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## Fundamental Physical Constants

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Extracts from Codata Bulletin Nr. 63 (Nov. 1986)

The tables attached list the 1986 recommended values of the fundamental physical constants, obtained from a least-quares fit of precise experimental data. For all details see the above-mentioned Codata Bulletin, which should be quoted as reference (i.e. do not quote "IAEA-NDS-50" as reference!).

Table 7. 1986 recommended values of the fundamental physical constants.

This list of the fundamental constants of physics and chemistry is based on a least-squares adjustment with 17 degrees of freedom. The digits in parentheses are the one-standard-deviation uncertainty in the last digits of the given value. Since the uncertainties of many of these entries are correlated, the full covariance matrix must be used in evaluating the uncertainties of quantities computed from them.

| Quantity | Symbol | Value | Units | Relative uncertainty (ppm) |
|---|---|---|---|---|
| | | GENERAL CONSTANTS | | |
| | | Universal Constants | | |
| speed of light in vacuum | $c$ | 299 792 458 | $\mathrm{m\,s^{-1}}$ | (exact) |
| permeability of vacuum | $\mu_0$ | $4\pi \times 10^{-7}$ | $\mathrm{N\,A^{-2}}$ | |
| | | =12.566 370 614... | $10^{-7}\,\mathrm{N\,A^{-2}}$ | (exact) |
| permittivity of vacuum | $\epsilon_0$ | $1/\mu_0 c^2$ | | |
| | | =8.854 187 817... | $10^{-12}\,\mathrm{F\,m^{-1}}$ | (exact) |
| Newtonian constant of gravitation | $G$ | 6.672 59(85) | $10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$ | 128 |
| Planck constant | $h$ | 6.626 0755(40) | $10^{-34}\,\mathrm{J\,s}$ | 0.60 |
| in electron volts, $h/\{e\}$ | | 4.135 6692(12) | $10^{-15}\,\mathrm{eV\,s}$ | 0.30 |
| $h/2\pi$ | $\hbar$ | 1.054 572 66(63) | $10^{-34}\,\mathrm{J\,s}$ | 0.60 |
| in electron volts, $\hbar/\{e\}$ | | 6.582 1220(20) | $10^{-16}\,\mathrm{eV\,s}$ | 0.30 |
| Planck mass, $(\hbar c/G)^{\frac{1}{2}}$ | $m_P$ | 2.176 71(14) | $10^{-8}\,\mathrm{kg}$ | 64 |
| Planck length, $\hbar/m_P c = (\hbar G/c^3)^{\frac{1}{2}}$ | $l_P$ | 1.616 05(10) | $10^{-35}\,\mathrm{m}$ | 64 |
| Planck time, $l_P/c = (\hbar G/c^5)^{\frac{1}{2}}$ | $t_P$ | 5.390 56(34) | $10^{-44}\,\mathrm{s}$ | 64 |
| | | Electromagnetic Constants | | |
| elementary charge | $e$ | 1.602 177 33(49) | $10^{-19}\,\mathrm{C}$ | 0.30 |
| | $e/h$ | 2.417 988 36(72) | $10^{14}\,\mathrm{A\,J^{-1}}$ | 0.30 |
| magnetic flux quantum, $h/2e$ | $\Phi_0$ | 2.067 834 61(61) | $10^{-15}\,\mathrm{Wb}$ | 0.30 |
| Josephson frequency-voltage ratio | $2e/h$ | 4.835 9767(14) | $10^{14}\,\mathrm{Hz\,V^{-1}}$ | 0.30 |
| quantized Hall conductance | $e^2/h$ | 3.874 046 14(17) | $10^{-5}\,\mathrm{S}$ | 0.045 |
| quantized Hall resistance, $h/e^2 = \frac{1}{2}\mu_0 c/\alpha$ | $R_H$ | 25 812.8056(12) | $\Omega$ | 0.045 |
| Bohr magneton, $e\hbar/2m_e$ | $\mu_B$ | 9.274 0154(31) | $10^{-24}\,\mathrm{J\,T^{-1}}$ | 0.34 |
| in electron volts, $\mu_B/\{e\}$ | | 5.788 382 63(52) | $10^{-5}\,\mathrm{eV\,T^{-1}}$ | 0.089 |
| in hertz, $\mu_B/h$ | | 1.399 624 18(42) | $10^{10}\,\mathrm{Hz\,T^{-1}}$ | 0.30 |
| in wavenumbers, $\mu_B/hc$ | | 46.686 437(14) | $\mathrm{m^{-1}\,T^{-1}}$ | 0.30 |
| in kelvins, $\mu_B/k$ | | 0.671 7099(57) | $\mathrm{K\,T^{-1}}$ | 8.5 |
| nuclear magneton, $e\hbar/2m_p$ | $\mu_N$ | 5.050 7866(17) | $10^{-27}\,\mathrm{J\,T^{-1}}$ | 0.34 |
| in electron volts, $\mu_N/\{e\}$ | | 3.152 451 66(28) | $10^{-8}\,\mathrm{eV\,T^{-1}}$ | 0.089 |
| in hertz, $\mu_N/h$ | | 7.622 5914(23) | $\mathrm{MHz\,T^{-1}}$ | 0.30 |
| in wavenumbers, $\mu_N/hc$ | | 2.542 622 81(77) | $10^{-2}\,\mathrm{m^{-1}\,T^{-1}}$ | 0.30 |
| in kelvins, $\mu_N/k$ | | 3.658 246(31) | $10^{-4}\,\mathrm{K\,T^{-1}}$ | 8.5 |

## ATOMIC CONSTANTS

| | | | | |
|---|---|---|---|---|
| fine-structure constant, $\frac{1}{2}\mu_0 ce^2/h$ | $\alpha$ | 7.297 353 08(33) | $10^{-3}$ | 0.045 |
| inverse fine-structure constant | $\alpha^{-1}$ | 137.035 9895(61) | | 0.045 |
| Rydberg constant, $\frac{1}{2}m_e c\alpha^2/h$ | $R_\infty$ | 10 973 731.534(13) | $m^{-1}$ | 0.0012 |
| in hertz, $R_\infty c$ | | 3.289 841 9499(39) | $10^{15}$ Hz | 0.0012 |
| in joules, $R_\infty hc$ | | 2.179 8741(13) | $10^{-18}$ J | 0.60 |
| in eV, $R_\infty hc/\{e\}$ | | 13.605 6981(40) | eV | 0.30 |
| Bohr radius, $\alpha/4\pi R_\infty$ | $a_0$ | 0.529 177 249(24) | $10^{-10}$ m | 0.045 |
| Hartree energy, $e^2/4\pi\epsilon_0 a_0 = 2R_\infty hc$ | $E_h$ | 4.359 7482(26) | $10^{-18}$ J | 0.60 |
| in eV, $E_h/\{e\}$ | | 27.211 3961(81) | eV | 0.30 |
| quantum of circulation | $h/2m_e$ | 3.636 948 07(33) | $10^{-4}$ $m^2 s^{-1}$ | 0.089 |
| | $h/m_e$ | 7.273 896 14(65) | $10^{-4}$ $m^2 s^{-1}$ | 0.089 |
| | | **Electron** | | |
| electron mass | $m_e$ | 9.109 3897(54) | $10^{-31}$ kg | 0.59 |
| | | 5.485 799 03(13) | $10^{-4}$ u | 0.023 |
| in electron volts, $m_e c^2/\{e\}$ | | 0.510 999 06(15) | MeV | 0.30 |
| electron–muon mass ratio | $m_e/m_\mu$ | 4.836 332 18(71) | $10^{-3}$ | 0.15 |
| electron–proton mass ratio | $m_e/m_p$ | 5.446 170 13(11) | $10^{-4}$ | 0.020 |
| electron–deuteron mass ratio | $m_e/m_d$ | 2.724 437 07(6) | $10^{-4}$ | 0.020 |
| electron–$\alpha$-particle mass ratio | $m_e/m_\alpha$ | 1.370 933 54(3) | $10^{-4}$ | 0.021 |
| electron specific charge | $-e/m_e$ | −1.758 819 62(53) | $10^{11}$ C $kg^{-1}$ | 0.30 |
| electron molar mass | $M(e), M_e$ | 5.485 799 03(13) | $10^{-7}$ kg/mol | 0.023 |
| Compton wavelength, $h/m_e c$ | $\lambda_C$ | 2.426 310 58(22) | $10^{-12}$ m | 0.089 |
| $\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$ | $\bar{\lambda}_C$ | 3.861 593 23(35) | $10^{-13}$ m | 0.089 |
| classical electron radius, $\alpha^2 a_0$ | $r_e$ | 2.817 940 92(38) | $10^{-15}$ m | 0.13 |
| Thomson cross section, $(8\pi/3)r_e^2$ | $\sigma_e$ | 0.665 246 16(18) | $10^{-28}$ $m^2$ | 0.27 |
| electron magnetic moment | $\mu_e$ | 928.477 01(31) | $10^{-26}$ J $T^{-1}$ | 0.34 |
| in Bohr magnetons | $\mu_e/\mu_B$ | 1.001 159 652 193(10) | | $1\times10^{-5}$ |
| in nuclear magnetons | $\mu_e/\mu_N$ | 1838.282 000(37) | | 0.020 |
| electron magnetic moment anomaly, $\mu_e/\mu_B - 1$ | $a_e$ | 1.159 652 193(10) | $10^{-3}$ | 0.0086 |
| electron g-factor, $2(1 + a_e)$ | $g_e$ | 2.002 319 304 386(20) | | $1\times10^{-5}$ |
| electron–muon magnetic moment ratio | $\mu_e/\mu_\mu$ | 206.766 967(30) | | 0.15 |
| electron–proton magnetic moment ratio | $\mu_e/\mu_p$ | 658.210 6881(66) | | 0.010 |
| | | **Muon** | | |
| muon mass | $m_\mu$ | 1.883 5327(11) | $10^{-28}$ kg | 0.61 |
| | | 0.113 428 913(17) | u | 0.15 |
| in electron volts, $m_\mu c^2/\{e\}$ | | 105.658 389(34) | MeV | 0.32 |
| muon–electron mass ratio | $m_\mu/m_e$ | 206.768 262(30) | | 0.15 |
| muon molar mass | $M(\mu), M_\mu$ | 1.134 289 13(17) | $10^{-4}$ kg/mol | 0.15 |
| muon magnetic moment | $\mu_\mu$ | 4.490 4514(15) | $10^{-26}$ J $T^{-1}$ | 0.33 |
| in Bohr magnetons, | $\mu_\mu/\mu_B$ | 4.841 970 97(71) | $10^{-3}$ | 0.15 |
| in nuclear magnetons, | $\mu_\mu/\mu_N$ | 8.890 5981(13) | | 0.15 |
| muon magnetic moment anomaly $[\mu_\mu/(e\hbar/2m_\mu)] - 1$ | $a_\mu$ | 1.165 9230(84) | $10^{-3}$ | 7.2 |
| muon g-factor, $2(1 + a_\mu)$ | $g_\mu$ | 2.002 331 846(17) | | 0.0084 |
| muon–proton magnetic moment ratio | $\mu_\mu/\mu_p$ | 3.183 345 47(47) | | 0.15 |

## Proton

| | | | | |
|---|---|---|---|---|
| proton mass | $m_p$ | 1.6726231(10) | $10^{-27}$ kg | 0.59 |
| | | 1.007276470(12) | u | 0.012 |
| in electron volts, $m_pc^2/\{e\}$ | | 938.27231(28) | MeV | 0.30 |
| proton-electron mass ratio | $m_p/m_e$ | 1836.152701(37) | | 0.020 |
| proton-muon mass ratio | $m_p/m_\mu$ | 8.8802444(13) | | 0.15 |
| proton specific charge | $e/m_p$ | 9.5788309(29) | $10^7$ C kg$^{-1}$ | 0.30 |
| proton molar mass | $M(\mathrm{p}), M_p$ | 1.007276470(12) | $10^{-3}$ kg/mol | 0.012 |
| proton Compton wavelength, $h/m_pc$ | $\lambda_{C,p}$ | 1.32141002(12) | $10^{-15}$ m | 0.089 |
| $\lambda_{C,p}/2\pi$ | $\bar{\lambda}_{C,p}$ | 2.10308937(19) | $10^{-16}$ m | 0.089 |
| proton magnetic moment | $\mu_p$ | 1.41060761(47) | $10^{-26}$ J T$^{-1}$ | 0.34 |
| in Bohr magnetons | $\mu_p/\mu_B$ | 1.521032202(15) | $10^{-3}$ | 0.010 |
| in nuclear magnetons | $\mu_p/\mu_N$ | 2.792847386(63) | | 0.023 |
| diamagnetic shielding correction for protons in pure water, spherical sample, 25 °C, $1-\mu_p'/\mu_p$ | $\sigma_{H_2O}$ | 25.689(15) | $10^{-6}$ | – |
| shielded proton moment ($H_2O$, sph., 25 °C) | $\mu_p'$ | 1.41057138(47) | $10^{-26}$ J T$^{-1}$ | 0.34 |
| in Bohr magnetons | $\mu_p'/\mu_B$ | 1.520993129(17) | $10^{-3}$ | 0.011 |
| in nuclear magnetons | $\mu_p'/\mu_N$ | 2.792775642(64) | | 0.023 |
| proton gyromagnetic ratio | $\gamma_p$ | 26752.2128(81) | $10^4$ s$^{-1}$ T$^{-1}$ | 0.30 |
| | $\gamma_p/2\pi$ | 42.577469(13) | MHz T$^{-1}$ | 0.30 |
| uncorrected ($H_2O$, sph., 25 °C) | $\gamma_p'$ | 26751.5255(81) | $10^4$ s$^{-1}$ T$^{-1}$ | 0.30 |
| | $\gamma_p'/2\pi$ | 42.576375(13) | MHz T$^{-1}$ | 0.30 |

## Neutron

| | | | | |
|---|---|---|---|---|
| neutron mass | $m_n$ | 1.6749286(10) | $10^{-27}$ kg | 0.59 |
| | | 1.008664904(14) | u | 0.014 |
| in electron volts, $m_nc^2/\{e\}$ | | 939.56563(28) | Mev | 0.30 |
| neutron-electron mass ratio | $m_n/m_e$ | 1838.683662(40) | | 0.022 |
| neutron-proton mass ratio | $m_n/m_p$ | 1.001378404(9) | | 0.009 |
| neutron molar mass | $M(\mathrm{n}), M_n$ | 1.008664904(14) | $10^{-3}$ kg/mol | 0.014 |
| neutron Compton wavelength, $h/m_nc$ | $\lambda_{C,n}$ | 1.31959110(12) | $10^{-15}$ m | 0.089 |
| $\lambda_{C,n}/2\pi$ | $\bar{\lambda}_{C,n}$ | 2.10019445(19) | $10^{-16}$ m | 0.089 |
| neutron magnetic moment * | $\mu_n$ | 0.96623707(40) | $10^{-26}$ J T$^{-1}$ | 0.41 |
| in Bohr magnetons | $\mu_n/\mu_B$ | 1.04187563(25) | $10^{-3}$ | 0.24 |
| in nuclear magnetons | $\mu_n/\mu_N$ | 1.91304275(45) | | 0.24 |
| neutron-electron magnetic moment ratio | $\mu_n/\mu_e$ | 1.04066882(25) | $10^{-3}$ | 0.24 |
| neutron-proton magnetic moment ratio | $\mu_n/\mu_p$ | 0.68497934(16) | | 0.24 |

## Deuteron

| | | | | |
|---|---|---|---|---|
| deuteron mass | $m_d$ | 3.3435860(20) | $10^{-27}$ kg | 0.59 |
| | | 2.013553214(24) | u | 0.012 |
| in electron volts, $m_dc^2/\{e\}$ | | 1875.61339(57) | MeV | 0.30 |
| deuteron-electron mass ratio | $m_d/m_e$ | 3670.483014(75) | | 0.020 |
| deuteron-proton mass ratio | $m_d/m_p$ | 1.999007496(6) | | 0.003 |
| deuteron molar mass | $M(\mathrm{d}), M_d$ | 2.013553214(24) | $10^{-3}$ kg/mol | 0.012 |
| deuteron magnetic moment * | $\mu_d$ | 0.43307375(15) | $10^{-26}$ J T$^{-1}$ | 0.34 |
| in Bohr magnetons, | $\mu_d/\mu_B$ | 0.4669754479(91) | $10^{-3}$ | 0.019 |
| in nuclear magnetons, | $\mu_d/\mu_N$ | 0.857438230(24) | | 0.028 |
| deuteron-electron magnetic moment ratio | $\mu_d/\mu_e$ | 0.4664345460(91) | $10^{-3}$ | 0.019 |
| deuteron-proton magnetic moment ratio | $\mu_d/\mu_p$ | 0.3070122035(51) | | 0.017 |

## PHYSICO-CHEMICAL CONSTANTS

| | | | | |
|---|---|---|---|---|
| Avogadro constant | $N_A, L$ | 6.022 1367(36) | $10^{23}$ mol$^{-1}$ | 0.59 |
| atomic mass constant | | | | |
| $m_u = \frac{1}{12}m(^{12}C)$ | $m_u$ | 1.660 5402(10) | $10^{-27}$ kg | 0.59 |
| in electron volts, $m_u c^2/\{e\}$ | | 931.494 32(28) | MeV | 0.30 |
| Faraday constant | $F$ | 96 485.309(29) | C mol$^{-1}$ | 0.30 |
| molar Planck constant | $N_A h$ | 3.990 313 23(36) | $10^{-10}$ J s mol$^{-1}$ | 0.089 |
| | $N_A hc$ | 0.119 626 58(11) | J m mol$^{-1}$ | 0.089 |
| molar gas constant | $R$ | 8.314 510(70) | J mol$^{-1}$ K$^{-1}$ | 8.4 |
| Boltzmann constant, $R/N_A$ | $k$ | 1.380 658(12) | $10^{-23}$ J K$^{-1}$ | 8.5 |
| in electron volts, $k/\{e\}$ | | 8.617 385(73) | $10^{-5}$ eV K$^{-1}$ | 8.4 |
| in hertz, $k/h$ | | 2.083 674(18) | $10^{10}$ Hz K$^{-1}$ | 8.4 |
| in wavenumbers, $k/hc$ | | 69.503 87(59) | m$^{-1}$ K$^{-1}$ | 8.4 |
| molar volume (ideal gas), $RT/p$ | | | | |
| $T = 273.15$K, $p = 101\,325$ Pa | $V_m$ | 22.414 10(19) | L/mol | 8.4 |
| Loschmidt constant, $N_A/V_m$ | $n_0$ | 2.686 763(23) | $10^{25}$ m$^{-3}$ | 8.5 |
| $T = 273.15$K, $p = 100$ kPa | $V_m$ | 22.711 08(19) | L/mol | 8.4 |
| Sackur-Tetrode constant | | | | |
| (absolute entropy constant), ** | | | | |
| $\frac{5}{2} + \ln\{(2\pi m_u k T_1/h^2)^{\frac{3}{2}} k T_1/p_0\}$ | | | | |
| $T_1 = 1$ K, $p_0 = 100$ kPa | $S_0/R$ | −1.151 693(21) | | 18 |
| $p_0 = 101\,325$ Pa | | −1.164 856(21) | | 18 |
| Stefan–Boltzmann constant, | | | | |
| $(\pi^2/60)k^4/\hbar^3 c^2$ | $\sigma$ | 5.670 51(19) | $10^{-8}$ W m$^{-2}$ K$^{-4}$ | 34 |
| first radiation constant, $2\pi hc^2$ | $c_1$ | 3.741 7749(22) | $10^{-16}$ W m$^2$ | 0.60 |
| second radiation constant, $hc/k$ | $c_2$ | 0.014 387 69(12) | m K | 8.4 |
| Wien displacement law constant, | | | | |
| $b = \lambda_{max} T = c_2/4.965\,114\,23\ldots$ | $b$ | 2.897 756(24) | $10^{-3}$ m K | 8.4 |

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

** The entropy of an ideal monatomic gas of relative atomic weight $A_r$ is given by

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

Table 8. Maintained units and standard values.

A summary of 'maintained' units and 'standard' values and their relationship to SI units, based on a least-squares adjustment with 17 degrees of freedom. The digits in parentheses are the one-standard-deviation uncertainty in the last digits of the given value. Since the uncertainties of many of these entries are correlated, the full covariance matrix must be used in evaluating the uncertainties of quantities computed from them.

| Quantity | Symbol | Value | Units | Relative uncertainty (ppm) |
|---|---|---|---|---|
| electron volt, $(e/\mathrm{C})\,\mathrm{J} = \{e\}\,\mathrm{J}$ | eV | 1.602 177 33(49) | $10^{-19}$ J | 0.30 |
| (unified) atomic mass unit, $1\ \mathrm{u} = m_u = \frac{1}{12}m(^{12}\mathrm{C})$ | u | 1.660 5402(10) | $10^{-27}$ kg | 0.59 |
| standard atmosphere | atm | 101 325 | Pa | (exact) |
| standard acceleration of gravity | $g_n$ | 9.806 65 | $\mathrm{m\,s^{-2}}$ | (exact) |
| | 'As-Maintained' Electrical Units | | | |
| BIPM maintained ohm, $\Omega_{69-\mathrm{BI}}$ | | | | |
| $\Omega_{\mathrm{BI85}} \equiv \Omega_{69-\mathrm{BI}}$(1 Jan 1985) | $\Omega_{\mathrm{BI85}}$ | $1 - 1.563(50)\times10^{-6}$ | $\Omega$ | |
| | | $= 0.999\,998\,437(50)$ | $\Omega$ | 0.050 |
| Drift rate of $\Omega_{69-\mathrm{BI}}$ | $\frac{d\Omega_{69-\mathrm{BI}}}{dt}$ | −0.0566(15) | $\mu\Omega$/a | — |
| BIPM maintained volt, | $\mathrm{V}_{76-\mathrm{BI}}$ | $1 - 7.59(30)\times10^{-6}$ | V | |
| $\mathrm{V}_{76-\mathrm{BI}} \equiv 483\,594\ \mathrm{GHz}(h/2e)$ | | $= 0.999\,992\,41(30)$ | V | 0.30 |
| BIPM maintained ampere, | $\mathrm{A}_{\mathrm{BI85}}$ | $1 - 6.03(30)\times10^{-6}$ | A | |
| $\mathrm{A}_{\mathrm{BIPM}} = \mathrm{V}_{76-\mathrm{BI}}/\Omega_{69-\mathrm{BI}}$ | | $= 0.999\,993\,97(30)$ | A | 0.30 |
| | X-Ray Standards | | | |
| Cu x-unit : $\lambda(\mathrm{CuK}\alpha_1) \equiv 1537.400\,\mathrm{xu}$ | xu($\mathrm{CuK}\alpha_1$) | 1.002 077 89(70) | $10^{-13}$ m | 0.70 |
| Mo x-unit : $\lambda(\mathrm{MoK}\alpha_1) \equiv 707.831\,\mathrm{xu}$ | xu($\mathrm{MoK}\alpha_1$) | 1.002 099 38(45) | $10^{-13}$ m | 0.45 |
| Å* : $\lambda(\mathrm{WK}\alpha_1) \equiv 0.209\,100\,$Å* | Å* | 1.000 014 81(92) | $10^{-10}$ m | 0.92 |
| lattice spacing of Si (in vacuum, 22.5 °C), + | $a$ | 0.543 101 96(11) | nm | 0.21 |
| $d_{220} = a/\sqrt{8}$ | $d_{220}$ | 0.192 015 540(40) | nm | 0.21 |
| molar volume of Si, $M(\mathrm{Si})/\rho(\mathrm{Si}) = N_A a^3/8$ | $V_m$(Si) | 12.058 8179(89) | $\mathrm{cm^3/mol}$ | 0.74 |

+ The lattice spacing of single-crystal Si can vary by parts in $10^7$ depending on the preparation process. Measurements at PTB indicate also the possibility of distortions from exact cubic symmetry of the order of 0.2 ppm.

Table 9. Energy conversion factors.

To use this table note that all entries on the same line are equal; the unit at the top of a column applies to all of the values beneath it.

*Example*: 1 eV = 806 544.10 $m^{-1}$

| | J | kg | $m^{-1}$ | Hz |
|---|---|---|---|---|
| 1 J = | 1 | $1/\{c^2\}$<br>$1.112\,650\,06\times10^{-17}$ | $1/\{hc\}$<br>$5.034\,1125(30)\times10^{24}$ | $1/\{h\}$<br>$1.509\,188\,97(90)\times10^{33}$ |
| 1 kg = | $\{c^2\}$<br>$8.987\,551\,787\times10^{16}$ | 1 | $\{c/h\}$<br>$4.524\,4347(27)\times10^{41}$ | $\{c^2/h\}$<br>$1.356\,391\,40(81)\times10^{50}$ |
| 1 $m^{-1}$ = | $\{hc\}$<br>$1.986\,4475(12)\times10^{-25}$ | $\{h/c\}$<br>$2.210\,2209(13)\times10^{-42}$ | 1 | $\{c\}$<br>$299\,792\,458$ |
| 1 Hz = | $\{h\}$<br>$6.626\,0755(40)\times10^{-34}$ | $\{h/c^2\}$<br>$7.372\,5032(44)\times10^{-51}$ | $1/\{c\}$<br>$3.335\,640\,952\times10^{-9}$ | 1 |
| 1 K = | $\{k\}$<br>$1.380\,658(12)\times10^{-23}$ | $\{k/c^2\}$<br>$1.536\,189(13)\times10^{-40}$ | $\{k/hc\}$<br>$69.503\,87(59)$ | $\{k/h\}$<br>$2.083\,674(18)\times10^{10}$ |
| 1 eV = | $\{e\}$<br>$1.602\,177\,33(49)\times10^{-19}$ | $\{e/c^2\}$<br>$1.782\,662\,70(54)\times10^{-36}$ | $\{e/hc\}$<br>$806\,554.10(24)$ | $\{e/h\}$<br>$2.417\,988\,36(72)\times10^{14}$ |
| 1 u = | $\{m_u c^2\}$<br>$1.492\,419\,09(88)\times10^{-10}$ | $\{m_u\}$<br>$1.660\,5402(10)\times10^{-27}$ | $\{m_u c/h\}$<br>$7.513\,005\,63(67)\times10^{14}$ | $\{m_u c^2/h\}$<br>$2.252\,342\,42(20)\times10^{23}$ |
| 1 hartree = | $\{2R_\infty hc\}$<br>$4.359\,7482(26)\times10^{-18}$ | $\{2R_\infty h/c\}$<br>$4.850\,8741(29)\times10^{-35}$ | $\{2R_\infty\}$<br>$21\,947\,463.067(26)$ | $\{2R_\infty c\}$<br>$6.579\,683\,8999(78)\times10^{15}$ |

| | K | eV | u | hartree |
|---|---|---|---|---|
| 1 J = | $1/\{k\}$<br>$7.242\,924(61)\times10^{22}$ | $1/\{e\}$<br>$6.241\,5064(19)\times10^{18}$ | $1/\{m_u c^2\}$<br>$6.700\,5308(40)\times10^{9}$ | $1/\{2R_\infty hc\}$<br>$2.293\,7104(14)\times10^{17}$ |
| 1 kg = | $\{c^2/k\}$<br>$6.509\,616(55)\times10^{39}$ | $\{c^2/e\}$<br>$5.609\,5862(17)\times10^{35}$ | $1/\{m_u\}$<br>$6.022\,1367(36)\times10^{26}$ | $\{c/2R_\infty h\}$<br>$2.061\,4841(12)\times10^{34}$ |
| 1 $m^{-1}$ = | $\{hc/k\}$<br>$0.014\,387\,69(12)$ | $\{hc/e\}$<br>$1.239\,842\,44(37)\times10^{-6}$ | $\{h/m_u c\}$<br>$1.331\,025\,22(12)\times10^{-15}$ | $1/\{2R_\infty\}$<br>$4.556\,335\,2672(54)\times10^{-8}$ |
| 1 Hz = | $\{h/k\}$<br>$4.799\,216(41)\times10^{-11}$ | $\{h/e\}$<br>$4.135\,6692(12)\times10^{-15}$ | $\{h/m_u c^2\}$<br>$4.439\,822\,24(40)\times10^{-24}$ | $1/\{2R_\infty c\}$<br>$1.519\,829\,8508(18)\times10^{-16}$ |
| 1 K = | 1 | $\{k/e\}$<br>$8.617\,385(73)\times10^{-5}$ | $\{k/m_u c^2\}$<br>$9.251\,140(78)\times10^{-14}$ | $\{k/2R_\infty hc\}$<br>$3.166\,829(27)\times10^{-6}$ |
| 1 eV = | $\{e/k\}$<br>$11\,604.45(10)$ | 1 | $\{e/m_u c^2\}$<br>$1.073\,543\,85(33)\times10^{-9}$ | $\{e/2R_\infty hc\}$<br>$0.036\,749\,309(11)$ |
| 1 u = | $\{m_u c^2/k\}$<br>$1.080\,9478(91)\times10^{13}$ | $\{m_u c^2/c\}$<br>$931.494\,32(28)\times10^{6}$ | 1 | $\{m_u c/2R_\infty h\}$<br>$3.423\,177\,25(31)\times10^{7}$ |
| 1 hartree = | $\{2R_\infty hc/k\}$<br>$3.157\,733(27)\times10^{5}$ | $\{2R_\infty hc/e\}$<br>$27.211\,3961(81)$ | $\{2R_\infty h/m_u c\}$<br>$2.921\,262\,69(26)\times10^{-8}$ | 1 |