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DAVID R. LIDE
Editor-in-Chief

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1999-2000

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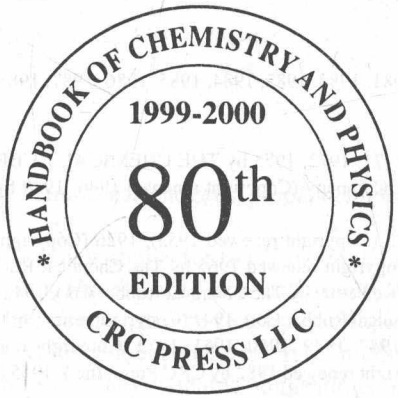
A Ready-Reference Book of Chemical and Physical Data



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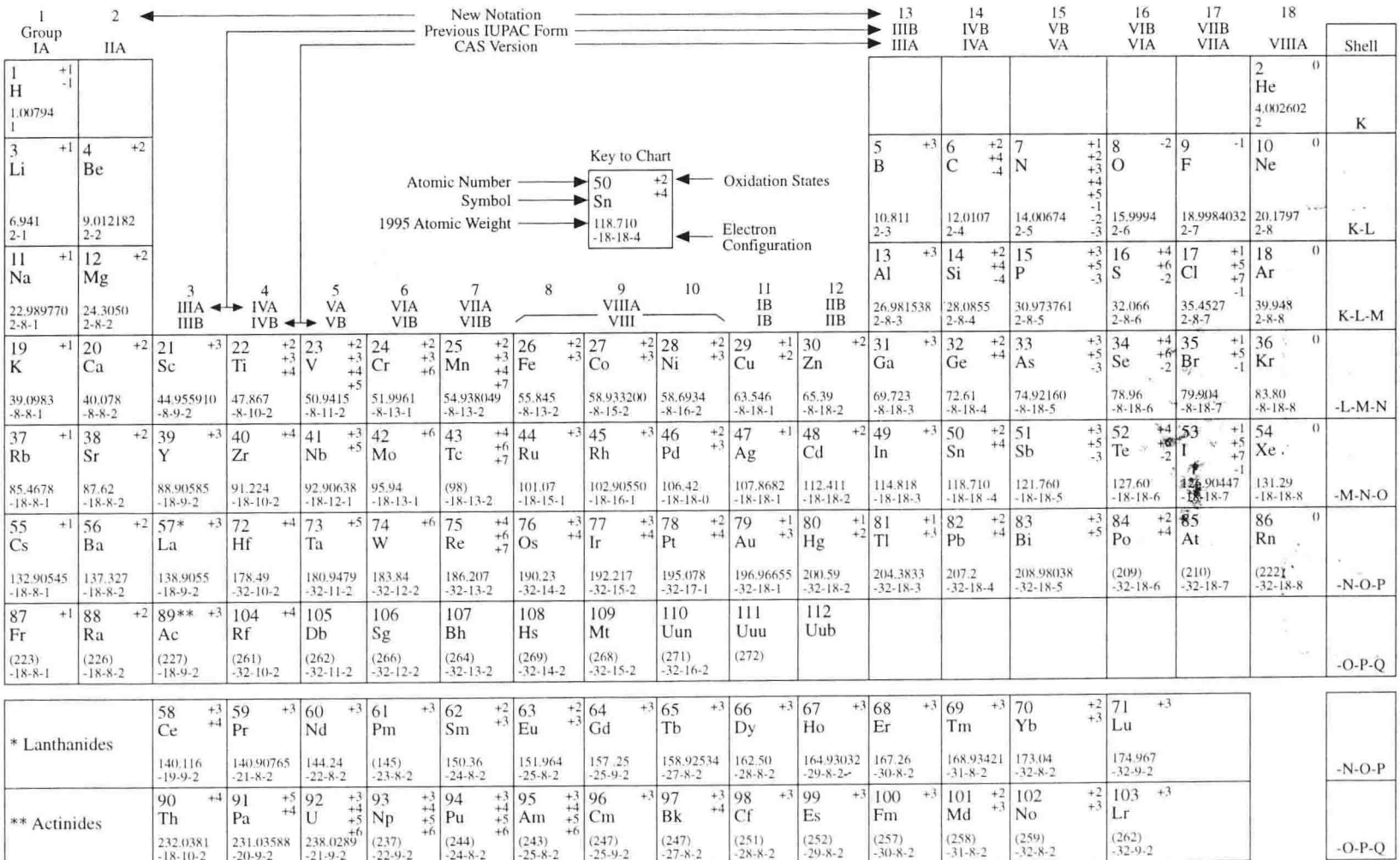

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87 +1 Fr (223) -18-8-1	88 +2 Ra (226) -18-8-2	89** +3 Ac (227) -18-9-2	104 +4 Rf (261) -32-10-2	105 Db (262) -32-11-2	106 Sg (266) -32-12-2	107 Bh (264) -32-13-2	108 Hs (269) -32-14-2	109 Mt (268) -32-15-2	110 Uun (271) -32-16-2	111 Uuu (272)	112 Uub							-O-P-Q

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* Lanthanides	+3 +4 Ce 140.116 -19-9-2	+3 Pr 140.90765 -21-8-2	+3 Nd 144.24 -22-8-2	+3 Pm (145) -23-8-2	+2 +3 Sm 150.36 -24-8-2	+2 +3 Eu 151.964 -25-8-2	+3 Gd 157.25 -25-9-2	+3 Tb 158.92534 -27-8-2	+3 Dy 162.50 -28-8-2	+3 Ho 164.93032 -29-8-2	+3 Er 167.26 -30-8-2	+3 Tm 168.93421 -31-8-2	+2 +3 Yb 173.04 -32-8-2	+3 Lu 174.967 -32-9-2	-N-O-P
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The new IUPAC format numbers the groups from 1 to 18. The previous IUPAC numbering system and the system used by Chemical Abstracts Service (CAS) are also shown. For radioactive elements that do not occur in nature, the mass number of the most stable isotope is given in parentheses.

References

1. G. J. Leigh, Editor, *Nomenclature of Inorganic Chemistry*, Blackwell Scientific Publications, Oxford, 1990.
2. *Chemical and Engineering News*, 63(5), 27, 1985.
3. Atomic Weights of the Elements, 1995, *Pure & Appl. Chem.*, 68, 2339, 1996.

Summary of the 1986 CODATA Recommended Values of the Fundamental Physical Constants

Quantity	Symbol	Value	Units	Relative Uncertainty (ppm)
speed of light in vacuum	c	299 792 458	$m\,s^{-1}$	(exact)
permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	$N\,A^{-2}$	
		$=12.566\,370\,614\ldots$	$10^{-7}\,N\,A^{-2}$	(exact)
permittivity of vacuum	ϵ_0	$1/\mu_0 c^2$		
		$=8.854\,187\,817\ldots$	$10^{-12}\,F\,m^{-1}$	(exact)
Newtonian constant of gravitation	G	6.672 59(85)	$10^{-11}\,m^3\,kg^{-1}\,s^{-2}$	128
Planck constant	h	6.626 0755(40)	$10^{-34}\,J\,s$	0.60
$h/2\pi$	$\hbar$	1.054 572 66(63)	$10^{-34}\,J\,s$	0.60
elementary charge	e	1.602 177 33(49)	$10^{-19}\,C$	0.30
magnetic flux quantum, $h/2e$	Φ_0	2.067 834 61(61)	$10^{-15}\,Wb$	0.30
electron mass	m_e	9.109 3897(54)	$10^{-31}\,kg$	0.59
proton mass	m_p	1.672 6231(10)	$10^{-27}\,kg$	0.59
proton-electron mass ratio	m_p/m_e	1836.152 701(37)		0.020
fine-structure constant, $\mu_0 ce^2/2h$	α	7.297 353 08(33)	10^{-3}	0.045
inverse fine-structure constant	α^{-1}	137.035 9895(61)		0.045
Rydberg constant, $m_e c\alpha^2/2h$	R_∞	10 973 731.534(13)	m^{-1}	0.0012
Avogadro constant	N_A, L	6.022 1367(36)	$10^{23}\,mol^{-1}$	0.59
Faraday constant, $N_A e$	F	96 485.309(29)	$C\,mol^{-1}$	0.30
molar gas constant	R	8.314 510(70)	$J\,mol^{-1}\,K^{-1}$	8.4
Boltzmann constant, R/N_A	k	1.380 658(12)	$10^{-23}\,J\,K^{-1}$	8.5
Stefan–Boltzmann constant, $(\pi^2/60)k^4/\hbar^3c^2$	σ	5.670 51(19)	$10^{-8}\,W\,m^{-2}\,K^{-4}$	34
		Non-SI units used with SI		
electron volt, $(e/C)\,J = \{e\}\,J$	eV	1.602 177 33(49)	$10^{-19}\,J$	0.30
(unified) atomic mass unit, $1\,u = m_u = \frac{1}{12}m(^{12}C)$	u	1.660 5402(10)	$10^{-27}\,kg$	0.59

CRC Handbook of Chemistry and Physics

80th Edition

EDITORIAL ADVISORY BOARD

PREFACE
80th Edition

The 80th Edition of the *Handbook of Chemistry and Physics* continues the tradition of updating existing tables with the most current data and intoducing new topics of interest to the scientific community. Among the new subjects covered in this edition are:

- Chemical kinetic data on reactions in the stratosphere
- Standard solutions for calibrating conductivity cells
- Properties of water and steam at high temperatures and pressures
- Density and other properties of ice and supercooled water
- Diffusion of gases in water
- Solubility of common salts in water at ambient temperatures

Significant updates and expansions have been made in the following areas:

- Heats of fusion
- Strengths of chemical bonds
- Sublimation pressure of solids
- Lattice energy of crystals
- Diffusion in semiconductors
- Properties of fundamental particles

Finally, the most recent Government list of chemical carcinogens, prepared under the National Toxicology Program, has been added.

The Editor will appreciate suggestions on new topics for the *Handbook* (and on older tables whose usefulness is questionable). Address all comments to Editor, *Handbook of Chemistry and Physics*, CRC Press LLC, 2000 Corporate Blvd. N. W., Boca Raton, FL 33431. Comments may also be sent by electronic mail to dlide@earthlink.net.

The *Handbook of Chemistry and Physics* is dependent on the efforts of many contributors throughout the world. The list of current contributors follows this Preface. Many valuable suggestions have come from the Editorial Advisory Board. Finally, the staff at CRC Press are instrumental to the success of the book. I wish particularly to thank Susan Fox, Karen Feinstein, and Carole Sweatman for their skill and dedication in carrying out the production process.

David R. Lide
March 5, 1999

This Edition is Dedicated to my Granddaughter, Kate Elizabeth Whitcomb

Note on the Ordering of Chemical Compounds: The decision on the order in which to list chemical compounds in a table is always difficult. An alphabetical list by name has the disadvantage that several different synonyms are often in common use, with the result that a reader may conclude incorrectly that a compound is not present if he looks it up under the wrong name. Listing by line formula is satisfactory for simple inorganic compounds, but is cumbersome for organics. A listing by molecular formula is attractive because clear rules can be given for locating a compound, but the user may have to go to some effort to determine the molecular formula. In this book the choice is made on pragmatic grounds. The long tables, Physical Constants of Organic Compounds and Physical Constants of Inorganic Compounds, are ordered by systematic name, but indexes to synonyms, formulas, and CAS Registry Numbers are provided. If the table is very short and includes only common substances, the listing is usually alphabetical by common name or formula. The remaining tables are ordered by molecular formula using a modification of the Hill convention. In this convention the molecular formula is written with C first, H second, and then all other elements in alphabetical order of their chemical symbols. For tables with organic compounds only, the sequence of entries is determined by the alphabetical order of elements in the molecular formula and the number of atoms of each element, in ascending order, e.g., C_3H_7Cl, C_3H_7N, C_3H_7NO, $C_3H_7NO_2$, etc. (For organic compounds, a quick way to determine the molecular formula is to use the Physical Constants of Organic Compounds table, which starts on Page **3**-1, and its synonym index on Page **3**-586.) In tables containing non-carbon compounds, those are listed first, followed by a separate listing of compounds that do contain carbon. This is in contrast to the strict Hill convention as followed by Chemical Abstracts Service, where the molecular formulas beginning with A and B precede the formulas for carbon-containing compounds, while those beginning with D... Z follow. For tabular displays, as opposed to an index, it appears more convenient to the user if the non-carbon compounds are listed as a block, rather than being split by the longer list of carbon compounds.

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Section 1
Basic Constants, Units, and Conversion Factors

FUNDAMENTAL PHYSICAL CONSTANTS

The 1986 CODATA Recommended Values of the Fundamental Physical Constants are summarized in the table. These values, which result from a least-squares adjustment carried out by the CODATA (Committee on Data for Science and Technology of the International Council of Scientific Unions) Task Group on Fundamental Constants, are recommended for general international use. Details may be found in the references.

REFERENCES

1. Cohen, E. R. and Taylor, B. N., *CODATA Bulletin No. 63,* 1986.
2. Cohen, E. R. and Taylor, B. N., *J. Phys. Chem. Ref. Data,* 17, 1795, 1988.
3. Cohen, E. R. and Taylor, B. N., *Rev. Mod. Phys.,* 59, 1121, 1987.
4. *NIST Physical Reference Data,* National Institute of Standards and Technology, Gaithersburg, MD. Available at the WWW address: http://physics.nist.gov/PhysRefData/contents.html

Fundamental Physical Constants

Quantity	Symbol	Value	Unit	Relative uncertainty (ppm)
FREQUENTLY USED CONSTANTS				
speed of light in vacuum	c	299 792 458	$m\ s^{-1}$	(exact)
permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	$N\ A^{-2}$	
		$=12.566\,370\,614...$	$10^{-7}\ N\ A^{-2}$	(exact)
permittivity of vacuum $1/\mu_0 c^2$	ε_0	8.854 187 817...	$10^{-12}\ F\ m^{-1}$	(exact)
Newtonian constant of gravitation	G	6.672 59(85)	$10^{-11}\ m^3\ kg^{-1}\ s^{-2}$	128.
Planck constant	h	6.626 075 5(40)	$10^{-34}\ J\ s$	0.60
$h/2\pi$	$\hbar$	1.054 572 66(63)	$10^{-34}\ J\ s$	0.60
elementary charge	e	1.602 177 33(49)	$10^{-19}\ C$	0.30
magnetic flux quantum $h/2e$	Φ_0	2.067 834 61(61)	$10^{-15}\ Wb$	0.30
electron mass	m_e	9.109 389 7(54)	$10^{-31}\ kg$	0.59
proton mass	m_p	1.672 623 1(10)	$10^{-27}\ kg$	0.59
proton-electron mass ratio	m_p/m_e	1 836.152 701(37)		0.020
fine-structure constant $\mu_0 c e^2/2h$	α	7.297 353 08(33)	10^{-3}	0.045
inverse fine-structure constant	α^{-1}	137.035 989 5(61)		0.045
Rydberg constant $m_e c\alpha^2/2h$	R_∞	10 973 731.534(13)	m^{-1}	0.0012
Avogadro constant	N_A, L	6.022 136 7(36)	$10^{23}\ mol^{-1}$	0.59
Faraday constant $N_A e$	F	96 485.309(29)	$C\ mol^{-1}$	0.30
molar gas constant	R	8.314 510(70)	$J\ mol^{-1}\ K^{-1}$	8.4
Boltzmann constant R/N_A	k	1.380 658(12)	$10^{-23}\ J\ K^{-1}$	8.5
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	5.670 51(19)	$10^{-8}\ W\ m^{-2}\ K^{-4}$	34.
UNIVERSAL CONSTANTS				
speed of light in vacuum	c	299 792 458	$m\ s^{-1}$	(exact)
permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	$N\ A^{-2}$	
		$= 12.566\,370\,614...$	$10^{-7}\ N\ A^{-2}$	(exact)
permittivity of vacuum $1/\mu_0 c^2$	ε_0	8.854 187 817...	$10^{-12}\ F\ m^{-1}$	(exact)
Newtonian constant of gravitation	G	6.672 59(85)	$10^{-11}\ m^3\ kg^{-1}\ s^{-2}$	128.
Planck constant	h	6.626 075 5(40)	$10^{-34}\ J\ s$	0.60
in electron volts: $h/\{e\}$		4.135 669 2(12)	$10^{-15}\ eV\ s$	0.30
$h/2\pi$	$\hbar$	1.054 572 66(63)	$10^{-34}\ J\ s$	0.60
in electron volts: $\hbar/\{e\}$		6.582 122 0(20)	$10^{-16}\ eV\ s$	0.30
Planck mass $(\hbar c/G)^{1/2}$	m_P	2.176 71(14)	$10^{-8}\ kg$	64.
Planck length $\hbar/m_P c = (\hbar G/c^3)^{1/2}$	l_P	1.616 05(10)	$10^{-35}\ m$	64.
Planck time $l_P/c = (\hbar G/c^5)^{1/2}$	t_P	5.390 56(34)	$10^{-44}\ s$	64.
ELECTROMAGNETIC CONSTANTS				
elementary charge	e	1.602 177 33(49)	$10^{-19}\ C$	0.30
	e/h	2.417 988 36(72)	$10^{14}\ A\ J^{-1}$	0.30
magnetic flux quantum $h/2e$	Φ_0	2.067 834 61(61)	$10^{-15}\ Wb$	0.30
Josephson frequency-voltage quotient	$2e/h$	4.835 976 7(14)	$10^{14}\ Hz\ V^{-1}$	0.30
quantized Hall conductance	e^2/h	3.874 046 14(17)	$10^{-5}\ S$	0.045
quantized Hall resistance $h/e^2 = \mu_0 c/2\alpha$	R_H	25 812.805 6(12)	Ω	0.045
Bohr magneton $e\hbar/2m_e$	μ_B	9.274 015 4(31)	$10^{-24}\ J\ T^{-1}$	0.34