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Quantities and units - Part 5: Thermodynamics (ISO 80000-5:2019)

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Quantities and units - Part 5: Thermodynamics (ISO 80000-5:2019)

Grandeurs et unités - Partie 5: Thermodynamique (ISO 80000-5:2019)

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European foreword

This document (EN ISO 80000-5:2019) has been prepared by Technical Committee ISO/TC 12 "Quantities and units" in collaboration with Technical Committee CEN/SS F02 “Units and symbols” the secretariat of which is held by CCMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2020, and conflicting national standards shall be withdrawn at the latest by April 2020.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www. iso. org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www. iso .org/iso/foreword. html.

This document was prepared by Technical Committee ISO/TC 12, *Quantities and units*, in collaboration with Technical Committee IEC/TC 25, *Quantities and units*.

This second edition cancels and replaces the first edition of (ISO 80000-5:2007), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the table giving the quantities and units has been simplified;

— some definitions and the remarks have been stated physically more precisely.

A list of all parts in the ISO 80000 and IEC 80000 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Quantities and units —

Part 5: Thermodynamics

1 Scope

This document gives names, symbols, definitions and units for quantities of thermodynamics. Where appropriate, conversion factors are also given.

2 Normative references

There are no normative references in this document.

Table 1 — Quantities and units used in thermodynamics

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-1	thermodynamic temperature	T, Θ	partial derivative of internal energy with respect to entropy at constant volume and constant number of particles in the system: $T = \left(\frac{\partial U}{\partial S}\right)_{V,N}$ where U is internal energy (item 5-20.2), S is entropy (item 5-18), V is volume (ISO 80000-3), and N is number of particles	K	It is measured with a primary thermometer, examples of which are gas thermometers of different kinds, noise thermometers, or radiation thermometers. The Boltzmann constant (ISO 80000-1) relates energy at the individual particle level with thermodynamic temperature. Differences of thermodynamic temperatures or changes may be expressed either in kelvin, symbol K, or in de grees Celsius, symbol °C (item 5-2). Thermodynamic temperature is one of the seven base quantities in the International System of Quantities, ISQ (see ISO 80000-1). **The International Temperature Scale of 1990** For the purpose of practical measurements, the International Temperature Scale of 1990, ITS-90, was adopted by CIPM in 1989, which is a close approximation to the thermodynamic temperature scale. The quantities defined by this scale are denoted T_{90} and t_{90}, respectively (replacing T_{68} and t_{68} defined by the International Practical Temperature Scale of 1968, IPTS-68), where $\frac{t_{90}}{1\,°\mathrm{C}} = \frac{T_{90}}{1\,\mathrm{K}} - 273{,}15$

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-1 *(cont.)*					The units of T_{90} and t_{90} are the kelvin, symbol K, and the degree Celsius, symbol °C (item 5-2), respectively. For further information, see References[5],[6]. For ready conversion between temperatures reported on the International Temperature Scale and thermodynamic temperatures the systematic deviations can be found in Reference[7].
5-2	Celsius temperature	t, ϑ	temperature difference from the thermodynamic temperature of the ice point is called the Celsius temperature t, which is defined by the quantity equation: $t = T - T_0$ where T is thermodynamic temperature (item 5-1) and $T_0 = 273{,}15\ \mathrm{K}$	°C	The unit degree Celsius is a special name for the kelvin for use in stating values of Celsius temperature. The unit degree Celsius is by definition equal in magnitude to the kelvin. A difference or interval of temperature may be expressed in kelvin or in degrees Celsius. The thermodynamic temperature T_0 is 0,01 K below the thermodynamic temperature of the triple point of water. The symbol °C for the degree Celsius shall be preceded by a space (see ISO 80000-1). Prefixes are not allowed in combination with the unit °C.
5-3.1	linear expansion coefficient	α_l	relative change of length with temperature: $\alpha_l = \frac{1}{l}\frac{\mathrm{d}l}{\mathrm{d}T}$ where l is length (ISO 80000-3) and T is thermodynamic temperature (item 5-1)	K^{-1}	The subscripts in the symbols may be omitted when there is no risk of confusion.
5-3.2	cubic expansion coefficient	α_V, γ	relative change of volume with temperature: $\alpha_V = \frac{1}{V}\frac{\mathrm{d}V}{\mathrm{d}T}$ where V is volume (ISO 80000-3) and T is thermodynamic temperature (item 5-1)	K^{-1}	Also called volumetric expansion coefficient. The subscripts in the symbols may be omitted when there is no risk of confusion.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-3.3	relative pressure coefficient	α_p	relative change of pressure with temperature at constant volume: $\alpha_p = \frac{1}{p}\left(\frac{\partial p}{\partial T}\right)_V$ where p is pressure (ISO 80000-4), T is thermodynamic temperature (item 5-1), and V is volume (ISO 80000-3)	K^{-1}	The subscripts in the symbols may be omitted when there is no risk of confusion.
5-4	pressure coefficient	β	change of pressure with temperature at constant volume: $\beta = \left(\frac{\partial p}{\partial T}\right)_V$ where p is pressure (ISO 80000-4), T is thermodynamic temperature (item 5-1), and V is volume (ISO 80000-3)	Pa/K $kg\ m^{-1}\ s^{-2}\ K^{-1}$	
5-5.1	isothermal compressibility	$\varkappa_T$	negative relative change of volume with pressure at constant temperature: $\varkappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T$ where V is volume (ISO 80000-3), p is pressure (ISO 80000-4), and T is thermodynamic temperature (item 5-1)	Pa^{-1} $kg^{-1}\ m\ s^2$	The subscripts in the symbols may be omitted when there is no risk of confusion.
5-5.2	isentropic compressibility	$\varkappa_S$	negative relative change of volume with pressure at constant entropy: $\varkappa_S = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_S$ where V is volume (ISO 80000-3), p is pressure (ISO 80000-4), and S is entropy (item 5-18)	Pa^{-1} $kg^{-1}\ m\ s^2$	The subscripts in the symbols may be omitted when there is no risk of confusion.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-6.1	heat, amount of heat	Q	difference between the increase in the internal energy (item 5-20.2) of a system and the work (ISO 80000-4) done on the system, provided that the amounts of substances within the system are not changed	J kg m^2 s^{-2}	The heat transferred in an isothermal phase transformation should be expressed as the change in the appropriate state functions, e.g. $T\,\Delta S$, where T is thermodynamic temperature (item 5-1) and S is entropy (item 5-18), or ΔH, where H is enthalpy (item 5-20.3). NOTE A supply of heat can correspond to an increase in thermodynamic temperature or to other effects, such as phase change or chemical processes; see item 5-6.2.
5-6.2	latent heat	Q	energy released or absorbed by a system during a constant-temperature process	J kg m^2 s^{-2}	Examples of latent heat are latent heat of fusion (melting) and latent heat of vaporization (boiling).
5-7	heat flow rate	$\dot{Q}$	time rate at which heat (item 5-6.1) crosses a given surface	W J/s kg m^2 s^{-3}	
5-8	density of heat flow rate	q, φ	quotient of heat flow rate and area: $q = \frac{\dot{Q}}{A}$ where $\dot{Q}$ is heat flow rate (item 5-7) and A is area (ISO 80000-3) of a given surface	W/m^2 kg s^{-3}	
5-9	thermal conductivity	λ, ($\varkappa$)	quotient of density of heat flow rate (item 5-8) and thermodynamic temperature gradient that has the same direction as the heat flow	W/(m K) kg m s^{-3} K^{-1}	
5-10.1	coefficient of heat transfer	K, (k)	quotient of density of heat flow rate (item 5-8) and thermodynamic temperature (item 5-1) difference	W/(m^2 K) kg s^{-3} K^{-1}	In building technology, the coefficient of heat transfer is often called thermal transmittance, with the symbol U (no longer recommended). See remark to item 5-13.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-10.2	surface coefficient of heat transfer	h, (α)	quotient of density of heat flow rate and the difference of the temperature at the surface and a reference temperature: $h = \frac{q}{(T_s - T_r)}$ where q is density of heat flow rate (item 5-8), T_s is the thermodynamic temperature (item 5-1) at the surface, and T_r is a reference thermodynamic temperature characterizing the adjacent surroundings	W/(m^2 K) kg s^{-3} K^{-1}	
5-11	thermal insulance, coefficient of thermal insulance	M	inverse of coefficient of heat transfer K: $M = \frac{1}{K}$ where K is coefficient of heat transfer (item 5-10.1)	m^2 K/W kg^{-1} s^3 K	In building technology, this quantity is often called thermal resistance, with the symbol R.
5-12	thermal resistance	R	quotient of thermodynamic temperature (item 5-1) difference and heat flow rate (item 5-7)	K/W kg^{-1} m^{-2} s^3 K	See remark to item 5-11.
5-13	thermal conductance	G, (H)	inverse of thermal resistance R: $G = \frac{1}{R}$ where R is thermal resistance (item 5-12)	W/K kg m^2 s^{-3} K^{-1}	See remark to item 5-11. This quantity is also called heat transfer coefficient. See item 5-10.1.
5-14	thermal diffusivity	a	quotient of thermal conductivity and the product of mass density and specific heat capacity: $a = \frac{\lambda}{\rho c_p}$ where λ is thermal conductivity (item 5-9), ρ is mass density (ISO 80000-4), and c_p is specific heat capacity at constant pressure (item 5-16.2)	m^2 s^{-1}	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-15	heat capacity	C	derivative of added heat with respect to thermodynamic temperature of a system: $C = \frac{dQ}{dT}$ where Q is amount of heat (item 5-6.1) and T is thermodynamic temperature (item 5-1)	J/K kg m^2 s^{-2} K^{-1}	Heat capacity is not completely defined unless specified as seen in items 5-16.2, 5-16.3 and 5-16.4.
5-16.1	specific heat capacity	c	quotient of heat capacity and mass: $c = \frac{C}{m}$ where C is heat capacity (item 5-15) and m is mass (ISO 80000-4)	J/(kg K) m^2 s^{-2} K^{-1}	For the corresponding quantities related to the amount of substance, see ISO 80000-9.
5-16.2	specific heat capacity at constant pressure	c_p	specific heat capacity (item 5-16.1) at constant pressure (ISO 80000-4)	J/(kg K) m^2 s^{-2} K^{-1}	Also called specific isobaric heat capacity.
5-16.3	specific heat capacity at constant volume	c_V	specific heat capacity (item 5-16.1) at constant volume (ISO 80000-3)	J/(kg K) m^2 s^{-2} K^{-1}	Also called specific isochoric heat capacity.
5-16.4	specific heat capacity at saturated vapour pressure	c_{sat}	specific heat capacity (item 5-16.1) at saturated vapour pressure (ISO 80000-4)	J/(kg K) m^2 s^{-2} K^{-1}	
5-17.1	ratio of specific heat capacities	γ	quotient of specific heat capacity at constant pressure and specific heat capacity at constant volume: $\gamma = \frac{c_p}{c_V}$ where c_p is specific heat capacity at constant pressure (item 5-16.2) and c_V is specific heat capacity at constant volume (item 5-16.3)	1	This quantity can also be expressed by $\gamma = \frac{C_p}{C_V}$ where C_p is heat capacity at constant pressure and C_V is heat capacity at constant volume.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-17.2	isentropic exponent, isentropic expansion factor	$\varkappa$	the negative of relative pressure change, divided by relative volume change, at constant entropy: $\varkappa = -\frac{V}{p}\left(\frac{\partial p}{\partial V}\right)_S$ where V is volume (ISO 80000-3), p is pressure (ISO 80000-4), and S is entropy (item 5-18)	1	For an ideal gas, $\varkappa$ is equal to γ (item 5-17.1).
5-18	entropy	S	natural logarithm of number of equally probable microscopic configurations in a macroscopic system, multiplied by the Boltzmann constant: $S = k \ln W$ where W is number of configurations and k is the Boltzmann constant (ISO 80000-1)	J/K kg m^2 s^{-2} K^{-1}	
5-19	specific entropy	s	quotient of entropy and mass: $s = \frac{S}{m}$ where S is entropy (item 5-18) and m is mass (ISO 80000-4)	J/(kg K) m^2 s^{-2} K^{-1}	For the corresponding quantity related to amount of substance, see ISO 80000-9.
5-20.1	energy <thermodynamics>	E	ability of a system to do work (ISO 80000-4)	J kg m^2 s^{-2}	Energy exists in different forms that are mutually transformable into each other, either totally or partially. In contrast to internal energy (item 5-20.2), energy is not a state function.
5-20.2	internal energy, thermodynamic energy	U	energy of a system whose change is given by the amount of the heat (item 5-6.1) transferred to the system and the work (ISO 80000-4) done on the system, provided that the system is closed and no chemical reactions occur	J kg m^2 s^{-2}	In thermodynamic text books, usually the formula $\Delta U = Q + W$ is used. Note that the zero of the energy is undefined.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-20.3	enthalpy	H	sum of internal energy of the system and the product of pressure and volume of the system: $H = U + pV$ where U is internal energy (item 5-20.2), p is pressure (ISO 80000-4), and V is volume (ISO 80000-3)	J kg m^2 s^{-2}	
5-20.4	Helmholtz energy, Helmholtz function	A, F	difference of internal energy of the system and the product of thermodynamic temperature and entropy of the system: $A = U - TS$ where U is internal energy (item 5-20.2), T is thermodynamic temperature (item 5-1), and S is entropy (item 5-18)	J kg m^2 s^{-2}	The name Helmholtz free energy is also used. However, this term is not recommended.
5-20.5	Gibbs energy, Gibbs function	G	difference of the enthalpy and the product of thermodynamic temperature and entropy of the system: $G = H - TS$ where H is enthalpy (item 5-20.3), T is thermodynamic temperature (item 5-1), and S is entropy (item 5-18)	J kg m^2 s^{-2}	The name Gibbs free energy is also used. However, this term is not recommended.
5-21.1	specific energy	e	quotient of energy and mass: $e = \frac{E}{m}$ where E is energy (item 5-20.1) and m is mass (ISO 80000-4)	J/kg m^2 s^{-2}	
5-21.2	specific internal energy, specific thermodynamic energy	u	quotient of internal energy and mass: $u = \frac{U}{m}$ where U is internal energy (item 5-20.2) and m is mass (ISO 80000-4)	J/kg m^2 s^{-2}	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-21.3	specific enthalpy	h	quotient of enthalpy and mass: $h = \frac{H}{m}$ where H is enthalpy (item 5-20.3) and m is mass (ISO 80000-4)	J/kg $m^2\ s^{-2}$	
5-21.4	specific Helmholtz energy, specific Helmholtz function	a, f	quotient of Helmholtz energy and mass: $a = \frac{A}{m}$ where A is Helmholtz energy (item 5-20.4) and m is mass (ISO 80000-4)	J/kg $m^2\ s^{-2}$	The name specific Helmholtz free energy is also used. However, this term is not recommended.
5-21.5	specific Gibbs energy, specific Gibbs function	g	quotient of Gibbs energy and mass: $g = \frac{G}{m}$ where G is Gibbs energy (item 5-20.5) and m is mass (ISO 80000-4)	J/kg $m^2\ s^{-2}$	The name specific Gibbs free energy is also used. However, this term is not recommended.
5-22	Massieu function	J	quotient of the negative of Helmholtz energy and temperature: $J = -\frac{A}{T}$ where A is Helmholtz energy (item 5-20.4) and T is thermodynamic temperature (item 5-1)	J/K $kg\ m^2\ s^{-2}\ K^{-1}$	
5-23	Planck function	Y	quotient of the negative of Gibbs energy and temperature: $Y = -\frac{G}{T}$ where G is Gibbs energy (item 5-20.5) and T is thermodynamic temperature (item 5-1)	J/K $kg\ m^2\ s^{-2}\ K^{-1}$	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-24	Joule-Thomson coefficient	μ_{JT}	change of thermodynamic temperature with respect to pressure in a Joule-Thomson process at constant enthalpy: $\mu_{JT} = \left(\frac{\partial T}{\partial p}\right)_H$ where T is thermodynamic temperature (item 5-1), p is pressure (ISO 80000-4) and H is enthalpy (item 5-20.3)	K/Pa $kg^{-1}\ m\ s^2\ K$	
5-25.1	efficiency <thermodynamics>	η	quotient of work (ISO 80000-4) delivered by a heat engine and supplied heat: $\eta = \frac{W}{Q}$ where W is work (ISO 80000-4) and Q is heat (item 5-6.1)	1	
5-25.2	maximum efficiency	η_{max}	efficiency determined by the quotient of the temperatures of the hot source and the cold sink: $\eta_{max} = 1 - \frac{T_c}{T_h}$ where T_c is the thermodynamic temperature (item 5-1) of the cold sink and T_h is the thermodynamic temperature (item 5-1) of the hot source	1	An ideal heat engine operating according to the Carnot process is delivering the maximum efficiency.
5-26	specific gas constant	R_s	quotient of the Boltzmann constant k (ISO 80000-1) and the mass m (ISO 80000-4) of the gas particle	J/(kg K) $m^2\ s^{-2}\ K^{-1}$	
5-27	mass concentration of water	w	quotient of mass of water and a specified volume: $w = \frac{m}{V}$ where m is mass (ISO 80000-4) of water, irrespective of the form of aggregation state, and V is volume (ISO 80000-3)	$kg\ m^{-3}$	Mass concentration of water at saturation is denoted w_{sat}.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-28	mass concentration of water vapour absolute humidity	v	quotient of mass of water vapour and a specified volume: $v = \frac{m}{V}$ where m is mass (ISO 80000-4) of water vapour and V is volume (ISO 80000-3)	kg m^{-3}	Mass concentration of water vapour at saturation is denoted v_{sat}.
5-29	mass ratio of water to dry matter	u	quotient of mass of water and mass of dry matter: $u = \frac{m}{m_d}$ where m is mass (ISO 80000-4) of water and m_d is mass of dry matter	1	Mass ratio of water to dry matter at saturation is denoted u_{sat}.
5-30	mass ratio of water vapour to dry gas	r, (x)	quotient of mass of water vapour and mass of dry gas: $r = \frac{m}{m_d}$ where m is mass (ISO 80000-4) of water vapour and m_d is mass of dry gas	1	Mass ratio of water vapour to dry gas at saturation is denoted r_{sat}. Mass ratio of water vapour to dry gas is also called mixing ratio.
5-31	mass fraction of water	w_{H_2O}	quantity given by: $w_{H_2O} = \frac{u}{1+u}$ where u is mass ratio of water to dry matter (item 5-29)	1	
5-32	mass fraction of dry matter	w_d	quantity given by: $w_d = 1 - w_{H_2O}$ where w_{H_2O} is mass fraction of water (item 5-31)	1	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
5-33	relative humidity	φ	quotient of partial pressure of water vapour and partial pressure at its saturation: $\varphi = \frac{p}{p_{sat}}$ where p is partial pressure (ISO 80000-4) of vapour and p_{sat} is its partial pressure at saturation at the same temperature	1	Relative humidity is often referred to as RH and expressed in percent. See also remark in item 5-35.
5-34	relative mass concentration of vapour	φ	quotient of mass concentration of water vapour and mass concentration at its saturation: $\varphi = \frac{v}{v_{sat}}$ where v is mass concentration of water vapour (item 5-28) and v_{sat} is its mass concentration of water vapour at saturation of the same temperature	1	For water vapour concentrations up to 1 kg/m^3, the relative humidity (item 5-33) is assumed to be equal to relative mass concentration of vapour. For details see Reference [8].
5-35	relative mass ratio of vapour	ψ	quotient of mass ratio of water vapour to dry gas and mass ratio of water vapour to dry gas at saturation: $\psi = \frac{r}{r_{sat}}$ where r is mass ratio of water vapour to dry gas (item 5-30) and r_{sat} is its mass ratio of water vapour to dry gas at saturation of the same temperature	1	This quantity is also used as an approximation of relative humidity (item 5-33).
5-36	dew-point temperature	T_d	temperature at which water vapour in the air reaches saturation under isobaric conditions	K	The corresponding Celsius temperature, denoted t_d, is still called dew-point temperature. The unit for the corresponding Celsius temperature is degree Celsius, symbol °C.

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Alphabetical index

The exact names of quantities are given in **bold face**. Other entries in the index are included to facilitate the search for a quantity.

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