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 —

Partie 1: Espace et temps
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
Partie 9: Physique atomique et nucléaire
Partie 10: Réactions nucléaires et rayonnements ionisants
Partie 12: Nombres caractéristiques
Partie 13: Physique de l'état solide

AMENDEMENT 1

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

Foreword

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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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Printed in Switzerland

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Quantities and units —

Part 1: Space and time
Part 2: Periodic and related phenomena
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AMENDMENT 1

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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.

STD.ISO 31-4-ENGL 1992 ■ 4851903 0775550 790 ■

ICS 01.060

Price based on 1 page

INTERNATIONAL STANDARD

ISO 31-4

Second edition
1992-09-01

Quantities and units —

Part 4:
Heat

Grandeurs et unités —
Partie 4: Chaleur

Reference number
ISO 31-4:1992(E)

ISO 31 PT*4 92 ■ 4851903 0508015 648 ■

Foreword

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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 31-4 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors.*

This second edition cancels and replaces the first edition (ISO 31-4:1978). The major technical changes from the first 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;

— the International Practical Temperature Scale 1968, IPTS-68, has been replaced by the International Temperature Scale 1990, ITS-90;

— a number of new items have been added.

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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Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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*

Annexes A and B of this part of ISO 31 are for information only.

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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 (Conférence 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.

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Quantities and units —

Part 4:
Heat

1 Scope

This part of ISO 31 gives names and symbols for quantities and units of heat. 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 31-0:1992, *Quantities and units — Part 0: General principles.*

ISO 31-8:1992, *Quantities and units — Part 8: Physical chemistry and molecular physics.*

Metrologia, **27** (1990), No. 1.

3 Names and symbols

The names and symbols for quantities and units of heat are given on the following pages.

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HEAT				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
4-1	thermodynamic temperature	T, (Θ)		Thermodynamic temperature is one of the base quantities on which the SI is based.
4-2	Celsius temperature	t, ϑ	$t = T - T_0$ where T_0 is defined as being equal to 273,15 K	The thermodynamic temperature T_0 is exactly 0,01 K below the thermodynamic temperature of the triple point of water.

Units				HEAT
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
4-1.a	kelvin	K	The kelvin, the unit of thermodynamic temperature, is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water	The units of thermodynamic and Celsius temperature interval or difference are identical. The CGPM has recommended that such intervals or differences should be expressed in kelvins (K) or in degrees Celsius (°C). Other names and symbols, such as "degré", "deg", "degree centigrade" or "degree", are deprecated. It should be noted that the symbol °C for the degree Celsius should be preceded by a space (see ISO 31-0:1992, subclause 3.4).
4-2.a	degree Celsius	°C	The degree Celsius is a special name for the kelvin for use in stating values of Celsius temperature	**The International Temperature Scale of 1990 (ITS-90)** For the purpose of practical measurements the International Temperature Scale of 1990 was adopted by the CIPM in 1989, in accordance with Resolution 7 of the 18th CGPM, 1987. It is based on a number of fixed points and interpolation procedures with the help of certain measuring instruments and defines the temperature down to 0,65 K. This scale supersedes the International Practical Temperature Scale of 1968, IPTS-68, (amended edition of 1975) and the 1976 Provisional 0,5 K to 30 K Temperature Scale. The quantities corresponding to thermodynamic temperature and Celsius temperature defined by this scale are indicated respectively by T_{90} and t_{90} (replacing T_{68} and t_{68} defined by IPTS-68), where $t_{90} = T_{90} - T_0$ T_{90} is called the International Kelvin Temperature and t_{90} the International Celsius Temperature. The units of T_{90} and t_{90} are the kelvin, K, and degree Celsius, °C, respectively, as in the case of T and t. For further information see *Metrologia*, **27** (1990), No. 1.

HEAT *(continued)* Quantities

Item No.	Quantity	Symbol	Definition	Remarks
4-3.1	linear expansion coefficient	α_l	$\alpha_l = \frac{1}{l}\frac{dl}{dT}$	The quantities 4-3.1 to 4-4 are not completely defined unless the type of change is specified. The subscripts in the symbols may be omitted when there is no risk of confusion. The name pressure coefficient and the symbol β are also used for the quantity 4-3.3.
4-3.2	cubic expansion coefficient	α_V, α, (γ)	$\alpha_V = \frac{1}{V}\frac{dV}{dT}$	
4-3.3	relative pressure coefficient	α_p	$\alpha_p = \frac{1}{p}\frac{dp}{dT}$	
4-4	pressure coefficient	β	$\beta = \frac{dp}{dT}$	
4-5.1	isothermal compressibility	$\varkappa_T$	$\varkappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T$	
4-5.2 (—)	isentropic compressibility	$\varkappa_S$	$\varkappa_S = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_S$	
4-6	heat, quantity of heat	Q		The heat transferred in an isothermal phase transformation, formerly called "latent heat", with the symbol L, should be expressed as the change in the appropriate thermodynamic functions, e.g. $T \cdot \Delta S$, where ΔS is the change in entropy, or ΔH, the change in enthalpy.
4-7	heat flow rate	Φ	Rate at which heat crosses a given surface	
4-8	areic heat flow rate, density of heat flow rate	q, φ	Heat flow rate divided by area	
4-9	thermal conductivity	λ, ($\varkappa$)	Areic heat flow rate divided by temperature gradient	
4-10.1	coefficient of heat transfer	K, (k)	Areic heat flow rate divided by temperature difference	In building technology, this quantity is often called thermal transmittance, with the symbol U.
4-10.2 (—)	surface coefficient of heat transfer	h, (α)	$q = h(T_s - T_r)$ where T_s is the temperature of the surface and T_r is a reference temperature characteristic of the external surroundings	

Units				HEAT (*continued*)
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
4-3.a	reciprocal kelvin, kelvin to the power minus one	K^{-1}		
4-4.a	pascal per kelvin	Pa/K		
4-5.a	reciprocal pascal, pascal to the power minus one	Pa^{-1}		
4-6.a	joule	J		
4-7.a	watt	W		
4-8.a	watt per square metre	W/m^2		
4-9.a	watt per metre kelvin	$W/(m \cdot K)$		
4-10.a	watt per square metre kelvin	$W/\left(m^2 \cdot K\right)$		

HEAT (*continued*) Quantities

Item No.	Quantity	Symbol	Definition	Remarks
4-11	thermal insulance, coefficient of thermal insulation	M	Temperature difference divided by areic heat flow rate. $M = 1/K$	In building technology this quantity is often called thermal resistance, with the symbol R.
4-12	thermal resistance	R	Temperature difference divided by heat flow rate	See remark on 4-11.
4-13 (—)	thermal conductance	G	$G = 1/R$	See remark on 4-11.
4-14 (*4-13.1*)	thermal diffusivity	a	$a = \frac{\lambda}{\varrho c_p}$ where λ is the thermal conductivity, ϱ the volumic mass and c_p the massic heat capacity at constant pressure	
4-15 (*4-14.1*)	heat capacity	C	When the temperature of a system is increased by dT as a result of the addition of a small quantity of heat dQ, the quantity dQ/dT is the heat capacity	This quantity is not completely defined unless the type of change is specified.
4-16.1 (*4-15.1*)	massic heat capacity, specific heat capacity	c	Heat capacity divided by mass	For the corresponding molar quantities, see ISO 31-8.
4-16.2 (*4-15.2*)	massic heat capacity at constant pressure, specific heat capacity at constant pressure	c_p		
4-16.3 (*4-15.3*)	massic heat capacity at constant volume, specific heat capacity at constant volume	c_V		
4-16.4 (*4-15.4*)	massic heat capacity at saturation, specific heat capacity at saturation	c_{sat}		

Units HEAT (*continued*)

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
4-11.a	square metre kelvin per watt	$m^2 \cdot K/W$		
4-12.a	kelvin per watt	K/W		
4-13.a	watt per kelvin	W/K		
4-14.a	square metre per second	m^2/s		
4-15.a	joule per kelvin	J/K		
4-16.a	joule per kilogram kelvin	$J/(kg \cdot K)$		

HEAT (*continued*) Quantities

Item No.	Quantity	Symbol	Definition	Remarks
4-17.1 (*4-16.1*)	ratio of the massic heat capacities, ratio of the specific heat capacities	γ	$\gamma = c_p/c_V$	
4-17.2 (*4-16.2*)	isentropic exponent	$\varkappa$	$\varkappa = -\frac{V}{p}\left(\frac{\partial p}{\partial V}\right)_S$	For an ideal gas, $\varkappa$ is equal to γ.
4-18 (*4-17.1*)	entropy	S	When a small quantity of heat dQ is received by a system the thermodynamic temperature of which is T, the entropy of the system is increased by dQ/T, provided that no irreversible change takes place in the system	
4-19 (*4-18.1*)	massic entropy, specific entropy	s	Entropy divided by mass	For the corresponding molar quantities, see ISO 31-8.
4-20.1 (—)	energy	E	All kinds of energy	
4-20.2 (*4-19.1*)	thermodynamic energy	U	For a closed thermodynamic system $\Delta U = Q + W$ where Q is heat transferred to the system and W is work done on the system	Thermodynamic energy is also called internal energy.
4-20.3 (*4-19.2*)	enthalpy	H	$H = U + pV$	
4-20.4 (*4-19.3*)	Helmholtz free energy, Helmholtz function	A, F	$A = U - TS$	
4-20.5 (*4-19.4*)	Gibbs free energy, Gibbs function	G	$G = U + pV - TS$	$G = H - TS$

Units				HEAT (*continued*)
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
4-17.a	one	1		See the introduction, subclause 0.3.2.
4-18.a	joule per kelvin	J/K		
4-19.a	joule per kilogram kelvin	J/(kg · K)		
4-20.a	joule	J		

HEAT (*concluded*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
4-21.1 (—)	massic energy, specific energy	e	Energy divided by mass	For the corresponding molar quantities, see ISO 31-8.
4-21.2 (*4-20.1*)	massic thermodynamic energy, specific thermodynamic energy	u	Thermodynamic energy divided by mass	Massic thermodynamic energy is also called massic internal energy.
4-21.3 (*4-20.2*)	massic enthalpy, specific enthalpy	h	Enthalpy divided by mass	
4-21.4 (*4-20.3*)	massic Helmholtz free energy, specific Helmholtz free energy, specific Helmholtz function	a, f	Helmholtz free energy divided by mass	
4-21.5 (*4-20.4*)	massic Gibbs free energy, specific Gibbs free energy, specific Gibbs function	g	Gibbs free energy divided by mass	
4-22 (*4-21.1*)	Massieu function	J	$J = -A/T$	
4-23 (*4-22.1*)	Planck function	Y	$Y = -G/T$	

Units				HEAT (*concluded*)
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
4-21.a	joule per kilogram	J/kg		
4-22.a	joule per kelvin	J/K		
4-23.a	joule per kelvin	J/K		

Annex A
(informative)

Units based on the foot, pound and second and some other units

The use of these units is deprecated.

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
4-1	thermodynamic temperature	4-1.A.a	degree Rankine: °R	$1\ °R = \frac{5}{9}\ K$ The symbol °R for the degree Rankine shall be preceded by a space.
—	Fahrenheit temperature, t_F	4-2.A.a	degree Fahrenheit: °F	$\frac{t_F}{°F} = \frac{9}{5}\frac{t}{°C} + 32 = \frac{9}{5}\frac{T}{K} - 459{,}67$ The unit degree Fahrenheit is identical with the unit degree Rankine. The symbol °F for the degree Fahrenheit shall be preceded by a space.
4-6	heat, quantity of heat	4-6.A.a	British thermal unit: Btu	1 Btu = 788,169 ft · lbf = 1 055,056 J This is the only British thermal unit used in this annex. It is equal to the "International Table British thermal unit" adopted by the Fifth International Conference on Properties of Steam (London, July 1956). Besides this a number of "British thermal units" were formerly used.
4-7	heat flow rate	4-7.A.a	British thermal unit per hour: Btu/h	1 Btu/h = 0,293 071 1 W
4-9	thermal conductivity	4-9.A.a	British thermal unit per second foot degree Rankine: Btu/(s · ft · °R)	1 Btu/(s · ft · °R) = 6 230,64 W/(m · K)

Units based on the foot, pound and second and some other units *(continued)*				
Quantity item No.	**Quantity**	**Unit item No.**	**Name of unit with symbol**	**Conversion factors and remarks**
4-10	coefficient of heat transfer	4-10.A.a	British thermal unit per second square foot degree Rankine: $\mathrm{Btu/(s \cdot ft^2 \cdot {}^\circ R)}$	$1\ \mathrm{Btu/(s \cdot ft^2 \cdot {}^\circ R)} = 20\ 441{,}7\ \mathrm{W/(m^2 \cdot K)}$
		4-10.A.b	British thermal unit per hour square foot degree Rankine: $\mathrm{Btu/(h \cdot ft^2 \cdot {}^\circ R)}$	$1\ \mathrm{Btu/(h \cdot ft^2 \cdot {}^\circ R)} = 5{,}678\ 26\ \mathrm{W/(m^2 \cdot K)}$
4-14	thermal diffusivity	4-14.A.a	square foot per second: $\mathrm{ft^2/s}$	$1\ \mathrm{ft^2/s} = 0{,}092\ 903\ 04\ \mathrm{m^2/s}$ (exactly)
4-16.1	massic heat capacity, specific heat capacity	4-16.A.a	British thermal unit per pound degree Rankine: $\mathrm{Btu/(lb \cdot {}^\circ R)}$	$1\ \mathrm{Btu/(lb \cdot {}^\circ R)} = 4\ 186{,}8\ \mathrm{J/(kg \cdot K)}$ (exactly)
4-19	massic entropy, specific entropy	4-19.A.a	British thermal unit per pound degree Rankine: $\mathrm{Btu/(lb \cdot {}^\circ R)}$	$1\ \mathrm{Btu/(lb \cdot {}^\circ R)} = 4\ 186{,}8\ \mathrm{J/(kg \cdot K)}$ (exactly)
4-21.1	massic energy, specific energy	4-21.A.a	British thermal unit per pound: Btu/lb	1 Btu/lb = 2 326 J/kg (exactly)
4-21.2	massic thermodynamic energy, specific thermodynamic energy			
4-21.3	massic enthalpy, specific enthalpy			

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Units based on the foot, pound and second and some other units *(concluded)*				
Quantity item No.	**Quantity**	**Unit item No.**	**Name of unit with symbol**	**Conversion factors and remarks**
4-21.4	massic Helmholtz free energy, specific Helmholtz free energy, specific Helmholtz function	4-21.A.a	British thermal unit per pound: Btu/lb	1 Btu/lb = 2 326 J/kg (exactly)
4-21.5	massic Gibbs free energy, specific Gibbs free energy, specific Gibbs function			

Annex B
(informative)

Other units given for information, especially regarding the conversion factor

The use of these units is deprecated.

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
4-6	heat, quantity of heat	4-6.B.a	15 °C calorie: cal_{15}	1 cal_{15} is the amount of heat required to warm 1 g of air-free water from 14,5 °C to 15,5 °C at a constant pressure of 101,325 kPa. 1 cal_{15} = 4,185 5 J This value is uncertain by 0,000 5 J. The International Union of Pure and Applied Physics in 1934 published a similar definition for the "gramme-calorie". The conversion factor shown above was proposed by the Comité consultatif de thermométrie et calorimétrie and adopted by the CIPM (1950) as being the most accurate value which could at that time be deduced from experiment.
		4-6.B.b	I.T. calorie: cal_{IT}	For this I.T. calorie (International Table calorie) the Fifth International Conference on Properties of Steam (London, July 1956) adopted the definition 1 cal_{IT} = 4,186 8 J 1 $Mcal_{IT}$ = 1,163 kW · h (exactly)
		4-6.B.c	thermochemical calorie: cal_{th}	1 cal_{th} = 4,184 J (exactly)

ISO 31 PT*4 92 ■ 4851903 0508034 5TT ■

UDC 389.15/.16:536:006.72

Descriptors: system of units, international system of units, units of measurement, quantities, heat, thermodynamics, symbols, definitions, conversion of units, conversion factor.

Price based on 15 pages