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Palladium-Catalyzed/Norbornene-Mediated *ortho*-Amination/*N*-Tosylhydrazone Insertion Reaction: An Approach to the Synthesis of *ortho*-Aminated Vinylarenes

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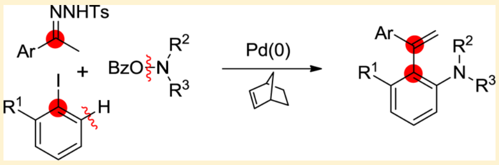
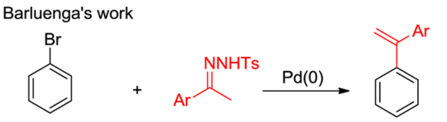
Supporting Information

ABSTRACT: *ortho*-Aminated vinylarene derivatives were obtained via a reaction of aryl iodides, *N*-benzoyloxyamines, and *N*-tosylhydrazones. This approach involves a palladium-catalyzed, norbornene-mediated *ortho*-amination/*N*-tosylhydrazone insertion reaction. In this transformation, one C−N bond and one C−C bond are formed and an amine group is introduced at the *ortho* position successfully.



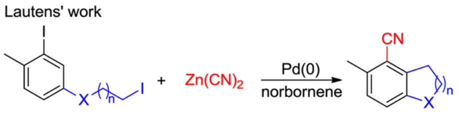
INTRODUCTION

Palladium-catalyzed cross-coupling reactions, which represent one of the most reliable and powerful tools for organic synthesis and natural product total synthesis, have attracted the interest of several groups.[1] More recently, considerable attention has been focused on the utility of *N*-tosylhydrazones as new cross-coupling partners in palladium-catalyzed transformations, as initially reported by Barluenga in 2007 (eq 1)[2] and further developed by Wang, Van Vranken, our group, and others.[3] Despite the variety of possibilities offered by this transformation, new chemical transformations based on this unique coupling must be developed to further increase its effectiveness and usefulness.



(1)

Combining multistep processes into a one-step protocol is an important goal of transition-metal-catalyzed reactions. A remarkable reaction of this type was first reported by Catellani and further modified by Lautens. This strategy provides a way to synthesize highly substituted aromatic compounds and fused aromatic rings from easily accessible starting materials in an efficient, atom-economical way using palladium-catalyzed, norbornene-mediated *ortho*-C−H functionalization followed by terminal cross-coupling processes. The scope of this reaction has been broadened considerably since its discovery.[4] For example, Lautens reported a palladium-catalyzed intramolecular alkylation/intermolecular cyanation reaction to afford polycyclic benzonitriles (eq 2).[5] We successfully modified this sequence by using *N*-tosylhydrazones as terminal reagents to give polycyclic vinylarenes via an intramolecular alkylation/*N*-tosylhydrazone insertion reaction (eq 3).[6] Recently, Dong and co-worker developed the first example of the formation of C−N bonds at the *ortho* position of aryl iodides via Catellani−Lautens-type C−H activation (eq 4).[7] Inspired by their work and in connection with our interest in using *N*-tosylhydrazones as new coupling partners in Catellani−Lautens reactions[6,8] and our interest in palladium-catalyzed insertion of *N*-tosylhydrazones,[3m−o,9] we report a palladium-catalyzed, norbornene-mediated *ortho*-amination/*N*-tosylhydrazone insertion reaction that affords *ortho*-aminated vinylarenes (eq 5).



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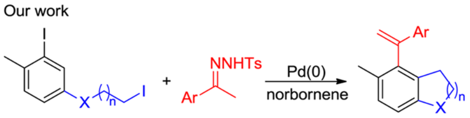

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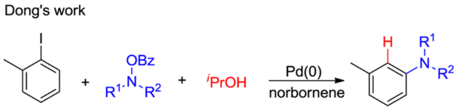

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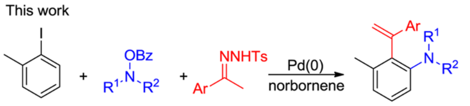

(5)

RESULTS AND DISCUSSION

Initially, we employed the 1-iodo-2-methylbenzene (**1a**), *N*-benzoyloxyamine **2a**, and *N*-tosylhydrazone **3a** as the substrates. To our delight, the product **4-1** was obtained in

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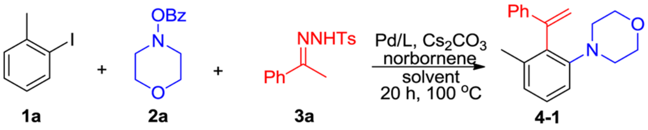
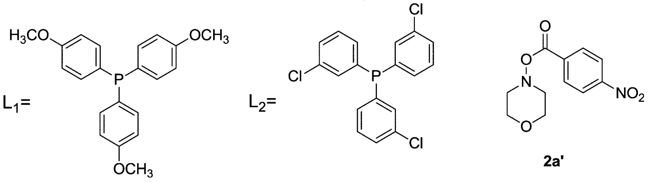
17% yield when the reaction was catalyzed by Pd(OAc)$_2$ (10 mol %)/TFP (20 mol %)/norbornene (1.0 equiv) in the presence of Cs_2CO_3 in CH_3CN (Table 1, entry 1). A further investigation of various solvents revealed that the reaction proceeded more efficiently in nonpolar solvents than in polar solvents (entries 2−6). The yield was slightly improved when CH_3CN was replaced by dioxane (entry 2). However, DCE and DMF were found to be less effective for this reaction (entries 4 and 5). Using nonpolar toluene gave a better yield (entry 6). According to previous reports, this result may be due to the fact that the more polar solvents increase the decomposition of *N*-benzoyloxyamine **2a**.[7,10] A series of mono- and bidentate phosphine ligands were then screened (entries 7−12). Only a trace amount of product was detected when Xphos was used (entry 7), and a lower yield was obtained with dppe (entry 8). Switching the ligand to dppb could not further improve the yield (entry 9). PPh_3 gave a better result compared with L_1 and L_2 (entries 10−12). Different palladium catalysts were surveyed, including Pd(II) and Pd(0) catalysts, and it was found that Pd(OAc)$_2$ catalyzed this reaction more effectively (entries 13−17). Lowering the catalyst loading to 5 mol % diminished the product yield (entry 18). Further inspection of the reaction conditions indicated that norbornene is essential for this reaction (entry 20), and decreasing the amount of norbornene relative to **1a** led to a decreased yield (data not shown in Table 1). In previous studies, Wang indicated that using triethylamine as a cobase was beneficial for the palladium-catalyzed insertion of *N*-tosylhydrazones.[3p,11] Addition of 2.0 equiv of NEt_3, however, led to a slight reduction in the yield (data not shown in Table 1). Glorius demonstrated that a more electron-deficient electrophilic amination reagent was found to be effective in Rh-catalyzed C−H amination reactions.[12] Nevertheless, an attempt to further improve the yield by employing electron-deficient **2a′** in this reaction was not successful (data not shown in Table 1). Finally, none of the desired product was detected without palladium catalyst or norbornene in control experiments (entries 19 and 20).

Table 1. Optimization of the Reaction Conditions[a]

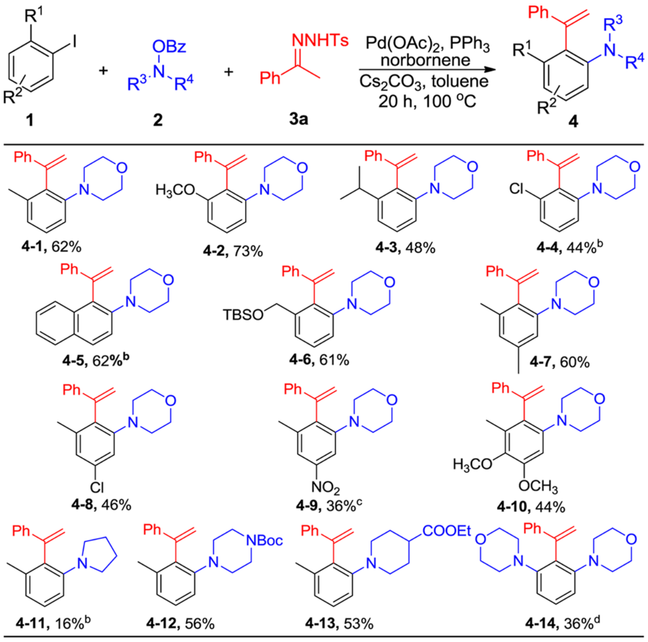


entry	catalyst	ligand	solvent	yield (%)
1	Pd(OAc)$_2$	TFP	CH_3CN	17
2	Pd(OAc)$_2$	TFP	dioxane	23
3	Pd(OAc)$_2$	TFP	DME	18
4	Pd(OAc)$_2$	TFP	DMF	<10
5	Pd(OAc)$_2$	TFP	DCE	trace
6	Pd(OAc)$_2$	TFP	toluene	47
7	Pd(OAc)$_2$	Xphos	toluene	trace
8	Pd(OAc)$_2$	dppe	toluene	16
9	Pd(OAc)$_2$	dppb	toluene	35
10	Pd(OAc)$_2$	PPh_3	toluene	62
11	Pd(OAc)$_2$	L_1	toluene	50
12	Pd(OAc)$_2$	L_2	toluene	49
13	$PdCl_2$	PPh_3	toluene	53
14	Pd(CH_3CN)$_2$$Cl_2$	PPh_3	toluene	61
15	Pd(PPh_3)$_4$	PPh_3	toluene	38
16	$Pd_2(dba)_3 \cdot CHCl_3$	PPh_3	toluene	37
17	$Pd_2(dba)_3$	PPh_3	toluene	32
18[b]	Pd(OAc)$_2$	PPh_3	toluene	50
19	none	PPh_3	toluene	0
20[c]	Pd(OAc)$_2$	PPh_3	toluene	0



[a] **1a** (0.3 mmol, 1.0 equiv), **2a** (0.33 mmol, 1.1 equiv), **3a** (0.75 mmol, 2.5 equiv), Pd (10 mol %), ligand (20 mol %), norbornene (0.3 mmol, 1.0 equiv), Cs_2CO_3 (1.5 mmol, 5.0 equiv), solvent (4.5 mL), 100 °C, 20 h. [b] 5 mol % Pd(OAc)$_2$ and 10 mol % PPh_3 were employed. [c] The reaction was carried out in the absence of norbornene.

Table 2. Scope of Aryl Iodides 1 and *N*-Benzoyloxyamines 2[a]

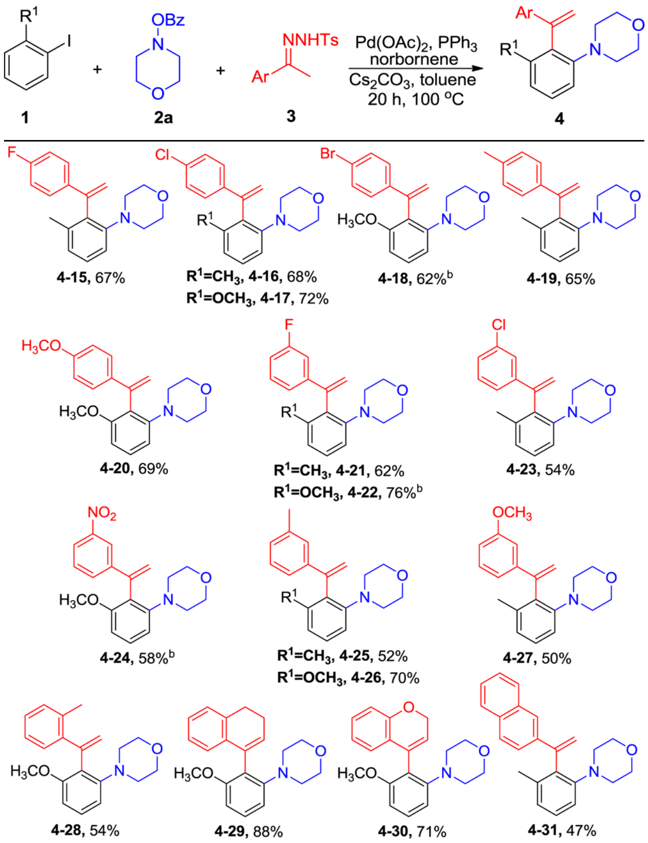


[a] Reaction conditions as in Table 1. [b] NMR yield. [c] TFP was used as the ligand. [d] 2.5 equiv of **2a**, 2.0 equiv of norbornene, and 6.0 equiv of Cs_2CO_3 were employed.

With the optimal conditions in hand, we turned to an exploration of the scope of this reaction with a variety of substituted aryl iodides and *N*-benzoyloxyamines. The results are summarized in Table 2. Both electron-donating and electron-withdrawing groups on the aromatic ring were compatible with the reaction. Highly sterically hindered 1-iodo-2-isopropylbenzene also led to the coupling product **4-3** in 48% yield. 2-Iodonaphthalene also worked, providing the aminated vinylarene **4-5** in moderate yield. It was noteworthy that a chloro-substituted product (**4-4**) could be obtained successfully, which would allow further metal-catalyzed coupling reactions. Furthermore, the reactions demonstrated high functional group tolerance. For instance, TBS ether and nitro groups were compatible, affording the corresponding products **4-6** and **4-9**. Next, we studied the scope of the electrophilic amine partner. Pyrrolidine gave the desired product **4-11** in a low yield. *N*-Benzoyloxyamines containing a Boc or ester protecting group were also compatible and afforded the corresponding amination products **4-12** and **4-13** in moderate yields. Finally, we were pleased to find that the 1,3-diamination product **4-14** could be obtained in 36% yield by a double C−H activation of both *ortho* positions of the aryl iodide. The low yield of **4-14** may be attributed to the steric hindrance of two morpholine groups.

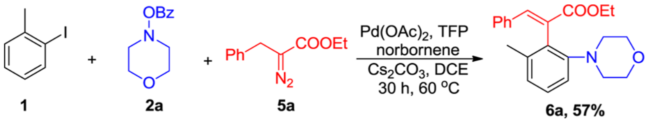
The scope of this reaction with various *N*-tosylhydrazones **3** was subsequently explored. *Ortho-*, *para-*, and *meta*-substituted *N*-tosylhydrazones were all good coupling partners in this reaction, affording the corresponding products in moderate to good yields (Table 3). Cyclic *N*-tosylhydrazones led to good yields of **4-29** and **4-30**, and naphthyl *N*-tosylhydrazone also worked efficiently to give **4-31**.

Table 3. Scope of *N*-Tosylhydrazones 3[a]

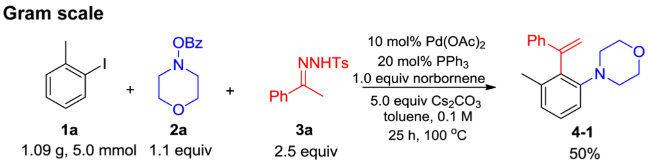


[a] Reaction conditions as in Table 1. [b] NMR yield.

To further demonstrate the generality of this reaction, α-diazocarbonyl compound **5a** was employed as substrate under slightly modified conditions. To our delight, the desired product **6a** was given in moderate yield.

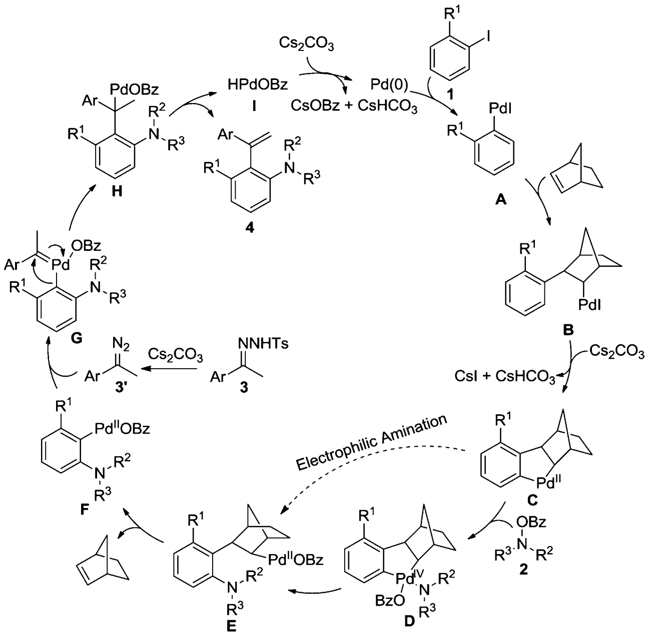


To further demonstrate the practical utility of the present protocol, we carried out the reaction with **1a**, **2a**, and **3a** on a gram scale. Gratifyingly, the desired product **4-1** was obtained in moderate yield.



On the basis of previous reports,[3,4,7,13] we envisioned a possible catalytic cycle for this palladium-catalyzed transformation (Scheme 1). Oxidative addition of substrate **1** to Pd(0) would produce intermediate **A**. Then the insertion of norbornene into **A** would furnish intermediate **B**. An electrophilic metalation at the *ortho* position would then occur, and subsequent elimination of HI would deliver **C**. A further oxidative addition of *N*-benzoyloxyamine **2** to species **C** would result in the formation of cyclic Pd(IV) complex **D**, followed by reductive elimination to produce the Pd(II) complex **E**. Alternatively, direct electrophilic amination of intermediate **C** could give **E**. Intermediate **F** resulting from norbornene release would then undergo palladium carbene formation and migratory insertion followed by *β*-H elimination to yield the product **4**.

Scheme 1. Possible Catalytic Cycle



■ CONCLUSION

We have developed a palladium-catalyzed, norbornene-mediated *ortho*-amination/*N*-tosylhydrazone insertion reaction to synthesize *ortho*-aminated vinylarenes. This approach affords a C−N bond and a C−C bond by using an electron-deficient *N*-benzoyloxyamine as an efficient electrophilic nitrogen source and an *N*-tosylhydrazone as a nucleophilic coupling partner in the termination steps. This transformation is complementary to the Catellani−Lautens reaction, Dong's work, and Barluenga's work. Importantly, this reaction further demonstrates the possibility of using *N*-tosylhydrazones as coupling partners in Catellani−Lautens reactions and the possibility of incorporating C−H activation in the palladium-catalyzed insertion of *N*-tosylhydrazones, which would open a new avenue for the development of more novel Pd-catalyzed insertions of *N*-tosylhydrazones.

■ EXPERIMENTAL SECTION

General Procedure for the Preparation of the Products 4. An dried Schlenk tube under an argon atmosphere was charged with aryl iodide **1** (0.3 mmol, 1.0 equiv), *N*-benzoyloxyamine **2** (0.33 mmol, 1.1 equiv), *N*-tosylhydrazone **3** (0.75 mmol, 2.5 equiv), Pd(OAc)$_2$ (6.7 mg, 0.03 mmol, 10 mol %), PPh$_3$ (15.7 mg, 0.06 mmol, 20 mol %), norbornene (28 mg, 0.3 mmol, 1.0 equiv), Cs$_2$CO$_3$ (487 mg, 1.5 mmol, 5.0 equiv), and toluene (4.5 mL). The mixture was stirred at room temperature for 15 min and then at 100 °C for 20 h. The resulting mixture was cooled to room temperature and filtered through Celite with EtOAc as the eluent. The solvents were evaporated under reduced pressure, and the residue was purified by flash chromatography on silica gel using petroleum ether/ethyl acetate to afford **4** in over 90% purity.

*4-(3-Methyl-2-(1-phenylvinyl)phenyl)morpholine (**4-1**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-1** (52 mg, 62% yield) as a colorless oil, slowly solidifying to a white solid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.26−7.21 (m, 6H), 7.04 (d, J = 7.2 Hz, 1H), 6.94 (d, J = 8.0 Hz, 1H), 5.94 (d, J = 1.2 Hz, 1H), 5.16 (d, J = 1.2 Hz, 1H), 3.50 (s, 2H), 3.34 (s, 2H), 3.01 (s, 2H), 2.58 (s, 2H), 2.25 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 151.1, 146.4, 141.2, 137.8, 137.6, 128.0, 127.9, 127.1, 125.8, 125.7, 117.9, 115.5, 67.1, 52.3, 20.7; HRMS (ESI) m/z calcd for C$_{19}$H$_{21}$NO [M + H]$^+$ 280.1696, found 280.1699.

*4-(3-Methoxy-2-(1-phenylvinyl)phenyl)morpholine (**4-2**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-2** (65 mg, 73% yield) as a yellow solid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.30−7.19 (m, 6H), 6.75−6.70 (m, 2H), 5.95 (d, J = 1.2 Hz, 1H), 5.31 (d, J = 1.2 Hz, 1H), 3.71 (s, 3H), 3.43 (t, J = 4.4 Hz, 4H), 2.83 (s, 4H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 158.1, 152.2, 142.9, 141.3, 128.8, 127.9, 127.0, 125.8, 125.7, 116.6, 112.5, 106.7, 67.1, 56.0, 51.8; HRMS (ESI) m/z calcd for C$_{19}$H$_{21}$NO$_2$ [M + H]$^+$ 296.1645, found 296.1648.

*4-(3-Isopropyl-2-(1-phenylvinyl)phenyl)morpholine (**4-3**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-3** (44 mg, 48% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.35−7.31 (m, 1H), 7.24−7.15 (m, 6H), 6.96 (d, J = 7.6 Hz, 1H), 5.95 (d, J = 1.2 Hz, 1H), 5.11 (d, J = 1.2 Hz, 1H), 3.53−3.48 (m, 2H), 3.33−3.27 (m, 2H), 3.25−3.20 (m, 1H), 3.02−2.97 (m, 2H), 2.54−2.50 (m, 2H), 1.22 (d, J = 6.8 Hz, 3H), 1.11 (d, J = 6.8 Hz, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 150.8, 148.7, 146.1, 141.6, 137.1, 130.4, 127.9, 127.1, 125.8, 121.6, 118.3, 114.9, 67.2, 52.5, 29.8, 25.0, 24.1; HRMS (ESI) m/z calcd for C$_{21}$H$_{25}$NO [M + H]$^+$ 308.2009, found 308.2011.

*4-(3-Chloro-2-(1-phenylvinyl)phenyl)morpholine (**4-4**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-4** (44% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.22 (d, J = 9.2 Hz, 7H), 6.96 (dd, J = 6.8 Hz, 2.0 Hz, 1H), 6.02 (s, 1H), 5.32 (s, 1H), 3.50 (s, 2H), 3.36 (s, 2H), 3.01 (s, 2H), 2.63 (s, 2H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 152.6, 144.3, 140.1, 136.1, 134.7, 128.9, 128.1, 127.3, 125.7, 124.7, 118.6, 117.4, 66.9, 51.9; HRMS (ESI) m/z calcd for C$_{18}$H$_{18}$ClNO [M + H]$^+$ 300.1150, found 300.1151.

*4-(1-(1-Phenylvinyl)naphthalen-2-yl)morpholine (**4-5**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-5** (62% yield) as a white liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.08−8.06 (m, 1H), 7.87−7.82 (m, 2H), 7.41−7.37 (m, 3H), 7.25−7.20 (m, 5H), 6.14 (d, J = 1.2 Hz, 1H), 5.29 (d, J = 1.2 Hz, 1H), 3.59−3.54 (m, 2H), 3.40−3.36 (m, 2H), 3.13−3.08 (m, 2H), 2.69−2.65 (m, 2H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 147.3, 145.4, 141.7, 133.8, 133.5, 131.0, 128.9, 128.0, 127.8, 127.2, 126.2, 126.1, 125.8, 124.7, 120.3, 116.9, 67.2, 52.1; HRMS (ESI) m/z calcd for C$_{22}$H$_{21}$NO [M + H]$^+$ 316.1696, found 316.1699.

*4-(3-(((tert-Butyldimethylsilyl)oxy)methyl)-2-(1-phenylvinyl)-phenyl)morpholine (**4-6**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-6** (75 mg, 61% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.49−7.38 (m, 2H), 7.25−7.24 (m, 5H), 7.07 (d, J = 7.2 Hz, 1H), 5.96 (d, J = 1.6 Hz, 1H), 5.22 (d, J = 1.2 Hz, 1H), 4.83 (d, J = 13.6 Hz, 1H), 4.64 (d, J = 13.6 Hz, 1H), 3.57−3.53 (m, 2H), 3.35 (s, 2H), 3.09 (d, J = 8.8 Hz, 2H), 2.62−2.58 (m, 2H), 0.97 (s, 9H), 0.09 (s, 3H), 0.07 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 150.5, 145.4, 141.0, 140.8, 135.6, 128.3, 128.0, 127.2, 125.8, 122.5, 119.1, 115.7, 67.1, 63.1, 52.3, 26.0, 18.4, −5.4; HRMS (ESI) m/z calcd for C$_{25}$H$_{35}$NO$_2$Si [M + H]$^+$ 410.2510, found 410.2513; EA calcd C 73.30%, H 8.61%, N 3.42%, found C 73.10%, H 8.42%, N 2.95%.

*4-(3,5-Dimethyl-2-(1-phenylvinyl)phenyl)morpholine (**4-7**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-7** (53 mg, 60% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.20 (d, J = 11.2 Hz, 5H), 6.87 (s, 1H), 6.74 (s, 1H), 5.92 (d, J = 1.2 Hz, 1H), 5.14 (d, J = 0.8 Hz, 1H), 3.49 (s, 2H), 3.33 (s, 2H), 3.00 (s, 2H), 2.57 (s, 2H), 2.34 (s, 3H), 2.21 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 151.0, 146.4, 141.4, 137.6, 137.5, 134.6, 128.0, 127.1, 126.4, 125.8, 118.6, 115.6, 67.1, 52.3, 21.3, 20.6; HRMS (ESI) m/z calcd for C$_{20}$H$_{23}$NO [M + H]$^+$ 294.1852, found 294.1854.

*4-(5-Chloro-3-methyl-2-(1-phenylvinyl)phenyl)morpholine (**4-8**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-8** (43 mg, 46% yield) as a white liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.26−7.19 (m, 5H), 7.02 (d, J = 1.6 Hz, 1H), 6.88 (d, J = 1.6 Hz, 1H), 5.96 (s, 1H), 5.16 (s, 1H), 3.49 (s, 2H), 3.33 (s, 2H), 3.00 (s, 2H), 2.59 (s, 2H), 2.21 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 152.2, 145.5, 140.5, 139.4, 135.6, 133.2, 128.1, 127.4, 125.7, 125.3, 118.2, 116.2, 66.9, 52.0, 20.7; HRMS (ESI) m/z calcd for C$_{19}$H$_{20}$ClNO [M + H]$^+$ 314.1306, found 314.1307; EA calcd C 72.72%, H 6.42%, N 4.46%, found C 72.58%, H 6.58%, N 4.00%.

*4-(3-Methyl-5-nitro-2-(1-phenylvinyl)phenyl)morpholine (**4-9**).* Flash chromatography on silica using petroleum ether/ethyl acetate (5% ethyl acetate in petroleum ether) as the eluent afforded **4-9** (35 mg, 36% yield) as a yellow liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.89 (d, J = 2.0 Hz, 1H), 7.75 (d, J = 2.0 Hz, 1H), 7.29−7.26 (m, 3H), 7.20−7.18 (m, 2H), 6.05 (s, 1H), 5.24 (s, 1H), 3.53 (s, 2H), 3.39 (s, 2H), 3.08 (s, 2H), 2.69 (s, 2H), 2.32 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 152.1, 147.6, 144.9, 143.7, 139.5, 139.4, 128.4, 127.9, 125.5, 120.0, 116.6, 112.7, 66.8, 51.9, 21.0; HRMS (ESI) m/z calcd for C$_{19}$H$_{20}$N$_2$O$_3$ [M + H]$^+$ 325.1547, found 325.1550.

*4-(4,5-Dimethoxy-3-methyl-2-(1-phenylvinyl)phenyl)morpholine (**4-10**).* Flash chromatography on silica using petroleum ether/ethyl acetate (5% ethyl acetate in petroleum ether) as the eluent afforded **4-10** (45 mg, 44% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.26−7.20 (m, 5H), 6.56 (s, 1H), 5.91 (d, J = 1.6 Hz, 1H), 5.10 (d, J = 1.6 Hz, 1H), 3.88 (s, 3H), 3.81 (s, 3H), 3.50 (d, J = 8.0 Hz, 2H), 3.32 (s, 2H), 2.95 (s, 2H), 2.54 (s, 2H), 2.19 (s, 3H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 152.1, 147.0, 146.2, 143.9, 141.7, 131.7, 131.3, 127.9, 127.1, 125.8, 115.7, 102.9, 67.1, 60.3, 55.7, 52.5, 13.6; HRMS (ESI) m/z calcd for C$_{21}$H$_{25}$NO$_3$ [M + H]$^+$ 340.1907, found 340.1912.

*1-(3-Methyl-2-(1-phenylvinyl)phenyl)pyrrolidine (**4-11**).* Flash chromatography on silica using petroleum ether/ethyl acetate (1% ethyl acetate in petroleum ether) as the eluent afforded **4-11** (16% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.38−7.36 (m, 2H), 7.29−7.22 (m, 3H), 7.15−7.11 (m, 1H), 6.70 (dd, J = 7.2 Hz, 15.6 Hz, 2H), 6.01 (d, J = 0.8 Hz, 1H), 5.20 (d, J = 0.8 Hz, 1H), 3.21 (s, 2H), 3.11 (s, 2H), 2.06 (s, 3H), 1.71 (t, J = 6.4 Hz, 4H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 148.5, 147.0, 140.7, 137.9, 128.2, 127.6, 127.2, 126.0, 125.6, 120.2, 115.5, 112.9, 50.6, 25.3, 21.0; HRMS (ESI) m/z calcd for C$_{19}$H$_{21}$N [M + H]$^+$ 264.1747, found 264.1750.

*tert-Butyl 4-(3-Methyl-2-(1-phenylvinyl)phenyl)piperazine-1-carboxylate (**4-12**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-12** (64 mg, 56% yield) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.23−7.19 (m, 6H), 7.05 (d, J = 7.6 Hz, 1H), 6.91 (d, J = 8.0 Hz, 1H), 5.94 (s, 1H), 5.14 (s, 1H), 3.26−3.22 (m, 2H), 3.02−2.94 (m, 4H), 2.50 (s, 2H), 2.27 (s, 3H), 1.42 (s, 9H); ^{13}C{H} NMR (100 MHz, CDCl$_3$) δ 154.7, 151.1, 146.3, 141.1, 137.9, 137.8, 128.0, 127.9, 127.1, 125.9, 125.6, 118.1, 115.4, 79.4, 51.9, 28.4, 20.7; HRMS (ESI) m/z calcd for $C_{24}H_{30}N_2O_2$ $[M + H]^+$ 379.2380, found 379.2383.

*Ethyl 1-(3-Methyl-2-(1-phenylvinyl)phenyl)piperidine-4-carboxylate (**4-13**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-13** (55 mg, 53% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22−7.17 (m, 6H), 7.01 (d, J = 7.2 Hz, 1H), 6.92 (d, J = 8.0 Hz, 1H), 5.93 (d, J = 1.2 Hz, 1H), 5.13 (d, J = 1.2 Hz, 1H), 4.09 (q, J = 7.2 Hz, 2H), 3.28 (d, J = 10.4 Hz, 1H), 2.74−2.66 (m, 2H), 2.49−2.39 (m, 1H), 2.23 (s, 3H), 2.21−2.15 (m, 1H), 1.67 (d, J = 17.6 Hz, 4H), 1.23−1.20 (m, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 175.2, 152.0, 146.4, 141.1, 137.9, 137.5, 127.9, 127.7, 127.0, 125.7, 125.4, 118.1, 115.1, 60.0, 53.0, 50.9, 41.0, 28.5, 20.7, 14.2; HRMS (ESI) m/z calcd for $C_{23}H_{27}NO_2$ $[M + H]^+$ 350.2115, found 350.2118; EA calcd C 79.05%, H 7.79%, N 4.01%, found C 79.03%, H 7.86%, N 3.70%.

*4,4′-(2-(1-Phenylvinyl)-1,3-phenylene)dimorpholine (**4-14**).* Flash chromatography on silica using petroleum ether/ethyl acetate (5% ethyl acetate in petroleum ether) as the eluent afforded **4-14** (38 mg, 36% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30−7.21 (m, 6H), 6.84 (d, J = 8.0 Hz, 2H), 5.94 (s, 1H), 5.51 (s, 1H), 3.46 (s, 8H), 2.84 (s, 8H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 152.2, 144.1, 142,1, 131.7, 128.8, 127.9, 126.9, 125.5, 116.2, 115.4, 67.0, 51.8; HRMS (ESI) m/z calcd for $C_{22}H_{26}N_2O_2$ $[M + H]^+$ 351.2067, found 351.2072.

*4-(2-(1-(4-Fluorophenyl)vinyl)-3-methylphenyl)morpholine (**4-15**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-15** (59 mg, 67% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25−7.16 (m, 3H), 7.04 (d, J = 7.6 Hz, 1H), 6.96−6.91 (m, 3H), 5.88 (d, J = 0.4 Hz, 1H), 5.13 (s, 1H), 3.51 (s, 2H), 3.35 (s, 2H), 3.03 (s, 2H), 2.56 (s, 2H), 2.25 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 163.4, 161.0, 151.0, 145.4, 137.7, 137.4, 137.3, 137.2, 128.1, 127.3, 127.2, 125.8, 118.0, 115.3, 114.9, 114.7, 67.1, 52.3, 20.6; HRMS (ESI) m/z calcd for $C_{19}H_{20}FNO$ $[M + H]^+$ 298.1602, found 298.1601; EA calcd C 76.74%, H 6.78%, N 4.71%, found C 76.61%, H 7.05%, N 4.28%.

*4-(2-(1-(4-Chlorophenyl)vinyl)-3-methylphenyl)morpholine (**4-16**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-16** (64 mg, 68% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25−7.20 (m, 3H), 7.15−7.13 (m, 2H), 7.04 (d, J = 7.6 Hz, 1H), 6.94 (d, J = 7.6 Hz, 1H), 5.93 (s, 1H), 5.17 (s, 1H), 3.51 (s, 2H), 3.35 (s, 2H), 3.02 (d, J = 8.8 Hz, 2H), 2.56 (s, 2H), 2.24 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 151.0, 145.3, 139.7, 137.7, 137.1, 132.8, 128.2, 128.1, 127.0, 125.9, 118.0, 116.0, 67.1, 52.3, 20.6; HRMS (ESI) m/z calcd for $C_{19}H_{20}ClNO$ $[M + H]^+$ 314.1306, found 314.1308; EA calcd C 72.72%, H 6.42%, N 4.46%, found C 72.59%, H 6.25%, N 4.07%.

*4-(2-(1-(4-Chlorophenyl)vinyl)-3-methoxyphenyl)morpholine (**4-17**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-17** (72% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, J = 8.4 Hz, 1H), 7.26 (s, 4H), 6.74−6.70 (m, 2H), 5.93 (s, 1H), 5.33 (s, 1H), 3.72 (s, 3H), 3.46−3.44 (m, 4H), 2.83 (s, 4H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 158.1, 152.1, 141.8, 139.9, 132.6, 129.0, 128.0, 127.0, 125.0, 117.1, 112.5, 106.7, 67.0, 56.0, 51.9; HRMS (ESI) m/z calcd for $C_{19}H_{20}ClNO_2$ $[M + H]^+$ 330.1255, found 330.1258.

*4-(2-(1-(4-Bromophenyl)vinyl)-3-methoxyphenyl)morpholine (**4-18**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-18** (62% yield) as a white liquid. HRMS (ESI) m/z calcd for $C_{19}H_{20}BrNO_2$ $[M + H]^+$ 374.0750, found 374.0752.

*4-(3-Methyl-2-(1-(p-tolyl)vinyl)phenyl)morpholine (**4-19**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-19** (57 mg, 65% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24−7.20 (m, 1H), 7.12 (d, J = 8.4 Hz, 2H), 7.05−7.01 (m, 3H), 6.93 (d, J = 7.6 Hz, 1H), 5.90 (d, J = 1.2 Hz, 1H), 5.10 (d, J = 1.2 Hz, 1H), 3.54−3.50 (m, 2H), 3.37 (s, 2H), 3.02 (d, J = 8.8 Hz, 2H), 2.63−2.59 (m, 2H), 2.32 (s, 3H), 2.22 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 151.1, 146.1, 138.1, 137.8, 137.6, 136.9, 128.7, 127.8, 125.6, 125.5, 117.7, 114.6, 67.2, 52.3, 21.1, 20.6; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO$ $[M + H]^+$ 294.1852, found 294.1855.

*4-(3-Methoxy-2-(1-(4-methoxyphenyl)vinyl)phenyl)morpholine (**4-20**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-20** (67 mg, 69% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28−7.24 (m, 1H), 7.21 (d, J = 9.2 Hz, 2H), 6.77 (d, J = 9.2 Hz, 2H), 6.73−6.69 (m, 2H), 5.86 (d, J = 1.6 Hz, 1H), 5.20 (d, J = 1.2 Hz, 1H), 3.78 (s, 3H), 3.70 (s, 3H), 3.48−3.46 (m, 4H), 2.85 (s, 4H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 158.8, 158.1, 152.1, 142.2, 133.7, 128.6, 126.9, 125.7, 114.6, 113.2, 112.3, 106.6, 67.1, 56.0, 55.2, 51.8; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO_3$ $[M + H]^+$ 326.1751, found 326.1754; EA calcd C 73.82%, H 7.12%, N 4.30%, found C 73.45%, H 7.02%, N 3.88%.

*4-(2-(1-(3-Fluorophenyl)vinyl)-3-methylphenyl)morpholine (**4-21**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-21** (55 mg, 62% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25−7.17 (m, 2H), 7.05−7.01 (m, 2H), 6.96−6.88 (m, 3H), 5.95 (d, J = 0.6 Hz, 1H), 5.20 (s, 1H), 3.51 (s, 2H), 3.34 (s, 2H), 3.01 (s, 2H), 2.56 (s, 2H), 2.25 (s, 3H), ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 164.1, 161.7, 151.0, 145.5, 145.4, 143.8, 143.7, 137.7, 137.1, 129.4, 129.3, 128.2, 125.9, 121.4, 121.3, 118.0, 116.6, 114.0, 113.7, 112.6, 112.4, 67.1, 52.3, 20.6; HRMS (ESI) m/z calcd for $C_{19}H_{20}FNO$ $[M + H]^+$ 298.1602, found 298.1603; EA calcd C 76.74%, H 6.78%, N 4.71%, found C 77.15%, H 6.82%, N 4.32%.

*4-(2-(1-(3-Fluorophenyl)vinyl)-3-methoxyphenyl)morpholine (**4-22**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-22** (76% yield) as a white solid. HRMS (ESI) m/z calcd for $C_{19}H_{20}FNO_2$ $[M + H]^+$ 314.1551, found 314.1553.

*4-(2-(1-(3-Chlorophenyl)vinyl)-3-methylphenyl)morpholine (**4-23**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-23** (50 mg, 54% yield) as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26−7.15 (m, 4H), 7.10−7.04 (m, 2H), 6.96 (d, J = 15.6 Hz, 1H), 5.95 (s, 1H), 5.20 (s, 1H), 3.51 (s, 2H), 3.35 (s, 2H), 3.01 (s, 2H), 2.56 (s, 2H), 2.25 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 151.0, 145.3, 143.2, 137.7, 137.0, 134.0, 129.2, 128.2, 127.1, 126.0, 125.8, 123.9, 118.1, 116.8, 67.1, 52.3, 20.7; HRMS (ESI) m/z calcd for $C_{19}H_{20}ClNO$ $[M + H]^+$ 314.1306, found 314.1308.

*4-(3-Methoxy-2-(1-(3-nitrophenyl)vinyl)phenyl)morpholine (**4-24**).* Flash chromatography on silica using petroleum ether/ethyl acetate (5% ethyl acetate in petroleum ether) as the eluent afforded **4-24** (58% yield) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13−8.06 (m, 2H), 7.58 (d, J = 15.6 Hz, 1H), 7.41 (t, J = 8.0 Hz, 1H), 7.34−7.30 (m, 1H), 6.79−6.74 (m, 2H), 6.08 (s, 1H), 5.50 (s, 1H), 3.74 (s, 3H), 3.41−3.39 (m, 4H), 2.83 (s, 4H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 157.9, 151.9, 148.2, 143.3, 140.8, 131.6, 129.5, 128.6, 123.9, 121.6, 120.6, 119.4, 112.6, 106.8, 66.8, 55.8, 51.8; HRMS (ESI) m/z calcd for $C_{19}H_{20}N_2O_4$ $[M + H]^+$ 341.1496, found 341.1499.

*4-(3-Methyl-2-(1-(m-tolyl)vinyl)phenyl)morpholine (**4-25**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-25** (46 mg, 52% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24−7.20 (m, 1H), 7.12 (d, J = 7.6 Hz, 1H), 7.09 (d, J = 8.4 Hz, 1H), 7.03 (d, J = 7.6 Hz, 2H), 6.99 (d, J = 7.6 Hz, 1H), 6.94 (d, J = 8.0 Hz, 1H), 5.92 (d, J = 1.2 Hz, 1H), 5.14 (d, J = 1.2 Hz, 1H), 3.52 (s, 2H), 3.36 (s, 2H), 3.00 (s, 2H), 2.60 (s, 2H), 2.30 (s, 3H), 2.24 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 151.1, 146.4, 141.1, 137.8, 137.7, 137.4, 127.9, 127.8, 127.8, 126.4, 125.7, 123.1, 117.9, 115.4, 67.2, 52.3, 21.5, 20.7; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO$ $[M + H]^+$ 294.1852, found 294.1851.

*4-(3-Methoxy-2-(1-(m-tolyl)vinyl)phenyl)morpholine (**4-26**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-26** (70% yield) as a solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (d, J = 8.8 Hz, 1H), 7.13−7.10 (m, 2H), 7.04−7.01 (m, 2H), 6.74−6.70 (m, 2H), 5.94 (s, 1H), 5.29 (s, 1H), 3.71 (s, 3H), 3.47−3.45 (m, 4H), 2.84 (s, 4H), 2.30 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 158.1, 152.1, 142.9, 141.2, 137.2, 128.7, 127.8, 126.4, 125.8, 123.1, 116.3, 112.4, 106.7, 67.1, 56.1, 51.8, 21.5; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO_2$ $[M + H]^+$ 310.1802, found 310.1804.

*4-(2-(1-(3-Methoxyphenyl)vinyl)-3-methylphenyl)morpholine (**4-27**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-27** (46 mg, 50% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25−7.14 (m, 2H), 7.02 (d, J = 7.6 Hz, 1H), 6.93 (d, J = 8.0 Hz, 1H), 6.83−6.76 (m, 3H), 5.94 (d, J = 1.6 Hz, 1H), 5.16 (d, J = 1.2 Hz, 1H), 3.75 (s, 3H), 3.55 (d, J = 15.2 Hz, 2H), 3.38 (s, 2H), 3.00 (s, 2H), 2.61 (s, 2H), 2.24 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 159.5, 151.1, 146.2, 142.8, 137.8, 137.5, 128.9, 128.0, 125.7, 118.6, 117.9, 115.8, 112.2, 111.9, 67.2, 55.2, 52.3, 20.7; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO_2$ $[M + H]^+$ 310.1802, found 310.1805.

*4-(3-Methoxy-2-(1-(o-tolyl)vinyl)phenyl)morpholine (**4-28**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-28** (50 mg, 54% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27−7.23 (m, 1H), 7.20−7.18 (m, 1H), 7.08−7.07 (m, 3H), 6.77−6.72 (m, 2H), 5.64 (d, J = 2.0 Hz, 1H), 5.50 (d, J = 2.0 Hz, 1H), 3.78 (s, 3H), 3.45 (t, J = 4.4 Hz, 4H), 2.73−2.71 (m, 4H), 2.14 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 157.8, 152.1, 142.5, 142.3, 134.7, 130.5, 129.1, 128.6, 128.1, 126.3, 125.1, 121.0, 113.1, 107.4, 66.8, 55.8, 52.3, 20.8; HRMS (ESI) m/z calcd for $C_{20}H_{23}NO_2$ $[M + H]^+$ 310.1802, found 310.1805.

*4-(2-(3,4-Dihydronaphthalen-1-yl)-3-methoxyphenyl)morpholine (**4-29**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-29** (85 mg, 88% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28−7.24 (m, 1H), 7.13 (d, J = 7.6 Hz, 1H), 7.09−7.05 (m, 1H), 7.00−6.96 (m, 1H), 6.71−6.68 (m, 2H), 6.64 (d, J = 7.6 Hz, 1H), 6.08−6.06 (m, 1H), 3.66 (s, 3H), 3.48−3.39 (m, 4H), 2.99−2.94 (m, 2H), 2.89−2.85 (m, 2H), 2.78−2.74 (m, 2H), 2.53−2.33 (m, 2H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 158.4, 152.4, 135.7, 135.6, 133.1, 129.2, 128.5, 127.1, 126.2, 125.9, 124.0, 123.4, 111.8, 106.4, 67.1, 56.0, 51.6, 28.1, 23.5; HRMS (ESI) m/z calcd for $C_{21}H_{23}NO_2$ $[M + H]^+$ 322.1802, found 322.1804; EA calcd C 78.47%, H 7.21%, N 4.36%, found C 78.03%, H 6.97%, N 4.04%.

*4-(2-(2H-Chromen-4-yl)-3-methoxyphenyl)morpholine (**4-30**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-30** (69 mg, 71% yield) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30−7.26 (m, 1H), 7.09−7.05 (m, 1H), 6.85 (dd, J = 1.2 Hz, 8.0 Hz, 1H), 6.75−6.67 (m, 3H), 6.64−6.62 (m, 1H), 5.83−5.81 (m, 1H), 4.94−4.90 (m, 1H), 4.86−4.81 (m, 1H), 3.70 (s, 3H), 3.48−3.46 (m, 4H), 2.99−2.94 (m, 2H), 2.82−2.77 (m, 2H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 158.3, 154.6, 152.3, 130.8, 129.1, 128.4, 125.1, 124.0, 122.4, 120.8, 120.6, 115.7, 111.8, 106.1, 67.1, 65.3, 55.9, 51.7; HRMS (ESI) m/z calcd for $C_{20}H_{21}NO_3$ $[M + H]^+$ 324.1594, found 324.1592.

*4-(3-Methyl-2-(1-(naphthalen-2-yl)vinyl)phenyl)morpholine (**4-31**).* Flash chromatography on silica using petroleum ether/ethyl acetate (4% ethyl acetate in petroleum ether) as the eluent afforded **4-31** (46 mg, 47% yield) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79−7.73 (m, 2H), 7.69−7.66 (m, 1H), 7.54−7.50 (m, 2H), 7.40−7.38 (m, 2H), 7.28−7.24 (m, 1H), 7.07 (d, J = 7.6 Hz, 1H), 6.97 (d, J = 7.6 Hz, 1H), 6.07 (d, J = 1.2 Hz, 1H), 5.26 (d, J = 1.2 Hz, 1H), 3.45 (s, 2H), 3.29 (s, 2H), 3.01 (s, 2H), 2.60 (s, 2H), 2.27 (s, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 151.2, 146.2, 138.4, 137.8, 137.5, 133.3, 132.8, 128.1, 128.0, 127.6, 127.5, 125.9, 125.8, 125.6, 124.4, 124.3, 118.0, 116.1, 67.1, 52.3, 20.7; HRMS (ESI) m/z calcd for $C_{23}H_{23}NO$ $[M + H]^+$ 330.1852, found 330.1854; EA calcd C 83.85%, H 7.04%, N 4.25%, found C 83.80%, H 6.93%, N 3.90%.

General Procedure for the Preparation of 6a. A dried Schlenk tube under an argon atmosphere was charged with aryl iodide **1a** (65.4 mg, 0.3 mmol, 1.0 equiv), N-benzoyloxyamine **2a** (124 mg, 0.45 mmol, 1.5 equiv), α-diazocarbonyl compound **5a** (73.4 mg, 0.36 mmol, 1.2 equiv), $Pd(OAc)_2$ (6.7 mg, 0.03 mmol, 10 mol %), TFP (14 mg, 0.06 mg, 20 mol %), norbornene (56 mg, 0.60 mmol, 2.0 equiv), Cs_2CO_3 (215 mg, 0.66 mmol, 2.2 equiv), and DCE (3.0 mL). The mixture was stirred at room temperature for 15 min and then at 60 °C for 30 h. The resulting mixture was cooled to room temperature and filtered through Celite with EtOAc as the eluent. The solvents were evaporated under reduced pressure, and the residue was purified by flash chromatography on silica gel using petroleum ether/ethyl acetate to afford pure **6a**.

*(E)-Ethyl 2-(2-Methyl-6-morpholinophenyl)-3-phenylacrylate (**6a**).* Flash chromatography on silica using petroleum ether/ethyl acetate (5% ethyl acetate in petroleum ether) as the eluent afforded **6a** (60 mg, 57% yield) as a colorless solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 (s, 1H), 7.31−7.26 (m, 1H), 7.23−7.16 (m, 3H), 7.08 (d, J = 7.2 Hz, 2H), 7.00−6.98 (m, 2H), 4.26−4.18 (m, 2H), 3.68−3.63 (m, 2H), 3.60−3.55 (m, 2H), 2.91−2.86 (m, 2H), 2.74−2.68 (m, 2H), 2.00 (s, 3H), 1.25−1.21 (m, 3H); ^{13}C{H} NMR (100 MHz, $CDCl_3$) δ 168.8, 151.5, 138.9, 137.5, 135.4, 132.6, 130.8, 129.4, 129.1, 128.8, 128.5, 126.1, 117.7, 67.4, 60.8, 52.3, 19.7, 14.4; HRMS (ESI) m/z calcd for $C_{22}H_{25}NO_3$ $[M + H]^+$ 352.1907, found 352.1891.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Copies of ^{1}H and ^{13}C spectra for new compounds and crystallographic data for **4-1** and **6a** (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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