JOC The Journal of Organic Chemistry
Article
pubs.acs.org/joc

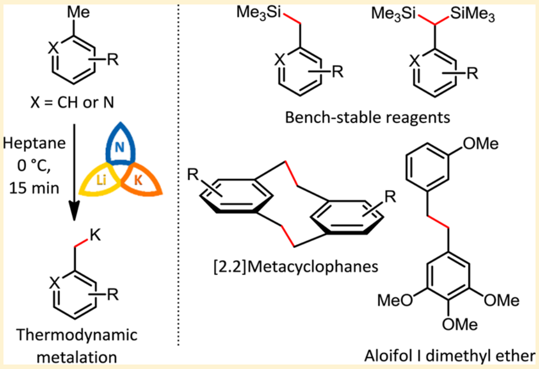
General Ambient Temperature Benzylic Metalations Using Mixed-Metal Li/K-TMP Amide

Atul Manvar,[†] Patricia Fleming,[†] and Donal F. O'Shea*,[†,‡]

[†]Department of Pharmaceutical and Medicinal Chemistry, Royal College of Surgeons in Ireland, Dublin 2, Ireland
[‡]School of Chemistry and Chemical Biology, University College Dublin, Belfield, Dublin 4, Ireland

Supporting Information

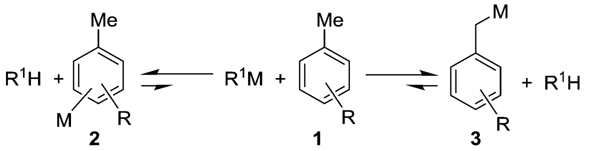
ABSTRACT: Highly regioselective benzylic metalations in hydrocarbon solvent have been achieved at rt and 0 °C using a mixed-metal Li/K-TMP amide comprised of KO*t*Bu, BuLi, and 2,2,6,6,-tetramethylpiperidine (TMP(H)). Mixing of KO*t*Bu, BuLi, and TMP(H) in heptane gave a solution of the base mixture which when used in deuterium labeling experiments confirmed the requirement of the three reagent components for both reactivity and selectivity. The reaction protocol is operationally straightforward and found to be applicable to a broad range of substrates. Upon generation of the metalated products, they are reacted in heptane at ambient temperature in a variety of synthetically useful ways. Illustrated examples include generation of the benzyltrimethylsilanes and α,α-bis(trimethylsilyl)toluenes reagents, which are bench-stable surrogates of benzyl anions and α-silyl carbanions utilized for nucleophilic addition and Peterson olefination reactions. Direct C−C couplings mediated by 1,2-dibromoethane provided entries into bibenzyls and [2.2]metacyclophanes. Comparison of reaction outcomes with the same reactions carried out in THF at −78 °C showed no negative effects for conducting the reactions under these milder more user-friendly conditions.



INTRODUCTION

The founding principles for the predictive use of organometallic bases for selective kinetic proton abstraction were established in the work of Curtin, Gilman, and Wittig[1−3] and expanded to the breadth of organic synthesis by the immense contributions of Schlosser,[4] Beak,[5] Snieckus,[5] and many others. The use of thermodynamic metalating conditions is often thought of as less challenging technically, but does also pose significant selectivity challenges. For example, substituted toluenes **1** are one group of substrates for which differentiation between kinetic and thermodynamic metalation sites is often a challenging issue depending upon the nature and position of the R substituent(s) on the aryl ring. Specifically, one or more directed *ortho* metalation product(s) **2** can exist, restricting attainment of the benzylic metalated product **3** with high selectivity (Scheme 1).[6] Numerous reports of lateral metalations (defined as deprotonation of a benzylic position that is lateral, or flanked by, a heteroatom containing substituent) have shown that they are highly substrate dependent leading to a myriad of conditions used with high selectivities often unachievable.[7]

Scheme 1. Competing Metalation Sites (M = Metal)



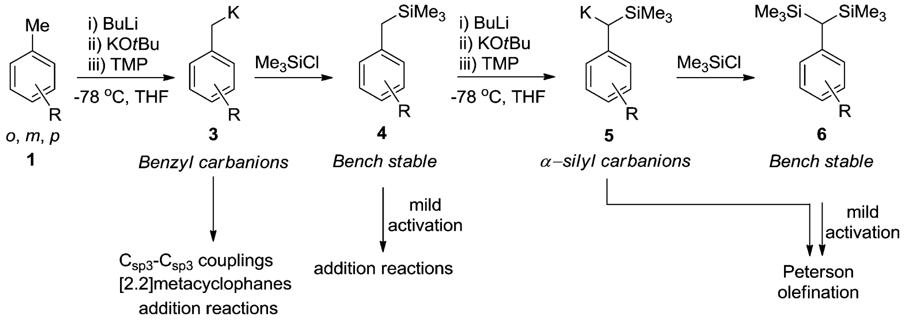
In previously reported work we have shown that, in THF at −78 °C, the use of the triad of reagents BuLi/KO*t*Bu/TMP(H) was a general method to achieve benzylic metalations with excellent selectivity, irrespective of whether the benzylic position is lateral (*ortho*) to a heteroatom containing substituent or not (i.e., *meta* or *para*) (Scheme 2).[8] This can be attributed to the enhanced reactivity of the *in situ* formed mixed Li/K metal TMP amide over LiTMP alone and the ability of the TMP(H) to facilitate an anion migration from kinetic aryl to thermodynamic benzylic position.[8b] The term LiNK was coined to describe the synergetic combination of the mixed metal amide containing lithium (Li), nitrogen (N) from the TMP, and potassium (K). For simplicity the benzylic species generated from the LiNK metalation are presented only as the K species based on the recent characterization of the PhLi/PhK/*t*BuOLi mediated metalation of toluene as benzylpotassium, though it should be understood that the exact nature of these organometallics could be substrate dependent and may be mixed metal species.[9]

The synthetic uses of these benzylic organometallics have included electrophile reactions,[8b] direct C_{sp^3}−C_{sp^3} coupling for bibenzyl,[10] and [2.2]metacyclophane[11] synthesis and further

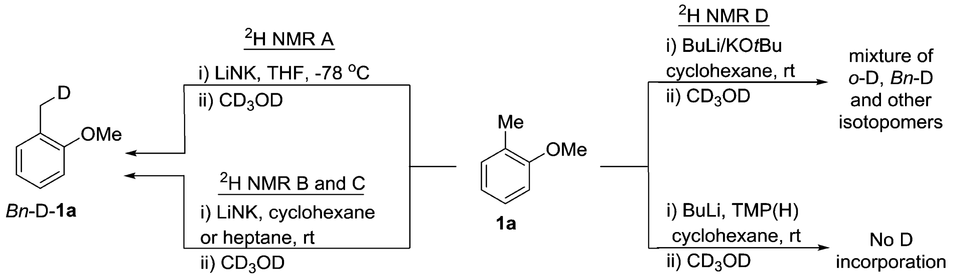
Received: July 6, 2015
Published: August 17, 2015

DOI: 10.1021/acs.joc.5b01540
J. Org. Chem. 2015, 80, 8727−8738

Scheme 2. Selective Benzylic Metalation and Bench Stable Equivalents



Scheme 3. Metalation of 1a Under Various Conditions[a]



[a]All reaction times of 15 min, 1.2 equiv of each reagent used.

transmetalation to Si by reaction with chlorotrimethylsilane providing access to the bench stable benzyltrimethylsilane class **4** (Scheme 2).[12] Alternative procedures for the synthesis of benzyltrimethylsilanes require Pd- or Ni-catalyzed cross-coupling of the organo-lithium or -magnesium substrates MCH_2SiMe_3, (M = Li or Mg) with aryl-halides, -methyl ethers, or -methylthioethers.[13] The synthetic advantage of silanes **4** lies in the fact that they can act as surrogates of benzyl anions and participate in nucleophilic addition reactions with mild silyloxide or fluoride activation (Scheme 2).[14]

Additionally, the utility of LiNK metalation (in THF at −78 °C) has been extended to include the regioselective benzylic metalation of substituted benzyltrimethylsilanes **4** generating the *α*-silyl carbanions **5**, which upon chlorotrimethylsilane quench yields the *α*,*α*-bis(trimethylsilyl)toluenes **6**.[15] The literature precedents for synthesis of reagents **6** using organometallic deprotonation as the key step are few.[16] Recently, the transition-metal-catalyzed cross-couplings of $(Me_3Si)_2MgBr{\cdot}LiCl$ or $(Me_3Si)_2ZnCl{\cdot}MgBrCl{\cdot}LiCl$ with aryl halides has been reported as an additional route to this reagent class.[17] The synthetic value of reagents **6** lies in their bench stability, yet under mild activation conditions they can react as equivalents of the *α*-silyl carbanions **5** in Peterson olefination reactions.[15,17,18] The utility of reagents **6** for *E*-selective Peterson olefination from *N*-phenyl imines has recently been reported.[15]

The ability of LiNK to favor the thermodynamic over kinetic metalation product at −78 °C in THF raised the possibility that this low temperature may not always be necessary to achieve selective metalation. Recognizing the instability of THF to strong bases at ambient temperature, we chose to investigate the reactivity and selectivity in hydrocarbon solvents with the key goals of making the use of the base mixture as operationally straightforward as possible and facilitating the generation of important silicon reagents.

Extensive studies of *o*-metalations in hydrocarbon solvents have been reported by Slocum and co-workers, yet the literature precedents on thermodynamic benzylic metalation in hydrocarbons are considerably less prevalent with poor selectivity and limited substrate scope often obtained.[19] The kinetic versus thermodynamic *o*- and benzylic deprotonation of *p*-tolylsulfonamide, *p*-tolylsulfonate, and *p*-toluamide have previously been investigated in the literature.[20] Arguably, a general ambient temperature method for benzylic metalation and electrophile reaction is desirable due to the broad synthetic potential of this reaction as outlined above.

■ RESULTS AND DISCUSSION

At the outset of our investigation into ambient temperature LiNK metalations in hydrocarbon solvents, 2-methylanisole (**1a**) was chosen as a model substrate. Previous reports have shown that selective benzylic lithiation of **1a** in hydrocarbons was challenging, for example, BuLi/cyclohexane (reflux, 10 h) gave Bn/*o* ratio of 67/33,[21a] BuLi/TMEDA/cyclohexane (rt, 10 h) gave a 25/75 Bn/*o* mixture,[21b] BuLi/KO*t*Bu/heptane (reflux, 4.5 h) gave 49/25 for Bn/*o* product ratio with the remaining being rearrangement products,[21b] while LDA/KO*t*Bu/hexane (25 °C, 10 h) provided 100/0: Bn/*o*.[21c]

To gain a comparative understanding about the reactivity and selectivity of LiNK metalation of **1a**, the following five reactions were carried out: (a) as per the previously established LiNK conditions with the three reagents BuLi, KO*t*Bu, TMP(H) at −78 °C in THF, (b) with BuLi, KO*t*Bu, TMP(H) at rt in cyclohexane, (c) with BuLi, KO*t*Bu, TMP(H) at rt in heptane, (d) with BuLi, KO*t*Bu at rt in cyclohexane, and (e) with BuLi/TMP(H) in cyclohexane at rt (Scheme 3). Each reaction was stirred for 15 min, the resulting metalated mixture treated with CD_3OD, and the deuterated products analyzed by ^1H and ^2H NMR. As anticipated, conditions (a) gave *Bn*-D-**1a** exclusively as product with good deuterium incorporation (>80%) (Figure 1, NMR A) and gratifyingly, a similar exclusively benzylic

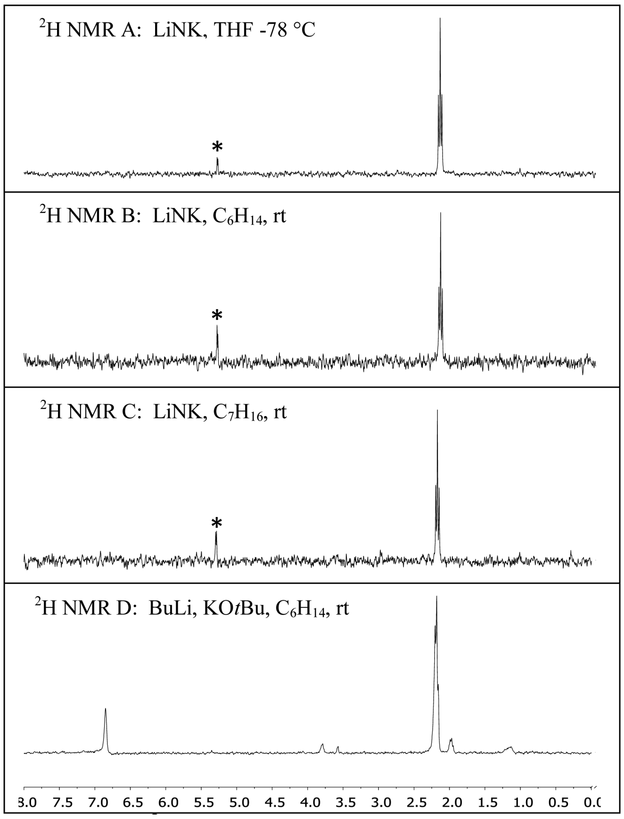


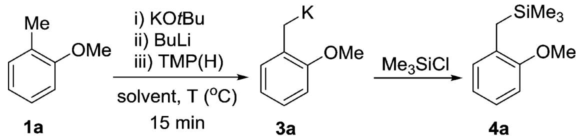
Figure 1. ^{2}H NMR spectra (*CD_2Cl_2).

deuterated product was observed for both hydrocarbon reactions (b) and (c) at rt (>65% *Bn*-D) with no detectable *o*-D incorporation (Figure 1, NMRs B and C). In contrast, when only the two components BuLi, KO*t*Bu were used, as in reaction (d), a complex mixture of deuterated isotopomers was obtained showing complete loss of selectivity (Figure 1, NMR D). When the alternative two reagents BuLi and TMP(H) were used as in conditions (e), no deuterium incorporation was detected showing that if LiTMP formed *in situ*,[22] it had insufficient basic strength to deprotonate under these conditions. Taken together these experiments highlight the significance of each component of the reagent mixture in delivering sufficient base strength yet maintaining a high degree of selectivity for benzylic metalation.

A further optimization was next conducted using TMSCl as electrophile. When conducting these experiments, it was found easiest to first sequentially add the three LiNK reagents (KO*t*Bu, BuLi, and TMP(H)) to the flask and then subsequently add the substrate **1a**, followed by the electrophile. Reactions in both cyclohexane and heptane at rt gave the expected TMS product **4a** in 65% and 69% yields, respectively (Scheme 4, entries 1 and 2). Lowering the reaction temperature to 0 °C gave a marginal improvement in the yields (entries 3 and 4), though starting material was recovered after workup. Increasing the LiNK mixture to 2 equiv in heptane at 0 °C gave complete conversion, with the best yield of 86% (entry 5). Collectively, these results suggest that 2.0 equiv of the preformed base mix KO*t*Bu/BuLi/TMP(H) in heptane at 0 °C followed by addition of substrate would be the optimal general procedure.

Prior to exploring the generality of this method, a temperature profile analysis of the formation and reaction of LiNK was undertaken (Figure 2). A stirred colorless suspension of KO*t*Bu in heptane was cooled in an ice-bath to 1 °C, and BuLi added dropwise giving a suspension of the Lochmann–Schlosser base with a 7 °C temperature rise.[23] Upon the addition of TMP(H) a temperature rise of 4 °C occurred with the formation of an orange-brown solution from which a trace of precipitate formed over the 5 min time period before it was used. These results showed that no large exotherm was associated with the formation of a 0.6 M solution of the LiNK reagent generated for these experiments. Upon addition of the substrate **1a** (1.0 mmol) no change in temperature was detected, and an immediate yellow suspension of **3a** formed. Next, upon addition of chlorotrimethylsilane electrophile a significant rise in temperature of 18 °C was observed. Once the reaction mixture had cooled back to 2 °C (30 min), 2 M HCl was added which also gave a significant temperature rise of 20 °C. Consequently, the electrophile quench and reaction workup steps are critical in terms of exotherms, confirming that it is advisible to conduct these reactions at 0 °C for temperature control. Similar incremental increases in temperature profile were observed when the reaction was carried out at rt (Figure S1).

Scheme 4. Screening of Hydrocarbon Solvents[a]

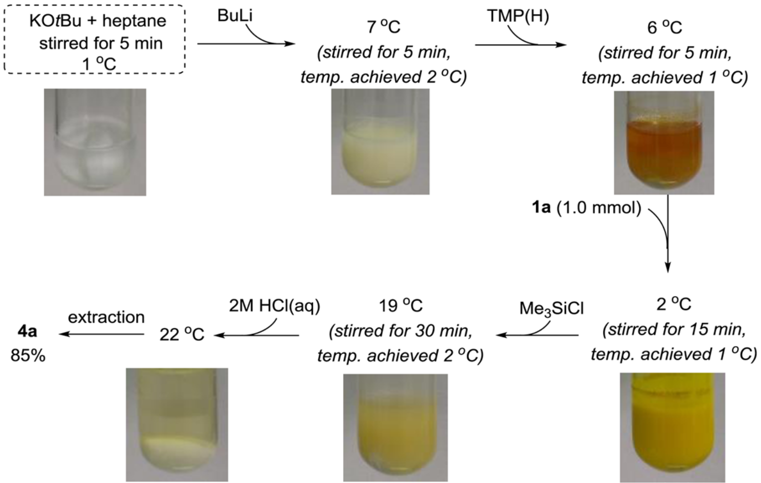


Entry	Solvent	T (°C)	Yield (%)
1	cyclohexane	rt	65
2	heptane	rt	69
3	cyclohexane	0	70
4	heptane	0	73
5	[b]heptane	0	86
6	[b]heptane	rt	86

[a] Conditions: **1a** (1.0 mmol), BuLi (1.2 mmol), KO*t*Bu (1.2 mmol), TMP(H) (1.2 mmol), solvent (2.5 mL), Me_3SiCl (2.5 mmol). [b] **1a** (1.0 mmol), BuLi (2.0 mmol), KO*t*Bu (2.0 mmol), TMP(H) (2.0 mmol), solvent (2.5 mL), TMSCl (2.5 mmol).

As there is a growing interest in the use of bench stable organosilicon reagents as carbanion equivalents, their synthesis was explored for a range of substrates using this approach.[12−14] Encouragingly, electron-rich toluenes such as 3-methylanisole (**1b**), 3,4,5-trimethoxyanisole (**1c**), and 2-*N*,*N*-trimethylaniline (**1d**) each gave their corresponding benzyltrimethylsilanes **4b–d** with high yields 88%, 73%, 92%, respectively (Scheme 5).

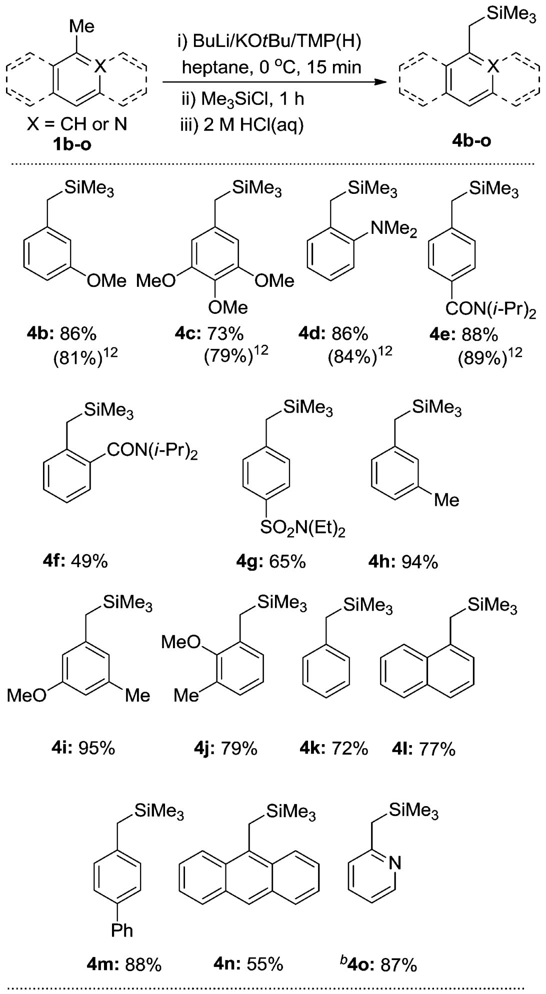
Comparison of the results for **4b–e** with those previously reported in THF at −78 °C showed yields to be within small experimental error differences (Scheme 5, yields given in brackets).[12] The electron-deficient *o*/*p* amido and sulfonamido-substituted toluenes were successfully converted to their corresponding silanes **4e–g** in 49–91% yields. For substrates containing more than one methyl group such as *m*-xylene (**1h**), 3,5-dimethylanisole (**1i**), and 2,6-dimethylanisole (**1j**), the procedure was equally successful with yields for **4h–j** ranging from 79 to 95% (Scheme 5). Next, the set of aromatic hydrocarbons **1k–n** was screened and found to be convertible to their corresponding benzyltrimethylsilanes **4k–n** in good yields, illustrating that heteroatom substituent is not an essential factor. The heterocycle, *α*-picoline **1o**, also reacted under the established conditions with product **4o** obtained in



[a]Condition: **1a** (1.0 equiv), BuLi (2.0 equiv), KO*t*Bu (2.0 equiv), TMP (2.0 equiv), Me_3SiCl (2.5 equiv).

Figure 2. Temperature profile of benzylic metalation, TMSCl reaction and workup.

Scheme 5. Synthesis of Substituted Benzyltrimethylsilane Reagents[a]



[a]Condition: Substrate (1.0 equiv), BuLi (2.0 equiv), KO*t*Bu (2.0 equiv), TMP(H) (2.0 equiv), and Me_3SiCl (2.5 equiv). [b]1.2 equiv of each BuLi/KO*t*Bu/TMP(H) used.[12] Reference for literature reported yields in THF at −78 °C.

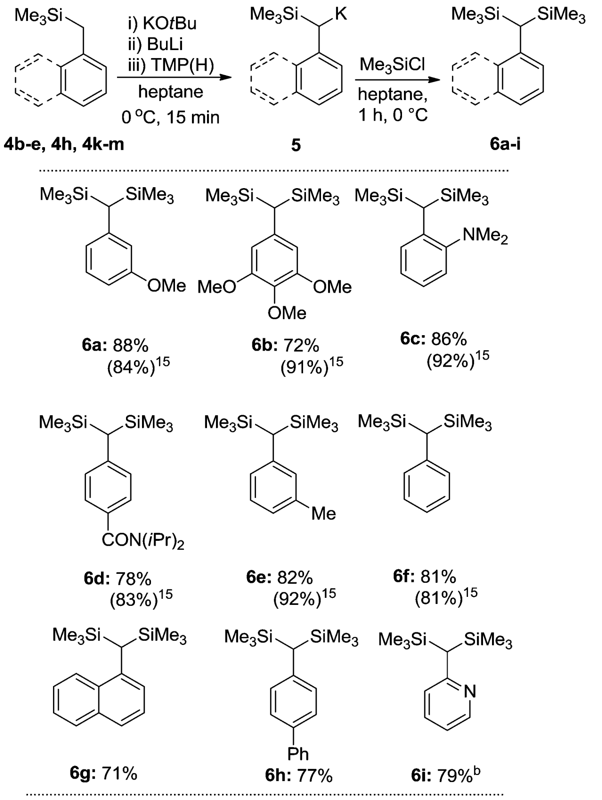
87% yield. One substrate limitation encountered was for halogenated toluenes, which were found to be incompatible with the metalation conditions, leading to complex product mixtures.

To further expand the repertoire of silicon reagents, the synthesis of *α*,*α*,-bis(trimethylsilyl)toluenes from benzyltrimethylsilanes was next addressed using **4b** as the test substrate. Pleasingly, following a 15 min LiNK metalation in heptane to form the *α*-silylcarbanion **5** and treatment with TMSCl, the bis(silane) product (**6a**) was selectively obtained in a 88% yield (Scheme 6). Substrates **4c−e** containing trimethoxy, *o*-dimethylamino, and *p*-amido substituents were also successfully converted to their corresponding di-TMS products **6b−d** in good to excellent yields (72−86%), which compared favorably with those previously reported in THF at −78 °C.[15] Notably, the presence of a competing methyl group in **4h** did not interfere with metalation regioselectivity, as product **6e** was obtained in a 82% yield. Trimethylsilanes **4k−m**, which contain no heteroatom substituent, were also converted to products **6f−h** with 81%, 71%, and 77% yields, respectively. Conveniently, a one-pot conversion of 2-picoline (**1o**) into bis-trimethylsilane (**6i**) was directly achieved with 2.2 equiv of the LiNK reagent (Scheme 6). Overall, a 2-fold LiNK metalation/TMSCl quench procedure at ambient temperature appears to be a routine general method for access to this class of Peterson olefination reagent.[15]

Transition-metal free coupling of two carbon nucleophiles generated by direct deprotonation is an atom-economical method for C−C bond formation.[24] In a previous report it was shown that LiNK metalation of toluenes in THF at −78 °C and treatment with 1,2-dibromoethane were an effective method to produce 1,2-diarylethanes.[10] As such, it was of interest to determine if this coupling was also achievable under ambient temperature heptane conditions. Generality of the reaction sequence was established with toluene substrates **1b−e,h,i** which were metalated and treated with 1,2-dibromoethane to provide the coupled products **7a−e** in moderate to excellent yields of 52−92% (Scheme 7, route A).

Comparison with previously reported results in −78 °C THF showed some marginally higher and some lower yields but with only one example, **7d**, showing a substantial difference.[10] Notably, the natural product Brittonin A, **7f**, was accessible with this approach in a single-step showing that conducting these

Scheme 6. Synthesis of Peterson Olefination Reagents



[a]Condition: Substrate (1.0 equiv), BuLi (2.0 equiv), KO*t*Bu (2.0 equiv), TMP(H) (2.0 equiv), and Me_3SiCl (2.5 equiv). [b]**1o** used as starting substrate with BuLi (2.2 equiv), KO*t*Bu (2.2 equiv), TMP(H) (2.2 equiv), and Me_3SiCl (2.5 equiv).[15]Reference for literature reported yields in THF at −78 °C.

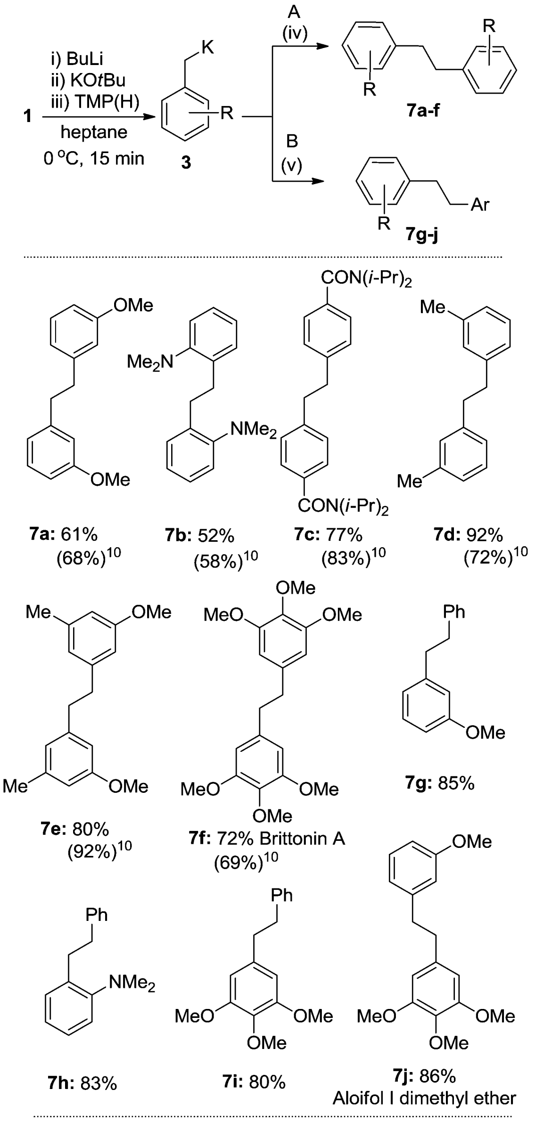
C−C bond forming reactions in hydrocarbon solvent had no negative effect. Efficient synthesis of bibenzyls with two differing aryl rings is also appealing and could be addressed by using substituted benzyl bromides electrophiles (Scheme 7, route B). As examples, **1b−d** were metalated with subsequent benzyl bromide reaction to afford **7g−i** in excellent yields (80−85%) and dimethyl ether derivative of Aloifol I natural product **7j** in 86%.

Finally, the ambient temperature metalation approach was applied to the synthesis of [2.2]metacylcyclophanes.[11] A double LiNK metalation of bibenzyls **7d,e** generated dimetalated species **8** which upon treatment with dibromoethane effectively ring closed to produce metacyclophanes **9a,b** in 29% and 31% yields, respectively (Scheme 8). This repetitive two-step synthesis of [2.2]metacyclophanes offers a straightforward entry into this strained cyclic system.

■ CONCLUSION

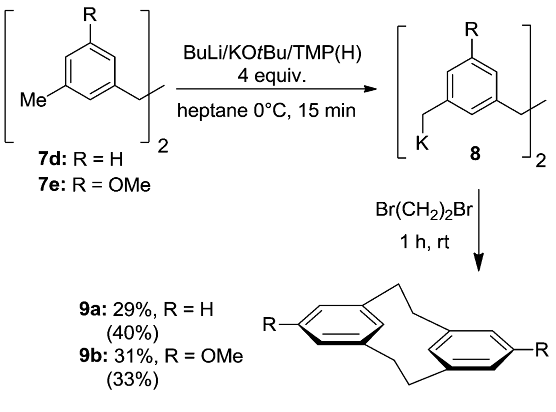
In summary, regioselective benzylic metalations of substituted toluenes, xylenes, and benzylsilanes can be successfully accomplished in hydrocarbon reaction media at 0 °C using the LiNK reagent triad. Subsequent reaction of the generated metalated species with TMSCl gave the corresponding benzyltrimethylsilanes and *α*,*α*-bis(trimethylsilyl)toluenes which are bench-stable pro-nucleophiles for addition and Peterson olefination reactions. This new approach provides routine access to these important Si-reagents which should find widespread use in organic chemistry. Direct C−C couplings

Scheme 7. C$_{sp^3}$−C$_{sp^3}$ Couplings and Benzylbromide Reactions[a]



[a]Conditions: **1** (1.0 equiv), BuLi (2.0 equiv), KO*t*Bu (2.0 equiv), TMP(H) (2.0 equiv). (iv) 1,2-dibromoethane (4.0 equiv), (v) $ArCH_2Br$ (4.0 equiv). Reference for literature reported yields in THF at −78 °C.[10]

Scheme 8. Synthesis of [2.2]metacyclophanes



also allowed for atom efficient synthesis of bibenzyl derivatives and [2.2]metacyclophane. Further synthetic and mechanistic studies involving the LiNK reagent are ongoing.

■ EXPERIMENTAL SECTION

General Information. All of the reactions involving air-sensitive reagents were performed under nitrogen either in oven- or flame-dried glassware using syringe-septum cap technique. All of the solvents were purified and degassed before use. 2,2,6,6-Tetramethylpiperidine, TMP(H), was distilled with CaH_2 prior to use. Heptane and cyclohexane were purified under nitrogen with CaH_2. THF was purified with Na/benzophenone. BuLi was purchased as a 2.5 M solution in hexanes. The exact concentration of the BuLi was determined by titration with diphenylacetic acid in THF prior to use. KO*t*Bu was sublimed prior to use. Chlorotrimethylsilane and CD_3OD was used as received. Chromatographic separations were carried out under pressure on Merck silica gel 60 or aluminum oxide 60 using flash-column techniques. Reactions were monitored by thin-layer chromatography (TLC) carried out on 0.25 mm silica gel coated aluminum plates with UV light (254 nm) as the visualizing agent. ^1H and ^{13}C NMR spectra were recorded at room temperature on a 400 and 600 MHz spectrometer. TOF mass analyzers were used for HRMS measurements. The yields are after column chromatography.

Metalation of 2-Methylanisole under Various Conditions (Scheme 3). *Reaction (i).* A solution of **1a** (124 μL, 1.0 mmol) in THF (2.5 mL) at −78 °C was treated with KO*t*Bu (135 mg, 1.2 equiv). Subsequently, BuLi (512 μL, 2.35 M in hexanes, 1.2 equiv) and TMP(H) (202 μL, 1.2 equiv) were slowly added. The resulting solution was stirred for 15 min at −78 °C. Methanol-d_4 (203 μL, 5.0 equiv) was added and warmed to rt, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness giving crude 1-methoxy-2-deuteriomethylbenzene *Bn*-D-**1a**.[8b] ^1H NMR (600 MHz, CH_2Cl_2): δ 7.17−7.10 (m, 2.55 H), 6.86−6.81 (m, 2.20H), 3.81 (s, 3H), 2.21−2.17 (m, 2.64H). ^2H NMR (92.07 MHz, CH_2Cl_2): 2.18 (t, 3H). (>75% D incorporation).

Reactions (ii) and (iii). A solution of **1a** (124 μL, 1.0 mmol) in heptane or cyclohexane (2.5 mL) at rt was treated with KO*t*Bu (135 mg, 1.2 equiv). BuLi (512 μL, 2.35 M in hexanes, 1.2 equiv) and TMP(H) (202 μL, 1.2 equiv) were slowly added. The resulting suspension was stirred for 15 min at rt. Methanol-d_4 (203 μL, 5.0 equiv) was added and stirred for 1 h, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness giving crude 1-methoxy-2-deuteriomethylbenzene *Bn*-D-**1a**.[8b] ^1H NMR (600 MHz, CH_2Cl_2): δ 7.16−7.09 (m, 3.18H), 6.87−6.81 (m, 2.55H), 3.81 (s, 3H), 2.20−2.15 (m, 2.90H). ^2H NMR (92.07 MHz, CH_2Cl_2): 2.18 (t, 3H). (>65% D incorporation).

Reaction (iv). A mixture of **1a** (124 μL, 1.0 mmol) and KO*t*Bu (135 mg, 1.2 equiv) in heptane (2.5 mL) at rt was treated with BuLi (512 μL, 2.35 M in hexanes, 1.2 equiv). The resulting suspension was stirred for 15 min at rt. Methanol-d_4 (203 μL, 5.0 equiv) was added and stirred for 1 h at rt, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness giving crude products. See the complex ^1H NMR in SI. ^2H NMR (92.07 MHz, CH_2Cl_2): δ 6.95−6.77 (m, 0.70H), 3.85−3.75 (m, 0.15H), 3.63−3.50 (m, 0.05H), 2.30−2.10 (m, 3H), 2.05−1.87 (m, 0.30H), 1.30−1.11 (m, 0.25H).

Reaction (v). **1a** (124 μL, 1.0 mmol) in heptane (2.5 mL) was treated with TMP(H) (202 μL, 1.2 equiv), and BuLi (512 μL, 2.35 M in hexanes, 1.2 equiv) and was slowly added. The resulting reaction mixture was stirred at rt for 15 min. Methanol-d_4 (203 μL, 5.0 equiv) was added and stirred for 1 h at rt, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness gave crude product. ^1H NMR (600 MHz, CH_2Cl_2): δ 7.21−7.12 (m, 2H), 6.90−6.82 (m, 2H), 3.83 (s, 3H), 2.24 (s, 2H). ^2H NMR (92.07 MHz, CH_2Cl_2): No signals observed.

Screening of Hydrocarbon Solvents (Scheme 4). *Entries 1−3.* A mixture of **1a** (124 μL, 1.0 mmol) and sublimed KO*t*Bu (135 mg, 1.2 equiv) in the corresponding solvent (2.5 mL) was treated with BuLi (512 μL, 1.2 equiv, 2.35 M in hexanes) at specified temperature in Scheme 4. TMP(H) (202 μL, 1.2 equiv) was added dropwise and was stirred for 15 min. Chlorotrimethylsilane (317 μL, 2.5 equiv) was added and stirred for 1 h, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (2 × 20 mL), and organic layers were combined, washed with brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography, eluting with cyclohexane yielded **4a** as colorless oil. The product yields are depicted in Scheme 4.

Entry 4. Sublimed KO*t*Bu (135 mg, 1.2 equiv) in heptane (2.5 mL) was treated with BuLi (512 μL, 1.2 equiv, 2.35 M in hexanes) at 0 °C. TMP(H) (202 μL, 1.2 equiv) was added dropwise, and the resulting suspension was stirred for 5 min. A solution of **1a** (124 μL, 1.0 mmol) in heptane (0.5 mL) was added dropwise, and the reaction mixture was stirred for 15 min. Chlorotrimethylsilane (317 μL, 2.5 equiv) was added and stirred for 1 h, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (2 × 20 mL), and organic layers were combined, washed with brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4a**[12] (142 mg, 73%) as a colorless oil.

Entries 5 and 6. Sublimed KO*t*Bu (224 mg, 2.0 equiv) in heptane (2.5 mL) was treated with BuLi (851 μL, 2.0 equiv, 2.35 M in hexanes) at rt. TMP(H) (338 μL, 2.0 equiv) was added dropwise, and the resulting suspension was stirred for 5 min. A solution of **1a** (124 μL, 1.0 mmol) in heptane (0.5 mL) was added dropwise, and the reaction mixture was stirred for 15 min. Chlorotrimethylsilane (317 μL, 2.5 equiv) was added and stirred for 1 h, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (2 × 20 mL), and organic layers were combined, washed with brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4a**[12] as a colorless oil. The product yields are depicted in Scheme 4. ^1H NMR (400 MHz, $CDCl_3$): δ 7.10−7.04 (m, 1H), 7.05−6.96 (m, 1H), 6.87−6.78 (m, 2H), 3.79 (s, 3H), 2.10 (s, 2H), −0.02 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.4, 129.4, 129.2, 124.9, 120.2, 109.8, 54.8, 20.5, −1.6. HRMS-EI $[M]^+$: 194.1125, $C_{11}H_{18}OSi$ requires 194.1127.

Exothermicity Analysis in Benzylic Metalation of 1a (Figure 2). Sublimed KO*t*Bu (224 mg, 2.0 equiv) in heptane (2.5 mL) was cooled at 1 °C. BuLi (832 μL, 2.0 equiv, 2.4 M in hexanes) was added dropwise with internal temperature monitored with a Hanna thermometer. The temperature of the reaction was increased from 1 to 7 °C. The reaction was stirred for 5 min and cooled to 2 °C. TMP(H) (338 μL, 2.0 equiv) was added dropwise, and the temperature of the reaction was increased up to 6 °C. The reaction was stirred for 5 min and cooled to 1 °C. A solution of **1a** (124 μL, 1.0 mmol) in heptane (0.5 mL) was added dropwise. The temperature was increased from 1 to 2 °C. The resulting precipitates were stirred for 15 min and cooled to 1 °C. Chlorotrimethylsilane (317 μL, 2.5 equiv) was added slowly, and the temperature of the reaction was increased from 1 to 19 °C. The reaction mass was stirred for 1 h and cooled to 2 °C. Two M HCl (10 mL) was slowly added, and the temperature of the reaction was increased from 2 to 22 °C. The residue was extracted with diethyl ether (2 × 20 mL), and organic layers were combined, washed with brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4a** (173 mg, 85%) as a colorless oil.

(3-Methoxybenzyl)trimethylsilane, 4b.[12] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added.

The resulting suspension was stirred for 5 min at 0 °C. A solution of **1b** (378 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at rt, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4b** (502 mg, 86%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.16−7.10 (m, 1H), 6.67−6.52 (m, 3H), 3.78 (s, 3H), 2.06 (s, 2H), 0.00 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.4, 142.2, 129.0, 120.7, 113.8, 109.1, 55.0, 27.2, −1.9 ppm. MS-EI $[M]^+$: 194.6, $C_{11}H_{18}OSi$ requires 194.3.

3,4,5-(Trimethoxybenzyl)trimethylsilane, 4c.[12] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1c** (505 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at rt, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL) and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with petroleum ether/ethyl acetate (1/1) yielded **4c** (560 mg, 73%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.20 (s, 2H), 3.82 (s, 6H), 3.81 (s, 3H), 2.02 (s, 2H), 0.01 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.7, 138.1, 136.7, 106.8, 62.7, 57.8, 29.2, −0.00 ppm. HRMS-ESI $[M + H]^+$: 255.1411, $C_{13}H_{23}O_3Si$ requires 255.1416.

***N,N*-Dimethyl-2-[(trimethylsilyl)methyl]aniline, 4d.**[12] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of 2-*N*,*N*-trimethylaniline **1d** (437 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified on alumina eluting with cyclohexane/ethyl acetate (95/5) yielded **4d** (540 mg, 86%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.09−7.05 (m, 2H), 7.02−6.98 (m, 1H), 6.96−6.91 (m, 1H), 2.62 (s, 6H), 2.17 (s, 2H), −0.03 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.0, 136.2, 129.7, 124.8, 123.3, 119.6, 44.8, 22.1, −1.2 ppm. MS-EI $[M]^+$: 207.7, $C_{12}H_{21}NSi$ requires 207.4.

***N,N*-Diisopropyl-4-[(trimethylsilyl)methyl]benzamide, 4e.**[12] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **1e** (660 mg, 3.0 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with ethyl acetate (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (9/1) yielded **4e** (772 mg, 88%) as a colorless solid, mp 53−54 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.17 (d, *J* = 8.4 Hz, 2H), 6.98 (d, *J* = 8.4 Hz, 2H), 4.25−3.25 (m, 2H), 2.08 (s, 2H), 1.75−0.75 (m, 12H), −0.02 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.4, 141.4, 134.5, 127.8, 125.8, 27.1, 20.8, −2.0 ppm. MS-EI $[M]^+$: 291.3, $C_{17}H_{29}NOSi$ requires 291.2.

***N,N*-Diisopropyl-2-[(trimethylsilyl)methyl]benzamide, 4f.**[25] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **1f** (660 mg, 3.0 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with ethyl acetate (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (8/2) yielded **4f** (429 mg, 49%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22−7.16 (m, 1H), 7.09−7.03 (m, 3H), 3.68 (m, 1H), 3.58 (m, 1H), 2.05 (s, 2H), 1.57−1.55 (m, 6H), 1.12 (d, *J* = 6.8 Hz, 3H), 1.04 (d, *J* = 6.8 Hz, 3H), 0.03 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.7, 137.3, 136.8, 128.8, 127.7, 125.2, 124.1, 50.6, 45.5, 23.8, 20.9, 20.8, 20.6, 20.4, −1.10 ppm. MS-EI $[M]^+$: 291.7, $C_{17}H_{29}NOSi$ requires 291.2.

***N,N*-Diethyl-4-[(trimethylsilyl)methyl]benzenesulfonamide, 4g.**[20a] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **1g** (682 mg, 3.0 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with ethyl acetate (3 × 20 mL) and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (8/2) yielded **4g** (584 mg, 65%) as a colorless solid. mp 45−47 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64 (d, *J* = 8.4 Hz, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 3.23 (q, 4H), 2.16 (s, 2H), 1.10 (t, 6H), −0.02 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.2, 135.8, 128.2, 127.0, 41.9, 27.7, 14.0, −2.0 ppm. MS-EI $[M]^+$: 299.2, $C_{14}H_{25}NO_2SSi$ requires 299.5.

Trimethyl(3-methylbenzyl)silane, 4h.[26] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1h** (367 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4h** (502 mg, 94%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.13−7.08 (m, 1H), 6.91−6.86 (m, 1H), 6.84−6.78 (m, 2H), 2.30 (s, 3H), 2.04 (s, 2H), −0.01 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.4, 137.5, 128.9, 128.0, 125.1, 124.6, 26.9, 21.4, −1.9 ppm. HRMS-EI $[M]^+$: 178.1179, $C_{11}H_{18}Si$ requires 178.1178.

(3-Methoxy-5-methylbenzyl)trimethylsilane, 4i. Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1i** (424 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added and stirred for 1 h at 0 °C and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (95/5) yielded **4i** (625 mg, 95%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.60−6.40 (m, 2H), 6.39−6.27 (m, 1H), 3.76 (s, 3H), 2.28 (s, 3H), 2.02 (s, 2H), 0.00 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.5, 141.9, 138.9, 121.6, 110.8, 110.1, 55.0, 27.1, 21.6, −1.8 ppm. HRMS-EI $[M]^+$: 208.1289, $C_{12}H_{20}OSi$ requires 208.1283.

(2-Methoxy-3-methylbenzyl)trimethylsilane, 4j. Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1j** (425 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added, stirred for 1 h at 0 °C and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (99/1) yielded **4j** (495 mg, 79%) as a colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 6.92−6.84 (m, 3H), 3.69 (s, 3H), 2.29 (s, 3H), 2.08 (s, 2H), 0.00 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.9, 133.5, 130.8, 127.6, 127.2, 123.5, 59.5, 20.4, 16.3, −1.4 ppm. HRMS-EI $[M]^+$: 208.1290, $C_{12}H_{20}OSi$ requires 208.1283.

Benzyltrimethylsilane, 4k.[12] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of toluene **1k** (320 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4k** (351 mg, 72%) as a colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.23−7.20 (m, 2H), 7.07 (m, 1H), 7.03−6.98 (m, 2H), 2.08 (s, 2H), −0.01 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.5, 128.1, 128.0, 123.8, 27.0, −1.9 ppm. MS-EI $[M]^+$: 164.6, $C_{10}H_{16}$ requires 164.3.

Trimethyl(naphthalen-1-ylmethyl)silane, 4l.[27] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of 1-methylnapthalene **1l** (426 μL, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4l** (494 mg, 77%) as a yellow oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.96−7.93 (m, 1H), 7.85−7.82 (m, 1H), 7.64−7.51 (m, 1H), 7.50−7.42 (m, 2H), 7.40−7.32 (m, 1H), 7.18−7.14 (m, 1H), 2.58 (s, 2H), 0.00 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.2, 133.9, 131.7, 128.6, 125.5, 125.3, 125.2, 125.0, 124.8, 124.6, 23.4, −1.2 ppm. MS-EI $[M]^+$: 214.6, $C_{14}H_{18}Si$ requires 214.4.

[(1,1′-Biphenyl)]-4-ylmethyl]trimethylsilane, 4m.[28] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1m** (505 mg, 3.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4m** (633 mg, 88%) as a colorless solid, mp 42−44 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 7.65−7.61 (m, 2H), 7.51 (d, *J* = 7.6 Hz, 2H), 7.48−7.43 (m, 2H), 7.37−7.32 (m, 1H), 7.11 (d, *J* = 7.6 Hz, 2H), 2.17 (s, 2H), 0.07 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.2, 139.7, 136.7, 128.7, 128.4, 126.8, 126.8, 126.7, 26.7, −1.9 ppm. MS-EI $[M]^+$: 240.6, $C_{16}H_{20}$ requires 240.4.

(Anthracen-9-ylmethyl)trimethylsilane, 4n.[29] Under inert atmosphere, a mixture of KO*t*Bu (673 mg, 6.0 mmol) in heptane (7.5 mL) at 0 °C was treated with BuLi (2.55 mL, 2.35 M in hexanes, 6.0 mmol), followed by TMP(H) (1.0 mL, 6.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1n** (576 mg, 3.0 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (952 μL, 7.5 mmol) was added, stirred it for 1 h at 0 °C, and 2 M HCl (20 mL) was slowly added. The residue was extracted with diethyl ether (3 × 20 mL), and organic layers were combined, washed with water (2 × 20 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4n** (434 mg, 55%) as a yellow solid, mp 45−47 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 8.26 (s, 1H), 8.22−8.19 (m, 2H), 8.02−8.00 (m, 2H), 7.51−7.45 (m, 4H), 3.20 (s, 2H), 0.03 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.6, 132.1, 129.5, 129.4, 125.8, 125.1, 124.9, 124.0, 19.3, 0.0 ppm. MS-EI $[M]^+$: 264.5, $C_{18}H_{20}$ requires 264.4.

2-[(Trimethylsilyl)methyl]pyridine, 4o.[30] Under inert atmosphere, a mixture of KO*t*Bu (135 mg, 1.2 mmol) in heptane (2.5 mL) at 0 °C was treated with BuLi (501 μL, 2.4 M in hexanes, 1.20 mmol), followed by TMP(H) (203 μL, 1.2 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1o** (99 μL, 1.0 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (317 μL, 2.50 mmol) was added, stirred for 1 h at 0 °C and NH_4Cl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **4o** (143 mg, 87%) as a colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 8.40−8.30 (m, 1H), 7.53−7.45 (m, 1H), 7.00−6.90 (m, 2H), 2.33 (s, 2H), 0.01 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.2, 148.9, 135.7, 122.1, 119.1, 30.2, −1.8 ppm. MS-EI $[M]^+$: 165.8, $C_9H_{15}NSi$ requires 165.3.

[(3-Methoxyphenylmethylene)bis(trimethylsilane)], 6a.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **4b** (49 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **6a** (59 mg, 88%) as a colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.09 (t, 1H), 6.60−6.56 (m, 1H), 6.53−6.48 (m, 2H), 3.77 (s, 3H), 1.47 (s, 1H), 0.03 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3, 144.7, 128.9, 121.5, 114.6, 108.3, 54.9, 29.8, 0.02 ppm. HRMS-EI $[M]^+$: 266.1533, $C_{14}H_{26}OSi_2$ requires 266.1522.

{[(3,4,5-Trimethoxyphenyl)methylene]bis(trimethylsilane)}, 6b.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **4c** (64 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was added. The residue was extracted with ethyl acetate (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (8/2) yielded **6b** (59 mg, 72%) as a colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ

6.13 (s, 2H), 3.81 (s, 3H), 3.80 (s, 6H), 1.40 (s, 1H), 0.04 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.7, 138.9, 134.4, 105.7, 61.0, 55.9, 29.9, 0.2 ppm. MS-EI $[M]^+$: 326.7, $C_{16}H_{30}O_3Si_2$ requires 326.6.

2-[Bis(trimethylsilyl)methyl]-*N*,*N*-dimethylaniline, 6c.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **4d** (52 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified on alumina eluting with cyclohexane yielded **6c** (60 mg, 86%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.10 (m, 1H), 7.06−6.92 (m, 3H), 2.58 (s, 6H), 2.49 (s, 1H), 0.03 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.1, 139.2, 129.0, 123.8, 123.4, 120.3, 45.1, 20.1, 0.4 ppm. MS-EI $[M]^+$: 279.3, $C_{15}H_{29}NSi_2$ requires 279.8.

4-[Bis(trimethylsilyl)methyl]-*N*,*N*-diisopropylbenzamide, 6d.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **4e** (73 mg, 0.25 mmol) in heptane (2.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane/ethyl acetate (8/2) yielded **6d** (71 mg, 78%) as a colorless solid, mp 55−56 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.17 (d, *J* = 8.1 Hz, 2H), 6.91 (d, *J* = 8.1 Hz, 2H), 3.70 (br, 2H), 1.53 (s, 1H), 1.33 (br, 12H), 0.02 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.5, 144.4, 133.7, 128.4, 125.9, 31.0, 29.8, 20.9, 0.1 ppm. MS-EI $[M]^+$: 364.4, $C_{20}H_{37}NOSi_2$ requires 364.2.

[(*m*-Tolylmethylene)bis(trimethylsilane)], 6e.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **4h** (45 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **6e** (64 mg, 82%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.08−7.04 (m, 1H), 6.83 (m, 1H), 6.73−6.72 (m, 2H), 2.28 (s, 3H), 1.45 (s, 1H), 0.02 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.9, 137.3, 129.6, 127.8, 125.7, 124.0, 29.3, 21.6, 0.2 ppm. MS-EI $[M]^+$: 250.2, $C_{14}H_{28}Si_2$ requires 250.5.

[(Phenylmethylene)bis(trimethylsilane)], 6f.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **4k** (41 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred it for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **6f** (48 mg, 81%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23−7.14 (m, 2H), 7.06−7.00 (m, 1H), 6.92 (d, *J* = 7.0 Hz, 2H), 1.49 (s, 1H), 0.03 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.1, 128.7, 127.9, 123.2, 29.5, 0.2 ppm. HRMS-EI $[M]^+$: 236.1411, $C_{13}H_{24}Si_2$ requires 236.1417.

(Naphthalen-1-ylmethylene)bis(trimethylsilane), 6g.[15] Under inert atmosphere, a suspension of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting mixture was stirred for 5 min at 0 °C. A solution of **4l** (54 mg, 0.25 mmol) in heptane (0.5 mL) was added dropwise, and the reaction mixture was stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **6g** (51 mg, 71%) as a green oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05−8.00 (m, 1H), 7.85−7.78 (m, 1H), 7.57 (d, *J* = 8.1 Hz, 1H), 7.50−7.41 (m, 2H), 7.40−7.33 (m, 1H), 7.17 (d, *J* = 7.2 Hz, 1H), 2.44 (s, 1H), 0.04 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.9, 134.3, 132.3, 128.9, 125.1, 125.1, 124.9, 124.6, 123.9, 22.1, 0.4 ppm. MS-EI $[M]^+$: 286.9, $C_{17}H_{26}Si_2$ requires 286.6.

[(1,1′-Biphenyl)-4-ylmethylene]bis(trimethylsilane), 6h.[15] Under inert atmosphere, a mixture of KO*t*Bu (56 mg, 0.50 mmol) in heptane (1.0 mL) at 0 °C was treated with BuLi (213 μL, 2.35 M in hexanes, 0.50 mmol), followed by TMP(H) (84 μL, 0.50 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **4m** (60 mg, 0.25 mmol) in heptane (2.0 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (79 μL, 0.63 mmol) was added, stirred for 1 h at 0 °C, and 2 M HCl (5 mL) was slowly added. The residue was extracted with diethyl ether (2 × 15 mL), and organic layers were combined, washed with water (2 × 5 mL) and brine (5 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **6h** (60 mg, 77%) as a colorless solid, mp 52−54 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.62−7.58 (m, 2H), 7.47−7.38 (m, 4H), 7.32−7.27 (m, 1H), 7.00 (d, *J* = 8.1 Hz, 2H), 1.56 (s, 1H), 0.06 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.7, 141.2, 136.0, 129.3, 128.8, 126.8, 126.7, 29.4, 0.3 ppm. MS-EI $[M]^+$: 312.4, $C_{19}H_{28}Si_2$ requires 312.6.

2-[Bis(trimethylsilyl)methyl]pyridine, 6i.[31] Under inert atmosphere, a mixture of KO*t*Bu (247 mg, 2.20 mmol) in heptane (2.5 mL) at 0 °C was treated with BuLi (917 μL, 2.35 M in hexanes, 2.20 mmol), followed by TMP(H) (371 μL, 2.20 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1o** (99 μL, 1.0 mmol) in heptane (0.5 mL) was added dropwise and stirred for 15 min at 0 °C. Chlorotrimethylsilane (381 μL, 3.0 mmol) was added, stirred for 1 h at 0 °C, and NH_4Cl (10 mL) was slowly added. The residue was extracted with diethyl ether (3 × 15 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica gel column chromatography eluting with cyclohexane yielded **6i** (187 mg, 79%) as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.42−8.38 (m, 1H), 7.48−7.38 (m, 1H), 6.94−6.83 (m, 2H), 1.88 (s, 1H), 0.03 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.1, 149.0, 135.4, 122.6, 118.3, 33.3, 0.1 ppm. MS-EI $[M]^+$: 237.3, $C_{12}H_{23}NSi_2$ requires 237.5.

1,2-Bis(3-methoxyphenyl)ethane, 7a.[10] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1b** (244 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1 h 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **7a** (148 mg, 61%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20 (t, *J* = 8.0 Hz, 2H), 6.80−6.73 (m, 6H), 3.77 (s, 6H), 2.90 (s, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.5, 143.3, 129.3, 120.8, 114.1, 111.2, 55.1, 37.8 ppm. MS-ESI $[M + H]^+$: 243.5, $C_{16}H_{18}O_2$ requires 243.3.

2,2′-[(Ethane-1,2-diyl)bis(*N*,*N*-dimethylaniline)], 7b.[10] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1d** (271 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1 h 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **7b** (139 mg, 52%) as a colorless solid, mp 54−56 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29 (d, *J* = 8.0 Hz, 2H), 7.18 (t, *J* = 8.0 Hz, 2H), 7.11 (d, *J* = 7.6 Hz, 2H), 7.03 (t, *J* = 7.6 Hz, 2H), 3.03 (d, 12H), 2.69 (s, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.8, 137.3, 129.7, 126.5, 123.3, 119.5, 45.2, 31.8 ppm. MS-EI $[M]^+$: 268.6, $C_{18}H_{24}N_2$ requires, 268.4.

4,4-[(Ethane-1,2-diyl)bis(*N*, *N*-diisopropylbenzamide)], 7c.[10] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **1e** (438 mg, 2.0 mmol) in heptane (5.0 mL) was added slowly and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **7c** (337 mg, 77%) as a colorless solid, mp 143−145 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20 (d, *J* = 8.0 Hz, 4H), 7.16 (d, *J* = 8.0 Hz, 4H), 3.68 (br, 4H), 1.32 (br, 24H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.0, 141.9, 136.5, 128.3, 125.6, 50.1, 45.8, 37.3, 20.6 ppm. MS-ESI $[M + H]^+$: 437.5, $C_{28}H_{41}N_2O_2$ requires, 437.3.

1,2-Di-*m*-tolylethane, 7d.[11a] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1h** (244 μL, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1 h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with diethyl ether (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **7d** (190 mg, 92%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24−7.19 (m, 2H), 7.09−6.99 (m, 6H), 2.91 (s, 4H), 2.37 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.9, 137.9, 129.2, 128.2, 126.6, 125.4, 38.0, 21.4 ppm. MS-EI $[M]^+$: 210.5, $C_{16}H_{18}$ requires 210.2.

1,2-Bis(3-methoxy-5-methylphenyl)ethane, 7e.[11a] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1i** (272 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1 h 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane yielded **7e** (214 mg, 80%) as a colorless solid, mp 81−83 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38 (d, *J* = 7.4 Hz, 2H), 6.80−6.65 (m, 4H), 3.82 (s, 6H), 2.91 (s, 4H), 2.22 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.6, 140.7, 130.4, 124.0, 120.1, 110.4, 55.2, 38.1, 15.8 ppm. MS-ESI $[M + Na]^+$: 293.5, $C_{18}H_{22}O_2Na$ requires 293.1.

1,2-Bis(3,4,5-trimethoxyphenyl)ethane, 7f.[11a] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol), in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol) followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A solution of **1c** (364 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (689 μL, 8.0 mmol) was added, the reaction stirred for 1h at 0 °C and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL) and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (95/5) yielded **7f** (262 mg, 72%) as a colorless solid, mp 140−141 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.36 (s, 4H), 3.82 (s, 18H), 2.84 (s, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.0, 137.4, 136.1, 105.4, 60.9, 56.0, 38.5 ppm. MS-ESI $[M + Na]^+$: 385.2, $C_{20}H_{26}O_6Na$ requires 385.5.

1-Methoxy-3-phenethylbenzene, 7g.[11a] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. **1b** (248 μL, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Benzyl bromide (594 μL, 5.0 mmol) was added, the reaction stirred for 1h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (95/5) yielded **7g** (360 mg, 85%) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33−7.27 (m, 2H), 7.24−7.18 (m, 4H), 6.83−6.79 (m, 1H), 6.78−6.73 (m, 2H), 3.80 (m, 3H), 2.97−2.89 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.6, 143.4, 141.7, 129.3, 128.4, 128.3, 125.9, 120.9, 114.2, 111.3, 55.1, 38.0, 37.8 ppm. MS-EI $[M]^+$: 212.5, $C_{15}H_{16}O$ requires 212.3.

***N*,*N*-Dimethyl-2-phenethylaniline, 7h.**[6] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. **1d** (290 μL, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Benzyl bromide (594 μL, 5.0 mmol) was added, the reaction stirred for 1h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (95/5) yielded **7h** (372 mg, 83%) as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.40−7.15 (m, 7H), 7.13−7.11 (m, 1H), 7.05−6.99 (m, 1H), 3.05−2.91 (m, 4H), 2.67 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.9, 142.5, 136.7, 129.6, 128.4, 128.3, 126.7, 125.7, 123.3, 119.6, 45.2, 36.8, 32.9 ppm. MS-EI $[M]^+$: 225.7, $C_{16}H_{11}N$ requires 225.3.

1,2,3-Trimethoxy-5-phenethylbenzene, 7i.[10] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. **1c** (364 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. Benzyl bromide (594 μL, 5.0 mmol) was added, the reaction stirred for 1 h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (90/10) yielded **7i** (440 mg, 80%) as colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.24−7.17 (m, 2H), 7.15−7.07 (m, 3H), 6.28 (s, 2H), 3.75 (s, 3H), 3.73 (s, 6H), 2.86−2.74 (m, 4H). ^{13}C NMR (100 MHz, CDCl$_3$): δ 153.0, 141.5, 137.4, 136.1, 128.5, 128.3, 125.9, 105.3, 60.8, 55.9, 38.3, 37.9 ppm. MS-EI [M]$^+$: 272.7, $C_{17}H_{20}O_3$ requires 272.3.

1,2,3-Trimethoxy-5-(3-methoxyphenethyl)benzene, 7j.[10] Under inert atmosphere, a mixture of KO*t*Bu (449 mg, 4.0 mmol) in heptane (5.0 mL) at 0 °C was treated with BuLi (1.70 mL, 2.35 M in hexanes, 4.0 mmol), followed by TMP(H) (675 μL, 4.0 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. **1c** (364 mg, 2.0 mmol) in heptane (1.0 mL) was added dropwise and stirred for 15 min at 0 °C. 3-Methoxybenzyl bromide (700 μL, 2.5 mmol) was added, the reaction stirred for 1 h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na$_2$SO$_4$, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (70/30) yielded **7j** (520 mg, 86%) as colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.21 (t, *J* = 8.0 Hz, 1H), 6.82−6.72 (m, 3H), 6.38 (s, 2H), 3.84 (s, 3H), 3.83 (s, 6H), 3.79 (s, 3H), 2.93−2.83 (m, 4H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 158.6, 152.0, 142.2, 136.4, 135.1, 128.3, 119.9, 113.2, 110.3, 104.4, 59.8, 55.0, 54.1, 37.2, 37.0 ppm. MS-EI [M]$^+$: 302.6, $C_{18}H_{22}O_4$ requires 302.4.

[2.2]Metacyclophane, 9a.[11a] Under inert atmosphere, a mixture of KO*t*Bu (216 mg, 1.92 mmol), in heptane (3.0 mL) at 0 °C was treated with BuLi (824 μL, 2.35 M in hexanes, 1.92 mmol), followed by TMP(H) (324 μL, 1.92 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **7d** (100 mg, 0.48 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (331 μL, 3.84 mmol) was added, the reaction stirred for 1 h at 0 °C, and 2 M HCl (10 mL) was added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na$_2$SO$_4$, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (98/2) yielded **9a** (29 mg, 29%) as a colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.33−7.27 (m, 2H), 7.11−7.05 (m, 4H), 4.29 (s, 2H), 3.17−3.05 (m, 4H), 2.17−2.04 (m, 4H). ^{13}C NMR (100 MHz, CDCl$_3$): δ 138.9, 136.5, 128.8, 125.4, 40.9 ppm. MS-EI [M]$^+$: 208.5, $C_{16}H_{16}$ requires 208.2.

5,13-Dimethoxy[2.2]metacylcophane, 9b.[11b] Under inert atmosphere, a mixture of KO*t*Bu (332 mg, 2.96 mmol) in heptane (3.0 mL) at 0 °C was treated with BuLi (1.24 mL, 2.35 M in hexanes, 2.96 mmol), followed by TMP(H) (500 μL, 2.96 mmol) was slowly added. The resulting suspension was stirred for 5 min at 0 °C. A suspension of **7e** (200 mg, 0.74 mmol) in heptane (3.0 mL) was added dropwise and stirred for 15 min at 0 °C. 1,2-Dibromoethane (510 μL, 5.92 mmol) was added, and the reaction stirred for 1h at 0 °C, and 2 M HCl (10 mL) was slowly added. The residue was extracted with ethyl acetate (2 × 25 mL), and organic layers were combined, washed with water (2 × 10 mL) and brine (10 mL), dried over Na$_2$SO$_4$, and concentrated to dryness. The product was purified by silica-gel column chromatography eluting with cyclohexane/ethyl acetate (95/5) yielded **9b** (62 mg, 31%) as a colorless solid, mp 170−171 °C. ^{1}H NMR (400 MHz, CDCl$_3$): δ 6.63 (s, 4H), 4.09 (s, 2H), 3.84 (s, 6H), 3.06−2.96 (m, 4H), 2.17−2.10 (m, 4H). ^{13}C NMR (100 MHz, CDCl$_3$): δ 160.5, 140.4, 129.5, 110.8, 55.3, 41.0 ppm. MS-EI [M]$^+$: 268.7, $C_{18}H_{20}O_2$ requires 268.3.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b01540.

^{1}H and ^{13}C spectra for all compounds (PDF)

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: donalfoshea@rcsi.ie.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

Financial support from IRC and Science Foundation Ireland is gratefully acknowledged.

■ REFERENCES

(1) Roberts, J. D.; Curtin, D. Y. *J. Am. Chem. Soc.* **1946**, *68*, 1658−1660.

(2) Gilman, H.; Langham, W.; Jacoby, A. L. *J. Am. Chem. Soc.* **1939**, *61*, 106−109.

(3) Wittig, G.; Pockels, U.; Dröge, H. *Ber. Dtsch. Chem. Ges. B* **1938**, *71*, 1903−1912.

(4) Schlosser, M. *Angew. Chem., Int. Ed.* **2005**, *44*, 376−393.

(5) Whilsler, M. C.; MacNeil, S.; Snieckus, V.; Beak, P. *Angew. Chem., Int. Ed.* **2004**, *43*, 2206−2225.

(6) Clark, R. D.; Jahangir, A. *Organic Reactions*; ACS: Washington, DC, 1995; Vol 47, pp 1−314.

(7) (a) Winkle, M. R.; Ronald, R. C. *J. Org. Chem.* **1982**, *47*, 2101−2108. (b) Ronald, R. C.; Winkle, M. R. *Tetrahedron* **1983**, *39*, 2031−2042. (c) Ludt, R. E.; Griffiths, J. S.; McGrath, K. N.; Hauser, C. R. *J. Org. Chem.* **1973**, *38*, 1668−1674. (d) Mao, C.-L.; Hauser, C. R. *J. Org. Chem.* **1970**, *35*, 3704−3708. (e) Fisher, L. E.; Caroon, J. M.; Jahangir; Stabler, S. R.; Lundberg, S.; Muchowski, J. M. *J. Org. Chem.* **1993**, *58*, 3643−3647. (f) Sibi, M. P.; Snieckus, V. *J. Org. Chem.* **1983**, *48*, 1935−1937. (g) Watanabe, H.; Hauser, C. R. *J. Org. Chem.* **1968**, *33*, 4278−4279. (h) Ludt, R. E.; Growther, G. P.; Hauser, C. R. *J. Org. Chem.* **1970**, *35*, 1288−1296. (i) Takagishi, H.; Schlosser, M. *Synlett* **1991**, *1991*, 119−121. (j) Klusener, P. A. A.; Hommes, H. H.; Verkruijsse, H. D.; Brandsma, L. *J. Chem. Soc., Chem. Commun.* **1985**, 1677−1678. (k) Faigl, F.; Marzi, E.; Schlosser, M. *Chem. - Eur. J.* **2000**, *6*, 771−777. (l) Fassler, J.; McCubbin, J. A.; Roglans, A.; Kimachi, T.; Hollett, J. W.; Kunz, R. W.; Tinkl, M.; Zhang, Y.; Wang, R.; Campbell, M.; Snieckus, V. *J. Org. Chem.* **2015**, *80*, 3368−3386.

(8) (a) Tricotet, T.; Fleming, P.; Cotter, J.; Hogan, A. L.; Strohmann, C.; Gessner, V. H.; O'Shea, D. F. *J. Am. Chem. Soc.* **2009**, *131*, 3142−3143. (b) Fleming, P.; O'Shea, D. F. *J. Am. Chem. Soc.* **2011**, *133*, 1698−1701.

(9) Unkelbach, C.; O'Shea, D. F.; Strohmann, C. *Angew. Chem., Int. Ed.* **2014**, *53*, 553−556.

(10) Blangetti, M.; Fleming, P.; O'Shea, D. F. *J. Org. Chem.* **2012**, *77*, 2870−2877.

(11) (a) Blangetti, M.; Fleming, P.; O'Shea, D. F. *Beilstein J. Org. Chem.* **2011**, *7*, 1249−1254. (b) Blangetti, M.; Müller-Bunz, H.; O'Shea, D. F. *Chem. Commun.* **2013**, *49*, 6125−6127. (c) Blangetti, M.; Müller-Bunz, H.; O'Shea, D. F. *Tetrahedron* **2013**, *69*, 4285−4291.

(12) Das, M.; O'Shea, D. F. *Tetrahedron* **2013**, *69*, 6448−6460.

(13) (a) Hayashi, T.; Katsuro, Y.; Okamoto, Y.; Kumada, M. *Tetrahedron Lett.* **1981**, *22*, 4449−4452. (b) Soderquist, J. A.; Santiago, B.; Rivera, I. *Tetrahedron Lett.* **1990**, *31*, 4981−4984. (c) Sengupta, S.; Leite, M.; Raslan, D. S.; Quesnelle, C.; Snieckus, V. *J. Org. Chem.* **1992**, *57*, 4066−4068. (d) Takahashi, H.; Hossain, K. M.; Nishihara, Y.; Shibata, T.; Takagi, K. *J. Org. Chem.* **2006**, *71*, 671−675. (e) Tobisu, M.; Kita, Y.; Ano, Y.; Chatani, N. *J. Am. Chem. Soc.* **2008**, *130*, 15982−15989. (f) Giannerini, M.; Fañanás-Mastral, M.; Feringa, B. L. *Nat. Chem.* **2013**, *5*, 667−672. (g) Leiendecker, M.; Hsiao, C.-C.; Guo, L.; Alandini, N.; Rueping, M. *Angew. Chem., Int. Ed.* **2014**, *53*, 12912−12915. (h) Leiendecker, M.; Chatupheeraphat, A.; Rueping, M. *Org. Chem. Front.* **2015**, *2*, 350−353. (i) Heijnen, D.; Horniloss, V.; Corbet, B. P.; Giannerini, M.; Feringa, B. L. *Org. Lett.* **2015**, *17*, 2262−2265.

(14) Das, M.; O'Shea, D. F. *J. Org. Chem.* **2014**, *79*, 5595−5607 and references cited therein..

(15) Das, M.; Manvar, A.; Jacolot, M.; Blangetti, M.; Jones, R.; O'Shea, D. *Chem. - Eur. J.* **2015**, *21*, 8737−8740.

(16) (a) Leung, W.-P.; Raston, C. L.; Skelton, B. W.; White, A. H. *J. Chem. Soc., Dalton Trans.* **1984**, 1801−1807. (b) Mills, R. J.; Taylor, N. J.; Snieckus, V. *J. Org. Chem.* **1989**, *54*, 4372−4385. (c) Chenard, B. L.; Slapak, C.; Anderson, D. K.; Swenton, J. S. *J. Chem. Soc., Chem. Commun.* **1981**, 179−180.

(17) (a) Werner, V.; Klatt, T.; Fujii, M.; Markiewicz, J.; Apeloig, Y.; Knochel, P. *Chem. - Eur. J.* **2014**, *20*, 8338−8342. (b) Klatt, T.; Werner, V.; Maximova, M. G.; Didier, D.; Apeloig, Y.; Knochel, P. *Chem. - Eur. J.* **2015**, *21*, 7830−7834. (c) Lasarte, J.; Palomo, C.; Picard, J. P.; Dunogues, J.; Aizpurua, J. M. *J. Chem. Soc., Chem. Commun.* **1989**, 72−74.

(18) (a) Ager, D. J. *Science of Synthesis Sect. A* **2010**, *47*, 85−104. (b) Palomo, C.; Aizpurua, J. M.; Garcia, J. M.; Ganboa, I.; Cossio, F. P.; Lecea, B.; Lopez, C. *J. Org. Chem.* **1990**, *55*, 2498−2503. (c) Takeda, T. *Modern Carbonyl Olefination*; Wiley-VCH: Weinheim, 2004; pp 18−93 and references cited therein.

(19) (a) Slocum, D. W.; Jennings, C. A. *J. Org. Chem.* **1976**, *41*, 3653−3664. (b) Boyer, S. K.; Fitz, J. J.; Gschwend, H. W.; Haider, H. M.; Hamdan, A. *J. Org. Chem.* **1982**, *47*, 3658−3660. (c) Slocum, D. W.; Reed, D.; Jackson, F., III; Friesen, C. *J. Organomet. Chem.* **1996**, *512*, 265−267. (d) Slocum, D. W.; Dietzel, P. *Tetrahedron Lett.* **1999**, *40*, 1823−1826. (e) Slocum, D. W.; Ray, J.; Shelton, P. *Tetrahedron Lett.* **2002**, *43*, 6071−6073. (f) Slocum, D. W.; Dumbris, S.; Brown, S.; Jackson, G.; LaMastus, R.; Mullins, E.; Ray, J.; Shelton, P.; Walstron, A.; Wilcox, J. M.; Holman, R. W. *Tetrahedron* **2003**, *59*, 8275−8284. (g) Slocum, D. W.; Carroll, A.; Dietzel, P.; Eilermann, S.; Culver, J. P.; McClure, B.; Brown, S.; Holman, R. W. *Tetrahedron Lett.* **2006**, *47*, 865−868. (h) Slocum, D. W.; Wang, S.; White, C. B.; Whitley, P. E. *Tetrahedron* **2010**, *66*, 4939−4942. (i) Slocum, D. W.; Reinscheld, T. K.; White, C. B.; Timmons, M. D.; Shelton, P. A.; Slocum, M. G.; Sandlin, R. D.; Holland, E. G.; Kusmic, D.; Jennings, J. A.; Tekin, K. C.; Nguyen, Q.; Bush, S. J.; Keller, J. M.; Whitley, P. E. *Organometallics* **2013**, *32*, 1674−1686.

(20) (a) MacNeil, S. L.; Familoni, O. B.; Snieckus, V. *J. Org. Chem.* **2001**, *66*, 3662−3670. (b) Alo, B. I.; Familoni, O. B.; Marsais, F.; Quequiner, G. J. *J. Chem. Soc., Perkin Trans. 1* **1990**, 1611−1614. (c) Beak, P.; Brown, R. A. *J. Org. Chem.* **1982**, *47*, 34−46.

(21) (a) Harmon, T. E.; Shirley, D. A. *J. Org. Chem.* **1974**, *39*, 3164−3165. (b) Bates, R. B.; Siahaan, T. J.; Suvannachut, K. J. *J. Org. Chem.* **1990**, *55*, 1328−1334. (c) Schlosser, M.; Maccaroni, P.; Marzi, E. *Tetrahedron* **1998**, *54*, 2763−2770.

(22) Kopka, I. E.; Fataftah, Z. A.; Rathke, M. W. *J. Org. Chem.* **1987**, *52*, 448−450.

(23) Lochmann, L. *Eur. J. Inorg. Chem.* **2000**, *2000*, 1115−1126.

(24) (a) Sun, C.-L.; Shi, Z.-J. *Chem. Rev.* **2014**, *114*, 9219−9280. (b) Shi, W.; Liu, C.; Lei, A. *Chem. Soc. Rev.* **2011**, *40*, 2761−2776.

(25) Xu, L. − W.; Chen, X. − H.; Shen, H.; Deng, Y.; Jiang, J. − X.; Jiang, K.; Lai, G. − Q.; Sheng, C. − Q. *Eur. J. Org. Chem.* **2012**, *2012*, 290−297.

(26) Fry, A. J.; Touster, J. *J. Org. Chem.* **1989**, *54*, 4829−4832.

(27) Molander, G. A.; Yun, C. − S.; Ribagorda, M.; Biolatto, B. *J. Org. Chem.* **2003**, *68*, 5534−5539.

(28) Huckins, J. R.; Rychnovsky, S. D. *J. Org. Chem.* **2003**, *68*, 10135−10145.

(29) Kendall, J. K.; Engler, T. A.; Shechter, H. *J. Org. Chem.* **1999**, *64*, 4255−4266.

(30) Schwieger, S.; Herzog, R.; Wagner, C.; Steinborn, D. *J. Organomet. Chem.* **2009**, *694*, 3548−3558.

(31) Hassall, K.; Schiesser, C. H.; White, J. M. *Organometallics* **2007**, *26*, 3094−3099.