International Standard ISO 31/8

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Quantities and units of physical chemistry and molecular physics

Grandeurs et unités de chimie physique et de physique moléculaire

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 31/8 was developed by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors and conversion tables*, and was circulated to the member bodies in July 1979.

It has been approved by the member bodies of the following countries :

Australia	France	Poland
Austria	Germany, F.R.	Portugal
Belgium	India	Romania
Brazil	Israel	South Africa, Rep. of
Bulgaria	Italy	Spain
Canada	Japan	Sweden
Cuba	Korea, Dem. P. Rep. of	United Kingdom
Czechoslovakia	Mexico	USA
Denmark	Netherlands	USSR
Egypt, Arab Rep. of	New Zealand	
Finland	Norway	

No member body expressed disapproval of the document.

This second edition cancels and replaces the first edition (i.e. ISO 31/8-1973).

Printed in Switzerland

Quantities and units of physical chemistry and molecular physics

Introduction

This document, containing a table of *quantities and units of physical chemistry and molecular physics*, is part 8 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on 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 the items 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.

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 symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

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

(1) When two types of sloping letters 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.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) 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).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

1) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

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

3) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.(1)

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements(2)

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

Special remarks

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

If the symbol for the substance is complicated, it is advisable to put it in brackets on the same line as the main symbol, $c(H_2SO_4)$.

The superscript * is used to mean "pure". The superscript ⊖ is used to mean "standard".

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

In this document, the annexes are integral parts of the standard.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Quantities
8-1.1 . . . 8-6.1

8. Physical chemistry and molecular physics

Item No.	Quantity	Symbol	Definition	Remarks
8-1.1	relative atomic mass of an element	A_r	The ratio of the average mass per atom of an element to 1/12 of the mass of an atom of nuclide ^{12}C.	These quantities are dimensionless. Example : $A_r(Cl) = 35{,}453$. Formerly called atomic weight.
8-1.2	relative molecular mass of a substance	M_r	The ratio of the average mass per molecule or specified entity of a substance to 1/12 of the mass of an atom of nuclide ^{12}C.	Formerly called molecular weight. The relative atomic or molecular mass depends on the nuclidic composition.
8-2.1	number of molecules or other elementary entities	N	Number of molecules or other elementary entities in a system.	This quantity is dimensionless.
8-3.1	amount of substance	n, (ν)		ν may be used as an alternative to n when n is used for number density of particles, see 8-10.1.
8-4.1	Avogadro constant	L, N_A	Number of molecules divided by the amount of substance.	$N_A = N/n$ $= (6{,}022\,045 \pm 0{,}000\,031) \times 10^{23}\ mol^{-1}$ [1]
8-5.1	molar mass	M	Mass divided by amount of substance.	$M = m/n$ where m is the mass of the substance.
8-6.1	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 $V_{m,0} = (0{,}022\,413\,83 \pm 0{,}000\,000\,70)\ m^3/mol$ [1].

(1) CODATA Bulletin 11 (1973).

8. Physical chemistry and molecular physics

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
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.		
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			

Quantities
8-7.1 . . . 8-16.1

8. Physical chemistry and molecular physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
8-7.1	molar internal energy	U_m, (E_m)	Internal energy divided by amount of substance.	$U_m = U/n$. See ISO 31/4. Similar definitions apply to other molar thermodynamic functions, for example H_m, A_m, G_m.
8-8.1	molar heat capacity	C_m	Heat capacity divided by amount of substance.	$C_m = C/n$. See ISO 31/4.
8-9.1	molar entropy	S_m	Entropy divided by amount of substance.	$S_m = S/n$. See ISO 31/4.
8-10.1	number density of molecules (or particles)	n	The number of molecules or particles divided by volume.	$n = N/V$
8-10.2	molecular concentration of substance B	C_B	The number of molecules of substance B divided by the volume of the mixture.	
8-11.1	density, (mass density)	ϱ	Mass divided by volume.	
8-11.2	mass concentration of substance B	ϱ_B	Mass of substance B divided by the volume of the mixture.	
8-12.1	mass fraction of substance B	w_B	Ratio of the mass of substance B to the mass of the mixture.	This quantity is dimensionless.
8-13.1	concentration of substance B, amount-of-substance concentration of substance B	c_B	Amount of substance of substance B divided by the volume of the mixture.	In chemistry also indicated as [B].
8-14.1 (—)	volume fraction of substance B	φ_B	$\varphi_B = \dfrac{x_B V_{m,B}}{\Sigma_A x_A V_{m,A}}$ where $V_{m,B}$ is the molar volume of the pure substance B at the same temperature and pressure.	This quantity is dimensionless. An alternative definition in which the molar volumes $V_{m,B}$ of the pure substances B are replaced by the partial molar volumes $(\partial V/\partial n_B)_{T,p,n_C,...}$ of the substances B is also used. The partial molar volume of the pure substance B may be indicated by V_B^* and is identical with $V_{m,B}$.
8-15.1 (8-14.1)	mole fraction of substance B	x_B, (y_B)	Ratio of the amount of substance of substance B to the amount of substance of the mixture.	These quantities are dimensionless. Alternative names for these quantities are "amount-of-substance fraction" and "amount-of-substance ratio" respectively.
8-15.2 (8-14.2)	mole ratio of solute substance B	r_B	Ratio of the amount of substance of solute substance B to the amount of substance of the solvent substance.	For a one-solute solution $r = x/(1 - x)$.
8-16.1 (8-15.1)	molality of solute substance B	b_B, m_B	The amount of substance of solute substance B in a solution divided by the mass of the solvent.	

8. Physical chemistry and molecular physics (continued)

Units
8-7.a . . . 8-16.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-7.a	joule per mole	J/mol			For the calories, see ISO 31/4, 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			The symbol L was adopted by the CGPM (1979) as an alternative to l for litre.
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 (exactly) = 1 mol/dm^3 (exactly)	
8-16.a	mole per kilogram	mol/kg			

Quantities
8-17.1 . . . 8-23.1

8. Physical chemistry and molecular physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
8-17.1 (8-16.1)	chemical potential of substance B	μ_B	For a mixture with component substances B, C,... $\mu_B = (\partial G/\partial n_B)_{T,\ p,\ n_C, ...}$ where n_B is the amount of substance of substance B and G is the Gibbs function.	For a pure substance $\mu = G/n = G_m$ where G_m is the molar Gibbs free energy. The symbol μ is also used for the quantity G_m/N_A, where N_A is the Avogadro constant.
8-18.1 (8-17.1)	absolute activity of substance B	λ_B	$\lambda_B = \exp(\mu_B/RT)$	This quantity is dimensionless. For R and T, see 8-35.1.
8-19.1 (8-18.1)	partial pressure of substance B (in a gaseous mixture)	p_B	For a gaseous mixture $p_B = x_B \cdot p$ where p is the pressure.	
8-20.1 (8-19.1)	fugacity of substance B (in a gaseous mixture)	f_B, $\tilde{p}_B$	For a gaseous mixture, f_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 f_B/p_B tends to 1 for an infinitely dilute gas.	$f_B = \lambda_B \cdot \lim_{p \to 0} (x_B p/\lambda_B)$. (For the symbol, see also 8-22.1.).
8-21.1 (—)	standard absolute activity of substance B (in a gaseous mixture)	$\lambda_B^\ominus$	$\lambda_B^\ominus = (p^\ominus/x_B) \lim_{p \to 0} (\lambda_B/p)$ where $p^\ominus$ is a standard pressure, usually 101,325 kPa.	This quantity is dimensionless. This quantity is a function only of temperature.
8-22.1 (8-20.1)	activity coefficient of substance B (in a liquid or a solid mixture)	f_B	For a liquid mixture $f_B = \lambda_B/(\lambda_B^* x_B)$ where λ^*_B is the absolute activity of the pure substance B at the same temperature and pressure.	These quantities are dimensionless. The name "activity factor" would be more systematic.
8-22.2 (—)	standard absolute activity of substance B (in a liquid or solid mixture)	$\lambda_B^\ominus$	$\lambda_B^\ominus = \lambda^*_B(p^\ominus)$	This quantity is a function only of temperature.
8-23.1 (8-21.1)	activity of solute substance B, relative activity of solute substance B (especially in a dilute liquid solution)	a_B, $a_{m,\ B}$	For a solute in a solution a_B is proportional to the absolute activity λ_B, the proportionality factor, which is a function of temperature and pressure only, being determined by the condition that at constant temperature and pressure a_B divided by the molality ratio $m_B/m^\ominus$ tends to 1 for infinite dilution; $m^\ominus$ is a standard molality, usually 1 mol/kg.	This quantity is dimensionless. $a_B = \lambda_B \cdot \lim_{\Sigma m_B \to 0} \frac{m_B/m^\ominus}{\lambda_B}$ The quantity $a_{c,\ B}$ similarly defined in terms of the concentration ratio $c_B/c^\ominus$ is also called : activity or relative activity of solute substance B; $c^\ominus$ is a standard concentration, usually 1 mol/dm³. $a_{c,\ B} = \lambda_B \cdot \lim_{\Sigma c_B \to 0} \frac{c_B/c^\ominus}{\lambda_B}$ The subscript c in $a_{c,\ B}$ is often omitted.

8. Physical chemistry and molecular physics (continued)

Units
8-17.a . . . 8-20.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-17.a	joule per mole	J/mol			
8-19.a	pascal	Pa			1 atm = 101 325 Pa (exactly). The use of this unit is deprecated. This does not imply that the use of 101 325 Pa as a reference pressure is deprecated.
8-20.a	pascal	Pa			See 8-19.a.