1. The Fundamental Constants

Werner Martienssen†

In the quantitative description of physical phenomena and physical relationships, we find constant parameters which appear to be independent of the scale of the phenomena, independent of the place where the phenomena happen, and independent of the time when the phenomena are observed. These parameters are called fundamental constants. In Sect. 1.1, we give a qualitative description of these basic parameters and explain how recommended values for the numerical values of the fundamental constants are found. In Sect. 1.2, we present tables of the most recently determined recommended numerical values for a large number of those fundamental constants which play a role in solid-state physics and chemistry and in materials science.

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1.1 What are the Fundamental Constants and Who Takes Care of Them?

The fundamental constants are constant parameters in the laws of nature. They determine the size and strength of the phenomena in the natural and technological worlds. We conclude from observation that the numerical values of the fundamental constants are independent of space and time; at least, we can say that if there is any dependence of the fundamental constants on space and time, then this dependence must be an extremely weak one. Also, we observe that the numerical values are independent of the scale of the phenomena observed; for example, they seem to be the same in astrophysics and in atomic physics. In addition, the numerical values are quite independent of the environmental conditions. So we have confidence in the idea that the numerical values of the fundamental constants form a set of numbers which are the same everywhere in the world, and which have been the same in the past and will be the same in the future. Whereas the properties of all material objects in nature are more or less subject to continuous change, the fundamental constants seem to represent a constituent of the world which is absolutely permanent.

On the basis of this expected invariance of the fundamental constants in space and time, it appears reasonable to relate the units of measurement for physical quantities to fundamental constants as far as possible. This would guarantee that also the units of measurement become independent of space and time and of environmental conditions. Within the frame work of the International System of Units (Système International d'Unités, abbreviated to SI), the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM) has succeeded in relating a large number of units of measurement for physical quantities to the numerical values of selected fundamental constants; however, several units for physical quantities are still represented by prototypes. For example, the unit of length 1 m, is defined as the distance light travels in vacuum during a fixed time; so the unit of length is related to the fundamental constant c, i. e., the speed of light, and the unit of time, 1 s. The unit of mass, 1 kg, however, is still represented by a prototype, the mass of a metal cylinder made of a platinum-iridium alloy, which is carefully stored at the International Office

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for Weights and Measures (Bureau International des Poids et Mesures, BIPM), at Sèvres near Paris. In a few years, however, it might become possible also to relate the unit of mass to one or more fundamental constants.

The fundamental constants play an important role in basic physics as well as in applied physics and technology; in fact, they have a key function in the development of a system of reproducible and unchanging units for physical quantities. Nevertheless, there is, at present, no theory which would allow us to calculate the numerical values of the fundamental constants. Therefore, National Institutes for Metrology (NIM), together with research institutes and university laboratories, are making efforts worldwide to determine the fundamental constants experimentally with the greatest possible accuracy and reliability. This, of course, is a continuous process, with hundreds of new publications every year.

The Committee on Data for Science and Technology (CODATA), established in 1966 as an interdisciplinary, international committee of the International Council of the Scientific Unions (ICSU), has taken the responsibility for improving the quality, reliability, processing, management, and accessibility of data of importance to science and technology. The CODATA task group on fundamental constants, established in 1969, has taken on the job of periodically providing the scientific and technological community with a self-consistent set of internationally recommended values of the fundamental constants based on all relevant data available at given points in time.

What is the meaning of *recommended values* of the fundamental constants?

Many fundamental constants are not independent of one another; they are related to one another by equations which allow one to calculate a numerical value for one particular constant from the numerical values of other constants. In consequence, the numerical value of a constant can be determined either by measuring it directly or by calculating it from the measured values of other constants related to it. In addition, there are usually several different experimental methods for measuring the value of any particular fundamental constant. This allows one to compute an adjustment on the basis of a least-squares fit to the whole set of experimental data in order to determine a set of best-fitting fundamental constants from the large set of all experimental data. Such an adjustment is done today about every four years by the CODATA task group mentioned above. The resulting set of best-fit values is then called the *CODATA recommended values of the fundamental constants* based on the adjustment of the appropriate year.

The Tables in Sect. 1.2 show the CODATA recommended values of the fundamental constants of science and technology based on the 2014 adjustment. This adjustment takes into account all data that became available before 31 December 2014. A detailed description of the adjustment has been published by *Mohr* et al. of the National Institute of Standards and Technology, Gaithersburg, in [1.1, 2].

1.2 The CODATA Recommended Values of the Fundamental Constants

1.2.1 The Most Frequently Used Fundamental Constants

Tables 1.1–1.9 list the CODATA recommended values of the fundamental constants based on the 2014 adjustment.

Table 1.1 Brief list of the most frequently used fundamental constants

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Speed of light in vacuum	c	299 792 458	m/s	Exact
Magnetic constant	$\mu_0 = 4\pi \times 10^{-7}$	$12.566370614\ldots \times 10^{-7}$	$\mathrm{N/A^2}$	Exact
Electric constant	$\varepsilon_0 = 1/(\mu_0 c^2)$	$8.854187817\ldots \times 10^{-12}$	F/m	Exact
Newtonian constant of gravitation	G	$6.67408(31) \times 10^{-11}$	$\mathrm{m^3/(kg\,s^2)}$	4.7×10^{-5}
Planck constant	h	$6.626070040(81) \times 10^{-15}$	J s	1.2×10^{-8}
Reduced Planck constant	$\hbar = h/(2\pi)$	$1.054571800(13) \times 10^{-16}$	J s	1.2×10^{-8}
Elementary charge	e	$1.6021766208(98) \times 10^{-19}$	C	6.1×10^{-9}
Fine-structure constant	$\alpha = (1/(4\pi\varepsilon_0))(e^2/(\hbar c))$	$7.2973525664(17) \times 10^{-3}$		2.3×10^{-10}
Magnetic flux quantum	$\Phi_0 = h/(2e)$	$2.067833831(13) \times 10^{-15}$	Wb	6.1×10^{-9}
Conductance quantum	$G_0 = 2e^2/h$	$7.7480917310(18) \times 10^{-5}$	S	2.3×10^{-10}
Rydberg constant	$R_\infty = \alpha^2 m_e c/(2h)$	10973731.568508(65)	1/m	6.6×10^{-12}
Electron mass	m_e	$9.10938356(11) \times 10^{-31}$	kg	1.2×10^{-8}
Proton mass	m_p	$1.672621898(21) \times 10^{-27}$	kg	1.2×10^{-8}
Proton–electron mass ratio	m_p/m_e	1836.15267389(17)		9.5×10^{-11}
Avogadro number	N_A, L	$6.022140857(74) \times 10^{23}$	1/mol	1.2×10^{-8}
Faraday constant	$F = N_A e$	96485.33289(59)	C/mol	6.2×10^{-9}
Molar gas constant	R	8.3144598(48)	J/(mol K)	5.7×10^{-7}
Boltzmann constant	$k = R/N_A$	$1.38064852(79) \times 10^{-23}$	J/K	1.8×10^{-6}
Stefan–Boltzmann constant	$\sigma = (\pi^2/60)[k^4/(\hbar^3 c^2)]$	$5.670367(13) \times 10^{-8}$	$\mathrm{W/(m^2\,K^4)}$	2.3×10^{-6}

1.2.2 Detailed Lists of the Fundamental Constants in Different Fields of Application

Table 1.2 Universal constants

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Speed of light in vacuum	c	299 792 458	m/s	Exact
Magnetic constant	$\mu_0 = 4\pi \times 10^{-7}$	$12.566370614\ldots \times 10^{-7}$	$\mathrm{N/A^2}$	Exact
Electric constant	$\varepsilon_0 = 1/(\mu_0 c^2)$	$8.854187817\ldots \times 10^{-12}$	F/m	Exact
Characteristic impedance of vacuum	$Z_0 = (\mu_0/\varepsilon_0)^{1/2} = \mu_0 c$	$376.730313461\ldots$	Ω	Exact
Newtonian constant of gravitation	G	$6.67408(31) \times 10^{-11}$	$\mathrm{m^3/(kg\,s^2)}$	4.7×10^{-5}
Reduced Planck constant	$\hbar = h/(2\pi)$	$1.054571800(13) \times 10^{-34}$	J s	1.2×10^{-8}
Planck constant	h	$6.626070040(81) \times 10^{-34}$	J s	1.2×10^{-8}
(Ratio)	$G/(\hbar c)$	$6.70861(31) \times 10^{-39}$	$(\mathrm{GeV}/c^2)^2$	4.7×10^{-5}
(Product)	$\hbar c$	197.3269788(12)	MeV fm	6.1×10^{-9}
(Product)	$c_1 = 2\pi h c^2$	$3.741771790(46) \times 10^{-16}$	$\mathrm{W\,m^2}$	1.2×10^{-8}
(Product)	$(1/\pi)c_1 = 2hc^2$	$1.191042953(15) \times 10^{-16}$	$\mathrm{W\,m^2/sr}$	1.2×10^{-8}
(Product)	$c_2 = h(c/k)$	$1.43877736(83) \times 10^{-2}$	m K	5.7×10^{-7}
Stefan–Boltzmann constant	$\sigma = (\pi^2/60)[k^4/(\hbar^3 c^2)]$	$5.670367(13) \times 10^{-8}$	$\mathrm{W/(m^2\,K^4)}$	2.3×10^{-6}
Wien displacement law constant	$b = \lambda_{max} T = c_2/4.965114231$	$2.8977729(17) \times 10^{-3}$	m K	5.7×10^{-7}
Planck mass	$m_P = (\hbar c/G)^{1/2}$	$2.176470(51) \times 10^{-8}$	kg	2.3×10^{-5}
Planck temperature	$T_P = (1/k)(\hbar c^5/G)^{1/2}$	$1.416808(33) \times 10^{32}$	K	2.3×10^{-5}
Planck length	$l_P = \hbar/(m_P c) = (\hbar G/c^3)^{1/2}$	$1.616229(38) \times 10^{-35}$	m	2.3×10^{-5}
Planck time	$t_P = l_P/c = (\hbar G/c^5)^{1/2}$	$5.39116(13) \times 10^{-44}$	s	2.3×10^{-5}

Table 1.3 Electromagnetic constants

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Elementary charge	e	$1.6021766208(98) \times 10^{-19}$	C	6.1×10^{-9}
(Ratio)	e/h	$2.417989262(15) \times 10^{14}$	A/J	6.1×10^{-9}
Fine-structure constant	$\alpha = (1/(4\pi\varepsilon_0))(e^2/(\hbar c))$	$7.2973525664(17) \times 10^{-3}$		2.3×10^{-10}
Inverse fine-structure constant	$1/\alpha$	137.035999139(31)		2.3×10^{-10}
Magnetic flux quantum	$\Phi_0 = h/(2e)$	$2.067833831(13) \times 10^{-15}$	Wb	6.1×10^{-9}
Conductance quantum	$G_0 = 2e^2/h$	$7.7480917310(18) \times 10^{-5}$	S	2.3×10^{-10}
Inverse of conductance quantum	$1/G_0$	12906.4037278(29)	Ω	2.3×10^{-10}
Josephson constant[a]	$K_J = 2e/h$	$483597.8525(30) \times 10^9$	Hz/V	6.1×10^{-9}
Von Klitzing constant[b]	$R_K = h/e^2 = \mu_0 c/(2\alpha)$	25812.8074555(59)	Ω	2.3×10^{-10}
Bohr magneton	$\mu_B = e\hbar/(2m_e)$	$927.4009994(57) \times 10^{-26}$ $5.7883818012(26) \times 10^{-5}$	J/T eV/T	6.2×10^{-9} 4.5×10^{-10}
(Ratio)	μ_B/h	$13.996245042(86) \times 10^9$	Hz/T	6.2×10^{-9}
(Ratio)	$\mu_B/(hc)$	46.68644814(29)	1/(m T)	6.2×10^{-9}
(Ratio)	μ_B/k	0.67171405(39)	K/T	5.7×10^{-7}
Nuclear magneton	$\mu_N = e\hbar/(2m_p)$	$5.050783699(31) \times 10^{-27}$ $3.1524512550(15) \times 10^{-8}$	J/T eV/T	6.2×10^{-9} 4.6×10^{-10}
(Ratio)	μ_N/h	7.622593285(47)	MHz/T	6.2×10^{-9}
(Ratio)	$\mu_N/(hc)$	$2.542623432(16) \times 10^{-2}$	1/(m T)	6.2×10^{-9}
(Ratio)	μ_N/k	$3.6582690(21) \times 10^{-4}$	K/T	5.7×10^{-7}

[a] See Table 2.16 for the conventional value adopted internationally for realizing representations of the volt using the Josephson effect.
[b] See Table 2.16 for the conventional value adopted internationally for realizing representations of the ohm using the quantum Hall effect.

Table 1.4 Thermodynamic constants

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Avogadro constant	N_A, L	$6.022140857(74) \times 10^{23}$	1/mol	1.2×10^{-8}
Atomic mass constant	$m_u = (1/12)m(^{12}C)$ $= (1/N_A) \times 10^{-3}$ kg	$1.660539040(20) \times 10^{-27}$	kg	1.2×10^{-8}
Energy equivalent of atomic mass constant	$m_u c^2$	$1.492418062(18) \times 10^{-10}$ 931.4940954(57)	J MeV	1.2×10^{-8} 6.2×10^{-9}
Faraday constant	$F = N_A e$	96485.33289(59)	C/mol	6.2×10^{-9}
Molar Planck constant	$N_A h$	$3.9903127110(18) \times 10^{-10}$	J s/mol	4.5×10^{-10}
(Product)	$N_A hc$	0.119626565582(54)	J m/mol	4.5×10^{-10}
Molar gas constant	R	8.3144598(48)	J/(K mol)	5.7×10^{-7}
Boltzmann constant	$k = R/N_A$	$1.38064852(79) \times 10^{-23}$ $8.6173303(50) \times 10^{-5}$	J/K eV/K	5.7×10^{-7} 5.7×10^{-7}
(Ratio)	k/h	$2.0836612(12) \times 10^{10}$	Hz/K	5.7×10^{-7}
(Ratio)	k/hc	69.503457(40)	1/(m K)	5.7×10^{-7}
Molar volume of ideal gas at STP	$V_m = RT/p$ at $T = 273.15$ K and $p = 100$ kPa	$22.710947(13) \times 10^{-3}$	m_3/mol	5.7×10^{-7}
Loschmidt constant	$n_0 = N_A/V_m$	$2.6516467(15) \times 10^{25}$	$1/m^3$	5.7×10^{-7}
Stefan–Boltzmann constant	$\sigma = (\pi^2/60)[k^4/(\hbar^3 c^2)]$	$5.670367(13) \times 10^{-8}$	$W/(m^2 K^4)$	2.3×10^{-6}
Wien displacement law constant	$b = \lambda_{max} T = c_2/4.965114231$	$2.8977729(17) \times 10^{-3}$	m K	5.7×10^{-7}

1.2.3 Constants from Atomic Physics and Particle Physics

Table 1.5 Constants from atomic physics

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Rydberg constant	$R_\infty = \alpha^2 m_e c/2h$	10973731.568508(65)	1/m	5.9×10^{-12}
(Product)	$R_\infty c$	$3.289841960355(19) \times 10^{15}$	Hz	5.9×10^{-12}
(Product)	$R_\infty hc$	$2.179872325(27) \times 10^{-18}$ 13.605693009(84)	J eV	1.2×10^{-8} 6.1×10^{-9}
Bohr radius	$a_0 = \alpha/(4\pi R_\infty)$ $= 4\pi\varepsilon_0 \hbar^2/(m_e e^2)$	$0.52917721067(12) \times 10^{-10}$	m	2.3×10^{-10}
Hartree energy	$E_H = e^2/(4\pi\varepsilon_0 a_0)$ $= 2R_\infty hc = \alpha^2 m_e c^2$	$4.359744650(54) \times 10^{-18}$ 27.21138602(17)	J eV	1.2×10^{-8} 6.1×10^{-9}
Quantum of circulation	$h/(2m_e)$	$3.6369475486(17) \times 10^{-4}$	m^2/s	4.5×10^{-10}
(Product)	h/m_e	$7.2738950972(33) \times 10^{-4}$	m^2/s	4.5×10^{-10}

Table 1.6 Properties of the electron

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Electron mass	m_e	$9.10938356(11) \times 10^{-31}$ $5.48579909070(16) \times 10^{-4}$	kg u	1.2×10^{-8} 2.9×10^{-11}
Energy equivalent of electron mass	$m_e c^2$	$8.18710565(10) \times 10^{-14}$ 0.5109989461(31)	J MeV	1.2×10^{-8} 6.2×10^{-9}
Electron–proton mass ratio	m_e/m_p	$5.44617021352(52) \times 10^{-4}$		9.5×10^{-11}
Electron–neutron mass ratio	m_e/m_n	$5.4386734428(27) \times 10^{-4}$		4.9×10^{-10}
Electron–muon mass ratio	m_e/m_μ	$4.83633170(11) \times 10^{-3}$		2.2×10^{-8}
Electron molar mass	$M(e) = N_A m_e$	$5.48579909070(16) \times 10^{-7}$	kg/mol	2.9×10^{-11}
Charge-to-mass ratio	$-e/m_e$	$-1.758820024(11) \times 10^{11}$	C/kg	6.2×10^{-9}
Compton wavelength	$\lambda_C = h/(m_e c)$	$2.4263102367(11) \times 10^{-12}$	m	4.5×10^{-10}
(Ratio)	$\lambda_C/(2\pi) = \alpha a_0 = \alpha^2/(4\pi R_\infty)$	$386.15926764(18) \times 10^{-15}$	m	4.5×10^{-10}
Classical electron radius	$r_e = \alpha^2 a_0$	$2.8179403227(19) \times 10^{-15}$	m	6.8×10^{-10}
Thomson cross section	$\sigma_e = (8\pi/3) r_e^2$	$0.66524587158(91) \times 10^{-28}$	m^2	1.4×10^{-9}
Magnetic moment	μ_e	$-928.4764620(57) \times 10^{-26}$	J/T	6.2×10^{-9}
Ratio of magnetic moment to Bohr magneton	μ_e/μ_B	−1.00115965218091(26)		2.6×10^{-13}
Ratio of magnetic moment to nuclear magneton	μ_e/μ_N	−1838.28197234(17)		9.5×10^{-11}
Ratio of magnetic moment to proton magnetic moment	μ_e/μ_p	−658.2106866(20)		3.0×10^{-9}
Ratio of magnetic moment to neutron magnetic moment	μ_e/μ_n	960.92050(23)		2.4×10^{-7}
Electron magnetic moment anomaly	$a_e = \lvert\mu_e\rvert/(\mu_B - 1)$	$1.15965218091(26) \times 10^{-3}$		2.3×10^{-10}
g-factor	$g_e = -2(1 + a_e)$	−2.00231930436182(52)		2.6×10^{-13}
Gyromagnetic ratio	$\gamma_e = 2\lvert\mu_e\rvert/\hbar$	$1.760859644(11) \times 10^{11}$	1/(s T)	6.2×10^{-9}
(Ratio)	$\gamma_e/(2\pi)$	28024.95164(17)	MHz/T	6.2×10^{-9}

Table 1.7 Properties of the proton

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Proton mass	m_p	$1.672621898(21) \times 10^{-27}$ 1.007276466879(91)	kg u	1.2×10^{-8} 9.0×10^{-11}
Energy equivalent of proton mass	$m_p c^2$	$1.503277593(18) \times 10^{-10}$ 938.2720813(58)	J MeV	1.2×10^{-8} 6.2×10^{-9}
Proton–electron mass ratio	m_p/m_e	1836.15267389(17)		9.5×10^{-11}
Proton–neutron mass ratio	m_p/m_n	0.99862347844(51)		5.1×10^{-10}
Proton molar mass	$M(p) = N_A m_p$	$1.007276466879(91) \times 10^{-3}$	kg/mol	9.0×10^{-11}
Charge-to-mass ratio	e/m_p	$9.578833226(59) \times 10^{7}$	C/kg	6.2×10^{-9}
Compton wavelength	$\lambda_{C,p} = h/(m_p c)$	$1.32140985396(61) \times 10^{-15}$	m	4.6×10^{-10}
(Ratio)	$(1/(2\pi))\lambda_{C,p}$	$0.210308910109(97) \times 10^{-15}$	m	4.6×10^{-10}
rms charge radius	R_p	$0.8751(61) \times 10^{-15}$	m	7.0×10^{-3}
Magnetic moment	μ_p	$1.4106067873(97) \times 10^{-26}$	J/T	6.9×10^{-9}
Ratio of magnetic moment to Bohr magneton	μ_p/μ_B	$1.5210322053(46) \times 10^{-3}$		3.0×10^{-9}
Ratio of magnetic moment to nuclear magneton	μ_p/μ_N	2.7928473508(85)		3.0×10^{-9}
Ratio of magnetic moment to neutron magnetic moment	μ_p/μ_n	−1.45989805(34)		2.4×10^{-7}
g-factor	$g_p = 2\mu_p/\mu_N$	5.585694702(17)		3.0×10^{-9}
Gyromagnetic ratio	$\gamma_p = 2\mu_p/\hbar$	$2.67522205(23) \times 10^{8}$	1/(s T)	6.9×10^{-9}
(Ratio)	$(1/(2\pi))\gamma_p$	42.57747892(29)	MHz/T	6.9×10^{-9}

Table 1.8 Properties of the neutron

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Neutron mass	m_n	$1.674927471(21) \times 10^{-27}$ 1.00866491588(49)	kg u	1.2×10^{-8} 4.9×10^{-10}
Energy equivalent	$m_n c^2$	939.5654133(58)	MeV	6.2×10^{-9}
Neutron–electron mass ratio	m_n/m_e	1838.68366158(90)		4.9×10^{-10}
Neutron–proton mass ratio	m_n/m_p	1.00137841898(51)		5.1×10^{-10}
Molar mass	$M(n) = N_A m_n$	$1.00866491588(49) \times 10^{-3}$	kg/mol	5.5×10^{-10}
Compton wavelength	$\lambda_{C,n} = h/(m_n c)$	$1.31959090481(88) \times 10^{-15}$	m	6.7×10^{-10}
(Ratio)	$(1/(2\pi))\lambda_{C,n}$	$0.21001941536(14) \times 10^{-15}$	m	6.7×10^{-10}
Magnetic moment	μ_n	$-0.96623650(23) \times 10^{-26}$	J/T	2.4×10^{-7}
Ratio of magnetic moment to Bohr magneton	μ_n/μ_B	$-1.04187563(25) \times 10^{-3}$		2.4×10^{-7}
Ratio of magnetic moment to nuclear magneton	μ_n/μ_N	−1.91304273(45)		2.4×10^{-7}
Ratio of magnetic moment to electron magnetic moment	μ_n/μ_e	$1.04066882(25) \times 10^{-3}$		2.4×10^{-7}
Ratio of magnetic moment to proton magnetic moment	μ_n/μ_p	−0.68497934(16)		2.4×10^{-7}
g-factor	$g_n = 2\mu_n/\mu_N$	−3.82608545(90)		2.4×10^{-7}
Gyromagnetic ratio	$\gamma_n = 2\lvert\mu_n\rvert/\hbar$	$1.83247172(43) \times 10^{8}$	1/(s T)	2.4×10^{-7}
(Ratio)	$(1/(2\pi))\gamma_n$	29.1646933(69)	MHz/T	2.4×10^{-7}

Table 1.9 Properties of the alpha particle

Quantity	Symbol and relation	Numerical value	Units	Relative standard uncertainty
Alpha particle mass[a]	m_α	$6.644657230(82) \times 10^{-27}$ $4.001506179127(63)$	kg u	1.2×10^{-8} 1.6×10^{-11}
Energy equivalent of alpha particle mass	$m_\alpha c^2$	$5.971920097(73) \times 10^{-10}$ $3727.379378(23)$	J MeV	1.2×10^{-8} 6.2×10^{-9}
Ratio of alpha particle mass to electron mass	m_α / m_e	$7294.29954136(24)$		3.3×10^{-11}
Ratio of alpha particle mass to proton mass	m_α / m_p	$3.97259968907(36)$		9.2×10^{-11}
Alpha particle molar mass	$M(\alpha) = N_A m_\alpha$	$4.001506179127(63) \times 10^{-3}$	kg/mol	1.6×10^{-11}

[a] The mass of the alpha particle in units of the atomic mass unit u is given by $m_\alpha = A_r(\alpha)\,u$; in words, the alpha particle mass is given by the relative atomic mass $A_r(\alpha)$ of the alpha particle, multiplied by the atomic mass unit u

References

1.1 P.J. Mohr, D.B. Newell, B.N. Taylor: CODATA recommended values of the fundamental physical constants, Rev. Mod. Phys. **88**, 35009 (2016)

1.2 NIST Physics Laboratory: Web pages of the Fundamental Constants Data Center National Institute of Standards and Technology, Gaithersburg, MD 20899–8420, USA, http://physics.nist.gov/constants