Ulimann's Encyclopedia
of Industrial Chemistry
Sixuh, Completely Revised Edition
Volume 18

Ullmann's Encyclopedia of Industrial Chemistry

Sixth, Completely Revised Edition

Volume 18

Information Storage

Materials

to

Ketones



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Ullmann's Encyclopedia of Industrial Chemistry

Volume 18

Ullmann's Encyclopedia of Industrial Chemistry

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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	$J kg^{-1}K^{-1}$	specific heat capacity
d	cm, m	diameter
d		relative density $(\varrho/\varrho_{\text{water}})$
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
$E_{\rm A}$	J	activation energy
f		activity coefficient
F	C/mol	Faraday constant
F	Ν	force
g	m/s ²	acceleration due to gravity
G	J	Gibbs free energy
h	m	height
ħ	$W \cdot s^2$	Planck constant
Н	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
1	m	length
m	g, kg, t	mass
Mr	8, -8,	relative molecular mass (molecular weight)
$n_{\rm D}^{20}$		refractive index (sodium D-line, 20 °C)
n	mol	amount of substance
NA	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	$J K^{-1} mol^{-1}$	gas constant
R	Ω	electric resistance
S	J/K	entropy
t	s, min, h, d, month, a	time

Symbols and Units (Continued from p. VII)

Symbol	Unit	Physical Quantity
t	°C	temperature
Τ	K	absolute temperature
ı	m/s	velocity
U	V	electric potential
IJ	1	internal energy
/	m^3 , L, mL, μ L	volume
v		mass fraction
V	J	work
В		mole fraction of substance B
		proton number, atomic number
Y		cubic expansion coefficient
ı	$W m^{-2} K^{-1}$	heat-transfer coefficient (heat-transfer number)
E .		degree of dissociation of electrolyte
α]	$10^{-2} \text{deg cm}^2 \text{g}^{-1}$	specific rotation
	Pa·s	dynamic viscosity
	°C	temperature
6		c_p/c_v
	$W m^{-1} K^{-1}$	thermal conductivity
	nm, m	wavelength
		chemical potential
,	Hz, s^{-1}	frequency
<i>'</i>	m ² /s	kinematic viscosity (η/ϱ)
•	Pa	osmotic pressure
Č	g/cm ³	density
	N/m	surface tension
	$Pa(N/m^2)$	shear stress
,		volume fraction
	$Pa^{-1} (m^2/N)$	compressibility

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

IX

Conversion Factors

SI unit	Non-SI unit	From SI to non-SI multiply by
Mass		
kg	pound (avoirdupois)	2.205
kg	ton (long)	9.842×10^{-4}
kg	ton (short)	1.102×10^{-3}
Volume		
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}
Temperature		
°C	°F	°C×1.8+32
Force		
N	dyne	1.0×10^{5}
Energy, Work		
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	$kW \cdot h$	2.778×10^{-7}
J	kp⋅m	1.020×10^{-1}
Pressure		
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)	1012	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	BAM	Bundesanstalt für Materialprüfung
a.c.	alternating current	DATE	(Federal Republic of Germany)
ACGIH	American Conference of	BAT	Biologischer
	Governmental Industrial Hygienists		Arbeitsstoff-Toleranz-Wert
ACS	American Chemical Society		(biological tolerance value for a
ADI	acceptable daily intake		working material, established by
ADN	accord européen relatif au transport		MAK Commission, see MAK)
	international des marchandises	Beilstein	Beilstein's Handbook of Organic
	dangereuses par voie de navigation		Chemistry, Springer, Berlin –
	interieure (European agreement	-	Heidelberg – New York
	concerning the international	BET	Brunauer – Emmett – Teller
	transportation of dangerous goods by	BGA	Bundesgesundheitsamt (Federal
	inland waterways)		Republic of Germany)
ADNR	ADN par le Rhin (regulation	BGBl.	Bundesgesetzblatt (Federal Republic
	concerning the transportation of		of Germany)
	dangerous goods on the Rhine and	BIOS	British Intelligence Objectives
	all national waterways of the		Subcommitee Report (see also FIAT)
v. 1	countries concerned)	BOD	biological oxygen demand
ADP	adenosine 5'-diphosphate	bp	boiling point
ADR	accord européen relatif au transport	B.P.	British Pharmacopeia
	international des marchandises	BS	British Standard
	dangereuses par route (European	ca.	circa
	agreement concerning the	calcd.	calculated
	international transportation of	CAS	Chemical Abstracts Service
	dangerous goods by road)	cat.	catalyst, catalyzed
AEC	Atomic Energy Commission (United	CEN	Comité Européen de Normalisation
	States)	cf.	compare
a.i.	Active ingredient	CFR	Code of Federal Regulations (United
AIChE	American Institute of Chemical	•	States)
	Engineers	cfu	colony forming units
AIME	American Institute of Mining,	Chap.	chapter
	Metallurgical, and Petroleum	ChemG	Chemikaliengesetz (Federal
	Engineers		Republic of Germany)
ANSI	American National Standards	C.I.	Colour Index
	Institute	CIOS	Combined Intelligence Objectives
AMP	adenosine 5'-monophosphate	CNIC	Subcommittee Report (see also FIAT)
APhA	American Pharmaceutical	CNS	central nervous system
	Association	Co.	Company
API	American Petroleum Institute	COD	chemical oxygen demand
ASTM	American Society for Testing and	conc.	concentrated
ATTI	Materials	const.	constant
ATP	adenosine 5'-triphosphate	Corp.	Corporation
	•	crit.	critical

p., pp.	page, pages		regulation in Federal Republic of
Patty	G. D. Clayton, F. E. Clayton (eds.):		Germany)
	Patty's Industrial Hygiene and	TA Lärm	Technische Anleitung zum Schutz
	Toxicology, 3rd ed., Wiley		gegen Lärm (low noise regulation in
	Interscience, New York		Federal Republic of Germany)
PB	Publication Board Report (U.S.	TDLo	lowest published toxic dose
report	Department of Commerce, Scientific	THF	tetrahydrofuran
-	and Industrial Reports)	TLC	thin layer chromatography
PEL	permitted exposure limit	TLV	Threshold Limit Value (TWA and
Ph	phenyl substituent (-C ₆ H ₅)		STEL); published annually by the
Ph. Eur.	European Pharmacopoeia, 2nd. ed.,		American Conference of
	Council of Europe, Strasbourg 1981		Governmental Industrial Hygienists
phr	part per hundred rubber (resin)		(ACGIH), Cincinnati, Ohio
PNS	peripheral nervous system	TOD	total oxygen demand
ppm	parts per million	TRK	Technische Richtkonzentration
q. v.	which see (quod vide)		(lowest technically feasible level)
ref.	refer, reference	TSCA	Toxic Substances Control Act
resp.	respectively		(United States)
R_f	retention factor (TLC)	TÜV	Technischer Überwachungsverein
R. H.	relative humidity		(Technical Control Board of the
RID	règlement international concernant		Federal Republic of Germany)
	le transport des marchandises	TWA	Time Weighted Average
	dangereuses par chemin de fer	UBA	Umweltbundesamt (Federal
	(international convention concerning		Environmental Agency)
	the transportation of dangerous	Ullmann	Ullmann's Encyclopedia of
	goods by rail)		Industrial Chemistry, 5th ed., VCH
RNA	ribonucleic acid		Verlagsgesellschaft, Weinheim,
	risk phrase according to		1985 – 1996; Ullmanns
(R-Satz)			Encyklopädie der Technischen
(11 5111)	Republic of Germany)		Chemie, 4th ed., Verlag Chemie,
rpm	revolutions per minute		Weinheim 1972 – 1984; 3rd ed.,
RTECS	Registry of Toxic Effects of		Urban und Schwarzenberg,
***	Chemical Substances, edited by the		München 1951 – 1970
	National Institute of Occupational	USAEC	United States Atomic Energy
	Safety and Health (United States)		Commission
(s)	solid	USAN	United States Adopted Names
SAE	Society of Automotive Engineers	USD	United States Dispensatory
0	(United States)	USDA	United States Department of
s.c.	subcutaneous		Agriculture
SI	International System of Units	U.S.P.	United States Pharmacopeia
SIMS	secondary ion mass spectrometry	UV	ultraviolet
S phrase		UVV	Unfallverhütungsvorschriften der
(S-Satz)	The second result of the second results are the second results and the second results are t		Berufsgenossenschaft (workplace
(Republic of Germany)		safety regulations in the Federal
STEL	Short Term Exposure Limit (see		Republic of Germany)
	TLV)	VbF	Verordnung in der Bundesrepublik
STP	standard temperature and pressure		Deutschland über die Errichtung und
	(0° C, 101.325 kPa)		den Betrieb von Anlagen zur
$T_{\rm g}$	glass transition temperature		Lagerung, Abfüllung und
TÅ Luft	Technische Anleitung zur		Beförderung brennbarer
	Reinhaltung der Luft (clean air		Flüssigkeiten (regulation in the
			Federal Republic of Germany

VDE

VDI

vol

vol.

concerning the construction and	VS.	versus
operation of plants for storage,	WGK	Wassergefährdungsklasse (water
operation of plants for storage,	OIL	hazard class)
filling, and transportation of	MILO	World Health Organization (United
flammable liquids; classification	WHO	
according to the flash point of		Nations)
liquids, in accordance with the	Winnack	er-Küchler Chemische Technologie,
classification in the United States)		4th ed., Carl Hanser Verlag,
Verband Deutscher		München, 1982-1986;
Elektroingenieure (Federal Republic		Winnacker-Küchler, Chemische
of Germany)		Technik: Prozesse und Produkte,
		Wiley-VCH, Weinheim, from 2003
Verein Deutscher Ingenieure		
(Federal Republic of Germany)	wt	weight
volume	\$	U.S. dollar, unless otherwise stated

Frequently Cited Companies (Abbreviations)

Machines Corporation

volume (of a series of books)

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

Country Codes

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

AT	Austria	ID	Indonesia
AU	Australia	IL	Israel
BE	Belgium	IT	Italy
BG	Bulgaria	JР	Japan *
BR	Brazil	LU	Luxembourg
CA	Canada	MA	Morocco
CH	Switzerland	NL	Netherlands *
CS	Czechoslovakia	NO	Norway
DD	German Democratic Republic	NZ	New Zealand
DE	Federal Republic of Germany	PL	Poland
	(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

^{*} 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)

,	
 "European" group designation and old IUPAC recommendation group designation to 1986 IUPAC proposal 	

	group designation to 1986 IUPAC proposal	signation	to 1986 IL	JPAC pro	posal									8			18
≰	"American" group designation, also used by the Chemical Abstracts Service until the end of 1986	" group d	esignation	n, also us	ed by the	Chemical	Abstract	s Service	until the	end of 19	98						VIIIA
	ZA			-								38	48	28	89	78	
四	7											13	14	15	16	11	1
6200	IIA		•									HIA	Ν	W	VIA	VIA	4.010/46
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×	ខ	Sc	F	>	ប៉	ž	Fe	ပိ	ž	Cu	Zu	Ge	69	As	88	Br	10.
9.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.409	69.723	16.53	1,572	78.95	191904	1. K. M. J.
37	38	39	40	41	42	43	44	45	46	47	48	49 PM	50g	191	2.9	63	
RB	Sr	>	Zr	NB	Mo	Tc.	Ru	Rh	Pd	Ag	8	LI LI	Si	SB	176		3
6,468	87.62	88.906	91.224	95.906	95.94	906.86	101.07	102.91	106.42	107.87	112.41	114.82	1,18,71	121.78	127,60	126.90	HED.
99	99		72	73	74	75	9/	11	78	79	80	81	82	83	184	86	
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a provisional IUPAC symbol

/u	103
Lu	Lr*
174.97	280.11
76	102
76	No•
173.04	259.10
69	101
Tm	Md*
168.93	258.10
68 Er 187.26	100 Fm*
67	99
Ho	Es*
164.93	252.08
66	98
Dy	Cf*
162.50	251.08
65	97
Tb	Bk*
158.93	247.07
64	96
Gd	Cm*
157.25	247.07
63	95
Eu	Am*
151.97	243.06
62	94
Sm	Pu*
150.36	244.06
61	93
Pm•	Np*
146.92	237.05
60	92
Nd	U•
144.24	238.03
59	91
Pr	Pa*
140.91	231.04
58	90
Ce	Th*
140.12	232.04
57	89
La	Ac*
138.91	227.03

* radioactive element; mass of most important isotope given.

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1. Magnetic Recording

1.1. Introduction

Magnetic recording technology is widespread in its adoption and its impact on our lives. Be it in portable audio recorders, hi-fi audio systems, video recorders, or in floppy or rigid disk systems in computers, the products of the technology are widely used and appreciated today. Novel data storage systems are being prepared and queuing up for possible launch into the market place. All these are propelled by mighty industrial concerns in various parts of the world primarily in America and Japan, but also in Europe.

The majority of audio and video recording has traditionally taken place using analogue techniques although in recent times products operating in the digital domain have been introduced. The future will see an accelerated shift to digital techniques and this means that there is a continued convergence of most recording technologies into the data storage arena where all information from whatever source can be recorded and manipulated using digital methods.

1.1.1. History

Magnetic recording [1] was first demonstrated by the Danish inventor VALDEMAR POULSEN in 1898. He developed a machine for recording voice messages onto steel wire and was able to demonstrate recording and replay in a recognizable form. This achievement quickly received acclaim. Despite the low signal levels and high levels of distortion in the recordings, developments of this equipment were made and a telephone message recording machine called

a Telegraphone was eventually put on the market. However the Telegraphone was not widely adopted, partly through its lack of clarity, and the full exploitation of the technology had to await the later developments of electronic technology and the means to reduce distortions.

A major step forward came in 1935 with the development in Germany by BASF and AEG of a machine called the Magnetophone. This machine, and its later variants, brought into play two new developments which remain today as the core of many magnetic recording systems. The first was the introduction of magnetic particles as the recording medium and the second was the use of a.c. bias to linearize the characteristics of the recording medium. With these developments record and replay with high clarity was achieved and it led eventually, with further progress, to the widespread adoption of a.c. biased recording systems. The most popular current manifestation of the technology is in the compact cassette audio system introduced by Philips in 1963.

Digital recording emerged during the late 1940s and 1950s in response to the need for back-up storage for computer devices. By these times magnetic tape recording for audio was in widespread use and the technology was adapted for the recording of digital waveforms without the use of a.c. bias. In the early machines bit packing densities were very low but this increased rapidly with successive generations of equipment. Record and replay took place at data rates which were slow compared with the processing rates of computers and access times to information became a critical issue. This led to the development of faster access mechanical systems such as the magnetic drum and later the very successful magnetic disk. The latter is now the mainstay of storage for computers and disk

systems exist in a variety of forms and formats employing rigid and flexible disk media.

Video recording first took place in "fixed head" systems similar to those used in audio and data recording. However, the wide bandwidths required by video signals meant that very high tape speeds had to be used and this required very long tapes for program length recordings. To alleviate this problem scanning head technology was developed in which tracks were recorded very close together in directions across the tape length to give very high area packing densities of information. First came the transverse scan technology introduced by Ampex in 1956 and later the helical scan technologies were introduced for domestic use and are now most widely manifested in VHS recorders [2]. Helical scan technology has now been adapted for use in data storage systems especially for computer back-up applications.

Recording technology continues to move forward and new developments invariably break fresh ground in terms of the amount of data stored per unit area of recording surface. Here comes the pressure for new and advanced recording media.

1.1.2. Magnetism and Magnetic Materials: Definitions (→ Magnetic Materials)

For a more detailed description of the terms used in the specification of magnetic materials, particularly those used in recording media and in magnetic heads, see, e.g., [3].

The magnetic properties of materials are often characterized by the *magnetic induction* or *flux density* within them. This quantity is represented by the symbol *B* and measured in units of tesla (T). In free space *B* is given by

$$B = \mu H 0 \tag{1}$$

where $\mu_0 = 4\pi \cdot 10^{-7}$ H/m is the permeability of free space and H is the magnetic field strength measured in A/m. The magnetic field is usually generated by a coil carrying a current and the magnitude of the field depends on that current and the geometry of the coil hence leading to a field strength which is expressed in A/m.

When the induction is measured inside a magnetic material it may be represented by

$$B = \mu \left(H + M \right) 0 \tag{2}$$

where H is the applied field strength and M is an additional contribution, measured in A/m, arising from the magnetic material and which is usually referred to as its magnetization. Sometimes Equation (2) is written in a modified form

$$B = \mu H + J0 \tag{3}$$

where J (sometimes the symbol I is used) is also referred to as the magnetization but it is now in units of Tesla. Both representations of magnetization appear in the literature but in this article both M and H will be quoted in the same units of A/m. This is the approach adopted in most publications although there is still a widespread use in many parts of industry and academia of cgs and some imperial units.

In ferromagnetic and ferrimagnetic materials the relationship between the magnetization produced in a material and the applied magnetic field is usually nonlinear. A typical relationship is shown in Figure 1. Starting with a demagnetized sample, that is one with zero net magnetization, the application of a magnetic field increasing from zero takes the magnetization along the curve a. First of all the magnetization rises very slowly, but as the field increases the rate of rise increases. Eventually the magnetization approaches a value known as the saturation magnetization M_s . This curve is known as the initial magnetization curve. On removal of the field the magnetization drops back to the value $M_{\rm r}$, known as the remanent magnetization. On increasing the field in a negative direction the magnetization eventually starts to reduce and is brought to zero at a field labeled $-H_c$ which is the negative value of the coercivity. Further increase of this field in the negative direction eventually takes the magnetization through to its negative saturation value of $-M_s$. Bringing the field back to zero and then increasing it again in a positive direction traces out a curve with the positive going arrows, which is a mirror image of that produced by negative going fields, and brings the material back to the positively saturated state. The curve just traversed is known as the major hysteresis loop and the quantities coercivity H_c , remanent magnetization M_r , saturation magnetization M_s , and hysteresis and loop