Supporting Information
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An Efficient Synthesis of Allenyl Perfluoroalkyl Ketones from Mono-1,2-addition/elimination Reactions of Allenoates with R_fMgX

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Supporting Information

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1. 4-Phenylbuta-2,3-dien-2-yl n-perfluorobutyl ketone (2a)

\[
\text{Ph} \quad \text{CO}_2\text{Et} \quad + \quad \text{n-C}_4\text{F}_9\text{MgX} \quad \text{anhydrous Et}_2\text{O} \quad \text{-80 °C to -70 °C, 30 min} \quad \text{-70 °C, 6 h} \quad \text{Ph} \quad \text{C}_4\text{F}_9-\text{n} \quad 2\text{a} \quad (74\%)
\]

**Method A:** To a dried Schlenk tube were added \( \text{n-C}_4\text{F}_9\text{I} \) (0.36 mL, \( d = 2.01 \text{ g/mL}, 0.72 \text{ g}, 2.09 \text{ mmol} \)) and 2.5 mL of anhydrous Et\(_2\)O. The resulting mixture was cooled to -80 °C in a cooling bath and a solution of EtMgBr (0.47 mL, 3.0 M in Et\(_2\)O, 1.41 mmol) was added dropwise at -80 °C with stirring. After the addition, 0.7 mL of anhydrous Et\(_2\)O was used to rinse the remaining EtMgBr. The resulting mixture was stirred for 70 min at this temperature. A solution of 1b (81.0 mg, 0.40 mmol) in 1 mL of anhydrous Et\(_2\)O was added dropwise at -80 °C with stirring. Then the mixture was allowed to warm up to -70 °C within 30 min and stirred at -70 °C for 6 h. The mixture was quenched with 5 mL of a saturated aqueous NH\(_4\)Cl solution at -70 °C. After being warmed up to rt naturally, the mixture was extracted with 20 mL \( \times 3 \) of Et\(_2\)O. The combined organic extracts were washed with 5 mL of brine and dried over anhydrous Na\(_2\)SO\(_4\). Filtration, evaporation, and chromatography on silica gel (eluent: petroleum ether (b.p. 60 ~ 90 °C)) afforded 2a (111.0 mg, 74%) as a liquid: \(^1\text{H NMR} \text{(300 MHz, CDCl}_3\text{)} \delta 7.42-7.23 \text{ (m, 5 H), 6.69 (q, } J = 2.6 \text{ Hz, 1 H), 2.03 (d, } J = 2.6 \text{ Hz, 3 H); } ^{13}\text{C NMR} \text{(75 MHz, CDCl}_3\text{)} \delta 217.1, 183.4 \text{ (t, } J = 23.9 \text{ Hz), 130.6, 129.0, 128.5, 127.7, 102.8, 98.8, 14.5; } ^{19}\text{F NMR} \text{(282 MHz, CDCl}_3\text{)} \delta -80.6 \sim -81.2 \text{ (m, 3 F), -113.5 \sim -114.0 \text{ (m, 2 F), -121.7 \sim -122.3 \text{ (m, 2 F), -125.1 \sim -125.7 \text{ (m, 2 F); MS (EI, 70 ev) } m/z (\%)} 377 (M}^+\text{+1, 3.89), 376 (M}^+, 24.69), 129 (100); IR \text{(neat, cm}^{-1}\text{) 3068, 3035, 2933,} \)

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1936, 1700, 1601, 1498, 1462, 1354, 1306, 1240, 1137, 1065, 1048, 1004; HRMS calcd for C_{15}H_{9}F_{9}O: 376.0510. Found: 376.0517.

A Large Scale Reaction:

4-phenylbuta-2,3-dien-2-yl n-perfluorobutyl ketone (2a)

\[
\text{Ph} = \text{CO}_2\text{Et} + n-C_4F_9\text{MgX} \xrightarrow{\text{anhydrous Et}_2\text{O}} \text{Ph} = \text{C}_4F_9-n \quad (83\%)
\]

An oven-dried three-necked round-bottom flask were charged with \(n-C_4F_9I\) (4.52 mL, \(d = 2.01\) g/mL, 9.09 g, 26.26 mmol) and 40 mL of anhydrous Et\(_2\)O. After the mixture was cooled to -80 °C in a cooling bath, a solution of EtMgBr (5.80 mL, 3.0 M in Et\(_2\)O, 17.4 mmol) was added dropwise at -80 °C with stirring within 15 min. After the addition, 10 mL of anhydrous Et\(_2\)O was used to rinse the remaining EtMgBr. The resulting mixture was stirred for 1.5 h at this temperature. A solution of 1b (1.0096 g, 5.0 mmol) in Et\(_2\)O (15 mL) was added dropwise with stirring within 5 min at -80 °C. The mixture was allowed to warm up to -70 °C within 30 min and stirred at -70 °C for 23 h monitored by TLC (petroleum ether/ethyl acetate = 40/1). The mixture was quenched with 15 mL of a saturated aqueous NH\(_4\)Cl solution at -70 °C. After the mixture was warmed up to rt naturally, 15 mL of H\(_2\)O was added. The organic layer was separated and the aqueous layer was extracted with 30 mL \(\times\) 3 of Et\(_2\)O. The combined organic extracts were washed with 10 mL of brine and dried over anhydrous
Na₂SO₄. Filtration, evaporation, and chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 80/1) of the crude product afforded 2a (1.5538 g, 83%) as a liquid.

The following compounds were prepared following Method A:

2. Octa-2,3-dien-2-yl n-perfluorobutyl ketone (2c)

\[
\begin{array}{c}
\text{n-C₄H₉} \quad \text{CO}_2\text{Et} \\
1\text{c}
\end{array} + \begin{array}{c}
\text{n-C₄F₉MgX} \\
3.5 \text{equiv}
\end{array} \xrightarrow{\text{anhydrous Et₂O}} \begin{array}{c}
\text{n-C₄H₉} \quad \text{CO}_2\text{C₄F₉-n} \\
2\text{c (66%)}
\end{array}
\]

The reaction of n-C₄F₉I (0.36 mL, \(d = 2.01 \text{ g/mL}, 0.72 \text{ g}, 2.09 \text{ mmol}) with EtMgBr (0.48 mL, 3.0 M in Et₂O, 1.44 mmol) in Et₂O (3.2 mL) at -80 °C afforded the Grignard reagent, which was reacted with 1c (72.1 mg, 0.40 mmol)/Et₂O (1 mL) at -70 °C for 15 h afforded 2c (92.4 mg, 66%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a liquid: ¹H NMR (300 MHz, CDCl₃) \(\delta\) 5.72-5.62 (m, 1 H), 2.19 (q, \(J = 7.2 \text{ Hz}, 2 \text{ H})\), 1.89 (d, \(J = 2.4 \text{ Hz}, 3 \text{ H}\), 1.53-1.30 (m, 4 H), 0.92 (t, \(J = 7.0 \text{ Hz}, 3 \text{ H}\); ¹³C NMR (75 MHz, CDCl₃) \(\delta\) 214.6, 184.0 (t, \(J = 23.6 \text{ Hz}\)), 99.5, 95.6, 30.7, 27.5, 22.1, 14.7, 13.7; ¹⁹F NMR (282 MHz, CDCl₃) \(\delta\) -81.0 ~ -81.2 (m, 3 F), -113.2 ~ -113.5 (m, 2 F), -122.1 ~ -122.5 (m, 2 F), -125.6 ~ -125.9 (m, 2 F); MS (EI, 70 ev) \(m/z\) (%) 356 (M⁺+1, 5.08), 355 (M⁺, 12.47), 313 (100); IR (neat, cm⁻¹) 2964, 2935, 2865, 1948, 1699, 1459, 1354, 1306, 1237, 1207, 1138, 1065, 1049, 1003; HRMS calcd for C₁₃H₁₃F₉O: 356.0823. Found: 356.0822.

3. Octa-2,3-dien-2-yl n-perfluorohexyl ketone (2d)

\[
\begin{array}{c}
\text{n-C₄H₉} \quad \text{CO}_2\text{Et} \\
1\text{c}
\end{array} + \begin{array}{c}
\text{n-C₆F₁₃MgX} \\
4.0 \text{ equiv}
\end{array} \xrightarrow{\text{anhydrous Et₂O}} \begin{array}{c}
\text{n-C₄H₉} \quad \text{C₆F₁₃-n} \\
2\text{d (63%)}
\end{array}
\]

\(\text{n-C₆F₁₃I (0.36 mL, } \text{d = 2.01 g/mL, 0.72 g, 2.09 mmol)}\) with EtMgBr (0.48 mL, 3.0 M in Et₂O, 1.44 mmol) in Et₂O (3.2 mL) at -70 °C afforded the Grignard reagent, which was reacted with 1c (72.1 mg, 0.40 mmol)/Et₂O (1 mL) at -70 °C for 15 h afforded 2d (92.4 mg, 66%) (eluent: petroleum ether(b.p. 30 ~ 60 °C)) as a liquid: ¹H NMR (300 MHz, CDCl₃) \(\delta\) 5.72-5.62 (m, 1 H), 2.19 (q, \(J = 7.2 \text{ Hz}, 2 \text{ H})\), 1.89 (d, \(J = 2.4 \text{ Hz}, 3 \text{ H}\), 1.53-1.30 (m, 4 H), 0.92 (t, \(J = 7.0 \text{ Hz}, 3 \text{ H}\); ¹³C NMR (75 MHz, CDCl₃) \(\delta\) 214.6, 184.0 (t, \(J = 23.6 \text{ Hz}\)), 99.5, 95.6, 30.7, 27.5, 22.1, 14.7, 13.7; ¹⁹F NMR (282 MHz, CDCl₃) \(\delta\) -81.0 ~ -81.2 (m, 3 F), -113.2 ~ -113.5 (m, 2 F), -122.1 ~ -122.5 (m, 2 F), -125.6 ~ -125.9 (m, 2 F); MS (EI, 70 ev) \(m/z\) (%) 356 (M⁺+1, 5.08), 355 (M⁺, 12.47), 313 (100); IR (neat, cm⁻¹) 2964, 2935, 2865, 1948, 1699, 1459, 1354, 1306, 1237, 1207, 1138, 1065, 1049, 1003; HRMS calcd for C₁₃H₁₃F₉O: 356.0823. Found: 356.0822.
The reaction of $n$-$C_6F_{13}I$ (0.52 mL, $d = 2.06$ g/mL, 1.07 g, 2.40 mmol) with EtMgBr (0.53 mL, 3.0 M in Et$_2$O, 1.59 mmol) in Et$_2$O (3.2 mL) at -80 °C afforded the Grignard reagent, which was reacted with 1c (73.4 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70 °C for 16 h afforded 2d (116.1 mg, 63 %) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a yellow liquid: $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 5.73-5.58 (m, 1 H), 2.19 (q, $J = 7.2$ Hz, 2 H), 1.89 (d, $J = 2.4$ Hz, 3 H), 1.53-1.30 (m, 4 H), 0.92 (t, $J = 7.2$ Hz, 3 H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 214.6, 184.0 (t, $J = 22.9$ Hz), 99.6, 95.6, 30.7, 27.5, 22.1, 14.7, 13.6; $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ -80.9 ~ -81.1 (m, 3 F), -113.0 ~ -113.4 (m, 2 F), -121.2 ~ -121.8 (m, 4 F), -122.8 ~ -123.2 (m, 2 F), -126.2 ~ -126.5 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 456 (M$^+$, 2.56), 95 (100); IR (neat, cm$^{-1}$) 2964, 2936, 2866, 1949, 1699, 1459, 1364, 1240, 1205, 1145, 1125, 1070, 1011; HRMS calcd for C$_{15}$H$_{13}$F$_{13}$O: 456.0759. Found: 456.0752.

4. Undeca-2,3-dien-2-yl $n$-perfluorobutyl ketone (2e)

\[
\begin{align*}
\text{CO}_2\text{Et} & \quad \text{EtMgBr} \\
\text{+} & \quad \text{Et}_2\text{O} \\
\text{3.5 equiv} & \quad \text{anhydrous Et}_2\text{O} \\
\text{3.5 equiv} & \quad \text{-80 °C to -70 °C, 30 min} \\
\text{-70 °C, 6 h} & \quad \text{n-C}_7\text{H}_{15} \\
\text{n-C}_4\text{F}_9\text{MgX} & \quad \text{O} \\
\text{1d} & \quad \text{Et}_2\text{O} \\
\text{2e (75%)} & \quad \text{n-C}_7\text{H}_{15} \end{align*}
\]

The reaction of $n$-$C_4F_9$I (0.36 mL, $d = 2.01$ g/mL, 0.72 g, 2.09 mmol) with EtMgBr (0.48 mL, 3.0 M in Et$_2$O, 1.44 mmol) in Et$_2$O (3.2 mL) at -80 °C afforded the Grignard reagent, which was reacted with 1d (88.9 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70 °C for 6 h afforded 2e (119.2 mg, 75%) (eluent: petroleum ether (b.p. 60 ~ 90 °C)) as a colorless liquid: $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 5.72-5.63 (m, 1 H), 2.17 (q, $J = 7.5$ Hz, 2 H), 1.89 (d, $J = 2.7$ Hz, 3 H), 1.53-1.40 (m, 2 H), 1.40-1.20 (m, 8 H), 0.89 (t, $J = 6.8$ Hz, 3
H), $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 214.6, 184.0 (t, $J = 23.4$ Hz), 99.5, 95.7, 31.7, 29.00, 28.96, 28.6, 27.8, 22.6, 14.8, 14.0; $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ -80.9 ~ -81.1 (m, 3 F), -113.1 ~ -113.5 (m, 2 F), -122.1 ~ -122.4 (m, 2 F), -125.5 ~ -125.8 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 398 (M$^+$, 0.76), 95 (100); IR (neat, cm$^{-1}$) 2960, 2932, 2860, 1948, 1699, 1458, 1354, 1307, 1237, 1207, 1138, 1065, 1007; HRMS calcd for C$_{16}$H$_{19}$F$_9$O: 398.1292. Found: 398.1293.

5. Undeca-2,3-dien-2-yl $n$-perfluorohexyl ketone (2f)

\[ \begin{align*}
\text{n-C}_7\text{H}_{15} & \quad \text{CO}_2\text{Et} \\
\text{n-C}_6\text{F}_{13}\text{MgX} & \quad \text{anhydrous Et}_2\text{O} \\
\text{4.0 equiv} & \quad -80 \degree \text{C to -70 \degree C, 30 min} \\
\text{-70 \degree C, 16 h} & \quad \text{n-C}_7\text{H}_{15} \quad \text{O} \\
\text{2f (68\%)} & \quad \text{C}_6\text{F}_{13}-n
\end{align*} \]

The reaction of $n$-C$_6$F$_{13}$I (0.52 mL, $d = 2.06$ g/mL, 1.07 g, 2.40 mmol) with EtMgBr (0.53 mL, 3.0 M in Et$_2$O, 1.59 mmol) in Et$_2$O (3.2 mL) at -80 °C afforded the Grignard reagent, which was reacted with 1d (90.2 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70 °C for 16 h afforded 2f (135.6 mg, 68%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a liquid: $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 5.73-5.60 (m, 1 H), 2.18 (q, $J = 7.4$ Hz, 2 H), 1.89 (d, $J = 2.7$ Hz, 3 H), 1.55-1.42 (m, 2 H), 1.40-1.20 (m, 8 H), 0.89 (t, $J = 6.8$ Hz, 3 H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 214.6, 184.0 (t, $J = 23.4$ Hz), 99.6, 95.6, 31.7, 29.02, 28.98, 28.6, 27.8, 22.6, 14.8, 14.0; $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ -80.8 ~ -81.0 (m, 3 F), -113.0 ~ -113.4 (m, 2 F), -121.1 ~ -121.7 (m, 4 F), -122.7 ~ -123.2 (m, 2 F), -126.1 ~ -126.4 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 498 (M$^+$, 0.92), 455 (M$^+$-C$_3$H$_7$, 6.34), 413 (M$^+$-C$_6$H$_{13}$, 55.02), 95 (100); IR (neat, cm$^{-1}$) 2960, 2932, 2860, 1948, 1699, 1459, 1364, 1316, 1240, 1206, 1145, 1125, 1070, 1016; HRMS calcd for C$_{18}$H$_{19}$F$_{13}$O: 498.1228. Found: 498.1225.
6. 1-Phenylbuta-2,3-dien-2-yl n-perfluorobutyl ketone (2g)

\[
\begin{align*}
\text{Bn} & \quad \text{CO}_2\text{Et} \quad + \quad \text{n-C}_4\text{F}_9\text{MgX} \\
\text{3.5 equiv} & \quad \text{anhydrous Et}_2\text{O} \quad \text{-80}\text{°C to -70}\text{°C, 30 min} \quad \text{-70}\text{°C, 16 h} \\
\text{Bn} & \quad \text{O} \quad \text{C}_4\text{F}_9\text{n} \quad \text{2g (58%)}
\end{align*}
\]

The reaction of \(\text{n-C}_4\text{F}_9\text{I}\) (0.36 mL, \(d = 2.01 \text{ g/mL}, 0.72 \text{ g}, 2.09 \text{ mmol}\)) with \(\text{EtMgBr}\) (0.48 mL, 3.0 M in \(\text{Et}_2\text{O}, 1.44 \text{ mmol}\)) in \(\text{Et}_2\text{O}\) (3.25 mL) at \(-80\text{ °C}\) afforded the Grignard reagent, which was reacted with \(\text{1e}\) (80.0 mg, 0.40 mmol)/\(\text{Et}_2\text{O}\) (1 mL) at \(-70\text{ °C}\) for 16 h afforded \(\text{2g}\) (86.1 mg, 58%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a yellow liquid: \(^1\text{H NMR (300 MHz, CDCl}_3)\ \delta 7.28-7.07\) (m, 5 H), 5.23 (t, \(J = 2.3\) Hz, 2 H), 3.53 (s, 2 H); \(^13\text{C NMR (75 MHz, CDCl}_3)\ \delta 218.5, 183.0\) (t, \(J = 24.1\) Hz), 137.6, 128.8, 128.5, 126.8, 104.0, 81.1, 34.1; \(^19\text{F NMR (282 MHz, CDCl}_3)\ \delta -80.9 ~ -81.2\) (m, 3 F), -113.2 ~ -113.4 (m, 2 F), -122.0 ~ -122.3 (m, 2 F), -125.5 ~ -125.8 (m, 2 F); MS (EI, 70 ev) \(m/z\) (%) 377 (M\(^+\)+1, 2.22), 376 (M\(^+\)), 91 (100); IR (neat, cm\(^{-1}\)) 3068, 3032, 2995, 2929, 1956, 1919, 1701, 1603, 1497, 1455, 1355, 1305, 1237, 1205, 1138, 1077, 1029; HRMS calcd for \(\text{C}_{13}\text{H}_9\text{F}_9\text{O}\): 376.0510. Found: 376.0499.

7. Hexa-1,2-dien-3-yl n-perfluorohexyl ketone (2h)

\[
\begin{align*}
\text{C}_3\text{H}_7\text{n} & \quad \text{CO}_2\text{Et} \quad + \quad \text{n-C}_6\text{F}_{13}\text{MgBr} \\
\text{3.5 equiv} & \quad \text{anhydrous Et}_2\text{O} \quad \text{-80}\text{°C to -70}\text{°C, 30 min} \quad \text{-70}\text{°C, 12 h} \\
\text{C}_3\text{H}_7\text{n} & \quad \text{O} \quad \text{C}_6\text{F}_{13}\text{n} \quad \text{2h (61%)}
\end{align*}
\]

The reaction of \(\text{n-C}_6\text{F}_{13}\text{I}\) (0.45 mL, \(d = 2.06 \text{ g/mL}, 0.93 \text{ g}, 2.08 \text{ mmol}\)) with \(\text{EtMgBr}\) (0.48 mL, 3.0 M in \(\text{Et}_2\text{O}, 1.44 \text{ mmol}\)) in \(\text{Et}_2\text{O}\) (3.2 mL) at \(-80\text{ °C}\) afforded the Grignard reagent, which was reacted with \(\text{1f}\) (60.7 mg, 0.40 mmol)/\(\text{Et}_2\text{O}\) (1 mL) at \(-70\text{ °C}\) for 16 h afforded \(\text{2h}\) (61%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a yellow liquid: \(^1\text{H NMR (300 MHz, CDCl}_3)\ \delta 7.28-7.07\) (m, 5 H), 5.23 (t, \(J = 2.3\) Hz, 2 H), 3.53 (s, 2 H); \(^13\text{C NMR (75 MHz, CDCl}_3)\ \delta 218.5, 183.0\) (t, \(J = 24.1\) Hz), 137.6, 128.8, 128.5, 126.8, 104.0, 81.1, 34.1; \(^19\text{F NMR (282 MHz, CDCl}_3)\ \delta -80.9 ~ -81.2\) (m, 3 F), -113.2 ~ -113.4 (m, 2 F), -122.0 ~ -122.3 (m, 2 F), -125.5 ~ -125.8 (m, 2 F); MS (EI, 70 ev) \(m/z\) (%) 377 (M\(^+\)+1, 2.22), 376 (M\(^+\)), 91 (100); IR (neat, cm\(^{-1}\)) 3068, 3032, 2995, 2929, 1956, 1919, 1701, 1603, 1497, 1455, 1355, 1305, 1237, 1205, 1138, 1077, 1029; HRMS calcd for \(\text{C}_{13}\text{H}_9\text{F}_9\text{O}\): 376.0510. Found: 376.0499.
°C for 12 h afforded 2h (102.8 mg, 61%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a liquid: $^1$H NMR (300 MHz, CDCl$_3$) δ 5.35 (t, $J = 2.6$ Hz, 2 H), 2.32-2.21 (m, 2 H), 1.55-1.40 (m, 2 H), 0.94 (t, $J = 7.4$ Hz, 3 H); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 218.1, 183.6 (t, $J = 23.9$ Hz), 103.8, 80.5, 29.3, 20.6, 13.4; $^{19}$F NMR (282 MHz, CDCl$_3$) δ -80.8 ~ -81.1 (m, 3 F), -112.9 ~ -113.2 (m, 2 F), -121.1 ~ -121.8 (m, 2 F), -121.4 ~ -121.6 (m, 2 F), -122.8 ~ -123.1 (m, 2 F), -126.1 ~ -126.4 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 429 (M$^{+}$+1, 1.02), 428 (M$^+$, 7.14), 109 (100); IR (neat, cm$^{-1}$) 2965, 2935, 2877, 1956, 1922, 1702, 1460, 1365, 1315, 1240, 1205, 1146, 1126, 1092, 1056; HRMS calcd for C$_{13}$H$_9$F$_{13}$O: 428.0446. Found: 428.0444.

8. 3-Phenylpenta-1,2-dienyl n-perfluorobutyl ketone (2i)

The reaction of n-C$_4$F$_9$I (0.41 mL, $d = 2.01$ g/mL, 0.82 g, 2.38 mmol) with EtMgBr (0.53 mL, 3.0 M in Et$_2$O, 1.59 mmol) in Et$_2$O (3.2 mL) at -80 °C afforded the Grignard reagent, which was reacted with The reaction of 1g (86.1 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70 °C for 21 h afforded 2i (82.2 mg, 53%) as a yellow liquid: $^1$H NMR (300 MHz, CDCl$_3$) δ 7.44-7.27 (m, 5 H), 6.53 (t, $J = 3.3$ Hz, 1 H), 2.73-2.55 (m, 2 H), 1.18 (t, $J = 7.5$ Hz, 3 H); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 217.9, 182.0 (t, $J = 24.8$ Hz), 132.3, 128.9, 128.5, 126.6, 114.1, 94.0, 23.3, 11.9; $^{19}$F NMR (282 MHz, CDCl$_3$) δ -80.9 ~ -81.2 (m, 3 F), -118.0 ~ -118.3 (m, 2 F), -122.7 ~ -123.0 (m, 2 F), -125.6 ~ -125.9 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 391 (M$^{+}$+1, 5.48), 390 (M$^+$, 30.29), 128 (100); IR (neat, cm$^{-1}$) 2976,
2940, 1932, 1708, 1596, 1452, 1402, 1354, 1237, 1137, 1080, 1013; HRMS calcd for C_{16}H_{11}F_{9}O: 390.0666. Found: 390.0670. According to the $^1$H NMR analysis of the crude reaction mixture there was 23% of 1g remaining.

9. 4,4-Pentamethylenebuta-2,3-dien-2-yl $n$-perfluorobutyl keone (2j)

![Chemical structure of 2j](image)

The reaction of $n$-C$_4$F$_9$I (0.36 mL, $d = 2.01$ g/mL, 0.72 g, 2.09 mmol) with EtMgBr (0.48 mL, 3.0 M in Et$_2$O, 1.44 mmol) in Et$_2$O (3.25 mL) at -80 °C afforded the Grignard reagent, which was reacted with 1h (77.6 mg, 0.40 mmol)/Et$_2$O (1 mL) at -60 °C for 17 h afforded 2j (109.6 mg, 74%) (eluuent: petroleum ether (b.p. 60 ~ 90 °C)) as a liquid: $^1$H NMR (300 MHz, CDCl$_3$) δ 2.33-2.14 (m, 4 H), 1.86 (s, 3 H), 1.78-1.45 (m, 6 H); $^{13}$C NMR (75 MHz, CDCl$_3$) δ 210.0, 184.1 (t, $J = 22.9$ Hz), 106.6 (t, $J = 2.0$ Hz), 97.7, 29.9, 26.2, 25.5, 15.0; $^{19}$F NMR (282 MHz, CDCl$_3$) δ -81.0 ~ -81.3 (m, 3 F), -113.4 (t, $J = 12.3$ Hz, 2 F), -122.2 ~ -122.5 (m, 2 F), -125.5 ~ -125.8 (m, 2 F); MS (El, 70 ev) m/z (%) 369 (M$^+$ +1, 4.09), 368 (M$^+$, 23.63), 121 (100); IR (neat, cm$^{-1}$) 2937, 2860, 1950, 1695, 1450, 1354, 1306, 1236, 1168, 1137, 1065, 1049, 1009; HRMS calcd for C$_{14}$H$_{13}$F$_{9}$O: 368.0823. Found: 368.0824.

10. 4,4-Pentamethylenebuta-2,3-dien-2-yl $n$-perfluorohexyl keone (2k)

![Chemical structure of 2k](image)
The reaction of $n$-C$_6$F$_{13}$I (0.54 mL, $d = 2.06$ g/mL, 1.11 g, purity: 98%, 2.44 mmol) with EtMgBr (0.54 mL, 3.0 M in Et$_2$O, 1.62 mmol) in Et$_2$O (3.2 mL) at -80°C afforded the Grignard reagent, which was reacted with 1h (77.0 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70°C for 16.5 h afforded 2k (102.0 mg, 55%) (eluent: petroleum ether (b.p. 60 ~ 90°C)) as a yellow liquid: $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 2.33-2.14 (m, 4 H), 1.87 (s, 3 H), 1.78-1.45 (m, 6 H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 210.0, 184.1 (t, $J = 22.4$ Hz), 106.5 (t, $J = 2.0$ Hz), 97.7, 29.9, 26.2, 25.5, 15.0; $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ -81.0 (t, $J = 9.9$ Hz, 3 F), -113.3 (t, $J = 13.3$ Hz, 2 F), -121.2 ~ -121.7 (m, 4 F), -122.8 ~ -123.2 (m, 2 F), -126.1 ~ -126.5 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 469 (M$^+$+1, 2.97), 468 (M$, 17.39$), 121 (100); IR (neat, cm$^{-1}$) 2937, 2861, 1950, 1696, 1450, 1363, 1345, 1319, 1239, 1144, 1125, 1069, 1017; HRMS calcd for C$_{16}$H$_{13}$F$_{13}$O: 468.0759. Found: 468.0760.

11. 4-Phenylhexa-2,3-dien-2-yl $n$-perfluorobutyl ketone (2l)

![Chemical structure](https://example.com/structure.png)

The reaction of $n$-C$_4$F$_9$I (0.36 mL, $d = 2.01$ g/mL, 0.72 g, 2.09 mmol) with EtMgBr (0.48 mL, 3.0 M in Et$_2$O, 1.44 mmol) in Et$_2$O (3.2 mL) at -80°C afforded the Grignard reagent, which was reacted with 1i (91.8 mg, 0.40 mmol)/Et$_2$O (1 mL) at -70°C for 16 h afforded 2l (114.1 mg, 71%) (eluent: petroleum ether (b.p. 60 ~ 90°C)) as a colorless liquid: $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.35-7.19 (m, 5 H), 2.64-2.46 (m, 2 H), 1.95 (s, 3 H), 1.10 (t, $J = 7.5$ Hz, 3 H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 215.6, 183.8 (t, $J = 23.6$ Hz), 133.3, 128.8, 128.2, 126.5, 112.3, 102.5, 23.5, 14.9, 11.9; $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ -81.0 (t, $J = 9.9$ Hz, 3 F), -113.3 (t, $J = 13.3$ Hz, 2 F), -121.2 ~ -121.7 (m, 4 F), -122.8 ~ -123.2 (m, 2 F), -126.1 ~ -126.5 (m, 2 F); MS (EI, 70 ev) $m/z$ (%) 469 (M$^+$+1, 2.97), 468 (M$, 17.39$), 121 (100); IR (neat, cm$^{-1}$) 2937, 2861, 1950, 1696, 1450, 1363, 1345, 1319, 1239, 1144, 1125, 1069, 1017; HRMS calcd for C$_{16}$H$_{13}$F$_{13}$O: 468.0759. Found: 468.0760.
CDCl₃) δ -80.9 ~ -81.1 (m, 3 F), -113.5 ~ -113.8 (m, 2 F), -122.0 ~ -122.3 (m, 2 F),
-125.3 ~ -125.6 (m, 2 F); MS (EI, 70 ev) m/z (%) 405 (M⁺+1, 7.07), 404 (M⁺, 37.31),
235 (100); IR (neat, cm⁻¹) 2976, 2937, 1931, 1699, 1495, 1458, 1353, 1303, 1237, 1207,

12. 4-Phenylhexa-2,3-dien-2-yl n-perfluorohexyl ketone (2m)

\[
\begin{array}{c}
\text{Ph} & \text{Et} \\
\text{CO₂Et} & \text{C₆F₁₃-MgX}
\end{array}
\rightarrow
\begin{array}{c}
\text{Ph} & \text{Et} \\
\text{O} & \text{C₆F₁₃-}⁻\text{n}
\end{array}
\]

The reaction of n-C₆F₁₃I (0.52 mL, d = 2.06 g/mL, 1.07 g, 2.40 mmol) with
EtMgBr (0.53 mL, 3.0 M in Et₂O, 1.59 mmol) in Et₂O (3.2 mL) at -80 °C afforded the
Grignard reagent, which was reacted with 1i (92.2 mg, 0.40 mmol)/Et₂O (1 mL) at -70
°C for 16.5 h afforded 2m (172.4 mg, 85 %) (eluent: petroleum ether (b.p. 60 ~ 90 °C))

as a liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.42-7.25 (m, 5 H), 2.70-2.55 (m, 2 H), 2.02
(s, 3 H), 1.17 (t, J = 7.2 Hz, 3 H); ¹³C NMR (75 MHz, CDCl₃) δ 215.6, 183.8 (t, J =
23.4 Hz), 133.3, 128.8, 128.2, 126.5, 112.3 (t, J = 2.1 Hz), 102.6, 23.6, 14.9, 11.9; ¹⁹F
NMR (282 MHz, CDCl₃) δ -80.8 ~ -81.0 (m, 3 F), -113.5 (t, J = 12.7 Hz, 2 F), -121.1 ~
-121.5 (m, 4 F), -122.8 ~ -123.1 (m, 2 F), -126.1 ~ -126.4 (m, 2 F); MS (EI, 70 ev) m/z
(%) 505 (M⁺+1, 4.96), 504 (M⁺, 23.64), 235 (100); IR (neat, cm⁻¹) 2976, 2938, 2884,
1932, 1699, 1598, 1496, 1459, 1364, 1240, 1203, 1144, 1069, 1008; HRMS calcd for
C₁₉H₁₃F₁₃O: 504.0759. Found: 504.0759.

13. Dodeca-8,9-diencyl n-perfluorobutyl ketone (2o)
The reaction of \( n\text{-C}_4\text{F}_9\text{I} \) (0.36 mL, \( d = 2.01 \text{ g/mL}, 0.72 \text{ g}, 2.09 \text{ mmol} \)) with \( \text{EtMgBr} \) (0.48 mL, 3.0 M in Et\(_2\)O, 1.44 mmol) in Et\(_2\)O (3.25 mL) at -80 °C afforded the Grignard reagent, which was reacted with \( 1\text{k} \) (83.4 mg, 0.40 mmol)/Et\(_2\)O (1 mL) at -70 °C for 16 h afforded \( 2\text{o} \) (122.1 mg, 77%) (eluent: petroleum ether (b.p. 30 ~ 60 °C)) as a colorless liquid: \(^{1}\text{H NMR} (300 \text{ MHz, CDCl}_3) \delta 5.18-5.03 \text{ (m, 2 H), 2.80 \text{ (t, } J = 6.9 \text{ Hz, 2 H), 2.34-2.22 \text{ (m, 2 H), 1.96-1.81 \text{ (m, 2 H), 1.39-1.11 \text{ (m, 8 H), 0.81 \text{ (t, } J = 6.6 \text{ Hz, 3 H})}, \) \( ^{13}\text{C NMR} (75 \text{ MHz, CDCl}_3) \delta 203.6, 193.2 \text{ (t, } J = 26.0 \text{ Hz), 93.6, 88.5, 36.8, 31.7, 29.1, 28.82, 28.76, 22.6, 21.3, 14.0; \) \( ^{19}\text{F NMR} (282 \text{ MHz, CDCl}_3) \delta -80.9 \sim -81.3 \text{ (m, 3 F), -120.4 \sim -120.7 \text{ (m, 2 F), -123.2 \sim -123.5 \text{ (m, 2 F), -125.8 \sim -126.1 \text{ (m, 2 F); MS (EI, 70 ev) } m/z (\%) 398 (M^+, 0.66), 109 (100); IR (neat, cm}^{-1}) 2960, 2930, 2859, 1965, 1759, 1459, 1402, 1355, 1237, 1138, 1085; \) HRMS calcd for \( \text{C}_{16}\text{H}_{19}\text{F}_{9}\text{O} \): 398.1292. Found: 398.1300.

**1. 4-Phenylbuta-2,3-dien-2-yl \( n\text{-perfluorohexyl ketone (2b)} \)**

\[ \text{Ph} - \text{C}\equiv\text{C} - \text{CH} = \text{CH} - \text{CO}_2\text{Et} + \text{PhMgBr} \rightarrow \text{Ph} - \text{C}\equiv\text{C} - \text{CH} = \text{CH}-\text{C}\equiv\text{C} - \text{C}_8\text{F}_{13} - \text{n} \]

**Method B:** To a dried Schlenk tube were added \( n\text{-C}_8\text{F}_{13}\text{I} \) (0.45 mL, \( d = 2.06 \text{ g/mL}, 0.93 \text{ g}, 2.09 \text{ mmol} \)) and 2.5 mL of anhydrous Et\(_2\)O. The resulting mixture was cooled to -80 °C in a cooling bath and a solution of PhMgBr (0.48 mL, 3.0 M in Et\(_2\)O, 1.44 mmol) was added dropwise at -80 °C with stirring within 5 min. After the addition, 0.7 mL of
anhydrous Et₂O was used to rinse the remaining PhMgBr. Then, the resulting mixture was stirred for 85 min at this temperature. A solution of 1b (80.3 mg, 0.40 mmol) in 1 mL of anhydrous Et₂O was added dropwise at -80 °C with stirring. Then the mixture was allowed to warm up to -70 °C within 30 min and stirred at -70 °C for 16 h. The mixture was quenched with 5 mL of a saturated aqueous NH₄Cl solution at -70 °C. After being warmed up to rt naturally, the mixture was extracted with 20 mL × 3 of Et₂O. The combined organic extracts were washed with 5 mL of brine and dried over anhydrous Na₂SO₄. After filtration, evaporation of the solvent, chromatography on silica gel (eluent: petroleum ether (b.p. 60 ~ 90 °C)) afforded 2b (132.1 mg, 70%) as a yellow liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.44-7.24 (m, 5 H), 6.69 (m, 1 H), 2.03 (d, J = 2.3 Hz, 3 H); ¹³C NMR (75 MHz, CDCl₃) δ 217.1, 183.4 (t, J = 23.9 Hz), 130.5, 129.0, 128.5, 127.7, 102.8, 98.7, 14.6; ¹⁹F NMR (282 MHz, CDCl₃) δ -80.8 ~ -81.0 (m, 3 F), -113.5 ~ -113.8 (m, 2 F), -121.1 ~ -121.7 (m, 4 F), -122.7 ~ -123.1 (m, 2 F), -126.1 ~ -126.4 (m, 2 F); MS (EI, 70 ev) m/z (%) 477 (M⁺+1, 4.78), 476 (M⁺, 25.60), 129 (100); IR (neat, cm⁻¹) 3035, 2934, 1936, 1703, 1600, 1498, 1461, 1364, 1315, 1240, 1205, 1145, 1071, 1015. HRMS calcd for C₁₇H₉F₁₃O: 476.0446. Found: 476.0447.

2. 1,1-Diphenylhexa-1,2-dien-3-yl n-perfluorobutyl ketone (2n)

Following Method B: The reaction of n-C₄F₉I (0.36 mL, d = 2.01 g/mL, 0.72 g, 2.09 mmol)/Et₂O (3.2 mL) with PhMgBr (0.48 mL, 3.0 M in Et₂O, 1.44 mmol) at -80°
afforded the Grignard reagent, which was reacted with 1j (122.3 mg, 0.40 mmol)/Et₂O (1 mL) at -70 °C for 25 h afforded 2n (159.7 mg, 83%) (elucent: petroleum ether (b.p. 60 ~ 90 °C)) as a colorless liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.45-7.28 (m, 10 H), 2.45 (t, J = 7.8 Hz, 2 H), 1.65-1.49 (m, 2 H), 0.93 (t, J = 7.4 Hz, 3 H); ¹³C NMR (75 MHz, CDCl₃) δ 215.4, 183.2 (t, J = 23.9 Hz), 133.7, 128.8, 128.4, 114.7 (t, J = 2.0 Hz), 106.5, 30.7, 20.9, 13.7; ¹⁹F NMR (282 MHz, CDCl₃) δ -81.0 ~ -81.1 (m, 3 F), -114.0 ~ -114.3 (m, 2 F), -121.9 ~ -122.2 (m, 2 F), -125.3 ~ -125.6 (m, 2 F); MS (EI, 70 ev) m/z (%) 481 (M⁺+1, 7.74), 480 (M⁺, 32.04), 233 (100); IR (neat, cm⁻¹) 3062, 2964, 2934, 2876, 1926, 1699, 1599, 1494, 1454, 1354, 1237, 1202, 1138, 1100, 1075, 1029; HRMS calcd for C₂₃H₁₇F₉O: 480.1136. Found: 480.1135.

Synthetic application of 4-phenylbuta-2,3-dien-2-yl n-perfluorobutyl ketone (2a):

1. 3-Methyl-2-(n-perfluorobutyl)-5-phenylpenta-3,4-dien-2-ol (7a)

![Chemical structure](image)

To a dried Schlenk tube were added 2a (75.4 mg, 0.20 mmol) and 2.0 mL of anhydrous Et₂O. After the mixture was cooled to -60 °C in a cool bath, a solution of CH₃Li (0.2 mL, 1.6 M in Et₂O, 0.32 mmol) was added dropwise at -60 °C with stirring for 19 h as monitored by TLC (petroleum ether/ethyl acetate = 5/1). The mixture was quenched with 5 mL of a saturated aqueous NH₄Cl solution at -60 °C. After warming up to rt naturally, the organic layer was separated and the aqueous layer was extracted with 20 mL × 3 of Et₂O. The combined organic extracts were washed with 5 mL of
brane and dried over anhydrous Na₂SO₄. Filtration, evaporation, and chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 40/1) afforded 7a (62.9 mg, 80%) as a colorless liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.39-7.20 (m, 5 H), 6.52-6.42 (m, 1 H), [2.66 (s, 0.28 H), 2.64 (s, 0.72 H), dr = 26/74, 1 H], 1.97 (t, J = 1.4 Hz, 3 H), [1.67 (s, 0.78 H), 2.64 (s, 2.49 H), dr = 26/74, 3 H]; MS (EI, 70 ev) m/z (%) 393 (M⁺+1, 2.69), 392 (M⁺, 16.41), 129 (100); IR (neat, cm⁻¹) 3544, 3032, 2935, 1952, 1600, 1498, 1461, 1378, 1353, 1236, 1134, 1072, 1017; Anal. Calcd for C₁₆H₁₃F₉O: C 48.99, H 3.34. Found: C 49.34, H 3.48.

2. 3-Methyl-4-(n-perfluorobutyl)-1-phenylocta-1,2-dien-4-ol (7b)

Following the procedure for the preparation of 7a, the reaction of 2a (94.8 mg, 0.25 mmol)/anhydrous Et₂O (2.5 mL) with n-BuLi (0.16 mL, 2.5 M in n-hexanes, 0.4 mmol) at -60 °C for 18 h afforded 7b (76.2 mg, 70%) (eluent: petroleum ether/ethyl acetate = 100/1 ~ 40/1) as a colorless liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.37-7.21 (m, 5 H), [6.53 (q, J = 2.7 Hz, 0.5 H), 6.47 (q, J = 3.0 Hz, 0.5 H), dr = 1/1], [2.57 (s, 0.5 H), 2.52 (s, 0.5 H), dr = 1/1], 2.00-1.80 (m, 5 H), 1.64-1.16 (m, 4 H), [0.99 (t, J = 7.2 Hz, 1.5 H), 0.94 (t, J = 7.2 Hz, 1.5 H), dr = 1/1]; MS (EI, 70 ev) m/z (%) 434 (M⁺, 3.01), 129 (100); IR (neat, cm⁻¹) 3543, 3033, 2963, 2936, 2874, 1950, 1600, 1498, 1463, 1381, 1348, 1235, 1134, 1055, 1002; Anal. Calcd for C₁₉H₁₉F₉O: C 52.54, H 4.41. Found: C 53.15, H 4.52.
3. 4-Allyl-3-methyl-2-(n-perfluorobutyl)-5-phenylfuran (8a)

\[
\text{Ph} \quad \text{C}_4\text{F}_9\text{-}n \quad + \quad \text{Br} \quad \text{C}_4\text{F}_9\text{-}n \quad \xrightarrow{\text{PdCl}_2 (5 \text{ mol\%})} \quad \text{Ph} \quad \text{C}_4\text{F}_9\text{-}n
\]

To a reaction tube was added 2a (76.2 mg, 0.20 mmol), allyl bromide (128.2 mg, 1.0 mmol, purity: 97%), 2 mL of DMA, and PdCl\(_2\) (2.2 mg, 0.01 mmol) at rt. Then the resulting mixture was stirred at 50 °C for 20.5 h as monitored by TLC (petroleum). After the reaction was complete, the mixture was quenched with 5 mL of water. The aqueous layer was extracted with 15 mL × 5 of Et\(_2\)O and dried over anhydrous Na\(_2\)SO\(_4\). Filtration, evaporation, and chromatography on silica gel (eluent: \(n\)-hexane) of the crude product afforded 8a (69.8 mg, 83%) as a colorless liquid: \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.64-7.55 (m, 2 H), 7.47-7.31 (m, 3 H), 6.10-5.94 (m, 1 H), 5.21-5.11 (m, 1 H), 5.07-4.95 (m, 1 H), 3.40-3.32 (m, 2 H), 2.12 (t, \(J = 2.3\) Hz, 3 H); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 152.3, 134.6, 134.4 (t, \(J = 29.6\) Hz), 130.0, 128.7, 128.4, 127.8, 126.3, 119.6, 116.1, 27.8, 8.0; \(^{19}\)F NMR (282 MHz, CDCl\(_3\)) \(\delta\) -80.9 ~ -81.2 (m, 3 F), -110.9 ~ -111.2 (m, 2 F), -123.8 ~ -124.1 (m, 2 F), -126.3 ~ -126.6 (m, 2 F); MS (EI, 70 ev) \(m/z\) (%): 417 (M\(^+\)1, 8.38), 416 (M\(^+\), 43.60), 247 (100); IR (neat, cm\(^{-1}\)) 3085, 3064, 2930, 1640, 1582, 1494, 1448, 1415, 1352, 1236, 1206, 1135, 1101, 1075, 1030; HRMS calcd for C\(_{18}\)H\(_{13}\)F\(_9\)O: 416.0823. Found: 416.0822.

4. 3-Methyl-2-n-perfluorobutyl-5-phenylfuran (8b)

\[
\text{Ph} \quad \text{C}_4\text{F}_9\text{-}n \quad \xrightarrow{\text{AuCl}_3 (5 \text{ mol\%})} \quad \text{Ph} \quad \text{C}_4\text{F}_9\text{-}n
\]

S16
To a dried Schlenk tube was added 2a (112.1 mg, 0.30 mmol), 1.5 mL of anhydrous CH₂Cl₂, and AuCl₃ (4.5 mg, 5 mol%) under the atmosphere of N₂ at rt. The resulting mixture was stirred for 24 h at rt as monitored by TLC (petroleum) followed by the addition of 20 mL of Et₂O. Evaporation, and purification by flash chromatography on silica gel (eluent: petroleum ether (b.p. 60 ~ 90 °C)) afforded 8b (103.4 mg, 92%) as a colorless liquid: ¹H NMR (300 MHz, CDCl₃) δ 7.72-7.62 (m, 2 H), 7.45-7.27 (m, 3 H), 6.56 (s, 1 H), 2.21 (t, J = 2.4 Hz, 3 H); ¹³C NMR (75 MHz, CDCl₃) δ 155.8, 134.8 (t, J = 31.7 Hz), 129.4, 128.8, 128.7, 127.6, 124.4, 109.4, 10.0; ¹⁹F NMR (282 MHz, CDCl₃) δ -80.9 ~ -81.2 (m, 3 F), -110.9 ~ 111.1 (m, 2 F), -123.8 ~ -124.1 (m, 2 F), -126.3 ~ -126.6 (m, 2 F); MS (EI, 70 ev) m/z (%) 377 (M⁺+1, 7.99), 376 (M⁺, 48.23), 207 (100); IR (neat, cm⁻¹) 3039, 2939, 1626, 1551, 1488, 1451, 1401, 1351, 1236, 1206, 1135, 1087, 1056, 1005; HRMS calcd for C₁₅H₉F₉O: 376.0510. Found: 376.0509.
References:

