INTERNATIONAL STANDARD

ISO 31-8

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Quantities and units —

Part 8:
Physical chemistry and molecular physics

Grandeurs et unités —

Partie 8: Chimie physique et physique moléculaire

Reference number
ISO 31-8:1992(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 31-8 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors*.

This third edition cancels and replaces the second edition (ISO 31-8:1980). 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;

— a number of new items have been added;

— a number of new chemical elements have been added in annex A.

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*

Annexes A, B and C form an integral part of this part of ISO 31.

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, symbols for substances are shown as subscripts, for example c_B, w_B, p_B.

Generally it is advisable to put symbols for substances and their states in parentheses on the same line as the main symbol, for example $c(H_2SO_4)$.

The superscript * is used to mean "pure". The superscript $^{\ominus}$ is used to mean "standard".

EXAMPLES

$V_m(K_2SO_4$, 0,1 mol · dm^{-3} in H_2O, 25 °C)
for molar volume.
$C^{\ominus}_{p,m}(H_2O$, g, 298,15 K) = 33,58 J · K^{-1} · mol^{-1}
for standard molar heat capacity at constant pressure.

In an expression such as $\varphi_B = x_B V^*_{m,B} / \Sigma x_A V^*_{m,A}$, where φ_B denotes the volume fraction of a particular substance B in a mixture of substances A, B, C, ..., where x_A denotes the mole fraction of the substance A and $V^*_{m,A}$ the molar volume of the pure substance A, and where all the molar volumes $V^*_{m,A}$, $V^*_{m,B}$, $V^*_{m,C}$, ..., are taken at the same temperature and pressure, the summation on the right-hand side is that over all the substances A, B, C, ..., of which a mixture is composed, so that $\Sigma x_A = 1$.

The names and symbols of the chemical elements are given in annex A.

Quantities and units —

Part 8:
Physical chemistry and molecular physics

1 Scope

This part of ISO 31 gives names and symbols for quantities and units of physical chemistry and molecular physics. 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 31-4:1992, *Quantities and units — Part 4: Heat.*

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 physical chemistry and molecular physics are given on the following pages.

PHYSICAL CHEMISTRY AND MOLECULAR PHYSICS				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
8-1.1	relative atomic mass	A_r	Ratio of the average mass per atom of an element to 1/12 of the mass of an atom of the nuclide ^{12}C	EXAMPLE $A_r(Cl) = 35{,}453$ Formerly called atomic weight.
8-1.2	relative molecular mass	M_r	Ratio of the average mass per molecule or specified entity of a substance to 1/12 of the mass of an atom of the nuclide ^{12}C	Formerly called molecular weight. The relative atomic or molecular mass depends on the nuclidic composition.
8-2	number of molecules or other elementary entities	N	Number of molecules or other elementary entities in a system	
8-3	amount of substance	n, (ν)		Amount of substance is one of the base quantities on which the SI is based. ν may be used as an alternative to n when n is used for number density of particles (see 8-10.1).
8-4	Avogadro constant	L, N_A	Number of molecules divided by amount of substance. $N_A = N/n$	$N_A = (6{,}022\ 136\ 7 \pm 0{,}000\ 003\ 6) \times 10^{23}\ \text{mol}^{-1}$ [1)]

1) CODATA Bulletin 63 (1986).

Item No.	Quantity	Symbol	Definition	Remarks
8-5	molar mass	M	Mass divided by amount of substance. $M = m/n$	m is the mass of the substance.
8-6	molar volume	V_m	Volume divided by amount of substance. $V_m = V/n$	The molar volume of an ideal gas at 273,15 K and 101,325 kPa is $V_{m,0} = (0{,}022\ 414\ 10 \pm 0{,}000\ 000\ 19)\ \text{m}^3/\text{mol}$ [1)]

1) CODATA Bulletin 63 (1986).

Units				PHYSICAL CHEMISTRY AND MOLECULAR PHYSICS
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
8-1.a	one	1		See the introduction, subclause 0.3.2.
8-2.a	one	1		See the introduction, subclause 0.3.2.
8-3.a	mole	mol	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. 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	The definition applies to unbound atoms of carbon 12, at rest and in their ground state.
8-4.a	reciprocal mole, mole to the power minus one	mol^{-1}		
8-5.a	kilogram per mole	kg/mol		$M = 10^{-3} M_r$ kg/mol = M_r kg/kmol = M_r g/mol where M_r is the relative molecular mass of a substance of definite chemical composition.
8-6.a	cubic metre per mole	m^3/mol		

PHYSICAL CHEMISTRY AND MOLECULAR PHYSICS (*continued*) Quantities

Item No.	Quantity	Symbol	Definition	Remarks
8-7	molar thermodynamic energy	U_m	Thermodynamic energy divided by amount of substance. $U_m = U/n$	This quantity is also called molar internal energy. See ISO 31-4. Similar definitions apply to other molar thermodynamic functions, for example H_m, A_m, G_m.
8-8	molar heat capacity	C_m	Heat capacity divided by amount of substance. $C_m = C/n$	See ISO 31-4.
8-9	molar entropy	S_m	Entropy divided by amount of substance. $S_m = S/n$	See ISO 31-4.
8-10.1	volumic number of molecules (or particles), number density of molecules (or particles)	n	Number of molecules or particles divided by volume. $n = N/V$	
8-10.2	molecular concentration of B	C_B	Number of molecules of B divided by the volume of the mixture	
8-11.1	volumic mass, mass density, density	ϱ	Mass divided by volume	
8-11.2	mass concentration of B	ϱ_B	Mass of B divided by the volume of the mixture	
8-12	mass fraction of B	w_B	Ratio of the mass of B to the mass of the mixture	
8-13	concentration of B, amount-of-substance concentration of B	c_B	Amount of substance of B divided by the volume of the mixture	In chemistry also indicated as [B].

Units	PHYSICAL CHEMISTRY AND MOLECULAR PHYSICS (*continued*)			
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
8-7.a	joule per mole	J/mol		For the various types of calorie, see ISO 31-4:1992, annex B.
8-8.a	joule per mole kelvin	J/(mol · K)		
8-9.a	joule per mole kelvin	J/(mol · K)		
8-10.a	reciprocal cubic metre, metre to the power minus three	m^{-3}		
8-11.a	kilogram per cubic metre	kg/m^3		
8-11.b	kilogram per litre	kg/l, kg/L		$1\ kg/l = 10^3\ kg/m^3 = 1\ kg/dm^3$ The symbol L was adopted by the CGPM (1979) as an alternative to l for the litre.
8-12.a	one	1		See the introduction, subclause 0.3.2.
8-13.a	mole per cubic metre	mol/m^3		
8-13.b	mole per litre	mol/l, mol/L		$1\ mol/l = 10^3\ mol/m^3 = 1\ mol/dm^3$

PHYSICAL CHEMISTRY AND MOLECULAR PHYSICS (*continued*) Quantities

Item No.	Quantity	Symbol	Definition	Remarks
8-14.1 (*8-15.1*)	mole fraction of B	x_B, (y_B)	Ratio of the amount of substance of B to the amount of substance of the mixture	Alternative names for these quantities are "amount-of-substance fraction" and "amount-of-substance ratio" respectively. For a one-solute solution, $r = x/(1 - x)$
8-14.2 (*8-15.2*)	mole ratio of solute B	r_B	Ratio of the amount of substance of B to the amount of substance of the solvent substance	
8-15 (*8-14.1*)	volume fraction of B	φ_B	For a mixture of substances, $\varphi_B = \frac{x_B V^*_{m,B}}{\Sigma x_A V^*_{m,A}}$ where the $V^*_{m,A}$ are the molar volumes of the pure substances A at the same temperature and pressure and where Σ denotes summation over all the substances	An alternative definition in which the molar volumes $V^*_{m,A}$ of the pure substances A are replaced by the partial molar volumes $(\partial V/\partial n_A)_{T,p,n_B,\ldots}$ of the substances A is also used.
8-16	molality of solute B	b_B, m_B	Amount of substance of solute B in a solution divided by the mass of the solvent	
8-17	chemical potential of B	μ_B	For a mixture of substances B, C, ..., $\mu_B = (\partial G/\partial n_B)_{T,p,n_C,\ldots}$ where n_B is the amount of substance of B and G is the Gibbs function	For a pure substance, $\mu = G/n = G_m$ where G_m is the molar Gibbs function. The symbol μ is also used for the quantity G_m/N_A, where N_A is the Avogadro constant.
8-18	absolute activity of B	λ_B	$\lambda_B = \exp(\mu_B/RT)$	For R, see 8-36. T is the thermodynamic temperature.
8-19	partial pressure of B (in a gaseous mixture)	p_B	For a gaseous mixture, $p_B = x_B \cdot p$ where p is the pressure	
8-20	fugacity of B (in a gaseous mixture)	$\tilde{p}_B$, (f_B)	For a gaseous mixture, $\tilde{p}_B$ is proportional to the absolute activity λ_B, the proportionality factor, which is a function of temperature only, being determined by the condition that at constant temperature and composition $\tilde{p}_B/p_B$ tends to 1 for an infinitely dilute gas	$\tilde{p}_B = \lambda_B \cdot \lim_{p \to 0} (x_B p/\lambda_B)$