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A Concise Summary of

Quantities, Units and Symbols in Physical Chemistry

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This list is intended as a ready reference to the symbols most frequently used by authors, teachers and students in chemistry and related disciplines. It is based on the more comprehensive second printing of the third edition of the IUPAC Green Book, "Quantities, Units and Symbols in Physical Chemistry", see References at the end of this document.

1 SI Base Units and Physical Quantities

A *physical quantity*, Q, is a product of a *numerical value* $\{Q\}$ and a *unit* $[Q]$, $Q = \{Q\} \cdot [Q]$. Physical quantities are organized in the International System of Units (SI) which is based on seven base units, listed below, having the same dimension as the associated physical quantities. The symbol for a physical quantity is a single letter of the Latin or Greek alphabet printed in italic (sloping) type. It may be modified by one or more subscripts and superscripts of specified meaning, or by information contained in parentheses. Symbols for units should be printed in Roman (upright) type. Neither symbol should be followed by a full stop (period). The physical quantity *amount of substance* is proportional to the number of specified elementary entities of a substance; the elementary entities may be chosen as convenient, not necessarily as physical real individual entities (e.g. atoms, molecules, ions, other particles or groups of particles). The proportionality factor is the reciprocal of the Avogadro constant N_A. The *amount of substance* should not be called 'number of moles'.

Examples for relations between *amount of substance* and other physical quantities (numerical values are approximate): 2 moles of N_2 contain 12.044×10^{23} molecules of N_2, the amount of N_2 equals the number of N_2 molecules divided by N_A; the mass of 1.5 moles of Hg_2Cl_2 is 708.13 g; 1 mole of photons with frequency 10^{14} Hz has an energy of 39.90 kJ; 1 mole of electrons contain 6.022×10^{23} electrons, has a mass of 5.485×10^{-7} kg and a charge of −96.48 kC.

Base Quantity		*SI Base Unit*		
Name	*Symbol*	*Name*	*Symbol*	*Dimension*
length	l	metre	m	L
mass	m	kilogram	kg	M
time	t	second	s	T
electric current	I	ampere	A	I
thermodynamic temperature	T	kelvin	K	Θ
amount of substance	n	mole	mol	N
luminous intensity	I_v	candela	cd	J

2 Important Quantities with SI Derived Units and Their Special Names and Symbols

Derived quantity	*SI derived unit* Name	*Symbol*	*in terms of SI base units*	
plane angle	radian	rad	m m^{-1}	= 1
solid angle	steradian	sr	m^2 m^{-2}	= 1
frequency	hertz	Hz	s^{-1}	
force	newton	N	m kg s^{-2}	
pressure, stress	pascal	Pa	N m^{-2}	= m^{-1} kg s^{-2}
energy, work, heat	joule	J	N m	= m^2 kg s^{-2}
power, radiant flux	watt	W	J s^{-1}	= m^2 kg s^{-3}
electric charge	coulomb	C	A s	
electric potential	volt	V	J C^{-1}	= m^2 kg s^{-3} A^{-1}
electric resistance	ohm	Ω	V A^{-1}	= m^2 kg s^{-3} A^{-2}
electric conductance	siemens	S	Ω^{-1}	= m^{-2} kg^{-1} s^3 A^2
electric capacitance	farad	F	C V^{-1}	= m^{-2} kg^{-1} s^4 A^2
magnetic flux	weber	Wb	V s	= m^2 kg s^{-2} A^{-1}
magnetic flux density	tesla	T	Wb m^{-2}	= kg s^{-2} A^{-1}
inductance	henry	H	V A^{-1} s	= m^2 kg s^{-2} A^{-2}
Celsius temperature	degree Celsius	°C	K	
luminous flux	lumen	lm	cd sr	= cd
illuminance	lux	lx	lm m^{-2}	= cd m^{-2}
activity, (radioactivity)	becquerel	Bq	s^{-1}	
absorbed dose, kerma	gray	Gy	J kg^{-1}	= m^2 s^{-2}
dose equivalent	sievert	Sv	J kg^{-1}	= m^2 s^{-2}
catalytic activity	katal	kat	mol s^{-1}	

rad and sr are derived units of dimension one (dimensionless). In practice, rad and sr may be used or omitted when appropriate and clarity is not lost. rad s^{-1} or simply s^{-1} is the unit for angular frequency or angular velocity, this may *not* be replaced with Hz.

The Celsius temperature t with unit °C is defined by $t/°C = T/K - 273.15$.

The katal should replace the '(enzyme) unit U', with 1 U = 1 μmol min^{-1} ≈ 16.67 nkat.

3 SI Prefixes

The prefixes are used to form names and symbols of decimal multiples and submultiples of SI units. Their symbols shall be printed in Roman type without space between prefix and unit symbol. Prefixes shall never be used by their own or combined.

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

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4 Recommended Symbols for Commonly Used Physical Quantities

Several physical quantities have more than one entry in the symbol column for different reasons: (1) The listed symbols are all in use (e.g. $p, (P)$ for pressure and Q, q for heat), but symbols in parentheses are not recommended. (2) Different symbols are used for the same physical quantity in different physical systems (e.g. electron spin quantum number s for a single electron or S for a collection of electrons). (3) Alternative symbols are recommended to avoid conflict in the notation for quantities which otherwise would have the same symbols (e.g. E_a to distinguish the energy of activation from another energy E in the same context). The unit 1 in the SI unit column signifies a dimensionless quantity. A quantity that is additive for independent, non-interacting subsystems is called *extensive*; examples are mass m, volume V, Gibbs energy G. When the symbol for the extensive quantity is a capital letter, the symbol used for the *specific* (meaning *divided by mass*) quantity is often the corresponding lower case letter (e.g. specific volume $v = V/m$). A subscript m on the symbol for the extensive quantity denotes the corresponding *molar* (meaning *divided by amount of substance*) quantity (e.g. molar volume $V_\mathrm{m} = V/n$). The subscript m may be omitted when there is no risk of ambiguity.
Subscripts and superscripts are printed in Roman type except when they are symbols for physical quantities. Symbols for units, numbers, labels, chemical elements, elementary particles, mathematical operators and irreducible representations of points groups are printed in Roman type. Vectors are printed in bold-faced italic type; they can alternatively be indicated by an arrow above the symbol.

4.1 Space and Time

Physical Quantity	*Symbol*	*SI unit*
Cartesian space coordinates	$x; y; z$	m
position vector	$\boldsymbol{r}$	m
length	l	m
special symbols:		
height	h	
breadth	b	
thickness	d, δ	
diameter, distance	d	
radius	r	
path length	s	
length of arc	s	
area	A, A_s, S	m^2
volume	$V, (v)$	m^3
plane angle	$\alpha, \beta, \gamma, \vartheta, \varphi$	rad, 1
solid angle	$\Omega, (\omega)$	sr, 1
time, duration	t	s
period	T	s
frequency	ν, f	Hz, s^{-1}
angular frequency	ω	rad s^{-1}, s^{-1}
characteristic time interval, relaxation time, time constant	τ, T	s
angular velocity	ω	rad s^{-1}, s^{-1}
velocity	$\boldsymbol{v}, \boldsymbol{u}, \boldsymbol{w}, \boldsymbol{c}, \dot{\boldsymbol{r}}$	m s^{-1}
speed	$v, u, w, c, \dot{r}$	m s^{-1}
acceleration	$\boldsymbol{a}$	m s^{-2}

4.2 Classical Mechanics

Physical Quantity	*Symbol*	*SI unit*
mass	m	kg
reduced mass	μ	kg
density, mass density	ρ	kg m^{-3}
specific volume	v	m^3 kg^{-1}
momentum	$\boldsymbol{p}$	kg m s^{-1}
angular momentum	$\boldsymbol{L}$	J s
moment of inertia	I, J	kg m^2
force	$\boldsymbol{F}$	N
moment of force, torque	$\boldsymbol{M}, (\boldsymbol{T})$	N m
energy	E	J
potential energy	E_p, V, Φ	J
kinetic energy	E_k, T, K	J
work	W, A, w	J
power	P	W
generalized coordinate	q	(varies)
generalized momentum	p	(varies)
Lagrange function	L	J
Hamilton function	H	J
action	S	J s
pressure	$p, (P)$	Pa, N m^{-2}
surface tension	γ, σ	N m^{-1}, J m^{-2}
weight	$G, (W, P)$	N
gravitational constant	G	N m^2 kg^{-2}

4.3 General Chemistry

Physical Quantity	*Symbol*	*SI unit*
number of entities	N	1
amount of substance, amount, (chemical amount)	n	mol
Avogadro constant	N_A, L	mol^{-1}
mass of atom, atomic mass	m_a, m	kg
mass of entity	m, m_f	kg
atomic mass constant	m_u	kg
molar mass	M	kg mol^{-1}
molar mass constant	M_u	g mol^{-1}
relative molecular mass, (relative molar mass, molecular weight)	M_r	1
relative atomic mass, (atomic weight)	A_r	1
molar volume	V_m	m^3 mol^{-1}
mass fraction	w	1
volume fraction	ϕ	1
mole fraction, amount-of-substance fraction, amount fraction	x, y	1
(total) pressure	$p, (P)$	Pa
partial pressure of B	p_B	Pa
mass concentration	γ, ρ	kg m^{-3}
number concentration	C, n	m^{-3}
(amount) concentration	c, [B]	mol m^{-3}
molality	m, b	mol kg^{-1}
surface concentration	Γ	mol m^{-2}
stoichiometric number	ν	1
extent of reaction, advancement	ξ	mol

4.4 Chemical Kinetics

Physical Quantity	*Symbol*	*SI unit*
rate of change		
of quantity X	$\dot{X}$	$[X]$ s^{-1}
of concentration of B (chemical reaction)	$r_\mathrm{B}, v_\mathrm{B}$	mol m^{-3} s^{-1}
rate of conversion	$\dot{\xi}$	mol s^{-1}
rate of reaction based on		
amount concentration	v, v_c	mol m^{-3} s^{-1}
number concentration, (reaction rate)	v, v_C	m^{-3} s^{-1}
overall order of reaction	m, n	1
rate constant (coefficient)	$k, k(T)$	$(\mathrm{m}^3\ \mathrm{mol}^{-1})^{m-1}$ s^{-1}
half life	$t_{1/2}$	s
(Arrhenius) activation energy	$E_\mathrm{A}, E_\mathrm{a}$	J mol^{-1}
standard enthalpy of activation	$\Delta^{\ddagger}H^{\ominus}$	J mol^{-1}
pre-exponential factor, frequency factor	A	$(\mathrm{m}^3\ \mathrm{mol}^{-1})^{m-1}$ s^{-1}
collision cross section	σ	m^2
collision frequency	$z_\mathrm{A}(\mathrm{A})$	s^{-1}
collision frequency factor	z_AB	m^3 mol^{-1} s^{-1}
quantum yield	Φ, ϕ	1

4.5 Atoms, Molecules and Spectroscopy

Physical Quantity	*Symbol*	*SI unit*
number:		
nucleon, mass	A	1
proton, atomic	Z	1
neutron	N	1
electroweak charge	Q_W	1
decay (rate) constant	λ, k	s^{-1}
ionization energy	E_i, I	J
electron affinity	E_{ea}, A	J
dissociation energy	E_d, D	J
quantum number:		
principal	n	1
electron orbital	l, L	1
-component	m_l, M_L	1
electron spin	s, S	1
-component	m_s, M_S	1
total angular momentum	J, F, N	1
-component	M_J, M_F, M_N	1
nuclear spin	I	1
-component	M_I	1
vibrational	v	1
internal vibrational	l, j, π	1
magnetic dipole moment	$\boldsymbol{m}, \boldsymbol{\mu}$	A m^2, J T^{-1}
gyromagnetic ratio	γ	s^{-1} T^{-1}
nuclear g-factor	g_N	1
Larmor angular frequency	ω_L	s^{-1}
quadrupole moment	$\boldsymbol{Q}; \boldsymbol{\Theta}$	C m^2
wavelength	λ	m
transition wavenumber	$\tilde{\nu}$	m^{-1}
total term	T	m^{-1}
electronic term	T_e	m^{-1}
vibrational term	G	m^{-1}
rotational term	F	m^{-1}
rotational constants		
in wavenumber	$\tilde{A}; \tilde{B}; \tilde{C}$	m^{-1}
in frequency	$A; B; C$	Hz

4.6 Electricity and Magnetism

Physical Quantity	*Symbol*	*SI unit*
electric current	I, i	A
electric current density	$\boldsymbol{j}, \boldsymbol{J}$	A m^{-2}
electric charge	Q	C
charge density	ρ	C m^{-3}
electric potential	V, ϕ	V, J C^{-1}
electric potential difference, electric tension	$U, \Delta V, \Delta\phi$	V
electric field strength	$\boldsymbol{E}$	V m^{-1}
electric displacement	$\boldsymbol{D}$	C m^{-2}
capacitance	C	F, C V^{-1}
permittivity	ε	F m^{-1}
relative permittivity	ε_r	1
dielectric polarization	$\boldsymbol{P}$	C m^{-2}
electric susceptibility	χ_e	1
electric dipole moment	$\boldsymbol{p}, \boldsymbol{\mu}$	C m
magnetic flux density	$\boldsymbol{B}$	T
magnetic flux	Φ	Wb
magnetic field strength	$\boldsymbol{H}$	A m^{-1}
permeability	μ	N A^{-2}, H m^{-1}
relative permeability	μ_r	1
magnetization	$\boldsymbol{M}$	A m^{-1}
magnetic susceptibility	$\chi, \kappa, (\chi_m)$	1
molar magnetic susceptibility	χ_m	m^3 mol^{-1}
electric resistance	R	Ω
conductance	G	S
resistivity	ρ	Ω m
conductivity	κ, γ, σ	S m^{-1}
self-inductance	L	H, V s A^{-1}
magnetic vector potential	$\boldsymbol{A}$	Wb m^{-1}
Poynting vector	$\boldsymbol{S}$	W m^{-2}

4.7 (Statistical) Thermodynamics

Physical Quantity	*Symbol*	*SI unit*
heat	Q, q	J
work	W, w	J
internal energy	U	J
enthalpy	H	J
temperature		
thermodynamic	$T, (\Theta)$	K
International	T_{90}	K
Celsius	θ, t	°C
entropy	S	J K^{-1}
Helmholtz energy	A, F	J
Gibbs energy	G	J
heat capacity	C_p, C_V	J K^{-1}
ratio C_p/C_V	$\gamma, (\kappa)$	1
Joule-Thomson coefficient	μ, μ_{JT}	K Pa^{-1}
compressibility	κ	Pa^{-1}
cubic expansion coefficient	α, α_V, γ	K^{-1}
chemical potential	μ	J mol^{-1}
standard reaction Gibbs energy	$\Delta_r G^{\circ}$	J mol^{-1}
affinity of reaction	$A, \mathcal{A}$	J mol^{-1}
fugacity	$f, \tilde{p}$	Pa
fugacity coefficient	ϕ	1
Henry's law constant	k_H	Pa
(relative) activity	a	1
activity coefficient		
referenced to Raoult's law	f	1
referenced to Henry's law		
molality basis	γ_m	1
concentration basis	γ_c	1
mole fraction basis	γ_x	1
osmotic coefficient,		
molality basis	ϕ_m	1
mole fraction basis	ϕ_x	1
osmotic pressure	Π	Pa
reaction quotient	Q	1
equilibrium constant,		
standard	K°, K	1
pressure basis	K_p	Pa$^{\Sigma\nu_B}$
concentration basis	K_c	(mol m^{-3})$^{\Sigma\nu_B}$
molality basis	K_m	(mol kg^{-1})$^{\Sigma\nu_B}$
density of states	$\rho(E, J, \cdots)$	J^{-1}
statistical weight, degeneracy	g, d, W, ω, β	1
partition function,		
single molecule	q, z	1
canonical ensemble, (system, assembly)	Q, Z	1
microcanonical	Ω, z, Z	1
grand canonical	Ξ	1
symmetry number	σ, s	1
characteristic temperature	Θ, θ	K

4.8 Electrochemistry

Physical Quantity	*Symbol*	*SI unit*
charge number of an ion	z	1
electrode potential	E, U	V
standard	E°	V
cell potential	E_{cell}	V
electrochemical potential	$\tilde{\mu}_B{}^{\alpha}$	J mol^{-1}
overpotential	η, E_η	V
mean ionic		
activity	$a_\pm$	1
activity coefficient	$\gamma_\pm$	1
molality	$m_\pm$	mol kg^{-1}
concentration	$c_\pm$	mol m^{-3}
ionic strength,		
molality basis	I_m, I	mol kg^{-1}
concentration basis	I_c, I	mol m^{-3}
pH	pH	1
electron number of an electrochemical reaction	z, n	1
electrokinetic potential	ζ	V
molar ionic conductivity	λ	S m^2 mol^{-1}
molar conductivity	Λ	S m^2 mol^{-1}
transport number	t	1
electric mobility	$u, (m)$	m^2 V^{-1} s^{-1}

4.9 Electromagnetic Radiation

Physical Quantity	*Symbol*	*SI unit*
radiant energy	Q, W	J
radiant intensity	I_e	W sr^{-1}
emissivity, emittance	ε	1
absorptance	α	1
reflectance	ρ, R	1
transmittance	τ, T	1
absorption coefficient,		
(linear) decadic	a, K	m^{-1}
(linear) napierian	α	m^{-1}
molar (decadic)	ε	m^2 mol^{-1}
molar napierian	κ	m^2 mol^{-1}
refractive index	n	1
molar refraction	R	m^3 mol^{-1}
angle of optical rotation	α	1, rad
absorbance (decadic)	A_{10}	1
absorbance (napierian)	A_e	1
net absorption cross section	σ_{net}	m^2
absorption cross section (integrated net)	G_{net}	m^2

4.10 Transport Properties

Physical Quantity	*Symbol*	*SI unit*
flux of mass m	q_m	kg s^{-1}
heat flux	Φ, P	W
heat flux density	J_q	W m^{-2}
flux density of mass	J_m	kg m^{-2} s^{-1}
thermal conductivity	λ, k	W m^{-1} K^{-1}
coefficient of heat transfer	$h, (k, K, \alpha)$	W m^{-2} K^{-1}
thermal diffusivity	a	m^2 s^{-1}
diffusion coefficient	D	m^2 s^{-1}
thermal diffusion coefficient	D^T	m^2 K^{-1} s^{-1}
viscosity	η	Pa s
kinematic viscosity	ν	m^2 s^{-1}

5 Units Outside the SI

5.1 Units Accepted for Use With the SI

The following units are not part of the SI; it is recognized by the CGPM that they will continue to be used in appropriate contexts.

Physical Quantity	*Unit*	*Symbol*	*Value in SI Units*
time	minute	min	60 s
time	hour	h	3600 s
time	day	d	86 400 s
plane angle	degree	°, deg	(π/180) rad
volume	litre	l, L	10^{-3} m^3
mass	tonne	t	10^3 kg
energy	electronvolt	eV	1.602 18×10^{-19} J
mass	dalton, unified atomic mass unit	Da, u	1.660 54×10^{-27} kg
length	nautical mile	M	1852 m
	astronomical unit	ua	1.495 98×10^{11} m

5.2 Other Units

These units are still used in older literature although their use is strongly discouraged. They are listed here only to facilitate their identification and conversion to SI units.

Physical Quantity	*Unit*	*Symbol*	*Value in SI Units*
length	ångström	Å	10^{-10} m
force	dyne	dyn	10^{-5} N
pressure	standard atmosphere	atm	101 325 Pa
	torr (mmHg)	Torr	133.322 Pa
energy	erg	erg	10^{-7} J
	calorie, thermochemical	cal$_{th}$	4.184 J
magnetic flux density	gauss	G	10^{-4} T
electric dipole moment	debye	D	3.335 64×10^{-30} C m
viscosity	poise	P	10^{-1} N s m^{-2}
kinematic viscosity	stokes	St	10^{-4} m^2 s^{-1}

6 Values of Some Fundamental Constants

Physical Quantity	*Symbol*	*Value in SI Units*
speed of light*	c_0, c	299 792 458 m s^{-1}
constant:		
atomic mass	m_u	1.660 538 782(83)×10^{-27} kg
electric	ε_0	8.854 187 817... ×10^{-12} F m^{-1}
fine-structure α	α^{-1}	137.035 999 676(94)
first radiation	c_1	3.741 771 18(19)×10^{-16} W m^2
standard acceleration*	g_n	9.806 65 m s^{-2}
magnetic*	μ_0	4π×10^{-7} H m^{-1}
molar gas	R	8.314 472(15) J K^{-1} mol^{-1}
second radiation	c_2	1.438 775 2(25)×10^{-2} m K
Avogadro	N_A, L	6.022 141 79(30)×10^{23} mol^{-1}
Boltzmann	k, k_B	1.380 650 4(24)×10^{-23} J K^{-1}
Faraday	F	9.648 533 99(24)×10^4 C mol^{-1}
Fermi coupling	G_F	1.166 37(1)×10^{-5} GeV^{-2}
Planck	h	6.626 068 96(33)×10^{-34} J s
Rydberg	R_∞	1.097 373 156 852 7(73)×10^7 m^{-1}
Stefan-Boltzmann	σ	5.670 400(40)×10^{-8} W m^{-2} K^{-4}
weak mixing angle θ_W	$\sin^2\theta_W$	0.222 55(56)
elementary charge	e	1.602 176 487(40)×10^{-19} C
electron mass	m_e	9.109 382 15(45)×10^{-31} kg
proton mass	m_p	1.672 621 637(83)×10^{-27} kg
neutron mass	m_n	1.674 927 211(84)×10^{-27} kg
Celsius scale zero*		273.15 K
triple point (H_2O)*		273.16 K
molar volume (ideal gas, t = 0 °C)	V_m	
p = 100 kPa		22.710 981(40) dm^3 mol^{-1}
p = 101.325 kPa		22.413 996(39) dm^3 mol^{-1}
Bohr radius	a_0	5.291 772 085 9(36)×10^{-11} m
Hartree energy	E_h	4.359 743 94(22)×10^{-18} J
Bohr magneton	μ_B	9.274 009 15(23)×10^{-24} J T^{-1}
nuclear magneton	μ_N	5.050 783 24(13)×10^{-27} J T^{-1}

* Those quantities are defined and therefore have no errors.

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