INTERNATIONAL STANDARD

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AMENDMENT 1
1998-12-15

Quantities and units —

Part 1: Space and time
Part 2: Periodic and related phenomena
Part 3: Mechanics
Part 4: Heat
Part 5: Electricity and magnetism
Part 6: Light and related electromagnetic radiations
Part 7: Acoustics
Part 8: Physical chemistry and molecular physics
Part 9: Atomic and nuclear physics
Part 10: Nuclear reactions and ionizing radiations
Part 12: Characteristic numbers
Part 13: Solid state physics

AMENDMENT 1

Grandeurs et unités —

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Partie 2: Phénomènes périodiques et connexes
Partie 3: Mécanique
Partie 4: Chaleur
Partie 5: Électricité et magnétisme
Partie 6: Lumière et rayonnements électromagnétiques connexes
Partie 7: Acoustique
Partie 8: Chimie physique et physique moléculaire
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Partie 10: Réactions nucléaires et rayonnements ionisants
Partie 12: Nombres caractéristiques
Partie 13: Physique de l'état solide

AMENDEMENT 1

Reference number
ISO 31 (parts 1 to 10, 12 and 13):1992/Amd.1:1998(E)

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 which 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.

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.

Amendment 1 to parts 1 to 10, 12 and 13 of International Standard ISO 31:1992 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors*.

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Quantities and units —

Part 1: Space and time
Part 2: Periodic and related phenomena
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Part 4: Heat
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Part 6: Light and related electromagnetic radiations
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Part 9: Atomic and nuclear physics
Part 10: Nuclear reactions and ionizing radiations
Part 12: Characteristic numbers
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AMENDMENT 1

Page v

Replace subclause 0.3.2 with the following text:

0.3.2 Remark on units for quantities of dimension one

The coherent unit for any quantity of dimension one 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

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 may be used.

EXAMPLE

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

Considering that plane angle is generally expressed as the ratio of two lengths and solid angle as the ratio of two areas, in 1995 the CGPM has specified that, in the International System of Units, the radian, rad, and the steradian, 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 may be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different nature but having the same dimension.

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Price based on 1 page

INTERNATIONAL STANDARD

ISO 31-10

Third edition
1992-11-01

Quantities and units —

Part 10:
Nuclear reactions and ionizing radiations

Grandeurs et unités —

Partie 10: Réactions nucléaires et rayonnements ionisants

Reference number
ISO 31-10:1992(E)

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 which 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.

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.

International Standard ISO 31-10 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors.*

This third edition cancels and replaces the second edition (ISO 31-10:1980). The major technical changes from the second edition are the following:

— the decision by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM) in 1980 concerning the status of supplementary units has been incorporated;

— units in use temporarily have been transferred to the "Conversion factors and remarks" column;

— the annex has been deleted.

The scope of Technical Committee ISO/TC 12 is standardization of units and symbols for quantities and units (and mathematical symbols) used within the different fields of science and technology, giving, where necessary, definitions of these quantities and units. Standard conversion factors for converting between the various units also come under the scope of the TC. In fulfilment of this responsibility, ISO/TC 12 has prepared ISO 31.

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ISO 31 consists of the following parts, under the general title *Quantities and units*:

- *Part 0: General principles*
- *Part 1: Space and time*
- *Part 2: Periodic and related phenomena*
- *Part 3: Mechanics*
- *Part 4: Heat*
- *Part 5: Electricity and magnetism*
- *Part 6: Light and related electromagnetic radiations*
- *Part 7: Acoustics*
- *Part 8: Physical chemistry and molecular physics*
- *Part 9: Atomic and nuclear physics*
- *Part 10: Nuclear reactions and ionizing radiations*
- *Part 11: Mathematical signs and symbols for use in the physical sciences and technology*
- *Part 12: Characteristic numbers*
- *Part 13: Solid state physics*

Introduction

0.1 Arrangement of the tables

The tables of quantities and units in ISO 31 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 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 parentheses 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 most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

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 (sloping) letter exist (for example as with ϑ, θ; φ, ϕ; g, g) only one of these is given. This does not mean that the other is not equally acceptable. In general it is recommended that such variants should 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.

0.3 Tables of units

0.3.1 General

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see ISO 31-0.

The units are arranged in the following way:

a) The names of the SI units are given in large print (larger than text size). The SI units have been adopted by the General Conference on Weights and Measures (Conference Générale des Poids et Mesures, CGPM).

The SI units and their decimal multiples and sub-multiples are recommended, although the decimal multiples and sub-multiples are not explicitly mentioned.

b) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

These units are separated by a broken line from the SI units for the quantities concerned.

c) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size) in the "Conversion factors and remarks" column.

d) The names of non-SI units which should not be combined with SI units are given only in annexes in some parts of ISO 31. These annexes are informative and not integral parts of the standard. They are arranged in three groups:

   1) special names of units in the CGS system;

   2) names of units based on the foot, pound and second and some other related units;

   3) names of other units.

0.3.2 Remark on units for quantities of dimension one

The coherent unit for any quantity of dimension one is the number one (1). When the value of such a quantity is expressed, the unit 1 is generally not written out explicitly. Prefixes shall not be used to form multiples or sub-multiples of this unit. Instead of prefixes, powers of 10 may be used.

EXAMPLES

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

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

Considering that plane angle is generally expressed as the ratio between two lengths, and solid angle as the ratio between an area and the square of a length, the CIPM specified in 1980 that, in the International System of Units, the radian and steradian are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as dimensionless derived quantities. The units radian and steradian may be used in expressions for derived units to facilitate distinction between quantities of different nature but having the same dimension.

0.4 Numerical statements

All numbers in the "Definition" column are exact.

When numbers in the "Conversion factors and remarks" column are exact, the word "exactly" is added in parentheses after the number.

0.5 Special remarks

In this part of ISO 31, the term "particle" includes particles without a rest mass as well as particles having a rest mass.

Several quantities given in this part of ISO 31 are spectral concentrations expressed in terms of energy, speed, solid angle, etc. The subscripts E, v and Ω are used as part of the symbol to indicate that the quantity has the dimension of a derivative with respect to E, v and Ω respectively. Spectral concentrations are also called distribution functions. The name of a quantity which is a spectral concentration may be shortened by replacing the words "spectral concentration of" by the adjective "spectral". In general, these distribution functions are only mentioned in the remarks column; see for example 10-12, 10-29, 10-31 and 10-32.

In the case of cross-sections, some of these distribution functions are given special names and are listed as separate items.

Quantities and units —

Part 10:
Nuclear reactions and ionizing radiations

1 Scope

This part of ISO 31 gives names and symbols for quantities and units of nuclear reactions and ionizing radiations. Where appropriate, conversion factors are also given.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 31. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 31 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 31-6:1992, *Quantities and units — Part 6: Light and related electromagnetic radiations.*

ISO 31-9:1992, *Quantities and units — Part 9: Atomic and nuclear physics.*

3 Names and symbols

The names and symbols for quantities and units of nuclear reactions and ionizing radiations are given on the following pages.

NUCLEAR REACTIONS AND IONIZING RADIATIONS — Quantities

Item No.	Quantity	Symbol	Definition	Remarks
10-1	reaction energy	Q	In a nuclear reaction, the sum of the kinetic and photon energies of the reaction products minus the sum of the kinetic and photon energies of the reactants	For exothermic nuclear reactions, $Q > 0$. For endothermic nuclear reactions, $Q < 0$. For beta disintegration, see ISO 31-9.
10-2	resonance energy	E_r, E_{res}	Kinetic energy of an incident particle, in the reference frame of the target, corresponding to a resonance in a nuclear reaction	
10-3.1	cross-section	σ	For a specified target entity and for a specified reaction or process produced by incident charged or uncharged particles of specified type and energy, the cross-section is the probability of this reaction or process for this target entity divided by the incident-particle fluence	The type of process is indicated by subscripts, e.g. absorption cross-section σ_a scattering cross-section σ_s fission cross-section σ_f.
10-3.2	total cross-section	σ_{tot}, σ_T	The sum of all cross-sections corresponding to the various reactions or processes between an incident particle of specified type and energy and a target particle	In the case of a narrow unidirectional beam of incident particles, this is the effective cross-section for the removal of an incident particle from the beam. See remark on 10-16.

Units			NUCLEAR REACTIONS AND IONIZING RADIATIONS	
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
10-1.a	joule	J		
10-1.b	electronvolt	eV		1 eV = (1,602 177 33 ± 0,000 000 49) × 10^{-19} J [1)] Quantity 10-1 is usually expressed in electronvolts.
1) CODATA Bulletin 63 (1986).				
10-2.a	joule	J		
10-2.b	electronvolt	eV		1 eV = (1,602 177 33 ± 0,000 000 49) × 10^{-19} J [1)] Quantity 10-2 is usually expressed in electronvolts.
1) CODATA Bulletin 63 (1986).				
10-3.a	square metre	m^2		barn (b), 1 b = 10^{-28} m^2

NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
10-4	angular cross-section	σ_Ω	Cross-section for ejecting or scattering a particle into an element of solid angle, divided by this element. $\sigma = \int \sigma_\Omega \, \mathrm{d}\Omega$	Quantities 10-4, 10-5 and 10-6 are sometimes called differential cross-sections. In accordance with conventions used in other parts of ISO 31, angular and spectral cross-sections are indicated by the use of subscripts. Information about incoming and outgoing particles may be added between parentheses, e.g. $\sigma_{\Omega,E}(\mathrm{n}E_0, \mathrm{p}E\vartheta)$ or $\sigma_{\Omega,E}(\mathrm{n}E_0, \mathrm{p})$ or $\sigma_{\Omega,E}(\mathrm{n}, \mathrm{p})$. The cross-section for a process in which an incoming neutron of energy E_0 causes the ejection of a proton within the energy interval $(E, E + \mathrm{d}E)$ and in the element of solid angle $\mathrm{d}\Omega$, about the scattering angle ϑ is $\sigma_{\Omega,E}(\mathrm{n}E_0, \mathrm{p}E\vartheta) \, \mathrm{d}\Omega \, \mathrm{d}E$. Sometimes the incoming and outgoing particles are indicated by subscripts, in which case the subscript Ω or E indicating the angular or spectral character could be placed in the superscript position, e.g. $\sigma_{\mathrm{n,p}}^{\Omega,E}(E_0)$ or $\sigma_{\mathrm{n,p}}^{\Omega,E}$. If, however, the subscripts Ω or E are omitted completely from the cross-section symbol, the angular or spectral character of the cross-section then follows only from the occurrence of the variable ϑ or E for the outgoing particles between the parentheses, e.g. $\sigma_{\mathrm{n,p}}(E_0, E\vartheta)$ or $\sigma_{\mathrm{n,p}}(E\vartheta)$. These variables should then never be omitted.
10-5	spectral cross-section	σ_E	Cross-section for a process in which the energy of the ejected or scattered particle is in an element of energy, divided by this element. $\sigma = \int \sigma_E \, \mathrm{d}E$	
10-6	spectral angular cross-section	$\sigma_{\Omega,E}$	Cross-section for ejecting or scattering a particle into an element of solid angle with energy in an element of energy, divided by the product of these two elements. $\sigma = \iint \sigma_{\Omega,E} \, \mathrm{d}\Omega \, \mathrm{d}E$	

Units NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
10-4.a	square metre per steradian	m^2/sr		
10-5.a	square metre per joule	m^2/J		
10-6.a	square metre per steradian joule	$m^2/(sr \cdot J)$		

NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
10-7.1	volumic cross-section, macroscopic cross-section	Σ	Sum of the cross-sections for a reaction or process of a specified type over all atoms in a given volume, divided by that volume	$\Sigma = n_1\sigma_1 + ... + n_i\sigma_i + ...$ where n_i is the number density and σ_i is the cross-section for atoms of type i. When the target particles of the medium are at rest, $\Sigma = 1/l$, where l is the mean free path (see 10-39).
10-7.2	volumic total cross-section, macroscopic total cross-section	Σ_{tot}, Σ_T	Sum of the total cross-sections for all atoms in a given volume, divided by that volume	See remark on 10-13.
10-8	particle fluence	Φ	At a given point in space, the number of particles incident on a small sphere, divided by the cross-sectional area of that sphere	Usually the word particle is replaced by the name of a specific particle, for example proton fluence.
10-9	particle fluence rate, (particle flux density)	φ	$\varphi = \frac{d\Phi}{dt}$	See also 10-31, where distribution functions are also included in the "Remarks" column.
10-10	energy fluence	Ψ	At a given point in space, the sum of the energies, exclusive of rest energy, of all the particles incident on a small sphere, divided by the cross-sectional area of that sphere	
10-11	energy fluence rate, (energy flux density)	ψ	$\psi = \frac{d\Psi}{dt}$	
10-12	current density of particles	J, (S)	Vector quantity, the integral of whose normal component over any surface is equal to the net number I of particles passing through that surface in a small time interval divided by that interval. $\int \boldsymbol{J} \cdot \boldsymbol{e}_n \, dA = dI/dt$ where $\boldsymbol{e}_n \, dA$ is a surface element	S is recommended when there is a possibility of confusion with the symbol J for electric current density. For neutron current density, the symbol J is generally used. The distribution functions expressed in terms of speed and energy, J_v and J_E, are related to J by $J = \int J_v \, dv = \int J_E \, dE$.

Units NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
10-7.a	reciprocal metre, metre to the power minus one	m^{-1}		
10-8.a	reciprocal square metre, metre to the power minus two	m^{-2}		
10-9.a	reciprocal square metre per second, metre to the power minus two per second	m^{-2}/s		
10-10.a	joule per square metre	J/m^2		
10-11.a	watt per square metre	W/m^2		
10-12.a	reciprocal square metre per second, metre to the power minus two per second	m^{-2}/s		

NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
10-13	linear attenuation coefficient	μ, μ_l	$\mu = -(1/J)\, \mathrm{d}J/\mathrm{d}x$ where J is the current density of a beam of particles parallel to the x-direction	μ is equal to the macroscopic total cross-section Σ_{tot} for removal of particles from the beam.
10-14	mass attenuation coefficient	μ_m	The linear attenuation coefficient divided by the volumic mass of the substance. $\mu_m = \mu/\varrho$	
10-15	molar attenuation coefficient	μ_c	$\mu_c = \mu/c$ where c is the amount-of-substance concentration	
10-16	atomic attenuation coefficient	μ_a, μ_{at}	$\mu_a = \mu/n$ where n is the number density of the atoms in the substance (see also 10-27)	μ_a is equal to the total cross-section σ_{tot} for removal of particles from the beam.
10-17	half-thickness, half-value thickness	$d_{1/2}$	Thickness of the attenuating layer that reduces the current density of a unidirectional beam to one-half of its initial value	For exponential attenuation, $d_{1/2} = (\ln 2)/\mu$. Other half-value thicknesses, such as that for attenuation of absorbed dose rate, are also used.
10-18	total linear stopping power	S, S_l	For an ionizing charged particle of energy E moving in the x-direction, $S = -\mathrm{d}E/\mathrm{d}x$	Also called stopping power. Both collision losses and radiation losses are included. The ratio of the total linear stopping power of a substance to that of a reference substance is called the relative linear stopping power. See also 10-54.
10-19	total atomic stopping power	S_a	$S_a = S/n$ where n is the number density of the atoms in the substance	

Units		NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)		
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
10-13.a	reciprocal metre, metre to the power minus one	m^{-1}		
10-14.a	metre squared per kilogram	m^2/kg		
10-15.a	metre squared per mole	m^2/mol		
10-16.a	metre squared	m^2		
10-17.a	metre	m		
10-18.a	joule per metre	J/m		
10-18.b	electronvolt per metre	eV/m		1 eV/m = (1,602 177 33 ± 0,000 000 49) × 10^{-19} J/m [1]
1) CODATA Bulletin 63 (1986).				
10-19.a	joule metre squared	$J \cdot m^2$		
10-19.b	electronvolt metre squared	$eV \cdot m^2$		1 $eV \cdot m^2$ = (1,602 177 33 ± 0,000 000 49) × 10^{-19} $J \cdot m^2$ [1]
1) CODATA Bulletin 63 (1986).				

NUCLEAR REACTIONS AND IONIZING RADIATIONS (*continued*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
10-20	total mass stopping power	S_m	Total linear stopping power divided by the volumic mass of the substance. $S_m = S/\varrho$	The ratio of the total mass stopping power of a substance to that of a reference substance is called the relative mass stopping power.
10-21	mean linear range	R, R_l	Distance that a particle penetrates in a given substance under specified conditions averaged over a group of particles having the same initial energy	
10-22	mean mass range	R_ϱ, (R_m)	Mean linear range multiplied by the volumic mass of the substance. $R_\varrho = R \cdot \varrho$	
10-23	linear ionization by a particle	N_{il}	Number of elementary charges of the same sign produced over an element of length of the path of an ionizing charged particle, divided by that element	Ionization due to secondary ionizing particles, etc., is included.
10-24	total ionization by a particle	N_i	Total number of elementary charges of the same sign produced by an ionizing charged particle along its entire path	$N_\text{i} = \int N_{il}\, \text{d}l$ See remark on 10-23.
10-25	average energy loss per ion pair formed, (average energy loss per elementary charge of the same sign produced)	W_i	Initial kinetic energy of an ionizing charged particle, divided by the total ionization produced by that particle	The quantity S_l/N_{il}, sometimes called the average energy per ion pair formed, should not be confused with W_i.
10-26	mobility	μ	Average drift velocity imparted to a charged particle in a medium by an electric field, divided by the field strength	