

ULLMANN'S Seventh Edition ENCYCLOPEDIA OF INDUSTRIAL CHEMISTRY

Ullmann's Encyclopedia of Industrial Chemistry

7th, Completely Revised Edition

Volume 19

Inclusion Compounds

to

Iron, 3. Direct Reduction Processes



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Symbols and Units

Symbols and units agree with SI standards (for conversion factors see page IX). The following list gives the most important symbols used in the encyclopedia. Articles with many specific units and symbols have a similar list as front matter.

Symbol	Unit	Physical Quantity
a_B		activity of substance B
A_r		relative atomic mass (atomic weight)
A	m^2	area
c_B	mol/m^3 , mol/L (M)	concentration of substance B
C	C/V	electric capacity
c_p, c_v	$\text{J kg}^{-1} \text{K}^{-1}$	specific heat capacity
d	cm , m	diameter
d		relative density (Q/Q_{water})
D	m^2/s	diffusion coefficient
D	Gy ($=\text{J}/\text{kg}$)	absorbed dose
e	C	elementary charge
E	J	energy
E	V/m	electric field strength
E	V	electromotive force
E_A	J	activation energy
f		activity coefficient
F	C/mol	Faraday constant
F	N	force
g	m/s^2	acceleration due to gravity
G	J	Gibbs free energy
h	m	height
$\hbar$	$\text{W}\cdot\text{s}^2$	Planck constant
H	J	enthalpy
I	A	electric current
I	cd	luminous intensity
k	(variable)	rate constant of a chemical reaction
k	J/K	Boltzmann constant
K	(variable)	equilibrium constant
l	m	length
m	g , kg , t	mass
M_r		relative molecular mass (molecular weight)
n_D^{20}		refractive index (sodium D-line, 20°C)
n	mol	amount of substance
N_A	mol^{-1}	Avogadro constant ($6.023 \times 10^{23} \text{ mol}^{-1}$)
P	Pa , bar^*	pressure
Q	J	quantity of heat
r	m	radius
R	$\text{J K}^{-1} \text{mol}^{-1}$	gas constant
R	Ω	electric resistance
S	J/K	entropy
t	s , min , h , d , month , a	time
t	$^\circ\text{C}$	temperature
T	K	absolute temperature
u	m/s	velocity
U	V	electric potential

Symbols and Units (Continued from p. VII)

Symbol	Unit	Physical Quantity
U	J	internal energy
V	m^3 , L, mL, μL	volume
w		mass fraction
W	J	work
x_B		mole fraction of substance B
Z		proton number, atomic number
α		cubic expansion coefficient
α	$\text{Wm}^{-2}\text{K}^{-1}$	heat-transfer coefficient (heat-transfer number)
α		degree of dissociation of electrolyte
$[\alpha]$	$10^{-2}\text{deg cm}^2\text{g}^{-1}$	specific rotation
η	$\text{Pa}\cdot\text{s}$	dynamic viscosity
θ	$^{\circ}\text{C}$	temperature
κ		c_p/c_v
λ	$\text{Wm}^{-1}\text{K}^{-1}$	thermal conductivity
λ	nm, m	wavelength
μ		chemical potential
ν	Hz , s^{-1}	frequency
ν	m^2/s	kinematic viscosity (η/ρ)
π	Pa	osmotic pressure
ρ	g/cm^3	density
σ	N/m	surface tension
τ	$\text{Pa (N/m}^2)$	shear stress
φ		volume fraction
χ	Pa^{-1} (m^2/N)	compressibility

*The official unit of pressure is the pascal (Pa).

Conversion Factors

SI unit	Non-SI unit	From SI to non-SI multiply by
<i>Mass</i>		
kg	pound (avoirdupois)	2.205
kg	ton (long)	9.842×10^{-4}
kg	ton (short)	1.102×10^{-3}
<i>Volume</i>		
m ³	cubic inch	6.102×10^4
m ³	cubic foot	35.315
m ³	gallon (U.S., liquid)	2.642×10^2
m ³	gallon (Imperial)	2.200×10^2
<i>Temperature</i>		
°C	°F	$^{\circ}\text{C} \times 1.8 + 32$
<i>Force</i>		
N	dyne	1.0×10^5
<i>Energy, Work</i>		
J	Btu (int.)	9.480×10^{-4}
J	cal (int.)	2.389×10^{-1}
J	eV	6.242×10^{18}
J	erg	1.0×10^7
J	kW·h	2.778×10^{-7}
J	kp·m	1.020×10^{-1}
<i>Pressure</i>		
MPa	at	10.20
MPa	atm	9.869
MPa	bar	10
kPa	mbar	10
kPa	mm Hg	7.502
kPa	psi	0.145
kPa	torr	7.502

Powers of Ten

E (exa)	10 ¹⁸	d (deci)	10 ⁻¹
P (peta)	10 ¹⁵	c (centi)	10 ⁻²
T (tera)	10 ¹²	m (milli)	10 ⁻³
G (giga)	10 ⁹	μ (micro)	10 ⁻⁶
M (mega)	10 ⁶	n (nano)	10 ⁻⁹
k (kilo)	10 ³	p (pico)	10 ⁻¹²
h (hecto)	10 ²	f (femto)	10 ⁻¹⁵
da (deca)	10	a (atto)	10 ⁻¹⁸

Abbreviations

The following is a list of the abbreviations used in the text. Common terms, the names of publications and institutions, and legal agreements are included along with their full identities. Other abbreviations will be defined wherever they first occur in an article. For further abbreviations, see page VII, Symbols and Units; page XIV, Frequently Cited Companies (Abbreviations), and page XV, Country Codes in patent references. The names of periodical publications are abbreviated exactly as done by Chemical Abstracts Service.

abs.	absolute	BGA	Bundesgesundheitsamt (Federal Republic of Germany)
a.c.	alternating current	BGB1.	Bundesgesetzblatt (Federal Republic of Germany)
ACGIH	American Conference of Governmental Industrial Hygienists	BIOS	British Intelligence Objectives Subcommittee Report (see also FIAT)
ACS	American Chemical Society	BOD	biological oxygen demand
ADI	acceptable daily intake	<i>bp</i>	boiling point
ADN	accord européen relatif au transport international des marchandises dangereuses par voie de navigation intérieure (European agreement concerning the international transportation of dangerous goods by inland waterways)	B.P.	British Pharmacopeia
		BS	British Standard
		ca.	circa
ADNR	ADN par le Rhin (regulation concerning the transportation of dangerous goods on the Rhine and all national waterways of the countries concerned)	calcd.	calculated
		CAS	Chemical Abstracts Service
		cat.	catalyst, catalyzed
ADP	adenosine 5'-diphosphate	CEN	Comité Européen de Normalisation
ADR	accord européen relatif au transport international des marchandises dangereuses par route (European agreement concerning the international transportation of dangerous goods by road)	cf.	compare
		CFR	Code of Federal Regulations (United States)
AEC	Atomic Energy Commission (United States)	cfu	colony forming units
a.i.	active ingredient	Chap.	chapter
AICHe	American Institute of Chemical Engineers	ChemG	Chemikaliengesetz (Federal Republic of Germany)
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers	C.I.	Colour Index
ANSI	American National Standards Institute	CIOS	Combined Intelligence Objectives Subcommittee Report (see also FIAT)
AMP	adenosine 5'-monophosphate	CNS	central nervous system
APhA	American Pharmaceutical Association	Co.	Company
API	American Petroleum Institute	COD	chemical oxygen demand
ASTM	American Society for Testing and Materials	conc.	concentrated
		const.	constant
ATP	adenosine 5'-triphosphate	Corp.	Corporation
BAM	Bundesanstalt für Materialprüfung (Federal Republic of Germany)	crit.	critical
BAT	Biologischer Arbeitsstofftoleranzwert (biological tolerance value for a working material, established by MAK Commission, see MAK)	CTFA	The Cosmetic, Toiletry and Fragrance Association (United States)
Beilstein	Beilstein's Handbook of Organic Chemistry, Springer, Berlin – Heidelberg – New York	DAB	Deutsches Arzneibuch, Deutscher Apotheker-Verlag, Stuttgart
BET	Brunauer – Emmett – Teller	d.c.	direct current
		decomp.	decompose, decomposition
		DFG	Deutsche Forschungsgemeinschaft (German Science Foundation)
		dil.	dilute, diluted
		DIN	Deutsche Industrienorm (Federal Republic of Germany)
		DMF	dimethylformamide
		DNA	deoxyribonucleic acid
		DOE	Department of Energy (United States)

DOT	Department of Transportation – Materials Transportation Bureau (United States)		gefährlicher Güter auf der Straße (regulation in the Federal Republic of Germany concerning the transportation of dangerous goods by road)
DTA	differential thermal analysis		
EC	effective concentration	GGVSee	Verordnung in der Bundesrepublik Deutschland über die Beförderung gefährlicher Güter mit Seeschiffen
EC	European Community		(regulation in the Federal Republic of Germany concerning the transportation of dangerous goods by sea-going vessels)
ed.	editor, edition, edited		
e.g.	for example		
emf	electromotive force		
EmS	Emergency Schedule		
EN	European Standard (European Community)	GLC	gas-liquid chromatography
EPA	Environmental Protection Agency (United States)	Gmelin	Gmelin's Handbook of Inorganic Chemistry, 8th ed., Springer, Berlin – Heidelberg –New York
EPR	electron paramagnetic resonance	GRAS	generally recognized as safe
Eq.	equation	Hal	halogen substituent (–F, –Cl, –Br, –I)
ESCA	electron spectroscopy for chemical analysis	Houben- Weyl	Methoden der organischen Chemie, 4th ed., Georg Thieme Verlag, Stuttgart
esp.	especially		
ESR	electron spin resonance	HPLC	high performance liquid chromatography
Et	ethyl substituent (–C ₂ H ₅)		
et al.	and others	IAEA	International Atomic Energy Agency
etc.	et cetera	IARC	International Agency for Research on Cancer, Lyon, France
EVO	Eisenbahnverkehrsordnung (Federal Republic of Germany)	IATA-DGR	International Air Transport Association, Dangerous Goods Regulations
exp (...)	e ^(...) , mathematical exponent	ICAO	International Civil Aviation Organization
FAO	Food and Agriculture Organization (United Nations)		
FDA	Food and Drug Administration (United States)	i.e.	that is
FD&C	Food, Drug and Cosmetic Act (United States)	i.m.	intramuscular
FHSA	Federal Hazardous Substances Act (United States)	IMDG	International Maritime Dangerous Goods Code
FIAT	Field Information Agency, Technical (United States reports on the chemical industry in Germany, 1945)	IMO	Inter-Governmental Maritime Consul- tive Organization (in the past: IMCO)
Fig.	figure	Inst.	Institute
<i>fp</i>	freezing point	i.p.	intraperitoneal
Friedländer	P. Friedländer, Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige Vol. 1–25, Springer, Berlin 1888–1942	IR	infrared
FT	Fourier transform	ISO	International Organization for Standardization
(g)	gas, gaseous	IUPAC	International Union of Pure and Applied Chemistry
GC	gas chromatography		
GefStoffV	Gefahrstoffverordnung (regulations in the Federal Republic of Germany con- cerning hazardous substances)	i.v.	intravenous
GGVE	Verordnung in der Bundesrepublik Deutschland über die Beförderung gefährlicher Güter mit der Eisenbahn (regulation in the Federal Republic of Germany concerning the transportation of dangerous goods by rail)	Kirk- Othmer	Encyclopedia of Chemical Technology, 3rd ed., 1991–1998, 5th ed., 2004–2007, John Wiley & Sons, Hoboken
GGVS	Verordnung in der Bundesrepublik Deutschland über die Beförderung	(1)	liquid
		Landolt- Börnstein	Zahlenwerte u. Funktionen aus Physik, Chemie, Astronomie, Geophysik u. Technik, Springer, Heidelberg 1950– 1980; Zahlenwerte und Funktionen aus Naturwissenschaften und Technik, Neue Serie, Springer, Heidelberg, since 1961
		LC ₅₀	lethal concentration for 50 % of the test animals
		LCLo	lowest published lethal concentration

LD ₅₀	lethal dose for 50 % of the test animals	OSHA	Occupational Safety and Health Administration (United States)
LDLo	lowest published lethal dose	p., pp.	page, pages
ln	logarithm (base e)	Patty	G.D. Clayton, F.E. Clayton (eds.): Patty's Industrial Hygiene and Toxicology, 3rd ed., Wiley Interscience, New York
LNG	liquefied natural gas	PB	Publication Board Report (U.S. Department of Commerce, Scientific and Industrial Reports)
log	logarithm (base 10)	PEL	permitted exposure limit
LPG	liquefied petroleum gas	Ph	phenyl substituent ($-\text{C}_6\text{H}_5$)
M	mol/L	Ph. Eur.	European Pharmacopoeia, Council of Europe, Strasbourg
M	metal (in chemical formulas)	phr	part per hundred rubber (resin)
MAK	Maximale Arbeitsplatzkonzentration (maximum concentration at the workplace in the Federal Republic of Germany); cf. Deutsche Forschungsgemeinschaft (ed.): Maximale Arbeitsplatzkonzentrationen (MAK) und Biologische Arbeitsstofftoleranzwerte (BAT), WILEY-VCH Verlag, Weinheim (published annually)	PNS	peripheral nervous system
max.	maximum	ppm	parts per million
MCA	Manufacturing Chemists Association (United States)	q.v.	which see (quod vide)
Me	methyl substituent ($-\text{CH}_3$)	ref.	refer, reference
Methodicum Chimicum	Methodicum Chimicum, Georg Thieme Verlag, Stuttgart	resp.	respectively
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods	R_f	retention factor (TLC)
MIK	maximale Immissionskonzentration (maximum immission concentration)	R.H.	relative humidity
min.	minimum	RID	réglement international concernant le transport des marchandises dangereuses par chemin de fer (international convention concerning the transportation of dangerous goods by rail)
mp	melting point	RNA	ribonucleic acid
MS	mass spectrum, mass spectrometry	R phrase	risk phrase according to ChemG and GefStoffV (Federal Republic of Germany)
NAS	National Academy of Sciences (United States)	(R-Satz)	
NASA	National Aeronautics and Space Administration (United States)	rpm	revolutions per minute
NBS	National Bureau of Standards (United States)	RTECS	Registry of Toxic Effects of Chemical Substances, edited by the National Institute of Occupational Safety and Health (United States)
NCTC	National Collection of Type Cultures (United States)	(s)	solid
NIH	National Institutes of Health (United States)	SAE	Society of Automotive Engineers (United States)
NIOSH	National Institute for Occupational Safety and Health (United States)	s.c.	subcutaneous
NMR	nuclear magnetic resonance	SI	International System of Units
no.	number	SIMS	secondary ion mass spectrometry
NOEL	no observed effect level	S phrase	safety phrase according to ChemG and GefStoffV (Federal Republic of Germany)
NRC	Nuclear Regulatory Commission (United States)	(S-Satz)	
NRDC	National Research Development Corporation (United States)	STEL	Short Term Exposure Limit (see TLV)
NSC	National Service Center (United States)	STP	standard temperature and pressure (0°C, 101.325 kPa)
NSF	National Science Foundation (United States)	T_g	glass transition temperature
NTSB	National Transportation Safety Board (United States)	TA Luft	Technische Anleitung zur Reinhaltung der Luft (clean air regulation in Federal Republic of Germany)
OECD	Organization for Economic Cooperation and Development	TA Lärm	Technische Anleitung zum Schutz gegen Lärm (low noise regulation in Federal Republic of Germany)
		TDLo	lowest published toxic dose

THF	tetrahydrofuran	UVV	Unfallverhütungsvorschriften der Berufsgenossenschaft (workplace safety regulations in the Federal Republic of Germany)
TLC	thin layer chromatography		
TLV	Threshold Limit Value (TWA and STEL); published annually by the American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, Ohio	VbF	Verordnung in der Bundesrepublik Deutschland über die Errichtung und den Betrieb von Anlagen zur Lagerung, Abfüllung und Beförderung brennbarer Flüssigkeiten (regulation in the Federal Republic of Germany concerning the construction and operation of plants for storage, filling, and transportation of flammable liquids; classification according to the flash point of liquids, in accordance with the classification in the United States)
TOD	total oxygen demand		
TRK	Technische Richtkonzentration (lowest technically feasible level)	VDE	Verband Deutscher Elektroingenieure (Federal Republic of Germany)
TSCA	Toxic Substances Control Act (United States)	VDI	Verein Deutscher Ingenieure (Federal Republic of Germany)
TÜV	Technischer Überwachungsverein (Technical Control Board of the Federal Republic of Germany)	vol	volume
TWA	Time Weighted Average	vol.	volume (of a series of books)
UBA	Umweltbundesamt (Federal Environmental Agency)	vs.	versus
Ullmann	Ullmann's Encyclopedia of Industrial Chemistry, 6th ed., Wiley-VCH, Weinheim 2002; Ullmann's Encyclopedia of Industrial Chemistry, 5th ed., VCH Verlagsgesellschaft, Weinheim 1985–1996; Ullmanns Encyklopädie der Technischen Chemie, 4th ed., Verlag Chemie, Weinheim 1972–1984; 3rd ed., Urban und Schwarzenberg, München 1951–1970	WGK	Wassergefährdungsklasse (water hazard class)
		WHO	World Health Organization (United Nations)
USAEC	United States Atomic Energy Commission	Winnacker-Küchler	Chemische Technologie, 4th ed., Carl Hanser Verlag, München, 1982–1986; Winnacker-Küchler, Chemische Technik: Prozesse und Produkte, Wiley-VCH, Weinheim, 2003–2006
USAN	United States Adopted Names		
USD	United States Dispensatory	wt	weight
USDA	United States Department of Agriculture	\$	U.S. dollar, unless otherwise stated
U.S.P.	United States Pharmacopeia		
UV	ultraviolet		

Frequently Cited Companies (Abbreviations)

Air Products	Air Products and Chemicals	IFP	Institut Français du Pétrole
Akzo	Algemene Koninklijke Zout Organon	INCO	International Nickel Company
Alcoa	Aluminum Company of America	3M	Minnesota Mining and Manufacturing Company
Allied	Allied Corporation	Mitsubishi Chemical	Mitsubishi Chemical Industries
Amer. Cyanamid	American Cyanamid Company	Monsanto	Monsanto Company
BASF	BASF Aktiengesellschaft	Nippon Shokubai	Nippon Shokubai Kagaku Kogyo
Bayer	Bayer AG	PCUK	Pechiney Ugine Kuhlmann
BP	British Petroleum Company	PPG	Pittsburg Plate Glass Industries
Celanese	Celanese Corporation	Searle	G.D. Searle & Company
Daicel	Daicel Chemical Industries	SKF	Smith Kline & French Laboratories
Dainippon	Dainippon Ink and Chemicals Inc.	SNAM	Società Nazionale Metandotti
Dow Chemical	The Dow Chemical Company	Sohio	Standard Oil of Ohio
DSM	Dutch Staats Mijnen	Stauffer	Stauffer Chemical Company
Du Pont	E.I. du Pont de Nemours & Company	Sumitomo	Sumitomo Chemical Company
Exxon	Exxon Corporation	Toray	Toray Industries Inc.
FMC	Food Machinery & Chemical Corporation	UCB	Union Chimique Belge
GAF	General Aniline & Film Corporation	Union Carbide	Union Carbide Corporation
W.R. Grace	W.R. Grace & Company	UOP	Universal Oil Products Company
Hoechst	Hoechst Aktiengesellschaft	VEBA	Vereinigte Elektrizitäts- und Bergwerks-AG
IBM	International Business Machines Corporation	Wacker	Wacker Chemie GmbH
ICI	Imperial Chemical Industries		

Country Codes

The following list contains a selection of standard country codes used in the patent references.

AT	Austria	IL	Israel
AU	Australia	IT	Italy
BE	Belgium	JP	Japan*
BG	Bulgaria	LU	Luxembourg
BR	Brazil	MA	Morocco
CA	Canada	NL	Netherlands*
CH	Switzerland	NO	Norway
CS	Czechoslovakia	NZ	New Zealand
DD	German Democratic Republic	PL	Poland
DE	Federal Republic of Germany (and Germany before 1949)*	PT	Portugal
DK	Denmark	SE	Sweden
ES	Spain	SU	Soviet Union
FI	Finland	US	United States of America
FR	France	YU	Yugoslavia
GB	United Kingdom	ZA	South Africa
GR	Greece	EP	European Patent Office*
HU	Hungary	WO	World Intellectual Property Organization
ID	Indonesia		

*For Europe, Federal Republic of Germany, Japan, and the Netherlands, the type of patent is specified: EP (patent), EP-A (application), DE (patent), DE-OS (Offenlegungsschrift), DE-AS (Auslegeschrift), JP (patent), JP-Kokai (Kokai tokkyo koho), NL (patent), and NL-A (application).

Periodic Table of Elements

element symbol, atomic number, and relative atomic mass (atomic weight)

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La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
138.91	140.12	140.91	144.24	146.92	150.36	151.97	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
227.03	232.04	231.04	238.03	237.05	244.06	243.06	247.07	247.07	251.08	252.08	257.10	258.10	259.10	260.11

* radioactive element; mass of most important isotope given.

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