	379	122	E			4,25	503	166
K	--		10,53	97	35	H			6	234	79	R			12,48	381	123	K			10,53	504	167
E	--		4,25	100	36	Y			10,07	235	80	Y			10,07	385	124	K			10,53	506	168
H	--		6	101	37	K			10,53	236	81	R			12,48	387	125	H			6	510	169
K	--		10,53	104	38	D			3,65	238	82	D			3,65	388	126	Y			10,07	512	170
R	--		12,48	105	39	K			10,53	242	83	C			8,18	392	127	H			6	515	171
R	--		12,48	111	40	E			4,25	247	84	D			3,65	395	128	H			6	518	172
E	--		4,25	118	41	D			3,65	248	85	Y			10,07	403	129	R			12,48	522	173
D	--		3,65	123	42	R			12,48	251	86	Y			10,07	404	130	E			4,25	523	174
R	--		12,48	126	43	H			6	254	87	E			4,25	412	131	K			10,53	524	175
D	--		3,65	127	44	E			4,25	255	88	H			6	413	132	L	2,36			527	176

Tasks for catalase molecule 8CAT.pdb

Protolytic constant pK_a isoelectric point IEP=pK_a calculate of side chains $\Sigma pK_{aRside\ group}$; Nterminal $pK_{aNterminal}NH_3^+$ and $pK_{aCterminal}COO^-$ constants sum divide with number of acid groups NpK_a:

$$IEP=pK_a=(\Sigma pKa_{Rside\ group}+pKa_{Nterminal}+pKa_{Cterminal})/NpKa$$

Acid groups number in sum NpKa=172.......+2.........= 174.....

527 amino acids of them for pK_a side groups number 172+2.

N-terminal Methionine M $pK_{aNterminal}$=9.21 and

C-terminal Lysine K $pKa_{Cterminal}$=2.34

Sum are calculate as

$\Sigma pKa=\Sigma pKa_{Rside\ group}+pK_{aNterminal}+pKa_{Cterminala}$=1339,51...........

1. Average constant $pK_{mean}=pK_a$=IEP **ISOELEKTRIC POINT**

NpKa=172.......+2........=174........ ;

IEP=ΣpKa/ NpKa =1339,51/ 174 =**7,698333**.............

At pH value on isoelectric point pH**=IEP total charge** is zero „**0**"

zero charge „**0**" **IEP**=pH

COOH & **-NH_3^+** positive **COO^-** & **NH_3^+** negative **-COO^-** & **-NH_2**

Underline existing!

2. 8CAT molecule charge sign (**+**). zero „**0**" or (**-**) at pH=7.36

Underline existing:

COOH,**NH_3^+** positive + pH=7.36<IEP=**7,7** negative-**COO^-**,**NH_2**.

3. 8CAT molecule charge **+**. zero „**0**" or **-** at **electrophoresis** pH **8.8**

Underline existing:

COOH,**NH_3^+** positive +IEP=**7,7**<pH = **8,8** negative **- COO^-**,**NH_2**

4. Calculate solution pH C=$10^{-7,021667}$ M 8CAT by *Ostwald dilution law*

concentration C in logarithm:

$$pH=\frac{pK_a-\log C}{2}=\frac{7,698333-\log 10^{-7,021667}}{2}=\frac{7,698333+7,021667}{2}=\mathbf{14,7201}/2=7,36......$$

Attractor 7,36 concentration of 8CAT is $10^{-7,021667}$..........M.

4b. What **1QQW.pdb** isoelectric point IEP=pH=$pK_{a\text{-}vid}$ at physiologic pH=7,36 ? To determine water solution pH with **CATALASE** concentration $C=10^{-7,021667}$ M ($^{mol}/_{Litre}$)!

Catalase (EC 1.11.1.6), present in Human erytrocites

```
    SQ SEQUENCE 527 >1QQW:A|PDBID|CHAIN|SEQUENCE 67384,637 g/mol
MADSRDPASDQMQHWKEQRAAQKADVLTTGAGNPVGDKLNVITVGPRGPLLVQDVVFTDEMAHFDRERIPERVVHAKGAG
AFGYFEVTHDITKYSKAKVFEHIGKKTPIAVRFSTVAGESGSADTVRDPRGFAVKFYTEDGNWDLVGNNTPIFFIRDPIL
FPSFIHSQKRNPQTHLKDPDMVWDFWSLRPESLHQVSFLFSDRGIPDGHRHMNGYGSHTFKLVNANGEAVYCKFHYKTDQ
GIKNLSVEDAARLSQEDPDYGIRDLFNAIATGKYPSWTFYIQVMTFNQAETFPFNPFDLTKVWPHKDYPLIPVGKLVLNR
NPVNYFAEVEQIAFDPSNMPPGIEASPDKMLQGRLFAYPDTHRHRLGPNYLHIPVNCPYRARVANYQRDGPMCMQDNQGG
APNYYPNSFGAPEQQPSALEHSIQYSGEVRRFNTANDDNVTQVRAFYVNVLNEEQRKRLCENIAGHLKDAQIFIQKKAVK
NFTEVHPDYGSHIQALLDKYNAEKPKNAIHTFVQSGSHLAAREKANL
```

AA	pKa_{COO-}	pKa_{NH3+}	pK_{RR}		Nr
M	--	9,21		1	1
D	--		3,65	3	2
R	--		12,48	5	3
D	--		3,65	6	4
D	--		3,65	10	5
K	--		10,53	13	6
H	--		6	14	7
K	--		10,53	16	8
E	--		4,25	17	9
R	--		12,48	19	10
K	--		10,53	23	11
D	--		3,65	25	12
D	--		3,65	37	13
K	--		10,53	38	14
R	--		12,48	47	15
D	--		3,65	54	16
D	--		3,65	59	17
E	--		4,25	60	18
H	--		6	63	19
D	--		3,65	65	20
R	--		12,48	66	21
E	--		4,25	67	22
R	--		12,48	68	23
E	--		4,25	71	24
R	--		12,48	72	25
H	--		6	75	26
K	--		10,53	77	27
Y	--		10,07	84	28
E	--		4,25	86	29
H	--		6	89	30
D	--		3,65	90	31
R	--		12,48	93	32
Y	--		10,07	94	33
K	--		10,53	96	34
K	--		10,53	98	35
E	--		4,25	101	36
H	--		6	102	37
K	--		10,53	105	38
R	--		12,48	106	39
R	--		12,48	112	40
E	--		4,25	119	41
D	--		3,65	124	42
R	--		12,48	127	43
D	--		3,65	128	44
K	--		10,53	135	45
Y	--		10,07	137	46
E	--		4,25	139	47
D	--		3,65	140	48
D	--		3,65	144	49
R	--		12,48	156	50
D	--		3,65	157	51
H	--		6	166	52
K	--		10,53	169	53
R	--		12,48	170	54
H	--		6	175	55
K	--		10,53	177	56
D	--		3,65	178	57
D	--		3,65	180	58
D	--		3,65	184	59
R	--		12,48	189	60
E	--		4,25	191	61
H	--		6	194	62
D	--		3,65	202	63
R	--		12,48	203	64
D	--		3,65	207	65
H	--		6	209	66
R	--		12,48	210	67
H	--		6	211	68
Y	--		10,07	215	69
H	--		6	218	70
K	--		10,53	221	71
E	--		4,25	228	72
Y	--		10,07	231	73
C	--		8,18	232	74
K	--		10,53	233	75
H	--		6	235	76
Y	--		10,07	236	77
K	--		10,53	237	78
D	--		3,65	239	79
K	--		10,53	243	80
E	--		4,25	248	81
D	--		3,65	249	82
R	--		12,48	252	83
E	--		4,25	256	84
D	--		3,65	257	85
D	--		3,65	259	86
Y	--		10,07	260	87
R	--		12,48	263	88
D	--		3,65	264	89
K	--		10,53	273	90
Y	--		10,07	274	91
Y	--		10,07	280	92
E	--		4,25	290	93
D	--		3,65	298	94
K	--		10,53	301	95
H	--		6	305	96
K	--		10,53	306	97
D	--		3,65	307	98
Y	--		10,07	308	99
K	--		10,53	315	100
R	--		12,48	320	101
Y	--		10,07	325	102
E	--		4,25	328	103
E	--		4,25	330	104
D	--		3,65	335	105
E	--		4,25	344	106
D	--		3,65	348	107
K	--		10,53	349	108
R	--		12,48	354	109
Y	--		10,07	358	110
D	--		3,65	360	111
H	--		6	362	112
R	--		12,48	363	113
H	--		6	364	114
R	--		12,48	365	115
Y	--		10,07	370	116
H	--		6	372	117
C	--		8,18	377	118
Y	--		10,07	379	119
R	--		12,48	380	120
R	--		12,48	382	121
Y	--		10,07	386	122
R	--		12,48	388	123
D	--		3,65	389	124
C	--		8,18	393	125
D	--		3,65	396	126
Y	--		10,07	404	127
Y	--		10,07	405	128
E	--		4,25	413	129
E	--		4,25	420	130
H	--		6	421	131
Y	--		10,07	425	132
E	--		4,25	428	133
R	--		12,48	430	134
R	--		12,48	431	135
D	--		3,65	437	136
D	--		3,65	438	137
R	--		12,48	444	138
Y	--		10,07	447	139
E	--		4,25	453	140
E	--		4,25	454	141
R	--		12,48	456	142
K	--		10,53	457	143
R	--		12,48	458	144
C	--		8,18	460	145
E	--		4,25	461	146
H	--		6	466	147
K	--		10,53	468	148
D	--		3,65	469	149
K	--		10,53	476	150
K	--		10,53	477	151
K	--		10,53	480	152
E	--		4,25	484	153
H	--		6	486	154
D	--		3,65	488	155
Y	--		10,07	489	156
H	--		6	492	157
D	--		3,65	498	158
K	--		10,53	499	159
Y	--		10,07	500	160
E	--		4,25	503	161
K	--		10,53	504	162
K	--		10,53	506	163
H	--		6	510	164
H	--		6	518	165
R	--		12,48	522	166
E	--		4,25	523	167
K	--		10,53	524	168
L	2,36	--		527	169

1303.23........../169...........=**7,48983**............. Number of pKa 167....+2....=169........=NpK 1QQW

Are present four Cysteine residues pK_{RR} =8.18; Sum of 169 pKa values in table 1303.23..........

Tasks for catalase molecule 1QQW.pdb

Protolytic constant pK_a isoelectric point IEP=pK_a calculate of side chains

$\Sigma pK_{aRside\ group}$; Nterminal $pK_{aNterminal}NH_3^+$ and $pK_{aCterminalCOO^-}$ constants

sum divide with number of acid groups NpK_a:

$IEP=pK_a=(\Sigma pKa_{Rside\ group}+pKa_{Nterminal}+pKa_{Cterminal})/NpKa$

Acid groups number in sum NpKa=167.......+2.........= 169.....

527 amino acids of them for pK_a side groups number 167+2.

N-terminal Methionine M $pK_{aNterminal}$=9.21 and

C-terminal Lysine K $pKa_{Cterminal}$=2.34

Sum are calculate as

$\Sigma pKa=\Sigma pKa_{Rside\ group}+pK_{aNterminal}+pKa_{Cterminala}$=1303.23...........

1. Average constant $pK_{mean}=pK_a$=IEP **ISOELEKTRIC POINT**

NpKa=167.......+2........=169........

IEP=ΣpKa/ NpKa =1303.23/ 169 =**7,48983**.............

At pH value on isoelectric point pH**=IEP total charge** is zero „**0**”

zero charge „**0**” **IEP**=pH

COOH & **-NH$_3^+$** positive **COO$^-$** & **NH$_3^+$** negative **-COO$^-$** & **-NH$_2$**

<u>Underline</u> existing!

2. 1QQW molecule charge sign (**+**). zero „**0**” or (**-**) at pH=7.36

<u>Underline</u> existing:

COOH,**NH$_3^+$** <u>positive</u> + pH=7.36<IEP=**7,49** negative-**COO$^-$**,**NH$_2$**.

3. 1QQW molecule charge **+**. zero „**0**” or **-** at **electrophoresis** pH **8.8**

<u>Underline</u> existing:

COOH,**NH$_3^+$** positive +IEP=**7,49**<pH = **8,8** <u>negative</u> **- COO$^-$**,**NH$_2$**

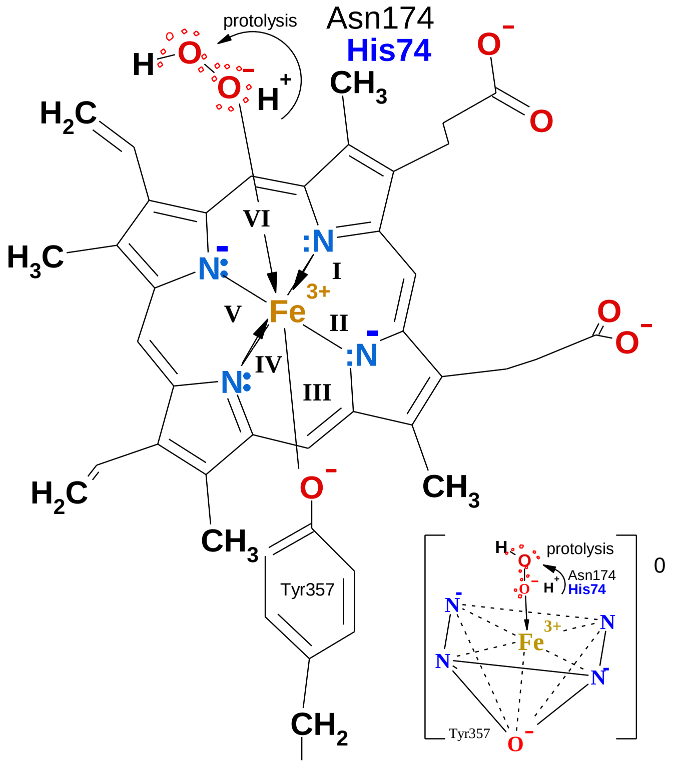
4. Calculate solution pH C=$10^{-7,23017}$ M 1QQW by *Ostwald dilution law*

concentration C in logarithm:

$$pH=\frac{pK_a-\log C}{2}=\frac{7,48983-\log 10^{-7,23017}}{2}=\frac{7,48983+7,23017}{2}=\mathbf{14,7201}/2=7,36......$$

Attractor 7,36 concentration of 1QQW is $10^{-7,23017}$..........M.

5. What secondary structures contains the CATALASE? ....**13 Alpha helixes** and ....**beta barrel 8 strands**.
6. What **alpha helices** constitute CATALASE polypeptide molecule? ....**13 Alpha-helices**
7. What **beta structure** and **sheets** and how many **beta strands** constitute CATALASE?
.............**beta-barrel structure** with ....**8 anti-parallel strands**.
8. What quaternary 4° structures components 3° subunits and what tertiary 3° structure domain units with its secondary 2° structures components are in given CATALASE unit?
.......4 four tetramer units of..........4 fourprotein chains; How many secondary 2° structures?
...........**13 Alpha-helices**; ....**beta-barrel structure** ....**8 anti-parallel beta strands**.
9. **Funnel channel** long, wide, deep in angstrems distance?.....25.Å..........20-15 Å..........33-19Å
10. Wht are 11 **hydrophobic** **Funnel** AA numbers on polypeptide chain? **Val115**.....,**Ala116**....,
Pro128....,**Phe152**....,**Phe153**....,**Phe163**....,**Ile164**....,**Pro178**.....,**Val181**....,**Leu198**.....,**Phe199**....
11. Wht are 14 **polar**-**charged** **Funnel** amino acids numbers on polypeptide chain ?!
......**Ser113**.......,**Glu118**........,**Ser121**........,**Arg126**........,**Asp127**........,**Gln167**........,**Lys168**......,
......**Lys176**.........,**Glu247**........,**His255**........,**Glu453**........,**Glu454**........,**Gln461**........,**His466**......
12. Whatare 31 amino acids numbers on polypeptide chain of Heme pocket tertiary 3° structure?
Val72....,Val73....,Ala75....,Val115.....,Ala116.......,Pro128.....,Gly130.....,Val145.....,
Gly146.....,Phe152.....,Phe153.....,Ile154.....,Ala157.....,Leu158.....,Leu159......,Phe160......,
Pro161....,Phe163......,Ile164......,Phe197......,Leu198......,Phe199......,Leu298....,Ala332.....,Phe333...,
Pro335......,Met349......,Leu350.......,Gly352.......,Phe355.........,Ala356.......,Pro358........,Ala434...
13. Heme pocket 8 **hydrophilic** amino acids numbers on polypeptide chain and 3 functions are?
...**Arg353**…….,……..**Tyr**^{357}...........**Arg71**…….,……**Arg111**……,…….**Glu329**......,....**Arg364**.....
1) **His74,Asn147** catalysis ....**H**$^+$ deprotonation for peroxide dismutation on **heme** iron
2) **H3=156-168 and H9=347-366** bind the ....**heme** prosthetic group..
3) binding ....**heme** propionic acid residues.
14. First Tertiary domain starting amino acid =....Asn3. and finishing amino acid=....Ala75..?
15. What two first alpha helices names are depicted? ....**H1**..,..**H2**..
16. Heme moiety domain starting amino acid =....Lys76. and finishing amino acid=....Asn320..?
17. 5 Helix names in **heme** domain:.....**H3**….,.....**H4**…..,.....**H5**…..,.......**H6**…..,......**H7**.....,
18. Beta sheet name and strands account: ....**beta-barrel and** ....**8 anti-parallel strands**.
19. Third domain starting amino acid =........Pro321. and finishing amino acid= ....Asp436. ?
20. Carboxy terminal starting amino acid =..... Asp437. and finishing amino acid= ......Asn500.?
21. **Carboxy-terminal** globulin 4 Helix names:..**H10**.........,**H11**……..,..**H12**……...,..**H13**.............
22. How many polypeptide chains are linked to each heme? ....one polypeptide chain..
23. What number of hems in biological unit of CATALASE **7cat.pdb**?...............four hemes.
24. What mass kD and number subunits make quaternary structure of CATALASE dumb-bell?..
.....four subunits, 60............kD each subunit molar mass, tetramer mass 60*4=.............240 kD.
25. **Heme** location distance from center the tetramer in angstroms is 45,66/2=22.83...........Å
26. How much **salt bridges** are present in tetramer?...28 bridges, Show **Arg**-**Asp**,**Glu** Functional groups interaction! **Arg**≡**C**— **N**H_3^+..........=>···**salt bridge**···<=.............$^-$**OOC** —**C**≡**Asp**,**Glu**..
27. Heme proximal components 6 and of α helix **H9** 3 amino acids numbers on polypeptide chain?
Val^{145}…..,**Pro**^{335}.....,**His**^{217}.....,**Arg**^{353}.....,**Ala**^{356}.....,**Tyr**^{357}......and **H9** **Arg**^{353}.....,**Ala**^{356}.....,**Tyr**^{357}......
28. Heme location, distal side structural components? distal side facing the........ channel contains
.............non polar and ....polar residues, some of which are contributed by the beta-barrel..........
29. What five 5 intermolecular forces are known in biochemistry and physiology of proteins? ...
1.**...Hydrogen bond** 2.**...Hydrophobic** 3.**.. Salt bridges** **4.-S-S-…disulfide bonds 5.…Coordinative bond**
30. What four **4** intermolecular forces fold protein chains of CATALASE? Call dentified!
1.**...Hydrogen bond** 2.**...Hydrophobic** 3.**.. Salt bridges** **5.…Coordinative bond**
31. Describe the CATALASE **heme** pocket vicinity components: pyrrole rings, propionic



acid residues, hydrophobic pocket complex maker atom bonding properties are coordination number N=VI...

32. Put in line six atoms which form coordinative bonds with ion Fe^{3+}! Iron!

:N,:N⁻,:N⁻,:N⁻, –O⁻, H-:•:O-:-O:•:-H.................

1 2 3 4 5 6....................

33. Do account coordination number **N=VI…** of iron **Fe** on center of given CATALASE Heme! Mark on left !

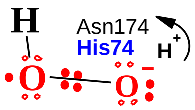
34. Which nonpolar, polar or ionic coordination bond of iron **Fe** belongs to **–O⁻** group of Tyr357? **Ionic bond**..............................

35. Explain Asn147,His74 role in CATALASE! Involved in proton H^+... transfer .... to connect with the hydroxyl group

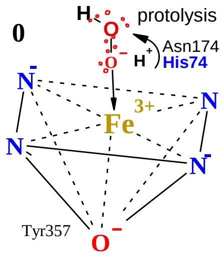
HO^-+H^+-Asn147,His74........................**->H_2O**

36. Show collision semi hexagonal, reverse piramidal coordination and give to coordinative complex neutral zero charge.......................

37. Peroxide deprotonate **H:-•:O-::-O⁻::** +H^+ and explain anion free electron reactivity! Reactive mean radical with free .... • electron anion with ....negative charge **HOO^-**..........



37.a Show peroxide anion and iron **Fe(III)** collision small activation energy 29 $^J/_{mol}$ as negative attracts positive ....charge



38. What and how in complex reaction sequence favors and produce the **CATALASE**? ....

1) favors stabile efficiency • 100% product essential unsaturated fatty acids ω=6, ω=3...

2) because erasing peroxide H_2O_2 to zero $[H_2O_2]^2$=.......... $^{mol}/_{liter}$..

3) **CATALASE** favors thirty million times 30•10⁶ production of life resources: ....
and ethylene group **-CH_2-CH_2-** on dehydrogenation to cis ....

39. Reaction non catalytic spontaneous disproportionation. Protolysis create anions collision!

Protolysis pK_a=11,75: $2H_2O_2+2H_2O \rightarrow H_3O^+ + HOO^- + ^-OOH + H_3O^+$................create dismutation collision :

$2H_2O_2+2H_2O \rightarrow H_3O^+ + HOO^- >< ^-OOH + H_3O^+ \rightarrow$ $O_{2aqua}+4H_2O+Q_{exothermic}$...............................;

deprotonate anion oxygen collision products = **oxygen** + **water** + **heat** .

40. Write the dismutation reaction mechanism in steps with protonation **His74**, Asn174 of peroxide deprotonation in collisions with active site **Fe(III)-O**-Tyr357-**E**:

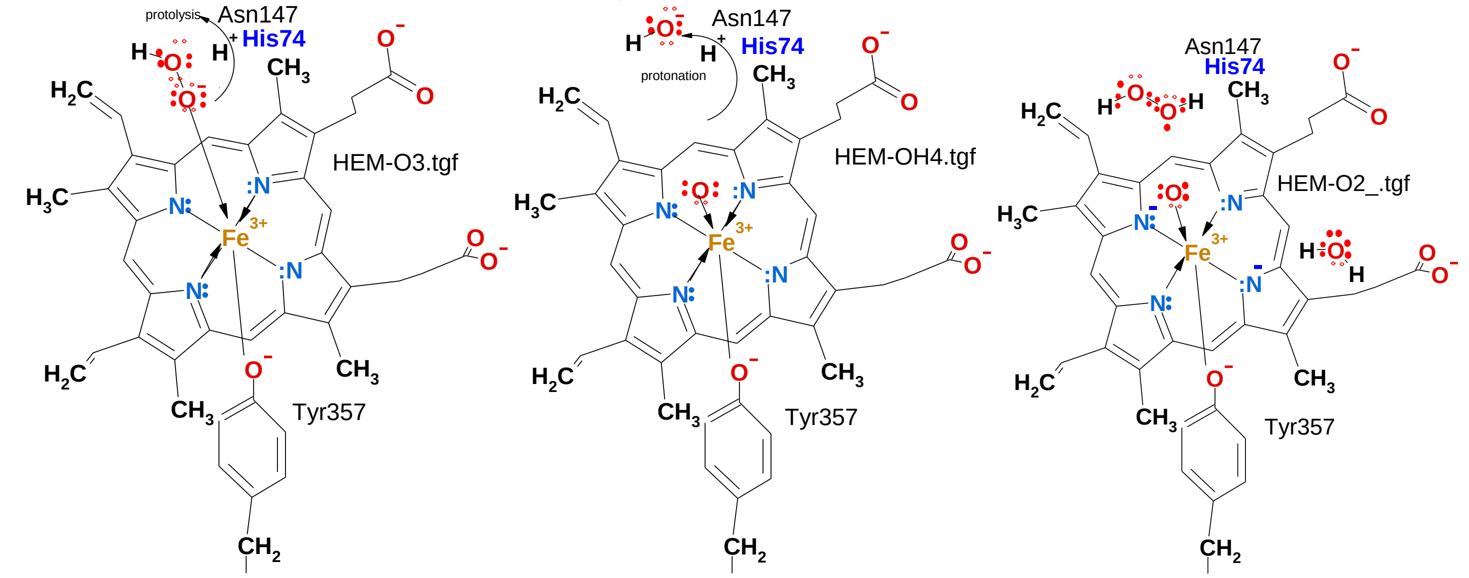
1. **H-O-O-H** $_{protolysis}$+**His74**+**Fe(III)-O**-Tyr357-**E**=>H^+-**His74**$_{protonate}$+**HOO^-→**+**Fe(III)-O**-Tyr357-**E** ....
2. H^+**His74**$_{protonation}$+**HOO^-→**+**Fe(III)-O**-Tyr357-**E**=>**HO^-**$_{Red}$+H^+**His74**$_{protonate}$+Ox**O-Fe(IV)-O**-Tyr357-**E**.......
3. **HO^-**$_{Red}$+ H^+-**His74**$_{protonate}$+Ox**O-Fe(IV)-O**-Tyr357-**E**=>$_{Red}$**H_2O**+**His74**+Ox**O-Fe(IV)-O**-Tyr357-**E** ....
4. =>**H-O-O-H** $_{protolysis}$+Asn147+**O-Fe(IV)-O**-Tyr357-**E** =>H^+Asn147+**HOO^-→**+**O-Fe(IV)-O**-Tyr357-**E** ....
5. H^+Asn147+**HOO^-→**+**O-Fe(IV)-O**-Tyr357-**E**=>**HO^-**$_{Red}$+H^+Asn147+Ox**O-O-Fe(IV)-O**-Tyr357-**E**.................
6. =>**HO^-**$_{Red}$+H^+Asn147+Ox**O-O-Fe(IV)-O**-Tyr357-**E**=>$_{Red}$**H_2O**+Asn147+Ox**O-O-Fe(IV)-O**-Tyr357-**E** ....
7. $_{Red}$**H_2O**+Ox**O-O-Fe(IV)-O**-Tyr357-**E**=>$_{Red}$**H_2O**+Ox**O=O**+-**Fe(III)-O**-Tyr357-**E** ....

Summary: $2H_2O_2$+**CAT**→H_3O^++**HOO^->Fe(III)<^-OOH**+H_3O^+→**O_{2aqua}+$2H_2O$+$Q_{exothermic}$+CAT**

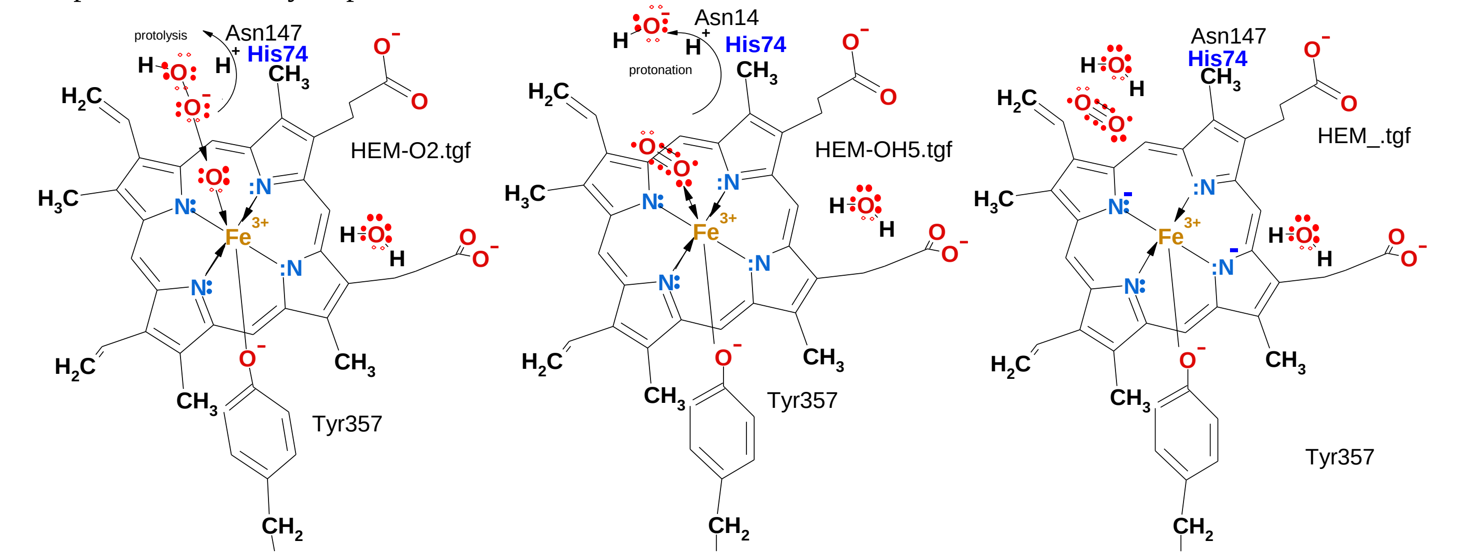
Protolysis activate transition state complex **oxygen**+ **water**+ **heat**+ CATALASE,

1. Colliding oxygen atom oxidized Ox **O-Fe**(**III**) and deprotonate on H^+ **His74**, Asn174;........
2. second oxygen atom reduced **HO^-**Red and protonated neutral about **H_2O**............

41. What is happen with CATALASE during life resources production O_2+H_2O+Q?



Hem pocket with 28 hydrophobic amino acids – in <u>waterless</u> medium oxidation-reduction reaction absent:



42. For what reason CATALASE is tightly bound to **NADPH**?

Tyr357-**OH**+Fe^{2+}+**NADP**$^+$+**H$_2$O**(H$^+$-His161)⇔Tyr357-**O**$^-$+Fe^{4+}+**NADPH**+**H$_3$O**$^+$+(His161)

NADPH stabilizing Tyr357-**O**$^-$ + Fe^{3+}ionic bond ....shifts equilibrium to right

with high rate protolysis attractors pH=7,36...... and concentration [**H$_2$O**]=55,3.......$^{mol}/_L$

43. Two beta sheets Intermolecular hydrogen bonds connecting in tetramer subunits with 4 beta strands.. 1st <u>page</u>:

44. Show Hydrogen <u>bond</u> between electronegative element atoms **O** and **N** peptide bond carbonyl >**C=O** and imino group hydrogen >**C=O…H—N**<...............................

and imino group hydrogen >**N—H** and carbonyl group >**N—H**...**O**=**C**<.........................

or between carbonyl >**C**=**O** and hydroxyl Ser hydrogen, amino residues >**C**=**O**...**H—O**—Ser....

or between carbonyl >**C**=**O** and amino hydrogen His residue >**C**=**O**..**H—N**<His.............

45. Arrhenius velocity constant **k**→ expression active collision number **e$^{-Ea/(RT)}$=exp(-E$_a$/(RT))**=0.988......!

$\vec{\mathbf{k}}$ = **A**....•**e$^{-Ea/(RT)}$**................

activation energy **E$_a$**,= 29...... $^J/_{mol}$ **;**
geometric factor **A=0,13** ...... and
the temperature **T=298,15** ..... K.

46. How many times decreases activation energy $\mathbf{E_a}$ for CATALASE to compare absence catalyst?
$\mathbf{E_{aCATALASE}}$ =29 J/mol; ....$\mathbf{E_{a(absence\ catalyst)}}$ =79000 J/mol
79000/29=2724 ....times smaller $\mathbf{E_a}$ for CATALASE.

47. How many times increases pre exponential - geometric factor for CATALASE?
.$\mathbf{A_{absence\ catalyst}=0.01}$............................., $\mathbf{A_{CATALASE}=0.13}$ ....and
0.13/0.01=13................................ **times** improve pre exponential - geometric factor $\mathbf{A_{CATALASE}}$.

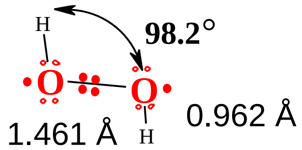
48. What physical meaning has Boltzmann exponential factor value 0.988 = **exp(-E$_a$/(RT))**?

$$\vec{k}=A\bullet e^{-\frac{Ea}{RT}}=A\bullet 0.988$$

Correct performed collision number is 988 of total 1000.
....

49. What physical meaning has pre exponential-geometric factor 1=**A**?
Perfect geometry of peroxide molecules for collision is **A**=1...
as from 100 total collisions correct collision number is 100.................

50. What physical meaning has perfect pre exponential-geometric factor?
fraction perfect is 1 as mean 100% ....perfect collisions .



51. Measure the geometry of peroxide bond angle, distance between **O – H** and **O - O** put in text boxes of structure!

52. What many times increases CATALASE velocity constant for 1 mol in liter $\mathbf{H_2O_2}$ conversion to life resources $\mathbf{O_2+H_2O+Q}$? **oxygen**+**water**+**heat** + CATALASE?

$$\sqrt{\vec{v}}={}^{\mathbf{CAT}}\sqrt{\vec{k}}\bullet[H_2O_2]=\mathbf{0.36}\bullet[H_2O_2];\ ....$$

.... $^{\mathbf{CAT}}\sqrt{\vec{k}}\,/\sqrt{\vec{k}}$ =0,36/1,19•10^{-8}=30•10^{6} .... times greater velocity constant.

53.0 Peroxide $\mathbf{H_2O_{2(aq)}+H_2O_{2(aq)}}$ oxygen atoms dismutation to => $\mathbf{O_{2aqua}+H_2O+H_2O+Q}$
Thermodynamics study ΔH_H, ΔS_H, ΔG_H dismutation. reaction as **exothermic** , **athermic**, **endothermic**?
Peroxide **2H:-••:O-:-O:••-:H** convertion to $\mathbf{O_{2aqua}}$ **+2H$_2$O +Q** at temperature 298.15 K, using the data table!

$$2H_2O_{2(aq)} \Rightarrow O_{2aqua} + 2H_2O + Q + \Delta G$$

Substance	$\Delta H°_H$, kJ/mol	$\Delta S°_H$, J/mol/K	$\Delta G°_H$, kJ/mol
$\mathbf{H_3O^+}$	-285,81	-3,854	-213,275
$\mathbf{O_{2aqua}}$	-11.715	110.876	16,4
$\mathbf{O_{2aqua}}$	**-11.70**	**-94,2**	**16,40**
$\mathbf{H_2O_{2\,l}}$	-237,129	69,91	-237,129
$\mathbf{H_2O}$	-285,85	69,9565	-237,191
$\mathbf{H_2O}$	**-286,65**	**-453,188**	**-151,549**
$\mathbf{H_2O_{2(aq)}}$	-191,17	143,9	-134,03
$\mathbf{H_2O_{2\,(aq)}}$	**-191,99**	**-481,688**	**-48,39**

CRC 2010 ;

Biothermodynamic 2006;

$\Delta H_{Hess}=\Delta H°_{O2}+2\Delta H°_{H2O}-2\Delta H°_{H2O2}$=**-201,02**.....=-201,06......kJ/mol
=**-11,7**-2***286,65**-(2***-191,99**)=**-201,02**......kJ/mol **exothermic**..
=-11,7-2*285,85-(2*-191,17)=-201,06......kJ/mol

2.$\Delta S_{dispersed}=-\Delta H_H/T$=-(**-201,02**)/298,15=**674,2** .....J/mol/K ; $\Delta S_{dispersed}=-\Delta H_H/T$=-(-201,06)/298,15=674,36....J/mol/K ;
$\Delta S_{Hess}=\Delta S°_{O2}+2\Delta S°_{H2O}-2\Delta S°_{H2O2}$=**-94,2**+2***-453,188**-(2***-481,688**)=**-37,2**....J/mol/K**;**
$\Delta S_{Hess}=\Delta S°_{O2}+2\Delta S°_{H2O}-2\Delta S°_{H2O2}$=110,876+2*69,9565-(2*143,9)=-37....J/mol/K**;**
2. $\Delta S_{total}=\Delta S_H+\Delta S_{dispersed}$=**-37,2+674,2=637**.....J/mol/K ΔS_{total}=-37,011+674,36=637,35......J/mol/K**;**
4. $\Delta G_{Hess}=\Delta H_H-T*\Delta S_H$=**-201,02**-298,15***-0,0372**=**-189,9**........ kJ/mol **exoergic**................. **spontaneous**...........
$\Delta G_{Hess}=\Delta H_H-T*\Delta S_H$=-201,06-298,15*-0,037=-190........ kJ/mol ;
T•ΔS_{total}=**0,637***298,15=**189,9**.........kJ/mol ; T•ΔS_{total}=0,63735*298,15=190.........kJ/mol;

High rate protolysis peroxide dismutation (oxidation – reduction).

$[H_2O_2]=1$; $10^{\wedge(-10)}$ M Biochemistry concentrations $[O_{2aqua}]=6*10^{-5}$ M, $[H_3O^+]=10^{-7,36}$ M, $[H_2O]=55,3$ M.

Red $H_2O_2+2H_2O=O_2+2H_3O^++2e^-$; $\mathbf{E}^\circ_{H2O2}=0,4495$ V **Absolute** standard potential;

$E_{Red}=E^\circ_{H2O2}+0,0591/2\bullet lg([O_{2aqua}]*[H_3O^+]^2/[H_2O_2]/[H_2O]^2)=0,4495+0,0591/2*log(6*10^{\wedge(-5)}*10^{\wedge(-7,36*2)}/10^{\wedge(-10)}/55,3^{\wedge 2})=0,08227$ V

$E_{Red}=E^\circ_{H2O2}+0.0591/2\bullet lg([O_{2aqua}]*[H_3O^+]^2/[H_2O_2]/[H_2O]^2)=0,4495+0.0591/2*lg(6*10^{\wedge(-5)}*10^{\wedge(-7.36*2)}/1/55.3^{\wedge 2})=-0.2132$ V

Ox $H_2O_2 + 2\ H_3O^+ + 2\ e^- = 4\ H_2O$; $-\mathbf{E}^\circ_{\mathbf{Ox}H2O2}=-1,6855$V **Absolute iverse** standard potential .

$-E_{Ox}=-E^\circ_{H2O2Ox}+0,0591/2\bullet log([H_2O]^4/[H_2O_2]/[H_3O^+]^2)=-1,6855+0,0591/2*log(55,3^{\wedge}4/10^{\wedge}(-7,36*2)/10^{\wedge(-10)})=-0,749$ V;

$-E_{Ox}=-E^\circ_{H2O2Ox}+0.0591/2\bullet log([H_2O_2]*[H_3O^+]^2/[H_2O]^4)= -1,6855+0.0591/2*lg(1*10^{\wedge(-7.36*2)}/55.3^{\wedge 4})= -2,3265$ V

$[\mathbf{H_2O_2}]=1$ M; $[\mathbf{H_2O_2}]=10^{\wedge}(-10)$ M; concentration $\mathbf{2H_2O_{2aq}=>O_{2aqua}+2H_2O}$;

$[\mathbf{H_2O_2}]=10^{\wedge(-10)}$ M; $\Delta\mathbf{G}_{\mathbf{eq}BioChem}=(\mathbf{E}^\circ_{\mathbf{Red}}-\mathbf{E}^\circ_{\mathbf{Ox}})*\mathbf{F}*\mathbf{n}=(0,08227-0,749)*96485*2=(-1,236)*96485*2=\mathbf{-128,7}$ $^{kJ}/_{mol}$;

$[\mathbf{H_2O_2}]=1$ M; $\Delta\mathbf{G}_{\mathbf{eq}BioChem}=(\mathbf{E}^\circ_{\mathbf{Red}}-\mathbf{E}^\circ_{\mathbf{Ox}})*\mathbf{F}*\mathbf{n}=(-0,2132-2,3265)*96485*2=(-2,5397)*96485*2=\mathbf{-490,1}$ $^{kJ}/_{mol}$;

$\Delta G_{Alberty}=G_{O2Biochem\_arteriaj}+2*G_{H2OBioChemistry}-2*G_{H2O2}=\mathbf{78,08+2*85,64-2*364,79=-480,22}$ $^{kJ}/_{mol}$;

Free energy change minimum mixture reaching at **favored absolute** potential standard equilibrium:

$\Delta G_{eqStandard}=(\mathbf{E}^\circ_{H2O2}-E^\circ_{H2O2Ox})*\mathbf{F}*\mathbf{n}=(0,4495-1,6855)*96485*2=(-1,1845)*96485*2=\mathbf{-238,5}$.... $^{kJ}/_{mol}$;

$\Delta G_{HessAlberty}=G_{O2}+2G_{H2O}-2G_{H2O2}=330+2*(0)-(2*\mathbf{284})=\mathbf{-238}$........ $^{kJ}/_{moll}$ **;** **Alberty**

Absolute potential **scale** is coinciding with **Alberty** **absolute** free energy **scale.**

$$\frac{[O_2]_{aqua}\cdot[H_2O]^2}{[H_2O_2]^2_{aqua}}=\mathbf{K}_{\mathbf{eq}Standard}=\mathbf{K}_{\mathbf{H2O2}}=\mathbf{exp(-\Delta G_{eqStandarta}/R/T)}=exp(238500/8,3144/298,15)=10^{41,8}........$$

Exothermic and exoergic $\mathbf{H_2O_2}$ dismutation reaction Hess law

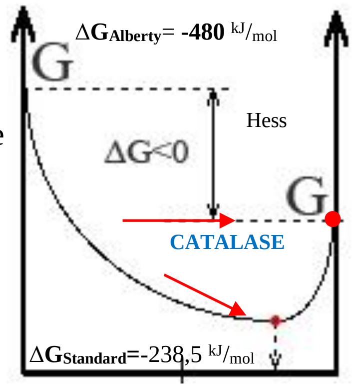
53.10 Homeostasis free energy change $\Delta\mathbf{G}_{Alberty}\mathbf{=-480,22}$.......... $^{kJ}/_{mol}$ is negative,

53.10a Hess **Alberty** free energy change $\Delta G_{HessAlberty}\mathbf{=-238}$........ $^{kJ}/_{mol}$ is negative,

53.11 Absolute potential scale $\Delta G_{eqStandard}\mathbf{=-238,5}$.......... $^{kJ}/_{mol}$ coinsiding with Absolute free energy scaling. reching equilibrium mixture constant

$\mathbf{K}_{\mathbf{eq}BioChem}=10^{41,8}$.............

Le Chatelier principle mean Prigogine attractor the free energy change minim ΔG_{min} reaching. High rate protolysis attractors pH=7,36, air oxygen 20,95% stay at equilibrium state, while homeostasis irreversibly continues, as is non equilibrium state. Prigogine attractors of Nobel Prize in Chemistry since 1977th . CATALAE erase peroxide molecules H_2O_2 in 100% efficiency for ω=6, ω=3 essential fatty acids elongation synthesis in peroxisomes. CATALASE reactivity is indispensible Brownian molecular engine for the irreversible homeostasis evolution and survival.



A+A 50% B+2 C
$\mathbf{2H_2O_{2}}_{(aq)}$ reactants and products $\mathbf{O_{2aqua}+2H_2O}$.

Conclusions

$\mathbf{H_2O_2+H_2O_2+Fe^{3+}\rightarrow H^++HOO^->Fe^{3+}<^-OOH+H^+\rightarrow O_{2aqua}+H_2O+H_2O+Q_{exothermic}+Fe^{3+}}$.

Protolysis activate transition state active complex **oxygen**+**water**+**heat** +<u>CATALASE</u>

CATALASE reactivity producing life resources $\mathbf{O_{2aqua}+2H_2O+Q}$

54.1. **Catalyst** CATALASE (CAT) is <u>involved</u> to reaction active transition state complex formation :

$\mathbf{H_2O_2...CAT...H_2O_2}$ and on finish released into products free unchanged CAT. ....

54.2. **Catalyst** CAT <u>decrease</u> activation energy $\mathbf{E_a}$ from 79000 J/mol to 29 J/mol times 2724 less.

54.3. **Catalyst** CAT <u>improve</u> geometric factor A=0.01 to A=0.13 times 13 better. ....

54.4. **Catalyst** CATALASE <u>increase</u> reaction velocity constant $\vec{\mathbf{k}}$ from $1.9\bullet 10^{-8}$ $M^{-1}s^{-1}$ to 0.36 $M^{-1}s^{-1}$ times $30\bullet 10^6$ thirty million more. ....

54.5. Prigogine attractor CATALASE reactivity is indispensable life molecular engine converting processes to ● 100% efficiency with erasing peroxide molecules.

54.6. CATALASE reactivity produces the life resources:

ω=6, ω=3 fatty acids **oxygen**+**water**+**heat;** $\mathbf{O_{2aqua}+2H_2O+Q}$.................

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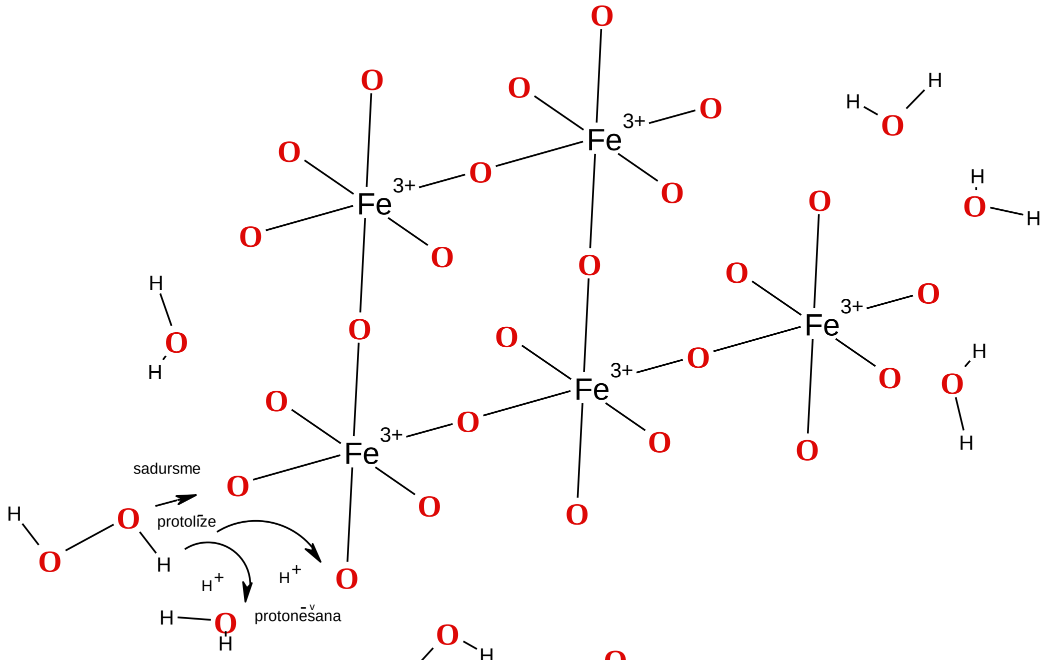
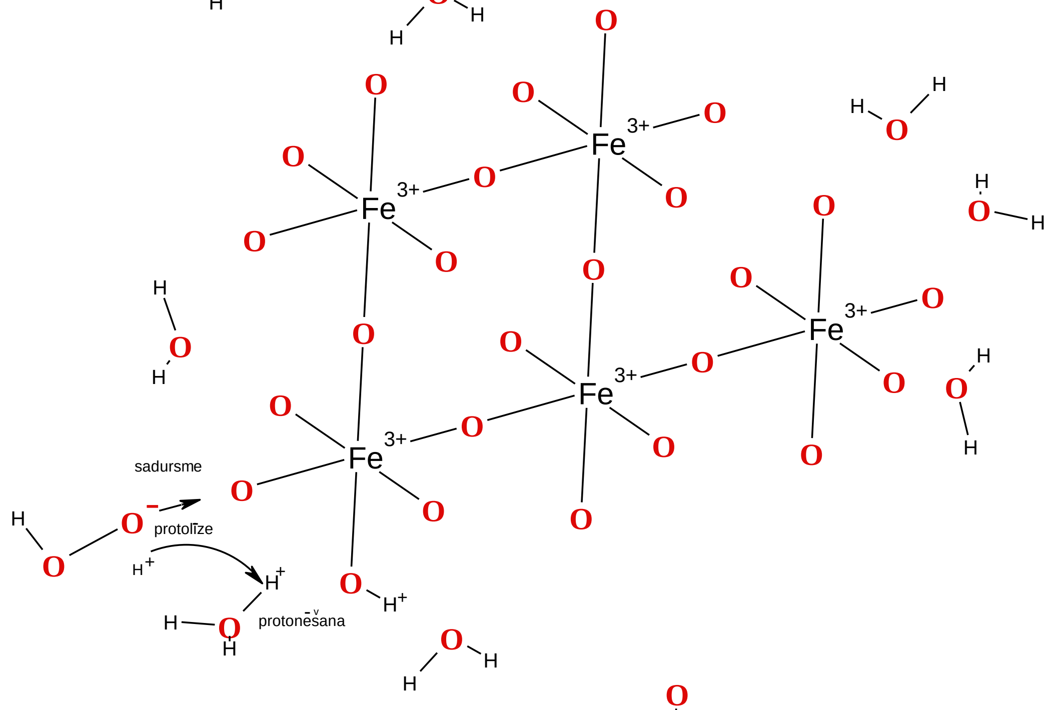
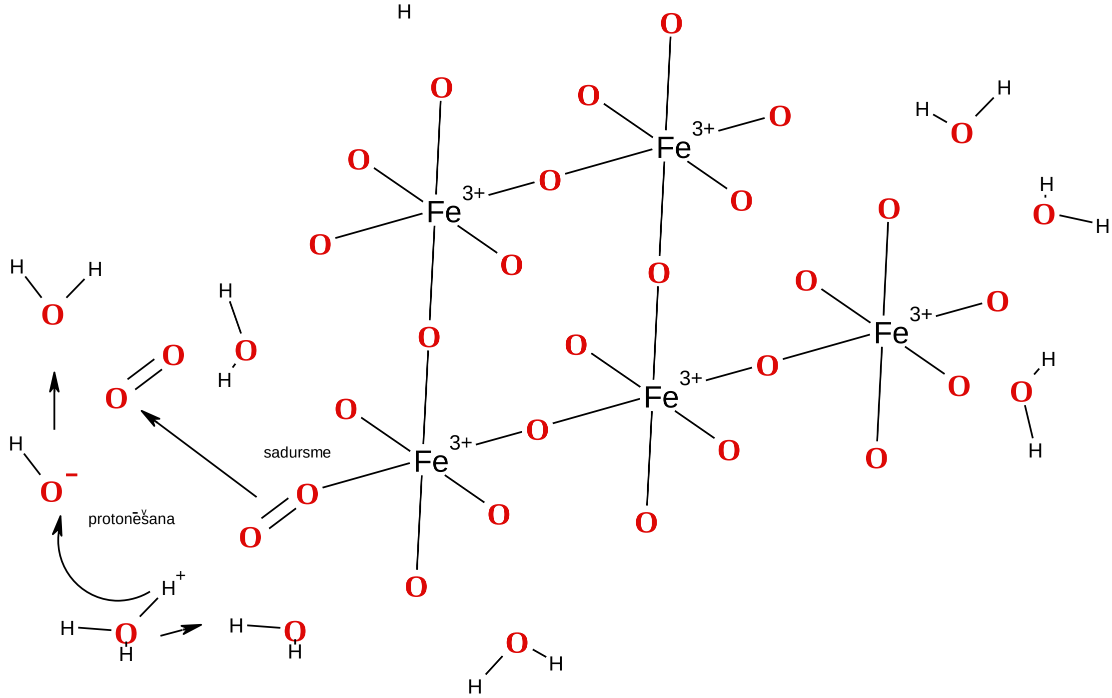
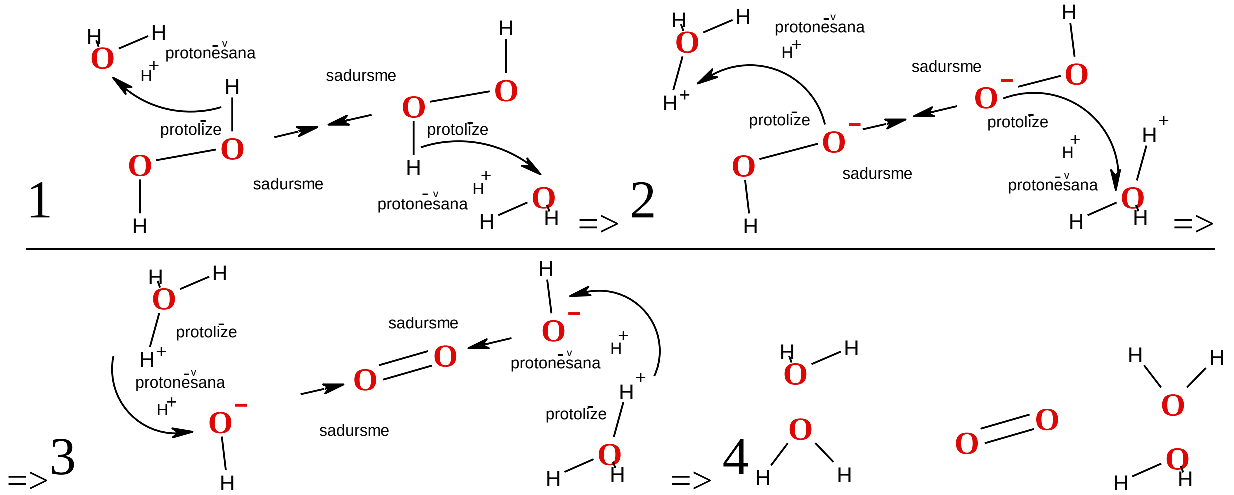
Catalyst by iron(III) oxide Fe_2O_3.







$$H_2O+H_2OO+OOH+H_2O\rightarrow H_3O^{+}+HOO^{-}><^{-}OOH+H_3O^{+}\rightarrow O_{2\,aqua}+2H_2O+2H_2O+Q_{exothermic}$$



$$H_2O_2+H_2O_2+CAT\rightarrow H^{+}+HOO^{-}>CAT<^{-}OOH+H^{+}\rightarrow O_{2\,aqua}+H_2O+H_2O+Q_{exothermic}+CAT$$

Catalyst by manganese(II) oxide MnO.