CRC Handbook of Chemistry and Physics

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PREFACE

The 87th Edition of the *CRC Handbook of Chemistry and Physics* continues the overall philosophy of this work, namely, to provide broad coverage of all types of physical science data commonly encountered by scientists and engineers. Notwithstanding the growing availability of specialized databases on the Internet, we feel there is still a need for a concise, reliable reference source spanning the full range of the physical sciences and focusing on key data that are frequently needed by R&D professionals, engineers, and students. The *CRC Handbook*, in its print, CD-ROM, and Internet formats, is aimed at serving these needs. The data contained in the *Handbook* have been carefully evaluated by experts in each field; quality control is a high priority and the sources are documented. The annual updates make it possible to add new and better data in a timely fashion. In this way we hope to continue the role of the *CRC Handbook* as a unique reference source.

Among the changes in the 87th Edition are major revisions of four heavily used tables:

- *Physical Constants of Inorganic Compounds* has been completely updated, and the number of compounds has been increased by 20%.
- *Bond Dissociation Energies* has been updated with results from the latest literature, and the coverage has been expanded to include organometallics, low molecular weight biochemical compounds, and positive ions. The total number of chemical bonds covered is now 4193, as compared to 2579 in the 86th Edition.
- *Table of the Isotopes*, the comprehensive listing of the energies and radiation properties of all known isotopes, has been brought up to date with results from the literature up to the beginning of 2006. This definitive compilation now includes over 4500 individual isotopes.
- *Scientific Abbreviations and Symbols* has been expanded to about 1100 entries and includes more acronyms from quantum chemistry and abbreviations for chemicals of environmental interest.

Fourteen other tables have been updated. Of particular note are two tables based on very recent IUPAC recommendations: *Standard Atomic Weights (2005)* and *Nomenclature for Inorganic Ions and Ligands*. There is also a new table on *Specific Enthalpies of Solution of Polymers and Copolymers*.

In addition to offering the full text of the print edition in searchable pdf format, the Internet version presents the major tables of numerical data in the form of interactive tables that can be sorted, filtered, and combined in various ways. Substances in these tables can be retrieved by searching on name, formula, or CAS Registry Number, and such a search can be combined with a request for a desired property. Thus one can request a specific property of a specific substance and receive a customized table with exactly that information. Inverse searches can also be done, in which one asks for all substances that have a set of properties falling within specified ranges.

The Editor appreciates suggestions on new topics for the *Handbook* and notification of any errors. Comments on the search software are also welcomed. Address all comments to Editor-in-Chief, *CRC Handbook of Chemistry and Physics*, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487. Comments may also be sent by electronic mail to drlide@post.harvard.edu.

The *Handbook of Chemistry and Physics* is dependent on the efforts of many contributors throughout the world. The list of current contributors follows this Preface. Valuable suggestions have been received from the Editorial Advisory Board and from many users. The assistance and support of Dr. Fiona Macdonald is greatly appreciated. Finally, I want to thank Ronel Decius and Robert Morris of Taylor & Francis for their excellent work in developing the programs for the Internet version.

David R. Lide
June 2006

The 87th Edition is dedicated to the memory of Elizabeth G. Breen, 1916-2005

How To Cite this Reference

The recommended form of citation is: David R. Lide, ed., *CRC Handbook of Chemistry and Physics, Internet Version 2007, (87th Edition), <http:/www.hbcpnetbase.com>,* Taylor and Francis, Boca Raton, FL, 2007. If a specific table is cited, use the format: "Physical Constants of Organic Compounds", in *CRC Handbook of Chemistry and Physics, Internet Version 2007, (87th Edition),* David R. Lide, ed., Taylor and Francis, Boca Raton, FL.

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FUNDAMENTAL PHYSICAL CONSTANTS

Peter J. Mohr and Barry N. Taylor

These tables give the 2002 self-consistent set of values of the basic constants and conversion factors of physics and chemistry recommended by the Committee on Data for Science and Technology (CODATA) for international use. The 2002 set replaces the previously recommended 1998 CODATA set. The 2002 adjustment takes into account the data considered in the 1998 adjustment as well as the data that became available between 31 December 1998, the closing date of that adjustment, and 31 December 2002, the closing date of the new adjustment.

This report was prepared by the authors under the auspices of the CODATA Task Group on Fundamental Constants. The members of the Task Group are:

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Reference

Mohr, P. J. and Taylor, B. N., *The 2002 CODATA Recommended Values of the Fundamental Physical Constants*, Web Version 4.0, NIST Physical Data web site <http://physics.nist.gov/cuu/constants> (December 2003); *Rev. Mod. Phys.* 76, No. 4, October 2004.

TABLE I. An Abbreviated List of the CODATA Recommended Values of the Fundamental Constants of Physics and Chemistry Based on the 2002 Adjustment

Quanity	**Symbol**	**Numerical value**	**Unit**	**Relative std. uncert.** u_r
speed of light in vacuum	c, c_0	299 792 458	m s^{-1}	(exact)
magnetic constant	μ_0	$4\pi \times 10^{-7}$	N A^{-2}	
		$= 12.566\,370\,614... \times 10^{-7}$	N A^{-2}	(exact)
electric constant $1/\mu_0 c^2$	ε_0	$8.854\,187\,817... \times 10^{-12}$	F m^{-1}	(exact)
Newtonian constant of gravitation	G	$6.6742(10) \times 10^{-11}$	$m^3\ kg^{-1}\ s^{-2}$	1.5×10^{-4}
Planck constant	h	$6.626\,0693(11) \times 10^{-34}$	J s	1.7×10^{-7}
$h/2\pi$	$\hbar$	$1.054\,571\,68(18) \times 10^{-34}$	J s	1.7×10^{-7}
elementary charge	e	$1.602\,176\,53(14) \times 10^{-19}$	C	8.5×10^{-8}
magnetic flux quantum $h/2e$	ϕ_0	$2.067\,833\,72(18) \times 10^{-15}$	Wb	8.5×10^{-8}
conductance quantum $2e^2/h$	G_0	$7.748\,091\,733(26) \times 10^{-5}$	S	3.3×10^{-9}
electron mass	m_e	$9.109\,3826(16) \times 10^{-31}$	kg	1.7×10^{-7}
proton mass	m_p	$1.672\,621\,71(29) \times 10^{-27}$	kg	1.7×10^{-7}
proton-electron mass ratio	m_p/m_e	1836.152 672 61(85)		4.6×10^{-10}
fine-structure constant $e^2/4\pi\varepsilon_0\hbar c$	α	$7.297\,352\,568(24) \times 10^{-3}$		3.3×10^{-9}
inverse fine-structure constant	α^{-1}	137.035 999 11(46)		3.3×10^{-9}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 525(73)	m^{-1}	6.6×10^{-12}
Avogadro constant	N_A, L	$6.022\,1415(10) \times 10^{23}$	mol^{-1}	1.7×10^{-7}
Faraday constant $N_A e$	F	96 485.3383(83)	C mol^{-1}	8.6×10^{-8}
molar gas constant	R	8.314 472(15)	J $mol^{-1}\ K^{-1}$	1.7×10^{-6}
Boltzmann constant R/N_A	k	$1.380\,6505(24) \times 10^{-23}$	J K^{-1}	1.8×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	$5.670\,400(40) \times 10^{-8}$	W $m^{-2}\ K^{-4}$	7.0×10^{-6}
Non-SI units accepted for use with the SI				
electron volt: (e/C) J	eV	$1.602\,176\,53(14) \times 10^{-19}$	J	8.5×10^{-8}
(unified) atomic mass unit	u	$1.660\,538\,86(28) \times 10^{-27}$	kg	1.7×10^{-7}
1 u = $m_u = (1/12)m(^{12}C) = 10^{-3}$ kg mol^{-1}/N_A				

TABLE II. The CODATA Recommended Values of the Fundamental Constants of Physics and Chemistry Based on the 2002 Adjustment

Quantity	**Symbol**	**Numerical value**	**Unit**	**Relative std. uncert. u_r**
Universal				
speed of light in vacuum	c, c_0	299 792 458	$\mathrm{m\ s^{-1}}$	(exact)
magnetic constant	μ_0	$4\pi \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	
		$= 12.566\ 370\ 614\ldots \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	(exact)
electric constant $1/\mu_0 c^2$	ε_0	$8.854\ 187\ 817\ldots \times 10^{-12}$	$\mathrm{F\ m^{-1}}$	(exact)
characteristic impedance of vacuum $\sqrt{\mu_0/\varepsilon_0} = \mu_0 c$	Z_0	376.730 313 461…	Ω	(exact)
Newtonian constant of gravitation	G	$6.6742(10) \times 10^{-11}$	$\mathrm{m^3\ kg^{-1}\ s^{-2}}$	1.5×10^{-4}
	$G/\hbar c$	$6.7087(10) \times 10^{-39}$	$(\mathrm{GeV}/c^2)^{-2}$	1.5×10^{-4}
Planck constant	h	$6.626\ 0693(11) \times 10^{-34}$	J s	1.7×10^{-7}
in eV s		$4.135\ 667\ 43(35) \times 10^{-15}$	eV s	8.5×10^{-8}
$h/2\pi$	$\hbar$	$1.054\ 571\ 68(18) \times 10^{-34}$	J s	1.7×10^{-7}
in eV s		$6.582\ 119\ 15(56) \times 10^{-16}$	eV s	8.5×10^{-8}
$\hbar c$ in MeV fm		197.326 968(17)	MeV fm	8.5×10^{-8}
Planck mass $(\hbar c/G)^{1/2}$	m_P	$2.176\ 45(16) \times 10^{-8}$	kg	7.5×10^{-5}
Planck temperature $(\hbar c^5/G)^{1/2}/k$	T_P	$1.416\ 79(11) \times 10^{32}$	K	7.5×10^{-5}
Planck length $\hbar/m_P c = (\hbar G/c^3)^{1/2}$	l_P	$1.616\ 24(12) \times 10^{-35}$	m	7.5×10^{-5}
Planck time $l_P/c = (\hbar G/c^5)^{1/2}$	t_P	$5.391\ 21(40) \times 10^{-44}$	s	7.5×10^{-5}
Electromagnetic				
elementary charge	e	$1.602\ 176\ 53(14) \times 10^{-19}$	C	8.5×10^{-8}
	e/h	$2.417\ 989\ 40(21) \times 10^{14}$	$\mathrm{A\ J^{-1}}$	8.5×10^{-8}
magnetic flux quantum $h/2e$	ϕ_0	$2.067\ 833\ 72(18) \times 10^{-15}$	Wb	8.5×10^{-8}
conductance quantum $2e^2/h$	G_0	$7.748\ 091\ 733(26)\times10^{-5}$	S	3.3×10^{-9}
inverse of conductance quantum	G_0^{-1}	12 906.403 725(43)	Ω	3.3×10^{-9}
Josephson constant[1] $2e/h$	K_J	$483\ 597.879(41)\times10^{9}$	$\mathrm{Hz\ V^{-1}}$	8.5×10^{-8}
von Klitzing constant[2] $h/e^2 = \mu_0 c/2\alpha$	R_K	25 812.807 449(86)	Ω	3.3×10^{-9}
Bohr magneton $e\hbar/2m_e$	μ_B	$927.400\ 949(80)\times10^{-26}$	$\mathrm{J\ T^{-1}}$	8.6×10^{-8}
in $\mathrm{eV\ T^{-1}}$		$5.788\ 381\ 804(39)\times10^{-5}$	$\mathrm{eV\ T^{-1}}$	6.7×10^{-9}
	μ_B/h	$13.996\ 2458(12)\times10^{9}$	$\mathrm{Hz\ T^{-1}}$	8.6×10^{-8}
	μ_B/hc	46.686 4507(40)	$\mathrm{m^{-1}\ T^{-1}}$	8.6×10^{-8}
	μ_B/k	0.671 7131(12)	$\mathrm{K\ T^{-1}}$	1.8×10^{-6}
nuclear magneton $e\hbar/2m_p$	μ_N	$5.050\ 783\ 43(43)\times10^{-27}$	$\mathrm{J\ T^{-1}}$	8.6×10^{-8}
in $\mathrm{eV\ T^{-1}}$		$3.152\ 451\ 259(21)\times10^{-8}$	$\mathrm{eV\ T^{-1}}$	6.7×10^{-9}
	μ_N/h	7.622 593 71(65)	$\mathrm{MHz\ T^{-1}}$	8.6×10^{-8}
	μ_N/hc	$2.542\ 623\ 58(22)\times10^{-2}$	$\mathrm{m^{-1}\ T^{-1}}$	8.6×10^{-8}
	μ_N/k	$3.658\ 2637(64)\times10^{-4}$	$\mathrm{K\ T^{-1}}$	1.8×10^{-6}
Atomic and Nuclear				
General				
Fine-structure constant $e^2/4\pi\varepsilon_0\hbar c$	α	$7.297\ 352\ 568(24)\times10^{-3}$		3.3×10^{-9}
inverse fine-structure constant	α^{-1}	137.035 999 11(46)		3.3×10^{-9}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 525(73)	$\mathrm{m^{-1}}$	6.6×10^{-12}
	$R_\infty c$	$3.289\ 841\ 960\ 360(22)\times10^{15}$	Hz	6.6×10^{-12}
	$R_\infty hc$	$2.179\ 872\ 09(37)\times10^{-18}$	J	1.7×10^{-7}
$R_\infty hc$ in eV		13.605 6923(12)	eV	8.5×10^{-8}
Bohr radius $\alpha/4\pi R_\infty = 4\pi\varepsilon_0\hbar^2/m_e e^2$	a_0	$0.529\ 177\ 2108(18)\times10^{-10}$	m	3.3×10^{-9}
Hartree energy $e^2/4\pi\varepsilon_0 a_0 = 2R_\infty hc = \alpha^2 m_e c^2$	E_h	$4.359\ 744\ 17(75)\times10^{-18}$	J	1.7×10^{-7}
in eV		27.211 3845(23)	eV	8.5×10^{-8}
quantum of circulation	$h/2m_e$	$3.636\ 947\ 550(24)\times10^{-4}$	$\mathrm{m^2 s^{-1}}$	6.7×10^{-9}
	h/m_e	$7.273\ 895\ 101(48)\times10^{-4}$	$\mathrm{m^2 s^{-1}}$	6.7×10^{-9}
Electroweak				
Fermi coupling constant[3]	$G_F/(\hbar c)^3$	$1.166\ 39(1)\times10^{-5}$	$\mathrm{GeV^{-2}}$	8.6×10^{-6}
weak mixing angle[4] θ_W (on-shell scheme) $\sin^2\theta_W = s_W^2 \equiv 1-(m_W/m_Z)^2$	$\sin^2\theta_W$	0.222 15(76)		3.4×10^{-3}
Electron, e^-				
electron mass	m_e	$9.109\ 3826(16)\times10^{-31}$	kg	1.7×10^{-7}
in u, $m_e = A_r(e)$ u (electron relative atomic mass times u)		$5.485\ 799\ 0945(24)\times10^{-4}$	u	4.4×10^{-10}

Quantity	Symbol	Numerical value	Unit	Relative std. uncert. u_r
energy equivalent	m_ec^2	$8.187\,1047(14)\times10^{-14}$	J	1.7×10^{-7}
in MeV		$0.510\,998\,918(44)$	MeV	8.6×10^{-8}
electron-muon mass ratio	m_e/m_μ	$4.836\,331\,67(13)\times10^{-3}$		2.6×10^{-8}
electron-tau mass ratio	m_e/m_τ	$2.875\,64(47)\times10^{-4}$		1.6×10^{-4}
electron-proton mass ratio	m_e/m_p	$5.446\,170\,2173(25)\times10^{-4}$		4.6×10^{-10}
electron-neutron mass ratio	m_e/m_n	$5.438\,673\,4481(38)\times10^{-4}$		7.0×10^{-10}
electron-deuteron mass ratio	m_e/m_d	$2.724\,437\,1095(13)\times10^{-4}$		4.8×10^{-10}
electron to alpha particle mass ratio	m_e/m_α	$1.370\,933\,555\,75(61)\times10^{-4}$		4.4×10^{-10}
electron charge to mass quotient	$-e/m_e$	$-1.758\,820\,12(15)\times10^{11}$	C kg^{-1}	8.6×10^{-8}
electron molar mass N_Am_e	$M(\mathrm{e}), M_e$	$5.485\,799\,0945(24)\times10^{-7}$	kg mol^{-1}	4.4×10^{-10}
Compton wavelength h/m_ec	λ_C	$2.426\,310\,238(16)\times10^{-12}$	m	6.7×10^{-9}
$\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$	$\bar{\lambda}_C$	$386.159\,2678(26)\times10^{-15}$	m	6.7×10^{-9}
classical electron radius $\alpha^2 a_0$	r_e	$2.817\,940\,325(28)\times10^{-15}$	m	1.0×10^{-8}
Thomson cross section $(8\pi/3)r_e^2$	σ_e	$0.665\,245\,873(13)\times10^{-28}$	m^2	2.0×10^{-8}
electron magnetic moment	μ_e	$-928.476\,412(80)\times10^{-26}$	J T^{-1}	8.6×10^{-8}
to Bohr magneton ratio	μ_e/μ_B	$-1.001\,159\,652\,1859(38)$		3.8×10^{-12}
to nuclear magneton ratio	μ_e/μ_N	$-1838.281\,971\,07(85)$		4.6×10^{-10}
electron magnetic moment anomaly $\lvert\mu_e\rvert/\mu_B - 1$	a_e	$1.159\,652\,1859(38)\times10^{-3}$		3.2×10^{-9}
electron g-factor $-2(1 + a_e)$	g_e	$-2.002\,319\,304\,3718(75)$		3.8×10^{-12}
electron-muon magnetic moment ratio	μ_e/μ_μ	$206.766\,9894(54)$		2.6×10^{-8}
electron-proton magnetic moment ratio	$\mu_e\mu_p$	$-658.210\,6862(66)$		1.0×10^{-8}
electron to shielded proton magnetic moment ratio (H_2O, sphere, 25°C)	μ_e/μ'_p	$-658.227\,5956(71)$		1.1×10^{-8}
electron-neutron magnetic moment ratio	μ_e/μ_n	$960.920\,50(23)$		2.4×10^{-7}
electron-deuteron magnetic moment ratio	μ_e/μ_d	$-2\,143.923\,493(23)$		1.1×10^{-8}
electron to shielded helion[5] magnetic moment ratio (gas, sphere, 25°C)	μ_e/μ'_h	$864.058\,255(10)$		1.2×10^{-8}
electron gyromagnetic ratio $2\lvert\mu_e\rvert/\hbar$	γ_e	$1.760\,859\,74(15)\times10^{11}$	s^{-1} T^{-1}	8.6×10^{-8}
	$\gamma_e/2\pi$	$28\,024.9532(24)$	MHz T^{-1}	8.6×10^{-8}
Muon, μ^-				
muon mass	m_μ	$1.883\,531\,40(33)\times10^{-28}$	kg	1.7×10^{-7}
in u, $m_\mu = A_r(\mu)$ u (muon relative atomic mass times u)		$0.113\,428\,9264(30)$	u	2.6×10^{-8}
energy equivalent	$m_\mu c^2$	$1.692\,833\,60(29)\times10^{-11}$	J	1.7×10^{-7}
in MeV		$105.658\,3692(94)$	MeV	8.9×10^{-8}
muon-electron mass ratio	m_μ/m_e	$206.768\,2838(54)$		2.6×10^{-8}
muon-tau mass ratio	m_μ/m_τ	$5.945\,92(97)\times10^{-2}$		1.6×10^{-4}
muon-proton mass ratio	m_μ/m_p	$0.112\,609\,5269(29)$		2.6×10^{-8}
muon-neutron mass ratio	m_μ/m_n	$0.112\,454\,5175(29)$		2.6×10^{-8}
muon molar mass N_Am_μ	$M(\mu), M_\mu$	$0.113\,428\,9264(30)\times10^{-3}$	kg mol^{-1}	2.6×10^{-8}
muon Compton wavelength $h/m_\mu c$	$\lambda_{C,\mu}$	$11.734\,441\,05(30)\times10^{-15}$	m	2.5×10^{-8}
$\lambda_{C,\mu}/2\pi$	$\bar{\lambda}_{C,\mu}$	$1.867\,594\,298(47)\times10^{-15}$	m	2.5×10^{-8}
muon magnetic moment	μ_μ	$-4.490\,447\,99(40)\times10^{-26}$	J T^{-1}	8.9×10^{-8}
to Bohr magneton ratio	μ_μ/μ_B	$-4.841\,970\,45(13)\times10^{-3}$		2.6×10^{-8}
to nuclear magneton ratio	μ_μ/μ_N	$-8.890\,596\,98(23)$		2.6×10^{-8}
muon magnetic moment anomaly $\lvert\mu_\mu\rvert/(e\hbar/2m_\mu) - 1$	α_μ	$1.165\,919\,81(62)\times10^{-3}$		5.3×10^{-7}
muon g-factor $-2(1 + \alpha_\mu)$	g_μ	$-2.002\,331\,8396(12)$		6.2×10^{-10}
muon-proton magnetic moment ratio	μ_μ/μ_p	$-3.183\,345\,118(89)$		2.8×10^{-8}
Tau, τ^-				
tau mass[6]	m_τ	$3.167\,77(52)\times10^{-27}$	kg	1.6×10^{-4}
in u, $m_\tau = A_r(\tau)$ u (tau relative atomic mass times u)		$1.907\,68(31)$	u	1.6×10^{-4}
energy equivalent	$m_\tau c^2$	$2.847\,05(46)\times10^{-10}$	J	1.6×10^{-4}
in MeV		$1776.99(29)$	MeV	1.6×10^{-4}
tau-electron mass ratio	m_τ/m_e	$3477.48(57)$		1.6×10^{-4}
tau-muon mass ratio	m_τ/m_μ	$16.8183(27)$		1.6×10^{-4}
tau-proton mass ratio	m_τ/m_p	$1.893\,90(31)$		1.6×10^{-4}
tau-neutron mass ratio	m_τ/m_n	$1.891\,29(31)$		1.6×10^{-4}
tau molar mass N_Am_τ	$M(\tau), M_\tau$	$1.907\,68(31)\times10^{-3}$	kg mol^{-1}	1.6×10^{-4}
tau Compton wavelength $h/m_\tau c$	$\lambda_{C,\tau}$	$0.697\,72(11)\times10^{-15}$	m	1.6×10^{-4}
$\lambda_{C,\tau}/2\pi$	$\bar{\lambda}_{C,\tau}$	$0.111\,046(18)\times10^{-15}$	m	1.6×10^{-4}

Quantity	**Symbol**	**Numerical value**	**Unit**	**Relative std. uncert. u_r**
Proton, p				
proton mass	m_p	1.672 621 71(29)×10^{-27}	kg	1.7×10^{-7}
in u, $m_p = A_r$(p) u (proton relative atomic mass times u)		1.007 276 466 88(13)	u	1.3×10^{-10}
energy equivalent	m_pc^2	1.503 277 43(26)×10^{-10}	J	1.7×10^{-7}
in MeV		938.272 029(80)	MeV	8.6×10^{-8}
proton-electron mass ratio	m_p/m_e	1836.152 672 61(85)		4.6×10^{-10}
proton-muon mass ratio	m_p/m_μ	8.880 243 33(23)		2.6×10^{-8}
proton-tau mass ratio	m_p/m_τ	0.528 012(86)		1.6×10^{-4}
proton-neutron mass ratio	m_p/m_n	0.998 623 478 72(58)		5.8×10^{-10}
proton charge to mass quotient	e/m_p	9.578 833 76(82)×10^{7}	C kg^{-1}	8.6×10^{-8}
proton molar mass N_Am_p	M(p), M_p	1.007 276 466 88(13)×10^{-3}	kg mol^{-1}	1.3×10^{-10}
proton Compton wavelength h/m_pc	$\lambda_{C,p}$	1.321 409 8555(88)×10^{-15}	m	6.7×10^{-9}
$\lambda_{C,p}/2\pi$	$\bar{\lambda}_{C,P}$	0.210 308 9104(14)×10^{-15}	m	6.7×10^{-9}
proton rms charge radius	R_p	0.8750(68)×10^{-15}	m	7.8×10^{-3}
proton magnetic moment	μ_p	1.410 606 71(12)×10^{-26}	J T^{-1}	8.7×10^{-8}
to Bohr magneton ratio	μ_p/μ_B	1.521 032 206(15)×10^{-3}		1.0×10^{-8}
to nuclear magneton ratio	μ_p/μ_N	2.792 847 351(28)		1.0×10^{-8}
proton *g*-factor $2\mu_p/\mu_N$	g_p	5.585 694 701(56)		1.0×10^{-8}
proton-neutron magnetic moment ratio	μ_p/μ_n	−1.459 898 05(34)		2.4×10^{-7}
shielded proton magnetic moment (H_2O, sphere, 25°C)	μ'_P	1.410 570 47(12)×10^{-26}	J T^{-1}	8.7×10^{-8}
to Bohr magneton ratio	μ'_P/μ_B	1.520 993 132(16)×10^{-3}		1.1×10^{-8}
to nuclear magneton ratio	μ'_P/μ_N	2.792 775 604(30)		1.1×10^{-8}
proton magnetic shielding correction $1-\mu'_P/\mu_P$ (H_2O, sphere, 25°C)	σ'_P	25.689(15)×10^{-6}		5.7×10^{-4}
proton gyromagnetic ratio $2\mu_p/\hbar$	γ_P	2.675 222 05(23)×10^{8}	s^{-1} T^{-1}	8.6×10^{-8}
	$\gamma_P/2\pi$	42.577 4813(37)	MHz T^{-1}	8.6×10^{-8}
shielded proton gyromagnetic ratio $2\mu'_p/\hbar$ (H_2O, sphere, 25°C)	γ'_P	2.675 153 33(23)×10^{8}	s^{-1} T^{-1}	8.6×10^{-8}
	$\gamma'_P/2\pi$	42.576 3875(37)	MHz T^{-1}	8.6×10^{-8}
Neutron, n				
neutron mass	m_n	1.674 927 28(29)×10^{-27}	kg	1.7×10^{-7}
in u, $m_n = A_r$ (n) u (neutron relative atomic mass times u)		1.008 664 915 60(55)	u	5.5×10^{-10}
energy equivalent	m_nc^2	1.505 349 57(26)×10^{-10}	J	1.7×10^{-7}
in MeV		939.565 360(81)	MeV	8.6×10^{-8}
neutron-electron mass ratio	m_n/m_e	1838.683 6598(13)		7.0×10^{-10}
neutron-muon mass ratio	m_n/m_μ	8.892 484 02(23)		2.6×10^{-8}
neutron-tau mass ratio	m_n/m_τ	0.528 740(86)		1.6×10^{-4}
neutron-proton mass ratio	m_n/m_p	1.001 378 418 70(58)		5.8×10^{-10}
neutron molar mass N_Am_n	M(n), M_n	1.008 664 915 60(55)×10^{-3}	kg mol^{-1}	5.5×10^{-10}
neutron Compton wavelength h/m_nc	$\lambda_{C,n}$	1.319 590 9067(88)×10^{-15}	m	6.7×10^{-9}
$\lambda_{C,n}/2\pi$	$\bar{\lambda}_{C,n}$	0.210 019 4157(14)×10^{-15}	m	6.7×10^{-9}
neutron magnetic moment	μ_n	−0.966 236 45(24)×10^{-26}	J T^{-1}	2.5×10^{-7}
to Bohr magneton ratio	μ_n/μ_B	−1.041 875 63(25)×10^{-3}		2.4×10^{-7}
to nuclear magneton ratio	μ_n/μ_N	−1.913 042 73(45)		2.4×10^{-7}
neutron *g*-factor $2\mu_n/\mu_N$	g_n	−3.826 085 46(90)		2.4×10^{-7}
neutron-electron magnetic moment ratio	μ_n/μ_e	1.040 668 82(25)×10^{-3}		2.4×10^{-7}
neutron-proton magnetic moment ratio	μ_n/μ_p	−0.684 979 34(16)		2.4×10^{-7}
neutron to shielded proton magnetic moment ratio (H_2O, sphere, 25°C)	μ_n/μ'_P	−0.684 996 94(16)		2.4×10^{-7}
neutron gyromagnetic ratio $2\lvert\mu_n\rvert/\hbar$	γ_n	1.832 471 83(46)×10^{8}	s^{-1} T^{-1}	2.5×10^{-7}
	$\gamma_n/2\pi$	29.164 6950(73)	MHz T^{-1}	2.5×10^{-7}
Deuteron, d				
deuteron mass	m_d	3.343 583 35(57)×10^{-27}	kg	1.7×10^{-7}
in u, $m_d = A_r$(d) u (deuteron relative atomic mass times u)		2.013 553 212 70(35)	u	1.7×10^{-10}
energy equivalent	m_dc^2	3.005 062 85(51)×10^{-10}	J	1.7×10^{-7}
in MeV		1875.612 82(16)	MeV	8.6×10^{-8}
deuteron-electron mass ratio	m_d/m_e	3670.482 9652(18)		4.8×10^{-10}
deuteron-proton mass ratio	m_d/m_p	1.999 007 500 82(41)		2.0×10^{-10}
deuteron molar mass N_Am_d	M(d), M_d	2.013 553 212 70(35)×10^{-3}	kg mol^{-1}	1.7×10^{-10}
deuteron rms charge radius	R_d	2.1394(28)×10^{-15}	m	1.3×10^{-3}

Quantity	Symbol	Numerical value	Unit	Relative std. uncert. u_r
deuteron magnetic moment	μ_d	0.433 073 482(38)×10^{-26}	J T^{-1}	8.7×10^{-8}
to Bohr magneton ratio	μ_d/μ_B	0.466 975 4567(50)×10^{-3}		1.1×10^{-8}
to nuclear magneton ratio	μ_d/μ_N	0.857 438 2329(92)		1.1×10^{-8}
deuteron-electron magnetic moment ratio	μ_d/μ_e	−4.664 345 548(50) ×10^{-4}		1.1×10^{-8}
deuteron-proton magnetic moment ratio	μ_d/μ_p	0.307 012 2084(45)		1.5×10^{-8}
deuteron-neutron magnetic moment ratio	μ_d/μ_n	−0.448 206 52(11)		2.4×10^{-7}
Helion, h				
helion mass[5]	m_h	5.006 412 14(86)×10^{-27}	kg	1.7×10^{-7}
in u, $m_h = A_r(h)$ u (helion relative atomic mass times u)		3.014 932 2434(58)	u	1.9×10^{-9}
energy equivalent	m_hc^2	4.499 538 84(77)×10^{-10}	J	1.7×10^{-7}
in MeV		2808.391 42(24)	MeV	8.6×10^{-8}
helion-electron mass ratio	m_h/m_e	5495.885 269(11)		2.0×10^{-9}
helion-proton mass ratio	m_h/m_p	2.993 152 6671(58)		1.9×10^{-9}
helion molar mass N_Am_h	$M(h)$, M_h	3.014 932 2434(58)×10^{-3}	kg mol^{-1}	1.9×10^{-9}
shielded helion magnetic moment (gas, sphere, 25°C)	μ'_h	−1.074 553 024(93)×10^{-26}	J T^{-1}	8.7×10^{-8}
to Bohr magneton ratio	μ'_h/μ_B	−1.158 671 474(14)×10^{-3}		1.2×10^{-8}
to nuclear magneton ratio	μ'_h/μ_N	−2.127 497 723(25)		1.2×10^{-8}
shielded helion to proton magnetic moment ratio (gas, sphere, 25°C)	μ'_h/μ_P	−0.761 766 562(12)		1.5×10^{-8}
shielded helion to shielded proton magnetic moment ratio (gas/H_2O, spheres, 25°C)	μ'_h/μ'_P	−0.761 786 1313(33)		4.3×10^{-9}
shielded helion gyromagnetic ratio $2\|\mu'_h\|\hbar$ (gas, sphere, 25°C)	γ'_h	2.037 894 70(18)×10^{8}	s^{-1} T^{-1}	8.7×10^{-8}
	$\gamma'_h/2\pi$	32.434 1015(28)	MHz T^{-1}	8.7×10^{-8}
Alpha particle, α				
alpha particle mass	m_α	6.644 6565(11)×10^{-27}	kg	1.7×10^{-7}
in u, $m_\alpha = A_r(\alpha)$ u (alpha particle relative atomic mass times u)		4.001 506 179 149(56)	u	1.4×10^{-11}
energy equivalent	$m_\alpha c^2$	5.971 9194(10)×10^{-10}	J	1.7×10^{-7}
in MeV		3727.379 17(32)	MeV	8.6×10^{-8}
alpha particle to electron mass ratio	m_α/m_e	7294.299 5363(32)		4.4×10^{-10}
alpha particle to proton mass ratio	m_α/m_p	3.972 599 689 07(52)		1.3×10^{-10}
alpha particle molar mass N_Am_α	$M(\alpha)$, M_α	4.001 506 179 149(56)×10^{-3}	kg mol^{-1}	1.4×10^{-11}
Physico-Chemical				
Avogadro constant	N_A, L	6.022 1415(10)×10^{23}	mol^{-1}	1.7×10^{-7}
atomic mass constant $m_u = (1/12)m(^{12}C) = 1\ u = 10^{-3}\ kg\ mol^{-1}/N_A$	m_u	1.660 538 86(28)×10^{-27}	kg	1.7×10^{-7}
energy equivalent	m_uc^2	1.492 417 90(26)×10^{-10}	J	1.7×10^{-7}
in MeV		931.494 043(80)	MeV	8.6×10^{-8}
Faraday constant[7] N_Ae	F	96 485.3383(83)	C mol^{-1}	8.6×10^{-8}
molar Planck constant	N_Ah	3.990 312 716(27) ×10^{-10}	J s mol^{-1}	6.7×10^{-9}
	N_Ahc	0.119 626 565 72(80)	J m mol^{-1}	6.7×10^{-9}
molar gas constant	R	8.314 472(15)	J mol^{-1} K^{-1}	1.7×10^{-6}
Boltzmann constant R/N_A	k	1.380 6505(24)×10^{-23}	J K^{-1}	1.8×10^{-6}
in eV K^{-1}		8.617 343(15)×10^{-5}	eV K^{-1}	1.8×10^{-6}
	k/h	2.083 6644(36) ×10^{10}	Hz K^{-1}	1.7×10^{-6}
	k/hc	69.503 56(12)	m^{-1} K^{-1}	1.7×10^{-6}
molar volume of ideal gas RT/p				
$T = 273.15$ K, $p = 101.325$ kPa	V_m	22.413 996(39) ×10^{-3}	m^3 mol^{-1}	1.7×10^{-6}
Loschmidt constant N_A/V_m	n_0	2.686 7773(47)×10^{25}	m^{-3}	1.8×10^{-6}
$T = 273.15$ K, $p = 100$ kPa	V_m	22.710 981(40) ×10^{-3}	m^3 mol^{-1}	1.7×10^{-6}
Sackur-Tetrode constant (absolute entropy constant)[8]				
$5/2 + \ln[(2\pi m_ukT_1/h^2)^{3/2}kT_1/p_0]$				
$T_1 = 1$ K, $p_0 = 100$ kPa	S_0/R	−1.151 7047(44)		3.8×10^{-6}
$T_1 = 1$ K, $p_0 = 101.325$ kPa		−1.164 8677(44)		3.8×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3c^2$	σ	5.670 400(40)×10^{-8}	W m^{-2} K^{-4}	7.0×10^{-6}
first radiation constant $2\pi hc^2$	c_1	3.741 771 38(64)×10^{-16}	W m^2	1.7×10^{-7}
first radiation constant for spectral radiance $2hc^2$	c_{1L}	1.191 042 82(20)×10^{-16}	W m^2 sr^{-1}	1.7×10^{-7}
second radiation constant hc/k	c_2	1.438 7752(25)×10^{-2}	m K	1.7×10^{-6}
Wien displacement law constant $b = \lambda_{max}T = c_2/4.965\,114\,231\ldots$	b	2.897 7685(51)×10^{-3}	m K	1.7×10^{-6}

[1] See the “Adopted values” table for the conventional value adopted internationally for realizing representations of the volt using the Josephson effect.

[2] See the “Adopted values” table for the conventional value adopted internationally for realizing representations of the ohm using the quantum Hall effect.

[3] Value recommended by the Particle Data Group (Hagiwara *et al.*, 2002).

[4] Based on the ratio of the masses of the W and Z bosons m_W/m_Z recommended by the Particle Data Group (Hagiwara et al., 2002). The value for $\sin^2\theta_W$ they recommend, which is based on a particular variant of the modified minimal subtraction ($\overline{\text{MS}}$) scheme, is $\sin^2 \hat{\theta}_W (M_Z) = 0.231\ 24(24)$.

[5] The helion, symbol h, is the nucleus of the ^{3}He atom.

[6] This and all other values involving m_τ are based on the value of $m_\tau c^2$ in MeV recommended by the Particle Data Group (Hagiwara et al., 2002), but with a standard uncertainty of 0.29 MeV rather than the quoted uncertainty of –0.26 MeV, +0.29 MeV.

[7] The numerical value of F to be used in coulometric chemical measurements is 96 485.336(16) [1.7×10^{-7}] when the relevant current is measured in terms of representations of the volt and ohm based on the Josephson and quantum Hall effects and the internationally adopted conventional values of the Josephson and von Klitzing constants K_{J-90} and R_{K-90} given in the “Adopted values” table.

[8] The entropy of an ideal monoatomic gas of relative atomic mass A_r is given by $S = S_0 + (3/2)R \ln A_r - R \ln(p/p_0) + (5/2)R \ln(T/\text{K})$.

TABLE III. Internationally Adopted Values of Various Quantities

Quantity	Symbol	Numerical value	Unit	Relative std. uncert. u_r
molar mass of ^{12}C	$M(^{12}\text{C})$	12×10^{-3}	kg mol^{-1}	(exact)
molar mass constant $M(^{12}\text{C})/12$	M_u	1×10^{-3}	kg mol^{-1}	(exact)
conventional value of Josephson constant	K_{J-90}	483 597.9	GHz V^{-1}	(exact)
conventional value of von Klitzing constant	R_{K-90}	25 812.807	Ω	(exact)
standard atmosphere		101 325	Pa	(exact)
standard acceleration of gravity	g_n	9.806 65	m s^{-2}	(exact)

TABLE IV. The Values of Some Energy Equivalents Derived From the Relations $E = mc^2 = hc/\lambda = h\nu = kT$, and Based on the 2002 CODATA Adjustment of the Values of the Constants

1 eV = (e/C) J, 1 u = m_u = (1/12)$m(^{12}\text{C})$ = 10^{-3} kg mol^{-1}/N_A, and $E_h = 2R_\infty hc = \alpha^2 m_e c^2$ is the Hartree Energy (hartree)

	Relevant unit			
	J	**kg**	**m^{-1}**	**Hz**
1 J	(1 J) = 1 J	(1 J)/c^2 =1.112 650 056 ×10^{-17} kg	(1 J)/hc = 5.034 117 20(86)×10^{24} m^{-1}	(1 J)/h =1.509 190 37(26)×10^{33} Hz
1 kg	(1 kg)c^2 = 8.987 551 787 ×10^{16} J	(1 kg) = 1kg	(1 kg)c/h = 4.524 438 91(77)×10^{41} m^{-1}	(1 kg)c^2/h = 1.356 392 66(23)×10^{50} Hz
1 m^{-1}	(1 m^{-1})hc = 1.986 445 61(34)×10^{-25} J	(1 m^{-1})h/c = 2.210 218 81(38)×10^{-42} kg	(1 m^{-1}) = 1 m^{-1}	(1 m^{-1})c = 299 792 458 Hz
1 Hz	(1 Hz)h = 6.626 0693(11) ×10^{-34} J	(1 Hz)h/c^2 = 7.372 4964(13)×10^{-51} kg	(1 Hz)/c = 3.335 640 952×10^{-9} m^{-1}	(1 Hz) = 1 Hz
1 K	(1 K)k = 1.380 6505(24) ×10^{-23} J	(1 K)k/c^2 =1.536 1808(27) ×10^{-40} kg	(1 K)k/hc = 69.503 56(12) m^{-1}	(1 K)k/h = 2.083 6644(36)×10^{10} Hz
1 eV	(1 eV) =1.602 176 53(14) ×10^{-19} J	(1 eV)/c^2 = 1.782 661 81(15)×10^{-36} kg	(1 eV)/hc = 8.065 544 45(69)×10^5 m^{-1}	(1 eV)/h = 2.417 989 40(21)×10^{14} Hz
1 u	(1 u)c^2 = 1.492 417 90(26) ×10^{-10} J	(1 u) = 1.660 538 86(28)×10^{-27} kg	(1 u)c/h = 7.513 006 608(50) ×10^{14} m^{-1}	(1 u)c^2/h = 2.252 342 718(15)×10^{23} Hz
1 E_h	(1 E_h) = 4.359 744 17(75)×10^{-18} J	(1 E_h)/c^2 = 4.850 869 60(83) ×10^{-35} kg	(1 E_h)/hc = 2.194 746 313 705(15)×10^7 m^{-1}	(1 E_h)/h = 6.579 683 920 721(44)×10^{15} Hz

TABLE V. The Values of Some Energy Equivalents Derived From the Relations $E = mc^2 = hc/\lambda = h\nu = kT$, and Based on the 2002 CODATA Adjustment of the Values of the Constants

1 eV = (e/C) J, 1 u = m_u = (1/12)$m(^{12}\text{C})$ = 10^{-3} kg mol^{-1}/N_A, and $E_h = 2R_\infty hc = \alpha^2 m_e c^2$ is the Hartree Energy (hartree)

	Relevant unit			
	K	**eV**	**u**	**E_h**
1 J	(1 J)/k = 7.242 963(13)×10^{22} K	(1 J) = 6.241 509 47(53)×10^{18} eV	(1 J)/c^2 =6.700 5361(11)×10^9 u	(1 J) = 2.293 712 57(39) ×10^{17} E_h
1 kg	(1 kg)c^2/k =6.509 650(11) ×10^{39} K	(1 kg)c^2 = 5.609 588 96(48)×10^{35} eV	(1 kg) = 6.022 1415(10)×10^{26} u	(1 kg)c^2 = 2.061 486 05(35)×10^{34} E_h
1 m^{-1}	(1 m^{-1})hc/k = 1.438 7752(25)×10^{-2} K	(1 m^{-1})hc = 1.239 841 91(11)×10^{-6} eV	(1 m^{-1})h/c = 1.331 025 0506(89) ×10^{-15} u	(1 m^{-1})hc = 4.556 335 252 760(30) ×10^{-8} E_h
1 Hz	(1 Hz)h/k = 4.799 2374(84)×10^{-11} K	(1 Hz)h = 4.135 667 43(35)×10^{-15} eV	(1 Hz)h/c^2 = 4.439 821 667(30)×10^{-24} u	(1 Hz)h = 1.519 829 846 006(10)×10^{-16} E_h
1 K	(1 K) = 1 K	(1 K)k = 8.617 343(15)×10^{-5} eV	(1 K)k/c^2 =9.251 098(16)×10^{-14} u	(1 K)k = 3.166 8153(55)×10^{-6} E_h
1 eV	(1 eV)/k = 1.160 4505(20)×10^4 K	(1 eV) = 1 eV	(1 eV)/c^2 = 1.073 544 171(92)×10^{-9} u	(1 eV) = 3.674 932 45(31) ×10^{-2} E_h
1 u	(1 u)c^2/k = 1.080 9527(19)×10^{13} K	(1 u)c^2 = 931.494 043(80)×10^6 eV	(1 u) = 1 u	(1 u)c^2 = 3.423 177 686(23) ×10^7 E_h
1 E_h	(1 E_h)/k = 3.157 7465(55) ×10^5 K	(1 E_h) = 27.211 3845(23) eV	(1 E_h)/c^2 = 2.921 262 323(19)×10^{-8} u	(1 E_h) = 1 E_h

FUNDAMENTAL PHYSICAL CONSTANTS — FREQUENTLY USED CONSTANTS

Quantity	Symbol	Value	Unit	Relative std. uncert. u_r
speed of light in vacuum	c, c_0	299 792 458	m s^{-1}	(exact)
magnetic constant	μ_0	$4\pi \times 10^{-7}$	N A^{-2}	
		$= 12.566\,370\,614\ldots \times 10^{-7}$	N A^{-2}	(exact)
electric constant $1/\mu_0 c^2$	ε_0	$8.854\,187\,817\ldots \times 10^{-12}$	F m^{-1}	(exact)
Newtonian constant of gravitation	G	$6.6742(10) \times 10^{-11}$	m^3 kg^{-1} s^{-2}	1.5×10^{-4}
Plank constant	h	$6.626\,0693(11) \times 10^{-34}$	J s	1.7×10^{-7}
$h/2\pi$	$\hbar$	$1.054\,571\,68(18) \times 10^{-34}$	J s	1.7×10^{-7}
elementary charge	e	$1.602\,176\,53(14) \times 10^{-19}$	C	8.5×10^{-8}
magnetic flux quantum $h/2e$	ϕ_0	$2.067\,833\,72(18) \times 10^{-15}$	Wb	8.5×10^{-8}
conductance quantum $2e^2/h$	G_0	$7.748\,091\,733(26) \times 10^{-5}$	S	3.3×10^{-9}
electron mass	m_e	$9.109\,3826(16) \times 10^{-31}$	kg	1.7×10^{-7}
proton mass	m_p	$1.672\,621\,71(29) \times 10^{-27}$	kg	1.7×10^{-7}
proton-electron mass ratio	m_p/m_e	1836.152 672 61(85)		4.6×10^{-10}
fine-structure constant $e^2/4\pi\varepsilon_0\hbar c$	α	$7.297\,352\,568(24) \times 10^{-3}$		3.3×10^{-9}
inverse fine-structure constant	α^{-1}	137.035 999 11(46)		3.3×10^{-9}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 525(73)	m^{-1}	6.6×10^{-12}
Avogadro constant	N_A, L	$6.022\,1415(10) \times 10^{23}$	mol^{-1}	1.7×10^{-7}
Faraday constant $N_A e$	F	96 485.3383(83)	C mol^{-1}	8.6×10^{-8}
molar gas constant	R	8.314 472(15)	J mol^{-1} K^{-1}	1.7×10^{-6}
Boltzmann constant R/N_A	k	$1.380\,6505(24) \times 10^{-23}$	J K^{-1}	1.8×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3c^2$	σ	$5.670\,400(40) \times 10^{-8}$	W m^{-2} K^{-4}	7.0×10^{-6}
Non-SI units accepted for use with the SI				
electron volt: (e/C) J	eV	$1.602\,176\,53(14) \times 10^{-19}$	J	8.5×10^{-8}
(unified) atomic mass unit 1 u= $m_u = {}^1/_{12}\, m(^{12}\mathrm{C}) = 10^{-3}$ kg mol$^{-1}/N_A$	u	$1.660\,538\,86(28) \times 10^{-27}$	kg	1.7×10^{-7}

STANDARD ATOMIC WEIGHTS (2005)

This table of atomic weights includes the changes made in 2005 by the IUPAC Commission on Isotopic Abundances and Atomic Weights. Those changes affected the following elements: Al, Au, Bi, Co, Cs, La, Mn, Na, Nd, P, Pt, Sm, Sc, Ta, Tb, and Th.

The Standard Atomic Weights apply to the elements as they exist naturally on Earth, and the uncertainties take into account the isotopic variation found in most laboratory samples. Further comments on the variability are given in the footnotes.

The number in parentheses following the atomic weight value gives the uncertainty in the last digit. An atomic weight entry in brackets indicates that the element that has no stable isotopes; the value given is the atomic mass in u (or the mass number, if the mass is not accurately known) for the isotope of longest half-life. Thorium, protactinium, and uranium have no stable isotopes, but the terrestrial isotopic composition is sufficiently uniform to permit a standard atomic weight to be specified.

References

1. *Chemistry International*, Vol. 27, No. 6, p.18, 2005.
2. Coplen, T. D., *Pure Appl. Chem.* 73, 667, 2001.
3. Coplen, T. D., *J. Phys. Chem. Ref. Data*, 30, 701, 2001.

Name	Symbol	Atomic no.	Atomic weight	Footnotes
Actinium	Ac	89	[227.0277]	a
Aluminum	Al	13	26.9815386(8)	
Americium	Am	95	[243.0614]	a
Antimony	Sb	51	121.760(1)	g
Argon	Ar	18	39.948(1)	g r
Arsenic	As	33	74.92160(2)	
Astatine	At	85	[209.9871]	a
Barium	Ba	56	137.327(7)	
Berkelium	Bk	97	[247.0703]	a
Beryllium	Be	4	9.012182(3)	
Bismuth	Bi	83	208.98040(1)	
Bohrium	Bh	107	[264.12]	a
Boron	B	5	10.811(7)	g m r
Bromine	Br	35	79.904(1)	
Cadmium	Cd	48	112.411(8)	g
Calcium	Ca	20	40.078(4)	g
Californium	Cf	98	[251.0796]	a
Carbon	C	6	12.0107(8)	g r
Cerium	Ce	58	140.116(1)	g
Cesium	Cs	55	132.9054519(2)	
Chlorine	Cl	17	35.453(2)	g m r
Chromium	Cr	24	51.9961(6)	
Cobalt	Co	27	58.933195(5)	
Copper	Cu	29	63.546(3)	r
Curium	Cm	96	[247.0704]	a
Darmstadtium	Ds	110	[271]	a
Dubnium	Db	105	[262.1141]	a
Dysprosium	Dy	66	162.500(1)	g
Einsteinium	Es	99	[252.0830]	a
Erbium	Er	68	167.259(3)	g
Europium	Eu	63	151.964(1)	g
Fermium	Fm	100	[257.0951]	a
Fluorine	F	9	18.9984032(5)	
Francium	Fr	87	[223.0197]	a
Gadolinium	Gd	64	157.25(3)	g
Gallium	Ga	31	69.723(1)	
Germanium	Ge	32	72.64(1)	
Gold	Au	79	196.966569(4)	
Hafnium	Hf	72	178.49(2)	
Hassium	Hs	108	[277]	a
Helium	He	2	4.002602(2)	g r
Holmium	Ho	67	164.93032(2)	
Hydrogen	H	1	1.00794(7)	g m r
Indium	In	49	114.818(3)	
Iodine	I	53	126.90447(3)	
Iridium	Ir	77	192.217(3)	
Iron	Fe	26	55.845(2)	
Krypton	Kr	36	83.798(2)	g m
Lanthanum	La	57	138.90547(7)	g
Lawrencium	Lr	103	[262.1097]	a
Lead	Pb	82	207.2(1)	g r
Lithium	Li	3	6.941(2)	b g m r
Lutetium	Lu	71	174.967(1)	g
Magnesium	Mg	12	24.3050(6)	
Manganese	Mn	25	54.938045(5)	
Meitnerium	Mt	109	[268.1388]	a
Mendelevium	Md	101	[258.0984]	a
Mercury	Hg	80	200.59(2)	
Molybdenum	Mo	42	95.94(2)	g
Neodymium	Nd	60	144.242(3)	g
Neon	Ne	10	20.1797(6)	g m
Neptunium	Np	93	[237.0482]	a
Nickel	Ni	28	58.6934(2)	
Niobium	Nb	41	92.90638(2)	
Nitrogen	N	7	14.0067(2)	g r
Nobelium	No	102	[259.1010]	a
Osmium	Os	76	190.23(3)	g
Oxygen	O	8	15.9994(3)	g r
Palladium	Pd	46	106.42(1)	g
Phosphorus	P	15	30.973762(2)	
Platinum	Pt	78	195.084(9)	
Plutonium	Pu	94	[244.0642]	a
Polonium	Po	84	[208.9824]	a
Potassium	K	19	39.0983(1)	g
Praseodymium	Pr	59	140.90765(2)	
Promethium	Pm	61	[144.9127]	a
Protactinium	Pa	91	231.03588(2)	
Radium	Ra	88	[226.0254]	a
Radon	Rn	86	[222.0176]	a
Rhenium	Re	75	186.207(1)	
Rhodium	Rh	45	102.90550(2)	
Roentgenium	Rg	111	[272.1535]	a
Rubidium	Rb	37	85.4678(3)	g
Ruthenium	Ru	44	101.07(2)	g
Rutherfordium	Rf	104	[261.1088]	a
Samarium	Sm	62	150.36(2)	g
Scandium	Sc	21	44.955912(6)	
Seaborgium	Sg	106	[266.1219]	a

Name	Symbol	Atomic no.	Atomic weight	Footnotes
Selenium	Se	34	78.96(3)	r
Silicon	Si	14	28.0855(3)	r
Silver	Ag	47	107.8682(2)	g
Sodium	Na	11	22.98976928(2)	
Strontium	Sr	38	87.62(1)	g r
Sulfur	S	16	32.065(5)	g r
Tantalum	Ta	73	180.94788(2)	
Technetium	Tc	43	[97.9072]	a
Tellurium	Te	52	127.60(3)	g
Terbium	Tb	65	158.92535(2)	
Thallium	Tl	81	204.3833(2)	
Thorium	Th	90	232.03806(2)	g
Thulium	Tm	69	168.93421(2)	
Tin	Sn	50	118.710(7)	g
Titanium	Ti	22	47.867(1)	
Tungsten	W	74	183.84(1)	
Ununbium	Uub	112	[285]	a
Ununhexium	Uuh	116	[289]	a
Ununquadium	Uuq	114	[289]	a
Uranium	U	92	238.02891(3)	g m
Vanadium	V	23	50.9415(1)	
Xenon	Xe	54	131.293(6)	g m
Ytterbium	Yb	70	173.04(3)	g
Yttrium	Y	39	88.90585(2)	
Zinc	Zn	30	65.409(4)	
Zirconium	Zr	40	91.224(2)	g

[a] No stable isotope exists. The atomic mass in u (or the mass number, if the mass is not accurately known) is given in brackets for the isotope of longest half-life.

[b] Commercially available Li materials have atomic weights that range between 6.939 and 6.996; if a more accurate value is required, it must be determined for the specific material.

[g] Geological specimens are known in which the element has an isotopic composition outside the limits for the normal material. The difference between the atomic weight of the element in such specimens and that given in the table may exceed the stated uncertainty.

[m] Modified isotopic compositions may be found in commercially available material because it has been subject to an undisclosed or inadvertent isotopic fractionation. Substantial deviations in atomic weight of the element from that given in the table can occur.

[r] Range in isotopic composition of normal terrestrial material prevents a more precise atomic weight being given; the tabulated value should be applicable to any normal material.

ATOMIC MASSES AND ABUNDANCES

This table lists the mass (in atomic mass units, symbol u) and the natural abundance (in percent) of the stable nuclides and a few important radioactive nuclides. A complete table of all nuclides may be found in Section 11 ("Table of the Isotopes").

The atomic masses were taken from the 2003 evaluation of Audi, Wapstra, and Thibault (References 2, 3). The number in parentheses following the mass value is the uncertainty in the last digit(s) given. An asterisk * after an entry indicates the mass value was derived not purely from experimental data, but at least partly from systematic trends.

Natural abundance values were taken from the IUPAC Technical Report "Atomic Weight of the Elements: Review 2000" (Reference 4); these entries are also followed by uncertainties in the last digit(s) of the stated values. This uncertainty includes both the estimated measurement uncertainty and the reported range of variation in different terrestrial sources of the element (see Reference 4 for full details and caveats regarding elements whose abundance is variable). The absence of an entry in the Abundance column indicates a radioactive nuclide not present in nature or an element whose isotopic composition varies so widely that a meaningful natural abundance cannot be defined.

References

1. Holden, N. E., "Table of the Isotopes", in Lide, D. R., Ed., *CRC Handbook of Chemistry and Physics, 86th Ed.*, CRC Press, Boca Raton FL, 2005.
2. Audi, G., Wapstra, A. H., and Thibault, *Nucl. Phys.*, A729, 336, 2003.
3. Audi, G., and Wapstra, A. H., Atomic Mass Data Center, World Wide Web site, <http://www.nndc.bnl.gov/amdc/index.html>
4. de Laeter, J. R., Böhlke, J. K., De Bièvre, P., Hidaka, H., Peiser, H. S., Rosman, K. J. R., and Taylor, P. D. P., *Pure Appl. Chem.* 75, 683, 2003.

Z	Isotope	Mass in u	Abundance in %
1	^{1}H	1.00782503207(10)	99.9885(70)
	^{2}H	2.0141017778(4)	0.0115(70)
	^{3}H	3.0160492777(25)	
2	^{3}He	3.0160293191(26)	0.000134(3)
	^{4}He	4.00260325415(6)	99.999866(3)
3	^{6}Li	6.015122795(16)	7.59(4)
	^{7}Li	7.01600455(8)	92.41(4)
4	^{9}Be	9.0121822(4)	100
5	^{10}B	10.0129370(4)	19.9(7)
	^{11}B	11.0093054(4)	80.1(7)
6	^{11}C	11.0114336(10)	
	^{12}C	12.0000000(0)	98.93(8)
	^{13}C	13.0033548378(10)	1.07(8)
	^{14}C	14.003241989(4)	
7	^{14}N	14.0030740048(6)	99.636(7)
	^{15}N	15.0001088982(7)	0.364(7)
8	^{16}O	15.99491461956(16)	99.757(16)
	^{17}O	16.99913170(12)	0.038(1)
	^{18}O	17.9991610(7)	0.205(14)
9	^{18}F	18.0009380(6)	
	^{19}F	18.99840322(7)	100
10	^{20}Ne	19.9924401754(19)	90.48(3)
	^{21}Ne	20.99384668(4)	0.27(1)
	^{22}Ne	21.991385114(19)	9.25(3)
11	^{22}Na	21.9944364(4)	
	^{23}Na	22.9897692809(29)	100
	^{24}Na	23.99096278(8)	
12	^{24}Mg	23.985041700(14)	78.99(4)
	^{25}Mg	24.98583692(3)	10.00(1)
	^{26}Mg	25.982592929(30)	11.01(3)
13	^{27}Al	26.98153863(12)	100
14	^{28}Si	27.9769265325(19)	92.223(19)
	^{29}Si	28.976494700(22)	4.685(8)
	^{30}Si	29.97377017(3)	3.092(11)
15	^{31}P	30.97376163(20)	100
	^{32}P	31.97390727(20)	
16	^{32}S	31.97207100(15)	94.99(26)
	^{33}S	32.97145876(15)	0.75(2)
	^{34}S	33.96786690(12)	4.25(24)
	^{35}S	34.96903216(11)	
	^{36}S	35.96708076(20)	0.01(1)
17	^{35}Cl	34.96885268(4)	75.76(10)
	^{37}Cl	36.96590259(5)	24.24(10)
18	^{36}Ar	35.967545106(29)	0.3365(30)
	^{38}Ar	37.9627324(4)	0.0632(5)
	^{40}Ar	39.9623831225(29)	99.6003(30)
19	^{39}K	38.96370668(20)	93.2581(44)
	^{40}K	39.96399848(21)	0.0117(1)
	^{41}K	40.96182576(21)	6.7302(44)
	^{42}K	41.96240281(24)	
	^{43}K	42.960716(10)	
20	^{40}Ca	39.96259098(22)	96.941(156)
	^{42}Ca	41.95861801(27)	0.647(23)
	^{43}Ca	42.9587666(3)	0.135(10)
	^{44}Ca	43.9554818(4)	2.086(110)
	^{45}Ca	44.9561866(4)	
	^{46}Ca	45.9536926(24)	0.004(3)
	^{47}Ca	46.9545460(24)	
	^{48}Ca	47.952534(4)	0.187(21)
21	^{45}Sc	44.9559119(9)	100
22	^{46}Ti	45.9526316(9)	8.25(3)
	^{47}Ti	46.9517631(9)	7.44(2)
	^{48}Ti	47.9479463(9)	73.72(3)
	^{49}Ti	48.9478700(9)	5.41(2)
	^{50}Ti	49.9447912(9)	5.18(2)
23	^{50}V	49.9471585(11)	0.250(4)
	^{51}V	50.9439595(11)	99.750(4)
24	^{50}Cr	49.9460442(11)	4.345(13)
	^{51}Cr	50.9447674(11)	
	^{52}Cr	51.9405075(8)	83.789(18)
	^{53}Cr	52.9406494(8)	9.501(17)
	^{54}Cr	53.9388804(8)	2.365(7)
25	^{54}Mn	53.9403589(14)	
	^{55}Mn	54.9380451(7)	100
26	^{52}Fe	51.948114(7)	
	^{54}Fe	53.9396105(7)	5.845(35)
	^{55}Fe	54.9382934(7)	
	^{56}Fe	55.9349375(7)	91.754(36)
	^{57}Fe	56.9353940(7)	2.119(10)
	^{58}Fe	57.9332756(8)	0.282(4)
	^{59}Fe	58.9348755(8)	
27	^{57}Co	56.9362914(8)	

Z	Isotope	Mass in u	Abundance in %
	^{58}Co	57.9357528(13)	
	^{59}Co	58.9331950(7)	100
	^{60}Co	59.9338171(7)	
28	^{58}Ni	57.9353429(7)	68.0769(89)
	^{59}Ni	58.9343467(7)	
	^{60}Ni	59.9307864(7)	26.2231(77)
	^{61}Ni	60.9310560(7)	1.1399(6)
	^{62}Ni	61.9283451(6)	3.6345(17)
	^{63}Ni	62.9296694(6)	
	^{64}Ni	63.9279660(7)	0.9256(9)
29	^{63}Cu	62.9295975(6)	69.15(3)
	^{64}Cu	63.9297642(6)	
	^{65}Cu	64.9277895(7)	30.85(3)
30	^{64}Zn	63.9291422(7)	48.268(321)
	^{65}Zn	64.9292410(7)	
	^{66}Zn	65.9260334(10)	27.975(77)
	^{67}Zn	66.9271273(10)	4.102(21)
	^{68}Zn	67.9248442(10)	19.024(123)
	^{70}Zn	69.9253193(21)	0.631(9)
31	^{67}Ga	66.9282017(14)	
	^{68}Ga	67.9279801(16)	
	^{69}Ga	68.9255736(13)	60.108(9)
	^{71}Ga	70.9247013(11)	39.892(9)
32	^{68}Ge	67.928094(7)	
	^{70}Ge	69.9242474(11)	20.38(18)
	^{72}Ge	71.9220758(18)	27.31(26)
	^{73}Ge	72.9234589(18)	7.76(8)
	^{74}Ge	73.9211778(18)	36.72(15)
	^{76}Ge	75.9214026(18)	7.83(7)
33	^{75}As	74.9215965(20)	100
34	^{74}Se	73.9224764(18)	0.89(4)
	^{75}Se	74.9225234(18)	
	^{76}Se	75.9192136(18)	9.37(29)
	^{77}Se	76.9199140(18)	7.63(16)
	^{78}Se	77.9173091(18)	23.77(28)
	^{79}Se	78.9184991(18)	
	^{80}Se	79.9165213(21)	49.61(41)
	^{82}Se	81.9166994(22)	8.73(22)
35	^{79}Br	78.9183371(22)	50.69(7)
	^{81}Br	80.9162906(21)	49.31(7)
36	^{78}Kr	77.9203648(12)	0.355(3)
	^{80}Kr	79.9163790(16)	2.286(10)
	^{82}Kr	81.9134836(19)	11.593(31)
	^{83}Kr	82.914136(3)	11.500(19)
	^{84}Kr	83.911507(3)	56.987(15)
	^{86}Kr	85.91061073(11)	17.279(41)
37	^{85}Rb	84.911789738(12)	72.17(2)
	^{86}Rb	85.91116742(21)	
	^{87}Rb	86.909180527(13)	27.83(2)
38	^{84}Sr	83.913425(3)	0.56(1)
	^{85}Sr	84.912933(3)	
	^{86}Sr	85.9092602(12)	9.86(1)
	^{87}Sr	86.9088771(12)	7.00(1)
	^{88}Sr	87.9056121(12)	82.58(1)
	^{89}Sr	88.9074507(12)	
	^{90}Sr	89.907738(3)	
39	^{89}Y	88.9058483(27)	100
40	^{90}Zr	89.9047044(25)	51.45(40)
	^{91}Zr	90.9056458(25)	11.22(5)
	^{92}Zr	91.9050408(25)	17.15(8)
	^{94}Zr	93.9063152(26)	17.38(28)
	^{96}Zr	95.9082734(30)	2.80(9)
41	^{93}Nb	92.9063781(26)	100
42	^{92}Mo	91.906811(4)	14.77(31)
	^{94}Mo	93.9050883(21)	9.23(10)
	^{95}Mo	94.9058421(21)	15.90(9)
	^{96}Mo	95.9046795(21)	16.68(1)
	^{97}Mo	96.9060215(21)	9.56(5)
	^{98}Mo	97.9054082(21)	24.19(26)
	^{99}Mo	98.9077119(21)	
	^{100}Mo	99.907477(6)	9.67(20)
43	^{97}Tc	96.906365(5)	
	^{98}Tc	97.907216(4)	
	^{99}Tc	98.9062547(21)	
44	^{96}Ru	95.907598(8)	5.54(14)
	^{98}Ru	97.905287(7)	1.87(3)
	^{99}Ru	98.9059393(22)	12.76(14)
	^{100}Ru	99.9042195(22)	12.60(7)
	^{101}Ru	100.9055821(22)	17.06(2)
	^{102}Ru	101.9043493(22)	31.55(14)
	^{104}Ru	103.905433(3)	18.62(27)
	^{106}Ru	105.907329(8)	
45	^{103}Rh	102.905504(3)	100
46	^{102}Pd	101.905609(3)	1.02(1)
	^{104}Pd	103.904036(4)	11.14(8)
	^{105}Pd	104.905085(4)	22.33(8)
	^{106}Pd	105.903486(4)	27.33(3)
	^{108}Pd	107.903892(4)	26.46(9)
	^{110}Pd	109.905153(12)	11.72(9)
47	^{107}Ag	106.905097(5)	51.839(8)
	^{109}Ag	108.904752(3)	48.161(8)
48	^{106}Cd	105.906459(6)	1.25(6)
	^{108}Cd	107.904184(6)	0.89(3)
	^{110}Cd	109.9030021(29)	12.49(18)
	^{111}Cd	110.9041781(29)	12.80(12)
	^{112}Cd	111.9027578(29)	24.13(21)
	^{113}Cd	112.9044017(29)	12.22(12)
	^{114}Cd	113.9033585(29)	28.73(42)
	^{116}Cd	115.904756(3)	7.49(18)
49	^{111}In	110.905103(5)	
	^{113}In	112.904058(3)	4.29(5)
	^{115}In	114.903878(5)	95.71(5)
50	^{112}Sn	111.904818(5)	0.97(1)
	^{113}Sn	112.905171(4)	
	^{114}Sn	113.902779(3)	0.66(1)
	^{115}Sn	114.903342(3)	0.34(1)
	^{116}Sn	115.901741(3)	14.54(9)
	^{117}Sn	116.902952(3)	7.68(7)
	^{118}Sn	117.901603(3)	24.22(9)
	^{119}Sn	118.903308(3)	8.59(4)
	^{120}Sn	119.9021947(27)	32.58(9)
	^{122}Sn	121.9034390(29)	4.63(3)
	^{124}Sn	123.9052739(15)	5.79(5)
51	^{121}Sb	120.9038157(24)	57.21(5)
	^{123}Sb	122.9042140(22)	42.79(5)
52	^{120}Te	119.904020(10)	0.09(1)
	^{122}Te	121.9030439(16)	2.55(12)
	^{123}Te	122.9042700(16)	0.89(3)
	^{124}Te	123.9028179(16)	4.74(14)
	^{125}Te	124.9044307(16)	7.07(15)
	^{126}Te	125.9033117(16)	18.84(25)
	^{128}Te	127.9044631(19)	31.74(8)

Z	Isotope	Mass in u	Abundance in %
	^{130}Te	129.9062244(21)	34.08(62)
53	^{123}I	122.905589(4)	
	^{125}I	124.9046302(16)	
	^{127}I	126.904473(4)	100
	^{129}I	128.904988(3)	
	^{131}I	130.9061246(12)	
54	^{124}Xe	123.9058930(20)	0.0952(3)
	^{126}Xe	125.904274(7)	0.0890(2)
	^{128}Xe	127.9035313(15)	1.9102(8)
	^{129}Xe	128.9047794(8)	26.4006(82)
	^{130}Xe	129.9035080(8)	4.0710(13)
	^{131}Xe	130.9050824(10)	21.2324(30)
	^{132}Xe	131.9041535(10)	26.9086(33)
	^{134}Xe	133.9053945(9)	10.4357(21)
	^{136}Xe	135.907219(8)	8.8573(44)
55	^{129}Cs	128.906064(5)	
	^{133}Cs	132.905451933(24)	100
	^{134}Cs	133.906718475(28)	
	^{136}Cs	135.9073116(20)	
	^{137}Cs	136.9070895(5)	
56	^{130}Ba	129.9063208(30)	0.106(1)
	^{132}Ba	131.9050613(11)	0.101(1)
	^{133}Ba	132.9060075(11)	
	^{134}Ba	133.9045084(4)	2.417(18)
	^{135}Ba	134.9056886(4)	6.592(12)
	^{136}Ba	135.9045759(4)	7.854(24)
	^{137}Ba	136.9058274(5)	11.232(24)
	^{138}Ba	137.9052472(5)	71.698(42)
	^{140}Ba	139.910605(9)	
57	^{138}La	137.907112(4)	0.090(1)
	^{139}La	138.9063533(26)	99.910(1)
58	^{136}Ce	135.907172(14)	0.185(2)
	^{138}Ce	137.905991(11)	0.251(2)
	^{140}Ce	139.9054387(26)	88.450(51)
	^{141}Ce	140.9082763(26)	
	^{142}Ce	141.909244(3)	11.114(51)
	^{144}Ce	143.913647(4)	
59	^{141}Pr	140.9076528(26)	100
60	^{142}Nd	141.9077233(25)	27.2(5)
	^{143}Nd	142.9098143(25)	12.2(2)
	^{144}Nd	143.9100873(25)	23.8(3)
	^{145}Nd	144.9125736(25)	8.3(1)
	^{146}Nd	145.9131169(25)	17.2(3)
	^{148}Nd	147.916893(3)	5.7(1)
	^{150}Nd	149.920891(3)	5.6(2)
61	^{145}Pm	144.912749(3)	
	^{147}Pm	146.9151385(26)	
62	^{144}Sm	143.911999(3)	3.07(7)
	^{147}Sm	146.9148979(26)	14.99(18)
	^{148}Sm	147.9148227(26)	11.24(10)
	^{149}Sm	148.9171847(26)	13.82(7)
	^{150}Sm	149.9172755(26)	7.38(1)
	^{152}Sm	151.9197324(27)	26.75(16)
	^{154}Sm	153.9222093(27)	22.75(29)
63	^{151}Eu	150.9198502(26)	47.81(6)
	^{153}Eu	152.9212303(26)	52.19(6)
64	^{152}Gd	151.9197910(27)	0.20(1)
	^{154}Gd	153.9208656(27)	2.18(3)
	^{155}Gd	154.9226220(27)	14.80(12)
	^{156}Gd	155.9221227(27)	20.47(9)
	^{157}Gd	156.9239601(27)	15.65(2)
	^{158}Gd	157.9241039(27)	24.84(7)
	^{160}Gd	159.9270541(27)	21.86(19)
65	^{159}Tb	158.9253468(27)	100
66	^{156}Dy	155.924283(7)	0.056(3)
	^{158}Dy	157.924409(4)	0.095(3)
	^{160}Dy	159.9251975(27)	2.329(18)
	^{161}Dy	160.9269334(27)	18.889(42)
	^{162}Dy	161.9267984(27)	25.475(36)
	^{163}Dy	162.9287312(27)	24.896(42)
	^{164}Dy	163.9291748(27)	28.260(54)
67	^{165}Ho	164.9303221(27)	100
68	^{162}Er	161.928778(4)	0.139(5)
	^{164}Er	163.929200(3)	1.601(3)
	^{166}Er	165.9302931(27)	33.503(36)
	^{167}Er	166.9320482(27)	22.869(9)
	^{168}Er	167.9323702(27)	26.978(18)
	^{170}Er	169.9354643(30)	14.910(36)
69	^{169}Tm	168.9342133(27)	100
70	^{168}Yb	167.933897(5)	0.13(1)
	^{169}Yb	168.935190(5)	
	^{170}Yb	169.9347618(26)	3.04(15)
	^{171}Yb	170.9363258(26)	14.28(57)
	^{172}Yb	171.9363815(26)	21.83(67)
	^{173}Yb	172.9382108(26)	16.13(27)
	^{174}Yb	173.9388621(26)	31.83(92)
	^{176}Yb	175.9425717(28)	12.76(41)
71	^{175}Lu	174.9407718(23)	97.41(2)
	^{176}Lu	175.9426863(23)	2.59(2)
72	^{174}Hf	173.940046(3)	0.16(1)
	^{176}Hf	175.9414086(24)	5.26(7)
	^{177}Hf	176.9432207(23)	18.60(9)
	^{178}Hf	177.9436988(23)	27.28(7)
	^{179}Hf	178.9458161(23)	13.62(2)
	^{180}Hf	179.9465500(23)	35.08(16)
73	^{180}Ta	179.9474648(24)	0.012(2)
	^{181}Ta	180.9479958(19)	99.988(2)
74	^{180}W	179.946704(4)	0.12(1)
	^{182}W	181.9482042(9)	26.50(16)
	^{183}W	182.9502230(9)	14.31(4)
	^{184}W	183.9509312(9)	30.64(2)
	^{186}W	185.9543641(19)	28.43(19)
75	^{185}Re	184.9529550(13)	37.40(2)
	^{187}Re	186.9557531(15)	62.60(2)
76	^{184}Os	183.9524891(14)	0.02(1)
	^{186}Os	185.9538382(15)	1.59(3)
	^{187}Os	186.9557505(15)	1.96(2)
	^{188}Os	187.9558382(15)	13.24(8)
	^{189}Os	188.9581475(16)	16.15(5)
	^{190}Os	189.9584470(16)	26.26(2)
	^{192}Os	191.9614807(27)	40.78(19)
77	^{191}Ir	190.9605940(18)	37.3(2)
	^{193}Ir	192.9629264(18)	62.7(2)
78	^{190}Pt	189.959932(6)	0.014(1)
	^{192}Pt	191.9610380(27)	0.782(7)
	^{194}Pt	193.9626803(9)	32.967(99)
	^{195}Pt	194.9647911(9)	33.832(10)
	^{196}Pt	195.9649515(9)	25.242(41)
	^{198}Pt	197.967893(3)	7.163(55)
79	^{197}Au	196.9665687(6)	100
	^{198}Au	197.9682423(6)	
80	^{196}Hg	195.965833(3)	0.15(1)

Z	Isotope	Mass in u	Abundance in %
	^{197}Hg	196.967213(3)	
	^{198}Hg	197.9667690(4)	9.97(20)
	^{199}Hg	198.9682799(4)	16.87(22)
	^{200}Hg	199.9683260(4)	23.10(19)
	^{201}Hg	200.9703023(6)	13.18(9)
	^{202}Hg	201.9706430(6)	29.86(26)
	^{203}Hg	202.9728725(18)	
	^{204}Hg	203.9734939(4)	6.87(15)
81	^{201}Tl	200.970819(16)	
	^{203}Tl	202.9723442(14)	29.52(1)
	^{205}Tl	204.9744275(14)	70.48(1)
82	^{204}Pb	203.9730436(13)	1.4(1)
	^{206}Pb	205.9744653(13)	24.1(1)
	^{207}Pb	206.9758969(13)	22.1(1)
	^{208}Pb	207.9766521(13)	52.4(1)
	^{210}Pb	209.9841885(16)	
83	^{207}Bi	206.9784707(26)	
	^{209}Bi	208.9803987(16)	100
84	^{209}Po	208.9824304(20)	
	^{210}Po	209.9828737(13)	
85	^{210}At	209.987148(8)	
	^{211}At	210.9874963(30)	
86	^{211}Rn	210.990601(7)	
	^{220}Rn	220.0113940(24)	
	^{222}Rn	222.0175777(25)	
87	^{223}Fr	223.0197359(26)	
88	^{223}Ra	223.0185022(27)	
	^{224}Ra	224.0202118(24)	
	^{226}Ra	226.0254098(25)	
	^{228}Ra	228.0310703(26)	
89	^{227}Ac	227.0277521(26)	
90	^{228}Th	228.0287411(24)	
	^{230}Th	230.0331338(19)	
	^{232}Th	232.0380553(21)	100
91	^{231}Pa	231.0358840(24)	100
92	^{233}U	233.0396352(29)	
	^{234}U	234.0409521(20)	0.0054(5)
	^{235}U	235.0439299(20)	0.7204(6)
	^{236}U	236.0455680(20)	
	^{238}U	238.0507882(20)	99.2742(10)
93	^{237}Np	237.0481734(20)	
	^{239}Np	239.0529390(22)	
94	^{238}Pu	238.0495599(20)	
	^{239}Pu	239.0521634(20)	
	^{240}Pu	240.0538135(20)	
	^{241}Pu	241.0568515(20)	
	^{242}Pu	242.0587426(20)	
	^{244}Pu	244.064204(5)	
95	^{241}Am	241.0568291(20)	
	^{243}Am	243.0613811(25)	
96	^{243}Cm	243.0613891(22)	
	^{244}Cm	244.0627526(20)	
	^{245}Cm	245.0654912(22)	
	^{246}Cm	246.0672237(22)	
	^{247}Cm	247.070354(5)	
	^{248}Cm	248.072349(5)	
97	^{247}Bk	247.070307(6)	
	^{249}Bk	249.0749867(28)	
98	^{249}Cf	249.0748535(24)	
	^{250}Cf	250.0764061(22)	
	^{251}Cf	251.079587(5)	
	^{252}Cf	252.081626(5)	
99	^{252}Es	252.082980(50)	
100	^{257}Fm	257.095105(7)	
101	^{256}Md	256.094060(60)	
	^{258}Md	258.098431(5)	
102	^{259}No	259.10103(11)*	
103	^{262}Lr	262.10963(22)*	
104	^{261}Rf	261.108770(30)*	
105	^{262}Db	262.11408(20)*	
106	^{263}Sg	263.11832(13)*	
107	^{264}Bh	264.12460(30)*	
108	^{265}Hs	265.13009(15)*	
109	^{268}Mt	268.13873(34)*	
110	^{281}Ds	281.16206(78)*	
111	^{272}Rg	273.15362(36)*	

ELECTRON CONFIGURATION AND IONIZATION ENERGY OF NEUTRAL ATOMS IN THE GROUND STATE

William C. Martin

The ground state electron configuration, ground level, and ionization energy of the elements hydrogen through rutherfordium are listed in this table. The electron configurations of elements heavier than neon are shortened by using rare-gas element symbols in brackets to represent the corresponding electrons. See the references for details of the notation for Pa, U, and Np. Ionization energies to higher states (and more precise values of the first ionization energy for certain elements) may be found in the table "Ionization Energies of Atoms and Atomic Ions" in Section 10 of this *Handbook*.

References

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2. Martin, W. C., and Wiese, W. L., "Atomic Spectroscopy", in *Atomic, Molecular, & Optical Physics Handbook*, ed. by G.W.F. Drake (AIP, Woodbury, NY, 1996) Chapter 10, pp. 135-153.

Z		Element	Ground-state configuration	Ground level	Ionization energy (eV)
1	H	Hydrogen	$1s$	$^2S_{1/2}$	13.5984
2	He	Helium	$1s^2$	$^1S_0$	24.5874
3	Li	Lithium	$1s^2\ 2s$	$^2S_{1/2}$	5.3917
4	Be	Beryllium	$1s^2\ 2s^2$	$^1S_0$	9.3227
5	B	Boron	$1s^2\ 2s^2\ 2p$	$^2P^o_{1/2}$	8.2980
6	C	Carbon	$1s^2\ 2s^2\ 2p^2$	$^3P_0$	11.2603
7	N	Nitrogen	$1s^2\ 2s^2\ 2p^3$	$^4S^o_{3/2}$	14.5341
8	O	Oxygen	$1s^2\ 2s^2\ 2p^4$	$^3P_2$	13.6181
9	F	Fluorine	$1s^2\ 2s^2\ 2p^5$	$^2P^o_{3/2}$	17.4228
10	Ne	Neon	$1s^2\ 2s^2\ 2p^6$	$^1S_0$	21.5645
11	Na	Sodium	[Ne] $3s$	$^2S_{1/2}$	5.1391
12	Mg	Magnesium	[Ne] $3s^2$	$^1S_0$	7.6462
13	Al	Aluminum	[Ne] $3s^2\ 3p$	$^2P^o_{1/2}$	5.9858
14	Si	Silicon	[Ne] $3s^2\ 3p^2$	$^3P_0$	8.1517
15	P	Phosphorus	[Ne] $3s^2\ 3p^3$	$^4S^o_{3/2}$	10.4867
16	S	Sulfur	[Ne] $3s^2\ 3p^4$	$^3P_2$	10.3600
17	Cl	Chlorine	[Ne] $3s^2\ 3p^5$	$^2P^o_{3/2}$	12.9676
18	Ar	Argon	[Ne] $3s^2\ 3p^6$	$^1S_0$	15.7596
19	K	Potassium	[Ar] $4s$	$^2S_{1/2}$	4.3407
20	Ca	Calcium	[Ar] $4s^2$	$^1S_0$	6.1132
21	Sc	Scandium	[Ar] $3d\ 4s^2$	$^2D_{3/2}$	6.5615
22	Ti	Titanium	[Ar] $3d^2\ 4s^2$	$^3F_2$	6.8281
23	V	Vanadium	[Ar] $3d^3\ 4s^2$	$^4F_{3/2}$	6.7462
24	Cr	Chromium	[Ar] $3d^5\ 4s$	$^7S_3$	6.7665
25	Mn	Manganese	[Ar] $3d^5\ 4s^2$	$^6S_{5/2}$	7.4340
26	Fe	Iron	[Ar] $3d^6\ 4s^2$	$^5D_4$	7.9024
27	Co	Cobalt	[Ar] $3d^7\ 4s^2$	$^4F_{9/2}$	7.8810
28	Ni	Nickel	[Ar] $3d^8\ 4s^2$	$^3F_4$	7.6398
29	Cu	Copper	[Ar] $3d^{10}\ 4s$	$^2S_{1/2}$	7.7264
30	Zn	Zinc	[Ar] $3d^{10}\ 4s^2$	$^1S_0$	9.3942
31	Ga	Gallium	[Ar] $3d^{10}\ 4s^2\ 4p$	$^2P^o_{1/2}$	5.9993
32	Ge	Germanium	[Ar] $3d^{10}\ 4s^2\ 4p^2$	$^3P_0$	7.8994
33	As	Arsenic	[Ar] $3d^{10}\ 4s^2\ 4p^3$	$^4S^o_{3/2}$	9.7886
34	Se	Selenium	[Ar] $3d^{10}\ 4s^2\ 4p^4$	$^3P_2$	9.7524
35	Br	Bromine	[Ar] $3d^{10}\ 4s^2\ 4p^5$	$^2P^o_{3/2}$	11.8138
36	Kr	Krypton	[Ar] $3d^{10}\ 4s^2\ 4p^6$	$^1S_0$	13.9996
37	Rb	Rubidium	[Kr] $5s$	$^2S_{1/2}$	4.1771
38	Sr	Strontium	[Kr] $5s^2$	$^1S_0$	5.6949
39	Y	Yttrium	[Kr] $4d\ 5s^2$	$^2D_{3/2}$	6.2173
40	Zr	Zirconium	[Kr] $4d^2\ 5s^2$	$^3F_2$	6.6339
41	Nb	Niobium	[Kr] $4d^4\ 5s$	$^6D_{1/2}$	6.7589
42	Mo	Molybdenum	[Kr] $4d^5\ 5s$	$^7S_3$	7.0924
43	Tc	Technetium	[Kr] $4d^5\ 5s^2$	$^6S_{5/2}$	7.28
44	Ru	Ruthenium	[Kr] $4d^7\ 5s$	$^5F_5$	7.3605

Z		Element	Ground-state configuration	Ground level	Ionization energy (eV)
45	Rh	Rhodium	[Kr] $4d^8\ 5s$	$^4F_{9/2}$	7.4589
46	Pd	Palladium	[Kr] $4d^{10}$	$^1S_0$	8.3369
47	Ag	Silver	[Kr] $4d^{10}\ 5s$	$^2S_{1/2}$	7.5762
48	Cd	Cadmium	[Kr] $4d^{10}\ 5s^2$	$^1S_0$	8.9938
49	In	Indium	[Kr] $4d^{10}\ 5s^2\ 5p$	$^2P^o_{1/2}$	5.7864
50	Sn	Tin	[Kr] $4d^{10}\ 5s^2\ 5p^2$	$^3P_0$	7.3439
51	Sb	Antimony	[Kr] $4d^{10}\ 5s^2\ 5p^3$	$^4S^o_{3/2}$	8.6084
52	Te	Tellurium	[Kr] $4d^{10}\ 5s^2\ 5p^4$	$^3P_2$	9.0096
53	I	Iodine	[Kr] $4d^{10}\ 5s^2\ 5p^5$	$^2P^o_{3/2}$	10.4513
54	Xe	Xenon	[Kr] $4d^{10}\ 5s^2\ 5p^6$	$^1S_0$	12.1298
55	Cs	Cesium	[Xe] $6s$	$^2S_{1/2}$	3.8939
56	Ba	Barium	[Xe] $6s^2$	$^1S_0$	5.2117
57	La	Lanthanum	[Xe] $5d\ 6s^2$	$^2D_{3/2}$	5.5769
58	Ce	Cerium	[Xe] $4f\ 5d\ 6s^2$	$^1G^o_4$	5.5387
59	Pr	Praseodymium	[Xe] $4f^3\ 6s^2$	$^4I^o_{9/2}$	5.473
60	Nd	Neodymium	[Xe] $4f^4\ 6s^2$	$^5I_4$	5.5250
61	Pm	Promethium	[Xe] $4f^5\ 6s^2$	$^6H^o_{5/2}$	5.582
62	Sm	Samarium	[Xe] $4f^6\ 6s^2$	$^7F_0$	5.6437
63	Eu	Europium	[Xe] $4f^7\ 6s^2$	$^8S^o_{7/2}$	5.6704
64	Gd	Gadolinium	[Xe] $4f^7\ 5d\ 6s^2$	$^9D^o_2$	6.1498
65	Tb	Terbium	[Xe] $4f^9\ 6s^2$	$^6H^o_{15/2}$	5.8638
66	Dy	Dysprosium	[Xe] $4f^{10}\ 6s^2$	$^5I_8$	5.9389
67	Ho	Holmium	[Xe] $4f^{11}\ 6s^2$	$^4I^o_{15/2}$	6.0215
68	Er	Erbium	[Xe] $4f^{12}\ 6s^2$	$^3H_6$	6.1077
69	Tm	Thulium	[Xe] $4f^{13}\ 6s^2$	$^2F^o_{7/2}$	6.1843
70	Yb	Ytterbium	[Xe] $4f^{14}\ 6s^2$	$^1S_0$	6.2542
71	Lu	Lutetium	[Xe] $4f^{14}\ 5d\ 6s^2$	$^2D_{3/2}$	5.4259
72	Hf	Hafnium	[Xe] $4f^{14}\ 5d^2\ 6s^2$	$^3F_2$	6.8251
73	Ta	Tantalum	[Xe] $4f^{14}\ 5d^3\ 6s^2$	$^4F_{3/2}$	7.5496
74	W	Tungsten	[Xe] $4f^{14}\ 5d^4\ 6s^2$	$^5D_0$	7.8640
75	Re	Rhenium	[Xe] $4f^{14}\ 5d^5\ 6s^2$	$^6S_{5/2}$	7.8335
76	Os	Osmium	[Xe] $4f^{14}\ 5d^6\ 6s^2$	$^5D_4$	8.4382
77	Ir	Iridium	[Xe] $4f^{14}\ 5d^7\ 6s^2$	$^4F_{9/2}$	8.9670
78	Pt	Platinum	[Xe] $4f^{14}\ 5d^9\ 6s$	$^3D_3$	8.9588
79	Au	Gold	[Xe] $4f^{14}\ 5d^{10}\ 6s$	$^2S_{1/2}$	9.2255
80	Hg	Mercury	[Xe] $4f^{14}\ 5d^{10}\ 6s^2$	$^1S_0$	10.4375
81	Tl	Thallium	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p$	$^2P^o_{1/2}$	6.1082
82	Pb	Lead	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^2$	$^3P_0$	7.4167
83	Bi	Bismuth	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^3$	$^4S^o_{3/2}$	7.2855
84	Po	Polonium	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^4$	$^3P_2$	8.414
85	At	Astatine	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^5$	$^2P^o_{3/2}$	
86	Rn	Radon	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^6$	$^1S_0$	10.7485
87	Fr	Francium	[Rn] $7s$	$^2S_{1/2}$	4.0727
88	Ra	Radium	[Rn] $7s^2$	$^1S_0$	5.2784
89	Ac	Actinium	[Rn] $6d\ 7s^2$	$^2D_{3/2}$	5.17
90	Th	Thorium	[Rn] $6d^2\ 7s^2$	$^3F_2$	6.3067
91	Pa	Protactinium	[Rn] $5f^2(^3H_4)\ 6d\ 7s^2$	$(4,3/2)_{11/2}$	5.89
92	U	Uranium	[Rn] $5f^3(^4I^o_{9/2})\ 6d\ 7s^2$	$(9/2,3/2)^o_6$	6.1941
93	Np	Neptunium	[Rn] $5f^4(^5I_4)\ 6d\ 7s^2$	$(4,3/2)_{11/2}$	6.2657
94	Pu	Plutonium	[Rn] $5f^6\ 7s^2$	$^7F_0$	6.0260
95	Am	Americium	[Rn] $5f^7\ 7s^2$	$^8S^o_{7/2}$	5.9738
96	Cm	Curium	[Rn] $5f^7\ 6d\ 7s^2$	$^9D^o_2$	5.9914
97	Bk	Berkelium	[Rn] $5f^9\ 7s^2$	$^6H^o_{15/2}$	6.1979
98	Cf	Californium	[Rn] $5f^{10}\ 7s^2$	$^5I_8$	6.2817
99	Es	Einsteinium	[Rn] $5f^{11}\ 7s^2$	$^4I^o_{15/2}$	6.42
100	Fm	Fermium	[Rn] $5f^{12}\ 7s^2$	$^3H_6$	6.50
101	Md	Mendelevium	[Rn] $5f^{13}\ 7s^2$	$^2F^o_{7/2}$	6.58
102	No	Nobelium	[Rn] $5f^{14}\ 7s^2$	$^1S_0$	6.65
103	Lr	Lawrencium	[Rn] $5f^{14}\ 7s^2\ 7p$?	$^2P^o_{1/2}$?	4.9?
104	Rf	Rutherfordium	[Rn] $5f^{14}\ 6d^2\ 7s^2$?	$^3F_2$?	6.0?

INTERNATIONAL TEMPERATURE SCALE OF 1990 (ITS-90)

B. W. Mangum

A new temperature scale, the International Temperature Scale of 1990 (ITS-90), was officially adopted by the Comité International des Poids et Mesures (CIPM), meeting 26—28 September 1989 at the Bureau International des Poids et Mesures (BIPM). The ITS-90 was recommended to the CIPM for its adoption following the completion of the final details of the new scale by the Comité Consultatif de Thermométrie (CCT), meeting 12—14 September 1989 at the BIPM in its 17th Session. The ITS-90 became the official international temperature scale on 1 January 1990. The ITS-90 supersedes the present scales, the International Practical Temperature Scale of 1968 (IPTS-68) and the 1976 Provisional 0.5 to 30 K Temperature Scale (EPT-76).

The ITS-90 extends upward from 0.65 K, and temperatures on this scale are in much better agreement with thermodynamic values that are those on the IPTS-68 and the EPT-76. The new scale has subranges and alternative definitions in certain ranges that greatly facilitate its use. Furthermore, its continuity, precision, and reproducibility throughout its ranges are much improved over that of the present scales. The replacement of the thermocouple with the platinum resistance thermometer at temperatures below 961.78°C resulted in the biggest improvement in reproducibility.

The ITS-90 is divided into four primary ranges:

1. Between 0.65 and 3.2 K, the ITS-90 is defined by the vapor pressure-temperature relation of ^{3}He, and between 1.25 and 2.1768 K (the λ point) and between 2.1768 and 5.0 K by the vapor pressure-temperature relations of ^{4}He. T_{90} is defined by the vapor pressure equations of the form:

   $$T_{90}/\mathrm{K} = A_0 + \sum_{i=1}^{9} A_i \left[\left(\ln(p/\mathrm{Pa}) - B\right)/C\right]^i$$

   The values of the coefficients A_i, and of the constants A_o, B, and C of the equations are given below.
2. Between 3.0 and 24.5561 K, the ITS-90 is defined in terms of a ^{3}He or ^{4}He constant volume gas thermometer (CVGT). The thermometer is calibrated at three temperatures — at the triple point of neon (24.5561 K), at the triple point of equilibrium hydrogen (13.8033 K), and at a temperature between 3.0 and 5.0 K, the value of which is determined by using either ^{3}He or ^{4}He vapor pressure thermometry.
3. Between 13.8033 K (–259.3467°C) and 1234.93 K (961.78°C), the ITS-90 is defined in terms of the specified fixed points given below, by resistance ratios of platinum resistance thermometers obtained by calibration at specified sets of the fixed points, and by reference functions and deviation functions of resistance ratios which relate to T_{90} between the fixed points.
4. Above 1234.93 K, the ITS-90 is defined in terms of Planck's radiation law, using the freezing-point temperature of either silver, gold, or copper as the reference temperature.

Full details of the calibration procedures and reference functions for various subranges are given in:

The International Temperature Scale of 1990, *Metrologia,* 27, 3, 1990; errata in *Metrologia,* 27, 107, 1990.

Defining Fixed Points of the ITS-90

Material[a]	Equilibrium state[b]	Temperature	
		T_{90} (K)	t_{90} (°C)
He	VP	3 to 5	–270.15 to –268.15
e-H_2	TP	13.8033	–259.3467
e-H_2 (or He)	VP (or CVGT)	≈17	≈ –256.15
e-H_2 (or He)	VP (or CVGT)	≈20.3	≈ –252.85
Ne[c]	TP	24.5561	–248.5939
O_2	TP	54.3584	–218.7916
Ar	TP	83.8058	–189.3442
Hg[c]	TP	234.3156	–38.8344
H_2O	TP	273.16	0.01
Ga[c]	MP	302.9146	29.7646
In[c]	FP	429.7485	156.5985
Sn	FP	505.078	231.928
Zn	FP	692.677	419.527
Al[c]	FP	933.473	660.323
Ag	FP	1234.93	961.78
Au	FP	1337.33	1064.18
Cu[c]	FP	1357.77	1084.62

Values of Coefficients in the Vapor Pressure Equations for Helium

Coef. or constant	^{3}He 0.65—3.2 K	^{4}He 1.25—2.1768 K	^{4}He 2.1768—5.0 K
A_0	1.053 447	1.392 408	3.146 631
A_1	0.980 106	0.527 153	1.357 655
A_2	0.676 380	0.166 756	0.413 923
A_3	0.372 692	0.050 988	0.091 159
A_4	0.151 656	0.026 514	0.016 349
A_5	–0.002 263	0.001 975	0.001 826
A_6	0.006 596	–0.017 976	–0.004 325
A_7	0.088 966	0.005 409	–0.004 973
A_8	–0.004 770	0.013 259	0
A_9	–0.054 943	0	0
B	7.3	5.6	10.3
C	4.3	2.9	1.9

---

[a] e-H_2 indicates equilibrium hydrogen, that is, hydrogen with the equilibrium distribution of its ortho and para states. Normal hydrogen at room temperature contains 25% para hydrogen and 75% ortho hydrogen.

[b] VP indicates vapor pressure point; CVGT indicates constant volume gas thermometer point; TP indicates triple point (equilibrium temperature at which the solid, liquid, and vapor phases coexist); FP indicates freezing point, and MP indicates melting point (the equilibrium temperatures at which the solid and liquid phases coexist under a pressure of 101 325 Pa, one standard atmosphere). The isotopic composition is that naturally occurring.

[c] Previously, these were secondary fixed points.

CONVERSION OF TEMPERATURES FROM THE 1948 AND 1968 SCALES TO ITS-90

This table gives temperature corrections from older scales to the current International Temperature Scale of 1990 (see the preceding table for details on ITS-90). The first part of the table may be used for converting Celsius temperatures in the range -180 to 4000°C from IPTS-68 or IPTS-48 to ITS-90. Within the accuracy of the corrections, the temperature in the first column may be identified with either t_{68}, t_{48}, or t_{90}. The second part of the table is designed for use at lower temperatures to convert values expressed in kelvins from EPT-76 or IPTS-68 to ITS-90.

The references give analytical equations for expressing these relations. Note that Reference 1 supersedes Reference 2 with respect to corrections in the 630 to 1064°C range.

References

1. Burns, G. W. et al., in *Temperature: Its Measurement and Control in Science and Industry*, Vol. 6, Schooley, J. F., Ed., American Institute of Physics, New York, 1993.
2. Goldberg, R. N. and Weir, R. D., *Pure and Appl. Chem.,* 1545, 1992.

t/°C	$t_{90}-t_{68}$	$t_{90}-t_{48}$
–180	0.008	0.020
–170	0.010	0.017
–160	0.012	0.007
–150	0.013	0.000
–140	0.014	0.001
–130	0.014	0.008
–120	0.014	0.017
–110	0.013	0.026
–100	0.013	0.035
–90	0.012	0.041
–80	0.012	0.045
–70	0.011	0.045
–60	0.010	0.042
–50	0.009	0.038
–40	0.008	0.032
–30	0.006	0.024
–20	0.004	0.016
–10	0.002	0.008
0	0.000	0.000
10	–0.002	–0.006
20	–0.005	–0.012
30	–0.007	–0.016
40	–0.010	–0.020
50	–0.013	–0.023
60	–0.016	–0.026
70	–0.018	–0.026
80	–0.021	–0.027
90	–0.024	–0.027
100	–0.026	–0.026
110	–0.028	–0.024
120	–0.030	–0.023
130	–0.032	–0.020
140	–0.034	–0.018
150	–0.036	–0.016
160	–0.037	–0.012
170	–0.038	–0.009
180	–0.039	–0.005
190	–0.039	–0.001
200	–0.040	0.003
210	–0.040	0.007
220	–0.040	0.011
230	–0.040	0.014
240	–0.040	0.018
250	–0.040	0.021
260	–0.040	0.024
270	–0.039	0.028
280	–0.039	0.030
290	–0.039	0.032
300	–0.039	0.034
310	–0.039	0.035
320	–0.039	0.036
330	–0.040	0.036
340	–0.040	0.037
350	–0.041	0.036
360	–0.042	0.035
370	–0.043	0.034
380	–0.045	0.032
390	–0.046	0.030
400	–0.048	0.028
410	–0.051	0.024
420	–0.053	0.022
430	–0.056	0.019
440	–0.059	0.015
450	–0.062	0.012
460	–0.065	0.009
470	–0.068	0.007
480	–0.072	0.004
490	–0.075	0.002
500	–0.079	0.000
510	–0.083	–0.001
520	–0.087	–0.002
530	–0.090	–0.001
540	–0.094	0.000
550	–0.098	0.002
560	–0.101	0.007
570	–0.105	0.011
580	–0.108	0.018
590	–0.112	0.025
600	–0.115	0.035
610	–0.118	0.047
620	–0.122	0.060
630	–0.125	0.075
640	–0.11	0.12
650	–0.10	0.15
660	–0.09	0.19
670	–0.07	0.24
680	–0.05	0.29
690	–0.04	0.32
700	–0.02	0.37
710	–0.01	0.41
720	0.00	0.45
730	0.02	0.49
740	0.03	0.53
750	0.03	0.56
760	0.04	0.60
770	0.05	0.63
780	0.05	0.66
790	0.05	0.69
800	0.05	0.72
810	0.05	0.75
820	0.04	0.76
830	0.04	0.79
840	0.03	0.81
850	0.02	0.83
860	0.01	0.85
870	0.00	0.87
880	–0.02	0.87
890	–0.03	0.89
900	–0.05	0.90
910	–0.06	0.92
920	–0.08	0.93
930	–0.10	0.94
940	–0.11	0.96
950	–0.13	0.97
960	–0.15	0.97
970	–0.16	0.99
980	–0.18	1.00
990	–0.19	1.02
1000	–0.20	1.04
1010	–0.22	1.05
1020	–0.23	1.07
1030	–0.23	1.10
1040	–0.24	1.12
1050	–0.25	1.14
1060	–0.25	1.17
1070	–0.25	1.19
1080	–0.26	1.20
1090	–0.26	1.20
1100	–0.26	1.2
1200	–0.30	1.4
1300	–0.35	1.5
1400	–0.39	1.6
1500	–0.44	1.8
1600	–0.49	1.9
1700	–0.54	2.1
1800	–0.60	2.2
1900	–0.66	2.3
2000	–0.72	2.5
2100	–0.79	2.7
2200	–0.85	2.9
2300	–0.93	3.1
2400	–1.00	3.2
2500	–1.07	3.4
2600	–1.15	3.7
2700	–1.24	3.8
2800	–1.32	4.0
2900	–1.41	4.2
3000	–1.50	4.4
3100	–1.59	4.6
3200	–1.69	4.8
3300	–1.78	5.1
3400	–1.89	5.3
3500	–1.99	5.5
3600	–2.10	5.8
3700	–2.21	6.0
3800	–2.32	6.3
3900	–2.43	6.6
4000	–2.55	6.8

T/K	$T_{90}-T_{76}$	$T_{90}-T_{68}$
5	–0.0001	
6	–0.0002	
7	–0.0003	
8	–0.0004	
9	–0.0005	
10	–0.0006	
11	–0.0007	
12	–0.0008	
13	–0.0010	
14	–0.0011	–0.006
15	–0.0013	–0.003
16	–0.0014	–0.004
17	–0.0016	–0.006
18	–0.0018	–0.008
19	–0.0020	–0.009
20	–0.0022	–0.009
21	–0.0025	–0.008
22	–0.0027	–0.007
23	–0.0030	–0.007
24	–0.0032	–0.006
25	–0.0035	–0.005
26	–0.0038	–0.004
27	–0.0041	–0.004
28		–0.005
29		–0.006
30		–0.006
31		–0.007
32		–0.008

T/K	$T_{90}-T_{76}$	$T_{90}-T_{68}$
33		–0.008
34		–0.008
35		–0.007
36		–0.007
37		–0.007
38		–0.006
39		–0.006
40		–0.006
41		–0.006
42		–0.006
43		–0.006
44		–0.006
45		–0.007
46		–0.007
47		–0.007
48		–0.006
49		–0.006
50		–0.006
51		–0.005
52		–0.005
53		–0.004
54		–0.003
55		–0.002
56		–0.001
57		0.000
58		0.001
59		0.002
60		0.003
61		0.003
62		0.004
63		0.004
64		0.005
65		0.005
66		0.006
67		0.006
68		0.007
69		0.007
70		0.007
71		0.007
72		0.007
73		0.007
74		0.007
75		0.008
76		0.008
77		0.008
78		0.008
79		0.008
80		0.008
81		0.008
82		0.008
83		0.008
84		0.008
85		0.008
86		0.008
87		0.008
88		0.008
89		0.008
90		0.008
91		0.008
92		0.008
93		0.008
94		0.008
95		0.008
96		0.008
97		0.009
98		0.009
99		0.009
100		0.009
110		0.011
120		0.013
130		0.014
140		0.014
150		0.014
160		0.014
170		0.013
180		0.012
190		0.012
200		0.011
210		0.010
220		0.009
230		0.008
240		0.007
250		0.005
260		0.003
270		0.001
273.16		0.000
300		–0.006
400		–0.031
500		–0.040
600		–0.040
700		–0.055
800		–0.089
900		–0.124

INTERNATIONAL SYSTEM OF UNITS (SI)

The International System of Units, abbreviated as SI (from the French name *Le Système International d'Unités*), was established in 1960 by the 11th General Conference on Weights and Measures (CGPM) as the modern metric system of measurement. The core of the SI is the seven base units for the physical quantities length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity. These base units are:

	SI base unit	
Base quantity	**Name**	**Symbol**
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

The SI base units are defined as follows:

meter: The meter is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

kilogram: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

second: The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.

ampere: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to $2 \cdot 10^{-7}$ newton per meter of length.

kelvin: The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

mole: The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

candela: The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

SI derived units

Derived units are units which may be expressed in terms of base units by means of the mathematical symbols of multiplication and division (and, in the case of °C, subtraction). Certain derived units have been given special names and symbols, and these special names and symbols may themselves be used in combination with those for base and other derived units to express the units of other quantities. The next table lists some examples of derived units expressed directly in terms of base units:

	SI derived unit	
Physical quantity	**Name**	**Symbol**
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
density, mass density	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
concentration (of amount of substance)	mole per cubic meter	mol/m^3
luminance	candela per square meter	cd/m^2
refractive index	(the number) one	1(a)

(a) The symbol "1" is generally omitted in combination with a numerical value.

For convenience, certain derived units, which are listed in the next table, have been given special names and symbols. These names and symbols may themselves be used to express other derived units. The special names and symbols are a compact form for the expression of units that are used frequently. The final column shows how the SI units concerned may be expressed in terms of SI base units. In this column, factors such as m^0, kg^0 ..., which are all equal to 1, are not shown explicitly.

			SI derived unit expressed in terms of:	
Physical quantity	**Name**	**Symbol**	**Other SI units**	**SI base units**
plane angle	radian(a)	rad	$m \cdot m^{-1} = 1$(b)	
solid angle	steradian(a)	sr(c)	$m^2 \cdot m^{-2} = 1$(b)	
frequency	hertz	Hz	s^{-1}	
force	newton	N	$m \cdot kg \cdot s^{-2}$	
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C	$s \cdot A$	
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$

magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius(d)	°C		K
luminous flux	lumen	lm	cd · sr(c)	$m^2 \cdot m^{-2} \cdot cd = cd$
illuminance	lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
activity (of a radionuclide)	becquerel	Bq		s^{-1}
absorbed dose, specific energy (imparted), kerma	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent, ambient dose equivalent, directional dose equivalent, personal dose equivalent, organ equivalent dose	sievert	Sv	J/kg	$m^2 \cdot s^{-2}$
catalytic activity	katal	kat		$s^{-1} \cdot mol$

(a) The radian and steradian may be used with advantage in expressions for derived units to distinguish between quantities of different nature but the same dimension. Some examples of their use in forming derived units are given in the next table.

(b) In practice, the symbols rad and sr are used where appropriate, but the derived unit “1” is generally omitted in combination with a numerical value.

(c) In photometry, the name steradian and the symbol sr are usually retained in expressions for units.

(d) It is common practice to express a thermodynamic temperature, symbol T, in terms of its difference from the reference temperature T_0 = 273.15 K. The numerical value of a Celsius temperature t expressed in degrees Celsius is given by t/°C = T/K-273.15. The unit °C may be used in combination with SI prefixes, e.g., millidegree Celsius, m°C. Note that there should never be a space between the ° sign and the letter C, and that the symbol for kelvin is K, not °K.

The SI derived units with special names may be used in combinations to provide a convenient way to express more complex physical quantities. Examples are given in the next table:

	SI derived unit		
Physical Quantity	**Name**	**Symbol**	**As SI base units**
dynamic viscosity	pascal second	Pa · s	$m^{-1} \cdot kg \cdot s^{-1}$
moment of force	newton meter	N · m	$m^2 \cdot kg \cdot s^{-2}$
surface tension	newton per meter	N/m	$kg \cdot s^{-2}$
angular velocity	radian per second	rad/s	$m \cdot m^{-1} \cdot s^{-1} = s^{-1}$
angular acceleration	radian per second squared	rad/s^2	$m \cdot m^{-1} \cdot s^{-2} = s^{-2}$
heat flux density, irradiance	watt per square meter	W/m^2	$kg \cdot s^{-3}$
heat capacity, entropy	joule per kelvin	J/K	$m^{-3} \cdot kg \cdot s^{-2} \cdot K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg · K)	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific energy	joule per kilogram	J/kg	$m^2 \cdot s^{-2}$
thermal conductivity	watt per meter kelvin	W/(m · K)	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
energy density	joule per cubic meter	J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
electric field strength	volt per meter	V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric charge density	coulomb per cubic meter	C/m^3	$m^{-3} \cdot s \cdot A$
electric flux density	coulomb per square meter	C/m^2	$m^{-2} \cdot s \cdot A$
permittivity	farad per meter	F/m	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
permeability	henry per meter	H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
molar energy	joule per mole	J/mol	$m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1}$
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol · K)	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
exposure (x and γ rays)	coulomb per kilogram	C/kg	$kg^{-1} \cdot s \cdot A$
absorbed dose rate	gray per second	Gy/s	$m^2 \cdot s^{-3}$
radiant intensity	watt per steradian	W/sr	$m^4 \cdot m^{-2} \cdot kg \cdot s^{-3} = m^2 \cdot kg \cdot s^{-3}$
radiance	watt per square meter steradian	$W/(m^2 \cdot sr)$	$m^2 \cdot m^{-2} \cdot kg \cdot s^{-3} = kg \cdot s^{-3}$
catalytic (activity) concentration	katal per cubic meter	kat/m^3	$m^{-3} \cdot s^{-1} \cdot mol$

In practice, with certain quantities preference is given to the use of certain special unit names, or combinations of unit names, in order to facilitate the distinction between different quantities having the same dimension. For example, the SI unit of frequency is designated the hertz, rather than the reciprocal second, and the SI unit of angular velocity is designated the radian per second rather than the reciprocal second (in this case retaining the word radian emphasizes that angular velocity is equal to 2π times the rotational frequency). Similarly the SI unit of moment of force is designated the newton meter rather than the joule.

In the field of ionizing radiation, the SI unit of activity is designated the becquerel rather than the reciprocal second, and the SI units of absorbed dose and dose equivalent the gray and sievert, respectively, rather than the joule per kilogram. In the field of catalysis, the SI unit of catalytic activity is designated the katal rather than the mole per second. The special names becquerel, gray, sievert, and katal were specifically introduced because of the dangers to human health which might arise from mistakes involving the units reciprocal second, joule per kilogram and mole per second.

Units for dimensionless quantities, quantities of dimension one

Certain quantities are defined as the ratios of two quantities of the same kind, and thus have a dimension which may be expressed by the number one. The unit of such quantities is necessarily a derived unit coherent with the other units of the SI and, since it is formed as the ratio of two identical SI units, the unit also may be expressed by the number one. Thus the SI unit of all quantities having the dimensional product one is the number one. Examples of such quantities are refractive index, relative permeability, and friction factor. Other quantities having the unit 1 include “characteristic numbers” like the Prandtl number and numbers which represent a count, such as a number of molecules, degeneracy (number of energy levels), and partition function in statistical thermodynamics. All of these quantities are described as being dimensionless, or of dimension one, and have the coherent SI unit 1. Their values are simply expressed as numbers and, in general, the unit 1 is not explicitly shown. In a few cases, however, a special name is given to this unit, mainly to avoid confusion between some compound derived units. This is the case for the radian, steradian and neper.

SI prefixes

The following prefixes have been approved by the CGPM for use with SI units. Only one prefix may be used before a unit. Thus 10^{-12} farad should be designated pF, not μμF.

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

The kilogram

Among the base units of the International System, the unit of mass is the only one whose name, for historical reasons, contains a prefix. Names and symbols for decimal multiples and submultiples of the unit of mass are formed by attaching prefix names to the unit name "gram" and prefix symbols to the unit symbol "g".

> *Example :* 10^{-6} kg = 1 mg (1 milligram) *but not* 1 μkg (1 microkilogram).

Units used with the SI

Many units that are not part of the SI are important and widely used in everyday life. The CGPM has adopted a classification of non-SI units: (1) units accepted for use with the SI (such as the traditional units of time and of angle); (2) units accepted for use with the SI whose values are obtained experimentally; and (3) other units currently accepted for use with the SI to satisfy the needs of special interests.

(1) Non-SI units accepted for use with the International System

Name	Symbol	Value in SI units
minute	min	1 min = 60 s
hour	h	1 h= 60 min = 3600 s
day	d	1 d = 24 h = 86 400 s
degree	°	1° = (π/180) rad
minute	’	1’ = (1/60)° = (π/10 800) rad
second	”	1” = (1/60)’ = (π/648 000) rad
liter	l, L	1L= 1 dm^3= 10^{-3} m^3
metric ton	t	1 t = 10^3 kg
neper(a)	Np	1 Np = 1
bel(b)	B	1 B = (1/2) ln 10 Np

(a) The neper is used to express values of such logarithmic quantities as field level, power level, sound pressure level, and logarithmic decrement. Natural logarithms are used to obtain the numerical values of quantities expressed in nepers. The neper is coherent with the SI, but is not yet adopted by the CGPM as an SI unit. In using the neper, it is important to specify the quantity.

(b) The bel is used to express values of such logarithmic quantities as field level, power level, sound-pressure level, and attenuation. Logarithms to base ten are used to obtain the numerical values of quantities expressed in bels. The submultiple decibel, dB, is commonly used.

(2) Non-SI units accepted for use with the International system, whose values in SI units are obtained experimentally

Name	Symbol	Value in SI Units
electronvolt(b)	eV	1 eV = 1.602 176 53(14) ·10^{-19} J(a)
dalton(c)	Da	1 Da = 1.660 538 86(28) · 10^{-27} kg(a)
unified atomic mass unit(c)	u	1 u = 1 Da
astronomical unit(d)	ua	1 ua = 1.495 978 706 91(06) · 10^{11} m(a)

(a) For the electronvolt and the dalton (unified atomic mass unit), values are quoted from the 2002 CODATA set of the Fundamental Physical Constants (p. 1-1 of this Handbook). The value given for the astronomical unit is quoted from the IERS Conventions 2003 (D.D. McCarthy and G. Petit, eds., IERS Technical Note 32, Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, 200). The value of ua in meters comes from the JPL ephemerides DE403 (Standish E.M. 1995, "Report of the IAU WGAS Sub-Group on Numerical Standards", in "Highlights of Astronomy", Appenlzer ed., pp 180-184, Kluwer Academic Publishers, Dordrecht). It has been determined in "TDB" units using Barycentric Dynamical Time TDB as a time coordinate for the barycentric system.

(b) The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum.

(c) The Dalton and unified atomic mass unit are alternative names for the same unit, equal to 1/12 of the mass of an unbound atom of the nuclide ^{12}C, at rest and in its ground state. The dalton may be combined with SI prefixes to express the masses of large molecules in kilodalton, kDa, or megadalton, MDa.

(d) The astronomical unit is a unit of length approximately equal to the mean Earth-Sun distance. It is the radius of an unperturbed circular Newtonian orbit about the Sun of a particle having infinitesimal mass, moving with a mean motion of 0.017 202 098 95 radians/day (known as the Gaussian constant).

(3) Other non-SI units currently accepted for use with the International System

Name	Symbol	Value in SI Units
nautical mile		1 nautical mile = 1852 m
knot		1 nautical mile per hour = (1852/3600) m/s
are		1 a = 1 dam^2 = 10^2 m^2
hectare	ha	1 ha = 1 hm^2 = 10^4 m^2
bar	bar	1 bar = 0.1 MPa = 100 kPa = 10^5 Pa
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
barn	b	1 b = 100 fm^2 = 10^{-28} m^2

Other non-SI units

The SI does not encourage the use of cgs units, but these are frequently found in old scientific texts. The following table gives the relation of some common cgs units to SI units.

Name	Symbol	Value in SI units
erg	erg	1 erg = 10^{-7} J
dyne	dyn	1 dyn = 10^{-5} N
poise	P	1P = 1dyn· s/cm^2 = 0.1 Pa·· s
stokes	St	1 St = 1 cm^2/s = 10^{-4} m^2/s
gauss	G	1G ≙ 10^{-4} T
oersted	Oe	1 Oe ≙ (1000/4π) A/m
maxwell	Mx	1Mx ≙ 10^{-8} Wb
stilb	sb	1 sb = 1 cd/cm^2 = 10^4 cd/m^2
phot	ph	1 ph = 10^4 lx
gal	Gal	1 Gal = 1 cm/s^2 = 10^{-2} m/s^2

Note: The symbol ≙ should be read as "corresponds to"; these units cannot strictly be equated because of the different dimensions of the electromagnetic cgs and the SI.

Examples of other non-SI units found in the older literature and their relation to the SI are given below. Use of these units in current texts is discouraged.

Name	Symbol	Value in SI units
curie	Ci	1 Ci = $3.7 \cdot 10^{10}$ Bq
roentgen	R	1 R = $2.58 \cdot 10^{-4}$ C/kg
rad	rad	1 rad = 1 cGy = 10^{-2} Gy
rem	rem	1 rem = 1 cSv = 10^{-2} Sv
X unit		1 X unit ≈ $1.002 \cdot 10^{-4}$ nm
gamma	γ	1 γ =1 nT = 10^{-9} T
jansky	Jy	1Jy = 10^{-26} W · m^{-2} · Hz^{-1}
fermi		1 fermi = 1 fm = 10^{-15} m
metric carat		1 metric carat = 200 mg = $2 \cdot 10^{-4}$ kg
torr	Torr	1 Torr = (101325/760) Pa
standard atmosphere	atm	1 atm = 101325 Pa
calorie(a)	cal	1 cal = 4.184 J
micron	μ	1 μ = 1 μm = 10^{-6} m

(a) Several types of calorie have been used; the value given here is the so-called "thermochemical calorie".

References

1. Taylor, B. N., *The International System of Units (SI)*, NIST Special Publication 330, National Institute of Standards and Technology, Gaithersburg, MD, 2001.
2. Bureau International des Poids et Mesures, *Le Système International d'Unités (SI)*, 7th French and English Edition, BIPM, Sèvres, France, 1998; 8th Edition to be published 2006.
3. Taylor, B. N., *Guide for the Use of the International System of Units (SI)*, NIST Special Publication 811, National Institute of Standards and Technology, Gaithersburg, MD, 1995.
4. NIST Physical Reference Data web site, <http://physics.nist.gov/cuu/Units/index.html>, October 2004.

CONVERSION FACTORS

The following table gives conversion factors from various units of measure to SI units. It is reproduced from NIST Special Publication 811, *Guide for the Use of the International System of Units (SI)*. The table gives the factor by which a quantity expressed in a non-SI unit should be multiplied in order to calculate its value in the SI. The SI values are expressed in terms of the base, supplementary, and derived units of SI in order to provide a coherent presentation of the conversion factors and facilitate computations (see the table "International System of Units" in this Section). If desired, powers of ten can be avoided by using SI Prefixes and shifting the decimal point if necessary.

Conversion from a non-SI unit to a different non-SI unit may be carried out by using this table in two stages, e.g.,

$$1\ \text{cal}_{\text{th}} = 4.184\ \text{J}$$

$$1\ \text{Btu}_{\text{IT}} = 1.055056\ \text{E+03 J}$$

Thus,

$$1\ \text{Btu}_{\text{IT}} = (1.055056\ \text{E+03} \div 4.184)\ \text{cal}_{\text{th}} = 252.164\ \text{cal}_{\text{th}}$$

Conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number equal to or greater than one and less than ten with six or fewer decimal places. This number is followed by the letter E (for exponent), a plus or a minus sign, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

$$3.523\ 907\ \text{E-02 is } 3.523\ 907 \times 10^{-2}$$

or

$$0.035\ 239\ 07$$

Similarly:

$$3.386\ 389\ \text{E+03 is } 3.386\ 389 \times 10^{3}$$

or

$$3\ 386.389$$

A factor in boldface is exact; i.e., all subsequent digits are zero. All other conversion factors have been rounded to the figures given in accordance with accepted practice. Where less than six digits after the decimal point are shown, more precision is not warranted.

It is often desirable to round a number obtained from a conversion of units in order to retain information on the precision of the value. The following rounding rules may be followed:

1. If the digits to be discarded begin with a digit less than 5, the digit preceding the first discarded digit is not changed.

Example: 6.974 951 5 rounded to 3 digits is 6.97

2. If the digits to be discarded begin with a digit greater than 5, the digit preceding the first discarded digit is increased by one.

Example: 6.974 951 5 rounded to 4 digits is 6.975

3. If the digits to be discarded begin with a 5 and at least one of the following digits is greater than 0, the digit preceding the 5 is increased by 1.

Example: 6.974 851 rounded to 5 digits is 6.974 9

4. If the digits to be discarded begin with a 5 and all of the following digits are 0, the digit preceding the 5 is unchanged if it is even and increased by one if it is odd. (Note that this means that the final digit is always even.)

Examples:
6.974 951 5 rounded to 7 digits is 6.974 952
6.974 950 5 rounded to 7 digits is 6.974 950

Reference

Taylor, B. N., *Guide for the Use of the International System of Units (SI)*, NIST Special Publication 811, 1995 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, 1995.

Factors in **boldface** are exact

To convert from	**to**	**Multiply by**	
abampere	ampere (A)	**1.0**	**E+01**
abcoulomb	coulomb (C)	**1.0**	**E+01**
abfarad	farad (F)	**1.0**	**E+09**
abhenry	henry (H)	**1.0**	**E–09**
abmho	siemens (S)	**1.0**	**E+09**
abohm	ohm (Ω)	**1.0**	**E–09**
abvolt	volt (V)	**1.0**	**E–08**
acceleration of free fall, standard (g_n)	meter per second squared (m/s^2)	**9.806 65**	**E+00**
acre (based on U.S. survey foot)[9]	square meter (m^2)	4.046 873	E+03
acre foot (based on U.S. survey foot)[9]	cubic meter (m^3)	1.233 489	E+03
ampere hour (A · h)	coulomb (C)	**3.6**	**E+03**
ångström (Å)	meter (m)	**1.0**	**E–10**
ångström (Å)	nanometer (nm)	**1.0**	**E–01**
are (a)	square meter (m^2)	**1.0**	**E+02**
astronomical unit (ua or AU)	meter (m)	1.495 979	E+11
atmosphere, standard (atm)	pascal (Pa)	**1.013 25**	**E+05**
atmosphere, standard (atm)	kilopascal (kPa)	**1.013 25**	**E+02**
atmosphere, technical (at)[10]	pascal (Pa)	**9.806 65**	**E+04**
atmosphere, technical (at)[10]	kilopascal (kPa)	**9.806 65**	**E+01**

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[9] The U.S. survey foot equals (1200/3937) m. 1 international foot = 0.999998 survey foot.

[10] One technical atmosphere equals one kilogram-force per square centimeter (1 at = 1 kgf/cm^2).

To convert from	to	Multiply by	
bar (bar)	pascal (Pa)	**1.0**	**E+05**
bar (bar)	kilopascal (kPa)	**1.0**	**E+02**
barn (b)	square meter (m^2)	**1.0**	**E–28**
barrel [for petroleum, 42 gallons (U.S.)](bbl)	cubic meter (m^3)	1.589 873	E–01
barrel [for petroleum, 42 gallons (U.S.)](bbl)	liter (L)	1.589 873	E+02
biot (Bi)	ampere (A)	**1.0**	**E+01**
British thermal unit$_{IT}$ (Btu$_{IT}$)[11]	joule (J)	1.055 056	E+03
British thermal unit$_{th}$ (Btu$_{th}$)[11]	joule (J)	1.054 350	E+03
British thermal unit (mean) (Btu)	joule (J)	1.055 87	E+03
British thermal unit (39 °F) (Btu)	joule (J)	1.059 67	E+03
British thermal unit (59 °F) (Btu)	joule (J)	1.054 80	E+03
British thermal unit (60 °F) (Btu)	joule (J)	1.054 68	E+03
British thermal unit$_{IT}$ foot per hour square foot degree Fahrenheit [$Btu_{IT} \cdot ft/(h \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	1.730 735	E+00
British thermal unit$_{th}$ foot per hour square foot degree Fahrenheit [$Btu_{th} \cdot ft/(h \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	1.729 577	E+00
British thermal unit$_{IT}$ inch per hour square foot degree Fahrenheit [$Btu_{IT} \cdot in/(h \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	1.442 279	E–01
British thermal unit$_{th}$ inch per hour square foot degree Fahrenheit [$Btu_{th} \cdot in/(h \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	1.441 314	E–01
British thermal unit$_{IT}$ inch per second square foot degree Fahrenheit [$Btu_{IT} \cdot in/(s \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	5.192 204	E+02
British thermal unit$_{th}$ inch per second square foot degree Fahrenheit [$Btu_{th} \cdot in/(s \cdot ft^2 \cdot °F)$]	watt per meter kelvin [$W/(m \cdot K)$]	5.188 732	E+02
British thermal unit$_{IT}$ per cubic foot (Btu_{IT}/ft^3)	joule per cubic meter (J/m^3)	3.725 895	E+04
British thermal unit$_{th}$ per cubic foot (Btu_{th}/ft^3)	joule per cubic meter (J/m^3)	3.723 403	E+04
British thermal unit$_{IT}$ per degree Fahrenheit ($Btu_{IT}/ °F$)	joule per kelvin (J/ k)	1.899 101	E+03
British thermal unit$_{th}$ per degree Fahrenheit ($Btu_{th}/ °F$)	joule per kelvin (J/ k)	1.897 830	E+03
British thermal unit$_{IT}$ per degree Rankine ($Btu_{IT}/ °R$)	joule per kelvin (J/ k)	1.899 101	E+03
British thermal unit$_{th}$ per degree Rankine ($Btu_{th}/ °R$)	joule per kelvin (J/ k)	1.897 830	E+03
British thermal unit$_{IT}$ per hour (Btu_{IT}/h)	watt (W)	2.930 711	E–01
British thermal unit$_{th}$ per hour (Btu_{th}/h)	watt (W)	2.928 751	E–01
British thermal unit$_{IT}$ per hour square foot degree Fahrenheit [$Btu_{IT}/(h \cdot ft^2 \cdot °F)$]	watt per square meter kelvin [$W/(m^2 \cdot K)$]	5.678 263	E+00
British thermal unit$_{th}$ per hour square foot degree Fahrenheit [$Btu_{th}/(h \cdot ft^2 \cdot °F)$]	watt per square meter kelvin [$W/(m^2 \cdot K)$]	5.674 466	E+00
British thermal unit$_{th}$ per minute (Btu_{th}/min)	watt (W)	1.757 250	E+01
British thermal unit$_{IT}$ per pound (Btu_{IT}/lb)	joule per kilogram (J/kg)	**2.326**	**E+03**
British thermal unit$_{th}$ per pound (Btu_{th}/lb)	joule per kilogram (J/kg)	2.324 444	E+03
British thermal unit$_{IT}$ per pound degree Fahrenheit [$Btu_{IT}/(lb \cdot °F)$]	joule per kilogram kelvin ($J/(kg \cdot K)$]	**4.1868**	**E+03**
British thermal unit$_{th}$ per pound degree Fahrenheit [$Btu_{th}/(lb \cdot °F)$]	joule per kilogram kelvin [$J/(kg \cdot K)$]	**4.184**	**E+03**
British thermal unit$_{IT}$ per pound degree Rankine [$Btu_{IT}/(lb \cdot °R)$]	joule per kilogram kelvin [$J/(kg \cdot K)$]	**4.1868**	**E+03**
British thermal unit$_{th}$ per pound degree Rankine [$Btu_{th}/(lb \cdot °R)$]	joule per kilogram kelvin [$J/(kg \cdot K)$]	**4.184**	**E+03**
British thermal unit$_{IT}$ per second (Btu_{IT}/s)	watt (W)	1.055 056	E+03
British thermal unit$_{th}$ per second (Btu_{th}/s)	watt (W)	1.054 350	E+03

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[11] The Fifth International Conference on the Properties of Steam (London, July 1956) defined the International Table calorie as 4.1868 J. Therefore the exact conversion factor for the International Table Btu is 1.055 055 852 62 kJ. Note that the notation for International Table used in this listing is subscript "IT". Similarily, the notation for thermochemical is subscript "th." Further, the thermochemical Btu, Btu$_{th}$, is based on the thermochemical calorie, cal$_{th}$, where cal$_{th}$ = 4.184 J exactly.

To convert from	to	Multiply by	
British thermal unit$_{IT}$ per second square foot degree Fahrenheit [Btu$_{IT}$/(s · ft^2 · °F)]	watt per square meter kelvin [W/(m^2 · K)]	2.044 175	E+04
British thermal unit$_{th}$ per second square foot degree Fahrenheit [Btu$_{th}$/(s · ft^2 · °F)]	watt per square meter kelvin [W/(m^2 · K)]	2.042 808	E+04
British thermal unit$_{IT}$ per square foot (Btu$_{IT}$/ft^2)	joule per square meter (J/m^2)	1.135 653	E+04
British thermal unit$_{th}$ per square foot (Btu$_{th}$/ft^2)	joule per square meter (J/m^2)	1.134 893	E+04
British thermal unit$_{IT}$ per square foot hour [(Btu$_{IT}$/(ft^2 · h)]	watt per square meter (W/m^2)	3.154 591	E+00
British thermal unit$_{th}$ per square foot hour [Btu$_{th}$/(ft^2 · h)]	watt per square meter (W/m^2)	3.152 481	E+00
British thermal unit$_{th}$ per square foot minute [Btu$_{th}$/(ft^2 · min)]	watt per square meter (W/m^2)	1.891 489	E+02
British thermal unit$_{IT}$ per square foot second [(Btu$_{IT}$/(ft^2 · s)]	watt per square meter (W/m^2)	1.135 653	E+04
British thermal unit$_{th}$ per square foot second [Btu$_{th}$/(ft^2 · s)]	watt per square meter (W/m^2)	1.134 893	E+04
British thermal unit$_{th}$ per square inch second [Btu$_{th}$/(in^2 · s)]	watt per square meter (W/m^2)	1.634 246	E+06
bushel (U.S.) (bu)	cubic meter (m^3)	3.523 907	E–02
bushel (U.S.) (bu)	liter (L)	3.523 907	E+01
calorie$_{IT}$ (cal$_{IT}$)[11]	joule (J)	**4.1868**	**E+00**
calorie$_{th}$ (cal$_{th}$)[11]	joule (J)	**4.184**	**E+00**
calorie (cal) (mean)	joule (J)	4.190 02	E+00
calorie (15 °C) (cal$_{15}$)	joule (J)	4.185 80	E+00
calorie (20 °C) (cal$_{20}$)	joule (J)	4.181 90	E+00
calorie$_{IT}$, kilogram (nutrition)[12]	joule (J)	**4.1868**	**E+03**
calorie$_{th}$, kilogram (nutrition)[12]	joule (J)	**4.184**	**E+03**
calorie (mean), kilogram (nutrition)[12]	joule (J)	4.190 02	E+03
calorie$_{th}$ per centimeter second degree Celsius [cal$_{th}$/(cm · s · °C)]	watt per meter kelvin [W/(m · K)]	**4.184**	**E+02**
calorie$_{IT}$ per gram (cal$_{IT}$/g)	joule per kilogram (J/kg)	**4.1868**	**E+03**
calorie$_{th}$ per gram (cal$_{th}$/g)	joule per kilogram (J/kg)	**4.184**	**E+03**
calorie$_{IT}$ per gram degree Celsius [cal$_{IT}$/(g · °C)]	joule per kilogram kelvin [J/(kg · K)]	**4.1868**	**E+03**
calorie$_{th}$ per gram degree Celsius [cal$_{th}$/(g · °C)]	joule per kilogram kelvin [J/(kg · K)]	**4.184**	**E+03**
calorie$_{IT}$ per gram kelvin [cal$_{IT}$/(g · K)]	joule per kilogram kelvin [J /(kg · K)]	**4.1868**	**E+03**
calorie$_{th}$ per gram kelvin [cal$_{th}$ / (g · K)]	joule per kilogram kelvin [J /(kg · K)]	**4.184**	**E+03**
calorie$_{th}$ per minute (cal$_{th}$/min)	watt (W)	6.973 333	E–02
calorie$_{th}$ per second (cal$_{th}$/s)	watt (W)	**4.184**	**E+00**
calorie$_{th}$ per square centimeter (cal$_{th}$/cm^2)	joule per square meter (J/m^2)	**4.184**	**E+04**
calorie$_{th}$ per square centimeter minute [cal$_{th}$/(cm^2 · min)]	watt per square meter (W/m^2)	6.973 333	E+02
calorie$_{th}$ per square centimeter second [cal$_{th}$/(cm^2 · s)]	watt per square meter (W/m^2)	**4.184**	**E+04**
candela per square inch (cd/in^2)	candela per square meter (cd/m^2)	1.550 003	E+03
carat, metric	kilogram (kg)	**2.0**	**E–04**
carat, metric	gram (g)	**2.0**	**E–01**
centimeter of mercury (0 °C)[13]	pascal (Pa)	1.333 22	E+03
centimeter of mercury (0 °C)[13]	kilopascal (kPa)	1.333 22	E+00
centimeter of mercury, conventional (cmHg)[13]	pascal (Pa)	1.333 224	E+03

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[12] The kilogram calorie or "large calorie" is an obsolete term used for the kilocalorie, which is the calorie used to express the energy content of foods. However, in practice, the prefix "kilo" is usually omitted.

[13] Conversion factors for mercury manometer pressure units are calculated using the standard value for the acceleration of gravity and the density of mercury at the stated temperature. Additional digits are not justified because the definitions of the units do not take into account the compressibility of mercury or the change in density caused by the revised practical temperature scale, ITS-90. Similar comments also apply to water manometer pressure units. Conversion factors for conventional mercury and water manometer pressure units are based on ISO 31-3.

To convert from	**to**	**Multiply by**	
centimeter of mercury, conventional (cmHg)[13]	kilopascal (kPa)	1.333 224	E+00
centimeter of water (4 °C)[13]	pascal (Pa)	9.806 38	E+01
centimeter of water, conventional (cmH_2O)[13]	pascal (Pa)	**9.806 65**	**E+01**
centipoise (cP)	pascal second (Pa · s)	**1.0**	**E–03**
centistokes (cSt)	meter squared per second (m^2/s)	**1.0**	**E–06**
chain (based on U.S survey foot) (ch)[9]	meter (m)	2.011 684	E+01
circular mil	square meter (m^2)	5.067 075	E–10
circular mil	square millimeter (mm^2)	5.067 075	E–04
clo	square meter kelvin per watt ($m^2 \cdot K/W$)	1.55	E–01
cord (128 ft^3)	cubic meter (m^3)	3.624 556	E+00
cubic foot (ft^3)	cubic meter (m^3)	2.831 685	E–02
cubic foot per minute (ft^3 /min)	cubic meter per second (m^3/s)	4.719 474	E–04
cubic foot per minute (ft^3 /min)	liter per second (L/s)	4.719 474	E–01
cubic foot per second (ft^3/s)	cubic meter per second (m^3/s)	2.831 685	E–02
cubic inch (in^3)[14]	cubic meter (m^3)	1.638 706	E–05
cubic inch per minute (in^3 /min)	cubic meter per second (m^3/s)	2.731 177	E–07
cubic mile (mi^3)	cubic meter (m^3)	4.168 182	E+09
cubic yard (yd^3)	cubic meter (m^3)	7.645 549	E–01
cubic yard per minute (yd^3/min)	cubic meter per second (m^3/s)	1.274 258	E–02
cup (U.S.)	cubic meter (m^3)	2.365 882	E–04
cup (U.S.)	liter (L)	2.365 882	E–01
cup (U.S.)	milliliter (mL)	2.365 882	E+02
curie (Ci)	becquerel (Bq)	**3.7**	**E+10**
darcy[15]	meter squared (m^2)	9.869 233	E–13
day (d)	second (s)	**8.64**	**E+04**
day (sidereal)	second (s)	8.616 409	E+04
debye (D)	coulomb meter (C · m)	3.335 641	E–30
degree (angle) (°)	radian (rad)	1.745 329	E–02
degree Celsius (temperature) (°C)	kelvin (K)	$T/\mathrm{K} = t/{}^{\circ}\mathrm{C} + \mathbf{273.15}$	
degree Celsius (temperature interval) (°C)	kelvin (K)	**1.0**	**E+00**
degree centigrade (temperature)[16]	degree Celsius (°C)	$t/{}^{\circ}\mathrm{C} \approx t/\mathrm{deg.cent.}$	
degree centigrade (temperature interval)[16]	degree Celsius (°C)	1.0	E+00
degree Fahrenheit (temperature) (°F)	degree Celsius (°C)	$t/{}^{\circ}\mathrm{C} = (t/{}^{\circ}\mathrm{F} - \mathbf{32})/\mathbf{1.8}$	
degree Fahrenheit (temperature) (°F)	kelvin (K)	$T/\mathrm{K} = (t/{}^{\circ}\mathrm{F} + \mathbf{459.67})/\mathbf{1.8}$	
degree Fahrenheit (temperature interval)(°F)	degree Celsius (°C)	5.555 556	E–01
degree Fahrenheit (temperature interval) (°F)	kelvin (K)	5.555 556	E–01
degree Fahrenheit hour per British thermal unit$_{IT}$ (°F · h/Btu_{IT})	kelvin per watt (K/W)	1.895 634	E+00
degree Fahrenheit hour per British thermal unit$_{th}$ (°F · h/Btu_{th})	kelvin per watt (K/W)	1.896 903	E+00
degree Fahrenheit hour square foot per British thermal unit$_{IT}$ (°F · h · ft^2 /Btu_{IT})	square meter kelvin per watt ($m^2 \cdot K/W$)	1.761 102	E–01
degree Fahrenheit hour square foot per British thermal unit$_{th}$ (°F · h · ft^2 /Btu_{th})	square meter kelvin per watt ($m^2 \cdot K/W$)	1.762 280	E–01
degree Fahrenheit hour square foot per British thermal unit$_{IT}$ inch [°F · h · ft^2 /(Btu_{IT} · in)]	meter kelvin per watt (m · K/W)	6.933 472	E+00
degree Fahrenheit hour square foot per British thermal unit$_{th}$ inch [°F · h · ft^2 /(Btu_{th} · in)]	meter kelvin per watt (m · K/W)	6.938 112	E+00
degree Fahrenheit second per British thermal unit$_{IT}$ (°F · s /Btu_{IT})	kelvin per watt (K/W)	5.265 651	E–04
degree Fahrenheit second per British thermal unit$_{th}$ (°F · s /Btu_{th})	kelvin per watt (K/W)	5.269 175	E–04
degree Rankine (°R)	kelvin (K)	$T/\mathrm{K} = (T/{}^{\circ}\mathrm{R})/\mathbf{1.8}$	
degree Rankine (temperature interval) (°R)	kelvin (K)	5.555 556	E–01
denier	kilogram per meter (kg/m)	1.111 111	E–07
denier	gram per meter (g/m)	1.111 111	E–04
dyne (dyn)	newton (N)	**1.0**	**E–05**
dyne centimeter (dyn · cm)	newton meter (N · m)	**1.0**	**E–07**
dyne per square centimeter (dyn/cm^2)	pascal (Pa)	**1.0**	**E–01**

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[14] The exact conversion factor is 1.638 706 4 E–05.

[15] The darcy is a unit for expressing the permeability of porous solids, not area.

[16] The centigrade temperature scale is obsolete; the degree centigrade is only approximately equal to the degree Celsius.

To convert from	to	Multiply by	
electronvolt (eV)	joule (J)	1.602 177	E–19
EMU of capacitance (abfarad)	farad (F)	**1.0**	**E+09**
EMU of current (abampere)	ampere (A)	**1.0**	**E+01**
EMU of electric potential (abvolt)	volt (V)	**1.0**	**E–08**
EMU of inductance (abhenry)	henry (H)	**1.0**	**E–09**
EMU of resistance (abohm)	ohm (Ω)	**1.0**	**E–09**
erg (erg)	joule (J)	**1.0**	**E–07**
erg per second (erg/s)	watt (W)	**1.0**	**E–07**
erg per square centimeter second |1obrkt&1ru|/(cm^2 · s)]	watt per square meter (W/m^2)	**1.0**	**E–03**
ESU of capacitance (statfarad)	farad (F)	1.112 650	E–12
ESU of current (statampere)	ampere (A)	3.335 641	E–10
ESU of electric potential (statvolt)	volt (V)	2.997 925	E+02
ESU of inductance (stathenry)	henry (H)	8.987 552	E+11
ESU of resistance (statohm)	ohm (Ω)	8.987 552	E+11
faraday (based on carbon 12)	coulomb (C)	9.648 531	E+04
fathom (based on U.S survey foot)[9]	meter (m)	1.828 804	E+00
fermi	meter (m)	**1.0**	**E–15**
fermi	femtometer (fm)	**1.0**	**E+00**
fluid ounce (U.S.) (fl oz)	cubic meter (m^3)	2.957 353	E–05
fluid ounce (U.S.) (fl oz)	milliliter (mL)	2.957 353	E+01
foot (ft)	meter (m)	**3.048**	**E–01**
foot (U.S survey ft)[9]	meter (m)	3.048 006	E–01
footcandle	lux (lx)	1.076 391	E+01
footlambert	candela per square meter (cd/m^2)	3.426 259	E+00
foot of mercury, conventional (ftHg)[13]	pascal (Pa)	4.063 666	E+04
foot of mercury, conventional (ftHg)[13]	kilopascal (kPa)	4.063 666	E+01
foot of water (39.2 °F)[13]	pascal (Pa)	2.988 98	E+03
foot of water (39.2 °F)[13]	kilopascal (kPa)	2.988 98	E+00
foot of water, conventional (ftH$_2$O)[13]	pascal (Pa)	2.989 067	E+03
foot of water, conventional (ftH$_2$O)[13]	kilopascal (kPa)	2.989 067	E+00
foot per hour (ft/h)	meter per second (m/s)	8.466 667	E–05
foot per minute (ft/min)	meter per second (m/s)	**5.08**	**E–03**
foot per second (ft/s)	meter per second (m/s)	**3.048**	**E–01**
foot per second squared (ft/s^2)	meter per second squared (m/s^2)	**3.048**	**E–01**
foot poundal	joule (J)	4.214 011	E–02
foot pound-force (ft · lbf)	joule (J)	1.355 818	E+00
foot pound-force per hour (ft · lbf/h)	watt (W)	3.766 161	E–04
foot pound-force per minute (ft · lbf/min)	watt (W)	2.259 697	E–02
foot pound-force per second (ft · lbf/s)	watt (W)	1.355 818	E+00
foot to the fourth power (ft^4)[17]	meter to the fourth power (m^4)	8.630 975	E–03
franklin (Fr)	coulomb (C)	3.335 641	E–10
gal (Gal)	meter per second squared (m/s^2)	**1.0**	**E–02**
gallon [Canadian and U.K (Imperial)] (gal)	cubic meter (m^3)	**4.546 09**	**E–03**
gallon [Canadian and U.K (Imperial)] (gal)	liter (L)	**4.546 09**	**E+00**
gallon (U.S.) (gal)	cubic meter (m^3)	3.785 412	E–03
gallon (U.S.) (gal)	liter (L)	3.785 412	E+00
gallon (U.S.) per day (gal/d)	cubic meter per second (m^3/s)	4.381 264	E–08
gallon (U.S.) per day (gal/d)	liter per second (L/s)	4.381 264	E–05
gallon (U.S.) per horsepower hour [gal / (hp · h)]	cubic meter per joule (m^3/J)	1.410 089	E–09
gallon (U.S.) per horsepower hour [gal / (hp · h)]	liter per joule (L/ J)	1.410 089	E–06
gallon (U.S.) per minute (gpm)(gal/min)	cubic meter per second (m^3/s)	6.309 020	E–05
gallon (U.S.) per minute (gpm)(gal/min)	liter per second (L/ s)	6.309 020	E–02
gamma (γ)	tesla (T)	**1.0**	**E–09**
gauss (Gs, G)	tesla (T)	**1.0**	**E–04**
gilbert (Gi)	ampere (A)	7.957 747	E–01

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[17] This is a unit for the quantity second moment of area, which is sometimes called the “moment of section” or “area moment of inertia” of a plane section about a specified axis.

To convert from	**to**	**Multiply by**	
gill [Canadian and U.K (Imperial)] (gi)	cubic meter (m^3)	1.420 653	E–04
gill [Canadian and U.K (Imperial)] (gi)	liter (L)	1.420 653	E–01
gill (U.S.) (gi)	cubic meter (m^3)	1.182 941	E–04
gill (U.S.) (gi)	liter (L)	1.182 941	E–01
gon (also called grade) (gon)	radian (rad)	1.570 796	E–02
gon (also called grade) (gon)	degree (angle) (°)	**9.0**	**E–01**
grain (gr)	kilogram (kg)	**6.479 891**	**E–05**
grain (gr)	milligram (mg)	**6.479 891**	**E+01**
grain per gallon (U.S.) (gr/gal)	kilogram per cubic meter (kg/m^3)	1.711 806	E–02
grain per gallon (U.S.) (gr/gal)	milligram per liter (mg/L)	1.711 806	E+01
gram-force per square centimeter (gf /cm^2)	pascal (Pa)	**9.806 65**	**E+01**
gram per cubic centimeter (g/cm^3)	kilogram per cubic meter (kg/m^3)	**1.0**	**E+03**
hectare (ha)	square meter (m^2)	**1.0**	**E+04**
horsepower (550 ft · lbf/s) (hp)	watt (W)	7.456 999	E+02
horsepower (boiler)	watt (W)	9.809 50	E+03
horsepower (electric)	watt (W)	**7.46**	**E+02**
horsepower (metric)	watt (W)	7.354 988	E+02
horsepower (U.K.)	watt (W)	7.4570	E+02
horsepower (water)	watt (W)	7.460 43	E+02
hour (h)	second (s)	**3.6**	**E+03**
hour (sidereal)	second (s)	3.590 170	E+03
hundredweight (long, 112 lb)	kilogram (kg)	5.080 235	E+01
hundredweight (short, 100 lb)	kilogram (kg)	4.535 924	E+01
inch (in)	meter (m)	**2.54**	**E–02**
inch (in)	centimeter (cm)	**2.54**	**E+00**
inch of mercury (32 °F)[13]	pascal (Pa)	3.386 38	E+03
inch of mercury (32 °F)[13]	kilopascal (kPa)	3.386 38	E+00
inch of mercury (60 °F)[13]	pascal (Pa)	3.376 85	E+03
inch of mercury (60 °F)[13]	kilopascal (kPa)	3.376 85	E+00
inch of mercury, conventional (inHg)[13]	pascal (Pa)	3.386 389	E+03
inch of mercury, conventional (inHg)[13]	kilopascal (kPa)	3.386 389	E+00
inch of water (39.2 °F)[13]	pascal (Pa)	2.490 82	E+02
inch of water (60 °F)[13]	pascal (Pa)	2.4884	E+02
inch of water, conventional (inH$_2$O)[13]	pascal (Pa)	2.490 889	E+02
inch per second (in/s)	meter per second (m/s)	**2.54**	**E–02**
inch per second squared (in/s^2)	meter per second squared (m/s^2)	**2.54**	**E–02**
inch to the fourth power (in^4)[17]	meter to the fourth power (m^4)	4.162 314	E–07
kayser (K)	reciprocal meter (m^{-1})	**1.0**	**E+02**
kelvin (K)	degree Celsius (°C)	t / °C = T/ K – **273.15**	
kilocalorie$_{\mathrm{IT}}$ (kcal$_{\mathrm{IT}}$)	joule (J)	**4.1868**	**E+03**
kilocalorie$_{\mathrm{th}}$ (kcal$_{\mathrm{th}}$)	joule (J)	**4.184**	**E+03**
kilocalorie (mean) (kcal)	joule (J)	4.190 02	E+03
kilocalorie$_{\mathrm{th}}$ per minute (kcal$_{\mathrm{th}}$ /min)	watt (W)	6.973 333	E+01
kilocalorie$_{\mathrm{th}}$ per second (kcal$_{\mathrm{th}}$ /s)	watt (W)	**4.184**	**E+03**
kilogram-force (kgf)	newton (N)	**9.806 65**	**E+00**
kilogram-force meter (kgf · m)	newton meter (N · m)	**9.806 65**	**E+00**
kilogram-force per square centimeter (kgf/cm^2)	pascal (Pa)	**9.806 65**	**E+04**
kilogram-force per square centimeter (kgf/cm^2)	kilopascal (kPa)	**9.806 65**	**E+01**
kilogram-force per square meter (kgf/m^2)	pascal (Pa)	**9.806 65**	**E+00**
kilogram-force per square millimeter (kgf/mm^2)	pascal (Pa)	**9.806 65**	**E+06**
kilogram-force per square millimeter (kgf/mm^2)	megapascal (MPa)	**9.806 65**	**E+00**
kilogram-force second squared per meter (kgf · s^2/m)	kilogram (kg)	**9.806 65**	**E+00**
kilometer per hour (km/h)	meter per second (m/s)	2.777 778	E–01
kilopond (kilogram-force) (kp)	newton (N)	**9.806 65**	**E+00**
kilowatt hour (kW · h)	joule (J)	**3.6**	**E+06**
kilowatt hour (kW · h)	megajoule (MJ)	**3.6**	**E+00**

To convert from	**to**	**Multiply by**	
kip (1 kip=1000 lbf)	newton (N)	4.448 222	E+03
kip (1 kip=1000 lbf)	kilonewton (kN)	4.448 222	E+00
kip per square inch (ksi) (kip/in^2)	pascal (Pa)	6.894 757	E+06
kip per square inch (ksi) (kip/in^2)	kilopascal (kPa)	6.894 757	E+03
knot (nautical mile per hour)	meter per second (m/s)	5.144 444	E–01
lambert[18]	candela per square meter (cd/m^2)	3.183 099	E+03
langley (cal$_{th}$/cm^2)	joule per square meter (J/m^2)	**4.184**	**E+04**
light year (l.y.)[19]	meter (m)	9.460 73	E+15
liter (L)[20]	cubic meter (m^3)	**1.0**	**E–03**
lumen per square foot (lm/ft^2)	lux (lx)	1.076 391	E+01
maxwell (Mx)	weber (Wb)	**1.0**	**E–08**
mho	siemens (S)	**1.0**	**E+00**
microinch	meter (m)	**2.54**	**E–08**
microinch	micrometer (μm)	**2.54**	**E–02**
micron (μ)	meter (m)	**1.0**	**E–06**
micron (μ)	micrometer (μm)	**1.0**	**E+00**
mil (0.001 in)	meter (m)	**2.54**	**E–05**
mil (0.001 in)	millimeter (mm)	**2.54**	**E–02**
mil (angle)	radian (rad)	9.817 477	E–04
mil (angle)	degree (°)	**5.625**	**E–02**
mile (mi)	meter (m)	**1.609 344**	**E+03**
mile (mi)	kilometer (km)	**1.609 344**	**E+00**
mile (based on U.S survey foot) (mi)[9]	meter (m)	1.609 347	E+03
mile (based on U.S survey foot) (mi)[9]	kilometer (km)	1.609 347	E+00
mile, nautical [21]	meter (m)	**1.852**	**E+03**
mile per gallon (U.S.) (mpg) (mi/gal)	meter per cubic meter (m/m^3)	4.251 437	E+05
mile per gallon (U.S.) (mpg) (mi/gal)	kilometer per liter (km/L)	4.251 437	E–01
mile per gallon (U.S.) (mpg) (mi/gal)[22]	liter per 100 kilometer (L/100 km)	divide 235.215 by number of miles per gallon	
mile per hour (mi/h)	meter per second (m/s)	**4.4704**	**E–01**
mile per hour (mi/h)	kilometer per hour (km/h)	**1.609 344**	**E+00**
mile per minute (mi/min)	meter per second (m/s)	**2.682 24**	**E+01**
mile per second (mi/s)	meter per second (m/s)	**1.609 344**	**E+03**
millibar (mbar)	pascal (Pa)	**1.0**	**E+02**
millibar (mbar)	kilopascal (kPa)	**1.0**	**E–01**
millimeter of mercury, conventional (mmHg)[13]	pascal (Pa)	1.333 224	E+02
millimeter of water, conventional (mmH$_2$O)[13]	pascal (Pa)	**9.806 65**	**E+00**
minute (angle) (')	radian (rad)	2.908 882	E–04
minute (min)	second (s)	**6.0**	**E+01**
minute (sidereal)	second (s)	5.983 617	E+01
oersted (Oe)	ampere per meter (A/m)	7.957 747	E+01
ohm centimeter (Ω · cm)	ohm meter (Ω · m)	**1.0**	**E–02**
ohm circular-mil per foot	ohm meter (Ω · m)	1.662 426	E–09
ohm circular-mil per foot	ohm square millimeter per meter (Ω · mm^2/m)	1.662 426	E–03
ounce (avoirdupois) (oz)	kilogram (kg)	2.834 952	E–02
ounce (avoirdupois) (oz)	gram (g)	2.834 952	E+01
ounce (troy or apothecary) (oz)	kilogram (kg)	3.110 348	E–02
ounce (troy or apothecary) (oz)	gram (g)	3.110 348	E+01
ounce [Canadian and U.K fluid (Imperial)] (fl oz)	cubic meter (m^3)	2.841 306	E–05
ounce [Canadian and U.K fluid (Imperial)] (fl oz)	milliliter (mL)	2.841 306	E+01

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[18] The exact conversion factor is $10^4/\pi$.

[19] This conversion factor is based on 1 d = 86 400 s; and 1 Julian century = 36 525 d. (See *The Astronomical Almanac for the Year 1995*, page K6, U.S. Government Printing Office, Washington, DC, 1994).

[20] In 1964 the General Conference on Weights and Measures reestablished the name "liter" as a special name for the cubic decimeter. Between 1901 and 1964 the liter was slightly larger (1.000 028 dm^3); when one uses high-accuracy volume data of that time, this fact must be kept in mind.

[21] The value of this unit, 1 nautical mile = 1852 m, was adopted by the First International Extraordinary Hydrographic Conference, Monaco, 1929, under the name "International nautical mile."

[22] For converting fuel economy, as used in the U.S., to fuel consumption.

To convert from	to	Multiply by	
ounce (U.S. fluid) (fl oz)	cubic meter (m^3)	2.957 353	E−05
ounce (U.S fluid) (fl oz)	milliliter (mL)	2.957 353	E+01
ounce (avoirdupois)-force (ozf)	newton (N)	2.780 139	E−01
ounce (avoirdupois)-force inch ($ozf \cdot in$)	newton meter ($N \cdot m$)	7.061 552	E−03
ounce (avoirdupois)-force inch ($ozf \cdot in$)	millinewton meter ($mN \cdot m$)	7.061 552	E+00
ounce (avoirdupois) per cubic inch (oz/ in^3)	kilogram per cubic meter (kg/m^3)	1.729 994	E+03
ounce (avoirdupois) per gallon [Canadian and U.K (Imperial)] (oz/gal)	kilogram per cubic meter (kg/m^3)	6.236 023	E+00
ounce (avoirdupois) per gallon [Canadian and U.K (Imperial)] (oz/gal)	gram per liter (g/L)	6.236 023	E+00
ounce (avoirdupois) per gallon (U.S.)(oz/gal)	kilogram per cubic meter (kg/m^3)	7.489 152	E+00
ounce (avoirdupois) per gallon (U.S.)(oz/gal)	gram per liter (g/L)	7.489 152	E+00
ounce (avoirdupois) per square foot (oz/ ft^2)	kilogram per square meter (kg/m^2)	3.051 517	E−01
ounce (avoirdupois) per square inch (oz/ in^2)	kilogram per square meter (kg/m^2)	4.394 185	E+01
ounce (avoirdupois) per square yard(oz/yd^2)	kilogram per square meter (kg/m^2)	3.390 575	E−02
parsec (pc)	meter (m)	3.085 678	E+16
peck (U.S.) (pk)	cubic meter (m^3)	8.809 768	E−03
peck (U.S.) (pk)	liter (L)	8.809 768	E+00
pennyweight (dwt)	kilogram (kg)	1.555 174	E−03
pennyweight (dwt)	gram (g)	1.555 174	E+00
perm (0 °C)	kilogram per pascal second square meter [$kg/(Pa \cdot s \cdot m^2)$]	5.721 35	E−11
perm (23 °C)	kilogram per pascal second square meter [$kg/(Pa \cdot s \cdot m^2)$]	5.745 25	E−11
perm inch (0 °C)	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]	1.453 22	E−12
perm inch (23 °C)	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]	1.459 29	E−12
phot (ph)	lux (lx)	**1.0**	**E+04**
pica (computer) (1/6 in)	meter (m)	4.233 333	E−03
pica (computer) (1/6 in)	millimeter (mm)	4.233 333	E+00
pica (printer's)	meter (m)	4.217 518	E−03
pica (printer's)	millimeter (mm)	4.217 518	E+00
pint (U.S dry) (dry pt)	cubic meter (m^3)	5.506 105	E−04
pint (U.S dry) (dry pt)	liter (L)	5.506 105	E−01
pint (U.S liquid) (liq pt)	cubic meter (m^3)	4.731 765	E−04
pint (U.S liquid) (liq pt)	liter (L)	4.731 765	E−01
point (computer) (1/72 in)	meter (m)	3.527 778	E−04
point (computer) (1/72 in)	millimeter (mm)	3.527 778	E−01
point (printer's)	meter (m)	3.514 598	E−04
point (printer's)	millimeter (mm)	3.514 598	E−01
poise (P)	pascal second ($Pa \cdot s$)	**1.0**	**E−01**
pound (avoirdupois) (lb)[23]	kilogram (kg)	4.535 924	E−01
pound (troy or apothecary) (lb)	kilogram (kg)	3.732 417	E−01
poundal	newton (N)	1.382 550	E−01
poundal per square foot	pascal (Pa)	1.488 164	E+00
poundal second per square foot	pascal second ($Pa \cdot s$)	1.488 164	E+00
pound foot squared ($lb \cdot ft^2$)	kilogram meter squared ($kg \cdot m^2$)	4.214 011	E−02
pound-force (lbf)[24]	newton (N)	4.448 222	E+00
pound-force foot ($lbf \cdot ft$)	newton meter ($N \cdot m$)	1.355 818	E+00
pound-force foot per inch ($lbf \cdot ft/in$)	newton meter per meter ($N \cdot m/m$)	5.337 866	E+01
pound-force inch ($lbf \cdot in$)	newton meter ($N \cdot m$)	1.129 848	E−01
pound-force inch per inch ($lbf \cdot in/in$)	newton meter per meter ($N \cdot m/m$)	4.448 222	E+00
pound-force per foot (lbf/ft)	newton per meter (N/m)	1.459 390	E+01
pound-force per inch (lbf/in)	newton per meter (N/m)	1.751 268	E+02
pound-force per pound (lbf/lb) (thrust to mass ratio)	newton per kilogram (N/kg)	**9.806 65**	**E+00**
pound-force per square foot (lbf/ft^2)	pascal (Pa)	4.788 026	E+01
pound-force per square inch (psi) (lbf/in^2)	pascal (Pa)	6.894 757	E+03

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[23] The exact conversion factor is 4.535 923 7 E−01. All units that contain the pound refer to the avoirdupois pound unless otherwise specified.

[24] If the local value of the acceleration of free fall is taken as g_n=9.806 65 m/ s^2 (the standard value), the exact conversion factor is 4.448 221 615 260 5 E+00.

To convert from	**to**	**Multiply by**	
pound-force per square inch (psi) (lbf/in^2)	kilopascal (kPa)	6.894 757	E+00
pound-force second per square foot (lbf · s/ft^2)	pascal second (Pa · s)	4.788 026	E+01
pound-force second per square inch (lbf · s/in^2)	pascal second (Pa · s)	6.894 757	E+03
pound inch squared (lb · in^2)	kilogram meter squared (kg · m^2)	2.926 397	E–04
pound per cubic foot (lb/ft^3)	kilogram per cubic meter (kg/m^3)	1.601 846	E+01
pound per cubic inch (lb/in^3)	kilogram per cubic meter (kg/m^3)	2.767 990	E+04
pound per cubic yard (lb/yd^3)	kilogram per cubic meter (kg/m^3)	5.932 764	E–01
pound per foot (lb/ft)	kilogram per meter (kg/m)	1.488 164	E+00
pound per foot hour [lb/(ft · h)]	pascal second (Pa · s)	4.133 789	E–04
pound per foot second [lb/(ft · s)]	pascal second (Pa · s)	1.488 164	E+00
pound per gallon [Canadian and U.K (Imperial)] (lb/gal)	kilogram per cubic meter (kg/m^3)	9.977 637	E+01
pound per gallon [Canadian and U.K (Imperial)] (lb/gal)	kilogram per liter (kg/L)	9.977 637	E–02
pound per gallon (U.S.) (lb/gal)	kilogram per cubic meter (kg/m^3)	1.198 264	E+02
pound per gallon (U.S.) (lb/gal)	kilogram per liter (kg/L)	1.198 264	E–01
pound per horsepower hour [lb/(hp · h)]	kilogram per joule (kg/J)	1.689 659	E–07
pound per hour (lb/h)	kilogram per second (kg/s)	1.259 979	E–04
pound per inch (lb/in)	kilogram per meter (kg/m)	1.785 797	E+01
pound per minute (lb/min)	kilogram per second (kg/s)	7.559 873	E–03
pound per second (lb/s)	kilogram per second (kg/s)	4.535 924	E–01
pound per square foot (lb/ft^2)	kilogram per square meter (kg/m^2)	4.882 428	E+00
pound per square inch (*not* pound-force) (lb/in^2)	kilogram per square meter (kg/m^2)	7.030 696	E+02
pound per yard (lb/yd)	kilogram per meter (kg/m)	4.960 546	E–01
psi (pound-force per square inch) (lbf/in^2)	pascal (Pa)	6.894 757	E+03
psi (pound-force per square inch) (lbf/in^2)	kilopascal (kPa)	6.894 757	E+00
quad (10^{15} Btu$_{IT}$)[11]	joule (J)	1.055 056	E+18
quart (U.S dry) (dry qt)	cubic meter (m^3)	1.101 221	E–03
quart (U.S dry) (dry qt)	liter (L)	1.101 221	E+00
quart (U.S liquid) (liq qt)	cubic meter (m^3)	9.463 529	E–04
quart (U.S liquid) (liq qt)	liter (L)	9.463 529	E–01
rad (absorbed dose) (rad)	gray (Gy)	**1.0**	**E–02**
rem (rem)	sievert (Sv)	**1.0**	**E–02**
revolution (r)	radian (rad)	6.283 185	E+00
revolution per minute (rpm) (r/min)	radian per second (rad/s)	1.047 198	E–01
rhe	reciprocal pascal second [(Pa · s)$^{-1}$]	**1.0**	**E+01**
rod (based on U.S survey foot) (rd)[9]	meter (m)	5.029 210	E+00
roentgen (R)	coulomb per kilogram (C/kg)	**2.58**	**E–04**
rpm (revolution per minute) (r/min)	radian per second (rad/s)	1.047 198	E–01
second (angle) (")	radian (rad)	4.848 137	E–06
second (sidereal)	second (s)	9.972 696	E–01
shake	second (s)	**1.0**	**E–08**
shake	nanosecond (ns)	**1.0**	**E+01**
slug (slug)	kilogram (kg)	1.459 390	E+01
slug per cubic foot (slug/ft^3)	kilogram per cubic meter (kg/m^3)	5.153 788	E+02
slug per foot second [slug/(ft · s)]	pascal second (Pa · s)	4.788 026	E+01
square foot (ft^2)	square meter (m^2)	**9.290 304**	**E–02**
square foot per hour (ft^2/h)	square meter per second (m^2/s)	**2.580 64**	**E–05**
square foot per second (ft^2/s)	square meter per second (m^2/s)	**9.290 304**	**E–02**
square inch (in^2)	square meter (m^2)	**6.4516**	**E–04**
square inch (in^2)	square centimeter (cm^2)	**6.4516**	**E+00**
square mile (mi^2)	square meter (m^2)	2.589 988	E+06
square mile (mi^2)	square kilometer (km^2)	2.589 988	E+00
square mile (based on U.S survey foot) (mi^2)[9]	square meter (m^2)	2.589 998	E+06
square mile (based on U.S survey foot) (mi^2)[9]	square kilometer (km^2)	2.589 998	E+00

To convert from	to	Multiply by	
square yard (yd^2)	square meter (m^2)	8.361 274	E–01
statampere	ampere (A)	3.335 641	E–10
statcoulomb	coulomb (C)	3.335 641	E–10
statfarad	farad (F)	1.112 650	E–12
stathenry	henry (H)	8.987 552	E+11
statmho	siemens (S)	1.112 650	E–12
statohm	ohm (Ω)	8.987 552	E+11
statvolt	volt (V)	2.997 925	E+02
stere (st)	cubic meter (m^3)	**1.0**	**E+00**
stilb (sb)	candela per square meter (cd/m^2)	**1.0**	**E+04**
stokes (St)	meter squared per second (m^2/s)	**1.0**	**E–04**
tablespoon	cubic meter (m^3)	1.478 676	E–05
tablespoon	milliliter (mL)	1.478 676	E+01
teaspoon	cubic meter (m^3)	4.928 922	E–06
teaspoon	milliliter (mL)	4.928 922	E+00
tex	kilogram per meter (kg/m)	**1.0**	**E–06**
therm (EC)[25]	joule (J)	**1.055 06**	**E+08**
therm (U.S.)[25]	joule (J)	**1.054 804**	**E+08**
ton, assay (AT)	kilogram (kg)	2.916 667	E–02
ton, assay (AT)	gram (g)	2.916 667	E+01
ton-force (2000 lbf)	newton (N)	8.896 443	E+03
ton-force (2000 lbf)	kilonewton (kN)	8.896 443	E+00
ton, long (2240 lb)	kilogram (kg)	1.016 047	E+03
ton, long, per cubic yard	kilogram per cubic meter (kg/m^3)	1.328 939	E+03
ton, metric (t)	kilogram (kg)	**1.0**	**E+03**
tonne (called “metric ton” in U.S.) (t)	kilogram (kg)	**1.0**	**E+03**
ton of refrigeration (12 000 Btu$_{IT}$/h)	watt (W)	3.516 853	E+03
ton of TNT (energy equivalent)[26]	joule (J)	**4.184**	**E+09**
ton, register	cubic meter (m^3)	2.831 685	E+00
ton, short (2000 lb)	kilogram (kg)	9.071 847	E+02
ton, short, per cubic yard	kilogram per cubic meter (kg/m^3)	1.186 553	E+03
ton, short, per hour	kilogram per second (kg/s)	2.519 958	E–01
torr (Torr)	pascal (Pa)	1.333 224	E+02
unit pole	weber (Wb)	1.256 637	E–07
watt hour (W · h)	joule (J)	**3.6**	**E+03**
watt per square centimeter (W/cm^2)	watt per square meter (W/m^2)	**1.0**	**E+04**
watt per square inch (W/in^2)	watt per square meter (W/m^2)	1.550 003	E+03
watt second (W · s)	joule (J)	**1.0**	**E+00**
yard (yd)	meter (m)	**9.144**	**E–01**
year (365 days)	second (s)	**3.1536**	**E+07**
year (sidereal)	second (s)	3.155 815	E+07
year (tropical)	second (s)	3.155 693	E+07

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[25] The therm (EC) is legally defined in the Council Directive of 20 December 1979, Council of the European Communities (now the European Union, EU). The therm (U.S.) is legally defined in the Federal Register of July 27, 1968. Although the therm (EC), which is based on the International Table Btu, is frequently used by engineers in the United States, the therm (U.S.) is the legal unit used by the U.S natural gas industry.

[26] Defined (not measured) value.

CONVERSION OF TEMPERATURES

From	**To**	
Celsius	Fahrenheit	$t_F/{}^\circ F = (9/5)\ t/{}^\circ C + 32$
	Kelvin	$T/K = t/{}^\circ C + 273.15$
	Rankine	$T/{}^\circ R = (9/5)\ (t/{}^\circ C + 273.15)$
Fahrenheit	Celsius	$t/{}^\circ C = (5/9)\ [(t_F/{}^\circ F) - 32]$
	Kelvin	$T/K = (5/9)\ [(t_F/{}^\circ F) - 32] + 273.15$
	Rankine	$T/{}^\circ R = t_F/{}^\circ F + 459.67$
Kelvin	Celsius	$t/{}^\circ C = T/K - 273.15$
	Rankine	$T/{}^\circ R = (9/5)\ T/K$
Rankine	Fahrenheit	$t_F/{}^\circ F = T/{}^\circ R - 459.67$
	Kelvin	$T/K = (5/9)\ T/{}^\circ R$

Definition of symbols:

T = thermodynamic (absolute) temperature

t = Celsius temperature (the symbol θ is also used for Celsius temperature)

t_F = Fahrenheit temperature

Designation of Large Numbers

	U.S.A.	**Other countries**
10^6	million	million
10^9	billion	milliard
10^{12}	trillion	billion
10^{15}	quadrillion	billiard
10^{18}	quintillion	trillion
100^{100}	googol	
10^{googol}	googolplex	

CONVERSION FACTORS FOR ENERGY UNITS

If greater accuracy is required, use the *Energy Equivalents* section of the *Fundamental Physical Constants* table.

	Wavenumber $\bar{\nu}$ **cm^{-1}**	**Frequency ν** **MHz**	**Energy E** **aJ**	**Energy E** **eV**	**Energy E** **E_h**	**Molar energy E_m** **kJ/mol**	**Molar energy E_m** **kcal/mol**	**Temperature T** **K**
$\bar{\nu}$: 1 cm^{-1}	$\doteq$ 1	2.997925×10^4	1.986447×10^{-5}	1.239842×10^{-4}	4.556335×10^{-6}	11.96266×10^{-3}	2.85914×10^{-3}	1.438769
ν: 1 MHz	$\doteq$ 3.33564×10^{-5}	1	6.626076×10^{-10}	4.135669×10^{-9}	1.519830×10^{-10}	3.990313×10^{-7}	9.53708×10^{-8}	4.79922×10^{-5}
1 aJ	$\doteq$ 50341.1	1.509189×10^9	1	6.241506	0.2293710	602.2137	143.9325	7.24292×10^4
E: 1 eV	$\doteq$ 8065.54	2.417988×10^8	0.1602177	1	3.674931×10^{-2}	96.4853	23.0605	1.16045×10^4
E_h	$\doteq$ 219474.63	6.579684×10^9	4.359748	27.2114	1	2625.500	627.510	3.15773×10^5
E_m: 1 kJ/mol	$\doteq$ 83.5935	2.506069×10^6	1.660540×10^{-3}	1.036427×10^{-2}	3.808798×10^{-4}	1	0.239006	120.272
1 kcal/mol	$\doteq$ 349.755	1.048539×10^7	6.947700×10^{-3}	4.336411×10^{-2}	1.593601×10^{-3}	4.184	1	503.217
T: 1 K	$\doteq$ 0.695039	2.08367×10^4	1.380658×10^{-5}	8.61738×10^{-5}	3.16683×10^{-6}	8.31451×10^{-3}	1.98722×10^{-3}	1

Examples of the use of this table:

$$1 \text{ aJ} \doteq 50341 \text{ cm}^{-1}$$

$$1 \text{ eV} \doteq 96.4853 \text{ kJ mol}^{-1}$$

The symbol $\doteq$ should be read as meaning corresponds to or is equivalent to.

$E = h\nu = hc\bar{\nu} = kT$; $E_m = N_A E$; E_h is the Hartree energy

CONVERSION FACTORS FOR PRESSURE UNITS

	Pa	**kPa**	**MPa**	**bar**	**atmos**	**Torr**	**μmHg**	**psi**
Pa	1	0.001	0.000001	0.00001	9.8692×10^{-6}	0.0075006	7.5006	0.0001450377
kPa	1000	1	0.001	0.01	0.0098692	7.5006	7500.6	0.1450377
MPa	1000000	1000	1	10	9.8692	7500.6	7500600	145.0377
bar	100000	100	0.1	1	0.98692	750.06	750060	14.50377
atmos	101325	101.325	0.101325	1.01325	1	760	760000	14.69594
Torr	133.322	0.133322	0.000133322	0.00133322	0.00131579	1	1000	0.01933672
μmHg	0.133322	0.000133322	1.33322×10^{-7}	1.33322×10^{-6}	1.31579×10^{-6}	0.001	1	1.933672×10^{-5}
psi	6894.757	6.894757	0.006894757	0.06894757	0.068046	51.7151	51715.1	1

To convert a pressure value from a unit in the left hand column to a new unit, multiply the value by the factor appearing in the column for the new unit. For example:

1 kPa = 9.8692×10^{-3} atmos
1 Torr = 1.33322×10^{-4} MPa

Notes: μmHg is often referred to as “micron”
Torr is essentially identical to mmHg
psi is an abbreviation for the unit pound–force per square inch
psia (as a term for a physical quantity) implies the true (absolute) pressure
psig implies the true pressure minus the local atmospheric pressure

CONVERSION FACTORS FOR THERMAL CONDUCTIVITY UNITS

MULTIPLY ↓ by appropriate factor to OBTAIN→	**Btu$_{IT}$ h^{-1} ft^{-1} °F^{-1}**	**Btu$_{IT}$ in. h^{-1} ft^{-2} °F^{-1}**	**Btu$_{th}$ h^{-1} ft^{-1} °F^{-1}**	**Btu$_{th}$ in. h^{-1} ft^{-2} °F^{-1}**	**cal$_{IT}$ s^{-1} cm^{-1} °C^{-1}**	**cal$_{th}$ s^{-1} cm^{-1} °C^{-1}**	**kcal$_{th}$ h^{-1} m^{-1} °C^{-1}**	**J s^{-1} cm^{-1} K^{-1}**	**W cm^{-1} K^{-1}**	**W m^{-1} K^{-1}**	**mW cm^{-1} K^{-1}**
Btu$_{IT}$ h^{-1} ft^{-1} °F^{-1}	1	12	1.00067	12.0080	4.13379×10^{-3}	4.13656×10^{-3}	1.48916	1.73073×10^{-2}	1.73073×10^{-2}	1.73073	17.3073
Btu$_{IT}$ in. h^{-1} ft^{-2} °F^{-1}	8.33333×10^{-2}	1	8.33891×10^{-2}	1.00067	3.44482×10^{-4}	3.44713×10^{-4}	0.124097	1.44228×10^{-3}	1.44228×10^{-3}	0.144228	1.44228
Btu$_{th}$ h^{-1} ft^{-1} °F^{-1}	0.999331	11.9920	1	12	4.13102×10^{-3}	4.13379×10^{-3}	1.48816	1.72958×10^{-2}	1.72958×10^{-2}	1.72958	17.2958
Btu$_{th}$ in. h^{-1} ft^{-2} °F^{-1}	8.32776×10^{-2}	0.999331	8.33333×10^{-2}	1	3.44252×10^{-4}	3.44482×10^{-4}	0.124014	1.44131×10^{-3}	1.44131×10^{-3}	0.144131	1.44131
cal$_{IT}$ s^{-1} cm^{-1} °C^{-1}	2.41909×10^{2}	2.90291×10^{3}	2.42071×10^{2}	2.90485×10^{3}	1	1.00067	3.60241×10^{2}	4.1868	4.1868	4.1868×10^{2}	4.1868×10^{3}
cal$_{th}$ s^{-1} cm^{-1} °C^{-1}	2.41747×10^{2}	2.90096×10^{3}	2.41909×10^{2}	2.90291×10^{3}	0.999331	1	3.6×10^{2}	4.184	4.184	4.184×10^{2}	4.184×10^{3}
kcal$_{th}$ h^{-1} m^{-1} °C^{-1}	0.671520	8.05824	0.671969	8.06363	2.77592×10^{-3}	2.77778×10^{-3}	1	1.16222×10^{-2}	1.16222×10^{-2}	1.16222	11.6222
J s^{-1} cm^{-1} K^{-1}	57.7789	6.93347×10^{2}	57.8176	6.93811×10^{2}	0.238846	0.239006	86.0421	1	1	1×10^{2}	1×10^{3}
W cm^{-1} K^{-1}	57.7789	6.93347×10^{2}	57.8176	6.93811×10^{2}	0.238846	0.239006	86.0421	1	1	1×10^{2}	1×10^{3}
W m^{-1} K^{-1}	0.577789	6.93347	0.578176	6.93811	2.38846×10^{-3}	2.39006×10^{-3}	0.860421	1×10^{-2}	1×10^{-2}	1	10
mW cm^{-1} K^{-1}	5.77789×10^{-2}	0.693347	5.78176×10^{-2}	0.693811	2.38846×10^{-4}	2.39006×10^{-4}	8.60421×10^{-2}	1×10^{-3}	1×10^{-3}	0.1	1

CONVERSION FACTORS FOR ELECTRICAL RESISTIVITY UNITS

To convert FROM ↓ multiply by appropriate factor to OBTAIN →	**abΩ cm**	**μΩ cm**	**Ω cm**	**StatΩ cm**	**Ω m**	**Ω cir. mil ft^{-1}**	**Ω in.**	**Ω ft**
abohm centimeter	1	1×10^{-3}	10^{-9}	1.113×10^{-21}	10^{-11}	6.015×10^{-3}	3.937×10^{-10}	3.281×10^{-11}
microohm centimeter	10^{3}	1	10^{-6}	1.113×10^{-18}	10^{-8}	6.015	3.937×10^{-7}	3.281×10^{-6}
ohm centimeter	10^{8}	10^{6}	1	1.113×10^{-12}	1×10^{-2}	6.015×10^{6}	3.937×10^{-1}	3.281×10^{-2}
statohm centimeter (esu)	8.987×10^{20}	8.987×10^{17}	8.987×10^{11}	1	8.987×10^{9}	5.406×10^{18}	3.538×10^{11}	2.949×10^{10}
ohm meter	10^{11}	10^{8}	10^{2}	1.113×10^{-10}	1	6.015×10^{8}	3.937×10^{1}	3.281
ohm circular mil per foot	1.662×10^{2}	1.662×10^{-1}	1.662×10^{-7}	1.850×10^{-19}	1.662×10^{-9}	1	6.54×10^{-6}	5.45×10^{-9}
ohm inch	2.54×10^{9}	2.54×10^{6}	2.54	2.827×10^{-12}	2.54×10^{-2}	1.528×10^{7}	1	8.3×10^{-2}
ohm foot	3.048×10^{10}	3.048×10^{7}	3.048×10^{-1}	3.3924×10^{-11}	3.048×10^{-1}	1.833×10^{8}	12	1

CONVERSION FACTORS FOR CHEMICAL KINETICS

Equivalent Second Order Rate Constants

B A	$cm^3\ mol^{-1}s^{-1}$	$dm^3\ mol^{-1}s^{-1}$	$m^3\ mol^{-1}s^{-1}$	cm^3 $molecule^{-1}s^{-1}$	$(mm\ Hg)^{-1}s^{-1}$	$atm^{-1}s^{-1}$	$ppm^{-1}min^{-1}$	$m^2\,kN^{-1}s^{-1}$
1 $cm^3\ mol^{-1}\ s^{-1}$ =	1	10^{-3}	10^{-6}	1.66×10^{-24}	$1.604 \times 10^{-5}\ T^{-1}$	$1.219 \times 10^{-2}\ T^{-1}$	2.453×10^{-9}	$1.203 \times 10^{-4}\ T^{-1}$
1 $dm^3\ mol^{-1}\ s^{-1}$ =	10^3	1	10^{-3}	1.66×10^{-21}	$1.604 \times 10^{-2}\ T^{-1}$	$12.19\ T^{-1}$	2.453×10^{-6}	$1.203 \times 10^{-1}\ T^{-1}$
1 $m^3\ mol^{-1}\ s^{-1}$ =	10^6	10^3	1	1.66×10^{-18}	$16.04\ T^{-1}$	$1.219 \times 10^4\ T^{-1}$	2.453×10^{-3}	$120.3\ T^{-1}$
1cm^3 $molecule^{-1}s^{-1}$ =	6.023×10^{23}	6.023×10^{20}	6.023×10^{17}	1	$9.658 \times 10^{18} T^{-1}$	$7.34 \times 10^{21}\ T^{-1}$	1.478×10^{15}	$7.244 \times 10^{19} T^{-1}$
1 $(mm\ Hg)^{-1}\ s^{-1}$ =	$6.236 \times 10^4\ T$	$62.36\ T$	$6.236 \times 10^{-2}\ T$	$1.035 \times 10^{-19}\ T$	1	760	4.56×10^{-2}	7.500
1 $atm^{-1}\,s^{-1}$	$82.06\ T$	$8.206 \times 10^{-2}\ T$	$8.206 \times 10^{-5}\ T$	$1.362 \times 10^{-22}\ T$	1.316×10^{-3}	1	6×10^{-5}	9.869×10^{-3}
1 $ppm^{-1}\ min^{-1}$ = at 298 K, 1 atm total pressure	4.077×10^8	4.077×10^5	407.7	6.76×10^{-16}	21.93	1.667×10^4	1	164.5
1 $m^2\,kN^{-1}s^{-1}$ =	$8314\ T$	$8.314\ T$	$8.314 \times 10^{-3}\ T$	$1.38 \times 10^{-20}\ T$	0.1333	101.325	6.079×10^{-3}	1

To convert a rate constant from one set of units A to a new set B find the conversion factor for the row A under column B and multiply the old value by it, e.g.. to convert cm^3 $molecule^{-1}$ s^{-1} to m^3 mol^{-1} s^{-1} multiply by 6.023×10^{17}.

Table adapted from High Temperature Reaction Rate Data No. 5, The University, Leeds (1970).

Equivalent Third Order Rate Constants

B A	$cm^6\ mol^{-2}s^{-1}$	$dm^6\ mol^{-1}s^{-1}$	$m^6\ mol^{-2}\,s^{-1}$	cm^6 $molecule^{-2}\,s^{-1}$	$(mm\ Hg)^{-2}\,s^{-1}$	$atm^{-2}\,s^{-1}$	$ppm^{-2}\,min^{-1}$	$m^4\,kN^{-2}s^{-1}$
1 $cm^6\ mol^{-2}\,s^{-1}$=	1	10^{-6}	10^{-12}	2.76×10^{-48}	$2.57 \times 10^{-10} T^{-2}$	$1.48 \times 10^{-4}\ \mathrm{T}^{-2}$	1.003×10^{-19}	$1.477 \times 10^{-8} T^{-2}$
1 $dm^6\ mol^{-2}\,s^{-1}$ =	10^6	1	10^{-6}	2.76×10^{-42}	$2.57 \times 10^{-4} T^{-2}$	$148\ T^{-2}$	1.003×10^{-13}	$1.477 \times 10^{-2} T^{-2}$
1 $m^6\ mol^{-2}\ s^{-1}$=	10^{12}	10^6	1	2.76×10^{-36}	$257\ T^{-2}$	$1.48 \times 10^8 T^{-2}$	1.003×10^{-7}	$1.477 \times 10^4 T^{-2}$
1cm^6 $molecule^{-2}s^{-1}$=	3.628×10^{47}	3.628×10^{41}	3.628×10^{35}	1	$9.328 \times 10^{37} T^{-2}$	$5.388 \times 10^{43} T^{-2}$	3.64×10^{28}	$5.248 \times 10^{39} T^{-2}$
1 $(mm\ Hg)^{-2}\ s^{-1}$ =	$3.89 \times 10^9\ T^2$	$3.89 \times 10^3\ T^2$	$3.89 \times 10^{-3}\ T^2$	$1.07 \times 10^{-38} T^2$	1	5.776×10^5	3.46×10^{-5}	56.25
1 $atm^{-2}\,s^{-1}$ =	$6.733 \times 10^3\ T^2$	$6.733 \times 10^{-3}\ T^2$	$6.733 \times 10^{-9}\ T^2$	$1.86 \times 10^{-44} T^2$	1.73×10^{-6}	1	6×10^{-11}	9.74×10^{-5}
1 $ppm^{-2}\ min^{-1}$= at 298K, 1 atm total pressure	9.97×10^{18}	9.97×10^{12}	9.97×10^6	2.75×10^{-29}	2.89×10^4	1.667×10^{10}	1	1.623×10^6
1 $m^1\,kN^{-2}s^{-1}$=	$6.91 \times 10^7\ T^2$	$6.91\ T^2$	$69.1 \times 10^{-5}\ T^2$	$1.904 \times 10^{-40}\ T^2$	0.0178	1.027×10^4	6.16×10^{-7}	1

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CONVERSION FACTORS FOR IONIZING RADIATION

Conversion Between SI and Other Units

Quantity	Symbol for quantity	Expression in SI units	Expression in symbols for SI units	Special name for SI units	Symbols using special names	Conventional units	Symbol for conventional unit	Value of conventional unit in SI units
Activity	A	1 per second	s^{-1}	becquerel	Bq	curie	Ci	3.7×10^{10} Bq
Absorbed dose	D	joule per kilogram	$\mathrm{J\ kg}^{-1}$	gray	Gy	rad	rad	0.01 Gy
Absorbed dose rate	$\dot{D}$	joule per kilogram second	$\mathrm{J\ kg}^{-1}\ \mathrm{s}^{-1}$		$\mathrm{Gy\ s}^{-1}$	rad	$\mathrm{rad\ s}^{-1}$	$0.01\ \mathrm{Gy\ s}^{-1}$
Average energy per ion pair	W	joule	J			electronvolt	eV	1.602×10^{-19} J
Dose equivalent	H	joule per kilogram	$\mathrm{J\ kg}^{-1}$	sievert	Sv	rem	rem	0.01 Sv
Dose equivalent rate	$\dot{H}$	joule per kilogram second	$\mathrm{J\ kg}^{-1}\ \mathrm{s}^{-1}$		$\mathrm{Sv\ s}^{-1}$	rem per second	$\mathrm{rem\ s}^{-1}$	$0.01\ \mathrm{Sv\ s}^{-1}$
Electric current	I	ampere	A			ampere	A	1.0 A
Electric potential difference	U, V	watt per ampere	$\mathrm{W\ A}^{-1}$	volt	V	volt	V	1.0 V
Exposure	$\dot{X}$	coulomb per kilogram	$\mathrm{C\ kg}^{-1}$			roentgen	R	$2.58 \times 10^{-4}\ \mathrm{C\ kg}^{-1}$
Exposure rate	X	coulomb per kilogram second	$\mathrm{C\ kg}^{-1}\ \mathrm{s}^{-1}$			roentgen	$\mathrm{R\ s}^{-1}$	$2.58 \times 10^{-4}\ \mathrm{C\ kg}^{-1}\ \mathrm{s}^{-1}$
Fluence	ϕ	1 per meter squared	m^{-2}			1 per centimeter squared	cm^{-2}	$1.0 \times 10^{4}\ \mathrm{m}^{-2}$
Fluence rate	Φ	1 per meter squared second	$\mathrm{m}^{-2}\ \mathrm{s}^{-1}$			1 per centimeter squared second	$\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$	$1.0 \times 10^{4}\ \mathrm{m}^{-2}\ \mathrm{s}^{-1}$
Kerma	K	joule per kilogram	$\mathrm{J\ kg}^{-1}$	gray	Gy	rad	rad	0.01 Gy
Kerma rate	$\dot{K}$	joule per kilogram second	$\mathrm{J\ kg}^{-1}\ \mathrm{s}^{-1}$		$\mathrm{Gy\ s}^{-1}$	rad per second	$\mathrm{rad\ s}^{-1}$	$0.01\ \mathrm{Gy\ s}^{-1}$
Lineal energy	y	joule per meter	$\mathrm{J\ m}^{-1}$			kiloelectron volt per micrometer	$\mathrm{keV\ \mu m}^{-1}$	$1.602 \times 10^{-10}\ \mathrm{J\ m}^{-1}$
Linear energy transfer	L	joule per meter	$\mathrm{J\ m}^{-1}$			kiloelectron volt per micrometer	$\mathrm{keV\ \mu m}^{-1}$	$1.602 \times 10^{-10}\ \mathrm{J\ m}^{-1}$
Mass attenuation coefficient	μ/ρ	meter squared per kilogram	$\mathrm{m}^{2}\ \mathrm{kg}^{-1}$			centimeter squared per gram	$\mathrm{cm}^{2}\ \mathrm{g}^{-1}$	$0.1\ \mathrm{m}^{2}\ \mathrm{kg}^{-1}$
Mass energy transfer coefficient	μ_{tr}/ρ	meter squared per kilogram	$\mathrm{m}^{2}\ \mathrm{kg}^{-1}$			centimeter squared per gram	$\mathrm{cm}^{2}\ \mathrm{g}^{-1}$	$0.1\ \mathrm{m}^{2}\ \mathrm{kg}^{-1}$
Mass energy absorption coefficient	μ_{en}/ρ	meter squared per kilogram	$\mathrm{m}^{2}\ \mathrm{kg}^{-1}$			centimeter squared per gram	$\mathrm{cm}^{2}\ \mathrm{g}^{-1}$	$0.1\ \mathrm{m}^{2}\ \mathrm{kg}^{-1}$
Mass stopping power	S/ρ	joule meter squared per kilogram	$\mathrm{J\ m}^{2}\ \mathrm{kg}^{-1}$			MeV centimeter squared per gram	$\mathrm{MeV\ cm}^{2}\ \mathrm{g}^{-1}$	$1.602 \times 10^{-14}\ \mathrm{J\ m}^{2}\ \mathrm{kg}^{-1}$
Power	P	joule per second	$\mathrm{J\ s}^{-1}$	watt	W	watt	W	1.0 W
Pressure	p	newton per meter squared	$\mathrm{N\ m}^{-2}$	pascal	Pa	torr	torr	(101325/760)Pa
Radiation chemical yield	G	mole per joule	$\mathrm{mol\ J}^{-1}$			molecules per 100 electron volts	molecules $(100\ \mathrm{eV})^{-1}$	$1.04 \times 10^{-7}\ \mathrm{mol\ J}^{-1}$
Specific energy	z	joule per kilogram	$\mathrm{J\ kg}^{-1}$	gray	Gy	rad	rad	0.01 Gy

Conversion of Radioactivity Units from MBq to mCi and μCi

MBq	mCi	MBq	mCi	MBq	mCi	MBq	mCi	MBq	mCi
7000	189.	700	18.9	70	1.89	7	189	0.7	18.9
6000	162.	600	16.2	60	1.62	6	162	0.6	16.2
5000	135.	500	13.5	50	1.35	5	135	0.5	13.5
4000	108.	400	10.8	40	1.08	4	108	0.4	10.8
3000	81.	300	8.1	30	810	3	81	0.3	8.1
2000	54.	200	5.4	20	540	2	54	0.2	5.4
1000	27.	100	2.7	10	270	1	27	0.1	2.7
900	24.	90	2.4	9	240	0.9	24		
800	21.6	80	2.16	8	220	0.8	21.6		

Conversion of Radioactivity Units from mCi and μCi to MBq

mCi	MBq	mCi	MBq	mCi	MBq	μCi	MBq	μCi	MBq	μCi	MBq
200	7400	40	1480	5	185	1000	37.0	200	7.4	30	1.11
150	5550	30	1110	4	148	900	33.3	100	3.7	20	0.74
100	3700	20	740	3	111	800	29.6	90	3.33	10	0.37
90	3330	10	370	2	74.0	700	25.9	80	2.96	5	0.185
80	2960	9	333	1	37.0	600	22.2	70	2.59	2	0.074
70	2590	8	296			500	18.5	60	2.22	1	0.037
60	2220	7	259			400	14.8	50	1.85		
50	1850	6	222			300	11.1	40	1.48		

Conversion of Radioactivity Units

100 TBq (10^{14} Bq) = 2.7 kCi (2.7×10^{3} Ci)
10 TBq (10^{13} Bq) = 270 Ci (2.7×10^{2} Ci)
1 TBq (10^{12} Bq) = 27 Ci (2.7×10^{1} Ci)
100 GBq (10^{11} Bq) = 2.7 Ci (2.7×10^{0} Ci)
10 GBq (10^{10} Bq) = 270 mCi (2.7×10^{-1} Ci)
1 GBq (10^{9} Bq) = 27 mCi (2.7×10^{-2} Ci)
100 MBq (10^{8} Bq) = 2.7 mCi (2.7×10^{-3} Ci)
10 MBq (10^{7} Bq) = 270 μCi (2.7×10^{-4} Ci)
1 MBq (10^{6} Bq) = 27 μCi (2.7×10^{-5} Ci)

100 kBq (10^{5} Bq) = 2.7 μCi (2.7×10^{-6}Ci)
10 kBq (10^{4} Bq) = 270 nCi (2.7×10^{-7} Ci)
1 kBq (10^{3} Bq) = 27 nCi (2.7×10^{-8} Ci)
100 Bq (10^{2} Bq) = 2.7 nCi (2.7×10^{-9} Ci)
10 Bq (10^{1} Bq) = 270 pCi (2.7×10^{-10} Ci)
1 Bq (10^{0} Bq) = 27 pCi (2.7×10^{-11} Ci)
100 mBq (10^{-1} Bq) = 2.7 pCi (2.7×10^{-12} Ci)
10 mBq (10^{-2} Bq) = 270 fCi (2.7×10^{-13} Ci)
1 mBq (10^{-3} Bq) = 27 fCi (2.7×10^{-14} Ci)

Conversion of Absorbed Dose Units

SI Units		Conventional	SI Units		Conventional
100 Gy (10^{2} Gy)	=	10,000 rad (10^{4} rad)	100 μGy (10^{-4} Gy)	=	10 mrad (10^{-2} rad)
10 Gy (10^{1} Gy)	=	1,000 rad (10^{3} rad)	10 μGy (10^{-5} Gy)	=	1 mrad (10^{-3} rad)
1 Gy (10^{0} Gy)	=	100 rad (10^{2} rad)	1 μGy (10^{-6} Gy)	=	100 μrad (10^{-4} rad)
100 mGy (10^{-1} Gy)	=	10 rad (10^{1} rad)	100 nGy (10^{-7} Gy)	=	10 μrad (10^{-5} rad)
10 mGy (10^{-2} Gy)	=	1 rad (10^{0} rad)	10 nGy (10^{-8} Gy)	=	1 μrad (10^{-6} rad)
1 mGy (10^{-3} Gy)	=	100 mrad (10^{-1} rad)	1 nGy (10^{-9} Gy)	=	100 nrad (10^{-7} rad)

Conversion of Dose Equivalent Units

100 Sv (10^{2} Sv) = 10,000 rem (10^{4} rem)
10 Sv (10^{1} Sv) = 1,000 rem (10^{3} rem)
1 Sv (10^{0} Sv) = 100 rem (10^{2} rem)
100 mSv (10^{-1} Sv) = 10 rem (10^{1} rem)
10 mSv (10^{-2} Sv) = 1 rem (10^{0} rem)
1 mSv (10^{-3} Sv) = 100 mrem (10^{-1} rem)

100 μSv (10^{-4} Sv) = 10 mrem (10^{-2} rem)
10 μSv (10^{-5} Sv) = 1 mrem (10^{-3} rem)
1 μSv (10^{-6} Sv) = 100 μrem (10^{-4} rem)
100 nSv (10^{-7} Sv) = 10 μrem (10^{-5} rem)
10 nSv (10^{-8} Sv) = 1 μrem (10^{-6} rem)
1 nSv (10^{-9} Sv) = 100 nrem (10^{-7} rem)

VALUES OF THE GAS CONSTANT IN DIFFERENT UNIT SYSTEMS

In SI units the value of the gas constant, *R*, is:

R = 8.314472 Pa m^3 K^{-1} mol^{-1}
= 8314.472 Pa L K^{-1} mol^{-1}
= 0.08314472 bar L K^{-1} mol^{-1}

This table gives the appropriate value of *R* for use in the ideal gas equation, $PV = nRT$, when the variables are expressed in other units. The following conversion factors for pressure units were used in generating the table:

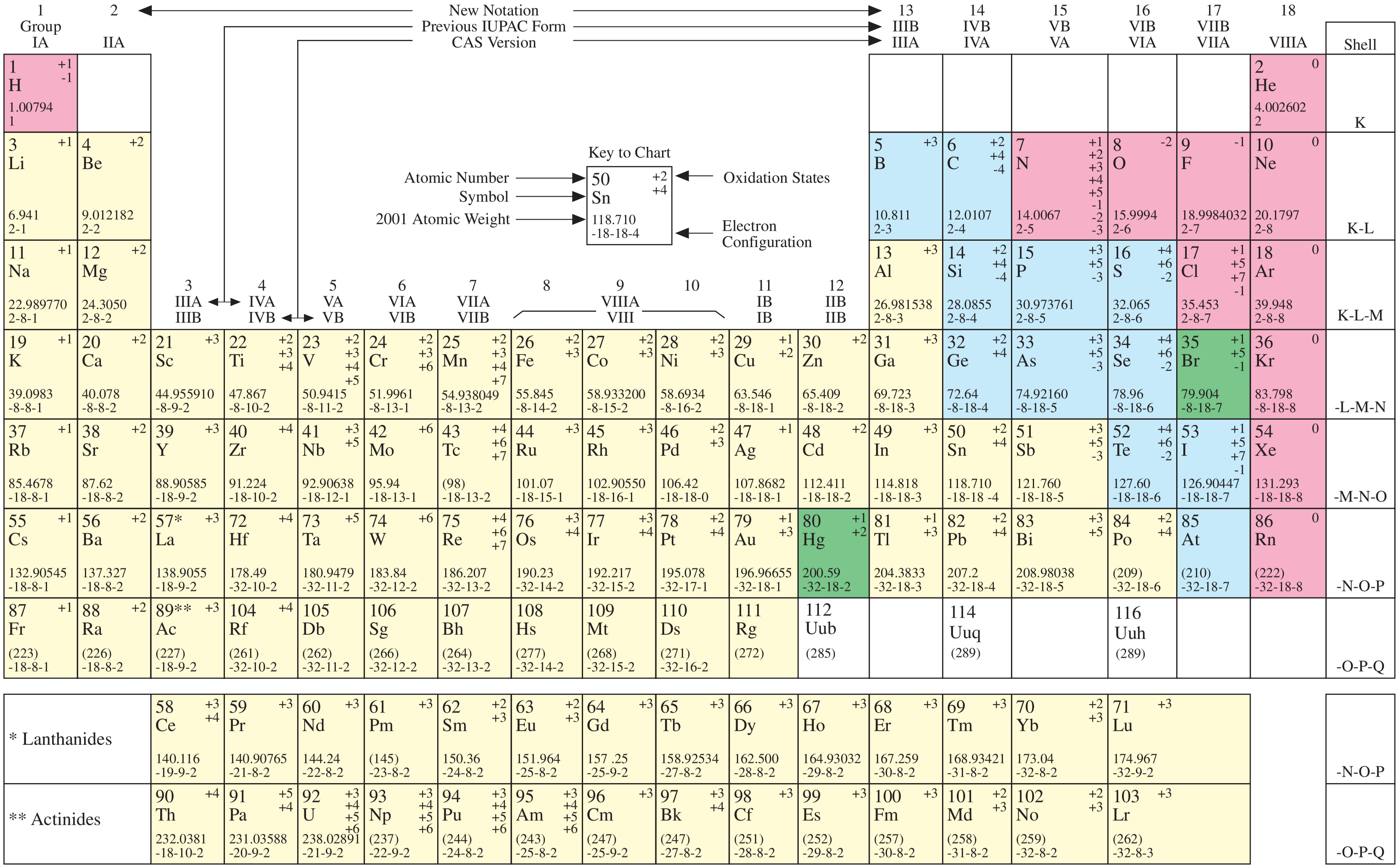
1 atm = 101325 Pa
1 psi = 6894.757 Pa
1 torr (mm Hg) = 133.322 Pa [at 0°C]
1 in Hg = 3386.38 Pa [at 0°C]
1 in H_2O = 249.082 Pa [at 4°C]
1 ft H_2O = 2988.98 Pa [at 4°C]

Reference

Mohr, P. J., and Taylor, B. N., "The 2002 CODATA Recommended Values of the Fundamental Physical Constants", *Rev. Mod. Phys.* 77, 1, 2005. See also <http://physics.nist.gov/constants>

Units of *V*, *T*, *n*			**Units of *P***						
V	***T***	***n***	**kPa**	**atm**	**psi**	**mmHg**	**in Hg**	**in H_2O**	**ft H_2O**
ft^3	K	mol	0.2936228	0.00289784	0.0425864	2.20236	0.0867070	1.17881	0.0982351
		lb·mol	133.1851	1.31443	19.3168	998.973	39.3296	534.704	44.5587
	°R	mol	0.1631238	0.00160990	0.0236591	1.22353	0.0481706	0.654900	0.0545751
		lb·mol	73.99170	0.730242	10.7316	554.984	21.8498	297.058	24.7548
cm^3	K	mol	8314.472	82.0574	1205.91	62363.8	2455.27	33380.4	2781.71
		lb·mol	3771381	37220.6	546993	282878000	1113690	15141100	1261760
	°R	mol	4619.151	45.5875	669.951	34646.5	1364.03	18544.7	1545.39
		lb·mol	2095211	20678.1	303885	15715400	618717	8411730	700979
L	K	mol	8.314472	0.0820574	1.20591	62.3638	2.45527	33.3804	2.78171
		lb·mol	3771.381	37.2206	546.993	28287.8	1113.69	15141.1	1261.76
	°R	mol	4.619151	0.0455875	0.669951	34.6465	1.36403	18.5447	1.54539
		lb·mol	2095.211	20.6781	303.885	15715.4	618.717	8411.73	700.979
m^3	K	mol	0.008314472	0.0000820574	0.00120591	0.0623638	0.00245527	0.0333804	0.00278171
		lb·mol	3.771381	0.0372206	0.546993	28.2878	1.11369	15.1411	1.26176
	°R	mol	0.004619151	0.0000455875	0.000669951	0.0346465	0.00136403	0.0185447	0.00154539
		lb·mol	2.095211	0.0206781	0.303885	15.7154	0.618717	8.41173	0.700979

PERIODIC TABLE OF THE ELEMENTS



New Notation
Previous IUPAC Form
CAS Version

Key to Chart

Atomic Number → 50
Symbol → Sn
2001 Atomic Weight → 118.710
Oxidation States → +2 +4
Electron Configuration → -18-18-4

1 Group IA	2 IIA	3 IIIA IIIB	4 IVA IVB	5 VA VB	6 VIA VIB	7 VIIA VIIB	8	9 VIIIA VIII	10	11 IB IB	12 IIB IIB	13 IIIB IIIA	14 IVB IVA	15 VB VA	16 VIB VIA	17 VIIB VIIA	18 VIIIA	Shell
1 H +1 -1 1.00794 1																	2 He 0 4.002602 2	K
3 Li +1 6.941 2-1	4 Be +2 9.012182 2-2											5 B +3 10.811 2-3	6 C +2 +4 -4 12.0107 2-4	7 N +1 +2 +3 +4 +5 -1 -2 -3 14.0067 2-5	8 O -2 15.9994 2-6	9 F -1 18.9984032 2-7	10 Ne 0 20.1797 2-8	K-L
11 Na +1 22.989770 2-8-1	12 Mg +2 24.3050 2-8-2											13 Al +3 26.981538 2-8-3	14 Si +2 +4 -4 28.0855 2-8-4	15 P +3 +5 -3 30.973761 2-8-5	16 S +4 +6 -2 32.065 2-8-6	17 Cl +1 +5 +7 -1 35.453 2-8-7	18 Ar 0 39.948 2-8-8	K-L-M
19 K +1 39.0983 -8-8-1	20 Ca +2 40.078 -8-8-2	21 Sc +3 44.955910 -8-9-2	22 Ti +2 +3 +4 47.867 -8-10-2	23 V +2 +3 +4 +5 50.9415 -8-11-2	24 Cr +2 +3 +6 51.9961 -8-13-1	25 Mn +2 +3 +4 +7 54.938049 -8-13-2	26 Fe +2 +3 55.845 -8-14-2	27 Co +2 +3 58.933200 -8-15-2	28 Ni +2 +3 58.6934 -8-16-2	29 Cu +1 +2 63.546 -8-18-1	30 Zn +2 65.409 -8-18-2	31 Ga +3 69.723 -8-18-3	32 Ge +2 +4 72.64 -8-18-4	33 As +3 +5 -3 74.92160 -8-18-5	34 Se +4 +6 -2 78.96 -8-18-6	35 Br +1 +5 -1 79.904 -8-18-7	36 Kr 0 83.798 -8-18-8	-L-M-N
37 Rb +1 85.4678 -18-8-1	38 Sr +2 87.62 -18-8-2	39 Y +3 88.90585 -18-9-2	40 Zr +4 91.224 -18-10-2	41 Nb +3 +5 92.90638 -18-12-1	42 Mo +6 95.94 -18-13-1	43 Tc +4 +6 +7 (98) -18-13-2	44 Ru +3 101.07 -18-15-1	45 Rh +3 102.90550 -18-16-1	46 Pd +2 +3 106.42 -18-18-0	47 Ag +1 107.8682 -18-18-1	48 Cd +2 112.411 -18-18-2	49 In +3 114.818 -18-18-3	50 Sn +2 +4 118.710 -18-18 -4	51 Sb +3 +5 -3 121.760 -18-18-5	52 Te +4 +6 -2 127.60 -18-18-6	53 I +1 +5 +7 -1 126.90447 -18-18-7	54 Xe 0 131.293 -18-18-8	-M-N-O
55 Cs +1 132.90545 -18-8-1	56 Ba +2 137.327 -18-8-2	57* La +3 138.9055 -18-9-2	72 Hf +4 178.49 -32-10-2	73 Ta +5 180.9479 -32-11-2	74 W +6 183.84 -32-12-2	75 Re +4 +6 +7 186.207 -32-13-2	76 Os +3 +4 190.23 -32-14-2	77 Ir +3 +4 192.217 -32-15-2	78 Pt +2 +4 195.078 -32-17-1	79 Au +1 +3 196.96655 -32-18-1	80 Hg +1 +2 200.59 -32-18-2	81 Tl +1 +3 204.3833 -32-18-3	82 Pb +2 +4 207.2 -32-18-4	83 Bi +3 +5 208.98038 -32-18-5	84 Po +2 +4 (209) -32-18-6	85 At (210) -32-18-7	86 Rn 0 (222) -32-18-8	-N-O-P
87 Fr +1 (223) -18-8-1	88 Ra +2 (226) -18-8-2	89** Ac +3 (227) -18-9-2	104 Rf +4 (261) -32-10-2	105 Db (262) -32-11-2	106 Sg (266) -32-12-2	107 Bh (264) -32-13-2	108 Hs (277) -32-14-2	109 Mt (268) -32-15-2	110 Ds (271) -32-16-2	111 Rg (272)	112 Uub (285)		114 Uuq (289)		116 Uuh (289)			-O-P-Q

* Lanthanides	58 Ce +3 +4 140.116 -19-9-2	59 Pr +3 140.90765 -21-8-2	60 Nd +3 144.24 -22-8-2	61 Pm +3 (145) -23-8-2	62 Sm +2 +3 150.36 -24-8-2	63 Eu +2 +3 151.964 -25-8-2	64 Gd +3 157 .25 -25-9-2	65 Tb +3 158.92534 -27-8-2	66 Dy +3 162.500 -28-8-2	67 Ho +3 164.93032 -29-8-2	68 Er +3 167.259 -30-8-2	69 Tm +3 168.93421 -31-8-2	70 Yb +2 +3 173.04 -32-8-2	71 Lu +3 174.967 -32-9-2		-N-O-P
** Actinides	90 Th +4 232.0381 -18-10-2	91 Pa +5 +4 231.03588 -20-9-2	92 U +3 +4 +5 +6 238.02891 -21-9-2	93 Np +3 +4 +5 +6 (237) -22-9-2	94 Pu +3 +4 +5 +6 (244) -24-8-2	95 Am +3 +4 +5 +6 (243) -25-8-2	96 Cm +3 (247) -25-9-2	97 Bk +3 +4 (247) -27-8-2	98 Cf +3 (251) -28-8-2	99 Es +3 (252) -29-8-2	100 Fm +3 (257) -30-8-2	101 Md +2 +3 (258) -31-8-2	102 No +2 +3 (259) -32-8-2	103 Lr +3 (262) -32-8-3		-O-P-Q

The new IUPAC format numbers the groups from 1 to 18. The previous IUPAC numbering system and the system used by Chemical Abstracts Service (CAS) are also shown. For radioactive elements that do not occur in nature, the mass number of the most stable isotope is given in parentheses. Elements 112, 114, and 116 have been reported but not confirmed.

References
1. G. J. Leigh, Editor, *Nomenclature of Inorganic Chemistry*, Blackwell Scientific Publications, Oxford, 1990.
2. *Chemical and Engineering News*, 63(5), 27, 1985.
3. Atomic Weights of the Elements, 2001, *Pure & Appl. Chem.*, 75, 1107, 2003.

🟨 Metallic solids
🟦 Non-metallic solids
🟩 Liquids
🟥 Gases

UNITS FOR MAGNETIC PROPERTIES

Quantity	Symbol	Gaussian & cgs emu [a]	Conversion factor, C [b]	SI & rationalized mks [c]
Magnetic flux density, magnetic induction	B	gauss (G) [d]	10^{-4}	tesla (T), Wb/m^2
Magnetic flux	Φ	maxwell (Mx), G · cm^2	10^{-8}	weber (Wb), volt second (V · s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization [g]	M	emu/cm^3 [h]	10^3	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2 [i]
(Mass) magnetization	σ, M	emu/g	1	A·m^2/kg
			$4\pi \times 10^{-7}$	Wb·m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	A ·m^2, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	Wb·m[i]
(Volume) susceptibility	χ,κ	dimensionless, emu/cm^3	4π	dimensionless
			$(4\pi)^2 \times 10^{-7}$	henry per meter (H/m), Wb/(A·m)
(Mass) susceptibility	χ_ρ,κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$	m^3/kg
			$(4\pi)^2 \times 10^{-10}$	H·m^2/kg
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$	m^3/mol
			$(4\pi)^2 \times 10^{-13}$	H·m^2/mol
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A·m)
Relative permeability[j]	μ_r	not defined		dimensionless
(Volume) energy density, energy product [k]	W	erg/cm^3	10^{-1}	J/m^3
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

[a] Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.

[b] Multiply a number in Gaussian units by C to convert it to SI (e.g., 1 G × 10^{-4} T/G = 10^{-4} T).

[c] SI (*Système International d'Unités*) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where $\mu_0 = 4\pi \times 10^{-7}$ H/m. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.

[d] 1 gauss = 10^5 gamma (γ).

[e] Both oersted and gauss are expressed as cm$^{-1/2}$·g$^{1/2}$·s^{-1} in terms of base units.

[f] A/m was often expressed as "ampere–turn per meter" when used for magnetic field strength.

[g] Magnetic moment per unit volume.

[h] The designation "emu" is not a unit.

[i] Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote *c*.

[j] $\mu_r = \mu/\mu_0 = 1+\chi$, all in SI. μ_r is equal to Gaussian μ.

[k] $B \cdot H$ and $\mu_0\, M \cdot H$ have SI units J/m^3; $M \cdot H$ and $B \cdot H/4\pi$ have Gaussian units erg/cm^3.

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