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ABSTRACT

This booklet provides a reference to the quantities, units, and their symbols which are used in physical science. It is a revision of a 1969 report and takes account of the progress which has been made in obtaining international agreement on the definitions, names, and symbols for units and on the rules for the expression of relations involving numbers between physical quantities and units. The report is divided into ten parts: (1) Physical Quantities, Units, and Numerical Values; (2) Recommended Mathematical Symbols; (3) Chemical Elements, Nuclides, and Particles; (4) Quantum States; (5) Nuclear Physics; (6) Thermodynamic Results; (7) Galvanic Cells; (8) Abbreviations of Common Words and Phrases; (9) Recommended Values of Physical Constants; and (10) Bibliography. (Author/TS)

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QUANTITIES, UNITS, AND SYMBOLS

A REPORT BY

THE SYMBOLS COMMITTEE OF
THE ROYAL SOCIETY

REPRESENTING

THE ROYAL SOCIETY
THE CHEMICAL SOCIETY
THE FARADAY SOCIETY
THE INSTITUTE OF PHYSICS

1971

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PREFACE

The 1969 Report of the Symbols Committee of the Royal Society entitled '*Symbols, signs, and abbreviations*' is now out of print; it was widely read and was clearly of considerable value. The Symbols Committee has therefore been charged with the preparation of a new report, which *inter alia* takes account of the progress which has been made in obtaining further international agreement on the definitions, names, and symbols for units and on the rules for the expression of relations involving numbers between physical quantities and units. The Committee feels that the new report is more properly entitled *Quantities, units, and symbols*.

The Committee has again accepted the recommendations of the following international bodies, on each of which the U.K. is represented:

The General Conference of Weights and Measures
The International Organization for Standardization
The International Union of Pure and Applied Physics
The International Union of Pure and Applied Chemistry
The International Electrotechnical Commission

The Committee has maintained close contact with the British Standards Institution which is pursuing a common aim towards the adoption of internationally recognized units and symbols, as shown in BS 3763, BS 1991, and in several other British Standards.

It is emphasized that the Symbols Committee recommends only those procedures and symbols which have been internationally agreed.

PART I

PHYSICAL QUANTITIES, UNITS, AND NUMERICAL VALUES

I.1. Introduction

The value of a *physical quantity* is equal to the product of a *numerical value* and a *unit*

$$\text{physical quantity} = \text{numerical value} \times \text{unit}.$$

Neither any physical quantity, nor the symbol used to denote it, should imply a particular choice of unit.

Operations on equations involving physical quantities, units, and numerical values, should follow the ordinary rules of algebra.

Thus the physical quantity called the wavelength λ of one of the yellow sodium lines has the value

$$\lambda = 5.896 \times 10^{-7}\,\mathrm{m}$$

where m is the symbol for the unit of length called the metre (see §I.3). This may equally well be written in the form

$$\lambda/\mathrm{m} = 5.896 \times 10^{-7}$$

or in any of the other ways of expressing the equality of λ and 5.896×10^{-7} multiplied by m. By definition (see §I.3)

$$\text{Å} = 10^{-10}\,\mathrm{m}$$

and

$$\mathrm{in} = 2.54 \times 10^{-2}\,\mathrm{m}$$

where Å and in are the symbols for the units of length called respectively the ångström and the inch; it follows that

$$\lambda/\text{Å} = (\lambda/\mathrm{m}) \times (\mathrm{m}/\text{Å}) = 5896$$

and

$$\lambda/\mathrm{in} = (\lambda/\mathrm{m}) \times (\mathrm{m}/\mathrm{in}) = 5.896 \times 10^{-7}/(2.54 \times 10^{-2}) \approx 2.321 \times 10^{-5}$$

Thus λ may be equated to $5.896 \times 10^{-7}\,\mathrm{m}$, or to 5896 Å, or to $2.321 \times 10^{-5}\,\mathrm{in}$, but may not be equated to 5.896×10^{-7} or to any other number.

It follows from the above discussion that the expression which is placed at the head of a column of numerical values of a physical quantity in a table should be a pure number, such as the quotient of the symbol for the physical quantity and the symbol for the unit used.

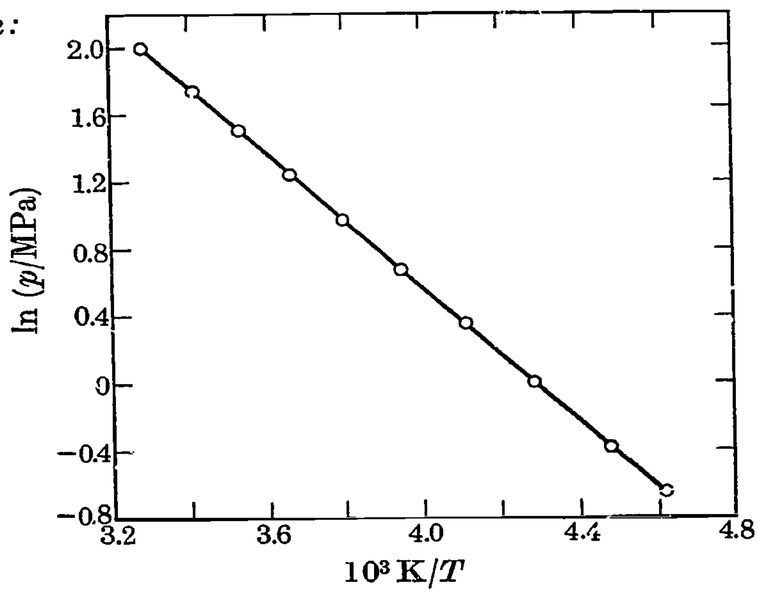
Example:

$\theta_C/°C$	T/K	$10^3 K/T$	p/MPa	$\ln(p/MPa)$	$V^g_m/cm^3 mol^{-1}$	pV^g_m/RT
−56.60	216.55	4.6179	0.5180	−0.6578	3177.6	0.9142
0.00	273.15	3.6610	3.4853	1.2486	456.97	0.7013
31.04	304.19	3.2874	7.3815	1.9990	94.060	0.2745

In this table T denotes thermodynamic temperature and K the unit of thermodynamic temperature called the kelvin. Expressions such as 'T(K)' or 'T, K' do not denote T divided by K and should be abandoned in favour of T/K.

Similarly, the expression used to define the numerical values of a physical quantity plotted on a graph should be a pure number, such as the quotient of the symbol for the physical quantity and the symbol for the unit used.

Example:



Algebraically equivalent forms such as kK/T or $(10^{-3}\ T/K)^{-1}$ may of course be used in place of $10^3\ K/T$.

A clear distinction should be drawn between physical quantities and units, and between the symbols for physical quantities and the symbols for units.

Symbols for physical quantities should be printed in italic (sloping) type. Symbols for units should be printed in roman (upright) type. In typescript the distinction should be made by underlining symbols for physical quantities in accord with standard printers' practice (see the Bibliography, §X.2.1 or §X.3.5).

Physical quantities and the symbols for physical quantities are dealt with in §I.2. The symbols for physical quantities specified there are recommendations.

Units and symbols for units are dealt with in §I.3. The symbols for units specified there are mandatory.

Numbers are dealt with in §I.4.

I.2. Physical quantities and symbols for physical quantities

I.2.1. *Physical quantities*

A physical quantity is defined by a complete specification of the operations used to measure the ratio (a pure number) of two particular values of that physical quantity.

Each physical quantity is given a name and a symbol which is an abbreviation for that name.

By international convention, seven physical quantities are chosen for use as dimensionally independent *base quantities*:

Physical quantity	Symbol for quantity
length	l
mass	m
time	t
electric current	I
thermodynamic temperature	T
luminous intensity	I_{v}
amount of substance	n

All other physical quantities are regarded as being *derived* from the base quantities. Plane angle and solid angle are sometimes regarded as base quantities.

I.2.2. *Symbols for physical quantities*

The symbol for a physical quantity should be a single letter of the latin or the greek alphabet.

An exception to this rule has been made for certain dimensionless quantities used in the study of transport processes, for which the internationally agreed symbols consist of two letters, the first a capital and the second lower case. Such two-letter symbols should be enclosed in parentheses. *Example:* Reynolds number: (Re).

When necessary the symbol for a physical quantity may be modified by attaching to it subscripts and/or superscripts and/or other modifying signs having specified meanings.

I.2.3. *Printing of symbols for physical quantities*

When letters of the latin alphabet are used as symbols for physical quantities they should be printed in italic type. When letters of the greek alphabet are used as symbols for physical quantities they should whenever possible be printed in sloping ('italic') rather than upright ('roman') type.

The symbols for vector quantities should be printed in bold faced italic type. *Examples:* force: $\boldsymbol{F}$, electric field strength: $\boldsymbol{E}$. (When the directional character of such quantities is not to be emphasized, the use of ordinary italic type remains as an alternative. However, the use of bold faced italic type will often remain convenient in order to allow the use of the same letters for other quantities.)

The symbols for tensors of the second rank should be printed in bold faced sans serif type which whenever possible should be italic (sloping) rather than roman (upright). *Examples:* **S**, **T**.

Abbreviations, i.e. shortened forms of names such as p.f. for partition function, should not be used in mathematical equations. When used in text they should be printed in roman (upright) type. (See also Part VIII.)

I.2.4. *Choice of symbols for physical quantities*

A list of recommended symbols for physical quantities is given in §I.2.10. Whenever possible the symbol used for a physical quantity should be that (or one of those) recommended there.

Even with the use of both capital and lower case letters, and of bold faced as well as ordinary italic (sloping) type as specified in §I.2.3, the available distinctive letter symbols are insufficient to enable each symbol to be allotted to a single quantity. Some alternatives are therefore given in the list in §I.2.10 where a need for them is most likely to arise or, occasionally, where alternative usages are firmly established and unobjectionable. In some instances a preference is expressed (see heading of §I.2.10) and the preferred symbol should then be used whenever possible; in others no preference is expressed.

Where it is necessary to choose from alternative symbols for a quantity, or to adopt a symbol for a quantity not listed in §I.2.10, consideration should be given to current practice by authorities in the field and to the desirability that symbols for quantities constituting a well defined class should as far as possible belong to the same alphabet, fount, and case.

In order to obtain additional flexibility, capital letters may be used as variants for lower case letters, and vice versa, if no ambiguity is likely to arise. For example, instead of d_i and d_e for internal and external diameter, d and D may be used. The recommended symbol for length is l and for inductance L, but l and L may also be used for two lengths or two inductances; if length and inductance appear together, however, l should be used only for length and L for inductance, and necessary distinctions between different lengths or between different inductances should be made by means of subscripts or other modifying signs.

I.2.5. *Modifying signs*

Letter symbols, numbers, or other signs, may be placed as subscripts or superscripts immediately after the symbol for a physical quantity in order to modify its meaning. A list of recommended symbols for some of the most commonly needed subscripts and superscripts is given in §I.2.9.

For the use of other subscripts and superscripts, and of other modifying signs, no rigid rules are laid down but a satisfactory notation should fulfil the following requirements:

(i) it should be unambiguous;
(ii) it should be simple, systematic, and easy to remember;
(iii) it should not use more letters than necessary;
(iv) it should not be too expensive or difficult to print.

Modifying signs such as dots, bars, or tildes (~) may be placed above (or excep tionally below) the symbol for a physical quantity. Such signs, however, should be used sparingly and should never be letters of the alphabet or numbers.

Brackets, including parentheses ( ), braces { }, square brackets [ ], and angle brackets ⟨ ⟩, should not be used around the symbol for a quantity in order to make it represent any other quantity, unless such use is consistently adopted for a whole class of quantities as in crystallography. In particular, the use of square brackets around a chemical formula to denote the concentration of the substance is recommended.

I.2.6. *Printing of subscripts and superscripts*

Subscripts or superscripts which are themselves symbols for physical quantities should be printed in italic (sloping) type. All other letter symbols used as subscripts or superscripts should be printed in roman (upright) type.

Example: C_p for heat capacity at constant pressure, but
C_{B} for heat capacity of substance B.

When two or more subscripts, or two or more superscripts, having separate meanings are attached to the same symbol they should be separated by commas.

Example: $C_{p,\mathrm{B}}$ for heat capacity at constant pressure of substance B.

Second-order superscripts or subscripts should be avoided as far as possible. Thus e^{x^2} may be printed as $\exp x^2$. Also $\Lambda_{\mathrm{NO}_3^-}$ may be printed as $\Lambda(\mathrm{NO}_3^-)$ and $\rho_{20\,^\circ\mathrm{C}}$ as $\rho(20\,^\circ\mathrm{C})$.

I.2.7. *Use of the words 'specific' and 'molar'*

The word 'specific' before the name of an extensive physical quantity is restricted to the meaning 'divided by mass'. For example, specific volume is the volume divided by the mass. When the extensive quantity is represented by a capital letter, the corresponding specific quantity may be represented by the corresponding lower case letter.

Examples: volume: V — specific volume: $v = V/m$
heat capacity: C_p — specific heat capacity: $c_p = C_p/m$.

The numerical value of a specific physical quantity depends on the units selected for the physical quantity and for the mass.

The word 'molar' before the name of an extensive quantity is restricted to the meaning 'divided by amount of substance'. For example, molar volume is the volume divided by the amount of substance. The subscript m attached to the symbol for the extensive quantity denotes the corresponding molar quantity.

Examples: volume: V — molar volume: $V_{\mathrm{m}} = V/n$
Gibbs function: G — molar Gibbs function: $G_{\mathrm{m}} = G/n$.

The subscript m may be omitted where there is no risk of ambiguity.

The numerical value of a molar physical quantity depends on the units selected for the physical quantity and for the amount of substance. The most commonly used unit for amount of substance is the mole (see §I.3.2).

I.2.8. *Partial molar quantities*

The symbol X_B, where X denotes an extensive quantity and B is the chemical symbol for a substance, denotes the partial molar quantity for the substance B defined by the relation: $X_B = (\partial X / \partial n_B)_{T,p,n_C,\ldots}$.

The partial molar quantity X_B for a pure substance B, which is identical with the molar quantity X_m for the pure substance B, may be denoted by X_B^*, where the superscript * denotes 'pure', so as to distinguish it from the partial molar quantity X_B for the substance B in a mixture.

I.2.9. *List of recommended subscripts and superscripts and other modifying signs to be used with the symbols for physical quantities*

(a) Subscripts

I, II ... 1, 2 ...	*especially with symbols for thermodynamic functions*, referring to different systems or different states of a system
A, B ...	referring to molecular species A, B...
i	referring to a typical ionic species i
u	referring to an undissociated molecule
p, V, T, S	indicating constant pressure, volume, temperature, entropy
p, m, c, a	*with symbol for an equilibrium constant*, indicating that it is expressed in terms of pressure, molality, concentration, or relative activity
g, l, s, c	referring to gas, liquid, solid, and crystalline states respectively
f, e, s, t, d	referring to fusion, evaporation, sublimation, transition, and dissolution or dilution respectively
c	referring to the critical state or indicating a critical value
C, D, F	*with symbols for optical properties*, referring to particular wavelengths.
+, −	referring to a positive or negative ion, or to a positive or negative electrode
∞	indicating limiting value at infinite dilution.

Some of the above subscripts may sometimes be more conveniently used as superscripts.

(b) Superscripts

⊖	standard in general
*	indicating a pure substance
id	ideal
E	excess

I.2.10. *List of recommended symbols for physical quantities*

It is recognized that according to context some departures from the recommended symbols will be necessary. Where two or more symbols separated by commas are given for a quantity, these symbols are regarded as alternatives for which no preference is expressed; where they are separated by a dotted line, the first is preferred.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

(*a*) Space and time

angle (plane angle)	$\alpha, \beta, \gamma, \theta, \phi$, etc.	spherical coordinates	r, θ, ϕ
solid angle	Ω, ω	position vector; radius vector	$\boldsymbol{r}$
length	l	area	$A \ldots S$
breadth	b	volume	$V \ldots v$
height	h	time	t
thickness	d, δ	angular velocity: $\mathrm{d}\theta/\mathrm{d}t$	ω
radius	r	angular acceleration: $\mathrm{d}\omega/\mathrm{d}t$	α
diameter: $2r$	d	velocity: $\mathrm{d}s/\mathrm{d}t$	u, v, w
distance along path	s, L	acceleration: $\mathrm{d}u/\mathrm{d}t$	a
generalized coordinate	q	acceleration of free fall	g
rectangular coordinates	x, y, z	speed of light in a vacuum	c
cylindrical coordinates	r, ϕ, z	Mach number	(Ma)

(*b*) Periodic and related phenomena

period	T	circular wavenumber: $2\pi\sigma$	k
relaxation time [1]	τ	circular wavevector	$\boldsymbol{k}$
frequency: $1/T$	ν, f	damping coefficient [3]	δ
rotational frequency	n	logarithmic decrement [3]: δ/ν	Λ
angular frequency [2]: $2\pi\nu$	ω	attenuation coefficient [4]	α
wavelength	λ	phase coefficient [4]	β
wavenumber : $1/\lambda$	$\sigma \ldots \tilde{\nu}$	propagation coefficient [4]: $\alpha + \mathrm{i}\beta$	γ
wavevector	$\boldsymbol{\sigma}$		

(1) When F is a function of time t given by $F(t) = A + B\exp(-t/\tau)$; τ is also called time constant.

(2) Also called pulsatance.

(3) When F is a function of time t given by $F(t) = A\exp(-\delta t)\sin\{2\pi\nu(t-t_0)\}$.

(4) When F is a function of distance x given by $F(x) = A\exp(-\alpha x)\cos\{\beta(x-x_0)\}$.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

(*c*) Mechanics

mass	m
density (mass density): m/V	ρ
relative density: ρ_2/ρ_1	d
specific volume: V/m	v
reduced mass: $m_1 m_2/(m_1+m_2)$	μ
momentum: mu	p
momentum (vector): $m\boldsymbol{u}$	$\boldsymbol{p}$
angular momentum	b, p_θ
angular momentum (vector): $\boldsymbol{r} \times \boldsymbol{p}$	$\boldsymbol{L}$
moment of inertia [1]	I, J
force	F
force (vector)	$\boldsymbol{F}$
weight	$G \ldots P, W$
bending moment	M
moment of force (vector): $\boldsymbol{r} \times \boldsymbol{F}$	$\boldsymbol{M}$
torque; moment of a couple	T
pressure	$p \ldots P$
normal stress	σ
shear stress	τ
linear strain: $\Delta l/l_0$	ϵ, e
shear strain; shear angle: $\Delta\theta/\theta_0$	γ
volume strain: $\Delta V/V_0$	θ
Young modulus: σ/ϵ	E
shear modulus: τ/γ	G
bulk modulus: $-p/\theta$	K
Poisson ratio	μ, ν
compressibility: $-V^{-1}\,\mathrm{d}V/\mathrm{d}p$	κ
second moment of area [2]	I_a
second polar moment of area [3]	I_p
section modulus	Z, W
coefficient of friction	$\mu \ldots f$
viscosity (dynamic viscosity)	$\eta \ldots \mu$
fluidity: $1/\eta$	ϕ
kinematic viscosity: η/ρ	ν
diffusion coefficient	D
surface tension	γ, σ
angle of contact	θ
work	W, A
energy	E, W
potential energy	E_p, V, Φ
kinetic energy	E_k, T, K
power	P
Hamiltonian function	H
Lagrangian function	L
gravitational constant	G
Reynolds number: $\rho ul/\eta$	(Re)

[1] $I_x = \int (x^2+y^2)\,\mathrm{d}m$. [2] $I_{a,y} = \iint x^2\,\mathrm{d}x\,\mathrm{d}y$. [3] $I_p = \iint (x^2+y^2)\,\mathrm{d}x\,\mathrm{d}y$.

(*d*) Thermodynamics

thermodynamic temperature	$T \ldots \Theta$
common temperature	t, θ
linear expansivity: $l^{-1}\,\mathrm{d}l/\mathrm{d}T$	α, λ
cubic expansivity: $V^{-1}\,\mathrm{d}V/\mathrm{d}T$	α, γ
heat; quantity of heat	q, Q
work; quantity of work	w, W
heat flow rate	$\Phi \ldots q$
thermal conductivity	$\lambda \ldots k$
heat capacity	C
specific heat capacity: C/m	c
specific heat capacity at constant pressure	c_p
specific heat capacity at constant volume	c_V
ratio c_p/c_V	γ, κ
thermal diffusivity: $\lambda/\rho c_p$	α
entropy	S
internal energy	$U \ldots E$
enthalpy: $U+pV$	H
Helmholtz function: $U-TS$	A, F
Gibbs function: $U+pV-TS$	G
Massieu function: $-A/T$	J
Planck function: $-G/T$	Y
specific entropy: S/m	s
specific internal energy: U/m	$u \ldots e$

[*Note*: *A*, *B* denotes no preference; *A*...*B* denotes *A* preferred]

specific enthalpy[1]: H/m	h	isentropic compressibility: $-V^{-1}(\partial V/\partial p)_S$	κ_S
specific Helmholtz function: A/m	a, f	isobaric expansivity: $V^{-1}(\partial V/\partial T)_p$	α
specific Gibbs function: G/m	g	thermal diffusion ratio	k_T
Joule–Thomson coefficient: $(\partial T/\partial P)_H$	μ, μ_{JT}	thermal diffusion factor	α_T
isothermal compressibility: $-V^{-1}(\partial V/\partial p)_T$	κ, κ_T	thermal diffusion coefficient	D_T

(*e*) Electricity and magnetism[2]

electric charge; quantity of electricity	Q	coupling coefficient: $L_{12}/(L_1L_2)^{\frac{1}{2}}$	k
electric current: $\mathrm{d}Q/\mathrm{d}t$	I	leakage coefficient: $1-k^2$	σ
charge density: Q/V	ρ	permeability: $\boldsymbol{B} = \mu\boldsymbol{H}$	μ
surface charge density: Q/A	σ	magnetic constant; permeability of a vacuum	μ_0
electric field strength	$\boldsymbol{E}$	relative permeability: μ/μ_0	μ_r
electric potential	V, ϕ	magnetic susceptibility: $\mu_r - 1$	χ_m
electric potential difference	$U \ldots V$	electromagnetic moment: $\boldsymbol{T} = \boldsymbol{m}\times\boldsymbol{B}$	$\boldsymbol{m}$
electromotive force	E	magnetization: $(\boldsymbol{B}/\mu_0) - \boldsymbol{H}$	$\boldsymbol{M}$
electric displacement	$\boldsymbol{D}$	magnetic polarization: $\boldsymbol{B} - \mu_0\boldsymbol{H}$	$\boldsymbol{J}$
electric flux	Ψ	electromagnetic energy density	w
capacitance	C	Poynting vector: $\boldsymbol{E}\times\boldsymbol{H}$	$\boldsymbol{S}$
permittivity: $\boldsymbol{D} = \epsilon\boldsymbol{E}$	ϵ	speed of propagation of electromagnetic waves in vacuum	c
electric constant; permittivity of a vacuum	ϵ_0	resistance	R
relative permittivity[3]: ϵ/ϵ_0	ϵ_r	resistivity: $\boldsymbol{E} = \rho\boldsymbol{J}$	ρ
electric susceptibility: $\epsilon_r - 1$	χ_e	conductivity: $1/\rho$	γ, σ
electric polarization: $\boldsymbol{D} - \epsilon_0\boldsymbol{E}$	$\boldsymbol{P}$	reluctance: U_m/Φ	R, R_m
electric dipole moment	$\boldsymbol{p} \ldots \boldsymbol{\mu}$	permeance: $1/R_m$	Λ
electric current density	$\boldsymbol{J}, \boldsymbol{j}$	number of turns	N
magnetic field strength	$\boldsymbol{H}$	number of phases	m
magnetic potential difference	U_m	number of pairs of poles	p
magnetomotive force: $\oint H_s \mathrm{d}s$	F_m	loss angle	δ
magnetic flux density; magnetic induction	$\boldsymbol{B}$	phase displacement	ϕ
magnetic flux	Φ	impedance: $R + \mathrm{i}X$	Z
magnetic vector potential	$\boldsymbol{A}$	reactance: $\mathrm{Im}\, Z$	X
self inductance	L	resistance: $\mathrm{Re}\, Z$	R
mutual inductance	M, L_{12}	quality factor: $\lvert X\rvert/R$	Q

(1) For the specific enthalpy change resulting from phase transitions the term specific latent heat is still used.

(2) Correspondences between certain quantities in this table and certain other quantities that arise when non-rationalized three-quantity systems of electric and magnetic equations are used can be found in the references given in the Bibliography, §X. 1.2, Part V: 1965, or §X.1.5.

(3) Also called dielectric constant, D, when it is independent of E.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

admittance: $1/Z$	Y	power, active	P
susceptance: Im Y	B	power, reactive	Q
conductance: Re Y	G	power, apparent	S

(*f*) Light and related electromagnetic radiation

The same symbol is often used for a pair of corresponding radiant and luminous quantities. Subscripts $_e$ for radiant and $_v$ for luminous may be used when necessary to distinguish these quantities.

velocity of electromagnetic waves in vacuum	c	illuminance; illumination	E, E_v
radiant energy	Q, Q_e	light exposure: $\int E\,dt$	H
radiant flux; radiant power	$\Phi, \Phi_e \ldots P$	luminous efficacy: Φ_v/Φ_e	K
radiant intensity	I, I_e	absorption factor; absorptance: Φ_a/Φ_0	α
radiance	L, L_e	reflexion factor; reflectance: Φ_r/Φ_0	ρ
radiant exitance	M, M_e	transmission factor; transmittance: Φ_{tr}/Φ_0	τ
irradiance	E, E_e	linear extinction coefficient	μ
emissivity	ϵ	linear absorption coefficient	a
quantity of light	Q, Q_v	refractive index	n
luminous flux	Φ, Φ_v	refraction: $(n^2-1)\,V/(n^2+2)$	R
luminous intensity	I, I_v	angle of optical rotation	α
luminance	L, L_v		
luminous exitance	M, M_v		

(*g*) Acoustics

velocity of sound	c	reflexion coefficient: P_r/P_0	ρ
velocity of longitudinal waves	c_l	acoustic absorption coefficient: $1-\rho$	$\alpha_a \ldots \alpha$
velocity of transverse waves	c_t	transmission coefficient: P_{tr}/P_0	τ
group velocity	c_g	dissipation coefficient: $\alpha_a - \tau$	δ
sound energy flux	P	loudness level	L_N
sound intensity	I, J		

For a more complete list of symbols for acoustic quantities see the Bibliography, §X.1.2, Part VII: 1965.

(*h*) Physical chemistry

relative atomic mass of an element ('atomic weight') (1)	A_r	relative molecular mass of a substance ('molecular weight') (1)	M_r

(1) The ratio of the average mass per atom (molecule) of the natural isotopic composition of an element (the elements) to 1/12 of the mass of an atom of the nuclide ^{12}C.

Examples: $A_r(K) = 39.102$ $A_r(Cl) = 35.453$ $M_r(KCl) = 74.555$

The concept of relative atomic or molecular mass may be extended to other specified isotopic compositions, but the natural isotopic composition is assumed unless some other composition is specified.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

amount of substance	n
molar mass: m/n	M
molar volume: V/n	V_m
molar internal energy: U/n	U_m
molar enthalpy: H/n	H_m
molar heat capacity: C/n	C_m
at constant pressure: C_p/n	$C_{p,m}$
at constant volume: C_V/n	$C_{V,m}$
molar entropy: S/n	S_m
molar Helmholtz function: A/n	A_m
molar Gibbs function: G/n	G_m
(molar) gas constant	R
compression factor: pV_m/RT	Z
mole fraction of substance B	x_B
mass fraction of substance B	w_B
volume fraction of substance B	ϕ_B
molality of solute B: (n_B divided by mass of solvent)	m_B
concentration ('molarity') of solute B: n_B/V	c_B, [B]
chemical potential of substance B: $(\partial G/\partial n_B)_{T,p,n_C,\ldots}$	μ_B
absolute activity of substance B: $\exp(\mu_B/RT)$	λ_B
partial pressure of substance B in a gas mixture: $x_B^g p$	p_B
fugacity of substance B in a gas mixture: $\lambda_B \lim_{p\to 0}(x_B^g p/\lambda_B)$	$f_B \ldots p_B^*$
relative activity of substance B	a_B
activity coefficient (mole fraction basis)	f_B
activity coefficient (molality basis)	γ_B
activity coefficient (concentration basis)	y_B
osmotic coefficient	$\phi \ldots g$
osmotic pressure	Π
surface concentration	Γ
electromotive force	E

Faraday constant	F
charge number of ion i	z_i
ionic strength: $\frac{1}{2}\Sigma_i m_i z_i^2$	I
velocity of ion i	v_i
electric mobility of ion i: $v_i = u_i E$	u_i
electrolytic conductivity [(1)]: $J = \kappa E$	κ
molar conductance of electrolyte: κ/c	Λ
transport number of ion i	t_i
molar conductance of ion i: $t_i \Lambda$	λ_i
overpotential	η
exchange current density	j_0
electrokinetic potential	ζ
intensity of light	I
transmittance: I/I_0	T
absorbance [(2)]: $-\lg T$	A
(linear) absorption coefficient: A/l	a
molar (linear) absorption coefficient: A/lc_B	ϵ
angle of optical rotation	α
specific optical rotatory power: $\alpha V/ml$	α_m
molar optical rotatory power: $\alpha/c_B l$	α_n
molar refraction: $(n^2-1)V_m/(n^2+2)$	R_m
stoichiometric coefficient of molecules B (negative for reactants, positive for products)	ν_B
general equation for a chemical reaction	$0 = \Sigma_B \nu_B B$
affinity of a reaction: $-\Sigma_B \nu_B \mu_B$	$A \ldots \mathscr{A}$
equilibrium constant	K
degree of dissociation	α
extent of reaction: $d\xi = dn_B/\nu_B$	ξ
rate of reaction: $d\xi/dt$	$\dot{\xi}, J$
rate constant of a reaction	k
activation energy of a reaction	E

(1) Formerly called specific conductance.

(2) Formerly called optical density.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

(*i*) Molecular physics

Avogadro constant	L, N_A
number of molecules	N
number density of molecules: N/V	n
molecular mass	m
molecular velocity	$\boldsymbol{c}(c_x, c_y, c_z)$, $\boldsymbol{u}(u_x, u_y, u_z)$
molecular position	$\boldsymbol{r}(x, y, z)$
molecular momentum	$\boldsymbol{p}(p_x, p_y, p_z)$
average velocity	$\langle \boldsymbol{c} \rangle, \langle \boldsymbol{u} \rangle, \boldsymbol{c}_0, \boldsymbol{u}_0$
average speed	$\langle c \rangle, \langle u \rangle, \bar{c}, \bar{u}$,
most probable speed	$\hat{c}, \hat{u}$
mean free path	l, λ
molecular attraction energy	ϵ
interaction energy between molecules i and j	ϕ_{ij}, V_{ij}
velocity distribution function: $N/V = \int f \mathrm{d}c_x \mathrm{d}c_y \mathrm{d}c_z$	$f(c)$
Boltzmann function	H
generalized coordinate	q
generalized momentum	p
volume in phase space	Ω
Boltzmann constant	k
$1/kT$ in exponential functions	β
partition function	Q, Z
grand partition function	Ξ
statistical weight	g
symmetry number	σ, s
dipole moment of molecule	p, μ
quadrupole moment of molecule	Θ
polarizability of molecule	α
Planck constant	h
Planck constant divided by 2π	$\hbar$
characteristic temperature	Θ
Debye temperature: $h\nu_D/k$	Θ_D
Einstein temperature: $h\nu_E/k$	Θ_E
rotational temperature: $h^2/8\pi^2 Ik$	Θ_r
vibrational temperature: $h\nu/k$	Θ_v
Stefan–Boltzmann constant: $2\pi^5 k^4/15c^2h^3$	σ
first radiation constant[1]: $2\pi hc^2$	c_1
second radiation constant: hc/k	c_2
rotational quantum number	J, K
vibrational quantum number	v

(*j*) Atomic and nuclear physics

nucleon number; mass number	A
atomic number; proton number	Z
neutron number: $A - Z$	N
(rest) mass of atom	m_a
unified atomic mass constant: $m_a(^{12}\mathrm{C})/12$	m_u
(rest) mass of electron	m_e
(rest) mass of proton	m_p
(rest) mass of neutron	m_n
elementary charge (of proton)	e
Planck constant	h
Planck constant divided by 2π	$\hbar$
Bohr radius: $h^2/\pi\mu_0 c^2 m_e e^2$	a_0
Rydberg constant: $\mu_0^2 m_e e^4 c^3/8h^3$	R_∞
magnetic moment of particle	μ
Bohr magneton: $eh/4\pi m_e$	μ_B
Bohr magneton number: μ/μ_B [2]	
nuclear magneton: $(m_e/m_p)\,\mu_B$	μ_N
gyromagnetic ratio: $2\pi\mu/Ih$	γ
g-factor	g
Larmor (angular) frequency: $e\boldsymbol{B}/2m_e$	ω_L
nuclear angular precession frequency: $ge\boldsymbol{B}/2m_p = \gamma \boldsymbol{B}$	ω_N
cyclotron angular frequency of electron: $e\boldsymbol{B}/m_e$	ω_c
nuclear quadrupole moment	Q
nuclear radius	R
orbital angular momentum quantum number	L, l

(1) See also page 45.

(2) No internationally agreed symbol has yet been recommended, but $p \ldots n$ are in use.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

spin angular momentum quantum number	S, s_i
total angular momentum quantum number	J, j_i
nuclear spin quantum number	I, J
hyperfine structure quantum number	F
principal quantum number	n, n_i
magnetic quantum number	M, m_i
fine structure constant: $\mu_0 e^2 c/2h$	α
electron radius: $\mu_0 e^2/4\pi m_e$	r_e
Compton wavelength: h/mc	λ_C
mass excess: $m_a - Am_u$	Δ
packing fraction: Δ/Am_u	f
mean life	τ
level width: $h/2\pi\tau$	Γ
activity: $-dN/dt$	A
specific activity: A/m	a
decay constant: A/N	λ
half-life: $(\ln 2)/\lambda$	$T_{\frac{1}{2}}, t_{\frac{1}{2}}$
disintegration energy	Q
spin-lattice relaxation time	T_1
spin-spin relaxation time	T_2
indirect spin-spin coupling	J

(*k*) Nuclear reactions and ionizing radiations

reaction energy	Q
cross section	σ
macroscopic cross section	Σ
impact parameter	b
scattering angle	θ, ϕ
internal conversion coefficient	α
linear attenuation coefficient	μ, μ_l
atomic attenuation coefficient	μ
mass attenuation coefficient	μ_m
linear stopping power	S, S_l
atomic stopping power	S_a
linear range	R, R_l
recombination coefficient	α

(*l*) Quantum mechanics

complex conjugate of Ψ	Ψ^*
probability density: $\Psi^*\Psi$	P
probability current density: $(h/2\pi i m)(\Psi^*\nabla\Psi - \Psi\nabla\Psi^*)$	S
charge density of electrons: $-eP$	ρ
electric current density of electrons: $-eS$	j
expectation value of A	$\langle A\rangle, \bar{A}$
commutator of A and B: $AB - BA$	$[A, B], [A, B]_-$
anticommutator of A and B: $AB + BA$	$[A, B]_+$
matrix element: $\int \phi_i^*(A\phi_j)\,d\tau$	A_{ij}
Hermitian conjugate of operator A	$A^\dagger$
momentum operator in coordinate representation	$+(h/2\pi i)\nabla$
annihilation operators	a, b, α, β
creation operators	$a^\dagger, b^\dagger, \alpha^\dagger, \beta^\dagger$

[*Note*: A, B or A ; B denote no preference ; $A \ldots B$ denotes A preferred]

(*m*) Solid state physics

fundamental translations for lattice	$\boldsymbol{a}, \boldsymbol{b}, \boldsymbol{c}$; $\boldsymbol{a}_1, \boldsymbol{a}_2, \boldsymbol{a}_3$
Miller indices	h, k, l; h_1, h_2, h_3
plane in lattice [1]	$(h\,k\,l)$; $(h_1\,h_2\,h_3)$
direction in lattice [1]	$[h\,k\,l]$; $[h_1\,h_2\,h_3]$
fundamental translations in reciprocal lattice	$\boldsymbol{a}^*, \boldsymbol{b}^*, \boldsymbol{c}^*$; $\boldsymbol{b}_1, \boldsymbol{b}_2, \boldsymbol{b}_3$
vector in crystal lattice	$\boldsymbol{r}$
distance between successive lattice planes	d
Bragg angle	θ
order of reflexion	n
short range order parameter	σ
long range order parameter	s
Burgers vector	$\boldsymbol{b}$
circular wavevector; propagation vector (of phonons)	$\boldsymbol{q}$
circular wavevector; propagation vector (of particles)	$\boldsymbol{k}$
effective mass of electron	m^*, m_{eff}
Fermi energy	$E_{\text{F}}, \epsilon_{\text{F}}$
Fermi circular wavevector	$\boldsymbol{k}_{\text{F}}$
work function	Φ
differential thermoelectric power	$S \ldots \Sigma$
Peltier coefficient	Π
Thomson coefficient	μ
piezoelectric coefficient (polarization/stress)	d_{mn}
characteristic (Weiss) temperature	$\Theta, \Theta_{\text{W}}$
Curie temperature	T_{C}
Néel temperature	T_{N}
Hall coefficient	R_{H}

(*n*) Molecular spectroscopy [2]

quantum number	
of component of electronic orbital angular momentum vector along symmetry axis	Λ, λ_i
of component of electronic spin along symmetry axis	Σ, σ_i
of total electronic angular momentum vector along symmetry axis	Ω, ω_i
of electronic spin	S
of nuclear spin	I
of vibrational mode	v
of vibrational angular momentum (linear molecules)	l
of total angular momentum (excluding nuclear spin)	J
of component of $\boldsymbol{J}$ in direction of external field	M, M_J
of component of $\boldsymbol{S}$ in direction of external field	M_S
of total angular momentum (including nuclear spin: $\boldsymbol{F} = \boldsymbol{J} + \boldsymbol{I}$)	F
of component of $\boldsymbol{F}$ in direction of external field	M_F
of component of $\boldsymbol{I}$ in direction of external field	M_I

[1] Braces { } and angle brackets ⟨ ⟩ are used to enclose symmetry-related sets (forms) of planes and directions respectively. Further details regarding crystallographic notation can be found in the tables listed in the Bibliography, §X.2.2.

[2] Further details can be found in the report listed in the Bibliography, §X.2.3.

quantum number (cont.)

of component of angular momentum along axis (linear and symmetric top molecules; excluding electron- and nuclear spin; for linear molecules $K = |\Lambda + l|$) — K

of total angular momentum (linear and symmetric top molecules; excluding electron- and nuclear spin: $J = N + S$ [1]) — N

of component of angular momentum along symmetry axis (linear and symmetric top molecules; excluding nuclear spin; for linear molecules: $P = |K + \Sigma|$ [2]) — P

degeneracy of vibrational mode — d

electronic term: E_e/hc [3] — T_e

vibrational term: E_{vib}/hc — G

coefficients in expression for vibrational term for diatomic molecule:
$G = \sigma_e(v+\frac{1}{2}) - x\sigma_e(v+\frac{1}{2})^2$ — σ_e and $x\sigma_e$

coefficients in expression for vibrational term for polyatomic molecule:
$G = \Sigma_j \sigma_j(v_j + \frac{1}{2}d_j) + \frac{1}{2}\Sigma_j\Sigma_k x_{jk}(v_j + \frac{1}{2}d_j)(v_k + \frac{1}{2}d_k)$ — σ_j and x_{jk}

rotational term: E_{rot}/hc — F

moment of inertia of diatomic molecule — I

rotational constant of diatomic molecule: $h/8\pi^2 cI$ — B

principal moments of inertia of polyatomic molecule ($I_A \leqslant I_B \leqslant I_C$) — I_A, I_B, I_C

rotational constants of polyatomic molecule: $A = h/8\pi^2 cI_A$, etc. — A, B, C

total term: $T_e + G + F$ — T

I.2.11. *Mathematical operations on physical quantities*

Addition and subtraction of two physical quantities are indicated by

$$a+b \quad \text{and} \quad a-b.$$

Multiplication of two (scalar [4]) physical quantities may be indicated in one of the following ways:

$$ab \quad a\,b \quad a\cdot b \quad a\times b.$$

Division of one quantity by another quantity may be indicated in one of the following ways:

$$\frac{a}{b} \quad a/b \quad ab^{-1},$$

or in any of the other ways of writing the product of a and b^{-1}.

These procedures can be extended to cases where one of the quantities or both are themselves products, quotients, sums, or differences of other quantities.

Brackets should be used in accordance with the rules of mathematics. If the solidus is used to separate the numerator from the denominator and if there is any doubt where the numerator starts or where the denominator ends, brackets should be used.

(1) System of loosely coupled electrons. (2) System of tightly coupled electrons.
(3) All energies are taken here with respect to the ground state as reference level.
(4) For vector quantities see p. 32.

Examples:

Expressions with a horizontal rule	Same expressions with a solidus
$\dfrac{a}{bcd}$	a/bcd
$\frac{2}{9}\sin kx,\ \frac{1}{2}RT$	$(2/9)\sin kx,\ RT/2$
$\dfrac{a}{b}-c$	$a/b-c$
$\dfrac{a}{b-c}$	$a/(b-c)$
$\dfrac{a-b}{c-d}$	$(a-b)/(c-d)$
$\dfrac{a}{c}-\dfrac{b}{d}$	$a/c-b/d$

Remark. It is recommended that in expressions like:

$$\sin\{2\pi(x-x_0)/\lambda\} \qquad \exp\{(r-r_0)/\sigma\}$$
$$\exp\{-V(r)/kT\} \qquad \surd(\epsilon/c^2)$$

the argument should always be placed between brackets, except when the argument is a simple product, for example: $\sin kx$, $\sin 2\pi\nu t$.

A list of recommended symbols for mathematical operators and mathematical constants will be found in Part II.

I.3. Units and symbols for units

I.3.1. *The International System of Units (SI)*

The International System of Units (SI) comprises the *SI units* and the *SI prefixes*.

The SI units are of three kinds: *base, supplementary*, and *derived*. There are seven base units (see §§I.3.2 and I.3.3), one for each of the seven physical quantities: length, mass, time, electric current, thermodynamic temperature, luminous intensity, and amount of substance, which are regarded as dimensionally independent. There are two supplementary units (see §I.3.4): one for plane angle and one for solid angle. The derived unit for any other physical quantity is that obtained by the dimensionally appropriate multiplication and division of the base units (see §I.3.6). Fifteen of the derived units have special names and symbols (see §I.3.5).

There is one and only one SI unit for each physical quantity. Decimal multiples of these units may, however, be constructed by use of the fourteen SI prefixes (see §I.3.7).

I.3.2. *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 circular 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.

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.

Note. 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.

Examples:

1 mole of HgCl has a mass equal to 0.236 04 kilogram.

1 mole of Hg_2Cl_2 has a mass equal to 0.472 08 kilogram.

1 mole of e^- has a mass equal to 5.4860×10^{-7} kilogram.

1 mole of a mixture containing $\frac{2}{3}$ mole of H_2 and $\frac{1}{3}$ mole of O_2 has a mass equal to 0.012 010 2 kilogram.

I.3.3. *Names and symbols for SI base units*

Physical quantity	Name of SI unit	Symbol for SI unit
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

I.3.4. *Names and symbols for SI supplementary units*

Physical quantity	Name of SI unit	Symbol for SI unit
plane angle	radian	rad
solid angle	steradian	sr

I.3.5. *Special names and symbols for SI derived units*

Physical quantity	Name of SI unit	Symbol for SI unit	Definition of SI unit	Equivalent form(s) of SI unit
energy	joule	J	$m^2 kg s^{-2}$	N m
force	newton	N	$m kg s^{-2}$	$J m^{-1}$
pressure	pascal	Pa	$m^{-1} kg s^{-2}$	$N m^{-2}$, $J m^{-3}$
power	watt	W	$m^2 kg s^{-3}$	$J s^{-1}$
electric charge	coulomb	C	s A	A s
electric potential difference	volt	V	$m^2 kg s^{-3} A^{-1}$	$J A^{-1} s^{-1}$, $J C^{-1}$
electric resistance	ohm	Ω	$m^2 kg s^{-3} A^{-2}$	$V A^{-1}$
electric conductance	siemens	S	$m^{-2} kg^{-1} s^3 A^2$	Ω^{-1}, $A V^{-1}$
electric capacitance	farad	F	$m^{-2} kg^{-1} s^4 A^2$	$A s V^{-1}$, $C V^{-1}$
magnetic flux	weber	Wb	$m^2 kg s^{-2} A^{-1}$	V s
inductance	henry	H	$m^2 kg s^{-2} A^{-2}$	$V A^{-1} s$
magnetic flux density	tesla	T	$kg s^{-2} A^{-1}$	$V s m^{-2}$, $Wb m^{-2}$
luminous flux	lumen(1)	lm	cd sr	
illumination	lux(1)	lx	m^{-2} cd sr	
frequency	hertz	Hz	s^{-1}	

(1) In the definition given here for these units, the steradian (sr) is treated as a base unit

I.3.6. *Examples of SI derived units and unit symbols for other quantities*

(This list is merely illustrative)

Physical quantity	SI unit	A symbol for SI unit
area	square metre	m^2
volume	cubic metre	m^3
wavenumber	1 per metre	m^{-1}
radioactivity	1 per second	s^{-1}
density	kilogram per cubic metre	$kg\,m^{-3}$
speed; 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	square metre per second	$m^2\,s^{-1}$
concentration (of amount of substance)	mole per cubic metre	$mol\,m^{-3}$
specific volume	cubic metre per kilogram	$m^3\,kg^{-1}$
molar volume	cubic metre per mole	$m^3\,mol^{-1}$
dynamic viscosity	pascal second	Pa s
moment of force	metre newton	N m
surface tension	newton per metre	$N\,m^{-1}$
heat flux density	watt per square metre	$W\,m^{-2}$
heat capacity	joule per kelvin	$J\,K^{-1}$
thermal conductivity	watt per metre kelvin	$W\,m^{-1}\,K^{-1}$
energy density	joule per cubic metre	$J\,m^{-3}$
molar heat capacity	joule per kelvin mole	$J\,K^{-1}\,mol^{-1}$
electric field strength	volt per metre	$V\,m^{-1}$
magnetic field strength	ampere per metre	$A\,m^{-1}$
electric charge density	coulomb per cubic metre	$C\,m^{-3}$
permittivity	farad per metre	$F\,m^{-1}$
current density	ampere per square metre	$A\,m^{-2}$
permeability	henry per metre	$H\,m^{-1}$
luminance	candela per square metre	$cd\,m^{-2}$

I.3.7. *SI prefixes*

The following prefixes may be used to construct decimal multiples of units.

Multiple	Prefix	Symbol	Multiple	Prefix	Symbol
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^{-18}	atto	a			

Decimal multiples of the kilogram, kg, should be formed by attaching an SI prefix not to kg but to g, in spite of the kilogram and not the gram being the SI base unit.

Examples: mg not μkg for 10^{-6} kg
Mg not kkg for 10^{3} kg

A symbol for an SI prefix may be attached to the symbol for an SI base unit (§I.3.3), or for an SI supplementary unit (§I.3.4), or for an SI derived unit having a special name and symbol (§I.3.5).

Examples: cm ns μA mK μmol μrad MHz daN kPa GV MΩ

An SI prefix is also sometimes attached to the symbol for a non-SI unit (see §§I.3.8 to I.3.10).

Examples: ml hbar kG kcal MeV

Compound prefixes should not be used.

Example: nm but not mμm for 10^{-9} m

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.

Example: cm^2 always means $(0.01\ m)^2$ and never $0.01\ m^2$

I.3.8. *Decimal multiples of SI units having special names*

These names are not part of the SI. It is recognized that their use may be continued for some time but it is recommended that except in special circumstances they should be progressively abandoned in scientific publications. The following list is not exhaustive.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
length	ångström	Å	$10^{-10}\ m = 10^{-1}\ nm$
length	micron	μm [1]	$10^{-6}\ m$
area	barn	b	$10^{-28}\ m^2$
volume	litre [2]	l	$10^{-3}\ m^3 = dm^3$
mass	tonne	t	$10^{3}\ kg = Mg$
force	dyne	dyn	$10^{-5}\ N$
pressure	bar	bar	$10^{5}\ Pa$

(1) The symbols μ and mμ, still unfortunately used by some spectroscopists and biologists, should give place to μm (micrometre) and nm (nanometre) respectively.

(2) By decision of the twelfth General Conference of Weights and Measures in October 1964 the old definition of the litre (leading to the value $1.000\,028\ dm^3$) was rescinded and the word litre reinstated as a special name for the cubic decimetre. Neither the word litre nor its symbol l should be used to express results of high precision.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
energy	erg	erg	10^{-7} J
kinematic viscosity	stokes	St	10^{-4} m^2 s^{-1}
dynamic viscosity	poise	P	10^{-1} Pa s
magnetic flux	maxwell	Mx	10^{-8} Wb
magnetic flux density [1]	gauss	G	10^{-4} T

I.3.9. *Other units now exactly defined in terms of the SI units*

These units are not part of the SI. It is recognized that their use may be continued for some time but it is recommended that except in special circumstances they should be progressively abandoned in scientific publications. Most of these units should not be used to form compound units. The following list is by no means exhaustive. Each of the definitions given in the fourth column is *exact*.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
length	inch	in	2.54×10^{-2} m
mass	pound (avoirdupois)	lb	0.453 592 37 kg
time	minute	min	60 s
	hour	h	60 min = 3 600 s
	day	d	24 h = 86 400 s
force	kilogram-force	kgf	9.806 65 N
pressure	atmosphere	atm	101 325 Pa
pressure	torr	Torr	(101 325/760) Pa [≈ 133.322 368 Pa]
pressure	conventional millimetre of mercury	mmHg	$13.5951 \times 980.665 \times 10^{-2}$ Pa [≈ 133.322 387 Pa]
energy	thermochemical calorie	cal_{th}	4.184 J
energy	I.T. calorie	cal_{IT}	4.1868 J
thermodynamic temperature (T)	degree Rankine	°R [2]	(5/9) K
Celsius temperature (t_C) [3]	degree Celsius	°C [2]	K

[1] The unit of magnetic flux density formerly called gamma, symbol γ, is equal to 1 nT.
[2] The ° sign and the letter following form one symbol and there should be no space between them. *Example:* 25 °C not 25° C.
[3] The Celsius temperature is the excess of the thermodynamic temperature over 273.15 K.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
Fahrenheit temperature (t_F) (1)	degree Fahrenheit	°F (2)	$(5/9)\,K$
radioactivity	curie	Ci	$3.7\times 10^{10}\ s^{-1}$
radiation (3)	rad	rad (4)	$10^{-2}\ J\ kg^{-1}$
	röntgen	R	$2.58\times 10^{-4}\ C\ kg^{-1}$

I.3.10. *Units defined in terms of certain physical constants*

These units are not part of the SI. The factors for conversion of these units to SI units are subject to change in the light of new experimental measurements of the constants involved. Their use outside the restricted contexts to which they are appropriate should be discouraged. The following list is not exhaustive.

Physical quantity	Name of unit	Symbol for unit	Conversion factor
length	astronomical unit	AU	$AU \approx 149\,600\times 10^{6}\ m$
	parsec	pc	$pc \approx 30\,857\times 10^{12}\ m$
mass	unified atomic mass unit	u	$u \approx 1.660\ 531\times 10^{-27}\ kg$
energy	electronvolt	eV	$eV \approx 1.602\ 191\ 7\times 10^{-19}\ J$

I.3.11. *'International' electric units*

These units are obsolete, having been replaced by the 'absolute' (SI) units in 1948. The conversion factors which should be used with electric measurements quoted in 'international' units depend on where and when the instruments used to make the measurements were calibrated. The following two sets of conversion factors refer respectively to the 'mean international' units estimated by the ninth General Conference of Weights and Measures in 1948, and to the 'U.S. international' units estimated by the U.S. National Bureau of Standards as applying to instruments calibrated by them before 1948.

1 'mean international ohm' = 1.00049 Ω

1 'mean international volt' = 1.00034 V

1 'U.S. international ohm' = 1.000495 Ω

1 'U.S. international volt' = 1.000330 V

(1) The Fahrenheit temperature is the excess of the thermodynamic temperature over 459.67 °R.

(2) The ° sign and the letter following form one symbol and there should be no space between them. *Example:* 25 °F not 25° F.

(3) A special unit which takes account of the relative potentials for damage by different radiations and other factors is the rem (acronym for radiation equivalent man).

(4) Whenever confusion with the symbol for the radian (angular measure) appears possible the symbol rd may be used.

I.3.12. *Electric and magnetic units belonging to unit-systems other than the SI*

Definitions of units used in the 'electrostatic CGS' and 'electromagnetic CGS' unit-systems can be found in either of two documents listed in the Bibliography, §X.1.2, Part V: 1965, or §X.1.5.

It appears that for many years to come a knowledge of the 'electromagnetic CGS' unit system will be a necessity for workers in magnetism, but for practical purposes it is usually sufficient to note that 1 gauss (G) corresponds to 10^{-4} T and that 1 oersted (Oe) corresponds to $10^3 (4\pi)^{-1}\,\mathrm{A\,m^{-1}} \approx 79.5775\,\mathrm{A\,m^{-1}}$.

I.3.13. *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.

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.

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

I.3.14. *Multiplication and division of units*

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

$$\mathrm{N\,m} \quad \text{or} \quad \mathrm{N \cdot m} \quad \text{or} \quad \mathrm{N \times m}$$

The representation Nm is not recommended.

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

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

or in any of the other ways of writing the product of m and $\mathrm{s^{-1}}$, but not $\mathrm{ms^{-1}}$.

These rules may be extended to more complex groupings but more than one solidus (/) should not be used in the same expression unless parentheses are used to eliminate ambiguity.

Examples: $\mathrm{J\,K^{-1}\,mol^{-1}}$ or J/(K mol) but not J/K/mol

$\mathrm{cm^2\,V^{-1}\,s^{-1}}$ or (cm/s)/(V/cm) but not cm/s/V/cm.

I.4. Numbers

I.4.1. *Printing of numbers*

Numbers should be printed in upright type. The decimal sign between digits in a number should be a point (.) or a comma (,). To facilitate the reading of long numbers the digits may be grouped in threes about the decimal sign but no point or comma should ever be used except for the decimal sign.

Example: 2 573.421 736 but not 2,573.421,736

When the decimal sign is placed before the first digit of a number a zero should always be placed before the decimal sign.

Example: 0.2573×10^4 but not $.2573 \times 10^4$

It is often convenient to print numbers with just one digit before the decimal sign.

Example: 2.573×10^3

I.4.2. *Multiplication and division of numbers*

The multiplication sign between numbers should be a cross ($\times$).

Example: 2.3×3.4

Division of one number by another may be indicated in any of the ways:

$$\tfrac{136}{273} \quad \text{or} \quad 136/273 \quad \text{or} \quad 136 \times (273)^{-1}$$

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: (136/273)/2.303 or 136/(273 × 2.303) but never 136/273/2.303

PART II

RECOMMENDED MATHEMATICAL SYMBOLS

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

equal to	$=$	smaller than	$<$
not equal to	$\neq$	larger than	$>$
identically equal to	$\equiv$	smaller than or equal to	$\leqslant$
corresponds to	$\triangleq$	larger than or equal to	$\geqslant$
approximately equal to	$\approx$	much smaller than	$\ll$
approaches	$\rightarrow$	much larger than	$\gg$
asymptotically equal to	$\simeq$	plus	$+$
proportional to	$\propto$	minus	$-$
infinity	∞	plus or minus	$\pm$
		minus or plus	$\mp$

a multiplied by b (1)	ab, $a \cdot b$, $a \times b$
a divided by b (1)	a/b, $\frac{a}{b}$, ab^{-1}
magnitude of a	$\|a\|$
a raised to power n	a^n
square root of a	$a^{\frac{1}{2}}$, $\sqrt{a}$
nth root of a	$a^{1/n}$, $a^{\frac{1}{n}}$, $\sqrt[n]{a}$
mean value of a	$\langle a \rangle$, $\bar{a}$
factorial p (2)	$p!$
binomial coefficient (3)	$\binom{n}{p}$

When letters of the alphabet are used to form mathematical operators (*Examples:* d, Δ, ln, exp) or as mathematical constants (*Examples:* e, π) they should be printed in roman (upright) type so as to distinguish them from the symbols for physical quantities which should be printed in italic (sloping) type

sum	Σ
product	Π
function of x	$f(x)$, $\mathrm{f}(x)$
limit to which $f(x)$ tends as x approaches a	$\lim\limits_{x \to a} f(x)$, $\lim_{x \to a} f(x)$

(1) See also §I.2.11.

(2) $p! = 1 \times 2 \times 3 \times \ldots \times (p-1) \times p$ where p is a positive integer.

(3) $\binom{n}{p} = n!/(n-p)!p!$ where n and p are positive integers and $n \geqslant p$ and where $0! = 1$.

[Note: A, B denotes no preference; $A \ldots B$ denotes A preferred]

finite increment of x	Δx
variation of x	δx
differential coefficient of $f(x)$ with respect to x	$\frac{\mathrm{d}f}{\mathrm{d}x}$, $\mathrm{d}f/\mathrm{d}x$, $f'(x)$
differential coefficient of order n of $f(x)$	$\frac{\mathrm{d}^{\mathrm{n}}f}{\mathrm{d}x^{\mathrm{n}}}$, $\mathrm{d}^{\mathrm{n}}f/\mathrm{d}x^{\mathrm{n}}$, $f^{(\mathrm{n})}(x)$
partial differential coefficient of $f(x, y, \ldots)$ with respect to x when $y, \ldots$ are held constant	$\frac{\partial f(x, y, \ldots)}{\partial x}$, $\left(\frac{\partial f}{\partial x}\right)_y$, $(\partial f/\partial x)_y$
operator $\frac{\partial}{\partial x}$ or with single variable $\frac{\mathrm{d}}{\mathrm{d}x}$	D
the total differential of f	$\mathrm{d}f$
indefinite integral of $f(x)$ with respect to x	$\int f(x)\,\mathrm{d}x$
definite integral of $f(x)$ from $x = a$ to $x = b$	$\int_a^b f(x)\,\mathrm{d}x$
integral of $f(x)$ with respect to x round a closed contour	$\oint f(x)\,\mathrm{d}x$
exponential of x	$\exp x$, e^x
base of natural logarithms	e
logarithm to the base a of x	$\log_a x$
natural logarithm of x	$\ln x$, $\log_{\mathrm{e}} x$
common logarithm of x	$\lg x$. $\log_{10} x \ldots \log x$
binary logarithm of x	$\mathrm{lb}\, x$, $\log_2 x$
ratio of circumference to diameter of a circle	π
sine of x	$\sin x$
cosine of x	$\cos x$
tangent of x	$\tan x$
cotangent of x	$\cot x$
secant of x	$\sec x$
cosecant of x	$\mathrm{cosec}\, x$
inverse sine of x	$\arcsin x \ldots \sin^{-1} x$
inverse cosine of x	$\arccos x \ldots \cos^{-1} x$
inverse tangent of x	$\arctan x \ldots \tan^{-1} x$
inverse cotangent of x	$\mathrm{arccot}\, x \ldots \cot^{-1} x$
inverse secant of x	$\mathrm{arcsec}\, x \ldots \sec^{-1} x$
inverse cosecant of x	$\mathrm{arccosec}\, x \ldots \mathrm{cosec}^{-1} x$
hyperbolic sine of x	$\sinh x$
hyperbolic cosine of x	$\cosh x$
hyperbolic tangent of x	$\tanh x$
hyperbolic cotangent of x	$\coth x$
hyperbolic secant of x	$\mathrm{sech}\, x$
hyperbolic cosecant of x	$\mathrm{cosech}\, x$

[Note: A, B denotes no preference; $A \dots B$ denotes A preferred]

inverse hyperbolic sine of x	$\operatorname{arsinh} x \dots \sinh^{-1} x$
inverse hyperbolic cosine of x	$\operatorname{arcosh} x \dots \cosh^{-1} x$
inverse hyperbolic tangent of x	$\operatorname{artanh} x \dots \tanh^{-1} x$
inverse hyperbolic cotangent of x	$\operatorname{arcoth} x \dots \coth^{-1} x$
inverse hyperbolic secant of x	$\operatorname{arsech} x \dots \operatorname{sech}^{-1} x$
inverse hyperbolic cosecant of x	$\operatorname{arcosech} x \dots \operatorname{cosech}^{-1} x$
complex operator: $i^2 + 1 = 0$	i, j
real part of z	$\operatorname{Re} z$
imaginary part of z	$\operatorname{Im} z$
modulus of z	$\lvert z \rvert$
argument of z	$\arg z$
complex conjugate of z	z^*
transpose of matrix A	$\tilde{A}$, A^{T}
complex conjugate matrix of matrix A	A^*
Hermitian conjugate matrix of matrix A	$A^{\dagger}$
vector	$\boldsymbol{A} \dots \vec{A}$
magnitude of vector A	$\lvert \boldsymbol{A} \rvert, A$
scalar product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{A} \cdot \boldsymbol{B}$
vector product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{A} \times \boldsymbol{B}, \boldsymbol{A} \wedge \boldsymbol{B}$
dyadic product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{AB}$
differential vector operator	$\nabla, \frac{\partial}{\partial \boldsymbol{r}}$
gradient of ϕ	$\operatorname{grad} \phi, \nabla \phi$
divergence of $\boldsymbol{A}$	$\nabla \cdot \boldsymbol{A}, \operatorname{div} \boldsymbol{A}$
curl of $\boldsymbol{A}$	$\nabla \times \boldsymbol{A}, \nabla \wedge \boldsymbol{A}, \operatorname{curl} \boldsymbol{A}, \operatorname{rot} \boldsymbol{A}$
Laplacian of ϕ	$\nabla^2 \phi$
d'Alembertian of ϕ	$\Box \phi$
scalar product of tensors $\boldsymbol{S}$ and $\boldsymbol{T}$	$\boldsymbol{S} : \boldsymbol{T}$
tensor product of tensors $\boldsymbol{S}$ and $\boldsymbol{T}$	$\boldsymbol{S} \cdot \boldsymbol{T}$
product of tensor $\boldsymbol{S}$ and vector $\boldsymbol{A}$	$\boldsymbol{S} \cdot \boldsymbol{A}$

PART III

CHEMICAL ELEMENTS, NUCLIDES, AND PARTICLES

III.1. *Definitions*

A nuclide is a species of atoms identical as regards atomic number (proton number) and mass number (nucleon number). Two or more nuclides having the same atomic number but different mass numbers are called isotopes or isotopic nuclides. Two or more nuclides having the same mass number are called isobars or isobaric nuclides.

III.2. *Symbols for elements and nuclides*

Symbols for chemical elements should be written in roman type. The symbol is not followed by a full stop.

Examples: Ca, C, H, He

The attached numerals specifying a nuclide are as follows:

$$\text{mass number}\ {}^{14}\mathrm{N}_{2\ \text{atoms/molecule}}$$

The atomic number may be placed in the left subscript position.

The right superscript position should be used, when required, to indicate ionic charge, state of excitation, or oxidation number.

Examples:

ionic charge: Cl^-, SO_4^{2-}, Ca^{2+}, PO_4^{3-}
electronic excited states: He^*, NO^*
nuclear excited states: $^{110}\mathrm{Ag}^*$, $^{110}\mathrm{Ag}^{m}$
oxidation number: $\mathrm{K}_6\mathrm{M}^{\mathrm{IV}}\mathrm{Mo}_9\mathrm{O}_{32}$

III.3. *Symbols for particles and quanta*

neutron	n	pion	π
proton	p	muon	μ
deuteron	d	electron	e
triton	t	neutrino	ν
α-particle	α	photon	γ

It is recommended that the following notation should be used:

Hyperons: Upright capital greek letters to indicate specific particles, e.g. Λ, Σ.

Nucleons: Upright lower case n and p to indicate neutron and proton respectively.

Mesons: Upright lower case greek letters to indicate specific particles, e.g. π, μ, τ.

Leptons: L-particles; e.g. e, ν.

It is recommended that the charge of particles be indicated by adding the superscript +, −, or 0.

Examples:

$$\pi^+, \pi^-, \pi^0; \quad p^+, p^-; e^+, e^-.$$

If with the symbols p and e no sign is shown then the symbols should refer to the positive proton and the negative electron respectively.

The symbol ~ above the symbol of a particle should indicate the corresponding antiparticle (e.g. $\tilde{\nu}$ for anti-neutrino).

III.4. *Notation for nuclear reactions*

The meaning of the symbolic expression indicating a nuclear reaction should be the following:

initial nuclide (incoming particle(s), or quanta   outgoing particle(s) or quanta) final nuclide

Examples:

$^{14}N(\alpha, p)^{17}O$ $\quad$ $^{59}Co(n, \gamma)^{60}Co$

$^{23}Na(\gamma, 3n)^{20}Na$ $\quad$ $^{31}P(\gamma, pn)^{29}Si$

PART IV

QUANTUM STATES

IV.1. *General rules*

A letter symbol indicating the quantum state of *a system* should be printed in capital upright type. A letter symbol indicating the quantum state of *a single electron* should be printed in lower case upright type.

IV.2. *Atomic spectroscopy*

The letter symbols indicating quantum states are:

$L, l = 0$: S, s	$L, l = 4$: G, g	$L, l = 8$: L, l
$= 1$: P p	$= 5$: H, h	$= 9$: M, m
$= 2$: D, d	$= 6$: I, i	$= 10$: N, n
$= 3$: F, f	$= 7$: K, k	$= 11$: O, o

A right hand subscript indicates the total angular momentum quantum number J or j. A left hand superscript indicates the spin multiplicity $2S+1$.

Examples: ${}^2\mathrm{P}_{\frac{3}{2}}$ - state ($J = \frac{3}{2}$, multiplicity 2)

$\mathrm{p}_{\frac{3}{2}}$ - electron ($j = \frac{3}{2}$)

An atomic electron configuration is indicated symbolically by:

$$(nl)^{\kappa}\,(n'l')^{\kappa'} \ldots.$$

The quantum symbols s, p, d, f, ... are used instead of $l = 0, 1, 2, 3, \ldots$.

Example: the atomic configuration: $(1\mathrm{s})^2\,(2\mathrm{s})^2\,(2\mathrm{p})^3$

IV.3. *Molecular spectroscopy*

The letter symbols indicating molecular electronic quantum states are for *linear molecules*:

$$\Lambda, \lambda = 0: \Sigma, \sigma$$
$$= 1: \Pi, \pi$$
$$= 2: \Delta, \delta$$

and for *non-linear molecules*:

A, a; B, b; E, e; etc.

A left hand superscript indicates the spin multiplicity. For molecules having a symmetry centre the parity symbol g or u, indicating respectively symmetric or antisymmetric behaviour on inversion, is attached as a right hand subscript. A + or − sign attached as a right hand superscript indicates the symmetry as regards reflexion in any plane through the symmetry axis of the molecules.

Examples: Σ_g^+, Π_u, $^2\Sigma$, $^3\Pi$, etc.

The letter symbols indicating the vibrational angular momer [illegible] ;ates in the case of *linear molecules* are:

$$l = 0: \Sigma$$
$$= 1: \Pi$$
$$= 2: \Delta$$

IV.4. *Nuclear spectroscopy*

The spin and parity assignment of a nuclear state is

$$J^{\pi}$$

where the parity symbol π is + for even and − for odd parity.

Examples:

$$3^+, 2^-, \text{etc.}$$

A shell model configuration is indicated symbolically by:

$$(n\,l\,j)^{\kappa}\,(n'l'j')^{\kappa'}$$

where the first bracket refers to the proton shell and the second to the neutron shell. Negative values of κ or κ' indicate holes in a completed shell. Instead of $l = 0, 1, 2, 3, \ldots$ the quantum state symbols s, p, d, f, ... are used.

Example:

The nuclear configuration $(1\,\mathrm{d}\,\tfrac{3}{2})^3\,(1\,\mathrm{f}\,\tfrac{7}{2})^2$.

IV.5. *Spectroscopic transitions*

The upper level and the lower level are indicated by ′ and ″ respectively.

Examples:

$$h\nu = E' - E'' \qquad \sigma = T' - T''$$

A spectroscopic transition should be indicated by writing the upper state first and the lower state second, connected by a dash in between.

Examples:

$^2P_{\frac{1}{2}}$—$^2S_{\frac{1}{2}}$	for an electronic transition
(J', K')—(J'', K'')	for a rotational transition
v'—v''	for a vibrational transition

Absorption transition and emission transition may be indicated respectively by arrows ← and →.

Examples:

$(J', K') \leftarrow (J'', K'')$ absorption from (J'', K'') to (J', K')

${}^2P_{\frac{1}{2}} \rightarrow {}^2S_{\frac{1}{2}}$ emission from ${}^2P_{\frac{1}{2}}$ to ${}^2S_{\frac{1}{2}}$

The difference Δ between two quantum numbers should be that of the upper state minus that of the lower state.

Example:

$$\Delta J = J' - J''$$

The indications of the branches of the rotation band should be as follows:

$$\begin{aligned} \Delta J = J' - J'' &= -2\text{: O-branch} \\ &= -1\text{: P-branch} \\ &= 0\text{: Q-branch} \\ &= +1\text{: R-branch} \\ &= +2\text{: S-branch} \end{aligned}$$

PART V

NUCLEAR PHYSICS

V.1. *Notation for covariant character of coupling*

S	scalar coupling	A	axial vector coupling
V	vector coupling	P	pseudoscalar coupling
T	tensor coupling		

V.2. *Character of transitions*

Multipolarity of transition:

electric or magnetic	monopole	E0 or M0
	dipole	E1 or M1
	quadrupole	E2 or M2
	octupole	E3 or M3
	2^n-pole	E*n* or M*n*

parity change in transition:

transition *with* parity change: yes

transition *without* parity change: no

V.3. *Sign of polarization vector* (*Basel convention*)

In nuclear interactions the positive polarization of particles with spin $\frac{1}{2}$ is taken in the direction of the vector product

$$\boldsymbol{k}_{\mathrm{i}} \times \boldsymbol{k}_{\mathrm{o}},$$

where $\boldsymbol{k}_{\mathrm{i}}$ and $\boldsymbol{k}_{\mathrm{o}}$ are the circular wavevectors of the incoming and outgoing particles respectively.

PART VI

THERMODYNAMIC RESULTS

Thermodynamic results for chemical or physical processes should be expressed by quoting the equation for the process (with such specification of the physical states of the participating substances as may be necessary) followed by the value of the change in the appropriate thermodynamic function.

Examples:

$$H_2(g) + \tfrac{1}{2}O_2(g) = H_2O(l); \qquad \Delta H(298.15\,K) = -285.83\,kJ\,mol^{-1}$$

$$2H_2(g) + O_2(g) = 2H_2O(l); \qquad \Delta H(298.15\,K) = -571.66\,kJ\,mol^{-1}$$

$$H_2O(l) = H_2O(g); \qquad \Delta H(298.15\,K) = +44.01\,kJ\,mol^{-1}$$

The following symbols should be used to specify physical states. They should be printed in roman type and should be placed in parentheses after the formula of the substance as in the examples given above.

g	gaseous
l	liquid
s	solid
c	crystalline
aq	dissolved at effectively infinite dilution in water.

PART VII

GALVANIC CELLS

VII.1. *The electromotive force of a cell*

The cell should be represented by a diagram, e.g.

$$Zn|Zn^{2+}|Cu^{2+}|Cu.$$

The electromotive force is equal in sign and magnitude to the electrical potential of the metallic conducting lead on the right when that of the similar lead on the left is taken as zero, the circuit being open.

When the reaction of the cell is written as

$$\tfrac{1}{2}Zn + \tfrac{1}{2}Cu^{2+} \rightarrow \tfrac{1}{2}Zn^{2+} + \tfrac{1}{2}Cu,$$

this implies a diagram so drawn that this reaction takes place when positive electricity flows through the cell from left to right. If this is the direction of the current when the cell is short-circuited, as in the present example, the electromotive force is positive.

If, however, the reaction is written as

$$\tfrac{1}{2}Cu + \tfrac{1}{2}Zn^{2+} \rightarrow \tfrac{1}{2}Cu^{2+} + \tfrac{1}{2}Zn$$

this implies the diagram $Cu|Cu^{2+}|Zn^{2+}|Zn$

and the electromotive force of the cell so specified is negative.

VII.2. *The electromotive force of a half cell and the so-called 'electrode potential'*

The term 'electromotive force of a half cell' as applied to half cells written as follows:

$$Zn^{2+}|Zn$$
$$Cl^-|Cl_2, Pt$$
$$Cl^-|AgCl, Ag$$
$$Fe^{2+}, Fe^{3+}|Pt$$

means the electromotive forces of the cells:

$Pt, H_2|H^+|Zn^{2+}|Zn$	implying the reaction	$\tfrac{1}{2}H_2 + \tfrac{1}{2}Zn^{2+} \rightarrow H^+ + \tfrac{1}{2}Zn$
$Pt, H_2|H^+|Cl^-|Cl_2, Pt,$		$\tfrac{1}{2}H_2 + \tfrac{1}{2}Cl_2 \rightarrow H^+ + Cl^-$
$Pt, H_2|H^+|Cl^-|AgCl, Ag$		$\tfrac{1}{2}H_2 + AgCl \rightarrow H^+ + Cl^- + Ag$
$Pt, H_2|H^+|Fe^{2+}, Fe^{3+}|Pt$		$\tfrac{1}{2}H_2 + Fe^{3+} \rightarrow H^+ + Fe^{2+}$

where the electrode on the left is a *standard hydrogen electrode*.

These electromotive forces may also be called *relative electrode potentials* or, in brief, *electrode potentials*.

On the other hand, the term 'electromotive force of a half cell' as applied to half cells written as follows:

$$Zn|Zn^{2+}$$
$$Pt, Cl_2|Cl^-$$
$$Ag, AgCl|Cl^-$$
$$Pt|Fe^{2+}, Fe^{3+}$$

means the electromotive forces of the cells:

$Zn\|Zn^{2+}\|H^+\|H_2, Pt$	implying the reaction	$\frac{1}{2}Zn + H^+ \rightarrow \frac{1}{2}Zn^{2+} + \frac{1}{2}H_2$
$Pt, Cl_2\|Cl^-\|H^+\|H_2, Pt$		$Cl^- + H^+ \rightarrow \frac{1}{2}Cl_2 + \frac{1}{2}H_2$
$Ag, AgCl\|Cl^-\|H^+\|H_2, Pt$		$Ag + Cl^- + H^+ \rightarrow AgCl + \frac{1}{2}H_2$
$Pt\|Fe^{2+}, Fe^{3+}\|H^+\|H_2, Pt$		$Fe^{2+} + H^+ \rightarrow Fe^{3+} + \frac{1}{2}H_2$

where the electrode on the right is a *standard hydrogen electrode*.

These electromotive forces should not be called electrode potentials.

PART VIII

ABBREVIATIONS OF COMMON WORDS AND PHRASES

This list is not intended to be exhaustive. The words in this list will often be given in full in the text, but where abbreviations are used the following forms are recommended. Such abbreviations should be printed in roman type (except for *ca.*).

absolute	abs.
alternating current	a.c.
anhydrous	anhyd.
approximate(-ly)	approx., *ca.*
aqueous	aq.
average	av.
boiling point	b.p.
calculated	calc.
centre of gravity	c.g.
coefficient	coeff.
compound	cpd
concentrated	conc.
constant	const.
corrected	corr.
critical	crit.
crystalline	cryst.
current density	c.d.
decomposition	decomp.
diameter, inside	i.d.
diameter, outside	o.d.
dilute	dil.
direct current	d.c.
distilled	dist.
electromagnetic unit	e.m.u.
electromotive force	e.m.f.
electron spin resonance	e.s.r.
electrostatic unit	e.s.u.
equation	eqn
experiment	expt
experimental	exptl
freezing point	f.p.
Greenwich mean time	G.M.T.
infrared	i.r.
insoluble	insol.
liquid	liq.
magnetomotive force	m.m.f.
maximum	max.
melting point	m.p.
minimum	min.
nuclear magnetic resonance	n.m.r.
observed	obs.
per cent	% (or in full)
potential difference	p.d.
precipitate	ppt.
preparation	prep.
radio frequency	r.f.
recrystallized	recryst.
relative humidity	r.h.
root mean square	r.m.s.
section, paragraph	§
soluble	sol.
solution	soln
standard temperature and pressure	s.t.p.
temperature	temp.
ultraviolet	u.v.
universal time	U.T.
vacuum	vac.
vapour density	v.d.
vapour pressure	v.p.
volume	vol.

PART IX

RECOMMENDED VALUES OF PHYSICAL CONSTANTS

The following values have been recommended by the CODATA Committee (20 August 1970). The standard-deviation uncertainty is given below each value. Details concerning the development of this self-consistent set of values and their uncertainties are given by Taylor, Parker & Langenberg (1969); see the Biblio graphy, §X.2.4.

Quantity	Symbol	Value and standard-deviation uncertainty
speed of light in a vacuum	c	$2.997\,925\,0 \times 10^{8}\ \mathrm{m\,s^{-1}}$ 10
magnetic constant, permeability of a vacuum	μ_0	$4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$ (exact)
electric constant, permittivity of a vacuum	$\epsilon_0 = \mu_0^{-1}c^{-2}$	$8.854\,185\,3 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ 58
fine structure constant	$\alpha = \mu_0 e^2 c/2h$	$7.297\,351 \times 10^{-3}$ 11
	α^{-1}	$137.036\,02$ 21
charge of a proton	e	$1.602\,191\,7 \times 10^{-19}\ \mathrm{C}$ 70
Planck constant	h	$6.626\,196 \times 10^{-34}\ \mathrm{J\,s}$ 50
	$\hbar = h/2\pi$	$1.054\,591\,9 \times 10^{-34}\ \mathrm{J\,s}$ 80
	$h/2e$	$2.067\,853\,8 \times 10^{-15}\ \mathrm{J\,s\,C^{-1}}$ 69
Avogadro constant	L, N_A	$6.022\,169 \times 10^{23}\ \mathrm{mol^{-1}}$ 40
unified atomic mass constant	m_u	$1.660\,531 \times 10^{-27}\ \mathrm{kg}$ 11
rest mass:		
of electron	m_e	$9.109\,558 \times 10^{-31}\ \mathrm{kg}$ 54
	m_e/m_u	$5.485\,930 \times 10^{-4}$ 34
of proton	m_p	$1.672\,614 \times 10^{-27}\ \mathrm{kg}$ 11
	m_p/m_u	$1.007\,276\,61$ 8

Quantity	Symbol	Value and standard-deviation uncertainty
rest mass (*cont.*):		
of proton	m_p/m_e	1836.109
		11
of neutron	m_n	$1.674\,920 \times 10^{-27}$ kg
		11
	m_n/m_u	1.008 665 20
		10
Faraday constant	F	$9.648\,670 \times 10^{4}$ C mol^{-1}
		54
Rydberg constant	$R_\infty = \mu_0^2 m_e e^4 c^3/8h^3$	$1.097\,373\,12 \times 10^{7}$ m^{-1}
		11
Bohr radius	$a_0 = h^2/\pi\mu_0 c^2 m_e e^2$	$5.291\,771\,5 \times 10^{-11}$ m
		81
electron radius	$r_e = \mu_0 e^2/4\pi m_e$	$2.817\,939 \times 10^{-15}$ m
		13
Bohr magneton	$\mu_B = eh/4\pi m_e$	$9.274\,096 \times 10^{-24}$ J T^{-1}
		65
magnetic moment:		
of electron	μ_e	$9.284\,851 \times 10^{-24}$ J T^{-1}
		65
	μ_e/μ_B	1.001 159 638 9
		31
of proton	μ_p	$1.410\,620\,3 \times 10^{-26}$ J T^{-1}
		99
	μ_p/μ_B	$1.521\,032\,64 \times 10^{-3}$
		46
gyromagnetic ratio of protons in H_2O	γ_p'	$2.675\,127\,0 \times 10^{8}$ s^{-1} T^{-1}
		82
	$\gamma_p'/2\pi$	$4.257\,597 \times 10^{7}$ s^{-1} T^{-1}
		13
γ_p' corrected for diamagnetism of H_2O	γ_p	$2.675\,196\,5 \times 10^{8}$ s^{-1} T^{-1}
		82
	$\gamma_p/2\pi$	$4.257\,707 \times 10^{7}$ s^{-1} T^{-1}
		13
nuclear magneton	$\mu_N = (m_e/m_p)\mu_B$	$5.050\,951 \times 10^{-27}$ J T^{-1}
		50
magnetic moment of protons in H_2O (μ_p')	μ_p'/μ_B	$1.520\,993\,12 \times 10^{-3}$
		10
	μ_p'/μ_N	2.792 709
		17
μ_p' corrected for diamagnetism of H_2O (μ_p)	μ_p/μ_N	2.792 782
		17

Quantity	Symbol	Value and standard-deviation uncertainty
Compton wavelength:		
of electron	$\lambda_C = h/m_e c$	$2.426\,309\,6 \times 10^{-12}$ m 74
of proton	$\lambda_{C,p} = h/m_p c$	$1.321\,440\,9 \times 10^{-15}$ m 90
of neutron	$\lambda_{C,n} = h/m_n c$	$1.319\,621\,7 \times 10^{-15}$ m 90
gas constant	R	$8.314\,34$ J K^{-1} mol^{-1} 35
Boltzmann constant	$k = R/L$	$1.380\,622 \times 10^{-23}$ J K^{-1} 59
Stefan–Boltzmann constant	$\sigma = 2\pi^5 k^4/15h^3c^2$	$5.669\,61 \times 10^{-8}$ W m^{-2} K^{-4} 96
first radiation constant [1]	$c_1 = 2\pi hc^2$	$3.741\,844 \times 10^{-16}$ J m^2 s^{-1} 30
	$8\pi hc$	$4.992\,579 \times 10^{-24}$ J m 38
second radiation constant	$c_2 = hc/k$	$1.438\,833 \times 10^{-2}$ m K 61
gravitational constant	G	$6.673\,2 \times 10^{-11}$ N m^2 kg^{-2} 31

(1) The spectral radiant exitance (formerly called spectral radiant emittance and sometimes emissive power), M_λ, is given by

$$M_\lambda = 2\pi hc^2 \lambda^{-5}/\{\exp(hc/kT\lambda) - 1\};$$

the spectral radiant energy density, w_λ, is given by

$$w_\lambda = 8\pi hc \lambda^{-5}/\{\exp(hc/kT\lambda) - 1\};$$

unfortunately there is no accepted name or symbol for the constant $8\pi hc$.

PART X

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X.1. General sources

X.1.1. *The publications of the bodies of the Metre Convention*

The proceedings of the General Conference, the International Committee, the Consultative Committees, and the International Bureau are published under the auspices of the Bureau in the following series:

Comptes rendus des séances de la Conférence Générale des Poids et Mesures; Procès-Verbaux des séances du Comité International des Poids et Mesures; Sessions des Comités Consultatifs;

Recueil de Travaux du Bureau International des Poids et Mesures (this compilation brings together articles published in scientific and technical journals and books, as well as certain work published in the form of duplicated reports.)

The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) ceased in 1966 by a decision of the International Committee.

From time to time the International Bureau publishes a report on the development of the Metric System throughout the world, entitled *Les récents progrès du Système Métrique.*

Since 1965 the international journal *Metrologia*, edited under the auspices of the International Committee of Weights and Measures, has published articles on the principal work on scientific metrology carried out throughout the world and on the improvement in measuring methods and standards, units, etc., as well as reports concerning the activities, decisions, and recommendations of the various bodies created under the Metre Convention.

X.1.2. *The publications of the work of Technical Committee no.* 12 *of the International Organization for Standardization (ISO/TC* 12)

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The published parts are:

Part I: 1965 Basic quantities and units of the SI and quantities and units of space and time.
Part II: 1958 Quantities and units of periodic and related phenomena.
Part III: 1960 Quantities and units of mechanics.
Part IV: 1960 Quantities and units of heat.

Part V: 1965 Quantities and units . electricity and magnetism.
Part VII: 1965 Quantities and units of acoustics.
Part XI: 1961 Mathematical signs and symbols for use in science and technology.

In the United Kingdom these can be purchased from the British Standards Institution (see note 3 below for the address).

The parts in preparation are:

DIR 839 Quantities and units of nuclear reactions and ionizing radiation.
DIR 838 Quantities and units of atomic and nuclear physics.
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Notes

1. The foregoing Bibliography is inevitably selective rather than comprehensive.
2. Many of the items listed (especially those under the heading Supplementary literature) are subject to repeated revision; all such titles should be consulted in their latest edition.
3. The publications labelled with the prefix BS are issued by the British Standards Institution, 2 Park Street, London W1A 2BS.

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