
# LATE TRANSITION METAL CATALYZED CHELATION-ASSISTED C-H ALKYNYLATION REACTIONS

**Eric Tan**

UNIVERSITAT ROVIRA i VIRGILI

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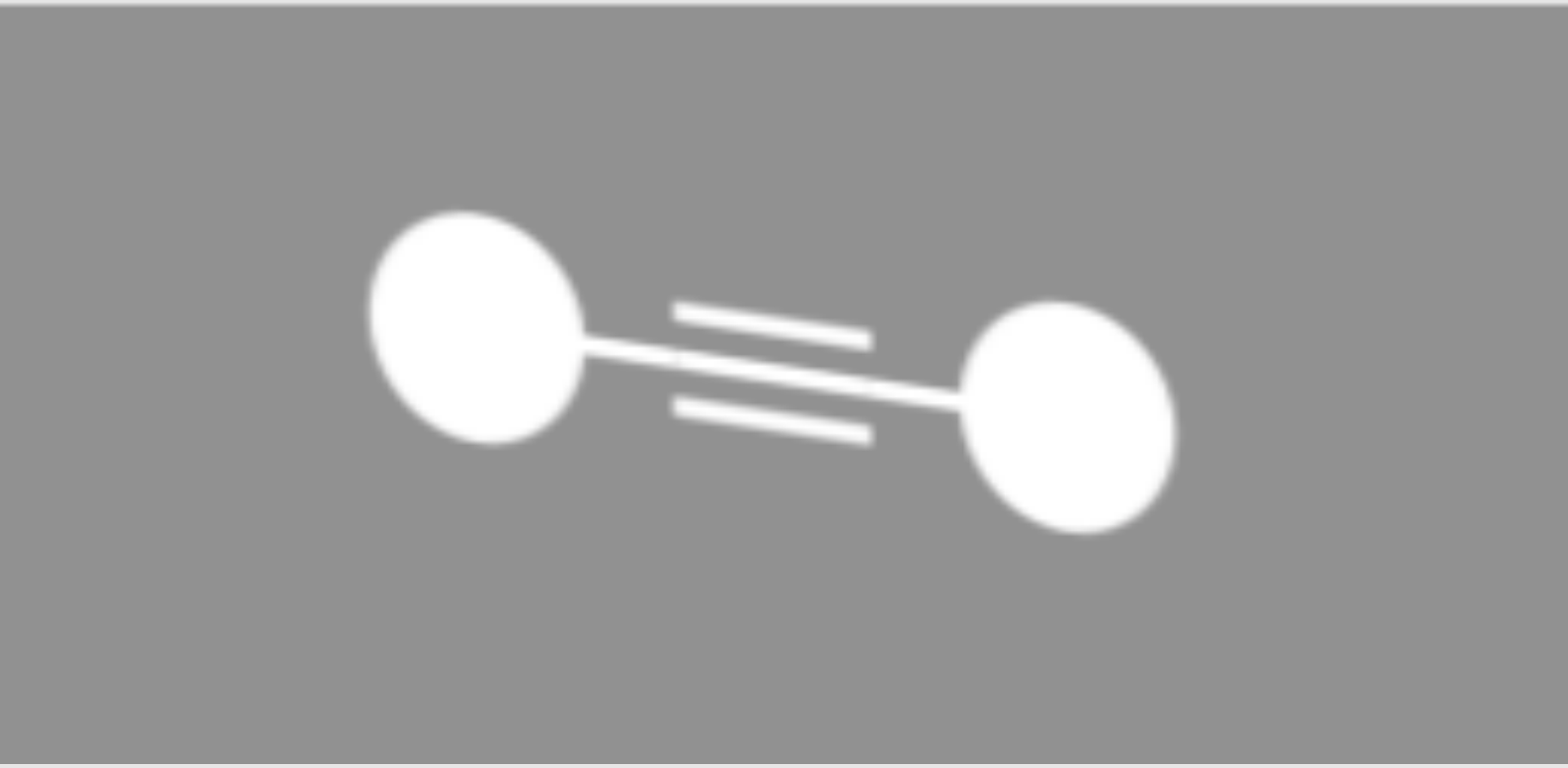

**TESI DOCTORAL – TESIS DOCTORAL- DOCTORAL THESIS**
**2019**

*Eric Tan*

# Late Transition Metal Catalyzed Chelation-Assisted C-H Alkynylation Reactions

DOCTORAL THESIS

Supervised by Prof. Antonio M. Echavarren

Institut Català d´Investigació Química (ICIQ)


UNIVERSITAT ROVIRA i VIRGILI

Tarragona 2019

I STATE that the present study, entitled "Late Transition Metal-Catalyzed Chelation-Assisted C−H Alkynylation Reactions", presented by Eric Tan to award the degree of Doctor, has been carried out under my supervision at the Institut Català d´Investigació Química (ICIQ).

Tarragona, October 8th, 2019

Doctoral Thesis Supervisor

Prof. Antonio M. Echavarren Pablos

*A Yasmine*

*"A good scientist is pathologically optimistic"*

Jean-Pierre Sauvage

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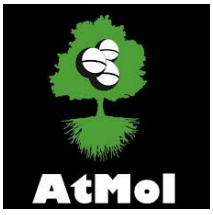






Publications arising from the work presented in this manuscript:

*1) "Ruthenium-Catalyzed Peri- and Ortho-Alkynylation with Bromoalkynes via Insertion and Elimination"*
Tan, E.; Konovalov, A. I.; Fernandez, A.; Dorel, R.; Echavarren, A. M. *Org. Lett.* **2017***, 19,* 5561−5564. Highlighted by T. Swager in *Synfacts*, **2017**, *13*, 1254.

*2) "Broad-Scope Rh-Catalyzed Inverse-Sonogashira Reaction Directed by Weakly Coordinating Groups."*
Tan, E.;[+] Quinonero, O.;[+] De Orbe, E.; Echavarren, A. M. *ACS Catal.* **2018**, *8*, 2166−2172.

*3) "Modular Access to Dibenzopentalenes via Rh-Catalyzed C−H Alkynylation of Benzaldehydes"*
Tan, E.; Nannini, L.; Echavarren, A. M. *manuscript under preparation*

*4) "Ir-Catalyzed C($sp^3$)−H Alkynylation"*
Tan, E.; Zanini, M.; Echavarren, A. M. *manuscript under preparation*

*5) "Ortho-Functionalizaton of Nitrobenzenes via Catalytic Electrophilic Rhodation"*
Tan, E.; García-Morales, C.; Guilem Mayans, J.; Echavarren. A. M. *manuscript under preparation*

Publications arising from the work carried out during the research stay in Munich:

*6) "Synthesis of Functionalized Diaryl Sulfides by a Cobalt-Catalyzed Coupling Between Organozinc Pivalates and Diaryl Disulfides."*
Dong, Z-B.; Balkenhohl, M.; Tan, E.; Knochel, P. *Org. Lett.* ***2018***, 20, 7581−7584.

*7) "Cobalt-Catalyzed Electrophilic Amination with Anthranils: an Expedient Route to Condensed Quinolines."*
Jie, L.;[+] Tan, E.;[+] Keller, N.;[+] Chen, Y.-H.; Zehetmaier, P.; Jakowetz, A.; Bein, T.; Knochel, P. *J. Am. Chem. Soc.* **2018**, *141*, 98−103.

Publication arising from the work carried out during the research stay at Syngenta:

8) "*Iridium-Catalyzed Ionic Hydrogenation of Oximes and Other Substrates"*

Cope, J. C.; Tan, E.; Pinson, B.; Grushin, V.; Robinson, A.; Mas Rosello, J.; Cramer, N.; Smejkal, T. *manuscript under preparation*

Publications arising from the work carried out during undergraduate studies:

*9) "$HBF_4$ as Catalyst in Nucleophilic Substitutions of Propargylic Alcohols."*
Barreiro, E.; Sanz-Vidal, A.; Tan, E.; Lau, S. H.; Sheppard, T.; Diez-Gonzalez, S. *Eur. J. Org. Chem.* **2015***,* 7544−7549.

*10) "Microwave-Assisted Formylations of Weakly Basic Anilines with Methyl Formate Catalyzed by Calcium and Hydrogen Triflimides."*
Tan, E.**;** Ung, S.; Corbet, M. *Eur. J. Org. Chem.* **2016***, 1836−1840.*

*11) "Aluminium, Gallium and Indium Complexes Supported by a Chiral Phenolato-Prolinolato Dianionic ligand."*
Maudoux, N.; Tan, E.**;** Hu, Y.; Roisnel, T.; Dorcet, V.; Carpentier, J.-F., Sarazin, Y. *Main Group Met. Chem.* **2016**, 39, 131−143.

[+] denotes equal contribution

# TABLE OF CONTENTS

## Prologue

This thesis is divided into three parts: a general introduction on alkynes, C−H activation and C−H alkynylation, and two research chapters. These three parts are preceded by the abstract and general objectives, and followed by the overall conclusions. Each research chapter contains five sections including a brief introduction on the research topic, the objectives to be achieved in the chapter, the results and discussion of the investigation, the conclusions reached and the experimental section. The references and numbering are organized by chapters.

The **General Introduction** provides an overview on the importance of alkynes as building blocks and functional groups. Methods for their introduction onto organic fragments are briefly reviewed. Then in the second part of the general introduction, an introduction to the field of C−H activation, followed by an overview of precedents in C−H alkynylation reactions are given.

**Chapter I**, *« Ru- and Rh-Catalyzed Chelation-Assisted C($sp^2$)−H Alkynylation Reactions with Bromo-Alkynes »*, presents the development of a general catalytic system, based on ruthenium and rhodium catalysts, that allows the alkynylation of a broad range of C($sp^2$)−H bonds. This work was done in collaboration with Dr. Araceli Gabriela Fernandez, who studied the scope of the alkynylation of benzoic acids, Dr. Andrey Konovalov, who computed the mechanism on the alkynylation of naphthols and benzoic acids, Dr. Ruth Dorel, who studied the synthesis of benzofluoranthene, Dr. Ophélie Quinonero, who studied the scope and the mechanism of the alkynylation of benzoic esters and benzyl ethers, Dr. Elena M. de Orbe, who computed the mechanism of this reaction using the rhodium catalyst, and Joan Guillem Mayans, who performed the Hammett analysis of the alkynylation of nitrobenzenes. This work was published in *Org. Lett.* **2017***, 19,* 5561−5564, *ACS Catal.* **2018**, *8*, 2166−2172, and two other manuscripts are in preparation.

**Chapter II**, *« Iridium-Catalyzed C($sp^3$)−H Alkynylation »*, presents the extension into the C($sp^3$)−H bonds of the catalytic system developped in **chapter I**. This work was done in collaboration with Margherita Zanini, who studied the scope of the alkynylation of oxime ethers derived from alcohols. A manuscript of this work is in preparation.

## Abbreviations and Acronyms

In this manuscript, the abbreviations and acronyms most commonly used in organic and organometallic chemistry have been used following the recommendations of "Guidelines of Authors" of the Journal of Organic Chemistry.

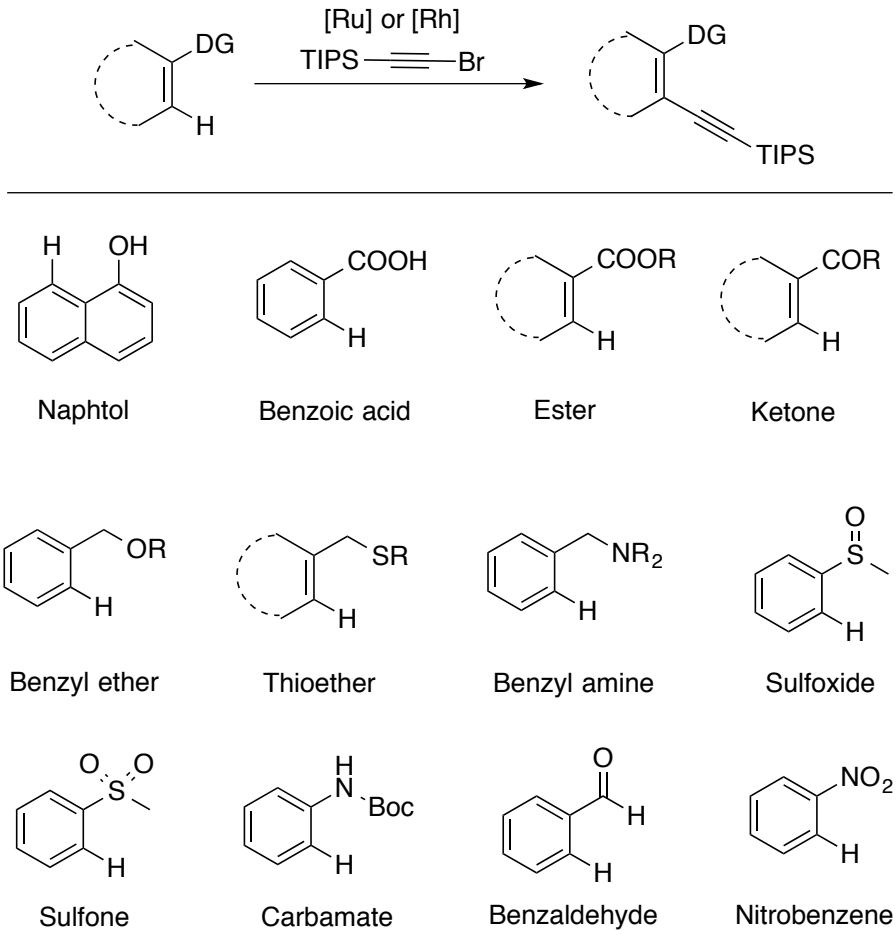
Additional abbreviations and acronyms used in this manuscript are listed below:

| | |
|---|---|
| APCI | atmospheric pressure chemical ionization |
| *dr* | diastereomeric ratio |
| ESI | electrospray ionization |
| Int | intermediate |
| L | ligand |
| MALDI | matrix assisted laser desorption ionization |
| MS | mass spectrometry/molecular sieves |
| $OTf^-$ | triflate |
| ORTEP | oak ridge thermal ellipsoid plot |
| TS | transition state |
| PAH | polyaromatic hydrocarbons |
| DG | directing group |
| EBX | 1-{[Tris-(1-methylethyl)silyl]ethynyl]}-1,2-benziodoxol-3(1H)-one |
| DCE | 1,2-dichloroethane |
| OFET | organic field-effect transistor |
| CMD | concerted metalation deprotonation |

## Abstract

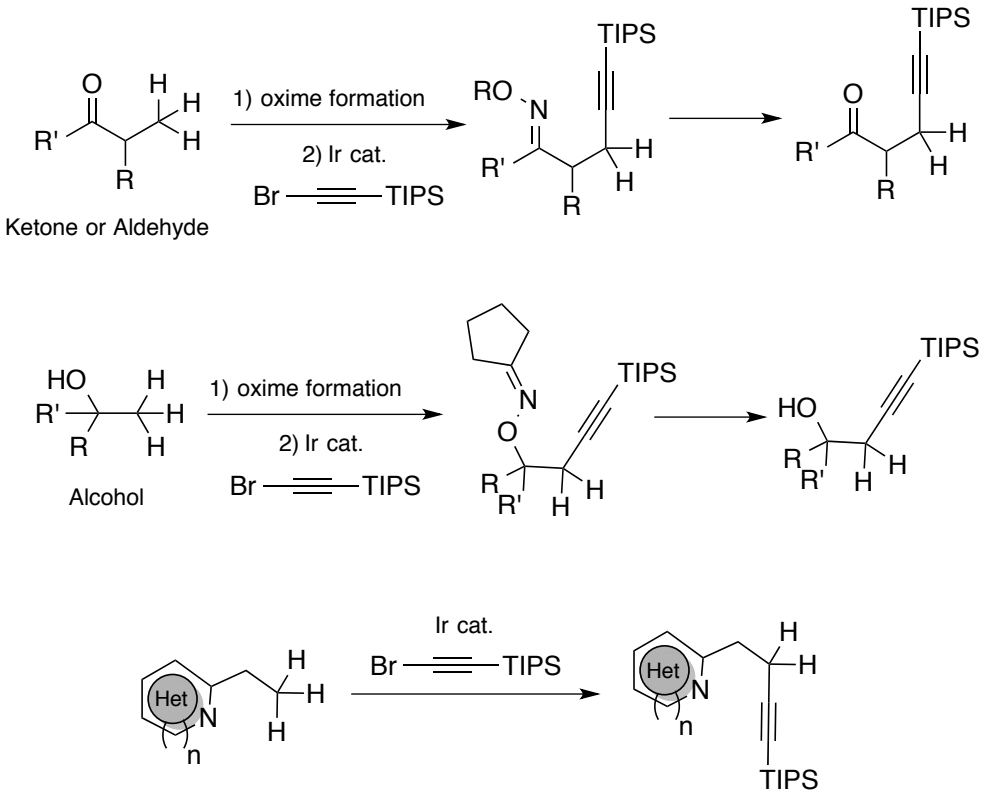
Our research group is interested in the synthesis of building blocks containing acetylenes, in order to fuel a research program based on the use of gold catalysts for the synthesis of complex molecules by activation of alkynes. We focused on the direct C−H alkynylation of functionalized molecules, using the functional group as handle for the introduction of alkynes. Although several reports on the chelation-assisted C−H alkynylation already existed at the beginning of these PhD studies, all of them used substrates bearing amides or nitrogen coordinating groups such as heterocycles or imine derivatives, thus limiting its use in synthesis as the chelating groups need to be installed and/or removed.

Therefore, we developed a catalytic system, based on ruthenium and rhodium catalysts, able to convert C($sp^2$)−H bonds into C($sp^2$)−alkyne bonds using a broad range of widely used functional groups (Scheme 1), such as phenolic -OH, carboxilic acid, ester, ketone, ether, amine, thioether, sulfoxide, sulfone, phenol ester, carbamate, aldehyde and nitro groups. We next applied these reactions in the synthesis of polyaromatic hydrocarbons (PAH) such as extended fluoranthenes and dibenzopentalenes. The mechanisms were studied both experimentally and computationally, showing that the efficiency of these catalytic systems arises from two low-barrier steps: bromo-alkyne insertion into a ruthena- or rhoda-cycle, followed by bromide elimination. In the case of nitrobenzenes, we also observed an interesting electrophilic C−H rhodation process.




**Scheme 1.** Ru- and Rh-catalyzed C($sp^2$)–H alkynylation.

Finally, we extended this catalytic system to the alkynylation of C($sp^3$)–H bonds using an iridium catalyst and using oxime ethers or nitrogen heterocycles as directing groups (Scheme 2).




**Scheme 2.** Ir-catalyzed C($sp^3$)−H alkynylation.

## General Objectives

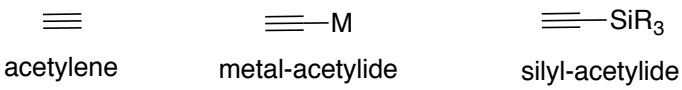
The aim of this Doctoral Thesis was to develop homogeneous catalytic systems able to convert C−H bonds in functionalized molecules into C−alkyne bonds (alkynylation reactions).

A second major objective was to apply the newly developed alkynylation reactions for the synthesis of complex molecules, such as polyaromatic hydrocarbons (PAH), as well as for the late-stage functionalization of biologically relevant molecules.

# *General Introduction*

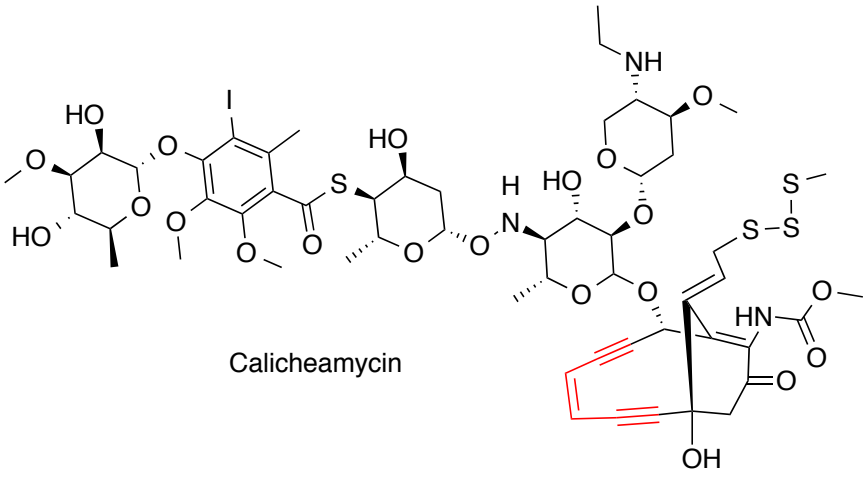
## Alkynes as Important Building Blocks

The simplest form of alkyne, acetylene, is a gas that is mainly produced by combustion of methane or hydrolysis of calcium carbide. It is used in a range of industrial applications, but in the chemical industry, it is one of the most important feedstock chemical used to produce different intermediates on large scale.[1] In the fine chemical industry, its handling is facilitated by its deprotonation in the form of a metal acetylide or by a protection in the form a silyl-acetylene, thus allowing to use a two-carbon building block in synthesis (Scheme 1).




**Scheme 1.** Acetylene, metal-acetylide and silyl-acetylene.

More complex alkynes can play key roles in natural products, drugs, or functional materials. In the case of calicheamycin (Scheme 2), a natural product found on a rock by touring scientists, the ene-diyne motif - an alkene conjugated with two alkynes - imparts antitumor activity and numerous medicinal chemistry programs dedicated to the synthesis of other ene-diyne containing drugs have been developed.[2]

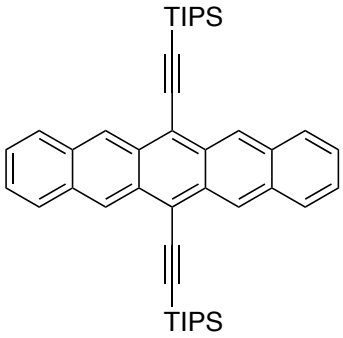



**Scheme 2.** Calicheamycin. Ene-diyne motif in red.

1 Pässler, Peter; Hefner, Werner; Buckl, Klaus; Meinass, Helmut; Meiswinkel, Andreas; Wernicke, Hans-Jürgen; Ebersberg, Günter; Müller, Richard; Bässler, Jürgen; Behringer, Hartmut; Mayer, Dieter (2008). "Acetylene Chemistry". *Ullmann's Encyclopedia of Industrial Chemistry.*

2 Nicolaou, K. C.; Montagnon, T. (2008) Molecules that changed the world. Weinheim, Germany: WileyVCH Publishers.

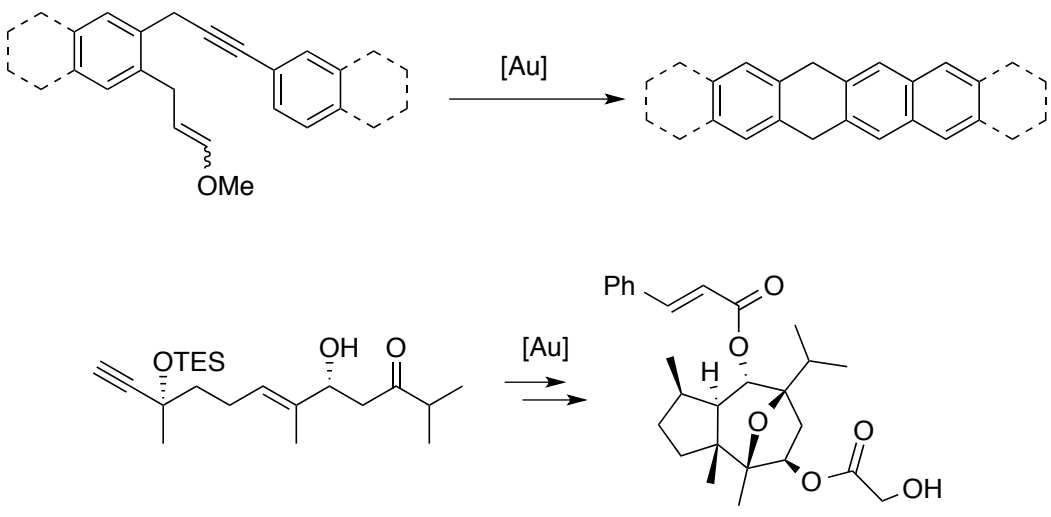
In the field of organic electronics, TIPS-pentacene is widely used as a high-performance small molecule for OFET applications, as the TIPS-acetylene group imparts high solubility in organic solvents, higher stability, allowing it to be easily processed into devices (Scheme 3).[3]




TIPS-pentacene

**Scheme 3.** TIPS-pentacene.

As a functional group in organic chemistry, alkynes are one of the most versatile synthetic handles, being able to participate in different types of transformations.[4] As examples using gold catalysis, our group exploited the intramolecular reaction of alkynes with alkenes to generate complex molecular structures relevant in material science (acenes[5] as potential organic electronics) or human health (englerins[6] as an antitumor agent) (Scheme 4).




(-)-englerin A

3 (a) Anthony, J. E.; Brooks, J. S.; Eaton, D. L.; Parkin, S. R. *J. Am. Chem. Soc.* **2001**, *123*, 482−483. (b) Anthony, J. E. *Angew. Chem. Int. Ed.* **2008**, *47*, 452−483.

4 (a) *Acetylene Chemistry: Chemistry, Biology and Material Science*; F. Diederich, P. J. Stang, R. R. Tykwinski, Eds.; Wiley-VCH: Weinheim, Germany, 2005. (b) Boyd, G. V. *The Chemistry of Triple Bonded Functional Groups*; Patai, S., Ed.; Wiley: Hoboken, NJ, 1994; Chapter 5.

5 Dorel, R.; McGonigal, P. R.; Echavarren, A. M. *Angew. Chem. Int. Ed.* **2015**, *55*, 11120−11123.

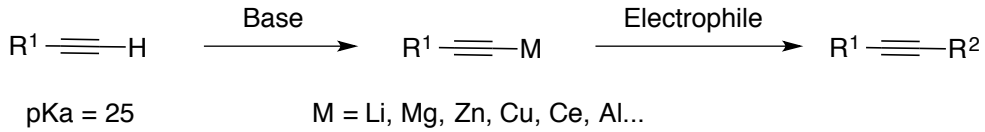
6 Molawi K.; Delpont N.; Echavarren A. M., *Angew. Chem. Int. Ed.* **2010**, *49*, 3517−3519.

**Scheme 4.** Access to hydroacenes (top) and Englerin A (bottom) *via* gold(I)-catalyzed intramolecular reaction of alkynes with alkenes.

Therefore, the development of methods for the introduction of alkynes onto organic molecules is of high interest.

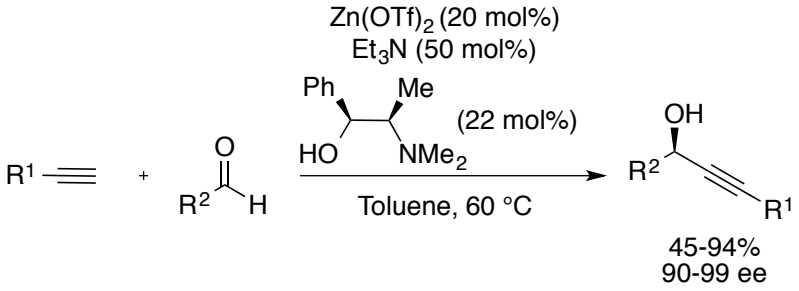
## Methods for the Introduction and Synthesis of Alkynes

Terminal alkynes ($pK_a$ = 24) can be deprotonated by a strong base, thus generating a metal-acetylide that can react with a range of electrophiles. Different metals, such as Li, Mg, Zn, Ce, Cu, Al can be used and generate different types of reactivity (Scheme 5).[7]




**Scheme 5.** Metal-acetylide: synthesis *via* deprotonation and reaction with electrophile.

A general method for the enantioselective alkynylation of aldehydes was developed by Carreira using zinc-acetylides in the presence of (+)-*N*-methylephedrine ligand (Scheme 6).[8]



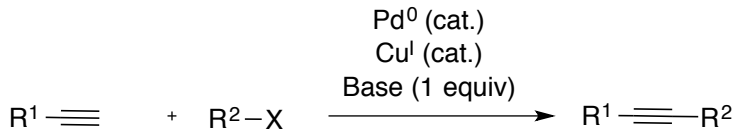

**Scheme 6.** Enantioselective addition of zinc-acetylides to aldehydes.

Alkynes can also be introduced onto an organic fragment using the Sonogashira reaction. This general method allows the formation of C(sp)–C($sp^2$) bonds from aryl or alkenyl (pseudo)halides and terminal alkynes, using a palladium catalyst, a copper co-catalyst and a secondary or tertiary amine (Scheme 7).[9] The mechanism follows the general scheme of cross-coupling reactions, with an oxidative addition of an aryl (pseudo)halide onto a Pd(0) catalyst, followed by transmetallation with a copper acetylide and reductive elimination. The copper acetylide is formed by deprotonation of a Cu π-complex with a base.

7 Organometallics in Synthesis – A Manual. Schlosser, M. (2002), John Wiley & Sons Ltd. West Sussex.

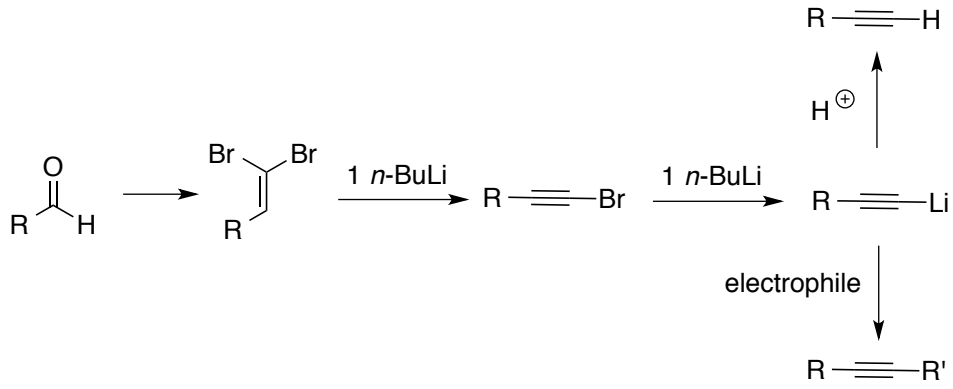
8 Frantz, D. E.; Fässler, R.; Carreira E. M. *J. Am. Chem. Soc.* **2000**, *122*, 1806−1807. (b) Anand, N. K.; Carreira, E. M. *J. Am. Chem. Soc.* **2001**, *123*, 9687−9688.

9 (a) Sonogashira, K.; Tohda, Y.; Hagihara, N.; *Tetrahedron Lett.* **1975**, *16*, 4467−4470. (b) Chinchilla, R.; Najera, C. *Chem. Rev.* **2007**, *107*, 874−922.




**Scheme 7.** Sonogashira reaction.

Instead of adding an alkyne onto an organic fragment, alkynes can also be formed by elimination reactions. A typical example is the Corey-Fuchs reaction (Scheme 8),[10] where a vinyldibromo intermediate generated from an aldehyde is treated with *n*-Buli. The first equivalent deprotonates the vinylhydrogen and forces the elimination of *n*-BuH and LiBr, thus generating a bromoalkyne. The second equivalent of *n*-BuLi exchanges the bromide with lithium, and allows the formation of either a terminal alkyne by protic quench, or an internal alkyne by reaction with an electrophile. This sequence, consisting of an olefination followed by elimination, allows the homologation of aldehydes to alkynes.

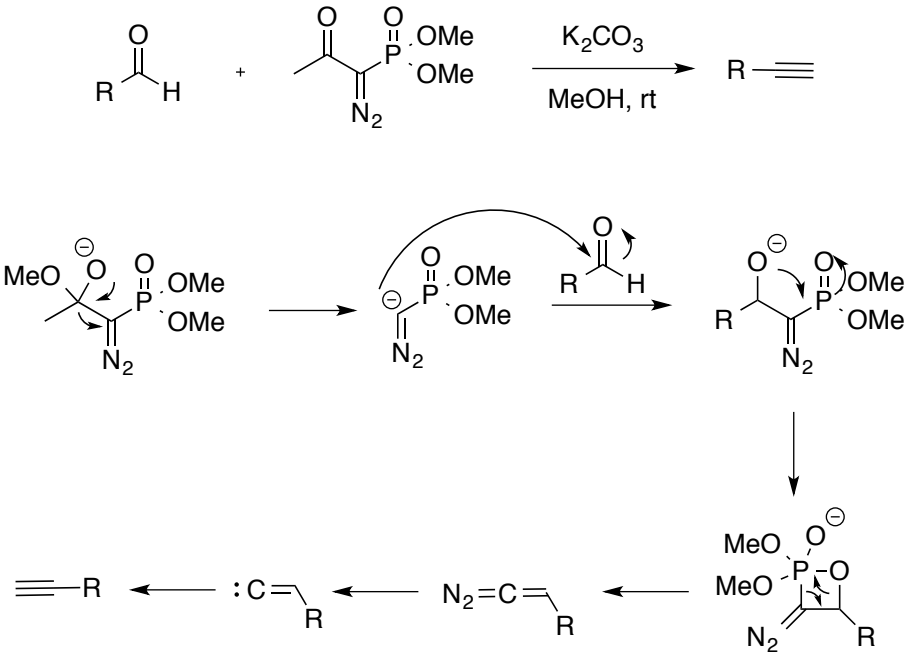



**Scheme 8.** Corey-Fuchs reaction.

The same transformation can be achieved using the Ohira-Bestmann reagent under mild conditions (Scheme 9).[11] The diazophosphonate, which is an improved version of the Seyferth-Gilbert reagent, reacts with aldehydes and ketones to generate an oxaphosphetane, similarly to the Wittig reaction. After cycloelimination, a diazoalkene is formed and loss of nitrogen gives a vinylidene carbene that yields the desired alkyne after 1,2-H migration.

10 Corey, E. J.; Fuchs, P. L. *Tetrahedron Lett.* **1972**, *13*, 3769−3772.

11 (a) Seyferth, D.; Marmor, R. S.; Hilbert, P. *J. Org. Chem.,* **1971,** *36*, 1379−1386. (b) Gilbert, J. C.; Weerasooriya, U. *J. Org. Chem.* **1982**, *47*, 1837−1845. (c) Ohira, S. *Synth. Commun.* **1989**, *19*, 561−564. (d) Roth, G. J.; Liepold, B.; Müller, S. G.; Bestmann, H. J. *Synthesis* **2004**, *1*, 59−62.



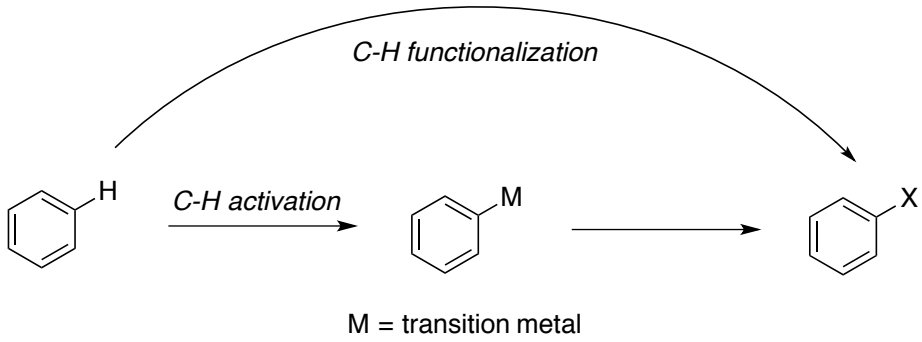

**Scheme 9.** Synthesis of alkynes with the Ohira-Bestmann reagent.

With these different methods in mind, we focused on developing an alternative retrosynthetic disconnection in the context of alkynylation. We sought to use simple functional groups as handle for the introduction of alkynes by metal-catalyzed C−H alkynylation reactions. These reactions would proceed by chelation-assisted C−H activation, followed by reaction with an acetylene donor.

## C−H Activation: General Introduction

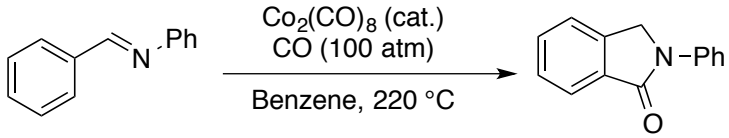
Traditional organic synthesis makes new bonds by using the available functional groups leaving the rest of the inert C−H bonds untouched. In recent years, the ability to activate these 'unreactive' C−H bonds and transform them using transition metals enabled the construction of organic molecules in more direct way than using established approaches. The field studying their transformation using the transition metals is mostly called C−H activation or C−H functionalization.

The terms "C−H functionnalization" and "C−H activation" have different meanings. The term "C−H functionalization" describes the transformation of a C−H bond into a C−X bond, where X is different from H (Scheme 10). The term "C−H activation" describes the replacement of a C−H bond by a C−M bond, where M is a transition metal that can be more easily functionalized. A C−H activation followed by a reaction from C−M to C−X is therefore a key part of a metal-catalyzed C−H functionalization process.



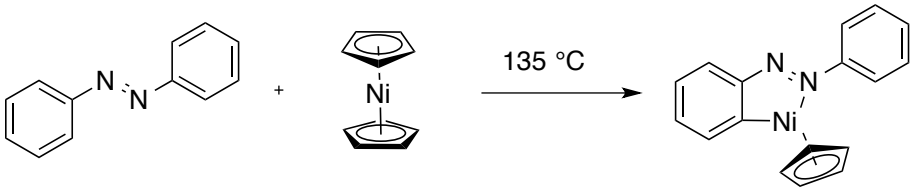

**Scheme 10.** C−H activation and C−H functionalization.

Although no organometallic intermediate had been isolated at that time, the first reaction occurring through C−H activation was reported in 1955 by Murahashi.[12] The reaction of $Co_2(CO)_8$ with aromatic aldimines under pressure of carbon monoxide at high temperatures formed isoindolinones (Scheme 11).




**Scheme 11.** Cobalt-mediated synthesis of isoindolines by reaction of aromatic aldimines with carbon monoxide.

In 1963, Kleiman and Dubeck showed that the *ortho*-C−H bond of azobenzene can be metalated using stoichiometric amount of dicyclopentadienylnickel to afford a five-membered nickelacycle (Scheme 12).[13] This is the first isolation of an organometallic intermediate generated by C−H activation.



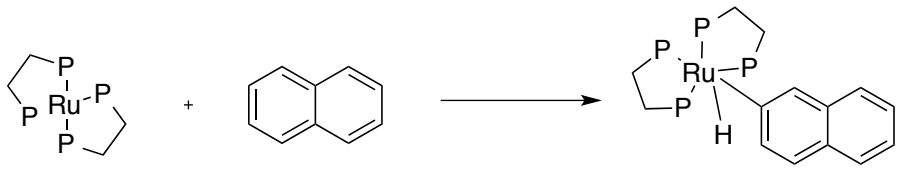

**Scheme 12.** Formation of nickelacycle by C−H activation of azobenzene.

In 1965, Chatt and Davidson showed that a ruthenium(0) complex was able to activate a C−H bond of naphthalene at the less sterically hindered position without the need of a chelating group (Scheme 13).[14]

12 Murahashi, S. *J. Am. Chem. Soc.* **1955**, *77*, 6403−6404.

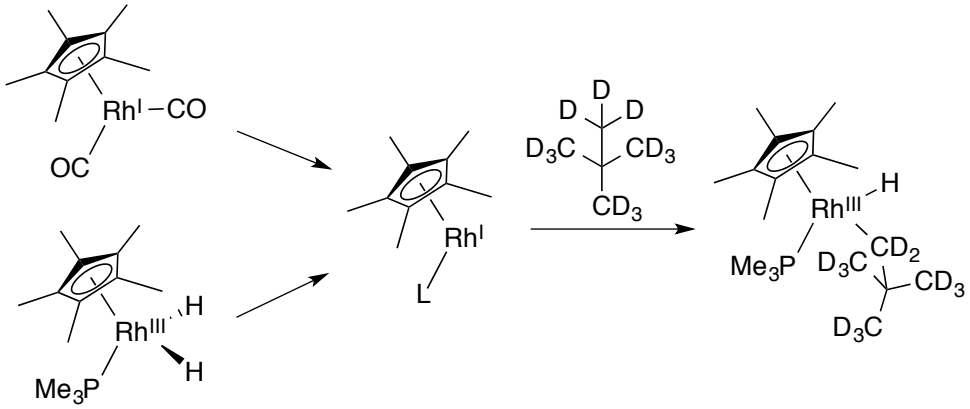
13 Kleiman, J. P.; Dubeck, M. *J. Am. Chem. Soc.* **1963**, *85*, 1544−1545.

14 Chatt, J.; Davidson, J. M. *J. Chem. Soc.* **1965**, 843−855.




**Scheme 13.** C−H activation of naphthalene by Ru(0) complex.

Two decades later, Bergman,[15] Graham,[16] and Jones[17] reported the first examples of oxidative addition of unactivated alkane C−H bonds to Cp*($PMe_3$)M (M = Ir, Rh) fragments, resulting in metal alkyl−hydride products (Scheme 14). These results represent the first observations of C($sp^3$)−H activation through oxidative addition. In particular, Bergman showed that under photochemical conditions the electron rich complex RhCp*($PMe_3$)$(H)_2$ releases $H_2$ and undergoes oxidative addition on the C−H bond to generate a hydrido(alkyl)metal complex.




**Scheme 14.** C−H activation of unactivated alkanes by Cp*M(I) complexes (M = Rh or Ir).

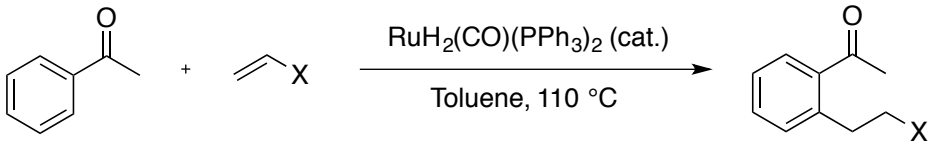
Although other examples of stoichiometric C−H bond cleavage by various metals appeared, catalytic versions remained undeveloped for a long time. In 1993, Murai reported the Ru-catalyzed C−H functionalization of aromatic ketones with alkenes (Scheme 15).[18] Very high yields and regioselectivties could be achieved through the use of a simple and weakly coordinating directing group such as ketones. This reaction inspired many other chelation-assisted C−H functionalizations of arenes. However, an important drawback in this and related reactions is the C−H activation *via* oxidative addition, forming a Ru(II)−H hydride intermediate, which limits the subsequent elementary organometallic step mainly to migratory insertions.

15 Janowicz, A. H.; Bergman, R. G. *J. Am. Chem. Soc.* **1982**, *104*, 352−354.

16 Hoyano, J. K.; Graham, W. A. G. *J. Am. Chem. Soc.* **1982**, *104*, 3723−3725

17 Jones, W. D.; Feher, F. J. *Organometallics*, **1983**, *2*, 562−563.

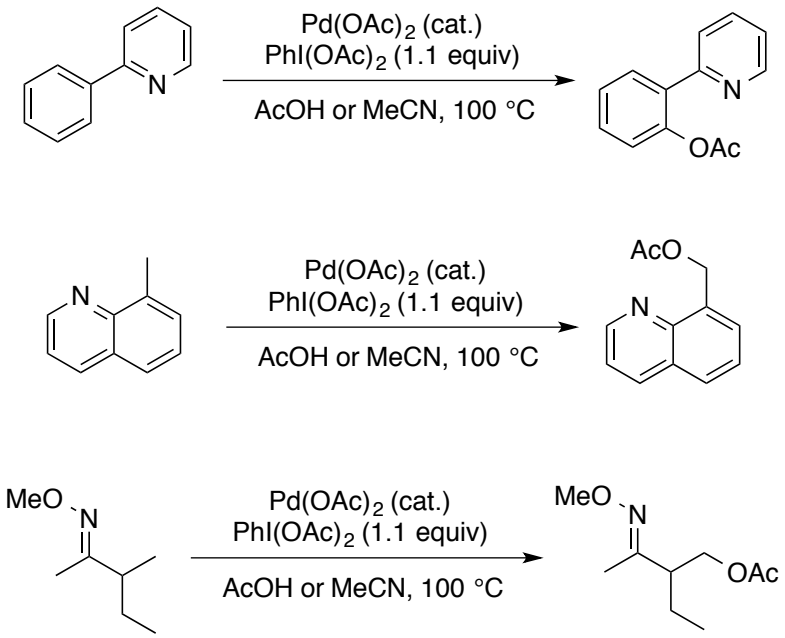
18 Murai, S.; Kakiuchi, F.; Sekine, S.; Tanaka, Y.; Kamatani, A.; Sonoda, M.; Chatani, N. *Nature,* **1993**, *366,* 529−531.




**Scheme 15.** Murai reaction.

**Seminal studies on catalytic C−H functionalizations using Pd(II), Rh(III) and Ru(II)**

In the early 2000s, different research groups showed that Pd(II) metallacycles, generated by concerted-metalation-deprotonation-type (CMD) C−H activation, can be engaged in further functionnalization reactions in a catalytic manner. This opened up new possibilities by exploiting the versatile reactivity of organopalladium(II) intermediates known for decades from the field of cross-coupling reactions. Sanford showed in 2004 that oximes and pyridines can be used as directing groups for the β-C($sp^2$)−H and β-C($sp^3$)−H functionalization using I(III) oxidants (Scheme 16).[19]

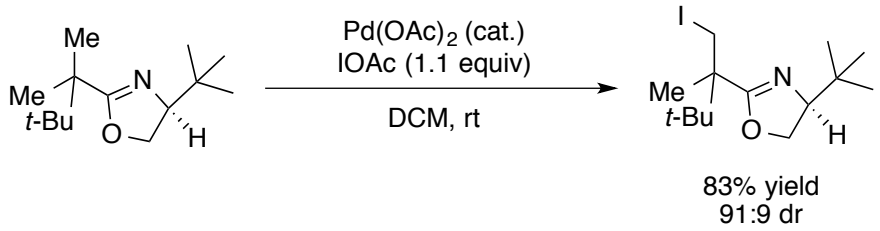



**Scheme 16.** Pd(II)-catalyzed C−H oxidation directed by nitrogen heterocycles (top and middle) and oximes (bottom).

One year later, Yu showed that asymmetric C−H activation was possible, using a chiral directing group and a Pd(II) source (Scheme 17).[20]

19 (a) Dick, A. R.; Hull, K. L.; Sanford, M. S. *J. Am. Chem. Soc.* **2004**, *126*, 2300−2301. (b) Desai, L. V.; Hull, K. L.; Sanford, M. S. *J. Am. Chem. Soc.* **2004**, *126*, 9542−9543.

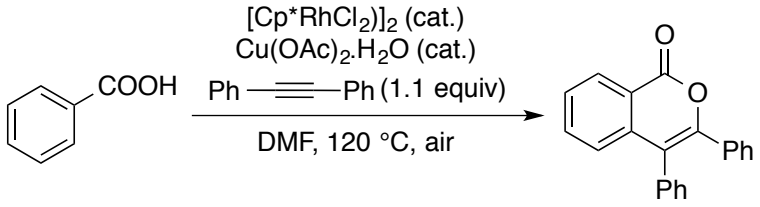
20 Giri, R.; Chen, X.; Yu, J.-Q. *Angew. Chem. Int. Ed.* **2005**, *44*, 2112−2115.




**Scheme 17.** Pd(II)-catalyzed asymmetric C−H iodination directed by a chiral oxazolidine.

Other highly active catalysts for mechanistically related chelation-assisted C−H functionalizations are based on rhodium and ruthenium.

The first example using Cp*Rh(III) as catalyst was reported by Satoh and Miura in 2007, who showed that benzoic acids can react with internal alkynes in the presence of a copper oxidant to form isocoumarins (Scheme 18).[21] The alkyne reacts with the rhodacyclic intermediate in a migratory insertion step, followed by reductive elimination promoted by the copper salt.

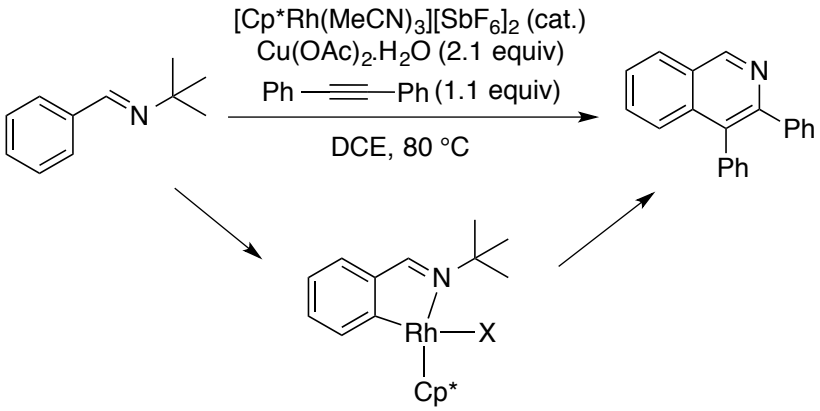



**Scheme 18.** Cp*Rh(III)-catalyzed oxidative cyclization of benzoic acids with internal alkynes.

One year later, Jones performed mechanistic work by isolating the metallacycles generated by reaction from a Cp*Rh(III) salt and phenyl-aldimine and showed their reactivity with internal alkynes to yield isoquinolines (Scheme 19).[22]

21 (a) Uera, K.; Satoh, T.; Miura, M. *Org. Lett.* **2007**, *97*, 1407−1409. (b) Funes-Ardoiz, I.; Maseras, F. *Angew. Chem. Int. Ed.* **2016**, *55*, 2765−2767.

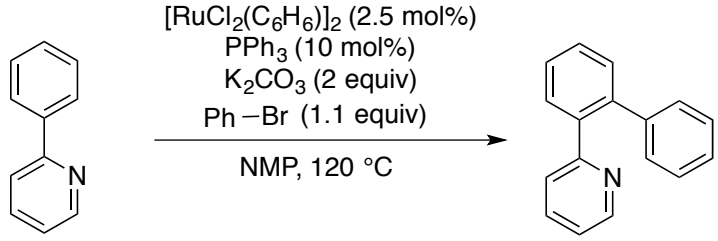
22 Li, L.; Brennessel, W. W.; Jones, W. D. *J. Am. Chem. Soc*. **2008**, *130*, 12414−12419.




**Scheme 19.** Formation of Cp*-rhodacycles and reaction with internal alkynes.

Fagnou later exploited these reactivities for the synthesis of nitrogen heterocycles, and further provided seminal mechanistic insight into those reactions.[23]

These seminal reports inspired many other research groups to develop reactions varying directing groups and coupling partners.[24] In the case of ruthenium, work by Oi and Inoue showed that a Ru(II) catalyst can react with 2-pyridylbenzene to generate a metallacycle (Scheme 20), which can further react with arylhalides resulting in an *ortho*-arylation reaction.[25] In comparison to Pd(II), Cp*Rh(III) or Cp*Ir(III), Ru(II) metallacycles have a better ability to react with aryl halides, presumably *via* more facile oxidative addition/reductive elimination. Further mechanistic work by Dixneuf and Bruneau in collaboration with Maseras and Jutand showed that the C−H activation occurs through a concerted-metalation-deprotonation mechanism, similarly to Pd(II).[26]




23 (a) Stuart, D. R.; Bertrand-Laperle, M.; Burgess, K. M. N.; Fagnou K. *J. Am. Chem. Soc.* **2008**, *130*, 16474−16475. (b) Stuart, D. R.; Alsabeh, P.; Kuhn, M.; Fagnou, K. *J. Am. Chem. Soc.* **2010**, *132*, 18326−18339.

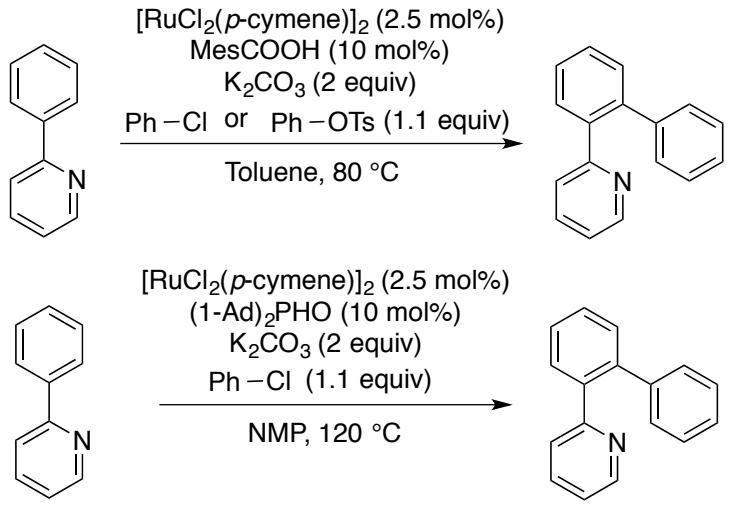
24 (a) Colby, D. A.; Bergman, R.; Ellman, J. A. *Chem. Rev.* **2010**, *110*, 624−655. (b) Song, G; Wang, F.; Li, X. *Chem. Soc. Rev.* **2012**, *41*, 3651−3678. (c) Kuhl, N.; Schröder, N.; Glorius, F. *Adv. Synth. Catal.* **2014**, *356*, 1443−1460.

25 (a) Oi, S.; Fukita, S.; Hirata, N.; Watanuki, N.; Miyano, S.; Inoue, Y. *Org. Lett.* **2001**, *3*, 2579−2581. (b) Oi, S.; Ogino, Y.; Fukita, S.; Inoue, Y. *Org. Lett.* **2002**, *4*, 1783−1785.

26 (a) Arockiam, P. B.; Bruneau, C.; Dixneuf, P. *Chem. Rev.* **2012,** *111,* 5879−5918. (b) Ferrer, E. F.; Bruneau, C.; Dixneuf, P.; Jutand, A. *J. Am. Chem. Soc.* **2011**, *133*, 10161−10170. (c) Özdemir, I.; Demir, S.; Cetinkaya, B.; Gourlaouen, C.; Maseras, F.; Bruneau, C.; Dixneuf, P. H. *J. Am. Chem. Soc.* **2008**, *130*, 1156−1159.

**Scheme 20.** Ru(II)-catalyzed arylation of 2-pyridyl-benzene with aryl halides.

Ligands such as phosphine oxide[27] or bulky carboxylates[28] were developed by Ackermann to broaden the scope of Ru(II)-catalyzed C−H functionalization reactions (Scheme 21).




**Scheme 21.** Ligand-promoted Ru(II)-catalyzed arylation of 2-pyridyl-benzene with aryl halides.

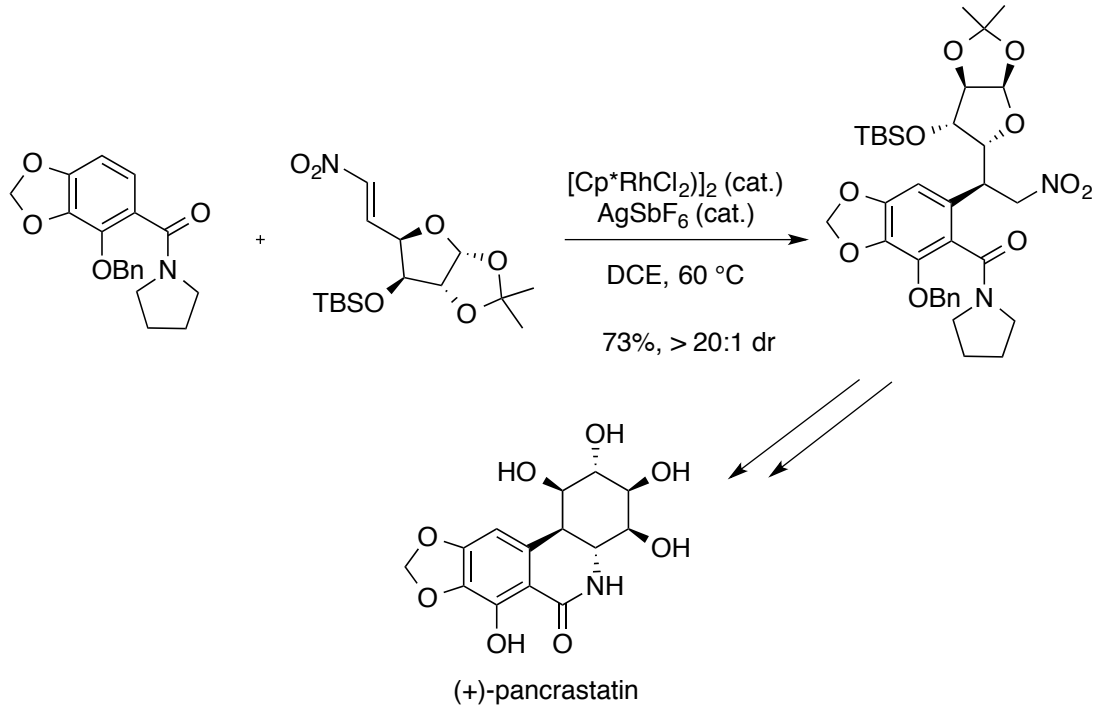
**Applications in the total synthesis of natural products or drugs**

The rapid development of the field led to applications of the reactions developed above in the synthesis of natural products and drugs. Thus, Ellman applied the diastereoselective Cp*Rh(III)-catalyzed reaction of anilide with nitroalkene as a key step in the synthesis of (+)-pancratistatin (Scheme 22).[29]

27 Ackermann, L. *Org. Lett.* **2005**, *7*, 3123−3125.

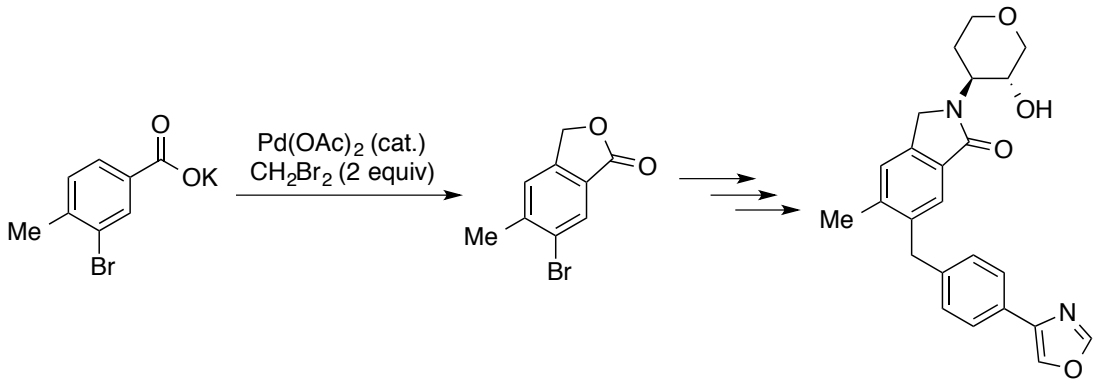
28 Ackermann, L.; Vicente, R.; Althammer, A. *Org. Lett.* **2008**, *10*, 2299−2302.

29 Potter, T. J.; Ellman, J. A. *Org. Lett.* **2017**, *19*, 2985−2988.




**Scheme 22.** Cp*Rh(III)-catalyzed reaction of anilide and nitroalkene in the synthesis of (+)-pancratistatin.

The Pd-catalyzed *ortho*-alkylation of benzoic acids developed by Yu allowed Pfizer to access different γ- and δ-lactams (Scheme 23), which were positive allosteric activators of the muscarinic M1 receptor.[30]




**Scheme 23.** Pd(II)-catalyzed *ortho*-alkylation of benzoic acid in the synthesis of allosteric activator of the muscarinic M1 receptor.

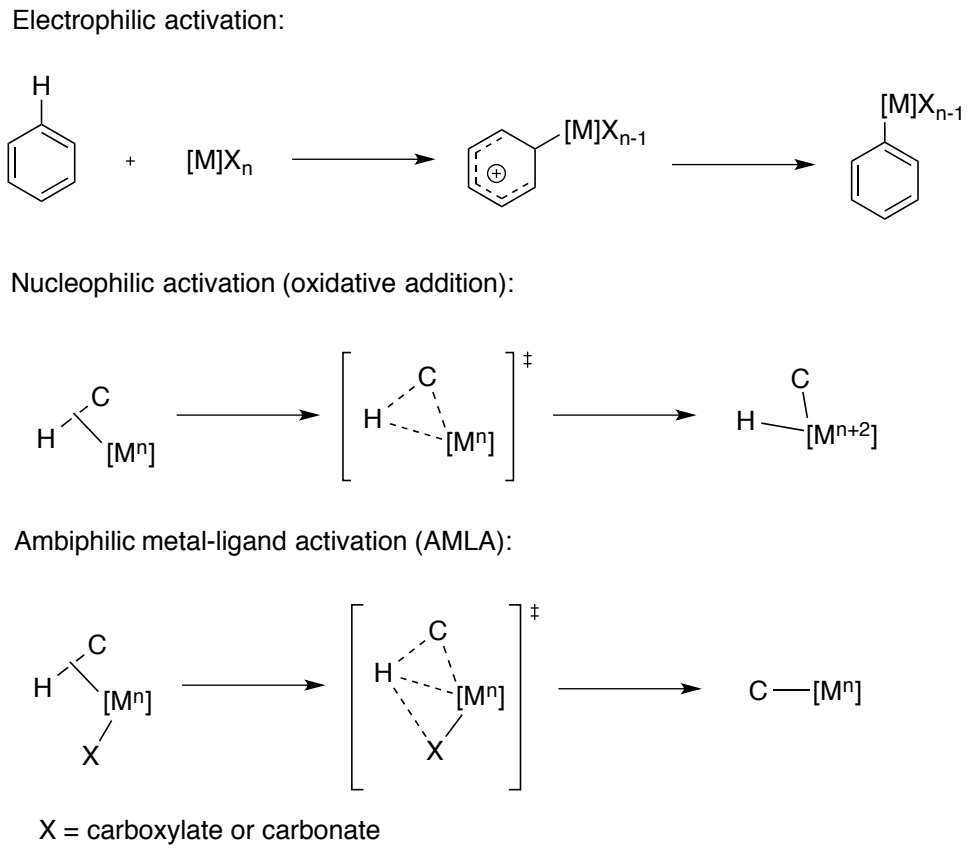
**Mechanistic considerations**

At the early stage of the development of the field of C−H activation using late transition metals, different mechanisms were proposed (Scheme 24). Thus, an electrophilic activation was

30 Davoren, J. E.; Garnsey, M.; Pettersen, B.; Brodney, M. A.; Edgerton, J. R.; Fortin, J.-P.; Grimwood, S.; Harris, A. R.; Jenkinson, S.; Kenakin, T.; Lazzaro, J. T.; Lee, C.-W.; Lotarski, S. M.; Nottebaum, L.; O'Neil, S. V.; Popiolek, M.; Ramsey, S.; Steyn, S. J.; Thorn, C. A.; Zhang, L.; Webb, D. *J. Med. Chem.* **2017**, *60*, 6649−6663.

proposed to occur with electrophilic transition metal species, whereas nucleophilic, oxidative addition pathways were suggested with electron-rich low-valent transition metal centers.

Electron poor, late transition metals in high oxidation states, such as Pd(II), Pt(II), Rh(III), Ir(III) and Ru(II), may react *via* electrophilic activation mechanisms, as the initial (C−H)-to-metal coordination features a strong sigma-donation and weak π-back-donation, and a heterolytic cleavage (deprotonation) by an external anion is usually followed. A variant of this mechanism exists, known in different names such as ambiphilic metal-ligand activation (AMLA), concerted metalation deprotonation, and internal electrophilic substitution (IES), where an intramolecular deprotonation by a heteroatom-based ligand, such as a halide or an alkoxy anion, or a bridging ligand, such as an acyloxy or a carbonate anion, takes place *via* a cyclic concerted mechanism. Alternatively, low valent, late transition metals may induce C−H activation *via* oxidative addition and this can be favored by electron-rich ligands such as phosphines or NHC−ligands.




**Scheme 24.** Mechanisms of C−H activation in late-transition metals.

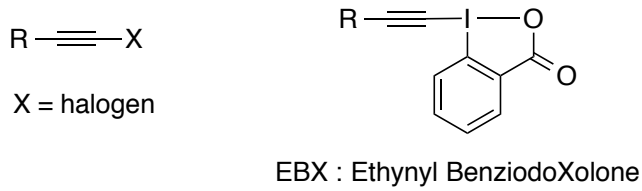
## Precedents in C($sp^2$)−H Alkynylation

Although the Sonogashira reaction is the most general method for the formation of C(sp)−C($sp^2$) bonds from aryl or alkenyl (pseudo)halides and terminal alkynes, its main

limitation resides in the synthetic availability of the required (pseudo)-halides. In recent years, an alternative approach emerged involving the alkynylation of C($sp^2$)−H bonds with terminal alkynes or activated acetylenes such as ethynylbenziodoxolone (EBX) reagents or haloalkynes using transition-metal catalysts.

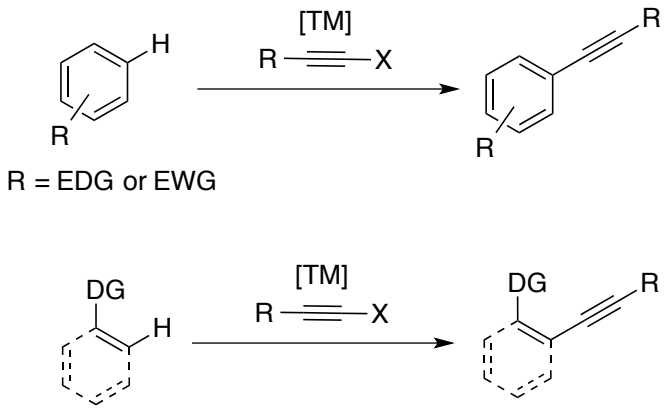
**Terminal alkynes and activated acetylenes: Halo-alkynes and ethynylbenziodoxolone (EBX)**

Often named inverse-Sonogashira coupling, the reaction of preactivated alkynes with C−H bonds offers a complemental strategy to the classical Sonogashira reaction. Ethynylbenziodoxolones (EBX) or 1-haloalkynes can be used as acetylene donors (Scheme 25).[31] These reagents offer several advantages compared to terminal alkynes: 1) Alkyne-homocouplings are often avoided, 2) milder reactions conditions can be achieved, and 3) no terminal oxidant are needed, so functional groups sensitive to oxidation can be tolerated. On the other hand, these reagents have to be synthesized from terminal alkynes, often using strong oxidants, acids or bases. Terminal alkynes can also be used in the presence of terminal oxidant, which can be a reagent, a transition metal, or air.




**Scheme 25.** Halo-alkynes and Ethynylbenziodoxolone (EBX).

On the C($sp^2$)−H fragment, the formation of C−M bond by C−H activation can rely on the innate reactivity of the arene or on the use of a directing group (Scheme 26).[32]



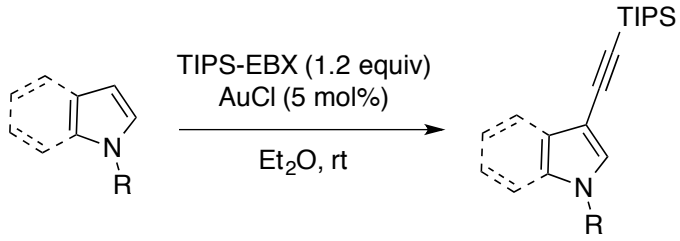

**Scheme 26.** C($sp^2$)−H activation: innate reactivity of arenes or chelation-assistance.

31 (a) Waser, J. *Synlett* **2016**, *27*, 2761−2773. (b) Wu, W.; Jiang, H. *Acc. Chem. Res.* **2014**, *47*, 2485−2504.

32 Dudnik, A. S.; Gevorgyan, V. *Angew. Chem., Int. Ed.* **2010**, *49*, 2096−2098.

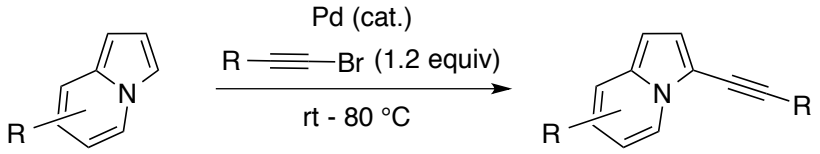
**Innate reactivity of arenes**

Waser designed the reagent EBX and reported its use in the gold-catalyzed direct alkynylation of indoles and pyrroles (Scheme 27).[33] Later, the same group reported the direct alkynylation of other electron-rich heterocycles under similar conditions.[34]



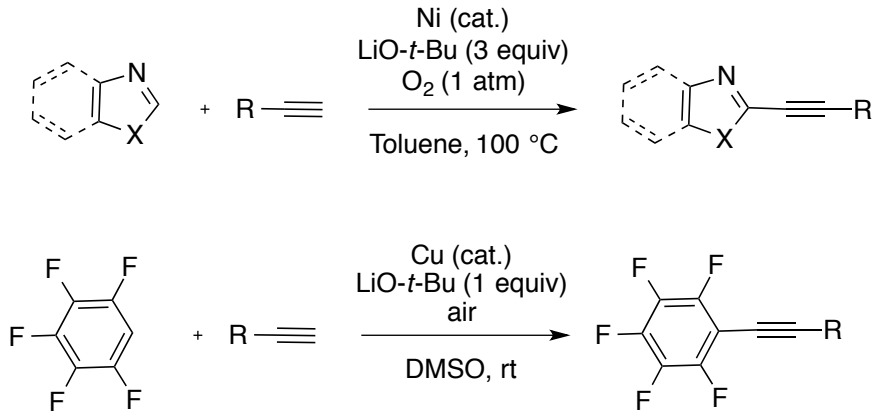

**Scheme 27.** Au(I)-catalyzed direct alkynylation of pyrroles and indoles using EBX.

Gevorgyan showed that bromo-alkynes can react with aryl Pd(II) intermediate generated by electrophilic C−H metalation of *N*-fused heterocycles (Scheme 28).[35]




**Scheme 28.** Pd(II)-catalyzed direct alkynylation of *N*-fused heterocycles using bromo-alkynes.

Satoh and Miura and Piguel revealed that the C-2 position of azoles could be selectively alkynylated using bromoalkynes under Ni and Cu catalysts, respectively (Scheme 29).[36] This reaction presumably exploits the C2-acidity of azole and proceeds through deprotonation by a strong base and transmetallation to Ni or Cu catalyst.




33 Brand, J. P.; Charpentier, J.; Waser, J. *Angew. Chem., Int. Ed.* **2009**, *48*, 9346−9349.

34 Brand, J. P.; Charpentier, J.; Waser, J. *Angew. Chem., Int. Ed.* **2010**, *49*, 7304−7307.

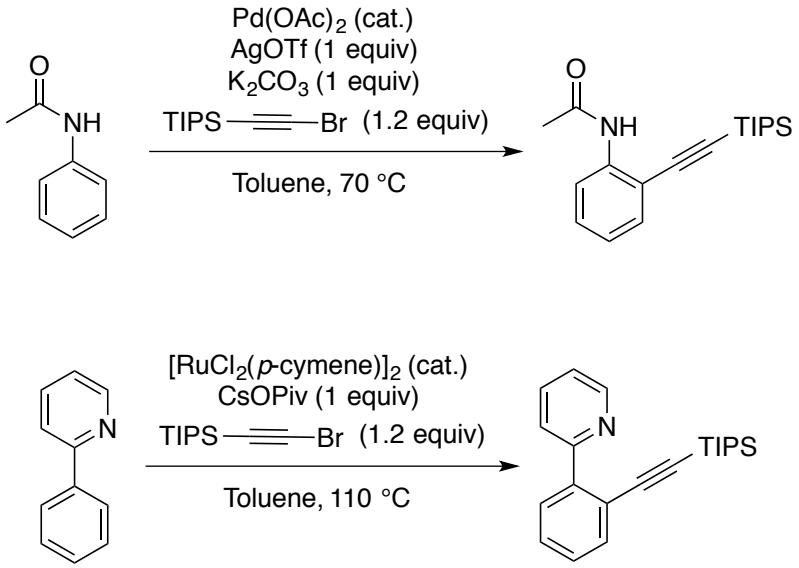
35 Seregin, I. V.; Ryabova, V.; Gevorgyan, V. *J. Am. Chem. Soc.* **2007**, *129*, 7742−7743.

36 (a) Matsuyama, N.; Hirano, K.; Satoh, T.; Miura, M. *Org. Lett.* **2009**, *11*, 4156−4159. (b) Besselievre, F.; Piguel, S. *Angew. Chem., Int. Ed.* **2009**, *48*, 9553−9556

**Scheme 29.** Ni- or Cu-catalyzed direct C2-alkynylation of azoles with bromo-alkynes.

**Chelation assistance**

Another strategy to achieve site-selectivity in the C−H alkynylation reactions is the introduction of a directing group. This Lewis-basic functional group directs the transition metal and guides it to the desired C−H bond, *via* a mechanism discussed in pp. 39−40. Using this process, Tobisu and Chatani reported the first chelation-assisted C−H alkynylation of arenes, using anilides as substrates (Scheme 30, top).[37] Later, the same group reported the ruthenium-catalyzed C−H alkynylation of arenes directed by heterocycles (Scheme 30, bottom).[38]




**Scheme 30.** Pd(II)-catalyzed alkynylation of anilides (top) and Ru(II)-catalyzed C−H alkynylation of arenes directed by nitrogen-heterocycles (bottom).

Although a variety of directing groups has been reported, at the time we started this PhD work, all were typically amides or nitrogen coordinating groups such as heterocycles or imine derivatives (oxime, nitrone, azomethine).[39] The catalytic system consisting of a Cp*Rh(III) catalyst combined with EBX as alkynylating reagent developed by Li and Loh allowed the alkynylation of a broad range of arenes using strongly coordinating directing groups (Scheme 31, top).[40] Glorius also applied it for the alkynylation of alkenes using amides as directing groups (Scheme 31, bottom).[41]

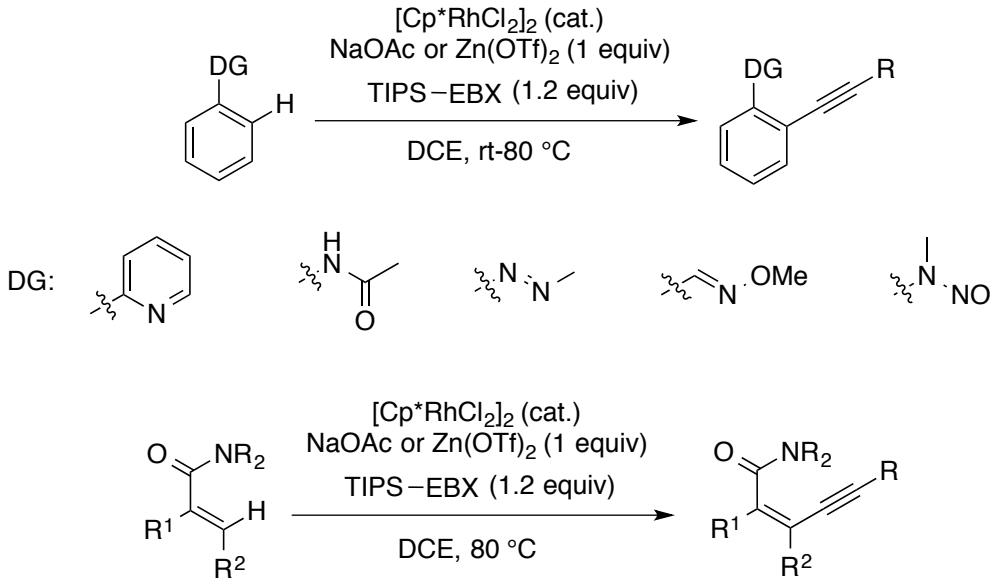
37 Tobisu, M.; Ano, Y.; Chatani, N. *Org. Lett.* **2009**, *11*, 3250−3252.

38 Ano, Y.; Tobisu, M.; Chatani, N. *Synlett* **2012**; *23*, 2763−2767.

39 Chen, Z.; Wang, B.; Zhang, J.; Yu, W.; Liu, Z.; Zhang, Y. *Org. Chem. Front.* **2015**, *2*, 1107−1295.

40 (a) Feng, C.; Loh, T. P. *Angew. Chem. Int. Ed.* **2014**, *53*, 2722−2726. (b) Xie, F.; Qi, Z.; Yu, S.; Li, X. *J. Am. Chem. Soc.* **2014**, *136*, 4780−4787.

41 Collins, K. D.; Lied, F.; Glorius, F. *Chem. Commun.* **2014**, *50*, 4459−4461.

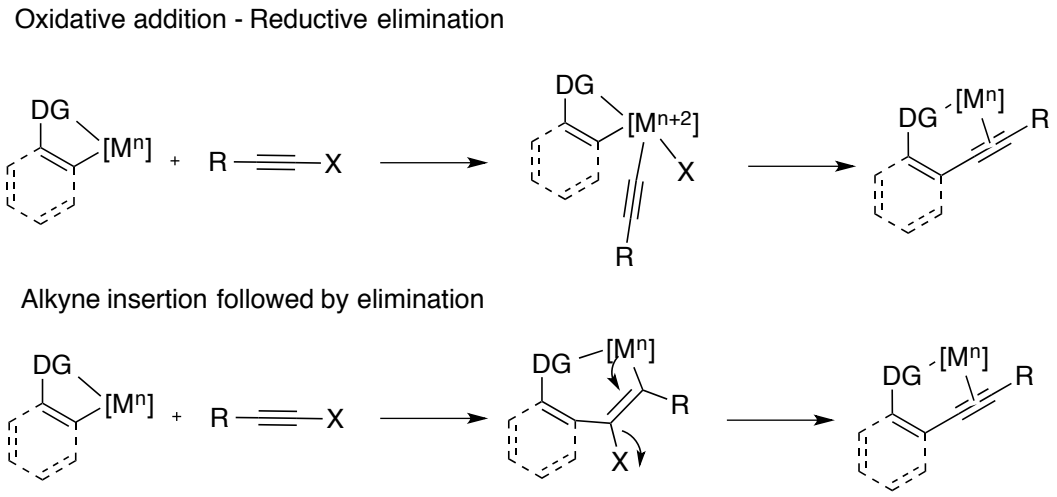



**Scheme 31.** Cp*Rh(III)-catalyzed alkynylation of arenes directed by strongly coordinating groups (top) and Cp*Rh(III)-catalyzed alkynylation alkenyl-C($sp^2$)−H bonds directed by amides (bottom).

As in most cases the directing groups need to be installed and/or removed, the applicability of this strategy in multistep synthesis is limited. Therefore, to render this approach useful, we pursued the development of new protocols using instead widely used functional groups serving as synthetic handles.

**Mechanistic considerations of the alkynylation step**

Once the chelation-assisted C−H activation occurs, the alkyne can react with the metallacycle following different mechanistic pathways. Using activated acetylenes such as EBX or 1-haloalkynes, initial coordination of the electrophilic alkyne reagent to the metal center can be followed by oxidative addition and reductive elimination. This pathway is favored for metals in low oxidation states with electron rich ligands, and this probably occurs for highly electrophilic EBX. Although it cannot be excluded for halo-alkynes, an insertion-elimination pathway seems a more viable alternative for metals of higher oxidation states, considering the charge distribution of halo-alkynes (Scheme 32).




**Scheme 32.** Reaction between a metallacycle and an acetylene donor.

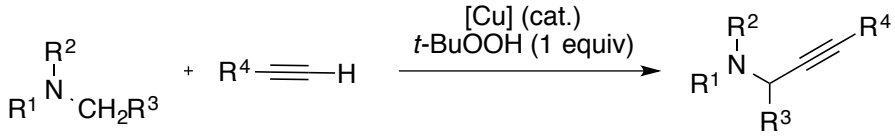
Indeed, Sarpong and Musaev found that bromo-alkynes react with a Pd(II)-metallacycle *via* an insertion, followed by bromide elimination pathway, whereas iodo-alkynes react with a Pd(II)-palladacycle *via* an oxidative addition-reductive elimination pathway.[42] They also found that the efficiency of the alkynylation lies in the release of ring-strain of the metallacycle in the transition state of the alkyne insertion step and in a β-metal effect stabilizing a carbocationic transition state in the bromide elimination step. [43]

In the cases of when terminal alkynes are used, transmetalations of in-situ activated alkynes to the metallacycle followed by a reductive elimination are the most frequently proposed mechanism.

## Precedents in C($sp^3$)−H Alkynylation

C($sp^3$)−H bonds can be alkynylated following two general mechanistic pathways. Firstly, a radical can be generated at the α-position of a heteroatom, which reacts with different alkyne donors. Thus, in 2004, Li reported a seminal study on the Cu-catalyzed alkynylation of C($sp^3$)−H bonds adjacent to a nitrogen atom, using terminal alkynes in the presence of an oxidant (Scheme 33).[44] This reaction either proceeds by the generation of a radical α to the nitrogen-atom, or was proposed to proceed by formation of an imine by treatment with *t*BuOOH followed by addition of the copper acetylide. Later, many examples varying the transition metal and alkyne donors were reported.[45]

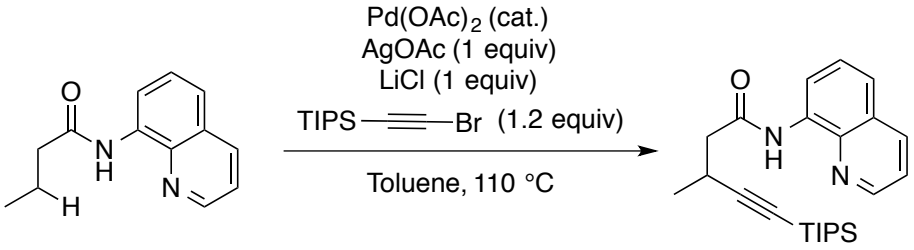
42 Haines, B. E.; Sarpong, R.; Musaev; D. G. *J. Am. Chem. Soc*. **2018**, *140*, 10612−10618.
43 Usui, K.; Haines, B. E.; Musaev, D. G.; Sarpong, R. *ACS Catal.* **2018**, *8*, 4516−4527.
44 Li, Z.; Li, C.-J. *J. Am. Chem. Soc.* **2004**, *126*, 11810−11811.
45 Le Vaillant, F.; Waser, J. *Chem. Sci.* **2019**, *10*, 8909−8923.




**Scheme 33.** Cu-catalyzed oxidative C($sp^3$)−H bonds alkynylation.

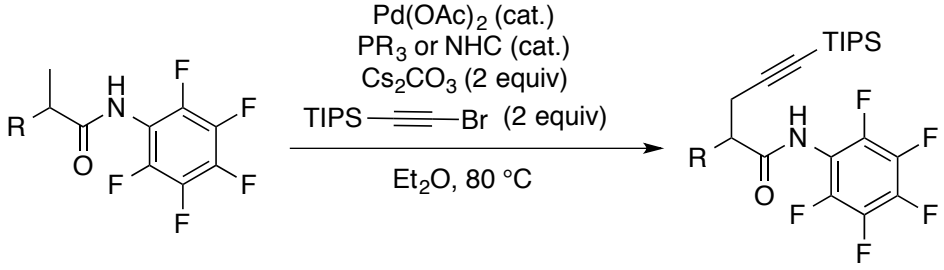
Alternatively, C($sp^3$)−H bonds can be alkynylated by catalytic chelation assisted C−H functionalization using a transition metal. These reactions follow the same mechanistic pathway as in the functionalization of C($sp^2$)−H bonds (cf. pp. 40−41). However, the lower acidity and the absence of π-interactions between the substrate and the catalyst render the C−H cleavage more difficult. Moreover, the migratory insertion into of unsaturated substrates into C($sp^3$)−M bonds is much less common than the corresponding insertion into C($sp^2$)−M bonds.

The first example of C($sp^3$)−H alkynylation was reported by Tobisu and Chatani using palladium as catalyst and a bidentate 8-aminoquinoline as directing group (Scheme 34).[46] With bromo-alkynes as alkynylating reagent, different secondary and primary C−H bonds could be alkynylated.




**Scheme 34.** Pd(II)-catalyzed C($sp^3$)−H alkynylation directed by a bidentate 8-aminoquinoline directing group.

Yu showed that the β-C($sp^3$)−H bonds of weakly coordinating amides could be alkynylated using bromo-alkynes, this time using a Pd(0) catalyst in the presence of an electron-donating ligand (phosphine or NHC) (Scheme 35).[47] This reaction presumably occurs through first oxidative addition of the Pd(0) catalyst to the bromo-alkyne, followed by chelation-assisted C−H activation of the alkynyl-Pd(II) intermediate.

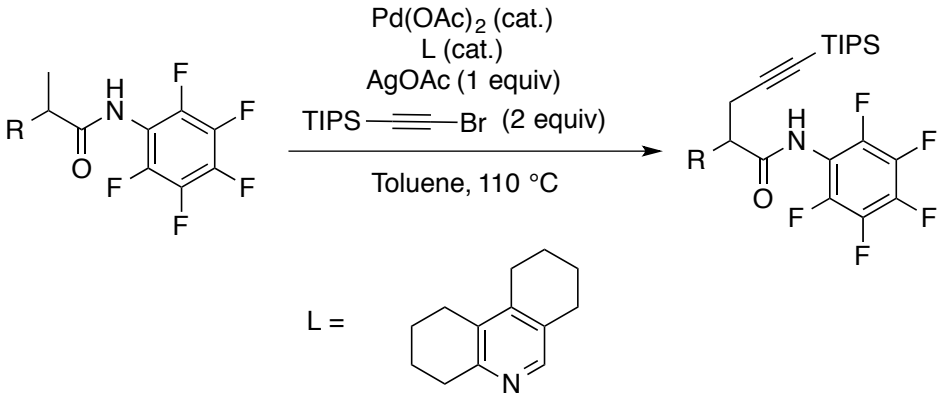



46 Ano, Y.; Tobisu, M.; Chatani, N. *J. Am. Chem. Soc.* **2011**, *133*, 12984−12986.

47 He, J.; Wasa, M.; Chan, K. S. L.; Yu, J.-Q. *J. Am. Chem. Soc.* **2013**, *135*, 3387−3388.

**Scheme 35.** Pd(0)-catalyzed C($sp^3$)−H alkynylation directed by a weakly coordinating amide in the presence of an electron-rich ligand.

The same group later disclosed that a similar transformation could be catalyzed by Pd(II), where a weakly coordinated amide allows the assistance of a pyridine-type ligand (Scheme 36).[48] The reaction was proposed to occur by a Pd(II)/Pd(IV) catalytic cycle.



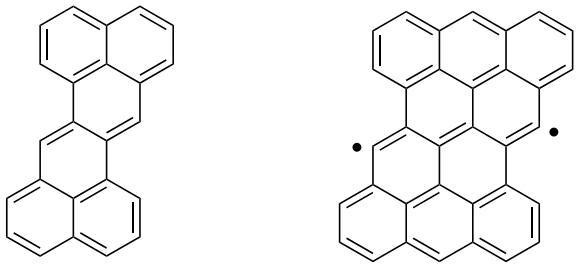

**Scheme 36.** Pd(II)-catalyzed C($sp^3$)−H alkynylation directed by a weakly coordinating amide in the presence of pyridine-type ligand.

48 (a) Fu, H.; Shen, P.-X.; He, J.; Zhang, F.; Li, S.; Wang, P.; Liu, T.; Yu, J.-Q. *Angew. Chem. Int. Ed.* **2017**, *56*, 1873−1876. (b) Liu, T.; Qiao, J. X.; Poss, M. A.; Yu, J.-Q. *Angew. Chem. Int. Ed.* **2017**, *56*, 10924−10927. (c) Wu, Q.-F.; Shen, P.-X.; He, J.; Wang, X.-B.; Zhang, F.; Shao, Q.; Zhu, R.-Y.; Mapelli, C.; Qiao, J. X.; Poss, M. A.; Yu J.-Q. *Science* **2017**, *355*, 499−503.

# *Chapter I: Ru- and Rh-Catalyzed Chelation-Assisted C($sp^2$)-H Alkynylation with Bromo-Alkynes*

## Introduction

Zethrene is a Z-shaped conjugated polycyclic hydrocarbon containing a 1,3-butadiene moiety in the π-conjugated framework. This molecule displays a singlet diradical ground state, which imparts magnetic properties and potential applications in areas such as organic electronics, photonics, spintronics, and energy storage.[1] The initial goal of this PhD work was the synthesis of superzethrene,[2] a laterally-extended zethrene, which is predicted to have larger diradical character (Scheme 1). However, its synthesis could be challenging because of its expected high reactivity and the lack of synthetic routes to access such large conjugated polycyclic hydrocarbon.

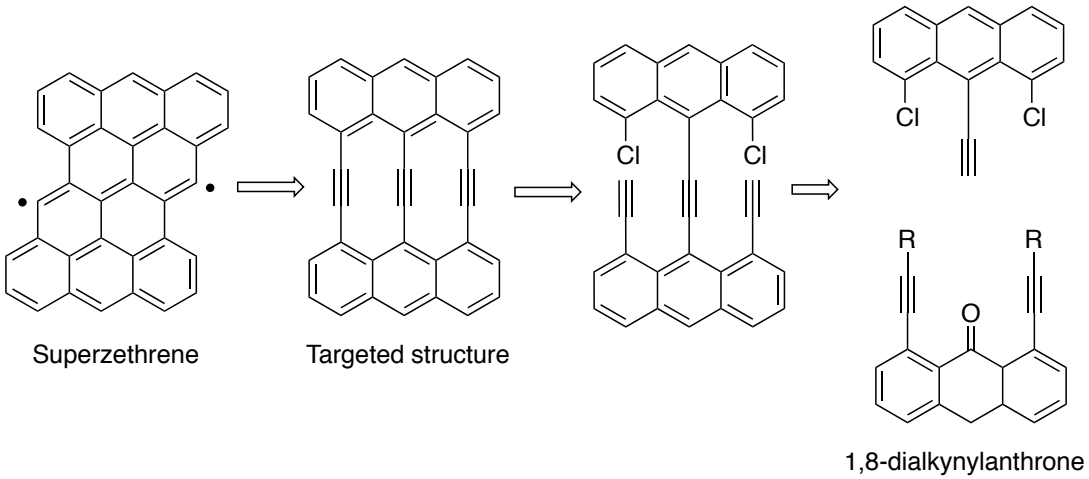


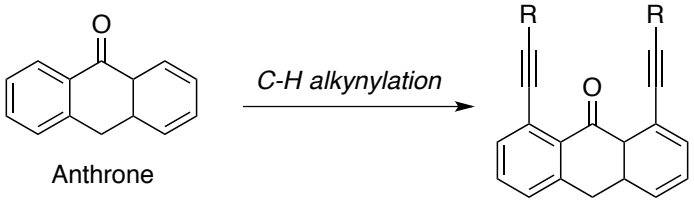

**Scheme 1.** Zethrene and superzethrene.

Among the different synthetic routes that we considered, we chose a convergent synthesis consisting on a first step based on the C−H alkynylation of anthrone (Scheme 2). This C−H functionalization reaction would deliver a 1,8-dialkynylanthrone, which would react with a metal-acetylide to generate an intermediate that would cyclize under palladium catalysis. The resulting target structure would cyclize in a Bergmann-type rearrangement to yield superzethrene.

1 (a) Sun, Z.; Ye, Q.; Chi, C.; Wu, J. *Chem. Soc. Rev.* **2012**, *41*, 7857−7889. (b) Abe, M. *Chem. Rev.* **2013**, *113*, 7011−7088. (c) Sun, Z.; Zeng, Z. Wu, J. *Acc. Chem. Res.* **2014**, *47*, 2582−2591. (d) Kubo, T. *Chem. Rec.* **2015**, *15*, 218−232. (e) Miyoshi, H.; Nobusue, S.; Shimizu, A.; Tobe, Y. *Chem. Soc. Rev.* **2015**, *44*, 6560−6577.

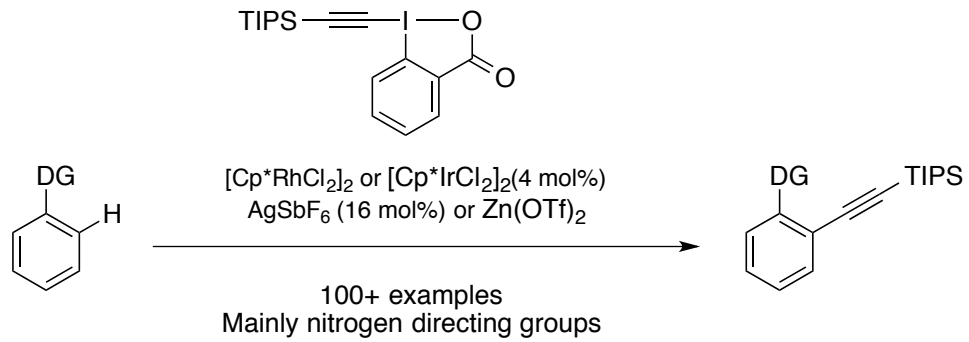
2 6 months after the beginning of this PhD work, the group of J. Wu reported the synthesis of a diversely substituted super-heptazethrene: Zeng, W.; Sun, Z.; Herng, T. S.; Goncalves, T. P.; Gopalakrishna, T. Y.; Huang, K.-W.; Ding, J.; Wu, W. *Angew. Chem. Int. Ed.* **2016**, *128*, 8757−8761.




**Scheme 2.** Synthetic route based on a C−H alkynylation of anthrone and a cycloisomerization of aryl-acetylenes.

The C−H alkynylation of anthrone is challenging because the ketone is a weakly coordinating group. Indeed, only few C−H functionalizations of anthrone are known.[3] To design such a reaction, we took inspiration from a protocol developped by Li (Scheme 3) that allows the alkynylation of arenes directed by a broad range of strongly coordinating directing groups.[4] This reaction uses EBX as alkynylating reagent with a Cp*Rh(III) catalyst.

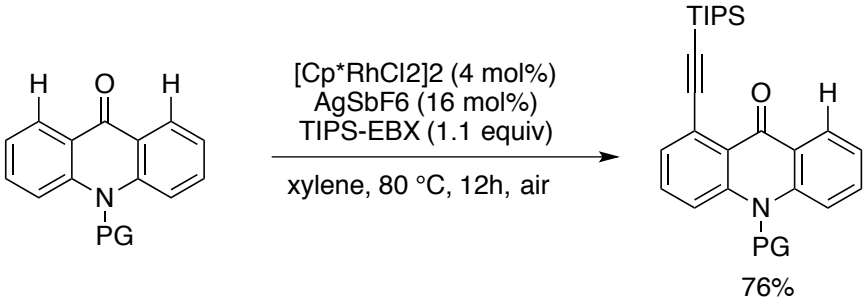



3 (a) Tan, G.; You, Q.; You, J. *ACS Catal.* **2018**, *8*, 8709−8714. (b) Kim, J.; Chang, S. *Angew. Chem. Int. Ed.* **2014**, *53*, 2203−2207. (c) Gandeepan, P.; Parthasarathy, K.; Cheng, C.-H. *J. Am. Chem. Soc.,* **2010**, *132*, 8569−8571.

4 Xie, F.; Qi, Z.; Yu, S.; Li, X. *J. Am. Chem. Soc.* **2014**, *136*, 4780−4787.

**Scheme 3.** Rh(III)-catalyzed C-H alkynylation of arenes with EBX using strongly coordinating directing groups.

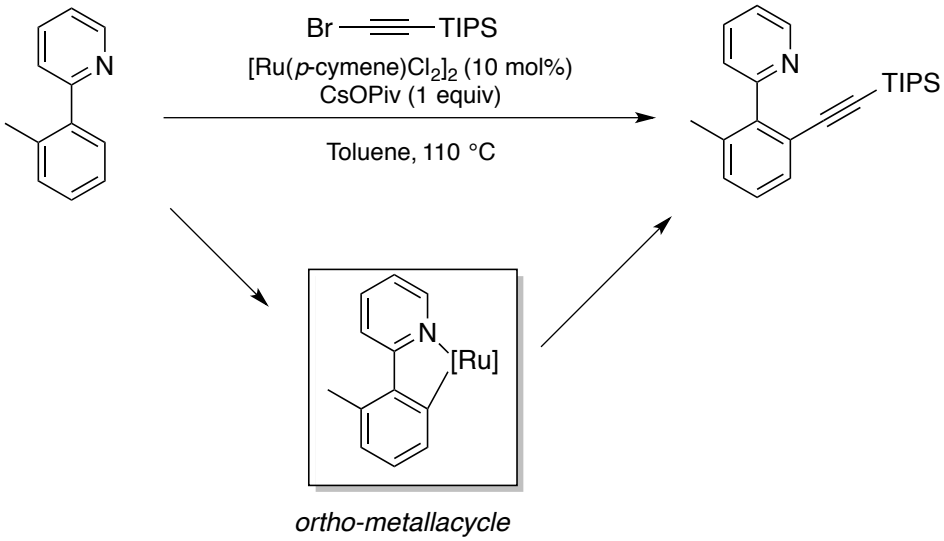
As part of a medicical chemistry program, Hong applied this reaction to acridone, a molecule related to anthrone, to achieve the mono-selective alkynylation.[5]




**Scheme 4.** Rh(III)-catalyzed *peri* C−H alkynylation of acridone with EBX

With these precedents in mind, initial screening of reaction conditions using anthrone as substrate and EBX as alkynylating reagent in presence of different transition metal catalysts led to the degradation of EBX without productive conversion of anthrone.

Tobisu and Chatani reported the C−H alkynylation of phenyl-heterocycles using TIPS-bromo-acetylene as alkynylating reagent and $[RuCl_2(p\text{-cymene})]_2$ as catalyst (Scheme 5).[6] This reaction was proposed to occur via *ortho* C−H activation to generate an *ortho*-metallacycle, followed by an alkynylation step.

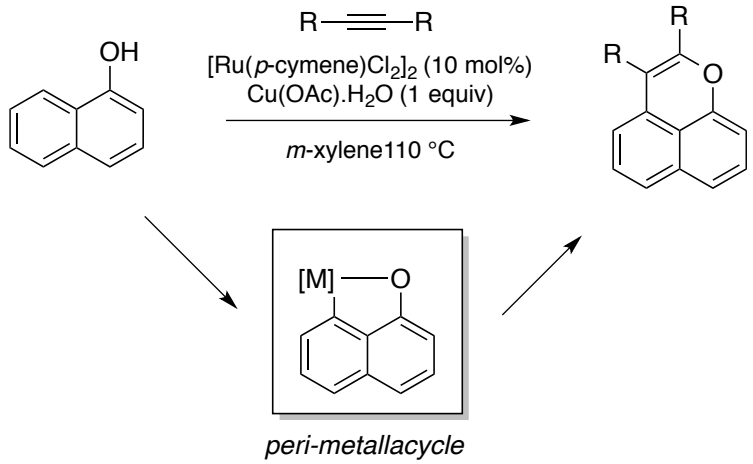



**Scheme 5.** Ru(II)-catalyzed C−H alkynylation of phenyl-pyridines via *ortho*-C−H activation.

5 Kang, D.; Hong, S. *Org. Lett.* **2015**, *17*, 938−1941.

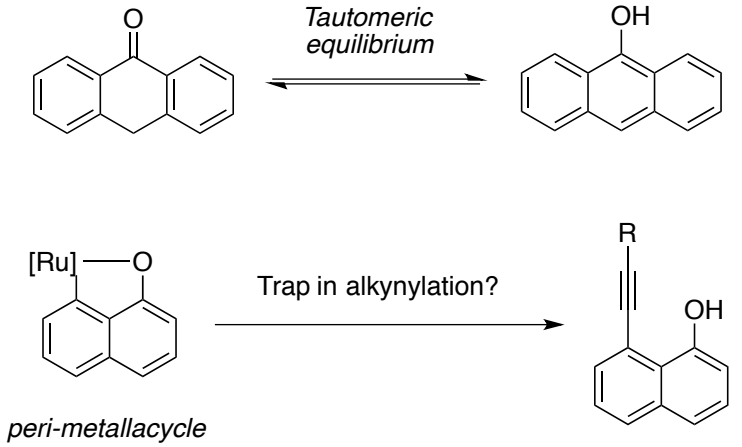
6 Ano, Y.; Tobisu, M.; Chatani, N. *Synlett,* **2012**, *23*, 2763−2767.

Ackermann reported that the same ruthenium complex could catalyze the annulation of 1-naphthols with alkynes (Scheme 6).[7] This reaction was proposed to occur via *peri* C-H activation to generate a *peri*-metallacycle, followed by alkyne coordination, migratory insertion and reductive elimination.




**Scheme 6.** Ru(II)-catalyzed annulation of 1-naphthols with internal alkynes via *peri* C−H activation.

Considering the tautomeric equilibrium of anthrone with its phenolic form (Scheme 7, top), we wondered whether or not the *peri*-ruthenacycle generated from anthrone could be trapped with TIPS-bromoacetylene, under the conditions reported by Tobisu and Chatani[6] (Scheme 7, bottom).




**Scheme 7.** Tautomeric equilibrium of anthrone (top) and trapping of *peri*-ruthenacycle in alkynylation reaction.

7 Thirunavukkarasu, V. C.; Donati, M.; Ackermann, L. *Org. Lett.* **2012**, *14*, 3416−3419.

## Objectives

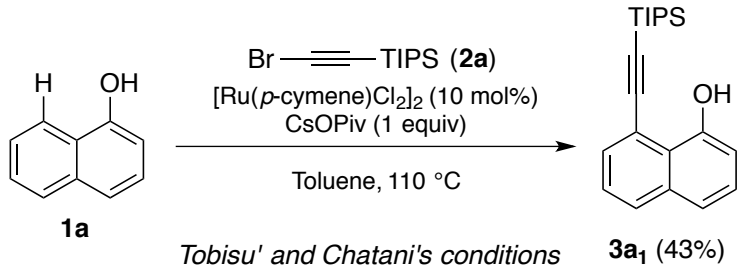
Considering the potential of superzethrene in the field of organic electronics, we attempted its synthesis using a synthetic route based on the C−H alkynylation of anthrone.

Although several reports on the chelation-assisted C−H alkynylation already existed at the beginning of these PhD studies, all used substrates bearing amides or nitrogen coordinating groups such as heterocycles or imine derivatives. The protocol using a Cp*Rh(III) catalyst with EBX as alkynylating reagent failed to provide any alkynylated product. Therefore, we embarked on the search of a general catalytic system allowing the alkynylation of a broad range of $C(sp^2)$−H bonds, with the ultimate goal that this could be applied for anthrone.

## Results and Discussion

### Alkynylation of naphthols

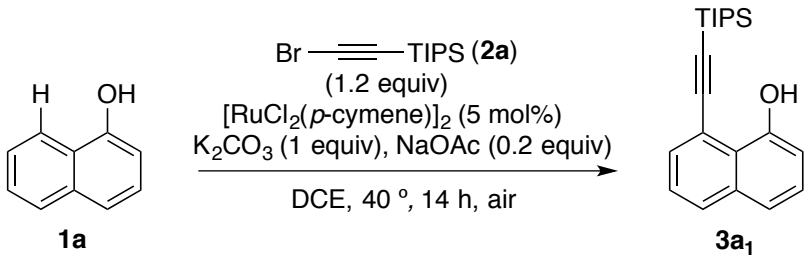
Initial experiments showed that the reaction of 1-naphthol (**1a**) with TIPS-bromoacetylene (**2a**) under conditions reported by Tobisu and Chatani[8] afforded *peri*-alkynylated derivative **3a$_1$** in 43% yield.




**Scheme 8.** Initial experiment on the *peri*-C−H alkynylation of naphthol (**1a**).

Further optimization of solvent, bases and temperature increased the yield up to 95%. Control experiments showed that the reaction could be carried out in the presence of air (Table1, entries 1−2) and required a stoichiometric amount of $K_2CO_3$ (Table 1, entries 4−5). In the presence of other metal complexes, the reaction did not take place satisfactorily (Table 1, entries 6−9). No reaction was observed with TIPS-EBX instead of **2a** (Table 1, entry 10).

**Table 1.** Ruthenium-catalyzed *peri*-C−H alkynylation: deviation from optimized conditions.[a]



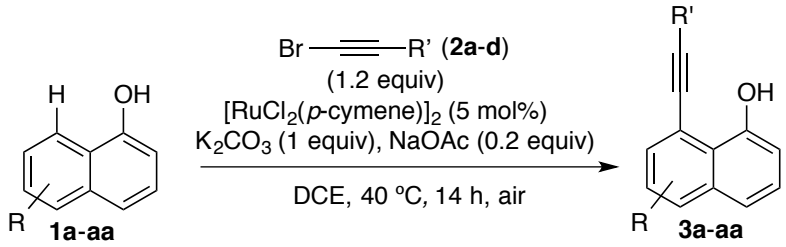

| Entry[a] | Variation from the standard conditions | Yield[b,c] |
|---|---|---|
| 1 | none | 95 (92) |
| 2 | under Ar | 95 |
| 3 | in MeCN | 25 |
| 4 | without $K_2CO_3$ | 10 |
| 5 | without $K_2CO_3$ and NaOAc | 0 |
| 6 | $[Cp^*RhCl_2]_2$ instead of [Ru] | 17 |

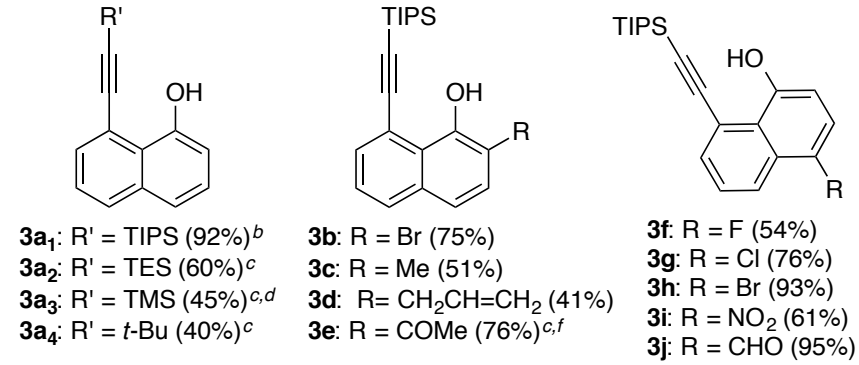
8 Ano, Y.; Tobisu, M.; Chatani, N. *Synlett,* **2012**, *23*, 2763−2767.

| | | |
|---|---|---|
| 7 | $[Cp^*IrCl_2]_2$ instead of [Ru] | 32 |
| 8 | $Cp^*Co(CO)I_2$ instead of [Ru] | 0 |
| 9 | $Pd(OAc)_2$ instead of [Ru] | 0 |
| 10 | With TIPS-EBX instead of **2a** | 0 |

[a]Reaction conditions: **1a** (0.2 mmol), **2a** (1.2 equiv), $K_2CO_3$ (1 equiv), NaOAc (0.2 equiv), [RuCl2(p-cymene)]2 (5 mol %), air, 14 h. [b]Yield determined by $^1H$ NMR using dodecane as internal standard. [c] Isolated yield in parenthesis. TIPS-EBX: 1-{[tris-(1-methylethyl)silyl]ethynyl]}-1,2-benziodoxol-3(1H)-one.

Reaction of **1a** with TMS- (**2b**) and TES-protected bromoacetylene (**2c**) gave **3a₂** and **3a₃** in lower yields (Scheme 9). Similarly, reaction of **1a** with 1-bromo-3,3-dimethylbut-1-yne (**2d**) gave **3a₄** in 40% yield. Under the conditions optimized for the formation of **3a₁**, or using slightly different conditions, naphtols **1b-r** bearing a wide range of substituents and pyrel-1-ol (**1s**) provided alkynylated products **3b-s** in 51-93% yields. Hydrogen-bonded phenols **1e** and **1r** with *ortho*-keto or ester groups reacted uneventfully. Similarly, free $NH_2$ (**3n**) and OH (**3o**) groups were well tolerated. The double alkynylation of 1,5-dihydroxynaphthalenes **1t-u** afforded products **3t-u** in 43-45% yields. On the other hand, reaction of acetal protected 1,4,5-trihydroxynapthalene **1v** with **2a** afforded [2,2'-binaphthalene]-1,1'-diol **3v** as a result of the oxidative dimerization of the electron-rich naphtol. The structure of **3i** was confirmed by X-ray diffraction. Alkynylation of 4-hydroxycoumarin (**1x**) afforded **3x** in 66% yield. The reaction can also be applied for the alkynylation of nitrogen-containing heterocycles, which are often problematic substrates in C−H functionalizations. Thus 4-hydroxyquinolines **1y-z** gave rise to **3y-z**, whereas decoquinate (**1aa**) led to **3aa**, in an example of late-stage functionalization of a pharmaceutical compound.

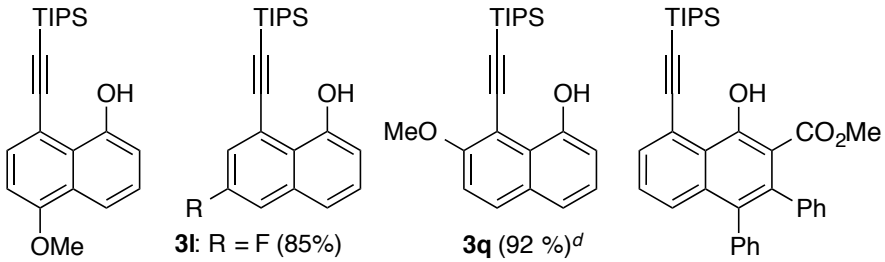



**3a$_1$**: R' = TIPS (92%)[b]
**3a$_2$**: R' = TES (60%)[c]
**3a$_3$**: R' = TMS (45%)[c,d]
**3a$_4$**: R' = *t*-Bu (40%)[c]

**3b**: R = Br (75%)
**3c**: R = Me (51%)
**3d**: R= $CH_2CH{=}CH_2$ (41%)
**3e**: R = COMe (76%)[c,f]

**3f**: R = F (54%)
**3g**: R = Cl (76%)
**3h**: R = Br (93%)
**3i**: R = $NO_2$ (61%)
**3j**: R = CHO (95%)

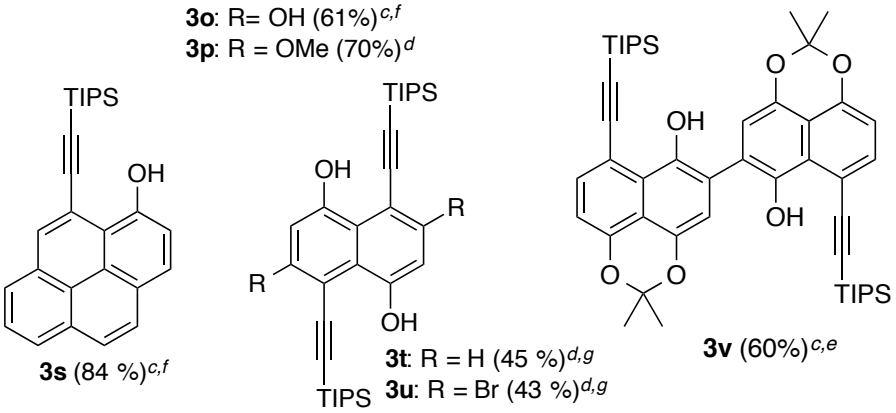



**3k** (94 %)

**3l**: R = F (85%)
**3m**: R = Br (90%)
**3n**: R= $NH_2$ (47%)[e]
**3o**: R= OH (61%)[c,f]
**3p**: R = OMe (70%)[d]

**3q** (92 %)[d]

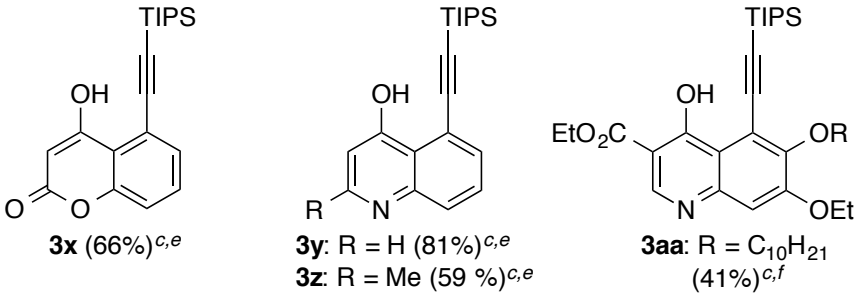
**3r** (75 %)[c,e]




**3s** (84 %)[c,f]

**3t**: R = H (45 %)[d,g]
**3u**: R = Br (43 %)[d,g]

**3v** (60%)[c,e]




**3x** (66%)[c,e]

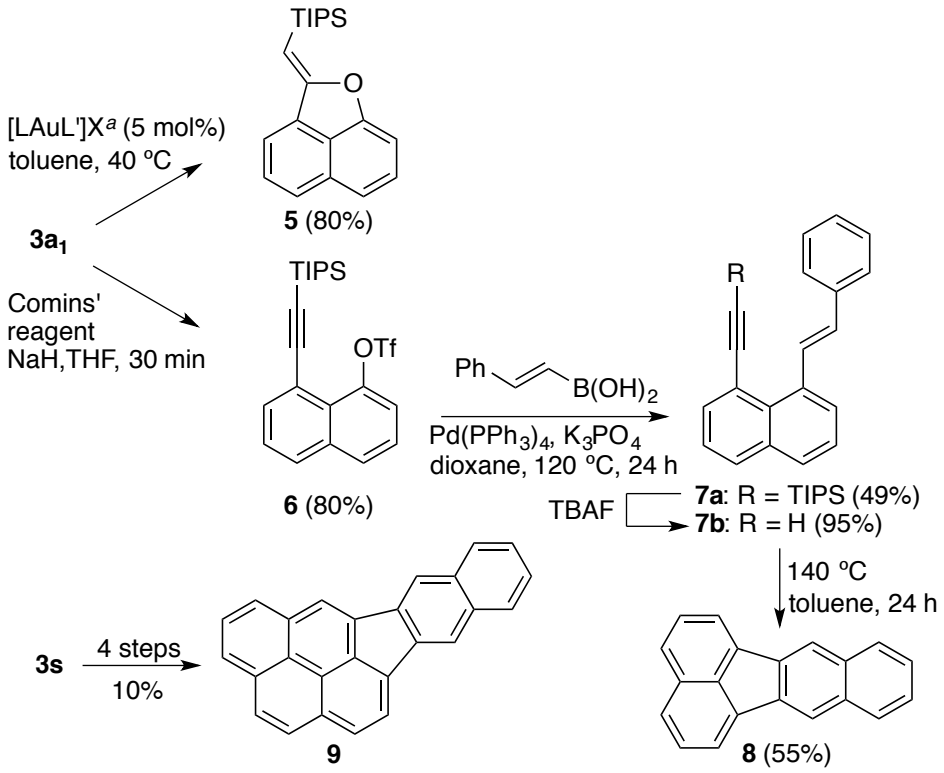
**3y**: R = H (81%)[c,e]
**3z**: R = Me (59 %)[c,e]

**3aa**: R = $C_{10}H_{21}$ (41%)[c,f]

Reaction conditions:[a] **1a-u** (0.2 mmol), $K_2CO_3$ (1 equiv), NaOAc (0.2 equiv), [$RuCl_2$(*p*-cymene)]$_2$ (5 mol %), **2a-d** (1.2 equiv), DCE (1.5 mL), 40 °C, air, 14 h. [b] 7 mmol scale. [c] KOAc (2 equiv.) instead of $K_2CO_3$ and NaOAc (0.2 equiv). [d] 60 °C. [e] 95 °C. [f] 110 °C. [g] **2a** (2.2 equiv) and $K_2CO_3$ (2.0 equiv) and NaOAc (0.4 equiv).

**Scheme 9.** Ru(II)-catalyzed *peri* C−H alkynylation of naphthols.

The cyclization of **3a$_1$** with a gold(I) catalyst proceeds in a 5-*exo*-*dig* manner to form naphtofuranylidene **5** (Scheme 10). The hydroxy group can be used as a handle for the formation of C−C bonds *via* the corresponding triflates. Thus, we prepared benzo[*k*]fluoranthene (**8**) in three steps from the aryl triflate **6** by Suzuki cross-coupling to give **7a**, desilylation and [4+2] intramolecular cycloaddition of **7b** (Scheme 10). As a second example in the context of fluoranthene synthesis, benzo[5,6]indeno[1,2,3-*cd*]pyrene (**9**) was obtained from **3s** in 10% overall yield.




[a] [LAuL']X = [(2,4-*t*Bu$_2$C$_6$H$_3$O)$_3$PAuNCMe]SbF$_6$

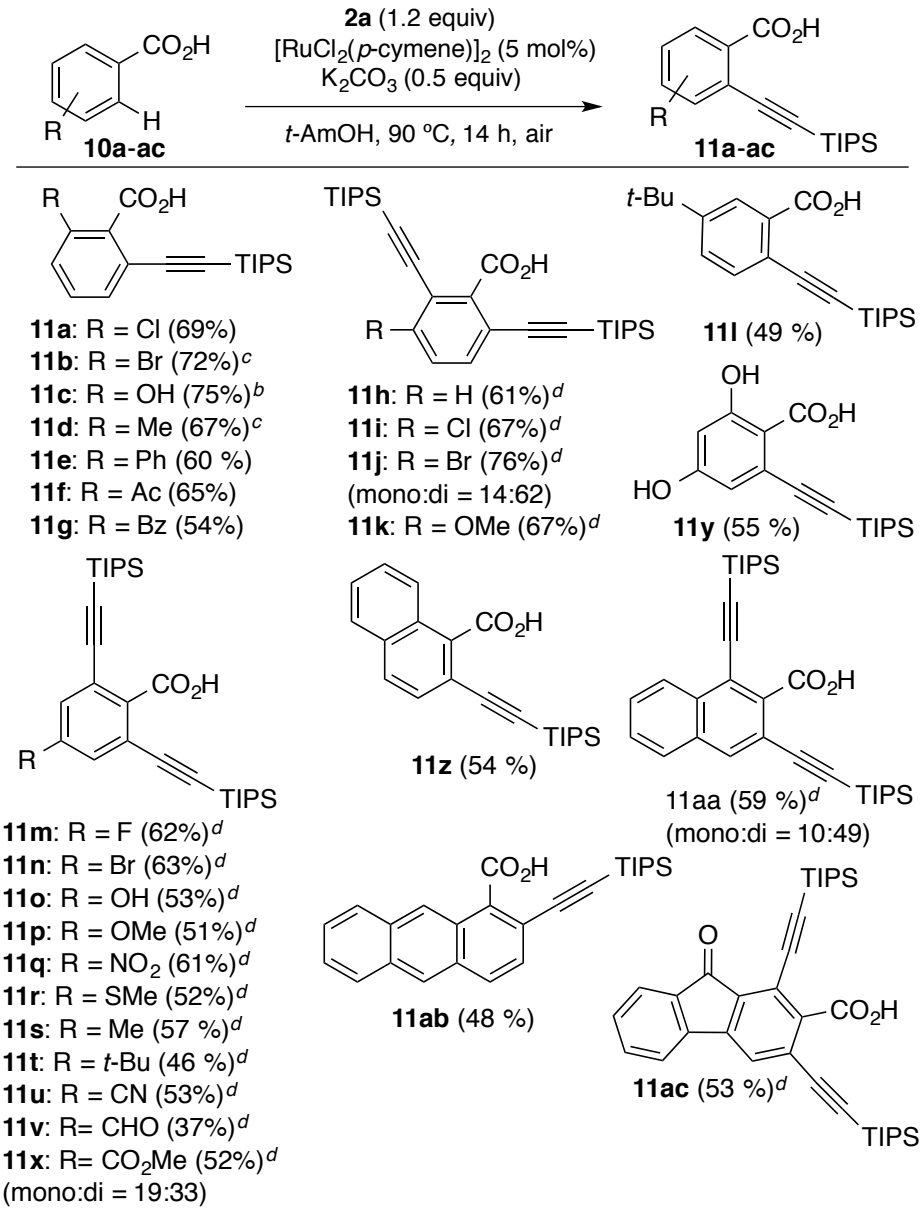
**Scheme 10.** Synthesis of naphtofuranylidene and fluoranthenes.

**Alkynylation of benzoic acids**

Under conditions similar to those developed for the *peri*-alkynylation, but using *tert*-amyl alcohol as the solvent at 90 °C, benzoic acids were alkynylated at the *ortho* position in a general manner (Table 3).[9] The reaction tolerates a wide range of functional groups including halides (**11a-b**, **11i-j**, **11m-n**), hydroxyl groups (**11c**, **11y**, **11o**), nitro (**11q**), thioether (**11r**), carbonyl (**11f-g**, **11v**), ester (**11x**) and nitrile (**11u**). Products of double alkynylation (**11h-k**,

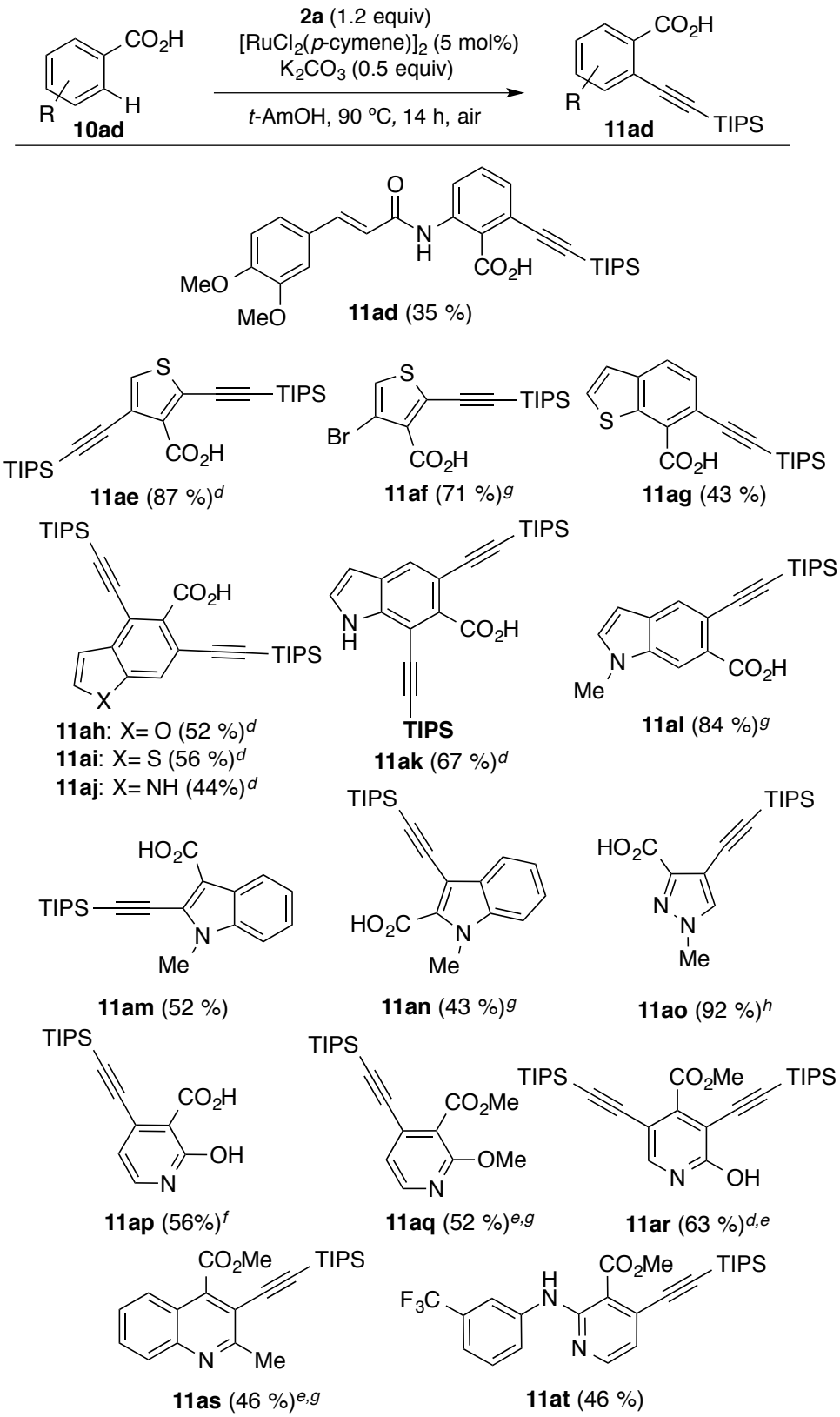
9 These conditions are milder than those developed independently by the group of Ackermann using a biscarboxylate Ru(II) complex (110-120 ºC, 1,4-dioxane). (a) Mei, R.; Zhang, S.-K.; Ackermann, L. *Org. Lett.* **2017**, *19*, 3171−3174. (b) Huang, H.; Nakanowatari, S.; Ackermann, L. *Org. Lett.* **2017**, *17*, 4620−4623.

**11m-x**, **11ac**) were obtained for substrates with two free *ortho* positions, although **11l** with a *tert*-butyl group at *meta* gave monoalkynylated **11l** as the major compound.




**Scheme 11.** Ruthenium-catalyzed *ortho* C−H alkynylation of benzoic acids.

Carboxylic acid derivatives of many heterocyclic systems, including thiophenes, benzothiophenes, benzofurans, indoles, pyrazoles, pyridines, and quinolines were also alkynylated to give the corresponding products **11ae-at** in moderate to good yields. As an exception, the alkynylation of 2-hydroxynicotinic acid (**10ap**) had to be performed at higher temperature (110 °C). Under the developed conditions, the late stage functionalization of antiallergic drug tranilast (**10ad**) and analgesic niflumic acid (**10at**) led selectively to **11ad** and **11at**, respectively.

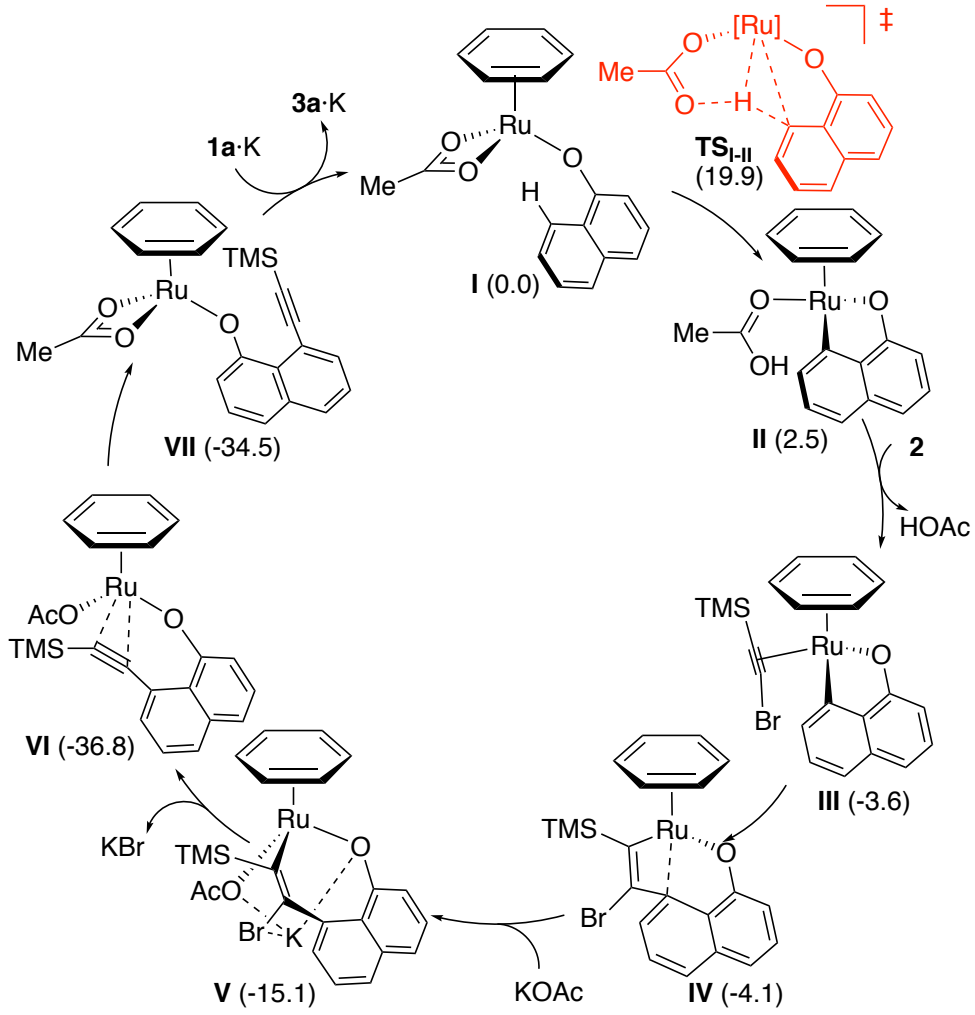



**Scheme 12.** Ruthenium-catalyzed *ortho*-C−H alkynylation of heteroaromatic acids.

**DFT calculations on the Ru-catalyzed alkynylation reactions**

According to our DFT data, the C−H ruthenation is the rate-determining in the *peri*-alkynylation reaction (Scheme 13). Thus, **I** leads to ruthenacycle **II** by acetate-assisted C−H

activation *via* $\mathbf{TS_{I\text{-}II}}$ ($\Delta G^{\ddagger}$ = 19.9 kcal·mol$^{-1}$), which is followed by dissociative ligand substitution through a coordinatively unsaturated complex to form **III**. Alternative *ortho*-ruthenation was also considered and ruled out on the basis of higher activation energy ($\Delta G^{\ddagger}$ = 26.0 kcal·mol$^{-1}$). Subsequent alkynylation proceeds *via* insertion to produce **IV** ($\Delta G^{\ddagger}$ = 13.5 kcal·mol$^{-1}$), which then undergoes KOAc-assisted bromide elimination from **V** with a minimal barrier of 0.5 kcal·mol$^{-1}$ to furnish **VI** and **VII**. Final exchange with the potassium salt of the starting naphthol liberates the product of *peri*-alkynylation and closes the catalytic cycle. The C−C bond formation *via* oxidative addition of the C−Br bond to the Ru(II) center was found to be much less likely ($\Delta G^{\ddagger}$ = 31.7 kcal·mol$^{-1}$).




**Scheme 13.** Mechanism of the Ru-catalyzed *peri*-C−H alkynylation according to DFT calculations.

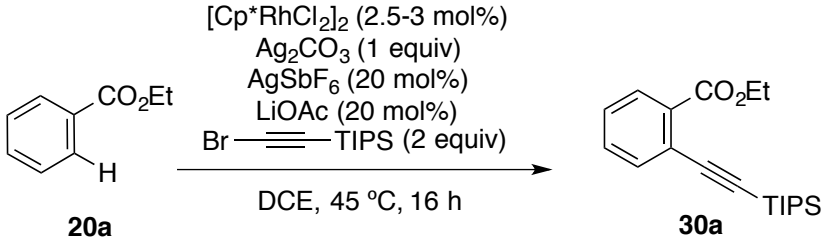
**Alkynylation of benzoic esters, phenones and benzyl ethers**

We next focused on the alkynylation of other substrates containing widely used functional groups such as esters, ketones or ethers. The reaction methyl benzoate (**10a**) with TIPS-

bromoacetylene (**2a**) under conditions developed for the alkynylation of naphthols or benzoic acids did not give any conversion.

Instead, we discovered that a combination of $[Cp^*RhCl_2]_2$ (2.5 mol %), $AgSbF_6$ (20 mol %), $Ag_2CO_3$ (1 equiv), LiOAc (20 mol %) in 1,2-dichloroethane (DCE) at 45 °C provided **30a** in 69% yield (Table 1, entry 1). Control experiments showed the essential role of all reaction components (Table 1, entries 2−11). Thus, lower yields of **30a** were obtained at temperatures lower or higher than 45 °C (Table 1, entries 2 and 3). Similar results were obtained by decreasing the amount of $Ag_2CO_3$ to 0.5 equiv or replacing this silver salt by $K_2CO_3$ (Table 1, entries 4 and 5). Solvents different than DCE led to poor results (Table 1, entries 6−11).

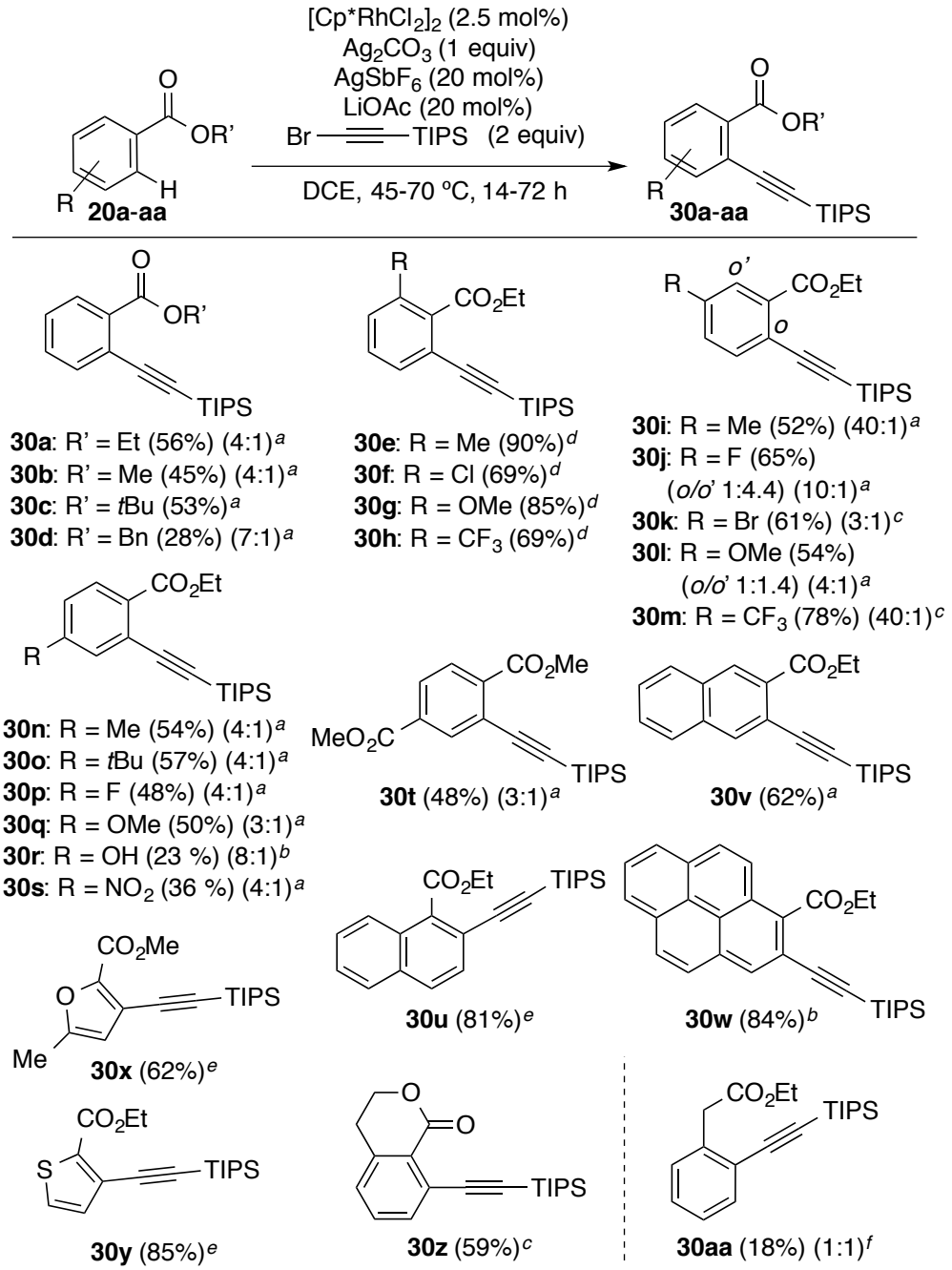
**Table 2.** Rh-catalyzed *ortho*-C−H alkynylation of ethyl benzoate: optimization of reaction conditions




| Entry[a] | Variation from the standard conditions[a] | Yield[b] |
|---|---|---|
| 1 | none | 69 |
| 2 | at 25 ºC[c] | 35 |
| 3 | at 65 ºC[c] | 16 |
| 4 | with $Ag_2CO_3$ (0.5 equiv)[d] | 41 |
| 5 | with $K_2CO_3$ (1 equiv)[d] | 5 |
| 6 | in dichloromethane[e] | 10 |
| 7 | in toluene[e] | 0 |
| 8 | in *tert*-AmOH[e] | 0 |
| 9 | in $Et_2O$[e] | 4 |
| 10 | in EtOAc[e] | 18 |
| 11 | in MeOH[e] | 0 |

[a] Standard reaction conditions: **20a** (0.2 mmol), **1** (2 equiv), $[Cp^*RhCl_2]_2$ (2.5 mol% for DG = ester, $Ag_2CO_3$ (1 equiv), $AgSbF_6$ (0.2 equiv), LiOAc (0.2 equiv), DCE, 16 h, 45 °C. [b] Yield of the monoalkynylated product determined by $^1H$ NMR using bromomesitylene as internal standard. [c] Instead of 45 °C. [d] Instead of $Ag_2CO_3$ (1 equiv). [e] Instead of DCE.

Different alkyl benzoates **20a-d** could be *ortho*-alkynylated, with ethyl benzoate **20a** giving the highest yield (Scheme 14). Electron-donating alkyl or methoxy groups and electron-withdrawing substituents such as $NO_2$, $CF_3$, and different halides at the *ortho*, *meta* or *para* positions were well tolerated, affording alkynylated products **30e-w** in 23-90% yield. In the case of *meta*-substituted substrates **20i**,**k**,**m**, the alkynylation occurred at the least sterically hindered site. However, fluoro and methoxy derivatives **20j** and **20l** favor formation of the 1,2,3-trisubstituted compounds **30j** and **30l**, respectively. The alkynylation of ethyl 1-naphthoate (**20u**) and ethyl pyrene-1-carboxylate (**20w**) does not take place at the *peri*-position, leading instead to *ortho*-functionalized products **30u** and **30w**, respectively. Reaction of ethyl 2-naphthoate (**20v**) afforded exclusively the product of alkynylation at C−3 (**30v**). Furan and thiophene esters were also alkynylated to give **30x** (62%) and **30y** (85%), respectively. The carbonyl group of isochroman-1-one is also an effective directing group, affording **30z** in 59% yield. On the other hand, the alkynylation of ethyl phenylacetate required heating at 90 °C and was less efficient, leading to **30aa** in 18% yield along with an equivalent amount of the dialkynylated product.

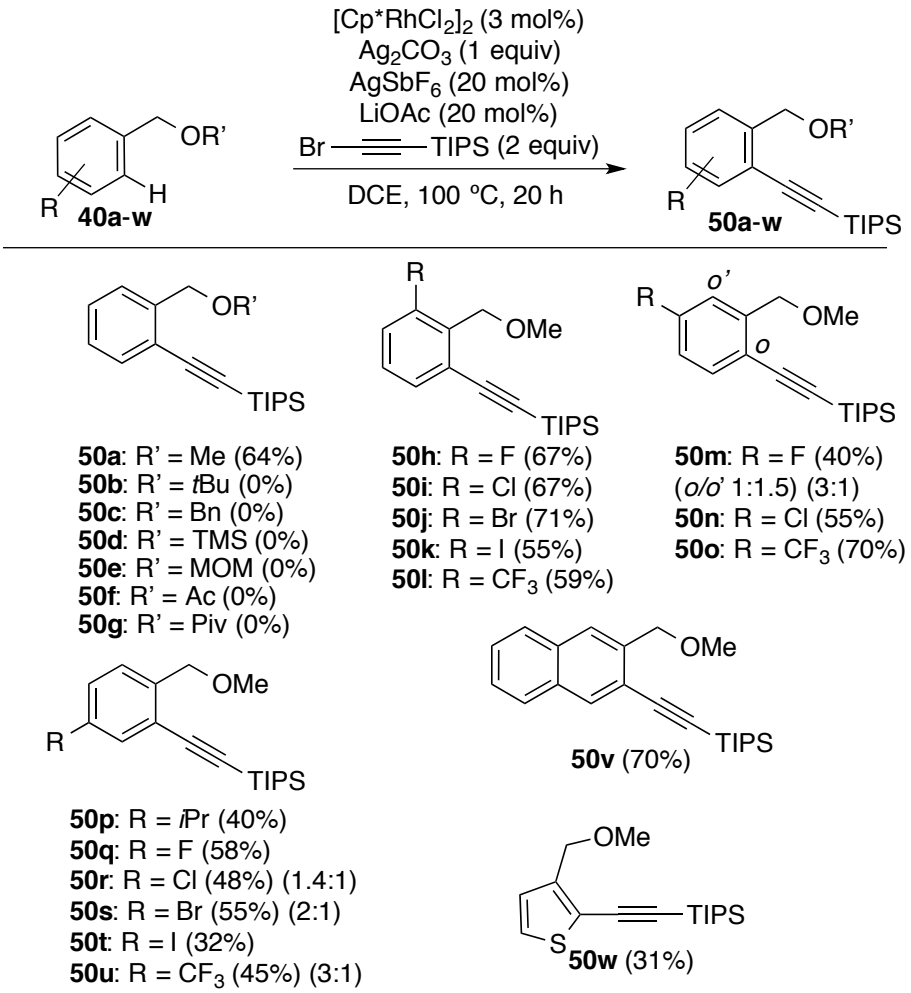



Conditions: [a] 45 °C, 16–24 h. [b] 45 °C, 48 h. [c] 45 °C, 72 h. [d] 60 °C, 48 h. [e] 70 °C, 24–72 h. [f] 90 °C, 72 h. (0.2 mmol scale) Yields of isolated mono-alkynylated products are shown. In cases in which diakynylated products were also formed, mono- *vs.* dialkynylation selectivity is shown in parentheses.

**Scheme 14.** Rh-catalyzed *ortho*-C−H alkynylation of alkyl benzoates

Although treatment of benzyl methyl ether (**40a**) with bromoacetylene **2a** under the same conditions did not lead to the product of alkynylation, simply increasing the temperature to 100 °C led to **50a** in 64 % yield. Substrates **40b-d** with bulkier alkyl or silyl groups failed to give the expected products (Scheme 15). Similarly, MOM-protected benzyl alcohol **40e** and esters **40f-g** were unreactive substrates. On the other hand, methyl benzyl ethers bearing

diverse substituents at the *ortho*, *meta* or *para* positions such as *i*-Pr, $CF_3$, fluoro, chloro, bromo, or iodo led to *o*-alkynylated products **50h-u** in 32-71% yields. As observed for the benzoates, the alkynylation of *meta*-substituted substrates **40n-o** occurred at the least sterically hindered site, whereas fluoro derivative **40m** led to a mixture of *ortho*-alkynylated derivatives **50m**, favoring the formation of the 1,2,3-trisubstituted product. Again, the alkynylation of naphthyl derivative **40v** takes place at C−3 to form **50v** in 70% yield. The reaction of thiophene **40w** provided **50w**, the product of C−2 alkynylation, which was isolated in 31% yield.

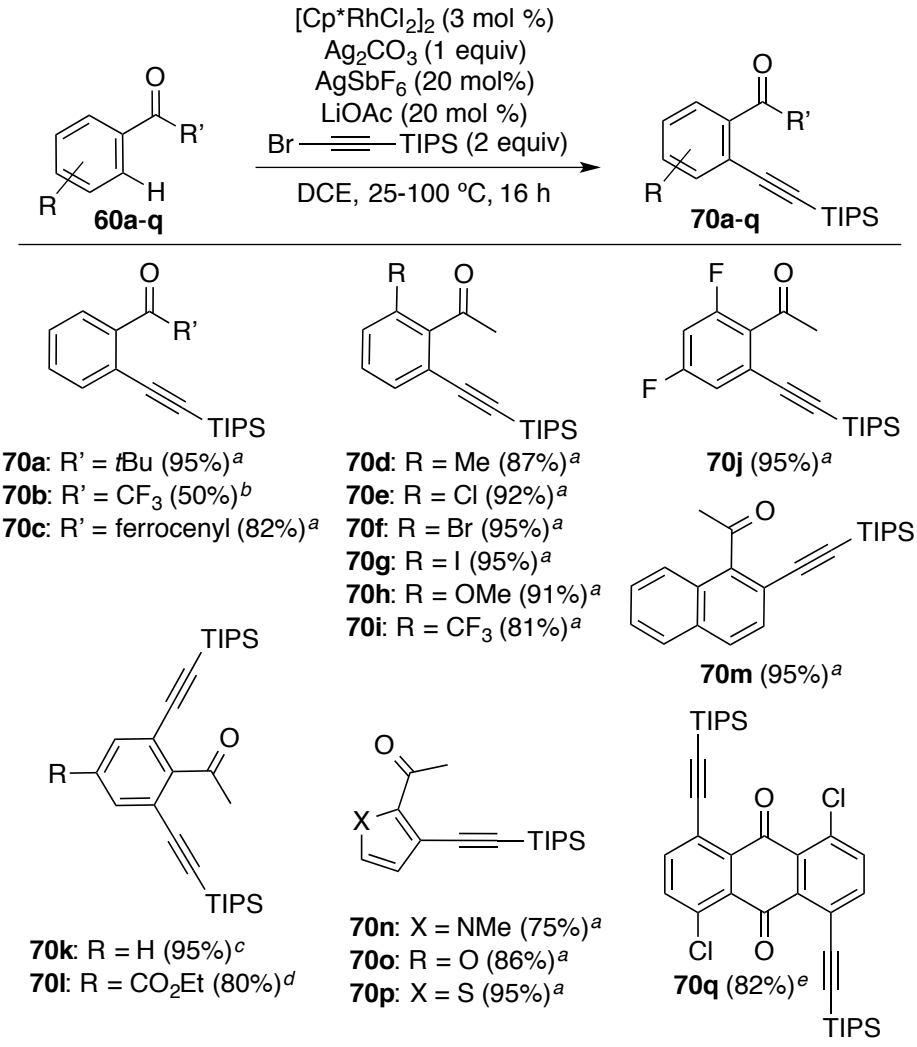



Yields of isolated monoalkynylated products are shown. In cases in which diakynylated products were also formed, mono- vs. dialkynylation selectivity is shown in parentheses.

**Scheme 15.** Rh-catalyzed *ortho*-C−H alkynylation of benzyl ethers.

Under conditions similar to those used for the reaction of the ester derivatives, a wide variety of aryl ketones **60a-p** could be alkynylated in a general manner to give **70a-p** in good to excellent yield (Scheme 15). Bis(alkynylated)acetophenone **70k** was obtained in quantitative yield from acetophenone at room temperature, while bulkier alkyl substituents allowed a mono-selective alkynylation, affording products **70a-c** in 50-95% yield. Diverse substituents

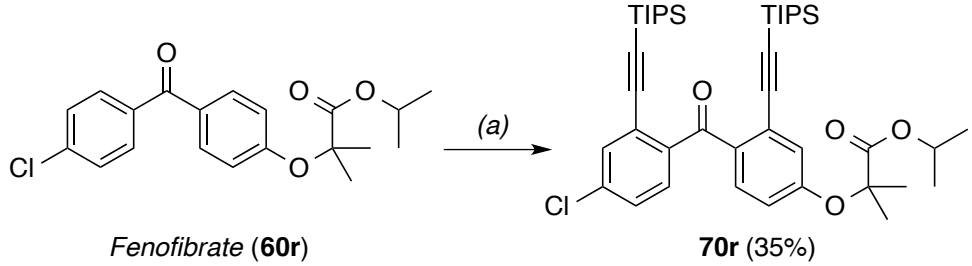
at the *ortho* position of acetophenone were well tolerated to give products **70d-i** in 81-95% yield. 2-Acetyl derivatives *N*-methyl-pyrrole (**60n**), furan (**60o**), and thiophene (**60p**) were alkynylated at C-3 in 75-95% yield. The double alkynylation of 1,5-dichloroanthraquinone (**6q**) proceeded at 100 °C to give dialkynylated product **70q** in 82% yield.




Conditions: [a] 45 °C, (1 equiv **2a**). [b] 90 °C, (1 equiv **2a**). [c] 25 °C, (2 equiv **2a**). [d] 45 °C, (2 equiv **2a**). [e] 100 °C, (2 equiv **2a**).

**Scheme 16.** Rh-catalyzed *ortho*-C−H alkynylation of phenones.

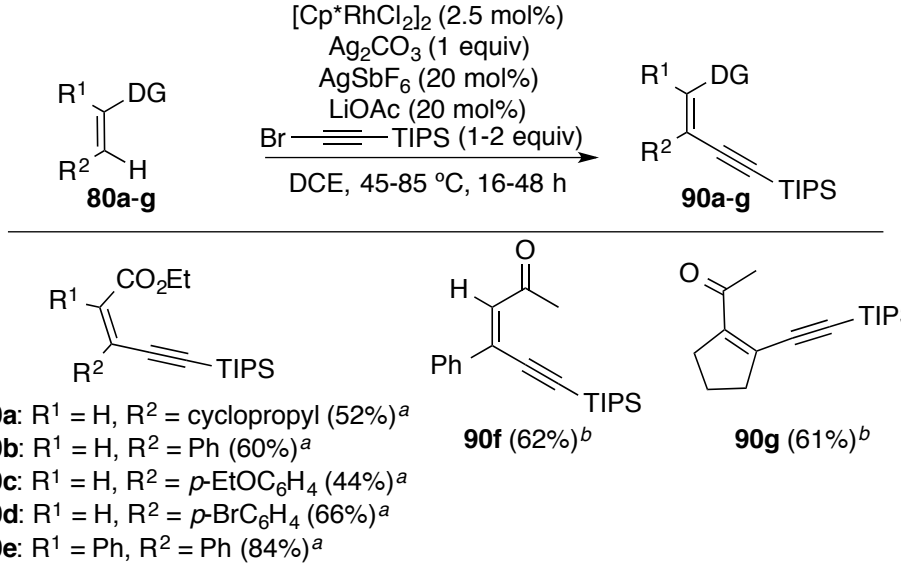
As an example of late-stage functionalization of a pharmaceutical compound, fenofibrate **60r** was alkynylated to give **70r** as the major compound in 35% yield (Scheme 16).



[a] Standard conditions for the Rh-catalyzed reaction using 2 equiv of bromoalkyne, at 50 °C, 14 h.

**Scheme 17.** Late-stage alkynylation of fenofibrate.

The alkynylation of vinyl C−H bonds of α,β-unsaturated esters **80a-e** and ketones **80f-g** proceeded under the standard conditions at 45-85 °C to afford a series of *Z*-configured 1,3-enynes **90a-g** in 44-84% yield, with total control of the configuration (Scheme 17).




**90a**: $R^1$ = H, $R^2$ = cyclopropyl (52%)[a]
**90b**: $R^1$ = H, $R^2$ = Ph (60%)[a]
**90c**: $R^1$ = H, $R^2$ = *p*-$EtOC_6H_4$ (44%)[a]
**90d**: $R^1$ = H, $R^2$ = *p*-$BrC_6H_4$ (66%)[a]
**90e**: $R^1$ = Ph, $R^2$ = Ph (84%)[a]

**90f** (62%)[b]

**90g** (61%)[b]

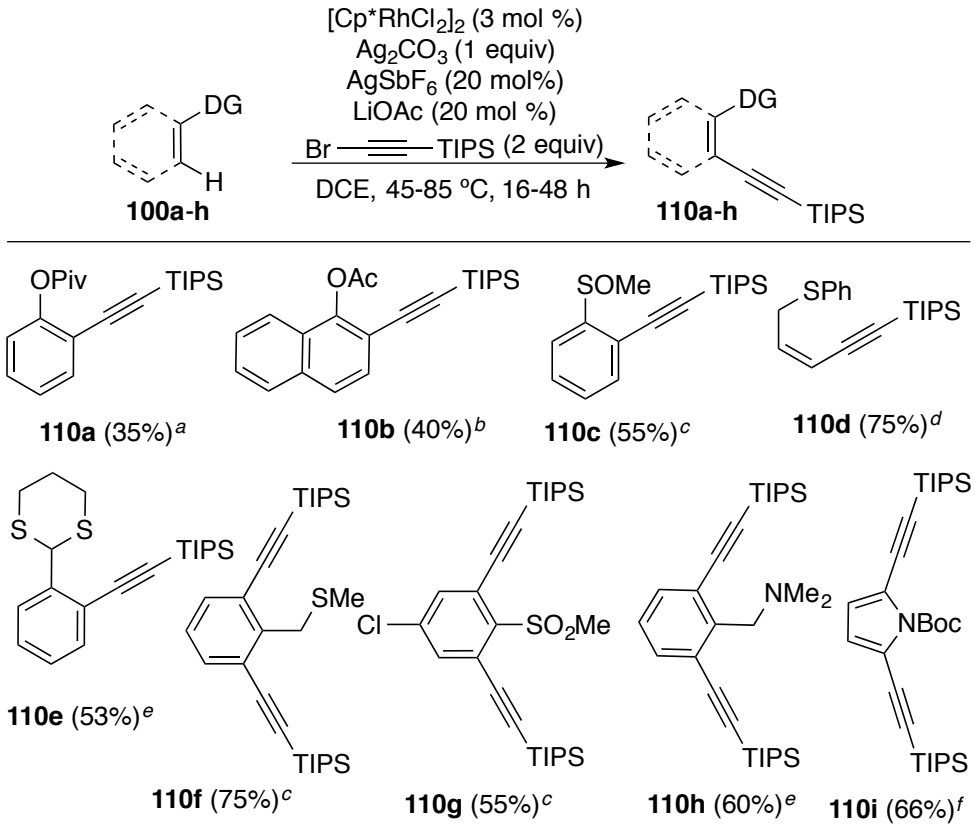
Conditions: [a] 85 °C 48 h, (2 equiv **1**). [b] 45 °C, 16 h (1 equiv **1**).

**Scheme 18.** Alkynylation of vinyl C−H bonds.

**Alkynylation using amine, thioether, sulfoxide, sulfone, carbamate and phenol esters as directing groups**

With slight modification of the reaction conditions, we discovered that other functional groups are viable directiong groups (Scheme 18). As rare examples of the use of simple phenol ester as directing group,[10] the *ortho*-alkynylation of phenol pivalate (**100a**) and 1-naphtol acetate (**100b**) led to **110a-b** in moderate yields. Although considered to bind too tightly to metals to be involved in catalytic processes, strongly coordinating groups could also be used under similar conditions. Thus, the reaction proceeds on substrates bearing sulfoxide, thioether, thioacetal, sulfone, or tertiary amine functional groups, giving products **110c-h** in 53-75% yield. Boc-protected pyrrole **100i** could also be dialkynylated to give product **110i** in 66% yield.

10 Xiao, B.; Fu, Y.; Xu, J.; Gong, T.-J.; Dai, J.-J.; Yi, J.; Liu, L. *J. Am. Chem. Soc.* **2010**, *132*, 468−469.




Conditions: [a] 90 °C, 72 h. [b] 70 °C, 24 h. [c] 100 °C, 16 h. [d] 50 °C, (**1**, 1.1 equiv), 16 h [e] 90 °C, 16 h. [f] 45 °C, 16 h.

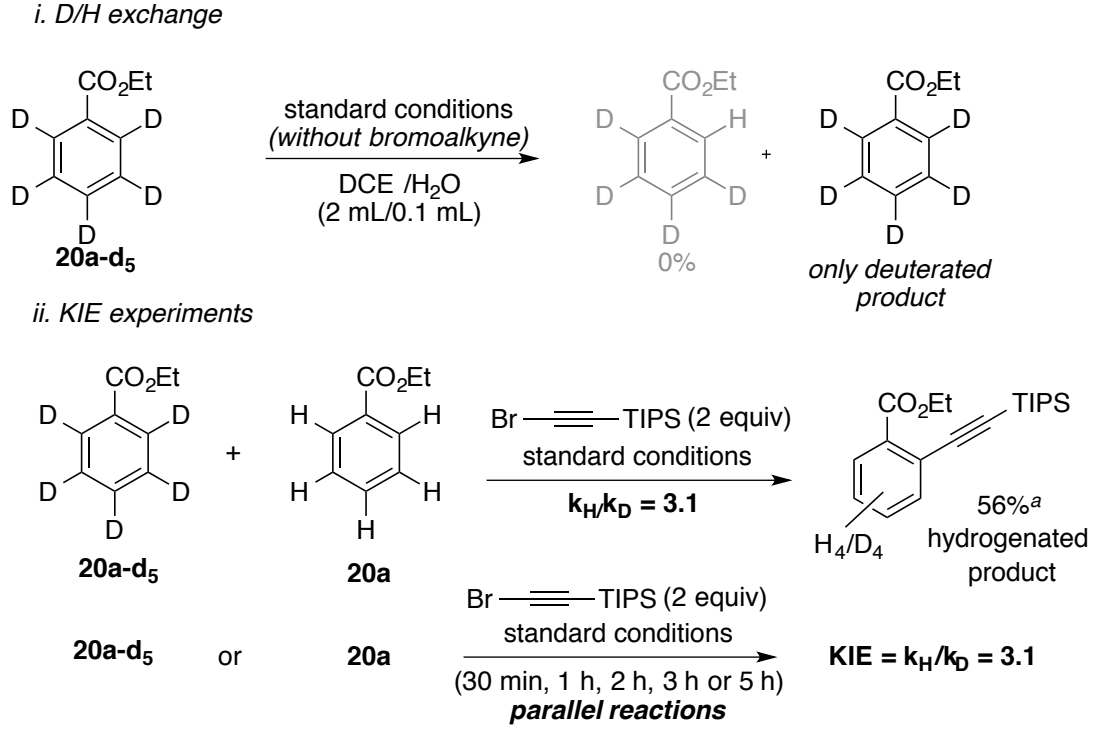
**Scheme 19.** Rh-catalyzed C($sp^2$)−H alkynylation with orther directing groups.

**Mechanistic studies of the rhodium-catalyzed C($sp^2$)−H alkynylation directed by weakly coordinating groups**

Several experiments were carried out in order to shed light on the reaction mechanism. First, the C−H functionalization step was found to be irreversible according to the reaction of **20a-$d_5$** in the presence of water and in the absence of bromoalkyne **2a** (Scheme 19, i). The intermolecular and parallel competition experiments between deuterated and hydrogenated labelled substrates (Scheme 19, ii) showed the same kinetic isotope effect (KIE = 3.1) in both cases, indicating that the C−H bond cleavage probably occurs in the rate-determining step of the catalytic cycle, which is consistent with related rhodium-catalyzed C−H functionalizations.[11] Finally, the intermolecular competition between electron rich and electron poor substrates (Scheme 19, iii) suggests that substrates bearing electron donating groups (Me or MeO) at the *meta* position of the C−H functionalization site are more reactive.

11 David R.; Stuart D.R.; Alsabeh P.; Kuhn M.; Fagnou K. *J. Am. Chem. Soc.* **2010**, *132*, 18326−18339.

This result indicates that the C−H functionalization step might occur through an electrophilic aromatic substitution-type mechanism.[12]

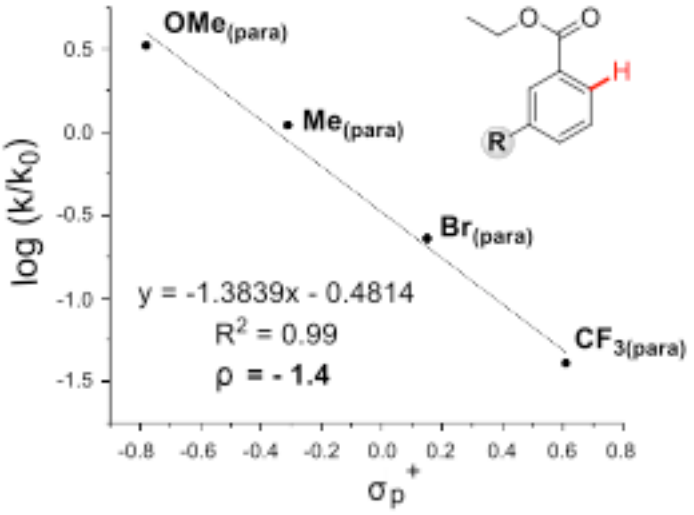



[a] Yield of the monoalkynylated product determined by $^1$H NMR using bromomesitylene as internal standard.

**Scheme 20.** D/H exchange, kinetic and competition experiments.

A Hammett correlation was found ($R^2$ = 0.99 using $\sigma_p^+$) for *meta*-substituted substrates (Scheme 20). A negative ρ value also suggests that electron density decreases at the aryl ring in the product-determining step, which is in accordance with a C−H functionalization step occurring through an electrophilic aromatic substitution-type mechanism.

12 Xiao, B.; Fu, Y.; Xu, J.; Gong, T.-J.; Dai, J.-J.; Yi, J.; Liu, L. *J. Am. Chem. Soc.* **2010**, *132*, 468−469.

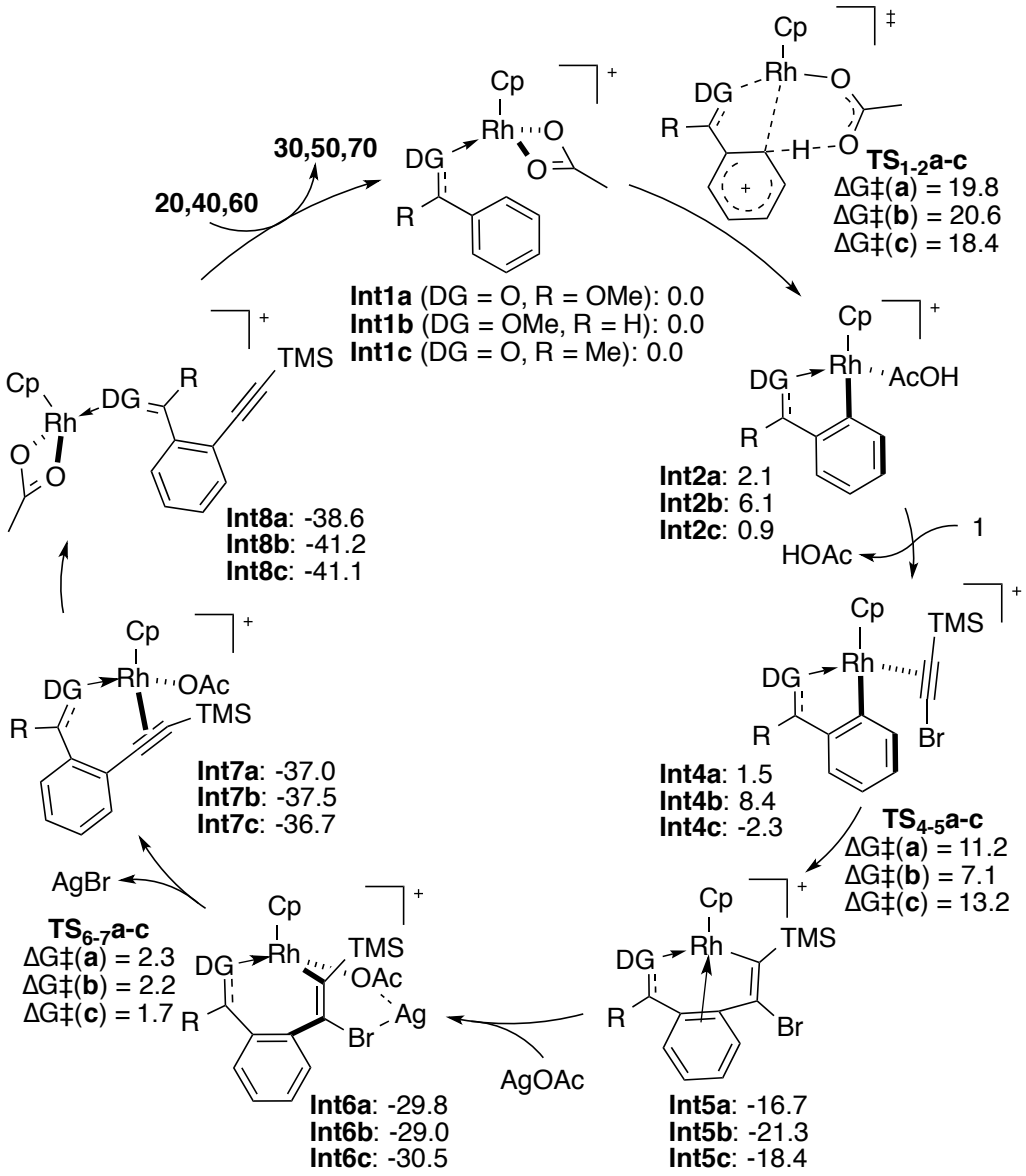



**Scheme 21.** Hammett-plot for the reaction of *m*-substituted benzoates.

To get a deeper insight into the reaction mechanism, we performed DFT calculations (Scheme 21).[13] According to our studies, the C−H functionalization of methyl benzoate (**20b**) proceeds from **Int1a** by the intramolecular assistance of the acetate ligand through the 6-membered cyclic transition state **TS$_{1\text{-}2}$a** ($\Delta G^{\ddagger}$ = 19.8 kcal/mol). The alternative 4-membered cyclic transition state ($\Delta G^{\ddagger}$ = 34.6 kcal/mol) or the intermolecular acetate-assisted C−H activation ($\Delta G^{\ddagger}$ = 51.2 kcal/mol) would require much higher energy barriers. Analysis of the Mulliken atomic charges in **Int1a**, **Ts$_{1\text{-}2}$a** and **Int2a** shows that the process involves an ambiphilic metal ligand activation.[14] Both an electrophilic metal center and an intramolecular basic ligand are key for the concerted heterolytic scission of the C−H bond and formation of the C−Rh bond. The resulting **Int2a** undergoes dissociative ligand exchange with bromoacetylene **2a** through **Int3a** (not shown) to form the ($\eta^2$-alkyne)rhodium complex **Int4a**. Subsequent alkyne insertion ($\Delta G^{\ddagger}$ = 11.2 kcal/mol) to give **Int5a**, followed by AgOAc-assisted bromide elimination ($\Delta G^{\ddagger}$ = 2.3 kcal/mol) leads to **Int7a** and then, **Int8a**. The catalytic cycle restarts upon ligand exchange, delivering the final alkynylated product **30ab** and regenerating **Int1a**.

13 (a) DFT calculations were performed using the Gaussian 09 suite of programs, using wB97XD. Rh, Ag and Br atoms were described by ECP with the LANL2DZ basis set. Polarization functions were added for Rh ($\zeta_f$= 1.35), Ag ($\zeta_f$= 1.611) and Br ($\zeta_d$= 0.428). The 6-31G(d) basis set was employed for all remaining atoms. Full geometry optimizations were carried out in 1,2-dichloroethane, through an implicit solvent SMD. (b) Sperger, T.; Sanhueza, I. A.; Kalvet, I.; Schoenebeck, F. *Chem. Rev.* **2015**, *115*, 9532−9586.

14 Selected discussions of C−H activation mechanisms: (a) Qi, X.; Li, Y.; Bai, R.; Lan, Y. *Acc. Chem. Res.* **2017**, *50*, 2799−2808. (b) Roudesly, F.; Oble, J.; Poli, G. *J. Mol. Catal. A: Chem.* **2017**, *426*, 275−296. (c) Ackermann, L. *Chem. Rev.* **2011**, *111*, 1315−1345. (d) Lapointe, D.; Fagnou, K. *Chem. Lett.* **2010**, *39*, 1118−1126. (e) Boutadla, Y.; Davies, D. L.; Macgregor, S. A.; Poblador-Bahamonde, A. I. *Dalton Trans.* **2009**, 5820−5831. (f) Gorelsky, S. I.; Lapointe, D.; Fagnou K. *J. Am. Chem. Soc.* **2008**, *130*, 10848−10849. (g) Oxgaard, J.; Tenn, W. J., III; Nielsen, R. J.; Periana, R. A.; Goddard, W. A., III *Organometallics* **2007**, *26*, 1565−1567. (h) García-Cuadrado, D.; de Mendoza, P.; Braga, A. A. C.; Maseras, F.; Echavarren, A. M. *J. Am. Chem. Soc.* **2007**, *129*, 6880−6886. (i) Li, L.; Brennessel, W. W.; Jones, W. D. *Organometallics*, **2009**, *28*, 3492−3500.




[a] Free energies in kcal/mol

**Scheme 22.** Proposed mechanism of the Rh-catalyzed C($sp^2$)−H alkynylation based on DFT calculations.[a]

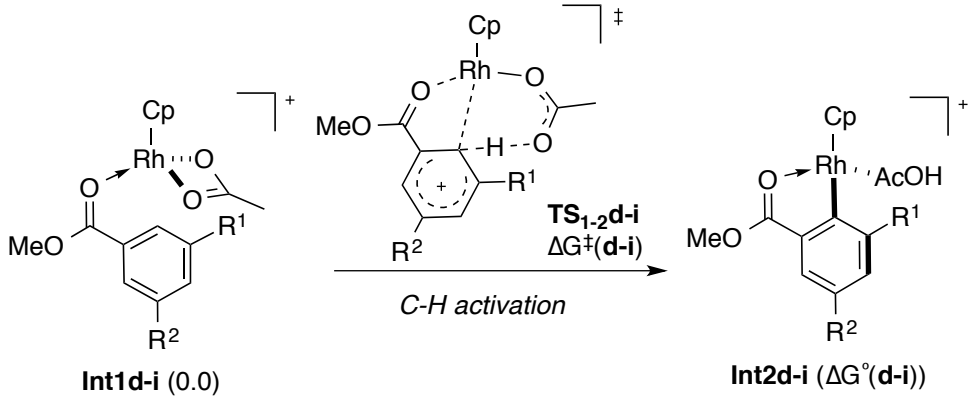
Alternative alkynylation pathways were also considered, although they proved to be less favored. For instance, the oxidative addition of the C(sp)−Br bond to the metal center in **Int4a** to form a Rh(V) intermediate[15] demands a highly unlikely activation energy of 41.6 kcal/mol. Based on the computed energies, the C−H metalation is the rate-determining step, which is in agreement with the experimental results. Similar energy profiles were found in the case of methyl benzyl ether **40a** (Scheme 21, pathway **b**) and acetophenone **60k** (Scheme 21, pathway **c**), which means that the same reaction mechanism presumably operates for them. Consistently with the experimental results, among the different substrates, the C−H functionalization of the

15 Vásquez-Céspedes, S.; Wang, X.; Glorius, F. *ACS Catal.* **2018**, *8*, 242−257.

ketones is the most energetically favored ($\Delta G^{\ddagger}$ = 18.4 kcal/mol), whereas the corresponding benzyl ethers is the most energetically costly ($\Delta G^{\ddagger}$ = 20.6 kcal/mol).

In addition, the C−H activation step was computed for differently *meta*-substituted methyl benzoates to study the influence of the electronic effects on the energy barrier. Calculations showed that the more electron-rich the substituent is, the lower the activation energy results (Table 3, entries 1−4). This is in total agreement with the experimental results observed for *m*-substituted ethyl benzoates (Scheme 20) and supports an electrophilic substitution- type mechanism for the formation of the five-membered ring rhodacycle. In the case of *meta*-fluoro benzoate, the C−H activation preferentially occurs at the *ortho*- ($\Delta G^{\ddagger}$ = 17.8 kcal/mol, Table 3, entry 6) rather than the *para*-position ($\Delta G^{\ddagger}$ = 19.5 kcal/mol, Table 3, entry 5) respect to the fluoro substituent. This *ortho* fluorine-effect has been experimentally observed with fluoro-*meta*-substituted benzoate **30j** (Scheme 14) or benzyl ether compounds **50m** (Scheme 15), as the metal−carbon bond strength would be increased at this position.[16]

**Table 3.** Substituent effects in the activation energy of the C−H activation of benzoates.



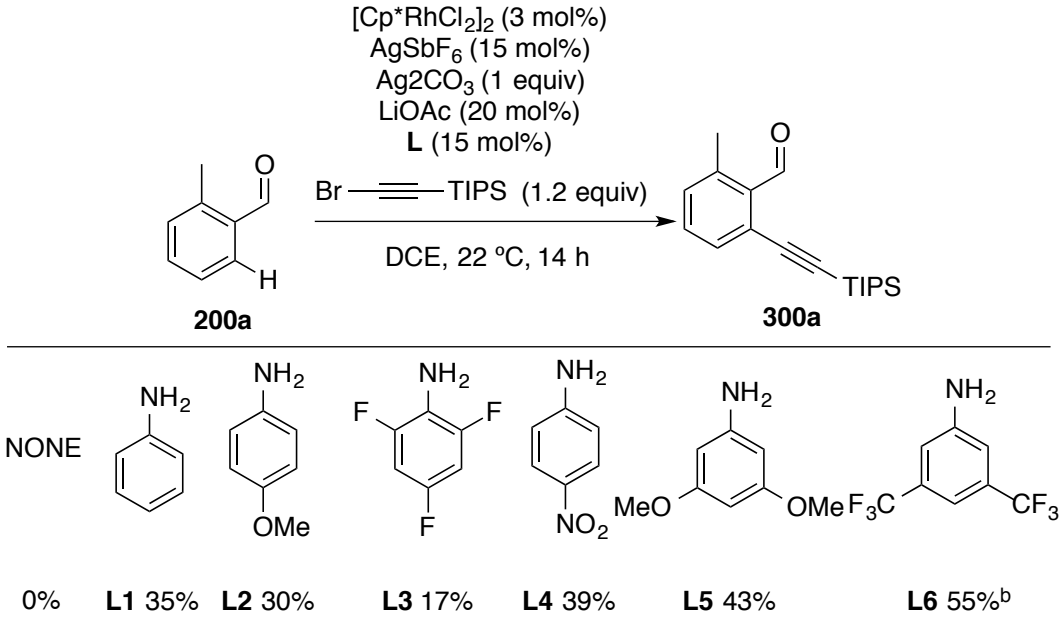

| Entry | $R^1$ | $R^2$ | **$TS_{1\text{-}2}$d-i** | $\Delta G^{\ddagger}$ (**d-i**) | **Int2d-i** | $\Delta G^{\circ}$ (**d-i**) |
|---|---|---|---|---|---|---|
| 1 | H | OMe | **$TS_{1\text{-}2}$d** | 17.2 | **Int2d** | 2.9 |
| 2 | H | Me | **$TS_{1\text{-}2}$e** | 18.9 | **Int2e** | 3.3 |
| 3 | H | Br | **$TS_{1\text{-}2}$f** | 20.8 | **Int2f** | 3.1 |
| 4 | H | $CF_3$ | **$TS_{1\text{-}2}$g** | 21.5 | **Int2g** | 3.4 |
| 5 | H | F | **$TS_{1\text{-}2}$h** | 19.5 | **Int2h** | 2.5 |
| 6 | F | H | **$TS_{1\text{-}2}$i** | 17.8 | **Int2i** | 2.7 |

[a] Free energies in kcal/mol

**Alkynylation of benzaldehydes**

16 (a) Clot, E.; Mégret C.; Eisenstein O.; Perutz R.N. *J. Am. Chem. Soc*., **2009**, *131*, 7817−7827. (b) Evans M.E.; Burke C.L.; Yaibuathes S.; Clot E.; Eisenstein O.; Jones W.D. *J. Am. Chem. Soc*., **2009**, *131*, 13464−13473. (c) Clot, E.; Besora, M.; Maseras, F.; Mégret, C; Eisenstein, O.; Oelckers, B.; Perutz, R. B. *Chem. Commun.* **2003**, 490−491.

Given the broad scope of the catalytic system developed above, we next attempted to extend it to benzaldehydes as substrate. However, initial experiment of 2-methylbenzaldehyde (**200a**) with **2a** in the presence of $[Cp^*RhCl_2]_2$ (3 mol %), $AgSbF_6$ (20 mol %), $Ag_2CO_3$ (1 equiv), LiOAc (20 mol %) in DCE at 100 °C did not give any conversion (Scheme 22). We envisioned that the formation of an imine transient-directing group (TDG),[17] by reaction of catalytic amount of aniline with the substrate might generate a more efficient directing group and enable this transformation.[18] Thus, addition of 15 mol% of aniline afforded 2-methyl-6-((triisopropylsilyl)ethynyl)benzaldehyde (**300a**) in 35% yield. Screening of other electron-rich and electron-poor anillines (**L2-L6**) showed that 3,5-bis(trifluoromethyl)aniline **L6** was the best, giving **300a** in 55% isolated yield.




[a] Yields are based on UPLC-MS analysis using biphenyl as internal standard. [b]Isolated yield.

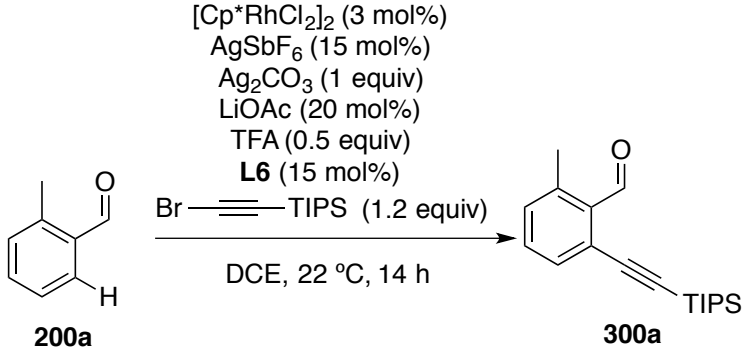
17 For reviews on the use of TDG: (a) Zhao, Q.; Poisson, T.; Pannecoucke, X.; Besset, T. *Synthesis* **2017**, *49*, 4808−4826. (b) Gandeepan, P.; Ackermann, L. *Chem.* **2018**, *4*, 199−222. (c) St John-Campbella, S.; Bull, J. A. *Org. Biomol. Chem*. **2018**,*16*, 4582−4595. For early references: (d) Jun, C.-H.; Lee, H.; Hong, J.-B. *Org. Chem.* **1997**, *62*, 1200−1201. (e) Jun, C.-H.; Moon, C. W.; Hong, J.-B.; Lim, S.-G.; Chung, K.-Y.; Kim, Y.-H. *Chem. Eur. J.* **2002**, *8*, 485−492. For examples using Pd-catalysis: (f) Zhang, F. L.; Hong, K.; Li, T.-J.; Park, H.; Yu, J. Q. *Science* **2016**, *351*, 252−256. (g) Yang, K.; Li, Q.; Liu, Y.; Li, G.; Ge, H. *J. Am. Chem. Soc.* **2016**, *138*, 12775−12778. (h) Liu, X.−H.; Park, H.; Hu, J.-H.; Hu, Y.; Zhang, Q.-L.; Wang, B.-L.; Sun, B.; Yeung, K.-S.; Zhang, F.-L.; Yu, J.-Q. *J. Am. Chem. Soc*. **2017**, *139*, 888−896. (i) Xu, J.; Liu, Y.; Wang, Y.; Li, Y.; Xu, X.; Jin, Z. *Org. Lett.* **2017**, *19*, 1562−1565. (j) Chen, X.-Y.; Ozturk, S.; Sorensen, E. J. *Org. Lett.* **2017**, *19*, 1140−1143. (k) Zhang, X.; Zheng, H.; Li, J.; Xu, F.; Zhao, J.; Yan, H. *J. Am. Chem. Soc.* **2017**, *139*, 14511−14517. (l) Yao, Q.-J.; Zhang, S.; Zhan, B.-B.; Shi, B.-F. *Angew. Chem., Int. Ed.* **2017**, *56*, 6617−6621. (m) Tang, M.; Yu, Q.; Wang, Z.; Zhang, C.; Sun, B.; Yi, Y.; Zhang, F. *Org. Lett.* **2018**, *20*, 7620−7623.

18 For examples using Rh(III)- or Ir(III)-catalysis: (a) Lian, Y.; Hummel, J. R.; Bergman, R. G.; Ellman, J. A. *J. Am. Chem. Soc.* **2013**, *135*, 12548−12551. (b) Zhang, Y.−F.; Wu, B.; Shi, Z.−J. *Chem. Eur. J.* **2016**, *22*, 17808−17812. (c) Hu, W.; Zheng, Q.; Sun, S.; Cheng, J. *Chem. Commun*. **2017**, *53*, 6263−6266. (d) Mu, D.; Wang, X.; Chen, G.; He, G. *J. Org. Chem.* **2017**, *82*, 4497− 4503. (e) Wang, X.; Song, S.; Jiao, N. *Chin. J. Chem.* **2018**, *36*, 213−216. (f) Kim, S.; Han, S. H.; Mishra, N. K.; Chun, R.; Jung, Y. H.; Kim, H. S.; Park, J. S.; Kim, I. S. *Org. Lett.* **2018**, *20*, 4010−4014. (g) Hande, A. E.; Ramesh, V. B.; Prabhu, K. R. *Chem. Commun.* **2018,** *54*, 12113−12116.

**Scheme 22.** Evaluation of aniline promoters for the *ortho*-C−H alkynylation of 2-methylbenzaldehyde (**200a**).

Further optimization of reaction conditions revealed the crucial role of trifluoroacetic acid as additive, with 0.5 equiv as optimal loading, allowing the isolation of **300a** in 95% yield (Table 4, entries 1−3). Control experiments showed the essential role of all reaction components (Table 4, entries 4−7). Other catalysts used in C−H functionalization, such as $MnBr(CO)_5$, $Cp^*Co(CO)I_2$, $Pd(OAc)_2$, or $RuCl_2(p\text{-cymene})]_2$ did not give any product (Table 4, entry 8). Replacing $Ag_2CO_3$ by $K_2CO_3$ (Table 1, entry 9) or AgOAc (Table 4, entry 10) shuts down the reaction or led to lower yield, respectively. $[Cp^*RhCl_2]_2$ can be replaced by the corresponding iridium catalyst, with similar yield obtained (Table 4, entry 11). The reaction is not sensitive to the presence of water (Table 4, entry 12).

**Table 4.** Rh-catalyzed *ortho*-C−H alkynylation of benzaldehydes: reaction optimization.




**200a** **300a**

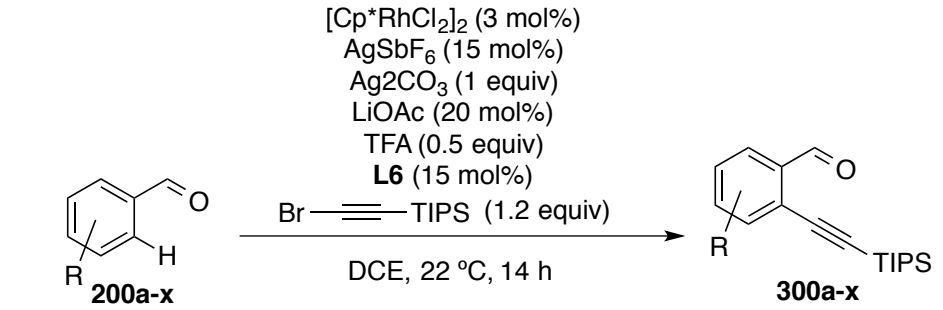
| Entry | Variation from the standard conditions | Yield[a] |
|---|---|---|
| 1 | none | (95) |
| 2 | With 0.1 equiv TFA | 28 |
| 3 | With 5 equiv TFA | 70 |
| 4 | Without $[Cp^*RhCl_2]_2$ | 0 |
| 5 | Without $Ag_2CO_3$ | 0 |
| 6 | Without LiOAc | 60 |
| 7 | Without Aniline | 0 |
| 8 | With $MnBr(CO)_5$ or $Cp^*Co(CO)I_2$ or $Pd(OAc)_2$ or $RuCl_2(p\text{-cymene})]_2$ instead of $[Cp^*RhCl_2]$ | 0 |
| 9 | With $K_2CO_3$ instead of $Ag_2CO_3$ | 0 |
| 10 | With AgOAc (1 equiv) instead of $Ag_2CO_3$ | 85 |
| 11 | With $[Cp^*IrCl_2]_2$ instead of $[Cp^*RhCl_2]_2$ | 93 |

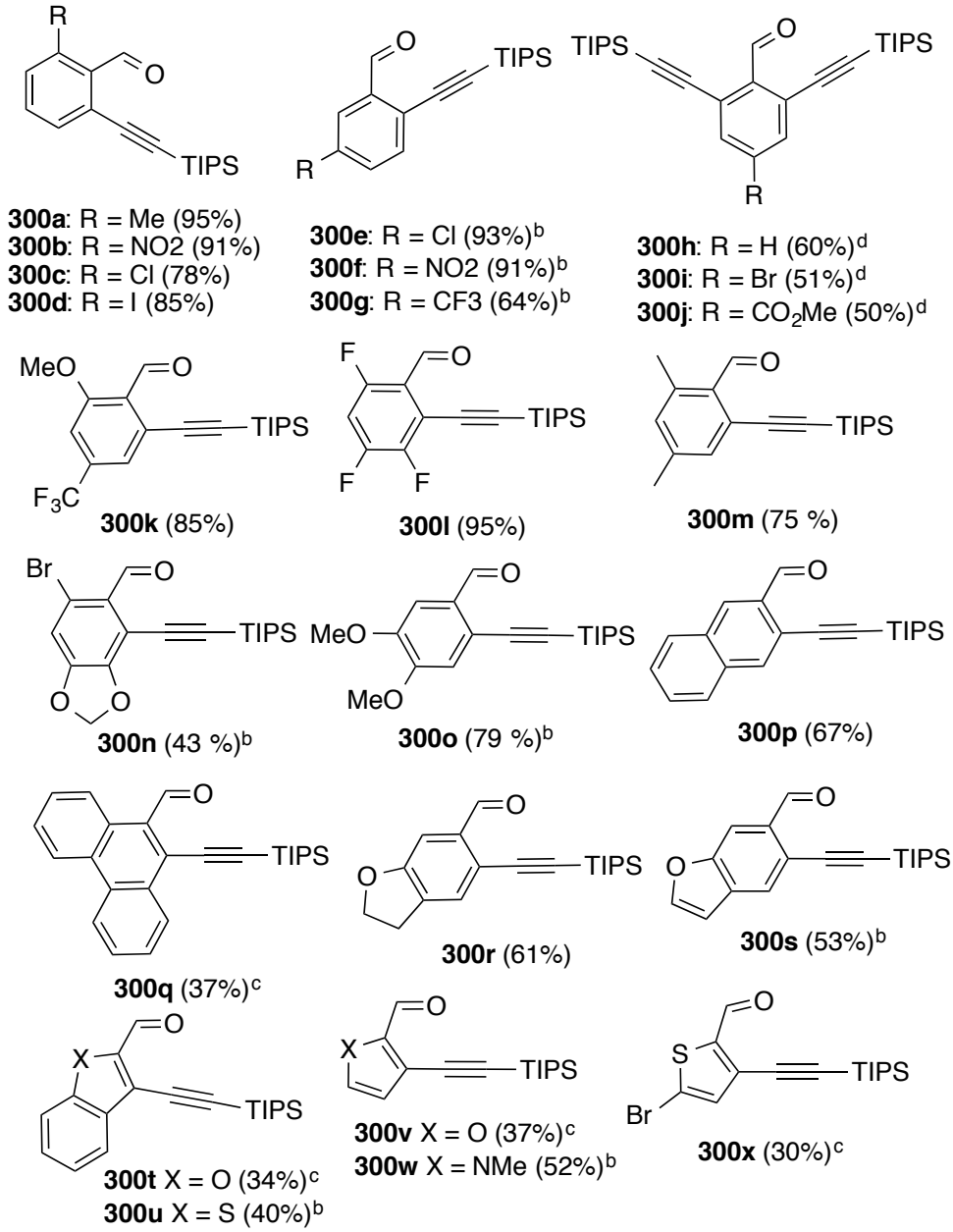
| 12 | With 0.5 equiv $H_2O$ | 95 |
|---|---|---|

[a]Yield determined by UPLC-MS using biphenyl as internal standard. [b]Isolated yield in parenthesis.

With the optimized conditions in hand, we next explored the scope of the reaction (Scheme 23). Different substituents, such as halides, nitro, alkyl, ester, acetal and ether could be tolerated. *Ortho-, meta-, and para*-substituted benzaldehydes **200a-p** could be alkynylated in 50-95% yield. In case of meta-substituted substrates **200e-g**, the alkynylation occurred selectively as the least hindered position. For *para*-substituted benzaldehydes **200h-j**, the dialkynylated products **300h-j** were obtained selectively in 50-61% yield. This result not only showcases the efficiency of the catalytic system, but also demonstrate the easy access to different *o*,*o*-dialkynylated benzaldehydes, that are important motifs in supramolecular and material sciences.[19] Polysubstituted benzaldehydes, with electron-rich or electron-withdrawing groups can also be alkynylated. The alkynylation of 2-formylnaphthaldehyde occurred at the least hindered position in 67% yield. The alkynylation of different electron-rich heterocycles **300t-x** occurred in moderate yield and required higher temperature (70-120 °C).

19 (a) Hong, K-I.; Yoon, H.; Jang, W.−D. *Chem. Commun.* **2015**, *51*, 7486−7488. (b) Tomizaki, K.; Loewe, R. S.; Kirmaier, C.; Schwartz, J. K.; Retsek, J. L.; Bocian, D. F.; Holten, D.; Lindsey, J. S. *J. Org. Chem.* **2002**, *67*, 6519−6534.

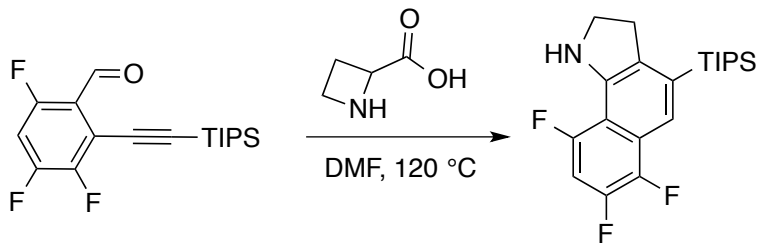



[a] Reaction run on 0.2 mmol scale, isolated yield in parentheses. [b] at 70 °C. [c] at 120 °C. [d] with 2 equiv. of bromo-alkyne.

**Scheme 23.** Rh-catalyzed *ortho* C−H alkynylation of benzaldehydes.

In one more step, 2,3-dihydro-1*H*-benzo[*g*]indole **300y** could be synthesized in 50 % yield by reaction of 2-alkynyl benzaldehyde **300l** with L-azetidine-2-carboxylic acid (Scheme 24).[20]




**300l** (50 %) **300y** (50 %)

**Scheme 24.** Synthesis of 2,3-dihydro-1*H*-benzo[*g*]indole (**300y**) *via* decarboxylative cyclization.

**Synthesis of dibenzo[*a,e*]pentalenes**

Building on the recent studies on the synthesis of hydroacenes developed in our group,[21] we pursued the synthesis of dibenzo[*a,e*]pentalenes which can be regarded as acene-like molecules containing intercalated five-membered rings. These molecules have attracted attention because of their potential in organic electronics, especially as organic semiconductors.[22] The substituents on the 5,10-positions and on the two fused benzene rings have shown to impart drastically changed properties compared to the parent dibenzopentalenes.[23] Therefore, the development of methods allowing the modular synthesis of substituted dibenzo[*a,e*]pentalenes is of high interest.

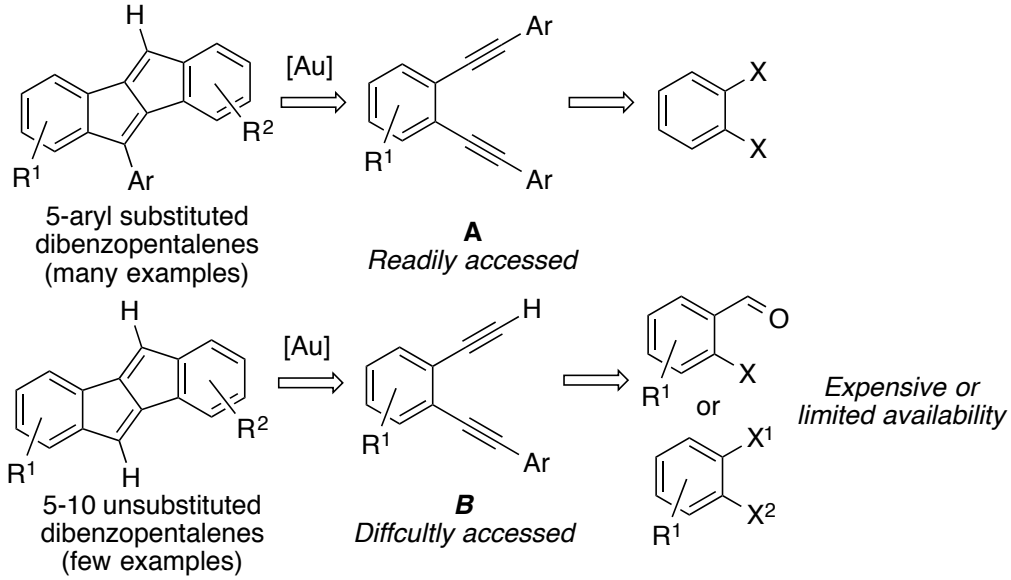
20 Samala, S; Singh, G.; Kumar, R.; Ampapathi, R. S.; Kundu, B. *Angew. Chem. Int. Ed.* **2015**, *54*, 9564−9567.

21 (a) Dorel, R.; McGonigal, P. R.; Echavarren, A. M. *Angew. Chem. Int. Ed.* **2015***, 55*, 11120−11123. (b) Dorel, R.; Echavarren, A. M. *Eur. J. Org. Chem.* **2017,** 14−24. (c) Zuzak, R.; Dorel, R.; Krawiec, M.; Such, B.; Kolmer, M.; Szymonski, M.; Echavarren, A.M.; Godlewski, S. *ACS Nano* **2017**, *11*, 9321−9329. (d) Zuzak, R.; Dorel, R.; Kolmer, M.; Szymonski, M.; Godlewski, S.; Echavarren, A. M. *Angew. Chem. Int. Ed.* **2018**, *57,* 10500−10505.

22 (a) Kawase, T.; Fujiwara, T.; Kitamura, C.; Konishi, A.; Hirao, Y.; Matsumoto, K.; Kurata, H.; Kubo, T.; Shinamura, S.; Mori, H.; Miyazaki, E.; Takimiya, K. *Angew. Chem. Int. Ed.* **2010**, *49*, 7728−7732. (b) Grenz, D. C.; Schmidt, M.; Kratzert, D.; Esser, B. *J. Org. Chem.* **2018**, *83*, 656−663. (c) Oshima, H.; Fukazawa, A.; Yamaguchi, S. *Angew. Chem. Int. Ed.* **2017**, *56*, 1−7.

23 (a) Liu, C.; Xu, S.; Zhu, W.; Zhu, X.; Hu, W.; Li, Z.; Wang, Z. *Chem. Eur. J.* **2015**, *21*, 17016−17022. (b) Dai, G.; Chang, J.; Zhang, W.; Bai, S.; Huang, K.−W.; Xu, J.; Chi, C. *Chem. Commun.* **2015**, *51*, 503−506.

Among the different known methods,[24] the gold(I)-catalyzed cyclization of 1,5-diynes of type **A** has been the most studied (Scheme 25).[25] However, this method allows to access mainly dibenzo[*a,e*]pentalenes with an aryl-substituent at the 5- or 10-position, because the starting 1,5-diynes are often symmetrical and prepared *via* Sonogashira coupling from 1,2-dihalobenzenes. Alternatively, 5,10-unsubstituted dibenzo[*a,e*]pentalenes can be prepared *via* 1,5-diynes of type **B**, which are synthesized *via* Sonogashira coupling followed by Seyferth-Gilbert homologation, from 2-halobenzaldehydes. However, limited availability of 2-halobenzaldehyde derivatives has impeded the preparation of more 5,10-unsubstituted dibenzo[*a,e*]pentalenes, and as a result, only a few 5,10-unsubstituted dibenzo[a,e]pentalenes have been synthesized.

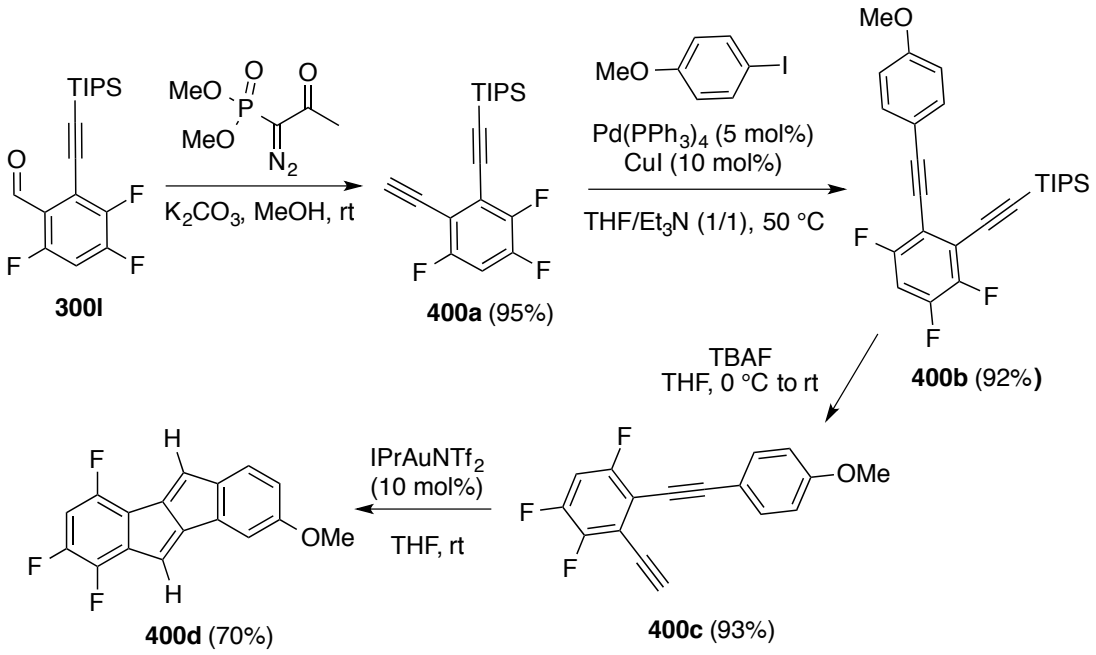



**Scheme 25.** Dibenzo[*a,e*]pentalenes *via* Au(I)-catalyzed cycloisomerization of 1,5-diynes.

24 For the Pd− or Ni−catalyzed coupling of aryl acetylenes, see: (a) Chakraborty, M.; Tessier, C. A.; Youngs, W. J. *J. Org. Chem.* **1999**, *64*, 2947−2949. (b) Kawase, T.; Konishi, A.; Hirao, Y.; Matsumoto, K.; Kurata, H.; Kubo, T. *Chem. Eur. J.* **2009**, *15*, 2653−2661. (c) Maekawa, T.; Segawa, Y.; Itami, K. *Chem. Sci.* **2013**, *4*, 2369−2373. (d) Shen, J.; Yuan, D.; Qiao, Y.; Shen, X.; Zhang, Z.; Zhong, Y.; Yi, Y.; Zhu, X. *Org. Lett.* **2014**, *16*, 4924−4927. (e) Levi, Z. U.; Tilley, T. D. *J. Am. Chem. Soc.* **2009**, *131*, 2796−2797. (f) Zhao, J.; Oniwa, K.; Asao, N.; Yamamoto, Y.; Jin, T. *J. Am. Chem. Soc.* **2013**, *135*, 10222−10225. Using $B(C_6F_5)_3$ as electrophilic reagent: (g) Chen, C.; Harhausen, M.; Liedtke, R.; Bussmann, K.; Fukazawa, A.; Yamaguchi, S.; Petersen, J. L.; Daniliuc, C. G.; Frçhlich, R.; Kehr, G.; Erker, G. *Angew. Chem. Int. Ed.* **2013**, *52*, 1−6.

25 For selected references, see: (a) Hashmi, A. S. K.; Wieteck, M.; Braun, I.; Nösel, P.; Jongbloed, L.; Rudolph, M.; Rominger, F. *Adv. Synth. Catal.* **2012**, *354*, 555−562. (b) Wurm, T.; Bucher, J.; Duckworth, S. B.; Rudolph, M.; Rominger, F.; Hashmi, A. S. K. *Angew. Chem. Int. Ed.* **2017**, *56*, 1−6. (c) Wurm, T.; Rüdiger, T. C.; Schulmeister, J.; Koser, S.; Rudolph, M.; Rominger, F.; Bunz, U. H. F.; Hashmi, A. S. K. *Chem. Eur. J.* **2018**, *24*, 2735−2740. (d) Sekine, K.; Schulmeister, J.; Paulus, F.; Goetz, K. P.; Rominger, F.; Rudolph, M.; Zaumseil, J.; Hashmi, A. S. K. *Chem. Eur. J.* **2019**, *25*, 216−220. (e) Tavakkolifard, S.; Sekine, K.; Reichert, L.; Ebrahimi, M.; Museridz, K.; Michel, E.; Rominger, F.; Babaahmadi, R.; Ariafard, A.; Yates, B. F.; Rudolph, M.; Hashmi, A. S. K. *Chem. Eur. J.* **2019**, *25*, 12180−12186.

Therefore, we explored the synthesis of 5,10-unsubstituted dibenzo[*a,e*]pentalenes using a sequential Rh/Pd/Au catalysis. In recent years, the synthesis of fluorinated polyarenes has gained momentum because fluorine substituents often impart higher solubility and improved electronic properties.[26] Therefore, we first targeted pin-point fluorinated dibenzo[a,e]pentalenes, and started our synthesis with the inexpensive 2,4,5-trifluorobenzaldehyde (**200l**). The scale up of the alkynylation of **200l** to gram-scale occurred without erosion in the isolated yield. Subsequent Ohira-Bestmann homologation, Suzuki-Miyaura coupling with 4-methoxybenzeneboronic acid and TBAF-mediated desilylation afforded diyne **400c** in 61% yield over 4 steps. Upon reaction with 10 mol% of gold catalyst $IPrAuNTf_2$ in THF, dibenzo[*a,e*]pentalene **400d** was isolated and characterized by X-ray diffraction.



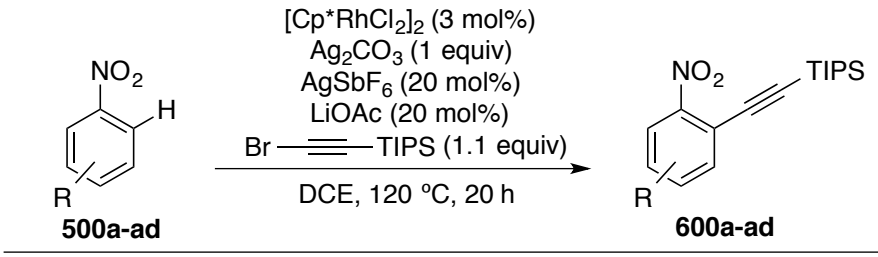

**Scheme 26.** Synthesis of dibenzo[*a,e*]pentalene **400d** *via* sequential Rh/Pd/Au catalysis.

**Alkynylation of nitrobenzene**

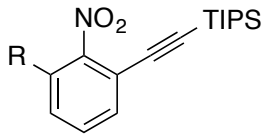
We next found that nitrobenzenes can also be *ortho* C−H alkynylated using our catalytic system. Thus, a combination of $[Cp^*RhCl_2]_2$ (3 mol %), $AgSbF_6$ (20 mol %), $Ag_2CO_3$ (1 equiv), LiOAc (20 mol %) in DCE at 120 °C provided **600a** in 95% yield (Scheme 27). Functionalities such as aldehyde, halides, tertiary amine, ether and alkyl groups at the *ortho*, *meta* or *para* positions were well tolerated, leading to **600a-l** in 30-95% yield. In the case of *meta*-substituted nitrobenzenes **600h-i**, the alkynylation occurred at the least hindered site, whereas fluoro and methoxy substituents in **600f** and **600g** favor the formation of 1,2,3-

26 Fuchibe, K.; Morikawa, T.; Shigeno, K.; Fujita, T.; Ichikawa J. *Org. Lett.* **2015**, *17*, 126−1129.

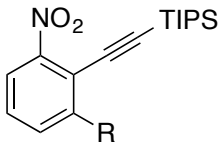
trisubstituted nitrobenzenes. Polysubstituted **600m-ac** or polyaromatic **600ab-ad** nitrobenzenes could also be alkynylated in 40-81% yield.



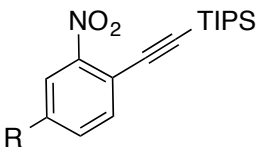

**500a-ad** **600a-ad**



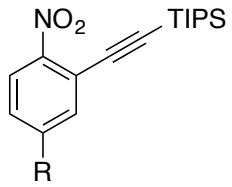
**600a**: R = Me (95%)
**600b**: R = CHO (74%)
**600c**: R = Et (91%)
**600d**: R = F (54%)
**600e**: R = I (71%)



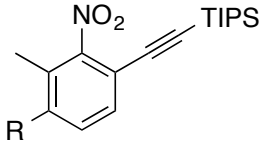
**600f**: R = F (61%, 2:1)[a]
**600g**: R = OMe (30%, 2:1)[a]



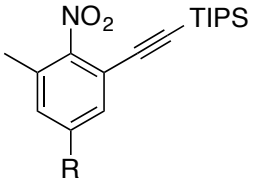
**600h**: R = Me (85%)
**600i**: R = $NMe_2$ (65%)



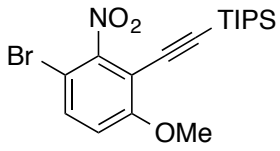
**600j**: R = H (75%, 4:1)[a]
**600k**: R = Cl (34%, 2:1)[a]
**600l**: R = F (56%, 2:1)[a]



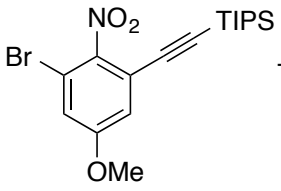
**600m**: R = Me (86%)[b]
**600n**: R = CF3 (32%)[b]
**600o**: R = F (65%)[b]
**600p**: R = Cl (66%)[b]
**600q**: R = Br (67%)[b]
**600r**: R = OMe (81%)[b]



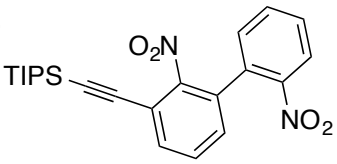
**600s**: R = Me (95%)
**600t**: R = $CF_3$ (48%)
**600u**: R = F (65%)
**600v**: R = Cl (60%)
**600w**: R = Br (71%)
**600x**: R = OMe (95%)



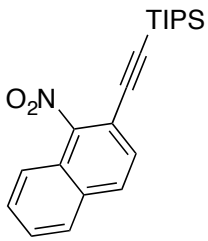
**600y** (81%)



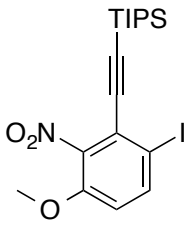
**600z** (72%)



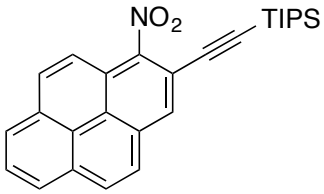
**600aa** (40%, 3:1)



**600ab** (41%)



**600ac** (55%)

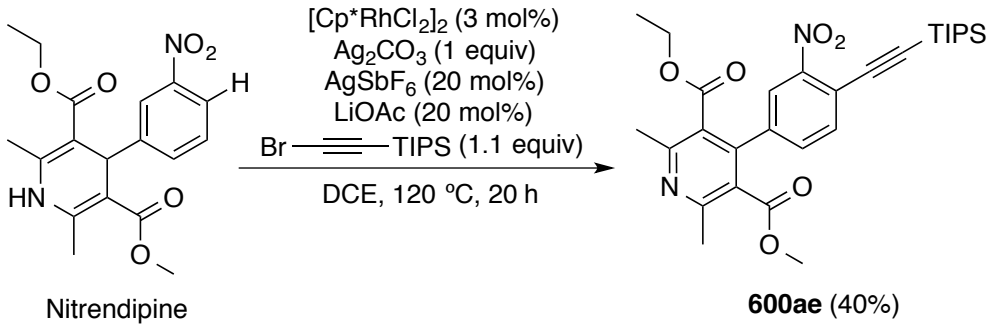


**600ad** (80%)

Yields of isolated monoalkynylated products are shown. In cases in which dialkynylated products were also formed, mono- vs dialkynylation selectivity is shown in parentheses. [a]With 2 equiv. of bromo-alkyne. [b]At 100 °C.

**Scheme 27.** Rh-catalyzed *ortho* C−H alkynylation of nitrobenzenes.

Under the same conditions, the alkynylation of nitrendipine (**500ae**), an antihypertensive agent, occurred in 40% yield (Scheme 28) with concomitant oxidation of the 1,4-dihydropyridine ring, thus demonstrating the potential of this reaction in the late-stage functionalization of complex pharmaceuticals.

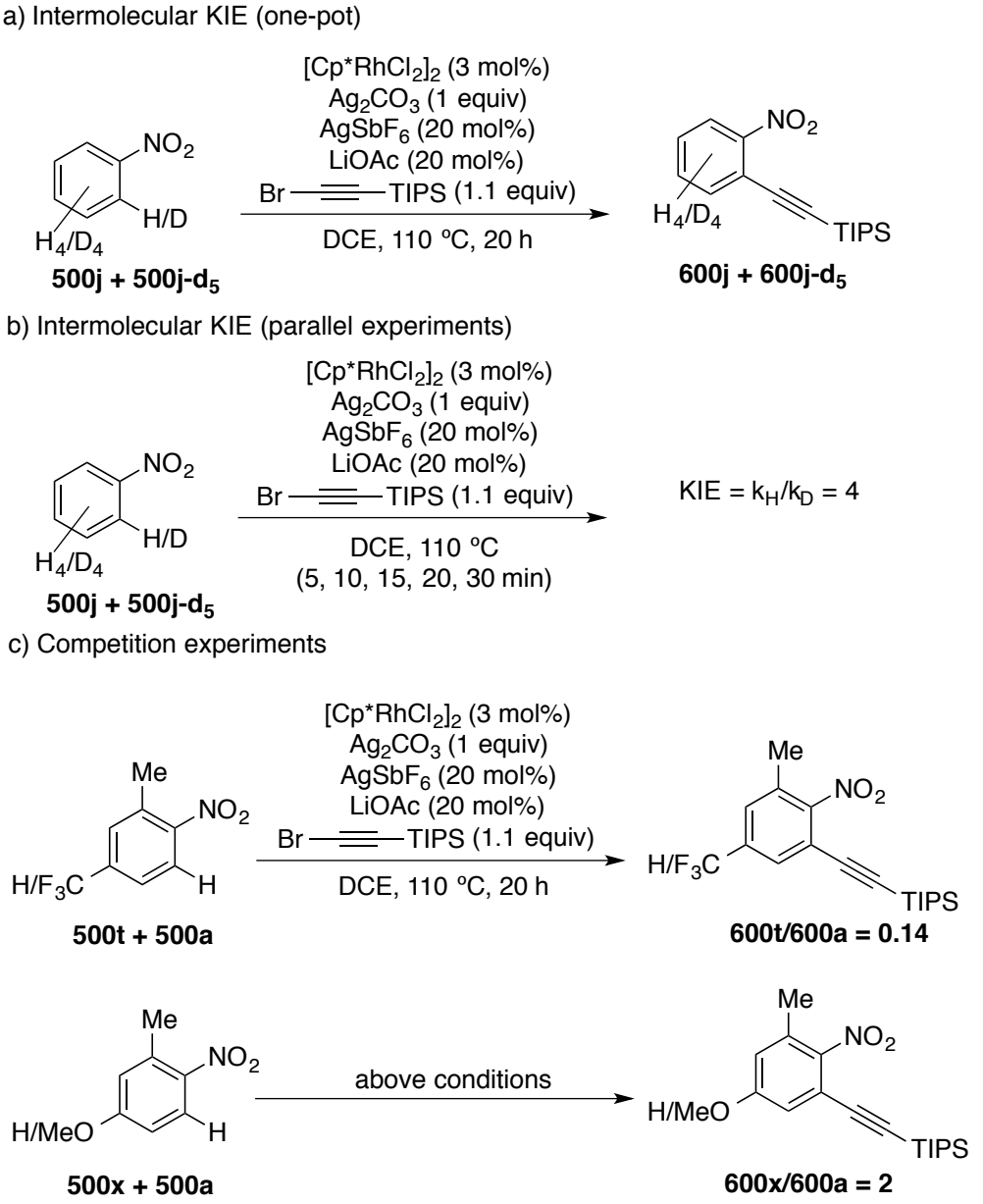



Nitrendipine **600ae** (40%)

**Scheme 28.** Late-stage alkynylation of nitrendipine.

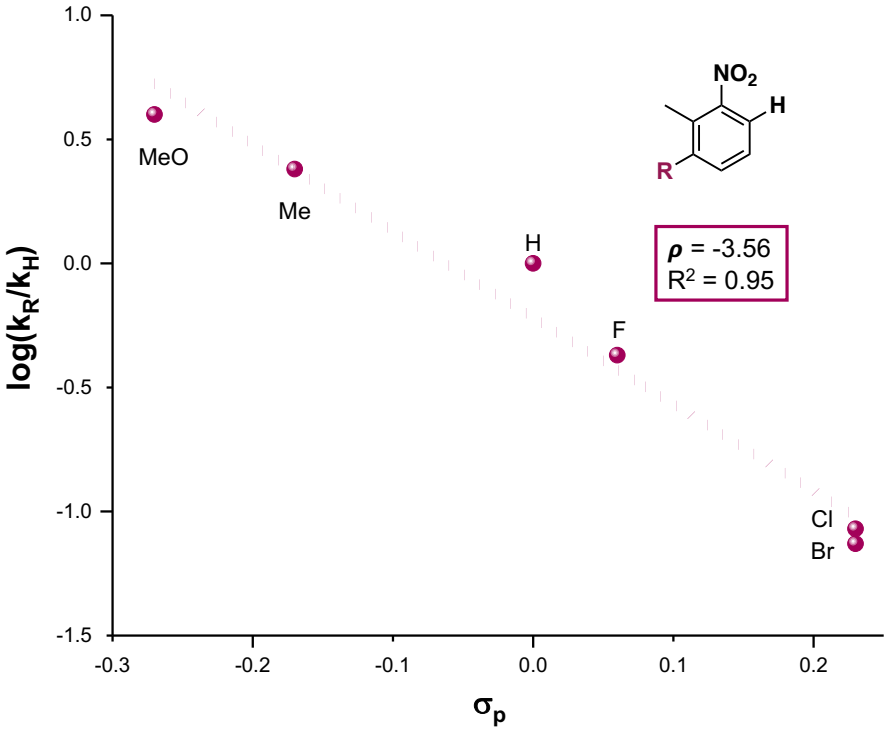
**Mechanistic studies of the alkynylation of nitrobenzenes**

We next studied the mechanism of the Rh-catalyzed C−H alkynylation. A significant kinetic isotope effect (KIE = 3.8−4.0) was observed using deuterated (**500j-d$_5$**) and hydrogenated (**500j**) labeled substrates, either by independent or competition experiments (Scheme 29, a-b), suggesting that the C−H bond cleavage may occur in the turnover determining step of the catalytic cycle. To gain insight into this C−H activation event, we next performed intermolecular competition experiments between 2-methylnitrobenzene (**500a**) and *p*-$CF_3$-2-methylnitrobenzene (**500t**) or *p*-MeO-2-methylnitrobenzene (**500x**). The results showed the electron-donating substituent (OMe) gave faster rate than the electron-poor substituent ($CF_3$) (Scheme 29, c).




**Scheme 29.** KIE and competition experiments.

Intrigued by these findings and to understand whether or not a positive charge could build-up *ortho* to the nitro group, we performed initial rates measurements of different *meta*-substituted 2-methylnitrobenzenes derivatives. A Hammett correlation was found ($R^2$ = 0.97 using $\sigma_p$) with a negative ρ value (ρ = -3.5), which indicates that there is a decrease of electron density at the aryl ring in the C−H activation step.




**Scheme 30.** Hammett plot of *meta*-substituted 2-methylnitrobenzenes derivatives.

## Conclusions

In conclusion, a general catalytic system, based on ruthenium and rhodium catalysts, allowing the alkynylation of a broad range of C($sp^2$)−H bonds was developed. These reactions exploit the presence of a chelating group at the *ortho*-position of arenes and in some cases the β-position of alkenes to direct the transition metal. The directing groups include: phenolic –OH, carboxylic acid, ester, ketone, ether, amine, thioether, sulfoxide, sulfone, phenol ester, carbamate, aldehyde and nitro groups.

These catalytic reactions were next applied in the synthesis of polyaromatic hydrocarbons (PAH). The alkynylation of naphthols granted access to fluoranthenes, with three additional steps. The alkynylation of benzaldehydes allowed the synthesis of diverse 1,5-enynes, that were cyclized using catalysis to synthesize dibenzopentalenes.

The mechanisms of these reactions were studied both experimentally and computationally. With both ruthenium and rhodium catalyst, the efficiency of these catalytic systems arises from two low-barrier steps: bromo-alkyne insertion into a ruthena- or rhodacycle, followed by bromide elimination. In the case of the rhodium catalysis, we found that the C−H activation step occurs through an electrophilic concerted metalation deprotonation. Interestingly, we found that the C−H activation of nitrobenzenes also occurs through this mechanism.

## Experimental Section

### General Methods

Reactions were carried out under argon atmosphere in solvents dried by passing through an activated alumina column on a PureSolv$^{TM}$ solvent purification system (Innovative Technologies, Inc., MA). Analytical thin layer chromatography was carried out using TLC-aluminum sheets with 0.2 mm of silica gel (Merck $GF_{234}$) using UV light as the visualizing agent and an acidic solution of vanillin in ethanol as the developing agent. Chromatographic purifications were carried out using automated flash chromatographer CombiFlash Companion. Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator. All reagents were used as purchased with no further purification, unless otherwise stated. Bromo-alkynes **2a, 2b, 2c, 2d**, **2e,** and 1-naphtols **1k,**[27] **1d,**[28] **1r**[29] were prepared according to previous reports. Their spectral data are consistent with those previously reported.

NMR spectra were recorded at 298 K (unless otherwise stated) on a Bruker Avance 300, Bruker Avance 400 Ultrashield and Bruker Avance 500 Ultrashield apparatuses. The signals are given as δ / ppm (multiplicity, coupling constant (Hertz), number of protons) downfield from tetramethylsilane, with calibration on the residual protio-solvent used ($\delta_H$ = 7.27 ppm and $\delta_C$ = 77.00 ppm for $CDCl_3$, $\delta_H$ = 5.32 ppm and $\delta_C$ = 53.84 ppm for $CD_2Cl_2$). Mass spectra were recorded on a Waters Micromass LCT Premier (ESI), Waters Micromass GCT (EI, CI) and Bruker Daltonics Autoflex (MALDI) spectrometers. Melting points were determined using a Büchi melting point apparatus.

Crystal structure determinations were carried out using a Bruker-Nonius diffractomer equipped with an APPEX 2 4K CCD area detector, a FR591 rotating anode with $MoK_a$ radiation, Montel mirrors as monochromator and a Kryoflex low temperature device (T = –173 ºC). Full-sphere data collection was used with w and j scans. *Programs used*: Data collection APEX-2, data reduction Bruker Saint V/.60A and absorption correction SADABS. Structure Solution and Refinement: Crystal structure solutions were achieved using direct methods as implement in SHELXTL and visualized using the program XP. Missing atoms were subsequently located from difference Fourier synthesis and added to the atom list. Least-squares refinement on F2 using all measured intensities was carried out using the program SHELXTL. All non-hydrogen atoms were refined including anisotropic displacement parameters.

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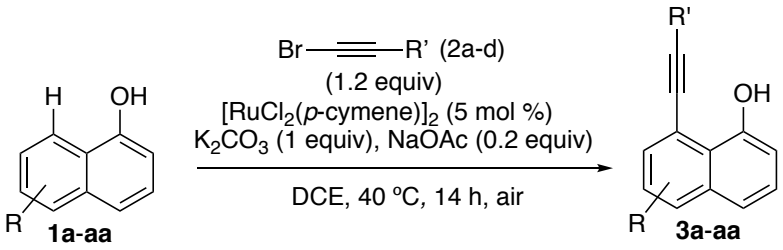
[27] Sakata, J.; Ando, Y.; Ohmori, K.; Suzuki, K. *Org. Lett.* **2015**, *17*, 3746−3749.

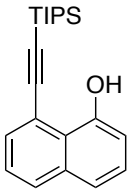
[28] White, D. R.; Hutt, J. T.; Wolfe, J. P. *J. Am. Chem. Soc.* **2015**, *137*, 11246−11249.

[29] Peng, S.; Wang, L.; Wang, J. *Chem. Eur. J.* **2013**, *19*, 13322−13327.

**General procedure for the alkynylation of naphthols (A)**

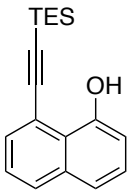



1-Naphthols **1a-aa** (0.20 mmol), $K_2CO_3$ (28.0 mg, 0.20 mmol, 1.0 equiv), $[RuCl_2(p\text{-cymene})]_2$ (6.2 mg, 0.05 mmol, 5 mol %), NaOAc (4.0 mg, 0.04 mmol, 0.2 equiv) and dichloroethane (2 mL) were weighted in air and placed in a 20 mL screw capped test tube. 1-Bromo-2-(triisopropylsylil)acetylene **2a** (62.7 mg, 0.24 mmol, 1.2 equiv) was then added and the reaction mixture was stirred at the appointed temperature for 14 h. After cooling to ambient temperature, the solvent was removed under reduced pressure and the residue was purified by column chromatography with a gradient from 100 % cyclohexane to 100 % ethyl acetate to yield products **3a-aa**.



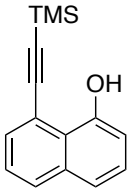

**8-((Triisopropylsilyl)ethynyl)naphthalen-1-ol ($3a_1$).** General procedure A at 40 ºC and obtained as a yellow liquid in 92% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.23 (s, 1H), 7.81 (dd, *J* = 8.3, 1.2 Hz, 1H), 7.64 (dd, *J* = 7.1, 1.2 Hz, 1H), 7.44 – 7.29 (m, 3H), 7.02 (dd, *J* = 5.8, 3.1 Hz, 1H), 1.23 – 1.17 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 153.9, 135.1, 132.8, 130.2, 127.5, 124.8, 122.8, 120.5, 115.2, 111.8, 107.1, 99.8, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{28}NaOSi$ $[M+Na]^+$: 347.1802. Found: 347.1792.

*Note*: This reaction was also conducted at a 7.00 mmol scale without observing any decrease in the yield of **$3a_1$**.

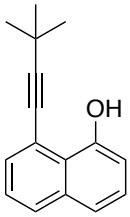



**8-((Triethylsilyl)ethynyl)naphthalen-1-ol ($3a_2$).** General procedure A at 40 ºC using (bromoethynyl)triethylsilane **2b** (1.2 equiv) instead of (bromoethynyl)-triisopropyl-silane **2a** and KOAc (2 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a black liquid in 60% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.22 (s, 1H), 7.83 (dd, *J* = 8.3, 1.3 Hz, 1H), 7.65 (dd, *J* = 7.1,

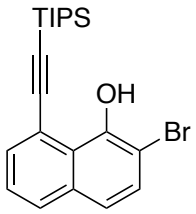
1.3 Hz, 1H), 7.42 (dd, *J* = 11.5, 8.3 Hz, 1H), 7.41 (s, 1H), 7.38 (dd, *J* = 8.3, 7.1 Hz, 1H), 7.03 (dd, *J* = 5.9, 2.9 Hz, 1H), 1.13 (t, *J* = 7.9 Hz, 9H), 0.80 (q, *J* = 7.9, 0.6 Hz, 6H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 153.9, 135.1, 132.7, 130.3, 127.5, 124.8, 122.9, 120.6, 115.1, 111.8, 106.4, 100.7, 7.5, 4.2. **HRMS** (ESI-) *m/z* calc. for $C_{18}H_{21}OSi$ $[M-H]^-$: 281.1367. Found: 281.1361.




**8-((Trimethylsilyl)ethynyl)naphthalen-1-ol (3a$_3$).** General procedure A at 60 ºC using (bromoethynyl)trimethylsilane **2c** (1.2 equiv) instead of (bromoethynyl)triisopropyl-silane **2a** and KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a black liquid in 45%. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 9.13 (s, 1H), 7.80 (dd, *J* = 8.3, 1.3 Hz, 1H), 7.61 (dd, *J* = 7.2, 1.3 Hz, 1H), 7.41 – 7.31 (m, 3H), 7.00 (dd, *J* = 5.4, 3.5 Hz, 1H), 0.35 (s, 9H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 153.8, 135.1, 132.4, 130.4, 127.5, 124.8, 122.8, 120.6, 115.0, 111.8, 105.2, 102.8, -0.4. **HRMS** (ESI+) *m/z* calc. for $C_{15}H_{17}OSi$ $[M+H]^+$: 241.1043. Found: 241.1032.

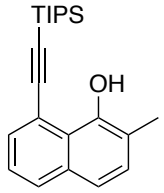



**8-(3,3-Dimethylbut-1-yn-1-yl)naphthalen-1-ol (3a$_4$).** General procedure A at 40 ºC using 1-bromo-3,3-dimethylbut-1-yne **2d** (1.2 equiv) instead of (bromoethynyl)triisopropylsilane **1a** and KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a black liquid in 40%. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.15 (s, 1H), 7.75 (d, *J* = 8.3 Hz, 1H), 7.51 (d, *J* = 7.1 Hz, 1H), 7.39 – 7.31 (m, 3H), 6.97 (dd, *J* = 5.5, 3.4 Hz, 1H), 1.42 (s, 9H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 154.0, 135.2, 131.7, 129.3, 127.2, 124.9, 122.7, 120.4, 115.7, 111.3, 106.1, 79.3, 30.5, 28.5. **HRMS** (ESI+) *m/z* calc. for $C_{16}H_{17}O$ $[M+H]^+$: 225.1274. Found: 225.1275.

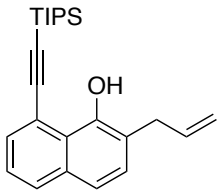



**2-Bromo-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3b).** General procedure A at 40 ºC and obtained as a yellow liquid in 75% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 9.69 (s, 1H), 7.80

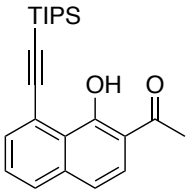
– 7.75 (dd, *J* = 7.2, 0.9 Hz, 1H), 7.68 (dd, *J* = 7.2, 0.9 Hz, 1H), 7.60 (d, *J* = 8.7 Hz, 1H), 7.42 – 7.35 (t, *J* = 7.2, 1H), 7.26 (d, *J* = 8.7 Hz, 1H), 1.21 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 150.3, 134.0, 133.7, 131.3, 130.1, 125.2, 123.1, 121.1, 115.1, 106.3, 106.2, 101.0, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}BrOSi$ [M-H]$^-$: 401.0942. Found: 401.0935.




**2-Methyl-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3c).** General procedure A at 40 ºC and obtained as a yellow liquid in 51%yield. **$^{1}$H NMR** (400 MHz, $CDCl_3$) δ 9.26 (s, 1H), 7.75 (d, *J* = 8.2 Hz, 1H), 7.62 (d, *J* = 7.1 Hz, 1H), 7.33 – 7.26 (m, 3H), 2.41 (s, 3H), 1.25 – 1.18 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 150.9, 133.7, 133.1, 130.4, 130.2, 123.8, 122.5, 120.7, 119.7, 114.7, 107.4, 99.5, 18.5, 16.5, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{22}H_{29}OSi$ [M-H]$^-$: 337.1993. Found: 337.1999.

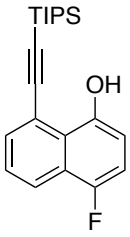



**2-Allyl-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3d).** General procedure A at 40 ºC and obtained as a black liquid in 41% yield. **$^{1}$H NMR** (400 MHz, $CDCl_3$) δ 9.29 (s, 1H), 7.76 (dd, *J* = 8.3, 1.1 Hz, 1H), 7.62 (dd, *J* = 7.1, 1.3 Hz, 1H), 7.37 – 7.28 (m, 3H), 6.09 (ddt, *J* = 16.8, 10.0, 6.7 Hz, 1H), 5.14 (dq, *J* = 17.0, 1.7 Hz, 1H), 5.08 (ddt, *J* = 10.0, 2.3, 1.3 Hz, 1H), 3.58 (dt, *J* = 6.7, 1.3 Hz, 2H), 1.27 – 1.12 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 150.6, 136.9, 133.8, 133.0, 130.1, 129.2, 124.1, 122.7, 122.6, 120.0, 115.4, 114.9, 107.3, 99.7, 34.4, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{24}H_{31}OSi$ [M-H]$^-$: 363.2150. Found: 363.2143.

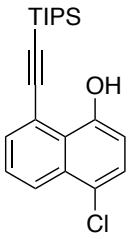



**1-(1-Hydroxy-8-((triisopropylsilyl)ethynyl)naphthalen-2-yl)ethan-1-one (3e).** General procedure A at 110 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a black liquid in 76% yield. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 7.74 (dd, *J* = 7.3, 1.2 Hz, 1H), 7.65 (dd, *J* = 8.2, 1.1 Hz, 1H), 7.61 (d, *J* = 8.8 Hz, 1H), 7.48 (dd, *J* = 8.1, 7.3 Hz, 1H), 7.18 (d, *J* = 8.8 Hz, 1H), 2.68 (s, 3H), 1.21 – 1.18 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 204.1, 163.9,

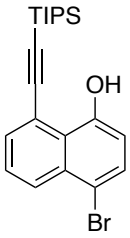
138.3, 134.7, 128.9, 128.1, 125.6, 124.7, 121.4, 118.6, 113.6, 107.4, 97.2, 27.1, 18.8, 11.6. **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{30}NaO_2Si$ $[M+Na]^+$: 389.1907. Found: 389.1905.




**4-Fluoro-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3f).** General procedure A at 40 ºC and obtained as a brown liquid in 76% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.99 (s, 1H), 8.09 (d, *J* = 8.5 Hz, 1H), 7.71 (dd, *J* = 7.1, 1.1 Hz, 1H), 7.45 (dd, *J* = 8.4, 7.2 Hz, 1H), 7.14 – 7.09 (m, 1H), 6.91 (dd, *J* = 8.5, 4.7 Hz, 1H), 1.24 – 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 152.4 (d, *J* = 243.2 Hz), 149.8 (d, *J* = 3.3 Hz), 133.6, 125.2 (d, *J* = 1.9 Hz), 124.5 (d, *J* = 17.8 Hz), 122.9 (d, *J* = 3.5 Hz), 122.5 (d, *J* = 6.1 Hz), 115.6 (d, *J* = 3.2 Hz), 110.8 (d, *J* = 21.5 Hz), 110.6 (d, *J* = 7.8 Hz), 106.1, 100.9, 18.6, 11.3. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -131.84 (dd, *J* = 9.8, 4.7 Hz). **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}FOSi$ $[M-H]^-$: 341.1742. Found: 341.1743.

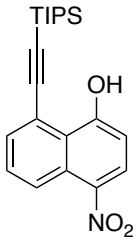



**4-Chloro-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3g).** General procedure A at 40 ºC and obtained as a white solid in 76% yield. **M.p. =** 39-41 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.31 (s, 1H), 8.26 (dd, *J* = 8.6, 1.2 Hz, 1H), 7.70 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.48 (t, *J* = 8.3 Hz, 2H), 6.93 (d, *J* = 8.3 Hz, 1H), 1.25 – 1.16 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 153.1, 133.6, 131.6, 127.7, 126.7, 125.9, 123.7, 122.8, 115.8, 111.8, 106.2, 101.0, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}ClOSi$ $[M-H]^-$: 357.1087. Found: 357.1449.

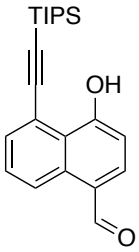



**4-Bromo-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3h).** General procedure A at 40 ºC and obtained as a yellow solid in 93% yield. **M.p. =** 44-46 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.37 (s, 1H), 8.27 (d, *J* = 8.6 Hz, 1H), 7.75 – 7.67 (m, 2H), 7.54 – 7.44 (m, 1H), 6.91 (d, *J* = 8.3 Hz, 1H), 1.25 – 1.19 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 153.8, 133.6, 132.7, 131.4,

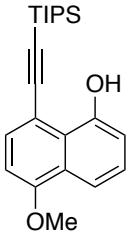
129.5, 126.2, 124.0, 115.8, 112.8, 112.5, 106.2, 101.1, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{28}BrOSi$ $[M+H]^+$: 403.1087. Found: 403.1088.




**4-Nitro-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3i).** General procedure A at 40 ºC and obtained as a white solid in 61% yield. **M.p. =** 109-111 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 10.17 (s, 1H), 8.78 (dd, *J* = 8.9, 1.1 Hz, 1H), 8.32 (d, *J* = 8.7 Hz, 1H), 7.75 (dd, *J* = 7.2, 1.1 Hz, 1H), 7.61 (dd, *J* = 8.9, 7.2 Hz, 1H), 6.98 (d, *J* = 8.7 Hz, 1H), 1.24 – 1.14 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 159.7, 139.2, 134.0, 128.5, 128.0, 127.8, 125.4, 122.3, 116.1, 110.4, 105.3, 103.0, 18.6, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}NO_3Si$ $[M-H]^-$: 368.1687. Found: 368.1696.

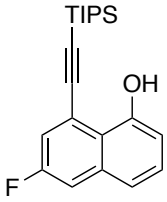



**4-Hydroxy-5-((triisopropylsilyl)ethynyl)-1-naphthaldehyde (3j).** General procedure A at 40 ºC and obtained as a yellow liquid in 95% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 10.17 (s, 1H), 10.16 (s, 1H), 9.51 (dd, *J* = 8.7, 1.2 Hz, 1H), 7.93 (d, *J* = 8.1 Hz, 1H), 7.77 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.62 (dd, *J* = 8.7, 7.2 Hz, 1H), 7.11 (d, *J* = 8.1 Hz, 1H), 1.29 – 1.18 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 192.0, 160.0, 140.5, 133.9, 133.1, 128.2, 127.3, 124.4, 122.6, 115.6, 111.2, 106.1, 101.8, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{29}O_2Si$ $[M+H]^+$: 353.1931. Found: 353.1934.

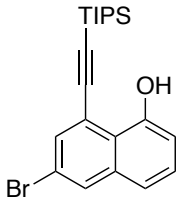



**5-Methoxy-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3k).** General procedure A at 40 ºC and obtained as a brown solid in 94% yield. **M.p. =** 41-43 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 9.30 (s, 1H), 7.83 (d, *J* = 8.4 Hz, 1H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.40 (t, *J* = 8.0 Hz, 1H), 7.05

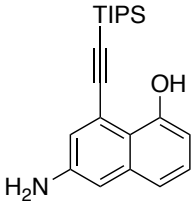
(d, *J* = 7.6 Hz, 1H), 6.71 (d, *J* = 8.1 Hz, 1H), 3.99 (s, 3H), 1.27 – 1.16 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 156.7, 153.8, 133.4, 127.0, 126.9, 123.5, 114.1, 112.6, 107.4, 107.2, 103.3, 97.8, 55.7, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{31}O_2Si$ $[M+H]^+$: 355.2088. Found: 355.2093.




**6-Fluoro-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3l).** General procedure A at 40 ºC and obtained as a brown liquid in 85% yield. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 9.13 (s, 1H), 7.45 – 7.36 (m, 3H), 7.31 (dd, *J* = 8.2, 0.9 Hz, 1H), 6.95 (dd, *J* = 7.6, 0.9 Hz, 1H), 1.23 – 1.17 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 159.0 (d, *J* = 246.5 Hz), 154.1 (d, *J* = 1.1 Hz), 136.1 (d, *J* = 9.2 Hz), 128.7, 122.1 (d, *J* = 26.8 Hz), 120.2, 119.9 (d, *J* = 5.4 Hz), 117.8 (d, *J* = 10.0 Hz), 113.6 (d, *J* = 19.9 Hz), 111.2 (d, *J* = 2.4 Hz), 105.6 (d, *J* = 3.1 Hz), 101.3, 18.6, 11.3. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -116.5 (t, *J* = 8.9 Hz). **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}FOSi$ $[M-H]^-$: 341.1742. Found: 341.1744.

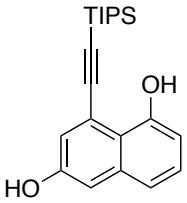



**6-Bromo-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3m).** General procedure A at 40 ºC and obtained as a yellow solid in 90% yield. **M.p. =** 50-52 ºC. **$^{1}$H NMR** (300 MHz, $CDCl_3$) δ 9.11 (s, 1H), 7.94 (d, *J* = 1.9 Hz, 1H), 7.66 (d, *J* = 2.0 Hz, 1H), 7.41 (t, *J* = 7.9 Hz, 1H), 7.31 – 7.24 (m, 1H), 6.99 (dd, *J* = 7.7, 1.1 Hz, 1H), 1.21 – 1.16 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 154.0, 136.0, 135.0, 132.1, 128.6, 121.3, 119.6, 118.2, 117.3, 112.3, 105.4, 101.5, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{26}BrOSi$ $[M-H]^-$: 401.0942. Found: 401.0936.

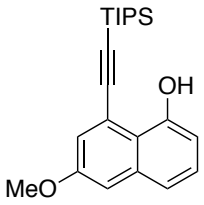



**6-Amino-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3n).** General procedure A at 95 ºC and obtained as a black liquid in 47% yield. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 9.02 (s, 1H), 7.28 (t, *J* = 7.9 Hz, 1H), 7.15 – 7.12 (m, 1H), 7.11 (d, *J* = 2.4 Hz, 1H), 6.98 (d, *J* = 2.3 Hz, 1H), 6.76 (dd, *J* = 7.6, 1.1 Hz, 1H), 3.82 (br s, 2H), 1.24 – 1.17 (m, 21H). **$^{13}$C NMR** (126 MHz,

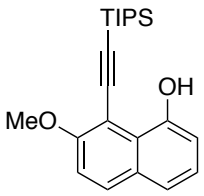
$CDCl_3$) δ 154.0, 142.9, 136.8, 127.9, 124.1, 118.5, 117.5, 116.3, 111.5, 108.5, 106.9, 99.3, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{28}NOSi$ $[M-H]^-$: 338.1946. Found: 338.1934.



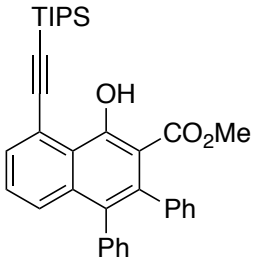

**8-((Triisopropylsilyl)ethynyl)naphthalene-1,6-diol (3o).** General procedure A at 110 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a black liquid in 61% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.17 (s, 1H), 7.32 (t, *J* = 7.9 Hz, 1H), 7.27 (d, *J* = 2.6 Hz, 1H), 7.19 (dd, *J* = 8.2, 0.9 Hz, 1H), 7.14 (d, *J* = 2.5 Hz, 1H), 6.85 (dd, *J* = 7.6, 1.1 Hz, 1H), 5.73 (br s, 1H), 1.22 – 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 153.8, 152.2, 136.5, 128.1, 123.9, 119.2, 118.5, 116.9, 112.5, 109.6, 106.3, 100.2, 18.6, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{27}O_2Si$ $[M-H]^-$: 339.1786. Found: 339.1790.



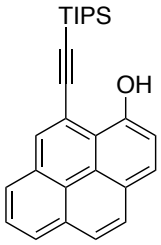

**6-Methoxy-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3p).** General procedure A at 60 ºC and obtained as a black liquid in 70% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 9.11 (s, 1H), 7.39 – 7.26 (m, 3H), 7.15 (d, *J* = 2.6 Hz, 1H), 6.87 (dd, *J* = 7.5, 1.2 Hz, 1H), 3.92 (s, 3H), 1.24 – 1.17 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 156.1, 154.0, 136.5, 128.1, 124.8, 119.4, 118.3, 116.7, 109.7, 108.7, 106.5, 99.7, 55.4, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{31}O_2Si$ $[M+H]^+$: 355.2088. Found: 355.2086.



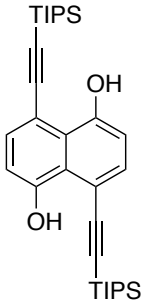

**7-Methoxy-8-((triisopropylsilyl)ethynyl)naphthalen-1-ol (3q).** General procedure A at 60 ºC and obtained as a yellow liquid in 92% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.43 (s, 1H), 7.79 (d, *J* = 9.1 Hz, 1H), 7.34 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.28 (t, *J* = 7.8 Hz, 1H), 7.19 (d, *J* = 9.1 Hz, 1H), 7.00 (dd, *J* = 7.4, 1.3 Hz, 1H), 4.00 (s, 3H), 1.27 – 1.23 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 160.8, 153.2, 131.5, 130.2, 125.2, 123.7, 120.3, 112.4, 112.1, 105.5, 103.0, 101.4, 56.5, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{22}H_{29}O_2Si$ $[M-H]^-$: 353.1942. Found: 353.1942.




**Methyl 1-hydroxy-3,4-diphenyl-8-((triisopropylsilyl)ethynyl)-2-naphthoate (3r)**. General procedure A at 95 ºC starting from methyl 1-hydroxy-3,4-diphenyl-2-naphthoate (**1r**) (0.10 mmol) and using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a brown oil in 75% yield. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 10.74 (s, 1H), 7.73 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.49 (dd, *J* = 8.6, 1.2 Hz, 1H), 7.34 – 7.30 (m, 1H), 7.23 – 7.17 (m, 3H), 7.14 – 7.08 (m, 3H), 7.05 (m, 4H), 3.50 (s, 3H), 1.26 – 1.19 (s, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 170.0, 154.5, 139.8, 138.5, 137.6, 135.1, 134.0, 131.6, 131.4, 129.8, 128.5, 127.7, 127.1, 127.0, 126.6, 126.3, 122.6, 117.7, 114.5, 107.1, 99.4, 51.9, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{35}H_{37}O_3Si$ [M-H]$^-$: 533.2517. Found: 533.2521.

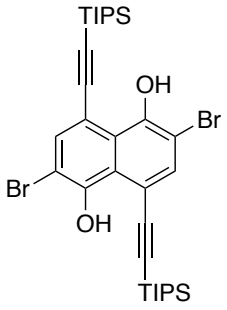



**10-((Triisopropylsilyl)ethynyl)pyren-1-ol (3s).** General procedure A at 110 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a white solid in 84% yield. **M.p. =** 105-107 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.68 (s, 1H), 8.17 (s, 1H), 8.11 – 8.06 (m, 2H), 8.00 – 7.89 (m, 3H), 7.83 (d, *J* = 8.9 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 1H), 1.31 – 1.23 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 153.2, 134.8, 131.8, 130.3, 127.8, 127.7, 126.3, 126.2, 125.7, 125.1, 125.1, 124.2, 123.5, 115.6, 115.3, 114.6, 107.6, 99.3, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{27}H_{29}OSi$ [M-H]$^-$: 397.1993. Found: 397.1989.

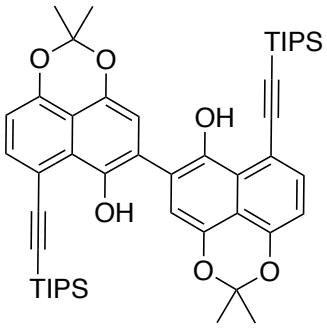



**4,8-Bis((triisopropylsilyl)ethynyl)naphthalene-1,5-diol (3t).** General procedure A at 60 ºC starting from naphthalene-1,5-diol (**1t**) (0.20 mmol) and using 2.2 equiv of

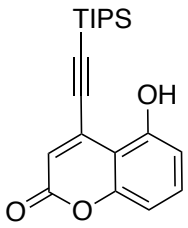
(bromoethynyl)triisopropylsilane (**2a**), 2.0 equiv of $K_2CO_3$ and 0.4 equiv of NaOAc. Obtained as a yellow solid in 45% yield. **M.p.** = 194-196 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.84 (s, 2H), 7.58 (d, *J* = 8.1 Hz, 2H), 6.90 (d, *J* = 8.1 Hz, 2H), 1.22 – 1.12 (m, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 155.9, 135.2, 124.5, 111.9, 107.0, 106.8, 99.2, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{32}H_{49}O_2Si_2$ $[M+H]^+$: 521.3266. Found: 521.3281.



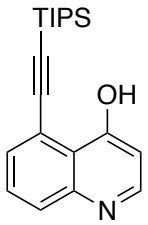

**2,6-Dibromo-4,8-bis((triisopropylsilyl)ethynyl)naphthalene-1,5-diol (3u).** General procedure A at 60 ºC starting from 2,6-dibromonaphthalene-1,5-diol (**1u**) (0.20 mmol) and using 2.2 equiv of (bromoethynyl)triisopropylsilane **2a**, 2.0 equiv of $K_2CO_3$ and 0.4 equiv of NaOAc. Obtained as a yellow solid in 43% yield. **M.p.** = 177-179 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 10.25 (s, 2H), 7.79 (s, 2H), 1.21 – 1.15 (m, 42H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 152.4, 138.7, 123.5, 108.1, 106.0, 104.6, 101.6, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{32}H_{45}Br_2O_2Si_2$ $[M-H]^-$: 675.1330. Found: 675.1352.



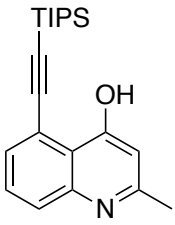

**2,2,2',2'-Tetramethyl-7,7'-bis((triisopropylsilyl)ethynyl)-[5,5'-binaphtho[1,8-*de*][1,3]dioxine]-6,6' -diol (3v).** General procedure A at 95 ºC starting from 2,2-dimethylnaphtho[1,8-*de*][1,3]dioxin-6-ol **(1v)** (0.14 mmol) and using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a brown oil in 75% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.72 (s, 2H), 7.63 (d, *J* = 7.9 Hz, 2H), 7.01 (s, 2H), 6.82 (d, *J* = 7.9 Hz, 2H), 1.67 (s, 12H), 1.16 (s, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 149.4, 144.9, 140.2, 134.9, 123.4, 122.5, 114.3, 113.5, 109.2, 108.7, 106.9, 101.5, 98.1, 25.1, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{48}H_{61}O_6Si_5$ $[M-H]^-$: 789.4012; found: 789.4000.



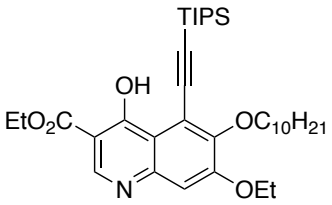

**5-Hydroxy-4-((triisopropylsilyl)ethynyl)-2*H*-chromen-2-one (3x).** General procedure A at 40 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc and obtained as a white solid in 66% yield. **M.p.** = 188-190 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 9.76 (br s, 1H), 7.54 – 7.47 (m, 1H), 7.39 (m, 2H), 5.84 (s, 1H), 1.25 – 1.12 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 164.8, 162.2, 154.2, 131.6, 130.1, 118.8, 116.7, 115.3, 103.6, 103.4, 94.9, 18.5, 11.1. **HRMS** (ESI-) *m/z* calc. for $C_{20}H_{26}O_3Si$ [M-H]$^-$: 341.1578. Found: 341.1578.




**5-((Triisopropylsilyl)ethynyl)quinolin-4-ol (3y).** General procedure A at 95 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a white solid in 81% yield. **M.p.** = 232-234 ºC. **$^1$H NMR** (500 MHz, $CD_3OD$) δ 7.82 (d, *J* = 7.3 Hz, 1H), 7.57 (m, 1H), 7.52 – 7.45 (m, 2H), 6.25 (d, *J* = 7.3 Hz, 1H), 1.20 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 178.8, 141.0, 138.2, 132.1, 130.5, 125.4, 121.7, 118.2, 110.0, 106.9, 97.5, 18.6, 11.4 (3 drops of $CD_3OD$ are added to a solution of **3y** in $CDCl_3$ (0.5 mL) to increase its solubility and record $^{13}$C NMR spectrum. **HRMS** (ESI-) *m/z* calc. for $C_{20}H_{26}NOSi$ [M-H]$^-$: 324.1789. Found: 324.1773.

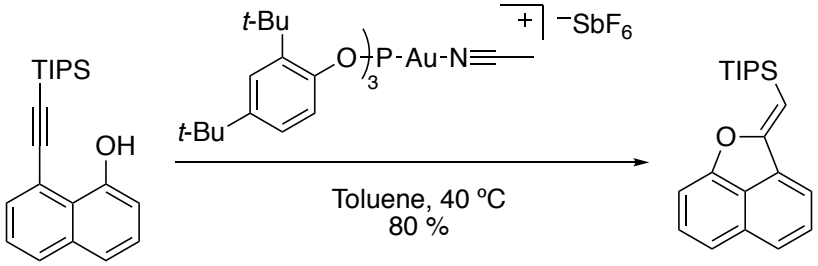



**2-Methyl-5-((triisopropylsilyl)ethynyl)quinolin-4-ol (3z)**. General procedure A at 95 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a yellow solid in 59% yield. **M.p.** = 204-206 ºC. **$^1$H NMR (400 MHz, $CDCl_3$)** δ 7.78 – 7.72 (m, 1H), 7.53 (dd, *J* = 7.4, 1.1 Hz, 1H), 7.45 – 7.39 (m, 1H), 6.02 (br s, 1H), 2.33 (s, 3H), 1.06 (s, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ 178.4, 150.4, 141.8, 132.0, 130.4, 124.5, 121.6, 119.4, 109.3, 107.5, 97.0, 29.7, 18.7, 11.5. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{28}NOSi$ [M-H]$^-$: 338.1946. Found: 338.1933.



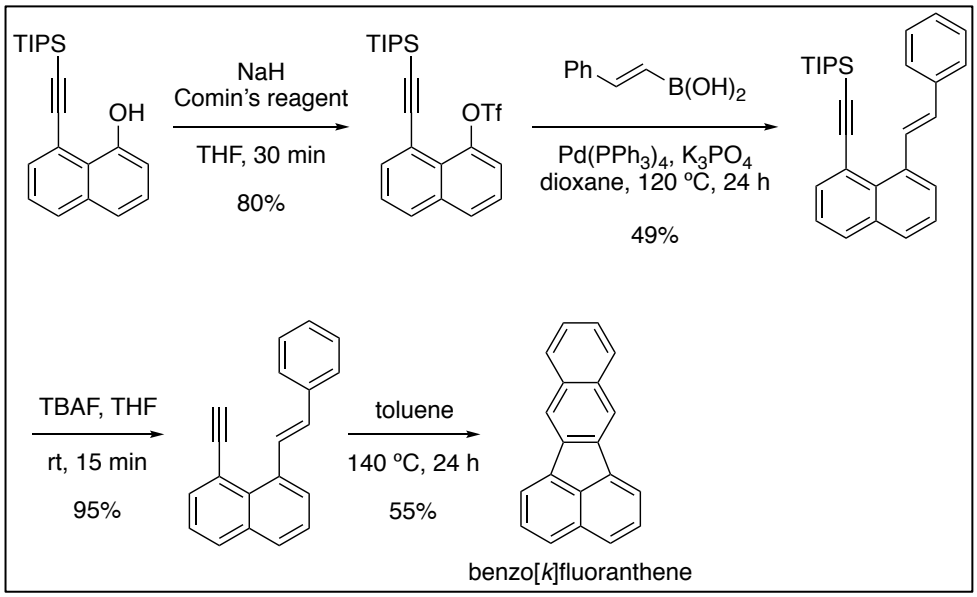

**Ethyl 6-(decyloxy)7-ethoxy-4-hydroxy-5-((triisopropylsilyl)ethynyl)-quinoline-3-carboxylate (3aa).** General procedure (A) at 115 ºC using KOAc (2.0 equiv) instead of $K_2CO_3$ and NaOAc. Obtained as a yellow solid in 41% yield. **M.p. =** 179-181 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.96 (s, 1H), 7.32 (s, 1H), 4.47 (q, *J* = 7.1 Hz, 2H), 4.19 (q, *J* = 7.0 Hz, 2H), 4.14 (t, *J* = 6.8 Hz, 2H), 1.86 (m, *J* = 7.0 Hz, 2H), 1.52 (t, *J* = 7.0 Hz, 3H), 1.46 (m, 5H), 1.33 – 1.23 (m, 12H), 1.18 (m, 21H), 0.88 (t, *J* = 7.0 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 170.6, 167.2, 156.4, 153.1, 150.1, 149.8, 114.4, 113.2, 110.5, 103.0, 102.4, 101.0, 73.8, 64.4, 61.7, 31.9, 30.3, 29.6, 29.6, 29.6, 29.3, 26.0, 22.7, 18.7, 14.6, 14.2, 14.1, 11.5. **HRMS** (ESI-) *m/z* calc. for $C_{35}H_{54}NO_5Si$ $[M-H]^-$: 596.3777. Found: 596.3774.

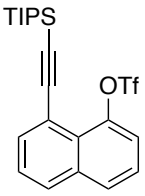
**Synthesis of naphtofuranylidene:**



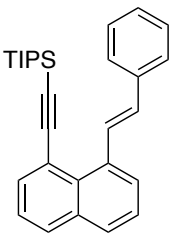

**(*Z*)-((2*H*-Naphtho[1,8-*bc*]furan-2-ylidene)methyl)triisopropylsilane (5).** $CH_2Cl_2$ was added to a vial containing **3a$_1$** (40 mg, 0.12 mmol) and cationic complex [tris(2,4-di-*tert*-butylphenyl)phosphiteAu(MeCN]$SbF_6$ (3.3 mg, 2.5 mol %). The mixture was stirred for 14 h at 40 ºC. The solvent was then evaporated and the residue purified by column chromatography (cHex:EtOAc 9:1). Obtained as yellow needles in 80 % yield. **M.p. =** 60-62 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.70 (dd, *J* = 7.5, 1.1 Hz, 1H), 7.60 – 7.54 (m, 2H), 7.41 (dd, *J* = 8.3, 7.2 Hz, 1H), 7.36 – 7.33 (m, 1H), 6.80 (d, *J* = 7.2 Hz, 1H), 5.44 (s, 1H), 1.41 – 1.33 (m, 3H), 1.15 (d, *J* = 7.4 Hz, 18H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 164.6, 156.8, 132.1, 131.3, 129.1, 129.1, 128.2, 124.8, 117.0, 116.8, 101.4, 94.8, 18.9, 11.8. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{29}OSi$ $[M+H]^+$: 325.1982. Found: 325.1975.

**Synthesis of benzo[*k*]fluoranthenes**

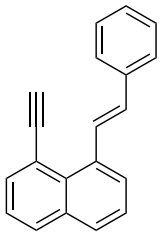


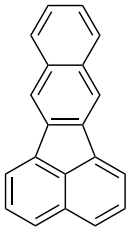

**8-((Triisopropylsilyl)ethynyl)naphthalen-1-yl trifluoromethanesulfonate (6).** NaH (60% in mineral oil, 271.2 mg, 6.78 mmol) was added to a solution of **3a$_1$** (2.00 g, 6.16 mmol) and Comin's reagent (2.90 g, 7.40 mmol) in anhydrous THF (60 mL) at 0 ºC and the resulting mixture was allowed to warm to rt. After stirring for 30 min a saturated solution of $NH_4Cl$ (100 mL) was added followed by EtOAc (50 mL) and the aqueous layer was extracted with EtOAc (80 mL). The combined organic phases were dried over $MgSO_4$, filtered, and concentrated under reduced pressure. Purification by column chromatography (cHex:EtOAc 98:2) afforded the product **6** as a pale yellow solid in 80% yield. **M.p.** = 56-58 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 7.3, 1.3 Hz, 1H), 7.87 (dd, *J* = 3.5, 1.1 Hz, 1H), 7.85 (dd, *J* = 3.7, 1.3 Hz, 1H), 7.55 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.52 (d, *J* = 8.5 Hz, 1H), 7.48 (d, *J* = 7.9 Hz, 1H), 1.35 – 1.20 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 146.1, 136.9, 135.5, 129.4, 128.8, 126.5, 125.5, 125.4, 119.45 (q, *J* = 1.8 Hz), 118.89 (q, *J* = 322.3 Hz), 117.7, 105.5, 98.9, 18.8, 11.4. **$^{19}$F{H} NMR** (376 MHz, $CDCl_3$) δ -71.4. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{27}F_3NaO_3SSi$ $[M+Na]^+$: 479.1294. Found: 479.1286.



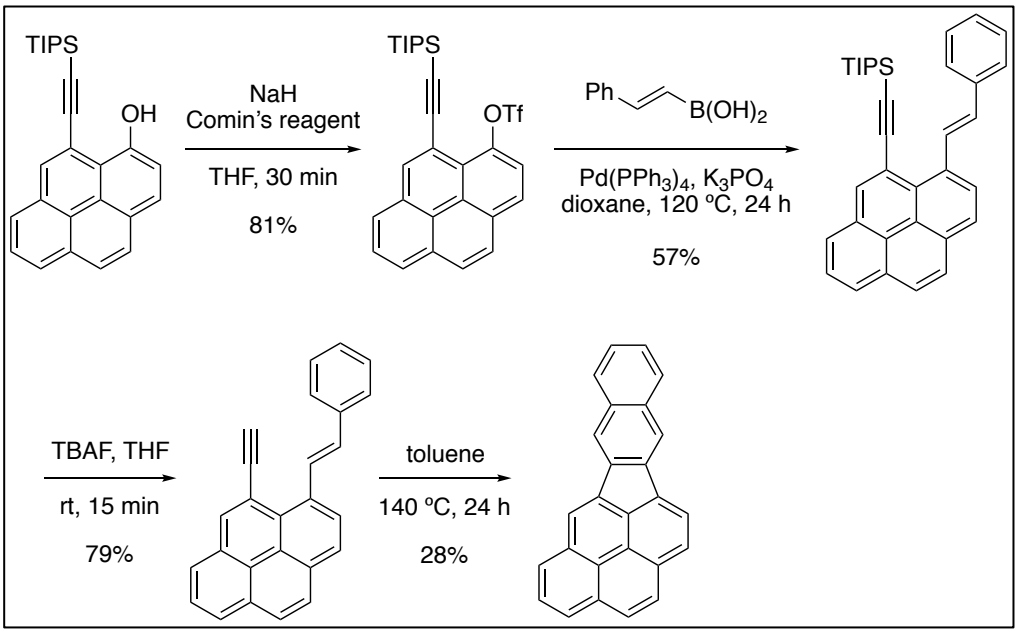
**(*E*)-Triisopropyl((8-styrylnaphthalen-1-yl)ethynyl)silane (7a).** Dioxane (10 mL) was added to a flask containing **6** (500 mg, 1.10 mmol), (*E*)-styrylboronic acid (243.1 mg, 1.64 mmol), anhydrous $K_3PO_4$ (700.5 mg, 3.30 mmol), and $Pd(PPh_3)_4$ (63.6 mg, 0.06 mmol) under Ar atmosphere, and the resulting mixture was stirred at 120 ºC for 24 h. After cooling down to rt a saturated solution of $NH_4Cl$ (20 mL) was added followed by EtOAc (30 mL) and the aqueous layer was extracted with EtOAc (30 mL). The combined organic phases were dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The product **7a** was obtained as a white solid after purification by column chromatography (cHex:$CH_2Cl_2$ 99:1) followed by washing with MeOH in 49% yield. **M.p. =** 72-74 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.66 (dd, *J* = 15.7, 0.7 Hz, 1H), 7.86 (td, *J* = 7.5, 1.4 Hz, 2H), 7.80 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.67 (dt, *J* = 7.2, 1.1 Hz, 1H), 7.57 – 7.53 (m, 2H), 7.52 – 7.47 (m, 1H), 7.43 (dd, *J* = 8.2, 7.2 Hz, 1H), 7.39 – 7.34 (m, 2H), 7.31 – 7.27 (m, 1H), 6.96 (d, *J* = 15.6 Hz, 1H), 1.03 (d, *J* = 6.5 Hz, 18H), 0.99 – 0.91 (m, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 138.2, 137.3, 136.2, 134.4, 130.8, 130.8, 129.9, 129.8, 128.9, 128.4, 127.3, 127.3, 127.1, 126.0, 125.0, 120.3, 109.1, 98.0, 18.7, 11.4. **HRMS** (LDI+) *m/z* calc. for $C_{29}H_{34}Si$ $[M]^+$: 410.2430. Found: 410.2425.

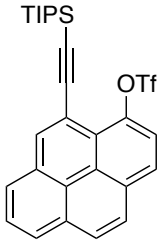


**(*E*)-1-Ethynyl-8-styrylnaphthalene (7b).** TBAF (1.0 M in THF, 0.44 mmol, 0.44 mL) was added to a solution of **7a** (150.0 mg, 0.37 mmol) in anhydrous THF (7 mL) at 0 ºC and the resulting mixture was allowed to warm up to rt and stirred for 30 min. The reaction was then diluted with EtOAc (10 mL) and quenched by the addition of a saturated solution of $NH_4Cl$ (15 mL). The aqueous layer was extracted with EtOAc (10 mL) and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated under reduced pressure. Purification by column chromatography (cHex) afforded the product **7b** as a white solid in 95% yield. **M.p.** = 105-107 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.69 (dd, *J* = 15.9, 1.0 Hz, 1H), 7.89 (dd, *J* = 8.3, 1.3 Hz, 1H), 7.86 (dd, *J* = 7.2, 1.3 Hz, 1H), 7.82 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.69 (dt, *J* = 7.2, 1.1 Hz, 1H), 7.63 – 7.58 (m, 2H), 7.52 (dd, *J* = 8.1, 7.2 Hz, 1H), 7.48 – 7.39 (m, 3H), 7.34 – 7.29 (m, 1H), 6.88 (d, *J* = 15.9 Hz, 1H), 3.55 (s, 1H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 137.9, 137.1, 135.4, 134.3, 131.5, 130.7, 130.4, 129.5, 128.9, 128.7, 127.3, 127.0, 126.6, 126.2, 125.0, 118.7, 86.1, 82.9. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{15}$ $[M+H]^+$: 255.1168. Found: 255.1167.



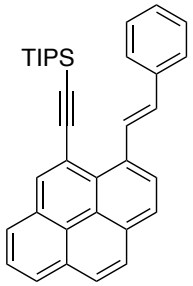
**Benzo[*k*]fluoranthene (8).** A suspension of **7b** (25.4 mg, 0.1 mmol) in toluene (1 mL) was heated at 140 ºC in a sealed tube for 24 h. After cooling down to rt the solvent was evaporated under reduced pressure and the crude was purified by column chromatography (cHex:$CH_2Cl_2$ 95:5) to give a pale yellow solid, which was further purified by washing with pentane to yield 54% of **8**. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.34 (s, 2H), 8.05 (dd, *J* = 6.9, 0.6 Hz, 2H), 8.00 – 7.95 (m, 2H), 7.88 (dd, *J* = 8.3, 0.6 Hz, 2H), 7.71 (d, *J* = 7.0 Hz, 1H), 7.69 (d, *J* = 7.0 Hz, 1H), 7.55 – 7.50 (m, 2H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 137.8, 136.9, 135.3, 133.5, 130.5, 128.7, 128.2, 126.2, 126.0, 120.2, 119.2. The spectroscopic data were consistent with those previously reported.[30]



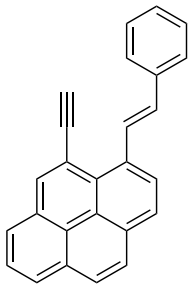




[30] Yamaguchi, M.; Higuchi, M.; Tazawa, K.; Manabe, K. *J. Org. Chem.* **2016**, *81*, 3967–3974.

**10-((Triisopropylsilyl)ethynyl)pyren-1-yl trifluoromethanesulfonate (6a).** Procedure described for **6** starting from **3s** (1.43 g, 3.59 mmol). The product **6a** was obtained as a yellow solid after purification by column chromatography (cHex) followed by washing of the resulting solid with MeOH in 81% yield. **M.p. =** 127-129 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.52 (s, 1H), 8.26 (dd, *J* = 7.7, 2.2 Hz, 1H), 8.21 (dd, *J* = 8.2, 3.5 Hz, 2H), 8.15 – 8.04 (m, 3H), 8.01 (d, *J* = 8.5 Hz, 1H), 1.36 – 1.29 (m, 3H), 1.26 (d, *J* = 6.2 Hz, 18H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 143.5, 138.8, 131.1, 130.9, 130.0, 128.3, 127.2, 127.1, 127.1, 126.2, 125.9, 125.7, 123.4, 122.5, 119.80, 119.0 (q, *J* = 322.3 Hz), 116.0, 105.7, 98.0, 18.8, 11.5. **$^{19}$F NMR{H}** (376 MHz, $CDCl_3$) δ -71.2. **HRMS** (ESI+) *m/z* calc. for $C_{28}H_{29}F_3NaO_3SSi$ $[M+Na]^+$: 553.1451. Found: 553.1451.

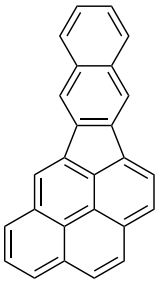



**(*E*)-Triisopropyl((3-styrylpyren-4-yl)ethynyl)silane (7aa).** Procedure described for **7a** starting from **6a** (1.00 g, 1.88 mmol). The product **7aa** was obtained as a yellow solid after purification by column chromatography (cHex:EtOAc 1:0 to 99:1) followed by washing of the resulting solid with MeOH in 57% yield. **M.p. =** 138-140 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.99 (d, *J* = 15.8 Hz, 1H), 8.47 (s, 1H), 8.23 (d, *J* = 8.1 Hz, 1H), 8.18 (d, *J* = 8.3 Hz, 2H), 8.13 (dd, *J* = 7.7, 1.1 Hz, 1H), 8.07 – 7.95 (m, 3H), 7.65 – 7.58 (m, 2H), 7.43 – 7.35 (m, 2H), 7.34 – 7.28 (m, 1H), 7.15 (d, *J* = 15.8 Hz, 1H), 1.14 – 0.93 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 138.3, 138.0, 134.8, 131.4, 131.1, 131.0, 130.4, 130.2, 128.4, 127.8, 127.4, 127.2, 127.1, 127.0, 126.9, 126.2, 126.1, 125.9, 125.6, 124.6, 124.5, 119.6, 109.5, 97.6, 18.7, 11.5. **HRMS** (LDI+) *m/z* calc. for $C_{35}H_{36}Si$ $[M]^+$: 484.2586. Found: 484.2584.



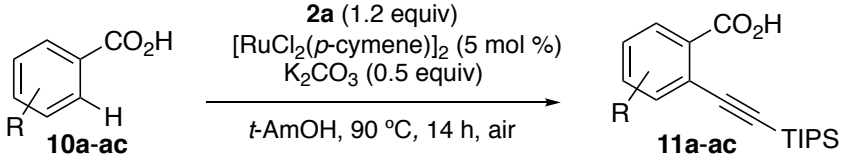
**(*E*)-10-Ethynyl-1-styrylpyrene (7ba).** Procedure described for **7b** starting from **7aa** (484.8 mg, 1.00 mmol). The product **7ba** was obtained as a yellow solid after purification by column chromatography (cHex:EtOAc 95:5) followed by washing of the resulting solid with MeOH

in 79% yield. **M.p. =** 140-142 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 9.05 (d, *J* = 16.0 Hz, 1H), 8.51 (s, 1H), 8.26 – 8.18 (m, 3H), 8.14 (d, *J* = 7.5 Hz, 1H), 8.09 – 7.98 (m, 3H), 7.67 (d, *J* = 7.6 Hz, 2H), 7.45 (t, *J* = 7.7 Hz, 2H), 7.33 (t, *J* = 7.6 Hz, 1H), 7.06 (d, *J* = 16.0 Hz, 1H), 3.63 (s, 1H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 138.0, 137.6, 134.6, 131.4, 131.1, 130.9, 130.1, 130.0, 128.8, 127.9, 127.5, 127.5, 126.9, 126.7, 126.7, 126.4, 126.3, 126.1, 125.6, 124.7, 124.7, 118.1, 86.6, 82.5. **HRMS** (LDI+) *m/z* calc. for $C_{26}H_{16}$ $[M]^+$: 328.1252. Found: 328.1258.



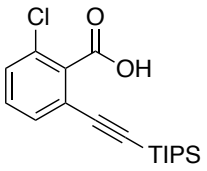
**Benzo[5,6]indeno[1,2,3-*cd*]pyrene (9).** Procedure described for **8** starting from **7ba** (98.5 g, 0.3 mmol). The product was obtained as a yellow solid with limited solubility in standard organic solvents after purification by column chromatography (cHex:$CH_2Cl_2$ 7:3) followed by washing of the resulting solid with MeOH in 28% yield. **M.p. =** 225-227 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$, 323K) δ 8.55 (s, 1H), 8.48 (s, 1H), 8.41 (d, *J* = 7.8 Hz, 1H), 8.36 (s, 2H), 8.23 (t, *J* = 8.0 Hz, 2H), 8.12 (d, *J* = 9.2 Hz, 1H), 8.10 – 8.02 (m, 2H), 7.99 (d, *J* = 6.6 Hz, 2H), 7.60 – 7.47 (m, 2H). **$^{13}$C NMR** (126 MHz, $CDCl_3$, 323K) δ 139.7, 137.6, 135.6, 133.9, 133.4, 133.1, 133.0, 132.4, 130.7, 130.6, 128.9, 128.7, 127.8, 127.5, 127.3, 126.6, 126.3, 126.1, 125.9, 125.2, 123.7, 122.0, 121.5, 120.1, 120.0, 119.4. **HRMS** (LDI+) *m/z* calc. for $C_{26}H_{14}$ $[M]^+$: 326.1096. Found: 326.1088.

**General procedure for the alkynylation of carboxylic acids (B)**

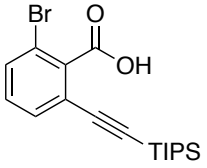



Benzoic acid **10a-at** (0.20 mmol), $K_2CO_3$ (13.8 mg, 0.10 mmol, 0.5 equiv), $[RuCl_2(p\text{-cymene})]_2$ (6.2 mg, 0.05 mmol, 5 mol%) and *tert*-amyl alcohol (1.5 mL) were placed in a 5 mL-vial. 1-Bromo-2-(triisopropylsylil)acetylene **2a** (62.7 mg, 0.24 mmol, 1.2 equiv) was then added and the reaction mixture was stirred at the appointed temperature for 14 h. After cooling to ambient temperature aqueous HCl (1% v/v, 1 mL) was added, the mixture was extracted with EtOAc (3x3 mL), and the combined organic layers dried over $MgSO_4$, filtered and

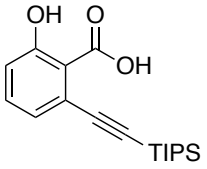
concentrated under reduced pressure. The residue was purified by preparative TLC with cHex/EtOAc/AcOH (90/9/1) to yield the corresponding products **11a-at**.




**2-Chloro-6-((triisopropylsilyl)ethynyl)benzoic acid (11a).** General procedure B at 90 ºC and obtained as a white solid in 69% yield. **M.p.** = 99-101 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.47 (dd, *J* = 8, 1.1 Hz, 1H), 7.39 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.32 (t, 8.0 Hz, 1H), 1.14 – 1.12 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.0, 135.2, 131.2, 130.8, 130.4, 129.5, 123.0, 102.2, 97.5, 18.6, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{18}H_{24}ClO_2Si$ $[M-H]^-$: 335.1240; found: 335.1232. The spectroscopic data were consistent with those previously reported.[31]



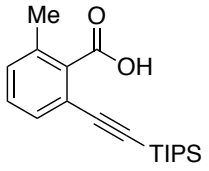

**2-Bromo-6-((triisopropylsilyl)ethynyl)benzoic acid (11b).** General procedure B at 70 ºC and obtained as a white solid in 72% yield. **M.p.** = 110-112 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.56 (dd, *J* = 8.0, 1.0 Hz, 1H), 7.51 (dd, *J* = 8.0, 1.0 Hz, 1H), 7.24 (t, *J* = 8.0 Hz, 1H), 1.15 – 1.10 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 172.0, 137.3, 132.6, 131.7, 130.5, 123.0, 118.7, 102.2, 97.5, 18.6, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{18}H_{24}BrO_2Si$ $[M-H]^-$: 379.0734; found: 379.0722.



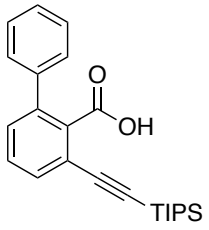

**2-Hydroxy-6-((triisopropylsilyl)ethynyl)benzoic acid (11c).** General procedure B at 90 ºC and obtained as a white solid in 65% yield. **M.p.** = 96-98 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.39 (t, *J* = 6.6 Hz, 1H), 7.14 (d, *J* = 7.2 Hz, 1H), 7.05 (d, *J* = 6.2 Hz, 1H), 1.22 – 1.08 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.4, 163.5, 134.8, 126.2, 122.1, 119.9, 112.0, 104.6, 102.6, 18.5, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{18}H_{25}O_3Si$ $[M-H]^-$: 317.1578; found: 317.1572.

*Note*: This reaction was also carried out starting from 10 mmol of **10c** (1.38 g) obtaining the product **11c** in 75% yield (2.39 g, 7.51 mmol).

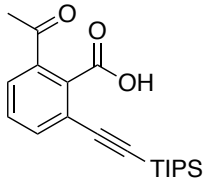
[31] Chen, C.; Liu, P.; Tang, J.; Deng, G.; Zeng, Xiaoming, Z. *J. Org. Chem.* **2016**, *81*, 3967–3974.



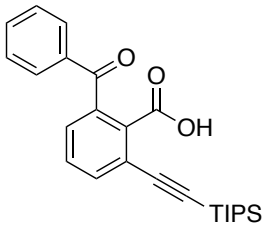

**2-Methyl-6-((triisopropylsilyl)ethynyl)benzoic acid (11d).** General procedure B at 70 ºC and obtained as a white solid in 67% yield. **M.p.** = 182-184 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.42 (d, *J* = 7.7 Hz, 1H), 7.29 (t, *J* = 7.7 Hz, 1H), 7.21 (d, *J* = 7.7 Hz, 1H), 2.45 (s, 3H), 1.16-1.13 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 174.0, 135.7, 135.0, 130.7, 130.4, 129.6, 121.5, 104.0, 95.4, 19.9, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{19}H_{27}O_2Si$ $[M-H]^-$: 315.1786; found: 315.1796. The spectroscopic data were consistent with those previously reported.[31]




**3-((Triisopropylsilyl)ethynyl)-[1,1'-biphenyl]-2-carboxylic acid (11e).** General procedure B at 90 ºC and obtained as yellow oil in 60% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 7.58 (dd, *J* = 7.6, 1.3 Hz, 1H), 7.49 – 7.31 (m, 7H), 1.18 – 1.11 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 172.9, 140.6, 139.8, 134.5, 132.1, 130.0, 129.7, 128.4, 128.3, 127.8, 121.9, 103.7, 95.9, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{24}H_{29}O_2Si$ $[M-H]^-$: 377.1942; found: 377.1941.

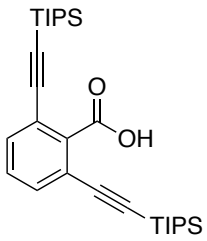



**2-Acetyl-6-((triisopropylsilyl)ethynyl)benzoic acid (11f).** General procedure B at 90 ºC and obtained as a colorless oil in 65% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 7.63 – 7.59 (m, 2H), 7.52 – 7.49 (m, 1H), 1.87 (s, 3H), 1.20 – 1.13 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.4, 150.5, 135.2, 134.0, 126.0, 121.9, 121.5, 104.2, 101.2, 100.5, 26.2, 18.6, 11.3. **HRMS** ($ESI^-$) *m/z* calc. for $C_{20}H_{27}O_3Si$ $[M-H]^-$: 343.1735; found: 343.1745.

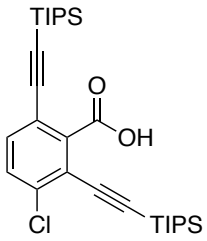



**2-Benzoyl-6-((triisopropylsilyl)ethynyl)benzoic acid (11g).** General procedure B at 90 ºC

and obtained as a white solid in 54% yield. **M.p.** = 143-146 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$, 233K) δ 7.84 – 7.68 (m, 2H), 7.66 – 7.35 (m, 6H), 1.26 – 1.04 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$, 233K)[32] δ 196.2, 172.2, 167.4, 150.4, 140.4, 138.4, 136.2, 136.1, 135.4, 134.6, 133.7, 132.6, 130.7, 130.1, 129.6, 128.9, 128.7, 128.3, 125.6, 125.0, 123.9, 122.8, 121.7, 104.6, 103.0, 101.0, 98.4, 18.8, 18.7, 11.2, 11.0. **HRMS** (ESI-) *m/z* calc. for $C_{25}H_{29}O_3Si$ $[M-H]^-$: 405.1891; found: 405.1889.

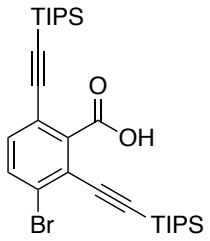



**2,6-Bis((triisopropylsilyl)ethynyl)benzoic acid (11h).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ (27.6 mg, 0.20 mmol) and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). (125.4 mg, 0.48 mmol). Obtained as a white solid in 61% yield. **M.p. =** 173-175 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 7.8 Hz, 2H), 7.35 (t, *J* = 7.8 Hz, 1H), 1.13 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.0, 137.0, 133.3, 129.8, 122.6, 103.4, 96.8, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{45}O_2Si_2$ $[M-H]^-$: 481.2964; found: 481.2962.

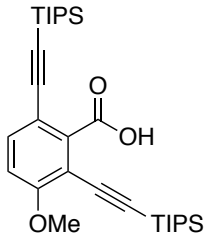



**3-Chloro-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11i).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 76% yield. **M.p.** = 174-176 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.6 Hz, 2H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.4, 138.9, 137.2, 133.2, 130.5, 121.8, 120.5, 103.6, 102.2, 99.3, 97.6, 18.6, 11.2 (2 peaks missing due to overlapping). **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{44}ClO_2Si_2$ $[M-H]^-$: 515.2574; found: 515.2574.

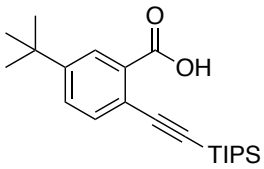
[32] At this temperature two different conformations were observed.



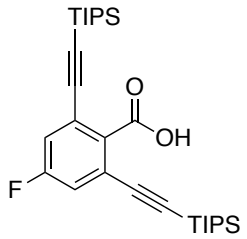

**3-Bromo-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11j).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 62% yield. **M.p. =** 166-168 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.60 (d, *J* = 8.4 Hz, 1H), 7.30 (d, *J* = 8.4 Hz, 1H), 1.14 – 1.12 (m, 21H), 1.11 – 1.08 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.5, 139.1, 133.8, 133.3, 126.9, 123.9, 121.2, 103.1, 102.4, 101.2, 97.9, 18.8, 18.7, 11.4, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{44}BrO_2Si_2$ $[M-H]^-$: 559.2069; found: 559.2043.



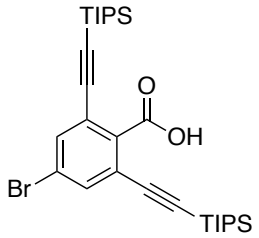

**3-Methoxy-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11k).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 67% yield. **M.p.** = 175-177 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.7 Hz, 1H), 6.88 (d, *J* = 8.7 Hz, 1H), 3.89 (s, 3H), 1.12 (s, 21H), 1.11 (s, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 170.8, 160.8, 138.8, 134.4, 114.1, 112.1, 111.9, 103.3, 101.6, 98.7, 94.0, 56.2, 18.6, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{47}O_3Si_2$ $[M-H]^-$: 511.3069; found: 511.3066.



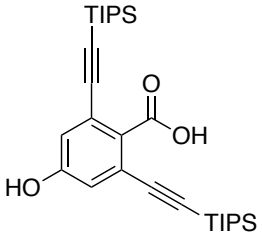

**5-(*tert*-Butyl)-2-((triisopropylsilyl)ethynyl)benzoic acid (11l).** General procedure B at 90 ºC and obtained as a colorless oil in 49% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 1.9 Hz, 1H), 7.58 (d, *J* = 8.1 Hz, 1H), 7.54 (dd, *J* = 8.2, 2.0 Hz, 1H), 1.36 (s, 9H), 1.19 – 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 169.6, 152.0, 134.5, 131.4, 129.3, 128.1, 120.3, 104.9, 98.03, 34.9, 31.0, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{22}H_{33}O_2Si$ $[M-H]^-$: 357.2255; found: 357.2250.



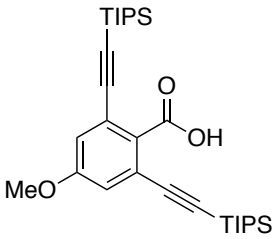

**4-Fluoro-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11m).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid 62% yield. **M.p.** = 181-183 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.6 Hz, 2H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.1, 162.44 (d, *J* = 252.0 Hz), 133.2, 125.1 (d, *J* = 10.6 Hz), 120.5 (d, *J* = 23.1 Hz), 102.4 (d, *J* = 2.6 Hz), 98.5, 18.7, 11.4. **$^{19}$F{$^1$H} NMR** (376 MHz, $CDCl_3$) δ -110.4. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{44}FO_2Si_2$ $[M-H]^-$: 499.2869; found: 499.2870.



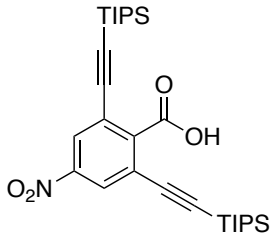

**4-Bromo-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11n).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 63% yield. **M.p.** = 189-192 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.62 (s, 2H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.6, 136.0, 135.6, 124.0, 123.6, 101.9, 98.7, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{44}BrO_2Si_2$ $[M-H]^-$: 559.2069; found: 559.2060.



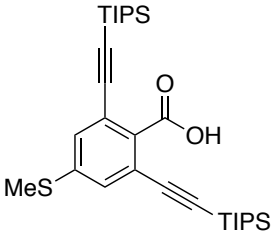

**4-Hydroxy-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11o).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 53% yield. **M.p.** = 166-169 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 6.98 (s, 2H), 1.09 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.0, 156.5, 129.7, 124.5, 120.5, 103.3, 97.0, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{45}O_3Si_2$ $[M-H]^-$: 497.2913; found: 497.2905.



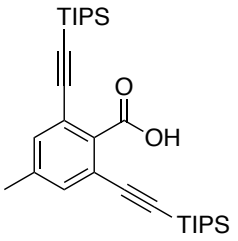

**4-Methoxy-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11p).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 51% yield. **M.p.** = 161-163 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.02 (s, 2H), 3.85 (s, 3H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 170.9, 159.9, 129.6, 124.3, 118.9, 103.4, 96.5, 55.6, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{47}O_3Si_2$ $[M-H]^-$: 511.3069; found: 511.3068.



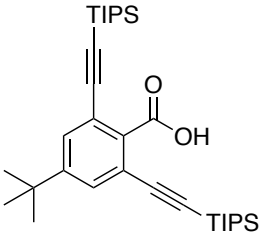

**4-Nitro-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11q).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a**. Obtained as a white solid in 61% yield. **M.p.** = 201-204 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.27 (s, 2H), 1.15 – 1.10 (m, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.4, 148.0, 141.7, 127.1, 124.1, 100.9, 100.5, 18.5, 11.1. **HRMS** (ESI-) *m/z* calc. for $C_{29}H_{44}NO_4Si_2$ $[M-H]^-$: 526.2814; found: 526.2802.



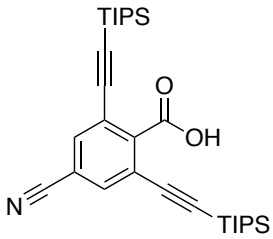

**4-Methylthio-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11r).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 52% yield. **M.p.** = 206-208 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.31 (s, 2H), 2.51 (s, 3H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.1, 142.0, 133.1, 130.1, 123.3, 103.2, 97.2, 18.7, 15.8, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{47}O_2SSi_2$ $[M-H]^-$: 527.2841; found: 527.2834.



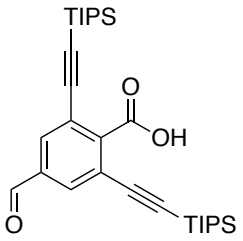

**4-Methyl-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11s).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 57% yield. **M.p.** = 202-205 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.32 (s, 2H), 2.34 (s, 3H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.6, 139.9, 134.4, 133.7, 122.2, 103.4, 96.1, 20.8, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{47}O_2Si_2$ $[M-H]^-$: 495.3120; found: 495.3124.



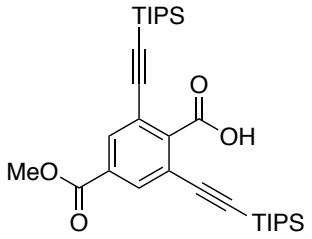

**4-(*tert*-Butyl)-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11t).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 46% yield. **M.p.** = 201-203 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.50 (s, 2H), 1.34 (s, 9H), 1.12 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.2, 153.0, 134.3, 130.4, 122.2, 103.9, 95.7, 34.7, 30.9, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{33}H_{53}O_2Si_2$ $[M-H]^-$: 537.3590; found: 537.3603.



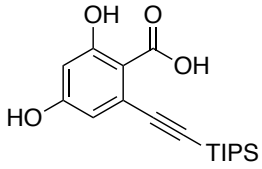

**4-Cyano-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11u).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 53% yield. **M.p.** = 165-167 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 6.77 (s, 2H), 1.09 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 170.6, 170.6, 147.6, 126.8, 124.4, 119.4, 104.1, 95.9, 18.8, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{44}NO_2Si_2$ $[M-H]^-$: 506.2916; found 506.2911.




**4-Formyl-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11v).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a yellow solid in 37% yield. **M.p.** = 144-147 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 10.01 (s, 1H), 7.96 (s, 2H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 190.5, 169.4, 141.8, 136.8, 133.4, 123.5, 101.9, 99.0, 18.7, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{30}H_{45}O_3Si_2$ $[M-H]^-$: 509.2913; found: 509.2918.

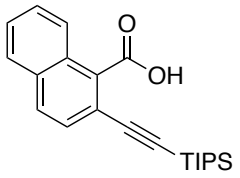



**4-(Methoxycarbonyl)-2,6-bis((triisopropylsilyl)ethynyl)benzoic acid (11x).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 33% yield. **M.p.** = 206-208 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.10 (s, 2H), 3.96 (s, 3H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 169.7, 165.4, 140.8, 133.7, 131.6, 122.8, 102.3, 98.0, 52.8, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{31}H_{47}O_4Si_2$ $[M-H]^-$: 539.3018; found: 539.3019.

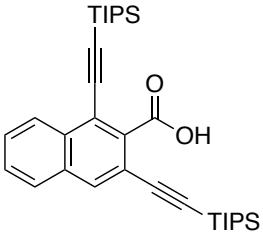



**2,4-Dihydroxy-6-((triisopropylsilyl)ethynyl)benzoic acid (11y).** General procedure B at 90 ºC and obtained as a white solid in 55% yield. **M.p.** = 199-201 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 6.67 (d, *J* = 2.6 Hz, 1H), 6.51 (d, *J* = 2.6 Hz, 1H), 5.49 (s, 1H), 1.64 (s, 1H), 1.25 – 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 170.6, 165.7, 160.7, 123.4, 114.5, 105.9, 105.5, 104.2, 103.1, 18.5, 11.1. **HRMS** ($ESI^-$) *m/z* calc. for $C_{18}H_{25}O_4Si$ $[M-H]^-$: 333.1528; found: 333.1528.

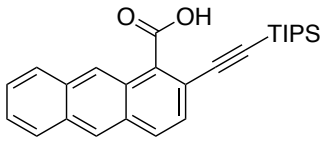
*Note*: This reaction was also carried out starting from 6.5 mmol of **10y** (1.00 g) obtaining the product **11y** in 55% yield (1.20 g, 3.58 mmol).



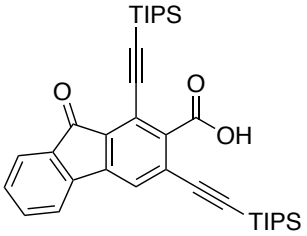

**2-((Triisopropylsilyl)ethynyl)-1-naphthoic acid (11z).** General procedure B at 90 ºC and obtained as a yellow solid in 54% yield. **M.p.** = 146-148 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.10 (dd, *J* = 8.7, 0.9 Hz, 1H), 7.89 – 7.84 (m, 2H), 7.63 – 7.50 (m, 3H), 1.24 – 1.16 (m, 21H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 173.2, 133.1, 132.7, 130.2, 129.4, 129.0, 128.2, 127.8, 127.1, 125.2, 119.9, 104.4, 97.4, 18.7, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{22}H_{27}O_2Si$ $[M-H]^-$: 351.1786; found: 351.1785.




**1,3-Bis((triisopropylsilyl)ethynyl)-2-naphthoic acid (11aa).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a yellow solid in 49% yield. **M.p.** = 199-202 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.48 – 8.44 (m, 1H), 8.05 (s, 1H), 7.83 (ddd, *J* = 8.5, 1.3, 0.6 Hz, 1H), 7.65 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.60 (ddd, *J* = 8.1, 6.9, 1.4 Hz, 1H), 1.23 – 1.18 (m, 21H), 1.18 – 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 169.3, 135.8, 133.4, 132.8, 132.4, 128.4, 128.1, 127.9, 127.0, 119.9, 117.9, 103.5, 102.6, 100.9, 95.4, 18.7, 18.7, 11.4, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{33}H_{47}O_2Si_2$ $[M-H]^-$: 531.3120; found: 531.3123.

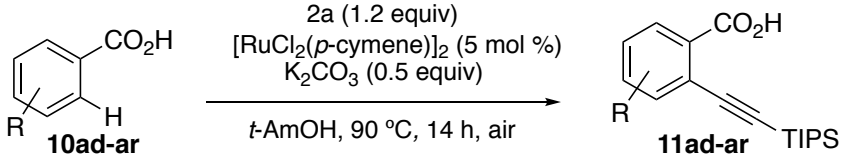



**2-((Triisopropylsilyl)ethynyl)anthracene-1-carboxylic acid (11ab).** General procedure B at 90 ºC and obtained as a yellow solid in 48% yield. **M.p.** = 192-194 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.76 (s, 1H), 8.43 (s, 1H), 8.05-7.99 (m, 3H), 7.55 – 7.50 (m, 3H), 1.24-1.19 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 173.4, 133.0, 132.6, 132.1, 130.8, 130.3, 128.7, 128.0, 127.9, 127.2, 126.9, 126.5, 126.4, 124.5, 120.0, 104.9, 98.6, 18.8, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{26}H_{29}O_2Si$ $[M-H]^-$: 401.1942; found: 401.1945.

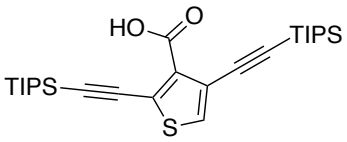



**9-Oxo-1,3-bis((triisopropylsilyl)ethynyl)-9*H*-fluorene-2-carboxylic acid (11ac).** General procedure B at 90 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a yellow solid in 71% yield. **M.p.** = 234-236 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 7.75 (d, *J* = 7.4 Hz, 1H), 7.64 – 7.57 (m, 2H), 7.54 (tt, *J* = 7.4, 1.2 Hz, 1H), 7.38 (tt, *J* = 7.3, 1.2 Hz, 1H), 1.32 – 1.07 (m, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 189.9, 169.8, 145.6, 141.3, 139.0, 134.6, 134.6, 133.0, 130.3, 127.7, 124.6, 123.8, 120.8, 119.5, 105.2, 103.1, 101.1, 98.7, 18.6, 11.3, 11.3 (one peak missing due to ovelapping). **HRMS** (ESI+) *m/z* calc. for $C_{36}H_{49}O_3Si_2$ $[M+H]^+$: 585.3215; found: 585.3218.

**General Procedure for the alkynylation of heteroaromatic acids (C)**

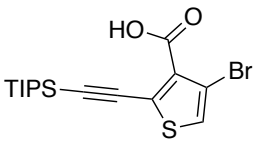



Heteroaromatic acid **10ad-ar** (0.20 mmol), $K_2CO_3$ (13.8 mg, 0.10 mmol, 0.5 equiv), $[RuCl_2(p\text{-cymene})]_2$ (6.2 mg, 0.05 mmol, 5 mol%) and *tert*-amyl alcohol (1.5 mL) were placed in a 5 mL-vial. 1-Bromo-2-(triisopropylsylil)acetylene **2a** (62.7 mg, 0.24 mmol, 1.2 equiv) was then added and the reaction mixture was stirred at the appointed temperature for 14 h. After cooling to ambient temperature, the solvent is removed under reduced pressure and the residue is purified by column chromatography with a gradient from 100 % cyclohexane to 80/20 ethyl acetate/methanol to yield products **11ad-ar**.

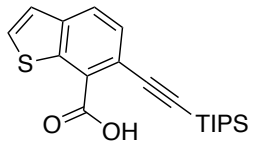



**2,4-Bis((triisopropylsilyl)ethynyl)thiophene-3-carboxylic acid (11ad).** General procedure (C) at 95 ºC starting from thiophene-3-carboxylic acid **10ad** (25.6 mg, 0.20 mmol) using 1.0 equiv of $K_2CO_3$ (27.6 mg, 0.20 mmol) and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a** (125.4 mg, 0.48 mmol). Brown solid (85.1 mg, 0.17 mmol, yield = 87%).

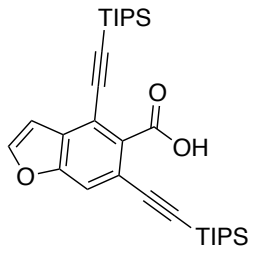
**M.p.** = 149-151 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.36 (s, 1H), 1.14 – 1.11 (m, 42H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 164.9, 134.6, 130.6, 129.7, 123.0, 104.2, 99.3, 96.8, 94.8, 18.6, 18.6, 11.3, 11.2. **HRMS** (ESI-) *m/z* calc. for $C_{27}H_{43}O_2SSi_2$ $[M-H]^-$: 487.2528; found: 487.2520.



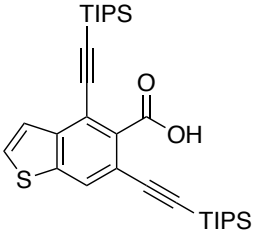

**4-Bromo-2-((triisopropylsilyl)ethynyl)thiophene-3-carboxylic acid (11ae).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$. Obtained as a black oil in 71% yield. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.19 (s, 1H), 1.14 – 1.11 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.8, 132.6, 131.2, 124.8, 110.5, 105.3, 96.6, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{16}H_{23}BrNaO_2SSi$ $[M+Na]^+$: 409.0264; found: 409.0266.



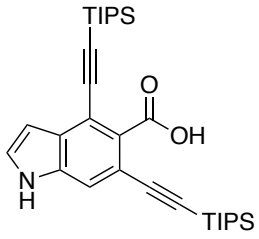

**6-((Triisopropylsilyl)ethynyl)benzo[*b*]thiophene-7-carboxylic acid (11af).** General procedure C at 95 ºC and obtained as a white solid in 43% yield. **M.p.** = 189-191 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.1 Hz, 1H), 7.70 (d, *J* = 5.6 Hz, 1H), 7.65 (d, *J* = 8.2 Hz, 1H), 7.40 (d, *J* = 5.6 Hz, 1H), 1.31 – 1.16 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 167.9, 141.8, 140.9, 132.4, 130.4, 127.5, 125.0, 123.1, 119.7, 105.2, 102.0, 18.7, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{20}H_{25}O_2SSi$ $[M-H]^-$: 357.1350; found: 357.1353.



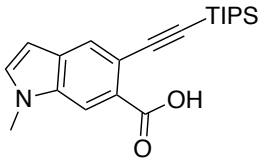

**4,6-Bis((triisopropylsilyl)ethynyl)benzofuran-5-carboxylic acid (11ag).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene (**2a**). Obtained as a white solid in 52% yield. **M.p.** = 169-171 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 7.75 (d, *J* = 2.2 Hz, 1H), 7.68 (d, *J* = 1.0 Hz, 1H), 6.96 (dd, *J* = 2.2, 1.0 Hz, 1H), 1.19 – 1.11 (m, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 171.3, 154.2, 147.6, 132.3, 130.8, 118.8, 116.6, 116.0, 107.4, 103.8, 100.9, 100.4, 95.7, 18.7, 18.6, 11.3, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{31}H_{45}O_3Si_2$ $[M-H]^-$: 521.2913; found: 521.2918.



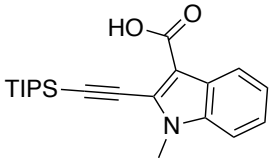
**4,6-Bis((triisopropylsilyl)ethynyl)benzo[*b*]thiophene-5-carboxylic acid (11ah).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a.** Obtained as a black liquid in 56% yield. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 0.7 Hz, 1H), 7.65 (dd, *J* = 5.5, 0.8 Hz, 1H), 7.63 (d, *J* = 5.5 Hz, 1H), 1.20 – 1.16 (m, 21H), 1.16 – 1.13 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 170.6, 141.0, 140.5, 133.6, 129.6, 127.3, 124.5, 117.7, 117.4, 103.6, 101.4, 100.8, 95.8, 18.7, 18.6, 11.3, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{31}H_{45}O_2SSi_2$ [M-H]$^-$: 537.2684; found: 537.2664.




**4,6-Bis((triisopropylsilyl)ethynyl)-1*H*-indole-5-carboxylic acid (11ai).** General procedure C at 95 ºC using 1.5 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a.** Obtained as a black liquid in 44% yield. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.43 (s, 1H), 7.60 (d, *J* = 1.0 Hz, 1H), 7.36 (dd, *J* = 3.4, 2.5 Hz, 1H), 6.79 (ddd, *J* = 3.2, 2.1, 1.0 Hz, 1H), 1.19 – 1.17 (m, 21H), 1.16 – 1.14 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 170.5, 135.2, 130.2, 129.5, 127.3, 116.6, 115.6, 115.0, 104.9, 104.1, 102.0, 99.2, 93.6, 18.7, 18.7, 18.7, 11.4, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{31}H_{46}NO_2Si_2$ [M-H]$^-$: 520.3073; found: 520.3047.

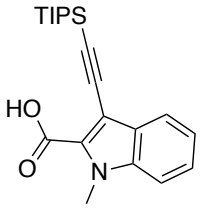



**1-Methyl-5-((triisopropylsilyl)ethynyl)-1*H*-indole-6-carboxylic acid (11aj).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a**. Obtained as a yellow solid in 84% yield. **M.p.** = 199-201 ºC. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.35 (t, *J* = 0.7 Hz, 1H), 7.92 (d, *J* = 0.5 Hz, 1H), 7.29 (d, *J* = 3.1 Hz, 1H), 6.55 (dd, *J* = 3.1, 0.9 Hz, 1H), 3.90 (s, 3H), 1.22 – 1.18 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 167.5, 136.1, 133.7, 131.4, 127.5, 123.7, 114.4, 112.0, 106.4, 101.6, 97.6, 33.2, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{28}NO_2Si$ [M-H]$^-$: 354.1895; found: 354.1896.

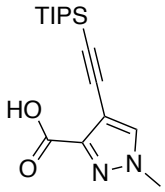



**1-Methyl-2-((triisopropylsilyl)ethynyl)-1*H*-indole-3-carboxylic acid (11ak).** General procedure C at 95 ºC and obtained as a white solid in 52% yield. **M.p.** = 194-196 ºC. **$^1$H NMR**

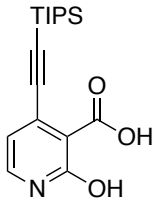
(400 MHz, $CDCl_3$) δ 8.30 – 8.25 (m, 1H), 7.41 – 7.31 (m, 3H), 3.92 (s, 3H), 1.31 – 1.22 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 169.4, 136.8, 127.8, 126.2, 124.2, 122.6, 122.4, 110.0, 109.6, 105.7, 96.1, 31.0, 18.7, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{28}NO_2Si$ $[M-H]^-$: 354.1895; found: 354.1888. The spectroscopic data were consistent with those previously reported.[31]



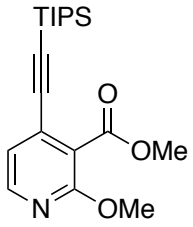

**1-Methyl-3-((triisopropylsilyl)ethynyl)-1*H*-indole-2-carboxylic acid (11al).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$ and obtained as a white solid in 43% yield. **M.p.** = 209-211 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.82 (dt, *J* = 8.1, 1.0 Hz, 1H), 7.49 – 7.41 (m, 2H), 7.29 (ddd, *J* = 8.0, 6.1, 1.8 Hz, 1H), 4.13 (s, 3H), 1.28 – 1.20 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 163.5, 138.8, 129.0, 127.9, 126.6, 121.8, 121.8, 110.6, 105.4, 101.2, 99.0, 32.5, 18.7, 11.4. **HRMS** (ESI-) *m/z* calc. for $C_{21}H_{28}NO_2Si$ $[M-H]^-$: 354.1895; found: 354.1883.



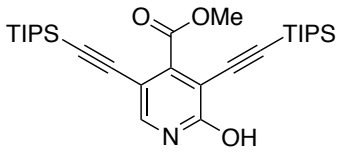

**1-Methyl-4-((triisopropylsilyl)ethynyl)-1*H*-pyrazole-3-carboxylic acid (11am).** General procedure C at 95 ºC using 1.5 equiv of $K_2CO_3$ and obtained as a brown solid in 92% yield. **M.p.** = 159-161 ºC. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.65 (s, 1H), 4.19 (s, 3H), 1.19 – 1.10 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 162.5, 141.7, 133.3, 109.1, 97.9, 96.6, 40.4, 18.6, 11.3. **HRMS** (ESI-) *m/z* calc. for $C_{16}H_{25}N_2O_2Si_2$ $[M-H]^-$: 305.1691; found: 305.1686.



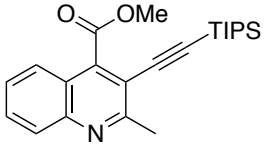

**2-Hydroxy-4-((triisopropylsilyl)ethynyl)nicotinic acid (11an).** General procedure C at 120 ºC using 0.5 equiv of $KHCO_3$ (10.0 mg, 0.1 mmol) instead of $K_2CO_3$. Obtained as a yellow solid in 56% yield. **M.p.** = 259-261 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.48 (d, *J* = 5.1 Hz, 1H), 7.89 (d, *J* = 5.1 Hz, 1H), 7.60 (s, 1H), 1.47 (h, *J* = 7.5 Hz, 3H), 1.19 (d, *J* = 7.4 Hz, 18H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 169.9, 165.8, 164.9, 143.6, 129.7, 119.9, 119.3, 117.8, 18.5, 10.9. **HRMS** (ESI+) *m/z* calc. for $C_{17}H_{24}NO_3Si$ $[M+H]^+$: 318.1531; found: 318.1522.




**Methyl 2-methoxy-4-((triisopropylsilyl)ethynyl)nicotinate (11ao).** General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$ (27.6 mg, 0.20 mmol). After 14 h at 95 ºC the reaction was cooled down to room temperature and the solvent evaporated under reduced pressure. MeI (5 equiv), $K_2CO_3$ (2.0 equiv), and MeCN (3 mL) were subsequently added and the resulting mixture stirred at 60 ºC for 4 h. The mixture is then concentrated under reduced pressure and the residue is purified by column chromatography. Obtained as a white solid in 52% yield. **M.p.** = 44-46 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.13 (d, *J* = 5.3 Hz, 1H), 6.95 (d, *J* = 5.3 Hz, 1H), 3.96 (s, 3H), 3.90 (s, 3H), 1.15 – 1.09 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 166.0, 160.5, 147.6, 131.4, 119.4, 119.2, 101.3, 100.3, 54.1, 52.6, 18.5, 11.1. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{30}NO_3Si$ $[M+H]^+$: 348.1989; found: 348.1990.

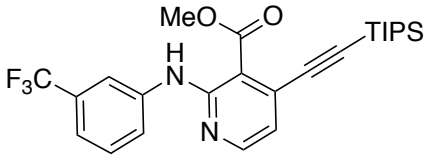



**Methyl 2-hydroxy-3,5-bis((triisopropylsilyl)ethynyl)isonicotinate (11ap).** General procedure C at 95 ºC using 1.5 equiv of $K_2CO_3$ and 2.4 equiv of 1-bromo-2-(triisopropylsylil)acetylene **2a.** After 14 h at 95 ºC the reaction was cooled down to room temperature and the solvent evaporated under reduced pressure. MeI (5.0 equiv), $K_2CO_3$ (2.0 equiv), and MeCN (3 mL) were subsequently added and the resulting mixture stirred at 60 ºC for 4 h. The mixture is then concentrated under reduced pressure and the residue is purified by column chromatography. Obtained as a brown solid in 63% yield. **M.p.** = 49-51 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.54 (s, 1H), 7.37 (s, 1H), 4.02 (s, 3H), 1.51 – 1.37 (m, 3H), 1.18 – 1.15 (m, 39H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 165.4, 164.8, 164.2, 149.8, 132.1, 119.0, 117.7, 114.6, 102.5, 97.7, 52.5, 18.7, 18.5, 11.3, 10.9. **HRMS** (ESI+) *m/z* calc. for $C_{29}H_{47}NNaO_3Si_2$ $[M+Na]^+$: 536.2987; found: 536.2986.



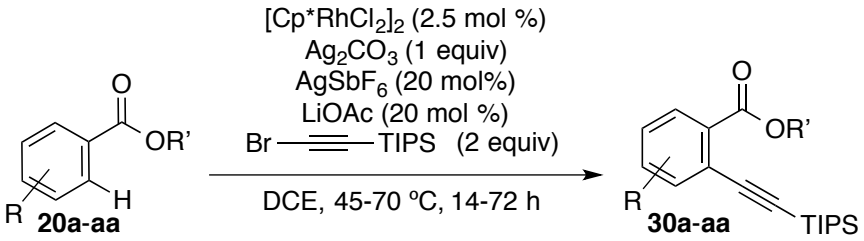

**Methyl 2-methyl-3-((triisopropylsilyl)ethynyl)quinoline-4-carboxylate (11aq)**. General procedure C at 95 ºC using 1.0 equiv of $K_2CO_3$. After 14 h at 95 ºC the reaction was cooled down to room temperature and the solvent evaporated under reduced pressure. MeI (5.0 equiv),

$K_2CO_3$ (2.0 equiv), and MeCN (3 mL) were subsequently added and the resulting mixture stirred at 60 ºC for 4 h. The mixture is then concentrated under reduced pressure and the residue is purified by column chromatography. Obtained as a brown solid 46% yield. **M.p.** = 79-81 ºC. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.06 – 8.00 (m, 1H), 7.76 – 7.67 (m, 2H), 7.54 (td, *J* = 7.4, 1.3 Hz, 1H), 4.06 (s, 3H), 2.91 (s, 3H), 1.24 – 1.11 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 167.1, 159.7, 146.2, 142.1, 130.4, 129.0, 127.2, 124.5, 122.0, 114.5, 102.6, 101.3, 52.9, 24.9, 18.6, 11.3. **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{32}NO_2Si$ $[M+H]^+$: 382.2197; found: 382.2190.



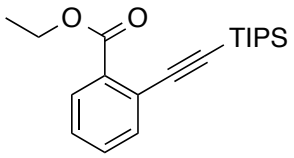

**methyl 2-((3-(trifluoromethyl)phenyl)amino)-4-((triisopropylsilyl)ethynyl)-nicotinate (11ar).** General procedure C at 95 ºC starting from 2-((3-(trifluoromethyl)phenyl)amino)-nicotinic acid **10ar** (0.30 mmol). After 14 h at 95 ºC the reaction was cooled down to room temperature and the solvent evaporated under reduced pressure. MeI (5.0 equiv), $K_2CO_3$ (2.0 equiv), and MeCN (3 mL) were subsequently added and the resulting mixture stirred at 60 ºC for 4 h. The mixture is then concentrated under reduced pressure and the residue is purified by column chromatography. Obtained as a brown liquid in 46% yield. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 10.21 (s, 1H), 8.27 (d, *J* = 5.0 Hz, 1H), 8.02 (t, *J* = 2.0 Hz, 1H), 7.88 – 7.76 (m, 1H), 7.50 – 7.39 (m, 1H), 7.33 – 7.23 (m, 1H), 6.95 (d, *J* = 5.0 Hz, 1H), 3.97 (s, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 168.2, 155.6, 150.8, 140.2, 134.3, 131.1 (q, *J* = 32 Hz), 129.1, 123.7, 124.1 (q, *J* = 271 Hz), 120.4, 119.1 (q, *J* = 4 Hz), 117.3 (q, *J* = 4 Hz), 108.4, 104.4, 101.9, 52.2, 18.6, 11.3. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -62.74. **HRMS** (ESI+) *m/z* calc. for $C_{25}H_{32}F_3N_2O_2Si$ $[M+H]^+$: 477.2180. Found: 477.2181.

**General Procedure for the alkynylation of alkyl benzoates and benzyl ethers (D)**

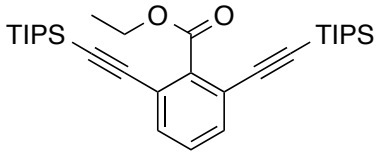



$(RhCp^*Cl_2)_2$ (3 mol%) $AgSbF_6$ (20 mol%), LiOAc (20 mol%), Ag2CO3 (1 equiv) were weighted in a 10 mL tube inside a glovebox and dissolved in technical DCE (2 mL). Benzoic esters (0.20 mmol) or benzyl ethers (0.20 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) were then added with a Hamilton syringe and the reaction mixture was stirred for

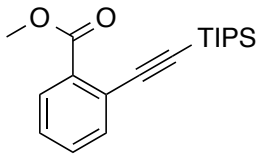
corresponding time (16-72h) and temperature (45-100 ºC) according to the conversion estimated by TLC (100% Toluene). After cooling at ambient temperature, bromomesitylene (1 eq) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The residue was purified by silica gel chromatography column with Toluene 100% as eluent to yield the corresponding mono alkynylated products and depending on the selectivity of the reaction some dialkynylated products which most of the time came along in the first fractions with some residual 1-bromo-2-(triisopropylsilyl)acetylene. In this case, when dialkynylated compound was present, it was then re-purified from residual with a second silica gel chromatography column using Cyclohexane 100% to Cyclohexane/EtOAc 90:10 as eluent.



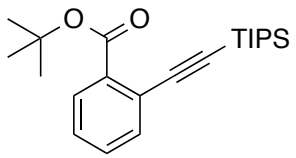

**Ethyl 2-((triisopropylsilyl)ethynyl)benzoate** (**3a**). General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 56% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.85 (dd, J = 7.7, 1.5 Hz, 1H), 7.59 (dd, J = 7.6, 1.5 Hz, 1H), 7.42 (td, J = 7.5, 1.6 Hz, 1H), 7.34 (td, J = 7.6, 1.5 Hz, 1H), 4.39 (q, J = 7.1 Hz, 2H), 1.38 (t, J = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 166.7, 135.1, 133.2, 131.3, 130.0, 128.1, 123.5, 105.3, 96.5, 61.4, 18.8 (6C), 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{31}O_2Si^+$ $[M+H]^+$: 331.2088; found: 331.2080.



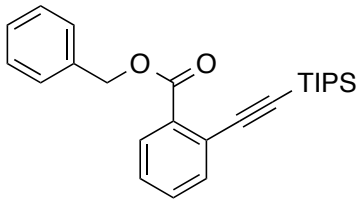

**Ethyl 2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30a"**). Compound **30a"** was obtained as a white crystalline solid in 14% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.45 (d, *J* = 7.8 Hz, 2H), 7.27 (dd, *J* = 7.6, 7.5 Hz, 1H), 4.36 (q, *J* = 7.2 Hz, 2H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.5, 139.8, 132.7 (2C), 128.9, 121.2 (2C), 103.3 (2C), 95.5 (2C), 62.0, 18.8 (12C), 14.2, 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{51}O_2Si_2^+$ $[M+H]^+$: 511.3422; found: 511.3433. **Mp** 58-60 ºC.



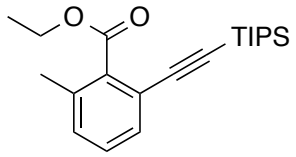
**Methyl 2-((triisopropylsilyl)ethynyl)benzoate** (**30b**). General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 45% yield. **$^1$H NMR** (500 MHz, Chloroform-d) δ 7.88 (d, J = 8.0 Hz, 1H), 7.59 (d, J = 7.7 Hz, 1H), 7.46 – 7.40 (td, J = 7.6, 1.3 Hz, 1H), 7.35 (td, J = 7.6, 1.3 Hz, 1H), 3.91 (d, J = 1.0 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 167.3, 135.1, 132.8, 131.5, 130.3, 128.1, 123.5, 105.3, 96.4, 52.3, 18.8 (6C), 11.5 (3C). Data were in agreement with existing literature.




***Tert-butyl 2-((triisopropylsilyl)ethynyl)benzoate*** (**30c**). General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 53% yield. **$^1$H NMR** (500 MHz, Chloroform-d) δ 7.72 (dd, J = 7.7, 0.9 Hz, 1H), 7.56 (d, J = 7.6 Hz, 1H), 7.38 (td, J = 7.5, 0.9 Hz, 1H), 7.31 (t, J = 7.6 Hz, 1H), 1.60 (s, 9H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 165.9, 135.04, 135.01, 130.7, 129.5, 127.9, 123.1, 105.4, 96.1, 81.7, 28.3 (3C), 18.8 (6C), 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{34}NaO_2Si^+$ $[M+Na]^+$: 381.2220; found: 381.2220.

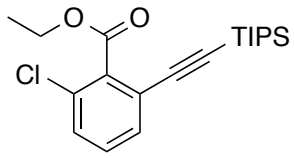



**Benzyl 2-((triisopropylsilyl)ethynyl)benzoate** (**30d**). General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 28% yield. **$^1$H NMR** (500 MHz, Chloroform-d) δ 7.89 (dd, J = 7.9, 1.4 Hz, 1H), 7.61 (dd, J = 7.9, 1.3 Hz, 1H), 7.48 – 7.40 (m, 3H), 7.40 – 7.28 (m, 4H), 5.38 (s, 2H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 166.2, 136.3, 135.2, 132.7, 131.5, 130.2, 128.6 (2C), 128.3 (2C), 128.2, 128.0, 123.9, 105.2, 96.9, 66.9, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{25}H_{32}NaO_2Si^+$ $[M+Na]^+$: 415.2064; found: 415.2059. **HRMS** (ESI+) *m/z* calc. for $C_{25}H_{32}NaO_2Si^+$ $[M+Na]^+$: 415.2064; found: 415.2059.

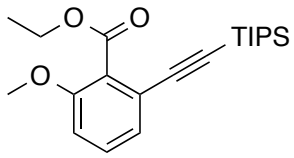



**Ethyl 2-methyl-6-((triisopropylsilyl)ethynyl)benzoate** (**30e**). General procedure D at 60 ºC for 48h and obtained as a colorless oil in 90% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.35 (ddd, *J* = 7.7, 1.2, 0.6 Hz, 1H), 7.22 (t, *J* = 7.7 Hz, 1H), 7.15 (ddd, *J* = 7.7, 1.3, 0.7 Hz, 1H), 4.38 (q, *J* = 7.1 Hz, 2H), 2.32 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H), 1.12 (s, 21H). **$^{13}$C NMR**

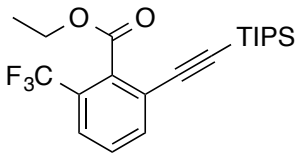
(126 MHz, Chloroform-*d*) δ 168.6, 136.8, 134.8, 130.4, 130.1, 128.9, 120.8, 104.2, 94.2, 61.3, 19.4, 18.6 (6C), 14.2, 11.3 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{33}O_2Si^+$ $[M+H]^+$: 345.2244; found: 345.2259.




**Ethyl 2-chloro-6-((triisopropylsilyl)ethynyl)benzoate** (**30f**). General procedure D at 60 ºC for 48 h and obtained as a colorless oil in 69% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.41 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.34 (dd, *J* = 8.2, 1.2 Hz, 1H), 7.26 (dd, *J* = 8.2, 7.7 Hz, 1H), 4.41 (q, *J* = 7.1 Hz, 2H), 1.39 (t, *J* = 7.2 Hz, 3H), 1.11 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.1, 136.8, 131.2, 130.8, 130.0, 129.4, 122.8, 102.7, 96.4, 62.1, 18.7 (6C), 14.2, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{30}ClO_2Si^+$ $[M+H]^+$: 365.1698; found: 365.1701.

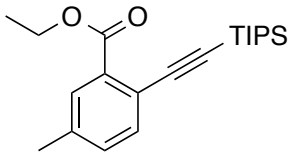



**Ethyl 2-methoxy-6-((triisopropylsilyl)ethynyl)benzoate** (**30g).** General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 90% yield. **$^1$H NMR** (500 MHz, Chloroform-d) δ 7.26 (t, J = 8.0 Hz, 1H), 7.10 (d, J = 7.7 Hz, 1H), 6.88 (d, J = 8.4 Hz, 1H), 4.37 (q, J = 7.1 Hz, 2H), 3.81 (s, 3H), 1.36 (t, J = 7.1 Hz, 3H), 1.11 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 167.0, 156.1, 130.2, 126.9, 125.2, 122.1, 111.6, 103.6, 94.8, 61.6, 56.2, 18.7 (6C), 14.2, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{33}O_3Si^+$ $[M+H]^+$: 361.2193; found: 361.2183.

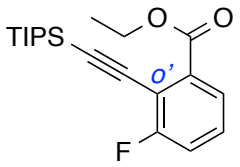



**Ethyl 2-(trifluoromethyl)-6-((triisopropylsilyl)ethynyl)benzoate** (**30h**). General procedure D at 60 ºC for 48 h and obtained as a slightly yellow oil in 69% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.69 (ddd, *J* = 7.8, 1.2, 0.6 Hz, 1H), 7.61 (ddd, *J* = 8.0, 1.2, 0.6 Hz, 1H), 7.46 (tq, *J* = 7.9, 0.9 Hz, 1H), 4.40 (q, *J* = 7.2 Hz, 2H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.12 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.4, 136.3, 135.3 (q, *J* = 2.2 Hz), 129.3, 127.7 (q, *J* = 32.5 Hz), 125.8 (q, *J* = 4.6 Hz), 124.4 (q, *J* = 273 Hz), 122.8, 102.4, 97.2, 62.4, 18.7 (6C),

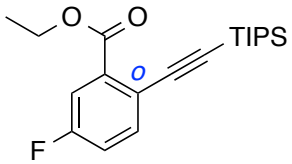
14.0, 11.4 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-*d*) δ -60.25. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{29}F_3NaO_2Si^+$ $[M+Na]^+$: 421.1781; found: 421.1782.




**Ethyl 5-methyl-2-((triisopropylsilyl)ethynyl)benzoate** (**30i**). General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 48% yield. **$^{1}$H NMR** (400 MHz, Chloroform-d) δ 7.65 (dt, J = 1.9, 0.8 Hz, 1H), 7.47 (d, J = 7.9 Hz, 1H), 7.22 (ddd, J = 7.9, 1.9, 0.8 Hz, 1H), 4.38 (q, J = 7.1 Hz, 2H), 2.37 (s, 3H), 1.38 (t, J = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-d) δ 166.7, 138.2, 134.9, 132.9, 131.9, 130.3, 120.4, 105.3, 95.1, 61.1, 21.3, 18.7 (6C), 14.3, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{33}O_2Si^+$ $[M+H]^+$: 345.2244; found: 345.2249.

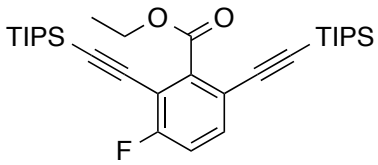



**Ethyl 3-fluoro-2-((triisopropylsilyl)ethynyl)benzoate** (**30j'**)**.** General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 53% yield. **$^{1}$H NMR** ($^{1}$H{$^{19}$F}, 400 MHz, Chloroform-*d*) δ 7.64 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.31 (dd, *J* = 8.1, 7.9 Hz, 1H), 7.21 (dd, *J* = 8.3, 1.3 Hz, 1H), 4.40 (q, *J* = 7.1 Hz, 2H), 1.39 (t, *J* = 7.1 Hz, 3H), 1.16 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-d) δ 165.7 (d, J = 3.3 Hz), 164.4 (d, J = 252.2 Hz), 135.1, 128.9 (d, J = 8.5 Hz), 125.6 (d, J = 3.6 Hz), 118.5 (d, J = 22.1 Hz), 112.4 (d, J = 17.8 Hz), 103.5 (d, J = 4.9 Hz), 97.2, 61.6, 18.8 (6C), 14.4, 11.4 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-*d*) δ -107.23. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{30}FO_2Si^+$ $[M+H]^+$: 349.1994; found: 349.2003.

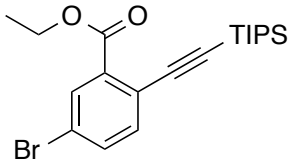



**Ethyl 5-fluoro-2-((triisopropylsilyl)ethynyl)benzoate** (**30j**). Compound **30j** was obtained as a colorless oil in 12% yield. **$^{1}$H NMR** ($^{1}$H{$^{19}$F}, 400 MHz, Chloroform-*d*) δ 7.57 (d, *J* = 8.9 Hz, 1H), δ 7.55 (d, *J* = 2.7 Hz, 1H), 7.13 (dd, *J* = 8.6, 2.8 Hz, 1H), 4.39 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-d) δ 165.4, 161.8 (d, J = 250.7 Hz), 137.1, 135.1, 119.8, 118.8 (d, J = 21.9 Hz), 117.1 (d, J = 24.1 Hz), 104.2, 96.3,

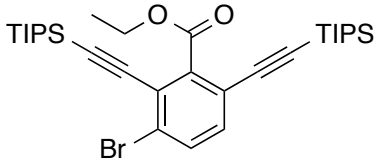
61.7, 18.8 (6C), 14.4, 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}376 MHz, Chloroform-*d*) δ -110.66. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}FNaO_2Si^+$ $[M+Na]^+$: 371.1813; found: 371.1819.



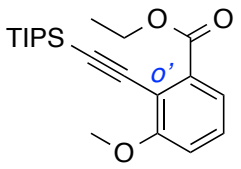

**Ethyl 3-fluoro-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30j"**). Compound **3j"** was obtained as a colorless oil in 7% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.41 (dd, *J* = 8.6, 5.0 Hz, 1H), 7.04 (t, *J* = 8.6 Hz, 1H), 4.36 (q, *J* = 7.2 Hz, 2H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.12 (s, 21H), 1.10 (s, 21H). 13C NMR (126 MHz, Chloroform-d) δ 166.36 (d, J = 3.1 Hz), 162.72 (d, J = 256.9 Hz), 141.69, 134.26 (d, J = 8.3 Hz), 117.24 (d, J = 4.2 Hz), 116.45 (d, J = 22.2 Hz), 110.56 (d, J = 19.1 Hz), 102.28, 101.96 (d, J = 3.7 Hz), 96.0, 95.1, 62.2, 18.74 (6C), 18.70 (6C), 14.1, 11.4 (3C), 11.3 (3C). **$^{19}$F NMR** (376 MHz, Chloroform-*d*) δ -106.42 **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{49}FNaO_2Si_2^+$ $[M+Na]^+$: 551.3147; found: 551.3154. **Mp** 61-66 ºC.



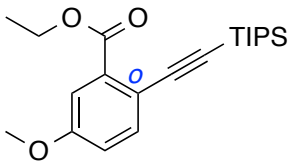

**Ethyl 5-bromo-2-((triisopropylsilyl)ethynyl)benzoate** (**30k**). General procedure D at 45 ºC for 72 h, and obtained as a colorless oil in 61% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.99 (d, *J* = 2.1 Hz, 1H), 7.54 (dd, *J* = 8.3, 2.1 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 4.38 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 165.1, 136.2, 134.5, 134.2, 132.8, 122.4, 121.9, 104.1, 98.0, 61.6, 18.7 (6C), 14.3, 11.3 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}BrNaO_2Si^+$ $[M+Na]^+$: 431.1012; found: 431.1012.



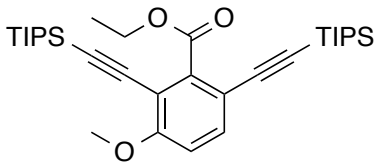

**Ethyl 3-bromo-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30k"**). Compound **30k"** was obtained as a colorless oil in 14% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.55 (d, *J* = 8.4 Hz, 1H), 7.26 (d, *J* = 8.3 Hz, 1H), 4.35 (q, *J* = 7.2 Hz, 2H), 1.36 (t, *J* = 7.2 Hz, 3H), 1.13 (s, 21H), 1.10 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.7, 141.5, 133.1, 133.0, 126.5, 123.1, 120.1, 102.4, 101.7, 101.3, 96.7, 62.3, 18.8 (6C), 18.7 (6C), 14.1, 11.40 (3C), 11.37 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{50}BrO_2Si_2^+$ $[M+H]^+$: 589.2527; found: 589.2519.



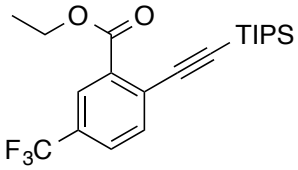

**Ethyl 3-methoxy-2-((triisopropylsilyl)ethynyl)benzoate** (**30l'**). General procedure D at 45 ºC for 20 h, and obtained as an inseparable mixture with its monoalkynylated regioisomer (**3l**) in a ratio 1.4:1 as a colorless oil in 55% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.36 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.28 (dd, *J* = 8.3, 7.8 Hz, 1H), 6.99 (dd, *J* = 8.3, 1.1 Hz, 1H), 4.37 (q, *J* = 7.1 Hz, 2H), 3.87 (s, 3H), 1.37 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.1, 162.0, 135.5, 128.8, 121.5, 113.7, 112.8, 101.7, 100.2, 61.4, 56.3, 18.8 (6C), 14.4, 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{32}NaO_3Si^+$ $[M+Na]^+$: 383.2013; found: 383.2011.



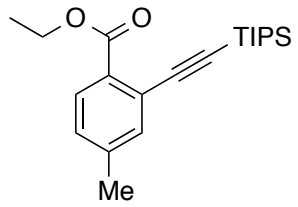

**Ethyl 5-methoxy-2-((triisopropylsilyl)ethynyl)benzoate** (**30l**). Compound **3l** was obtained in an inseparable mixture with its monoalkynylated regioisomer (**3l'**) in a ratio 1:1.4 as a colorless oil in 55% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.50 (d, *J* = 8.5 Hz, 1H), 7.35 (d, *J* = 2.7 Hz, 1H), 6.96 (dd, *J* = 8.6, 2.8 Hz, 1H), 4.39 (q, *J* = 7.1 Hz, 2H), 3.84 (s, 3H), 1.38 (t, *J* = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.6, 159.2, 136.5, 134.6, 117.9, 115.8, 114.6, 105.3, 94.2, 61.5, 55.7, 18.9 (6C), 14.5, 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{32}NaO_3Si^+$ $[M+Na]^+$: 383.2013; found: 383.2016.



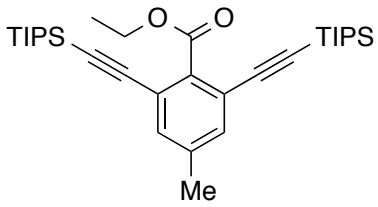

**Ethyl 3-methoxy-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30l"**). Compound **3l"** was obtained as a slightly beige solid in 14% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.40 (d, *J* = 8.6 Hz, 1H), 6.81 (d, *J* = 8.7 Hz, 1H), 4.34 (q, *J* = 7.2 Hz, 2H), 3.86 (s, 3H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.11 (s, 21H), 1.10 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.2, 160.8, 141.6, 134.1, 113.0, 111.4, 111.0, 103.3, 100.1, 99.1, 93.0, 62.0, 56.4, 18.77 (6C), 18.75 (6C), 14.1, 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{32}H_{52}NaO_3Si_2^+$ $[M+Na]^+$: 563.3347; found: 563.3359. **Mp**: 85-90 ºC.



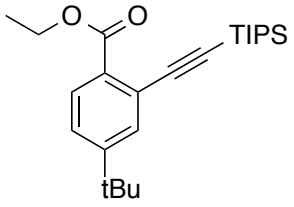

**Ethyl 5-(trifluoromethyl)-2-((triisopropylsilyl)ethynyl)benzoate** (**30m**)**.** General procedure, at 45 ºC for 72 h and obtained as a colorless oil in 78% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 8.12 (d, *J* = 1.6 Hz, 1H), 7.70 (d, *J* = 8.1 Hz, 1H), 7.65 (dd, *J* = 8.3, 1.6 Hz, 1H), 4.42 (q, *J* = 7.1 Hz, 2H), 1.40 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 165.3, 135.6, 133.7, 130.0 (q, *J* = 33.4 Hz), 127.7 (q, *J* = 3.6 Hz), 127.2, 127.1 (q, *J* = 3.6 Hz), 123.6 (q, *J* = 273 Hz), 103.91, 100.3, 61.8, 18.8 (6C), 14.4, 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -63.05. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{29}F_3NaO_2Si^+$ $[M+Na]^+$: 421.1781; found: 421.1782.



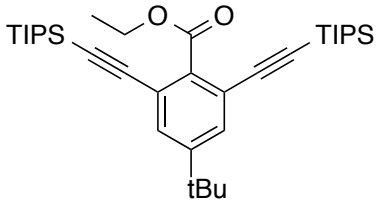

**Ethyl 4-methyl-2-((triisopropylsilyl)ethynyl)benzoate** (**30n**). General procedure, at 45 ºC for 24 h and obtained as a colorless oil 54% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.77 (d, *J* = 8.0 Hz, 1H), 7.39 (dt, *J* = 1.8, 0.7 Hz, 1H), 7.15 (ddd, *J* = 8.0, 1.8, 0.7 Hz, 1H), 4.37 (q, *J* = 7.1 Hz, 2H), 2.36 (brt, *J* = 0.7 Hz, 3H), 1.37 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 166.6, 141.8, 135.6, 130.28, 130.26, 129.0, 123.5, 105.6, 95.9, 61.1, 21.3, 18.8 (6C), 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{32}NaO_2Si^+$ $[M+Na]^+$: 367.2064; found: 367.2067.



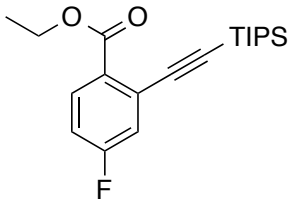

**Ethyl 4-methyl-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30n"**). Compound **3n"** was obtained as a colorless oil in 13% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.26 (brq, *J* = 0.7 Hz, 2H), 4.34 (q, *J* = 7.2 Hz, 2H), 2.30 (brt, *J* = 0.7 Hz, 3H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.7, 139.1, 137.2, 133.3 (2C), 121.1 (2C), 103.5 (2C), 94.8 (2C), 61.8, 21.0, 18.8 (12C), 14.2, 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{32}H_{53}O_2Si_2^+$ $[M+H]^+$: 525.3579; found: 525.3579.



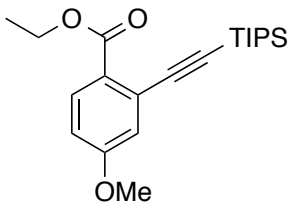

**Ethyl 4-(tert-butyl)-2-((triisopropylsilyl)ethynyl)benzoate** (**30o**)**.** General procedure D at 45 ºC for 16 h and obtained as a colorless oil in 57% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.80 (d, J = 8.3 Hz, 1H), 7.57 (d, J = 2.0 Hz, 1H), 7.37 (dd, J = 8.3, 2.0 Hz, 1H), 4.38 (q, J = 7.1 Hz, 2H), 1.37 (t, J = 7.1 Hz, 3H), 1.32 (s, 9H), 1.16 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.6, 154.8, 132.0, 130.4, 130.0, 125.5, 123.2, 105.9, 95.5, 61.1, 34.9, 31.1 (3C), 18.8 (6C), 14.5, 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{24}H_{38}NaO_2Si^+$ $[M+Na]^+$: 409.2533; found: 409.2536.



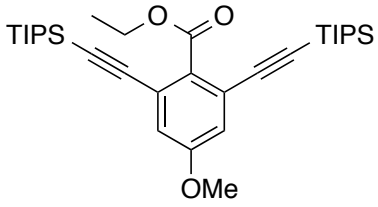

**Ethyl 4-(tert-butyl)-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30o"**). Compound 3**o"** was obtained as a colorless oil in 15% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.43 (s, 2H), 4.34 (q, *J* = 7.2 Hz, 2H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.30 (s, 9H), 1.12 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.7, 152.3, 137.3, 129.9 (2C), 120.9 (2C), 103.8 (2C), 94.5 (2C), 61.8, 34.8, 31.1 (3C), 18.8 (12C), 14.1, 11.5 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{35}H_{58}NaO_2Si_2^+$ $[M+Na]^+$: 589.3868; found: 589.3878.



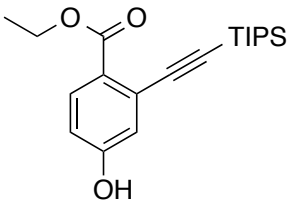

**Ethyl 4-fluoro-2-((triisopropylsilyl)ethynyl)benzoate** (**30p**)**.** General procedure D at 45 ºC for 20 h and obtained as a colorless oil in 48% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.90 (dd, *J* = 8.8, 5.8 Hz, 1H), 7.26 (dd, *J* = 9.1, 2.7 Hz, 1H), 7.04 (ddd, *J* = 8.8, 7.9, 2.7 Hz, 1H), 4.38 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 165.6, 164.1 (d, J = 253.3 Hz), 132.7 (d, *J* = 9.5 Hz), 129.2 (d, *J* = 3.2 Hz), 126.2 (d, *J* = 10.2 Hz), 121.7 (d, *J* = 23.0 Hz), 115.6 (d, *J* = 21.7 Hz), 104.1 (d, *J* = 2.5 Hz), 98.4, 61.4, 18.8 (6C), 14.5, 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -108.41. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}FNaO_2Si^+$ $[M+Na]^+$: 371.1813; found: 371.1816.



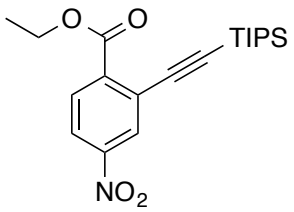

**Ethyl 4-methoxy-2-((triisopropylsilyl)ethynyl)benzoate** (**30q**)**.** General procedure D at 45 ºC for 24 h and obtained as a colorless oil in 50% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 8.8 Hz, 1H), 7.06 (d, *J* = 2.7 Hz, 1H), 6.86 (dd, *J* = 8.8, 2.7 Hz, 1H), 4.36 (q, *J* = 7.1 Hz, 2H), 3.84 (s, 3H), 1.37 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 166.1, 161.8, 132.4, 125.5, 125.3, 120.0, 114.1, 105.4, 96.5, 60.9, 55.6, 18.8 (6C), 14.6, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{32}NaO_3Si^+$ $[M+Na]^+$: 383.2013; found: 383.2016.



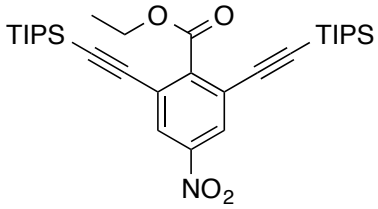

**Ethyl 4-methoxy-2,6-bis((triisopropylsilyl)ethynyl)benzoate** (**30q"**)**.** Compound **30q"** was obtained as a colorless oil in 16% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 6.96 (s, 2H), 4.32 (q, *J* = 7.2 Hz, 2H), 3.81 (s, 3H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.11 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.5, 159.4, 132.7, 122.7 (2C), 118.4 (2C), 103.4 (2C), 95.2 (2C), 61.8, 55.7, 18.7 (12C), 14.2, 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{32}H_{52}NaO_3Si_2^+$ $[M+Na]^+$: 563.3347; found: 563.3346.



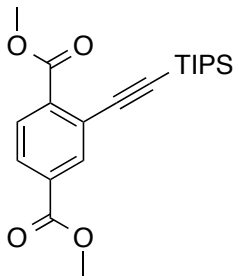

**Ethyl 4-hydroxy-2-((triisopropylsilyl)ethynyl)benzoate** (**30r**). General procedure D at 45 ºC for 48 h and obtained as a white solid in 23% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 8.7 Hz, 1H), 7.05 (d, *J* = 2.6 Hz, 1H), 6.81 (dd, *J* = 8.6, 2.6 Hz, 1H), 4.36 (q, *J* = 7.1 Hz, 2H), 1.37 (t, *J* = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 166.5, 158.5, 132.8, 125.8, 125.0, 121.8, 115.6, 105.2, 96.9, 61.2, 18.8 (6C), 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{30}NaO_3Si^+$ $[M+Na]^+$: 369.1856; found: 369.1859. **Mp**: 64-68 ºC.



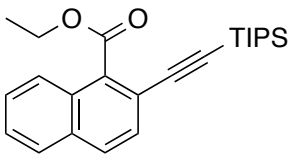

**Ethyl 4-nitro-2-((triisopropylsilyl)ethynyl)benzoate (30s).** General procedure D at 45 ºC for 20 h and obtained as an orange oil in 36% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 8.36 (d, *J* = 2.3 Hz, 1H), 8.15 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.97 (d, *J* = 8.6 Hz, 1H), 4.42 (q, *J* = 7.1 Hz, 2H), 1.40 (t, *J* = 7.1 Hz, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 165.1, 149.2, 138.6, 131.0, 129.4, 125.1, 122.5, 102.6, 100.6, 62.2, 18.8 (6C), 14.4, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}NNaO_4Si^+$ $[M+Na]^+$: 398.1758; found: 398.1761.



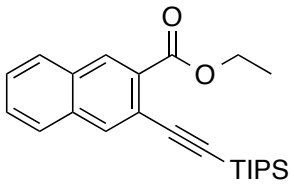

**Ethyl 4-nitro-2,6-bis((triisopropylsilyl)ethynyl)benzoate (30s").** Compound **30s"** was obtained as an orange oil in 13% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 8.22 (s, 2H), 4.38 (q, *J* = 7.2 Hz, 2H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.12 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 167.1, 147.7, 144.7, 126.9 (2C), 123.1 (2C), 101.0 (2C), 99.3 (2C), 62.6, 18.7 (12C), 12.8, 11.3 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{49}NNaO_4Si_2^+$ $[M+Na]^+$: 578.3092; found: 578.3102.



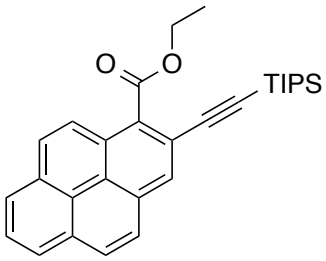

**Dimethyl 2-((triisopropylsilyl)ethynyl)terephthalate (30t).** General procedure D at 45 ºC for 20 h and obtained as a colorless oil in 48% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 8.20 (dd, *J* = 1.7, 0.6 Hz, 1H), 7.98 (dd, *J* = 8.2, 1.7 Hz, 1H), 7.90 (dd, *J* = 8.2, 0.5 Hz, 1H), 3.94 (s, 3H), 3.92 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.6, 165.8, 136.5, 135.8, 132.8, 130.3, 128.8, 123.8, 104.1, 97.8, 52.7, 52.6, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{30}NaO_4Si^+$ $[M+Na]^+$: 397.1806; found: 397.1811.



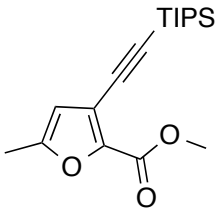

**Ethyl 2-((triisopropylsilyl)ethynyl)-1-naphthoate** (**30u**). General procedure D at 70 ºC for 24 h and obtained as a colorless oil in 81% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.86 – 7.75 (m, 3H), 7.57 – 7.45 (m, 3H), 4.53 (q, *J* = 7.2 Hz, 2H), 1.46 (t, *J* = 7.2 Hz, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 168.5, 135.1, 132.8, 129.5, 129.4, 129.0, 128.3, 127.7, 127.1, 125.1, 119.0, 104.7, 96.1, 61.9, 18.8 (6C), 14.4, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{24}H_{33}O_2Si^+$ $[M+H]^+$: 381.2244; found: 381.2250.



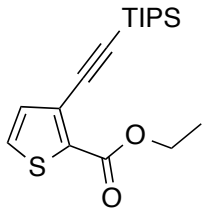

**Ethyl 3-((triisopropylsilyl)ethynyl)-2-naphthoate** (**30v**). General procedure D at 45 ºC for 20 h and obtained as a colorless oil in 62% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 8.39 (s, 1H), 8.10 (s, 1H), 7.87 (ddd, *J* = 8.0, 1.5, 0.7 Hz, 1H), 7.80 (ddd, *J* = 7.9, 1.4, 0.7 Hz, 1H), 7.58-7.50 (m, 2H), 4.45 (q, *J* = 7.1 Hz, 2H), 1.44 (t, *J* = 7.1 Hz, 3H), 1.19 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 166.7, 135.3, 134.2, 131.8, 131.1, 130.0, 128.9, 128.5, 127.5, 127.4, 119.5, 105.6, 95.2, 61.4, 18.9 (6C), 14.5, 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{24}H_{32}NaO_2Si^+$ $[M+Na]^+$: 403.2064; found: 403.2070.



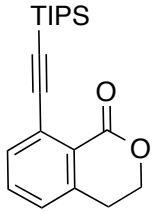

**Ethyl 5-((triisopropylsilyl)ethynyl)-5a1,10-dihydropyrene-4-carboxylate** (**30w**). General procedure D at 45 ºC for 48 h and obtained as a beige solid in 84% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 8.28 (s, 1H), δ 8.17 (d, *J* = 7.6 Hz, 1H), δ 8.16 (d, *J* = 7.5 Hz, 1H), 8.11 (d, *J* = 9.2 Hz, 1H), 8.08 (d, *J* = 9.2 Hz, 1H), 8.05 (d, *J* = 8.9 Hz, 1H), 8.00 (t, *J* = 7.6 Hz, 1H), 7.94 (d, *J* = 8.9 Hz, 1H), 4.64 (q, *J* = 7.2 Hz, 2H), 1.53 (t, *J* = 7.2 Hz, 3H), 1.23 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 168.9, 131.7, 131.3, 131.1, 130.8, 129.3, 129.1, 129.0, 128.1, 126.8, 126.6, 126.2, 126.0, 124.2, 124.0, 123.9, 118.7, 105.1, 95.2, 62.0, 18.9 (6C), 14.5, 11.6 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{30}H_{35}O_2Si^+$ $[M+H]^+$: 455.2401; found: 455.2404. *m/z* calc. for $C_{30}H_{34}NaO_2Si^+$ $[M+Na]^+$: 477.2220; found: 477.2213. **Mp**: 96-100 ºC.



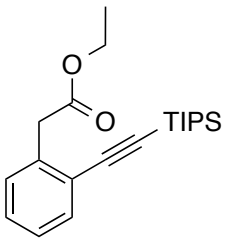

**Methyl 5-methyl-3-((triisopropylsilyl)ethynyl)furan-2-carboxylate (30x).** General procedure D at 70 ºC for 72 h and obtained as a slightly yellow oil in 66% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 6.18 (q, *J* = 1.0 Hz, 1H), 3.88 (s, 3H), 2.33 (d, *J* = 1.0 Hz, 3H), 1.12 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 158.8, 156.2, 144.3, 116.0, 112.4, 99.2, 97.4, 51.9, 18.7 (6C), 13.8, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{18}H_{28}NaO_3Si^+$ $[M+Na]^+$: 343.1700; found: 343.1706.



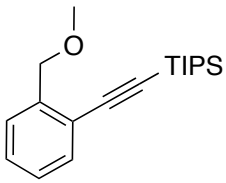

**Methyl 3-((triisopropylsilyl)ethynyl)thiophene-2-carboxylate (30y).** General procedure D at 70 ºC for 48 h and obtained as a yellow oil in 85% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 5.1 Hz, 1H), 7.15 (d, *J* = 5.1 Hz, 1H), 4.40 (q, *J* = 7.1 Hz, 2H), 1.39 (t, *J* = 7.1 Hz, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 161.5, 135.1, 133.4, 130.1, 126.9, 100.6, 97.8, 61.4, 18.8 (6C), 14.5, 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{18}H_{28}NaO_2SSi^+$ $[M+Na]^+$: 359.1471; found: 359.1475.



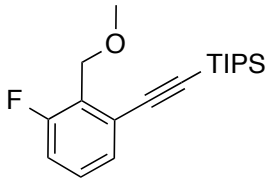

**8-((Triisopropylsilyl)ethynyl)isochroman-1-one (30z).** General procedure D at 45 ºC for 72 h, and obtained as a colorless oil (22 mg, 0.05 mmol, 25% yield). **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.56 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.41 (t, *J* = 7.7 Hz, 1H), 7.17 (dd, *J* = 7.6, 1.1 Hz, 1H), 4.44 (t, *J* = 5.9 Hz, 2H), 3.00 (t, *J* = 5.9 Hz, 2H), 1.16 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 162.4, 140.7, 134.9, 132.2, 127.0, 126.4, 125.9, 104.7, 99.0, 66.6, 29.0, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}O_2Si^+$ $[M+H]^+$: 329.1931; found: 329.1948.



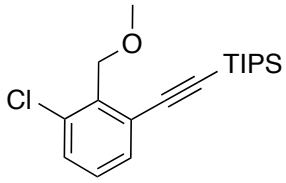

**Ethyl 2-(2-((triisopropylsilyl)ethynyl)phenyl)acetate (30aa).** General procedure D at 90 ºC for 72 h and obtained as a colorless oil18% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.50 (dt, *J* = 7.6, 1.0 Hz, 1H), 7.29-7.28 (m, 2H), 7.24-7.19 (m, 1H), 4.14 (q, *J* = 7.1 Hz, 2H), 3.87 (s, 2H), 1.24 (t, *J* = 7.1 Hz, 3H), 1.13 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 171.2, 136.5, 132.9, 129.8, 128.6, 127.1, 124.0, 105.1, 95.2, 61.0, 39.9, 18.8 (6C), 14.3, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{33}O_2Si^+$ $[M+H]^+$: 345.2244; found: 345.2234.



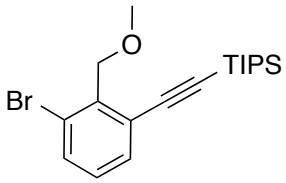

**Triisopropyl((2-(methoxymethyl)phenyl)ethynyl)silane (50a).** General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 64% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.48 (dd, J = 7.7, 1.3 Hz, 1H), 7.46 (dd, J = 7.7, 0.9 Hz, 1H), 7.33 (td, J = 7.6, 1.4 Hz, 1H), 7.22 (td, J = 7.5, 1.3 Hz, 1H), 4.67 (s, 2H), 3.44 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 140.5, 132.7, 128.7, 127.3, 127.2, 122.2, 104.6, 95.6, 72.9, 58.7, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{30}NaOSi^+$ $[M+Na]^+$: 325.1958; found: 325.1963.



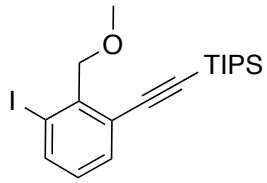

**((3-Fluoro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane (50h).** General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 67% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.31 (dd, J = 7.7, 1.1 Hz, 1H), 7.23 (td, J = 8.0, 5.5 Hz, 1H), 7.04 (ddd, J = 9.4, 8.2, 1.2 Hz, 1H), 4.70 (d, J = 1.7 Hz, 2H), 3.41 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 161.9 (d, J = 248.7 Hz), 129.7 (d, J = 9.5 Hz), 128.9 (d, J = 3.4 Hz), 126.7 (d, J = 16.5 Hz), 126.6 (d, J = 5.5 Hz), 116.1 (d, J = 22.9 Hz), 103.8 (d, J = 4.0 Hz), 96.0, 66.4 (d, J = 3.1 Hz), 58.4, 18.8 (6C), 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -116.64. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}FNaOSi^+$ $[M+Na]^+$: 343.1864; found: 343.1861.



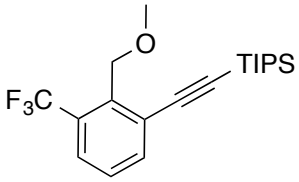

**((3-Chloro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50i**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 67% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.42 (dd, J = 7.7, 1.3 Hz, 1H), 7.36 (dd, J = 8.1, 1.3 Hz, 1H), 7.19 (t, J = 7.9 Hz, 1H), 4.79 (s, 2H), 3.42 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 136.9, 136.1, 131.7, 130.1, 129.2, 126.7, 104.3, 96.0, 70.1, 58.5, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}ClNaOSi^{+}$ $[M+Na]^{+}$: 359.1568; found: 359.1563.



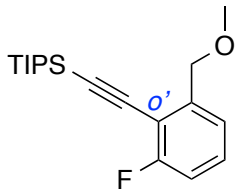

**((3-Bromo-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50j**)**.** General procedure D at 100 ºC for 20 h, and obtained as a yellow oil in 71% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.54 (dd, J = 8.0, 1.2 Hz, 1H), 7.46 (dd, J = 7.7, 1.2 Hz, 1H), 7.10 (t, J = 7.9 Hz, 1H), 4.79 (s, 2H), 3.43 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 138.5, 133.4, 132.3, 129.4, 126.7, 126.2, 104.4, 96.1, 72.4, 58.5, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}BrNaOSi^{+}$ $[M+Na]^{+}$: 403.1063; found: 403.1063.



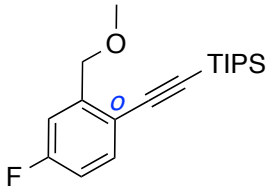

**((3-Iodo-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50k**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 55% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.82 (dd, J = 7.9, 1.2 Hz, 1H), 7.48 (dd, J = 7.7, 1.2 Hz, 1H), 6.92 (t, J = 7.8 Hz, 1H), 4.77 (s, 2H), 3.43 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 141.4, 140.2, 133.2, 129.5, 125.8, 104.7, 101.4, 95.9, 76.3, 58.5, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}INaOSi^{+}$ $[M+Na]^{+}$: 451.0925; found: 451.0922.



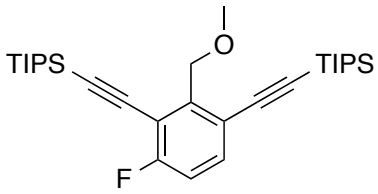
**Triisopropyl((2-(methoxymethyl)-3-(trifluoromethyl)phenyl)ethynyl)silane (50l).** General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 55% yield. **$^{1}$H NMR** (5 00 MHz, Chloroform-d) δ 7.70 (dd, J = 7.8, 1.3 Hz, 1H), 7.63 (dd, J = 7.9, 0.6 Hz, 1H), 7.37 (td, J = 7.8, 0.9 Hz, 1H), 4.77 (d, J = 1.2 Hz, 2H), 3.45 (s, 3H), 1.16 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 137.7 (d, J = 1.5 Hz), 136.8, 130.4 (q, J = 30.8 Hz), 128.21, 127.4, 126.2 (q, J = 5.7 Hz), 124.0 (q, J = 270 Hz), 104.0, 96.8, 69.1 (q, J = 1.9 Hz), 59.0, 18.8 (6C), 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -59.15. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}F_3NaOSi^+$ $[M+Na]^+$: 393.1832; found: 393.1820.



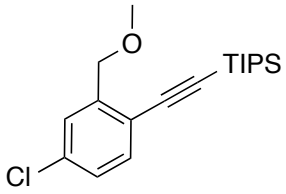

**((2-Fluoro-6-(methoxymethyl)phenyl)ethynyl)triisopropylsilane (50m').** General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 24% yield. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}FNaOSi^+$ $[M+Na]^+$: 343.1864; found: 343.1856. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.34 – 7.22 (m, 2H), 6.99 (td, J = 8.4, 7.9, 1.4 Hz, 1H), 4.65 (s, 2H), 3.45 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 163.5 (d, J = 251.6 Hz), 143.0, 129.6 (d, J = 8.6 Hz), 122.6 (d, J = 3.4 Hz), 114.2 (d, J = 21.2 Hz), 110.9 (d, J = 16.3 Hz), 102.0 (d, J = 3.6 Hz), 97.3, 72.4 (d, J = 3.2 Hz), 58.8, 18.8 (6C), 11.4 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -109.84. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}FNaOSi^+$ $[M+Na]^+$: 343.1864; found: 343.1856.



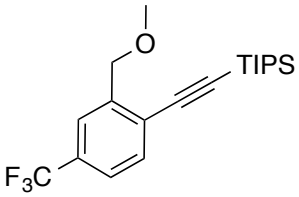

**((4-Fluoro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane (50m).** Compound **5m** was obtained as a colorless oil in 16% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.44 (dd, J = 8.5, 5.6 Hz, 1H), 7.19 (dd, J = 9.7, 2.7 Hz, 1H), 6.91 (td, J = 8.4, 2.7 Hz, 1H), 4.64 (s, 2H), 3.45 (s, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 163.0 (d, J = 249.6 Hz), 143.7, 134.4 (d, J = 8.6 Hz), 117.63, 114.183, 114.177 (d, J = 45.1 Hz), 103.4, 95.4 (d, J = 1.5 Hz), 72.4, 58.8, 18.8 (6C), 11.4 (3C).**$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -110.32. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}FNaOSi^+$ $[M+Na]^+$: 343.1864; found: 343.1867.



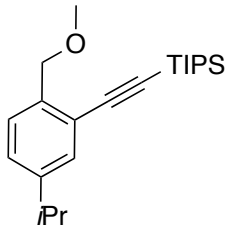

**((4-Fluoro-2-(methoxymethyl)-1,3-phenylene)bis(ethyne-2,1-diyl)bis(triisopropylsilane)** (**50m"**). Compound **50m"** was obtained as a colorless oil in 16% yield. **$^{1}$H NMR** (400 MHz, Chloroform-d) δ 7.42 (dd, J = 8.6, 5.5 Hz, 1H), 6.98 (t, J = 8.5 Hz, 1H), 4.78 (s, 2H), 3.41 (s, 3H), 1.15 (s, 21H), 1.14 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-d) δ 163.2 (d, J = 255.4 Hz), 143.5, 134.0 (d, J = 8.4 Hz), 121.0 (d, J = 3.7 Hz), 115.4 (d, J = 22.3 Hz), 114.0 (d, J = 16.5 Hz), 103.8, 101.7 (d, J = 4.1 Hz), 97.3, 94.6, 70.9 (d, J = 2.4 Hz), 58.7, 18.81 (6C), 18.77 (6C), 11.5 (3C), 11.4 (3C). **$^{19}$F NMR** (376 MHz, Chloroform-d) δ -106.12. **HRMS** (ESI+) *m/z* calc. for $C_{30}H_{49}FNaOSi2^{+}$ $[M+Na]^{+}$: 523.3198; found: 523.3214.



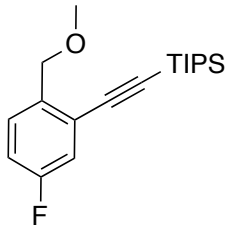

**((4-Chloro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50n**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 55% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.47 (d, J = 2.2 Hz, 1H), 7.39 (d, J = 8.2 Hz, 1H), 7.19 (dd, J = 8.2, 2.2 Hz, 1H), 4.62 (s, 2H), 3.45 (s, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 142.6, 134.8, 133.7, 127.4, 127.2, 120.2, 103.3, 96.9, 72.3, 58.8, 18.8 (6C), 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}ClNaOSi^{+}$ $[M+Na]^{+}$: 359.1568; found: 359.1573.



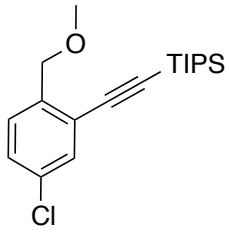

**Triisopropyl((2-(methoxymethyl)-4-(trifluoromethyl)phenyl)ethynyl)silane** (**50o**)**.** General procedure, at 100 ºC for 20 h and obtained as a yellow oil 70% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.75 (brs, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.47 (brd, J = 8.1, 1H), 4.69 (s, 2H), 3.48 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 141.7, 132.8 (2C), 130.5 (q, J = 32.5 Hz), 125.30, 124.0 (q, J = 271 Hz), 123.9 (q, J = 3.6 Hz), 103.0, 99.0, 72.4, 58.9, 18.8 (6C), 11.4 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -62.90. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}F_3NaOSi^{+}$ $[M+Na]^{+}$: 393.1832; found: 393.1832.



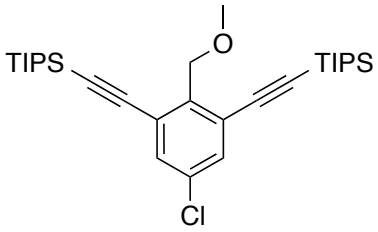

**Triisopropyl((5-isopropyl-2-(methoxymethyl)phenyl)ethynyl)silane** (**50p**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil 40% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.47 (dd, J = 1.7, 0.9 Hz, 1H), 7.35 – 7.39 (m, 2H) , 4.64 (s, 2H), 3.43 (s, 3H), 1.31 (s, 9H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 150.3, 137.6, 129.5, 127.4, 126.1, 121.9, 105.2, 94.6, 72.7, 58.6, 34.6, 31.4 (9C), 18.9 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{38}NaOSi^{+}$ $[M+Na]^{+}$: 381.2584; found: 381.2597.



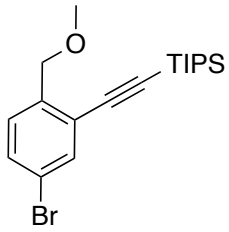

**((5-Fluoro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50q**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 58% yield. **$^{1}$H NMR** ($^{1}$H{$^{19}$F} 400 MHz, Chloroform-d) δ 7.31 (dd, J = 7.7, 1.3 Hz, 1H), 7.23 (t, J = 8.0 Hz, 1H), 7.04 (dd, J = 8.3, 1.3 Hz, 1H), 4.70 (s, 2H), 3.41 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 161.9 (d, J = 248.6 Hz), 129.7 (d, J = 9.5 Hz), 128.9 (d, J = 3.3 Hz), 126.7 (d, J = 16.6 Hz), 126.6 (d, J = 5.5 Hz), 116.1 (d, J = 22.7 Hz), 103.8 (d, J = 4.1 Hz), 96.0, 66.4 (d, J = 3.1 Hz), 58.4, 18.8 (6C), 11.5 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H} 376 MHz, Chloroform-d) δ -116.64. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}FNaOSi^{+}$ $[M+Na]^{+}$: 343.1864; found: 343.1859.



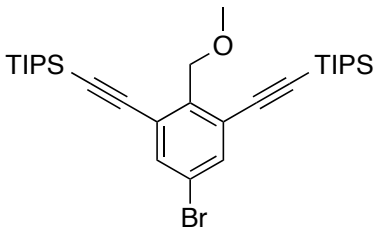

**((5-Chloro-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane** (**50r**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 48% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.45 (d, J = 2.2 Hz, 1H), 7.39 (d, J = 8.3 Hz, 1H), 7.30 (dd, J = 8.3, 2.2 Hz, 1H), 4.61 (s, 2H), 3.43 (s, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 139.1, 132.9, 132.2, 128.9, 128.6, 123.6, 103.0, 97.3, 72.3, 58.7, 18.8 (6C), 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}ClNaOSi^{+}$ $[M+Na]^{+}$: 359.1568; found: 359.1569.



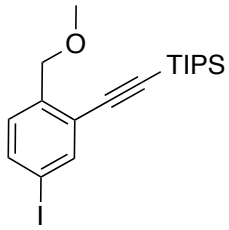

**((5-Chloro-2-(methoxymethyl)-1,3-phenylene)bis(ethyne-2,1diyl))bis(triisopropylsilane) (50r").** Compound **50r"** was obtained as a colorless oil in 34% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.43 (s, 2H), 4.75 (s, 2H), 3.39 (s, 3H), 1.14 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 139.6, 133.5, 132.7 (2C), 126.7 (2C), 103.4 (2C), 96.7 (2C), 70.5, 58.6, 18.8 (12 C), 11.5 (6C). **HRMS** (ESI+) m/z calc. for $C_{30}H_{49}ClNaOSi_2^+$ $[M+Na]^+$: 539.2903; found: 539.2904.



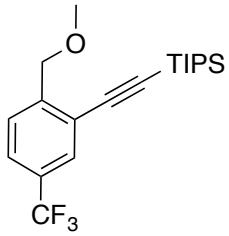

**((5-Bromo-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane (50s)**. General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 55% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.60 (d, J = 2.1 Hz, 1H), 7.45 (dd, J = 8.3, 2.1 Hz, 1H), 7.33 (d, J = 8.3 Hz, 1H), 4.60 (s, 2H), 3.43 (s, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 139.6, 135.0, 131.8, 128.8, 123.9, 120.7, 102.9, 97.4, 72.3, 58.7, 18.8 (6C), 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}BrNaOSi^+$ $[M+Na]^+$: 403.1063; found: 403.1058.



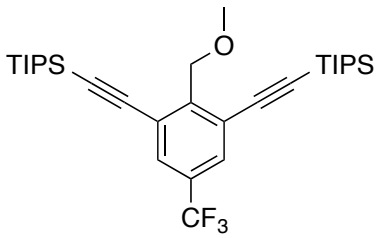

**((5-Bromo-2-(methoxymethyl)-1,3-phenylene)bis(ethyne-2,1-diyl)bis(triisopropylsilane) (50s").** Compound **50s"** was obtained as a colorless oil in 28% yield). **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.58 (s, 2H), 4.74 (s, 2H), 3.39 (s, 3H), 1.14 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 140.1, 135.5 (2C), 126.9 (2C), 121.3, 103.2 (2C), 96.8 (2C), 70.6, 58.6, 18.8 (12 C), 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{30}H_{49}BrNaOSi_2^+$ $[M+Na]^+$: 583.2398; found: 583.2420.




**((5-Iodo-2-(methoxymethyl)phenyl)ethynyl)triisopropylsilane (50t).** General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 32% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.79 (d, J = 1.8 Hz, 1H), 7.65 (dd, J = 8.2, 1.8 Hz, 1H), 7.19 (d, J = 8.2 Hz, 1H), 4.59 (s, 2H), 3.43 (s, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 140.8, 140.3, 137.7, 128.9, 124.1, 102.7, 97.5, 91.9, 72.4, 58.7, 18.8, 11.4. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{29}INaOSi^{+}$ $[M+Na]^{+}$: 451.0925; found: 451.0929.

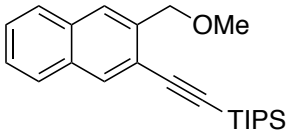



**Triisopropyl(2-methoxymethyl)-5-(trifluoromethyl)phenyl)ethynyl)silane (50u**). General procedure D at 100 ºC for 20 h and obtained as a yellow oil in 45% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.70 (dt, J = 1.7, 0.8 Hz, 1H), 7.61 (dt, J = 8.2, 0.7 Hz, 1H), 7.57 (dd, J = 8.2, 1.8 Hz, 1H), 4.69 (s, 2H), 3.47 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 144.6, 129.7 (q, J = 33 Hz), 129.3 (q, J = 3.7 Hz), 127.2, 125.2 (q, J = 3.8 Hz), 123.9 (q, J = 272 Hz), 122.4, 102.7, 98.0, 72.4, 58.9, 18.8 (6C), 11.4 (3C). **$^{19}$F NMR** ($^{19}$F{$^{1}$H}, 376 MHz, Chloroform-d) δ -62.80. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{29}F_3NaOSi^{+}$ $[M+Na]^{+}$: 393.1832; found: 393.1850.

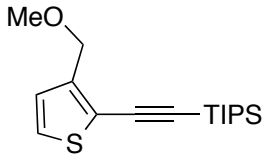



**2-(Methoxymethyl)-5-(trifluoromethyl)-1,3-phenylenebisethyne-2,1-diylbistriisopropyl) silane (50u").** Compound **50u"** was obtained as a colorless oil in 16% yield). **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.66 (s, 2H), 4.82 (s, 2H), 3.41 (s, 3H), 1.15 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 144.4, 130.7 (q, J = 33.2 Hz), 129.3 (q, J = 3.6 Hz, 2C), 126.1 (2C), 123.4 (q, J = 272.6 Hz), 103.2 (2C), 97.3 (2C), 70.7, 58.8, 18.8 (12C), 11.4 (6C). **$^{19}$F NMR**

($^{19}F\{^{1}H\}$, 376 MHz, Chloroform-d) δ -63.22. **HRMS** (ESI+) m/z calc. for $C_{31}H_{49}F_3NaOSi_2^+$ $[M+Na]^+$: 573.3166; found: 573.3187.

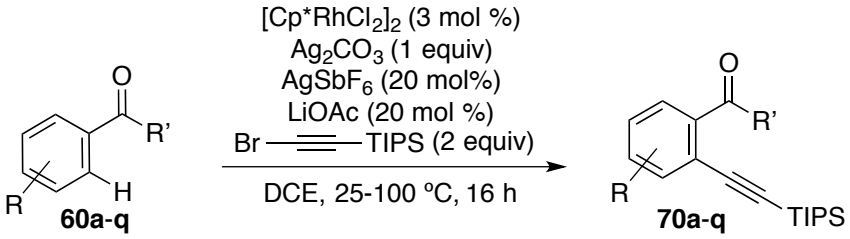



**Triisopropyl((3-(methoxymethyl)naphthalen-2-yl)ethynyl)silane** (**50v**). General procedure D at 100 ºC for 14h and obtained as yellow liquid in 70 % yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 8.03 (s, 1H), 7.90 (s, 1H), 7.85 – 7.75 (m, 2H), 7.52 – 7.43 (m, 2H), 4.82 (s, 2H), 3.55 (s, 3H), 1.20 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 136.47, 132.97, 132.68, 132.12, 127.80, 127.34, 126.81, 126.24, 125.66, 119.74, 104.57, 95.17, 72.98, 58.72, 18.71, 11.36. **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{32}NaOSi$ $[M+Na]^+$: 375.2115. Found: 375.2116.



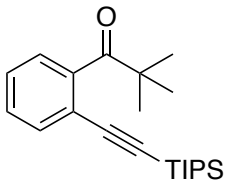

**Triisopropyl((3-(methoxymethyl)thiophen-2-yl)ethynyl)silane** (**50w**). General procedure D at 45 ºC for 20 h, and obtained as a yellow oil in 31% yield. **$^{1}$H NMR** (300 MHz, Chloroform-d) δ 7.18 (d, J = 5.2 Hz, 1H), 7.03 (d, J = 5.2 Hz, 1H), 4.53 (s, 2H), 3.36 (s, 3H), 1.13 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 143.8, 127.8, 126.4, 121.7, 98.7, 98.1, 68.4, 58.2, 18.8 (6C), 11.4 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{17}H_{28}NaOSSi$ $[M+Na]^+$: 331.1522. Found: 331.1524.

**General Procedure for the alkynylation of aryl ketones (E)**

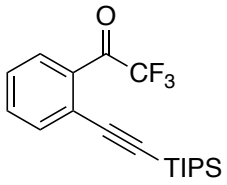



$[Cp^*RhCl_2]_2$ (3.72 mg, 6.00 μmol, 3 mol %), $Ag_2CO_3$ (55.1 mg, 0.20 mmol, 1 equiv), LiOAc (2.64 mg, 0.04 mmol, 0.2 equiv), $AgSbF_6$ (13.74 mg, 0.04 mmol, 0.2 equiv) were weighted in a vial inside a glovebox and dichloroethane (1 mL) is added. Corresponding ketone **60a-q** (0.20 mmol) and 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (57.5 mg, 0.22 mmol, 1.1 equiv) are then added and the vial is sealed. The reaction mixture is stirred at the appointed temperature for 16 h. After cooling to the appointed temperature, the reaction mixture is

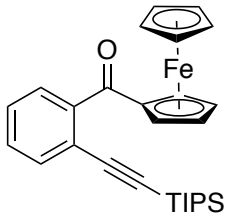
filtrated through celite and purified by column chromatography, with a gradient from cyclohexane 100% to 1/1 cyclohexane/ethyl acetate to yield corresponding product.



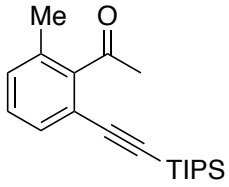

**2,2-Dimethyl-1-(2-((triisopropylsilyl)ethynyl)phenyl)propan-1-one** (**70a**). General procedure E at 45 °C and obtained at a colorless liquid in 95% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.55 – 7.48 (m, 1H), 7.33 – 7.25 (m, 2H), 7.13 (m, 1H), 1.27 (s, 9H), 1.10 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 212.30, 144.13, 133.50, 128.10, 127.51, 124.43, 120.04, 104.76, 94.92, 45.08, 26.89, 18.59, 11.28. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{34}NaO_2Si$ $[M+Na]^+$: 365.2271. Found: 365.2272.



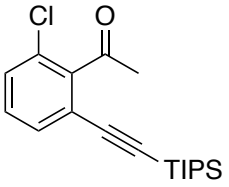

**2,2,2-Trifluoro-1-(2-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70b**). General procedure E at 90 ºC and obtained as yellow liquid in 50% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.78 (dt, *J* = 8.0, 1.3 Hz, 1H), 7.71 – 7.66 (m, 1H), 7.56 (td, *J* = 7.7, 1.3 Hz, 1H), 7.43 (td, *J* = 7.7, 1.3 Hz, 1H), 1.15 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 180.86 (q, *J* = 33 Hz), 135.51, 133.02, 132.59, 129.11 (q, *J* = 3 Hz), 127.86, 124.42, 116.19 (q, *J* = 289 Hz), 103.50, 98.86, 18.57, 11.28. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -71.90. **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{29}F_3NaO_2Si$ $[M+Na+OMe]^+$: 409.1781. Found: 409.1790.



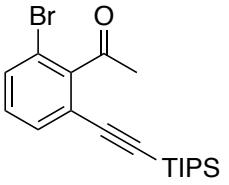

**2-((Triisopropylsilyl)ethynyl)benzoyl ferrocene** (**70c**). General procedure E at 45 ºC and obtained as a brown liquid in 83% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.54 (m, 2H), 7.39 (m, 2H), 4.77 (t, *J* = 1.9 Hz, 2H), 4.51 (t, *J* = 1.9 Hz, 2H), 4.21 (s, 5H), 1.00 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 200.00, 143.20, 133.53, 129.29, 127.84, 126.98, 120.90, 104.53, 96.66, 78.52, 72.56, 71.34, 69.93, 18.56, 11.12. **HRMS** (ESI+) *m/z* calc. for $C_{28}H_{34}NaOSiFe$ $[M+Na]^+$: 491.1667. Found: 491.1670.



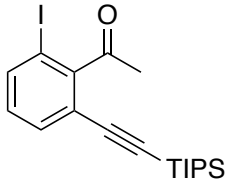

**1-(2-Methyl-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70d**). General procedure E at 45 ºC and obtained as a yellow liquid in 87% yield. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 7.36 – 7.30 (m, 1H), 7.23 – 7.11 (m, 2H), 2.59 (s, 3H), 2.24 (s, 3H), 1.11 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 205.69, 144.77, 133.10, 130.55, 130.37, 128.41, 119.08, 104.22, 95.85, 31.72, 19.04, 18.54, 11.23. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{30}NaOSi$ $[M+Na]^+$: 337.1958. Found: 337.1954.



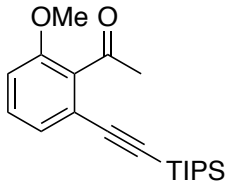

**1-(2-Chloro-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70e**)**.** General procedure E at 45 ºC and obtained as a light yellow liquid in 92% yield. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 7.39 (dd, *J* = 7.5, 1.3 Hz, 1H), 7.32 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.23 (dd, *J* = 8.1, 7.6 Hz, 1H), 2.58 (s, 3H), 1.10 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 201.36, 143.78, 131.09, 129.49, 129.44, 128.74, 121.02, 102.37, 97.32, 31.06, 18.49, 11.17. **HRMS** (ESI+) *m/z* calc. for $C_{17}H_{27}NaClOSi$ $[M+Na]^+$: 357.1412. Found: 357.1414.



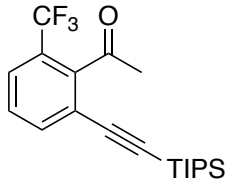

**1-(2-Bromo-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70f**)**.** General procedure E at 45 ºC and obtained as a colorless liquid in 95% yield. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 7.49 (dd, *J* = 8.1, 1.0 Hz, 1H), 7.43 (dd, *J* = 7.8, 1.0 Hz, 1H), 7.16 (t, *J* = 7.9 Hz, 1H), 2.58 (s, 3H), 1.09 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 202.08, 145.77, 132.56, 131.61, 129.58, 121.02, 116.64, 102.41, 97.49, 30.76, 18.52, 11.19. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{28}BrOSi$ $[M+H]^+$: 379.1087. Found: 379.1087.



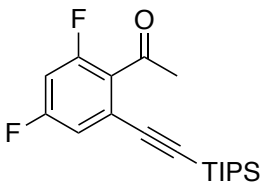
**1-(2-Iodo-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one (70g).** General procedure E at 45 ºC and obtained as a yellow liquid in 95% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.75 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.46 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.00 (t, *J* = 7.9 Hz, 1H), 2.59 (s, 3H), 1.09 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 203.72, 149.55, 138.89, 132.30, 129.63, 120.29, 102.65, 97.51, 88.61, 30.20, 18.50, 11.17. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{27}NaIOSi$ $[M+Na]^+$: 449.0768. Found: 449.0773.



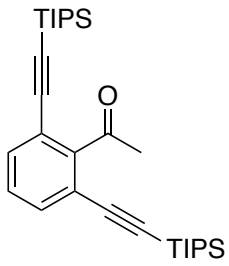

**1-(2-Methoxy-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one (70h).** General procedure E at 45 ºC and obtained as a light yelow liquid in 91% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.23 (dd, *J* = 8.4, 7.7 Hz, 1H), 7.08 (dd, *J* = 7.7, 0.9 Hz, 1H), 6.87 (dd, *J* = 8.4, 0.9 Hz, 1H), 3.79 (s, 3H), 2.52 (s, 3H), 1.10 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 202.64, 155.23, 134.46, 129.61, 125.03, 120.42, 111.29, 103.41, 95.35, 55.72, 31.54, 18.50, 11.18. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{30}NaO_2Si$ $[M+Na]^+$: 353.1907. Found: 353.1902.



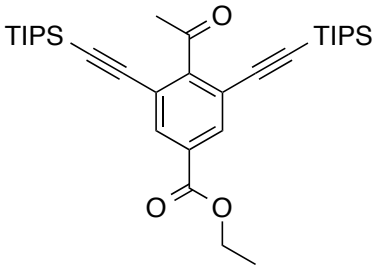

**1-(2-(Trifluoromethyl)-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one (70i**). General procedure E at 45 ºC and obtained as a light yellow liquid in 81% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.67 (d, *J* = 7.8 Hz, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.44 (tq, *J* = 7.9, 0.9 Hz, 1H), 2.62 (s 3H), 1.13 – 1.08 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 201.94, 143.54 (q, *J* = 2 Hz), 136.20, 128.69, 126.42 (q, *J* = 32 Hz), 125.87 (q, J = 5 Hz) 123.22 (q, J = 275 Hz), 120.81, 102.13, 98.62, 31.41, 18.52, 11.21. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -58.84. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{27}NaF_3OSi$ $[M+Na]^+$: 391.1675. Found: 391.1690.



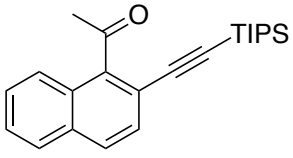
**1-(2,4-Difluoro-6-((triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70j**). General procedure E at 45 ºC and obtained as yellow liquid in 95% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.03 (ddd, *J* = 8.6, 2.4, 1.3 Hz, 1H), 6.82 (ddd, *J* = 9.7, 8.6, 2.4 Hz, 1H), 2.59 (d, *J* = 1.6 Hz, 3H), 1.11 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 197.41, 162.69 (dd, *J* = 245 Hz, *J* = 15 Hz), 159.36 (dd, *J* = 245 Hz, *J* = 15 Hz), 128.45 (dd, *J* = 18 Hz, *J* = 4 Hz), 123.68 (dd, *J* = 18 Hz, *J* = 4 Hz), 116.40 (dd, *J* = 23 Hz, *J* = 4 Hz), 104.87 (t, 25 Hz), 101.79 (dd, *J* =3 Hz, *J* = 1Hz), 99.04, 31.73, 18.52, 11.18. **$^{19}$F NMR** (376 MHz, $CDCl_3$) δ -107.20, -111.35. **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{26}NaF_2OSi$ $[M+Na]^+$: 359.1613. Found: 359.1604.



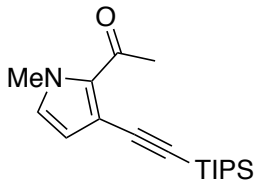

1-**(2,6-bis((Triisopropylsilyl)ethynyl)phenyl)ethan-1-one** (**70k**). General procedure E at room temperature using 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2 equiv) and obtained as a colorless oil in 94% yield. **$^{1}$H NMR** (300 MHz, Chloroform-d) δ 7.43 (d, J = 7.7 Hz, 2H), 7.24 (t, J = 7.7, 1H), 2.60 (s, 3H), 1.10 (m, 42H). **$^{13}$C NMR** (75 MHz, CDCl3) δ 203.11, 148.08, 132.48, 128.32, 119.30, 102.98, 96.28, 31.11, 18.55, 11.22. **HRMS** (ESI+) m/z calc. for $C_{30}H_{48}NaO_2Si_2$ [M+Na]+: 503.3136. Found: 503.3137.



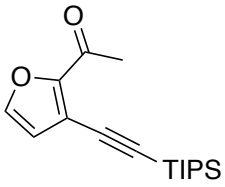

**Ethyl 4-acetyl-3,5-bis((triisopropylsilyl)ethynyl)benzoate** (**70l**). General procedure D at 45 ºC for 20 h and obtained as a white cristalline solid in 80% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 8.04 (s, 2H), 4.40 (q, *J* = 7.1 Hz, 2H), 2.59 (s, 3H), 1.40 (t, *J* = 7.1 Hz, 3H), 1.10 (s, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 202.5, 164.9, 151.5, 133.3 (2C), 131.0, 120.0 (2C), 102.2 (2C), 97.7 (2C), 61.8, 31.0, 18.7 (12C), 14.4, 11.4 (6C). **HRMS** (ESI+) *m/z* calc. for $C_{33}H_{53}O_3Si_2^+$ $[M+H]^+$: 553.3528; found: 553.3525. **Mp**: 43-48 ºC.



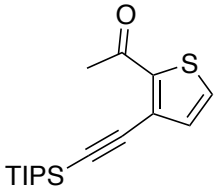
**1-(2-((Triisopropylsilyl)ethynyl)naphthalen-1-yl)ethan-1-one** (**70m**). General procedure E at 45 ºC and obtained as a brown liquid in 93% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.84 – 7.80 (m, 1H), 7.79 (d, *J* = 8.4 Hz, 1H), 7.73 – 7.69 (m, 1H), 7.54 – 7.49 (m, 3H), 2.78 (s, 3H), 1.16 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 205.44, 143.28, 132.84, 128.84, 128.70, 128.35, 128.24, 127.48, 126.97, 124.58, 116.65, 104.50, 97.62, 32.31, 18.60, 11.28. **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{30}NaOSi$ $[M+Na]^+$: 373.1958. Found: 373.1960.



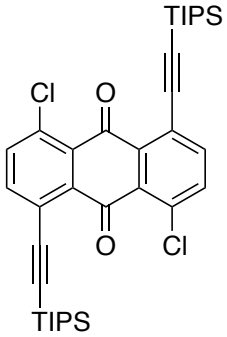

**1-(1-Methyl-3-((triisopropylsilyl)ethynyl)-1H-pyrrol-2-yl)ethan-1-one** (**70n**). General procedure E at 45 ºC and obtained as a light yellow liquid in 74% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 6.65 (d, *J* = 2.6 Hz, 1H), 6.30 (d, *J* = 2.6 Hz, 1H), 3.88 (s, 3H), 2.71 (s, 3H), 1.11 (s, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 189.40, 132.37, 129.25, 113.98, 113.63, 102.32, 96.56, 38.66, 29.93, 18.63, 11.34. **HRMS** (ESI+) *m/z* calc. for $C_{18}H_{29}NNaOSi$ $[M+Na]^+$: 326.1911. Found: 326.1908.



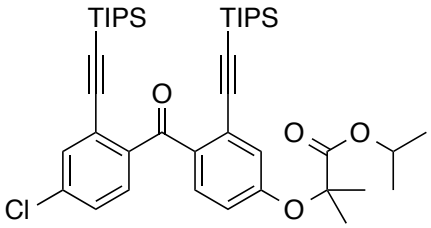

**1-(3-((Triisopropylsilyl)ethynyl)furan-2-yl)ethan-1-one** (**70o**). General procedure starting E at 45 ºC and obtained as a light yellow liquid in 86% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.50 (d, *J* = 1.8 Hz, 1H), 6.56 (d, *J* = 1.8 Hz, 1H), 2.62 (s, 3H), 1.12 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 185.63, 152.94, 145.35, 116.15, 114.71, 101.64, 97.52, 27.64, 18.54, 11.18. **HRMS** (ESI+) *m/z* calc. for $C_{17}H_{26}NaO_2Si$ $[M+Na]^+$: 313.1594. Found: 313.1596.



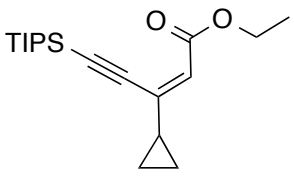

**1-(3-((Triisopropylsilyl)ethynyl)thiophen-2-yl)ethan-1-one** (**70p**)**.** General procedure E at 45 ºC and obtained a light yellow liquid in 95% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.49 (d, *J* = 5.1 Hz, 1H), 7.16 (d, *J* = 5.1 Hz, 1H), 2.78 (s, 3H), 1.13 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 191.05, 146.12, 133.71, 131.61, 125.60, 101.17, 100.17, 28.88, 18.58, 11.23. **HRMS** (ESI+) *m/z* calc. for $C_{17}H_{27}OSSi$ $[M+H]^+$: 307.1546. Found: 307.1545.




**1,5-Dichloro-4,8-bis((triisopropylsilyl)ethynyl)anthracene-9,10-dione** (**70q**). General procedure E using $[Cp^*RhCl_2]_2$ (4 mol%), and 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2.2 equiv) at 100 ºC. Obtained as a yellow liquid in 82% yield. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.4 Hz, 2H), 1.19 (m, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 180.85, 138.95, 137.80, 135.07, 132.70, 131.83, 121.32, 102.93, 99.71, 18.64, 11.35. **HRMS** (ESI+) *m/z* calc. for $C_{36}H_{46}NaCl_2O_2Si_2$ $[M+Na]^+$: 659.2306. Found: 659.2334.

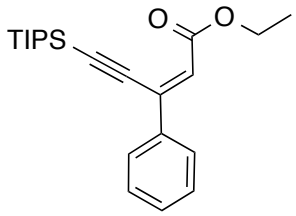



**Isopropyl-2-(4-(4-chloro-2-((triisopropylsilyl)ethynyl)benzoyl)-3-triisopropyl-silyl-ethynylphenoxy-2-methylpropanoate** (**70r**). General procedure D at 50 ºC for 20 h and obtained as a colorless oil in 36% yield. **$^1$H NMR** (500 MHz, Chloroform-d) δ 7.52 (d, J = 8.7 Hz, 1H), 7.47 (d, J = 2.1 Hz, 1H), 7.38 (d, J = 8.3 Hz, 1H), 7.29 (dd, J = 8.3, 2.1 Hz, 1H), 6.96 (d, J = 2.6 Hz, 1H), 6.74 (dd, J = 8.8, 2.6 Hz, 1H), 5.07 (h, J = 6.3 Hz, 1H), 1.63 (s, 6H), 1.21 (d, J = 6.3 Hz, 6H), 1.09 – 0.90 (m, 42H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 193.8, 173.0, 158.5, 140.4, 136.5, 133.8, 132.75, 132.72, 131.0, 128.5, 125.2, 124.2, 124.1, 117.5, 104.8, 103.4, 98.5, 98.5, 79.6, 69.5, 25.5 (2C), 21.7 (3C), 18.7 (6C), 18.7 (6C), 11.5 (2C), 11.3 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{42}H_{61}ClNaO4Si2^+$ $[M+Na]^+$: 743.3689; found: 743.3711.

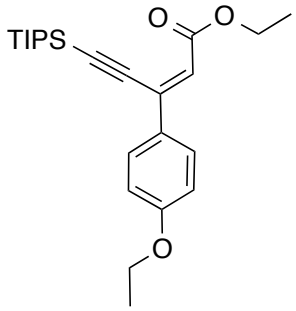



**Ethyl (Z)-3-cyclopropyl-5-(triisopropylsilyl)pent-2-en-4-ynoate** (**90a**)**.** General procedure D at 85 ºC for 48 h and obtained as a colorless oil in 52% yield. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 6.12 (s, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 1.65 (tt, *J* = 8.0, 4.7 Hz, 1H), 1.26 (t,

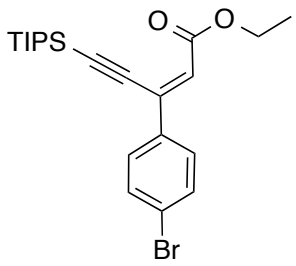
*J* = 7.1 Hz, 3H), 1.11 (s, 21H), 1.01 – 0.92 (m, 2H), 0.85 – 0.73 (m, 2H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 164.7, 141.9, 122.9, 103.9, 99.9, 60.0, 18.7 (6C), 18.3, 14.5, 11.4 (3C), 7.7 (2C). **HRMS** (ESI+) *m/z* calc. for $C_{19}H_{33}O_2Si^+$ $[M+H]^+$: 321.2244; found: 321.2246.




**Ethyl (Z)-3-phenyl-5-(triisopropylsilyl)pent-2-en-4-ynoate (90b).** General procedure D at 85 ºC for 48 h and obtained as a yellow oil in 60% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.79 – 7.70 (m, 2H), 7.43 – 7.34 (m, 3H), 6.55 (s, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 165.2, 137.5, 135.7, 129.8, 128.6 (2C), 127.3 (2C), 124.0, 106.0, 103.1, 60.5, 18.8 (6C), 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{32}NaO_2Si^+$ $[M+Na]^+$: 379.2064; found: 379.2073.

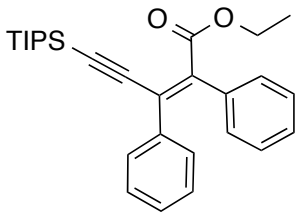



**Ethyl (Z)-3-(4-ethoxyphenyl)-5-(triisopropylsilyl)pent-2-en-4-ynoate (90c).** General procedure D at 85 ºC for 48 h and obtained as a colorless oil 44% yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.74 – 7.65 (m, 2H), 6.92 – 6.84 (m, 2H), 6.47 (s, 1H), 4.26 (q, *J* = 7.1 Hz, 2H), 4.06 (q, *J* = 7.0 Hz, 2H), 1.42 (t, *J* = 7.0 Hz, 3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 165.4, 160.5, 135.2, 129.6, 128.8 (2C), 121.7, 114.5 (2C), 105.5, 103.2, 63.7, 60.3, 18.8 (6C), 14.9, 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{24}H_{36}NaO_3Si^+$ $[M+Na]^+$: 423.2326; found: 423.2331.

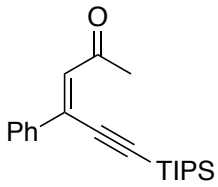



**Ethyl (Z)-3-(4-bromophenyl)-5-(triisopropylsilyl)pent-2-en-4-ynoate (90d).** General procedure D at 85 ºC for 48 h and obtained as a yellow oil 66% yield. **$^{1}$H NMR** (400 MHz,

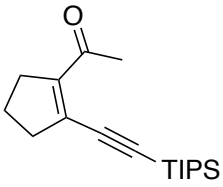
Chloroform-*d*) δ 7.64 – 7.56 (m, 2H), 7.55 – 7.45 (m, 2H), 6.52 (s, 1H), 4.27 (q, *J* = 7.1 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.16 (s, 21H). **$^{13}$C NMR** (101 MHz, Chloroform-*d*) δ 164.9, 136.4, 134.5, 131.8 (2C), 128.8 (2C), 124.3, 124.2, 106.5, 102.6, 60.6, 18.8 (6C), 14.5, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{32}BrO_2Si^+$ $[M+H]^+$: 435.1349; found: 435.1368.




**Ethyl (Z)-2,3-diphenyl-5-(triisopropylsilyl)pent-2-en-4-ynoate** (**90e**)**.** General procedure D at 85 ºC for 48 h and obtained as a colorless oil 84% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.33 – 7.23 (m, 2H), 7.24 – 7.10 (m, 8H), 4.33 (q, *J* = 7.1 Hz, 2H), 1.34 (t, *J* = 7.1 Hz, 3H), 1.14 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 168.8, 140.7, 137.0, 135.2, 129.9 (2C), 129.5 (2C), 128.3 (2C), 128.1, 128.04, 127.96 (2C), 125.5, 105.9, 99.3, 61.6, 18.8 (6C), 14.2, 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{28}H_{36}NaO_2Si^+$ $[M+Na]^+$: 455.2377; found: 455.2377.

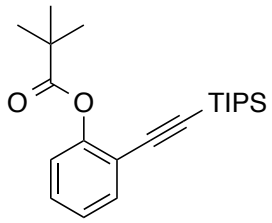



**(Z)-4-Phenyl-6-(triisopropylsilyl)hex-3-en-5-yn-2-one** (**90f**). General procedure E at 45 ºC and obtained as a brown liquid in 61% yield. **$^{1}$H NMR** (500 MHz, Chloroform-*d*) δ 7.76 – 7.71 (m, 2H), 7.41 – 7.37 (m, 3H), 6.74 (s, 1H), 2.63 (s, 3H), 1.21 – 1.13 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 198.06, 137.49, 133.89, 133.23, 129.84, 128.53, 127.24, 107.66, 103.72, 30.51, 18.60, 11.30. **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{30}NaOSi$ $[M+Na]^+$: 349.1958. Found: 349.1960.

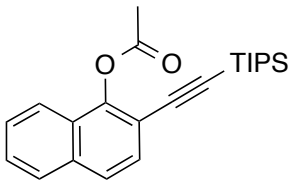



**1-(2-((Triisopropylsilyl)ethynyl)cyclopent-1-en-1-yl)ethan-1-one** (**90g**). General procedure E starting from 1-(cyclopent-1-en-1-yl)ethan-1-one (**8g**) (2 equiv) and 1-Bromo-2-(triisopropylsilyl)acetylene (**1**) (0.2 mmol, 1 equiv) at 45 ºC and obtained as a yellow liquid in 60% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 2.70 (m, 4H), 2.59 (s, 3H), 1.92 – 1.78 (m, 2H), 1.09 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 196.55, 147.49, 134.11, 105.86, 103.15,

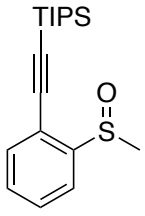
40.94, 32.86, 29.52, 21.62, 18.55, 11.19. **HRMS** (ESI+) *m/z* calc. for $C_{18}H_{30}NaOSi$ $[M+Na]^+$: 313.1958. Found: 313.1967.



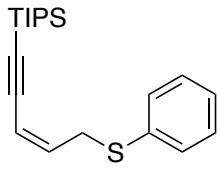

**2-((Triisopropylsilyl)ethynyl)phenyl pivalate (110a).** General procedure D at 90ºC for 72 h and obtained as a colorless oil in 35% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.53 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.31 (ddd, *J* = 8.2, 7.4, 1.7 Hz, 1H), 7.16 (td, *J* = 7.6, 1.2 Hz, 1H), 7.05 (dd, *J* = 8.2, 1.1 Hz, 1H), 1.39 (s, 9H), 1.12 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 176.5, 151.6, 134.7, 129.4, 125.6, 122.4, 117.7, 102.1, 95.8, 39.3, 27.4 (3C), 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{22}H_{35}O_2Si^+$ $[M+H]^+$: 359.2401; found: 359.2417.



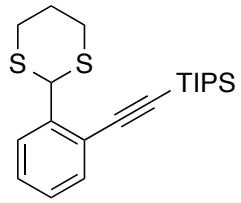

**2-((Triisopropylsilyl)ethynyl)naphthalen-1-yl acetate (110b).** General procedure D at 70 ºC for 24 h and obtained as a dark yellow solid in 40% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.86 – 7.78 (m, 2H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.57 – 7.43 (m, 3H), 2.48 (s, 3H), 1.17 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-*d*) δ 168.5, 148.9, 134.3, 129.2, 128.1, 127.3, 127.2, 127.1, 125.9, 121.5, 114.1, 102.4, 97.0, 21.0, 18.8 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{23}H_{30}NaO_2Si^+$ $[M+Na]^+$: 389.1907; found: 389.1918. **Mp**: 47-51 ºC.



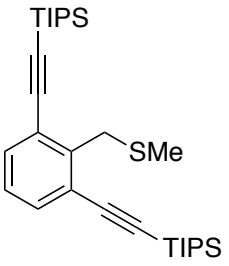

**Triisopropyl((2-(methylsulfinyl)phenyl)ethynyl)silane (110c)**. General procedure E at 100 ºC and obtained as a yellow liquid in 55% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.94 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.56 (td, *J* = 7.8, 1.3 Hz, 1H), 7.51 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.42 (td, *J* = 7.8, 1.3 Hz, 1H), 2.83 (s, 3H), 1.15 – 1.10 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 147.47, 133.12, 130.18, 129.57, 123.04, 119.39, 101.17, 100.97, 42.08, 18.57, 11.19. **HRMS** (ESI+) *m/z* calc. for $C_{18}H_{28}NaOSSi$ $[M+Na]^+$: 343.1522. Found: 343.1518.



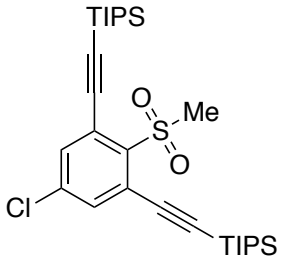

**(Z)-Triisopropyl(5-(phenylthio)pent-3-en-1-yn-1-yl)silane (110d).** General procedure E at 50 ºC and obtained as a yellow liquid in 83% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.42 – 7.37 (m, 2H), 7.32 – 7.25 (m, 2H), 7.22 – 7.16 (m, 1H), 6.00 (dt, *J* = 10.7, 7.5 Hz, 1H), 5.63 (dt, *J* = 10.7, 1.0 Hz, 1H), 3.87 (dd, *J* = 7.5, 1.0 Hz, 2H), 1.13 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 139.26, 135.42, 129.32, 128.75, 126.05, 112.03, 102.45, 97.47, 32.96, 18.63, 11.24. **HRMS** (ESI+) *m/z* calc. for $C_{20}H_{31}SSi$ $[M+H]^+$: 331.1910. Found: 331.1909.



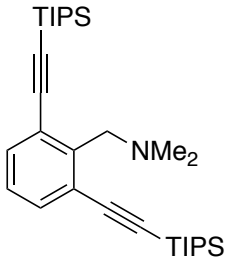

**((2-(1,3-Dithian-2-yl)phenyl)ethynyl)triisopropylsilane** (**110e**). General procedure D at 90 ºC for 16 h and obtained as a colorless solid in 53% yield. **$^{1}$H NMR** (500 MHz, Chloroform-d) δ 7.63 (dd, J = 7.9, 1.3 Hz, 1H), 7.47 (dd, J = 7.9, 1.3 Hz, 1H), 7.32 (td, J = 7.6, 1.4 Hz, 1H), 7.23 (td, J = 7.6, 1.3 Hz, 1H), 5.87 (s, 1H), 3.04 (ddd, J = 14.9, 12.5, 2.4 Hz, 2H), 2.91 (ddd, J = 14.4, 4.2, 3.0 Hz, 2H), 2.17 (dtt, J = 13.8, 4.5, 2.4 Hz, 1H), 1.94 (dtt, J = 14.1, 12.5, 3.1 Hz, 1H), 1.18 (s, 21H). **$^{13}$C NMR** (126 MHz, Chloroform-d) δ 140.9, 132.8, 129.2, 128.1, 128.0, 122.2, 104.2, 96.0, 49.4, 32.5 (2C), 25.4, 18.9 (6C), 11.5 (3C). **HRMS** (ESI+) *m/z* calc. for $C_{21}H_{33}S_2Si$ $[M+H]^+$: 377.1784. Found: 377.1787. **Mp**: 56-60 ºC.



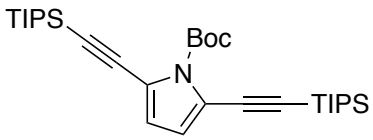

**((2-((Methylthio)methyl)-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane)** (**110f**). General procedure E using 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2.1 equiv) at 100 ºC and obtained as a light yellow liquid in 75% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 7.7 Hz, 2H), 7.18 – 7.10 (t, *J* = 7.7 Hz 1H), 4.14 (s, 3H), 2.13 (s, 3H), 1.16 (s, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 143.31, 133.09, 126.40, 123.66, 104.70, 96.11, 34.64, 18.68, 15.35, 11.36. **HRMS** (ESI+) *m/z* calc. for $C_{30}H_{31}SSi_2$ $[M+H]^+$: 499.3245. Found: 499.3254.




**((5-Chloro-2-(methylsulfonyl)-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane)** (**110g**). General procedure E using 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2.1 equiv) at 100 ºC. Obtained as a yellow liquid in 41% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.54 (s, 2H), 3.28 (s, 3H), 1.14 (m, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 139.93, 137.84, 135.46, 125.68, 103.76, 101.47, 42.95, 18.58, 11.28. **HRMS** (ESI+) *m/z* calc. for $C_{29}H_{48}ClSO_2Si_2$ $[M+H]^+$: 551.2597. Found: 551.2613.

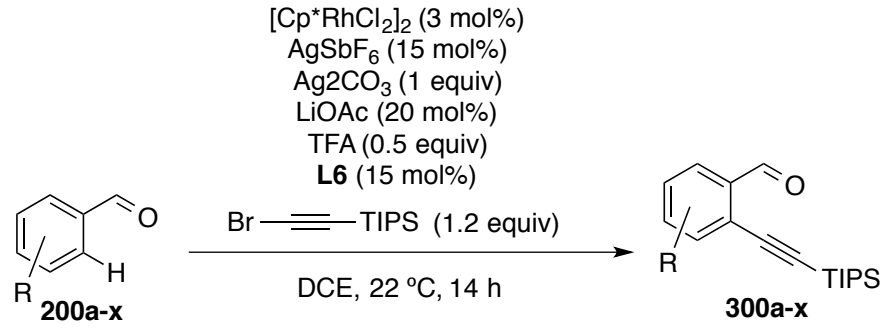



**1-(2,6-Bis((triisopropylsilyl)ethynyl)phenyl)-N,N-dimethylmethanamine** (**110h**)**.** General procedure E at 90 ºC using 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2.1 equiv) and obtained as a yellow liquid in 50% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 7.7 Hz, 2H), 7.15 (t, *J* = 7.7 Hz, 1H), 3.83 (s, 2H), 2.33 (s, 6H), 1.14 (s, 42H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 142.57, 133.33, 126.74, 125.12, 105.46, 94.84, 59.44, 45.85, 18.72, 11.39. **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{54}NSi_2$ $[M+H]^+$: 496.3789. Found: 496.3809.

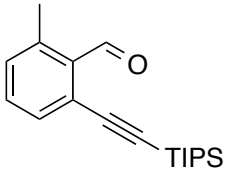



***Tert*-butyl 2,5-bis((triisopropylsilyl)ethynyl)-1H-pyrrole-1-carboxylate** (**110i**). General procedure E using 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (2.1 equiv) at 45 ºC and obtained as a yellow liquid in 66% yield. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 6.45 (s, 2H), 1.62 (s, 9H), 1.12 (m, 42H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 147.58, 119.83, 116.67, 97.91, 96.20, 84.85, 27.84, 18.63, 11.36. **HRMS** (ESI+) *m/z* calc. for $C_{31}H_{53}NaNO_2Si_2$ $[M+Na]^+$: 550.3507. Found: 550.3513.

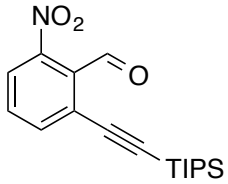
**General procedure for the alkynylation of benzaldehydes (F):**



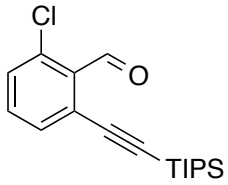

$[Cp^*RhCl_2]_2$ (3 mol %), $Ag_2CO_3$ (1 equiv), LiOAc (0.2 equiv), $AgSbF_6$ (0.2 equiv) were weighted in a vial inside a glovebox and dichloroethane (0.2M) is added. Corresponding aldehyde **200a-x** (0.2 mmol), 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (1.1 equiv), 3,5-bis(trifluoromethyl)aniline (0.15 equiv) and TFA (0.5 equiv) are then added and the vial is sealed. The reaction mixture is stirred at the appointed temperature for 16 h. After cooling to the room temperature, the reaction mixture is filtrated through celite and purified by column chromatography, with a gradient from cyclohexane 100% to 1/1 cyclohexane/ethyl acetate to yield corresponding product **300a-x**.



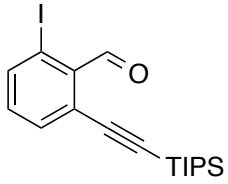

**2-Methyl-6-((triisopropylsilyl)ethynyl)benzaldehyde (300a).** General procedure F at room temperature. Obtained as a yellow solid in 95% yield. (melting point = 45 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.83 (s, 1H), 7.46 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.18 (d, *J* = 7.5 Hz, 1H), 2.60 (s, 3H), 1.13 (d, *J* = 2.4 Hz, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** = δ 194.0, 140.5, 134.2, 132.4, 132.0, 131.9, 128.8, 102.9, 99.2, 21.4, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{19}H_{28}NaOSi$ [M+Na]-: 323.1802. Found: 323.1800.



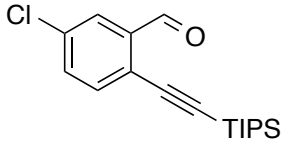

**2-Nitro-6-((triisopropylsilyl)ethynyl)benzaldehyde (300b).** General procedure F at room temperature. Obtained as an orange solid in 91% yield (melting point = 45 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.49 (s, 1H), 7.86 – 7.78 (m, 2H), 7.62 (t, *J* = 8.0 Hz, 1H), 1.14 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 188.3, 148.1, 137.7, 132.7, 132.1, 125.6, 123.4, 101.6, 100.4, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{25}NaO_3Si$ [M+Na]-: 354.1496. Found: 354.1490.



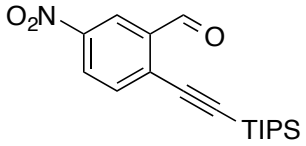

**2-Chloro-6-((triisopropylsilyl)ethynyl)benzaldehyde (300c).** General procedure F at room temperature. Obtained as a white solid in 78% yield (melting point = 40 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.64 (s, 1H), 7.51 (m, 1H), 7.40 (m, 2H), 1.13 (m, 23H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** = δ 189.7, 135.2, 133.3, 133.1, 133.0, 131.2, 127.9, 102.0, 100.7, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{25}ClNaOSi$ [M+Na]-: 343.1255. Found: 343.1259.




**2-Iodo-6-((triisopropylsilyl)ethynyl)benzaldehyde (300d).** General procedure (F) at room temperature. Obtained as a yellow solid in 85% yield (melting point = 57 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.41 (s, 1H), 7.99 – 7.93 (m, 1H), 7.59 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.13 (t, *J* = 7.8 Hz, 1H), 1.13 (m, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 191.9, 141.7, 135.9, 134.5, 133.0, 128.5, 101.6, 101.2, 94.3, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{25}NaIOSi$ [M+Na]-: 435.0612. Found: 435.0609.

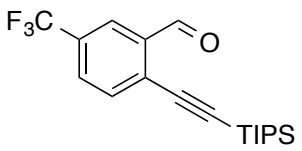



**5-Chloro-2-((triisopropylsilyl)ethynyl)benzaldehyde (300e).** General procedure F at 70 °C. Obtained as a yellow liquid in 82% yield. **$^1$H NMR (400 MHz, Chloroform-*d*)** δ = 10.53 (s, 1H), 7.86 (d, *J* = 2.1 Hz, 1H), 7.56 – 7.44 (m, 2H), 1.16 – 1.10 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 190.5, 137.4, 135.4, 135.2, 133.8, 127.0, 125.4, 101.0, 100.6, 18.8, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{19}H_{29}ClNaO_2Si$ [M+Na]-: 375.1518. Found: 375.1516.

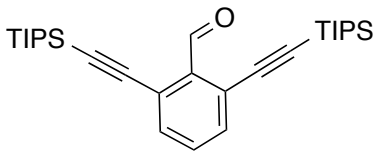



**5-Nitro-2-((triisopropylsilyl)ethynyl)benzaldehyde (300f).** General procedure F at room temperature. Obtained as a red solid in 90% yield (melting point = 61 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.60 (s, 1H), 8.71 (d, *J* = 2.4 Hz, 1H), 8.38 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.77 (d, *J* = 8.5 Hz, 1H), 1.19 – 1.10 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 189.4,

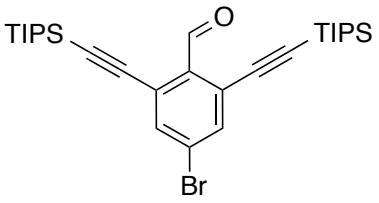
147.5, 137.1, 135.2, 132.5, 127.7, 122.3, 106.2, 100.3, 18.7, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{25}NaNO_3Si$ [M+Na]-: 354.1496. Found: 354.1491.



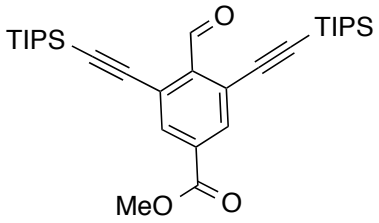

**5-(Trifluoromethyl)-2-((triisopropylsilyl)ethynyl)benzaldehyde (300g)**. General procedure F at 70 °C. Obtained as a yellow solid in 64% yield (melting point = 46 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.61 (s, 1H), 8.21 – 8.14 (m, 1H), 7.77 (dd, *J* = 8.2, 1.9 Hz, 1H), 7.71 (d, *J* = 8.2 Hz, 1H), 1.19 – 1.12 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 190.21, 136.44, 134.44, 130.79 (q, *J* = 33.7 Hz), 130.17, 129.87 (q, *J* = 3.6 Hz), 124.09 (q, *J* = 3.9 Hz), 123.2 (q, *J* = 270.2 Hz), 102.74, 100.62, 18.61, 11.20. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -63.31. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{29}F_3NaO_2Si$ [M+Na+CH3O]-: 409.1781. Found: 409.1775.



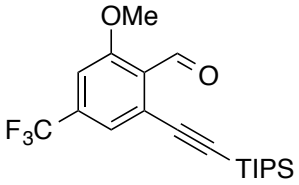

**2,6-Bis((triisopropylsilyl)ethynyl)benzaldehyde (300h).** General procedure F at room temperature using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**). 60% yield as a white solid (melting point = 50 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.72 (d, *J* = 1.3 Hz, 1H), 7.57 – 7.51 (m, 2H), 7.42 (m, 1H), 1.15 (d, *J* = 1.5 Hz, 42H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 190.4, 137.1, 134.3, 132.0, 125.3, 103.1, 99.1, 18.6, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{29}H_{46}NaOSi_2$ [M+Na]-: 489.2979. Found: 489.2982.



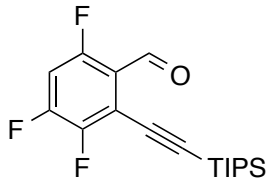

**4-Bromo-2,6-bis((triisopropylsilyl)ethynyl)benzaldehyde (300i).** General procedure F at room temperature using 2 equiv 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**). Obtained as a brown solid in 51% yield (melting point = 81 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.64 (s, 1H), 7.66 (s, 2H), 1.14 (m, 42H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 189.6, 136.9, 135.9, 126.8, 126.8, 101.7, 101.1, 18.8, 11.4. **HRMS** (ESI) *m/z* calc. for $C_{29}H_{45}BrNaOSi_2$ [M+Na]-: 567.2085. Found: 567.2085.



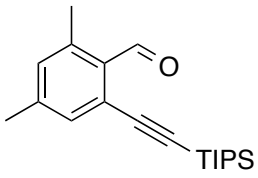

**Methyl 4-formyl-3,5-bis((triisopropylsilyl)ethynyl)benzoate (300j).** General procedure F at room temperature using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**). Obtained as a red solid in 50% yield (melting point = 62 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 10.73 (s, 1H), 8.12 (s, 2H), 3.96 (m, 3H), 1.14 (m, 42H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 190.0, 165.0, 139.7, 134.8, 133.2, 125.5, 102.1, 100.4, 52.8, 18.6, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{31}H_{48}NaO_3Si_2$ [M+Na]-: 547.3034. Found: 547.3050.



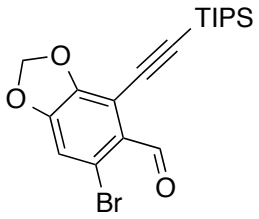

**2-Methoxy-4-(trifluoromethyl)-6-((triisopropylsilyl)ethynyl)benzaldehyde (300k).** General procedure F at room temperature. Obtained as a white solid in 85% yield (melting point = 55 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 10.62 (s, 1H), 7.38 (m, 1H), 7.14 – 7.12 (m, 1H), 3.96 (s, 3H), 1.13 (m, 21H). **$^{13}$C NMR (75 MHz, Chloroform-*d*)** δ = 189.2, 160.4, 135.4 (q, *J* = 33.0 Hz), 127.9, 127.7, 123.0 (q, *J* = 3.9 Hz), 122.9 (q, *J* = 275.6 Hz), 108.4 (q, *J* = 3.6 Hz), 101.9, 101.0, 56.3, 18.6, 11.2. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = - 63.80. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{27}F_3NaO_2Si$ [M+Na]-: 407.1625. Found: 407.1624.



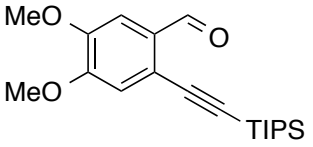

**3,4,6-Trifluoro-2-((triisopropylsilyl)ethynyl)benzaldehyde (300l).** General procedure F at room temperature. Obtained as a red solid in 95% yield (melting point = 42 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 10.41 (d, *J* = 1.1 Hz, 1H), 6.98 (td, *J* = 9.8, 6.1 Hz, 1H), 1.20 – 1.08 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 186.3 (d, *J* = 2.5 Hz), 158.2 (ddd, *J* = 263.1, 11.7, 3.3 Hz), 153.7 (dt, *J* = 260.6, 14.1 Hz), 149.0 (ddd, *J* = 252.8, 13.4, 4.1 Hz), 121.2 (dd, *J* = 8.7, 3.9 Hz), 117.6 – 116.9 (m), 109.5 (d, *J* = 5.1 Hz), 106.8 (dd, *J* = 27.1, 21.2 Hz), 93.3 (t, *J* = 4.0 Hz), 18.6, 11.3. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -116.5 (dt, *J* = 14.8, 9.7 Hz), -123.3 (dt, *J* = 21.3, 9.5 Hz), -136.8 (ddd, *J* = 21.2, 14.8, 6.2 Hz). **HRMS** (ESI) *m/z* calc. for $C_{18}H_{23}F_3NaOSi$ [M+Na]-: 363.1362. Found: 363.1364.



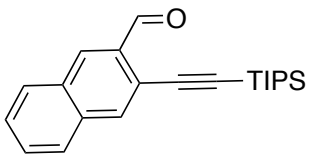

**2,4-Dimethyl-6-((triisopropylsilyl)ethynyl)benzaldehyde (300m)**. General procedure F at room temperature. Obtained as a white solid in 75% yield (melting point = 71 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.77 (s, 1H), 7.27 (m, 1H), 7.02 – 6.99 (m, 1H), 2.58 (s, 3H), 2.34 (s, 3H), 1.13 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 193.8, 143.3, 140.6, 133.1, 132.4, 132.0, 129.1, 103.1, 98.6, 21.5, 21.3, 18.7, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{30}NaOSi$ [M+Na]-: 337.1958. Found: 337.1956.



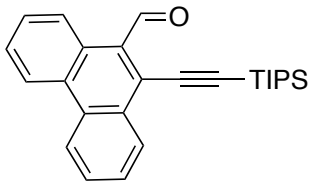

**6-Bromo-4-((triisopropylsilyl)ethynyl)benzo[*d*][1,3]dioxole-5-carbaldehyde (300n).** General procedure F at 70 °C. Obtained as a yellow solid in 43% yield (melting point = 102 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.35 (s, 1H), 7.04 (s, 1H), 6.15 (s, 2H), 1.14 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 189.4, 151.5, 151.1, 127.8, 118.7, 114.0, 108.2, 105.1, 103.3, 95.9. **HRMS** (ESI) *m/z* calc. for $C_{19}H_{25}NaBrO_3Si$ [M+Na]-: 431.0649. Found: 431.0642.



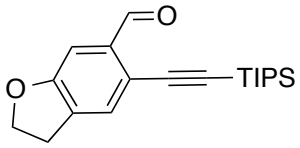

**4,5-Dimethoxy-2-((triisopropylsilyl)ethynyl)benzaldehyde (300o).** General procedure F at 70 °C. Obtained as a white solid in 79% yield (melting point = 92 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.43 (s, 1H), 7.37 (s, 1H), 6.95 (s, 1H), 3.95 (s, 3H), 3.92 (s, 3H), 1.12 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 190.6, 153.6, 149.9, 130.8, 121.8, 114.8, 108.1, 102.0, 97.5, 56.4, 56.2, 18.8, 11.4. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{30}NaO_3Si$ [M+Na]-: 369.1856. Found: 369.1868.



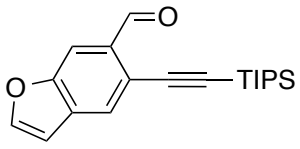
**3-((Triisopropylsilyl)ethynyl)-2-naphthaldehyde (300p)**. General procedure F at room temperature. Obtained as a white solid in 67% yield (melting point = 65 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.73 (s, 1H), 8.44 (s, 1H), 8.08 (s, 1H), 7.94 (dd, *J* = 8.1, 1.5 Hz, 1H), 7.85 – 7.78 (m, 1H), 7.58 (m, 2H), 1.18 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 192.0, 135.4, 134.1, 132.4, 132.0, 130.0, 129.4, 129.0, 127.8, 127.6, 121.4, 102.6, 98.0, 18.7, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{22}H_{28}NaOSi$ [M+Na]-: 359.1802. Found: 359.1800.




**10-((Triisopropylsilyl)ethynyl)phenanthrene-9-carbaldehyde (300q).** General procedure F at 120 °C. Obtained as a yellow solid in 37% yield (melting point = 87 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 11.29 (d, *J* = 1.1 Hz, 1H), 9.35 (ddd, *J* = 6.0, 3.1, 1.6 Hz, 1H), 8.77 – 8.72 (m, 1H), 8.68 (t, *J* = 6.4 Hz, 2H), 7.83 (tt, *J* = 8.3, 1.4 Hz, 1H), 7.77 – 7.68 (m, 3H), 1.27 – 1.20 (m, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 195.2, 132.5, 132.4, 131.2, 130.5, 130.3, 130.1, 128.6, 128.3, 128.2, 127.9, 127.7, 126.6, 123.0, 122.6, 108.4, 100.6, 29.8, 18.9, 11.6. **HRMS** (ESI) *m/z* calc. for $C_{26}H_{30}NaOSi$ [M+Na]-: 409.1958. Found: 409.1940.

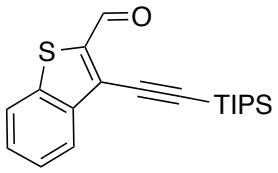



**5-((Triisopropylsilyl)ethynyl)-2,3-dihydrobenzofuran-6-carbaldehyde (300r).** General procedure F at room temperature. Obtained as a yellow solid in 61% yield (melting point = 40 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.45 (d, *J* = 0.8 Hz, 1H), 7.79 (d, *J* = 1.2 Hz, 1H), 6.93 (s, 1H), 4.73 – 4.62 (m, 2H), 3.25 (td, *J* = 8.8, 1.3 Hz, 2H), 1.14 (dm, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 190.3, 164.7, 130.6, 129.1, 128.9, 123.7, 113.6, 102.2, 98.3, 72.5, 28.8, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{28}NaO_2Si$ [M+Na]-: 351.1751. Found: 351.1759.

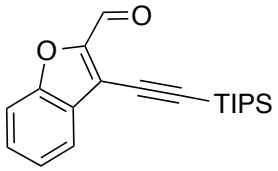



**5-((Triisopropylsilyl)ethynyl)benzofuran-6-carbaldehyde (300s).** General procedure F at 70 °C. Obtained a yellow liquid in 53%. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.67 (s, 1H), 8.20 (d, *J* = 0.5 Hz, 1H), 7.73 (d, *J* = 2.3 Hz, 1H), 7.70 (t, *J* = 0.8 Hz, 1H), 6.86 (dd, *J* = 2.2, 1.0 Hz, 1H), 1.15 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 191.7, 157.4, 147.9, 132.1,

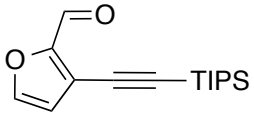
128.4, 123.3, 121.1, 116.6, 107.7, 102.5, 98.3, 18.8, 11.4. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{26}NaO_2Si$ [M+Na]-: 349.1594. Found: 349.1599.



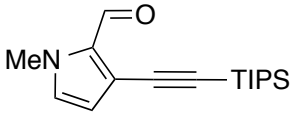

**3-((Triisopropylsilyl)ethynyl)benzo[*b*]thiophene-2-carbaldehyde (300t).** General procedure F at 70 °C. Obtained as a yellow solid in 40% yield (melting point = 98 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.42 (d, *J* = 1.0 Hz, 1H), 8.10 – 8.04 (m, 1H), 7.89 – 7.84 (m, 1H), 7.59 – 7.47 (m, 2H), 1.19 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 184.5, 144.4, 141.0, 139.6, 128.8, 128.1, 125.7, 124.9, 123.2, 102.6, 97.1, 29.7, 18.7, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{20}H_{26}NaOSSi$ [M+Na]-: 365.1366. Found: 365.1358.



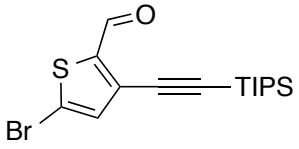

**3-((Triisopropylsilyl)ethynyl)benzofuran-2-carbaldehyde (300u).** General procedure F at 120 °C. Obtained as a yellow solid in 34% yield (melting point = 85 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.06 (s, 1H), 7.79 (dt, *J* = 7.9, 1.1 Hz, 1H), 7.61 – 7.49 (m, 2H), 7.40 (ddd, *J* = 8.1, 6.4, 1.7 Hz, 1H), 1.19 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 177.8, 155.3, 153.3, 130.0, 127.8, 124.6, 122.5, 116.3, 112.8, 104.3, 93.8, 18.7, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{21}H_{30}NaO_3Si$ [M+Na]-: 381.1856. Found: 381.1858.




**3-((Triisopropylsilyl)ethynyl)furan-2-carbaldehyde (300v)** General procedure F at 120 °C. Obtained as a brown liquid in 37% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 9.80 (d, *J* = 0.9 Hz, 1H), 7.60 (d, *J* = 1.4 Hz, 1H), 6.59 (d, *J* = 1.8 Hz, 1H), 1.12 (m, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 175.8, 153.6, 147.4, 120.1, 115.4, 101.3, 94.9, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{16}H_{25}O_2Si$ [M+H]-: 277.1618. Found: 277.1605.

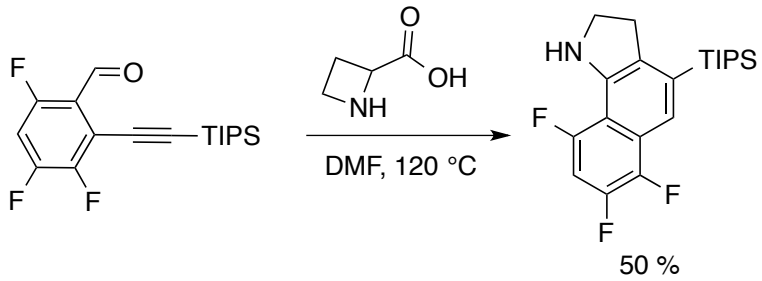


**1-Methyl-3-((triisopropylsilyl)ethynyl)-1*H*-pyrrole-2-carbaldehyde (300w).** General procedure F at 70 °C. Obtained as a red solid in 52% yield (melting point = 85 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 9.85 (s, 1H), 6.75 (d, *J* = 2.6 Hz, 1H), 6.29 (d, *J* = 2.7 Hz, 1H), 3.92 (s, 3H), 1.11 (m, 22H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 179.6, 133.0, 130.8, 119.3, 113.4, 98.8, 95.5, 37.1, 18.8, 11.4. **HRMS** (ESI) *m/z* calc. for $C_{17}H_{27}NNaOSi$ [M+Na]-: 312.1754. Found: 312.1740.




**5-Bromo-3-((triisopropylsilyl)ethynyl)thiophene-2-carbaldehyde (300x).** General procedure F at 120 °C. Obtained as a yellow solid in 30% yield (melting point = 61 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ 10.01 (s, 1H), 7.17 (s, 1H), 1.12 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 181.8, 145.8, 134.6, 131.4, 123.9, 100.7, 97.0, 18.7, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{16}H_{23}NaBrOSSi$ [M+Na]-: 393.0341. Found: 339.0320.

**Synthesis of 2,3-dihydro-1*H*-benzo[*g*]indole (300y):**



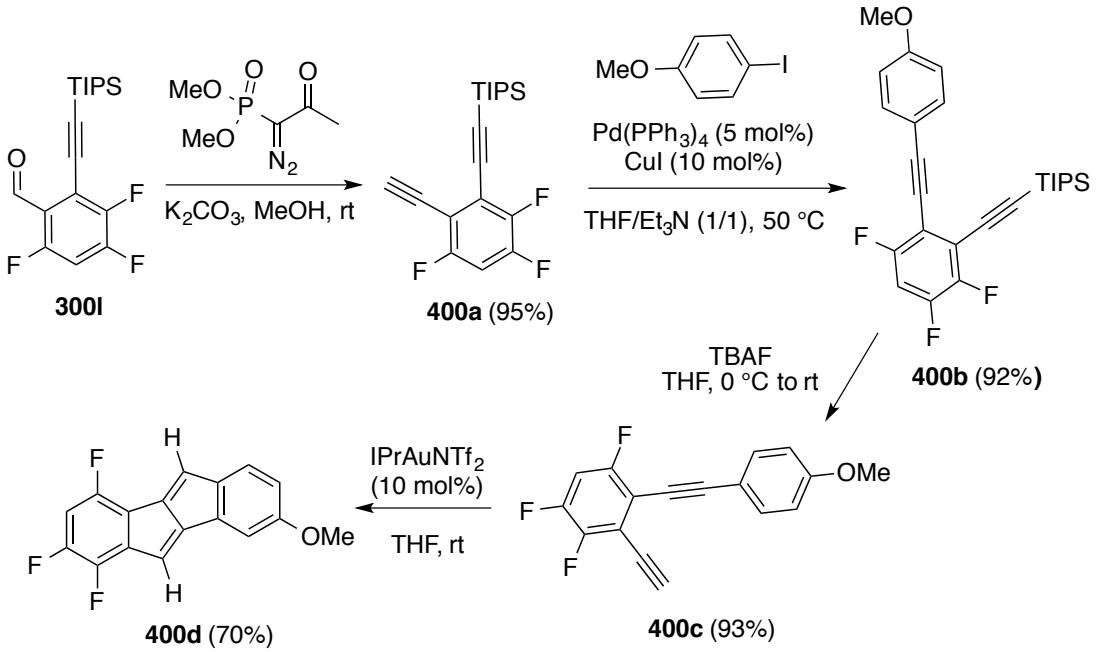

3,4,6-Trifluoro-2-((triisopropylsilyl)ethynyl)benzaldehyde (**300l**, 0.2 mmol, 1 equiv) and L-azetidine-2-carboxylic acid (1.1 equiv) are placed in a vial and stirred at 120 °C overnight. The reaction is cooled to room temperature and diluted with water, extracted with DCM, dried MgSO4 and concentrated. The crude is then purified by column chromatography using a gradient from cyclohexane 100% to ethyl acetate 100%. Obtained as a brown oil in 50% yield.

**6,7,9-Trifluoro-4-(triisopropylsilyl)-2,3-dihydro-1*H*-benzo[*g*]indole (300y)**

**$^1$H NMR (500 MHz, Chloroform-*d*)** δ 7.53 (d, *J* = 2.4 Hz, 1H), 6.84 (ddd, *J* = 11.7, 10.1, 6.1 Hz, 1H), 3.72 (t, *J* = 8.8 Hz, 2H), 3.19 (t, *J* = 8.8 Hz, 2H), 1.53 (m, 3H), 1.13 (m, 18H). **$^{13}$C NMR (126 MHz, Chloroform-*d*)** δ = 186.4, 154.6 (ddd, *J* = 248.4, 10.9, 3.7 Hz), 145.7 – 143.3 (m), 144.9 (m), 141.8 (ddd, *J* = 246.1, 11.7, 5.1 Hz), 134.0, 129.3, 124.4 (dd, *J* = 14.0,

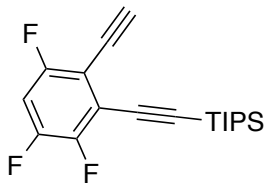
6.7 Hz), 117.4 (td, *J* = 4.5, 2.2 Hz), 108.7 (dd, *J* = 16.0, 4.3 Hz), 106.4, 100.3 (dd, *J* = 27.5, 25.0 Hz), 47.8, 31.6, 19.0, 12.0. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -119.8 (dd, *J* = 18.6, 11.6 Hz), -140.7 (dd, *J* = 18.7, 10.0 Hz), -153.2 (td, *J* = 19.0, 6.1 Hz). **HRMS** (ESI) *m/z* calc. for $C_{21}H_{29}F_3NSi$ [M+H]-: 380.2016. Found: 380.2016.

**Synthesis of dibenzopentalenes:**




Seyferth-Gilberth homologation:

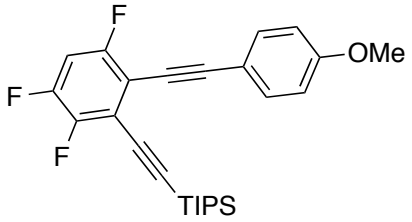
2-alkynylbenzaldehyde **300l** (1 equiv) and potassium carbonate (2 equiv) were placed in an oven dried round bottom flask under argon. Anhydrous methanol (0.1M) was added and the mixture was stirred at room temperature under an argon atmosphere for 5 min. Dimethyl (1-diazo-2-oxopropyl)phosphonate solution (10% in acetonitrile) (1.1 equiv) was added to reaction mixture. The mixture was stirred at room temperature under an argon atmosphere for 4 hours. The reaction was monitored by thin layer chromatography. The reaction mixture was diluted with ether and washed with aqueous sodium bicarbonate (5%) and dried over sodium sulfate. Solvent was evaporated and the crude was purified using column chromatography, with a gradient from cyclohexane 100% to cyclohexane/ethyl acetate 1/1 to yield the corresponding product to yield **400a** in 90% yiled as a colorless oil.




**((2-Ethynyl-3,5,6-trifluorophenyl)ethynyl)triisopropylsilane (400a): $^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.00 – 6.83 (m, 1H), 3.49 (d, *J* = 0.9 Hz, 1H), 1.15 (d, *J* = 2.5 Hz, 21H). **$^{13}$C NMR (126 MHz, Chloroform-*d*)** δ 159.9 – 157.7 (m), 151.6 – 149.3 (m), 148.2 (ddd, *J* = 250.7, 13.7, 4.0 Hz), 118.2 (d, *J* = 15.5 Hz), 110.6 – 110.2 (m), 106.0 – 105. (m), 105.7 (m) , 95.7 (t, *J* = 4.1 Hz), 87.0 (dd, *J* = 4.2, 2.4 Hz), 74.2 (t, *J* = 2.8 Hz), 18.7, 11.3. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -110.5 (ddd, *J* = 13.5, 8.6, 5.0 Hz), -130.6 (ddd, *J* = 21.7, 9.8, 5.0 Hz), -137.4 (ddd, *J* = 20.6, 13.6, 6.5 Hz). **HRMS** (APCI) *m/z* calc. for $C_{19}H_{24}F_3Si$ [M+H]: 337.1594. Found: 375.1596.

Sonogashira coupling:

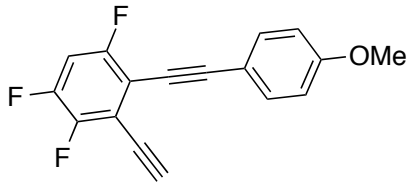
Terminal alkyne **400a** (0.2 mmol, 1 equiv), 4-methoxybenzeneboronic acid (1 equiv), CuI (0.1 equiv) and $Pd(PPh_3)_4$ were weighted inside a vial in a glovebox. Dry THF (0.1M) and dry triethylamine (0.1M) are then added and the reaction is stirred at 50 °C overnight. The reaction mixture is then concentrated under vacuum and purified using column chromatography, with a gradient from cyclohexane 100% to cyclohexane/ethyl acetate 1/1 to yield **400b** in 95% yield as a colorless oil.




**Triisopropyl((2,3,5-trifluoro-6-((4-methoxyphenyl)ethynyl)phenyl)ethynyl)silane (400b). $^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.52 – 7.46 (m, 2H), 6.98 – 6.90 (m, 1H), 6.90 – 6.86 (m, 2H), 3.84 (s, 3H), 1.15 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 160.3, 157.9 (ddd, *J* = 250.0, 10.7, 3.1 Hz), 150.0 (m), 148.4 (m), 133.5, 117.0 (dt, *J* = 15.0, 3.5 Hz), 114.7, 114.0, 112.0 (dd, *J* = 18.9, 3.9 Hz), 105.6 (dd, *J* = 27.5, 21.7 Hz), 104.8 (d, *J* = 5.0 Hz), 99.2 (dd, *J* = 4.3, 2.3 Hz), 96.3 (t, *J* = 4.1 Hz), 78.8 (t, *J* = 2.9 Hz), 55.4, 18.7, 11.3. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -110.2 (ddd, *J* = 13.2, 8.6, 4.3 Hz), -132.0 (ddd, *J* = 21.7, 9.8, 4.3 Hz), -137.4 (ddd, *J* = 21.8, 13.4, 6.5 Hz). **HRMS** (APCI) *m/z* calc. for $C_{26}H_{30}F_3OSi$ [M+H]: 443.2013. Found: 443.2011.

Removal of silyl group:

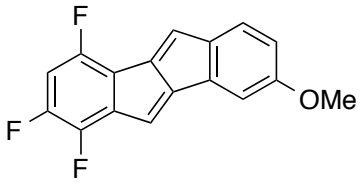
Diyne **400b** (0.2 mmol, 1 equiv) was dissolved in dry THF at 0 °C under argon. TBAF (1.1 equiv, 1M in THF) is then added dropwise. The reaction was warmed to room temperature and monitored by TLC. After completion, the reaction was is quenched with water, extracted with DCM, dried over MgSO4, concentrated and the crude was purified using column chromatography, with a gradient from cyclohexane 100% to cyclohexane/ethyl acetate 1/1 to yield **400c** in 85% yield as a colorless oil.




**3-Ethynyl-1,2,5-trifluoro-4-((4-methoxyphenyl)ethynyl)benzene (400c). $^{1}$H NMR (400 MHz, Chloroform-*d*)** δ = 7.53 – 7.49 (m, 1H), 6.97 (ddd, *J* = 9.9, 8.6, 6.7 Hz, 1H), 6.91 – 6.87 (m, 1H), 3.83 (s, 3H), 3.71 (d, *J* = 0.8 Hz, 1H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 160.5, 157.6 (ddd, *J* = 250.4, 10.6, 3.2 Hz), 149.5 (m), 148.4 (m), 133.53, 114.44, 114.20, 112.49 (dd, *J* = 19.2, 4.1 Hz), 106.39 (dd, *J* = 27.3, 21.7 Hz), 99.67 (dd, *J* = 4.0, 2.4 Hz), 88.78 (d, *J* = 4.8 Hz), 78.55 (t, *J* = 2.8 Hz), 74.13 (t, *J* = 4.4 Hz), 55.38. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -110.3 (dd, *J* = 13.4, 4.3 Hz), -131.9 (dd, *J* = 21.5, 4.3 Hz), -136.5 – -138.8 (m). **HRMS** (APCI) *m/z* calc. for $C_{17}H10F_3O$ [M+H]: 287.0678. Found: 287.0678.

Au(I)-catalyzed cyclization of diynes:

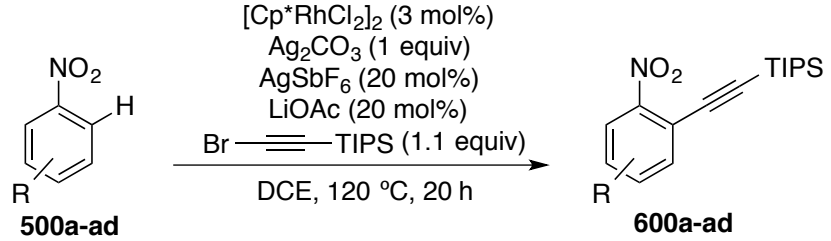
Diyne **400c** (0.2 mmol, 1 equiv) was dissolved in THF at room temperature under air. $IPrAuNTf_2$ (10 mol %) is then added and the reaction mixture was stirred overnight at room temperature overnight. The reaction mixture was then concentrated under vacuo and purified using column chromatography, with a gradient from cyclohexane 100% to cyclohexane/ethyl acetate 1/1 to yield **400d** in 70% yield as red solid.



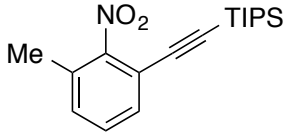

**1,3,4-Trifluoro-7-methoxyindeno[2,1-*a*]indene (400d). $^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 6.97 (d, *J* = 8.1 Hz, 1H), 6.56 – 6.52 (m, 2H), 6.46 – 6.42 (m, 1H), 6.40 (dd, *J* = 8.2, 2.4 Hz, 1H), 6.29 (dd, *J* = 2.6, 1.7 Hz, 1H), 3.77 (s, 3H). **$^{13}$C NMR (126 MHz, Chloroform-*d*)** δ 160.9, 151.6, 151.0 (m), 150.4 (m), 147.0 (m), 143.5 (m), 132.48 (d, *J* = 18.0 Hz), 131.06 (dd, *J* = 4.1, 1.6 Hz), 127.50, 126.63, 123.39, 118.01 (q, *J* = 2.5 Hz), 114.44, 112.27, 111.25, 105.37 (dd, *J* = 27.7, 22.3 Hz), 55.60. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -123.0 (dd, *J* = 16.7, 8.2 Hz), -136.2 (dd, *J* = 21.3, 10.8 Hz), -143.8 – -145.8 (m). **HRMS** (APCI) *m/z* calc. for

$C_{17}H_{10}F_3OSi$ [M+H]: 287.0678. Found: 287.0677. X-ray quality crystals were obtained by slow evaporation in $CDCl_3$.

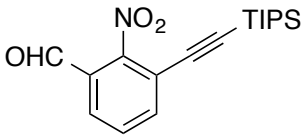
**General procedure for the *ortho* C-H alkynylation of nitrobenzenes (G)**



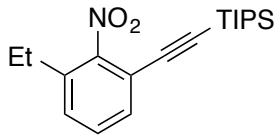

$[Cp^*RhCl_2]_2$ (3 mol %), $Ag_2CO_3$ (1 equiv), LiOAc (0.2 equiv), $AgSbF_6$ (0.2 equiv) were weighted in a vial inside a glovebox and dichloroethane (0.15M) is added. Corresponding nitrobenzene **500a-ad** (0.2 mmol) and 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) (1.1 equiv) are then added and the vial is sealed. The reaction mixture is stirred at 120 °C for 16 h. After cooling to the room temperature, the reaction mixture is filtrated through celite and purified by column chromatography, with a gradient from cyclohexane 100% to 1/1 cyclohexane/ethyl acetate to yield corresponding product **600a-ad**.



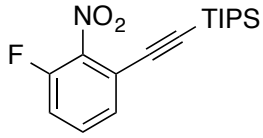

**Triisopropyl((3-methyl-2-nitrophenyl)ethynyl)silane (600a).** General procedure G and obtained as a colorless liquid in 95% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.43 (dt, *J* = 7.6, 1.0 Hz, 1H), 7.32 (t, *J* = 7.7 Hz, 1H), 7.24 (ddd, *J* = 7.6, 1.5, 0.7 Hz, 1H), 2.34 (s, 3H), 1.13 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 153.3, 131.1, 131.0, 129.7, 116.5, 99.5, 98.6, 18.5, 17.3, 11.2. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{28}NO_2Si$ [M+H]-: 318.1884. Found: 318.1884.



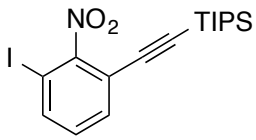

**2-Nitro-3-((triisopropylsilyl)ethynyl)benzaldehyde (600b).** General procedure G and obtained as an orange solid in 74% yield (melting point = 50 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 10.49 (s, 1H), 7.81 (m, 2H), 7.60 (t, *J* = 8.0 Hz, 1H), 1.13 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 188.3, 148.1, 137.7, 132.8, 132.1, 125.7, 123.4, 101.7, 100.4, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{25}NNaO_3Si$ [M+Na]-: 354.1496. Found: 354.1496.



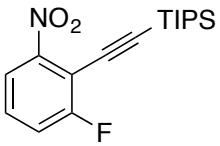

**((3-Ethyl-2-nitrophenyl)ethynyl)triisopropylsilane (600c).** General procedure G and obtained as a yellow liquid in 91% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.41 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 1H), 7.27 (dd, *J* = 7.4, 1.8 Hz, 1H), 2.61 (q, *J* = 7.6 Hz, 2H), 1.23 (t, *J* = 7.6 Hz, 3H), 1.11 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 153.0, 135.4, 130.9, 129.8, 129.6, 116.3, 99.4, 98.4, 24.4, 18.5, 14.8, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{19}H_{30}NO_2Si$ [M+H]-: 332.2040. Found: 332.2027.




**((3-Fluoro-2-nitrophenyl)ethynyl)triisopropylsilane (600d).** General procedure G and obtained as a colorless liquid in 54% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.49 – 7.36 (m, 2H), 7.22 (ddd, *J* = 9.6, 7.9, 1.8 Hz, 1H), 1.13 (s, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 153.5 (d, *J* = 258 Hz), 131.60 (d, *J* = 8 Hz), 129.14 (d, *J* = 3 Hz), 119.0, 117.1, 116.9, 101.4, 98.1 (d, *J* = 3.7 Hz), 18.48, 11.12. **HRMS** (APCI) *m/z* calc. for $C_{17}H_{25}FNO_2Si$ [M+H]-: 322.1633. Found: 322.1632.

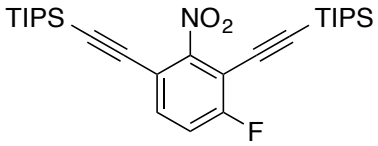



**((3-Iodo-2-nitrophenyl)ethynyl)triisopropylsilane (600e).** General procedure G and obtained as a colorless liquid in 71% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.81 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.53 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.12 (t, *J* = 7.9 Hz, 1H), 1.10 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 157.2, 139.6, 132.6, 130.5, 117.3, 100.7, 98.3, 84.4, 18.5, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{17}H_{25}INO_2Si$ [M+H]-: 430.0694. Found: 430.0702.

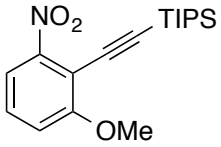



**((2-Fluoro-6-nitrophenyl)ethynyl)triisopropylsilane (600f).** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a red solid in 60% yield (melting point = 70 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.83 (dt, *J* = 7.7, 1.4 Hz, 1H), 7.46 – 7.32 (m, 2H), 1.15 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 163.9 (d, *J* = 255.7 Hz), 150.8, 128.8 (d, *J* = 8.8 Hz), 120.03 (d, *J* = 4.9 Hz), 119.77 (d, *J* = 20.5 Hz),

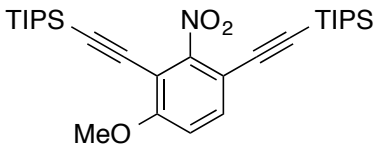
108.59 (d, *J* = 20.5 Hz), 107.84 (d, *J* = 4.9 Hz), 93.24, 18.50, 11.17. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -104.62 (dd, *J* = 8.0, 5.5 Hz). **HRMS** (APCI) *m/z* calc. for $C_{17}H_{25}FNO_2Si$ [M+H]-: 322.1633. Found: 322.1644.



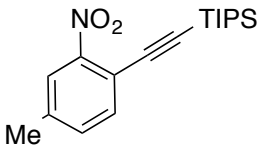

**((4-Fluoro-2-nitro-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane) (600f').** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a white solid in 30% yield (melting point = 70 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.48 (dd, *J* = 8.7, 5.2 Hz, 1H), 7.16 (t, *J* = 8.4 Hz, 1H), 1.10 (m, 42H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 162.1 (d, *J* = 259.4 Hz), 155.3, 133.7 (d, *J* = 8.6 Hz), 117.3 (d, *J* = 22.0 Hz), 112.9 (d, *J* = 4.4 Hz), 107.0 (d, *J* = 21.9 Hz), 106.2 (d, *J* = 3.6 Hz), 99.6 (d, *J* = 1.8 Hz), 97.6 (d, *J* = 1.6 Hz), 91.6, 18.5, 18.4, 11.1, 11.1. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -103.51 (dd, *J* = 8.0, 5.2 Hz). **HRMS** (APCI) *m/z* calc. for $C_{28}H_{45}FNO_2Si_2$ [M+H]-: 502.2967. Found: 502.2969.



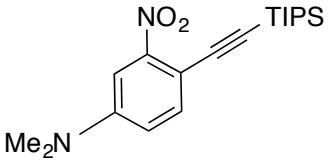

**Triisopropyl((2-methoxy-6-nitrophenyl)ethynyl)silane (600g).** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a brown solid in 30% yield (melting point = 75 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.52 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.35 (t, *J* = 8.3 Hz, 1H), 7.09 (dd, *J* = 8.4, 1.1 Hz, 1H), 3.92 (s, 3H), 1.15 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 162.1, 152.2, 128.7, 115.9, 114.6, 108.4, 105.9, 96.1, 56.6, 18.6, 11.3. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{28}NO_3Si$ [M+H]-: 334.1833. Found: 334.1828.



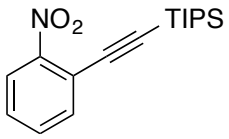

**((4-Methoxy-2-nitro-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane) (600g').** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a brown solid in 15% yield (melting point = 85 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.46 (d, *J* = 8.7 Hz, 1H), 6.90 (d, *J* = 8.8 Hz, 1H), 3.93 (s, 3H), 1.12 (s, 21H), 1.11 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 160.7, 156.0, 133.6, 111.9, 108.43 106.8, 104.1, 98.6, 97.0, 94.5, 18.5, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{29}H_{48}NO_3Si_2$ [M+H]-: 514.3167. Found: 514.3169.



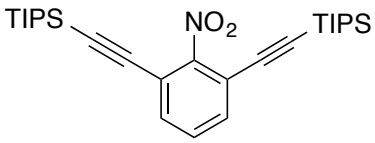

**Triisopropyl((4-methyl-2-nitrophenyl)ethynyl)silane (600h).** General procedure G and obtained as a red solid in 85% yield (melting point = 55 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.82 (dd, *J* = 1.8, 0.9 Hz, 1H), 7.55 (d, *J* = 7.9 Hz, 1H), 7.35 (ddd, *J* = 7.9, 1.8, 0.8 Hz, 1H), 2.44 (s, 3H), 1.16 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 149.8, 139.6, 135.1, 133.3, 124.7, 115.7, 101.2, 99.4, 21.2, 18.5, 11.2. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{28}NO_2Si$ [M+H]-: 318.1884. Found: 318.1882.




***N*,*N*-Dimethyl-3-nitro-4-((triisopropylsilyl)ethynyl)aniline (600i).** General procedure G and obtained as a red solid in 65% yield (melting point = 105 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.46 (d, *J* = 8.8 Hz, 1H), 7.21 (d, *J* = 2.7 Hz, 1H), 6.78 (dd, *J* = 8.8, 2.7 Hz, 1H), 3.04 (s, 6H), 1.15 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 151.2, 149.7, 135.9, 115.3, 106.50, 104.8, 102.3, 95.7, 40.1, 18.6, 11.3. **HRMS** (ESI) *m/z* calc. for $C_{19}H_{31}N_2O_2Si$ [M+H]-: 347.2149. Found: 347.2146.

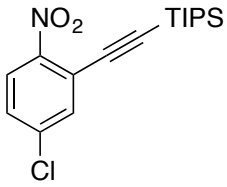



**Triisopropyl((2-nitrophenyl)ethynyl)silane (600j).** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and as a white solid in 75% yield (melting point = 55 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 8.03 (dd, *J* = 8.2, 0.9 Hz, 1H), 7.69 (dd, *J* = 7.7, 1.3 Hz, 1H), 7.57 (td, *J* = 7.6, 1.3 Hz, 1H), 7.49 – 7.42 (m, 1H), 1.17 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 150.0, 135.4, 132.6, 128.6, 124.4, 118.7, 101.1, 100.8, 18.6, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{17}H_{25}NNaO_2Si$ [M+Na]-: 326.1547. Found: 326.1536.

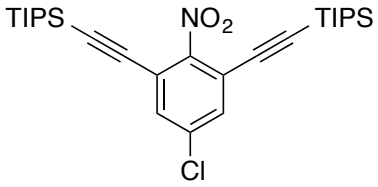



**((2-Nitro-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane) (600j').** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a purple solid in 15% yield (melting point = 75 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ =

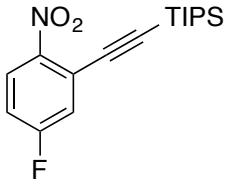
7.52 (d, *J* = 8.2 Hz, 2H), 7.37 (dd, *J* = 8.2, 7.1 Hz, 1H), 1.12 (s, 42H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 154.8, 132.9, 129.6, 116.8, 99.9, 98.5, 18.5, 11.1. **HRMS** (ESI) *m/z* calc. for $C_{28}H_{45}NNaO_2Si_2$ [M+Na]-: 506.2881. Found: 506.2861.



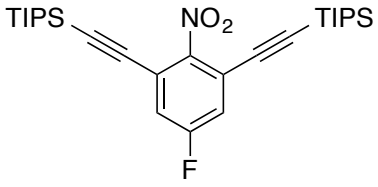

**((5-Chloro-2-nitrophenyl)ethynyl)triisopropylsilane (600k).** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained in 34% yield as a white solid (melting point = 60 °C). **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 8.00 (d, *J* = 8.8 Hz, 1H), 7.62 (d, *J* = 2.3 Hz, 1H), 7.40 (dd, *J* = 8.8, 2.3 Hz, 1H), 1.14 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 155.1, 139.2, 135.0, 128.8, 125.9, 120.4, 103.0, 99.9, 18.6, 11.2. **HRMS** (APCI) *m/z* calc. for $C_{17}H_{25}ClNO_2Si$ [M+H]-: 338.1338. Found: 338.1340.



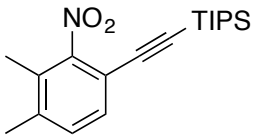

**((5-Chloro-2-nitro-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane) (600k').** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a yellow liquid in 18% yield. **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 7.47 (s, 2H), 1.10 (m, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 153.1, 135.6, 132.5, 118.3, 101.7, 97.4, 18.5, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{28}H_{45}ClNO_2Si_2$ [M+H]-: 518.2672. Found: 518.2673.



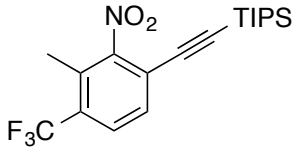

**((5-Fluoro-2-nitrophenyl)ethynyl)triisopropylsilane (600l).** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a red liquid in 56% yield. **$^{1}$H NMR (300 MHz, Chloroform-*d*)** δ = 8.09 (dd, *J* = 9.1, 5.1 Hz, 1H), 7.33 (dd, *J* = 8.5, 2.8 Hz, 1H), 7.13 (ddd, *J* = 9.1, 7.2, 2.8 Hz, 1H), 1.14 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 164.2 (d, *J* = 257.2 Hz), 146.2, 127.2 (d, *J* = 10.2 Hz), 122.0 (d, *J* = 24.5 Hz), 121.5 (d, *J* = 11.0 Hz), 116.0 (d, *J* = 23.4 Hz), 103.0, 100.1 (d, *J* = 2.1 Hz), 18.6, 11.2. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -104.60 (td, *J* = 7.9, 5.1 Hz). **HRMS** (APCI) *m/z* calc. for $C_{17}H_{25}FNO_2Si$ [M+H]-: 322.1633. Found: 322.1641.



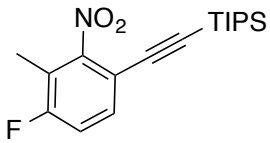

**((5-Fluoro-2-nitro-1,3-phenylene)bis(ethyne-2,1-diyl))bis(triisopropylsilane) (600l').** General procedure G using 2 equiv of 1-Bromo-2-(triisopropylsilyl)acetylene (**2a**) and obtained as a yellow liquid in 30% yield. **$^{1}$H NMR (400 MHz, Chloroform-*d*)** δ = 7.19 (s, 2H), 1.10 (m, 42H). **$^{13}$C NMR (75 MHz, Chloroform-*d*)** δ = 161.5 (d, *J* = 253.4 Hz), 154.0, 119.9 (d, *J* = 24.7 Hz), 119.0 (d, *J* = 11.5 Hz), 101.6, 97.7, 18.5, 11.1. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -108.68 (t, *J* = 8.1 Hz). **HRMS** (APCI) *m/z* calc. for $C_{28}H_{45}FNO_2Si_2$ [M+H]-: 502.2967. Found: 502.2965.



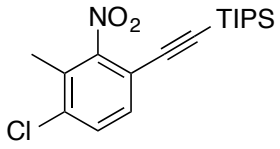

**((3,4-Dimethyl-2-nitrophenyl)ethynyl)triisopropylsilane (600m).** General procedure G at 110 °C and obtained as a white solid in 86% yield (melting point = 89 °C). **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 7.30 (d, *J* = 7.9 Hz, 1H), 7.18 (d, *J* = 7.9 Hz, 1H), 2.32 (s, 3H), 2.18 (s, 3H), 1.10 (s, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ 154.2, 139.3, 131.0, 130.4, 128.0, 113.9, 99.8, 97.6, 20.4, 18.7, 14.4, 11.3. **HRMS** (APCI) m/z calcd for $C_{19}H_{30}NO_2Si$ [M+H] : 332.2040. Found 332.2042.



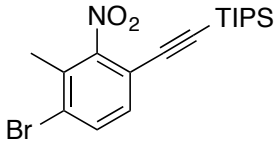

**Triisopropyl((3-methyl-2-nitro-4-(trifluoromethyl)phenyl)ethynyl)silane (600n).** General procedure G at 110 °C and obtained as a white solid in 32% yield (melting point 83 °C). **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ 7.68 (d, *J* = 8.2 Hz, 1H), 7.51 (d, *J* = 8.2 Hz, 1H), 2.39 (d, *J* = 1.6 Hz, 3H), 1.14 – 1.08 (m, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 155.0, 130.8 (q, *J* = 31.3 Hz), 128.8 (q, *J* = 31.3 Hz), 127.1 (q, *J* = 5.7 Hz), 123.2 (q, *J* = 274.13 Hz), 120.1, 102.44, 98.2, 18.6, 13.8 (q, *J* = 2.4 Hz), 11.26. **$^{19}$F{$^{1}$H} NMR (471 MHz, $CDCl_3$)** δ = -61.4. **HRMS** (APCI) m/z calcd for $C_{19}H_{27}F_3NO_2Si$ [M+H] : 386.1758. Found 386.1753.



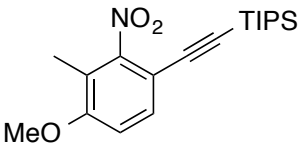
**((4-Fluoro-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600o).** General procedure G and obtained as a white solid at 110 °C in 65% yield (melting point = 44 °C). **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 7.41 (dd, *J* = 8.6, 5.3 Hz, 1H), 7.11 (t, *J* = 8.7 Hz, 1H), 2.23 (d, *J* = 2.1 Hz, 3H), 1.10 (s, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 160.5 (d, *J* = 252.4 Hz), 154.4, 132.2 (d, *J* = 8.74 Hz), 118.7 (d, *J* = 22.4 Hz), 117.1 (d, *J* = 23.6 Hz), 112.8 (d, *J* = 4.3 Hz), 98.64 (d, *J* = 1.6 Hz), 98.59 (d, *J* = 1.9 Hz), 30.5, 18.7, 11.3, 10.0 (d, *J* = 4.1 Hz). **$^{19}$F{$^{1}$H} NMR (471 MHz, $CDCl_3$)** δ = -110.2. **HRMS** (APCI) m/z calcd for $C_{18}H_{27}FNO_2Si$ [M+H] : 336.1790. Found 336.1775.




**((4-Chloro-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600p).** General procedure (G) at 110 ° and obtained as a white solid in C 65% yield (melting point = 70 °C). **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 7.41 (d, *J* = 8.4 Hz, 1H), 7.35 (d, *J* = 8.4 Hz, 1H), 2.32 (s, 3H), 1.10 (d, *J* = 3.5 Hz, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 154.4, 135.8, 131.4, 130.6, 128.5, 115.1, 100.0, 98.6, 18.6, 15.3, 11.3. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}ClNO_2Si$ [M+H]: 352.1494. Found: 352.1491.

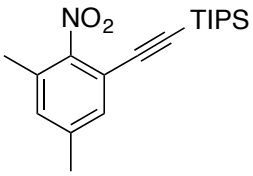



**((4-Bromo-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600q).** General procedure (G) at 110 °C qnd obtained as a white solid in 67% yield (melting point = 83 °C). **$^{1}$H NMR** (500 MHz, **Chloroform-*d***) δ 7.60 (d, *J* = 8.3 Hz, 1H), 7.27 (d, *J* = 8.4 Hz, 1H), 2.35 (s, 3H), 1.10 (d, *J* = 3.6 Hz, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ 154.1, 133.9, 131.5, 130.0, 126.0, 115.7, 100.2, 98.7, 18.6, 18.3, 11.3. **HRMS** (APCI) m/z calcd for $C_{18}H_{27}BrNO_2Si$ [M+H] : 396.0989. Found 396.0983.

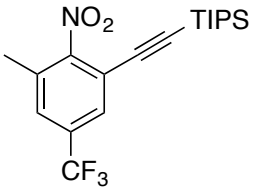



**Triisopropyl((4-methoxy-3-methyl-2-nitrophenyl)ethynyl)silane (600r).** General procedure G at 110 °C and obtained as a white solid in 86% yield (melting point = 99 °C). **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 7.38 (d, *J* = 8.6 Hz, 1H), 6.84 (d, *J* = 8.6 Hz, 1H), 3.88 (s, 3H), 2.13 (s, 3H), 1.10 (s, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 158.2, 154.5, 131.8,

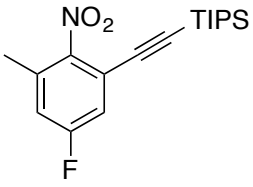
119.2, 111.1, 108.2, 99.7, 96.2, 56.3, 18.68, 11.4, 10.9. **HRMS** (APCI) m/z calcd for $C_{19}H_{30}NO_3Si$ [M+H] : 348.1989. Found 348.1993.



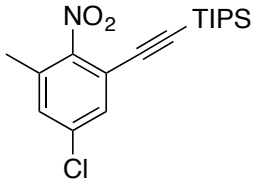

**((3,5-Dimethyl-2-nitrophenyl)ethynyl)triisopropylsilane (600s).** Grocedure procedure G and obtained as a white solid in 95% yield (melting point = 55 °C). **$^1$H NMR (400 MHz, Chloroform-*d*)** δ = 7.23 (s, 1H), 7.04 (s, 1H), 2.34 (s, 3H), 2.30 (s, 3H), 1.13 (s, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 151.1, 140.2, 131.8, 131.4, 129.8, 116.4, 99.8, 97.9, 20.9, 18.5, 17.4, 11.2. **HRMS** (APCI) *m/z* calc. for $C_{19}H_{30}NO_2Si$ [M+H]: 332.2040. Found: 332.2038.



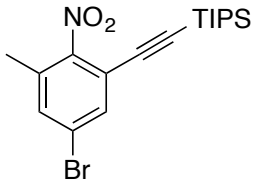

**Triisopropyl((3-methyl-2-nitro-5-(trifluoromethyl)phenyl)ethynyl)silane (600t).** General procedure G and obtained as a yellow liquid in 32% yield. **$^1$H NMR (500 MHz, Chloroform-*d*)** δ = 7.68 – 7.64 (m, 1H), 7.50 (dd, *J* = 1.9, 1.0 Hz, 1H), 2.39 (s, 3H), 1.13 – 1.09 (m, 21H). **$^{13}$C NMR (126 MHz, Chloroform-*d*)** δ = 154.9, 132.1 (q, *J* = 33.5 Hz), 130.9, 128.0 (q, *J* = 3.7 Hz), 127.8 (q, *J* = 3.7 Hz), 122.7 (q, *J* = 273.2 Hz), 117.5, 101.4, 100.0, 97.9, 18.5, 17.3, 11.1. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -63.29. **HRMS** (APCI) *m/z* calc. for $C_{19}H_{27}F_3NO_2Si$ [M+H]-: 386.1758. Found: 386.1763.



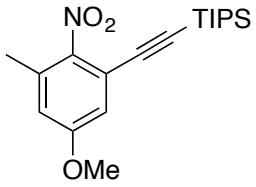

**((5-Fluoro-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600u).** General procedure G and obtained as a yellow liquid in 65% yield. **$^1$H NMR (400 MHz, Chloroform-*d*)** δ = 7.10 (ddd, *J* = 8.3, 2.7, 0.6 Hz, 1H), 6.97 – 6.92 (m, 1H), 2.34 (d, *J* = 0.7 Hz, 3H), 1.10 (m, 21H). **$^{13}$C NMR (101 MHz, Chloroform-*d*)** δ = 161.8 (d, *J* = 252.3 Hz), 149.7, 133.0 (d, *J* = 9.4 Hz), 118.9 (d, *J* = 10.8 Hz), 118.1 (d, *J* = 23.2 Hz), 117.8 (d, *J* = 24.8 Hz), 100.4, 98.4 (d, *J* = 2.8 Hz), 18.5, 17.8 (d, *J* = 1.4 Hz), 11.1. **$^{19}$F NMR (376 MHz, Chloroform-*d*)** δ = -109.29 (t, *J* = 8.4 Hz). **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}FNO_2Si$ [M+H]-: 336.1790. Found: 336.1804.



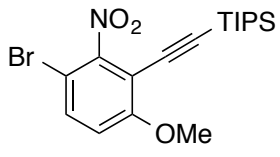

**((5-Chloro-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600v).** General procedure G and obtained as a yellow liquid in 66% yield. **$^{1}$H NMR (400 MHz, Chloroform-*d*)** δ = 7.39 (dd, *J* = 2.2, 0.7 Hz, 1H), 7.23 (dq, *J* = 2.3, 0.8 Hz, 1H), 2.31 (d, *J* = 0.7 Hz, 3H), 1.10 (m, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 151.6, 135.5, 131.7, 130.9, 130.7, 118.2, 100.6, 98.2, 18.5, 17.4, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}ClNO_2Si$ [M+H]-: 352.1494. Found: 352.1501.



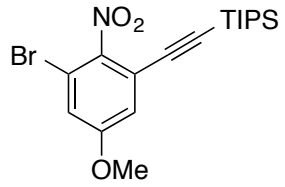

**((5-Bromo-3-methyl-2-nitrophenyl)ethynyl)triisopropylsilane (600w).** General procedure G and obtained as a yellow liquid in 67% yield. **$^{1}$H NMR (400 MHz, Chloroform-*d*)** δ = 7.55 (dd, *J* = 2.1, 0.7 Hz, 1H), 7.39 (dq, *J* = 1.5, 0.7 Hz, 1H), 2.31 (d, *J* = 0.7 Hz, 3H), 1.12 – 1.09 (m, 21H). **$^{13}$C NMR (101 MHz, $CDCl_3$)** δ = 152.1, 133.9, 133.5, 131.8, 123.5, 118.3, 100.7, 98.1, 18.5, 17.3, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}BrNO_2Si$ [M+H]-: 396.0989. Found: 396.0990.



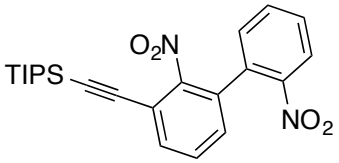

**Triisopropyl((5-methoxy-3-methyl-2-nitrophenyl)ethynyl)silane (600x)**. General procedure G and obtained as a yellow liquid in 81% yield. **$^{1}$H NMR (500 MHz, Chloroform-*d*)** δ = 6.86 (d, *J* = 2.7 Hz, 1H), 6.71 (dd, *J* = 2.7, 0.8 Hz, 1H), 3.82 (s, 3H), 2.31 (s, 3H), 1.11 (m, 21H). **$^{13}$C NMR (126 MHz, $CDCl_3$)** δ = 159.8, 146.9, 132.4, 118.4, 116.8, 115.6, 99.9, 98.4, 55.7, 18.5, 18.2, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{19}H_{30}NO_3Si$ [M+H]-: 348.1989. Found: 348.1999.



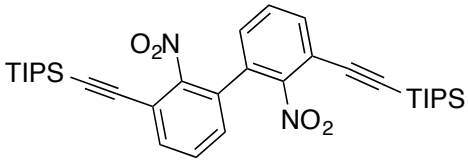
**((3-Bromo-6-methoxy-2-nitrophenyl)ethynyl)triisopropylsilane (600y)**. General procedure G and obtained as a red solid in 81% yield (melting point = 79 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.49 (d, *J* = 9.0 Hz, 1H), 6.86 (d, *J* = 9.0 Hz, 1H), 3.91 (s, 3H), 1.12 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 160.3, 153.9, 133.3, 113.2, 108.3, 105.1, 102.1, 94.3, 56.7, 18.4, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}BrNO_3Si$ [M+H]-: 412.0938. Found: 412.0946.




**((3-Bromo-5-methoxy-2-nitrophenyl)ethynyl)triisopropylsilane (600z).** General procedure G and obtained as a yellow solid in 72% yield (melting point = 85 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.50 (d, *J* = 9.0 Hz, 1H), 6.87 (d, *J* = 9.0 Hz, 1H), 3.92 (s, 3H), 1.12 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 160.4, 133.3, 113.2, 108.40 106.3, 105.1, 102.2, 94.3, 56.7, 18.5, 11.1. **HRMS** (ESI) *m/z* calc. for $C_{18}H_{26}BrNNaO_3Si$ [M+H]-: 434.0758. Found: 434.0756.

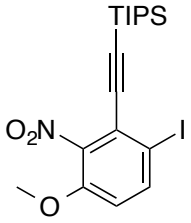



**((2,2'-Dinitro-[1,1'-biphenyl]-3-yl)ethynyl)triisopropylsilane (600aa).** General procedure G and obtained as a red solid in 40% yield (melting point = 100 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 8.14 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.69 – 7.57 (m, 3H), 7.49 (t, *J* = 7.8 Hz, 1H), 7.33 (dd, *J* = 7.2, 1.9 Hz, 1H), 7.26 (dd, *J* = 7.7, 1.4 Hz, 1H), 1.11 (q, *J* = 2.6 Hz, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 150.9, 148.0, 133.4, 133.1, 131.6, 131.5, 130.7, 130.0, 130.0, 129.6, 125.0, 117.3, 100.1, 99.0. **HRMS** (APCI) *m/z* calc. for $C_{23}H_{29}N_2O_4Si$ [M+H]-: 425.1891. Found: 425.1881.

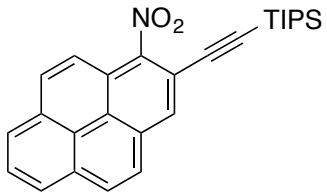



**2,2'-Dinitro-[1,1'-biphenyl]-3,3'-diyl)bis(ethyne-2,1-diylbis(triisopropylsilane) (600aa').** General procedure G and obtained as a yellow solid in 15% yield (melting point = 150 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.66 (dd, *J* = 7.8, 1.4 Hz, 2H), 7.46 (t, *J* = 7.8 Hz, 2H), 7.30 (dd, *J* = 7.8, 1.4 Hz, 2H), 1.13 (d, *J* = 2.7 Hz, 42H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ =

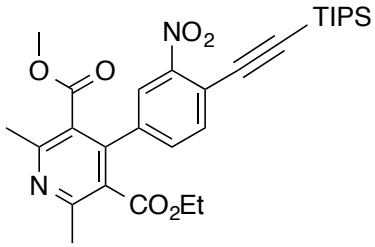
151.9, 134.1, 130.0, 129.9, 128.5, 117.6, 100.6, 98.7, 18.5, 11.1. **HRMS** (APCI) *m/z* calc. for $C_{34}H_{49}N_2O_4Si_2$ [M+H]-: 605.3225. Found: 605.3244.




**((6-Iodo-3-methoxy-2-nitrophenyl)ethynyl)Triisopropylsilane (600ac).** General procedure G and obtained as a white solid in 55% yield (melting point = 60 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.82 (d, *J* = 8.9 Hz, 1H), 6.75 (d, *J* = 8.9 Hz, 1H), 3.87 (s, 3H), 1.13 (d, *J* = 2.9 Hz, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 150.4, 143.7, 140.2, 123.4, 114.1, 104.6, 100.5, 89.1, 56.7, 18.6, 11.2. **HRMS** (APCI) *m/z* calc. for $C_{18}H_{27}INO_3Si$ [M+H]-: 460.0799. Found: 460.0809.




**Triisopropyl((1-nitropyren-2-yl)ethynyl)silane (600ad).** General procedure G and obtained as a brown solid in 80% yield (melting point = 120 °C). **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 8.30 – 8.07 (m, 6H), 7.98 (m, 2H), 1.22 (s, 21H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 149.9, 146.5, 131.6, 130.7, 130.1, 129.8, 128.1, 127.2, 127.1, 126.7, 125.9, 123.6, 123.2, 122.4, 119.9, 113.7, 100.4, 99.1, 18.6, 11.3. **HRMS** (APCI) *m/z* calc. for $C_{27}H_{30}NO_2Si$ [M+H]-: 428.2040. Found: 428.2033.




**3-Ethyl 5-methyl 2,6-dimethyl-4-(3-nitro-4-((triisopropylsilyl)ethynyl)phenyl)pyridine-3,5-dicarboxylate (600ad).** General procedure G starting from nitrendipine and obtained as a purple liquid in 40% yield. **$^1$H NMR (300 MHz, Chloroform-*d*)** δ = 7.97 (d, *J* = 1.8 Hz, 1H), 7.69 (d, *J* = 8.0 Hz, 1H), 7.46 (dd, *J* = 8.0, 1.8 Hz, 1H), 4.14 (q, *J* = 7.1 Hz, 2H), 3.67 (s, 3H), 2.64 (s, 3H), 2.63 (s, 3H), 1.17 (s, 21H), 1.10 (t, *J* = 7.1, 3H). **$^{13}$C NMR (75 MHz, $CDCl_3$)** δ = 179.1, 167.6, 167.1, 156.2, 149.6, 143.2, 137.0, 135.2, 132.2, 126.6, 126.3, 124.2, 118.8,

102.8, 100.4, 61.9, 52.6, 23.0, 18.6, 18.3, 13.8, 11.2. **HRMS** (ESI) *m/z* calc. for $C_{29}H_{39}N_2O_6Si$ [M+H]-: 539.2572. Found: 539.2572.

**DFT calculations of the ruthenium catalytic system**

All DFT calculations were carried out using the Gaussian09 suite of programs.[33] The geometries were fully optimized without any constrains using the PBE0 functional[34] and ultrafine integration grid which gives very good agreement with experimental geometries. Solvent effects were taken into account by means of PCM solvation model[35] with dichloroethane as a solvent ($\varepsilon = 10.125$). The K, Ru and Br atoms were described with Stuttgart RECP and associated basis set[36] augmented with additional polarization functions ($\zeta d = 1.000$, $\zeta f = 1.235$, and $\zeta d = 0.428$ for K, Ru, and Br, respectively).[37] For all other atoms, standard full electron Pople's basis set 6-31+G(d,p)[38] was used. This basis set is denoted as BS1. All computed structures were characterized as local stationary points via analytical frequency calculations at the standard state (298.15 K, 1 atm). For saddle points, IRC analysis[39] with subsequent geometry optimization was performed to verify that they are linked to the corresponding minima on the potential energy surface. Additional single-point calculations based on PBE0/BS1 optimized geometries were performed with Martin's general purpose double hybrid functional B2GP-PLYP[40] augmented with additional dispersion correction D3(BJ)[41] and a larger basis set combination denoted as BS2. This includes def2-QZVP basis set with the corresponding ECPs for K, Ru, and Br atoms obtained from the EMSL basis set exchange and full electron 6-311+G(2d,p) basis set[42] for the remaining atoms. The B2GP-PLYP-D3(BJ)/BS2 single-point energies modified by the Gibbs free energy correction from the PBE0/BS1 calculations were used to describe the reaction energies throughout the study.

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33 Gaussian 09, Revision B.1, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, J. A.; Peralta, Jr. J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R.L.; Morokuma, K.;, Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, Ö.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford CT **2009**.

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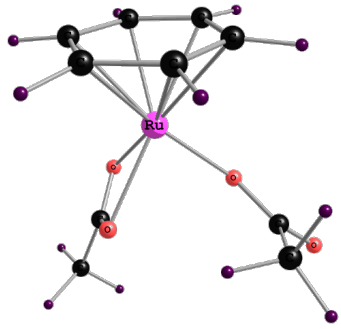
Molecular modeling and geometry visualization were performed using the ChemCraft program.[43]

**[(C$_6$H$_6$)Ru(OAc)$_2$] Catalyst**



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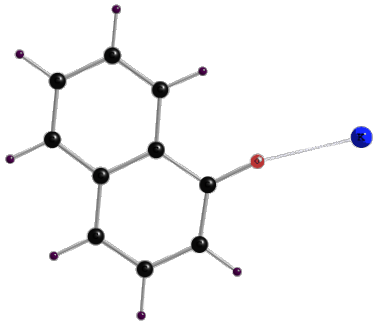
**G = -783.323238**

**C$_{10}$H$_7$OK**



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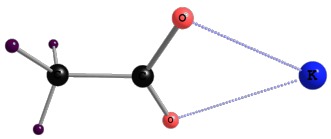

**E = -783.487072**

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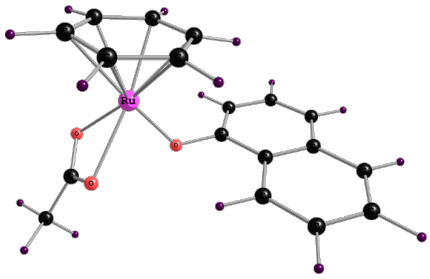
**[(C$_6$H$_6$)Ru(κ$^2$-OAc)(OC$_{10}$H$_7$)] Int-I**



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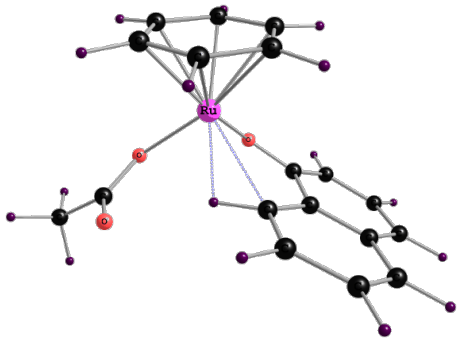
**[(C$_6$H$_6$)Ru(κ$^2$-OAc)(OC$_{10}$H$_7$)], agostic inter**



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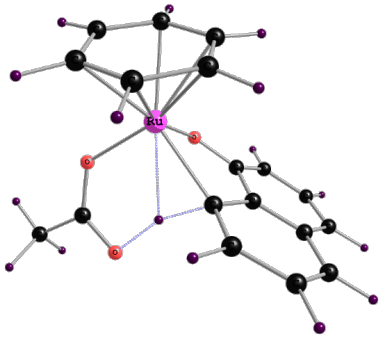
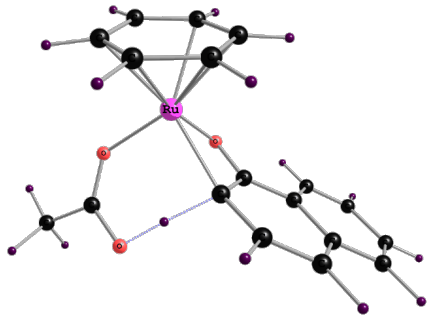


**E = -1015.248726**

**G = -1015.004809**

43 Zhurko, G. A. ChemCraft 1.6, http://www.chemcraftprog.com.

**TS C-H ortho-activation, 6-membered ring**



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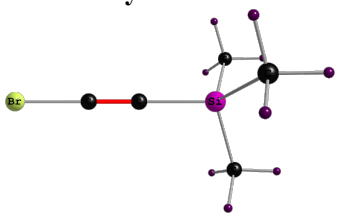
**G = -1014.994991**

**TMS-acetylene-Br**



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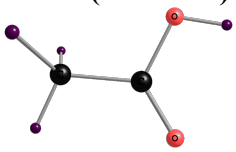
**AcOH (monomer)**



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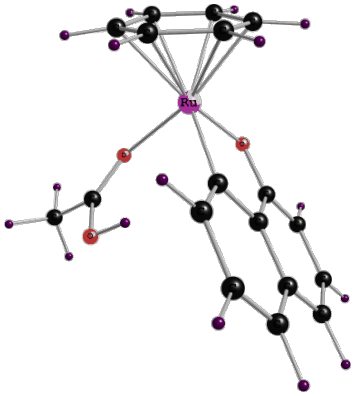
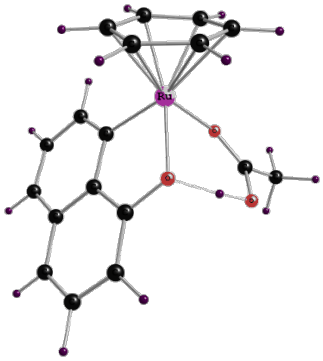
**[(C$_6$H$_6$)Ru(κ$^2$-C$_{10}$H$_6$O)(HOAc)] Int-II**



**E = -1015.271673**

**G = -1015.023017**

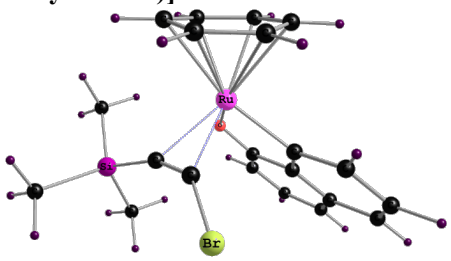
**[(C$_6$H$_6$)Ru(κ$^2$-C$_{10}$H$_6$O)(HOAc)], Int-IIa**



**E = -1015.281680**

**G = -1015.032558**

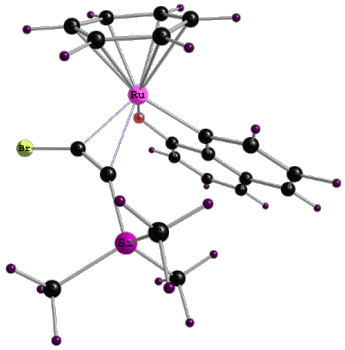
**[(C$_6$H$_6$)Ru(κ$^2$-C$_{10}$H$_6$O)(π-TMS-acetylene-Br)] Int-IIIa**



**E = -3845.154690**

**G = -3844.853960**

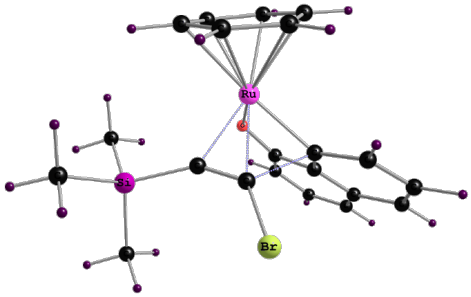
**[(C$_6$H$_6$)Ru(κ$^2$-C$_{10}$H$_6$O)(π-TMS-acetylene-Br)], Int-IIIb**



**E = -3845.153810**

**G = -3844.852757**

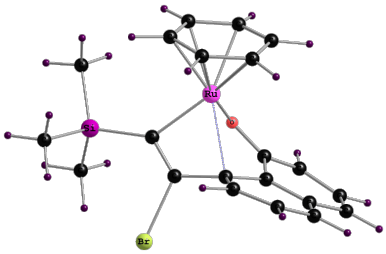
**TS insertion**



**E =** **-3845.132657**

**G =** **-3844.832413**

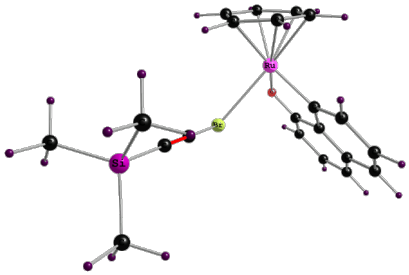
**Insertion intermediate Int-IV**



**E =** **-3845.157369**

**G =** **-3844.854796**

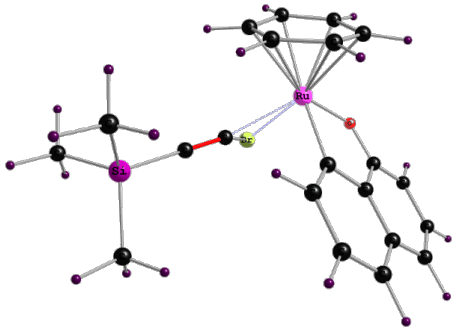
**[($C_6H_6$)Ru($\kappa^2$-$C_{10}H_6O$)(σ-TMS-acetylene-Br)] Int-V**



**E =** **-3845.119506**

**G =** **-3844.825111**

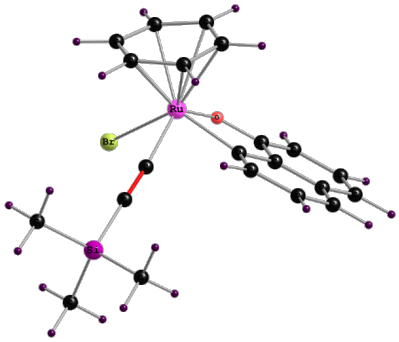
**TS C-Br oxidative addition**



**E =** **-3845.101011**

**G =** **-3844.803389**

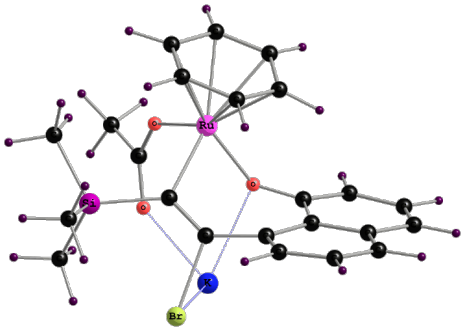
**Oxidative addition intermediate Int-VI**



**E =** **-3845.138457**

**G =** **-3844.840015**

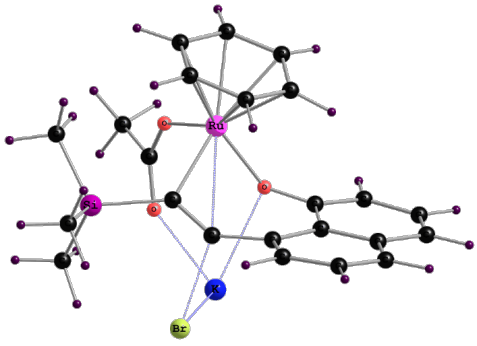
**Insertion intermediate with coordinated KOAc, Int-VII**



**E =** **-4673.305030**

**G =** **-4672.961352**

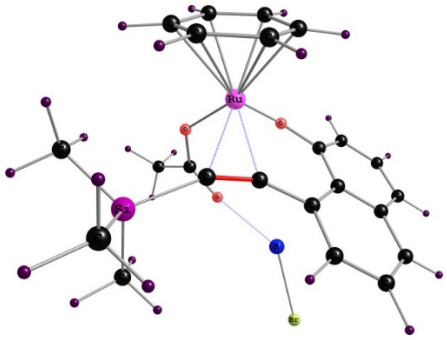
**TS K-Br elimination**



**E = -4673.305175**

**G = -4672.960475**

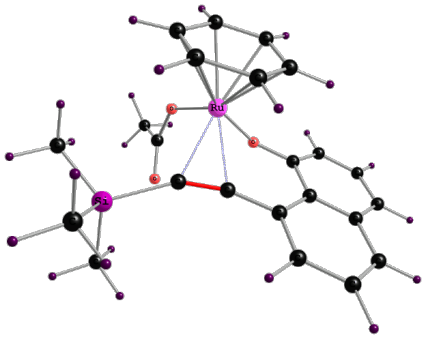
**[($C_6H_6$)Ru($\kappa^2$-$RC_{10}H_6O$)(OAc)] with KBr, Int-VIII**



**E = -4673.332115**

**G = -4672.994413**

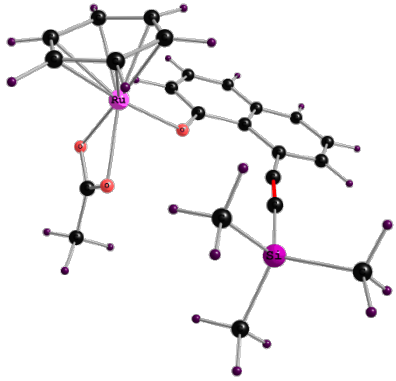
**[($C_6H_6$)Ru($\kappa^2$-$RC_{10}H_6O$)(OAc)], Int-IX**



**E = -1499.794286**

**G = -1499.445959**

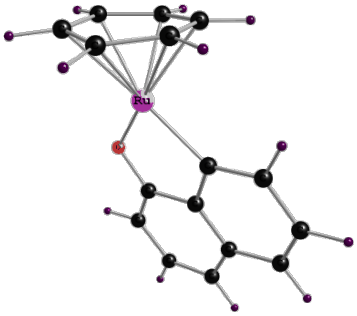
**[($C_6H_6$)Ru($RC_{10}H_6O$)($\kappa^2$-OAc)], Int-X**



**E = -1499.789959**

**G = -1499.442369**

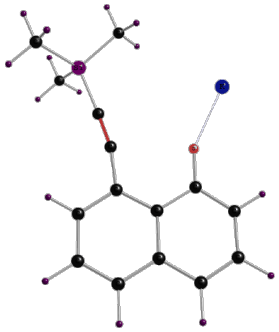
**[($C_6H_6$)Ru($\kappa^2$-$C_{10}H_6O$)], Int-XI**



**E = -786.306811**

**G = -786.113973**

**Free product**



**E = -1544.383158**

**G = -1544.181904**

**DFT calculations of the rhodium catalytic system**

Calculations were performed by means of the Gaussian 09 suite of programs.[1] DFT was applied using wB97XD.[2] Rh, Ag, K and Br atoms were described by ECP with the LANL2DZ basis set.[3] Polarization functions were added for Rh (ζf= 1.35), Ag (ζf= 1.611), K (ζd= 1.000) and Br (ζd= 0.428).[4] The 6-31G(d) basis set[5] was employed for all remaining atoms (C, H, O, Si and F). Full geometry optimizations were carried out in 1,2-dichloroethane, through an implicit solvent SMD.[6] The stationary points were characterized by vibrational analysis. Transition states were identified by the presence of one imaginary frequency while minima by a full set of real frequencies. The connectivity of the transition states was confirmed by relaxing each transition state towards both the reactant and the product. Reported energies are potential energies (E) and free energies (G) in solution, computed at 298 K and 1 atm. Mulliken charges[7] were calculated at the same level of theory.

1 Gaussian 09, Revision B.1, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, J. A.; Peralta, Jr. J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R.L.; Morokuma, K.;, Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, Ö.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford CT **2009**.

2 Chai, J.−D.; Head−Gordon, M. *Phys. Chem. Chem. Phys.* **2008**, *10*, 6615−6620.

3 Wadt, W. R.; Hay, P. J. *J. Chem. Phys.* **1985**, *82*, 284−298.

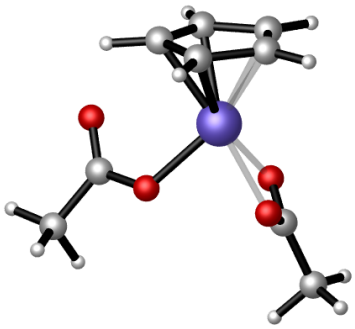
4 (a) Ehlers, A.; Böhme, M.; Dapprich, S.; Gobbi, A.; Höllwarth, A.; Jonas, V.; Köhler,K.; Stegmann, R.; Veldkamp, A.; Frenking, G. *Chem. Phys. Lett.* **1993**, *208*, 111−114. (b) Höllwarth, A.; Böhme, M.; Dapprich, S.; Ehlers, A. W.; Gobbi, A.; Jonas, V.; Köhler, K. F.; Stegmann, R.; Veldkamp, A.; Frenking, G. *Chem. Phys. Lett.* **1993**, *208*, 237−240.

5 Hehre, W. J.; Ditchfield, R.; Pople, J. A. *J. Chem. Phys.* **1972**, *56*, 2257−2261.

6 Marenich, A. V.; Cramer, C. J.; Truhlar, D. G. *J. Phys. Chem. B.* **2009**, *113*, 6378−6396.

7 Mulliken, R. S. *J. Chem. Phys.* **1955**, *23*, 1833−1840.

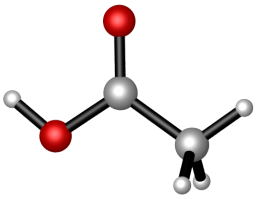
**Int0**



E = -759.835759 Hartrees

G = -759.689661 Hartrees

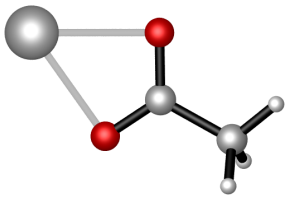
**AcOH**



E = -229.014845 Hartrees

G = -228.979969 Hartrees

**AgOAc**



E = -374.200558 Hartrees

G = -374.182650 Hartrees

**AgBr**

E = -159.009364 Hartrees

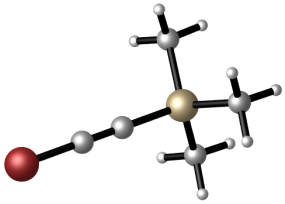
G = -159.034547 Hartrees

**$Ag^+$**

E = -145.614434 Hartrees

G = -145.631040 Hartrees

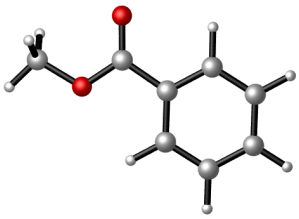
**(Bromoethynyl)trimethylsilane (1b)**



E = -498.509006 Hartrees

G = -498.423476 Hartrees

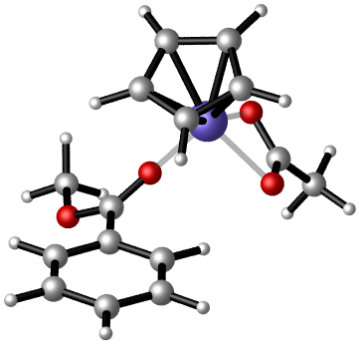
**2b**



E = -459.980113 Hartrees

G = -459.868594 Hartrees

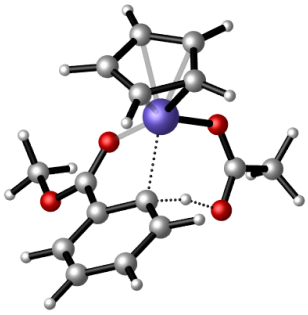
**Int1a**



E = -991.249669 Hartrees

G = -991.013054 Hartrees

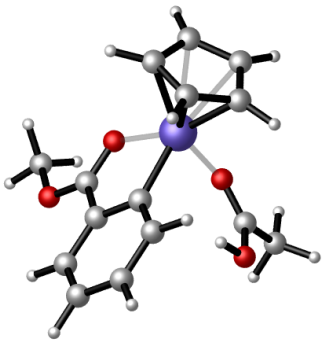
**$TS_{1-2}a$**



E = -991.213896 Hartrees

G = -990.981500 Hartrees

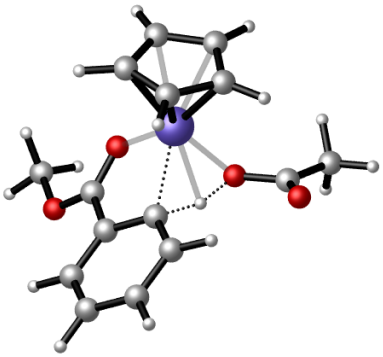
**Int2a**



E = -991.246363 Hartrees

G = -991.009660 Hartrees

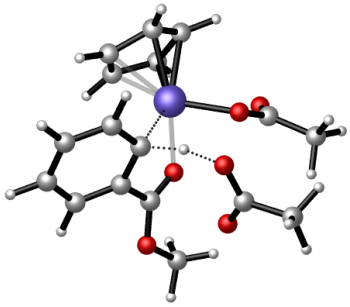
**$TS_{1-2}j$**



E = -991.191243 Hartrees

G = -990.957960 Hartrees

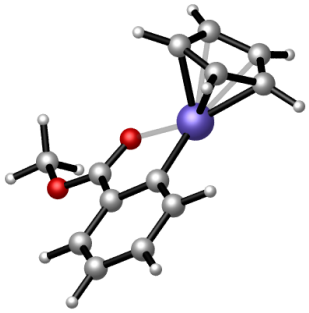
**$TS_{1-2}k$**



E = -1219.760091 Hartrees

G = -1219.483103 Hartrees

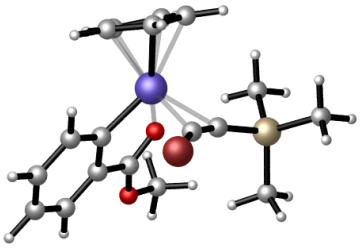
**Int3a**



E = -762.203068 Hartrees

G = -762.022642 Hartrees

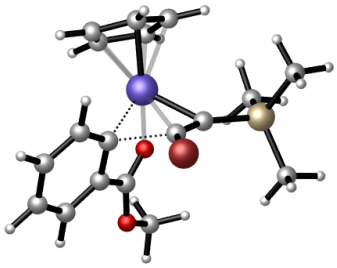
**Int4a**



E = -1260.747432 Hartrees

G = -1260.454187 Hartrees

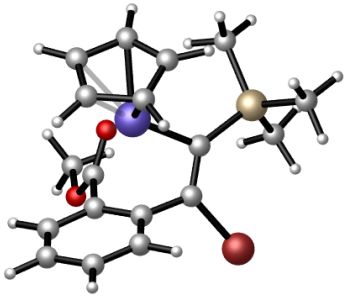
**$TS_{4\text{-}5}$a**



E = -1260.727359 Hartrees

G = -1260.436304 Hartrees

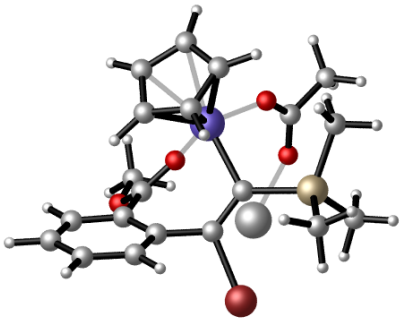
**Int5a**



E = -1260.775909 Hartrees

G = -1260.483099 Hartrees

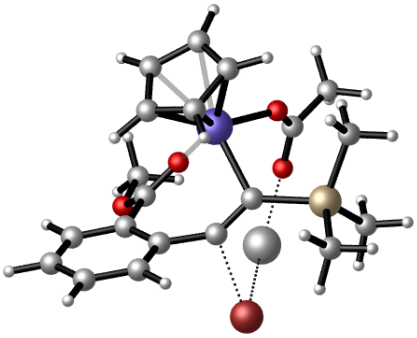
**Int6a**



E = -1635.024754 Hartrees

G = -1634.686713 Hartrees

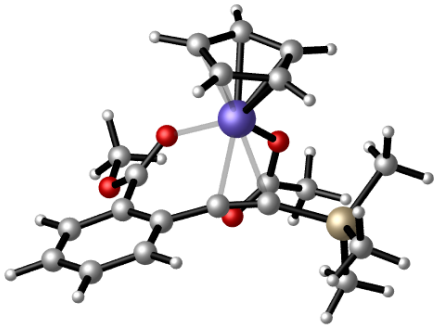
**$TS_{6\text{-}7}$a**



E = -1635.019263 Hartrees

G = -1634.683017 Hartrees

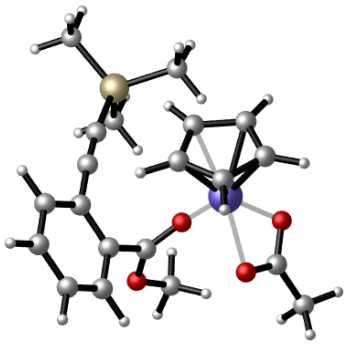
**Int7a**



E = -1476.006275 Hartrees

G = -1475.663590 Hartrees

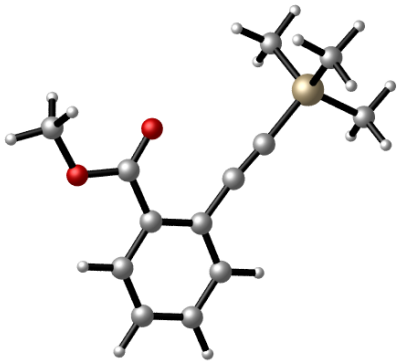
**Int8a**



E = -1476.005955 Hartrees

G = -1475.666163 Hartrees

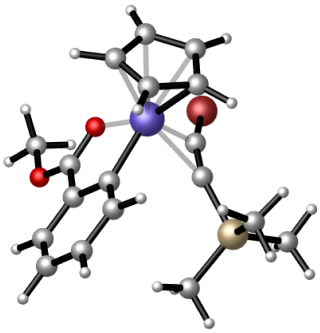
**3ab**



E = -944.731447 Hartrees

G = -944.521070 Hartrees

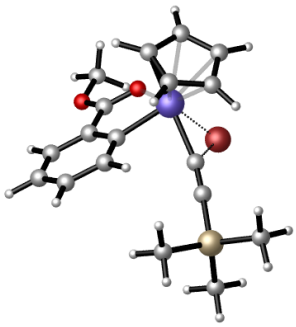
**Int9a**



E = -1260.745639 Hartrees

G = -1260.454738 Hartrees

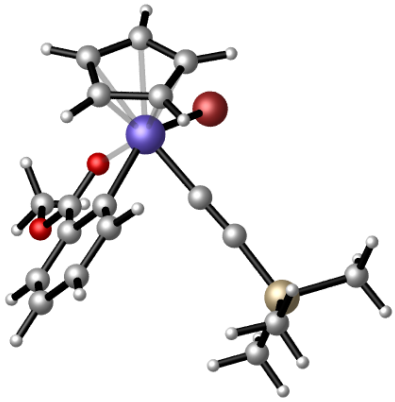
**$TS_{9\text{-}10}$a**



E = -1260.677441 Hartrees

G = -1260.390234 Hartrees

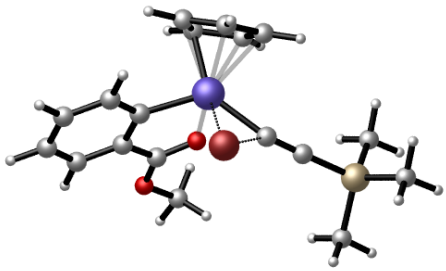
**Int10a**



E = -1260.696418 Hartrees

G = -1260.407151 Hartrees

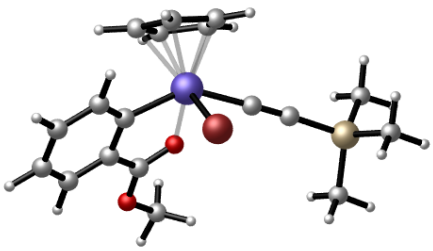
**$TS_{4\text{-}12}$a**



E = -1260.675950 Hartrees

G = -1260.387830 Hartrees

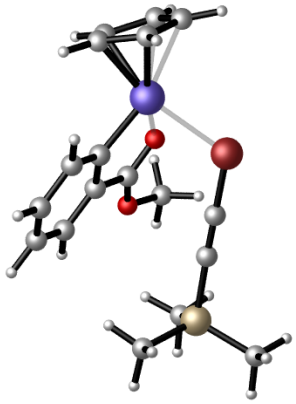
**Int12a**



E = -1260.690983 Hartrees

G = -1260.402271 Hartrees

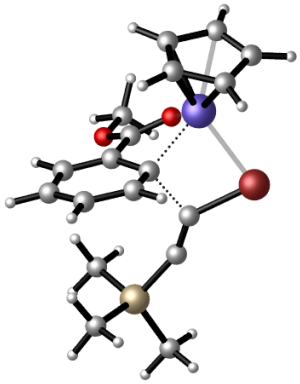
**Int13a**



E = -1260.725162 Hartrees

G = -1260.439357 Hartrees

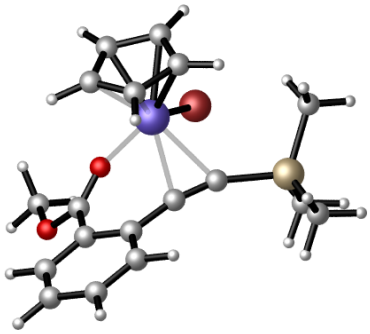
**$TS_{13\text{-}14}$a**



E = -1260.657483 Hartrees

G = -1260.369805 Hartrees

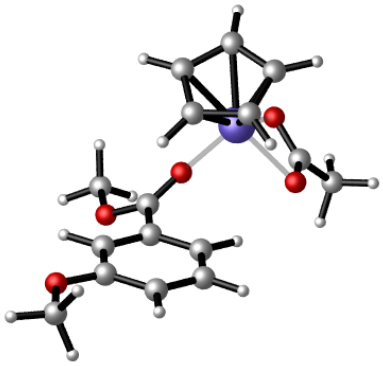
**Int14a**



E = -1260.804724 Hartrees

G = -1260.513573 Hartrees

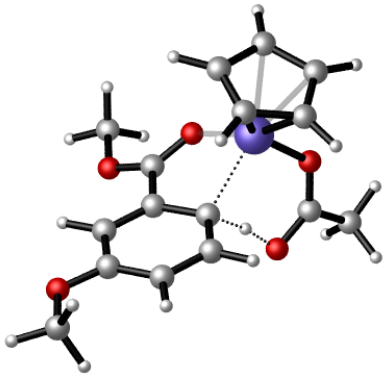
**Int1d**



E =-1105.739099 Hartrees

G =-1105.471243 Hartrees

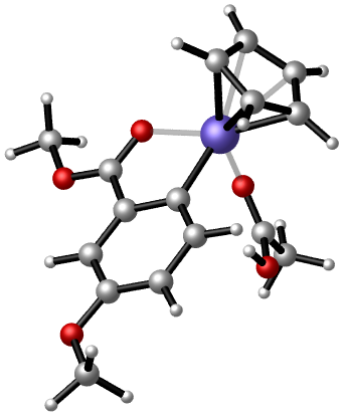
**$TS_{1\text{-}2}$d**



E =-1105.705687 Hartrees

G =-1105.443791 Hartrees

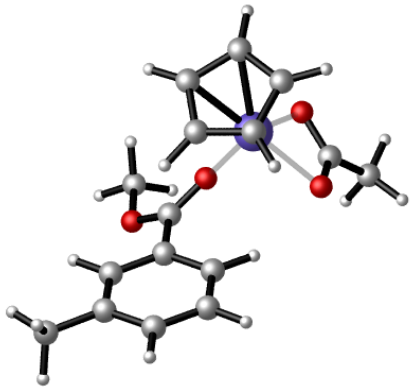
**Int2d**



E =-1105.733910 Hartrees

G =-1105.466640 Hartrees

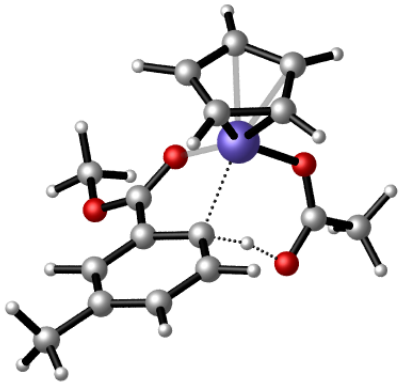
**Int1e**



E =-1030.558347 Hartrees

G =-1030.294924 Hartrees

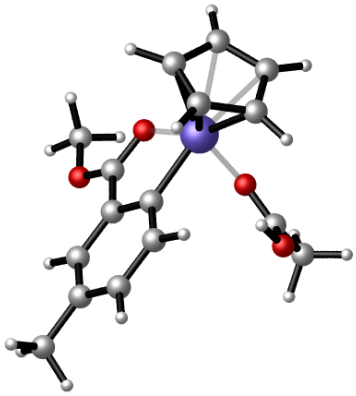
**$TS_{1-2}$e**



E =-1030.522412 Hartrees

G =-1030.264837 Hartrees

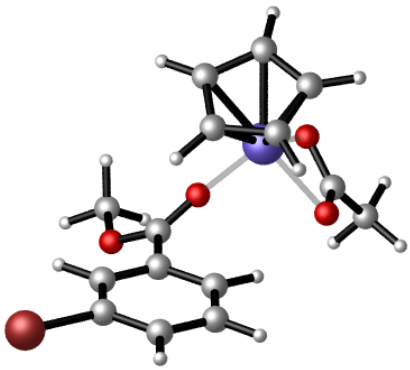
**Int2e**



E =-1030.554765 Hartrees

G =-1030.289636 Hartrees

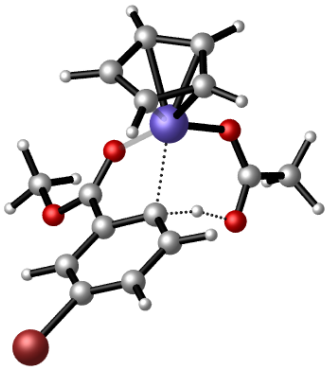
**Int1f**



E =-1003.827036 Hartrees

G =-1003.603556 Hartrees

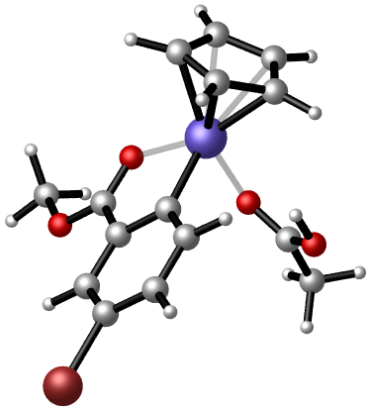
**$TS_{1-2}$f**



E =-1003.789525 Hartrees

G =-1003.570464 Hartrees

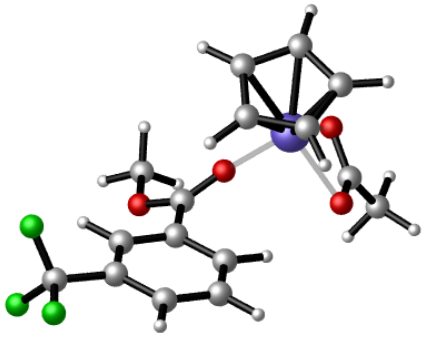
**Int2f**



E =-1003.824161 Hartrees

G =-1003.598562 Hartrees

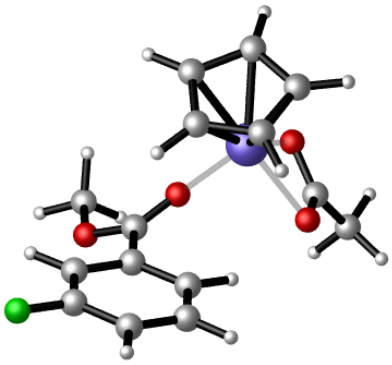
**Int1g**



E =-1328.199264 Hartrees

G =-1327.963256 Hartrees

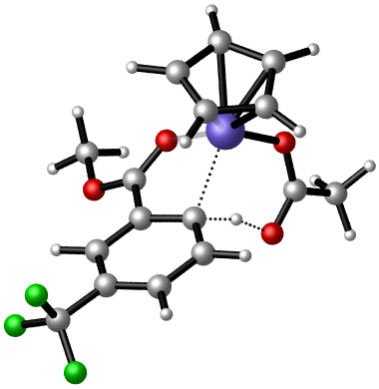
**Int1h**



E =-1090.456123 Hartrees

G =-1090.228175 Hartrees

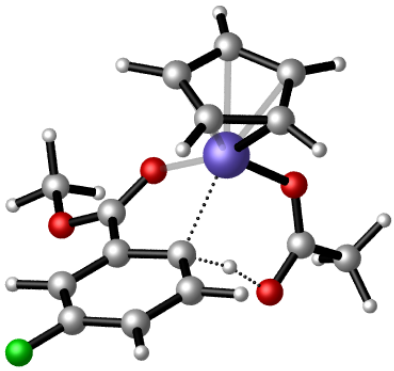
**$TS_{1-2}g$**



E =-1328.161041 Hartrees

G =-1327.928989 Hartrees

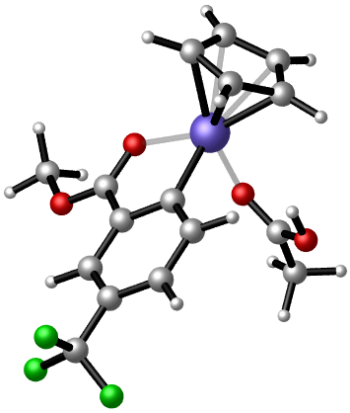
**$TS_{1-2}h$**



E =-1090.419871 Hartrees

G =-1090.197179 Hartrees

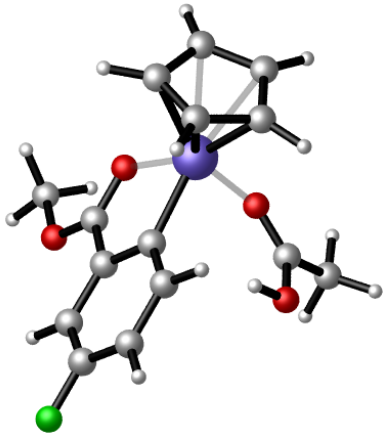
**Int2g**



E =-1328.197035 Hartrees

G =-1327.957888 Hartrees

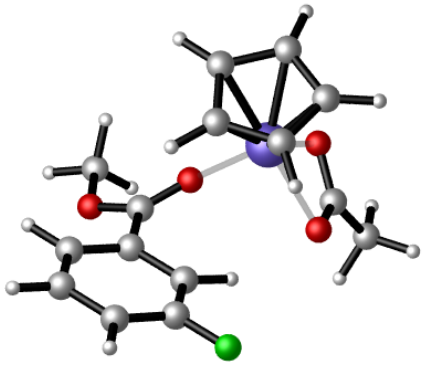
**Int2h**



E =-1090.451066 Hartrees

G =-1090.224180 Hartrees

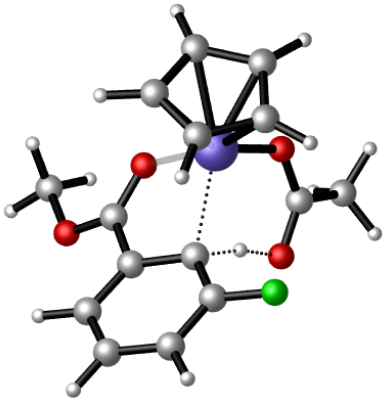
**Int1i**



E =-1090.456510 Hartrees

G =-1090.229672 Hartrees

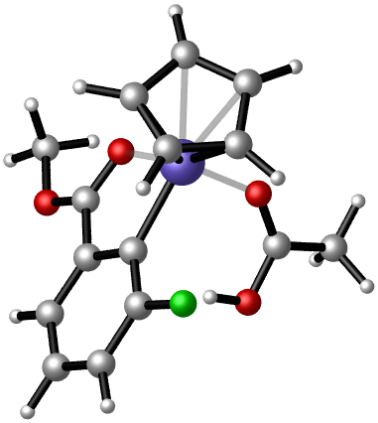
**$TS_{1\text{-}2}$i**



E=-1090.424301 Hartrees

G =-1090.201309 Hartrees

**Int2i**



E =-1090.454551 Hartrees

G =-1090.225422 Hartrees

**Crystallographic data**

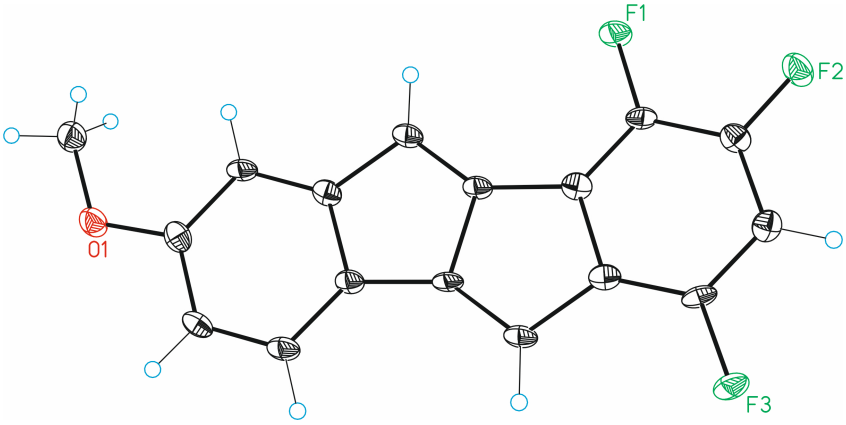


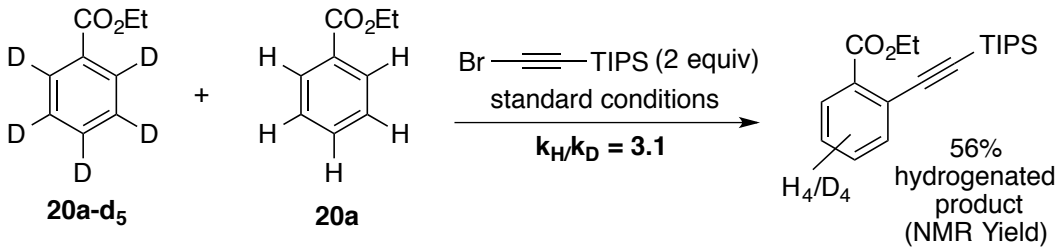

**Table 5**. Crystal data and structure refinement for **400d**.

| | | |
|---|---|---|
| Identification code | ETK361P1 | |
| Empirical formula | C17 H9 F3 O | |
| Formula weight | 286.24 | |
| Temperature | 100(2)K | |
| Wavelength | 0.71073 Å | |
| Crystal system | monoclinic | |
| Space group | P 21/c | |
| Unit cell dimensions | a = 6.1433(4)Å | a= 90°. |
| | b = 24.4095(19)Å | b = 92.144(6)°. |
| | c = 7.9266(5)Å | g = 90°. |
| Volume | 1187.80(14) $Å^3$ | |
| Z | 4 | |
| Density (calculated) | 1.601 $Mg/m^3$ | |
| Absorption coefficient | 0.131 $mm^{-1}$ | |
| F(000) | 584 | |
| Crystal size | 0.100 x 0.050 x 0.010 $mm^3$ | |
| Theta range for data collection | 2.703 to 32.122°. | |
| Index ranges | -8<=h<=9,-36<=k<=36,-11<=l<=10 | |
| Reflections collected | 17108 | |
| Independent reflections | 3902[R(int) = 0.0575] | |
| Completeness to theta =32.122° | 93.6% | |
| Absorption correction | Multi-scan | |
| Max. and min. transmission | 1.00 and 0.55 | |
| Refinement method | Full-matrix least-squares on $F^2$ | |
| Data / restraints / parameters | 3902/ 0/ 191 | |
| Goodness-of-fit on $F^2$ | 1.042 | |

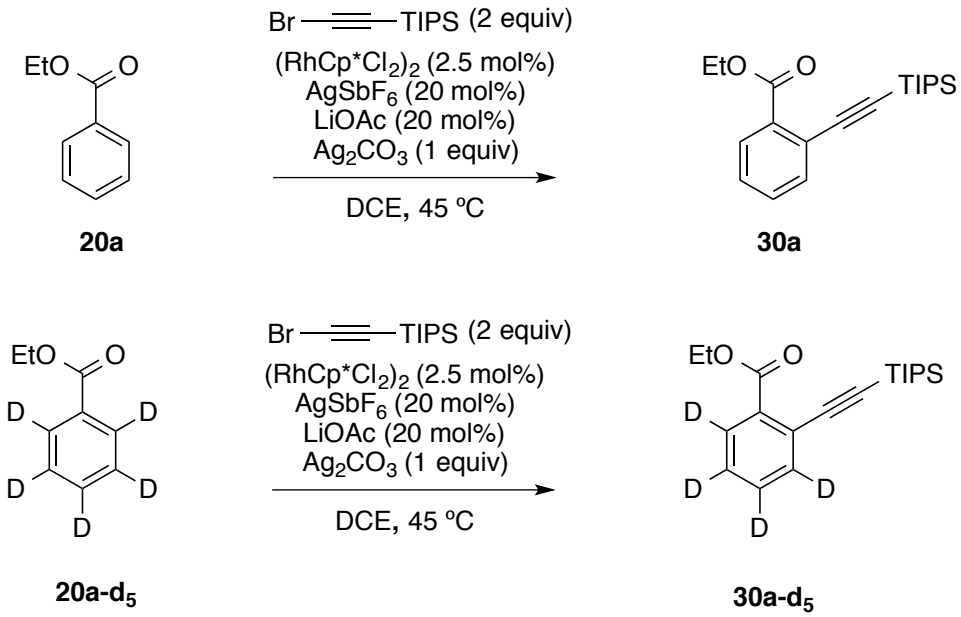
| | |
|---|---|
| Final R indices [I>2sigma(I)] | R1 = 0.0720, wR2 = 0.1951 |
| R indices (all data) | R1 = 0.0987, wR2 = 0.2140 |
| Largest diff. peak and hole | 0.725 and -0.705 e.Å$^{-3}$ |

**Kinetic isotopic effect studies**

**Kinetic isotope effect in the alkynylation of benzoic esters:**



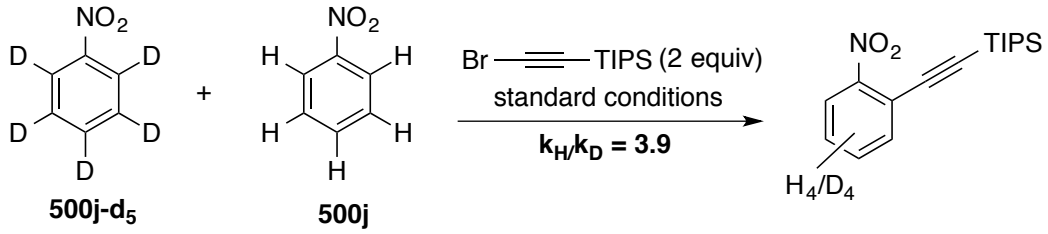

$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, $Ag_2CO_3$, were dissolved in DCE (2 mL) in a 10 mL tube. Benzoic esters **20a** (0.2 mmol) and **20a-d$_5$** (0.2 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (0.4 mmol) were then added with a Hamilton syringe and the reaction mixture was stirred 45 ºC for 16 h. After cooling at ambient temperature, bromomesitylene (2 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of the mono-alkynylated product was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard. The residue was purified by silica gel chromatography column with Toluene 100% as eluent to yield the corresponding mono alkynylated products (**30a**+**30a-d$_5$**) KIE value (3.1) was determined by the ratio of desired products.




$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, $Ag_2CO_3$, were dissolved in DCE (2 mL) in a 10 mL tube. Benzoic esters (**20a** or **20a-d$_5$**) (0.15 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (0.3 mmol) were then added with a Hamilton syringe and the reaction mixture was stirred 45

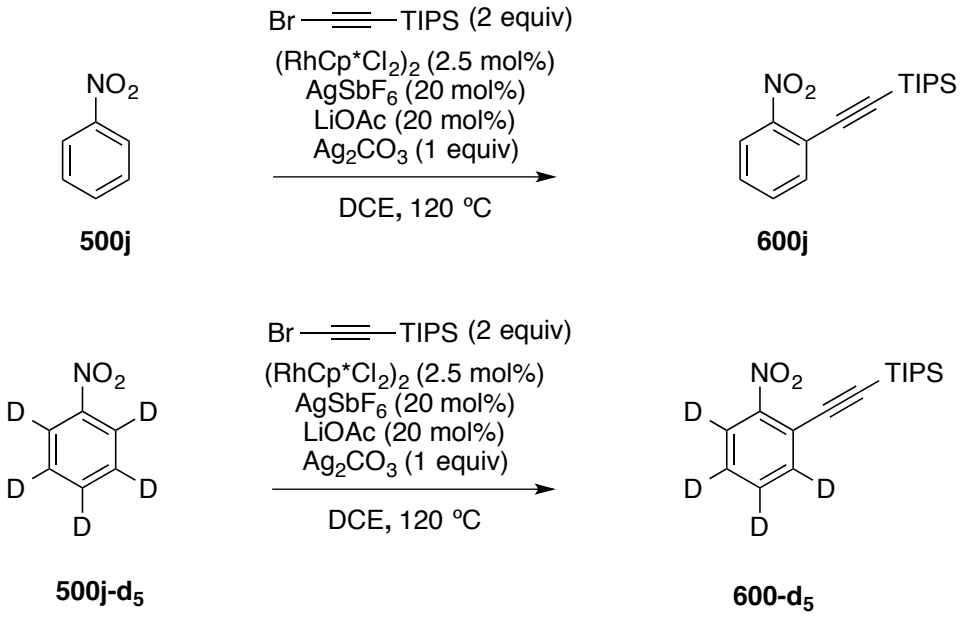
ºC for the indicated time : 30 min, 1 h, 2h, 3h or 5h (five parallel runs). After cooling at ambient temperature, bromomesitylene (1 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of the mono-alkynylated product was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard. KIE value (3.1) was determined by comparing the relative initial rates.

**Kinetic isotope effect in the alkynylation of nitrobenzenes:**




**500j-d$_5$** **500j**

$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, $Ag_2CO_3$, were dissolved in DCE (2 mL) in a 10 mL tube. Nitrobenzenes **500j** (0.2 mmol) and **500j-d$_5$** (0.2 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (0.4 mmol) were then added with a Hamilton syringe and the reaction mixture was stirred 45 ºC for 16 h. After cooling at ambient temperature, bromomesitylene (2 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of the mono-alkynylated product was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard. KIE value (3.9) was determined by the ratio of desired products.



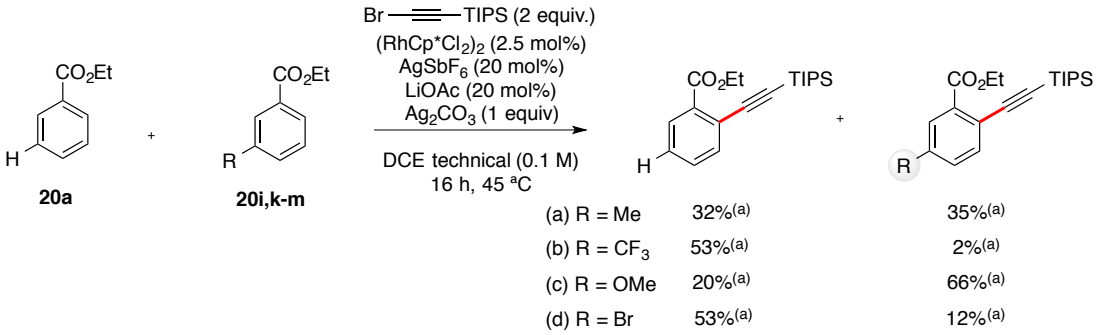

**500j** **600j**

**500j-d$_5$** **600-d$_5$**

$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, $Ag_2CO_3$, were dissolved in DCE (2 mL) in a 10 mL tube. Nitrobenzenes (**500j** or **500j-$d_5$**) (0.15 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (0.3 mmol) were then added with a Hamilton syringe and the reaction mixture was stirred 45 ºC for the indicated time : 5 min, 10 min, 15 min, 20 min or 30 min (five parallel runs). After cooling at ambient temperature, bromomesitylene (1 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of the mono-alkynylated product was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard. KIE value (4) was determined by comparing the relative initial rates.

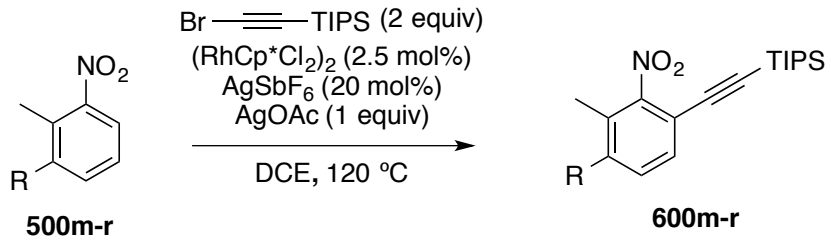
## Hammett plots

### Hammett plot in the alkynylation of benzoic esters




$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, $Ag_2CO_3$, were dissolved in DCE (2 mL) in a 10 mL tube. Ethyl benzoate (**20a**) (0.2 mmol, 1 equiv) and *m*-substituted benzoates (**20i,k-m**) (1 equiv) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (2 equiv) were then added with a Hamilton syringe and the reaction mixture was stirred 45 ºC for 16 h. After cooling at ambient temperature, bromomesitylene (1 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of each mono-alkynylated product (**30a** and **30i,k-m**) was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard.

### Hammett plot in the alkynylation of nitrobenzenes




$(RhCp^*Cl_2)_2$, $AgSbF_6$, LiOAc, AgOAc, were dissolved in DCE (2 mL) in a 10 mL tube. Nitrobenzenes (**500m-r**) (0.15 mmol) and 1-bromo-2-(triisopropylsilyl)acetylene (**2a**) (0.3 mmol) were then added with a Hamilton syringe and the reaction mixture was stirred 45 ºC for the indicated time : 5 min, 10 min, 15 min, 20 min or 30 min (five parallel runs). After cooling at ambient temperature, bromomesitylene (1 equiv) was added as internal standard through an Hamilton syringe and the crude mixture was filtrated in a pipette through a short plug of silica and washed with DCM. After filtration, the solvents were removed under vacuum. The yield of the mono-alkynylated product was determined by $^1$H NMR analysis of the crude using bromomesitylene as internal standard.

# Chapter II: Ir-Catalyzed C($sp^3$)-H Alkynylation

## Introduction

The activation of C($sp^3$)−H bonds is more difficult than the activation of C($sp^2$)−H bonds because of the lower acidity of C($sp^3$)−H bonds and the absence of π-interaction with the transition metal. All the examples of chelation-assisted C($sp^3$)−H alkynylation reported so far use palladium as catalyst (cf. General Introduction − Precedents in C($sp^3$)−H alkynylation section). However, these reactions require either the use of a bidentate directing group − that needs to be installed and/or removed − or the use of a specific ligand, that might require further optimization for complex substrates.

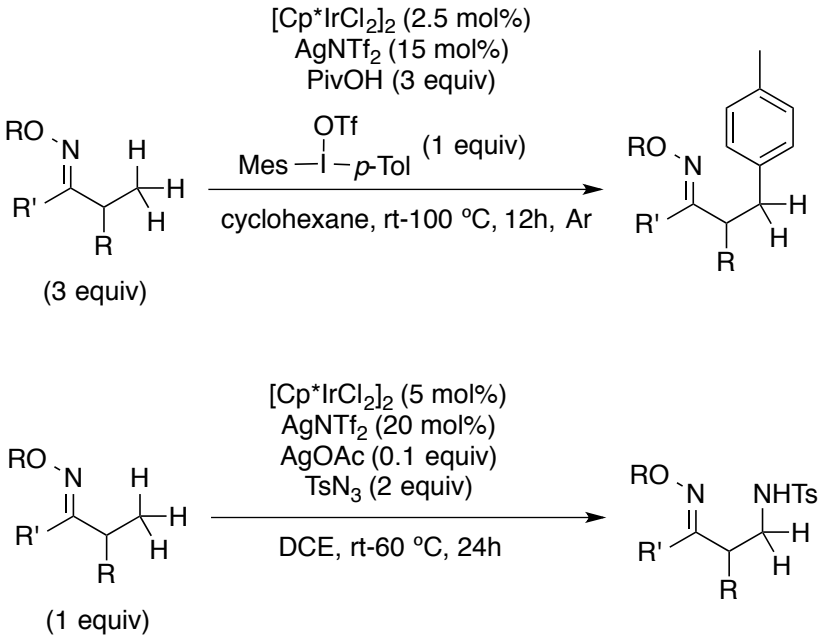
In line with a simple, yet broad-ranging catalytic system presented in chapter **I**, we sought to use transition metals such as ruthenium or rhodium as catalysts. However, the majority of C($sp^3$)−H functionalizations occuring through a CMD pathway with these metals require high temperature,[1] thus limiting the potential to design new and mild C($sp^3$)−H alkynylation using ruthenium or rhodium as catalyst.

Instead, the corresponding $[Cp^*IrCl_2]_2$ catalyst is known to activate C($sp^3$)−H bonds under mild conditions in the context of C−H amination and C−H arylation (Scheme 1).[2] Therefore, we selected this metal to develop a C($sp^3$)−H alkynylation reaction.

1 Reports using Rh(III): (a) Liu, B.; Zhou, T.; Li, B.; Xu, S.; Song, H.; Wang, B. *Angew. Chem., Int. Ed.* **2014**, *53*, 4191−4195. (b) Wang, H.; Tang, G.; Li X. *Angew. Chem., Int. Ed.* **2015**, 54, 13049−13052. (c) Wang, X.; Yu, DG.; Glorius, F. *Angew. Chem., Int. Ed.* **2015**, *54*, 10280−10283 (d) Huang, X.; Wang, Y.; Lan, J.; You, J. *Angew. Chem., Int. Ed.* **2015**, *54*, 9404−9408. (e) Wang, N.; Li, R.; Li, L.; Xu, S.; Song, S.; Wang, B. *J. Org. Chem.,* **2014,** *79,* 5379−5385. (f) Han, S.; Park, J.; Kim, S.; Lee, S. H.; Sharma, S.; Mishra, N. K.; Jung, Y. H.; Kim, I. S. *Org. Lett.* **2016**, *18*, 4666−4669. (g) Hu, X.-H.; Yang, X.-F.; Loh, T.-P. *ACS Catal.* **2016** *6* 5930−5934. (h) Tang, C.; Zou, M.; Liu, J.; Wen, X.; Sun, X.; Zhang, Y.; Jiao, N. *Chem. Eur. J.* **2016**, *22*, 11165−11169. (i) Kong, L.; Liu, B.; Zhou, X.; Wang, F.; Li, X. *Chem. Commun.,* **2017**, *53*, 10326−10329. (j) Kong, L.; Zhou, X.; Xu, Y.; Li, X. *Org. Lett.* **2017**, *19*, 3644−3647. (k) Liu, B.; Hu, P.; Zhou, X.; Bai, D.; Chang, J.; Li, X. *Org. Lett.* **2017**, *19*, 2086−2089. (l) Yuan, C.; Tu, G.; Zhao, Y. *Org. Lett.* **2017**, *19*, 356−359.

Reports using Ru(II): (m) Liu, B.; Li, B.; Wang, B. *Chem. Commun.,* **2015**, *51*, 16334−16337. (n) Sundaraju, B.; Achard, M.; Sharma, G. V. M.; Bruneau, C. *J. Am. Chem. Soc.* **2011**, *133*, 10340−10343.

2 (a) Gao, P.; Guo, W.; Xue, J.; Zhao, Y.; Yuan, Y.; Xia, Y.; Shi, Z. *J. Am. Chem. Soc.* **2015**, *137*, 12231−12240. (b) Kang, T.; Kim, Y.; Lee, D.; Wang, Z.; Chang, S. *J. Am. Chem. Soc.,* **2014**, *136*, 4141−4144. (c) Kang, T.; Kim, H.; J. G.; Chang, S. *Chem. Commun.* **2014**, *50*, 12073−12075.




**Scheme 1.** Ir(III)-catalyzed C($sp^3$)–H arylation (top) and amidation (bottom) directed by oximes ethers.

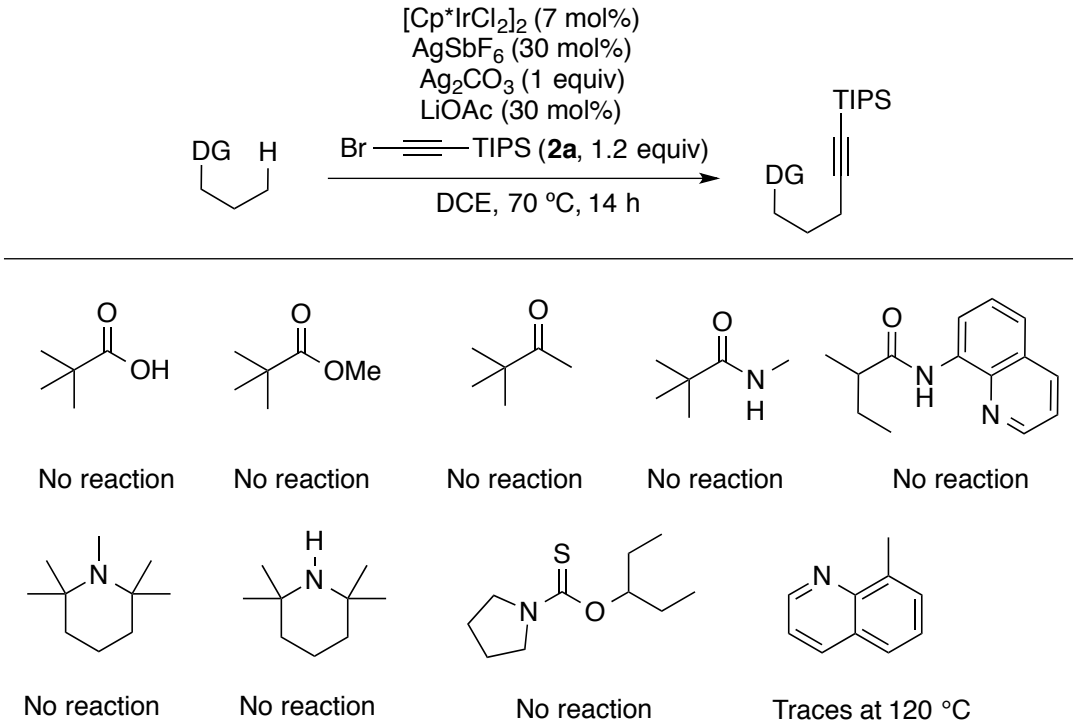
## Objectives

In the **chapter I**, we described a general catalytic system based on ruthenium or rhodium, able to convert $C(sp^2)$−H bonds into $C(sp^2)$−alkyne bonds using simple functional groups as chelating group.

In this chapter, we present our efforts to extend this catalytic system to the alkynylation of $C(sp^3)$−H bonds.

## Results and Discussion

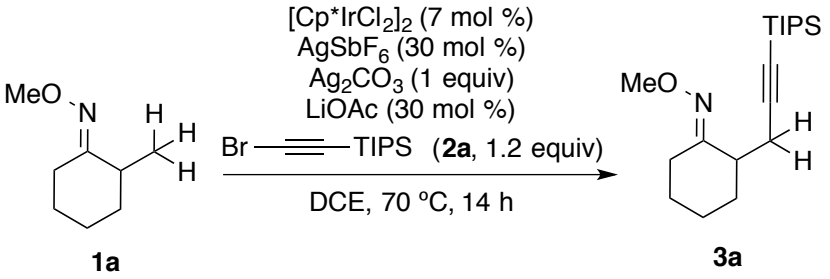
To develop a chelation-assisted C($sp^3$)−H alkynylation reaction, we initially selected $[Cp^*IrCl_2]_2$ as catalyst, bromo-alkyne **2a** as alkynylating reagent and used conditions from chapter **I** on a range of substrates (Scheme 2). Substrates contaning chelating groups such as carboxylic acid, ester, ketone, amide, amine or O-thiocarbamate β to a primary C($sp^3$)−H bond did not undergo alkynylation under our standard conditions.



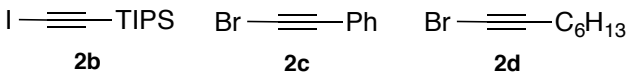

**Scheme 2.** Screening of directing groups in the chelation-assisted Ir-catalyzed C($sp^3$)−H alkynylation.

However, we found that the methyl oxime ether derivative of 2-methylcyclohexanone (**1a**) could be alkynylated in 78% yield (Table 1, entry 1). Control experiments showed the essential role of all reaction components (Table 1, entries 2−5). Other catalysts used in C−H functionalization, such as $MnBr(CO)_5$, $Cp^*Co(CO)I_2$, $Pd(OAc)_2$ or $[RuCl_2(p\text{-cymene})]_2$ (Table 1, entry 6) were inactive. The use of other silver salts (Table 1, entry 7), lower catalyst loading (Table 1, entry 8), lower or higher temperature (Table 1, entry 9) or other solvents (Table 1 entries 10−12) gave lower yield. The use of other bromo- or iodo-alkynes, such as **2b-d** led to no conversion (entry 14).

**Table 1.** Ir-catalyzed C($sp^3$)−H alkynylation of **1a**: optimization of reaction conditions[a]



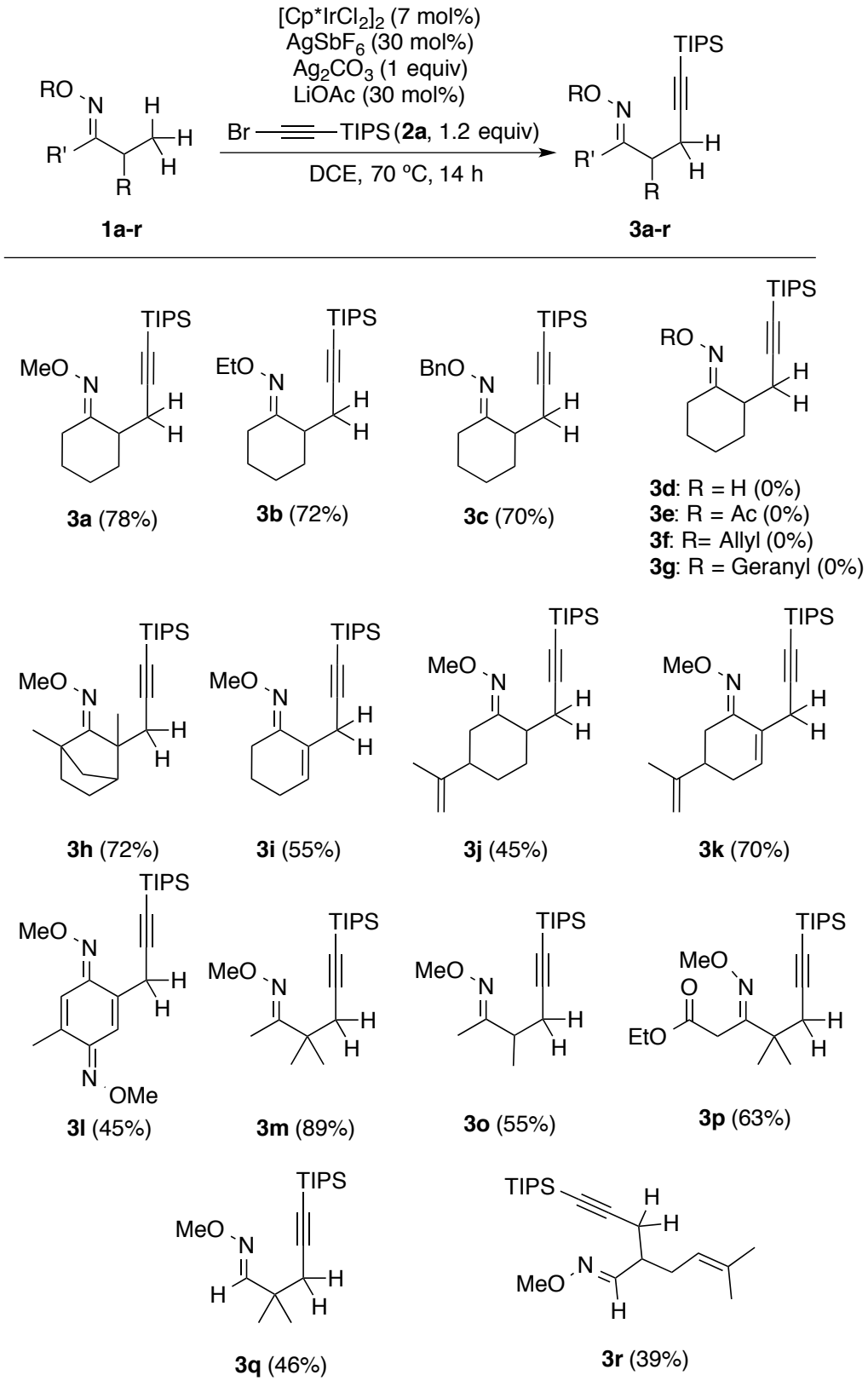

| Entry[a] | Variation from the standard conditions[a] | Yield[b] |
|---|---|---|
| 1 | none | 80 (78) [b] |
| 2 | Without $[Cp^*IrCl_2]$ | 0 |
| 3 | Without $Ag_2CO_3$ | 0 |
| 4 | Without LiOAc | 0 |
| 5 | Without $AgSbF_6$ | 0 |
| 6 | With $MnBr(CO)_5$ or $Cp^*Co(CO)I_2$ or $Pd(OAc)_2$ or $[RuCl_2(p\text{-cymene})]_2$ or instead of $[Cp^*IrCl_2]$ | 0 |
| 7 | With $AgNO_3$ or $Ag_2O$ instead of $Ag_2CO_3$ | 0 |
| 8 | With 3 or 5 mol % of catalyst instead of 7 mol % | 25 or 50 |
| 9 | At 25 ºC or 80 ºC | 60 |
| 10 | With THF instead of DCE | 50 |
| 11 | With *tert*-amyl alcohol instead of DCE | 20 |
| 12 | With DCE/TFE (1/1) or DCE/HFIP (1/1) instead of DCE | 50 or 40 |
| 13 | With **2b** or **2c** or **2d** | 0 |




[a] Standard reaction conditions: **1a** (0.2 mmol), **2a** (1.2 equiv), $[Cp^*RhCl_2]_2$ (7 mol%), $Ag_2CO_3$ (1 equiv), $AgSbF_6$ (0.3 equiv), LiOAc (0.3 equiv), DCE, 14 h, 70 °C. [b] Yield determined by $^1H$ NMR using an internal standard. [c]Isolated yield in parentheses.

Using our optimized conditions, different alkyl oximes **1a-c** derived from 2-methylcyclohexanone could be alkynylated, with methyl oxime **1a** giving the highest yield (Scheme 3). Other free oxime **1d**, oxime ester **1e** or allylic oxime ethers **1f-g** gave no conversion. Sterically bulky methyl group bonded to quaternary carbon derived from fenchone **1h** could be alkynylated in 72% yield. The allylic $C(sp^3)$−H bonds in **1i** was selectively alkynylated, while potentially reactive neighboring $C(sp^2)$−H remained inert. Ketoximes derived from dihydrocarvone **1j** and (R)-carvone **1k** could be alkynylated in 45% and 70% yield. Acyclic

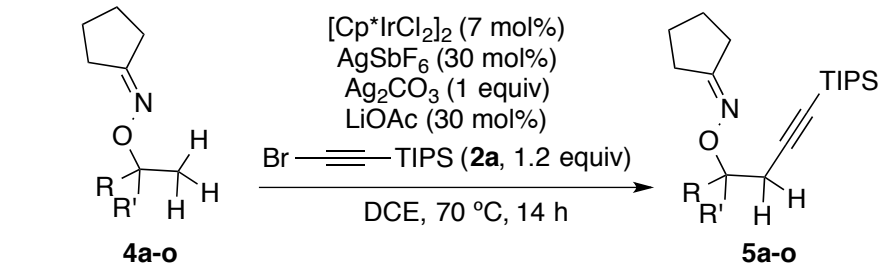
ketoximes bearing α-quaternary centers **1m** or α-hydrogen atoms **1o** could also be alkynylated, unlike palladium catalysis that requires a specific ligand in each case. It is noteworthy that the reaction can tolerate an ester (**3p)**. We also found that aldoximes derived from pivalaldehyde (**1q)** or from 2,5-dimethylhex-4-enal (**1r**) could be alkynylated in 46% and 39% yield, respectively. To the best of our knowledge, this is the first use of aldoximes as directing group in C−H functionalization.

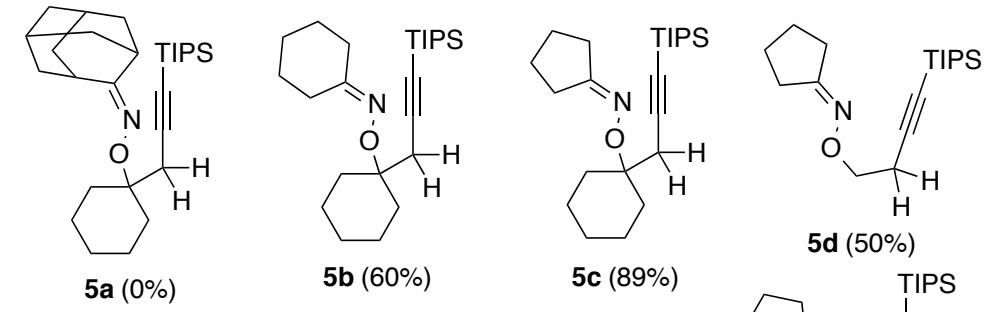



**Scheme 3.** Ir-catalyzed C($sp^3$)−H alkynylation of oxime ethers derived from ketones and aldehydes.

We next found that ether oximes derived from alcohols could also be alkynylated under identical conditions (Scheme 4). Among the different oxime ethers derived from 1-methylcyclohexanol

**4a-c**, the one derived from cyclopentanone **4c** gave the highest yield (89%). Primary **4d** secondary **4e-i**, or tertiary **4k** alcohol derivatives could be alkynylated in 44-80 % yield. The presence of a bulky adamantane group in **4l** did not have any effect on the reactivity. In **4m**, the alkynylation at the α-C($sp^3$)−H position occurred selectively even in the presence of an aromatic ring at the β-position. The presence of an ether or an alkene in **4n** or **4o** was well tolerated, leading to **5n** and **5o** in 51 % and 56 % (brsm) yield, respectively.

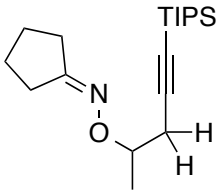


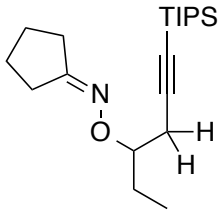


**5a** (0%)

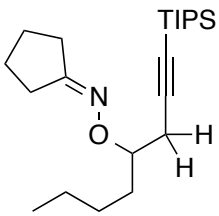

**5b** (60%)

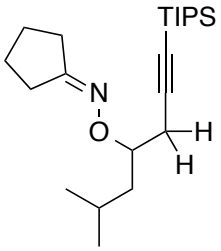

**5c** (89%)

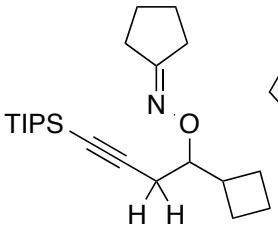

**5d** (50%)

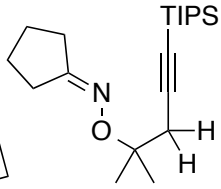

**5e** (44%)[a]

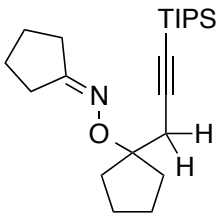

**5f** (71%)

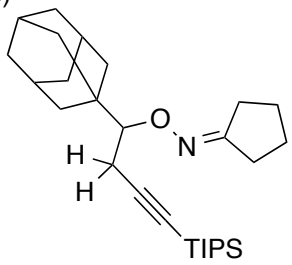

**5g** (62%)

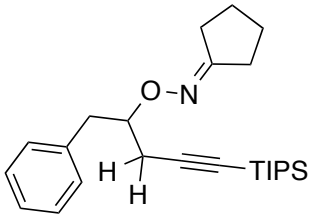

**5h** (72%)

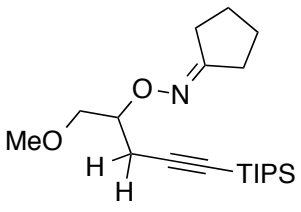

**5i** (58%)

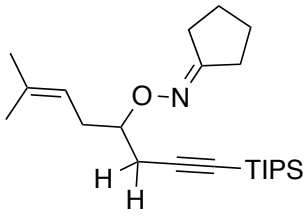

**5j** (73%)[b]


**5k** (80%)


**5l** (77%)


**5m** (64%)

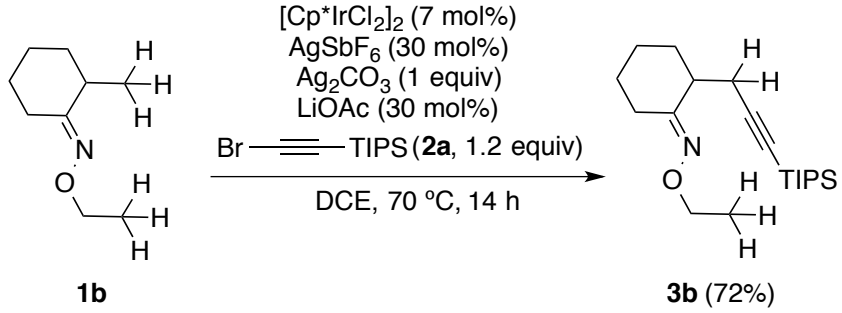

**5n** (51%)


**5o** (56%) brsm

[a]dialkynylated product isolated in 21% yield. [b]obtained as a 3:1 mixture of mono- and dialkynylated products.

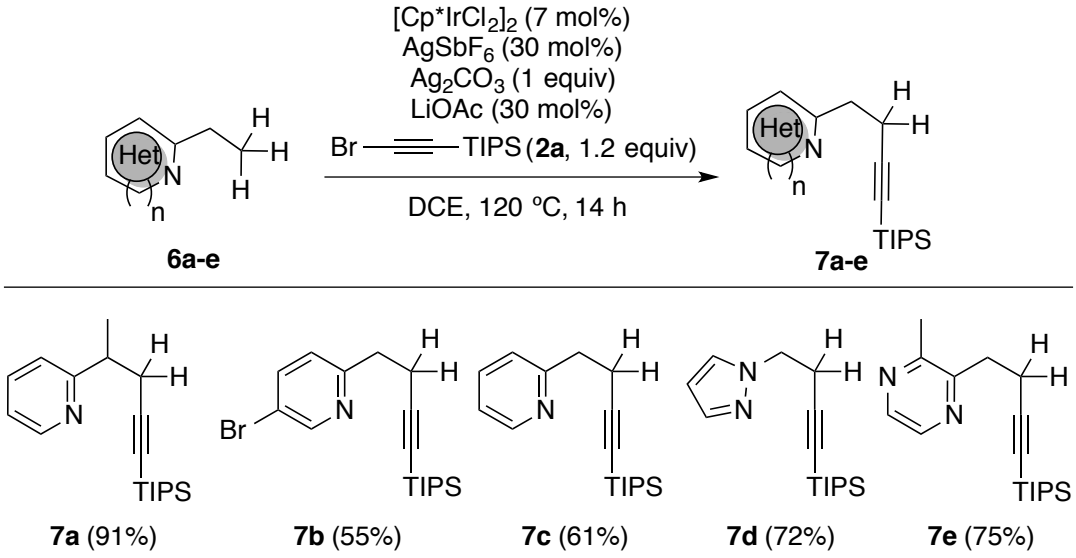
**Scheme 4.** Ir-catalyzed C($sp^3$)−H alkynylation of oxime ethers derived from alcohols.

In an intramolecular competition experiment (Scheme 5), we found that the alkynylation in **1b** occurred exclusively at the β-position of the imine, and not on the alcohol side.




**Scheme 5.** Regioselectivy in the Ir-catalyzed C($sp^3$)−H alkynylation of **1b**.

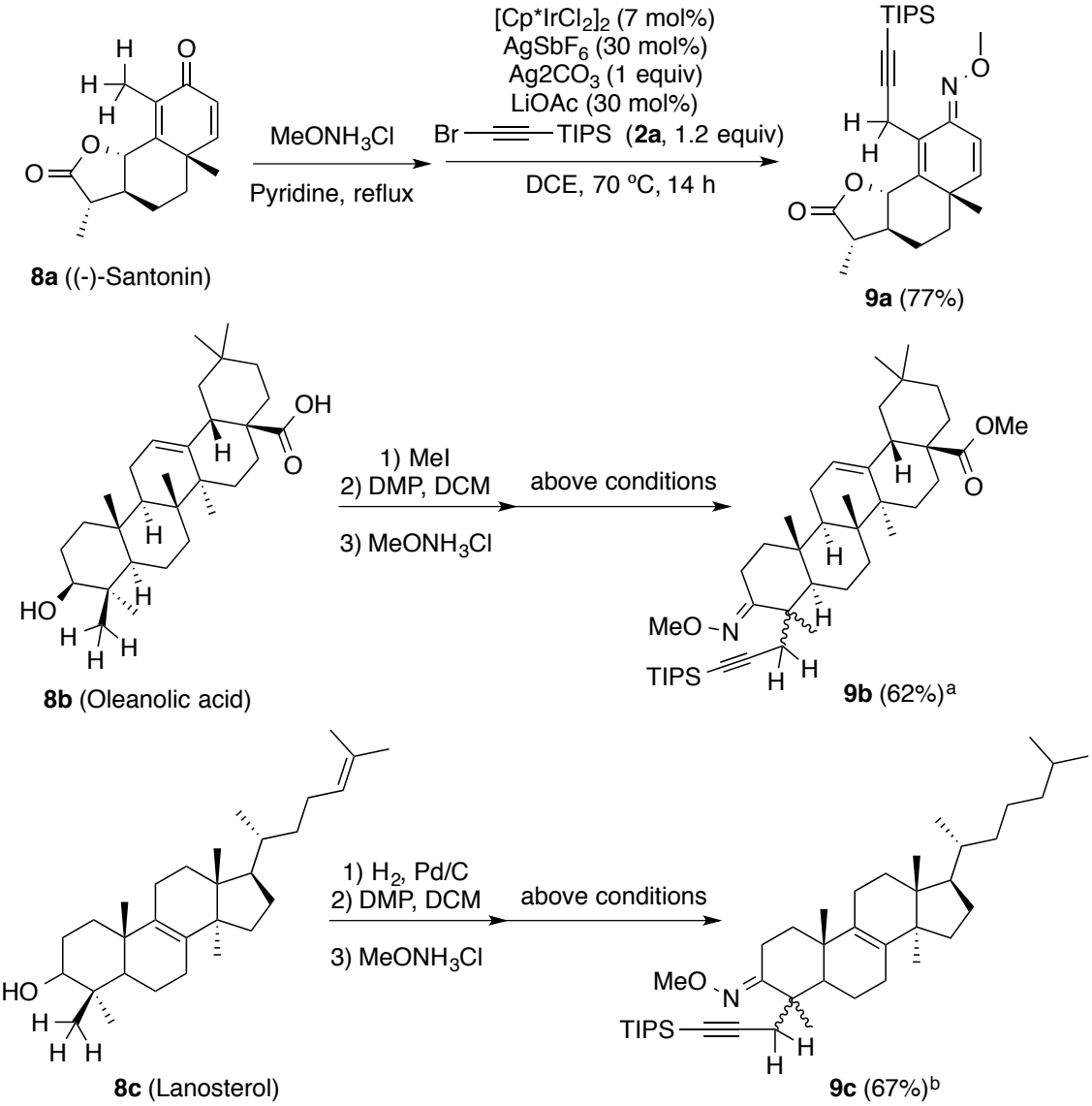
In an attempt to extend further the scope of this reaction, we found that nitrogen heterocycles such as pyridines **6a-c**, pyrazoles **6d** or pyrazine **6e** could direct the C−H alkynylation at higher temperature (120 °C) to form products **7a-e** in 55-91% yield (Scheme 6).




**Scheme 6.** Ir-catalyzed C($sp^3$)−H alkynylation of *N*-heterocycles.

We next applied the reaction to the late-stage functionalization of ketoximes derived from naphtofuran or terpenoid natural products (Scheme 7). Thus, the ketoxime derivative of (-)-santonin **8a** was alkynylated in 77% yield. The carboxylic acid in oleanolic acid **8b** was esterified, its alcohol oxidized under Dess-Martin conditions and converted to the methyl oxime and subjected our the optimized alkynylation conditions to yield a separable mixture of products

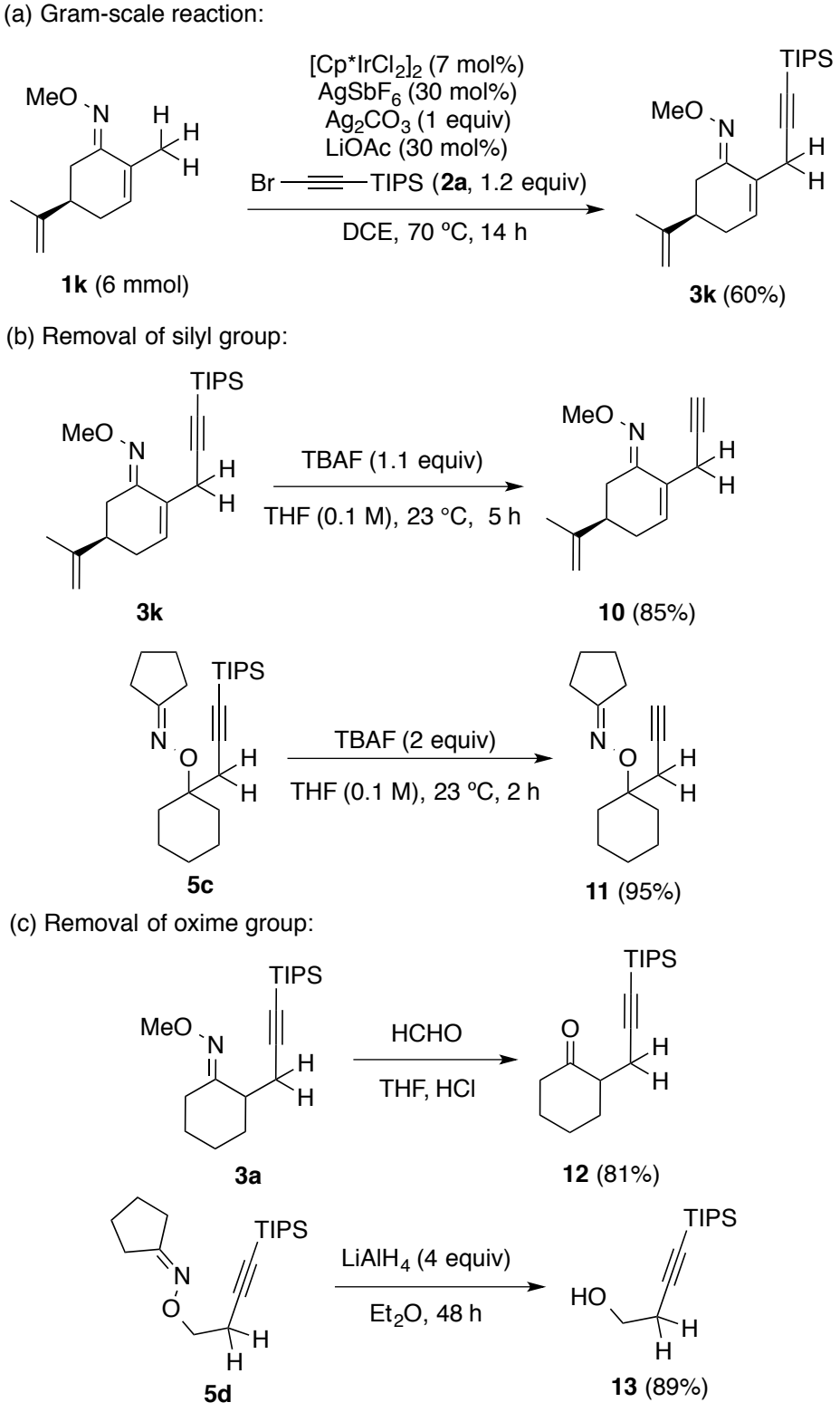
**9ba:9bb** in 62%. The trisubstituted alkene in lanosterol **8c** was hydrogenated using Pd/C as catalyst, the alcohol oxidized under Dess-Martin conditions and the resulting ketone converted into the methyl oxime. Upon C−H alkynylation, two diastereoisomeric products **9ca** and **9cb** were isolated in 67% yield.




[a]two diastereoisomers were isolated (ratio 1:5). [b]two diastereoisomers were isolated (ratio 1:6).

**Scheme 7.** Late-stage functionalization of santonin, oleanolic acid and lanosterol.

To further demonstrate the synthetic potential of this reaction, we conducted the alkynylation of **1k** on 6 mmol scale and 1.115 g (60% yield) of **3k** was isolated (Scheme 7, a). The silyl groups in **3k** and in **5c** were removed in 85% and 95% yield respectively (Scheme 7, b). Finally, the oximes in **3a** could be converted back into the corresponding ketone in 81% yield, by treatment with formaldehyde under acidic condition and **5d** was reduced with $LiAlH_4$ to afford the corresponding alcohol in 89% yield.




**Scheme 8.** (a) Gram-scale reaction. (b) Deprotection of alkynes. (c) Cleavage of oximes. TBAF = tetrabutyl-ammonium fluoride.

## Conclusions

We developed a method for the β-alkynylation of ketones, aldehydes and alcohols using an oxime as directing group. The reaction is selective towards primary $C(sp^3)$–H bonds and tolerates the presence of functional groups such as ester, ether or alkenes. Cyclic and acyclic aliphatic substrates, as well as natural product derivatives were successful substrates. Basic heterocycles such as pyridine, pyrazole or pyrazine could also be used as directing group.

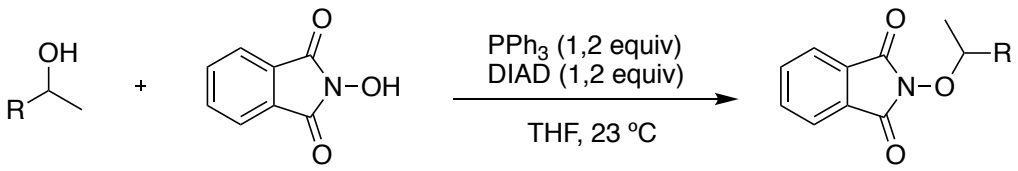
## Experimental Section

### General Methods

Reactions were carried out under argon atmosphere in solvents dried by passing through an activated alumina column on a PureSolv$^{TM}$ solvent purification system (Innovative Technologies, Inc., MA). Analytical thin layer chromatography was carried out using TLC-aluminum sheets with 0.2 mm of silica gel (Merck $GF_{234}$) using UV light as the visualizing agent and an acidic solution of vanillin in ethanol as the developing agent. Chromatographic purifications were carried out using automated flash chromatographer CombiFlash Companion. Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator. All reagents were used as purchased with no further purification, unless otherwise stated. Bromo-alkynes **2a, 2b, 2c, 2d** and oximes **1a-r** were prepared according to previous reports.[3] Their spectral data are consistent with those previously reported.

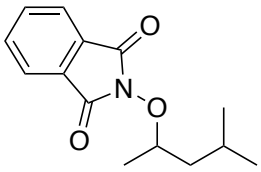
NMR spectra were recorded at 298 K (unless otherwise stated) on a Bruker Avance 300, Bruker Avance 400 Ultrashield and Bruker Avance 500 Ultrashield apparatuses. The signals are given as δ / ppm (multiplicity, coupling constant (Hertz), number of protons) downfield from tetramethylsilane, with calibration on the residual protio-solvent used ($\delta_H$ = 7.27 ppm and $\delta_C$ = 77.00 ppm for $CDCl_3$, $\delta_H$ = 5.32 ppm and $\delta_C$ = 53.84 ppm for $CD_2Cl_2$). Mass spectra were recorded on a Waters Micromass LCT Premier (ESI), Waters Micromass GCT (EI, CI) and Bruker Daltonics Autoflex (MALDI) spectrometers. Melting points were determined using a Büchi melting point apparatus.

**General procedure for the activation of primary and secondary alcohols (A)**

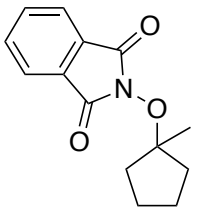



To a stirred solution of the alcohol (1 equiv), 2-hydroxyisoindoline-1,3-dione (1,2 equiv) and triphenylphosphane (1,2 equiv) in THF (0,25 M) at 0 ºC, diisopropyl (E)-diazene-1,2-dicarboxylate (1,2 equiv) was added dropwise over one hour, the reaction was then warmed up at 23 ºC and stirred until no starting material was detected by TLC. The solvent was then removed under reduced pressure and the resulting residue was purified by column chromatography on silica gel to give the corresponding N-alkoxyphthalimide.

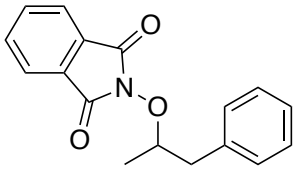
3 For bromo-alkynes see chapter **I**. For oximes, see: (a) Gao, P.; Guo, W.; Xue, J.; Zhao, Y.; Yuan, Y.; Xia, Y.; Shi, Z. *J. Am. Chem. Soc.* **2015**, *137*, 12231−12240. (b) Kang, T.; Kim, Y.; Lee, D.; Wang, Z.; Chang, S. *J. Am. Chem. Soc.,* **2014**, *136*, 4141−4144. (c) Kang, T.; Kim, H.; J. G.; Chang, S. *Chem. Commun.* **2014**, *50*, 12073−12075.



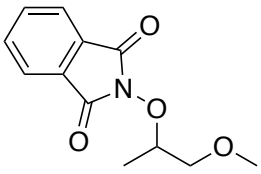
**2-((4-Methylpentan-2-yl)oxy)Isoindoline-1,3-dione (4h0).** General procedure A and obtained as a white solid in in 85% yield. **M.p.** 68-71ºC. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.9 – 7.8 (m, 2H), 7.8 – 7.7 (m, 2H), 4.5 (dq, *J* = 7.6, 6.0 Hz, 1H), 2.0 – 1.9 (m, 1H), 1.8 (ddd, *J* = 13.3, 7.6, 6.6 Hz, 1H), 1.4 – 1.4 (m, 1H), 1.3 (d, *J* = 6.1 Hz, 3H), 1.0 (d, *J* = 6.5 Hz, 3H), 0.9 (d, *J* = 6.6 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 164.5, 134.5, 129.2, 123.5, 83.0, 44.4, 24.9, 22.9, 22.7, 19.6. **HRMS** (ESI) *m/z* calculated for $C_{14}H_{17}NNaO_3^+$ $[M+Na]^+$: 270,1101, found: 270,1098.



**2-((1-methylcyclopentyl)oxy)Isoindoline-1,3-dione (4k0).** General pocedure A and obtained as a white solid in 53% yield. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.8 – 7.8 (m, 1H), 7.7 – 7.7 (m, 1H), 2.1 – 2.0 (m, 1H), 2.0 – 1.9 (m, 1H), 1.6 (qdd, *J* = 8.1, 6.6, 4.7 Hz, 1H), 1.6 – 1.5 (m, 1H), 1.4 (s, 2H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.9, 134.5, 134.5, 129.4, 123.4, 123.4, 97.9, 38.0, 24.5, 24.4. **HRMS** (ESI) *m/z* calculated for $C_{14}H_{15}NNaO_3^+$ $[M+Na]^+$: 268,0944, found: 268,0950.

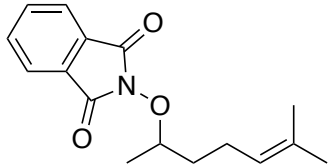


**2-((1-Phenylpropan-2-yl)oxy)isoindoline-1,3-dione** (4**m0**). General procedure A in 68% yield as a white solid. **M.p.** 90-93 ºC. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.8 (dd, *J* = 5.4, 3.1 Hz, 2H), 7.8 – 7.7 (m, 2H), 7.3 – 7.2 (m, 3H), 7.2 (ddt, *J* = 7.5, 6.0, 2.0 Hz, 1H), 4.7 – 4.6 (m, 1H), 3.2 (dd, *J* = 13.8, 5.6 Hz, 1H), 2.9 (dd, *J* = 13.8, 7.8 Hz, 1H), 1.3 (d, *J* = 6.2 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 164.4, 137.3, 134.6, 129.4, 129.1, 128.6, 126.6, 123.6, 84.8, 41.5, 18.5. **HRMS** (ESI) *m/z* calculated for $C_{17}H_{16}NO_3^+$ $[M+H]^+$: 282,1125, found: 282,1116.

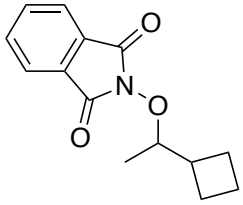


**2-((1-methoxypropan-2-yl)oxy)Isoindoline-1,3-dione (4n0).** General procedure A and obtained in 20 % yield as a yellow oil. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.7 – 7.7 (m, 2H), 7.7 – 7.6

(m, 2H), 4.5 – 4.4 (m, 1H), 3.6 (dd, *J* = 10.9, 6.1 Hz, 1H), 3.4 (dd, *J* = 10.8, 3.5 Hz, 1H), 3.2 (s, 3H), 1.3 (d, *J* = 6.5 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 163.7, 134.3, 128.8, 123.3, 82.4, 74.9, 59.0, 15.8. **HRMS** (ESI) *m/z* calculated for $C_{12}H_{14}NO4^+$ $[M+H]^+$: 236,0917, found: 236,0922.

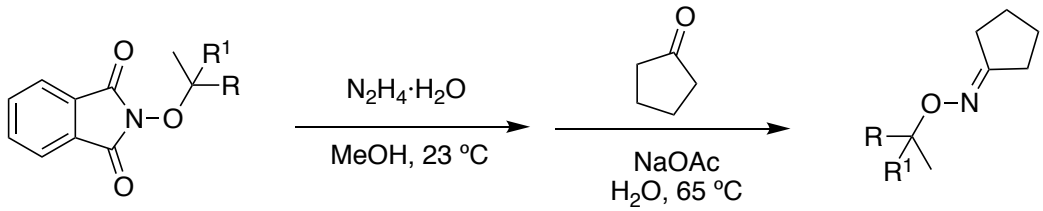


**2-((6-methylhept-5-en-2-yl)oxy)Isoindoline-1,3-dione (4o0).** General procedure A and obtained as a yellow oil in 92 % yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.8 (dd, *J* = 5.5, 3.1 Hz, 2H), 7.8 – 7.7 (m, 2H), 5.1 (ddq, *J* = 8.6, 5.8, 1.5 Hz, 1H), 4.4 (h, *J* = 6.3 Hz, 1H), 2.2 (q, *J* = 7.7 Hz, 2H), 1.9 (ddt, *J* = 13.4, 8.6, 6.5 Hz, 1H), 1.7 (d, *J* = 1.4 Hz, 3H), 1.6 (m, 4H), 1.6 (d, *J* = 1.5 Hz, 1H), 1.3 (d, *J* = 6.3 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 164.4, 134.5, 132.3, 129.1, 123.6, 123.5, 84.2, 35.1, 25.8, 24.0, 18.9, 17.8. **HRMS** (ECI) *m/z* calculated for $C_{16}H_{19}NNaO_3^+$ $[M+Na]^+$: 296,1257 found: 296,1266.



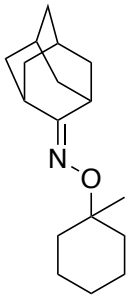
**2-(1-cyclobutylethoxy)Isoindoline-1,3-dione (4i0).** General procedure A and obtained as a yellow oil in 73 % yield. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 7.8 (dddd, *J* = 6.9, 5.0, 3.0, 1.3 Hz, 2H), 7.8 – 7.6 (m, 2H), 4.4 – 4.2 (m, 1H), 2.7 – 2.5 (m, 1H), 2.1 – 2.0 (m, 3H), 2.0 – 1.7 (m, 3H), 1.2 (dt, *J* = 6.3, 1.0 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 164.4, 134.5, 134.4, 129.2, 123.5, 88.0, 39.7, 25.9, 24.7, 18.5, 16.3. **HRMS** (ECI) *m/z* calculated for $C_{14}H_{15}NNaO_3^+$ $[M+Na]^+$: 268,0944 found: 268,0952.

**General Procedure for the synthesis of the ketoximes (B)**

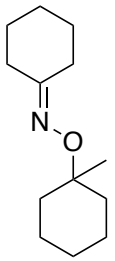



To a solution of N-alkoxyphthalimide (1 equiv) in MeOH (0,55 M), hydrazine monohydrate (1 equiv) was added slowly at 23 ºC. After stirring for 30 minutes, cyclopentanone (3 equiv), sodium

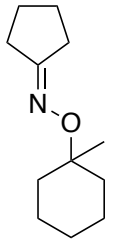
acetate (5 equiv), and water (1,4 M) was added to the reaction mixture. The resulting mixture was heated to 65 °C and stirred for 5 h. The mixture was then cooled to room temperature, filtered to remove the precipitate and the liquid phase was washed three times with $Et_2O$, the collected organic phases were dried over MgSO4, filtered, and concentrated under reduce. The crude product was purified by column chromatography on silica gel.



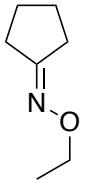
**(1*r*,5*R*,7*S*,*Z*)-Adamantan-2-one *O*-(1-methylcyclohexyl) oxime (4a).** General procedure B and obtained in 68% yield as a yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 3.58 (t, *J* = 3.30 Hz, 1H), 2.59 – 2.51 (m, 1H), 2.01 – 1.97 (m, 1H), 1.93 (ddd, *J* = 13.48, 8.23, 2.87 Hz, 4H), 1.88 – 1.75 (m, 10H), 1.59 – 1.18 (m, 12H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.7, 77.2, 39.3, 37.9, 36.8, 36.6, 36.4, 29.7, 28.2, 26.0, 25.9, 22.4. **HRMS** (ESI) *m/z* calculated for $C_{17}H_{28}NO^+$ $[M+H]^+$: 262.2165, found: 262.2164.



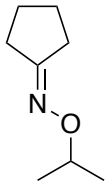
**Cyclohexanone *O*-(1-methylcyclohexyl) oxime (4b).** General procedure B and obtained in 81% yield as a yellow oil. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 2.53 – 2.47 (m, 2H), 2.23 – 2.17 (m, 2H), 1.83 (ddt, *J* = 13.06, 4.93, 2.55 Hz, 2H), 1.68 – 1.61 (m, 2H), 1.58 (p, *J* = 2.88 Hz, 4H), 1.56 – 1.45 (m, 3H), 1.45 – 1.37 (m, 2H), 1.37 – 1.28 (m, 2H), 1.24 (s, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 159.2, 77.5, 36.3, 32.7, 27.4, 26.2, 26.2, 26.0, 25.9, 25.4, 22.4, 15.4.



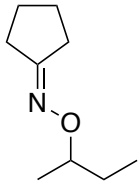
**Cyclopentanone *O*-(1-methylcyclohexyl) oxime (4c).** General procedure B and obtained in 64% yield as a yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 2.41 (tdd, *J* = 7.57, 2.38, 1.10 Hz, 2H), 2.34 (tt, *J* = 5.23, 1.48 Hz, 2H), 1.87 – 1.78 (m, 2H), 1.76 – 1.67 (m, 4H), 1.50 (ddt, *J* = 12.55, 6.88, 3.46 Hz, 3H), 1.46 – 1.25 (m, 5H), 1.23 (s, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.5, 78.0, 36.5, 31.2, 27.7, 26.3, 26.0, 25.4, 24.9, 22.5. **HRMS** (ESI) *m/z* calculated for $C_{12}H_{22}NO^+$ $[M+H]^+$: 196,1696, found: 196,1695.



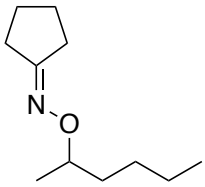
**Cyclopentanone *O*-ethyl oxime (4d).** Ethoxyamine hydrochloride (585 mg, 6,00 mmol) and sodium acetate (656 mg, 8,00 mmol) were added to a stirred solution of cyclopentanone (177 µl, 2 mmol) in Water (4 mL) andEtOH (2 mL) and the mixture was stirred at 65 ºC for 3h. After cooling to room temperature, the aqueous layer was extracted with EtOAc and the extracted organic phase dried over $Na_2SO_4$ filtered and dried under reduced pressure. The residue was purified by column chromatography on silica gel with pentane as eluent to give the pure oxime **4d** in 40% yield. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.05 (q, *J* = 7.06 Hz, 1H), 2.43 – 2.24 (m, 2H), 1.81 – 1.65 (m, 2H), 1.22 (t, *J* = 7.01 Hz, 1H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 166.1, 69.0, 31.1, 27.7, 25.2, 24.8, 14.9. **HRMS** (ESI) *m/z* calculated for $C_7H_{14}NO^+$ $[M+H]^+$: 128,1070, found: 128,1073.



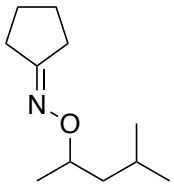
**Cyclopentanone *O*-isopropyl oxime (4e).** General procedure B and obtained in 80% yield as a colorless oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.27 (hept, *J* = 6.21 Hz, 1H), 2.52 – 2.27 (m, 4H), 1.88 – 1.66 (m, 4H), 1.21 (d, *J* = 6.23 Hz, 6H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.8, 74.8, 31.1, 27.8, 25.3, 24.8, 22.0. **HRMS** (ESI) *m/z* calculated for $C_8H_{16}NO^+$ $[M+H]^+$: 142.1226, found: 142.1223



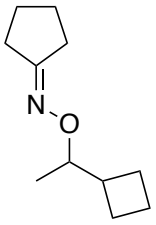
**Cyclopentanone *O*-(*sec*-butyl) oxime (4f).** General procedure B and obtained in 85% yield as a yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 4.04 (h, *J* = 6.23 Hz, 1H), 2.42 – 2.31 (m, 4H), 1.76 – 1.68 (m, 4H), 1.68 – 1.57 (m, 1H), 1.54 – 1.39 (m, 1H), 1.18 (d, *J* = 6.28 Hz, 3H), 0.89 (t, *J* = 7.47 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.7, 79.8, 31.1, 28.7, 27.7, 25.3, 24.8, 19.5, 9.8. **HRMS** (ESI) *m/z* calculated for $C_9H_{18}NO^+$ $[M+H]^+$: 156,1383, found: 156,1382.



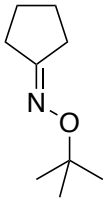
**Cyclopentanone *O*-hexan-2-yl oxime (4g).** General procedure B and obtained in 81% yield as a pale yellow oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.08 (h, *J* = 6.24 Hz, 1H), 2.34 (dddd, *J* = 13.54, 7.27, 5.06, 1.12 Hz, 4H), 1.77 – 1.65 (m, 4H), 1.66 – 1.55 (m, 1H), 1.47 – 1.36 (m, 1H), 1.36 – 1.23 (m, 4H), 1.17 (d, *J* = 6.26 Hz, 3H), 0.91 – 0.84 (m, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.5, 78.6, 35.7, 31.1, 27.9, 27.7, 25.3, 24.8, 22.9, 20.1, 14.2. **HRMS** (ESI) *m/z* calculated for $C_{11}H_{22}NO^+$ $[M+H]^+$: 184.1696, found: 184.1696.



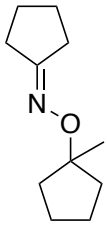
**Cyclopentanone *O*-(4-methylpentan-2-yl) oxime (4h).** General procedure B and obtained in 83% yield as a yellow oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.24 – 4.12 (m, 1H), 2.40 – 2.29 (m, 4H), 1.78 – 1.66 (m, 5H), 1.60 – 1.50 (m, 1H), 1.27 – 1.21 (m, 1H), 1.19 (d, *J* = 6.18 Hz, 3H), 0.89 (dd, *J* = 6.66, 5.88 Hz, 6H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.6, 77.0, 45.1, 31.1, 27.8, 25.3, 25.0, 24.8, 23.1, 23.0, 20.7. **HRMS** (ESI) *m/z* calculated for $C_{11}H_{22}NO^+$ $[M+H]^+$: 184,1696, found: 184,1695.



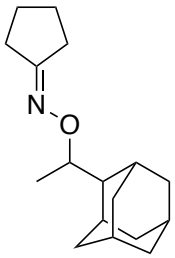
**cyclopentanone *O*-(1-cyclobutylethyl) oxime (4i).** General procedure B and obtained in 88% yield as a colorless oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.03 (dq, *J* = 7.64, 6.24 Hz, 1H), 2.42 – 2.30 (m, 5H), 2.01 – 1.75 (m, 6H), 1.74 – 1.68 (m, 4H), 1.09 (d, *J* = 6.22 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.7, 82.1, 40.6, 31.1, 27.7, 25.3, 25.2, 24.8, 24.6, 18.4, 17.5. **HRMS** (ESI) *m/z* calculated for $C_{11}H_{20}NO^+$ $[M+H]^+$: 182,1539, found: 182,1527



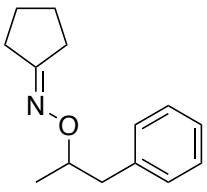
**Cyclopentanone *O*-(*tert*-butyl) oxime (4j).** General procedure B and obtained in 72% yield as a yellow oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 2.48 – 2.25 (m, 4H), 1.83 – 1.65 (m, 4H), 1.25 (s, 7H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.1, 77.3, 31.1, 27.8, 27.6, 25.3, 24.8.



**Cyclopentanone *O*-(1-methylcyclopentyl) oxime (4k).** General procedure B and obtained in 78% yield as a yellow oil **$^1$H NMR** (400 MHz, $CDCl_3$) δ 2.39 – 2.31 (m, 4H), 1.94 (dddd, $J$ = 13.12, 7.25, 3.10, 1.32 Hz, 2H), 1.70 (m, 6H), 1.58 (m, 2H), 1.52 – 1.41 (m, 2H), 1.37 (s, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.5, 88.5, 38.1, 31.0, 27.5, 25.2, 25.0, 24.7, 24.5. **HRMS** (ESI) *m/z* calculated for $C_{11}H_{20}NO^+$ $[M+H]^+$: 182.1544, found: 182.1539.

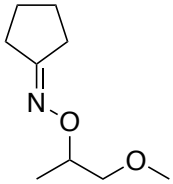


**Cyclopentanone *O*-(1-((1*R*,3*S*,5*r*,7*r*)-adamantan-2-yl)ethyl) oxime (4l)**. General procedure B and obtained in 74% yield as a yellow oil **$^1$H NMR** (500 MHz, $CDCl_3$) δ 3.65 (q, $J$ = 6.45 Hz, 1H), 2.40 (dddq, $J$ = 7.19, 3.54, 2.20, 1.14 Hz, 2H), 2.38 – 2.32 (m, 2H), 1.96 (p, $J$ = 3.21 Hz, 3H), 1.78 – 1.68 (m, 7H), 1.65 (m, 6H), 1.53 (m, 3H), 1.11 (d, $J$ = 6.47 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.3, 86.4, 38.5, 37.5, 36.5, 31.1, 28.6, 27.8, 25.3, 24.8, 13.8. **HRMS** (ESI) *m/z* calculated for $C_{17}H_{28}NO^+$ $[M+H]^+$: 262.2174, found: 262.2165

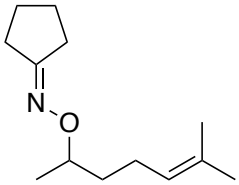


**Cyclopentanone *O*-(1-phenylpropan-2-yl) oxime (4m)**. General procedure B and obtained in 74% yield as a yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 7.35 – 7.29 (m, 2H), 7.28 – 7.21 (m,

3H), 4.55 – 4.31 (m, 1H), 3.06 (dd, *J* = 13.54, 5.91 Hz, 1H), 2.78 (dd, *J* = 13.53, 6.84 Hz, 1H), 2.54 – 2.32 (m, 4H), 1.88 – 1.65 (m, 4H), 1.24 (d, *J* = 6.29 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.2, 139.0, 129.8, 128.2, 126.1, 79.2, 42.3, 31.1, 28.0, 25.3, 24.8, 19.4. **HRMS** (ESI) *m/z* calculated for $C_{14}H_{20}NO^+$ $[M+H]^+$: 218.1535, found: 218.1539

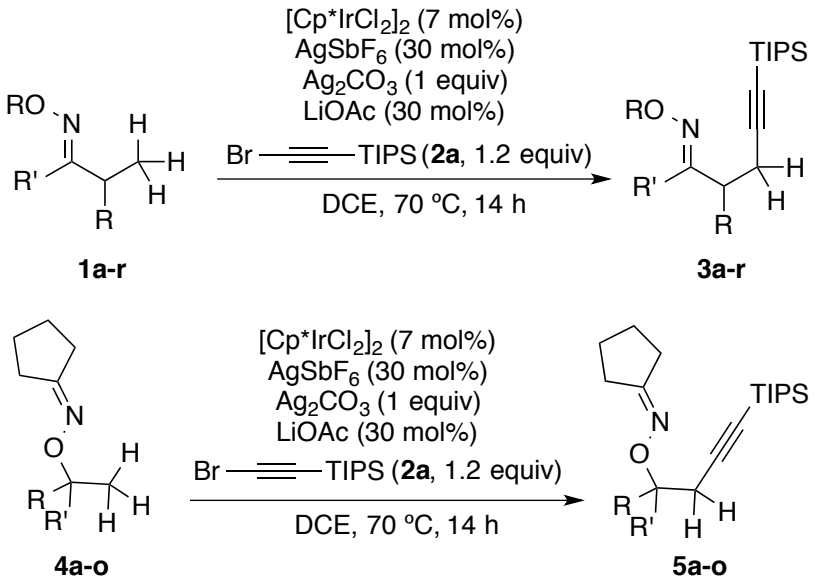


**Cyclopentanone *O*-(1-methoxypropan-2-yl) oxime (4n)**. General procedure B and obtained in 77% yield as a yellow oil. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 4.28 – 4.19 (m, 1H), 3.45 (dd, *J* = 10.25, 5.72 Hz, 1H), 3.34 (dd, *J* = 10.27, 4.61 Hz, 1H), 3.31 (s, 3H), 2.38 – 2.31 (m, 2H), 2.31 – 2.26 (m, 2H), 1.72 – 1.59 (m, 4H), 1.16 (d, *J* = 6.45 Hz, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 166.2, 77.4, 75.3, 59.2, 30.9, 27.7, 25.1, 24.6, 16.9. **HRMS** (ESI) *m/z* calculated for $C_9H_{17}NNaO_2^+$ $[M+Na]^+$: 194.1151, found: 194.1149

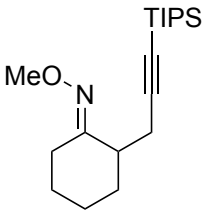


**Cyclopentanone *O*-(6-methylhept-5-en-2-yl) oxime (4o)**. General procedure B and obtained in 93% yield as a pale yellow oil. **$^{1}$H NMR** (400 MHz, $CDCl_3$) δ 5.10 (ddq, *J* = 8.59, 5.73, 1.34 Hz, 1H), 4.09 (h, *J* = 6.28 Hz, 1H), 2.41 – 2.29 (m, 4H), 2.02 (q, *J* = 7.77 Hz, 2H), 1.75 – 1.67 (m, 4H), 1.65 (t, *J* = 1.30 Hz, 3H), 1.67 – 1.58 (m, 4H), 1.57 (s, 3H), 1.50 – 1.38 (m, 1H), 1.19 (dd, *J* = 6.27, 0.95 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.5, 131.5, 124.5, 78.1, 36.0, 31.0, 27.7, 25.8, 25.3, 24.8, 24.2, 20.1, 17.6. **HRMS** (ESI) *m/z* calculated for $C_{13}H_{24}NO^+$ $[M+H]^+$: 210.1852, found: 210.1855

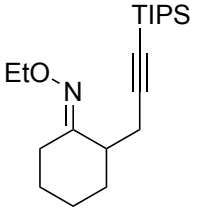
**General procedure for the Ir-catalyzed C-H alkynylation (C)**




In a glovebox, a microwave vial is charged with $[Cp^*IrCl_2]_2$ (7 mol %), $AgSbF_6$ (30 mol %), LiOAc (30 mol %), $Ag_2CO_3$ (1 equiv) and filled with DCE (1.5 mL). Substrate **1a-r,4a-o** (0.2 mmol) and (bromoethynyl)triisopropylsilane (**2a**) (1.1 equiv) are then added. The vial is heated with stirring at 70 °C outside of the glovebox. The reaction was then cooled to room temperature and filtered through a pad of Celite®, washed with $CH_2Cl_2$, and the solvent removed under reduced pressure. The residue was purified by column chromatography on silica gel.

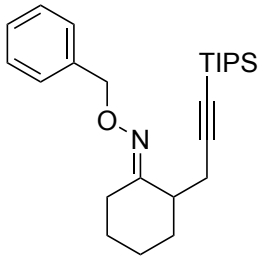



**(*E*)-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)Cyclohexan-1-one *O*-methyl oxime (3a)**. General procedure C in 78% yield as a colorless oil. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 3.79 (s, 3H), 2.81 (ddd, *J* = 14.1, 5.6, 3.6 Hz, 1H), 2.73 – 2.59 (m, 1H), 2.44 – 2.30 (m, 2H), 2.20 – 1.95 (m, 2H), 1.81 – 1.62 (m, 2H), 1.56 – 1.41 (m, 3H), 1.05 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 160.3, 107.7, 81.4, 61.2, 41.6, 32.3, 26.2, 24.2, 24.1, 22.2, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{19}H_{36}NOSi$ $[M+H]^+$: 322.2561, found: 322.2560.

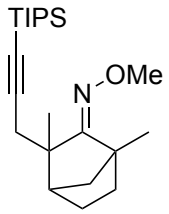



**(*E*)-2-(3-(triisopropylsilyl)Prop-2-yn-1-yl)cyclohexan-1-one *O*-ethyl oxime (3b)**. General procedure C and obtained in 72% yield as a colorless oil. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 4.03 (q,

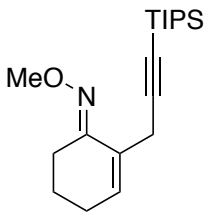
*J* = 7.0 Hz, 2H), 2.91 – 2.79 (m, 1H), 2.74 – 2.60 (m, 1H), 2.43 – 2.31 (m, 2H), 2.19 – 1.96 (m, 2H), 1.79 – 1.64 (m, 2H), 1.48 (qt, *J* = 5.4, 1.7 Hz, 3H), 1.22 (t, *J* = 7.0 Hz, 3H), 1.09 – 1.03 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 159.9, 108.0, 81.3, 68.9, 41.7, 32.3, 26.1, 24.4, 24.2, 22.2, 18.8, 14.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{20}H_{38}NOSi$ $[M+H]^+$: 336.2717, found: 336.2704.



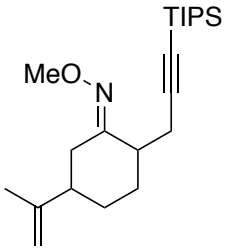

**(*E*)-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)Cyclohexan-1-one *O*-benzyl oxime (3c)**. General procedure C and obtained in 70% yield as a colorless oil. **$^{1}$H NMR** (300 MHz, $CDCl_3$) δ 7.39 – 7.23 (m, 5H), 5.05 (s, 2H), 2.95 (dt, *J* = 14.0, 4.6 Hz, 1H), 2.78 – 2.60 (m, 1H), 2.38 (q, *J* = 3.8 Hz, 2H), 2.25 – 2.10 (m, 1H), 2.02 (ddd, *J* = 14.7, 9.9, 4.5 Hz, 1H), 1.70 (t, *J* = 6.1 Hz, 2H), 1.52 – 1.42 (m, 3H), 1.12 – 0.95 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 160.9, 138.5, 128.4, 128.24 127.7, 107.8, 81.4, 75.5, 41.8, 32.4, 26.2, 24.7, 24.3, 22.2, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{25}H_{40}NOSi$ $[M+H]^+$: 398.2874, found: 398.2871.



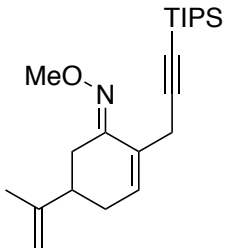

**(*E*)-1,3-Dimethyl-3-(3-(triisopropylsilyl)prop-2-yn-1-yl)bicyclo[2.2.1]heptan-2-one *O*-methyl oxime (3h)**. General procedure C and obtained in 72% yield as a colorless oil. **$^{1}$H NMR** (300 MHz, $CDCl_3$) δ 3.74 (s, 3H), 2.60 (d, *J* = 3.6 Hz, 2H), 1.94 (td, *J* = 12.2, 3.5 Hz, 1H), 1.83 – 1.78 (m, 2H), 1.63 – 1.55 (m, 2H), 1.35 (dtd, *J* = 8.7, 5.5, 3.2 Hz, 2H), 1.27 (s, 3H), 1.23 (s, 3H), 1.08 (s, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 170.4, 106.9, 81.2, 61.3, 52.8, 48.2, 45.1, 40.6, 31.4, 25.9, 25.4, 23.3, 22.6, 22.2, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{40}NOSi$ $[M+H]^+$: 362.2874, found: 362.2866.



**(*E*)-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)Cyclohex-2-en-1-one *O*-methyl oxime (3i)**. General procedure C and obtained in 55% yield as a colorless oil. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 6.53 (tt, *J* = 4.4, 1.7 Hz, 1H), 3.85 (s, 3H), 3.28 (q, *J* = 2.1 Hz, 2H), 2.53 (dd, *J* = 7.2, 6.1 Hz, 2H), 2.20 (dtt, *J* = 8.5, 4.5, 2.3 Hz, 2H), 1.70 (p, *J* = 6.3 Hz, 2H), 1.10 – 1. 05 (m 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 154.4, 133.1, 129.7, 105.9, 83.5, 61.9, 25.2, 23.1, 21.9, 21.3, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{19}H_{34}NOSi$ $[M+H]^+$: 320.2404, found: 320.2409.

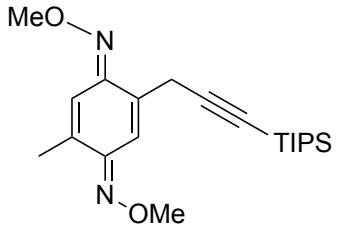



**(*E*)-5-(prop-1-en-2-yl)-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)Cyclohexan-1-one *O*-methyl oxime (3j)**. General procedure C and obtained in 45% yield as a colorless oil. **$^1$H NMR** (300 MHz, *CDCl3*) δ 4.74 (q, *J* = 1.4 Hz, 2H), 3.80 (s, 3H), 3.31 (ddd, *J* = 13.6, 3.9, 2.1 Hz, 1H), 2.83 – 2.72 (m, 1H), 2.41 – 2.22 (m, 3H), 2.05 (tt, *J* = 12.1, 3.6 Hz, 1H), 1.92 (ddd, *J* = 12.8, 3.4, 2.2 Hz, 1H), 1.74 (t, *J* = 1.1 Hz, 3H), 1.62 – 1.52 (m, 1H), 1.46 – 1.24 (m, 2H), 1.06 (d, *J* = 3.9 Hz, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 159.2, 148.6, 109.5, 108.1, 81.2, 45.0, 42.6, 32.4, 30.8, 29.9, 21.7, 20.9, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{40}NOSi$ $[M+H]^+$: 362.2874, found: 362.2873.

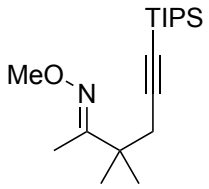



**(*E*)-5-(prop-1-en-2-yl)-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)Cyclohex-2-en-1-one *O*-methyl oxime (3k)**. General procedure C and obtained in 70% yield as a colorless oil. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 6.56 – 6.49 (m, 1H), 4.80 – 4.75 (m, 2H), 3.87 (s, 3H), 3.29 (dt, *J* = 3.3, 1.6 Hz, 2H), 3.13 (ddd, *J* = 16.4, 3.8, 1.7 Hz, 1H), 2.34 (dddd, *J* = 13.8, 12.6, 6.5, 2.8 Hz, 2H), 2.13 (dddd, *J* = 15.4, 12.4, 5.8, 3.0 Hz, 1H), 2.01 (dd, *J* = 16.4, 12.5 Hz, 1H), 1.75 (t, *J* = 1.1 Hz, 3H), 1.25 (s, 2H), 1.10 – 1.05 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 154.5, 153.9, 148.0, 132.4, 129.5, 110.1, 105.8, 83.6, 61.9, 40.3, 30.5, 28.0, 21.7, 20.8, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{24}H_{36}NOSi$ $[M+H]^+$: 382.2561, found: 382.2547.

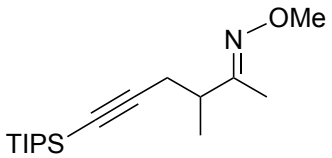
The reaction was also carried out on gram-scale starting from 1.074 g of (*E*)-2-methyl-5-(prop-1-en-2-yl)cyclohex-2-en-1-one *O*-methyl oxime (**1k**), yielding 1.115 g of **3k**.



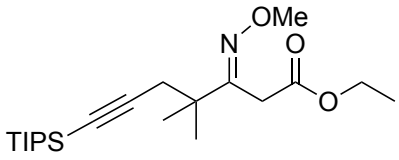

**(1*E*,4*E*)-2-Methyl-5-(3-(triisopropylsilyl)prop-2-yn-1-yl)cyclohexa-2,5-diene-1,4-dione *O*,*O*-dimethyl dioxime (3l)**. General procedure C and obtained in 45% yield as a colorless oil. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 7.60 (t, *J* = 1.8 Hz, 1H), 6.94 (q, *J* = 1.3 Hz, 1H), 4.01 (s, 3H), 3.99 (s, 3H), 3.52 (d, *J* = 1.8 Hz, 2H), 2.10 (d, *J* = 1.4 Hz, 3H), 1.13 – 1.06 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 151.2, 149.1, 138.1, 136.1, 116.5, 116.2, 104.2, 84.9, 62.9, 62.7, 21.7, 18.8, 17.5, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{21}H_{35}N_2O_2Si$ $[M+H]^+$: 382.2561, found: 382.2547.



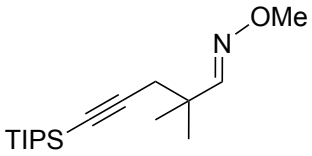

**(*E*)-3,3-Dimethyl-6-(triisopropylsilyl)hex-5-yn-2-one *O*-methyl oxime (3m)**. General procedure C and obtained in 89% yield as a colorless oil. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 3.81 (s, 3H), 2.41 (s, 2H), 1.80 (s, 3H), 1.19 (s, 6H), 1.10 – 1.05 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 161.0, 106.2, 82.5, 61.3, 40.4, 31.5, 25.2, 18.8, 11.4, 10.6. **HRMS** (ESI) *m/z* calculated for $C_{21}H_{35}N_2O_2Si$ $[M+H]^+$: 375.2462, found: 375.2460. **HRMS** (APCI) *m/z* calculated for $C_{18}H_{36}NOSi$ $[M+H]^+$: 310.2561, found: 310.2571.



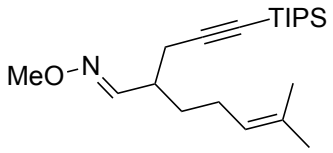

**(*E*)-3-Methyl-6-(triisopropylsilyl)hex-5-yn-2-one *O*-methyl oxime (3o)**. General procedure C and obtained in 55% yield as a colorless oil. **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 3.81 (d, *J* = 0.8 Hz, 3H), 2.63 – 2.53 (m, 1H), 2.50 – 2.27 (m, 2H), 1.79 (d, *J* = 0.8 Hz, 3H), 1.18 (d, *J* = 6.9 Hz, 3H), 1.12 – 1.06 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 159.5, 106.5, 82.1, 61.3, 39.4, 29.8, 25.1, 18.7, 17.6, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{17}H_{34}NOSi$ $[M+H]^+$: 296.2404, found: 296.2407.



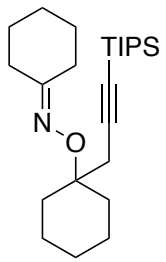
**Ethyl (*E*)-3-(methoxyimino)-4,4-dimethyl-7-(triisopropylsilyl)hept-6-ynoate (3p)**. General procedure C and obtained in 63% yield as a colorless oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.13 (q, *J* = 7.1 Hz, 2H), 3.80 (s, 3H), 3.24 (s, 2H), 2.45 (s, 2H), 1.28 – 1.14 (m, 9H), 1.10 – 0.95 (m, 22H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 169.4, 157.8, 105.8, 82.9, 61.6, 60.9, 40.1, 32.1, 31.4, 24.9, 18.8, 14.2, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{21}H_{39}NNaO_3Si$ $[M+Na]^+$: 404.2591, found: 404.2592.




**(*E*)-2,2-Dimethyl-5-(triisopropylsilyl)pent-4-ynal *O*-methyl oxime (3q)**. General procedure C and obtained in 46% yield as a colorless oil. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 7.36 (s, 1H), 3.80 (s, 3H), 2.35 (s, 2H), 1.19 (s, 6H), 1.17 – 0.98 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 156.3, 105.2, 83.1, 61.4, 36.7, 32.1, 25.2, 18.8, 11.4. **HRMS** (APCI) *m/z* calculated for $C_{17}H_{34}NOSi$ $[M+H]^+$: 296.2404, found: 296.2412.

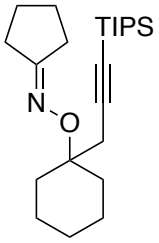



**(*E*)-6-Methyl-2-(3-(triisopropylsilyl)prop-2-yn-1-yl)hept-5-enal *O*-methyl oxime (3r)**. General procedure C and obtained in 39% yield as a colorless oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 7.22 (d, *J* = 7.3 Hz, 1H), 5.43 (tq, *J* = 7.2, 1.5 Hz, 1H), 3.81 (s, 3H), 2.95 – 2.92 (m, 2H), 2.36 (dt, *J* = 14.0, 7.2 Hz, 1H), 2.05 (dt, *J* = 8.8, 7.1 Hz, 2H), 1.67 – 1.66 (m, 3H), 1.55 (s, 3H), 1.46 – 1.36 (m, 2H), 1.12 – 1.05 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 155.2, 130.7, 125.3, 106.2, 82.7, 61.3, 34.7, 34.0, 30.1, 25.6, 18.8, 18.3, 16.3, 11.5.

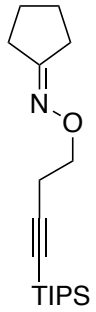



**Cyclohexanone *O*-(1-(3-(triisopropylsilyl)prop-2-yn-1-yl)cyclohexyl) oxime (5b)**. General procedure C and obtained in 60% yield as a pale yellow oil. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 2.59 (s, 2H), 2.48 (td, *J* = 5.7, 4.9, 2.2 Hz, 2H), 2.20 – 2.13 (m, 2H), 1.94 – 1.86 (m, 2H), 1.64 (ddd, *J* = 13.5, 10.8, 6.3 Hz, 4H), 1.58 (dq, *J* = 6.5, 3.9, 3.0 Hz, 5H), 1.52 – 1.43 (m, 4H), 1.25 – 1.15 (m, 1H), 1.10 – 0.95 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 159.5, 106.7, 81.7, 79.0,

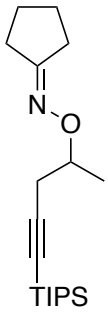
33.3, 32.6, 30.7, 27.4, 26.2, 26.2, 25.8, 25.5, 22.0, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{24}H_{44}NOSi^+$ $[M+H]^+$: 390.3187, found: 364,3189.




**Cyclopentanone *O*-(1-(3-(triisopropylsilyl)prop-2-yn-1-yl)cyclohexyl) oxime (5c)**. General procedure C and obtained in 89% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, CDCl3) δ 2.57 (s, 2H), 2.42 (ddd, *J* = 7.38, 5.15, 2.82 Hz, 2H), 2.36 – 2.30 (m, 2H), 1.94 – 1.85 (m, 2H), 1.75 – 1.68 (m, 4H), 1.68 – 1.56 (m, 4H), 1.54 – 1.43 (m, 4H), 1.10 – 1.03 (m, 21H).**$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.8, 106.5, 81.7, 79.2, 33.5, 31.1, 31.0, 27.6, 25.8, 25.4, 24.8, 22.0, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{23}H_{42}NOSi^+$ $[M+H]^+$: 376.3030, found: 376,3044.

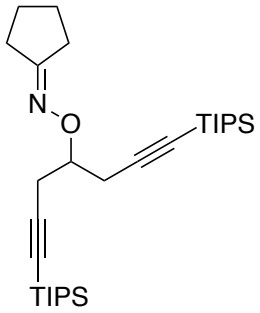



**Cyclopentanone *O*-(4-(triisopropylsilyl)but-3-yn-1-yl) oxime (5d)**. General procedure C and obtained in 50% yield as a colorless oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.13 (t, *J* = 7.1 Hz, 2H), 2.59 (t, *J* = 7.1 Hz, 2H), 2.45 – 2.31 (m, 4H), 1.80 – 1.66 (m, 4H), 1.12 – 0.97 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 167.1, 105.5, 81.6, 71.8, 31.1, 27.8, 25.3, 24.8, 21.2, 18.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{18}H_{34}NOSi^+$ $[M+H]^+$: 308.2404, found: 308.2403.

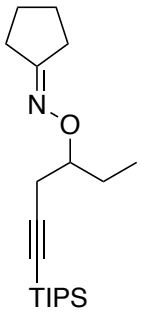



**Cyclopentanone *O*-(5-(triisopropylsilyl)pent-4-yn-2-yl) oxime (5e)**. General procedure C and obtained in 44% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.35 – 4.21 (m, 1H), 2.64 (dd, *J* = 16.6, 4.1 Hz, 1H), 2.47 – 2.41 (dd, *J* = 16.6, 7.6 Hz, 1H), 2.41 (m, 4H), 1.72 (ddp, *J* = 5.8, 3.8, 1.9 Hz, 4H), 1.35 (d, *J* = 6.3 Hz, 3H), 1.12 – 0.96 (m, 21H). **$^{13}$C NMR** (101

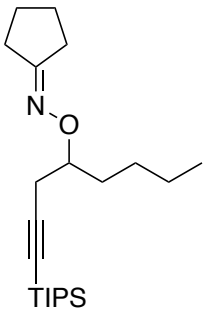
MHz, CDCl3) δ 166.7, 105.5, 82.0, 76.9, 31.1, 27.9, 27.1, 25.3, 24.8, 19.0, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{19}H_{36}NOSi^+$ $[M+H]^+$: 322.2561, found: 322.2564



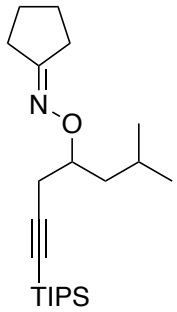

**Cyclopentanone *O*-(1,7-bis(triisopropylsilyl)hepta-1,6-diyn-4-yl) oxime (5ee)**. General procedure C and obtained in 21% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.28 (p, *J* = 5.7 Hz, 1H), 2.73 (dd, *J* = 5.8, 1.0 Hz, 4H), 2.46 – 2.30 (m, 4H), 1.76 – 1.67 (m, 4H), 1.17 – 0.94 (m, 42H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 167.4, 104.8, 82.4, 79.0, 31.1, 27.9, 25.3, 24.8, 24.1, 18.8, 18.7, 18.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{30}H_{56}NOSi_2^+$ $[M+H]^+$: 502.3895, found: 502.3896.



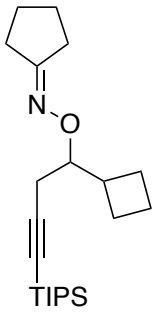

**Cyclopentanone *O*-(6-(triisopropylsilyl)hex-5-yn-3-yl) oxime (5f)**. General procedure C and obtained in 71% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 4.06 (tt, *J* = 7.29, 4.70 Hz, 1H), 2.62 (dd, *J* = 16.79, 4.37 Hz, 1H), 2.48 (dd, *J* = 16.81, 7.24 Hz, 1H), 2.44 – 2.30 (m, 4H), 1.87 – 1.75 (m, 1H), 1.72 (tq, *J* = 5.60, 2.07 Hz, 5H), 1.10 – 1.02 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.7, 105.7, 81.9, 81.8, 31.1, 27.8, 25.8, 25.3, 25.0, 24.8, 18.8, 11.4, 9.9. **HRMS** (ESI) *m/z* calculated for $C_{20}H_{38}NOSi^+$ $[M+H]^+$: 336.2717, found: 336.2719.



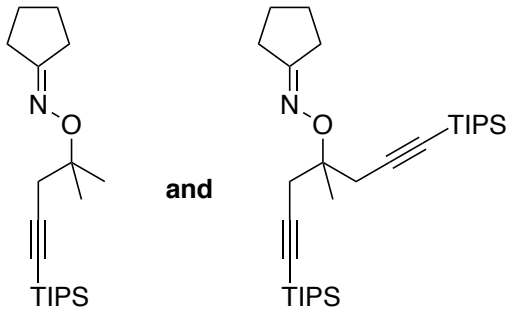
**Cyclopentanone *O*-(1-(triisopropylsilyl)oct-1-yn-4-yl) oxime (5g)**. General procedure C and obtained in 62% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.11 (tt, *J* = 7.5, 4.7 Hz, 1H), 2.62 (dd, *J* = 16.8, 4.1 Hz, 1H), 2.47 (dd, *J* = 16.8, 7.3 Hz, 1H), 2.42 – 2.31 (m, 4H), 1.87 – 1.60 (m, 6H), 1.50 – 1.27 (m, 4H), 1.15 – 0.94 (m, 21H), 0.90 (t, *J* = 7.1 Hz, 3H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.7, 105.8, 82.0, 80.9, 32.6, 31.2, 28.0, 27.9, 25.6, 25.4, 24.9, 23.0, 18.9, 14.2, 11.6. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{42}NOSi^+$ $[M+H]^+$: 364.3030, found: 364,3031.




**Cyclopentanone *O*-(6-methyl-1-(triisopropylsilyl)hept-1-yn-4-yl) oxime (5h)**. General procedure C and obtained in 72% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, $CDCl_3$) δ 4.19 (tdd, *J* = 7.41, 5.88, 3.81 Hz, 1H), 2.64 (dd, *J* = 16.67, 3.81 Hz, 1H), 2.45 (dd, *J* = 16.69, 7.58 Hz, 1H), 2.41 – 2.32 (m, 4H), 1.81 (dq, *J* = 13.39, 6.70 Hz, 1H), 1.76 – 1.69 (m, 4H), 1.64 – 1.57 (m, 2H), 1.10 – 1.02 (m, 21H), 0.92 (d, *J* = 6.66 Hz, 6H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 166.6, 105.8, 81.9, 79.2, 41.9, 31.1, 27.9, 26.0, 25.3, 24.9, 24.8, 23.5, 22.6, 18.8, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{42}NOSi^+$ $[M+H]^+$: 364.3030, found: 364,3037.




**Cyclopentanone *O*-(1-cyclobutyl-4-(triisopropylsilyl)but-3-yn-1-yl) oxime (5i)**. General procedure C and obtained in 58% yield as a colorless oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 4.06 (td, *J* = 6.9, 4.4 Hz, 1H), 2.81 – 2.68 (m, 1H), 2.54 (dd, *J* = 16.9, 4.4 Hz, 1H), 2.48 – 2.38 (m, 3H), 2.34 (td, *J* = 7.1, 3.7 Hz, 2H), 2.04 – 1.96 (m, 2H), 1.95 – 1.82 (m, 3H), 1.82 – 1.75 (m, 1H), 1.72 (ddp, *J* = 5.7, 3.9, 2.0 Hz, 4H), 1.09 – 0.98 (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.7, 105.7, 83.7, 81.5, 38.2, 31.1, 27.9, 25.3, 24.9, 24.8, 24.8, 23.4, 18.8, 18.6, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{40}NOSi^+$ $[M+H]^+$: 362.2874, found: 364,2861.



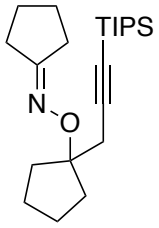

**3:1**

**Cyclopentanone *O*-(2-methyl-5-(triisopropylsilyl)pent-4-yn-2-yl) oxime (5j) cyclopentanone *O*-(4-methyl-1,7-bis(triisopropylsilyl)hepta-1,6-diyn-4-yl) oxime (5jj)**. The two compounds were obtained following the general procedure C as an unseparable mixture (**5j**:**5jj**=3:1) in 72% overall yield.

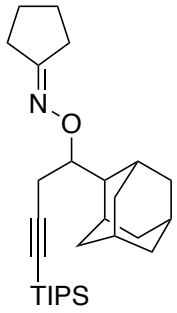
**5j $^{1}$H NMR** (300 MHz, $CDCl_3$) δ 2.55 (s, 2H), 2.42 – 2.29* (m, 4H), 1.70* (tdd, *J* = 7.56, 3.63, 2.10 Hz, 4H), 1.36 (s, 6H), 1.09 – 1.02* (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 166.4, 106.5, 82.1, 78.9, 32.0, 31.1, 29.7, 27.7, 25.5, 25.3, 24.8, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{20}H_{38}NOSi^+$ $[M+H]^+$: 336.2717, found: 336.2716.

**5jj $^{1}$H NMR** (300 MHz, $CDCl_3$) δ 2.75 (d, *J* = 16.72 Hz, 2H), 2.64 (d, *J* = 16.72 Hz, 2H), 2.42 – 2.28* (m, 4H), 1.70* (tdd, *J* = 7.56, 3.63, 2.10 Hz, 4H), 1.44 (d, *J* = 3.62 Hz, 3H), 1.10 – 1.02* (m, 21H). **$^{13}$C NMR** (101 MHz, $CDCl_3$) δ 165.8, 105.6, 81.7, 80.1, 32.0, 31.1, 29.7, 27.7, 25.5, 25.3, 24.8, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{31}H_{58}NOSi_2^+$ $[M+H]^+$: 516.4051, found: 516.4050.

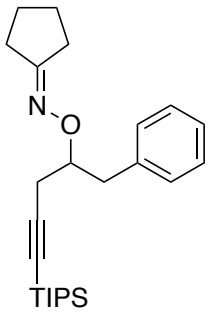
* These signals overlap with the corresponding signal of the other compound.



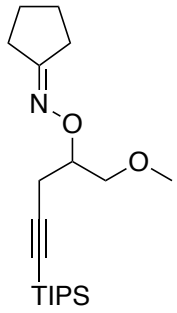

**Cyclopentanone *O*-(1-(3-(triisopropylsilyl)prop-2-yn-1-yl)cyclopentyl) oxime (5k)**. General procedure C in 80% yield as a pale yellow oil. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 2.71 (s, 2H), 2.40 – 2.30 (m, 4H), 1.97 – 1.89 (m, 2H), 1.88 – 1.79 (m, 2H), 1.76 – 1.66 (m, 6H), 1.65 – 1.57 (m, 2H), 1.09 – 1.00 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 166.4, 106.9, 90.1, 80.9, 35.9, 31.2, 29.4, 27.8, 25.3, 25.1, 24.8, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{22}H_{40}NOSi^+$ $[M+H]^+$: 362.2874, found: 362,2871.



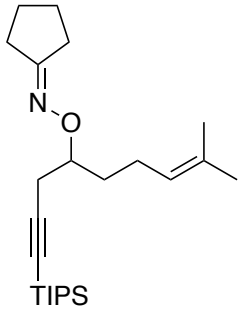

**Cyclopentanone *O*-(1-((1*R*,3*S*,5*r*,7*r*)-adamantan-2-yl)-4-(triisopropylsilyl)but-3-yn-1-yl) oxime (5l)**. General procedure C and obtained in 77% yield as a yellow oil. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 3.75 (t, *J* = 5.97 Hz, 1H), 2.57 (dd, *J* = 17.16, 5.92 Hz, 1H), 2.51 (dd, *J* = 17.18, 6.06 Hz, 1H), 2.47 – 2.38 (m, 2H), 2.33 (tt, *J* = 6.26, 2.29 Hz, 2H), 1.96 (p, *J* = 3.09 Hz, 3H), 1.71 (m, 10H), 1.64 (m, 6H), 1.16 – 0.92 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.2, 107.4, 88.7, 81.3, 38.9, 37.4, 37.4, 31.0, 28.5, 27.9, 25.4, 24.8, 20.4, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{28}H_{48}NOSi^+$ $[M+H]^+$: 442.3500, found: 442.3503.



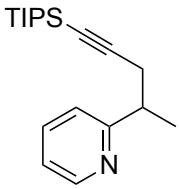

**Cyclopentanone *O*-(1-phenyl-5-(triisopropylsilyl)pent-4-yn-2-yl) oxime (5m)**. General procedure C in 64% yield as a yellow oil. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 7.26 (h, *J* = 2.69 Hz, 4H), 7.23 – 7.17 (m, 1H), 4.34 (tdd, *J* = 7.06, 5.57, 4.11 Hz, 1H), 3.11 (dd, *J* = 13.85, 5.61 Hz, 1H), 3.01 (dd, *J* = 13.85, 6.89 Hz, 1H), 2.58 (dd, *J* = 16.81, 4.15 Hz, 1H), 2.48 (dd, *J* = 16.83, 7.26 Hz, 1H), 2.44 – 2.29 (m, 4H), 1.72 (ddp, *J* = 5.86, 3.79, 1.88 Hz, 4H), 1.14 – 1.03 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 167.1, 138.5, 129.9, 128.3, 126.3, 105.4, 82.6, 81.3, 38.8, 31.1, 28.1, 25.3, 24.8, 24.7, 18.8, 11.5. **HRMS** (ESI) *m/z* calculated for $C_{25}H_{40}NOSi^+$ $[M+H]^+$: 398.2874, found: 398.2874.



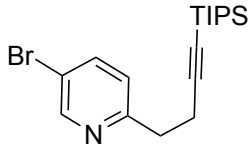
**Cyclopentanone *O*-(1-methoxy-5-(triisopropylsilyl)pent-4-yn-2-yl) oxime (5n)**. General procedure C and obtained in 51% yield as a colorless oil. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 4.35 – 4.28 (m, 1H), 3.68 – 3.65 (m, 2H), 3.39 (s, 3H), 2.63 (dd, *J* = 16.83, 4.92 Hz, 1H), 2.57 (dd, *J* = 16.85, 7.36 Hz, 1H), 2.45 – 2.40 (m, 2H), 2.37 – 2.32 (m, 2H), 1.71 (m, 4H), 1.09 – 0.99 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 167.4, 104.9, 82.1, 79.9, 72.8, 59.5, 31.1, 28.0, 25.3, 24.8, 22.5, 18.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{20}H_{38}NO_2Si^+$ $[M+H]^+$: 352,2666, found: 352,2661.



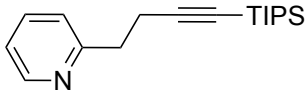

**Cyclopentanone *O*-(8-methyl-1-(triisopropylsilyl)non-7-en-1-yn-4-yl) oxime (5o)**. General procedure C and obtained in 32% yield (56% brsm) as a pale yellow oil. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 5.13 (tdq, *J* = 7.2, 2.9, 1.4 Hz, 1H), 4.11 (tt, *J* = 7.6, 4.3 Hz, 1H), 2.64 (dd, *J* = 16.8, 4.1 Hz, 1H), 2.48 (dd, *J* = 16.8, 7.5 Hz, 1H), 2.43 – 2.37 (m, 2H), 2.34 (m, 2H), 2.09 (q, *J* = 7.3, 6.8 Hz, 2H), 1.84 – 1.69 (m, 7H), 1.67 (d, *J* = 1.3 Hz, 3H), 1.59 (d, *J* = 1.3 Hz, 3H), 1.10 – 1.00 (m, 23H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 166.6, 131.9, 124.3, 105.7, 81.9, 80.2, 32.9, 31.1, 27.9, 25.8, 25.5, 25.3, 24.8, 24.1, 18.8, 17.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{24}H_{44}NOSi^+$ $[M+H]^+$: 390.3187, found: 390.3187.



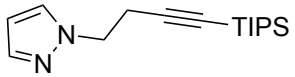

**2-(5-(triisopropylsilyl)pent-4-yn-2-yl)Pyridine (7a)**. General procedure C at 120 °C and obtained in 91% yield as a pale yellow oil. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 8.53 (ddd, *J* = 4.9, 1.9, 0.9 Hz, 1H), 7.57 (td, *J* = 7.7, 1.8 Hz, 1H), 7.20 (dt, *J* = 7.8, 1.1 Hz, 1H), 7.09 (ddd, *J* = 7.6, 4.9, 1.2 Hz, 1H), 3.13 (h, *J* = 7.0 Hz, 1H), 2.62 (qd, *J* = 16.8, 7.0 Hz, 2H), 1.40 (d, *J* = 6.9 Hz, 3H), 1.10 – 0.95 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 164.5, 149.3, 136.3, 121.9, 121.5, 107.4, 81.7, 41.5, 27.5, 19.8, 18.7, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{19}H_{32}NSi^+$ $[M+H]^+$: 302.2299, found: 302.2311.



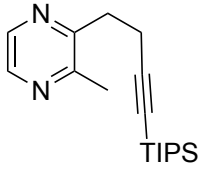

**5-Bromo-2-(4-(triisopropylsilyl)but-3-yn-1-yl)pyridine (7b)**. General procedure C at 120 °C and obtained in 55% yield as a pale yellow oil. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 8.57 (dd, *J* = 2.4, 0.8 Hz, 1H), 7.68 (dd, *J* = 8.3, 2.4 Hz, 1H), 7.12 (dd, *J* = 8.3, 0.7 Hz, 1H), 2.95 (t, *J* = 7.1 Hz, 2H), 2.72 – 2.61 (m, 2H), 1.03 – 0.72 (m, 21H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 158.8, 150.5, 138.8, 124.7, 118.5, 107.6, 81.6, 36.9, 20.1, 18.7, 11.3. **HRMS** (ESI) *m/z* calculated for $C_{18}H_{29}NBrSi^+$ $[M+H]^+$: 366.1247, found: 366.1254.



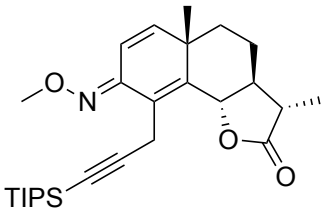

**2-(4-(triisopropylsilyl)but-3-yn-1-yl)Pyridine (7c)**. General procedure C at 120 °C and obtained in 61% yield as a pale yellow oil. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 8.55 – 8.48 (m, 1H), 7.57 (td, *J* = 7.5, 1.6 Hz, 1H), 7.21 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.14 – 7.06 (m, 1H), 2.99 (t, *J* = 7.2 Hz, 2H), 2.69 (t, *J* = 7.2 Hz, 2H), 1.05 – 0.95 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 160.2, 149.4, 136.3, 123.4, 121.5, 108.0, 81.2, 37.6, 20.3, 18.7, 11.3. **HRMS** (ESI) *m/z* calculated for $C_{18}H_{30}NSi^+$ $[M+H]^+$: 288.2142, found: 288.2150.



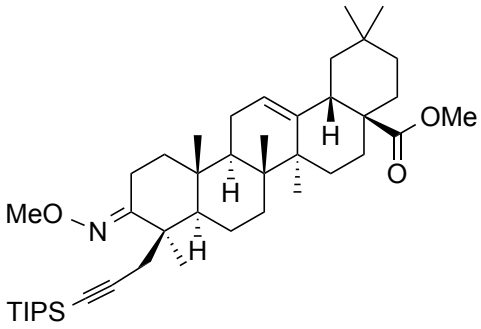

**1-(4-(triisopropylsilyl)but-3-yn-1-yl)-1*H*-Pyrazole (7d)**. General procedure C at 120 °C and obtained in 72% yield as a pale yellow oil. **$^1$H NMR** (300 MHz, Chloroform-*d*) δ 7.48 (dd, *J* = 12.6, 2.1 Hz, 2H), 6.20 (t, *J* = 2.1 Hz, 1H), 4.27 (t, *J* = 6.8 Hz, 2H), 2.79 (t, *J* = 6.8 Hz, 2H), 1.08 – 1.01 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 139.8, 129.6, 105.3, 104.5, 83.2, 51.2, 22.2, 18.7, 11.3. **HRMS** (ESI) *m/z* calculated for $C_{16}H_{29}N_2Si^+$ $[M+H]^+$: 277.2095, found: 277.2090.

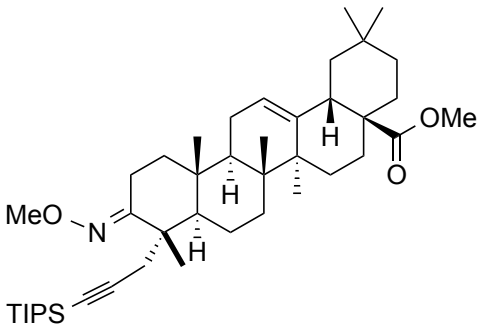



**2-Methyl-3-(4-(triisopropylsilyl)but-3-yn-1-yl)pyrazine (7e)**. General procedure C at 120 °C and obtained in 75% yield as a pale yellow oil. **$^1$H NMR** (400 MHz, Chloroform-*d*) δ 8.35 – 8.30 (m, 1H), 8.28 (d, *J* = 2.6 Hz, 1H), 3.04 (t, *J* = 7.3 Hz, 2H), 2.75 (t, *J* = 7.3 Hz, 2H), 2.60 (d, *J* = 0.6 Hz, 3H), 1.07 – 0.89 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 154.1, 152.6, 141.7, 107.6, 81.3, 33.6, 22.0, 18.6, 11.3. **HRMS** (ESI) *m/z* calculated for $C_{18}H_{31}N_2Si^+$ $[M+H]^+$: 303.2251, found: 303.2240.




**(3*S*,3a*S*,5a*S*,9b*S*,*E*)-8-(methoxyimino)-3,5a-Dimethyl-9-(3-(triisopropylsilyl)prop-2-yn-1-yl)-3a,4,5,5a,8,9b-hexahydronaphtho[1,2-*b*]furan-2(3*H*)-one (9a)**. General procedure C and obtained in 77% yield as a white solid. **$^{1}$H NMR** (400 MHz, Chloroform-*d*) δ 6.78 (d, *J* = 10.2 Hz, 1H), 5.93 (d, *J* = 10.2 Hz, 1H), 4.74 (d, *J* = 11.2 Hz, 1H), 3.91 (s, 3H), 3.78 – 3.62 (m, 2H), 2.32 (dq, *J* = 12.2, 6.9 Hz, 1H), 2.02 – 1.92 (m, 1H), 1.90 – 1.79 (m, 1H), 1.74 (ddd, *J* = 13.1, 3.7, 2.2 Hz, 1H), 1.69 – 1.57 (m, 1H), 1.47 (td, *J* = 13.0, 4.4 Hz, 1H), 1.32 – 1.15 (m, 6H), 1.00 – 0.75 (m, 21H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 177.7, 147.4, 144.7, 139.2, 123.3, 113.1, 108.6, 81.9, 78.4, 62.2, 53.2, 41.0, 38.6, 25.7, 23.8, 18.7, 16.9, 12.4, 11.4. **HRMS** (ESI) *m/z* calculated for $C_{27}H_{41}NNaO_3Si^+$ $[M+Na]^+$: 478.2748, found: 478.2751.




**Methyl (4a*S*,6a*S*,6b*R*,8a*R*,9*R*,12a*R*,12b*R*,14b*S*,*E*)-10-(methoxyimino)-2,2,6a,6b,9,12a-hexamethyl-9-(3-(triisopropylsilyl)prop-2-yn-1-yl)-1,3,4,5,6,6a,6b,7,8,8a,9,10,-11,12,12a,12b,13,14b-octadecahydropicene-4a(2*H*)-carboxylate (minor product)**

**Methyl (4a*S*,6a*S*,6b*R*,8a*R*,9*S*,12a*R*,12b*R*,14b*S*,*E*)-10-(methoxyimino)-2,2,6a,6b,9,12a-hexamethyl-9-(3-(triisopropylsilyl)prop-2-yn-1-yl)-1,3,4,5,6,6a,6b,7,8,8a,9,10,-11,12,12a,12b,13,14b-octadecahydropicene-4a(2*H*)-carboxylate (major product)**

General procedure C and obtained in 62% yield as white solids. d.r. = 1:5.

Even if the two diastereomers have been separated, the relative configuration of the quaternary center couldn't be assigned.

Compound 1: minor product.

**$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 5.27 (t, *J* = 3.63 Hz, 1H), 3.81 (s, 3H), 3.62 (s, 3H), 3.12 (ddd, *J* = 14.72, 4.37, 2.92 Hz, 1H), 2.85 (dd, *J* = 13.88, 4.56 Hz, 1H), 2.64 (d, *J* = 17.00 Hz, 1H), 2.38 (d, *J* = 17.00 Hz, 1H), 2.02 – 1.81 (m, 4H), 1.75 – 1.58 (m, 6H), 1.56 – 1.44 (m, 3H), 1.35 – 1.24 (m, 6H), 1.09 (s, 3H), 1.08 – 0.96 (m, 27H), 0.92 (s, 3H), 0.89 (s, 3H), 0.73 (s, 3H). **$^{13}$C NMR**

(126 MHz, $CDCl_3$) δ 178.4, 163.0, 144.0, 122.2, 106.0, 82.7, 61.2, 57.8, 51.7, 47.8, 46.9, 46.0, 43.7, 41.8, 41.4, 39.5, 37.4, 34.0, 33.2, 32.9, 32.5, 30.8, 30.5, 27.8, 26.8, 26.0, 23.8, 23.6, 23.3, 23.2, 19.4, 18.9, 18.8, 17.5, 16.9, 15.4, 11.5.

**HRMS** (ESI) *m/z* calculated for $C_{43}H_{72}NO^+$ $[M+H]^+$: 678.5276, found: 678.5277.

Compound 2: major product.

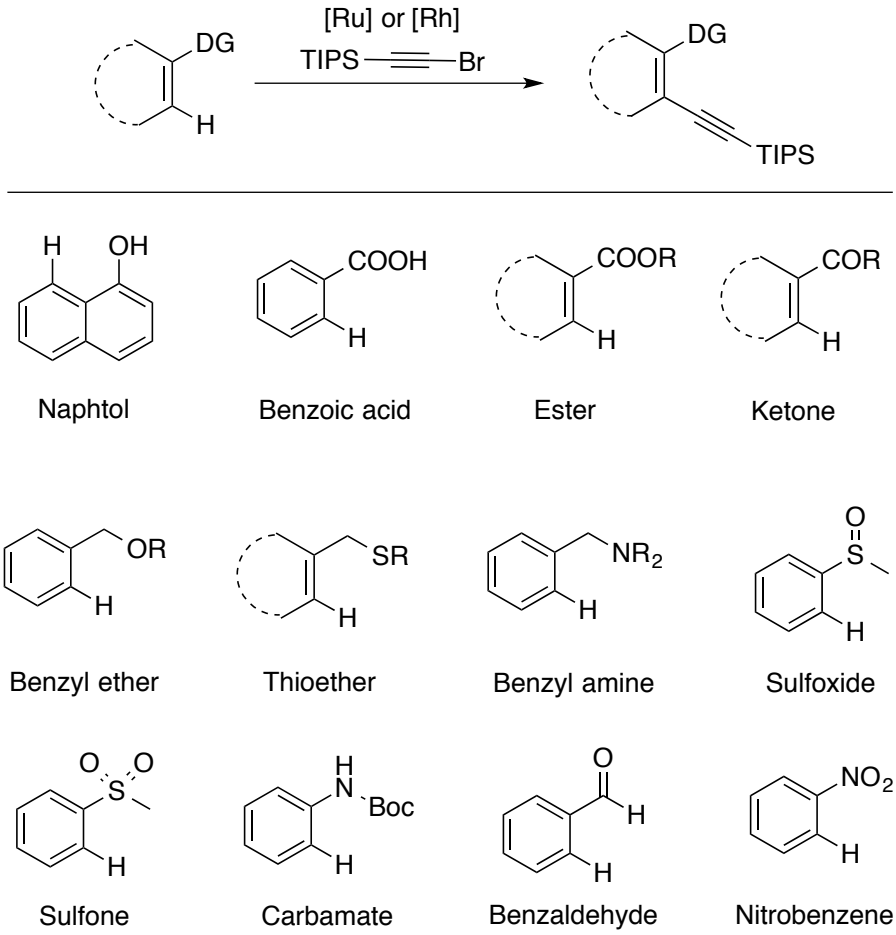
**$^1$H NMR** (500 MHz, $CDCl_3$) δ 5.30 (t, *J* = 3.66 Hz, 1H), 3.81 (d, *J* = 1.53 Hz, 3H), 3.63 (d, *J* = 1.03 Hz, 3H), 2.95 (ddd, *J* = 17.23, 5.81, 2.45 Hz, 1H), 2.87 (dd, *J* = 13.98, 4.63 Hz, 1H), 2.79 (d, *J* = 16.60 Hz, 1H), 2.35 (d, *J* = 16.59 Hz, 1H), 2.15 – 2.04 (m, 1H), 2.02 – 1.89 (m, 3H), 1.78 (dd, *J* = 11.78, 2.13 Hz, 1H), 1.74 – 1.65 (m, 2H), 1.65 – 1.59 (m, 4H), 1.59 – 1.45 (m, 4H), 1.44 – 1.28 (m, 4H), 1.10 (s, 3H), 1.09 – 0.98 (m, 26H), 0.99 – 0.97 (m, 3H), 0.93 (s, 3H), 0.90 (s, 3H), 0.76 (s, 3H). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 178.4, 162.1, 144.0, 122.5, 107.8, 81.3, 61.3, 51.7, 50.0, 46.9, 46.7, 46.0, 43.3, 41.9, 41.5, 39.5, 36.7, 34.0, 33.3, 32.5, 32.3, 31.1, 30.9, 27.8, 25.9, 24.5, 23.8, 23.6, 23.2, 19.3, 18.9, 18.9, 18.7, 17.0, 14.7, 11.5.

**HRMS** (ESI) *m/z* calculated for $C_{43}H_{72}NO^+$ $[M+H]^+$: 678.5276, found: 678.5273.

# *General Conclusions*

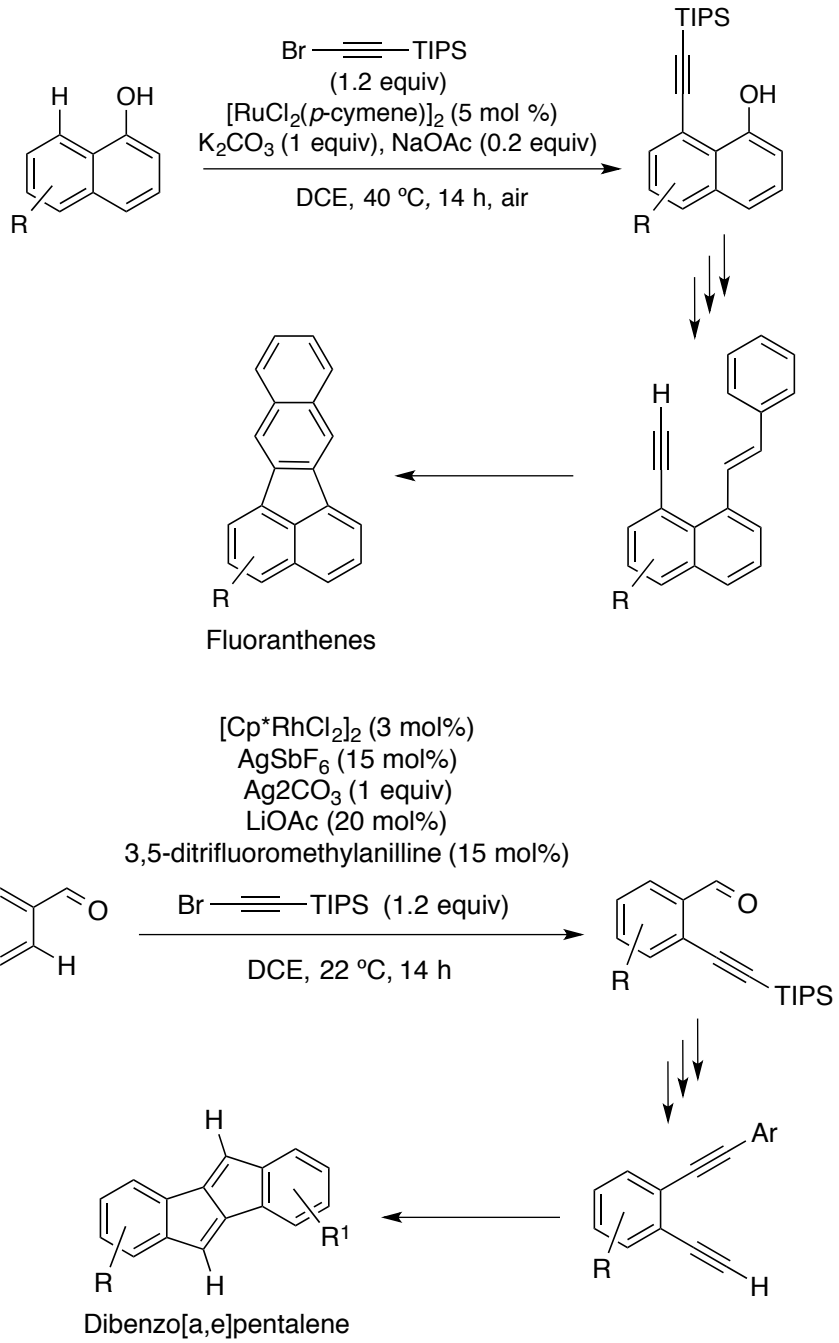
The research presented in this Doctoral Thesis has led to the following results:

A general catalytic system, based on ruthenium and rhodium catalysts, allowing the alkynylation of a broad range of C($sp^2$)-H bonds was developed. These reactions exploit the presence of a chelating group at the *ortho*-position of arenes and in some cases the β-position of alkenes to direct the transition metal. The directing groups include: phenolic –OH, carboxylic acid, ester, ketone, ether, amine, thioether, sulfoxide, sulfone, phenol ester, carbamate, aldehyde and nitro groups (Scheme 1).




**Scheme 1.** Ru- and Rh-catalyzed C($sp^2$)-H alkynylation.

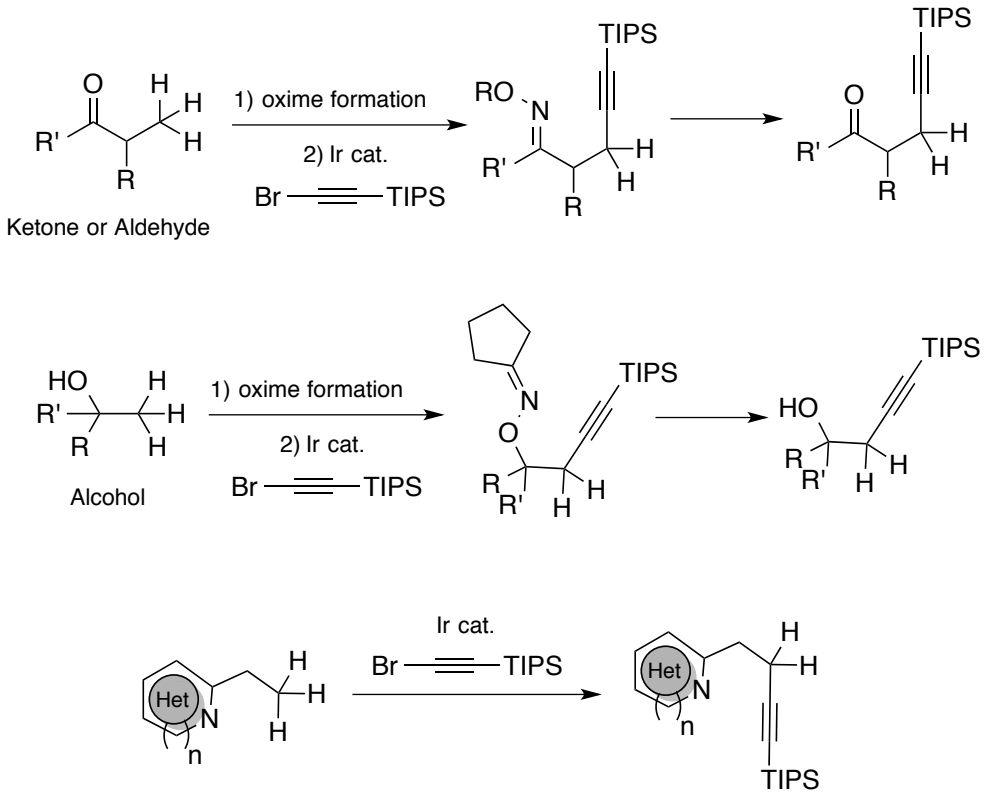
These catalytic reactions were next applied in the synthesis of polyaromatic hydrocarbons (PAH). The alkynylation of naphthols granted access to fluoranthenes, with three additional steps (Scheme 2, top). The alkynylation of benzaldehydes allowed the synthesis of diverse 1,5-enynes, that were cyclized using catalysis to synthesize dibenzopentalenes (Scheme 2, bottom).




**Scheme 2.** Top: access to fluoranthenes (via alkynylation of naphthols); Bottom: access to dibenzopentalenes (via *ortho*-alkynylation of benzaldehydes).

The mechanisms of these reactions were studied both experimentally and computationally. With both ruthenium and rhodium catalyst, the efficiency of these catalytic systems arises from two low-barrier steps: bromo-alkyne insertion into a ruthena- or rhodacycle, followed by bromide elimination. In the case of the rhodium catalysis, we found that the C-H activation step occurs through an electrophilic concerted metalation deprotonation. Interestingly, we found that the C-H activation of nitrobenzenes also occurs through this mechanism.

We finally extended this catalytic system to the C($sp^3$)-H bonds using oximes or nitrogen-containing heterocycles as directing group (Scheme 3). This reaction is selective towards C($sp^3$)-H bonds and can be applied to the late-stage functionalization of natural products.




**Scheme 3.** Ir-catalyzed C($sp^3$)-H alkynylation.

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