JOC The Journal of Organic Chemistry

Note

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J. Org. Chem., **Just Accepted Manuscript** • DOI: 10.1021/acs.joc.9b00673 • Publication Date (Web): 26 Apr 2019

ACS Publications

is published by the American Chemical Society. 1155 Sixteenth Street N.W., Washington, DC 20036

Synthesis of *N*-Arylpyrazoles by Palladium-Catalyzed Coupling of Aryl Triflates with Pyrazole Derivatives

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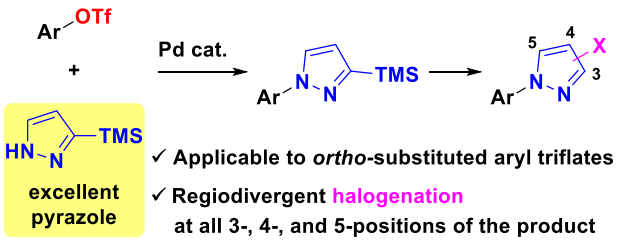


Abstract

A method for synthesis of *N*-arylpyrazoles by palladium-catalyzed coupling of aryl triflates with pyrazole derivatives is described. Using *t*BuBrettPhos as a ligand, the palladium-catalyzed C–N coupling of a variety of aryl triflates including *ortho*-substituted ones with pyrazole derivatives proceeded efficiently to give *N*-arylpyrazole products in high yields. 3-

Trimethylsilylpyrazole was found as an excellent pyrazole substrate for the coupling, and the corresponding product, 1-aryl-3-trimethylsilylpyrazole, also served as a great template for syntheses of *N*-arylpyrazole derivatives, as demonstrated by regioselective halogenation at 3-, 4- and 5-positions of the pyrazole ring.

N-Arylpyrazoles are a class of important compounds because of their interesting biological activities as agrochemicals and pharmaceuticals.[1] A variety of strategies have been developed for preparation of *N*-arylpyrazoles,[2,3] and one of the most efficient methods for the synthesis of *N*-arylpyrazoles is transition-metal-catalyzed cross-coupling of aryl halides with 1*H*-pyrazoles (**Figure 1**).[2] Copper catalysts have been frequently used in the C–N coupling reaction to form *N*-arylpyrazoles, and many researchers have developed new copper catalyst systems to improve the reaction efficiency.[4] On the other hand, synthesis of *N*-arylpyrazoles by palladium-catalyzed C–N coupling of aryl halides with 1*H*-pyrazoles has been relatively less explored,[5,6] and for example, only a few examples of the coupling of *ortho*-substituted aryl halides has been reported in publications.[5c,5f]

Aryl triflates are also common electrophiles in palladium-catalyzed C–N coupling reactions, while copper catalysts have rarely been applied to the reaction of aryl triflates[7,8] because of their reluctance to react with this class of substrates.[6a] The use of aryl triflates in the cross-coupling reactions is sometimes advantageous because aryl triflates can be easily prepared from phenolic compounds, which are more widely accessible than aryl halides.[9] However, metal-catalyzed coupling of aryl triflates with 1*H*-pyrazoles have been achieved only for limited sets of substrates,[8] and development of a general protocol for synthesis of *N*-arylpyrazoles by the C–N coupling is still desired.[10] During the course of our study of the rhodium-catalyzed deallylative

alkenylation reactions,[11] we envisioned that a method for the C–N coupling reactions of *ortho*-substituted aryl triflates with a pyrazole derivative would provide an efficient route to prepare substrates for the deallylative alkenylation. After screening of the reaction conditions, we found that the palladium-catalyzed C–N coupling of an aryl triflates derived from an *ortho*-prenylated phenol with 3-trimethylsilylpyrazole proceeded efficiently, but the generality of the C–N coupling reaction was not investigated.

Herein, we report the details of the C–N coupling reaction to form *N*-arylpyrazoles including modification of the previous reaction conditions and wide substrate scope. The great utility of 3-trimethylsilylpyrazole was also demonstrated by the excellent reactivity in the C–N coupling reaction and the applicability of the coupling products for regiodivergent halogenation at all 3-, 4-, and 5-positions on the pyrazole ring.

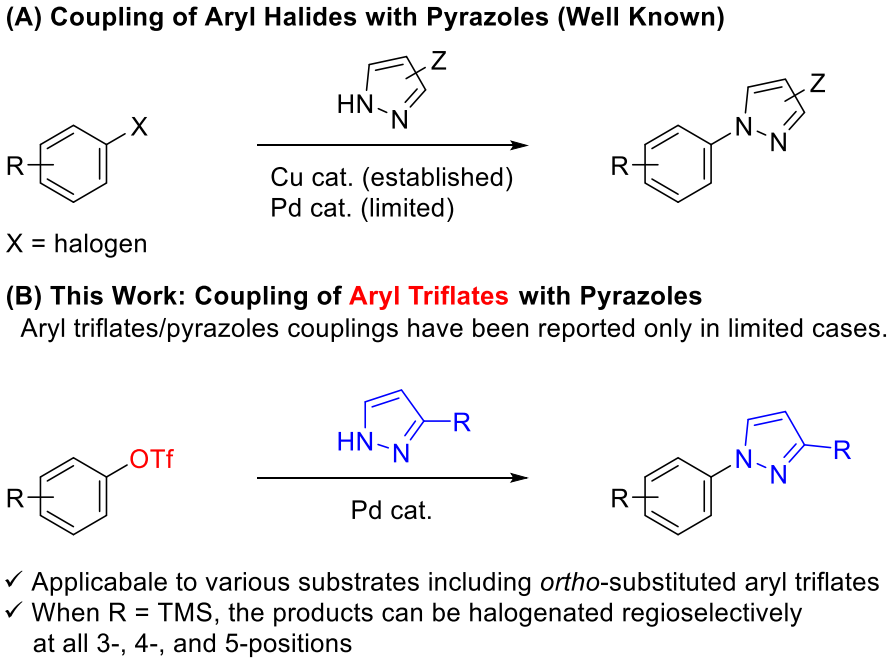
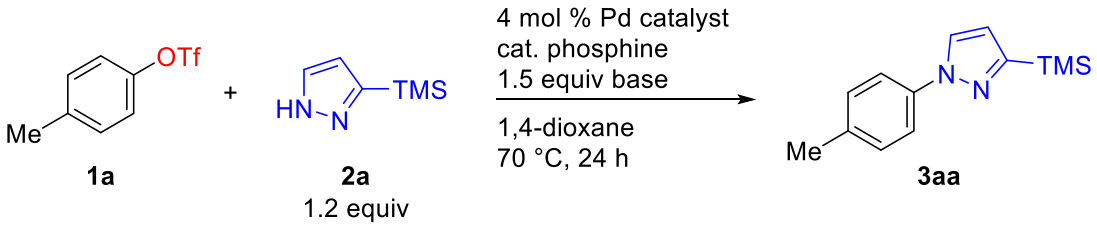


Figure 1. Metal-catalyzed C–N coupling of aryl (pseudo)halides with pyrazole derivatives.

In our previous publication showing one example of the aryl triflate/pyrazole coupling, 10 mol % of 1/2 $Pd_2(dba)_3$ and 20 mol % of *t*BuBrettPhos were used to achieve 85% yield of the product.[11] We began our investigation of the general protocol of the C–N coupling reaction by modification of the previous protocol, especially to reduce the amounts of palladium catalysts and ligands. We first examined the coupling of simple aryl triflate substrate **1a** with 3-trimethylsilylpyrazole (**2a**) to see if the catalyst loading can be reduced. When the reaction of *p*-tolyl triflate (**1a**) with **2a** was performed using 4 mol % of 1/2 $Pd_2(dba)_3$ and 8 mol % of *t*BuBrettPhos in 1,4-dioxane in the presence of potassium phosphate as a base at 70 ºC for 24 h, the desired *N*-arylpyrazole product **3aa** was obtained in 96% NMR yield (Table 1, entry 1). The use of $Pd(dba)_2$ instead of $Pd_2(dba)_3$ was also effective to give **3aa** in 94% NMR yield (entry 2). Reduction of the amount of *t*BuBrettPhos was then investigated, and the reactions were found to proceed efficiently using only 6 mol % of the ligand with either $Pd_2(dba)_3$ or $Pd(dba)_2$ (entries 3 and 4). Particularly, the reaction with 4 mol % of $Pd(dba)_2$ and 6 mol % of *t*BuBrettPhos provided **3aa** in 98% NMR yield (entry 4). The use of other ligands such as *t*BuXPhos, BrettPhos, and XPhos gave either lower yield or no detectable amount of **3aa** (entries 5-7). The reaction using the *t*BuXPhos/NaO^{t}Bu system, developed for aryl bromide/pyrazole coupling,[5a] did not give **3aa** and resulted in decomposition of the aryl triflate substrate (entry 8). The reaction in toluene also provided **3aa** only in 58% NMR yield (entry 9). Therefore, the reaction conditions shown in entry 4 were determined to be optimum and used for further examination.

Table 1. Palladium-Catalyzed C–N Coupling of Aryl Triflate 1a with Pyrazole Derivative 2a[a]

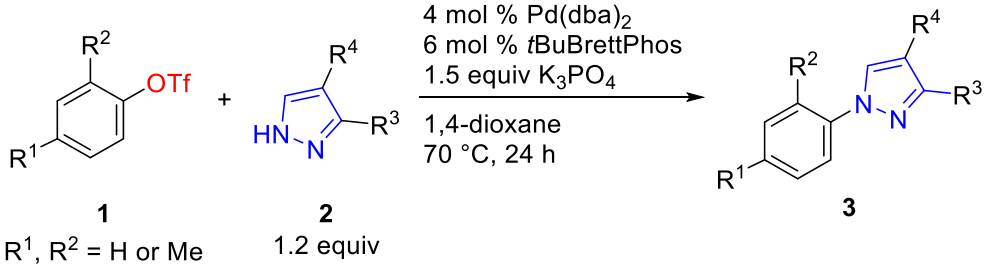


entry	Pd catalyst	phosphine	base	solvent	NMR yield
1	1/2 $Pd_2(dba)_3$	8 mol % *t*BuBrettPhos	K_3PO_4	1,4-dioxane	96%
2	$Pd(dba)_2$	8 mol % *t*BuBrettPhos	K_3PO_4	1,4-dioxane	94%
3	1/2 $Pd_2(dba)_3$	6 mol % *t*BuBrettPhos	K_3PO_4	1,4-dioxane	94%
4	$Pd(dba)_2$	6 mol % *t*BuBrettPhos	K_3PO_4	1,4-dioxane	98%
5	$Pd(dba)_2$	6 mol % *t*BuXPhos	K_3PO_4	1,4-dioxane	63%
6	$Pd(dba)_2$	6 mol % BrettPhos	K_3PO_4	1,4-dioxane	nd[b]
7	$Pd(dba)_2$	6 mol % XPhos	K_3PO_4	1,4-dioxane	nd[b]
8	$Pd(dba)_2$	6 mol % *t*BuXPhos	NaO^tBu	1,4-dioxane	nd[b]
9	$Pd(dba)_2$	6 mol % *t*BuBrettPhos	K_3PO_4	toluene	58%

[a]Reaction conditions: **1a** (0.3 mmol), **2a** (0.36 mmol), Pd catalyst (0.012 mmol), phosphine (0.018 or 0.024 mmol), solvent (1.5 mL), 70 °C, 24 h. [b]Not detected.

The C–N coupling was then examined for various sets of substrates by isolating the *N*-arylpyrazole products (Table 2). Product **3aa** formed by the reaction of *p*-tolyl triflate (**1a**) with **2a** under the standard conditions was isolated in 98% yield (entry 1), and in this case, reduction of the catalyst loading to 2 mol % of $Pd(dba)_2$ and 3 mol % of *t*BuBrettPhos had little effect on the yield (entry 2). The C–N coupling of **1a** with 3-substituted pyrazoles such as those bearing *tert*-butyl (**2b**), phenyl (**2c**), and methyl (**2d**) groups gave the desired products **3ab-3ad** in high yields (entries 3-5). In addition, pyrazoles with no substituents at the 3-position were also applicable to this reaction, and the coupling of **1a** with pyrazole (**2e**) and 4-trimethylsilylpyrazole (**2f**) provided the corresponding products **3ae** and **3af** in 84 and 69% yields, respectively (entries 6 and 7). The reaction of *o*-tolyl triflate (**1b**) with various pyrazoles was next examined. Under the standard reaction conditions, 3-substituted pyrazoles **2a-2c** were coupled smoothly even with the sterically-congested aryl triflate **1b** to give products **3ba**-**3bc** in excellent yields (entries 8-10).[12] However, the reaction of **1b** with pyrazole derivatives possessing a smaller group such as H or Me group, at the 3-position (**2d-2f**) resulted in low yields (entry 11-13). It is unclear why the reactivity of the pyrazole derivatives with large substituents at the 3-position is higher than those with a small group in this reaction, but as Buchwald and coworkers reported for a palladium-catalyzed coupling reaction,[13] formation of pyrazolyl-bridged palladium dimers, which may inhibit the reaction, are less likely to occur, when the 3-position possesses a large substituent.

Table 2. Palladium-Catalyzed C–N Coupling of Aryl Triflates with 3-Substituted Pyrazole Derivatives[a]



1
R^1, R^2 = H or Me

2
1.2 equiv

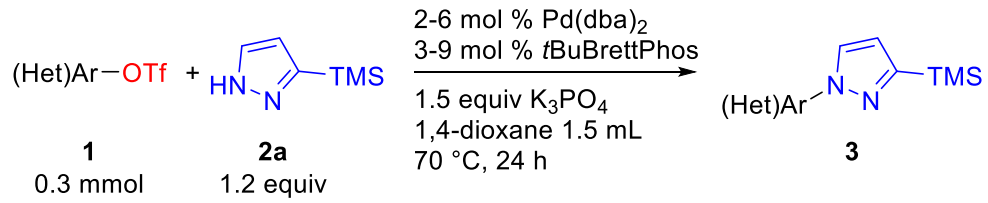
3

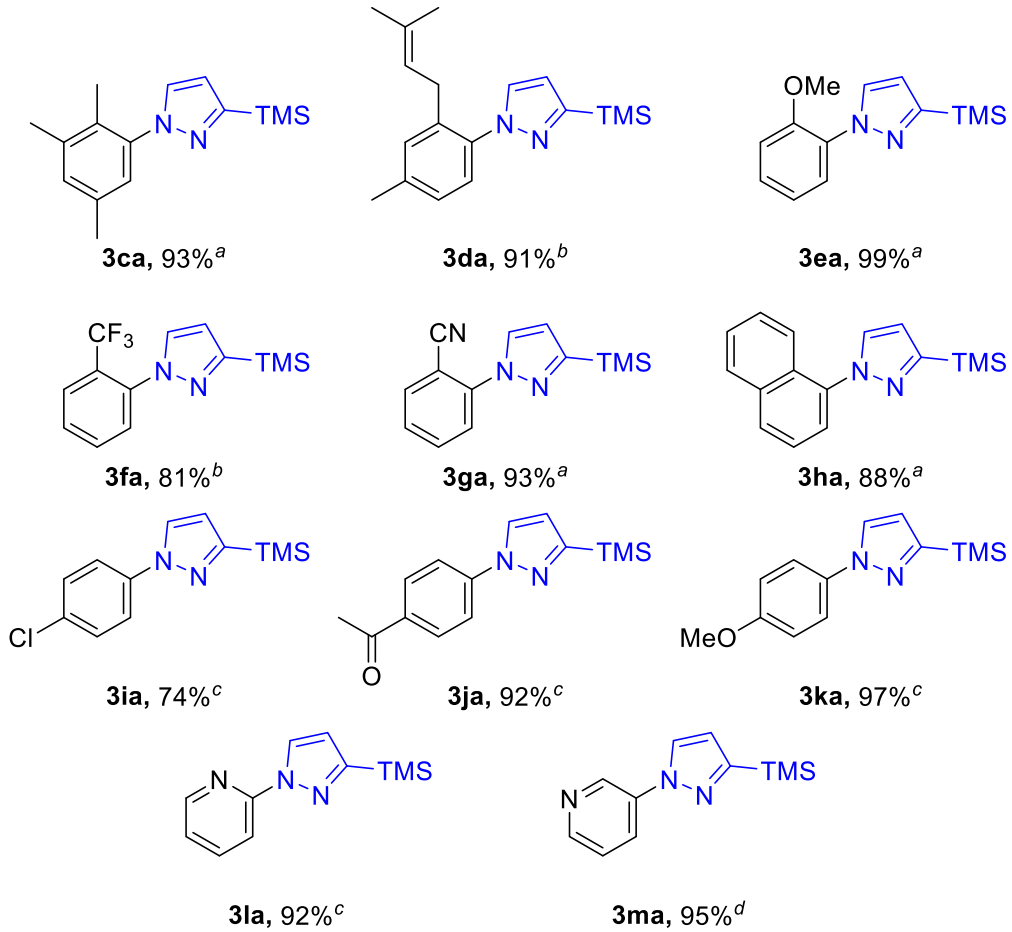
entry	aryl triflate **1**	R^1	R^2	pyrazole **2**	R^3	R^4	product **3**	yield
1	**1a**	Me	H	**2a**	TMS	H	**3aa**	98%
2[b]	**1a**	Me	H	**2a**	TMS	H	**3aa**	97%
3	**1a**	Me	H	**2b**	^{t}Bu	H	**3ab**	quant
4	**1a**	Me	H	**2c**	Ph	H	**3ac**	97%
5	**1a**	Me	H	**2d**	Me	H	**3ad**	90%
6	**1a**	Me	H	**2e**	H	H	**3ae**	84%
7	**1a**	Me	H	**2f**	H	TMS	**3af**	69%
8	**1b**	H	Me	**2a**	TMS	H	**3ba**	95%
9	**1b**	H	Me	**2b**	^{t}Bu	H	**3bb**	95%
10	**1b**	H	Me	**2c**	Ph	H	**3bc**	92%
11	**1b**	H	Me	**2d**	Me	H	**3bd**	25%
12	**1b**	H	Me	**2e**	H	H	**3be**	trace
13	**1b**	H	Me	**2f**	H	TMS	**3bf**	trace

[a]Reaction conditions: **1** (0.3 mmol), **2** (0.36 mmol), $Pd(dba)_2$ (0.012 mmol), *t*BuBrettPhos (0.018 mmol), 1,4-dioxane (1.5 mL), 70 ºC. [b]Performed with 0.006 mmol (2 mol %) $Pd(dba)_2$ and 0.009 mmol (3 mol %) *t*BuBrettPhos.

The C–N coupling reaction was applicable to aryl triflates possessing a variety of functional groups (Table 3). The reaction of 2,3,5-trimethylphenyl triflate (**1c**) afforded 93% yield of product **3ca**. A substrate possessing an *ortho*-prenyl group (**1d**) coupled with **2a** effectively to give **3da** in 91% yield by using 6 mol % of the palladium catalyst. Aryl triflate **1e** bearing an *ortho*-methoxy group showed excellent reactivity to give **3ea** in 99% yield. Substrates bearing electron-withdrawing trifluoromethyl and cyano groups reacted with **2a** as well to afford the corresponding *N*-arylpyrazoles **3fa** and **3ga** in 81% and 93% yields, respectively. 1-Naphthyltriflate (**1h**) could also be applied for the C–N coupling reaction to form **3ha** in 88% yield.[14] The reactions of aryl triflates with various para substituents such as chloro, acetyl, and methoxy groups proceed in the presence of only 2 mol % of the palladium catalyst to give the corresponding *N*-arylpyrazoles **3ia**-**3ka** in 74-97% yields. The coupling of **1i** resulted in lower yield than others, because further C–N coupling at the chlorinated carbon of **3ia** partially occurred as a side reaction. The reaction of 2-pyridyl triflate (**1l**) with **2a** gave **3la** in 92% yield using 2 mol % of the palladium catalyst. In the coupling of 3-pyridyl triflate (**1m**), pyrazole **2a** was used as a limiting reagent because **3ma** and **2a** were difficult to separate by silica gel column chromatography and 95% yield of **3ma** was obtained. In the reactions with 3-substituted pyrazoles, two regioisomeric *N*-arylation products, 3- and 5-substituted *N*-arylpyrazoles could be obtained theoretically, but only 3-substituted *N*-arylpyrazoles were observed in the coupling reactions described here. The structures of the products were determined by ^{1}H NMR using a coupling constant analysis method reported by Cristau and Taillefer.[4b]

Table 3. Palladium-Catalyzed C–N Coupling of Various Aryl Triflates with 2a





[a]Reaction conditions: **1** (0.3 mmol), **2a** (0.36 mmol), $Pd(dba)_2$ (0.012 mmol, 4 mol %), *t*BuBrettPhos (0.018 mmol, 6 mol %), K_3PO_4 (1.5 equiv), 1,4-dioxane (1.5 mL), 70 °C, 24 h. [b]Performed with 0.018 mmol of $Pd(dba)_2$ (6 mol %) and 0.027 mmol of *t*BuBrettPhos (9 mol %). [c]Performed with 0.006 mmol of $Pd(dba)_2$ (2 mol %) and 0.009 mmol of *t*BuBrettPhos (3 mol %).

[d]Performed with 0.36 mmol of **1m**, 0.3 mmol of **2a**, 0.006 mmol of $Pd(dba)_2$ (2 mol %) and 0.009 mmol of *t*BuBrettPhos (3 mol %).

The 1-aryl-3-trimethylsilylpyrazole framework, formed by the C–N coupling with **2a**, found to serve as a great template for the synthesis of various *N*-arylpyrazole derivatives (Figure 2). First, deprotection of the trimethylsilyl group of **3aa** was readily accomplished by treatment with ethanolic KOH solution to give **3ae** in 89% yield. Regioselective introduction of halogeno groups at all 3-, 4-, and 5-positions were also possible, because each of these positions has mutually different character and orthogonal reactivities.[15] The 3-position of **3aa** has the trimethylsilyl group and its removal under mild conditions would generate a carbanion at the 3-position, which may react with electrophilic halogenating agents. Therefore, the reaction of **3aa** with *N*-chlorosuccinimide (NCS) in the presence of silver fluoride in acetonitrile provided 1-aryl-3-chloropyrazole **4** in 86% yield. The use of 1,2-dibromotetrachloroethane (DBTCE) instead of NCS also gave the corresponding bromination product **5** in 45% yield. The 4-position of **3aa** is the most nucleophilic, and direct reaction of *N*-bromosuccinimide (NBS) with **3aa**, followed by deprotection of the trimethylsilyl group led to the formation of 1-aryl-4-bromopyrazole **6** in 87% yield. The 5-position of **3aa** bears the most acidic proton on the pyrazole ring. The reaction of **3aa** with *n*-butyllithium and then with tetrabromomethane installed a bromo group at the 5-position, and subsequent deprotection of the trimethylsilyl group formed 1-aryl-5-bromopyrazole **7** in 45% yield (70% NMR yield).

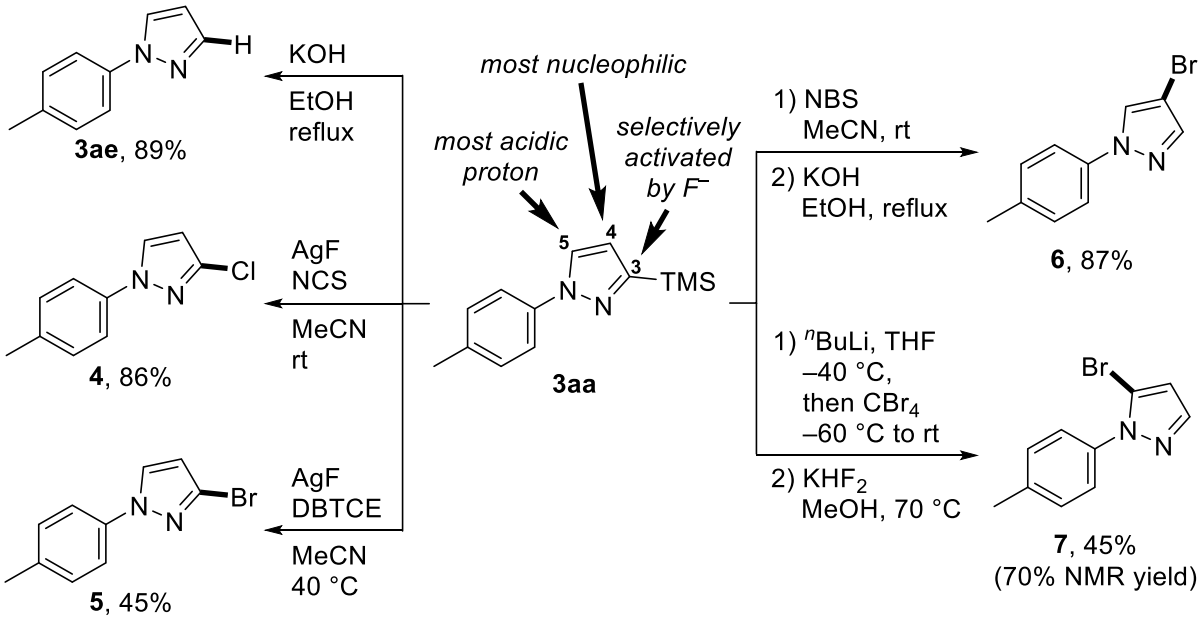


Figure 2. Regiodivergent derivatization of 1-aryl-3-trimethylsilylpyrazole 3aa

In summary, we developed a protocol for the C–N coupling between aryl triflates and pyrazole derivatives using 2-6 mol % of a palladium catalyst and 3-9 mol % of *t*BuBrettPhos. The reaction was applicable to various sets of substrates including sterically-congested aryl triflates bearing ortho substituents and various reactive functional groups tolerated the reaction conditions. The 1-aryl-3-trimethylsilylpyrazole framework, readily formed by the C–N coupling developed here, can serve as a useful template for the synthesis of various *N*-arylpyrazole derivatives, as demonstrated by regiodivergent halogenation at all 3-, 4-, and 5-positions.

Experimental Section

Unless otherwise noted, all reactions were carried out under nitrogen, and commercial reagents were used as received. $Pd_2(dba)_3$ was purchased from Aldrich and used as received. $Pd(dba)_2$ was purchased from Tokyo Chemical Industry Co., Ltd. and used as received. *t*BuBrettPhos, *t*BuXPhos, BrettPhos and XPhos were purchased from Aldrich and used as received. K_3PO_4 was purchased from Junsei Chemical Co., Ltd. and dried by Kugelrohr prior to use. 1,4-Dioxnae was purchased from FUJIFILM Wako Pure Chemical Corporation and used as received. Pyrazoles **2a**[11], **2b**[16] and **2f**[17] were prepared according to the literature procedures. Pyrazoles **2c** and **2d** were purchased from Tokyo Chemical Industry Co., Ltd. and used as received. Pyrazole **2e** was purchased from Nacalai Tesque, Inc. and used as received. Aryl triflates **1a**, **1b**, **1e**-**1k** were prepared according to the literature procedure using corresponding phenol derivatives.[18] Heteroaryl triflates **1l**[9b] and **1m**[9b] were prepared according to the literature procedures. ^1H and $^{13}C\{^1H\}$ spectra were recorded on a JEOL ECX-400, AL-400, or ALPHA-400 spectrometer. IR spectra were recorded on a JASCO FT/IR-410 infrared spectrometer. Flash chromatography was performed using a EPCLC-AI-580S (Yamazen Corporation) with silica gel 40 μm. ESI-MS was performed on a JEOL JMS-T100LCS.

*Preparation of 2,3,5-Trimethylphenyl Trifluoromethanesulfonate (**1c**).* To a solution of 2,4,5-trimethylphenol (2.72 g, 20.0 mmol) and 2.4 mL of pyridine in 50 mL dichloromethane at 0 ºC was added Tf_2O (6.41 g, 22.7 mmol) dropwise, and the mixture was stirred for 2 h at room temperature. After this period, 1 M HCl aq was added to the mixture, which was then extracted three times with dichloromethane. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated. Kugelrohr distillation of the crude material afforded 4.79 g of **1c** (17.9 mmol, 90% yield) as a colorless oil; ^1H NMR (400 MHz, $CDCl_3$): δ 2.22 (s, 3H),

2.28 (s, 3H), 2.31 (s, 3H), 6.90 (s, 1H), 6.99 (s, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) : δ 12.5, 20.1, 20.8, 118.6 (q, *J* = 320.0 Hz), 119.1, 126.1, 130.5, 136.8, 139.4, 148.3; IR (neat): 2927 w, 2871 w, 1623 w, 1574 w, 1495 w, 1451 w, 1420 , 1281 w, 1248 s, 1213 s, 1143 s, 1040 s, 1018 w, 968 m, 917 s, 853 m, 823 s, 766 w, 748 w, 711 w, 661 w, 610 m cm-1; HRMS (ESI-TOF) m/z: $[M+Na^+]$ Calcd for $C_{10}H_{11}F_3NaO_3S^+$ 291.0273; Found 291.0265.

Preparation of 4-Methyl-2-(3-methylbut-2-en-1-yl)phenol. 4-Methyl-2-(3-methylbut-2-en-1-yl)phenol was prepared according to the literature procedure.[19] To a solution of *p*-cresol (4.32 g, 39.9 mmol) in 80 mL Et_2O was added Na (1.95 g, 84.8 mmol) portionwise, and the mixture was stirred at room temperature for 30 min. Prenyl chloride (4.16 g, 39.8 mmol) was added to the resulting mixture and heated to reflux for 1 h. After this period, the mixture was acidified with 0.1 N HCl aq and extracted three times with Et_2O. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated. Purification of the crude material by silica gel column chromatography (hexane:AcOEt = 91:9) afforded 5.88 g of 4-methyl-2-(3-methylbut-2-en-1-yl)phenol (33.4 mmol, 84% yield) as a colorless oil. The analytical data for 4-methyl-2-(3-methylbut-2-en-1-yl)phenol are in good agreement with those reported in literature.[20]

*Preparation of 4-Methyl-2-(3-methylbut-2-en-1-yl)phenyl Trifluoromethanesulfonate (**1d**).* To a solution of 4-methyl-2-(3-methylbut-2-en-1-yl)phenol (0.798 g, 4.53 mmol) and 0.6 mL of pyridine in 20 mL dichloromethane at 0 ºC was added Tf_2O (1.57 g, 5.56 mmol) dropwise, and the mixture was stirred for 4.5 h at room temperature. After this period, 1 M HCl aq was added to the mixture, which was then extracted three times with dichloromethane. The combined organic layers were washed with brine, dried over MgSO4, filtered and concentrated. Purification of the crude material by silica gel column chromatography (hexane:AcOEt = 98:2)

afforded 1.32 g of **1d** (4.28 mmol, 94% yield) as a colorless oil.; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.71 (s, 3H), 1.77 (d, *J* = 1.2 Hz, 3H), 2.34 (s, 3H), 3.38 (d, *J* = 7.1 Hz, 2H), 5.21-5.26 (m, 1H), 7.03-7.12 (m, 3H); ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) : δ 17.8, 20.9, 25.7, 28.3, 118.6 (q, *J* = 325 Hz), 120.5, 120.8, 128.1, 131.4, 134.0, 134.4, 138.3, 145.9; IR (neat): 3014 m, 2969 s, 2917 s, 1860 s, 1612 m, 1507 s, 1448 s, 1376 s, 1347 m, 1260 s, 1203 s, 1149 m, 1108 s, 1040 w, 985 w, 922 m, 879 m, 848 m, 811 s, 787 s, 737 w, 717 w cm^{-1}; HRMS (ESI-TOF) m/z: [M+Na^{+}] Calcd for $C_{13}H_{15}F_3NaO_3S^{+}$ 331.0586; Found 331.0588.

General Procedure A for Palladium-Catalyzed Amination of Aryl Triflates with Pyrazole Derivatives. In a glove box, $Pd(dba)_2$, (2-6 mol %) *t*BuBrettPhos (3-9 mol %), K_3PO_4 (1.5 equiv) and 1,4-dioxane (1.5 mL) were placed in an oven-dried 10 mL Schlenk flask containing a stirring bar. After taken out of the glove box, the mixture was heated with an oil bath whose temperature was maintained at 120 ºC for 5 min, and then cooled to room temperature. In the glove box, aryl triflates **1** (0.3 mmol) and pyrazole derivatives **2** (0.36 mmol) were added to the premixed solution, and the reaxtion mixture was stirred at 70 ºC for 24 h. After this period, the resulting mixture was diluted with dichloromethane, passed through a pad of Celite, and concentrated in vacuo. Silica gel column chromatography of the crude material followed by drying in vacuo afforded *N*-arylpyrazoles **3**.

*1-(4-Methylphenyl)-3-(trimethylsilyl)-1H-pyrazole (**3aa**).* General Procedure A was followed with **1a** (72.9 mg, 0.303 mmol) and **2a** (50.0 mg, 0.356 mmol). Silica gel column chromatography (hexane:AcOEt = 96:4) afforded 68.1 mg of **3aa** (0.296 mmol, 98% yield) as a white solid: Mp = 32-34 ºC; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.30 (s, 9H), 2.36 (s, 3H), 6.62 (d, *J* = 2.7 Hz, 1H), 7.28-7.30 (m, 2H), 7.72-7.76 (m, 2H), 8.26 (d, *J* = 2.4 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -0.9, 20.8, 114.1, 119.6, 127.7, 130.6, 136.5, 139.1, 154.6.; IR

(KBr): 3143 m, 3116 w, 3052 m, 2956 s, 2898 s, 1906 w, 1707 w, 1609 m, 1594 m, 1523 s, 1488 s, 1457 m, 1408 s, 1381 w, 1354 s, 1308 s, 1292 , 1248 s, 1213 m, 1192 s, 1120 m, 1110 s, 1067 m, 1039 s, 971 s, 946 m, 840 s, 813 s, 754 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^+] Calcd for $C_{13}H_{19}N_2Si^+$ 231.1312; Found 231.1310.

*3-tert-Butyl-1-(4-methylphenyl)-1H-pyrazole (**3ab**).* General Procedure A was followed with **1a** (71.5 mg, 0.298 mmol) and **2b** (43.0 mg, 0.346 mmol). Silica gel column chromatography (hexane:AcOEt = 95:5) afforded 63.8 mg of **3ab** (0.298 mmol, quant) as a white solid: Mp = 34.5-36 ºC; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 1.33 (s, 9H), 2.34 (s, 3H), 6.37 (d, *J* = 2.4 Hz, 1H), 7.25-7.28 (m, 2H), 7.67-7.70 (m, 2H), 8.12 (d, *J* = 2.7 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 30.8, 32.9, 104.7, 118.9, 127.7, 130.6, 135.9, 139.2, 163.6; IR (KBr): 3149 m, 3128 w, 3044 m, 2959 s, 2865 s, 1902 w, 1701 w, 1608 s, 1531 s, 1483 s, 1457 s, 1391 s, 1381 s, 1365 s, 1342 m, 1317 m, 1270 s, 1206 m, 1184 m, 1171 s, 1120 m, 1110 m, 1073 m, 1046 s, 982 s, 949 s, 836 s, 812 s, 755 s, 723 m cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^+] Calcd for $C_{14}H_{19}N_2^+$ 215.1543; Found 215.1544.

*3-Phenyl-1-(4-methylphenyl)-1H-pyrazole (**3ac**).*[21] General Procedure A was followed with **1a** (72.6 mg, 0.302 mmol) and **2c** (52.1 mg, 0.361 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 68.3 mg of **3ac** (0.292 mmol, 97% yield) as a white solid; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.38 (s, 3H), 6.94 (d, *J* = 2.4 Hz, 1H), 7.32-7.36 (m, 3H), 7.42-7.46 (m, 2H), 7.79-7.82 (m, 2H), 7.95-7.98 (m, 2H), 8.34 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 105.5, 119.3, 126.4, 128.7, 129.2, 129.5, 130.7, 134.3, 136.7, 139.0, 153.0.

*3-Methyl-1-(4-methylphenyl)-1H-pyrazole (**3ad**).*[22] General Procedure A was followed with **1a** (72.5 mg, 0.302 mmol) and **2d** (30.2 mg, 0.368 mmol). Silica gel column chromatography

(hexane:AcOEt = 97:3) afforded 46.6 mg of **3ad** (0.271 mmol, 90% yield) as a white solid; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.28 (s, 3H), 2.34 (s, 3H), 6.26 (d, *J* = 2.4 Hz, 1H), 7.24-7.28 (m, 2H), 7.65-7.68 (m, 2H), 8.12 (d, *J* = 2.0 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 13.7, 20.8, 107.9, 118.9, 128.1, 130.6, 136.0, 139.1, 150.4.

*1-(4-Methylphenyl)-1H-pyrazole (**3ae**).*[4b] General Procedure A was followed with **1a** (73.0 mg, 0.304 mmol) and **2e** (24.7 mg, 0.363 mmol). Silica gel column chromatography (hexane:AcOEt = 96:4) afforded 40.2 mg of **3ae** (0.254 mmol, 84% yield) as a pale yellow oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.36 (s, 3H), 6.48 (dd, *J* = 2.5 Hz, 1.8 Hz, 1H), 7.28-7.31 (m, 2H), 7.66 (d, *J* = 1.6 Hz, 1H), 7.70-7.74 (m, 2H), 8.26 (dd, *J* = 2.5 Hz, 0.6 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 108.1, 119.4, 127.6, 130.7, 136.6, 139.1, 141.3.

*1-(4-Methylphenyl)-4-(trimethylsilyl)-1H-pyrazole (**3af**).* General Procedure A was followed with **1a** (72.3 mg, 0.301 mmol) and **2f** (51.5 mg, 0.367 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 47.9 mg of **3af** (0.208 mmol, 69% yield) as a white solid: Mp = 51-53 ºC; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.26 (s, 9H), 2.36 (s, 3H), 7.29 (d, *J* = 8.2 Hz, 2H), 7.67 (s, 1H), 7.72-7.75 (m, 2H), 8.26 (s, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -0.2, 20.8, 117.2, 119.5, 130.7, 132.3, 136.6, 138.9, 145.8; IR (KBr): 3112 w, 2954 s, 2897 m, 1527 s, 1424 w, 1400 m, 1359 m, 1326 m, 1299 w, 1249 s, 1214w, 1199 m, 1183 w, 1156 s, 1119 w, 1107 w, 1038 m, 986 w, 960 m, 833 s, 814 s, 753 s cm^{-1}; HRMS (ESI-TOF) m/z: $[M+H^+]$ Calcd for $C_{13}H_{19}N_2Si^+$ 231.1312; Found 231.1313.

*1-(2-Methylphenyl)-3-(trimethylsilyl)-1H-pyrazole (**3ba**).* General Procedure A was followed with **1b** (73.0 mg, 0.304 mmol) and **2a** (50.6 mg, 0.361 mmol). Silica gel column chromatography (hexane:AcOEt = 98:2 to 97:3) afforded 66.4 mg of **3ba** (0.288 mmol, 95% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.29 (s, 9H), 2.24 (s, 3H), 6.60 (d, *J*

= 2.0 Hz, 1H), 7.29-7.39 (m, 4H), 7.88 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -0.8, 18.4, 112.9, 126.4, 127.3, 128.8, 131.4, 132.1, 134.1, 141.2, 153.8; IR (neat): 3045 w, 2957 s, 2898 m, 1604 w, 1584 m, 1505 s, 1461 m, 1421 m, 1382 w, 1351 w, 1301 s, 1249 s, 1180 s, 1122 m, 1033 m, 971 s, 950 w, 839 s, 755 s, 716 m cm^{-1}; HRMS (ESI-TOF) m/z: $[M+H^+]$ Calcd for $C_{13}H_{19}N_2Si^+$ 231.1312; Found 231.1313.

*3-tert-Butyl-1-(2-methylphenyl)-1H-pyrazole (**3bb**).* General Procedure A was followed with **1b** (72.2 mg, 0.301 mmol) and **2b** (45.0 mg, 0.362 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3 to 95:5) afforded 61.5 mg of **3bb** (0.287 mmol, 95% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 1.33 (s, 9H), 2.27 (s, 3H), 6.35 (d, *J* = 2.4 Hz, 1H), 7.29-7.35 (m, 4H), 7.72 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 18.7, 30.9, 32.8, 103.3, 126.2, 127.3, 128.4, 131.5, 132.2, 133.9, 141.4, 163.0; IR (neat): 3033 w, 2960 s, 2929 s, 2902 s, 2866 m, 1606 w, 1584 m, 1524 s, 1499 s, 1480 m, 1461 s, 1393 m, 1362 s, 1263 s, 1206 m, 1166 m, 1124 w, 1068 w, 1048 s, 982 m, 951 s, 861 w, 799 w, 758 s, 718 s, 677 m, 639 w cm^{-1}; HRMS (ESI-TOF) m/z: $[M+H^+]$ Calcd for $C_{14}H_{19}N_2^+$ 215.1543; Found 215.1544.

*3-Phenyl-1-(2-methylphenyl)-1H-pyrazole (**3bc**).*[23] General Procedure A was followed with **1b** (72.2 mg, 0.301 mmol) and **2c** (52.2 mg, 0.362 mmol). Silica gel column chromatography (hexane:AcOEt = 96:4) afforded 64.8 mg of **3bc** (0.277 mmol, 92% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.34 (s, 3H), 6.92 (d, *J* = 2.4 Hz, 2H), 7.30-7.45 (m, 7H), 7.92-7.95 (m, 3H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 18.5, 104.3, 126.3, 126.5, 127.5, 128.5, 129.0, 129.4, 132.2, 133.2, 134.0, 134.6, 141.1, 152.7.

*3-Methyl-1-(2-methylphenyl)-1H-pyrazole (**3bd**).*[22] General Procedure A was followed with **1b** (73.8 mg, 0.307 mmol) and **2d** (30.3 mg, 0.369 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 13.1 mg of **3bd** (0.0761 mmol, 25% yield) as a colorless oil; ^{1}H

NMR (400 MHz, $(CD_3)_2CO$): δ 2.26 (s, 3H), 2.27 (s, 3H), 6.24 (d, *J* = 2.4 Hz, 1H), 7.27-7.36 (m, 4H), 7.72 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ 13.7, 18.5, 106.6, 126.5, 127.3, 128.5, 132.07, 132.11, 133.9, 141.3, 149.7.

*1-(2,4,5-Trimethylphenyl)-3-(trimethylsilyl)-1H-pyrazole (**3ca**).* General Procedure A was followed with **1c** (82.0 mg, 0.306 mmol) and **2a** (51.2 mg, 0.365 mmol). Silica gel column chromatography (hexane:AcOEt = 98:2 to 97:3) afforded 73.8 mg of **3ca** (0.286 mmol, 93% yield) as a colorless oil; ^1H NMR (400 MHz, $(CD_3)_2CO$): δ 0.28 (s, 9H), 1.98 (s, 3H), 2.30 (s, 6H), 6.58 (d, *J* = 2.4 Hz, 1H), 6.97 (s, 1H), 7.08 (s, 1H), 7.77 (d, *J* = 2.0 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -0.8, 14.1, 20.3, 20.7, 112.6, 125.2, 130.1, 131.2, 131.7, 136.1, 138.8, 141.3, 153.4; IR (neat): 2956 m, 2921 w, 2898 w, 2864 w, 1617 w, 1580 w, 1494 m, 1452 w, 1385 w, 1354 w, 1302 w, 1248 m, 1157 m, 1124 w, 1050 w, 976 w, 940 w, 842 s, 755 m, 718 w, 698 w, 632 w cm^{-1}; HRMS (ESI-TOF) m/z: $[M+H^+]$ Calcd for $C_{15}H_{23}N_2Si^+$ 259.1625; Found 259.1626.

*1-[4-Methyl-2-(3-methylbut-2-en-1-yl)phenyl]-3-(trimethylsilyl)-1H-pyrazole (**3da**).* General Procedure A was followed with **1d** (95.7 mg, 0.310 mmol) and **2a** (50.9 mg, 0.363 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 84.2 mg of **3da** (0.282 mmol, 91% yield) as a colorless oil; ^1H NMR (400 MHz, $(CD_3)_2CO$): δ 0.28 (s, 9H), 1.52 (s, 3H), 1.62 (d, *J* = 1.2 Hz, 3H), 2.36 (s, 3H), 3.25 (d, *J* = 7.4 Hz, 2H), 5.08-5.13 (m, 1H), 6.58 (d, *J* = 2.4 Hz, 1H), 7.11-7.13 (m, 1H), 7.17-7.19 (m, 2H), 7.78 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -0.8, 17.8, 21.1, 25.8, 30.7, 112.7, 123.7, 126.8, 127.9, 131.6, 131.8, 132.7, 138.0, 138.5, 138.9, 153.7; IR (neat): 3026 w, 2958 s, 2924 s, 2857 m, 1611 w, 1510 s, 1439 m, 1376 w, 1353 w, 1304 m, 1248 s, 1184 s, 1154 w, 1122 w, 1099 w, 1058 m, 1035 m, 971 s, 913 w, 843 s, 755 s cm^{-1}; HRMS (ESI-TOF) m/z: $[M+H^+]$ Calcd for $C_{18}H_{27}N_2Si^+$ 299.1938; Found 299.1938.

*1-(2-Methoxyphenyl)-3-(trimethylsilyl)-1H-pyrazole (**3ea**).* General Procedure A was followed with **1e** (76.0 mg, 0.297 mmol) and **2a** (50.3 mg, 0.359 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 72.3 mg of **3ea** (0.293 mmol, 99% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.29 (s, 9H), 3.93 (s, 3H), 6.58 (d, *J* = 2.4 Hz, 1H), 7.05-7.10 (m, 1H), 7.22 (dd, *J* = 8.4 Hz, 1.4 Hz, 1H), 7.30-7.35 (m, 1H), 7.79 (dd, *J* = 7.8 Hz, 1.6 Hz, 1H), 8.21 (d, *J* = 2.7 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -0.9, 56.3, 112.9, 113.4, 121.7, 125.5, 128.5, 130.7, 132.2, 151.6, 153.4; IR (neat): 2956 m, 2898 w, 2839 w, 1598 w, 1509 s, 1484 w, 1470 m, 1420 w, 1352 w, 1321 w, 1301 m, 1283 m, 1246 s, 1184 m, 1161 w, 1124 m, 1049 m, 1027 m, 970 m, 948 w, 842 s, 794 w, 753 s, 698 w, 672 w, 632 w cm^{-1}; HRMS (ESI-TOF) m/z: [M+Na^{+}] Calcd for $C_{13}H_{18}N_2NaOSi^{+}$ 269.1081; Found 269.1081.

*1-[2-(Trifluoromethyl)phenyl]-3-(trimethylsilyl)-1H-pyrazole (**3fa**).* General Procedure A was followed with **1f** (89.2 mg, 0.303 mmol) and **2a** (50.0 mg, 0.356 mmol). Silica gel column chromatography (hexane:AcOEt = 96:4) afforded 69.3 mg of **3fa** (0.244 mmol, 81% yield) as a pale yellow oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.29 (s, 9H), 6.63 (d, *J* = 2.4 Hz, 1H), 7.60-7.62 (m, 1H), 7.68-7.73 (m, 1H), 7.80-7.85 (m, 1H), 7.90-7.93 (m, 2H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -1.0, 113.5, 124.3 (q, *J* = 272.8 Hz), 126.0 (q, *J* = 31.3 Hz), 128.1 (q, *J* = 5.3 Hz), 129.5, 129.7, 132.4 (q, *J* = 1.9 Hz), 134.1, 140.0, 154.9; IR (neat): 2958 m, 2899 w, 1609 m, 1588 m, 1509 s, 1464 s, 1422 w, 1355 w, 1316 s, 1273 m, 1250 s, 1187, 1136 s, 1113 s, 1077 m, 1054 s, 1039 s, 970 m, 843 757 s, 700 m, 677 w, 647 w, 632 m; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{13}H_{16}F_3N_2Si^{+}$ 285.1029; Found 285.1030.

*2-[3-(Trimethylsilyl)-1H-pyrazol-1-yl]benzonitrile (**3ga**).* General Procedure A was followed with **1g** (76.4 mg, 0.304 mmol) and **2a** (49.7 mg, 0.354 mmol). Silica gel column chromatography (hexane:AcOEt = 95:5) afforded 68.4 mg of **3ga** (0.283 mmol, 93% yield) as a

colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.33 (s, 9H), 6.73 (d, *J* = 2.4 Hz, 1H), 7.55-7.59 (m, 1H), 7.82-7.88 (m, 2H), 7.92-7.94 (m, 1H), 8.33 (d, *J* = 2.4 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -1.1, 106.6, 114.7, 117.7, 124.7, 128.2, 130.4, 134.9, 135.6, 142.7, 156.4; IR (neat): 3112 w, 2957 m, 2898 w, 1601 m, 1579 m, 507 s, 1487 m, 1461 m, 1417 w, 1318 s, 1299 m, 1250 s, 1185 m, 1164 w, 1113 w, 1067 w, 1044 m, 1023 m, 968 s, 946 w, 844 s, 758 s, 700 w, 667 m, 633 m cm^{-1}; HRMS (ESI-TOF) m/z: [M+Na^{+}] Calcd for $C_{13}H_{15}N_3NaSi^{+}$ 264.0928; Found 264.0927.

*1-(Naphthalen-1-yl)-3-(trimethylsilyl)-1H-pyrazole (**3ha**).* General Procedure A was followed with **1h** (81.5 mg, 0.295 mmol) and **2a** (50.1 mg, 0.357 mmol). Silica gel column chromatography (hexane:AcOEt = 96:4) afforded 69.6 mg of **3ha** (0.261 mmol, 88% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.33 (s, 9H), 6.72 (d, *J* = 2.0 Hz, 1H), 7.53-7.64 (m, 4H), 7.88-7.91 (m, 1H), 8.02-8.05 (m, 2H), 8.06 (d, *J* = 2.4 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -0.8, 113.3, 123.6, 124.4, 126.2, 127.4, 127.8, 129.0, 129.4, 129.9, 132.7, 135.4, 138.6, 154.6; IR (neat): 3055 w, 2956 m, 2897 m, 1560 w, 1577 w, 1513 m, 1491 m, 1466 w, 1428 m, 1395 m, 1301 m, 1249 s, 1196 w, 1171 w, 1120 m, 1020 w, 1003 w, 968 m, 934 w, 842 s, 800 s, 771 s, 757 s, 698 w, 663 w, 632 m cm^{-1}; HRMS (ESI-TOF) m/z: [M+Na^{+}] Calcd for $C_{16}H_{18}N_2NaSi^{+}$ 289.1132; Found 289.1130.

*1-(4-Chlorophenyl)-3-(trimethylsilyl)-1H-pyrazole (**3ia**).* General Procedure A was followed with **1i** (78.3 mg, 0.300 mmol) and **2a** (50.1 mg, 0.357 mmol). Silica gel column chromatography (hexane:AcOEt = 98:2) afforded 55.7 mg of **3ia** (0.222 mmol, 74% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.30 (s, 9H), 6.66 (d, *J* = 2.7 Hz, 1H), 7.50-7.54 (m, 2H), 7.89-7.92 (m, 2H), 8.35 (d, *J* = 2.4 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$): δ -1.0, 114.7, 121.0, 128.0, 130.2, 131.7, 140.0, 155.6; IR (neat): 2957 m, 2898 w, 1598 m, 1505 s,

1433 w, 1407 w, 1356 w, 1314 m, 303 m, 1249 s, 1220 w, 1191 s, 1095 m, 1067 w, 1036 m, 1011 w, 969 s, 947 m, 842 s, 753 s, 699 w, 633 m cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^+] Calcd for $C_{12}H_{16}ClN_2Si^+$ 251.0766; Found 251.0765.

*1-{4-[3-(Trimethylsilyl)-1H-pyrazol-1-yl]phenyl}ethan-1-one (**3ja**).* General Procedure A was followed with **1j** (79.6 mg, 0.297 mmol) and **2a** (51.2 mg, 0.365 mmol). Silica gel column chromatography (hexane:AcOEt = 95:5 to 90:10) afforded 70.6 mg of **3ja** (0.273 mmol, 92% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.32 (s, 9H), 2.61 (s, 3H), 6.71 (d, *J* = 2.4 Hz, 1H), 8.01-8.04 (m, 2H), 8.10-8.14 (m, 2H), 8.47 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -1.1, 26.6, 115.1, 119.0, 128.3, 130.7, 135.5, 144.2, 156.4, 196.7; IR (neat): 3135 w, 3114 w, 3003 w, 297 m, 2898 w, 1683 s, 1604 s, 1519 s, 1493 w, 1435 s, 1411 s, 1360 s, 1308 s, 1266 s, 1193 s, 1177 m, 1114 w, 1065 w, 1034 m, 967 s, 944 m, 842 s, 757 s, 724 w cm^{-1}; HRMS (ESI-TOF) m/z: [M+Na^+] Calcd for $C_{14}H_{18}N_2NaOSi^+$ 281.1081; Found 281.1082.

*1-(4-Methoxyphenyl)-3-(trimethylsilyl)-1H-pyrazole (**3ka**).* General Procedure A was followed with **1k** (76.0 mg, 0.297 mmol) and **2a** (50.0 mg, 0.356 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 70.9 mg of **3ka** (0.288 mmol, 97% yield) as a white solid: Mp = 39-41 ºC ; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.29 (s, 9H), 3.84 (s, 3H), 6.60 (d, *J* = 2.0 Hz, 1H), 7.02-7.06 (m, 2H), 7.74-7.78 (m, 2H), 8.20 (d, *J* = 2.4 Hz, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $(CD_3)_2CO$) : δ -0.9, 55.8, 114.0, 115.2, 121.1, 127.7, 135.0, 154.3, 159.0; IR (KBr): 3114 w, 3058 m, 2959 m, 2838 m, 1935 w, 1905 w, 1871 w, 1698 w, 1667 w, 1608 m, 1521 s, 1446 m, 1311 s, 1296 s, 1247 s, 1183 s, 1114 m, 1068 m, 1041 s, 971 s, 950 m, 847 s, 755 s, 696 m, 634 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^+] Calcd for $C_{13}H_{19}N_2OSi^+$ 247.1261; Found 247.1263.

*2-[3-(Trimethylsilyl)-1H-pyrazol-1-yl]pyridine (**3la**).* General Procedure A was followed with **1l** (69.4 mg, 0.306 mmol) and **2a** (50.3 mg, 0.359 mmol). Silica gel column chromatography (hexane:AcOEt = 97:3) afforded 61.4 mg of **3la** (0.282 mmol, 92% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.32 (s, 9H), 6.65 (d, *J* = 2.7 Hz, 1H), 7.30 (ddd, *J* = 7.2 Hz, 4.9 Hz, 1.2 Hz, 1H), 7.96 (ddd, *J* = 8.3 Hz, 7.3 Hz, 1.9 Hz, 1H), 8.06 (dt, *J* = 8.4 Hz, 0.9 Hz, 1H), 8.44 (ddd, *J* = 4.8 Hz, 1.7 Hz, 0.9 Hz, 1H), 8.61 (d, *J* = 2.4 Hz, 1H).; ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -1.1, 113.1, 114.3, 122.4, 127.5, 139.7, 149.1, 152.6, 156.7; IR (neat): 3065 w, 3017 w, 2957 s, 2898 w, 1614 m, 1595 s, 1578 s, 1497 s, 1471 s, 1457 s, 1410 w, 1310 s, 1249 s, 1223 w, 1197 s, 1145 m, 1099 w, 1048 s, 1035 m, 992 w, 966 s, 952 m, 842 s, 777 s, 759 s, 739 w, 717 m cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{11}H_{16}N_3Si^{+}$ 218.1108; Found 218.1110.

*3-[3-(Trimethylsilyl)-1H-pyrazol-1-yl]pyridine (**3ma**).* General Procedure A was followed with **1m** (81.2 mg, 0.357 mmol) and **2a** (41.8 mg, 0.298 mmol). Silica gel column chromatography (hexane:AcOEt = 92:8 to 80:20) afforded 61.4 mg of **3ma** (0.282 mmol, 95% yield) as a colorless oil; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 0.32 (s, 9H), 6.71 (d, *J* = 2.4 Hz, 1H), 7.51 (ddd, *J* = 8.4 Hz, 4.7 Hz, 0.6 Hz, 1H), 8.24 (ddd, *J* = 8.4 Hz, 2.5 Hz, 1.6 Hz, 1H), 8.43 (d, *J* = 2.4 Hz, 1H), 8.51 (dd, *J* = 4.7 Hz, 1.6 Hz, 1H), 9.13 (d, *J* = 2.4 Hz, 1H).; ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ -1.0, 114.9, 124.8, 126.7, 128.2, 137.5, 141.3, 148.1, 156.2; IR (neat): 3106 w, 3045 w, 2957 m, 2898 w, 1587 s, 1502 s, 1479 m, 1458 m, 1430 m, 1359 w, 1311 s, 1250 s, 1181 m, 1121 w, 1101 w, 1074 w, 1048 m, 1019 m, 969 s, 947 m, 843 s, 805 m, 755 s, 718 m, 704 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{11}H_{16}N_3Si^{+}$ 218.1108; Found 218.1108.

*Deprotection of **3aa** to Form 1-(4-Methylphenyl)-1H-pyrazole (**3ae**).*[4b] A solution of **3aa** (34.6 mg, 0.150 mmol) in 20% ethanolic KOH (1.5 mL) was refluxed for 12 h under air. After this

period, water was added to the mixture, which was then extracted three times with AcOEt. The combined organic layers were washed with brine, dried over MgSO4, filtered and concentrated. Silica gel column chromatography (hexane:AcOEt = 95:5) of the crude material afforded 21.0 mg (0.133 mmol, 89% yield) of **3ae** as a pale yellow oil.

*Desilylative Chlorination to Form 3-Chloro-1-(4-methylphenyl)-1H-pyrazole (**4**).*[24] In a glove box, **3aa** (23.2 mg, 0.101 mmol), *N*-chlorosuccinimide (40.5 mg, 0.303 mmol), AgF (37.9 mg, 0.299 mmol), and 0.2 mL of MeCN were placed in an oven-dried sealed tube containing magnetic stirring bar. The mixture was stirred in the dark at room temperature for 20 h. After this period, the resulting mixture was diluted with dichloromethane, passed through a pad of Celite, and concentrated in vacuo. Silica gel column chromatography (hexane:AcOEt = 99:1) of the crude material afforded 16.8 mg (0.0872 mmol, 86% yield) of **4** as a white solid: Mp = 77-79 ºC ; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.37 (s, 3H), 6.50 (d, *J* = 2.7 Hz, 1H), 7.32 (d, *J* = 7.8 Hz, 2H), 7.67 (d, *J* = 8.6 Hz, 2H), 8.31 (d, *J* = 2.7 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 107.6, 119.3, 130.2, 130.8, 137.4, 138.4, 141.4; IR (KBr): 3164 m, 3119 m, 3049 m, 2920 m, 2855 w, 1902 w, 1720 w, 1607 m, 1518 s. 1499 s, 1431 m, 1408 s, 1369 s, 1350 s, 1278 w, 1216 m, 1200 s, 1110 m, 1046 s, 970 m, 942 s, 862 w, 817 s, 757 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{10}H_{10}ClN_2^{+}$ 193.0527; Found 193.0527.

*Desilylative Bromination to Form 3-Bromo-1-(4-methylphenyl)-1H-pyrazole (**5**).*[24] In a glove box, **3aa** (23.1 mg, 0.100 mmol), 1,2-dibromo-1,1,2,2-tetrachloroethane (163 mg, 0.501 mmol), AgF (63.3 mg, 0.499 mmol), and 0.2 mL of MeCN were placed in an oven-dried sealed tube containing magnetic stirring bar. The mixture was stirred in the dark at 40 ºC for 20 h. After this period, the resulting mixture was diluted with dichloromethane, passed through a pad of Celite, and concentrated in vacuo. Silica gel column chromatography (hexane:AcOEt = 98:2) of the

crude material afforded 10.7 mg (0.0451 mmol, 45% yield) of **5** as a white solid: Mp = 69-71 ºC ; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.37 (s, 3H), 6.58 (d, *J* = 2.4 Hz, 1H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.68 (d, *J* = 8.6 Hz, 2H), 8.27 (d, *J* = 2.7 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 111.0, 119.3, 128.1, 130.3, 130.8, 137.5, 138.4; IR (KBr): 3154 w, 3127 w, 2919 m, 2854 w, 1610 w, 1594 w, 1524 s, 1495 m, 1407 m, 1364 s, 1342 s, 1266 w, 1214 w, 1193 m, 1119 w, 106 w, 1045 s, 956 s, 939 m, 849 w, 835 w, 809 s, 749 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{10}H_{10}BrN_2^{+}$ 237.0022; Found 237.0021.

*4-Bromination of **3aa** Followed by Deprotection to Form 4-Bromo-1-(4-methylphenyl)-1H-pyrazole (**6**).* In a glove box, **3aa** (22.9 mg, 0.0994 mmol), *N*-bromosuccinimide (19.8 mg, 0.111 mmol), and 0.2 mL of MeCN were placed in an oven-dried sealed tube containing magnetic stirring bar. The mixture was stirred at room temperature for 1 h, and the resulting mixture was concentrated in vacuo. Then a solution of the crude material solution in 20% ethanolic KOH (1.5 mL) was refluxed for 8 h under air. After this period, water was added to the mixture, which was then extracted three times with AcOEt. The combined organic layers were washed with brine, dried over MgSO4, filtered and concentrated. Silica gel column chromatography (hexane:AcOEt = 97:3) of the crude material afforded 20.6 mg (0.0869 mmol, 87% yield) of **6** as a white solid: Mp = 88-90 ºC ; ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.37 (s, 3H), 7.32 (d, *J* = 8.2 Hz, 2H), 7.70-7.72 (m, 3H), 8.44 (s, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$) : δ 20.8, 95.7, 119.4, 128.3, 130.8, 137.5, 138.5, 141.7; IR (KBr): 3112 s, 3044 m, 2918 m, 1697 w, 1608 w, 1525 s, 1509 s, 1426 m, 1398 s, 1380 s, 1335 s, 1244 m, 1214 w, 1193 m, 1150 m, 1109 m, 1033 s, 950 s, 850 s, 816 s cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{10}H_{10}BrN_2^{+}$ 237.0022; Found 237.0024.

*5-Bromination of **3aa** Followed by Deprotection to Form 5-Bromo-1-(4-methylphenyl)-1H-pyrazole (**7**).*[25] To a solution of **3aa** (23.4 mg, 0.102 mmol) in 1 mL of THF at -40 ºC was added

^{n}BuLi in hexane (1.50 M, 0.150 mmol) dropwise and the mixture was stirred for 2 h. The resulting mixture was then cooled to -60 ºC, and tetrabromomethane in THF solution was added dropwise (1.00 M, 0.250 mmol) to the mixture, which was stirred for 1 h at this temperature and for another 1 h at room temperature. After this period, water was added to the reaction mixture, which was then extracted with three times with Et_2O. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, concentrated and purified by silica gel column chromatography (hexane:AcOEt = 98:2) to give a mixture of **3aa** and the 5-bromination product. To a round bottom flask charged with the obtained mixture was added KHF_2 (39.8 mg, 0.510 mmol) and MeOH 4 mL, and the mixture was stirred for 3 h at 70 ºC. After this period, water was added to the resulting mixture, which was extracted three times with AcOEt. The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated. Silica gel column chromatography (hexane:AcOEt = 97:3) of the crude material afforded a mixture of **3ae** and **7**, and the NMR yield of **7** (0.0709 mmol, 70% NMR yield) was determined by ^{1}H NMR analysis. Gel permeation chromatography (GPC) of the mixture afforded 10.8 mg of pure **7** (0.0456 mmol, 45% yield) as a pale yellow oil: ^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ 2.42 (s, 3H), 6.58 (d, *J* = 2.0 Hz, 1H), 7.35-7.37 (m, 2H), 7.42-7.45 (m, 2H), 7.68 (d, *J* = 2.0 Hz, 1H); ^{13}C{^{1}H} NMR (100 MHz, $(CD_3)_2CO$): δ 21.1, 111.0, 113.0, 126.3, 130.3, 137.7, 139.4, 142.0; IR (neat): 3040 w, 2922 w, 2855 w, 1518 s, 1407 m, 1391 s, 1237 w, 1178 w, 1111 w, 1040 w, 1020 w, 967 m, 917 m, 872 w, 820 m, 799 w, 772 m, 711 w cm^{-1}; HRMS (ESI-TOF) m/z: [M+H^{+}] Calcd for $C_{10}H_{10}BrN_2^{+}$ 237.0022; Found 237.0026.

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at http://pubs.acs.org.

Copies of ^{1}H and $^{13}C\{^{1}H\}$ NMR spectra (PDF)

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Notes

The authors declare no competing financial interest.

Acknowledgements

This work was supported in part by JSPS KAKENHI Grant Numbers JP17K19126, JP16H04150 and JP15H05839 (Middle Molecular Strategy). T. K. is also grateful for support by JSPS KAKENHI Grant Number JP16H01040 (Precisely Designed Catalysts with Customized Scaffolding). S. O. is also grateful for support by the Research Grant of Keio Leading-edge Laboratory of Science & Technology.

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