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**MANUAL OF
SYMBOLS AND TERMINOLOGY
FOR PHYSICOCHEMICAL QUANTITIES
AND UNITS**

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PREFACE

The Commission on Symbols, Terminology, and Units is a part of the Division of Physical Chemistry of the International Union of Pure and Applied Chemistry. Its general responsibilities are to secure clarity and precision, and wider agreement in the use of symbols, by chemists in different countries, among physicists, chemists, and engineers, and by editors of scientific journals. In pursuing these aims, liaison is maintained with other international organizations and in particular with the Commission on Symbols, Units and Nomenclature of the International Union of Pure and Applied Physics (SUN Commission) and Technical Committee 12 of the International Organization for Standardization (ISO/TC 12). References to the publications of these organizations are given in 13.1 and 13.2 of this Manual. These publications may be referred to for more extended coverage of symbols for quantities, and related information, not commonly used by chemists. The recommendations presented here are generally in agreement with those of the SUN Commission and ISO/TC 12.

The present publication supersedes the Commission's publication of 1959 (Reference 13.3) in English and French and its translations into other languages.

M. L. MCGLASHAN
Chairman

Commission on Symbols, Terminology, and Units

Department of Chemistry
University of Exeter
Exeter
August 1969

Preface to 1973 Edition

The text of the 1969 edition of this Manual has been revised to take account of recent decisions by the Comité International des Poids et Mesures concerning use of the International System of Units, summarized in the document, 'Le Système International d'Unités (SI)', published by the Bureau International des Poids et Mesures in a second edition in 1973 (translations of this document into English have been prepared jointly and published separately by the National Physical Laboratory, UK, and the National Bureau of Standards, USA). Section 2.8 of the Manual has been revised in collaboration with IUPAC's Commission on Molecular Structure and Spectroscopy. Attention is called also to separate publication by IUPAC of an Appendix entitled, 'Definitions, Terminology, and Symbols in Colloid and Surface Chemistry—I', prepared by the Commission on Colloid and Surface Chemistry. References to the publications cited are included in Section 13.

M. A. PAUL
Chairman

Commission on Symbols, Terminology, and Units

National Academy of Sciences
Washington, DC
October 1973

2. RECOMMENDED NAMES AND SYMBOLS FOR QUANTITIES IN CHEMISTRY AND PHYSICS

The following list contains the recommended symbols for the most important quantities likely to be used by chemists. Whenever possible the symbol used for a physical quantity should be that recommended. In a few cases where conflicts were foreseen alternative recommendations have been made. Bold-faced italic (sloping) as well as ordinary italic (sloping) type can also sometimes be used to resolve conflicts. Further flexibility can be obtained by the use of capital letters as variants for lower-case letters, and *vice versa*, when no ambiguity is thereby introduced.

For example, d and D may be used instead of d_i and d_o for internal and external diameter in a context in which no quantity appears, such as diffusion coefficient, for which the recommended symbol is D . Again, the recommended symbol for power is P and for pressure is p or P , but P and p may be used for two powers or for two pressures; if power and pressure appear together, however, P should be used only for power and p only for pressure, and necessary distinctions between different powers or between different pressures should be made by the use of subscripts or other modifying signs.

When the above recommendations are insufficient to resolve a conflict or where a need arises for other reasons, an author is of course free to choose an *ad hoc* symbol. Any *ad hoc* symbol should be particularly carefully defined.

In the following list, where two or more symbols are indicated for a given quantity and are separated only by commas (without parentheses), they are on an equal footing; symbols within parentheses are reserve symbols.

Any description given after the name of a physical quantity is merely for identification and is not intended to be a complete definition.

Vector notation (bold-faced italic or sloping type) is used where appropriate in Section 2.6; it may be used when convenient also for appropriate quantities in other Sections.

2.1 Space, time, and related quantities

2.1.01	length	l
2.1.02	height	h
2.1.03	radius	r
2.1.04	diameter	d
2.1.05	path, length of arc	s
2.1.06	wavelength	λ
2.1.07	wavenumber: $1/\lambda$	$\sigma^{(1)}, \tilde{\nu}^{(2)}$
2.1.08	plane angle	$\alpha, \beta, \gamma, \theta, \phi$
2.1.09	solid angle	ω, Ω
2.1.10	area	$A, S, A_s^{(3)}$
2.1.11	volume	V
2.1.12	time	t
2.1.13	frequency	ν, f
2.1.14	circular frequency: $2\pi\nu$	ω

(1) In solid-state studies, wavevector \mathbf{k} is used ($|\mathbf{k}| = 2\pi/\lambda$).

(2) For electromagnetic radiation referred to a vacuum $\tilde{\nu} = \nu/c = 1/\lambda_{\text{vac}}$ is preferred.

(3) The symbol A_s may be used when necessary to avoid confusion with the symbol A for Helmholtz energy.

2.1.15	period: $1/\nu$	T
2.1.16	characteristic time interval, relaxation time, time constant	τ
2.1.17	velocity	v, u, w, c
2.1.18	angular velocity: $d\phi/dt$	ω
2.1.19	acceleration	a
2.1.20	acceleration of free fall	g

2.2 Mechanical and related quantities

2.2.01	mass	m
2.2.02	reduced mass	μ
2.2.03	specific volume (volume divided by mass)	v
2.2.04	density (mass divided by volume)	ρ
2.2.05	relative density (ratio of the density to that of a reference substance)	d
2.2.06	moment of inertia	I
2.2.07	momentum	p
2.2.08	force	F
2.2.09	weight	$G, (W)$
2.2.10	moment of force	M
2.2.11	angular momentum	L
2.2.12	work (force times path)	w, W
2.2.13	energy	E
2.2.14	potential energy	E_p, V, Φ
2.2.15	kinetic energy	E_k, T, K
2.2.16	Hamiltonian function	H
2.2.17	Lagrangian function	L
2.2.18	power (energy divided by time)	P
2.2.19	pressure	$p, (P)$
2.2.20	normal stress	σ
2.2.21	shear stress	τ
2.2.22	linear strain (relative elongation): $\Delta l/l_0$	ϵ, e
2.2.23	volume strain (bulk strain): $\Delta V/V_0$	θ
2.2.24	modulus of elasticity (normal stress divided by linear strain, Young's modulus)	E
2.2.25	shear modulus (shear stress divided by shear angle)	G
2.2.26	compressibility: $-V^{-1}(dV/dp)$	κ
2.2.27	compression (bulk) modulus: $-V_0(\Delta p/\Delta V)$	K
2.2.28	velocity of sound	c
2.2.29	viscosity	$\eta, (\mu)$
2.2.30	fluidity: $1/\eta$	ϕ
2.2.31	kinematic viscosity: η/ρ	ν
2.2.32	friction coefficient (frictional force divided by normal force)	$\mu, (f)$
2.2.33	surface tension	γ, σ
2.2.34	angle of contact	θ
2.2.35	diffusion coefficient	D
2.2.36	mass transfer coefficient (dimension of length divided by time)	k_d

2.3 Molecular and related quantities

2.3.01	relative atomic mass of an element (formerly called 'atomic weight') ⁽¹⁾	A_r
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⁽¹⁾ The ratio of the average mass per atom of an element to 1/12 of the mass of an atom of nuclide ^{12}C .

Example: $A_r(\text{Cl}) = 35.453$

2.3.02	relative molecular mass of a substance (formerly called 'molecular weight') ⁽¹⁾	M_r
2.3.03	molar mass (mass divided by amount of substance)	M
2.3.04	Avogadro constant	L, N_A
2.3.05	number of molecules or other entities	N
2.3.06	amount of substance ⁽²⁾	$n, (\nu)$
2.3.07	mole fraction of substance B: $n_B/\sum_i n_i$	x_B, y_B
2.3.08	mass fraction of substance B	w_B
2.3.09	volume fraction of substance B	ϕ_B
2.3.10	molality of solute substance B (amount of B divided by mass of solvent) ⁽³⁾	m_B
2.3.11	amount-of-substance concentration of substance B (amount of B divided by the volume of the solution) ⁽⁴⁾	$c_B, [B]$
2.3.12	mass concentration of substance B (mass of B divided by the volume of the solution)	ρ_B
2.3.13	surface concentration, surface excess	Γ
2.3.14	collision diameter of a molecule	d, σ
2.3.15	mean free path	l, λ
2.3.16	collision number (number of collisions divided by volume and by time)	Z
2.3.17	grand partition function (system)	Ξ
2.3.18	partition function (system)	Q, Z
2.3.19	partition function (particle)	q, z
2.3.20	statistical weight	g
2.3.21	symmetry number	σ, s
2.3.22	characteristic temperature	Θ

2.4 Thermodynamic and related quantities

2.4.01	thermodynamic temperature, absolute temperature	T
2.4.02	Celsius temperature	$t, \theta^{(5)}$
2.4.03	(molar) gas constant	R
2.4.04	Boltzmann constant	k
2.4.05	heat	$q, Q^{(6)}$
2.4.06	work	$w, W^{(6)}$
2.4.07	internal energy	$U, (E)$
2.4.08	enthalpy: $U + pV$	H
2.4.09	entropy	S
2.4.10	Helmholtz energy: $U - TS$	A
2.4.11	Massieu function: $-A/T$	J
2.4.12	Gibbs energy: $H - TS$	G
2.4.13	Planck function: $-G/T$	Y
2.4.14	compression factor: pV_m/RT	Z
2.4.15	heat capacity	C
2.4.16	specific heat capacity (heat capacity divided by mass; the name 'specific heat' is not recommended)	c

⁽¹⁾ The ratio of the average mass per formula unit of a substance to 1/12 of the mass of an atom of nuclide ^{12}C .

Example: $M_r(\text{KCl}) = 74.555$

⁽²⁾ See Section 1.2.

⁽³⁾ A solution having a molality equal to 0.1 mol kg⁻¹ is sometimes called a 0.1 molal solution or a 0.1 m solution.

⁽⁴⁾ This quantity may be simply called 'concentration' when there is no risk of ambiguity. A solution with an amount-of-substance concentration of 0.1 mol dm⁻³ is often called a 0.1 molar solution or a 0.1 M solution.

⁽⁵⁾ Where symbols are needed to represent both time and Celsius temperature, t is the preferred symbol for time and θ for Celsius temperature.

⁽⁶⁾ It is recommended that $q > 0$ and $w > 0$ both indicate *increase* of energy of the system under discussion. Thus $\Delta U = q + w$.

2.4.17	ratio C_p/C_V	$\gamma, (\kappa)$
2.4.18	Joule-Thomson coefficient	μ
2.4.19	thermal conductivity	λ, k
2.4.20	thermal diffusivity: $\lambda/\rho C_p$	a
2.4.21	coefficient of heat transfer (density of heat flow rate divided by temperature difference)	h
2.4.22	cubic expansion coefficient: $V^{-1}(\partial V/\partial T)_p$	α
2.4.23	isothermal compressibility: $-V^{-1}(\partial V/\partial p)_T$	κ
2.4.24	pressure coefficient: $(\partial p/\partial T)_V$	β
2.4.25	chemical potential of substance B	μ_B
2.4.26	absolute activity of substance B: $\exp(\mu_B/RT)$	λ_B
2.4.27	fugacity	f, \bar{p}
2.4.28	osmotic pressure	Π
2.4.29	ionic strength: $(I_m = \frac{1}{2}\sum_i m_i z_i^2 \text{ or } I_c = \frac{1}{2}\sum_i c_i z_i^2)$	I
2.4.30	activity, relative activity of substance B	a_B
2.4.31	activity coefficient, mole fraction basis	f_B
2.4.32	activity coefficient, molality basis	γ_B
2.4.33	activity coefficient, concentration basis	γ'_B
2.4.34	osmotic coefficient	ϕ

2.5 Chemical reactions

2.5.01	stoichiometric coefficient of substance B (negative for reactants, positive for products)	ν_B
2.5.02	general equation for a chemical reaction	$0 = \sum_B \nu_B B$
2.5.03	extent of reaction: $(d\xi = dn_B/\nu_B)$	ξ
2.5.04	rate of reaction: $d\xi/dt$ (see Section 11)	$\dot{\xi}, J$
2.5.05	rate of increase of concentration of substance B: dc_B/dt	v_B, r_B
2.5.06	rate constant	k
2.5.07	affinity of a reaction: $-\sum_B \nu_B \mu_B$	$A, (\mathcal{A})$
2.5.08	equilibrium constant	K
2.5.09	degree of dissociation	α

2.6 Electricity and magnetism

2.6.01	elementary charge (of a proton)	e
2.6.02	quantity of electricity	Q
2.6.03	charge density	ρ
2.6.04	surface charge density	σ
2.6.05	electric current	I
2.6.06	electric current density	j
2.6.07	electric potential	V, ϕ
2.6.08	electric potential difference: IR	$U, \Delta V, \Delta \phi$
2.6.09	electric field strength	E
2.6.10	electric displacement	D
2.6.11	capacitance	C
2.6.12	permittivity: $(D = \epsilon E)$	ϵ
2.6.13	permittivity of vacuum	ϵ_0
2.6.14	relative permittivity ⁽¹⁾ : ϵ/ϵ_0	$\epsilon_r, (\epsilon)$
2.6.15	dielectric polarization: $D - \epsilon_0 E$	P
2.6.16	electric susceptibility: $\epsilon_r - 1$	χ_e
2.6.17	electric dipole moment	p, p_e
2.6.18	permanent dipole moment of a molecule	p, μ
2.6.19	induced dipole moment of a molecule	p, p_i
2.6.20	electric polarizability of a molecule	α
2.6.21	magnetic flux	Φ
2.6.22	magnetic flux density, magnetic induction	B
2.6.23	magnetic field strength	H
2.6.24	permeability: $(B = \mu H)$	μ
2.6.25	permeability of vacuum	μ_0

⁽¹⁾ Also called dielectric constant, and sometimes denoted by D , when it is independent of E .

2.6.26	relative permeability: μ/μ_0	μ_r
2.6.27	magnetization: $(\mathbf{B}/\mu_0) - \mathbf{H}$	\mathbf{M}
2.6.28	magnetic susceptibility: $\mu_r - 1$	$\chi, (\chi_m)$
2.6.29.1	Bohr magneton	μ_B
2.6.29.2	nuclear magneton	μ_N
2.6.29.3	<i>g</i> -factor	<i>g</i>
2.6.29.4	gyromagnetic ratio, magnetogyric ratio	γ
2.6.30	electromagnetic moment: $(\mathbf{E}_p = -\mathbf{m} \cdot \mathbf{B})$	\mathbf{m}, μ
2.6.31	resistance	<i>R</i>
2.6.32	resistivity (formerly called specific resistance): ($\mathbf{E} = \rho \mathbf{j}$)	ρ
2.6.33	conductivity (formerly called specific conductance): ($\mathbf{j} = \kappa \mathbf{E}$)	$\kappa, (\sigma)$
2.6.34	self-inductance	<i>L</i>
2.6.35	mutual inductance	<i>M, L</i> ₁₂
2.6.36	reactance	<i>X</i>
2.6.37	impedance (complex impedance): $R + iX$	<i>Z</i>
2.6.38	loss angle	δ
2.6.39	admittance (complex admittance): $1/Z$	<i>Y</i>
2.6.40	conductance: ($Y = G + iB$)	<i>G</i>
2.6.41	susceptance: ($Y = G + iB$)	<i>B</i>

2.7 Electrochemistry

2.7.01	Faraday constant	<i>F</i>
2.7.02	charge number of an ion B (positive for cations, negative for anions)	<i>z</i> _B
2.7.03	charge number of a cell reaction	<i>n, (z)</i>
2.7.04	electromotive force	<i>E, E</i> _{MF}
2.7.05	electrochemical potential of ionic component B: $\mu_B + z_B F \phi$	$\tilde{\mu}_B$
2.7.06	electric mobility (velocity divided by electric field strength)	<i>u, μ</i>
2.7.07	electrolytic conductivity (formerly called specific conductance)	$\kappa, (\sigma)$
2.7.08	molar conductivity of electrolyte or ion ⁽¹⁾ : κ/c	<i>A, λ</i> ⁽²⁾
2.7.09	transport number (transference number or migration number)	<i>t</i>
2.7.10	overpotential	η
2.7.11	exchange current density	<i>j</i> ₀
2.7.12	electrochemical transfer coefficient	<i>α</i>
2.7.13	electrokinetic potential (zeta potential)	ζ
2.7.14	thickness of diffusion layer	δ
2.7.15	inner electric potential	ϕ
2.7.16	outer electric potential	ψ
2.7.17	surface electric potential difference: $\phi - \psi$	χ

⁽¹⁾ The word molar, contrary to the general rule given in Section 1.4, here means 'divided by amount-of-substance concentration'.

⁽²⁾ The formula unit whose concentration is *c* must be specified.

Example: $\lambda(\text{Mg}^{2+}) = 2\lambda(\frac{1}{2}\text{Mg}^{2+})$

A is used for an electrolyte and *λ* for individual ions.

2.8 Light and related electromagnetic radiation ⁽¹⁾

2.8.01	Planck constant	h
2.8.02	Planck constant divided by 2π	\hbar
2.8.03	radiant energy	$Q^{(2)}$
2.8.04	radiant flux, radiant power	$\Phi^{(2)}, P$
2.8.05	radiant intensity: $d\Phi/d\omega$	$I^{(2)}$
2.8.06	radiance: $(dI/dS)/\cos \theta$	$L^{(2)}$
2.8.07	radiant excitance: $d\Phi/dS$	$M^{(2)}$
2.8.08	irradiance: $d\Phi/dS$	$E^{(2)}$
2.8.09	absorptance, absorption-factor ⁽³⁾ (ratio of absorbed to incident radiant or luminous flux)	$\alpha^{(3)}$
2.8.10	reflectance, reflection factor ⁽³⁾ (ratio of reflected to incident radiant or luminous flux)	$\rho^{(3)}, R$
2.8.11	transmittance, transmission factor ⁽³⁾ (ratio of transmitted to incident radiant or luminous flux)	$\tau^{(3)}$
2.8.12	internal transmittance ⁽³⁾ (transmittance of the medium itself, disregarding boundary or container influence)	$\tau_i^{(3)}, T$
2.8.13.1	internal transmission density ⁽³⁾ , (decadic) absorbance ⁽⁴⁾ : $\log_{10}(1/T)$	$D_i^{(3)}, A$
2.8.13.2	Napierian absorbance: $\ln(1/T)$	B
2.8.14.1	(linear) (decadic) absorption coefficient ^(3,4) : A/l	$a^{(3)}, K$
2.8.14.2	Napierian absorption coefficient: B/l	α
2.8.15	absorption index: $B/4\pi\tilde{\nu}l = \alpha/4\pi\tilde{\nu}$	k
2.8.16.1	specific (decadic) absorption coefficient ⁽⁵⁾ : $A/\rho_B l$	$a^{(7,8)}$
2.8.16.2	specific Napierian absorption coefficient ⁽⁵⁾ : $B/\rho_B l$	$\mu^{(7,8)}$
2.8.17.1	molar (decadic) absorption coefficient ^(4,6) : $A/c_B l$	$\epsilon^{(7,8)}$
2.8.17.2	molar Napierian absorption coefficient ⁽⁶⁾ : $B/c_B l$	$\kappa^{(7,8)}$
2.8.18	quantum yield	Φ
2.8.19	exposure: $\int E dt$	H
2.8.20	velocity of light <i>in vacuo</i>	c

⁽¹⁾ References to the symbols used in defining the quantities in 2.8 are as follows:

l	2.1.01	$\tilde{\nu}$	2.1.07	θ	2.1.08	ω	2.1.09
S	2.1.10	V	2.1.11	τ	2.1.12	c_B	2.3.11
ρ_B	2.3.12	Φ	2.8.04	I	2.8.05	E	2.8.08
T	2.8.12	A	2.8.13.1	B	2.8.13.2	α	2.8.14.2
k	2.8.15	n	2.8.21.1				

⁽²⁾ The same symbol is often used also for the corresponding luminous quantity. Subscripts *e* for energetic and *v* for visible may be added whenever confusion between these quantities might otherwise occur.

⁽³⁾ These names and symbols are in agreement with those adopted jointly by the International Commission of Illumination (CIE) and the International Electrotechnical Commission (IEC).

⁽⁴⁾ The terms extinction (for 2.8.13.1) and extinction coefficient (for 2.8.14.1) are unsuitable because extinction is reserved for diffusion of radiation rather than absorption. Molar absorptivity (for 2.8.17.1) should be avoided because the meaning, absorptance per unit length, has been accepted internationally for the term absorptivity.

⁽⁵⁾ The word specific, contrary to the general rule given in Section 1.4, here means 'divided by mass concentration'.

⁽⁶⁾ The word molar, contrary to the general rule given in Section 1.4, here means 'divided by amount-of-substance concentration'.

⁽⁷⁾ For measurements on solutions, $1/T$ is ordinarily replaced by T_0/T where T_0 is the internal transmittance of the solvent medium and T is the internal transmittance of the solution. If a double-beam spectrometer is used in solution spectrometry, T_0/T is given directly, provided the boundary and container influences have been equalized between the two cells; in addition to the physical matching of the sample and reference cells this requires that there be no significant difference between n_{solvent} and n_{solution} .

⁽⁸⁾ For measurements on solutions, it is tacitly assumed that the solution obeys the Beer-Lambert law unless the solute concentration is specified. The temperature should be specified.

2.8.21.1	refractive index (of a non-absorbing material)	n
2.8.21.2	complex refractive index of an absorbing material: $n + ik$	\hat{n}
2.8.22	molar refraction: $(n^2 - 1)V_m/(n^2 + 2)$	R_m
2.8.23	angle of optical rotation	α

2.9 Transport properties⁽¹⁾

2.9.01	Flux (of a quantity X)	J_X, J
2.9.02	Reynolds number: $\rho v l / \eta$	Re
2.9.03	Euler number: $\Delta p / \rho v^2$	Eu
2.9.04	Froude number: $v / (lg)^{1/2}$	Fr
2.9.05	Grashof number: $l^3 g \alpha \Delta \theta \rho^2 / \eta^2$	Gr
2.9.06	Weber number: $\rho v^2 l / \gamma$	We
2.9.07	Mach number: v / c	Ma
2.9.08	Knudsen number: λ / l	Kn
2.9.09	Strouhal number: $l f / v$	Sr
2.9.10	Fourier number: $a \Delta t / l^2$	Fo
2.9.11	Peclet number: vl / a	Pe
2.9.12	Rayleigh number: $l^3 g \alpha \Delta \theta \rho / \eta a$	Ra
2.9.13	Nusselt number: hl / k	Nu
2.9.14	Stanton number: $h / \rho v c_p$	St
2.9.15	Fourier number for mass transfer: Dt / l^2	Fo^*
2.9.16	Peclet number for mass transfer: vl / D	Pe^*
2.9.17	Grashof number for mass transfer: $-l^3 g (\partial \rho / \partial x)_{T,p} \Delta x \rho / \eta^2$	Gr^*
2.9.18	Nusselt number for mass transfer ⁽²⁾ : $k_d l / D$	Nu^*
2.9.19	Stanton number for mass transfer: k_d / v	St^*
2.9.20	Prandtl number: $\eta / \rho a$	Pr
2.9.21	Schmidt number: $\eta / \rho D$	Sc
2.9.22	Lewis number: a / D	Le
2.9.23	Magnetic Reynolds number: $v \mu \kappa l$	Re_m
2.9.24	Alfvén number: $v(\rho \mu)^{1/2} / B$	Al
2.9.25	Hartmann number: $Bl(\kappa / \eta)^{1/2}$	Ha
2.9.26	Cowling number: $B^2 / \mu \rho v^2$	Co

2.10 Symbols for particular cases of physical quantities

It is much more difficult to make detailed recommendations on symbols for physical quantities in particular cases than in general cases. The reason is the incompatibility between the need for specifying numerous details and the need for keeping the printing reasonably simple. Among the most awkward things to print are superscripts to subscripts and subscripts to subscripts. Examples of symbols to be avoided are:

$$\lambda_{\text{NO}_3} \quad \Delta H_{25^\circ\text{C}} \quad (pV)_{\theta=0}^0$$

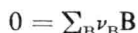
The problem is vastly reduced if it is recognized that two different kinds of notation are required for two different purposes. In the formation of general fundamental relations the most important requirement is a notation that is easy to understand and easy to remember. In applications to particular cases, in quoting numerical values, and in tabulation, the most important requirement is complete elimination of any possible ambiguity even at the cost of an elaborate notation.

The advantage of a dual notation is already to some extent accepted in the

⁽¹⁾ See footnote (1) on page 6.

⁽²⁾ The name Sherwood number, symbol Sh has been widely used.

case of concentration. The recommended notation for the formulation of the equilibrium constant K_c for the general reaction:



is

$$K_c = \prod_B (c_B)^{\nu_B}$$

but when we turn to a particular example it is better to use a notation such as:



$$\frac{[\text{HOBr}][\text{H}^+][\text{Br}^-]}{[\text{Br}_2]} = K_c$$

$$K_c(25^\circ\text{C}) = 6 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$$

Once the principle of dual notation is accepted, its adaptability and usefulness become manifest in all fields of physical chemistry. It will here be illustrated by just a few examples.

The general relation between the molar conductivity of an electrolyte and the molar conductivities of the two ions is written most simply and most clearly as:

$$\Lambda = \lambda^+ + \lambda^-$$

but when it comes to giving values in particular cases a much more appropriate notation is:

$$\lambda(\frac{1}{2}\text{Mg}^{2+}) = 53 \text{ S cm}^2 \text{ mol}^{-1} \text{ at } 25^\circ\text{C}$$

$$\lambda(\text{Cl}^-) = 76 \text{ S cm}^2 \text{ mol}^{-1} \text{ at } 25^\circ\text{C}$$

$$\Lambda(\frac{1}{2}\text{MgCl}_2) = 129 \text{ S cm}^2 \text{ mol}^{-1} \text{ at } 25^\circ\text{C}$$

$$\Lambda(\text{MgCl}_2) = 258 \text{ S cm}^2 \text{ mol}^{-1} \text{ at } 25^\circ\text{C}$$

The general relation between the partial molar volumes of the two components A and B of a binary mixture is written most simply:

$$n_A dV_A + n_B dV_B = 0 \quad (T, p \text{ const.})$$

But when it comes to specifying values, a completely different notation is called for, such as:

$$V(\text{K}_2\text{SO}_4, 0.1 \text{ mol dm}^{-3} \text{ in } \text{H}_2\text{O}, 25^\circ\text{C}) = 48 \text{ cm}^3 \text{ mol}^{-1}$$

Each kind of notation is appropriate to its purpose.

A last example will be given relating to optical rotation. The relations between the angle α of rotation of the plane of polarization and the amount n , or the number N of molecules, of the optically active substance in the path of a light beam of cross-section A can be clearly expressed in the form:

$$\alpha = n\alpha_n/A = N\alpha_N/A$$

where α_n is the molar optical rotatory power and α_N the molecular optical rotatory power. When on the other hand it is desired to record an experimental measurement, an appropriate notation would be:

$$\alpha(589.3 \text{ nm}, 20^\circ\text{C}, \text{sucrose}, 10 \text{ g dm}^{-3} \text{ in } \text{H}_2\text{O}, 10 \text{ cm}) = +66.470^\circ$$

2.11 Recommended superscripts

The following superscripts are recommended:

- ° or * pure substance
- ∞ infinite dilution
- id ideal
- ° or ⊖ standard in general
- ‡ activated complex, transition state

3. UNITS AND SYMBOLS FOR UNITS

3.1 Printing of symbols for units

The symbol for a unit should be printed in roman (upright) type, should remain unaltered in the plural, and should not be followed by a full stop except when it occurs at the end of a sentence in text.

Example: 5 cm but not 5 cms and not 5 cm. and not 5 cms.

The symbol for a unit derived from a proper name should begin with a capital roman (upright) letter.

Examples: J for joule and Hz for hertz

Any other symbol for a unit should be printed in lower case roman (upright) type.

3.2 Printing of prefixes

Symbols for prefixes for units should be printed in roman (upright) type with no space between the prefix and the unit. Compound prefixes should be avoided. (See Section 3.11)

Example: ns but not m μ s for 10^{-9} s

3.3 Combination of prefixes and symbols

A combination of prefix and symbol for a unit is regarded as a single symbol which may be raised to a power without the use of brackets.

Examples: cm² means (cm)² and μ s⁻¹ means (μ s)⁻¹

3.4 Multiplication and division of units

A product of two units may be represented in any of the ways:

$$N\ m \text{ or } N \cdot m \text{ or } N.m \text{ or } N \times m$$

The representation Nm is not recommended.

A quotient of two units may be represented in any of the ways:

$$\frac{m}{s} \text{ or } m/s \text{ or } m\ s^{-1}$$

or in any of the other ways of writing the product of m and s⁻¹.

These rules may be extended to more complex groupings but more than one solidus (/) should never be used in the same expression unless parentheses are used to eliminate ambiguity.

Example: J K⁻¹ mol⁻¹ or J/(K mol) but never J/K/mol

3.5 The International System of Units

The name International System of Units has been adopted by the Conférence Générale des Poids et Mesures for the system of units based on a selected set of dimensionally independent *SI Base Units*.

The SI Base Units are the metre, kilogram, second, ampere, kelvin, candela, and mole. In the International System of Units there is one and only one *SI Unit* for each physical quantity. This is either the appropriate SI Base Unit itself (see Section 3.7) or the appropriate *SI Derived Unit* formed by multiplication and/or division of two or more SI Base Units (see Section 3.10). A few such SI Derived Units have been given special names and symbols (see Section 3.9). There are also two *SI Supplementary Units* for which it is not decided whether they are SI Base Units or SI Derived Units (see Section 3.8).

Any of the approved decimal prefixes, called *SI Prefixes*, may be used to construct decimal multiples or submultiples of SI Units (see Section 3.11).

It is recommended that only units composed of SI Units and SI Prefixes be used in science and technology.

3.6 Definitions of the SI Base Units

metre: The metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

kilogram: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

second: The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

ampere: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

kelvin: The kelvin, unit of thermodynamic temperature, is the fraction $1/273.16$ of the thermodynamic temperature of the triple point of water⁽¹⁾.

candela: The candela is the luminous intensity, in the perpendicular direction, of a surface of $1/600\,000$ square metre of a black body at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre.

mole: The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

Some examples of the use of the mole:

- 1 mole of HgCl has a mass of 236.04 grams
- 1 mole of Hg_2Cl_2 has a mass of 472.08 grams
- 1 mole of Hg_2^{2+} has a mass of 401.18 grams and a charge of 192.97 kilocoulombs
- 1 mole of $\frac{1}{2}\text{Ca}^{2+}$ has a mass of 20.04 grams and a charge of 96.49 kilocoulombs
- 1 mole of $\text{Cu}_{0.5}\text{Zn}_{0.5}$ has a mass of 64.46 grams
- 1 mole of $\text{Fe}_{0.91}\text{S}$ has a mass of 82.88 grams
- 1 mole of e^- has a mass of 548.60 micrograms, a charge of -96.49 kilocoulombs, and contains 6.02×10^{23} electrons
- 1 mole of a mixture containing the mole fractions $x(\text{N}_2) = 0.7809$, $x(\text{O}_2) = 0.2905$, $x(\text{Ar}) = 0.0093$, and $x(\text{CO}_2) = 0.0003$ has a mass of 28.964 grams
- 1 mole of photons whose frequency is 10^{14} Hz has energy 39.90 kilojoules
(The numerical values in these examples are approximate.)

⁽¹⁾ In October 1967 the thirteenth Conférence Générale des Poids et Mesures recommended that the kelvin, symbol K, be used for thermodynamic temperature and for thermodynamic temperature interval, and that the unit-symbols °K and deg be abandoned.

3.7 Names and symbols for SI Base Units

<i>physical quantity</i>	<i>name of SI Unit</i>	<i>symbol for SI Unit</i>
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance ⁽¹⁾	mole	mol
luminous intensity	candela	cd

3.8 Names and symbols for SI Supplementary Units

<i>physical quantity</i>	<i>name of SI Unit</i>	<i>symbol for SI Unit</i>
plane angle	radian	rad
solid angle	steradian	sr

3.9 Special names and symbols for certain SI Derived Units

<i>physical quantity</i>	<i>name of SI Unit</i>	<i>symbol for SI Unit</i>	<i>definition of SI Unit</i>
force	newton	N	m kg s^{-2}
pressure, stress	pascal	Pa	$\text{m}^{-1} \text{kg s}^{-2} (= \text{N m}^{-2})$
energy	joule	J	$\text{m}^2 \text{kg s}^{-2}$
power	watt	W	$\text{m}^2 \text{kg s}^{-3} (= \text{J s}^{-1})$
electric charge	coulomb	C	s A
electric potential difference	volt	V	$\text{m}^2 \text{kg s}^{-3} \text{A}^{-1} (= \text{J A}^{-1} \text{s}^{-1})$
electric resistance	ohm	Ω	$\text{m}^2 \text{kg s}^{-3} \text{A}^{-2} (= \text{V A}^{-1})$
electric conductance	siemens	S	$\text{m}^{-2} \text{kg}^{-1} \text{s}^3 \text{A}^2 (= \text{A V}^{-1} = \Omega^{-1})$
electric capacitance	farad	F	$\text{m}^{-2} \text{kg}^{-1} \text{s}^4 \text{A}^2 (= \text{A s V}^{-1})$
magnetic flux	weber	Wb	$\text{m}^2 \text{kg s}^{-2} \text{A}^{-1} (= \text{V s})$
inductance	henry	H	$\text{m}^2 \text{kg s}^{-2} \text{A}^{-2} (= \text{V A}^{-1} \text{s})$
magnetic flux density	tesla	T	$\text{kg s}^{-2} \text{A}^{-1} (= \text{V s m}^{-2})$
luminous flux	lumen	lm	cd sr
illuminance	lux	lx	$\text{m}^{-2} \text{cd sr}$
frequency	hertz	Hz	s^{-1}
activity (of radioactive source)	becquerel	Bq	s^{-1}
absorbed dose (of radiation)	gray	Gy	$\text{m}^2 \text{s}^{-2} (= \text{J kg}^{-1})$

3.10 SI Derived Units and Unit-symbols for other quantities
(This list is not exhaustive.)

<i>physical quantity</i>	<i>SI Unit</i>	<i>symbol for SI Unit</i>
area	square metre	m^2
volume	cubic metre	m^3
density	kilogram per cubic metre	kg m^{-3}
velocity	metre per second	m s^{-1}
angular velocity	radian per second	rad s^{-1}
acceleration	metre per second squared	m s^{-2}
kinematic viscosity, diffusion coefficient	square metre per second	$\text{m}^2 \text{s}^{-1}$
dynamic viscosity	newton-second per square metre	N s m^{-2}
molar entropy, molar heat capacity	joule per kelvin mole	$\text{J K}^{-1} \text{mol}^{-1}$
concentration	mole per cubic metre	mol m^{-3}
electric field strength	volt per metre	V m^{-1}
magnetic field strength	ampere per metre	A m^{-1}
luminance	candela per square metre	cd m^{-2}

⁽¹⁾ See Section 1.2

3.11 SI Prefixes

<i>fraction</i>	<i>prefix</i>	<i>symbol</i>	<i>multiple</i>	<i>prefix</i>	<i>symbol</i>
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	μ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

The names and symbols of decimal multiples and sub-multiples of the unit of mass, which already contains a prefix, are constructed by adding the appropriate prefix to the word gram and symbol g:

Examples: mg not μ kg μ g not nkg Mg not kkg

3.12 The degree Celsius

<i>physical quantity</i>	<i>name of unit</i>	<i>symbol for unit</i>	<i>definition of unit</i>
Celsius temperature	degree Celsius	$^{\circ}\text{C}$ ⁽¹⁾	$^{\circ}\text{C} = \text{K}$

The Celsius temperature t , is defined by $t = T - T_0$ where $T_0 = 273.15 \text{ K}$. This leads to $t/^{\circ}\text{C} = T/\text{K} - 273.15$.

3.13 Decimal fractions and multiples of SI Units having special names

The following units do not belong to the International System of Units, but in view of existing practice the Comité International des Poids et Mesures has considered (1969) that it was preferable to keep them for the time being (along with several other specified units not particularly relevant to chemistry) for use with those of the International System.

<i>physical quantity</i>	<i>name of unit</i>	<i>symbol for unit</i>	<i>definition of unit</i>
length	ångström	Å	10^{-10} m
cross section	barn	b	10^{-28} m^2
volume	litre ⁽²⁾	l, L	10^{-3} m^3
mass	tonne	t	10^3 kg
pressure	bar	bar	10^5 Pa

Other units with special names based on the c.g.s. system and the electromagnetic c.g.s. system ⁽³⁾ are preferably not to be used; among these are the erg (10^{-7} J), the dyne (10^{-5} N), the poise (0.1 Pa s), the stokes ($10^{-4} \text{ m}^2 \text{ s}^{-1}$), the gauss (corresponding to 10^{-4} T) ⁽³⁾, the oersted (corresponding to $1000/4\pi \text{ A m}^{-1}$) ⁽³⁾, and the maxwell (corresponding to 10^{-8} Wb) ⁽³⁾. The name micron and symbol μ should not be used for the unit of length, 10^{-6} m , which has the SI name micrometre and symbol μm .

3.14 Some other units now exactly defined in terms of the SI units

The CIPM (1969) recognized that users of the SI will wish to employ with it certain units not part of it but which are important and are widely used. These units are given in the following table. The combination of units of this table with SI units to form compound units should, however, be authorized only in limited cases.

⁽¹⁾ The $^{\circ}$ sign and the letter following form one symbol and there should be no space between them.

Example: 25°C not 25°C .

⁽²⁾ By decision of the Twelfth Conférence Générale des Poids et Mesures in October 1964, the old definition of the litre ($1.000\,028 \text{ dm}^3$) was rescinded. The word litre is now regarded as a special name for the cubic decimetre. Neither the word litre nor its symbol should be used to express results of high precision. The alternative symbol L was recommended by CIPM to CGPM in 1978.

⁽³⁾ The electromagnetic c.g.s. system is a three-dimensional system of units in which the unit of electric current and units for other electric and magnetic quantities are considered to be derived from the centimetre, gram, and second as base units. The electric and magnetic units of this system cannot strictly speaking be compared to the corresponding units of the SI, which has four dimensions when only units derived from the metre, kilogram, second, and ampere are considered.