

Periodic Table of the Elements

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.00794 +1 -1																	2 He 4.00260 0
2	3 Li 6.941 +1	4 Be 9.01218 +2																10 Ne 20.180 0
3	11 Na 22.98977 +1	12 Mg 24.305 +2																18 Ar 39.948 0
4	19 K 39.0983 +1	20 Ca 40.08 +2	21 Sc 44.9559 +3	22 Ti 47.867 +3	23 V 50.9415 +2	24 Cr 51.996 +2	25 Mn 54.9380 +2	26 Fe 55.845 +2	27 Co 58.9332 +2	28 Ni 58.693 +2	29 Cu 63.546 +2	30 Zn 65.409 +2	31 Ga 69.723 +3	32 Ge 72.64 +3	33 As 74.9216 +3	34 Se 78.96 +2	35 Br 79.904 -1	36 Kr 83.798 0
5	37 Rb 85.4678 +1	38 Sr 87.62 +2	39 Y 88.9059 +3	40 Zr 91.224 +4	41 Nb 92.9064 +4	42 Mo 95.94 +3	43 Tc 98 +4	44 Ru 101.07 +4	45 Rh 102.906 +3	46 Pd 106.42 +2	47 Ag 107.868 +1	48 Cd 112.41 +2	49 In 114.818 +3	50 Sn 118.71 +2	51 Sb 121.760 +3	52 Te 127.60 -2	53 I 126.904 -1	54 Xe 131.29 0
6	55 Cs 132.905 +1	56 Ba 137.33 +2	57 La 138.9055 +3	72 Hf 178.49 +4	73 Ta 180.948 +5	74 W 183.84 +6	75 Re 186.207 +7	76 Os 190.23 +6	77 Ir 192.217 +3	78 Pt 195.08 +2	79 Au 196.967 +1	80 Hg 200.59 +2	81 Tl 204.383 +3	82 Pb 207.2 +2	83 Bi 208.980 +3	84 Po 209 +2	85 At 210 +4	86 Rn 222 0
7	87 Fr (223) +1	88 Ra (226) +2	89 Ac (227) +3	104 Rf (261) +4	105 Db (262) +4	106 Sg (266) +4	107 Bh (272) +4	108 Hs (277) +4	109 Mt (276) +3	110 Ds (281) +3	111 Rg (280) +2	112 Cn (285) +3	113** Uut (284) +3	114 Uuq (289) +3	115 Uup (288) +3	116 Uuh (292) +3	117 Uus (?) +3	118 Uuo (294) +3
													66 Dy 162.500 +3	67 Ho 164.930 +3	68 Er 167.259 +3	69 Tm 168.934 +3	70 Yb 173.04 +2	71 Lu 174.9668 +3
													98 Cf (251) +3	99 Es (252) +3	100 Fm (257) +3	101 Md (258) +2	102 No (259) +3	103 Lr (262) +3
													94 Pu (244) +3	95 Am (243) +4	96 Cm (247) +4	97 Bk (247) +3	98 Cf (251) +3	99 Es (252) +3
													93 Np (237) +3	94 Pu (244) +3	95 Am (243) +4	96 Cm (247) +4	97 Bk (247) +3	98 Cf (251) +3
													92 U 238.029 +4	93 Np 237 +3	94 Pu 238.029 +4	95 Am 243 +3	96 Cm 247 +3	97 Bk 247 +3
													91 Pa 231.036 +3	92 U 238.029 +4	93 Np 237 +3	94 Pu 244 +3	95 Am 243 +4	96 Cm 247 +3
													90 Th 232.038 +4	91 Pa 231.036 +3	92 U 238.029 +4	93 Np 237 +3	94 Pu 244 +3	95 Am 243 +4

KEY

Atomic Mass →

12.011

Symbol →

C

Atomic Number →

6

← Selected Oxidation States

-4
+2
+4

Chemistry Equations & Constants

Throughout the test the following symbols have the definitions specified unless otherwise noted.

L, mL = liter(s), milliliter(s)

g = gram(s)

nm = nanometer(s)

atm = atmosphere(s)

mm Hg = millimeters of mercury

J, kJ = joule(s), kilojoule(s)

V = volt(s)

mol = mole(s)

ATOMIC STRUCTURE

$$E = h\nu$$

$$c = \lambda\nu$$

E = energy

ν = frequency

λ = wavelength

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light, $c = 2.998 \times 10^8$ m s⁻¹

Avogadro's number = 6.022×10^{23} mol⁻¹

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

EQUILIBRIUM

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}, \text{ where } a A + b B \rightleftharpoons c C + d D$$

$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$= K_a \times K_b$$

$$\text{pH} = -\log[H^+], \text{ pOH} = -\log[OH^-]$$

$$14 = \text{pH} + \text{pOH}$$

$$\text{pH} = \text{p}K_a + \log \frac{[A^-]}{[HA]}$$

$$\text{p}K_a = -\log K_a, \text{ p}K_b = -\log K_b$$

Equilibrium Constants

K_c (molar concentrations)

K_p (gas pressures)

K_a (weak acid)

K_b (weak base)

K_w (water)

KINETICS

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$t_{1/2} = \frac{0.693}{k}$$

k = rate constant

t = time

$t_{1/2}$ = half-life

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$P_A = P_{\text{total}} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{\text{total}} = P_A + P_B + P_C + \dots$$

$$n = \frac{m}{M}$$

$$K = ^\circ\text{C} + 273$$

$$D = \frac{m}{V}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

Molarity, M = moles of solute per liter of solution

$$A = abc$$

P = pressure

V = volume

T = temperature

n = number of moles

m = mass

M = molar mass

D = density

KE = kinetic energy

v = velocity

A = absorbance

a = molar absorptivity

b = path length

c = concentration

Gas constant, $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

$= 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$

$= 62.36 \text{ L torr mol}^{-1} \text{ K}^{-1}$

$1 \text{ atm} = 760 \text{ mm Hg}$

$= 760 \text{ torr}$

STP = 0.00°C and 1.000 atm

THERMOCHEMISTRY/ ELECTROCHEMISTRY

$$q = mc\Delta T \quad q = mH_F \quad q = mH_V$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K$$

$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

H_V = heat of vaporization H_F = heat of fusion

q = heat

m = mass

c = specific heat capacity

T = temperature

S° = standard entropy

H° = standard enthalpy

G° = standard free energy

n = number of moles

E° = standard reduction potential

I = current (amperes)

q = charge (coulombs)

t = time (seconds)

Faraday's constant, $F = 96,485 \text{ coulombs per mole of electrons}$

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

**RELATIVE STRENGTHS OF ACIDS IN AQUEOUS
SOLUTION AT 1 atm AND 298 K**

Conjugate Pairs		K_a
ACID	BASE	
$\text{HI} = \text{H}^+ + \text{I}^-$		very large
$\text{HBr} = \text{H}^+ + \text{Br}^-$		very large
$\text{HCl} = \text{H}^+ + \text{Cl}^-$		very large
$\text{HNO}_3 = \text{H}^+ + \text{NO}_3^-$		very large
$\text{H}_2\text{SO}_4 = \text{H}^+ + \text{HSO}_4^-$		large
$\text{H}_2\text{O} + \text{SO}_2 = \text{H}^+ + \text{HSO}_3^-$		1.5×10^{-2}
$\text{HSO}_4^- = \text{H}^+ + \text{SO}_4^{2-}$		1.2×10^{-2}
$\text{H}_3\text{PO}_4 = \text{H}^+ + \text{H}_2\text{PO}_4^-$		7.5×10^{-3}
$\text{Fe}(\text{H}_2\text{O})_6^{3+} = \text{H}^+ + \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+}$		8.9×10^{-4}
$\text{HNO}_2 = \text{H}^+ + \text{NO}_2^-$		4.6×10^{-4}
$\text{HF} = \text{H}^+ + \text{F}^-$		3.5×10^{-4}
$\text{Cr}(\text{H}_2\text{O})_6^{3+} = \text{H}^+ + \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}$		1.0×10^{-4}
$\text{CH}_3\text{COOH} = \text{H}^+ + \text{CH}_3\text{COO}^-$		1.8×10^{-5}
$\text{Al}(\text{H}_2\text{O})_6^{3+} = \text{H}^+ + \text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$		1.1×10^{-5}
$\text{H}_2\text{O} + \text{CO}_2 = \text{H}^+ + \text{HCO}_3^-$		4.3×10^{-7}
$\text{HSO}_3^- = \text{H}^+ + \text{SO}_3^{2-}$		1.1×10^{-7}
$\text{H}_2\text{S} = \text{H}^+ + \text{HS}^-$		9.5×10^{-8}
$\text{H}_2\text{PO}_4^- = \text{H}^+ + \text{HPO}_4^{2-}$		6.2×10^{-8}
$\text{NH}_4^+ = \text{H}^+ + \text{NH}_3$		5.7×10^{-10}
$\text{HCO}_3^- = \text{H}^+ + \text{CO}_3^{2-}$		5.6×10^{-11}
$\text{HPO}_4^{2-} = \text{H}^+ + \text{PO}_4^{3-}$		2.2×10^{-13}
$\text{HS}^- = \text{H}^+ + \text{S}^{2-}$		1.3×10^{-14}
$\text{H}_2\text{O} = \text{H}^+ + \text{OH}^-$		1.0×10^{-14}
$\text{OH}^- = \text{H}^+ + \text{O}^{2-}$		$< 10^{-36}$
$\text{NH}_3 = \text{H}^+ + \text{NH}_2^-$		very small

Note: $\text{H}^+(\text{aq}) = \text{H}_3\text{O}^+$

Sample equation: $\text{HI} + \text{H}_2\text{O} = \text{H}_3\text{O}^+ + \text{I}^-$

**CONSTANTS FOR VARIOUS EQUILIBRIA
AT 1 atm AND 298 K**

$\text{H}_2\text{O}(\ell) = \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$	$K_w = 1.0 \times 10^{-14}$
$\text{H}_2\text{O}(\ell) + \text{H}_2\text{O}(\ell) = \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$	$K_w = 1.0 \times 10^{-14}$
$\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) = \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$	$K_b = 5.6 \times 10^{-10}$
$\text{NaF}(\text{aq}) + \text{H}_2\text{O}(\ell) = \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq}) + \text{HF}(\text{aq})$	$K_b = 1.5 \times 10^{-11}$
$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\ell) = \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$	$K_b = 1.8 \times 10^{-5}$
$\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) = \text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq})$	$K_b = 1.8 \times 10^{-4}$
$\text{Ag}(\text{NH}_3)_2^+(\text{aq}) = \text{Ag}^+(\text{aq}) + 2\text{NH}_3(\text{aq})$	$K_{eq} = 8.9 \times 10^{-8}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) = 2\text{NH}_3(\text{g})$	$K_{eq} = 6.7 \times 10^5$
$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) = 2\text{HI}(\text{g})$	$K_{eq} = 3.5 \times 10^{-1}$

Compound	K_{sp}	Compound	K_{sp}
AgBr	5.0×10^{-13}	Li_2CO_3	2.5×10^{-2}
AgCl	1.8×10^{-10}	PbCl_2	1.6×10^{-5}
Ag_2CrO_4	1.1×10^{-12}	PbCO_3	7.4×10^{-14}
AgI	8.3×10^{-17}	PbCrO_4	2.8×10^{-13}
BaSO_4	1.1×10^{-10}	PbI_2	7.1×10^{-9}
CaSO_4	9.1×10^{-6}	ZnCO_3	1.4×10^{-11}

STANDARD ELECTRODE POTENTIALS	
Ionic Concentrations 1 M Water At 298 K, 1 atm	
Half-Reaction	E^0 (volts)
$\text{F}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{F}^-$	+2.87
$8\text{H}^+ + \text{MnO}_4^- + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51
$\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au}(\text{s})$	+1.50
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-$	+1.36
$14\text{H}^+ + \text{Cr}_2\text{O}_7^{2-} + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1.23
$4\text{H}^+ + \text{O}_2(\text{g}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$	+1.23
$4\text{H}^+ + \text{MnO}_2(\text{s}) + 2\text{e}^- \rightarrow \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1.22
$\text{Br}_2(\ell) + 2\text{e}^- \rightarrow 2\text{Br}^-$	+1.09
$\text{Hg}^{2+} + 2\text{e}^- \rightarrow \text{Hg}(\ell)$	+0.85
$\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Hg}_2^{2+} + 2\text{e}^- \rightarrow 2\text{Hg}(\ell)$	+0.80
$\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$	+0.77
$\text{I}_2(\text{s}) + 2\text{e}^- \rightarrow 2\text{I}^-$	+0.54
$\text{Cu}^+ + \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.52
$\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightarrow \text{SO}_2(\text{aq}) + 2\text{H}_2\text{O}$	+0.17
$\text{Sn}^{4+} + 2\text{e}^- \rightarrow \text{Sn}^{2+}$	+0.15
$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+} + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.26
$\text{Co}^{2+} + 2\text{e}^- \rightarrow \text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+} + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.45
$\text{Cr}^{3+} + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- + \text{H}_2(\text{g})$	-0.83
$\text{Mn}^{2+} + 2\text{e}^- \rightarrow \text{Mn}(\text{s})$	-1.19
$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.66
$\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$	-2.37
$\text{Na}^+ + \text{e}^- \rightarrow \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+} + 2\text{e}^- \rightarrow \text{Ca}(\text{s})$	-2.87
$\text{Sr}^{2+} + 2\text{e}^- \rightarrow \text{Sr}(\text{s})$	-2.89
$\text{Ba}^{2+} + 2\text{e}^- \rightarrow \text{Ba}(\text{s})$	-2.91
$\text{Cs}^+ + \text{e}^- \rightarrow \text{Cs}(\text{s})$	-2.92
$\text{K}^+ + \text{e}^- \rightarrow \text{K}(\text{s})$	-2.93
$\text{Rb}^+ + \text{e}^- \rightarrow \text{Rb}(\text{s})$	-2.98
$\text{Li}^+ + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.04