

# ULLMANN'S

## Renewable Resources



# Ullmann's Renewable Resources



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# Ullmann's Renewable Resources

# ULLMANN'S

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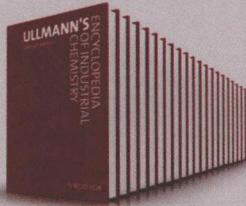
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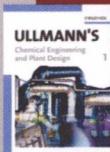


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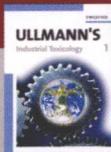


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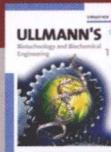
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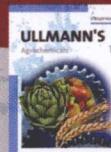
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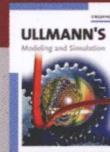
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## Preface

This handbook features selected articles from the 7<sup>th</sup> edition of *ULLMANN'S Encyclopedia of Industrial Chemistry*, including newly written articles that have not been published in a printed edition before. True to the tradition of the ULLMANN'S Encyclopedia, products and processes are addressed from an industrial perspective, including production figures, quality standards and patent protection issues where appropriate. Safety and environmental aspects which are a key concern for modern process industries are likewise considered.

More content on related topics can be found in the complete edition of the ULLMANN'S Encyclopedia.

## About ULLMANN'S

ULLMANN'S Encyclopedia is the world's largest reference in applied chemistry, industrial chemistry, and chemical engineering. In its current edition, the Encyclopedia contains more than 30,000 pages, 15,000 tables, 25,000 figures, and innumerable literature sources and cross-references, offering a wealth of comprehensive and well-structured information on all facets of industrial chemistry.

1,100 major articles cover the following main areas:

- Agrochemicals
- Analytical Techniques
- Biochemistry and Biotechnology
- Chemical Reactions
- Dyes and Pigments
- Energy
- Environmental Protection and Industrial Safety
- Fat, Oil, Food and Feed, Cosmetics
- Inorganic Chemicals
- Materials
- Metals and Alloys
- Organic Chemicals
- Pharmaceuticals
- Polymers and Plastics
- Processes and Process Engineering
- Renewable Resources
- Special Topics

First published in 1914 by Professor Fritz Ullmann in Berlin, the *Enzyklopädie der Technischen Chemie* (as the German title read) quickly became the standard reference work in industrial chemistry. Generations of chemists have since relied on ULLMANN'S as their prime reference source. Three further German editions followed in 1928–1932, 1951–1970, and in 1972–1984. From 1985 to 1996, the 5<sup>th</sup> edition of ULLMANN'S Encyclopedia of Industrial Chemistry was the first edition to be published in English rather than German language. So far, two more complete English editions have been published; the 6<sup>th</sup> edition of 40 volumes in 2002, and the 7<sup>th</sup> edition in 2011, again comprising 40 volumes. In addition, a number of smaller topic-oriented editions have been published.

Since 1997, *ULLMANN'S Encyclopedia of Industrial Chemistry* has also been available in electronic format, first in a CD-ROM edition and, since 2000, in an enhanced online edition. Both electronic editions feature powerful search and navigation functions as well as regular content updates.

## Symbols and Units

Symbols and units agree with SI standards (for conversion factors see page XI). 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)
$A$	$\text{m}^2$	area
$c_B$	$\text{mol}/\text{m}^3$ , $\text{mol}/\text{L}$ (M)	concentration of substance B
$C$	$\text{C}/\text{V}$	electric capacity
$c_p, c_v$	$\text{J kg}^{-1} \text{K}^{-1}$	specific heat capacity
$d$	$\text{cm}, \text{m}$	diameter
$d$		relative density ( $\rho/\rho_{\text{water}}$ )
$D$	$\text{m}^2/\text{s}$	diffusion coefficient
$D$	$\text{Gy} (= \text{J/kg})$	absorbed dose
$e$	C	elementary charge
$E$	J	energy
$E$	$\text{V}/\text{m}$	electric field strength
$E$	V	electromotive force
$E_A$	J	activation energy
$f$		activity coefficient
$F$	$\text{C/mol}$	Faraday constant
$F$	N	force
$g$	$\text{m/s}^2$	acceleration due to gravity
$G$	J	Gibbs free energy
$h$	m	height
$h$	$\text{W}\cdot\text{s}^2$	Planck constant
$H$	J	enthalpy
$I$	A	electric current
$I$	cd	luminous intensity
$k$	(variable)	rate constant of a chemical reaction
$k$	$\text{J/K}$	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
$N_A$	$\text{mol}^{-1}$	Avogadro constant ( $6.023 \times 10^{23} \text{ mol}^{-1}$ )
$P$	Pa, bar*	pressure
$Q$	J	quantity of heat
$r$	m	radius
$R$	$\text{JK}^{-1} \text{mol}^{-1}$	gas constant
$R$	$\Omega$	electric resistance
$S$	$\text{J/K}$	entropy
$t$	s, min, h, d, month, a	time
$t$	°C	temperature
$T$	K	absolute temperature
$u$	$\text{m/s}$	velocity
$U$	V	electric potential

## X Symbols and Units

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Symbols and Units (Continued from p. IX)

Symbol	Unit	Physical Quantity
$U$	J	internal energy
$V$	$\text{m}^3$ , L, mL, $\mu\text{L}$	volume
$w$		mass fraction
$W$	J	work
$x_B$		mole fraction of substance B
$Z$		proton number, atomic number
$\alpha$		cubic expansion coefficient
$\alpha$	$\text{W m}^{-2}\text{K}^{-1}$	heat-transfer coefficient (heat-transfer number)
$\alpha$		degree of dissociation of electrolyte
$[\alpha]$	$10^{-2}\text{deg cm}^2\text{g}^{-1}$	specific rotation
$\eta$	$\text{Pa}\cdot\text{s}$	dynamic viscosity
$\theta$	$^\circ\text{C}$	temperature
$\kappa$		$c_p/c_v$
$\lambda$	$\text{W m}^{-1}\text{K}^{-1}$	thermal conductivity
$\lambda$	nm, m	wavelength
$\mu$		chemical potential
$v$	$\text{Hz}, \text{s}^{-1}$	frequency
$\nu$	$\text{m}^2/\text{s}$	kinematic viscosity ( $\eta/\rho$ )
$\pi$	Pa	osmotic pressure
$\varrho$	$\text{g/cm}^3$	density
$\sigma$	N/m	surface tension
$\tau$	$\text{Pa (N/m}^2\text{)}$	shear stress
$\varphi$		volume fraction
$\chi$	$\text{Pa}^{-1} (\text{m}^2/\text{N})$	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)	$9.842 \times 10^{-4}$
kg	ton (short)	$1.102 \times 10^{-3}$
<i>Volume</i>		
$\text{m}^3$	cubic inch	$6.102 \times 10^4$
$\text{m}^3$	cubic foot	35.315
$\text{m}^3$	gallon (U.S., liquid)	$2.642 \times 10^2$
$\text{m}^3$	gallon (Imperial)	$2.200 \times 10^2$
<i>Temperature</i>		
$^\circ\text{C}$	$^\circ\text{F}$	$^\circ\text{C} \times 1.8 + 32$
<i>Force</i>		
N	dyne	$1.0 \times 10^5$
<i>Energy, Work</i>		
J	Btu (int.)	$9.480 \times 10^{-4}$
J	cal (int.)	$2.389 \times 10^{-1}$
J	eV	$6.242 \times 10^{18}$
J	erg	$1.0 \times 10^7$
J	kW·h	$2.778 \times 10^{-7}$
J	kp·m	$1.020 \times 10^{-1}$
<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)	$10^9$	$\mu$ (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 IX, Symbols and Units; page XVI, Frequently Cited Companies (Abbreviations), and page XVII, 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 interieure (European agreement concerning the international transportation of dangerous goods by inland waterways)	B.P.	British Pharmacopeia
ADNR	ADN par le Rhin (regulation concerning the transportation of dangerous goods on the Rhine and all national waterways of the countries concerned)	BS	British Standard
ADP	adenosine 5'-diphosphate	ca.	circa
ADR	accord européen relatif au transport international des marchandises dangereuses par route (European agreement concerning the international transportation of dangerous goods by road)	calcd.	calculated
AEC	Atomic Energy Commission (United States)	CAS	Chemical Abstracts Service
a.i.	active ingredient	cat.	catalyst, catalyzed
AICheE	American Institute of Chemical Engineers	CEN	Comité Européen de Normalisation
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers	cf.	compare
ANSI	American National Standards Institute	CFR	Code of Federal Regulations (United States)
AMP	adenosine 5'-monophosphate	cfu	colony forming units
APhA	American Pharmaceutical Association	Chap.	chapter
API	American Petroleum Institute	ChemG	Chemikaliengesetz (Federal Republic of Germany)
ASTM	American Society for Testing and Materials	C.I.	Colour Index
ATP	adenosine 5'-triphosphate	CIOS	Combined Intelligence Objectives Subcommittee Report (see also FIAT)
BAM	Bundesanstalt für Materialprüfung (Federal Republic of Germany)	CNS	central nervous system
BAT	Biologischer Arbeitsstofftoleranzwert (biological tolerance value for a working material, established by MAK Commission, see MAK)	Co.	Company
Beilstein	Beilstein's Handbook of Organic Chemistry, Springer, Berlin – Heidelberg – New York	COD	chemical oxygen demand
BET	Brunauer – Emmett – Teller	conc.	concentrated
		const.	constant
		Corp.	Corporation
		crit.	critical
		CTFA	The Cosmetic, Toiletry and Fragrance Association (United States)
		DAB	Deutsches Arzneibuch, Deutscher Apotheker-Verlag, Stuttgart
		d.c.	direct current
		decomp.	decompose, decomposition
		DFG	Deutsche Forschungsgemeinschaft (German Science Foundation)
		dil.	dilute, diluted
		DIN	Deutsche Industriennorm (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	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	effective concentration		gas-liquid chromatography
EC	European Community	GLC	Gmelin's Handbook of Inorganic Chemistry, 8th ed., Springer, Berlin – Heidelberg – New York
ed.	editor, edition, edited	Gmelin	generally recognized as safe
e.g.	for example		halogen substituent ( $-F$ , $-Cl$ , $-Br$ , $-I$ )
emf	electromotive force	GRAS	Methoden der organischen Chemie, 4th ed., Georg Thieme Verlag, Stuttgart
EmS	Emergency Schedule	Hal	high performance liquid chromatography
EN	European Standard (European Community)	Houben-Weyl	International Atomic Energy Agency
EPA	Environmental Protection Agency (United States)	HPLC	International Agency for Research on Cancer, Lyon, France
EPR	electron paramagnetic resonance	IAEA	International Air Transport Association, Dangerous Goods Regulations
Eq.	equation	IARC	International Civil Aviation Organization
ESCA	electron spectroscopy for chemical analysis	IATA-DGR	International Maritime Dangerous Goods Code
esp.	especially	ICAO	Inter-Governmental Maritime Consultative Organization (in the past: IMCO)
ESR	electron spin resonance	i.e.	Institute
Et	ethyl substituent ( $-C_2H_5$ )	i.m.	intraperitoneal
et al.	and others	IMDG	International Organization for Standardization
etc.	et cetera	IMO	International Union of Pure and Applied Chemistry
EVO	Eisenbahnverkehrsordnung (Federal Republic of Germany)	Inst.	intravenous
exp (...)	$e^{(\dots)}$ , mathematical exponent	i.p.	Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., 1991–1998, 5th ed., 2004–2007, John Wiley & Sons, Hoboken
FAO	Food and Agriculture Organization (United Nations)	IR	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
FDA	Food and Drug Administration (United States)	ISO	LC <sub>50</sub> lethal concentration for 50 % of the test animals
FD&C	Food, Drug and Cosmetic Act (United States)	IUPAC	LCL <sub>0</sub> lowest published lethal concentration
FHSA	Federal Hazardous Substances Act (United States)	i.v.	
FIAT	Field Information Agency, Technical (United States reports on the chemical industry in Germany, 1945)	Kirk-	
Fig.	figure	Othmer	
fp	freezing point	(1)	
Friedländer	P. Friedländer, Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige Vol. 1–25, Springer, Berlin 1888–1942	Landolt-	
FT	Fourier transform	Börnstein	
(g)	gas, gaseous		
GC	gas chromatography		
GefStoffV	Gefahrstoffverordnung (regulations in the Federal Republic of Germany concerning hazardous substances)		
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)		
GGVS	Verordnung in der Bundesrepublik Deutschland über die Beförderung		

LD <sub>50</sub>	lethal dose for 50 % of the test animals	OSHA	Occupational Safety and Health Administration (United States)
LDLo	lowest published lethal dose		
ln	logarithm (base e)	p., pp.	page, pages
LNG	liquefied natural gas	Patty	G.D. Clayton, F.E. Clayton (eds.): Patty's Industrial Hygiene and Toxicology, 3rd ed., Wiley Interscience, New York
log	logarithm (base 10)		
LPG	liquefied petroleum gas	PB	Publication Board Report (U.S. Department of Commerce, Scientific and Industrial Reports)
M	mol/L	report	
M	metal (in chemical formulas)	PEL	permitted exposure limit
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)	Ph	phenyl substituent ( $-C_6H_5$ )
max.	maximum	Ph. Eur.	European Pharmacopoeia, Council of Europe, Strasbourg
MCA	Manufacturing Chemists Association (United States)	phr	part per hundred rubber (resin)
Me	methyl substituent ( $-CH_3$ )	PNS	peripheral nervous system
Methodicum	Methodicum Chemicum, Georg Thieme Chemicum Verlag, Stuttgart	ppm	parts per million
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods	q.v.	which see (quod vide)
MIK	maximale Immissionskonzentration (maximum immission concentration)	ref.	refer, reference
min.	minimum	resp.	respectively
mp	melting point	R <sub>f</sub>	retention factor (TLC)
MS	mass spectrum, mass spectrometry	R.H.	relative humidity
NAS	National Academy of Sciences (United States)	RID	réglement international concernant le transport des marchandises dangereuses par chemin de fer (international convention concerning the transportation of dangerous goods by rail)
NASA	National Aeronautics and Space Administration (United States)	RNA	ribonucleic acid
NBS	National Bureau of Standards (United States)	R phrase (R-Satz)	risk phrase according to ChemG and GefStoffV (Federal Republic of Germany)
NCTC	National Collection of Type Cultures (United States)	rpm	revolutions per minute
NIH	National Institutes of Health (United States)	RTECS	Registry of Toxic Effects of Chemical Substances, edited by the National Institute of Occupational Safety and Health (United States)
NIOSH	National Institute for Occupational Safety and Health (United States)	(s)	solid
NMR	nuclear magnetic resonance	SAE	Society of Automotive Engineers (United States)
no.	number	s.c.	subcutaneous
NOEL	no observed effect level	SI	International System of Units
NRC	Nuclear Regulatory Commission (United States)	SIMS	secondary ion mass spectrometry
NRDC	National Research Development Corporation (United States)	S phrase (S-Satz)	safety phrase according to ChemG and GefStoffV (Federal Republic of Germany)
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 <sub>g</sub>	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		Verband Deutscher Elektroingenieure (Federal Republic of Germany)
TOD	total oxygen demand		Verein Deutscher Ingenieure (Federal Republic of Germany)
TRK	Technische Richtkonzentration (lowest technically feasible level)		volume
TSCA	Toxic Substances Control Act (United States)	VDE	volume (of a series of books)
TÜV	Technischer Überwachungsverein (Technical Control Board of the Federal Republic of Germany)	VDI	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	Mitsubishi Chemical Industries
Amer.	American Cyanamid	Monsanto	Monsanto Company
Cyanamid	Company	Nippon Shokubai	Nippon Shokubai Kagaku Kogyo Shokubai
BASF	BASF Aktiengesellschaft	PCUK	Pechiney Ugine Kuhlmann
Bayer	Bayer AG	PPG	Pittsburg Plate Glass Industries
BP	British Petroleum Company	Searle	G.D. Searle & Company
Celanese	Celanese Corporation	SKF	Smith Kline & French Laboratories
Daicel	Daicel Chemical Industries	SNAM	Societá Nazionale Metandotti
Dainippon	Dainippon Ink and Chemicals Inc.	Sohio	Standard Oil of Ohio
Dow Chemical	The Dow Chemical Company	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.

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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		

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\*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)

A "European" group designation and old IUPAC recommendation

1 *Group classification to 10086 III IDAC*

group designation to 1986 IUPAC proposal

1 group designation to 1986 IUPAC proposal

<sup>a</sup> 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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