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# Pd-catalyzed coupling of arylamines and 2-bromo-3,3,3-trifluoropropene

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**Abstract**

Palladium-catalyzed coupling of arylamines and 2-bromo-3,3,3-trifluoropropene (BTP) was investigated. When a toluene solution of aniline and BTP was heated at 110 °C in the presence of $Pd_2(dba)_3{\cdot}CHCl_3$, 1,1′-diphenylphosphinoferrocene and $Cs_2CO_3$ under an argon atmosphere, *N*-(1,1,1-trifluoro-2-propylidene)aniline was obtained in excellent GC and $^{19}F$ NMR yields (99%) and isolated yield (92%). $Cs_2CO_3$ was exclusively effective in the coupling reaction among the bases tested. The coupling using 2-aminobenzonitriles as substrates provided not only 2-*N*-(1,1,1-trifluoro-2-propylidene)aminobenzonitriles but also 4-amino-2-trifluoromethylquinolines and 2-trifluoromethyl-4-*N*-(1,1,1-trifluoro-2-propylidene)aminoquinolines. The strong electron-withdrawing character of $CF_3$ will enhance the acidity of the methyl proton in the *N*-(1,1,1-trifluoromethyl-2-propylidene)amino group, resulting in the attack of the methyl proton to the carbon in the cyano group to give 4-amino-2-trifluoromethylquinolines. Moreover, the one-pot synthesis of 2-trifluoromethylindoles with 2-bromoanilines and BTP was achieved by use of $Pd(OAc)_2$, 2-dicyclohexylphosphino-2′,4′,6′-triisopropylbipenyl and $Cs_2CO_3$. The Pd-catalyzed intramolecular Heck coupling of the vinyl group in 2-bromo-*N*-(1-trifluoromethyl)vinylanilines, which is the tautmeric isomer of 2-bromo-*N*-(1,1,1-trifluoro-2-propylidene)anilines, and the C—Br bond presumably furnished indole rings. The C—N double bond of *N*-(1,1,1-trifluoro-2-propylidene) amino group obtained here was smoothly hydrogenated to *N*-(1-methyl-2,2,2-trifluoro)ethylamino group using $LiAlH_4$ or $H_2$ with Pd/C.


*Keywords:* Palladium; 2-Bromo-3,3,3-trifluoropropene; Amination; 4-Amino-2-trifluoromethylquinoline; 2-Trifluoromethylindole

## 1. Introduction

Development of highly selective synthesis of imines and enamines is of great interest because they are useful intermediates for introducing nitrogen-containing fragments in a synthetic sequence due to their versatile reactivities [1]. While condensation of amine and carbonyl compounds is fairly general for the synthesis of imines [2], it presents several limitations, such as harsh reaction conditions and low functional group tolerance. Recently, several groups have successfully extended the Buchwald-Hartwig amination [3] for the preparation of imines or enamines through the coupling of alkenyl bromides or triflates with amines to overcome these problems [4]. On the other hand, development of new methodology for the synthesis of *N*-(fluorinatedalkyl)imines and enamines have received less attention although fluorinated organic compounds are valuable materials in medicinal and agricultural sciences because of their various significant bioactivities [5]. With regard to aryl-*N*-(fluorinatedalkyl)imines, the low nucleophilicity of arylamines and the low boiling point of fluorinated carbonyl compounds would prevent us from using the condensation. Indeed, *N*-(1,1,1-trifluoro-2-propylidene)aniline synthesis from aniline and 1,1,1-trifluoroacetone (boiling point = 22 °C) is a sole example [6]; the yield of the imine was considerably low (25%) under mild conditions (25 °C, 48 h). Recently, aza-Wittig reaction of iminophosphoranes and 1,1,1-trifluoroacetone has been developed for the synthesis of 4-methoxy-*N*-(1,1,1-trifluoro-2-propylidene)aniline from triphenylphosphine-4-methoxyphenylimine and 1,1,1-trifluoroacetone [7]. Although this method gives an excellent yield, synthesis of the raw material is somewhat troublesome. In any case, 1,1,1-trifluoroacetone is rather expensive as a versatile reagent.

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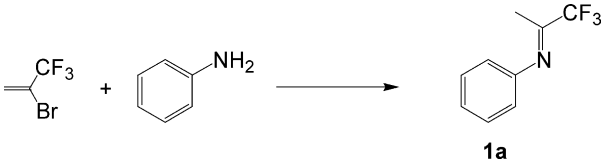
1,2-Dibromo-3,3,3-trifluoropropane (DBTFP) and 2-bromo-3,3,3-trifluoropropene (BTP) are useful reagents for introduction of $CF_3$ group in organic molecules accompanied by C–C and C–O bond formation [8–13]. Although BTP as well as 1,1,1-trifluoroacetone is volatile (b.p. = 34 °C), abstracting HBr with a base from non-volatile DBTFP (b.p. = 116 °C) readily gives BTP [14].

Based on our previous success of the palladium-catalyzed carboalkoxylation of BTP with bulky alcohols to give trifluoromethacrylate esters [15], we were intrigued by the possibility that the vinyl palladium intermediate generated from Pd(0) and BTP might undergo C–N bond formation with arylamines; transition metal catalyzed C–N bond formation using BTP have not been reported. Herein, we report the integration of our studies into the development of palladium-catalyzed C–N bond formation to give *N*-(1,1,1-trifluoro-2-propylidene)aniline derivatives.

## 2. Results and discussion

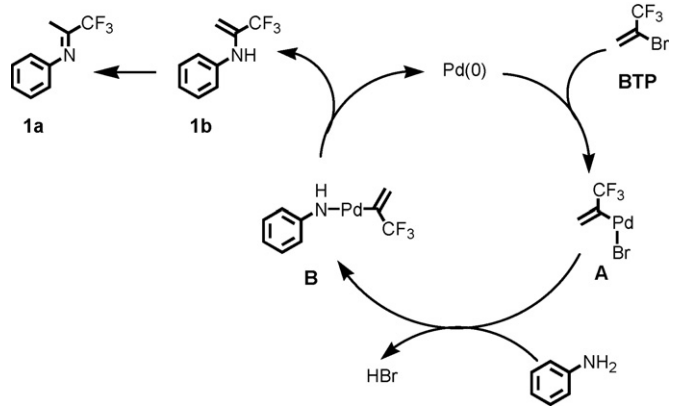
### 2.1. Coupling of BTP and anilines

When a 10 mL Pyrex-glass test tube with a screw stopper containing aniline (1.0 mmol), $Pd_2(dba)_3{\cdot}CHCl_3$ (0.05 mmol, dba = dibenzalacetone), 1,1′-diphenylphosphinoferrocene (dppf, 0.15 mmol), $Cs_2CO_3$ (1.2 mmol) and 2-bromo-3,3,3-trifluoropropene (BTP, 1.2 mmol) in toluene (2.0 mL) was heated at 110 °C for 15 h under an argon atmosphere, *N*-(1,1,1-trifluoro-2-propylidene)aniline (**1a**) was obtained in the excellent GC and $^{19}F$ NMR yields (99%) and isolated yield (92%) (Eq. (1)).




(1)

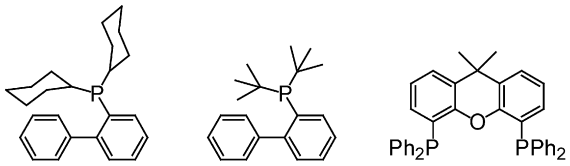
As depicted in Scheme 1, the coupling of aniline and BTP is considered to proceed as follows [4]; (i) oxidative addition of BTP to palladium to produce a vinyl palladium intermediate A; (ii) a vinyl palladium anilide intermediate B is formed through proton abstraction from aniline coordinated to A by a base; and




Scheme 1.

Table 1
Pd-catalyzed coupling of aniline and BTP to **1a** with various phosphine ligands[a]

| Run | Ligand | Aniline conversion (%)[b] | NMR yield (%) |
|---|---|---|---|
| 1 | $PPh_3$ | 2 | 2 |
| 2 | $PCy_3$ | 1 | Trace |
| 3 | ligand A | 85 | 9 |
| 4 | JohnPhos | 38 | 32 |
| 5 | dppf | 99 | 99 |
| 6 | dppe | 39 | 3 |
| 7 | dppp | 51 | 22 |
| 8 | dppb | 83 | 80 |
| 9 | BINAP | 79 | 78 |
| 10 | Xantphos | 48 | 48 |




[a] Aniline 1.0 mmol, BTP 1.2 mmol, $Pd_2(dba)_3$ 0.05 mmol, ligand (P atom) 0.15 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 110 °C, 15 h.
[b] Determined by GC.

(iii) *N*-(1-trifluoromethyl)vinylaniline **1b** reductively eliminates from B. Since **1b** was not detected even in the $^{19}F$ NMR spectrum of the crude reaction solution, the vinylamino group in **1b** appears to isomerize smoothly to an alkylideneamino group to give **1a**. This feature seems reasonable because, in general, an imine form is thermodynamically more stable in tautomeric equilibrium between imine and enamine.

The yield of **1a** was dependent on the phosphine ligand used. As seen in Table 1, dppf, dppb and BINAP were effective for the coupling. Of them, dppf revealed the highest activity for **1a** formation (run 5). When ligand A or dppe was employed, the yield of **1a** was much lower than the aniline conversion (runs 3 and 6). Decomposition of the products may occur, though the decomposed products were not identified.

Further exploration using dppf revealed that the satisfactory yields of **1a** were obtained in the range of [P]/[Pd] = 2–4 (Table 2). Particularly, the excellent yield was obtained at the ratio of [P]/[Pd] = 3 (run 12).

When the $Pd_2(dba)_3$-dppf catalyzed coupling was performed with various bases, $Cs_2CO_3$ was exclusively effective base for the present coupling (run 14 in Table 3). Barluenga and coworkers reported that the combination of BINAP as a ligand and $NaO^tBu$ as a base is the optimized reaction condition for

Table 2
Pd-catalyzed coupling of aniline and BTP to **1a** with various [P]/[Pd][a]

| Run | [P]/[Pd] | Aniline conversion (%)[b] | NMR yield (%) |
|---|---|---|---|
| 11 | 2 | 93 | 92 |
| 12 | 3 | 99 | 99 |
| 13 | 4 | 91 | 89 |

[a] Aniline 1.0 mmol, BTP 1.2 mmol, $Pd_2(dba)_3$ 0.05 mmol, dppf 0.10–0.20 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 110 °C, 15 h.
[b] Determined by GC.

Table 3
Pd-catalyzed coupling of aniline and BTP to 1a with various bases[a]

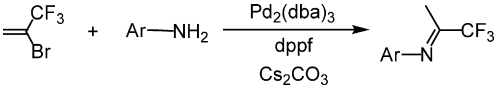
| Run | Base | Aniline conversion (%) | NMR yield (%) |
|---|---|---|---|
| 14 | $Cs_2CO_3$ | 99 | 99 |
| 15 | $K_2CO_3$ | 99 | 30 |
| 16 | $Na_2CO_3$ | 1 | 0 |
| 17 | $Li_2CO_3$ | 14 | 0 |
| 18 | CsOH | 11 | 11 |
| 19 | $K_3PO_4$ | 28 | 26 |
| 20 | NaO$^t$Bu | 2 | Trace |
| 21 | $Et_3N$ | 1 | 0 |

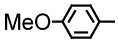
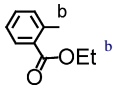
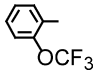
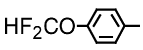
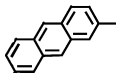
[a] Aniline 1.0 mmol, BTP 1.2 mmol, $Pd_2(dba)_3$ 0.05 mmol, dppf 0.15 mmol, base 1.2 mmol, toluene 2 mL, 110 °C, 15 h.

the Pd-catalyzed coupling of α-bromostyrenes and amines [4a]. In our work, the use of BINAP and NaO$^t$Bu also exhibited an excellent $^{19}$F NMR yield (99%). However, a conventional column technique used here (see Section 4) was unsuitable for the separation of a product and BINAP and/or its decomposition products. Other bulky monodentate or bidentate phosphines (JohnPhos and Xanthphos, see Table 1) with NaO$^t$Bu showed lower yields (26% and 8%) than those with $Cs_2CO_3$. Therefore, the coupling was mainly examined with combination of dppf and $Cs_2CO_3$.

Use of $Cs_2CO_3$ as a base usually gives desired products in excellent yield because of its solubility in organic solvents and basicity [3f]. Recent investigation has proposed the other role of $Cs_2CO_3$ which is to stabilize an acylpalladium-aqua intermediate in the Pd-catalyzed carbohydroxylation [16]. We have also concluded that the remarkable rate acceleration by $Li_2CO_3$ in the Pd-catalyzed carbonylalkoxylation of BTP is due to similar stabilization of the acylpalladium-alkoxo intermediate [15]. We have no evidence, but as for the coupling with BTP, carbonate ion may interact with an F atom in BTP to increase the reaction rate. This characteristic of our coupling is remarkably

Table 4
Pd-catalyzed coupling of various anilines and BTP[a]




| Run | Ar– | Product | NMR yield (%) | Isolated yield (%) | Run | Ar– | Product | NMR yield (%) | Isolated yield (%) |
|---|---|---|---|---|---|---|---|---|---|
| 22 |  | **2a** | 61 | 44 | 34 |  | **14a** | 63 | 52 |
| 23 |  | **3a** | 99 | 59 | 35 |  | **15a** | 90 | – |
| 24 |  | **4a** | 99 | 89 | 36 |  | **16a** | 99 | 55 |
| 25 |  | **5a** | 99 | 57 | 37 |  | **17a** | 95 | 77 |
| 26 |  | **6a** | 77 | 42 | 38 |  | **18a** | 94 | 80 |
| 27 |  | **7a** | 63 | – | 39 |  | **19a** | 83 | 59 |
| 28 |  | **8a** | 40 | 40 | 40 |  | **20a** | 58 | 43 |
| 29 |  | **9a** | 99 | – | 41 |  | **21a** | 99 | 59 |
| 30 |  [b] | **10a** | 32 | – | 42 |  | **22a** | 99 | 63 |
| 31 |  | **11a** | 23 | – | 43 |  | **23a** | 99 | 69 |
| 32 |  | **12a** | 84 | – | 44 |  | **24a** | 98 | 92 |
| 33 |  [c] | **13a** | 43 | 33 | 45 |  | **25a** | 59 | 27 |

[a] Ar–$NH_2$ 1.0 mmol, BTP 1.2 mmol, $Pd_2(dba)_3$ 0.05 mmol, dppf 0.15 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 110 °C, 15 h.
[b] An enamine form, **10b**, was also obtained with 24% NMR yield (see text).
[c] BTP 2.4 mmol. See Table 9.

different from that of the Pd-catalyzed amination of vinyl bromides or vinyl triflates where NaO$^t$Bu is used as an optimal base [3].

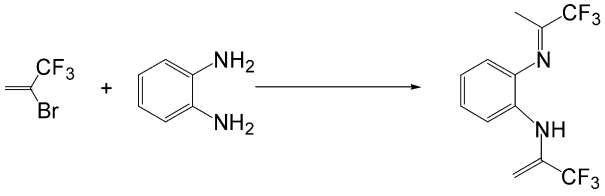
The scope of various anilines and arylamines as substrates was examined for the coupling (Table 4). The present amination widely tolerates the substitution in the aromatic ring. Only *o*-carboxyethyleniline gave both the imine and enamine product (run 30).

We attempted to isolate the desired products, **2a–25a**, using a neutral silica column, because imines and enamines are inclined to decompose at a contact of acidic media in general. However, several anilines afforded the appreciably lower isolated yields than the $^{19}$F NMR yields, or could not be isolated.

As described in Section 1, the condensation of aniline and 1,1,1-trifluoroacetone afforded **1a** in low yield (25% in ref. [6], 22% for our experiment). Even though the reaction was carried out under the same conditions as our coupling (at 110 °C for 15 h), the yields were not higher than 55%. As for the other anilines, lower yields (**3a** 47%, **4a** 28%, **8a** 2%, **9a** 2%, **16a** 3% and **20a** 5%) were also obtained under the same conditions as ref. [6] than those in Table 4. The reaction at 110 °C for 15 h led to the improved yields: **3a** 77%, **4a** 85%, **8a** 3%, **9a** 9%, **16a** 12% and **20a** 41%. However, these yields are still lower than those in Table 4. Thus, the coupling described here is effective for the imine synthesis using arylamines.

The results of the condensation of BTP with aniline derivatives revealed the general order of reactivity of anilines. Thus, the compounds with an electron-withdrawing group, which reduces the basicity of an amino group, afforded a low yield (**8a**, **9a**, **16a** and **20a**). In contrast as shown in Table 4, the present coupling obviously gave the relatively higher yields than the condensation reaction condition even when anilines with low nucleophilicity were employed: **8a** 40%, **9a** 99%, **16a** 99% and **20a** 58%. Thus, the present coupling is tolerant to a wide range of substituents. The effect of the substituent in our coupling could be explained in terms of neither electronic nor steric effect. Nevertheless, this applicability seems important characteristic of the coupling in contrast to the condensation.

Interestingly, one of the two amino groups in *o*-phenylenediamine converted to *N*-(1,1,1-trifluoromethyl-2-propylidene) amino group, and the other to *N*-(1-trifluoromethyl)vinylamino one (Eq. (2), **26a**). To the best of our knowledge, **26a** is the first example of the unsymmetrical Schiff-type base obtained from *o*-phenylenediamine derivatives and containing similar imino and enamino building block [17]. This unique structure is discussed in terms of hydrogen bond.




**26a** (isolated yield 34 %)

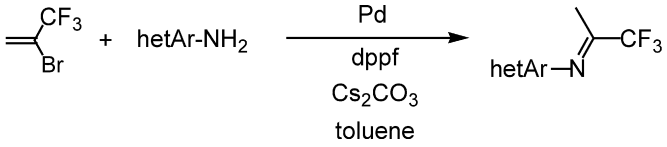
(2)

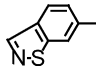
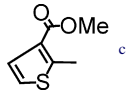
This coupling reaction also proceeded with heteroarylamines and anilines condensed with a heteroaromatic ring as shown in Table 5. With 3-aminopyridine, the moderate yield was obtained not with $Pd_2(dba)_3$ but with $Pd(OAc)_2$ (run 46). The dba ligands in $Pd_2(dba)_3$ may retard the coupling through the interaction with nitrogen atom in pyridine.

Both imine (**30a**) and enamine (**30b**) were obtained from methyl 2-amino-3-thiophenecarboxylate as a substrate (run 49).

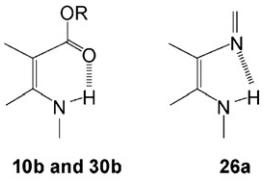
It is worth noting that the enamine forms isolated were only **10b**, **26a** and **30b**. Generally electron-donating groups stabilize the enamine form. We can find the substrates possessing electron-donating group in Table 4: methyl (runs 22–24), *tert*-butyl (run 25) and methoxy (run 41) groups and so on. However, the enamine forms were not detected even in the crude reaction solution by $^{19}$F NMR for these substrates. We now consider the stabilization by hydrogen bond between the amino proton of the *N*-(1-trifluoromethyl)vinylamino group and the adjacent alkoxycarbonyl or imino group as depicted in Scheme 2 [18,19]. Since electron-withdrawing nature of $CF_3$ in the *N*-(1-trifluoromethyl)vinylamino group enhances moderately the

Table 5
Pd-catalyzed coupling of various heteroarylamines and BTP[a]




| Run | hetAr– | Product | NMR yield (%) | Isolated yield (%) | Run | hetAr– | Product | NMR yield (%) | Isolated yield (%) |
|---|---|---|---|---|---|---|---|---|---|
| 46 |  [b] | **27a** | 58 | 39 | 48 |  | **29a** | 42 | 30 |
| 47 |  | **28a** | 21 | 19 | 49 |  [c] | **30a** | 15 | 4 |

[a] hetAr-$NH_2$ 1.0 mmol, BTP 1.2 mmol, $Pd_2(dba)_3$ 0.05 mmol, dppf 0.15 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 110 °C, 15 h.
[b] $Pd(OAc)_2$ was used.
[c] An enamine form, **31b**, was obtained with 14% NMR and 6% isolated yield (see text).

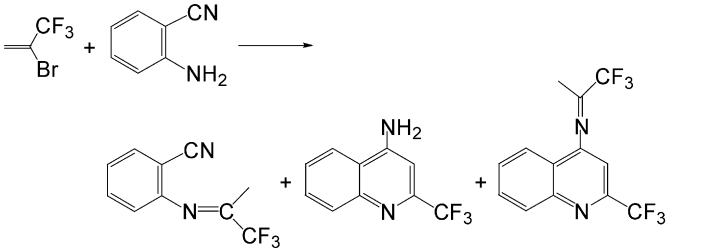



Scheme 2.

cationic character of the amino proton, it may also contribute to the stabilization by the hydrogen bond.

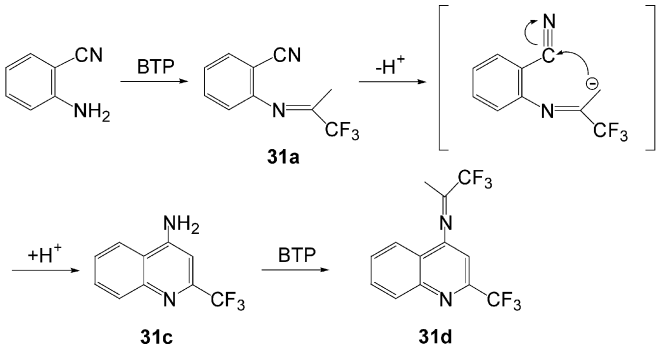
### 2.2. Pd-catalyzed coupling of 2-aminobenzonitriles with BTP (synthesis of 4-amino-2-trifluoromethylquinolines and 2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)aminoquinolines

It is quite interesting that the coupling of 2-aminobenzonitrile with BTP provided 4-amino-2-trifluoromethylquinoline (**31c**) and 2-trifluoromethyl-4-*N*-(1,1,1-trifluoro-2-propylidene)aminoquinoline (**31d**) with the concomitant formation of **31a** (Eq. (3)); **31c** and **31d** were isolated by passing through a silica gel column (35% and 11%, respectively). The yields of **31c** and **31d** were enhanced by the use of 2.4 equiv. of BTP to 2-aminobenzonitrile (**31c**: 37 → 41%, **31d**: 10 → 17%).




(3)

This reaction is considered to proceed in a consecutive manner as depicted in Eq. (4). First, **31a** was formed in the same manner as shown in Scheme 1. The acidity of the methyl proton of the *N*-(1,1,1-trifluoromethyl-2-propylidene)amino group in **31a** will be so high due to the strong electron-withdrawing character of $CF_3$ that it readily dissociates as a proton. The carbanion generated on the methyl group will attack the carbon of the cyano group, followed by cyclization to 4-amino-2-trifluoromethylquinoline **31c**. Another molecule of BTP reacts with the amino group of **31c** to produce **31d**. The formation of **31d** suggests that **31a** is *E* form probably due to the order of the bulkiness ($CF_3 > CH_3$).




(4)

Table 6
Dependence of loaded amount of $Cs_2CO_3$ on yield of **31a**, **31c** and **31d** in Pd-catalyzed coupling of BTP and 2-aminobenzonitrile[a]

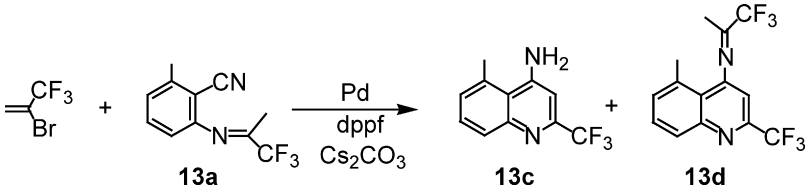
| Run | [$Cs_2CO_3$]/[substrate] | NMR yield (%) | | | | |
|---|---|---|---|---|---|---|
| | | **31a** | **31c** | **31d** | **31a + 31c + 31d** | **31c + 31d** |
| 50 | 1.2 | 2 | 37 | 10 | 49 | 47 |
| 51 | 2.4 | 3 | 33 | 27 | 63 | 60 |

[a] 2-Aminobenzonitrile 0.5 mmol, BTP 1.2 mmol, $Pd(dba)_2$ 0.05 mmol, dppf 0.075 mmol, toluene 2 mL, 110 °C, 15 h.

Table 6 shows the dependence of the product distribution on the loaded amount of $Cs_2CO_3$. By increasing the [$Cs_2CO_3$]/[substrate] ratio from 1.2 to 2.4; the total yield of (**31a + 31c + 31d**), the ratio of **31d** to **31c** (0.3 → 0.8) and the total yield of (**31c + 31d**) were enhanced. Thus, $Cs_2CO_3$ facilitates not only the amination but also the cyclization of **31a** to **31c**.

The cyclization step was investigated with 6-methyl-*N*-(1,1,1-trifluoromethyl-2-propylidene)aminobenzonitrile (**13a**), which can be isolated from the reaction mixture of 2-amino-5-methylbenzonitrile and BTP in a good yield (run 33 in

Table 7
Pd-catalyzed coupling of BTP and 5-methyl-2-*N*-(1,1,1-trifluoro-2-propylidene)aminobenzonitrile[a]




| Run | [BTP]/[**13a**] | [$Cs_2CO_3$]/[**13a**] | NMR yield of **13c** (%) | NMR yield of **13d** (%) |
|---|---|---|---|---|
| 52 | 1.2 | 1.2 | 7 | 48 |
| 53 | 1.2 | 2.4 | 0 | 67 |
| 54 | 0 | 0 | 0 | 0 |

[a] **13a** 0.5 mmol, $Pd(dba)_2$ 0.05 mmol, dppf 0.075 mmol, toluene 2 mL, 110 °C, 15 h.

Table 4). As seen in Table 7, the excess amount of $Cs_2CO_3$ is favourable for not only the cyclization of **13a** to **13c** but also the amination of **13c** and **13d**. Furthermore, both compounds were not formed without $Cs_2CO_3$ (run 54). Therefore, we can conclude that $Cs_2CO_3$ is indispensable for the cyclization.

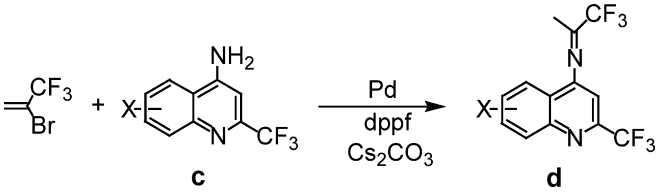
It should be noted that the step of **13a** → **13c** scarcely proceeded without $Pd(dba)_2$ and dppf. Thus, a base, which will abstract a proton from the (1,1,1-trifluoro-2-propylidene)amino group in **13a**, alone does not bring about the formation of **13c**. Indeed, no desired product was formed by use of either 2.4 equiv. of $Cs_2CO_3$ or 1.2 equiv. of the other base such as NaO$^t$Bu and NaOH. It is known that palladium(II) ions catalyze hydration of nitriles, where palladium enhances the electrophilicity of carbon in cyano group through the coordination to a lone pair of nitrogen [20]. In the cyclization of **13a** to **13c**, it is possible that palladium activates cyano group similarly. The increase in the electrophilicity of cyano group in this manner is known for the cyclization assisted by the other metal species or electron-withdrawing group [21,22].

In addition, the coupling of various isolated **c** and BTP was investigated (Table 8). The coupling proceeded under similar conditions in Table 1 in rather low yield (runs 55 and 56). The excellent yields were obtained at the higher ratio of [BTP]/[**35c**] (run 57). However, we failed in producing **31d** in a satisfactory yield at the ratio of [BTP]/[**31c**] = 10. We consider that hydrophobicity made by the large amount of BTP might be unfavourable for the ionic intermediate in Scheme 1, while F atom near the amino group in **35c** would attract BTP to the reaction site.

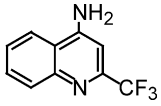
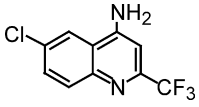
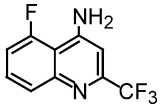
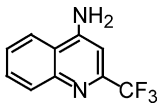
Next we examined the second amination in Eq. (4) by use of $Pd(OAc)_2$, dppf and $Cs_2CO_3$. 4-Amino-2-trifluoromethylquinolines are regarded as pyridine derivatives, and $Pd(OAc)_2$ is suitable for the coupling with pyridine as described above (run 46 in Table 5). Again the desired product was not obtained efficiently (run 58). It can be concluded that several factors make the second amination step difficult.

The results in Tables 6–8 strongly support the consecutive mechanism shown in Eq. (4). These three products were obtained from various 2-aminobenznitriles (Table 9). Although the product distribution seems independent on the substituent on the phenyl ring, halogenobenzonitriles tend to give 4-amino-2-trifluorimethylquinollines (runs 61–63). 4-Amino-2-trifluoromethylquinolines represent an important class of compounds which have interesting pharmacological properties and so are widely used in medicinal chemistry [23,24]. There have been two reports concerning the synthesis of 4-amino-2-trifluoromethylquinolines. One is the cyclization of aniline and ethyl 2-(trifluoroacetyl)acetate to 4-hydroxy-2-trifluoromethylquinoline, followed by the reaction with $POCl_3$ to 4-chloro-2-trifluoromethylquinoline and the amination of Cl with $NH_3$ or amines [25]. The other is the reaction of aniline and 2-phenylimino-1,1,1,4,4,4-hexafluorobutane in the presence of KOH to 4-*N*-phenylamino-2-trifluoromethylquinoline [26]. One step formation presented here is remarkably simpler than these two methods.

Table 8
Pd-catalyzed coupling of 4-amino-2-trifluoromethylquinolines and BTP[a]

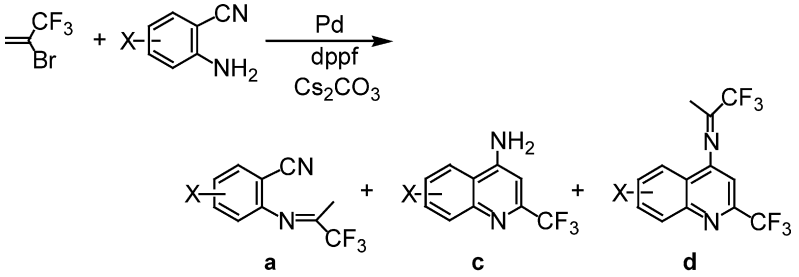


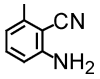
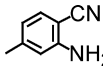
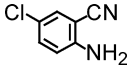
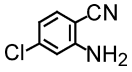
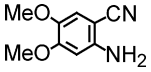

**c** **d**

| Run | **c** | | [BTP]/[**c**] | Product | NMR yield (%) |
|---|---|---|---|---|---|
| 55 |  | **31c** | 1.5 | **31d** | 19 |
| 56 |  | **33c** | 1.2 | **33d** | 4 |
| 57 |  | **35c** | 10 | **35d** | 90 |
| 58[b] |  | **31c** | 12 | **31d** | 6 |

[a] 4-Amino-2-trifluoromethylquinolines 0.2 mmol, $Pd(dba)_2$ 0.05 mmol, dppf 0.075 mmol, $Cs_2CO_3$ 0.24 mmol, toluene 0.5–2 mL, 110 °C, 15 h.
[b] $Pd(OAc)_2$ was used instead of $Pd(dba)_2$.

Table 9
Pd-catalyzed coupling of 2-aminobenzonitriles and BTP[a]

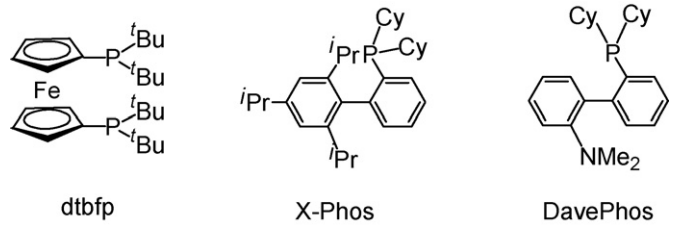



| Run | | Yield (%) NMR isolated | | | Yield (%) NMR isolated | | | Yield (%) NMR isolated | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 59 |  | **13a** | 43 | 33 | **13c** | 7 | — | **13d** | 13 | 8 |
| 60 |  | **32a** | 4 | – | **32c** | 26 | 17 | **32d** | 44 | – |
| 61 |  | – | – | – | **33c** | 66 | 39 | **33d** | 5 | – |
| 62 |  | – | – | – | **34c** | 35 | 10 | – | – | – |
| 63 |  | – | – | – | **35c** | 50 | 48 | **35d** | 20 | – |
| 64 |  | **36a** | 19 | – | **36c** | 23 | 20 | **36d** | 33 | 23 |

[a] 2-Aminobenzonitriles 1.0 mmol, BTP 2.4 mmol, $Pd_2(dba)_3$ 0.05 mmol, dppf 0.15 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 110 °C, 15 h.

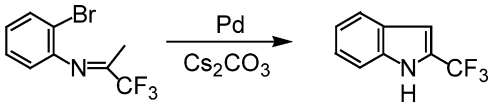
### 2.3. Pd-catalyzed coupling of 2-haloanilines and BTP (synthesis of 2-trifluoromethylindoles)

As seen in Table 4, 2-bromo-*N*-(1,1,1-trifluoromethyl-2-propylidene)aniline (**15a**) was obtained from 2-bromoaniline by use of $Pd_2(dba)_3$ and dppf. It was found that the use of $Pd(OAc)_2$ instead of $Pd_2(dba)_3$ gave 2-trifluoromethylindole, **15e**, in low $^{19}F$ NMR yield (11% at 110 °C and 21% at 125 °C). Similarly the use of $Pd(OAc)_2$ and more bulky di-*tert*-butylphoshinoferrocene (dtbpf, Scheme 3) than dppf furnished **15e** (23% at 125 °C). This finding stimulated us to apply the present coupling to the one-pot synthesis of **15e**, because 2-trifluoromethylindole is one of the most important intermediate for medicinal and agricultural chemicals [27,28]. The use of $Pd(OAc)_2$ and X-Phos (Scheme 3) gave the highest yield of **15e**, 70%, with 10% of **15a** at 125 °C. Since various combination of Pd species and bulky phosphines readily converted **15a** into **15e** (Table 10), **15a** seems an intermediate. Thus, this reaction is considered to proceed as follows (Eq. (5)): (i) the coupling of 2-bromoaniline and BTP to **15a**; (ii) palladium oxidatively inserts into the phenyl-Br bond of 2-bromo-*N*-(1-trifluoromethyl)vinylaniline, **15b**, which is the tautmeric isomer of **15a**; and (iii) *endo*-cyclization through




Scheme 3.

Table 10
Pd-catalyzed cyclization of 2-bromo-*N*-(1,1,1-trifluoro-2-propylidene)aniline[a]

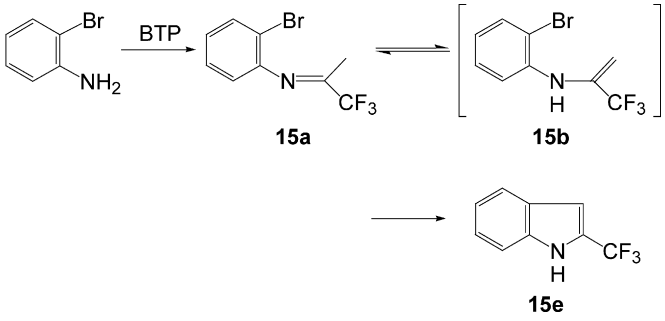



**15a** **15e**

| Run | Pd species | Phosphine[b] | NMR yield of **15e** (%) |
|---|---|---|---|
| 65 | $Pd(dba)_2$ | dppf | 44 |
| 66 | $Pd(dba)_2$ | dtbfp | 43 |
| 67 | $Pd(OAc)_2$ | dtbfp | 56 |
| 68 | $Pd(dba)_2$ | X-Phos | 85 |
| 69 | $Pd(OAc)_2$ | X-Phos | 97 |

[a] **15a** 0.5 mmol, Pd 0.05 mmol, phosphine 0.075 mmol, $Cs_2CO_3$ 0.6 mmol, toluene 2 mL, 125 °C, 15 h.
[b] The structures of dtbfp and X-Phos are sepicted in Scheme 2.

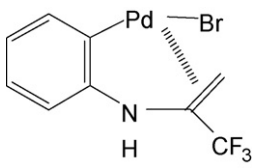
the Heck-type reaction between phenyl-Pd-Br and the C–C double bond in the vinyl group of **15b** intramoleculary to 2-trifluoromethylindole, **15e** [4d,29].




(5)

Free tautmeric isomer **15b** was not detected either even in the crude reaction solution by $^{19}F$ NMR. Probably the bulky phoshine on Pd species used here stabilize the enamine-like intermediate in Scheme 4.

Recently, a reaction path similar to Eq. (5) has been proposed in the Pd-catalyzed coupling of alkenylbromides and 2-bromoaniline [4d] or cyclization of 2-bromo-*N*-(α-methylbenzylidene)anilines [29] to indoles, which possess aryl, alkyl or alkoxy groups at the 2-position. We tried to apply their best condition ($Pd_2(dba)_3$, JohnPhos or DavePhos (Scheme 3), NaO$^t$Bu and toluene solvent) to the coupling here. However,



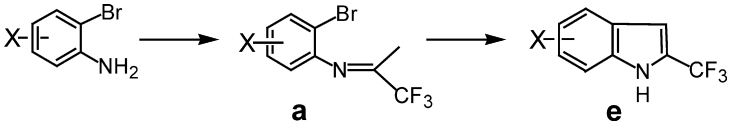

Scheme 4.

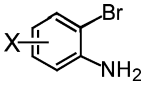
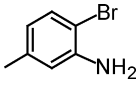
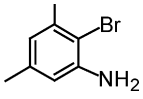
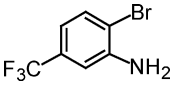
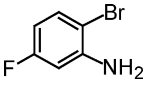
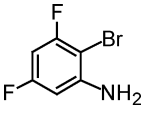
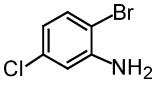
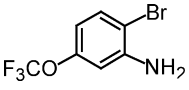
Table 11
Pd-catalyzed cyclization of 2-bromo-*N*-(1,1,1-trifluoro-2-propylidene)aniline with various bases[a]

| Run | Base | NMR yield of 15e(%) |
|---|---|---|
| 70 | $Cs_2CO_3$ | 97 |
| 71 | $Na_2CO_3$ | 4 |
| 72 | $Li_2CO_3$ | 1 |
| 73 | $K_3PO_4$ | 31 |
| 74 | NaO$^t$Bu | 13 |
| 75 | $NEt_3$ | 5 |

[a] **15a** 0.5 mmol, $Pd(OAc)_2$ 0.05 mmol, X-Phos 0.075 mmol, base 0.6 mmol, toluene 2 mL, 125 °C, 15 h.

Table 12
Pd-catalyzed 2-trifluoromethylindole synthesis[a]




| Run |  | | NMR yield (%) | | | Yield NMR (%) isolated |
|---|---|---|---|---|---|---|
| 76 |  | **37a** | 16 | **37e** | 64 | 48 |
| 77 |  | **38a** | 17 | **38e** | 17 | – |
| 78 |  | **39a** | 17 | **39e** | 81 | 40 |
| 79 |  | **40a** | 16 | **40e** | 84 | 46 |
| 80 |  | **41a** | 11 | **41e** | 46 | – |
| 81 |  | **42a** | 10 | **42e** | 44 | – |
| 82 |  | **43a** | – | **43e** | 66 | 39 |

[a] 2-Bromoanilines 1.0 mmol, BTP 1.2 mmol, $Pd(OAc)_2$ 0.10 mmol, X-Phos 0.15 mmol, $Cs_2CO_3$ 1.2 mmol, toluene 2 mL, 125 °C, 15 h.

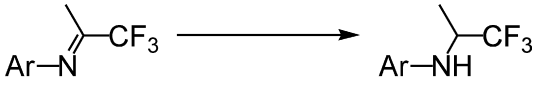
we could not obtain **15e** in a moderate yield (0% with JohnPhos and 8% with DavePhos). The most remarkable difference between their method and our coupling is the base used. The authors of ref. [29] reported that $Cs_2CO_3$ is unsuitable. On the contrary, $Cs_2CO_3$ may play the special role in the reaction with fluorinated substrates as described above. Indeed, $Cs_2CO_3$ was most efficient in the cyclization of **15a** to **15e** (run 70 in Table 11). Nazaré and co-workers recently reported that the condensation of 2-chloroanilines and cyclic ketones by use of [Pd(P$^t$Bu$_3$)$_2$] catalyst caused a similar cascade indole synthesis [30]. Since $Cs_2CO_3$ gave the moderate yield in their literature, $Cs_2CO_3$ may work in a different manner from that described above.

There have been many reports for 2-trifluoromethylindole synthesis. The Pd-catalyzed coupling of 2-iodoaniline and trifluoromethylacetylenes affords the mixture of 2-trifluoromethyl and 3-trifluoromethylindoles [31]. The same problem in regioselectivity was observed in the photochemical reaction of indole and $CF_3I$ [32] and $CF_2I_2$ [33] as well as the radical reaction of indole and bis(trifluoromethyl)peroxide [34]. Although several regio-controlled syntheses of 2-trifluoromethylindoles using methyl 3-*N*-aryl-4,4,4-trifluorobutenoate [35], *N*-trimethylsilyl-*o*-tluidine [36], 2-(*N*-trifluoroacetylamino)benzylmethylethers [37] or 3-trifluoromethylquinoline [38] were reported, the Pd-catalyzed coupling here is more practical and convenient method than those methods.

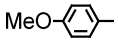
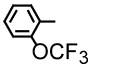
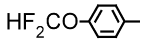
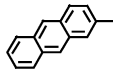
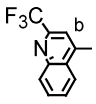
Further, in order to show the utility of the present reaction system, we contemplated the one-pot synthesis of 2-trifluoromethylindoles from BTP and various types of 2-bromoanilines under the optimized reaction condition, $Pd(OAc)_2$, X-Phos and $Cs_2CO_3$ at 125 °C (Table 12). We are pleased to find that this tandem Heck reaction also proceeded smoothly and provided desired indoles in an excellent $^{19}$F NMR yield with small amount of recovery of the imines. Thus, the present reaction condition is very broadly applicable and highly tolerant for a substituent of 2-bromoanilines. For example, 2-bromoanilines bearing electron-withdrawing groups such as $CF_3$, F and Cl gave the desired product **39e**–**42e** in good to high yield (runs 78–81). In the case of the reaction with 2-bromo-3-methylaniline, **38e** was obtained in a low yield, suggesting the steric bulkiness of methyl group (run 77).

No homoamination product of 2-bromoanilines was obtained under the present reaction condition. Presumably, due to the strong electron-withdrawing nature of $CF_3$ group, the oxidative

Table 13
Hydrogenation of *N*-(1,1,1-trifluoro-2-propylidene)amino group[a]




**a** **f**

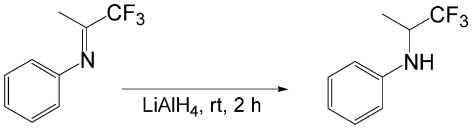
| Run | Ar– | Product | NMR yield (%) | Isolated yield (%) | Run | Ar– | Product | NMR yield (%) | Isolated yield (%) |
|---|---|---|---|---|---|---|---|---|---|
| 83 |  | **2f** | 67 | 56 | 93 |  | **20f** | 78 | 25 |
| 84 |  | **3f** | 62 | 38 | 94 |  | **21f** | 80 | 51 |
| 85 |  | **4f** | 99 | 72 | | | | | |
| 86 |  | **5f** | 75 | 59 | 95 |  | **22f** | 75 | – |
| 87 |  | **6f** | 66 | 24 | 96 |  | **23f** | 41 | 40 |
| 88 |  | **14f** | 61 | 50 | 97 |  | **24f** | 95 | 84 |
| 89 |  | **15f** | 75 | 23 | 98 |  | **25f** | 99 | 76 |
| 90 |  | **17f** | 71 | 58 | 99 |  | **27f** | 58 | 39 |
| 91 |  | **18f** | 69 | 62 | | | | | |
| 92 |  | **19f** | 55 | 55 | 100 |  | **31f** | 92 | 83 |

[a] Ar-N=C(CH$_3$)(CF$_3$) 0.33 M, solvent THF (0.5–3.0 mL), [substrate]/[LiAlH$_4$] = 1, rt, 2 h.
[b] Solvent diethylether, 24 h.

addition of the C–Br bond of BTP to palladium might be faster than that of 2-bromoanilines. Surprisingly, the C–Br bond in BTP is more activated than phenyl-I bond; 2-iodoaniline gave **15e** (47% $^{19}$F NMR yield) with 2-iodo-*N*-(1,1,1-trifluoromethyl-2-propylidene)aniline (**44a**, 7% $^{19}$F NMR yield).

### 2.4. Hydrogenation of *N*-(1,1,1-trifluoro-2-propylidene)amino group

The C–N double bond of *N*-(1,1,1-trifluoro-2-propylidene) aniline was readily hydrogenated to *N*-[(1-methyl-2,2,2-tri fluoro)ethyl]aniline using $LiAlH_4$ [6,7] in THF or diethyl ether with 89% $^{19}$F NMR yield and 68% isolated yield under mild conditions (Eq. (6)).




**1a** **1f** (6)

Although hydrogen and Pd/C catalyst [38] could also furnish **1f**, severer conditions (100 °C and 12 h) were required and the yield was lower (49% isolated yield) than that when $LiAlH_4$ was used. The results for the hydrogenation of the other aryl and heteroarylimines are listed in Table 13.

Recently, direct synthesis of *N*-(1-methyl-2,2,2-trifluoro) ethylanilines by the reaction of anilines and 1,1,1-trifluoroacetone in sodium cyanoborohydride was reported [39]. However, the reducing reagent used there is highly toxic. In the previous patents, (1-methyl-2,2,2-trifluoro)ethylamine was used as an amination reagent of a hydroxyl group [40]. This amine seems useful, because aryl(1-methyl-2,2,2-trifluoroethyl)amine can be obtained through the Buchbald-Hartwig amination with arylhalides and (1-methyl-2,2,2-trifluoro)ethylamine. However, several steps are required for their preparation: hydrogenation of oxime obtained from hydroxylamine and 1,1,1-trifluoroacetone [41,42], reduction of benzyl(1,1,1-trifluoro-2-propilidene)amine by 1,8-diazabicyclo[5.4.0]-7-undecene (DBU) and benzylamine [42] or the amination of bromo-1,1,1-trifluoropropane with $NH_3$ [40].

## 3. Conclusion

Here, we presented the conventional and efficient synthesis of *N*-(1,1,1-trifluoro-2-propylidene)arylamines through the Pd-catalyzed coupling of arylamines and 2-bromo-3,3,3-trifluoropropene (BTP). Particularly, the cascade synthesis of 4-amino-2-trifluoromethylquinolines from 2-aminobenzonitriles and 2-trifluoromethylindoles from 2-haloanilines seems to be important for medicinal and agricultural sciences. The C–N double bonds in aryl(1,1,1-trifluoro-2-propylidene)amines were readily hydrogenated to the corresponding aryl(1-methyl-2,2,2-trifluoroethyl)amines; they are also the important candidates for biologically active chemicals.

## 4. Experimental

### 4.1. General techniques

$^1$H-, $^{19}$F- and $^{13}$C NMR spectra were recorded in $CDCl_3$ on Bruker DRX-250 ($^1$H 250 MHz and $^{19}$F 235 MHz) and DRX-500 ($^{13}$C 125 MHz) spectrometers using tetramethylsilane for $^1$H- and $^{13}$C NMR and fluorotrichlomethane for $^{19}$F NMR as an internal reference. Chemical shifts are given in ppm ($\delta$). Multiplicities are indicated by s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), brs (broad singlet) and brd (broad doublet). GC analyses were performed on a Shimadzu GC-14A with FID using ULBON HR-1 capillary column (i.d. 0.25 mm × 50 m, Shinwa Chemical Industries, Ltd.). Developed chromatograms were visualized by UV light, $I_2$ stain or phosphomolybdic acid stain. Flash chromatography was performed on silica gel (MERK C60). Super dehydrated toluene and THF were supplied from Kanto Chemical Co. Inc. $Li_2CO_3$, $Na_2CO_3$, $K_2CO_3$ and $Cs_2CO_3$ were dried with a heating gun under a reduced pressure. Other commercially available reagents were used without further purification.

### 4.2. Typical procedure for the amination

Procedure for the coupling of BTP and an arylamine is given as an example hereinafter. A Pyrex-glass test tube with a screw stopper containing $Pd_2(dba)_3{\cdot}CHCl_3$ (0.05 mmol), dppf (0.15 mmol) and $Cs_2CO_3$ (1.2 mmol) equipped with a magnetic stirring bar was purged with argon. Toluene (2.0 mL) was added and the mixture was stirred on an ice bath. After the addition of aniline (1.0 mmol) and BTP (1.2 mmol), the reactor was heated for 15 h at 110 °C. Internal standards (hexadecane for GC and 2,2,2-trifluoroethanol for $^{19}$F NMR) were added to the solution after the reaction. Small aliquots of the mixture were analyzed by use of GC and $^{19}$F NMR. The residual reaction mixture was filtered through a Celite® (diethylether, 20 mL). After the solvent was evaporated, the resulting crude products were purified with a silica gel column (eluent hexane:ethyl acetate = 10:1–4:1) to give **1a** (92% yield, yellow oil).

### 4.3. Typical procedure for the hydrogenation of aromatic imines

The hydrogenation of aromatic imines was accomplished with the following two examples. One is the method where $LiAlH_4$ was used. A glass flask containing $LiAlH_4$ (0.97 mmol) equipped with a magnetic stirring bar was purged with argon, followed by the addition of THF (1.0 mL) and stirring for 5 min at room temperature. After that, 2.0 mL of THF solution of **1a** (1.0 mmol) was added and stirred for 2 h at room temperature. After completion of the reaction, ethyl acetate was added to deactivate the residual $LiAlH_4$ and an internal standard (2,2,2-trifluoroethanol for $^{19}$F NMR) was added to the reaction solution. $^{19}$F NMR spectrum of the filtrate revealed the formation of **1f** in 89% yield. Then the mixture was filtered through a Celite® (ethyl acetate, 20 mL). After the solvent was evaporated, the resulting crude products were purified with

a silica gel column (eluent hexane:ethyl acetate = 10:1–4:1) to give **1f** (68% yield, yellow oil). The other is the method where hydrogen was used with Pd/C catalyst. A stainless steel autoclave containing **1a** (10.7 mmol), 10 wt% Pd/C (50 mg) and toluene (10 mL) equipped with a stirring bar was pressurized with hydrogen (5 atm at room temperature) and heated for 12 h at 100 °C. After completion of the reaction, the reaction mixture was filtered through a Celite® (ethyl acetate, 20 mL). After the solvent was evaporated, the resulting crude products were purified with a silica gel column to give **1f** (49% yield).

### *4.4. Characterization of products*

#### *4.4.1. N-(1,1,1-trifluoro-2-propylidene)aniline (**1a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.02 (q, $J_{HF}$ = 0.4 Hz, 3H), 6.79 (dt, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 1.1 Hz, 2H), 7.18 (tt, $J_{HH}$ = 7.5 Hz, $J_{HH}$ = 1.1 Hz, 1H), 7.36–7.39 (m, 2H). $^{13}$C NMR: δ 14.4, 118.6, 119.7 (q, $J_{CF}$ = 278.3 Hz), 125.2, 129.2, 147.6, 157.4 (q, $J_{CF}$ = 34.0 Hz). $^{19}$F NMR: δ −75.0 ($J_{FH}$ = 0.4 Hz).

#### *4.4.2. 4-Methyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**2a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.03 (s, 3H), 2.35 (s, 3H), 6.70 (d, $J_{HH}$ = 8.2 Hz, 2H), 7.17 (d, $J_{HH}$ = 8.2 Hz, 2H). $^{13}$C NMR: δ 14.3, 20.9, 119.0, 119.9 (q, $J_{CF}$ = 278.2 Hz), 129.7, 134.9, 144.9, 157.1 (q, $J_{CF}$ = 33.8 Hz). $^{19}$F NMR: δ −74.9.

#### *4.4.3. 2-Methyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**3a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.96 (s, 3H), 2.08 (s, 3H), 6.60 (d, $J_{HH}$ = 7.7 Hz, 1H), 7.07 (dd, $J_{HH}$ = 7.5 Hz, $J_{HH}$ = 7.5 Hz, 1H), 7.18 (dd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 7.5 Hz, 1H), 7.22 (d, $J_{HH}$ = 7.5 Hz, 1H). $^{13}$C NMR: δ 14.5, 17.3, 117.4, 120.0 (q, $J_{CF}$ = 278.4 Hz), 125.1, 126.5, 126.9, 130.8, 146.4, 157.3 (q, $J_{CF}$ = 33.8 Hz). $^{19}$F NMR: δ −74.8.

#### *4.4.4. 3,5-Dimethyl-N-(1,1,1-trifluoro-2-propylidene) aniline (**4a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.02 (s, 3H), 2.31 (s, 6H), 6.40 (s, 2H), 6.80 (s, 1H). $^{13}$C NMR: δ 14.3, 21.2, 116.2, 120.5 (q, $J_{CF}$ = 278.3 Hz), 126.6, 138.9, 147.6, 155.4 (q, $J_{CF}$ = 33.8 Hz). $^{19}$F NMR: δ 75.0.

#### *4.4.5. 4-tert-Butyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**5a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.33 (s, 9H), 2.04 (s, 3H), 6.73 (d, $J_{HH}$ = 6.8 Hz, 2H), 7.38 (d, $J_{HH}$ = 6.8 Hz, 2H). $^{13}$C NMR: δ 14.4, 31.3, 34.4, 118.7, 120.0 (q, $J_{CF}$ = 278.2 Hz), 125.9, 144.8, 148.2, 156.9 (q, $J_{CF}$ = 33.8 Hz). $^{19}$F NMR: δ −74.9.

#### *4.4.6. 4-Vinyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**6a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.04 (s, 3H), 5.24 (d, $J_{HH}$ = 10.9 Hz, 1H), 5.73 (d, $J_{HH}$ = 17.6 Hz, 1H), 6.70 (dd, $J_{HH}$ = 10.9 Hz, $J_{HH}$ = 17.6 Hz, 1H), 6.77 (d, $J_{HH}$ = 8.4 Hz, 2H), 7.42 (d, $J_{HH}$ = 8.4 Hz, 2H). $^{13}$C NMR: δ 14.5, 113.6, 119.2, 119.7 (q, $J_{CF}$ = 278.3 Hz), 127.0, 134.8, 136.0, 147.0, 157.4 (q, $J_{CF}$ = 33.9 Hz). $^{19}$F NMR: δ −74.9.

#### *4.4.7. 3-Ethynyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**7a**)*

$^{19}$F NMR: δ −75.0.

#### *4.4.8. 2-Trifluoromethyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**8a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.97 (s, 3H), 6.73 (d, $J_{HH}$ = 7.8 Hz, 1H), 7.26 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.7 Hz, 1H), 7.54 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.7 Hz, 1H), 7.68 (d, $J_{HH}$ = 7.8 Hz, 1H). $^{13}$C NMR: δ 15.1, 118.6, 119.2 (q, $J_{CF}$ = 278.4 Hz), 119.3 (q, $J_{CF}$ = 31.2 Hz), 123.5 (q, $J_{CF}$ = 272.9 Hz), 124.9, 126.8 (q, $J_{CF}$ = 5.1 Hz), 132.9, 146.1, 159.7 (q, $J_{CF}$ = 34.8 Hz). $^{19}$F NMR: δ −75.4, −62.2.

#### *4.4.9. 3-Trifluoromethy-N-(1,1,1-trifluoro-2-propylidene) aniline (**9a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.04 (s, 3H), 6.97 (d, $J_{HH}$ = 7.9 Hz, 1H), 7.06 (s, 1H), 7.45 (d, $J_{HH}$ = 7.8 Hz, 1H), 7.50 (dd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 7.8 Hz, 1H). $^{13}$C NMR: δ 14.6, 115.7 (q, $J_{CF}$ = 3.8 Hz), 119.5 (q, $J_{CF}$ = 278.4 Hz), 122.0 (q, $J_{CF}$ = 3.8 Hz), 122.1, 123.8 (q, $J_{CF}$ = 272.4 Hz), 130.0, 131.9 (q, $J_{CF}$ = 32.7 Hz), 148.1, 158.9 (q, $J_{CF}$ = 34.5 Hz). $^{19}$F NMR: δ −75.1, −63.2.

#### *4.4.10. Ethyl 2-N-(1,1,1-trifluoro-2-propylidene)aminobenzonate (**10a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.34 (t, $J_{HH}$ = 7.2 Hz, 3H), 1.96 (s, 3H), 4.30 (q, $J_{HH}$ = 7.2 Hz, 2H), 6.67–6.69 (m, 1H), 7.19–7.23 (m, 1H), 7.49–7.53 (m, 1H), 8.03 (dd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 1.3 Hz, 1H). $^{13}$C NMR: δ 14.1, 15.1, 61.2, 118.8, 119.5, 120.0 (q, $J_{CF}$ = 278.2 Hz), 124.5, 131.6, 133.3, 148.5, 157.4 (q, $J_{CF}$ = 34.4 Hz), 165.7. $^{19}$F NMR: δ −75.1.

#### *4.4.11. Ethyl 2-N-(1-trifluoromethylviny)aminobenzonate (**10b**)*

*Yellow oil*. $^{1}$H NMR: δ 1.40 (t, $J_{HH}$ = 7.1 Hz, 3H), 4.37 (q, $J_{HH}$ = 7.1 Hz, 2H), 5.30 (brs, 2H), 6.86 (ddd, $J_{HH}$ = 8.1 Hz, $J_{HH}$ = 6.7 Hz, $J_{HH}$ = 1.7 Hz, 1H), 7.39 (dd, $J_{HH}$ = 8.5 Hz, $J_{HH}$ = 1.7 Hz, 1H), 7.42 (ddd, $J_{HH}$ = 8.5 Hz, 6.7 Hz, $J_{HH}$ = 1.5 Hz, 1H), 8.02 (dd, $J_{HH}$ = 8.1 Hz, $J_{HH}$ = 1.5 Hz, 1H), 9.37 (brs, 1H). $^{13}$C NMR: δ 14.2, 61.1, 99.2 (q, $J_{CF}$ = 4.0 Hz), 114.5 116.1, 119.1, 122.2 (q, $J_{CF}$ = 275.0 Hz), 131.7, 134.1, 135.7 (q, $J_{CF}$ = 32.4 Hz), 145.7, 168.2. $^{19}$F NMR: δ −72.0 (brs).

#### *4.4.12. 4-N-(1,1,1-Trifluoro-2-propylidene) aminoacetophenone (**11a**)*

$^{19}$F NMR: δ −75.1.

#### *4.4.13. 3-N-(1,1,1-Trifluoro-2-propylidene) aminobenzonitrile (**12a**)*

$^{19}$F NMR: δ −75.1.

*4.4.14. 6-Methyl-2-N-(1,1,1-trifluoro-2-propylidene) benzonitrile (**13a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.07 (s, 3H), 2.57 (s, 3H), 6.70 (d, $J_{HH}$ = 7.9 Hz, 1H), 7.12 (d, $J_{HH}$ = 7.8 Hz, 1H), 7.47 (dd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 7.8 Hz, 1H). $^{13}$C NMR: δ 15.2, 20.7, 103.1, 115.0, 116.0, 119.2 (q, $J_{CF}$ = 278.7 Hz), 126.4, 133.2, 143.4, 150.6, 160.4 (q, $J_{CF}$ = 35.0 Hz). $^{19}$F NMR: δ −74.9.

*4.4.15. 4-Bromo-N-(1,1,1-trifluoro-2-propylidene)aniline (**14a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.03 (s, 3H), 6.68 (d, $J_{HH}$ = 8.6 Hz, 2H), 7.50 (d, $J_{HH}$ = 8.6 Hz, 2H). $^{13}$C NMR: δ 14.5, 118.5, 119.6 (q, $J_{CF}$ = 278.4 Hz), 120.7, 132.3, 146.5, 158.2 (q, $J_{CF}$ = 34.1 Hz). $^{19}$F NMR: δ −75.0.

*4.4.16. 2-Bromo-N-(1,1,1-trifluoro-2-propylidene)aniline (**15a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.98 (s, 3H), 6.75 (dd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 1.6 Hz, 2H), 7.01–7.05 (m, 1H), 7.29–7.34 (m, 1H), 7.60 (dd, $J_{HH}$ = 8.1 Hz, $J_{HH}$ = 1.3 Hz, 1H). $^{13}$C NMR: δ 15.2, 112.3, 119.3, 119.6 (q, $J_{CF}$ = 278.5 Hz), 126.2, 128.3, 133.3, 146.3, 159.8 (q, $J_{CF}$ = 34.4 Hz). $^{19}$F NMR: δ −74.9.

*4.4.17. 2-Chloro-N-(1,1,1-trifluoro-2-propylidene)aniline (**16a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.99 (s, 3H), 6.78 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 1.4 Hz, 2H), 7.18 (ddd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.27 (ddd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.42 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 1.4 Hz, 1H). $^{13}$C NMR: δ 15.2, 119.5 (q, $J_{CF}$ = 278.5 Hz), 119.6, 122.8, 126.0, 127.6, 130.2, 144.8, 160.0 (q, $J_{CF}$ = 34.4 Hz). $^{19}$F NMR: δ −74.9.

*4.4.18. 3-Chloro-N-(1,1,1-trifluoro-2-propylidene)aniline (**17a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.04 (s, 3H), 6.66–6.69 (m, 1H), 6.81 (dd, $J_{HH}$ = 2.0 Hz, $J_{HH}$ = 2.0 Hz, 1H), 7.14–7.18 (m, 1H), 7.31 (dd, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 8.0 Hz, 1H). $^{13}$C NMR: δ 14.6, 116.9, 118.8, 119.3 (q, $J_{CF}$ = 276.8 Hz), 125.2, 130.4, 135.0, 148.7, 158.5 (q, $J_{CF}$ = 34.0 Hz). $^{19}$F NMR: δ −74.9.

*4.4.19. 4-Fluoro-N-(1,1,1-trifluoro-2-propylidene)aniline (**18a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.04 (s, 3H), 6.75–6.80 (m, 2H), 7.08 (dd, $J_{HH}$ = 8.6 Hz, $J_{HH}$ = 8.5 Hz, 2H). $^{13}$C NMR: δ 14.4, 116.1 (d, $J_{CF}$ = 22.7 Hz), 119.7 (q, $J_{CF}$ = 278.3 Hz), 120.6 (d, $J_{CF}$ = 8.2 Hz), 143.5 (d, $J_{CF}$ = 2.9 Hz), 158.0 (q, $J_{CF}$ = 34.0 Hz), 160.5 (d, $J_{CF}$ = 244.1 Hz). $^{19}$F NMR: δ −118.4 (tt, $J_{FH}$ = 8.5 Hz, $J_{FH}$ = 4.8 Hz), −75.0.

*4.4.20. 2-Fluoro-5-methyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**19a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.02 (d, $J_{HF}$ = 1.7 Hz, 3H), 2.32 (s, 3H), 6.70–6.72 (m, 1H), 6.91–6.94 (m, 1H), 7.01–7.02 (m, 1H). $^{13}$C NMR: δ 15.1 (d, $J_{CF}$ = 3.1 Hz), 20.6, 115.8 (d, $J_{CF}$ = 19.7 Hz), 119.0 (q, $J_{CF}$ = 278.3 Hz), 122.1 (d, $J_{CF}$ = 1.1 Hz), 126.9 (d, $J_{CF}$ = 4.5 Hz), 134.4 (d, $J_{CF}$ = 2.1 Hz), 134.4 (d, $J_{CF}$ = 19.1 Hz), 149.1 (d, $J_{CF}$ = 243.8 Hz), 159.9 (q, $J_{CF}$ = 34.2 Hz). $^{19}$F NMR: δ −131.6 (brs), −74.8.

*4.4.21. 3,4-Difluoro-N-(1,1,1-trifluoro-2-propylidene) aniline (**20a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.05 (s, 3H), 6.52 (dddd, $J_{HH}$ = 8.7 Hz, $J_{HF}$ = 3.8 Hz, $J_{HH}$ = 2.5 Hz, $J_{HF}$ = 1.8 Hz, 1H), 6.67 (ddd, $J_{HF}$ = 10.7 Hz, $J_{HF}$ = 6.9 Hz, $J_{HH}$ = 2.5 Hz, 1H), 7.18 (ddd, $J_{HF}$ = 10.1 Hz, $J_{HH}$ = 8.7 Hz, $J_{HF}$ = 8.5 Hz, 1H). $^{13}$C NMR: δ 14.5, 108.7 (d, $J_{CF}$ = 19.5 Hz), 114.8 (dd, $J_{CF}$ = 6.1 Hz, $J_{CF}$ = 3.7 Hz), 117.9 (dd, $J_{CF}$ = 18.3 Hz, $J_{CF}$ = 1.3 Hz), 119.4 (q, $J_{CF}$ = 278.4 Hz), 144.8 (dd, $J_{CF}$ = 6.8 Hz, $J_{CF}$ = 3.3 Hz), 148.0 (dd, $J_{CF}$ = 246.4 Hz, $J_{CF}$ = 12.6 Hz), 150.6 (dd, $J_{CF}$ = 250.1 Hz, $J_{CF}$ = 13.6 Hz), 159.0 (dq, $J_{CF}$ = 34.4 Hz, $J_{CF}$ = 1.3 Hz). $^{19}$F NMR: δ −142.5 (dddd, $J_{FF}$ = 21.4 Hz, $J_{FH}$ = 10.1 Hz, $J_{FH}$ = 6.9 Hz, $J_{FH}$ = 3.8 Hz), −135.9 (dddd, $J_{FF}$ = 21.4 Hz, $J_{FH}$ = 10.7 Hz, $J_{FH}$ = 8.5 Hz, $J_{FH}$ = 1.8 Hz), −75.0.

*4.4.22. 4-Methoxy-N-(1,1,1-trifluoro-2-propylidene)aniline (**21a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.07 (s, 3H), 3.82 (s, 3H), 6.71 (d, $J_{HH}$ = 9.0 Hz, 2H), 6.85 (d, $J_{HH}$ = 9.0 Hz, 2H). $^{13}$C NMR: δ 14.4, 55.5, 114.4, 120.0 (q, $J_{CF}$ = 278.2 Hz), 120.9, 140.4, 156.8 (q, $J_{CF}$ = 33.8 Hz), 157.4. $^{19}$F NMR: δ −74.8.

*4.4.23. 2-Trifluoromethoxy-N-(1,1,1-trifluoro-2-propylidene)aniline (**22a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.00 (s, 3H), 6.85–6.87 (m, 1H), 7.19–7.23 (m, 1H), 7.30–7.33 (m, 2H). $^{13}$C NMR: δ 15.2, 119.0 (q, $J_{CF}$ = 278.4 Hz), 121.0 (q, $J_{CF}$ = 258.3 Hz), 120.7, 122.5, 126.2, 127.7, 137.7, 140.4, 160.3 (q, $J_{CF}$ = 34.5 Hz). $^{19}$F NMR: δ −75.1, −58.4.

*4.4.24. 4-Difluoromethoxy-N-(1,1,1-trifluoro-2-propylidene)aniline (**23a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.03 (s, 3H), 6.50 (t, $J_{HF}$ = 73.8 Hz, 1H), 6.80 (d, $J_{HH}$ = 8.8 Hz, 2H), 7.15 (d, $J_{HH}$ = 8.8 Hz, 2H). $^{13}$C NMR: δ 14.5, 116.0 (t, $J_{CF}$ = 260.0 Hz), 119.7 (q, $J_{CF}$ = 278.3 Hz), 120.7, 120.8, 144.9, 148.5 (t, $J_{CF}$ = 2.9 Hz), 158.2 (q, $J_{CF}$ = 34.1 Hz). $^{19}$F NMR: δ −81.2 (d, $J_{FH}$ = 73.8 Hz), −75.0.

*4.4.25. 1-N-(1,1,1-Trifluoro-2-propylidene) aminonaphthalene (**24a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.00 (s, 3H), 6.75 (dd, $J_{HH}$ = 7.3 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.44 (dd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 7.3 Hz, 1H), 7.47 (ddd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 6.9 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.51 (ddd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 6.9 Hz, $J_{HH}$ = 1.3 Hz, 1H), 7.67 (d, $J_{HH}$ = 8.2 Hz, 2H), 7.85 (dd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 1.3 Hz, 1H). $^{13}$C NMR: δ 14.7, 112.9, 119.7 (q, $J_{CF}$ = 278.6 Hz), 122.7, 125.1, 125.3, 125.4, 126.2, 126.6, 128.1, 134.0, 143.8, 158.6 (q, $J_{CF}$ = 34.0 Hz). $^{19}$F NMR: δ −74.5.

*4.4.26. 2-N-(1,1,1-Trifluoro-2-propylidene) aminoanthracene (**25a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.13 (s, 3H), 7.03 (dd, $J_{HH}$ = 8.9 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.30 (d, $J_{HH}$ = 1.5 Hz, 1H),

7.46 (ddd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 6.0 Hz, $J_{HH}$ = 2.2 Hz, 1H), 7.48 (ddd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 6.0 Hz, $J_{HH}$ = 2.2 Hz, 1H), 7.98 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 2.2 Hz, 1H), 8.00 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 2.2 Hz, 1H), 8.04 (d, $J_{HH}$ = 8.9 Hz, 1H), 8.36 (s, 1H), 8.43 (s, 1H). $^{13}$C NMR: δ 14.7, 118.7, 119.8 (q, $J_{CF}$ = 278.3 Hz), 120.1, 125.4, 125.8, 125.9, 126.5, 127.9, 128.3, 129.6, 129.8, 131.4, 131.5, 132.3, 144.5, 157.7 (q, $J_{CF}$ = 33.9 Hz). $^{19}$F NMR: δ −74.8.

*4.4.27. N-(1,1,1-Trifluoro-2-propylidene)-N′-(1-trifluoromethylvinyl)-o-phneylenediamine (**26a**)*

*Yellow oil*. $^{1}$H NMR: δ 1.57 (s, 3H), 2.63 (d, $J_{HH}$ = 14.2 Hz, 1H), 2.81 (d, $J_{HH}$ = 14.2 Hz, 1H), 3.71 (s, 1H), 6.88 (dd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.12 (ddd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.17 (ddd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.32 (dd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H). $^{13}$C NMR: δ 23.1, 31.9, 72.9 (q, $J_{CF}$ = 25.7 Hz), 119.9 (q, $J_{CF}$ = 276.7 Hz), 122.2, 123.2, 126.1 (q, $J_{CF}$ = 288.3 Hz), 129.5, 129.6, 136.9, 154.9 (q, $J_{CF}$ = 35.1 Hz). $^{19}$F NMR: δ −81.5, −72.3.

*4.4.28. 3-N-(1,1,1-Trifluoro-2-propylidene)aminopyridine (**27a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.06 (s, 3H), 7.16 (ddd, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 2.4 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.33 (dd, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 4.8 Hz, 1H), 8.13 (d, $J_{HH}$ = 2.4 Hz, 1H), 8.44 (dd, $J_{HH}$ = 4.8 Hz, $J_{HH}$ = 1.5 Hz, 1H). $^{13}$C NMR: δ 14.6, 119.4 (q, $J_{CF}$ = 278.3 Hz), 123.7, 126.5, 140.0, 143.4, 146.8, 159.2 (q, $J_{CF}$ = 34.5 Hz). $^{19}$F NMR: δ −75.0.

*4.4.29. 6-N-(1,1,1-Trifluoro-2-propylidene) aminobenzothiazole (**28a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.07 (s, 3H), 6.98 (dd, $J_{HH}$ = 8.6 Hz, $J_{HH}$ = 2.0 Hz, 1H), 7.37 (d, $J_{HH}$ = 2.0 Hz, 1H), 8.13 (d, $J_{HH}$ = 8.6 Hz, 1H), 8.95 (s, 1H). $^{13}$C NMR: δ 14.7, 111.2, 118.4, 119.6 (q, $J_{CF}$ = 278.5 Hz), 124.2, 134.8, 145.3, 151.0, 153.4, 158.4 (q, $J_{CF}$ = 34.2 Hz). $^{19}$F NMR: δ −74.9.

*4.4.30. 2-Methyl-5-N-(1,1,1-trifluoro-2-propylidene) aminoindole (**29a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.08 (s, 3H), 2.45 (d, $J_{HH}$ = 0.8 Hz, 3H), 6.20 (q, $J_{HH}$ = 0.8 Hz, 1H), 6.63 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 1.9 Hz, 1H), 6.93 (d, $J_{HH}$ = 1.9 Hz, 1H), 7.27 (d, $J_{HH}$ = 8.3 Hz, 1H), 7.89 (brs, 1H). $^{13}$C NMR: δ 13.7, 14.4, 100.7, 109.7, 110.5, 114.0, 120.1 (q, $J_{CF}$ = 278.3 Hz), 129.3, 134.0, 136.4, 140.3, 156.1 (q, $J_{CF}$ = 33.2 Hz). $^{19}$F NMR: δ −74.7.

*4.4.31. Methyl 2-N-(1,1,1-trifluoro-2-propylidene) aminothiophene-3-carboxylate (**30a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.13 (s, 3H), 3.80 (s, 3H), 7.00 (d, $J_{HH}$ = 5.6 Hz, 1H), 7.33 (d, $J_{HH}$ = 5.6 Hz, 1H). $^{13}$C NMR: δ 15.7, 51.7, 117.6, 119.0, 119.2 (q, $J_{CF}$ = 278.3 Hz), 128.2, 155.3, 162.2 (q, $J_{CF}$ = 34.7 Hz), 162.7. $^{19}$F NMR: δ −74.9.

*4.4.32. Methyl 2-N-(1-trifluoromethylviny) aminothiophene-3-carboxylate (**30b**)*

*Yellow oil*. $^{1}$H NMR: δ 3.87 (s, 3H), 5.23 (d, $J_{HH}$ = 3.7 Hz, 1H), 5.27 (m, 1H), 6.54 (d, $J_{HH}$ = 5.7 Hz, 1H), 7.19 (d, $J_{HH}$ = 5.7 Hz, 1H), 9.89 (s, 1H). $^{13}$C NMR: δ 51.6, 94.5 (q, $J_{CF}$ = 3.9 Hz), 110.0, 110.2, 121.1 (q, $J_{CF}$ = 274.5 Hz), 125.4, 134.3 (q, $J_{CF}$ = 33.0 Hz), 155.3, 166.1. $^{19}$F NMR: δ −71.1 (brs).

*4.4.33. 2-[N-(1,1,1-Trifluoro-2-propylidene)amino] benzonitrile (**31a**)*

*Brownish solid*. $^{1}$H NMR: δ 5.17 (s, 2H), 6.89 (s, 1H), 7.52 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 7.0 Hz, $J_{HH}$ = 1.2 Hz, 1H), 7.71 (ddd, $J_{HH}$ = 8.5 Hz, $J_{HH}$ = 7.0 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.79 (d, $J_{HH}$ = 8.4 Hz, 1H), 8.09 (d, $J_{HH}$ = 8.5 Hz, 1H). $^{13}$C NMR: δ 99.1 (q, $J_{CF}$ = 2.4 Hz), 118.7, 120.2, 121.8 (q, $J_{CF}$ = 275.3 Hz), 126.6, 130.4, 130.6, 148.0, 148.6 (q, $J_{CF}$ = 33.6 Hz), 151.4. $^{19}$F NMR: δ −75.0.

*4.4.34. 4-Amino-2-trifluoromethylquinoline (**31c**)*

*Brownish solid*. $^{1}$H NMR: δ 5.17 (s, 2H), 6.89 (s, 1H), 7.52 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 7.0 Hz, $J_{HH}$ = 1.2 Hz, 1H), 7.71 (ddd, $J_{HH}$ = 8.5 Hz, $J_{HH}$ = 7.0 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.79 (d, $J_{HH}$ = 8.4 Hz, 1H), 8.09 (d, $J_{HH}$ = 8.5 Hz, 1H). $^{13}$C NMR: δ 99.1 (q, $J_{CF}$ = 2.4 Hz), 118.7, 120.2, 121.8 (q, $J_{CF}$ = 275.3 Hz), 126.6, 130.4, 130.6, 148.0, 148.6 (q, $J_{CF}$ = 33.6 Hz), 151.4. $^{19}$F NMR: δ −68.2.

*4.4.35. 4-N-(1,1,1-Trifluoro-2-propylidene)amino-2-trifluoromethylquinoline (**31d**)*

*Brownish oil*. $^{1}$H NMR: δ 2.04 (s, 3H), 7.06 (s, 1H), 7.66–7.67 (m, 2H), 7.86 (ddd, $J_{HH}$ = 8.5 Hz, $J_{HH}$ = 5.7 Hz, $J_{HH}$ = 2.7 Hz, 1H), 8.25 (d, $J_{HH}$ = 8.5 Hz, 1H). $^{13}$C NMR: δ 15.5, 103.7, 119.8 (q, $J_{CF}$ = 279.0 Hz), 120.9, 122.1 (q, $J_{CF}$ = 275.4 Hz), 123.2, 129.7, 131.3, 132.3, 148.9, 149.2 (q, $J_{CF}$ = 34.9 Hz), 154.5, 162.0 (q, $J_{CF}$ = 35.0 Hz). $^{19}$F NMR: δ −74.7, −68.0.

*4.4.36. 4-Amino-5-methyl-2-trifluoromethylquinoline (**13c**)*

$^{19}$F NMR: δ −68.7.

*4.4.37. 5-Methyl-2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)aminoquinoline (**13d**)*

*Brownish oil*. $^{1}$H NMR: δ 2.06 (s, 3H), 2.61 (s, 3H), 6.83 (s, 1H), 7.41 (d, $J_{HH}$ = 7.1 Hz, 1H), 7.69 (dd, $J_{HH}$ = 8.5 Hz, $J_{HH}$ = 7.1 Hz, 1H), 8.08 (d, $J_{HH}$ = 8.5 Hz, 1H). $^{13}$C NMR: δ 15.5, 24.3, 103.9, 119.2 (q, $J_{CF}$ = 276.7 Hz), 120.8, 122.4 (q, $J_{CF}$ = 275.3 Hz), 129.0, 130.9, 131.2, 135.0, 147.6 (q, $J_{CF}$ = 35.0 Hz), 149.8, 154.9, 157.9 (q, $J_{CF}$ = 35.2 Hz). $^{19}$F NMR: δ −75.3, −68.1.

*4.4.38. 4-Methyl-2-[N-(1,1,1-trifluoro-2-propylidene) amino]benzonitrile (**32a**)*

$^{19}$F NMR: δ −75.0.

*4.4.39. 4-Amino-7-methyl-2-trifluoromethylquinoline (**32c**)*

*Brownish solid*. $^{1}$H NMR: δ 2.54 (s, 3H), 4.94 (s, 2H), 6.86 (s, 1H), 7.38 (dd, $J_{HH}$ = 8.6 Hz, $J_{HH}$ = 1.6 Hz, 1H), 7.68 (d, $J_{HH}$ = 8.6 Hz, 1H), 7.90 (s, 1H). $^{13}$C NMR: δ 21.6, 99.4 (q,

$J_{CF}$ = 2.4 Hz), 116.6, 119.7, 122.5 (q, $J_{CF}$ = 275.2 Hz), 128.8, 129.7, 141.0, 148.3, 149.5 (q, $J_{CF}$ = 33.5 Hz), 151.0. $^{19}$F NMR: δ −68.4.

*4.4.40. 7-Methyl-2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)aminoquinoline (**32d**)*

$^{19}$F NMR: δ −74.8, −68.2.

*4.4.41. 4-Amino-6-chloro-2-trifluoromethylquinoline (**33c**)*

*Yellow solid*. $^{1}$H NMR: δ 4.96 (s, 2H), 6.94 (s, 1H), 7.68 (dd, $J_{HH}$ = 9.0 Hz, $J_{HH}$ = 2.2 Hz, 1H), 7.78 (d, $J_{HH}$ = 2.2 Hz, 1H), 8.05 (d, $J_{HH}$ = 9.0 Hz, 1H). $^{13}$C NMR: δ 99.9 (q, $J_{CF}$ = 2.3 Hz), 120.1, 122.3 (q, $J_{CF}$ = 275.5 Hz), 132.2, 133.1, 133.4, 147.4, 149.7 (q, $J_{CF}$ = 33.9 Hz), 151.2. $^{19}$F NMR: δ −68.6.

*4.4.42. 6-Chloro-2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)aminoquinoline (**33d**)*

$^{19}$F NMR: δ −75.0, −68.1.

*4.4.43. 4-Amino-7-chloro-2-trifluoromethylquinoline (**34c**)*

*Brownish solid*. $^{1}$H NMR: δ 5.01 (s, 2H), 6.90 (s, 1H), 7.50 (dd, $J_{HH}$ = 9.0 Hz, $J_{HH}$ = 2.1 Hz, 1H), 7.72 (d, $J_{HH}$ = 9.0 Hz, 1H), 8.11 (d, $J_{HH}$ = 2.1 Hz, 1H). $^{13}$C NMR: δ 99.6 (q, $J_{CF}$ = 2.4 Hz), 117.0, 121.5, 121.5 (q, $J_{CF}$ = 275.4 Hz), 127.5, 129.6, 136.6, 148.7, 149.7 (q, $J_{CF}$ = 34.0 Hz), 151.2. $^{19}$F NMR: δ −68.6.

*4.4.44. 4-Amino-5-fluoro-2-trifluoromethylquinoline (**35c**)*

*Brownish solid*. $^{1}$H NMR: δ 5.61 (s, 2H), 6.81 (s, 1H), 7.14 (ddd, $J_{HF}$ = 13.7 Hz, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.61 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HF}$ = 8.1 Hz, $J_{HH}$ = 7.8 Hz, 1H), 7.87 (d, $J_{HH}$ = 8.4 Hz, 1H). $^{13}$C NMR: δ 99.8 (q, $J_{CF}$ = 2.1 Hz), 109.6 (d, $J_{CF}$ = 9.0 Hz), 111.4 (d, $J_{CF}$ = 23.0 Hz), 122.2 (q, $J_{CF}$ = 275.3 Hz), 127.3 (d, $J_{CF}$ = 3.8 Hz), 130.7 (d, $J_{CF}$ = 11.0 Hz), 150.4 (q, $J_{CF}$ = 35.4 Hz), 151.2, 152.4 (d, $J_{CF}$ = 2.7 Hz), 160.4 (d, $J_{CF}$ = 250.7 Hz). $^{19}$F NMR: δ −115.1 (ddd, $J_{FH}$ = 13.7 Hz, $J_{FH}$ = 8.1 Hz, $J_{FH}$ = 4.0 Hz), −68.7.

*4.4.45. 5-Fluoro-2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)amino-quinoline (**35d**)*

*Brownish oil*. $^{1}$H NMR: δ 2.06 (s, 3H), 7.02 (s, 1H), 7.30 (ddd, $J_{HF}$ = 11.5 Hz, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 0.6 Hz, 1H), 7.78 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 8.0 Hz, $J_{HF}$ = 5.6 Hz, 1H), 8.06 (d, $J_{HH}$ = 8.4 Hz, 1H). $^{13}$C NMR: δ 15.7, 105.4, 111.7 (d, $J_{CF}$ = 10.8 Hz), 114.2 (d, $J_{CF}$ = 20.9 Hz), 119.7 (q, $J_{CF}$ = 278.7 Hz), 121.8 (q, $J_{CF}$ = 275.6 Hz), 127.4 (d, $J_{CF}$ = 4.5 Hz), 131.9 (d, $J_{CF}$ = 15.8 Hz), 144.1 (q, $J_{CF}$ = 34.7 Hz), 150.2 (q, $J_{CF}$ = 35.2 Hz), 150.4, 153.6 (d, $J_{CF}$ = 3.6 Hz), 158.6 (d, $J_{CF}$ = 259.4 Hz). $^{19}$F NMR: δ −111.8 (dd, $J_{FH}$ = 11.5 Hz, $J_{FH}$ = 5.6 Hz), −72.1, −68.3.

*4.4.46. 4,5-Dimethoxy-2-[N-(1,1,1-trifluoro-2-propylidene)amino]benzonitrile (**36a**)*

*Yellow oil*. $^{1}$H NMR: δ 2.12 (s, 3H), 3.90 (s, 3H), 3.92 (s, 3H), 6.40 (s, 1H), 7.03 (s, 1H). $^{13}$C NMR: δ 15.4, 56.4, 92.7, 103.0, 113.7, 116.4, 119.2 (q, $J_{CF}$ = 278.7 Hz), 145.5, 146.6, 153.7, 161.0 (q, $J_{CF}$ = 34.8 Hz). $^{19}$F NMR: δ −74.8.

*4.4.47. 4-Amino-6,7-dimethoxy-2-trifluoromethylquinoline (**36c**)*

*Brownish solid*. $^{1}$H NMR: δ 3.94 (s, 3H), 3.96 (s, 3H), 5.00 (s, 2H), 6.84 (s, 1H), 6.98 (s, 1H), 7.39 (s, 1H). $^{13}$C NMR: δ 56.0, 56.2, 98.6, 99.0 (q, $J_{CF}$ = 2.5 Hz), 109.0, 113.5, 122.0 (q, $J_{CF}$ = 274.7 Hz), 145.2, 146.6 (q, $J_{CF}$ = 33.6 Hz), 149.9, 153.1, 171.3. $^{19}$F NMR: δ −67.9.

*4.4.48. 6,7-Dimethoxy-2-trifluoromethyl-4-N-(1,1,1-trifluoro-2-propylidene)aminoquinoline (**36d**)*

*Pale pinkish solid*. $^{1}$H NMR: δ 2.06 (s, 3H), 3.99 (s, 3H), 4.06 (s, 3H), 6.79 (s, 1H), 6.94 (s, 1H), 7.54 (s, 1H). $^{13}$C NMR: δ 15.3, 56.1, 56.4, 99.4, 102.8, 108.8, 115.9, 119.2 (q, $J_{CF}$ = 278.6 Hz), 121.6 (q, $J_{CF}$ = 274.8 Hz), 145.5, 146.1 (q, $J_{CF}$ = 34.7 Hz), 151.3, 154.1, 160.6 (q, $J_{CF}$ = 35.2 Hz). $^{19}$F NMR: δ −74.6, −67.6.

*4.4.49. 2-Trifluoromethylindole (**15e**)*

*Yellow solid*. $^{1}$H NMR: δ 6.94 (q, $J_{HF}$ = 1.1 Hz, 1H), 7.20 (ddd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.4 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.33 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 7.4 Hz, 1H), 7.44 (dd, $J_{HH}$ = 7.8 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.69 (d, $J_{HH}$ = 7.8 Hz, 1H), 8.43 (brs, 1H). $^{13}$C NMR: δ 104.3 (q, $J_{CF}$ = 3.3 Hz), 111.7, 121.2, 121.3 (q, $J_{CF}$ = 267.7 Hz), 122.1, 124.8, 125.7 (q, $J_{CF}$ = 39.8 Hz), 126.6, 136.2. $^{19}$F NMR: δ −60.8 (d, $J_{FH}$ = 1.1 Hz).

*4.4.50. 2-Bromo-4-methyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**37a**)*

$^{19}$F NMR: δ −75.0.

*4.4.51. 5-Methyl-2-trifluoromethylindole (**37e**)*

*Yellowish brown solid*. $^{1}$H NMR: δ 2.45 (s, 3H), 6.84 (s, 1H), 7.15 (dd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 0.9 Hz, 1H), 7.31 (d, $J_{HH}$ = 8.4 Hz, 1H), 7.45 (s, 1H), 8.26 (brs, 1H). $^{13}$C NMR: δ 21.3, 103.8 (q, $J_{CF}$ = 3.4 Hz), 111.3, 121.3 (q, $J_{CF}$ = 267.5 Hz), 121.5, 125.7 (q, $J_{CF}$ = 38.9 Hz), 126.6, 126.9, 130.5, 134.5. $^{19}$F NMR: δ −60.8.

*4.4.52. 2-Bromo-4,6-dimethyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**38a**)*

$^{19}$F NMR: δ −75.0.

*4.4.53. 5,7-Dimethyl-2-trifluoromethylindole (**38e**)*

$^{19}$F NMR: δ −61.1.

*4.4.54. 2-Bromo-4-trifluoromethyl-N-(1,1,1-trifluoro-2-propylidene)aniline (**39a**)*

$^{19}$F NMR: δ −75.0, −62.7.

*4.4.55. 2,5-Bis(trifluoromethyl)indole (**39e**)*

*Green oil*. $^{1}$H NMR: δ 7.02 (s, 1H), 7.52 (d, $J_{HH}$ = 8.7 Hz, 1H), 7.57 (dd, $J_{HH}$ = 8.7 Hz, $J_{HH}$ = 1.4 Hz, 1H), 7.80 (s, 1H), 8.59 (brs, 1H). $^{13}$C NMR: δ 105.1 (q, $J_{CF}$ = 3.3 Hz), 112.3, 120.1 (q, $J_{CF}$ = 4.3 Hz), 120.8 (q, $J_{CF}$ = 268.1 Hz), 121.6 (q, $J_{CF}$ = 3.4 Hz),

123.9 (q, $J_{CF}$ = 32.2 Hz), 124.8 (q, $J_{CF}$ = 271.6 Hz), 125.9, 127.6 (q, $J_{CF}$ = 39.3 Hz), 137.3. $^{19}$F NMR: δ −61.2 (brs), −61.1 (brs).

*4.4.56. 2-Bromo-4-fluoro-N-(1,1,1-trifluoro-2-propylidene)aniline (**40a**)*

$^{19}$F NMR: δ −123.1, −74.9.

*4.4.57. 5-Fluoro-2-trifluoromethylindole (**40e**)*

*Brown solid*. $^{1}$H NMR: δ 6.88 (s, 1H), 7.07 (ddd, $J_{HF}$ = 9.1 Hz, $J_{HF}$ = 9.0 Hz, $J_{HH}$ = 2.5 Hz, 1H), 7.31 (dd, $J_{HF}$ = 9.2 Hz, $J_{HH}$ = 2.5 Hz, 1H), 7.35 (dd, $J_{HF}$ = 9.0 Hz, $J_{HF}$ = 4.3 Hz, 1H), 8.64 (brs, 1H). $^{13}$C NMR: δ 104.2 (dq, $J_{CF}$ = 5.0 Hz, $J_{CF}$ = 3.4 Hz), 106.7 (d, $J_{CF}$ = 23.7 Hz), 112.7 (d, $J_{CF}$ = 9.7 Hz), 113.7 (d, $J_{CF}$ = 26.8 Hz), 121.0 (q, $J_{CF}$ = 267.8 Hz), 127.0 (d, $J_{CF}$ = 10.5 Hz), 127.4 (q, $J_{CF}$ = 39.2 Hz), 132.8, 158.4 (d, $J_{CF}$ = 236.8 Hz). $^{19}$F NMR: δ −122.9 (ddd, $J_{FH}$ = 9.2 Hz, $J_{FH}$ = 9.1 Hz, $J_{FH}$ = 4.3 Hz), −61.1 (d, $J_{FH}$ = 0.8 Hz).

*4.4.58. 2-Bromo-4,6-difluoro-N-(1,1,1-trifluoro-2-propylidene)aniline (**41a**)*

$^{19}$F NMR: δ −118.2, −114.0, −74.7.

*4.4.59. 5,7-Difluoro-2-trifluoromethylindole (**41e**)*

$^{19}$F NMR: δ −130.6, −120.0, −61.2.

*4.4.60. 2-Bromo-4-chloro-N-(1,1,1-trifluoro-2-propylidene)aniline (**42a**)*

$^{19}$F NMR: δ −75.0.

*4.4.61. 5-Chloro-2-trifluoromethylindole (**42e**)*

$^{19}$F NMR: δ −61.2.

*4.4.62. 5-Trifluoromethoxy-2-trifluoromethylindole (**43e**)*

*Brown solid*. $^{1}$H NMR: δ 6.95 (q, $J_{HF}$ = 1.1 Hz, 1H), 7.22 (dd, $J_{HH}$ = 8.9 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.43 (d, $J_{HH}$ = 8.9 Hz, 1H), 7.55 (s, 1H), 8.48 (brs, 1H). $^{13}$C NMR: δ 104.6 (q, $J_{CF}$ = 3.4 Hz), 112.7, 114.4, 119.2, 120.8 (q, $J_{CF}$ = 256.1 Hz), 120.9 (q, $J_{CF}$ = 268.0 Hz), 126.8, 127.6 (q, $J_{CF}$ = 39.2 Hz), 134.3, 143.9 (q, $J_{CF}$ = 1.9 Hz). $^{19}$F NMR: δ −61.1 (d, $J_{FH}$ = 1.1 Hz), −58.5 (dd, $J_{FH}$ = 0.8 Hz, $J_{FH}$ = 0.8 Hz).

*4.4.63. 2-Iodo-N-(1,1,1-trifluoro-2-propylidene)aniline (**44a**)*

$^{19}$F NMR: δ −75.0.

*4.4.64. N-[1-(Trifluoromethyl)ethyl]aniline (**1f**)*

*Yellow oil*. $^{1}$H NMR: δ 1.39 (d, $J_{HH}$ = 6.8 Hz, 3H), 3.55 (brd, $J_{HH}$ = 8.2 Hz, 1H), 3.98–4.05 (m, 1H), 6.60 (d, $J_{HH}$ = 7.8 Hz, 2H), 6.78 (tt, $J_{HH}$ = 7.4 Hz, $J_{HH}$ = 0.9 Hz, 1H), 7.18–7.22 (m, 2H). $^{13}$C NMR: δ 15.2 (q, $J_{CF}$ = 2.1 Hz), 51.4 (q, $J_{CF}$ = 30.5 Hz), 113.5, 118.9, 126.3 (q, $J_{CF}$ = 282.8 Hz), 129.6, 145.9. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.6 Hz).

*4.4.65. 4-Methyl-N-[1-(trifluoromethyl)ethyl]aniline (**2f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.36 (d, $J_{HH}$ = 6.8 Hz, 3H), 2.24 (s, 3H), 3.42 (brs, 1H), 3.93–3.99 (m, 1H), 6.58 (d, $J_{HH}$ = 8.3 Hz, 2H), 7.00 (d, $J_{HH}$ = 8.3 Hz, 2H). $^{13}$C NMR: δ 15.2 (q, $J_{CF}$ = 2.2 Hz), 20.4, 51.8 (q, $J_{CF}$ = 30.3 Hz), 113.7, 126.4 (q, $J_{CF}$ = 283.0 Hz), 128.2, 129.9, 143.7. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.8 Hz).

*4.4.66. 2-Methyl-N-[1-(trifluoromethyl)ethyl]aniline (**3f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.42 (d, $J_{HH}$ = 6.8 Hz, 3H), 2.17 (s, 3H), 3.45 (brd, $J_{HH}$ = 8.4 Hz, 1H), 4.03–4.13 (m, 1H), 6.69 (d, $J_{HH}$ = 7.9 Hz, 1H), 6.72 (ddd, $J_{HH}$ = 7.6 Hz, $J_{HH}$ = 7.4 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.08 (d, $J_{HH}$ = 7.4 Hz, 1H), 7.13 (dd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 7.6 Hz, 1H). $^{13}$C NMR: δ 15.5 (q, $J_{CF}$ = 2.2 Hz), 17.3, 51.3 (q, $J_{CF}$ = 30.3 Hz), 110.9, 118.5, 122.4, 126.3 (q, $J_{CF}$ = 282.8 Hz), 127.2, 130.6, 144.0. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.6 Hz).

*4.4.67. 3,5-Dimethyl-N-[1-(trifluoromethyl)ethyl]aniline (**4f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.35 (d, $J_{HH}$ = 6.8 Hz, 3H), 2.17 (s, 6H), 3.44 (brd, $J_{HH}$ = 8.1 Hz, 1H), 3.95–4.03 (m, 1H), 6.28 (s, 2H), 6.44. $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.1 Hz), 21.4, 51.3 (q, $J_{CF}$ = 30.3 Hz), 111.4, 120.8, 126.3 (q, $J_{CF}$ = 282.7 Hz), 139.1, 146.0. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.7 Hz).

*4.4.68. 4-Tert-butyl-N-[1-(trifluoromethyl)ethyl]aniline (**5f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.27 (s, 9H), 1.37 (d, $J_{HH}$ = 6.9 Hz, 3 H), 2.24, 3.48 (brd, $J_{HH}$ = 7.3 Hz, 1H), 3.94–4.01 (m, 1H), 6.60–6.63 (m, 2H), 7.19–7.24 (m, 2H). $^{13}$C NMR: δ 15.2 (q, $J_{CF}$ = 3.1 Hz), 31.5, 51.6 (q, $J_{CF}$ = 30.3 Hz), 113.2, 126.2, 126.4 (q, $J_{CF}$ = 282.7 Hz), 141.7, 143.6, 171.2. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.7 Hz).

*4.4.69. 4-Vinyl-N-[1-(trifluoromethyl)ethyl]aniline (**7f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.39 (d, $J_{HH}$ = 6.8 Hz, 3H), 3.63 (brs, 1H), 4.00–4.05 (m, 1H), 5.05 (dd, $J_{HH}$ = 10.9 Hz, $J_{HH}$ = 0.7 Hz, 1H), 5.56 (dd, $J_{HH}$ = 17.6 Hz, $J_{HH}$ = 0.7 Hz, 1H), 6.58–6.64 (m, 3H), 7.26–7.28 (m, 2H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.1 Hz), 51.2 (q, $J_{CF}$ = 30.6 Hz), 110.4, 113.4, 126.2 (q, $J_{CF}$ = 282.9 Hz), 127.4, 128.7, 136.3, 145.6. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.6 Hz).

*4.4.70. 5-Methyl-2-trifluoromethyl-4-N-[1-(trifluoromethyl)ethyl]amino-quinoline (**13f**)*

*Yellow solid*. $^{1}$H NMR: δ 1.56 (d, $J_{HH}$ = 6.8 Hz, 3H), 2.98 (s, 3H), 4.32–4.39 (m, 1H), 5.85 (brd, $J_{HH}$ = 8.3 Hz, 1H), 6.78 (s, 1H), 7.29 (d, $J_{HH}$ = 7.2 Hz, 1H), 7.55 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 7.2 Hz, 1H), 7.96 (d, $J_{HH}$ = 8.3 Hz, 1H). $^{13}$C NMR: δ 14.7 (q, $J_{CF}$ = 2.1 Hz), 24.8, 50.8 (q, $J_{CF}$ = 31.1 Hz), 95.9, 119.5, 121.7 (q, $J_{CF}$ = 275.4 Hz), 125.6 (q, $J_{CF}$ = 282.4 Hz), 129.8, 131.9, 148.2 (q, $J_{CF}$ = 33.7 Hz), 149.9, 152.3. $^{19}$F NMR: δ −77.2 (d, $J_{FH}$ = 6.3 Hz), −68.6.

*4.4.71. 4-Bromo-N-[1-(trifluoromethyl)ethyl]aniline (**14f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.38 (d, $J_{HH}$ = 6.8 Hz, 3H), 3.59 (brd, $J_{HH}$ = 8.7 Hz, 1H), 3.92–3.99 (m, 1H), 6.52–6.55 (m, 2H), 7.26–7.29 (m, 2H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.1 Hz), 51.4 (q, $J_{CF}$ = 30.5 Hz), 108.5, 115.1, 126.1 (q, $J_{CF}$ = 283.0 Hz), 132.1, 145.0. $^{19}$F NMR: δ −77.6 ($J_{FH}$ = 6.5 Hz).

*4.4.72. 2-Bromo-N-[1-(trifluoromethyl)ethyl]aniline (**15f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.45 (d, $J_{HH}$ = 6.8 Hz, 3H), 4.01–4.06 (m, 1H), 4.33 (brd, $J_{HH}$ = 8.4 Hz, 1H), 6.65 (ddd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.4 Hz, 1H), 6.74 (d, $J_{HH}$ = 7.9 Hz, 1H), 7.19 (ddd, $J_{HH}$ = 7.9 Hz, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H), 7.44 (dd, $J_{HH}$ = 7.7 Hz, $J_{HH}$ = 1.5 Hz, 1H). $^{13}$C NMR: δ 15.3 (q, $J_{CF}$ = 2.2 Hz), 51.4 (q, $J_{CF}$ = 30.8 Hz), 110.3, 112.3, 119.4, 126.1 (q, $J_{CF}$ = 282.8 Hz), 128.5, 132.8, 143.0. $^{19}$F NMR: δ −77.6 ($J_{FH}$ = 6.5 Hz).

*4.4.73. 3-Chloro-N-[1-(trifluoromethyl)ethyl]aniline (**17f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.38 (d, $J_{HH}$ = 6.8 Hz, 3 H), 3.64 (brd, $J_{HH}$ = 8.6 Hz, 1H), 3.94–4.01 (m, 1H), 6.52 (dd, $J_{HH}$ = 8.6 Hz, $J_{HH}$ = 2.2 Hz, 1H), 6.64 (dd, $J_{HH}$ = 2.2 Hz, $J_{HH}$ = 2.0 Hz, 1H), 6.74 (ddd, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 2.0 Hz, $J_{HH}$ = 0.7 Hz, 1H), 7.09 (dd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 8.0 Hz, 1H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.2 Hz), 51.2 (q, $J_{CF}$ = 30.7 Hz), 111.7, 113.3, 118.8, 126.1 (q, $J_{CF}$ = 282.9 Hz), 130.4, 135.2, 147.1. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.5 Hz).

*4.4.74. 4-Fluoro-N-[1-(trifluoromethyl)ethyl]aniline (**18f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.38 (d, $J_{HH}$ = 6.8 Hz, 3H), 3.45 (brs, 1H), 3.88–3.95 (m, 1H), 6.58–6.63 (m, 2H), 6.88–6.93 (m, 2H). $^{13}$C NMR: δ 15.2 (q, $J_{CF}$ = 2.2 Hz), 52.3 (q, $J_{CF}$ = 30.3 Hz), 114.7 (d, $J_{CF}$ = 7.4 Hz), 115.9 (d, $J_{CF}$ = 22.5 Hz), 126.3 (q, $J_{CF}$ = 282.9 Hz), 142.3 (d, $J_{CF}$ = 2.1 Hz), 156.5 (d, $J_{CF}$ = 236.8 Hz). $^{19}$F NMR: δ −126.5 (tt, $J_{FH}$ = 8.4 Hz, $J_{FH}$ = 4.2 Hz), −77.7 ($J_{FH}$ = 6.6 Hz).

*4.4.75. 2-Fluoro-5-methyl-N-[1-(trifluoromethyl) ethyl]aniline (**19f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.41 (d, $J_{HH}$ = 6.8 Hz, 3 H), 2.27 (s, 3H), 3.81 (brs, 1H), 3.96–4.03 (m, 1H), 6.48–6.50 (m, 1H), 6.57 (d, $J_{HH}$ = 8.3 Hz, 1H), 6.86 (dd, $J_{HF}$ = 11.5 Hz, $J_{HH}$ = 8.3 Hz, 1H). $^{13}$C NMR: δ 15.3 (q, $J_{CF}$ = 2.2 Hz), 21.2, 51.3 (q, $J_{CF}$ = 30.6 Hz), 113.8, 113.9 (d, $J_{CF}$ = 17.0 Hz), 118.7 (d, $J_{CF}$ = 6.8 Hz), 126.1 (q, $J_{CF}$ = 282.8 Hz), 134.0 (d, $J_{CF}$ = 11.4 Hz), 134.2 (d, $J_{CF}$ = 35.2 Hz), 149.9 (d, $J_{CF}$ = 236.0 Hz). $^{19}$F NMR: δ −141.2 (brs), −77.7 ($J_{FH}$ = 6.5 Hz).

*4.4.76. 3,4-Difluoro-N-[1-(trifluoromethyl)ethyl]aniline (**20f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.40 (d, $J_{HH}$ = 6.8 Hz, 3 H), 3.55 (brd, $J_{HH}$ = 7.3 Hz, 1H), 3.86–3.93 (m, 1H), 6.33 (dddd, $J_{HH}$ = 9.1 Hz, $J_{HF}$ = 3.3 Hz, $J_{HH}$ = 3.0 Hz, $J_{HF}$ = 1.6 Hz, 1H), 6.47 (ddd, $J_{HF}$ = 12.5 Hz, $J_{HF}$ = 6.6 Hz, $J_{HH}$ = 3.0 Hz, 1H), 6.98 (m, 1H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.1 Hz), 52.0 (q, $J_{CF}$ = 30.6 Hz), 102.5 (d, $J_{CF}$ = 21.1 Hz), 108.7–108.8 (m), 117.7 (dd, $J_{CF}$ = 18.1 Hz, $J_{CF}$ = 1.8 Hz), 126.0 (q, $J_{CF}$ = 283.0 Hz), 142.8–144.8 (m), 151.8 (dd, $J_{CF}$ = 246.0 Hz, $J_{CF}$ = 13.5 Hz). $^{19}$F NMR: δ −151.3 (dddd, $J_{FF}$ = 21.8 Hz, $J_{FH}$ = 9.8 Hz, $J_{FH}$ = 6.6 Hz, $J_{FH}$ = 3.3 Hz), −136.9 (m), −77.7 ($J_{FH}$ = 6.5 Hz).

*4.4.77. 4-Methoxy-N-[1-(trifluoromethyl)ethyl]aniline (**21f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.35 (d, $J_{HH}$ = 6.9 Hz, 3H), 3.30 (brs, 1H), 3.73 (s, 3H), 3.86–3.91 (m, 1H), 6.61–6.64 (m, 2H), 6.76–6.80 (m, 2H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.2 Hz), 52.6 (q, $J_{CF}$ = 30.0 Hz), 55.6, 114.8, 115.2, 126.4 (q, $J_{CF}$ = 282.8 Hz), 140.0, 153.0. $^{19}$F NMR: δ −77.6 ($J_{FH}$ = 6.7 Hz).

*4.4.78. 2-Trifluoromethoxy-N-[1-(trifluoromethyl) ethyl]aniline (**22f**)*

$^{19}$F NMR: δ −78.0, −58.3.

*4.4.79. 4-Difluoromethoxy-N-[1-(trifluoromethyl) ethyl]aniline (**23f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.39 (d, $J_{HH}$ = 6.8 Hz, 3H), 3.57 (brd, $J_{HH}$ = 8.2 Hz, 1H), 3.92–3.99 (m, 1H), 6.38 (t, $J_{HF}$ = 74.6 Hz, 1H), 6.61–6.64 (m, 2H), 6.94–7.00 (m, 2H). $^{13}$C NMR: δ 15.2 (q, $J_{CF}$ = 2.2 Hz), 51.8 (q, $J_{CF}$ = 30.5 Hz), 114.3, 116.4 (t, $J_{CF}$ = 259.3 Hz), 121.5, 126.4 (q, $J_{CF}$ = 282.9 Hz), 143.4 (t, $J_{CF}$ = 3.0 Hz), 143.8. $^{19}$F NMR: δ −80.5 (t, $J_{FH}$ = 74.6 Hz), −77.7 ($J_{FH}$ = 6.5 Hz).

*4.4.80. 1-N-[1-(Trifluoromethyl)ethyl]aminonaphthalene (**24f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.45 (d, $J_{HH}$ = 6.2 Hz, 3 H), 4.17–4.22 (m, 2H), 6.70 (dd, $J_{HH}$ = 7.5 Hz, $J_{HH}$ = 1.3 Hz, 1H), 7.29–7.35 (m, 2H), 7.39–7.45 (m, 2H), 7.74–7.80 (m, 2H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.1 Hz), 51.6 (q, $J_{CF}$ = 30.4 Hz), 106.2, 119.2, 119.7, 123.7, 125.2, 126.0, 126.3, 126.4 (q, $J_{CF}$ = 282.6 Hz), 134.5, 141.1. $^{19}$F NMR: δ −77.3 ($J_{FH}$ = 5.5 Hz).

*4.4.81. 2-N-[1-(Trifluoromethyl)ethyl]aminoanthracene (**25f**)*

*Pale yellow oil*. $^{1}$H NMR: δ 1.49 (d, $J_{HH}$ = 6.2 Hz, 3H), 3.84 (brs, 1H), 4.20–4.28 (m, 1H), 6.93 (dd, $J_{HH}$ = 9.0 Hz, $J_{HH}$ = 2.3 Hz, 1H), 6.99 (s, 1H), 7.35 (ddd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 6.7 Hz, $J_{HH}$ = 1.2 Hz, 1H), 7.41 (ddd, $J_{HH}$ = 8.2 Hz, $J_{HH}$ = 6.8 Hz, $J_{HH}$ = 1.3 Hz, 1H), 7.84 (d, $J_{HH}$ = 9.0 Hz, 1H), 7.88–7.92 (m, 2H), 8.15 (s, 1H), 8.26 (s, 1H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.5 Hz), 51.2 (q, $J_{CF}$ = 30.8 Hz), 103.3, 123.1, 124.0, 125.1, 126.2, 126.3 (q, $J_{CF}$ = 282.8 Hz), 127.7, 128.2, 129.8, 130.0, 132.6, 133.0, 142.6. $^{19}$F NMR: δ −77.4 ($J_{FH}$ = 6.6 Hz).

*4.4.82. 3-N-[1-(Trifluoromethyl)ethyl]aminopyridine (**27f**)*

*Red powder*. $^{1}$H NMR: δ 1.42 (d, $J_{HH}$ = 6.6 Hz, 3H), 3.96 (brs, 1H), 3.96–4.06 (m, 1H), 6.97 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 1.8 Hz, 1H), 7.12 (dd, $J_{HH}$ = 8.3 Hz, $J_{HH}$ = 4.7 Hz, 1H), 8.03 (dd, $J_{HH}$ = 4.7 Hz, $J_{HH}$ = 1.1 Hz, 1H), 8.10 (d, $J_{HH}$ = 2.9 Hz, 1H). $^{13}$C NMR: δ 15.1 (q, $J_{CF}$ = 2.2 Hz), 51.0 (q, $J_{CF}$ = 30.7 Hz), 119.3, 123.8, 126.1 (q, $J_{CF}$ = 283.0 Hz), 136.5, 140.1, 142.2. $^{19}$F NMR: δ −77.7 ($J_{FH}$ = 6.2 Hz).

*4.4.83. 2-Trifluoromethyl-4-N-[1-(trifluoromethyl) ethyl]aminoquinoline (**31f**)*

*Yellow powder*. $^{1}$H NMR: δ 1.60 (d, $J_{HH}$ = 6.8 Hz, 3H), 4.36–4.44 (m, 1H), 5.12 (brd, $J_{HH}$ = 8.7 Hz, 1H), 6.87 (s,

1H), 7.59 (ddd, $J_{HH}$ = 8.1 Hz, $J_{HH}$ = 7.3 Hz, $J_{HH}$ = 1.0 Hz, 1H), 7.76 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 7.3 Hz, $J_{HH}$ = 1.2 Hz, 1H), 7.79 (d, $J_{HH}$ = 8.1 Hz, 1H), 8.14 (d, $J_{HH}$ = 8.4 Hz, 1H). $^{13}$C NMR: δ 14.9 (q, $J_{CF}$ = 2.2 Hz), 50.5 (q, $J_{CF}$ = 31.5 Hz), 95.3, 118.4, 118.9, 121.7 (q, $J_{CF}$ = 275.5 Hz), 125.6 (q, $J_{CF}$ = 282.5 Hz), 127.1, 130.5, 131.0, 147.7, 148.8 (q, $J_{CF}$ = 33.7 Hz), 149.5. $^{19}$F NMR: δ −77.2 (d, $J_{FH}$ = 6.3 Hz), −68.4.

#### *4.4.84. 5-Fluoro-2-trifluoromethyl-4-N-[1-(trifluoromethyl)ethyl]aminoquinoline (**36f**)*

*White powder*. δ 1.57 (d, $J_{HH}$ = 6.8 Hz, 3H), 4.31–4.39 (m, 1H), 6.48 (brdd, $J_{HF}$ = 21.6 Hz, $J_{HH}$ = 8.5 Hz, 1H), 6.82 (s, 1H), 7.19 (ddd, $J_{HF}$ = 14.7 Hz, $J_{HH}$ = 8.0 Hz, $J_{HH}$ = 0.8 Hz, 1H), 7.63 (ddd, $J_{HH}$ = 8.4 Hz, $J_{HH}$ = 8.0 Hz, $J_{HF}$ = 6.1 Hz, 1H), 7.91 (d, $J_{HH}$ = 8.4 Hz, 1H). $^{13}$C NMR: δ 14.8 (q, $J_{CF}$ = 2.1 Hz), 50.5 (q, $J_{CF}$ = 31.8 Hz), 95.7, 109.8 (d, $J_{CF}$ = 7.6 Hz), 111.7 (d, $J_{CF}$ = 24.3 Hz), 121.5 (q, $J_{CF}$ = 275.6 Hz), 125.5 (q, $J_{CF}$ = 282.7 Hz), 127.1 (d, $J_{CF}$ = 3.7 Hz), 129.9 (d, $J_{CF}$ = 11.4 Hz), 149.7 (d, $J_{CF}$ = 32.5 Hz), 149.8, 150.5 (d, $J_{CF}$ = 3.9 Hz), 159.3 (d, $J_{CF}$ = 248.6 Hz). $^{19}$F NMR: δ −115.1 (dddd, $J_{FH}$ = 21.6 Hz, $J_{FH}$ = 14.7 Hz, $J_{FH}$ = 6.1 Hz, $J_{FH}$ = 3.4 Hz), −77.1 (d, $J_{FH}$ = 6.32Hz), −68.7.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.molcata.2007.11.013.

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