

ULLMANN'S Seventh Edition ENCYCLOPEDIA OF INDUSTRIAL CHEMISTRY

Ullmann's Encyclopedia of Industrial Chemistry

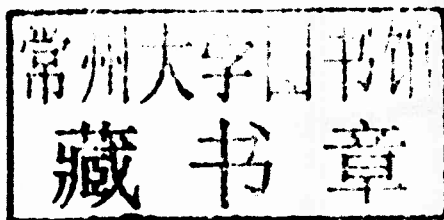
7th, Completely Revised Edition

Volume 25

Nucleic Acids

to

Paints and Coatings, 2. Types



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Ullmann's Encyclopedia of Industrial Chemistry

Volume 25

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	$J\text{ kg}^{-1}\text{ K}^{-1}$	specific heat capacity
d	cm, m	diameter
d		relative density (ρ/ρ_{water})
D	m^2/s	diffusion coefficient
D	Gy ($=J/kg$)	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	$JK^{-1}\text{ mol}^{-1}$	gas constant
R	Ω	electric resistance
S	J/K	entropy
t	s, min, h, d, month, a	time
t	°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	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
ADP	adenosine 5'-diphosphate	cat.	catalyst, catalyzed
ADR	accord européen relatif au transport international des marchandises dangereuses par route (European agreement concerning the international transportation of dangerous goods by road)	CEN	Comité Européen de Normalisation
		cf.	compare
AEC	Atomic Energy Commission (United States)	CFR	Code of Federal Regulations (United States)
a.i.	active ingredient	cfu	colony forming units
AICHe	American Institute of Chemical Engineers	Chap.	chapter
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers	ChemG	Chemikaliengesetz (Federal Republic of Germany)
ANSI	American National Standards Institute	C.I.	Colour Index
AMP	adenosine 5'-monophosphate	CIOS	Combined Intelligence Objectives Subcommittee Report (see also FIAT)
APhA	American Pharmaceutical Association	CNS	central nervous system
API	American Petroleum Institute	Co.	Company
ASTM	American Society for Testing and Materials	COD	chemical oxygen demand
		conc.	concentrated
ATP	adenosine 5'-triphosphate	const.	constant
BAM	Bundesanstalt für Materialprüfung (Federal Republic of Germany)	Corp.	Corporation
BAT	Biologischer Arbeitsstofftoleranzwert (biological tolerance value for a working material, established by MAK Commission, see MAK)	crit.	critical
		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
		d.c.	direct current
BET	Brunauer – Emmett – Teller	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 (regulation in the Federal Republic of Germany concerning the transportation of dangerous goods by sea-going vessels)
EC	European Community		
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)	i.e.	that is
FDA	Food and Drug Administration (United States)	i.m.	intramuscular
FD&C	Food, Drug and Cosmetic Act (United States)	IMDG	International Maritime Dangerous Goods Code
FHSA	Federal Hazardous Substances Act (United States)	IMO	Inter-Governmental Maritime Consul- tative Organization (in the past: IMCO)
FIAT	Field Information Agency, Technical (United States reports on the chemical industry in Germany, 1945)	Inst.	Institute
Fig.	figure	i.p.	intraperitoneal
<i>fp</i>	freezing point	IR	infrared
Friedländer	P. Friedländer, Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige Vol. 1–25, Springer, Berlin 1888–1942	ISO	International Organization for Standardization
FT	Fourier transform	IUPAC	International Union of Pure and Applied Chemistry
(g)	gas, gaseous	i.v.	intravenous
GC	gas chromatography	Kirk- Othmer	Encyclopedia of Chemical Technology, 3rd ed., 1991–1998, 5th ed., 2004–2007, John Wiley & Sons, Hoboken
GefStoffV	Gefahrstoffverordnung (regulations in the Federal Republic of Germany con- cerning hazardous substances)	(1)	liquid
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)	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
GGVS	Verordnung in der Bundesrepublik Deutschland über die Beförderung	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		
log	logarithm (base 10)	PB	Publication Board Report (U.S. Department of Commerce, Scientific and Industrial Reports)
LPG	liquefied petroleum gas	PEL	permitted exposure limit
M	mol/L	Ph	phenyl substituent ($-\text{C}_6\text{H}_5$)
M	metal (in chemical formulas)	Ph. Eur.	European Pharmacopoeia, Council of Europe, Strasbourg
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)	phr	part per hundred rubber (resin)
max.	maximum	PNS	peripheral nervous system
MCA	Manufacturing Chemists Association (United States)	ppm	parts per million
Me	methyl substituent ($-\text{CH}_3$)	q.v.	which see (quod vide)
Methodicum	Methodicum Chemicum, Georg Thieme Chemicum Verlag, Stuttgart	ref.	refer, reference
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods	resp.	respectively
MIK	maximale Immissionskonzentration (maximum immission concentration)	R_f	retention factor (TLC)
min.	minimum	R.H.	relative humidity
mp	melting point	RID	règlement international concernant le transport des marchandises dangereuses par chemin de fer (international convention concerning the transportation of dangerous goods by rail)
MS	mass spectrum, mass spectrometry	RNA	ribonucleic acid
NAS	National Academy of Sciences (United States)	R phrase	risk phrase according to ChemG and GefStoffV (Federal Republic of Germany)
NASA	National Aeronautics and Space Administration (United States)	(R-Satz)	
NBS	National Bureau of Standards (United States)	rpm	revolutions per minute
NCTC	National Collection of Type Cultures (United States)	RTECS	Registry of Toxic Effects of Chemical Substances, edited by the National Institute of Occupational Safety and Health (United States)
NIH	National Institutes of Health (United States)	(s)	solid
NIOSH	National Institute for Occupational Safety and Health (United States)	SAE	Society of Automotive Engineers (United States)
NMR	nuclear magnetic resonance	s.c.	subcutaneous
no.	number	SI	International System of Units
NOEL	no observed effect level	SIMS	secondary ion mass spectrometry
NRC	Nuclear Regulatory Commission (United States)	S phrase	safety phrase according to ChemG and GefStoffV (Federal Republic of Germany)
NRDC	National Research Development Corporation (United States)	(S-Satz)	
NSC	National Service Center (United States)	STEL	Short Term Exposure Limit (see TLV)
NSF	National Science Foundation (United States)	STP	standard temperature and pressure (0°C, 101.325 kPa)
NTSB	National Transportation Safety Board (United States)	T_g	glass transition temperature
OECD	Organization for Economic Cooperation and Development	TA Luft	Technische Anleitung zur Reinhaltung der Luft (clean air regulation in Federal Republic of Germany)
		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	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)
TLV	Threshold Limit Value (TWA and STEL); published annually by the American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, Ohio	VDE	Verband Deutscher Elektroingenieure (Federal Republic of Germany)
TOD	total oxygen demand	VDI	Verein Deutscher Ingenieure (Federal Republic of Germany)
TRK	Technische Richtkonzentration (lowest technically feasible level)	vol	volume
TSCA	Toxic Substances Control Act (United States)	vol.	volume (of a series of books)
TÜV	Technischer Überwachungsverein (Technical Control Board of the Federal Republic of Germany)	vs.	versus
TWA	Time Weighted Average	WGK	Wassergefährdungsklasse (water hazard class)
UBA	Umweltbundesamt (Federal Environmental Agency)	WHO	World Health Organization (United Nations)
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	Winnacker-Küchler	Chemische Technologie, 4th ed., Carl Hanser Verlag, München, 1982–1986; Winnacker-Küchler, Chemische Technik: Prozesse und Produkte, Wiley-VCH, Weinheim, 2003–2006
USAEC	United States Atomic Energy Commission	wt	weight
USAN	United States Adopted Names	\$	U.S. dollar, unless otherwise stated
USD	United States Dispensatory		
USDA	United States Department of Agriculture		
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.	American Cyanamid Company	Monsanto	Monsanto Company
Cyanamid	BASF Aktiengesellschaft	Nippon	Nippon Shokubai Kagaku Kogyo Shokubai
BASF	Bayer AG	PCUK	Pechiney Ugine Kuhlmann
Bayer	British Petroleum Company	PPG	Pittsburg Plate Glass Industries
BP	Celanese Corporation	Searle	G.D. Searle & Company
Celanese	Daicel Chemical Industries	SKF	Smith Kline & French Laboratories
Daicel	Dainippon Ink and Chemicals Inc.	SNAM	Società Nazionale Metandotti
Dainippon	The Dow Chemical Company	Sohio	Standard Oil of Ohio
Dow Chemical	DSM	Stauffer	Stauffer Chemical Company
DSM	Dutch Staats Mijnen	Sumitomo	Sumitomo Chemical Company
Du Pont	E.I. du Pont de Nemours & Company	Toray	Toray Industries Inc.
Exxon	Exxon Corporation	UCB	Union Chimique Belge
FMC	Food Machinery & Chemical Corporation	Union Carbide	Union Carbide Corporation
GAF	General Aniline & Film Corporation	UOP	Universal Oil Products Company
W.R. Grace	W.R. Grace & Company	VEBA	Vereinigte Elektrizitäts- und Bergwerks-AG
Hoechst	Hoechst Aktiengesellschaft	Wacker	Wacker Chemie GmbH
IBM	International Business Machines Corporation		
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)

1A "European" group designation and old IUPAC recommendation																0	
1 group designation to 1986 IUPAC proposal																18	
IA "American" group designation, also used by the Chemical Abstracts Service until the end of 1986																VIII A	
1	2A															2	7B
H	2															He	17
1.0079	IIA															4.0026	VIA
3	4															9	10
Li	Be															F	Ne
6.941	9.0122															18.998	20.180
11	12	3A	4A	5A	6A	7A	8	8	8	8	1B	2B					18
Na	Mg	3	4	5	6	7	8	9	10	11	12					Cl	Ar
22.990	24.305	IIIB	IVB	VB	VIB	VII B	VIII	VIII	VIII	IB	IB					32.066	39.948
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.409	69.723	72.61	74.922	78.96	79.904	83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc*	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
85.468	87.62	88.906	91.224	92.906	95.94	98.906	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
55	56											81	82	83	84	85	86
Cs	Ba											Tl	Pb	Bi	Po*	At*	Rn*
132.91	137.33											204.38	207.2	208.98	209.99	222.02	
87	88											113	114	115	116		118
Fr*	Ra*											Uut*	Uuq	Uup*	Uuh		Uuo*
223.02	226.03											112	111	110	111		

^a provisional IUPAC symbol

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
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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