

DEVELOPMENT AND APPLICATIONS OF THE PALLADIUM-CATALYZED
ENANTIOSELECTIVE OXIDATION OF SECONDARY ALCOHOLS

Thesis by
David Christopher Ebner

In Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

California Institute of Technology

Pasadena, California

2009

(Defended September 11, 2008)

© 2009

David Christopher Ebner

All Rights Reserved

To my family

ACKNOWLEDGEMENTS

First, I need to thank Professor Brian Stoltz, who has been a great advisor, mentor, and friend. His enthusiasm and passion for chemistry is contagious. At the end of our discussions, I have always had new ideas and felt more excitement and motivation for research. I appreciate that he has given me a fairly long leash to explore but has been there for guidance when research is not going as well. Brian has also created an amazing training environment within the lab, as his attention to detail and drive for excellence have prepared me for my future career.

I have also had an outstanding thesis committee: Professor Bob Grubbs, Professor John Bercaw, and Professor Peter Dervan. Professor Grubbs, the chair of my committee, has always had insightful questions, comments, and suggestions, and he has never complained when I run to him with last-minute recommendation letter requests. After taking two courses with Professor Bercaw, I was delighted to have him on my committee. His feedback on my research and proposals has been invaluable, and I have enjoyed our interactions during my time here. While Professor Dervan is the newest member of my committee, he has already provided beneficial guidance and support.

I am deeply indebted to Professor J. Thomas Ippoliti, my undergraduate research advisor. I probably would not be in organic chemistry if he had not taken a chance and allowed a freshman with no organic experience to join his labs. I have always been amazed at his ability to maintain a well-balanced life while supporting a thriving undergraduate research lab and committing so much to his courses, and I consider him a great role model and friend.

Thanks to Lynne Martinez, Dian Buchness, Laura Howe, and Anne Penney for keeping our lab and the department going with a smile. Tom Dunn and Scott Ross have kept the instruments running for me, and Rick Gerhart has been nice enough not to scold me too much when I show up with yet another stuck joint or broken flash column.

I have had the immense pleasure of working with a talented and creative group of coworkers in the Stoltz lab. First, I would like to acknowledge my baymates over the years: Professor Govindasamy Sekar, Mike Meyer, Kristin Finch, Dr. Kousuke Tani, Professor Andy Harned, TC Scotton, Dr. Xiaoqing Han, Allen Hong, and even the Symyx PPR machine. There have been many, and in some cases our time together has been brief, but I have had positive experiences with every one of them. Finally, I can leave the bay in Allen's capable hands.

I really appreciate the support of the older students in the lab, particularly when I was just a naïve first year. Dr. Doug Behenna was instrumental in getting those first few reactions going, and he was always so tolerant of me stopping by to pester him with all kinds of chemistry questions. Professor Neil Garg was also great for chemistry questions and just chatting about life in general. Dr. Raissa Trend is a good friend and was a vital resource for all things organometallic, especially when I was struggling to make palladium complexes or had to use a special technique.

My fellow classmates, Dr. Ryan McFadden and Dr. Dan Caspi, were a great pair of guys with which to learn the ropes in the Stoltz lab. We all started on the same project, and conversations with them my first year really helped get my chemistry working.

I also have to express my gratitude for my other project mates over the years. Professor Eric Ferreira is one of the most amazing, hardworking chemists I have known. He had a hand in getting most of the palladium oxidation projects going in the lab. Dr. Jeff Bagdanoff and Raissa were also instrumental in the oxidative kinetic resolution project, as many of their studies led to my successes in the lab. Dr. Shyam Krishnan was also indirectly on the alcohol oxidation project. He had many helpful chemistry suggestions and put an incredible amount of work to get the big paper on our syntheses of alkaloids out the door. Collaborating with Dr. Zoltán Novák, a postdoctoral scholar in the Stoltz lab, on the kinetic resolution / Claisen chemistry was a very rewarding experience, both personally and scientifically. Our collaborator at the University of York, Professor Peter O'Brien, has been very generous in sending along the latest diamine ligand from his group for us to test in the resolution, and I am happy that our combined efforts were ultimately very fruitful. Dr. Uttam Tambar was a great project mate for the amurensinine research. He taught me a lot about total synthesis and dealing with frustration with a project, and chatting with him my first year was really what convinced me that the Stoltz lab was the place to be.

JT Mohr has been a good friend and an excellent resource for information in topics ranging from pK_a 's to rubik's cubes. He has also been a key player in both the weekly racquetball games and the group poker games, which have been a good distraction from the daily grind of chemistry. Thanks to everyone else involved with those too!

Thank you also to those who proofread portions of my thesis: Dr. Jan Streuff, Jenn Stockdill, Dr. Amanda Jones, and Pam Tadross. I especially owe Jan, who read

through all the chapters of my thesis and had some good comments. I also appreciate the efforts of those who read through my proposals and papers over the years. I don't remember too many specific names, but hopefully you know who you are! Nat Sherden and Hosea Nelson were also very willing to listen to my complaining and provide welcome distractions during long nights spent typing in the computer room, for which I am very grateful.

I look forward to Monday night burgers with Jenny Roizen, Jenn, Andre, and the rest of the BC folk every week. Thanks to Narae Park and Sandy Ma for getting together with me for a few beers at the end of the day once in awhile. Thomas Jensen was only here for 9 months, but I feel like I have known him much longer, and I have valued his friendship.

In addition to where she is mentioned above, Jenn Stockdill at least deserves her own paragraph (but I will try to keep it brief). She joined the lab not too long after I did, and she has been a fellow member of Crellin 264 and a dear friend ever since. I can always count on her for a chat about chemistry or life in general, lunch or late night ice cream runs, and even a few too many margaritas at Amigo's. She is one of the few people who consistently understands my strange sense of humor, for which I am ever grateful. Jenn also was kind enough to play her music loud over and over, so that I might learn the words. She is so thoughtful.

I am very privileged to have gotten to know Professor Jen Dionne more recently. She has been a good support for me while writing my thesis, spending many a day at Broad typing away. She has also been an outstanding host, and I have had many lunches and dinners at her apartment (sometimes she is even there too!).

John Keith has been a great friend over the years. Starting in first year when we fought our way through the organometallic problem sets together, chemistry discussions with him have always been enlightening. He was also a good gym buddy, keeping me motivated to do something athletic on occasion.

Dr. Gavin Murphy, Adam Dennis, Dr. Cristal Gama, and Tammy Campbell have all been close friends throughout my time at Caltech. I enjoyed spending many a night at Amigo's with them. Gavin and Adam were also always ready and willing to join an impromptu poker game.

Even though we are different in some ways, Erik Rodriguez and I have somehow gotten along really well. Wednesday night drinking (yes, it is exactly what it sounds like) was definitely a high point of the week for years. Erik has always been good for a trip to Amigo's too, and he epitomizes the 'work hard, play hard' mentality that I have yet to successfully emulate. There is never a dull moment when Erik is around, but he has also been a great listener when I have needed to do some venting.

Dr. Heather Murrey has also been a very close friend during my time at Caltech. She is an outstanding cook and could drink almost anyone under the table, especially if tequila was involved. She has really been the leader of the gang, getting everyone together and organizing the parties. I have also had many stimulating scientific discussions with her, as her talents in the lab are matched only by her intellectual brilliance.

Chad Vecitis was my roommate for most of my graduate career. I have played more games of Rikiki with him than I can count. From day I arrived in our apartment

first year, he has been a solid and dependable friend. I guess we Midwesterners just stick together.

None of this work would have been possible without the strong support of my mom, dad, and sister. I can't imagine a better environment in which to grow up. My parents have made so many sacrifices to get me where I am today, and I can't thank them enough for that. Apparently, I tried to show my appreciation by taking off halfway across the country, hardly ever visiting, and calling far too infrequently, but they have taken it all and loved me anyway.

There are so many other people to thank, but this has already gotten way too long, and I know you are anxious to get to the actual chemistry that these people made possible, so I will end here. Okay, one more: thanks for reading!

ABSTRACT

The development of new methods for the preparation of chiral alcohols is vital due to the presence of alcohols in natural products, pharmaceuticals, and a variety of synthetic materials, as well as their versatility as synthetic intermediates. Until recently, oxidative kinetic resolution has been a relatively underdeveloped strategy for obtaining enantioenriched alcohols.

The development of a palladium-catalyzed aerobic system for the enantioselective oxidation of secondary alcohols is described. This mild method utilizes (–)-sparteine as a chiral ligand to resolve a wide range of benzylic, allylic, and cyclopropylcarbonyl alcohols to high enantiomeric excesses with excellent selectivity. The resolution of pharmaceutical intermediates and the Claisen rearrangement of resolved allylic alcohols demonstrate the utility of the method.

Mechanistic insights have driven further catalyst development. Anionic ligand modification has provided more efficient catalysts for the resolution of a broader array of substrates. Neutral ligand studies have led to an enantioselective alcohol oxidation system with a diamine pseudo-enantiomeric to (–)-sparteine, allowing access to enantioenriched alcohols in either enantiomeric series.

This methodology has been applied to the enantioselective total synthesis of (–)-amurensinine via a selective C–H insertion, an aryne C–C insertion, and an oxidative kinetic resolution with (–)-sparteine. Use of an alternative diamine in the resolution results in a formal synthesis of (+)-amurensinine.

TABLE OF CONTENTS

Dedication.....	iii
Acknowledgements	iv
Abstract.....	x
Table of Contents	xi
List of Figures	xviii
List of Schemes.....	xxx
List of Tables	xxxiv
List of Abbreviations.....	xxxix
CHAPTER 1: Introduction to Enantioselective Oxidation Chemistry.....	1
1.1 Oxidation in Biological Systems.....	1
1.2 Enantioselective Oxidations in Synthetic Chemistry	2
1.2.1 Oxygenase-Type Reactions	2
1.2.2 Oxidase-Type Reactions.....	3
1.3 Oxidative Kinetic Resolution of Alcohols.....	4
1.3.1 Kinetic Resolutions	4
1.3.2 Previous Catalytic Enantioselective Alcohol Oxidations.....	5
1.3.3 Subsequent Enantioselective Alcohol Oxidations	10
1.4 Conclusion	15

1.5 Notes and References	16
--------------------------------	----

CHAPTER 2: The Development of the Palladium-Catalyzed Oxidative Kinetic

Resolution of Secondary Alcohols	22
2.1 Background and Introduction.....	22
2.2 Reaction Development.....	24
2.2.1 Original Conditions.....	24
2.2.2 Rate Acceleration with Exogenous Base and a Non-Oxidizing Alcohol	26
2.2.3 Chloroform as Solvent in the Resolution	31
2.3 Conclusion	36
2.4 Experimental Section.....	37
2.4.1 Materials and Methods	37
2.4.2 General Oxidative Kinetic Resolution Conditions.....	38
2.4.3 Screening and Optimization Studies	41
2.4.4 Methods for Determination of Conversion.....	44
2.4.5 Methods for Determination of Enantiomeric Excess	44
2.5 Notes and References	45

CHAPTER 3: Scope and Applications of the Oxidative Kinetic Resolution of

Secondary Alcohols	54
3.1 Background and Introduction.....	54
3.2 Substrate Scope of the Palladium-Catalyzed Enantioselective Oxidation.....	55
3.2.1 Benzylic Alcohols	55
3.2.2 Allylic Alcohols.....	59
3.2.3 Cyclopropylcarbinyl Alcohols.....	64
3.2.4 General Trends and Limitations.....	66
3.2.5 Selectivity Model	67
3.3 Applications	68
3.3.1 <i>meso</i> -Diol Desymmetrizations.....	68
3.3.2 Kinetic Resolution / Claisen Sequence	70
3.3.3 Resolution of Pharmaceutical Intermediates	72
3.3.4 Resolution of Intermediates in Natural Product Syntheses	73
3.4 Conclusion	75
3.5 Experimental Section.....	77
3.5.1 Materials and Methods	77
3.5.2 General Oxidative Kinetic Resolution Conditions	79
3.5.3 Preparative Procedures	82
3.5.4 Methods for Determination of Conversion.....	121
3.5.5 Methods for Determination of Enantiomeric Excess	124
3.6 Notes and References	128

APPENDIX 1: Spectra Relevant to Chapter 3	136
CHAPTER 4: Advanced Catalyst Design in the Oxidative Kinetic Resolution.....	225
4.1 Background and Introduction.....	225
4.2 Counterion Studies in the Kinetic Resolution.....	232
4.2.1 Phenoxides.....	232
4.2.2 Bromide as Counterion in the Resolution	241
4.3 Neutral Ligand Studies	249
4.3.1 Background and Early Results.....	249
4.3.2 (–)-Cytisine-Based Diamines in the Oxidative Kinetic Resolution with PdCl ₂	253
4.3.3 Alternative Diamine with PdBr ₂ in the Oxidative Kinetic Resolution	261
4.4 Conclusion	265
4.5 Experimental Section.....	266
4.5.1 Materials and Methods	266
4.5.2 Preparation of Palladium Complexes and Diamines.....	267
4.5.3 General Procedures	274
4.5.4 Preparative Resolution of Alcohols	283
4.5.5 Methods for Determination of Conversion.....	287

4.5.6 Methods for Determination of Enantiomeric Excess	288
4.6 Notes and References	289
APPENDIX 2: Spectra Relevant to Chapter 4	293
APPENDIX 3: X-Ray Crystallographic Data Relevant to Chapter 4.....	306
A3.1 Pd(N-Me Diamine)Cl ₂ (269).....	306
A3.2 Pd(N-Et Diamine)Cl ₂ (270)	314
A3.3 Pd(N-Me Diamine)Br ₂ (274)	323
CHAPTER 5: A Convergent Total Synthesis of (+)-Amurensinine and Formal	
Synthesis of (–)-Amurensinine via Oxidative Kinetic Resolution	329
5.1 Background and Introduction.....	329
5.1.1 Isopavine Natural Products.....	329
5.1.2 Previous Isopavine Syntheses.....	330
5.1.3 Retrosynthetic Analysis of Amurensinine.....	331
5.2 Total Synthesis of (+)-Amurensinine	332
5.2.1 Initial Route	332
5.2.2 Alternate End Sequence	338

	xvi
5.2.3 Final Route to (+)-Amurensinine.....	339
5.3 Formal Synthesis of (-)-Amurensinine	343
5.3.1 Enantioenriched Ketosilane Reduction	343
5.3.2 Preparation of Enantioenriched Hydroxysilane by Resolution	344
5.4 Conclusion	345
5.5 Experimental Section.....	347
5.5.1 Materials and Methods	347
5.5.2 Preparative Procedures	348
5.6 Notes and References	379
APPENDIX 4: Synthetic Summary for (+)-Amurensinine.....	383
APPENDIX 5: Spectra Relevant to Chapter 5	386
APPENDIX 6: The Development of a Scaleable Acyl-Alkylation of Arynes and Application to the Construction of 1,3-Dihydroxynaphthalenes.....	419
A6.1 Background and Introduction	419
A6.2 The Development of a Scaleable Aryne Insertion into β -Ketoesters.....	421
A6.3 Application to the Construction of 1,3-Dihydroxynaphthalenes	422

	xvii
A6.4 Conclusion	423
A6.5 Experimental Section	424
A6.5.1 Materials and Methods.....	424
A6.5.2 Preparative Procedures.....	425
A6.6 Notes and References	428
APPENDIX 7: Spectra Relevant to Appendix 6	429
APPENDIX 8: Notebook Cross-Reference.....	436
Comprehensive Bibliography	441
About the Author.....	463

LIST OF FIGURES

CHAPTER 1

Figure 1.1.1	Oxygenase and oxidase enzymes	1
Figure 1.2.1	Synthetic asymmetric oxygenase-type chemistry	3
Figure 1.2.2	Proposed synthetic asymmetric oxidase-type chemistry	4
Figure 1.3.1	Kinetic resolution overview	5

CHAPTER 2

Figure 2.2.1	Structures of ligands in Table 2.2.1	25
--------------	--	----

CHAPTER 3

Figure 3.2.1	Enantioenriched ketones obtained from the resolution.....	65
Figure 3.2.2	Alcohols of low reactivity in the oxidation.....	66
Figure 3.2.3	Alcohols oxidized with low selectivity.....	67

APPENDIX 1

Figure A1.1	^1H NMR (300 MHz, CDCl_3) of compound (-)- 74	137
Figure A1.2	Infrared spectrum (thin film/ NaCl) of compound (-)- 74	138
Figure A1.3	^{13}C NMR (75 MHz, CDCl_3) of compound (-)- 74	138
Figure A1.4	^1H NMR (300 MHz, CDCl_3) of compound (-)- 76	139
Figure A1.5	Infrared spectrum (thin film/ NaCl) of compound (-)- 76	140
Figure A1.6	^{13}C NMR (75 MHz, CDCl_3) of compound (-)- 76	140

Figure A1.7 ^1H NMR (300 MHz, CDCl_3) of compound (-)- 96	141
Figure A1.8 Infrared spectrum (thin film/ NaCl) of compound (-)- 96	142
Figure A1.9 ^{13}C NMR (75 MHz, CDCl_3) of compound (-)- 96	142
Figure A1.10 ^1H NMR (300 MHz, CDCl_3) of compound (<i>S</i>)- 102	143
Figure A1.11 Infrared spectrum (thin film/ NaCl) of compound (<i>S</i>)- 102	144
Figure A1.12 ^{13}C NMR (75 MHz, CDCl_3) of compound (<i>S</i>)- 102	144
Figure A1.13 ^1H NMR (300 MHz, CDCl_3) of compound (+)- 111	145
Figure A1.14 Infrared spectrum (thin film/ NaCl) of compound (+)- 111	146
Figure A1.15 ^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 111	146
Figure A1.16 ^1H NMR (300 MHz, CDCl_3) of compound (+)- 112	147
Figure A1.17 Infrared spectrum (thin film/ NaCl) of compound (+)- 112	148
Figure A1.18 ^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 112	148
Figure A1.19 ^1H NMR (300 MHz, CDCl_3) of compound (+)- 113	149
Figure A1.20 Infrared spectrum (thin film/ NaCl) of compound (+)- 113	150
Figure A1.21 ^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 113	150
Figure A1.22 ^1H NMR (300 MHz, C_6D_6) of compound 202	151
Figure A1.23 Infrared spectrum (thin film/ NaCl) of compound 202	152
Figure A1.24 ^{13}C NMR (75 MHz, C_6D_6) of compound 202	152
Figure A1.25 ^1H NMR (300 MHz, CDCl_3) of compound 203	153
Figure A1.26 Infrared spectrum (thin film/ NaCl) of compound 203	154
Figure A1.27 ^{13}C NMR (75 MHz, CDCl_3) of compound 203	154
Figure A1.28 ^1H NMR (300 MHz, CDCl_3) of compound (+)- 114	155
Figure A1.29 Infrared spectrum (thin film/ NaCl) of compound (+)- 114	156

Figure A1.30	^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 114	156
Figure A1.31	^1H NMR (300 MHz, CDCl_3) of compound 205	157
Figure A1.32	Infrared spectrum (thin film/ NaCl) of compound 205	158
Figure A1.33	^{13}C NMR (75 MHz, CDCl_3) of compound 205	158
Figure A1.34	^1H NMR (300 MHz, CDCl_3) of compound (+)- 115	159
Figure A1.35	Infrared spectrum (thin film/ NaCl) of compound (+)- 115	160
Figure A1.36	^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 115	160
Figure A1.37	^1H NMR (300 MHz, CDCl_3) of compound 207	161
Figure A1.38	Infrared spectrum (thin film/ NaCl) of compound 207	162
Figure A1.39	^{13}C NMR (75 MHz, CDCl_3) of compound 207	162
Figure A1.40	^1H NMR (300 MHz, CDCl_3) of compound (+)- 116	163
Figure A1.41	Infrared spectrum (thin film/ NaCl) of compound (+)- 116	164
Figure A1.42	^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 116	164
Figure A1.43	^1H NMR (300 MHz, CDCl_3) of compound 209	165
Figure A1.44	Infrared spectrum (thin film/ NaCl) of compound 209	166
Figure A1.45	^{13}C NMR (75 MHz, CDCl_3) of compound 209	166
Figure A1.46	^1H NMR (300 MHz, CDCl_3) of compound (+)- 117	167
Figure A1.47	Infrared spectrum (thin film/ NaCl) of compound (+)- 117	168
Figure A1.48	^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 117	168
Figure A1.49	^1H NMR (300 MHz, CDCl_3) of compound 212	169
Figure A1.50	Infrared spectrum (thin film/ NaCl) of compound 212	170
Figure A1.51	^{13}C NMR (75 MHz, CDCl_3) of compound 212	170
Figure A1.52	^1H NMR (300 MHz, CDCl_3) of compound (+)- 118	171

Figure A1.53 Infrared spectrum (thin film/NaCl) of compound (+)- 118	172
Figure A1.54 ¹³ C NMR (75 MHz, CDCl ₃) of compound (+)- 118	172
Figure A1.55 ¹ H NMR (300 MHz, CDCl ₃) of compound (-)- 120	173
Figure A1.56 Infrared spectrum (thin film/NaCl) of compound (-)- 120	174
Figure A1.57 ¹³ C NMR (75 MHz, CDCl ₃) of compound (-)- 120	174
Figure A1.58 ¹ H NMR (300 MHz, CDCl ₃) of compound 216	175
Figure A1.59 Infrared spectrum (thin film/NaCl) of compound 216	176
Figure A1.60 ¹³ C NMR (75 MHz, CDCl ₃) of compound 216	176
Figure A1.61 ¹ H NMR (300 MHz, CDCl ₃) of compound (-)- 122	177
Figure A1.62 Infrared spectrum (thin film/NaCl) of compound (-)- 122	178
Figure A1.63 ¹³ C NMR (75 MHz, CDCl ₃) of compound (-)- 122	178
Figure A1.64 ¹ H NMR (300 MHz, CDCl ₃) of compound 217	179
Figure A1.65 Infrared spectrum (thin film/NaCl) of compound 217	180
Figure A1.66 ¹³ C NMR (75 MHz, CDCl ₃) of compound 217	180
Figure A1.67 ¹ H NMR (300 MHz, CDCl ₃) of compound (-)- 123	181
Figure A1.68 Infrared spectrum (thin film/NaCl) of compound (-)- 123	182
Figure A1.69 ¹³ C NMR (75 MHz, CDCl ₃) of compound (-)- 123	182
Figure A1.70 ¹ H NMR (300 MHz, CDCl ₃) of compound 221	183
Figure A1.71 Infrared spectrum (thin film/NaCl) of compound 221	184
Figure A1.72 ¹³ C NMR (75 MHz, CDCl ₃) of compound 221	184
Figure A1.73 ¹ H NMR (300 MHz, CDCl ₃) of compound (-)- 124	185
Figure A1.74 Infrared spectrum (thin film/NaCl) of compound (-)- 124	186
Figure A1.75 ¹³ C NMR (75 MHz, CDCl ₃) of compound (-)- 124	186

Figure A1.76	^1H NMR (300 MHz, CDCl_3) of compound 152	187
Figure A1.77	Infrared spectrum (thin film/ NaCl) of compound 152	188
Figure A1.78	^{13}C NMR (75 MHz, CDCl_3) of compound 152	188
Figure A1.79	^1H NMR (300 MHz, CDCl_3) of compound 153	189
Figure A1.80	Infrared spectrum (thin film/ NaCl) of compound 153	190
Figure A1.81	^{13}C NMR (75 MHz, CDCl_3) of compound 153	190
Figure A1.82	^1H NMR (300 MHz, CDCl_3) of compound 154	191
Figure A1.83	Infrared spectrum (thin film/ NaCl) of compound 154	192
Figure A1.84	^{13}C NMR (75 MHz, CDCl_3) of compound 154	192
Figure A1.85	^1H NMR (300 MHz, CDCl_3) of compound 155	193
Figure A1.86	Infrared spectrum (thin film/ NaCl) of compound 155	194
Figure A1.87	^{13}C NMR (75 MHz, CDCl_3) of compound 155	194
Figure A1.88	^1H NMR (300 MHz, CDCl_3) of compound 156	195
Figure A1.89	Infrared spectrum (thin film/ NaCl) of compound 156	196
Figure A1.90	^{13}C NMR (75 MHz, CDCl_3) of compound 156	196
Figure A1.91	^1H NMR (300 MHz, CDCl_3) of compound 157	197
Figure A1.92	Infrared spectrum (thin film/ NaCl) of compound 157	198
Figure A1.93	^{13}C NMR (75 MHz, CDCl_3) of compound 157	198
Figure A1.94	^1H NMR (300 MHz, CDCl_3) of compound 158	199
Figure A1.95	Infrared spectrum (thin film/ NaCl) of compound 158	200
Figure A1.96	^{13}C NMR (75 MHz, CDCl_3) of compound 158	200
Figure A1.97	^1H NMR (300 MHz, CDCl_3) of compound 159	201
Figure A1.98	Infrared spectrum (thin film/ NaCl) of compound 159	202

Figure A1.99	^{13}C NMR (75 MHz, CDCl_3) of compound 159	202
Figure A1.100	^1H NMR (300 MHz, CDCl_3) of compound 160	203
Figure A1.101	Infrared spectrum (thin film/ NaCl) of compound 160	204
Figure A1.102	^{13}C NMR (75 MHz, CDCl_3) of compound 160	204
Figure A1.103	^1H NMR (300 MHz, CDCl_3) of compound 161	205
Figure A1.104	Infrared spectrum (thin film/ NaCl) of compound 161	206
Figure A1.105	^{13}C NMR (75 MHz, CDCl_3) of compound 161	206
Figure A1.106	^1H NMR (300 MHz, CDCl_3) of compound 162	207
Figure A1.107	Infrared spectrum (thin film/ NaCl) of compound 162	208
Figure A1.108	^{13}C NMR (75 MHz, CDCl_3) of compound 162	208
Figure A1.109	^1H NMR (300 MHz, CDCl_3) of compound 163	209
Figure A1.110	Infrared spectrum (thin film/ NaCl) of compound 163	210
Figure A1.111	^{13}C NMR (75 MHz, CDCl_3) of compound 163	210
Figure A1.112	^1H NMR (300 MHz, CDCl_3) of compound 164	211
Figure A1.113	Infrared spectrum (thin film/ NaCl) of compound 164	212
Figure A1.114	^{13}C NMR (75 MHz, CDCl_3) of compound 164	212
Figure A1.115	^1H NMR (300 MHz, CDCl_3) of compound 165	213
Figure A1.116	Infrared spectrum (thin film/ NaCl) of compound 165	214
Figure A1.117	^{13}C NMR (75 MHz, CDCl_3) of compound 165	214
Figure A1.118	^1H NMR (300 MHz, CDCl_3) of compound 166	215
Figure A1.119	Infrared spectrum (thin film/ NaCl) of compound 166	216
Figure A1.120	^{13}C NMR (75 MHz, CDCl_3) of compound 166	216
Figure A1.121	^1H NMR (300 MHz, CDCl_3) of compound 167	217

Figure A1.122	Infrared spectrum (thin film/NaCl) of compound 167	218
Figure A1.123	¹³ C NMR (75 MHz, CDCl ₃) of compound 167	218
Figure A1.124	¹ H NMR (300 MHz, CDCl ₃) of compound 168	219
Figure A1.125	Infrared spectrum (thin film/NaCl) of compound 168	220
Figure A1.126	¹³ C NMR (75 MHz, CDCl ₃) of compound 168	220
Figure A1.127	¹ H NMR (300 MHz, CDCl ₃) of compound 169	221
Figure A1.128	Infrared spectrum (thin film/NaCl) of compound 169	222
Figure A1.129	¹³ C NMR (75 MHz, CDCl ₃) of compound 169	222
Figure A1.130	¹ H NMR (300 MHz, CDCl ₃) of compound 170	223
Figure A1.131	Infrared spectrum (thin film/NaCl) of compound 170	224
Figure A1.132	¹³ C NMR (75 MHz, CDCl ₃) of compound 170	224

CHAPTER 4

Figure 4.1.1	Theoretical calculations on the enantioselective oxidation.....	228
Figure 4.1.2	Structure of Pd(sparteine)Cl ₂	229
Figure 4.1.3	Structure of Pd(sparteine)(OAc) ₂	230
Figure 4.1.4	Structure of palladium alkoxide 232	231
Figure 4.2.1	Structure of Pd(sparteine)(OC ₆ F ₅) ₂	234
Figure 4.2.2	Structure of Pd(sparteine)Br ₂	242
Figure 4.3.1	Previously examined unsuccessful ligands.....	250
Figure 4.3.2	Ligands not promoting oxidative kinetic resolution.....	251
Figure 4.3.3	Structure of <i>N</i> -methyl complex 269	256
Figure 4.3.4	Structure of <i>N</i> -ethyl complex 270	257

Figure 4.3.5	Structure of dibromide complex 274	262
--------------	---	-----

APPENDIX 2

Figure A2.1	^1H NMR (500 MHz, CDCl_3) of compound 243	294
Figure A2.2	Infrared spectrum (thin film/ NaCl) of compound 243	295
Figure A2.3	^{13}C NMR (126 MHz, CDCl_3) of compound 243	295
Figure A2.4	^1H NMR (300 MHz, CDCl_3) of compound 269	296
Figure A2.5	Infrared spectrum (thin film/ NaCl) of compound 269	297
Figure A2.6	^{13}C NMR (75 MHz, CDCl_3) of compound 269	297
Figure A2.7	^1H NMR (300 MHz, CDCl_3) of compound 270	298
Figure A2.8	Infrared spectrum (thin film/ NaCl) of compound 270	299
Figure A2.9	^{13}C NMR (75 MHz, CDCl_3) of compound 270	299
Figure A2.10	^1H NMR (300 MHz, CDCl_3) of compound 274	300
Figure A2.11	Infrared spectrum (thin film/ NaCl) of compound 274	301
Figure A2.12	^{13}C NMR (75 MHz, CDCl_3) of compound 274	301
Figure A2.13	^1H NMR (500 MHz, CDCl_3) of compound 267	302
Figure A2.14	Infrared spectrum (thin film/ NaCl) of compound 267	303
Figure A2.15	^{13}C NMR (126 MHz, CDCl_3) of compound 267	303
Figure A2.16	^1H NMR (500 MHz, CDCl_3) of compound 268	304
Figure A2.17	Infrared spectrum (thin film/ NaCl) of compound 268	305
Figure A2.18	^{13}C NMR (126 MHz, CDCl_3) of compound 268	305

APPENDIX 3

Figure A3.1.1	Pd(N-Me Diamine)Cl ₂ (269).....	306
Figure A3.1.2	Pd(N-Me Diamine)Cl ₂ (269).....	308
Figure A3.1.3	Unit cell of Pd(N-Me Diamine)Cl ₂ (269).....	309
Figure A3.1.4	Stereo view of unit cell of Pd(N-Me Diamine)Cl ₂ (269).....	309
Figure A3.2.1	Pd(N-Et Diamine)Cl ₂ (270).....	314
Figure A3.2.2	Pd(N-Et Diamine)Cl ₂ (270).....	316
Figure A3.2.3	Unit cell of Pd(N-Et Diamine)Cl ₂ (270).....	317
Figure A3.2.4	Stereo view of unit cell of Pd(N-Et Diamine)Cl ₂ (270).....	317
Figure A3.3.1	Pd(N-Me Diamine)Br ₂ (274).....	323
Figure A3.3.2	Pd(N-Me Diamine)Br ₂ (274).....	325

CHAPTER 5

Figure 5.1.1	Representative isopavine natural products.....	329
--------------	--	-----

APPENDIX 5

Figure A5.1	¹ H NMR (300 MHz, CDCl ₃) of compound 301	387
Figure A5.2	Infrared spectrum (thin film/NaCl) of compound 301	388
Figure A5.3	¹³ C NMR (75 MHz, CDCl ₃) of compound 301	388
Figure A5.4	¹ H NMR (500 MHz, CDCl ₃) of compound 296	389
Figure A5.5	Infrared spectrum (thin film/NaCl) of compound 296	390
Figure A5.6	¹³ C NMR (125 MHz, CDCl ₃) of compound 296	390
Figure A5.7	¹ H NMR (300 MHz, C ₆ D ₆) of compound 303	391
Figure A5.8	Infrared spectrum (thin film/NaCl) of compound 303	392

Figure A5.9	^{13}C NMR (75 MHz, C_6D_6) of compound 303	392
Figure A5.10	^1H NMR (300 MHz, CDCl_3) of compound 304	393
Figure A5.11	Infrared spectrum (thin film/ NaCl) of compound 304	394
Figure A5.12	^{13}C NMR (75 MHz, CDCl_3) of compound 304	394
Figure A5.13	^1H NMR (300 MHz, C_6D_6) of compound (+)- 308	395
Figure A5.14	Infrared spectrum (thin film/ NaCl) of compound (+)- 308	396
Figure A5.15	^{13}C NMR (75 MHz, C_6D_6) of compound (+)- 308	396
Figure A5.16	^1H NMR (500 MHz, CDCl_3) of compound (-)- 309	397
Figure A5.17	Infrared spectrum (thin film/ NaCl) of compound (-)- 309	398
Figure A5.18	^{13}C NMR (125 MHz, CDCl_3) of compound (-)- 309	398
Figure A5.19	^1H NMR (500 MHz, CDCl_3) of compound (+)- 293	399
Figure A5.20	Infrared spectrum (thin film/ NaCl) of compound (+)- 293	400
Figure A5.21	^{13}C NMR (125 MHz, CDCl_3) of compound (+)- 293	400
Figure A5.22	^1H NMR (300 MHz, CDCl_3) of compound (+)- 282	401
Figure A5.23	Infrared spectrum (thin film/ NaCl) of compound (+)- 282	402
Figure A5.24	^{13}C NMR (75 MHz, CDCl_3) of compound (+)- 282	402
Figure A5.25	^1H NMR (300 MHz, CDCl_3) of compound (\pm)- 314	403
Figure A5.26	Infrared spectrum (thin film/ NaCl) of compound (\pm)- 314	404
Figure A5.27	^{13}C NMR (126 MHz, CDCl_3) of compound (\pm)- 314	404
Figure A5.28	^1H NMR (300 MHz, C_6D_6) of compound (+)- 321	405
Figure A5.29	Infrared spectrum (thin film/ NaCl) of compound (+)- 321	406
Figure A5.30	^{13}C NMR (75 MHz, C_6D_6) of compound (+)- 321	406
Figure A5.31	^1H NMR (300 MHz, C_6D_6) of compound (-)- 315	407

Figure A5.32 Infrared spectrum (thin film/NaCl) of compound (–)- 315	408
Figure A5.33 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (–)- 315	408
Figure A5.34 ¹ H NMR (300 MHz, C ₆ D ₆) of compound (–)- 316	409
Figure A5.35 Infrared spectrum (thin film/NaCl) of compound (–)- 316	410
Figure A5.36 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (–)- 316	410
Figure A5.37 ¹ H NMR (300 MHz, C ₆ D ₆) of compound (–)- 317	411
Figure A5.38 Infrared spectrum (thin film/NaCl) of compound (–)- 317	412
Figure A5.39 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (–)- 317	412
Figure A5.40 ¹ H NMR (300 MHz, C ₆ D ₆) of compound (–)- 318	413
Figure A5.41 Infrared spectrum (thin film/NaCl) of compound (–)- 318	414
Figure A5.42 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (–)- 318	414
Figure A5.43 ¹ H NMR (300 MHz, C ₆ D ₆) of compound (+)- 319	415
Figure A5.44 Infrared spectrum (thin film/NaCl) of compound (+)- 319	416
Figure A5.45 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (+)- 319	416
Figure A5.46 ¹ H NMR (300 MHz, C ₆ D ₆) of compound (–)- 320	417
Figure A5.47 Infrared spectrum (thin film/NaCl) of compound (–)- 320	418
Figure A5.48 ¹³ C NMR (75 MHz, C ₆ D ₆) of compound (–)- 320	418

APPENDIX 7

Figure A7.1 ¹ H NMR (300 MHz, CDCl ₃) of compound 327	430
Figure A7.2 Infrared spectrum (thin film/NaCl) of compound 327	431
Figure A7.3 ¹³ C NMR (75 MHz, CDCl ₃) of compound 327	431
Figure A7.4 ¹ H NMR (300 MHz, CDCl ₃) of compound 330	432

Figure A7.5 Infrared spectrum (thin film/NaCl) of compound 330	433
Figure A7.6 ^{13}C NMR (75 MHz, CDCl_3) of compound 330	433
Figure A7.7 ^1H NMR (300 MHz, CDCl_3) of compound 334	434
Figure A7.8 Infrared spectrum (thin film/NaCl) of compound 334	435
Figure A7.9 ^{13}C NMR (75 MHz, CDCl_3) of compound 334	435

LIST OF SCHEMES

CHAPTER 1

Scheme 1.3.1	Rychnovsky's chiral TEMPO-based oxidation.....	6
Scheme 1.3.2	Chiral nitroxyl oxidation under electrolysis.....	6
Scheme 1.3.3	Nitroxyl oxidation with a chiral base.....	7
Scheme 1.3.4	Ohkuba ruthenium-catalyzed transfer hydrogenation	8
Scheme 1.3.5	Noyori ruthenium-catalyzed transfer hydrogenation.....	8
Scheme 1.3.6	Uemura ruthenium-catalyzed transfer hydrogenation	9
Scheme 1.3.7	Katsuki aerobic enantioselective alcohol oxidation	10
Scheme 1.3.8	Manganese-catalyzed oxidation with $\text{PhI}(\text{OAc})_2$	11
Scheme 1.3.9	Gao iridium-catalyzed transfer hydrogenation.....	11
Scheme 1.3.10	Ikariya iridium-catalyzed aerobic oxidation	12
Scheme 1.3.11	Toste vanadium-catalyzed aerobic oxidation.....	13
Scheme 1.3.12	Chen vanadium-catalyzed aerobic oxidations.....	14
Scheme 1.3.13	Onomura copper-catalyzed enantioselective oxidations.....	15

CHAPTER 2

Scheme 2.1.1	Uemura oxidation conditions	23
Scheme 2.1.2	Uemura oxidation proposed mechanism.....	23
Scheme 2.2.1	Original resolution conditions	26
Scheme 2.2.2	Potential role of excess (-)-sparteine.....	29
Scheme 2.2.3	Synthesis of palladium carbonate 69	30

Scheme 2.2.4	Possible racemization mechanism with <i>tert</i> -butoxide	31
--------------	--	----

CHAPTER 3

Scheme 3.2.1	Synthesis of 2-arylcycloalkenols	62
Scheme 3.2.2	Model for selectivity of the resolution.....	68
Scheme 3.3.1	Desymmetrization of <i>meso</i> -diol 146	69
Scheme 3.3.2	Desymmetrization of polyether <i>meso</i> -diols	69
Scheme 3.3.3	Oxidative cyclization of a Claisen product.....	72
Scheme 3.3.4	Resolved alcohols as pharmaceutical intermediates.....	73
Scheme 3.3.5	Enantioselective oxidations for natural product synthesis.....	74

CHAPTER 4

Scheme 4.1.1	Resolution with (–)-sparteine and Pd(OAc) ₂	225
Scheme 4.1.2	Proposed mechanistic role of counterion	226
Scheme 4.1.3	Model for selectivity of the resolution.....	232
Scheme 4.3.1	Diamine 248 in asymmetric transformations	253
Scheme 4.3.2	Known syntheses of (–)-cytisine-based diamines	254
Scheme 4.3.3	Syntheses of novel diamines	255
Scheme 4.3.4	Synthesis of dichloride complexes of diamines	255
Scheme 4.3.5	Comparison of selectivity with different diamine ligands.....	261
Scheme 4.3.6	Synthesis of dibromide complex 274	262

CHAPTER 5

Scheme 5.1.1	Classical approach to isopavine synthesis	330
Scheme 5.1.2	Auxiliary-based synthesis of (-)-amurensinine.....	330
Scheme 5.1.3	Retrosynthesis of (+)-amurensinine.....	331
Scheme 5.2.1	Synthesis of aryne precursor 296	332
Scheme 5.2.2	Synthesis of β -ketoester 304	333
Scheme 5.2.3	Aryne insertion	333
Scheme 5.2.4	Diastereoselective ketone reduction of hydroxyester (\pm)- 308	334
Scheme 5.2.5	Resolution of hydroxyester (\pm)- 309	335
Scheme 5.2.6	Initial route to complete (+)-amurensinine	336
Scheme 5.2.7	Possible racemization mechanism.....	337
Scheme 5.2.8	Lactonization by epimerization of hydroxyester (\pm)- 309	337
Scheme 5.2.9	Long route to complete (+)-amurensinine	338
Scheme 5.2.10	Hydroxysilane (\pm)- 317 oxidative kinetic resolution.....	340
Scheme 5.2.11	Non-enantioselective oxidations of hydroxysilane (\pm)- 317	341
Scheme 5.2.12	Rate enhancement with Pd(sparteine)Br ₂	342
Scheme 5.2.13	Final route to complete (+)-amurensinine.....	342
Scheme 5.3.1	Diastereoselective ketosilane reduction.....	344
Scheme 5.3.2	Resolution with diamine 248 under O ₂	345
Scheme 5.3.3	Resolution with diamine 248 under ambient air	345

APPENDIX 4

Scheme A4.1	Synthesis of silyl triflate 296	384
Scheme A4.2	Synthesis of β -ketoester 304	384

Scheme A4.3	Synthesis of (+)-amurensinine ((+)- 282)	385
-------------	--	-----

APPENDIX 6

Scheme A6.1.1	Kobayashi's aryne preparation	419
Scheme A6.1.2	Aryne insertion and possible mechanism	420
Scheme A6.1.3	Ring expansion by aryne insertion	420
Scheme A6.2.1	Initial procedure with byproduct	421
Scheme A6.2.2	Final large scale aryne insertion	422
Scheme A6.3.1	Base-promoted dihydroxynaphthalene formation	423

LIST OF TABLES

CHAPTER 2

Table 2.2.1	Initial ligand screen for the oxidative kinetic resolution	24
Table 2.2.2	Catalyst activity versus (-)-sparteine loading	26
Table 2.2.3	Base screening studies with amines and carbonates.....	27
Table 2.2.4	Catalyst activity with (-)-sparteine and other amines	28
Table 2.2.5	Comparison of various conditions in toluene.....	29
Table 2.2.6	Evaluation of <i>tert</i> -butoxide additives	31
Table 2.2.7	Solvent screen with Pd(sparteine)Cl ₂	33
Table 2.2.8	IR data supporting hydrogen-bond donation.....	34
Table 2.2.9	Chloroform:toluene ratio variation.....	35
Table 2.2.10	Chloroform conditions with O ₂ or ambient air.....	35
Table 2.4.1	Methods for determination of conversion.....	44
Table 2.4.2	Methods for determination of enantiomeric excess.....	44

CHAPTER 3

Table 3.1.1	Various conditions for enantioselective alcohol oxidation.....	55
Table 3.2.1	Resolution of 1-arylethanols	57
Table 3.2.2	Resolution of other benzylic alcohols.....	59
Table 3.2.3	Resolution of cyclic allylic alcohols.....	61
Table 3.2.4	Resolution of 2-arylcycloalkenols	63
Table 3.2.5	Resolution of 3-substituted allylic alcohols	64

Table 3.2.6	Resolution of cyclopropylcarbinyl alcohols.....	65
Table 3.3.1	Claisen rearrangement of allylic alcohols.....	71
Table 3.5.1	Methods for determination of conversion.....	121
Table 3.5.2	Methods for determination of enantiomeric excess.....	124

CHAPTER 4

Table 4.1.1	Palladium source screen in toluene	227
Table 4.2.1	Phenoxide screen with (\pm)-1-phenylpropanol	235
Table 4.2.2	Phenoxide screen with (\pm)-1-phenylethanol	236
Table 4.2.3	Phenoxide screen with secondary alcohol (\pm)- 73	238
Table 4.2.4	BINOL-derived phenoxides as additives	240
Table 4.2.5	Counterion variation with phenoxides.....	241
Table 4.2.6	Rate of oxidation of various palladium precatalysts	243
Table 4.2.7	Various dibromide precursors in the resolution	243
Table 4.2.8	Solvent screen with Pd(sparteine)Br ₂	245
Table 4.2.9	Pd(sparteine)Br ₂ conditions in toluene	246
Table 4.2.10	Slow substrates with Pd(sparteine)Cl ₂	247
Table 4.2.11	Substrate scope with Pd(sparteine)Br ₂	249
Table 4.3.1	Oxidation rates with various diamines.....	252
Table 4.3.2	Diamine substituent screen in the resolution	258
Table 4.3.3	<i>N</i> -Ethyl diamine resolution in toluene with Pd(nbd)Cl ₂	259
Table 4.3.4	<i>N</i> -Methyl diamine resolution in chloroform with Pd(nbd)Cl ₂	260
Table 4.3.5	Optimization of with <i>N</i> -methyl diamine and PdBr ₂ sources	263

Table 4.3.6	Scope with dibromide catalysts of <i>N</i> -methyl diamine.....	264
Table 4.5.1	Methods for determination of conversion.....	287
Table 4.5.2	Methods for determination of enantiomeric excess.....	288

APPENDIX 3

Table A3.1.1	Crystal data and structure refinement for DCE03 (CCDC 274539).....	307
Table A3.1.2	Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for DCE03 (CCDC 274539). $U(\text{eq})$ is defined as the trace of the orthogonalized U^{ij} tensor.....	310
Table A3.1.3	Selected bond lengths [\AA] and angles [$^\circ$] for DCE03 (CCDC 274539).....	310
Table A3.1.4	Bond lengths [\AA] and angles [$^\circ$] for DCE03 (CCDC 274539)....	311
Table A3.1.5	Anisotropic displacement parameters ($\text{\AA}^2 \times 10^4$) for DCE03 (CCDC 274539). The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 \cdot a^2 \cdot U^{11} + \dots + 2h \cdot k \cdot a \cdot b \cdot U^{12}]$	312
Table A3.1.6	Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for DCE03 (CCDC 274539).....	313
Table A3.2.1	Crystal data and structure refinement for DCE02 (CCDC 274867)	315
Table A3.2.2	Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for DCE02 (CCDC	

	274867). $U(\text{eq})$ is defined as the trace of the orthogonalized U^{ij} tensor.....	318
Table A3.2.3	Selected bond lengths [\AA] and angles [$^\circ$] for DCE02 (CCDC 274867).....	318
Table A3.2.4	Bond lengths [\AA] and angles [$^\circ$] for DCE02 (CCDC 274867)....	319
Table A3.2.5	Anisotropic displacement parameters ($\text{\AA}^2 \times 10^4$) for DCE02 (CCDC 274867). The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 \cdot a^2 \cdot U^{11} + \dots + 2h \cdot k \cdot a \cdot b \cdot U^{12}]$	321
Table A3.2.6	Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for DCE02 (CCDC 274867)	322
Table A3.3.1	Crystal data and structure refinement for DCE04 (CCDC 639648)	324
Table A3.3.2	Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for DCE04 (CCDC 639648). $U(\text{eq})$ is defined as the trace of the orthogonalized U^{ij} tensor.....	326
Table A3.3.3	Selected bond lengths [\AA] and angles [$^\circ$] for DCE04 (CCDC 639648).....	326
Table A3.3.4	Bond lengths [\AA] and angles [$^\circ$] for DCE04 (CCDC 639648)....	327
Table A3.3.5	Anisotropic displacement parameters ($\text{\AA}^2 \times 10^4$) for DCE04 (CCDC 639648). The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 \cdot a^2 \cdot U^{11} + \dots + 2h \cdot k \cdot a \cdot b \cdot U^{12}]$	328

CHAPTER 5

Table 5.5.1	Radical inhibitor screening	370
-------------	-----------------------------------	-----

APPENDIX 6

Table A6.2.1	Screen of reagent ratios in the aryne insertion	422
--------------	---	-----

APPENDIX 8

Table A8.1	Compounds appearing in Chapter 3: scope and applications of the oxidative kinetic resolution of secondary alcohols.....	437
Table A8.2	Compounds appearing in Chapter 4: advanced catalyst design in the oxidative kinetic resolution	439
Table A8.3	Compounds appearing in Chapter 5: a convergent total synthesis of (+)-amurensinine and formal synthesis of (-)-amurensinine via oxidative kinetic resolution.....	439
Table A8.4	Compounds appearing in Appendix 6: the development of a scaleable acyl-alkylation of arynes and application to the construction of 1,3-dihydroxynaphthalenes	440

LIST OF ABBREVIATIONS

$[\alpha]_D$	specific rotation at wavelength of sodium D line
Å	angstrom(s)
abs.	absolute
Ac	acetyl
app.	apparent
aq	aqueous
Ar	aryl, argon
atm	atmosphere(s)
B3LYP	Becke, three-parameter, Lee-Yang-Parr functional
BHT	2,6-di- <i>tert</i> -butyl-4-methylphenol
BINAP	2,2'-bis(diphenylphosphino)-1,1'-binaphthalene
BINOL	1,1'-bi(2-naphthol)
Bn	benzyl
Boc	<i>tert</i> -butoxycarbonyl
br.	broad
Bu	1-butyl
<i>i</i> -Bu	2-methyl-1-propyl
<i>s</i> -Bu	2-butyl
(<i>S,S</i>)- <i>t</i> -Bu-BOX	2,2'-isopropylidenebis[(4 <i>S</i>)-4- <i>tert</i> -butyl-2-oxazoline]
<i>c</i>	concentration for optical rotation
calcd	calculated
CCDC	Cambridge Crystallographic Data Centre
cf.	compare
cm	centimeter(s)
COD	<i>cis,cis</i> -1,5-cyclooctadiene
comp.	complex
conc.	concentrated
conv	conversion
d	doublet
DABCO	1,4-diazabicyclo[2.2.2]octane
dba	dibenzylideneacetone
DBU	1,8-diazabicyclo[5.4.0]undec-7-ene

DCE	1,2-dichloroethane
dec.	decomposition
°	degrees
°C	degrees Celsius
DFT	density functional theory
(DHQ) ₂ PHAL	hydroquinine 1,4-phthalazinediyl diether
DIBAL-H	diisobutylaluminum hydride
(-)-DIOP	(-)-(4 <i>R</i> ,5 <i>R</i>)-2,2-dimethyl-4,5-bis[(diphenylphosphino)-methyl]-1,3-dioxolane
DMAP	4-dimethylaminopyridine
DMF	<i>N,N</i> -dimethylformamide
DMP	Dess-Martin periodinane
DPPA	diphenylphosphoryl azide
e	electron
ee	enantiomeric excess
EI	electron impact
equiv	equivalent(s)
ES	electrospray ionization
Et	ethyl
FAB	fast atom bombardment
FID	flame ionization detector
g	gram(s)
GC	gas chromatography
h	hour(s)
<i>hν</i>	light
hNK-1	human neurokinin-1
HPLC	high performance liquid chromatography
HRMS	high resolution mass spectrometry
Hz	hertz
IR	infrared (spectroscopy)
<i>J</i>	coupling constant
<i>k</i>	reaction rate constant
L	L-type ligand
λ	wavelength
lit.	literature
M	molar, metal, or molecular ion

m	meter(s), multiplet
<i>m/z</i>	mass to charge ratio
Me	methyl
mg	milligram(s)
MHz	megahertz
μL	microliter(s)
μm	micrometer(s)
min	minute(s)
mL	milliliter(s)
mm	millimeter(s)
mmol	millimole(s)
mol	mole(s)
mp	melting point
Ms	methanesulfonyl
MS	molecular sieves
MTBE	<i>tert</i> -butyl methyl ether
N	normal
nbd	norbornadiene
NBS	<i>N</i> -bromosuccinimide
<i>p</i> -Nbz	<i>para</i> -nitrobenzoyl
nm	nanometer(s)
NMR	nuclear magnetic resonance (spectroscopy)
[O]	oxidation
<i>p</i>	<i>para</i>
<i>p</i> -ABSA	<i>para</i> -acetamidobenzenesulfonyl azide
Ph	phenyl
pH	hydrogen ion concentration
PhH	benzene
(<i>S,S</i>)-Ph-PYBOX	2,6-bis[(<i>S</i>)-4- <i>tert</i> -butyl-2-oxazoliny]pyridine
Piv	pivaloyl
pK_a	acid dissociation constant
ppm	parts per million
<i>i</i> -Pr	2-propyl
<i>n</i> -Pr	<i>n</i> -propyl
psi	pounds per square inch
Py	pyridine

q	quartet
ref	reference
R_f	retention factor
s	selectivity factor
s	singlet
S_N1	nucleophilic substitution, unimolecular
S_N2	nucleophilic substitution, bimolecular
Sub	substrate
t	triplet
TBAF	tetrabutylammonium fluoride
TBS	<i>tert</i> -butyldimethylsilyl
TEMPO	2,2,6,6-tetramethylpiperidine 1-oxyl
Tf	trifluoromethanesulfonate
TFA	trifluoroacetate
THF	tetrahydrofuran
TIPS	triisopropylsilyl
TLC	thin-layer chromatography
TMS	trimethylsilyl
Ts	<i>para</i> -toluenesulfonyl
UV	ultraviolet light
Vis	visible light
w/v	weight to volume ratio
w/w	weight to weight ratio
X	halide, anionic ligand