Supporting Information

for

Synthesis and synthetic applications of (4-hydroxyphenyl)perfluoroalkyl-methanols

Kyu Terashima,¹ Tomoko Kawasaki-Takasuka,¹ Ichiro Minami,² Takashi Yamazaki*¹

¹ Division of Applied Chemistry, Institute of Engineering, Tokyo University of Agriculture and Technology, 2-24-16 Nakamachi, Koganei 184-8588, Japan.
² Division of Machine Elements, Luleå University of Technology, Luleå SE-97187, Sweden.
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1. General information

Most of reactions where an organic solvent was employed were performed under argon with magnetic stirring using flame-dried glassware. Unless otherwise noted, materials were obtained from commercial suppliers including anhydrous THF, Et₂O, and CH₂Cl₂, and were used without further purification. Analytical thin-layer chromatography (TLC) was routinely used for monitoring reactions by generally using a mixture of hexane and ethyl acetate. Spherical neutral silica gel (63–210 nm) was employed for usual column chromatography.

¹H (300.40 MHz), ¹³C (75.45 Hz), and ¹⁹F (282.65 Hz) NMR spectra were recorded in CDCl₃ unless otherwise noted, and chemical shifts were reported in parts per million (ppm), downfield from internal tetramethylsilane (Me₄Si: δ 0.00, for ¹H and ¹³C) or hexafluorobenzene (C₆F₆: δ −163.00 for ¹⁹F). Data were tabulated in the following order: number of protons, multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; quint, quintet; sex, sextet; m, multiplet; br, broad peak), coupling constants in Hertz. In the case of ¹³C NMR for the compounds with C₃F₇ and C₆F₁₃ groups, because multiple coupling of fluorine possessing carbon atoms made their observation difficult even after long data acquisition time, these data are not shown. Infrared (IR) spectra were reported in wave numbers (cm⁻¹).

High resolution mass spectrometry was performed by the positive ionization mode.

1-(Allyloxy)-4-bromobenzene [1], 1-(allyloxy)-3-bromobenzene [2], 1-(allyloxy)-2-bromobenzene [3], and 1-bromo-4-((tetrahydro-2H-pyran-2-yl)oxy)benzene [4] were synthesized following to the reported procedures.

2. Synthetic procedure and characterization of new compounds

2.1. 2-Phenylethyl 2,2,3,3,4,4,4-heptafluorobutyrate

To a 30 mL round-bottomed flask, 2-phenylethanol (2.4463 g, 20.025 mmol) and heptafluorobutyric acid (4.7318 g, 22.107 mmol) were introduced, where conc. H₂SO₄ (0.60 mL, 11 mmol) was added slowly at 0 °C. After stirring for 24 h at room temperature, the reaction mixture was treated with sat. NaHCO₃ aq. at 0 °C, and after stirring for 15 min. at the same temperature, the solution was extracted with CH₂Cl₂. After the organic layer was washed with sat. NaCl aq. and dried over anhydrous Na₂SO₄, concentration in vacuo afforded the crude product (referred to as usual work up) which was purified by column chromatography (hexane:AcOEt=15:1) to give the desired product (5.9953 g, 18.842 mmol, 94%).

Rf=0.68 (hexane:AcOEt=8:1). ¹H NMR: δ 3.05 (2H, t, J=7.2 Hz), 4.57 (2H, t, J=7.2 Hz), 7.21–7.36 (5H, m). ¹³C NMR: δ 34.5, 68.8, 127.1, 128.7, 128.9, 136.1, 158.2 (t, J=29.8 Hz).
To a 30 mL two-necked round-bottomed flask were added 1-(allyloxy)-4-bromobenzene (0.2579 g, 1.209 mmol) and THF (1 mL), where BuLi (a 1.53 M hexane solution, 0.72 mL, 1.1 mmol) was dropped slowly at −80 °C, and the mixture was stirred for 30 min at the same temperature. To this mixture was added a solution of 2-phenylethyl 2,2,3,3,4,4,4-heptafluorobutyrate (0.3185 g, 1.000 mmol) in THF (1.0 mL) via a syringe. After 1 h at the same temperature, the reaction mixture was quenched with 1 M HCl and extracted with AcOEt three times. After usual workup, the resultant crude product was purified by column chromatography (hexane) to give the desired product 3a (0.2920 g, 0.8327 mmol, 83%) as a colorless oil.

Rf=0.13 (hexane). 1H NMR: δ 4.65 (2H, dt, J=5.4, 1.5 Hz), 5.36 (1H, dq, J=10.5, 1.5 Hz), 5.44 (1H, dq, J=17.4, 1.5 Hz), 6.05 (1H, ddt, J=17.4, 10.5, 5.4 Hz), 6.98-7.03 (2H, m), 8.07 (2H, d, J=8.7 Hz). 13C NMR: δ 69.1, 115.0, 118.4, 124.4, 131.9, 132.86, 132.91, 133.0, 164.4, 181.3 (t, J=25.4 Hz). 19F NMR: δ −126.84 (2F, m), −114.60 (1F, d, J=9.0 Hz), −114.53 (1F, d, J=9.0 Hz), −81.43 (3F, t, J=9.0 Hz). IR (CHCl₃) ν 3087, 2988, 2938, 2873, 1696, 1599, 1234, 1163, 909, 732 cm⁻¹. HRMS (FAB+, m/z): [M+Na]⁺ Calcd for C₁₃H₁₀F₇NaO₂, 331.0564; Found, 331.0601.

2.2 1-(4-(Allyloxy)phenyl)-2,2,3,4,4,4-heptafluorobutan-1-one (3a)

To a 30 mL two-necked round-bottomed flask were added 1-(allyloxy)-4-bromobenzene (0.2579 g, 1.209 mmol) and THF (1 mL), where BuLi (a 1.53 M hexane solution, 0.72 mL, 1.1 mmol) was dropped slowly at −80 °C, and the mixture was stirred for 30 min at the same temperature. To this mixture was added a solution of 2-phenylethyl 2,2,3,4,4,4-heptafluorobutyrate (0.3185 g, 1.000 mmol) in THF (1.0 mL) via a syringe. After 1 h at the same temperature, the reaction mixture was quenched with 1 M HCl and extracted with AcOEt three times. After usual workup, the resultant crude product was purified by column chromatography (hexane) to give the desired product 3a (0.2920 g, 0.8327 mmol, 83%) as a colorless oil.

Rf=0.13 (hexane). 1H NMR: δ 4.65 (2H, dt, J=5.4, 1.5 Hz), 5.36 (1H, dq, J=10.5, 1.5 Hz), 5.44 (1H, dq, J=17.4, 1.5 Hz), 6.05 (1H, ddt, J=17.4, 10.5, 5.4 Hz), 6.98-7.03 (2H, m), 8.07 (2H, d, J=8.7 Hz). 13C NMR: δ 69.1, 115.0, 118.4, 124.4, 131.9, 132.86, 132.91, 133.0, 164.4, 181.3 (t, J=25.4 Hz). 19F NMR: δ −126.84 (2F, m), −114.60 (1F, d, J=9.0 Hz), −114.53 (1F, d, J=9.0 Hz), −81.43 (3F, t, J=9.0 Hz). IR (CHCl₃) ν 3087, 2988, 2938, 2873, 1696, 1599, 1234, 1163, 909, 732 cm⁻¹. HRMS (FAB+, m/z): [M+Na]⁺ Calcd for C₁₃H₁₀F₇NaO₂, 331.0564; Found, 331.0601.

2.3 In situ MPV reduction by using commercially available MgBr₂ [5]

2.3.1. 1-(4-(Allyloxy)phenyl)-2,2,3,4,4,4-heptafluorobutan-1-ol (4ab)

To a 30 mL two-necked round-bottomed flask were added 1-(allyloxy)-4-bromobenzene (0.2579 g, 1.209 mmol) and THF (1 mL), where BuLi (a 1.53 M hexane solution, 0.72 mL, 1.1 mmol) was dropped slowly at −80 °C, and the mixture was stirred for 30 min at the same temperature. To this mixture was added a solution of 2-phenylethyl 2,2,3,4,4,4-heptafluorobutyrate (0.3185 g, 1.000 mmol) in THF (1.0 mL) via a syringe. After 1 h at the same temperature, anhydrous MgBr₂ (0.2035 g, 1.103 mmol) was added to the solution and the whole was stirred for 30 min at −80 °C. To the solution was added i-PrOH (0.23 mL, 3.0 mmol) and the mixture was stirred for 1 h at 80 °C. After usual workup, the resultant crude product was purified by column chromatography (hexane: AcOEt=10:1→8:1) to give the desired product 4ab as a yellow oil (0.2947 g, 0.8872 mmol,
2.4. In situ MPV reduction by using MgBr₂ prepared in situ (General procedure 1)

To a 30 mL two-necked round-bottomed flask were added ArBr (1.2 mmol, 1.2 eq.) and THF (1 mL), where BuLi (a 2.7 M hexane solution, 0.40 mL, 1.1 mmol, 1.1 eq.) was dropped slowly at −80 °C, and the mixture was stirred for 30 min at the same temperature. To this mixture was added a solution of the perfluorinated ester (1 mmol, 1.0 eq.) in THF (1.0 mL) via a syringe. After 1 h at the same temperature, the reaction mixture was transferred via cannula to the other 30 mL two-necked round-bottomed flask which was filled with a THF solution of MgBr₂ prepared from Mg (0.0528 g, 2.20 mmol) and 1,2-dibromoethane (0.19 mL, 2.2 mmol) in THF (1 mL) mixing for 1 h at room temperature under argon. After 30 min., to the solution was added i-PrOH (0.23 mL, 3.0 mmol) and the mixture was stirred for a further period (see Table 2) at 80 °C. After usual workup, the resultant crude product was purified by column chromatography to give desired product.

Following to this “General procedure 1” by using 1-(allyloxy)-4-bromobenzene (0.2552 g, 1.209 mmol) and ethyl heptfluorobutyrate (0.175 mL, 1.01 mmol), 4ab was obtained as a yellow oil (0.2950 g, 0.8880 mmol, 89%).

Rf=0.42 (hexane:AcOEt=5:1). ¹H NMR: δ 2.39 (1H, d, J=4.8 Hz), 4.56 (2H, d, J=4.5 Hz), 5.14 (1H, dt, J=17.7, 5.7 Hz), 5.39 (1H, d, J=10.5 Hz), 5.43 (1H, d, J=17.4 Hz), 6.01 (1H, ddt, J=17.1, 10.8, 5.1 Hz), 6.94-7.02 (2H, m), 7.39 (2H, d, J=8.4 Hz). ¹³C NMR: δ 68.8, 71.4 (dd, J=29.2, 22.3 Hz), 114.7, 117.8, 126.3, 129.3, 132.8, 159.4. ¹⁹F NMR: δ −128.18 (1F, dm, J=285.2 Hz), −127.52 (1F, dm, J=290.8 Hz), −126.13 (1F, dm, J=290.8 Hz), −120.01 (1F, dm, J=281.8 Hz), −82.11 (3F, m). IR (CHCl₃) ν 3423, 3025, 2938, 2870, 1618, 1510, 1231, 1178, 1119, 792 cm⁻¹. HRMS (FAB+, m/z): [M⁺] Calcd for C₁₃H₁₁F₇O₂, 332.0642; Found, 331.0644.

2.4.1. 1-{4-( Allyloxy)phenyl}-2,2,2-trifluoroethan-1-ol (4aa) [6]

Following to the “General procedure 1” using 1-(allyloxy)-4-bromobenzene (0.2552 g, 1.198 mmol) and ethyl trifluoroacetate (0.12 mL, 1.00 mmol), 0.1500 g (0.6460 mmol) of 4aa was obtained in 65% yield.

Rf=0.27 (hexane:AcOEt=6:1). ¹H NMR: δ 2.62 (1H, brs), 4.56 (2H, dt, J=5.4, 1.5 Hz), 4.96 (1H, q, J=6.9 Hz), 5.30 (1H, dq, J=10.5, 1.5 Hz), 5.42 (1H, dq, J=17.1, 1.5 Hz), 6.05 (1H, ddt, J=17.1, 10.5, 5.4 Hz), 6.92-6.96 (2H, m), 7.37-7.39 (2H, m). ¹³C NMR: δ 68.8, 72.4 (q, J=32.2 Hz), 114.8, 117.9, 124.3 (q, J=281.0 Hz), 126.2, 128.7, 159.4. ¹⁹F NMR: δ −79.81 (d, J=6.8 Hz).
2.4.2. 1-{4-(Allyloxy)phenyl}-2,2,3,3,4,4,5,5,6,6,7,7-tridecafluoroheptan-1-ol (4ad)

Following to the “General procedure 1” using 1-(allyloxy)-4-bromobenzene (0.2552 g, 1.198 mmol) and methyl tridecafluoroacetanate (0.3786 mL, 1.00 mmol), 0.3121 g (0.6472 mmol) of 4ad was obtained in 65% yield as a yellow solid.

mp. 50.4-52.1 ºC. Rf=0.33 (hexane:AcOEt=6:1). 1H NMR: δ 2.38 (1H, d, J=5.1 Hz), 4.56 (2H, dt, J=5.1, 1.5 Hz), 5.15 (1H, dt, J=17.7, 6.0 Hz), 5.31 (1H, dq, J=10.5, 1.5 Hz), 5.42 (1H, dq, J=17.1, 1.5 Hz), 6.06 (1H, ddt, J=17.1, 10.5, 5.4 Hz), 6.94 (1H, ddd, J=8.4, 2.4, 1.2 Hz), 7.03-7.05 (2H, m), 7.31 (1H, t, J=8.4 Hz). 13C NMR: δ 68.8, 71.4 (q, J=32.2 Hz), 114.8, 117.9, 124.3 (q, J=281.2 Hz), 126.2, 128.73, 128.75, 132.8, 159.4. 19F NMR: δ –79.5 (d, J=6.8 Hz). IR (CHCl3) ν 3440, 3085, 2926, 2867, 1589, 1258, 1171, 1121, 932, 713 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C16H11F13O2, 482.0546; Found, 482.0567.

2.4.3. 1-{3-(Allyloxy)phenyl}-2,2,2-trifluoroethan-1-ol (4ba)

Following to the “General procedure 1” using 1-(allyloxy)-3-bromobenzene (0.2552 g, 1.198 mmol) and ethyl trifluoroacetate (0.12 mL, 1.00 mmol), 0.1583 g (0.6817 mmol) of 4ba was obtained in 68% yield as a yellow oil.

Rf=0.27 (hexane:AcOEt=6:1). 1H NMR: δ 2.65 (1H, brs), 4.55 (2H, dt, J=5.4, 1.5 Hz), 4.98 (1H, q, J=7.2 Hz), 5.30 (1H, dq, J=10.5, 1.5 Hz), 5.42 (1H, dq, J=17.4, 1.5 Hz), 6.06 (1H, ddt, J=17.1, 10.5, 5.4 Hz), 6.96 (1H, ddd, J=8.4, 2.4, 1.2 Hz), 7.03-7.05 (2H, m), 7.31 (1H, t, J=8.4 Hz). 13C NMR: δ 68.8, 71.4 (q, J=32.2 Hz), 114.8, 117.9, 124.3 (q, J=281.2 Hz), 126.2, 128.73, 128.75, 132.8, 159.4. 19F NMR: δ –79.5 (d, J=6.8 Hz). IR (CHCl3) ν 3440, 3085, 2926, 2867, 1589, 1258, 1171, 1121, 932, 713 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C11H13F3O2, 232.0706; Found, 232.0736.

2.4.4. 1-{3-(Allyloxy)phenyl}-2,2,3,3,4,4,4,4-heptafluorobutan-1-ol (4bb)

Following to the “General procedure 1” using 1-(allyloxy)-3-bromobenzene (0.2552 g, 1.198 mmol) and ethyl heptafluorobutyrate (0.175 mL, 1.01 mmol), 0.2870 g (0.8639 mmol) of 4bb was obtained in 86% yield as a yellow oil.

Rf=0.33 (hexane:AcOEt=6:1). 1H NMR: δ 2.53 (1H, d, J=5.4 Hz), 4.55 (2H, dt, J=5.4, 1.5 Hz), 5.16 (1H, dt, J=17.7, 5.7 Hz), 5.22 (1H, dq, J=10.5, 1.5 Hz), 5.42 (1H, dq, J=17.4,
1.5 Hz), 6.06 (1H, ddt, J=17.4, 10.5, 5.4 Hz), 6.97 (1H, ddd, J=8.4, 2.4, 1.2 Hz), 7.02-7.04 (2H, m), 7.29-7.35 (1H, m). ¹³C NMR: δ 68.9, 71.8 (dd, J=29.2, 21.0 Hz), 114.4, 116.0, 117.9, 120.6, 129.5, 132.8, 135.5, 158.6. ¹⁹F NMR: δ –128.00 (1F, dm, J=287.5 Hz), –127.55 (1F, dm, J=292.0 Hz), –126.09 (1F, dm, J=294.2 Hz), –119.75 (1F, dm, J=282.9 Hz), –82.1 ~ –82.0 (3F, m). IR (CHCl₃) ν 3447, 3088, 3028, 2916, 2872, 1589, 1344, 1227, 1115, 792 cm⁻¹. HRMS (FAB+, m/z): [M⁺] Calcd for C₁₃H₁₁F₃O₂, 332.0642; Found, 332.0670.

2.4.5. 1-{2-(Allyloxy)phenyl}-2,2,2-trifluoroethan-1-ol (4ca)

Following to the “General procedure 1” using 1-(allyloxy)-2-bromobenzene (0.2552 g, 1.198 mmol) and ethyl trifluoroacetate (0.12 mL, 1.00 mmol), 0.1707 g (0.7351 mmol) of 4ca was obtained in 74% yield as a yellow oil.

RF=0.33 (hexane:AcOEt=6:1). ¹H NMR: δ 3.70 (1H, d, J=7.8 Hz), 4.61 (2H, dt, J=5.4, 1.5 Hz), 5.28 (1H, dq, J=8.1, 7.4 Hz), 5.32 (1H, dq, J=10.2, 1.5 Hz), 5.41 (1H, dq, J=17.4, 1.5 Hz), 6.04 (1H, ddt, J=17.4, 10.5, 5.4 Hz), 6.93 (1H, d, J=8.1 Hz), 6.94-7.04 (1H, td, J=7.5, 1.2 Hz), 7.35 (1H, dd, J=8.4, 7.8, 1.8 Hz), 7.39 (1H, d, J=7.5 Hz). ¹³C NMR: δ 68.2, 69.4 (q, J=32.8 Hz), 112.3, 118.0, 121.1, 122.3, 124.6 (q, J=282.3 Hz), 129.2, 130.4, 132.4, 156.4. ¹⁹F NMR: δ –79.3 (d, J=7.1 Hz). IR (CHCl₃) ν 3481, 3074, 3022, 2932, 2877, 1494, 1247, 1217, 1171, 756 cm⁻¹. HRMS (FAB+, m/z): [M⁺]+ Calcd for C₁₁H₁₁F₃O₂, 233.0706; Found, 233.0715.

2.4.6. 1-{2-(Allyloxy)phenyl}-2,2,3,3,4,4-heptafluorobutan-1-ol (4cb)

Following to the “General procedure 1” using 1-(allyloxy)-2-bromobenzene (0.2552 g, 1.200 mmol) and ethyl heptafluorobutyrate (0.175 mL, 1.01 mmol), 0.2655 g (0.7992 mmol) of 4cb was obtained in 80% yield as a yellow oil.

RF=0.26 (hexane:AcOEt=6:1). ¹H NMR: δ 3.83 (1H, d, J=8.7 Hz), 4.62 (2H, d, J=5.1 Hz), 5.32 (1H, d, J=10.6 Hz), 5.41 (1H, d, J=17.4 Hz), 5.47 (1H, ddd, J=20.7, 8.7, 5.0 Hz), 6.04 (1H, ddt, J=17.4, 10.5, 5.4 Hz), 6.95 (1H, d, J=8.7 Hz), 7.03 (1H, t, J=7.5 Hz), 7.34-7.38 (2H, m). ¹³C NMR: δ 69.1 (dd, J=29.4, 22.2 Hz), 69.3, 112.4, 118.0, 121.1, 122.0, 129.9, 130.5, 132.3, 156.8. ¹⁹F NMR: δ –128.64 (1F, dm, J=280.4 Hz), –128.15 (1F, dm, J=290.9 Hz), –126.59 (1F, dm, J=282.9 Hz), –119.44 (1F, dm, J=280.7 Hz), –82.13 ~ –82.06 (3F, m). IR (CHCl₃) ν 3466, 3077, 3028, 2927, 2872, 1594, 1230, 1191, 1120, 756 cm⁻¹. HRMS (FAB+, m/z): [M⁺]+ Calcd for C₁₃H₁₁F₃O₂, 332.0642; Found, 332.0679.
2.4.7. 2,2,2-Trifluoro-1-(4-methoxyphenyl)ethan-1-ol (4da) [7]

Following to the “General procedure 1” using 4-bromoanisole (0.2244 g, 1.200 mmol) and ethyl trifluoroacetate (0.12 mL, 1.00 mmol), 0.1366 g (0.6626 mmol) of 4da was obtained in 66% yield as a yellow oil.

Rf=0.26 (hexane:AcOEt=6:1). 1H NMR: δ 2.60 (1H, d, J=7.8 Hz), 3.82 (3H, s), 4.97 (1H, q, J=6.9 Hz), 6.91-6.96 (2H, m), 7.38-7.41 (2H, m). 13C NMR: δ 55.2, 72.2 (q, J=31.6 Hz), 113.9, 124.3 (q, J=281.6 Hz), 126.2, 128.8, 160.2. 19F NMR: δ −79.82 (d, J=6.8 Hz).

2.4.8. 2,2,3,3,4,4,4-Heptafluoro-1-(4-methoxyphenyl)butan-1-ol (4db)

Following to the “General procedure 1” using 4-bromoanisole (0.2244 g, 1.200 mmol) and ethyl heptafluorobutyrate (0.175 mL, 1.01 mmol), 0.2421 g (0.7907 mmol) of 4db was obtained in 79% yield as a yellow solid.

mp. 43.9-44.8 °C. Rf=0.26 (hexane:AcOEt=6:1). 1H NMR: δ 2.44 (1H, d, J=4.8 Hz), 3.83 (3H, s), 5.14 (1H, dt, J=17.4, 5.4 Hz), 6.91-6.96 (2H, m), 7.39 (2H, d, J=8.7 Hz). 13C NMR: δ 55.2, 71.5 (dd, J=28.5, 22.3 Hz), 113.9, 126.1, 129.3, 160.4. 19F NMR: δ −128.28 (1F, dm, J=282.9Hz), −127.50 (1F, dm, J=294.2 Hz), −126.12 (1F, dm, J=294.2 Hz), −119.86 (1F, dm, J=282.9 Hz), −82.14 ~ −82.07 (3F, m). IR (CHCl3) v 3496, 3014, 2966, 2943, 2844, 1613, 1518, 1349, 1233, 843 cm⁻¹. HRMS (FAB+, m/z): [M+H]+ Calcd for C13H10F7O2, 307.0564; Found, 307.0600.

2.4.9. 2,2,2-Trifluoro-1-(2-methoxyphenyl)ethan-1-ol (4ea) [7]

Following to the “General procedure 1” using 2-bromoanisole (0.2244 g, 1.200 mmol) and ethyl trifluoroacetate (0.12 mL, 1.00 mmol), 0.1331 g (0.6456 mmol) of 4ea was obtained in 65% yield as a yellow oil.

Rf=0.26 (hexane:AcOEt=6:1). 1H NMR: δ 3.66 (1H, d, J=7.8 Hz), 3.89 (3H, s), 5.27 (1H, dq, J=7.2, 6.9 Hz), 6.94-7.04 (2H, m), 7.35-7.40 (2H, m). 13C NMR: δ 55.6, 69.3 (q, J=32.9 Hz), 111.2, 120.9, 122.0, 124.6 (q, J=281.9 Hz), 129.1, 130.5, 157.4. 19F NMR: δ −79.35 (d, J=6.8 Hz).

2.4.10. 2,2,3,3,4,4,4-Heptafluoro-1-(2-methoxyphenyl)butan-1-ol (4eb)

Following to the “General procedure 1” using 2-bromoanisole (0.2244 g, 1.200 mmol) and ethyl heptafluorobutyrate (0.175 mL, 1.01 mmol), 0.2514 g (0.8212 mmol) of 4eb was obtained in 82% yield as a yellow solid.
phenyl]heptan 2.5. 375. 1346, 1226, 1121, 970, 795 –

(1H, d, J=20.6, 6.4, 5.4 Hz), 6.96 (1H, d, J=8.1 Hz), 7.02 (1H, td, J=7.5, 0.9 Hz), 7.33-7.41 (2H, m). 13C NMR: δ 55.7, 69.4 (dd, J=29.1, 22.3 Hz), 111.3, 121.0, 121.6, 129.9, 130.6, 157.8. 19F NMR: δ –128.44 (1F, dm, J=280.7 Hz), –128.12 (1F, dm, J=295.2 Hz), –126.48 (1F, dm, J=292.0 Hz), –119.28 (1F, dm, J=280.6 Hz), –82.09 ~ –82.02 (3F, m). IR (CHCl3) ν 3466, 3011, 2940, 2841, 2051, 1602, 1467, 1440, 1351, 822 cm\(^{-1}\). HRMS (FAB+, m/z): [M+H]\(^+\) Calcd for C\(_{11}\)H\(_{10}\)F\(_2\)O\(_2\), 307.0564; Found, 307.0593.

2.5. In situ MPV reduction by using MgBr\(_2\) prepared in situ (General procedure 2)

2.5.1. 2,2,3,3,4,4,4-Heptafluoro-1-[4-{(tetrahydro-2H-pyran-2-yl)oxy}phenyl]butan-1-ol (4fb)

Following to the “General procedure 1” using 1-bromo-4-[(tetrahydro-2H-pyran-2-yl)oxy]benzene (0.3090 g, 1.201 mmol), the reaction mixture was worked up with water. Then, the mixture was filtered with Celite to remove the insoluble solid and extracted with AcOEt three times. After evaporation, the obtained crude product was dissolved in a minimum volume of CH\(_2\)Cl\(_2\) where hexane was added until white precipitation was generated. After washing the solid with hexane, 0.2974 g (0.7904 mmol, 79%) of the desired product 4fb was obtained as a white solid (1:1 diastereomeric mixture) (Starting from 1-bromo-4-[(tetrahydro-2H-pyran-2-yl)oxy]benzene (1.5427 g, 6.0000 mmol) and ethyl heptafluoroacetate ((1.2111 g, 5.0027 mmol), 1.6760 g (3.7537 mmol, 75%) of 4fb was obtained).

mp. 104.2-105.1 °C. Rf=0.30 (hexane:AcOEt=6:1). 1H NMR: δ 1.57-2.06 (6H, m), 2.43 (1H, d, J=5.1 Hz), 3.59-3.63 (1H, m), 3.83-3.94 (1H, m), 5.14 (1H, dt, J=17.4, 6.0 Hz), 5.44-5.46 (1H, m), 7.07-7.10 (2H, m), 7.36-7.39 (2H, m). 13C NMR: δ 18.7, 25.0, 30.2, 62.2, 71.5 (dd, J=29.2, 22.0 Hz) and 71.6 (dd, J=29.2, 22.0 Hz) (diastereomer pair), 96.28 and 96.33 (diastereomer pair), 116.3 and 116.4 (diastereomer pair), 127.0, 129.2, 157.9. 19F NMR: δ –128.42 (1F, dm, J=287.5 Hz), –127.61 (1F, dm, J=294.2 Hz), –126.17 (1F, dm, J=297.6 Hz), –119.96 (1F, dm, J=279.4 Hz), –82.15 (3F, m). IR (KBr) ν 3363, 2955, 2881, 1612, 1514, 1346, 1226, 1121, 970, 795 cm\(^{-1}\). HRMS (FAB+, m/z): [M-H]\(^-\) Calcd for C\(_{15}\)H\(_{14}\)F\(_2\)O\(_3\), 375.0826; Found, 375.0803.

2.5.2. 2,2,3,3,4,4,5,5,6,6,7,7-Tridecafluoro-1-[4-{(tetrahydro-2H-pyran-2-yl)oxy}phenyl]heptan-1-ol (4fd)

Following to the “General procedure 2” using 1-bromo-4-[(tetrahydro-2H-pyran-2-yl)oxy]benzene (1.5427 g, 6.0000 mmol) and methyl tridecafluoroheptanoate (1.8914 g, 375.0826; Found, 375.0803.
5.0025 mmol), 1.9729 g (3.748 mmol) of 4fd was obtained in 75% yield (1:1 diastereomere mixture as a white solid.

mp. 113.5-114.6 °C. Rf=0.30 (hexane:AcOEt=6:1). 1H NMR: δ 1.54-2.10 (6H, m), 2.42 (1H, brs), 3.60-3.64 (1H, m), 3.86-3.93 (1H, m), 5.17 (1H, dt, J=18.0, 5.4 Hz), 5.43-5.47 (1H, m), 7.08-7.10 (2H, m), 7.37-7.40 (2H, m). 13C NMR (acetone-δ6): δ 19.5, 25.9, 31.0, 62.4, 71.8 (dd, J=29.2, 21.8 Hz) and 71.9 (dd, J=29.2, 21.8 Hz) (diastereomer pair), 96.9 and 97.0 (diastereomer pair), 116.88 and 116.91 (diastereomer pair), 129.1, 130.3, 158.7. 19F NMR: δ −128.09 (1F, dm, J=298.8 Hz), −127.33 (1F, dm, J=285.2 Hz), −126.79 (1F, dm, J=298.8 Hz), −124.11 (2F, m), −123.34 (2F, m), −122.52 (2F, m), −119.35 (1F, dm, J=280.7 Hz), −82.05 (3F, m). IR (KBr) ν 3371, 2949, 2889, 1904, 1610, 1586, 1514, 1232, 1032, 972 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C18H13F13O3, 526.0808; Found, 526.0846.

2.6 Ethyl 4-[[{(1,1-dimethylethoxy)carbonyl}oxy]benzoate (6)

To a 30 mL two-necked round-bottomed flask were added ethyl 4-hydroxybenzoate (3.3242 g, 20.004 mmol), N,N-dimethyl-4-aminopyridine (0.2451 g, 2.006 mmol), CH2Cl2 (20 mL), triethylamine (3.0 mL, 22 mmol), and di-t-butyl dicarbonate (4.4830 g, 20.540 mmol), and the mixture was stirred for 30 min. at room temperature. The reaction mixture was quenched with 0.5 M NaHSO4 and extracted with CH2Cl2 three times. After usual workup, the obtained crude product was purified by column chromatography (hexane:AcOEt=15:1) to give desired product 6 (5.0909 g, 19.118 mmol, 96%) as a white solid.

mp. 66.8-67.6 °C. Rf=0.40 (hexane:AcOEt=20:1). 1H NMR: δ 1.39 (3H, t, J=7.2 Hz), 1.57 (9H, s), 4.37 (2H, q, J=7.2 Hz), 7.22-7.27 (2H, m), 8.04-8.09 (2H, m). 13C NMR: δ 14.2, 27.5, 60.9, 83.9, 121.0, 127.8, 131.0, 151.0, 154.4, 165.6. IR (CHCl3) ν 3067, 3052, 2988, 2938, 2909, 1767, 1721, 1303, 1018, 898 cm⁻¹. HRMS (FAB+, m/z): [M+H]+ Calcd for C14H15O5, 276.1227; Found, 276.1253.

2.7. 1-[[{(1,1-Dimethylethoxy)carbonyl}oxy]phenyl]-2,2,3,3,4,4,5,5,6-nonnafluoropentan-1-one (3b)

To a 50 mL two-necked round-bottomed flask were added ethyl 4-[[{(1,1-dimethylethoxy)carbonyl}oxy]benzoate (0.2668 g, 1.002 mmol), C4F9 (0.5223 g, 1.510 mmol) and Et2O (5 mL), where MeLi-LiBr complex (a 1.5 M Et2O solution, 1.0 mL, 1.5 mmol) was dropped slowly at −80 °C. After 1 h at the same temperature, the reaction mixture was quenched with H2O and the solution was extracted with Et2O. After the Et2O layer was washed
with sat. NaCl aq. and dried over anhydrous Na₂SO₄, concentration in vacuo afforded the crude product which was purified by column chromatography (hexane:CH₂Cl₂=1:1) to give the desired product 3b as colorless liquid (0.4006 g, 0.9099 mmol, 91%).

Rf=0.57 (hexane:CH₂Cl₂=1:1). ¹H NMR: δ 1.58 (9H, s), 7.38 (2H, d, J=8.7 Hz), 8.12 (2H, dt, J=8.7 Hz). ¹³C NMR: δ 27.5, 84.7, 121.8, 128.6, 132.1, 150.5, 156.4, 181.9 (t, J=26.1 Hz). ¹⁹F NMR: δ –126.47 (2F, m), –123.16 (2F, m), –114.18 (2F, m), –82.18 (3F, t, J=9.3 Hz). IR(CHCl₃) ν 3021, 2985, 1761, 1709, 1602, 1372, 1216, 1138, 841, 757 cm⁻¹. HRMS (FAB+, m/z): [M+H]⁺ Calcd for C₁₆H₁₅F₉O₄, 441.0743; Found, 441.0734.

2.8. 1-[4-[(1,1-Dimethylethoxy)carbonyl]oxy]phenyl]-2,2,3,3,4,4,5,5,5-nonafluoropentan-1-ol (4gc)

To a 30 mL two-necked round-bottomed flask were added ethyl 4-[(1,1-dimethyl-ethoxy)carbonyl]oxy]benzoate (0.2664 g, 1.000 mmol), C₂F₅OH (0.5191 g, 1.501 mmol) and Et₂O (2 mL), where MeLi-LiBr complex (a 1.5 M Et₂O solution, 1.0 mL, 1.5 mmol) was dropped slowly at –80 °C. After 1 h at the same temperature, via cannula, the reaction mixture was transferred to the another 30 mL two-necked round-bottomed flask which was filled with a Et₂O solution of the MgBr₂ prepared from a mixture of Mg (0.0730 g, 3.00 mmol) and 1,2-dibromoethane (0.5642 g, 3.003 mmol) in Et₂O (1 mL) for 1 h at room temperature under argon. After 30 min., to the solution was added i-PrOH (0.23 mL, 3.0 mmol) and the mixture was stirred for 1 h at 50 °C. After usual workup, the resultant crude product was purified by column chromatography (hexane:AcOEt=6:1) to give 0.2914 g (0.6650 mmol) of the desired product 4gc in 67% yield.

mp. 103.8-105.1 °C. Rf=0.42 (hexane:AcOEt=4:1). ¹H NMR: δ 1.57 (9H, s), 2.51 (1H, d, J=5.1 Hz), 5.21 (1H, dt, J=17.7, 5.1 Hz), 7.22-7.26 (2H, m), 7.48 (2H, d, J=8.4 Hz). ¹³C NMR (acetone-d₆): δ 27.8, 71.5 (dd, J=28.5, 21.7Hz), 83.7, 122.0, 130.3, 133.7, 152.4, 152.7. ¹⁹F NMR: δ –128.21 (1F, dm, J=291.8 Hz), –127.43 (1F, dm, J=284.9 Hz), –126.72 (1F, dm, J=293.1 Hz), –123.4 (2F, m), –119.23 (1F, dm, J=280.4 Hz), –82.18 (3F, m). IR (KBr) ν 2990, 2942, 1924, 1732, 1600, 1510, 1375, 1315, 901 cm⁻¹. HRMS (FAB+, m/z): [M+H]⁺ Calcd for C₁₆H₁₅F₉O₄, 443.0899; Found, 443.0903.

2.9. General procedure for the deprotection of the allyl group (General procedure 3)

2.9.1. 2,2,3,3,4,4,4-Heptafluoro-1-(4-hydroxyxyphenyl)butan-1-ol (2ab)

To a 9 mL ACE GLASS® were added 4ab (0.0999 g, 0.0301 mmol), MeCN (1.5 mL), and NaI (1.8 mmol, 6.0 eq.). After charged with Ar gas, TMSCI (0.23 mL, 1.8 mmol, 6.0 eq.) was added to the
mixture and stirred at 50 °C for 1 h. The reaction mixture was quenched with sat. Na₂S₂O₃ aq. and extracted with Et₂O three times. After usual workup, the resultant crude product was purified by column chromatography (hexane:AcOEt=3:1) to give the desired product 2ab (0.0639 g, 0.219 mmol, 73%) as a white solid.

2.10. General procedure for the deprotection of the THP group (General procedure 4)

To a 50 mL round-bottomed flask were added 4fb (1.8814 g, 5.0000 mmol), MeOH (15 mL) and p-TsOH-H₂O (0.0978 g, 0.514 mmol, 10 mol%) and the mixture was stirred at r.t. for 1 h. Then, sat. NaHCO₃ aq. was added to the mixture and MeOH was removed in vacuo. The residue was extracted with Et₂O three times and the Et₂O layer was dried over anhydrous Na₂SO₄. The solvent was concentrated in vacuo and the precipitate was washed with hexane to give the desired product 2ab as white solid (1.3305 g, 4.5542 mmol, 91%).

mp. 107.1-109.8 °C. Rf=0.33 (hexane:AcOEt=3:1). ¹H NMR: δ 2.39 (1H, d, J=5.1 Hz), 4.93 (1H, s), 5.14 (1H, dt, J=17.4, 5.1 Hz), 6.85-6.90 (2H, m), 7.35 (2H, d, J=8.4 Hz). ¹³C NMR (DMSO-d₆): δ 69.8 (dd, J=29.1, 21.0 Hz), 114.9, 125.7, 129.6, 158.1. ¹⁹F NMR: δ −128.16 (1F, dm, J=284.9 Hz), −127.53 (1F, dm, J=295.4 Hz), −126.12 (1F, dm, J=298.5 Hz), −120.07 (1F, dm, J=282.7 Hz), −82.12 (3F, m). IR (KBr) ν 3270, 2817, 2697, 1906, 1604, 1421, 1125, 1015, 918, 807 cm⁻¹. HRMS (FAB+, m/z): [M+H]+ Calcd for C₁₉H₁₃F₂O₂, 293.0407; Found, 293.0444.

2.9.2. 2,2,2-Trifluoro-1-(3-hydroxyxyphenyl)ethan-1-ol (2aa) [8]

Following to the “General procedure 3” using 4aa (0.1447 g, 0.3077 mmol), 0.0415 g (0.216 mmol) of 2aa was obtained in 72% yield as a white solid.

Rf=0.30 (hexane:AcOEt=3:1). ¹H NMR (acetone-d₆): δ 5.06 (1H, qd, J=7.2, 5.4 Hz), 5.76 (1H, d, J=5.4 Hz), 6.85 (2H, d, J=8.4 Hz), 7.34 (2H, d, J=8.1 Hz), 8.68 (1H, s). ¹³C NMR (acetone-d₆): δ 72.2 (q, J=29.7 Hz), 115.7, 115.8, 126.1 (q, J=277.9 Hz), 129.8, 158.8. ¹⁹F NMR (acetone-d₆): δ −77.38 (d, J=6.8 Hz).

2.9.3. 2,2,3,3,4,4,5,5,6,6,7,7,7-Tridecafluoro-1-(4-hydroxyphenyl)heptan-1-ol (2ad)

Following to the “General procedure 3” using 4ad (0.1447 g, 0.3077 mmol), 0.0930 g (0.216 mmol) of 2ad was obtained in 70% yield as a white solid.

Following to the “General procedure 4” using 4fd (2.6315 g, 5.0000 mmol), 2.1012 g (4.7520 mmol) of 2ad was obtained in 95% yield as a white solid.

mp. 111.1-113.1 °C. Rf=0.33 (hexane:AcOEt=3:1). ¹H NMR: δ 2.43 (1H, d, J=5.1 Hz),
2.9.4. 2,2,3,3,4,4,4-Heptafluoro-1-(3-hydroxyxyphenyl)butan-1-ol (2bb)

Following to the “General procedure 3” using 4bb (0.0996 g, 0.300 mmol), 0.0779 g (0.268 mmol) of 2bb was obtained in 89% yield as a white solid.

mp. 84.2-86.3 °C. Rf=0.33 (hexane:AcOEt=3:1). 1H NMR: δ 3.71 (1H, s), 5.11 (1H, dd, J=17.7, 6.0 Hz), 6.87-6.91 (1H, dd, J=8.1, 2.7 Hz), 6.94 (1H, s), 6.99 (1H, d, J=7.2 Hz), 7.26 (H, t, J=7.2 Hz). 13C NMR (acetone-d6): δ 71.8 (dd, J=28.5, 21.0 Hz), 116.0, 116.8, 120.2, 130.0, 137.7, 158.2. 19F NMR: δ −125.29 (1F, dm, J=284.9 Hz), −126.14 (1F, d, J=285.2 Hz), −127.58 (1F, dm, J=290.9 Hz), −126.11 (1F, d, J=290.8 Hz), −119.84 (1F, dm, J=282.9 Hz), −82.14 ~ −82.07 (3F, m). IR (KBr) ν 3270, 2817, 2697, 1906, 1604, 1241, 1125, 1015, 918, 807 cm⁻¹. HRMS (FAB+, m/z): [M+H]+ Calcd for C₃₂H₂₆F₁₉O₂, 442.0423; Found, 442.0425.

2.9.5. 2,2,3,3,4,4,4-Heptafluoro-1-(2-hydroxyxyphenyl)butan-1-ol (2cb)

Following to the “General procedure 3” using 4cb (0.0997 g, 0.300 mmol), (0.0358 g, 0.1225 mmol) of 2cb was obtained in 41% yield as a white solid.

mp. 61.5-62.9 °C. Rf=0.30 (hexane:AcOEt=3:1). 1H NMR: δ 3.53 (1H, d, J=6.9 Hz), 5.36-5.47 (1H, m), 6.28 (s, 1H), 6.88 (1H, dd, J=7.5, 1.2 Hz), 6.96 (1H, td, J=7.5, 1.2 Hz), 7.20 (d, J=7.8 Hz), 7.26-7.32 (1H, m). 13C NMR (acetone-d6): δ 65.5 (dd, J=28.5, 21.0 Hz), 116.1, 120.4, 122.5, 130.2, 130.8, 156.1. 19F NMR: δ −128.16 (1F, dm, J=284.9 Hz), −127.53 (1F, dm, J=295.4 Hz), −126.12 (1F, d, J=298.5 Hz), −120.07 (1F, dm, J=282.7 Hz), −82.12 (3F, m). IR (KBr) ν 3257, 2924, 2854, 1615, 1600, 1461, 1351, 1224, 1116, 917 cm⁻¹. ν HRMS (FAB+, m/z): [M+H]+ Calcd for C₃₂H₂₆F₁₉O₂, 292.0329; Found, 292.0335.

2.11. 2,2,3,3,4,4,5,5,5-Nonafluoro-1-(4-hydroxyxyphenyl)pentan-1-ol (2ac)

To a 30 mL round-bottomed flask were added 4gc (0.4427 g, 1.0010 mmol) and MeOH (5 mL), where 10 M NaOH (1 mL) was dropped slowly at −10 °C, and the mixture was stirred for 1 h at room temperature. Then, the reaction mixture was quenched with 4 M HCl at −10 °C and the
mixture was extracted with Et₂O three times. The combined Et₂O layer was washed with brine and dried over anhydrous Na₂SO₄. The solvent was removed in vacuo to give 0.3393 g (0.9919 mmol) of the white solid!  

2ac which was found to be almost pure. (99% yield).

mp. 107.1-109.8 °C. Rf=0.40 (CHCl₃:acetone=8:1). ¹H NMR: δ 2.40 (1H, d, J=4.8 Hz), 4.94 (1H, brs), 5.15 (1H, dt, J=17.1, 5.4 Hz), 6.88 (2H, d, J=8.7 Hz), 7.36 (2H, d, J=8.4 Hz). ¹³C NMR (DMSO-d₆): δ 70.2 (dd, J=29.2, 21.7 Hz), 115.0, 125.8, 129.6, 158.2. ¹⁹F NMR: δ –128.13 (1F, dm, J=287.7 Hz), –127.34 (1F, dm, J=282.9 Hz), –126.76 (1F, dm, J=288.4 Hz), –123.48 (2F, m), –119.70 (1F, dm, J=285.2 Hz), –82.18 (3F, m). IR (KBr) ν 3426, 3038, 1901, 1615, 1519, 1456, 1353, 1135, 1038, 889 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C₁₁H₁₁F₉O₂, 342.0297; Found, 342.0268.

2.12. General procedure for the chlorination of the benzylic alcohols (General procedure 5)

2.12.1. 4-(1-Chloro-2,2,3,3,4,4,4-heptafluorobutyl)phenol (7b)

Following to the “General procedure 5”, DMF (0.0296 g, 0.409 mmol) and 2ac (0.6842 g, 2.000 mmol) were used for the synthesis of 7c.

Rf=0.58 (CH₂Cl₂). ¹H NMR: δ 5.06 (1H, brs), 5.22 (1H, t, J=12.3 Hz), 6.82-6.87 (2H, m), 7.34-7.37 (2H, m). ¹⁹F NMR: δ –127.27 (1F, dm, J=150.0 Hz), –127.16 (1F, dm, J=150.0 Hz), –121.56 (2F, m), –117.47 (1F, dm, J=277.0 Hz), –115.64 (1F, dm, J=274.7 Hz), –82.14 (3F, m).
2.12.3. 4-(1-Chloro-2,2,3,3,4,4,5,5,6,6,7,7,7-tridecafluorohexyl)phenol (7d)

Following to the “General procedure 5”, DMF (0.0296 g, 0.409 mmol) and 2ad (0.8843 g, 2.000 mmol) were used for the synthesis of 7d.

Rf=0.58 (CH₂Cl₂). 1H NMR: δ 5.10 (1H, brs), 5.22 (1H, t, J=12.6 Hz), 6.82-6.86 (2H, m), 7.34-7.37 (2H, m). 19F NMR: δ −127.49 (2F, m), −124.08 (2F, m), −123.13 (2F, m), −120.66 (2F, m), −117.31 (1F, dm, J=278.3 Hz), −115.61 (1F, dm, J=273.6 Hz), −82.07 (3F, m).

2.13. The reduction of the benzylic chlorides (General procedure 6)

2.13.1. 4-(2,2,3,3,4,4,4-Heptafluorobutyl)phenol (8b)

To a 30 mL two-necked round-bottomed flask equipped with reflux condenser containing NaBH₄ (0.1644 g, 3.998 mmol) was added THF (5 mL), where 7b prepared from 2ab (0.5843 g, 2.000 mmol) in THF (2 mL) was introduced slowly at −10 °C, and the mixture was stirred for 30 min at room temperature and then 1 h at 80 °C. The reaction mixture was quenched with 1 M HCl at 0 °C and the usual workup afforded the crude product which was purified by column chromatography (CH₂Cl₂) to give 0.5120 g (1.854 mmol) of the desired product 8b in 93% 2-step yield from 2ab as a white solid.

mp. 76.6-78.0 °C. Rf=0.43 (CH₂Cl₂). 1H NMR: δ 3.28 (2H, t, J=18.9 Hz), 4.84 (1H, s), 6.82 (2H, d, J=8.4 Hz), 7.16 (2H, d, J=8.1 Hz). 13C NMR (acetone-d₆): δ 36.2 (t, J=22.3 Hz), 116.3, 120.5, 133.0, 158.3. 19F NMR: δ −128.34 (2F, s), −124.89 (2F, m), −82.64 (3F, m). IR (KBr) ν 3403, 3049, 2947, 1899, 1616, 1518, 1449, 1348 1261, 845 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C₁₀H₇F₇O, 276.0380; Found, 276.0390.

2.13.2. 4-(2,2,3,3,4,4,5,5,5-Nonafluoropentyl)phenol (8c)

Following to the “General procedure 6”, 8c was prepared from 2ac (0.6842 g, 2.000 mmol) and 0.6347 g (1.946 mmol) of 8c was isolated in 97% 2-step yield from 2ac as a white solid.

mp. 72.1-74.8 °C. Rf=0.43 (CH₂Cl₂). 1H NMR: δ 3.29 (2H, t, J=18.9 Hz), 4.87 (1H, s), 6.83 (2H, d, J=8.4 Hz), 7.16 (2H, d, J=8.4 Hz). 13C NMR (acetone-d₆): δ 36.2 (t, J=21.7 Hz), 116.2, 120.5, 133.0, 158.2. 19F NMR: δ −127.25 (2F, m), −125.16 (2F, m), −114.99 (2F, m), −82.31 (3F, m). IR (KBr) ν 3409, 3058, 2956, 1898, 1615, 1517, 1450, 1351, 1245, 845 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C₁₀H₇F₉O, 326.0348; Found, 326.0354.
2.13.3. 4-(2,2,3,3,4,4,5,5,6,6,7,7,7-Tridecafluoroxy)phenol (8d)

Following to the “General procedure 6”, 8d was prepared from 2ad (0.8844 g, 2.000 mmol) and 0.7618 g (1.788 mmol) of 8d was isolated in 89% 2-step yield from 2ad as a white solid.

mp. 91.7-93.0 °C. Rf=0.43 (CH2Cl2). 1H NMR: δ 3.29 (2H, t, J=18.9 Hz), 4.85 (1H, s), 6.83 (2H, d, J=8.4 Hz), 7.16 (2H, d, J=8.4 Hz). 13C NMR (acetone-d6): δ 36.4 (t, J=21.7 Hz), 116.2, 120.4, 133.0, 158.3. 19F NMR: δ −127.42 (2F, m), −124.21 (4F, m), −123.15 (2F, m), −114.77 (2F, m), −82.07 (3F, m). IR (KBr) ν 3351, 3029, 2956, 1897, 1616, 1517, 1453, 1358, 1233, 788 cm⁻¹. HRMS (FAB+, m/z): [M]⁺ Calcd for C13H7F13O, 426.0284; Found, 426.0258.

2.14. The introduction of a polyfluoroalkoxy group (General procedure 7)

2.14.1. 4-(2,2,3,3,4,4,4-Heptafluoro-1-(2,2,2-trifluoroethoxy))butylphenol (9ab)

To a 30 mL two-necked round-bottomed flask equipped with reflux condenser containing NaH (55% dispersion in paraffin liquid, 0.1922 g, 4.4068 mmol) was added DME (2 mL), where 2,2,2-trifluoroethanol (0.4808 g, 4.806 mmol) in DME (3 mL) was introduced slowly and the reaction mixture was stirred for 30 min at the same temperature. Then, 7b prepared from 2ab (0.5843 g, 2.000 mmol) in DME (3 mL) was added slowly and the reaction mixture was stirred for 12 h at 80 °C. The reaction mixture was quenched with 1 M HCl at 0 °C and the mixture was extracted with Et2O three times. The usual workup afforded the crude product which was purified by column chromatography (CH2Cl2) to give 0.6741 g (1.8016 mmol) of the desired product 9ab in 90% 2-step yield from 2ab as a yellow solid.

mp. 73.2-75.1 °C. Rf=0.27 (hexane:CH2Cl2=1:2). 1H NMR: δ 3.71 (1H, dq, J=12.0, 8.4 Hz), 3.83 (1H, dq, J=12.0, 8.4 Hz), 4.89 (1H, dd, J=18.6, 3.3 Hz), 4.99 (1H, brs), 6.90 (2H, d, J=8.4 Hz), 7.22 (2H, d, J=8.4 Hz). 13C NMR (acetone-d6): δ 66.6 (q, J=34.1 Hz), 79.6 (dd, J=31.6, 20.4 Hz), 116.6, 121.6, 126.6 (q, J=276.1 Hz), 131.6, 160.1. 19F NMR: δ −128.53 (1F, dm, J=287.5 Hz), −128.38 (1F, dm, J=295.4 Hz), −126.15 (1F, dm, J=288.6 Hz), −117.95 (1F, dm, J=287.5 Hz), −82.20 (3F, m), −75.26 (3F, t, J=9.0 Hz). IR (KBr) v 3316, 3034, 2947, 2713, 2459, 2114, 1904, 1516, 1227, 945 cm⁻¹. HRMS (FAB+, m/z): [M+H]⁺ Calcd for C12H9F19O2, 375.0437; Found, 375.0480.

2.14.2. 4-(2,2,3,3,4,4,5,5,6,6,7,7,7-Tridecafluoroxy-1-(2,2,2-trifluoroethoxy)heptyl)phenol (9ad)

Following to the “General procedure 7”, 9ad was prepared from 2ad (0.8844 g, 2.000 mmol) and 0.9567 g (1.778 mmol) of 9ad was obtained in 89% 2-step yield from 7c as a
yellow solid.

mp. 83.2–85.6 °C. Rf=0.30 (hexane:AcOEt=3:1). 1H NMR: δ 3.70 (1H, dq, J=12.0, 8.4 Hz), 3.82 (1H, dq, J=12.0, 8.4 Hz), 4.92 (1H, dd, J=18.6, 4.2 Hz), 5.02 (1H, brs), 6.91 (2H, d, J=8.7 Hz), 7.32 (2H, d, J=8.7 Hz). 13C NMR (acetone-d6): δ 66.7 (q, J=35.0 Hz), 79.9 (dd, J=32.2, 21.1 Hz), 116.7, 121.7, 126.6 (q, J=277.2 Hz), 131.6, 160.3. 19F NMR: δ –128.30 (1F, dm, J=298.8 Hz), –127.27 (1F, dm, J=284.9 Hz), –126.75 (1F, dm, J=289.7 Hz), –124.86 (1F, dm, J=294.2 Hz), –124.23 (1F, dm, J=305.0 Hz), –123.46 (1F, dm, J=287.5 Hz), –122.95 (2F, m), –122.83 (1F, dm, J=292.0 Hz), –117.54 (1F, dm, J=289.7 Hz) –82.20 (3F, m), –75.30 (3F, t, J=9.0 Hz). IR (KBr) ν: 3392, 3044, 2944, 2710, 2466, 2149, 1901, 1516, 1223, 943 cm⁻¹. HRMS (FAB+, m/z): [M+H]⁺ Calcd for C₁₃H₁₂F₁₈O₂, 525.0342; Found, 525.0343.

2.14.3. 4-(2,2,3,3,4,4,4-Heptafluoro-1-(3,3,4,4,5,5,6,6,6-nonafluorohexyloxy)butyl)-phenol (9bb)

Following to the “General procedure 7”, 3,3,4,4,5,5,6,6,6-nonfluorohexan-1-ol (1.2682 g, 4.8021 mmol) was used instead of 2,2,2-trifluoroethanol and 0.7729 g (1.4744mmol) of 9bb was obtained in 74% 2-step yield from 2ab as a brown liquid.

Rf=0.27 (hexane:CH₂Cl₂:1:2). 1H NMR: δ 2.43 (2H, tt, J=18.6, 6.3 Hz), 3.57 (1H, dt, J=9.9, 6.3 Hz), 3.72 (1H, dt, J=9.9, 6.3 Hz), 4.70 (1H, dd, J=18.0, 3.3 Hz), 4.97 (1H, brs), 6.89 (2H, d, J=8.7 Hz), 7.30 (2H, d, J=8.4 Hz). 13C NMR (acetone-d6): δ 31.7 (t, J=21.0 Hz), 62.1 (t, J=4.3 Hz), 79.0 (dd, J=31.0, 20.4 Hz), 116.3, 122.6, 131.3, 159.8. 19F NMR: δ –128.41 (1F, dm, J=290.2 Hz), –128.34 (1F, dm, J=294.5 Hz), –127.39 (2F, m), –125.97 (1F, dm, J=285.2 Hz), –125.95 (2F, m), –117.80 (1F, dm, J=287.5 Hz), –115.09 (2F, m), –82.36 – –82.11 (6F, m). IR (CHCl₃) ν: 3337, 3023, 2900, 1614, 1516, 1425, 1220, 1136, 880, 760 cm⁻¹. HRMS (FAB+, m/z): [M⁺] Calcd for C₁₃H₁₂F₁₈O₂, 538.0420; Found, 538.0443.

2.14.4. 4-(2,2,3,3,4,4,4,5,5,6,6,7,7,7-Tridecafluoro-1-(3,3,4,4,5,5,6,6,6-nonfluorohexyloxy)heptyl)phenol (9bd)

Following to the “General procedure 7”, 3,3,4,4,5,5,6,6,6-nonfluorohexan-1-ol (1.2684 g, 4.803 mmol) and 7d prepared from 2ad (0.8843 g, 2.000 mmol) were used, and after purification by column chromatography (CH₂Cl₂), the obtained solid was washed with hexane to give 0.6352 g (0.9229 mmol) of the desired product 9bd in 46% 2-step yield from 2ad as a white solid.
mp. 90.0-90.5 °C. Rf=0.40 (hexane:AcOEt=3:1). ¹H NMR: δ 2.43 (2H, tt, J=18.3, 6.3 Hz), 3.57 (1H, dt, J=9.9, 6.3 Hz), 3.63 (1H, dt, J=9.9, 6.3 Hz), 4.73 (1H, dd, J=18.9, 3.3 Hz), 4.93 (1H, brs), 6.89 (2H, d, J=8.7 Hz), 7.31 (2H, d, J=8.1 Hz). ¹³C NMR (Acetone-d₆): δ 31.5 (t, J=21.1 Hz), 62.0 (t, J=4.0 Hz), 79.1 (dd, J=31.6, 21.0 Hz), 116.2, 122.5, 131.3, 159.7. ¹⁹F NMR: δ –128.27 (1F, dm, J=305.5 Hz), –127.42 (2F, m), –126.72 (1F, dm, J=297.9 Hz), –125.99 (2F, m), –125.96 (1F, dm, J=307.8 Hz), –124.80 (1F, dm, J=283.2 Hz), –124.25 (1F, dm, J=282.9 Hz), –123.54 (1F, dm, J=290.3 Hz), –123.41 (1F, dm, J=287.6 Hz), –122.86 (1F, dm, J=288.3 Hz), –122.26 (1F, dm, J=285.2 Hz), –117.35 (1F, dm, J=289.7 Hz), –115.09 (2F, m), –82.33 (3F, m), –82.11 (3F, m). IR (KBr) ν 3213, 2969, 2707, 2491, 1617, 1517, 1368, 1233, 1136, 878 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C₁₉H₁₉F₂₂O₂, 688.0324; Found, 688.0352.

2.15. 1-(Allyloxy)-4-(2,2,3,3,4,4,4-heptafluorobutyl)benzene (10)

To a 30 mL two-necked round-bottomed flask equipped with reflux condenser, K₂CO₃ (0.1970, 1.425 mmol), 8b (0.2762 g, 1.000 mmol) and acetone (4 mL/mmol) were introduced, where allyl bromide (0.12 mL, 1.4 mmol) was added. After stirring for 12 h under reflux temperature, the solvent was removed in vacuo where 1 M HCl was added and the mixture was extracted with Et₂O. After usual workup, the crude product was purified by column chromatography (hexane:AcOEt=1:40 to 20:1) to give the desired product 10 as a colorless liquid (0.3110 g, 0.9835 mmol, 98%).

Rf=0.53 (hexane:AcOEt=20:1). ¹H NMR: δ 3.29 (2H, t, J=18.6 Hz), 4.54 (2H, dt, J=5.1, 1.5 Hz), 5.30 (1H, ddt, J=10.7, 2.7, 1.5 Hz), 5.42 (1H, ddt, J=17.1, 2.7, 1.5 Hz), 6.06 (1H, ddt, J=17.1, 10.5, 5.4 Hz), 6.89-6.93 (2H, m), 7.20 (2H, d, J=8.4 Hz). ¹³C NMR: δ 36.0 (t, J=22.3 Hz), 68.8, 114.8, 117.7, 120.9, 131.9, 133.1, 158.6. ¹⁹F NMR: δ –125.54 (2F, m), –115.69 (2F, m), –81.76 (3F, t, J=9.0 Hz). IR (CHCl₃) ν 3013, 2938, 1614, 1514, 1353, 1667, 1171, 1115, 940, 849 cm⁻¹. HRMS (FAB+, m/z): [M]+ Calcd for C₁₉H₁₉F₇O, 316.0693; Found, 316.0726.

2.16. F-POSS (11b)

To a 10 mL two-necked round-bottomed were added 10 (0.3075 g, 0.9725 mmol), 11a [9] (0.0427 g, 0.101 mmol), and H₂PtCl₆·6H₂O (0.0054 g, 0.010 mmol, i-PrOH (0.10 mL) solution). After stirring for 18 h under 90 °C, the mixture was filtered with Celite (washed with Et₂O) and the solvent was removed in vacuo. The crude product was purified by column chromatography (hexane:AcOEt=10:1 to 6:1) to give the desired product 11b as a white solid (0.0886 g, 0.0302 mmol, 30%).
mp. 98.6-99.8 °C. Rf=0.21 (hexane:AcOEt=10:1).

\[^1\text{H} \text{NMR}: \delta 0.76 (16\text{H}, \text{m}), 1.87 (16\text{H}, \text{m}), 3.21 (16\text{H}, \text{t}, J=18.9 \text{ Hz}), 3.94 (16\text{H}, \text{t}, J=6.3 \text{ Hz}), 6.83 (16\text{H}, \text{d}, J=8.4 \text{ Hz}), 7.12 (16\text{H}, \text{d}, J=8.1 \text{ Hz}). \[^{13}\text{C} \text{NMR}: \delta 22.7, 35.9 (\text{t}, J=22.3 \text{ Hz}), 69.3, 114.4, 120.6, 131.8, 158.9. \[^{19}\text{F} \text{NMR}: \delta -128.66 (16\text{F}, \text{m}), -115.76 (16\text{F}, \text{m}), -81.88 (24\text{F}, \text{t}, J=9.3 \text{ Hz}). \text{IR (KBr)} \nu 3040, 2942, 2867, 2297, 1893, 1614, 1515, 1354, 1219, 1118 \text{ cm}^{-1}. \]  

Anal. Calcd for C\textsubscript{104}H\textsubscript{96}F\textsubscript{56}O\textsubscript{19}Si\textsubscript{8} C, 42.51; H, 3.29; F, 36.21; O, 10.35; Si, 7.65. Found: C, 42.72; H, 3.17.

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3. Spectral data
2-Phenylethyl 2,2,3,3,4,4,4-heptafluorobutyrate

$^1$H NMR

$^{13}$C NMR
1-{4-(Allyloxy)phenyl}-2,2,3,3,4,4,4-heptafluorobutan-1-one (3a)

$^1$H NMR

$^{13}$C NMR
1-{4-(Allyloxy)phenyl}-2,2,3,4,4,4-heptafluorobutan-1-ol (4ab)

$^1$H NMR

$^1$C NMR
1-{4-(Allyloxy)phenyl}-2,2,3,3,4,4,5,5,6,6,7,7,7-tridecafluoroheptan-1-ol (4ad)

$^1$H NMR

$^{13}$C NMR
1-(3-(Allyloxy)phenyl)-2,2,2-trifluoroethan-1-ol (4ba)

$^1$H NMR

\[ \text{structure} \]

$^1$C NMR

\[ \text{structure} \]
1-{3-(Allyloxy)phenyl}-2,2,3,3,4,4,4-heptafluorobutan-1-ol (4bb)

$^1$H NMR

$^1$C NMR
1-{2-(Allyloxy)phenyl}-2,2,2-trifluoroethan-1-ol (4ca)

$^{1}H$ NMR

$^{13}C$ NMR
1-[2-(Allyloxy)phenyl]-2,2,3,3,4,4,4-heptafluorobutan-1-ol (4cb)

\[ \text{O} \quad \text{OH} \]
\[ \text{C}_2 \text{F}_7 \]

\(^1H \text{ NMR}\)

\(^{13}C \text{ NMR}\)
2,2,3,3,4,4,4-Heptafluoro-1-(4-methoxyphenyl)butan-1-ol (4db)

$^1$H NMR

$^{13}$C NMR
$\text{2,2,3,3,4,4,4-Heptafluoro-1-(2-methoxyphenyl)butan-1-ol (4eb)}$

$^1\text{H NMR}$

$^1\text{C NMR}$

$^{13}\text{C NMR}$
2,2,3,3,4,4,4-Heptafluoro-1-[4-[(tetrahydro-2H-pyran-2-yl)oxy]phenyl]butan-1-ol (4fb)

$^1$H NMR

$^{13}$C NMR
2,2,3,3,4,4,5,5,6,6,7,7,7-Tridecafluoro-1-[4-[(tetrahydro-2H-pyran-2-yl)oxy]phenyl]-heptan-1-ol
(4fd)

$^1$H NMR

$^{13}$C NMR
Ethyl 4-[(1,1-dimethylethoxy)carbonyl]oxy]benzoate (6)

$^1$H NMR

$^{13}$C NMR
1-[(1,1-Dimethylethoxy)carbonyl]oxy]phenyl]-2,3,3,4,4,5,5,5-nonfluoropentan-1-one (3b)

$^1$H NMR

$^{13}$C NMR
1-[(1,1-Dimethylethoxy)carbonyl]oxy]phenyl]-2,2,3,4,4,5,5,5-nonafluoropentan-1-ol (4gc)

$\mathrm{^{1}H\ NMR}$

$\mathrm{^{13}C\ NMR}$
2,2,3,3,4,4,4-Heptafluoro-1-(4-hydroxyxyphenyl)butan-1-ol (2ab)

\[ ^1H\text{ NMR} \]

\[ ^{13}C\text{ NMR} \]

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-S35-
2,2,3,3,4,4,5,6,6,7,7,7-Tridecafluoro-1-(4-hydroxyphenyl)heptan-1-ol (2ad)

$^{1}$H NMR

$^{13}$C NMR
2,2,3,3,4,4,4-Heptafluoro-1-(3-hydroxyoxyphenyl)butan-1-ol (2bb)

$^1$H NMR

$^{13}$C NMR
2,2,3,3,4,4,4-Heptafluoro-1-(2-hydroxyxyphenyl)butan-1-ol (2cb)

$^1$H NMR

$^13$C NMR
2,2,3,3,4,4,5,5,5-Nonafluoro-1-(4-hydroxyphenyl)pentan-1-ol (2ac)

$^1$H NMR

$^13$C NMR
4-(2,2,3,4,4,4-Heptafluorobutyl)phenol (8b)

$^1$H NMR

$^1$C NMR

$^{13}$C NMR
4-(2,2,3,3,4,4,5,5,5-Nonafluoropentyl)phenol (8c)

$^1$H NMR

$^{13}$C NMR
4-(2,2,3,4,4,5,5,6,6,7,7,7-Tridecafluorohexyl)phenol (8d)

\[ \text{H NMR} \]

\[ \text{C}_{6}\text{F}_{13} \]

\[ \text{C NMR} \]

\[ \text{C}_{6}\text{F}_{13} \]
4-{2,2,3,4,4,4-Heptafluoro-1-(2,2,2-trifluoroethoxy)}butylphenol (9ab)

$^1$H NMR

$^{13}$C NMR
4-{2,2,3,4,4,5,5,6,6,7,7,7-Tridecafluoro-1-(2,2,2-trifluoroethoxy)heptyl}phenol (9ad)

$^{1}\text{H NMR}$

$^{13}\text{C NMR}$
4-{2,2,3,4,4,4-Heptafluoro-1-(3,3,4,4,5,5,6,6,6-nonafluorohexyloxy)butyl}phenol (9bb)

$^1$H NMR

$^{13}$C NMR
4-{2,2,3,4,4,4,5,6,6,6,6,7,7,7-Tridecafluoro-1-(3,3,4,4,5,5,6,6,7,7,7-nonafluoro-hexyloxy)heptyl}phenol (9bd)

$^1$H NMR

$^1$C NMR
1-(Allyloxy)-4-(2,2,3,3,4,4,4-heptafluorobutyl)benzene (10)

$^1$H NMR

$^{13}$C NMR
F-POSS (11b)

$^1$H NMR

$^1$C NMR