

Fundamental Physical Constants

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CODATA Recommended Values of the Fundamental Physical Constants—2006				
Quantity	Symbol	Value	Unit	Relative standard uncertainty u_r
UNIVERSAL				
speed of light in vacuum	c, c_0	299 792 458	m s ⁻¹	(exact)
magnetic constant	μ_0	$4\pi 10^{-7}$	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)
characteristic impedance of vacuum $\sqrt{[\mu_0 / \epsilon_0]} = \mu_0 c$	Z_0	376.730 313 461 . . .	Ω	(exact)
Newtonian constant of gravitation	G	6.674 28(67) $\times 10^{-11}$	m ³ kg s ⁻²	1.0×10^{-4}
	$G \hbar c$	6.708 81(67) $\times 10^{-39}$	c	1.0×10^{-4}
Planck constant	h	6.626 068 96 (33) $\times 10^{-34}$	J s	5.0×10^{-8}
in eV s		4.135 667 33 (10) $\times 10^{-15}$	eV s	2.5×10^{-8}
$h/2\pi$	$\hbar$	1.054 571 628 (53) $\times 10^{-34}$	J s	5.0×10^{-8}
in eV s		6.582 118 99 (16) $\times 10^{-16}$	eV s	2.5×10^{-8}
$\hbar c$ in MeV fm		197.326 9631 (49)	MeV fm	2.5×10^{-8}

Planck mass $(\hbar c/G)^{1/2}$	m_P	2.176 44(11) $\times 10^{-8}$	kg	5.0×10^{-5}
energy equivalent in GeV	$m_P c^2$	1.220 892(61) $\times 10^{19}$	GeV	5.0×10^{-5}
k	T_P	1.416 785(71) $\times 10^{32}$	K	5.0×10^{-5}
Planck length $\hbar / m_P c = (\hbar G/c^3)^{1/2}$	l_P	1.616 252(81) $\times 10^{-35}$	m	5.0×10^{-5}
Planck time $l_P/c = (\hbar G/c^5)^{1/2}$	t_P	5.391 24(27) $\times 10^{-44}$	s	5.0×10^{-5}
ELECTROMAGNETIC				
elementary charge	e	1.602 176 487 (40) $\times 10^{-19}$	C	2.5×10^{-8}
	$e/\hbar$	2.417 989 454 (60) $\times 10^{14}$	A J ⁻¹	2.5×10^{-8}
magnetic flux quantum $\hbar/2e$	Φ_0	2.067 833 667 (52) $\times 10^{-15}$	Wb	2.5×10^{-8}
conductance quantum $2e^2/\hbar$	G_0	7.748 091 7004 (53) $\times 10^{-5}$	S	6.8×10^{-10}
inverse of conductance quantum	G_0^{-1}	12 906.403 7787(88)	Ω	6.8×10^{-10}
Josephson constant ^a $2e/\hbar$	K_J	483 597.891 (12) $\times 10^9$	Hz V ⁻¹	2.5×10^{-8}
von Klitzing constant ^b $\hbar/e^2 = \mu_0 c/2\alpha$	R_K	25 812.807 557 (18)	Ω	6.8×10^{-10}
Bohr magneton $e\hbar/2m_e$	μ_B	927.400 915 (23) $\times 10^{-26}$	J T ⁻¹	2.5×10^{-8}
in eV T ⁻¹		5.788 381 7555 (79) $\times 10^{-5}$	eV T ⁻¹	1.4×10^{-9}
	$\mu_B/\hbar$	13.996 246 04 (35) $\times 10^9$	Hz T ⁻¹	2.5×10^{-8}
	$\mu_B/\hbar c$	46.686 4515 (12)	m ⁻¹ T ⁻¹	2.5×10^{-8}
	μ_B/k	0.671 7131(12)	K T ⁻¹	1.7×10^{-6}

nuclear magneton $e\hbar/2m_p$	μ_N	5.050 783 24 (13) $\times 10^{-27}$	J T ⁻¹	2.5×10^{-8}
in eV T ⁻¹		3.152 451 2326 (45) $\times 10^{-8}$	eV T ⁻¹	1.4×10^{-9}
	$\mu_N/\bullet$	7.622 593 84 (19)	MHz T ⁻¹	2.5×10^{-8}
	μ_N/hc	2.542 623 616 (64) $\times 10^{-2}$	m ⁻¹ T ⁻¹	2.5×10^{-8}
	μ_N/k	3.658 2637(64) $\times 10^{-4}$	K T ⁻¹	1.7×10^{-6}
ATOMIC AND NUCLEAR				
General				
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	7.297 352 5376 (50) $\times 10^{-3}$		6.8×10^{-10}
inverse fine-structure constant	α^{-1}	137.035 999 679(94)		6.8×10^{-10}
Rydberg constant $\alpha^2 m_e c/2\bullet$	R_∞	10 973 731.568 527 (73)	m ⁻¹	6.6×10^{-12}
	$R_\infty c$	3.289 841 960 361(22) $\times 10^{15}$	Hz	6.6×10^{-12}
	$R_\infty hc$	2.179 871 97 (11) $\times 10^{-18}$	J	5.0×10^{-8}
$R_\infty hc$ in eV		13.605 691 93 (34)	eV	2.5×10^{-8}
Bohr radius $\alpha/4\pi R_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2$	a_0	0.529 177 208 59(36) $\times 10^{-10}$	m	6.8×10^{-10}
Hartree energy $e^2/4\pi\epsilon_0 a_0 = 2R_\infty \bullet c = \alpha^2 m_e c^2$	E_h	4.359 743 94 (22) $\times 10^{-18}$	J	5.0×10^{-8}
in eV		27.211 383 86 (68)	eV	2.5×10^{-8}
quantum of circulation	$\bullet/2m_e$	3.636 947 5199 (50) $\times 10^{-4}$	m ² s ⁻¹	1.4×10^{-9}
	$\bullet/m_e$	7.273 895 040 (10) $\times 10^{-4}$	m ² s ⁻¹	1.4×10^{-9}

Electroweak				
Fermi coupling constant ^c	$G_F / (\hbar c)^3$	1.166 37(1) × 10 ⁻⁵	GeV ⁻²	8.6 × 10 ⁻⁶
weak mixing angle ^d θ_W (on-shell scheme)				
$\sin^2 \theta_W = s_W^2 \times 1 - (m_W / m_Z)^2$	$\sin^2 \theta_W$	0.222 55(56)		2.5 × 10 ⁻³
Electron, e ⁻				
electron mass	m_e	9.109 382 15 (45) × 10 ⁻³¹	kg	5.0 × 10 ⁻⁸
in u, $m_e = A_r(e)$ u (electron rel. atomic mass times u)		5.485 799 0943 (23) × 10 ⁻⁴	u	4.2 × 10 ⁻¹⁰
energy equivalent	$m_e c^2$	8.187 104 38 (41) × 10 ⁻¹⁴	J	5.0 × 10 ⁻⁸
in MeV		0.510 998 910 (13)	MeV	2.5 × 10 ⁻⁸
electron-muon mass ratio	m_e / m_μ	4.836 331 71 (12) × 10 ⁻³		2.5 × 10 ⁻⁸
electron-tau mass ratio	m_e / m_τ	2.875 64(47) × 10 ⁻⁴		1.6 × 10 ⁻⁴
electron-proton mass ratio	m_e / m_p	5.446 170 2177 (24) × 10 ⁻⁴		4.3 × 10 ⁻¹⁰
electron-neutron mass ratio	m_e / m_n	5.438 673 4459 (33) × 10 ⁻⁴		6.0 × 10 ⁻¹⁰
electron-deuteron mass ratio	m_e / m_d	2.724 437 1093 (12) × 10 ⁻⁴		4.3 × 10 ⁻¹⁰
electron to alpha particle mass ratio	m_e / m_α	1.370 933 555 70(58) × 10 ⁻⁴		4.2 × 10 ⁻¹⁰
electron charge to mass quotient	$-e / m_e$	-1.758 820 150 (44) × 10 ¹¹	C kg ⁻¹	2.5 × 10 ⁻⁸
electron molar mass $N_A m_e$	$M(e), M_e$	5.485 799 0943 (23) × 10 ⁻⁷	kg mol ⁻¹	4.2 × 10 ⁻¹⁰
Compton wavelength $\hbar / m_e c$	λ_C	2.426 310 2175 (33) × 10 ⁻¹²	m	1.4 × 10 ⁻⁹
$\lambda_C / 2\pi = \alpha a_0 = \alpha^2 / 4\pi R_\infty$	$\tilde{\lambda}_C$	386.159 264 59 (53) × 10 ⁻¹⁵	m	1.4 × 10 ⁻⁹

classical electron radius $\alpha^2 a_0$	r_e	2.817 940 2894 (58) $\times 10^{-15}$	m	2.1×10^{-9}
Thomson cross section $(8\pi/3) r_e^2$	σ_e	0.665 245 8558 (27) $\times 10^{-28}$	m ²	4.1×10^{-9}
electron magnetic moment	μ_e	−928.476 377 (23) $\times 10^{-26}$	J T ^{−1}	2.5×10^{-8}
to Bohr magneton ratio	μ_e / μ_B	−1.001 159 652 181 11(74)		7.4×10^{-13}
to nuclear magneton ratio	μ_e / μ_N	−1838.281 970 92(80)		4.3×10^{-10}
electron magnetic moment anomaly $ \mu_e /\mu_B - 1$	a_e	1.159 652 181 11(74) $\times 10^{-3}$		6.4×10^{-10}
electron g -factor $-2(1 + a_e)$	g_e	−2.002 319 304 3622(15)		7.4×10^{-13}
electron-muon magnetic moment ratio	μ_e / μ_μ	206.766 9877 (52)		2.5×10^{-8}
electron-proton magnetic moment ratio	μ_e / μ_p	−658.210 6848 (54)		8.1×10^{-9}
electron to shielded proton magnetic moment ratio (H ₂ O, sphere, 25 °C)	μ_e / μ'_p	−658.227 5971 (72)		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	−2143.923 498 (18)		8.4×10^{-9}
electron to shielded helion magnetic moment ratio (gas, sphere, 25 °C)	μ_e / μ'_h	864.058 257 (10)		1.2×10^{-8}
electron gyromagnetic ratio $2 \mu_e /\hbar$	γ_e	1.760 859 770 (44) $\times 10^{11}$	s ^{−1} T ^{−1}	2.5×10^{-8}
	$\gamma_e / 2\pi$	28 024.953 64 (70)	MHz T ^{−1}	2.5×10^{-8}
Muon, μ^-				
muon mass	m_μ	1.883 531 30 (11) $\times 10^{-28}$	kg	5.6×10^{-8}

in u, $m_\mu = A_r(\mu)$ u (muon rel. atomic mass times u)		0.113 428 9256 (29)	u	2.5×10^{-8}
energy equivalent	$m_\mu c^2$	1.692 833 510 (95) $\times 10^{-11}$	J	5.6×10^{-8}
in MeV		105.658 3668 (38)	MeV	3.6×10^{-8}
muon-electron mass ratio	m_μ / m_e	206.768 2823 (52)		2.5×10^{-8}
muon-tau mass ratio	m_μ / m_τ	5.945 92(97) $\times 10^{-2}$		1.6×10^{-4}
muon-proton mass ratio	m_μ / m_p	0.112 609 5261 (29)		2.5×10^{-8}
muon-neutron mass ratio	m_μ / m_n	0.112 454 5167 (29)		2.5×10^{-8}
muon molar mass $N_A m_\mu$	$M(\mu)$, M_μ	0.113 428 9256 (29) $\times 10^{-3}$	kg mol ⁻¹	2.5×10^{-8}
muon Compton wavelength $\bullet / m_\mu c$	$\lambda_{C,\mu}$	11.734 441 04 (30) $\times 10^{-15}$	m	2.5×10^{-8}
$\lambda_{C,\mu} / 2\pi$	$\tilde{\lambda}_{C,\mu}$	1.867 594 295 (47) $\times 10^{-15}$	m	2.5×10^{-8}
muon magnetic moment	μ_μ	-4.490 447 86 (16) $\times 10^{-26}$	J T ⁻¹	3.6×10^{-8}
to Bohr magneton ratio	μ_μ / μ_B	-4.841 970 49 (12) $\times 10^{-3}$		2.5×10^{-8}
to nuclear magneton ratio	μ_μ / μ_N	-8.890 597 05 (23)		2.5×10^{-8}
muon magnetic moment anomaly $ \mu_\mu / (e \hbar / 2 m_\mu) - 1$	a_μ	1.165 920 69 (60) $\times 10^{-3}$		5.2×10^{-7}
muon g -factor $-2(1 + a_\mu)$	g_μ	-2.002 331 8414(12)		6.0×10^{-10}
muon-proton magnetic moment ratio	μ_μ / μ_p	-3.183 345 137 (85)		2.7×10^{-8}
Tau, τ–				
tau mass ^e	m_τ	3.167 77(52) $\times 10^{-27}$	kg	1.6×10^{-4}

in u, $m_\tau = A_\tau(\tau)$ u (tau rel. atomic mass times u)		1.907 68(31)	u	1.6×10^{-4}
energy equivalent	$m_\tau c^2$	2.847 05(46) $\times 10^{-10}$	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 $N_A m_\tau$	$M(\tau), M_\tau$	1.907 68(31) $\times 10^{-3}$	kg mol ⁻¹	1.6×10^{-4}
tau Compton wavelength $\hbar / m_\tau c$	$\lambda_{C,\tau}$	0.697 72(11) $\times 10^{-15}$	m	1.6×10^{-4}
$\lambda_{C,\tau} / 2\pi$	$\tilde{\lambda}_{C,\tau}$	0.111 046(18) $\times 10^{-15}$	m	1.6×10^{-4}
Proton, p				
proton mass	m_p	1.672 621 637 (83) $\times 10^{-27}$	kg	5.0×10^{-8}
in u, $m_p = A_p(p)$ u (proton rel. atomic mass times u)		1.007 276 466 77(10)	u	1.0×10^{-10}
energy equivalent	$m_p c^2$	1.503 277 359 (75) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		938.272 013 (23)	MeV	2.5×10^{-8}
proton-electron mass ratio	m_p / m_e	1836.152 672 47(80)		4.3×10^{-10}
proton-muon mass ratio	m_p / m_μ	8.880 243 39 (23)		2.5×10^{-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 24(46)		4.6×10^{-10}
proton charge to mass quotient	e / m_p	9.578 833 92 (24) $\times 10^7$	C kg ⁻¹	2.5×10^{-8}

proton molar mass $N_A m_p$	$M(p), M_p$	1.007 276 466 $77(10) \times 10^{-3}$	kg mol ⁻¹	1.0×10^{-10}
proton Compton wavelength $\bullet / m_p c$	$\lambda_{C,p}$	1.321 409 8446 $(19) \times 10^{-15}$	m	1.4×10^{-9}
$\lambda_{C,p} / 2\pi$	$\tilde{\lambda}_{C,p}$	0.210 308 908 $61(30) \times 10^{-15}$	m	1.4×10^{-9}
proton rms charge radius	R_p	$0.8768(69) \times 10^{-15}$	m	7.8×10^{-3}
proton magnetic moment	μ_p	1.410 606 662 $(37) \times 10^{-26}$	J T ⁻¹	2.6×10^{-8}
to Bohr magneton ratio	μ_p / μ_B	1.521 032 209 $(12) \times 10^{-3}$		8.1×10^{-9}
to nuclear magneton ratio	μ_p / μ_N	2.792 847 356 (23)		8.2×10^{-9}
proton g -factor $2\mu_p / \mu_N$	g_p	5.585 694 713 (46)		8.2×10^{-9}
proton-neutron magnetic moment ratio	μ_p / μ_n	-1.459 898 06 (34)		2.4×10^{-7}
shielded proton magnetic moment (H ₂ O, sphere, 25 °C)	μ'_p	1.410 570 419 $(38) \times 10^{-26}$	J T ⁻¹	2.7×10^{-8}
to Bohr magneton ratio	μ'_p / μ_B	1.520 993 128 $(17) \times 10^{-3}$		1.1×10^{-8}
to nuclear magneton ratio	μ'_p / μ_N	2.792 775 598 (30)		1.1×10^{-8}
proton magnetic shielding correction $1 - \mu'_p / \mu_p$				
(H ₂ O, sphere, 25 °C)	σ'_p	$25.694(14) \times 10^{-6}$		5.3×10^{-4}
proton gyromagnetic ratio $2\mu_p / \hbar$	γ_p	2.675 222 099 $(70) \times 10^8$	s ⁻¹ T ⁻¹	2.6×10^{-8}
	$\gamma_p / 2\pi$	42.577 4821 (11)	MHz T ⁻¹	2.6×10^{-8}
shielded proton gyromagnetic ratio $2\mu'_p / \hbar$				

(H ₂ O, sphere, 25 °C)	γ'_p	2.675 153 362 (73)×10 ⁸	s ⁻¹ T ⁻¹	2.7×10 ⁻⁸
	$\gamma'_p/2\pi$	42.576 3881 (12)	MHz T ⁻¹	2.7×10 ⁻⁸
Neutron, n				
neutron mass	m_n	1.674 927 211 (84)×10 ⁻²⁷	kg	5.0×10 ⁻⁸
in u, $m_n = A_r(n)$ u (neutron rel. atomic mass times u)		1.008 664 915 97(43)	u	4.3×10 ⁻¹⁰
energy equivalent	$m_n c^2$	1.505 349 505 (75)×10 ⁻¹⁰	J	5.0×10 ⁻⁸
in MeV		939.565 346 (23)	MeV	2.5×10 ⁻⁸
neutron-electron mass ratio	m_n / m_e	1838.683 6605 (11)		6.0×10 ⁻¹⁰
neutron-muon mass ratio	m_n / m_μ	8.892 484 09 (23)		2.5×10 ⁻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	1.001 378 419 18(46)		4.6×10 ⁻¹⁰
neutron molar mass $N_A m_n$	$M(n), M_n$	1.008 664 915 97(43)×10 ⁻³	kg mol ⁻¹	4.3×10 ⁻¹⁰
neutron Compton wavelength $\bullet / m_n c$	$\lambda_{C,n}$	1.319 590 8951 (20)×10 ⁻¹⁵	m	1.5×10 ⁻⁹
$\lambda_{C,n}/2\pi$	$\lambda_{C,n}$	0.210 019 413 82(31)×10 ⁻¹⁵	m	1.5×10 ⁻⁹
neutron magnetic moment	μ_n	-0.966 236 41 (23)×10 ⁻²⁶	J T ⁻¹	2.4×10 ⁻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 <i>g</i> -factor $2\mu_n / \mu_N$	g_n	-3.826 085 45 (90)		2.4×10 ⁻⁷

neutron-electron magnetic moment ratio	μ_n/μ_e	1.040 668 82 (25) $\times 10^{-3}$		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 ₂ O, sphere, 25 °C)	μ_n/μ'_p	-0.684 996 94 (16)		2.4×10^{-7}
neutron gyromagnetic ratio $2 \mu_n /\hbar$	γ_n	1.832 471 85 (43) $\times 10^8$	s ⁻¹ T ⁻¹	2.4×10^{-7}
	$\gamma_n/2\pi$	29.164 6954 (69)	MHz T ⁻¹	2.4×10^{-7}
Deuteron, d				
deuteron mass	m_d	3.343 583 20 (17) $\times 10^{-27}$	kg	5.0×10^{-8}
in u, $m_d = A_r(d)$ u (deuteron rel. atomic mass times u)		2.013 553 212 724(78)	u	3.9×10^{-11}
energy equivalent	$m_d c^2$	3.005 062 72 (15) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		1875.612 793 (47)	MeV	2.5×10^{-8}
deuteron-electron mass ratio	m_d/m_e	3670.482 9654 (16)		4.3×10^{-10}
deuteron-proton mass ratio	m_d/m_p	1.999 007 501 08(22)		1.1×10^{-10}
deuteron molar mass $N_A m_d$	$M(d), M_d$	2.013 553 212 724(78) $\times 10^{-3}$	kg mol ⁻¹	3.9×10^{-11}
deuteron rms charge radius	R_d	2.1402(28) $\times 10^{-15}$	m	1.3×10^{-3}
deuteron magnetic moment	μ_d	0.433 073 465 (11) $\times 10^{-26}$	J T ⁻¹	2.6×10^{-8}
to Bohr magneton ratio	μ_d/μ_B	0.466 975 4556 (39) $\times 10^{-3}$		8.4×10^{-9}
to nuclear magneton ratio	μ_d/μ_N	0.857 438 2308 (72)		8.4×10^{-9}

deuteron <i>g</i> factor μ_d/μ_N	g_d	0.857 438 2308 (72)		8.4×10^{-9}
deuteron–electron magnetic moment ratio	μ_d/μ_e	−4.664 345 537 (39) $\times 10^{-4}$		8.4×10^{-9}
deuteron–proton magnetic moment ratio	μ_d/μ_p	0.307 012 2070 (24)		7.7×10^{-9}
deuteron–neutron magnetic moment ratio	μ_d/μ_n	−0.448 206 52 (11)		2.4×10^{-7}
Triton, t				
triton mass	m_t	5.007 355 88 (25) $\times 10^{-27}$	kg	5.0×10^{-8}
in u, $m_t = A_r(t)$ u (triton rel. atomic mass times u)		3.015 500 7134 (25)	u	8.3×10^{-10}
energy equivalent	$m_t c^2$	4.500 387 03 (22) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		2808.920 906 (70)	MeV	2.5×10^{-8}
triton–electron mass ratio	m_t/m_e	5496.921 5269 (51)		9.3×10^{-10}
triton–proton mass ratio	m_t/m_p	2.993 717 0309 (25)		8.4×10^{-10}
triton molar mass $N_A m_t$	$M(t), M_t$	3.015 500 7134 (25) $\times 10^{-3}$	kg mol ^{−1}	8.3×10^{-10}
triton magnetic moment	μ_t	1.504 609 361 (42) $\times 10^{-26}$	J T ^{−1}	2.8×10^{-8}
to Bohr magneton ratio	μ_t/μ_B	1.622 393 657 (21) $\times 10^{-3}$		1.3×10^{-8}
to nuclear magneton ratio	μ_t/μ_N	2.978 962 448 (38)		1.3×10^{-8}
triton <i>g</i> factor $2\mu_t/\mu_N$	g_t	5.957 924 896 (76)		1.3×10^{-8}
triton–electron magnetic moment ratio	μ_t/μ_e	−1.620 514 423 (21) $\times 10^{-3}$		1.3×10^{-8}
triton–proton magnetic moment ratio	μ_t/μ_p	1.066 639 908 (10)		9.8×10^{-9}
triton–neutron magnetic moment ratio	μ_t/μ_n	−1.557 185 53 (37)		2.4×10^{-7}
Helion, h				

helion mass ^f	m_h	5.006 411 92 (25) $\times 10^{-27}$	kg	5.0×10^{-8}
in u, $m_h = A_r(h)$ u (helion rel. atomic mass times u)		3.014 932 2473 (26)	u	8.6×10^{-10}
energy equivalent	$m_h c^2$	4.499 538 64 (22) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		2808.391 383 (70)	MeV	2.5×10^{-8}
helion-electron mass ratio	m_h / m_e	5495.885 2765 (52)		9.5×10^{-10}
helion-proton mass ratio	m_h / m_p	2.993 152 6713 (26)		8.7×10^{-10}
helion molar mass $N_A m_h$	$M(h)$, M_h	3.014 932 2473 (26) $\times 10^{-3}$	kg mol ⁻¹	8.6×10^{-10}
shielded helion magnetic moment (gas, sphere, 25 °C)	μ'_h	-1.074 552 982 (30) $\times 10^{-26}$	J T ⁻¹	2.8×10^{-8}
to Bohr magneton ratio	μ'_h / μ_B	-1.158 671 471 (14) $\times 10^{-3}$		1.2×10^{-8}
to nuclear magneton ratio	μ'_h / μ_N	-2.127 497 718 (25)		1.2×10^{-8}
shielded helion to proton magnetic moment ratio (gas, sphere, 25 °C)	μ'_h / μ_p	-0.761 766 558 (11)		1.4×10^{-8}
shielded helion to shielded proton				
magnetic moment ratio (gas/ H ₂ O, 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	2.037 894 730 (56) $\times 10^8$	s ⁻¹ T ⁻¹	2.8×10^{-8}
	$\gamma'_h / 2\pi$	32.434 101 98 (90)	MHz T ⁻¹	2.8×10^{-8}
Alpha particle, α				
alpha particle mass	m_α	6.644 656 20 (33) $\times 10^{-27}$	kg	5.0×10^{-8}
in u, $m_\alpha = A_r(\alpha)$ u (alpha particle				

rel. atomic mass times u)		4.001 506 179 127(62)	u	1.5×10^{-11}
energy equivalent	$m_\alpha c^2$	5.971 919 17 (30) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		3727.379 109 (93)	MeV	2.5×10^{-8}
alpha particle to electron mass ratio	m_α / m_e	7294.299 5365 (31)		4.2×10^{-10}
alpha particle to proton mass ratio	m_α / m_p	3.972 599 689 51(41)		1.0×10^{-10}
alpha particle molar mass $N_A m_\alpha$	$M(\alpha), M_\alpha$	4.001 506 179 127(62) $\times 10^{-3}$	kg mol ⁻¹	1.5×10^{-11}
PHYSICOCHEMICAL				
Avogadro constant	N_A, L	6.022 141 79 (30) $\times 10^{23}$	mol ⁻¹	5.0×10^{-8}
atomic mass constant				
$m_0 = 1/12 m(^{12}\text{C}) = 1 \text{ u} = 10^{-3} \text{ kg mol}^{-1} / N_A$	m_0	1.660 538 782 (83) $\times 10^{-27}$	kg	5.0×10^{-8}
energy equivalent	$m_0 c^2$	1.492 417 830 (74) $\times 10^{-10}$	J	5.0×10^{-8}
in MeV		931.494 028 (23)	MeV	2.5×10^{-8}
Faraday constant ^g $N_A e$	F	96 485.3399 (24)	C mol ⁻¹	2.5×10^{-8}
molar Planck constant	$N_A h$	3.990 312 6821 (57) $\times 10^{-10}$	J s mol ⁻¹	1.4×10^{-9}
	$N_A hc$	0.119 626 564 72(17)	J m mol ⁻¹	1.4×10^{-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 6504(24) $\times 10^{-23}$	J K ⁻¹	1.7×10^{-6}
in eV K ⁻¹		8.617 343(15) $\times 10^{-5}$	eV K ⁻¹	1.7×10^{-6}
	k / h	2.083 6644(36) $\times 10^{10}$	Hz K ⁻¹	1.7×10^{-6}

	k/hc	69.503 56(12)	$\text{m}^{-1} \text{K}$ -1	1.7×10^{-6}
molar volume of ideal gas RT/p $T=273.15 \text{ K}$, $p=101.325 \text{ kPa}$	V_m	22.413 996(39) $\times 10^{-3}$	m^3 mol^{-1}	1.7×10^{-6}
Loschmidt constant N_A/V_m $T=273.15 \text{ K}$, $p=100 \text{ kPa}$	n_0	2.686 7774(47) $\times 10^{25}$	m^{-3}	1.7×10^{-6}
Sackur-Tetrode constant (absolute entropy constant) ^h $52 + \ln[(2\pi m_0 k T_1 / \bullet^2)^{3/2} k T_1 / p_0]$ $T_1=1 \text{ K}$, $p_0=100 \text{ kPa}$	S_0/R	-1.151 7047 (44)		3.8×10^{-6}
$T_1=1 \text{ K}$, $p_0=101.325 \text{ kPa}$		-1.164 8677 (44)		3.8×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3c^2$	σ	5.670 400(40) $\times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	7.0×10^{-6}
first radiation constant $2\pi\hbar c^2$	c_1	3.741 771 18 (19) $\times 10^{-16}$	W m^2	5.0×10^{-8}
first radiation constant for spectral radiance $2\hbar c^2$	c_{1L}	1.191 042 759 (59) $\times 10^{-16}$	W m^2 sr^{-1}	5.0×10^{-8}
second radiation constant $\hbar c/k$	c_2	1.438 7752(25) $\times 10^{-2}$	m K	1.7×10^{-6}
Wien displacement law constants $b=\lambda_{\max} T=c_2/4.965 114 231 \dots$	b	2.897 7685(51) $\times 10^{-3}$	m K	1.7×10^{-6}
$b'=\nu_{\max}/T=2.821 439 372 \dots$ c/c_2	b'	5.878 933(10) $\times 10^{10}$	Hz K -1	1.7×10^{-6}

^a See the "Adopted values" table for the conventional value adopted internationally for realizing representations of the volt using the Josephson effect.

^b See the "Adopted values" table for the conventional value adopted internationally for realizing representations of the ohm using the quantum Hall effect.

^c Value recommended by the Particle Data Group (Yao et al., *J. Phys.* **63**, 1, 2006).

^d Based on the ratio of the masses of the W and Z bosons m_W/m_Z recommended by the Particle Data Group (Yao et al., *J. Phys.* **63**, 1, 2006). The value for $\sin^2\theta_W$ they recommend, which is based on a particular variant of the modified minimal subtraction ($\overline{MS}$) scheme, is $\sin^2\theta_W(M_Z)=0.231\,22(15)$.

^e This and all other values involving m_e are based on the value of $m_e c^2$ in MeV recommended by the Particle Data Group (Yao et al., *J. Phys.* **63**, 1, 2006), but with a standard uncertainty of 0.29 MeV rather than the quoted uncertainty of -0.26 MeV, $+0.29$ MeV.

^f The helion, symbol h, is the nucleus of the ^3He atom.

^g The numerical value of F to be used in coulometric chemical measurements is $96\,485.3401(48)$ [5.0×10^{-8}] 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.

^h The entropy of an ideal monoatomic gas of relative atomic mass A_r is given by $S=S_0+32\,R\ln A_r-52\,R\ln(p/p_0)+52\,R\ln(T/K)$.

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Internationally Adopted Values of Various Quantities

Quantity	Symbol	Value	Unit	Relative standard uncertainty u_r
relative atomic mass ^a of ^{12}C	$A_r(^{12}\text{C})$	12		(exact)
molar mass constant	M_u	1×10^{-3}	kg mol ⁻¹	(exact)
molar mass of ^{12}C	$M(^{12}\text{C})$	12×10^{-3}	kg mol ⁻¹	(exact)

conventional value of Josephson constant ^b	K_{90}	483 597.9	GHz V ⁻¹	(exact)
conventional value of von Klitzing constant ^c	R_{K-90}	25 812.807	Ω	(exact)
standard atmosphere		101 325	Pa	(exact)

^a The relative atomic mass $A_r(X)$ of particle X with mass $m(X)$ is defined by $A_r(X) = m(X)/m_u$, where $m_u = m(^{12}\text{C})/12 = M_u/N_A = 1 \text{ u}$ is the atomic mass constant, M_u is the molar mass constant, N_A is the Avogadro constant, and u is the unified atomic mass unit.

Thus the mass of particle X is $m(X) = A_r(X)u$ and the molar mass of X is $M(X) = A_r(X)M_u$.

^b This is the value adopted internationally for realizing representations of the volt using the Josephson effect.

^c This is the value adopted internationally for realizing representations of the ohm using the quantum Hall effect.

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CODATA Recommended Values of Energy Equivalents—2006

Relevant unit

	J	kg	m ⁻¹	Hz
1 J	(1 J) = 1 J	(1 J)/ $c^2 = 1.112$ 650 056 ... $\times 10$ ⁻¹⁷ kg	(1 J)/ $hc = 5.034$ 117 47(25) $\times 10^{24}$ m ⁻¹	(1 J)/ $h = 1.509$ 190 450(75) $\times$ ³³ Hz
1 kg	(1 kg) $c^2 = 8.987$ 551 787 ... $\times 10^{16}$ J	(1 kg) = 1 kg	(1 kg) $c/h = 4.524$ 439 15(23) $\times 10^{41}$ m ⁻¹	(1 kg) $c^2/h =$ 1.356 392 733 (68) $\times 10^{50}$ Hz
1 m ⁻¹	(1 m ⁻¹) $hc = 1.986$ 445 501(99) $\times 10$ ⁻²⁵ J	(1 m ⁻¹) $h/c = 2.210$ 218 70(11) $\times 10^{-42}$ kg	(1 m ⁻¹) = 1 m ⁻¹	(1 m ⁻¹) $hc =$ 299 792 458 Hz
1 Hz	(1 Hz) $h = 6.626$ 068 96(33) $\times 10^{-34}$ J	(1 Hz) $h/c^2 = 7.372$ 496 00(37) $\times 10^{-51}$ kg	(1 Hz)/ $c = 3.335$ 640 951 ... $\times 10^{-9}$ m ⁻¹	(1 Hz) = 1 Hz

1 K	$(1 \text{ K})k = 1.380\,6504(24) \times 10^{-23} \text{ J}$	$(1 \text{ K})k/c^2 = 1.536\,1807(27) \times 10^{-40} \text{ kg}$	$(1 \text{ K})k/hc = 69.503\,56(12) \text{ m}^{-1}$	$(1 \text{ K})k/\bullet = 2.083\,6644(36) \times 10^{10} \text{ Hz}$
1 eV	$(1 \text{ eV}) = 1.602\,176\,487(40) \times 10^{-19} \text{ J}$	$(1 \text{ eV})/c^2 = 1.782\,661\,758(44) \times 10^{-36} \text{ kg}$	$(1 \text{ eV})/hc = 8.065\,544\,65(20) \times 10^5 \text{ m}^{-1}$	$(1 \text{ eV})/\bullet = 2.417\,989\,454(60) \times 10^{14} \text{ Hz}$
1 u	$(1 \text{ u})c^2 = 1.492\,417\,830(74) \times 10^{-10} \text{ J}$	$(1 \text{ u}) = 1.660\,538\,782(83) \times 10^{-27} \text{ kg}$	$(1 \text{ u})c/\bullet = 7.513\,006\,671(11) \times 10^{14} \text{ m}^{-1}$	$(1 \text{ u})c^2/\bullet = 2.252\,342\,7369(32) \times 10^{23} \text{ Hz}$
1 E_h	$(1 E_h) = 4.359\,743\,94(22) \times 10^{-18} \text{ J}$	$(1 E_h)/c^2 = 4.850\,869\,34(24) \times 10^{-35} \text{ kg}$	$(1 E_h)/hc = 2.194\,746\,313\,705(15) \times 10^7 \text{ m}^{-1}$	$(1 E_h)/\bullet = 6.579\,683\,920\,722(44) \times 10^{15} \text{ Hz}$

The values of some energy equivalents derived from the relations $E = mc^2 = hc/\lambda = h\nu = kT$, and based on the 2006 CODATA adjustment of the values of the constants; $1 \text{ eV} = (e/C) \text{ J}$, $1 \text{ u} = m_0 = 112 m(^{12}\text{C}) = 10^{-3} \text{ kg mol}^{-1}/N_A$, and $E_h = 2R_\infty hc = \alpha^2 m_e c^2$ is the Hartree energy (hartree).

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CODATA Recommended Values of Energy Equivalents—2006

Relevant unit

	K	eV	u	E_h
1 J	$(1 \text{ J})/k = 7.242\,963(13) \times 10^{22} \text{ K}$	$(1 \text{ J}) = 6.241\,509\,65(16) \times 10^{18} \text{ eV}$	$(1 \text{ J})/c^2 = 6.700\,536\,41(33) \times 10^9 \text{ u}$	$(1 \text{ J}) = 2.293\,712\,69(11) \times 10^{17} E_h$
1 kg	$(1 \text{ kg})c^2/k = 6.509\,651(11) \times 10^{39} \text{ K}$	$(1 \text{ kg})c^2 = 5.609\,589\,12(14) \times 10^{35} \text{ eV}$	$(1 \text{ kg}) = 6.022\,141\,79(30) \times 10^{26} \text{ u}$	$(1 \text{ kg})c^2 = 2.061\,486\,16(10) \times 10^{34} E_h$

1 m -1	$(1 \text{ m}^{-1})hc/k = 1.438\,7752(25) \times 10^{-2} \text{ K}$	$(1 \text{ m}^{-1})hc = 1.239\,841\,875(31) \times 10^{-6} \text{ eV}$	$(1 \text{ m}^{-1})\bullet/c = 1.331\,025\,0394(19) \times 10^{-15} \text{ u}$	$(1 \text{ m}^{-1})hc = 4.556\,335\,252\,760(30) \times 10^{-8} E_h$
1 Hz	$(1 \text{ Hz})\bullet/k = 4.799\,2374(84) \times 10^{-11} \text{ K}$	$(1 \text{ Hz})\bullet = 4.135\,667\,33(10) \times 10^{-15} \text{ eV}$	$(1 \text{ Hz})\bullet/c^2 = 4.439\,821\,6294(64) \times 10^{-24} \text{ u}$	$(1 \text{ Hz})\bullet = 1.519\,829\,846\,006(10) \times 10^{-16} E_h$
1 K	$(1 \text{ K}) = 1 \text{ K}$	$(1 \text{ K})k = 8.617\,343(15) \times 10^{-5} \text{ eV}$	$(1 \text{ K})k/c^2 = 9.251\,098(16) \times 10^{-14} \text{ u}$	$(1 \text{ K})k = 3.166\,8153(55) \times 10^{-6} E_h$
1 eV	$(1 \text{ eV})/k = 1.160\,4505(20) \times 10^4 \text{ K}$	$(1 \text{ eV}) = 1 \text{ eV}$	$(1 \text{ eV})/c^2 = 1.073\,544\,188(27) \times 10^{-9} \text{ u}$	$(1 \text{ eV}) = 3.674\,932\,540(92) \times 10^{-2} E_h$
1 u	$(1 \text{ u})c^2/k = 1.080\,9527(19) \times 10^{13} \text{ K}$	$(1 \text{ u})c^2 = 931.494\,028(23) \times 10^6 \text{ eV}$	$(1 \text{ u}) = 1 \text{ u}$	$(1 \text{ u})c^2 = 3.423\,177\,7149(49) \times 10^7 E_h$
1 E_h	$(1 E_h)/k = 3.157\,7465(55) \times 10^5 \text{ K}$	$(1 E_h) = 27.211\,383\,86(68) \text{ eV}$	$(1 E_h)/c^2 = 2.921\,262\,2986(42) \times 10^{-8} \text{ u}$	$(1 E_h) = 1 E_h$

The values of some energy equivalents derived from the relations $E = m\epsilon^2 = hc/\lambda = h\nu = kT$, and based on the 2006 CODATA adjustment of the values of the constants; $1 \text{ eV} = (e/C) \text{ J}$, $1 \text{ u} = m_u = 112 m(^{12}\text{C}) = 10^{-3} \text{ kg mol}^{-1}/N_A$, and $E_h = 2R_\infty hc = \alpha^2 m_e c^2$ is the Hartree energy (hartree).

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