

# Ullmann's Encyclopedia of Industrial Chemistry

Fifth, Completely Revised Edition

Volume A 28:

Water to Zirconium and Zirconium Compounds

Editors: Barbara Evers, Stephen Hawkins



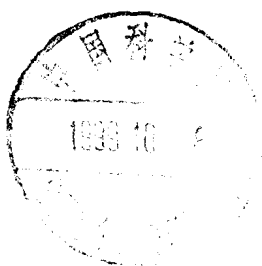
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Volume A 28

Water  
to  
Zirconium and  
Zirconium Compounds



# Ullmann's Encyclopedia of Industrial Chemistry

Volumes A 1 – A 28: alphabetically arranged articles  
Volumes B 1 – B 8: basic knowledge

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## Symbols and Units

Symbols and units agree with SI standards (for conversion factors see pp. VIII–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                                                          |
| $c_B$         | $\text{mol}/m^3$ , $\text{mol}/L$ (M) | concentration of substance B                                  |
| $C$           | C/V                                   | electric capacity                                             |
| $c_p$ , $c_v$ | $J\text{ kg}^{-1}K^{-1}$              | specific heat capacity                                        |
| $d$           | cm, m                                 | diameter                                                      |
| $d$           |                                       | relative density ( $\rho/\rho_{\text{water}}$ )               |
| $D$           | $m^2/s$                               | 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                                           |
| $E_A$         | 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                                                        |
| $h$           | $W \cdot s^2$                         | 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                                           |
| $N_A$         | $\text{mol}^{-1}$                     | Avogadro constant ( $6.023 \times 10^{23} \text{ mol}^{-1}$ ) |
| $p$           | Pa, bar *                             | pressure                                                      |
| $Q$           | J                                     | quantity of heat                                              |
| $r$           | m                                     | radius                                                        |
| $R$           | $J\text{ K}^{-1}\text{mol}^{-1}$      | gas constant                                                  |
| $R$           | $\Omega$                              | 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                                                      |

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

Symbols and units (continued from p. VII)

| Symbol     | Unit                                                 | Physical Quantity                                |
|------------|------------------------------------------------------|--------------------------------------------------|
| $U$        | V                                                    | electric potential                               |
| $U$        | J                                                    | internal energy                                  |
| $V$        | m <sup>3</sup> , L, mL                               | volume                                           |
| $w$        |                                                      | mass fraction                                    |
| $W$        | J                                                    | work                                             |
| $x_B$      |                                                      | mole fraction of substance B                     |
| $Z$        |                                                      | proton number, atomic number                     |
| $\alpha$   |                                                      | cubic expansion coefficient                      |
| $\alpha$   | W m <sup>-2</sup> K <sup>-1</sup>                    | heat-transfer coefficient (heat-transfer number) |
| $\alpha$   |                                                      | degree of dissociation of electrolyte            |
| $[\alpha]$ | 10 <sup>-2</sup> deg cm <sup>2</sup> g <sup>-1</sup> | specific rotation                                |
| $\eta$     | Pa · s                                               | dynamic viscosity                                |
| $\theta$   | °C                                                   | temperature                                      |
| $\kappa$   |                                                      | $c_p/c_v$                                        |
| $\lambda$  | W m <sup>-1</sup> K <sup>-1</sup>                    | thermal conductivity                             |
| $\lambda$  | nm, m                                                | wavelength                                       |
| $\mu$      |                                                      | chemical potential                               |
| $\nu$      | Hz, s <sup>-1</sup>                                  | frequency                                        |
| $\nu$      | m <sup>2</sup> /s                                    | kinematic viscosity ( $\eta/\rho$ )              |
| $\pi$      | Pa                                                   | osmotic pressure                                 |
| $\rho$     | g/cm <sup>3</sup>                                    | density                                          |
| $\sigma$   | N/m                                                  | surface tension                                  |
| $\tau$     | Pa (N/m <sup>2</sup> )                               | shear stress                                     |
| $\varphi$  |                                                      | volume fraction                                  |
| $\chi$     | Pa <sup>-1</sup> (m <sup>2</sup> /N)                 | compressibility                                  |

## 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>      |                       |                               |
| m <sup>3</sup>     | cubic inch            | $6.102 \times 10^4$           |
| m <sup>3</sup>     | cubic foot            | 35.315                        |
| m <sup>3</sup>     | gallon (U.S., liquid) | $2.642 \times 10^2$           |
| m <sup>3</sup>     | gallon (Imperial)     | $2.200 \times 10^2$           |
| <i>Temperature</i> |                       |                               |
| °C                 | °F                    | °C $\times 1.8 + 32$          |
| <i>Force</i>       |                       |                               |
| N                  | dyne                  | $1.0 \times 10^5$             |

Conversion factors (continued from p. VIII)

| SI unit             | Non-SI unit | From SI to non-SI multiply by |
|---------------------|-------------|-------------------------------|
| <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                         |

### Prefixes for Powers of Ten

|                    |                  |                     |                      |
|--------------------|------------------|---------------------|----------------------|
| E (exa) $10^{18}$  | M (mega) $10^6$  | d (deci) $10^{-1}$  | n (nano) $10^{-9}$   |
| P (peta) $10^{15}$ | k (kilo) $10^3$  | c (centi) $10^{-2}$ | p (pico) $10^{-12}$  |
| T (tera) $10^{12}$ | h (hecto) $10^2$ | m (milli) $10^{-3}$ | f (femto) $10^{-15}$ |
| G (giga) $10^9$    | da (deca) 10     | μ (micro) $10^{-6}$ | 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 p. VII (Symbols and Units), p. XIV (Companies and Country Codes in Patent References). The names of periodical publications are abbreviated exactly as done by Chemical Abstracts Service.

|       |                                                                                                                                                                                                                                                    |       |                                                                                                                                                                                                                            |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| abs.  | absolute                                                                                                                                                                                                                                           |       | of dangerous goods on                                                                                                                                                                                                      |
| a.c.  | alternating current                                                                                                                                                                                                                                |       | the Rhine and all national                                                                                                                                                                                                 |
| ACGIH | American Conference of Govern-<br>mental Industrial Hygienists                                                                                                                                                                                     |       | waterways of the countries<br>concerned)                                                                                                                                                                                   |
| ACS   | American Chemical Society                                                                                                                                                                                                                          | ADP   | adenosine 5'-diphosphate                                                                                                                                                                                                   |
| ADI   | acceptable daily intake                                                                                                                                                                                                                            | ADR   | accord européen relatif au<br>transport international des<br>marchandises dangereuses<br>par route (European agree-<br>ment concerning the inter-<br>national transportation<br>of dangerous goods by inland<br>waterways) |
| ADN   | accord européen relatif au trans-<br>port international des marchand-<br>ises dangereuses par voie de<br>navigation intérieure (European<br>agreement concerning the<br>international transportation<br>of dangerous goods by inland<br>waterways) | AEC   | Atomic Energy Commission<br>(United States)                                                                                                                                                                                |
| ADNR  | ADN par le Rhin (regulation<br>concerning the transportation                                                                                                                                                                                       | AICbE | American Institute of Chemical<br>Engineers                                                                                                                                                                                |

|           |                                                                                                                                    |           |                                                                                                       |
|-----------|------------------------------------------------------------------------------------------------------------------------------------|-----------|-------------------------------------------------------------------------------------------------------|
| AIME      | American Institute of Mining, Metallurgical, and Petroleum Engineers                                                               | CTFA      | The Cosmetic, Toiletry and Fragrance Association (United States)                                      |
| AMP       | adenosine 5'-monophosphate                                                                                                         | DAB 9     | Deutsches Arzneibuch, 9th ed., Deutscher Apotheker-Verlag, Stuttgart 1986                             |
| APhA      | American Pharmaceutical Association                                                                                                | d.c.      | direct current                                                                                        |
| API       | American Petroleum Institute                                                                                                       | decomp.   | decompose, decomposition                                                                              |
| ASTM      | American Society for Testing and Materials                                                                                         | DFG       | Deutsche Forschungsgemeinschaft (German Science Foundation)                                           |
| ATP       | adenosine 5'-triphosphate                                                                                                          | dil.      | dilute, diluted                                                                                       |
| BAM       | Bundesanstalt für Materialprüfung (Federal Republic of Germany)                                                                    | DIN       | Deutsche Industrie Norm (Federal Republic of Germany)                                                 |
| BAT       | Biologischer Arbeitsstoff-Toleranzwert (biological tolerance value for a working material, established by MAK Commission, see MAK) | DMF       | dimethylformamide                                                                                     |
| Beilstein | Beilstein's Handbook of Organic Chemistry, Springer, Berlin-Heidelberg-New York                                                    | DNA       | deoxyribonucleic acid                                                                                 |
| BET       | Brunauer-Emmett-Teller                                                                                                             | DOE       | Department of Energy (United States)                                                                  |
| BGA       | Bundesgesundheitsamt (Federal Republic of Germany)                                                                                 | DOT       | Department of Transportation - Materials Transportation Bureau (United States)                        |
| BGBI.     | Bundesgesetzblatt (Federal Republic of Germany)                                                                                    | DTA       | differential thermal analysis                                                                         |
| BIOS      | British Intelligence Objectives Subcommittee Report (see also FIAT)                                                                | EC        | effective concentration                                                                               |
| BOD       | biological oxygen demand                                                                                                           | EC        | European Community                                                                                    |
| <i>bp</i> | boiling point                                                                                                                      | ed.       | editor, edition, edited                                                                               |
| B.P.      | British Pharmacopeia                                                                                                               | e.g.      | for example                                                                                           |
| BS        | British Standard                                                                                                                   | emf       | electromotive force                                                                                   |
| ca.       | circa                                                                                                                              | EmS       | Emergency Schedule                                                                                    |
| calcd.    | calculated                                                                                                                         | EN        | European Standard (European Community)                                                                |
| CAS       | Chemical Abstracts Service                                                                                                         | EPA       | Environmental Protection Agency (United States)                                                       |
| cat.      | catalyst, catalyzed                                                                                                                | EPR       | electron paramagnetic resonance                                                                       |
| cf.       | compare                                                                                                                            | Eq.       | equation                                                                                              |
| CFR       | Code of Federal Regulations (United States)                                                                                        | ESCA      | electron spectroscopy for chemical analysis                                                           |
| Chap.     | chapter                                                                                                                            | esp.      | especially                                                                                            |
| ChemG     | Chemikaliengesetz (Federal Republic of Germany)                                                                                    | ESR       | electron spin resonance                                                                               |
| C.I.      | Colour Index                                                                                                                       | Et        | ethyl substituent ( $-C_2H_5$ )                                                                       |
| CIOS      | Combined Intelligence Objectives-Subcommittee Report (see also FIAT)                                                               | et al.    | and others                                                                                            |
| CNS       | central nervous system                                                                                                             | etc.      | et cetera                                                                                             |
| Co.       | Company                                                                                                                            | EVO       | Eisenbahnverkehrsordnung (Federal Republic of Germany)                                                |
| COD       | chemical oxygen demand                                                                                                             | exp (...) | $e^{(\dots)}$ , mathematical exponent                                                                 |
| conc.     | concentrated                                                                                                                       | FAO       | Food and Agriculture Organization (United Nations)                                                    |
| const.    | constant                                                                                                                           | FDA       | Food and Drug Administration (United States)                                                          |
| Corp.     | Corporation                                                                                                                        | FD & C    | Food, Drug and Cosmetic Act (United States)                                                           |
| crit.     | critical                                                                                                                           | FHSA      | Federal Hazardous Substances Act (United States)                                                      |
|           |                                                                                                                                    | FIAT      | Field Information Agency, Technical (United States reports on the chemical industry in Germany, 1945) |
|           |                                                                                                                                    | Fig.      | figure                                                                                                |

|             |                                                                                                                                                                                                                            |                   |                                                                                                                                                                                                                              |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>fp</i>   | freezing point                                                                                                                                                                                                             | IATA-DGR          | International Air Transport Association, Dangerous Goods Regulations                                                                                                                                                         |
| Friedländer | P. Friedländer, Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige, Vol. 1–25, Springer, Berlin 1888–1942                                                                                               | ICAO              | International Civil Aviation Organization                                                                                                                                                                                    |
| FT          | Fourier transform                                                                                                                                                                                                          | i.e.              | that is                                                                                                                                                                                                                      |
| (g)         | gas, gaseous                                                                                                                                                                                                               | i.m.              | intramuscular                                                                                                                                                                                                                |
| GC          | gas chromatography                                                                                                                                                                                                         | IMDG              | International Maritime Dangerous Goods Code                                                                                                                                                                                  |
| GefStoffV   | Gefahrstoffverordnung (regulations in the Federal Republic of Germany concerning hazardous substances)                                                                                                                     | IMO               | Inter-Governmental Maritime Consultative Organization (in the past: IMCO)                                                                                                                                                    |
| 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)            | Inst.             | Institute                                                                                                                                                                                                                    |
| 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)               | i.p.              | intraperitoneal                                                                                                                                                                                                              |
| 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) | IR                | infrared                                                                                                                                                                                                                     |
| GLC         | gas-liquid chromatography                                                                                                                                                                                                  | ISO               | International Organization for Standardization                                                                                                                                                                               |
| Gmelin      | Gmelin's Handbook of Inorganic Chemistry, 8th ed., Springer, Berlin–Heidelberg–New York                                                                                                                                    | IUPAC             | International Union of Pure and Applied Chemistry                                                                                                                                                                            |
| GRAS        | generally recognized as safe                                                                                                                                                                                               | i.v.              | intravenous                                                                                                                                                                                                                  |
| Hal         | halogen substituent (–F, –Cl, –Br, –I)                                                                                                                                                                                     | Kirk-Othmer       | Encyclopedia of Chemical Technology, 3rd ed., J. Wiley & Sons, New York–Chichester–Brisbane–Toronto 1978–1984                                                                                                                |
| Houben-Weyl | Methoden der organischen Chemie, 4th ed., Georg Thieme Verlag, Stuttgart                                                                                                                                                   | (l)               | liquid                                                                                                                                                                                                                       |
| HPLC        | high performance liquid chromatography                                                                                                                                                                                     | 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 |
| IAEA        | International Atomic Energy Agency                                                                                                                                                                                         | LC <sub>50</sub>  | lethal concentration for 50 % of the test animals                                                                                                                                                                            |
| IARC        | International Agency for Research on Cancer, Lyon, France                                                                                                                                                                  | LCLo              | lowest published lethal concentration                                                                                                                                                                                        |
|             |                                                                                                                                                                                                                            | LD <sub>50</sub>  | 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 Arbeitsplatzkonzentration (maximum concentration at the workplace in the Federal Republic of Germany); cf. Deutsche Forschungsgemeinschaft (ed.): Maximale Arbeits-                                                 |

|            |                                                                                                                                      |                   |                                                                                                                                                                                    |
|------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | platzkonzentrationen (MAK) und Biologische Arbeitsstoff-Toleranz-Werte (BAT), VCH Verlagsgesellschaft, Weinheim (published annually) | Patty             | G. D. Clayton, F. E. Clayton (eds.): Patty's Industrial Hygiene and Toxicology, 3rd ed., Wiley Interscience, New York                                                              |
| max.       | maximum                                                                                                                              | PB report         | Publication Board Report (U.S. Department of Commerce, Scientific and Industrial Reports)                                                                                          |
| MCA        | Manufacturing Chemists Association (United States)                                                                                   | PEL               | permitted exposure limit                                                                                                                                                           |
| Me         | methyl substituent ( $-\text{CH}_3$ )                                                                                                | Ph                | phenyl substituent ( $-\text{C}_6\text{H}_5$ )                                                                                                                                     |
| Methodicum | Methodicum Chemicum, Georg Thieme Verlag, Stuttgart                                                                                  | Ph. Eur.          | European Pharmacopoeia, 2nd. ed., Council of Europe, Strasbourg 1981 -                                                                                                             |
| MFAG       | Medical First Aid Guide for Use in Accidents Involving Dangerous Goods                                                               | phr               | part per hundred rubber (resin)                                                                                                                                                    |
| MIK        | maximale Immissionskonzentration (maximum immission concentration)                                                                   | PNS               | peripheral nervous system                                                                                                                                                          |
| min.       | minimum                                                                                                                              | ppm               | parts per million                                                                                                                                                                  |
| mp         | melting point                                                                                                                        | q. v.             | which see (quod vide)                                                                                                                                                              |
| MS         | mass spectrum, mass spectrometry                                                                                                     | ref.              | refer, reference                                                                                                                                                                   |
| NAS        | National Academy of Sciences (United States)                                                                                         | resp.             | respectively                                                                                                                                                                       |
| NASA       | National Aeronautics and Space Administration (United States)                                                                        | $R_f$             | retention factor (TLC)                                                                                                                                                             |
| NBS        | National Bureau of Standards (United States)                                                                                         | R. H.             | relative humidity                                                                                                                                                                  |
| NCTC       | National Collection of Type Cultures (United States)                                                                                 | RID               | règlement international concernant le transport des marchandises dangereuses par chemin de fer (international convention concerning the transportation of dangerous goods by rail) |
| NIH        | National Institutes of Health (United States)                                                                                        | RNA               | ribonucleic acid                                                                                                                                                                   |
| NIOSH      | National Institute for Occupational Safety and Health (United States)                                                                | R phrase (R-Satz) | risk phrase according to ChemG and GefStoffV (Federal Republic of Germany)                                                                                                         |
| NMR        | nuclear magnetic resonance                                                                                                           | rpm               | revolutions per minute                                                                                                                                                             |
| no.        | number                                                                                                                               | RTECS             | Registry of Toxic Effects of Chemical Substances, edited by the National Institute of Occupational Safety and Health (United States)                                               |
| NOEL       | no observed effect level                                                                                                             | (s)               | solid                                                                                                                                                                              |
| NRC        | Nuclear Regulatory Commission (United States)                                                                                        | SAE               | Society of Automotive Engineers (United States)                                                                                                                                    |
| NRDC       | National Research Development Corporation (United States)                                                                            | s.c.              | subcutaneous                                                                                                                                                                       |
| NSC        | National Service Center (United States)                                                                                              | SI                | International System of Units                                                                                                                                                      |
| NSF        | National Science Foundation (United States)                                                                                          | SIMS              | secondary ion mass spectrometry                                                                                                                                                    |
| NTSB       | National Transportation Safety Board (United States)                                                                                 | S phrase (S-Satz) | safety phrase according to ChemG and GefStoffV (Federal Republic of Germany)                                                                                                       |
| OECD       | Organization for Economic Cooperation and Development                                                                                | STEL              | Short Term Exposure Limit (see TLV)                                                                                                                                                |
| OSHA       | Occupational Safety and Health Administration (United States)                                                                        | STP               | standard temperature and pressure ( $0^\circ\text{C}$ , 101.325 kPa)                                                                                                               |
| p., pp.    | page, pages                                                                                                                          | $T_g$             | glass transition temperature                                                                                                                                                       |
|            |                                                                                                                                      | 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)                                                                                                          | UVV              | Unfallverhütungsvorschriften der Berufsgenossenschaft (workplace safety regulations in the Federal Republic of Germany)                                                                                                                                                                                                                                                                                                                             |
| TDLo    | lowest published toxic dose                                                                                                                         |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| THF     | tetrahydrofuran                                                                                                                                     | 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) |
| TLC     | thin layer chromatography                                                                                                                           |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| TLV     | Threshold Limit Value (TWA and STEL); published annually by the American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, Ohio | VDE              | Verband Deutscher Elektrotechniker (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 | Ullmanns Encyklopädie der Technischen Chemie, 4th ed., Verlag Chemie, Weinheim 1972–1984; 3rd ed., Urban und Schwarzenberg, München 1951–1970       | Winnacker-Kühler | Chemische Technologie, Carl Hanser Verlag, München                                                                                                                                                                                                                                                                                                                                                                                                  |
| 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                                                                                                                                         |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

**Abbreviations for the Names of Frequently Cited Companies**

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



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**Cross References**

|                                           |                                                                   |
|-------------------------------------------|-------------------------------------------------------------------|
| Weed Killers → Weed Control               | Xenon Fluorides → Noble Gases                                     |
| Weld Cladding → Corrosion, B1             | Xenon Oxides → Noble Gases                                        |
| Wheat → Cereals and Cereal Products       | Xylenols → Cresols and Xylenols                                   |
| Whey → Cheese, Processed Cheese, and Whey | Xylidinesulfonic Acids → Benzenesulfonic<br>Acids and Derivatives |
| Whisky → Spirits                          | Xylitol → Sugar Alcohols                                          |
| Wollastonite → Silicates                  | Ytterbium → Rare Earth Elements                                   |
| Wood Gasification → Gas Production        | Yttrium → Rare Earth Elements                                     |
| Wood Pulp → Paper and Pulp                | Ziegler-Natta Catalysts → Polyolefins                             |
| Xanthan Gum → Polysaccharides             | Zinc White → Pigments, Inorganic                                  |
| Xanthene Dyes → Triarylmethane Dyes       | Zone Melting → Crystal Growth                                     |
| Xenon → Noble Gases                       |                                                                   |

# Water

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