

COMPREHENSIVE ORGANIC TRANSFORMATIONS

A Guide to
Functional Group Preparations
Second Edition

Richard C. Larock



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FOREWORD

The first edition of this book, *Comprehensive Organic Transformations – A Guide to Functional Group Transformations*, which appeared in 1989, delivered in abundance the information promised by the title. It was truly comprehensive, as it covered countless reactions (starting from or leading to the core functional groups of organic chemistry, from $C\equiv C$ to hydroxyl and amino to carbonyl to carboxylic acid and derivatives), and contained zillions of useful references. Packed within a thousand or so pages was an enormous amount of valuable and readily located synthetic chemistry, covering the literature up to 1987 (mainly from 1950–1987).

No wonder then that Richard Larock's *Comprehensive Organic Transformations* treatise became a mainstay of academic and industrial synthetic chemists, a great place to look when confronted with a new problem or task. For students, *Comprehensive Organic Transformations* has served as a concentrated one-volume guide to synthesis, and as a way to deepen and broaden their command of the vast body of knowledge that is synthetic chemistry. It is precisely because *Comprehensive Organic Transformations* has been of such value to chemists that its devotees, including myself, have hoped that an updated version would be forthcoming as an aid to keeping abreast of the avalanche of new developments in the field of synthesis. I've heard synthetic chemists joke that there are two types of colleagues: those who try to keep up with the literature and fail, and those who have stopped trying. Not so. Richard Larock is a different breed; he is still trying, and he has succeeded. In this new work, the second edition of *Comprehensive Organic Transformations*, Richard provides us with another scientific treasure chest and a powerful tool in dealing with the superhuman task of keeping up to date in chemistry.

In his Foreword to the first edition of *Comprehensive Organic Transformations*, H.C. Brown wrote "One must admire Richard Larock's courage in undertaking this monumental task". I agree completely. But, there is an additional comment that I am moved to make on the second edition: Thanks, Richard, for the valiant effort which produced this book; indeed, many thanks from us all.

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Harvard University

PREFACE

Organic synthesis is one of the most rapidly developing areas in all of chemistry. Every day useful new reagents and reactions are reported worldwide in the chemical literature. It is increasingly difficult for the organic chemist to keep up with the latest in synthetic organic methodology without spending an inordinate amount of time reading a wide variety of chemical journals, including many whose focus is not strictly synthetic organic chemistry.

In recent years, a variety of reviews, books and multi-volume treatises have appeared to aid the organic chemist interested in synthetic methodology, but many of these are either inconvenient, limited in scope, or prohibitively expensive for personal use or for those just entering the field. The intent of the present volume is to provide a comprehensive, highly condensed, systematic collection of useful synthetic methodology that both the beginning student and the long-time practitioner of organic synthesis will find useful.

This book began in 1973 as a series of graduate course handouts on the most important methodology for the synthesis of the major organic functional groups. Like the aforementioned publications, this reference work grew rapidly over the years to a major treatise covering a vast amount of synthetic organic chemistry. In the mid 1980's it was felt that the synthetic organic chemistry community might benefit from this compilation, so a serious effort was made to thoroughly update and organize the material for publication. The result was the first edition of *Comprehensive Organic Transformations*, which appeared in late 1989, and covered the literature through 1987. With the success of that first edition and the continuing need for a single, comprehensive inexpensive compilation on organic synthetic methodology, the author was encouraged to attempt the present major update.

The author takes full responsibility for the reactions, reagents and references covered. In choosing material for this text, the author has observed the following general guidelines. All reactions covered should be either very general in scope or else so unique that the methodology will find real synthetic utility. Yields should generally be at least 50%. Reagents should be readily available or easily prepared and handled in the laboratory. As much as possible, similar transformations appear together in as concise a format as possible. Significant limitations in methodology are noted. No effort has been made to cover the use of protecting groups, since excellent reviews on this subject are already available. Likewise, heterocyclic chemistry has consciously been omitted, except where heterocycles have been employed to effect simple functional group manipulations. Synthetically useful, multiple functional group transformations have been covered and cross-referenced in appropriate sections, although they present certain organizational problems. To those chemists whose contributions to synthetic methodology may have been slighted or altogether ignored, I apologize. It would be appreciated if major errors or omissions are brought to the author's attention, so that future printings and subsequent editions may be corrected.

As in the first edition, all reactions have been systematically organized according to the functional group being synthesized, with no attempt to cover the less important functional groups. Within each chapter, the methodology is further subdivided into major processes, such as oxidation, reduction, alkylation, etc. It is hoped that the reader will easily find the desired transformation by skimming the detailed Table of Contents, although an extensive Transformation Index is available.

The first edition of *Comprehensive Organic Transformations* covered some 160 or more primary chemical journals and a number of books and reviews published up to 1987. The present update has been generated by carefully scanning every page of the *Journal of the American Chemical Society*, the *Journal of Organic Chemistry*, *Tetrahedron Letters* and *Synlett* for the years 1988 through 1995, and checking references therein for additional material. Unfortunately, there simply was not enough time available to the author to review the other major, synthetic organic chemistry journals, as thoroughly. Thirty nine new journals and numerous additional reviews and books have been covered in this edition. Obscure journals not readily available to most synthetic organic chemists have been avoided. The names of authors have been omitted to save space. Original publications describing a new transformation have usually been cited, but they have on occasion been omitted if they do not necessarily describe the best reaction conditions for running the reaction or purvey little of the scope of the reaction. References containing full experimental procedures, though they may be buried in an experimental section, have been favored over communications lacking such details. An attempt has been made to highlight reviews and significant publications. The immediate problem one encounters is in deciding where to draw the line on references. Initial reports of a useful, new reaction have received complete coverage. However, a time soon comes when a truly significant reaction, such as the use of ester enolates in synthesis, appears routinely in publication after publication and no reviews have appeared. In such situations, the author has tended to include most of the new material and has not had the time to omit the more inconsequential earlier references.

It is hoped that the reader finds this latest effort worthwhile and will not hesitate to make suggestions on ways this material may be improved. Corrections, additions and suggestions would be deeply appreciated.

Richard C. Larock
Ames, Iowa USA

ABOUT THE AUTHOR

Richard C. Larock was born in Berkeley, California, in 1944 and raised in the San Francisco Bay Area.

He received his B.S. degree *summa cum laude* in chemistry, at the University of California at Davis, in 1967. While there, he participated in the University of California Education Abroad Program in Göttingen, West Germany, and did undergraduate research with Professor George Zweifel. He was also elected to Phi Kappa Phi and Phi Beta Kappa National Honor Societies and received the Outstanding Achievement Award in the Department of Chemistry, and the Herbert A. Young Award for highest achievement in the College of Letters and Science.

Dr. Larock received an NSF Graduate Fellowship to pursue his graduate training at Purdue University, working with 1979 Nobel Laureate, Herbert C. Brown, on the mercuration of organoboranes. After obtaining his Ph.D. in 1971, he received an NSF Postdoctoral Fellowship to work with 1990 Nobel Laureate, E. J. Corey, at Harvard University.

In 1972, he joined the organic chemistry faculty at Iowa State University, where he is presently University Professor of Chemistry. His early work at Iowa State, on new applications of organomercurials in organic synthesis, earned him an Alfred P. Sloan Foundation Fellowship and a DuPont Young Faculty Scholarship, and culminated in the publication of two books in the area: *Organomercury Compounds in Organic Synthesis* and *Solvomercuration/Demercuration Reactions in Organic Synthesis*.

Dr. Larock's use of organomercurials to generate synthetically valuable organopalladium intermediates encouraged him to move into the exciting new field of organopalladium chemistry, where his scientific contributions have involved the application of vinylpalladium chemistry to organic synthesis, the discovery of new routes to π -allylpalladium compounds, the development of new methodology based on palladium migration chemistry, the synthesis of prostaglandins *via* palladium intermediates, and most recently, palladium(II)-catalyzed cyclizations and oxidations, and the palladium(0)-catalyzed annulation of alkenes, dienes and alkynes. This work has been described in over 150 publications and 30 patents. Current interests also include the synthesis of industrially useful oils and biodegradable polymers from natural oils, particularly soybean oil.

Dr. Larock has recently been awarded 1997 and 1998 Merck Academic Development Awards in Chemistry, received a 1998 Regent's Award for Faculty Excellence at Iowa State University, and in 1999 been named University Professor of Chemistry.

ACKNOWLEDGMENTS

The preparation of a book of this magnitude requires the assistance of a number of people. The author is indebted to Iowa State University for providing the time and assistance necessary for the preparation of much of this book, and a faculty improvement leave in 1994 to help get this second edition off the ground. The Department of Chemistry at the University of Hawaii at Manoa is gratefully acknowledged for having provided a visiting professorship in 1985 (which allowed the author to push the original manuscript through to publication), and an office during my 1994 faculty improvement leave.

To all those around me who have had to "endure" this book for so long, your encouragement, patience and perseverance are deeply appreciated. The author is particularly indebted to Professor John Maves for all the personal impositions created by this entire endeavor. I thank my students – who have often had to take a back seat to this project – for their understanding and patience.

I must also acknowledge a core of dedicated secretaries, who over the years continually updated the early material for classroom use, particularly Mrs. Helen Eggleston and Mrs. Denise Junod. The author is especially indebted to Mrs. Nancy Qvale, who was responsible for the preparation of a major portion of the final manuscript for the first edition.

Finally, the author wishes to thank his parents Hazel and Ralph Larock for having provided genes with the perseverance and perfectionism necessary to complete this project, when it seemed that the project would never end.

LITERATURE ABBREVIATIONS

Acct Chem Res	<i>Accounts of Chemical Research</i>
Acta Chem Scand	<i>Acta Chemica Scandinavica</i>
Acta Chem Scand B	<i>Acta Chemica Scandinavica. Series B: Organic Chemistry and Biochemistry</i>
Acta Chimica Sinica	<i>Acta Chimica Sinica</i>
Adv Alicyclic Chem	<i>Advances in Alicyclic Chemistry</i>
Adv Biochem Eng	<i>Advances in Biochemical Engineering</i>
Adv Carbohydr Chem	<i>Advances in Carbohydrate Chemistry</i>
Adv Catalysis	<i>Advances in Catalysis</i>
Adv Chem Ser	<i>Advances in Chemistry Series</i>
Adv Heterocyclic Chem	<i>Advances in Heterocyclic Chemistry</i>
Adv Org Chem	<i>Advances in Organic Chemistry: Methods and Results</i>
Adv Organometal Chem	<i>Advances in Organometallic Chemistry</i>
Adv Photochem	<i>Advances in Photochemistry</i>
Adv Phys Org Chem	<i>Advances in Physical Organic Chemistry</i>
Agric Biol Chem	<i>Agricultural and Biological Chemistry</i>
Anal Chem	<i>Analytical Chemistry</i>
Anal de Quim	<i>Anales de Quimica</i>
Angew	<i>Angewandte Chemie</i>
Angew Int	<i>Angewandte Chemie, International Edition in English</i>
Ann	<i>Justus Liebig's Annalen der Chemie</i>
Ann Chim	<i>Annales de Chimie</i>
Ann Chim (Rome)	<i>Annali di Chimica (Rome)</i>
Ann NY Acad Sci	<i>Annals of the New York Academy of Sciences</i>
Ann Rep Med Chem	<i>Annual Reports in Medicinal Chemistry</i>
Appl Environ Microbiol	<i>Applied and Environmental Microbiology</i>
Appl Microbiol	<i>Applied Microbiology</i>
Appl Microbiol Biotechnol	<i>Applied Microbiology and Biotechnology</i>
Appl Radiat Isot	<i>Applied Radiation and Isotopes</i>
Arch Biochem Biophys	<i>Archives of Biochemistry and Biophysics</i>
Arch Pharm	<i>Archiv der Pharmazie</i>
Arkiv Kemi	<i>Arkiv for Kemi</i>
Arzneim Forsch	<i>Arzneimittel-Forschung</i>
Austral J Chem	<i>Australian Journal of Chemistry</i>
BCSJ	<i>Bulletin of the Chemical Society of Japan</i>
Ber	<i>Berichte der Deutschen Chemischen Gesellschaft</i>
Biocatalysis	<i>Biocatalysis</i>
Biochem	<i>Biochemistry</i>
Biochem Biophys Res Commun	<i>Biochemical and Biophysical Research Communications</i>
Biochem J	<i>Biochemical Journal</i>
Biochim Biophys Acta	<i>Biochimica et Biophysica Acta</i>
Bio Med Chem Lett	<i>Bioorganic and Medicinal Chemistry Letters</i>


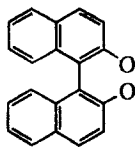
Bioorg Chem	<i>Bioorganic Chemistry</i>
BSCF	<i>Bulletin de la Societe Chimique de France</i>
Bull Acad Polon Sci, Ser Sci Chem	<i>Bulletin de l'Academie Polonaise des Sciences, Serie des Sciences Chimiques</i>
Bull Acad Sci USSR, Div Chem Sci	<i>Bulletin of the Academy of Sciences of the USSR, Division of Chemical Science</i>
Bull Korean Chem Soc	<i>Bulletin of the Korean Chemical Society</i>
Bull Russ Acad Sci, Div Chem Sci	<i>Bulletin of the Russian Academy of Sciences, Division of Chemical Sciences</i>
Bull Soc Chim Belg	<i>Bulletin des Societes Chimiques Belges</i>
CA	<i>Chemical Abstracts</i>
Can J Chem	<i>Canadian Journal of Chemistry</i>
Cancer Lett	<i>Cancer Letters</i>
Carbohydr Res	<i>Carbohydrate Research</i>
Catal Rev	<i>Catalysis Reviews</i>
CC	<i>Journal of the Chemical Society: Chemical Communications</i>
Chem Eng News	<i>Chemical and Engineering News</i>
Chem in Britain	<i>Chemistry in Britain</i>
Chem Ind	<i>Chemistry and Industry</i>
Chem Listy	<i>Chemicke Listy</i>
Chem Pharm Bull	<i>Chemical and Pharmaceutical Bulletin</i>
Chem Phys Lipids	<i>Chemistry and Physics of Lipids</i>
Chem Rev	<i>Chemical Reviews</i>
Chem Scripta	<i>Chemica Scripta</i>
Chem Soc Rev	<i>Chemical Society Reviews</i>
Chem Weekb	<i>Chemisch Weekblad</i>
Chem Zeitung	<i>Chemiker Zeitung</i>
Chem Zentr	<i>Chemisches Zentralblatt</i>
Chimia	<i>Chimia</i>
Chim Ind (Milan)	<i>Chimica e l'Industria (Milan)</i>
CL	<i>Chemistry Letters</i>
Coll Czech Chem Commun	<i>Collection of Czechoslovak Chemical Communications</i>
Compt Rend	<i>Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences</i>
Compt Rend C	<i>Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences. Serie C: Sciences Chimiques</i>
Curr Sci	<i>Current Science</i>
Discuss Faraday Soc	<i>Discussions of the Faraday Society</i>
Dokl	<i>Proceedings of the Academy of Sciences of the USSR, Chemistry Section</i>
Experientia	<i>Experientia</i>
Fortschr Chem Forsch	<i>Fortschritte der Chemischen Forschung</i>
Fund Res Homogeneous Catal	<i>Fundamental Research in Homogeneous Catalysis</i>
Gazz Chim Ital	<i>Gazzetta Chimica Italiana</i>
Helv	<i>Helvetica Chimica Acta</i>
Heterocycles	<i>Heterocycles</i>

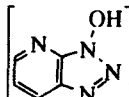
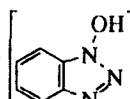

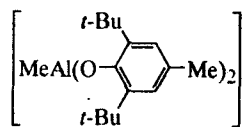
Ind Eng Chem	<i>Industrial and Engineering Chemistry</i>
Ind J Chem	<i>Indian Journal of Chemistry</i>
Ind J Chem B	<i>Indian Journal of Chemistry. Section B: Organic Chemistry and Medicinal Chemistry</i>
Inorg	<i>Inorganic Chemistry</i>
Int J Peptide Protein Res	<i>International Journal of Peptide and Protein Research</i>
Int J Sulfur Chem	<i>International Journal of Sulfur Chemistry</i>
Intra-Science Chem Reports	<i>Intra-Science Chemistry Reports</i>
Israel J Chem	<i>Israel Journal of Chemistry</i>
Izv Akad Nauk SSSR, Ser Khim	<i>Izvestiia Akademii Nauk SSSR. Seriya Khimicheskaya</i>
J Am Oil Chem Soc	<i>Journal of the American Oil Chemists' Society</i>
J Am Pharm Assoc	<i>Journal of the American Pharmaceutical Association</i>
J Antibiotics	<i>Journal of Antibiotics</i>
J Bacteriol	<i>Journal of Bacteriology</i>
J Biochem (Tokyo)	<i>Journal of Biochemistry (Tokyo)</i>
J Biol Chem	<i>Journal of Biological Chemistry</i>
J Catalysis	<i>Journal of Catalysis</i>
J Chem Ed	<i>Journal of Chemical Education</i>
J Chem Eng Data	<i>Journal of Chemical and Engineering Data</i>
J Chem Res (S)	<i>Journal of Chemical Research. Synopses</i>
J Fluorine Chem	<i>Journal of Fluorine Chemistry</i>
J Gen Chem USSR	<i>Journal of General Chemistry of the USSR</i>
J Gen Microbiol	<i>Journal of General Microbiology</i>
J Heterocyclic Chem	<i>Journal of Heterocyclic Chemistry</i>
J Ind Chem Soc	<i>Journal of the Indian Chemical Society</i>
J Korean Chem Soc	<i>Journal of the Korean Chemical Society</i>
J Label Compds	<i>Journal of Labelled Compounds</i>
J Label Cpds Radiopharm	<i>Journal of Labelled Compounds and Radiopharmaceuticals</i>
J Lipid Res	<i>Journal of Lipid Research</i>
J Med Chem	<i>Journal of Medicinal Chemistry</i>
J Mol Catal	<i>Journal of Molecular Catalysis</i>
J Nat Prod	<i>Journal of Natural Products</i>
J Nucl Med	<i>Journal of Nuclear Medicine</i>
J Pharm Sci	<i>Journal of Pharmaceutical Sciences</i>
J Photochem	<i>Journal of Photochemistry</i>
J Phys Chem	<i>Journal of Physical Chemistry</i>
J Phys Org Chem	<i>Journal of Physical Organic Chemistry</i>
J Polym Sci, Polym Chem Ed	<i>Journal of Polymer Science: Polymer Chemistry Edition</i>
J Prakt Chem	<i>Journal für Praktische Chemie</i>
J Russ Phys Chem Soc	<i>Journal of the Russian Physical Chemical Society</i>
J Sci Ind Res B	<i>Journal of Scientific and Industrial Research. Part B: Physical Sciences</i>
J Vitaminol (Osaka)	<i>Journal of Vitaminology</i>
JACS	<i>Journal of the American Chemical Society</i>
JCS	<i>Journal of the Chemical Society</i>
JCS A	<i>Journal of the Chemical Society. Section A: Inorganic, Physical and Theoretical</i>
JCS B	<i>Journal of the Chemical Society. Section B: Physical Organic</i>
JCS C	<i>Journal of the Chemical Society. Section C: Organic</i>

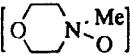
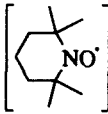

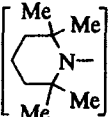
JCS D	<i>Journal of the Chemical Society. Section D: Chemical Communications</i>
JCS Dalton	<i>Journal of the Chemical Society: Dalton Transactions</i>
JCS Japan	<i>Journal of the Chemical Society of Japan</i>
JCS Perkin I	<i>Journal of the Chemical Society: Perkin Transactions I</i>
JCS Perkin II	<i>Journal of the Chemical Society: Perkin Transactions II</i>
JOC	<i>Journal of Organic Chemistry</i>
JOC USSR	<i>Journal of Organic Chemistry of the USSR</i>
JOMC	<i>Journal of Organometallic Chemistry</i>
Macromolecules	<i>Macromolecules</i>
Mendeleev Commun	<i>Mendeleev Communications</i>
Methods Carbohydr Chem	<i>Methods in Carbohydrate Chemistry</i>
Monatsh	<i>Monatshefte für Chemie</i>
Natl Prod Repts	<i>Natural Product Reports</i>
Nature	<i>Nature</i>
Naturwiss	<i>Naturwissenschaften</i>
Newer Methods Prep Org Chem	<i>Newer Methods of Preparative Organic Chemistry</i>
Nouv J Chim	<i>Nouveau Journal de Chimie</i>
Nucleosides and Nucleotides	<i>Nucleosides and Nucleotides</i>
Org Mag Rqs	<i>Organic Magnetic Resonance</i>
Org Photochem	<i>Organic Photochemistry</i>
Org Prep Proc	<i>Organic Preparations and Procedures</i>
Org Prep Proc Int	<i>Organic Preparations and Procedures International</i>
Org Rxs	<i>Organic Reactions</i>
Org Syn	<i>Organic Syntheses</i>
Org Syn Coll Vol	<i>Organic Syntheses. Collective Volume</i>
Organomet	<i>Organometallics</i>
Organomet Chem Rev A	<i>Organometallic Chemistry Reviews. Section A: Subject Reviews</i>
Organomet Chem Syn	<i>Organometallics in Chemical Synthesis</i>
Phosphorus	<i>Phosphorus and the Heavier Group Va Elements</i>
Phosphorus and Sulfur	<i>Phosphorus and Sulfur and the Related Elements</i>
Photochem Photobiol	<i>Photochemistry and Photobiology</i>
Phytochemistry	<i>Phytochemistry</i>
Pol J Chem	<i>Polish Journal of Chemistry</i>
Polym J	<i>Polymer Journal</i>
Proc Acad Sci USSR, Chem Sec	<i>Proceedings of the Academy of Sciences of the USSR. Chemistry Section</i>
Proc Chem Soc	<i>Proceedings of the Chemical Society (London)</i>
Proc Ind Acad Sci A	<i>Proceedings—Indian Academy of Sciences. Section A, Part 1: Chemical Sciences</i>
Proc Natl Acad Sci USA	<i>Proceedings of the National Academy of Sciences of the United States of America</i>
Prog Inorg Chem	<i>Progress in Inorganic Chemistry</i>
Prostaglandins	<i>Prostaglandins</i>
PSS	<i>Phosphorus, Sulfur, and Silicon and the Related Elements</i>

Pure Appl Chem	<i>Pure and Applied Chemistry</i>
Quart Rev	<i>Quarterly Reviews—Chemical Society, London</i>
Rec Chem Prog	<i>Record of Chemical Progress</i>
Rec Trav Chim	<i>Recueil des Travaux Chimiques des Pays-Bas</i>
Recl J R Neth Chem Soc	<i>Recueil: Journal of the Royal Netherlands Chemical Society</i>
Rev Chem Intermed	<i>Reviews of Chemical Intermediates</i>
Rev Pure Appl Chem	<i>Reviews of Pure and Applied Chemistry</i>
Rocz	<i>Roczniki Chemii</i>
Russ Chem Rev	<i>Russian Chemical Reviews</i>
Russ J Chem	<i>Russian Journal of Chemistry</i>
S Afr J Chem	<i>South African Journal of Chemistry</i>
SL	<i>Synlett</i>
Soc Chem Ind	<i>Society of Chemical Industry, London Chemical Engineering Group, Proceedings</i>
Steroids	<i>Steroids</i>
Syn	<i>Synthesis</i>
Syn Commun	<i>Synthetic Communications</i>
Tetr	<i>Tetrahedron</i>
Tetr Asym	<i>Tetrahedron: Asymmetry</i>
TL	<i>Tetrahedron Letters</i>
Topics Curr Chem	<i>Topics in Current Chemistry</i>
Topics Stereochem	<i>Topics in Stereochemistry</i>
Trans Faraday Soc	<i>Transactions of the Faraday Society</i>
Transition Met Chem	<i>Transition Metal Chemistry (New York)</i>
Z Chem	<i>Zeitschrift für Chemie</i>
Z Naturforsch B	<i>Zeitschrift für Naturforschung. Teil B: Anorganische Chemie, Organische Chemie, Biochemie, Biophysik, Biologie</i>
Zh Obshch Khim	<i>Zhurnal Obshchei Khimii</i>

CHEMICAL ABBREVIATIONS

Ac	acetyl
acac	acetylacetonate $[\text{CH}_3\text{COCHCOCH}_3]$
acaen	<i>N,N'</i> -bis(1-methyl-3-oxobutylidene)ethylenediamine
AIBN	2,2'-azobisisobutyronitrile $[\text{Me}_2\text{C}(\text{CN})\text{N}=\text{NC}(\text{CN})\text{Me}_2]$
Am	amyl
aq	aqueous
Ar	aryl
	9-borabicyclo[3.3.1]nonyl
9-BBN	9-borabicyclo[3.3.1]nonane
BINAP	2,2'-bis(diphenylphosphino)-1,1'-binaphthyl
	
BINOL	
bipy	2,2'-bipyridyl
Boc	<i>tert</i> -butoxycarbonyl
Bu	butyl
c	cyclo
CAN	ceric ammonium nitrate
cat	catalytic
CB	catecholborane $\left[\text{C}_6\text{H}_4\text{O}_2\text{BH} \right]$
COD	<i>cis,cis</i> -1,5-cyclooctadiene
COT	1,3,5-cyclooctatriene
Cp	cyclopentadienyl
Cy	cyclohexyl
DABCO	1,4-diazabicyclo[2.2.2]octane
DBA	dibenzylideneacetone $[\text{PhCH}=\text{CHCOCH}=\text{CHPh}]$
DBN	1,5-diazabicyclo[4.3.0]non-5-ene
DBU	1,8-diazabicyclo[5.4.0]undec-7-ene
DCC	dicyclohexylcarbodiimide
DDQ	2,3-dichloro-5,6-dicyano-1,4-benzoquinone
DEAD	diethyl azodicarboxylate
diop	(2,3)-O-isopropylidene-2,3-dihydroxy-1,4-bis(diphenylphosphino)-butane
DMAP	4-dimethylaminopyridine
DMBI	1,3-dimethyl-2-phenylbenzimidizoline $\left[\text{C}_6\text{H}_4\text{N}_2\text{CH}_2\text{CH}_3 \right]$

DME	1,2-dimethoxyethane
DMF	<i>N,N</i> -dimethylformamide
DMSO	dimethylsulfoxide
dppb	1,4-bis(diphenylphosphino)butane $[\text{Ph}_2\text{P}(\text{CH}_2)_4\text{PPh}_2]$
dppe	1,2-bis(diphenylphosphino)ethane $[\text{Ph}_2\text{PCH}_2\text{CH}_2\text{PPh}_2]$
dppf	1,1'-bis(diphenylphosphino)ferrocene
dppp	1,3-bis(diphenylphosphino)propane $[\text{Ph}_2\text{P}(\text{CH}_2)_3\text{PPh}_2]$
E^+	electrophile
EDA	ethylenediamine $[\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2]$
EDTA	ethylenediaminetetraacetate
Et	ethyl
Fer	ferrocenyl
fos	6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-3,5-octanedionato $[\text{CF}_3\text{CF}_2\text{CF}_2\text{COCHCOC}(\text{CH}_3)_3]$
Fp	dicarbonyl(η^5 -cyclopentadienyl)iron(I) $[\text{Fe}(\text{CO})_2(\text{cyclopentadienyl})]$
Het	heterocycle
hfacac	1,1,1,5,5,5-hexafluoroacetylacetonate $[\text{CF}_3\text{COCHCOCF}_3]$
HMPA = HMPT	hexamethylphosphoramide
HOAt	1-hydroxy-7-azabenzotriazole 
HOBT	1-hydroxybenzotriazole 
<i>i</i>	iso
Ipc	isopinocampheyl 
L	ligand
LDA	lithium diisopropylamide $[\text{LiN}(i\text{-C}_3\text{H}_7)_2]$
<i>m</i>	meta
MAD	methylaluminum bis(2,6-di- <i>t</i> -butyl-4-methylphenoxide)
	
Me	methyl
MEM	methoxyethoxymethyl $[\text{CH}_3\text{OCH}_2\text{CH}_2\text{OCH}_2-]$
Mes	mesityl
mesal	<i>N</i> -methylsalicylalimine
MOM	methoxymethyl $[\text{CH}_3\text{OCH}_2]$
Ms	methanesulfonyl
<i>n</i>	normal

NADPH	nicotinamide adenine dinucleotide phosphate
NBA	<i>N</i> -bromoacetamide
NBD	norbomadiene
NBS	<i>N</i> -bromosuccinimide
NCS	<i>N</i> -chlorosuccinimide
NIS	<i>N</i> -iodosuccinimide
NMO	<i>N</i> -methylmorpholine oxide 
NMP	<i>N</i> -methyl-2-pyrrolidone
Nuc	nucleophile
<i>o</i>	ortho
<i>p</i>	para
PCC	pyridinium chlorochromate
PDC	pyridinium dichromate
PEG-400	poly(ethylene glycol)-400
Ph	phenyl
phen	1,10-phenanthroline
PPA	polyphosphoric acid
PPTS	pyridinium <i>p</i> -toluenesulfonate
Pr	propyl
py	pyridine
R	an organic group
R _f	perfluoroalkyl
Salen	<i>N,N'</i> -ethylenebis(salicylideneiminato)
salophen	<i>o</i> -phenylenebis(salicylideneiminato)
<i>sec</i>	secondary
Sia	1,2-dimethylpropyl [(CH ₃) ₂ CHCHCH ₃]
S,S-chiraphos	(<i>S,S</i>)-2,3-bis(diphenylphosphino)butane [(<i>S,S</i>)-Ph ₂ PCH(CH ₃)CH(CH ₃)PPh ₂]
<i>t</i>	tertiary
TCNE	tetracyanoethylene
TEMPO	2,2,6,6-tetramethylpiperidine-1-oxyl 
Tf	trifluoromethanesulfonyl
Th	2-thienyl 
THF	tetrahydrofuran
THP	2-tetrahydropyranyl
TMEDA	<i>N,N,N',N'</i> -tetramethylethylenediamine [Me ₂ NCH ₂ CH ₂ NMe ₂]
TMP	2,2,6,6-tetramethylpiperidine 
Tol	tolyl
tolbinap	2,2'-bis(di- <i>p</i> -tolylphosphino)-1,1'-binaphthyl
tp	tetraphenylporphyrin
Ts	<i>p</i> -toluenesulfonyl

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