https://doi.org/10.25143/data-booklet-chemistry_RSU-2020

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DEPARTMENT OF HUMAN PHYSIOLOGY
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DATA BOOKLET FOR MEDICAL CHEMISTRY

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Periodic Table

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8
1 **H** Hydrogen 1.008								
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012							
11 **Na** Sodium 22.990	12 **Mg** Magnesium 24.305							
19 **K** Potassium 39.098	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.956	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.942	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.938	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933
37 **Rb** Rubidium 85.468	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.906	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.906	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium 98.907	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.906
55 **Cs** Cesium 132.905	56 **Ba** Barium 137.328	57-71	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.948	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217
87 **Fr** Francium 223.020	88 **Ra** Radium 226.025	89-103	104 **Rf** Rutherfordium [261]	105 **Db** Dubnium [262]	106 **Sg** Seaborgium [266]	107 **Bh** Bohrium [264]	108 **Hs** Hassium [269]	109 **Mt** Meitnerium [278]

Lanthanide Series	57 **La** Lanthanum 138.905	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.908	60 **Nd** Neodymium 144.243	61 **Pm** Promethium 144.913	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964
Actinide Series	89 **Ac** Actinium 227.028	90 **Th** Thorium 232.038	91 **Pa** Protactinium 231.036	92 **U** Uranium 238.029	93 **Np** Neptunium 237.048	94 **Pu** Plutonium 244.064	95 **Am** Americium 243.061

10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
								2 **He** Helium 4.003
			5 **B** Boron 10.811	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998	10 **Ne** Neon 20.180
			13 **Al** Aluminum 26.982	14 **Si** Silicon 28.086	15 **P** Phosphorus 30.974	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
28 **Ni** Nickel 58.693	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.631	33 **As** Arsenic 74.922	34 **Se** Selenium 78.971	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
46 **Pd** Palladium 106.42	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.414	49 **In** Indium 114.818	50 **Sn** Tin 118.711	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.6	53 **I** Iodine 126.904	54 **Xe** Xenon 131.294
78 **Pt** Platinum 195.085	79 **Au** Gold 196.967	80 **Hg** Mercury 200.592	81 **Tl** Thallium 204.383	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.980	84 **Po** Polonium [208.982]	85 **At** Astatine 209.987	86 **Rn** Radon 222.018
110 **Ds** Darmstadtium [281]	111 **Rg** Roentgenium [280]	112 **Cn** Copernicium [285]	113 **Nh** Nihonium [286]	114 **Fl** Flerovium [289]	115 **Mc** Moscovium [289]	116 **Lv** Livermorium [293]	117 **Ts** Tennessine [294]	118 **Og** Oganesson [294]

64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.925	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.930	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.934	70 **Yb** Ytterbium 173.055	71 **Lu** Lutetium 174.967
96 **Cm** Curium 247.070	97 **Bk** Berkelium 247.070	98 **Cf** Californium 251.080	99 **Es** Einsteinium [254]	100 **Fm** Fermium 257.095	101 **Md** Mendelevium 258.1	102 **No** Nobelium 259.101	103 **Lr** Lawrencium [262]

Classification of Inorganic Compounds

Group of inorganic compounds	Examples
Metals Me	**Cu, Pb, Ag**
Non metals	**S, P, O_2, N_2**
Oxides A_nO_m	
Acidic oxides (*make acid when react with water*)	SO_2, CO_2, P_2O_5, NO_2 $CO_2 + H_2O \leftrightarrows H_2CO_3$
Amphoteric oxides (*make both acid or base when react with water*)	Al_2O_3, ZnO $ZnO + H_2O \rightarrow H_2ZnO_2$ $ZnO + H_2O \rightarrow Zn(OH)_2$
Basic oxides (*make base when react with water*)	Na_2O, CaO, MgO $CaO + H_2O \rightarrow Ca(OH)_2$
***Acidic** oxides **react** with **bases** producing **salts** but **do not react with acids**!* $CO_2 + 2NaOH \rightarrow Na_2CO_3$ ***Amphoteric** oxides **react** with both **acids** and **bases** producing **salts**!* $ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$ $ZnO + 2NaOH \rightarrow Na_2ZnO_2 + H_2O$ ***Basic** oxides **react** with **acids** producing **salts** but **do not react with bases**!* $CaO + 2HCl \rightarrow CaCl_2$	
Acids $\mathbf{H_nX^{n-}}$ (produce $\mathbf{H^+}$ ions)	HCl, H_2SO_4, H_3PO_4 $HCOOH$, CH_3COOH
Bases $\mathbf{Me^{m+}(OH)_m}$ (produce $\mathbf{OH^-}$ ions)	$NaOH$, KOH, $Ca(OH)_2$ $Cu(OH)_2$, $Al(OH)_3$, NH_4OH ($NH_3 \cdot H_2O$)
Acids** always **react** with **bases** producing **salt** and **water *(neutralisation reaction)* **Acid + Base → Salt +** $\mathbf{H_2O}$ $\mathbf{H^+ + OH^- \rightarrow H_2O}$ $HCl + NaOH \rightarrow NaCl + H_2O$ $2CH_3COOH + Ca(OH)_2 \rightarrow (CH_3COO)_2Ca + 2H_2O$ $NH_4OH + HNO_3 \rightarrow NH_4NO_3 + H_2O$ ($NH_3 + HNO_3 \rightarrow NH_4NO_3$)	
Salts $\mathbf{Me_nX_m}$	$NaCl$, $CuSO_4$, NH_4Cl, CH_3COONa, PbI_2

Solubility Table of Acids, Bases and Salts in Water

	H^+	NH_4^+	K^+	Na^+	Li^+	Ba^{2+}	Sr^{2+}	Ca^{2+}	Mg^{2+}	Al^{3+}
OH^-	H_2O	s	s	s	s	s	m	m	n	n
F^-	s	s	s	s	n	m	n	n	m	m
Cl^-	s	s	s	s	s	s	s	s	s	s
Br^-	s	s	s	s	s	s	s	s	s	s
I^-	s	s	s	s	s	s	s	s	s	s
S^{2-}	s	s	s	s	s	s	s	+	n	+
SO_3^{2-}	s ↑	s	s	s	s	n	n	n	m	+
SO_4^{2-}	∞	s	s	s	s	n	n	m	s	s
PO_4^{3-}	s	s	s	s	m	n	n	n	n	n
CO_3^{2-}	s ↑	s	s	s	s	n	n	n	n	+
SiO_3^{2-}	n	–	s	s	s	n	n	n	n	n
NO_3^-	∞	s	s	s	s	s	s	s	s	s
CH_3COO^-	s	s	s	s	s	s	s	s	s	s

	Zn^{2+}	Fe^{2+}	Fe^{3+}	Mn^{2+}	Pb^{2+}	Cu^{2+}	Hg^{2+}	Ag^+	Cr^{3+}
OH^-	n	n	n	n	n	n	–	–	n
F^-	m	m	n	s	m	s	+	s	m
Cl^-	s	s	s	s	m	s	s	n	s
Br^-	s	s	s	s	m	s	m	n	s
I^-	s	s	–	s	n	–	n	n	s
S^{2-}	n	n	+	n	n	n	n	n	–
SO_3^{2-}	n	n	+	n	n	–	–	n	–
SO_4^{2-}	s	s	s	s	n	s	+	m	s
PO_4^{3-}	n	n	n	n	n	n	n	n	n
CO_3^{2-}	n	n	+	n	n	–	–	n	–
SiO_3^{2-}	n	n	n	n	n	n	–	–	–
NO_3^-	s	s	s	s	s	s	s	s	s
CH_3COO^-	s	s	s	s	s	s	s	s	s

s	soluble
m	slightly soluble
n	practically insoluble
∞	unlimited solubility
s ↑	decomposes in water with gas emission
+	reacts with water
–	substance in water solution does not exist

Molecular Masses of Some Common Substances

Table shows **molecular mass** of some common substances in **g/mol**

	OH^-	Cl^-	S^{2-}	SO_4^{2-}	PO_4^{3-}	CO_3^{2-}	NO_3^-	CH_3COO^-
H^+	18.02	36.46	34.09	98.03	98.00	62.03	63.02	60.06
NH_4^+	35.06	53.50	68.17	132.11	149.12	96.11	80.06	77.10
Li^+	23.95	42.39	45.95	109.89	115.79	73.89	68.95	65.99
Na^+	40.00	58.44	78.05	141.99	163.94	105.99	85.00	82.04
K^+	56.11	74.55	110.27	174.21	212.27	138.21	101.11	98.15
Mg^{2+}	58.33	95.21	56.38	120.32	262.87	84.32	148.33	142.41
Ca^{2+}	74.10	110.98	72.15	136.09	310.18	100.09	164.10	158.18
Ba^{2+}	171.35	208.23	169.40	233.34	601.93	197.34	261.35	255.43
Al^{3+}	78.01	133.33	150.17	341.99	121.95	–	213.01	204.13
Zn^{2+}	99.40	136.28	97.45	161.39	386.08	125.39	189.40	183.48
Fe^{2+}	89.87	126.75	87.92	151.86	357.49	115.86	179.87	173.95
Fe^{3+}	106.88	162.20	207.91	399.73	150.82	–	241.88	233.00
Pb^{2+}	241.22	278.10	239.27	303.21	811.54	267.21	331.22	325.30
Cu^{2+}	97.57	134.45	95.62	159.56	380.59	–	187.57	181.65

Some other substances

HCOOH	46.03
CO	28.01
CO_2	44.01
N_2	28.02
O_2	32.00
O_3	48.00
$NaHCO_3$	84.01
Glucose $C_6H_{12}O_6$	180.18
Fructose $C_6H_{12}O_6$	180.18

SO_2	64.01
K_2CrO_4	194.20
$K_2Cr_2O_7$	294.20
$NiSO_4$	154.70
$NiCl_2$	129.59
AgCl	143.32
$CrCl_3$	158.35
I_2	253.80
Sucrose $C_{12}H_{22}O_{11}$	342.34

Molecular masses of all elements and substances can always be found using a Periodic table! Molecular masses found on this page could vary from other similar tables or calculations slightly.

Number Prefixes, Greek Letters and Unit Conversion

Common SI prefixes for numbers

Prefix	Symbol	Meaning	Example
giga-	**G**	1’000’000’000 or $\mathbf{10^{9}}$	1 gigamole (Gmol) = $1 \cdot 10^{9}$mol
mega-	**M**	1’000’000 or $\mathbf{10^{6}}$	1 megamole (Mmol) = $1 \cdot 10^{6}$mol
kilo-	**k**	1’000 or $\mathbf{10^{3}}$	1 kilomole (kmol) = $1 \cdot 10^{3}$mol
deci-	**d**	1/10 or $\mathbf{10^{-1}}$	1 decimole (dmol) = 0.1 mol
centi-	**c**	1/100 or $\mathbf{10^{-2}}$	1 centimole (cmol) = 0.01mol
milli-	**m**	1/1’000 or $\mathbf{10^{-3}}$	1 millimole (mmol) = $1 \cdot 10^{-3}$mol
micro-	**μ**	1/1’000’000 or $\mathbf{10^{-6}}$	1 micromole (μmol) = $1 \cdot 10^{-6}$mol
nano-	**n**	1/1’000’000’000 or $\mathbf{10^{-9}}$	1 nanomole (nmol) = $1 \cdot 10^{-9}$mol

Greek letters with pronunciation

Upper case letter	Lower case letter	Pronounced
Α	α	*alpha*
Β	β	*beta*
Γ	γ	*gamma*
Δ	δ	*delta*
Ε	ε	*epsilon*
Ζ	ζ	*zeta*
Η	η	*eta*
Θ	θ	*theta*
Ι	ι	*iota*
Κ	κ	*kappa*
Λ	λ	*lambda*
Μ	μ	*mu*

Upper case letter	Lower case letter	Pronounced
Ν	ν	*nu*
Ξ	ξ	*xi*
Ο	ο	*omikron*
Π	π	*pi*
Ρ	ρ	*rho*
Σ	σ	*sigma*
Τ	τ	*tau*
Υ	υ	*upsilon*
Φ	φ	*phi*
Χ	χ	*chi*
Ψ	ψ	*psi*
Ω	ω	*omega*

Some selected unit conversion

$$1\ \text{atm} = 1.01 \cdot 10^{5}\ \text{Pa} = 760\ \text{mm Hg}$$

$$1\ \text{dm}^3 = 1\ \text{L} = 0.001\ \text{m}^3 = 1000\ \text{cm}^3 = 1000\ \text{mL}$$

$$T\ [\text{K}] = t\ [°\text{C}] + 273.15$$

Quantities, Units and Constants

Physical quantity	Symbol	Unit	Examples
Amount of substance	**n**	mol	$n_{NaCl} = 0.17$ mol
Mass	**m**	g kg, t	$m_{sugar} = 0.73$ g $m_{NaCl} = 1.34$ kg
Volume	**V**	L, dm^3 mL, m^3	$V_{NaCl\ sol.} = 0.174$ L $V_{H_2O} = 0.25$ mL
Density	**ρ**	g/mL kg/ m^3	$\rho_{NaOH\ sol.} = 1.04$ g/mL $\rho_{H_2O} = 1000\ kg/m^3$
Molar mass	**M**	g/mol	$M_{CaCO_3} = 100$ g/mol
Mass fraction	**w**	[0 ÷ 1]	$w_{CaSO_4} = 0.740$
Mass fraction, %	$\mathbf{w_{\%}}$	% [0% ÷ 100%]	$w_{\% CaSO_4} = 74.0$ %
Molar concentration (molarity)	$\mathbf{c_M}$	mol/L = M	$c_{M_{H_2SO_4}} = 2.5$ mol/L $c_{M_{H_2SO_4}} = 2.5$ M [*2.5 molar solution of H_2SO_4*]
Mass concentration	**γ**	mg/mL	$\gamma_{NaCl} = 5$ mg/mL
Temperature	**t**	°C	t = 23.0 °C
Absolute temperature	**T**	K	T = 296.15 K

Physical constant	Symbol	Value	Unit
Universal gas constant	**R**	**8.3145**	$\frac{J}{K \cdot mol}$
Molar volume of an ideal gas at 273.15 K and $1.01 \cdot 10^5$ Pa	$\mathbf{V_o}$	**22.4**	L/mol
Specific heat capacity of water (equal to 1 calorie)	$\mathbf{C_p}$	**4.18**	$\frac{J}{g \cdot K}$

Concentration Calculation Formulas

Physical quantity	Formula
Amount of substance (from mass)	$n_{substance} = \frac{m_{substance}}{M_{substance}}$
Density of the solution	$\rho_{solution} = \frac{m_{solution}}{V_{solution}}$
Mass fraction in percent (from solution mass)	$w_{\%}(solute) = \frac{m_{solute} \cdot 100}{m_{solution}}$
Mass fraction in percent (from solution volume)	$w_{\%}(solute) = \frac{m_{solute} \cdot 100}{\rho_{solution} \cdot V_{solution}}$
Molar concentration (molarity, from solute amount)	$c_{M,\,solute} = \frac{n_{solute}}{V_{solution}}$
Molar concentration (molarity, from solute mass)	$c_{M,\,solute} = \frac{m_{solute}}{M_{solute} \cdot V_{solution}}$
Mass concentration	$\gamma_{solute} = \frac{m_{solute}}{V_{solution}}$
Dilution (for various concentrations)	$c_1 \cdot V_1 = c_2 \cdot V_2$

Standard Electrode Potentials

Oxidized form	Number of electrons e^-	Reduced form	Standard potential E^o at 25 °C, V
$F_2(g)$	2	$2F^-$	+ 2.87
$H_2O_2 + 2H^+$	2	$2H_2O(l)$	+ 1.78
$MnO_4^- + 8H^+$	5	$Mn^{2+} + 4H_2O(l)$	+ 1.51
$Cr_2O_7^{2-} + 14H^+$	6	$2Cr^{3+} + 7H_2O(l)$	+ 1.36
$Cl_2(g)$	2	$2Cl^-$	+ 1.36
$O_2(g) + 4H^+$	4	$2H_2O(l)$	+ 1.23
$Br_2(g)$	2	$2Br^-$	+ 1.07
$NO_3^- + 2H^+$	2	$NO_2^- + H_2O(l)$	+ 0.93
Ag^+	1	$Ag(s)$	+ 0.80
Fe^{3+}	1	Fe^{2+}	+ 0.77
$O_2(g) + 2H^+$	2	H_2O_2	+ 0.70
$MnO_4^- + 2H_2O(l)$	3	$MnO_2(s) + 4OH^-$	+ 0.60
MnO_4^- (*in basic env.*)	1	MnO_4^{2-}	+ 0.56
$I_2(s)$	2	$2I^-$	+ 0.54
Cu^{2+}	2	$Cu(s)$	+ 0.34
$SO_4^{2-} + 2H^+$	2	$SO_3^{2-} + H_2O(l)$	+ 0.17
$S(s) + 2H^+$	2	H_2S	+ 0.14
$S_4O_6^{2-}$	2	$2S_2O_3^{2-}$	+ 0.08
$NO_3^- + H_2O(l)$	2	$NO_2^- + 2OH^-$	+ 0.01
$2H^+$	**2**	**$H_2(g)$**	**0.00**
$CrO_4^{2-} + 4H_2O(l)$	3	$Cr(OH)_3(s) + 5OH^-$	– 0.13
Ni^{2+}	2	$Ni(s)$	– 0.25
$S(s)$	2	S^{2-}	– 0.43
$2CO_2(g) + 2H^+$	2	$H_2C_2O_4$	– 0.49
Cr^{3+}	3	$Cr(s)$	– 0.74
Zn^{2+}	2	$Zn(s)$	– 0.76
$SO_4^{2-} + H_2O(l)$	2	$SO_3^{2-} + 2OH^-$	– 0.93
Al^{3+}	3	$Al(s)$	– 1.66
Li^+	1	$Li(s)$	– 3.04

All species are in aqueous (aq) solutions unless indicated otherwise.

Haynes, William M. (ed.) (2010). *CRC Handbook of Chemistry and Physics (*91st ed.).
Boca Raton, FL: CRC Press (Taylor & Francis Group). ISBN 978-1-4398-2077-3.

Electrolytes, Ions and Solutions

Ostwald's dilution law (for weak electrolytes only) $K_{dis} = \frac{\alpha^2 \cdot c_M}{1-\alpha}$ $1-\alpha \approx 1$	$AB \rightleftharpoons A^+ + B^-$ $[A^+] = [B^-] = c_{dis} = \alpha \cdot c_M$
Disociation degree α $\alpha = \frac{n_{\text{ionised}}}{n_{\text{total}}} = \frac{c_{M\ \text{ionised}}}{c_{M\ \text{total}}}$ $\alpha = \sqrt{\frac{K_{dis.}}{C_M}}$	*Example:* $K_{dis.} = 1.75 \cdot 10^{-5}; c_M = 0.010\ M$ $\alpha = \sqrt{\frac{1.75 \cdot 10^{-5}}{0.01}} = 0.04$
Electrolytes	Non-electrolytes $\alpha = 0$ Weak electrolytes $0 < \alpha < 1$ Strong electrolytes $\alpha \approx 1$
Osmotic pressure *π, kPa* $\pi = i \cdot c_M \cdot R \cdot T$	*Example:* At 25.0 °C or 298.15 K 0.200 M glucose solution (non-electrolyte, $\alpha \approx 0$; $i = 1$) $\pi = 1 \cdot 0.200 \cdot 8.3145 \cdot 298.15 = 496\ kPa$ 0.200 M Na_2SO_4 solution (strong electrolyte, $\alpha \approx 1$; $i = 3$) $\pi = 3 \cdot 0.200 \cdot 8.3145 \cdot 298.15 = 1490\ kPa$
Isotonic coefficient *i* $i = 1 + \alpha(N-1)$ *N – the number of particles produced when dissociating*	*Example:* Na_2SO_4 (strong electrolyte), $\alpha \approx 1$ $Na_2SO_4 \rightarrow \underline{\mathbf{2}}Na^+ + \underline{\mathbf{1}}SO_4^{2-}$ $N = \underline{\mathbf{2}} + \underline{\mathbf{1}} = 3$ $i = 1 + 1(3-1) = 3$
Chemical equilibrium $aA + bB \rightleftharpoons cC + dD$ $K_{eq} = \frac{[C]^c \cdot [D]^d}{[A]^a \cdot [B]^b}$	*Example:* $Ca_3(PO_4)_2(s) \rightleftharpoons 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$ $K_{eq} = \frac{[Ca^{2+}]^3 \cdot [PO_4^{3-}]^2}{[Ca_3(PO_4)_2]}$ $K_{sp} = [Ca^{2+}]^3 \cdot [PO_4^{3-}]^2$

Thermodynamic and Reaction Kinetics Calculations

Gibbs free energy

$$\mathbf{\Delta G = \Delta H - T \cdot \Delta S}$$

$\mathbf{\Delta G < 0}$	process (reaction) is spontaneous
$\mathbf{\Delta G > 0}$	process is non-spontaneous
$\mathbf{\Delta G = 0}$	process is in an equilibrium

$$\textbf{Reactants} \rightarrow \textbf{Products}$$

Enthalpy of reaction

$$\Delta H^o_{reaction} = \sum \Delta H^o_{products} - \sum \Delta H^o_{reactants}$$

Entropy of reaction

$$\Delta S^o_{reaction} = \sum \Delta S^o_{products} - \sum \Delta S^o_{reactants}$$

Gibbs free energy of reaction

$$\Delta G^o_{reaction} = \sum \Delta G^o_{products} - \sum \Delta G^o_{reactants}$$

Example: $CuCl_2(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + 2NaCl(aq)$

$$\Delta H^o_{reaction} = \left(\Delta H^o_{Cu(OH)_2} + 2 \cdot \Delta H^o_{NaCl}\right) - \left(\Delta H^o_{CuCl_2} + 2 \cdot \Delta H^o_{NaOH}\right)$$

$$\Delta S^o_{reaction} = \left(\Delta S^o_{Cu(OH)_2} + 2 \cdot \Delta S^o_{NaCl}\right) - \left(\Delta S^o_{CuCl_2} + 2 \cdot \Delta S^o_{NaOH}\right)$$

$$\Delta G^o_{reaction} = \Delta H^o_{reaction} - T \cdot \Delta S^o_{reaction}$$

or

$$\Delta G^o_{reaction} = \left(\Delta G^o_{Cu(OH)_2} + 2 \cdot \Delta G^o_{NaCl}\right) - \left(\Delta G^o_{CuCl_2} + 2 \cdot \Delta G^o_{NaOH}\right)$$

Reaction kinetics

1st rate reaction kinetics

$$A \rightarrow \text{products}$$

$$t_{1/2} = \frac{\ln 2}{{}_1k}$$

Example:
1st rate reaction constant ${}_1k = 1.7 \cdot 10^{-3}$

$$t_{1/2} = \frac{0.693}{1.7 \cdot 10^{-3}} = 407.6 \text{ s}$$

Acid-Base Calculations

Formula	Example
$pH = -\log_{10}[H^+] = -lg[H^+]$	pH of 0.085 M HNO_3 $pH = -lg(0.085) = 1.07$
$pOH = -lg[OH^-]$	pH of 0.00765 M KOH; $[KOH] = [OH^-]$ $pOH = -lg(0.00765) = 2.116$ $pH = 14 - pOH = 11.884$
$pH + pOH = 14$	
$[H^+] = 10^{-pH}$ $[OH^-] = 10^{-pOH}$	$pH = 1.00; [H^+] = 10^{-1.00} = 0.10\ M$
$[H^+] = \alpha \cdot c_{M_a}$ $[OH^-] = \alpha \cdot c_{M_b}$	HCl is strong acid, strong electrolyte, $\alpha \approx 1$ $c_M = 0.12\ M$ $[H^+] = 1 \cdot 0.12 = 0.12\ M$ $pH = -lg(0.12) = 0.92$
$[H^+] = \sqrt{K_a \cdot c_M}$ $[OH^-] = \sqrt{K_b \cdot c_M}$	$K = 1.78 \cdot 10^{-5}; c_M = 0.100\ M$ $[H^+] = \sqrt{1.78 \cdot 10^{-5} \cdot 0.1} = 0.00133\ M$
$pK_a = -lg[K_a]$ $pK_b = -lg[K_b]$	$K_a = 1.74 \cdot 10^{-5}$ $pK_a = -lg(1.74 \cdot 10^{-5}) = 4.759$
$K = 10^{-pK}$	$pK_a = 4.75;\ K = 10^{-4.75} = 1.78 \cdot 10^{-5}$
General dissociation constant **weak acid:** $K_a = K_{dis} = \frac{[H^+] \cdot [A^-]}{[HA]}$	$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ $K_a = K_{dis} = \frac{[H^+] \cdot [CH_3COO^-]}{[CH_3COOH]}$
General dissociation constant **weak base:** $K_b = K_{dis} = \frac{[OH^-] \cdot [B^+]}{[BOH]}$	$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ $K_b = K_{dis} = \frac{[OH^-] \cdot [NH_4^+]}{[NH_4OH]}$
pH for **weak acid:** $pH = \frac{pK_a - lgc_{M_a}}{2}$	$pK_a = 4.75; c_M = 0.100\ M$ $pH = \frac{4.75 - lg0.1}{2} = \frac{4.75 - (-1)}{2} = \frac{5.75}{2} = 2.875$
pOH for **weak base:** $pOH = \frac{pK_b - lgc_{M_b}}{2}$	$pK_b = 4.75; c_M = 0.0100\ M$ $pOH = \frac{4.75 - lg0.01}{2} = \frac{4.75 - (-2)}{2} = \frac{6.75}{2} = 3.375$

Acid and Base Dissociation Constants

Some selected acidic substance dissociation constants

Name	Formula	K_a	pK_a
Hydrochloric acid	HCl	$1 \cdot 10^{7}$	–7
Sulphuric acid	H_2SO_4	(I) $1 \cdot 10^{2}$ (II) $1.1 \cdot 10^{-2}$	–2 1.96
Nitric acid	HNO_3	$3.4 \cdot 10^{1}$	–1.53
Oxalic acid	$H_2C_2O_4$	(I) $5.6 \cdot 10^{-2}$ (II) $1.5 \cdot 10^{-4}$	1.25 3.81
Sulphurous acid	H_2SO_3	(I) $1.4 \cdot 10^{-2}$ (II) $6 \cdot 10^{-8}$	1.85 7.2
Phosphoric acid	H_3PO_4	(I) $6.9 \cdot 10^{-3}$ (II) $6.2 \cdot 10^{-8}$ (III) $4.8 \cdot 10^{-13}$	2.16 7.21 12.32
Hydrofluoric acid	HF	$6.3 \cdot 10^{-4}$	3.20
Acetylsalicylic acid	$C_9H_8O_4$	$3.3 \cdot 10^{-4}$	3.48
Formic acid	$HCOOH$	$1.8 \cdot 10^{-4}$	3.75
Ascorbic acid	$C_6H_8O_6$	(I) $9.1 \cdot 10^{-5}$ (II) $2 \cdot 10^{-12}$	4.04 11.7
Acetic acid	CH_3COOH	$1.75 \cdot 10^{-5}$	4.756
Carbonic acid	H_2CO_3	(I) $4.5 \cdot 10^{-7}$ (II) $4.7 \cdot 10^{-11}$	6.35 10.33
Hydrogen sulphide	H_2S	(I) $8.9 \cdot 10^{-8}$ (II) $1 \cdot 10^{-19}$	7.05 19
Silicic acid	H_2SiO_3	(I) $1 \cdot 10^{-10}$ (II) $1.58 \cdot 10^{-12}$	9.9 11.8

Some selected basic substance dissociation constants

Name	Formula	K_b	pK_b
Lead (II) hydroxide	$Pb(OH)_2$	(I) $2.0 \cdot 10^{-4}$	3.70
Zinc hydroxide	$Zn(OH)_2$	(II) $4.0 \cdot 10^{-5}$	4.40
Ammonia	NH_3 ($NH_3 \cdot H_2O$)	$1.8 \cdot 10^{-5}$	4.75
Copper (II) hydroxide	$Cu(OH)_2$	(II) $3.4 \cdot 10^{-7}$	6.47
Iron (III) hydroxide	$Fe(OH)_3$	(I) $7.8 \cdot 10^{-8}$ (II) $3.9 \cdot 10^{-10}$ (III) $6.8 \cdot 10^{-12}$	7.11 9.41 11.17
Aluminium hydroxide	$Al(OH)_3$	(III) $1.4 \cdot 10^{-9}$	8.86
Chromium (III) hydroxide	$Cr(OH)_3$	(III) $1.0 \cdot 10^{-10}$	9.99

Notes the dissociation step described by K value.

Haynes, William M. (ed.) (2010). *CRC Handbook of Chemistry and Physics (*91st ed.).
Boca Raton, FL: CRC Press (Taylor & Francis Group). ISBN 978-1-4398-2077-3.

Buffer Solutions

Buffer system can be composed of:

1) **weak acid** and **its salt**
(mixed together directly or created with **weak acid** and **strong base in limited supply**);
2) **weak base** and **its salt**
(mixed together directly or created with **weak base** and **strong acid in limited supply**);
3) **weak bivalent acid** and its **acidic salt**;
4) **two salts** of the **same polyvalent acid**
(differing in 1 hydrogen ion; the salt that contains greater number of H^+ acts as the acid in a buffer system).

Buffer solution (weak acid/salt of weak acid) $pH = pK_a + \lg\left(\frac{n_{conj.\ base}}{n_{acid}}\right)$ $pH = pK_a + \lg\left(\frac{c^0_{c.base} \cdot V^0_{c.base}}{c^0_{acid} \cdot V^0_{acid}}\right)$	Calculate pH of a buffer, if it is composed from 300 mL of 0.150 M HCOOH (week acid) and 200 mL of 0.0900 M HCOONa (salt of weak acid, acts as conj. base) solution, $pK_a = 3.7$ $pH = 3.7 + \lg\left(\frac{0.09 \cdot 0.2}{0.3 \cdot 0.15}\right) = 3.7 - 0.398 = 3.3$
Buffer solution (weak base/salt of weak base) $pOH = pK_b + \lg\left(\frac{n_{conj.\ acid}}{n_{base}}\right)$ $pOH = pK_b + \lg\left(\frac{c^0_{c.acid} \cdot V^0_{c.acid}}{c^0_{base} \cdot V^0_{base}}\right)$	Calculate pH of a buffer, if it is composed from 80 mL of 0.10 M NH_4OH (week base) and 120 mL of 0.17 M NH_4Cl (salt of weak base, acts as conj. acid) solution, $pK_b = 4.75$ $pOH = 4.75 + \lg\left(\frac{0.17 \cdot 0.12}{0.1 \cdot 0.08}\right) = 5.16$ $pH = 14 - pOH = 8.84$
Buffer capacity β, mol/L $\beta = \frac{n_{H^+_{added}}}{\lvert\Delta pH\rvert \cdot V_{buffer\ solution}}$ $\beta = \frac{n_{OH^-_{added}}}{\lvert\Delta pOH\rvert \cdot V_{buffer\ solution}}$	Find buffer capacity for 50. mL of a buffer solution to which 0.11 mol of strong acid was added causing pH change $\Delta pH = 0.27$ $\beta = \frac{0.11\ mol}{0.27 \cdot 0.05\ L} = 8.1\ mol/L$

Complex Compounds

Charges and coordination numbers of central ions

(only some common examples included)

Charge of central ion	Coordination number by empiric rule	Examples
+1	2	Ag^{+}, Au^{+}
+2	4	$Cu^{2+}, Hg^{2+}, Pt^{2+}, Ni^{2+}, Zn^{2+}, Cd^{2+}, Co^{2+}, Pb^{2+}$
+3	6	$Fe^{3+}, Al^{3+}, Cr^{3+}, Co^{3+}$

Some exceptions	Coordination number
Li^{+}	4
Fe^{2+}	6
Au^{3+}	4

Ligand "strength" of some common ligands

$$CO > CN^{-} > NO_2^{-} > NH_3 > H_2O > C_2O_4^{2-} > OH^{-} > NO_3^{-} > Cl^{-} > SCN^{-} > S^{2-} > Br^{-} > I^{-}$$

Instability of complex compounds

$$\mathbf{Na_3[Cr(OH)_6] \rightarrow 3Na^{+} + [Cr(OH)_6]^{3-}}$$

$$\mathbf{[Cr(OH)_6]^{3-} \rightleftharpoons Cr^{3+} + 6OH^{-}}$$

$$K_{inst.} = K_{dis.} = \frac{[Cr^{3+}] \cdot [OH^{-}]^6}{[[Cr(OH)_6]^{3-}]}$$

$$K_{stab.} = \frac{1}{K_{instab.}}$$

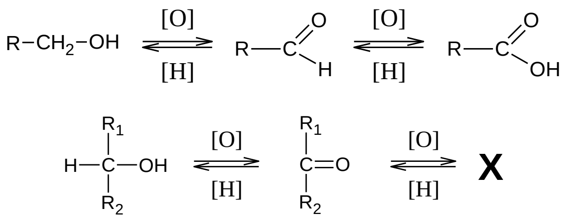
Some Common Functional Groups and Types of Reactions

Some common functional groups

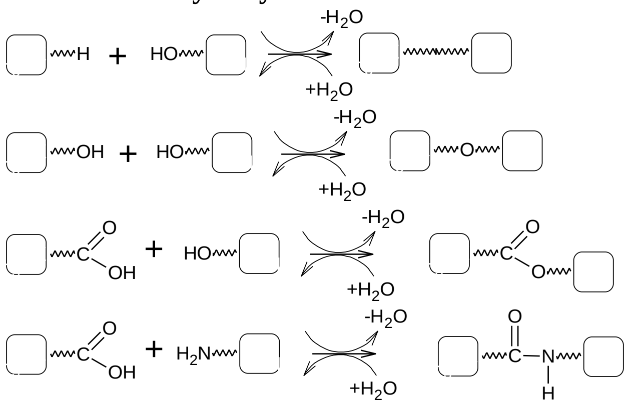
Functional group	Structure	Prefix	Main class of organic compounds	Comments
Alcohol	—OH	**hydroxy-**	Alcohols	Slightly acidic, H^+ donor
Carbonyl **aldehyde**	—C(=O)H	**formyl-**	Aldehydes	—
Carbonyl **ketone**	—C(=O)—	**oxo-**	Ketones	—
Carboxylic acid	—C(=O)OH	**carboxy-**	Carboxylic acids	Acidic, H^+ donor
Amine	—NH_2	**amino-**	Amines	Basic, H^+ acceptor

Schematics of some major types of organic reactions

- **Oxidation-Reduction**



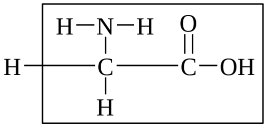
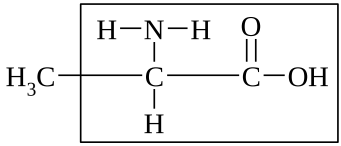
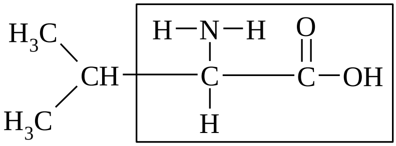
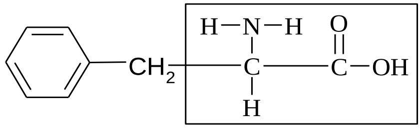
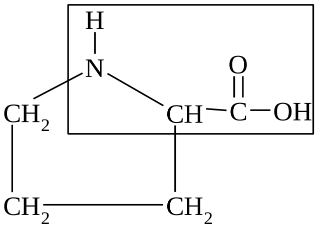
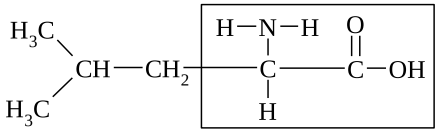
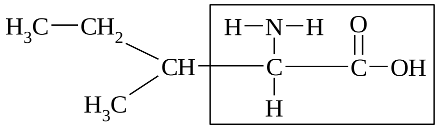
- **Condensation** and **Hydrolysis**



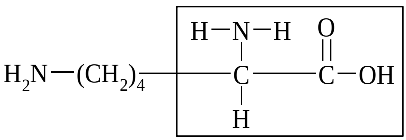
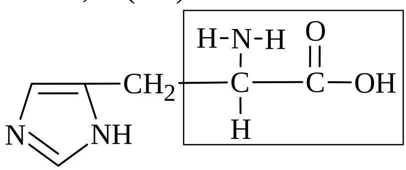
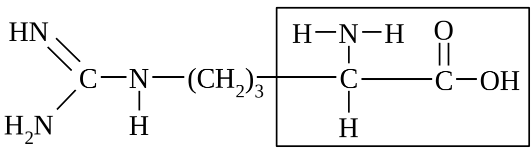
etc.

α-Amino Acids

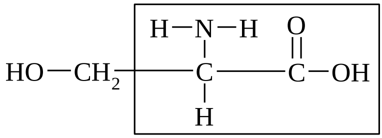
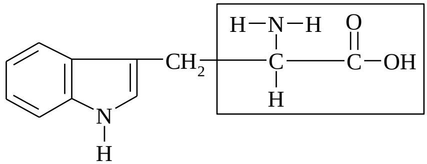
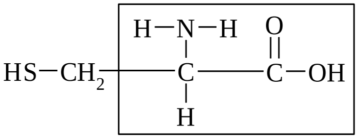
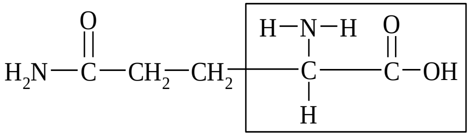
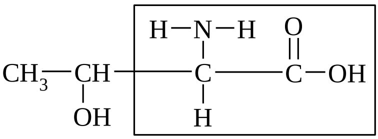
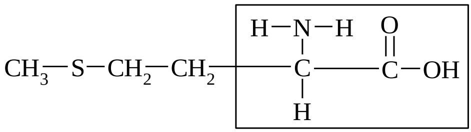
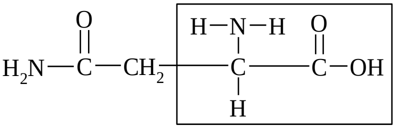
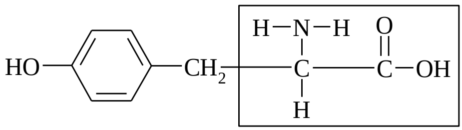
Nonpolar, aliphatic R groups

Glycine, G (Gly) 	Alanine, A (Ala) 
Valine, V (Val) 	Phenylalanine, F (Phe) 
Proline, P (Pro) 	Leucine, L (Leu)  Isoleucine, I (Ile) 

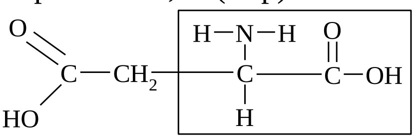
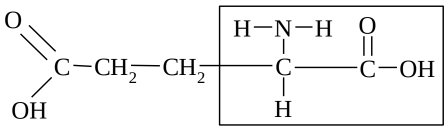
Basic α-amino acids

Lysine, K (Lys) 	Histidine, H (His) 
Arginine, R (Arg)	

Polar, uncharged R groups

Serine, S (Ser) 	Tryptophan, W (Trp) 
Cysteine, C (Cys) 	Glutamine, Q (Gln) 
Threonine, T (Thr) 	Methionine, M (Met) 
Asparagine, N (Asn) 	Tyrosine, Y (Tyr) 

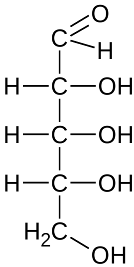
Acidic α-amino acids

Aspartic acid, D (Asp) 	Glutamic acid, E (Glu) 

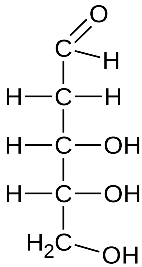
For each amino acid: Name, Single letter code (three letter code).

Structural Formulas of Carbohydrates: Fischer projections

Pentose – Aldopentose

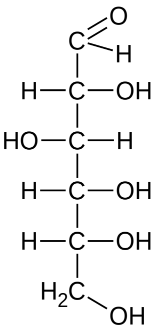


Ribose

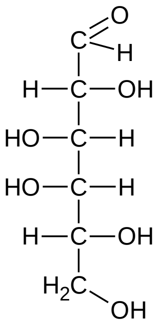


2-Deoxyribose

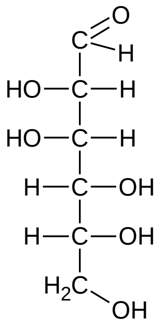
Hexose – Aldohexose



Glucose

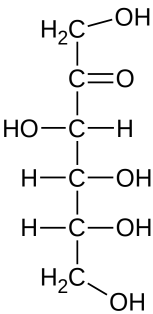


Galactose



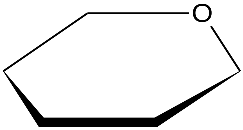
Mannose

Hexose – Ketohexose

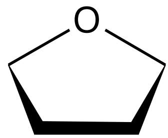


Fructose

Structural Formulas of Carbohydrates: Haworth projections

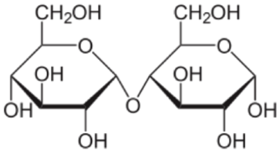


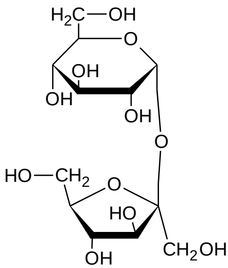
pyranose cycle

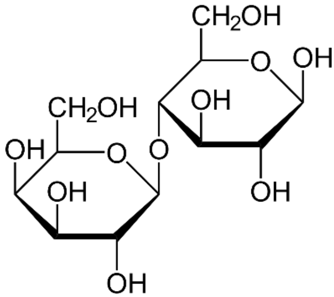


furanose cycle

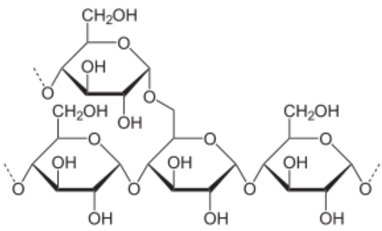
Examples of Disaccharides

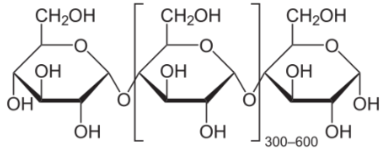






Examples of Polysaccharides





Lipids and Fatty Acids

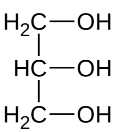
Saturated fatty acids

Common name	C:Double bonds
Caprylic acid	8:0
Capric acid	10:0
Lauric acid	12:0
Myristic acid	14:0
Palmitic acid	16:0
Stearic acid	18:0
Arachidic acid	20:0
Behenic acid	22:0
Lignoceric acid	24:0
Cerotic acid	26:0

Unsaturated fatty acids

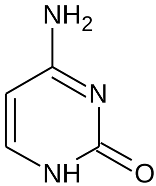
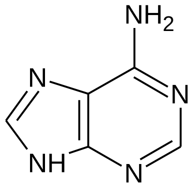
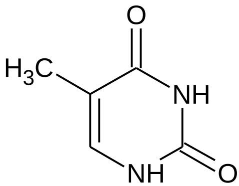
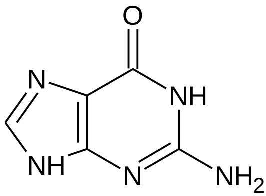
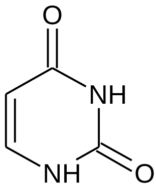
Common name	Δ^x	C:Double bonds
Myristoleic acid	cis-Δ^9	14:1
Palmitoleic acid	cis-Δ^9	16:1
Sapienic acid	cis-Δ^6	16:1
Oleic acid	cis-Δ^9	18:1
Elaidic acid	trans-Δ^9	18:1
Vaccenic acid	trans-Δ^{11}	18:1
Linoleic acid	cis,cis-Δ^9,Δ^{12}	18:2
Linoelaidic acid	trans,trans-Δ^9,Δ^{12}	18:2
α-Linolenic acid	cis,cis,cis-$\Delta^9,\Delta^{12},\Delta^{15}$	18:3
Arachidonic acid	cis,cis,cis,cis-$\Delta^5,\Delta^8,\Delta^{11},\Delta^{14}$	20:4
Eicosapentaenoic acid	cis,cis,cis,cis,cis-$\Delta^5,\Delta^8,\Delta^{11},\Delta^{14},\Delta^{17}$	20:5
Erucic acid	cis-Δ^{13}	22:1
Docosahexaenoic acid	cis,cis,cis,cis,cis,cis-$\Delta^4,\Delta^7,\Delta^{10},\Delta^{13},\Delta^{16},\Delta^{19}$	22:6

Glycerol (Glycerine, Propane-1,2,3-triol)

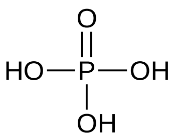


Elements of DNA / RNA

Nitrogen bases

Pyrimidine bases	Purine bases
 **Cytosine**	 **Adenine**
 **Thymine**	 **Guanine**
 **Uracil**	

Phosphoric acid H_3PO_4



Data Booklet for Medical Chemistry.
Authors: Mihails Haļitovs, Ilmārs Rikmanis, Agnese Brangule.
Rīga: Rīga Stradiņš University (Department of Human Physiology and Biochemistry), 2020. 23 p.

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