

Ullmann's Encyclopedia of Industrial Chemistry

Sixth, Completely Revised Edition

Volume 33 Size Enlargement
to
Starch

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Volume 33

Ullmann's Encyclopedia of Industrial Chemistry

Volumes 1 - 39: Alphabetically Arranged Articles
Volume 40: Index

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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	$J\text{ kg}^{-1}\text{ K}^{-1}$	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
$\hbar$	$\text{W} \cdot s^2$	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	$J\text{ K}^{-1}\text{ mol}^{-1}$	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	$^{\circ}\text{C}$	temperature
T	K	absolute temperature
u	m/s	velocity
U	V	electric potential
U	J	internal energy
V	$\text{m}^3, \text{L}, \text{mL}, \mu\text{L}$	volume
w		mass fraction
W	J	work
x_{B}		mole fraction of substance B
Z		proton number, atomic number
α		cubic expansion coefficient
α	$\text{W m}^{-2}\text{K}^{-1}$	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	$\text{W m}^{-1}\text{K}^{-1}$	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	$\text{Pa (N/m}^2\text{)}$	shear stress
φ		volume fraction
χ	$\text{Pa}^{-1} (\text{m}^2/\text{N})$	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)	9.842×10^{-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	BAM	Bundesanstalt für Materialprüfung (Federal Republic of Germany)
a.c.	alternating current	BAT	Biologischer Arbeitsstoff-Toleranz-Wert (biological tolerance value for a working material, established by MAK Commission, see MAK)
ACGIH	American Conference of Governmental Industrial Hygienists	Beilstein	Beilstein's Handbook of Organic Chemistry, Springer, Berlin – Heidelberg – New York
ACS	American Chemical Society	BET	Brunauer – Emmett – Teller
ADI	acceptable daily intake	BGA	Bundesgesundheitsamt (Federal Republic of Germany)
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)	BGBL	Bundesgesetzblatt (Federal Republic of Germany)
ADNR	ADN par le Rhin (regulation concerning the transportation of dangerous goods on the Rhine and all national waterways of the countries concerned)	BIOS	British Intelligence Objectives Subcommittee Report (see also FIAT)
ADP	adenosine 5'-diphosphate	BOD	biological oxygen demand
ADR	accord européen relatif au transport international des marchandises dangereuses par route (European agreement concerning the international transportation of dangerous goods by road)	<i>bp</i>	boiling point
AEC	Atomic Energy Commission (United States)	B.P.	British Pharmacopeia
a.i.	Active ingredient	BS	British Standard
AICHe	American Institute of Chemical Engineers	ca.	circa
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers	calcd.	calculated
ANSI	American National Standards Institute	CAS	Chemical Abstracts Service
AMP	adenosine 5'-monophosphate	cat.	catalyst, catalyzed
APhA	American Pharmaceutical Association	CEN	Comité Européen de Normalisation
API	American Petroleum Institute	cf.	compare
ASTM	American Society for Testing and Materials	CFR	Code of Federal Regulations (United States)
ATP	adenosine 5'-triphosphate	cfu	colony forming units
		Chap.	chapter
		ChemG	Chemikaliengesetz (Federal Republic of Germany)
		C.I.	Colour Index
		CIOS	Combined Intelligence Objectives Subcommittee Report (see also FIAT)
		CNS	central nervous system
		Co.	Company
		COD	chemical oxygen demand
		conc.	concentrated
		const.	constant
		Corp.	Corporation
		crit.	critical

CTFA	The Cosmetic, Toiletry and Fragrance Association (United States)	FIAT	Field Information Agency, Technical (United States reports on the chemical industry in Germany, 1945)
DAB 9	Deutsches Arzneibuch, 9th ed., Deutscher Apotheker-Verlag, Stuttgart 1986	Fig.	figure
d.c.	direct current	<i>fp</i>	freezing point
decomp.	decompose, decomposition	Friedländer	P. Friedländer, Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige, Vol. 1 – 25, Springer, Berlin 1888 – 1942
DFG	Deutsche Forschungsgemeinschaft (German Science Foundation)	FT	Fourier transform
dil.	dilute, diluted	(g)	gas, gaseous
DIN	Deutsche Industrie Norm (Federal Republic of Germany)	GC	gas chromatography
DMF	dimethylformamide	GefStoffV	Gefährstoffverordnung (regulations in the Federal Republic of Germany concerning hazardous substances)
DNA	deoxyribonucleic acid	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)
DOE	Department of Energy (United States)	GGVS	Verordnung in der Bundesrepublik Deutschland über die Beförderung gefährlicher Güter auf der Straße (regulation in the Federal Republic of Germany concerning the transportation of dangerous goods by road)
DOT	Department of Transportation – Materials Transportation Bureau (United States)	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)
DTA	differential thermal analysis	GLC	gas-liquid chromatography
EC	effective concentration	Gmelin	Gmelin's Handbook of Inorganic Chemistry, 8th ed., Springer, Berlin – Heidelberg – New York
EC	European Community	GRAS	generally recognized as safe
ed.	editor, edition, edited	Hal	halogen substituent (–F, –Cl, –Br, –I)
e.g.	for example	Houben-Weyl	Methoden der organischen Chemie, 4th ed., Georg Thieme Verlag, Stuttgart
emf	electromotive force	HPLC	high performance liquid chromatography
EmS	Emergency Schedule	IAEA	International Atomic Energy Agency
EN	European Standard (European Community)	IARC	International Agency for Research on Cancer, Lyon, France
EPA	Environmental Protection Agency (United States)		
EPR	electron paramagnetic resonance		
Eq.	equation		
ESCA	electron spectroscopy for chemical analysis		
esp.	especially		
ESR	electron spin resonance		
Et	ethyl substituent (–C ₂ H ₅)		
et al.	and others		
etc.	et cetera		
EVO	Eisenbahnverkehrsordnung (Federal Republic of Germany)		
exp (...) e(...)	mathematical exponent		
FAO	Food and Agriculture Organization (United Nations)		
FDA	Food and Drug Administration (United States)		
FD & C	Food, Drug and Cosmetic Act (United States)		
FHSA	Federal Hazardous Substances Act (United States)		

IATA-DGR	International Air Transport Association, Dangerous Goods Regulations		
ICAO	International Civil Aviation Organization		
i.e.	that is		
i.m.	intramuscular		
IMDG	International Maritime Dangerous Goods Code		
IMO	Inter-Governmental Maritime Consultative Organization (in the past: IMCO)		
Inst.	Institute		
i.p.	intraperitoneal		
IR	infrared		
ISO	International Organization for Standardization		
IUPAC	International Union of Pure and Applied Chemistry		
i.v.	intravenous		
Kirk-Othmer	Encyclopedia of Chemical Technology, 3rd ed., J. Wiley & Sons, New York – Chichester – Brisbane – Toronto 1978 – 1984; 4th ed., J. Wiley & Sons, New York – Chichester – Brisbane – Toronto 1991 – 1998		
(l)	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		
LDLo	lowest published lethal dose		
ln	logarithm (base e)		
LNG	liquefied natural gas		
log	logarithm (base 10)		
LPG	liquefied petroleum gas		
M	mol/L		
M	metal (in chemical formulas)		
MAK	Maximale Arbeitsplatz-Konzentration (maximum concentration at the workplace in the		
	Federal Republic of Germany); cf.: Deutsche Forschungsgemeinschaft (ed.): Maximale Arbeitsplatz-konzentrationen (MAK) und Biologische Arbeitsstoff-Toleranz-Werte (BAT), WILEY-VCH Verlag, Weinheim (published annually)		
	max.	maximum	
MCA	Manufacturing Chemists Association (United States)		
Me	methyl substituent (–CH ₃)		
Methodicum	Chimicum Methodicum Chimicum, Georg Thieme Verlag, Stuttgart		
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods		
MIK	maximale Immissionskonzentration (maximum immission concentration)		
min.	minimum		
mp	melting point		
MS	mass spectrum, mass spectrometry		
NAS	National Academy of Sciences (United States)		
NASA	National Aeronautics and Space Administration (United States)		
NBS	National Bureau of Standards (United States)		
NCTC	National Collection of Type Cultures (United States)		
NIH	National Institutes of Health (United States)		
NIOSH	National Institute for Occupational Safety and Health (United States)		
NMR	nuclear magnetic resonance		
no.	number		
NOEL	no observed effect level		
NRC	Nuclear Regulatory Commission (United States)		
NRDC	National Research Development Corporation (United States)		
NSC	National Service Center (United States)		
NSF	National Science Foundation (United States)		
NTSB	National Transportation Safety Board (United States)		
OECD	Organization for Economic Cooperation and Development		
OSHA	Occupational Safety and Health Administration (United States)		

p., pp.	page, pages		regulation in Federal Republic of Germany)
Patty	G. D. Clayton, F. E. Clayton (eds.): Patty's Industrial Hygiene and Toxicology, 3rd ed., Wiley Interscience, New York	TA Lärm	Technische Anleitung zum Schutz gegen Lärm (low noise regulation in Federal Republic of Germany)
PB	Publication Board Report (U.S. Department of Commerce, Scientific and Industrial Reports)	TDLo	lowest published toxic dose
report		THF	tetrahydrofuran
PEL	permitted exposure limit	TLC	thin layer chromatography
Ph	phenyl substituent ($-\text{C}_6\text{H}_5$)	TLV	Threshold Limit Value (TWA and STEL); published annually by the American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, Ohio
Ph. Eur.	European Pharmacopoeia, 2nd. ed., Council of Europe, Strasbourg 1981	TOD	total oxygen demand
phr	part per hundred rubber (resin)	TRK	Technische Richtkonzentration (lowest technically feasible level)
PNS	peripheral nervous system	TSCA	Toxic Substances Control Act (United States)
ppm	parts per million	TÜV	Technischer Überwachungsverein (Technical Control Board of the Federal Republic of Germany)
q. v.	which see (quod vide)	TWA	Time Weighted Average
ref.	refer, reference	UBA	Umweltbundesamt (Federal Environmental Agency)
resp.	respectively	Ullmann	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
R_f	retention factor (TLC)	USAEC	United States Atomic Energy Commission
R. H.	relative humidity	USAN	United States Adopted Names
RID	règlement international concernant le transport des marchandises dangereuses par chemin de fer (international convention concerning the transportation of dangerous goods by rail)	USD	United States Dispensary
RNA	ribonucleic acid	USDA	United States Department of Agriculture
R phrase	risk phrase according to ChemG and GefStoffV (Federal Republic of Germany)	U.S.P.	United States Pharmacopoeia
(R-Satz)		UV	ultraviolet
rpm	revolutions per minute	UVV	Unfallverhütungsvorschriften der Berufsgenossenschaft (workplace safety regulations in the Federal Republic of Germany)
RTECS	Registry of Toxic Effects of Chemical Substances, edited by the National Institute of Occupational Safety and Health (United States)	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)
(s)	solid		
SAE	Society of Automotive Engineers (United States)		
s.c.	subcutaneous		
SI	International System of Units		
SIMS	secondary ion mass spectrometry		
S phrase	safety phrase according to ChemG and GefStoffV (Federal Republic of Germany)		
(S-Satz)			
STEL	Short Term Exposure Limit (see TLV)		
STP	standard temperature and pressure (0°C , 101.325 kPa)		
T_g	glass transition temperature		
TA Luft	Technische Anleitung zur Reinhaltung der Luft (clean air		

	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)	vs.	versus
VDE	Verband Deutscher Elektroingenieure (Federal Republic of Germany)	WGK	Wassergefährdungsklasse (water hazard class)
VDI	Verein Deutscher Ingenieure (Federal Republic of Germany)	WHO	World Health Organization (United Nations)
vol	volume	Winnacker-Küchler	Chemische Technologie, 4th ed., Carl Hanser Verlag, München, 1982-1986; Winnacker-Küchler, Chemische Technik: Prozesse und Produkte, Wiley-VCH, Weinheim, from 2003
vol.	volume (of a series of books)	wt	weight
		\$	U.S. dollar, unless otherwise stated

Frequently Cited Companies (Abbreviations)

Air Products	Air Products and Chemicals	ICI	Imperial Chemical Industries
Akzo	Algemene Koninklijke Zout Organon	IFP	Institut Français du Pétrole
Alcoa	Aluminum Company of America	INCO	International Nickel Company
Allied	Allied Corporation	3M	Minnesota Mining and Manufacturing Company
Amer.	American Cyanamid Company	Mitsubishi	Mitsubishi Chemical Industries
Cyanamid	Cyanamid Company	Monsanto	Monsanto Company
BASF	BASF Aktiengesellschaft	Nippon	Nippon Shokubai Kagaku Kogyo
Bayer	Bayer AG	Shokubai	
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 Inc.	SKF	Smith Kline & French Laboratories
Dow Chemical	The Dow Chemical Company	SNAM	Società Nazionale Metandotti
DSM	Dutch Staats Mijnen	Sohio	Standard Oil of Ohio
Du Pont	E.I. du Pont de Nemours & Company	Stauffer	Stauffer Chemical Company
Exxon	Exxon Corporation	Sumitomo	Sumitomo Chemical Company
FMC	Food Machinery & Chemical Corporation	Toray	Toray Industries Inc.
GAF	General Aniline & Film Corporation	UCB	Union Chimique Belge
W.R. Grace	W.R. Grace & Company	Union Carbide	Union Carbide Corporation
Hoechst	Hoechst Aktiengesellschaft	UOP	Universal Oil Products Company
IBM	International Business Machines Corporation	VEBA	Vereinigte Elektrizitäts- und Bergwerks-AG
		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	JP	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 (and Germany before 1949) *	PL	Poland
DK	Denmark	PT	Portugal
ES	Spain	SE	Sweden
FI	Finland	SU	Soviet Union
FR	France	US	United States of America
GB	United Kingdom	YU	Yugoslavia
GR	Greece	ZA	South Africa
HU	Hungary	EP	European Patent Office *
		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)

1A "European" group designation and old IUPAC recommendation

1 group designation to 1986 IUPAC proposal

IA "American" group designation, also used by the Chemical Abstracts Service until the end of 1986

1	2A	3A	4A	5A	6A	7A	8	8	8	10	11	12	13	14	15	16	17	18
H	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.0079	IIA	IIIA	IVA	VA	VIA	VIIA	VIII	VIII	VIII	IB	IIB	IIIB	IIIB	IIIA	IVA	VIA	VIA	IIA
Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Sc
6.941	9.0122	10.811	12.011	14.007	15.999	18.998	20.180	22.990	24.305	26.982	28.086	30.974	32.066	35.453	39.948	39.098	40.078	44.956
22.990	24.305	26.982	28.086	30.974	32.066	35.453	39.948	39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546
58.933	59.948	63.546	65.409	69.723	72.61	74.922	78.96	79.904	83.80	87.62	91.224	92.906	95.94	98.906	101.07	102.91	106.42	107.87
107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29	132.91	137.33	138.91	140.12	140.91	144.24	146.93	150.36	151.97	157.25	158.93
158.93	162.50	164.93	167.26	168.93	173.04	174.97	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98
208.98	212.02	214.90	218.78	223.02	226.03	227.03	232.04	231.04	238.03	237.05	244.06	243.06	247.07	251.08	252.08	257.10	258.10	259.10
259.10	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11	260.11

^a provisional IUPAC symbol

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244.06	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 251.08	99 Es 252.08	100 Fm 257.10	101 Md 258.10	102 No 259.10	103 Lr 260.11

* radioactive element; mass of most important isotope given.

Contents

Size Enlargement	1	Solid – Liquid Separation, Introduction .	455
Size Reduction	41	Solid – Solid Separation, Introduction ..	463
Skeletal Muscle Relaxants	83	Solids Handling	489
Skin Cosmetics	95	Solids Technology, Introduction	497
Soaps	129	Solvents	509
Sodium Amide	151	Sonochemistry	583
Sodium and Sodium Alloys	163	Sorbic Acid	607
Sodium Carbonates	187	Spasmolytics	617
Sodium Chloride	207	Specialty Plastics	635
Sodium Compounds, Organic	231	Spirits	659
Sodium Hydroxide	235	Sprayforming of Metals	675
Sodium Sulfates	247	Spraying and Atomizing of Liquids	687
Soil	263	Stains, Microscopic	705
Solar Technology	391	Starch	721
Soldering and Brazing	443		

Cross References

Smectites → Clays 8	Solar Cells → Photovoltaic Cells 26
Snail Control → Molluscicides 22	Sorbitol → Sugar Alcohols 34
SNG → Gas Production 15	Sorbose → Vitamins 38
Soda → Sodium Carbonates 33	Soybean Oil → Fats and Fatty Oils 13
Sodium Borohydride → Hydrides 16	Spandex → Fibers, 4. Synthetic Organic 13
Sodium Bromide → Bromine Compounds 5	Spices → Flavors and Fragrances 14 ; → Seasonings 32
Sodium Iodide → Iodine and Iodine Compounds 18	Spirit of Turpentine → Turpentine 37
Sodium Nitrate → Nitrates and Nitrites 22	Spunbonded Fabrics → Nonwoven Fabrics 23
Sodium Permanganate → Manganese Compounds 20	Sputtering → Thin Films 36
Sodium Peroxide → Peroxo Compounds, Inorganic 25	Stains → Wood, Surface Treatment 39 Starch Syrups → Glucose and Glucose-Containing Syrups 15
Sodium Sulfide → Sulfides, Polysulfides, and Sulfanes 34	Stearic Acid → Fatty Acids 13
	Stearyl Alcohol → Fatty Alcohols 13

Size Enlargement

See also Solids Technology, Introduction

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1. Introduction	1	4.1.2. Pan and Drum Agglomeration	17
2. Binding Mechanisms of Agglomerates	3	4.1.3. Mixer and Fluidized Bed Agglomeration	18
2.1. Tensile Strength of Agglomerates		4.1.3.1. Pan and Drum Mixers	18
Derived from Attractive Forces	3	4.1.3.2. Horizontal Mixers	18
2.2. Attractive Forces in Size Enlargement in Air	4	4.1.3.3. High-Speed Mixers	18
2.2.1. Electrostatic Forces	5	4.1.3.4. Fluidized-Bed Agglomeration	18
2.2.2. Van der Waals Forces	5	4.2. Agglomerate Formation from Moist Material	19
2.2.3. Capillary Forces	6	4.2.1. Introduction	19
2.2.4. Solid Bridges	6	4.2.2. Agglomeration Equipment for Plastic Materials	20
2.2.5. Influence of Particle Surface Roughness on Binding	8	4.3. Drying Processes	21
2.2.6. Strengthening of Binding Forces	9	4.3.1. Atomization Drying	22
2.3. Attractive Forces of Particles in a Liquid Medium	9	4.3.1.1. Fundamentals of Atomization Drying	22
2.3.1. DLVO theory	9	4.3.1.2. Fluidized-Bed Spray Drying	23
2.3.2. Flocculation by Polymeric Flocculants	10	4.3.1.3. Combination Processes	23
3. Characterization of Agglomerates	11	4.3.2. Contact Drying	24
3.1. Particle Size, Particle Size Distribution	11	4.3.3. Vacuum Drying	25
3.1.1. Agglomerate Density and Porosity	11	4.4. Spherical Agglomeration	26
3.1.2. Definition	11	4.5. Pressure Agglomeration	28
3.1.3. Densities	12	4.5.1. Compression Equations	29
3.1.4. Porosities	12	4.5.2. Stamp Presses	30
3.3. Agglomerate Strength	14	4.5.3. Roller Presses	31
3.4. Redispersion	14	4.5.4. Tableting	33
4. Size Enlargement Processes	16	4.5.4.1. Tableting Equipment	33
4.1. Growth Agglomeration (Pelletization)	16	4.5.4.2. Tablet Pressing	34
4.1.1. Agglomeration Kinetics	16	4.5.4.3. Tableting Problems	35
		4.5.4.4. Effect of Compression Rate and Humidity	35
		5. References	37

1. Introduction

In the broadest sense of the term, size enlargement includes all processes in which fine particles, dispersed in either gas or liquid, aggregate to form a coarser product. The collection of particles that results is called an agglomerate or granule. Depending on the process, the size of the agglomerate is between 0.02 and 50 mm. In most cases, the preferred particle shape is spher-

ical. In many processes, the product is a cylindrical section such as a tablet or some other regular geometrical shape. Size enlargement is used in many industries, such as fertilizer production, iron ore, nuclear fuel, pulverized fuel ash, ceramics, light-weight aggregate production, carbon blacks, catalysts, pesticides, and pharmaceutical products.

There are other reasons for the production and use of agglomerates: