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Fluorinatd Molecules

Palladium-Catalysed Synthesis of α-(Trifluoromethyl)styrenes by Means of Directed C–H Bond Functionalization

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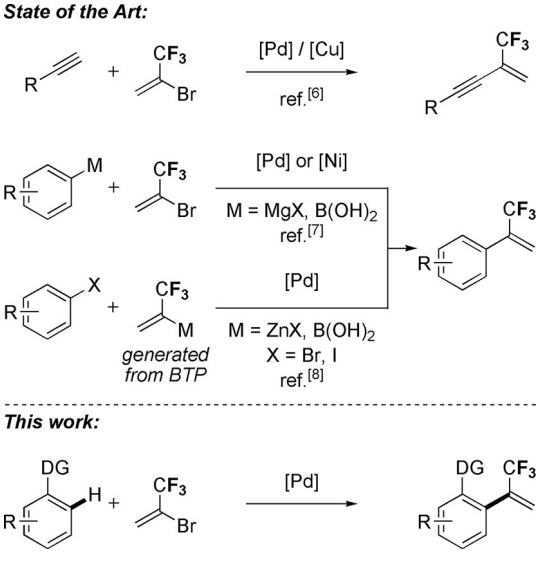
Abstract: We report the first introduction of 2-bromo-3,3,3-trifluoropropene (BTP) by directed C–H bond functionalization. The developed method gives straightforward access to α-(trifluoromethyl)styrene derivatives without prior prefunctionalization of the substrates. This palladium-catalysed transformation was applied to a broad range of substrates, and the corresponding trifluoromethylated products were obtained in good yields. This approach represents an alternative pathway to the classical method previously used to access such molecules.

Introduction

During the last 10 years, organofluorine chemistry has undergone a tremendous expansion. Due to the high impact of fluorinated molecules in the discovery and development of new pharmaceuticals and agrochemicals, the demand for fluorinated molecules is rapidly increasing.[1] This mainly results from the remarkable properties of the fluorine atom and fluorinated groups.[2] The introduction of such fluorine-containing moieties into molecules strongly affects their biological and physical properties. Particular attention has been paid to the trifluoromethyl group.[3] This group can easily replace a methyl group, for example, to avoid in vivo hydrolysis, although its steric demand is closer to that of an isopropyl group than a methyl group. Hence, a wide range of elegant and straightforward methods to introduce this key motif into molecules have been reported. Among these recent advances, direct C–H bond functionalization has appeared as an atom-economical pathway for the introduction of fluorinated moieties, and particularly for the introduction of the CF_3 group.[4] However, although this latter approach has been widely explored, the direct introduction of small building blocks bearing a CF_3 moiety has been less studied. Part of the portfolio of trifluoromethylated building blocks, 2-bromo-3,3,3-trifluoropropene (BTP) has appeared as an excellent and readily available reagent. This reagent is not classified as an ozone-depleting agent, and it has turned out to be an interesting and inexpensive candidate for use as a fire suppressant.[5] This building block has been already used in classical cross-coupling reactions to access α-(trifluoromethyl)vinyl derivatives, either directly or through conversion into the corresponding organometallic species (B or Zn) (Scheme 1). Regarding the first approach, in 1993 Hu and coworkers reported a Sonagashira cross-coupling reaction with BTP as a coupling partner.[6] Later, Deng and coworkers demonstrated the arylation of BTP by means of a palladium-catalysed Suzuki cross-coupling reaction.[7] The Yamakawa group went on to report a nickel- and palladium-catalysed Corriu–Kumada reaction with BTP.[8] In parallel, the formation of the corresponding organozinc or organoboron species and their use in Negishi and Suzuki cross-coupling reactions were reported by Jiang and Xu.[9] However, to the best of our knowledge, no report dealing with direct C–H bond functionalization with BTP has been reported. Hence, as part of our ongoing research program devoted to the direct introduction of fluorinated building blocks,[10] in this paper, we report the use of BTP for the direct introduction of the α-(trifluoromethyl)vinyl motif into aromatic rings. This atom-



Scheme 1. State-of-the art and proposed approach. DG = directing group.

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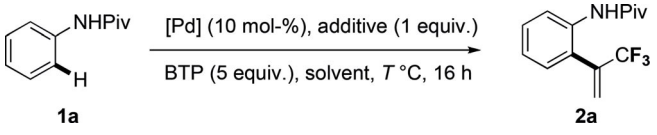
economical approach should give a rapid and straightforward access to α-(trifluoromethyl)styrene derivatives.

Results and Discussion

At the outset of the project, we chose *N*-pivaloylaniline (**1a**) as a model substrate to determine the reaction conditions (Table 1).

Table 1. Optimization of the reaction conditions.[a]



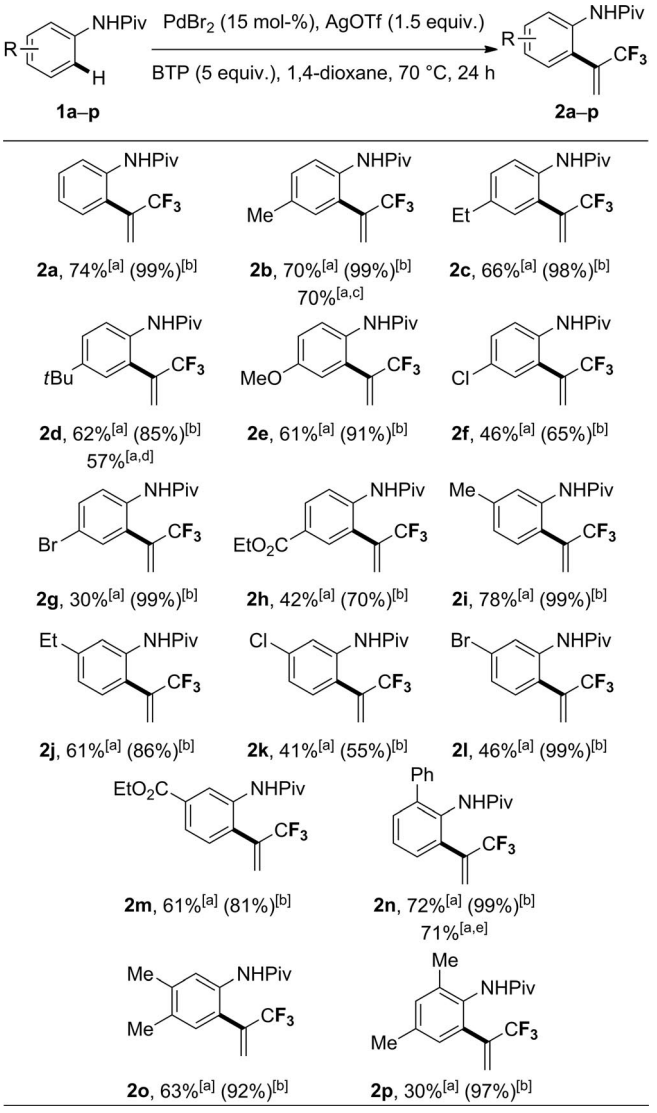
1a **2a**

Entry	[Pd]	Additive	Solvent	*T* [°C]	Yield [%][b]
1	$PdCl_2$	AgOTf	DMF	90	13
2	$PdCl_2$	AgOTf	toluene	90	0
3	$PdCl_2$	AgOTf	THF	90	18
4	$PdCl_2$	AgOTf	1,4-dioxane	90	38
5	$PdCl_2$	Ag_2O	1,4-dioxane	90	0
6	$PdCl_2$	$Cu(OAc)_2$	1,4-dioxane	90	0
7	$Pd(TFA)_2$	AgOTf	1,4-dioxane	90	19
8	$Pd(OAc)_2$	AgOTf	1,4-dioxane	90	18
9	$PdBr_2$	AgOTf	1,4-dioxane	90	40
10[c]	$PdBr_2$	AgOTf	1,4-dioxane	90	61
11[c,d]	$PdBr_2$	AgOTf	1,4-dioxane	70	99 (74)[e]

[a] **1a** (0.2 mmol), BTP (1 mmol), [Pd] (0.02 mmol), additive (0.2 mmol), solvent (2 mL). [b] Yields were determined by ^{19}F NMR spectroscopic analysis using α,α,α-trifluoroacetophenone as an internal standard. [c] 1.5 equiv. of AgOTf was used. [d] 15 mol-% of [Pd] was used, and the reaction time was extended to 24 h. [e] Isolated yield.

An initial attempt was carried out using $PdCl_2$ as the catalyst in the presence of AgOTf in DMF at 90 °C. Pleasingly, the desired α-(trifluoromethyl)styryl derivative (i.e., **2a**) was obtained in 13 % yield (Table 1, Entry 1). A screening of solvents showed that toluene was inefficient (Table 1, Entry 2), whereas THF gave a slight enhancement of the yield with 18 % (Table 1, Entry 3). By switching from THF to 1,4-dioxane, the yield increased to 38 % (Table 1, Entry 4). A survey of additives revealed that AgOTf was crucial to ensure a decent conversion into the desired product (i.e., **2a**), since no reaction occurred when Ag_2O or $Cu(OAc)_2$ was used (Table 1, Entries 5 and 6). Finally, several palladium catalysts were evaluated: $Pd(TFA)_2$, $Pd(OAc)_2$, and $PdBr_2$ (Table 1, Entries 7–9), of which $PdBr_2$ was the most efficient (40 %) (Table 1, Entry 9). An increase in the amount of AgOTf from 1.0 to 1.5 equiv. provided the desired product (i.e., **2a**) in 61 % yield (Table 1, Entry 10). To our delight, a decrease in the temperature to 70 °C, along with the use of 15 mol-% $PdBr_2$, gave the α-(trifluoromethyl)styrene **2a** in almost quantitative yield, as determined by ^{19}F NMR spectroscopy, and 74 % isolated yield (Table 1, Entry 11). Note, that under our optimized conditions, other nitrogen-based directing groups were inefficient at promoting the reaction.[11]

Having established the optimized reaction conditions, we next sought to investigate the scope of the reaction with other substrates (Scheme 2).

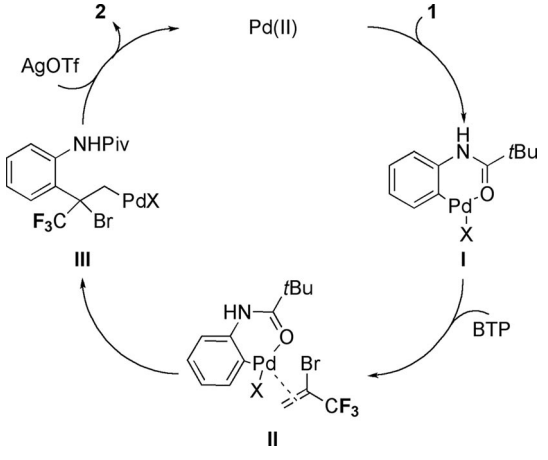


Scheme 2. Scope of the reaction. [a] Isolated yields. [b] Yields were determined by ^{19}F NMR spectroscopic analysis using α,α,α-trifluoroacetophenone as an internal standard. [c] Reaction was carried out on a 4.18 mmol scale. [d] Reaction was carried out on a 4.26 mmol scale. [e] Reaction was carried out on a 3.95 mmol scale.

First *para*-substituted anilides bearing an electron-donating group were studied. *para*-Methyl-, -ethyl-, and -*tert*-butyl-substituted anilides were readily converted into the corresponding trifluoromethylated products (i.e., **2b**–**2d**) in good yields. The reaction was readily carried out on a larger scale, which demonstrates the versatility of the process. Indeed, **2b** and **2d** were obtained in similar yields, 70 and 57 %, respectively, when the reactions were carried out on a ca. 4 mmol scale. The electron-donating methoxy group was tolerated, and the resulting α-(trifluoromethyl)styrene derivative (i.e., **2e**) was isolated in 61 % yield. Interestingly, anilides bearing a halogen atom in the *para* position reacted under our reaction conditions to give trifluoromethylated products **2f** and **2g** in moderate yields. Note that no alteration of the halogen atom was observed, since no trace of product **2a** (which would result from a dehalogenation process) was detected in the crude reaction mixture. An ester moi-

ety was compatible with this transformation, which demonstrates the functional-group tolerance of our method. The reaction was then tested with *meta*-substituted anilides **1i**–**1m** as substrates. Alkyl-substituted anilides gave the desired products (i.e., **2i** and **2j**) in fairly decent yields (78 and 61 %, respectively). Halogen-substituted anilides **1k** and **1l** gave the corresponding trifluorovinyl compounds (i.e., **2k** and **2l**) in moderate yields, still with no alteration of the C–halogen bond, thus opening the possibility of postfunctionalization. In addition, the ester-substituted anilide **1m** gave **2m** in 61 % isolated yield. The presence of an *ortho* substituent did not hamper the reaction, and **2n** was isolated in 72 % yield, and in 71 % yield on a gram scale. Disubstituted anilides **1o**–**1p** reacted smoothly to give trifluoromethylated adducts **2o**–**2p** in moderate to good yields.

Based on a previous paper,[12] we propose the following redox-neutral mechanism to explain the reaction outcome (Scheme 3). First, the Pd catalyst reacts with *N*-pivaloylaniline **1** to form the corresponding palladacycle (i.e., **I**). This species then coordinates to BTP (intermediate **II**), and carbopalladation of the alkene takes place. The resulting organopalladium species (i.e., **III**) undergoes β-halide elimination to deliver the product **2** and regenerates the catalyst.[12,13] As we know that the presence of AgOTf is crucial for the success of the process, we speculate that it could assist with the β-halide elimination. However, we cannot rule out a plausible Pd^{II}/Pd^{IV} catalytic cycle, since no clear evidence about the reaction mechanism was obtained.

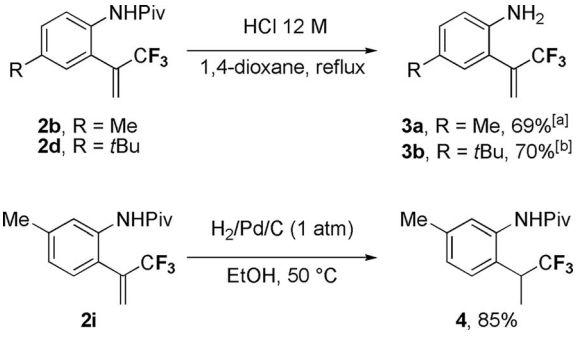


Scheme 3. Proposed mechanism.

Finally, we investigated the versatility of our products (Scheme 4). The directing group was readily cleaved under acidic conditions to give the desired aniline derivatives (i.e., **3a** and **3b**) in 69 and 70 % yields, respectively. Selective reduction of the double bond was achieved using Pd/C as a catalyst under hydrogen to provide anilide **4** in 85 % yield.

Conclusions

We describe in this paper the first direct introduction of the α-(trifluoromethyl)vinyl motif by means of directed C–H bond functionalization. This method was applied to a broad range of anilide derivatives to give the corresponding α-(trifluoromethyl)styryl derivatives in moderate to good yields. The products were subsequently modified to demonstrate the versatility of these trifluoromethylated building blocks.



Scheme 4. Synthetically useful transformations of the products. [a] Reaction was carried out on a 3 mmol scale. [b] Reaction was carried out on a 1 mmol scale.

Experimental Section

General Methods: All reactions were carried out using oven-dried glassware and magnetic stirring under argon, unless otherwise stated. Reaction temperatures are reported as the temperatures of the bath surrounding the vessel. NMR spectra were recorded with a Bruker DXP 300 instrument; ^1H NMR spectra at 300.1 MHz, ^{13}C NMR spectra at 75.5 MHz, ^{19}F NMR spectra at 282.4 MHz. Chemical shifts (δ) are quoted in parts per million (ppm), and spectra were calibrated using the residual solvent peak for $CDCl_3$ (δ_H = 7.26 ppm; δ_C = 77.0 ppm) or using external $CFCl_3$ (δ_F = 0.0 ppm). The following abbreviations have been used: δ (chemical shift), J (coupling constant), br. (broad), s (singlet), d (doublet), dd (doublet of doublets), t (triplet), q (quartet), m (multiplet). High-resolution mass spectra (HRMS) were recorded with a Waters LCT Premier instrument. Infrared spectra were recorded with a Perkin–Elmer Paragon 100 (ATR) FTIR spectrometer; the wave numbers ($\tilde{\nu}$) of recorded IR signals are quoted in cm^{-1}. Melting points were recorded with a Kofler apparatus. Analytical thin-layer chromatography was carried out on precoated silica gel 60 Alugram® Xtra SIL G/UV_{254} sheets with a layer thickness of 200 µm. Spots on the plates were visualized with short-wave UV light (λ = 254 nm), and/or staining with phosphomolybdic acid or $KMnO_4$ solution followed by heating. Flash chromatography was carried out on Merck silica gel (40–63 mesh) either by the standard technique, or by using a Biotage Isolera One flash purification system (gradient of solvents). Reverse-phase chromatography was carried out with a puriFlash® 215 instrument using a puriFlash® C18HP 15 µm 55G Flash column. AgOTf was purchased from ABCR, and $PdBr_2$ from Alfa Aesar, and both were stored in a glove box. Dry 1,4-dioxane (sealed bottle) was purchased from Acros Organics, and 2-bromo-3,3,3-trifluoropropene (BTP) from Fluorochem, and both were used as received.

General Procedure for the Synthesis of Pivalamides 1: Pivaloyl chloride (1.4 mL, 11 mmol, 1.1 equiv.) was slowly added to a solution of the aniline derivative (1.2 g, 10 mmol, 1.0 equiv.) and Et_3N (1.5 mL, 11 mmol, 1.1 equiv.) in dry THF (30 mL) at 0 °C. The reaction mixture was then allowed to warm to room temperature, and stirred for an additional 3 h. The formed triethylammonium chloride was removed by filtration, and the solvents were removed under vacuum. The residue was purified by chromatography on silica gel. All the spectral data of the pivalamides (**1a**, **1b**, **1f**),[14a] **1d**,[14b] (**1e**,

1h),[14c] **1g**,[14d] **1i**,[14e] (**1k**, **1l**, **1m**, **1p**),[14f] **1n**,[14g] and **1o**[14h] are in agreement with literature data.

***N*-(4-Ethylphenyl)pivalamide (1c):** Purification by silica gel column chromatography (height 100 mm, width 80 mm; eluent: petroleum ether/EtOAc, from 80:20 to 66:34) gave **1c** (0.89 g, 86 %) as a white solid, on a 5.0 mmol scale. R_f (petroleum ether/Et_2O, 66:34) = 0.75; m.p. 117–118 °C. IR: $\tilde{\nu}$ = 3325, 2955, 1651, 1599, 1514, 1407, 833, 712 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.43 (d, J = 8.4 Hz, 2 H), 7.28 (br. s, 1 H), 7.14 (d, J = 8.4 Hz, 2 H), 2.61 (q, J = 7.5 Hz, 2 H), 1.31 (s, 9 H), 1.21 (t, J = 7.5 Hz, 3 H) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.4, 140.2, 135.6, 128.2, 120.1, 39.5, 28.3, 27.6, 15.7 ppm. HRMS (ESI^+): calcd. for $C_{13}H_{20}NO$ $[M + H]^+$ 206.1545; found 206.1544 (+0.5 ppm).

***N*-(3-Ethylphenyl)pivalamide (1j):** Purification by silica gel column chromatography (height 100 mm, width 80 mm; eluent: petroleum ether/EtOAc, from 80:20 to 66:34) gave **1j** (1.21 g, 89 %) as a white solid, on a 6.6 mmol scale. R_f (petroleum ether/EtOAc, 66:34) = 0.78; m.p. 121–122 °C. IR: $\tilde{\nu}$ = 3310, 2968, 1652, 1590, 1539, 1428, 794, 697 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.46 (s, 1 H), 7.38–7.28 (m, 2 H), 7.24–7.17 (m, 1 H), 6.95 (d, J = 6.6 Hz, 1 H), 2.64 (q, J = 7.5 Hz, 2 H), 1.33 (s, 9 H), 1.24 (t, J = 7.5 Hz, 3 H) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 145.3, 138.0, 128.8, 123.7, 119.5, 117.2, 39.6, 28.9, 27.6, 15.5 ppm. HRMS (ESI^+): calcd. for $C_{13}H_{20}NO$ $[M + H]^+$ 206.1545; found 206.1541 (–1.9 ppm).

Typical Procedure for the Palladium-Catalysed Synthesis of α-(Trifluoromethyl)styrenes: A dried tube was loaded with $PdBr_2$ (8.0 mg, 0.03 mmol, 0.15 equiv.), AgOTf (77.1 mg, 0.3 mmol, 1.5 equiv.), and pivalamide **1** (0.2 mmol, 1.0 equiv.) under Ar. Then 1,4-dioxane (2 mL) and 2-bromo-3,3,3-trifluoropropene (0.1 mL, 1.0 mmol, 5.0 equiv.) were added. The tube was sealed, and the suspension was stirred at 70 °C for 24 h. The reaction mixture was diluted with diethyl ether (10 mL), and filtered through a plug of Celite®. The solvents were removed under vacuum, and the residue was purified by a flash chromatography with a Biotage Isolera One flash purification system.

***N*-[2-(3,3,3-Trifluoroprop-1-en-2-yl)phenyl]pivalamide (2a):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2a** (40 mg, 74 %) as a beige solid. R_f (petroleum ether/Et_2O, 75:25) = 0.39; m.p. 66–67 °C. IR: $\tilde{\nu}$ = 3328, 2963, 1694, 1651, 1510, 1174, 1163, 1119, 770, 749 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.23 (d, J = 8.1 Hz, 1 H), 7.48 (br. s, 1 H), 7.43–7.37 (m, 1 H), 7.21–7.11 (m, 2 H), 6.27 (s, 1 H), 5.69 (s, 1 H), 1.26 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.7 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 136.7 (q, $J_{C,F}$ = 31.5 Hz), 136.0, 130.1, 130.0, 125.0 (q, $J_{C,F}$ = 5.4 Hz), 124.2, 124.0, 122.7 (q, $J_{C,F}$ = 274.0 Hz), 122.3, 40.0, 27.5 ppm. HRMS (ESI^+): calcd. for $C_{14}H_{17}F_3NO$ $[M + H]^+$ 272.1262; found 272.1258 (–1.5 ppm).

***N*-[4-Methyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2b):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2b** (40 mg, 70 %) as a beige solid; the reaction was also run on a 4.18 mmol scale to give **2b** (850 mg, 70 %). R_f (petroleum ether/Et_2O, 75:25) = 0.42; m.p. 46–47 °C. IR: $\tilde{\nu}$ = 3325, 2962, 1652, 1505, 1154, 1124, 1119, 1071, 819, 806, 749 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.03 (d, J = 8.4 Hz, 1 H), 7.38 (br. s, 1 H), 7.20 (dd, J = 8.1, J = 1.2 Hz, 1 H), 7.00 (br. s, 1 H), 6.23 (d, J = 1.2 Hz, 1 H), 5.65 (d, J = 1.2 Hz, 1 H), 2.32 (s, 3 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.6 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 136.3 (q, $J_{C,F}$ = 31.6 Hz), 133.9, 133.3, 130.6, 130.5, 124.7 (q, $J_{C,F}$ = 5.1 Hz), 124.6, 122.7 (q, $J_{C,F}$ = 274.1 Hz), 122.5, 39.7, 27.5, 20.7 ppm. HRMS (ESI^+): calcd. for $C_{15}H_{19}F_3NO$ $[M + H]^+$ 286.1419; found 286.1421 (+0.7 ppm).

***N*-[4-Ethyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2c):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 85:15 to 75:25) gave **2c** (39 mg, 66 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.37; m.p. 49–50 °C. IR: $\tilde{\nu}$ = 3272, 2982, 1646, 1514, 1166, 1153, 1126, 1069, 960, 825, 648 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.05 (d, J = 8.4 Hz, 1 H), 7.40 (br. s, 1 H), 7.23 (dd, J = 8.4, J = 1.8 Hz, 1 H), 7.01 (d, J = 1.8 Hz, 1 H), 6.24 (d, J = 1.2 Hz, 1 H), 5.67 (d, J = 1.2 Hz, 1 H), 2.62 (q, J = 7.5 Hz, 2 H), 1.25 (s, 9 H), 1.22 (t, J = 7.5 Hz, 3 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.6 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.4, 140.2, 136.4 (q, $J_{C,F}$ = 31.6 Hz), 133.5, 129.4, 129.3, 124.7 (q, $J_{C,F}$ = 5.1 Hz), 124.6, 122.7 (q, $J_{C,F}$ = 274.1 Hz), 122.6, 39.7, 28.1, 27.5, 15.5 ppm. HRMS (ESI^+): calcd. for $C_{16}H_{20}F_3NONa$ $[M + Na]^+$ 322.1395; found 322.1389 (–1.9 ppm).

***N*-[4-(*tert*-Butyl)-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2d):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2d** (41 mg, 62 %) as a beige solid; the reaction was also run on a 4.26 mmol scale to give **2d** (800 mg. 57 %). R_f (petroleum ether/Et_2O, 75:25) = 0.40; m.p. 76–77 °C. IR: $\tilde{\nu}$ = 3278, 2967, 1645, 1514, 1395, 1368, 1344, 1267, 1176, 1128, 1071, 956, 820, 639 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.08 (d, J = 8.7 Hz, 1 H), 7.42 (dd, J = 8.7, J = 2.1 Hz, 1 H), 7.41 (br. s, 1 H), 7.18 (d, J = 2.1 Hz, 1 H), 6.25 (d, J = 1.2 Hz, 1 H), 5.68 (d, J = 1.2 Hz, 1 H), 1.30 (s, 9 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.6 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.4, 147.1, 136.6 (q, $J_{C,F}$ = 31.5 Hz), 133.3, 127.0, 126.9, 124.7 (q, $J_{C,F}$ = 5.1 Hz), 124.1, 122.8 (q, $J_{C,F}$ = 274.3 Hz), 122.1, 39.8, 34.3, 31.2, 27.5 ppm. HRMS (ESI^+): calcd. for $C_{18}H_{25}F_3NO$ $[M + H]^+$ 328.1888; found 328.1873 (–4.6 ppm).

***N*-[4-Methoxy-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2e):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 92:8 to 85:15) gave **2e** (37 mg, 61 %) as a beige solid. R_f (petroleum ether/Et_2O, 75:25) = 0.17; m.p. 60–61 °C. IR: $\tilde{\nu}$ = 3309, 2840, 1646, 1614, 1501, 1220, 1174, 1118, 1066, 1041, 803 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.93 (d, J = 9.0 Hz, 1 H), 7.26 (br. s, 1 H), 6.94 (dd, J = 9.0, J = 3.0 Hz, 1 H), 6.75 (d, J = 3.0 Hz, 1 H), 6.21 (d, J = 1.2 Hz, 1 H), 5.67 (d, J = 1.2 Hz, 1 H), 3.79 (s, 3 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.5 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.6, 156.2, 136.0 (q, $J_{C,F}$ = 31.7 Hz), 128.9, 127.0, 125.0, 124.7 (q, $J_{C,F}$ = 5.2 Hz), 122.7 (q, $J_{C,F}$ = 274.0 Hz), 115.7, 115.0, 55.5, 39.6, 27.5 ppm. HRMS (ESI^+): calcd. for $C_{15}H_{19}F_3NO_2$ $[M + H]^+$ 302.1368; found 302.1370 (+0.7 ppm).

***N*-[4-Chloro-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2f):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2f** (28 mg, 46 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.44; m.p. 67–68 °C. IR: $\tilde{\nu}$ = 3321, 2963, 1651, 1497, 1169, 1165, 1123, 897, 818, 802, 641 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.19 (d, J = 9.0 Hz, 1 H), 7.43 (br. s, 1 H), 7.37 (dd, J = 9.0, J = 1.8 Hz, 1 H), 7.19 (d, J = 1.8 Hz, 1 H), 6.30 (s, 1 H), 5.71 (s, 1 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.5 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 135.2 (q, $J_{C,F}$ = 32.0 Hz), 134.7, 130.1, 129.9, 129.1, 125.7 (q, $J_{C,F}$ = 5.1 Hz), 125.6, 123.4, 122.4 (q, $J_{C,F}$ = 274.1 Hz), 39.9, 27.4 ppm. HRMS (ESI^+): calcd. for $C_{14}H_{15}{}^{35}ClF_3NONa$ $[M + Na]^+$ 328.0692; found 328.0683 (–2.7 ppm).

***N*-[4-Bromo-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2g):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **2g** (21 mg, 30 %) as a yellow solid. R_f (petroleum ether/Et_2O, 75:25) = 0.44; m.p. 78–79 °C. IR: $\tilde{\nu}$ = 3305, 2962, 1717, 1652, 1494, 1256, 1164, 1121, 1067, 883, 816, 799, 638 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.16 (d, J = 8.7 Hz, 1 H), 7.51 (d, J = 8.7 Hz, 1 H), 7.43 (br. s, 1 H), 7.33 (s, 1 H), 6.30 (s, 1 H), 5.71 (s, 1 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.5 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 135.2, 135.1 (q, $J_{C,F}$ = 32.0 Hz), 133.0, 132.7, 125.9 (q, $J_{C,F}$ = 5.1 Hz), 125.8, 123.6, 122.4 (q, $J_{C,F}$ = 274.1 Hz), 116.6, 39.9, 27.4 ppm. HRMS (ESI^+): calcd. for $C_{14}H_{15}{}^{79}BrF_3NONa$ [M + Na]$^+$ 372.0187; found 372.0179 (–2.2 ppm).

Ethyl 4-Pivalamido-3-(3,3,3-trifluoroprop-1-en-2-yl)benzoate (2h): Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **2h** (29 mg, 42 %) as a beige solid. R_f (petroleum ether/Et_2O, 75:25) = 0.25; m.p. 45–46 °C. IR: $\tilde{\nu}$ = 3447, 2975, 1717, 1585, 1512, 1480, 1285, 1264, 1170, 1123, 1107, 1069, 1022, 768, 637 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.47 (d, J = 8.7 Hz, 1 H), 8.07 (dd, J = 8.7, J = 1.8 Hz, 1 H), 7.88 (d, J = 1.8 Hz, 1 H), 7.65 (br. s, 1 H), 6.36 (d, J = 1.2 Hz, 1 H), 5.74 (d, J = 1.2 Hz, 1 H), 4.37 (q, J = 7.2 Hz, 2 H), 1.39 (t, J = 7.2 Hz, 3 H), 1.27 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.6 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 165.6, 140.1, 135.6 (q, $J_{C,F}$ = 32.1 Hz), 131.7, 131.6, 126.0 (q, $J_{C,F}$ = 5.1 Hz), 125.5, 123.0, 122.4 (q, $J_{C,F}$ = 274.3 Hz), 120.4, 61.1, 40.2, 27.4, 14.3 ppm. HRMS (ESI^+): calcd. for $C_{17}H_{20}F_3NO_3Na$ [M + Na]$^+$ 366.1293; found 366.1290 (–0.8 ppm).

***N*-[5-Methyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2i):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 80:20 to 70:30) gave **2i** (44 mg, 78 %) as a beige solid. R_f (petroleum ether/Et_2O, 75:25) = 0.50; m.p. 93–94 °C. IR: $\tilde{\nu}$ = 3305, 2968, 1646, 1514, 1480, 1344, 1186, 1159, 1125, 816, 612 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.08 (s, 1 H), 7.45 (br. s, 1 H), 7.08 (d, J = 7.8 Hz, 1 H), 6.95 (d, J = 7.8 Hz, 1 H), 6.24 (d, J = 1.2 Hz, 1 H), 5.65 (d, J = 1.2 Hz, 1 H), 2.37 (s, 3 H), 1.26 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.7 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 140.3, 136.2 (q, $J_{C,F}$ = 31.6 Hz), 135.7, 129.9, 124.9 (q, $J_{C,F}$ = 5.1 Hz), 124.8, 122.73 (q, $J_{C,F}$ = 274.1 Hz), 122.66, 121.4, 39.9, 27.5, 21.5 ppm. HRMS (ESI^+): calcd. for $C_{15}H_{19}F_3NO$ [M + H]$^+$ 286.1419; found 286.1412 (–2.4 ppm).

***N*-[5-Ethyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2j):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 80:20 to 70:30) gave **2j** (37 mg, 61 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.43; m.p. 79–80 °C. IR: $\tilde{\nu}$ = 3326, 2968, 1652, 1494, 1346, 1189, 1167, 1116, 1075, 965, 831, 627 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.12 (d, J = 1.5 Hz, 1 H), 7.47 (br. s, 1 H), 7.11 (d, J = 7.8 Hz, 1 H), 6.97 (dd, J = 7.8, J = 1.5 Hz, 1 H), 6.25 (d, J = 1.2 Hz, 1 H), 5.66 (d, J = 1.2 Hz, 1 H), 2.66 (q, J = 7.5 Hz, 2 H), 1.26 (s, 9 H), 1.25 (t, J = 7.5 Hz, 3 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.7 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 146.6, 136.2 (q, $J_{C,F}$ = 31.5 Hz), 135.8, 129.9, 129.8, 124.9 (q, $J_{C,F}$ = 5.1 Hz), 123.6, 122.7 (q, $J_{C,F}$ = 274.1 Hz), 121.5, 39.9, 28.9, 27.5, 15.3 ppm. HRMS (ESI^+): calcd. for $C_{16}H_{20}F_3NONa$ [M + Na]$^+$ 322.1395; found 322.1397 (+0.6 ppm).

***N*-[5-Chloro-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2k):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2k** (25 mg, 41 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.37; m.p. 187–188 °C. IR: $\tilde{\nu}$ = 3315, 2969, 1659, 1496, 1342, 1220, 1166, 1149, 1126, 1087, 966, 795, 781, 726, 664 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.48 (d, J = 7.8 Hz, 1 H), 7.29–7.18 (m, 2 H), 7.04 (br. s, 1 H), 6.04 (s, 1 H), 5.69 (s, 1 H), 1.28 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –66.7 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 177.0, 135.6 (q, $J_{C,F}$ = 31.6 Hz), 134.9, 133.5, 133.2, 130.5, 129.1, 128.2, 124.0 (q, $J_{C,F}$ = 5.1 Hz), 122.8 (q, $J_{C,F}$ = 273.5 Hz), 39.2, 27.4 ppm. HRMS (ESI^+): calcd. for $C_{14}H_{15}{}^{35}ClF_3NONa$ [M + Na]$^+$ 328.0692; found 328.0699 (+2.1 ppm).

***N*-[5-Bromo-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2l):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **2l** (32 mg, 46 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.56; m.p. 114–115 °C. IR: $\tilde{\nu}$ = 3319, 2969, 1652, 1479, 1342, 1187, 1163, 1127, 1084, 817, 609 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.55 (d, J = 1.8 Hz, 1 H), 7.47 (br. s, 1 H), 7.27 (dd, J = 8.4, J = 1.8 Hz, 1 H), 7.05 (d, J = 8.4 Hz, 1 H), 6.30 (d, J = 1.2 Hz, 1 H), 5.70 (d, J = 1.2 Hz, 1 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.7 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 137.2, 135.5 (q, $J_{C,F}$ = 31.9 Hz), 131.1, 127.0, 125.7 (q, $J_{C,F}$ = 5.2 Hz), 124.7, 124.1, 122.5, 122.4 (q, $J_{C,F}$ = 274.1 Hz), 40.0, 27.4 ppm. HRMS (ESI^+): calcd. for $C_{14}H_{15}{}^{79}BrF_3NONa$ [M + Na]$^+$ 372.0187; found 372.0196 (+2.4 ppm).

Ethyl 3-Pivalamido-4-(3,3,3-trifluoroprop-1-en-2-yl)benzoate (2m): Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **2m** (42 mg, 61 %) as a beige solid. R_f (petroleum ether/Et_2O, 75:25) = 0.19; m.p. 60–61 °C. IR: $\tilde{\nu}$ = 3272, 2969, 1717, 1653, 1485, 1287, 1256, 1227, 1191, 1171, 1111, 1064, 1024, 903, 774, 742, 628 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 8.76 (d, J = 1.5 Hz, 1 H), 7.76 (dd, J = 8.4, J = 1.5 Hz, 1 H), 7.43 (br. s, 1 H), 7.21 (d, J = 8.4 Hz, 1 H), 6.23 (d, J = 1.2 Hz, 1 H), 5.64 (d, J = 1.2 Hz, 1 H), 4.31 (q, J = 7.2 Hz, 2 H), 1.32 (t, J = 7.2 Hz, 3 H), 1.20 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.4 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.6, 165.8, 136.2, 135.6 (q, $J_{C,F}$ = 32.0 Hz), 132.3, 130.2, 128.6, 125.3 (q, $J_{C,F}$ = 5.1 Hz), 125.2, 123.3, 122.4 (q, $J_{C,F}$ = 274.4 Hz), 61.3, 39.9, 27.4, 14.3 ppm. HRMS (ESI^+): calcd. for $C_{17}H_{20}F_3NO_3Na$ [M + Na]$^+$ 366.1293; found 366.1302 (+2.5 ppm).

***N*-[3-(3,3,3-Trifluoroprop-1-en-2-yl)-1,1′-biphenyl-2-yl]pivalamide (2n):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 75:25) gave **2n** (50 mg, 72 %) as a yellow solid; the reaction was also run on a 3.95 mmol scale to give **2n** (970 mg, 71 %). R_f (petroleum ether/Et_2O, 75:25) = 0.17; m.p. 160–161 °C. IR: $\tilde{\nu}$ = 3314, 2974, 1651, 1497, 1455, 1219, 1167, 1122, 964, 757, 738, 699 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.32–7.18 (m, 8 H), 6.82 (br. s, 1 H), 6.04 (d, J = 1.2 Hz, 1 H), 5.75 (d, J = 1.2 Hz, 1 H), 1.02 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –66.9 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 177.2, 141.6, 139.0, 136.1 (q, $J_{C,F}$ = 31.3 Hz), 133.7, 133.0, 131.1, 130.0, 128.8, 128.1, 127.5, 127.4, 123.7 (q, $J_{C,F}$ = 5.1 Hz), 123.1 (q, $J_{C,F}$ = 273.6 Hz), 38.8, 27.2 ppm. HRMS (ESI^+): calcd. for $C_{20}H_{20}F_3NONa$ [M + Na]$^+$ 370.1395; found 370.1389 (1.6 ppm).

***N*-[4,5-Dimethyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2o):** Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 90:10 to 80:20) gave **2o** (38 mg, 63 %) as a yellow solid. R_f (petroleum ether/Et_2O, 75:25) = 0.37; m.p. 82–83 °C. IR: $\tilde{\nu}$ = 3272, 2963, 1651, 1495, 1455, 1175, 1119, 1103, 949, 876, 675, 640 cm^{-1}. ^1H NMR (300.1 MHz, $CDCl_3$): δ = 7.96 (s, 1 H), 7.36 (br. s,

1 H), 6.96 (s, 1 H), 6.21 (d, J = 0.9 Hz, 1 H), 5.63 (d, J = 0.9 Hz, 1 H), 2.27 (s, 3 H), 2.23 (s, 3 H), 1.25 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.6 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 176.5, 138.7, 136.2 (q, $J_{C,F}$ = 31.5 Hz), 133.5, 132.7, 130.8, 124.6 (q, $J_{C,F}$ = 5.1 Hz), 123.7, 122.8 (q, $J_{C,F}$ = 274.1 Hz), 122.2, 39.7, 27.5, 19.8, 19.1 ppm. HRMS (ESI$^+$): calcd. for $C_{16}H_{21}F_3NO$ [M + H]$^+$ 300.1575; found 300.1563 (–4.0 ppm).

***N*-[4,6-Dimethyl-2-(3,3,3-trifluoroprop-1-en-2-yl)phenyl]pivalamide (2p):** Purification by reverse-phase chromatography (carried out on a puriFlash® C18HP 15 µm 55G flash column; eluent: H_2O/CH_3CN) gave **2p** (18 mg, 30 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.23; m.p. 152–153 °C. IR: $\tilde{\nu}$ = 3332, 2961, 1651, 1506, 1355, 1237, 1162, 1152, 1116, 966, 861, 667 cm^{-1}. ^{1}H NMR (300.1 MHz, $CDCl_3$): δ = 7.09 (s, 1 H), 6.91 (br. s, 2 H), 6.01 (s, 1 H), 5.57 (s, 1 H), 2.31 (s, 3 H), 2.19 (s, 3 H), 1.26 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.4 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 177.0, 136.9, 136.8, 136.4 (q, $J_{C,F}$ = 31.2 Hz), 132.2, 132.1, 131.2, 128.6, 123.1 (q, $J_{C,F}$ = 5.3 Hz), 123.0 (q, $J_{C,F}$ = 273.5 Hz), 39.1, 27.6, 20.9, 18.2 ppm. HRMS (ESI$^+$): calcd. for $C_{16}H_{21}F_3NO$ [M + H]$^+$ 300.1575; found 300.1570 (–1.7 ppm).

General Procedure for the Removal of the Directing Group: Compound **2b** or **2d** (1.0 mmol) was dissolved in a mixture of 1,4-dioxane (5 mL) and HCl (12 M; 5 mL), and the reaction mixture was heated at reflux overnight. The mixture was cooled to room temperature, then Na_2CO_3 (satd. aq.) was added until the pH had reached 9–10. The mixture was extracted with ethyl acetate (3 × 30 mL). The combined organic phases were washed with brine (20 mL) and dried with anhydrous $MgSO_4$, and then the solvents were evaporated under reduced pressure. The residue was purified by silica gel column chromatography.

4-Methyl-2-(3,3,3-trifluoroprop-1-en-2-yl)aniline (3a): Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **3a** (412 mg, 69 %) as a yellow liquid on a 3.0 mmol scale. R_f (petroleum ether/Et_2O, 75:25) = 0.40. IR: $\tilde{\nu}$ = 3385, 2924, 1624, 1506, 1344, 1156, 1117, 958, 814 cm^{-1}. ^{1}H NMR (300.1 MHz, $CDCl_3$): δ = 6.94 (d, J = 8.1 Hz, 1 H), 6.93 (s, 1 H), 6.59 (d, J = 8.1 Hz, 1 H), 6.12 (s, 1 H), 5.61 (s, 1 H), 3.55 (br. s, 2 H), 2.21 (s, 3 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.2 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 142.0, 136.4 (q, $J_{C,F}$ = 31.0 Hz), 130.5, 130.4, 127.2, 123.8 (q, $J_{C,F}$ = 5.3 Hz), 123.1 (q, $J_{C,F}$ = 274.0 Hz), 118.9, 115.9, 20.0 ppm. HRMS (ESI$^+$): calcd. for $C_{10}H_{11}F_3N$ [M + H]$^+$ 202.0844; found 202.0840 (–2.0 ppm).

4-(*tert*-Butyl)-2-(3,3,3-trifluoroprop-1-en-2-yl)aniline (3b): Purification by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, from 95:5 to 85:15) gave **3b** (171 mg, 70 %) as a yellow liquid. R_f (petroleum ether/Et_2O, 75:25) = 0.36. IR: $\tilde{\nu}$ = 3347, 2964, 1623, 1505, 1345, 1162, 1124, 969, 826 cm^{-1}. ^{1}H NMR (300.1 MHz, $CDCl_3$): δ = 7.24 (d, J = 8.4 Hz, 1 H), 7.09 (s, 1 H), 6.70 (d, J = 8.4 Hz, 1 H), 6.20 (s, 1 H), 5.69 (s, 1 H), 3.67 (br. s, 2 H), 1.29 (s, 9 H) ppm. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –67.3 (s) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 141.8, 141.1, 136.7 (q, $J_{C,F}$ = 31.0 Hz), 126.98, 126.94, 124.0 (q, $J_{C,F}$ = 5.2 Hz), 123.1 (q, $J_{C,F}$ = 274.4 Hz), 118.7, 115.7, 33.9, 31.4 ppm. HRMS (ESI$^+$): calcd. for $C_{13}H_{17}F_3N$ [M + H]$^+$ 244.1313; found 244.1314 (+0.4 ppm).

***N*-[5-Methyl-2-(1,1,1-trifluoropropan-2-yl)phenyl]pivalamide (4):** Compound **2i** (28 mg, 0.1 mmol) and Pd/C (10 %, w/w; 100 mg) were added to EtOH (2 mL). The suspension was stirred at 50 °C under hydrogen (1 atm) overnight. The mixture was cooled to room temperature, then it was diluted with diethyl ether (10 mL), and filtered through a plug of Celite®. The solvents were removed under vacuum, and the crude residue was purified by silica gel column chromatography (Biotage system 25 g; height 80 mm, width 30 mm; eluent: petroleum ether/Et_2O, 80:20 to 75:25) to give **4** (24 mg, 85 %) as a white solid. R_f (petroleum ether/Et_2O, 75:25) = 0.22; m.p. 110–111 °C. IR: $\tilde{\nu}$ = 3282, 2925, 1647, 1496, 1163, 1129, 1106, 1042, 986, 812 cm^{-1}. ^{1}H NMR (300.1 MHz, $CDCl_3$): δ = 7.29 (d, J = 8.1 Hz, 1 H), 7.28 (s, 1 H), 7.10 (d, J = 8.1 Hz, 1 H), 3.61–3.50 (m, 1 H), 2.34 (s, 3 H), 1.51 (d, J = 7.2 Hz, 3 H), 1.34 (s, 9 H) ppm; note that one proton (NH) is missing. ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –71.8 (d, J = 9.0 Hz) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 177.3, 138.7, 135.5, 127.9, 127.7, 127.6, 127.5 (q, $J_{C,F}$ = 280.1 Hz), 127.4, 39.4, 37.7 (q, $J_{C,F}$ = 27.1 Hz), 27.6, 20.9, 13.7 (q, $J_{C,F}$ = 3.0 Hz) ppm. HRMS (ESI$^+$) calcd. for $C_{15}H_{21}F_3NO$ [M + H]$^+$ 288.1575; found 288.1573 (–0.7 ppm).

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