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Synthesis of trifluoromethyl alcohols from *tert*-butoxy-β-(trifluoromethyl)styrenes and trifluoromethylbenzyl ketones under the conditions of the Leuckart–Wallach reaction

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ABSTRACT

A novel pathway towards trifluoromethylalcohols by an unexpected reaction of *tert*-butoxy-β-(trifluoromethyl)styrenes or corresponding trifluoromethylbenzyl ketones under the conditions of the Leuckart–Wallach reaction was elaborated.

1. Introduction

The reductive amination of carbonyl compounds is attractive for organic synthesis because ketones or aldehydes can be directly transformed to the corresponding primary or secondary alkylamines in one-pot reactions without isolation of the intermediate imines or semi-aminals [1,2]. One of the oldest and widely used pathways is the Leuckart–Wallach reaction, which includes a number of methods, using formic acid or formates as reducing agents [3–7]. On the other hand, a new catalytic olefination reaction of aldehydes or ketones was discovered by our research group, recently [8]. Based on this reaction, we elaborated new methods for the synthesis of various fluorinated alkenes such as β-chloro-β-(trifluoromethyl)styrenes **1**, β-bromo-β-(trifluoromethyl)styrenes **2** or β-bromo-β-fluorostyrenes [9–15]. The vinylic halogen atom of such alkenes can be easily substituted by different nucleophiles [16,17]. With different alcoholates corresponding alkoxy-β-(trifluoromethyl)styrenes were prepared [18]. Here we describe our results of the reaction of new *tert*-butoxy-β-(trifluoromethyl)styrenes and derived from it trifluoromethylbenzyl ketones under the conditions of the Leuckart–Wallach reaction.

2. Results and discussion

According to our recent protocol [18] seven new *tert*-butoxy-β-(trifluoromethyl)styrenes **3**, contaminated with small amounts of its regioisomers **4**, were prepared in good to excellent yields (Scheme 1, Table 1).

Obviously the core of the *tert*-butoxy-β-(trifluoromethyl)styrenes **3** or **4** includes an enolether moiety. In combination with the *tert*-butyl group, which is known to be a good leaving group, one could expect that these compounds can be used as close relatives of the corresponding ketones in various reactions. Having both these facts in mind the prepared mixtures of *tert*-butoxy-β-(trifluor-

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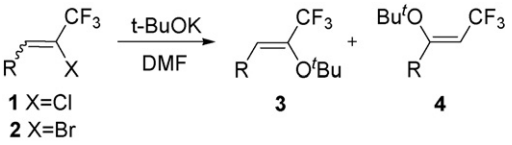
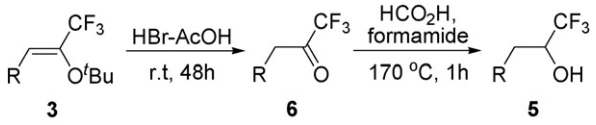


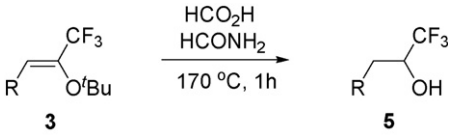
Scheme 1. Synthesis of *tert*-butoxy-β-(trifluoromethyl)styrenes **3** and **4**.



Scheme 3. Preparation of trifluoromethylalcohols **5** via trifluoromethyl ketones **6**.

Table 1
Results of syntheses of *tert*-butoxy-β-(trifluoromethyl)styrenes **3** and trifluoromethyl alcohols **5**

Entry	Compounds	R	Yield **3** + **4** (%)	Ratio **3**:**4**	Yield **5** (%)
1	**2a**	4-ClC_6H_4	84	86:14	67
2	**1b**	4-$NO_2C_6H_4$	68	100:0	64
3	**2c**	3-$MeOC_6H_4$	88	92:8	54
4	**2d**	2-$MeOC_6H_4$	97	100:0	47
5	**2e**	2-BrC_6H_4	70	100:0	49
6	**2f**	4-BrC_6H_4	72	92:8	71
7	**2g**	Ph	74	90:10	58



Scheme 2. Synthesis of trifluoromethyl alcohols **5**.

omethyl)styrenes **3** and **4** were treated with formic acid and formamide at 170 °C. Surprisingly, we found trifluoromethyl alcohols **5** as the only products instead of the expected amines (Scheme 2, Table 1).

The structure of the obtained compounds was confirmed mainly by NMR spectroscopy and ESI-MS analysis. Moreover, the ^1H NMR and ^{19}F NMR spectroscopic data of compound **5g** agree with previously published values [19].

The reactions proceeded in good to high yields for all substituted aryl compounds. It should be noted, that in all cases the alcohols were obtained as single regioisomers **5**. No analogous products derived from the minor regioisomeric styrenes **4** were found.

The synthesized trifluoromethyl alcohols **5** are quite interesting compounds. For example enantiopure trifluoromethyl alcohols are versatile intermediates for the synthesis of antiferroelectric liquid crystalline molecules [20,21] and recently trifluoromethylated GABA [22] and mevalonate analogues [23] were prepared. Similar trifluoromethyl alcohols were previously prepared by nucleophilic trifluoromethylation of the corresponding aldehydes using Rupert's reagent [24–26] or analogues [27,28]. However, most variations of the Rupert–Prakash reaction have a common drawback: frequently low yields were obtained with enolizable carbonyl compounds [29]. Thus, our pathway efficiently supplements the existing methods.

We also tried to synthesize trifluoromethyl substituted amines from trifluoromethyl-benzyl ketones **6**, which were prepared from the *tert*-butoxy-β-(trifluoromethyl)styrenes **3** by solvolysis with HBr/HOAc. Heating of thus prepared trifluoromethyl ketones **6** with excess formic acid and formamide (Leuckart–Wallach reaction) also lead to trifluoromethylalcohols **5** instead of the expected amines. However, the overall yield of **5** based on **1** or **2** is lower in the latter three-step reactions. The ketones **6** might be intermediates of the reactions of the enol ethers **3** with formic acid and formamide (Scheme 3, Table 2). A similar reduction was observed when benzophenones were heated with formamide giving diarylcarbinols as major products. Deuteration experiments revealed the reduction occurring by hydride transfer from the formate to the ketone [6]. Generally trifluoromethyl ketones were reduced with borohydrides to give the corresponding alcohols [30].

Table 2
Results of synthesis and reduction of trifluoromethylketones **6**

Entry	Compounds (**3**:**4** ratio)	R	Yield **6** (%)	Yield **5** (%)
8	**a** (86:14)	4-ClC_6H_4	59	67
9	**b** (100:0)	4-$NO_2C_6H_4$	56	65
10	**c** (92:8)	3-$MeOC_6H_4$	47	56

3. Conclusion

We discovered a new pathway towards trifluoromethyl alcohols **5** from *tert*-butoxy-β-(trifluoromethyl)styrenes **3** or corresponding trifluoromethylbenzyl ketones **6** under the conditions of the Leuckart–Wallach reaction. Since the expected trifluoromethyl amines were not found in the product mixture, we continue our efforts to prepare these products.

4. Experimental

4.1. General

NMR spectra were recorded on Bruker ARX 300 MHz and Bruker AMX Avance 400 spectrometers in $CDCl_3$ with TMS and CCl_3F as internal standards. Mass spectra (ESI-MS) were measured on a MicroTof Bruker Daltonics. Column chromatography and TLC were performed on silica gel Merck 60 and Merck $60F_{254}$ plates, respectively. The β-chloro- **1** and β-bromo-β-trifluoromethylstyrenes **2** were synthesized according to our previously reported procedures [10,14].

4.2. Synthesis of tert-butoxy-β-(trifluoromethyl)styrenes (general procedure)

A 50 mL one neck round bottomed flask was charged with dry DMF (10 mL) and the corresponding styrene (**1** or **2**) (5 mmol) and cooled down to 0 °C. Then a cooled to 0 °C solution of *t*-BuOK (670 mg, 6 mmol) in dry DMF (10 mL) was added dropwise with stirring. The reaction mixture was stirred for 24 h at room temperature and poured into water (200 mL). The products were extracted with CH_2Cl_2 (3 × 20 mL). The combined extract was washed with water (2× 50 mL) and brine (50 mL) and dried over Na_2SO_4. CH_2Cl_2 was evaporated in vacuum, and the residue was passed through a short filter with silica gel using hexane or appropriate mixtures of hexane and CH_2Cl_2. The regioisomers **3** and **4** could not be separated by column chromatography. ^1H NMR data of compounds **3a–d**, **f**, **g** are in agreement with literature values.

4.2.1. 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-4-chlorobenzene (3a)

Obtained as a 86:14 mixture with 1-[(1*Z*)-1-*tert*-butoxy-3,3,3-trifluoroprop-1-enyl]-4-chlorobenzene (**4a**) from styrene **2a** (1425 mg, 5 mmol). Yield (**3** + **4**): 1168 mg, 84%, colorless oil. Regioisomer **3a**: ^{1}H NMR ($CDCl_3$): δ 1.36 (s, 9H, $OC(CH_3)_3$), 6.62 (s, 1H, CH=CCF_3), 7.36 (d, J = 8.6 Hz, 2H, Ar), 7.63 (d, J = 8.6 Hz, 2H, Ar); Regioisomer **4a**: ^{1}H NMR ($CDCl_3$): δ 1.29 (s, 9H, $OC(CH_3)_3$), 5.33 (q, J = 7.6 Hz, 1H, $CHCF_3$), 7.38 (d, J = 8.6 Hz, 2H, Ar), 7.45 (d, J = 8.6 Hz, 2H, Ar).

4.2.2. 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-4-nitrobenzene (3b)

Obtained from styrene **1b** (1250 mg, 5 mmol). Yield: 1200 mg, 83%, yellow oil; ^{1}H NMR ($CDCl_3$): δ 1.32 (s, 9H, $OC(CH_3)_3$), 6.69 (s, 1H, CH=CCF_3), 7.83 (d, J = 8.8 Hz, 2H, Ar), 8.22 (d, J = 8.8 Hz, 2H, Ar).

4.2.3. 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-3-methoxybenzene (3c)

Obtained as a 92:8 mixture with 1-[(1*Z*)-1-*tert*-butoxy-3,3,3-trifluoroprop-1-enyl]-3-methoxybenzene (**4c**) from styrene **2c** (1405 mg, 5 mmol). Yield (**3** + **4**): 1205 mg, 88%, colorless oil; Regioisomer **3c**: ^{1}H NMR ($CDCl_3$): δ 1.36 (s, 9H, $OC(CH_3)_3$), 3.84 (s, 3H, OCH_3), 6.65 (s, 1H, CH=CCF_3), 6.85–6.90 (m, 1H, Ar), 7.21 (d, J = 7.3 Hz, 1H, Ar), 7.26–7.32 (m, 2H, Ar); Regioisomer **4c** ^{1}H NMR ($CDCl_3$): δ 1.30 (s, 9H, $OC(CH_3)_3$), 3.83 (s, 3H, OCH_3), 5.84 (q, J = 7.8 Hz, 1H, $CHCF_3$), 6.93–6.98 (m, 1H, Ar), 7.03–7.11 (m, 1H, Ar).

4.2.4. 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-2-methoxybenzene (3d)

Obtained from styrene **2d** (1405 mg, 5 mmol). Yield: 1363 mg, 97%, colorless oil; ^{1}H NMR ($CDCl_3$): δ 1.28 (s, 9H, $OC(CH_3)_3$), 3.85 (s, 3H, OCH_3), 6.89 (d, J = 8.0 Hz, 1H, Ar), 6.94 (t, J = 7.6 Hz, 1H, Ar), 6.95 (s, 1H, CH=CCF_3), 7.28 (td, J = 8.0 and 1.4 Hz, 1H, Ar), 7.96 (dd, J = 7.6 and 1.4 Hz, 1H, Ar).

4.2.5. 4.2.5 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-2-bromobenzene (3e)

Obtained from styrene **2e** (1650 mg, 5 mmol). Yield: 1131 mg, 70%, colorless oil; ^{1}H NMR ($CDCl_3$): δ 1.24 (s, 9H, $OC(CH_3)_3$), 6.86 (s, 1H, CH=CCF_3), 7.19 (t, J = 7.8 Hz, 1H, Ar), 7.33 (t, J = 7.8 Hz, 1H, Ar), 7.62 (d, J = 7.8 Hz, 1H, Ar), 7.86 (d, J = 7.8 Hz, 1H, Ar).

4.2.6. 1-[(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]-4-bromobenzene (3f)

Obtained as a 92:8 mixture with 1-[(1*Z*)-1-*tert*-butoxy-3,3,3-trifluoroprop-1-enyl]-4-bromobenzene (**4f**) from styrene **2f** (1425 mg, 5 mmol). Yield (**3** + **4**): 1153 mg, 71%, colorless oil. Regioisomer **3f**: ^{1}H NMR ($CDCl_3$): δ 1.30 (s, 9H, $OC(CH_3)_3$), 6.55 (s, 1H, CH=CCF_3), 7.47 (d, J = 8.7 Hz, 2H, Ar), 7.52 (d, J = 8.7 Hz, 2H, Ar); ^{19}F NMR (282 MHz, $CDCl_3$): δ −67.23 (s, CF_3); ^{13}C NMR ($CDCl_3$): δ 28.8 ($OC(CH_3)_3$), 84.6 ($OC(CH_3)_3$), 120.8 (q, J = 4.5 Hz, CH=CCF_3), 121.2 (q, J = 276.7 Hz, CF_3), 140.7 (q, J = 32.7 Hz, C–CF_3); 129.4, 131.2, 131.5, 132.3 (Ar). Regioisomer **4f**: ^{1}H NMR ($CDCl_3$): δ 1.23 (s, 9H, $OC(CH_3)_3$), 5.28 (q, J = 7.7 Hz, 1H, $CHCF_3$), 7.33 (d, J = 8.5 Hz, 2H, Ar); ^{19}F NMR (282 MHz, $CDCl_3$): δ −56.91 (d, J = 7.7 Hz, CF_3); ^{13}C NMR ($CDCl_3$): δ 29.4 ($OC(CH_3)_3$), 82.6 ($OC(CH_3)_3$), 106.6 (q, J = 34.9 Hz, C=$CHCF_3$); 129.0, 129.8, 132.2, 137.2 (Ar). Anal. Calcd. for $C_{13}H_{14}BrF_3O$: C, C 48.32; H, 4.37. Found: C, 48.42; H, 4.33.

4.2.7. [(1Z)-2-tert-Butoxy-3,3,3-trifluoroprop-1-enyl]benzene (3g)

Obtained as a 90:10 mixture with [(1*Z*)-1-*tert*-butoxy-3,3,3-trifluoroprop-1-enyl]benzene (**4g**) from styrene **2g** (1255 mg, 5 mmol). Yield (**3** + **4**): 903 mg, 74%, colorless oil; Regioisomer **3g**: ^{1}H NMR ($CDCl_3$): δ 1.36 (s, 9H, $OC(CH_3)_3$), 6.68 (s, 1H, CH=CCF_3), 7.34 (d, J = 7.3 Hz, 1H, Ar), 7.40 (t, J = 7.3 Hz, 2H, Ar), 7.69 (d, J = 7.3 Hz, 2H, Ar). Regioisomer **4g**: ^{1}H NMR ($CDCl_3$): δ 1.30 (s, 9H, $OC(CH_3)_3$), 5.84 (q, J = 7.8 Hz, 1H, $CHCF_3$), 7.49–7.54 (m, 2H, Ar), the other signals are identical to those of the regioisomer **3g**.

4.3. General procedure for the synthesis of the 3-aryl-1,1,1-trifluoropropan-2-ols **5**

A mixture of corresponding *tert*-butoxy-β-(trifluoromethyl)-styrenes **3**, **4** (1 mmol) or ketone **6** (1 mmol), formic acid (184 mg, 4 mmol) and formamide (1.5 mL) were heated at 170 °C with reflux condenser for 1 h. The reaction mixture was allowed to cool to room temperature, diluted with CH_2Cl_2 (10 mL) and poured into water (100 mL). The reaction products were extracted with CH_2Cl_2 (3× 30 mL) and combined extract was dried over $MgSO_4$. CH_2Cl_2 was evaporated in vacuo and the residue was purified by column chromatography (silica gel, gradient cyclohexane/ethyl acetate).

4.3.1. 3-(4-Chlorophenyl)-1,1,1-trifluoropropan-2-ol (5a)

Yield: 150 mg, 67%, colorless crystals, mp 66–67 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.46 (br s, 1H, OH), 2.78 (dd, J = 14.3 and 10.0 Hz, 1H, CH_2), 2.98 (dd, J = 14.3 and 2.9 Hz, 1H, CH_2), 3.98–4.11 (m, 1H, CHOH), 7.16 (d, J = 8.4 Hz, 2H, 4-ClC_6H_4–), 7.28 (d, J = 8.4 Hz, 2H, 4-ClC_6H_4–); ^{19}F NMR (282 MHz, $CDCl_3$): δ −79.59 (d, J = 6.5 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 35.4, 71.3 (q, J = 31.0 Hz, C–CF_3), 124.8 (q, J = 282.1 Hz, CF_3), 128.9, 130.8, 133.1, 134.3. Anal. calcd. for $C_9H_8ClF_3O$: C, 48.13; H, 3.59. Found: C, 48.13; H 3.49.

4.3.2. 3-(4-Nitrophenyl)-1,1,1-trifluoropropan-2-ol (5b)

Yield: 150 mg, 64%, viscous oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.98 (dd, J = 14.2 and 10.0 Hz, 1H, CH_2), 3.08–3.17 (m, 2H), 4.16–4.30 (m, 1H, CHOH), 7.46 (d, J = 8.7 Hz, 2H, 4-$NO_2C_6H_4$–), 8.12 (d, J = 8.7 Hz, 2H, 4-$NO_2C_6H_4$–); ^{19}F NMR (282 MHz, $CDCl_3$): δ −79.68 (d, J = 6.4 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 35.8, 70.8 (q, J = 31.4 Hz, C–CF_3), 124.7 (q, J = 282.4 Hz, CF_3), 123.7, 130.5, 144.1, 146.9. Anal. calcd. for $C_9H_8F_3NO_3$: C, 45.97; H, 3.43; N, 5.96; Found: C, 45.83; H, 3.31; N, 5.73. ESI-MS (m/z): calcd. for $C_9H_8F_3NO_3$ $[M]^+$ 235.0456, found 235.0450.

4.3.3. 3-(3-Methoxyphenyl)-1,1,1-trifluoropropan-2-ol (5c)

Yield: 120 mg, 54%, pale yellow solid, mp 58–59 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.50 (br s, 1H, OH), 2.78 (dd, J = 14.2 and 10.2 Hz, 1H, CH_2), 3.01 (dd, J = 14.2 and 2.7 Hz, 1H, CH_2), 3.78 (s, 3H, MeO), 4.03–4.16 (m, 1H, CHOH), 6.76–6.85 (m, 3H, 3-$MeOC_6H_4$–), 7.24 (t, J = 7.7 Hz, 1H, 3-$MeOC_6H_4$–); ^{19}F NMR (282 MHz, $CDCl_3$): δ −79.59 (d, J = 6.7 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 36.2, 55.2, 71.3 (q, J = 30.8 Hz, C–CF_3), 112.5, 115.2, 121.7, 124.9 (q, J = 282.1 Hz, CF_3), 129.8, 137.3, 159.8. Anal. calcd. for $C_{10}H_{11}F_3O_2$: C, 54.55; H, 5.04. Found: C, 54.88; H 5.33. ESI-MS (m/z): calcd. for $C_{10}H_{11}F_3O_2$ [M]+ 220.0711, found 220.0705.

4.3.4. 3-(2-Methoxyphenyl)-1,1,1-trifluoropropan-2-ol (5d)

Yield: 101 mg, 47%, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.95 (dd, J = 14.0 and 10.0 Hz, 1H, CH_2), 3.07 (dd, J = 14.0 and 3.0 Hz, 1H, CH_2), 3.87 (s, 3H, MeO), 4.11–4.23 (m, 1H, CHOH), 6.91 (d, J = 7.8 Hz, 1H, 2-$MeOC_6H_4$–), 6.97 (d, J = 7.8 Hz, 1H, 2-$MeOC_6H_4$–), 7.19 (dd, J = 7.8 and 1.3 Hz, 1H, 2-$MeOC_6H_4$–), 7.28 (td, J = 7.8 and 1.3 Hz, 1H, 2-$MeOC_6H_4$–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -79.90 (d, J = 6.8 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 31.6, 55.5, 70.8 (q, J = 30.6 Hz, C–CF_3), 125.1 (q, J = 282.0 Hz, CF_3),

110.5, 121.2, 124.1, 128.8, 131.6, 157.3. Anal. calcd. for $C_{10}H_{11}F_3O_2$: C, 54.55; H, 5.04. Found: C, 54.43; H 4.63.

*4.3.5. 3-(2-Bromophenyl)-1,1,1-trifluoropropan-2-ol (**5e**)*

Yield: 132 mg, 49%, yellowish solid, mp 56–57 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.33 (br s, 1H, OH), 2.90 (dd, J = 14.2 and 10.4 Hz, 1H, CH_2), 3.28 (dd, J = 14.3 and 2.8 Hz, 1H, CH_2), 4.20–4.34 (m, 1H, CHOH), 7.15 (td, J = 7.0 and 2.7 Hz, 1H, 2-BrC_6H_4–), 7.23–7.33 (m, 2H, 2-BrC_6H_4–), 7.57 (d, J = 7.9 Hz, 1H, 2-BrC_6H_4–); ^{19}F NMR (282 MHz, $CDCl_3$): δ −79.77 (d, J = 6.6 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 36.5, 69.8 (q, J = 31.1 Hz, C–CF_3), 124.6, 124.8 (q, J = 282.1 Hz, CF_3), 127.6, 129.0, 132.3, 133.0, 135.2. Anal. calcd. for $C_9H_8BrF_3O$: C, 40.18; H, 3.00. Found: C, 40.64; H 2.97.

*4.3.6. 3-(4-Bromophenyl)-1,1,1-trifluoropropan-2-ol (**5f**)*

Yield: 190 mg, 71%, white crystals, mp 75–76 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.25 (br s, 1H, OH), 2.80 (dd, J = 14.2 and 9.9 Hz, 1H, CH_2), 2.98 (dd, J = 14.2 and 2.8 Hz, 1H, CH_2), 4.03–4.13 (m, 1H, CHOH), 7.13 (d, J = 8.4 Hz, 2H, 4-BrC_6H_4–), 7.45 (d, J = 8.4 Hz, 2H, 4-BrC_6H_4–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -79.61 (d, J = 6.6 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 35.5, 71.3 (q, J = 31.1 Hz, C–CF_3), 121.2, 124.8 (q, J = 282.1 Hz, CF_3), 131.2, 131.8, 134.8. Anal. calcd. for $C_9H_8BrF_3O$: C, 40.18; H, 3.00. Found: C, 40.64; H 3.06.

*4.3.7. 3-Phenyl-1,1,1-trifluoropropan-2-ol (**5g**)*

Yield: 120 mg, 58%, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.61 (br s, 1H, OH), 2.82 (dd, J = 14.2 and 10.2 Hz, 1H, CH_2), 3.03 (dd, J = 14.2 and 2.9 Hz, 1H, CH_2), 4.03–4.17 (m, 1H, CHOH), 7.22–7.37 (m, 5H, C_6H_5–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -79.59 (d, J = 6.5 Hz, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 36.1, 71.4 (q, J = 30.8 Hz, C–CF_3), 124.9 (q, J = 282.1 Hz, CF_3), 127.2, 128.7, 129.4, 135.9. ^{1}H NMR and ^{19}F NMR spectra are in agreement with published data [19]. Anal. calcd. for $C_9H_9F_3O$: C, 56.84; H, 4.77. Found: C, 56.47; H 4.86.

*4.4. General procedure for the synthesis of the 3-aryl-1,1,1-trifluoroacetones **6***

A mixture of the corresponding *tert*-butoxy-β-(trifluoromethyl)styrenes **3** and **4** (2 mmol), 48% HBr (670 mg, 4 mmol) and glacial acetic acid (4 mL) were stirred at room temperature for 48 h. The reaction mixture was diluted with CH_2Cl_2 (20 mL) and poured into water (100 mL). The reaction products were extracted with CH_2Cl_2 (3 × 30 mL) and the combined extract was dried over $MgSO_4$. CH_2Cl_2 was evaporated in vacuo and the residue was purified by column chromatography (silica gel, CH_2Cl_2).

*4.4.1. 3-(4-Chlorophenyl)-1,1,1-trifluoroacetone (**6a**)*

White powder (264 mg, 59%), mp 88–89 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.98 (s, 2H, CH_2), 7.14 (d, J = 8.4 Hz, 2H, 4-ClC_6H_4–), 7.33 (d, J = 8.4 Hz, 2H, 4-ClC_6H_4–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -78.42 (s, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 42.2 (CH_2), 115.7 (q, J = 292.4 Hz, CF_3), 129.1, 131.0, 132.6, 134.1, 188.5 (q, J = 35.3 Hz, C–CF_3). ^{1}H NMR spectra are in agreement with published data [31].

*4.4.2. 3-(4-Nitrophenyl)-1,1,1-trifluoroacetone (**6b**)*

Yellow solid (260 mg, 56%), mp 81–82 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.18 (s, 2H, CH_2), 7.41 (d, J = 8.7 Hz, 2H, 4-$NO_2C_6H_4$–), 8.23 (d, J = 8.7 Hz, 2H, 4-$NO_2C_6H_4$–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -78.56 (s, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 42.4 (CH_2), 115.2 (q, J = 292.0 Hz, CF_3), 124.0, 130.8, 137.6, 147.7, 187.6 (q, J = 36.2 Hz, C–CF_3). ESI-MS (m/z): calcd. for $C_9H_6F_3NO_3$ [M]+ 233.0300, found 233.0294.

*4.4.3. 3-(3-Methoxyphenyl)-1,1,1-trifluoroacetone (**6c**)*

Pale yellow viscous oil (206 mg, 47%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.79 (s, 3H, MeO), 3.97 (s, 2H, CH_2), 6.72–6.81 (m, 2H, 3-$MeOC_6H_4$–), 6.87 (dt, J = 7.9 and 2.0 Hz, 1H, 3-$MeOC_6H_4$–), 7.27 (t, J = 7.9 Hz, 1H, 3-$MeOC_6H_4$–); ^{19}F NMR (282 MHz, $CDCl_3$): δ -78.31 (s, CF_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 43.0 (CH_2), 55.2 (OCH_3), 113.4, 115.37, 115.42 (q, J = 292.4 Hz, CF_3), 121.9, 129.9, 131.7, 159.9, 188.7 (q, J = 35.3 Hz, C–CF_3). ^{1}H NMR spectra are in agreement with published data [32].

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