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Iridium-Catalyzed Direct Arene C–H Bond Amidation with Sulfonyl- and Aryl Azides

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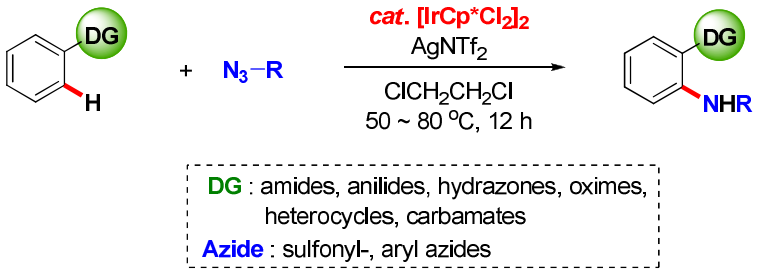
Abstract

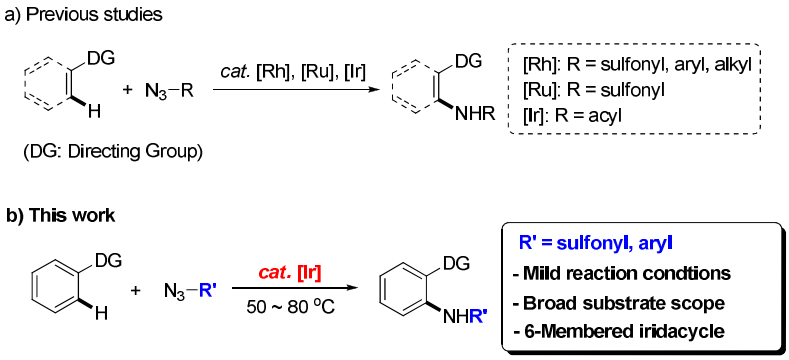


Iridium-catalyzed direct ortho C–H amidation of arenes has been shown to work well with sulfonyl- and aryl azides as the nitrogen source. The reaction proceeds efficiently with a broad range of substrates bearing conventional directing groups with excellent functional group compatibility under mild conditions. In addition, substrates forming not only 5- but also 6-membered iridacycle intermediates undergo the C–H amidation with high selectivity.

Transition metal-catalyzed C–N bond formation has attracted a great attention because of its high synthetic values in diverse research areas.[1] In particular, the Cu- and Pd-catalyzed *N*-arylation of aryl(pseudo)halides has been extensively explored.[2-3] More recently, a direct C–H amination strategy has been actively investigated using arenes instead of aryl halides to react with either amines or pre-activated amino precursors.[4] In these procedures, oxidative conditions are applied when amines are allowed to react.[5] On the other hand, the amination takes place in the absence of external oxidants when pre-activated amino precursors such as halogenated amines are employed, but generating halide salts as the byproducts.[6]

In our continuing efforts to develop efficient and selective C–N bond-forming reactions,[7] we recently disclosed Rh- and Ru-catalyzed direct C–H amination protocols using organic azides as the amino source (Scheme 1a).[8-9]

Scheme 1.

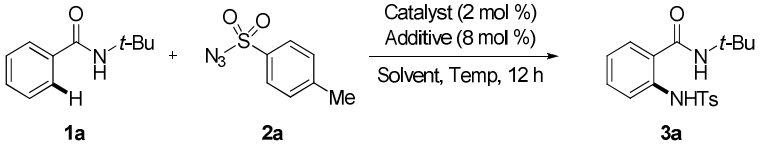


The reactions are characterized to have wide substrate scope, mild conditions, and high functional group tolerance. Significantly, the amination proceeds in the absence of external oxidants to release molecular nitrogen as the single byproduct. It was demonstrated that a wide range of azides could be applicable upon the choice of catalytic systems.[10-11]

More recently, acyl azides were also efficiently utilized in the direct amidation of arenes and alkenes under Ir-catalyzed conditions.[12] Described herein is a new aspect of this chemistry: not only the scope of amino sources are expanded now to include sulfonyl- and aryl azides, but also the amidation of a new type of substrates forming a 6-membered iridacycle intermediate can be successfully amidated (Scheme 1b).

We initially tried to optimize the amidation conditions in a reaction of *N*-*tert*-butylbenzamide (**1a**) with *p*-toluenesulfonyl azide (**2a**) (Table 1). High yield of the desired product **3a** was obtained at 80 °C when $[IrCp^*Cl_2]_2$ (2 mol %) was used in the presence of $AgNTf_2$ additive (entry 2), and the reaction did not proceed in the absence of a silver additive (entry 1). While a similar yield was also obtained at 50 °C (entry 3), different silver species and solvents other than 1,2-dichloroethane were less effective (entries 4–8). It is noteworthy that the amidation took place even at room temperature albeit with slightly lower yield under the present catalyst system (entry 9). Interestingly, previously reported other catalytic systems[8-9] including $[RhCp^*Cl_2]_2$ and $[Ru(p\text{-cymene})Cl_2]_2$ displayed much lower activity when compared to the current iridium system at 50 °C (entries 10–11).

Table 1. Optimization of the Ir-Catalyzed Amidation[a]



1a **2a** **3a**

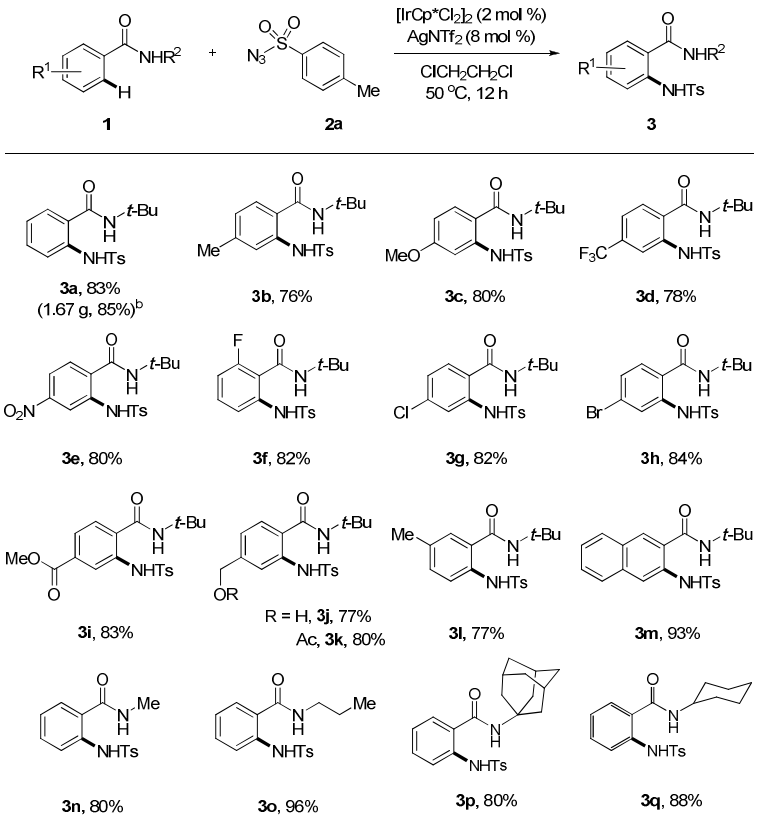
entry	catalyst	additive	solvent	temp (°C)	yield (%)[b]
1	$[IrCp^*Cl_2]_2$	-	$ClCH_2CH_2Cl$	80	N.R.
2	**$[IrCp^*Cl_2]_2$**	**$AgNTf_2$**	**$ClCH_2CH_2Cl$**	**80**	**90**
3	$[IrCp^*Cl_2]_2$	$AgNTf_2$	$ClCH_2CH_2Cl$	**50**	**87**
4	$[IrCp^*Cl_2]_2$	$AgSbF_6$	$ClCH_2CH_2Cl$	50	84
5	$[IrCp^*Cl_2]_2$	$AgPF_6$	$ClCH_2CH_2Cl$	50	57
6	$[IrCp^*Cl_2]_2$	$AgBF_4$	$ClCH_2CH_2Cl$	50	75
7	$[IrCp^*Cl_2]_2$	$AgNTf_2$	Toluene	50	14
8	$[IrCp^*Cl_2]_2$	$AgNTf_2$	*t*-AmylOH	50	32
9	$[IrCp^*Cl_2]_2$	$AgNTf_2$	$ClCH_2CH_2Cl$	**25**	**78**
10	$[RhCp^*Cl_2]_2$	$AgSbF_6$	$ClCH_2CH_2Cl$	50	3
11	$[Ru(p\text{-cymene})Cl_2]_2$	$AgNTf_2$	$ClCH_2CH_2Cl$	50	15

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (1.1 equiv), catalyst (2 mol %), additive (8 mol %) in solvent (0.5 mL) at the indicated temperature for 12 h. [b] Yield was determined by ^1H NMR spectroscopy by using anisol as an internal standard.

With the optimized conditions in hand, we then investigated the scope of benzamide substrates in reaction with *p*-toluenesulfonyl azide (Scheme 2). Electronic variation of substituents did not much influence the reaction efficiency (**3a**–**3e**). The amidation conditions were compatible with various functional groups such as fluoro, chloro, bromo, ester, free hydroxy and its acetate (**3f**–**3k**). In addition, the amidation was highly regioselective as proved in the reaction of *meta*-substituted benzamide and 2-naphthamide (**3l** and **3m**, respectively). Variation of the *N*-alkyl moiety of secondary benzamides was observed to be highly flexible (**3n**–**3q**). Moreover, the amidation of benzamide was easily scaled-up without difficulty even using 1 mol % of the Ir catalyst (**3a**).

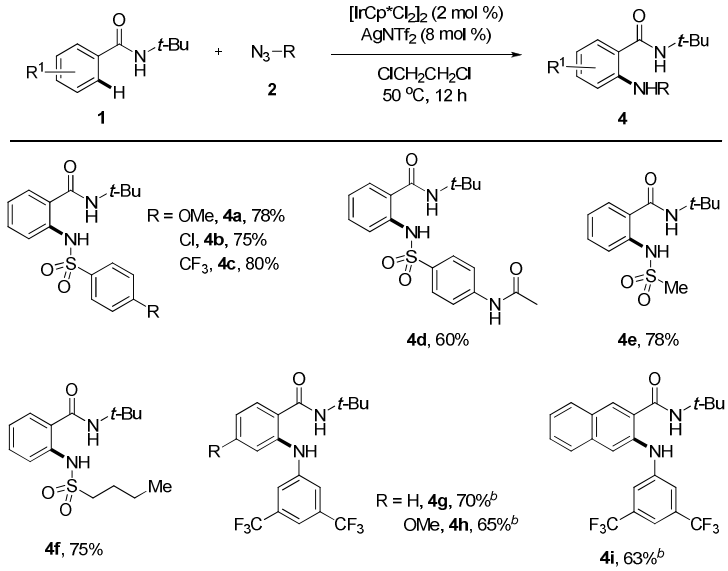
The scope of organic azides was subsequently examined in the amidation of *N*-*tert*-butylbenzamide (Scheme 3). Arenesulfonyl azides substituted with methoxy, chloro, trifluoromethyl, and acetamido groups were reacted without difficulty (**4a**–**4d**). Aliphatic variants also worked well (**4e**–**4f**). In addition, aryl azides readily participated in the direct amination to provide *N,N*-diarylamines (**4g**–**4i**).

Scheme 2. Scope of Benzamides[a]



[a] Reaction conditions : **1** (0.2 mmol), **2a** (1.1 equiv), $[IrCp^*Cl_2]_2$ (2 mol %), $AgNTf_2$ (8 mol %) in 1,2-dichloroethane (0.5 mL) at 50 °C for 12 h. [b] **1** (1.0 g, 5.6 mmol), **2a** (1.0 equiv), $[IrCp^*Cl_2]_2$ (1 mol %), $AgNTf_2$ (4 mol %) in 1,2-dichloroethane (7.5 mL) at 50 °C for 12 h.

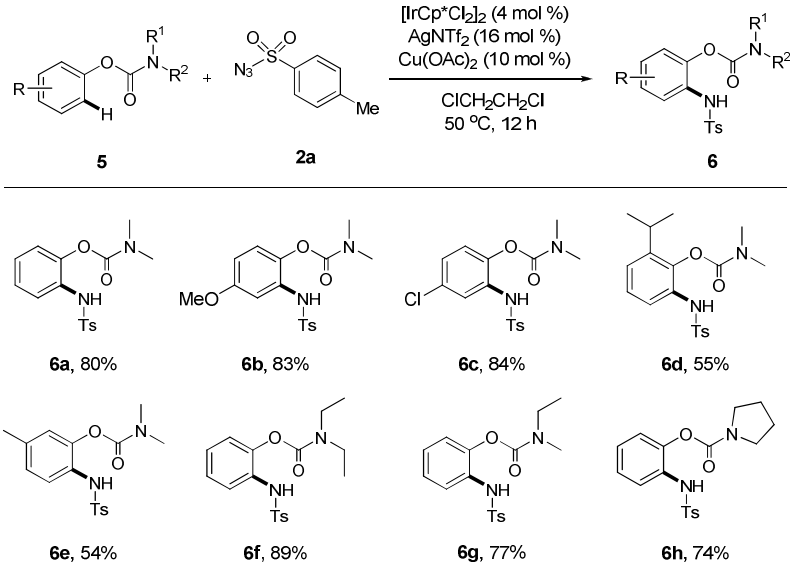
Scheme 3. Scope of Sulfonyl- and Aryl Azides[a]



[a] Reaction conditions: **1** (0.2 mmol), **2** (1.1 equiv), $[IrCp^*Cl_2]_2$ (2 mol %), $AgNTf_2$ (8 mol %) in 1,2-dichloroethane (0.5 mL) at 50 °C for 12 h. [b] Substrates (1.8 equiv, 0.36mmol) were used.

After successful exploration of the scope of benzamides in the direct amidation, we turned our attention to substrates bearing readily removable directing groups (Scheme 4).[13]

Scheme 4. Scope of Aryl Carbamates[a]



[a] Reaction conditions: **5** (1.8 equiv, 0.36 mmol), **2a** (0.2 mmol), $[IrCp^*Cl_2]_2$ (4 mol %), $AgNTf_2$ (16 mol %), $Cu(OAc)_2$ (10 mol %) in 1,2-dichloroethane (0.5 mL) at 50 °C for 12 h.

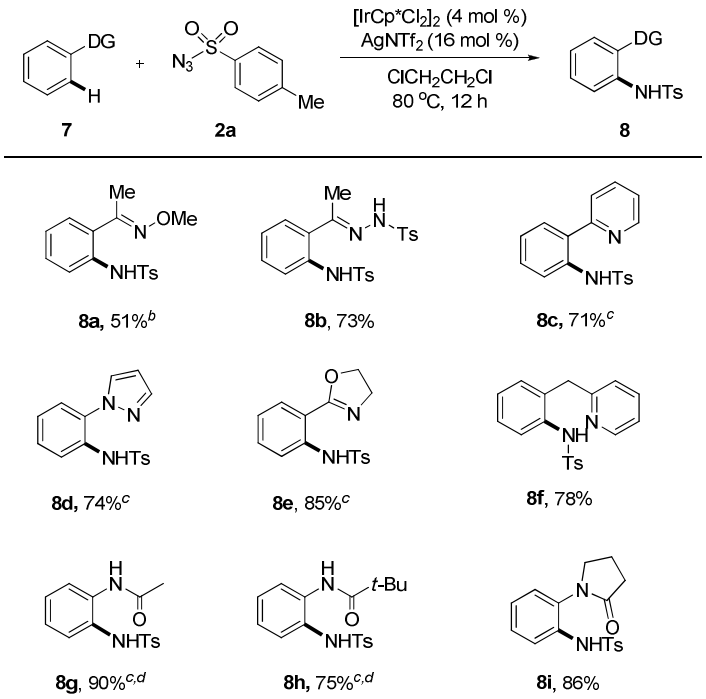
We decided to examine aryl carbamates first since they are also easily prepared from the corresponding phenols.[14] Those substrates were found to undergo the amidation with high efficiency under slightly modified conditions, but requiring acetate additive in this case. Among acetate additives screened, $Cu(OAc)_2$ showed the highest reaction efficiency while NaOAc provided slightly lower yields. Although the exact role of acetate additive is not clear at this stage, it is assumed that an acetate facilitates the ligand exchange in the cationic iridium species to increase the catalytic activity in the C–H activation process.[15]

The amidation took place smoothly irrespective of the electronic nature of substrates (**6a**–**6c**). It was observed that substituents positioned at the *ortho* or *meta* relative to the carbamate group slightly decreased the reactivity (**6d**–**6e**). Variation of *N*-substituents of aryl carbamates did not result in any deteriorating effects (**6f**–**6h**). In a sharp contrast, our previous Rh- and Ru-catalytic systems were ineffective for this type of substrates (<5% yields).

The facile reaction of aryl carbamates observed above is significant in that the Ir-catalyzed direct C–H amidation approach can now be applicable to substrates forming not only 5- but also 6-membered iridacycle intermediates.

Additional substrates bearing various coordinating groups were next investigated (Scheme 5).

Scheme 5. Scope of Various Chelating Groups[a]



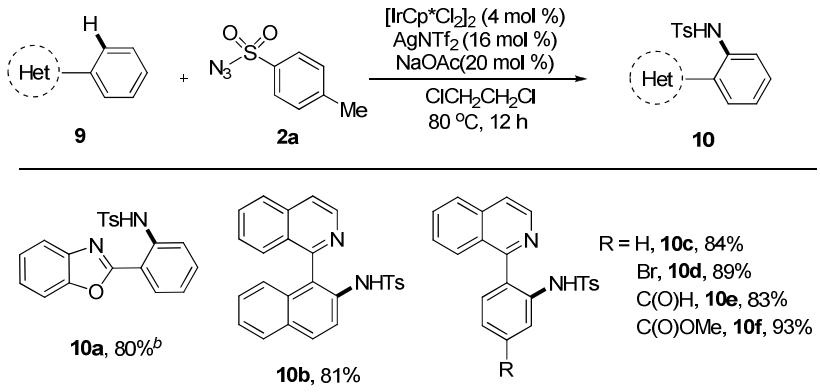
[a] Reaction conditions: **7** (0.2 mmol), **2a** (1.1 equiv), $[IrCp^*Cl_2]_2$ (4 mol %), $AgNTf_2$ (16 mol %) in 1,2-dichloroethane (0.5 mL) at 80 °C for 12 h. [b] For 24 h. [c] Substrates (1.8 equiv, 0.36 mmol) were used. [d] At 50 °C.

We were pleased to see that representative chelates such as ketoxime, substituted hydrazone, 2-pyridine, 2-pyrazol, and 2-azoline all facilitated the *ortho* C–H amidation albeit at slightly higher temperature (**8a**–**8e**). Moreover, 2-benzylpyridine, anilides, and *N*-phenyl-pyrrolidone underwent the amidation in high yields presumabably through the corresponding 6-membered iridacycles (**8f**–**8i**).

Direct C–H amidation of heterocycles was briefly examined since the products are widely utilized in medicinal and coordination chemistry (Scheme 6).[16] Reaction of 2-phenylbenzoxazole was smooth to afford the corresponding amidated product (**10a**) that is often used as a precursor of biosensors or biologically active

ligands. 1-Arylisoquinoline derivatives were also amidated in the presence of acetate additives. As mentioned above, we assume that an acetate additive facilitates C–H bond activation process for substrates especially showing low reactivity.[15] In this case, unlike aryl carbamates, NaOAc displayed higher additive effects. 1-(2-Amidonaphthyl)isoquinoline (**10b**) was obtained in high yield, which was utilized in catalysis or for the stereoselective synthesis by forming chiral β-diketimine-supported metal complexes.[17] Again, an excellent level of functional group tolerance was observed in the amidation of 1-arylisoquinoline derivatives (**10d**–**10f**).[18]

Scheme 6. Scope of Benzoxazole and Isoquinolines[a]



[a] Reaction conditions: **9** (0.2 mmol), **2a** (1.1 equiv), $[IrCp^*Cl_2]_2$ (4 mol %), $AgNTf_2$ (16 mol %), NaOAc(20 mol %) in 1,2-dichloroethane (0.5 mL) at 80 °C for 12 h. [b] Substrate (1.8 equiv, 0.36 mmol) was used in the absence of NaOAc.

Described herein is the Ir-catalyzed direct C(sp^2)–H amidation of arenes with sulfonyl- and aryl azides as the amino source. The procedure is convenient to carry out under mild conditions, and a wide range of substrates forming not only 5- but also 6-membered iridacycle intermediates are efficiently amidated with high functional group tolerance. The amidated products have versatile utilities in such areas as organic synthesis and coordination or medicinal chemistry.

Experimental Section

General Methods. Unless otherwise stated, all commercial reagents and solvents were used without additional purification. Thin layer chromatography (TLC) was performed on 0.25 mm silica gel 60 plates. Visualization on TLC was achieved by the use of UV light (254 nm). Column chromatography was undertaken on silica gel using a proper eluent system. ^{1}H NMR was recorded 400 MHz spectrometer, referenced to the appropriate solvent peak

or 0.0 ppm for tetramethylsilane. The following abbreviations were used to describe peak splitting patterns when appropriate: br = broad, s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublet, td = triplet of doublet, ddd = doublet of doublet of doublet, m = multiplet. Coupling constants, *J*, were reported in hertz unit (Hz). ^{13}C NMR was recorded on 100 MHz spectrometer, referenced to the center of a triplet at 77.0 ppm of chloroform-*d*. High resolution mass spectra (HRMS) were acquired with Time-of-flight-Quadrupole (TOF-Q) via electron spray ionization (ESI) or with a magnetic sector–electric sector via electron ionization (EI). Infrared (IR) spectra were recorded neat in 0.5 mm path length using a NaCl cell. Frequencies are given in reciprocal centimeters (cm^{-1}) and only selected absorbance is reported. All solvents were freshly distilled before used, and other reagents or catalysts were directly used from purchased without further purification unless otherwise specified.

Preparation of substrates. Benzamides **1**,[8b] organic azides **2**,[9] aryl carbamates **5**,[14b] ketoximes (**7a**),[19] tosylhydrazone derivatives (**7b**),[20] anilides (**7g**–**7h**),[21] 2-phenylbenzoxazole (**9a**),[22] and 1-arylisoquinoline derivatives (**9b**–**9f**)[23] were prepared according to the previously reported procedures.

General procedure for the amidation of benzamides with organic azides. To a screw capped vial with a spinvane triangular-shaped Teflon stir bar were added benzamide (**1**, 0.2 mmol), sulfonyl- or aryl azide (**2**, 0.22 mmol), $[IrCp^*Cl_2]_2$ (3.2 mg, 0.004 mmol, 2 mol %), $AgNTf_2$ (6.2 mg, 0.016 mmol, 8 mol %) and 1,2-dichloroethane (0.5 mL) under atmospheric conditions. The reaction mixture was stirred in a pre-heated oil bath at 50 ^{o}C for 12 h, filtered through a pad of celite and then washed with EtOAc (10 mL × 3). Organic solvents were removed under reduced pressure and the residue was purified by chromatography on silica gel (*n*-hexane/EtOAc) to give the desired product **3** or **4**.

***N*-(*tert*-Butyl)-2-(4-methylphenylsulfonamido)-4-nitrobenzamide (3e).** White solid (63.1 mg, 80%); m.p. 201–203 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.90 (s, 1H), 8.42 (d, *J* = 2.2 Hz, 1H), 7.74 (dd, *J* = 8.6, 2.2 Hz, 1H), 7.70 (d, *J* = 8.3 Hz, 2H), 7.53 (d, *J* = 8.6 Hz, 1H), 7.26 – 7.20 (m, 2H), 6.20 (s, 1H), 2.37 (s, 3H), 1.44 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 149.5, 144.4, 139.8, 136.0, 129.9, 128.2, 127.2, 126.8, 117.4, 114.8,

53.0, 28.5, 21.5; IR (NaCl) 3415, 2087, 1644, 1399, 1352, 1254, 1161, 1092, 966, 769, 618 cm^{-1}; HRMS (ESI) m/z calcd. for $C_{18}H_{21}N_3O_5S$ $[M+Na]^+$: 414.1100, found: 414.1087. R_f (*n*-hexane/EtOAc, 3/1): 0.34

***N*-(*tert*-Butyl)-2-fluoro-6-(4-methylphenylsulfonamido)benzamide (3f)**. White solid (58.5 mg, 80%); m.p. 134–136 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 11.33 (s, 1H), 7.69 (d, J = 8.4 Hz, 2H), 7.49 (m, J = 8.5, 0.9 Hz, 1H), 7.32 – 7.24 (m, 1H), 7.21 (m, J = 8.0, 0.7 Hz, 2H), 6.76 (ddd, J = 12.0, 8.3, 1.1 Hz, 1H), 6.41 (d, J = 13.8 Hz, 1H), 2.37 (s, 3H), 1.40 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 164.0, 161.6, 159.2, 143.6, 141.0, 141.0, 136.7, 132.4, 132.3, 129.6, 127.2, 116.9, 116.9, 110.9, 110.8, 110.7, 52.4, 28.7, 21.5; IR (NaCl) 3464, 3381, 2972, 2086, 1644, 1614, 1580, 1537, 1462, 1368, 1311, 1232, 1185, 1163, 1092, 1024, 805, 706, 661 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{21}FN_2O_3S$ $[M]^+$: 364.1257, found: 364.1255; R_f (*n*-hexane/EtOAc, 3/1): 0.35.

4-Bromo-*N*-(*tert*-butyl)-2-(4-methylphenylsulfonamido)benzamide (3h). Light yellow solid (71.1 mg, 84%); m.p. 201–203 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.93 (s, 1H), 7.84 (d, J = 1.9 Hz, 1H), 7.68 (d, J = 8.4 Hz, 2H), 7.24–7.18 (m, 2H), 7.19–7.06 (m, 2H), 5.85 (s, 1H), 2.37 (s, 3H), 1.39 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 143.8, 140.0, 136.5, 129.7, 127.8, 127.1, 126.4, 126.3, 123.9, 121.0, 52.4, 28.6, 21.5; IR (NaCl) 3392, 2961, 2925, 2870, 1639, 1588, 1566, 1529, 1479, 1456, 1375, 1335, 1251, 1185, 1089, 941, 915, 774, 686 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{21}BrN_2O_3S$ $[M]^+$: 424.0456, found: 424.0455; R_f (*n*-hexane/EtOAc, 3/1): 0.32.

2-(4-Acetamidophenylsulfonamido)-*N*-(*tert*-butyl)benzamide (4d). White solid (46.8 mg, 60%); m.p. 167–169 °C; ^1H NMR (400 MHz, , $CDCl_3$) δ 10.85 (s, 1H), 8.04 (s, 1H), 7.64–7.57 (m, 3H), 7.51 (d, J = 8.8 Hz, 2H), 7.38–7.28 (m, 2H), 7.02 (td, J = 7.4, 1.1 Hz, 1H), 6.00 (s, 1H), 2.14 (s, 3H), 1.39 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.1, 168.1, 142.2, 138.3, 133.9, 132.2, 128.2, 126.9, 123.8, 123.0, 121.5, 119.4, 52.3, 28.6, 24.5; IR (NaCl) 3355, 3191, 3114, 3062, 2971, 2929, 1686, 1637, 1593, 1532, 1493, 1402, 1368, 1330, 1265, 1186, 1159, 1093, 937, 612, 564, cm^{-1}; HRMS (EI) m/z calcd. for $C_{19}H_{23}N_3O_4S$ $[M]^+$: 389.1409, found: 389.1406; R_f (*n*-hexane/EtOAc, 1/1): 0.28.

2-[{3,5-Bis(trifluoromethyl)phenyl}amino]-*N*-(*tert*-butyl)-4-methoxybenzamide (4h). White solid (57.8 mg, 65%); m.p. 123–126 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.14 (s, 1H), 7.62 (s, 2H), 7.41 (d, J = 0.7 Hz,

1H), 7.35 (d, J = 8.7 Hz, 1H), 6.86 (d, J = 2.5 Hz, 1H), 6.43 (dd, J = 8.7, 2.5 Hz, 1H), 5.89 (s, 1H), 3.77 (s, 3H), 1.46 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 162.6, 145.1, 143.4, 133.1, 132.8, 132.5, 132.1, 129.2, 124.7, 122.0, 118.9, 118.9, 114.5, 114.5, 114.4, 113.6, 106.5, 100.4, 55.3, 51.8, 28.9; IR (NaCl) 3330, 2970, 1632, 1584, 1526, 1473, 1420, 1382, 1289, 1221, 1179, 1130, 1040, 987, 874, 771, 683 cm^{-1}; HRMS (EI) m/z calcd. for $C_{20}H_{20}F_6N_2O_2$ $[M]^+$: 434.1429, found: 434.1426; R_f (*n*-hexane/EtOAc 5/1): 0.52.

Analytic data of amidated benzamide products [(**3a-3d**, **3g**, **3i-3q**, **4a-4c**, **4f**),[9] **4e**,[8a] (**4g**, **4i**)[8b]] has been reported earlier by our group.

General procedure for the amidation of aryl carbamates with *p*-toluenesulfonyl azide. To a screw capped vial with a spinvane triangular-shaped Teflon stir bar were added aryl carbamate (**5**, 0.36 mmol), *p*-toluenesulfonyl azide (**2a**, 0.2 mmol), $[IrCp^*Cl_2]_2$ (6.4 mg, 0.008 mmol, 4 mol %), $AgNTf_2$ (12.4 mg, 0.032 mmol, 16 mol %), $Cu(OAc)_2$ (3.6 mg, 0.02 mmol, 10 mol %) and 1,2-dichloroethane (0.5 mL) under atmospheric conditions. The reaction mixture was stirred in a pre-heated oil bath at 50 °C for 12 h, filtered through a pad of celite and then washed with EtOAc (10 mL × 3). Organic solvents were removed under reduced pressure and the residue was purified by chromatography on silica gel (*n*-hexane/EtOAc) to give the desired product **6**.

2-(4-Methylphenylsulfonamido)phenyl dimethyl carbamate (6a). White solid (53.6 mg, 80%); m.p. 127–129 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.6 –7.58 (m, 2H), 7.51–7.45 (m, 1H), 7.2 –7.17 (m, 2H), 7.16–7.10 (m, 2H), 7.07 (s, 1H), 7.02–6.96 (m, 1H), 2.92 (d, J = 10.9 Hz, 6H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.7, 143.7, 143.6, 136.8, 129.5, 128.7, 127.0, 126.4, 125.9, 124.9, 122.6, 46.6, 46.4, 25.7, 24.9, 21.5; IR (NaCl) 3435, 1710, 1639, 1497, 1389, 1335, 1246, 1164, 1092, 919, 840, 814, 753, 665 cm^{-1}; HRMS (EI) m/z calcd. for $C_{16}H_{18}N_2O_4S$ $[M]^+$: 334.0987, found: 334.0986; R_f (*n*-hexane/EtOAc, 2/1): 0.30.

4-Methoxy-2-(4-methylphenylsulfonamido)phenyl dimethylcarbamate (6b). Yellow solid (60.3 mg, 83%); m.p. 109–111 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, J = 8.3 Hz, 2H), 7.24–7.20 (m, 2H), 7.04 (d, J = 3.0 Hz, 1H), 6.94 (s, 1H), 6.88 (d, J = 8.9 Hz, 1H), 6.64 (dd, J = 8.9, 3.0 Hz, 1H), 3.75 (s, 3H), 2.92 (d, J = 10.8 Hz, 6H), 2.38 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2, 154.0, 143.8, 137.0, 136.6, 129.6, 127.1, 123.2, 111.9, 109.4, 55.7, 36.8, 36.4, 21.5; IR (NaCl) 3267, 2936, 1728, 1600, 1511, 1446, 1387, 1308, 1253, 1208,

1159, 1066, 1038, 970, 854, 755, 667 cm^{-1}; HRMS (EI) m/z calcd. for $C_{17}H_{20}N_2O_5S$ $[M]^+$: 364.1093, found: 364.1090; R_f (*n*-hexane/EtOAc, 2/1): 0.37.

4-Chloro-2-(4-methylphenylsulfonamido)phenyl dimethyl carbamate (6c). Yellow solid (62.3 mg, 84%); m.p. 135–137 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, J = 8.4 Hz, 2H), 7.51 (d, J = 2.5 Hz, 1H), 7.35 (s, 1H), 7.22 (d, J = 8.5 Hz, 2H), 7.06 (dd, J = 8.7, 2.5 Hz, 1H), 6.92 (d, J = 8.7 Hz, 1H), 2.91 (d, J = 2.3 Hz, 6H), 2.38 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.3, 144.0, 141.8, 136.2, 131.0, 130.0, 129.6, 127.0, 125.9, 123.9, 123.8, 36.8, 36.4, 29.6, 21.5; IR (NaCl) 3440, 1712, 1641, 1493, 1385, 1335, 1250, 1163, 1117, 1092, 939, 813, 675 cm^{-1}; HRMS (EI) m/z calcd. for $C_{16}H_{17}ClN_2O_4S$ $[M]^+$: 368.0598, found: 368.0596; R_f (*n*-hexane/EtOAc, 3/1): 0.26.

2-Isopropyl-6-(4-methylphenylsulfonamido)phenyl dimethyl carbamate (6d). Brown solid (41.8 mg, 55%); m.p. 84–86 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.66–7.57 (m, 2H), 7.31–7.25 (m, 1H), 7.23–7.18 (m, 2H), 7.17–7.05 (m, 2H), 6.94 (s, 1H), 2.97 (s, 3H), 2.92 (s, 3H), 2.91–2.81 (m, 1H), 2.37 (s, 3H), 1.11 (d, J = 6.9 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.7, 143.4, 142.0, 141.4, 137.1, 129.4, 127.2, 126.2, 123.9, 123.2, 37.0, 36.3, 27.7, 22.7, 21.5; IR (NaCl) 3443, 2966, 2105, 1643, 1474, 1400, 1325, 1164, 1092, 983 cm^{-1}; HRMS (EI) m/z calcd. for $C_{19}H_{24}N_2O_4S$ $[M]^+$: 376.1457, found: 376.1455; R_f (*n*-hexane/EtOAc, 3/1): 0.16.

5-Methyl-2-(4-methylphenylsulfonamido)phenyl dimethyl carbamate (6e). Light brown solid (37.7 mg, 54%); m.p. 147–149 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, J = 8.3 Hz, 2H), 7.34 (d, J = 8.2 Hz, 1H), 7.23–7.16 (m, 2H), 6.98–6.90 (m, 1H), 6.88 (s, 1H), 6.81 (s, 1H), 2.92 (s, 3H), 2.86 (s, 3H), 2.37 (s, 3H), 2.27 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.7, 144.1, 143.5, 137.1, 136.9, 129.5, 127.1, 126.7, 125.9, 125.8, 123.1, 36.8, 36.4, 21.5, 20.9; IR (NaCl) 3269, 2926, 1729, 1597, 1509, 1448, 1407, 1384, 1334, 1263, 1165, 1114, 1092, 1019, 910, 882, 756, 527 cm^{-1}; HRMS (EI) m/z calcd. for $C_{17}H_{20}N_2O_4S$ $[M]^+$: 348.1144, found: 348.1147; R_f (*n*-hexane/EtOAc, 2/1): 0.29.

2-(4-Methylphenylsulfonamido)phenyl diethylcarbamate (6f). White solid (64.2 mg, 89%); m.p. 103–105 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, J = 8.4 Hz, 2H), 7.52–7.42 (m, 1H), 7.20 (d, J = 7.9 Hz, 2H), 7.17–7.05 (m, 2H), 7.03–6.98 (m, 1H), 6.95 (s, 1H), 3.32 (q, J = 7.2 Hz, 2H), 3.22 (q, J = 7.1 Hz, 2H), 2.37 (s,

3H), 1.16 (dt, J = 11.8, 7.2 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.0, 143.9, 143.6, 136.9, 129.5, 128.9, 127.0, 126.5, 126.0, 125.3, 122.5, 42.5, 42.0, 21.5, 14.2, 13.3; IR (NaCl) 3264, 3067, 2976, 2935, 2877, 1918, 1723, 1600, 1498, 1427, 1336, 1247, 1164, 1093, 1043, 961, 814, 753, 666, 568 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{22}N_2O_4S$ $[M]^+$: 362.1300, found: 362.1302; R_f (*n*-hexane/EtOAc, 2/1): 0.33.

(4-Methylphenylsulfonamido)phenyl ethyl(meth-yl) carbamate (6g). White solid (53.7 mg, 77%); m.p. 119–121 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63–7.55 (m, 2H), 7.52–7.43 (m, 1H), 7.19 (d, J = 8.6 Hz, 2H), 7.16–7.08 (m, 2H), 7.08–6.91 (m, 2H), 3.29 (dq, J = 24.6, 7.2 Hz, 2H), 2.88 (d, J = 26.2 Hz, 3H), 2.37 (s, 3H), 1.15 (td, J = 7.1, 4.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.4, 153.2, 144.0, 143.9, 143.7, 143.6, 136.8, 129.5, 128.9, 128.8, 127.0, 127.0, 126.5, 126.5, 126.0, 125.9, 125.4, 125.1, 122.6, 44.3, 44.1, 34.3, 33.8, 21.5, 13.3, 12.4; IR (NaCl) 3444, 2087, 1644, 1498, 1402, 1335, 1304, 1246, 1163, 1091, 752, 665 cm^{-1}; HRMS (EI) m/z calcd. for $C_{17}H_{20}N_2O_4S$ $[M]^+$: 348.1144, found: 348.1140; R_f (*n*-hexane/EtOAc, 3/1): 0.22.

2-(4-Methylphenylsulfonamido)phenylpyrrolidin-e-1-carboxylate (**6h**). Bright yellow solid (53.5 mg, 74%); m.p. 170–172 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, J = 8.3 Hz, 2H), 7.52–7.45 (m, 1H), 7.19 (d, J = 8.0 Hz, 2H), 7.15–7.10 (m, 2H), 7.09 (s, 1H), 7.06–6.99 (m, 1H), 3.42–3.35 (m, 2H), 3.34–3.28 (m, 2H), 2.37 (s, 3H), 1.92 (s, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.7, 143.7, 143.6, 136.8, 129.5, 128.7, 127.0, 126.4, 125.9, 124.9, 122.6, 46.6, 46.4, 25.7, 24.9, 21.5; IR (NaCl) 3266, 2976, 2880, 1727, 1600, 1498, 1414, 1337, 1248, 1120, 1104, 1092, 1058, 1018, 916, 814, 754, 667 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{20}N_2O_4S$ $[M]^+$: 360.1144, found: 360.1145; R_f (*n*-hexane/EtOAc, 2/1): 0.31.

General procedure for the amidation of chelate group-containing arenes with *p*-toluenesulfonyl azide. To a screw capped vial equipped with a spinvane triangular-shaped Teflon stir bar were added chelate group-containing arene (**7** or **9**, 0.2 mmol), *p*-toluenesulfonyl azide (**2a**, indicated molar ratio in Scheme 5 or 6), $[IrCp^*Cl_2]_2$ (6.4 mg, 0.008 mmol, 4 mol %), $AgNTf_2$ (12.4 mg, 0.032 mmol, 16 mol %) and 1,2-dichloroethane (0.5 mL) under atmospheric conditions. [Substrate (**9b-9f**) was used in the presence of NaOAc (3.3 mg, 0.040 mmol, 20 mol %)]. The reaction mixture was stirred in a pre-heated oil bath at the indicated temperature (50 °C or 80 °C) for 12 h. The reaction mixture was cooled to room temperature, filtered through a

pad of celite and then washed with EtOAc (10 mL × 3). Organic solvents were removed under reduced pressure and the residue was purified by chromatography on silica gel (*n*-hexane/EtOAc) to give the desired product **8** or **10.**

(*E*)-*N*-[2-{1-(Methoxyimino)ethyl}phenyl]-4-meth-ylbenzenesulfonamide (8a). Light yellow solid (32.5 mg, 51%); m.p. 127–129 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.75 (s, 1H), 7.63 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.58 (d, *J* = 8.3 Hz, 2H), 7.33–7.22 (m, 2H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.08 (td, *J* = 7.7, 1.3 Hz, 1H), 4.06 (s, 3H), 2.35 (s, 3H), 2.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 143.4, 136.4, 135.8, 129.7, 129.4, 128.4, 127.1, 124.5, 124.1, 121.8, 62.6, 21.5, 13.1; IR (NaCl) 3451, 3175, 2974, 2934, 2852, 2818, 1603, 1498, 1371, 1160, 1091, 919, 565 cm^{-1}; HRMS (EI) m/z calcd. for $C_{16}H_{18}N_2O_3S$ $[M]^+$: 318.1038, found: 318.1036; R_f (*n*-hexane/EtOAc, 3/1): 0.35.

(*E*)-4-Methyl-*N*-[2-{1-(2-tosylhydrazono)ethyl}phenyl]benzenesulfonamide (8b). White solid (65.0 mg, 73%); m.p. 181–183 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.51 (s, 1H), 8.08–8.00 (m, 3H), 7.72 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.57 (d, *J* = 8.3 Hz, 2H), 7.38 (d, *J* = 8.0 Hz, 2H), 7.32–7.20 (m, 2H), 7.15 (d, *J* = 8.0 Hz, 2H), 7.09–7.00 (m, 1H), 2.42 (s, 3H), 2.33 (s, 3H), 1.94 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.6, 145.0, 143.4, 136.5, 136.1, 134.5, 130.4, 130.2, 129.3, 128.6, 128.3, 127.3, 125.4, 124.0, 122.6, 21.7, 21.5, 14.9; IR (NaCl) 3204, 3065, 2924, 2361, 2339, 1599, 1496, 1400, 1338, 1164, 1091, 913, 815, 668 cm^{-1}; HRMS (EI) m/z calcd. for $C_{22}H_{23}N_3O_4S_2$ $[M]^+$: 457.1130, found: 457.1126; R_f (*n*-hexane/EtOAc, 2/1): 0.18.

4-Methyl-*N*-[2-(pyridin-2-yl)phenyl]benzenesulfonamide (8c). Yellow solid(46.1 mg, 71%); m.p. 106–108 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.14 (s, 1H), 8.63–8.56 (m, 1H), 7.80–7.65 (m, 2H), 7.52 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.42–7.29 (m, 4H), 7.24 (ddd, *J* = 7.5, 4.9, 1.1 Hz, 1H), 7.15 (td, *J* = 7.6, 1.3 Hz, 1H), 6.96 (d, *J* = 8.7 Hz, 2H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.1, 147.4, 142.9, 137.4, 136.8, 136.4, 130.1, 129.1, 128.5, 127.5, 126.7, 124.7, 123.4, 122.2, 122.1, 21.4; IR (NaCl) 3448, 2098, 1640, 1592, 1498, 1474, 1431, 1337, 1184, 1091, 927, 754, 657 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{16}N_2O_2S$ $[M]^+$: 324.0932, found: 324.0934; R_f (*n*-hexane/EtOAc, 5/1): 0.25.

***N*-[2-(1*H*-Pyrazol-1-yl)phenyl]-4-methylbenzenesulfonamide (8d).** White solid (46.4 mg, 74%); m.p. 94–96 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.04 (s, 1H), 7.88–7.63 (m, 2H), 7.43–7.23 (m, 4H), 7.23–7.10 (m, 2H), 7.01 (d, *J* = 8.0 Hz, 2H), 6.35 (s, 1H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.2, 141.1, 136.1, 131.3, 130.2, 129.3, 129.3, 127.9, 126.6, 125.9, 125.4, 121.8, 107.2, 21.4; IR (NaCl) 3443, 3428, 2922, 1920, 1735, 1597, 1505, 1434, 1390, 1333, 1166, 1092, 1052, 944, 910, 800, 764, 728, 675, 566 cm^{-1}; HRMS (EI) m/z calcd. for $C_{16}H_{15}N_3O_2S$ $[M]^+$: 313.0885, found: 313.0882; R_f (*n*-hexane/EtOAc, 5/1): 0.27.

***N*-[2-(4,5-Dihydrooxazol-2-yl)phenyl]-4-methylbenzenesulfonamide (8e).** Light yellow solid (53.8mg, 85%); m.p. 195–197 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.33 (s, 1H), 7.82–7.70 (m, 3H), 7.64 (dd, *J* = 8.5, 1.1 Hz, 1H), 7.38–7.29 (m, 1H), 7.20 (d, *J* = 8.4 Hz, 2H), 6.99 (td, *J* = 7.6, 1.1 Hz, 1H), 4.35 (t, *J* = 9.7 Hz, 2H), 4.13 (t, *J* = 9.3 Hz, 2H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 143.5, 139.1, 136.9, 132.3, 129.5, 129.3, 127.2, 122.2, 117.8, 113.5, 66.4, 54.4, 21.5; IR (NaCl) 3082, 3062, 2943, 2919, 2887, 2853, 1631, 1598, 1584, 1503, 1443, 1337, 1259, 1159, 1066, 942 cm^{-1}; HRMS (EI) m/z calcd. for $C_{16}H_{16}N_2O_3S$ $[M]^+$: 316.0882, found: 316.0882; R_f (*n*-hexane/EtOAc, 5/1): 0.24.

4-Methyl-*N*-[2-(pyridin-2-ylmethyl)phenyl]benzenesulfonamide (8f). Light brown oil (52.8 mg, 78%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.34 (s, 1H), 8.66–8.29 (m, 1H), 7.73–7.67 (m, 2H), 7.60 (td, *J* = 7.7, 1.8 Hz, 1H), 7.53 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.23–7.10 (m, 6H), 7.02 (td, *J* = 7.5, 1.3 Hz, 1H), 3.63 (s, 2H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.3, 148.6, 143.1, 138.4, 137.9, 136.5, 132.3, 130.2, 129.6, 128.0, 126.8, 125.3, 124.6, 122.9, 122.0, 41.4, 21.5; IR (NaCl) 3064, 2956, 2923, 2853, 1920, 1595,1571, 1494, 1476, 1438, 1335, 1289, 1274, 1240, 1162, 1107, 1093, 1019, 939, 814, 758, 660 cm^{-1}; HRMS (EI) m/z calcd. for $C_{19}H_{18}N_2O_2S$ $[M]^+$: 338.1089, found: 338.1089; R_f (*n*-hexane/EtOAc, 5/1): 0.30.

***N*-[2-(4-Methylphenylsulfonamido)phenyl]acetamide (8g).** White solid (54.8 mg, 90%); m.p. 142–144 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (s, 1H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.55 (d, *J* = 7.5 Hz, 2H), 7.50 (s, 1H), 7.21 (d, *J* = 7.6 Hz, 2H), 7.16 (t, *J* = 7.9 Hz, 1H), 6.97 (t, *J* = 7.9 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 1H), 2.39 (s, 3H), 2.08 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.8, 144.0, 135.8, 133.7, 129.6, 127.8, 127.7, 127.3, 127.2, 125.6, 123.7, 24.0, 21.5; IR (NaCl) 3326, 3254, 3129, 2925, 2868, 1668, 1598, 1528, 1496, 1400, 1307, 1160, 1091, 925,

814, 665 cm^{-1}; HRMS (EI) m/z calcd. for $C_{15}H_{16}N_2O_3S$ $[M]^+$: 304.0882, found: 304.0879; R_f (*n*-hexane/EtOAc, 5/1): 0.28.

***N*-[2-(4-Methylphenylsulfonamido)phenyl]pivalamide (8h).** Light brown solid (52.0mg, 75%); m.p. 186–188 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 8.43 (s, 1H), 7.87–7.76 (m, 1H), 7.53 (dd, *J* = 8.3, 1.3 Hz, 2H), 7.25–7.14 (m, 3H), 6.95–6.86 (m, 2H), 6.67–6.56 (m, 1H), 2.41 (s, 3H), 1.32 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.8, 144.0, 135.5, 135.1, 129.5, 128.3, 128.1, 127.5, 126.8, 124.9, 123.7, 39.8, 27.5, 21.5; IR (NaCl) 3419, 3361, 3131, 2965, 2873, 1660, 1597, 1524, 1496, 1450, 1401, 1331, 1159, 1091, 927, 813, 763, 717 cm^{-1}; HRMS (EI) m/z calcd. for $C_{18}H_{22}N_2O_3S$ $[M]^+$: 346.1351, found: 346.1348; R_f (*n*-hexane/EtOAc, 5/1): 0.32.

4-Methyl-*N*-[2-(2-oxopyrrolidin-1-yl)phenyl]benzenesulfonamide (8i). White solid (56.8 mg, 86%); m.p. 167–169 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 (s, 1H), 7.58–7.48 (m, 3H), 7.33–7.16 (m, 4H), 7.04 (dd, *J* = 7.8, 1.8 Hz, 1H), 3.29 (t, *J* = 7.0 Hz, 2H), 2.47 (t, *J* = 8.1 Hz, 2H), 2.39 (s, 3H), 1.84 (p, *J* = 7.6 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9, 143.2, 138.0, 133.5, 130.9, 129.3, 129.2, 127.6, 127.3, 126.6, 122.8, 50.5, 31.6, 21.4, 18.5; IR (NaCl) 3068, 2979, 2923, 2898, 1670, 1598, 1497, 1409, 1332, 1164, 1092, 912, 816, 764 cm^{-1}; HRMS (ESI) m/z calcd. for $C_{17}H_{18}N_2O_3S$ $[M+Na]^+$: 353.0936, found: 353.0930; R_f (*n*-hexane/EtOAc, 5/1): 0.30.

***N*-[2-(Benzo[*d*]oxazol-2-yl)phenyl]-4-methylbenzenesulfonamide (10a).** White solid (58.4 mg, 80%); m.p. 161–164 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 11.66 (s, 1H), 8.03 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.79–7.73 (m, 1H), 7.70 (td, *J* = 8.3, 1.5 Hz, 3H), 7.52–7.45 (m, 1H), 7.39–7.27 (m, 3H), 7.11–7.01 (m, 3H), 2.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5, 149.2, 143.7, 140.6, 138.2, 136.6, 132.6, 129.5, 128.5, 127.3, 125.8, 125.1, 123.2, 120.0, 119.0, 113.7, 110.5, 21.5; IR (NaCl) 3425, 3123, 2921, 1618, 1587, 1545, 1497, 1476, 1452, 1429, 1345, 1268, 1247, 1132, 1091, 1055, 946, 914, 895, 809, 759, 675 cm^{-1}; HRMS (EI) m/z calcd. for $C_{20}H_{16}N_2O_3S$ $[M]^+$: 364.0882, found: 364.0879; R_f (*n*-hexane/EtOAc, 4/1): 0.35.

***N*-[1-(Isoquinolin-1-yl)naphthalen-2-yl]-4-methylbenzenesulfonamide (10b).** Light yellow solid (69.0 mg, 81%); m.p. 213–215 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 8.65 (dd, *J* = 5.6, 3.5 Hz, 1H), 8.33 (s, 1H), 8.07–7.92 (m, 2H), 7.89–7.80 (m, 2H), 7.74 (d, *J* = 5.7 Hz, 1H), 7.60 (ddd, *J* = 8.3, 6.9, 1.3 Hz, 1H), 7.37 (ddd, *J* = 8.2, 6.8, 1.3 Hz, 1H), 7.14 (ddd, *J* = 8.4, 6.8, 1.4 Hz, 1H), 7.06 (ddd, *J* = 8.4, 6.9, 1.3 Hz, 1H), 6.99 (d, *J* = 8.3

Hz, 2H), 6.92–6.87 (d, 1H), 6.73 (d, J = 8.4, 1.2 Hz, 1H), 6.51 (d, J = 8.1 Hz, 2H), 2.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.2, 142.9, 142.2, 136.3, 136.1, 133.0, 132.3, 131.3, 130.1, 130.1, 129.0, 128.1, 127.6, 127.3, 127.1, 126.8, 126.6, 126.3, 126.1, 125.6, 123.8, 121.1, 21.3; IR (NaCl) 3449, 2097, 1632, 1605, 1475, 1388, 1336, 1297, 1239, 1162, 1115, 1049, 814, 602 cm^{-1}; HRMS (ESI) m/z calcd. for $C_{26}H_{20}N_2O_2S$ $[M+H]^+$: 425.1324, found: 425.1324; R_f (*n*-hexane/EtOAc, 4/1): 0.32.

***N*-[2-(Isoquinolin-1-yl)phenyl]-4-methylbenzenesulfonamide (10c).** White solid (62.5 mg, 84%); m.p. 158–161 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (s, 1H), 8.51 (d, J = 5.7 Hz, 1H), 7.88–7.84 (m, 1H), 7.83–7.76 (m, 1H), 7.68–7.58 (m, 2H), 7.53–7.41 (m, 2H), 7.40–7.23 (m, 3H), 6.91 (d, J = 8.3 Hz, 2H), 6.42 (d, J = 8.4 Hz, 2H), 1.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3, 142.5, 140.8, 137.2, 135.6, 135.3, 131.6, 131.0, 130.1, 129.8, 128.8, 127.6, 127.2, 126.9, 126.8, 126.6, 126.0, 125.2, 120.4, 21.1; IR (NaCl) 3426, 3058, 1621, 1554, 1492, 1394, 1379, 1337, 1266, 1183, 1165, 1091, 832, 813, 759, 690 cm^{-1}; HRMS (EI) m/z calcd. for $C_{22}H_{18}N_2O_2S$ $[M]^+$: 374.1089, found: 374.1088; R_f (*n*-hexane/EtOAc, 4/1): 0.36.

***N*-[5-Bromo-2-(isoquinolin-1-yl)phenyl]-4-methylbenzenesulfonamide (10d).** White solid (80.4 mg, 89%); m.p. 160–162 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.71 (s, 1H), 8.51 (d, J = 5.7 Hz, 1H), 8.03 (d, J = 1.9 Hz, 1H), 7.82 (d, J = 1.0 Hz, 1H), 7.71–7.65 (m, 1H), 7.64 (dd, J = 5.8, 0.9 Hz, 1H), 7.46–7.34 (m, 3H), 7.24 (d, J = 8.2 Hz, 1H), 6.95 (d, J = 8.4 Hz, 2H), 6.48–6.44 (m, 2H), 1.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.3, 142.9, 140.8, 137.2, 136.7, 135.4, 132.7, 130.3, 130.2, 129.6, 128.9, 128.4, 127.1, 127.1, 126.7, 126.5, 126.0, 123.3, 120.8, 21.1, IR (NaCl) 3438, 1621, 1593, 1550, 1483, 1452, 1375, 1333, 1245, 1165, 1109, 1091, 975, 920, 893, 826, 736, 696, 621 cm^{-1}; HRMS (ESI) m/z calcd. for $C_{22}H_{17}BrN_2O_2S$ $[M+Na]^+$: 475.0092, found: 475.0082; R_f (*n*-hexane/EtOAc, 4/1): 0.31.

***N*-[5-Formyl-2-(isoquinolin-1-yl)phenyl]-4-methylbenzenesulfonamide (10e).** White solid (66.6 mg, 83%); m.p. 156–158 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.13 (s, 1H), 9.70 (s, 1H), 8.57 (d, J = 5.7 Hz, 1H), 8.33 (s, 1H), 7.90–7.81 (m, 2H), 7.74–7.66 (m, 2H), 7.55 (d, J = 7.9 Hz, 1H), 7.48–7.33 (m, 2H), 6.95 (d, J = 8.4 Hz, 2H), 6.47 (d, J = 8.5 Hz, 2H), 1.87 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.3, 155.9, 142.9, 140.9, 137.2, 137.2, 136.4, 136.1, 135.4, 132.3, 130.4, 129.7, 129.0, 127.4, 127.2, 126.5, 126.0, 124.5, 121.3, 21.1; IR (NaCl)

3381, 3234, 2847, 1698, 1619, 1568, 1498, 1374, 1334, 1274, 1215, 1184, 1091, 877, 812, 691 cm^{-1}; HRMS (ESI) m/z calcd. for $C_{23}H_{18}N_2O_3S$ $[M+Na]^+$: 425.0936 , found: 425.0920; R_f (*n*-hexane/EtOAc, 3/1): 0.35.

Methyl-4-(isoquinolin-1-yl)-3-(4-methylphenylsulfonamido)benzoate (10f). White solid (80.5 mg, 93%); m.p. 160–162 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (s, 1H), 8.55 (d, *J* = 5.7 Hz, 1H), 8.50 (dd, *J* = 1.8, 0.4 Hz, 1H), 7.97 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.84 (dt, *J* = 8.3, 1.0 Hz, 1H), 7.72–7.61 (m, 2H), 7.49–7.30 (m, 3H), 6.98–6.88 (m, 2H), 6.44 (dd, *J* = 8.6, 0.7 Hz, 2H), 3.99 (s, 3H), 1.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 156.4, 143.0, 141.0, 137.4, 135.8, 135.6, 135.1, 131.9, 131.7, 130.5, 129.1, 128.8, 127.4, 127.3, 126.9, 126.7, 126.4, 126.2, 121.3, 52.7, 21.3; IR (NaCl) 3429, 3234, 3045, 2964, 1723, 1621, 1585, 1552, 1498, 1437, 1379, 1336, 1298, 1236, 1166, 1117, 1090, 995, 768, 697 cm^{-1}; HRMS (EI) m/z calcd. for $C_{24}H_{20}N_2O_4S$ $[M]^+$: 432.1144, found: 432.1142; R_f (*n*-hexane/EtOAc, 4/1): 0.21.

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Supporting Information Available. Copies of ^{1}H and ^{13}C NMR spectra data for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

Reference

(1) Hili, R.; Yudin, A. K. *Nat. Chem. Biol.* **2006**, *2*, 284. (b) Hartwig, J. F. *Nature* **2008**, *455*, 314.

(2) (a) Ullmann, F. *Ber. Dtsch. Chem. Ges.* **1903**, *36*, 2382. (b) Evano, G.; Blanchard, N.; Toumi, M. *Chem. Rev.* **2008**, *108*, 3054. (c) Rao, H.; Fu, H. *Synlett* **2011**, *6*, 745.

(3) (a) Paul, F.; Patt, J.; Hartwig, J. F. *J. Am. Chem. Soc.* **1994**, *116,* 5969. (b) Guram, A. S.; Buchwald, S. L. *J. Am. Chem. Soc.* **1994**, *116*, 7901.

(4) (a) Armstrong, A.; Collins, J. C.; *Angew. Chem., Int. Ed.* **2010**, *49*, 2282. (b) Cho, S. H.; Kim, J. Y.; Kwak, J.; Chang, S. *Chem. Soc. Rev.* **2011**, *40*, 5068. (c) Wencel-Delord, J.; Dröge, T.; Liu, F.; Glorius, F. *Chem. Soc. Rev.* **2011**, *40*, 4740.

(5) For the oxidative direct amination of activated arenes, see: (a) Wang, Q.; Schreiber, S. L. *Org. Lett.* **2009**, *11*, 5178. (b) Monguchi, D.; Fujiwara, T.; Furukawa, H.; Mori, A. *Org. Lett.* **2009**, *11*, 1607. For the oxidative direct amination of arenes containing chelating groups, see: (c) Xiao, B.; Gong, T.-J.; Xu, J.; Liu, Z.-J.; Liu, L. *J. Am. Chem. Soc*. **2011**, *133*, 1466. (d) John, A.; Nicholas, K. M. *J. Org. Chem.* **2011**, *76*, 4158.

(6) For the direct amination of (hetero)arenes using a pre-activated amino precursor, see: (a) Kawano, T.; Hirano, K.; Satoh, T.; Miura, M. *J. Am. Chem. Soc*. **2010**, *132*, 6900. (b) Sun, K.; Li, Y;. Xiong, T.; Zhang, J.; Zhang, Q. *J. Am. Chem. Soc.* **2011**, *133*, 1694. (c) Yoo, E. J.; Ma, S.; Mei, T.-S.; Chan, K. S. L.; Yu, J.-Q. *J. Am. Chem. Soc.* **2011**, *133*, 7652. (d) Ng, K.-H.; Zhou, Z.; Yu, W.-Y. *Org. Lett*. **2012**, *14*, 272. (e) Grohmann, C.; Wang, H.; Glorius, F. *Org. Lett*. **2012**, 14, 656.

(7) (a) Cho, S. H.; Kim, J. Y.; Lee, S. Y.; Chang, S. *Angew. Chem., Int. Ed.* **2009**, *48*, 9127. (b) Cho, S. H.; Yoon, J.; Chang, S. *J. Am. Chem. Soc*. **2011**, *133*, 5996. (c) Kim, H. J.; Kim, J.; Cho, S. H.; Chang, S. *J. Am. Chem. Soc*. **2011**, *133*, 16382.

(8) (a) Kim, J. Y.; Park, S. H.; Chang, S. *J. Am. Chem. Soc.* **2012**, *134*, 9110. (b) Ryu, J.; Shin, K.; Park, S. H.; Kim, J. Y.; Chang, S. *Angew. Chem., Int. Ed.* **2012**, *51*, 9904. (c) Shin, K.; Baek, Y.; Chang, S. *Angew. Chem., Int. Ed*. **2013**, *52*, 8031.

(9) Kim, J.; Kim, J.; Chang, S. *Chem. Eur. J*. **2013**, *19*, 7328.

(10) For selected examples of the metal-mediated C−H amination with azides, see: (a) Sun, K.; Sachwani, R.; Richert, K. J.; Driver, T. G. *Org. Lett*. **2009**, *11*, 3598. (b) Ichinose, M.; Suematsu, H.; Yasutomi, Y.; Nishioka, Y.; Uchida, T.; Katsuki, T. *Angew. Chem., Int. Ed*. **2011**, *50*, 9884. (c) Chiba, S. *Synlett* **2012**, *23*, 21. (d) Dequirez, G.; Pons, V.; Dauban, P. *Angew. Chem., Int. Ed.* **2012**, *51*, 7384.

(11) For recent Rh- and Ru-catalyzed aryl C–H amidations, see: (a) Nguyen, Q.; Sun, K.; Driver, T. G. *J. Am. Chem. Soc.* **2012**, *134*, 7262. (b) Yadav, M. R.; Rit, R. K.; Sahoo, A. K. *Org. Lett*. **2013**, *15*, 1638. (c)

Thirunavukkarasu, V. S.; Raghuvanshi, K.; Ackermann, L. *Org. Lett.* **2013**, *15*, 3286. (d) Yu, D.-G.; Suri, M.; Glorius, F. *J. Am. Chem. Soc.* **2013**, *135*, 8802.

(12) Ryu, J.; Kwak, J.; Shin, K.; Lee, D.; Chang, S. *J. Am. Chem. Soc*. **2013**, *135*, 12861.

(13) Rousseau, G.; Breit, B. *Angew. Chem., Int. Ed*. **2011**, *50*, 2450.

(14) For carbamate-directed C–H bond activation, see: (a) Zhao, X.; Yeung, C. S.; Dong, V. M. *J. Am. Chem. Soc.* **2010**, *132*, 5837. (b) John, A.; Nicholas, K. M. *J. Org. Chem*. **2012**, *77*, 5600. (c) Li, B.; Ma, J.; Liang, Y.; Wang, N.; Xu, S.; Song, H.; Wang, B. *Eur. J. Org. Chem.* **2013**, 1950.

(15) For an example of the acetate-promoted cyclometallation process, see: Boutadla, Y.; Davies, D. L.; Jones, R. C.; Singh, K. *Chem. Eur. J.* **2011**, *17*, 3438, and references cited therein.

(16) (a) Samota, M. K.; Seth, G. *Heteroatom Chem.* **2010**, *21*, 44. (b) Chen, M.; Lv, X.; Liu, Y.; Zhao, Y.; Liu, J.; Wang, P.; Guo, W. *Org. Biomol. Chem.* **2011**, *9*, 2345.

(17) (a) Cortright, S. B.; Huffman, J. C.; Yoder, R. A.; Coalter III, J. N.; Johnston, J. N. *Organometallics* **2004**, *23*, 2238. (b) Luesse, S. B.; Counceller, C. M.; Wilt, J. C.; Perkins, B. R.; Johnston, J. N. *Org. Lett.* **2008**, *10*, 2445.

(18) Nussbaum, F.; Miller, B.; Wild, S.; Hilger, C. S.; Schumann, S.; Zorbas, H.; Beck, W.; Steglich, W. *J. Med. Chem.* **1999**, *42*, 3478.

(19) Tsai, A. S.; Brasse, M.; Bergman, R. G.; Ellman, J. A. *Org. Lett*. **2011**, *13*, 540.

(20) Zhou, L.; Ye, F.; Ma, J.; Zhang, Y.; Wang, J. *Angew. Chem., Int. Ed*. **2011**, *50*, 3510.

(21) Cai, S.; Chen, C.; Sun, Z.; Xi, C. *Chem. Commun.* **2013**, *49*, 4552.

(22) Do, H.-Q.; Daugulis, O. *J. Am. Chem. Soc.* **2007**, *129*, 12404.

(23) Liu, S.-J.; Zhao, Q.; Fan, Q.-L.; Huang, W. *Eur. J. Inorg. Chem.* **2008**, 2177.