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1998 CODATA recommended values of the  
fundamental constants of physics and  
chemistry /  $\hbar c$  values from P.J. Mohr  
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# 1998 CODATA RECOMMENDED VALUES OF THE FUNDAMENTAL CONSTANTS OF PHYSICS AND CHEMISTRY

NIST SP 961 (Jan/2001) Values from: P. J. Mohr and B. N. Taylor, J. Phys. Chem. Ref. Data 28, 1713 (1999) and Rev. Mod. Phys. 72, 351 (2000).

A more extensive listing of constants is available in the above references and on the NIST Physics Laboratory Web site [physics.nist.gov/constants](http://physics.nist.gov/constants).

The number in parenthesis is the one-standard-deviation uncertainty in the last two digits of the given value.

| Quantity                                                                       | Symbol                         | Numerical value                                                         | Unit                                      | Quantity                                                   | Symbol                    | Numerical value                        | Unit                    |
|--------------------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------|-------------------------------------------|------------------------------------------------------------|---------------------------|----------------------------------------|-------------------------|
| speed of light in vacuum                                                       | $c$ , $c_0$                    | 299 792 458 (exact)                                                     | $\text{m s}^{-1}$                         | muon $g$ -factor $-2(1 + a_\mu)$                           | $g_\mu$                   | $-2.002\,331\,8320(13)$                |                         |
| magnetic constant                                                              | $\mu_0$                        | $4\pi \times 10^{-7}$ (exact)<br>$= 12.566\,370\,614... \times 10^{-7}$ | $\text{N A}^{-2}$<br>$\text{N A}^{-2}$    | muon-proton magnetic moment ratio                          | $\mu_\mu/\mu_p$           | $-3.183\,345\,39(10)$                  |                         |
| electric constant $1/\mu_0 c^2$                                                | $\epsilon_0$                   | $8.854\,187\,817... \times 10^{-12}$                                    | $\text{F m}^{-1}$                         | proton mass                                                | $m_p$                     | $1.672\,621\,58(13) \times 10^{-27}$   | kg                      |
| Newtonian constant of gravitation                                              | $G$                            | $6.673(10) \times 10^{-11}$                                             | $\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$ | energy equivalent in MeV                                   | $m_p c^2$                 | $938.271\,998(38)$                     | MeV                     |
| Planck constant                                                                | $h$                            | $6.626\,068\,76(52) \times 10^{-34}$                                    | J s                                       | proton-electron mass ratio                                 | $m_p/m_e$                 | $1\,836.152\,6675(39)$                 |                         |
| in eV s                                                                        | $h$                            | $4.135\,667\,27(16) \times 10^{-15}$                                    | eV s                                      | proton magnetic moment                                     | $\mu_p$                   | $1.410\,606\,633(58) \times 10^{-26}$  | J T $^{-1}$             |
| in eV s                                                                        | $h/2\pi$                       | $1.054\,571\,596(82) \times 10^{-34}$                                   | J s                                       | to nuclear magneton ratio                                  | $\mu_p/\mu_N$             | $2.792\,847\,337(29)$                  |                         |
| elementary charge                                                              | $e$                            | $1.602\,176\,462(63) \times 10^{-19}$                                   | C                                         | proton magnetic shielding correction $1 - \mu_p'/\mu_p$    | $\sigma_p$                | $25.687(15) \times 10^{-6}$            |                         |
| magnetic flux quantum $h/2e$                                                   | $\Phi_0$                       | $2.067\,833\,636(81) \times 10^{-15}$                                   | Wb                                        | proton gyromagnetic ratio $2\mu_p/h$                       | $\gamma_p$                | $2.675\,222\,12(11) \times 10^8$       | s $^{-1}$ T $^{-1}$     |
| Josephson constant $2e/h$                                                      | $K_J$                          | $483\,597.898(19) \times 10^9$                                          | Hz V $^{-1}$                              | (H $_2$ O, sphere, 25 °C)                                  | $\gamma_p/2\pi$           | $42.577\,4825(18)$                     | MHz T $^{-1}$           |
| von Klitzing constant $h/e^2 = \mu_0 c/2a$                                     | $R_K$                          | $25\,812.807\,572(95)$                                                  | $\Omega$                                  | shielded proton gyromagnetic ratio $2\mu_p'/h$             | $\gamma_p'$               | $2.675\,153\,41(11) \times 10^8$       | s $^{-1}$ T $^{-1}$     |
| Bohr magneton $eh/2m_e$                                                        | $\mu_B$                        | $927.400\,899(37) \times 10^{-26}$                                      | J T $^{-1}$                               | neutron mass in u                                          | $\gamma_p'/2\pi$          | $42.576\,3888(18)$                     | MHz T $^{-1}$           |
| in eV T $^{-1}$                                                                | $\mu_B$                        | $5.788\,381\,749(43) \times 10^{-5}$                                    | eV T $^{-1}$                              | energy equivalent in MeV                                   | $m_n$                     | $1.008\,664\,915\,78(55)$              | u                       |
| nuclear magneton $eh/2m_p$                                                     | $\mu_N$                        | $5.050\,783\,17(20) \times 10^{-27}$                                    | J T $^{-1}$                               | neutron-proton mass ratio                                  | $m_n c^2$                 | $939.565\,330(38)$                     | MeV                     |
| in eV T $^{-1}$                                                                | $\mu_N$                        | $3.152\,451\,238(24) \times 10^{-8}$                                    | eV T $^{-1}$                              | neutron magnetic moment                                    | $m_n/m_p$                 | $1.001\,378\,418\,87(58)$              | J T $^{-1}$             |
| fine-structure constant $e^2/4\pi\epsilon_0\hbar c$                            | $\alpha$                       | $7.297\,352\,533(27) \times 10^{-3}$                                    |                                           | to nuclear magneton ratio                                  | $\mu_n$                   | $-0.966\,236\,40(23) \times 10^{-26}$  | J T $^{-1}$             |
| inverse fine-structure constant                                                | $\alpha^{-1}$                  | $137.035\,999\,76(50)$                                                  |                                           | energy equivalent in MeV                                   | $\mu_n/\mu_N$             | $-1.913\,042\,72(45)$                  |                         |
| Rydberg constant $\alpha^2 m_e c/2h$                                           | $R_\infty$                     | $10\,973\,731.568\,549(83)$                                             | m $^{-1}$                                 | deuteron-proton mass ratio                                 | $m_d$                     | $2.013\,553\,212\,71(35)$              | u                       |
| energy equivalent in eV                                                        | $R_\infty c$                   | $3.289\,841\,960\,368(25) \times 10^{15}$                               | Hz                                        | energy equivalent in MeV                                   | $m_d c^2$                 | $1\,875.612\,762(75)$                  | MeV                     |
| Bohr radius $a/4\pi R_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2$                  | $a_0$                          | $0.529\,177\,2083(19) \times 10^{-10}$                                  | m                                         | deuteron magnetic moment                                   | $m_d/m_p$                 | $1.999\,007\,500\,83(44)$              |                         |
| Hartree energy $e^2/4\pi\epsilon_0 a_0 = 2R_\infty \hbar c = \alpha^2 m_e c^2$ | $E_h$                          | $4.359\,743\,81(34) \times 10^{-18}$                                    | J                                         | to nuclear magneton ratio                                  | $\mu_d$                   | $0.433\,073\,457(18) \times 10^{-26}$  | J T $^{-1}$             |
| in eV                                                                          | $E_h$                          | $27.211\,3834(11)$                                                      | eV                                        | helion ( $^3\text{He}$ nucleus) mass in u                  | $\mu_d/\mu_N$             | $0.857\,438\,2284(94)$                 |                         |
| electron mass                                                                  | $m_e$                          | $9.109\,381\,88(72) \times 10^{-31}$                                    | kg                                        | energy equivalent in MeV                                   | $m_h$                     | $3.014\,932\,234\,69(86)$              | u                       |
| in u                                                                           | $m_e$                          | $5.485\,799\,110(12) \times 10^{-4}$                                    | u                                         | shielded helion magnetic moment                            | $m_h c^2$                 | $2\,808.391\,32(11)$                   | MeV                     |
| energy equivalent in MeV                                                       | $m_e c^2$                      | $0.510\,998\,902(21)$                                                   | MeV                                       | (gas, sphere, 25 °C)                                       | $\mu_h$                   | $-1.074\,552\,967(45) \times 10^{-26}$ | J T $^{-1}$             |
| electron-muon mass ratio                                                       | $m_e/m_\mu$                    | $4.836\,332\,10(15) \times 10^{-3}$                                     |                                           | to Bohr magneton ratio                                     | $\mu_h/\mu_B$             | $-1.158\,671\,474(14) \times 10^{-3}$  |                         |
| electron-proton mass ratio                                                     | $m_e/m_p$                      | $5.446\,170\,232(12) \times 10^{-4}$                                    |                                           | alpha particle mass in u                                   | $\mu_h/\mu_N$             | $-2.127\,497\,718(25)$                 | u                       |
| electron charge to mass quotient                                               | $-e/m_e$                       | $-1.758\,820\,174(71) \times 10^{11}$                                   | C kg $^{-1}$                              | energy equivalent in MeV                                   | $m_\alpha c^2$            | $4.001\,506\,1747(10)$                 | MeV                     |
| Compton wavelength $h/m_e c$                                                   | $\lambda_C$                    | $2.426\,310\,215(18) \times 10^{-12}$                                   | m                                         | Avogadro constant                                          | $N_A$ , $L$               | $6.022\,141\,99(47) \times 10^{23}$    | mol $^{-1}$             |
| $\lambda_C/2\pi = a_0 = \alpha^2/4\pi R_\infty$                                | $\lambda_C$                    | $386.159\,2642(28) \times 10^{-15}$                                     | m                                         | atomic mass constant $\frac{1}{12} m(^{12}\text{C}) = 1$ u | $m_u$                     | $1.660\,538\,73(13) \times 10^{-27}$   | kg                      |
| classical electron radius $\alpha^2 a_0$                                       | $r_e$                          | $2.817\,940\,285(31) \times 10^{-15}$                                   | m                                         | energy equivalent in MeV                                   | $m_u c^2$                 | $931.494\,013(37)$                     | MeV                     |
| Thomson cross section $(8\pi/3)r_e^2$                                          | $\sigma_e$                     | $0.665\,245\,854(15) \times 10^{-28}$                                   | m $^2$                                    | Faraday constant $N_A e$                                   | $F$                       | $96\,485.3415(39)$                     | C mol $^{-1}$           |
| electron magnetic moment                                                       | $\mu_e$                        | $-928.476\,362(37) \times 10^{-26}$                                     | J T $^{-1}$                               | molar gas constant                                         | $R$                       | $8.314\,472(15)$                       | J mol $^{-1}$ K $^{-1}$ |
| to Bohr magneton ratio                                                         | $\mu_e/\mu_B$                  | $-1.001\,159\,652\,1869(41)$                                            |                                           | Boltzmann constant $R/N_A$                                 | $k$                       | $1.380\,6503(24) \times 10^{-23}$      | J K $^{-1}$             |
| to nuclear magneton ratio                                                      | $\mu_e/\mu_N$                  | $-1\,838.281\,9660(39)$                                                 |                                           | in eV K $^{-1}$                                            | $V_m$                     | $8.617\,342(15) \times 10^{-5}$        | eV K $^{-1}$            |
| electron magnetic moment anomaly $ \mu_e /\mu_B - 1$                           | $a_e$                          | $1.159\,652\,1869(41) \times 10^{-3}$                                   |                                           | molar volume of ideal gas $RT/p$                           | $\sigma$                  | $22.413\,996(39) \times 10^{-3}$       | m $^3$ mol $^{-1}$      |
| electron $g$ -factor $-2(1 + a_e)$                                             | $g_e$                          | $-2.002\,319\,304\,3737(82)$                                            |                                           | ( $T = 273.15$ K, $p = 101.325$ kPa)                       | $c_1$                     | $5.670\,400(40) \times 10^{-8}$        | W m $^{-2}$ K $^{-4}$   |
| electron-proton magnetic moment ratio                                          | $\mu_e/\mu_p$                  | $-658.210\,6875(66)$                                                    | u                                         | Stefan-Boltzmann constant $\pi^2 k^4/60\hbar^3 c^2$        | $c_2$                     | $3.741\,771\,07(29) \times 10^{-16}$   | W m $^2$                |
| muon mass in u                                                                 | $m_\mu$                        | $0.113\,428\,9168(34)$                                                  | u                                         | first radiation constant $2\pi\hbar c^2$                   |                           | $1.438\,7752(25) \times 10^{-2}$       | m K                     |
| energy equivalent in MeV                                                       | $m_\mu c^2$                    | $105.658\,3568(52)$                                                     | MeV                                       | second radiation constant $\hbar c/k$                      |                           |                                        |                         |
| muon-electron mass ratio                                                       | $m_\mu/m_e$                    | $206.768\,2657(63)$                                                     |                                           | When displacement law constant                             | $b$                       | $2.897\,7686(51) \times 10^{-3}$       | m K                     |
| muon magnetic moment                                                           | $\mu_\mu$                      | $-4.480\,448\,13(22) \times 10^{-26}$                                   | J T $^{-1}$                               | $b = \lambda_{\text{max}} T = c_2/4.965\,114\,231...$      | $xu(\text{Cu K}\alpha_1)$ | $1.002\,077\,03(28) \times 10^{-13}$   | m                       |
| to Bohr magneton ratio                                                         | $\mu_\mu/\mu_B$                | $-4.841\,970\,85(15) \times 10^{-3}$                                    |                                           | Cu x unit: $\lambda(\text{Mo K}\alpha_1)/1\,537.400$       | $xu(\text{Mo K}\alpha_1)$ | $1.002\,099\,59(53) \times 10^{-13}$   | m                       |
| muon magnetic moment anomaly                                                   | $ \mu_\mu /(\mu_B/2m_\mu) - 1$ | $-8.890\,597\,70(27)$                                                   |                                           |                                                            |                           |                                        |                         |
|                                                                                | $a_\mu$                        | $1.165\,916\,02(64) \times 10^{-3}$                                     |                                           |                                                            |                           |                                        |                         |

## Energy equivalents

|                   |                                              |                   |                                              |
|-------------------|----------------------------------------------|-------------------|----------------------------------------------|
| (1 J)             | $= 6.241\,509\,74(24) \times 10^{18}$ eV     | (1 eV)            | $= 1.602\,176\,462(63) \times 10^{-19}$ J    |
| (1 eV)            | $= 1.602\,176\,462(63) \times 10^{-19}$ J    | (1 eV)/ $\hbar c$ | $= 8.065\,544\,77(32) \times 10^5$ m $^{-1}$ |
| (1 eV)/ $\hbar c$ | $= 8.065\,544\,77(32) \times 10^5$ m $^{-1}$ | (1 eV)/ $\hbar$   | $= 2.417\,989\,491(95) \times 10^{14}$ Hz    |
| (1 eV)/ $\hbar$   | $= 2.417\,989\,491(95) \times 10^{14}$ Hz    | (1 eV)/ $k$       | $= 1.160\,4506(20) \times 10^4$ K            |



1998 CODATA RECOMMENDED VALUES OF THE FUNDAMENTAL PHYSICAL CONSTANTS

NIST SP 961A(Jan/2001) Values from: P. J. Mohr and B. N. Taylor, J. Phys.

A more extensive listing of constants is available in the above references an The number in parenthesis is the one-standard-deviation

| Quantity                                                                       | Symbol             | Numerical value                                                           | Unit                                      |
|--------------------------------------------------------------------------------|--------------------|---------------------------------------------------------------------------|-------------------------------------------|
| speed of light in vacuum                                                       | $c, c_0$           | 299 792 458 (exact)                                                       | $\text{m s}^{-1}$                         |
| magnetic constant                                                              | $\mu_0$            | $4\pi \times 10^{-7}$ (exact)<br>$= 12.566 370 614... \times 10^{-7}$     | $\text{N A}^{-2}$<br>$\text{N A}^{-2}$    |
| electric constant $1/\mu_0 c^2$                                                | $\epsilon_0$       | $8.854 187 817... \times 10^{-12}$                                        | $\text{F m}^{-1}$                         |
| Newtonian constant of gravitation                                              | $G$                | $6.673(10) \times 10^{-11}$                                               | $\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$ |
| Planck constant                                                                | $h$                | $6.626 068 76(52) \times 10^{-34}$<br>$4.135 667 27(16) \times 10^{-15}$  | $\text{J s}$<br>$\text{eV s}$             |
| in eV s                                                                        | $\hbar$            | $1.054 571 596(82) \times 10^{-34}$<br>$6.582 118 89(26) \times 10^{-16}$ | $\text{J s}$<br>$\text{eV s}$             |
| $h/2\pi$                                                                       |                    |                                                                           |                                           |
| in eV s                                                                        |                    |                                                                           |                                           |
| elementary charge                                                              | $e$                | $1.602 176 462(63) \times 10^{-19}$                                       | $\text{C}$                                |
| magnetic flux quantum $h/2e$                                                   | $\Phi_0$           | $2.067 833 636(81) \times 10^{-15}$                                       | $\text{Wb}$                               |
| Josephson constant $2e/h$                                                      | $K_J$              | $483 597.898(19) \times 10^9$                                             | $\text{Hz V}^{-1}$                        |
| von Klitzing constant $h/e^2 = \mu_0 c/2\alpha$                                | $R_K$              | $25 812.807 572(95)$                                                      | $\Omega$                                  |
| Bohr magneton $e\hbar/2m_e$                                                    | $\mu_B$            | $927.400 899(37) \times 10^{-26}$<br>$5.788 381 749(43) \times 10^{-5}$   | $\text{J T}^{-1}$<br>$\text{eV T}^{-1}$   |
| in eV T <sup>-1</sup>                                                          |                    |                                                                           |                                           |
| nuclear magneton $e\hbar/2m_p$                                                 | $\mu_N$            | $5.050 783 17(20) \times 10^{-27}$<br>$3.152 451 238(24) \times 10^{-8}$  | $\text{J T}^{-1}$<br>$\text{eV T}^{-1}$   |
| in eV T <sup>-1</sup>                                                          |                    |                                                                           |                                           |
| fine-structure constant $e^2/4\pi\epsilon_0\hbar c$                            | $\alpha$           | $7.297 352 533(27) \times 10^{-3}$<br>$137.035 999 76(50)$                |                                           |
| inverse fine-structure constant                                                | $\alpha^{-1}$      | $109 737 31.568 549(83)$                                                  | $\text{m}^{-1}$                           |
| Rydberg constant $\alpha^2 m_e c/2\hbar$                                       | $R_\infty$         | $3.289 841 960 368(25) \times 10^{15}$                                    | $\text{Hz}$                               |
| energy equivalent in eV                                                        | $R_\infty \hbar c$ | $13.605 691 72(53)$                                                       | $\text{eV}$                               |
| Bohr radius $\alpha/4\pi R_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2$             | $a_0$              | $0.529 177 2083(19) \times 10^{-10}$                                      | $\text{m}$                                |
| Hartree energy $e^2/4\pi\epsilon_0 a_0 = 2R_\infty \hbar c = \alpha^2 m_e c^2$ | $E_h$              | $4.359 743 81(34) \times 10^{-18}$<br>$97 211 3834(11)$                   | $\text{J}$<br>$\text{eV}$                 |



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The number in parenthesis is the one-standard-deviation uncertainty in the last two digits of the given value.

| Quantity                                                                       | Symbol             | Numerical value                                                     | Unit                                      | Quantity                                                               | Symbol                    | Numerical value                                                          | Unit                                |
|--------------------------------------------------------------------------------|--------------------|---------------------------------------------------------------------|-------------------------------------------|------------------------------------------------------------------------|---------------------------|--------------------------------------------------------------------------|-------------------------------------|
| speed of light in vacuum                                                       | $c, c_0$           | 299 792 458 (exact)                                                 | $\text{m s}^{-1}$                         | muon $g$ -factor $-2(1 + a_\mu)$                                       | $g_\mu$                   | $-2.002\,331\,8320(13)$                                                  |                                     |
| magnetic constant                                                              | $\mu_0$            | $4\pi \times 10^{-7}$ (exact)                                       | $\text{N A}^{-2}$                         | muon-proton magnetic moment ratio                                      | $\mu_\mu/\mu_p$           | $-3.183\,345\,39(10)$                                                    |                                     |
|                                                                                |                    | $= 12.566\,370\,614\dots \times 10^{-7}$                            | $\text{N A}^{-2}$                         | proton mass                                                            | $m_p$                     | $1.672\,621\,58(13) \times 10^{-27}$                                     | kg                                  |
| electric constant $1/\mu_0 c^2$                                                | $\epsilon_0$       | $8.854\,187\,817\dots \times 10^{-12}$                              | $\text{F m}^{-1}$                         | in u                                                                   |                           | $1.007\,276\,466\,88(13)$                                                | u                                   |
| Newtonian constant of gravitation                                              | $G$                | $6.673(10) \times 10^{-11}$                                         | $\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$ | energy equivalent in MeV                                               | $m_p c^2$                 | $938.271\,998(38)$                                                       | MeV                                 |
| Planck constant                                                                | $h$                | $6.626\,068\,76(52) \times 10^{-34}$                                | J s                                       | proton-electron mass ratio                                             | $m_p/m_e$                 | $1\,836.152\,6675(39)$                                                   |                                     |
| in eV s                                                                        |                    | $4.135\,667\,27(16) \times 10^{-15}$                                | eV s                                      | proton magnetic moment                                                 | $\mu_p$                   | $1.410\,606\,633(58) \times 10^{-26}$                                    | J T <sup>-1</sup>                   |
| $h/2\pi$                                                                       | $\hbar$            | $1.054\,571\,596(82) \times 10^{-34}$                               | J s                                       | to nuclear magneton ratio                                              | $\mu_p/\mu_N$             | $2.792\,847\,337(29)$                                                    |                                     |
| in eV s                                                                        |                    | $6.582\,118\,89(26) \times 10^{-16}$                                | eV s                                      | proton magnetic shielding correction $1 - \mu'_p/\mu_p \sigma'_p$      |                           | $25.687(15) \times 10^{-6}$                                              |                                     |
| elementary charge                                                              | $e$                | $1.602\,176\,462(63) \times 10^{-19}$                               | C                                         | (H <sub>2</sub> O, sphere, 25 °C)                                      |                           |                                                                          |                                     |
| magnetic flux quantum $h/2e$                                                   | $\Phi_0$           | $2.067\,833\,636(81) \times 10^{-15}$                               | Wb                                        | proton gyromagnetic ratio $2\mu_p/\hbar$                               | $\gamma_p$                | $2.675\,222\,12(14) \times 10^8$                                         | s <sup>-1</sup> T <sup>-1</sup>     |
| Josephson constant $2e/h$                                                      | $K_J$              | $483\,597.898(19) \times 10^9$                                      | Hz V <sup>-1</sup>                        | $\gamma_p/2\pi$                                                        |                           | $42.577\,4825(18)$                                                       | MHz T <sup>-1</sup>                 |
| von Klitzing constant $h/e^2 = \mu_0 c/2\alpha$                                | $R_K$              | $25\,812.807\,572(95)$                                              | $\Omega$                                  | $\gamma'_p$                                                            |                           | $2.675\,153\,44(11) \times 10^8$                                         | s <sup>-1</sup> T <sup>-1</sup>     |
| Bohr magneton $eh/2m_e$                                                        | $\mu_B$            | $927.400\,899(37) \times 10^{-26}$                                  | J T <sup>-1</sup>                         | shielded proton gyromagnetic ratio $2\mu'_p/\hbar$                     |                           |                                                                          |                                     |
| in eV T <sup>-1</sup>                                                          |                    | $5.788\,381\,749(43) \times 10^{-5}$                                | eV T <sup>-1</sup>                        | (H <sub>2</sub> O, sphere, 25 °C)                                      |                           |                                                                          |                                     |
| nuclear magneton $eh/2m_p$                                                     | $\mu_N$            | $5.050\,783\,17(20) \times 10^{-27}$                                | J T <sup>-1</sup>                         | neutron mass in u                                                      | $m_n$                     | $1.008\,664\,915\,78(55)$                                                | u                                   |
| in eV T <sup>-1</sup>                                                          |                    | $3.152\,451\,238(24) \times 10^{-8}$                                | eV T <sup>-1</sup>                        | energy equivalent in MeV                                               | $m_n c^2$                 | $939.565\,330(38)$                                                       | MeV                                 |
| fine-structure constant $e^2/4\pi\epsilon_0\hbar c$                            | $\alpha$           | $7.297\,352\,533(27) \times 10^{-3}$                                |                                           | neutron-proton mass ratio                                              | $m_n/m_p$                 | $1.001\,378\,418\,87(58)$                                                |                                     |
| inverse fine-structure constant                                                | $\alpha^{-1}$      | $137.035\,999\,76(50)$                                              |                                           | neutron magnetic moment                                                | $\mu_n$                   | $-0.966\,236\,40(23) \times 10^{-26}$                                    | J T <sup>-1</sup>                   |
| Rydberg constant $\alpha^2 m_e c^2/2h$                                         | $R_\infty$         | $10\,973\,731.568\,549(83)$                                         | m <sup>-1</sup>                           | to nuclear magneton ratio                                              | $\mu_n/\mu_N$             | $-1.913\,042\,72(45)$                                                    |                                     |
| energy equivalent in eV                                                        | $R_\infty c$       | $3.289\,841\,960\,368(25) \times 10^{15}$                           | Hz                                        | deuteron mass in u                                                     | $m_d$                     | $2.013\,553\,212\,71(35)$                                                | u                                   |
| Bohr radius $\alpha/4\pi R_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2$             | $R_\infty \hbar c$ | $13.605\,691\,72(53)$                                               | eV                                        | energy equivalent in MeV                                               | $m_d c^2$                 | $1\,875.612\,762(75)$                                                    | MeV                                 |
| Hartree energy $e^2/4\pi\epsilon_0 a_0 = 2R_\infty \hbar c = \alpha^2 m_e c^2$ | $a_0$              | $0.529\,177\,2083(19) \times 10^{-10}$                              | m                                         | deuteron-proton mass ratio                                             | $m_d/m_p$                 | $1.999\,007\,500\,83(41)$                                                |                                     |
| in eV                                                                          | $E_h$              | $4.359\,743\,81(34) \times 10^{-18}$                                | J                                         | deuteron magnetic moment                                               | $\mu_d$                   | $0.433\,073\,457(18) \times 10^{-26}$                                    | J T <sup>-1</sup>                   |
| electron mass                                                                  | $m_e$              | $27.211\,3834(11)$                                                  | eV                                        | to nuclear magneton ratio                                              | $\mu_d/\mu_N$             | $0.857\,438\,2284(94)$                                                   |                                     |
| in u                                                                           |                    | $9.109\,381\,88(72) \times 10^{-31}$                                | kg                                        | helion ( <sup>3</sup> He nucleus) mass in u                            | $m_h$                     | $3.014\,932\,234\,69(86)$                                                | u                                   |
| energy equivalent in MeV                                                       | $m_e c^2$          | $5.485\,799\,110(12) \times 10^{-4}$                                | u                                         | energy equivalent in MeV                                               | $m_h c^2$                 | $2\,808.391\,32(11)$                                                     | MeV                                 |
| electron-muon mass ratio                                                       | $m_e/m_\mu$        | $0.510\,998\,902(21)$                                               | MeV                                       | shielded helion magnetic moment                                        | $\mu'_h$                  | $-1.074\,552\,967(45) \times 10^{-26}$                                   | J T <sup>-1</sup>                   |
| electron-proton mass ratio                                                     | $m_e/m_p$          | $4.836\,332\,10(15) \times 10^{-3}$                                 |                                           | (gas, sphere, 25 °C)                                                   |                           |                                                                          |                                     |
| electron charge to mass quotient                                               | $-e/m_e$           | $-1.758\,820\,174(71) \times 10^{11}$                               | C kg <sup>-1</sup>                        | to Bohr magneton ratio                                                 | $\mu'_h/\mu_B$            | $-1.158\,671\,474(14) \times 10^{-3}$                                    |                                     |
| Compton wavelength $h/m_e c$                                                   | $\lambda_C$        | $2.426\,310\,215(18) \times 10^{-12}$                               | m                                         | to nuclear magneton ratio                                              | $\mu'_h/\mu_N$            | $-2.127\,497\,718(25)$                                                   |                                     |
| $\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$                         | $\lambda_C$        | $386.159\,2642(28) \times 10^{-15}$                                 | m                                         | alpha particle mass in u                                               | $m_\alpha$                | $4.001\,506\,1747(10)$                                                   | u                                   |
| classical electron radius $\alpha^2 a_0$                                       | $r_e$              | $2.817\,940\,285(31) \times 10^{-15}$                               | m                                         | energy equivalent in MeV                                               | $m_\alpha c^2$            | $3\,727.379\,04(15)$                                                     | MeV                                 |
| Thomson cross section $(8\pi/3)r_e^2$                                          | $\sigma_e$         | $0.665\,245\,854(15) \times 10^{-28}$                               | m <sup>2</sup>                            | Avogadro constant                                                      | $N_A, L$                  | $6.022\,141\,99(47) \times 10^{23}$                                      | mol <sup>-1</sup>                   |
| electron magnetic moment                                                       | $\mu_e$            | $-928.476\,362(37) \times 10^{-26}$                                 | J T <sup>-1</sup>                         | atomic mass constant $\frac{1}{12}m(^{12}\text{C}) = 1\text{ u}$       | $m_u$                     | $1.660\,538\,73(13) \times 10^{-27}$                                     | kg                                  |
| to Bohr magneton ratio                                                         | $\mu_e/\mu_B$      | $-1.001\,159\,652\,1869(41)$                                        |                                           | energy equivalent in MeV                                               | $m_u c^2$                 | $931.494\,013(37)$                                                       | MeV                                 |
| to nuclear magneton ratio                                                      | $\mu_e/\mu_N$      | $-1\,838.281\,9660(39)$                                             |                                           | Faraday constant $N_A e$                                               | $F$                       | $96\,485.3415(39)$                                                       | C mol <sup>-1</sup>                 |
| electron magnetic moment anomaly $ \mu_e /\mu_B - 1$                           | $a_e$              | $1.159\,652\,1869(41) \times 10^{-3}$                               |                                           | molar gas constant                                                     | $R$                       | $8.314\,472(15)$                                                         | J mol <sup>-1</sup> K <sup>-1</sup> |
| electron $g$ -factor $-2(1 + a_e)$                                             | $g_e$              | $-2.002\,319\,304\,3737(82)$                                        |                                           | Boltzmann constant $R/N_A$                                             | $k$                       | $1.380\,6503(24) \times 10^{-23}$                                        | J K <sup>-1</sup>                   |
| electron-proton magnetic moment ratio                                          | $\mu_e/\mu_p$      | $-658.210\,6875(66)$                                                |                                           | in eV K <sup>-1</sup>                                                  |                           | $8.617\,342(15) \times 10^{-5}$                                          | eV K <sup>-1</sup>                  |
| muon mass in u                                                                 | $m_\mu$            | $0.113\,428\,9168(34)$                                              | u                                         | molar volume of ideal gas $RT/p$                                       | $V_m$                     | $22.413\,996(39) \times 10^{-3}$                                         | m <sup>3</sup> mol <sup>-1</sup>    |
| energy equivalent in MeV                                                       | $m_\mu c^2$        | $105.658\,3568(52)$                                                 | MeV                                       | ( $T = 273.15\text{ K}, p = 101.325\text{ kPa}$ )                      |                           |                                                                          |                                     |
| muon-electron mass ratio                                                       | $m_\mu/m_e$        | $206.768\,2657(63)$                                                 |                                           | Stefan-Boltzmann constant $\pi^2 k^4/60\hbar^3 c^2$                    | $\sigma$                  | $5.670\,400(40) \times 10^{-8}$                                          | W m <sup>-2</sup> K <sup>-4</sup>   |
| muon magnetic moment                                                           | $\mu_\mu$          | $-4.490\,448\,13(22) \times 10^{-26}$                               | J T <sup>-1</sup>                         | first radiation constant $2\pi\hbar c^2$                               | $c_1$                     | $3.741\,771\,07(29) \times 10^{-16}$                                     | W m <sup>2</sup>                    |
| to Bohr magneton ratio                                                         | $\mu_\mu/\mu_B$    | $-4.841\,970\,85(15) \times 10^{-3}$                                |                                           | second radiation constant $\hbar c/k$                                  | $c_2$                     | $1.438\,7752(25) \times 10^{-2}$                                         | m K                                 |
| to nuclear magneton ratio                                                      | $\mu_\mu/\mu_N$    | $-8.890\,597\,70(27)$                                               |                                           | Wien displacement law constant                                         |                           |                                                                          |                                     |
| muon magnetic moment anomaly                                                   |                    |                                                                     |                                           | $b = \lambda_{\text{max}} T = c_2/4.965\,114\,231\dots$                | $b$                       | $2.897\,7686(51) \times 10^{-3}$                                         | m K                                 |
| $ \mu_\mu /(e\hbar/2m_\mu) - 1$                                                | $a_\mu$            | $1.165\,916\,02(64) \times 10^{-3}$                                 |                                           | Cu x unit: $\lambda(\text{Cu K}\alpha_1)/1\,537.400$                   | $xu(\text{Cu K}\alpha_1)$ | $1.002\,077\,03(28) \times 10^{-13}$                                     | m                                   |
|                                                                                |                    |                                                                     |                                           | Mo x unit: $\lambda(\text{Mo K}\alpha_1)/707.831$                      | $xu(\text{Mo K}\alpha_1)$ | $1.002\,099\,59(53) \times 10^{-13}$                                     | m                                   |
| Energy equivalents                                                             |                    |                                                                     |                                           |                                                                        |                           |                                                                          |                                     |
| $(1\text{ m}^{-1})c = 299\,792\,458\text{ Hz}$                                 |                    | $(1\text{ Hz})\hbar/k = 4.799\,2374(84) \times 10^{-11}\text{ K}$   |                                           | $(1\text{ J}) = 6.241\,509\,74(24) \times 10^{18}\text{ eV}$           |                           | $(1\text{ eV})/c^2 = 1.073\,544\,206(43) \times 10^{-9}\text{ u}$        |                                     |
| $(1\text{ m}^{-1})\hbar c/k = 1.438\,7752(25) \times 10^{-2}\text{ K}$         |                    | $(1\text{ Hz})\hbar = 4.135\,667\,27(16) \times 10^{-15}\text{ eV}$ |                                           | $(1\text{ eV}) = 1.602\,176\,462(63) \times 10^{-19}\text{ J}$         |                           | $(1\text{ kg}) = 6.022\,141\,99(47) \times 10^{26}\text{ u}$             |                                     |
| $(1\text{ m}^{-1})\hbar c = 1.239\,841\,857(49) \times 10^{-6}\text{ eV}$      |                    | $(1\text{ K})k/\hbar c = 69.503\,56(12)\text{ m}^{-1}$              |                                           | $(1\text{ eV})/\hbar c = 8.065\,544\,77(32) \times 10^5\text{ m}^{-1}$ |                           | $(1\text{ u}) = 1.660\,538\,73(13) \times 10^{-27}\text{ kg}$            |                                     |
| $(1\text{ m}^{-1})\hbar/c = 1.331\,025\,042(10) \times 10^{-15}\text{ u}$      |                    | $(1\text{ K})k/\hbar = 2.083\,6644(36) \times 10^{10}\text{ Hz}$    |                                           | $(1\text{ eV})/\hbar = 2.417\,989\,491(95) \times 10^{14}\text{ Hz}$   |                           | $(1\text{ u})c/\hbar = 7.513\,006\,658(57) \times 10^{14}\text{ m}^{-1}$ |                                     |
| $(1\text{ Hz})/c = 3.335\,640\,952 \times 10^{-9}\text{ m}^{-1}$               |                    | $(1\text{ K})k = 8.617\,342(15) \times 10^{-5}\text{ eV}$           |                                           | $(1\text{ eV})/k = 1.160\,4506(20) \times 10^4\text{ K}$               |                           | $(1\text{ u})c^2 = 931.494\,013(37) \times 10^6\text{ eV}$               |                                     |

|                                                              |                 |                                                        |
|--------------------------------------------------------------|-----------------|--------------------------------------------------------|
| in u                                                         |                 |                                                        |
| energy equivalent in MeV                                     | $m_e c^2$       | 5.485 799 110(12) $\times 10^{-4}$ u                   |
| electron-muon mass ratio                                     | $m_e/m_\mu$     | 0.510 998 902(21) MeV                                  |
| electron-proton mass ratio                                   | $m_e/m_p$       | 4.836 332 10(15) $\times 10^{-3}$                      |
| electron charge to mass quotient                             | $-e/m_e$        | 5.446 170 232(12) $\times 10^{-4}$                     |
| Compton wavelength $h/m_e c$                                 | $\lambda_C$     | -1.758 820 174(71) $\times 10^{11}$ C kg <sup>-1</sup> |
| $\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$       | $\lambda_C$     | 2.426 310 215(18) $\times 10^{-12}$ m                  |
| classical electron radius $\alpha^2 a_0$                     | $r_e$           | 386.159 2642(28) $\times 10^{-15}$ m                   |
| Thomson cross section $(8\pi/3)r_e^2$                        | $\sigma_e$      | 2.817 940 285(31) $\times 10^{-15}$ m <sup>2</sup>     |
| electron magnetic moment                                     | $\mu_e$         | 0.665 245 854(15) $\times 10^{-28}$ J T <sup>-1</sup>  |
| to Bohr magneton ratio                                       | $\mu_e/\mu_B$   | -928.476 362(37) $\times 10^{-26}$                     |
| to nuclear magneton ratio                                    | $\mu_e/\mu_N$   | -1.001 159 652 1869(41)                                |
| electron magnetic moment anomaly $ \mu_e /\mu_B - 1$         | $a_e$           | -1 838.281 9660(39)                                    |
| electron $g$ -factor $-2(1 + a_e)$                           | $g_e$           | 1.159 652 1869(41) $\times 10^{-3}$                    |
| electron-proton magnetic moment ratio                        | $\mu_e/\mu_p$   | -2.002 319 304 3737(82)                                |
| muon mass in u                                               | $m_\mu$         | -658.210 6875(66) u                                    |
| energy equivalent in MeV                                     | $m_\mu c^2$     | 0.113 428 9168(34) MeV                                 |
| muon-electron mass ratio                                     | $m_\mu/m_e$     | 105.658 3568(52)                                       |
| muon magnetic moment                                         | $\mu_\mu$       | 206.768 2657(63) J T <sup>-1</sup>                     |
| to Bohr magneton ratio                                       | $\mu_\mu/\mu_B$ | -4.490 448 13(22) $\times 10^{-26}$                    |
| to nuclear magneton ratio                                    | $\mu_\mu/\mu_N$ | -4.841 970 85(15) $\times 10^{-3}$                     |
| muon magnetic moment anomaly $ \mu_\mu /(e\hbar/2m_\mu) - 1$ | $a_\mu$         | -8.890 597 70(27)                                      |

|                          |                                                   |                                                                   |
|--------------------------|---------------------------------------------------|-------------------------------------------------------------------|
|                          | Energy eq                                         |                                                                   |
| $(1 \text{ m}^{-1})c$    | $= 299\,792\,458 \text{ Hz}$                      | $(1 \text{ Hz})h/k = 4.799\,237\,4(84) \times 10^{-11} \text{ K}$ |
| $(1 \text{ m}^{-1})hc/k$ | $= 1.438\,775\,2(25) \times 10^{-2} \text{ K}$    | $(1 \text{ Hz})h = 4.135\,667\,27(16) \times 10^{-15} \text{ eV}$ |
| $(1 \text{ m}^{-1})hc$   | $= 1.239\,841\,857(49) \times 10^{-6} \text{ eV}$ | $(1 \text{ K})k/hc = 69.503\,56(12) \text{ m}^{-1}$               |
| $(1 \text{ m}^{-1})h/c$  | $= 1.331\,025\,042(10) \times 10^{-15} \text{ u}$ | $(1 \text{ K})k/h = 2.083\,664\,4(36) \times 10^{10} \text{ Hz}$  |
| $(1 \text{ Hz})/c$       | $= 3.335\,640\,952 \times 10^{-9} \text{ m}^{-1}$ | $(1 \text{ K})k = 8.617\,342(15) \times 10^{-5} \text{ eV}$       |

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