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The Development of Complementary Allylic C-H Amination and Amidation Conditions for the Regioselective Functionalization of Group IX MCp*-π-Allyl Intermediates

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An abstract of
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Abstract

The Development of Complementary Allylic C-H Amination and Amidation Conditions for the Regioselective Functionalization of Group IX MCp*-π-Allyl Intermediates

By Jacob S. Burman

The following work will describe the research efforts aimed to uncover novel reactivity in the field of allylic C-H amination of mono-, di-, and trisubstituted olefins *via* π-allyl intermediates. The discovery, development, and related studies with Group IX MCp* catalysts for complementary reaction conditions to selectively target either amine regioisomer will also be discussed. Chapter 1 will cover the rising need for alternative contemporary methods to prepare target allylic amine products, focusing on the current approaches and mechanistic distinctions for allylic C-H amination techniques that proceed through metallonitene and/or π-allyl intermediates.

Chapter 2 will outline the research efforts for the discovery of reaction conditions for unprecedented intermolecular reactivity to target conjugated regioisomers from unsymmetrically disubstituted styrene derivatives. A significant expansion of nucleophile scope is shown for preferentially substituted amines bearing a single electron-withdrawing group. Additional preliminary work shows efficacy for the selective allylic C-H amination of terminal and trisubstituted olefins. Mechanistic details support the intermediacy of π-allyl intermediates and related studies determine the origin of high regioselectivity stems from a discrete thermodynamic equilibration process for C-N bond formation.

Chapter 3 will highlight the identification and use of dioxazolone amidating reagents to alter the mechanistic pathway for C-N bond formation toward an inner-sphere reductive elimination event from an acyl-nitrene a hypothesized M(V)Cp* intermediate. The reaction is highly tolerant for a variety of functional groups and provides complementary regioselectivity for the benzylic/branched amidation product from terminal, di-, or trisubstituted olefins. Studies reveal a necessity for effective pairing of catalyst and olefin substrate high yield and regioselectivity. Whereby RhCp* catalysts result in high yield and selectivity for disubstituted olefins, IrCp* catalysts show similar results when paired with terminal or trisubstituted olefins. Applications for the branched selective methodology have shown promise for the diastereoselective synthesis of *anti*-1,2-amino alcohol motifs.

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Acknowledgements

"If you are working on something exciting that you really care about, you don't have to be pushed. The vision pulls you." – Steve Jobs.

Ever since I can remember I have always had an enormous curiosity to understand the world around me. My passion quickly led me to chemistry as the most accessible way to explain the everyday natural phenomena. Throughout my experiences and education growing up I knew synthetic organic chemistry was my true calling. I was inspired by the thought that I may be able to utilize my textbook knowledge in unusual and creative ways to reshape the universe. Most people don't have a profession where they are as happy to do their work every day like me. I'm extremely fortunate to have the opportunity to study chemistry and contribute my own exciting and novel advances.

To Mom, Scott, and Katie I'm so thankful to have you all in my life. I was recently told how fortunate we are to be part of such a wonderful and caring family. I always feel as if I never properly conveyed how lucky I am to have your support. Through the hardships in my life you have been my rocks. There was nothing I couldn't tell you and there was never a second thought when you rushed to my aid. My family gives me strength to pursue my chemical passion and I wouldn't be the caring person I am today without their love. I love you all so much and there isn't a moment in my life I don't remember the kindness, encouragement, and guidance you have offered me.

To Simon, thank you for everything you have done for my benefit. I originally joined your research group because I knew that I would become an excellent chemist through your mentorship. You have provided me with opportunity after opportunity to support my professional growth and education. I will always appreciate your rigorous attention to detail and your honesty. How you always pushed me to improve my own technical methods. You were always available to help and certainly weren't opposed to coming into lab and help a younger inexperienced Jacob with a challenging separation, P.S. you've still got it! With the utmost sincerity, I owe my successes greatly in part to your guidance.

Thank you Karl, moving out to Atlanta would never have been a successful endeavor had it not been for you. Knowing you is a pleasure and I always look forward to seeing you when we need a break from our routines. You, like many others in my life, have offered me unwavering support, kindness and belief. I'm happy to have had you be part of my graduate school experience and having you in my life has reconnected me with the rest of our family.

To my best friends I can thank you for keeping me sane. CJ (Chinchilla Jorge), you have been THE bro since I first met you, it's been about 10 years since we first met. You totally get me CJ we laugh and joke constantly, and I know I can always tell you the exciting as well as the important things in my life. You're always there for me dude and you keep me talking more than anyone else. Allan, we were partners in crime for a long time and I'm thankful that Hayden made us sit with that weird kid for dinner so long ago! My experiences at CLU wouldn't have been half as fun without you. To Becca, Hayden, Randy, and Cameron I'm so glad we have stayed in touch, no matter when I come back home to visit you all have been able to make time for me despite working hard in our separate lives. Thank you for giving me multiple reasons to visit my home.

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For the Blakey Group members past and present who have contributed to my success and offered their friendship I want to thank you all for your support and I wish you all the best in your own successes. To Ashley and Thomas, we had a great time working together and it was great to be with such fun and kind people as I watched you both grow, stay true to your aspirations. Thank you Daniel for being a hilarious fun person who can participate in my shenanigans. Kim and Steven you're both really smart and will go far in whatever you choose, it's all about perseverance.

To my committee, Drs. Davies and Jui I thank you for your guidance and support through my development as a chemist. Specifically Dr. Davies thank you for supporting my involvement in CCHF opportunities and Dr. Jui for challenging me to further my education beyond my specialty. Also, to my other Emory professors Drs. McDonald, Liebeskind, and Scarborough, thank you for your valuable lessons and tutelage that has added to my fundamental chemical knowledge.

I am grateful for the opportunity to study my passion and be successful at Emory University.

"To live is the rarest thing in the world. Most people exist, that is all." – Oscar Wilde

Contents

Chapter 2: Reaction Discovery and Development for Conjugated Selective Oxidative Allylic C-H Amination of Disubstituted Olefins *via* RhCp*-π-Allyl Intermediates

List of Schemes

Chapter 1:

Chapter 2:

Chapter 3:

List of Figures

Chapter 1:

Chapter 2:

Chapter 3:

List of Tables

Chapter 2:

Chapter 3:

List of Abbreviations

Ac	Acetyl
AcOH	Acetic Acid
Aq	Aqueous
Bn	Benzyl
Boc	*tert*-Butyl Carbamoyl group
BQ	Benzoquinone
Bz	Benzoyl
$(BzO)_2$	Benzoyl Peroxide
CatBH	Catecholborane
Cbz	Benzyl Carbamoyl group
CCHF	Center for Selective C-H Functionalization
CMD	Concerted Metalation-Deprotonation
Cp	Cyclopentadienyl
Cp*	Pentamethylcyclopentadienyl
Cp^E	diethyl 2,4,5-trimethylcyclopenta-3,5-dienyl-1,3-dicarboxylate
d	doublet
DCE	1,2-dichloroethane
DCM	Dichloromethane
DIAD	Diisopropyl azodicarboxylate
DIBAL-H	Diisobutylaluminum hydride
DMAP	N,N-dimethylaminopyridine

DMPU	1,3-dimethyl-3,4,5,6-tetrahydro-2(1H)-pyrimidinone
DPP	*trans*-1,3-diphenylpropene (DPP)
DMF	N,N-dimethylformamide
Et	Ethyl
EtOAc	Ethyl Acetate
EtOH	Ethanol
Et_2O	Diethyl Ether
Imid.	imidazole
J	Nuclear Coupling Constant, Hz
L^L	Large Ligand
L^S	Small Ligand
m	multiplet
Me	Methyl
MeCN	Acetonitrile
MeOH	Methanol
mg	miligram
mL	milliliter
MOM	Methoxymethyl ether
mmol	millimole
NOE	Nuclear Overhauser Effect
NQ	1,4-Naphthoquinone
n-BuLi	*n*-butyllithium
o-Ns	*ortho*-Nitrobenzenesulfonyl

NTf_2	bis-Trifluormethylsulfonamido
OAc	Acetate
Pd/C	Palladium on Carbon
Ph	Phenyl
p	pentet
q	quartet
RT	Room Temperature
s	singlet
t	triplet
t-Bu	*tert*-Butyl
TBAF	tetrabutylammonium fluoride
TBAI	tetrabutylammonium iodide
TBS	*tert*-butyldimethylsilyl
TBDPS	*tert*-butyldiphenylsilyl
$TCESNH_2$	1,1',1''-Trichloroethoxysulfamate
THF	tetrahydrofuran
TLC	Thin-Layer Chromatography
Ts	4-toluenesulfonyl
$TsNH_2$	*p*-toluenesulfonamide
2-Naph	2-Naphthyl
1,10-phen	1,10-phenanthroline

Chapter 1:

Introduction and Background:

Hypothesis Driven Approach to the Development of Regiodivergent Conditions for the Allylic C-H Amination and Amidation of Disubstituted Olefins

1.1 Relevance of Nitrogen Containing Molecules for Drug Discovery

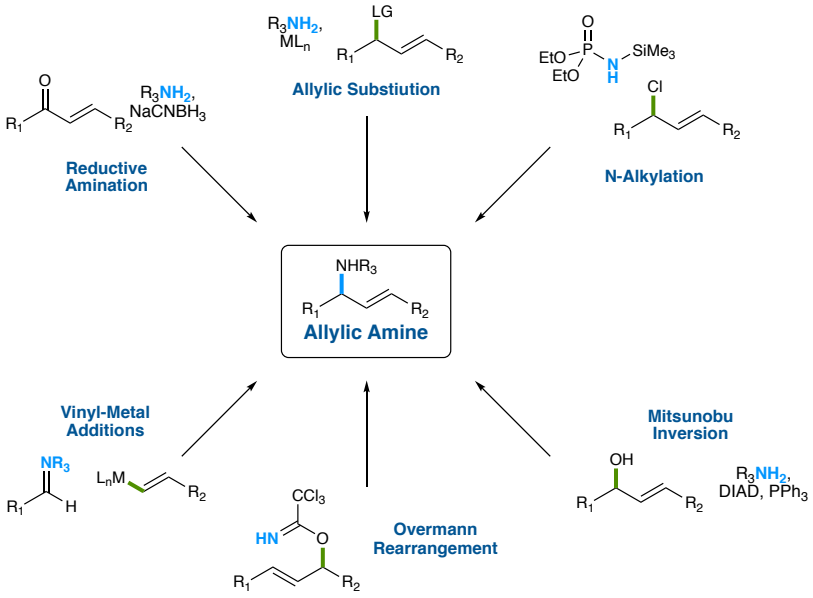
The pharmaceutical industry heavily relies on organic chemists to pinpoint bond disconnections for constructing bioactive target molecules. Predominately, nitrogen containing molecules are the linchpin structural component of biologically active pharmaceuticals, key to the observed interactions in their target. A survey of the 1,086 U.S. FDA approved drugs by Njardson in 2014 revealed that 84% contain at least one nitrogen atom additionally, 59% of the unique small molecules contain at least one nitrogen heterocycle.[1] This number is incredibly high when compared to the prevalence of other heteroatoms in active pharmaceuticals, sulfur (26%) and fluorine (13%). As such, methods development for the efficient and selective incorporation of nitrogen atoms has been a major thrust of research for decades.

Despite the major advances in photoredox[2-3] and transition-metal[4] catalyzed amination techniques, the prevailing methods for nitrogen installation in the pharmaceutical industry are entrenched in 20th century techniques. Typically, these methods involve prefunctionalization of starting materials and/or excessive functional group interconversions. While these textbook reactions reliably access the target molecule, the ensuant chemical waste and time invested to access each intermediate immediately detract from their benefits. Complementary approaches for direct nitrogen insertion into synthetic sequences represents a major challenge that the organic chemistry community is actively addressing.

1.2. Allylic Amines as Highly Desirable Intermediates for Targeted Synthesis

Allylic amines are significant to the expedient access of pharmaceutical intermediates and historically, there are diverse approaches to synthesis of this valuable framework (Scheme 1.1.). Rapid diversification of either the allyl/olefin or the amine fragment have spurred numerous studies for facile synthesis of allyl amines in classical literature.[5]

Scheme 1.1. Classic Examples for the Synthesis of Allylic Amines.



One such method for the synthesis of allylic amines is the reductive amination of α,ß-unsaturated ketones with ammonia or a substituted amine. Another common procedure is the generation of an imine from an aldehyde followed by an organometallic-mediated vinyl addition; enantioselective variants have been developed with the use of Ellman's auxiliary[6] and other

transition-metal mediated methods.[7-11] Other classic examples to prepare allylic amines include the Overmann rearrangement of allylic trichloroacetimidates,[12] Mitsunobu reaction of allyl alcohols with DIAD and PPh_3,[13] direct N-alkylation of allyl halides with specialized reagents,[14-16] as well as allylic substitution with prefunctionalized substrates (the latter of which will be discussed, *vide supra* section 1.3.2.).

Notwithstanding the transformative contributions that each of the aforementioned reactions has made for the field of organic synthesis, contemporary methods of the 21st century should focus on more flexible routes to synthesize complex fragments. To aid this mission, C-H functionalization methods have grown in popularity over the past decade as an attractive alternative to standard procedures requiring excessive functional group manipulations.

1.3. Allylic C-H Amination Methods: Key Developments for Contemporary Knowledge

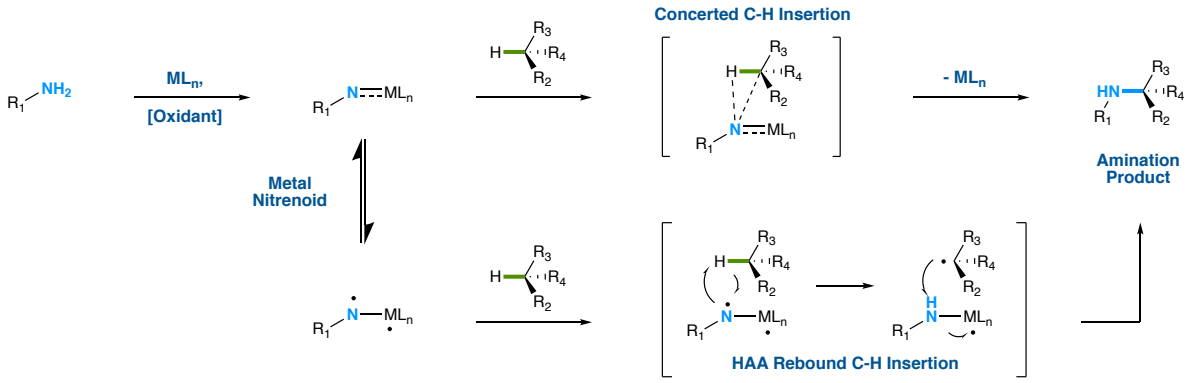
More specifically, increased research efforts for the direct oxidation of the allylic C-H bond of common feedstock olefin substrates has risen to complement the classical approaches to precise installation of allylic amine moieties. The major appeal to incorporating allylic C-H functionalization methods would result in removing extraneous redox/protection sequences that were previously routine. Robust methods are being developed that pay special regard to overcoming chemo- and regioselectivity issues from reactive metallonitrene and π-allyl intermediates. A variety of complementary approaches from two mechanistically different pathways has provided insight to provide high efficiency and contributed fundamental knowledge for future reaction development. These allylic C-H amination methodologies while still in their

infancy of being broadly accepted by the community, have made novel advances in the selective manipulation of olefins with applications to endeavors in total synthesis.

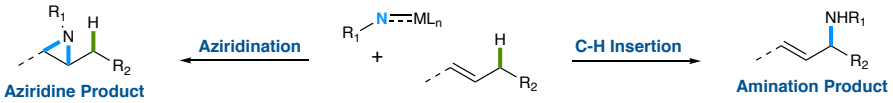
1.3.1. A Metallonitrene Approach for Allylic C-H Amination

Catalytic transfer of a nitrene moiety was first demonstrated by Breslow in the tosylamidation of cyclohexane with a cytochrome P-450 model in 1982.[17-18] The metallonitrene intermediate was first proposed as a key intermediate for the C-H cleavage. Subsequent studies disclosed the characterization of metal-nitrenoid species where mechanistically two distinct pathways can be at play for C-H insertion reactions (Scheme 1.2.).[19] Arising from more double-bond character in the metal-nitrenoid is the concerted C-H insertion mechanism (top), the other pathway stems from an N-centered radical nitrene species, stepwise process for hydrogen atom abstraction (HAA) and radical recombination (bottom). Metallonitrenes have been demonstrated to be very reactive toward sp^3 C-H bonds in a variety of studies, but chemoselectivity issues with the olefin moiety arises when targeting an allylic C-H bond.

Scheme 1.2. General Mechanisms for Known Metal-Nitrenoid C-H Insertion.

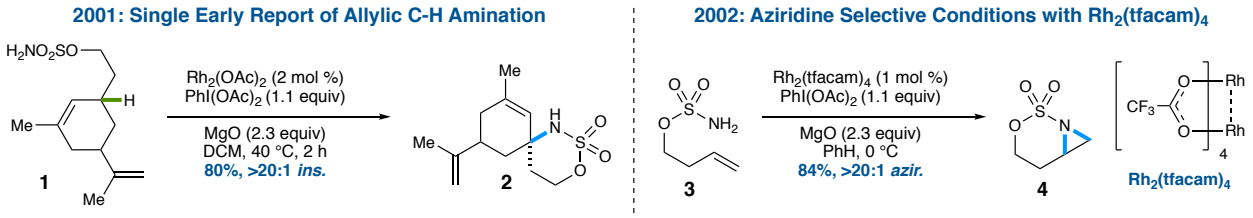


Scheme 1.3. Chemoselectivity Issues Arise in Nitrene Transfer for Allylic Systems.



Early on, Mansuy reported that Mn- and Fe-porphyrin catalysts were competent in olefin aziridination reactions when utilizing hypervalent iminoiodinanes as a nitrenoid precursor.[20] Metallonitrene intermediates are generally electrophilic and have difficulty differentiating between the aziridination or allylic C-H insertion product when shown the same allylic system (Scheme 1.3.). The following novel advances for metallonitrene allylic C-H amination identified key features to promoting high site-selectivity away from aziridination reactions. Intermolecular metallonitrene allylic C-H insertion reactions are rare and competitive with other sp^3 C-H bonds. Most cases shown to date for metallonitrene intermediates that exhibit high site-selectivity for allylic C-H amination have occurred intramolecularly.

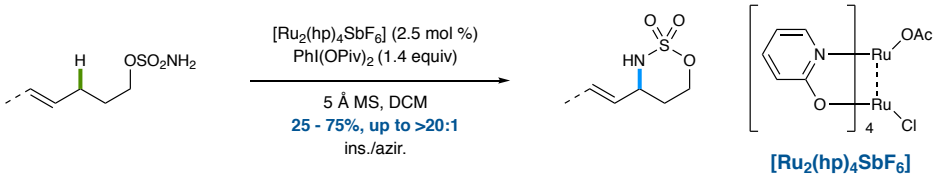
Scheme 1.4. Dirhodium Carboxylates Show Bias for Aziridination with Metallonitrenes.



Early examples of metallonitrene chemistry involve intramolecular sp^3 C-H amination or aziridination. Du Bois and co-workers report in 2001 initial amination conditions with $Rh_2(OAc)_4$ which promotes the intramolecular nitrene insertion for predominately 6-membered rings (Scheme 1.4.).[21] A single entry with terpene **1** notes a chemoselectivity preference for the allylic

C-H amination product **2** instead of the more geometrically constrained aziridine adduct. Du Bois concurrently shows that a very similar catalytic system with $Rh_2(tfacam)_4$ demonstrates the large bias in a simpler substrate (**3**) for exclusive formation of aziridine **4** in high yield.[22] A subsequent report disclosed enantioselective dirhodium sp^3 C-H functionalization conditions with entries for allylic C-H insertion but the results were modest yielding (43-55%) with low *ee* for *trans*-olefins and up to 84% *ee* for *cis*-olefins.[23]

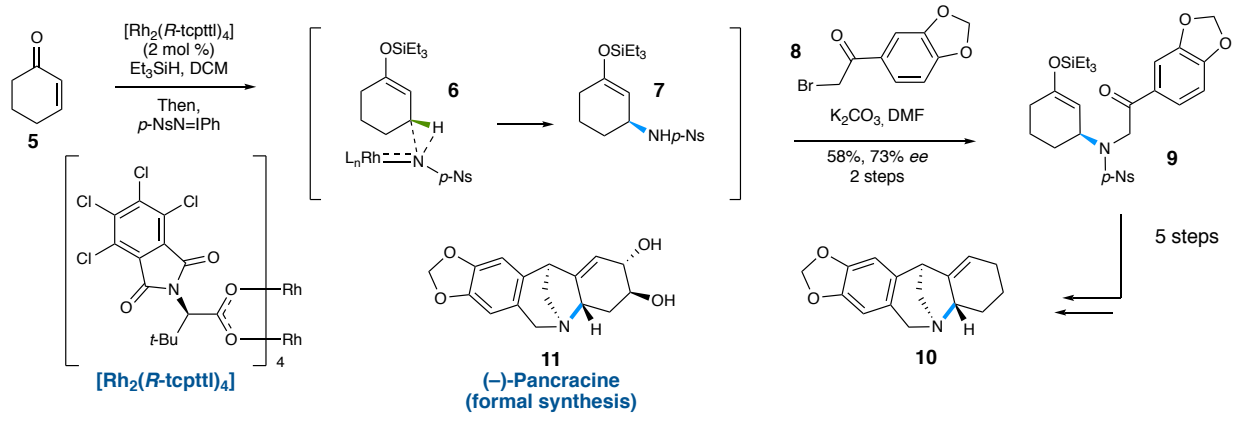
Scheme 1.5. Mixed-Valent Diruthenium(II/III) Complex Promotes Allylic C-H Amination.



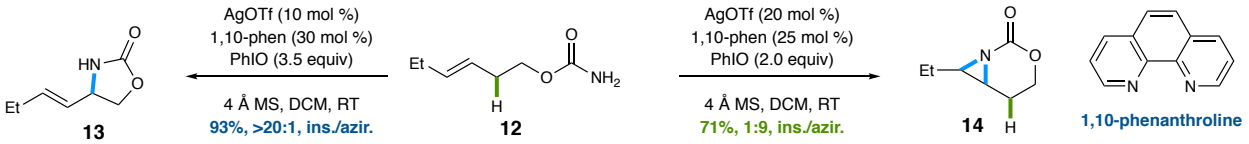
Later on, Du Bois and co-workers demonstrated that a novel mixed-valent diruthenium(II/III) complex could catalyze an intramolecular allylic C-H amination (Scheme 1.5.).[24] One advantage of using this catalyst system lies in its robustness toward oxidative conditions with hypervalent iodine reagents arising from the higher catalyst oxidation potential. $[Ru_2(hp)_4Cl]$ displayed notable chemoselectivity as well as high efficiency for allylic C-H amidation in the presence of a hypervalent iodine oxidant, wherein the allylic C-H bond was selectively reacted in all cases. Computational calculations and experimental analyses in collaboration with Musaev suggested the formation of a diruthenium-imidyl diradical species as a key intermediate being responsible for the observed chemoselectivity for allylic C-H bonds. This pathway being similar to the radical rebound pathway for step-wise nitrene insertion.

Hashimoto and coworkers described a unique application of enantioselective allylic C-H amination for the formal synthesis of (-)-pancracine (Scheme 1.6).[25] The novel dirhodium tetracarboxylate catalyst developed in their lab, [Rh_2(*R*-tcpttl)$_4$], showed preference for intermolecular reactivity with sp^3 C-H insertion reactions.[26] Treatment of cyclohexanone **5** with Et_3SiH generates a discrete silyl-enol ether (**6**) and, in the presence of [Rh_2(*R*-tcpttl)$_4$] with the hypervalent iodine amination reagent, *p*-NsN=IPh, provides the aminated product **7** *via* a concerted Rh-nitrenoid allylic C-H functionalization mechanism. Allylic C-H amination was the major product due to the sterically congested Rh-nitrenoid species. N-alkylation of the crude intermediate with the bromo-ketone **8** resulted in the isolation of amine product **9** in 58% yield over 2 steps with good enantioselectivity. Further manipulations of the allylic amination product provided access to intermediate **10** which matched a common intermediate in the synthesis by Overman and Shim (17 steps), thereby completing Hashimoto's formal synthesis in 7 steps (3 steps to the natural product).[27] Hashimoto's demonstration of Rh-nitrenoid allylic C-H amination in the synthesis of (-)-pancracine has marked another achievement for C-H functionalization methods being key to expedient access to complex products.

Scheme 1.6. Formal Synthesis of (-)-Pancracine by Rh(II)-Metallonitrene Allylic C-H Amination.

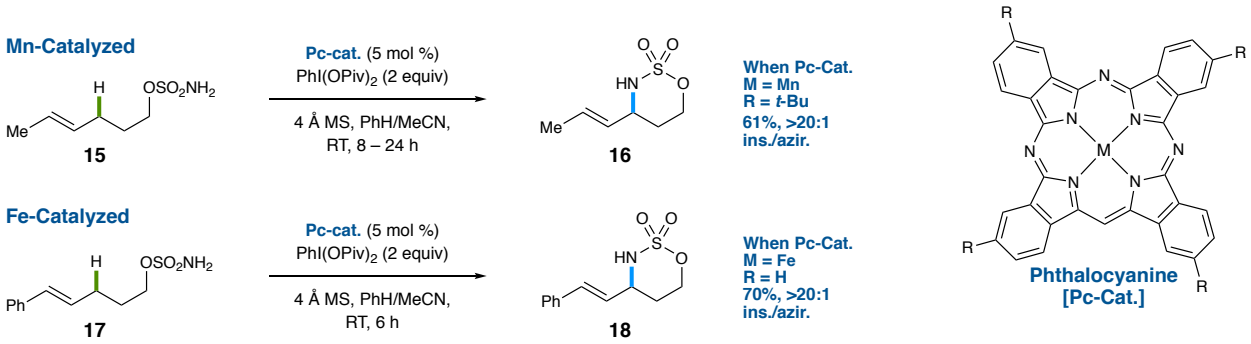


Scheme 1.7. Chemoselective Conditions for Divergent Aziridination and Allylic C-H Amination.



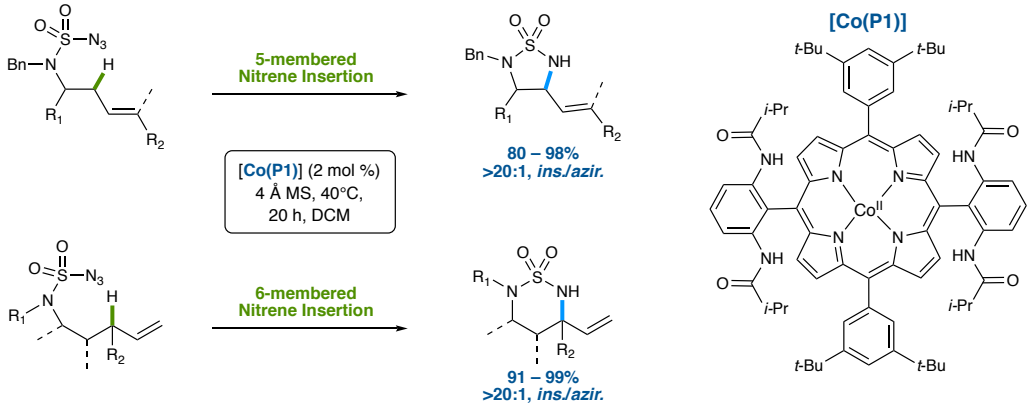
Schomaker and co-workers presented a sound strategy to overcome the chemoselectivity issues of Ag(I)-nitrenoids between the aziridine and allylic C-H amination products, based on finely tuning the ligand's concentration. Applying simple knowledge of the relevant geometries from a mono- versus bis-ligated complex with 1,10-phenanthroline (Scheme 1.7.), they hypothesized that the Ag(I)-nitrene could be biased to either product. They demonstrated that a difference in ratios of ligand:metal vastly determined the selectivities between the two catalysts.[28-29] When a bis-homoallyl carbamate **12** was reacted with a 1:1.25 ratio of the AgOTf/1,10-phen catalyst system, aziridination occurred predominantly (**14**, 71%, 1:9 *ins./azir.*). In contrast, an increase of the AgOTf/1,10-phen ratio to 1:3 resulted in a reversal of chemoselectivity, leading exclusively to allylic C-H amination product (**13**, 93%, >20:1 *ins./azir.*). The authors go on to say that the steric bulk of the (mono-/bisligated) silver catalyst is responsible for this chemoselectivity switches; an open coordination site promotes the olefin aziridination, whereas congested metal center favors the allylic C-H insertion pathway. Extended studies with Schomaker and Berry collaboratively interrogate the catalyst properties and reaction kinetics to confirm these initial hypotheses marking the varying effects that ligand:catalyst stoichiometries have in tuning the allylic C-H amination reaction.[30-31]

Scheme 1.8. Phthalocyanine Catalysis for Intramolecular Allylic C-H Insertion.



Early works on nitrene transfer for sp^3 C-H functionalization with first-row transition-metals were mainly associated with porphyrin-, salen-, or metalloenzyme-based Mn(III)/Fe(III) complexes.[17-18,32] The early transition-metal catalysis with nitrenoids struggles to differentiate between C-H insertion and aziridination. In context to allylic C-H insertion with metal nitrenoids, recent literature by the White group demonstrates that phthalocyanine (Pc) based catalysts are capable of successfully differentiating aziridination and C-H insertion pathways (Scheme 1.8.),[33] other entries include benzylic, propargylic, and unactivated sp^3 C-H bonds. An additional report by White shows that an analogous Fe-Pc catalyst under similar conditions also promotes selective allylic C-H amination.[34] The Fe-Pc catalyst was commented to exhibit behavior related to the HAA rebound pathway due to the high spin state of the metallonitrene intermediate.[35] Competitive aziridination reactions are concerted events engaging the π-system and would not be viable under the radical rebound pathway.

Scheme 1.9. Co(II)-Metalloradical Catalysis for Intramolecular Allylic C-H Amination.

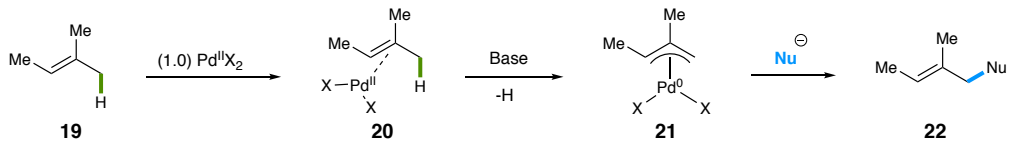


Zhang has reported heavily on the versatile catalytic activity of Co(II)-porphyrin complexes for C-H amination methods with various nitrene precursors for benzylic, propargylic, and unactivated sp^3 C-H bonds.[36] Key to overcoming selectivity for aziridination and target allylic C-H insertion, they devised the system below to generate 6-membered amination products from N-bishomoallylic sulfamoyl azides (Scheme 1.9.).[37] The aziridine product would be a higher energy pathway with greater geometric strain due to the 7-membered ring that would be the proposed product. This same method was applied later to the synthesis of 5-membered allylic C-H amination products.[38] The reactions are high yielding for allylic C-H amination with no evidence of the off-path aziridination.

Progress has been made over time to develop the intramolecular allylic C-H nitrene insertion chemistry away from the competitive aziridination reactions. But intermolecular reactivity for the reactive metallonitrene is still far from ideal, suffering from competitive reactions with other C-H bonds. Alternative methods for intermolecular reactivity would be ideal in pursuing novel routes to selectively target the allylic C-H bond to prepare diverse allylic amine scaffolds. Such chemistry would show promise for highly flexible approaches to aid convergent synthetic strategies.

1.3.2. Allylic C-H Amination Proceeding Through π-Allyl Intermediates

Scheme 1.10. Classic Stoichiometric Allylic C-H Functionalization *via* π-Allyl Intermediates.

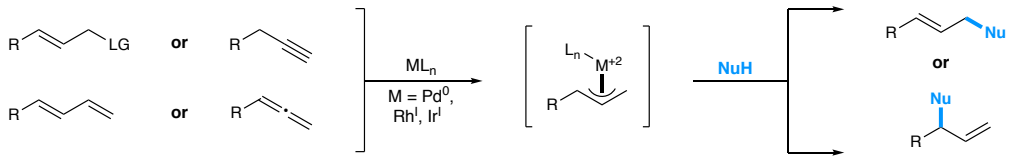


General Mechanism for Stoichiometric Pd-π-Allyl Complex Formation and Reaction

The selective manipulation of olefins to metal-π-allyl intermediates has been extensively studied to aid drug discovery efforts.[39] Palladium has a long standing history of generating π-allyl complexes from a variety of abundantly available functionalized olefins to form many different C-C, C-O, and C-N bonds.[40-41] In context to allylic C-H functionalization, early reports show that stoichiometric palladium reactions are known to generate π-allyl intermediates from unactivated olefins by a concerted *syn*-hydride transfer (**20** to **21**) followed by deprotonation with an exogenous base (Scheme 1.10.). These Pd-π-allyl complexes can be intercepted by carbon nucleophiles which represents an early entry for allylic C-H functionalization but catalytic

conditions remained elusive for decades. Contemporary contributors have been able to isolate other π-allyl complexes from the allylic C–H activation of terminal olefins to probe their catalytic competency.[42-43]

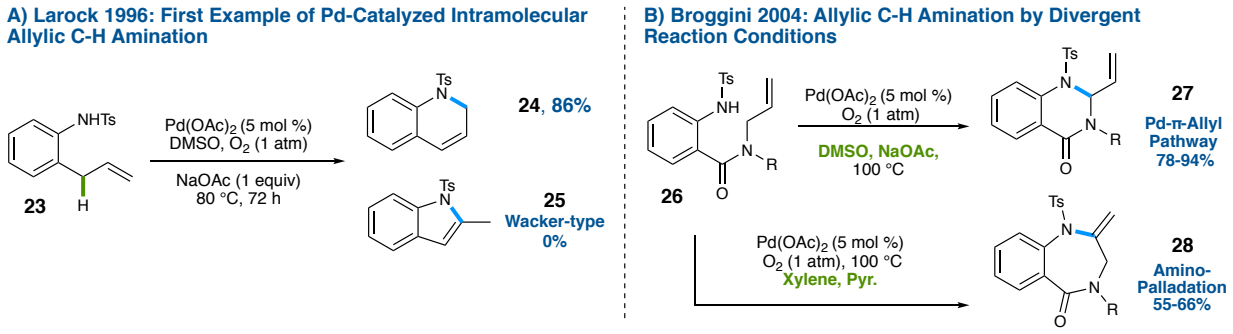
Scheme 1.11. Access to Transition-Metal π-Allyl Intermediates from Preoxidized Substrates.



Preoxidized Precursors are Utilized Catalytically to Access Metal-π-Allyl Intermediates

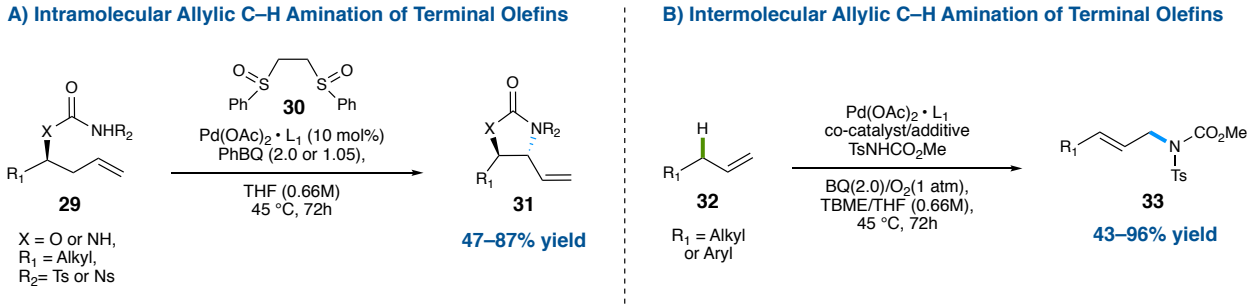
Reaction development to target transition-metal π-allyl intermediates due to their predictable behavior. Tsuji and Trost independently in the early 1970s both studied the foundation for allylic substitution methodologies; whereby the key π-allyl species was generated *via* oxidative addition into the π-system of olefins with an allylic leaving group (Scheme 1.11.).[44-45] Overall this process is redox neutral and overcomes the previous stoichiometric limitation from the direct functionalization of the allylic C-H bond. Many groups have studied the use of other metals and nucleophiles to expand the scope of allylic alkylations, aminations, and oxidations.[46] Additionally, contemporaries have demonstrated that other preoxidized precursors such as allenes, alkynes, and conjugated dienes are capable of generating π-allyl species *via* hydrometallation/isomerization mechanisms.[47-56] Accessing the same π-allyl intermediates directly from the allylic C-H bond of unfunctionalized olefins would present a more flexible approach to utilizing the well-studied intermediates.

Scheme 1.12. Early Examples of Catalytic Allylic C-H Amination *via* π-Allyl Intermediates.



The historical challenges for allylic C-H functionalization lie in finding suitable conditions that support Pd(II)-mediated electrophilic C-H cleavage and subsequent oxidation of the Pd(0) species to regenerate catalytic activity. When looking forward we find that over 30 years had passed since the discovery of π-allyl intermediates until the first application by Larock was reported for intramolecular installation of nitrogen moieties into allylic C-H bonds (Scheme 1.12.A.).[57] In 1996 Larock and coworkers demonstrated the first example of intramolecular allylic C-N bond formation for amination product **24**, as opposed to the expected Wacker-type product **25**, with oxygen as the terminal oxidant. In 2004, Broggini and co-workers also utilized an O_2 atmosphere for the intramolecular cyclization of N-allyl-anthranilamides **26** to provide either 6- or 7-membered ring products (**27** or **28**) when different solvents and bases were used (Scheme 1.12.B.).[58] Broggini's work directly correlates to switching mechanisms away from aminopalladation intermediates toward Pd-π-allyl species with the use of DMSO and NaOAc.

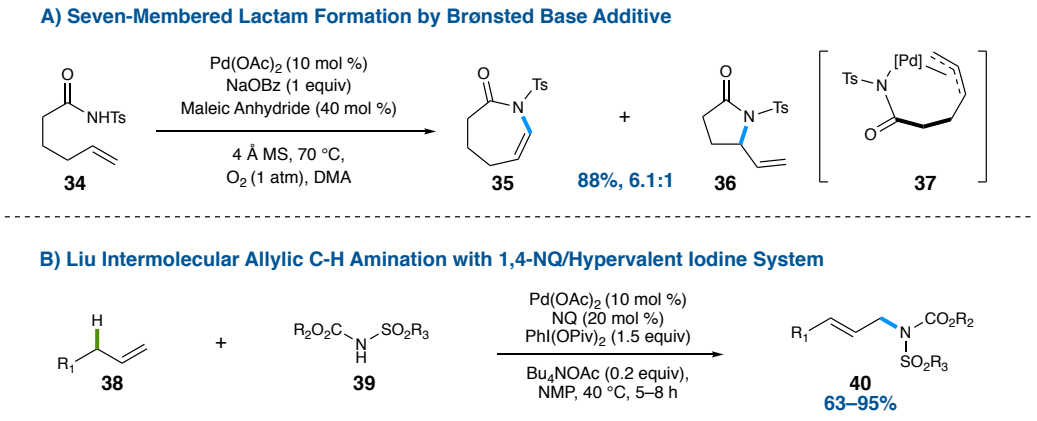
Scheme 1.13. White Group's Efforts in Allylic C-H Amination of Terminal Olefins.



Subsequent work by White has popularized the oxidative allylic C-H functionalization of terminal olefins for the past decade.[59-64] Moving away from high temperature reactions and observing DMSO as the key to Pd-π-allyl generation, they utilized a bidentate bissulfoxide **30** and benzoquinone (BQ) as the stoichiometric oxidant (Scheme 1.13.). Utilizing this reactive platform, with acetates and malonate-type stabilized nucleophiles, the White group created an efficient methodology for constructing C-C, C-O, and C-N bonds from terminal olefins. Specifically, allylic C-H amination methods required the use of specialized tosyl carbamate ($TsNHCO_2R$) amine nucleophiles for any reactivity. Amination methodologies were developed concurrently for intramolecular aminations[65] that provided the branched olefin, and intermolecular aminations[66] provided the linear products. Only recently did the White group overcome the previous limitation for the doubly protected nucleophile and successfully incorporated alkyl-substituted triflimides into allylic C-H amination methodologies.[67]

A rare approach to seven-membered lactams reported by Liu afforded regiodivergent intramolecular allylic C-H amination conditions (Scheme 1.14.A.).[68] To circumvent an exocyclization path leading to five-membered lactam **36**, sodium benzoate was employed as a Brønsted base additive that can promote Pd-N bond formation for the switch to endo-cyclization product **35**. On the basis of the deuterium-labeling studies and KIE experiments, the authors concluded that the reaction follows a rate-limiting C-H activation and subsequent reductive elimination process. These conditions were quickly applied to an intermolecular variant of this reaction[69] but additional study found that 1,4-naphthoquinone (NQ) and hypervalent iodine reagents proved to be optimal for the allylic C-H amination with N-sulfonyl carbamates (Scheme 1.14.B.).[70] Liu's contribution highlights the subtle changes to mechanism that can result in switching a regioselective outcome.

Scheme 1.14. Liu's Contributions to Allylic C-H Amination of Terminal Olefins.



1.3.3. Redefining Strategy with Allylic C-H Amination *via* π-Allyl Intermediates

1.3.3.1. Intramolecular Allylic C-H Amination as Key Step

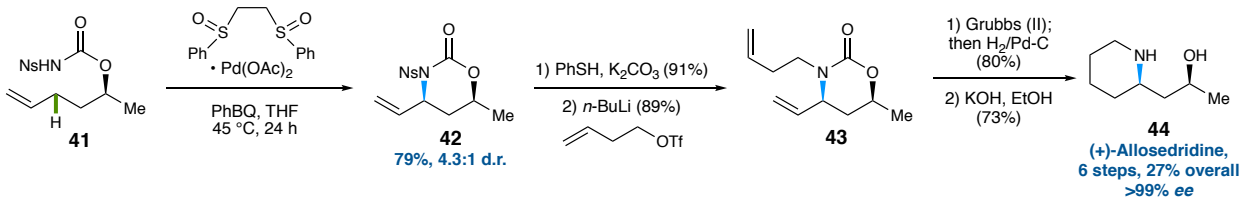


Figure 1.1. Intramolecular Allylic C-H Amination *via* π-Allyl Species for (+)-Allosedridine.

Predictable and selective C-H amination reactions are necessary to streamline the synthesis of nitrogen containing molecules by avoiding burdensome functional group interconversion which are tedious to carry through long synthetic sequences. We have previously discussed the intramolecular allylic C-H amination methodology by White to afford branched selective products.[65] The ability of this allylic C-H amination reaction to efficiently access optically enriched *syn*-1,3-amino alcohols is exemplified by the rapid synthesis of (+)-Allosedridine **44** (Figure 1.1). Starting from the commercially available enantioenriched bis-homoallylic alcohol, the sulfonylcarbamate is readily prepared in a single step to **41**. The amination methodology efficiently introduced nitrogen at the correct oxidation state in a mild facile approach in 79% yield, the correct diastereomer **42** was isolated separately >20:1 d.r.. The N-nosyl group was easily deprotected with PhSH/K2CO3, subsequent *N*-alkylation furnished **43** whereby the olefin moieties could form the piperdine core *via* Grubbs ring-closing metathesis. Hydrogenation, followed by basic hydrolysis completed the total synthesis of (+)-allosedridine **44** in six steps and 27% overall yield. By avoiding multiple functional group manipulations and exploiting the new disconnection

strategy that their allylic C-H amination uncovered, a quick and facile synthesis of a stereodefined alkaloid was possible.

1.3.3.2. Intermolecular Allylic C-H Amination as Key Step

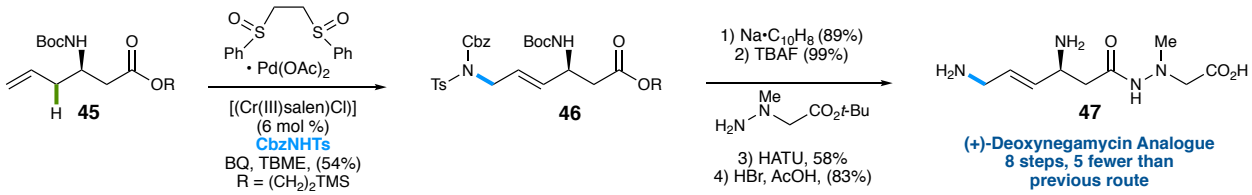


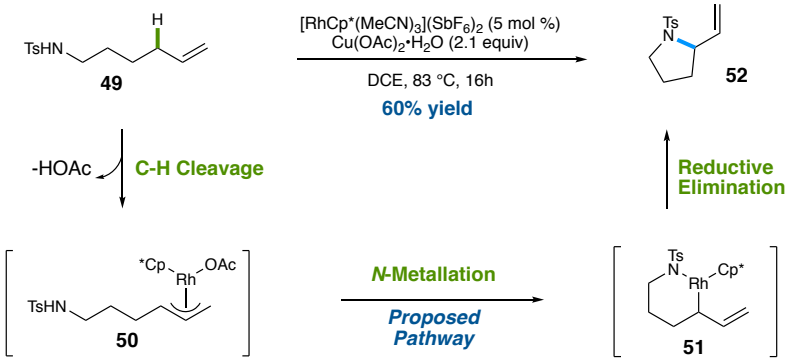
Figure 1.2. Synthesis of (+)-Deoxynegamycin Analogue *via* Allylic C-H Amination.

Importantly, the developing allylic C-H amination technologies *via* Pd-π-allyl intermediates has been effectively applied to complement known syntheses of complex targets. In the report by White for intermolecular Pd-catalyzed allylic amination method, they directly applied their reaction to the synthesis of (+)-deoxynegamycin analogue **47** as a streamlined approach to the bioactive molecule (Figure 1.2.).[66] Starting with commercial ß-homoallylglycine, nitrogen was incorporated in only two steps using the linear allylic amination for **46** in 54% yield. In contrast, the alternative approach began with an aspartic acid derivative whereby nitrogen installation performed by state-of-the-art allylic substitution in seven steps, further manipulation of nitrogen oxidation state was required to furnish the target compound.[71] Overall, the allylic C-H amination route to the (+)-deoxynegamycin analogue proceeded in five fewer steps, with five fewer functional group interconversions, and higher overall yield than the alternative allylic substitution from C-O to C-N bond-forming route.

1.4. RhCp-Derivatives as Catalysts for Allylic C-H Functionalization *via* π-Allyl Intermediates

In 2012, Cossy's seminal publication showed that rhodium(III)-pentamethyl-cyclopentadienyl (RhCp*) could catalyze the intramolecular allylic C-H amination of ω-unsaturated *N*-toluenesulfonamide terminal olefin **49** to result in a range of 2-vinyl pyrrolidine products (Scheme 1.15.).[72] At the time, this contribution represented a major advance for the allylic C-H oxidation of terminal olefins due the avoidance of generating active nitrene intermediates and the incorporation of a singly-protected nitrogen nucleophile (Pd-catalyzed amination methods required doubly protected sulfonyl-carbamates for activity). Their proposed mechanism involves an allylic C-H activation step to generate RhCp*-π-allyl complex **50**. Complex **50** would then engage the appendant sulfonamide through *N*-metalation to produce **51**, and subsequent reductive elimination would form the cyclized product **52**.

Scheme 1.15. RhCp*-Catalyzed Intramolecular Allylic Amination with *N*-Alkyl Sulfonamides.



Cossy: Seminal Work for the Intramolecular Allylic C-H Amination of Terminal Olefins

Additionally, their methodology was able to demonstrate intramolecular allylic C-H amination of 1,2-disubstituted olefin **53** in 50% yield but, the system exhibited no regioselectivity (1:1) for cycloadducts **54** or **55** (Figure 1.3). These initial experiments demonstrated unprecedented reactivity with RhCp* for the allylic C-H functionalization of terminal olefins and showed preliminary findings to functionalize 1,2-disubstituted olefins. But, there was no supporting data within Cossy's manuscript for the intermediacy of a RhCp*-π-allyl. Extending the methodology further would require evidence suggesting a clearer mechanistic pathway to develop a system capable of selectively functionalizing more substituted olefin substrates.

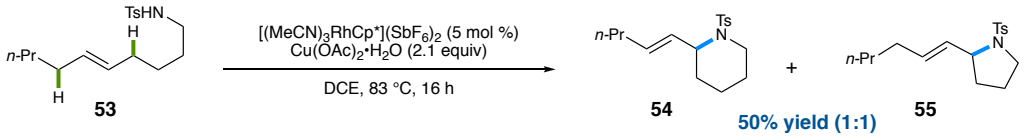


Figure 1.3. Unselective Intramolecular Allylic C-H Amination of a 1,2-Disubstituted Olefin.

Later on, Tanaka disclosed the catalytic activity of their $[RhCp^{E}Cl_2]_2$ complex for the oxidative directed sp^2 C-H olefination[73] notably, isolating catalytic quantities of the $RhCp^{E}$-π-allyl intermediate originating from 1-hexene. This initial finding supports that RhCp-derivatives were indeed capable of engaging the allylic C-H bond of unactivated terminal olefins. Building off Cossy's discovery, they turned their interests towards utilizing the new precatalyst towards allylic C-H functionalization, paying mind to confirming the proposed π-allyl intermediate (Figure 1.4.A.).[74]

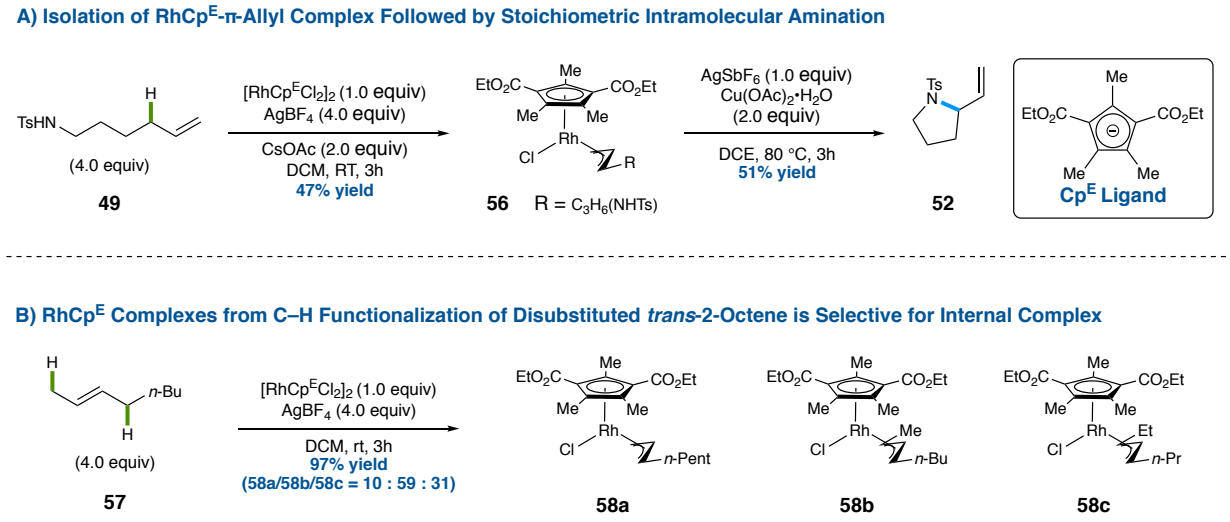


Figure 1.4. Tanaka's Investigation of $[RhCp^ECl_2]_2$ for Allylic C-H Activation.

By reacting ω-unsaturated terminal olefin **49** with $[RhCp^ECl_2]_2$ in the presence of 2.0 equivalents of CsOAc complex **56** was isolated in 47% yield. Similar to Cossy's reaction conditions, $RhCp^E$-π-allyl complex **56** was subjected to stoichiometric $AgSbF_6$ and $Cu(OAc)_2•H_2O$ to produce the intramolecular amination product **52** in 51% yield (Figure 1.4.A.). This experiment is highly suggestive of a π-allyl intermediate playing a role in the allylic amination proposed early on by Cossy.

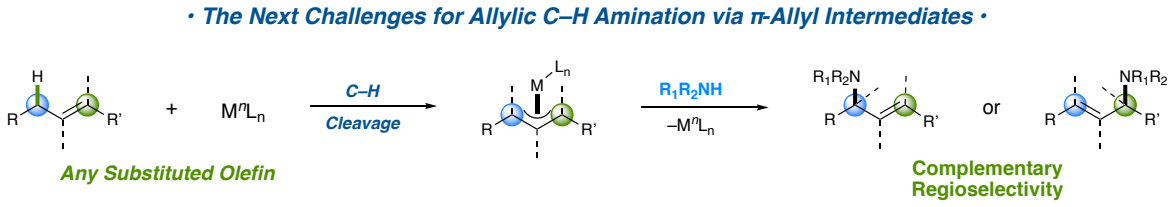
This reactivity was not unique to terminal olefins, Tanka's study goes on the demonstrate that simple unactivated terminal olefins can engage the $RhCp^E$ precatalyst in high yields (>90%) under modified conditions. Further investigation with $[RhCp^ECl_2]_2$ could also activate the allylic C-H bond of *trans*-2-octene **57** and result in a mixture of complexes **58a-c** in 97% yield (Figure 1.4.B). Remarkably, the $RhCp^E$ complexes generated from this reaction displayed an inherent regioselectivity for the internal complex **58b**, suggesting that RhCp-derivatives can selectively react with 1,2-disubstituted olefins without a directing group.

1.5. Addressing the Challenges of Intermolecular Reactivity for the Allylic C-H Amination of Olefins *via* π-Allyl Intermediates

Motivated by the early examples in the literature for allylic C-H amination *via* π-allyl intermediates and the direct applications of these methodologies to streamline the synthesis of fairly complex molecules urges us to explore complementary methods to functionalize olefin. One measure that prevents wide-spread adoption of these techniques to the community is the limited reaction partners in terminal olefins, with the inability to react with di-, tri-, or tetrasubstituted olefins. Additionally, regioselectivity for C-H amination reactions *via* π-allyl intermediates predominately produce linear products with a limited scope of available nucleophiles (sulfonyl carbamates).

To that end, a system capable of intermolecular allylic C-H amination of any substituted olefin *via* transition-metal π-allyl intermediates would represent a significant advance (Scheme 1.16.). Secondly, identification of novel conditions to determine the regioselectivity of higher-substituted π-allyl intermediates would provide complementary routes to allylic amine products. Finally, expanding the nucleophile scope for new or unidentified amine coupling partners would promote increased use of allylic C-H amination in the community due to more flexible approaches.

Scheme 1.16. Initial Challenges for Advancing Allylic C-H Amination *via* π-Allyl Intermediates.



Our group in the Blakey lab was inspired to address the clear gap for the generation of transition-metal π-allyl intermediates and regioselective control for the amination site of higher-substituted olefins through allylic C-H functionalization. The knowledge obtained by Cossy and Tanaka will be key to developing a regioselective intermolecular reaction *via* allylic C-H functionalization of 1,2-disubstituted olefins.

Building upon these precedents that 1) RhCp-derivatives selectively generate internal, disubstituted metal-π-allyl intermediates and 2) RhCp-derivatives are capable of catalytic allylic C-H amination of 1,2-disubstituted olefins will be the foundation for our studies in a regiodivergent reaction development strategy.

The hypotheses, reaction development, and mechanistic nuances of complementary intermolecular allylic C-H amination reactions of 1,2-disubstituted olefins for conjugated (Chapter 2)[75] and benzylic (Chapter 3)[76] will be discussed through this document (Figure 1.5). Additionally, studies related to enantioselectivity and applications towards the diastereoselective synthesis of 1,2-amino alcohols will also be discussed.

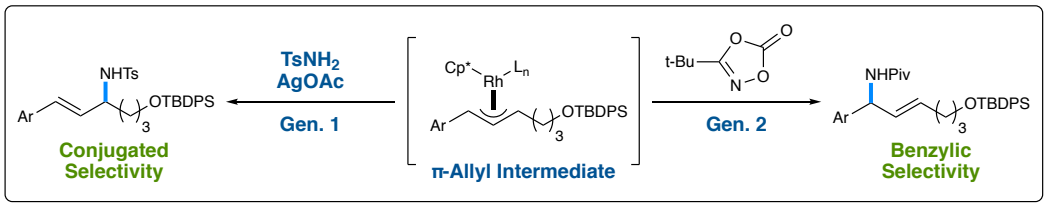


Figure 1.5. Regiodivergent Reaction Development for Conjugated and Benzylic Selectivity.

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Chapter 2:

Reaction Discovery and Development for Conjugated Selective Oxidative Allylic C-H Amination of Disubstituted Olefins *via* RhCp*-π-Allyl Intermediates

2.1. Reaction Design for Probing Allylic C-H Amination

2.1.1. Substrate Design Choice and Mechanistic Hypothesis

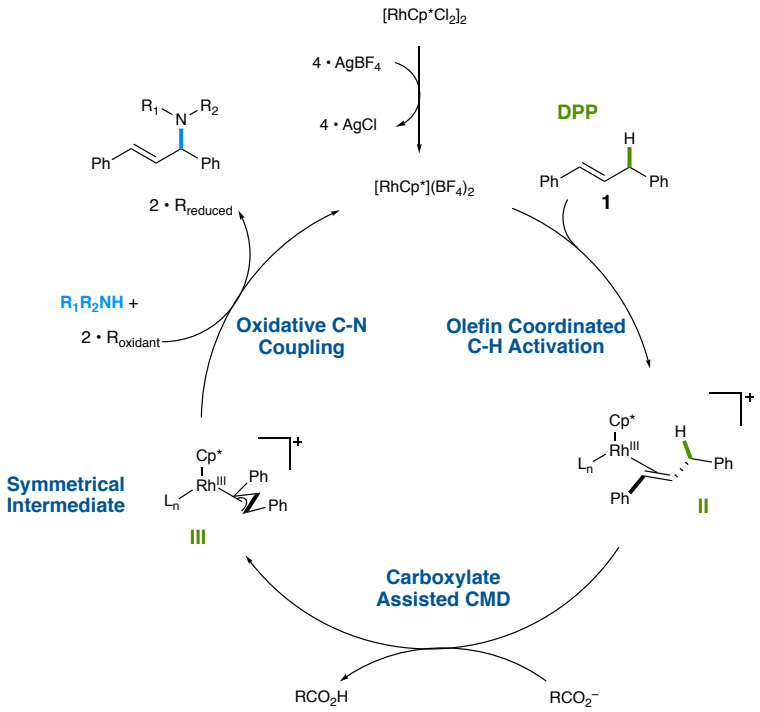


Figure 2.1. Proposed Rh-π-Allyl Intermediate is Symmetrical

To begin probing the field for intermolecular allylic C-H amination of disubstituted olefins it is necessary to evaluate an effective model system and mechanistic hypothesis. We identified *trans*-1,3-diphenylpropene **1** (DPP) as an excellent model substrate due to symmetry of the intended Rh-π-allyl intermediate. This substrate would allow us to pursue novel reactivity for 1,2-disubstituted olefins before studying the nuances of regioselectivity (Figure 2.1.). Mechanistically we can propose a cationic RhCp* species coordinating to the olefin moiety of DPP **1** to activate the allylic C-H bond in complex **II**. An exogenous carboxylate base would then

abstract the activated allylic proton and form symmetrical intermediate **III** *via* a Concerted Metalation-Deprotonation (CMD) mechanism known in RhCp*-catalyzed *ortho*-directed sp^2 C-H functionalization reactions.[1-3] A two-electron oxidation process with an amine nucleophile would hypothetically complete the redox cycle for an oxidative C-N coupling and provide a new approach for the synthesis of allylic amine products.

2.1.2. Reaction Design and Development with Initial Experiments

In choosing an appropriate precatalyst for allylic C-H amination we considered known RhCp complexes in the literature and selected commercially available $[RhCp^*Cl_2]_2$ as well as the easily accessible $[RhCp^ECl_2]_2$ because they were demonstrated by Cossy[4] and Tanaka[5] to be competent for the allylic C-H functionalization of disubstituted olefins. $AgBF_4$ was used initially as the halide scavenging salt for the chloride (Cl^-) ions to liberate cationic RhCp-species as the probable active catalyst. $TsNHCO_2Me$ was selected as the first nucleophile to be studied since no other amine nucleophiles capable of intermolecular allylic C-H functionalization with π-allyl intermediates were known prior to this investigation. Additionally, to keep close to literature precedent we examined 1,4-dioxane and 1,2,-dichloroethane (DCE) for the solvent as well as $Cu(OAc)_2$ for the stoichiometric oxidant and base for catalytic turnover (Figure 2.2.).

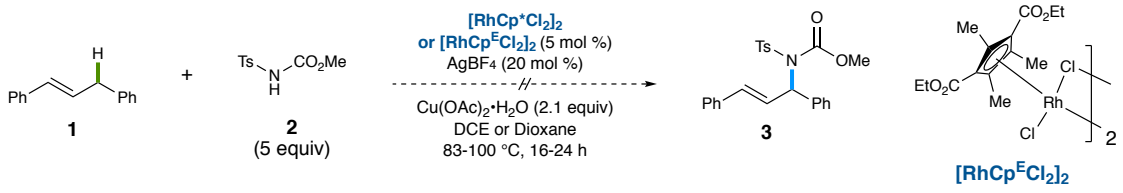


Figure 2.2. Tested Intramolecular Literature Conditions for Intermolecular C–H Amination.

Multiple attempts with the established literature conditions confirmed that $[RhCp^*Cl_2]_2$ and $[RhCp^ECl_2]_2$ were ineffective at forming C-H amination product **3** (Figure 2.2). These preliminary failures caused us to reevaluate certain mechanistic assumptions regarding access to the Rh-π-allyl intermediate, efficiency of the copper(II) oxidant, and the capacity for tosyl carbamates to engage in this new reaction platform.

After the unsuccessful attempts to form any aminated products, we questioned whether the intended Rh-π-allyl intermediate was being generated or even accessible from DPP with these conditions. To confirm whether DPP **1** was an effective olefin to generate a Rh-π-allyl intermediate I modified Tanaka's mild conditions to isolate a Rh-π-allyl complex from our disubstituted olefin. Using $[RhCp^ECl_2]_2$ with 10 equivalents of DPP, 4.0 equivalents of $AgBF_4$ and CsOAc as the base, we successfully isolated the corresponding $RhCp^E$-π-allyl complex **4** in 75% yield (Figure 7). After isolating complex **4**, we were certain that $RhCp^E$ was capable of allylic C-H activation to access the key π-allyl intermediate in our proposed reaction pathway. The challenge for intermolecular reactivity for amination products must lie elsewhere in the conditions.

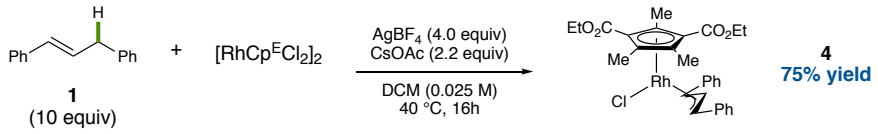


Figure 2.3. Stoichiometric Complexation of Rh^{III}-Cp^E-π-Allyl Complex.

Since we have successfully isolated a Rh-π-allyl complex, we next we hypothesized that $Cu(OAc)_2$ is simply an incompatible oxidant for intermolecular allylic C-H amination of more 1,2-disubstiuted olefins. Silver(I) salts have been effective oxidants for other $[RhCp^*Cl_2]_2$ catalyzed systems[7-9] and comparatively redox potentials of Cu^{II} and Ag^I are 0.32 V and 0.80 V

respectively in aqueous solutions (Ag^{I} in DCM exhibits a 0.65 V redox potential).[10] Despite the difference for redox potentials in organic vs. aqueous solvents, Ag^{I} being ~0.5 V greater in oxidizing potential than Cu^{II} sources should still exhibit a similar relationship without a direct comparison in the same organic solvent. Switching the oxidant from $Cu(OAc)_2$ to AgOAc would maintain the same ratios of oxidant and the carboxylate base would remain in the system. When substituting the copper salt for AgOAc, the reaction of DPP **1** and tosyl-carbamate **2** produced the decarboxylated C-H amination product **5** in 22% yield (Figure 2.4.).

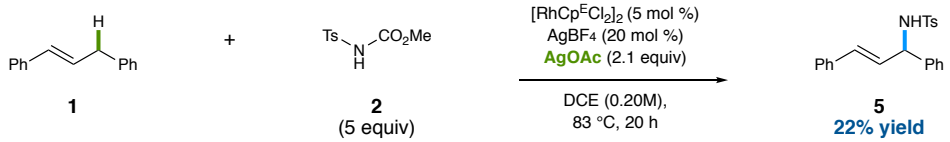


Figure 2.4. AgOAc as Oxidant Promotes Alternative Amination.

Currently there is no evidence for the direct amination of DPP with $TSNHCO_2Me$ for product **3**, but *p*-toluenesulfonamide ($TsNH_2$, **6**) was observed in the crude reaction ^1H NMR spectrum. We can assume that given this information, the tosyl carbamate **2** decarboxylates releasing CO_2 under the reaction conditions to generate the active nucleophile (**6**) *in situ* which then intercepts the Rh-π-allyl intermediate. After switching the nitrogen nucleophile to 5.0 equivalents of $TsNH_2$ **6** and maintaining 2.10 equivalents of AgOAc as the oxidant, our hypothesis was confirmed with generation of allylic amine **5** in higher yield (48%). Lowering the nucleophile loading to 2.5 equivalents of $TsNH_2$ afforded higher yield of amination product (62%), suggesting competitive coordination of excess nucleophile has a negative impact on catalytic activity (Figure 2.5.).

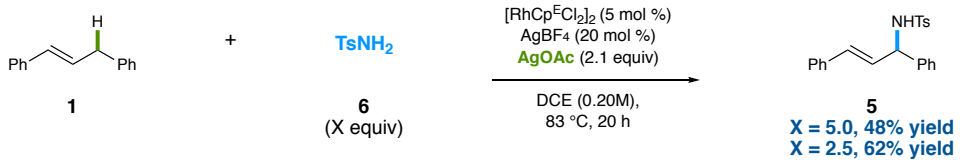


Figure 2.5. $TsNH_2$ is Demonstrated as the Active and Efficient Amine Nucleophile.

Despite the greatly improved results with the discovery of a more potent oxidant and appropriate nucleophile for intermolecular allylic amination, we still questioned the requirement for the unique $[RhCp^ECl_2]_2$ precatalyst. Direct comparison with commercially available $[RhCp^*Cl_2]_2$ under similar conditions exhibited nearly equivalent yield of allylic amine **5** (65%, Figure 2.6). At this point in our study we have exhibited new proof of concept in two ways towards our goals for advancing allylic C-H functionalization methods *via* π-allyl intermediates. One being the first instance of intermolecular reactivity for the allylic C-H functionalization of a disubstituted olefins (most likely proceeding through transition-metal π-allyl intermediates). Secondly, we have advanced the nucleophile scope to include a singly-protected sulfonamide as a viable amine source instead of the doubly-activated tosyl carbamates.

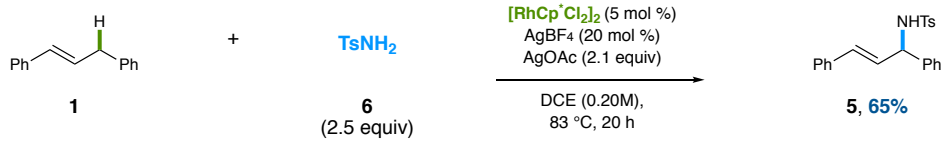


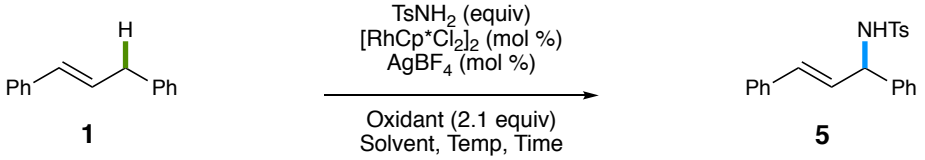
Figure 2.6. $[RhCp^*Cl_2]_2$ Precatalyst Demonstrates Equivalent Result to $[RhCp^ECl_2]_2$.

2.2. Optimization of Allylic C-H Amination on *trans*-1,3-Diphenylpropene

After determining a successful set of conditions for good yield of allylic C-H amination product **5** we were well-positioned to optimize the reaction parameters (Table 2.1.). It was found that full consumption of DPP **1** was achieved within 2 hours at 80 °C in DCE, resulting in good yield of amide product **5** (64%, entry 1). By extending the total reaction time to 4 hours we could observe consistent 75% average yield at 80 °C (entry 2). When lowering the reaction temperature to 60 °C we observed a slight increase in yield suggesting that the higher temperature could be responsible for deleterious side reactions (80%, entry 3). Decreasing the nucleophile loading of $TsNH_2$ from 2.5 to 1.25 equivalents showed a slight decrease in yield (74%, entry 4). To understand the effects of catalyst concentration with respect to yield, we observed that decreasing the RhCp* precatalyst loading to 1 mol % resulted in another elevation in yield (85%, entry 6). This result suggests that higher concentrations of catalyst is also detrimental to product formation.

It became necessary to perform control experiments to determine the necessity of $[RhCp^*Cl_2]_2$, $AgBF_4$, and AgOAc for allylic amination. We found that the RhCp* precatalyst was essential to the amination reaction, returning near quantitative yield of DPP **1** in its absence (entry 7). Interestingly when $AgBF_4$ was left out of the reaction no amination product was observed, despite using 2.5 equivalents of AgOAc to compensate for the missing noncoordinating halide scavenger (entry 8). The amination of DPP does not occur in the absence of AgOAc, further highlighting the requirement for a stoichiometric oxidant and carboxylate base as outlined in our mechanistic hypothesis (entry 9).

Table 2.1. Optimization of Allylic C-H Amination of *trans*-1,3,-Diphenyl Propene.



1 **5**

Entry	$TsNH_2$ (equiv)	[Rh] (mol %)	$AgBF_4$ (mol %)	Oxidant	Solvent	Temp (° C)	Time (h)	% Yield[a]
1	2.5	5.0	20	AgOAc	DCE	80	2	64
2	2.5	5.0	20	AgOAc	DCE	80	4	75
3	2.5	5.0	20	AgOAc	DCE	60	4	80
4	1.25	5.0	20	AgOAc	DCE	60	4	74
5	2.5	2.5	10	AgOAc	DCE	60	4	80
6	2.5	1.0	4	AgOAc	DCE	60	4	85
7	2.5	0	20	AgOAc	DCE	60	4	0
8[b]	2.5	5.0	0	AgOAc	DCE	60	4	0
9	2.5	5.0	20	—	DCE	60	4	0
10	2.5	5.0	20	$Cu(OAc)_2$	DCE	60	4	9
11	2.5	5.0	20	$Cu(OAc)_2$	DCE	80	16	46
12	2.5	5.0	20	Ag_2CO_3	DCE	60	4	Trace
13	2.5	5.0	20	AgOAc	THF	60	4	54
14	2.5	5.0	20	AgOAc	MTBE	60	4	15
15	2.5	5.0	20	AgOAc	Toluene	40	4	0
16	2.5	5.0	20	AgOAc	DCE	40	8	55
17	2.5	5.0	20	AgOAc	DCE	40	24	60
18	2.5	5.0	20	AgOAc	DCE	23	24	77
19	2.5	5.0	20	AgOAc	DCE	40	24	3
20	2.5	1.0	4	AgOAc	DCE	40	24	85
21	**2.5**	**1.0**	**4**	**AgOAc**	**DCM**	**40**	**24**	**93(88)[c]**
22	2.0	1.0	4	AgOAc	DCM	40	24	80
23	1.1	1.0	4	AgOAc	DCM	40	24	74

[a] Yields reported are an average of two trials determined by ^1H NMR analysis using di-*tert*-butylbiphenyl as an external standard. [b] 2.50 equiv of AgOAc was used. [c] Isolated yield in parentheses.

Early in our preliminary studies our reaction design steered us away from using other stoichiometric oxidants due to the efficiency seen with AgOAc. Since that time, we have developed more robust conditions with $TsNH_2$ and wondered if incorporating the ideal amine nucleophile would allow high yield using alternative oxidant sources. To understand the effect of Ag^I as a stoichiometric oxidant we opted to reinvestigate $Cu(OAc)_2$ because it would still contain the necessary carboxylate base for the proposed CMD of the C-H functionalization. After reacting 2.1 equivalents of $Cu(OAc)_2$ under our mild reaction conditions, 60 °C for 4 hours, we observed minimal product (9%) formation highlighting the difference between the analogous salts under the amination conditions (entry 10). Higher yields could be observed when using $Cu(OAc)_2$ and 5 mol % $[RhCp^*Cl_2]_2$ at high temperatures Although the allylic amination reaction with similar to the report by Cossy[4] at reflux temperature did notice an appreciable amount of product (46%), but the disparity further emphasizes the efficiency of the silver-promoted conditions (entry 11). Interested in the necessity for the carboxylate base in the reaction conditions, we sought Ag_2CO_3 as a substitute and were not surprised to observe trace amounts of the amine product in the crude ^1H NMR (entry 12).

With the efficiency of the reaction demonstrated for a halogenated solvent (DCE) we were interested in observing other benign solvents that could improve the yield of amination product **5**. Tetrahydrofuran (THF) was selected as commonly accessible solvent that has seen use in directed C(sp^2)-H functionalization.[11] Using THF we observed a lower product formation when compared to the halogenated solvent under the same conditions (54%, entry 13). Switching to another ethereal solvent, methyl *tert*-butyl ether (MTBE), resulted in even lower yield (15%, entry 14). When studying the effects of non-polar toluene in the allylic amidation we no observed product (entry 15). The results of this preliminary solvent screen and my physical observations suggest

that solubility issues arise between the catalyst, nucleophile, and oxidant when trying to implement nonpolar solvents for allylic amination.

The reaction was decreased further to 40 °C to aim for more mild conditions that could be applied to a wide variety of substrates. To our satisfaction even under the short reaction times, 4-8 hours, we could observe a substantial level of allylic amine **5** (55-60%, entries 16-17). Extending the reaction time to 24 hours with 5 mol % $[RhCp^*Cl_2]_2$ at 40 °C exhibited a 77% yield of allylic amination product (entry 18). Running the amination reaction at room temperature (23 °C) produced minimal product (3%, entry 19) and informed us to maintain mild heating for the remainder of the optimization.

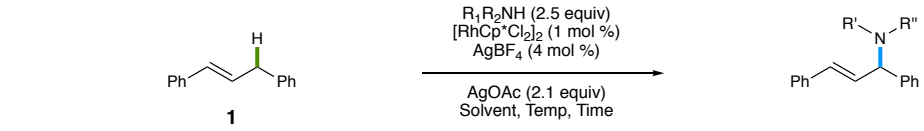
Synthesizing the information gained from the extensive optimization of reaction parameters we examined minimal catalyst loading (1 mol % $[RhCp^*Cl_2]_2$) under the mild reaction conditions (40 °C for 24 hours) and detected 85% yield of amine **5** (entry 20). We were urged to examine dichloromethane (DCM) as a substitute since the reaction was efficient at lower reaction temperatures and it is a more readily accessible solvent. When DCM was used as the solvent, we were pleased to observe 93% yield; under the same conditions we could isolate 88% yield of amination product (entry 21). We were tempted to study 2.0 – 1.1 equivalents of nucleophile with the mild reaction conditions and observed slight decrease in yield (74-80%, entry 22-23), and so we against applying this modification. Our optimized conditions can be highlighted in Table 2.1. (entry 21) as a general reaction platform for examining other olefin substrates and amine nucleophiles.

2.3. Amine Nucleophile Studies for Allylic C-H Functionalization of DPP

2.3.1. Successful Amination Nucleophiles for DPP

As stated earlier, the allylic C-H amination with $TsNH_2$ is a fundamental advance for the intermolecular functionalization of π-allyl intermediates due to utilizing an amine nucleophile with a single electron-withdrawing group. The successful high yielding optimization of the amination reaction with DPP left us well positioned to explore other nucleophiles for the transformation with this ideal olefin substrate (Table 2.2.). To test the limits of substitution on our amine source we first went to N-methyl-sulfonamide (TsNHMe), to our delight the small substituent on did not inhibit the reactivity high yield of amination product **7** was observered with the optimized conditions. However, using nucleophiles with a larger N-substituent such as N-benzylsulfonamide (TsNHBn) and N-tosylaniline (TsNHPh) results in no product formation at 40° C. To remedy this reactivity challenge for sterically demanding nucleophiles, simply elevating the temperature to 60 °C for 24 hours resulted in the generation of amination products **8** and **9** in 41% and 44% yield respectively. The amination conditions were also amenable to incorporating the more easily cleavable *ortho*-nitrobenzenesulfonamide (*o*-$NsNH_2$) as a nucleophile, low yield of amine **10** was observed at 40 °C for 24 hours (30%), but extending the reaction time to 48 hours resulted in 76% yield.

Table 2.2. Amine Nucleophiles for Allylic C-H Functionalization of *trans*-1,3-Diphenylpropene.



7, (88%)[a]	**8,** (44%)[c]	**9,** (41%)[c]	**10,** (76%)[b]	**11,** (82%)[b]
12, (80%)[d]	**13,** (95%)[d]	**14,** (15%)[d]	**15,** (78%)[d]	**16,** (26%)[d,e] (1.6:1 d.r.)

Yields are reported for isolated product. [a] Reaction was run in DCM at 40 °C for 24 h. [b] Reaction was run in DCM at 40 °C for 48 h. [c] Reaction was run in DCE at 60 °C for 24 h. [d] Reaction was run in DCE at 60 °C for 48 h. [e] 5.0 equivalents of nucleophile was used.

We were then interested in exploring sulfamates as competent amine nucleophiles because they are functionally similar to sulfonamides and exhibit excellent pharmaceutical properties in active pharmaceuticals such as the mono-saccharide based topiramate.[12] We first investigated 1,1',1''-trichloroethoxysulfamate ($TCESNH_2$) due to its wide use in nitrene-based C-H amination methods, aiming to provide another use for the common reagent.[13] Upon treatment of DPP **1** with $TCESNH_2$ under our optimized conditions the reaction mixture still contained noticeable quantities of starting olefin; allowing the reaction to proceed for 48 hours at 40 °C resulted in full consumption of DPP **1** and amination product **11** was isolated in high yield (82%). Unsurprisingly since sulfamates exhibited generally slower reactions with DPP, when studying the unactivated sulfamate ($Ph(CH_2)_3OSO_2NH_2$) we saw no indication of amination product at 40 °C. When the unactivated sulfamate was studied at 60 °C for 48 hours we were able to isolate the new allylic amine product **12** in good yield (80%).

The first experiment with $CbzNH_2$ with the optimized amination conditions for DPP delivered low yield of amination product (40 °C, 24 h; 11%). Excited by the initial reactivity with a carbamate nucleophile, slight modification to the optimized conditions afforded excellent yield of the aminated product **13** (60 °C, 48 h; 95%). When moving to $BocNH_2$ as a possible amine source we were disappointed to isolate low yields of the amination product **14** (60 °C, 48 h; 15%). Despite multiple attempts to modify the conditions for $BocNH_2$ the yield never increased past this initial result, we hypothesized that both the Boc- moiety for the nucleophile and product were susceptible to decomposition with stoichiometric AcOH generated over time and inhibit further catalysis. To highlight the use of our allylic amination for new applications in peptide synthesis we tested Cbz-glycine-OMe as a competent nucleophile with DPP and successfully isolated the functionalized amine **15** in good yield (60 °C, 48 h; 76%). When studying the more sterically demanding Cbz-alanine-OMe for the amination reaction, we were required to increase nucleophile loading to 5.0 equivalents and still observed low yield of amine **16** with minimal diastereoselectivity (60 °C, 48 h; 26%).

2.3.2. Unsuccessful Amination Nucleophiles for DPP

Unprotected aniline ($PhNH_2$) as well as simple amide nucleophiles such as acetamide ($AcNH_2$) and trifluoroacetamide (CF_3CONH_2) which were found to be ineffective for the amination of DPP under the RhCp*-catalyzed conditions. In all cases the crude ^1H NMR spectrum indicated essentially no reaction with DPP and which implies that the more nucleophilic amines sequester the active cationic RhCp* catalyst to a strongly coordinated inactive species. The only observed product in the case of trifluoroacetamide were minimal quantities of allyl acetate.

2.3.3. Conclusion of Key Advances for Allylic C-H Amination Nucleophiles

We have demonstrated excellent reactivity with the newly developed system for allylic C-H amination *via* π-allyl intermediates of a model disubstituted olefin (DPP). Previously the only nucleophiles for intermolecular allylic C-H amination were doubly-protected tosyl-carbamates, this work has demonstrated largely different functional group tolerance for singly-protected sulfonamides, sulfamates, and carbamates. The method is also capable of incorporating *N*-substituents amines into the amination methodology. Despite the initial problems observed for sterically demanding or strongly coordinating amine nucleophiles, we have begun contributing to our goals outlined at the outset of this study for expanding the nucleophile scope for intermolecular allylic C-H amination.

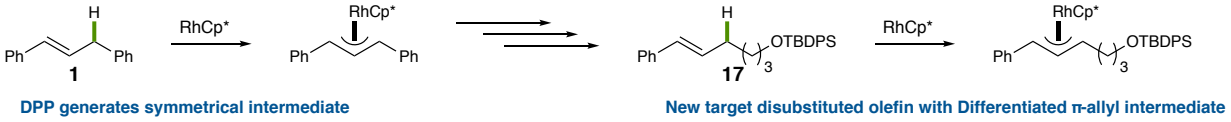
2.4. Efforts Towards Regioselective Allylic C-H Amination of Unfunctionalized Olefins

2.4.1. Studies for Allylic C-H Amination of Unsymmetrical Disubstituted Olefins

2.4.1.1. Design Choice and Access to Unsymmetrical *trans-β*-Alkylstyrene Derivatives

Now that we have successfully developed a high yielding novel system for allylic C-H amination of a disubstituted olefin producing a symmetrical π-allyl intermediate we must explore olefin for regioselectivity with a new system. To differentiate the π-allyl intermediate beyond aryl electronic effects, we aimed for a linear alkyl-chain substituted at the allylic position such as *trans-β*-alkylstyrene **17**. Synthesizing the intended *trans*-disubstituted olefin must be achieved in a selective manner to truly evaluate the regioselectivity and yield for the more complex system.

Scheme 2.1. Target for New olefin Substrate with Differentiated π-Allyl Intermediate.



When evaluating standard methods to synthesize olefins, one-pot hydroboration/Suzuki couplings were very prevalent in the literature. But in our hands, all attempts at this one-pot protocol afforded good yield of cross-coupled olefins but, the hydroboration step using catecholborane was not regioselective for the *trans*-vinylborane intermediate and noticeable quantities of 1,1'-disubstituted olefin **19** was also generated through this method. While methods

do exist to separate olefin isomers of this nature *via* silver-impregnated silica gel chromatography,[14] this route is undesirable as the method requires intensive preparation of TLC plates and silica-gel and cannot be stored for extended periods of time.

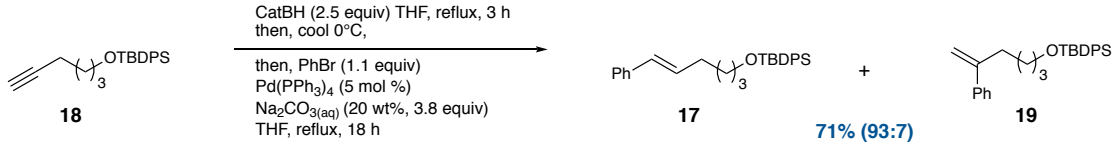
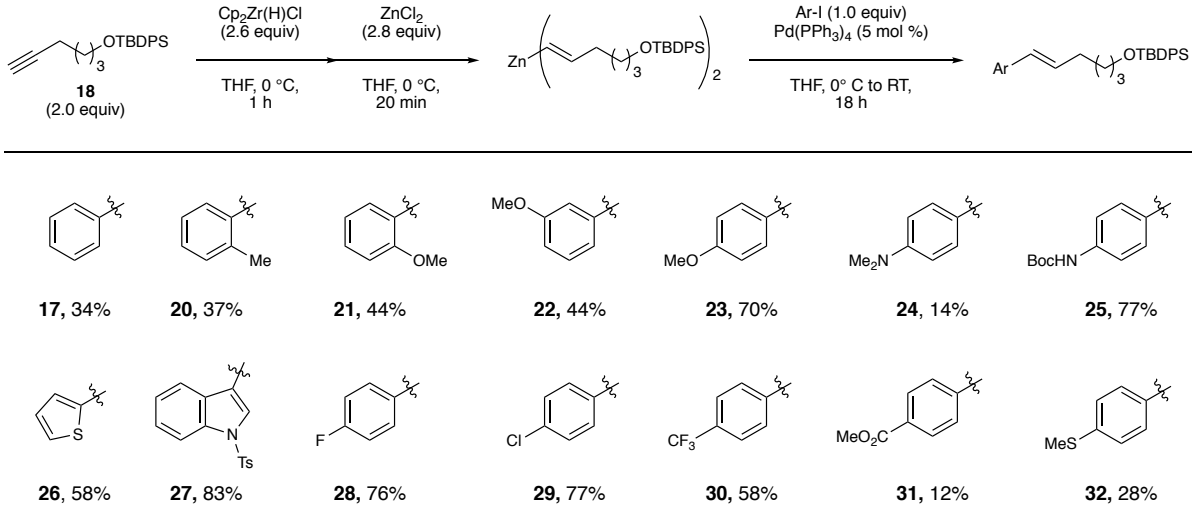


Figure 2.7. One-Pot Hydroboration/Suzuki Coupling of Alkyne to *trans*-Olefin.

An alternative Negishi coupling was identified for the synthesis of the potent anti-tumor natural product FR901464 initiated by a hydrozirconation of an advance alkyne intermediate using Schwartz's reagent ($Cp_2Zr(H)Cl$).[15] The general mechanism after hydrozirconation proceeds through transmetallation to $ZnCl_2$ to generate the active nucleophilic component for cross-coupling. When applying the method to the synthesis of our ideal phenyl substituted *trans-ß*-alkylstyrene **17**, alkyne **18** effectively generated the cross-coupled product through the hydrozirconation method and the *trans*-styrene product was isolated with perfect olefin geometry (Table 2.3.; **17**, 34%). Utilizing this one-pot procedure we were able to prepare a variety of *trans-ß*-alkylstyrene derivatives **20-32** summarized in Table 2.3.. While low yielding in some cases, we considered this route sufficient for our exploratory reactions and no optimization was undertaken for this cross-coupling procedure. Thus, we now have access to a full range of olefin electronics to explore the regioselective allylic C-H amination.

Table 2.3. Selective *ß*-Alkylstyrene Synthesis *via* Hydrozirconation/Negishi Cross-Coupling.



2.4.1.2 Steric Assessment for Alkyl Group of Disubstituted Olefins

After gaining access to the *trans-ß*-alkylstyrenes substrate class, we were now set to further understand the potential utility of this reaction by investigated the efficiency and regioselectivity of the allylic C-H amination. In these reactions, 2 mol % of $[RhCp^*Cl_2]_2$ precatalyst was used to ensure complete reaction within a 24 hour time frame for all substrates. Amination of electronically neutral Ph-styrene **17** with $TsNH_2$ gave an 86% combined yield of amination products, favoring the conjugated isomer **33*c*** over the benzylic amine **33*b*** in a ratio of 6.3:1 (Figure 2.8.).

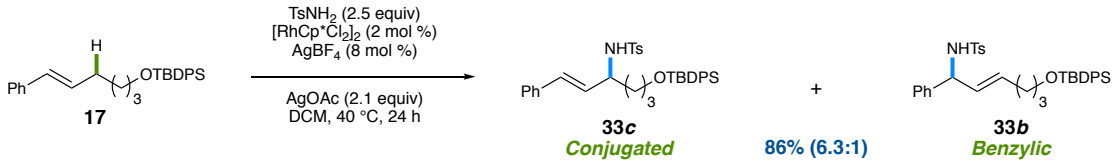
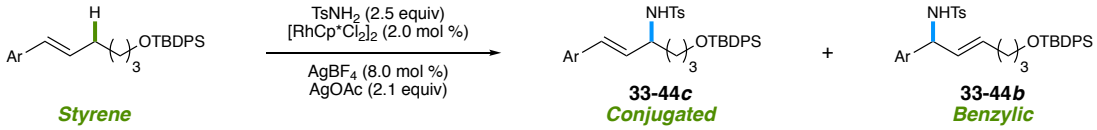


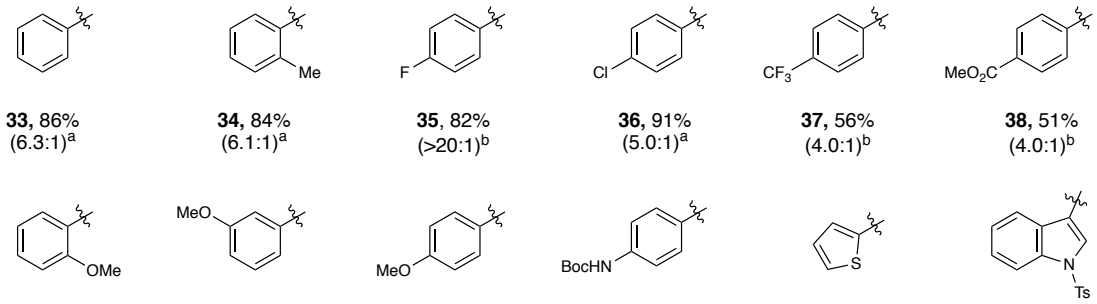
Figure 2.8. Initial Survey for Conjugated Regioselectivity of Ph-Substituted *trans-ß*-Alkylstyrene.

Conjugated regioselectivity was observed for all *trans-ß*-alkylstyrene substrates investigated in the study (Table 2.4.). Introduction of an *ortho*-methyl substituent to the arene had little impact on the yield or selectivity, the amination products **34*c*** and **34*b*** were isolated in 84% yield with a 6.1:1 regioselectivity. Electron-withdrawing groups such as halogens, trifluoromethyl, and ester moieties were tolerated on the aryl ring, although slightly elevated temperatures (60 °C) were necessary to achieve full conversion of the starting material within 24 hours. Regioselectivities were moderate for the electron-poor arenes (4:1–5:1), although in the case of the *para*-fluoro-substituted **35*c***, >20:1 selectivity was observed for the conjugated product.

Electron-rich *ortho*-, *meta*-, and *para*- methoxides as the aryl substituent were aminated in good to excellent yield (**39**-**41**, 65 –87%), particularly important is the trend that *meta*-methoxy amine **40** demonstrated lower conjugated selectivity; a plausible explanation could be related to the inductive withdrawing effects of the moiety relative to the styrene-substitution (9.5:1). *Ortho*-**21** And *para*-methoxy-**23** substrates were aminated with perfect conjugated regioselectivity (>20:1). During our studies of nitrogen-nucleophile reactivity (*vide supra* section 2.3.) we observed that unhindered sulfonamides were generally more efficient nucleophiles than hindered carbamates. Based on these observations we assumed that Boc-protected aniline **25** would not act as a competitive amine nucleophile and be tolerated under the oxidative conditions. This prediction was indeed the case and conjugated allylic amine **42** was exclusively formed as the major regioisomer in 74% yield.

Table 2.4. Allylic C-H Amination Regioselectivity Profile for *trans-ß*-Alkylstyrene Derivatives.





33, 86% (6.3:1)[a]
34, 84% (6.1:1)[a]
35, 82% (>20:1)[b]
36, 91% (5.0:1)[a]
37, 56% (4.0:1)[b]
38, 51% (4.0:1)[b]
39, 79% (>20:1)[b]
40, 65% (9.5:1)[a]
41, 87% (>20:1)[b]
42, 74% (>20:1)[b]
43, 42% (5.4:1)[b]
44, 52% (>20:1)[c]

Yields are reported for isolated amination product. Ratios of regioisomers ***Conjugated***:***Benzylic*** were determined by ^{1}H NMR analysis of the crude reaction mixture and are shown within parentheses. [a] Reaction was run in DCM at 40 °C for 24 h. [b] Reaction was run in DCE at 60 °C for 24 h. [c] Reaction was run in DCE at 80 °C for 48 h.

In addition to the simple styrene derivatives, heteroaromatic 2-vinylthiophene **26** and 3-vinylindole **27** were also investigated. 2-Vinylthiophene amination products **43** were isolated in 42% yield as a 5.4:1 mixture of regioisomers at 60 °C for 24 hours. Observing the reaction progress of 3-vinylindole **27** at lower temperature 40 – 60 °C never resulted in full consumption of starting material. Simply elevating the reaction temperature to 80 °C for 48 h resulted in full conversion of starting material to exclusively the conjugated allylic amine **44** in 52% yield (>20:1).

Disappointingly, multiple attempts to functionalize the thioanisole olefin **32** failed and was attributed to greater coordination of the sulfur moiety to deactivate the active catalyst. Likewise, allylic C-H amination of dimethylamino olefin **24** resulted in a mixture of products indicating successful amination, but the oxidative conditions were most likely not amenable to the longevity of the reactive electron-rich aniline product.

2.4.1.3. Steric Effects at the Homo-Allylic Center for Allylic C-H Amination

In our current set of results, we had established excellent reactivity for the allylic C-H amination of unsymmetrical disubstituted olefins *via* π-allyl intermediates. But, our series of evaluated substrates focused on the electronic parameters of the arene that contribute to high yield and regioselectivity and neglect an analysis for steric bulk of the unsymmetrical 1,2-disubstituted olefin. We aimed to further understand the steric effects in context to substitution at the homo-allylic carbon beyond a 2° linear alkyl chain.

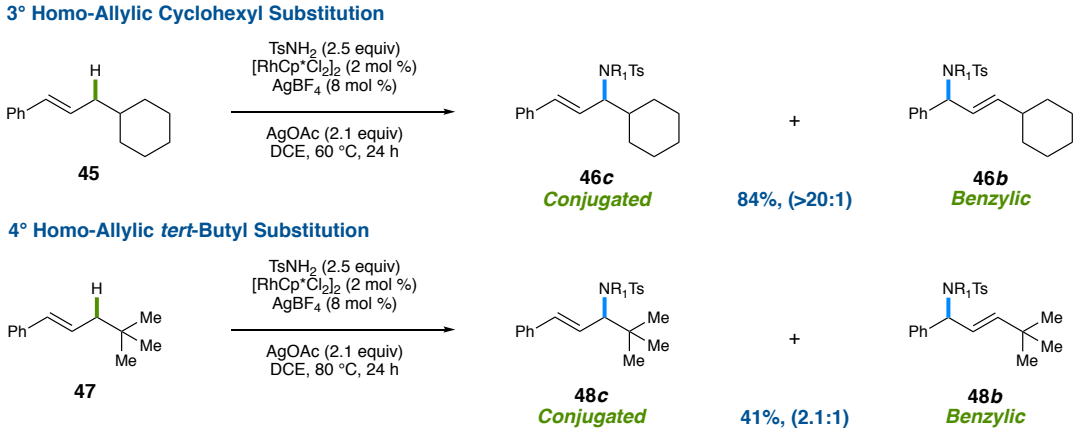


Figure 2.9. Exploration of 3° and 4° Homo-Allylic Substitution for Allylic C-H Amination.

After preparing 3° cyclohexyl-substituted olefin **45**, the mild 40 °C reaction conditions produced no amination product but, simply elevating the temperature to 60 °C observed exclusive formation the conjugated amine product **46*c*** in 84% isolated yield (Figure 2.9.). The selectivity demonstrated for **46*c*** is quite curious despite the increase in steric bulk adjacent to the site of C-N bond. Although after preparing 4° *tert*-butyl-substituted **47** and subjecting the olefin to amination conditions at 80 °C we observed a low yield and regioselectivity (**48*c*/48*b***, 41%, 2.1:1) in favor of

the conjugated product. From these results it is evident that while allylic C-H amination of *trans*-disubstituted olefins bearing a 3° homo-allylic substituent proceeds with high efficiency for conjugated amination products. Alternatively, similar substrate bearing a 4° homo-allylic substituent cannot overcome the competitive steric environment to deliver high yield and regioselectivity.

2.4.1.4. *cis*-Disubstituted Olefins under the RhCp*-catalyzed Allylic C-H amination

With such exemplary results with *trans*-disubstituted olefins explored in our allylic amination studies we questioned whether the reaction could be applied toward *cis*-olefins. Initial reactions with *cis*-*ß*-methylstyrene **49** showed no incorporation of $TsNH_2$ under the optimized conditions for DPP **1** (Figure 2.10). Only when increasing the reaction temperature to 80 °C were we able to observe any amination product which, to our surprise converted exclusively to the *trans*-amination product **50** in modest yield (28%). Closer inspection of the crude ^1H NMR data revealed baseline levels of *trans*-*ß*-methylstyrene in the reaction mixture, suggesting that either a metal- or acid-mediated isomerization event converts the *cis*-olefin to the reactive *trans*-olefin.

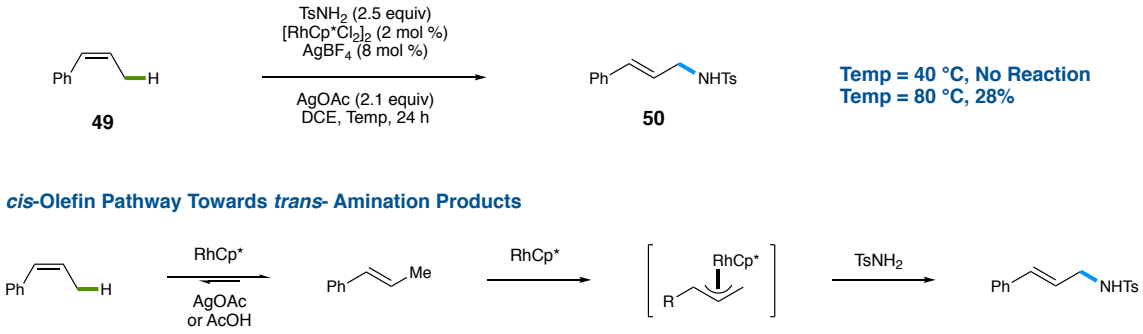


Figure 2.10. *cis*-*ß*-Methylstyrene Converts to *trans*- Amination Products *via in situ* Isomerization.

To further confirm this *cis* to *trans* olefin isomerization phenomenon against the analogous disubstituted styrenes studied we sought to prepare *cis-ß*-alkylstyrene **52**. A well-precedented room temperature Sonogashira coupling with alkyne **18** and phenyliodide afforded alkyne **51** in 88% yield (Figure 2.11.). Experimentation with Lindlar's catalyst (poisoned Pd/C/$CaCO_3$) known to selectively reduce alkynes to *cis*-olefins resulted in over-reduction in our hands to the saturated alkane. With the experience that we have gained in using Schwartz's reagent for the syn-selective hydrozirconation to prepare our *trans-ß*-alkylstyrenes, we questioned if using this for a disubstituted alkyne could deliver a *cis*-olefin product after quenching the zirconocene adduct with H_2O. After reacting alkyne **51** with Schwartz's reagent for 24 hours and quenching the reaction mixture with H_2O we were able to successfully acquire *cis-ß*-alkylstyrene **52** in 33% yield. When applying the RhCp*-catalyzed allylic C-H amination to *cis-ß*-alkylstyrene **52** at elevated temperature, the results were consistent with the olefin isomerization event and only *trans*-olefin amination products **33*c*/33*b*** were observed (56%, 8.1:1; Figure 2.11.). The data for *cis*-olefins studied at this time implies that the active RhCp* catalyst in the system chemoselectively engages the allylic C-H bond of *trans*-disubstituted olefins over the *cis*-isomer.

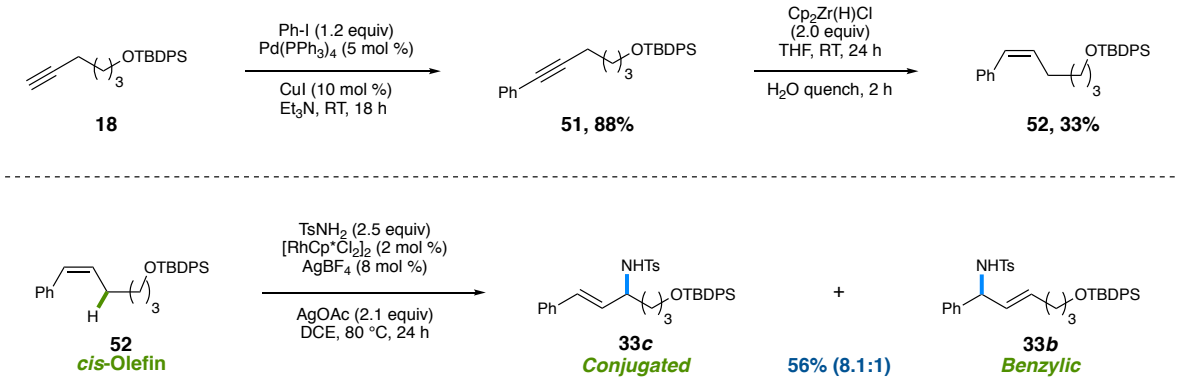


Figure 2.11. Synthesis of *cis-ß*-Alkylstyrene and RhCp*-Catalyzed Amination for *trans*-Product.

2.4.2. Preliminary Investigation for Amination of Terminal Olefins

After demonstrating unprecedented intermolecular reactivity for disubstituted olefins, we wondered if the RhCp*-catalyzed allylic C-H amination methodology could be applied to terminal olefins. Successful amination under the Rh-catalysis would provide an alternative to accessing π-allyl intermediates from unfunctionalized terminal olefins which was previously only possible with Pd-catalysis.[16-17] Successful implementation of RhCp* as a competent catalyst for allylic C-H functionalization of terminal olefins would highlight the utility of our developed system and provide complementary access to allylic amine products.

We identified allylbenzene **53** as a perfect model to test our allylic amination methodology for terminal olefins. Utilizing the conditions optimized for disubstituted olefins, the reaction of allylbenzene and $TsNH_2$ afforded exclusively the linear amination product **50** in 40% yield (Figure 2.12.). It is worth noting that increasing the temperature for higher conversion leads to increased levels of cinnamaldehyde side-product. This system was also capable of using N-methylsulfonamide (TsNHMe) as a nucleophile to provide the linear amination product **54** in 51% yield and >20:1 regioselectivity (, Figure 2.12.).

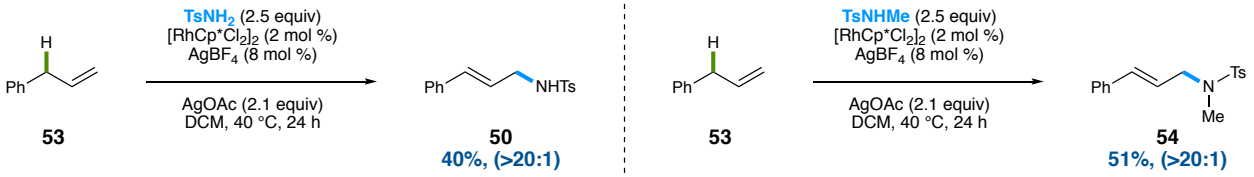


Figure 2.12. Preliminary Results in RhCp*-Catalyzed Allylic C-H Amination of Terminal Olefins.

2.4.3. Preliminary Investigation for Allylic Amination of a Trisubstituted Olefin

In our efforts to probe the limits of olefin substitution for the RhCp*-catalyzed allylic C-H amination methodology we sought to explore the possibility for trisubstituted olefins being amenable to the transformation. We identified 2-methyl-1-phenylpropene **55** as a perfect system to explore not just the reactivity for trisubstituted olefins but also the regioselectivity preference for the *cis*- or *trans*-methyl protons. Our studies have suggested that the allylic C-H activation event cannot occur at the allylic protons of a *cis*-olefins and we were curious if the same trend would apply in this competitive environment.

At low temperature (40 °C) there was no amination reaction observed, a trisubstituted olefin is presumably more challenging for the allylic C-H activation event. Simply elevating the temperature to 80 °C for 24 hours afforded allylic amine **56** in 39% yield as single product (Figure 2.13.). Moreover, the isolated material was confirmed by 1-D NOE ^{1}H NMR with a correlation between the allylic and olefinic protons. Our hypothesis was validated with confirmation from the NOE experiment for trisubstituted olefins being selective for the *trans*-allylic C-H bonds under the RhCp*-catalyzed conditions. This result demonstrates the first instance for intermolecular allylic C-H functionalization *via* π-allyl intermediates of a trisubstituted olefin and sets a foundation for future studies in olefin functionalizations.

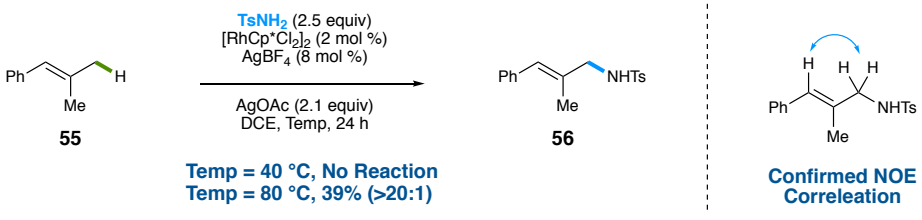


Figure 2.13. Regioselective Allylic C-H Amination of a Trisubstituted Olefin.

2.5. Initial Mechanistic Experiments for Allylic C-H Amination

2.5.1 Revelation of Thermodynamic Equilibration

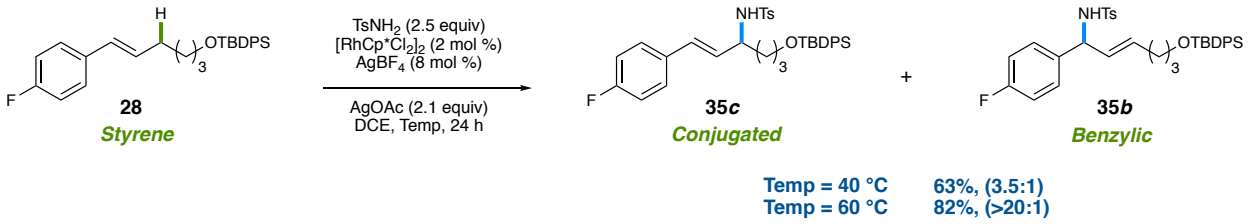


Figure 2.14. 4-Fluoro-*ß*-alkylstyrene Exhibits Higher Regioselectivity at Elevated Temperature.

Our studies found that amination of 4-fluorostyrene **28** exhibited lower yield and a drastic difference in regioselectivity at 40 °C (63%, 3.5:1) when compared to the analogous 60 °C trial (82%, >20:1) (Figure 2.15). To assess whether the elevated regioselectivity was the result of an uncommon kinetic selectivity[18] or a thermodynamic equilibration, we performed an experiment to observe the styrene **28**, conjugated amine **35*c***, benzylic amine **35*b***, and allylic-acetate **57** over the course of 48 hours by ^{1}H NMR (Figure 2.15.). Under standard conditions using 1,4-dinitrobenzene as an internal standard, after 24 hours of progress at 40 °C the reaction mixture of **28**:**35*c***:**35*b***:**57** (styrene/conjugated/benzylic/allylic-acetate) consisted of 3/60/15/10% respectively. The reaction was then heated to 60 °C for an additional 24 hours to result in 0/78/3/1% of **28**:**35*c***:**35*b***:**57**. Our observations confirmed a thermal equilibration of products toward amine **35*c***, but this behavior was not consistent for every substrate examined in our study.

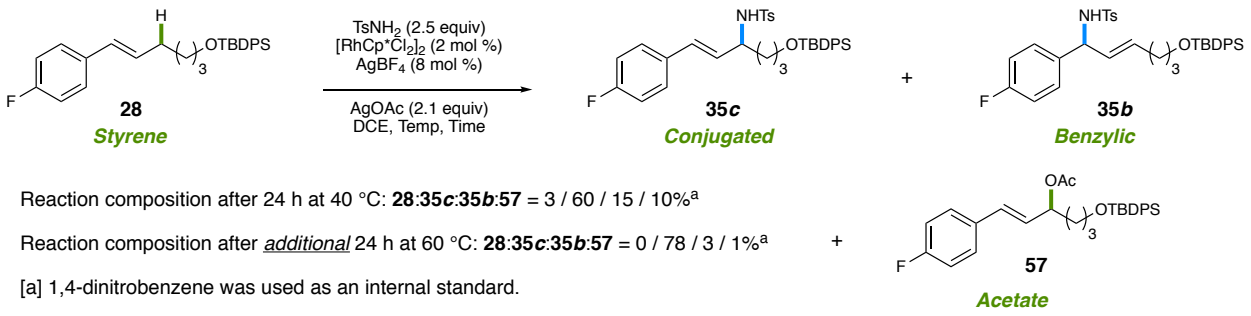


Figure 2.15. Temperature Study Reveals Thermodynamic Equilibration.

2.5.2. Initial Insight into Reversibility of C-H Cleavage

To further gain mechanistic understanding of the RhCp*-catalyzed allylic C-H amination, we turned to probe the reversibility of the C-H cleavage step to generate the π-allyl intermediate. Some reports of group IX MCp*-catalysts for directed C(sp^2)-H functionalization detail a reversible C-H cleavage step for vinyl C(sp^2)-H bonds.[19] To determine an initial sense for mechanistic pathways we designed the following experiment to probe the reversibility of the C-H functionalization step (Figure 2.16.). Under our standard RhCp*-catalyzed oxidative conditions, the reaction of 4-OMe styrene **23** and 2.5 equivalents of $TsND_2$ was doped with 10 equivalents of AcOD and run to partial completion (1 h) to observe possible deuterium incorporation in the starting olefin and amination products. After isolating the remaining starting olefin **23** (30%) and the mixture of amination products **41*c***/**41*b*** (29%, 5:1), we observed no evidence of deuterium incorporation, which suggests the irreversibility of the C-H cleavage step.

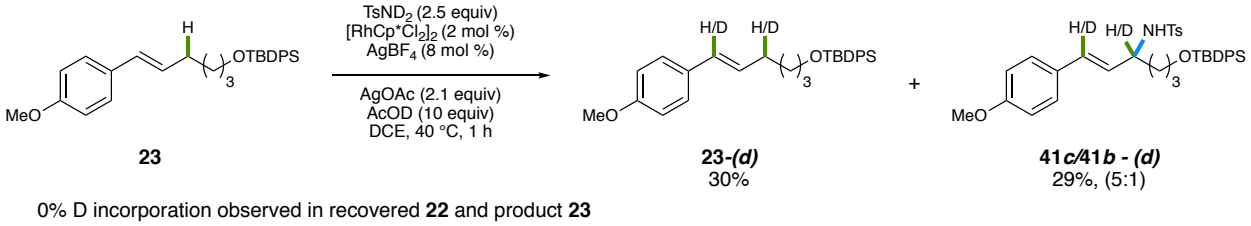


Figure 2.16. Deuterium Exchange Experiment under Amination Conditions with AcOD Doping.

2.5.3. RhCp^E-π-Allyl Complex as Mechanistic Intermediate

At the outset of study, there was no supporting evidence of the Rh-π-allyl intermediate being on-path towards allylic C-H amination products. Before the initial reaction discovery I had prepared RhCp^E-π-allyl complex **4**, at this time I hypothesized that this material could be utilized as the precatalyst for allylic amination of DPP **1** and good yield would support the on-path intermediacy of an analogous π-allyl complex (Figure 2.17.). When reacting 10 mol % of RhCp^E-π-allyl complex **4** relative to DPP with 2.5 equivalents of $TsNH_2$, 2.1 equivalents of AgOAc, at 80 °C, the amination product was isolated in 63% yield. Effectively utilizing complex **4** as a catalyst further supports the likelihood of π-allyl intermediates on-path to allylic amination product **5**.

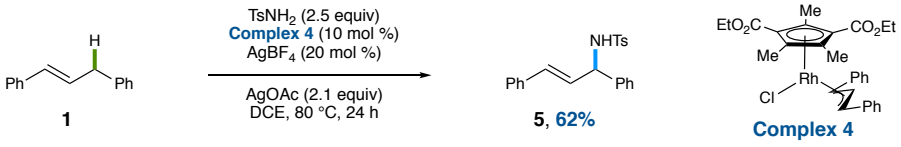


Figure 2.17. RhCp^E-π-Allyl Complex Utilized as Catalyst for Allylic C-H Amination.

With the mechanistic data from this study we know with certainty that allylic C-H functionalization is irreversible due to the lack of deuterium incorporation in the starting material **23** or products **41*c***/**41*b***. The catalytic experiment using $RhCp^E$ complex **4** as a catalyst highly supports the assumption of an on-path RhCp*-π-allyl intermediate. We have also observed the reversibility of C-N bond formation at elevated temperature *via* a thermodynamically induced equilibration of reaction constituents for the lowest energy, conjugated amination product **35*c***. At this time, it is clear that the mechanistic underpinnings of the reaction are far more complicated than the original proposal outlined at the outset of this study. Further work must be done to fully elucidate the key steps of the transformation for a clear understanding moving forward.

2.6. Attempts for Enantioselective Allylic C-H Functionalization *via* π-Allyl Intermediates

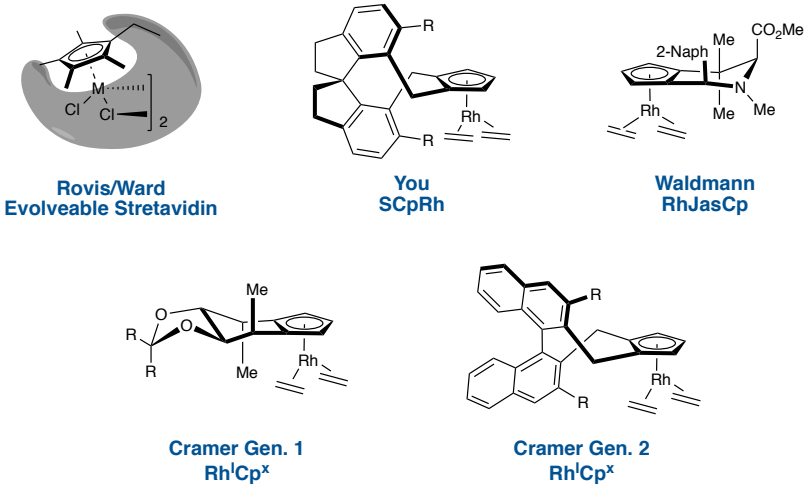
2.6.1. Efforts with Cramer Group's Chiral $RhCp^X$ Catalysts

2.6.1.1. Background and Analysis for Investigation

Pursuing enantioselective reaction conditions would promote further use of the allylic C-H amination technology by the synthetic community. Currently, there are a number of identified reports to explore for chiral group IX MCp catalysts. To date all the various chiral RhCp catalysts had only been used in directed sp^2 C-H functionalization. In furthering our goals for an enantioselective allylic C-H amination it became necessary to carefully evaluate the catalyst options before beginning a synthesis campaign.

In 2012 Rovis and Ward collaborated on the development of a streptavidin derivative metalloenzyme with a biotin tethered RhCp* derivative (Scheme 2.2.) for the enantioselective sp^2 C-H functionalization of pivaloyl-protected benzhydroxamic acids to dihydroisoquinolones.[20] It has been known through the work of Fagnou[1] and Glorius[21] that achiral RhCp* can achieve the same transformation at room temperature. In developing the streptavidin metalloenzyme scaffold it was necessary to design a free carboxylate residue in the enzyme's active pocket that would promote the required concerted metalation-deprotonation step (CMD). While this method was proficient for the published transformation it required an aqueous buffer system which we know hinders the allylic C-H amination of disubstituted olefins we have previously described.

Scheme 2.2. Known Chiral Group IX MCp Catalysts for sp^2 C-H Functionalization.



In the same year as Rovis and Ward, the Cramer group reported the development of a C_2 symmetric chiral Rh(I)Cp^X precatalyst.[22] Interestingly, commercially available sugar D-mannitol was utilized as the chiral base to diversify their Gen. 1. Cp ligands. The main diversifiable position to modulate is the "back-wall" diol portion of the ligand while maintaining a static "side-wall" for

the methyl substituents derived from the reduction of alcohols in the natural sugar source. Subsequent reports by Cramer described the synthesis of a new Gen. 2 C_2 symmetric Cp^X ligand derived from an enantiopure binol-scaffold which provides a fixed "back-wall" and modular "side-walls" enabled by a late-stage diversification route embedded in the synthesis. With both Gen 1. (D-mannitol-derived)[23] and Gen. 2. (binol-derived)[24-31] ligand sets the Cramer group has contributed remarkably to the field of asymmetric catalysis with Ru-, Rh-,and $IrCp^X$ complexes.[23-34]

In 2016 the You group, inspired by the work of Cramer , developed the synthesis of a series of chiral C_2 symmetric 1,1′-spirobiindane-based Cp-ligands with a spirocyclic backbone.[35] The spirocyclic Rh(I)Cp catalyst was utilized for the directed Heck-type oxidative coupling reaction of biaryl heterocycles with alkenes to generate axially chiral products. Previous efforts for the method using Cramer's catalyst only saw moderate enantioselectivity for the same transformation.[30] The main thrust for developing this method is that installation of axially chiral moieties is becoming increasingly important in natural product synthesis and pharmaceutical development. The You group's contribution to chiral Cp ligands highlights access to more a rigid spirocyclic scaffold that can complement the preexisting catalysts from the Cramer group.

Worth mentioning but unpublished prior to our investigation was Waldmann's report highlighting their accomplishments for the generation of a library of chiral JasCp ligands.[37] The synthesis of chiral dihydroisoquinolones was implemented as the pilot reaction to observe the effectiveness of the new RhJasCp catalysts with generally high *ee* (84-93%). This series of ligands are inherently different than the design of Cramer's D-mannitol derived Gen. 1 $RhCp^X$ catalysts because of shorter syntheses and more facile diversification. The *endo*- and *exo*-ligands are accessible from the [6+3] cycloaddition of a glycine-based aldimine and a substituted fulvene to

generate the chiral JasCp ligands.[38-39] Despite the more expedient synthesis of these ligands, the key drawback for our lab to explore the RhJasCp ligands is that access to each individual catalyst requires the use of toxic thallium(I) salts for transmetallation to a rhodium(I) source and chromatography maintained in an inert atmosphere with eluent at -40 °C. With no prior knowledge of the RhJasCp catalysts and the soon after awareness of hazardous and extreme isolation measures, these catalysts were not explored in our studies.

With the available chiral RhCp ligands, we identified the Cramer group's experience and knowledge would be the ideal choice to pursue for our allylic C-H amination methodology. The underlying mechanistic model for the Rh(I)Cp^X catalysts is from two main assumptions.[29] First being that coordination of a third ligand (substrate, L_{sub}) to prochiral **58** would equally access psuedotetrahedral enantiomers **59/60** having a stereogenic central metal atom and secondly, each enantiomer should deliver a distinct product (Figure 2.18.).

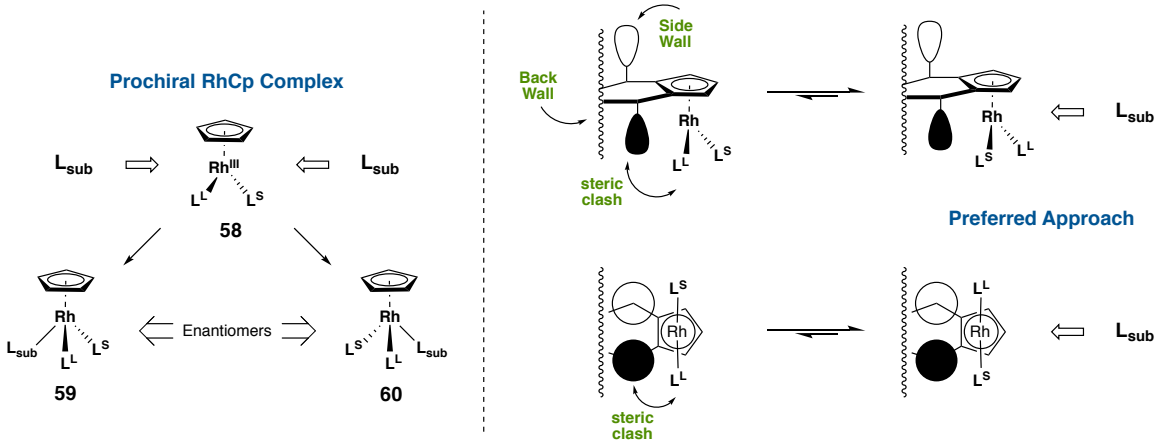


Figure 2.18. Chiral RhCp Ligand Analysis for Enantiocontrol.

The initial identification of 1,2-disubstituted cyclopentadienyl ligands were chosen because of the ability to divide the ligand in half, functionalizing one end to provide the steric bulk for the "back-wall" and "side-wall." The size of the "walls" for the Cp ligand dictate where other substrates (L_{sub}) approach the metal when L^S and L^L are oriented in a parallel fashion. L^L Will align itself away from the side-wall of the ligand ensuring that the greater the difference between L^S and L^L are, the more selective the catalyst will be in generating a single enantiomer (Figure 2.18.).

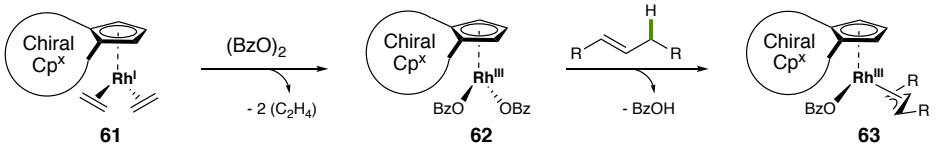


Figure 2.19. Hypothesis for Chiral Rh-π-Allyl Complex with Chiral $RhCp^X$ Catalysts.

In this way we can imagine our π-allyl intermediate **63** engaging the $RhCp^X$ catalysts in the same fashion. With our hypothesis being that the large aryl substituent represents L^L and the alkyl chain represents L^S, we can imagine a model for enantioselective catalysis (Figure 2.19.). Despite the low oxidation state of Rh(I)Cp^X precatalysts, the Rh(III)Cp^X species are easily accessible in solution *via* an oxidation event with benzoyl peroxide $(BzO)_2$ to generate a Rh(III)Cp^X-dibenzoate complex **62**. This is an attractive pathway because we know that carboxylates are necessary for the concerted metalation-deprotonation step to form the π-allyl intermediate so benzoate ion should not inhibit reactivity and possibly be an effective alternative oxidant for the amination methodology. We then initiated a collaboration with the Cramer group who are experts in synthesizing advanced libraries of the $RhCp^X$ catalysts through the research exchange opportunities provided by the Center for Selective C-H Functionalization (CCHF).

2.6.1.2. Amine Nucleophiles for Enantioselectivity

At the outset of the investigation it was necessary to prepare racemic samples of the amination product. To follow the mechanistic underpinning of the $RhCp^X$ catalysts beginning with two carboxylate ligands coordinated to the metal center, we utilized $RhCp^*(OAc)_2$ as the precatalyst and confirmed conversion of Ph-styrene **17** in modest yield and regioselectivity to allylic amines **33*c*/33*b*** (36%, 4.3:1; Figure 2.20.). With the success of observing product with the unoptimized precatalyst and racemic HPLC traces for the amination products, we were equipped to move forward with the chiral catalysts.

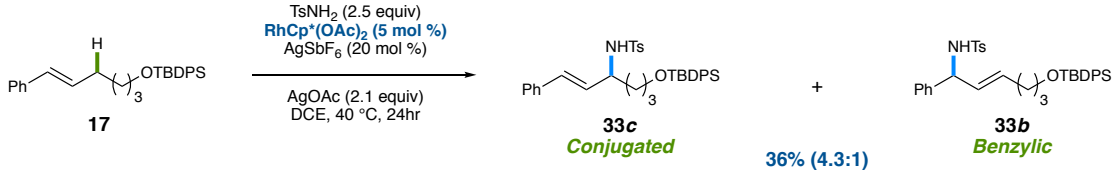


Figure 2.20. $RhCp^*(OAc)_2$ Confirmed as a Possible Catalyst for Allylic C-H Amination.

At the outset of our study we probed two sets of conditions when surveying the enantioselective conditions for allylic C-H amination. Since the $RhCp^X$ precatalysts begin at Rh(I) and our method assumes the necessity for a cationic Rh(III) species we can concurrently screen the conditions utilizing both AgOAc and $(BzO)_2$ as the stoichiometric oxidants to initiate the catalytic process. We began with the Gen. 1. D-mannitol inspired **$RhCp^X$[1]** precatalyst under both sets of oxidizing conditions (Scheme 2.3.).

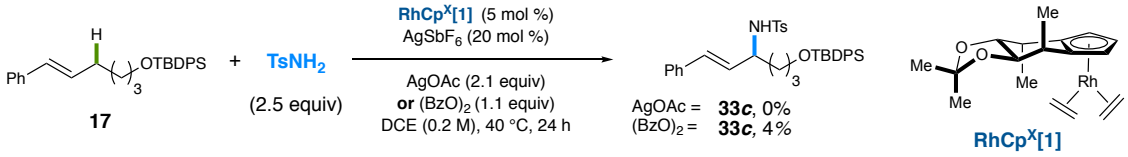
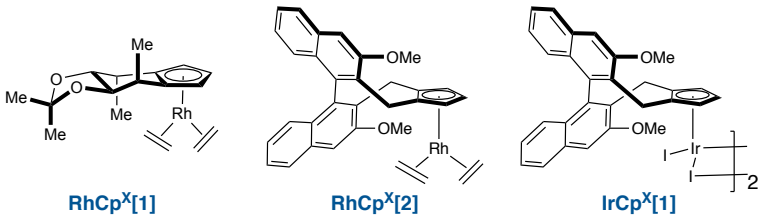


Figure 2.21. Initial Experiment with $RhCp^X$[1] with AgOAc/$(BzO)_2$ Oxidant.

Surprisingly, the AgOAc promoted conditions were unable to produce any observable product while the $(BzO)_2$ oxidizing conditions were able to observe near catalytic quantities for conversion (Figure 2.21.). This result infers that while AgOAc has been necessary for the turn-over of Rh(III) species in solution, the oxidant may not be able to oxidize the Rh(I)Cp^X directly to the active species. Subsequent experiments with the Gen. 2 **$RhCp^X$[2]** (Scheme 2.3.) catalyst under the two sets of oxidizing conditions observed the same outcome. Even more shockingly, 0% *ee* was observed for all products coming from these initial experiments.

Scheme 2.3. Investigated $RhCp^X$ and $IrCp^X$ Catalysts.



At this point it was very clear that it was necessary to not only discover a catalyst that would deliver high levels of enantioselectivity, but also optimize the reaction parameters based on the new system. New conditions were designed for enantioselective catalysis with the $RhCp^X$ catalysts where I include stoichiometric $(BzO)_2$ relative to precatalyst to access the active

Rh(III)Cp^X. While the reported racemic reaction is optimal under acidic conditions due to the acetic acid being generated, inclusion of an exogenous base could facilitate higher conversions. When using 2.0 equiv of cesium carbonate we saw no conversion toward amination products and coagulation of the solid components preventing a homogeneous solution (Figure 2.22.). Basic conditions clearly inhibit what little reactivity we had with the new catalysts and we determined that acidic conditions were ideal for further investigating the reaction.

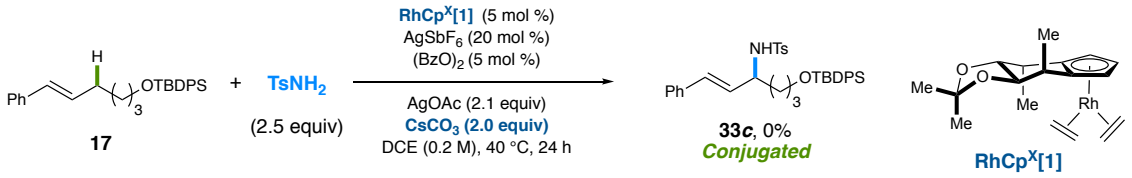


Figure 2.22. Basic Conditions Found to be Ineffective for RhCp^X System.

To probe acidic conditions for allylic C-H amination, acid sources were chosen carefully. It was clear that 2-10 equivalents of AcOH does not greatly inhibit the racemic amination method from previous studies. Possibly, the initial generation of acid is hindered under these conditions which resulted in limited turnovers of olefin **17**. We ventured to try subtle sources of H^+ *via* "hidden acid catalysis" whereby the introduction of a reagent that readily loses H^+ would help facilitate further reactivity. Hidden acid catalysis has been revealed to give increased reactivity when being substituted for a range of conjugate metal-bases.[40-43] In a study by Hintermann et. al. they found that by introducing *t*-BuCl to readily decompose into isobutene and HCl *in situ*, the reaction time decreased from two days to 20 minutes with the added effect of increasing yield from 65% to 86%.

In my hands applying the same method with 20% *t*-BuCl and a basic silver to promote formation of HCl saw an increase in yield to 28%, but 0% *ee* was observed for this set of conditions (Figure 2.23.). We have successfully increased yield for the allylic amination with RhCp^X catalysts but have not understood the effects related to high enantioselectivity at this time.

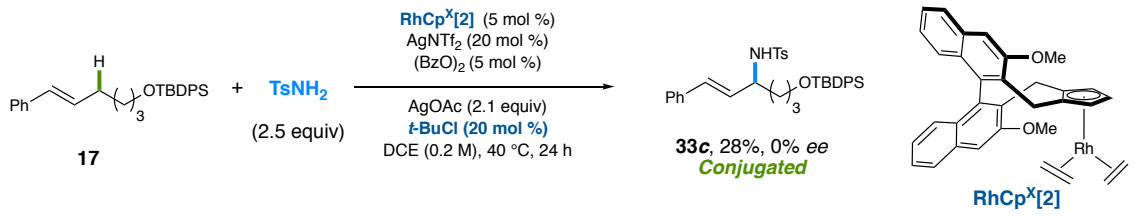


Figure 2.23. Hidden Acid Catalysis Demonstrates Initial Reactivity with Gen 2. RhCp^X Catalyst.

Since previous experiments confirmed that the allylic C-H amination was not exclusive to RhCp* with $[IrCp^*Cl_2]_2$ being a competent catalyst for the transformation we deemed it necessary to explore both group IX metals for enantioselectivity. Using the available **IrCp^X[1]** dimer we deemed it unnecessary to complicate the reaction mixture with $(BzO)_2$ when Ir(III) precatalyst enters at the correct oxidation state. Using the chiral Ir-dimer complex under standard conditions as well as doping with *t*-BuCl showed little effect on the overall yield of the reaction and consistently no observed enantioselectivity (12-13%, 0% *ee*).

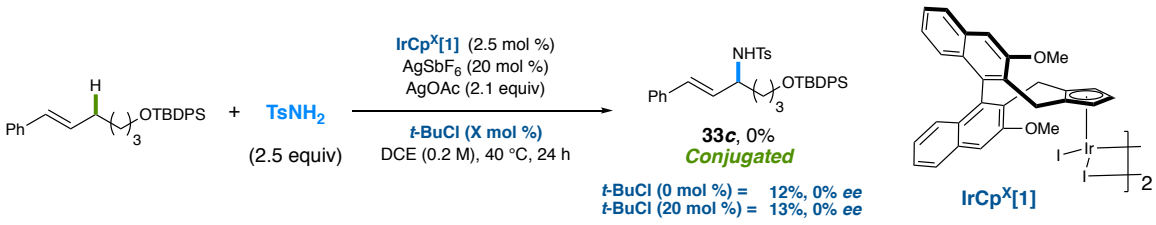


Figure 2.24. Hidden Acid Catalysis Shows No Effect on Conversion with Ir(III)Cp^X Catalyst.

To offer insight into why the initial survey of chiral Cp^X ligands resulted in 0% *ee* for the allylic C-H amination would be from a previous experiment (*vide infra* Section 2.5.1.). The mechanistic experiment that I had designed for the racemic amination revealed that a thermal equilibration was occurring that reversibly funneled all products toward the conjugated regioisomer. In assuming that even the major conjugated product is equally susceptible to the same reversible pathway that the minor products undergo, then we most likely destroy any accumulated enantioselectivity over extended reaction periods. This is even more evident in that despite low yields, the conjugated product is the only observed amination product. To circumvent this issue, it became clear that amination nucleophiles would not be beneficial to further investigate enantioselective reaction conditions with these catalysts.

2.6.1.3. Indoles as Nucleophiles for Enantioselectivity

At the time, concurrent investigations from our lab by Caitlin Farr confirmed that carbon-carbon bond formation was possible utilizing electron-rich indoles as nucleophiles for an allylic C-H arylation methodology. In using these indole nucleophiles, it is more likely that C-C bond formation is not reversible which would allow us to analyze enantioselectivity from products that leave the catalytic cycle. For this strategy we utilized *N*-tosyl indole **64**, the preliminary studies have found this to be an effective nucleophile delivering the arylation product **65** in moderate yield but perfect regioselectivity by ^{1}H NMR (43%, >20:1). With racemic samples in hand we can now analyze the results of our enantioselective experiments. When applying the chiral Gen. 2 $RhCp^X$ catalyst to the indole nucleophile we observed a slightly higher yield with *t*-BuCl (34% vs. 42%) but no levels of enantioselectivity were observed for the transformation.

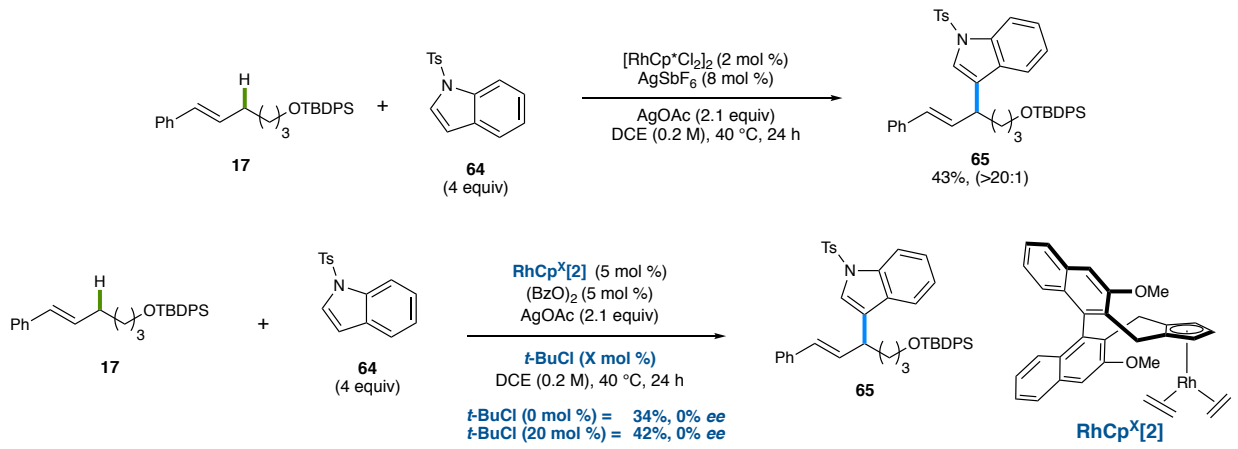


Figure 2.25. Reactions of *N*-Tosyl-Indole for Enantioselective Allylic C-H Arylation.

2.6.2. Dual Allylic C-H Activation / Allylic Substitution for Enantioselectivity *via* Allylic Acetate Intermediate.

In hypothesizing why the repeated experimentation with the chiral group IX MCp^X complexes were incapable of delivering any enantioselectivity, I analyzed the reaction components in the mixture. The allylic acetate side-product might be an important intermediate on the path to amination/arylation products. If the initial C-H functionalization of olefins produces an allylic acetate as the first intermediate, we can imagine taking advantage of the acetate intermediate generated on the same path toward product. The literature is prevalent with methods to enantioselectively functionalize allylic acetates *via* allylic substitution with a variety of palladium/ligand sets. The Trost-ligand Pd(II)-complex was identified as the optimal starting point because it is known to facilitate enantioselective allylic alkylation and amination reactions which engage allylic acetates as the leaving group.[44-47] Hybrid conditions were proposed to pair equal parts achiral $[RhCp^*Cl_2]_2$ with the Trost catalyst **Pd(II)-Trost** to intercept the generated allylic acetate (Figure 2.26).

When surveying reactivity under amination conditions we were fortunate to observe 45% yield of amination regioisomers (3.5:1 r.r.) but after isolating the major conjugated product for HPLC analysis the product observed was for 0% *ee*. When the same conditions were applied to indole-arylation, the resultant reaction mixture contained several unidentifiable products and no evidence of the intended arylation product. Clearly the nuances of the catalytic activity observed for utilizing the allylic acetate intermediate are far more complicated than originally identified at the outset of this hypothesis.

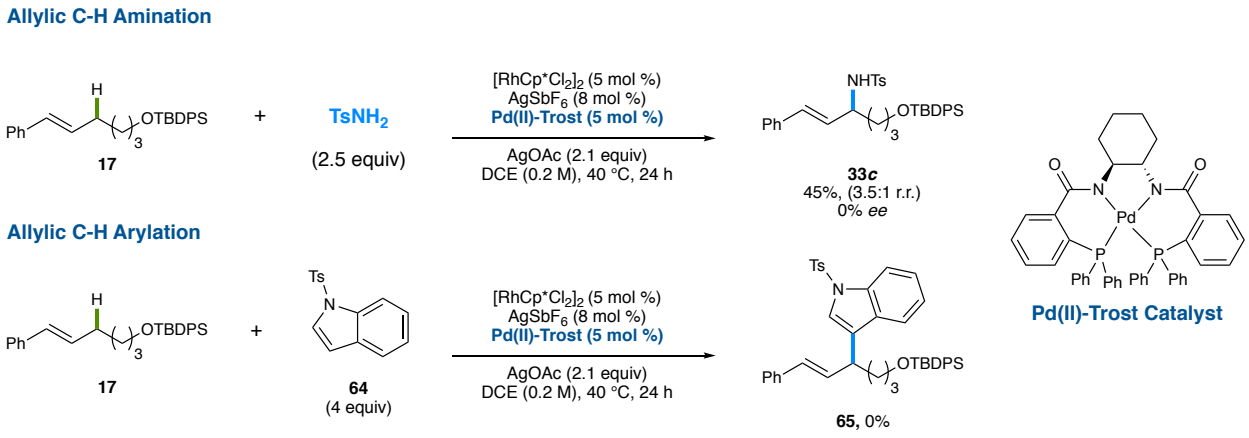


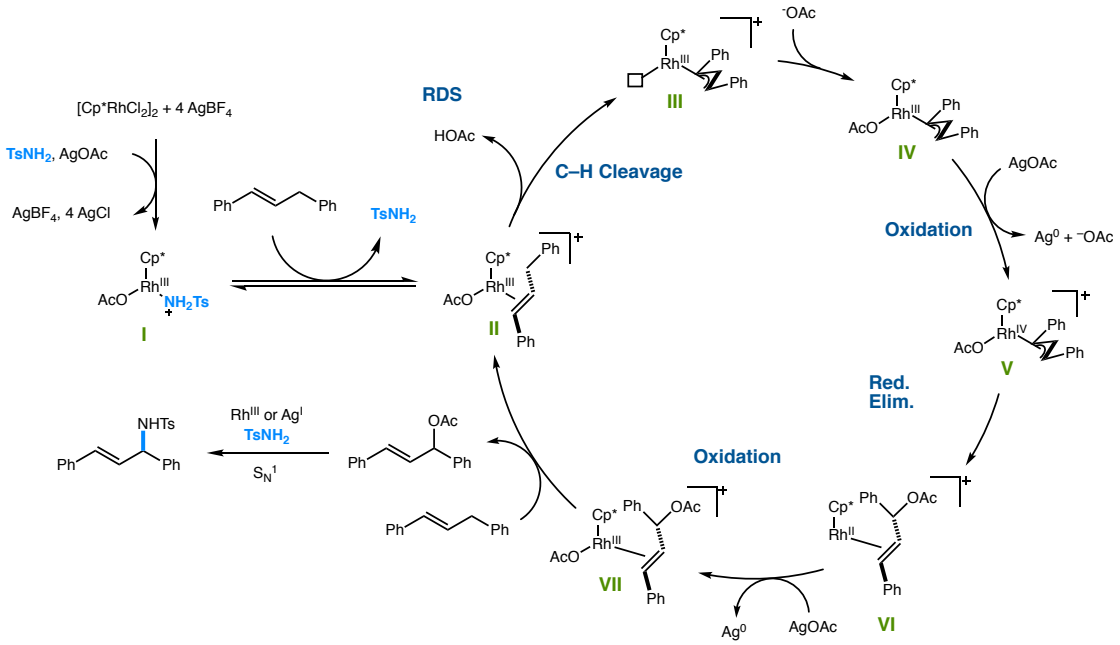
Figure 2.26. Studies of Pd(II)-Trost Ligand to Intercept Allylic Acetate Intermediate.

2.6.3. Interpretation of Enantioselectivity through Mechanistic Findings

Through the work of other contributors in the Blakey group in collaboration with the Baik group, we have a thorough understanding of the mechanism behind the allylic C-H amination and the role of the allylic acetate in the mechanism. Our original assumption is that C-N bond formation occurs through either an inner-sphere reductive elimination or outer-sphere nucleophilic attack by the amine nucleophile to the RhCp*-π-allyl intermediate. The same assumption was

made for the competitive appearance of allylic acetate side-product. In reality the allylic acetate is the key common intermediate on path to allylic C-H amination products. Key contributions to support the mechanistic findings were only possible with the diligent efforts of Dr. Robert J. Harris and Daniel C. Salgueiro.

Scheme 2.4. Mechanistic Proposal for Ag-Promoted RhCp*-Catalyzed Allylic C-H Amination.



The proposed mechanism is supported by careful kinetic experiments, electrochemical analysis, manipulation of RhCp*-π-allyl intermediates, and computational experiments to support experimental findings (Scheme 2.3.). The mechanism begins first by the $[RhCp^*Cl_2]_2$ dimer-precatalyst forming the monomeric resting state Rh-complex **I**. At this stage, association of the olefin becomes a fully coordinated cationic RhCp* complex **II**. The rate-determining step is the initial C-H cleavage mediated by a concerted metalation-deprotonation (CMD) mechanism by the coordinated acetate ligand to access RhCp*-π-allyl complex **III**. Coordination of free

acetate ligand to complex **IV** is followed by a single-electron oxidation facilitated by AgOAc to access Rh(IV)-π-allyl intermediate **V**. The oxidation event accesses an unstable Rh(IV) intermediate which in-turn promotes a fast inner-sphere reductive elimination for Rh(II)-complex **VI**. A second single-electron oxidation event by another equivalent of AgOAc results in Rh(III)Cp* complex **VII**. Ligand exchange between a new olefin substrate and the allylic acetate intermediate complete the catalytic cycle for Rh(III)Cp* catalysis. Additional experiments support that the allylic acetate side-product is capable of engaging either cationic RhCp* or the Ag^{+} ion *via* a traditional S_N1 pathway to access the allylic amine product. This also explains the observed thermodynamic equilibration of products toward conjugated amines due to a common intermediate, possibly an allyl cation species.

With the mechanistic proposal supported by experimental data it is clear why the extensive reaction sets to optimize the chiral $RhCp^X$ catalyst for allylic amination afforded 0% *ee* in every experiment. The true C-N bond forming step to access high-value allylic amine products never occurred at the Rh-center so the chiral catalysts could never control enantioselectivity for these products. To effectively utilize these catalysts for allylic C-H functionalization would require access to reagents that interact with the MCp^X-π-allyl intermediate faster than the oxidatively-induced reductive elimination to produce the allylic acetate side-product.

2.7. Conclusion and Future Directions

At the beginning of this study we set out to explore the next challenges for intermolecular allylic C-H functionalization *via* π-allyl intermediates in context to expanding the scope of viable olefins and nucleophile coupling partners. Where the previous systems that relied on palladium

catalysis were only capable of functionalizing the allylic C-H bond of terminal olefins, the developed RhCp*-catalyzed system has demonstrated novel reactivity with terminal, di-, and trisubstituted olefins. The very limited scope of nucleophile partners for amination reactions was further expanded to include singly-protected (sometimes N-substituted) sulfonamides, sulfamates, and carbamates. Despite the highly oxidizing conditions, the reaction is tolerant of a variety of electron-neutral, -donating, and -withdrawing (hetero)aromatics.

Interestingly, the RhCp* catalyst is highly chemoselective for functionalizing *trans*-olefins over analogous *cis*-olefins. Mechanistic data from this study suggests that while the RhCp* catalyzed C-H activation step is irreversible, the C-N bond forming step is reversible under reaction conditions which leads to high selectivity for conjugated amines. Contributions outside the scope of this work have led to the determination that with the current set of AgOAc-oxidizing, RhCp*-catalyzed conditions with $TsNH_2$ as the nucleophile cannot lead to an enantioselective transformation.

The groundbreaking work to contribute to the development of a regime of C-H functionalization in its infancy has led to other inspired works for C-O[49] and C-C[50-51] bond formation. We have completed half of our goals to develop conditions that access π-allyl intermediates from an unfunctionalized disubstituted olefin and promoted the functionalization toward a specific (conjugated) regioisomer. Further study on this system will be conducted toward the creation of complementary conditions that selectively target the opposite (benzylic) regioisomer.

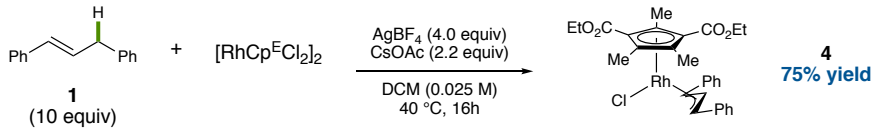
Experimental Procedures and Characterization Data

General Experimental:

^{1}H and ^{13}C NMR spectra were recorded on either a Bruker Ascend 600 spectrometer (600 MHz ^{1}H, 150 MHz ^{13}C), Varian Inova 600 spectrometer (600 MHz ^{1}H, 150 MHz ^{13}C), Varian INOVA 500 spectrometer (500 MHz ^{1}H, 125 MHz ^{13}C), Varian Inova 400 spectrometer (400 MHz ^{1}H, 100 MHz ^{13}C), Varian VNMRS 400 spectrometer (400 MHz ^{1}H, 100 MHz ^{13}C), or Mercury 300 PLUS (300 MHz ^{1}H, 75 MHz ^{13}C) at room temperature in $CDCl_3$ (neutralized and dried using anhydrous K_2CO_3) with internal $CHCl_3$ as the reference (7.26 ppm for ^{1}H and 77.16 ppm for ^{13}C), unless otherwise stated. Chemical shifts (δ values) were reported in parts per million (ppm) and coupling constants (*J* values) in Hz. Multiplicity was indicated using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, qn = quintet, m = multiplet, b = broad. The broad singlet impurity at 1.25 ppm in ^{1}H NMR and 29.7 in ^{13}C NMR is identified as Apiezon brand H grease.[52] Infrared (IR) spectra were recorded using Thermo Electron Corporation Nicolet 380 FT-IR spectrometer. High-resolution mass spectra were obtained using a Thermo Electron Corporation Finigan LTQFTMS (at the Mass Spectrometry Facility, Emory University). Analytical thin layer chromatography (TLC) was performed on pre-coated glass backed EMD 0.25 mm silica gel 60 plates. Visualization was accomplished with UV light, ethanolic anisaldehyde, or $KMnO_4$. Flash column chromatography was carried out using Silicycle SilaFlash® F60 silica gel (40-63 μm). Preparatory thin layer chromatography was performed on precoated glass backed Silicycle SiliaPure® 1.0 mm silica gel 60 plates. All reactions and prepared solutions were conducted using anhydrous solvents in oven-dried and nitrogen charged glassware. Anhydrous

solvents were obtained by passage through activated alumina using a Glass Contours solvent purification system unless otherwise noted. 1,2-Dichloroethane was stirred for 12 hours over CaH_2, distilled under inert atmosphere, degassed and stored over 4Å molecular sieves. Solvents used in workup, extraction and column chromatography were used as received from commercial suppliers without further purification. All reagents were purchased from Sigma Aldrich, Alfa Aesar, Oakwood, or Strem and used as received unless otherwise noted. 4Å molecular sieves were activated by flame drying under reduced pressure (0.2 torr).

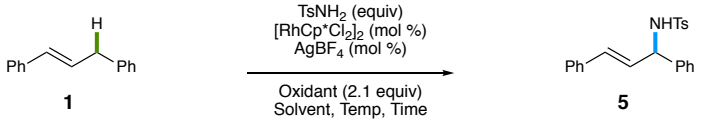
Synthesis of RhCp^{E}-π-Allyl Complex 4.



Inside an N_2 atmosphere glovebox, an oven dried 7 mL vial equipped with a magnetic stir bar was added AgBF4 (46 mg, 0.24 mmol) CsOAc (24.9 mg, 0.127 mmol), and [RhCp^{E}Cl$_2$]$_2$ (49 mg, 0.0576 mmol). The vial was then fitted with a septum cap and removed from the glovebox and DCM (1 mL) was added to the mixture followed by *trans*-1,3-diphenylpropene (0.11 mL, 0.59 mmol). The mixture was heated to 40 °C for 16 hours. The reaction mixture was allowed to cool to room temperature and filtered through a medium porosity fritted funnel and washed with DCM (10 mL). The resulting solution was washed with brine (3 mL) and this mixture was stirred for 10 minutes before extraction with DCM (3 x 5 mL). The combined organic extracts were dried with Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to afford the title complex as a red solid (52 mg, 75% yield).

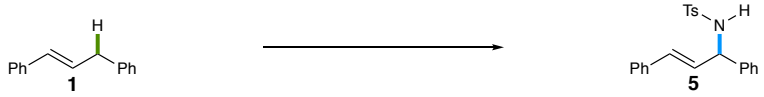
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (m, 4H), 7.39 – 7.31 (m, 6H), 5.82 (td, *J* = 11.2, 2.0 Hz, 1H) 1H), 5.23 (d, J = 11.2 Hz, 2H), 4.16-3.97 (m, 4H), 1.53 (s, 3H), 1.40 (s, 6H), 1.25 (t, J = 7.1, 6H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$): δ 164.3, 137.7, 128.9, 127.9, 127.5, 109.7 (d, J = 5.8 Hz), 105.3 (d, J = 5.4 Hz), 88.3 (d, J = 6.7 Hz), 83.8 (d, J = 6.5 Hz), 79.6 (d, J = 8.6 Hz), 61.3, 14.2, 10.2, 9.8 ppm. **MS** (FTMS + p NSI): Calculated [m/z] = 582.10387, Observed [m/z] = 582.10467. **IR** (thin film); 1725, 1225 cm^{-1}.

General Procedure A: Optimization of Allylic C–H Amination



Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide, $[RhCp^*Cl_2]_2$, silver tetrafluoroborate, and oxidant (0.540 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial capped with a septum, under N_2 atmosphere a 0.20 M stock solution of *trans*-1,3-diphenylpropene was prepared in the solvent of choice. An aliquot of the stock solution (1.3 mL, 50 mg, 0.260 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to the appropriate temperature and stirred for the allotted amount of time. A solution of 4,4'-di-*tert*-butyl-1-1'-biphenyl (693 mg, 2.6 mmol) in 1,2-dichloroethane was prepared in a 5 mL volumetric flask (0.52 M) as an internal standard. The reaction mixture was cooled to room temperature, exposed to air, and an aliquot of the 4,4'-di-*tert*-butyl-1-1'-biphenyl standard solution (500 µL, 0.260 mmol, 1.0 equiv) was added to the crude mixture. The resulting mixture was filtered over celite and the celite was rinsed with EtOAc (7 mL). The combined filtrate was concentrated under reduced pressure and analyzed by ^1H NMR.

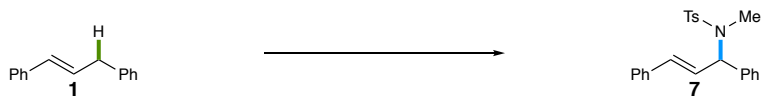
Procedures for the Allylic C–H Amination of *trans*-1,3-diphenylpropene.



(*E*)-*N*-(1,3-diphenylallyl)-4-methylbenzenesulfonamide (5).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (110 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (1.6 mg, 0.0026 mmol), silver tetrafluoroborate (2.0 mg, 0.010 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (200 mg, 1.04 mmol) in dichloromethane (5.2 mL) was prepared. An aliquot of the stock solution (1.3 mL, 50 mg, 0.260 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide the title compound as a white solid (85 mg, 88% yield). The compound exhibited identical ^1H and ^{13}C NMR data to previous reports.[53]

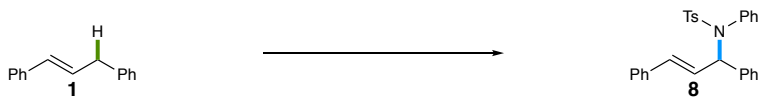
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (d, J = 8.3 Hz, 2H), 7.28 – 7.15 (m, 12H), 6.36 (dd, J = 15.9, 1.2 Hz, 1H), 6.08 (dd, J = 15.8, 6.8 Hz, 1H), 5.12 (td, J = 6.9, 1.2 Hz, 1H), 4.87 (d, J = 7.0 Hz, 1H), 2.34 (s, 3H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 143.5, 139.7, 137.8, 136.2, 132.3, 129.60 128.9, 128.6, 128.3, 128.1, 127.5, 127.2, 126.7, 59.9, 21.6 ppm.



(*E*)-*N*-(1,3-diphenylallyl)-*N*,4-dimethylbenzenesulfonamide (7).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *N*-methyl-*p*-toluenesulfonamide (240.5 mg, 1.29 mmol), $[RhCp^*Cl_2]_2$ (3.1 mg, 0.00515 mmol), silver tetrafluoroborate (4.2 mg, 0.0206 mmol), and silver acetate (182 mg, 1.08 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (149.7 mg, 0.771 mmol) was prepared in dichloromethane (3.9 mL) was prepared. An aliquot of the stock solution (2.6 mL, 99.9 mg, 0.514 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (100:0 to 85:15) to provide the title compound as an opaque oil (171.4 mg, 88% yield). The compound exhibited identical ^1H and ^{13}C NMR data to previous reports.[54]

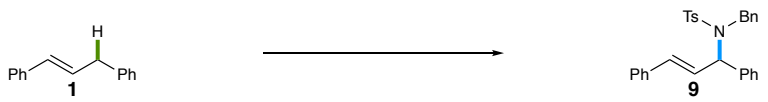
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (m, 2H), 7.34 – 7.25 (m, 8H), 7.22 – 7.19 (m, 4H), 6.37 (d, *J* = 16.2 Hz, 1H), 6.13 (dd, *J* = 15.9, 7.6 Hz, 1H), 5.84 (d, *J* = 7.3 Hz, 1H), 2.70 (s, 3H), 2.33 (s, 3H) ppm. **^{13}C NMR** (126 MHz, $CDCl_3$) δ 143.3, 138.7, 136.7, 136.3, 134.9, 129.6, 128.7, 128.7, 128.1, 128.0, 127.9, 127.6, 126.6, 123.9, 62.5, 30.3, 21.6 ppm.



(*E*)-*N*-(1,3-diphenylallyl)-4-methyl-*N*-phenylbenzenesulfonamide (8).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *N*-phenyl-*p*-toluenesulfonamide (160 mg, 0.650 mmol), $[RhCp^*Cl_2]_2$ (1.6 mg, 0.00257 mmol), silver tetrafluoroborate (2.2 mg, 0.0113 mmol), and silver acetate (92 mg, 0.551 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (250 mg, 1.29 mmol) was prepared in 1,2-dichloroethane (6.5 mL). An aliquot of the stock solution (1.3 mL, 50 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (99:1 to 80:20) to provide the title compound as a white solid (49 mg, 44% yield).

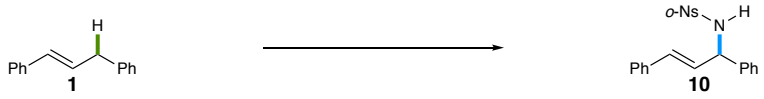
^{1}H NMR (600 MHz, $CDCl_3$): δ7.59 (d, J = 8.2 Hz, 2H), 7.33 – 7.24 (m, 11H), 7.19 – 7.17 (m, 4H), 6.81 (d, J = 7.3 Hz, 2H), 6.64 (d, J = 15.8 Hz, 1H), 6.31 (dd, J = 15.8, 8.8 Hz, 1H), 6.18 (d, J = 8.8 Hz, 1H), 2.38 (s, 3H) ppm. **^{13}C NMR** (75 MHz, $CDCl_3$) δ 143.3, 139.4, 138.0, 136.5, 136.3, 134.0, 132.7, 129.4, 128.7, 128.7, 128.6, 128.6, 128.4, 128.2, 127.9, 127.9, 126.7, 126.2, 65.3, 21.6 ppm. **HRMS** (+ APCI): Calculated for $C_{28}H_{26}NO_2S$ $[M+H]^+$ 440.1679**,** observed 440.1668. **IR** (thin film); 3028, 2924, 1159, 695 cm^{-1}.



(*E*)-*N*-benzyl-*N*-(1,3-diphenylallyl)-4-methylbenzenesulfonamide (9).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *N*-benzyl-*p*-toluenesulfonamide (167 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (1.7 mg, 0.00275 mmol), silver tetrafluoroborate (2.3 mg, 0.0118 mmol), and silver acetate (92 mg, 0.551 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (250 mg, 1.29 mmol) was prepared in 1,2-dichloroethane (6.5 mL). An aliquot of the stock solution (1.3 mL, 50 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (99:1 to 80:20) to provide the title compound as an opaque oil (48 mg, 41% yield).

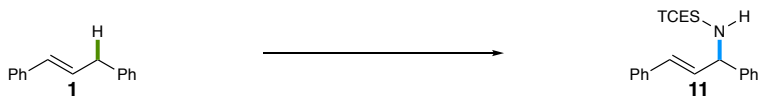
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.2 Hz, 2H), 7.29 – 7.23 (m, 4H), 7.21 – 7.16 (m, 9H), 7.13 – 7.12 (m, 2H), 7.08 –7.07 (m, 2H), 6.33 (d, *J* = 15.9 Hz, 1H), 6.18 (dd, *J* = 15.9, 8.0 Hz, 1H), 5.76 (d, *J* = 8.0 Hz, 1H), 4.53 (d, *J* = 15.7 Hz, 1H), 4.30 (d, *J* = 15.7 Hz, 1H), 2.91 (s, 3H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 143.2, 138.6, 138.3, 137.6, 136.5, 133.9, 129.6, 128.63, 128.61, 128.5, 128.4, 128.3, 128.0, 127.9, 127.6, 127.3, 126.7, 126.2, 63.7, 49.3, 21.6 ppm. **HRMS** (- NSI): Calculated for $C_{27}H_{29}ClNO_2S$ $[M+Cl]^-$ 488.1459**,** observed 488.1457. **IR** (thin film); 3060, 3028, 2924, 1335, 1155, 694 cm^{-1}.



(*E*)-*N*-(1,3-diphenylallyl)-2-nitrobenzenesulfonamide (10).

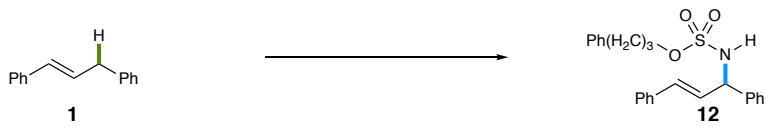
Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *o*-nitrobenzenesulfonamide (260 mg, 1.29 mmol), $[RhCp^*Cl_2]_2$ (3.2 mg, 0.00515 mmol), silver tetrafluoroborate (4.0 mg, 0.0206 mmol), and silver acetate (180 mg, 1.08 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (100 mg, 0.514 mmol) was prepared in 1,2-dichloroethane (2.6 mL). The solution was transferred to the vial containing the solid reagents and the mixture was heated at 40 °C for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 75:25) to provide the title compound as a yellow solid (155 mg, 76% yield). The compound exhibited identical ^1H and ^{13}C NMR data to previous reports.[55]

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.83 (dd, J = 7.9, 1.4 Hz, 1H), 7.73 (dd, J = 8.0, 1.3 Hz, 1H), 7.52 (td, J = 7.8, 1.4 Hz, 1H), 7.42 (td, J = 7.7, 1.3 Hz, 1H), 7.29 (m, 10H), 6.43 (dd, J = 15.9, 1.3 Hz, 1H), 6.19 (dd, J = 15.8, 6.6 Hz, 1H), 5.92 (d, J = 8.9 Hz, 1H), 5.35 (ddd, J = 8.5, 6.6, 1.3 Hz, 1H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 147.5, 138.8, 135.8, 134.9, 133.1, 133.1, 132.7, 131.2, 128.8, 128.7, 128.3, 128.3, 127.6, 127.2, 126.7, 125.1, 60.8 ppm.



2,2,2-trichloroethyl (*E*)-(1,3-diphenylallyl)sulfamate (11).

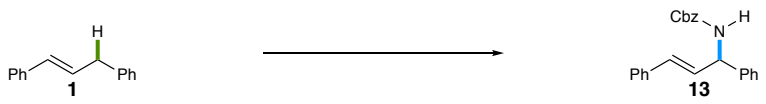
Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added trichloroethoxysulfamate (148 mg, 0.648 mmol), $[RhCp^*Cl_2]_2$ (1.8 mg, 0.00291 mmol), silver tetrafluoroborate (2.0 mg, 0.0103 mmol), and silver acetate (90 mg, 0.540 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (149.4 mg, 0.768 mmol) was prepared in dichloromethane (3.9 mL). An aliquot of the stock solution (1.3 mL, 49.7 mg, 0.256 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide the title compound as a white solid (89 mg, 82% yield). **^{1}H NMR** (600 MHz, $CDCl_3$): δ 7.41 (d, J = 4.4 Hz, 4H), 7.39 – 7.31 (m, 5H), 7.28 – 7.26 (m, 1H), 6.66 (dd, J = 15.8, 1.3 Hz, 1H), 6.38 (dd, J = 15.8, 6.6 Hz, 1H), 5.36 (td, J = 7.0, 1.3 Hz, 1H), 5.03 (d, J = 7.1 Hz, 1H), 4.50 (q, J = 10.8 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 139.2, 135.9, 133.4, 129.3, 128.8, 128.7, 128.5, 127.4, 127.3, 126.9, 93.4, 78.4, 61.0 ppm. **HRMS** (- APCI): Calculated for $C_{17}H_{15}O_3NCl_3S$ $[M-H]^-$ 417.984**,** observed 417.9849. **IR** (thin film); 3296, 1362, 1176, 744, 694, cm^{-1}.



3-phenylpropyl (*E*)-(1,3-diphenylallyl)sulfamate (12).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added 3-phenylpropyl sulfamate (140 mg, 0.650 mmol), $[RhCp^*Cl_2]_2$ (1.8 mg, 0.00291 mmol), silver tetrafluoroborate (2.3 mg, 0.0118 mmol), and silver acetate (91 mg, 0.545 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (149 mg, 0.766 mmol) was prepared in 1,2-dichloroethane (3.9 mL). An aliquot of the stock solution (1.3 mL, 49.7 mg, 0.256 mmol) was transferred to the vial containing the solid reagents. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide the title compound as a white solid (83 mg, 80% yield).

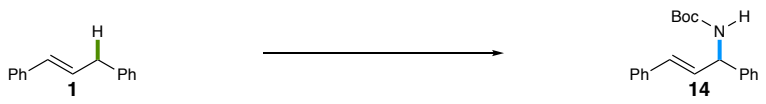
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.39 – 7.30 (m, 9H), 7.28 – 7.24 (m, 3H), 7.18 (t, J = 7.3 Hz, 1H), 7.06 –7.04 (m, 2H), 6.62 (dd, J = 15.8, 1.0 Hz, 1H), 6.33 (dd, J = 15.8, 6.7 Hz, 1H), 5.25 (td, J = 7.0, 1.3 Hz, 1H), 4.82 (t, J = 5.8 Hz, 1H), 4.05 (dt, J = 9.5, 6.4 Hz, 1H), 3.95 (dt, J = 9.5, 6.4 Hz, 1H), 2.55 (t, J = 5.0 Hz, 2H), 1.89 – 1.79 (m, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 140.6, 139.8, 136.0, 132.7, 129.1, 128.8, 128.6, 128.5, 128.4, 128.3, 128.1, 127.3, 126.8, 126.2, 70.2, 60.4, 31.7, 30.4 ppm. **HRMS** (- APCI): Calculated for $C_{24}H_{24}O_3NS$ $[M-H]^-$ 406.1482**,** observed 406.1479. **IR** (thin film); 3291, 3027, 2924, 1171, 932, 745, 697 cm^{-1}.



Benzyl (*E*)-(1,3-diphenylallyl)carbamate (13).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added benzyl carbamate (97 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (1.6 mg, 0.00257 mmol), silver tetrafluoroborate (2.0 mg, 0.0103 mmol), and silver acetate (91 mg, 0.540 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (250 mg, 1.29 mmol) was prepared in 1,2-dichloroethane (6.5 mL). An aliquot of the stock solution (1.3 mL, 50 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (100:0 to 80:20) to provide the title compound as a white solid (84 mg, 95% yield). The compound exhibited identical ^1H and ^{13}C NMR data to previous reports.[56]

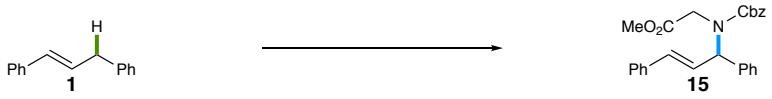
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.37 –7.22 (m, 15H), 6.55 (d, J = 15.9 Hz, 1H), 6.33 (dd, J = 15.9, 6.0 Hz, 1H), 5.54 (bs, 1H), 5.18 – 5.10 (m, 3H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 155.7, 141.0, 136.5, 136.5, 131.4, 129.2, 129.0, 128.7, 128.6, 128.3, 127.9, 127.9, 127.2, 126.7, 67.2, 56.9, 29.9 ppm.



***tert*-Butyl (*E*)-(1,3-diphenylallyl)carbamate (14).**

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *tert*-butyl carbamate (75 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (1.6 mg, 0.00257 mmol), silver tetrafluoroborate (2.0 mg, 0.0103 mmol), and silver acetate (91 mg, 0.540 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (250 mg, 1.29 mmol) was prepared in 1,2-dichloroethane (6.5 mL). An aliquot of the stock solution (1.3 mL, 50 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 48 hours.After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (100:0 to 80:20) to provide the title compound as a white solid (12 mg, 15% yield). The compound exhibited identical ^1H and ^{13}C NMR data to previous reports.[57]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.38 – 7.21 (m, 10H), 6.54 (dd, *J* = 15.9, 1.5 Hz, 1H), 6.32 (dd, *J* = 15.9, 6.1 Hz, 1H), 5.46 (bs, 1H), 4.96 (bs, 1H), 1.45 (s, 9H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.7, 141.0, 136.5, 136.5, 131.4, 129.2, 129.0, 128.7, 128.7, 128.3, 128.0, 127.9, 127.2, 126.7, 67.2, 57.0 ppm.



Methyl (*E*)-*N*-((benzyloxy)carbonyl)-*N*-(1,3-diphenylallyl)glycinate (15).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added $[RhCp^*Cl_2]_2$ (1.6 mg, 0.00257 mmol), silver tetrafluoroborate (2.0 mg, 0.0103 mmol), and silver acetate (91 mg, 0.540 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (149.7 mg, 0.257 mmol) and methyl ((benzyloxy)carbonyl)glycinate (0.36 mL, 431 mg, 1.93 mmol) was prepared in 1,2-dichloroethane (3.9 mL). An aliquot of the stock solution [1.3 mL (50 mg, 0.257 mmol, *trans*-1,3-diphenylpropene), (144 mg, 0.643 mmol, ((benzyloxy)carbonyl)glycinate ester) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (99:1 to 80:20) to provide the title compound as a clear oil (83 mg, 78% yield).

^{1}H NMR (500 MHz, DMSO-d_6, 80 °C): δ 7.45 (d, J = 7.0 Hz, 2H), 7.44 – 7.25 (m, 13H), 6.66 – 6.58 (m, 2H), 5.91 (bs, 1H), 5.16 –5.10 (m, 2H), 4.06 (s, 2H), 3.49 (s, 3H) ppm. **^{13}C NMR** (125 MHz, DMSO-d_6, 80 °C) δ 169.5, 155.0, 139.3, 136.3, 136.1, 132.7, 128.2, 128.1, 128.0, 127.5, 127.4, 127.3, 127.1, 127.0, 126.5, 126.2, 66.5, 61.5, 51.2, 39.5 ppm. **HRMS** (+ NSI): Calculated for $C_{26}H_{24}NO_4$ $[M-H]^+$ 414.1700**,** observed 414.1702. **IR** (thin film); 3029, 2953, 1756, 1702 cm^{-1}.

Methyl *N*-((benzyloxy)carbonyl)-*N*-((*R*,*E*)-1,3-diphenylallyl)-*L*-alaninate (16).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added $[RhCp^*Cl_2]_2$ (1.6 mg, 0.0026 mmol), silver tetrafluoroborate (2.3 mg, 0.012 mmol), and silver acetate (91 mg, 0.54 mmol) and methyl ((benzyloxy)carbonyl)alanate (304 mg, 1.29 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (200 mg, 1.03 mmol)was prepared in 1,2-dichloroethane (5.2 mL). An aliquot of the stock solution (1.3 mL, 50 mg, 0.257 mmol) was then transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL), and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (99:1 to 80:20) on silica gel to provide the title compound as a mixture of diastereomers as an opaque oil (29 mg, 26% yield). The ratio of diastereomers was determined to be 1.6:1 based on the ^1H NMR at 80 °C in DMSO-d_6 of the mixture of products. Further purification of the mixture by preparative thin layer chromatography eluted in Hexanes:EtOAc (93:7, 8 sweeps) provided two distinct product bands.

The top band corresponds to major diastereomer (relative stereochemistry not determined).

Top Band Diastereomer

^{1}H NMR (500 MHz, DMSO-d_6, 80 °C): δ 7.46 – 7.25 (m, 15H), 6.77 (dd, J = 15.9, 7.6 Hz, 1H), 6.68 (d, J = 15.9 Hz, 1H), 5.87 (bs, 1H), 5.12 (d, J = 12.5 Hz, 1H), 5.08 (d, J = 12.6 Hz, 1H), 4.28 (q, J = 6.9 Hz, 1H), 3.51 (s, 3H), 1.11 (d, J = 6.8 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ ^{13}C NMR (151 MHz, $CDCl_3$) δ 172.5, 155.7 (bs), 142.0, 139.8 (bs), 137.73, 136.9 (bs), 136.3 (bs), 133.74, 128.7 (bs), 128.6 (bs), 128.4 (bs), 128.3 (bs), 128.2 (bs), 128.1 (bs), 128.1 (bs), 127.9 (bs), 127.4, 127.2, 126.7 (bs), 126.3 (bs), 67.7, 62.0, 54.2, 53.4, 52.3, 52.0, 42.9, 32.1, 22.9, 21.0, 16.8, 15.6, 14.3 ppm. **HRMS** (+ APCI): Calculated for $C_{27}H_{28}NO_4$ $[M+H]^+$ 430.2013**,** observed 430.2012. **IR** (thin film); 3028, 2924, 1742, 1697, 1422, 1271, 745, 696 cm^{-1}.

The lower band corresponds to the minor diastereomer (relative stereochemistry not determined).

Lower Band Diastereomer

^{1}H NMR (500 MHz, DMSO-d_6, 80 °C): δ 7.48 – 7.45 (m, 4H), 7.37 – 7.27 (m, 11H), 6.75 (dd, J = 15.8, 8.0 Hz, 1H), 6.67 (d, J = 15.9 Hz, 1H), 5.79 (d, J = 8.3 Hz, 1H), 5.11 (d, J = 12.5 Hz, 1H), 5.06 (d, J = 12.5 Hz, 1H), 4.30 (q, J = 6.8 Hz, 1H), 3.42 (s, 3H), 1.45 (d, J = 6.9 Hz, 3H) ppm. **^{13}C NMR** (125 MHz, DMSO-d_6, 80 °C) δ 172.5, 172.0, 155.6 (bs), 142.9, 139.4 (bs), 136.6, 136.4, 134.4 (bs), 131.7, 130.7, 128.8, 128.79 (bs), 128.75 (bs), 128.72 (bs), 128.6, 128.4, 128.2 (bs), 128.1 (bs), 128.0, 127.9, 127.7 (bs), 127.5, 127.3, 127.1, 126.8, 126.7 (bs), 126.6, 126.5, 75.3, 67.7, 62.3, 53.6 (bs), 52.1, 51.6, 32.1, 29.8, 22.9, 21.0, 17.7 (bs), 14.3 ppm. **HRMS** (+ APCI): Calculated for $C_{27}H_{28}NO_4$ $[M+H]^+$ 430.2013**,** observed 430.2018. **IR** (thin film); 3029, 2924, 2853, 1742, 1698, 1450, 1270, 745, 696 cm^{-1}.

General Procedures for the Synthesis of *trans*-Olefins with Aryl Iodides

General Procedure B: Synthesis of *trans*-Olefins with Solid Aryl Iodides

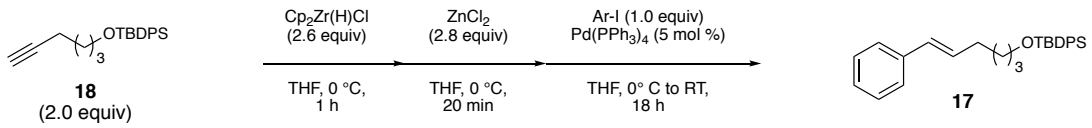
Inside a N_2 atmosphere glovebox was weighed $Cp_2Zr(H)Cl$ (2.6 equiv) in a 250 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. Anhydrous $ZnCl_2$ (2.6 equiv) was weighed in a 100 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. $Pd(PPh_3)_4$ (0.06 equiv) was weighed in a 25 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. All flasks with reagents were then removed from the glovebox. The flask containing $Cp_2Zr(H)Cl$ was placed under positive pressure of N_2 gas and cooled to 0 °C followed by the addition of THF (60 mL). The mixture was stirred at 0 °C for 10 mins. *tert*-Butyl(hex-5-yn-1-yloxy)diphenylsilane (2.0 equiv) was weighed into an oven-dried 25 mL round bottom flask whereupon the atmosphere was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to establish a N_2 atmosphere. The alkyne was then dissolved in THF (10 mL) and the resulting solution was added by syringe to the cooled suspension of $Cp_2Zr(H)Cl$. The resulting mixture was stirred for 1 hour at 0 °C. The flask containing the $ZnCl_2$ was placed under positive pressure of N_2 gas and the $ZnCl_2$ was dissolved in THF (40 mL). The $ZnCl_2$ solution was added to the reaction mixture by cannula at 0 °C whereupon the alkenyl-zinc was formed over 20 minutes as a homogenous yellow solution. The flask containing $Pd(PPh_3)_4$ was placed under positive pressure of N_2 gas and THF (5 mL) was added. The respective aryl iodide (1.0 equiv) was weighed into an oven-dried 15 mL vial which was then fitted with a septum cap. The atmosphere of the vial containing the aryl-iodide was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to

establish a N_2 atmosphere. The aryl iodide was dissolved in THF (5 mL) and added by syringe to the flask of $Pd(PPh_3)_4$. Upon full dissolution of the mixture of $Pd(PPh_3)_4$ and aryl iodide, the resulting solution was added by syringe to the reaction mixture at 0 °C. The reaction mixture was allowed to warm to room temperature and stirred for 16 hours. The crude mixture was then concentrated under reduced pressure to approximately 50 mL and diluted with hexanes (100 mL). The crude solution was filtered through a pad of silica gel and the silica gel was rinsed with a 90:10 solution of Hexanes:Et_2O (100 mL). The filtrate was concentrated under reduced pressure and the residue was purified by flash chromatography on silica gel to provide the corresponding *trans*-alkyl-aryl olefin.

General Procedure C: Synthesis of *trans*-Olefins with Liquid Aryl Iodides

The following procedure is adapted from the cited literature procedure.[7] Inside a N_2 atmosphere glovebox was weighed $Cp_2Zr(H)Cl$ (2.6 equiv) in a 250 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. Anhydrous $ZnCl_2$ (2.6 equiv) was weighed in a 100 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. $Pd(PPh_3)_4$ (0.06 equiv) was weighed in a 25 mL round bottom flask equipped with an appropriate magnetic stir bar which was then fitted with a septum cap. All flasks with reagents were then removed from the glovebox. The flask containing $Cp_2Zr(H)Cl$ was placed under positive pressure of N_2 gas and cooled to 0 °C followed by the addition of THF (60 mL). The mixture was stirred at 0 °C for 10 mins. *tert*-Butyl(hex-5-yn-1-yloxy)diphenylsilane (2.0 equiv) was weighed into an oven-dried 25 mL round bottom flask whereupon the atmosphere was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to

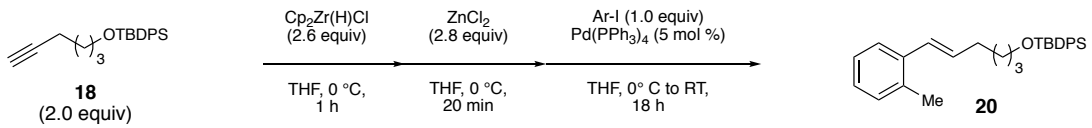
establish a N_2 atmosphere. The alkyne was then dissolved in THF (10 mL) and the resulting solution was added by syringe to the cooled suspension of $Cp_2Zr(H)Cl$. The resulting mixture was then stirred for 1 hour at 0 °C. The flask containing the $ZnCl_2$ was placed under positive pressure of N_2 gas and the $ZnCl_2$ was dissolved in THF (40 mL). The $ZnCl_2$ solution was added to the reaction mixture by cannula at 0 °C whereupon the alkenyl-zinc was formed over 20 minutes as a homogenous yellow solution. The flask containing $Pd(PPh_3)_4$ was placed under positive pressure of N_2 gas and THF (10 mL) was added. The respective aryl iodide (1.0 equiv) was added to the solution of $Pd(PPh_3)_4$ by syringe. The resulting solution of $Pd(PPh_3)_4$ and aryl iodide was added by syringe to the reaction mixture at 0 °C. The reaction mixture was allowed to warm to room temperature and stirred for 16 hours. The crude mixture was then concentrated under reduced pressure to approximately 50 mL and diluted with 100 mL of hexanes. The crude solution was filtered through a pad of silica gel and the silica gel was rinsed with a 90:10 solution of Hexanes:Et_2O (100 mL). The filtrate was concentrated under reduced pressure and the residue was purified by flash chromatography on silica gel to provide the corresponding *trans*-alkyl-aryl olefins.



(*E*)-*tert*-butyldiphenyl((6-phenylhex-5-en-1-yl)oxy)silane (17).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (1.01 g, 3.92 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (1.02 g, 3.03 mmol), $ZnCl_2$ (580 mg, 4.26 mmol), iodobenzene (0.50 mL, 918 mg, 4.50 mmol), and $Pd(PPh_3)_4$ (118 mg, 0.102 mmol), produced the title compound as a colorless oil (426 mg, 34% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 – 7.70 (m, 4H), 7.47 – 7.30 (m, 10H), 7.22 (t, J = 7.1 Hz, 1H), 6.39 (d, J = 15.9 Hz, 1H), 6.23 (dt, J = 15.8, 6.8 Hz, 1H), 3.72 (t, J = 6.1 Hz, 2H), 2.23 (q, J = 6.8 Hz, 2H), 1.69 – 1.54 (m, 4H) 1H), 1.05 (s, 9H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$): 138.0, 135.7, 134.2, 131.1, 130.0, 129.7, 128.6, 127.7, 126.0, 77.2, 63.9, 32.9, 32.2, 27.0, 25.7, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{28}H_{35}OSi$ $[M+H]^+$ 415.2463**,** observed 415.2456. **IR** (thin film); 2929, 2855, 1105, 699 cm^{-1}.

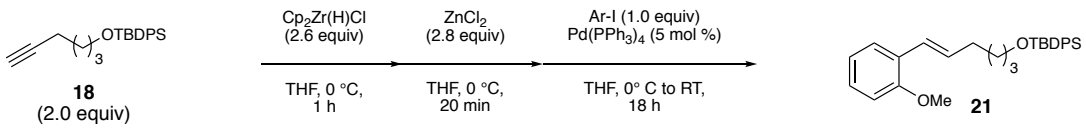


(*E*)-*tert*-butyldiphenyl((6-(*o*-tolyl)hex-5-en-1-yl)oxy)silane (20).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.02 g, 7.83 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.14 mg, 8.36 mmol), 2-iodotoluene

(0.38 mL, 654 mg, 3.00 mmol), $Pd(PPh_3)_4$ (210 mg, 0.182 mmol) produced the title compound as a clear oil (482 mg, 37% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.71 – 7.69 (m, 4H), 7.45 –7.38 (m, 7H), 7.18 – 7.12 (m, 3H), 6.57 (d, *J* = 15.7 Hz, 1H), 6.09 (dt, *J* = 15.7, 6.9 Hz, 1H), 3.72 (t, *J* = 6.2 Hz, 2H), 2.34 (s, 3H), 2.24 (q, *J* = 7.1 Hz, 2H), 1.69 – 1.56 (m, 4H), 1.08 (S, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 137.2, 135.7, 135.0, 134.2, 132.4, 130.3, 129.7, 127.9, 127.7, 126.9, 126.1, 125.6, 63.9, 33.2, 32.2, 27.0, 25.8, 20.0, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{29}H_{37}OSi$ $[M+H]^+$ 429.2628**,** observed 429.2617. **IR** (thin film); 2930, 2857, 1110, 702 cm^{-1}.

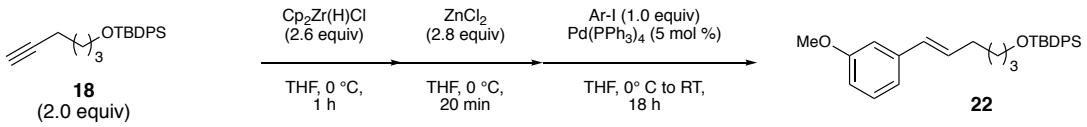


(*E*)-*tert*-butyl((6-(2-methoxyphenyl)hex-5-en-1-yl)oxy)diphenylsilane (21).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.03 g, 7.87 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.17 g, 8.58 mmol), 2-iodoanisole (0.39 mL, 702 mg, 3.00 mmol), $Pd(PPh_3)_4$ (214 mg, 0.185 mmol) produced the title compound after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (90:10 to 70:30) and further purification with silica gel treated with $AgNO_3$[14] in a gradient of Hexanes:Toluene (75:25 to 60:40) as an opaque yellow oil (592 mg, 44% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.36 (m, 7H), 7.19 (td, *J* = 7.8, 1.7 Hz, 1H), 6.91 (t, *J* = 7.5 Hz, 1H), 6.86 (d, *J* = 8.2 Hz, 1H), 6.70 (d, *J* = 16.0 Hz, 1H), 6.19 (dt, *J* = 15.9,

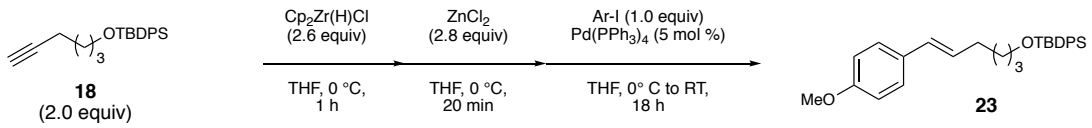
6.9 Hz, 1H), 3.84 (s, 3H), 3.69 (t, *J* = 6.3 Hz, 2H), 2.22 (qd, *J* = 7.2, 1.4 Hz, 2H), 1.66 – 1.53 (m, 4H), 1.06 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 156.4, 135.7, 134.3, 131.8, 129.6, 127.9, 127.7, 127.1, 126.5, 124.5, 120.8, 110.9, 64.0, 55.6, 33.3, 32.3, 27.0, 25.9, 19.4 ppm. **HRMS** (+ APCI): Calculated for $C_{29}H_{37}O_2Si$ $[M+H]^+$ 445.2557, observed 445.2550. **IR** (thin film); 2930, 2856, 1104, 699 cm^{-1}.



(*E*)-*tert*-butyl((6-(3-methoxyphenyl)hex-5-en-1-yl)oxy)diphenylsilane (22).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.02 g, 7.83 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.16 g, 8.51 mmol), 3-iodoanisole (0.40 mL, 702 mg, 3.00 mmol), $Pd(PPh_3)_4$ (220 mg, 0.190 mmol) produced the title compound as a clear yellow oil **(**589 mg, 44% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (90:10 to 60:40).

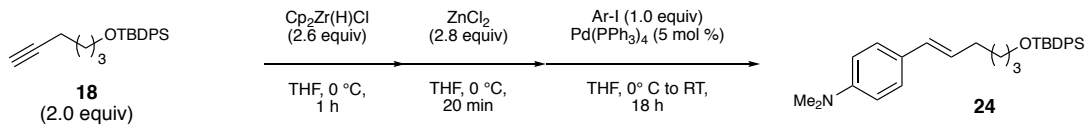
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.36 (m, 6H), 7.21 (t, *J* = 7.9 Hz, 1H), 6.94 (d, *J* = 7.6 Hz, 1H), 6.88 (s, 1H), 6.76 (dd, *J* = 8.2, 2.6 Hz, 1H), 6.33 (d, *J* = 15.9 Hz, 1H), 6.20 (dt, *J* = 15.8, 6.8 Hz, 1H), 3.82 (s, 3H), 3.69 (t, *J* = 6.2 Hz, 2H), 2.20 (q, *J* = 7.1 Hz, 2H), 1.65 – 1.52 (m, 4H), 1.06 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$): δ 159.9, 139.5, 135.7, 134.2, 131.4, 129.9, 129.7, 129.6, 127.7, 118.8, 112.6, 111.4, 63.9, 55.3, 32.8, 32.2, 27.0, 25.7, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{29}H_{35}O_2Si$ $[M-H]^+$ 443.2401**,** observed 443.2405. **IR** (thin film); 2930, 1107, 701 cm^{-1}.



(*E*)-*tert*-butyl((6-(4-methoxyphenyl)hex-5-en-1-yl)oxy)diphenylsilane (23).

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (2.02 g, 7.83 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.16 g, 8.51 mmol), 4-iodoanisole (710 mg, 3.03 mmol), $Pd(PPh_3)_4$ (208 mg, 0.180 mmol) produced the title compound as a clear oil (942 mg, 70% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (90:10 to 60:40).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.70 – 7.68 (m, 4H) 7.45 – 7.37 (m, 6H), 7.28 (d, J = 8.7 Hz, 2H), 6.85 (d, J = 8.2 Hz, 2H), 6.32 (d, J = 15.8 Hz, 1H), 6.07 (dt, J = 14.5, 6.9 Hz, 1H), 3.81 (s, 3H), 3.70 (t, J = 6.3 Hz, 1H), 2.19 (q, J = 7.1 Hz, 2H), 1.66 – 1.53 (m, 4H), 1.07 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 158.7, 135.7, 134.2, 130.9, 129.6, 129.3, 128.9, 127.7, 127.1, 114.0, 63.9, 55.4, 32.9, 32.2, 27.0, 25.9, 19.4. ppm. **HRMS** (+ NSI): Calculated for $C_{29}H_{37}O_2Si$ $[M+H]^+$ 445.2557**,** observed 445.2564 $[M+H]^+$. **IR** (thin film); 2930, 2856, 1509, 1244, 1106, 701 cm^{-1}.

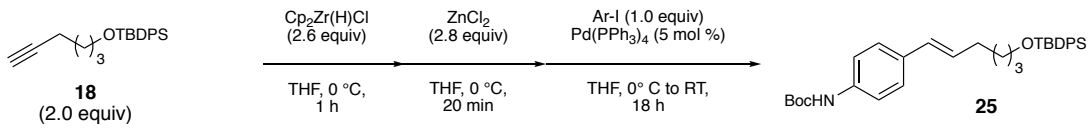


(*E*)-4-(6-((*tert*-butyldiphenylsilyl)oxy)hex-1-en-1-yl)-*N*,*N*-dimethylaniline (24)

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (2.03 g, 7.87 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.28 g, 9.39 mmol), 4-iodothioanisole

(756 mg, 3.02 mmol), $Pd(PPh_3)_4$ (209 mg, 0.181 mmol) produced the title compound as a white solid (389 mg, 28% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.67 (d, *J* = 7.1 Hz, 4H), 7.46 – 7.30 (m, 6H), 7.23 (d, *J* = 8.2 Hz, 1H), 6.68 (d, *J* = 8.3 Hz, 1H), 6.27 (d, *J* = 15.4 Hz, 1H), 5.99 (dt, *J* = 14.9, 7.3 Hz, 1H), 3.68 (t, *J* = 6.3 Hz, 2H), 2.94 (s, 6H), 2.16 (q, *J* = 6.9 Hz, 2H), 1.64 – 1.59 (m, 2H), 1.56 – 1.49 (m, 2H), 1.05 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 149.76, 135.71, 134.25, 129.71, 129.62, 127.74, 127.71, 126.93, 126.88, 112.82, 63.98, 40.84, 32.91, 32.24, 27.03, 26.00, 19.37 ppm. **HRMS** (+ APCI): Calculated for $C_{30}H_{30}NOSi$ $[M+H]^+$ 458.2874**,** observed 458.2874.

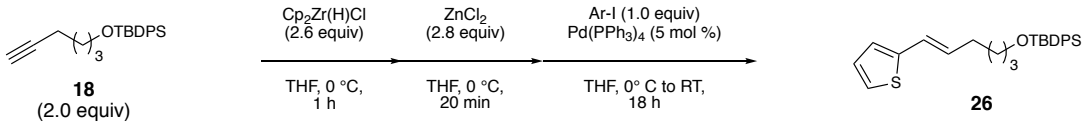


***tert*-butyl (*E*)-(4-(6-((*tert*-butyldiphenylsilyl)oxy)hex-1-en-1-yl)phenyl)carbamate (25).**

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (1.70 g, 6.59 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.07 g, 6.15 mmol), $ZnCl_2$ (957 mg, 7.02 mmol), *tert*-butyl (4-iodophenyl)carbamate (960 mg, 3.01 mmol), $Pd(PPh_3)_4$ (209 mg, 0.183 mmol) produced the title compound as a light yellow oil (1.23 g, 77% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Et_2O (99:1 to 80:20).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.36 (m, 6H), 7.30 – 7.25 (m, 4H), 6.45 (bs, 1H), 6.30 (d, *J* = 15.8 Hz, 1H), 6.11 (dt, *J* = 15.8, 6.9 Hz, 1H), 3.69 (t, *J* = 6.3 Hz, 2H), 2.18 (q, *J* = 6.6 Hz, 2H), 1.65 – 1.51 (m, 4 H), 1.52 (s, 9H), 1.06 (s, 9H) ppm. **^{13}C NMR** (125

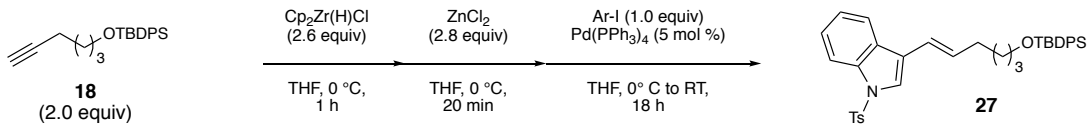
MHz, $CDCl_3$): δ 152.8, 137.1, 135.7, 134.1, 132.9, 129.6, 129.4, 129.0, 127.7, 126.5, 118.6, 80.5, 63.9, 32.8, 32.2, 28.5, 27.0, 25.7, 19.3 ppm. **HRMS** (+ NSI): Calculated for $C_{33}H_{44}NO_3Si$ $[M+H]^+$ 530.3085**,** observed 530.3085 $[M+H]^+$. **IR** (thin film); 2931, 2857, 1716, 1518, 1156, 752, 700 cm^{-1}.



(*E*)-*tert*-butyldiphenyl((6-(thiophen-2-yl)hex-5-en-1-yl)oxy)silane (26).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.01 g, 7.79 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.11 g, 6.26 mmol), $ZnCl_2$ (1.14 g, 8.36 mmol), 2-iodothiophene (0.33 mL, 630 mg, 3.0 mmol), $Pd(PPh_3)_4$ (210 mg, 0.182 mmol) produced the title compound as a light yellow oil (1.049 g, 83% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

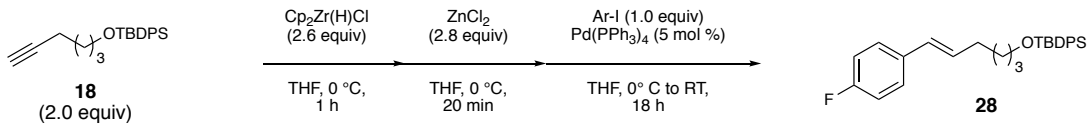
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.37 (m, 6H), 7.09 (d, *J* = 5.1 Hz, 1H), 6.94 (dd, *J* = 5.1, 3.5 Hz, 1H), 6.86 (d, *J* = 3.3 Hz, 1H), 6.49 (d, *J* = 15.6 Hz, 1H), 6.05 (dt, *J* = 15.6, 6.9 Hz, 1H), 3.69 (t, *J* = 6.3 Hz, 2H), 2.17 (qd, *J* = 7.2, 1.4 Hz, 3H), 1.64 – 1.52 (m, 4H), 1.06 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$): δ 143.3, 135.7, 134.2, 131.1, 129.7, 127.7, 127.3, 124.3, 123.3, 123.2, 63.9, 32.7, 32.2, 27.0, 25.6, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{26}H_{33}OSSi$ $[M+H]^+$ 421.2016**,** observed 421.2029. **IR** (thin film); 2930, 2856, 1106, 697 cm^{-1}.



(*E*)-3-(6-((*tert*-butyldiphenylsilyl)oxy)hex-1-en-1-yl)-1-tosyl-1*H*-indole (27).

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (1.73 g, 6.71 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (970 mg, 7.12 mmol), 3-iodo-1-tosyl-1*H*-indole (1.19 g, 3.00 mmol), $Pd(PPh_3)_4$ (210 mg, 0.181 mmol) produced the title compound as a clear yellow oil (1.00 g, 55% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Et_2O:Toluene (98:1 :1to 79:20:1).

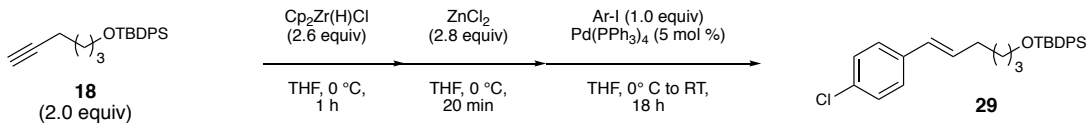
^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 (d, *J* = 8.3 Hz, 1H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.71 – 7.68 (m, 5H), 7.52 (s, 1H), 7.44 – 7.36 (m, 6H), 7.33 (t, *J* = 8.3 Hz, 1H), 7.26 (tt, *J* = 6.8, 1.0 Hz, 1H), 7.21 (d, *J* = 8.1 Hz, 2H), 6.41 (d, *J* = 16.1 Hz, 1H), 6.26 (dt, *J* = 16.0, 6.8 Hz, 1H), 3.71 (t, *J* = 6.2 Hz, 2H), 2.33 (s, 3H), 2.24 (q, *J* = 6.6 Hz, 2H), 1.68 – 1.55 (m, 4H), 1.07 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 145.0, 135.7, 135.6, 135.3, 134.2, 132.8, 130.0, 129.7, 129.5, 127.7, 126.9, 124.9, 123.4, 122.8, 121.2, 120.5, 120.4, 113.9, 63.9, 33.4, 32.2, 27.0, 25.7, 21.7, 19.4 ppm. **HRMS** (+ APCI): Calculated for $C_{37}H_{42}NO_3SSi$ $[M+H]^+$ 608.2649**,** observed 608.2645. **IR** (thin film); 2930, 2857, 1174, 1094, 729, 700 cm^{-1}.



(*E*)-*tert*-butyl((6-(4-fluorophenyl)hex-5-en-1-yl)oxy)diphenylsilane (28).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.03 g, 7.87 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.10 g, 6.24 mmol), $ZnCl_2$ (1.15 g, 8.44 mmol), 1-fluoro-4-iodobenzene (0.35 mL, 666 mg, 3.0 mmol), $Pd(PPh_3)_4$ (210 mg, 0.182 mmol) produced the title compound as a clear oil (982 mg, 76 %yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

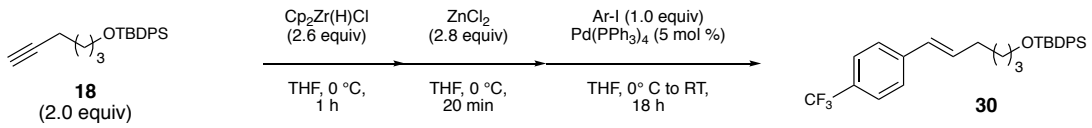
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.37 (m, 6H), 7.29 (dd, J = 8.6, 5.5 Hz, 2H), 6.98 (t, J = 8.7 Hz, 2H), 6.32 (d, J = 15.8 Hz, 1H), 6.11 (dt, J = 15.7, 6.9 Hz, 1H), 3.70 (t, J = 6.3 Hz, 2H), 2.19 (q, J = 7.1 Hz, 2H), 1.65 – 1.54 (m, 4H), 1.06 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$): δ 162.0 (d, J_{CF} = 246 Hz), 135.7, 134.2, 134.1 (d, J_{CF} = 3.2 Hz), 130.8 (d, J_{CF} = 2.2 Hz), 129.7, 128.9, 127.7, 127.4 (d, J_{CF} = 7.8 Hz), 115.42 (d, J_{CF} = 21.5 Hz), 63.9, 32.8, 32.2, 27.0, 25.7, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{28}H_{34}OFSi$ $[M+H]^+$ 433.2358**,** observed 433.2361. **IR** (thin film); 2930, 2856, 1507, 1228, 1108, 701 cm^{-1}.



(*E*)-*tert*-butyl((6-(4-chlorophenyl)hex-5-en-1-yl)oxy)diphenylsilane (29).

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (2.05 g, 7.95mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.03 g, 6.03 mmol), $ZnCl_2$ (1.15 mg, 8.44 mmol), 1-chloro-4-iodobenzene (720 mg, 3.02 mmol), $Pd(PPh_3)_4$ (210 mg, 0.182 mmol) produced the title compound as a clear oil (1.04 g, 77% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10). **Note:** The four aryl protons of the chloro-arene are a unique phenomenon without coupling patterns reported as a singlet in $CDCl_3$. The reported **^{1}H NMR** spectra in Acetone-d_6 show a coupling pattern associated to the previously specified protons and can account for the anomaly.

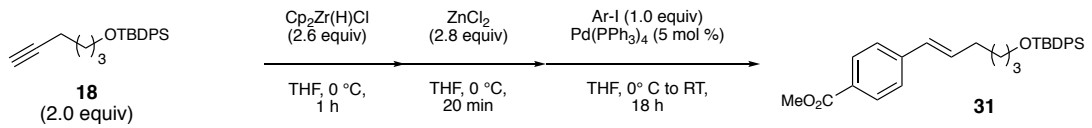
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.68 – 7.66 (m, 4H), 7.44 – 7.36 (m, 6H), 7.25 (s, 4H), 6.30 (dt, *J* = 15.8, 1.4 Hz, 1H), 6.18 (dt, *J* = 15.8, 6.8 Hz, 1H), 3.69 (t, *J* = 6.2 Hz, 2H), 2.19 (qd, *J* = 7.2, 1.3 Hz, 2H), 1.64 – 1.52 (m, 4H), 1.06 (s, 9H). **^{1}H NMR** (500 MHz, Acetone-d_6): δ 7.71 – 7.69 (m, 4H), 7.47 – 7.39 (m, 8H), 7.31 (d, *J* = 8.5 Hz, 2H), 6.40 (d, *J* = 16.0 Hz, 1H), 6.32 (dt, *J* = 15.9, 6.6 Hz, 1H), 3.74 (t, *J* = 6.1 Hz, 2H), 2.22 (q, *J* = 6.9 Hz, 2H), 1.69 – 1.57 (m, 4H), 1.04 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 136.5, 135.7, 134.2, 132.4, 131.8, 129.7, 128.9, 128.7, 127.7, 127.3, 63.9, 32.8, 32.2, 27.0, 25.6, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{28}H_{34}OClSi$ $[M+H]^+$ 449.2062z**,** observed 449.2067. **IR** (thin film); 2929, 2856, 1090, 700 cm^{-1}.



(*E*)-*tert*-butyldiphenyl((6-(4-(trifluoromethyl)phenyl)hex-5-en-1-yl)oxy)silane (30).

Following General Procedure C, the reaction of $Cp_2Zr(H)Cl$ (2.02 g, 7.83 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.09 g, 6.2 mmol), $ZnCl_2$ (1.15 g, 8.44 mmol), 4-iodobenzotrifluoride (0.44 mL, 816 mg, 3.0 mmol), $Pd(PPh_3)_4$ (220 mg, 0.19 mmol) produced the title compound as a clear oil (839 mg, 58% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.54 (d, J = 7.8 Hz, 2H) 7.45 – 7.36 (m, 8H), 6.39 (d, J = 16.0 Hz, 1H), 6.31 (dt, J = 15.9, 6.6 Hz, 1H), 3.70 (t, J = 6.1 Hz, 2H), 2.24 (q, J = 6.5 Hz, 2H), 1.66 – 1.55 (m, 4H), 1.06 (s, 9H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ 141.5 (q, J_{CF} = 0.6 Hz), 135.7, 134.2, 134.0, 129.7, 128.9, 128.6, 127.7, 126.2, 125.6 (q, J_{CF} = 3.8 Hz), 123.4, 63.8, 32.9, 32.2, 27.0, 25.5, 19.4 ppm. **HRMS** (+ NSI): Calculated for $C_{29}H_{34}OF_3Si$ $[M+H]^+$ 483.2326**,** observed 483.2321. **IR** (thin film); 2931, 2857, 1323, 1106, 1066, 700 cm^{-1}.

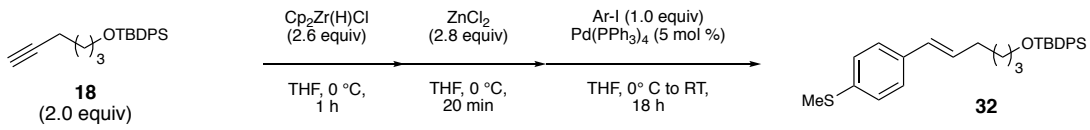


Methyl (*E*)-4-(6-((*tert*-butyldiphenylsilyl)oxy)hex-1-en-1-yl)benzoate (31).

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (2.05 g, 7.95 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.06 g, 6.12 mmol), $ZnCl_2$ (1.16 g, 8.51 mmol), methyl 4-

iodobenzoate (782 mg, 2.98 mmol), $Pd(PPh_3)_4$ (210 mg, 0.181 mmol) produced the title compound as an opaque yellow oil (175 mg, 12 %yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (100:0 to 95:5).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.97 (d, *J* = 8.3 Hz, 2H), 7.69 – 7.67 (m, 4H), 7.44 – 7.36 (m, 8H), 6.40 (d, *J* = 16.0 Hz, 1H), 6.34 (dt, *J* = 15.8, 6.3 Hz, 1H), 3.91 (s, 3H), 3.70 (t, *J* = 6.1 Hz, 2H), 2.23 (q, *J* = 6.8 Hz, 2H), 1.66 – 1.54 (m, 4H), 1.06 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 167.2, 142.5, 135.7, 134.2, 134.1, 130.0, 129.7, 129.3, 128.4, 127.7, 125.9, 63.8, 52.2, 33.0, 32.2, 27.0, 25.5, 19.4 ppm. **HRMS** (+ APCI): Calculated for $C_{30}H_{34}OF_3Si$ $[M+H]^+$ 473.2507**,** observed 473.2514. **IR** (thin film); 2930, 2856, 1718, 1274, 1105, 700 cm^{-1}.



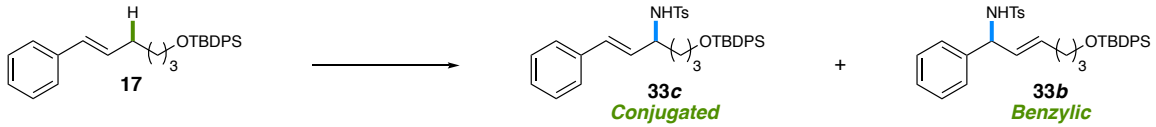
(*E*)-*tert*-butyl((6-(4-(methylthio)phenyl)hex-5-en-1-yl)oxy)diphenylsilane (32)

Following General Procedure B, the reaction of $Cp_2Zr(H)Cl$ (2.03 g, 7.87 mmol), *tert*-butyl(hex-5-yn-1-yloxy)diphenylsilane (2.05 g, 6.09 mmol), $ZnCl_2$ (1.28 g, 9.39 mmol), 4-iodothioanisole (756 mg, 3.02 mmol), $Pd(PPh_3)_4$ (209 mg, 0.181 mmol) produced the title compound as a white solid (389 mg, 28% yield) after purification by flash chromatography on silica gel in a gradient of Hexanes:Toluene (97:3 to 90:10).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.67 (d, *J* = 9.4 Hz, 4H), 7.44 – 7.40 (m, 2H), 7.25 (d, *J* = 8.1 Hz, 2H), 7.19 (d, *J* = 8.3 Hz, 2H), 6.30 (d, *J* = 15.8 Hz, 1H), 6.16 (dt, *J* = 15.7, 6.9 Hz, 1H), 3.68 (t, *J* = 6.2 Hz, 2H), 2.48 (s, 3H), 2.18 (q, *J* = 7.0 Hz, 1H), 1.64 – 1.58 (m, 2H), 1.57 – 1.52 (m, 2H),

1.05 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ 136.67, 135.72, 135.16, 134.22, 130.68, 129.66, 129.37, 127.73, 127.06, 126.49, 63.90, 32.87, 32.22, 27.03, 25.72, 19.38, 16.28 ppm. **HRMS** (+ APCI): Calculated for $C_{29}H_{37}OSSi$ $[M+H]^+$ 461.2329**,** observed 461.2324.

Procedures for the Allylic Amination of *trans*-Aryl-Alkyl Olefins

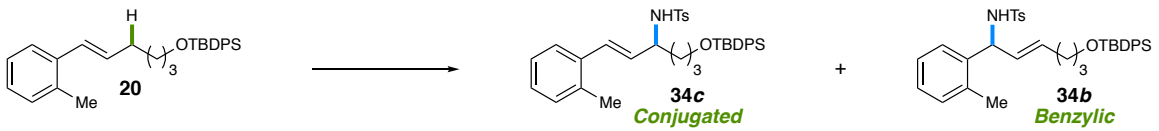


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-phenylhex-1-en-3-yl)-4-methylbenzenesulfonamide (33*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (110 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (3.2 mg, 0.0051 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (92 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **17** (315 mg, 0.760 mmol) in dichloromethane (3.9 mL) was prepared. An aliquot of the stock solution (1.3 mL, 105 mg, 0.253 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24

hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **33*c***:**33*b*** was determined to be 6.3:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 80:20) to provide a mixture of amination product regioisomers as a sticky clear oil (**33*c***:**33*b***, 6.3:1; 127.5 mg, 86% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **33*c*** as a single regioisomer (23 mg).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8.3 Hz, 2H), 7.64 – 7.61 (m, 4H), 7.43 – 7.35 (m, 6H), 7.27 – 7.24 (m, 2H), 7.21 (tt, *J* = 7.2, 1.3 Hz, 1H), 7.16 (d, *J* = 8.6 Hz, 2H), 7.11 – 7.09 (m, 2H), 6.20 (d, *J* = 15.9 Hz, 1H), 5.70 (dd, *J* = 15.9, 7.3 Hz, 1H), 4.52 (d, *J* = 7.7 Hz, 1H), 3.95 (qn, *J* = 6.8 Hz, 1H), 3.62 (t, *J* = 6.0 Hz, 2H), 2.29 (s, 3H), 1.66 (q, *J* = 7.2 Hz, 2H), 1.61 – 1.49 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 143.3, 138.3, 136.4, 135.7, 133.9, 131.7, 129.8, 129.6, 129.0, 128.6, 127.9, 127.8, 127.4, 126.5, 63.4, 56.2, 32.5, 28.5, 27.0, 21.5, 19.6 ppm. **HRMS** (- NSI): Calculated for **$C_{35}H_{40}NO_3SSi$** $[M-H]^-$ 582.2504, observed 582.2514. **IR** (thin film); 3265, 2928, 2856, 1427, 1324, 1159, 1110, 703 cm^{-1}.

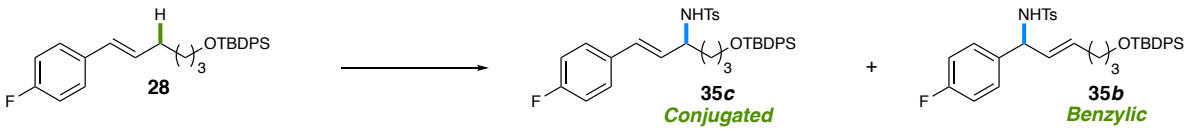


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(*o*-tolyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (34*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (114 mg, 0.666 mmol), $[RhCp^*Cl_2]_2$ (3.4 mg, 0.0055 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **20** (455 mg, 1.06 mmol) in dichloromethane (5.3 mL) was prepared. An aliquot of the stock solution (1.3 mL, 111 mg, 0.26 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **34*c***:**34*b*** was determined to be 6.1:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (99:1 to 75:25) to provide a mixture of amination product regioisomers as a sticky clear oil (**34*c***:**34*b***, 6.1:1; 130 mg, 84% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **34*c*** as a single regioisomer (7 mg).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.64 – 7.62 (m, 4H), 7.43 – 7.40 (m, 2H), 7.38 – 7.35 (m, 4H), 7.19 (d, *J* = 8.4 Hz, 2H), 7.14 – 7.04 (m, 4H), 6.46 (d, *J* = 15.7 Hz, 1H), 5.62 (dd, *J* = 15.7, 7.4 Hz, 1H), 4.59 (t, *J* = 7.0 Hz, 1H), 3.98 (qn, *J* = 7.0 Hz, 1H), 3.63 (t, *J* = 6.0 Hz, 2H), 2.31 (s, 3H), 2.19 (s, 3H), 1.69 (q, *J* = 7.6, 7.1 Hz, 2H), 1.63 – 1.53 (m, 2H), 1.04 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 143.3, 138.4, 135.7, 135.5, 135.4, 133.9, 130.5, 130.3, 129.8, 129.7, 129.6, 127.8, 127.8, 127.4, 126.0, 125.8, 63.4, 56.4, 32.7, 28.5, 27.0, 21.5, 19.8, 19.4 ppm.

HRMS (- APCI): Calculated for **$C_{36}H_{42}NO_3SSi$** $[M-H]^-$ 596.2660, observed 596.2657. **IR** (thin film); 3265, 2929, 2856, 1158, 1109, 703 cm^{-1}.

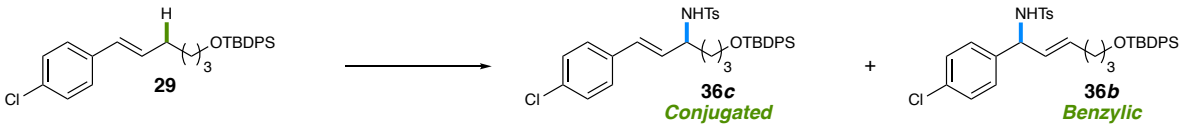


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-fluorophenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (35*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (113 mg, 0.660 mmol), $[RhCp^*Cl_2]_2$ (3.4 mg, 0.0055 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (92 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **28** (133 mg, 0.307 mmol) in 1,2-dichloroethane (1.55 mL) was prepared. An aliquot of the stock solution (1.3 mL, 111 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^1H NMR and the ratio of regioisomers **35*c***:**35*b*** was determined to be ≥20:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 80:20) to provide a mixture of amination product regioisomers as a sticky clear oil (**35*c*:35*b***, ≥20:1; 128 mg, 82% yield). Further purification by

flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **35*c*** as a single regioisomer (126 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.70 (d, J = 8.3 Hz, 2H), 7.64 – 7.61 (m, 4H), 7.44 – 7.40 (m, 2H), 7.38 – 7.34 (m, 4H), 7.16 (d, J = 8.0 Hz, 2H), 7.06 (dd, J = 8.6, 5.4 Hz, 2H), 6.94 (t, J = 8.7 Hz, 2H), 6.18 (d, J = 15.8 Hz, 1H), 5.63 (dd, J = 15.9, 7.3 Hz, 1H), 4.72 (d, J = 7.5 Hz, 1H), 3.93 (qn, J = 7.1 Hz, 1H), 3.60 (t, J = 6.0 Hz, 2H), 2.29 (s, 3H), 1.65 (q, J = 7.8, 6.9 Hz, 2H), 1.61 – 1.47 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 162.4 (d, J_{CF} = 247.1 Hz), 143.3, 138.3, 135.7, 133.8, 132.6 (d, J_{CF} = 3.3 Hz), 130.5, 129.8, 129.6, 128.8 (d, J_{CF} = 2.3 Hz), 128.0 (d, J_{CF} = 8.1 Hz), 127.8 (d, J_{CF} = 0.8 Hz), 127.4, 115.4 (d, J_{CF} = 21.6 Hz), 63.3, 56.2, 32.4, 28.5, 27.0, 21.5, 19.3 ppm. **HRMS** (- APCI): Calculated for **$C_{35}H_{39}NO_3FSSi$** $[M-H]^-$ 600.24, observed 600.2412. **IR** (thin film); 3268, 2930, 2857, 1508, 1157, 1093, 703 cm^{-1}.

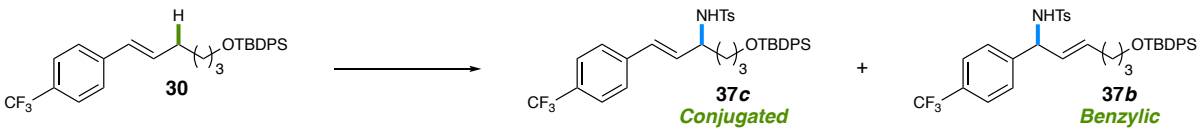


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-chlorophenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (36*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (114 mg, 0.666 mmol), $[RhCp^*Cl_2]_2$ (3.5 mg, 0.0057 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a

stock solution of *trans-ß*-alkyl styrene **29** (220 mg, 0.490 mmol) in dichloromethane (2.6 mL) was prepared. An aliquot of the stock solution (1.3 mL, 110 mg, 0.245 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **36*c*:36*b*** was determined to be 5.0:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (97:3 to 75:25) to provide a mixture of amination product regioisomers as a sticky clear oil (**36*c*:36*b***, 5.0:1; 138 mg, 91% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **36*c*** as a single regioisomer (25 mg).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8.3 Hz, 2H), 7.63 – 7.61 (m, 4H), 7.44 – 7.40 (m, 2H), 7.38 – 7.34 (m, 4H), 7.22 (d, *J* = 8.5 Hz, 2H), 7.16 (d, *J* = 7.9 Hz, 2H), 7.02 (d, *J* = 8.5 Hz, 2H), 6.17 (d, *J* = 15.8 Hz, 1H), 5.70 (dd, *J* = 15.9, 7.3 Hz, 1H), 4.71 (d, *J* = 7.7 Hz, 1H), 3.94 (qn, *J* = 7.2 Hz, 1H), 3.61 (t, *J* = 6.1 Hz, 2H), 2.30 (s, 3H), 1.65 (q, *J* = 7.5, 7.0 Hz, 2H), 1.59 – 1.46 (m, 2H), 1.04 (s, 9H). ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 143.4, 138.3, 135.7, 134.9, 133.8, 133.4, 130.4, 129.8, 129.6, 128.7, 128.6, 127.8, 127.7, 127.4, 63.3, 56.1, 32.4, 28.5, 27.0, 21.5, 19.3 ppm. **HRMS** (- APCI): Calculated for **$C_{35}H_{39}ClNO_3SSi$** $[M-H]^-$ 616.2114, observed 616.2110. **IR** (thin film); 3263, 2929, 2856, 1158, 1091, 703 cm^{-1}.

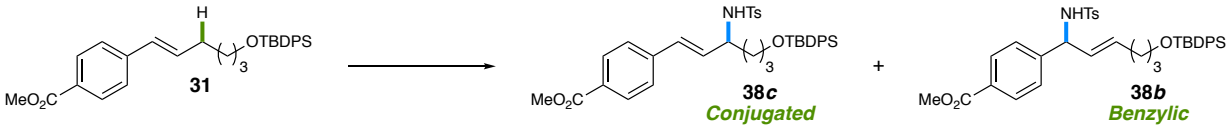


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-(trifluoromethyl)phenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (37*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (112 mg, 0.654 mmol), $[RhCp^*Cl_2]_2$ (3.5 mg, 0.00566 mmol), silver tetrafluoroborate (4.4 mg, 0.023 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-β*-alkyl styrene **30** (366 mg, 0.758 mmol) in 1,2-dichloroethane (3.9 mL) was prepared. An aliquot of the stock solution (1.3 mL, 122 mg, 0.253 mmol) was transferred to the vial containing the solid reagents. The mixture resulting was then heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **37*c***:**37*b*** was determined to be 4.0:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (97:3 to 75:25) to provide a mixture of amination product regioisomers as a sticky clear oil (**37*c***:**37*b***, 4.0:1; 93 mg, 56% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **37*c*** as a single regioisomer (22 mg).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.69 (d, J = 8.3 Hz, 2H), 7.63 – 7.61 (m, 4H), 7.51 (d, J = 8.2 Hz, 2H), 7.44 – 7.40 (m, 2H), 7.38 –7.35 (m, 4H), 7.20 (d, J = 8.2 Hz, 2H), 7.16 (d, J = 8.0 Hz, 2H),

6.27 (d, J = 15.9 Hz, 1H), 5.83 (dd, J = 15.9, 7.1 Hz, 1H), 4.59 (bs, 1H), 3.98 (qn, J = 6.9 Hz, 1H), 3.61 (t, J = 6.0 Hz, 2H), 2.29 (s, 3H), 1.66 (q, J = 7.2 Hz, 2H), 1.59 –1.46 (m, 2H), 1.04 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 143.5, 139.9, 138.3, 135.7, 133.8, 131.9, 130.2, 129.8, 129.8, 129.7, 127.8, 127.4, 126.6, 125.5 (q, J_{CF} = 3.9 Hz), 125.1, 123.3, 63.3, 56.0, 32.3, 28.4, 27.0, 21.5, 19.4 ppm. **HRMS** (- APCI): Calculated for **$C_{36}H_{39}NO_3SSi$** $[M-H]^-$ 650.2378, observed 650.2372. **IR** (thin film); 3268, 2930, 2857, 1323, 1158, 1109, 703 cm^{-1}.

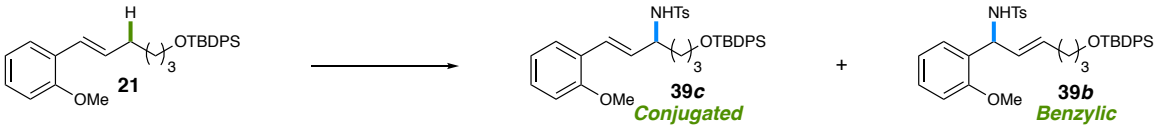


Methyl (*E*)-4-(6-((*tert*-butyldiphenylsilyl)oxy)-3-((4-methylphenyl)sulfonamido)hex-1-en-1-yl)benzoate (38*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (53 mg, 0.30 mmol), $[RhCp^*Cl_2]_2$ (1.6 mg, 0.0026 mmol), silver tetrafluoroborate (2.0 mg, 0.011 mmol), and silver acetate (42 mg, 0.25 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 10 mL round-bottom flask fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **31** (170 mg, 0.360 mmol) in 1,2-dichloroethane (1.8 mL) was prepared. An aliquot of the stock solution (0.6 mL, 57 mg, 0.12 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure.

The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **38*c***:**38*b*** was determined to be 4.0:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 60:40) to provide a mixture of amination product regioisomers as a sticky yellow oil (**38*c***:**38*b***, 4.0:1; 39 mg, 51% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 70:30) provided **38*c*** as a single regioisomer (26 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, *J* = 8.4 Hz, 2H), 7.69 (d, *J* = 8.3 Hz, 1H), 7.63 – 7.61 (m, 4H), 7.44 – 7.40 (m, 2H), 7.38 –7.34 (m, 4H), 6.25 (d, *J* = 15.8 Hz, 2H), 7.16 –7.14 (m, 4H), 5.84 (dd, *J* = 15.9, 7.2 Hz, 1H), 4.68 (d, *J* = 7.7 Hz, 1H), 3.97 (qn, *J* = 7.8, 7.2 Hz, 1H), 3.92 (s, 3H), 3.61 (t, *J* = 6.0 Hz, 2H), 2.28 (s, 3H), 1.66 (q, *J* = 7.4 Hz, 2H), 1.59 – 1.45 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 166.9, 143.5, 140.9, 138.2, 135.7, 133.8, 131.8, 130.6, 129.9, 129.8, 129.7, 129.2, 127.8, 127.4, 126.4, 63.3, 56.1, 52.3, 32.3, 28.4, 27.0, 21.6, 19.3 ppm. **HRMS** (+ NSI): Calculated for **$C_{37}H_{44}NO_5SSi$** $[M+H]^+$ 642.2704, observed 642.2735 . **IR** (thin film); 3274, 2951, 2857, 1720, 1281, 1109, 703 cm^{-1}.

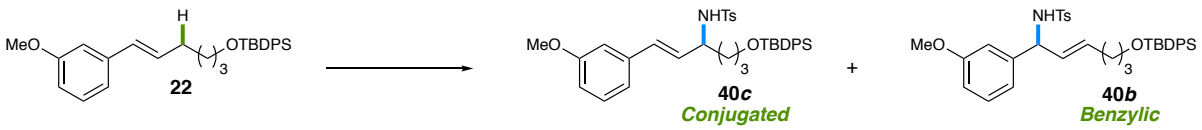


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(2-methoxyphenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (39*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (114 mg, 0.665 mmol), $[RhCp^*Cl_2]_2$ (3.3 mg, 0.0051 mmol),

silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial 15 mL fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-β*-alkyl styrene **21** (280 mg, 0.630 mmol) in 1,2-dichloroethane (3.1 mL) was prepared. An aliquot of the stock solution (1.3 mL, 117 mg, 0.264 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **39*c***:**39*b*** was determined to be ≥20:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide a mixture of amination product regioisomers as a clear sticky oil (**39*c***:**39*b***, ≥20:1; 124 mg, 79% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **39*c*** as a single regioisomer (124 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ7.71 (d, *J* = 8.3 Hz, 2H), 7.65 – 7.62 (m, 4H), 7.43 – 7.40 (m, 2H), 7.38 – 7.34 (m, 4H), 7.20 (ddd, *J* = 8.2, 7.6, 1.7 Hz, 1H), 7.15 (d, *J* = 8.0 Hz, 2H), 7.06 (dd, *J* = 7.6, 1.7 Hz, 1H), 6.85 – 6.82 (m, 2H), 6.58 (d, *J* = 15.9 Hz, 1H), 5.74 (dd, *J* = 16.0, 7.4 Hz, 1H), 4.54 (d, *J* = 7.7 Hz, 1H), 3.95 (qn, *J* = 7.7 Hz, 1H), 3.80 (s, 3H), 3.61 (t, *J* = 6.1 Hz, 2H), 2.29 (s, 3H), 1.68 (q, *J* = 7.2 Hz, 2H), 1.63 – 1.50 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 156.7, 143.1, 138.3, 135.7, 133.9, 129.7, 129.5, 129.4, 128.8, 127.8, 127.4, 126.9, 126.5, 125.3, 120.5, 110.8, 63.4, 56.8, 55.5, 32.5, 28.5, 27.0, 21.5, 19.3 ppm. **HRMS** (- APCI): Calculated for **$C_{36}H_{42}NO_4SSi$** $[M-H]^-$ 612.2609, observed 612.2626. **IR** (thin film); 3266, 2929, 2857, 1105, 700 cm^{-1}.

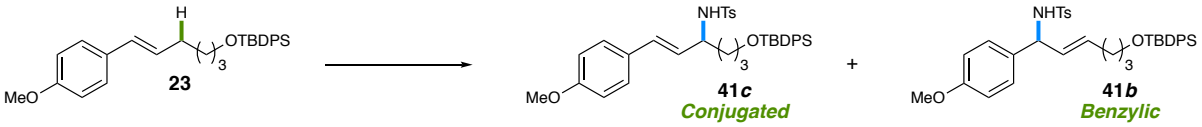


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(3-methoxyphenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (40*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (114 mg, 0.666 mmol), $[RhCp^*Cl_2]_2$ (3.6 mg, 0.0058 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial 7 mL fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **22** (149 mg, 0.335 mmol) in 1,2-dichloroethane (1.7 mL) was prepared. An aliquot of the stock solution (1.3 mL, 114 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **40*c***:**40*b*** was determined to be 9.5:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 80:20) to provide a mixture of amination product regioisomers as a sticky yellow oil (**40*c***:**40*b***, 9.5:1; 102 mg, 65% yield). Further purification by preparative thin layer chromatography on silica gel in a gradient of Hexanes:EtOAc (85:15, 4 sweeps) provided **40*c*** as a single regioisomer (9 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 (d, J = 8.3 Hz, 2H), 7.64 – 7.62 (m, 4H), 7.44 –7.34 (m, 6H), 7.19 – 7.16 (m, 3H), 6.77 (dd, J = 8.3, 2.4 Hz, 1H), 6.70 (d, J = 7.6 Hz, 1H), 6.63 (t, J = 1.8 Hz,

1H), 6.18 (d, J = 15.9 Hz, 1H), 5.70 (dd, J = 15.8, 7.3 Hz, 1H), 4.52 (d, J = 7.8 Hz, 1H), 3.95 (qn, J = 7.2 Hz, 1H), 3.79 (s, 3H), 3.61 (t, J = 6.0 Hz, 2H), 2.30 (s, 2H), 1.66 (q, J = 7.3 Hz, 2H), 1.60 – 1.47 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 159.8, 143.4, 138.3, 137.8, 135.7, 133.8, 131.6, 129.8, 129.7, 129.5, 129.3, 127.8, 127.4, 119.2, 113.4, 111.9, 63.4, 56.2, 55.3, 32.5, 28.5, 27.0, 21.6, 19.4 ppm. **HRMS** (- APCI): Calculated for **$C_{36}H_{42}NO_4SSi$** $[M-H]^-$ 612.2609, observed 612.2602. **IR** (thin film); 3270, 2930, 2856, 1156, 1108, 702 cm^{-1}.

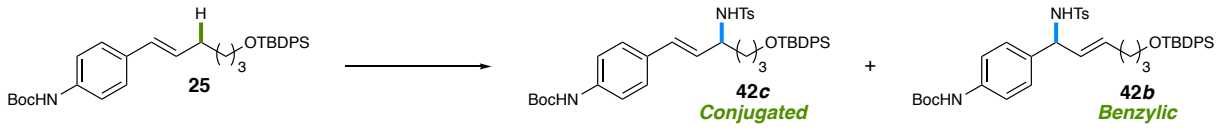


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-methoxyphenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (41*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (113 mg, 0.663 mmol), $[RhCp^*Cl_2]_2$ (3.4 mg, 0.0055 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-β*-alkyl styrene **23** (342 mg, 0.769 mmol) in dichloromethane (3.9 mL) was prepared. An aliquot of the stock solution (1.3 mL, 114 mg, 0.256 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure.

The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **41*c*:41*b*** was determined to be ≥20:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (97:3 to 75:25) to provide a mixture of amination product regioisomers as a white solid (**41*c*:41*b***, ≥20:1; 137 mg, 87% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 80:20) provided **41*c*** as a single regioisomer (133 mg).

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.1 Hz, 2H), 7.64 – 7.62 (m, 4H), 7.44 – 7.34 (m, 6H), 7.16 (d, *J* = 7.7 Hz, 2H), 7.04 (d, *J* = 8.7 Hz, 2H), 6.79 (d, *J* = 8.7 Hz, 2H), 6.14 (d, *J* = 15.8 Hz, 1H), 5.56 (dd, *J* = 15.8, 7.4 Hz, 1H), 4.49 (d, *J* = 7.6 Hz, 1H), 3.92 (qn, *J* = 6.9 Hz, 1H), 3.80 (s, 3H), 3.61 (t, *J* = 6.0 Hz, 2H), 2.31 (s, 3H), 1.68 – 1.49 (m, 4H), 1.03 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$): δ 159.4, 143.3, 138.4, 135.7, 133.9, 131.2, 129.8, 129.6, 129.2, 127.8, 127.7, 127.4, 126.8, 114.0, 63.4, 56.4, 55.5, 32.6, 28.5, 27.0, 21.6, 19.6 ppm. **HRMS** (- APCI): Calculated for $C_{36}H_{42}NO_4SSi$ $[M-H]^-$ 612.2609**,** observed 612.2608. **IR** (thin film); 3266, 2929, 2856, 1158, 1109, 704 cm^{-1}.

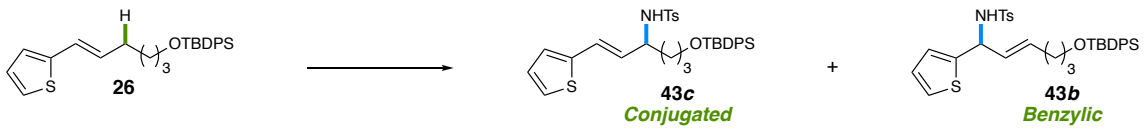


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-(dimethylamino)phenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (42*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (114 mg, 0.666 mmol), $[RhCp^*Cl_2]_2$ (3.4 mg, 0.0055 mmol),

silver tetrafluoroborate (4.3 mg, 0.022 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **25** (275 mg, 0.519 mmol) in 1,2-dichloroethane (2.6 mL) was prepared. An aliquot of the stock solution (1.3 mL, 137 mg, 0.260 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **42*c***:**42*b*** was determined to be ≥20:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 to 60:40) to provide a mixture of amination product regioisomers as a sticky yellow oil (**42*c***:**42*b***, ≥20:1; 132 mg, 74% yield). Further purification by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (80:20 to 60:40) provided **42*c*** as a single regioisomer (130 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.71 (d, *J* = 8.3 Hz, 2H), 7.65 – 7.63 (m, 4H), 7.44 – 7.40 (m, 2H), 7.38 – 7.35 (m, 4H), 7.26 (d, *J* = 8.4 Hz, 2H), 7.14 (d, *J* = 7.9 Hz, 2H), 7.02 (d, *J* = 8.6 Hz, 2H), 6.63 (bs, 1H), 6.12 (d, *J* = 15.8 Hz, 1H), 5.62 (dd, *J* = 15.8, 7.4 Hz, 1H), 5.00 (d, *J* = 7.9 Hz, 1H), 3.92 (qn, *J* = 7.0 Hz, 1H), 3.61 (t, *J* = 6.0 Hz, 2H), 2.28 (s, 3H), 1.68 – 1.64 (m, 2H), 1.61 – 1.49 (m, 2H), 1.53 (s, 9H), 1.04 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 152.8, 143.2, 138.3, 137.9, 135.6, 133.8, 131.2, 131.0, 129.7, 129.6, 127.7, 127.5, 127.3, 127.1, 118.3, 80.7, 63.4, 56.3, 32.4, 28.5, 28.4, 27.0, 21.5, 19.3 ppm. **HRMS** (- NSI): Calculated for **$C_{40}H_{49}N_2O_5SSi$** $[M-H]^-$ 697.3130, observed 697.3137. **IR** (thin film); 3269, 2930, 1710, 1519, 1110, 906, 728 cm^{-1}.

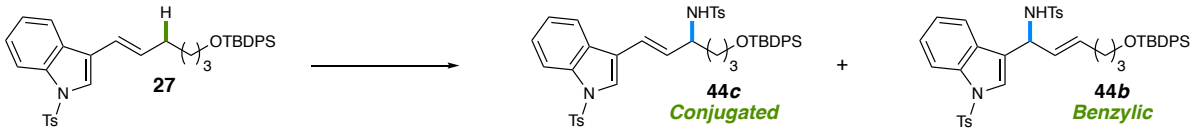


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(thiophen-2-yl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (43*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (115 mg, 0.671 mmol), $[RhCp^*Cl_2]_2$ (3.6 mg, 0.0058 mmol), silver tetrafluoroborate (4.1 mg, 0.021 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-vinyl thiophene **26** (218 mg, 0.516 mmol) in dichloromethane (2.6 mL) was prepared. An aliquot of the stock solution (1.3 mL, 108 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **43*c***:**43*b*** was determined to be 5.4:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide a mixture of amination product regioisomers as a sticky clear oil (**43*c***:**43*b*,** 63 mg, 5:1, 86% yield). Further purification by preparative thin layer chromatography on silica gel in a gradient of Hexanes:EtOAc (85:15, 5 sweeps) provided **43*c*** as a single regioisomer.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.3 Hz, 2H), 7.64 – 7.62 (m, 4H), 7.44 – 7.40 (m, 2H), 7.39 – 7.35 (m, 6H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.11 (d, *J* = 5.0 Hz, 1H), 6.92 (dd, *J* = 5.1, 3.5 Hz,

1H), 6.77 (d, J = 3.4 Hz, 1H), 6.34 (d, J = 15.7 Hz, 1H), 5.55 (dd, J = 15.7, 7.2 Hz, 1H), 4.54 (d, J = 7.8 Hz, 1H), 3.90 (qn, J = 7.0 Hz, 1H), 3.60 (t, J = 6.1 Hz, 2H), 2.31 (s, 3H), 1.63 (q, J = 7.2 Hz, 2H), 1.58 – 1.40 (m, 2H), 1.03 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 143.4, 141.4, 138.2, 135.7, 133.8, 129.8, 129.7, 128.4, 127.82, 127.7, 127.4, 126.1, 124.9, 124.5, 63.3, 56.0, 32.4, 28.5, 27.0, 21.6, 19.3 ppm. **HRMS** (- APCI): Calculated for **$C_{33}H_{38}NO_3S_2Si$** $[M-H]^-$ 588.2068, observed 588.2061. **IR** (thin film); 3269, 2928, 2856, 1427, 1324, 1159, 1110, 703 cm^{-1}.

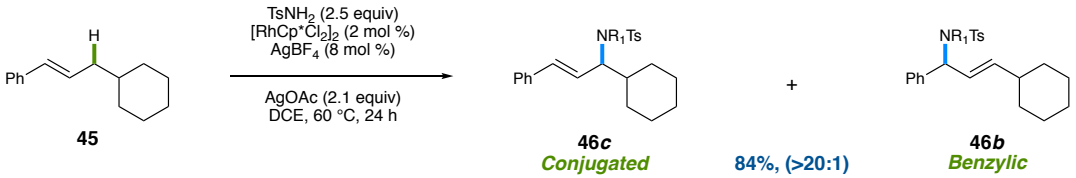


(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(1-tosyl-1*H*-indol-3-yl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (44*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (117 mg, 0.683 mmol), $[RhCp^*Cl_2]_2$ (3.4 mg, 0.0055 mmol), silver tetrafluoroborate (4.4 mg, 0.023 mmol), and silver acetate (91 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-3-vinyl indole **27** (361 mg, 0.608 mmol) in dichloromethane (3.0 mL) was prepared. An aliquot of the stock solution (1.3 mL, 156 mg, 0.257 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 80 °C and stirred for 48 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure.

The crude reaction mixture was analyzed by ^{1}H NMR and the ratio of regioisomers **44*c***:**44*b*** was determined to be ≥20:1. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (85:15 to 60:40) to provide a mixture of amination product regioisomers as a sticky yellow oil (**44*c***:**44*b***, ≥20:1; 103 mg, 52% yield). Further purification by preparative thin layer chromatography on silica gel in Hexanes:EtOAc (80:20, 3 sweeps) provided **44*c*** as a single regioisomer (68 mg).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.97 (d, *J* = 8.3 Hz, 1H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.69 (d, *J* = 8.3 Hz, 2H), 7.64 – 7.62 (m, 4H), 7.42 – 7.30 (m, 9H), 7.23 – 7.18 (m, 3H), 7.04 (d, *J* = 8.0 Hz, 2H), 6.28 (d, *J* = 16.1 Hz, 1H), 5.77 (dd, *J* = 16.1, 7.4 Hz, 1H), 4.86 (d, *J* = 7.7 Hz, 1H), 3.97 (qn, *J* = 7.0 Hz, 1H), 3.62 (t, *J* = 6.0 Hz, 2H), 2.33 (s, 3H), 2.11 (s, 2H), 1.70 – 1.50 (m, 4H), 1.04 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 145.2, 143.4, 138.3, 135.6, 135.5, 135.2, 133.8, 130.3, 130.1, 129.8, 129.6, 128.8, 127.8, 127.4, 127.0, 125.0, 124.1, 123.5, 122.4, 120.5, 119.7, 113.8, 63.4, 56.6, 32.4, 28.5, 27.0, 21.7, 21.3, 19.3 ppm. **HRMS** (- APCI): Calculated for **$C_{44}H_{47}N_2O_5S_2Si$** [M-H]$^{-}$ 775.2701, observed 775.2686. **IR** (thin film); 3277, 2929, 2856, 1173, 1092, 907, 729, 702 cm^{-1}.

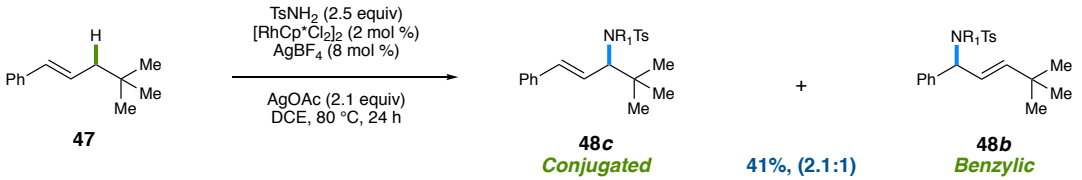


(*E*)-*N*-(1-cyclohexyl-3-phenylallyl)-4-methylbenzenesulfonamide (46*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL test-tube equipped with a magnetic stir bar was added *p*-toluenesulfonamide (46 mg, 0.27 mmol), $[RhCp^*Cl_2]_2$ (1.3 mg, .0021 mmol), silver tetrafluoroborate (4.0 mg, 0.0205 mmol), and silver acetate (37 mg, 0.22 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of (*E*)-(3-cyclohexylprop-1-en-1-yl)benzene (61 mg, 0.30 mmol) in 1,2-dichloroethane (1.5 mL) was prepared. An aliquot of the stock solution (0.5 mL, 20.3 mg, 0.10 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and only a single regioisomer of product **46*c*** was observed. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Pentane:EtOAc (95:5 to 80:20) to provide the title compound as a white solid (31 mg, 84% yield).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, J = 8.3 Hz, 2H), 7.26 – 7.18 (m, 3H), 7.16 (d, J = 8.0 Hz, 2H), 7.08 – 7.06 (m, 2H), 6.05 (d, J = 15.8 Hz, 1H), 5.68 (dd, J = 15.9, 8.0 Hz, 1H), 4.42 (d, J = 8.3 Hz, 1H), 3.73 (q, J = 8.0 Hz, 1H), 2.27 (s, 3H), 1.86 – 1.62 (m, 5H), 1.50 – 1.41 (m, 1H), 1.23 – 0.95 (m, 5H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$) δ 143.3, 138.3, 136.5, 132.2, 129.6, 128.5, 127.7, 127.4, 127.3, 126.4, 61.5, 43.1, 29.2, 26.4, 26.1, 21.5 ppm. **HRMS** (+ ESI): Calculated for

$NaC_{22}H_{27}NO_2S$ $[M+Na]^+$ 392.1655, observed 392.1658. **IR** (thin film); 3269, 2923, 2852, 1184 cm^{-1}.

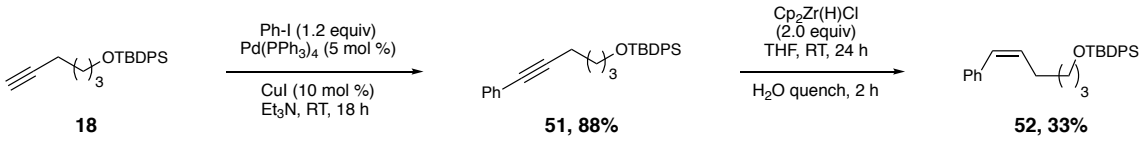


(*E*)-*N*-(4,4-dimethyl-1-phenylpent-1-en-3-yl)-4-methylbenzenesulfonamide (48*c*).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL test-tube equipped with a magnetic stir bar was added *p*-toluenesulfonamide (45 mg, 0.26 mmol), $[RhCp^*Cl_2]_2$ (1.1 mg, 0.0018 mmol), silver tetrafluoroborate (1.5 mg, 0.0077 mmol), and silver acetate (34 mg, 0.20 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, (*E*)-(4,4-dimethylpent-1-en-1-yl)benzene (16 mg, 0.092 mmol) was dissolved in 1,2-dichloroethane (0.30 mL) and added to the test-tube containing the solid reagents. The vial containing the olefin was rinsed with 1,2-dichloroethane (0.16 mL) and added to the reaction mixture. The resulting mixture was heated to 80 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was analyzed by ^1H NMR and the ratio of regioisomers **48*c***:**48*b*** was determined to be 2.1:1. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Pentane:EtOAc (95:5 to 85:15) to provide a mixture of amination product regioisomers as a yellow oil (**48*c***:**48*b***, 2.1:1; 13 mg, 41% yield).

Further purification by preparative thin layer chromatography on silica gel in Pentane:EtOAc (90:10, 3 sweeps) provided **48*c*** as a single regioisomer (2 mg).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.3 Hz, 2H), 7.25 – 7.17 (m, 3H), 7.12 (d, *J* = 8.1 Hz, 2H), 7.03 – 7.01 (m, 2H), 5.95 (d, *J* = 15.8 Hz, 1H), 5.68 (dd, *J* = 15.8, 8.5 Hz, 1H), 4.43 (d, *J* = 9.2 Hz, 1H), 3.58 (t, *J* = 8.4 Hz, 1H), 2.21 (s, 3H), 0.93 (s, 9H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$) δ 143.3, 138.1, 136.5, 133.1, 129.6, 128.5, 127.7, 127.5, 126.4, 125.6, 65.6, 35.1, 26.6, 21.5 ppm. **HRMS** (+ ESI): Calculated for **$C_{16}H_{16}NO_2S$** [**M-C_4H_9**]$^+$ 286.0902, observed 286.0897. **IR** (thin film); 3282, 2924, 2873, 1149 cm^{-1}.



***tert*-Butyldiphenyl((6-phenylhex-5-yn-1-yl)oxy)silane (51).**

To a flame-dried 25 mL round-bottom flask equipped with a magnetic stir bar was weighed $Pd(PPh_3)_2Cl_2$ (110 mg, 0.156 mmol) and CuI (57 mg, 0.30 mmol). The flask was then fitted with a septum cap and the atmosphere within was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to establish a N_2 atmosphere. In a separate oven-dried 15 mL vial was weighed *tert*-Butyl(hex-5-yn-1-yloxy)diphenylsilane (1.05 g, 3.12 mmol) which was then fitted with a septum cap. The atmosphere within the vial was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to establish a N_2 atmosphere. Iodobenzene (0.40 mL, 732 mg, 3.59 mmol) and Et_3N (6 mL) was added to the vial of alkyne by syringe and the resulting solution was transferred to the flask containing the solid reagents. The resulting mixture was allowed to stir at room temperature for 16

hours. The reaction mixture was diluted with Et_2O (30 mL) and washed sequentially with H_2O (2 x 30 mL) and brine (1 x 30 mL). The organic layer was dried with $MgSO_4$ and concentrated under reduced pressure. The crude residue was purified by flash chromatography on silica gel in a gradient of Hexanes:Et_2O (100:0 to 90:10) to provide the title compound as an opaque yellow oil (1.147 g, 89% yield).

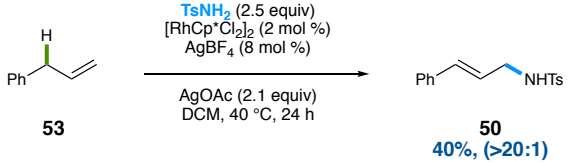
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 4H), 7.44 – 7.36 (m, 8H), 7.30 – 7.26 (m, 3H), 3.72 (t, *J* = 6.0 Hz, 2H), 2.42 (t, *J* = 6.7 Hz, 2H), 1.78 – 1.68 (m, 4H), 1.07 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 135.7, 134.2, 131.7, 129.7, 128.3, 127.8, 127.6, 124.2, 90.4, 80.9, 63.6, 31.9, 27.0, 25.4, 19.6 ppm. **HRMS** (+ APCI): Calculated for **$C_{28}H_{33}OSi$** $[M+H]^+$ 413.2295, observed 413.2304. **IR** (thin film); 3070, 2930, 2857, 1105, 700, 690 cm^{-1}.

(*Z*)-*tert*-butyldiphenyl((6-phenylhex-5-en-1-yl)oxy)silane (52).

Inside a N_2 atmosphere glovebox, an oven-dried 50 mL round-bottom flask equipped with a magnetic stir was added $Cp_2Zr(H)Cl$ (1.024 g, 3.97 mmol) which was then fitted with a septum cap and removed from the glovebox. The flask was then placed under positive pressure of N_2 gas and THF (10 mL) was added. To an oven-dried 15 mL vial was weighed *tert*-butyldiphenyl((6-phenylhex-5-yn-1-yl)oxy)silane (848 mg, 2.06 mmol) and the vial was fitted with a septum cap. The atmosphere within the vial was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to establish a N_2 atmosphere. THF (10 mL) was added to dissolve the alkyne and the resulting solution was transferred to the flask containing $Cp_2Zr(H)Cl$ by syringe. The reaction mixture was allowed to stir for 20 hours at room temperature. After completion of the reaction confirmed by TLC, the reaction was quenched with H_2O (5 mL) and stirred for an additional 2 hours. The reaction mixture was then diluted with Et_2O (30 mL) and washed sequentially with H_2O (2 x 20 mL) and brine (1 x 20 mL). The organic layer was dried over $MgSO_4$ and concentrated under

reduced pressure. The crude residue was purified by flash chromatography on silica gel in a gradient of Hexanes:Toluene (95:5 to 85:15) to provide the title compound as a clear light yellow oil (284 mg, 33% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.67 – 7.66 (m, 4H), 7.44 – 7.40 (m, 2H), 7.39 – 7.36 (m, 4H), 7.36 – 7.31 (m, 2H), 7.28 – 7.26 (m, 2H), 7.24 – 7.20 (tt, *J* = 7.3, 1.7 Hz, 1H), 6.41 (d, *J* = 11.7 Hz, 1H), 5.65 (dt, *J* = 11.7, 7.2 Hz, 1H), 3.66 (t, *J* = 6.2 Hz, 2H), 2.33 (qd, *J* = 7.3, 1.8 Hz, 2H), 1.63 – 1.51 (m, 4H), 1.05 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 137.9, 135.7, 134.2, 133.2, 129.6, 129.0, 128.9, 128.3, 127.7, 126.6, 63.8, 32.4, 28.5, 27.0, 26.4, 19.4 ppm. **HRMS** (+ APCI): Calculated for **$C_{28}H_{35}OSi$** $[M+H]^+$ 415.2452, observed 415.2451. **IR** (thin film); 3070, 2929, 2856, 1106, 698 cm^{-1}.

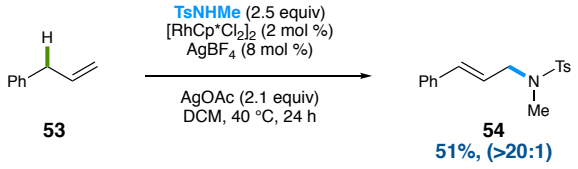


***N*-cinnamyl-4-methylbenzenesulfonamide (50).**

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL test-tube equipped with a magnetic stir bar was added *p*-toluenesulfonamide (86 mg, 0.50 mmol), $[RhCp^*Cl_2]_2$ (2.4 mg, 0.0039 mmol), silver tetrafluoroborate (3.1 mg, 0.016 mmol), and silver acetate (70 mg, 0.42 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of allyl benzene (107 µL, 0.80 mmol) in 1,2-dichloroethane (4.0 mL) was prepared. An aliquot of the stock solution (1.0 mL, 24 mg, 0.20 mmol) was transferred to the vial containing the

solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Pentane:EtOAc (95:5 to 80:20) to provide the title compound as a white solid (23 mg, 40% yield). The compound exhibited identical ^{1}H and ^{13}C NMR data to previous reports.[58]

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (d, J = 8.3 Hz, 1H), 7.35 – 7.21 (m, 8H), 6.45 (d, J = 15.8 Hz, 1H), 6.03 (dt, J = 15.8, 6.4 Hz, 1H), 4.58 (bs, 1H), 3.77 (td, J = 6.3, 1.5 Hz, 2H), 2.43 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 143.7, 137.2, 136.2, 133.3, 129.9, 128.7, 128.1, 127.4, 126.5, 124.2, 45.7, 21.7.



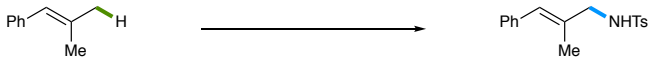
53 **54** **51%, (>20:1)**

***N*-cinnamyl-*N*,4-dimethylbenzenesulfonamide (54).**

Inside an N_2 atmosphere glovebox, to an oven-dried 50 mL round bottom flask equipped with a magnetic stir bar was added $[RhCp^*Cl_2]_2$ (35 mg, 0.057 mmol) and silver tetrafluoroborate (49 mg, 0.25 mmol). The reaction flask was capped with a septum and removed from the glovebox. The reaction flask was then opened in air and *p*-toluenesulfonamide (1.40 g, 7.56 mmol) and silver acetate (1.05 g, 6.29 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap whereupon the atmosphere was exchanged under vacuum (3 x cycles, 3 minutes per cycle) to establish a N_2 atmosphere. The solids were then suspended in 1,2-dichloroethane (15 mL)

and allyl benzene (0.40 mL, 3.0 mmol) was added to the reaction vessel was prepared. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over a pad of celite through a 75 mL coarse-porosity fritted funnel. The celite was rinsed with EtOAc (100 mL) and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Pentane:EtOAc (98:2 to 80:20) to provide the title compound as a white solid (462 mg, 51% yield).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.31 – 7.28 (m, 4H), 7.28 – 7.23 (m, 1H), 6.47 (dt, *J* = 15.8, 1.3 Hz, 1H), 6.06 (dt, *J* = 15.8, 6.7 Hz, 1H), 3.79 (dd, *J* = 6.7, 1.1 Hz, 2H) 2.71 (s, 3H), 2.44 (s, 3H) ppm. **^{13}C NMR** (100 MHz, $CDCl_3$) δ 143.6, 136.3, 134.6, 134.3, 129.9, 128.8, 128.1, 127.7, 126.6, 123.8, 52.8, 34.5, 21.7 ppm. **HRMS** (+ ESI): Calculated for **$NaC_{17}H_{19}NO_2S$** $[M+Na]^+$ 324.1029, observed 324.1030. **IR** (thin film); 3027, 2923, 1158, 1335, 724, 546 cm^{-1}.



55 **56**

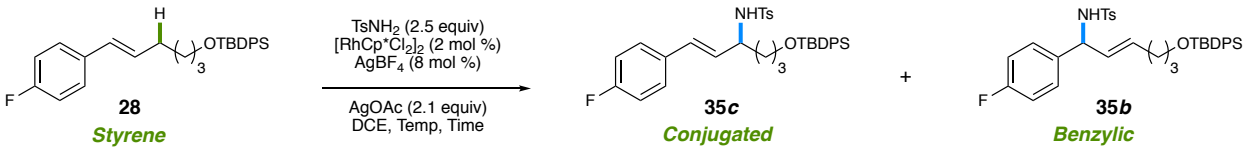
(*E*)-4-methyl-*N*-(2-methyl-3-phenylallyl)benzenesulfonamide (56).

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (220 mg, 1.28 mmol), $[RhCp^*Cl_2]_2$ (8.0 mg, 0.013 mmol), silver tetrafluoroborate (11 mg, 0.057 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of 2-

methyl-1-phenyl-1-propene (0.19 mL, 171 mg, 1.29 mmol) in 1,2-dichloroethane (6.5 mL) was prepared. An aliquot of the stock solution (1.3 mL, 34 mg, 0.26 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 80 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide the title compound as a white solid (30 mg, 39% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.78 (d, J = 8.3 Hz, 2H), 7.38 – 7.28 (m, 4H), 7.21 (tt, J = 6.7, 1.2 Hz, 1H), 7.13 (d, J = 7.2 Hz, 2H), 6.34 (s, 1H), 4.66 (t, J = 6.4 Hz, 1H), 3.66 (d, J = 7.5 Hz, 2H), 2.42 (s, 3H), 1.79 (s, 3H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 143.6, 137.3, 137.1, 133.3, 129.8, 128.9, 128.2, 128.0, 127.3, 126.8, 51.8, 21.7, 16.1 ppm. **HRMS** (+ APCI): Calculated for **$C_{17}H_{20}NO_2S$** $[M+H]^+$ 302.1209, observed 302.1204. **IR** (thin film); 3278, 2922, 1321, 1154, 699, 662 cm^{-1}.

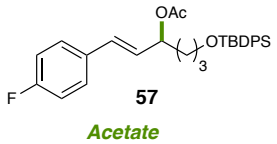
Temperature Study Revealing Thermodynamic Equilibration.



Reaction composition after 24 h at 40 °C: **28**:**35*c***:**35*b***:**57** = 3 / 60 / 15 / 10%[a]

Reaction composition after *additional* 24 h at 60 °C: **28**:**35*c***:**35*b***:**57** = 0 / 78 / 3 / 1%[a]

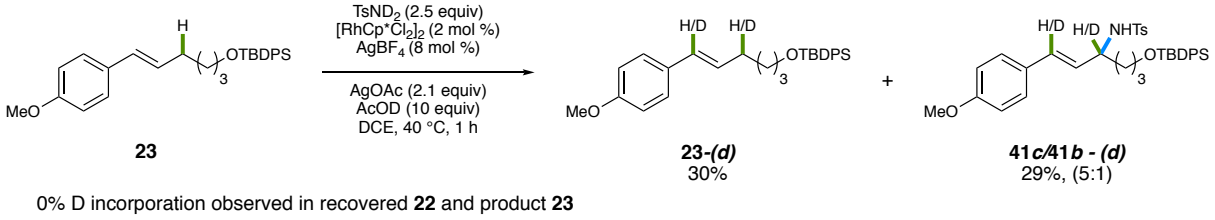
[a] 1,4-dinitrobenzene was used as an internal standard.



Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (115 mg, 0.671 mmol), $[RhCp^*Cl_2]_2$ (3.2 mg, 0.0051 mmol), silver tetrafluoroborate (4.0 mg, 0.021 mmol), and silver acetate (90 mg, 0.54 mmol). After

all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 7 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **28** (139 mg, 0.321 mmol) and 1,4-dinitrobenzene (13.5 mg, 0.0803 mmol) in 1,2-dichloroethane (1.6 mL) was prepared. An aliquot of the stock solution (1.3 mL, 113 mg, 0.261 mmol) was transferred to the vial containing the solid reagents. The mixture was heated to 40 °C and stirred for 24 hours. After 24 hours, an aliquot of the solution (0.2 mL) was removed and the reaction mixture was immediately placed on a preset 60 °C hot plate to be further heated for an additional 24 hours. The previously removed aliquot from the reaction mixture was then filtered through celite and the celite was rinsed with EtOAc (5 mL). The filtered aliquot was concentrated under reduced pressure and analyzed by ^{1}H NMR to provide the given yields based on the internal standard (**28**:**35*c***:**35*b***:**57** = 3:60:15:10 %). After additional heating of the reaction mixture at 60 °C for 24 hours had finished, the reaction was allowed to cool to room temperature. The crude mixture was filtered over celite, the celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The filtered aliquot was concentrated under reduced pressure and analyzed by ^{1}H NMR to provide the given yields based on the internal standard (**28**:**35*c***:**35*b***:**57** = 0:78:3:1 %).

Procedure for the Deuterium Exchange Study

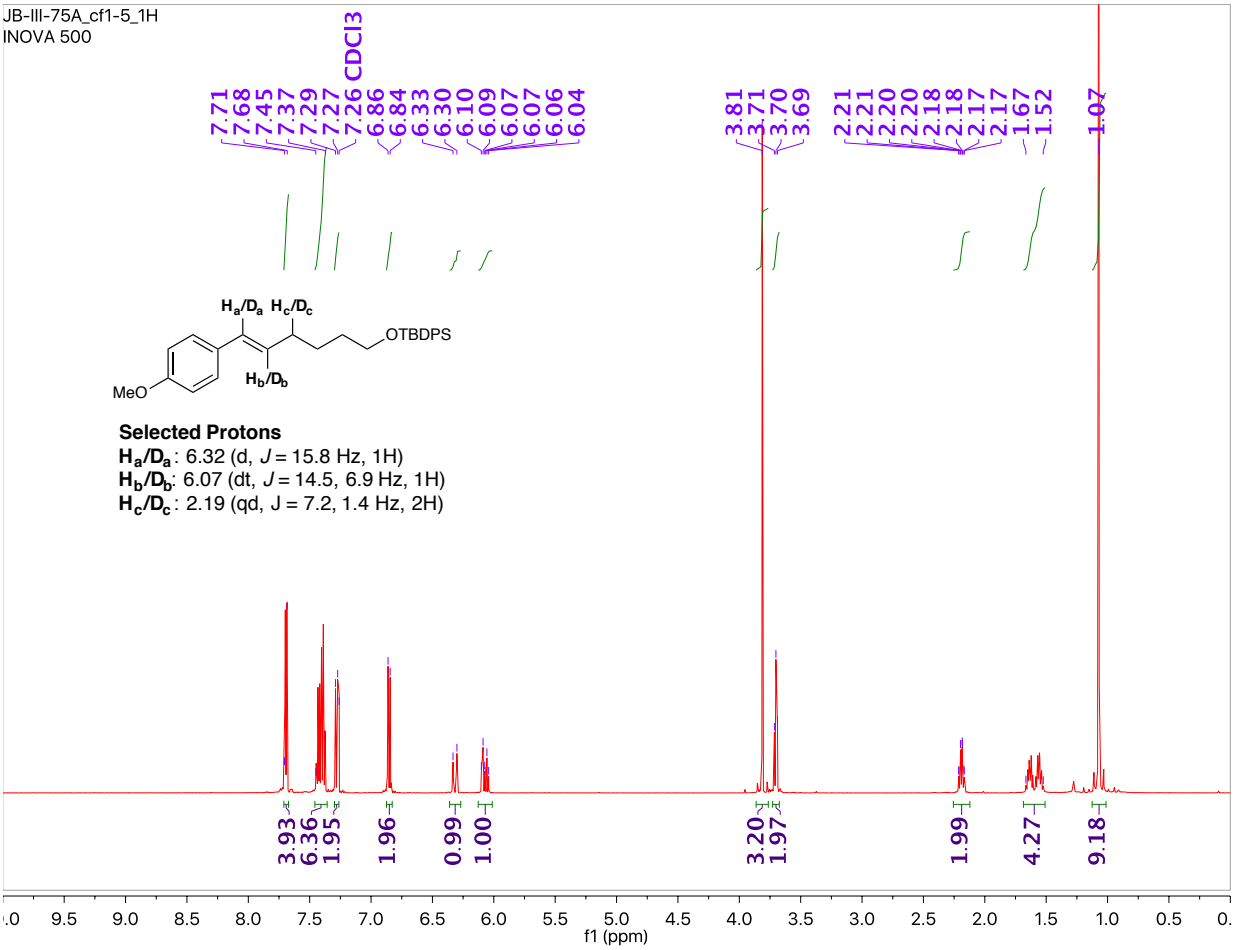


23 | **23-*(d)*** 30% | **41*c*/41*b* - *(d)*** 29%, (5:1)

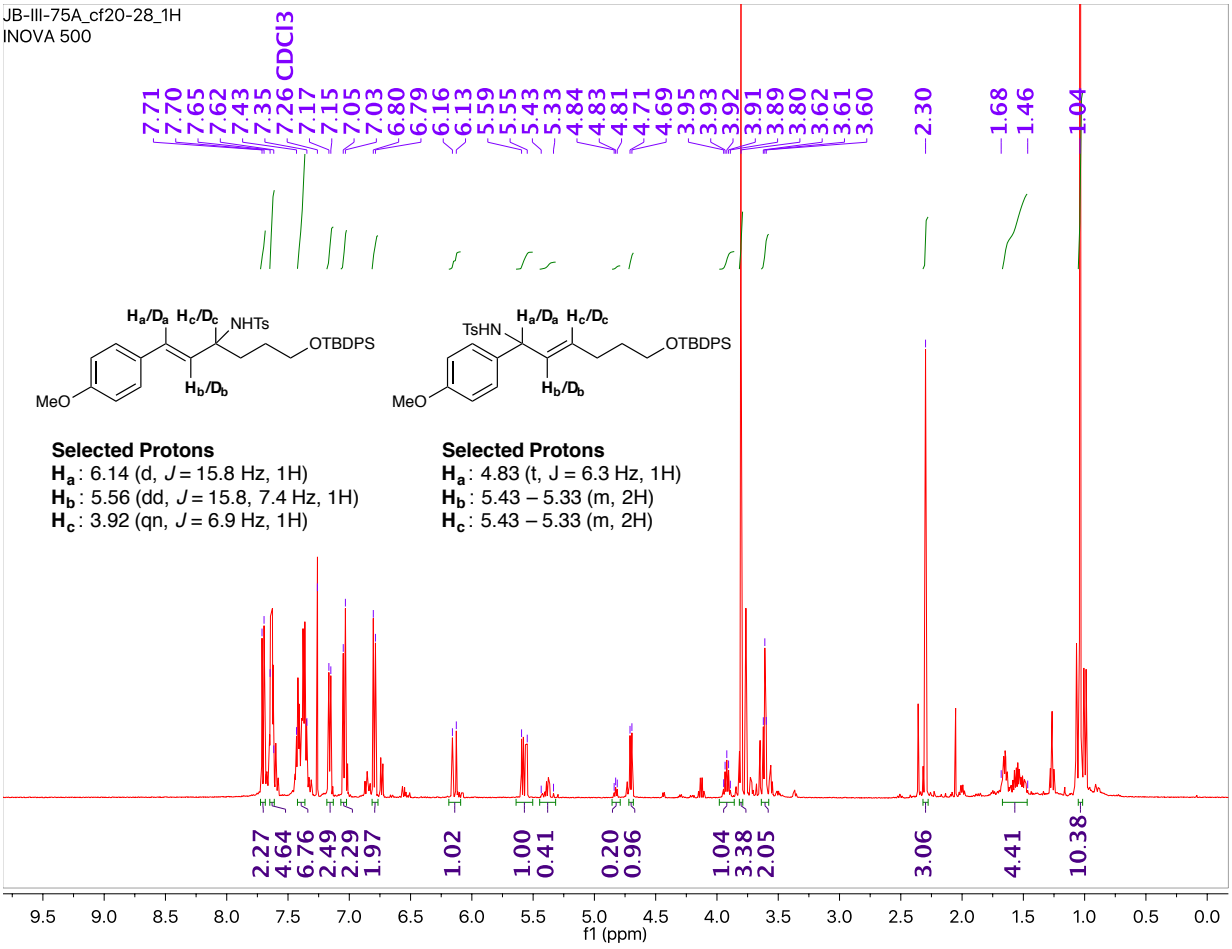
0% D incorporation observed in recovered **22** and product **23**

Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added N-*d_2*-*p*-toluenesulfonamide (110 mg, 0.643 mmol), $[RhCp^*Cl_2]_2$ (3.2 mg, 0.0051 mmol), silver tetrafluoroborate (4.5 mg, 0.023 mmol), and silver acetate (91.5 mg, 0.55 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried 7 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans-ß*-alkyl styrene **23** (278 mg, 0.625 mmol) in dichloromethane (3.1 mL) was prepared. An aliquot of the stock solution (1.3 mL, 120 mg, 0.271 mmol) was transferred to the vial containing the solid reagents. Then D-OAc (0.15 mL, 157 mg, 2.62 mmol) was added to the vial by syringe. The resulting mixture was heated to 40 °C and stirred for 1 hour. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude reaction mixture was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 80:20) to give recovered starting material **23** (35 mg, 29%) and a mixture of amination product regioisomers **41*c***:**41*b*** (4.4:1, 49 mg, 30% yield). Integration of the ^1H NMR spectra of both the isolated starting material and amination product mixture showed no deuterium incorporation into either the allylic position, or at either of the vinylic positions (see spectra below).

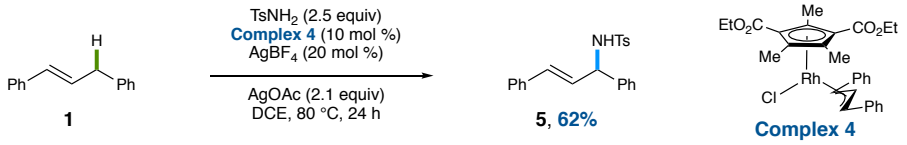
Recovered (*E*)-*tert*-butyl((6-(4-methoxyphenyl)hex-5-en-1-yl)oxy)diphenylsilane (23).



(*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-methoxyphenyl)hex-1-en-3-yl)-4-methylbenzenesulfonamide (41*c*).



Experimental Procedure for RhCp^E Complex (4) as Catalyst for Allylic Amination



Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added *p*-toluenesulfonamide (110 mg, 0.643 mmol), [RhCp*Cl_2]$_2$ (1.6 mg, 0.0026 mmol), silver tetrafluoroborate (10 mg, 0.051 mmol), and silver acetate (90 mg, 0.54 mmol). After all solids were weighed, the reaction vial was fitted with a septum cap and removed from the glovebox. In a separate oven-dried vial fitted with a septum cap, under N_2 atmosphere, a stock solution of *trans*-1,3-diphenylpropene (200 mg, 1.03 mmol) in 1,2-dichloroethane (5.2 mL) was prepared. An aliquot of the stock solution (1.3 mL, 50 mg, 0.26 mmol) was transferred to the vial containing the solid reagents. In a separate oven-dried 15 mL vial fitted with a septum cap, under N_2 atmosphere, a stock solution of Rh-complex **1** (33.6 mg, 0.00559 mmol) in 1,2-dichloroethane (0.5 mL) was prepared. An aliquot of the former stock solution (0.23 mL, 15.4 mg, 0.026 mmol) was transferred to the vial containing the solid reagents. The resulting mixture of all reagents was heated to 80 °C and stirred for 20 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. The crude mixture was then purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (95:5 to 75:25) to provide the title compound as a white solid (59 mg, 62% yield).

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Chapter 3:

Group IX MCp* Benzylic/Branched Selective Amidation:

Revelation of Catalyst-Substrate Matching for Efficient Catalysis

3.1. Introduction and Hypothesis for Benzylic Selective Allylic C-H Amidation

As previously described in this document I have effectively developed conditions utilizing a RhCp* precatalyst for the conjugated selective allylic C-H amination of disubstituted olefins proceeding *via* organometallic π-allyl intermediates. Our research goals for allylic C-H functionalization methods strive to develop complementary catalytic systems that provide access to both regioisomers of allylic amines from the same RhCp*-π-allyl intermediate. To target the opposite (benzylic) regioisomer we must identify nucleophiles or reagents that operate by a different mechanism compared to the Ag-promoted thermal equilibration seen in our conjugated selective amination conditions (Figure 3.1.).

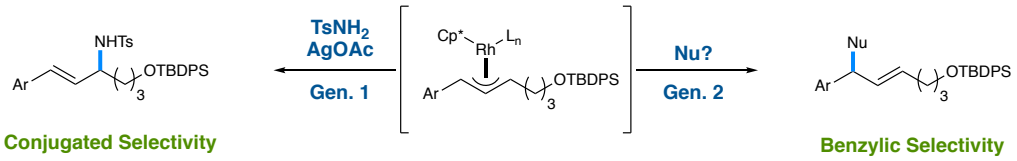


Figure 3.1. New Reaction Design to Access Complementary Regioselectivity.

After a thorough literature search on trends that may bias the RhCp*-π-allyl intermediate to result in high regioselectivities for the benzylic regioisomer, I identified trends from Pd- and Cu-catalyzed allylic substitution methods that would lead to complementary reactivity. These studies report that an inner-sphere reductive elimination of the nucleophile from the π-allyl intermediate plays a key role in generating high regioselectivities for the branched/benzylic product.[1] By translating this lesson from classic allylic substitution literature to our system with

RhCp*-π-allyl intermediates, I became determined to identify reagents or nucleophiles that would induce an inner-sphere reductive elimination to provide a benzylic selective reaction.

We hypothesized that 3-substituted dioxazolones, established as oxidative amidating reagents by Chang and co-workers in directed sp^2 C-H amidation processes,[2-7] would operate through a Rh(III/V) catalytic cycle in our allylic C-H functionalization strategy (Figure 3.2.A.). After the dioxazolone reagent undergoes an oxidative event, releasing CO_2, at the open coordinate Rh(III)Cp*-π-allyl intermediate, a Rh(V)-acyl-nitrenoid species would be generated and be prone to a facile inner-sphere reductive elimination to generate the benzylic amide product (Figure 3.2.B.). In line with our goal for a complementary regioselective allylic C-H functionalization reaction, the likely result would be the target benzylic amide regioisomer. Such an outcome would significantly enhance both the strategic utility and our understanding of RhCp*-catalyzed allylic C-H functionalization methods.

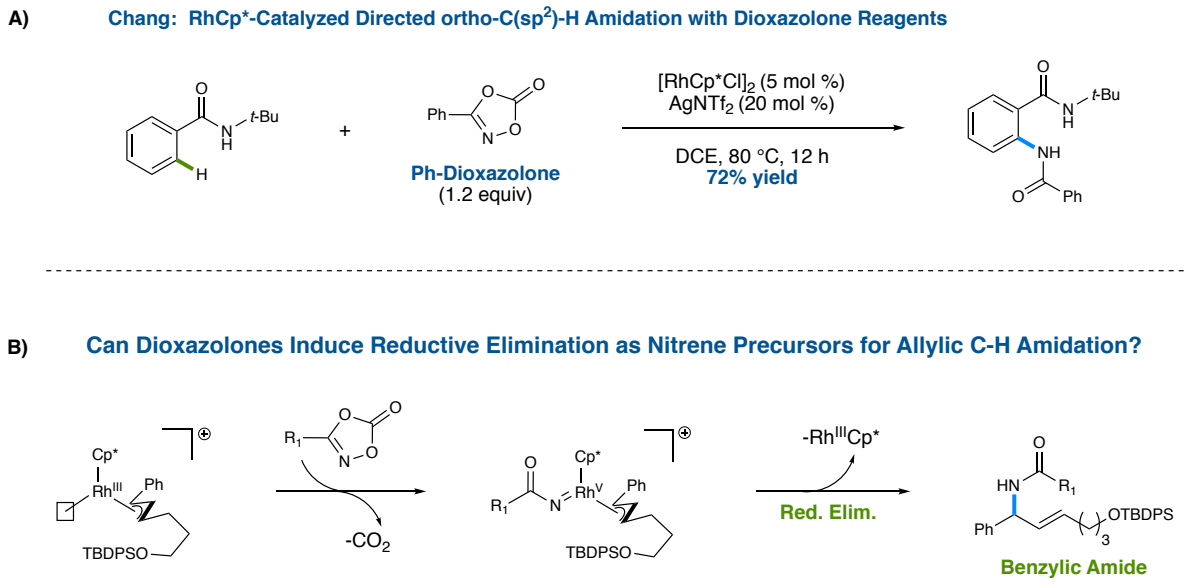


Figure 3.2. Dioxazolone Amidating Reagents Proposed as a Solution for Benzylic Selective Allylic C-H Functionalization Methods.

During the preparation of this work to be disseminated to the community, consistent with our hypothesis for an inner-sphere reductive elimination pathway being key to the discovery of branched/benzylic regioselectivity, Rovis[8] and Glorius[9] also demonstrated that IrCp* complexes promote branch-selective allylic amidation reactions of unactivated terminal olefins. In the following studies, I report that RhCp* and IrCp* complexes exhibit entirely different reactivity profiles with different classes of olefin substrates. While IrCp* complexes are required for more selective reactions of unactivated terminal olefins, RhCp* complexes are significantly more effective for regioselective amidation of trans-disubstituted olefins (Figure 3.3.).

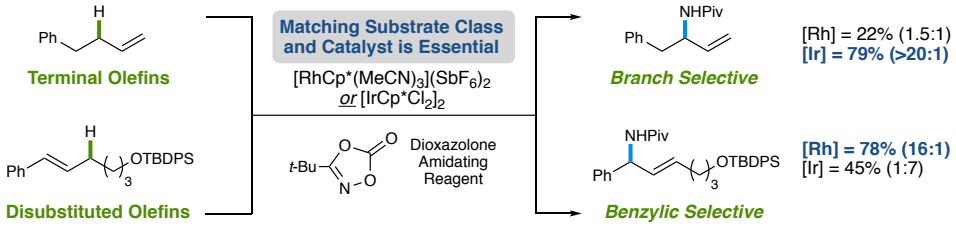


Figure 3.3. Matching Substrate to Catalyst is Essential for High-Performing Allylic Amidation.

3.2. Reaction Discovery of Benzylic Selective Allylic C-H Amidation

It was necessary to prepare the dioxazolone reagent before I could begin the investigation. Literature conditions to access the amidating reagent involve reacting 1,1'-carbonyldiimidazole (CDI) as the carbonyl trap with the free, carboxylic acid derived, hydroxamic acid. Commercially available benzohydroxamic acid **1** was reacted under literature conditions[10] with stoichiometric CDI to produce phenyl-dioxazolone **2** in 57% yield (Figure 3.4.).

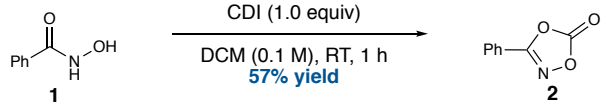


Figure 3.4. Literature Preparation of Phenyl-Dioxazolone.

With the amidating reagent in hand I set out with an initial set of conditions to observe the reactivity for allylic C-H amidation of the disubstituted *trans-ß*-alkylstyrene **3**. $RhCp^*(OAc)_2$ was selected as the precatalyst for this reaction to incorporate both the required RhCp* and carboxylate base. 1.5 Equivalents of phenyl-dioxazolone **2** was serendipitously paired with 20 mol % $AgSbF_6$ as an additive for this first trial, which successfully resulted in 43% yield of intended amidation products **4** and **5** (Figure 3.5.). The allylic C-H amidation reaction is tentatively benzylic selective with respect to the isolated amide products; this assignment is due to the complicated crude mixtures under ^1H NMR analysis making accurate regioselectivity assignments difficult.

Additional reactions with $RhCp^*(OAc)_2$ were avoided due to my theory that the inactive precatalyst would not dissociate to a cationic RhCp* species consistently between trials to afford an open coordination site for the olefin substrate. When switching to $[RhCp^*(MeCN)_3](SbF_6)_2$ as

an alternative precatalyst with 10 mol % CsOAc as the external carboxylate source, consistent 51% yield of the amidation products was observed for this transformation (Figure 3.5.).

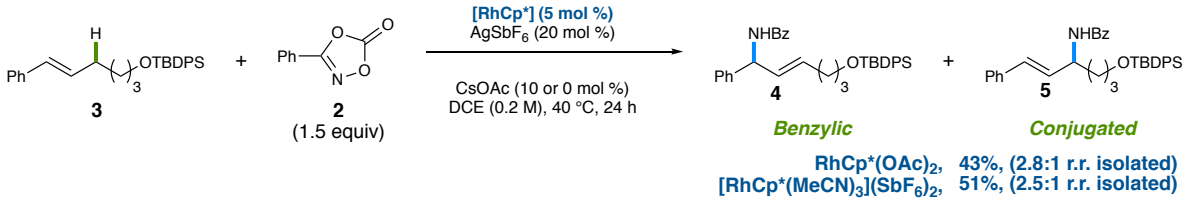


Figure 3.5. Identification of $[RhCp^*(MeCN)_3](SbF_6)_2$ as Ideal Precatalyst.

The initial amidation experiments never fully consumed the styrene **3** which left us to question whether extended reaction time could increase the yield of amidation product. Additionally, since the previous hypothesis for improved reactivity most likely originated from the sequestering of the cationic RhCp* species to inactive $RhCp^*(OAc)_2$, the ratio of RhCp*:CsOAc was decreased to 1:1 to promote higher efficiency. When the reaction of *trans-ß*-alkylstyrene **3** and phenyl-dioxazolone **2** with 5 mol % of $[RhCp^*(MeCN)_3](SbF_6)_2$ and CsOAc was conducted for 48 hours, the starting material was not fully consumed and TLC data had not changed from the 24-hour time point (Figure 3.6.). Nevertheless, slightly higher yield of amide products (58%) was isolated from the reaction mixture, predominately consisting of the benzylic amide regioisomer (5:1).

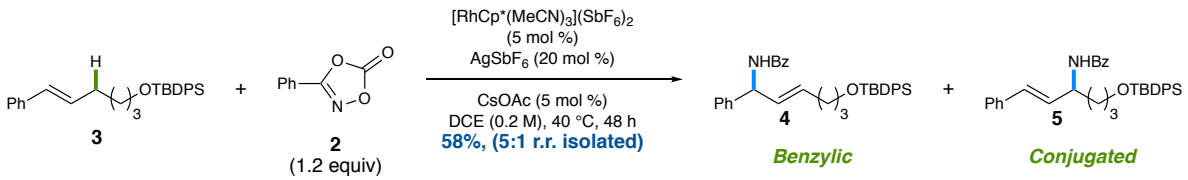


Figure 3.6. Slightly Improved Performance for Extended Time and 1:1 ratio of RhCp*:CsOAc.

Despite the good preliminary results for this novel reactivity, the exact identities of the all amidation products eluded characterization. The complex side-products became a growing issue for accurately exploring the regioselective outcome for the allylic amidation methodology. Our early hypothesis for the complex reaction mixture was that amidation with phenyl-dioxazolone would install a benzamide moiety that would engage cationic RhCp* species in *ortho*-directed sp^2 C-H functionalization reactions. This interaction would then detract from productive turn-overs of catalyst and lead to off-path side-products through unknown routes.

As a possible solution to avoid utilizing a dioxazolone reagent that would install the benzamide group, a simple solution was devised. By switching to *tert*-butyl dioxazolone **6** as the amidating reagent, the possible pivalamide product would be less likely to engage in aforementioned off-path reactions. My hypothesis was proven true when simply using the alkyl-substituted dioxazolone afforded a reaction mixture that allowed for a clear regiochemical assignment of 14:1 in favor of benzylic amide regioisomer **7** in 52% yield (Figure 3.7.). With the ideal dioxazolone that would not engage in deleterious side-reactions, we were ready to further study the necessary conditions for a high yielding and selective transformation for the benzylic amide product.

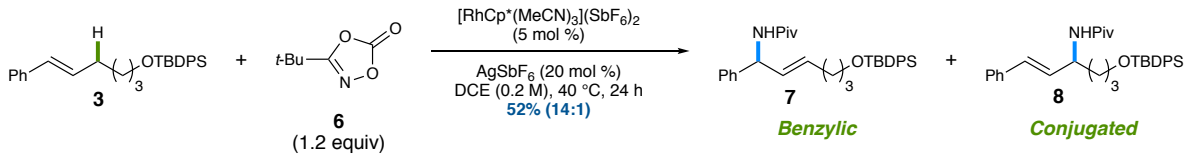
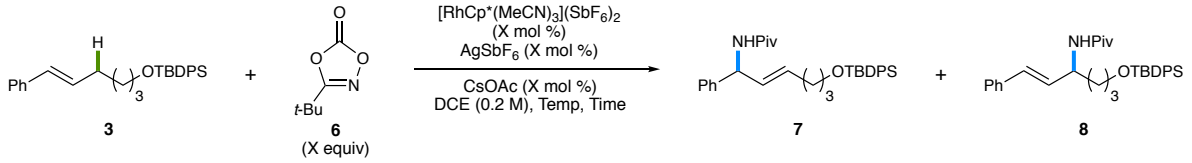


Figure 3.7. *tert*-Butyl Dioxazolone as a Simple Amidating Reagent.

3.3. Optimization and Control Experiments for Benzylic Selective Allylic

With preliminary conditions discovered for the allylic C-H amidation of *trans-ß*-alkylstyrene **3** I was ready to probe conditions for optimal yield of the transformation (Table 3.1). After repeating our initial result using 1.2 equivalents of *tert*-butyl-dioxazolone **6** we found the transformation delivered good yield and regioselectivity of the benzylic amide product when compared with an internal standard (entry 1, 62%, 12:1). To raise the yield of amide product, I determined to increase the ratio of dioxazolone **6** and observed little difference between 2.0 (78%) and 3.0 (76%) equivalents of the amidating reagent (entries 2-3).

Table 3.1. Optimization of Benzylic Selective Allylic C-H Amidation of Disubstituted Olefin **3**.



Entry	**xx** (equiv)	[Rh] (mol %)	$AgSbF_6$ (mol %)	CsOAc (mol %)	Temp (° C)	Time (h)	Yield[a] (%)	r.r[a]
1	1.2	5	20	5	40	24	62	12:1
2	2.0	5	20	5	40	24	78	13:1
3	3.0	5	20	5	40	24	76	12:1
4	2.0	5	20	5	40	48	82	11:1
5	2.0	5	20	5	60	24	68	9:1
6	2.0	5	0	5	40	24	25	7:1
7[b]	2.0	5	0	5	40	24	29	6:1
8[c]	2.0	0	20	5	40	24	0	—
9	2.0	5	20	0	40	24	0	—
10	2.0	5	20	20	40	24	7	N.D
11[d]	**2.0**	**5**	**30**	**5**	**40**	**24**	**84(78)**	**16:1**
12	2.0	5	50	5	40	24	27	14:1

[a] Yields and product ratios (**7:8**) were determined by ^1H NMR using 1,4-dinitrobenzene as an internal standard in the crude reaction mixture. [b] 20 mol % of $NaSbF_6$ was used instead of $AgSbF_6$. [c] ≤5% quantities of conjugated aryl-diene were observed. [d] Isolated yield in parentheses.

Full consumption of the styrene **3** had not been observed through the course of these studies which directed us to study the reaction over 48 hours, the result being an incremental increase in yield and slight loss in regioselectivity (entry 4, 82%, 11:1). We then questioned if the allylic amidation methodology might benefit from higher temperatures like the previously discussed conjugated selective amination method. At 60 °C we observe a decrease in yield of amides **7/8** as well as a noticeable loss of regioselectivity for the transformation (entry 5, 68%, 9:1).

To further understand the effect that $AgSbF_6$ plays we studied the amidation reaction in its absence and found that the additive is necessary for high yield and regioselectivity (entry 6, 25%, 6:1). To determine whether the observed effect was due to SbF_6^-, we swapped the silver salt for the analogous $NaSbF_6$ and the outcome appears as if no additive were present at all (entry 7, 29%, 7:1). These results signify that this behavior is unique to Ag^+ in solution and at this stage, the exact role of the silver salt remains unknown. Ag(I)-salts are known to play unclear non-innocent roles in many Pd-catalyzed C-H functionalization reactions.[11] Although, it is plausible that Ag^+ activates the dioxazolone for oxidative addition to the Rh(III) species and remains coordinated during the C−N bond-forming step, thus impacting both efficiency and regioselectivity of the reaction.

Control experiments without the RhCp* precatalyst and CsOAc confirms their necessity for efficient amidation (entries 8-9). Also, the relative ratio of RhCp*/CsOAc proved to be critical for efficient reactivity whereby oversaturation of CsOAc resulted in little activity for the amidation, most likely due to the excess acetate sequestering the catalyst to inactive $RhCp^*(OAc)_2$ (entry 10). Curiously, when the amount of $AgSbF_6$ was increased to 30 mol % we observe the highest yield and regioselectivity for the benzylic amide **7** (entry 11, 82%, 16:1). Increased amounts of $AgSbF_6$ resulted in an inhibitory effect for the amidation reaction (entry 12, 27%,

14:1), most likely due to allylic acetate generation *via* conjugated amination mechanism. We felt ready to pursue the full scope of the allylic amidation with a 78% isolated yield (entry 11).

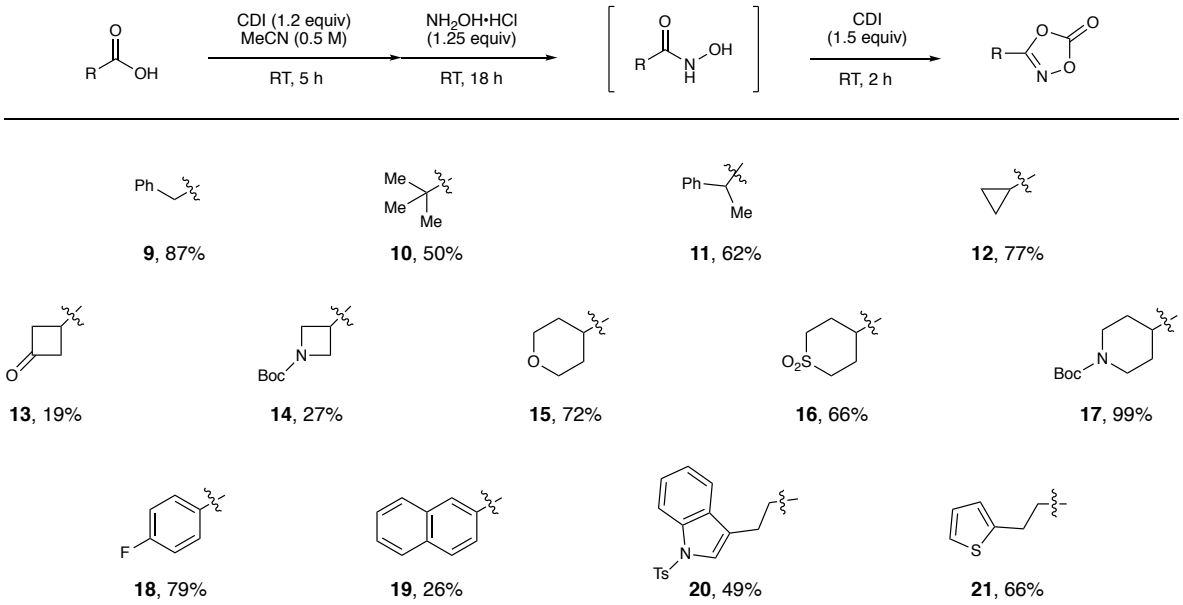
3.4. Synthesis and Access to Novel 3-Substiuted Dioxazolone Amidating Reagents

After establishing effective conditions for the benzylic selective C-H amidation of the *trans-ß*-alkylstyrene substrate, we turned our attention to preparing novel dioxazolone reagents to observe the functional-group compatibility for the new transformation. When looking for the possible methods to easily access dioxazolone reagents, we found that known procedures required 2-3 synthetic steps from available carboxylic acids.[2-7,10] Usually these manipulations entail transforming either the carboxylic acid or ester to the hydroxamic acid, then a separate step using 1,1'-carbonyldiimidazole (CDI) will trap the hydroxamic acid into the dioxazolone. To expedite the synthesis of the amidating reagent for further study in the methodology I sought to develop a one-pot procedure for the direct synthesis of the dioxazolone reagent.

The key to developing the one-pot synthesis was understanding the different solubilities between the carboxylic acid, CDI, hydroxamic acid, and dioxazolone. Many carboxylic acids are insoluble in dichloromethane, which is routinely used for the second step to synthesize the dioxazolone by trapping the hydroxamic acid with CDI. After screening different solvents, I identified acetonitrile as an effective polar solvent to easily allow the formation of each reactive intermediate *en route* to the dioxazolone. Also, the method utilizes multiple equivalents of CDI instead of other N-acylating reagents that would complicate the reaction mixture. The one-pot

synthesis is very appealing due to a simple filtration through a pad of silica-gel to afford pure product in most cases.

Table 3.2. One-Pot Direct Synthesis of Dioxazolone Reagents from Carboxylic Acids.



The reported yields are of isolated dioxazolone.

All reported compounds made through this method were single trials with the one-pot procedure and further attempts to optimize yields were determined unnecessary with adequate material in-hand (Table 3.2). Using the unoptimized one-pot synthesis was effective in transforming simple alkyl carboxylic acids directly to the dioxazolone in good to excellent yields (**9** – **12**, 50 – 87%). Preparation of a variety of dioxazolones with heteroatom moieties was also performed efficiently and yields varied depending on time spent on silica gel during filtration (**13** – **17**, 19 –99%). Nevertheless, aryl-substituted dioxazolones could be prepared with the one-pot procedure as well (**18** – **19**, 26 – 79%). Also, carboxylic acids with tethered heteroaromatic moieties could also be handled effectively with this procedure (**20** – **21**, 49 – 66%).

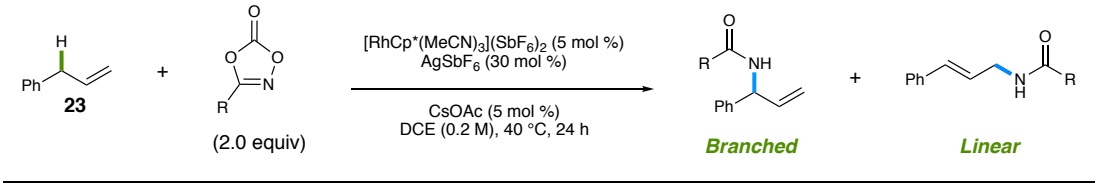
3.5. Dioxazolone Substituent Effects for the Allylic C-H Amidation of Allylbenzene

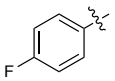
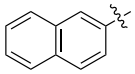
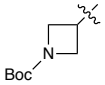
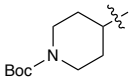
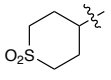
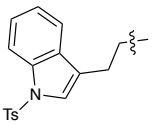
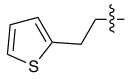
With the easy access to dioxazolone reagents we were ready to explore the substituent effects and functional-group compatibility for high branched selectivity for a range of alkyl-, aryl-, and heterocyclic-substituents using allylbenzene **23** as a simple model olefin (Table 3.3). Methyl dioxazolone exhibited excellent yield of the acetamide amidation product, but the low branched regioselectivity observed might be attributed to smaller steric-bulk (**24**, 95%, 3:1). When benzyl dioxazolone **9** was utilized with presumably larger steric bulk, to our surprise the regioselectivity remained the same while maintaining good yield (**25**, 76%, 3:1); this effect is most likely attributed to the steric bulk or higher substitution centered at α-carbon of the amidating reagent. Similarly, when cyclopropyl dioxazolone **12** with small steric bulk was tested under the Rh-catalyzed conditions, we again observe good yield of amidation products with low regioselectivity (**26**, 75%, 2:1). When switching to *tert*-butyl dioxazolone **6** we see an increase in regioselectivity for the branched regioisomer and good yield of amidation products (**27**, 69%, 8:1), further suggesting that greater α-substitution has a correlation to improved branched selectivity with the amidation methodology. A dioxazolone bearing an α-stereocenter **11** was studied and afforded the corresponding amide in good yield and regioselectivity, but only limited diastereoselectivity was observed for this dioxazolone (**28**, 68%, 7:1, 1.5:1 d.r.).

We were curious to see how aryl-substituted dioxazolones effect the branched selective allylic C-H amidation due to their prevalence in directed *ortho*-C(sp^2)-H functionalization. When switching to the easily prepared phenyl dioxazolone **2** we observed the highest regioselectivity for

the branched amide product however, the yield was low (**29**, 36%, 16:1). Similarly, when aryl-substituted dioxazolones such as 4-fluoro **18** or 2-naphthyl **19** were subjected to the Rh-catalyzed amidation conditions we saw consistent results with low yield (20 – 30%) and high branched selectivity (12:1 – 14:1) of the corresponding amide products **30-31**. One explanation for the disparity in yield can be attributed to the resultant aryl-substituted amide products engaging in iterative directed C(sp^2)-H amidations and prevent further allylic amidations.[7]

Table 3.3. Dioxazolone Substituent Effects for Amidation of Allylbenzene.



				
24, 95% (3:1)	**25**, 76% (3:1)	**26**, 75% (2:1)	**27**, 69% (8:1)	**28**, 68% (7:1), 1.5:1 d.r.
				
29, 36% (16:1)	**30**, 20% (14:1)	**31**, 30% (12:1)	**32**, 89% (5:1)	**33**, 78% (7:1)
				
34, 79% (10:1)	**35**, 86% (9:1)	**36**, 98% (14:1)	**37**, 89% (7:1)	**38**, 43% (5:1)

Yields are of isolated amide products and the regiomeric ratio (**Branched**:**Linear**) is based upon analysis of the crude ^{1}H NMR spectrum of the crude reaction mixtures.

Despite the less than ideal reactivity presented by aryl-substituted dioxazolones we moved forward to understand the effects that heteroatoms play in the branched selective allylic C-H amidation. The ketone moiety of cyclobutanone **13** was tolerated excellently, the amide products

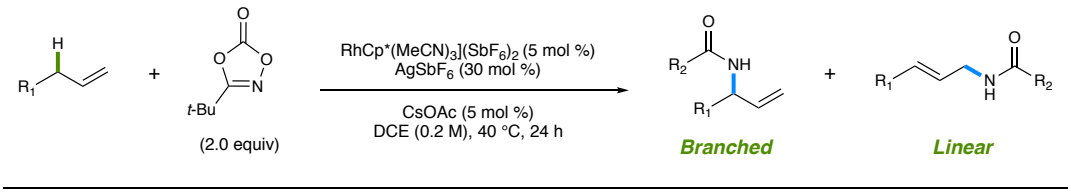
were isolated in high yield and good regioselectivity (**32**, 89%, 5:1). Cyclic Boc-protected amines such as azetidine **33** and piperidine **34** were generated effectively in high yields and regioselectivities (78%, 7:1 and 79%, 10:1 respectively). 4-Pyran-susbtituted dioxazolone **15** also demonstrated no inhibitory effect on reactivity and **35*b*** and **35*l*** were isolated in high yield and good regioselectivity (86%, 9:1). Interestingly, the polar cyclic sulfone effected a near quantitative transformation to the branched amide product in excellent regioselectivity (**36**, 98%, 14:1). Also, dioxazolones with oxidatively-sensitive functionality such as tethered 3-(N-tosyl)-indole **20** and 2-thiophene **21** were tolerated effectively under the reaction conditions in good yields and moderate regioselectivities (**37**, 89%, 7:1 and **38**, 43%, 5:1).

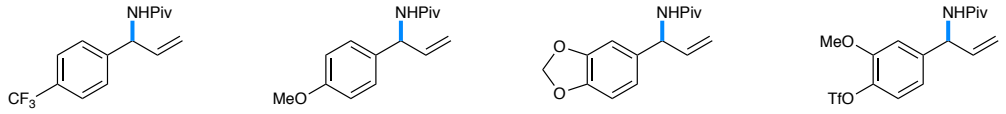
Curiously to fully evaluate the trends seen for dioxazolone substitution two factors stand out leading to higher regioselectivities for branched amides. First being that dioxazolones with larger α-substituents or α-branching lead to higher regioselectivity for branched amides. Secondly, substituents that are inductively withdrawing provide higher selectivities and yields of amidation products under the Rh-catalyzed conditions. An additional observation that contributes to lower branched selectivity is the formation of ene-amide side-products most likely arising from the branched amide product undergoing olefin isomerization over time under the reaction conditions.

3.6. Studies for Efficient MCp*-Catalyzed Allylic C-H Amidation of Terminal Olefins

3.6.1. RhCp*-Catalyzed Allylic Amidation of Allylbenzene Derivatives

Table 3.4. Electronic Effects for the Allylic C-H Amidation of Allylbenzene Derivatives.





39	**40**	**41**	**42**
42%, (10:1)	73%, (>20:1)	63%, (>20:1)	48%, (12:1)

Yields are of isolated amide products and the regiomeric ratio of amide products (**Branched**:**Linear**) is based upon analysis of the crude ^{1}H NMR spectrum of the crude reaction mixtures.

To expand the scope of the allylic amidation methodology we turned our attention to other allylbenzene derivatives after the success of functionalizing allylbenzene with a variety of dioxazolone reagents. These substrates were ideal to probe the electronic effects that would directly compare the π-allyl intermediates for high yield and regioselectivity (Table 3.4). The electron-deficient 4-CF_3-substituted allylbenzene was amidated with *tert*-butyl dioxazolone **6** in modest yield with good selectivity for the branched product (**39**, 42%, 10:1). When electron-rich 4-OMe-allylbenzene was subjected to the reaction conditions we observed good yield and exclusive formation of the branched amide product (**40**, 73%, >20:1). The Rh-catalyzed amidation method could be extended to the electron-rich safrole and afford good yield of the branched

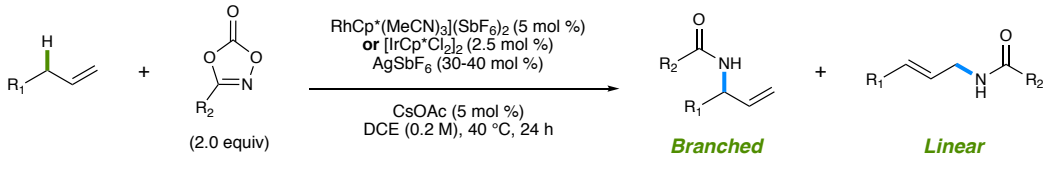
product (**41**, 63%, >20:1). Allylic amidation of the eugenol-derivative proceeded smoothly with high regioselectivity and retention of the aryl-triflate moiety (**42**, 48%, 12:1) demonstrating compatibility with functional groups that might engage in competitive oxidative addition reactions during conventional allylic substitution reactions. It is clear from the given data that substrates that push electron-density towards the π-allyl intermediate generally lead to high yield and selectivity for the branched amide product.

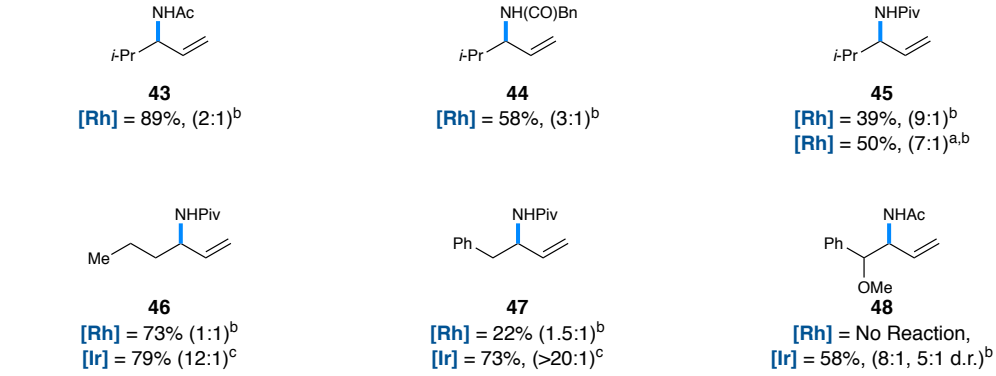
3.6.2. Studies to Determine IrCp* is Optimal for Terminal Olefins

After observing the electronic effects for allylbenzene derivatives we were interested in seeing the efficacy for unactivated terminal olefins as successful amidation substrates. We identified 4-methylpentene as an ideal starting point to probe this effect and observed less than ideal reactivity with a range of alkyl dioxazolones (Table 3.5.). While methyl-dioxazolone could afford high yield of amidation product the regioselectivity for the branched isomer was low (**43**, 89%, 2:1). When moving to the slightly larger benzyl-dioxazolone we isolated modest yield of the amide products but saw little improvement to the regioselectivity (**44**, 58%, 3:1). We relied on the trends observed for dioxazolone substitution and saw that the reaction of *tert*-butyl-dioxazolone with 4-methylpentene resulted in modest yield with but higher regioselectivity was observed for the branched amide product (**45**, 39%, 9:1). We aimed to increase the yield of the transformation with *tert*-butyl-dioxazolone and chose to increase the temperature slightly to 60 °C, this change afforded a slight increase in yield for amides **45** but regioselectivity was lowered as well (50%, 7:1).

After applying the Rh-catalyzed conditions with *tert*-butyl-dioxazolone to 1-hexene good yield of amidation products were observed but no selectivity was shown for this substrate (**46**, [Rh]; 73%, 1:1). When moving to 4-phenylbutene, a worse result was obtained with low yield and essentially no differentiation for the branched or linear product (**47**, [Rh]; 22%, 1.5:1). Additionally, an olefin with a homo-allylic stereocenter exhibited no reactivity under the rhodium catalysis. While RhCp* was effective under the optimized reaction scheme for disubstituted olefins as well as initially exploring the methodology with allybenzene derivatives, it was clear that the catalyst was not optimal for unactivated terminal olefins.

Table 3.5. Allylic C-H Amidation of Unactivated Terminal Olefins is Selective with IrCp*.





Yields are of isolated amide products and the regiomeric ratio of amide products (**Branched**:**Linear**) is based upon analysis of the crude ^{1}H NMR spectrum of the crude reaction mixtures. [Rh] = $RhCp^*(MeCN)_3](SbF_6)_2$. [Ir] = $[IrCp^*Cl_2]_2$. [a] 60 °C. [b] 30 mol % $AgSbF_6$. [c] 40 mol % $AgSbF_6$.

To revive reactivity for unactivated terminal olefins, working with Caitlin Farr we proposed $[IrCp^*Cl_2]_2$ as a solution to improve regioselectivity for amidation; Ir-C bonds of π-allyl complexes are generally shorter due to greater back-bonding character with the π-system and

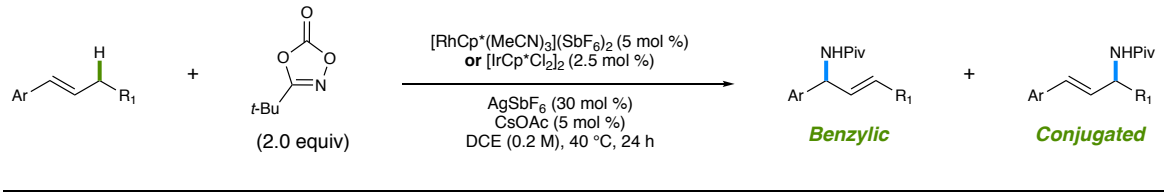
should bias reductive elimination towards the branched regioisomer. The IrCp* catalyst showed remarkable improvement under similar reaction conditions with the previously problematic substrates. With only a minor increase in yield, amidation of 1-hexene was successfully performed with high regioselectivity for the branched amide product (**46**, [Ir]; 79%, 12:1). Likewise, when 4-phenylbutene was subjected to the Ir-catalyzed conditions the amide product was observed in good yield and near perfect regioselectivity (**47**, [Ir]; 73%, 20:1). Pleasingly, the IrCp* catalyst was able to turn on reactivity for the previously inactive olefin with a homo-allylic stereocenter in moderate yield with modest diastereoselectivity (**48**, [Ir]; 58%, 8:1, 5:1 d.r.). From these results, as well as concurrent studies by Rovis[8] and Glorius,[9] it is apparent that for the substrate class of terminal olefins IrCp* precatalysts appear to be the most effective for a high yield and branch selective allylic C-H amidation.

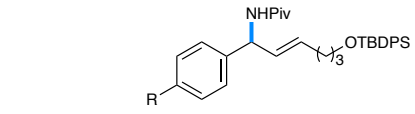
3.7. Catalyst Studies for Benzylic Selective Amidation of Disubstituted Olefins

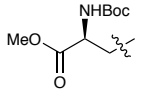
To complete our initial investigation of this novel allylic amidation reaction, we addressed the generality of benzylic selective amidation of *trans-β*-alkylstyrene substrates (Table 3.6). Although our initial reaction optimization had identified $[RhCp^*(MeCN)_3](SbF_6)_2$ as an excellent precatalyst for these compounds, the improved performance of $[IrCp^*Cl_2]_2$ in the amidation of unactivated terminal olefins caused us to evaluate both metals for this transformation. With our optimized result for phenyl-substituted olefin **3** under the Rh-catalyzed conditions being 78% isolated yield with 16:1 regioselectivity for the benzylic amide product **7**, we were shocked to see

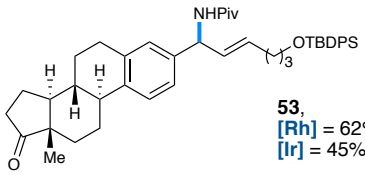
that using the IrCp* precatalyst demonstrated a shift in regioselectivity, becoming more selective for the conjugated amide in lower yield (**7**/**8**, [Ir] = 45%, 1:7).

Table 3.6. Comparison of RhCp* vs. IrCp* Precatalysts for the Allylic C-H Amidation of Disubstituted Olefins.

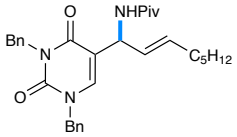




	[Rh]	[Ir]
7/8, R = H	78%, (16:1)	45%, (1:7)
49, R = OMe	86%, (>20:1)	39%, (7:1)
50, R = NHBoc	62%, (>20:1)	6%, (1.5:1)
51, R = CF_3	19%, (9:1)	28% (1:19)
52, R = 	71% (16:1)	48%, (1:5)



53,
[Rh] = 62%, (>20:1)
[Ir] = 45%, (1:2)



54,
[Rh] = No Reaction,
[Ir] = 41%, (1.2:1)

Yields are of isolated amide products and the regiomeric ratio of amide products (***Benzylic***:***Conjugated***) is based upon analysis of the crude ^{1}H NMR spectrum of the crude reaction mixtures.

This behavior for increased conjugated regioselectivity was consistent with all disubstituted olefins examined under the Ir-catalyzed conditions, but the trends were inconsistent. [RhCp*(MeCN)$_3$](SbF$_6$)$_2$ remained the most efficient catalyst for high regioselectivity for the benzylic amide product. In the case of electron-rich 4-OMe-substituted styrene the Rh-catalyzed conditions delivered exclusively the benzylic amide regioisomer **49** in high yield ([Rh], 86%, >20:1), the IrCp* precatalyst resulted in predominately the benzylic amide but the yield and regioselectivity was lower in this case ([Ir], 39%, 7:1). The electron-deficient 4-CF_3-substituted styrene was amidated in low yield and was selective for the benzylic amide **51** with the RhCp*

precatalyst (**51**, [Rh]; 19%, 9:1) however, this substrate under the Ir-catalyzed conditions completely inverted the regioselectivity to the conjugated regioisomer (**51**, [Ir]; 28%, 1:19).

More complex substrates were also amenable to the allylic C-H amidation methodology. A protected tyrosine amino-acid derivative was amidated with high efficiency for the benzylic amide **52** with $[RhCp^*(MeCN)_3](SbF_6)_2$, but when the same substrate was subjected to the Ir-catalyzed conditions we see a similar skewing of amide products favoring conjugated regioselectivity (**52**, [Rh] = 71%, 16:1; [Ir] = 48%, 1:5). Also, estrone derived styrene exclusively formed the benzylic amide product under Rh catalysis in good yield (**53**, [Rh]; 62%, >20:1) but, only modest yield of the estrone amidation products were observed with minimal regioselectivity for the conjugated product using $[IrCp^*Cl_2]_2$ (**53**, [Ir]; 45%, 1:2). We note that functional group compatibility differences also emerged during this study. In the case of a Boc-protected aniline styrene, the RhCp* complex is an effective catalyst (**50**, [Rh]; 62%, > 20:1); however, the substrate proved to be unstable under the IrCp* reaction conditions, and only a 6% yield was observed. In contrast, the uracil derivative was incompatible under the Rh-catalyzed amidation conditions, but the IrCp* catalyst was able to promote formation of amide products (**54**, [Ir], 41%, 1.2:1).

After the initial interrogation of group IX MCp* catalysts for the allylic C-H amidation of disubstituted *trans-ß*-alkylstyrene derivatives the data is evident that RhCp* far outshines IrCp* as a catalyst for the benzylic selective transformation. At this time, it is unclear what the key differences between the MCp* catalysts play in differentiating the reactivity profiles of disubstituted olefins and further study of the proposed π-allyl intermediates guided by experimental and computational analysis will be necessary to fully elucidate these effects.

3.8. Studies for the Allylic Amidation of a Model Trisubstituted Olefin

To further extend the allylic amidation methodology and aim toward our overarching research goal of developing reactions that are capable of functionalizing any substituted olefin we turned our attention to trisubstituted olefin **55**. The divergent reactivity seen in the amidation of terminal and disubstituted olefins was also seen for this trisubstituted olefin. The RhCp* complex proved to be ineffective independent of the dioxazolone used or other modifications to the reaction conditions. $[IrCp^*Cl_2]_2$ on the other hand promoted highly regioselective reactions to generate the branched amide product in >20:1 regioselectivity (Figure 3.8).

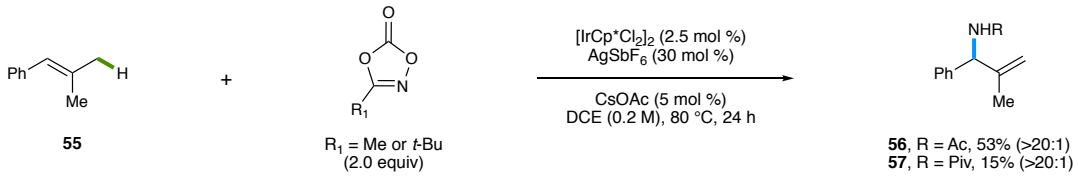


Figure 3.8. IrCp* is Effective for the Allylic Amidation of a Trisubstituted Olefin.

At low temperature (40 °C) the reaction did not produce and observable products, only when the reaction was run at 80 °C was the amidation method able to generate product. Consistent with previous observations, methyl-dioxazolone afforded greater yields of amide product (**56**, 53%) compared to the sterically demanding *tert*-butyl-dioxazolone (**57**, 15%). The regioselectivity observed in these reactions mirrors the branched selectivity observed in terminal olefins, reflecting the similarities in the structures of the intermediate π-allyl complexes. These results represent a significant first step in addressing the reactivity challenge of trisubstituted olefins for a branch selective transformation.

3.9. Stoichiometric Studies and Preparation of M(III)Cp*-π-Allyl Complexes

3.9.1. Synthesis and Characterization for the RhCp*- and IrCp*-π-Allyl Complexes

In an attempt to understand the regioselectivity differences observed for the RhCp* and IrCp* catalyzed reactions of disubstituted olefins, we prepared the corresponding discrete π-allyl complexes **58** and **59** from their respective MCp*trisacetonitrile monomers via allylic C-H activation and subsequent isomerization of 4-phenylbutene (Figure 3.9). The π-allyl complexation procedure for the isomerization was adapted from Tanaka's work by Dr. Robert Harris in our lab. He found that reactions at 40 °C would afford a mixture of terminal and internal RhCp*-π-allyl complexes but, heating the constituents to 80 °C effectively isomerized the mixture completely to the thermodynamic internal disubstituted complex. Isolation of these analogous π-allyl complexes was only possible after the workup procedure to introduce the stabilizing chloride ion. In my hands, the reaction was applied effectively to isolate RhCp* complex **58** in 61% yield and the IrCp* complex **59** in 40% yield.

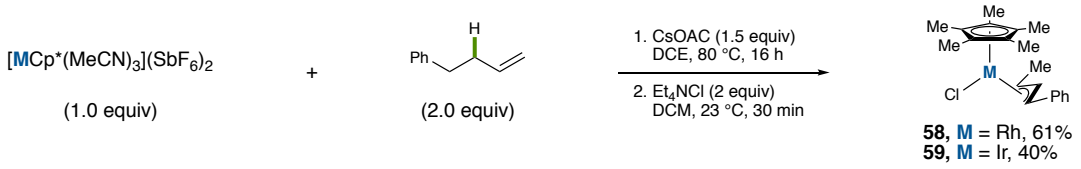


Figure 3.9. Synthesis of RhCp*- and IrCp*-π-Allyl Complexes *via* Allylic C-H Activation.

The unambiguous structures of each complex were obtained by X-ray crystallography in collaboration with Dr. John Bacsa. Comparison of the two structures shows that they are isomorphous and isostructural, although each of the M-C bond distances is slightly longer in the

RhCp* complex **58** than they are in the analogous IrCp* complex **59** (Figure 3.10.); Ir-C bonds are known to be shorter than their analogous Rh-C bonds in similar systems due to lanthanide contraction.[13] In both cases the M-C bond adjacent to the phenyl group (M-C11; Rh = 2.2235(7) Å, Ir = 2.2095(17) Å) is slightly elongated compared to the M-C bond adjacent to the methyl substituent on the π-allyl component (M-C13; Rh = 2.2008 (7)Å, Ir = 2.1813(17) Å). Although each of the M-C bond distances is slightly longer in the RhCp*-π-allyl complex **58** than they are in the analogous IrCp*-π-allyl complex **59**, there are no structural features that would explain the significant differences in regioselectivities that are observed in the catalytic reaction conditions.

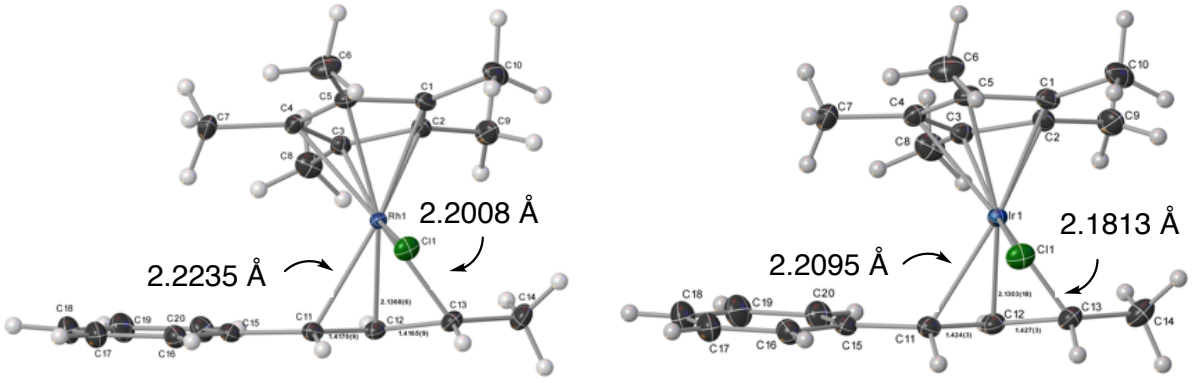


Figure 3.10. X-Ray Crystal Structure of RhCp*(Left, **58**) and IrCp*(Right, **59**) Complexes. Key bond lengths for Rh complex 39: M−C11 = 2.2235(7) Å, M−C13 = 2.2008(7) Å, and for Ir complex 40: M−C11 = 2.2095(17) Å, M−C13 = 2.1813(17) Å.

3.9.2. Stoichiometric Amidation Reactions of MCp*-π-Allyl Complexes

When each of these complexes was subjected to *tert*-butyl-dioxazolone in the presence of $AgSbF_6$ as a halide scavenger, the corresponding amides were obtained in good yields and regioselectivities that reflected the catalytic reactions (Figure 3.11). The reaction of RhCp* complex **58** resulted in 64% yield of amide products with a regioselectivity of 11:1 for the benzylic regioisomer while IrCp* complex **59** gave 66% yield of amides **60** and **61** with a 1:2.3 preference for the conjugated isomer.

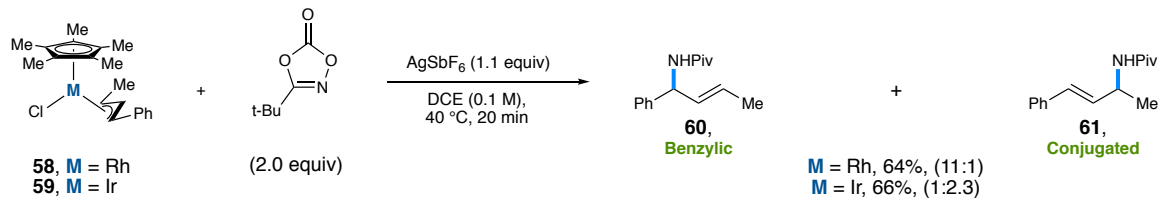


Figure 3.11. Reaction of RhCp*- and IrCp*-π-Allyl Complexes Mirror Catalytic Activity.

Despite the lack of information gained from the crystal structures of the MCp*-π-allyl complexes, we are optimistic looking forward. The provided mechanistic evaluation from these stoichiometric experiments, and work by Rovis and Glorius, are highly suggestive of an inner-sphere reductive elimination pathway from a key π-allyl intermediate, most likely *via* a M(III)Cp*/ M(V)Cp* redox cycle. Detailed computational and experimental studies are ongoing in our laboratory to elucidate the origins of the complimentary reactivity observed in this study.

3.10. Diastereoselective Allylic C-H Amidation for the Synthesis of 1,2-Amino Alcohols

3.10.1. 1,2-Amino Alcohols in Synthesis and Methods Development

With the preliminary allylic C-H amidation methodology reported to provide access to high regioselectivity for branched/benzylic amide products we determined to apply the method to access useful synthetic moieties. Our studies identified 1,2-aminoalcohols as a promising target to expand the technique as they are important synthetic intermediates for the complex synthesis of active pharmaceuticals. Not only are 1,2-amino alcohols present in natural products and active pharmaceuticals,[14-19] but the moiety is key to ligand development for streamlining enantioselective transformations (Figure 3.12).[20-23]

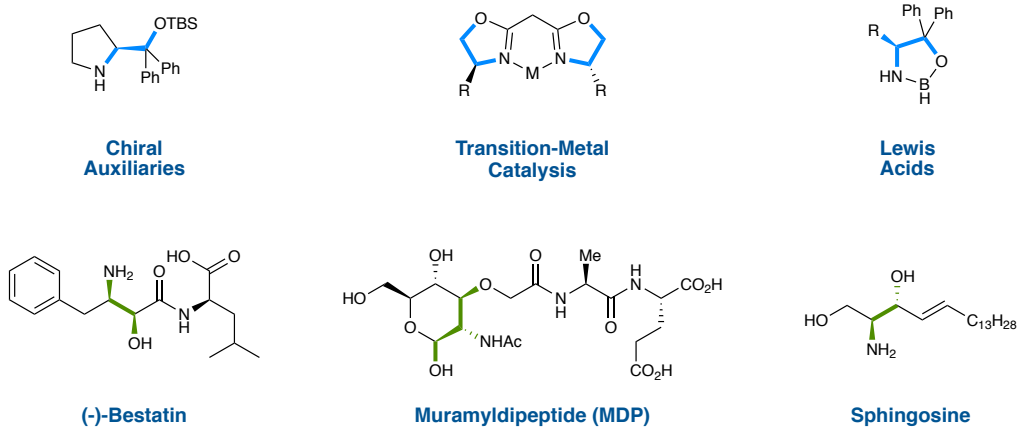


Figure 3.12. 1,2-Amino Alcohols are Present in Bioactive Molecules and Necessary for Enantioselective Transformations.

3.10.2. Plans for Synthesis and Determination Stereochemistry for 1,2-Amino Alcohols

From our preliminary investigation for the diastereoselective amidation of a homo-allylic ether **62** we can propose a clear disconnection to readily prepare high-value 1,2-amino alcohols (Figure 3.13.). Accessing a wide variety of homo-allylic ethers is a trivial matter with allylation reactions of commercially available aldehydes followed by capping the oxygen with a choice protecting group which would allow high flexibility for synthetic approaches to 1,2-amino alcohol scaffolds.[24-27] More so, development of diastereoselective amidation conditions can be paired with the enantioselective allylation of aldehydes[29-31] to prepare terminal olefins that access a single diastereomer from the subsequent transformation.

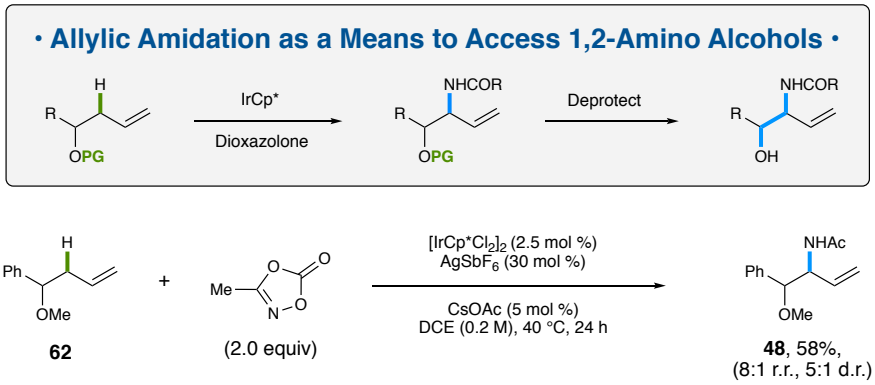
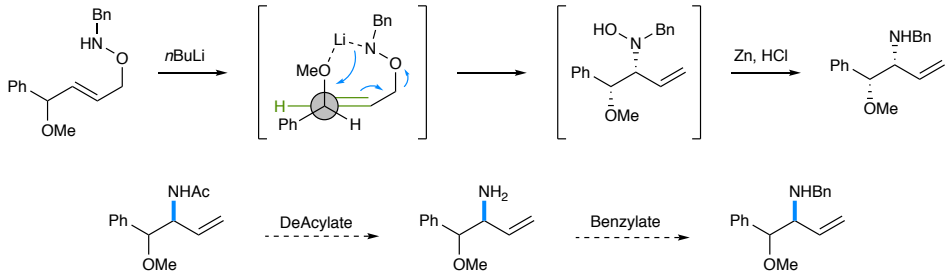


Figure 3.13. Allylic C-H Amidation of Protected Homo-Allylic Ethers for 1,2-Amino Alcohols.

At this point it became necessary to determine the relative *syn*- or *anti*- stereochemistry for the diastereoselective amidation. There are many ways to determine the relative stereochemical assignment, do we try to selectively crystallize the major diastereomer and confirm by X-ray analysis, or transform the amide product into a known molecule with absolute stereochemical assignments?

The simple functionalized ether compound **48*b*** that we had access to at the outset of this endeavor maps on very closely to the syn-relationship of the benzyl-protected allylic amine (Scheme 3.1.). Accessing the *syn*-aminoether in the original report was done through an intramolecular [2,3] sigmatropic rearrangement of N-benzyl-O-allylic hydroxylamine and subsequent reduction to the afford a single diastereomer. The absolute configuration of the rearrangement was confirmed *via* X-ray analysis of the HCl salt of the product. Our strategy to access the same product for comparison is simple, beginning with our allylic amidation product we can deacylate the acetamide moiety to the free amine and then an N-benzylation reaction would deliver comparable material.

Scheme 3.1. Confirm Relative Stereochemistry by Accessing Known Benzyl Amine.



Derivatization of 1,2-Amino Ether can Prepare Known Benzyl Amine

3.10.3. Derivatization Studies of Amidation Product to Access *syn*-Benzyl Amine

With the report of IrCp*-catalyzed allylic C-H amidation from Rovis, it became apparent that the preliminary conditions we utilized were likely not ideal for pursuing further reactivity with the 1,2-aminoether substrate class. Their report noted very similar conditions to my studies but, the major difference being 15 mol % $AgNTf_2$ and 20 mol % LiOAc instead of our 30 mol % $AgSbF_6$ and 5 mol % CsOAc. Their results indicated a slight elevation in yield utilizing the

triflimide salt with higher regioselectivities for similar substrates.[8] When using their conditions for the allylic amidation of 1,2-aminoether **62** the results showed slightly improved yield, greatly improved regioselectivity, with the same level of diastereoselectivity (Figure 3.14., **48** 62%, >20:1, 5:1 d.r.). This suggests that improvements to yield and regioselectivity can be further optimized in additional related studies and these conditions were adopted to access allylic amide products from the diastereoselective transformation.

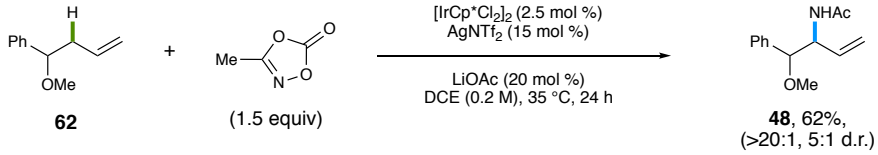


Figure 3.14. Rovis Amidation Conditions Show Improved Yield and Regioselectivity.

To deacylated the amidation product, I first attempted to utilize acid-catalyzed conditions prevalent in the literature and subjected 1,2-amidoether to reflux in concentrated HCl (Figure 3.15.). The evidence supported full consumption of the starting material but the simple deacylation was not achieved from this material with the major product being unidentifiable diastereomeric products, as well as loss of the olefin moiety and d.r. from 5:1 to 1.7:1. The erosion of the d.r. can most likely be attributed to the benzylic methoxy-ether under forcing acid-catalyzed conditions which would promote the loss of methanol and under S_n1 or S_n2 pathways.

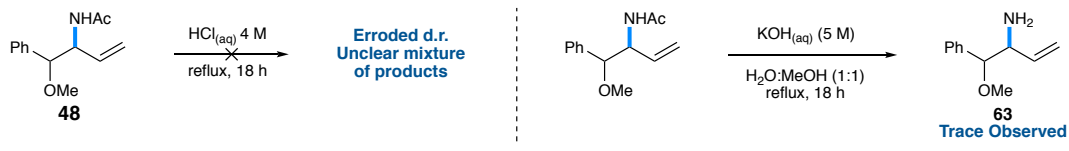
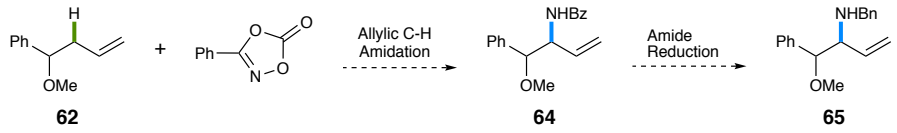


Figure 3.15. Acid- and Base-Catalyzed Deacylation of Amide Product.

Further experimentation under forcing acid-catalyzed conditions were inadvisable at this time so we turned toward base-promoted deacylation procedures. MacMillan and Fu demonstrated in a previous report an effective deacylation for the synthesis of a chiral BOX ligand with a basic KOH_{aq}/MeOH mixture at reflux.[32] Applying the same reaction conditions to the mixture of amidation diastereomers for 24 hours at 75 °C did not afford high conversion by ^1H NMR, containing mostly unreacted starting material. Additional reactions for 48-72 hours and higher temperatures (up to 100 °C) had little effect and mostly unreacted amide starting material was isolated from these mixtures. Acid/base extraction methods were able to provide an analytical sample of the target deacylated amine **63**; overnight benchtop storage caused decomposition of the material to unidentifiable side-products. This route to access the targeted benzyl amine was set aside to pursue an alternative route beginning from the allylic amidation.

Concurrent efforts for the allylic C-H amidation of the homo-allylic ether substrates revealed another opportunity for accessing the targeted benzyl amine. Instead of performing the allylic amidation step with methyl dioxazolone and proceeding with functional group manipulations hinging on a singular N-benzylation of a 1° amine, switching to phenyl-dioxazolone should allow for a more facile access to benzyl amine **65**. The new strategy is contingent on the allylic amidation of homo-allylic ether followed by reduction of the benzamide product to afford the target benzyl amine (Scheme 3.2.).

Scheme 3.2. New Strategy to for Amidation with Phenyl-Dioxazolone to Access Benzyl Amine.



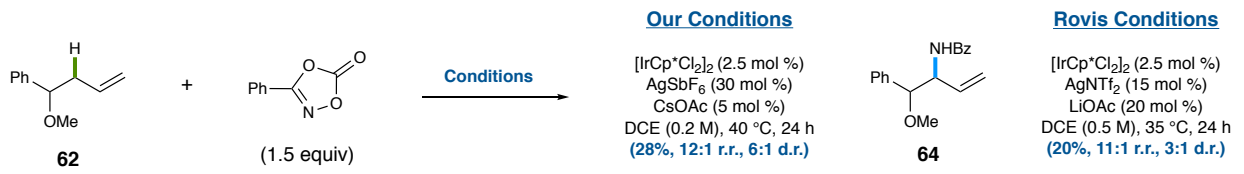


Figure 3.16. Comparison of Conditions for Diastereoselective Amidation with Ph-Dioxazolone.

To understand the differences in dioxazolone reagents on this new system we used both sets of conditions at our disposal to access the allylic benzamide **64**. In both cases low yield was observed for the amidation product under ours and Rovis' conditions which has been the normality for aryl substituted dioxazolones (Figure 3.16.). While consistent regioselectivity for the branched amide is observed in both cases, our developed conditions resulted in higher diastereoselectivity (**64**, 27%, 12:1 r.r., 6:1 d.r.). At this point there is no clear indication of the counterion effects for the varying silver or acetate salts besides higher diastereoselectivity. With the allylic benzamide material in hand, albeit in low yields, we were equipped to move forward with accessing the targeted benzyl amine **65**.

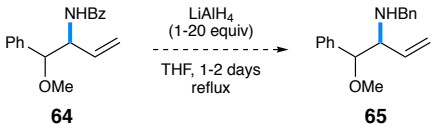


Figure 3.17. Attempted $LiAlH_4$ Reduction of Benzamide Amidation Product.

The complete reduction of amides with lithium aluminum hydride ($LiAlH_4$) is a well-known routine transformation.[33] Despite this fact, Multiple attempts were made to completely reduce allylic benzamide **64** modelling a variety of literature precedent. Reacting the amide with $LiAlH_4$ did not fully convert the starting material to new products over one or two

days, even with large excess of the reagent up to 20 equivalents in some cases (Figure 3.17.). Most likely this particular amide has a congested steric environment preventing the full reduction of the amide moiety. The resultant crude products could not be isolated *via* chromatography or acid/base extraction methods on the μmolar scale. ^{1}H NMR analysis of the crude reaction mixture were able to identify a mixture of olefin products but lacked the evidence consistent with the literature data for benzyl amine **65** to confirm a major diastereomer.

3.10.4. Amidation of Protected Homo-Allylic Alcohols

To fully promote the use of the allylic amidation methodology for synthesizing representative 1,2-aminoalcohols it is imperative to test the method against different oxygen protecting groups. In this way we can also test functional group compatibility and gain further understanding into the ideal model system to optimize the reaction.

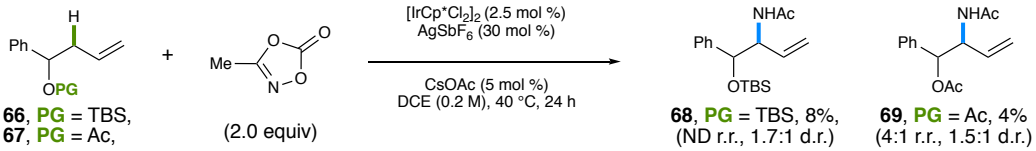
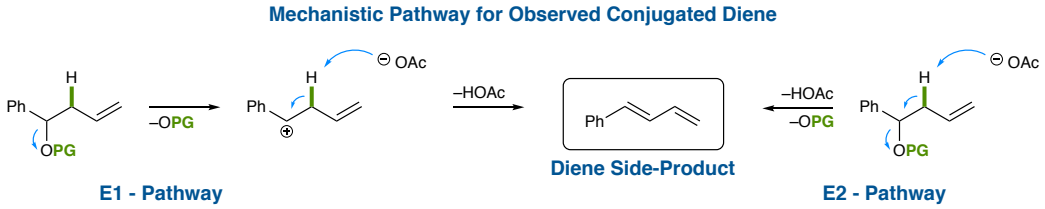


Figure 3.18. Labile Acetyl and Silyl Protecting Groups Inhibit Productive Allylic Amidation.

The first easily accessible substrate has been protected with a *tert*-butyldimethylsilane (TBS) homo-allylic ether **66** (Figure 3.18.). The TBS-silyl ether was not an optimal substrate for the amidation method with the resulting low yield, indeterminable regioselectivity from the crude reaction mixture, and minimal observed diastereoselectivity (**68**, 8%, ND r.r., 1.7:1 d.r.). Likewise, the homo-allylic acetate substrate **67** exhibited similar reactivity with low yield and minimal

observed diastereoselectivity (**69**, 4%, 4:1 r.r., 1.5:1 d.r.). Interpreting the ^{1}H NMR data from the respective crude reaction mixture shows that both reactions contained mostly starting material. Baseline peaks observed in this crude reaction mixture denotes a complex mixture of olefin products. What was identified from the product mixture is the elimination product for the conjugated diene through an E1/E2 mechanism from the free acetate in solution (Scheme 3.3.). With this particular substrate class, silyl and acetyl protecting groups are easily labile and hinder catalysis with the elimination side-products.

Scheme 3.3. Labile Protecting Groups are Prime for Elimination Under Reaction Conditions.



With the acetate and silyl protecting groups being a hindrance to the model system to access 1,2-aminoalcohols, we were encouraged to look at more robust protecting groups for further substrate design. Since the 1,2-aminoether **62** studied earlier in our allylic amidation methods demonstrated consistent results, we opted to probe ether-based protecting groups as an attractive alternative. The respective homo-allylic methoxymethyl ether (MOM) **70** and benzyl ether **71** substrates were prepared for the allylic amidation (Figure 3.19.).

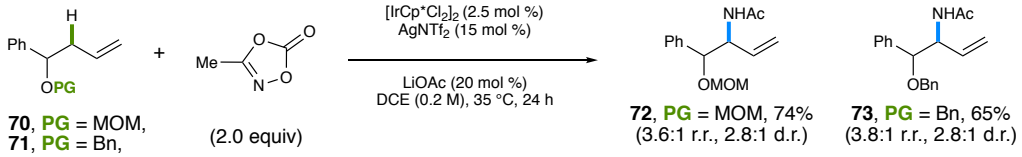


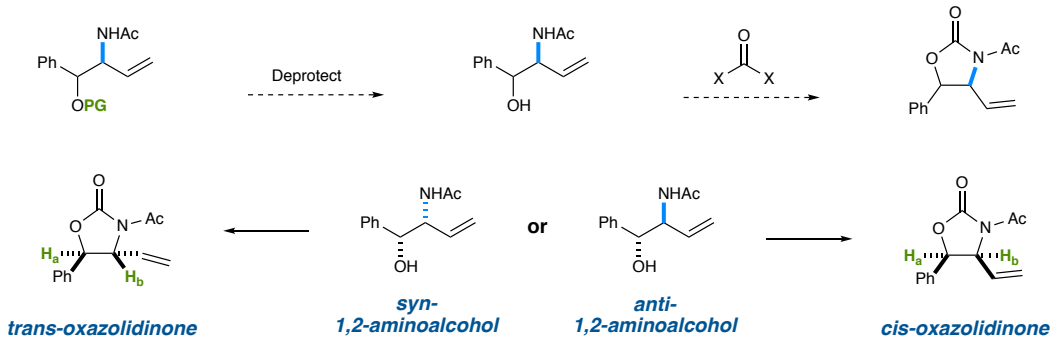
Figure 3.19. Robust Ether Protecting Groups are Effective for Allylic Amidation.

Amidation of homo-allylic MOM ether **70** with Me-Dioxazolone under the Rovis conditions afforded the intended branched amide with moderate regio- and diastereoselectivity (**72**, 64%, 3.6:1 r.r., 2.5:1 d.r.). Under similar conditions the homo-allylic benzyl ether **71** was successfully amidated in good yield and with slightly higher levels of regio- and diastereoselectivity (**73**, 65%, 3.8:1 r.r., 2.8:1 d.r.). This data, combined with previous experiments of the homo-allylic -Me, -Ac, and -TBS substrates, suggests that as the steric bulk of oxygen substitution increases, the diastereoselectivity decreases. Future work will involve probing the origins of diastereoselectivity and how the IrCp* electronics can perturb the system for higher regioselectivity and d.r..

3.10.5. Determination of *anti*-Selective Allylic C-H Amidation of Homo-Allylic Ethers

Since the amidation procedure is applicable to ether substrates with robust protecting groups we can now reevaluate our route to determine the major diastereomer. Beginning from one of the readily cleavable protecting groups at our disposal to access the free alcohol, we can then treat the product with a carbonyl equivalent to trap the 1,2-aminoalcohol to a more rigid oxazolidinone (Scheme 3.4.). This oxazolidinone target is desirable because with the rigid framework it should be simple to deduce the major diastereomer based on 1D-NOE experiments along with coupling constants (*J*) for the *trans*-/*cis*- protons. It is known that cyclization of a *syn*-1,2-aminoalcohol leads to a *trans*-oxazolidinone, which has a smaller J_{ab} than the corresponding *cis*-oxazolidinone derived from an *anti*-1,2-aminoalcohol, consistent with expectations based on Karplus curve analysis.[34-35]

Scheme 3.4. Derivatization Strategy for Oxazolidinone of 1,2-Amino Alcohols.



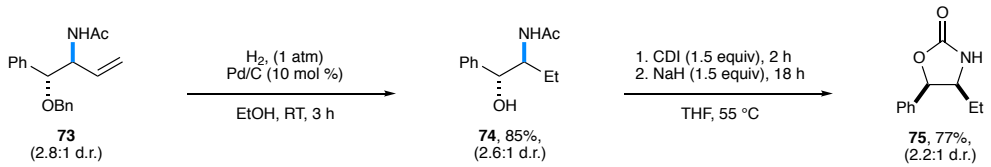


Figure 3.20. Derivatization of Benzyl-Ether Amidation Product to Oxazolidinone.

To begin our strategy, it was not necessary to maintain the olefin moiety in the amide product so long as the resulting oxazolidinone relative stereochemistry was retained for NMR analysis (Figure 3.20.). After adapting a procedure for olefin hydrogenation and hydrogenolysis of a benzyl ether,[36] **73** was reacted with Pd/C under a balloon of hydrogen proceeded smoothly to isolate the free alcohol **74** in high yield (85%, 2.6:1 d.r.). To effectively trap the free alcohol with the amide moiety, a procedure was adapted for this step using 1-1'-carbonyldimidazole (CDI) as the carbonyl equivalent.[37] By first reacting the free alcohol **74** with 1.5 equivalents of CDI for two hours at 55 °C, followed by the addition of 1.5 equivalents of NaH and stirring for 18 hours, oxazolidinone **75** was isolated in good yield maintaining an appreciable d.r. (77%, 2.2:1 d.r.). Curiously, the reaction conditions provided the deacylated oxazolidinone confirmed by ^{1}H NMR and LC-MS, most likely due to the imidazolide anion cleaving the acyl group.

We analyzed the ^{1}H NMR data to confirm the connectivity of **75** for the mixture of oxazolidinone diastereomers. Following the lead reference for this particular substitution pattern of oxazolidinone, we found the literature data for coupling constants consistent with our experimentally obtained material. Further proof was established when the material was analyzed by 1-D NOE experiments to confirm spatial relationships between the benzylic proton of the oxazolidinone diastereomers. When the major diastereomer was irradiated at 5.76 ppm (H_a), the only correlating proton signals observed were from the aromatic region and the α-nitrogen proton (H_b), suggesting that this signal is consistent with a *cis*-oxazolidinone relating to the *anti*-1,2-

aminoalcohol (Figure 3.21.). When the benzylic proton (H_a) of the minor diastereomer was irradiated at 5.14 ppm (H_b), a noticeable correlation was observed between H_a and the ethyl group (~1.79-1.73 ppm, CH_2; 1.01 ppm, CH_3) of the oxazolidinone. With the minor diastereomer showing clear spatial proximity to the ethyl group of the oxazolidinone we can confidently assign it as a *trans*-oxazolidinone relating to the *syn*-1,2-aminoalcohol.

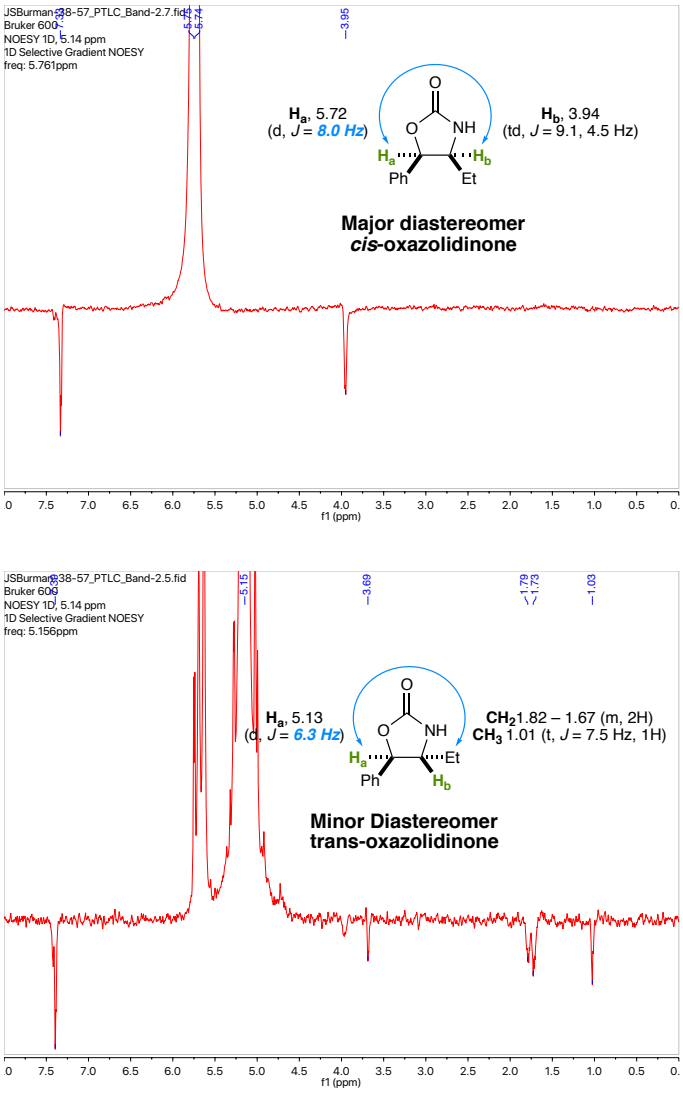
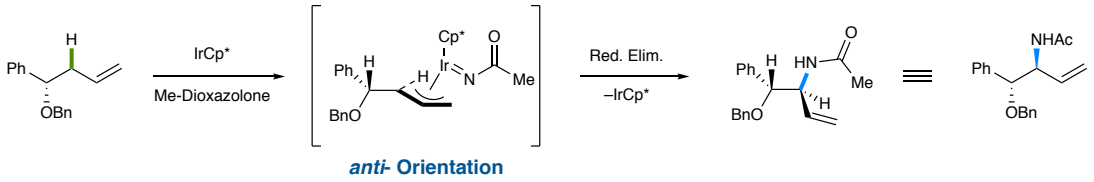


Figure 3.21. 1-D NOE Experiments Determined *Anti*-Diastereoselectivity for Allylic Amidation.

3.10.6. Mechanistic Evaluation of *Anti*-Diastereoselectivity for Allylic C-H Amidation

After having confirmed an *anti*-relationship for the major diastereomer from the allylic amidation we sought to understand the origin of this selectivity. In developing a mechanistic model, we needed to envision the possible intermediates that would play a key role leading to reductive elimination of the IrCp*-nitrenoid (Scheme 3.5.). The IrCp*-π-allyl complex shown in the orientation below, originating from a single enantiomer, would lead to the *anti*-relationship for the 1,2-amino ether product. Two key interactions are proposed to bias the formation of the IrCp*-π-allyl complex from the homo-allylic ether substrates being studied.

Scheme 3.5. *Anti*- Orientation of IrCp*-π-Allyl Intermediate Towards 1,2-Amino Alcohols.



The first argument being that the diastereotopic allylic C-H bond prior to π-allyl generation most likely sits antiperiplanar to the benzyl ether (Figure 23.A.). In this fashion we can hypothesize that molecular orbital effects maintain this conformation by stabilizing the transition state for π-allyl formation. As the allylic C-H bond begins to break in figure 23.A., a stabilization of the allylic C(sp^3)σ* orbital rehybridizing to an occupied *p*-orbital donates into the C-O(σ*) occurs. Reorienting the complex as a Newman projection allows us to more accurately view the bias between generating the relative *anti*- or *syn*-complex (Figure 23.B.). The proposed molecular orbital stabilization effect promotes the vinyl substituent to sit between the -H and -OBn groups in the *anti*-Model for diastereoselectivity. A clear gauche interaction can be observed in the ensuant

IrCp*-π-allyl complex being formed for the *syn*-model. Taken with these hypothesized effects for the preferred orientation of π-allyl formation an additional result conducted by Amaan Kazerouni in the Blakey group. He demonstrates that under very similar reaction conditions with a substrate where the -OBn group is substituted for a -Me substituent a minimal 1.8:1 diastereoselectivity was observed. Without the additive molecular orbital effect I have proposed for the preferential antiperiplanar relationship of the allylic C-H(σ*) and homo-allylic C-OBn(σ*) in the transition state leading to π-allyl formation, the steric gauche effect is not strong enough to enforce higher selectivity for this transformation.

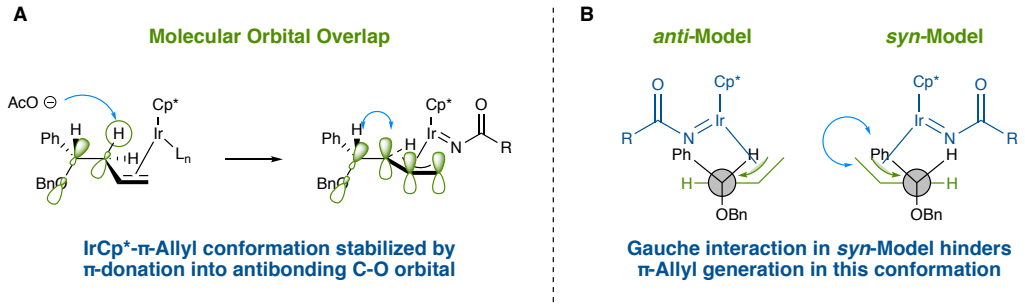


Figure 3.23. Rationalization of *Anti*-Diastereoselectivity for Allylic C-H Amidation.

3.11. Conclusion and Future Directions

In the work I have described we have developed conditions to access to the benzylic/branched amidation regioisomer for the allylic C-H functionalization of terminal, di-, and trisubstituted olefins proceeding through organometallic π-allyl intermediates. The regioselectivities observed for this transformation directly complement the previously reported RhCp*-catalyzed allylic C-H amination technology for conjugated/linear products. What was revealed through the natural course of the study was a key differentiation of the two RhCp* and IrCp* precatalysts to interact preferentially with olefin substrate classes. The synthesis and reactions of stochiometric RhCp*- and IrCp*-π-allyl complexes provide products with regioselectivities that are consistent with the catalytic reactions, and they support a mechanism in which these π-allyl complexes are oxidized to fleeting M(V)-nitrenoid intermediates that subsequently undergo inner-sphere reductive elimination. The development of the allylic amidation conditions described prompted identification of a new method to access relevant 1,2-amino alcohol motifs in an *anti*-diastereoselective manner. Further work in this methodology to demonstrate its utility has birthed an enantioselective variant of this reaction from others in the Blakey lab. To fully understand the diverging catalyst/substrate interactions, additional mechanistic and computational studies are necessary.

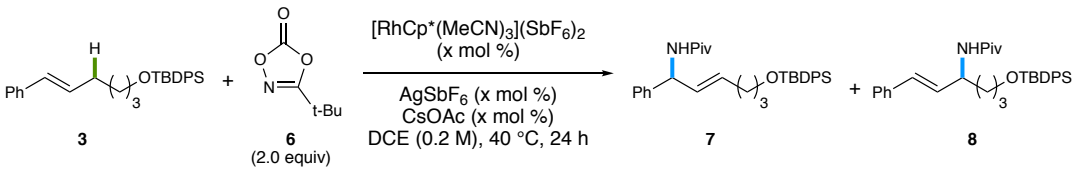
Experimental Procedures and Characterization Data of Compounds

General Experimental

^{1}H and ^{13}C NMR spectra were recorded on either a Bruker Ascend 600 spectrometer (600 MHz ^{1}H, 150 MHz ^{13}C), Varian Inova 600 spectrometer (600 MHz ^{1}H, 150 MHz ^{13}C), Varian INOVA 500 spectrometer (500 MHz ^{1}H, 125 MHz ^{13}C), Varian Inova 400 spectrometer (400 MHz ^{1}H, 100 MHz ^{13}C), Varian VNMRS 400 spectrometer (400 MHz ^{1}H, 100 MHz ^{13}C), or Mercury 300 PLUS (300 MHz ^{1}H, 75 MHz ^{13}C) at room temperature in $CDCl_3$ (neutralized and dried using anhydrous K_2CO_3) with internal $CHCl_3$ as the reference (7.26 ppm for ^{1}H and 77.16 ppm for ^{13}C), unless otherwise stated. Chemical shifts (δ values) were reported in parts per million (ppm) and coupling constants (*J* values) in Hz. Multiplicity was indicated using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, qn = quintet, m = multiplet, b = broad. The broad singlet impurity at 1.26 ppm in ^{1}H NMR and 29.8 in ^{13}C NMR is identified as Apiezon brand H grease.[8] Infrared (IR) spectra were recorded using Thermo Electron Corporation Nicolet 380 FT-IR spectrometer. High-resolution mass spectra were obtained using a Thermo Electron Corporation Finigan LTQFTMS (at the Mass Spectrometry Facility, Emory University). Analytical thin layer chromatography (TLC) was performed on pre-coated glass backed EMD 0.25 mm silica gel 60 plates. Visualization was accomplished with UV light, ethanolic anisaldehyde, or $KMnO_4$. Flash column chromatography was carried out using Silicycle SilaFlash® F60 silica gel (40-63 μm). Preparatory thin layer chromatography was performed on precoated glass backed Silicycle SiliaPure® 1.0 mm silica gel 60 plates. All reactions and prepared solutions were conducted using anhydrous solvents in oven-dried and nitrogen charged glassware. Anhydrous solvents were obtained by passage through activated alumina using a Glass Contours solvent purification system

or Dri-Solve® reagent bottles unless otherwise noted. 1,2-Dichloroethane was stirred for 12 hours over CaH_2, distilled under inert atmosphere, degassed and stored over 4Å molecular sieves. Solvents used in workup, extraction and column chromatography were used as received from commercial suppliers without further purification. All reagents were purchased from Sigma Aldrich, Alfa Aesar, Oakwood Chemicals, ArkPharm or Strem Chemicals and used as received unless otherwise noted. 4Å molecular sieves were activated by flame drying under reduced pressure (0.2 torr).

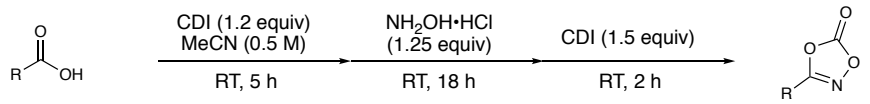
Optimization Procedure for the Development of Allylic C–H Amidation



3 **6** (2.0 equiv) **7** **8**

Inside of an N_2 atmosphere glove box, $AgSbF_6$, $[RhCp^*(MeCN)_3](SbF_6)_2$ (0.05 equiv), and CsOAc were weighed into a single 4 mL vial equipped with a stir bar for each trial. The vial was then fit with a septum cap and removed from the glovebox. In a separate oven-dried 7 mL vial fit with a septum cap, a 0.40 M stock solution of olefin **3** was prepared under inert atmosphere in 1,2-dichloroethane. In another separate oven-dried 7 mL vial, a 0.40 M stock solution of *tert*-butyl dioxazolone **6** was prepared in 1,2-dichloroethane in the following fashion to establish an inert atmosphere; the dioxazolone **6** was weighed into the 7 mL vial, fit with a septum cap and the vial was immersed in a dry-ice/acetone bath until frozen and then vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). An aliquot of olefin solution (0.25 mL, 42 mg, 0.10 mmol) and an aliquot of the dioxazolone solution (0.25 mL, 29 mg, 0.20 mmol) were added sequentially to the vial with solid reagents. The reaction mixture was heated to the appropriate temperature for the allotted amount of time. The reaction mixture was removed from heat and allowed to cool to room temperature. Then the crude mixture was opened, and an aliquot of a 1,4-dinitrobenzene stock solution was added (400 µL, 0.025 mmol, 0.25 equiv). The resulting solution was filtered over celite, and the celite was rinsed with EtOAc (5 mL). The combined filtrate was concentrated under reduced pressure and analyzed by ^1H NMR for yields and regiomeric ratios of amides **7**/**8**.

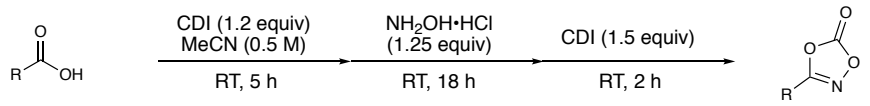
General Procedures for New Dioxazolone Synthesis



General Procedure A - New Dioxazolones from Solid Carboxylic Acids

To an oven dried 15 mL vial with a stir bar was weighed 1,1'-carbonyldiimidazole (1.2 equiv), the vial was then fitted with a septum cap and the air was exchanged for an N_2 atmosphere (3x cycles, 1 minute per cycle). Acetonitrile (6 mL) was then added to the vial which resulted in a suspension of the CDI. The vial was quickly opened and the solid carboxylic acid (3 mmol, 1 equiv) was added then and quickly resealed. Immediate evidence of CO_2 evolution was seen, and the reaction was allowed to stir for 5 hours. The vial was then reopened and NH_2OH•HCl (1.25 equiv) was added and the vial was quickly resealed and allowed to stir for 18 hours. The resulting cloudy solution was then reopened to air and CDI (1.5 equiv) was added, quickly resealed and allowed to stir for 2 hours. After TLC had indicated the presence of the new dioxazolone, the reaction was quenched with 1 M $HCl_{(aq)}$ (50 mL) and organics were extracted from the aqueous layer 3x with dichloromethane (30 mL). The combined organic extracts were then washed with brine and dried over $MgSO_4$. The organic extracts were filtered and concentrated under reduced pressure. The resulting crude dioxazolone was then dissolved in minimal dichloromethane and filtered through

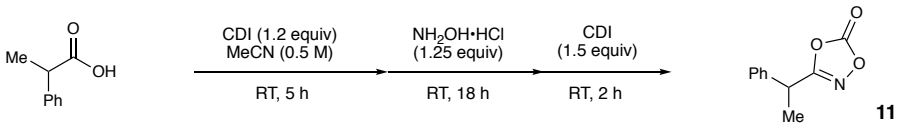
a pad of silica gel. The silica gel was then rinsed with dichloromethane (150 mL) and concentrated to afford the pure dioxazolone.



General Procedure B - New Dioxazolones from Liquid Carboxylic Acids

To an oven dried 15 mL vial with a stir bar was weighed 1,1'-carbonyldiimidazole (1.2 equiv), the vial was then fitted with a septum cap and the air was exchanged for an N_2 atmosphere (3x cycles, 1 minute per cycle). Acetonitrile (6 mL) was then added to the vial, followed by the carboxylic acid *via* syringe which resulted in a suspension of the CDI. Immediate evidence of CO_2 evolution was seen, and the reaction was allowed to stir for 5 hours. The vial was then reopened and NH_2OH•HCl (1.25 equiv) was added and the vial was quickly resealed and allowed to stir for 18 hours. The resulting cloudy solution was then reopened to air and CDI (1.5 equiv) was added, quickly resealed and allowed to stir for 2 hours. After TLC had indicated the presence of the new dioxazolone, the reaction was quenched with 1 M $HCl_{(aq)}$ (50 mL) and organics were extracted from the aqueous layer 3x with dichloromethane (30 mL). The combined organic extracts were then washed with brine and dried over $MgSO_4$. The organic extracts were filtered and concentrated under reduced pressure. The resulting crude dioxazolone was then dissolved in minimal dichloromethane and filtered through a pad of silica gel. The silica gel was then rinsed with dichloromethane (150 mL) and concentrated to afford the pure dioxazolone.

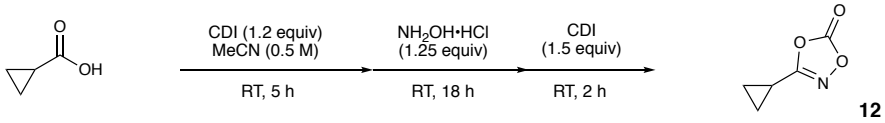
New Dioxazolone Characterization Data



Dioxazolone (11) – 3-(1-phenylethyl)-1,4,2-dioxazol-5-one

Following General Procedure B, the reaction of 2-phenylpropanpoic acid (0.41 mL, 3.0 mmol), the first portion of CDI (590 mg, 3.64 mmol), NH_2OH•HCl (274 mg, 3.94 mmol), and the second portion of CDI (729 mg, 4.50 mmol), produced the title compound as a clear oil (355 mg, 62% yield).

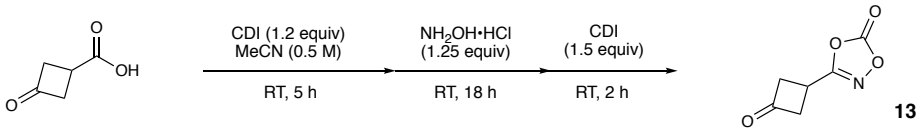
^{1}H NMR (600 MHz, $CDCl_3$): 7.40 (ddd, J = 7.5, 6.2, 1.4 Hz, 2H), 7.35 (tt, J = 7.2, 2.4, 1H), 7.30 (dd, J = 7.2, 1.5 Hz, 2H), 4.07 (q, J = 7.3 Hz, 1H), 1.68 (d, J = 7.3 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 168.5, 154.2, 137.0, 129.4, 128.6, 127.5, 37.2, 17.4 ppm. **HRMS** (+ NSI): Calculated for $C_8H_{10}NO_4S$ $[M+H]^+$ 192.0655**,** observed 192.0655. **IR** (thin film); 2988, 1869, 1824, 1631, 964, 759, 697 cm^{-1}.



Dioxazolone (12) – 3-cyclopropyl-1,4,2-dioxazol-5-one

Following General Procedure B, the reaction of cyclopropanecarboxylic acid (0.24 mL, 3.0 mmol), the first portion of CDI (587 mg, 3.62 mmol), NH_2OH•HCl (270 mg, 3.88 mmol), and the second portion of CDI (730 mg, 4.50 mmol), produced the title compound as a white solid (295 mg, 77% yield).

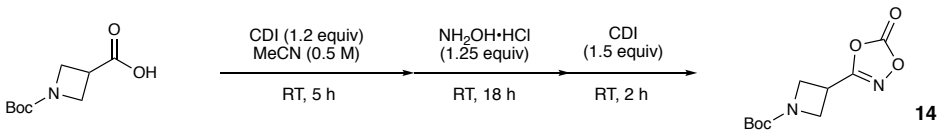
^{1}H NMR (600 MHz, $CDCl_3$): δ 1.91 (ttd, *J* = 8.8, 5.1, 0.5 Hz, 1H), 1.22 – 1.17 (m, 2H), 1.16 – 1.12 (m, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 168.0, 154.1, 7.5, 5.6 ppm. **HRMS** (- NSI): Calculated for $C_6H_8NO_4$ $[M\text{-}H+MeOH]^-$ 158.0459**,** observed 158.0459. **IR** (thin film); 2995, 1881, 1851, 1825, 1629, 763 cm^{-1}.



Dioxazolone (13) – 3-(3-oxocyclobutyl)-1,4,2-dioxazol-5-one

Following General Procedure for A, the reaction of 3-oxocyclobutane-1-carboxylic acid (261 mg, 3.0 mmol), the first portion of CDI (583 mg, 3.60 mmol), NH_2OH•HCl (280 mg, 4.03 mmol), and the second portion of CDI (732 mg, 4.50 mmol), produced the title compound as a white solid (90 mg, 19% yield).

^{1}H NMR (600 MHz, $CDCl_3$): δ 3.64 (dt, *J* = 15.0, 7.7 Hz, 1H), 3.56 (d, *J* = 7.7 Hz, 4H) ppm. **^{13}C-NMR** (150 MHz, $CDCl_3$) δ 199.6, 167.1, 153.7, 51.6, 19.8 ppm. **HRMS** (- NSI): Calculated for $C_7H_8NO_5$ $[M\text{-}H+MeOH]^-$ 186.0408**,** observed 186.0407. **IR** (thin film); 2937, 1865, 1789, 1623, 763 cm^{-1}.

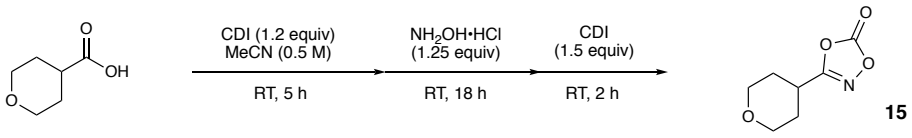


Dioxazolone (14) – *tert*-butyl 3-(5-oxo-1,4,2-dioxazol-3-yl)azetidine-1-carboxylate

Following General Procedure A, the reaction of 1-(*tert*-butoxycarbonyl)azetidine-3-carboxylic acid (600 mg, 3.00 mmol), the first portion of CDI (584 mg, 3.60 mmol), NH_2OH•HCl (270 mg,

3.88 mmol), and the second portion of CDI (740 mg, 4.56 mmol), produced the title compound as a clear oil (193 mg, 27% yield).

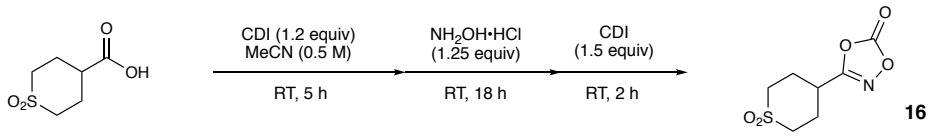
^{1}H NMR (600 MHz, $CDCl_3$): δ 4.28 (t, *J* = 9.0 Hz, 2H), 4.18 (dd, *J* = 9.1, 5.9 Hz, 2H), 3.73 (tt, *J* = 8.9, 5.9 Hz, 1H), 1.45 (s, 9H) ppm. **^{13}C-NMR** (150 MHz, $CDCl_3$) δ 165.9, 155.7, 153.7, 80.9, 51.1, 28.4, 24.4 ppm. **HRMS** (+ NSI): Calculated for $C_{10}H_{15}N_2O_5$ $[M+H]^+$ 243.0976**,** observed 243.0979. **IR** (thin film); 2978, 2900, 1871, 1839, 1367, 1145 cm^{-1}.



Dioxazolone (15) – 3-(tetrahydro-2*H*-pyran-4-yl)-1,4,2-dioxazol-5-one

Following General Procedure A, the reaction of tetrahydro-2*H*-pyran-4-carboxylic acid (395 mg, 3.04 mmol), the first portion of CDI (583 mg, 3.60 mmol), NH_2OH•HCl (269 mg, 3.87 mmol), and the second portion of CDI (731 mg, 4.51 mmol), produced the title compound as a white solid (371 mg, 72% yield).

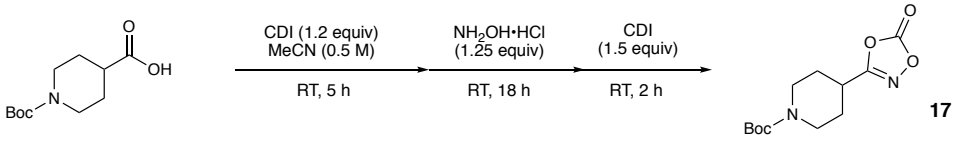
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.04 (dt, *J* = 11.9, 3.6 Hz, 2H), 3.51 (td, *J* = 11.4, 2.7 Hz, 2H), 2.95 (tt, *J* = 10.9, 4.3 Hz, 1H), 2.01 – 1.80 (m, 4H) ppm. **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.1, 154.1, 66.5, 32.3, 27.8 ppm. **HRMS** (+ NSI): Calculated for $C_7H_{10}O_4N$ $[M+H]^+$ 172.0604**,** observed 172.0603. **IR** (thin film); 2960, 2852, 1824, 1652, 980, 759 cm^{-1}.



Dioxazolone (16) – 3-(1,1-dioxidotetrahydro-2*H*-thiopyran-4-yl)-1,4,2-dioxazol-5-one

The preparation of the title compound was made following General Procedure A The reaction of tetrahydro-2*H*-thiopyran-4-carboxylic acid 1,1-dioxide (536 mg, 3.01 mmol), the first portion of CDI (541 mg, 3.34 mmol), NH_2OH•HCl (280 mg, 4.03 mmol), and the second portion of CDI (738 mg, 4.55 mmol), produced the title compound as a white solid (392 mg, 66% yield). ***Note** a modification to the workup procedure: 100 mL of Hexanes:EtOAc (1:1) was used to filter the concentrated residue instead of dichloromethane.

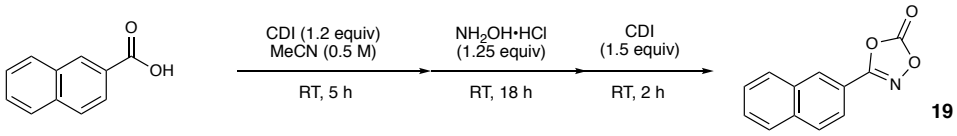
^{1}H NMR (600 MHz, $(CD_3)_2CO$): δ 3.38 (td, *J* = 9.7, 4.8 Hz, 1H), 3.29 – 3.14 (m, 4H), 2.55 – 2.49 (m, 2H), 2.35 (dtd, *J* = 13.8, 10.1, 3.3 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $(CD_3)_2CO$) δ 168.1, 155.1, 49.9, 32.2, 26.9 ppm. **HRMS** (+ NSI): Calculated for $C_8H_{10}NO_4S$ $[M+H_3O]^+$ 216.0331**,** observed 216.0422. **IR** (thin film); 3385 (broad), 2989, 2940, 1828, 1637, 761 cm^{-1}.



Dioxazolone (17) – *tert*-butyl 4-(5-oxo-1,4,2-dioxazol-3-yl)piperidine-1-carboxylate

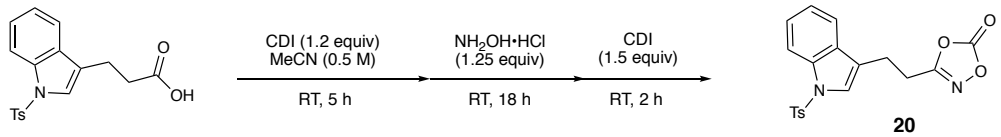
Following General Procedure A, the reaction of 1-(*tert*-butoxycarbonyl)-piperidine-4 carboxylic acid (518 mg, 3.0 mmol), the first portion of CDI (588 mg, 3.63 mmol), NH_2OH•HCl (265 mg, 3.8 mmol), and the second portion of CDI (732 mg, 4.5 mmol), produced the title compound as a colorless sticky oil (801 mg, 99% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ 4.11 (bs, 2H), 2.90 (t, *J* = 11.3 Hz, 2H), 2.84 (ddt, *J* = 11.1, 7.7, 3.8 Hz, 1H), 2.91 (t, *J* = 12.9 Hz, 2H), 2.85 (tt, *J* = 11.1, 3.8 Hz, 2H), 1.98 (d, *J* = 13.2 Hz, 2H), 1.70 (dtd, *J* = 13.4, 11.3, 4.3 Hz, 2H), 1.45 (s, 9H) ppm. **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.1, 154.6, 154.0, 80.3, 42.7, 33.2, 28.5, 27.3 ppm. **HRMS** (+ NSI): Calculated for $C_{12}H_{19}O_5N_2$ $[M+H]^+$ 271.1289**,** observed 271.1292. **IR** (thin film); 2975, 2932, 1830, 1684, 1159 cm^{-1}.



Dioxazolone (19) – 3-(naphthalen-2-yl)-1,4,2-dioxazol-5-one

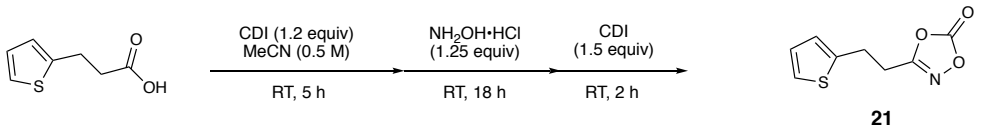
Following General Procedure A, the reaction of 2-naphthoic acid (518 mg, 3.0 mmol), the first portion of CDI (588 mg, 3.6 mmol), NH_2OH•HCl (265 mg, 3.8 mmol), and the second portion of CDI (732 mg, 4.5 mmol), produced the title compound as an off-white solid (168 mg, 26% yield). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 8.37 (s, 1H), 7.98 (t, *J* = 8.6 Hz, 2H), 7.92 (d, *J* = 8.2 Hz, 1H), 7.87 (dd, *J* = 8.6, 1.8 Hz, 1H), 7.65 (dddd, *J* = 21.8, 8.2, 6.9, 1.4 Hz, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 163.9, 154.0, 135.7, 132.6, 129.7, 129.3, 129.3, 128.5, 128.3, 127.8, 121.6, 117.4 ppm. **HRMS** (+ APCI): Calculated for $C_{12}H_8O_3N$ $[M+H]^+$ 214.0499**,** observed 214.0497. **IR** (thin film); 3060, 2924, 1855, 1828, 1612, 758 cm^{-1}.



Dioxazolone (20) – 3-(2-(1-tosyl-1*H*-indol-3-yl)ethyl)-1,4,2-dioxazol-5-one

Following General Procedure B, the reaction of 3-(1-tosyl-1*H*-indol-3-yl)propanoic acid (525 mg, 1.53 mmol), the first portion of CDI (392 mg, 2.45 mmol), NH_2OH•HCl (274 mg, 3.94 mmol), and the second portion of CDI (380 mg, 2.34 mmol), produced the title compound as a white solid (290 mg, 49% yield).

^{1}H NMR (600 MHz, $CDCl_3$): 8.01 (d, *J* = 8.3 Hz, 1H), 7.73 (d, *J* = 7.8 Hz, 2H), 7.45 (d, *J* = 7.7 Hz, 1H), 7.41 (s, 1H), 7.35 (t, *J* = 7.7 Hz, 1H), 7.27 (d, *J* = 7.7 Hz, 1H), 7.22 (d, *J* = 7.9 Hz, 2H) 3.12 (t, *J* = 7.2 Hz, 2H), 3.02 (t, *J* = 7.3 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 165.72, 153.93, 145.28, 135.47, 135.17, 130.09, 129.97, 126.86, 125.37, 123.67, 123.56, 119.12, 118.95, 114.19, 24.83, 21.72, 20.31 ppm. **HRMS** (+ NSI): Calculated for $C_8H_{10}NO_4S$ $[M+H]^+$ 192.0655**,** observed 192.0655. **IR** (thin film); 2988, 1869, 1824, 1631, 964, 759, 697 cm^{-1}.



Dioxazolone (21) – 3-(2-(thiophen-2-yl)ethyl)-1,4,2-dioxazol-5-one

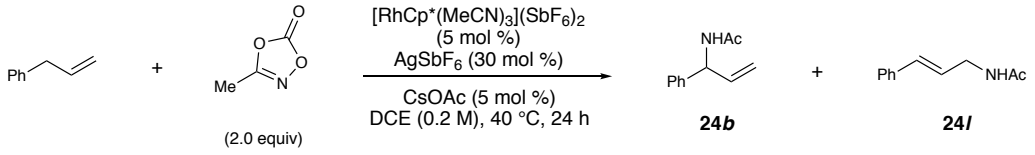
Following General Procedure A, the reaction of 3-(thiophen-3-yl)propanoic acid (469 mg, 3.00 mmol), the first portion of CDI (537 mg, 3.31 mmol), NH_2OH•HCl (281 mg, 4.04 mmol), and the

second portion of CDI (732 mg, 4.51 mmol), produced the title compound as a white solid (392 mg, 66% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.20 (dd, *J* = 5.2, 1.2 Hz, 1H), 6.95 (dd, *J* = 5.1, 3.4 Hz, 1H), 6.87 (dd, *J* = 3.4, 1.0 Hz, 1H), 3.27 (t, *J* = 7.7 Hz, 2H), 3.00 (t, *J* = 7.5 Hz, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 165.5, 154.0, 140.2, 127.3, 125.8, 124.7, 27.3, 24.9 ppm. **HRMS** (+ NSI): Calculated for $C_8H_{10}NO_4S$ $[M+H_3O]^+$ 216.0331**,** observed 216.0422. **IR** (thin film); 2925, 1867, 1824, 1637, 697 cm^{-1}.

Dioxazolone Scope with Allylbenzene

Amide Regioisomers 24



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.2 mg, 0.0061 mmol), $AgSbF_6$ (10.4 mg, 0.0303 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.3 mg, 0.0052 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. Allylbenzene (32μL, 29 mg, 0.24 mmol) was delivered into a separate oven-dried 4 mL vial with a septum cap under N_2 atmosphere and 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 4 mL vial was weighed 3-methyl-1,4,2-dioxazol-5-one (24.7 mg, 0.244 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (0.30 mL) was then added to

the vial of dioxazolone. An aliquot of allylbenzene solution (0.25 mL, 12 mg, 0.10 mmol) and dioxazolone solution (0.25 mL, 21 mg, 0.20 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 3:1 mixture of regioisomers (**24*b***:**24*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **24*b*** as a white solid (15 mg, 84%) and **24*l*** as an opaque oil (2 mg, 11%).

24*b* – *N*-(1-phenylallyl)acetamide

The title compound exhibited identical ^{1}H NMR data to previous reports.[39]

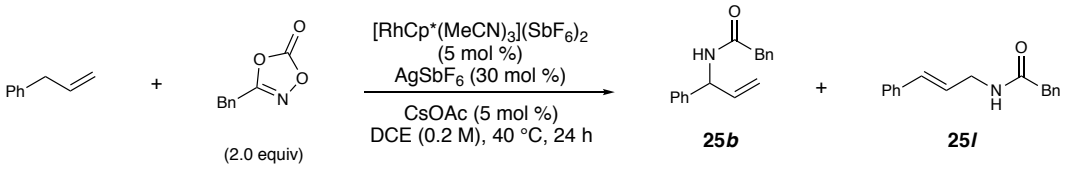
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.39 – 7.32 (m, 2H), 7.29 (t, *J* = 6.3 Hz, 3H), 6.22 (bs, 1H), 6.01 (ddd, *J* = 16.0, 10.3, 5.3 Hz, 1H), 5.61 (t, *J* = 6.8 Hz, 1H), 5.27 (d, *J* = 10.3 Hz, 1H), 5.22 (d, *J* = 17.1 Hz, 1H), 2.84 (s, 1H), 2.05 (s, 3H).

24*l* – *N*-cinnamylacetamide

The title compound exhibited identical ^{1}H NMR data to previous reports.[40]

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.36 (d, *J* = 7.5 Hz, 2H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 (t, *J* = 7.2 Hz, 1H), 6.52 (d, *J* = 15.9 Hz, 1H), 6.20 (dt, *J* = 15.9, 6.4 Hz, 1H), 5.56 (bs, 1H), 4.04 (t, *J* = 5.9 Hz, 2H), 2.03 (s, 3H).

Amide Regioisomers 25



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.2 mg, 0.0063 mmol), $AgSbF_6$ (10.5 mg, 0.0306 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.3 mg, 0.0051 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. Allylbenzene (32μL, 29 mg, 0.24 mmol) was delivered into a separate oven-dried 4 mL vial with a septum cap under N_2 atmosphere and 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 4 mL vial was weighed 3-benzyl-1,4,2-dioxazol-5-one (45 mg, 0.25 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (0.30 mL) was added to the vial of dioxazolone. An aliquot of allylbenzene solution (0.25 mL, 12 mg, 0.10 mmol) and dioxazolone solution (0.25 mL, 38 mg, 0.21 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 3:1 mixture of regioisomers (**25*b***:**25*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give branched isomer **25*b*** as a white solid (16 mg, 64%) and linear isomer **25*l*** as a white solid (3 mg, 8%).

25*b* – **2-phenyl-*N*-(1-phenylallyl)acetamide**

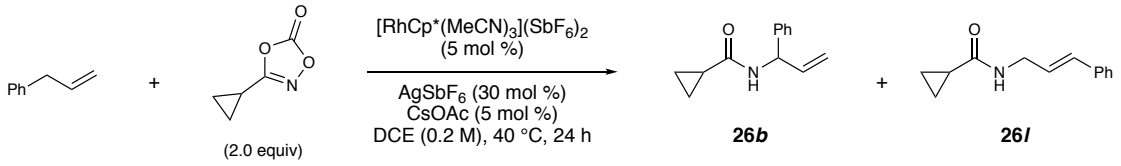
The title compound exhibited identical ^{1}H NMR data to previous reports.[41]

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 (t, *J* = 7.4 Hz, 1H), 7.32 – 7.22 (m, 3H), 7.16 (d, *J* = 7.7 Hz, 1H), 5.91 (ddd, *J* = 16.2, 10.3, 4.4 Hz, 1H), 5.64 (s, 1H), 5.16 (d, *J* = 10.4 Hz, 1H), 5.04 (m, *J* = 17.2 Hz, 2H), 3.64 (d, *J* = 16.0 Hz, 0H), 3.60 (d, *J* = 16.0 Hz, 1H).

25*l* – ***N*-cinnamyl-2-phenylacetamide**

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.37 (t, *J* = 7.3 Hz, 2H), 7.34 – 7.27 (m, 7H), 7.23 (dq, *J* = 5.6, 2.7 Hz, 1H), 6.39 (d, *J* = 15.9 Hz, 1H), 6.11 (dt, *J* = 15.8, 6.2 Hz, 1H), 5.47 (s, 1H), 4.01 (t, *J* = 5.9 Hz, 2H), 3.63 (s, 1H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 170.8, 136.4, 134.8, 132.0, 129.5, 129.1, 128.6, 127.7, 127.5, 126.3, 125.4, 43.9, 41.6, 29.7 ppm. **HRMS** (+ NSI): Calculated for $C_{17}H_{18}NO$ $[M+H]^+$ 252.1383**,** observed 252.1384. **IR** (thin film); 3290, 2921, 1644, 692 cm^{-1}.

Amide Regioisomers 26



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.0 mg, 0.010 mmol), $AgSbF_6$ (21 mg, 0.058 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In an oven-dried 4 mL vial was weighed 3-cyclopropyl-1,4,2-dioxazol-5-one (62 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) was added to the vial of dioxazolone followed by addition of allylbenzene (32μL, 29 mg, 0.24 mmol). An aliquot

of the solution (1.0 mL, [allylbenzene, 24 mg, 0.20 mmol], [dioxazolone, 52 mg, 0.41 mmol]) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 2:1 mixture of regioisomers (**26*b***:**26*l***). The crude residue was filtered through a column of silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to provide a mixture of amidation products (31 mg). Purification of the mixture was performed by preparative thin-layer chromatography using Hexanes:EtOAc (80:20, 3 sweeps) to provide **26*b*** as a white solid (20 mg, 50%) and **26*l*** as an opaque oil (10 mg, 25%).

26*b* – *N*-(1-phenylallyl)cyclopropanecarboxamide

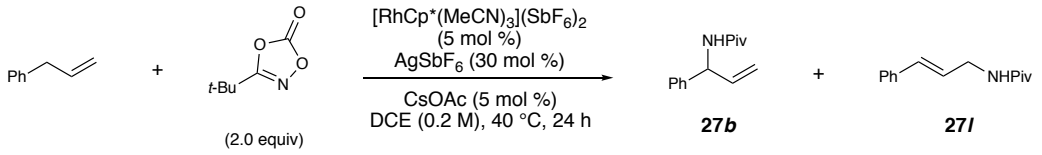
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.38 – 7.33 (m, 2H), 7.33 – 7.27 (m, 3H), 6.03 (ddd, *J* = 17.1, 10.4, 5.3 Hz, 1H), 5.88 (d, *J* = 8.3 Hz, 1H), 5.66 (dd, *J* = 7.9, 5.6 Hz, 1H), 5.31 – 5.21 (m, 2H), 1.37 (tt, *J* = 7.9, 4.6 Hz, 1H), 1.09 – 0.93 (m, 2H), 0.84 – 0.67 (m, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 172.7, 140.9, 137.6, 128.9, 127.8, 127.4, 115.9, 55.4, 15.0, 7.5, 7.4 ppm. **HRMS** (+ NSI): Calculated for $C_{13}H_{16}NO$ $[M+H]^+$ 202.1226**,** observed 202.1226. **IR** (thin film); 3274, 3062, 3011, 1636, 1553, 699 cm^{-1}.

26*l* – *N*-cinnamylcyclopropanecarboxamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.39 – 7.34 (m, 2H), 7.31 (t, *J* = 7.6 Hz, 2H), 7.24 (tt, *J* = 6.6, 1.5 Hz, 1H), 6.54 (d, *J* = 15.8 Hz, 1H), 6.21 (dt, *J* = 15.8, 6.4 Hz, 1H), 5.72 (bs, 1H), 4.07 (td, *J* = 6.2, 1.5 Hz, 2H), 1.36 (tt, *J* = 7.9, 4.6 Hz, 1H), 1.05 – 0.97 (m, 2H), 0.84 – 0.72 (m, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 173.5, 136.7, 132.3, 128.7, 127.9, 126.5, 126.0, 42.0, 15.0, 7.4 ppm.

HRMS (+ NSI): Calculated for $C_{13}H_{16}NO$ $[M+H]^+$ 202.1226**,** observed 202.1226. **IR** (thin film); 3295, 3079, 3004, 2923, 1631, 1548, 687 cm^{-1}.

Amide Regioisomers 27



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.2 mg, 0.011 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.8 mg, 0.011 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (69 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 58 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 8:1 mixture of regioisomers (**27*b***:**27*l***). The crude residue was purified by flash chromatography on silica gel

using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **27*b*** as a white solid (26 mg, 60%) and **27*l*** as an opaque oil (4 mg, 9%).

27*b* – *N*-(1-phenylallyl)pivalamide

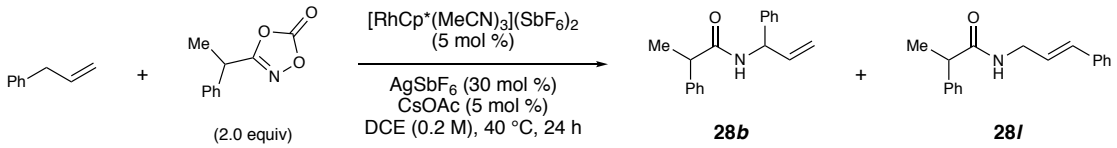
The titled compound exhibited identical ^{1}H NMR data to previous reports.[42]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37 – 7.31 (m, 2H), 7.31 – 7.24 (m, 3H), 6.02 (ddd, *J* = 17.1, 10.3, 5.3 Hz, 1H), 5.88 (d, *J* = 7.2 Hz, 1H), 5.62 (dd, *J* = 7.8, 5.5 Hz, 1H), 5.24 (ddd, *J* = 10.4, 1.6, 1.2 Hz, 1H), 5.18 (ddd, *J* = 17.1, 1.7, 1.2 Hz, 1H), 1.22 (s, 9H).

27*l* – *N*-cinnamylpivalamide

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 (d, *J* = 7.2 Hz, 2H), 7.31 (t, *J* = 7.7 Hz, 2H), 7.24 (dt, *J* = 6.6, 1.6 Hz, 1H), 6.52 (d, *J* = 15.8 Hz, 1H), 6.20 (dt, *J* = 15.8, 6.4 Hz, 1H), 5.72 (s, 1H), 4.04 (td, *J* = 6.4, 1.5 Hz, 2H), 1.23 (s, 9H). **^{13}C NMR** (150 MHz, $CDCl_3$) δ 178.37, 136.71, 132.33, 128.75, 127.88, 126.52, 126.00, 41.83, 38.92, 29.86, 27.80. **HRMS** (+ NSI): Calculated for $C_{14}H_{20}NO$ $[M+H]^+$ 218.1545**,** observed 218.1538. **IR** (thin film); 3290, 2921, 1644, 692 cm^{-1}.

Amide Regioisomers 28



Inside an N_2 atmosphere glovebox, to an oven-dried 7 mL vial equipped with a magnetic stir bar was added CsOAc (2.0 mg, 0.010 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.7 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was

weighed 3-(1-phenylethyl)-1,4,2-dioxazol-5-one (214 mg, 1.12 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and then 1,2-dichloroethane (1.4 mL) was added. In a separate oven-dried 4 mL vial under N_2 atmosphere was added allylbenzene (58μL, 51 mg, 0.44 mmol) followed by 1,2-dichloroethane (1.2 mL) were sequentially added into the vial of dioxazolone. An aliquot of the allylbenzene solution (0.5 mL, 24 mg, 0.20 mmol) and the dioxazolone solution (0.5 mL, 76 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 7:1 mixture of regioisomers (**28*b***:**28*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 60:40) to give **28*b*** as an opaque oil of diastereomers (29 mg, 1.5:1, 55%) and **28*l*** as a white solid (7 mg, 13%).

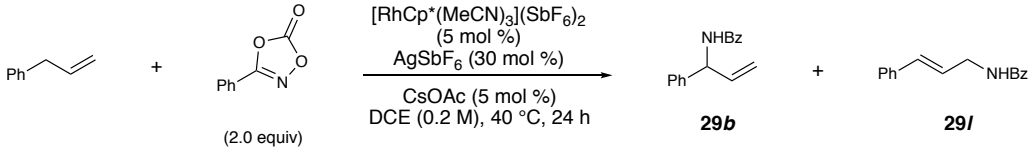
28*b* – 2-phenyl-*N*-(1-phenylallyl)propenamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.38 – 7.30 (m, 12H), 7.29 – 7.26 (m, 2H), 7.25 – 7.21 (m, 2H), 7.21 – 7.18 (m, 2H), 7.10 – 7.05 (m, 2H), 5.96 – 5.82 (m, 2H), 5.65 – 5.52 (m, 4H), 5.18 (d, *J* = 10.3 Hz, 1H), 5.12 – 5.04 (m, 2H), 4.90 (dt, *J* = 17.2, 1.1 Hz, 1H), 3.63 (q, *J* = 7.2 Hz, 1H), 3.57 (q, *J* = 7.1 Hz, 1H), 1.54 (d, *J* = 7.2 Hz, 3H), 1.53 (d, *J* = 7.2 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 173.29, 173.19, 141.57, 141.30, 140.73, 140.61, 137.48, 137.30, 129.13, 129.10, 128.86, 128.74, 127.80, 127.79, 127.78, 127.60, 127.52, 127.50, 127.28, 126.95, 116.06, 115.51, 55.13, 54.94, 47.37, 18.57, 18.56 ppm. **HRMS** (+ NSI): Calculated for $C_{18}H_{20}ON$ $[M+H]^+$ 266.1539**,** observed 266.1540. **IR** (thin film); 3284, 3029, 2927, 1645, 1539, 698 cm^{-1}.

28*l* – *N*-cinnamyl-2-phenylpropanamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.40 – 7.33 (m, 2H), 7.35 – 7.29 (m, 3H), 7.32 – 7.26 (m, 4H), 7.25 – 7.19 (m, 1H), 6.34 (d, *J* = 16.0 Hz, 1H), 6.10 (dt, *J* = 15.8, 6.1 Hz, 1H), 5.42 (bs, 1H), 3.99 (t, *J* = 5.9 Hz, 2H), 3.60 (q, *J* = 7.1 Hz, 1H), 1.56 (d, *J* = 7.1 Hz, 6H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 174.01, 141.5, 136.7, 131.9, 129.2, 128.7, 127.9, 127.8, 127.5, 126.5, 125.7, 47.4, 41.7, 18.7 ppm. **HRMS** (+ NSI): Calculated for $C_{18}H_{20}ON$ $[M+H]^+$ 266.1539**,** observed 266.1540. **IR** (thin film); 3291, 3027, 2924, 2852, 1646, 1539, 697 cm^{-1}.

Amide Regioisomers 29



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.3 mg, 0.012 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.2 mg, 0.0098 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-phenyl-1,4,2-dioxazol-5-one (78 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 65 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL)

and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 16:1 mixture of regioisomers (**29*b***:**29*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **29*b*** as a white solid (14 mg, 30%) and **29*l*** as a white solid (3 mg, 6%).

29*b* – *N*-(1-phenylallyl)benzamide

The title compound exhibited identical ^{1}H NMR data to previous reports.[43]

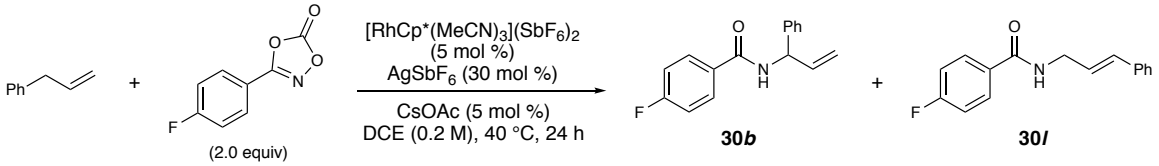
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 – 7.76 (m, 2H), 7.53 – 7.48 (m, 1H), 7.46 – 7.40 (m, 2H), 7.40 – 7.35 (m, 4H), 7.34 – 7.27 (m, 1H), 6.38 (d, *J* = 7.3 Hz, 1H), 6.12 (ddt, *J* = 11.6, 10.0, 5.3 Hz, 1H), 5.86 (ddt, *J* = 6.6, 3.8, 1.6 Hz, 1H), 5.35 – 5.28 (m, 2H) ppm.

29*l* – *N*-cinnamylbenzamide

The title compound exhibited identical ^{1}H NMR data to previous reports.[44]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.1 Hz, 2H), 7.51 (t, *J* = 7.5, 1H), 7.45 (t, *J* = 7.5 Hz, 2H), 7.38 (d, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.5 Hz, 2H), 6.61 (d, *J* = 16.0 Hz, 1H), 6.31 (dt, *J* = 15.9, 6.3 Hz, 1H), 6.23 (bs, 1H), 4.26 (t, *J* = 6.0 Hz, 1H) ppm.

Amide Regioisomer 30



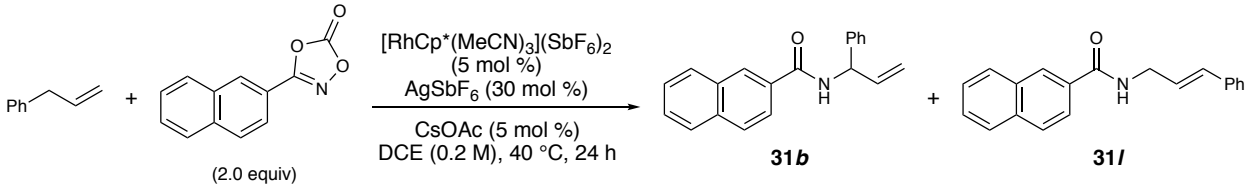
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.2 mg, 0.011mmol), $AgSbF_6$ (23 mg, 0.063 mmol), and

$[RhCp^*(MeCN)_3](SbF_6)_2$ (8.4 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(4-fluorophenyl)-1,4,2-dioxazol-5-one (89 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and Allylbenzene (32μL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 74 mg, 0.41 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 14:1 mixture of regioisomers (**30*b***:**30*l***). The crude residue was filtered through a column of silica gel by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to provide a mixture of amidation products (15 mg). Purification was performed by preparative thin-layer chromatography using Hexanes:EtOAc (85:15, 2 sweeps, then 80:20, 1 sweep) to afford the **30*b*** as a white solid (10 mg, 20% yield).

10*b* – 4-fluoro-*N*-(1-phenylallyl)benzamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.81 (ddd, J = 8.8, 5.1, 2.5 Hz, 2H), 7.40 – 7.35 (m, 4H), 7.33 – 7.30 (m, 1H), 7.11 (t, J = 8.6 Hz, 2H), 6.31 (d, J = 7.0 Hz, 1H), 6.11 (ddd, J = 17.1, 10.4, 5.3 Hz, 1H), 5.83 (dd, J = 7.8, 5.5 Hz, 1H), 5.36 – 5.24 (m, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 165.4, 164.8 (d, $J_{C\text{-}F}$ = 252 Hz), 140.4, 137.1, 130.5 (d, $J_{C\text{-}F}$ = 3.1 Hz), 129.31 (d, $J_{C\text{-}F}$ = 8.9 Hz), 128.9, 127.9, 127.3, 116.3, 115.7 (d, $J_{C\text{-}F}$ = 22.0 Hz), 55.6 ppm. **HRMS** (+ NSI): Calculated for $C_{16}H_{15}NO$ $[M+H]^+$ 256.1132**,** observed 256.1139. **IR** (thin film); 3290, 3064, 2924, 1633, 1603, 1536, 1499, 1234, 699 cm^{-1}.

Amide Regioisomers 31



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.1 mg, 0.0056 mmol), $AgSbF_6$ (10.2 mg, 0.0297 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.5 mg, 0.0054 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. Allylbenzene (32μL, 29 mg, 0.24 mmol) was delivered into a separate oven-dried 4 mL vial with a septum cap under N_2 atmosphere and 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 4 mL vial was weighed 3-(naphthalen-2-yl)-1,4,2-dioxazol-5-one (51 mg, 0.24 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (0.30 mL) was added to the vial of dioxazolone. An aliquot of allylbenzene solution (0.25 mL, 12 mg, 0.10 mmol) and dioxazolone solution (0.25 mL, 43 mg, 0.20 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 12:1 mixture of regioisomers (**31*b***:**31*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **31*b*** as a yellow solid (7 mg, 25%) and a mixture of amidation products containing **31*l*** (5 mg). **31*l*** was further purified by

preparative thin-layer chromatography using Hexanes:EtOAc (80:20, 2 sweeps) to afford **31*l*** as a yellow oil (3 mg, 7%).

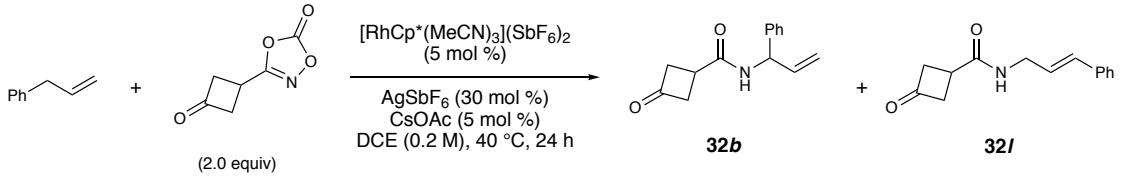
31*b* – *N*-(1-phenylallyl)-2-naphthamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 8.31 (s, 1H), 7.99 – 7.81 (m, 4H), 7.55 (dt, *J* = 15.8, 6.8 Hz, 2H), 7.41 (dt, *J* = 15.0, 7.5 Hz, 4H), 7.32 (t, *J* = 7.1 Hz, 1H), 6.53 (d, *J* = 7.5 Hz, 1H), 6.17 (ddd, *J* = 16.4, 10.3, 5.3 Hz, 1H), 5.93 (t, *J* = 6.8 Hz, 1H), 5.35 (d, *J* = 18.2 Hz, 1H), 5.34 (d, *J* = 9.2 Hz, 1H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 166.7, 140.7, 137.3, 135.0, 132.8, 131.7, 129.1, 129.0, 128.7, 128.0, 127.9, 127.8, 127.6, 127.5, 127.0, 123.7, 116.4, 55.8 ppm. **HRMS** (+ NSI): Calculated for $C_{20}H_{18}NO$ $[M+H]^+$ 288.1383**,** observed 288.1384. **IR** (thin film); 3293, 2923, 1625, 1531, 699 cm^{-1}.

31*l* – *N*-cinnamyl-2-naphthamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 8.33 (s, 1H), 7.96 – 7.82 (m, 5H), 7.56 (dddd, *J* = 16.0, 8.2, 6.9, 1.4 Hz, 2H), 7.40 (d, *J* = 7.2 Hz, 2H), 7.33 (t, *J* = 7.6 Hz, 2H), 6.65 (d, *J* = 15.8 Hz, 1H), 6.35 (dt, *J* = 15.8, 6.4 Hz, 1H), 6.36 (bs, 1H), 4.33 (td, *J* = 6.4, 1.4 Hz, 4H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ167.3, 136.5, 134.8, 132.7, 132.6, 131.7, 128.9, 128.6, 128.5, 127.8, 127.8, 127.7, 127.4, 126.8, 126.4, 125.4, 123.6, 42.3 ppm. **HRMS** (+ NSI): Calculated for $C_{20}H_{18}NO$ $[M+H]^+$ 288.1388**,** observed 288.1382. **IR** (thin film); 3330, 2922, 1652, 1457, 1377 cm^{-1}.

Amide Regioisomers 32



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.4 mg, 0.012 mmol), $AgSbF_6$ (22 mg, 0.060 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.6 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(3-oxocyclobutyl)-1,4,2-dioxazol-5-one (74 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and Allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 62 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 5:1 mixture of regioisomers (**32*b***:**32*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to give **32*b*** as a white solid (36 mg, 67%) and a mixture containing **32*l*** (16 mg, 22%). **32*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (50:50, 1 sweep) to afford **32*l*** as a white solid (5 mg).

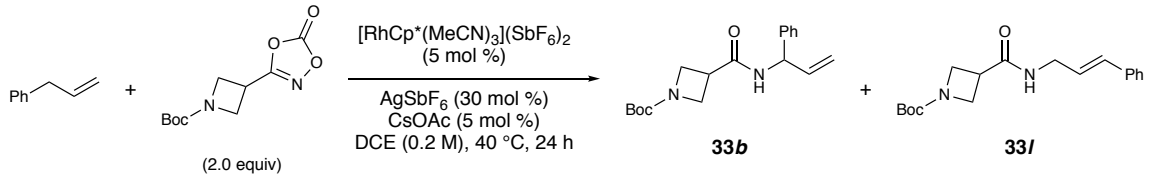
32*b* – 3-oxo-*N*-(1-phenylallyl)cyclobutane-1-carboxamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.36 (t, *J* = 7.4 Hz, 2H), 7.33 – 7.27 (m, 3H), 6.07 (d, *J* = 7.5 Hz, 1H), 6.02 (ddd, *J* = 17.0, 10.3, 5.4 Hz, 1H), 5.66 (dd, *J* = 8.0, 5.7 Hz, 1H), 5.27 (d, *J* = 10.3 Hz, 1H), 5.21 (d, *J* = 17.1 Hz, 1H), 3.47 (dddq, *J* = 20.3, 17.1, 6.5, 3.4 Hz, 2H), 3.17 (ddddd, *J* = 31.3, 17.2, 8.6, 5.6, 2.6 Hz, 2H), 3.03 (tt, *J* = 8.6, 6.7 Hz, 1H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 204.0, 172.2, 140.3, 137.1, 129.0, 128.1, 127.3, 116.3, 55.7, 51.7, 51.6, 28.9 ppm. **HRMS** (+ APCI): Calculated for $C_{14}H_{16}NO_2$ $[M+H]^+$ 230.1176**,** observed 230.1178. **IR** (thin film); 3293, 2924, 1787, 1646, 1537, 701 cm^{-1}.

32*l* – *N*-cinnamyl-3-oxocyclobutane-1-carboxamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.36 (d, *J* = 7.5 Hz, 2H), 7.32 (t, *J* = 7.6 Hz, 2H), 7.29 – 7.23 (m, 1H), 6.55 (d, *J* = 16.0 Hz, 1H), 6.21 (dt, *J* = 15.7, 6.5 Hz, 1H), 5.72 (bs, 1H), 4.11 (t, *J* = 6.1 Hz, 2H), 3.58 – 3.48 (m, 2H), 3.26 – 3.16 (m, 2H), 3.01 (qn, *J* = 7.6 Hz, 1H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 203.9, 172.9, 136.4, 133.1, 128.8, 128.1, 126.5, 125.0, 51.8, 42.2, 29.0 ppm. **HRMS** (+ APCI): Calculated for $C_{14}H_{16}NO_2$ $[M+H]^+$ 230.1176**,** observed 230.1178. **IR** (thin film); 3292, 2925, 1780, 1700, 1636, 691 cm^{-1}.

Amide Regioisomers 33



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.3 mg, 0.012 mmol), $AgSbF_6$ (21 mg, 0.058 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.4 mg, 0.010 mmol). After all solids were weighed, the reaction vial

was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed *tert*-butyl 3-(5-oxo-1,4,2-dioxazol-3-yl)azetidine-1-carboxylate (116 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and Allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 97 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 7:1 mixture of regioisomers (**33*b***:**33*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to give **33*b*** as a white solid (44 mg, 70%) and **33*l*** as a white solid (5 mg, 8%).

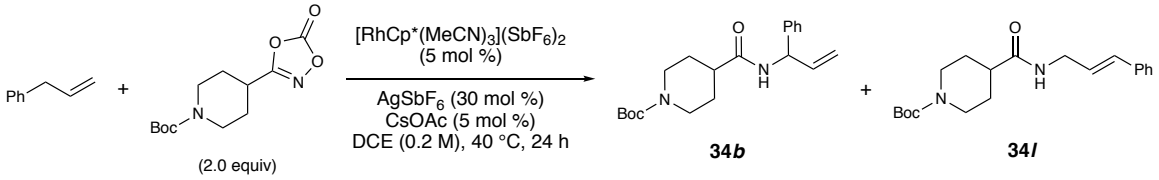
33*b* – *tert*-butyl 3-((1-phenylallyl)carbamoyl)azetidine-1-carboxylate

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 (tt, *J* = 7.1, 1.0 Hz, 2H), 7.31 – 7.27 (m, 3H), 6.01 (ddd, *J* = 17.1, 10.3, 5.4 Hz, 1H), 5.87 (d, *J* = 8.2 Hz, 1H), 5.65 (dd, *J* = 8.0, 5.6 Hz, 1H), 5.26 (ddd, *J* = 10.3, 1.6, 1.0 Hz, 1H), 5.20 (ddd, *J* = 17.1, 1.7, 1.0 Hz, 1H), 4.10 (dd, *J* = 19.0, 6.8 Hz, 2H), 4.03 (dt, *J* = 21.5, 8.6 Hz, 2H), 3.20 (tt, *J* = 8.7, 6.0 Hz, 1H), 1.42 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 170.7, 156.3, 140.3, 137.0, 129.0, 128.0, 127.3, 116.3, 79.9, 55.4, 51.8, 33.6, 28.5 ppm. **HRMS** (- APCI): Calculated for $C_{18}H_{23}N_2O_3$ $[M-H]^-$ 315.1714**,** observed 315.1716. **IR** (thin film); 3289, 2976, 2888, 1733, 1700, 1652, 1365, 1137 cm^{-1}.

33*l* – *tert*-butyl 3-(cinnamylcarbamoyl)azetidine-1-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.35 (d, *J* = 7.2 Hz, 2H), 7.31 (t, *J* = 7.6 Hz, 2H), 7.25 (t, *J* = 7.2 Hz, 1H), 6.53 (d, *J* = 15.8 Hz, 1H), 6.18 (dt, *J* = 15.8, 6.4 Hz, 1H), 5.61 (s, 1H), 4.13 (bs, 2H), 3.19 (qn, *J* = 7.9 Hz, 1H), 1.44 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 171.5, 156.4, 136.4, 133.0, 128.8, 128.1, 126.6, 125.1, 80.0, 52.0, 42.0, 33.7, 28.5 ppm. **HRMS** (- APCI): Calculated for $C_{18}H_{23}N_2O_3$ $[M-H]^-$ 315.1714**,** observed 315.1720. **IR** (thin film); 3030, 2923, 2852, 1700, 1684, 1653, 1394, 1143, 701 cm^{-1}.

Amide Regioisomers 34



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.0 mg, 0.0051 mmol), $AgSbF_6$ (10.3 mg, 0.0300 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.6 mg, 0.0055 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. Allylbenzene (32µL, 12 mg, 0.10 mmol) was delivered into a separate oven-dried 4 mL vial with a septum cap under N_2 atmosphere and 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 4 mL vial was weighed *tert*-butyl 4-(5-oxo-1,4,2-dioxazol-3-yl)piperidine-1-carboxylate (66.5 mg, 0.246 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (0.30 mL) was added to the vial of dioxazolone. An aliquot of allylbenzene solution (0.25 mL, 13 mg, 0.11 mmol) and dioxazolone solution (0.25 mL, 55 mg, 0.20 mmol) was transferred to the vial containing the solid reagents.

The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 10:1 mixture of regioisomers (**34*b***:**34*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **34*b*** as a white solid (24 mg, 70%) and a mixture of products containing **34*l*** (5 mg). **34*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (50:50, 1 sweep) to afford **34*l*** as a white solid (3 mg, 9%).

34*b* – *tert*-butyl 4-((1-phenylallyl)carbamoyl)piperidine-1-carboxylate

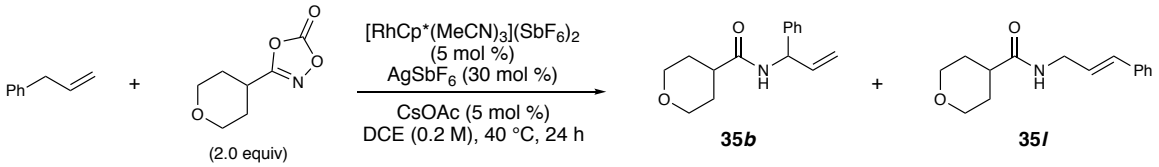
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 (t, *J* = 7.3 Hz, 2H), 7.31 – 7.27 (m, 3H), 5.71 (d, *J* = 7.7 Hz, 1H), 5.68 – 5.54 (m, 1H), 5.26 (d, *J* = 10.3 Hz, 1H), 5.19 (d, *J* = 17.1 Hz, 1H), 4.14 (s, 2H), 2.74 (s, 2H), 2.27 (ddd, *J* = 11.6, 8.4, 3.6 Hz, 1H), 1.83 (t, *J* = 15.5 Hz, 2H), 1.65 (qnd, *J* = 13.5, 4.2 Hz, 2H), 1.45 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 173.4, 154.8, 140.6, 137.3, 129.0, 127.9, 127.3, 116.0, 79.8, 55.0, 43.6, 42.9, 28.9, 28.7, 28.6 ppm. **HRMS** (+ NSI): Calculated for $C_{20}H_{29}O_3N_2$ $[M+H]^+$ 345.2173**,** observed 345.2173. **IR** (thin film); 3292, 2925, 1691, 1647, 1164 cm^{-1}.

34*l* – *tert*-butyl 4-(cinnamylcarbamoyl)piperidine-1-carboxylate

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.31 (td, *J* = 7.0, 6.5, 1.8 Hz, 2H), 7.24 (tt, *J* = 6.6, 1.7 Hz, 1H), 6.52 (d, *J* = 15.8 Hz, 1H), 6.18 (dt, *J* = 15.8, 6.4 Hz, 1H), 5.55 (s, 1H), 4.16 (bs, 2H), 4.05 (td, *J* = 6.4, 1.4 Hz, 2H), 2.75 (bs, 2H), 2.25 (tt, *J* = 11.7, 3.7 Hz, 1H), 1.66 (qd, *J* = 12.1, 4.3 Hz, 2H), 1.46 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 174.23, 154.82, 136.56, 132.65, 128.77, 127.98, 126.52, 125.51, 79.80, 43.63, 41.70, 32.09, 28.86, 28.59, 22.85,

14.28 ppm. **HRMS** (+ NSI): Calculated for $C_{20}H_{29}O_3N_2$ $[M+H]^+$ 345.2173**,** observed 345.2173. **IR** (thin film); 3304, 2923, 1692, 1653, 1167 cm^{-1}.

Amide Regioisomers 35



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.4 mg, 0.012 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.6 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(tetrahydro-2*H*-pyran-4-yl)-1,4,2-dioxazol-5-one (84 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and Allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 70 mg, 0.41 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 9:1 mixture of regioisomers (**35*b***:**35*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give **35*b*** as a white solid (37 mg, 76%) and a mixture of

products containing **35*l*** (8 mg). **35*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (30:70, 1 sweep) to afford **35*l*** as a white solid (5 mg, 10%).

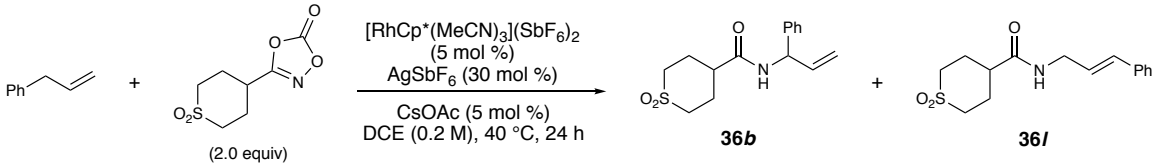
35*b* – *N*-(1-phenylallyl)tetrahydro-2*H*-pyran-4-carboxamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 – 7.32 (m, 2H), 7.32 – 7.26 (m, 3H), 6.02 (ddd, *J* = 17.2, 10.3, 5.2 Hz, 1H), 5.84 (d, *J* = 6.9 Hz, 1H), 5.63 (t, *J* = 6.5 Hz, 1H), 5.26 (dt, *J* = 10.4, 1.2 Hz, 1H), 5.20 (dt, *J* = 17.1, 1.3 Hz, 1H), 4.10 – 3.88 (m, 2H), 3.40 (tdd, *J* = 11.4, 6.0, 2.6 Hz, 2H), 2.40 (td, *J* = 11.2, 5.5 Hz, 1H), 1.89 – 1.71 (m, 4H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 173.83, 140.38, 137.12, 128.95, 127.93, 127.25, 116.19, 67.28, 55.22, 42.31, 29.39, 29.24 ppm. **HRMS** (+ NSI): Calculated for $C_{15}H_{20}NO_2$ $[M+H]^+$ 246.1494**,** observed 246.1487. **IR** (thin film); 3293, 2922, 1684, 667 cm^{-1}.

35*l* – *N*-cinnamyltetrahydro-2*H*-pyran-4-carboxamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.39 – 7.29 (m, 4H), 7.26 – 7.22 (m, 1H), 6.52 (d, *J* = 15.9 Hz, 1H), 6.19 (dt, *J* = 15.9, 6.4 Hz, 1H), 5.57 (bs, 1H), 4.09 – 3.99 (m, 4H), 3.42 (td, *J* = 11.4, 3.1 Hz, 2H), 2.36 (td, *J* = 10.9, 5.1 Hz, 1H), 1.88 – 1.75 (m, 4H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 174.1, 136.6, 132.6, 128.8, 128.0, 126.5, 125.5, 67.4, 42.5, 41.7, 29.5 ppm. **HRMS** (+ NSI): Calculated for $C_{15}H_{20}NO_2$ $[M+H]^+$ 246.1494**,** observed 246.1487. **IR** (thin film); 3330, 2922, 1684, 668 cm^{-1}.

Amide Regioisomers 36



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.3 mg, 0.012 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.3 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. The vial with the solid reagents was opened to air and 3-(1,1-dioxidotetrahydro-2*H*-thiopyran-4-yl)-1,4,2-dioxazol-5-one (86 mg, 0.39 mmol) was added, resealed with septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). The vial with dioxazolone and other solid reagents was refitted with its septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.0 mL) and allylbenzene (27 μL, 24 mg, 0.20 mmol) were added sequentially. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 14:1 mixture of regioisomers (**36*b***:**36*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (50:50 to 0:100) to give **36*b*** as a white solid (55 mg, 95%) and a mixture of products containing **36*l*** (9 mg). **36*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (30:70, 2 sweeps) to afford **36*l*** as a white solid (3 mg, 3%).

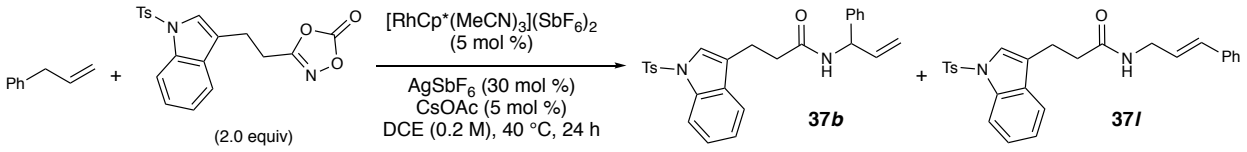
36*b* – *N*-(1-phenylallyl)tetrahydro-2*H*-thiopyran-4-carboxamide 1,1-dioxide

^{1}H NMR (600 MHz, $(CD_3)_2CO$)) δ 7.71 (d, *J* = 7.2 Hz, 1H), 7.33 (d, *J* = 4.4 Hz, 1H), 7.26 (dq, *J* = 8.6, 3.9 Hz, 1H), 6.05 (ddd, *J* = 17.2, 10.3, 5.8 Hz, 1H), 5.62 (ddt, *J* = 8.7, 5.8, 1.5 Hz, 1H), 5.21 (dt, *J* = 17.2, 1.5 Hz, 1H), 5.16 (dt, *J* = 10.3, 1.5 Hz, 1H), 3.23 – 2.96 (m, 4H), 2.72 (tt, *J* = 7.3, 5.7 Hz, 1H), 2.33 – 2.25 (m, 2H), 2.25 – 2.18 (m, 2H) ppm. **^{13}C NMR** (150 MHz, (CD3)2CO) δ 172.94, 142.51, 139.25, 129.31, 128.03, 127.93, 115.60, 55.70, 50.67, 50.64, 28.31. **HRMS** (+ NSI): Calculated for $C_{15}H_{20}O_3NS$ $[M+H]^+$ 294.1158**,** observed 294.1160. **IR** (thin film); 3392 (broad), 3064, 2932, 1701, 1652, 1118, 658 cm^{-1}.

36*l* – *N*-cinnamyltetrahydro-2*H*-thiopyran-4-carboxamide 1,1-dioxide

^{1}H NMR (500 MHz, $(CD_3)_2CO$)) δ 7.43 (bs, 1H) 7.43 – 7.38 (m, 2H), 7.31 (t, *J* = 7.7 Hz, 2H), 7.23 (tt, *J* = 7.9, 1.5 Hz, 1H), 6.55 (d, *J* = 15.9 Hz, 1H), 6.28 (dt, *J* = 15.9, 6.0 Hz, 1H), 3.98 (td, *J* = 5.9, 1.6 Hz, 1H), 3.19 – 3.10 (m, 2H), 3.10 – 3.01 (m, 2H), 2.66 (ddd, *J* = 13.4, 7.8, 5.4 Hz, 1H), 2.29 – 2.25 (m, 4H) ppm. **^{13}C NMR** (150 MHz, $(CD_3)_2CO$)) δ 172.7, 137.0, 130.8, 128.5, 127.4, 126.6, 126.2, 49.7, 40.8, 27.5 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{20}O_3NS$ $[M+H]^+$ 294.1158 observed 294.1161. **IR** (thin film); 3307, 2924, 2853, 1646, 1285, 1121 cm^{-1}.

Amide Regioisomers 37



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.0 mg, 0.010 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.4 mg, 0.010 mmol), 3-(2-(1-tosyl-1*H*-indol-3-yl)ethyl)-1,4,2-

dioxazol-5-one (155 mg, 0.403 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. 1,2-dichloroethane (1.0 mL) and Allylbenzene (27 μL, 24 mg, 0.20 mmol) were sequentially added into the vial of solid reagents and dioxazolone. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 7:1 mixture of regioisomers (**37*b***:**37*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to give a mixture of products consisting of amidation products **37*b***, **37*l***, and **Ene-amide 37** (82 mg, 89% yield, branched:linear:ene-amide, 15:2:1). Analytical samples of **37*b*** and **37*l*** were obtained *via* preparative thin-layer chromatography using Hexanes:EtOAc (50:50, 2 sweeps).

37*b* – *N*-(1-phenylallyl)-3-(1-tosyl-1*H*-indol-3-yl)propanamide

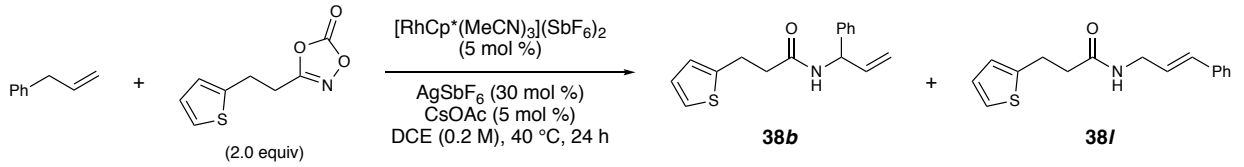
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.97 (d, *J* = 8.3 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 2H), 7.49 (dt, *J* = 7.8, 0.9 Hz, 1H), 7.36 – 7.27 (m, 5H), 7.22 (ddd, *J* = 8.2, 7.2, 1.0 Hz, 1H), 7.21 – 7.17 (m, 4H), 5.93 (ddd, *J* = 17.1, 10.3, 5.2 Hz, 1H), 5.63 – 5.60 (m, 2H), 5.21 (d, *J* = 10.6 Hz, 1H), 5.10 (dd, *J* = 17.1, 0.7 Hz, 1H), 3.05 (tdd, *J* = 7.2, 2.2, 1.0 Hz, 2H), 2.58 (td, *J* = 7.9, 7.4, 1.7 Hz, 2H), 2.32 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 170.9, 144.9, 140.5, 137.2, 135.4, 135.4, 130.7, 129.9, 128.9, 127.8, 127.3, 126.9, 124.9, 123.3, 123.1, 121.9, 119.5, 116.1, 113.8, 55.3, 36.3, 21.7, 21.0 ppm. **HRMS** (+ APCI): Calculated for $C_{27}H_{27}N_2O_3S$ $[M+H]^+$ 459.1737**,** observed 459.1740. **IR** (thin film); 3282, 3060, 2921, 1639, 1362, 1169, 665 cm^{-1}.

37*l* – *N*-cinnamyl-3-(1-tosyl-1*H*-indol-3-yl)propanamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.98 (d, *J* = 8.3 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 2H), 7.51 (d, *J* = 7.7 Hz, 1H), 7.37 (s, 1H), 7.34 – 7.27 (m, 5H), 7.27 – 7.20 (m, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 6.43 (dt,

J = 15.8, 1.4 Hz, 1H), 6.06 (dt, *J* = 15.8, 6.4 Hz, 1H), 5.48 (bs, 1H), 3.99 (td, *J* = 6.3, 1.4 Hz, 2H), 3.05 (td, *J* = 7.6, 1.1 Hz, 2H), 2.56 (t, *J* = 8.4 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 171.7, 144.9, 136.5, 135.4, 132.5, 130.8, 130.0, 128.7, 127.9, 126.9, 126.5, 125.4, 124.9, 123.3, 123.1, 122.0, 119.6, 113.9, 41.8, 36.4, 21.7, 21.1 ppm. **HRMS** (+ APCI): Calculated for $C_{27}H_{27}N_2O_3S$ $[M+H]^+$ 459.1737**,** observed 459.1741. **IR** (thin film); 3292, 3060, 2923, 1642, 1365, 1171, 668 cm^{-1}.

Amide Regioisomers 38



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.9 mg, 0.010 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.7 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(2-(thiophen-2-yl)ethyl)-1,4,2-dioxazol-5-one (95 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and Allylbenzene (32µL, 29 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 24 mg, 0.20 mmol), (dioxazolone – 79 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite

was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 5:1 mixture of regioisomers (**38*b***:**38*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to give **38*b*** as an opaque oil (18 mg, 34%) and a mixture containing **38*l*** (6 mg). **38*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (70:30, 2 sweeps) to afford **38*l*** as a white solid (5 mg, 9%).

38*b* – *N*-(1-phenylallyl)-3-(thiophen-2-yl)propenamide

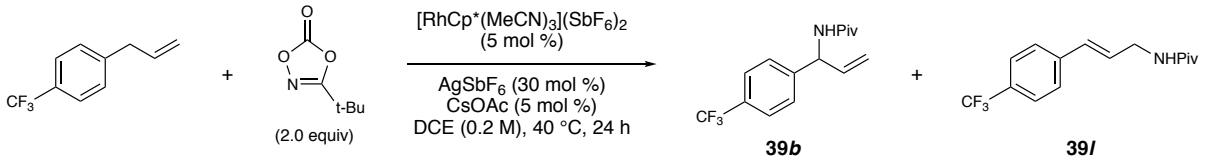
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 – 7.30 (m, 2H), 7.29 – 7.26 (m, 1H), 7.22 – 7.19 (m, 2H), 7.12 (dd, *J* = 5.1, 1.2 Hz, 1H), 6.90 (dd, *J* = 5.1, 3.4 Hz, 1H), 6.82 – 6.78 (m, 1H), 5.95 (ddd, *J* = 17.1, 10.3, 5.0 Hz, 1H), 5.68 – 5.59 (m, 2H), 5.21 (d, *J* = 10.3 Hz, 1H), 5.10 (d, *J* = 17.1 Hz, 1H), 3.21 (td, *J* = 7.4, 1.5 Hz, 2H), 2.57 (td, *J* = 7.4, 0.9 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 170.6, 143.4, 140.6, 137.2, 128.9, 127.8, 127.4, 127.1, 125.6, 123.7, 116.0, 55.2, 38.9, 26.0 ppm. **HRMS** (+ APCI): Calculated for $C_{16}H_{18}NOS$ $[M+H]^+$ 272.1104**,** observed 272.1106. **IR** (thin film); 3281, 3063, 2923, 1637, 1539, 698 cm^{-1}.

38*l* – *N*-cinnamyl-3-(thiophen-2-yl)propenamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.37 – 7.28 (m, 4H), 7.24 (dt, *J* = 7.5, 1.9 Hz, 1H), 7.13 (dd, *J* = 5.1, 1.2 Hz, 1H), 6.91 (dd, *J* = 5.1, 3.4 Hz, 1H), 6.86 – 6.83 (m, 1H), 6.45 (d, *J* = 15.9 Hz, 1H), 6.13 (dt, *J* = 15.8, 6.3 Hz, 1H), 5.50 (bs, 1H), 4.03 (td, *J* = 6.1, 1.4 Hz, 2H), 3.22 (t, *J* = 7.8 Hz, 2H), 2.57 (t, *J* = 7.4 Hz, 2H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 171.4, 143.5, 136.6, 132.3, 128.7, 127.9, 127.1, 126.5, 125.6, 125.0, 123.7, 41.7, 38.9, 29.9, 26.0 ppm. **HRMS** (+ APCI): Calculated for $C_{16}H_{18}NOS$ $[M+H]^+$ 272.1104**,** observed 272.1107. **IR** (thin film); 3294, 3080, 2923, 2852, 1645, 1541, 692 cm^{-1}.

Amidation of Terminal Olefins

Amide Regioisomers 39



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.9 mg, 0.010 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.7 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (125 mg, 0.87 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (2.2 mL) and 1-allyl-4-(trifluoromethyl)benzene (74 µL, 82 mg, 0.44 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 37 mg, 0.20 mmol), (dioxazolone – 57 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 10:1 mixture of regioisomers (**39*b*:39*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to **39*b*** as a white solid (19 mg, 34%) and a mixture containing **39*l*** (7 mg). **39*l*** was further purified by

preparative thin-layer chromatography using Hexanes:EtOAc (70:30, 2 sweeps) to afford **39*l*** as an opaque oil solid (5 mg, 9%).

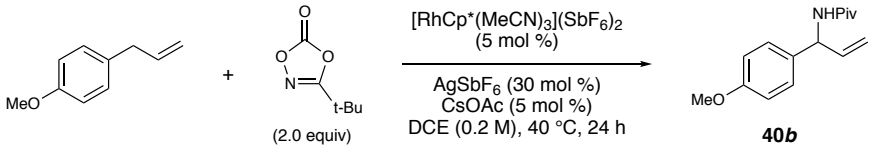
39*b* – *N*-(1-(4-(trifluoromethyl)phenyl)allyl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.60 (d, *J* = 8.1 Hz, 2H), 7.39 (d, *J* = 8.5 Hz, 2H), 6.01 (ddd, *J* = 17.1, 10.4, 5.5 Hz, 1H), 5.90 (d, *J* = 7.9 Hz, 1H), 5.66 (t, *J* = 6.8 Hz, 1H), 5.30 (ddd, *J* = 10.4, 1.6, 0.9 Hz, 1H), 5.19 (ddd, *J* = 17.1, 1.7, 0.9 Hz, 1H), 1.23 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.65, 145.14, 136.99, 130.03(d, J_{C-F} = 32.4 Hz), 127.48, 125.86 (q, J_{C-F} = 4.1 Hz), 117.11, 110.22, 54.76, 38.97, 27.73 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{19}NOF_3$ $[M+H]^+$ 286.1413**,** observed 286.1416. **IR** (thin film); 3336, 2967, 1636, 1521, 1326, 1126, 1080 cm^{-1}.

39*l* – (*E*)-*N*-(3-(4-(trifluoromethyl)phenyl)allyl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.56 (d, *J* = 8.1 Hz, 2H), 7.45 (d, *J* = 8.1 Hz, 2H), 6.53 (d, *J* = 15.9 Hz, 1H), 6.30 (dt, *J* = 15.9, 6.2 Hz, 1H), 5.78 (bs, 1H), 4.07 (td, *J* = 6.0, 1.6 Hz, 2H), 1.24 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 178.5, 140.2, 130.7, 129.8, 129.6, 129.0, 126.9, 125.70 (q, J_{C-F} = 3.8 Hz), 41.6, 39.0, 27.8 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{19}NOF_3$ $[M+H]^+$ 286.1413**,** observed 286.1415. **IR** (thin film); 3335, 2964, 1634, 1520, 1327, 1126 cm^{-1}.

Amide Regioisomer 40



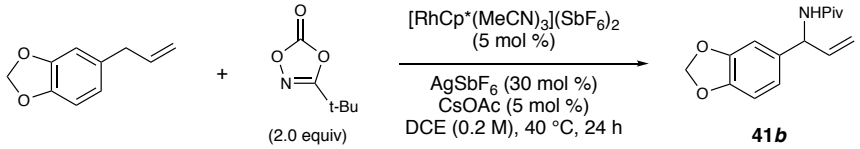
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.011 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.7 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (69 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and 4-allylanisole (38µL, 36 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 30 mg, 0.20 mmol), (dioxazolone – 57 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**40*b***:**40*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to provide **40*b*** as a white solid (36 mg, 73% yield).

40*b* – *N*-(1-(4-methoxyphenyl)allyl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.20 (d, *J* = 8.5 Hz, 2H), 6.87 (d, *J* = 8.7 Hz, 2H), 6.00 (ddd, *J* = 17.1, 10.4, 5.1 Hz, 1H), 5.81 (d, *J* = 7.9 Hz, 1H), 5.56 (dd, *J* = 7.8, 5.4 Hz, 1H), 5.23 (dt, *J* = 10.3,

1.4 Hz, 1H), 5.17 (dt, J = 17.1, 1.4 Hz, 1H), 3.80 (s, 3H), 1.21 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 177.43, 159.15, 137.79, 133.06, 128.46, 115.39, 114.25, 55.44, 55.42, 54.32, 38.88, 27.73 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{22}NO_2$ $[M+H]^+$ 248.1645**,** observed 248.1645. **IR** (thin film); 3330, 2958, 1635, 1510, 829 cm^{-1}.

Amide Regioisomer 23



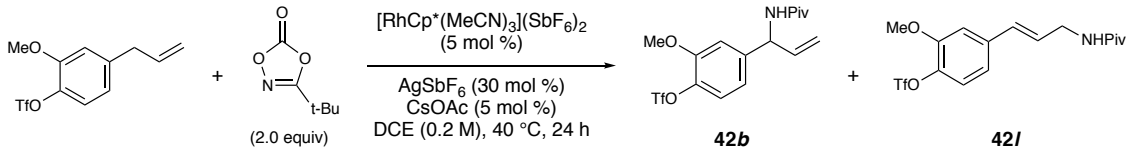
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.9 mg, 0.010 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (68 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and safrole (36 µL, 39 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 33 mg, 0.20 mmol), (dioxazolone – 57 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of

regioisomers (**41*b***:**41*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to provide **41*b*** as a white solid (33 mg, 63% yield).

41*b* – *N*-(1-(benzo[*d*][1,3]dioxol-5-yl)allyl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 6.81 – 6.72 (m, 3H), 5.97 (ddd, *J* = 10.3, 5.1, 1.6 Hz, 1H), 5.95 (s, 2H), 5.79 (d, *J* = 6.7 Hz, 1H), 5.52 (ddt, *J* = 7.0, 5.1, 1.8 Hz, 1H), 5.23 (ddd, *J* = 10.3, 1.7, 1.1 Hz, 1H), 5.17 (ddd, *J* = 17.1, 1.8, 1.1 Hz, 1H), 1.22 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) ^{13}C NMR (151 MHz, $CDCl_3$) δ 177.45, 148.08, 147.14, 137.64, 134.94, 120.57, 115.66, 108.53, 107.79, 101.25, 54.70, 38.89, 27.73 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{20}NO_3$ $[M+H]^+$ 262.1438**,** observed 262.1438. **IR** (thin film); 3336, 2961, 1633, 1485, 1232, 1037, 931, cm^{-1}.

Amide Regioisomers 42



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.011 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (68 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) followed by addition of 1,2-dichloroethane (0.60 mL). In a separate oven-dried 4 mL vial was weighed 4-allyl-2-

methoxyphenyl trifluoromethanesulfonate (71 mg, 0.24 mmol), the vial was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) followed by addition of 1,2-dichloroethane (0.60 mL). An aliquot of the eugenol-triflate solution (0.5 mL, 51 mg, 0.20 mmol) and the dioxazolone solution (0.5 mL, 57 mg, 0.40 mmol) was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 12:1 mixture of regioisomers (**42*b***:**42*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to give **42*b*** as a yellow solid (33 mg, 37%) and a mixture of products containing **42*l*** (6 mg). **42*l*** was further purified by preparative thin-layer chromatography using Hexanes:EtOAc (70:30, 2 sweeps) to afford **42*l*** as a white solid (5 mg, 6%).

42*b* – 2-methoxy-4-(1-pivalamidoallyl)phenyl trifluoromethanesulfonate

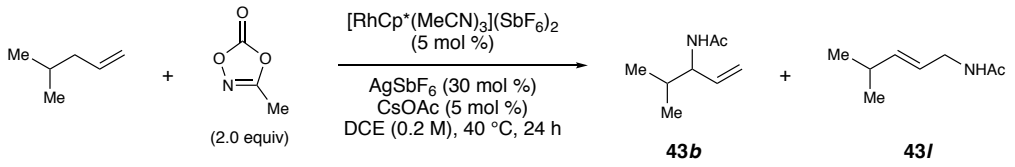
^{1}H NMR (600 MHz, $CDCl_3$): δ 7.17 (d, *J* = 8.3 Hz, 1H), 6.95 (d, *J* = 2.0 Hz, 1H), 6.87 (ddd, *J* = 8.3, 2.0, 0.7 Hz, 1H), 5.99 (ddd, *J* = 17.1, 10.3, 5.5 Hz, 1H), 5.89 (d, *J* = 7.7 Hz, 1H), 5.62 (dd, *J* = 7.4, 5.7 Hz, 1H), 5.30 (ddd, *J* = 10.3, 1.7, 0.9 Hz, 1H), 5.22 (ddd, *J* = 17.1, 1.7, 0.9 Hz, 1H), 3.89 (s, 3H), 1.23 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.66, 151.60, 142.73, 138.06, 136.71, 122.72, 119.14, 118.86 (q, *J* = 320.4 Hz), 117.05, 112.33, 56.32, 54.56, 38.96, 27.71 ppm. **HRMS** (+ APCI): Calculated for $C_{16}H_{21}NO_5F_3S$ $[M+H]^+$ 396.1087**,** observed 396.1089. **IR** (thin film); 3335, 2968, 1639, 1502, 1420, 1203, 878, 615 cm^{-1}.

42*l* – (*E*)-2-methoxy-4-(3-pivalamidoprop-1-en-1-yl)phenyl trifluoromethanesulfonate

^{1}H NMR (600 MHz, $CDCl_3$): 7.15 (d, *J* = 8.4 Hz, 1H), 7.00 (d, *J* = 2.0 Hz, 1H), 6.94 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.47 (d, *J* = 15.8 Hz, 1H), 6.21 (dt, *J* = 15.8, 6.3 Hz, 1H), 5.77 (bs, 1H), 4.04 (td, *J* =

6.1, 1.5 Hz, 3H), 3.93 (s, 3H), 1.24 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ ^{13}C NMR (151 MHz, $CDCl_3$) δ 178.50, 151.58, 138.18, 130.71, 128.39, 122.65, 119.19, 118.88 (q, J = 320.6 Hz) 110.74, 56.35, 41.64, 38.95, 32.09, 27.79, 22.85, 14.28 ppm. **HRMS** (+ APCI): Calculated for $C_{16}H_{21}NO_5F_3S$ $[M+H]^+$ 396.1087**,** observed 396.1089. **IR** (thin film); 3325, 2973z, 1635, 1507, 875, 614 cm^{-1}.

Amide Regioisomers 43



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.0 mg, 0.01 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(methyl)-1,4,2-dioxazol-5-one (49 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and 4-methylpentene (30 µL, 30 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 16 mg, 0.20 mmol), (dioxazolone – 41 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was

concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 2:1 mixture of regioisomers (**43*b***:**43*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to give a mixture of amidation regioisomers **43*b***/**43*l*** as an opaque oil (25 mg, 89% yield, 3:1).

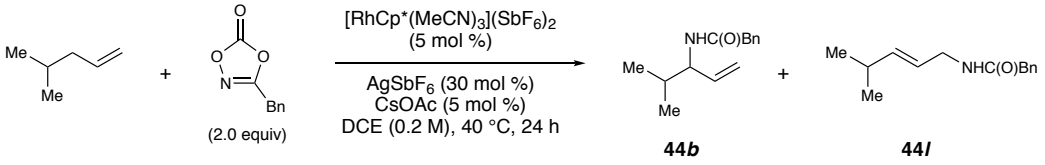
The ^{1}H NMR data has been assigned by analogy from the mixture of **43*b*/43*l***, an asterisk (*) in the listed data is assigned to **43*l***.

43*b* – *N*-(4-methylpent-1-en-3-yl)acetamide

43*l* – (*E*)-*N*-(4-methylpent-2-en-1-yl)acetamide

^{1}H NMR (600 MHz, acetone-d_6): δ *7.10 (bs, 1H), 7.01 (bs, 1H), 5.79 (ddd, *J* = 16.8, 10.5, 6.2 Hz, 1H), *5.55 (dd, *J* = 15.5, 6.6 Hz, 1H), *5.39 (dt, *J* = 15.4, 6.1 Hz, 1H), 5.12 (dt, *J* = 17.2, 1.6 Hz, 1H), 5.05 (dt, *J* = 10.4, 1.3 Hz, 1H), 4.27 (dtt, *J* = 9.2, 6.1, 1.6 Hz, 1H), 1.90 (d, *J* = 1.9 Hz, 3H), *3.71 (t, *J* = 5.4 Hz, 2H), *2.24 (dq, *J* = 13.3, 6.9 Hz, 1H), *1.86 (d, *J* = 1.6 Hz, 2H), *1.76 (dq, *J* = 13.1, 6.7 Hz, 1H), *0.95 (d, *J* = 6.8 Hz, 6H), 0.87 (dd, *J* = 6.8, 2.9 Hz, 6H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.9, 169.6, 141.1, 136.8, 122.7, 115.8, 56.8, 41.8, 32.2, 30.9, 23.6, 23.4, 22.3, 18.8, 18.3 ppm. **HRMS** (+ APCI): Calculated for $C_8H_{16}NO$ $[M+H]^+$ 142.1226**,** observed 142.1226. **IR** (thin film); 3412, 3296, 3084, 2962, 2930, 1654, 1539, 664 cm^{-1}.

Amide Regioisomers 44



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.011 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(benzyl)-1,4,2-dioxazol-5-one (87 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and 4-methylpentene (30 μL, 36 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 16 mg, 0.20 mmol), (dioxazolone – 72 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR observed a 3:1 (**44*b*:44*l***) regiomeric ratio in favor of branched allylic amide **44*b***. The crude residue was purified by flash chromatography on silica gel in a gradient of Hexanes:EtOAc (90:10 -> 0:100) to provide a mixture of amidation regioisomers as an opaque oil (25 mg, 58% yield, 4:1). The ^{1}H NMR data has been assigned by analogy.

(44*b*) *N*-(4-methylpent-1-en-3-yl)-2-phenylacetamide

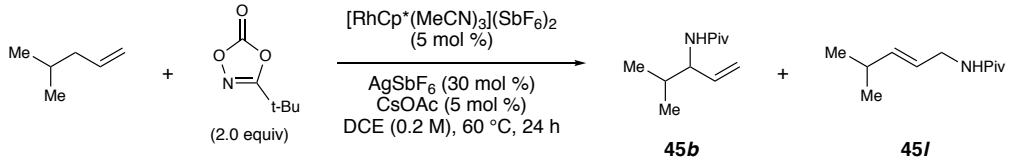
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41 – 7.33 (m, 2H), 7.35 – 7.25 (m, 3H), 5.66 (ddd, *J* = 17.1, 10.5, 5.6 Hz, 1H), 5.25 (bs, 1H), 5.05 (dt, *J* = 10.5, 1.4 Hz, 1H), 4.95 (dt, *J* = 17.2, 1.5 Hz, 1H), 4.33 (dtt, *J* = 8.8, 5.5, 1.5 Hz, 1H), 3.65 (d, *J* = 16.1 Hz, 1H), 3.62 (d, *J* = 10.0 Hz, 1H), 1.71 (dq, *J* = 13.6, 6.8 Hz, 1H), 0.79 (d, *J* = 6.8 Hz, 3H), 0.73 (d, *J* = 6.9 Hz, 3H) ppm.

(44*l*) (*E*)-*N*-(4-methylpent-2-en-1-yl)-2-phenylacetamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41 – 7.33 (m, 2H), 7.35 – 7.25 (m, 3H), 5.45 (ddt, *J* = 15.3, 6.4, 1.3 Hz, 1H), 5.35 (bs, 1H), 5.31 (dtd, *J* = 15.4, 6.0, 1.3 Hz, 1H), 3.78 (t, *J* = 5.8 Hz, 2H), 3.63 (d, *J* = 2.5 Hz, 2H), 3.59 (s, 2H), 2.22 (dt, *J* = 12.9, 6.4 Hz, 1H), 0.93 (d, *J* = 6.8 Hz, 6H) ppm.

^{13}C NMR (150 MHz, $CDCl_3$) δ 170.81, 170.49, 140.63, 136.69, 135.16, 135.07, 129.63, 129.60, 129.56, 129.27, 129.16, 127.63, 127.50, 122.64, 115.41, 56.39, 44.24, 44.04, 41.63, 32.10, 30.81, 22.34, 18.75, 17.90 ppm. **HRMS** (+ APCI): Calculated for $C_{14}H_{20}NO$ $[M+H]^+$ 218.1539**,** observed 218.1539. **IR** (thin film); 3286, 3064, 2960, 2928, 1638, 1540, 695 cm^{-1}.

Amide Regioisomers 25



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.2 mg, 0.012 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.6 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (128 mg, 0.90 mmol). The vial with dioxazolone was

fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (2.2 mL) and 4-methylpentene (56 µL, 37 mg, 0.44 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 17 mg, 0.20 mmol), (dioxazolone – 58 mg, 0.41 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 60 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 7:1 (**45*b***:**45*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to give a mixture of amide regioisomers **45*b*/45*l*** as an opaque oil (18 mg, 50% yield, 10:1).

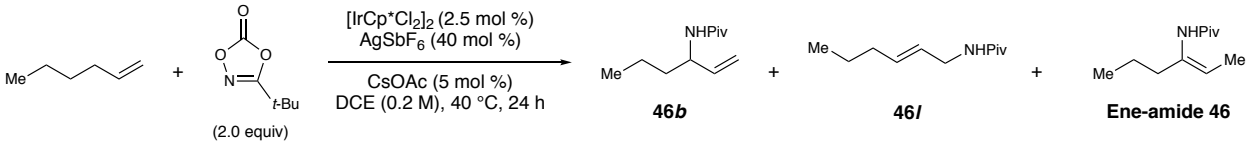
The ^{1}H NMR data has been assigned by analogy from the mixture of **45*b*/45*l***, an asterisk (*) in the listed data is assigned to **45*l***.

45*b* – *N*-(4-methylpent-1-en-3-yl)pivalamide

45*l* – (*E*)-*N*-(4-methylpent-2-en-1-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 5.77 (ddd, *J* = 17.0, 10.6, 5.5 Hz, 1H), *5.60-5.55 (m, 2H), 5.54 (bs, 1H), *5.39 (dtd, *J* = 15.3, 6.2, 1.2 Hz, 1H), 5.13 (dt, *J* = 5.9, 1.5 Hz, 1H), 5.10 (dt, *J* = 12.5, 1.5 Hz, 1H), 4.35 (dtt, *J* = 8.9, 5.5, 1.6 Hz, 1H), *3.80 (t, *J* = 5.8 Hz, 2H), *2.38 – 2.22 (m, 1H), 1.82 (dtd, *J* = 13.6, 6.8, 5.6 Hz, 1H), *1.32 (s, 9H), *1.21 (d, *J* = 10.4 Hz, 6H),1.23 (s, 9H), 0.91 (d, *J* = 6.8 Hz, 3H), 0.89 (d, *J* = 6.9 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 178.19, 177.79, 140.77, 137.27, 123.12, 115.29, 56.00, 41.66, 39.07, 38.80, 32.25, 30.88, 29.66, 27.95, 27.86, 27.77, 22.40, 18.94, 18.52, 18.13 ppm. **HRMS** (+ APCI): Calculated for $C_{11}H_{22}NO$ $[M+H]^+$ 184.1696**,** observed 184.1695. **IR** (thin film); 3327, 2958, 2928, 1631, 1532, cm^{-1}.

Amide Regioisomers 46



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.9 mg, 0.010 mmol), $AgSbF_6$ (28 mg, 0.081 mmol), and $[IrCp^*Cl_2]_2$ (4.1 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (126 mg, 0.88 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) followed by addition of 1,2-dichloroethane (2.2 mL). An aliquot of dioxazolone solution (1.0 mL, 57 mg, 0.40 mmol) and 1-hexene (25 μL, 17 mg, 0.20 mmol) were sequentially added to the vial with solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 12:1 mixture of regioisomers (**46*b*/46*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to provide a mixture of amidation regioisomers consisting of **46*b***, **46*l***, and **Ene-amide 46** as a white solid (34 mg, 79% yield, >20:1:1).

The ^{1}H NMR data has been assigned by analogy from the mixture of **46*b*/46*l***, an asterisk (*) in the listed data is assigned to **46*l*** or **Ene-amide 46**.

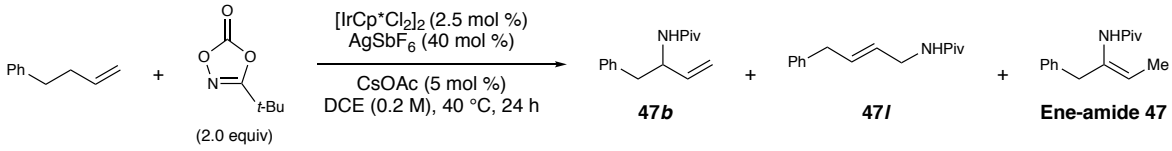
46*b* – *N*-(hex-1-en-3-yl)pivalamide

46*l* – (*E*)-*N*-(hex-2-en-1-yl)pivalamide

Ene-amide 46 – *N*-(hex-2-en-3-yl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 5.76 (ddd, *J* = 17.2, 10.4, 5.4 Hz, 1H), *5.62 – 5.51 (m, 2H), 5.45 (bs, 1H), *5.41 – 5.31 (m, 1H), 5.11 (dt, *J* = 17.2, 1.5 Hz, 1H), 5.07 (dt, *J* = 10.4, 1.4 Hz, 1H), 4.45 (qn, *J* = 7.7 Hz, 1H), *4.29 (p, *J* = 7.2 Hz, 1H), *3.80 (ddd, *J* = 6.2, 5.4, 1.3 Hz, 1H), *2.06 – 1.96 (m, 2H), 1.58 – 1.49 (m, 1H), 1.45 (dddd, *J* = 13.3, 9.6, 7.7, 5.8 Hz, 1H), 1.34 (ddtd, *J* = 14.1, 9.4, 7.4, 3.4 Hz, 2H), 1.20 (s, 9H), *1.19 (s, 9H), 1.18 (s, 9H), 0.92 (t, *J* = 7.3 Hz, 3H), *0.87 (t, *J* = 7.5 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.75, *177.65, *177.44, 138.96, *133.61, *132.27, *131.49, *130.55, *126.15, 114.40, *51.95, 50.76, *46.01, *41.63, 38.87, 37.21, *34.44, 29.83, 27.79, *29.74, *25.38, *22.83, *22.41, *20.92, 19.14, *17.91, *14.25, 14.03 *13.77, *13.63, *10.29 ppm. **HRMS** (+ APCI): Calculated for $C_{11}H_{22}NO$ $[M+H]^+$ 184.1696**,** observed 184.1696. **IR** (thin film); 3334, 2926, 1633, 1529 cm^{-1}.

Amide Regioisomers 47



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.011 mmol), $AgSbF_6$ (28 mg, 0.081 mmol), and $[IrCp^*Cl_2]_2$ (4.2 mg, 0.0052 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (68 mg, 0.48 mmol). The vial with dioxazolone was fit with a septum cap,

immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.2 mL) and 4-phenylbutene (36 μL, 31 mg, 0.24 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 26 mg, 0.20 mmol), (dioxazolone – 57 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**47*b*/47*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to provide a mixture of products consisting of amidation products **47*b***, **47*l***, and **Ene-amide 47** as a white solid (29 mg, 79% yield, >20:1:1).

The ^{1}H NMR data has been assigned by analogy from the mixture of **47*b*/47*l***, an asterisk (*) in the listed data is assigned to **47*l*** or **Ene-amide 47**.

47*b* – *N*-(1-phenylbut-3-en-2-yl)pivalamide

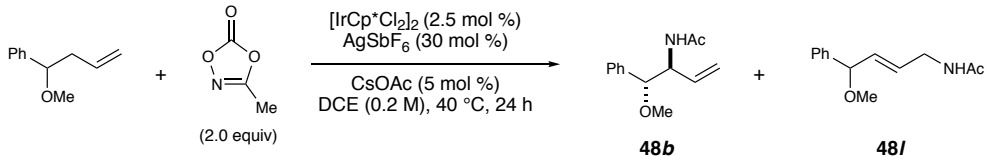
47*l* – (*E*)-*N*-(4-phenylbut-2-en-1-yl)pivalamide

Ene-amide 47 – *N*-(1-phenylbut-2-en-2-yl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.29 (t, *J* = 7.4 Hz, 2H), 7.22 (t, *J* = 7.4 Hz, 1H), 7.17 (d, *J* = 6.9 Hz, 2H), *6.49 (d, *J* = 15.7 Hz, 1H), *6.18 (dd, *J* = 16.0, 5.6 Hz, 1H), 5.85 (ddd, *J* = 17.1, 10.5, 5.2 Hz, 1H), *5.81 – *5.72 (m, 1H), *5.57 – 5.49 (m, 1H), 5.46 (d, *J* = 8.1 Hz, 1H), 5.12 – 5.04 (m, 2H), 4.78 (dtdt, *J* = 8.4, 6.8, 5.2, 1.7 Hz, 1H), *3.85 (td, *J* = 5.9, 1.3 Hz, 2H), *2.92 (dd, *J* = 13.7, 6.6 Hz, 1H), *2.83 (dd, *J* = 13.7, 6.8 Hz, 1H), 1.22 (s, 9H), *1.20 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ *178.26, 177.70, *177.61, *140.13, 138.04, 137.34, *136.86, *131.98, *131.35, *129.74, 129.64, *128.70, *128.66, *128.63, 128.49, *128.31, *127.74, *127.62,

*126.90, 126.76, *126.53, *126.31, 114.90, 51.55, *46.25, *41.42, 41.03, 38.86, *38.81, *29.85, *27.77, 27.65, *27.53, *20.73, *14.27 ppm. **HRMS** (+ APCI): Calculated for $C_{15}H_{22}NO$ $[M+H]^+$ 232.1696**,** observed 232.1696. **IR** (thin film); 3338, 3028, 2958, 1631, 1563, 698 cm^{-1}.

Amidation Regioisomers 48



48b ***48l***

Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (5.1 mg, 0.027 mmol), $AgSbF_6$ (48 mg, 0.140 mmol), and $[IrCp^*Cl_2]_2$ (10 mg, 0.013 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(methyl)-1,4,2-dioxazol-5-one (107 mg, 1.06 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (1.6 mL) was added. In a separate oven-dried 4 mL vial was weighed 4-methoxy-4-phenylbutene (87 mg, 0.54 mmol). The vial with 4-methoxy-4-phenylbutene was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (1.6 mL) was added. An aliquot of the prepared olefin solution (1.5 mL, 81 mg, 0.50 mmol) and dioxazolone solution (1.5 mL, 100 mg, 1.0 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite

was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 8:1(5:1 d.r.) mixture of regioisomers (**48*b*/48*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (70:30 to 0:100) to give **48*b*** as a white solid (64 mg, 5:1 d.r., 58%).

48*b* – *N*-(1-methoxy-1-phenylbut-3-en-2-yl)acetamide

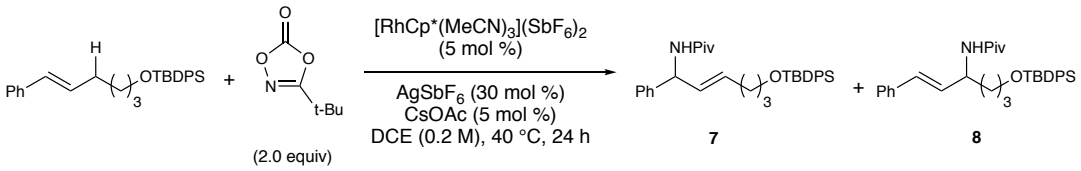
***Anti* 48*b* – ^{1}H NMR** (600 MHz, $CDCl_3$): δ 7.39 – 7.32 (m, 2H), 7.31 – 7.26 (m, 3H), 5.96 (d, *J* = 9.1 Hz, 1H), 5.73 (ddd, *J* = 17.3, 10.5, 5.9 Hz, 1H), 5.08 (dt, *J* = 10.5, 1.5 Hz, 1H), 5.00 (dt, *J* = 17.2, 1.5 Hz, 1H), 4.72 – 4.68 (m, 1H), 4.40 (d, *J* = 3.5 Hz, 1H), 3.33 (s, 3H), 2.04 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.37, 137.79, 132.85, 128.45, 127.98, 127.08, 117.12, 85.43, 57.55, 56.43, 23.64 ppm.

***Syn* 48*b*– ^{1}H NMR** (600 MHz, $CDCl_3$): δ 7.39 – 7.32 (m, 2H), 7.31 – 7.26 (m, 3H), 5.91 (ddd, *J* = 17.5, 10.2, 5.5 Hz, 1H), 5.68 (bs, 1H), 5.20 – 5.15 (m, 2H), 4.72 – 4.68 (m, 1H), 4.32 (d, *J* = 3.9 Hz, 1H), 3.29 (s, 3H), 1.94 (s, 3H), ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.51, 138.27, 135.76, 128.19, 127.11, 116.24, 84.40, 57.77, 56.32, 23.39 ppm.

HRMS (+ NSI): Calculated for $C_{13}H_{17}NO_2Na$ $[M+Na]^+$ 242.1152**,** observed 242.1152.

Allylic C-H Amidation of Disubstituted Olefins

Amide Regioisomers 7 and 8



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.0 mg, 0.010 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.4 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (70.4 mg, 0.491 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) followed by addition of 1,2-dichloroethane (0.60 mL). In a separate oven-dried 4 mL vial, (*E*)-*tert*-butyldiphenyl((6-phenylhex-5-en-1-yl)oxy)silane (100 mg, 0.24 mmol) was weighed, fitted with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) followed by addition of 1,2-dichloroethane (0.60 mL). An aliquot of olefin solution (0.50 mL, 83 mg, 0.20 mmol) and an aliquot of the dioxazolone solution (0.50 mL, 59 mg, 0.40 mmol) were added sequentially to the vial with solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis

of the crude reaction mixture by ^{1}H NMR showed a 16:1 mixture of regioisomers (**7:8**). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 0:100) to give a mixture of **7**/**8** as a sticky opaque oil (80 mg, 78% yield, 12:1).

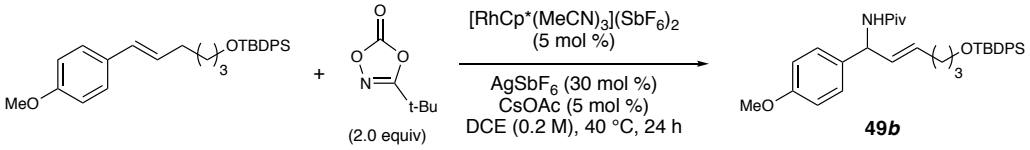
The ^{1}H NMR data has been assigned by analogy from the mixture of **7:8**, an asterisk (*) in the listed data is assigned to **8**.

7 – (*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-phenylhex-2-en-1-yl)pivalamide

8 – (*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-phenylhex-1-en-3-yl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.66 (dd, *J* = 7.9, 1.3 Hz, 4H), 7.42 (t, *J* = 7.3, 1.3 Hz, 2H), 7.37 (t, *J* = 7.2 Hz, 4H), 7.32 (t, *J* = 7.5 Hz, 2H), 7.28 – 7.23 (m, 3H), *6.49 (d, *J* = 15.6 Hz, 1H), *6.11 (dd, *J* = 15.9, 6.2 Hz, 1H), 5.84 (d, *J* = 7.5 Hz, 1H), 5.63 – 5.55 (m, 2H), 5.56 (q, *J* = 4.9, 3.5 Hz, 1H), *4.63 (qn, *J* = 6.4 Hz, 2H), 3.71 (q, *J* = 5.1, 4.6 Hz, 2H), 3.67 (t, *J* = 6.3 Hz, 0H), 2.18 (q, *J* = 9.0, 1.8 Hz, 2H), 1.65 (qn, *J* = 6.8 Hz, 2H), *1.22 (s, 9H), 1.21 (s, 9H), *1.06 (s, 9H), 1.05 (s, 9H). ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ *177.7, 177.3, 141.9, 136.9, 135.7, 134.1, *134.1, *134.0, 132.4, *130.5, *130.3, 129.8, *129.7, 129.6, 128.8, *128.7, *127.8, 127.7, 127.4, 127.0, *126.5, 63.7, 63.4, 54.4, *50.6, *38.9, 38.8, 32.1, *31.7, 29.8, 29.2, 28.7, *27.8, 27.7, *27.1, 27.0, *19.6, 19.4 ppm. **HRMS** (+ APCI): Calculated for $C_{33}H_{44}NO_2Si$ $[M+H]^+$ 514.3136**,** observed 514.3137. **IR** (thin film); 3339, 3037, 2930, 2857, 1635, 1107, 699 cm^{-1}.

Amide Regioisomer 49

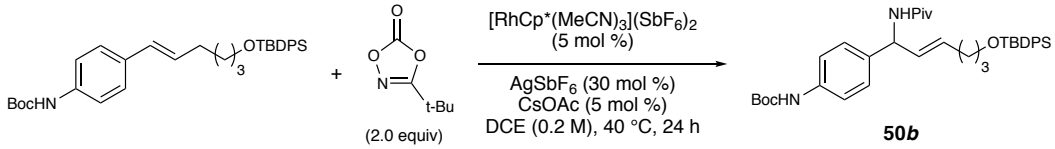


Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.0 mg, 0.0050 mmol), $AgSbF_6$ (10 mg, 0.032 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.5 mg, 0.0054 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (70 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 7 mL vial was weighed (*E*)-*tert*-butyl((6-(4-methoxyphenyl)hex-4-en-1-yl)oxy)diphenylsilane (102 mg, 0.23 mmol) the vial was then fit with a septum cap and vacuum was used to establish and N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.57 mL) was added. An aliquot of the prepared dioxazolone solution (0.25 mL, 57 mg, 0.40 mmol) and olefin (0.25 mL, 44 mg, 0.20 mmol) were sequentially transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a >20:1 mixture of regioisomers (**49*b*:49*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:Et_2O (90:10 to 0:100) to give **49*b*** as a clear sticky oil (47 mg, 86%, >20:1).

49*b* – (*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-methoxyphenyl)hex-2-en-1-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.65 (dd, *J* = 8.0, 1.5 Hz, 4H), 7.42 (tt, *J* = 6.9, 2.4 Hz, 2H), 7.37 (t, *J* = 7.0 Hz, 4H), 7.16 (d, *J* = 8.5 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 2H), 5.77 (d, *J* = 7.9 Hz, 1H), 5.61 – 5.53 (m, 2H), 5.49 (dd, *J* = 7.9, 3.7 Hz, 1H), 3.79 (s, 3H), 3.66 (t, *J* = 6.4 Hz, 2H), 2.21 – 2.13 (m, 2H), 1.65 (qn, *J* = 6.6 Hz, 2H), 1.20 (s, 9H), 1.04 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 177.26, 158.91, 135.68, 134.13, 133.99, 131.95, 129.96, 129.69, 128.19, 127.74, 114.12, 63.37, 55.43, 53.81, 38.83, 32.13, 28.68, 27.74, 27.01, 19.38 ppm. **HRMS** (+ NSI): Calculated for $C_{34}H_{46}NO_3Si$ $[M+H]^+$ 544.3242**,** observed 544.3240.

Amide Regioisomer 31



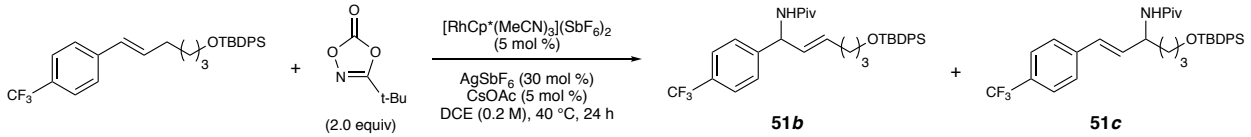
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.010 mmol), $AgSbF_6$ (21 mg, 0.061 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.4 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (125 mg, 0.87 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (1.1 mL) was added. In a separate oven-dried 7 mL vial was weighed *tert*-butyl (*E*)-(4-(6-((*tert*-butyldiphenylsilyl)oxy)hex-2-en-1-yl)phenyl)carbamate (468 mg, 0.88 mmol) the vial was then fit

with a septum cap and vacuum was used to establish and N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (2.2 mL) was added. An aliquot of the prepared dioxazolone solution (0.50 mL, 57 mg, 0.40 mmol) and olefin (0.50 mL, 106 mg, 0.20 mmol) were sequentially transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**50*b***:**50*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:Et_2O (90:10 to 0:100) to give **50*b*** as a white solid (78 mg, 62%, >20:1).

50*b* – *tert*-butyl (*E*)-(4-(6-((*tert*-butyldiphenylsilyl)oxy)-1-pivalamidohex-2-en-1-yl)phenyl)carbamate

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.67 – 7.61 (m, 4H), 7.44 – 7.39 (m, 2H), 7.39 – 7.35 (m, 4H), 7.30 (d, *J* = 8.8 Hz, 2H), 7.15 (d, *J* = 8.5 Hz, 2H), 6.46 (s, 1H), 5.77 (d, *J* = 7.9 Hz, 1H), 5.61 – 5.49 (m, 2H), 5.48 (dd, *J* = 7.9, 3.4 Hz, 1H), 3.65 (t, *J* = 6.3 Hz, 2H), 2.20 – 2.11 (m, 2H), 1.63 (qn, *J* = 6.8 Hz, 2H), 1.52 (s, 9H), 1.19 (s, 9H), 1.04 (s, 9H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$) δ 177.28, 152.87, 137.58, 136.49, 135.68, 134.12, 132.25, 129.76, 129.69, 127.75, 127.69, 118.89, 80.74, 63.36, 53.91, 38.82, 32.11, 28.68, 28.48, 27.72, 27.01, 19.38 ppm. **HRMS** (+ APCI): Calculated for $C_{38}H_{53}N_2O_4Si$ $[M+H]^+$ 629.37691**,** observed 629.3772.

Amide Regioisomers 51

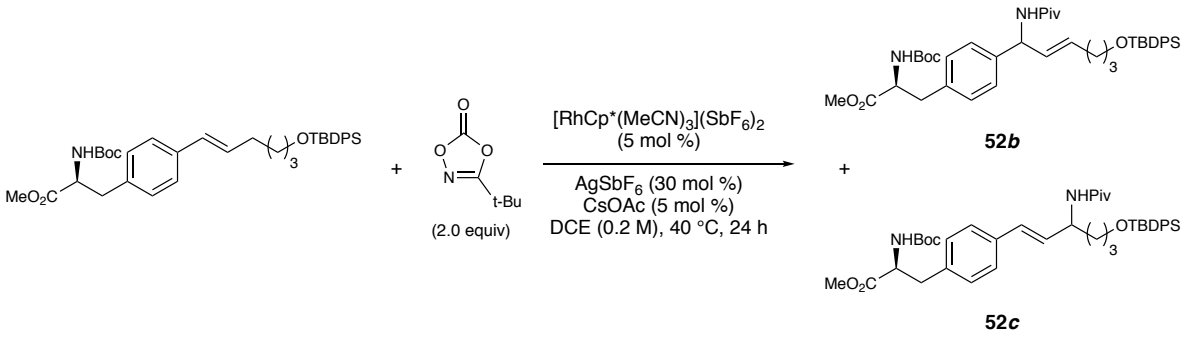


Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (0.9 mg, 0.005 mmol), $AgSbF_6$ (9.5 mg, 0.027 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.2 mg, 0.0050 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (127 mg, 0.887 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (1.1 mL) was added. In a separate oven-dried 7 mL vial was weighed *tert*-butyl (*E*)-*tert*-butyldiphenyl((6-(4-(trifluoromethyl)phenyl)hex-5-en-1-yl)oxy)silane (390 mg, 0.808 mmol) the vial was then fit with a septum cap and vacuum was used to establish and N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (2.0 mL) was added. An aliquot of the prepared dioxazolone solution (0.25 mL, 29 mg, 0.20 mmol) and olefin (0.25 mL, 49 mg, 0.10 mmol) were sequentially transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^1H NMR showed a 9:1 mixture of regioisomers (**51*b***:**51*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (95:5 to 60:40) to give **51*b*** as a clear oil (11 mg, 19%, >20:1).

51*b* – (*E*)-*N*-(6-((*tert*-butyldiphenylsilyl)oxy)-1-(4-(trifluoromethyl)phenyl)hex-2-en-1-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.64 (dd, *J* = 7.9, 1.5 Hz, 4H), 7.55 (d, *J* = 8.2 Hz, 2H), 7.44 – 7.39 (m, 2H), 7.37 (t, *J* = 7.1 Hz, 4H), 7.32 (d, *J* = 8.1 Hz, 2H), 5.87 (d, *J* = 6.4 Hz, 1H), 5.59 – 5.52 (m, 3H), 3.65 (t, *J* = 6.3 Hz, 2H), 2.17 (dt, *J* = 8.3, 6.0 Hz, 2H), 1.64 (dt, *J* = 13.9, 6.5 Hz, 2H), 1.21 (s, 9H), 1.04 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.56, 145.95, 135.68, 134.07, 133.85, 129.78, 129.74, 129.08, 127.80, 127.77, 127.16, 126.70, 125.71 (q, J_{C-F} = 3.2 Hz), 63.24, 54.47, 38.87, 31.93, 28.73, 27.70, 27.00, 19.38 ppm. **HRMS** (+ APCI): Calculated for $C_{34}H_{43}F_3NO_2Si$ $[M+H]^+$ 582.3010**,** observed 582.3013.

Amide Regioisomers 52



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.0 mg, 0.0050 mmol), $AgSbF_6$ (11 mg, 0.032 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (4.5 mg, 0.0050 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (70 mg, 0.49 mmol). The vial with dioxazolone was

fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 7 mL vial was weighed methyl (*S*,*E*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-(6-((*tert*-butyldiphenylsilyl)oxy)hex-1-en-1-yl)phenyl)propanoate (172 mg, 0.28 mmol) the vial was then fit with a septum cap and vacuum was used to establish and N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.70 mL) was added. An aliquot of the prepared dioxazolone solution (0.25 mL, 57 mg, 0.40 mmol) and olefin (0.25 mL, 61 mg, 0.20 mmol) were sequentially transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 16:1(1:1 d.r.) mixture of regioisomers (**52*b*:52*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:Et_2O (90:10 to 0:100) to give **52*b*/52*c*** as a clear sticky oil (50 mg, 71%, 13:1**,** 1:1 d.r.).

The ^{1}H NMR data has been assigned by analogy from the mixture of **52*b*/52*c***, an asterisk (*) in the listed data is assigned to **52*c***.

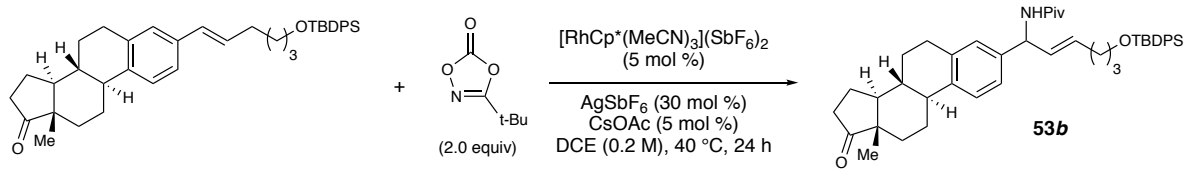
52*b* – methyl (2*S*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-((*E*)-6-((*tert*-butyldiphenylsilyl)oxy)-1-pivalamidohex-2-en-1-yl)phenyl)propanoate

52*c* – methyl (2*S*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-((*E*)-6-((*tert*-butyldiphenylsilyl)oxy)-3-pivalamidohex-1-en-1-yl)phenyl)propanoate

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.65 (dd, *J* = 8.0, 1.4 Hz, 4H), 7.42 (t, *J* = 7.3 Hz, 2H), 7.37 (t, *J* = 7.2 Hz, 4H), 7.16 (d, *J* = 7.9 Hz, 2H), 7.07 (d, *J* = 7.9 Hz, 2H), *6.44 (d, *J* = 15.8 Hz, 1H), *6.07 (dd, *J* = 15.9, 6.3 Hz, 1H), 5.80 (dd, *J* = 7.8, 3.4 Hz, 1H), 5.64 – 5.48 (m, 2H), 4.96 (d, *J* = 8.4 Hz,

1H), 4.58 (d, *J* = 7.8 Hz, 1H), *4.38 (bs, 1H), 3.71 (s, 3H), 3.66 (t, *J* = 6.3 Hz, 2H), 3.10 (dd, *J* = 13.8, 5.3 Hz, 1H), 3.02 (dd, *J* = 12.8, 5.4 Hz, 1H), 2.17 (q, *J* = 7.9 Hz, 2H), 1.65 (qn, *J* = 7.0 Hz, 2H), *1.43 (s, 9H), 1.41 (bs, 9H), *1.21 (s, 9H), 1.20 (s, 9H), *1.05 (s, 9H), 1.04 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ *177.72, 177.32, 172.45, 155.23, *154.50, 140.62, 140.59, *135.91, *135.85, 135.68, *135.52, *135.49, 135.18, *134.37, 134.13, *134.05, *134.02, *133.89, 132.46, *130.19, *130.09, *129.73, 129.70, 129.64, *129.52, *127.91, 127.75, *127.54, 127.19, *126.72, *125.66, 80.10, *63.65, 63.39, *56.06, 54.48, 54.06, 52.38, *50.62, *38.91, 38.86, 38.09, *34.38, 32.12, *31.73, 30.47, *29.16, 28.72, 28.45, 27.80, 27.74, 27.05, 27.02, *22.84, *21.33, 19.38, *14.27 ppm. **HRMS** (+ NSI): Calculated for $C_{42}H_{59}N_2O_6Si$ $[M+H]^+$ 715.4137**,** observed 715.4133.

Amide Regioisomer 53



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.9 mg, 0.010 mmol), $AgSbF_6$ (20 mg, 0.058 mmol), and $[RhCp^*(MeCN)_3](SbF_6)_2$ (8.5 mg, 0.010 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (68 mg, 0.44 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.60 mL) was added. In a separate oven-dried 7 mL vial was weighed (8*R*,9*S*,13*S*,14*S*)-3-((*E*)-6-((*tert*-

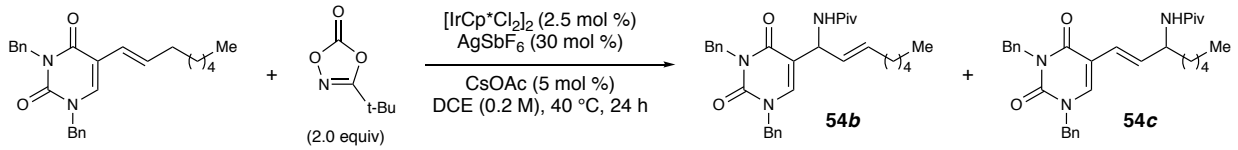
butyldiphenylsilyl)oxy)hex-1-en-1-yl)-13-methyl-6,7,8,9,11,12,13,14,15,16-decahydro-17*H*-cyclopenta[*a*]phenanthren-17-one (241 mg, 0.408 mmol) the vial was then fit with a septum cap and vacuum was used to establish and N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (1.0 mL) was added. An aliquot of the prepared dioxazolone solution (0.50 mL, 57 mg, 0.40 mmol) and olefin (0.50 mL, 120 mg, 0.20 mmol) were sequentially transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**53*b*:53*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 50:50) to give **53*b*/53*c*** as a clear sticky oil (85 mg, 62%, >20:1).

53*b* – *N*-((*E*)-6-((*tert*-butyldiphenylsilyl)oxy)-1-((8*R*,9*S*,13*S*,14*S*)-13-methyl-17-oxo-7,8,9,11,12,13,14,15,16,17-decahydro-6*H*-cyclopenta[*a*]phenanthren-3-yl)hex-2-en-1-yl)pivalamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.66 (dd, *J* = 8.0, 1.4 Hz, 4H), 7.42 (t, *J* = 7.5, 1.3 Hz, 2H), 7.39 – 7.33 (m, 4H), 7.24 (d, *J* = 8.1 Hz, 1H), 7.02 (d, *J* = 8.1 Hz, 1H), 6.97 (s, 1H), 5.83 (d, *J* = 7.9 Hz, 1H), 5.65 – 5.52 (m, 2H), 5.48 (dd, *J* = 7.9, 4.8 Hz, 1H), 3.67 (t, *J* = 6.3 Hz, 2H), 2.88 (dd, *J* = 9.9, 4.5 Hz, 2H), 2.51 (dd, *J* = 19.1, 8.4 Hz, 1H), 2.44 – 2.38 (m, 1H), 2.29 (td, *J* = 10.9, 4.1 Hz, 1H), 2.20 – 2.11 (m, 4H), 2.10 – 2.04 (m, 1H), 2.02 (dddd, *J* = 11.4, 8.4, 5.6, 3.6 Hz, 1H), 1.69 – 1.56 (m, 5H), 1.56 – 1.48 (m, 3H), 1.48 – 1.39 (m, 1H), 1.21 (d, *J* = 1.1 Hz, 9H), 1.04 (s, 9H), 0.91 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 220.94, 177.29, 139.38, 139.35, 138.91, 136.86, 135.67, 134.15, 132.09, 129.93, 129.89, 129.68, 127.74, 127.68, 127.67, 125.80, 124.20, 124.18, 63.40, 54.25, 54.24, 50.66, 48.12, 44.50, 38.85, 38.26, 36.00, 32.13, 31.75, 29.60, 28.71, 27.75,

27.01, 26.64, 25.84, 21.74, 19.38, 13.99 ppm. **HRMS** (+ NSI): Calculated for $C_{45}H_{60}NO_3Si$ $[M+H]^+$ 690.4337**,** observed 690.4346. **IR** (thin film); 3350, 2930, 2857, 1736, 1642, 1106, 729, 701 cm^{-1}.

Amide Regioisomers 54



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.2 mg, 0.011 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[IrCp^*Cl_2]_2$ (4.3 mg, 0.0054 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (128 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle) and 1,2-dichloroethane (1.1 mL) was added to the vial. In a separate oven-dried 4 mL vial was weighed (*E*)-1,3-dibenzyl-5-(oct-1-en-1-yl)pyrimidine-2,4(1*H*,3*H*)-dione (181 mg, 0.45 mmol) and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (1.1 mL) was added to the vial. An aliquot of uracil-olefin solution (0.50 mL, 82 mg, 0.20 mmol) and dioxazolone solution (0.50 ml, 58 mg, 0.40 mmol) were sequentially added to the vial of solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated

under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 1.2:1 mixture of regioisomers (**54*b*:54*c***). The crude residue was filtered through a column of silica gel using a gradient of Hexanes:EtOAc (70:30 to 50:50) to afford a crude orange oil (75 mg). The residue was then purified by preparative thin-layer chromatography on silica gel using Hexanes:EtOAc (25:75, 3 sweeps) to give **54*b*** as a white solid (25 mg) and **54*c*** as a white solid (16 mg). Combined yield of amidation products is 41 mg, 41% yield.

54*b* – (*E*)-*N*-(1-(1,3-dibenzyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-5-yl)oct-2-en-1-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.44 (d, *J* = 6.7 Hz, 2H), 7.40 – 7.33 (m, 3H), 7.33 – 7.25 (m, 5H), 7.17 (s, 1H), 7.07 (d, *J* = 8.8 Hz, 1H), 5.61 (dd, *J* = 15.5, 6.0 Hz, 1H), 5.54 (dt, *J* = 16.0, 6.4 Hz, 1H), 5.16 (dd, *J* = 9.1, 6.4 Hz, 1H), 5.13 (s, 2H), 4.98 (d, *J* = 14.8 Hz, 1H), 4.79 (d, *J* = 14.8 Hz, 1H), 1.97 (q, *J* = 7.0 Hz, 2H), 1.36 – 1.16 (m, 4H), 1.14 (s, 9H), 0.86 (t, *J* = 7.1 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.57, 162.84, 151.33, 139.78, 136.78, 135.24, 133.14, 129.26, 129.03, 128.68, 128.55, 128.31, 128.05, 127.79, 113.38, 52.67, 51.24, 44.63, 38.84, 32.17, 31.45, 28.73, 27.51, 22.59, 14.18 ppm. **HRMS** (+ APCI): Calculated for $C_{31}H_{40}N_3O_3$ $[M+H]^+$ 502.3064**,** observed 502.3069. **IR** (thin film); 3368, 2956, 2926, 1702, 1639, 1450, 697 cm^{-1}.

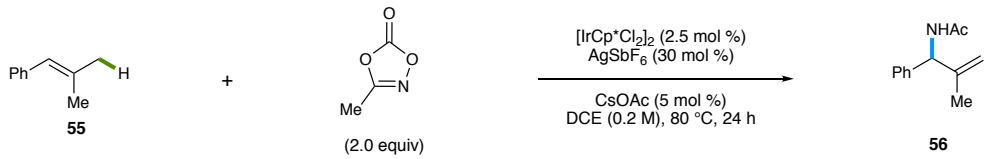
54*c* – (*E*)-*N*-(1-(1,3-dibenzyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-5-yl)oct-1-en-3-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.47 (d, *J* = 6.9 Hz, 2H), 7.40 – 7.33 (m, 3H), 7.33 – 7.20 (m, 5H), 7.13 (s, 1H), 6.45 (dd, *J* = 15.8, 6.9 Hz, 1H), 6.11 (ddd, *J* = 15.7, 1.4, 0.6 Hz, 1H), 5.51 (d, *J* = 8.3 Hz, 1H), 5.17 (s, 2H), 4.96 (d, *J* = 17.6 Hz, 1H), 4.92 (d, *J* = 17.6 Hz, 1H), 4.41 (qn, *J* = 7.4 Hz, 1H), 1.60 – 1.44 (m, 2H), 1.33 – 1.21 (m, 6H), 0.85 (t, *J* = 6.9 Hz, 3H) ppm. **^{13}C NMR** (150 MHz,

$CDCl_3$) δ 177.77, 161.85, 151.14, 139.22, 136.90, 135.33, 132.26, 129.29, 129.03, 128.69, 128.57, 128.13, 127.74, 122.14, 111.50, 52.57, 51.69, 44.91, 38.88, 35.33, 31.66, 27.77, 25.71, 22.64, 14.12 ppm. **HRMS** (+ APCI): Calculated for $C_{31}H_{40}N_3O_3$ $[M+H]^+$ 502.3064**,** observed 502.3072. **IR** (thin film); 3348, 2929, 1702, 1645, 1450, 698 cm^{-1}.

Amidation of Trisubstituted Olefin 55

Amide Regioisomer 56



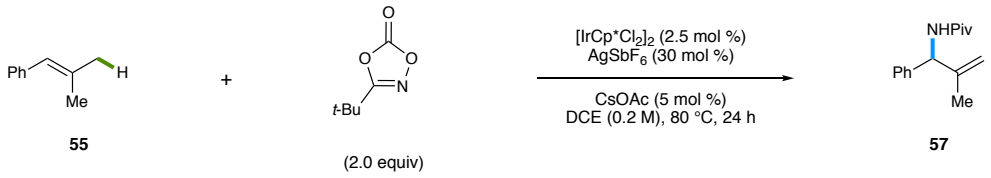
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.2 mg, 0.0051 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[IrCp^*Cl_2]_2$ (4.2 mg, 0.0052 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(methyl)-1,4,2-dioxazol-5-one (46 mg, 0.85 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (1.1 mL) and trisubstituted olefin **55** (32 µL, 29 mg, 0.22 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 26 mg, 0.20 mmol), (dioxazolone – 40 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under

reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**56*b*:56*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to provide **56*b*** amide as a white solid (20 mg, 53%).

56*b* – *N*-(2-methyl-1-phenylallyl)acetamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 (t, *J* = 7.3 Hz, 2H), 7.32 – 7.28 (m, 3H), 5.02 (q, *J* = 1.4 Hz, 1H), 4.99 (d, *J* = 0.8 Hz, 1H), 2.03 (s, 3H), 1.67 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 168.97, 144.08, 140.09, 128.96, 127.93, 127.56, 111.61, 58.60, 23.55, 20.60 ppm. **HRMS** (+ APCI): Calculated for $C_{12}H_{16}NO$ $[M+H]^+$ 190.1226**,** observed 190.1226. **IR** (thin film); 3281, 3062, 2923, 1646, 1540, 699 cm^{-1}.

Amide Regioisomer 57



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (2.1 mg, 0.0051 mmol), $AgSbF_6$ (22 mg, 0.064 mmol), and $[IrCp^*Cl_2]_2$ (4.2 mg, 0.0052 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(*tert*-butyl)-1,4,2-dioxazol-5-one (182 mg, 1.27 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle). 1,2-dichloroethane (3.2 mL) and trisubstituted olefin

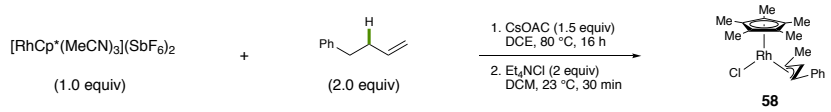
55 (93 μL, 83 mg, 0.62 mmol) were sequentially added into the vial of dioxazolone. An aliquot of the prepared solution [1.0 mL, (olefin – 26 mg, 0.20 mmol), (dioxazolone – 57 mg, 0.40 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a >20:1 mixture of regioisomers (**57*b*:57*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (90:10 to 0:100) to provide **57*b*** as a white solid (7 mg, 15%).

57*b* – *N*-(2-methyl-1-phenylallyl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.34 (t, *J* = 7.3 Hz, 2H), 7.32 – 7.25 (m, 3H), 5.91 (d, *J* = 6.1 Hz, 1H), 5.44 (d, *J* = 7.9 Hz, 1H), 5.00 (q, *J* = 2.0, 1.2 Hz, 1H), 4.94 (d, *J* = 0.9 Hz, 1H), 1.68 (s, 3H), 1.22 (s, 9H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 177.36, 144.44, 140.27, 128.92, 127.82, 127.48, 111.49, 58.33, 38.90, 27.73, 20.58 ppm. **HRMS** (+ APCI): Calculated for $C_{12}H_{22}NO$ $[M+H]^+$ 232.1696**,** observed 232.1696. **IR** (thin film); 3301, 2955, 2871, 1634, 1526, 699 cm^{-1}.

Preparation of MCp*-π-Allyl Complexes

Synthesis of Rh-π-allyl Complex 58

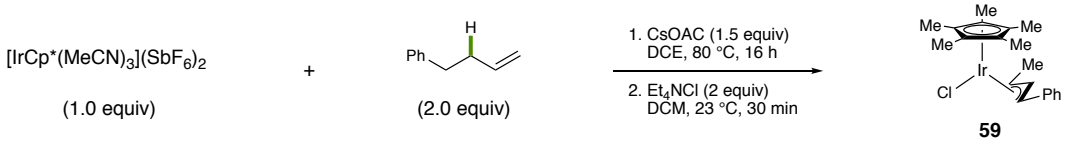


$[RhCp^*(MeCN)_3](SbF_6)_2$ (650 mg, 0.78 mmol) and CsOAc (243 mg, 1.27 mmol) were added to a 100 mL oven-dried round bottom flask charged with a magnetic stir bar in a glove box. The flask was capped with a rubber septum and removed from the glovebox. 1,2-Dichloroethane (30 mL) and 4-phenylbutene (250 μL, 1.66 mmol) were added via syringe, and the reaction was stirred at 80 °C for 16 hours. After 16 hours, the reaction was cooled to room temperature. NEt_4Cl (300 mg, 1.81 mmol) was dissolved in dichloromethane (3 mL) and the resulting solution was added to the reaction via syringe and allowed to stir for 30 min. The reaction mixture was then filtered through celite, eluted with dichloromethane, and concentrated under reduce pressure. The resulting solid was purified by flash column chromatography on silica gel using Hexanes:EtOAc (90:10 to 70:30) to give **58** as a red solid (192 mg, 61%). X-ray quality crystals were obtained by vapor-diffusion in DCM/Pentane.

(58) – Chloro-(η3-1-methyl-3-phenylallyl)-(η5-pentamethylcyclopentadienyl)-rhodium

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.29 (m, 4 H), 7.22-7.16, (m, 1 H), 4.67 (d, J = 10.7, 1 H), 4.55 (td, J_{HH} = 11.1 Hz, J_{Rh-H} = 2.0, 1 H), 3.73 (dq, J = 10.7, 6.3 Hz, 1 H), 1.69 (d, J = 6.3 Hz, 3 H), 1.35 (s, 15 H). **^{13}C NMR (125 MHz, $CDCl_3$)**: δ 139.0, 128.7, 126.1, 126.0, 97.8 (d, J_{Rh-C} = 6.8 Hz), 89.0 (d, J_{Rh-C} = 6.3 Hz), 77.3 (d, J_{Rh-C} = 7.3 Hz), 58.4 (d, J_{Rh-C} = 10.9 Hz), 8.6 ppm. **HRMS (+ ESI)**: Calculated for $C_{20}H_{26}ClRh$ $[M]^+$ 404.0778**,** observed 404.0778.

Synthesis of Ir-π-allyl Complex 59



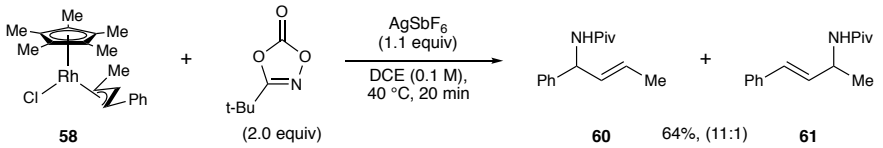
$[IrCp^*(MeCN)_3](SbF_6)_2$ (51 mg, 0.055 mmol) and CsOAc (16 mg, 0.085 mmol) were added to a 7 mL oven-dried vial charged with a magnetic stir bar in a glove box. The vial was sealed with a septum cap and removed from the glovebox. 1,2-Dichloroethane (2.0 mL) and 4-phenylbutene (16 µL, 0.11 mmol) were added via syringe, and the reaction was stirred at 80 °C for 16 h. After 16 hours, the reaction was cooled to room temperature. NEt_4Cl (21 mg, 0.12 mmol) was dissolved in dichloromethane (0.20 mL) and the resulting solution was added to the reaction via syringe and allowed to stir for 30 min. The reaction mixture was then filtered through celite, eluted with dichloromethane, and concentrated under reduce pressure. The crude mixture was purified by by flash column chromatography on silica gel using Hexanes:EtOAc (95:5 to 70:30) to give **59** as a yellow solid (11 mg, 40%).

(59) – Chloro-(η3-1-methyl-3-phenylallyl)-(η5-pentamethylcyclopentadienyl)-iridium

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.30 – 7.21 (m, 4H), 7.14 (t, *J* = 7.0 Hz, 1H), 4.82 (t, *J* = 9.4 Hz, 3H), 4.42 (d, *J* = 9.7 Hz, 1H), 3.33 (dq, *J* = 9.1, 6.1 Hz, 1H), 1.64 (d, *J* = 6.1 Hz, 3H), 1.41 (s, 15H) ppm. **^{13}C NMR (125 MHz, $CDCl_3$)**: δ 141.02, 128.73, 125.88, 125.42, 92.23, 79.84, 61.54, 54.77, 18.38, 8.17 ppm. **HRMS (+ APCI)**: Calculated for $C_{20}H_{26}Ir$ $[M]^+$ 459.1658**,** observed 459.1657.

Stoichiometric Experiments with MCp*-π-Allyl Complexes

Complex 58 with *t*-Bu-Dioxazolone



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was weighed $AgSbF_6$ (9.5 mg, 0.028 mmol). The vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed Rh-complex **58** (32 mg, 0.080 mmol), the vial was fit with a septum cap and vacuum was used to establish a N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.32 mL) was used to dissolve the solid. In a separate oven-dried 4 mL vial was weighed *t*-Bu-dioxazolone (46 mg, 0.32 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.40 mL) was added. Into the vial of $AgSbF_6$ was dispensed an aliquot of Rh-complex solution (0.10 ml, 10 mg, 0.025 mmol) and an aliquot of the dioxazolone solution (0.07 mL, 8.1 mg, 0.056 mmol). The reaction mixture was placed on a heating block set to 40 °C for 20 minutes. TLC was used to confirm full consumption of the Rh-complex, then the reaction mixture was filtered through celite and rinsed with dichloromethane (7 mL). The crude mixture was concentrated under reduced pressure and analysis of the crude mixture by ^1H NMR showed a 11:1 mixture of regioisomers (**60:61**). The crude mixture was purified by preparative thin-layer chromatography using Hexanes:EtOAc (80:20, 1 sweep) to give **60** as a white solid (3.1 mg, 54%) and **61** as a white solid (0.6 mg, 10%).

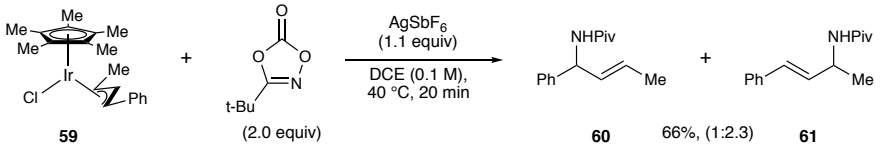
(60) – (*E*)-*N*-(1-phenylbut-2-en-1-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 – 7.29 (m, 2H), 7.29 – 7.23 (m, 3H), 5.87 (d, *J* = 7.9 Hz, 1H), 5.65 – 5.59 (m, 2H), 5.57 – 5.52 (m, 1H), 1.77 – 1.65 (m, 3H), 1.22 (s, 9H) ppm. **^{13}C NMR (125 MHz, $CDCl_3$)**: δ 177.39, 141.87, 130.73, 128.77, 127.66, 127.45, 126.98, 54.54, 38.88, 27.75, 17.95 ppm. **HRMS (+ APCI)**: Calculated for $C_{15}H_{22}NO$ $[M+H]^+$ 232.1696**,** observed 232.1696.

(61) – (*E*)-*N*-(4-phenylbut-3-en-2-yl)pivalamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.36 (d, *J* = 7.2 Hz, 1H), 7.31 (t, *J* = 7.7 Hz, 2H), 7.23 (dt, *J* = 6.6, 1.5 Hz, 1H), 6.49 (dd, *J* = 16.0, 1.4 Hz, 1H), 5.57 (d, *J* = 7.5 Hz, 1H), 4.75 (hd, *J* = 6.8, 1.4 Hz, 1H), 1.33 (d, *J* = 6.8 Hz, 3H), 1.22 (s, 9H) ppm. **^{13}C NMR (150 MHz, $CDCl_3$)**: δ 177.62, 136.84, 131.33, 129.72, 128.71, 127.75, 126.52, 46.24, 38.83, 27.77, 20.72 ppm. **HRMS (- APCI)**: Calculated for $C_{20}H_{26}Ir$ $[M-H]^+$ 230.1550**,** observed 230.1550.

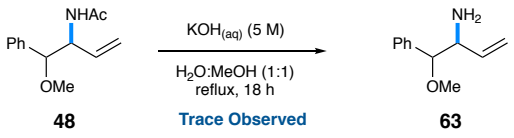
Complex 59 with *t*-Bu-Dioxazolone



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was weighed $AgSbF_6$ (8.2 mg, 0.024 mmol). The vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed Ir-complex **59** (10.4 mg, 0.0210 mmol), the vial was fit with a septum cap and vacuum was used to establish a N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.20 mL) was used to dissolve

the solid. In a separate oven-dried 4 mL vial was weighed *t*-Bu-dioxazolone **2** (46 mg, 0.32 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 minute per cycle), then 1,2-dichloroethane (0.40 mL) was added. Into the vial of $AgSbF_6$ was dispensed an aliquot of Ir-complex solution (0.10 ml, 10 mg, 0.025 mmol) and an aliquot of the dioxazolone solution (0.07 mL, 8.1 mg, 0.056 mmol). The reaction mixture was placed on a heating block set to 40 °C for 20 minutes. TLC was used to confirm full consumption of the Rh-complex, then the reaction mixture was filtered through celite and rinsed with dichloromethane (7 mL). The crude mixture was concentrated under reduced pressure and analysis of the crude reaction mixture by ^{1}H NMR showed 1:2.3 mixture of regioisomers (**60:61**). The crude mixture was purified by preparative thin-layer chromatography using Hexanes:EtOAc (80:20, 1 sweep) to give **60** as a white solid (1.0 mg, 21%) and **61** was isolated as a white solid (2.1 mg, 45%).

Homo-allylic Amidation Reactions and Product Derivatizations

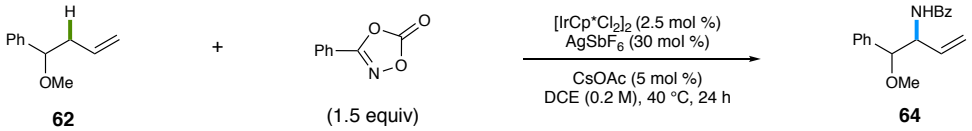


48 Trace Observed **63**

In a 5 mL round-bottom flask equipped with a stir bar was transferred 1,2-amidoether **48*b*** (44 mg, 0.20 mmol, 5.2:1 d.r.) followed by addition of a 6 M solution of KOH (2 mL). The round-bottom flask was fit with a reflux condenser and the reaction was heated to 100 °C for 2 days. After allowing the reaction mixture to cool to room temperature, the reaction was diluted with 5 mL of DI H_2O and DCM (5 x 2 mL) was used to extract from the aqueous layer. The combined organic

extracts were dried with $NaSO_4$, filtered and concentrated under reduced pressure. Analysis of the crude ^1H NMR showed the presence of the unreacted amide and indicative peaks of the deacylated amine. The material was redissolved in DCM (~5 mL) followed by then subjected to 1 M HCl extraction (1 mL x 5 times). The HCl extracts were basified to >12 pH using reagent grade 50 wt% KOH (~ 1 mL) and then DCM was used to extract the amine product from the solution

HRMS (+ APCI): Calculated for $C_{11}H_{16}NO$ $[M+H]^+$ 178.1226**,** observed 178.1226.



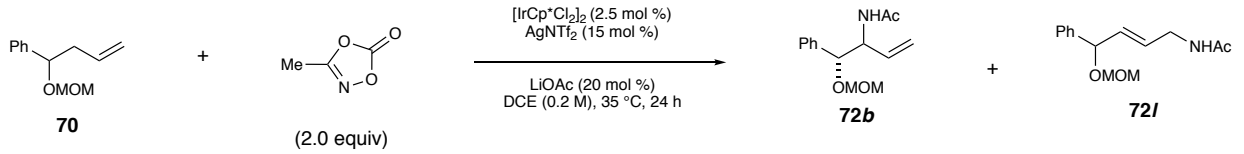
Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added CsOAc (1.2 mg, 0.0063 mmol), $AgSbF_6$ (8.0 mg, 0.023 mmol), and $[IrCp^*Cl_2]_2$ (2.0 mg, 0.0025 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(phenyl)-1,4,2-dioxazol-5-one (80 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle) followed by addition of 1,2-dichloroethane (0.6 mL). In a separate oven-dried 4 mL vial was weighed 4-methoxy-4-phenylbutene (40 mg, 0.25 mmol). The vial with 4-methoxy-4-phenylbutene was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle), then 1,2-dichloroethane (0.6 mL) was added. An aliquot of the prepared olefin solution (0.25 mL, 17 mg, 0.10 mmol) and dioxazolone solution (0.5 mL, 33 mg, 0.20 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was

filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 12:1 (6:1 d.r.) mixture of regioisomers (**64*b*:64*l***). The crude residue was filtered over a column of silica gel using a gradient of Hexanes:EtOAc (95:5 to 50:50) to give a mixture of amidation products (11 mg). The mixture of amidation products was further purified by preparative thin-layer chromatography on silica gel using Hexanes:EtOAc (2 x sweeps 80:20, then 1 x sweep 25:75) to give the intended 1,2-amidoether benzamide amidation diastereomers as a white solid (8.0 mg, 28%).

*Signals unambiguously corresponds to the ***syn-diastereomer***

(64) - *N*-(1-methoxy-1-phenylbut-3-en-2-yl)benzamide

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.81 (dd, *J* = 8.3, 1.3 Hz, 2H), * 7.74 – 7.68 (m, 2H), 7.56 – 7.49 (m, 2H), 7.50 – 7.43 (m, 3H), 7.43 – 7.36 (m, 4H), 7.38 – 7.28 (m, 7H), 6.63 (d, *J* = 9.0 Hz, 1H), *6.37 (d, *J* = 7.8 Hz, 1H), *6.02 (ddd, *J* = 17.2, 10.5, 5.5 Hz, 1H), 5.83 (ddd, *J* = 17.2, 10.5, 5.8 Hz, 1H), * 5.28 – 5.20 (m, 2H), 5.14 (dt, *J* = 10.5, 1.4 Hz, 1H), 5.10 (dt, *J* = 17.2, 1.4 Hz, 1H), 4.94 (dddd, *J* = 10.9, 5.4, 3.4, 1.6 Hz, 1H,*1H overlap), 4.53 (d, *J* = 3.6 Hz, 1H), *4.45 (d, *J* = 3.8 Hz, 1H), 3.37 (s, 3H), *3.30 (s, 3H) ppm.



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added LiOAc (3.3 mg, 0.050 mmol), $AgNTf_2$ (15 mg, 0.038 mmol), and $[IrCp^*Cl_2]_2$ (5.6 mg, 0.0070 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(methyl)-1,4,2-dioxazol-5-one (47 mg, 0.49 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle) followed by addition of 1,2-dichloroethane (0.30 mL). In a separate oven-dried 4 mL vial was weighed (1-(methoxymethoxy)but-3-en-1-yl)benzene (58.7 mg, 0.305 mmol) and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle), then 1,2-dichloroethane (0.30 mL) was added. An aliquot of the prepared olefin solution (0.25 mL, 49 mg, 0.25 mmol) and dioxazolone solution (0.25 mL, 39 mg, 0.39 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 35 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 3.5:1 (2.8:1 d.r.) mixture of regioisomers (**72*b***/**72*c***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (70:30 to 0:100) to give **72*b*** as a white solid (26 mg, 2.3:1 d.r. 55%) and **72*l*** as an opaque oil (9.0 mg, 13%).

72*b* - *N*-(1-(methoxymethoxy)-1-phenylbut-3-en-2-yl)acetamide

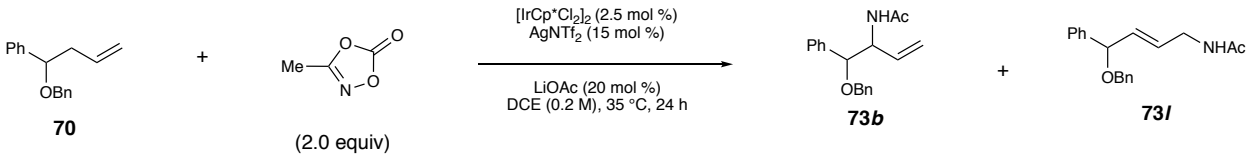
***Anti* 72*b*– ^{1}H NMR** (600 MHz, $CDCl_3$): δ 7.37 – 7.26 (m, 5H), 6.10 (d, J = 9.0 Hz, 1H), 5.77 (ddd, J = 17.2, 10.5, 5.8 Hz, 1H), 5.12 (dt, J = 10.5, 1.4 Hz, 1H), 5.04 (dt, J = 17.2, 1.5 Hz, 1H), 4.80

(d, *J* = 3.7 Hz, 1H), 4.76 (tdq, *J* = 7.5, 3.8, 1.7 Hz, 1H), 4.67 (d, *J* = 6.6 Hz, 1H), 4.59 (d, *J* = 6.7 Hz, 1H), 3.42 (s, 3H), 2.02 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.47, 138.04, 133.05, 128.42, 128.04, 127.08, 117.29, 95.60, 80.97, 56.24, 56.09, 23.56 ppm.

***Syn* 72b – ^{1}H NMR** (600 MHz, $CDCl_3$): δ 7.37 – 7.26 (m, 5H), 5.91 (ddd, *J* = 17.3, 10.5, 4.8 Hz, 1H), 5.78 (d, *J* = 10.2 Hz, 1H), 5.23 – 5.16 (m, 2H), 4.81 – 4.74 (m, 1H), 4.59 (d, *J* = 6.7 Hz, 1H), 4.56 (d, *J* = 6.7 Hz, 1H), 3.37 (s, 3H), 1.95 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.64, 138.28, 135.80, 128.48, 128.27, 128.04, 127.20, 116.26, 94.70, 78.88, 56.38, 56.10, 23.33 ppm.

73*l* - (*E*)-*N*-(4-(methoxymethoxy)-4-phenylbut-2-en-1-yl)acetamide

^{1}H NMR (600 MHz, $CDCl_3$): δ 7.38 – 7.32 (m, 4H), 7.31 – 7.28 (m, 1H), 5.75 (td, *J* = 3.1, 1.4 Hz, 2H), 5.47 (bs, 1H), 5.12 – 5.07 (m, 1H), 4.68 (d, *J* = 6.7 Hz, 1H), 4.59 (d, *J* = 6.7 Hz, 0H), 3.90 (dt, *J* = 5.7, 3.5 Hz, 2H), 3.37 (s, 3H), 1.98 (s, 3H) ppm.



Inside an N_2 atmosphere glovebox, to an oven-dried 4 mL vial equipped with a magnetic stir bar was added LiOAc (13.2 mg, 0.200 mmol), $AgSbF_6$ (58 mg, 0.169 mmol), and $[IrCp^*Cl_2]_2$ (20 mg, 0.025 mmol). After all solids were weighed, the reaction vial was fit with a septum cap and removed from the glovebox. In a separate oven-dried 4 mL vial was weighed 3-(methyl)-1,4,2-dioxazol-5-one (180 mg, 1.06 mmol). The vial with dioxazolone was fit with a septum cap, immersed in a dry-ice/acetone bath to freeze the oil, and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle) and 1,2-dichloroethane (1.1 mL) was added. In a separate oven-dried 4 mL vial was weighed (1-(benzyloxy)but-3-en-1-yl)benzene (266 mg, 0.54 mmol). The vial

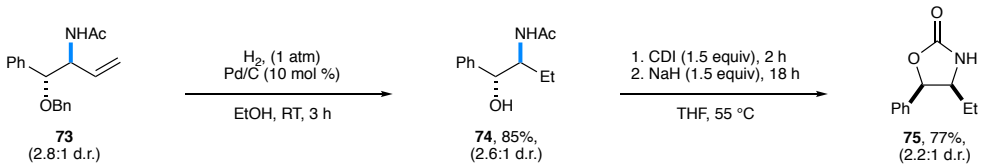
with 4-methoxy-4-phenylbutene was fit with a septum cap and vacuum was used to establish an N_2 atmosphere (3 cycles, 1 min/cycle) and 1,2-dichloroethane (1.1 mL) was added. An aliquot of the prepared olefin solution (1.0 mL, 81 mg, 0.50 mmol) and dioxazolone solution (1.0 mL, 100 mg, 1.0 mmol)] was transferred to the vial containing the solid reagents. The resulting mixture was heated to 40 °C and stirred for 24 hours. After cooling to room temperature, the crude mixture was filtered over celite. The celite was rinsed with EtOAc (7 mL) and the combined filtrate was concentrated under reduced pressure. Analysis of the crude reaction mixture by ^{1}H NMR showed a 3.8:1 (2.8:1 d.r.) mixture of regioisomers (**73*b***/**73*l***). The crude residue was purified by flash chromatography on silica gel using a gradient of Hexanes:EtOAc (50:50 to 0:100) to give **73*b*** as a white solid (92.9 mg, 2.7:1 d.r., 49%) and **73*l*** as an opaque oil (29.3 mg, 16%).

73*b* - *N*-(1-(benzyloxy)-1-phenylbut-3-en-2-yl)acetamide

***Anti* 73*b* – ^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.42 – 7.27 (m, 5H), 5.78 (ddd, *J* = 17.2, 10.5, 6.0 Hz, 1H), 5.81 (d, *J* = 8.6, 1H), 5.09 (dt, *J* = 10.5, 1.5 Hz, 1H), 4.99 (dt, *J* = 17.2, 1.5 Hz, 1H), 4.70 – 4.66 (m, 1H), 4.67 (d, *J* = 12.3 Hz, 1H), 4.59 (d, *J* = 3.5 Hz, 1H), 4.27 (d, *J* = 12.1 Hz, 1H), 1.93 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.11, 138.03, 137.91, 135.78, 132.71, 128.56, 128.38, 127.92, 127.91, 127.87, 127.07, 127.06, 117.25, 82.36, 71.05, 56.35, 23.39 ppm.

***Syn* 73*b* – ^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.42 – 7.27 (m, 5H), 5.92 (ddd, *J* = 17.5, 10.2, 5.3 Hz, 1H), 5.70 (d, *J* = 9.4 Hz, 1H), 5.21 – 5.14 (m, 2H), 4.74 (dtd, *J* = 9.0, 3.8, 1.9 Hz, 1H), 4.56 (d, *J* = 11.8 Hz, 1H), 4.52 (d, *J* = 3.8 Hz, 1H), 4.32 (d, *J* = 11.7 Hz, 1H), 1.91 (s, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 169.35, 138.30, 137.82, 128.42, 128.41, 128.14, 127.90, 127.86, 116.06, 81.85, 71.10, 56.33, 23.26 ppm.

HRMS (+ NSI): Calculated for $C_{19}H_{22}NO_2$ $[M-H]^+$ 296.1645**,** observed 296.1647



In a 4 mL vial was transferred benzyl ether amidation product **73*b*** (92 mg, 0.31 mmol). Then Pd/C (75 mg, 5 wt%, 0.033 mmol) was weighed into the vial followed by addition of a stir bar and sealed with a septa cap. The vial was then subjected to vacuum and and the atmosphere was exchanged to establish an H_2 atmosphere with a balloon (3 x cycles, 1 min/cycle). Then wet ethanol (1.5 mL) was added to the reaction vial and the contents were stirred for 3 h. At this time the reaction was opened to air and filtered through a plug of celite, the celite was rinsed with EtOAc (~ 7 mL) and the reaction mixture was concentrated under reduced pressure. The crude residue was by flash column chromatography on silica gel using a gradient of Hexanes:EtOAc (70:30 to 0:100) to give the intended 1,2-amidoalcohol **74** as a white solid (54.9 mg, 85%, 2.6:1 d.r.).

***(74)* - *N*-(1-hydroxy-1-phenylbutan-2-yl)acetamide**

***Anti* – (74) ^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.37 – 7.30 (m, 4H), 7.29 – 7.26 (m, 1H), 5.44 (d, J = 8.5 Hz, 3H), 4.88 (d, J = 2.8 Hz, 1H), 4.20 – 4.11 (m, 1H), 2.02 (s, 3H), 1.55 – 1.43 (m, 2H), 0.90 (t, J = 7.4 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 171.90, 140.76, 128.29, 127.69, 126.58, 76.80, 57.51, 23.36, 22.53, 11.03 ppm.

***Syn* – (74) ^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.37 – 7.30 (m, 4H), 7.29 – 7.26 (m, 1H), 5.67 (d, J = 8.8 Hz, 1H), 4.71 (d, J = 4.9 Hz, 1H), 3.95 (tt, J = 9.3, 4.9 Hz, 1H), 1.94 (s, 3H), 1.64 (dqd, J = 15.1, 7.5, 5.1 Hz, 1H), 1.29 – 1.20 (m, 1H), 0.93 (t, J = 7.4 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 171.31, 142.09, 128.48, 127.84, 126.28, 75.96, 57.58, 24.65, 23.39, 10.81 ppm.

HRMS (+ APCI): Calculated for $C_{12}H_{18}NO_2$ $[M+H]^+$ 208.1332**,** observed 208.1334.

In an oven-dried 4 mL vial equipped with a stir-bar was weighed of 1,2-amidoalcohol **74** (4.5 mg, 0.022 mmol, 2.6:1 d.r.). The vial was sealed with a septa cap and vacuum was used to

establish an N_2 atmosphere (3 cycles, 1 min/cycle). Anhydrous THF (0.20 mL) was added to the vial followed by quick addition of solid 1,1´-carbonyldiimidazole (5.3 mg, 0.033 mmol, 1.5 equiv.) by opening the cap under positive pressure of N_2 and resealing the system. The resulting solution was stirred at 55 °C for 2 h. Then NaH (60 % in mineral oil, 1 mg, 0.03 mmol, 1.3 equiv.) was added as a solid by opening the cap under positive pressure of N_2 and resealing the system. The reaction mixture was then stirred at 55 °C 18 h. The reaction was quenched with sat. aq. NH_4Cl (1 mL) and diluted with EtOAc (1 mL). The organic layer was transferred, and the aqueous layer was extracted with ethyl acetate (3 x 1 mL). The organic extracts were washed with brine, dried over MgSO4, filtered and concentrated under reduced pressure. The crude reaction mixture was analyzed by ^{1}H NMR and determined a preservation of diastereomer ratio (2.2:1). The crude material was purified by preparative thin-layer chromatography on silica gel (Hexanes:EtOAc, 30:70, 1 x sweep) and the mixture of oxazolidinone diastereomers were isolated as a white solid (3.2 mg, 77 %, 2.2:1).

***Cis* 75 – ^{1}H NMR** (600 MHz, $CDCl_3$) 7.43 – 7.34 (m, 3H), 7.31 (d, J = 8.6 Hz, 2H), 5.72 (d, J = 8.0 Hz, 1H), 5.66 (s, 1H), 5.13 (d, J = 6.3 Hz, 1H), 3.94 (td, J = 9.1, 4.5 Hz, 1H), 1.14 – 1.02 (m, 2H), 0.78 (t, J = 7.4 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 159.30, 138.58, 129.06, 128.63, 126.32, 81.22, 58.54, 24.88, 10.45 ppm.

***trans* 75 – ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.43 – 7.34 (m, 3H), 7.31 (d, J = 6.8 Hz, 2H), 5.60 (s, 1H), 3.67 (q, J = 6.3, 5.6 Hz, 1H), 1.83 – 1.73 (m, 1H), 1.70 (dt, J = 13.8, 7.4 Hz, 1H), 1.01 (t, J = 7.5 Hz, 3H) ppm. **^{13}C NMR** (150 MHz, $CDCl_3$) δ 158.91, 138.58, 129.09, 128.71, 125.99, 83.45, 62.10, 27.97, 9.87 ppm.

HRMS (+ NSI): Calculated for $C_{11}H_{14}NO_2$ $[M+H]^+$ 192.1019**,** observed 192.1020.

X-Ray Crystallography Data

X-Ray Crystallography Structure Experimental Data for Complex 58

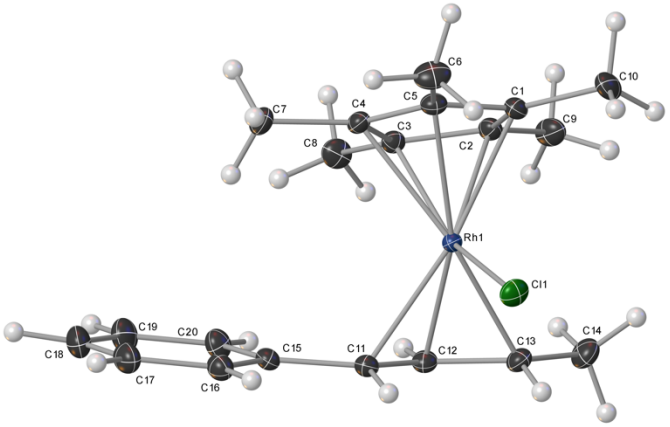


Figure S1. Crystal Structure of Rh-π-Allyl Complex **58**.

Experimental. Single orange block-shaped crystals of **Rh-p-allyl-Cl** were recrystallised from a mixture of DCM and pentane by vapor diffusion. A suitable crystal 0.37×0.32×0.28 mm^3 was selected and mounted on a loop with paratone oil on an XtaLAB Synergy, Dualflex, HyPix diffractometer. The crystal was kept at a steady T = 100.02(10) K during data collection. The structure was solved with the **ShelXT** (Sheldrick, 2015) structure solution program using the Intrinsic Phasing solution method and by using **Olex2** (Dolomanov et al., 2009) as the graphical interface. The model was refined with version 2018/3 of **ShelXL** (Sheldrick, 2015) using Least Squares minimisation.

Crystal Data. $C_{20}H_{26}ClRh$, M_r = 404.77, monoclinic, $P2_1/c$ (No. 14), a = 7.4511(10) Å, b = 12.8249(10) Å, c = 18.6937(10) Å, □ = 94.110(10)°, □ = □ = 90°, V = 1781.8(3) $Å^3$, T = 100.02(10) K, Z = 4, Z' = 1, □(MoK□) = 1.103 mm^{-1}, 119524 reflections measured, 15581 unique (R_{int} = 0.0215) which were used in all calculations. The final wR_2 was 0.0482 (all data) and R_1 was 0.0201 (I > 2σ(I))

Table S1. Relevant Crystal Data for Rh-π-allyl Complex **58**.

Compound	**Rh-p-allyl-Cl**
Formula	$C_{20}H_{26}ClRh$
$D_{calc.}$/ g cm^{-3}	1.509
m/mm^{-1}	1.103
Formula Weight	404.77
Colour	orange
Shape	block
Size/mm^3	0.37×0.32×0.28
T/K	100.02(10)
Crystal System	monoclinic
Space Group	$P2_1/c$
a/Å	7.4511(10)
b/Å	12.8249(10)
c/Å	18.6937(10)
a/°	90
b/°	94.110(10)
g/°	90
V/Å^3	1781.8(3)
Z	4
Z'	1
Wavelength/Å	0.71073
Radiation type	MoK_a

$Q_{min}/^{\circ}$	1.927
$Q_{max}/^{\circ}$	46.218
Measured Refl.	119524
Independent Refl.	15581

Table S2. Structure Quality Indicators.

Reflections: Refinement:

Reflections:	d min (Mo) 0.49	I/σ 88.7	Rint 2.15%	complete 98% (IUCr) 100%
Refinement:	Shift -0.010	Max Peak 1.3	Min Peak -1.1	GooF 1.197

An orange block-shaped crystal with dimensions 0.37×0.32×0.28 mm 3 was mounted on a loop with paratone oil. Data were collected using an XtaLAB Synergy, Dualflex, HyPix diffractometer equipped with an Oxford Cryosystems low-temperature device operating at T = 100.02(10) K.

Data were measured using w scans using MoK a radiation. The total number of runs and images was based on the strategy calculation from the program CrysAlisPro (Rigaku, V1.171.40.37a, 2019). The maximum resolution that was achieved was Q = 46.218° (0.49 Å).

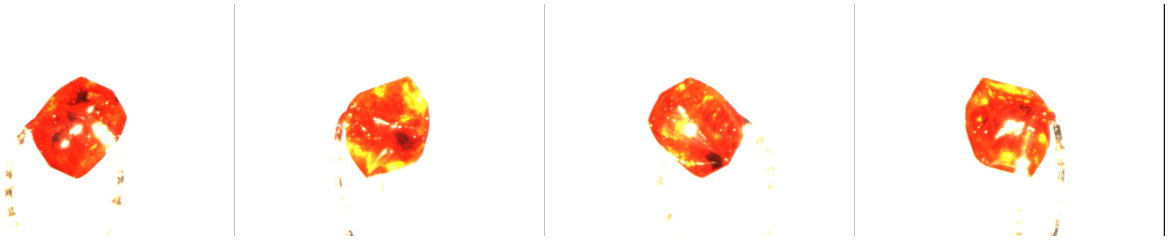
The diffraction pattern was indexed. The total number of runs and images was based on the strategy calculation from the program CrysAlisPro (Rigaku, V1.171.40.37a, 2019) and the unit cell was refined using CrysAlisPro on 85788 reflections, 72% of the observed reflections.

Data reduction, scaling and absorption corrections were performed using CrysAlisPro (Rigaku, V1.171.40.37a, 2019). The final completeness is 100.00 % out to 46.218° in Q. A numerical absorption correction based on Gaussian integration over a multifaceted crystal model was performed using CrysAlisPro (Rigaku, V1.171.40.37a, 2019). An empirical absorption correction

using spherical harmonics as implemented in SCALE3 ABSPACK in CrysAlisPro (Rigaku, V1.171.40.37a, 2019) was also applied. The absorption coefficient μ of this material is 1.103 mm -1 at this wavelength (l = 0.711Å) and the minimum and maximum transmissions are 0.564 and 1.000.

The structure was solved and the space group P2 1 /c (# 14) determined by the ShelXT (Sheldrick, 2015) structure solution program using Intrinsic Phasing and refined by Least Squares using version 2018/3 of ShelXL (Sheldrick, 2015). All non-hydrogen atoms were refined anisotropically. All hydrogen atom positions were located from the electron density maps and refined using restraints.

Figure S2. Images of the Crystal on the Diffractometer.



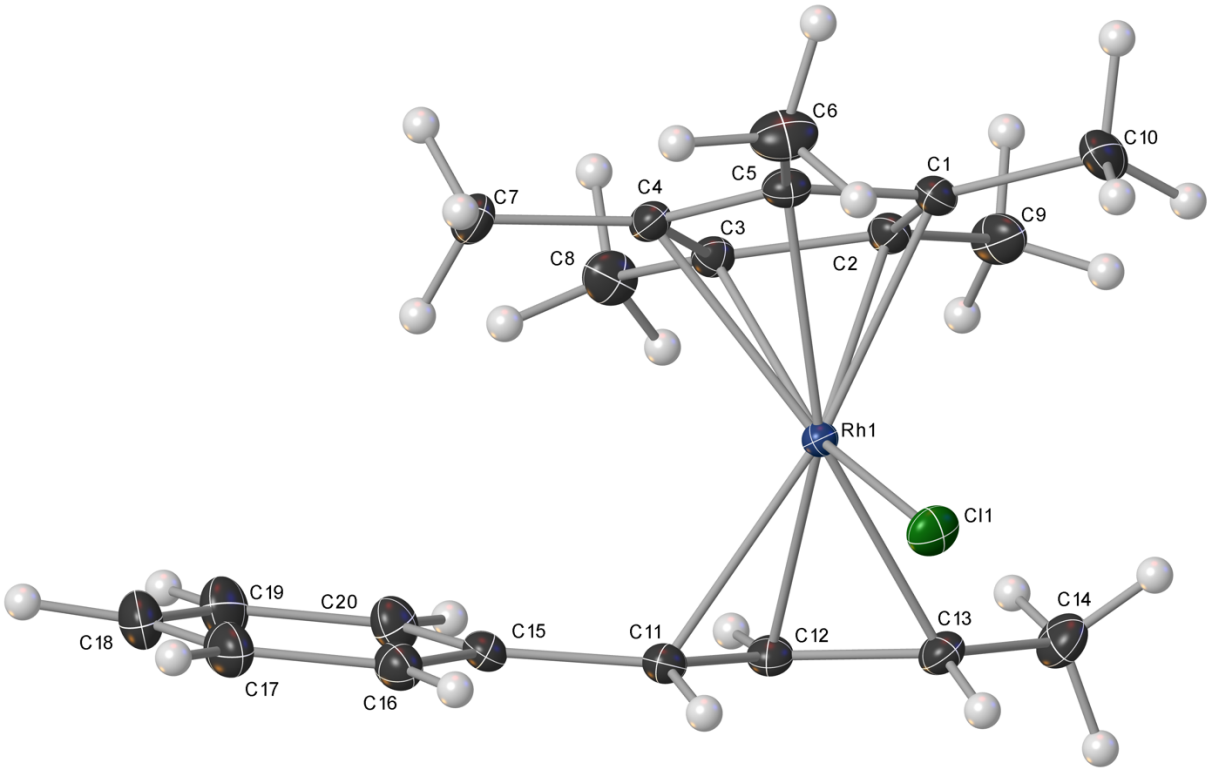


Figure S3. Thermal ellipsoid representation of Rh-π-Allyl Complex **58**.

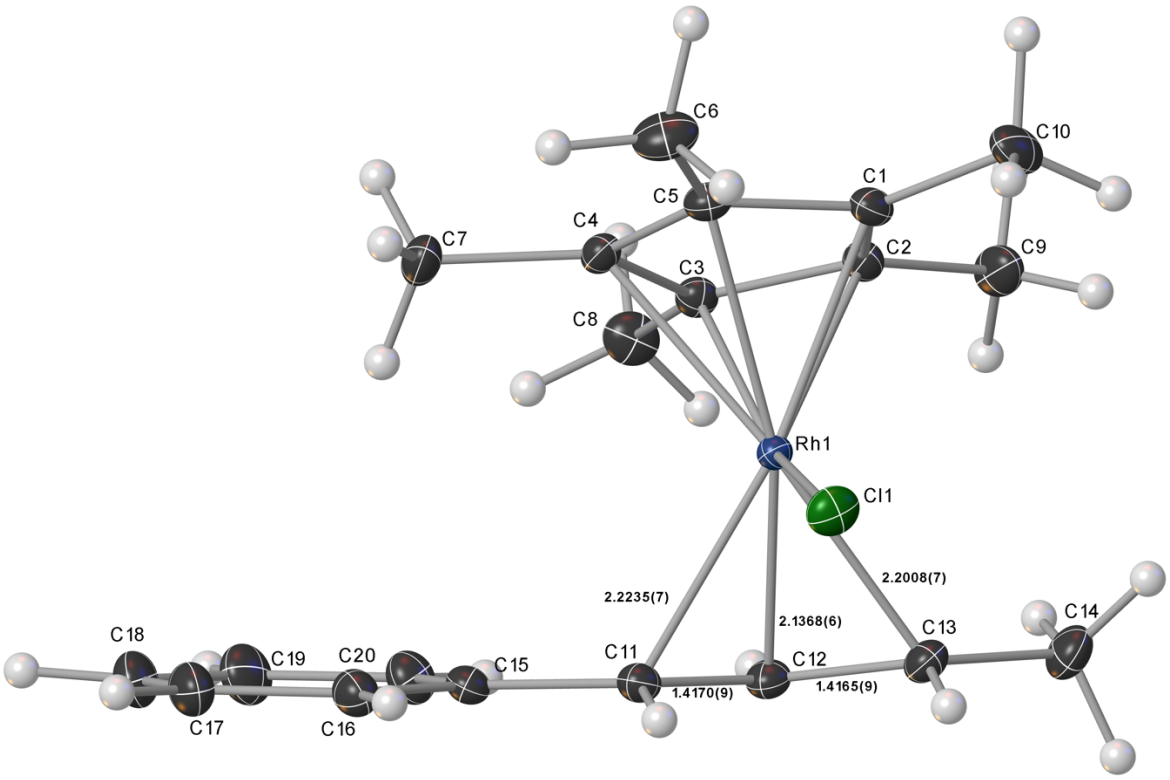


Figure S4. Thermal ellipsoid representation of Rh-π-Allyl Complex **58**.

Figure S5. Data Plots: Diffraction Data.

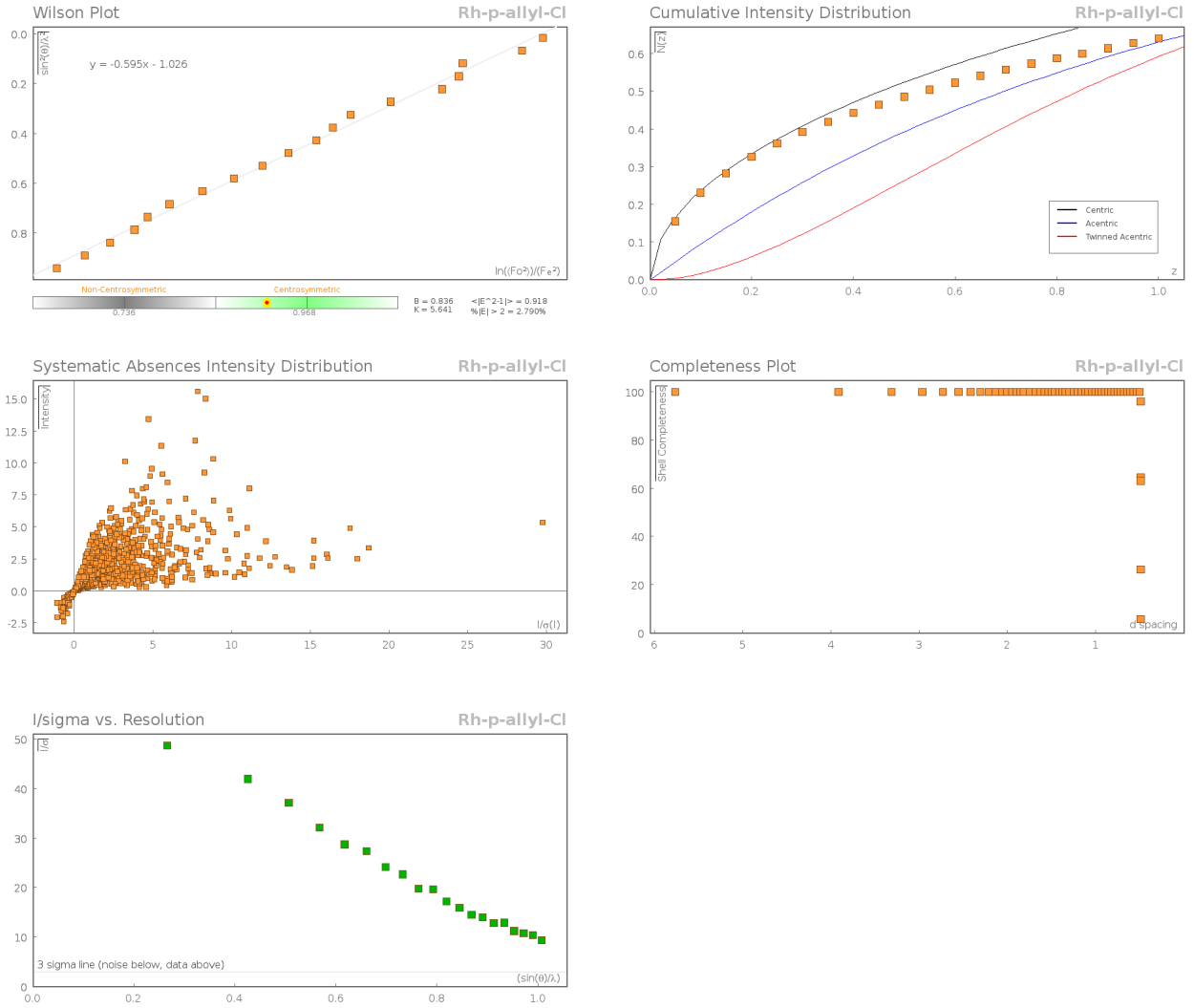


Figure S6. Data Plots: Refinement and Data.

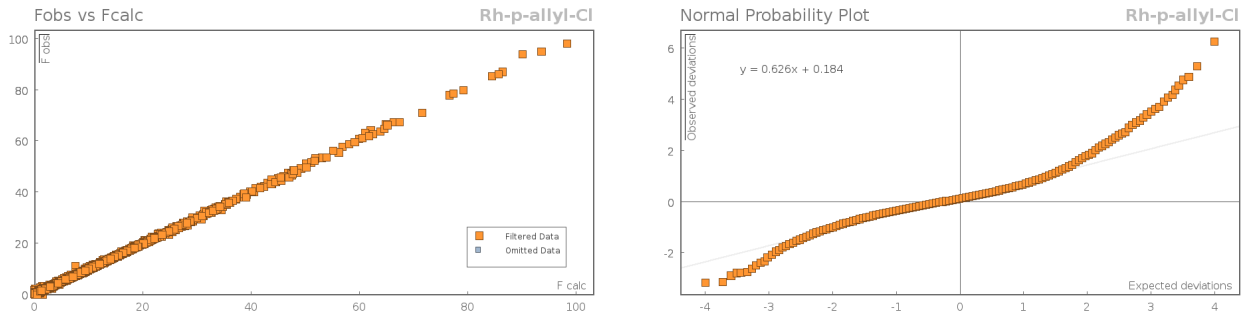


Table S3. Reflection Statistics.

Total reflections (after filtering)	121235	Unique reflections	15581
Completeness	0.997	Mean I/□	57.92
hkl_{max} collected	(15, 25, 37)	hkl_{min} collected	(-15, -26, -37)
hkl_{max} used	(15, 26, 37)	hkl_{min} used	(-15, 0, 0)
Lim d_{max} collected	100.0	Lim d_{min} collected	0.36
d_{max} used	12.82	d_{min} used	0.49
Friedel pairs	22515	Friedel pairs merged	1
Inconsistent equivalents	2	R_{int}	0.0215
R_{sigma}	0.0113	Intensity transformed	0
Omitted reflections	0	Omitted by user (OMIT hkl)	0
Multiplicity	(17090, 17005, 9592, 5123, 2113, 964, 511, 103, 13)	Maximum multiplicity	21
Removed systematic absences	1711	Filtered off (Shel/OMIT)	0

Table S4. Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($Å^2 \times 10^3$) for Rh-π-Allyl Complex 38. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{ij}.

Atom	**x**	**y**	**z**	U_{eq}
Rh1	5419.0(2)	8666.3(2)	1743.9(2)	9.52(1)
Cl1	3969.0(2)	10355.2(2)	1616.0(2)	17.35(3)
C1	8193.1(8)	9251.4(5)	1765.4(4)	14.39(8)
C2	8224.6(8)	8236.7(5)	2065.5(3)	13.69(8)

Atom	x	y	z	U_{eq}
C3	7469.4(8)	7528.6(5)	1520.5(3)	12.77(8)
C4	7092.3(8)	8109.3(5)	864.8(3)	13.00(8)
C5	7492.9(8)	9166.2(5)	1016.8(3)	14.17(8)
C6	7417.0(12)	10056.7(6)	501.7(5)	22.90(13)
C7	6428.2(10)	7654.8(6)	157.7(4)	19.22(11)
C8	7454.8(11)	6367.3(5)	1577.7(5)	19.63(11)
C9	8989.2(10)	7927.6(7)	2796.1(4)	20.67(12)
C10	8891.3(11)	10234.4(6)	2110.2(5)	22.98(13)
C11	2716.2(8)	7938.7(5)	1561.9(3)	13.92(8)
C12	3573.9(9)	7666.3(5)	2237.1(3)	14.51(8)
C13	4019.0(9)	8476.8(5)	2733.2(3)	15.32(9)
C14	4965.5(11)	8261.7(7)	3452.6(4)	20.60(11)
C15	2321.7(8)	7213.5(5)	963.1(3)	14.32(8)
C16	1421.4(10)	7606.1(6)	337.5(4)	17.75(10)
C17	1058.5(12)	6982.1(7)	-263.1(4)	23.05(13)
C18	1571.4(12)	5938.6(7)	-247.6(5)	25.34(14)
C19	2435.6(13)	5530.9(6)	374.5(5)	24.68(14)
C20	2808.1(11)	6156.6(5)	976.5(4)	19.25(11)

Table S5. Anisotropic Displacement Parameters ($\times 10^4$) Rh-π-Allyl Complex 38. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2} \times U_{11} + \ldots + 2hka^* \times b^* \times U_{12}]$.

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
Rh1	9.36(1)	9.68(1)	9.62(1)	-0.32(1)	1.29(1)	-0.06(1)
Cl1	19.64(6)	12.10(5)	20.69(6)	0.24(4)	4.23(5)	3.33(4)

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
C1	11.76(19)	14.7(2)	16.9(2)	-2.33(16)	2.17(16)	-2.43(15)
C2	11.08(18)	16.8(2)	13.01(19)	-0.54(16)	-0.10(15)	0.55(15)
C3	11.81(18)	12.56(18)	13.98(19)	-0.10(14)	1.26(15)	1.28(14)
C4	12.66(19)	15.13(19)	11.37(18)	-0.83(15)	2.07(14)	0.82(15)
C5	13.3(2)	14.37(19)	15.2(2)	1.90(16)	3.70(16)	-0.51(15)
C6	24.4(3)	20.6(3)	24.6(3)	9.2(2)	8.3(2)	0.5(2)
C7	18.9(3)	25.8(3)	13.1(2)	-5.0(2)	1.49(18)	0.8(2)
C8	20.2(3)	12.9(2)	25.7(3)	0.8(2)	1.3(2)	3.00(19)
C9	15.5(2)	30.9(3)	15.1(2)	1.8(2)	-2.49(18)	3.2(2)
C10	18.4(3)	19.7(3)	31.1(4)	-8.9(2)	3.5(2)	-6.5(2)
C11	11.95(19)	14.64(19)	15.3(2)	-0.84(16)	1.89(15)	-0.96(15)
C12	14.6(2)	15.2(2)	14.1(2)	0.68(16)	3.72(16)	-2.28(16)
C13	16.1(2)	17.4(2)	12.90(19)	-0.57(16)	3.97(16)	0.33(17)
C14	24.4(3)	25.2(3)	12.5(2)	-0.1(2)	3.4(2)	1.3(2)
C15	12.14(19)	15.2(2)	15.7(2)	-0.77(16)	1.59(16)	-3.11(15)
C16	16.9(2)	19.9(2)	16.2(2)	0.31(18)	0.07(18)	-2.02(19)
C17	21.5(3)	30.4(3)	16.9(3)	-2.7(2)	-1.1(2)	-4.2(3)
C18	25.3(3)	28.0(3)	22.6(3)	-9.2(3)	1.2(2)	-7.6(3)
C19	28.0(4)	17.7(3)	28.2(3)	-6.4(2)	0.8(3)	-4.2(2)
C20	20.9(3)	14.6(2)	22.0(3)	-1.71(19)	-0.3(2)	-2.40(19)

Table S6. Bond Lengths in Å for Rh-π-Allyl Complex **58**.

Atom	Atom	Length/Å
Rh1	Cl1	2.4247(2)
Rh1	C1	2.1967(7)
Rh1	C2	2.2034(7)
Rh1	C3	2.1746(6)
Rh1	C4	2.2494(6)
Rh1	C5	2.2244(6)
Rh1	C11	2.2235(7)
Rh1	C12	2.1368(6)
Rh1	C13	2.2008(7)
C1	C2	1.4166(9)
C1	C5	1.4621(9)
C1	C10	1.4924(9)
C2	C3	1.4482(8)
C2	C9	1.4950(9)
C3	C4	1.4446(8)
C3	C8	1.4933(9)
C4	C5	1.4125(9)
C4	C7	1.4960(9)
C5	C6	1.4923(9)
C11	C12	1.4170(9)
C11	C15	1.4686(9)
C12	C13	1.4165(9)
C13	C14	1.4988(10)
C15	C16	1.3996(10)
C15	C20	1.4028(10)

C16	C17	1.3894(11)
C17	C18	1.3915(14)
C18	C19	1.3904(14)
C19	C20	1.3937(11)

Table S7. Bond Angles in ° for Rh-π-Allyl Complex **58**.

Atom	**Atom**	**Atom**	**Angle/°**
C1	Rh1	Cl1	96.237(19)
C1	Rh1	C2	37.56(2)
C1	Rh1	C4	63.37(2)
C1	Rh1	C5	38.62(2)
C1	Rh1	C11	170.72(2)
C1	Rh1	C13	121.63(3)
C2	Rh1	Cl1	131.115(17)
C2	Rh1	C4	63.59(2)
C2	Rh1	C5	63.36(2)
C2	Rh1	C11	140.18(2)
C3	Rh1	Cl1	153.463(17)
C3	Rh1	C1	63.87(2)
C3	Rh1	C2	38.63(2)
C3	Rh1	C4	38.07(2)
C3	Rh1	C5	63.10(2)
C3	Rh1	C11	109.27(2)
C3	Rh1	C13	117.98(2)
C4	Rh1	Cl1	118.558(16)

C5	Rh1	Cl1	90.366(18)
C5	Rh1	C4	36.80(2)
C11	Rh1	Cl1	88.140(18)
C11	Rh1	C4	107.35(2)
C11	Rh1	C5	133.53(2)
C12	Rh1	Cl1	106.43(2)
C12	Rh1	C1	146.18(3)
C12	Rh1	C2	111.06(3)
C12	Rh1	C3	99.37(3)
C12	Rh1	C4	122.14(2)
C12	Rh1	C5	158.94(2)
C12	Rh1	C11	37.86(2)
C12	Rh1	C13	38.08(2)
C13	Rh1	Cl1	86.953(19)
C13	Rh1	C2	103.93(3)
C13	Rh1	C4	154.13(2)
C13	Rh1	C5	159.58(2)
C13	Rh1	C11	66.65(3)
C2	C1	Rh1	71.48(3)
C2	C1	C5	107.76(5)
C2	C1	C10	127.56(7)
C5	C1	Rh1	71.72(4)
C5	C1	C10	124.46(6)
C10	C1	Rh1	126.51(5)
C1	C2	Rh1	70.96(3)
C1	C2	C3	107.63(5)
C1	C2	C9	126.85(6)
C3	C2	Rh1	69.61(3)

C3	C2	C9	125.43(6)
C9	C2	Rh1	127.41(5)
C2	C3	Rh1	71.76(3)
C2	C3	C8	125.42(6)
C4	C3	Rh1	73.77(3)
C4	C3	C2	108.41(5)
C4	C3	C8	124.95(6)
C8	C3	Rh1	130.29(5)
C3	C4	Rh1	68.16(3)
C3	C4	C7	125.51(6)
C5	C4	Rh1	70.64(3)
C5	C4	C3	107.37(5)
C5	C4	C7	127.12(6)
C7	C4	Rh1	127.14(5)
C1	C5	Rh1	69.67(3)
C1	C5	C6	123.70(6)
C4	C5	Rh1	72.56(3)
C4	C5	C1	108.67(5)
C4	C5	C6	127.36(6)
C6	C5	Rh1	128.25(5)
C12	C11	Rh1	67.75(4)
C12	C11	C15	125.14(6)
C15	C11	Rh1	120.80(4)
C11	C12	Rh1	74.39(4)
C13	C12	Rh1	73.40(4)
C13	C12	C11	118.15(6)
C12	C13	Rh1	68.51(3)
C12	C13	C14	121.70(6)

C14	C13	Rh1	123.61(5)
C16	C15	C11	117.83(6)
C16	C15	C20	118.05(6)
C20	C15	C11	124.12(6)
C17	C16	C15	121.46(7)
C16	C17	C18	119.99(8)
C19	C18	C17	119.29(7)
C18	C19	C20	120.81(8)
C19	C20	C15	120.38(7)

Table S8. Torsion Angles in ° for Rh-π-Allyl Complex **58**.

Atom	**Atom**	**Atom**	**Atom**	**Angle/°**
Rh1	C1	C2	C3	60.24(4)
Rh1	C1	C2	C9	-122.99(7)
Rh1	C1	C5	C4	-62.45(4)
Rh1	C1	C5	C6	123.12(7)
Rh1	C2	C3	C4	65.17(4)
Rh1	C2	C3	C8	-126.95(7)
Rh1	C3	C4	C5	60.03(4)
Rh1	C3	C4	C7	-120.87(6)
Rh1	C4	C5	C1	60.62(4)
Rh1	C4	C5	C6	-125.21(7)
Rh1	C11	C12	C13	60.93(5)
Rh1	C11	C15	C16	-98.52(6)
Rh1	C11	C15	C20	80.74(8)
Rh1	C12	C13	C14	-117.13(6)

C1	C2	C3	Rh1	-61.10(4)
C1	C2	C3	C4	4.07(7)
C1	C2	C3	C8	171.95(6)
C2	C1	C5	Rh1	62.80(4)
C2	C1	C5	C4	0.35(7)
C2	C1	C5	C6	-174.09(6)
C2	C3	C4	Rh1	-63.87(4)
C2	C3	C4	C5	-3.84(7)
C2	C3	C4	C7	175.26(6)
C3	C4	C5	Rh1	-58.46(4)
C3	C4	C5	C1	2.16(7)
C3	C4	C5	C6	176.33(7)
C5	C1	C2	Rh1	-62.95(4)
C5	C1	C2	C3	-2.71(7)
C5	C1	C2	C9	174.06(6)
C7	C4	C5	Rh1	122.45(7)
C7	C4	C5	C1	-176.93(6)
C7	C4	C5	C6	-2.75(11)
C8	C3	C4	Rh1	128.18(7)
C8	C3	C4	C5	-171.79(6)
C8	C3	C4	C7	7.32(10)
C9	C2	C3	Rh1	122.07(6)
C9	C2	C3	C4	-172.76(6)
C9	C2	C3	C8	-4.88(10)
C10	C1	C2	Rh1	122.27(7)
C10	C1	C2	C3	-177.49(6)
C10	C1	C2	C9	-0.72(11)
C10	C1	C5	Rh1	-122.22(7)

C10	C1	C5	C4	175.33(6)
C10	C1	C5	C6	0.90(10)
C11	C12	C13	Rh1	-61.45(5)
C11	C12	C13	C14	-178.57(6)
C11	C15	C16	C17	177.50(7)
C11	C15	C20	C19	-177.76(7)
C12	C11	C15	C16	178.34(6)
C12	C11	C15	C20	-2.40(10)
C15	C11	C12	Rh1	112.86(6)
C15	C11	C12	C13	173.79(6)
C15	C16	C17	C18	0.87(12)
C16	C15	C20	C19	1.50(11)
C16	C17	C18	C19	0.40(13)
C17	C18	C19	C20	-0.69(14)
C18	C19	C20	C15	-0.27(13)
C20	C15	C16	C17	-1.81(11)

Table S9. Hydrogen Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($Å^2 \times 10^3$) for Rh-π-Allyl Complex 38. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{ij}.

Atom	x	y	z	U_{eq}
H9A	8395(14)	7338(6)	2988(6)	33.2(10)
H8A	7185(15)	6142(10)	2047(3)	33.2(10)
H10A	8915(15)	10203(10)	2623(2)	33.2(10)
H9B	8863(16)	8509(6)	3111(6)	33.2(10)
H8B	6596(12)	6062(10)	1233(5)	33.2(10)
H10B	8149(14)	10811(7)	1949(6)	33.2(10)
H10C	10090(7)	10361(10)	1976(6)	33.2(10)
H7A	7375(12)	7257(7)	-31(6)	33.2(10)
H9C	10244(6)	7770(8)	2783(7)	33.2(10)
H6A	6858(13)	9876(10)	41(4)	33(4)
H6B	6784(13)	10638(7)	686(6)	33.2(10)
H7B	6074(14)	8193(7)	-179(6)	33.2(10)
H8C	8630(8)	6119(10)	1487(6)	33.2(10)
H7C	5419(10)	7204(7)	208(7)	33.2(10)
H6C	8629(8)	10271(9)	441(6)	33.2(10)
H14A	5613(13)	7616(5)	3450(7)	29(2)
H14B	4098(13)	8217(8)	3806(5)	29(2)
H14C	5797(12)	8810(6)	3588(7)	29(2)
H20	3380(18)	5848(11)	1409(5)	26(2)
H19	2790(20)	4802(6)	391(9)	37(2)
H16	1011(19)	8325(6)	311(8)	26(2)
H17	457(19)	7287(12)	-692(6)	37(2)
H18	1390(20)	5503(11)	-672(6)	37(2)

H11	2012(18)	8553(9)	1529(8)	23(2)
H12	4070(17)	6983(10)	2339(7)	17(3)
H13	3256(17)	9066(9)	2727(8)	23(2)

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X-Ray Crystallography Structure Experimental Data for Complex 59

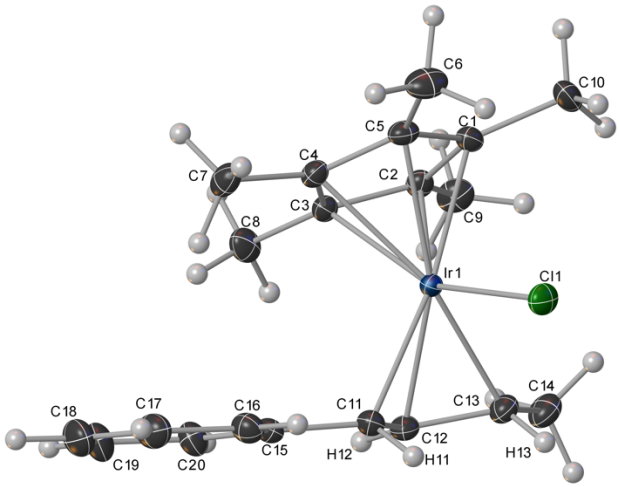


Figure S5. Crystal Structure of Ir-π-Allyl Complex **59**.

Experimental. Single orange block-shaped crystals of **Ir-Cl-allyl** were recrystallised from a mixture of DCM and pentane by vapor diffusion. A suitable crystal 0.36×0.29×0.23 mm^3 was selected and mounted on a loop with paratone oil on an XtaLAB Synergy, Dualflex, HyPix diffractometer. The crystal was kept at a steady T = 100.00(10) K during data collection. The structure was solved with the **ShelXT** (Sheldrick, 2015) structure solution program using the Intrinsic Phasing solution method and by using **Olex2** (Dolomanov et al., 2009) as the graphical interface. The model was refined with version 2018/3 of **ShelXL** (Sheldrick, 2015) using Least Squares minimisation.

Crystal Data. $C_{20}H_{26}ClIr$, M_r = 494.06, monoclinic, $P2_1/c$ (No. 14), a = 7.46343(7) Å, b = 12.81878(13) Å, c = 18.68909(19) Å, □ = 93.9187(9)°, □ = □ = 90°, V = 1783.85(3) $Å^3$, T = 100.00(10) K, Z = 4, Z' = 1, □(MoK□) = 7.629 mm^{-1}, 115550 reflections measured, 14094 unique (R_{int} = 0.0530) which were used in all calculations. The final wR_2 was 0.0641 (all data) and R_1 was 0.0290 (I > 2σ(I)).

Table S10. Relevant Crystal Data for Rh-π-allyl Complex **59**.

Compound	**Ir-Cl-allyl**
Formula	$C_{20}H_{26}ClIr$
$D_{calc.}$/ g cm^{-3}	1.84
m/mm^{-1}	7.629
Formula Weight	494.06
Colour	orange
Shape	block
Size/mm^3	0.36×0.29×0.23
T/K	100.00(10)
Crystal System	monoclinic
Space Group	$P2_1/c$
a/Å	7.46343(7)
b/Å	12.81878(13)
c/Å	18.68909(19)
a/°	90
b/°	93.9187(9)
g/°	90
V/Å^3	1783.85(3)
Z	4
Z'	1
Wavelength/Å	0.71073
Radiation type	MoK_a

$Q_{min}/^{\circ}$	1.928
$Q_{max}/^{\circ}$	44.169
Measured Refl.	115550
Independent Refl.	14094
Reflections with I > 2σ(I)	12230
R_{int}	0.053
Parameters	205
Restraints	0
Largest Peak	3.798
Deepest Hole	-3.782
GooF	1.094
wR_2 (all data)	0.0641
wR_2	0.0622
R_1 (all data)	0.0366
R_1	0.029
Creation Method	
Solution	Olex2 1.2-alpha (compiled 2018.07.26 svn.r3523 for OlexSys, GUI svn.r5532)
Refinement	

Table S11. Structure Quality Indicators.

Reflections:	d min (Mo) 0.51	I/σ 35.6	Rint 5.30%	complete 99% (IUCr) 100%
Refinement:	Shift -0.002	Max Peak 3.8	Min Peak -3.8	GooF 1.094

An orange block-shaped crystal with dimensions 0.36×0.29×0.23 mm^3 was mounted on a loop with paratone oil. Data were collected using an XtaLAB Synergy, Dualflex, HyPix diffractometer equipped with an Oxford Cryosystems low-temperature device operating at T = 100.00(10) K.

Data were measured using □ scans using MoK□ radiation. The total number of runs and images was based on the strategy calculation from the program **CrysAlisPro** (Rigaku, V1.171.40.37a, 2019). The maximum resolution that was achieved was □ = 44.169° (0.51 Å).

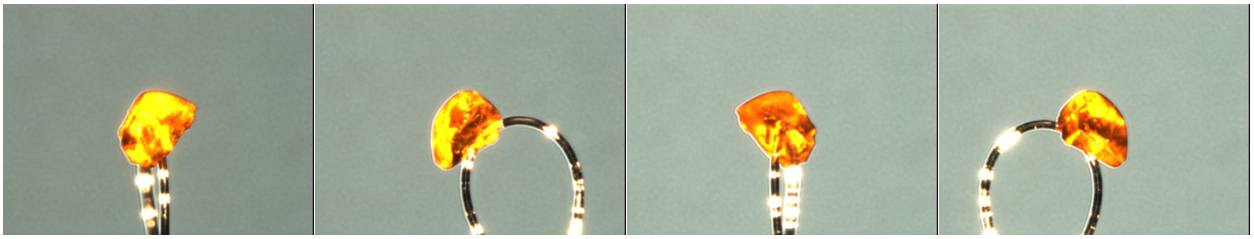
The diffraction pattern was indexed. The total number of runs and images was based on the strategy calculation from the program **CrysAlisPro** (Rigaku, V1.171.40.37a, 2019) and the unit cell was refined using **CrysAlisPro** on 58508 reflections, 51% of the observed reflections.

Data reduction, scaling and absorption corrections were performed using **CrysAlisPro** (Rigaku, V1.171.40.37a, 2019). The final completeness is 100.00 % out to 44.169° in □. A numerical absorption correction based on Gaussian integration over a multifaceted crystal model was performed using **CrysAlisPro** (Rigaku, V1.171.40.37a, 2019). An empirical absorption correction using spherical harmonics as implemented in SCALE3 ABSPACK in **CrysAlisPro** (Rigaku, V1.171.40.37a, 2019) was also applied. The absorption coefficient □ of this material is 7.629 mm^{-1} at this wavelength (□ = 0.711Å) and the minimum and maximum transmissions are 0.238 and 0.761.

The structure was solved and the space group $P2_1/c$ (# 14) determined by the **ShelXT** (Sheldrick, 2015) structure solution program using Intrinsic Phasing and refined by Least Squares using version 2018/3 of **ShelXL** (Sheldrick, 2015). All non-hydrogen atoms were refined anisotropically. Hydrogen atom positions were calculated geometrically and refined using the riding model. Hydrogen atom positions were calculated geometrically and refined using the riding model.

There is a single molecule in the asymmetric unit, which is represented by the reported sum formula. In other words: Z is 4 and Z' is 1.

Figure S6. Images of the Crystal on the Diffractometer.



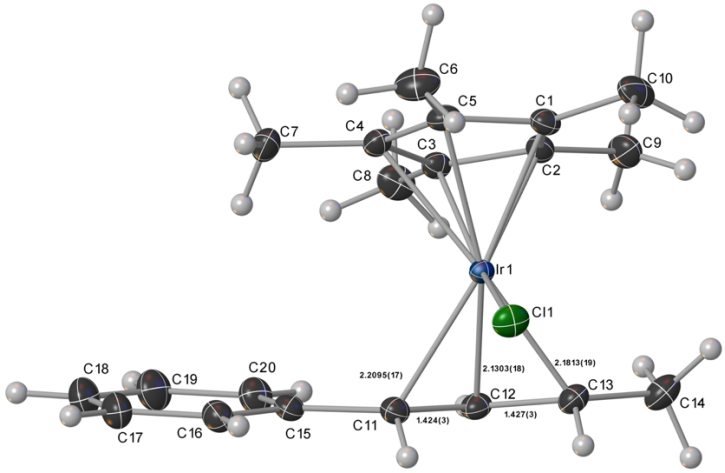


Figure S7. Thermal ellipsoid representation of Ir-π-Allyl Complex **59**.

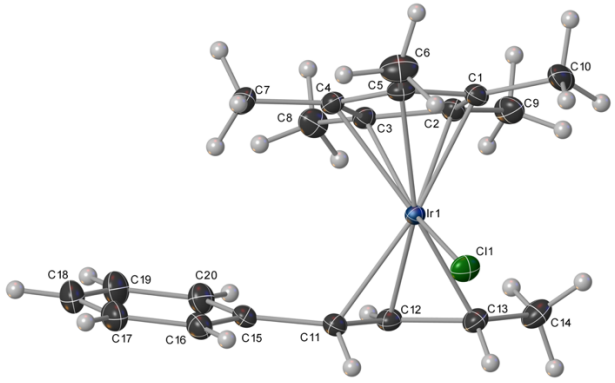


Figure S8. Thermal ellipsoid representation of Ir-π-Allyl Complex **59**.

Figure S10. Data Plots: Diffraction Data.

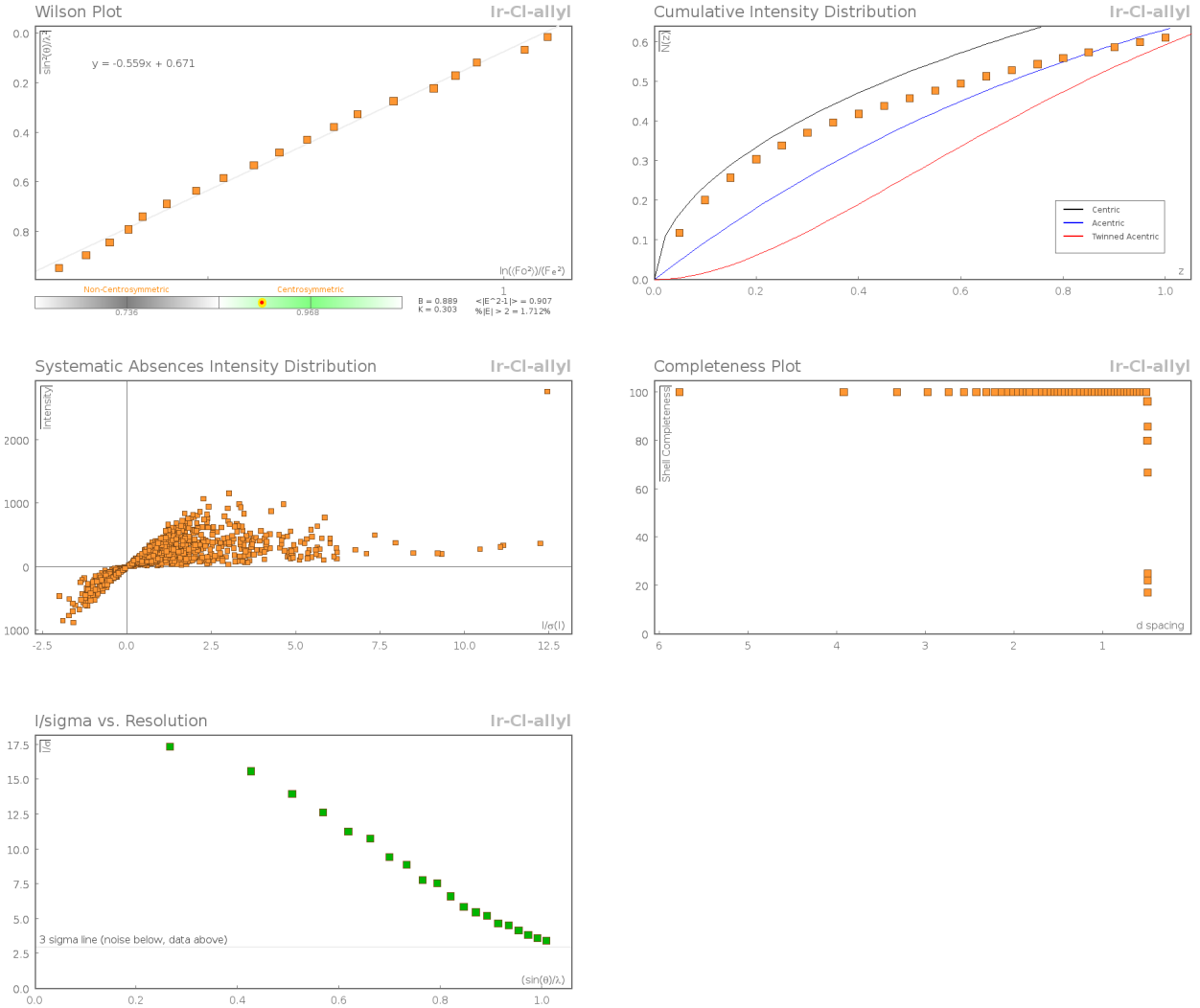


Figure S11. Data Plots: Refinement and Data.

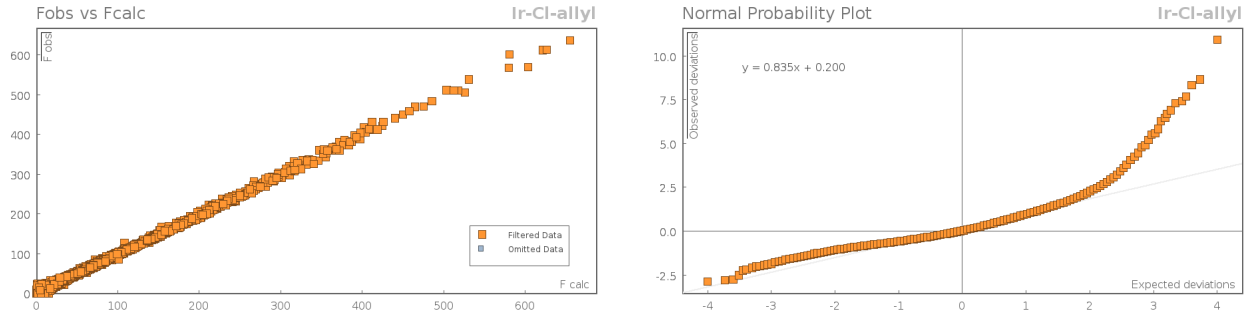


Table S12. Reflection Statistics.

Total reflections (after filtering)	117366
Completeness	1
hkl_{max} collected	(15, 25, 37)
hkl_{max} used	(14, 25, 36)
Lim d_{max} collected	20
d_{max} used	12.82
Friedel pairs	24390
Inconsistent equivalents	1
R_{sigma}	0.0281
Omitted reflections	0
Multiplicity	(17239, 18084, 10529, 4804, 2248, 1076, 363, 101, 26, 1, 3)
Removed systematic absences	1816

Table S13. Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($Å^2 \times 10^3$) for Ir-π-Allyl Complex 39. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{ij}.

Atom	x	y	z	U_{eq}
C3	2534(2)	2502.9(13)	3487.5(10)	15.3(2)
C4	2905(2)	3103.5(14)	4137.4(9)	16.3(2)
C5	2493(2)	4158.3(14)	3973.7(10)	17.3(3)
C1	1815(2)	4230.5(14)	3224.4(10)	16.8(3)
C2	1801(2)	3200.5(14)	2933.7(10)	16.0(2)
C8	2551(3)	1343.0(15)	3444.0(13)	23.3(3)
C7	3577(3)	2669.9(19)	4848.9(11)	23.6(3)
C10	1092(3)	5200.8(17)	2867.1(14)	26.4(4)
C9	1028(3)	2881.1(19)	2207.6(12)	23.8(3)
C6	2571(3)	5059.4(19)	4480.1(13)	27.7(4)
C15	7671(2)	2220.4(14)	4034.5(10)	17.3(3)
C16	8570(3)	2617.0(17)	4658.8(11)	21.0(3)
C17	8939(3)	1995(2)	5258.7(12)	27.1(4)
C18	8433(4)	953(2)	5246.3(14)	30.8(5)
C19	7572(4)	541.5(18)	4627.6(14)	28.7(4)
C20	7197(3)	1165.9(16)	4025.4(13)	23.3(3)
C11	7270(2)	2947.4(14)	3433.7(10)	16.4(3)
C12	6425(2)	2657.3(14)	2756.3(10)	17.4(3)
C13	5967(3)	3482.8(15)	2265.0(10)	18.6(3)
C14	5054(3)	3255.7(18)	1553.1(12)	24.9(4)
Cl1	6034.4(7)	5316.0(3)	3381.8(3)	20.48(7)
Ir1	4573.3(2)	3647.7(2)	3247.3(2)	11.63(1)

Table S14: Anisotropic Displacement Parameters ($\times 10^4$) Ir-π-Allyl Complex 39. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2} \times U_{11} + ... + 2hka^* \times b^* \times U_{12}]$.

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
C3	13.8(6)	14.0(6)	18.1(6)	1.3(5)	2.0(5)	-1.4(4)
C4	15.0(6)	18.7(6)	15.4(6)	1.5(5)	2.4(5)	-1.7(5)
C5	15.7(6)	17.4(6)	19.3(7)	-3.2(5)	5.1(5)	-0.2(5)
C1	13.7(6)	16.3(6)	20.5(7)	2.0(5)	2.3(5)	2.3(5)
C2	13.0(6)	18.2(6)	16.7(6)	1.1(5)	-0.3(5)	-1.3(5)
C8	22.6(8)	14.5(6)	32.6(10)	0.8(6)	1.1(7)	-2.6(6)
C7	21.6(8)	32.1(10)	17.1(7)	6.0(6)	1.7(6)	-1.9(7)
C10	19.6(8)	21.4(8)	38.6(11)	10.8(8)	4.4(7)	6.1(6)
C9	17.8(7)	32.2(10)	20.8(8)	-2.2(7)	-2.8(6)	-3.8(7)
C6	27.1(9)	26.7(9)	30.2(10)	-11.9(8)	9.4(8)	-1.1(7)
C15	14.5(6)	18.3(6)	19.1(7)	1.2(5)	1.9(5)	3.9(5)
C16	19.9(7)	24.0(8)	19.0(7)	-0.3(6)	-0.7(6)	3.3(6)
C17	24.2(9)	35.9(11)	20.8(8)	4.0(7)	-1.2(7)	4.0(8)
C18	30.4(10)	34.8(11)	27.0(10)	10.7(9)	0.8(8)	9.0(9)
C19	31.9(11)	22.0(8)	32.2(11)	7.3(8)	0.9(8)	5.0(8)
C20	25.8(9)	17.9(7)	26.0(9)	2.0(6)	0.3(7)	3.2(6)
C11	14.3(6)	17.0(6)	18.2(6)	0.7(5)	2.0(5)	1.7(5)
C12	17.3(6)	18.1(6)	17.2(6)	-0.5(5)	4.7(5)	2.1(5)
C13	19.7(7)	20.7(7)	15.8(6)	0.5(5)	4.4(5)	-0.3(5)
C14	30.4(10)	25.8(9)	19.5(8)	-0.6(7)	8.7(7)	-2.2(7)
Cl1	21.76(18)	14.10(15)	26.1(2)	-0.69(13)	4.96(15)	-3.90(13)
Ir1	11.28(2)	11.08(2)	12.64(2)	0.35(2)	1.55(1)	-0.03(2)

Table S15. Bond Lengths in Å for Ir-π-Allyl Complex **59**.

Atom	Atom	Length/Å
C3	C4	1.449(3)
C3	C2	1.447(2)
C3	C8	1.489(3)
C3	Ir1	2.1827(17)
C4	C5	1.415(3)
C4	C7	1.496(3)
C4	Ir1	2.2556(18)
C5	C1	1.459(3)
C5	C6	1.492(3)
C5	Ir1	2.2296(18)
C1	C2	1.427(3)
C1	C10	1.495(3)
C1	Ir1	2.1875(17)
C2	C9	1.495(3)
C2	Ir1	2.1882(17)
C15	C16	1.401(3)
C15	C20	1.397(3)
C15	C11	1.474(3)
C16	C17	1.388(3)
C17	C18	1.388(4)
C18	C19	1.388(4)
C19	C20	1.394(3)
C11	C12	1.424(3)
C11	Ir1	2.2095(17)
C12	C13	1.427(3)

C12	Ir1	2.1302(18)
C13	C14	1.482(3)
C13	Ir1	2.1811(19)
Cl1	Ir1	2.4059(4)

Table S16. Bond Angles in ° for Ir-π-Allyl Complex **59**.

Atom	**Atom**	**Atom**	**Angle/°**
C4	C3	C8	125.08(17)
C4	C3	Ir1	73.70(10)
C2	C3	C4	108.21(15)
C2	C3	C8	125.60(17)
C2	C3	Ir1	70.87(9)
C8	C3	Ir1	130.65(14)
C3	C4	C7	125.52(17)
C3	C4	Ir1	68.25(10)
C5	C4	C3	107.48(15)
C5	C4	C7	126.99(17)
C5	C4	Ir1	70.61(10)
C7	C4	Ir1	127.00(13)
C4	C5	C1	108.90(15)
C4	C5	C6	127.16(19)
C4	C5	Ir1	72.61(10)
C1	C5	C6	123.77(18)
C1	C5	Ir1	69.16(10)
C6	C5	Ir1	127.94(14)

C5	C1	C10	124.92(18)
C5	C1	Ir1	72.28(10)
C2	C1	C5	107.45(15)
C2	C1	C10	127.32(18)
C2	C1	Ir1	70.99(10)
C10	C1	Ir1	127.12(14)
C3	C2	C9	125.71(17)
C3	C2	Ir1	70.46(9)
C1	C2	C3	107.86(15)
C1	C2	C9	126.25(17)
C1	C2	Ir1	70.93(10)
C9	C2	Ir1	127.88(14)
C16	C15	C11	117.75(17)
C20	C15	C16	117.88(18)
C20	C15	C11	124.36(18)
C17	C16	C15	121.4(2)
C18	C17	C16	120.1(2)
C19	C18	C17	119.3(2)
C18	C19	C20	120.7(2)
C19	C20	C15	120.6(2)
C15	C11	Ir1	120.82(13)
C12	C11	C15	124.50(17)
C12	C11	Ir1	67.85(10)
C11	C12	C13	116.76(17)
C11	C12	Ir1	73.88(10)
C13	C12	Ir1	72.61(11)
C12	C13	C14	120.49(18)
C12	C13	Ir1	68.75(10)

C14	C13	Ir1	123.94(15)
C3	Ir1	C4	38.05(7)
C3	Ir1	C5	63.11(7)
C3	Ir1	C1	64.23(6)
C3	Ir1	C2	38.66(6)
C3	Ir1	C11	109.56(7)
C3	Ir1	Cl1	153.32(5)
C4	Ir1	Cl1	117.84(5)
C5	Ir1	C4	36.79(7)
C5	Ir1	Cl1	90.28(5)
C1	Ir1	C4	63.50(7)
C1	Ir1	C5	38.56(7)
C1	Ir1	C2	38.08(7)
C1	Ir1	C11	170.97(7)
C1	Ir1	Cl1	96.76(5)
C2	Ir1	C4	63.69(7)
C2	Ir1	C5	63.56(7)
C2	Ir1	C11	140.38(7)
C2	Ir1	Cl1	132.41(5)
C11	Ir1	C4	107.51(7)
C11	Ir1	C5	133.47(7)
C11	Ir1	Cl1	86.74(5)
C12	Ir1	C3	99.78(7)
C12	Ir1	C4	122.72(7)
C12	Ir1	C5	159.50(7)
C12	Ir1	C1	146.37(7)
C12	Ir1	C2	110.98(7)
C12	Ir1	C11	38.27(7)

C12	Ir1	C13	38.64(7)
C12	Ir1	Cl1	105.78(5)
C13	Ir1	C3	119.16(7)
C13	Ir1	C4	155.47(7)
C13	Ir1	C5	158.90(7)
C13	Ir1	C1	121.26(7)
C13	Ir1	C2	104.23(7)
C13	Ir1	C11	67.15(7)
C13	Ir1	Cl1	86.29(5)

Table S17. Hydrogen Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($Å^2 \times 10^3$) for Ir-π-Allyl Complex 39. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{ij}.

Atom	x	y	z	U_{eq}
H8A	2872.27	1132.96	2976.59	35
H8B	1379.71	1078.11	3526.27	35
H8C	3411.86	1070.28	3800.98	35
H7A	4544.35	2192.92	4783.73	35
H7B	2619.83	2309.28	5061.85	35
H7C	3999.36	3229.21	5157.76	35
H10A	1809.4	5787.05	3029.49	40
H10B	-126.57	5306.57	2985.58	40
H10C	1127.57	5131.78	2356.8	40
H9A	1160.29	3441.38	1874.47	36
H9B	-223.21	2720.78	2231.04	36

H9C	1650.23	2276.03	2051	36
H6A	3166.79	4850.03	4928.68	42
H6B	1373.8	5286.07	4557.45	42
H6C	3223.35	5621.84	4279.94	42
H16	8927.89	3312.16	4671.49	25
H17	9526.33	2276.17	5669.2	33
H18	8667.8	534.48	5648.42	37
H19	7241.01	-158.09	4614.79	34
H20	6626.28	877.88	3613.74	28
H11	8230.86	3459.03	3387.49	20
H12	6135.62	1928.58	2639.7	21
H13	6942.56	3989.66	2236.87	22
H14A	4424.41	2604.33	1572.41	37
H14B	5930.02	3212.35	1201.35	37
H14C	4215.69	3803.41	1424.29	37

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