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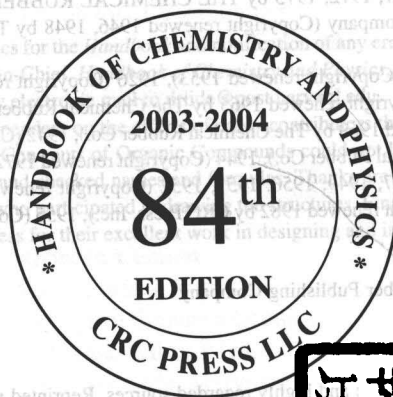
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CRC Handbook of Chemistry and Physics

A Ready-Reference Book of Chemical and Physical Data



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Former Director, Standard Reference Data

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This Edition is dedicated to the memory of the late Mary Eleanor Lide.

Mary Eleanor Lide

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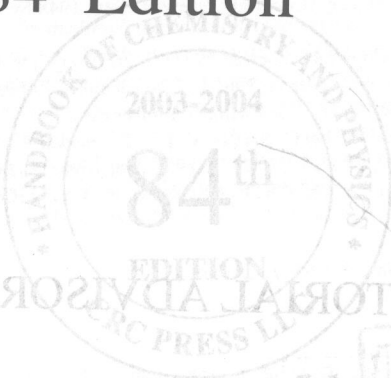
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PREFACE

The 84th Edition of the *CRC Handbook of Chemistry and Physics* features a completely new version of the most heavily used table in the book, Physical Constants of Organic Compounds. This is the first revision of the table since 1994. Compounds have been selected for inclusion in the new table by a careful screening of lists of organic compounds that are important in laboratory research, industrial chemistry, environmental protection, drug development, and other active areas. In this way priorities were established for choosing the most significant compounds out of the millions of organic substances that have been reported in the literature. Property data for the selected compounds have been updated, and new structure diagrams, which show much more detail than the previous structures, have been drawn for all the compounds. The format has also been changed. While previously the structures were in a separate part of the book from the data table, the matching structures now appear on a facing page to the tabular data. We hope that users find this layout more convenient, and we welcome comments on the new arrangement.

Other new features of the 84th Edition include:

- An update and expansion of the table of Critical Constants of Fluids, with many new compounds and recently published data.
- A new version of Properties of Refrigerants, which covers fluids now used in refrigeration systems and those being considered as substitutes because of environmental factors.
- A new table on Fermi Energy and Related Properties of Metals.
- New tables of practical laboratory data such as Flame and Bead Tests, Flame Temperatures, and Density of Ethanol-Water Mixtures.
- An update of lists of Chemical Carcinogens and Interstellar Molecules.
- Update of the new feature introduced in the 83rd Edition listing other reliable sources of physical and chemical data. This section, which appears as Appendix B, includes data-oriented journals, institutional data centers, and major handbooks, as well as a list of Web addresses for the most important physical and chemical data sources on the Internet. The Web addresses have been brought up to date for this edition and new sources have been added.

The Editor appreciates suggestions on new topics for the *Handbook* and notification of any errors. Input from users plays a key role in keeping the book up to date. Address all comments to Editor-in-Chief, *Handbook of Chemistry and Physics*, CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, FL 33431. Comments may also be sent by electronic mail to drlide@post.harvard.edu.

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. The new table of Physical Constants of Organic Compounds could not have been completed without the help of Dr. Fiona Macdonald, who oversaw the structure drawing and checked names and formulas. Thanks are also due to Janice Shackleton, Trupti Desai, Nazila Kamaly, Matt Griffiths, and Lawrence Braschi, who participated in drawing the structures. Finally, I want to thank Susan Fox, Sara Kreisman, and James Yanchak of the editorial group at CRC Press for their excellent work in designing and implementing the new layout of the table.

David R. Lide
February 25, 2003

This Edition is dedicated to my grandchildren:

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the user if the non-carbon compounds are listed as a block, rather than being split by the longer list of carbon compounds.

February 22, 2003
David R. Fiske 7591 ©

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STANDARD ATOMIC WEIGHTS (2001)

Z	Element	Symbol	Atomic Weight	Z	Element	Symbol	Atomic Weight
1	Hydrogen	H	1.00794(7)	58	Cerium	Ce	140.116(1)
2	Helium	He	4.002602(2)	59	Praseodymium	Pr	140.90765(2)
3	Lithium	Li	6.941(2)	60	Neodymium	Nd	144.24(3)
4	Beryllium	Be	9.012182(3)	61	Promethium	Pm	[144.9127]
5	Boron	B	10.811(7)	62	Samarium	Sm	150.36(3)
6	Carbon	C	12.0107(8)	63	Europium	Eu	151.964(1)
7	Nitrogen	N	14.0067(2)	64	Gadolinium	Gd	157.25(3)
8	Oxygen	O	15.9994(3)	65	Terbium	Tb	158.92534(2)
9	Fluorine	F	18.9984032(5)	66	Dysprosium	Dy	162.500(1)
10	Neon	Ne	20.1797(6)	67	Holmium	Ho	164.93032(2)
11	Sodium	Na	22.989770(2)	68	Erbium	Er	167.259(3)
12	Magnesium	Mg	24.3050(6)	69	Thulium	Tm	168.93421(2)
13	Aluminum	Al	26.981538(2)	70	Ytterbium	Yb	173.04(3)
14	Silicon	Si	28.0855(3)	71	Lutetium	Lu	174.967(1)
15	Phosphorus	P	30.973761(2)	72	Hafnium	Hf	178.49(2)
16	Sulfur	S	32.065(5)	73	Tantalum	Ta	180.9479(1)
17	Chlorine	Cl	35.453(2)	74	Tungsten	W	183.84(1)
18	Argon	Ar	39.948(1)	75	Rhenium	Re	186.207(1)
19	Potassium	K	39.0983(1)	76	Osmium	Os	190.23(3)
20	Calcium	Ca	40.078(4)	77	Iridium	Ir	192.217(3)
21	Scandium	Sc	44.955910(8)	78	Platinum	Pt	195.078(2)
22	Titanium	Ti	47.867(1)	79	Gold	Au	196.96655(2)
23	Vanadium	V	50.9415(1)	80	Mercury	Hg	200.59(2)
24	Chromium	Cr	51.9961(6)	81	Thallium	Tl	204.3833(2)
25	Manganese	Mn	54.938049(9)	82	Lead	Pb	207.2(1)
26	Iron	Fe	55.845(2)	83	Bismuth	Bi	208.98038(2)
27	Cobalt	Co	58.933200(9)	84	Polonium	Po	[208.9824]
28	Nickel	Ni	58.6934(2)	85	Astatine	At	[209.9871]
29	Copper	Cu	63.546(3)	86	Radon	Rn	[222.0176]
30	Zinc	Zn	65.409(4)	87	Francium	Fr	[223.0197]
31	Gallium	Ga	69.723(1)	88	Radium	Ra	[226.0254]
32	Germanium	Ge	72.64(1)	89	Actinium	Ac	[227.0277]
33	Arsenic	As	74.92160(2)	90	Thorium	Th	232.0381(1)
34	Selenium	Se	78.96(3)	91	Protactinium	Pa	231.03588(2)
35	Bromine	Br	79.904(1)	92	Uranium	U	238.02891(3)
36	Krypton	Kr	83.798(2)	93	Neptunium	Np	[237.0482]
37	Rubidium	Rb	85.4678(3)	94	Plutonium	Pu	[244.0642]
38	Strontium	Sr	87.62(1)	95	Americium	Am	[243.0614]
39	Yttrium	Y	88.90585(2)	96	Curium	Cm	[247.0704]
40	Zirconium	Zr	91.224(2)	97	Berkelium	Bk	[247.0703]
41	Niobium	Nb	92.90638(2)	98	Californium	Cf	[251.0796]
42	Molybdenum	Mo	95.94(2)	99	Einsteinium	Es	[252.0830]
43	Technetium	Tc	[97.9072]	100	Fermium	Fm	[257.0951]
44	Ruthenium	Ru	101.07(2)	101	Mendelevium	Md	[258.0984]
45	Rhodium	Rh	102.90550(2)	102	Nobelium	No	[259.1010]
46	Palladium	Pd	106.42(1)	103	Lawrencium	Lr	[262.1097]
47	Silver	Ag	107.8682(2)	104	Rutherfordium	Rf	[261.1088]
48	Cadmium	Cd	112.411(8)	105	Dubnium	Db	[262.1141]
49	Indium	In	114.818(3)	106	Seaborgium	Sg	[266.1219]
50	Tin	Sn	118.710(7)	107	Bohrium	Bh	[264.12]
51	Antimony	Sb	121.760(1)	108	Hassium	Hs	[277]
52	Tellurium	Te	127.60(3)	109	Meitnerium	Mt	[268.1388]
53	Iodine	I	126.90447(3)	110	Ununnilium	Uun	[281]
54	Xenon	Xe	131.293(6)	111	Unununium	Uuu	[272.1535]
55	Cesium	Cs	132.90545(2)	112	Ununbium	Uub	[285]
56	Barium	Ba	137.327(7)	114	Ununquadium	Uuq	[289]
57	Lanthanum	La	138.9055(2)	116	Ununhexium	Uuh	[289]

Fundamental Physical Constants — Frequently used constants

Quantity	Symbol	Value	Unit	Relative std. uncert. u_r
speed of light in vacuum	c, c_0	299 792 458	m s^{-1}	(exact)
magnetic constant	μ_0	$4\pi \times 10^{-7}$ $= 12.566\,370\,614\dots \times 10^{-7}$	N A^{-2} N A^{-2}	(exact)
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817\dots \times 10^{-12}$	F m^{-1}	(exact)
Newtonian constant of gravitation	G	$6.673(10) \times 10^{-11}$	$\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$	1.5×10^{-3}
Planck constant	h	$6.626\,068\,76(52) \times 10^{-34}$	J s	7.8×10^{-8}
$h/2\pi$	$\hbar$	$1.054\,571\,596(82) \times 10^{-34}$	J s	7.8×10^{-8}
elementary charge	e	$1.602\,176\,462(63) \times 10^{-19}$	C	3.9×10^{-8}
magnetic flux quantum $h/2e$	Φ_0	$2.067\,833\,636(81) \times 10^{-15}$	Wb	3.9×10^{-8}
conductance quantum $2e^2/h$	G_0	$7.748\,091\,696(28) \times 10^{-5}$	S	3.7×10^{-9}
electron mass	m_e	$9.109\,381\,88(72) \times 10^{-31}$	kg	7.9×10^{-8}
proton mass	m_p	$1.672\,621\,58(13) \times 10^{-27}$	kg	7.9×10^{-8}
proton-electron mass ratio	m_p/m_e	1 836.152 6675(39)		2.1×10^{-9}
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	$7.297\,352\,533(27) \times 10^{-3}$		3.7×10^{-9}
inverse fine-structure constant	α^{-1}	137.035 999 76(50)		3.7×10^{-9}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 549(83)	m^{-1}	7.6×10^{-12}
Avogadro constant	N_A, L	$6.022\,141\,99(47) \times 10^{23}$	mol^{-1}	7.9×10^{-8}
Faraday constant $N_A e$	F	96 485.3415(39)	C mol^{-1}	4.0×10^{-8}
molar gas constant	R	8.314 472(15)	$\text{J mol}^{-1} \text{K}^{-1}$	1.7×10^{-6}
Boltzmann constant R/N_A	k	$1.380\,6503(24) \times 10^{-23}$	J K^{-1}	1.7×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	$5.670\,400(40) \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	7.0×10^{-6}
Non-SI units accepted for use with the SI				
electron volt: $(e/C) \text{ J}$	eV	$1.602\,176\,462(63) \times 10^{-19}$	J	3.9×10^{-8}
(unified) atomic mass unit $1 \text{ u} = m_u = \frac{1}{12} m(^{12}\text{C})$ $= 10^{-3} \text{ kg mol}^{-1}/N_A$	u	$1.660\,538\,73(13) \times 10^{-27}$	kg	7.9×10^{-8}

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