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Quantities and units —

Part 10: Atomic and nuclear physics

Grandeurs et unités —

Partie 10: Physique atomique et nucléaire

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for whom a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 80000-10 was prepared by Technical Committee ISO/TC 12, *Quantities and units,* in co-operation with IEC/TC 25, *Quantities and units*.

This first edition of ISO 80000-10 cancels and replaces ISO 31-9:1992 and ISO 31-10:1992. It also incorporates Amendments ISO 31-9:1992/Amd.1:1998 and ISO 31-10:1992/Amd.1:1998. The major technical changes from the previous standards are the following:

— Annex A and Annex B to ISO 31-9:1992 have been deleted (as they are covered by ISO 80000-9);

— Annex C to ISO 31-9:1992 has become Annex A;

— Annex D to ISO 31-9:1992 has been deleted;

— the presentation of numerical statements has been changed;

— the *Normative references* have been changed;

— items 10-33 and 10-53 from ISO 31-10:1992 have been deleted;

— new items have been added;

— many definitions have been re-formulated;

— newer values for fundamental constants have been used.

ISO 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 1: General*

— *Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*

— *Part 3: Space and time*

— *Part 4: Mechanics*

— *Part 5: Thermodynamics*

— *Part 7: Light*

— *Part 8: Acoustics*

— *Part 9: Physical chemistry and molecular physics*

— *Part 10: Atomic and nuclear physics*

— *Part 11: Characteristic numbers*

— *Part 12: Solid state physics*

IEC 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 6: Electromagnetism*

— *Part 13: Information science and technology*

— *Part 14: Telebiometrics related to human physiology*

Introduction

0.1 Arrangements of the tables

The tables of quantities and units in this International Standard are arranged so that the quantities are presented on the left-hand pages and the units on the corresponding right-hand pages.

All units between two full lines on the right-hand pages belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of an item has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parenthesis on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

0.2 Tables of quantities

The names in English and in French of the most important quantities within the field of this International Standard are given together with their symbols and, in most cases, their definitions. These names and symbols are recommendations. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed on the left hand pages of the table; they are not intended to be complete.

The scalar, vector or tensor character of quantities is pointed out, especially when this is needed for the definitions.

In most cases only one name and only one symbol for the quantity are given; where two or more names or two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When two types of italic letters exist (for example as with ϑ and θ; φ and ϕ; *a* and a; *g* and g), only one of these is given. This does not mean that the other is not equally acceptable. It is recommended that such variants not be given different meanings. A symbol within parentheses implies that it is a reserve symbol, to be used when, in a particular context, the main symbol is in use with a different meaning.

In this English edition, the quantity names in French are printed in an italic font, and are preceded by *fr*. The gender of the French name is indicated by (m) for masculine and (f) for feminine, immediately after the noun in the French name.

0.3 Tables of units

0.3.1 General

The names of units for the corresponding quantities are given together with the international symbols and the definitions. These unit names are language-dependent, but the symbols are international and the same in all languages. For further information, see the SI Brochure (8th edition, 2006) from BIPM and ISO 80000-1.

The units are arranged in the following way:

a) The coherent SI units are given first. The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM). The coherent SI units and their decimal multiples and submultiples formed with the SI prefixes are recommended, although the decimal multiples and submultiples are not explicitly mentioned.

b) Some non-SI units are then given, namely those accepted by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM), or by the International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), or by ISO and IEC, for use with the SI.

   Such units are separated from the SI units in the item by use of a broken line between the SI units and the other units.

c) Non-SI units currently accepted by the CIPM for use with the SI are given in small print (smaller than the text size) in the "Conversion factors and remarks" column.

d) Non-SI units that are not recommended are given only in annexes in some parts of this International Standard. These annexes are informative, in the first place for the conversion factors, and are not integral parts of the standard. These deprecated units are arranged in two groups:

   1) units in the CGS system with special names;

   2) units based on the foot, pound, second, and some other related units.

e) Other non-SI units given for information, especially regarding the conversion factors, are given in informative annexes in some parts of this International Standard.

0.3.2 Remark on units for quantities of dimension one, or dimensionless quantities

The coherent unit for any quantity of dimension one, also called a dimensionless quantity, is the number one, symbol 1. When the value of such a quantity is expressed, the unit symbol 1 is generally not written out explicitly.

EXAMPLE 1 Refractive index $n = 1{,}53 \times 1 = 1{,}53$

Prefixes shall not be used to form multiples or submultiples of this unit. Instead of prefixes, powers of 10 are recommended.

EXAMPLE 2 Reynolds number $Re = 1{,}32 \times 10^3$

Considering that the plane angle is generally expressed as the ratio of two lengths and the solid angle as the ratio of two areas, in 1995 the CGPM specified that, in the SI, the radian, symbol rad, and steradian, symbol sr, are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as derived quantities of dimension one. The units radian and steradian are thus equal to one; they may either be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different kind but having the same dimension.

0.4 Numerical statements in this International Standard

The sign = is used to denote "is exactly equal to", the sign ≈ is used to denote "is approximately equal to", and the sign := is used to denote "is by definition equal to".

Numerical values of physical quantities that have been experimentally determined always have an associated measurement uncertainty. This uncertainty should always be specified. In this International Standard, the magnitude of the uncertainty is represented as in the following example.

EXAMPLE $l = 2{,}347\,82(32)$ m

In this example, $l = a(b)$ m, the numerical value of the uncertainty b indicated in parentheses is assumed to apply to the last (and least significant) digits of the numerical value a of the length l. This notation is used when b represents the standard uncertainty (estimated standard deviation) in the last digits of a. The numerical example given above may be interpreted to mean that the best estimate of the numerical value of the length l, when l is expressed in the unit metre is 2,347 82, and that the unknown value of l is believed to lie between (2,347 82 – 0,000 32) m and (2,347 82 + 0,000 32) m with a probability determined by the standard uncertainty 0,000 32 m and the probability distribution of the values of l.

0.5 Special remarks

0.5.1 Quantities

The fundamental physical constants given in ISO 80000-10 are quoted in the consistent values of the fundamental physical constants published in “2006 CODATA recommended values”. See the CODATA website: http://physics.nist.gov/cuu/constants/index.html.

0.5.2 Special units

Individual scientists should have the freedom to use non-SI units when they see a particular scientific advantage in their work. For this reason, non-SI units which are relevant for atomic and nuclear physics are listed in Annex A.

Quantities and units —

Part 10:
Atomic and nuclear physics

1 Scope

ISO 80000-10 gives the names, symbols, and definitions for quantities and units used in atomic and nuclear physics. Where appropriate, conversion factors are also given.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 80000-3:2006, *Quantities and units — Part 3: Space and time*

ISO 80000-4:2006, *Quantities and units — Part 4: Mechanics*

ISO 80000-5:2007, *Quantities and units — Part 5: Thermodynamics*

IEC 80000-6:2008, *Quantities and units — Part 6: Electromagnetism*

ISO 80000-7:2008, *Quantities and units — Part 7: Light*

ISO 80000-9:2009, *Quantities and units — Part 9: Physical chemistry and molecular physics*

3 Names, symbols, and definitions

The names, symbols, and definitions for quantities and units used in atomic and nuclear physics are given on the following pages.

ATOMIC AND NUCLEAR PHYSICS | **QUANTITIES**

Item No.	Name	Symbol	Definition	Remarks
10-1.1 *(9-1)*	atomic number, proton number *fr numéro* (m) *atomique, nombre* (m) *de protons*	Z	number of protons in an atomic nucleus	A nuclide is a species of atom with specified numbers of protons and neutrons. Nuclides with the same value of Z but different values of N are called isotopes of an element. The ordinal number of an element in the periodic table is equal to the atomic number. The atomic number equals the charge of the nucleus in units of the elementary charge (item 10-5.1).
10-1.2 *(9-2)*	neutron number *fr nombre* (m) *de neutrons*	N	number of neutrons in an atomic nucleus	Nuclides with the same value of N but different values of Z are called isotones. $N - Z$ is called the neutron excess number.
10-1.3 *(9-3)*	nucleon number, mass number *fr nombre* (m) *de nucléons, nombre* (m) *de masse*	A	number of nucleons in an atomic nucleus	$A = Z + N$ Nuclides with the same value of A are called isobars.
10-2 *(9-5.1)* *(9-5.2)* *(9-5.3)*	rest mass, proper mass *fr masse* (f) *au repos, masse* (f) *propre*	$m(\mathrm{X})$, m_X	for particle X, mass (ISO 80000-4:2006, item 4-1) of that particle at rest	Specifically, for an electron: $m_\mathrm{e} = 9{,}109\ 382\ 15(45) \times 10^{-31}$ kg; for a proton: $m_\mathrm{p} = 1{,}672\ 621\ 637(83) \times 10^{-27}$ kg; for a neutron: $m_\mathrm{n} = 1{,}674\ 927\ 211(84) \times 10^{-27}$ kg [2006 CODATA recommended values]. Rest mass is often denoted m_0.
10-3 (—)	rest energy *fr énergie* (f) *au repos*	E_0	for a particle, $E_0 = m_0 c_0^2$ where m_0 is the rest mass (item 10-2) of that particle, and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	Name	Symbol	Definition	Conversion factors and remarks
10-1.a	one	1		See the Introduction, 0.3.2.
10-2.a	kilogram	kg		
10-2.b	dalton, unified atomic mass unit	Da u	1 dalton is equal to 1/12 times the mass of a free carbon 12 atom, at rest and in its ground state	1 Da = 1 u = 1,660 538 782(83) $\times$ 10^{-27} kg [2006 CODATA recommended values].
10-3.a	joule	J		

(continued)

ATOMIC AND NUCLEAR PHYSICS — **QUANTITIES**

Item No.	Name	Symbol	Definition	Remarks
10-4.1 (*9-4.1*)	atomic mass, nuclidic mass *fr* *masse* (f) *atomique*, *masse* (f) *nucléidique*	$m(\mathrm{X})$, m_a	rest mass (ISO 80000-4:2006, item 4-1) of a neutral atom or a nuclide X in the ground state	$\frac{m_\mathrm{a}}{m_\mathrm{u}}$ is called the relative atomic mass.
10-4.2 (*9-4.2*)	unified atomic mass constant *fr* *constante* (f) *unifiée de masse atomique*	m_u	1/12 of the mass (ISO 80000-4:2006, item 4-1) of a neutral atom of the nuclide $^{12}\mathrm{C}$ in the ground state at rest	$m_\mathrm{u} = 1{,}660\ 538\ 782(83) \times 10^{-27}$ kg [2006 CODATA recommended values].
10-5.1 (*9-6*)	elementary charge *fr* *charge* (f) *élémentaire*	e	negative of electric charge (IEC 80000-6:2008, item 6-2) of the electron	$e = 1{,}602\ 176\ 487(40) \times 10^{-19}$ C [2006 CODATA recommended values].
10-5.2 (—)	charge number, ionization number *fr* *nombre* (m) *de charge*, *charge* (f) *ionique*	c	for a particle, the electric charge (IEC 80000-6:2008, item 6-2) divided by the elementary charge (item 10-5.1)	A particle is said to be electrically neutral if its charge number is equal to zero. The charge number of a particle can be positive, negative, or zero. The state of charge of a particle may be presented as a superscript to the symbol of that particle, e.g. H^+, He^{++}, Al^{3+}, Cl^-, $\mathrm{S}^=$, N^{3-}
10-6.1 (*9-7*)	Planck constant *fr* *constante* (f) *de Planck*	h	elementary quantum of action (ISO 80000-4:2006, item 4-37)	$h = 6{,}626\ 068\ 96(33) \times 10^{-34}$ J s [2006 CODATA recommended values]. Energy E of harmonic vibration of frequency f can change for multiples of $\Delta E = hf = \hbar\omega$ only.
10-6.2 (—)	reduced Planck constant *fr* *constante* (f) *de Planck réduite*	$\hbar$	$\hbar = \frac{h}{2\pi}$ where h is the Planck constant (item 10-6.1)	$\hbar = 1{,}054\ 571\ 628(53) \times 10^{-34}$ J s [2006 CODATA recommended values]. $\hbar$ is sometimes known as hbar or the Dirac constant.

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-4.a	kilogram	kg		
10-4.b	dalton, unified atomic mass unit	Da, u	1 dalton is equal to 1/12 times the mass of a free carbon 12 atom, at rest and in its ground state	1 Da = 1 u = 1,660 538 782(83) × 10^{-27} kg [2006 CODATA recommended values].
10-5.a	coulomb	C		
10-6.a	joule second	J · s		

(continued)

ATOMIC AND NUCLEAR PHYSICS				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-7 *(9-8)*	Bohr radius *fr rayon* (m) *de Bohr*	a_0	$a_0 = \frac{4\pi\varepsilon_0 \hbar^2}{m_e e^2}$ where ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), $\hbar$ is the reduced Planck constant (item 10-6.2), m_e is the rest mass of electron (item 10-2), and e is the elementary charge (item 10-5.1)	a_0 = 0,529 177 208 59(36) × 10^{-10} m [2006 CODATA recommended values]. The radius of the electron orbital in the H-atom in its ground state is a_0 in the Bohr model of the atom.
10-8 *(9-9)*	Rydberg constant *fr constante* (f) *de Rydberg*	R_∞	$R_\infty = \frac{e^2}{8\pi\varepsilon_0 a_0 h c_0}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), a_0 is the Bohr radius (item 10-7), h is the Planck constant (item 10-6.1), and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	R_∞ = 10 973 731,568 527(73) m^{-1} [2006 CODATA recommended values] The quantity $R_y = R_\infty \cdot hc_0$ is called Rydberg energy.
10-9 *(9-10)*	Hartree energy *fr énergie* (f) *de Hartree*	E_H, E_h	$E_H = \frac{e^2}{4\pi\varepsilon_0 a_0}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), and a_0 is the Bohr radius (item 10-7)	E_H = 4,359 743 94(22) × 10^{-18} J [2006 CODATA recommended values]. The energy of the electron in H-atom in its ground state is $-E_H$. $E_H = 2R_\infty \cdot hc_0$.

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-7.a	metre	m		ångström (Å), 1 Å := 10^{-10} m
10-8.a	metre to the power minus one	m^{-1}		
10-9.a	joule	J		

(continued)