PROGRESS IN STANDARDIZATION 2

A GUID[illegible]ONAL RECOM[illegible]NS ON NAMES AND SYMBOLS FOR QUANTITIES AND ON UNITS OF MEASUREMENT

D. ARMSTRONG LOWE

WORLD HEALTH ORGANIZATION
GENEVA
1975

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A GUIDE TO INTERNATIONAL RECOMMENDATIONS ON NAMES AND SYMBOLS FOR QUANTITIES AND ON UNITS OF MEASUREMENT

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INTRODUCTION

Any reader who has compared several different text books on the same technical subject, or who regularly reads technical periodicals published in several different countries, is well aware of the difficulties that arise through differences in terminology and nomenclature. At the personal level, such differences hinder comprehension and may form a barrier between an author and his readers; at the national and international levels they make it difficult—to say the least—to compare the results of different workers and laboratories and carry out fully effective worldwide comparative studies.

Nowhere is this problem more apparent than in the area of the names and symbols for quantities and the units in which they are measured. And yet—at least in theory—no terminological problem seems easier of solution, in view of the many international recommendations that are available. Great progress has been made in recent years. The International Organization for Standardization, the International Electrotechnical Commission, and numerous international scientific unions have, working in close liaison, achieved a very large measure of agreement with respect to quantity names and symbols; and they have, with very few exceptions, recommended the use of the SI units adopted by the Conférence générale des Poids et Mesures.

The principal problem of the moment is that of translating the recommendations of these international bodies into action on the part of the scientific community—particularly authors and editors. To the author working in a narrow field of specialization this is fairly simple, since he can usually obtain and follow the relevant recommendation with little difficulty; but the writer whose subject covers several different disciplines, and above all the editor, is faced with a formidable task. The recommendations have appeared in a large number of different publications, many of which are not readily available; and even when they are available the task of searching for a given recommendation in the mass of literature involved is such as to deter even the most ardent supporter of standardization.

This compilation has been prepared to fill the need for a concise practical guide that can be used by the busy author or editor who needs to refer to a given recommendation at a moment's notice. It is divided into two main sections, the first dealing primarily with quantities and the second with units. The first part lists quantity names alphabetically, together with numerous cross references under names that are no longer recommended or are deprecated. It provides answers to the following questions:

1. What is the recommended name for a given quantity?
2. What symbol has been recommended for the quantity?
3. In what unit should the quantity be measured?
4. What instructions have been given for the use of the name, the symbol, and the unit?

It also lists any other recommendations that may have been made with respect to the quantity in question, identifies the organizations that have made the recommendations, and provides references to the original sources. It should be noted that this first part of the Guide is not an exhaustive dictionary of recommended nomenclature. In general, it includes entries only for (*a*) measurable physical quantities and (*b*) factors, phenomena, etc. to which symbols have been assigned, even though they may not be measurable quantities. Within those limits, however, it attempts to list every recommendation that has been made by the organizations listed on page 6, except for a few that deal with certain engineering specialties.

The second section gives an alphabetic list of names of units, together with their correct symbols, and—for non-SI units—provides factors for conversion into SI units. Thus an editor, for example, who is faced with a manuscript that recommends the application of a pesticide at the rate of x pounds per acre can look up " pound per acre " in this list and find a factor for converting the figure into the correct SI unit, kilogram per square metre. Following this list is an alphabetic list of symbols for units that provides cross references to the names of the units.

A table of the most recent values for the fundamental physical constants is also included, and a series of annexes describe the SI system, list the SI units and the acceptable non-SI units, and give rules for the printing of symbols and numbers. A further annex provides factors for converting clinical chemistry values from the traditional form to " amount of substance concentration " values.

The coverage, as will be seen from the following list of bodies whose recommendations are included, is wide:

Committee on Data for Science and Technology (of the International Council of Scientific Unions)
Conférence générale des Poids et Mesures
International Commission on Radiation Units and Measurements
International Committee for Standardization in Hematology (of the International Society of Hematology)
International Electrotechnical Commission
International Federation of Clinical Chemistry
International Organization for Standardization
International Union of Biochemistry
International Union of Geodesy and Geophysics
International Union of Physiological Sciences
International Union of Pure and Applied Chemistry
International Union of Pure and Applied Physics
World Association of Societies of Pathology

Some readers may be prompted to wonder why, in a series devoted to standards in " areas directly or indirectly related to public health ", such full coverage should be given to the physical sciences. The answer is that there is, today, little that is not related, in one way or another, to health. Medicine makes use of advanced electronic equipment; spectroscopy, spectrophotometry, and chromatography of all types are routinely used analytical techniques; ionizing radiation is used in diagnosis and therapy, and there is concern over its effects, and those of microwave radiation, on health. The list could be continued indefinitely, and the history of science and medicine teaches us that it would be presumptuous to attempt to draw a dividing line between what is and what is not applicable to health. Consequently no such attempt has been made.

A perusal of the first part of this Guide will show the far-reaching agreement that has been reached on quantity names and symbols in the different branches of the physical sciences. Numerous discrepancies remain, but most of these are perfectly legitimate in that they represent the different requirements of the different disciplines. A few of the discrepancies are less easy to explain, and if the publication of this guide serves to draw attention to—and eventually eliminate—them it will have served a useful purpose.

It must be emphasized that this compilation is intended to be a guide to the recommendations of the international scientific organizations, and not to replace them. For detailed information on these recommendations, the sole authoritative sources are the publications of the organizations themselves.

ACKNOWLEDGEMENTS

The preparation of this Guide would not have been possible without the assistance of many people and organizations. In particular, I express my sincere thanks to the following persons for providing information and patiently answering my many queries. I am especially indebted to Monsieur J. Terrien, Director, Bureau international des Poids et Mesures, for reading the proofs (in their French version) of the sections dealing with the SI.

BUREAU INTERNATIONAL DES POIDS ET MESURES
Dr. J. Terrien, Director

INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS
Dr Harold O. Wyckoff, Chairman
Professor K. Lidén, Scientific Secretary

INTERNATIONAL ELECTROTECHNICAL COMMISSION
Mr J. Blanc, Senior Engineer

INTERNATIONAL FEDERATION OF CLINICAL CHEMISTRY
Dr R. Dybkaer, Vice-President

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
Dr N. N. Chopra, Director, Technical Coordination

INTERNATIONAL UNION OF BIOCHEMISTRY
Dr W. J. Whelan, General Secretary

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
Professor Paul Melchior, Secretary General

INTERNATIONAL UNION OF PHYSIOLOGICAL SCIENCES
Dr James D. Hardy, Chairman, Board for Definition of Terms

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY
Dr M. Williams, Executive Secretary

INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS
Professor U. Stille, Secretary, Commission on Symbols, Units and Nomenclature

WORLD ASSOCIATION OF SOCIETIES OF PATHOLOGY
Dr C. E. D. Taylor, Secretary, Commission on World Standards

Finally, I thank my wife for helping in many ways, and more particularly for calculating most of the conversion factors given on pages 263-281.

NOTE

In accordance with the practice of the International Organization for Standardization in all its publications, and with the preference implied in most internationally recommended rules for the printing of numbers, the comma is used for the decimal point throughout this Guide.

Many of the " symbols " listed in the Guide are in fact abbreviations rather than symbols. For the sake of simplicity, however, the term " symbol " is used throughout, and should be understood to mean " symbol or abbreviation ".

The spellings " metre " and " kilogram " are used in both the US and British editions (prepared by the National Bureau of Standards and the National Physical Laboratory) of the official translation of the BIPM publication *Le système international d'unités*, " in the hope of securing world-wide uniformity in the English spelling of the names of the units of the International System ". With the same hope, these spellings are used throughout this Guide.

In order to save space, complex unit symbols are usually written with parentheses throughout the Guide rather than with exponents [e.g., cubic metre per kilogram second is symbolized $m^3/(kg \cdot s)$ rather than $m^3 \cdot kg^{-1} \cdot s^{-1}$]. This should not be taken to imply that the use of parentheses is preferable; the exponential form is equally acceptable.

QUANTITIES:

NAMES, SYMBOLS, AND UNITS FOR THEIR MEASUREMENT

QUANTITIES: NAMES, SYMBOLS, AND UNITS FOR THEIR MEASUREMENT

The list of quantities that follows is arranged in five columns. The entries in each of these columns are explained below.

Column 1

Recommended names for quantities are listed in the first column.[a] Occasionally more than one recommended name is listed: if two such names are separated only by a semicolon, it is to be understood that no preference is being expressed. If, however, the second name is given within parentheses, this is an indication that the term within parentheses is *not* recommended and is included for the purpose of identification. Examples:

transmittance; transmission factor	either term acceptable; no preference
volume strain; (bulk strain)	" volume strain " is recommended, " bulk strain " is not

Parentheses are also used to enclose statements of the area of application of the listed quantity name—for example, temperature, ambient (physiology). A third use of parentheses is to enclose nonessential words in a quantity name. For example, the following entry

thickness,
(effective), of (diffuse electrochemical)
double layer; Debye length

indicates that the preferred full names are " effective thickness of diffuse electrochemical double layer " and " Debye length ", and that the short form " thickness of double layer " is equally acceptable (when its meaning is apparent from the context in which it is used).

Column 2

The recommended symbols (or abbreviations—see note on page 7) are listed in the second column. Frequently more than one symbol is given. If the symbols are separated only by commas, the order in which they are listed implies no preference. Symbols that are not enclosed within parentheses are preferred; those that are printed within parentheses are reserve symbols.

Columns 3 and 4

The SI units and their symbols are listed in the third and fourth columns. The references listed in the last column do not necessarily apply to these units. Some organizations merely recommend the use of SI units, but do not specify the unit to be used for a given quantity. In such cases the appropriate unit has been inserted by the author.

The units listed as " reciprocal second ", " reciprocal metre ", etc., may also be given in the form " 1 per second ", " 1 per metre ", etc. In this guide they are listed in the form of reciprocals in accordance with the practice of the International Organization for Standardization.

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[a] Attention is drawn to the fact that a few of the organizations referred to in this Guide are concerned primarily with symbols rather than quantity names. Thus IEC (41) states that " Names are used only for identification, and . . . are not part of this recommendation ", while IUPAP (110) notes that " In general no special attention is paid to the name of the quantity ".

Multiples and submultiples of the SI units are not listed but are just as acceptable as the units that are listed. If, for example, the SI unit listed in columns 3 and 4 is farad (F), the submultiples microfarad (μF) and picofarad (pF) are equally acceptable. (For a full explanation of multiples and submultiples of the SI units, see Annex 1, page 293).

The Conférence générale des Poids et Mesures has accepted certain non-SI units for general use with the SI. Some of these are relevant so often in the list of quantities that attention is not drawn to them. Thus the degree Celsius (°C) may be used instead of the kelvin (K), the degree (°) instead of the radian (rad), and the minute (min) or hour (h) instead of the second (s).

The listing of the numeral " 1 " in the third column indicates that the quantity in question is dimensionless.

Column 5

The last column is reserved for equations identifying the quantities (such equations are given only for identification, and are not intended to be complete definitions); for instructions on the use of the names, symbols, and units; and for references to the organizations that have made the recommendations. For the latter purpose, the following acronyms are used.

CBN	Council on Biochemical Nomenclature (IUPAC-IUB)
CCC	Commission on Clinical Chemistry (IUPAC)
CGPM	Conférence générale des Poids et Mesures
CODATA	Committee on Data for Science and Technology (International Council of Scientific Unions)
IAG	International Association of Geodesy
IAMAP	International Association of Meteorology and Atmospheric Physics
IAU	International Astronomical Union
ICRU	International Commission on Radiation Units and Measurements
ICSH	International Committee for Standardization in Hematology (International Society of Hematology)
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry
ISO	International Organization for Standardization
IUB	International Union of Biochemistry
IUGG	International Union of Geodesy and Geophysics
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IUPS	International Union of Physiological Societies
WASP	World Association of (Anatomic and Clinical) Pathology

A capital letter T, either standing alone or following one of the above acronyms, indicates a tentative recommendation that has not yet received final approval.

Miscellaneous notes

Greek letters. Several Greek letters have more than one form in the lower case (e.g., ϵ and ε, θ and ϑ, ϕ and φ, κ and $\varkappa$). Throughout this compilation only the first of each pair of these forms is used.

Meaning of " molar " and " specific ". Throughout the lists the terms " molar " and " specific " are used with their internationally agreed meanings (" divided by amount of substance " for the former and " divided by mass " for the latter). A few minor exceptions that have been sanctioned by the international scientific unions are noted in the " remarks " column of the list of quantities. It should be noted that the meanings of these two terms given above have rendered certain commonly used terms (e.g., " molar concentration ") incorrect; attention is drawn to such terms, which should no longer be used, in the " remarks " column.

Coverage

Attention is drawn to the fact that the first part of this Guide is not intended to be a complete dictionary of quantity names. Quantities are included only if they have been the subject of an international recommendation, and a very large number of quantity names will therefore not be found in the Guide.

Quantity	Symbol(s) for quantity	SI unit	Symbol for SI unit	Definitions, non-SI units, references, remarks
absolute activity *see* activity, absolute				
absolute temperature *see* temperature, thermodynamic				
absorbance *see* internal transmission density				
absorbance, napierian *see remarks under* internal transmission density				
absorbed dose (ionizing radiation)	D	gray	Gy	The limit of mean specific energy imparted as the mass approaches zero: $D = \mathrm{d}\bar{\epsilon}/\mathrm{d}m \lim_{m\to 0} \bar{z}$ (ICRU, 21). ISO (14) does not differentiate between mean specific energy imparted and absorbed dose, and gives only the latter. " Gray " is a special name for the SI unit joule per kilogram (J/kg) adopted by the 15th CGPM, 1975, for the measurement of absorbed dose. Non-SI unit accepted by CGPM for use for a limited time: rad (the symbol rd may be used if necessary to avoid confusion with the radian). 1 rad = 10^{-2} J/kg = 10^{-2} Gy. See also *specific energy imparted, mean*; and see Annex 6, page 304
absorbed dose index (radiation protection)	D_I	gray	Gy	(ICRU, 21). For the gray, see remarks under *absorbed dose*, above
absorbed dose rate	$\dot{D}$	gray per second	Gy/s	(ICRU, 21). Non-SI unit: rad per second (rad/s). For the gray and the rad, see remarks under *absorbed dose*, above. 1 rad/s = 10^{-2} Gy/s [1 Gy/s = 1 J/(kg·s) = 1 W/kg]
absorptance; absorption factor	α	1		$\alpha = \Phi_a/\Phi_0$ (ratio of absorbed to incident radiant or luminous flux). For spectroscopy, IUPAC (75) prefers the term " absorptance ". This quantity includes the absorption properties