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Prigogine absolute energy attractors for dissolution, protolysis, and reduction-oxidation of sulfur compounds

Substance	$\Delta H°_H$ kJ/mol	$\Delta S°_H$ J/mol/K	$\Delta G°_H$, kJ/mol
H_2S^{gas}	formation	ΔG°-33,4	**55,7436**
H_2S^{gas}	Solubility	promote	**69,073**
H_2S^{gas}	-20.6	205.81	-33,4
H_2S_{aq}	**-22.9596**	**-256.064**	**53,3896**
H_2S_{aq}	$E°_{S\downarrow/H2Saq}$=	**-0,025735** V	**53,3896**
H_2S_{aq}	S+2H(Pt)=	H_2S_{aq}	**53,3866**
HS^-	-16,3	67	12,5
HS^- G_{e-}	formation	12,5	**31,69**
HS^-	$E°_{S\downarrow/S2-}$=	**-0,8517**V	**90,5336**
HS^-	pK_{a1}=7.05	favored	**81.138**
HS^-	pK_{a2}=19	-	**92.65**
S_{rombic}	formation	-	**3.5436**
S_{rombic}	$E°_{S\downarrow/H2Saq}$=	**-0.025735** V	**3.5436**
S^{2-}	33,1	-14,6	85,8
S^{2-} G_{e-}	formation	85,8	2***34,1432**
S^{2-}	$E°_{S\downarrow/S2-}$=	**-0,79853**V	**157,63**

G_{H2}^{gas}=**85.6** kJ/mol; $G_{H2S_{aq}}$=**53.3896** kJ/mol; $G_{S_{rhombic}}$=**3.5436** kJ/mol; favored $G_{H2S}^{gas}=\Delta G_{Hess\_H2S}^{gas}+(G_{S_{rombic}}+G_{H2})$= **55,7436** kJ/mol. $G_{H2S}^{gas}=G_{H2S_{aq}}-(\Delta G_{eq}+G_{H2O})$ =**84,343-(15,27+0)=69,073** kJ/mol; [1] $\Delta G_{H2S}^{gas}=\Delta H_H-T*\Delta S_H$=-20.6-298.15*0.20581=-81.96 kJ/mol; 2006. Massachusetts Technology Inst. pH=7.36 Alberty [8] $G_{H2S_{aq}}=G_{S_{rombic}}+2G_{H3O+}-(\Delta G_{eqH2S_{aq}}+2G_{H2O})$=**53,3896** kJ/mol; $G_{H2S_{aq}}=\Delta G_{HessH2S}+(2G_{H(Pt)}+G_{S_{rombic}})$=**53,3866** kJ/mol; [1] $\Delta G_{HS-}=\Delta H_H-T*\Delta S_H$=-16,3-298,15*0,067=-36,276 kJ/mol; $G_{e-}=G_{HS-}-(G_{Sr}+0,5G_{H2}+\Delta G°_{HS-})$=**31,69** kJ/mol; pK_{a2}=19 $G_{HS-aq}=G_{S_{rombic}}+2G_{H2O}-(\Delta G_{eqHS-aq}+G_{OH})$=**90,5336** kJ/mol; favored $G_{HS-}=\Delta G_{eq}-G_{H3O+}+(G_{H2S}+G_{H2O})$=**81.138** kJ/mol; $G_{HS-}=G_{S2-}+G_{H3O+}-(\Delta G_{eq}+G_{H2O})$=**92.65** kJ/mol; $G_{S_{rombic}}=G_{H2S}^{gas}-(\Delta G_{Hess\_H2S}^{gas}+G_{H2})$=**3.5436** kJ/mol; favored $G_{S_{rombic}}=\Delta G_{eqH2S_{aq}}-2G_{H3O+}+(G_{H2S_{aq}}+2G_{H2O})$=**3.5436** kJ/mol; [1] $\Delta G_{HS-}=\Delta H_H-T*\Delta S_H$=33,1-298,15*-0,0146=-36,276 kJ/mol; $2G_{e-}=G_{S2-}-(G_{Sr}+\Delta G°_{S2-})$=**157,63-(3,5436**+85,8)= **2*34,1432** kJ/mol; $G_{S2-aq}=G_{S_{rombic}}+G_{H2O}-(\Delta G_{eqS2-aq})$=**157,63** kJ/mol;

Formation from elements $S_{rhombic}+H_2^{gas}=H_2S^{gas}$ G_{H2}^{gas}=**85.6** kJ/mol; shows energy content G_{H2S}^{gas}=**55,7436** kJ/mol; Energy content is $G_{H2S}^{gas}=\Delta G°_{H2S}^{gas}+(G_{S_{rombic}}+G_{H2})$=-33,4+(**3.5436**+**85.6**)=**55,7436** kJ/mol. [1,8]
Energy content is $G_{S_{rombic}}=G_{H2S}^{gas}-(\Delta G°_{H2S}^{gas}+G_{H2})$=**55,7436**-(-33.4+**85.6**)=**3.5436** kJ/mol. [1,8]
Formation $S_{rhombic}+0,5H_2^{gas}+e^-=HS^-$;

$\Delta G°_{HS-}=G_{HS-}-(G_{Sr}+0,5G_{H2}+G_{e-})$=**90,5336-(3,5436**+0,5***85,6**+G_{e-})=12,5 kJ/mol.
$G_{e-}=G_{HS-}-(G_{Sr}+0,5G_{H2}+\Delta G°_{HS-})$=**90,5336-(3,5436**+0,5***85,6**+12,5)=**31,69** kJ/mol.
$G_{HS-}=\Delta G°_{HS-}+(G_{Sr}+0,5G_{H2}+G_{e-})$=12,5+(**3,5436**+0,5***85,6**+**31,69**)=**90,5336** kJ/mol.

Formation $S_{rhombic}+2e^-=S^{2-}$; $\Delta G°_{S2-}=G_{S2-}-(G_{Sr}+2G_{e-})$=**157,63-(3,5436**+2$G_{e-}$)=85,8 kJ/mol.

$2G_{e-}=G_{S2-}-(G_{Sr}+\Delta G°_{S2-})$=**157,63-(3,5436**+85,8)=**2*34,1432** kJ/mol.
$G_{S2-}=\Delta G°_{S2-}+(G_{Sr}+2G_{e-})$=85,8+(**3,5436**+2***34,1432**)=**157,63** kJ/mol.

Solubility $H_2S^{gas}+H_2O=H_2S_{aq}$ 3.98 g/L 20° C [30] M_{H2S}=34.08 g/mol product $K_{sp}=[H_2S_{aq}]$=3.98/34.08=0.11678 M at equilibrium constant is $K_{eq}=K_{sp}/[H_2O]$=0.116784/1/55.3=0.0021118 with free energy change endoergonic

$\Delta G_{eq}=-R•T•\ln(K_{eq})$=-8.3144*298.15*ln(0.0021118)=$G_{H2S_{aq}}-(G_{H2S}^{gas}+G_{H2O})$=**15.27** kJ/mol.
$\Delta G_{eq}=G_{H2S_{aq}}-(G_{H2S}^{gas}+G_{H2O})$=**84,343-(69,073**+0)=**15,27** kJ/mol.

The free energy per mole of hydrogen sulfide is $G_{H2S}^{gas}=G_{H2S_{aq}}-(\Delta G_{eq}+G_{H2O})$ =**84,343-(15,27**+0)=**69,073** kJ/mol.
$S^{2-}=S_{rombic}+H_2O+2e^-$; Standard potential $E°_{classic}$=-0.4763 V [1], plus water account logarithm -0.0591/2*log($[H_2O]^1$)=-0.0515 and the coupled sum ΔE°=+0.10166-0.37239 expressed absolute potential has $E°_{S\downarrow/S2-}=E°_{classic}$-0.0591/2*log($[H_2O]^1$)+ΔE°=-0.4763-0.0515+0.10166-0.37239=**-0.79853**V;

$\Delta G_{eqS2-}=E°_{S2-}*F*n$=**-0,79853***96485*2=**-154,09** kJ/mol . $G_{S_{rombic}}$=**3.5436** kJ/mol;

$\Delta G_{eqS2-aq}=G_{S_{rombic}}+G_{H2O}+2G_{e-}-(G_{S2-aq})$=**3,5436**+0+2*0-(**157,6336**)=**-154,09** kJ/mol;
$2G_{e-}=\Delta G_{eqS2-aq}-G_{S_{rombic}}-G_{H2O}+(G_{S2-aq})$=**-154,09-3,5436**-0+(**157,6336**)=**0** kJ/mol;
$G_{S2-aq}=G_{S_{rombic}}+G_{H2O}+2G_{e-}-(\Delta G_{eqS2-aq})$=**3,5436+0+2*0-(-154,09)=157,63** kJ/mol;

$HS^-+OH^-=S_{rombic}+2H_2O+2e^-$; Standard potential $E°_{classic}$=-0.478 V [1], plus water account logarithm -0.0591/2*log($[H_2O]^2$)=-0.103 and the coupled sum ΔE°=+0.10166-0.37239 expressed absolute potential has

$E°_{S\downarrow/HS-}=E°_{classic}$-0.0591/2*log($[H_2O]^2$)+ΔE°=-0.478-0.103+0.10166-0.37239=**-0.8517** V;

$\Delta G_{eqHS-}=E_{HS-}*F*n$=**-0,8517***96485*2=**-164,35** kJ/mol;

$\Delta G_{eqHS-aq}=G_{S_{rombic}}+2G_{H2O}+2G_{e-}-(G_{HS-aq}+G_{OH})$=**3,5436**+2*0+2*0-(**90,5336+77,36**)=**-164,35** kJ/mol;
$G_{HS-aq}=G_{S_{rombic}}+2G_{H2O}+2G_{e-}-(\Delta G_{eqHS-aq}+G_{OH})$=**3,5436**+2*0+2*0-(**-164,35+77,36**)=**90,5336** kJ/mol;
$2G_{e-}=\Delta G_{eqHS-aq}-G_{S_{rombic}}-2G_{H2O}+(G_{HS-aq}+G_{OH})$=**-164,35-3,5436**-2*0+(**90,5336+77,36**)=**0** kJ/mol;

$H_2S_{aq}+2H_2O=S_{rombic}+2H_3O^++2e^-$; Standard potential $E°_{classic}$=0,142 V [1], plus water account logarithm -0,0591/2*log(1/$[H_2O]^2$)=0,103 and the coupled sum ΔE°=+0,10166-0,37239 expressed absolute potential has

$E°_{S\downarrow/H2S}=E°_{classic}$-0,0591/2*log(1/$[H_2O]^2$)+ΔE°=0,142+0,103+0,10166-0,37239=**-0,025735** V;

$\Delta G_{eqH2S}=E°_{H2S}*F*n$=**-0,025735***96485*2=**-4,966** kJ/mol ;

$\Delta G_{eqH2S_{aq}}=G_{S_{rombic}}+2G_{H3O+}+2G_{e-}-(G_{H2S_{aq}}+2G_{H2O})$=**3,5436**+2***22,44**+2*0-(**53,3896**+2*0)=**-4,966** kJ/mol;
$G_{S_{rombic}}=\Delta G_{eqH2S_{aq}}-2G_{H3O+}-2G_{e-}+(G_{H2S_{aq}}+2G_{H2O})$=**-4,966**-2***22,44**-2*0+(**53,3896**+2*0)=**3,5436** kJ/mol; favored

$G_{H2Saq}=G_{Srombic}+2G_{H3O+}+2G_{e-}-(\Delta G_{eqH2Saq}+2G_{H2O})=3,5436+2*22,44+2*0-(-4,966+2*0)=53,3896$ kJ/mol;
$2G_{e-}=\Delta G_{eqH2Saq}-G_{Srombic}-2G_{H3O+}+(G_{H2Saq}+2G_{H2O})=-4,966-3,5436-2*22,44+(53,3896+2*0)=2*0$ kJ/mol;
[1] $pK_{a1}=7,05$; $pK_{a2}=19$; $pK_{a1}=7,05$ $H_2S+H_2O=HS^-+H_3O^+$; $K_{eq1}=K_{a1}/[H_2O]=10^{\wedge(-7,05)}/55,3=10^{\wedge(-8,7927)}$;
$\Delta G_{eq}=-R\bullet T\bullet\ln(K_{eq})=-8,3144*298,15*\ln(10^{\wedge(-8,7927)})=G_{HS-}+G_{H3O}-(G_{H2S}+G_{H2O})=50,188$ kJ/mol;
$\Delta G_{eq}=G_{HS-}+G_{H3O}-(G_{H2S}+G_{H2O})=81,138+22,44-(53,3896+0)=50,188$ kJ/mol ;
$G_{HS-}=\Delta G_{eq}-G_{H3O}+(G_{H2S}+G_{H2O})=50,188-22,44+(53,3896+0)=81,138$ kJ/mol ;
$pK_{a2}=19$ $HS^-+H_2O=S^{2-}+H_3O^+$; $K_{eq1}=K_{a1}/[H_2O]=10^{\wedge(-19)}/55,3=10^{\wedge(-20,74)}$;
$\Delta G_{eq}=-R\bullet T\bullet\ln(K_{eq})=-8,3144*298,15*\ln(10^{\wedge(-20,74)})=G_{S2-}+G_{H3O}-(G_{HS-}+G_{H2O})=118,40$ kJ/mol;
$\Delta G_{eq}=G_{S2-}+G_{H3O}-(G_{HS-}+G_{H2O})=186,4936+22,44-(90,5336+0)=118,40$ kJ/mol ;
$G_{S2-}=\Delta G_{eq}-G_{H3O}+(G_{HS-}+G_{H2O})=118,40-22,44+(90,5336+0)=186,4936$ kJ/mol ;
$G_{HS-}=G_{S2-}+G_{H3O}-(\Delta G_{eq}+G_{H2O})=186,4936+22,44-(118,40+0)=90,5336$ kJ/mol ;
Sulfur reduction inverse potential: $S_{rombic}+2H_3O^++2e^-=H_2S_{aq}+2H_2O$; $-E°_S=0,025735$ V;
$\underline{2H(Pt)}+2H_2O=2H_3O^++2e^-$; $E°_H=-0,27073$ V; summary reaction $S_{rombic}+\underline{2H(Pt)}=H_2S_{aq}$;
$\Delta G_{eq}=(E°_H-E°_S)\bullet F\bullet n=(-0,27073+0,025735)*96485*2=-0,244995*96485*2=-47,277$ kJ/mol;
$\Delta G_{HessH2S}=G_{H2Saq}-(2G_{H(Pt)}+G_{Srombic})=53,3866-(2*48,56+3,5436)=-47,277$ kJ/mol .
$G_{H2Saq}=\Delta G_{HessH2S}+(2G_{H(Pt)}+G_{Srombic})=-47,277+(2*48,56+3,5436)=53,3866$ kJ/mol;
Alberty [8] and CRC [1] data: $G_{H2}^{gas}=85,6$ kJ/mol , $G_{H2Saq}=53,3866$ kJ/mol [8] and $\Delta G°_{H2O}=-237,191$ kJ/mol;
$\Delta G°_{H2S}^{gas}=-81,98$ kJ/mol [1] allow calculating free energy content $G_{Srombic}=3,5436$ kJ/mol; $G_{O2}^{gas}=303,1$ kJ/mol, etc. relative to the zero of water and carbon dioxide gas reference $G_{H2O}=G_{CO2}^{gas}=G_{e-}=0$ kJ/mol.
[1] $H_2SO_{4(l)}$ Formation from elements sulfuric acid liquid and sulfates: $S_{rombic}+2O_2^{gas}+H_2^{gas}=H_2SO_{4(l)}$;
$\Delta G°_{H2SO4Form}=G_{H2SO4(l)}-(G_{Srombic}+2G_{O2}+G_{H2}^{gas})=-690,0$ kJ/mol; [1] Content per mol of $H_2SO_{4(l)}$ is
$G_{H2SO4(l)}=\Delta G°_{H2SO4Form}+(G_{Srombic}+2G_{O2}+G_{H2}^{gas})=-690,0+(3,5436+2*303,1+85,6)=5,3436$ kJ/mol;
[1] Formation SO_3 from free elements $S_{rombic}+1,5O_2^{gas}=SO_3$: $\Delta G°_{SO3Form}=G_{SO3}-(3,5436+1,5*303,1)=-373,8$ kJ/mol;
$G_{SO3}=\Delta G°_{SO3Form}+(G_{Srombic}+1,5G_{O2})=-373,8+(3,5436+1,5*303,1)=84,3936$ kJ/mol;
The formation of 100% sulfuric acid when oleum dissolves in water is exoergonic $SO_3+H_2O=H_2SO_{4(l)}$:
$\Delta G°_{SO3+H2O}=G_{H2SO4(l)}-(G_{SO3}+G_{H2O})=5,1436-(84,2436+0)=-79,1$ kJ/mol;
[1] The protolysis $pK_{a1}=-2,8$ equilibrium $H_2SO_4+H_2O=HSO_4^-+H_3O^+$ in mol fractions is calculated by dividing the acid $K_{eq1}=K_{a1}/[H_2O]=10^{\wedge(2,8)}/55,3=11,41$ constant K_{a1} by water $[H_2O]=55,3$ M. Prigogine attractor and Hess expression are equal exoergonic: $\Delta G_{eqH2SO4}=-R\bullet T\bullet\ln(K_{eq})=-8,3144*298,15*\ln(11,409717)=-6,0349$ kJ/mol
G_{H3O} is $\Delta G_{eqH2SO4}=G_{HSO4-}+G_{H3O}-(G_{H2SO4}+G_{H2O})=27,5835+22,44-(56,0586+0)=-6,0349$ kJ/mol
$G_{HSO4-}=\Delta G_{eqH2SO4}-G_{H3O}+(G_{H2SO4}+G_{H2O})=-6,0349-22,44+(56,0585+0)=27,5835$ kJ/mol; content H_2SO_4 obtained
$G_{H2SO4}=G_{HSO4-}+G_{H3O}-(\Delta G_{eqH2SO4}+G_{H2O})=27,5835+22,44-(-6,035+0)=56,0585$ kJ/mol;
Protolysis $HSO_4^-+H_2O=SO_4^{2-}+H_3O^+$ $pK_{a2}=1,99$
$K_{eq2}=K_{a2}/[H_2O]=10^{\wedge(-1,99)}/55,3=0,0001850$ energy change has
$\Delta G_{eqHSO4}=-R\bullet T\bullet\ln(K_{eq2})=-8,3144*298,15*\ln(0,000185)=G_{SO42-}+G_{H3O}-(G_{HSO4-}+G_{H2O})=21,3069$ kJ/mol. Hess expression $\Delta G_{eqHSO4}=G_{SO42-}+G_{H3O}-(G_{HSO4-}+G_{H2O})=26,4509+22,44-(27,584+0)=21,3064$ kJ/mol free energy of
$G_{HSO4-}=G_{SO42-}+G_{H3O}-(\Delta G_{eqHSO4}+G_{H2O})=26,4509+22,44-(21,3069+0)=27,584$kJ/mol and
SO_4^{2-} anion mol is $G_{SO42-}=\Delta G_{eqHSO4}-G_{H3O}+(G_{HSO4-}+G_{H2O})=21,3069-22,44+(27,584+0)=26,4509$ kJ/mol;
[1] HSO_4^- Formation $S_{rombic}+2O_2^{gas}+0,5H_2^{gas}+e-=HSO_4^-$; $G_{e-}=161,206$ kJ/mol; $G_{HSO4}=27,5835$ kJ/mol; $pK_{a2}=1,99$;
$\Delta G°_{HSO4}=G_{HSO4}-(G_{Srombic}+2G_{O2}+0,5G_{H2}^{gas}+G_{e-})=27,5835-(3,5436+2*303,1+0,5*85,6+161,206)=-744,5$ kJ/mol;
$G_{HSO4}=\Delta G°_{HSO4}+(G_{Srombisks}+2G_{O2}+0,5G_{H2}^{gas}+G_{e-})=-744,5+(3,5436+2*303,1+0,5*85,6+161,206)=27,5835$ kJ/mol;
$G_{e-}=G_{HSO4}-(G_{Srombic}+2G_{O2}+0,5G_{H2}^{gas}+\Delta G°_{HSO4})=27,5837-(3,5436+2*303,1+0,5*85,6-744,5)=119,54$ kJ/mol;
[1] SO_4^{2-} Formation $S_{rombic}+2O_2^{gas}+2*e-=SO_4^{2-}$;
$\Delta G°_{SO42}=G_{SO42}-(G_{Srombic}+2G_{O2}+2G_{e-})=26,44977-(3,5436+2*303,1+2*80,603)=-744,5$ kJ/mol;
$2G_{e-}=G_{SO42}-(G_{Srombic}+2G_{O2}+\Delta G°_{SO42})=26,44977-(3,5436+2*303,1-744,5)=161,20617=2*80,603$ kJ/mol;
[8] SO_4^{2-} Formation $S_{rombic}+2O_2^{gas}+2*e-=SO_4^{2-}$;
$\Delta G°_{SO42}=G_{SO42}-(G_{Srombic}+2G_{O2}+2G_{e-})=26,44977-(3,5436+2*303,1+2*80,603)=-747,75$ kJ/mol;
$2G_{e-}=G_{SO42}-(G_{Srombic}+2G_{O2}+\Delta G°_{SO42})=26,44977-(3,5436+2*303,1-747,75)=164,456=2*82,228$ kJ/mol;
https://en.wikipedia.org/wiki/Sulfur_dioxide
Solubility constants in mol fractions $K_{eq}=K_{sp}/[H_2O]$ calculates dividing saturate product with water $[H_2O]$.
Saturated dissolute 94 g/L SO_2 M=64,066 g/mol $[SO_2]=94/64,066=1,46724$ M sulfurous $M_{H2SO3}=82,075$ g/mol acid density **1,05** g/mL mas $m_{solution}=1050$ g/L and $m_{H2O}=1050-120,4327=929,5673$ g; $n_{H2O}=929,5673/18=51,64$ M give water concentration. Mas of acid $m_{H2SO3}=[SO_2]*M_{H2SO3}=1,46724$ M*82,075 g/mol$=120,4237$ g/L. Free energy change in: $SO_2^{gas}+H_2O=H_2SO_{3aq}$ for constant $K_{sp}=[H_2SO_3]/[SO_2^{gas}]/[H_2O]=1,46724/1/51,64=0,02841286$ is
$\Delta G_{eqH2SO3}=-R\bullet T\bullet\ln(K_{eq})=-8,3144*298,15*\ln(0,02841286)=G_{H2SO3}-(G_{SO2}^{gas}+G_{H2O})=8,827285$ kJ/mol

free energy change $\Delta G_{eqH2SO3}=G_{H2SO3}-(G_{SO2}^{gas}+G_{H2O})=$**101,54764-(7,44883+0)=8,827285** $^{kJ}/_{mol}$.

$G_{SO2}^{gas}=G_{H2SO3}-(\Delta G_{eqH2SO3}+G_{H2O})=$**101,54764-(8,827285+0)=7,44883** $^{kJ}/_{mol}$; 2=<pH<7 [17]

Formation from free elements $S_{rombic}+O_2^{gas}=SO_2^{gas}$: $\Delta G°_{SO2Form}=G_{SO2}^{gas}-$**(3,5436+303,1)**=-300,1 $^{kJ}/_{mol}$;

$G_{SO2}^{gas}=\Delta G°_{SO2Form}+(G_{Srombic}+G_{O2})=$**-300,1+(3,5436+303,1)=6,5436** $^{kJ}/_{mol}$;

Sulfurous acid formation from elements $S_{rombic}+1{,}5O_2^{gas}+H_2^{gas}=H_2SO_{3aq}$ and solubility $SO_2^{gas}+H_2O=H_2SO_{3aq}$.

Substance	$\Delta H°_H$, $^{kJ}/_{mol}$	$\Delta S°_H$, $^{J}/_{mol/K}$	$\Delta G°_H$, $^{kJ}/_{mol}$
H_2O	-285,85	69,9565	-237,191
H_2O	**-286,65**	**-453,188**	**-151,549**
SO_3	-441,0	113,8	-373,8
SO_3	formation liq uid -373,8		**84,3936**
H_2SO_4	-814,0	156,9	-690,0
H_2SO_4	formation	liquid -690	**5,3436**
H_2SO_4	pK_{a1}=-2,8	protolysis	**56,0585**
HSO_4^-	-909,3	20,1	-744,5
HSO_4G_{e-}	formation	-744,5	**119,54**
HSO_4^-	pK_{a2}=1,99	protolysis	**27,584**
$SO_4^{2-}G_{e-}$	formation	-744,5	**80,603**
SO_4^{2-}	**-907,62**	**-536,2**	**-747,77**
$SO_4^{2-}G_{e-}$	formation[8]	**-747,75**	**82,228**
SO_4^{2-}	pK_{a2}=1,99	protolysis	**26,4509**
SO_4^{2-}	$E°_{HSO3-}$=	**0,10726**	**26,44996**
SO_4^{2-}	$E°_{SO32-}$=	**0,05576**	**26,44996**
SO_4^{2-}	$E°_{SO32-}$=	**-1,2522**	**54,9256**
SO_2^{gas}	−296,81	248,223	-300,1
SO_2^{gas}	formation	-300,1	**6,5436**
SO_2^{gas}	K_{sp}=0,02841	2<pH<7	**7,44883**
H_2SO_3	formation [8]	**-509,736**	**34,0575**
H_2SO_3	pK_{a1}=1,857		**34,0575**
HSO_3^-	-626,2	139,7	-527,7
HSO_3^-	G_{e-} formation	-527,7	**128,2536**
HSO_3^-	pK_{a2}=7,172		**32,125**
HSO_3^-	$E°_{HSO3-}$=	**0,10726**	**73,072**
SO_3^{2-}	$E°_{SO32-}$=	**0,05576**	**60,56996**
SO_3^{2-}	-635,5	-29	-486,5
SO_3^{2-}	G_{e-}formation	-486,5	**38,242**
SO_3^{2-}	pK_{a2}=7,172		**43,0036**
SO_3^{2-}	$E°_{SO32-OH}$=	**-1,25223**	**141,8484**

Biochemistry water has standard free energy $G_{H2O}=$**85,6** $^{kJ}/_{mol}$ [8]

$G_{H2O}=\Delta G_{H2OAlberty}-(\Delta G°_{H2O})=$**-151,549**-(-237,191)=**85,6** $^{kJ}/_{mol}$.

$\Delta G_H=\Delta H_H-T*\Delta S_H=$**-286,65**-298,15*-**0,453188**=**-151,549** $^{kJ}/_{mol}$;

[1] $\Delta G_H=\Delta H_H-T*\Delta S_H$=-441-298,15*0,1138=-474,92947 $^{kJ}/_{mol}$;

$G_{SO3}=\Delta G°_{SO3Form}+(G_{Srombic}+$**1,5**$G_{O2})=$**84,3936** $^{kJ}/_{mol}$;

[1] $\Delta G_H=\Delta H_H-T*\Delta S_H$=-814,0-298,15*0,1569=-860,78 $^{kJ}/_{mol}$;

$G_{H2SO4}=\Delta G°_{H2SO4}+G_{Srombic}+2\Delta G_{O2}+G_{H2}^{gas}+G_{H2O}=$**5,3436** $^{kJ}/_{mol}$;

$G_{H2SO4}=G_{HSO4-}+G_{H3O}-(\Delta G_{eqH2SO4}+G_{H2O})=$**56,0585** $^{kJ}/_{mol}$;

[1] $\Delta G=\Delta H-T*\Delta S$=-909,3-298,15*0,0201=-915,293 kJ/mol;

$G_{e-}=G_{HSO4}-(G_{Srombic}+2G_{O2}+0{,}5G_{H2}^{gas}+\Delta G°_{HSO4})=$**119,54** $^{kJ}/_{mol}$;

$G_{HSO4-}=\Delta G_{eqH2SO4}-G_{H3O}+(G_{H2SO4}+G_{H2O})=$**27,584** $^{kJ}/_{mol}$;

[1] $2G_{e-}=G_{SO42-}-(G_{Srombic}+2G_{O2}+\Delta G°_{SO42})=$**161,2062=2*80,60** $^{kJ}/_{mol}$;

[8] $\Delta G_{SO42-}=\Delta H-T*\Delta S=$**-907,62**-298,15*-**0,5362**=**-747,75** $^{kJ}/_{mol}$;

[8] $2G_{e-}=G_{SO42-}-(G_{Srombic}+2G_{O2}+\Delta G°_{SO42})=$**164,456=2*82,228** $^{kJ}/_{mol}$;

$G_{SO42-}=\Delta G_{eqHSO4}-G_{H3O}+(G_{HSO4-}+G_{H2O})=$**26,4509** $^{kJ}/_{mol}$; 2=<pH<7

$G_{SO42-}=\Delta G_{eqHSO42-}-3G_{H3O}+(G_{HSO3}+4G_{H2O})=$**26,44996** $^{kJ}/_{mol}$;

$G_{SO42-}=\Delta G_{eqSO32-}-2G_{H3O}+(G_{SO32-}+3G_{H2O})=$**26,44996** $^{kJ}/_{mol}$;

$G_{SO42-}=\Delta G_{eqSO32-OH}-G_{H2O}+(G_{SO32-}+2G_{OH})=$**54,9256** $^{kJ}/_{mol}$;

[1] $\Delta G_H=\Delta H_H-T*\Delta S_H$=-296,81-298,15*0,248223=-370,82 $^{kJ}/_{mol}$;

$G_{SO2}=\Delta G°_{SO2Form}+(G_{Srombic}+G_{O2})=$**6,5436** $^{kJ}/_{mol}$;

$G_{SO2}^{gas}=G_{H2SO3}-(\Delta G_{eqH2SO3}+G_{H2O})=$**7,44883** $^{kJ}/_{mol}$;

$G_{H2SO3}=\Delta G°_{H2SO3}+(G_{Srombic}+1{,}5DG_{O2}+G_{H2gas})=$**34,0575** $^{kJ}/_{mol}$;

$G_{H2SO3}=G_{HSO3-}+G_{H3O}-(\Delta G_{eqH2SO3}+G_{H2O})=$**34,0575** $^{kJ}/_{mol}$; pH=1,85

[1] $\Delta G_H=\Delta H_H-T*\Delta S_H$=-626,2-298,15*0,1397=-667,85 $^{kJ}/_{mol}$;

$G_{e-}=G_{HSO3-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+\Delta G°_{HSO3})=$**128,2536** $^{kJ}/_{mol}$;

$G_{HSO3-}=G_{SO32-}+G_{H3O}-(\Delta G_{eqHSO3}+G_{H2O})=$**32,125** $^{kJ}/_{mol}$;

$G_{HSO3}=G_{SO42-}+3G_{H3O}-(\Delta G_{eqHSO4-}+4G_{H2O})=$**73,072** $^{kJ}/_{mol}$;

$G_{SO32-}=G_{SO42-}+2G_{H3O}-(\Delta G_{eqSO32-}+3G_{H2O})=$**60,56996** $^{kJ}/_{mol}$;

[1] $\Delta G_H=\Delta H_H-T*\Delta S_H$=-635,5-298,15*-0,029=-626,85 $^{kJ}/_{mol}$;

$2G_{e-}=G_{SO32-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+\Delta G°_{SO32})=$**76,484=2*38,24** $^{kJ}/_{mol}$;

$G_{SO32-}=\Delta G_{eqHSO3}+G_{H3O}-(G_{HSO3-}+G_{H2O})=$**43,0036** $^{kJ}/_{mol}$; pH=7,172;

$G_{SO32-}=G_{SO42-}+G_{H2O}-(\Delta G_{eqSO32-OH}+2G_{OH})=$**141.8484** $^{kJ}/_{mol}$; pH>7

https://en.wikipedia.org/wiki/Sulfurous_acid

[1] At equilibrium in mol fractions $K_{eq}=K_a/[H_2O]$ dividing the acid constant by water $[H_2O]$=55,3 M.

Free energy change of protolysis $H_2SO_3+H_2O=HSO_3^-+H_3O^+$; equilibrium

pK_{a1}=1,857; $K_{eq1}=K_{a1}/[H_2O]=10^{\wedge(-1{,}857)}/55{,}3=10^{\wedge(-3{,}5997251)}$ is

$\Delta G_{eqH2SO3}=-R•T•\ln(K_{eq1})=-8{,}3144*298{,}15*\ln(10^{\wedge(-3{,}5997251)})=$**20,5075** $^{kJ}/_{mol}$.

$\Delta G_{eqH2SO3}=G_{HSO3-}+G_{H3O}-(G_{H2SO3}+G_{H2O})=$**32,125+22,44-(34,0575+0)=20,5075** $^{kJ}/_{mol}$.

$G_{H2SO3}=G_{HSO3-}+G_{H3O}-(\Delta G_{eqH2SO3}+G_{H2O})=$ **32,125+22,44-(20,5075+0)=34,0575** $^{kJ}/_{mol}$; pH=1,857

Formation [8] $\Delta G°_{H2SO3}=G_{H2SO3}-(G_{Srombic}+1{,}5DG_{O2}+G_{H2gas})=$**34,0575-(3,5436**+1,5***303,1+85,6)= -509,736** $^{kJ}/_{mol}$;

$G_{H2SO3}=\Delta G°_{H2SO3}+(G_{Srombic}+1{,}5DG_{O2}+G_{H2gas})=$**-509,736+(3,5436**+1,5***303,1+85,6)=34,0576** $^{kJ}/_{mol}$;

[1] Protolysis $HSO_3^-+H_2O=SO_3^{2-}+H_3O^+$; pK_{a2}=7,172; $K_{eq2}=K_{a2}/[H_2O]=10^{\wedge(-7{,}172)}/55{,}3=10^{\wedge(-8{,}9147)}$;

$\Delta G_{eqHSO3}=-R•T•\ln(K_{eq2})$=-8; 3144*298,15*$\ln(10^{\wedge(-8{,}9147)})=$**50,8848** $^{kJ}/_{mol}$;

$\Delta G_{eqHSO3}=G_{SO32-}+G_{H3O}-(G_{HSO3-}+G_{H2O})=$**60,56996+22,44-(32,125+0)=50,8848** $^{kJ}/_{mol}$;

$G_{SO32-}=\Delta G_{eqHSO3}+G_{H3O}-(G_{HSO3-}+G_{H2O})=$**50,8848-22,44+(32,125+0)=60,56996** $^{kJ}/_{mol}$;

$G_{HSO3-}=G_{SO32-}+G_{H3O}-(\Delta G_{eqHSO3}+G_{H2O})=$**60,56996+22,44-(50,8848+0)=32,125** $^{kJ}/_{mol}$;

Formation $HSO_3^-=S_{romb}+1{,}5O_2+H_2^{gas}/2+e^-$;[1] $SO_4^{2-}=S_{romb}+1{,}5O_2+H_2^{gas}/2+2e^-$; [1,8]

Formation $\Delta G°_{HSO3}=G_{HSO3-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+G_{e-})=$**101,54764-(3,544** +1,5***303,1+85,6**/2+G_{e-})=-527,7 $^{kJ}/_{mol}$;

$G_{e-}=G_{HSO3-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+\Delta G°_{HSO3})=$**101,54764-(3,544** +1,5***303,1+85,6**/2-527,7)=**128,2536** $^{kJ}/_{mol}$;

Formation $\Delta G°_{SO32}=G_{SO32-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+2G_{e-})=$**90,9781-(3,544** +1,5***303,1+85,6**/2+2G_{e-})=-486,5 $^{kJ}/_{mol}$;

$2G_{e^-}=G_{SO32^-}-(G_{Srom}+1{,}5\Delta G_{O2}+G_{H2}^{gas}/2+\Delta G°_{SO32})=\mathbf{90{,}9781}-(\mathbf{3{,}544}+1{,}5*\mathbf{303{,}1}+\mathbf{85{,}6}/2-486{,}5)=\mathbf{76{,}484}=2*\mathbf{38{,}242}$ $^{kJ}/_{mol}$;

$2<pH<7$ $HSO_3^- + 4H_2O = SO_4^{2-} + 3H_3O^+ + \mathbf{2e}^-$; Classic standard potential $E°_{classic}=0.172$ V [1], plus water account $-0.0591/2*\log(1/[H_2O]^4)=0.206$ and common sum $\Delta E°=+0.10166-0.37239$ absolute potential has

$E°_{HSO3^-}=E°-0{,}0591/2*\log(1/[H_2O]^4)+\Delta E°=0{,}172-0{,}0591/2*\log(1/55{,}3\text{^}4)+0{,}10166-0{,}37239=\mathbf{0{,}10726}$ V;

$$2<pH<7{,}172\ E_{HSO3^-}=E°_{HSO3^-}+0{,}0591/2*\log\frac{[SO_4^{2-}]\cdot[H_3O^+]^3}{[HSO_3^-]\cdot[H_2O]^4}=\mathbf{0{,}10726}\ \text{V}+0{,}0591/2*\log\frac{[SO_4^{2-}]\cdot[H_3O^+]^3}{[HSO_3^-]\cdot[H_2O]^4}$$

$\Delta\mathbf{G}_{\mathbf{eq}HSO3^-}=E°_{HSO4^-}\bullet F\bullet n=\mathbf{0{,}10726}*96485*2=\mathbf{20{,}69796}$ $^{kJ}/_{mol}$,

$\Delta\mathbf{G}_{\mathbf{eq}HSO3^-}=G_{SO42^-}+3\mathbf{G}_{\mathbf{H3O}}+2G_{e^-}-(G_{HSO3^-}+4\mathbf{G}_{\mathbf{H2O}})=\mathbf{26{,}44996}+3*22{,}44+2*\mathbf{0}-(\mathbf{73{,}072}+4*0)=\mathbf{20{,}69797}$ $^{kJ}/_{mol}$;

$G_{HSO3^-}=G_{SO42^-}+3\mathbf{G}_{\mathbf{H3O}}+2G_{e^-}-(\Delta\mathbf{G}_{\mathbf{eq}HSO4^-}+4\mathbf{G}_{\mathbf{H2O}})=\mathbf{26{,}44996}+3*22{,}44+2*\mathbf{0}-(\mathbf{20{,}69796}+4*0)=\mathbf{73{,}072}$ $^{kJ}/_{mol}$;

$G_{SO42^-}=\Delta\mathbf{G}_{\mathbf{eq}HSO42^-}-3\mathbf{G}_{\mathbf{H3O}}-2G_{e^-}+(G_{HSO3^-}+4\mathbf{G}_{\mathbf{H2O}})=\mathbf{20{,}69796}-3*22{,}44-2*\mathbf{0}+(\mathbf{73{,}072}+4*0)=\mathbf{26{,}44996}$ $^{kJ}/_{mol}$;

$2G_{e^-}=\Delta\mathbf{G}_{\mathbf{eq}HSO42^-}-3\mathbf{G}_{\mathbf{H3O}}-G_{SO42^-}+(G_{HSO3^-}+4\mathbf{G}_{\mathbf{H2O}})=\mathbf{20{,}69796}-3*22{,}44-\mathbf{26{,}44996}+(\mathbf{73{,}072}+4*0)=2*\mathbf{0}$ $^{kJ}/_{mol}$;

$HSO_3^- + 4H_2O = SO_4^{2-} + 3H_3O^+ + \mathbf{2e}^-$; $SO_3^{2-} + 3H_2O = SO_4^{2-} + 2H_3O^+ + \mathbf{2e}^-$;

$pH>7{,}172$ $SO_3^{2-} + 3H_2O = SO_4^{2-} + 2H_3O^+ + \mathbf{2e}^-$; Classic standard potential $E°_{classic}=0{,}172$ V [1] , plus water account $-0.0591/2*\log(1/[H_2O]^3)=0.15449$ and common sum $\Delta E°=+0.10166-0.37239$ absolute standard potential is

$E°_{H2SO3}=E°_{Classic}-0{,}0591/2*\log(1/[H_2O]^3)+\Delta E°=0{,}172-0{,}0591/2*\log(1/55{,}3\text{^}3)+0{,}10166-0{,}37239=\mathbf{0{,}055763}$ V;

$$pH>7{,}172\ E_{HSO3^-}=E°_{HSO3^-}+0{,}0591/2\bullet\log\frac{[SO_4^{2-}]\cdot[H_3O^+]^2}{[SO_3^{2-}]\cdot[H_2O]^3}=\mathbf{0{,}055763}\ \text{V}+0{,}0591/2\bullet\log\frac{[SO_4^{2-}]\cdot[H_3O^+]^2}{[SO_3^{2-}]\cdot[H_2O]^3}$$

$\Delta\mathbf{G}_{\mathbf{eq}HSO3^-}=E°_{HSO3^-}\bullet F\bullet n=\mathbf{0{,}055763}*96485*2=\mathbf{10{,}7600}$ $^{kJ}/_{mol}$;

$\Delta\mathbf{G}_{\mathbf{eq}SO32^-}=G_{SO42^-}+2\mathbf{G}_{\mathbf{H3O}}+2G_{e^-}-(G_{SO32^-}+3\mathbf{G}_{\mathbf{H2O}})=\mathbf{26{,}44996}+2*22{,}44+2*\mathbf{0}-(\mathbf{60{,}56996}+3*0)=\mathbf{10{,}7600}$ $^{kJ}/_{mol}$;

$G_{SO42^-}=\Delta\mathbf{G}_{\mathbf{eq}SO32^-}-2\mathbf{G}_{\mathbf{H3O}}-2G_{e^-}+(G_{SO32^-}+3\mathbf{G}_{\mathbf{H2O}})=\mathbf{10{,}7600}-2*22{,}44-2*\mathbf{0}+(\mathbf{60{,}56996}+3*0)=\mathbf{26{,}44996}$ $^{kJ}/_{mol}$;

$G_{SO32^-}=G_{SO42^-}+2\mathbf{G}_{\mathbf{H3O}}+2G_{e^-}-(\Delta\mathbf{G}_{\mathbf{eq}SO32^-}+3\mathbf{G}_{\mathbf{H2O}})=\mathbf{26{,}44996}+2*22{,}44+2*\mathbf{0}-(\mathbf{10{,}7600}+3*0)=\mathbf{60{,}56996}$ $^{kJ}/_{mol}$;

$2G_{e^-}=\Delta\mathbf{G}_{\mathbf{eq}SO32^-}-2\mathbf{G}_{\mathbf{H3O}}-G_{SO42^-}+(G_{SO32^-}+3\mathbf{G}_{\mathbf{H2O}})=\mathbf{10{,}7600}-2*22{,}44-\mathbf{26{,}44996}+(\mathbf{60{,}56996}+3*0)=2*\mathbf{0}$ $^{kJ}/_{mol}$;

Formation $S_{romb}+2O_2^{gas}+2e^-=SO_4^{2-}$;

$\Delta\mathbf{G}_{SO42^-}=G_{SO42^-}-(\mathbf{G}_{Sromb}+\mathbf{G}_{O2}^{gas}+2*G_{e^-})=\mathbf{26{,}44996}-(\mathbf{3{,}5436}+2*\mathbf{303{,}1}+2*\mathbf{94{,}841})=-744{,}5$ $^{kJ}/_{mol}$;

$2*G_{e^-}=G_{SO42^-}-(\mathbf{G}_{Sromb}+2*\mathbf{G}_{O2}^{gas}+\Delta\mathbf{G}_{SO42^-})=\mathbf{26{,}44996}-(\mathbf{3{,}5436}+2*\mathbf{303{,}1}-744{,}5)=\mathbf{161{,}20636}=2*\mathbf{80{,}60318}$ $^{kJ}/_{mol}$;

$SO_3^{2-} + 2OH^- = SO_4^{2-} + H_2O + 2e^-$; $pH>7$; - Standard potential $E°_{classic}=-0.93$ V [1], plus water account logarithm $-0.0591/2*\log([H_2O])=0.0515$ and the coupled sum $\Delta E°=+0.10166-0.37239$ expressed absolute potential has

$E°_{SO32-OH}=E°_{classic}-0{,}0591/2*\lg([H_2O])+\Delta E°=-0{,}93-0{,}0591/2*\log(55{,}3)+0{,}10166-0{,}37239=\mathbf{-1{,}25223}$ V;

$$E_{SO32-OH}=E°_{SO32-OH}+\frac{0.0591}{2}\bullet\log\frac{[SO_4^{2-}]\cdot[H_2O]}{[SO_3^{2-}]\cdot[OH^-]^2}=\mathbf{-1{,}252}\ \text{V}+\frac{0.0591}{2}\bullet\log\frac{[SO_4^{2-}]\cdot[H_2O]}{[SO_3^{2-}]\cdot[OH^-]^2}$$

$\Delta\mathbf{G}_{\mathbf{eq}SO42-OH}=E°_{SO32-OH}\bullet F\bullet n=\mathbf{-1{,}25223}*96485*2=\mathbf{-241{,}6428}$ $^{kJ}/_{mol}$;

$\Delta\mathbf{G}_{\mathbf{eq}SO32-OH}=G_{SO42^-}+\mathbf{G}_{\mathbf{H2O}}+2G_{e^-}-(G_{SO32^-}+2\mathbf{G}_{\mathbf{OH}})=\mathbf{54{,}9256}+\mathbf{0}+2*\mathbf{0}-(\mathbf{141{,}8484}+2*77{,}36)=\mathbf{-241{,}6428}$ $^{kJ}/_{mol}$;

$G_{SO32^-}=G_{SO42^-}+\mathbf{G}_{\mathbf{H2O}}+2G_{e^-}-(\Delta\mathbf{G}_{\mathbf{eq}SO32-OH}+2\mathbf{G}_{\mathbf{OH}})=\mathbf{54{,}9256}+\mathbf{0}+2*\mathbf{0}-(\mathbf{-241{,}6428}+2*77{,}36)=\mathbf{141{,}8484}$ $^{kJ}/_{mol}$;

$G_{SO42^-}=\Delta\mathbf{G}_{\mathbf{eq}SO32-OH}-\mathbf{G}_{\mathbf{H2O}}-2G_{e^-}+(G_{SO32^-}+2\mathbf{G}_{\mathbf{OH}})=\mathbf{-241{,}6428}-\mathbf{0}-2*\mathbf{0}+(\mathbf{141{,}8484}+2*77{,}36)=\mathbf{54{,}9256}$ $^{kJ}/_{mol}$;

$2G_{e^-}=\Delta\mathbf{G}_{\mathbf{eq}SO32-OH}-\mathbf{G}_{\mathbf{H2O}}-G_{SO42^-}+(G_{SO32^-}+2\mathbf{G}_{\mathbf{OH}})=\mathbf{-241{,}6428}-\mathbf{0}-\mathbf{54{,}9256}+(\mathbf{141{,}8484}+2*77{,}36)=\mathbf{2}*0$ $^{kJ}/_{mol}$;

References.

1. W.M.Haynes. Handbook of Chemistry and Physics .97th ed. CRC Press Taylor and Francis Group; 2017 2643.
2. Prigogine I, Defey R. Chemical Thermodynamics. Longmans Green & co ©; 1954.
3. Prigogine I, Nicolis G. Self-Organization in Non-Equilibrium Systems. Wiley, 1977.
4. Prigogine I. Time, Structure and Fluctuations. Lecture, The Nobel Praise in Chemistry; 1977.
5. Kuman M. New light on the attractors creating order out of the chaos. *Int J Complement Alt Med.* **11**(6), 337, (2018) ;
6. Nelson DL, Cox MM. Lehninger Principles of Biochemistry. 5th ed. New York: W.H. Freman and company; 2008.
7. Xing W, Yin G, Zhang J. Rotating Electrode Method and Oxygen Reduction Electrocatalysts. *Elsevier*; 6 (2014).
8. Alberty RA. Biochemical Thermodynamic's : Applications of Mathematics. John Wiley & Sons, Inc. 1-463, (2006).
9. Pinard MA, Mahon B, McKenna R. Probing the Surface of Human Carbonic Anhydrase for Clues towards the Design of Isoform Specific Inhibitors. *BioMed Research International*; **2015**, 3 (2015).
11. Balodis J. PRACTICAL WORKS IN PHYSICAL CHEMISTRY PART II. Izdevniecība «Zvaigzne», Rīga, 1975, p.149. Latvian.
14. Kaksis A. The Biosphere Self-Organization Attractors drive perfect order homeostasis reactions to link bioenergetic with functionally activate oxygen and carbon dioxide molecules. 7th International Conference on New Trends in Chemistry September 25-26, 2021.
15. Kaksis A. HIGH RATE PROTOLYSIS ATTRACTORS ACTIVATE energy over zero GH2O=GCO2gas=0 kJ/mol of water and carbon dioxide. FREE ENERGY CONTENT as BIOSPHERE Self-ORGANIZATION creates PERFECT ORDER IRREVERSIBLE HOMEOSTASIS PROGRESS. 9th International Conference, MAY 2023, p.14-19.
16. Loach, P.A. (I 976) In Handbook of Biochemistry and Molecular Biology, 3rd edn (Fasman, G.D. ed.), Physical and Chemical Data, Vol. 1, pp. 122-130 e, CRC Press, Boca Raton, FL
17. A.M. Suchotina, Handbook of Electro-Chemistry, Petersburg ,1981."Chimia"© Russian
18. S.Kortly and L.Shucha. Handbook of chemical equilibria in analytical chemistry. 1985.EllisHorwood Ltd.©
19. University Alberta Data Tables Molar Thermodynamic Properties of Pure Substances 1997. http://www.vhem.ualberta.ca/
20. Boca Raton, FL. Free **FAD** bound to a specific flavo-protein (for example succinate dehydrogenase) a different **E°**
21. David A. Harris, "Bio-energetic at a Glance". **b** Blackwell Science Ltd ©, 1995, p.116.
22. Daniel C. Harris, "Quantitative chemical analysis". W.H.Freeman and Company New York ©, 7th ed.2007, p828
23. E. Newton Harvey, "The oxidation-reduction potential of the Luciferin-Oxyluciferin system". JGP.1927, p385
24. https://en.wikipedia.org/wiki/Atomic_radii_of_the_elements_(data_page)#Atomic_radius
25. Kaksis A, The discovery of Hydrogen electrode reference E Ꜧ= -0.2965 Volts in absolute potential scale synchronizes the sciences with absolute free energy scale. 10th International Conference on New Trends in Chemistry 19-21 April, 2024.p.25. BOOK OF ABSTRACTS.
26. K.P. Mishchenko, Thermodynamics of Electrolyte Solutins, MTP International Review of Sciences – Volume 10, Thermochemistry and Thermodynamics, (Butterworths, London, 1972)
27. https://en.wikipedia.org/wiki/Carbon_dioxide
28. https://en.wikipedia.org/wiki/Ammonia_solution
29. https://en.wikipedia.org/wiki/Oxalic_acid
30. https://en.wikipedia.org/wiki/Hydrogen_sulfide
31. David G. Wahman, Matthew D. Pinelli, Michael R. Schock, Darren A. Lytle, Theoretical equilibrium lead(II) solubility revisited: Open source code and practical relationships, AWWA Water Sci. 2021 October 26; 3(5): . doi:10.1002/aws2.1250.
32. Thuy Nguyen Thanh Tran, Susi Jin, Marine Cuisinier, Brian D Adams, Douglas G Ivey, Reaction mechanisms for electrolytic manganese dioxide in rechargeable aqueous zinc-ion batteries, Department of Chemical and Materials Engineering, University of Alberta, Edmonton, AB T6G 1H9 Canada, Salient Energy Inc., Dartmouth, NS B3B 1C4 Canada, Scientific Reports, 2021 Oct 21;11:20777. p. 3. email: tthuy@ualberta.ca
33. University of Rode Island K_a, K_{sp}, K_f,, Thermodynamic **Δ H S** G, $E°_{Classic}$, equations.
34. D.D. Wagman, W.H. Evans, V.B. Parker, R.H. Schumm, I.B. Halow, M. Sylvia, K.L. Churney, R.L. Nuttal, The NBS tables of chemical thermodynamic properties. Selected values for inorganic and C_1 and C_2 organic substances in SI units, Journal of Physical and Chemical Reference Data 11 (1982) Supplement 2.
35. J.A.Bourdoiseau, R.Sabot, M.Jeannin, F.Termemil, Ph.Refait, Determination of standard Gibbs free energy of formation of green rusts and its application to the Fe(II–III) hydroxy-oxalate. Colloids and Surfaces A: Physicochemical and Engineering Aspects. Volume 410, ELSEVIER 2012, Pages 72-80.
36. Keyvan Malaie, Fritz Scholz, Uwe Schröder, Harm Wulff, Heike Kahlert, Determining the Gibbs Energy Contributions of Ion and Electron Transfer for Proton Insertion in ϵ-MnO2. ChemPhysChem published by Wiley-VCH GmbH, 2022 Oct 17;23(24):e202200364. doi: 10..
37. PH. Refait, C.Bon, L.Simon, G.Bourrie, F.Trolard, J.Bessiere and J.-M.R.Genin, Chemical composition and Gibbs standard free energy of formation of Fe(II)-Fe(III) hydroxysulphate green rust and Fe(II) hydroxide. Clay Minerals (1999) 34,499-510 .

38. D. D. PERRIN, DISSOCIATION CONSTANTS OF INORGANIC ACIDS AND BASES IN AQUEOUS SOLUTION. publications.iupac.org/pac/pdf/1969/pdf/2002x0133.pdf