Chapter 1

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Fundamental physical constants (SI)

(1986 recommended values of the fundamental physical constants. The digits in parentheses are the one-standard-deviation uncertainty in the last digits of the given value.)

Quantity	Symbol	Value	Units	Relative uncertainty (ppm)
GENERAL CONSTANTS				
UNIVERSAL CONSTANTS				
speed of light in vacuum	c	299 792 458	$m\ s^{-1}$	(exact)
permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	$N\ A^{-2}$	
		$= 12.566\ 370\ 614\ldots$	$10^{-7}\ N\ A^{-2}$	(exact)
permittivity of vacuum	ε_0	$1/\mu_0 c^2$		
		$= 8.854\ 187\ 817\ldots$	$10^{-12}\ F\ m^{-1}$	(exact)
Newtonian constant of gravitation	G	6.672 59(85)	$10^{-11}\ m^3\ kg^{-1}\ s^{-2}$	128
Planck constant	h	6.626 075 5(40)	$10^{-34}\ J\ s$	0.60
in electron volts, $h/\{e\}$		4.135 669 2(12)	$10^{-15}\ eV\ s$	0.30
$h/2\pi$	$\hbar$	1.054 572 66(63)	$10^{-34}\ J\ s$	0.60
in electron volts, $\hbar/\{e\}$		6.582 122 0(20)	$10^{-16}\ eV\ s$	0.30
Planck mass, $(\hbar c/G)^{\frac{1}{2}}$	m_P	2.176 71(14)	$10^{-8}\ kg$	64
Planck length, $\hbar/m_P c = (\hbar G/c^3)^{\frac{1}{2}}$	l_P	1.616 05(10)	$10^{-35}\ m$	64
Planck time, $l_P/c = (\hbar G/c^5)^{\frac{1}{2}}$	t_P	5.390 56(34)	$10^{-44}\ s$	64
ELECTROMAGNETIC CONSTANTS				
elementary charge	e	1.602 177 33(49)	$10^{-19}\ C$	0.30
	e/h	2.417 988 36(72)	$10^{14}\ A\ J^{-1}$	0.30
magnetic flux quantum, $h/2e$	Φ_0	2.067 834 61(61)	$10^{-15}\ Wb$	0.30
Josephson frequency–voltage ratio	$2e/h$	4.835 976 7(14)	$10^{14}\ Hz\ V^{-1}$	0.30
quantized Hall conductance	e^2/h	3.874 046 14(17)	$10^{-5}\ S$	0.045
quantized Hall resistance, $h/e^2 = \frac{1}{2}\mu_0 c/\alpha$	R_H	25 812.805 6(12)	Ω	0.045

Bohr magneton, $e\hbar/2m_e$	μ_B	9.274 015 4(31)	10^{-24} J T^{-1}	0.34
in electron volts, $\mu_B/\{e\}$		5.788 382 63(52)	10^{-5} eV T^{-1}	0.089
in hertz, μ_B/h		1.399 624 18(42)	10^{10} Hz T^{-1}	0.30
in wavenumbers, μ_B/hc		46.686 437(14)	m^{-1} T^{-1}	0.30
in kelvins, μ_B/k		0.671 709 9(57)	K T^{-1}	8.5
nuclear magneton, $e\hbar/2m_p$	μ_N	5.050 786 6(17)	10^{-27} J T^{-1}	0.34
in electron volts, $\mu_N/\{e\}$		3.152 451 66(28)	10^{-8} eV T^{-1}	0.089
in hertz, μ_N/h		7.622 591 4(23)	MHz T^{-1}	0.30
in wavenumbers, μ_N/hc		2.542 622 81(77)	10^{-2} m^{-1} T^{-1}	0.30
in kelvins, μ_N/k		3.658 246(31)	10^{-4} K T^{-1}	8.5

ATOMIC CONSTANTS

ATOM

fine-structure constant, $\frac{1}{2}\mu_0 ce^2/h$	α	7.297 353 08(33)	10^{-3}	0.045
inverse fine-structure constant	α^{-1}	137.035 989 5(61)		0.045
Rydberg constant, $\frac{1}{2}m_e c\alpha^2/h$	R_∞	10 973 731.534(13)	m^{-1}	0.0012
in hertz, $R_\infty c$		3.289 841 949 9(39)	10^{15} Hz	0.0012
in joules, $R_\infty hc$		2.179 874 1(13)	10^{-18} J	0.60
in electron volts, $R_\infty hc/\{e\}$		13.605 698 1(40)	eV	0.30
Bohr radius, $\alpha/4\pi R_\infty$	a_0	0.529 177 249(24)	10^{-10} m	0.045
Hartree energy, $e^2/4\pi\varepsilon_0 a_0 = 2R_\infty hc$	E_h	4.359 748 2(26)	10^{-18} J	0.60
in electron volts, $E_h/\{e\}$		27.211 396 1(81)	eV	0.30
quantum of circulation	$h/2m_e$	3.636 948 07(33)	10^{-4} m^2 s^{-1}	0.089
	h/m_e	7.273 896 14(65)	10^{-4} m^2 s^{-1}	0.089

ELECTRON

electron mass	m_e	9.109 389 7(54)	10^{-31} kg	0.59
		5.485 799 03(13)	10^{-4} u	0.023
in electron volts, $m_e c^2/\{e\}$		0.510 999 06(15)	MeV	0.30
electron–muon mass ratio	m_e/m_μ	4.836 332 18(71)	10^{-3}	0.15
electron–proton mass ratio	m_e/m_p	5.446 170 13(11)	10^{-4}	0.020
electron–deuteron mass ratio	m_e/m_d	2.724 437 07(6)	10^{-4}	0.020
electron–α-particle mass ratio	m_e/m_α	1.370 933 54(3)	10^{-4}	0.021

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Fundamental physical constants (SI) (*cont.*)

Quantity	Symbol	Value	Units	Relative uncertainty (ppm)
electron specific charge	$-e/m_e$	−1.758 819 62(53)	10^{11} C kg^{-1}	0.30
electron molar mass	M(e), M_e	5.485 799 03(13)	10^{-7} kg mol^{-1}	0.023
Compton wavelength, $h/m_e c$	λ_C	2.426 310 58(22)	10^{-12} m	0.089
$\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$	$\lambda\!\!\!^{-}_C$	3.861 593 23(35)	10^{-13} m	0.089
classical electron radius, $\alpha^2 a_0$	r_e	2.817 940 92(38)	10^{-15} m	0.13
Thomson cross-section, $(8\pi/3)r_e^2$	σ_e	0.665 246 16(18)	10^{-28} m^2	0.27
electron magnetic moment	μ_e	928.477 01(31)	10^{-26} J T^{-1}	0.34
in Bohr magnetons	μ_e/μ_B	1.001 159 652 193(10)		1×10^{-5}
in nuclear magnetons	μ_e/μ_N	1838.282 000(37)		0.020
electron magnetic moment anomaly, $\mu_e/\mu_B - 1$	a_e	1.159 652 193(10)	10^{-3}	0.0086
electron g-factor, $2(1 + a_e)$	g_e	2.002 319 304 386(20)		1×10^{-5}
electron–muon magnetic moment ratio	μ_e/μ_μ	206.766 967(30)		0.15
electron–proton magnetic moment ratio	μ_e/μ_p	658.210 688 1(66)		0.010
MUON				
muon mass	m_μ	1.883 532 7(11)	10^{-28} kg	0.61
		0.113 428 913(17)	u	0.15
in electron volts, $m_\mu c^2/\{e\}$		105.658 389(34)	MeV	0.32
muon–electron mass ratio	m_μ/m_e	206.768 262(30)		0.15
muon molar mass	$M(\mu)$, M_μ	1.134 289 13(17)	10^{-4} kg mol^{-1}	0.15
muon magnetic moment	μ_μ	4.490 451 4(15)	10^{-26} J T^{-1}	0.33
in Bohr magnetons	μ_μ/μ_B	4.841 970 97(71)	10^{-3}	0.15
in nuclear magnetons	μ_μ/μ_N	8.890 598 1(13)		0.15
muon magnetic moment anomaly, $[\mu_\mu/(e\hbar/2m_\mu)] - 1$	a_μ	1.165 923 0(84)	10^{-3}	7.2
muon g-factor, $2(1 + a_\mu)$	g_μ	2.002 331 846(17)		0.0084
muon–proton magnetic moment ratio	μ_μ/μ_p	3.183 345 47(47)		0.15

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PROTON				
proton mass	m_p	1.672 623 1(10)	10^{-27} kg	0.59
		1.007 276 470(12)	u	0.012
in electron volts, $m_p c^2/\{e\}$		938.272 31(28)	MeV	0.30
proton–electron mass ratio	m_p/m_e	1836.152 701(37)		0.020
proton–muon mass ratio	m_p/m_μ	8.880 244 4(13)		0.15
proton specific charge	e/m_p	9.578 830 9(29)	10^7 C kg^{-1}	0.30
proton molar mass	M(p), M_p	1.007 276 470(12)	10^{-3} kg mol^{-1}	0.012
proton Compton wavelength, $h/m_p c$	$\lambda_{C,p}$	1.321 410 02(12)	10^{-15} m	0.089
$\lambda_{C,p}/2\pi$	$\lambda\!\!\!^{-}_{C,p}$	2.103 089 37(19)	10^{-16} m	0.089
proton magnetic moment	μ_p	1.410 607 61(47)	10^{-26} J T^{-1}	0.34
in Bohr magnetons	μ_p/μ_B	1.521 032 202(15)	10^{-3}	0.010
in nuclear magnetons	μ_p/μ_N	2.792 847 386(63)		0.023
diamagnetic shielding correction for protons in pure water, spherical sample, 25 °C, $1-\mu'_p/\mu_p$	σ_{H_2O}	25.689(15)	10^{-6}	—
shielded proton moment (H_2O, sph., 25 °C)	μ'_p	1.410 571 38(47)	10^{-26} J T^{-1}	0.34
in Bohr magnetons	μ'_p/μ_B	1.520 993 129(17)	10^{-3}	0.011
in nuclear magnetons	μ'_p/μ_N	2.792 775 642(64)		0.023
proton gyromagnetic ratio	γ_p	26 752.2128(81)	10^4 s^{-1} T^{-1}	0.30
	$\gamma_p/2\pi$	42.577 469(13)	MHz T^{-1}	0.30
uncorrected (H_2O, sph., 25 °C)	γ'_p	26 751.5255(81)	10^4 s^{-1} T^{-1}	0.30
	$\gamma'_p/2\pi$	42.576 375(13)	MHz T^{-1}	0.30
NEUTRON				
neutron mass	m_n	1.674 928 6(10)	10^{-27} kg	0.59
		1.008 664 904(14)	u	0.014
in electron volts, $m_n c^2/\{e\}$		939.565 63(28)	MeV	0.30
neutron–electron mass ratio	m_n/m_e	1838.683 662(40)		0.022
neutron–proton mass ratio	m_n/m_p	1.001 378 404(9)		0.009
neutron molar mass	M(n), M_n	1.008 664 904(14)	10^{-3} kg mol^{-1}	0.014
neutron Compton wavelength, $h/m_n c$	$\lambda_{C,n}$	1.319 591 10(12)	10^{-15} m	0.089
$\lambda_{C,n}/2\pi$	$\lambda\!\!\!^{-}_{C,n}$	2.100 194 45(19)	10^{-16} m	0.089

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Fundamental physical constants (SI) (*cont.*)

Quantity	Symbol	Value	Units	Relative uncertainty (ppm)
neutron magnetic moment[(a)]	μ_n	0.966 237 07(40)	10^{-26} J T^{-1}	0.41
in Bohr magnetons	μ_n/μ_B	1.041 875 63(25)	10^{-3}	0.24
in nuclear magnetons	μ_n/μ_N	1.913 042 75(45)		0.24
neutron–electron magnetic moment ratio	μ_n/μ_e	1.040 668 82(25)	10^{-3}	0.24
neutron–proton magnetic moment ratio	μ_n/μ_p	0.684 979 34(16)		0.24
DEUTERON				
deuteron mass	m_d	3.343 586 0(20)	10^{-27} kg	0.59
		2.013 553 214(24)	u	0.012
in electron volts, $m_d c^2/\{e\}$		1875.613 39(57)	MeV	0.30
deuteron–electron mass ratio	m_d/m_e	3670.483 014(75)		0.020
deuteron–proton mass ratio	m_d/m_p	1.999 007 496(6)		0.003
deuteron molar mass	M(d), M_d	2.013 553 214(24)	10^{-3} kg mol^{-1}	0.012
deuteron magnetic moment[(a)]	μ_d	0.433 073 75(15)	10^{-26} J T^{-1}	0.34
in Bohr magnetons	μ_d/μ_B	0.466 975 447 9(91)	10^{-3}	0.019
in nuclear magnetons	μ_d/μ_N	0.857 438 230(24)		0.028
deuteron–electron magnetic moment ratio	μ_d/μ_e	0.466 434 546 0(91)	10^{-3}	0.019
deuteron–proton magnetic moment ratio	μ_d/μ_p	0.307 012 203 5(51)		0.017
PHYSICO-CHEMICAL CONSTANTS				
Avogadro constant	N_A, L	6.022 136 7(36)	10^{23} mol^{-1}	0.59
atomic mass constant, $m_u = \frac{1}{12}m(^{12}C)$	m_u	1.660 540 2(10)	10^{-27} kg	0.59
in electron volts, $m_u c^2/\{e\}$		931.494 32(28)	MeV	0.30
Faraday constant	F	96 485.309(29)	C mol^{-1}	0.30

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molar Planck constant	$N_A h$	3.990 313 23(36)	10^{-10} J s mol^{-1}	0.089
	$N_A hc$	0.119 626 58(11)	J m mol^{-1}	0.089
molar gas constant	R	8.314 510(70)	J mol^{-1} K^{-1}	8.4
Boltzmann constant, R/N_A	k	1.380 658(12)	10^{-23} J K^{-1}	8.5
in electron volts, $k/\{e\}$		8.617 385(73)	10^{-5} eV K^{-1}	8.4
in hertz, k/h		2.083 674(18)	10^{10} Hz K^{-1}	8.4
in wavenumbers, k/hc		69.503 87(59)	m^{-1} K^{-1}	8.4
molar volume (ideal gas), RT/p				
$T = 273.15$ K, $p = 101\,325$ Pa	V_m	22.414 10(19)	L mol^{-1}	8.4
Loschmidt constant, N_A/V_m	n_0	2.686 763(23)	10^{25} m^{-3}	8.5
$T = 273.15$ K, $p = 100$ kPa	V_m	22.711 08(19)	L mol^{-1}	8.4
Sackur–Tetrode constant (absolute entropy constant),[b] $\frac{5}{2} + \ln\{(2\pi m_u kT_1/h^2)^{\frac{3}{2}} kT_1/p_0\}$				
$T_1 = 1$ K, $p_0 = 100$ kPa	S_0/R	−1.151 693(21)		18
$p_0 = 101\,325$ Pa		−1.164 856(21)		18
Stefan–Boltzmann constant, $(\pi^2/60)k^4/\hbar^3 c^2$	σ	5.670 51(19)	10^{-8} W m^{-2} K^{-4}	34
first radiation constant, $2\pi hc^2$	c_1	3.741 774 9(22)	10^{-16} W m^2	0.60
second radiation constant, hc/k	c_2	0.014 387 69(12)	m K	8.4
Wien displacement law constant, $b = \lambda_{max} T = c_2/4.965\,114\,23\ldots$	b	2.897 756(24)	10^{-3} m K	8.4

[a] The scalar magnitude of the neutron moment is listed here. The neutron magnetic dipole is directed oppositely to that of the proton, and corresponds to the dipole associated with a spinning negative charge distribution. The vector sum, $\mu_d = \mu_p + \mu_n$, is approximately satisfied.

[b] The entropy of an ideal monatomic gas of relative atomic weight A_r is given by

$$S = S_0 + \tfrac{3}{2}R \ln A_r - R \ln(p/p_0) + \tfrac{5}{2}R \ln(T/K).$$

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Fundamental physical constants (SI) (*cont.*)

MAINTAINED UNITS AND STANDARD VALUES

A summary of 'maintained' units and 'standard' values and their relationship to SI units, based on a least-squares adjustment with 17 degrees of freedom. The digits in parentheses are the one-standard-deviation uncertainty in the last digits of the given value.

Quantity	Symbol	Value	Units	Relative uncertainty (ppm)
electron volt, (e/C) J $= \{e\}$ J	eV	1.602 177 33(49)	10^{-19} J	0.30
(unified) atomic mass unit, 1 u $= m_u = \frac{1}{12}m(^{12}C)$	u	1.660 540 2(10)	10^{-27} kg	0.59
standard atmosphere	atm	101 325	Pa	(exact)
standard acceleration of gravity	g_n	9.806 65	m s^{-2}	(exact)
'AS-MAINTAINED' ELECTRICAL UNITS				
BIPM[a] maintained ohm, Ω_{69-BI}				
$\Omega_{BI85} \equiv \Omega_{69-BI}$ (1 Ja[illegible] 1985)	Ω_{BI85}	$1 - 1.563(50) \times 10^{-6}$	Ω	
		$= 0.999\,998\,437(50)$	Ω	0.050
drift rate of Ω_{69-BI}	$\frac{d\Omega_{69-BI}}{dt}$	$-0.0566(15)$	$\mu\Omega/a$	—
BIPM maintained volt,	V_{76-BI}	$1 - 7.59(30) \times 10^{-6}$	V	
$V_{76-BI} \equiv 483\,594$ GHz$(h/2e)$		$= 0.999\,992\,41(30)$	V	0.30
BIPM maintained ampere,	A_{BI85}	$1 - 6.03(30) \times 10^{-6}$	A	
$A_{BIPM} = V_{76-BI}/\Omega_{69-BI}$		$= 0.999\,993\,97(30)$	A	0.30
X-RAY STANDARDS				
Cu x-unit: $\lambda(CuK\alpha_1) \equiv 1537.400$ xu	xu(CuKα_1)	1.002 077 89(70)	10^{-13} m	0.70
Mo x-unit: $\lambda(MoK\alpha_1) \equiv 707.831$ xu	xu(MoKα_1)	1.002 099 38(45)	10^{-13} m	0.45
Å*: $\lambda(WK\alpha_1) \equiv 0.209\,100$ Å*	Å*	1.000 014 81(92)	10^{-10} m	0.92

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lattice spacing of Si (in vacuum, 22.5 °C)[b]	a	0.543 101 96(11)	nm	0.21
$d_{220} = a/\sqrt{8}$	d_{220}	0.192 015 540(40)	nm	0.21
molar volume of Si, $M(\mathrm{Si})/\rho(\mathrm{Si}) = N_A a^3/8$	$V_m(\mathrm{Si})$	12.058 817 9(89)	$\mathrm{cm^3\,mol^{-1}}$	0.74

[a] BIPM: Bureau International des Poids et Mésures.

[b] The lattice spacing of single-crystal Si can vary by parts in 10^7 depending on the preparation process. Measurements at Physikalisch-Technische Bundesanstalt (FRG) indicate also the possibility of distortions from exact cubic symmetry of the order of 0.2 ppm.

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Fundamental physical constants (c.g.s.)

Speed of light in vacuum	$c = 2.997\,924\,58 \times 10^{10}\,\mathrm{cm\,s^{-1}}$
Gravitational constant	$G = 6.672\,59 \times 10^{-8}\,\mathrm{dyn\,cm^2\,g^{-2}}$
Planck's constant	$h = 6.626\,075\,5 \times 10^{-27}\,\mathrm{erg\,s}$
Electron charge	$e = 4.803\,206\,8 \times 10^{-10}\,\mathrm{esu}$
Mass of electron	$m_e = 9.109\,389\,7 \times 10^{-28}\,\mathrm{g}$
Mass of proton	$m_p = 1.672\,623\,1 \times 10^{-24}\,\mathrm{g}$
Mass of neutron	$m_n = 1.674\,928\,6 \times 10^{-24}\,\mathrm{g}$
Atomic mass unit (amu)	$m_u = 1.660\,540\,2 \times 10^{-24}\,\mathrm{g}$
Proton-electron mass ratio	$m_p/m_e = 1\,836.152\,701$
Fine structure constant	$hc/2\pi e^2 = 1/\alpha = 137.035\,989\,5$
Classical electron radius	$e^2/m_e c^2 = r_e = 2.817\,940\,92 \times 10^{-13}\,\mathrm{cm}$
Bohr radius	$h^2/4\pi^2 m_e e^2 = a_0 = 0.529\,177\,249 \times 10^{-8}\,\mathrm{cm}$
Electron Compton wavelength	$h/m_e c = \lambda_c = 2.426\,310\,58 \times 10^{-10}\,\mathrm{cm}$
Rydberg constant	$2\pi^2 m_e e^4/ch^3 = R_\infty = 109\,737.315\,34\,\mathrm{cm^{-1}}$
Boltzmann constant	$k = 1.380\,658 \times 10^{-16}\,\mathrm{erg\,K^{-1}}$
Stefan–Boltzmann constant	$\sigma = 2\pi^5 k^4/15\,h^3 c^2$ $= 5.670\,51 \times 10^{-5}\,\mathrm{erg\,cm^{-2}\,K^{-4}\,s^{-1}}$
Thomson cross-section	$8\pi r_e^2/3 = {}_e\sigma = 0.665\,246\,16 \times 10^{-24}\,\mathrm{cm^{-2}}$
Bohr magneton	$eh/4\pi m_e = \mu_B = 9.274\,015\,4 \times 10^{-21}\,\mathrm{gauss\,cm^3}$

(Based on constants recommended by the 1986 CODATA Committee in previous table.)

Sun–Earth system constants

Equatorial radius for Earth	$a_e = 6378.140\,\mathrm{km}$
Dynamical form-factor for Earth	$J_2 = 0.001\,082\,63$
Gravity at Earth's surface (mean)	$g_e = 980.7\,\mathrm{cm\,s^{-2}}$
Ratio of mass of Moon to that of Earth	$\mu = 0.012\,300\,02$
Lunar distance (mean)	$3.844\,01 \times 10^{10}\,\mathrm{cm}$
Astronomical unit	$\mathrm{AU} = 1.495\,978\,70 \times 10^{13}\,\mathrm{cm}$
Mass of the Earth	$M_e = 5.976 \times 10^{27}\,\mathrm{g}$
Solar parallax	$\pi_\odot = 8''.794\,148$
Tropical year (1900.0)	365.242 days
	3.1557×10^7 ephemeris seconds
Ephemeris day	86 400 ephemeris seconds
Constant of aberration (2000.0)	$K = 20''.495\,52$
Obliquity of the ecliptic (2000.0)	$\varepsilon = 23°\,26'\,21''.448$
General precession in longitude per Julian century (2000.0)	$p = 5029''.0966$
Constant of nutation (2000.0)	$N = 9''.2055$
Earth's magnetic dipole moment	$M_e = 8.02 \times 10^{22}\,\mathrm{Am^2}$
Angular rotation rate of Earth	$\Omega = 7.292\,115 \times 10^{-5}\,\mathrm{rad\,s^{-1}}$
Average depth of ocean	$H = 3800\,\mathrm{m}$
Flattening of Earth	$1/f = 298.257$

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Cosmological data

Hubble constant	$H_0 = (50\text{–}100)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ $= (1.6\text{–}3.2) \times 10^{-18}\,\mathrm{s^{-1}}$
Hubble time	$1/H_0 = (19.6\text{–}9.78) \times 10^9\,y$
Hubble distance	$R = c/H_0 = (6050\text{–}3025)\,\mathrm{Mpc}$
Critical density	$\rho_c = 3H_0^2/8\pi G$ $= (5\text{–}20) \times 10^{-30}\,\mathrm{g\,cm^{-3}}$
Volume	$\frac{4}{3}\pi R^3 = (9\text{–}1) \times 10^{11}\,\mathrm{Mpc^3}$
Smoothed density of galactic material throughout universe (Allen 1973)	$2 \times 10^{-31}\,\mathrm{g\,cm^{-3}}$ $1 \times 10^{-7}\,\mathrm{atom\,cm^{-3}}$ $3 \times 10^9\,M_\odot\,\mathrm{Mpc^{-3}}$
Space density of galaxies	$0.02\,\mathrm{Mpc^{-3}}$
Luminous emission from galaxies	$3 \times 10^8\,L_\odot\,\mathrm{Mpc^{-3}}$
Mean sky brightness from galaxies	$1.4(m_V = 10)\,\mathrm{deg^{-2}}$
Cosmic background thermodynamic temperature	$2.74 \pm 0.09\,\mathrm{K}$
Weak coupling constant	$g_{wk} = 1.435 \times 10^{-49}\,\mathrm{erg\,cm^3}$

Unit conversions

1 keV: $hc/E = 12.398\,54 \times 10^{-8}$ cm — 1 keV = 1.602177×10^{-9} erg
1 keV: $E/h = 2.417\,965 \times 10^{17}$ Hz — 1 joule = 10^7 erg
1 keV: $E/k = 11.6048 \times 10^6$ K — 1 calorie = 4.184 joule
1.0 EHz: $h\nu = 4.135\,71$ keV
1 parsec = 3.261 633 light years = $3.085\,678 \times 10^{18}$ cm
1 light year = $9.460\,530 \times 10^{17}$ cm
1 XU = $1.002\,09 \times 10^{-11}$ cm
1 Ångstrom $\equiv 1 \times 10^{-8}$ cm
1 amu: $Mc^2 = 1.492\,41 \times 10^{-3}$ erg = 931.494 MeV
760 torr = 1.013×10^6 dyn cm^{-2} = 1 atmos. = 1.013 bars = 1.013×10^5 Pascals
1 Rayleigh $\equiv (1/4\pi) \times 10^6$ photons cm^{-2} s^{-1} sr^{-1}
1 Uhuru ct s^{-1} = 1.7×10^{-11} erg cm^{-2} s^{-1} (2–6 keV)
= 2.4×10^{-11} erg cm^{-2} s^{-1} (2–10 keV)
1 flux unit $\equiv 10^{-26}$ watt m^{-2} Hz^{-1} $\equiv$ 1 Jansky
1.0 μJy = 10^{-11} erg cm^{-2} s^{-1} EHz^{-1}
= 0.242×10^{-11} erg cm^{-2} s^{-1} keV^{-1} = 1.509×10^{-3} keV cm^{-2} s^{-1} keV^{-1}
1 curie: amount of material undergoing 3.7×10^{10} disintegrations s^{-1}
1 nautical mile = 1852 m
1 statute mile = 1609.344 m
intensity (erg cm^{-2} s^{-1} Hz^{-1}) = $3.33 \times 10^{-19}\,\lambda^2$(Å) intensity (erg cm^{-2} s^{-1} Å^{-1})
1 barn = 10^{-24} cm^2
1 tesla = 10^4 Gauss
0 °C = 273.15 K

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Conversion tables

(A given amount of a physical quantity, expressed in the units of one system, is expressed as an equivalent number of units in another system.)

Quantity	Amount	Unit	Amount	Unit
LENGTH				
	1	meter (SI)	= 1.000 00E + 02	centimeter (cgs)
	1	light year	= 9.460 53E + 15	meter (SI)
	1	parsec	= 3.085 68E + 16	meter (SI)
	1	Ångstrom	= 1.000 01E − 10	meter (SI)
	1	Ångstrom	= 1.000 01E − 08	centimeter (cgs)
	1	micron	= 1.000 00E − 06	meter (SI)
	1	XU	= 1.002 09E − 13	meter (SI)
	1	fermi	= 1.000 00E − 15	meter (SI)
	1	nautical mile	= 1.852 00E + 03	meter (SI)
	1	statute mile	= 1.609 34E + 03	meter (SI)
	1	astron. unit (AU)	= 1.495 98E + 11	meter (SI)
	1	solar radius	= 6.959 90E + 08	meter (SI)
	1	centimeter (cgs)	= 3.240 78E − 19	parsec
	1	centimeter (cgs)	= 6.684 56E − 14	astron. unit (AU)
	1	meter (SI)	= 3.240 78E − 17	parsec
	1	meter (SI)	= 6.684 54E − 12	astron. unit (AU)
	1	inch (Eng)	= 2.540 00E − 02	meter (SI)
MASS				
	1	kilogram (SI)	= 1.000 00E + 03	gram (cgs)
	1	at. mass unit (amu)	= 1.660 54E − 24	gram (cgs)
	1	at. mass unit (amu)	= 1.660 54E − 27	kilogram (SI)
	1	solar mass	= 1.989 10E + 33	gram (cgs)
	1	solar mass	= 1.989 10E + 30	kilogram (SI)

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	1	gram (cgs) = 6.022 14E + 23	at. mass unit (amu)
	1	gram (cgs) = 5.027 40E − 34	solar mass
	1	kilogram (SI) = 6.022 14E + 26	at. mass unit (amu)
	1	kilogram (SI) = 5.027 40E − 31	solar mass
	1	kilogram (SI) = 2.204 62E + 00	pound (avdp.)
	1	kilogram (SI) = 3.527 40E + 01	ounce (avdp.)
	1	pound (avdp.) = 4.535 92E − 01	kilogram (SI)
	1	pound (avdp.) = 1.600 00E + 01	ounce (avdp.)
	1	ounce (avdp.) = 2.834 95E + 01	gram (cgs)
	1	gram (cgs) = 3.527 40E − 02	ounce (avdp.)
ENERGY			
	1	joule (SI) = 1.000 00E + 07	erg (cgs)
	1	joule (SI) = 6.241 51E + 18	electron volt (eV)
	1	erg (cgs) = 1.000 00E − 07	joule (SI)
	1	erg (cgs) = 6.241 51E + 11	electron volt
	1	electron volt = 1.602 18E − 12	erg (cgs)
	1	amu × c^2 = 9.314 95E + 08	electron volt
	1	gm (cgs) × c^2 = 5.609 59E + 32	electron volt
	1	calorie = 4.184 00E + 00	joule (SI)
FORCE			
	1	newton (SI) = 1.000 00E + 05	dyne (cgs)
	1	dyne (cgs) = 1.000 00E − 05	newton (SI)
PRESSURE			
	1	pascal (SI) = 1.000 00E + 00	newton m^{-2} (SI)
	1	bar = 1.000 00E + 06	dyne cm^{-2} (cgs)
	1	bar = 9.869 23E − 01	atmosphere
	1	torr = 1.333 22E − 03	bar
POWER			
	1	watt (SI) = 1.000 00E + 07	erg s^{-1} (cgs)
	1	horsepower = 7.457 00E + 02	watt (SI)
	1	Btu s^{-1} (Eng) = 1.055 80E + 03	watt (SI)

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Conversion tables (*cont.*)

Quantity	Amount	Unit	Amount	Unit
TIME				
	1	second (SI)	= 1	second (cgs)
	1	minute	= 6.000 00E + 01	second
	1	hour	= 3.600 00E + 03	second
	1	day	= 8.640 00E + 04	second
	1	tropical year	= 3.155 69E + 07	second
	1	tropical year	= 3.652 42E + 02	day
	1	second	= 3.168 88E − 08	tropical year
	1	sidereal second	= 9.972 70E − 01	second
	1	sidereal year	= 3.652 56E + 02	day
TEMPERATURE				
	T	kelvin	$= T - 273.15$	celsius
	T	kelvin	$= (9/5) \times (T - 273.15) + 32$	fahrenheit
	T	celsius	$= T + 273.15$	kelvin
	T	fahrenheit	$= (5/9) \times (T - 32) + 273.15$	kelvin
	T	celsius	$= (9/5) \times T + 32$	fahrenheit
	T	fahrenheit	$= (5/9) \times (T - 32)$	celsius
Energy equivalence	1	electron volt	= 1.160 48E + 04	kelvin
Temperature equivalence	1	kelvin	= 8.617 12E − 05	electron volt
ELECTRICITY AND MAGNETISM				
Charge	1	coulomb	= 2.997 92E + 09	statcoulomb
Charge density	1	coulomb m^{-3}	= 2.997 92E + 03	statcoul cm^{-3}
Current	1	ampere (coul s^{-1})	= 2.997 92E + 09	statampere
Current density	1	ampere m^{-2}	= 2.997 92E + 05	statamp cm^{-2}
Electric field	1	volt m^{-1}	= 3.335 65E − 05	statvolt cm^{-1}
Potential	1	volt	= 3.335 65E − 03	statvolt

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Resistance	1	ohm = 1.112 65E − 12	$s\,cm^{-1}$
Resistivity	1	ohm m = 1.112 65E − 10	s
Conductance	1	siemens, mho = 8.987 52E + 11	$cm\ s^{-1}$
Conductivity	1	mho m^{-1} = 8.987 52E + 09	s^{-1}
Capacitance	1	farad = 8.987 52E + 11	cm
Magnetic flux	1	weber = 1.000 00E + 08	gauss cm^2 (maxwell)
Magnetic flux density	1	tesla = 1.000 00E + 04	gauss
Magnetic field	1	ampere-turn m^{-1} = 1.256 64E − 02	oersted
Inductance	1	henry = 1.112 65E − 12	$s^2\,cm^{-1}$
MISCELLANEOUS			
Radio-activity	1	curie (SI) = 3.700 00E + 10	disinteg. s^{-1}
Intensity	1	rayleigh = 7.957 75E + 04	ph $cm^{-2}\,s^{-1}\,sr^{-1}$
Flux density	1	fu or jansky = 1.000 00E − 26	watt $m^{-2}\,Hz^{-1}$
Flux density	1	jansky = 1.00000E − 05	erg $cm^{-2}\,s^{-1}\,EHz^{-1}$
Flux density	1	jansky = 2.42000E − 06	erg $cm^{-2}\,s^{-1}\,keV^{-1}$
Flux density	1	jansky = 1.50900E + 03	keV $cm^{-2}\,s^{-1}\,keV^{-1}$
Energy equivalence	1	eV:1.239 85E + 04	Ångstrom
Energy equivalence	1	eV:2.417 97E + 14	Hz
Wavelength equivalence	1	Ångstrom:1.239 85E + 04	eV
Angle	1	arcsec = 4.848 14E − 06	radian
Angle	1	arcmin = 2.908 88E − 04	radian
Angle	1	degree = 1.745 33E − 02	radian
Solid angle	1	$arcsec^2$ = 2.350 40E − 11	steradian
Solid angle	1	$arcmin^2$ = 8.461 70E − 08	steradian
Solid angle	1	deg^2 = 3.046 20E −04	steradian

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Numerical constants

$\pi = 3.141\,592\,7$
$e = 2.718\,281\,8$
$\ln 2 = 0.693\,147\,2$
$\log_{10} 2 = 0.301\,030\,0$
$\ln 10 = 2.302\,585\,1$
$\log_{10} e = 0.434\,294\,5$
$(2\pi)^{1/2} = 2.506\,628$
$\pi^2 = 9.869\,604$
$2^{10} = 1024$
$e^{-1} = 0.367\,879\,4$
$\Gamma(n+1) = n!$, integer n
$\Gamma(1/2) = \pi^{1/2}$
Feigenbaum's number: $\delta = 4.669\,201\,6$

rad $= 57.295\,78$ deg
$= 3.437\,747 \times 10^3$ arcmin
$= 2.062\,648 \times 10^5$ arcsec
steradian $= 32\,400/\pi^2 = 3.2828 \times 10^3$ deg^2
$= 1.1818 \times 10^7$ arcmin^2
$= 4.2545 \times 10^{10}$ arcsec^2
degree $= 0.017\,453\,3$ rad
arcmin $= 2.908\,88 \times 10^{-4}$ rad
arcsec $= 4.848\,137 \times 10^{-6}$ rad
deg$^2 = 3.0462 \times 10^{-4}$ steradian
arcmin$^2 = 8.4617 \times 10^{-8}$ steradian
arcsec$^2 = 2.3504 \times 10^{-11}$ steradian

Powers of 2:

n	2^n	$\log 2^n$
0	1	0.00
1	2	0.30
2	4	0.60
3	8	0.90
4	16	1.20
5	32	1.51
6	64	1.81
7	128	2.11
8	256	2.41
9	512	2.71
10	1024	3.01
11	2048	3.31
12	4096	3.61
13	8192	3.91
14	16 384	4.21
15	32 768	4.52
20	1 048 576	6.02
25	33 554 432	7.53
n		$0.301n$

Number system conversions:

Decimal	Octal	Binary	Hexadecimal
0	0	0000	0
1	1	0001	1
2	2	0010	2
3	3	0011	3
4	4	0100	4
5	5	0101	5
6	6	0110	6
7	7	0111	7
8	10	1000	8
9	11	1001	9
10	12	1010	A
11	13	1011	B
12	14	1100	C
13	15	1101	D
14	16	1110	E
15	17	1111	F
16	20	10000	10

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Mathematical formulae

$$(a+x)^n = a^n + na^{n-1}x + \frac{n(n-1)}{2!}a^{n-2}x^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}x^3 + \cdots + nax^{n-1} + x^n,$$

where n is any positive integer.

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots.$$

$$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots \text{ for } -1 < x \leqslant 1.$$

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots, \qquad \cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \cdots.$$

$$\int u\,dv = uv - \int v\,du + C, \qquad \int_0^{\pi} \sin^2 nx\,dx = \int_0^{\pi} \cos^2 nx\,dx = \frac{\pi}{2}$$

for an integer, $n \neq 0$.

$$\int_0^{\infty} e^{-a^2x^2}\,dx = \pi^{1/2}/2a, \qquad \int_0^{\infty} x^n e^{-ax}\,dx = \Gamma(n+1)/a^{n+1}.$$

$$F(u) = \int_{-\infty}^{\infty} f(x)\,e^{-2\pi iux}\,dx \leftrightarrow f(x) = \int_{-\infty}^{\infty} F(u)\,e^{2\pi iux}.$$

$n! \approx (2\pi)^{1/2} n^{n+1/2} e^{-n}$ (for large n).

$$\int_a^b f(x)\,dx = -\int_b^a f(x)\,dx, \qquad \int_a^b f(x)\,dx = \int_a^c f(x)\,dx + \int_c^b f(x)\,dx.$$

$$\frac{d}{dx} f[u(x)] = \frac{df}{du}\frac{du}{dx}, \qquad \frac{d}{dx}[u(x)v(x)] = v\frac{du}{dx} + u\frac{dv}{dx}.$$

$$\frac{d}{dx}\ln y(x) = y'(x)/y(x), \qquad 2.30 \log_{10} x = \log_e x$$

$\sin(A+B) = \sin A \cos B + \cos A \sin B.$

$\cos(A+B) = \cos A \cos B - \sin A \sin B.$

$e^{ix} = \cos x + i \sin x.$

Elementary particles (short list)

Particle	Charge	Mass (amu)	Spin	Magnetic moment	Mean life[a] (s)
Photon	0	0	1	0	stable
π-meson	$+1, -1$	0.149 84	1	0	2.60×10^{-8}
	0	0.144 90	0	0	0.83×10^{-16}
Neutrino	0	$< 10^{-6}$	1/2	~ 0	stable
Electron, positron	$-1, +1$	0.000 548 6	1/2	$1.001\,160\,\mu_B$[b]	stable
μ-meson	$-1, +1$	0.1134	1/2	$0.004\,842\,\mu_B$	2.20×10^{-6}
Proton	$+1, -1$	1.007 276	1/2	$2.792\,85\,\mu_B$[c]	stable
Neutron	0	1.008 665	1/2	$-1.913\,04\,\mu_N$	917 ± 14

[a] half-life = mean life $\times \ln 2$

[b] $\mu_B = eh/4\pi m_e c = 9.274\,015\,4(31) \times 10^{-24}\,J\,T^{-1}$

[c] $\mu_N = eh/4\pi m_p c = 5.050\,786\,6(17) \times 10^{-27}\,J\,T^{-1}$.

(Data from 'Reviews of Particle Properties', *Rev. Mod. Phys.* **52**, No. 2, April 1980)

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Elementary Particles

(The second column is the isospin t, while the next column is the spin and parity, J^P. Masses and lifetimes have generally been rounded; see the original reference for error bars and a complete listing of particle properties.)

Particle	t	J^P	Mass (MeV)	Mean life (s)
LEPTONS				
e		$\frac{1}{2}$	0.511 003	Stable
μ		$\frac{1}{2}$	105.6594	$2.197\,14 \times 10^{-6}$
τ		$\frac{1}{2}$	1784	5×10^{-13}
NONSTRANGE BARYONS				
p	$\frac{1}{2}$	$\frac{1}{2}^+$	938.280	Stable
n	$\frac{1}{2}$	$\frac{1}{2}^+$	939.573	925
Δ	$\frac{3}{2}$	$\frac{3}{2}^+$	1232	6×10^{-24}
STRANGENESS = −1 BARYONS				
Λ	0	$\frac{1}{2}^+$	1115.60	2.63×10^{-10}
Σ^+	1	$\frac{1}{2}^+$	1189.36	8.00×10^{-11}
Σ^0	1	$\frac{1}{2}^+$	1192.46	6×10^{-20}
Σ^-	1	$\frac{1}{2}^+$	1197.34	1.48×10^{-10}
STRANGENESS = −2 BARYONS				
Ξ^0	$\frac{1}{2}$	$\frac{1}{2}^+$	1314.9	2.9×10^{-10}
Ξ^-	$\frac{1}{2}$	$\frac{1}{2}^+$	1321.3	1.64×10^{-10}
STRANGENESS = −3 BARYON				
Ω^-	0	$\frac{3}{2}^+$	1672.5	8.2×10^{-11}
NONSTRANGE CHARMED BARYON				
Λ_c^+	0	$\frac{1}{2}^+$	2282	1×10^{-13}
NONSTRANGE MESONS				
$\pi^\pm$	1	0^-	139.567	2.603×10^{-8}
π^0	1	0^-	134.963	8.3×10^{-17}
η	0	0^-	548.8	8×10^{-19}
ρ	1	1^-	769	4.3×10^{-24}
ω	0	1^-	782.6	6.6×10^{-23}
η'	0	0^-	957.6	2.4×10^{-21}
ϕ	0	1^-	1019.6	1.6×10^{-22}
J/Ψ	0	1^-	3096.9	1.0×10^{-20}
Υ		1^-	9456	1.6×10^{-20}
STRANGENESS = −1 MESONS				
$K^\pm$	$\frac{1}{2}$	0^-	493.67	1.237×10^{-8}
$K^0, \bar{K}^0$	$\frac{1}{2}$	0^-	497.7	K_S: 8.92×10^{-11} K_L: 5.18×10^{-8}
CHARMED NONSTRANGE MESONS				
$D^\pm$	$\frac{1}{2}$	0^-	1869.4	9×10^{-13}
$D^0, \bar{D}^0$	$\frac{1}{2}$	0^-	1864.7	5×10^{-13}
CHARMED STRANGE MESON				
$F^\pm$	0	0^-	2021	2×10^{-13}

(From Shapiro, S. L. & Teukolsky, S. A., *Black Holes, White Dwarfs, and Neutron Stars*, John Wiley and Sons, 1983, with permission.)

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Energy conversions

1 erg	= 1 dyne-centimeter = 10^{-7} joule
1 joule	= 1 newton-meter
1 foot-pound	= 1.356 joule
1 calorie	= 4.184 joule
1 Btu	= 1.055×10^{3} joule
1 horsepower-hour	= 2.6845×10^{6} joule
1 kilowatt-hour	= 3.6×10^{6} joule = 3.413×10^{3} Btu
1 MeV	= 1.6×10^{-13} joule
Energy of fission of 1 atom of ^{235}U	= 199 MeV = 3.2×10^{-11} joule
Energy equivalent of 1 ton of TNT	= 4.2×10^{9} joule
Energy of fission of 1 kilogram of ^{235}U	= 20 kilotons of TNT
Hydrogen fusion:	$D + T \rightarrow {}_{2}He^{4} + n + 17.6$ MeV
Energy equivalent of 1 gram of matter	= 9×10^{13} joule
High heat value of 1 ton of coal	= 26×10^{6} Btu
High heat value of 1 cord of red oak	= 30×10^{6} Btu
High heat value of 100 gallons of fuel oil	= 15×10^{6} Btu
High heat value of 20 000 cu ft natural gas	= 20×10^{6} Btu
US energy consumption	= 10^{20} joule yr^{-1} (proj. 1970–2000)
Earth's daily receipt of solar energy	= 1.49×10^{22} joule = 4.2×10^{12} Mwh
Earth's rotational energy	= 2.2×10^{29} joule
Earth's total heat content	= 3×10^{31} joule
1 D-cell flashlight battery	= 10^{4} watt-s = 10^{4} joule

Prefixes and symbols

(used with SI units to indicate decimal multiples and submultiples)

Multiples			Submultiples		
Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	P	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	μ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10	deca	da	10^{-18}	atto	a

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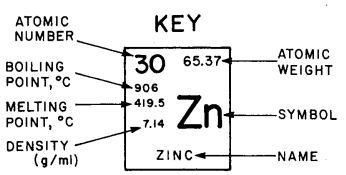
Periodic table of the elements

PERIODIC TABLE OF THE ELEMENTS



GROUP IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII		
1 1.00797 -252.7 -259.2 0.071 H HYDROGEN									
3 6.939 1330 180.5 0.53 Li LITHIUM	4 9.0122 2770 1277 1.85 Be BERYLLIUM								
11 22.9898 892 97.8 0.97 Na SODIUM	12 24.312 1107 650 1.74 Mg MAGNESIUM								
19 39.102 760 63.7 0.86 K POTASSIUM	20 40.08 1440 838 1.55 Ca CALCIUM	21 44.956 2730 1539 3.0 Sc SCANDIUM	22 47.90 3260 1668 4.51 Ti TITANIUM	23 50.942 3450 1900 6.1 V VANADIUM	24 51.996 2665 1875 7.19 Cr CHROMIUM	25 54.938 2150 1245 7.43 Mn MANGANESE	26 55.847 3000 1536 7.86 Fe IRON	27 58.933 2900 1495 8.9 Co COBALT	28 58.71 2730 1453 8.9 Ni NICKEL
37 85.47 688 38.9 1.53 Rb RUBIDIUM	38 87.62 1380 768 2.6 Sr STRONTIUM	39 88.905 2927 1509 4.47 Y YTTRIUM	40 91.22 3580 1852 6.49 Zr ZIRCONIUM	41 92.906 3300 2468 8.4 Nb NIOBIUM	42 95.94 5560 2610 10.2 Mo MOLYBDENUM	43 (98) — 2140 11.5 Tc TECHNETIUM	44 101.07 4900 2500 12.2 Ru RUTHENIUM	45 102.905 4500 1966 12.4 Rh RHODIUM	46 106.4 3980 1552 12.0 Pd PALLADIUM
55 132.905 690 28.7 1.90 Cs CESIUM	56 137.34 1640 714 3.5 Ba BARIUM	57 138.91 3470 920 6.17 La LANTHANUM	72 178.49 5400 2222 13.1 Hf HAFNIUM	73 180.948 5425 2996 16.6 Ta TANTALUM	74 183.85 5930 3410 19.3 W WOLFRAM	75 186.2 5900 3180 21.0 Re RHENIUM	76 190.2 5500 3000 22.6 Os OSMIUM	77 192.2 5300 2454 22.5 Ir IRIDIUM	78 195.09 4530 1769 21.4 Pt PLATINUM
87 (223) — (27) — Fr FRANCIUM	88 (226) — 700 5.0 Ra RADIUM	89 (227) — 1050 — Ac ACTINIUM	104						

58 140.12 3468 795 6.67 Ce CERIUM	59 140.907 3127 935 6.77 Pr PRASEODYMIUM	60 144.24 3027 1024 7.00 Nd NEODYMIUM	61 (147) — (1027) — Pm PROMETHIUM	62 150.35 1900 1072 7.54 Sm SAMARIUM	63 151.96 1439 826 5.26 Eu EUROPIUM	64 157.25 3000 1312 7.89 Gd GADOLINIUM
90 232.038 3850 1750 11.7 Th THORIUM	91 (231) — (1230) 15.4 Pa PROTACTINIUM	92 238.03 3818 1132 19.07 U URANIUM	93 (237) — 637 19.5 Np NEPTUNIUM	94 (242) 3235 640 — Pu PLUTONIUM	95 (243) — — 11.7 Am AMERICIUM	96 (247) — — — Cm CURIUM

VALUES FOR GASEOUS ELEMENTS ARE FOR LIQUIDS AT THE BOILING POINT.

OUTLINE - SYNTHETICALLY PREPARED.

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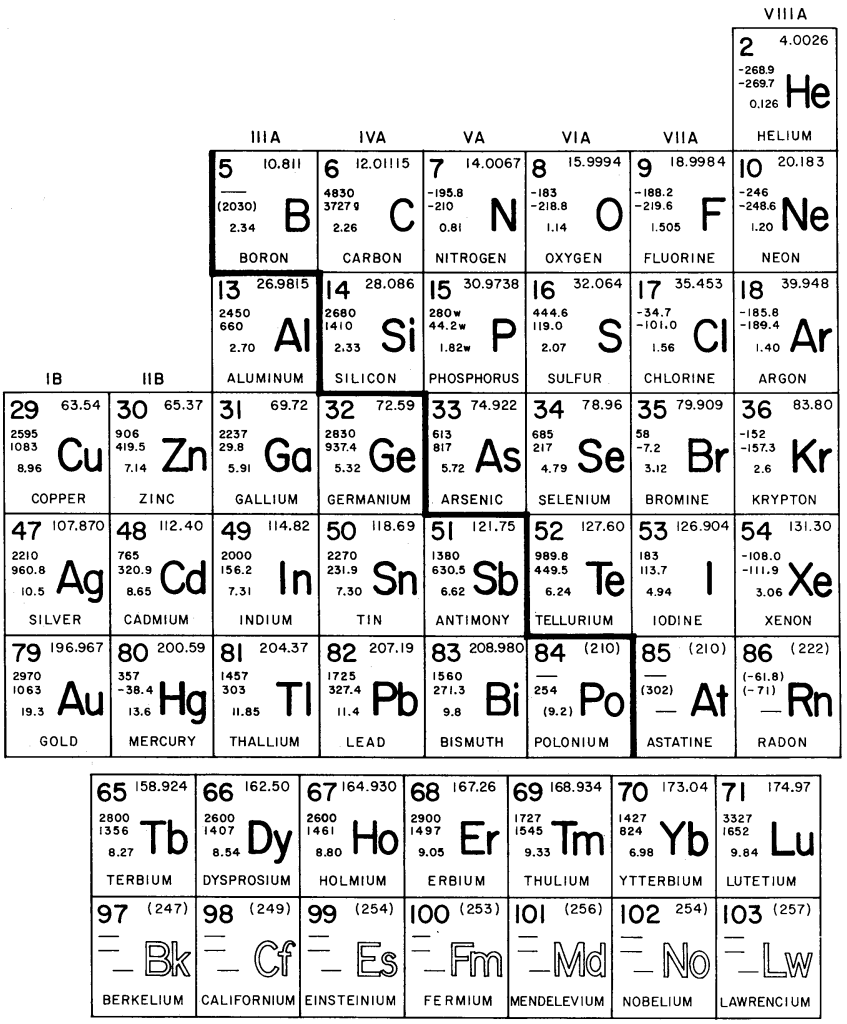
Periodic table of the elements (*cont.*)



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Greek alphabet

A	α	Alpha	N	ν	Nu
B	β	Beta	Ξ	ξ	Xi
Γ	γ	Gamma	O	o	Omicron
Δ	δ	Delta	Π	π	Pi
E	ε	Epsilon	P	ρ	Rho
Z	ζ	Zeta	Σ	σ	Sigma
H	η	Eta	T	τ	Tau
Θ	θ	Theta	Υ	υ	Upsilon
I	ι	Iota	Φ	ϕ	Phi
K	κ	Kappa	X	χ	Chi
Λ	λ	Lambda	Ψ	ψ	Psi
M	μ	Mu	Ω	ω	Omega

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