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Catalyst-free Hydroxytrifluoromethylation of Alkenes Using Iodotrifluoromethane

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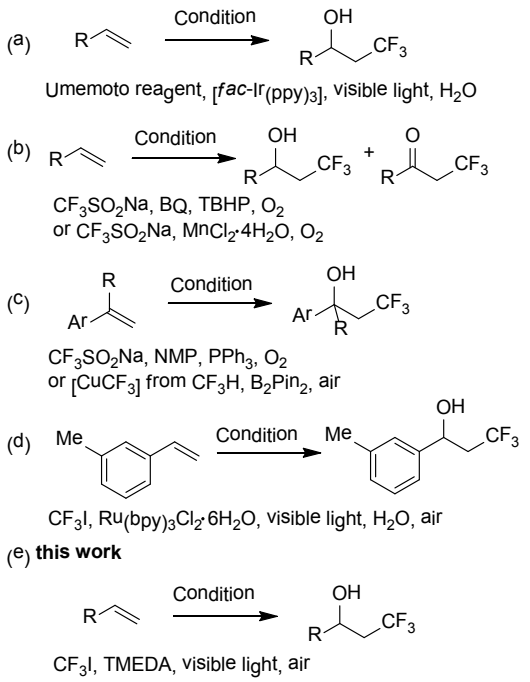
The importance of CF_3-containing molecules in pharmaceuticals, agrochemicals and materials intrigues the intense interest in synthetic methodology of these compounds. With a purpose to enrich trifluoromethylation methodology, we carefully examined the substrate scope of hydroxytrifluoromethylation of alkenes using iodotrifluoromethane, and the reaction provided β-trifluoromethyl alcohols in good yields under extremely mild conditions without catalysts. We found that our reaction can be applied to not only styrenes but also to various aliphatic alkenes with excellent selectivity; no ketones were detected in most of our cases. Another feature of our discovery is "simple". The reaction was carried out in air, irradiated by visible light, at room temperature and most importantly no catalyst was needed. A solution of CF_3I in DMSO was used as the facile trifluoromethylating reagent, which simplified the utilization of gaseous CF_3I. Based on ^{19}F NMR spectroscopy, we observed a halogen bond between CF_3I and tertiary amine in this reaction. The interaction may promote single electron transfer by the visible light irradiation.

Background and Originality Content

The importance of CF_3-containing molecules in pharmaceuticals, agrochemicals and materials intrigues the intense interest in synthetic methodology of these compounds.[1] β-trifluoromethyl alcohols are one of important CF_3-containing intermediates, and the synthesis of these compounds could be conveniently realized through hydroxytrifluoromethylation of alkenes.[2-5] Photoredox hydroxytrifluoromethylation of alkenes was realized by Umemoto reagent (S-(trifluoromethyl)dibenzothiophenium) efficiently in 2012 (Scheme 1a).[2] It was the first photocatalytic hydroxytrifluoromethylation reaction of alkenes, showing the power of visible light photocatalysis in synthetic chemistry. However, Umemoto reagent that they used was an expensive electrophilic trifluoromethylating reagent. Later, the Langlois reagent (CF_3SO_2Na) was applied to generate β-trifluoromethyl alcohols by the catalysis of Mn salt/O_2[3a] or by oxidation of excessive *tert*-butyl hydroperoxide (TBHP) with one equivalent of benzoquinone (BQ)[3b] (Scheme 1b). Langlois reagent (CF_3SO_2Na) was also used to produce β-trifluoromethyl alcohols through paired electrolysis in organic-aqueous media.[3c] The use of Langlois reagent (CF_3SO_2Na) which is cheap and easily available enriches the method of producing β-trifluoromethyl alcohols. And no strong oxidative initiator was used in those reactions although sometimes the selectivity was not very good because the generation of α-trifluoromethyl ketones were unavoidable.[3] When an α-substituted styrene was used and the substituted group prevented the over-oxidation, a tertiary β-trifluoromethyl alcohol could be obtained as a single product under the conditions of Langlois reagent/*N*-methyl-2-pyrrolidone (NMP)/O_2[4a] or the conditions of (CF_3H)-derived CF_3Cu/bis(pinacolato)diboron (B_2Pin_2)/air[4b] (Scheme 1c). Both reactions occurred under air conditions, and oxygen acted as a green source of oxygen. Very recently, a Ru-catalyzed visible-light promoted photoredox reaction of a styrene with CF_3I provided a β-trifluoromethyl benzyl alcohol in 51% yield (Scheme 1d).[5] Oxytrifluoromethylation of alkenes provided derivatives which could generate β-trifluoromethyl alcohols by a two-step process.[6] Therefore, although excellent work was done, the substrate scope was limited to aromatic alkenes and few examples used aliphatic alkenes.



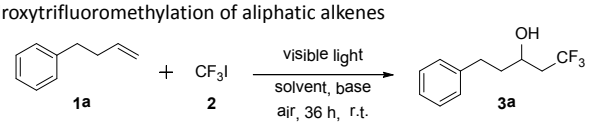
Scheme 1. Hydroxytrifluoromethylation of alkenes

CF_3I is a useful and inexpensive starting material for trifluoromethylation. CF_3I can produce trifluoromethyl radical by light or heat.[7] After continuous exploration, Me_3Al[8a], Et_2Zn[8b], $FeSO_4/H_2O/DMSO$[8c], Et_3B/O_2[9], $Na_2S_2O_4$[10a], tetrakis(dimethylamino)ethylene (TDAE)[10b], and Ru[10c] complex can all trigger CF_3I to give trifluoromethyl radical. Currently, visible light-promoted photoredox system is extensively applied in the generation of trifluoromethyl radical from CF_3I with the catalysts of Ir and Ru complexes.[5,11] Notably, Ritter et al. discovered a liquid phase halogen-bonded adduct of CF_3I with tetramethylguanidine (TMG), which reacted with alkenes in photocatalytic conditions.[12] Halogen-bond interaction was also applied to the radical addition reactions of long-chained perfluoroalkyl iodide (e.g. C_4F_9I) with unactivated alkenes and isonitriles, and specifically these fantastic reactions were promoted with visible light in the absence of photocatalysts which were normally expensive and hard to remove.[13,14] Oxygen usually hampers radical reactions. However, oxygen was found to compatible with photoredox reactions and acted as a source for hydroxy.[5,15] In the end, we applied the hydroxytrifluoromethylation of alkenes with CF_3I in the absence of photocatalyst under the visible light irradiation and air atmosphere. The feature of this work is exceptionally wide substrate scope, not only applied to styrenes, but also to aliphatic alkenes which are barely realized before.

Results and Discussion

The protocol was initially evaluated with 4-phenyl-1-butene (**1a**) as a model substrate to react with 2 equivalents of CF_3I (**2**) using 4 equivalents of *N*,*N*,*N*′,*N*′-tetramethylethane-1,2-diamine (TMEDA) as base in solvent under visible light irradiation by 24 W fluorescent lamp in air (Table 1). Among the common solvents including DMF, DMAc, THF, acetonitrile and DMSO, all of them promoted the reaction and DMSO was the best solvent giving product **3a** in 90% yield (Table 1, entries 1-5; detected by ^{19}F NMR spectroscopy). To our delight, employing TMEDA as a base with white light irradiation provided **3a** in 90% yield and other bases can not provided **3a** in a good yield (Table 1, entries 5-7). It is worth noting that **3a** could not be obtained in the dark condition, in the absence of the base, or under a nitrogen atmosphere (Table 1, entries 8-10).

Table 1. Condition Screening of visible light-promoted catalyst-free hydroxytrifluoromethylation of aliphatic alkenes

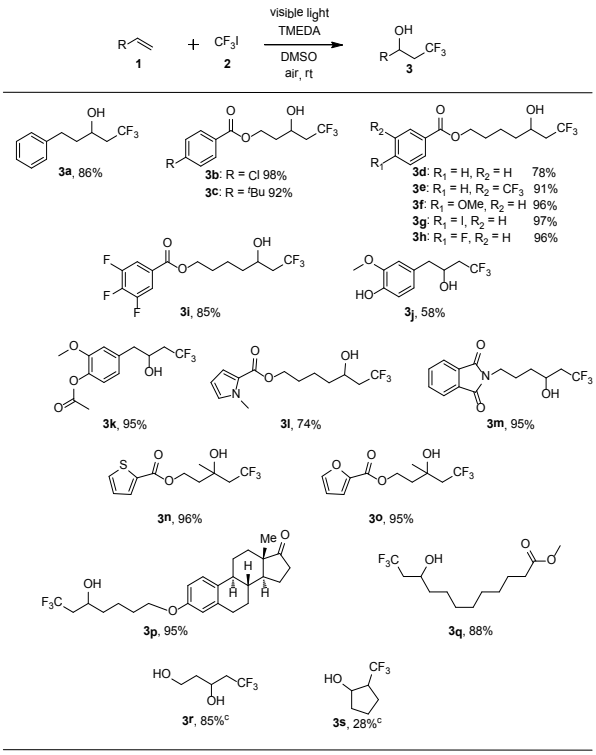


Entry[a]	light	solvent	base	Yield (%)[b]
1	white light	DMF	TMEDA	87
2	white light	DMAc	TMEDA	84
3	white light	THF	TMEDA	55
4	white light	CH_3CN	TMEDA	78
5	white light	DMSO	TMEDA	90
6	white light	DMSO	Et_3N	30
7	white light	DMSO	TEEDA	31
8	dark	DMSO	TMEDA	0
9	white light	DMSO	/	0
10[c]	white light	DMSO	TMEDA	0

[a]Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), base (0.8 mmol), anhydrous solvent (2 mL), irradiated by 24 W fluorescent lamp, room temperature, under an air atmosphere, 36 h; [b]Yield were determined by ^{19}F NMR spectroscopy using benzotrifluoride as the internal standard; [c]The reaction was carried out under a nitrogen atmosphere.

With the optimal reaction conditions identified (Table 1, entry 5), the substrate scope of the radical hydroxytrifluoromethylation reaction was examined. A wide range of unactivated terminal alkenes were applicable to the reaction and provided the CF_3-substituted alcohols in moderate to good yields. A series of functional groups, including ester (**3b–i**, **3l**, **3n**, **3o**, **3q**), heterocyclic (**3l–o**), halogen (**3b**, **3g**, **3h**, **3i**), ketone (**3p**), phthalimide (**3m**) moieties, and hydroxy (**3r**) were well tolerated under the reaction conditions, and might be attributed to the mild reaction conditions employed. The natural product eugenol and its derivatives (**3j**, **3k**) also provide good yields. In addition, terminal alkenes derived from relatively complex molecules estrone (**3p**) were compatible with the reaction conditions and yielded the desired products in satisfactory yields, which demonstrates the potential of the hydroxytrifluoromethylation reaction in late-stage functionalization. The alkenes with α-substituted methyl group were compatible in this condition and the isolated yield of the alcohols were excellent (**3n**, 96%; **3o**, 95%). However, cyclopentene gave a low yield of product **3s**.

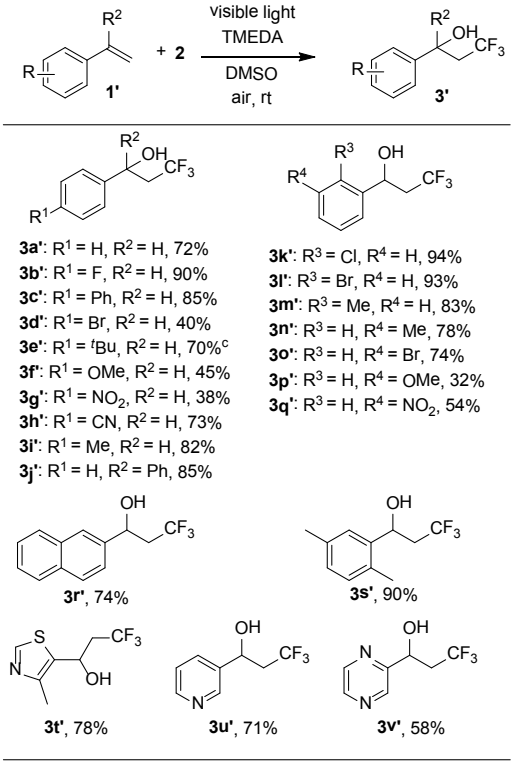
Table 2. Substrate scope of catalyst-free hydroxytrifluoromethylation of aliphatic alkenes[a,b]



[a]Reaction conditions: **1** (0.2 mmol), **2** (0.4 mmol), TMEDA (0.8 mmol), anhydrous DMSO (2 mL), 24 W white fluorescent irradiation, room temperature, under an air atmosphere, 36 h; [b] Isolated yield. [c]Yield were determined by ^{19}F NMR spectroscopy using benzotrifluoride as the internal standard.

We also explored the substrate scope of aromatic and heteroaromatic alkenes (the optimized conditions see the Supporting Information). As shown in Table 3, a wide variety of styrenes bearing either electron-withdrawing or electron-donating substituents on the aryl ring could be transformed into the corresponding hydroxytrifluoromethylation compounds in moderate to good yields. Styrenes bearing different halogen atoms smoothly produced the corresponding products (**3b'**, **3d'**, **3k'** and **3l'**) in good yields. Styrenes with the electron-donating substituents (**3e'**, **3f'**, **3i'**, **3m'**, **3n'**, **3p'** and **3s'**) afforded the corresponding products in moderate yields. The disubstituted alkenes underwent the desired reaction giving product (**3j'**) effectively. Remarkably, styrenes with the electron-withdrawing group efficiently gave product (**3g'**, **3h'**, **3q'**) in good yield. In addition, this reaction could also be applied to naphthalene and heterocyclic aryl alkenes such as vinylnaphthalenes (**3r'**), a thiazole derivative (**3t'**), 2-vinylpyridine (**3u'**), 2-vinylpyrazine (**3v'**) gain corresponding products in moderate to good yields.

Table 3. Substrate scope of catalyst-free hydroxytrifluoromethylation of aromatic and heteroaromatic alkenes[a,b]



[a]Reaction conditions: **1'** (0.2 mmol), **2** (0.4 mmol), TMEDA (0.4 mmol), anhydrous DMSO (2 mL), 24 W white fluorescent irradiation, room temperature, under an air atmosphere, 36 h; [b]Isolated yield. [c] Isolated yield of ketone was 5%.

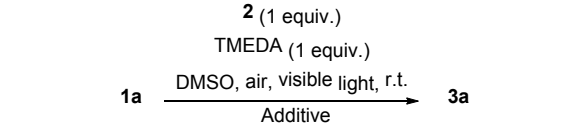
"Generality" is very important for a reaction. Previous hydroxytrifluoromethylation focused on styrenes. For examples, Akita et al. found the reactions of Umemoto reagent with styrenes could provide β-trifluoromethyl alcohols in good selectivity.[2] However, the reaction of 1-octene didn't occur. To best of our knowledge, only two examples of aliphatic alkenes were used and the reactions were not well selective. 1-octene provided 45% yield of a β-trifluoromethyl alcohol which were mixed with 13% yield of an α-trifluoromethyl ketone product. When *cis*-cyclooctene were used, the yields of the alcohol and the ketone were 35% and 30%, respectively.[3a] As we showed in Table 2, we provided nineteen examples of aliphatic alkenes with various structures. All of them were in good selectivities, providing β-trifluoromethyl alcohol products without the detection of any α-trifluoromethyl ketones by ^{19}F NMR monitoring.

The selectivity of our reaction were also good for styrene substrates. As shown in Table 3, most of our examples were the substrates without α-substituent. The signals assigned to the ketone products in ^{19}F NMR monitoring were observed only for three special substrates with electron-donating groups in phenyl rings (4-methoxystyrene, 3-methoxystyrene and 4-*tert*-butylstyrene). For **3f'**, the ^{19}F NMR yield of alcohol product was 83% accompanying with a 14% yield of ketone by-product. These two products were hard to separate due to the close polarity. As a result, we only isolated 45% yield of the pure alcohol

product. 4-*tert*-Butylstyrene gave a 5% isolated yield of ketone product **4a** (Table 3). The reason for low yield of **3d'** and **3p'** was unclear. In other cases of Table 3, no ketones were detected. α-substituent on styrenes could prevent the over-oxidation to avoid the ketone products as shown in Lei[4a] and Tsui[4b] work. In our experiment, 1,1-diphenylethene gave a 85% yield of the β-trifluoromethyl alcohol **3j'**, which were about two times higher than the yield reported by Tsui[4b].

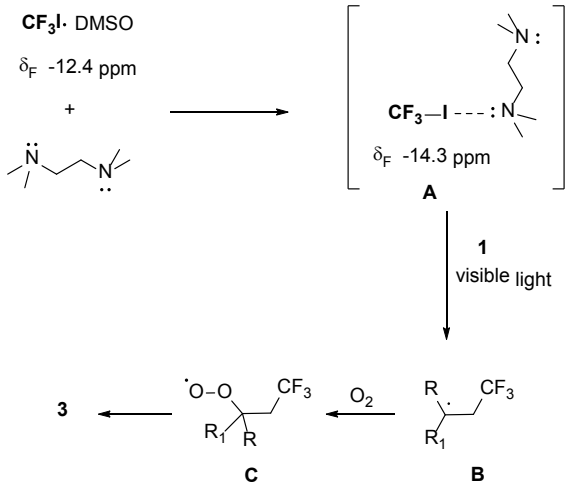
Iodotrifluoromethane is a readily available trifluoromethylating reagent and works as a trifluoromethyl radical source.[7-12] The price of iodotrifluoromethane is much lower than electrophilic trifluoromethylating reagent. However, CF_3I are a gas at room temperature and its operation is not easy. Ritter et al. reported a CF_3I·2DMSO complex.[12] Inspired by their work, we found that CF_3I can be well dissolved in DMSO to generate a solution with a constant concentration for two months (experimental procedure in supporting information). In Ritter's and later Jiao's work, photocatalyst was needed for trifluoromethylation from CF_3I.[5,12] But, in our experiments, no photocatalyst was needed and irradiation by visible light were enough to promote the reactions.

(a) Inhibition experiments



Additive		^{19}F NMR yield (%)
without additive		90
HO—⟨⟩—OH	(1 equiv.)	66
NO_2—⟨⟩—NO_2	(1 equiv.)	18

(b) Proposed mechanism



Some mechanistic experiments were carried out (Scheme 2). In the ^{19}F NMR spectra of pure iodotrifluoromethane and its mixtures with TMEDA in DMSO solvent, we found that the fluorine signal of a single CF_3I in DMSO was at -12.4 ppm. When CF_3I was combined with TMEDA, the fluorine signal of CF_3I was at -14.3 ppm in DMSO. The $\Delta|\delta\ (CF_3)|$ was 1.9 ppm. Therefore, we proposed that there was a halogen bond interaction between the nitrogen of TMEDA and the iodine atom of CF_3I.[12,14] On the other hand, using hydroquinone and 1,4-dinitrobenzene could partially inhibit the reaction (Scheme 2a). Based on the aforementioned phenomena, a mechanism is proposed (Scheme 2b). We speculate that a halogen bond interaction between the amine and iodotrifluoromethane produces an electron donor-receptor complex **A**. **A** is then excited by irradiation of visible light and a single electron transfer occurs. The formed trifluoroiodomethyl radical is then captured by olefin to produce a free radical intermediate **B**. The free radical intermediate **B** then captures O_2 from the air to produce a new peroxide radical **C** which provides the final product **3**.[15]

Scheme 2. Mechanistic study for the visible light induced hydroxytrifluoromethylation of alkenes under an air atomosphere

Conclusions

In summary, we developed a hydroxytrifluoromethylation reaction of various alkenes which occurred under visible light irradiation without using a photocatalyst. The inexpensive reagent CF_3I was used as an effective radical trifluoromethylating reagent. The substrate scope was wide; both styrenes and aliphatic alkenes were used. Various olefins can react to give the corresponding product in yields of up to 98% with a good selectivity.

Experimental

1. General Methods

All reagents were used without further purification. Thin layer chromatography (TLC) was visualized by staining with potassium permanganate. Chemical shifts for ^{1}H NMR spectra are reported in ppm downfield from TMS or residual $CHCl_3$ (δ 7.26 ppm). Chemical shifts for ^{19}F NMR are reported in ppm downfield from fluorotrichloromethane ($CFCl_3$). Chemical shifts for ^{13}C NMR spectra are recorded in ppm relative to residual chloroform (δ 77.0 ppm for $CDCl_3$). ^{13}C NMR was broad-band decoupled from hydrogen nuclei. Chemical shifts are expressed in parts per million (ppm) with respect to the residual solvent peak. Coupling constants are reported as hertz (Hz). Signal shapes and splitting patterns are indicated as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. GC-MS (EI) data were determined on an Agilent 5975C. HRMS (ESI) data were tested on a Water Micromass GCT Premier. Unless otherwise noted, solvents were freshly dried and degassed according to the purification handbook Purification of Laboratory Chemicals before using. Flash column chromatography was carried out using 300 - 400 mesh silica gel.

1.1 The preparation of a solution of CF_3I in DMSO

To 25 mL of Schlenk tube was added 10 mL of DMSO under air conditions. Plugged the Schlenk tube with a rubber stopper and inserted an flat balloon (without filling with gas) to ensure a stable pressure when filling CF_3I gas in. A steady stream of CF_3I gas was passed through the DMSO solution for half an hour to an hour. After the gas was introduced, 100 μl of the solution sample was taken out and 0.1 mmol of benzotrifluoride was added into the sample as an internal standard. By ^{19}F NMR analysis of the sample, the concentration of CF_3I is calculated. The concentrations were generally at from 3 to 4 mmol/mL. And the reagent can be stored at a constant concentration for 2 months.

1.2 General procedures for synthesis of 3

To a 25 mL Schlenk tube equipped with a rubber septum and a magnetic stirring bar was charged with DMSO (2 mL). Then alkene **1** (0.2 mmol), CF_3I (0.4 mmol), TMEDA (0.8 mmol) were added. The mixture was stirred under an air atmosphere by irradiation of 24 W white fluorescent lamp for 36 h. After the reaction was complete, the solution was added CH_2Cl_2 (15 mL) and washed with saturated brine (25 mL × 3). The organic layer was dried by anhydrous Na_2SO_4. After that, the organic layer was separated and concentrated under vacuum. The residue was purified with silica gel column chromatography to provide the desired product.

1.3 **General procedures for synthesis of 3'**

To a 25 mL Schlenk tube equipped with a rubber septum and a magnetic stirring bar was charged with DMSO (2 mL). Then alkene **1** (0.2 mmol), CF_3I (0.4 mmol), TMEDA (0.4 mmol) were added. The mixture was stirred under an air atmosphere by irradiation of 24 W white fluorescent lamp for 36 h. After the reaction was complete, the solution was added CH_2Cl_2 (15 mL) and washed with saturated brine (25 mL × 3). The organic layer was dried by anhydrous Na_2SO_4. After that, the organic layer was separated and concentrated under vacuum. The residue was purified with silica gel column chromatography to provide the desired product.

1,1,1-trifluoro-5-phenylpentan-3-ol (**3a**). yellow liquid, yield: 86%. IR (film) ν_{max}: 3410, 3029, 2927, 2861, 1603, 1497, 1386, 1259, 1143, 1073 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (t, *J* = 7.5 Hz, 2H), 7.22 (m, 3H), 4.09 – 4.00 (m, 1H), 2.88 – 2.67 (m, 2H), 2.39 – 2.22 (m, 2H), 2.01 (br, 1H), 1.90 – 1.81 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.1 (s), 128.5 (s), 128.4 (s), 126.4 (q, *J* = 275.4 Hz), 126.1 (s), 65.5 (q, *J* = 2.8 Hz), 41.2 (q, *J* = 26.4 Hz), 38.6 (s), 31.5 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.4 (t, *J* = 11.0 Hz). HRMS(EI) Calcd for $C_{11}H_{13}F_3O$ (M^+): 218.0918; found: 218.0916.

5,5,5-trifluoro-3-hydroxypentyl 4-chlorobenzoate (**3b**). yellow liquid, yield: 98%. IR (film) ν_{max}: 3467, 2964, 1717, 1596, 1489, 1402, 1277, 1123, 1016 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.5 Hz, 2H), 7.39 (d, *J* = 8.5 Hz, 2H), 4.63 – 4.53 (m, 1H), 4.44 – 4.35 (m, 1H), 4.21 – 4.11 (m, 1H), 2.97 (br, 1H), 2.47 – 2.16 (m, 2H), 2.10 – 1.80 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.1 (s), 139.7 (s), 130.9 (s), 128.8 (s), 128.2 (s), 126.1 (q, *J* = 275.4 Hz), 62.9 (q, *J* = 3.0 Hz), 61.5 (s), 41.1 (q, *J* = 26.8 Hz), 36.1 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.8 Hz). HRMS(EI) Calcd for $C_{12}H_{12}ClF_3O_3$ (M^+): 296.0427; found: 296.0435.

5,5,5-trifluoro-3-hydroxypentyl 4-(tert-butyl)benzoate (**3c**). yellow liquid, yield: 92%. IR (film) ν_{max}: 3466, 2966, 1717, 1610, 1464, 1367, 1281, 1190, 1122, 1018 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 – 7.92 (m, 2H), 7.48 – 7.43 (m, 2H), 4.66 – 4.58 (m, 1H), 4.43 – 4.35 (m, 1H), 4.21 – 4.12 (m, 1H),3.13 – 3.06 (m, 1H), 2.47 – 2.21 (m, 2H), 2.07 – 1.84 (m, 2H), 1.33 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.1 (s), 157.0 (s), 129.5 (s), 126.1 (q, *J* = 275.4 Hz), 126.9 (s), 125.4 (s), 63.1 – 62.9 (m), 61.0 (s), 41.1 (q, *J* = 26.8 Hz), 36.3 (s), 35.1 (s), 31.0 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.9 Hz). HRMS(ESI) Calcd for $C_{16}H_{22}F_3O_3$ $[M + H]^+$: 319.1516; found: 319.1514.

7,7,7-trifluoro-5-hydroxyheptyl benzoate (**3d**). yellow liquid, yield: 78%. IR (film) ν_{max}: 3462, 2950, 2869, 1717, 1602, 1585, 1453, 1386, 1278, 1147, 1027 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$)δ 8.03 (d, *J* = 7.3 Hz, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 4.33 (t, *J* = 6.5 Hz, 2H), 4.07 – 3.99 (m, 1H), 2.34 – 2.19 (m, 2H), 1.88 – 1.73 (m, 3H), 1.67 – 1.50 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.7 (s), 132.9 (s), 130.3 (s), 129.50 (s), 128.3 (s), 126.4 (q, *J* = 275.4 Hz), 66.0 – 65.8 (m), 64.7 (s), 41.2 (q, *J* = 26.4 Hz), 36.6 (s), 28.5 (s), 21.8 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 11.0 Hz). HRMS(EI) Calcd for $C_{14}H_{17}F_3O_3$ (M^+): 290.1130; found: 290.1135.

7,7,7-trifluoro-5-hydroxyheptyl 3-(trifluoromethyl)benzoate (**3e**). yellow liquid, yield: 91%. IR (film) ν_{max}: 3446, 2951, 1724,

1619, 1386, 1338, 1258, 1132, 1089, 1073 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.19 (d, *J* = 7.8 Hz, 1H), 7.78 (d, *J* = 7.7 Hz, 1H), 7.55 (t, *J* = 7.8 Hz, 1H), 4.35 (t, *J* = 6.5 Hz, 2H), 4.06 – 3.96 (m, 1H), 2.46 (br, 1H), 2.34 – 2.18 (m, 2H), 1.89 – 1.74 (m, 2H), 1.68 – 1.47 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) ^3C NMR (101 MHz, $CDCl_3$) δ 165.4 (s), 132.7 (s), 131.1(s), 131.0 (q, *J* = 32.4 Hz), 129.4 (q, *J* = 3.6 Hz), 129.0 (s), 126.4 (q, *J* = 3.8 Hz), 126.4 (q, *J* = 276.0 Hz), 123.6 (q, *J* = 270.7 Hz), 65.8 (q, *J* = 2.6 Hz), 65.3 (s), 41.1 (q, *J* = 26.4 Hz), 36.6 (s), 28.3 (s), 21.7 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.9 (s, 3F), -63.6 (t, *J* = 11.0 Hz, 3F). HRMS(EI) Calcd for $C_{15}H_{16}F_6O_3$ (M^+): 358.1004; found: 358.0994.

7,7,7-trifluoro-5-hydroxyheptyl 4-methoxybenzoate (**3f**). yellow liquid, yield: 96%. IR (film) v_{max}: 3467, 2946, 1710, 1607, 1513, 1386, 1258, 1170, 1147, 1030 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.8 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 2H), 4.27 (t, *J* = 6.5 Hz, 2H), 4.05 – 3.96 (m, 1H), 3.82 (s, 3H), 2.54 (br, 1H), 2.34 – 2.16 (m, 2H), 1.83 – 1.70 (m, 2H), 1.65 – 1.44 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5 (s), 163.3 (s), 131.5 (s), 126.4 (q, *J* = 275.4 Hz), 122.6 (s), 113.5 (s), 65.8 (q, *J* = 2.8 Hz), 64.4 (s), 55.3 (s), 41.1 (q, *J* = 26.4 Hz), 36.6 (s), 28.4 (s), 21.7 (s).^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 11.0 Hz). HRMS(EI) Calcd for $C_{15}H_{19}F_3O_4$ (M^+): 320.1235; found: 320.1234.

7,7,7-trifluoro-5-hydroxyheptyl 4-iodobenzoate (**3g**). white solid, yield: 97%. m.p.: 56 – 57 ℃. IR (film) v_{max}: 3486, 2957, 2853, 1717, 1702, 1588, 1395, 1181, 1128, 1079, 1008 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, *J* = 8.2 Hz, 2H), 7.71 (d, *J* = 8.2 Hz, 2H), 4.30 (t, *J* = 6.4 Hz, 2H), 4.06 – 3.96 (m, 1H), 2.35 – 2.18 (m, 3H), 1.84 – 1.72 (m, 2H), 1.66 – 1.45 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2 (s), 137.6 (s), 130.9 (s), 129.6 (s), 126.3 (q, *J* = 275.4 Hz), 100.7 (s), 65.8 (q, *J* = 3.0 Hz), 64.9 (s), 41.1 (q, *J* = 26.4 Hz), 36.6 (s), 28.3 (s), 21.7 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.9 Hz). HRMS(ESI) Calcd for $C_{14}H_{17}F_3IO_3$ [M + H]$^+$: 417.0169; found: 417.0168.

7,7,7-trifluoro-5-hydroxyheptyl 4-fluorobenzoate (**3h**). yellow liquid, yield: 96%. IR (film) v_{max}: 3462, 2949, 1698, 1533, 1415, 1384, 1323, 1248, 1116, 1056, 1018 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.07 – 7.97 (m, 2H), 7.09 (t, *J* = 8.4 Hz, 2H), 4.31 (t, *J* = 6.4 Hz, 2H), 4.08 – 3.96 (s, 1H), 2.40 – 2.15 (m, 3H), 1.86 – 1.72 (m, 2H), 1.70 – 1.44 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ165.8 (s), 165.7 (d, *J* = 254.8 Hz), 132.0 (d, *J* = 9.4 Hz), 126.4 (d, *J* = 3.0 Hz), 126.3 (q, *J* = 275.4 Hz), 115.5 (d, *J* = 22.0 Hz), 65.8 (q, *J* = 2.8 Hz), 64.9 (s), 41.1 (q, *J* = 26.4 Hz), 36.6 (s), 28.4 (s), 21.7 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.9 Hz, 3F), -102.8 – -108.6 (m, 1F). HRMS(ESI) Calcd for $C_{14}H_{17}F_4O_3$ [M + H]$^+$: 309.1108; found: 309.1107.

7,7,7-trifluoro-5-hydroxyheptyl 3,4,5-trifluorobenzoate (**3i**). yellow liquid, yield: 85%. IR (film) v_{max}: 3447, 2950, 1731, 1625, 1530, 1441, 1356, 1255, 1226, 1148, 1088, 1049 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.62 (m, 2H), 4.33 (t, *J* = 6.6 Hz, 2H), 4.08 – 3.99 (m, 1H), 2.35 – 2.19 (m, 2H), 1.88 – 1.71 (m, 3H), 1.68 – 1.45 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$)δ 163.9 (s), 151.0 (ddd, *J* = 251.8, 10.3, 3.4 Hz), 143.1 (dt, *J* = 259.2, 15.3 Hz), 126.4 (q, *J* = 275.4 Hz), 126.2 (td, *J* = 7.2, 4.3 Hz), 114.1 (dd, *J* = 16.4, 6.4 Hz), 66.0 – 65.8 (m), 65.6 (s), 41.2 (q, *J* = 26.1 Hz), 36.6 (s), 28.4 (s), 21.7 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.6 (t, *J* = 11.0 Hz, 3F), -132.7 – -132.9 (m, 2F), -152.7 – -153.0 (m, 1F). HRMS(EI) Calcd for $C_{14}H_{14}F_6O_3$ (M^+): 344.0847; found: 344.0857.

2-methoxy-4-(4,4,4-trifluoro-2-hydroxybutyl)phenol (**3j**). yellow liquid, yield: 58%. IR (film) v_{max}: 3417, 2942, 2849, 1605, 1518, 1432, 1378, 1270, 1143, 1035, 1000 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 6.89 – 6.83 (m, 1H), 6.74 – 6.67 (m, 2H), 5.68 (br, 1H), 4.22 – 4.12 (m, 1H), 3.87 (s, 3H), 2.80 (dd, J = 13.6, 4.3 Hz, 1H), 2.69 (dd, J = 13.7, 8.3 Hz, 1H), 2.38 – 2.24 (m, 2H), 2.16 – 2.00 (m, 1H).^{13}C NMR (101 MHz, $CDCl_3$) δ 146.7 (s), 144.6 (s), 128.5 (s), 126.1 (q, *J* = 275.4 Hz), 122.1 (s), 114.6 (s), 111.8 (s), 67.0 (q, *J* = 2.7 Hz), 55.9 (s), 43.2 (s), 40.2 (q, *J* = 27.0 Hz).^{19}F NMR (376 MHz, $CDCl_3$) δ -63.4 (t, *J* = 10.9 Hz). HRMS(EI) Calcd for $C_{11}H_{13}F_3O_3$ (M^+): 250.0817; found: 250.0810.

2-methoxy-4-(4,4,4-trifluoro-2-hydroxybutyl)phenyl acetate (**3k**). yellow liquid, yield: 95%. IR (film) v_{max}: 3475, 2944, 1763, 1606, 1510, 1421, 1374, 1272, 1201, 1151, 1036, 1005 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 6.96 (d, *J* = 8.0 Hz, 1H), 6.80 (s, 1H), 6.76 (d, *J* = 8.1 Hz, 1H), 4.20 – 4.11 (m, 1H), 3.80 (s, 3H), 2.81 (dd, J = 13.7, 4.4 Hz, 1H), 2.70 (dd, J = 13.7, 8.4 Hz, 1H), 2.37 – 2.23 (m, 6H).^{13}C NMR (101 MHz, $CDCl_3$) δ 169.3 (s), 151.0 (s), 138.6 (s), 136.0 (s), 126.2 (q, *J* = 275.4 Hz), 122.8 (s), 121.5 (s), 113.6 (s), 66.7 (q, *J* = 2.8 Hz), 55. 8 (s), 43.4 (s), 40.3 (q, *J* = 27.0 Hz), 20.6 (s).^{19}F NMR (376 MHz, $CDCl_3$) δ -63.3 (t, *J* = 10.9 Hz). HRMS(EI) Calcd for $C_{13}H_{15}F_3O_4$ (M^+): 292.0922; found: 292.0918.

7,7,7-trifluoro-5-hydroxyheptyl 1-methyl-1H-pyrrole-2-carboxylate (**3l**). yellow liquid, yield: 74%. IR (film) v_{max}: 3463, 2949, 1702, 1533, 1483, 1415, 1383, 1323, 1250, 1119, 1056, 1018 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 6.95 – 6.92 (m, 1H), 6.79 – 6.76 (m, 1H), 6.12 – 6.08 (m, 1H), 4.23 (t, *J* = 6.5 Hz, 2H), 4.07 – 3.97 (m, 1H), 3.91 (s, 3H), 2.34 – 2.16 (m, 3H), 1.81 – 1.69 (m, 2H), 1.67 – 1.53 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.4 (s), 129.5 (s), 126.4 (q, *J* = 275.4 Hz), 122.4 (s), 117.8 (s), 107.8 (s), 65.9 (q, *J* = 2.8 Hz), 63.4 (s), 41.1 (q, *J* = 26.4 Hz), 36.7 (s), 63.4 (s), 28.5 (s), 21.7 (s).^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 11.0 Hz). HRMS(EI) Calcd for $C_{13}H_{18}F_3NO_3$ (M^+): 293.1239; found: 293.1237.

2-(6,6,6-trifluoro-4-hydroxyhexyl)isoindoline-1,3-dione (**3m**). white solid, yield: 95%. m.p.: 71 - 72 ℃. IR (film) v_{max}: 3470, 2953, 2928, 1769, 1704, 1440, 1426, 1345, 1269, 1134, 1067, 1054, 1026 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.81 – 7.75 (m, 2H), 7.71 – 7.64 (m, 2H), 4.09 – 3.99 (m, 1H), 3.69 (t, *J* = 7.0 Hz, 2H), 2.90 (br, 1H), 2.35 – 2.12 (m, 2H), 1.92 – 1.68 (m, 2H), 1.60 – 1.49 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5 (s), 133.9 (s), 131.8 (s), 126.3 (q, *J* = 275.4 Hz), 123.1 (s), 65.5 – 65.3 (m), 41.0 (q, *J* = 26.5 Hz), 37.4 (s), 34.0 (s), 24.4 (s).^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.9 Hz). HRMS(ESI) Calcd for $C_{14}H_{15}F_3NO_3$ [M + H]$^+$: 302.0999; found: 302.0997.

5,5,5-trifluoro-3-hydroxy-3-methylpentyl thiophene-2-carboxylate (**3n**). yellow liquid, yield: 96%. IR (film) v_{max}: 3466, 3105, 2977, 1705, 1526, 1463, 1420, 1362, 1263, 1170, 1101, 1046 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.78 (dd, *J* = 3.8, 1.2 Hz, 1H), 7.55 (dd, *J* = 5.0, 1.2 Hz, 1H), 7.09 (dd, *J* = 5.0, 3.8 Hz, 1H), 4.49 (t, *J* = 6.6 Hz, 2H), 2.52 – 2.37 (m, 3H), 2.15 – 1.96 (m, 2H), 1.42 (s, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1 (s), 133.6 (s), 133.3 (s), 132.6 (s), 127.8 (s), 126.0 (q, *J* = 275.4 Hz), 69.5 (q, *J* = 2.0 Hz), 61.1 (s), 44.9 (q, *J* = 26.1 Hz), 40.2 (s), 27.2 (s).^{19}F NMR (376 MHz, $CDCl_3$) δ -60.2 (t, *J* = 11.4 Hz). HRMS(EI) Calcd for $C_{11}H_{13}F_3O_3S$ (M^+): 282.0538; found: 282.0532.

5,5,5-trifluoro-3-hydroxy-3-methylpentyl furan-2-carboxylate

(**3o**). yellow liquid, yield: 95%. IR (film) ν_{max}: 3480, 3144, 2980, 1717, 1582, 1474, 1387, 1304, 1265, 1233, 1182, 1124, 1017 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.55 (m, 1H), 7.17 – 7.14 (m, 1H), 6.50 – 6.48 (m, 1H), 4.49 (t, *J* = 6.6 Hz, 2H), 2.47 – 2.35 (m, 3H), 2.14 – 1.93 (m, 2H), 1.41 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.5 (s), 146.5 (s), 144.4 (s), 125.9 (q, *J* = 277.8 Hz), 118.2 (s), 111.9 (s), 69.5 (q, *J* = 2.8 Hz), 61.0 (s), 44.8 (q, *J* = 26.1 Hz), 40.0 (s), 27.4 – 26.8 (m). ^{19}F NMR (376 MHz, $CDCl_3$) δ -60.3 (t, *J* = 11.4 Hz). HRMS(ESI) Calcd for $C_{11}H_{14}F_3O_4$ $[M + H]^+$: 267.0839; found: 267.0838.

(8R,9S,13S,14S)-13-methyl-3-((7,7,7-trifluoro-5-hydroxyheptyl)oxy)-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (**3p**). white solid, yield: 95%. m.p.: 115 – 116 ℃. IR (film) ν_{max}: 3545, 3420, 2929, 2865, 1725, 1611, 1572, 1499, 1437, 1375, 1339, 1277, 1251, 1145, 1087, 1058, 1028, 1005 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.19 (d, *J* = 8.3 Hz, 1H), 6.71 (d, *J* = 8.2 Hz, 1H), 6.64 (s, 1H), 4.08 – 4.00 (m, 1H), 3.98 – 3.89 (m, 2H), 2.97 – 2.78 (m, 2H), 2.58 – 1.93 (m, 10H), 1.87 – 1.73 (m, 2H), 1.71 – 1.39 (m, 9H), 1.33 – 1.19 (m, 1H), 0.90 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 221.1 (s), 156.9 (s), 137.7 (s), 132.0 (s), 126.4 (q, *J* = 275.4 Hz), 126.2 (s), 114.5 (s), 112.0 (s), 67.5 (s), 66.0 – 65.8 (m), 50.3 (s), 48.0 (s), 43.9 (s), 41.1 (q, *J* = 26.4 Hz), 38.3 (s), 36.8 (s), 35.8 (s), 31.5 (s), 29.6 (s), 28.9 (s), 26.5 (s), 25.8 (s), 21.8 (s), 21.5 (s), 13.8 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5 (t, *J* = 10.9 Hz). HRMS(EI) Calcd for $C_{25}H_{33}F_3O_3$ (M^+): 438.2382; found: 438.2388.

methyl 12,12,12-trifluoro-10-hydroxydodecanoate (**3q**). yellow liquid, yield: 88%. IR (film) ν_{max}: 3424, 2927, 2851, 1728, 1467, 1439, 1385, 1282, 1153, 1097, 1047, 1026 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 4.00 – 3.92 (m, 1H), 3.63 (s, 3H), 2.31 – 2.15 (m, 5H), 1.63 –1.17 (m, 14H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 174.4 (s), 126.5 (q, *J* = 277.1 Hz), 66.2– 66.0 (m), 51.4 (s), 41.1 (q, *J* = 26.3 Hz), 37.1 (s), 34.0 (s), 29.2 (s), 29.1 (s), 29.0 (s), 25.1 (s), 24.8 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.6 (t, *J* = 11.0 Hz). HRMS(EI) Calcd for $C_{13}H_{23}F_3O_3$ (M^+): 284.1599; found: 284.1592.

3,3,3-trifluoro-1-phenylpropan-1-ol (**3a'**).[3] yellow liquid, yield: 92%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.29 (m, 5H), 5.07 (dd, *J* = 9.0, 3.5 Hz, 1H), 2.71 – 2.55 (m, 1H), 2.52 – 2.37 (m, 1H), 2.23 (br, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.9 (t, *J* = 10.6 Hz).

3,3,3-trifluoro-1-(4-fluorophenyl)propan-1-ol (**3b'**).[3] yellow liquid, yield: 90%. ^1H NMR (400 MHz, $CDCl_3$) δ (dd, *J* = 8.4, 5.5 Hz, 2H), 7.06 (t, *J* = 8.6 Hz, 2H), 5.05 (d, *J* = 8.4 Hz, 1H), 2.69 – 2.51 (m, 1H), 2.49 – 2.34 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.6 Hz, 3F), -113.6 – -113.8 (m, 1F).

1-([1,1'-biphenyl]-4-yl)-3,3,3-trifluoropropan-1-ol (**3c'**).[3c] yellow liquid, yield: 85%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.55 (m, 4H), 7.50 – 7.42 (m, 4H), 7.41 – 7.33 (m, 1H), 5.18 – 5.09 (m, 1H), 2.75 – 2.40 (m, 2H), 2.27 – 2.11 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.7 (t, *J* = 10.6 Hz).

1-(4-bromophenyl)-3,3,3-trifluoropropan-1-ol (**3d'**).[3a,3b] yellow liquid, yield: 40%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 7.9 Hz, 2H), 7.23 (d, *J* = 8.1 Hz, 2H), 5.02 (d, *J* = 8.2 Hz, 1H), 2.66 – 2.50 (m, 1H), 2.47 – 2.25 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.7 (t, *J* = 10.5 Hz).

1-(4-(tert-butyl)phenyl)-3,3,3-trifluoropropan-1-ol (**3e'**).[3c] yellow liquid, yield: 70%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.2 Hz, 2H), 7.29 (d, *J* = 8.2 Hz, 2H), 5.02 (dd, *J* = 9.1, 3.3 Hz, 1H), 2.67 – 2.52 (m, 1H), 2.50 – 2.32 (m, 2H), 1.34 (s, 9H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.7 Hz).

3,3,3-trifluoro-1-(4-methoxyphenyl)propan-1-ol (**3f'**).[3b,3c] yellow liquid, yield: 45%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, *J* = 8.7 Hz, 2H), 6.90 (d, *J* = 8.6 Hz, 2H), 5.02 (dd, *J* = 8.8, 3.7 Hz, 1H), 3.81 (s, 3H), 2.71 – 2.53 (m, 1H), 2.50 – 2.34 (m, 1H), 2.16 (br, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.6 Hz).

3,3,3-trifluoro-1-(4-nitrophenyl)propan-1-ol (**3g'**).[3] yellow liquid, yield: 38%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 8.6 Hz, 2H), 7.57 (d, *J* = 8.6 Hz, 2H), 5.22 (dd, *J* = 8.6, 3.1 Hz, 1H) 2.72 – 2.38 (m, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.6 (t, *J* = 10.4 Hz).

4-(3,3,3-trifluoro-1-hydroxypropyl)benzonitrile (**3h'**).[3b,3c] yellow liquid, yield: 73%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.1 Hz, 2H), 7.51 (d, *J* = 8.2 Hz, 2H), 5.15 (d, *J* = 8.7 Hz, 1H), 2.67 – 2.52 (m, 2H), 2.51 – 2.35 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.6 (t, *J* = 10.4 Hz).

3,3,3-trifluoro-1-(p-tolyl)propan-1-ol (**3i'**).[3b] yellow liquid, yield: 82%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 7.9 Hz, 2H), 5.02 (dd, *J* = 8.7, 2.2 Hz, 1H), 2.69 – 2.52 (m, 1H), 2.49 – 2.36 (m, 1H), 2.34 (s, 3H), 2.15 (s, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.7 Hz).

3,3,3-trifluoro-1,1-diphenylpropan-1-ol (**3j'**).[4b] yellow liquid, yield: 85%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, *J* = 7.8 Hz, 4H), 7.35 (t, *J* = 7.7 Hz, 4H), 7.28 (t, *J* = 7.3 Hz, 2H), 3.22 (q, *J* = 10.3 Hz, 2H), 2.68 (s, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.2 (t, *J* = 10.3 Hz).

1-(2-chlorophenyl)-3,3,3-trifluoropropan-1-ol (**3k'**).[3a,3c] yellow liquid, yield: 94%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.60 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.37 – 7.28 (m, 2H), 7.24 (td, *J* = 7.6, 1.6 Hz, 1H), 5.51 – 5.44(m, 1H), 2.66 – 2.34 (m, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.9 (t, *J* = 10.5 Hz).

1-(2-bromophenyl)-3,3,3-trifluoropropan-1-ol (**3l'**). yellow liquid, yield: 93%. IR (film) ν_{max}: 3421, 3068, 2926, 1710, 1570, 1469, 1378, 1250, 1200, 1141, 1107, 1029 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 7.7 Hz, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.37 (t, *J* = 7.6 Hz, 1H), 7.22 – 7.15 (m, 1H), 5.48 – 5.40 (m, 1H), 2.62 – 2.51 (m, 2H), 2.50 – 2.36 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.1 (s), 132.9 (s), 129.6 (s), 128.0 (s), 127.2 (s), 125.9(q, *J* = 276.2 Hz), 121.2 (s), 67.6 (q, *J* = 3.3 Hz), 41.2 (q, *J* = 27.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.5 Hz). HRMS(EI) Calcd for $C_9H_8BrF_3O$ (M^+): 267.9711; found: 267.9708

3,3,3-trifluoro-1-(o-tolyl)propan-1-ol (**3m'**).[3a] yellow liquid, yield: 83%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.45 (m, 1H), 7.28 – 7.13 (m, 3H), 5.34 – 5.22 (m, 1H), 2.62 – 2.47 (m, 1H), 2.43 – 2.31 (m, 5H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -64.2 (t, *J* = 10.7 Hz).

3,3,3-trifluoro-1-(m-tolyl)propan-1-ol (**3n'**).[3a] yellow liquid, yield: 78%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.23 (t, *J* = 3.7 Hz, 1H), 7.13 (dd, *J* = 17.1, 7.6 Hz, 3H), 5.02 (dd, *J* = 8.8, 2.3 Hz, 1H), 2.67 – 2.53 (m, 1H), 2.52 – 2.38 (m, 2H), 2.35 (s, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.7 Hz).

1-(3-bromophenyl)-3,3,3-trifluoropropan-1-ol (**3o'**). yellow liquid, yield: 74%. IR (film) ν_{max}: 3399, 3066, 2918, 1573, 1475, 1431, 1378, 1258, 1199, 1138, 1071 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.56 (m, 1H), 7.49 (dt, *J* = 7.3, 1.7 Hz, 1H), 7.34 – 7.27 (m, 2H), 5.09 – 5.01 (m, 1H), 2.72 (d, *J* = 2.2 Hz, 1H), 2.67 – 2.36 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 144.5 (s), 131.4 (s), 130.4 (s), 128.8 (s), 125.7 (q, *J* = 275.8 Hz), 124.3 (s), 122.8 (s), 68.1 (q, *J* = 3.2 Hz), 42.7 (q, *J* = 27.1 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.7 (t, *J* = 10.5 Hz). HRMS(EI) Calcd for $C_9H_8B_rF_3O$ (M^+): 267.9711; found:

267.9704.

3,3,3-trifluoro-1-(3-methoxyphenyl)propan-1-ol (**3p'**). yellow liquid, yield: 32%. IR (film) ν_{max}: 3431, 2947, 2841, 1603, 1490, 1436, 1377, 1320, 1262, 1127, 1047 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$)δ 7.29 (t, *J* = 7.9 Hz, 1H), 6.96 – 6.91 (m, 2H), 6.88 – 6.83 (m, 1H), 5.04 (dd, *J* = 9.0, 3.0 Hz, 1H), 3.82 (s, 3H), 2.69 – 2.52 (m, 1H), 2.51 – 2.37 (m, 1H), 2.28 (br, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.9 (s), 144.0 (s), 129.9 (s), 125.9 (q, *J* = 275.7 Hz), 117.8 (s), 113.8(s), 111.2(s), 68.7 (q, *J* = 3.2 Hz), 55.3(s), 42.8 (q, *J* = 27.0 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.8 (t, *J* = 10.7 Hz). HRMS(EI) Calcd for $C_{10}H_{11}F_3O_2$ (M^+): 220.0711; found: 220.0706.

3,3,3-trifluoro-1-(3-nitrophenyl)propan-1-ol (**3q'**).[3a] yellow liquid, yield: 52%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 8.14 (d, *J* = 8.2 Hz, 1H), 7.72 (d, *J* = 7.7 Hz, 1H), 7.55 (t, *J* = 7.9 Hz, 1H), 5.20 (dd, *J* = 8.6, 3.2 Hz, 1H), 3.01 (s, 1H), 2.71 – 2.39 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.6 (t, *J* = 10.5 Hz).

3,3,3-trifluoro-1-(naphthalen-2-yl)propan-1-ol (**3r'**).[3a,3b] yellow liquid, yield: 74%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.76 (m, 4H), 7.57 – 7.43 (m, 3H), 5.23 (dd, *J* = 8.7, 2.7 Hz, 1H), 2.79 – 2.63 (m, 1H), 2.60 – 2.39 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.7 (td, *J* = 10.6, 2.2 Hz).

1-(2,5-dimethylphenyl)-3,3,3-trifluoropropan-1-ol (**3s'**). yellow liquid, yield: 90%. IR (film) ν_{max}: 3236, 2924, 2872, 1618, 1506, 1456, 1376, 1310, 1271, 1245, 1138, 1093 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.32 (br, 1H), 7.08 – 7.02 (m, 2H), 5.30 – 5.28 (m, 1H), 2.65 – 2.42 (m, 2H), 2.34 (s, 3H), 2.31 (s, 3H), 2.15 (br, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.2 (s), 136.2 (s), 130.8 (s), 130.6 (s), 128.7 (s), 126.1 (q, *J* = 275.9 Hz), 125.6 (s), 65.1 (q, *J* = 3.2 Hz), 41.9 (q, *J* = 26.8 Hz), 21.0 (s), 18.2 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -64.2 (t, *J* = 10.7 Hz). HRMS(EI) Calcd for $C_{11}H_{13}F_3O$ (M^+): 218.0918; found: 218.0914.

3,3,3-trifluoro-1-(4-methylthiazol-5-yl)propan-1-ol (**3t'**). yellow liquid, yield: 78%. IR (film) ν_{max}: 3438, 3170, 3068, 1549, 1417, 1380, 1258, 1178, 1142, 1104, 1022 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.62 (s, 1H), 5.39 (dd, *J* = 7.7, 4.2 Hz, 1H), 3.62 (s, 1H), 2.81 – 2.63 (m, 1H), 2.55 – 2.42 (m, 1H), 2.40 – 2.35 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.5 (s), 148.6 (s), 134.2 (s), 125.3 (q, *J* = 277.5 Hz), 63.0 – 61.3 (m), 43.0 (q, *J* = 27.3 Hz), 15.0 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ -64.0 (t, *J* = 10.4 Hz). HRMS(EI) Calcd for $C_8H_8F_3NOS$ (M^+): 211.0279; found: 211.0273.

3,3,3-trifluoro-1-(pyridin-2-yl)propan-1-ol (**3u'**). yellow liquid, yield: 71%. IR (film) ν_{max}: 3181, 2918, 1606, 1564, 1419, 1379, 1252, 1135, 1066, 1005 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.53 – 8.46 (m, 2H), 7.32 (d, *J* = 5.3 Hz, 2H), 5.08 (dd, *J* = 8.8, 2.8 Hz, 1H), 2.37 – 2.33 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.5 (s), 144.2 (s), 143.6 (s), 142.8 (s), 125.9 (q, *J* = 277.4 Hz), 66.9 (q, *J* = 3.1 Hz), 41.4 (q, *J* = 27.3 Hz). HRMS(EI) Calcd for $C_8H_8F_3NO$ (M^+): 191.0558; found: 191.0553.

3,3,3-trifluoro-1-(pyrazin-2-yl)propan-1-ol (**3v'**). yellow liquid, yield: 58%. IR (film) ν_{max}: 3332, 2924, 1647, 1532, 1382, 1257, 1139, 1062, 1020, 1002 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.75 (s, 1H), 8.55 (s, 2H), 5.20 (dd, *J* = 8.3, 3.4 Hz, 1H), 3.82 (br, 1H), 2.85 – 2.70 (m, 1H), 2.68 – 2.53 (m, 1H).^{13}C NMR (101 MHz, $CDCl_3$) δ 152.0 (s), 149.70 (s), 149.65 (s), 125.7 (q, *J* = 276.9Hz), 120.8 (s), 67.1 (q, *J* = 3.3 Hz), 42.6 (q, *J* = 27.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.3 (t, *J* = 10.5 Hz). HRMS(EI) Calcd for $C_7H_7F_3N_2O$ (M^+):192.0510; found: 192.0507.

1-(4-(tert-butyl)phenyl)-2-hydroxyethan-1-one(**4a'**).[16] yellow liquid, yield: 5%. ^1H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.4 Hz, 2H), 7.52 (d, *J* = 8.4 Hz, 2H), 3.77 (q, *J* = 10.1 Hz, 2H), 1.35 (s, 9H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.0 (t, *J* = 10.1 Hz).

Supporting Information

The supporting information for this article is available on the WWW under https://doi.org/10.1002/cjoc.2018xxxxx.

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References

[1] (a) Dolbier, Jr.; W. R. Structure, Reactivity, and Chemistry of Fluoroalkyl Radicals. *Chem. Rev.* **1996**, *96*, 1557-1584; (b) Merino, E.; Nevado, C. Addition of CF_3 Across Unsaturated Moieties: A Powerful Functionalization Tool. *Chem. Soc. Rev.* **2014**, *43*, 6598-6608; (c) Egami, H.; Sodeoka, M. Trifluoromethylation of Alkenes with Concomitant Introduction of Additional Functional Groups. *Angew. Chem. Int. Ed.* **2014**, *53*, 8294-8308; (d) Akita, M.; Koike, T. Sunlight-driven Trifluoromethylation of Olefinic Substrates by Photoredox Catalysis: A Green Organic Process. *C. R. Chim.* **2015**, *18*, 742-751; (e) Liu, X.; Xu, C.; Wang, M.; Liu, Q. Trifluoromethyltrimethylsilane: Nucleophilic Trifluoromethylation and Beyond. *Chem. Rev.* **2015**, *115*, 683-730; (f) Tian, Y.; Chen, S.; Gu, Q-S.; Lin, J-S.; Liu, X-Y. Amino-and azidotrifluoromethylation of alkenes. *Tetrahedron Lett*. **2018**, *59*, 203-215; (g) Guo, Y.; Huang, M-W.; Fu, X-L.; Liu, C.; Chen, Q-Y.; Zhao, Z-G.; Zeng, B-Z.; Chen, J. Recent catalytic syntheses of trifluoromethylthio-containing organic compounds by transition metals, chiral organocatalysts, and photocatalysts. *Chin. Chem. Lett*. **2017**, *28*, 719-728; (h) Sun, S-Z.; Xu, H.; Dai, H-X. Copper-catalyzed α-selective C–H trifluoromethylation of acrylamides with $TMSCF_3$. *Chin. Chem. Lett*. **2019,** doi.org/10.1016/j.cclet.2019.02.011.

[2] Yasu, Y.; Koike, T.; Akita, M. Three-component Oxytrifluoromethylation of Alkenes: Highly Efficient and Regioselective Difunctionalization of C=C Bonds Mediated by Photoredox Catalysts. *Angew. Chem. Int. Ed.* **2012**, *51*, 9567-9571.

[3] (a) Yang, Y.; Liu, Y.; Jiang, Y.; Zhang, Y.; Vicic, D. A. Manganese-catalyzed Aerobic Oxytrifluoromethylation of Styrene Derivatives Using CF_3SO_2Na as the Trifluoromethyl Source. *J. Org. Chem.* **2015**, *80*, 6639-6648; (b) Luo, H. Q.; Zhang, Z. P.; Dong, W.; Luo, X. Z. A Practical Method for Metal-free Radical Trifluoromethylation of Styrenes with $NaSO_2CF_3$, *Synlett.* 2014, **25**, 1307-1311; (c) Jud, W.; Kappe, C. O.; Cantillo, D. Catalyst-Free Oxytrifluoromethylation of Alkenes through Paired Electrolysis in Organic-Aqueous Media. *Chem. Eur. J.* **2018**, *24*, 17234-17238.

[4] (a) Liu, C.; Lu, Q.; Huang, Z.; Zhang, J.; Liao, F.; Peng, P.; Lei, A. NMP

and O_2 as Radical Initiator: Trifluoromethylation of Alkenes to Tertiary β-Trifluoromethyl Alcohols at Room Temperature. *Org. Lett.* **2015**, *17*, 6034-6037. (b) Yang, X.; He, L.; Tsui, G. C. Hydroxytrifluoromethylation of Alkenes Using Fluoroform-Derived $CuCF_3$. *Org. Lett.* **2017**, *19*, 2446-2449.

[5] Geng, X.; Lin, F.; Wang, X.; Jiao, N. Photoredox-catalyzed Hydroxyfluoroalkylation of Alkene with Simple Fluoroalkyl Iodides. *J. Photochem. Photobiol. A*. **2018**, *355*, 194-201.

[6] (a) Zhou, X.; Li, G.; Shao, Z.; Fang, K.; Gao, H.; Li, Y.; She, Y. Four-Component Acyloxy-Trifluoromethylation of Arylalkenes Mediated by a Photoredox Catalyst. *Org. Biomol. Chem.* **2019**,*17*, 24-29; (b) Li, Y.; Studer, A. Transition-Metal-Free Trifluoromethylaminoxylation of Alkenes. *Angew. Chem. Int. Ed.* **2012**, *51*, 8221-8224. (c) Jiang, X.-Y.; Qing, F.-L. Copper-Catalyzed Three-Component Oxytrifluoromethylation of Alkenes with Sodium Trifluoromethanesulfinate and Hydroxamic Acid. *Angew. Chem. Int. Ed.* **2013**, *52*, 14177-14180.

[7] (a) Haszeldine, R. N. The Reactions of Fluorocarbon Radicals. Part I. The Reaction of Iodotrifluoromethane with Ethylene and Tetrafluoroethylene. *J. Chem. Soc*. **1949**, 2856-2861; (b) Haszeldine, R. N.; Steele, B. R. The Addition of Free Radicals to Unsaturated Systems. Part II. Radical Addition to Olefins of the Type R· CH: CH_2. *J. Chem. Soc*. **1953**, 1199-1206; (c) Haszeldine, R. N.; Keen, D. W.; Tipping, A. E. Free-radical Additions to Unsaturated Systems. Part XVII. Reaction of Trifluoroiodomethane with Mixtures of Ethylene and Vinyl Fluoride and of Ethylene and Propene. *J. Chem. Soc. (C)*. **1970**, 414-421; (d) Gregory, R.; Haszeldine, R. N.; Tipping, A. E. Addition of Free Radicals to Unsaturated Systems. Part XVIII. The Direction of Radical Addition to 1, 3, 3, 3-Tetrafluoropropene. *J. Chem. So.c (C)*. **1970**, 1750-1758; (e) Gregory, R.; Haszeldine, R. N.; Tipping, A. E. Addition of Free Radicals to Unsaturated Systems. Part XIX. The Direction of Radical Addition to 1, 1, 1-Trifluorobut-2-ene. *J. Chem. Soc. (C)*. **1971**, 1216-1223; (f) Haszeldine, R. N.; Keen, D. W.; Robinson, P. J. Addition of Free Radicals to Unsaturated Systems. Part 24. Kinetics and Mechanism of the Gas-Phase Thermal Reactions of Trifluoroiodomethane with Propene. *J. Chem. Soc, Perkin. Trans. 2* **1983**, 1713-1717; (g) Guo, Q.; Wang, M.; Wang, Y.; Xu, Z.; Wang, R. Photoinduced, Copper-Catalyzed three Components Cyanofluoroalkylation of Alkenes with Fluoroalkyl Iodides as Fluoroalkylation Reagents. *Chem. Commun.* **2017**, *53*, 12317-12320.

[8] (a) Maruoka, K.; Sano, H.; Fukutani, Y.; Yamamoto, H. Organoaluminum-Induced Addition of Polyhalomethane to Olefins. *Chem. Lett.* **1985**, 1689-1692; (b) Mikami, K.; Tomita, Y.; Ichikawa, Y.; Amikura, K.; Itoh, Y. Radical Trifluoromethylation of Ketone Silyl Enol Ethers by Activation with Dialkylzinc. *Org. Lett.* **2006**, *8*, 4671-4673; (c) Ohtsuka, Y.; Uraguchi, D.; Yamamoto, K.; Tokuhisa, K.; Yamakawa, T. Syntheses of 2-(Trifluoromethyl)-1, 3-Dicarbonyl Compounds through Direct Trifluoromethylation with CF_3I and Their Application to Fluorinated Pyrazoles Syntheses. *Tetrahedron* **2012**, *68*, 2636-2649.

[9] (a) Itoh, Y.; Mikami, K. Facile Radical Trifluoromethylation of Lithium Enolates. *Org. Lett.* **2005**, *7*, 4883-4885; (b) Kischkewitz, M.; Okamoto, K.; Mück-Lichtenfeld, C.; Studer, A. Radical-polar Crossover Reactions of Vinylboron Ate Complexes. *Science* **2017**, *355*, 936-938.

[10] (a) Petrik, V.; Cahard, D. Radical Trifluoromethylation of Ammonium Enolates. *Tetrahedron Lett.* **2007**, *48*, 3327-3330; (b) Aït-Mohand, S.; Takechi, N.; Médebielle, M.; Dolbier, W. R. Nucleophilic Trifluoromethylation Using Trifluoromethyl Iodide. A New and Simple Alternative for The Trifluoromethylation of Aldehydes and Ketones. *Org. Lett.* **2001**, *3*, 4271-4273; (c) Herrmann, A. T.; Smith, L. L.; Zakarian, A. A Simple Method for Asymmetric Trifluoromethylation of N-acyl Oxazolidinones Via Ru-Catalyzed Radical Addition to Zirconium Enolates. *J. Am. Chem. Soc.* **2012**, *134*, 6976-6979.

[11] (a) Nagib, D. A.; Scott, M. E.; MacMillan, D. W. Enantioselective α-Trifluoromethylation of Aldehydes Via Photoredox Organocatalysis. *J. Am. Chem. Soc.* **2009**, *131*, 10875-10877; (b) Pham, P. V.; Nagib, D. A.; MacMillan, D. W. Photoredox Catalysis: A Mild, Operationally Simple Approach to the Synthesis of α-Trifluoromethyl Carbonyl Compounds. *Angew. Chem. Int. Ed.* **2011**, *50*, 6119-6122; (c) Nguyen, J. D.; Tucker, J. W.; Konieczynska, M. D.; Stephenson, C. R. Intermolecular Atom Transfer Radical Addition to Olefins Mediated by Oxidative Quenching of Photoredox Catalysts. *J. Am. Chem. Soc.* **2011**, *133*, 4160-4163; (d) Wallentin, C. J.; Nguyen, J. D.; Finkbeiner, P.; Stephenson, C. R.; Visible light-mediated Atom Transfer Radical Addition Via Oxidative and Reductive Quenching of Photocatalysts. *J. Am. Chem. Soc.* **2012**, *134*, 8875-8884; (e) Straathof, N. J.; Cramer, S. E.; Hessel, V.; Noël, T. Practical Photocatalytic Trifluoromethylation and Hydrotrifluoromethylation of Styrenes in Batch and Flow, *Angew. Chem. Int. Ed.* **2016**, *55*, 15549-15553; (f) Kublicki, M.; Durka, K.; Kliś, T. Merging Photoredox Catalysis with Allylboration. The Photochemical Perfluoroalkylation of Unsaturated Potassium Alkyltrifluoroborates and Synthesis of Fluorinated Alcohols. *Tetrahedron Lett*. **2018**, *59*, 2700-2703.

[12] Sladojevich, F.; McNeill, E.; Börgel, J.; Zheng, S. L.; Ritter, T. Condensed-Phase, Halogen-Bonded CF_3I and C_2F_5I Adducts for Perfluoroalkylation Reactions. *Angew. Chem. Int. Ed.* **2015**, 45, 3712-3716.

[13] (a) Tang, X.; Studer, A. Alkene 1, 2-Difunctionalization by Radical Alkenyl Migration, *Angew. Chem. Int. Ed.* **2018**, *57*, 814-817; (b) Tang, X.; Studer, A. α-Perfluoroalkyl-β-Alkynylation of Alkenes Via Radical Alkynyl Migration. *Chem. Sci.* **2017**, *8*, 6888-6892; (c) Wang, M. Y.; Cao, Y.; Liu, X.; Wang, N.; He, L. N.; Li, S. H. Photoinduced Radical-initiated Carboxylative Cyclization of Allyl Amines with Carbon Dioxide. *Green Chem.* **2017**, *19*, 1240-1244; (d) Wang, Y.; Wang, J.; Li, G. X.; He, G.; Chen, G. Halogen-bond-promoted Photoactivation of Perfluoroalkyl Iodides: A Photochemical Protocol for Perfluoroalkylation Reactions. *Org. Lett.* **2017**, *19*, 1442-1445; (e) Beniazza, R.; Remisse, L.; Jardel, D.; Lastécouères, D.; Vincent, J. M. Light-mediated Iodoperfluoroalkylation of Alkenes/Alkynes Catalyzed by Chloride Ions: Role of Halogen Bonding. *Chem. Commun.* **2018**, *54*, 7451-7454; (f) Yu, J. M.; Cai, C. Ambient-Light-Promoted Perfluoroalkylative Cyclization of β, γ-Unsaturated Hydrazones: Synthesis of Perfluoroalkylated Pyrazolines. *Eur. J. Org. Chem.* **2017**, *40*, 6008-6012.

[14] Sun, X.; Wang, W.; Li, Y.; Ma, J.; Yu, S. Halogen-bond-promoted Double Radical Isocyanide Insertion under Visible-light Irradiation: Synthesis of 2-fluoroalkylated Quinoxalines. *Org. Lett.* **2016**, *18*, 4638-4641.

[15] (a) Li, L.; Huang, M.; Liu, C.; Xiao, J. C.; Chen, Q. Y.; Guo, Y.; Zhao, Z. G. 2, 2, 2-Trifluoroethylation of Styrenes with Concomitant Introduction of A Hydroxyl Group From Molecular Oxygen by Photoredox Catalysis

Activated by Visible Light, *Org. Lett.* **2015**, *17*, 4714-4717; (b) Chen, T.; Guo, Y.; Sun, K.; Wu, L. Z.; Liu, W. Q.; Liu, C.; Liu, Y.; Chen, Q. Y. Photoinduced Hydroxylperfluoroalkylation of Styrenes. *Org. Chem. Front.* **2018**, *5*, 1045-1048.

[16] Maji, A.; Hazra, A.; Maiti, D. Direct synthesis of α-trifluoromethyl ketone from (hetero) arylacetylene: design, intermediate trapping, and mechanistic investigations. *Org. Lett.* **2014**, *16*, 4524-4527.

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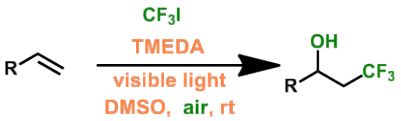
Entry for the Table of Contents

XXX

Catalyst-free Hydroxytrifluoromethylation of Alkenes Using Iodotrifluoromethane

Shaoben Su[a], Yong Guo[b,*] Qing-Yun Chen[b,*], Zhi-Gang Zhao[a,*], Bao-Yi Nian[c]



- 41 olefins
- yields up to 98%
- no photocatalyst
- inexpensive
- air atmosphere
- room temperature
- easy to operate
- good selectivity

The reaction can be applied to not only styrenes but also to various aliphatic alkenes with excellent selectivity. We propose a halogen bond interation promotes a single electron transfer under the visble light irradiation. No catalyst was needed. A solution of CF_3I in DMSO was used as the facile trifluoromethylating reagent.