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REFERENCE BOOK

General chemistry

Gomel 2010

MINISTRY of HEALTH CARE REPUBLIC of BELARUS
GOMEL STATE MEDICAL UNIVERSITY

Department of general and bioorganic chemistry

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Reference book. General chemistry Справочник основных физико-химических величин и постоянных для лабораторно-практических занятий к курсу по общей химии для студентов лечебного факультета, обучающихся на английском языке/ Авторы-составители: В.А. Филиппова, А.В. Лысенкова, Л.В. Чернышева. – Гомель: Учреждение образования «Гомельский государственный медицинский университет», 2010. – С.25.

Справочник включает основные физико-химические величины и постоянные предназначен для организации лабораторного практикума и самостоятельной работы студентов медицинского вуза, изучающих курс общей химии на английском языке.

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Periodic Table of the Elements

	I A	II A	III B	IV B	V B	VI B	VII B	VIII B			I B	II B	III A	IV A	V A	VI A	VII A	VIIIA
1	1 H 1.0079 Hydrogen																	2 He 4.002 Helium
2	3 Li 6.94 Lithium	4 Be 9.01 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 15.99 Oxygen	9 F 18.99 Fluorine	10 Ne 20.18 Neon
3	11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminum	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
4	19 K 39.09 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 51.99 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
5	37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98] Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.76 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
6	55 Cs 132.91 Cesium	56 Ba 137.33 Barium	57 La* 138.91 Lanthanum	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.84 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Tl 204.38 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po [209] Polonium	85 At [210] Astatine	86 Rn [222] Radon
7	87 Fr [223] Francium	88 Ra [226] Radium	89 Ac** [227] Actinium	104 Db [261] Dubnium	105 Jl [262] Jollotium	106 Rf [263] Rutherfordium	107 Bh [264] Borium	108 Hn [265] Hahnium	109 Mt [268] Meitnerium	110 Uun [269]	111 Uuu [272]	112 Uub [277]	113 Uut [282]	114 Uuq [285]		116 Uuh [289]		118 Uuo [293]

*	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 [145] Pm Promethium	62 150.36 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.92 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
*	90 232.03 Th Thorium	91 231.03 Pa Protactinium	92 238.03 U Uranium	93 [237] Np Neptunium	94 [244] Pu Plutonium	95 [244] Am Americium	96 [247] Cm Curium	97 [247] Bk Berkelium	98 [251] Cf Californium	99 [252] Es Einsteinium	100 [257] Fm Fermium	101 [258] Md Mendelevium	102 [259] No Nobelium	103 [260] Lr Lawrencium

Table 1

MOLAR MASSES of INORGANIC SUBSTANCES

	OH^-	O^{-2}	Cl^-	Br^-	I^-	S^{2-}	SO_3^{2-}	SO_4^{2-}	NO_3^-	PO_4^{3-}	CO_3^{2-}	SiO_3^{2-}
H^+	18	18	36.5	81	128	34	82	98	63	98	62	78
NH_4^+	35	-	53.5	98	145	68	116	132	80	149	96	112
Na^+	40	62	58.5	103	150	78	126	142	85	164	106	122
K^+	56	94	74.5	119	166	110	158	174	101	212	138	154
Mg^{2+}	58	40	95	184	278	56	104	120	148	262	84	100
Ca^{2+}	74	56	111	200	294	72	120	136	164	310	100	116
Ba^{2+}	171	153	208	297	391	169	217	233	261	601	197	213
Al^{3+}	78	102	133.5	267	408	150	294	342	213	122	234	282
Cr^{3+}	103	152	158.5	292	433	200	344	392	238	147	284	332
Zn^{2+}	99	81	136	225	319	97	145	161	189	385	125	141
Mn^{2+}	89	71	126	215	309	87	135	151	179	355	115	131
Fe^{2+}	90	72	127	216	310	88	136	152	180	358	116	132
Fe^{3+}	107	160	162.5	296	437	208	352	400	242	151	292	340
Cu^{2+}	98	80	135	224	318	96	144	160	188	382	124	140
Ag^+	125	232	143.5	188	235	248	294	312	170	419	276	292
Pb^{2+}	241	223	278	367	461	239	287	303	331	811	267	283

Table 2

SOLUBILITY of INORGANIC SUBSTANCES in WATER

Cations	**Anions**												
	OH^-	**F^-**	**Cl^-**	**Br^-**	**I^-**	**S^{2-}**	**SO_3^{2-}**	**SO_4^{2-}**	**NO_3^-**	**PO_4^{3-}**	**CO_3^{2-}**	**SiO_3^{2-}**	**CH_3COO^-**
NH_4^+	—	s	s	s	s	—	s	s	s	s	s	—	s
Na^+ **K^+**	s	s	s	s	s	s	s	s	s	s	s	s	s
Mg^{2+}	L	**in**	s	s	s	s	**in**	s	s	**in**	**in**	**in**	s
Ca^{2+}	L	**in**	s	s	s	L	**in**	L	s	**in**	**in**	**in**	s
Ba^{2+}	s	L	s	s	s	s	**in**	**in**	s	**in**	**in**	**in**	s
Al^{3+}	**in**	L	s	s	s	—	—	s	s	**in**	—	**in**	L
Cr^{3+}	**in**	in	s	s	s	—	—	s	s	**in**	—	**in**	s
Zn^{2+}	**in**	L	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Mn^{2+}	**in**	L	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Co^{2+} **Ni^{2+}**	**in**	s	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Fe^{2+}	**in**	**in**	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Fe^{3+}	**in**	**in**	s	s	s	—	—	s	s	**in**	**in**	**in**	s
Cd^{2+}	**in**	s	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Hg^{2+}	—	—	s	L	n	**in**	**in**	s	s	**in**	**in**	—	s
Cu^{2+}	**in**	**in**	s	s	s	**in**	**in**	s	s	**in**	**in**	**in**	s
Ag^+	—	s	in	**in**	in	**in**	**in**	L	s	**in**	**in**	**in**	s
Sn^{2+}	**in**	s	sp	s	s	**in**	—	s	—	**in**	—	—	s
Pb^{2+}	**in**	**in**	L	L	in	**in**	**in**	**in**	s	**in**	**in**	**in**	s

where **s –** soluble substances
in – insoluble substances
L – substances with low solubility

Table 3

GENERAL PHYSICAL CONSTANTS

Constants	Symbol	Value	SI units
Speed of light in vacuum	C	2.9979	$\times 10^{8}$m/s
Elementary charge	e	1.6022	10^{19} C
Avogadro constant	N_A	6.0220	10^{23}mol^{-1}
Atomic mass unit	amu[a]	1.6606	10^{-27}kg
Electron rest mass	m_e	9.1095	10^{-31}kg
Proton rest mass	m_p	1.6726	10^{-27}kg
Neutron rest mass	m_n	1.6750	10^{-27}kg
Planck constant	h	6.6262	10^{-34} J$\times$s
Rydberg constant[b]	R_∞	1.0974	10^{7} m^{-1}
Gas constant	R	8.3144	J/mol$\times$K
Gas molar volume	V_m	2.2414	10^{-2}m^3/mol

[a] The symbol amu is commonly used in this country, but u is the official symbol.
[b] The symbol R_∞ refers to the Rydberg constant for infinite nuclear mass.

Table 4

MOLAR BOILING-POINT ELEVATION and FREEZING-POINT DEPRESSION CONSTANTS of SEVERAL COMMON LIQUIDS

Solvent	Normal freezing point (°C)*	K_f (°C/m)	Normal boiling point (°C)*	K_b (°C/m)
Water	0	1.86	100	0.52
Benzene	5.5	5.12	80.1	2.53
Ethanol	- 117.3	1.99	78.4	1.22
Acetic acid	16.6	3. 90	117.9	2.93
Cyclohexane	6.6	20.0	80.7	2.79

* Measured at 1 atm.

Table 5

DISTRIBUTION of MAJOR IONS on OPPOSITE SIDES of THE MEMBRANE of A TYPICAL NERVE CELL

Ion	Concentration/ m*M*	
	Intracellular	Extracellular
Na^+	15	150
K^+	150	10
Cl^-	10	110

Table 6

DENSITY and CONCENTRATION of AQUEOUS SOLUTIONS (20° C)

g/mL	Concentration		g/mL	Concentration	
	w, %	C_M, mol/L		w,%	C_M, mol/L
SODIUM CHLORIDE					
1.0053	1	0.172	1.1009	14	2.639
1.0125	2	0.346	1.1162	16	3.057
1.0268	4	0.703	1.1319	18	3.489
1.0413	6	1.069	1.1478	20	3.930
1.0559	8	1.446	1.1640	22	4.384
1.0707	10	1.834	1.1804	24	4.849
1.0857	12	2.231	1.1972	26	5.329
HYDROCHLORIC ACID					
1.0032	1	0.275	1.1083	22	6.684
1.0082	2	0.553	1.1187	24	7.365
1.0181	4	1.117	1.1290	26	8.051
1.0279	6	1.692	1.1392	28	8.750
1.0376	8	2.277	1.1493	30	9.454
1.0474	10	2.872	1.1593	32	10.15
1.0574	12	3,481	1.1691	34	10.93
1.0675	14	4.099	1.1789	36	11.64
1.0776	16	4.729	1.1885	38	12.39
1.0878	18	5.371	1.1980	40	13.14
1.0980	20	6.023			

Table 7

SOME COMMON ACID-BASE INDICATORS

Color Indicator	In acid	In base	pH rage*
Thymol blue	Red	Yellow	1.2 – 2.8
Bromophenol blue	Yellow	Bluish purple	3.0 – 4.6
Methyl orange	Orange	Yellow	3.1 – 4.4
Methyl red	Red	Yellow	4.2 – 6.3
Chlorophenol blue	Yellow	Red	4.8 – 6.4
Bromothymol blue	Yellow	Blue	6.0 – 7.6
Cresol red	Yellow	Red	7.2 – 8.8
Phenolphthalein	Colorless	Reddish pink	8.3 – 10.0

* The pH range is defined as the range over which the indicator changes from the acid color to the base color.

Table 8

K_a and pK_a for ACIDS

Acid	pK_a	K_a
HClO	7.25	5.6×10^{-8}
HCl	-7	1.0×10^{7}
H_2SO_4	-3	1.0×10^{3}
H_3O^+	-1.74	55
HNO_3	-1.32	21
H_2SO_3	1.92	0.012
HF	3.13	7.2×10^{-4}
HNO_2	3.15	7.1×10^{-4}
HCOOH	3.70	2.2×10^{-4}
CH_3COOH	4.75	1.8×10^{-5}
HCN	9.00	1.0×10^{-9}
H_3BO_3	9.14	7.3×10^{-10}
NH_4^+	9.25	5.6×10^{-10}
H_2SiO_4	9.5	3.2×10^{-10}
H_2CO_3	6.52	3.0×10^{-7}
HCO_3^-	10.4	4.0×10^{11}
H_3PO_4	1.96	0.011
$H_2PO_4^-$	7.12	7.6×10^{-8}
HPO_4^{2-}	12.3	4.8×10^{-13}
H_2S	6.92	1.2×10^{-7}
HS^-	13	1.0×10^{-13}

Table 9

K_b and pK_b for BASIS

Base	K_b	pK_b
Ammonia	1.8×10^{-5}	4.75
Aniline	3.8×10^{-10}	9.42
Caffeine	4.1×10^{-4}	3.39
Cocaine	2.6×10^{-6}	5.59
Creatine	1.9×10^{-11}	10.7
Methylamine	4.4×10^{-4}	3.36
Morphine	7.4×10^{-7}	6.13
Urea	1.5×10^{-14}	13.82
Novocaine	7×10^{-6}	5.16
Pyridine	1.7×10^{-9}	8.77
Quinine	1.1×10^{-8}	5.96
Strychnine	1×10^{-6}	6.0
Ethylamine	5.6×10^{-4}	3.25

Table 10

K_{SP} for INORGANIC SUBSTENCES

Substances	K_{sp}	Substances	K_{sp}
Ag_3AsO_3	1.0×10^{-17}	AgBr	5.3×10^{-13}
AgNSC	1.1×10^{-12}	$CaHPO_4$	2.7×10^{-7}
AgCl	1.78×10^{-10}	$Ca(H_2PO_4)_2$	1.0×10^{-3}
Ag_2CrO_4	1.1×10^{-12}	$Ca_3(PO_4)_2$	2.0×10^{-29}
$Ag_2Cr_2O_7$	1.0×10^{-10}	$Ca(OH)_2$	2.0×10^{-14}
AgI	8.3×10^{-17}	CdS	1.0×10^{-29}
$AgIO_3$	3.0×10^{-8}	$Co(OH)_2$	2.0×10^{-16}
$AgNO_2$	1.6×10^{-4}	$CuSO_3$	2.5×10^{-10}
Ag_3PO_4	1.3×10^{-20}	CuS	6.3×10^{-36}
Ag_2S	6.3×10^{-50}	$Cu(OH)_2$	5.0×10^{-20}
Ag_2SO_4	$1.6\times\cdot10^{-5}$	$Cr(OH)_3$	6.3×10^{-31}
$Al(OH)_3$	1.0×10^{-32}	$Fe(OH)_2$	1.0×10^{-15}
$AlPO_4$	5.7×10^{-19}	$Fe(OH)_3$	3.2×10^{-38}
$BaCO_3$	5.1×10^{-9}	$FeCO_3$	3.5×10^{-11}
BaC_2O_4	1.1×10^{-7}	$FePO_4$	1.3×10^{-22}
$BaCr_2O_4$	1.2×10^{-10}	FeS	5.0×10^{-18}
BaF_2	1.1×10^{-6}	Hg_2Cl_2	1.3×10^{-18}
$Ba_3(PO_4)_2$	6.0×10^{-39}	HgS	4.0×10^{-53}
$BaSO_3$	8.0×10^{-7}	Hg_2SO_4	6.8×10^{-7}
$BaSO_4$	1.1×10^{-10}	Li_2CO_3	3.98×10^{-3}
$Ba(OH)_2$	5.0×10^{-3}	LiF	3.8×10^{-3}
$Ca(OH)_2$	5.5×10^{-6}	Li_3PO_4	3.2×10^{-9}
$CaCO_3$	4.8×10^{-10}	$MgCO_3$	4.0×10^{-5}
CaC_2O_4	2.3×10^{-9}	MgC_2O_4	8.6×10^{-5}
$CaSO_4$	9.1×10^{-6}	$Mg(OH)_2$	6.0×10^{-10}
CaF_2	4.0×10^{-11}	$Mg_3(PO_4)_2$	1.0×10^{-13}
$MnCO_3$	1.8×10^{-11}	PbS	2.5×10^{-27}
$Mn(OH)_2$	4.5×10^{-13}	$PbSO_4$	1.6×10^{-8}
MnS	2.5×10^{-10}	$SrCO_3$	1.1×10^{-10}
$Na[Sb(OH)_6]$	4.0×10^{-8}	$SrCrO_4$	3.5×10^{-5}
$Ni(OH)_2$	2.1×10^{-16}	$SrCr_2O_4$	5.5×10^{-8}
$PbBr_2$	9.1×10^{-6}	$Sr_3(PO_4)_2$	1.0×10^{-31}
$PbCO_3$	1.0×10^{-13}	$SrSO_4$	3.2×10^{-7}
$PbCl_2$	1.6×10^{-5}	$ZnCO_3$	1.4×10^{-11}
$PbCrO_4$	1.8×10^{-14}	ZnC_2O_4	1.5×10^{-9}
PbI_2	1.1×10^{-9}	$Zn(OH)_2$	7.1×10^{-18}
$Pb(OH)_2$	1.1×10^{-20}	ZnS	1.6×10^{-24}

Table 11

IONIC STRENGTH AND ACTIVITY COEFFICIENTS OF THE IONS

Ions	Ionic strength of the solution								
	0.0005	**0.001**	**0.01**	**0.02**	**0.1**	**0.2**	**0.3**	**0.5**	**1.0**
H^+	0.98	0.97	0.91	0.90	0.87	0.81	0.80	0.79	0.85
NH_4^+, K^+, Li^+, Cl^-, Br^-, I^-, NO_2^-, NO_3^-	0.98	0.96	0.90	0.87	0.75	0.67	0.62	0.55	0.44
OH^-, F^-, ClO_4^-	0.98	0.96	0.90	0.87	0.76	0.68	0.63	0.56	0.46
Na^+, $H_2PO_4^-$	0.98	0.96	0.90	0.87	0.77	0.73	0.70	0.67	0.63
Ca^{2+}, Cu^{2+}, Zn^{2+}, Fe^{2+}	0.90	0.87	0.68	0.64	0.41	0.33	0.28	0.25	0.21
Mg^{2+}, Be^{2+}	0.91	0.87	0.69	0.65	0.45	0.37	0.34	0.28	0.23
PO_4^{3-}	0.80	0.73	0.40	-	0.10	-	-	-	-
Al^{3+}, Fe^{3+}, Cr^{3+}	0.80	0.74	0.45	-	0.18	-	-	-	-

Table 12

HYDROLYSIS CONSTANTS and THE HYDROLYSIS PERCENTS of SALTS WHICH INVOLVES AN ANION of A WEAK ACID

Anion (base)	K_b	Hydrolysis percent	pH (0.1 mol/L)
ClO_3^-	1×10^{-14}	3.2×10^{-5}	7
HSO_3^-	8.3×10^{-13}	2.9×10^{-4}	4.6
SO_4^{2-}	8.3×10^{-13}	2.9×10^{-4}	7.4
$H_2PO_4^-$	9.1×10^{-13}	3.1×10^{-4}	4.6
F^-	1.4×10^{-11}	1.2×10^{-3}	8.1
NO_2^-	1.4×10^{-11}	1.2×10^{-3}	8.1
$HCOO^-$	1.4×10^{-11}	2.1×10^{-3}	8.3
CH_3COO^-	5.6×10^{-10}	7.5×10^{-3}	8.9
HCO_3^-	3.3×10^{-8}	0.06	8.5
HS^-	8.3×10^{-8}	0.1	10.0
HPO_4^{2-}	1.3×10^{-7}	0.12	9.7
SO_3^{2-}	1.6×10^{-7}	0.13	10.1
ClO^-	1.8×10^{-7}	0.14	10.1
CN^-	1.0×10^{-5}	1.0	11.0
CO_3^{2-}	2.5×10^{-4}	5.0	11.7
PO_4^{3-}	1.7×10^{-2}	33	12.5
S^{2-}	1.0×10^{-1}	60	12.8

Table 13

SOME COMMON ACIDS and THEIR CONJUGATED BASES

Acid		Conjugate base	
Name	**Formula**	**Name**	**Formula**
Hydrochloric asid	HCl	Chloride ion	Cl^-
Nitric asid	HNO_3	Nitrate ion	NO_3^-
Hydrocyanic asid	HCN	Cyan ion	CN^-
Percloric asid	$HClO_4$	Perclor ion	ClO_4^-
Sulfuric asid	H_2SO_4	Hydrogen sulfate ion	HSO_4^-
Hydrogen sulfate ion	HSO_4^-	Sulfate ion	SO_4^{2-}
Carbonic asid	H_2CO_3	Hydrogen carbonate ion	HCO_3^-
Hydrogen carbonate ion	HCO_3^-	Carbonate ion	CO_3^{2-}
Ammonium ion	NH_4^+	Ammonia	NH_3

Table 14

SELECTED STANDARD ENTHALPY of COMBUSTION for ORGANIC SUBSTANCES at 1 atm. AND 25°C

Substances	State	$\Delta_{com}H°_{298}$, kJ/mole	Substances	State	$\Delta_{com}H°_{298}$, kJ/mole
CH_4	g	-882	C_2H_4	g	-1390
CH_3Br	g	-770	C_2H_2	g	-1304
CH_3Cl	g	-686	C_2H_5OH	s	-1370
CH_3I	l	-814	NH_2CH_2COOH	s	-981
CH_3NH_2	solution	-1070	$CO(CH_3)_2$	l	-1780
CH_3OH	l	-715	C_6H_6	l	-3170
CH_2O	g	-561	$C_6H_5NH_2$	l	-3400
HCOOH	l	-262	$C_6H_5NO_2$	l	-3080
$CO(NH_2)_2$	s	-634	C_6H_5OH	l	-3060
$CHCl_3$	l	-346	glucose	s	-2810
CHI_3	s	-677	fructose	s	-2820
C_2H_6	g	-1540	CH_3COOH	l	-872

Table 15

SELECTED THERMADYNAMIC DATA at 1 atm. AND 25°C

Substances	State	$\Delta H^0 f$ (kJ/mol)	ΔG^0_f (kJ/mol)	S^0 (J/K×mol)
AgCl	s	-127	-109.7	96.1
$AgNO_3$	s	-123	-32.2	141
Ag_2O	s	-30.6	-10.8	122
Al	s	0	0	28.4
Al^{3+}	l	-524.7	-481.2	-313.4
Al_2O_3	s	-1670	-1576	51
$Al_2O_3 \cdot 3H_2O$	s	-656	-575	107
B_2O_3	s	-1264	-1184	54
H_3BO_3	s solution	-1088 -1067	-963 -963	89.6 160
Ba^{2+}	l	-538	-561	12.6
$BaCl_2$	s	-860	-811	126
$BaCl_2 \cdot 2H_2O$	s	-1460	-1300	203
$BaSO_4$	s	-1464	-1353	132
Br_2	l	0	0	152
Br_2^-	l	-121	103	81
C	s	0	0	5.7
CO	g	-111	-137	198
CO_2	g l	-394 -413	-394 -386	214 121
H_2CO_3	l	-700	-623	187
HCO_3^-	l	-691	-587	95
CO_3^{2-}	l	-676	-528	-53
Ca^{2+}	l	-543	-553	-55
CaO	s	-636	-604	40
$Ca(OH)_2$	s	-987	-897	76
$CaSO_4$	s	-1430	-1320	107
$CaSO_4 \cdot 2H_2O$	s	-2020	-1790	194
$CaCl_2$	s	-795	-750	114
$CaCl_2$	l	-877	-815	55
$CaCl_2 \cdot 6H_2O$	s	-2600		
$CaCO_3$	s	-1207	-1129	93
Cl_2	g	0	0	223
HCl	g	-92.3	-95.3	187
HCl	l	-167	-131	55
CrO_4^{2-}	l	-863	-706	38.5
$Cr_2O_7^{2-}$	l	-1461	-1257	214
Cu^{2+}	l	64.4	65	99
CuCl	s	-135	-119	92
$CuCl_2$	s	-206		
$CuSO_4$	s	-770	-662	113
$CuSO_4 \cdot 3H_2O$	s	-1680	-1400	225
$CuSO_4 \cdot 5H_2O$	s	-2280	-1880	306

Substances	State	$\Delta H^0 f$ (kJ/mol)	ΔG^0_f (kJ/mol)	S^0 (J/K×mol)
F^-	l	-329	-276	-10
HF	g	-269	-271	174
Fe	s	0	0	27.2
Fe^{2+}	l	-88	-85	-113
Fe^{3+}	l	-48	-11	-293
$FeCl_3$	s	-405		
$FeCl_3 \cdot 6H_2O$	s	-2220		
$FeSO_4$	s	-923	-820	108
$FeSO_4 \cdot 7H_2O$	s	-3000		
H_2	g	0	0	131
H^+	l	0	0	0
HO^-	l	-230	-157	-10.5
H_2O	l	-286	-238	70
H_2O	g	-242	-229	189
H_2O_2	l	-188	-118	
H_2O_2	solution	-191		
Hg	l	0	0	77
Hg	g	61	32	175
Hg^{2+}	l		-164	
$HgCl_2$	s	-230	-176	
Hg_2Cl_2	s	-264	-211	196
HgO	s	-90	-58.4	73
K^+	l	-251	-282	103
$KAl(SO_4)_2 \cdot 12H_2O$	s	-6050	-5176	688
KBr	s	-392	-380	96
KBr	l	-372	-385	183
KCl	s	-436	-408	83
KCl	g	-216	-235	240
KCl	l	-419	-414	158
$KClO_3$	s	-391	-290	143
KI	s	-328	-322	104
KI	l	-307	-334	112
KNO_3	s	-492	-393	133
KNO_3	l	-458	-393	290
$KMnO_4$	s	-814	-714	172
Li^+	l	-278	-294	14
LiOH	s	-487	-444	50
Li_2CO_3	s	-1215	-1130	90
Mg^{2+}	l	-462	-456	-118
$MgCO_3$	s	-1110	-1030	66
$MgCl_2$	s	-641	-592	90
$MgCl_2 \cdot 6H_2O$	s	-2500	-1280	366
MgO	s	-601	-570	27
$Mg(OH)_2$	s	-925	-834	63
$MgSO_4$	s	-1280	-1170	92

Substances	State	$\Delta H^0 f$ (kJ/mol)	ΔG^0_f (kJ/mol)	S^0 (J/K×mol)
$MgSO_4 \cdot 7H_2O$	s	-3380		
Mn^{2+}	l	-219	-223	-84
Mn^{3+}	l	-100		
$MnSO_4$	s	-1060	-956	112
N_2	g	0	0	191
NH_3	g	-46.2	-16.6	192
NH_3	l	-80.7	-26.6	110
NH_4^+	l	-133	-80	113
NH_4Cl	s	-315	-204	94.6
$(NH_4)_2SO_4$	s	-1180	-900	220
N_2O	g	81.6	104	220
NO	g	90	87	211
NO_2	g	34	52	240
N_2O_4	g	10	98	304
HNO_3	l	-173	-80	156
NO_3^-	l	-207	-114	146
Na	s	0	0	51
Na^+	l	-240	-262	60
Na_2CO_3	s	-1130	-1060	136
$Na_2CO_3 \cdot 10H_2O$	s	-4080	-3906	
$NaHCO_3$	s	-948	-852	102
NaF	s	-569	-541	58
NaCl	s	-411	-384	50
$NaNO_2$	s	-360		
$NaNO_3$	s	-425	-366	116
NaOH	s	-425	-380	60
Na_2SO_3	s	-1110	-1000	146
Na_2SO_4	s	-1380	-1270	149
$Na_2SO_4 \cdot 10H_2O$	s	-4320	-3640	592
$Na_2S_2O_3 \cdot 5H_2O$	s	-2600		
O_2	g	0	0	205
O_3	g	142	163	238
P_4(white)	s	0	0	44.4
P(red)	s	-18.4		
PCl_3	g	-306	-286	312
PCl_5	g	-398	-324	352
HPO_4^{2-}	l	-1299	-1094	-36
PO_4^{3-}	l	-1284	-1026	-218
Pb^{2+}	l	1.6	24.3	21.3
PbO	s	-218	-188	69
PbO_2	s	-277	-219	77
$Pb(CH_3COO)_2$	s	-965		

Substances	State	$\Delta H^0 f$ (kJ/mol)	ΔG^0_f (kJ/mol)	S^0 (J/K×mol)
$Pb(CH_3COO)_2 \cdot 3H_2O$	s	-1870		
S	s	0	0	32
SO_2	g	-296	-300	249
SO_3	g	-395	-370	256
H_2S	g	-20	-33	206
H_2SO_4	l	-907	-742	17
HSO_4^-	l	-886	-753	127
SO_4^{2-}	l	-907	-742	17.2
SiO_2	s	-859	-805	42
Zn^{2+}	l	-152	-147	106
ZnO	s	-348	-318	44
$ZnCl_2$	s	-416	-369	108
$ZnSO_4$	s	-979	-872	125
$ZnSO_4 \cdot 7H_2O$	s	-3080	-2560	386
Organic compounds				
CH_4	g	-75	-51	186
C_2H_2	g	207	209	201
C_2H_4	g	52	68	219
C_2H_6	g	-85	-33	229
C_6H_6	s	49	173	125
CH_3Cl	g	-82	-59	234
CH_2Cl_2	g	-88	-59	270
$CHCl_3$	g	-100	-67	296
CCl_4	l	-107	-64	310
CH_3Br	g	-27	-26	246
CH_2Br_2	g	-4.2	-6	294
$CHBr_3$	g	25	16	331
CBr_4	g	50	36	358
CH_3OH	l	-239	-166	127
C_2H_5OH	l	-277	-174	161
$C_3H_8O_3$ (glycerol)	l	-671	-479	205
CH_2O	g	-116	-110	218
CH_3CHO	g	-247	-139	264
CH_3COCH_3	l	-247	-154	199
HCOOH	l	-409	-346	129
$HCOO^-$	l	-410	-335	92
CH_3COOH	l	-484	-389	160
CH_3COO^-	l	-485	-404	205
C_3H_7COOH	l	-535	-376	226
$C_3H_7COO^-$	l	-536	-372	202
$C_{15}H_{32}COOH$	s	-891	-315	455
$C_{15}H_{32}COO^-$	l		-259	

Substances	State	$\Delta H^0 f$ (kJ/mol)	ΔG^0_f (kJ/mol)	S^0 (J/K×mol)
glucose	s l	-1274 -1263	-911 -915	212 264
glucoso-1-phosphoric acid	l		-1790	
Glysine	s l	-537 -523	-378 -380	104 159
Cystein	s	-533	-343	170

Table 16

STANDARD REDUCTION POTENTIALS for METALLS

Half-Reaction	φ°, V	Half-Reaction	φ°, V
$Li^+ + e^- \rightarrow Li$	-3.045	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
$K^+ + e^- \rightarrow K$	-2.925	$Mo^{3+} + 3e^- \rightarrow Mo$	-0.200
$Ba^{2+} + 2e^- \rightarrow Ba$	-2.900	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
$Ca^{2+} + 2e^- \rightarrow Ca$	-2.870	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
$Na^+ + e^- \rightarrow Na$	-2.714	$\mathbf{2H^+ + 2e^- \rightarrow H_2}$	**0.000**
$Mg^{2+} + 2e^- \rightarrow Mg$	-2.370	$Bi^{3+} + 3e^- \rightarrow Bi$	+0.215
$Al^{3+} + 3e^- \rightarrow Al$	-1.660	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.337
$Mn^{2+} + 2e^- \rightarrow Mn$	-1.180	$Ag^+ + e^- \rightarrow Ag$	+0.799
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.762	$Hg^{2+} + 2e^- \rightarrow Hg$	+0.854
$Cr^{3+} + 3e^- \rightarrow Cr$	-0.740	$Pd^{2+} + 2e^- \rightarrow Pd$	+0.987
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.440	$Pt^{2+} + 2e^- \rightarrow Pt$	+1.190
$Co^{2+} + 2e^- \rightarrow Co$	-0.280	$Au^{3+} + 3e^- \rightarrow Au$	+1.500

Table 17

STANDARD REDUCTION POTENTIALS at 25°C

Half-Reaction	φ°, V	Half-Reaction	φ°, V
$[Ag(NH_3)_2]^+ + e^- \rightarrow Ag + 2NH_3$	+0.373	$Cu^{2+} + Cl^- + e^- \rightarrow CuCl$	+0.54
$AlO_2^- + 2H_2O + 3e^- \rightarrow Al + 4OH^-$	-2.35	$Cu^{2+} + I^- + e^- \rightarrow CuI$	+0.86
$H_3AsO_4 + 2H^+ + 2e^- \rightarrow HAsO_2 + 2H_2O$	+0.56	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77
$[Au(CN)_2]^- + e^- \rightarrow Au + 2CN^-$	-0.61	$[Fe(CN)_6]^{3-} + e^- \rightarrow [Fe(CN)_6]^{4-}$	+0.356
$BiO_3^- + 6H^+ + 2e^- \rightarrow Bi^{3+} + 3H_2O$	+1.80	$Fe(OH)_3 + e^- \rightarrow Fe(OH)_2 + OH^-$	-0.56
$Br_2 + 2e^- \rightarrow 2Br^-$	+1.065	$Fe(OH)_2 + 2e^- \rightarrow Fe + 2OH^-$	-0.877
$BrO^- + 2H_2O + 2e^- \rightarrow Br^- + 2OH^-$	+0.76	$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	+1.77
$2BrO_3^- + 6H_2O + 10e^- \rightarrow Br_2 + 12OH^-$	+0.50	$H_2O_2 + 2e^- \rightarrow 2OH^-$	+0.88
$2BrO_3^- + 3H_2O + 6e^- \rightarrow Br^- + 6OH^-$	+0.61	$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	+0.68
$BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$	+1.45	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23
$2BrO_3^- + 12H^+ + 10e^- \rightarrow Br_2 + 6H_2O$	+1.51	$O_3 + 2H^+ + 2e^- \rightarrow O_2 + H_2O$	+2.07
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.359	$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	+0.92
$ClO^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-$	+0.88	$2HgCl_2 + 2e^- \rightarrow Hg_2Cl_2 + 2Cl^-$	0.62
$ClO_3^- + 3H_2O + 6e^- \rightarrow Cl^- + 6OH^-$	+0.63	$I_2 + 2e^- \rightarrow 2I^-$	+0.54
$ClO_3^- + 6H^+ + 6e^- \rightarrow Cl^- + 3H_2O$	+1.45	$IO_3^- + 3H_2O + 6e^- \rightarrow 2I^- + 6OH^-$	+0.26
$Co^{3+} + e^- \rightarrow Co^{2+}$	+1.84	$IO_3^- + 6H^+ + 6e^- \rightarrow I^- + 3H_2O$	+1.08
$[Co(NH_3)_6]^{3+} + e^- \rightarrow [Co(NH_3)_6]^{2+}$	-0.43	$2IO_3^- + 2H_2O + 10e^- \rightarrow I_2 + 12OH^-$	+0.21
$CrO_2^- + 2H_2O + 3e^- \rightarrow Cr + 4OH^-$	-1.2	$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	+0.56
$CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr(OH)_3 + 5OH^-$	-0.13	$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$	+0.60
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	+1.33	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.51
$Cu^{2+} + e^- \rightarrow Cu^+$	+0.153	$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	+1.23
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	+1.455	$2NO_3^- + 12H^+ + 10e^- \rightarrow N_2 + 6H_2O$	+1.24
$PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$	+1.68	$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	+0.96
$S + 2e^- \rightarrow S^{2-}$	-0.48	$NO_3^- + 3H^+ + 2e^- \rightarrow HNO_2 + H_2O$	+0.94
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + 2H_2O$	+0.17	$HNO_2 + H^+ + e^- \rightarrow NO + H_2O$	+0.99
$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$	+0.311	$NO_3^- + H_2O + 2e^- \rightarrow NO_2^- + 2OH^-$	+ 0.01
$SO_4^{2-} + H_2O + 2e^- \rightarrow SO_3^{2-} + 2OH^-$	-0.93	$NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$	+ 0.80
$S_2O_8^{2-} + 4e^- \rightarrow 2SO_4^{2-}$	+2.01	$SeO_8^{2-} + 4H^+ + 2e^- \rightarrow SeO_4^{2-} + H_2O$	+1.15
$S + 2H^+ + 2e^- \rightarrow H_2S$	+0.171	$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	+0.15
$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$	+0.31	$C_6H_4O_2 + 2H^+ + 2e^- \rightarrow C_6H_4(OH)_2$	+0.7
$SO_4^{2-} + 8H^+ + 6e^- \rightarrow S + 4H_2O$	+0.36	$HCHO + 2H^+ + 2e^- \rightarrow CH_3OH$	+0.19
$F_2 + 2e^- \rightarrow 2F^-$	+2.77	$CH_3CHO + 2H^+ + 2e^- \rightarrow C_2H_5OH$	+0.19
$PO_4^{3-} + 2H_2O + 2e^- \rightarrow HPO_3^{2-} + 3OH^-$	-1.12	$CH_3COOH + 2H^+ + 2e^- \rightarrow CH_3CHO + H_2O$	-0.12
$TeO_2 + 4H^+ + 4e^- \rightarrow Te + 2H_2O$	+0.53	$CO_2 + 2H^+ + 2e^- \rightarrow HCOOH$	-0.20

***** For all half-reaction is 1M for dissolved species and the pressure is 1 atm for gases.

Table 18

STANDARD REDUCTION POTENTIALS for SOME BIOLOGICAL HALF–REACTIONS at 298K (pH = 7)

System	**Half–Cell Reactions**	*φ°, V*
O_2 / H_2O	$O_2(q) + 4H^+ + 4e^- \rightarrow 2H_2O$	+0.816
Cu^{2+} /Cu^+ hemocyanin	$Cu^{2+} + e^- \rightarrow Cu^+$	+0.540
Cyt f^{3+} /Cyt f^{2+}	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.365
Cyt a^{3+} /Cyt a^{2+}	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.29
Cyt c^{3+} /Cyt c^{2+}	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.254
Fe^{3+} /Fe^{2+} hemoglobin	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.17
Fe^{3+} /Fe^{2+} myoglobin	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.046
Fumarate/succinate	$^-OOCCH=CHCOO^- + 2\ H^+ + 2e^- \rightarrow {}^-OOCCH_2CH_2COO^-$	+0.031
MB /MBH_2[b]	$MB + 2H^+ + 2e^- \rightarrow MBH_2$[b]	+0.011
Pyruvate /Lactate	$CH_3COCOO^- + 2H^+ + 2e^- \rightarrow CH_3CHOHCOO^-$	-0.185
Acetaldehyde /ethanol	$CH_3CHO + 2H^+ + 2e^- \rightarrow CH_3CH_2OH$	-0.197
FAD /$FADH_2$	$FAD\ 2H^+ + 2e^- \rightarrow FADH_2$	-0.219
NAD^+ /NADH	$NAD^+ + H^+ + 2e^- \rightarrow NADH$	-0.320
$NADP^+$ /NADPH	$NADP^+ + H^+ + 2e^- \rightarrow NADPH$	-0.324
CO_2 /Formate	$CO_2 + H^+ + 2e^- \rightarrow HCOO^-$	-0.414
H^+ /H_2	$2H^+ + 2e^- \rightarrow H_2$	-0.421
Fe^{3+} /Fe^{2+} ferredoxin	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	-0.432
Acetic acid /acetaldehyde	$CH_3COOH + 2H^+ + 2e^- \rightarrow CH_3CHO + H_2O$	-0.581
Acetate /pyruvate	$CH_3COOH + CO_2 + 2\ H^+ + 2e^- \rightarrow$ $\rightarrow CH_3COCOOH + H_2O$	-0.700

Table 19

STUDENT'S-*t* number

Student's-*t* Values at Common Confidence Levels				
Degrees of Freedom	50%	90%	95%	99%
1	1.000	6.314	12.71	63.66
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
4	0.741	2.132	2.776	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.500
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
20	0.687	1.725	2.086	2.845
infinite	0.674	1.645	1.960	2.576

Table 20

TYPES of CONCENTRATION UNITS

Concentration Units	Symbol	Units	Formulas for calculation:
Molarity	$\mathbf{C_M}$	mol/L	$\mathbf{C_M}=\frac{\nu(compound)}{V(solution)}$ $\mathbf{C_M}=\frac{1000\cdot T}{M(compound)}$ $\mathbf{C_M}=\frac{10\cdot\omega(\%)\cdot\rho}{M(compound)}$ $\mathbf{C_M}=C_n\cdot f_{eq}$
Molality	$\mathbf{C_m}$	mol/kg	$\mathbf{C_m}=\frac{\nu(compound)}{m(solvent)}$ $\mathbf{C_m}=\frac{m(compound)\cdot 1000}{M(compound)\cdot m(solvent),g}$
Normality	$\mathbf{C_N}$	mol/L	$\mathbf{C_n}=\frac{\nu_{eq}(compound)}{V(solution)}$ $\mathbf{C_n}=\frac{m(compound)}{M\cdot f_{eq}\cdot V(solution)}$ $\mathbf{C_n}=\frac{C_M}{f_{eq}}$ $\mathbf{C_n}=\frac{1000\cdot T(compound)}{f_{eq}\cdot M(compound)}$
Percent by Mass	$\boldsymbol{\omega}$	%	$\omega=\frac{m(compound)}{m(solution)}(\times 100\%)$ $\omega(\%)=\frac{C_M\cdot M}{10\cdot\rho}$
Titer	$\mathbf{T}$	g/sm^3 g/mL	$T=\frac{m(compound)}{V(solution)}$ $T=\frac{C_n\cdot M_{eq}(compound)}{1000}$
Mole Fraction	$\boldsymbol{\chi}$		$\chi=\frac{\nu(compound)}{\nu(compound)+\nu(solvent)}$

where f_{eq} – an equivalent factor;
ν *(compound)* – amount of a solute, mol;
ρ – density, g/ mL (g/sm^3);
υ_{eq}*(compound)* – amount of equivalents of a solute, mol;
M (compound) – molar mass of solute, g/mol;
M_{eq}*(compound)* – equivalent molar mass of a solute, g/mol;
V- volume of a solution, L

Table 21

THE INSTABILITY CONSTANTS

Complex ion	K_{ins}	Complex ion	K_{ins}
$[Ag(CN)_2]^-$	1.41×10^{-20}	$[CdI_4]^{2-}$	7.9×10^{-7}
$[Ag(NH_3)_2]^+$	5.75×10^{-8}	$[Cd(CN)_4]^{2-}$	7.76×10^{-18}
$[Ag(NO_2)_2]^-$	1.48×10^{-3}	$[Cu(NH_3)_4]^{2+}$	9.33×10^{-13}
$[Ag(NCS)_2]^-$	5.37×10^{-9}	$[Cu(NCS)_4]^{2-}$	3.02×10^{-7}
$[Ag(S_2O_3)_2]^{3-}$	3.47×10^{-14}	$[Co(NH_3)_4]^{2+}$	4.07×10^{-5}
$[Au(CN)_2]^-$	5.0×10^{-39}	$[Co(NH_3)_6]^{2+}$	8.51×10^{-6}
$[Bi(NCS)_6]^{3-}$	5.89×10^{-5}	$[Co(CN)_6]^{4-}$	8.13×10^{-20}
$[Cd(NH_3)_4]^{2+}$	2.88×10^{-7}	$[Co(NCS)_4]^{2-}$	6.31×10^{-3}
$[CdBr_4]^{2-}$	1.17×10^{-3}	$[Co(NH_3)_6]^{3+}$	6.17×10^{-36}
$[Co(CN)_6]^{3-}$	1.0×10^{-64}	$[PbBr_4]^{2-}$	1.0×10^{-3}
$[Cr(NCS)_6]^{3-}$	1.58×10^{-4}	$[PbI_4]^{2-}$	6.0×10^{-7}
$[Fe(CN)_6]^{4-}$	1.0×10^{-24}	$[Pb(NCS)_4]^{2-}$	0.14
$[Fe(CN)_6]^{3-}$	1.0×10^{-31}	$[Pb(S_2O_3)_4]^{6-}$	6.31×10^{-8}
$[Fe(NCS)_6]^{3-}$	5.89×10^{-4}	$[PbCl_4]^{2-}$	0.1
$[HgBr_4]^{2-}$	1.0×10^{-21}	$[PbBr_4]^{2-}$	7.9×10^{-14}
$[Hg(CN)_4]^{2-}$	3.1×10^{-42}	$[PtCl_4]^{2-}$	1.0×10^{-16}
$[HgCl_4]^{2-}$	8.5×10^{-16}	$[PtBr_4]^{2-}$	3.0×10^{-21}
$[Hg(NH_3)_4]^{2+}$	5.0×10^{-20}	$[Zn(NH_3)_4]^{2+}$	2.0×10^{-9}
$[HgI_4]^{2-}$	0.5×10^{-30}	$[ZnCl_4]^{2-}$	10
$[Hg(NCS)_4]^{2-}$	1.7×10^{-20}	$[ZnBr_4]^{2-}$	316.2
$[Mn(C_2O_4)_3]^{3-}$	3.8×10^{-20}	$[Zn(CN)_4]^{2-}$	1.0×10^{-19}
$[Ni(NH_3)_4]^{2+}$	3.4×10^{-8}	$[Zn(NCS)_4]^{2-}$	2.0×10^{-4}

Table 22

CONTENT of BIOESSENTIAL CHEMICAL ELEMENTS in A HUMAN BODY

Elements	Content in a human body (g/per 70 kg)	Percent by mass
Ag	7.9×10^{-4}	1.1×10^{-6}
Al	0.061	8.7×10^{-5}
Au	9.8×10^{-3}	1.4×10^{-5}
Br	0.26	3.7×10^{-4}
C	16000	22.8
Ca	1000	1.4
Cd	0.05	4.1×10^{-5}
Cl	95	0.14
Co	1.5×10^{-3}	2.1×10^{-6}
Cu	0.072	1.0×10^{-4}
F	2.6	3.7×10^{-3}
Fe	4.2	6.0×10^{-3}
I	0.012	1.7×10^{-5}
K	140	0.2
Mg	19	0.027
Mn	0.012	1.7×10^{-5}
Mo	9.5×10^{-3}	1.4×10^{-5}
N	1800	2.6
Na	100	0.14
Ni	0.001	1.4×10^{-6}
O	43 000	61.5
P	780	1.1
S	140	0.2
Se	0.014	2×10^{-5}
V	0.013	1.9×10^{-5}
W	0.013	1.9×10^{-5}
Zn	2.3	3.3×10^{-3}

FORMULAS FOR CALCULATIONS

1. Chemical thermodynamics:

1.1 The first law of chemical thermodynamics

- For an isolated system: U = const, $\Delta U = 0$
- For a closed system: $Q = \Delta U + A$
- For an open system: $\Delta U = Q \pm \mu\Delta\nu - A$

where Q – heat absorbed by a system, kJ,
A´ – useful work produced in a system, kJ,
$p\Delta V$ – work of gas expansion, kJ.
μ – proportionality coefficient named a chemical potential,
$\Delta\nu$ – change in chemical amount of substances, mol
U – internal energy of a system, kJ

1.2 The Hess's Law: $\Delta_r H = \sum\nu\Delta_f H$ (products) - $\sum\nu\Delta_f H$ (reactants)

where ν is a stoichiometrical coefficient
$\Delta_f H$ - enthalpy of formation, kJ/mol

1.3 The Second Law of Chemical Thermodynamics

- The Clausius Inequality is $\Delta S \geq Q/T$
- Boltzmann's equation is $S = k \times \ln W$

where k – the Boltzmann's coefficient ($k = 1.38 \times 10^{-23}$ J/K);
W – thermodynamics probability
S – entropy, kJ/mol×K
Q – heat, kJ
T – temperature

2. The Rates of Chemical Reactions

2.1 An average rate of homogeneous reactions $\vartheta = \pm\frac{[A]-[A]_0}{\tau}$,

where τ – time, s., min., hours
$[A]_0$ – initial molar concentration, mol/L
[A] – final molar concentration, mol/L.

2.2 Rate laws**:** Rate $\vartheta = k \times [A]^x \times [B]^y$

- Zero-Order Reactions rate $\vartheta = -\frac{d[A]}{d\tau} = = k \times [A]^0 = k$

where $k = \frac{[A]_0 - [A]}{\tau}$

- First-Order Reactions; Rate $\vartheta = -\frac{d[A]}{d\tau} = = k \times [A]$,

where k (s^{-1}) is the first-order rate constant. It can be calculated as follows:

$$k = \frac{1}{\tau} \times \ln\frac{[A]_0}{[A]}$$

$$\tau_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

- Second-Order Reactions; rate $\vartheta = k[A]^2$,

where k (s^{-1}) is the second-order rate constant. It can be calculated as follows

$$k = \frac{1}{\tau} \times \frac{[A]_0 - [A]}{[A]_0 \times [A]}$$

$$\tau_{1/2} = \frac{1}{k[A]_0}$$

2.3 Arrhenius equation: $k = k_0 \times e^{\frac{-E_a}{RT}}$

where k_0 – pre-exponential factor ,

E_a – activation energy, kJ/mol.

2.4 Michaelis-Menten equation:

$$\vartheta = \frac{k_2 \times [E]_{\text{overall}} \times [S]}{K_M + [S]}$$

where K_M is the equilibrium constant, known as Michaelis constant.

A multiplication $k_2 \times [E]_{\text{overall}}$ is constant and is defined as $\vartheta_{\max}$ (maximum rate).

3. Physical Properties of Solutions

3.1 Solubility of binary electrolyte:

$$S = \sqrt{K_{sp}}$$

where S – solubility, mol/L

K_{sp} – solubility constant

3.2. The first Raoult's Law: $\frac{P_0 - P}{P_0} = \chi(A)$

where $\chi(A)$ is a mole fraction of a solute

P_0 – the vapor pressure of a pure solvent

P – the vapor pressure of a solution.

Van't Hoff's factor (i) can be derived from the equation

$$\alpha = \frac{i - 1}{n - 1}$$

where n – a number ions contained in a molecule

i – Van't Hoff's factor.

3.3 Ebullioscopic Raoult's Law:

$\Delta T_b = K_b \times C_m$, (for nonelectrolytes),

$\Delta T_b = i \times K_b \times C_m$, (for electrolytes)

where ΔT_b is boiling-point elevation, which is equal to: $\Delta T_b = T_2 - T_1$,

T_1 and T_2 are boiling-points of a solvent and a solution correspondently

C_m – molality, mol/kg,

K_b – molar boiling-point elevation constant

3.4 Cryoscopic Raoult's Law

$\Delta T_f = K_f \times C_m$, (for nonelectrolytes),

$\Delta T_f = i \times K_f \times C_m$, (for electrolytes),

where ΔT_f is freezing point depression , which is equal to: $\Delta T_f = T_1 - T_2$,

T_1 and T_2 are freezing -points of a solvent and a solution correspondently,

K_f – molar freezing -point depression constant (1.86 for water).

3.5. Osmosis

$\pi = R \times T \times C_M$ (for nonelectrolytes),

$\pi = i \times R \times T \times C_M$ (for electrolytes)

where C_M – molarity, mol/L

R – gas constant (8.31 J/mol K)

T – temperature , K

4. Electrolyte solutions

4.1 The degree of ionization:

$$\alpha = \frac{\text{a number of ionized molecules}}{\text{a total number of dissolved molecules}}$$

4.2 Parameters calculated for strong electrolytes:

- ionic strength: $I = \frac{1}{2}\sum C_i \times Z_i^2$

where C_i is a molarity of ion, mol/L,

Z is charge number of ion i.

- activity: $\mathbf{a} = \gamma \times C_м$

where γ – activity coefficient of an individual ion (cation or anion), which expresses a deviation of a solution from ideal behavior.

4.3 Parameters calculated for weak electrolytes:

- ionization equilibrium constant:

$$K_{ins} = \frac{[Cat] \times [An]}{[CatAn]}$$

- weak acid: $K_a = c\alpha^2$
- weak base: $K_a = c\alpha^2$

where α - the degree of ionization

C – molarity, mol/L

5. Acid-base equilibrium

$pH = - \log [H^+]$

where $[H^+]$ is protons molarity, moL/L

6. Electrochemistry

The Nernst's equation: $\varphi_{Ox/\mathrm{Re}d} = \varphi^{0}_{Ox/\mathrm{Re}d} + \frac{\mathrm{R}\times\mathrm{T}}{\mathrm{n}\times\mathrm{F}} \times \ln \frac{[Ox]}{[\mathrm{Re}d]}$

where R – gas constant (8.31 J/mol K),
n – a number of gained or lost electrons,
F – Faraday constant (96500 C/mol)

The Nernst's equation for the membrane potential is

$$\varphi = \frac{R \times T}{n \times F} \times \ln \frac{[X]\cdot \text{external}}{[X]\cdot \text{internal}}$$

where $[X]_{external}$ and $[x]_{internal}$ are molarity of an ion in external and internal media,
n – an electric charge of an ion.

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