Oxidative Radical Addition−Chlorination of Alkenes to access 1,1-Dichloroalkanes from Simple Reagents

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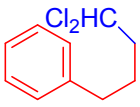
General Information. All the reactions were carried out at 70 °C for 12 h in a round-bottom flask equipped with a magnetic stir bar. Unless otherwise stated, all reagents and solvents were purchased from commercial suppliers and used without further purification. ^{1}H NMR and ^{13}C NMR spectra were recorded on a 400 MHz spectrometer in solutions of $CDCl_3$ using tetramethylsilane as the internal standard; δ values are given in ppm, and coupling constants (*J*) in Hz. GC-MS was obtained using electron ionization (EI).

Typical procedure: 1-(4,4-dichlorobutyl)benzene (Table 2, entry 1, 3aa). A mixture of allylbenzene (**1a**) (118 mg, 1.0 mmol), $CHCl_3$ (0.5 mL), TBHP (129 mg, 1.0 mmol, 70% in water), and Et_3N (1.0 mL) was added successively in a round-bottom flask, and the resulting solution was stirred for 12 h at 70 °C. The mixture was purified by column chromatography on silica gel to afford product **2a** with PE as the eluent.

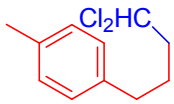
1-(4,4-dichlorobutyl)benzene (Table 2, entry 1, 3aa)



Yield: 77% (155 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.34 (t, *J* = 7.6 Hz, 2H), 7.24 (m, 3H), 5.77 (t, *J* = 6.0 Hz, 1H), 2.70 (t, *J* = 7.6 Hz, 2H), 2.45 (m, 2H), 1.92 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 141.1, 128.5, 128.3, 126.1, 73.4, 42.9, 34.7, 37.5; GC–MS m/z (% rel inten.): 202.02 (M^+, 13), 91.04 (100); Anal. Calcd for $C_{10}H_{12}Cl_2$: C, 59.13; H, 5.96. Found: C,

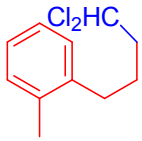
59.30; H, 5.88.

1-(4,4-dichlorobutyl)-4-methylbenzene (Table 2, entry 2, 3ba)



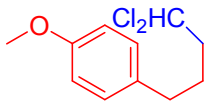
Yield: 71% (153 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.12 (d, J = 8.0 Hz, 2H), 7.08 (d, J = 8.0 Hz, 2H), 5.75 (t, J = 6.0 Hz, 1H), 2.65 (t, J = 7.6 Hz, 2H), 2.34 (s, 3H), 2.22 (m, 2H), 1.88 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 138.0, 135.6, 129.1, 128.2, 73.4, 42.9, 34.2, 27.6, 21.0; GC–MS m/z (% rel inten.): 216.04 (M^+, 98), 105.06 (100); Anal. Calcd for $C_{11}H_{14}Cl_2$: C, 60.85; H, 6.50. Found: C, 60.68; H, 6.61.

1-(4,4-dichlorobutyl)-2-methylbenzene (Table 2, entry 3, 3ca)



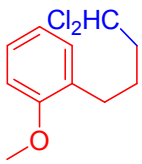
Yield: 75% (162 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.23 (m, 1H), 7.17 (m, 4H), 5.79 (t, J = 6.0 Hz, 1H), 2.69 (t, J = 8.0 Hz, 2H), 2.35 (s, 3H), 2.29 (m, 2H), 1.88 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 139.4, 135.8, 130.3, 128.7, 126.2, 126.0, 73.4, 43.3, 32.1, 26.4, 19.3; GC–MS m/z (% rel inten.): 216.03 (M^+, 83), 105.04 (100); Anal. Calcd for $C_{11}H_{14}Cl_2$: C, 60.85; H, 6.50. Found: C, 60.73; H, 6.58.

1-(4,4-dichlorobutyl)-4-methoxybenzene (Table 2, entry 4, 3da)



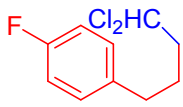
Yield: 80% (185 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.10 (d, J = 8.8 Hz, 2H), 6.86 (d, J = 8.8 Hz, 2H), 5.76 (t, J = 6.0 Hz, 1H), 3.81 (s, 3H), 2.63 (t, J = 7.6 Hz, 2H), 2.20 (m, 2H), 1.87 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 158.0, 133.2, 129.2, 113.9, 73.4, 55.2, 42.9, 33.8, 27.7; GC–MS m/z (% rel inten.): 232.05 (M^+, 85), 121.07 (100); Anal. Calcd for $C_{11}H_{14}Cl_2O$: C, 56.67; H, 6.05. Found: C, 56.59; H, 6.17.

1-(4,4-dichlorobutyl)-2-methoxybenzene (Table 2, entry 5, 3ea)



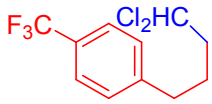
Yield: 78% (180 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.23 (m, 1H), 7.14 (d, J = 7.6 Hz, 1H), 6.92 (m, 1H), 6.88 (d, J = 7.6 Hz, 1H), 5.75 (t, J = 6.0 Hz, 1H),3.85 (s, 3H), 2.69 (t, J = 7.6 Hz, 2H), 2.23 (m, 2H), 1.88 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 157.4, 129.8, 129.6, 127.3, 120.4, 110.3, 73.6, 55.2, 43.1, 28.8, 26.2; GC–MS m/z (% rel inten.): 232.04 (M^+, 19), 121.06 (100); Anal. Calcd for $C_{11}H_{14}Cl_2O$: C, 56.67; H, 6.05. Found: C, 56.79; H, 6.13.

1-(4,4-dichlorobutyl)-3-fluorobenzene (Table 2, entry 6, 3fa)



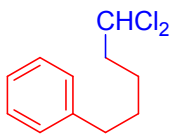
Yield: 88% (193 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.13 (m, 2H), 6.99 (m, 2H), 5.76 (t, J = 6.0 Hz, 1H), 2.66 (t, J = 7.6 Hz, 2H), 2.22 (m, 2H), 1.89 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 161.6 (d, $^1J_{C\text{-}F}$ = 242.4 Hz), 136.7 (d, $^4J_{C\text{-}F}$ = 3.3 Hz), 129.6 (d, $^3J_{C\text{-}F}$ = 7.7 Hz), 115.2 (d, $^2J_{C\text{-}F}$ = 21.0 Hz), 73.3, 42.8, 33.9, 27.5; GC–MS m/z (% rel inten.): 220.02 (M^+, 100); Anal. Calcd for $C_{10}H_{11}Cl_2F$: C, 54.32; H, 5.01. Found: C, 54.50; H, 5.10.

1-(4,4-dichlorobutyl)-3-(trifluoromethyl)benzene (Table 2, entry 7, 3ga)



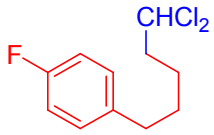
Yield: 82% (216 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.57 (d, J = 8.0 Hz, 2H), 7.31 (d, J = 8.0 Hz, 2H), 5.78 (t, J = 6.0 Hz, 1H), 2.75 (t, J = 7.6 Hz, 2H), 2.23 (t, J = 7.6 Hz, 2H), 1.93 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 145.2, 128.6, 125.4, 122.9, 73.1, 42.7, 34.5, 27.1; GC–MS m/z (% rel inten.): 270.01 (M^+, 11), 159.03 (100); Anal. Calcd for $C_{11}H_{11}Cl_2F_3$: C, 48.73; H, 4.09. Found: C, 48.66; H, 4.21.

1-(5,5-dichloropentyl)benzene (Table 2, entry 8, 3ha)



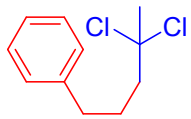
Yield: 79% (170 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.34 (t, J = 7.6 Hz, 2H), 7.26 (m, 3H), 5.77 (t, J = 6.0 Hz, 1H), 2.69 (t, J = 7.6 Hz, 2H), 2.78 (m, 2H), 1.74 (m, 2H), 1.63 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 141.9, 128.42, 128.40, 125.9, 73.5, 43.5, 35.6, 30.4, 25.6; GC–MS m/z (% rel inten.): 216.05 (M^+, 68), 91.02 (100); Anal. Calcd for $C_{11}H_{14}Cl_2$: C, 60.85; H, 6.50. Found: C, 60.97; H, 6.57.

1-(5,5-dichloropentyl)-3-fluorobenzene (Table 2, entry 9, 3ia)



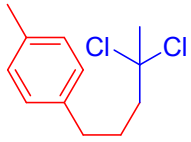
Yield: 86% (201 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.12 (m, 2H), 6.98 (m, 2H), 5.75 (t, J = 6.0 Hz, 1H), 2.62 (t, J = 7.6 Hz, 2H), 2.22 (m, 2H), 1.63 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 161.7 (d, $^{1}J_{C\text{-}F}$ = 241.9 Hz), 137.4 (d, $^{4}J_{C\text{-}F}$ = 3.6 Hz), 129.6 (d, $^{3}J_{C\text{-}F}$ = 7.7 Hz), 114.9 (d, $^{2}J_{C\text{-}F}$ = 20.9 Hz), 73.4, 43.4, 34.8, 30.4, 25.4; GC–MS m/z (% rel inten.): 234.03 (M^+, 13), 109.04 (100); Anal. Calcd for $C_{11}H_{13}Cl_2F$: C, 56.19; H, 5.57. Found: C, 56.08; H, 5.70.

1-(4,4-dichloropentyl)benzene (Table 2, entry 10, 3ab)



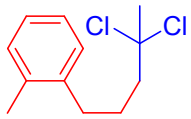
Yield: 77% (166 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.32 (t, J = 7.6 Hz, 2H), 7.23 (m, 3H), 2.71 (t, J = 7.6 Hz, 2H), 2.25 (m, 2H), 2.14 (s, 3H), 2.04 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 141.3, 128.4, 128.3, 126.0, 90.5, 49.1, 37.3, 35.0, 27.2; GC–MS m/z (% rel inten.): 216.05 (M^+, 37), 91.03 (100); Anal. Calcd for $C_{11}H_{14}Cl_2$: C, 60.85; H, 6.50. Found: C, 60.94; H, 6.66.

1-(4,4-dichloropentyl)-4-methylbenzene (Table 2, entry 11, 3bb)



Yield: 81% (186 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.1 (m, 4H), 2.69 (t, J = 7.6 Hz, 2H), 2.34 (s, 3H), 2.24 (m, 2H), 2.14 (s, 3H), 2.00 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 138.2, 135.5, 129.1, 128.2, 90.6, 49.1, 37.3, 34.6, 27.3, 21.0; GC–MS m/z (% rel inten.): 230.03 (M^+, 12), 105.06 (100); Anal. Calcd for $C_{12}H_{16}Cl_2$: C, 62.35; H, 6.98. Found: C, 62.23; H, 6.89.

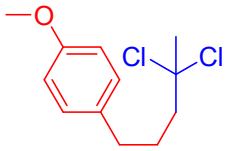
1-(4,4-dichloropentyl)-2-methylbenzene (Table 2, entry 12, 3cb)



Yield: 80% (184 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.16 (m, 4H), 2.69 (t, J = 7.6 Hz, 2H), 2.34 (s, 3H), 2.29 (m, 2H), 2.16 (s, 3H), 1.99 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz)

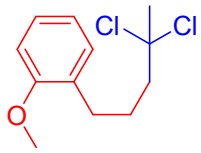
δ 139.6, 135.8, 130.2, 128.7, 126.1, 126.0, 90.5, 49.4, 37.3, 32.4, 26.1, 19.3; GC–MS m/z (% rel inten.): 230.07 (M^+, 12), 105.07 (100); Anal. Calcd for $C_{12}H_{16}Cl_2$: C, 62.35; H, 6.98. Found: C, 62.39; H, 7.09.

1-(4,4-dichloropentyl)-4-methoxybenzene (Table 2, entry 13, 3db)



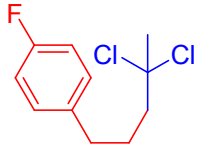
Yield: 78% (192 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.11 (d, J = 8.8 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 3.80 (s, 3H), 2.64 (t, J = 7.6 Hz, 2H), 2.23 (m, 2H), 2.13 (m, 3H), 1.98 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 157.9, 133.4, 129.2, 113.8, 90.6, 55.2, 49.1, 37.3, 34.1, 27.5; GC–MS m/z (% rel inten.): 246.06 (M^+, 48), 121.05 (100); Anal. Calcd for $C_{12}H_{16}Cl_2O$: C, 58.31; H, 6.52. Found: C, 58.44; H, 6.46.

1-(4,4-dichloropentyl)-2-methoxybenzene (Table 2, entry 14, 3eb)



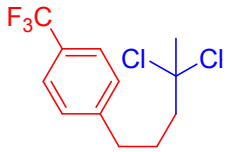
Yield: 73% (179 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.17 (m, 2H), 6.88 (m, 2H), 3.84 (s, 3H), 2.70 (t, J = 7.6 Hz, 2H), 2.27 (m, 2H), 2.14 (s, 3H), 1.98 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 157.4, 129.8, 129.7, 127.2, 120.4, 110.3, 90.8, 55.2, 49.4, 37.2, 29.4, 25.8; GC–MS m/z (% rel inten.): 246.04 (M^+, 36), 121.06 (100); Anal. Calcd for $C_{12}H_{16}Cl_2O$: C, 58.31; H, 6.52. Found: C, 58.36; H, 6.58.

1-(4,4-dichloropentyl)-4-fluorobenzene (Table 2, entry 15, 3fb)



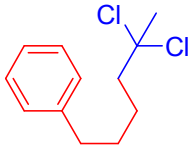
Yield: 87% (203 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.16 (m, 2H), 6.99 (m, 2H), 2.67 (t, J = 7.6 Hz, 2H), 2.22 (m, 2H), 2.14 (s, 3H), 2.01 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 161.4 (d, $^1J_{C\text{-}F}$ = 242.3 Hz), 136.9 (d, $^4J_{C\text{-}F}$ = 3.2 Hz), 129.6 (d, $^3J_{C\text{-}F}$ = 7.8 Hz), 115.1 (d, $^2J_{C\text{-}F}$ = 20.8 Hz), 90.4, 49.0, 37.4, 34.2, 27.3; GC–MS m/z (% rel inten.): 234.04 (M^+, 57), 122.98 (100); Anal. Calcd for $C_{11}H_{13}Cl_2F$: C, 56.19; H, 5.57. Found: C, 56.22; H, 5.69.

1-(4,4-dichloropentyl)-4-(trifluoromethyl)benzene (Table 2, entry 16, 3gb)



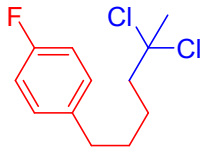
Yield: 77% (218 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.57 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 2.76 (t, J = 7.6 Hz, 2H), 2.23 (t, J = 7.6 Hz, 2H), 2.15 (s, 3H), 2.05 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 145.4, 128.6, 128.3, 125.4, 90.2, 48.9, 37.4, 34.8, 26.9; GC–MS m/z (% rel inten.): 284.01 (M^+, 66), 159.02 (100); Anal. Calcd for $C_{12}H_{13}Cl_2F_3$: C, 50.55; H, 4.60. Found: C, 50.71; H, 4.55.

1-(5,5-dichlorohexyl)benzene (Table 2, entry 17, 3hb)



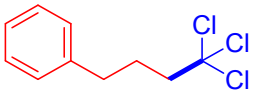
Yield: 81% (186 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.32 (t, J = 7.6 Hz, 2H), 7.22 (m, 3H), 2.69 (t, J = 7.6 Hz, 2H), 2.27 (m, 2H), 2.16 (s, 3H), 1.73 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 142.1, 128.3, 125.8, 90.7, 49.6, 37.3, 35.7, 30.8, 25.4; GC–MS m/z (% rel inten.): 230.05 (M^+, 39), 91.01 (100); Anal. Calcd for $C_{12}H_{16}Cl_2$: C, 62.35; H, 6.98. Found: C, 62.48; H, 7.09.

1-(5,5-dichlorohexyl)-4-fluorobenzene (Table 2, entry 18, 3ib)



Yield: 90% (223 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.14 (m, 2H), 6.98 (m, 2H), 2.64 (t, J = 7.6 Hz, 2H), 2.23 (m, 2H), 2.15 (s, 3H), 1.69 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 161.2 (d, $^{1}J_{C\text{-}F}$ = 241.9 Hz), 137.6 (d, $^{4}J_{C\text{-}F}$ = 3.2 Hz), 129.6 (d, $^{3}J_{C\text{-}F}$ = 7.8 Hz), 115.0 (d, $^{2}J_{C\text{-}F}$ = 20.9 Hz), 90.6, 49.5, 37.3, 34.8, 30.9, 25.2; GC–MS m/z (% rel inten.): 248.01 (M^+, 62), 109.02 (100); Anal. Calcd for $C_{12}H_{15}Cl_2F$: C, 57.85; H, 6.07. Found: C, 57.92; H, 6.22.

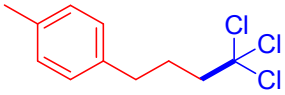
1-(4,4,4-trichlorobutyl)benzene (Table 2, entry 19, 3ac)



Yield: 65% (152 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.32 (t, J = 7.6 Hz,

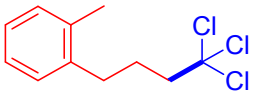
2H), 7.24 (m, 3H), 2.72 (m, 4H), 2.15 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 140.7, 128.5, 128.3, 126.2, 99.9, 54.5, 34.3, 27.9; GC–MS m/z (% rel inten.): 236.01 (M^+, 41), 91.02 (100); Anal. Calcd for $C_{10}H_{11}Cl_3$: C, 50.56; H, 4.67. Found: C, 50.40; H, 4.58.

1-(4,4,4-trichlorobutyl)-4-methylbenzene (Table 2, entry 20, 3bc)



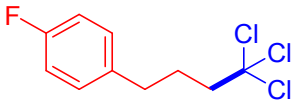
Yield: 67% (167 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.12 (m, 4H), 2.67 (m, 4H), 2.34 (s, 3H), 2.12 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 137.6, 135.7, 129.2, 128.2, 99.6, 54.5, 33.9, 27.9, 21.0; GC–MS m/z (% rel inten.): 250.01 (M^+, 55), 105.04 (100); Anal. Calcd for $C_{11}H_{13}Cl_3$: C, 52.52; H, 5.21. Found: C, 52.59; H, 5.33.

1-(4,4,4-trichlorobutyl)-2-methylbenzene (Table 2, entry 21, 3cc)



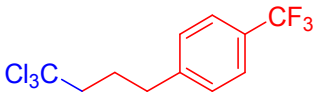
Yield: 65% (162 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.17 (m, 4H), 2.75 (m, 4H), 2.34 (s, 3H), 2.10 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 139.0, 135.6, 130.3, 128.7, 126.3, 126.1, 99.6, 54.7, 31.7, 26.7, 19.3; GC–MS m/z (% rel inten.): 250.00 (M^+, 39), 105.03 (100); Anal. Calcd for $C_{11}H_{13}Cl_3$: C, 52.52; H, 5.21. Found: C, 52.66; H, 5.18.

1-(4,4,4-trichlorobutyl)-4-fluorobenzene (Table 2, entry 22, 3fc)



Yield: 74% (187 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.16 (m, 2H), 7.00 (m, 2H), 2.71 (m, 4H), 2.1 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 161.8 (d, $^1J_{C\text{-}F}$ = 241.6 Hz), 136.3 (d, $^4J_{C\text{-}F}$ = 3.0 Hz), 129.6 (d, $^3J_{C\text{-}F}$ = 7.8 Hz), 115.3 (d, $^2J_{C\text{-}F}$ = 21.1 Hz), 99.6, 54.4, 33.5, 28.0; GC–MS m/z (% rel inten.): 254.00 (M^+, 53), 109.04 (100); Anal. Calcd for $C_{10}H_{10}Cl_3F$: C, 47.00; H, 3.94. Found: C, 47.05; H, 3.99.

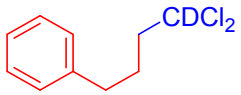
1-(4,4,4-trichlorobutyl)-4-(trifluoromethyl)benzene (Table 2, entry 23, 3gc)



Yield: 79% (272 mg); a pale yellow oily liquid; ^{1}H NMR ($CDCl_3$, 400 Hz) δ 7.58 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 7.6 Hz, 2H), 2.81 (t, J = 7.6 Hz, 2H), 2.71 (m, 4H), 2.13 (m, 2H); ^{13}C NMR

($CDCl_3$, 100 Hz) δ 144.8, 128.9, 128.6, 126.7, 125.5, 99.6,54.3, 34.1, 27.5; GC–MS m/z (% rel inten.): 304.01 (M^+, 61), 172.96 (100); Anal. Calcd for $C_{11}H_{10}Cl_3F_3$: C, 43.24; H, 3.30. Found: C, 43.38; H, 3.39.

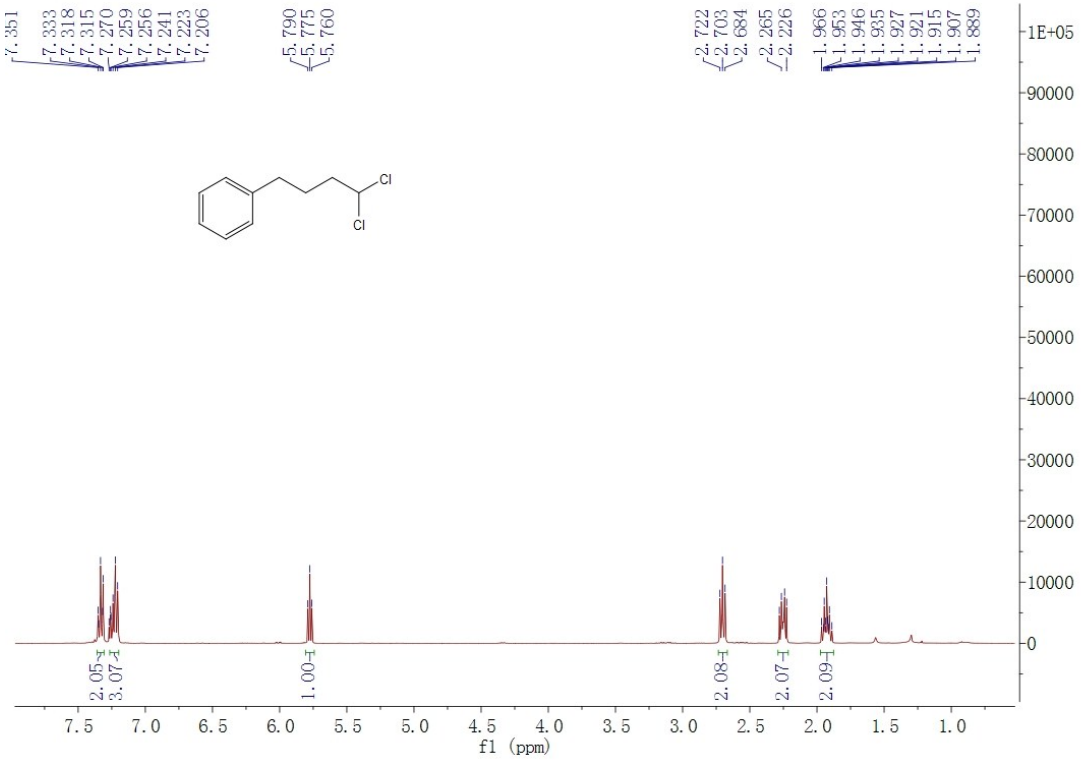
1-(4,4,4-trichlorobutyl)benzene (Scheme 3, 4)

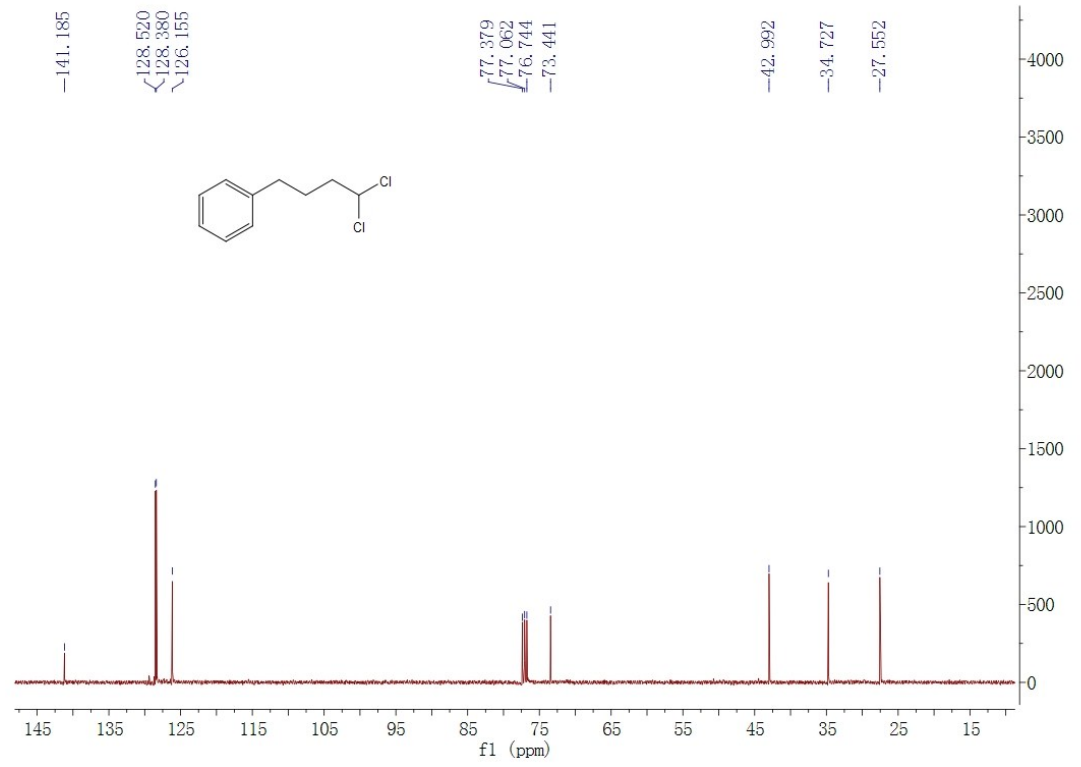


Yield: 77% (156 mg); a pale yellow oily liquid; ^1H NMR ($CDCl_3$, 400 Hz) δ 7.32 (t, J = 7.6 Hz, 2H), 7.22 (m, 3H), 2.69 (t, J = 7.6 Hz, 2H), 2.24 (t, J = 8.4 Hz, 2H), 1.92 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 141.1, 128.5, 128.3, 126.1, 42.8, 34.7, 27.4; GC–MS m/z (% rel inten.): 203.04 (M^+, 15), 91.00 (100); Anal. Calcd for $C_{10}H_{11}DCl_2$: C, 58.84; H, 6.42. Found: C, 58.92; H, 6.37.

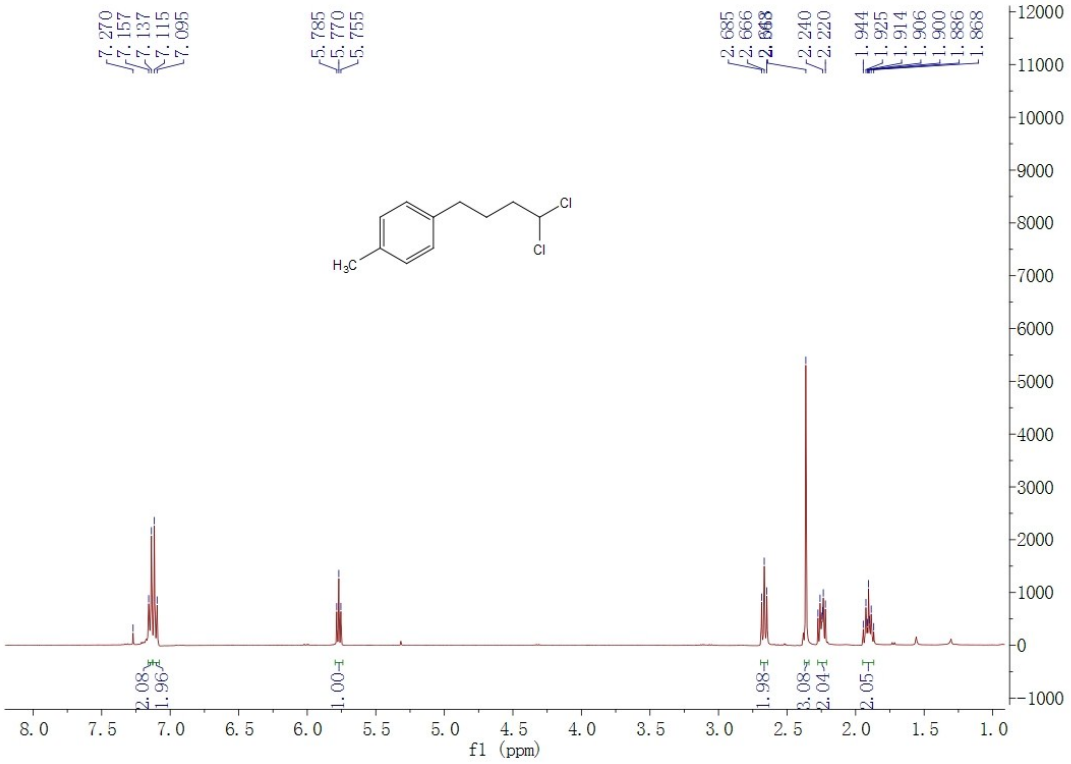
NMR Spectra

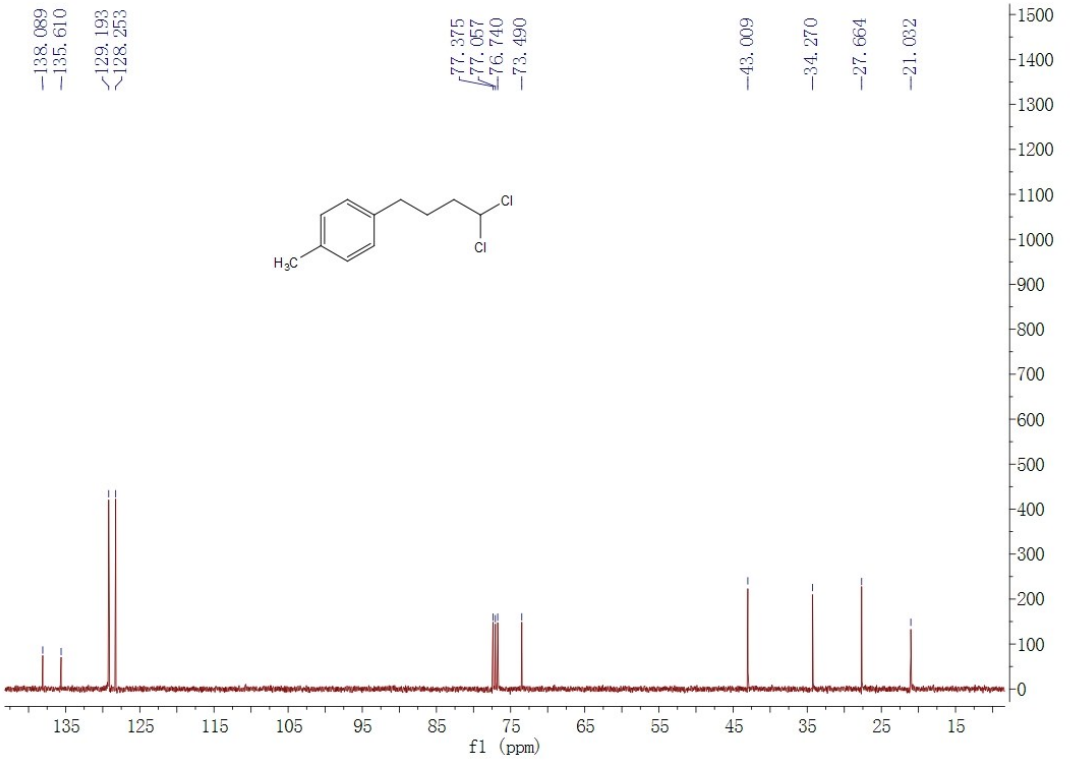
1-(4,4-dichlorobutyl)benzene (Table 2, entry 1, 3aa)



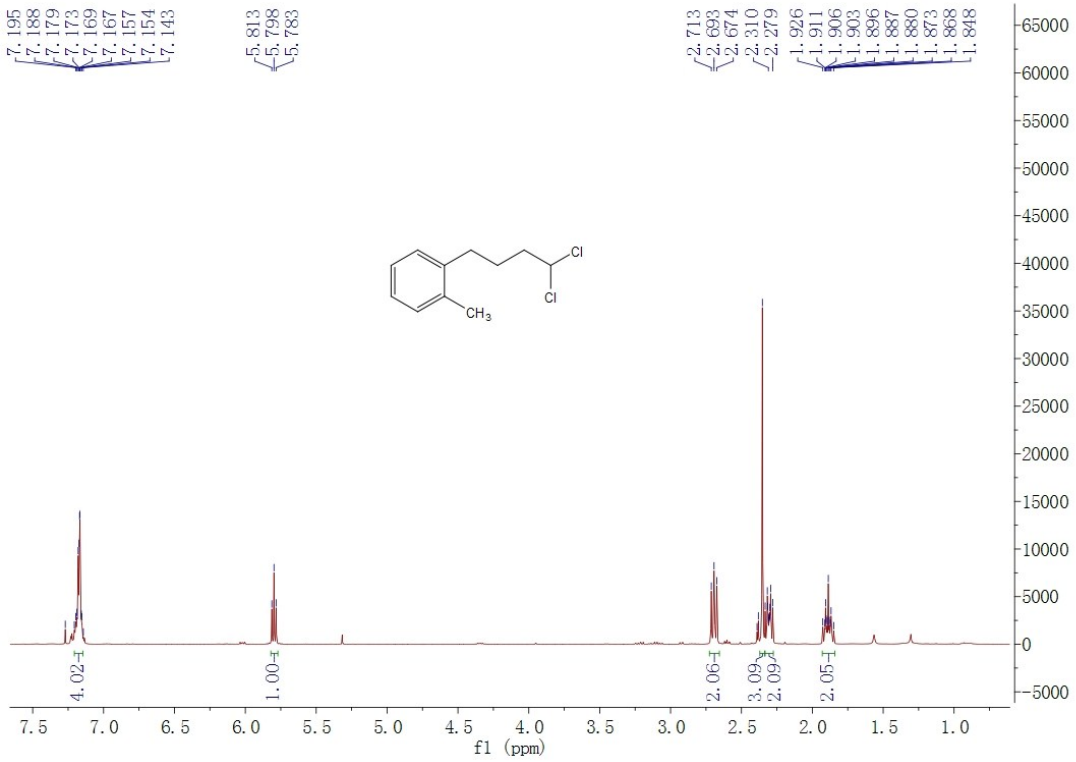


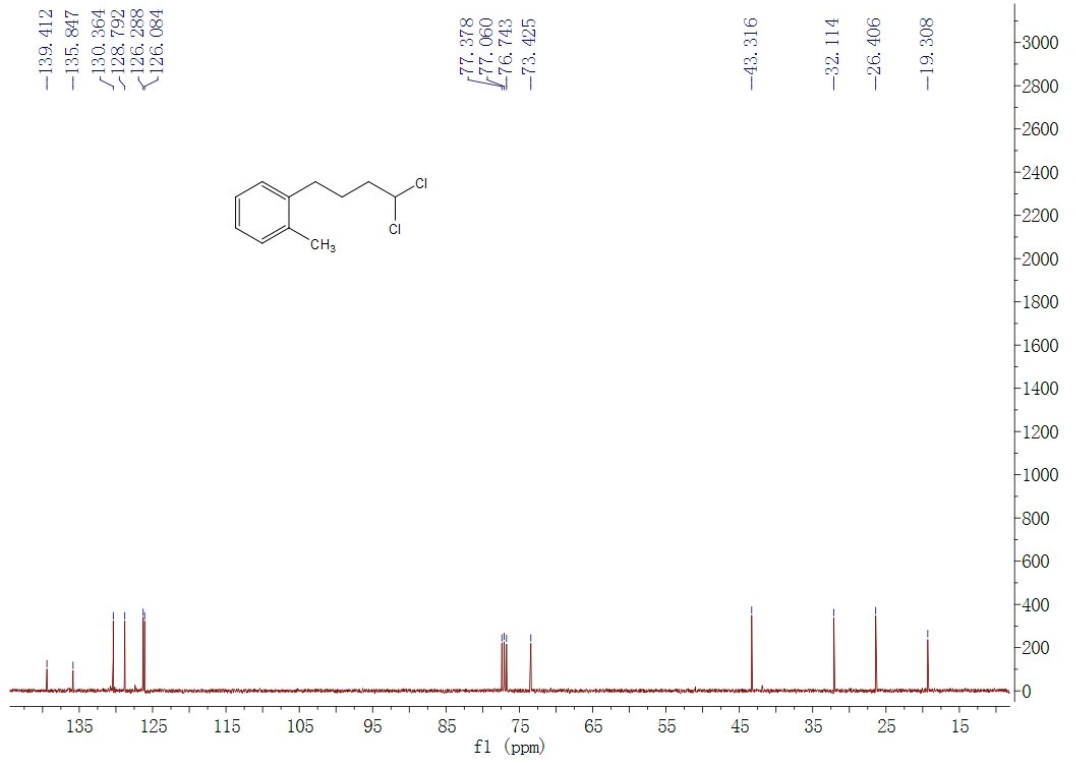
1-(4,4-dichlorobutyl)-4-methylbenzene (Table 2, entry 2, 3ba)



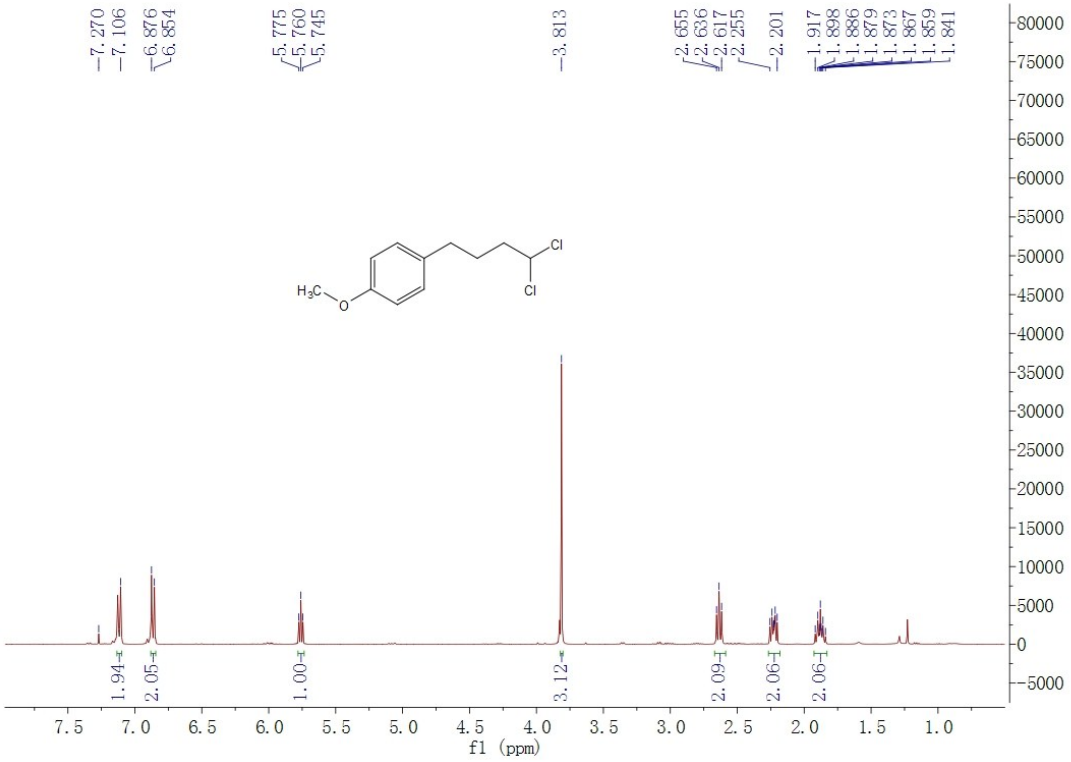


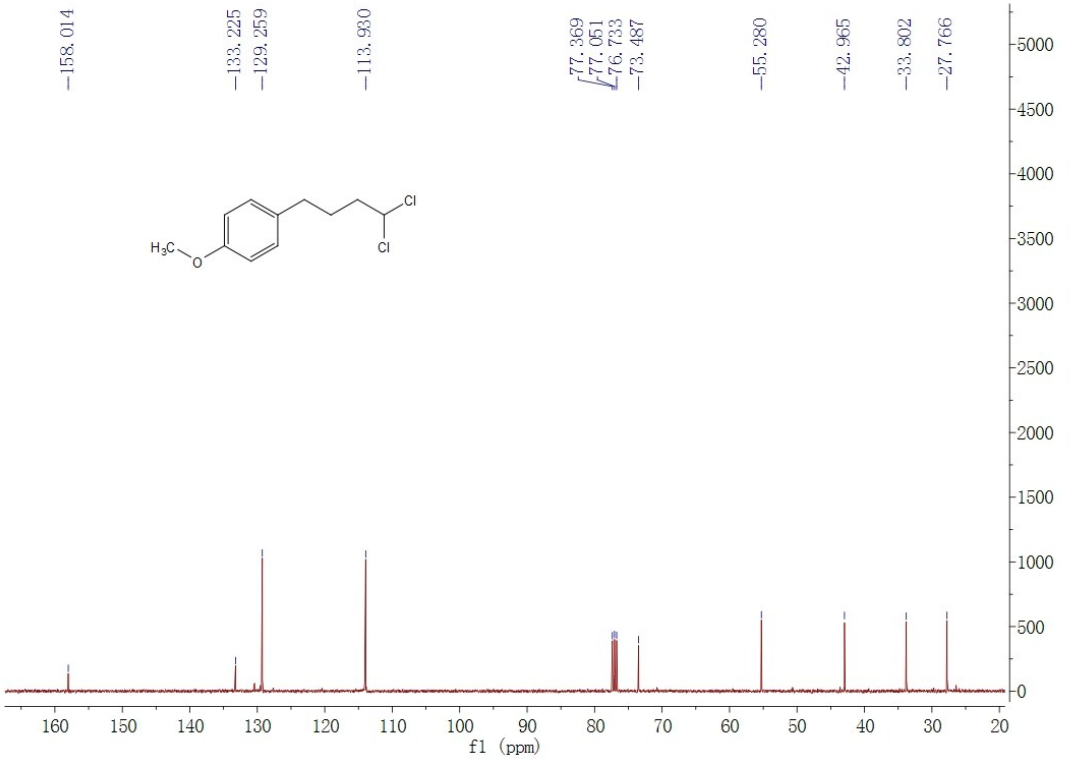
1-(4,4-dichlorobutyl)-2-methylbenzene (Table 2, entry 3, 3ca)



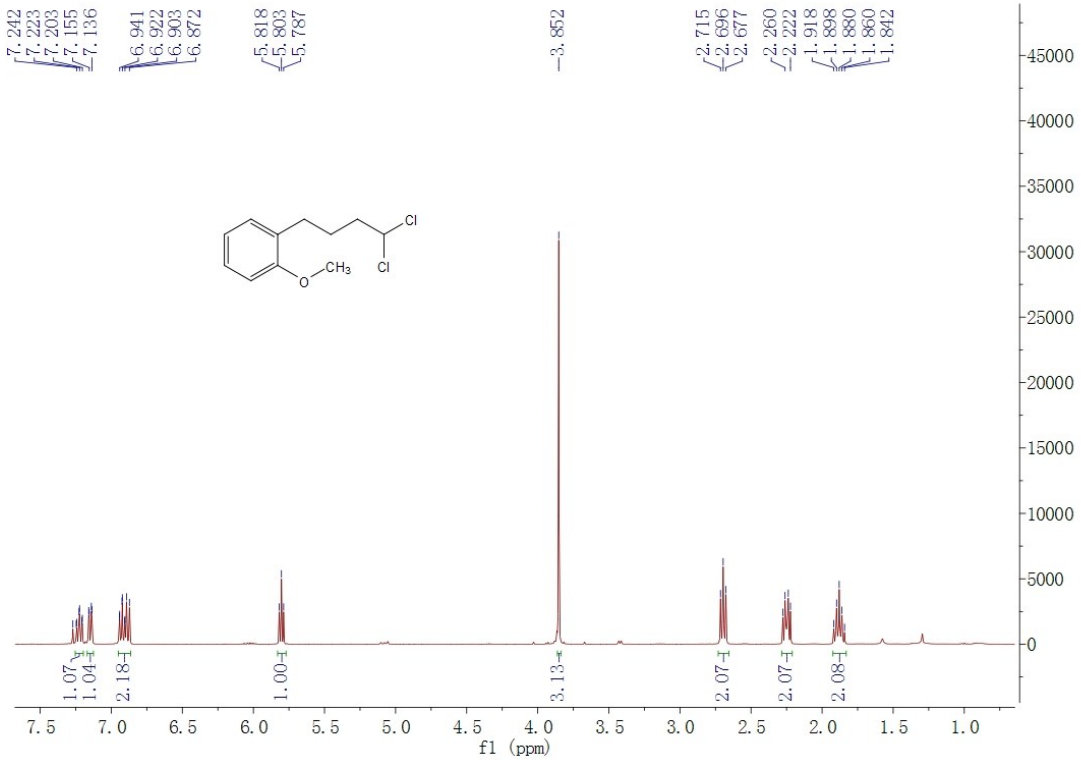


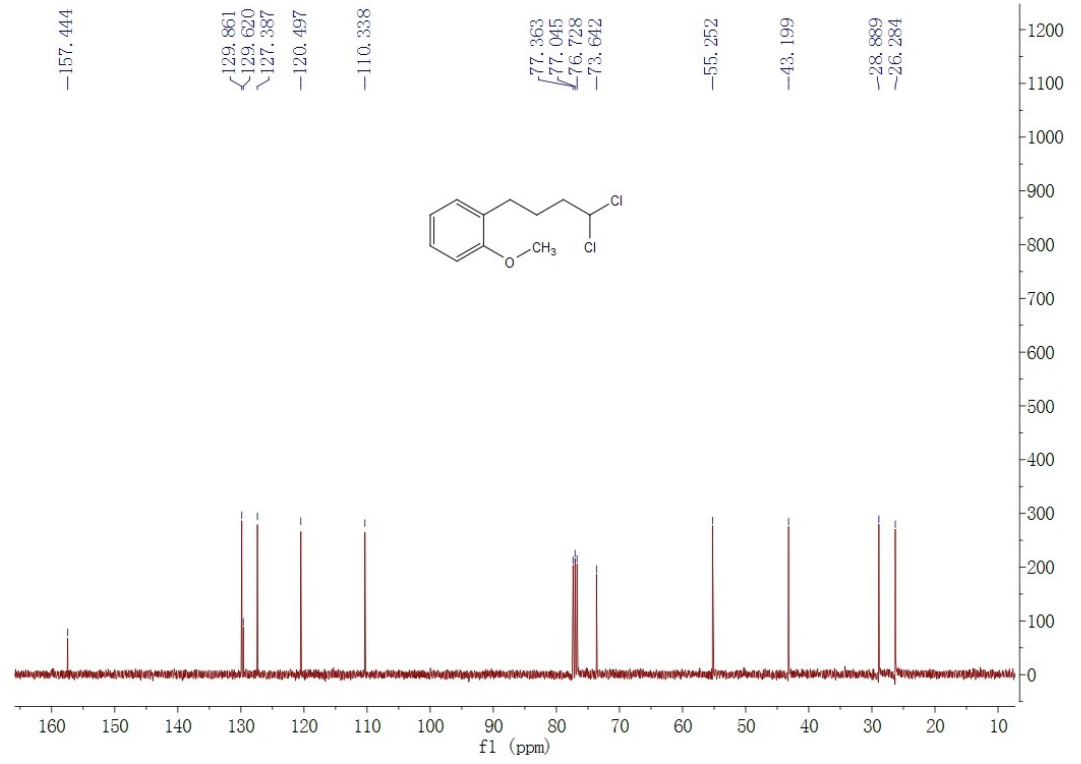
1-(4,4-dichlorobutyl)-4-methoxybenzene (Table 2, entry 4, 3da)



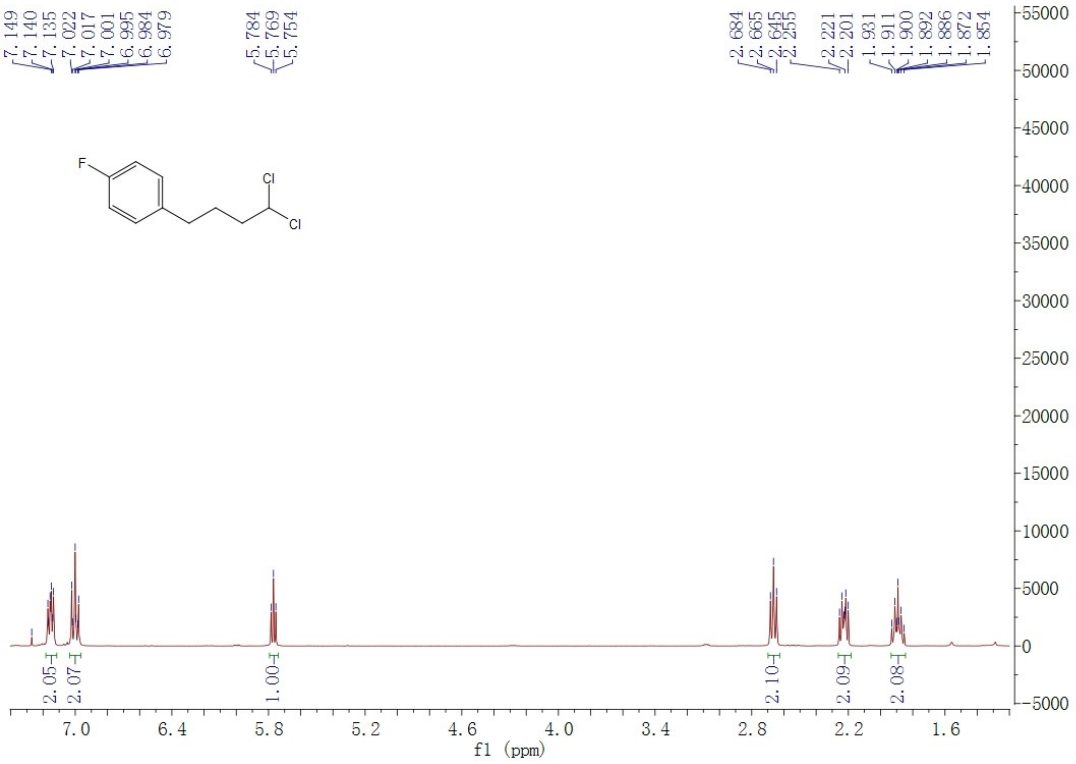


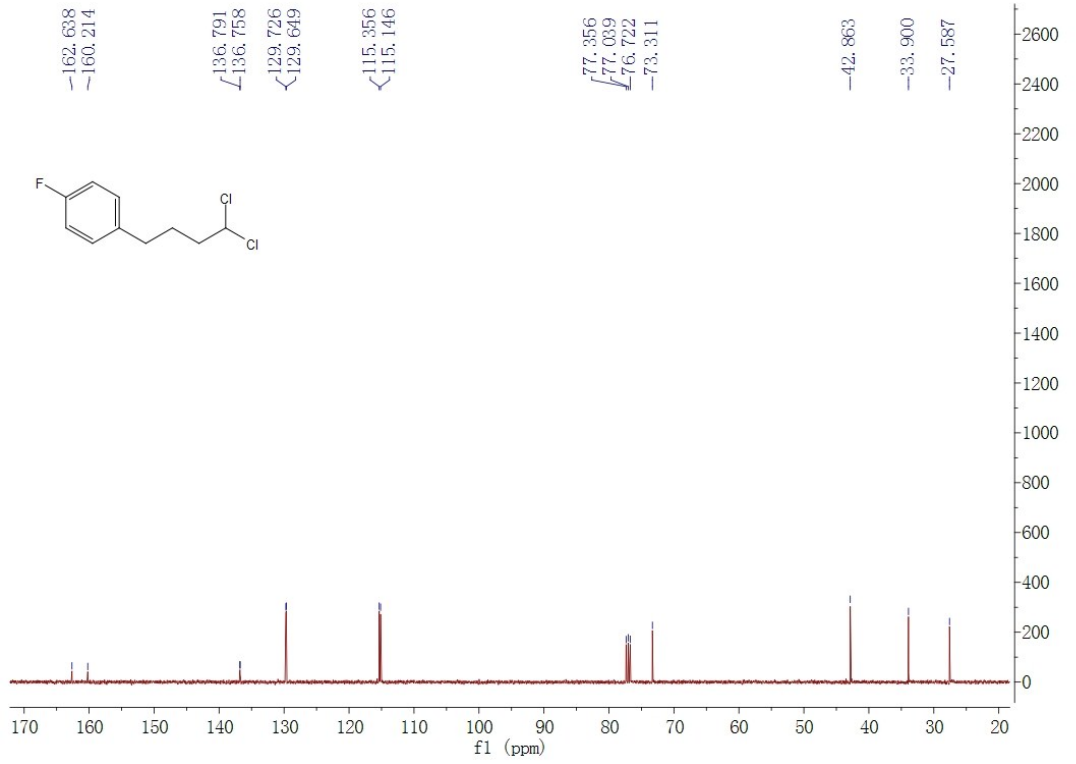
1-(4,4-dichlorobutyl)-2-methoxybenzene (Table 2, entry 5, 3ea)



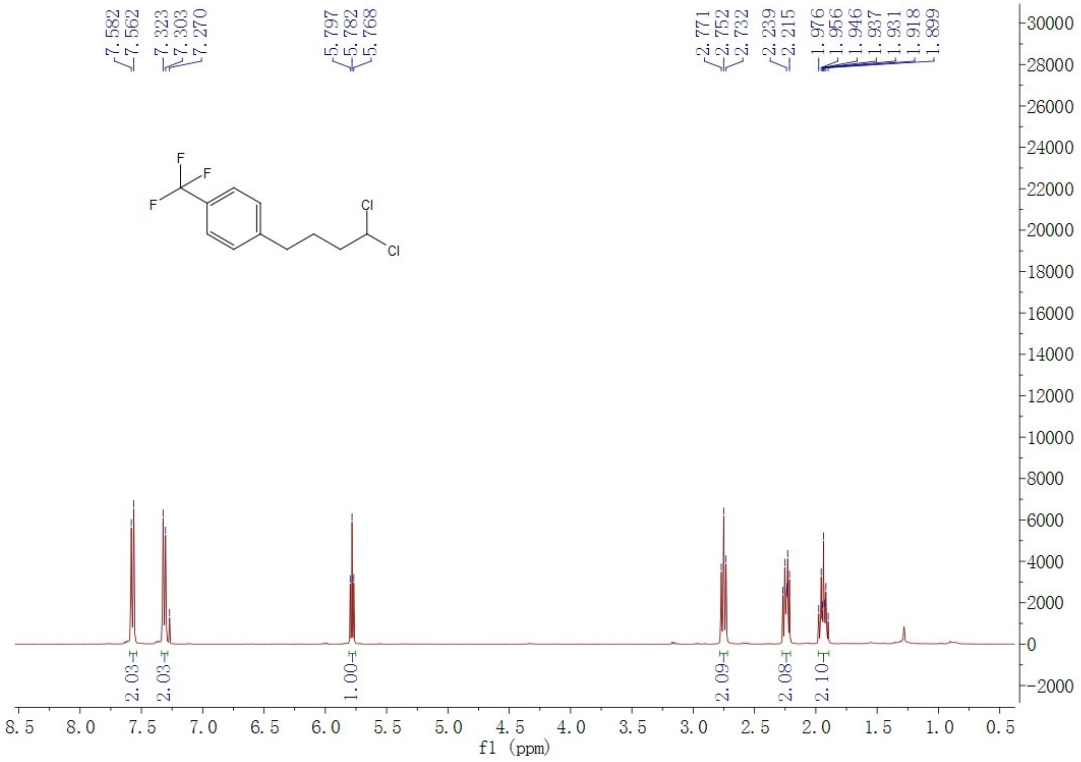


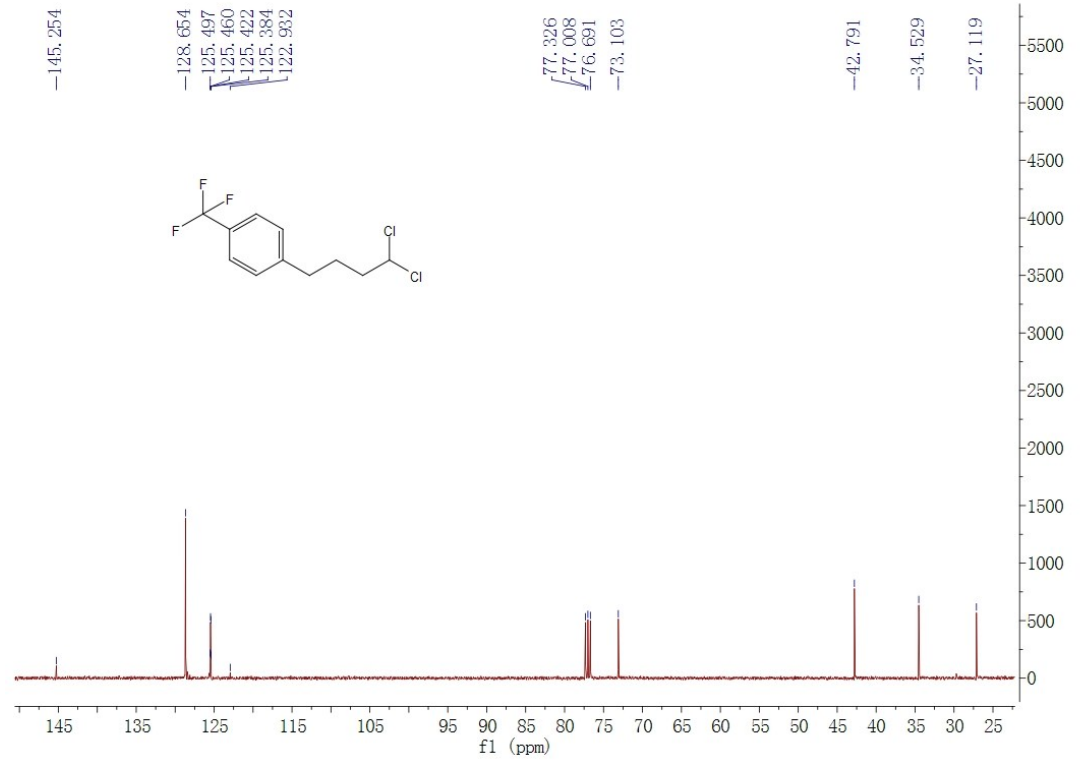
1-(4,4-dichlorobutyl)-3-fluorobenzene (Table 2, entry 6, 3fa)



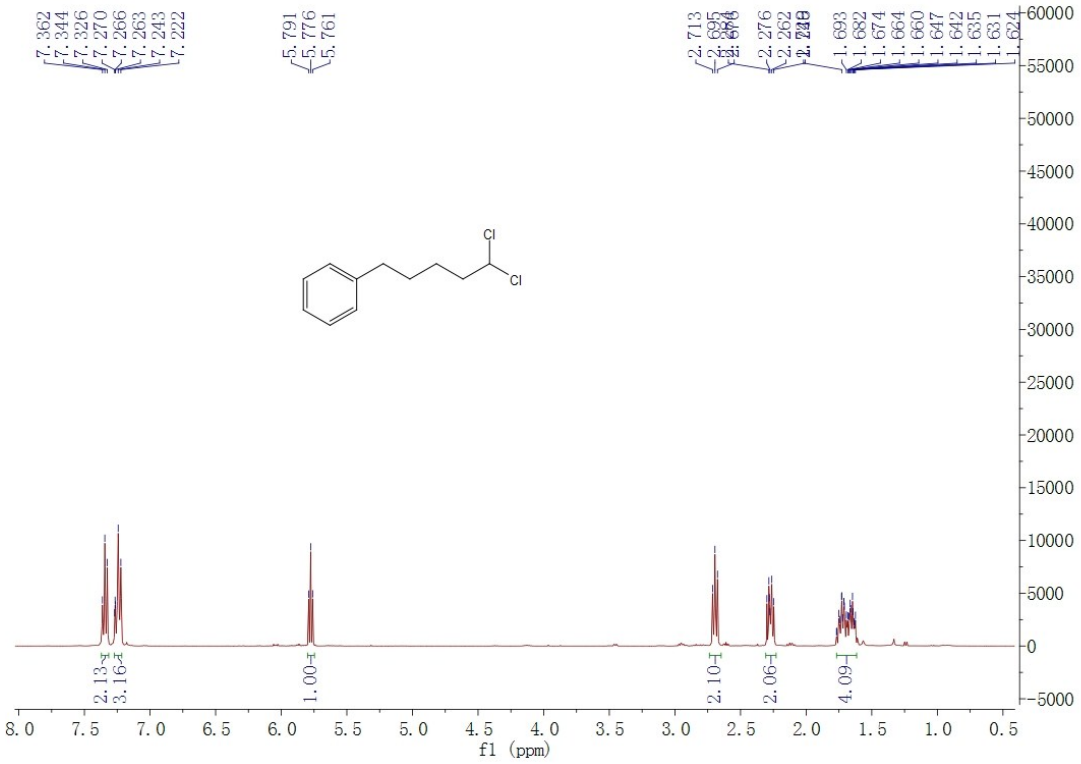


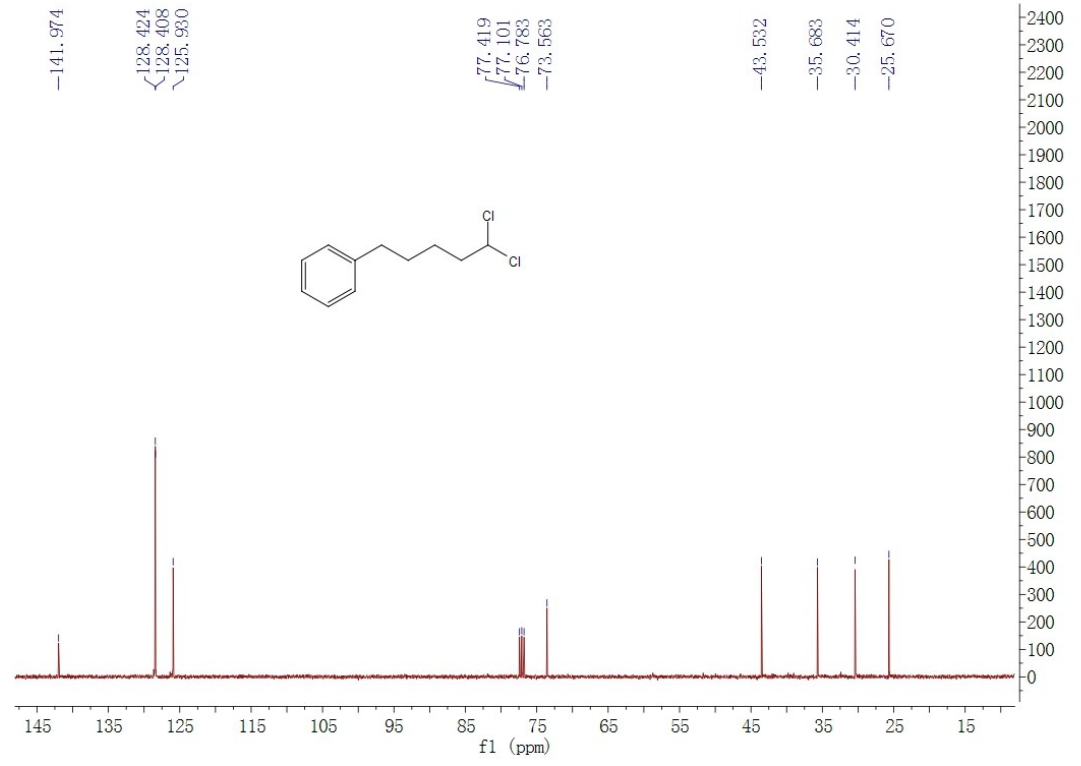
1-(4,4-dichlorobutyl)-3-(trifluoromethyl)benzene (Table 2, entry 7, 3ga)



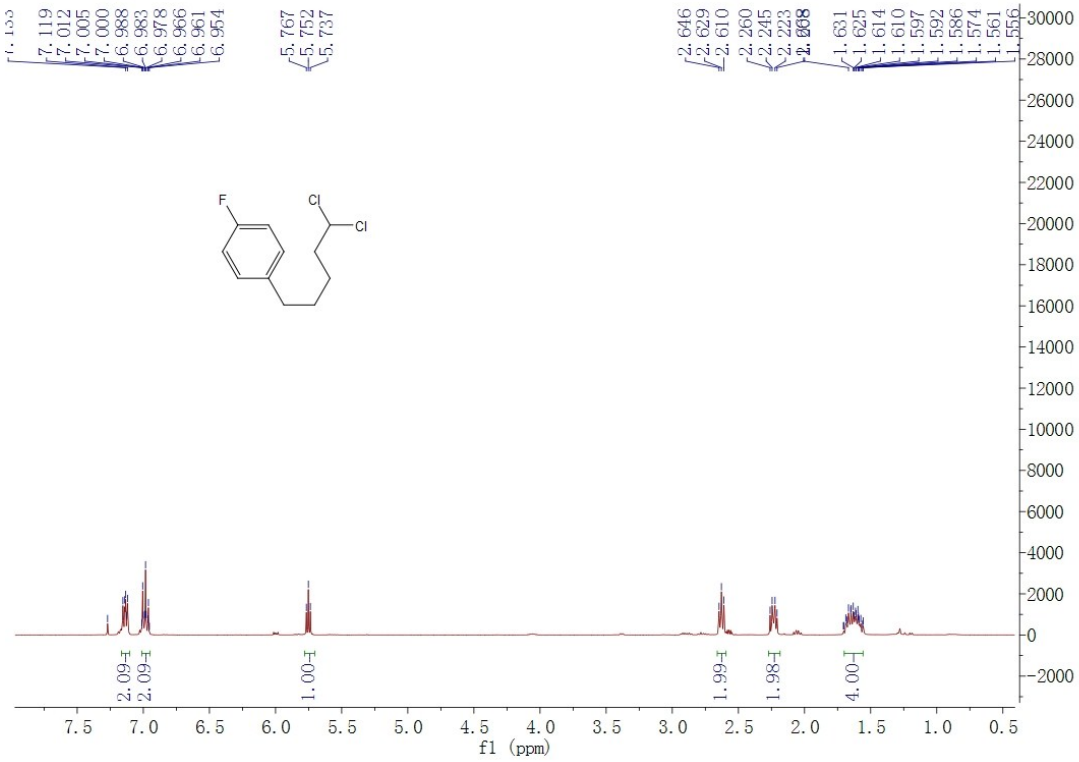


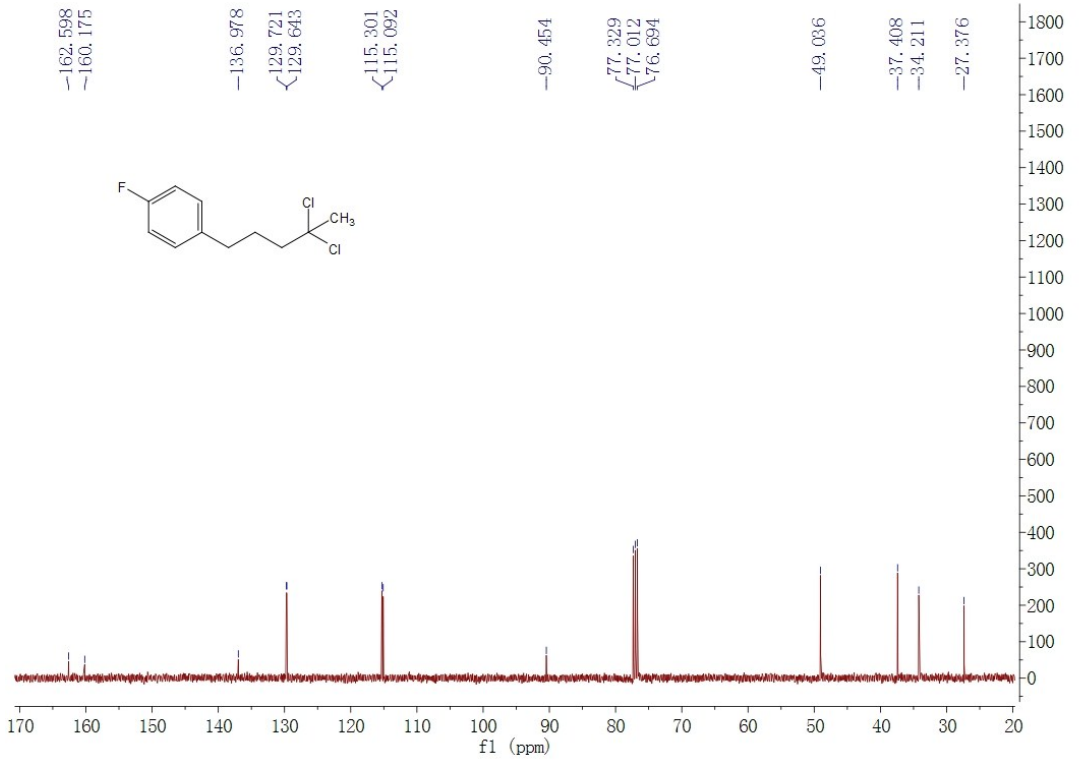
1-(5,5-dichloropentyl)benzene (Table 2, entry 8, 3ha)



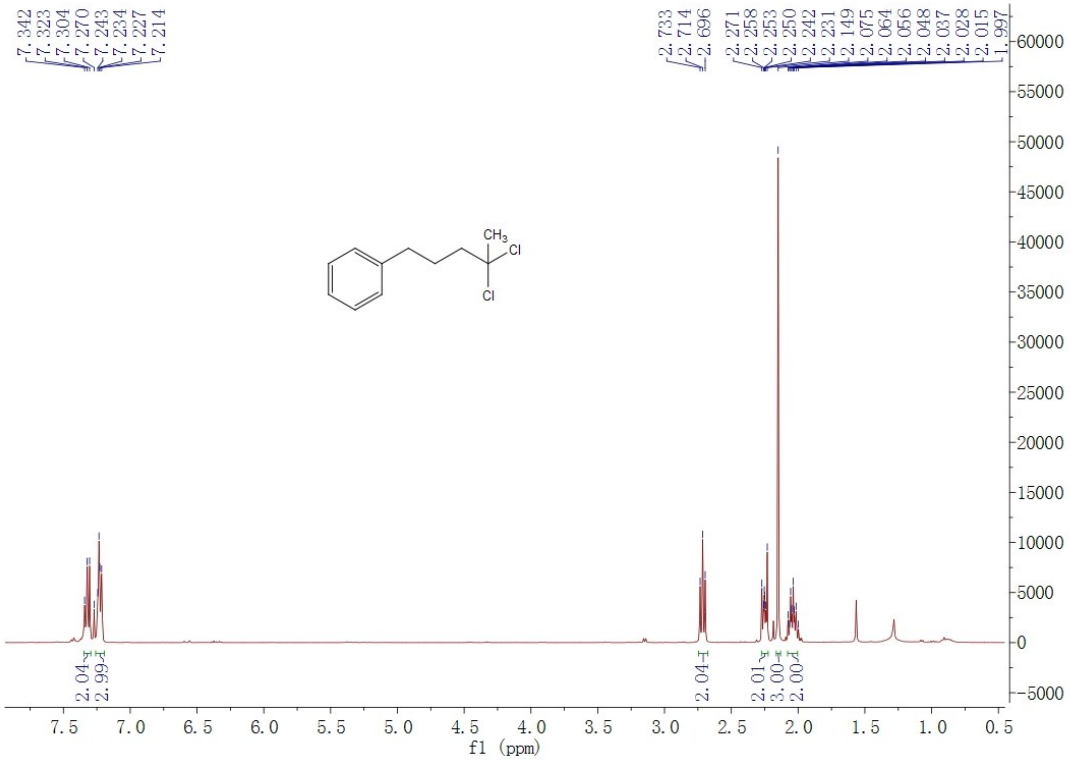


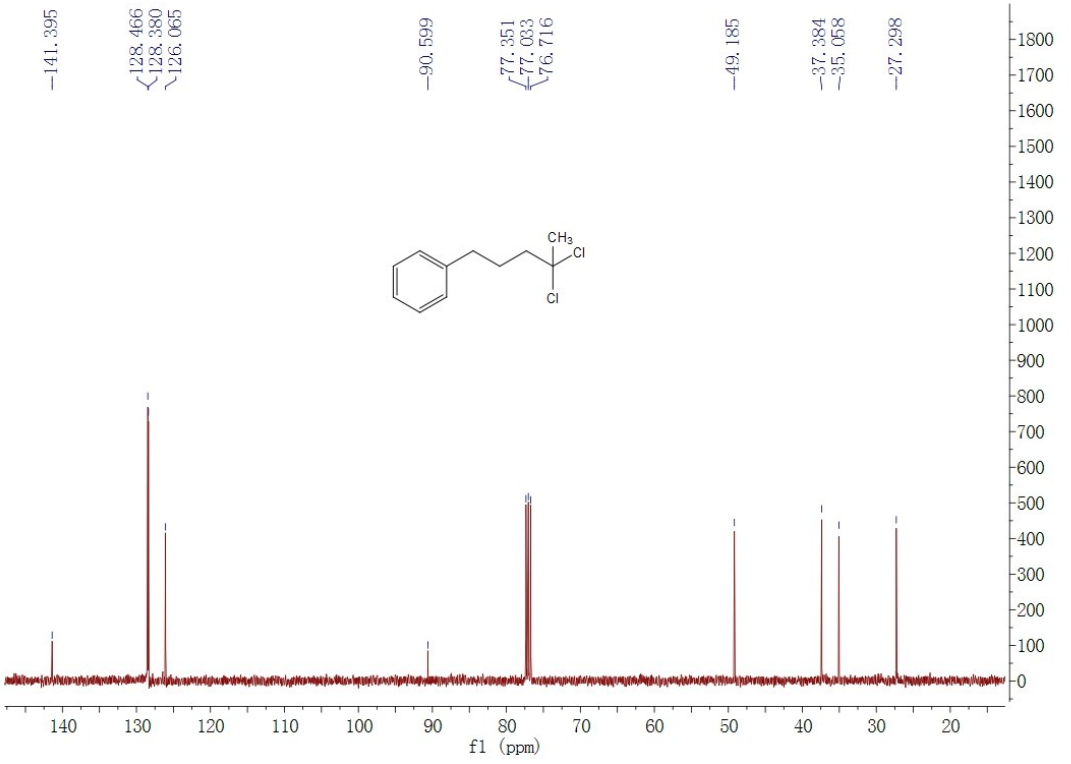
1-(5,5-dichloropentyl)-3-fluorobenzene (Table 2, entry 9, 3ia)



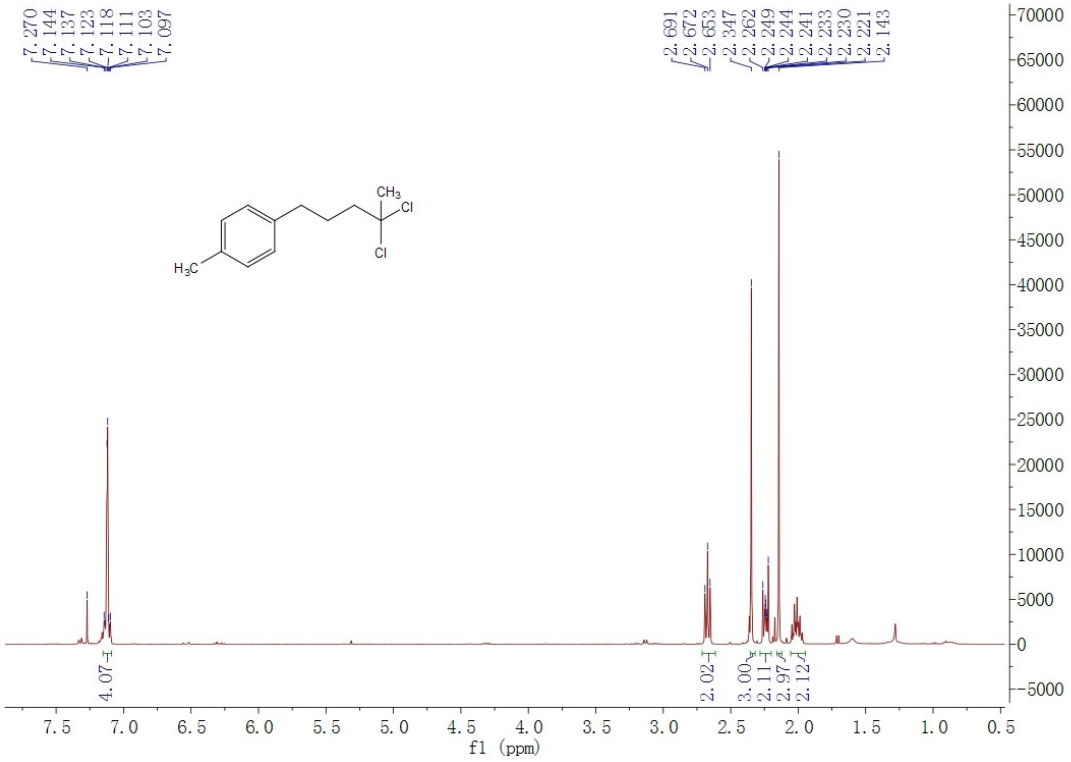


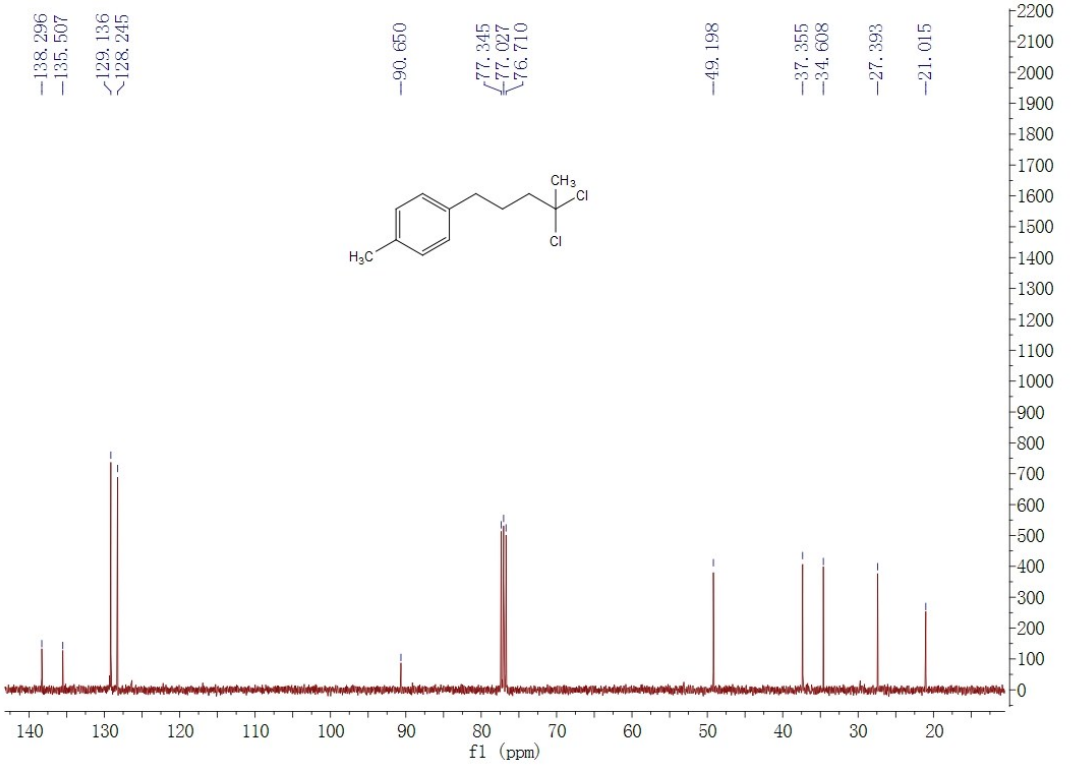
1-(4,4-dichloropentyl)benzene (Table 2, entry 10, 3ab)



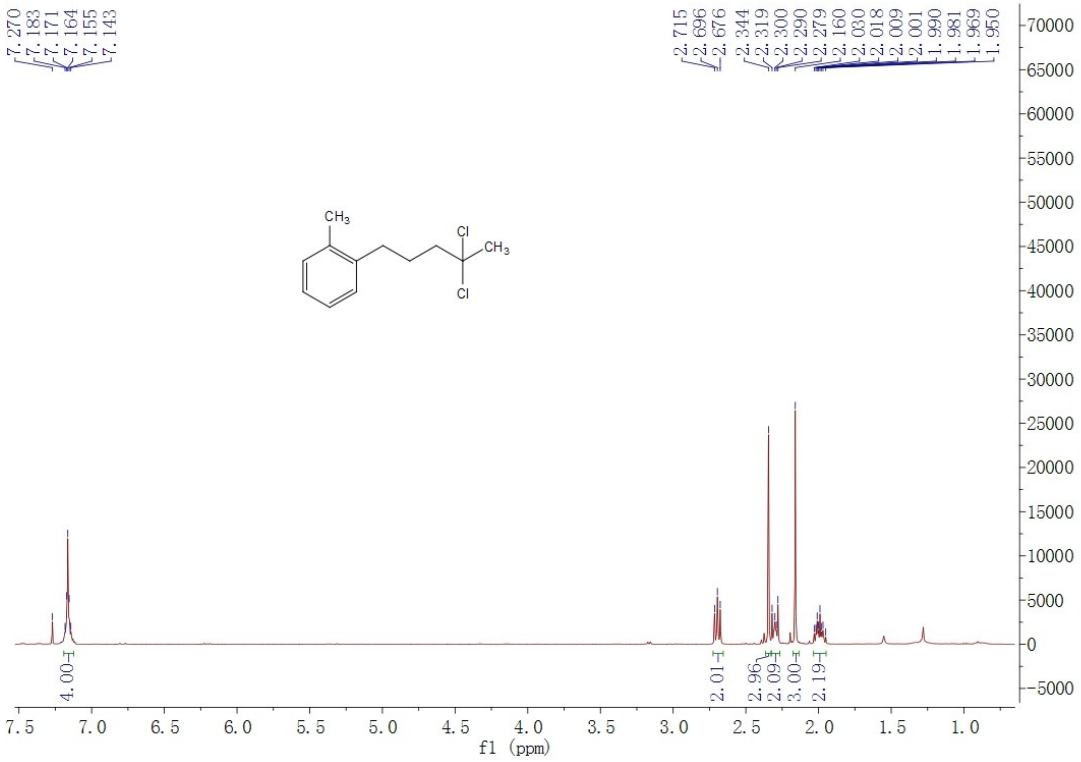


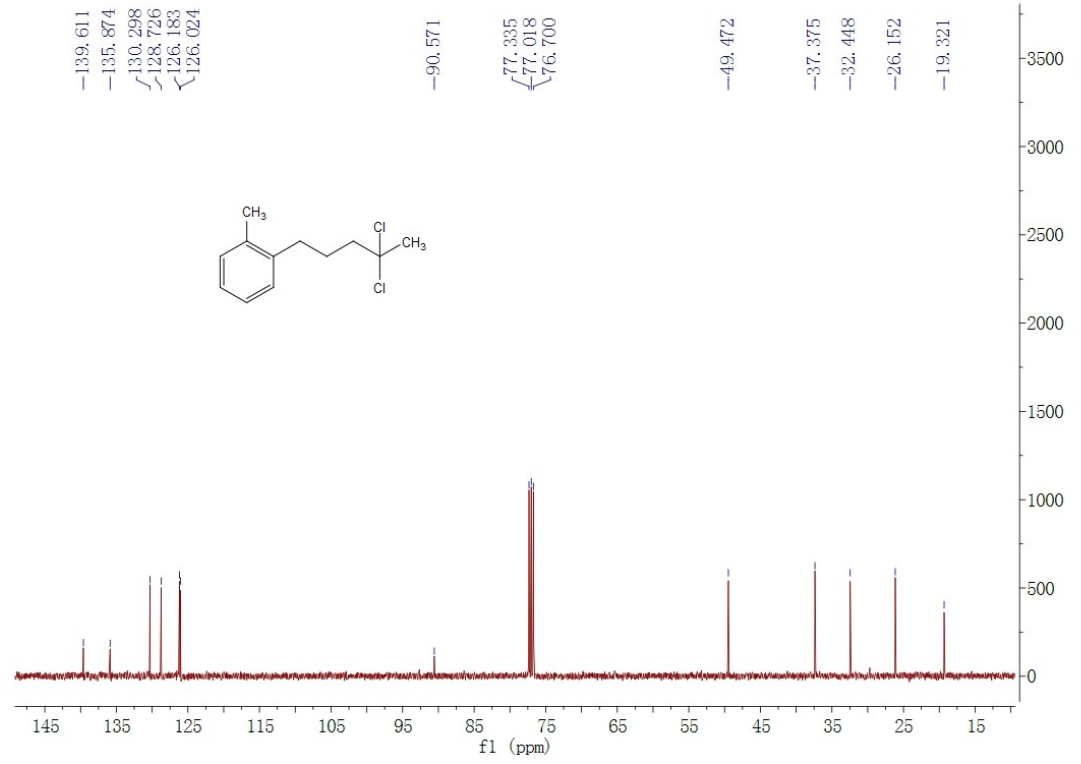
1-(4,4-dichloropentyl)-4-methylbenzene (Table 2, entry 11, 3bb)



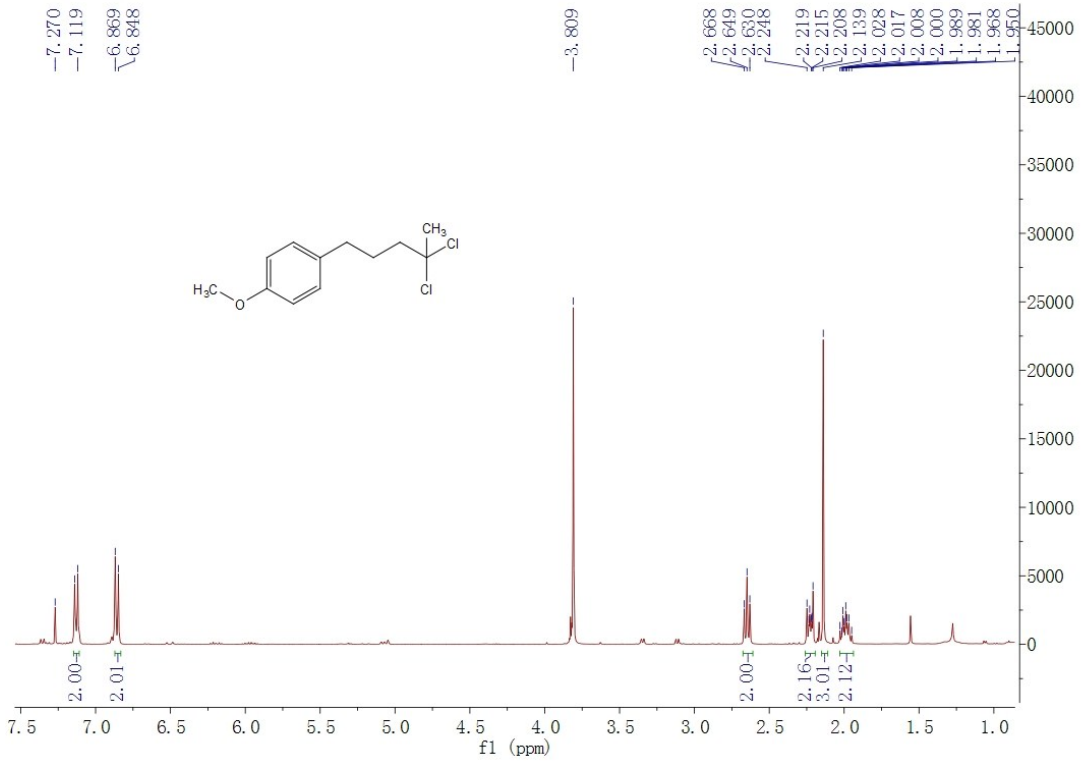


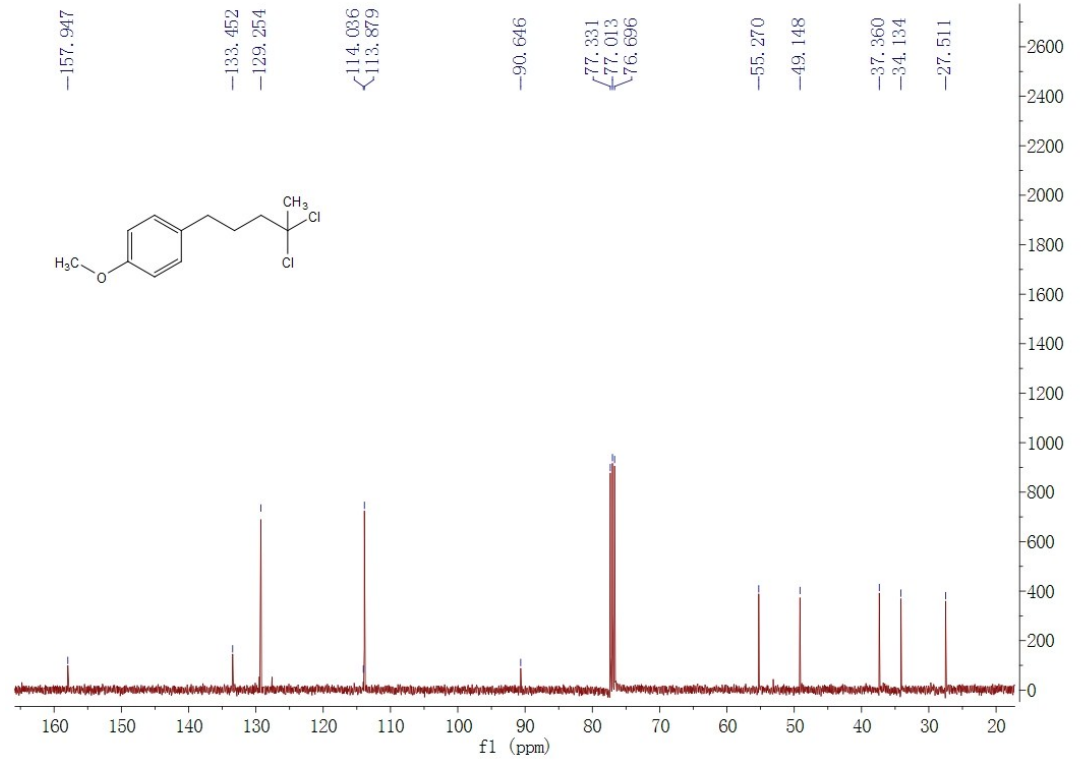
1-(4,4-dichloropentyl)-2-methylbenzene (Table 2, entry 12, 3cb)



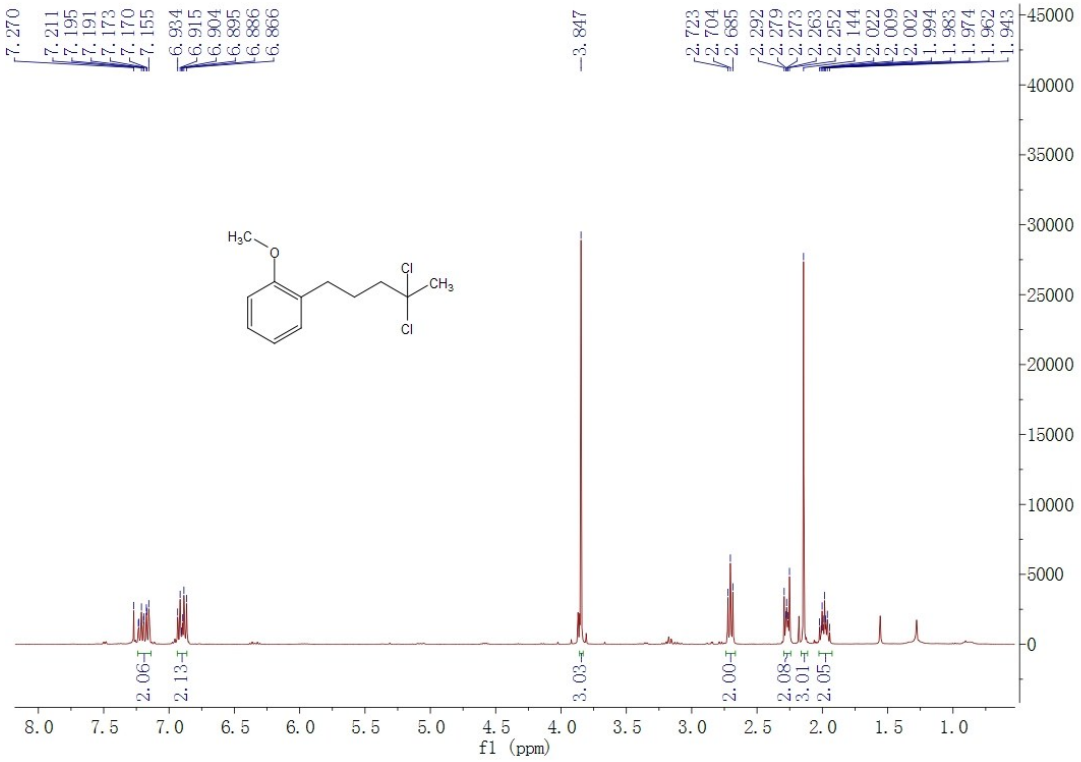


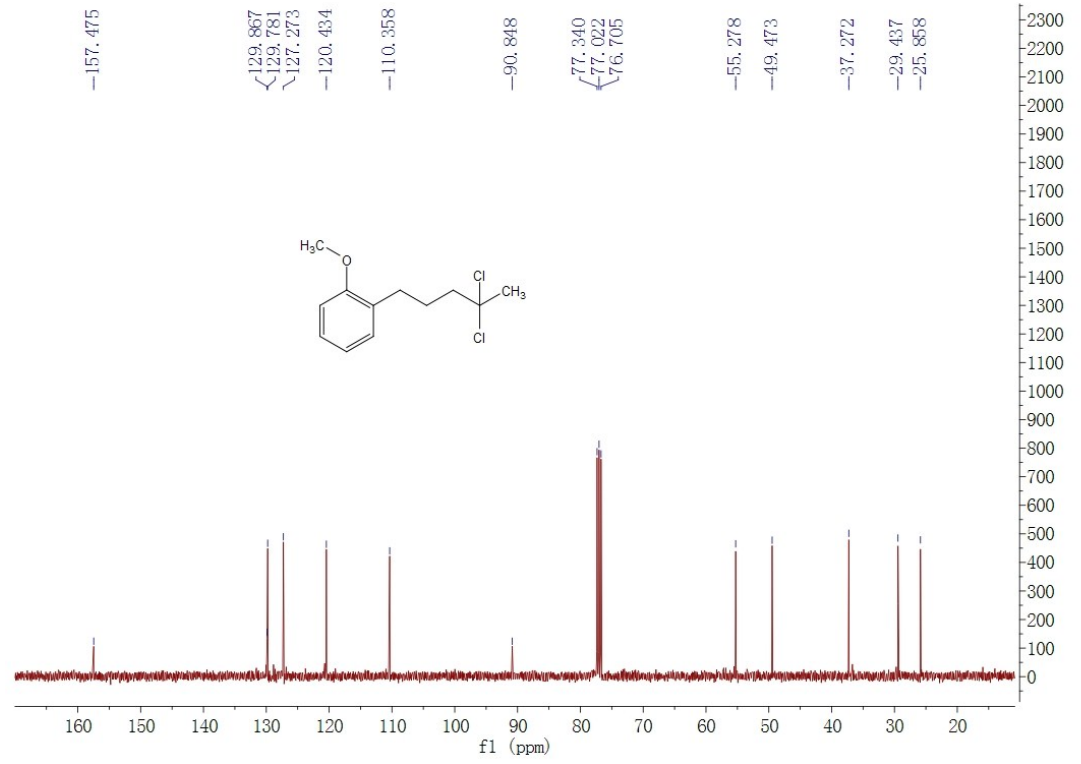
1-(4,4-dichloropentyl)-4-methoxybenzene (Table 2, entry 13, 3db)



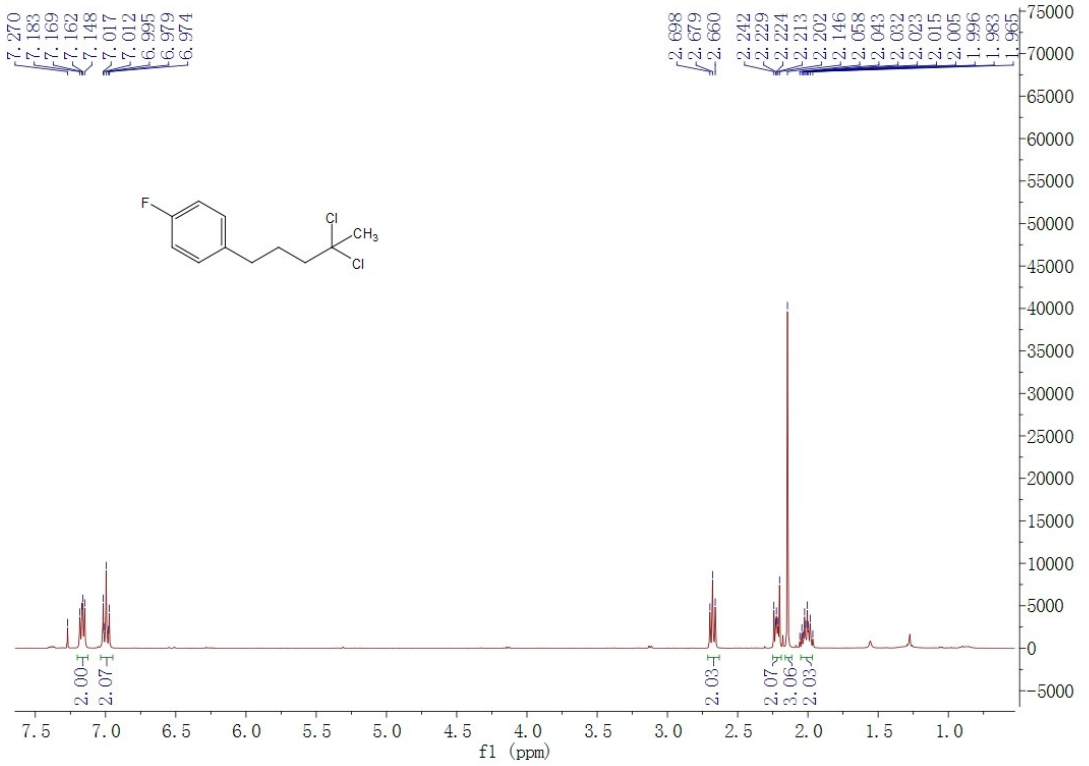


1-(4,4-dichloropentyl)-2-methoxybenzene (Table 2, entry 14, 3eb)

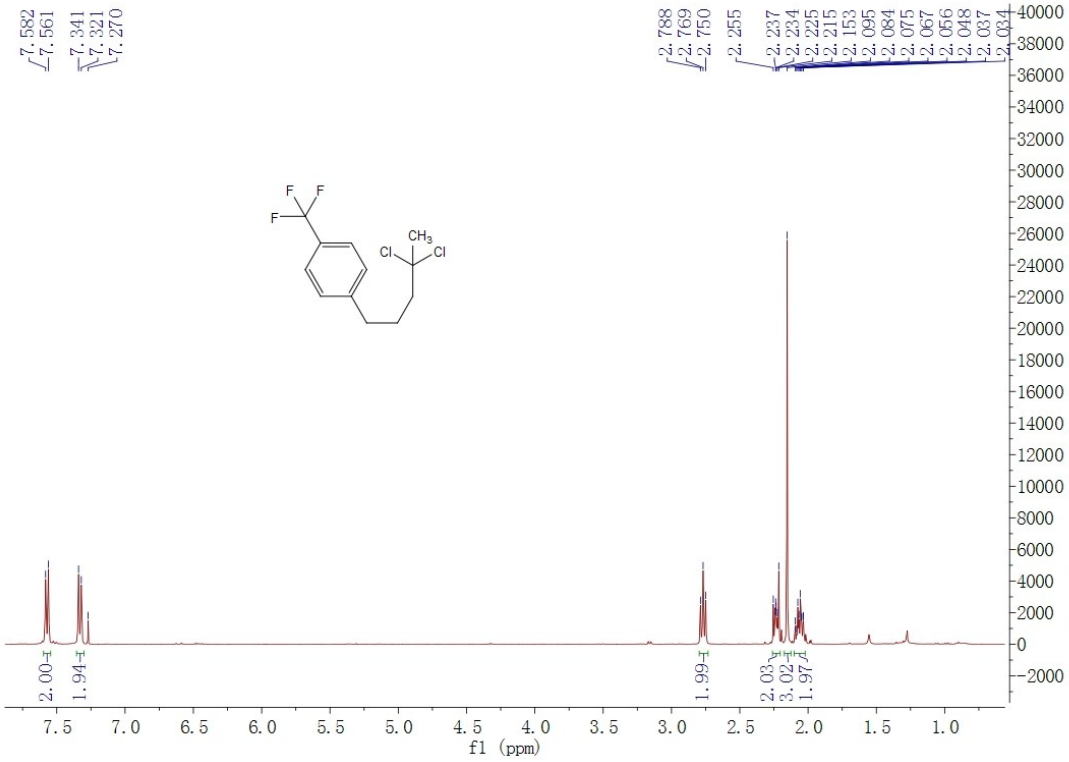


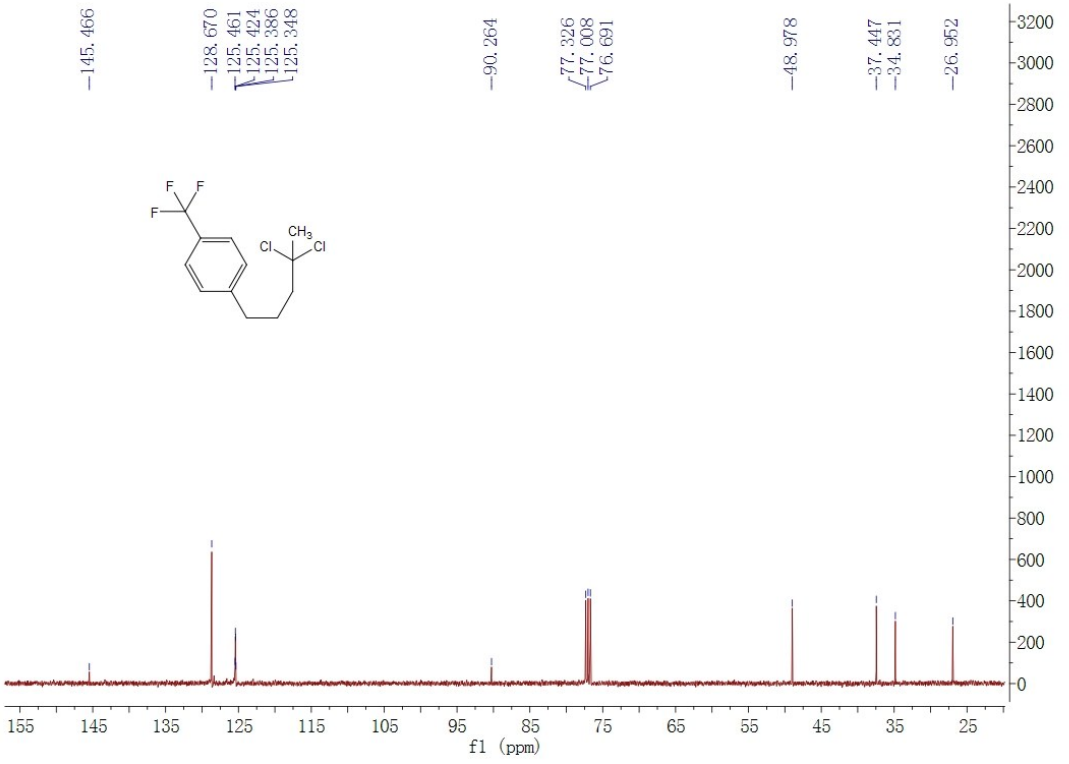


1-(4,4-dichloropentyl)-4-fluorobenzene (Table 2, entry 15, 3fb)

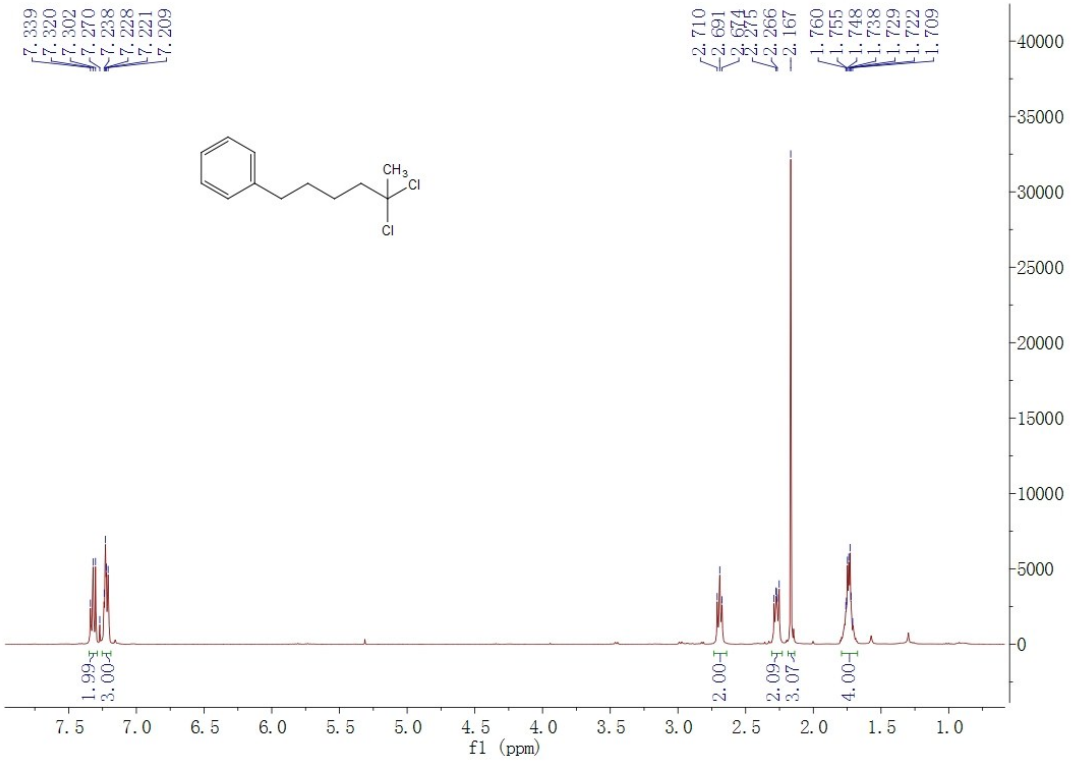


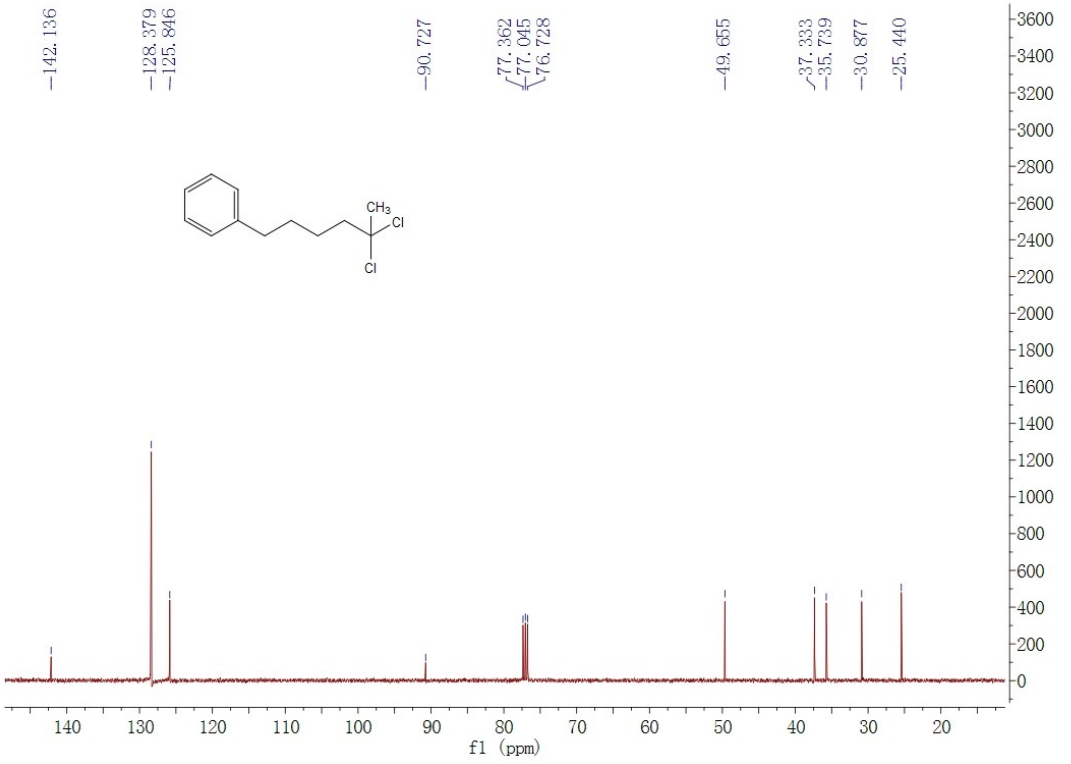
1-(4,4-dichloropentyl)-4-(trifluoromethyl)benzene (Table 2, entry 16, 3gb)



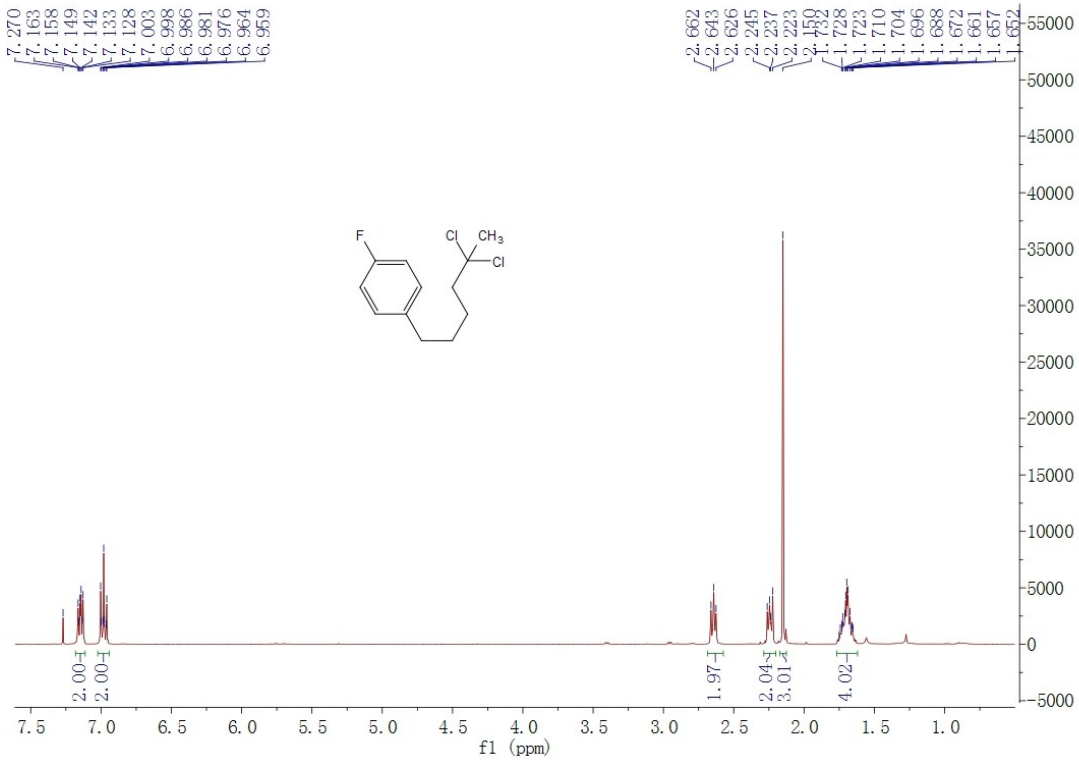


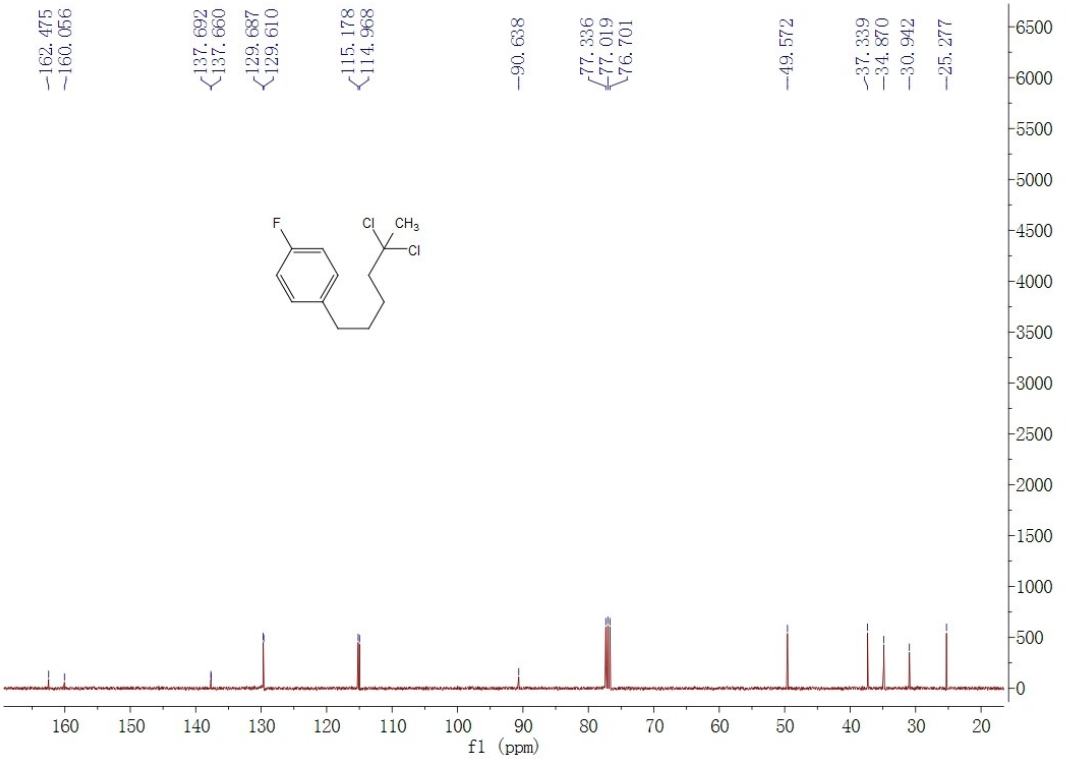
1-(5,5-dichlorohexyl)benzene (Table 2, entry 17, 3hb)



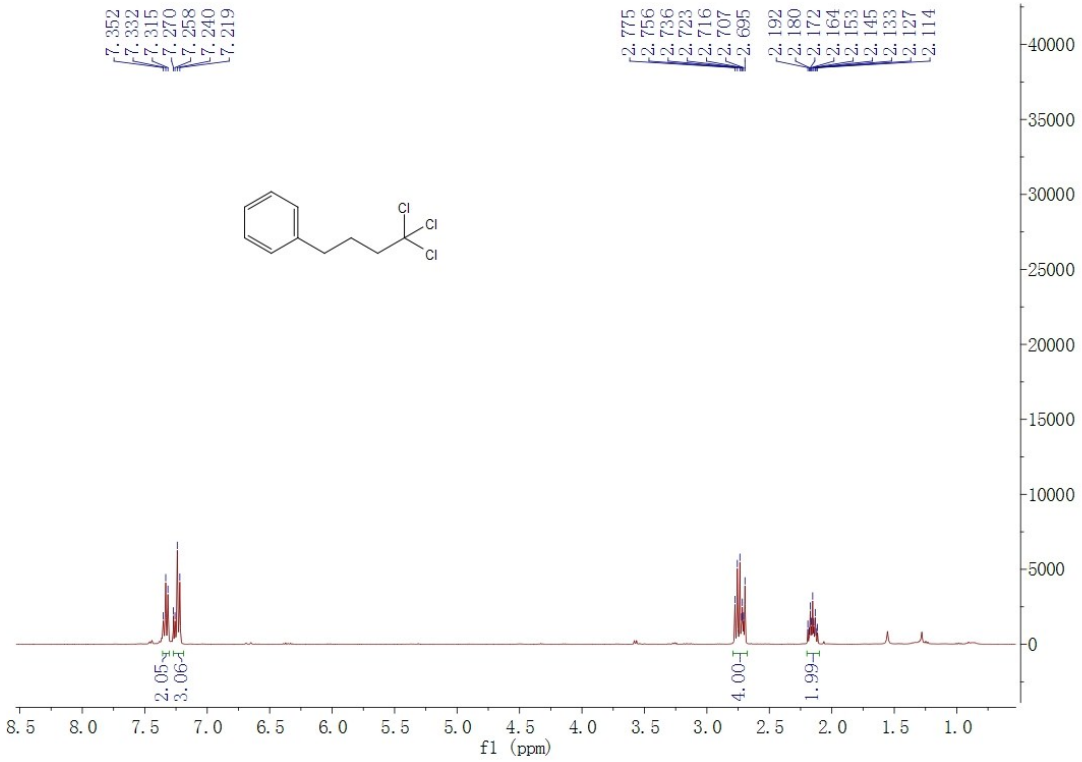


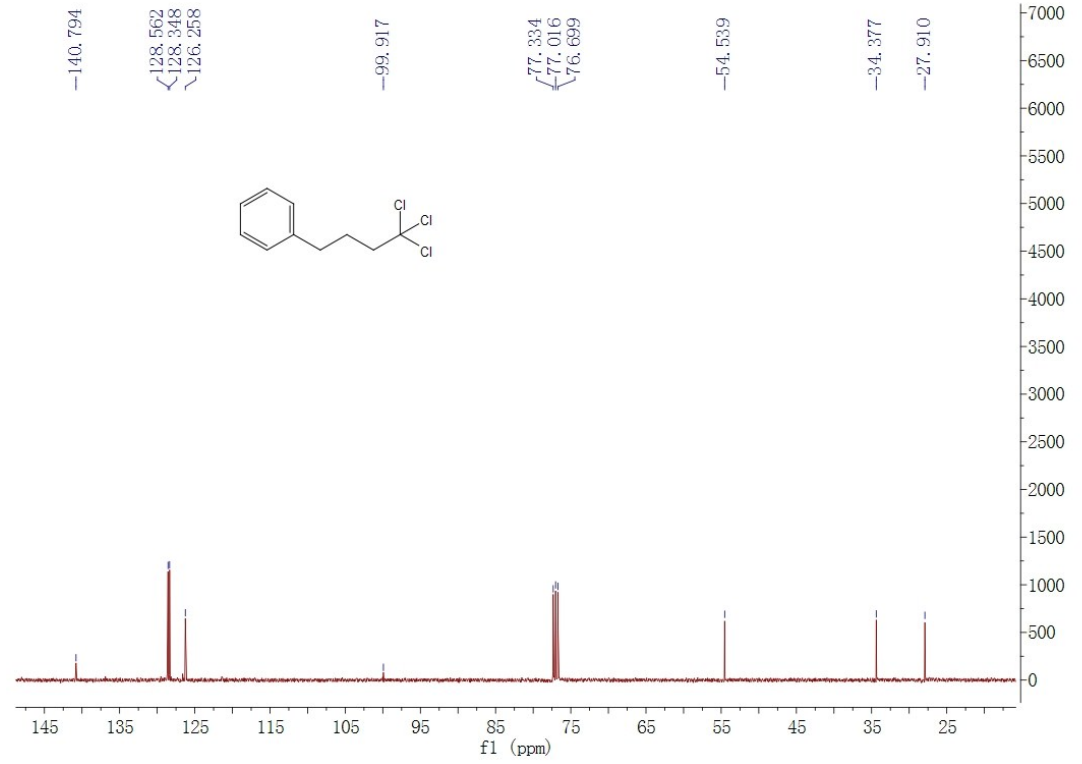
1-(5,5-dichlorohexyl)-4-fluorobenzene (Table 2, entry 18, 3ib)



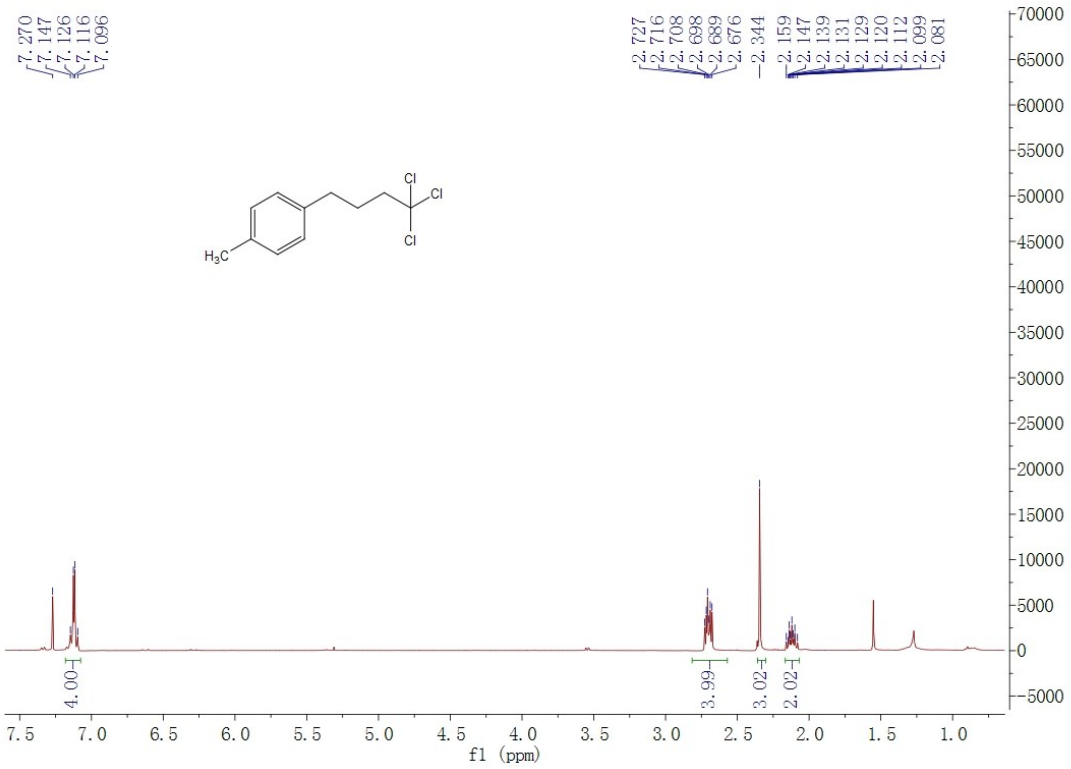


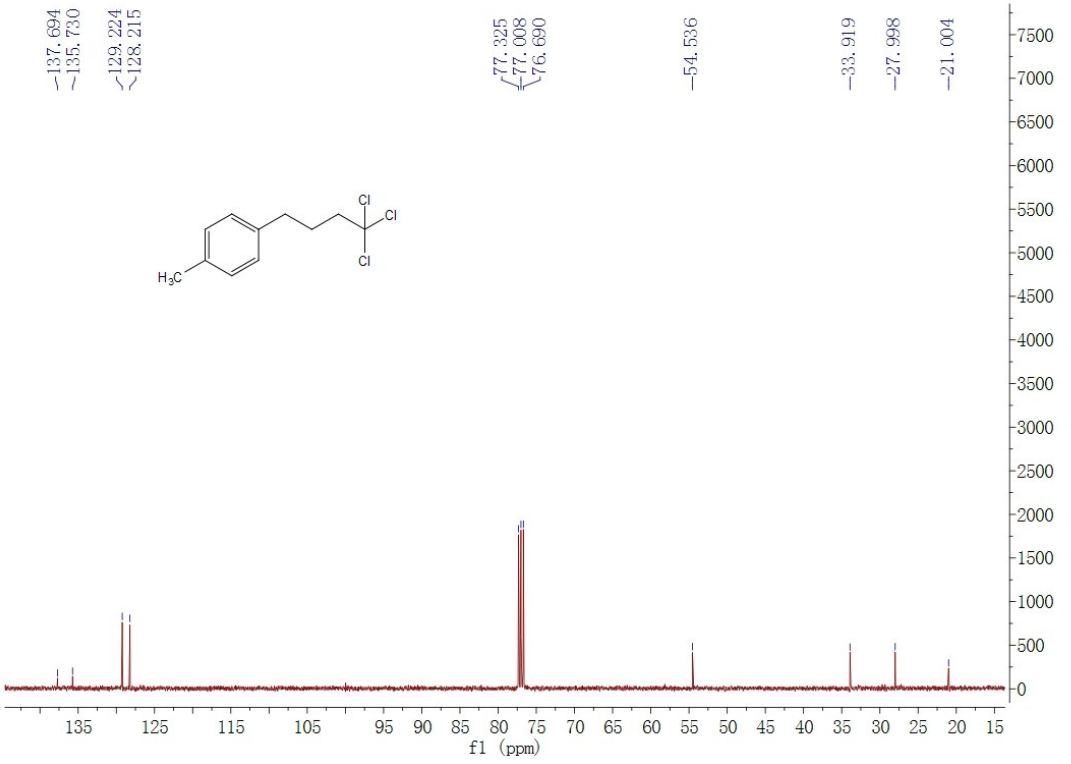
1-(4,4,4-trichlorobutyl)benzene (Scheme 2, 3ac)



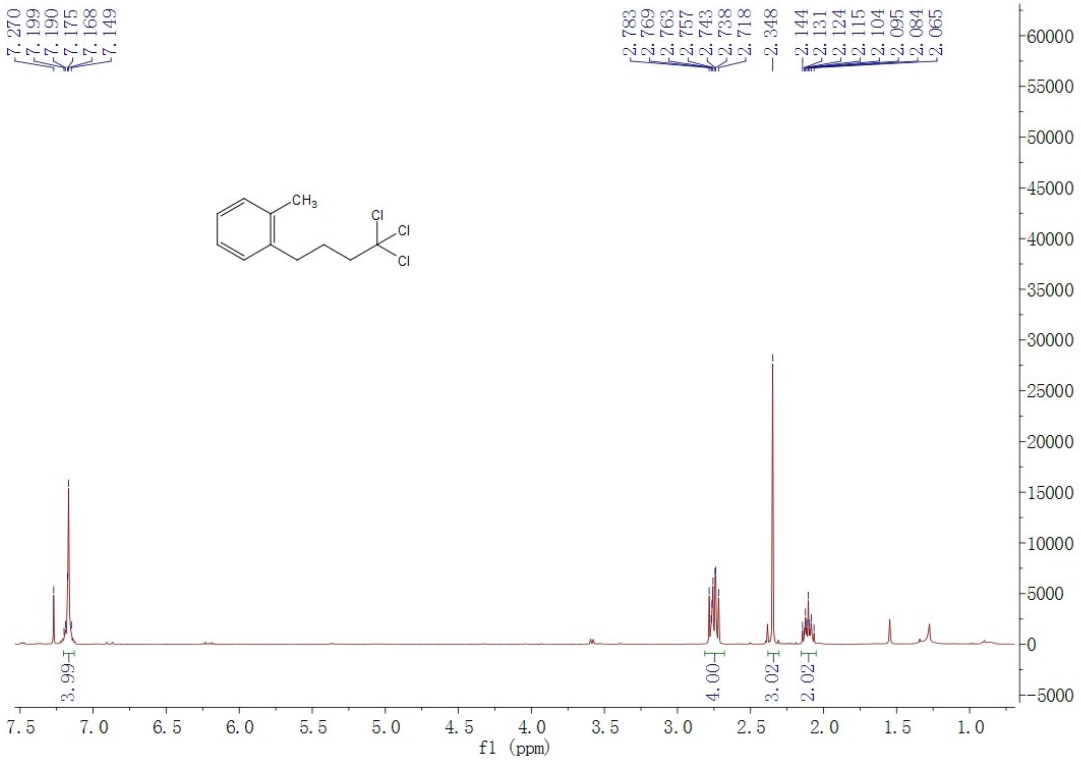


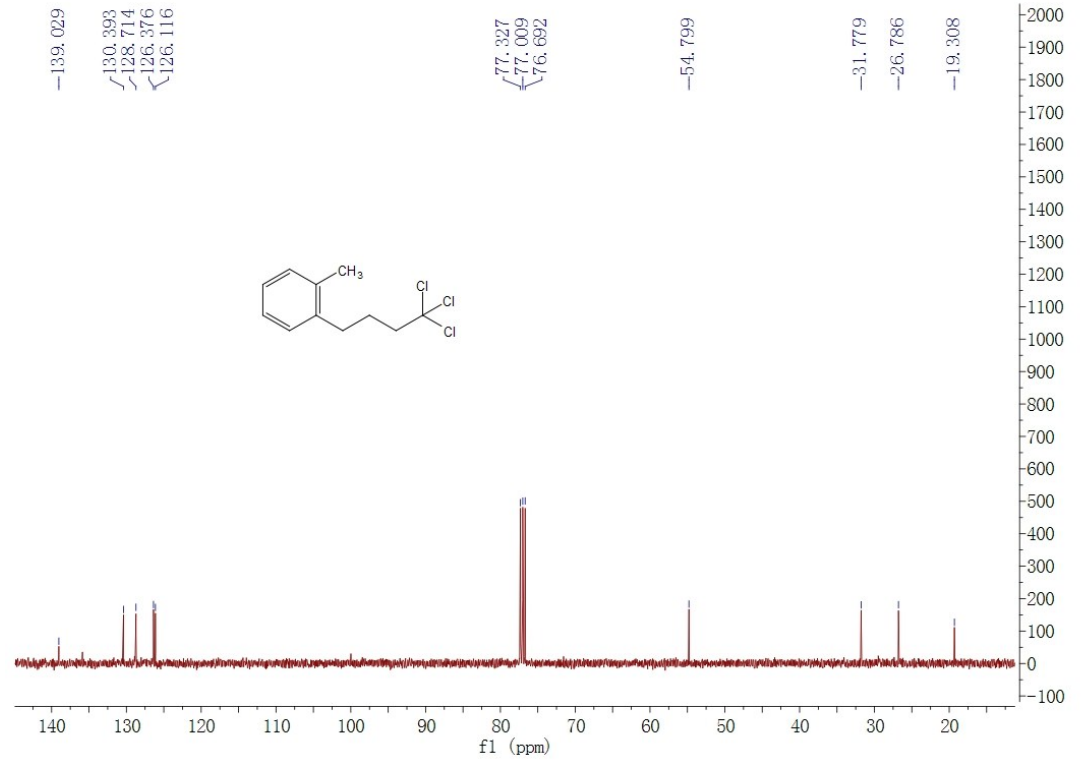
1-(4,4,4-trichlorobutyl)-4-methylbenzene (Scheme 2, 3bc)



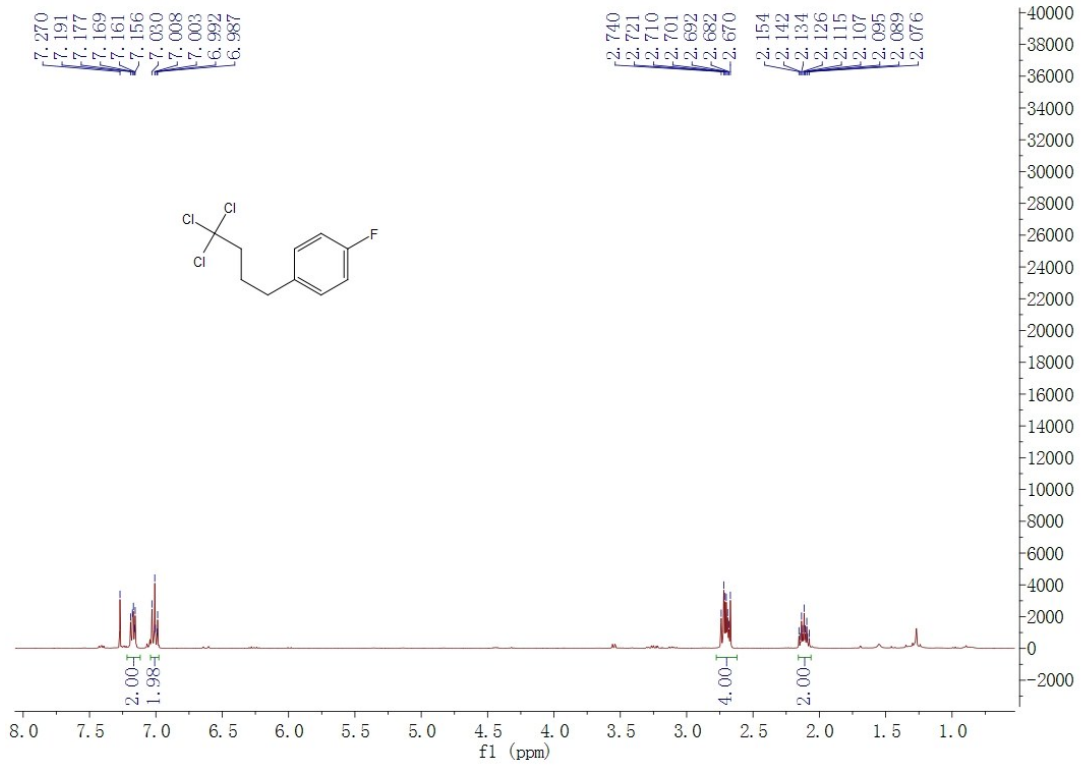


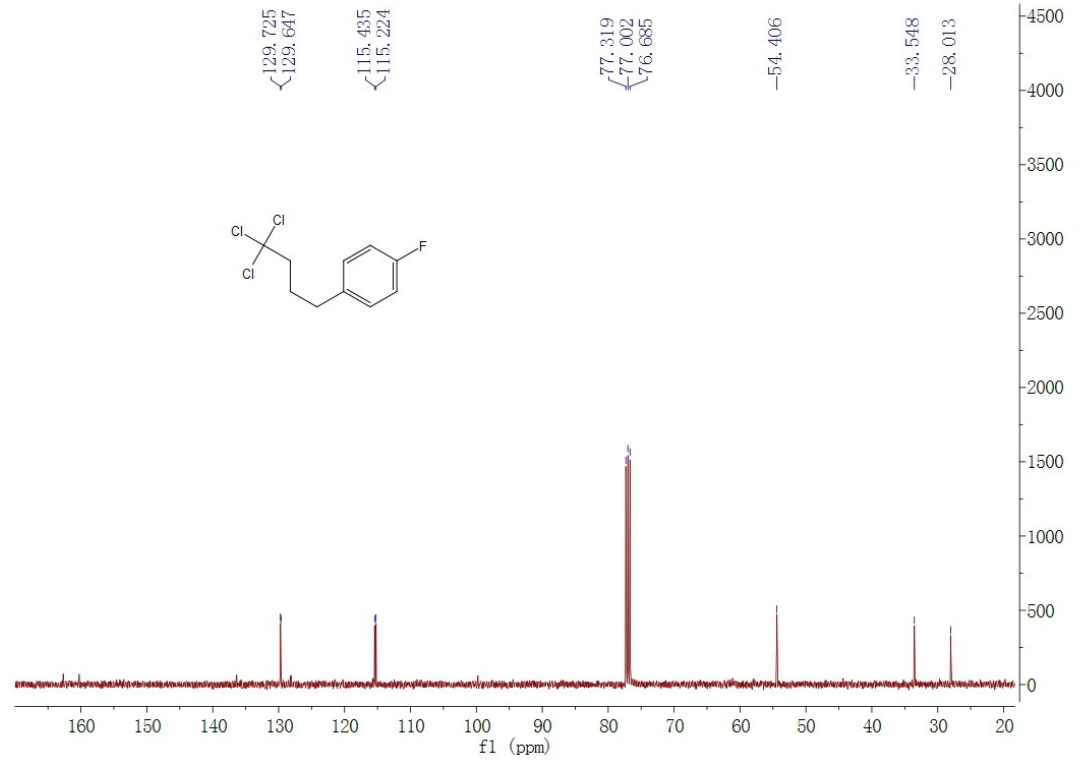
1-(4,4,4-trichlorobutyl)-2-methylbenzene (Scheme 2, 3cc)



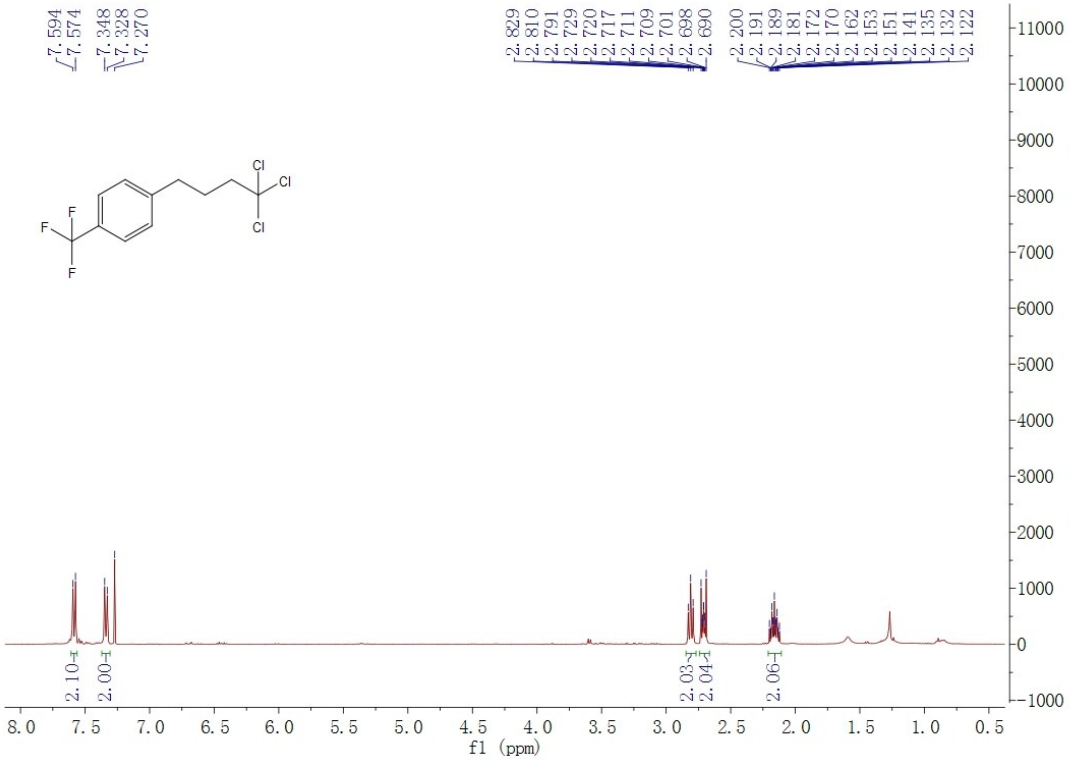


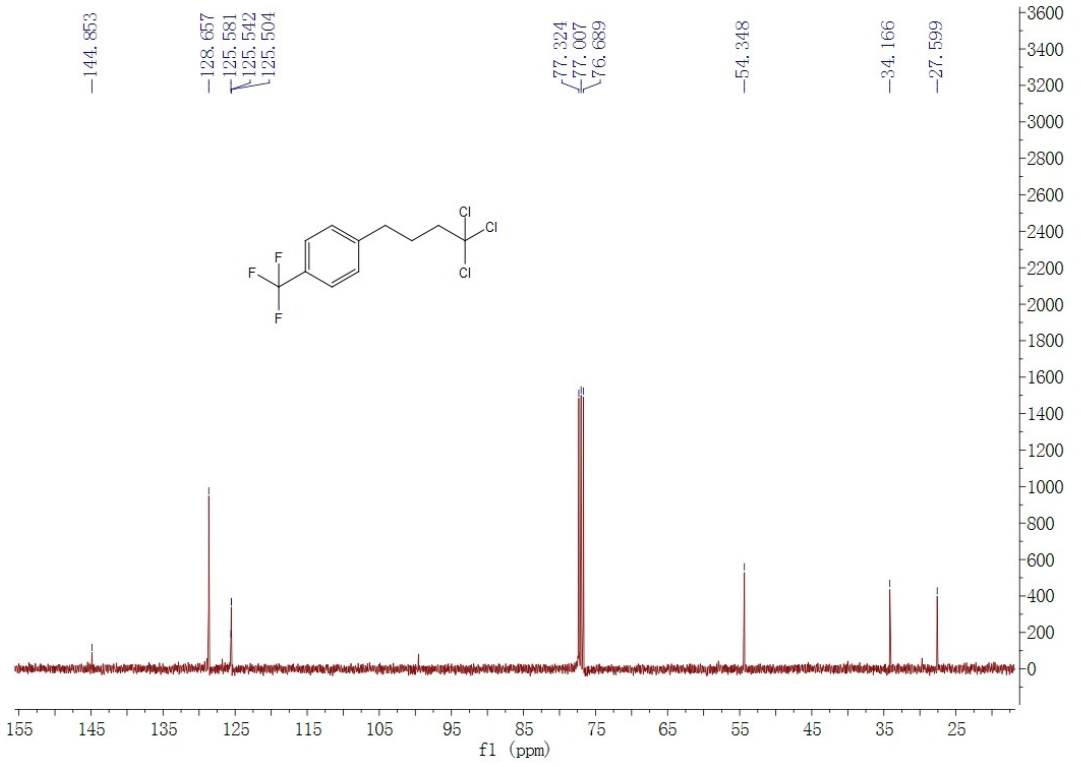
1-(4,4,4-trichlorobutyl)-4-fluorobenzene (Scheme 2, 3fc)





1-(4,4,4-trichlorobutyl)-4-(trifluoromethyl)benzene (Table 2, entry 23, 3gc)





1-(4,4,4-trichlorobutyl)benzene (Scheme 3, 4)