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ISO RECOMMENDATION

R 31

PART IV

QUANTITIES AND UNITS OF HEAT

1st EDITION

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Also issued in French and Russian. Copies to be obtained through the national standards organizations.

BRIEF HISTORY

The ISO Recommendation R 31, Part IV, *Quantities and Units of Heat*, was drawn up by Technical Committee ISO/TC 12, *Quantities, Units, Symbols, Conversion Factors and Conversion Tables*, the Secretariat of which is held by the Danish Standards Association, Dansk Standardiseringsråd (DS).

The ISO/TC 12 Secretariat drew up two drafts in succession, the second of which was studied by the Technical Committee during its fourth meeting, held in Copenhagen in November 1957. The Secretariat then prepared a third draft proposal, which was submitted by correspondence to the Members of the Technical Committee and was approved as a Draft ISO Recommendation.

It should be noted that the following international organizations have had these draft proposals sent to them and have taken part in the discussions at the meetings of Technical Committee ISO/TC 12:

International Commission on Illumination
International Committee on Weights and Measures
International Electrotechnical Commission
International Union of Pure and Applied Chemistry
International Union of Pure and Applied Physics
and its Sub-Committee SUN
Organisation Internationale de Métrologie Légale

On 31 March 1959, the Draft ISO Recommendation (No. 277) was distributed to all the ISO Member Bodies and was approved, subject to small modifications, by the following Member Bodies:

Australia	Greece	Pakistan
Austria	Hungary	Poland
Belgium	India	Portugal
Brazil	Ireland	Romania
Burma	Israel	Sweden
Czechoslovakia	Japan	Switzerland
Denmark	Netherlands	United Kingdom
France	New Zealand	U. S. A.
Germany	Norway	U. S. S. R.

One Member Body opposed the approval of the draft: Italy.

The Draft ISO Recommendation was submitted by correspondence to the ISO Council, which decided, in December 1960, to accept it as an ISO RECOMMENDATION.

Introduction

General remarks

This document, containing a table of *Quantities and Units of Heat*, is part of a more comprehensive publication dealing with quantities and units in various fields of science and technology.

Parts of this more comprehensive publication are the ISO Recommendation R 31/Part I (2nd edition):

The International System of Units and
Quantities and Units of Space and Time[1]),

the ISO Recommendation R 31/Part II:

Quantities and Units of Periodic and Related Phenomena

and the ISO Recommendation R 31/Part III:

Quantities and Units of Mechanics.

General information regarding the arrangement of the tables and the symbols and abbreviations used is to be found in the introduction to ISO/R 31/Part I, where the full definitions of basic units are given as an appendix.

The statements in the definition column for quantities are given merely for identification; they are not intended to be complete definitions.

Special remarks

Attention is drawn to the remarks 4-4.a and 4-5.a. Quantities involving heat in the present document can be expressed in units based on the various units of energy, given in Part III "Mechanics" item 3-22.
For simplicity, the present document includes only a selection of units.

[1]) The title of the first edition of this document was: "Fundamental Quantities and Units of the MKSA System and Quantities and Units of Space and Time".

4. Heat

Quantities
4-1.1 ... 4-6.1

Item No.	Quantity	Symbol	Definition [1])	Remarks
4-1.1	thermodynamic temperature, absolute temperature	T, Θ	The thermodynamic temperature is defined according to the principles of thermodynamics.	
4-2.1	customary temperature	t, θ, ϑ	$t = T - T_0$ where t and T are the customary and absolute (thermodynamic) temperatures, of the same system, and T_0 is fixed by convention.	
4-3.1	linear expansion coefficient	α, λ	$\alpha = \frac{1}{l}\frac{\mathrm{d}l}{\mathrm{d}T}$	These quantities are not completely defined unless the type of change is specified.
4-3.2	cubic expansion coefficient	α, β, γ	$\gamma = \frac{1}{V}\frac{\mathrm{d}V}{\mathrm{d}T}$	
4-3.3	pressure coefficient	β	$\beta = \frac{1}{p}\frac{\mathrm{d}p}{\mathrm{d}T}$	The quantity, pressure coefficient, as here defined is used only for gases.
4-4.1	heat, quantity of heat	Q		
4-5.1	heat flow rate	Φ, (q)	Heat crossing a surface divided by time.	
4-6.1	density of heat flow rate	q, (φ)	Heat flow rate divided by area.	

[1]) The statements in this column are given merely for identification, and they are not intended to be complete definitions.

4. Heat

Item No.	Name of unit and in certain cases abbreviation for this name	International symbolic abbreviation for unit	Definition	Conversion factors	Remarks
4-1.a	**degree Kelvin**	°K	The degree Kelvin is the unit of thermodynamic temperature as defined by the Conférence Générale des Poids et Mesures. (See ISO Recommendation R 31/Part I).		The entries in the 2nd and 3rd columns are more than names of units and symbolic abbreviations for units. They imply also the zero point used. The units of Kelvin and Celsius temperature interval or difference are identical. The Conférence Générale des Poids et Mesures has recommended that the name "degré" or its abbreviation deg should be used for temperature interval or difference. In English the name "degree" is used. The abbreviations °K and °C are still often used. Similarly, the units for interval of Rankine and Fahrenheit temperature are identical. For this common unit the names "Rankine degree" and "Fahrenheit degree" have been proposed and used with the abbreviations, degR and degF.
4-1.b	degree Rankine	°R	1 °R = $\frac{5}{9}$ °K		
4-2.a	degree Celsius	°C	The Celsius temperature t of a system is given by expressing in $t = T - T_o$ the absolute (thermodynamic) temperature T in degrees Kelvin and putting $T_o = 273.15$ °K	If t_C °C, t_F °F, T_K °K and T_R °R relate to one and the same physical state, then the numerical values t_C, t_F, T_K and T_R are connected by: $t_C = \frac{5}{9}(t_F - 32)$ $= T_K - 273.15$ $= \frac{5}{9} T_R - 273.15$	**The "International Temperature Scale of 1948"** For purposes of practical measurements the Conférence Générale des Poids et Mesures has adopted a temperature scale based on a number of fixed points (that can be reproduced with high accuracy) and on certain procedures for interpolation. This scale is called the International Temperature Scale of 1948. Temperatures on it are indicated by t_{int} °C(Int.1948). The Comité International des Poids et Mesures has adopted an international Kelvin temperature scale, indication T_{int} °K (Int.1948). This is defined by $T_{int} = t_{int} + 273.15$
4-2.b	degree Fahrenheit	°F	The Fahrenheit temperature t of a system is given by expressing in $t = T - T_o$ the absolute (thermodynamic) temperature T in degrees Rankine and putting $T_o = 459.67$ °R		°R should not be mistaken for an abbreviation for the abandoned degree Réaumur.
4-3.a	reciprocal degree, deg^{-1}				
4-3.b	reciprocal Fahrenheit degree, $degF^{-1}$				
4-4.a	joule	J			For other units see 3-22.b...m*)
4-5.a	watt	W			For other units see 3-23.b...i*)
4-6.a	watt per square metre	W/m^2			

*) ISO Recommendation R 31/Part III: *Quantities and Units of Mechanics.*

Quantities
4-7.1 ... 4-14.1

4. Heat (continued)

Item No.	Quantity	Symbol	Definition[1])	Remarks
4-7.1	thermal conductivity	λ, (k)	Density of heat flow rate divided by temperature gradient.	
4-8.1	coefficient of heat transfer	h, K, U, α	Density of heat flow rate divided by temperature difference.	The symbols h and α are preferred for surface coefficient of heat transfer.
4-9.1	thermal diffusivity	a, $(\alpha, \varkappa, \kappa)$	$a = \frac{\lambda}{\varrho c_p}$ (λ = thermal conductivity, ϱ = density, c_p = specific heat capacity at constant pressure)	
4-10.1	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.
4-11.1	specific heat capacity	c	Heat capacity divided by mass.	The quantities expressed in terms of units involving the mole are to be found in the section dealing with chemistry.
4-11.2	specific heat capacity at constant pressure	c_p		
4-11.3	specific heat capacity at constant volume	c_v		
4-12.1	ratio of the specific heat capacities	γ, $\varkappa$, κ	$\gamma = c_p/c_v$	This quantity is dimensionless.
4-13.1	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 take place in the system.	
4-14.1	specific entropy	s	Entropy divided by mass.	See remark 4-11.1...3

[1]) See footnote on page 4.

4. Heat (continued)

Units
4-7.a ... 4-14.c

Item No.	Name of unit and in certain cases abbreviation for this name	International symbolic abbreviation for unit	Definition	Conversion factors	Remarks
4-7.a	watt per metre degree, W/(m·deg)				
4-7.b	I.T.calorie per second centimetre degree, $cal_{IT}/(s \cdot cm \cdot deg)$			1 $cal_{IT}/(s \cdot cm \cdot deg)$ = 418.68 W/(m·deg) (exactly)	
4-7.c	British thermal unit per second foot Fahrenheit degree, Btu/(s·ft·degF)			1 Btu/(s·ft·degF) = 6230.64 W/(m·deg)	
4-8.a	watt per square metre degree, $W/(m^2 \cdot deg)$				
4-8.b	I.T.calorie per second square centimetre degree, $cal_{IT}/(s \cdot cm^2 \cdot deg)$			1 $cal_{IT}/(s \cdot cm^2 \cdot deg)$ = 4.1868×10^4 $W/(m^2 \cdot deg)$ (exactly)	
4-8.c	British thermal unit per second square foot Fahrenheit degree, $Btu/(s \cdot ft^2 \cdot degF)$			1 $Btu/(s \cdot ft^2 \cdot degF)$ = 20 441.7 $W/(m^2 \cdot deg)$	
4-9.a	square metre per second	m^2/s			
4-9.b	square foot per second	ft^2/s		1 ft^2/s = 0.092 903 0 m^2/s	
4-10.a	joule per degree, J/deg				
4-11.a	joule per kilogramme degree, J/(kg·deg)				
4-11.b	I.T.calorie per gramme degree, $cal_{IT}/(g \cdot deg)$			1 $cal_{IT}/(g \cdot deg)$ = 4186.8 J/(kg·deg) (exactly)	
4-11.c	British thermal unit per pound Fahrenheit degree, Btu/(lb·degF)			1 Btu/(lb·degF) = 4186.8 J/(kg·deg) (exactly)	
4-13.a	joule per degree Kelvin	J/°K			
4-14.a	joule per kilogramme degree Kelvin	J/(kg·°K)			
4-14.b	I.T.calorie per gramme degree Kelvin	$cal_{IT}/(g \cdot °K)$		1 $cal_{IT}/(g \cdot °K)$ = 4186.8 J/(kg·°K) (exactly)	
4-14.c	British thermal unit per pound degree Rankine	Btu/(lb·°R)		1 Btu/(lb·°R) = 4186.8 J/(kg·°K) (exactly)	

Quantities
4-15.1...4-18.1

4. Heat (continued)

Item No.	Quantity	Symbol	Definition[1])	Remarks
4-15.1	internal energy	U, (E)		
4-15.2	enthalpy	H, (I)	$H = U + pV$	
4-15.3	free energy	F	$F = U - TS$	The free energy here defined is that defined by Helmholtz.
4-15.4	Gibbs function	G	$G = U + pV - TS$	$G = H - TS$ In French: enthalpie libre
4-16.1	specific internal energy	u, (e)	Internal energy divided by mass.	See remark 4-11.1...3
4-16.2	specific enthalpy	h, (i)	Enthalpy divided by mass.	
4-16.3	specific free energy	f	Free energy divided by mass.	
4-16.4	specific Gibbs function	g	Gibbs function divided by mass.	In French: enthalpie libre massique
4-17.1	latent heat	L	Quantity of heat absorbed or released in an isothermal transformation of phase.	This quantity is not completely defined unless a sign convention is specified.
4-18.1	specific latent heat	l	Magnitude of latent heat divided by mass.	See remark 4-11.1...3

[1]) See footnote on page 4.

4. Heat (continued)

Item No.	Name of unit and in certain cases abbreviation for this name	International symbolic abbreviation for unit	Definition	Conversion factors	Remarks
4-15.a	joule	J			
4-16.a	joule per kilogramme	J/kg			
4-16.b	I.T. calorie per gramme	cal_{IT}/g		1 cal_{IT}/g = 4186.8 J/kg (exactly)	
4-16.c	British thermal unit per pound	Btu/lb		1 Btu/lb = 2326 J/kg (exactly)	
4-17.a	joule	J			
4-18.a	joule per kilogramme	J/kg			