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Preparation of Highly Functionalized Alkylzinc Halides from Alkyl Bromides using Mg, $ZnCl_2$ and LiCl

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General information: All reactions were carried out under an argon atmosphere in dried glassware. Syringes and needles were flushed with argon three times before use. THF was continuously refluxed and freshly distilled from sodium benzophenone ketyl under nitrogen and kept over 4 Å molecular sieves. Yields refer to isolated yields of compounds estimated to be of > 95 % purity as determined by ^{1}H-NMR and capillary-GC analysis. NMR spectra were recorded on solutions in deuterated chloroform ($CDCl_3$) with residual chloroform (δ 7.25 ppm for ^{1}H NMR and δ 77.0 ppm for ^{13}C NMR) or deuterated benzene (C_6D_6) with residual benzene (7.15 ppm for ^{1}H NMR and δ 128.0 ppm for ^{13}C NMR). Abbreviations for signal coupling are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet.

Starting Materials: Commercially available starting materials were purchased from commercial sources and used without further purification.

General procedures for the preparation of various metal salt *solutions:*

$ZnCl_2$ 1M in THF:
A *Schlenk*-flask was charged with $ZnCl_2$ (20.45 g, 0.15 mol) and dried for 6 h at 150 °C under high vacuum ($5\cdot10^{-2}$ mbar)(dry stirring). Careful addition of THF (150 mL) (heat development!) and stirring overnight furnishes a clear colourless solution, which is kept over molecular sieves (4 Å)

CuCN·2 LiCl 1M in THF:
A *Schlenk*-flask was charged with LiCl (16.96 g, 0.40 mol) and CuCN·2 LiCl (17.95 g, 0.20 mol) and dried for 6 h at 150 °C under high vacuum ($5\cdot10^{-2}$ mbar; dry stirring). Careful addition of THF (200 mL) (heat development!) and stirring overnight furnishes a slightly yellowish to greenish solution which is kept over molecular sieves (4 Å). A dark green to black colour indicates the presence of Cu(II), this solution should not be used.

General procedure for the preparation of alkylzinc reagents using the Mg/$ZnCl_2$/LiCl method:
An argon flushed *Schlenk*-flask was charged with LiCl (1.25-2.5 equiv) and dried 5-10 min at 400 °C (heat gun) under high vacuum ($5\cdot10^{-2}$ mbar). Mg-turnings or powder (2.5 equiv) were added under argon and heated additionally for 5 min at 400 °C. The flask was evacuated and backfilled with argon three times before $ZnCl_2$ solution (1M in THF, 1.1 equiv) was added with a syringe. A solution of alkyl bromide (1.0 equiv) (along with internal standard: tetradecane) in THF (2.5 mL/mmol) was added at 25 °C and the resulting solution was stirred at the appropriate temperature. The completion of the insertion reaction was checked by GC analysis of reaction aliquots quenched with a solution of saturated NH_4Cl in water. After complete conversion (>95%) the remaining Mg was allowed to

settle down and the resulting alkylzinc solution was seperated and canulated to a new dried and argon flushed flask. (Important note: Separation from remaining magnesium should be performed as soon as the conversion is complete, otherwise decomposition of the organometallic reagent is observed.)

Procedures for the preparation of products ***3a-l*** *of* ***TABLE 1*** *and* ***Scheme 3-4*** *using the Mg/$ZnCl_2$/LiCl method:*

Ethyl 7-oxo-7-p-tolylheptanoate (3a).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and ethyl 6-bromohexanoate (**2a**, 893 mg, 4 mmol). The reaction was carried out at 20 ˚C for 2.5 h and provided the alkylzinc reagent **1a** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. 4-Methylbenzoyl chloride (433 mg, 2.8 mmol, 0.7 equiv) was added dropwise at -30 °C under argon. The mixture was stirred for 2.5 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL) and conc. aqueous ammonia (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:7) to yield compound **3a** (516 mg, 70%) as white powder. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.87–7.80 (m, 2H), 7.26–7.20 (m, 2H), 4.10 (q, $^3J_{HH}$ = 7.2 Hz, 2H), 2.96–2.89 (m, 2H), 2.39 (s, 3H), 2.30 (t, $^3J_{HH}$ = 7.6 Hz, 2H), 1.79–1.60 (m, 4H), 1.47–1.34 (m, 2H), 1.23 (t, $^3J_{HH}$ = 7.2 Hz, 3H); ^{13}C (75 MHz, $CDCl_3$) δ 199.9, 173.7, 143.6, 134.5, 129.2, 128.1, 60.2, 38.2, 34.1, 28.8, 24.8, 23.9, 21.6, 14.2; MS (EI, 70 eV): m/z 262 (<1) [M^+], 134 (59), 119 (100), 91 (22), 65 (5); HRMS: *m/z* calcd. for $C_{16}H_{22}O_3$ (M^+) 262.1569, found 262.1567; FT-IR

(Diamond-ATR, neat) $\tilde{\nu}$ 2988 (w), 2946 (m), 2930 (m), 1728 (s), 1670 (vs), 1606 (s), 1464 (s), 1408 (m), 1344 (s), 1240 (s), 1178 (s), 1160 (s), 1122 (s), 1096 (s), 1010 (s), 972 (s), 812 (vs), 762 (s), 728 (s), 694 (m) cm^{-1}, mp (˚C) = 56-57.

Ethyl 7-p-tolylheptanoate (3b).

The general procedure was followed using Mg-turnings (122 mg, 5 mmol), LiCl (106 mg, 2.5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and ethyl 6-bromohexanoate (**2a**, 447 mg, 2 mmol). The reaction was carried out at 20 ˚C for 2.5 h and provided the alkylzinc reagent **1a** which was transferred to an argon flushed flask.

A mixture of $Pd(OAc)_2$ (6 mg, $2.8\cdot10^{-2}$ mmol, 1.4 mol%), Ru-Phos (26 mg, $5.6\cdot10^{-2}$ mmol, 2.8 mol%) and *p*-bromotoluene (240 mg, 1.4 mmol, 0.7 equiv) in 2 mL THF was added at 20°C and the reaction mixture stirred for 1.5 h before being quenched with sat. aqueous NH_4Cl solution (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:60) to yield compound **3b** (270 mg, 82%) as colourless liquid. ^1H NMR (300 MHz, $CDCl_3$): δ 7.15–7.06 (m, 4H), 4.15 (q, $^3J_{HH}$ = 7.2 Hz, 2H), 2.60 (m, 2H), 2.34 (s, 3H), 2.33–2.28 (m, 2H), 1.74-1.59 (m, 4H), 1.46-1.33 (m, 2H), 1.28 (t, $^3J_{HH}$ = 7.1 Hz, 3H); ^{13}C (75 MHz, $CDCl_3$) δ 173.8, 139.4, 135.1, 128.9, 128.3, 60.2, 35.3, 34.3, 31.2, 28.8, 24.9, 21.00, 14.2; MS (EI, 70 eV): m/z 234 (15) [M^+], 188 (18), 144 (42), 105 (100), 85 (11), 71 (14), 57 (18); HRMS: *m/z* calcd. for $C_{15}H_{22}O_2$ (M^+) 234.1620, found 234.1614; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2980 (w), 2930 (m), 2858 (w), 1733 (vs), 1515 (w), 1463 (w), 1446 (w), 1372 (w), 1348 (w), 1177 (m), 1133 (w), 806 (w) cm^{-1}.

Ethyl 5-(2-chlorophenyl)-5-oxopentanoate (3c).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and ethyl 4-bromobutanoate (**2b**, 893 mg, 4 mmol). The reaction was carried out at 20 ˚C for 1.5 h and provided the alkylzinc reagent **1b** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. 2-Chlorobenzoyl chloride (490 mg, 2.8 mmol, 0.7 equiv) was added dropwise at -30 °C under argon. The mixture was stirred for 2.5 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (25 mL) and conc. aqueous ammonia (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:5) to yield compound **3c** (516 mg, 65%) as colourless liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.45–7.27 (m, 4H), 4.12 (q, $^3J_{HH}$ = 7.2 Hz, 2H), 3.00 (t, $^3J_{HH}$ = 7.2 Hz, 2H), 2.40 (t, $^3J_{HH}$ = 7.2 Hz, 2H), 2.09–1.98 (m, 2H), 1.24 (t, $^3J_{HH}$ = 7.2 Hz, 3H); ^{13}C (75 MHz, $CDCl_3$) δ 202.7, 173.1, 139.4, 131.6, 130.7, 130.5, 128.7, 126.9, 60.4, 41.8, 33.2, 19.3, 14.2; MS (EI, 70 eV): m/z 254 (6) [M^+], 211 (12), 210 (11), 209 (40), 208 (23), 181 (28), 154 (16), 141 (100), 111 (39), 75 (10); HRMS: *m/z* calcd. for $C_{13}H_{15}ClO_3$ (M^+) 254.0710, found 254.0701; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2980 (w), 2940 (w), 2874 (vw), 1728 (vs), 1698 (s), 1590 (m), 1432 (m), 1374 (m), 1204 (s), 1028 (s), 754 (vs) cm^{-1}.

7-(4-Chlorophenyl)-2,2-dimethyl-7-oxoheptanenitrile (3d).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and 6-bromo-2,2-dimethylhexanenitrile (**2c**, 817 mg, 4 mmol). The reaction was carried out at 0 ˚C for

5 h and provided the alkylzinc reagent **1c** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. 4-Chlorobenzoyl chloride (490 mg, 2.8 mmol, 0.7 equiv) was added dropwise at -30 °C under argon. The mixture was stirred for 2.5 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (25 mL) and conc. aqueous ammonia (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:7) to yield compound **3d** (606 mg, 83%) as white powder. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.90–7.85 (m, 2H), 7.45–7.39 (m, 2H), 2.97 (t, $^3J_{HH}$ = 7.2 Hz, 2H), 1.83–1.69 (m, 2H), 1.59–1.51 (m, 4H), 1.33 (s, 6H); ^{13}C (75 MHz, $CDCl_3$) δ 198.4, 139.4, 135.2, 129.4, 128.9, 125.0, 40.9, 38.2, 32.3, 26.6, 25.0, 23.9; MS (EI, 70 eV): m/z 263 (<1) [M^+], 156 (16), 154 (52), 139 (100), 111 (20); HRMS: *m/z* calcd. for $C_{15}H_{18}ClNO$ (M^+) 263.1077, found 263.1068; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2978 (m), 2936 (m), 1680 (vs), 1584 (m), 1570 (m), 1396 (m), 1370 (m), 1322 (m), 1260 (m), 1220 (m), 1204 (m), 1094 (s), 1010 (m), 986 (s), 836 (vs), 735 (m) cm^{-1}, mp (°C) = 78-79.

6-(4-Fluorophenylthio)-2,2-dimethylhexanenitrile (3e).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and 6-bromo-2,2-dimethylhexanenitrile (**2c**, 817 mg, 4 mmol). The reaction was carried out at 0 °C for 5 h and provided the alkylzinc reagent **1c** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. *S*-4-Fluorophenyl benzenesulfonothioate (751 mg, 2.8 mmol, 0.7 equiv) was added at -30 °C under argon. The mixture was stirred for 16 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL) and conc. aqueous ammonia (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:7) to yield compound **3e** (610 mg, 86%) as yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.36–7.28 (m, 2H), 7.02–6.93 (m, 2H), 2.86 (t, $^3J_{HH}$ = 7.1 Hz, 2H), 1.68–1.43 (m, 6H), 1.31 (s, 6H); ^{13}C (75 MHz, $CDCl_3$) δ 161.7 (d, $^1J_{CF}$ = 246.1 Hz), 132.3 (d, $^3J_{CF}$ = 8.0 Hz), 131.1 (d, $^4J_{CF}$ = 3.1 Hz) 124.9, 115.9 (d, $^2J_{CF}$ = 21.9 Hz), 40.5, 34.7 (d, $^6J_{CF}$ = 0.8 Hz), 32.3, 29.0, 26.5, 24.3; MS (EI, 70 eV): m/z 251 (86) [M^+], 218 (10), 141 (74), 128 (100), 124 (17); HRMS: *m/z* calcd. for $C_{14}H_{18}SFN$ (M^+) 251.1144, found 251.1143; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2938 (w), 2234 (w), 1490 (vs), 1472 (m), 1462 (m), 1220 (vs), 1156 (m), 1090 (m), 824 (vs), 734 (m), 630 (m), 622 (m) cm^{-1}.

2,2-Dimethyl-6-p-tolyl-hexanenitrile (3f).

The general procedure was followed using Mg-turnings (122 mg, 5 mmol), LiCl (106 mg, 2.5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and 6-bromo-2,2-dimethylhexane-nitrile (**2c**, 407 mg, 2 mmol). The reaction was carried out at 20 °C for 2.5 h and provided the alkylzinc reagent **1c** which was transferred to an argon flushed flask.

A mixture of $Pd(OAc)_2$ (6 mg, $2.8\cdot10^{-2}$ mmol, 1.4 mol%), Ru-Phos (26 mg, $5.6\cdot10^{-2}$ mmol, 2.8 mol%) and *p*-bromotoluene (240 mg, 1.4 mmol, 0.7 equiv) in 2 mL THF was added at 20°C and the reaction mixture stirred for 1.5 h before being quenched with sat. aqueous NH_4Cl solution (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:50) to yield compound **3f**

(211 mg, 70%) as colourless liquid. ^{1}H NMR (300 MHz, C_6D_6): δ 7.07–6.98 (m, 4H), 2.43-2.35 (m, 2H), 2.16 (s, 3H), 1.44-1.23 (m, 4H), 1.08–0.99 (m, 2H), 0.82 (s, 6H); ^{13}C (75 MHz, $CDCl_3$) δ 139.1, 134.9, 129.0, 128.2, 124.3, 40.6, 35.2, 31.8, 31.4, 26.0, 24.7, 20.7; MS (EI, 70 eV): m/z 215 (27) [M$^+$], 200 (9), 144 (7), 105 (100), 91 (11), 71 (22); HRMS: *m/z* calcd. for $C_{15}H_{21}N$ (M$^+$) 215.1674, found 215.1661; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 3048 (w), 2977 (m), 2936 (vs), 2860 (m), 1515 (s), 1470 (m), 1458 (m), 1391 (w), 1369 (w), 1206 (w), 841 (w), 807 (m) cm^{-1}.

5-(2-Bromophenyl)-5-oxopentanenitrile (3g).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and 4-bromobutanenitrile (**2d**, 592 mg, 4 mmol). The reaction was carried out at 20 ˚C for 1 h and provided the alkylzinc reagent **1d** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. 2-Bromobenzoyl chloride (615 mg, 2.8 mmol, 0.7 equiv) was added dropwise at -30 °C under argon. The mixture was stirred for 2 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (25 mL) and conc. aqueous ammonia (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:3) to yield compound **3g** (587 mg, 70%) as yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.63–7.59 (m, 1H), 7.42–7.28 (m, 3H), 3.11 (t, $^3J_{HH}$ = 6.8 Hz, 2H), 5.52 (t, $^3J_{HH}$ = 7.1 Hz, 2H), 2.10 (pent, $^3J_{HH}$ = 6.9 Hz, 2H); ^{13}C (75 MHz, $CDCl_3$) δ 202.3, 141.0, 133.8, 131.9, 128.3, 127.6, 119.2, 118.6, 40.5, 19.7, 16.5; MS (EI, 70 eV): m/z 251 (3) [M$^+$], 185 (97), 183 (100), 157 (16), 155 (15); HRMS: *m/z* calcd. for $C_{11}H_{10}BrNO$ (M$^+$) 250.9946, found 250.9933; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 3675 (vw), 2977 (w), 2961 (w), 2960 (w), 2246 (w), 1697 (s), 1587 (m), 1428 (m), 755 (vs) cm^{-1}.

7-chloro-1-(2-chlorophenyl)heptan-1-one (3h).

The general procedure was followed using Mg-turnings (244 mg, 10 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 4.4 mL, 4.4 mmol) and 1-bromo-6-chlorohexane (**2e**, 798 mg, 4 mmol). The reaction was carried out at 20 ˚C for 40 min and provided the alkylzinc reagent **1e** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 4.0 mL, 1.0 equiv) was added at -30 °C and the mixture stirred for 30 min. 2-Chlorobenzoyl chloride (490 mg, 2.8 mmol, 0.7 equiv) was added dropwise at -30 °C under argon. The mixture was stirred for 2.5 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (25 mL) and conc. aqueous ammonia (25 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:10) to yield compound **3h** (457 mg, 63%) as colourless liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.44–7.27 (m, 4H), 3.52 (t, $^3J_{HH}$ = 6.6 Hz, 2H), 2.93 (t, $^3J_{HH}$ = 7.3 Hz, 2H), 1.83–1.68 (m, 4H), 1.52–1.32 (m, 4H); ^{13}C (75 MHz, $CDCl_3$) δ 203.6, 139.7, 131.5, 130.7, 130.5, 128.7, 126.9, 45.0, 42.8, 32.4, 28.4, 26.6, 23.9; MS (EI, 70 eV): m/z 258 (<1) [M$^+$], 156 (23), 154 (81), 139 (100), 111 (19) HRMS: *m/z* calcd. for $C_{13}H_{16}Cl_2O$ (M$^+$) 258.0578, found 258.0567; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2936 (m), 2860 (w), 1698 (s), 1590 (m), 1466 (m), 1432 (s), 1287 (m), 1268 (m), 1208 (m), 1062 (m), 756 (vs), 730 (s), 644 (s) cm^{-1}.

5-Cyclohex-2-en-1-yl-*N*,*N*-diethylpentanamide (3i)

The general procedure was followed using Mg-turnings (122 mg, 5 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and 5-bromo-*N*,*N*-diethylpentanamide (**2f**, 472 mg, 2 mmol) dissolved in THF (3 mL). The reaction was carried out at 25 ˚C for 1 h and provided the alkylzinc reagent **1f** which was transferred to an argon flushed flask.
CuCN·2 LiCl (1M solution in THF, 0.4 mL, 0.2 equiv) was added at -20 °C and the mixture stirred for 30 min. 3-Bromocyclohexene (225 mg, 1.4 mmol, 0.7 equiv) was added at -20 °C under argon. The mixture was stirred for 1 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL) and conc. aqueous ammonia (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (ethyl acetate/pentane = 1:4) to yield compound **3i** (232 mg, 70%) as colorless liquid.
^1H NMR (300 MHz, $CDCl_3$): δ 5.64-5.51 (m, 2H), 3.37-3.23 (m, 4H), 2.28-2.23 (m, 2H) 2.03-1.09 (m, 19H); ^{13}C (75 MHz, $CDCl_3$) δ 172.2, 132.1, 126.7, 41.9, 40.0 36.1, 35.0, 33.1, 29.0, 26.8, 25.7, 25.3, 21.5, 14.4, 13.1; MS (EI, 70 eV): m/z 237 (9) [M^+], 156 (15), 115 (100), 100 (59), 58 (38); HRMS: *m/z* calcd. for $C_{15}H_{27}NO$ (M^+) 237.2093, found 237.2097; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2967 (m), 2931 (s), 2861 (m), 1616 (vs), 1480 (m), 1448 (m), 1430 (s), 1380 (m), 1362 (m), 1264 (m), 1221 (w) cm^{-1}.

{3-[3-(Benzylthio)propyl]phenyl}(phenyl)methanone (3j).

The general procedure was followed using Mg-powder (122 mg, 5 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and [3-(3-bromopropyl)phenyl] (phenyl)-methanone (**2g**, 606 mg, 2 mmol) dissolved in THF (3 mL). The reaction was carried out at 25 ˚C for 1.5 h and provided the alkylzinc reagent **1g** which was transferred to an argon flushed flask.

S-benzyl benzenesulfonothioate (370 mg, 1.4 mmol, 0.7 equiv) was added at -20 °C and the mixture stirred for 1 h. The solution was allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:19) to yield compound **3j** (254 mg, 58%) as colorless liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.79-7.70 (m, 4H), 7.60-7.44 (m, 3H), 7.31-7.22 (m, 7H), 3.70 (s, 2H), 2.75 (t, $^3J_{HH}$ = 7.3 Hz, 2H), 2.44 (t, $^3J_{HH}$ = 7.0 Hz, 2H), 1.95-1.85 (m, 2H); ^{13}C (75 MHz, $CDCl_3$) δ 196.4, 146.7, 138.4, 137.9, 137.5, 137.5, 135.4, 132.2, 130.4, 129.9, 128.8, 128.5, 128.4, 128.2, 127.0, 36.6, 34.7, 30.6, 30.4; MS (EI, 70 eV): m/z 346 (52) [M^+] 255 (12), 222 (21), 209 (100), 196 (18), 145 (28), 105 (55), 91 (79); HRMS: *m/z* calcd. for $C_{23}H_{22}OS$ (M^+) 346.1391, found 346.1394; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 3059 (w), 3027 (w), 2922 (w), 2857 (w), 1653 (vs), 1604 (s), 1578 (w), 1568 (w), 1494 (w), 1446 (m), 1412 (w), 1315 (m), 1310 (m), 1276 (vs), 1202 (w), 1176 (m), 1148 (w), 1072 (w), 1028 (w), 1020 (w), 1000 (w), 938 (m), 922 (m), 847 (w), 787 (w), 768 (w), 740 (w), 697 (vs), 680 (m) cm^{-1}.

[3-(3-Cyclohex-2-en-1-ylpropyl)phenyl](phenyl)methanone (3k).

The general procedure was followed using Mg-powder (122 mg, 5 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and [3-(3-bromopropyl)phenyl] (phenyl)-methanone (**2g**, 606 mg, 2 mmol) dissolved in THF (3 mL). The reaction was carried out at 25 ˚C for 1.5 h and provided the alkylzinc reagent **1g** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 0.4 mL, 0.2 equiv) was added at -20 °C and the mixture stirred for 30 min. 3-Bromocyclohexene (225 mg, 1.4 mmol, 0.7 equiv) was added at -20 °C under argon. The mixture was stirred for 1 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL) and conc. aqueous ammonia (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (diethyl ether/pentane = 1:9) to yield compound **3k** (261 mg, 61%) as colorless liquid.

^{1}H NMR (300 MHz, $CDCl_3$): δ 7.43-6.97 (m, 9H), 5.70-5.56 (m, 2H), 3.02 (s, 1H) 2.60-2.53 (m, 2H), 2.10 (brs, 1H), 1.79-1.17 (m, 9H); ^{13}C (75 MHz, $CDCl_3$) δ 144.5, 141.5, 141.3, 132.1, 128.6, 128.4, 127.3, 127.2, 126.8, 126.8, 126.8, 126.7, 35.9, 35.6, 35.0, 29.0, 28.5, 25.4, 21.5; MS (EI, 70 eV): m/z 304 (59) [M^+], 209 (100), 196 (42), 183 (22), 118 (18), 105 (92), 77 (75); HRMS: *m/z* calcd. For $C_{22}H_{24}O$ (M^+) 304.1827, found 304.1804; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2971 (m), 2941 (s), 2859 (m), 1659 (vs), 1610 (s), 1582 (w), 1560 (w), 1493 (w), 1314 (m), 1321 (m), 1275 (vs), 1243 (w), 1153 (m), 1144 (w), 1111 (w), 1022 (w), 1020 (w), 998 (w), 846 (w), 787 (w), 768 (w), 740 (w), 690 (s), 680 (m) cm^{-1}.

Ethyl 2-(1,4-dioxaspiro[4.5]dec-8-ylmethyl)acrylate (3l).

The general procedure was followed using Mg-turnings (122 mg, 5 mmol), LiCl (212 mg, 5 mmol), $ZnCl_2$ (1M solution in THF, 2.2 mL, 2.2 mmol) and 8-bromo-1,4-dioxaspiro[4.5]decane (**2h**, 442 mg, 2 mmol) dissolved in THF (3 mL). The reaction was carried out at 25 ˚C for 2 h and provided the alkylzinc reagent **1h** which was transferred to an argon flushed flask.

CuCN·2 LiCl (1M solution in THF, 0.4 mL, 0.2 equiv) was added at -20 °C and the mixture stirred for 30 min. ethyl 2-

(bromomethyl)acrylate (270 mg, 1.4 mmol, 0.7 equiv) was added at -20 °C under argon. The mixture was stirred for 1 h and allowed to warm up slowly to 20 °C before being quenched with sat. aqueous NH_4Cl solution (20 mL) and conc. aqueous ammonia (20 mL). The aqueous layer was extracted with diethyl ether three times. The combined organic extracts were dried over Na_2SO_4 and concentrated *in vacuo*. The crude residue was purified by flash column chromatography on silica gel (ethyl acetate/pentane = 1:9) to yield compound **3l** (245 mg, 69%) as colorless liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.13 (d, $^3J_{HH}$ = 1.7 Hz, 1H), 5.46-5.45 (m, 1H), 4.18 (q, $^3J_{HH}$ = 7.3 Hz, 2H), 3.90 (s, 4H), 2.21 (d, $^3J_{HH}$ = 6.8 Hz, 2H), 1.74-1.64 (m, 4H), 1.53-1.43 (m, 3H), 1.27 (t, $^3J_{HH}$ = 7.3 Hz, 3H), 1.28-1.21 (m, 2H); ^{13}C (75 MHz, $CDCl_3$) δ 167.3, 139.3, 125.8, 109.0, 64.2, 60.5, 38.8, 35.1, 34.3, 29.9, 14.2; MS (EI, 70 eV): m/z 254 (<1) [M^+], 198 (3), 181 (5), 99 (100), 86 (13); HRMS: *m/z* calcd. for $C_{14}H_{22}O_4$ (M^+) 254.1518, found 254.1494; FT-IR (Diamond-ATR, neat) $\tilde{\nu}$ 2980 (w), 2930 (m), 2879 (m), 2860 (w), 1713 (vs), 1629 (w), 1477 (vw), 1446 (w), 1410 (w), 1371 (w), 1329 (w), 1301 (m), 1284 (w), 1200 (m), 1174 (m), 1156 (m), 1133 (m), 1104 (vs), 1076 (m), 1067 (w), 1033 (m), 1001 (w), 982 (w), 929 (m), 884 (w), 857 (vw), 820 (w), 768 (vw), 661 (w) cm^{-1}.

Preparation of Highly Functionalized Alkylzinc Halides from Alkyl Bromides using Mg, $ZnCl_2$ and LiCl

^{1}H and ^{13}C spectra

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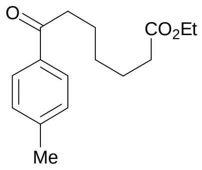
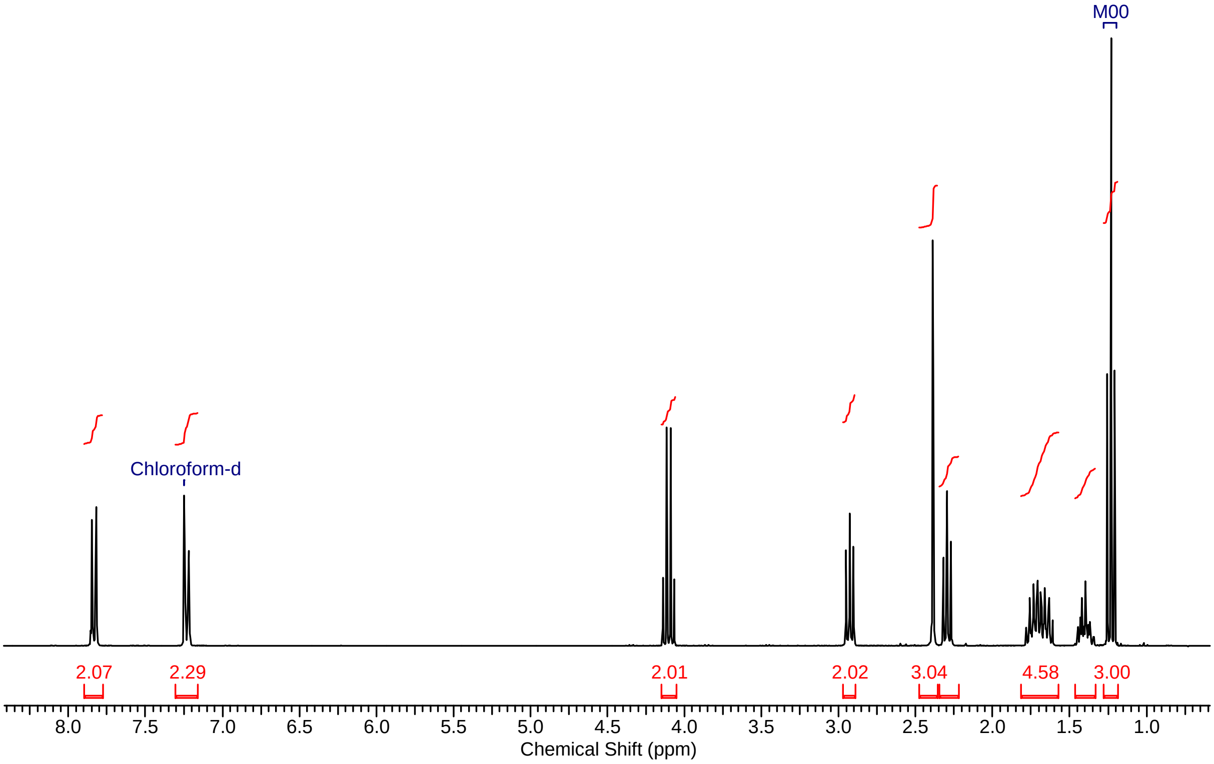
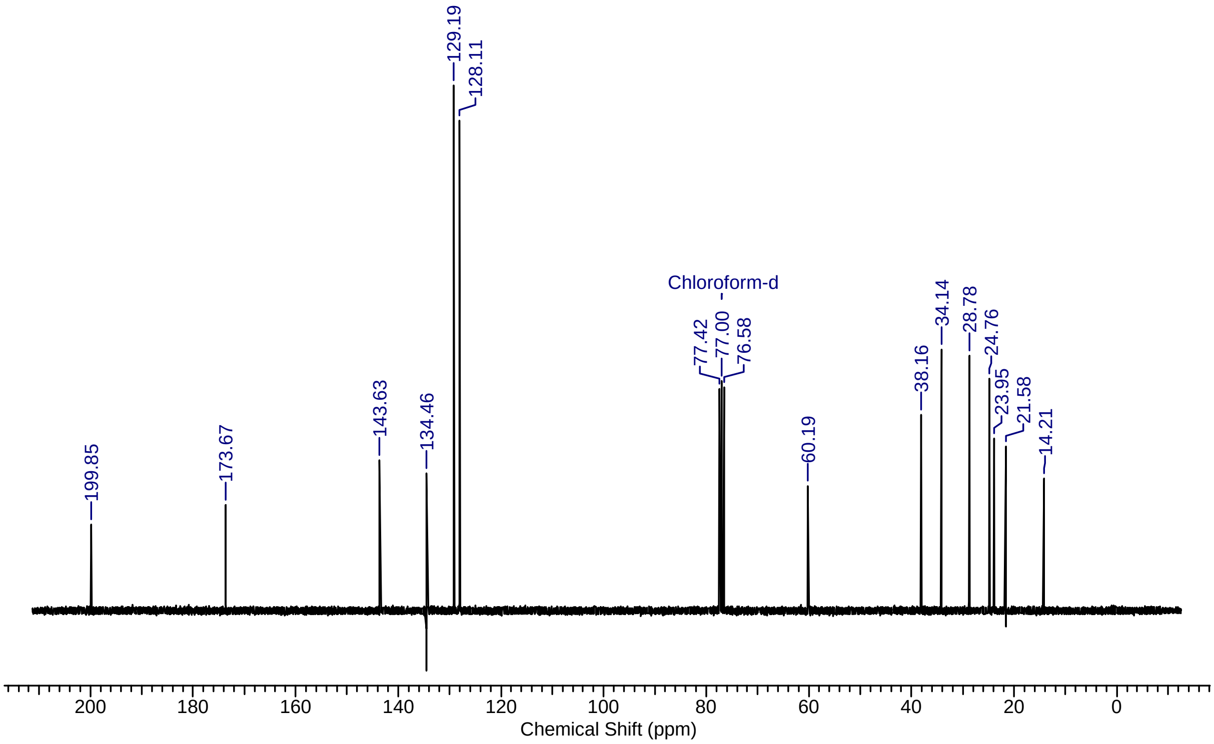
e-mail: paul.knochel@cup.uni-muenchen.de

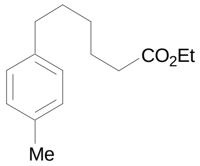
Compound 3a

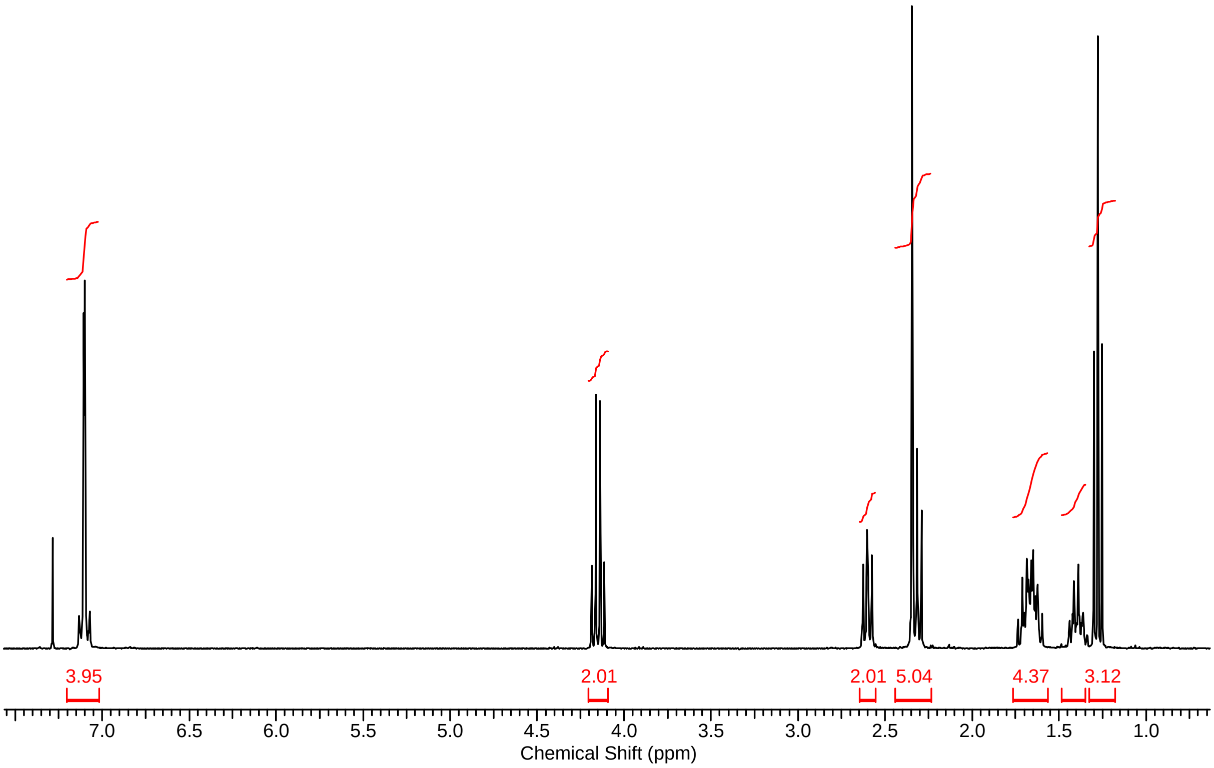

O
CO2Et
Me


M00
Chloroform-d
2.07
2.29
2.01
2.02
3.04
4.58
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)


199.85
173.67
143.63
134.46
129.19
128.11
Chloroform-d
77.42
77.00
76.58
60.19
38.16
34.14
28.78
24.76
23.95
21.58
14.21
200
180
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

Compound 3b


CO$_2$Et
Me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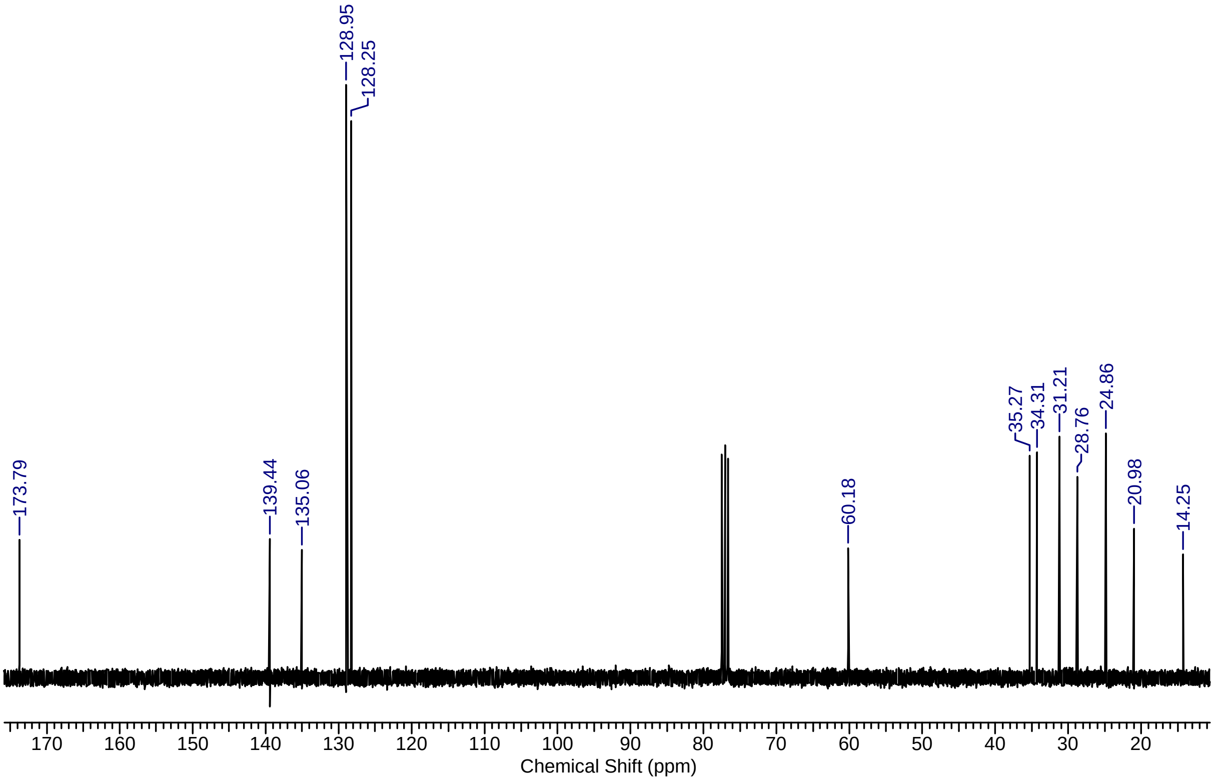
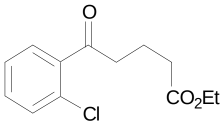
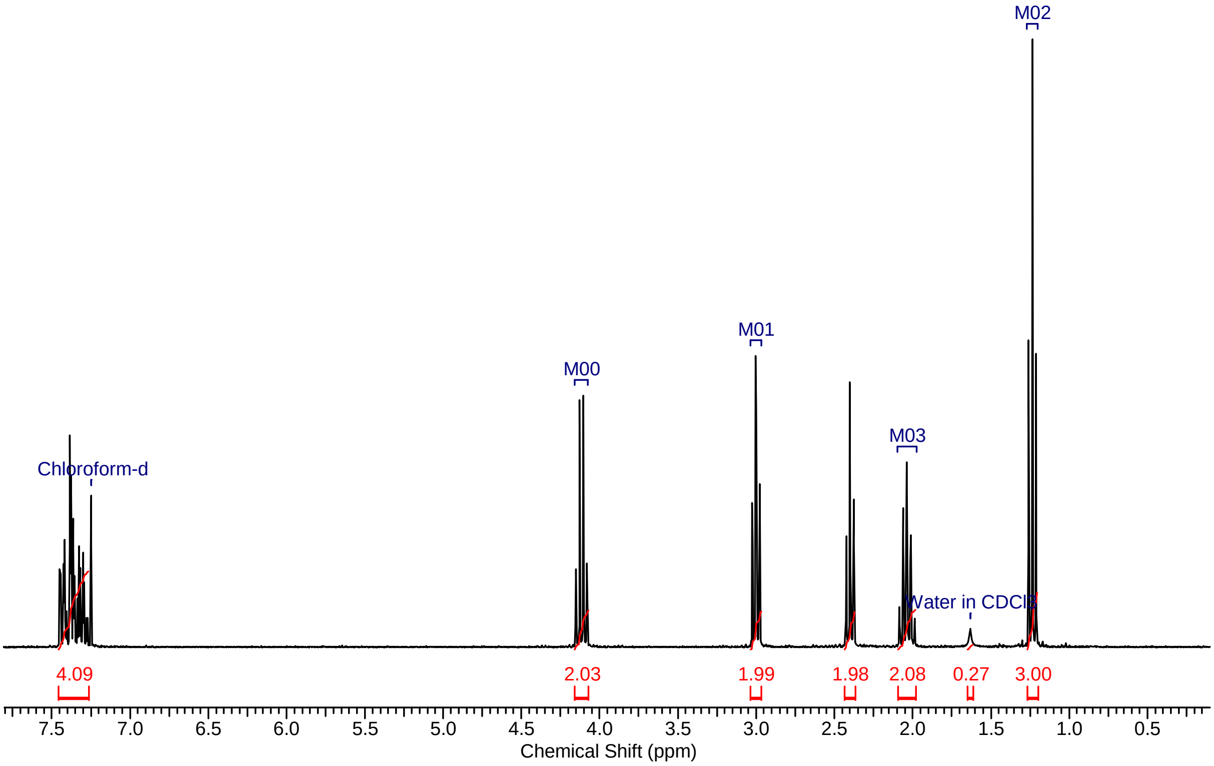
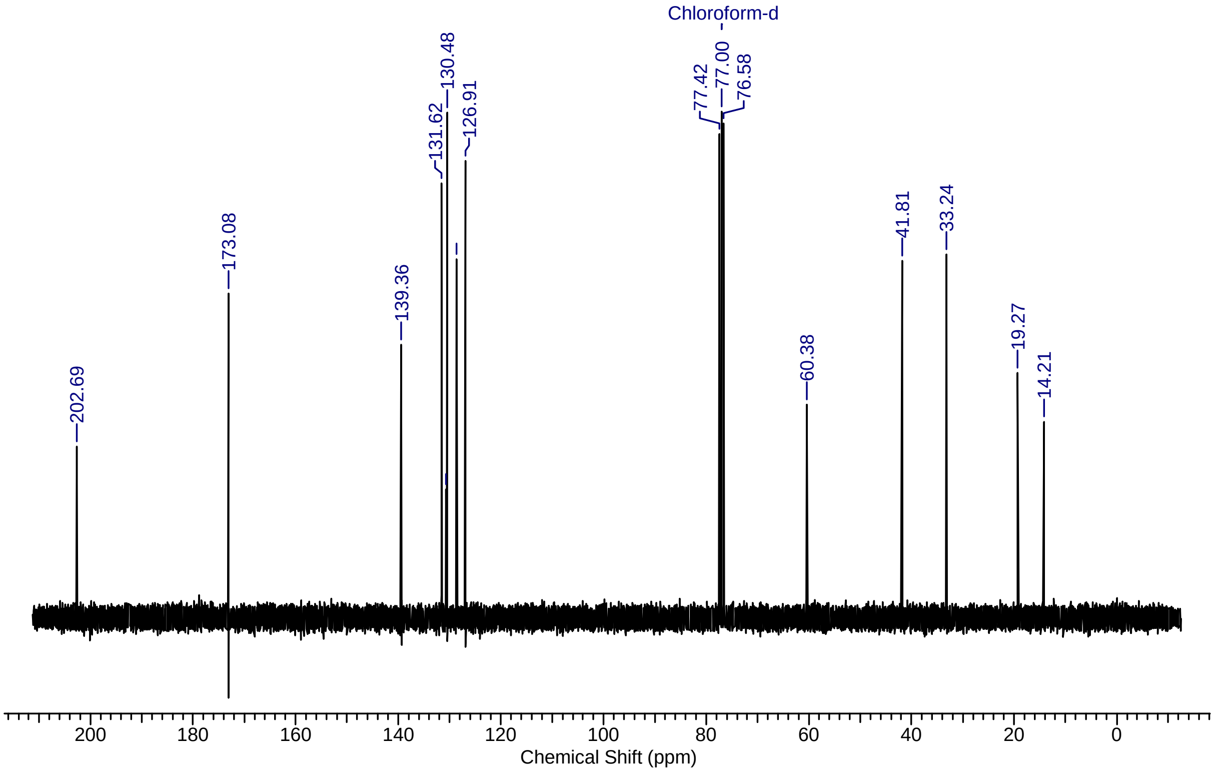
2.01
2.01
5.04
4.37
3.12
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)


173.79
139.44
135.06
128.95
128.25
60.18
35.27
34.31
31.21
28.76
24.86
20.98
14.25
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
Chemical Shift (ppm)

Compound 3c


O
Cl
CO_2Et


M02
M01
M00
M03
Chloroform-d
Water in CDCl3
4.09
2.03
1.99
1.98
2.08
0.27
3.00
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Chemical Shift (ppm)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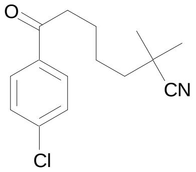
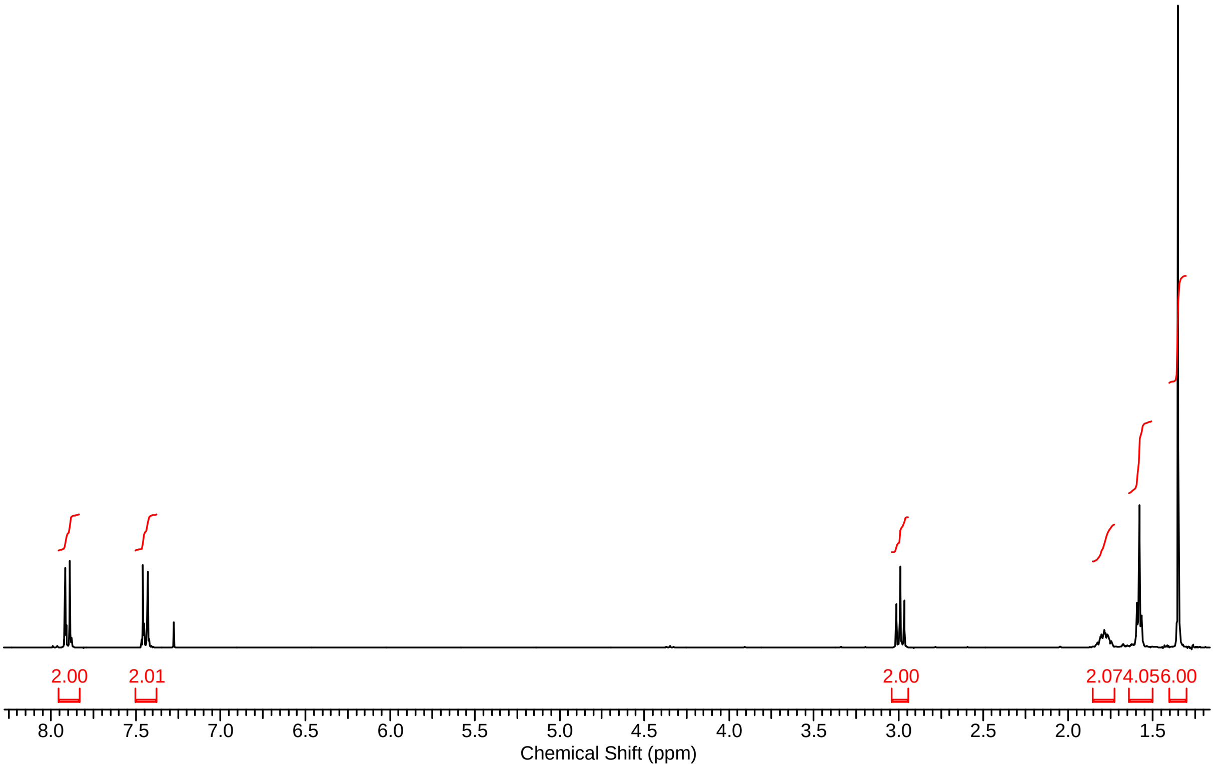
130.48
126.91
77.42
77.00
76.58
60.38
41.81
33.24
19.27
14.21
200
180
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

Compound 3d


O
CN
Cl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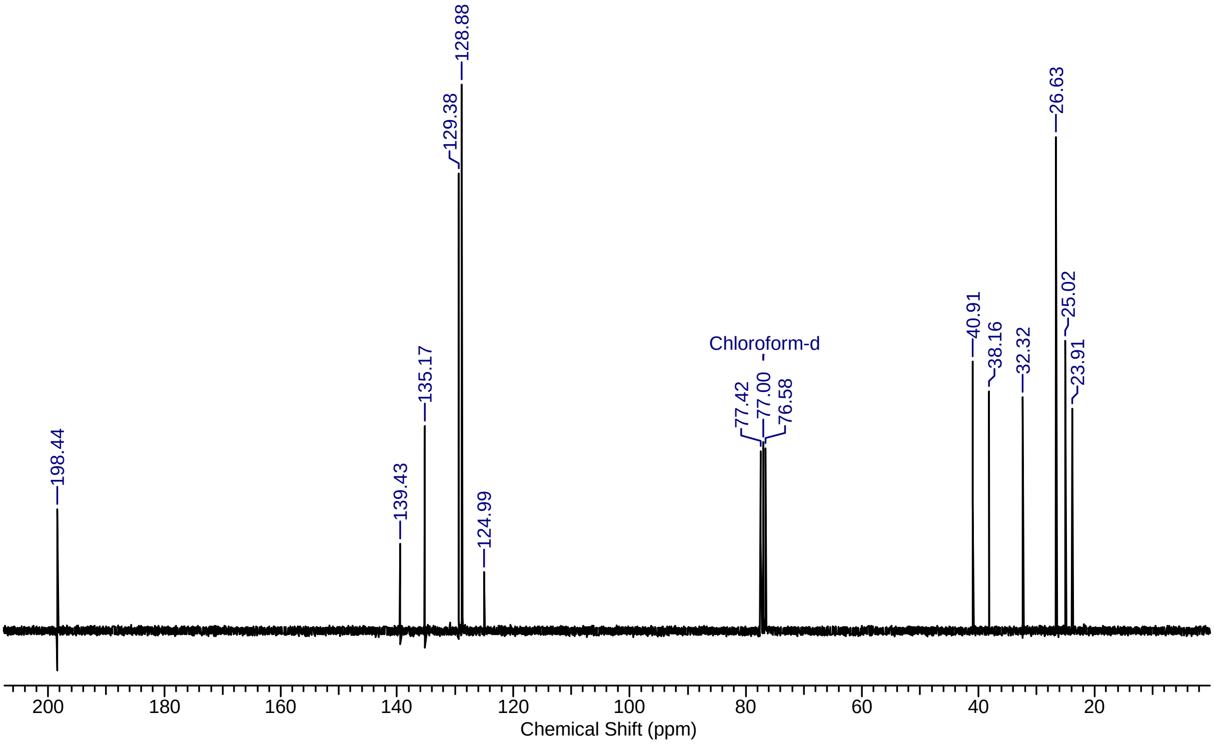
2.00
2.07
4.05
6.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Chemical Shift (ppm)


198.44
139.43
135.17
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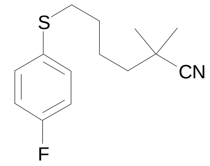
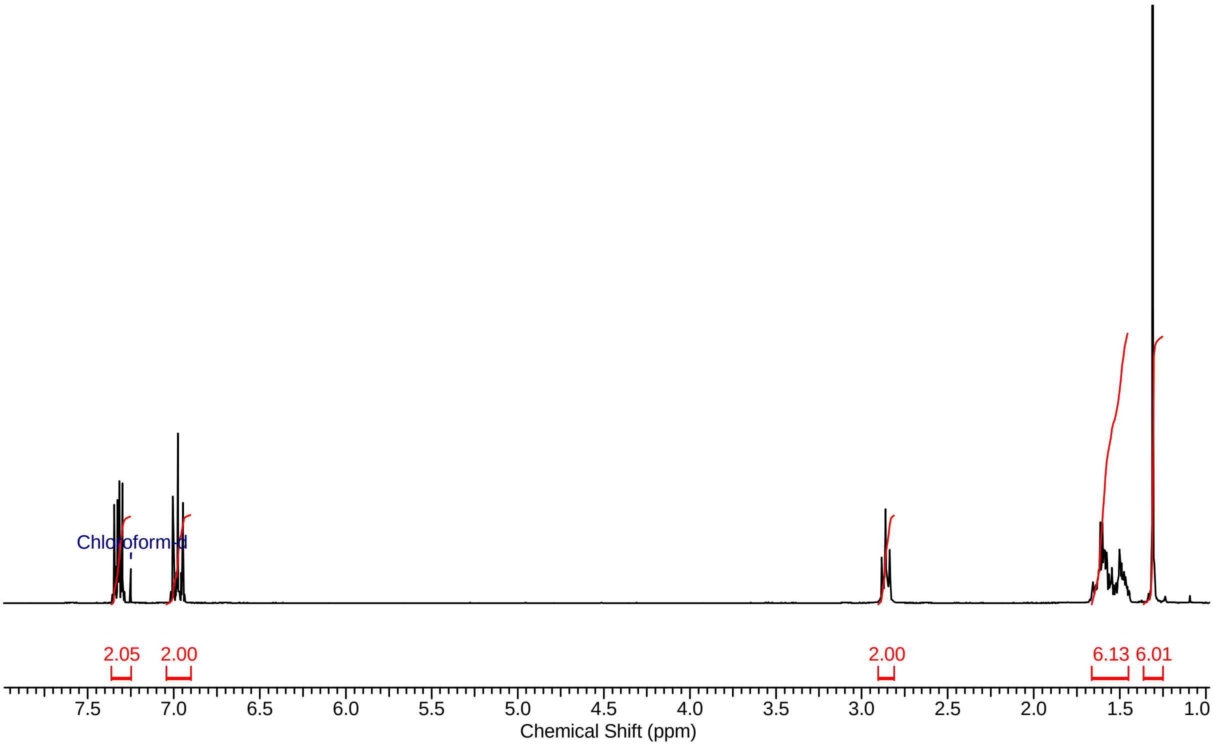
128.88
124.99
Chloroform-d
77.42
77.00
76.58
40.91
38.16
32.32
26.63
25.02
23.91
200
180
160
140
120
100
80
60
40
20
Chemical Shift (ppm)

Compound 3e


S
CN
F


Chloroform-d
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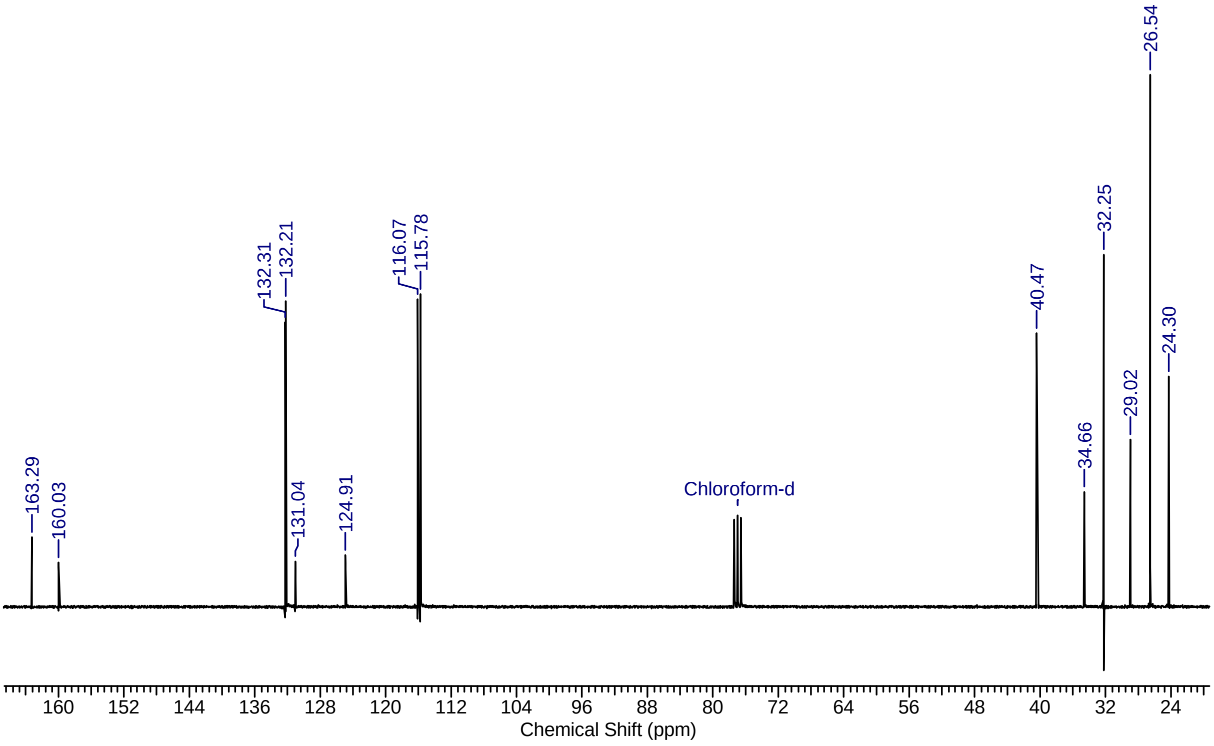
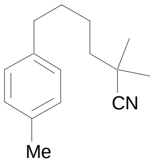
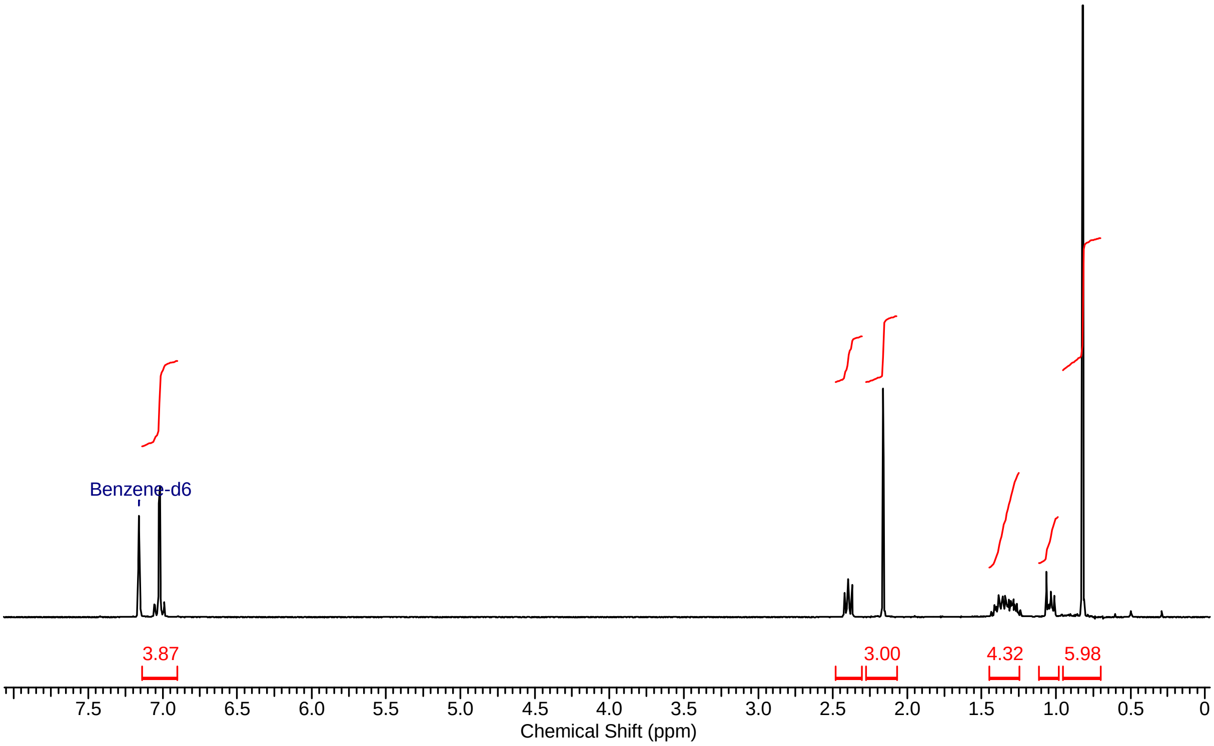
2.00
2.00
6.13
6.01
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)


163.29
160.03
132.31
132.21
131.04
124.91
116.07
115.78
Chloroform-d
40.47
34.66
32.25
29.02
26.54
24.30
160
152
144
136
128
120
112
104
96
88
80
72
64
56
48
40
32
24
Chemical Shift (ppm)

Compound 3f


CN
Me


Benzene-d6
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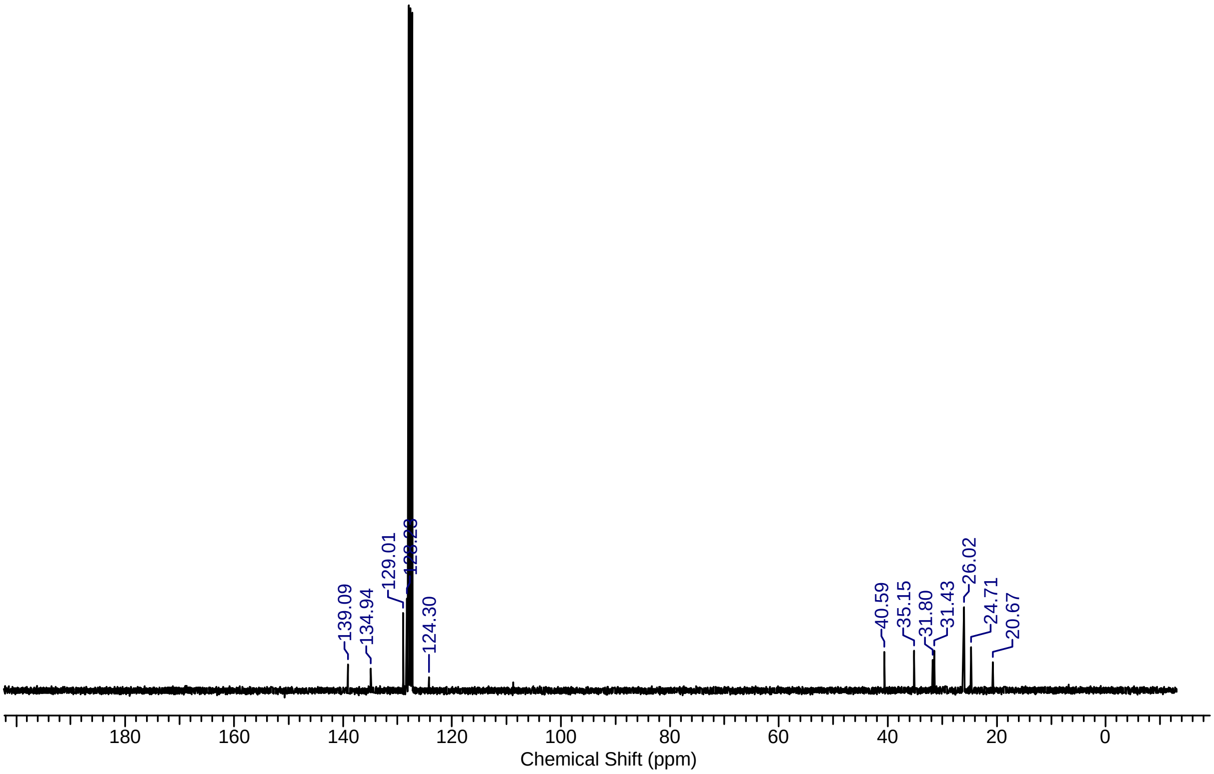
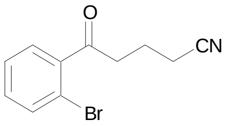
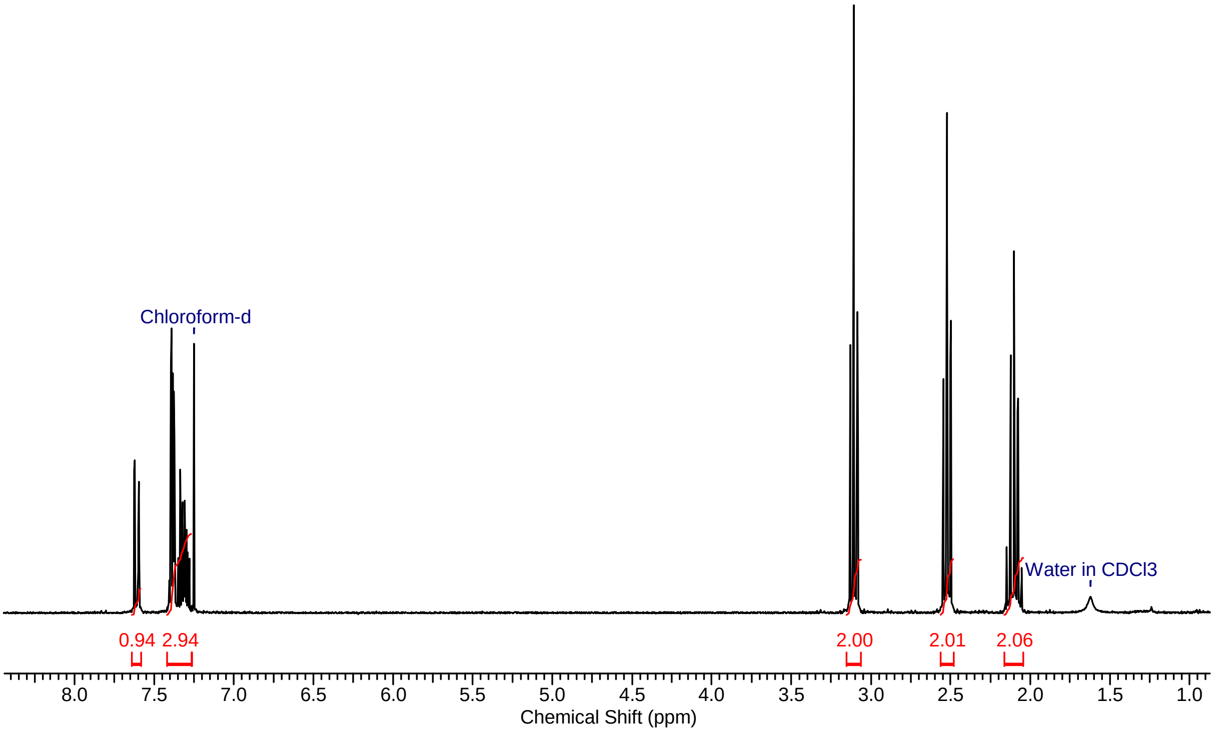
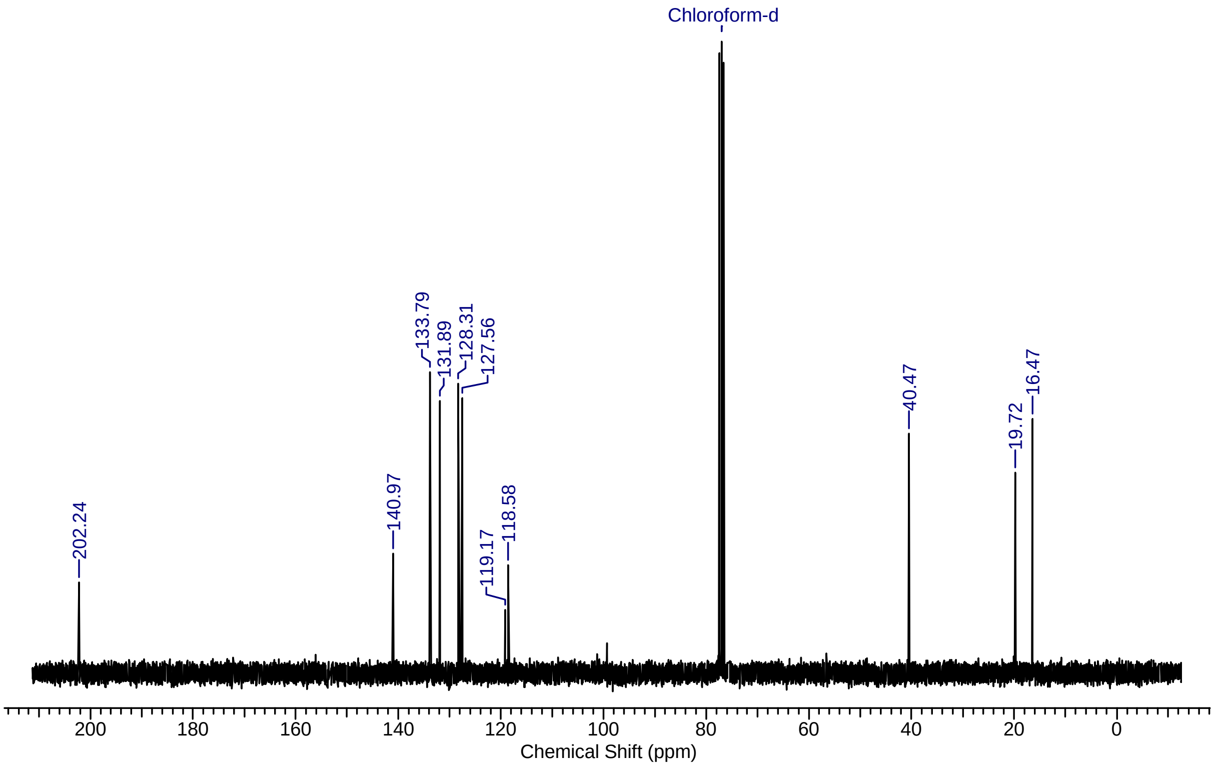
3.00
4.32
5.98
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)


139.09
134.94
129.01
128.23
124.30
40.59
35.15
31.80
31.43
26.02
24.71
20.67
180
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

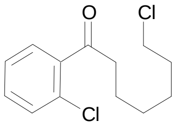
Compound 3g

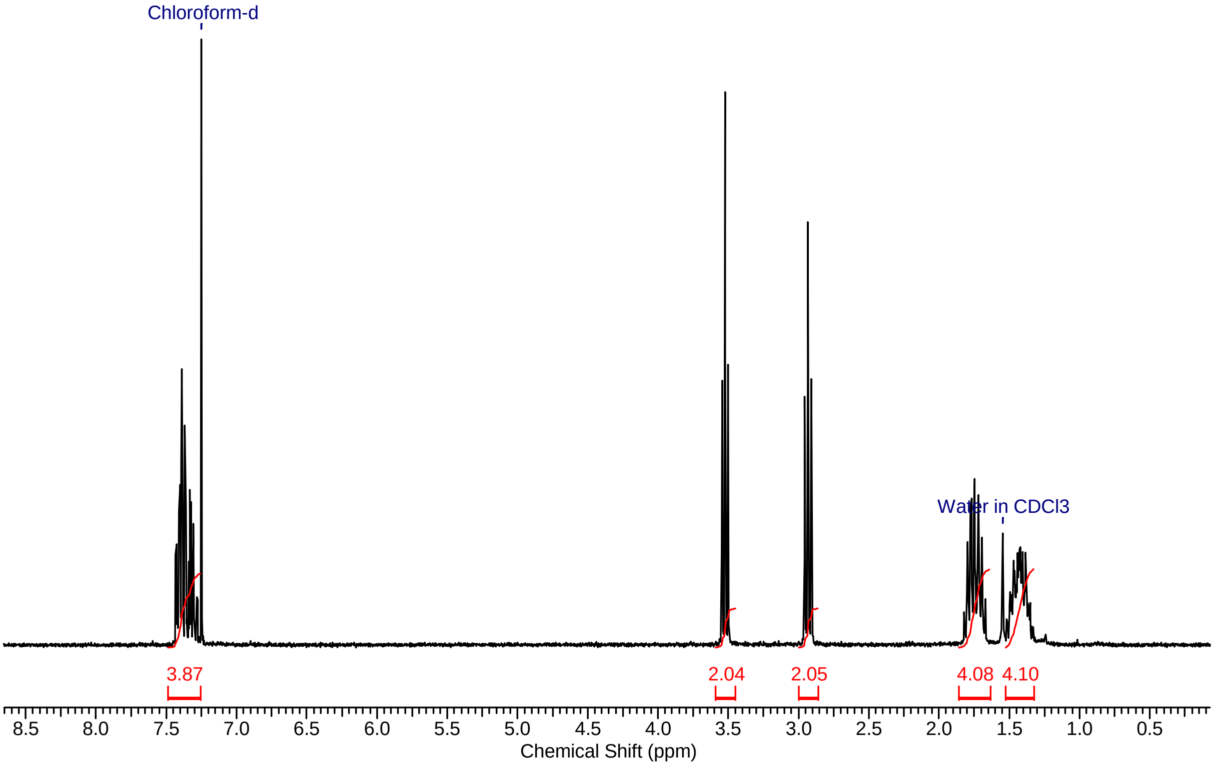

O
CN
Br

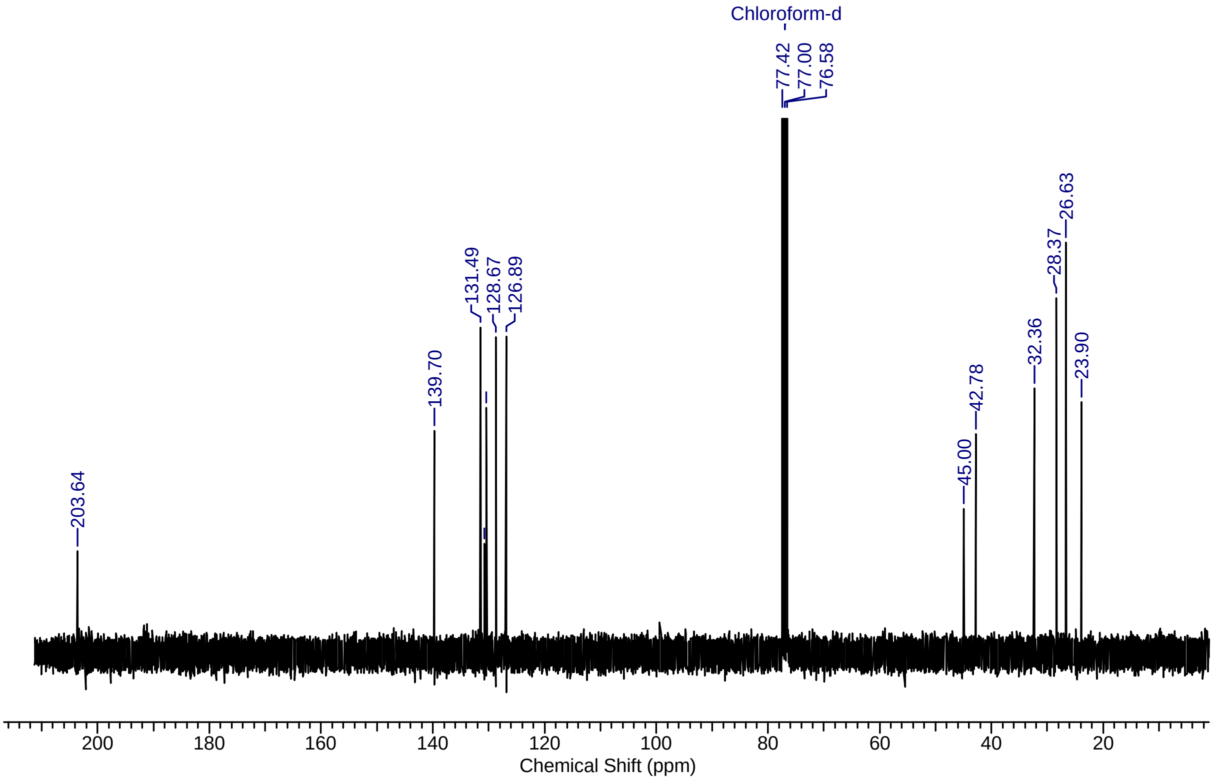

Chloroform-d
Water in CDCl3
0.94
2.94
2.00
2.01
2.06
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)


Chloroform-d
202.24
140.97
133.79
131.89
128.31
127.56
119.17
118.58
40.47
19.72
16.47
200
180
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

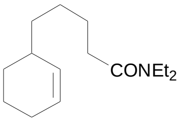
Compound 3h

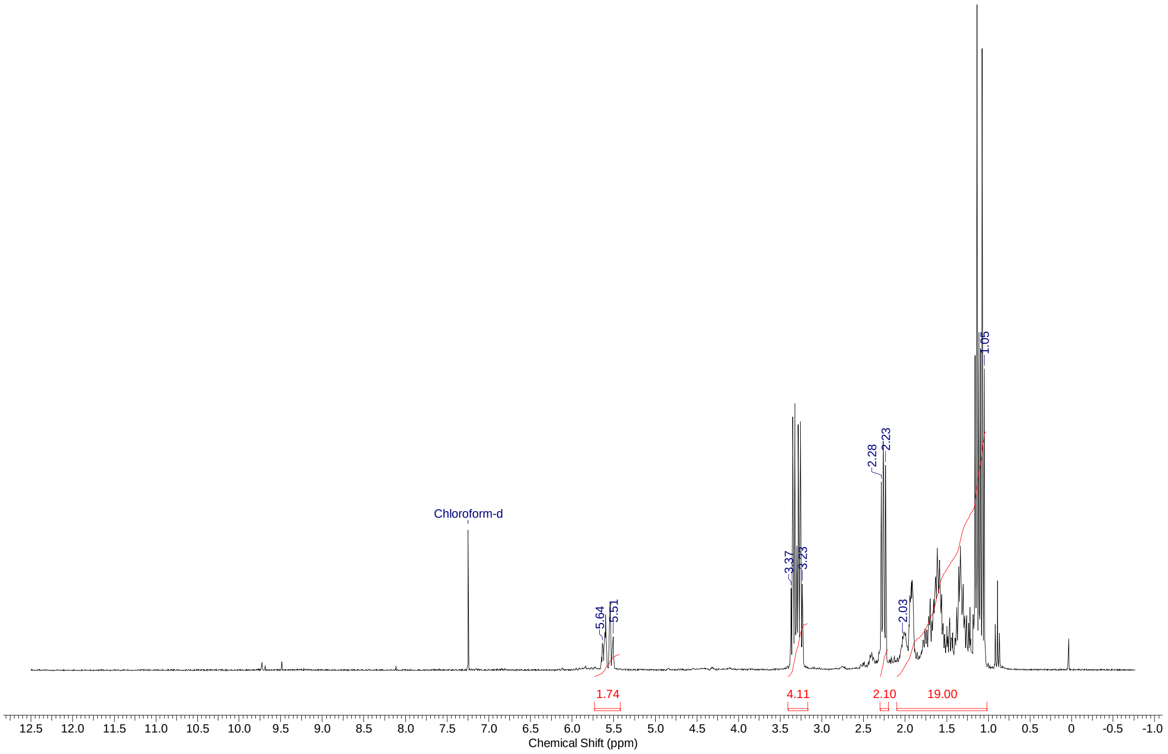

O
Cl
Cl

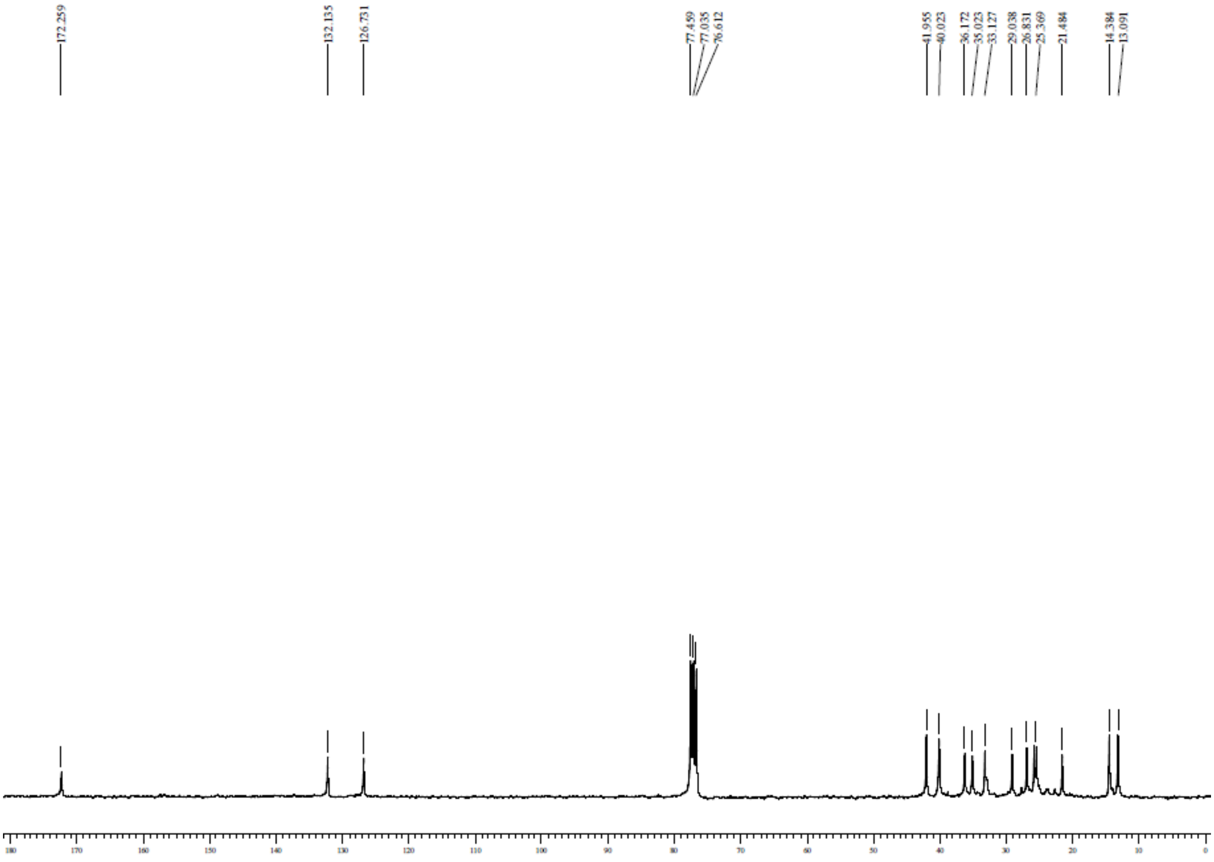

Chloroform-d
Water in CDCl3
3.87
2.04
2.05
4.08
4.10
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Chemical Shift (ppm)


Chloroform-d
77.42
77.00
76.58
203.64
139.70
131.49
128.67
126.89
45.00
42.78
32.36
28.37
26.63
23.90
200
180
160
140
120
100
80
60
40
20
Chemical Shift (ppm)

Compound 3i


CONEt$_2$


Chloroform-d
5.64
5.51
3.37
3.23
2.28
2.23
2.03
1.05
1.74
4.11
2.10
19.00
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5 -1.0
Chemical Shift (ppm)


172.259
132.135
126.731
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77.035
76.612
41.955
40.023
36.172
35.023
33.127
29.038
26.831
25.369
21.484
14.384
13.091
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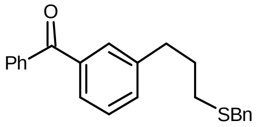
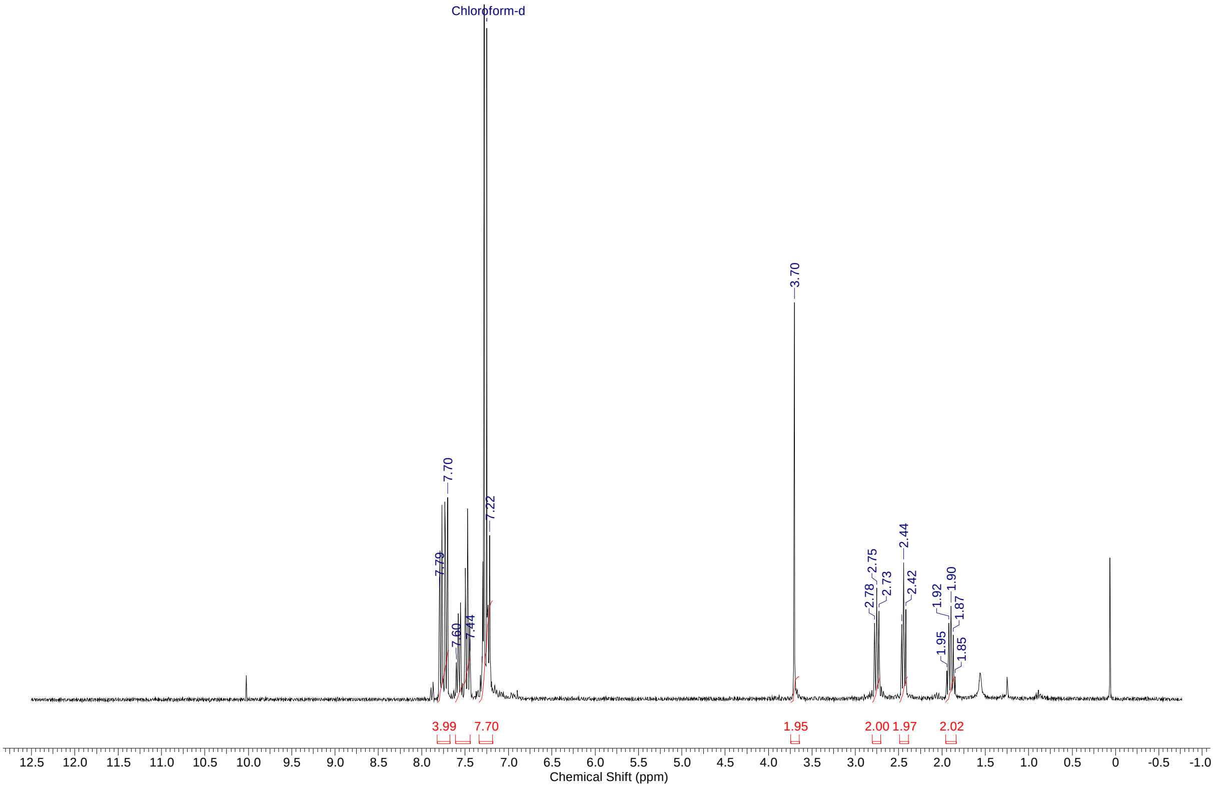
Compound 3j


O
Ph
SBn


Chloroform-d
7.79
7.70
7.60
7.44
7.22
3.70
2.78
2.75
2.73
2.44
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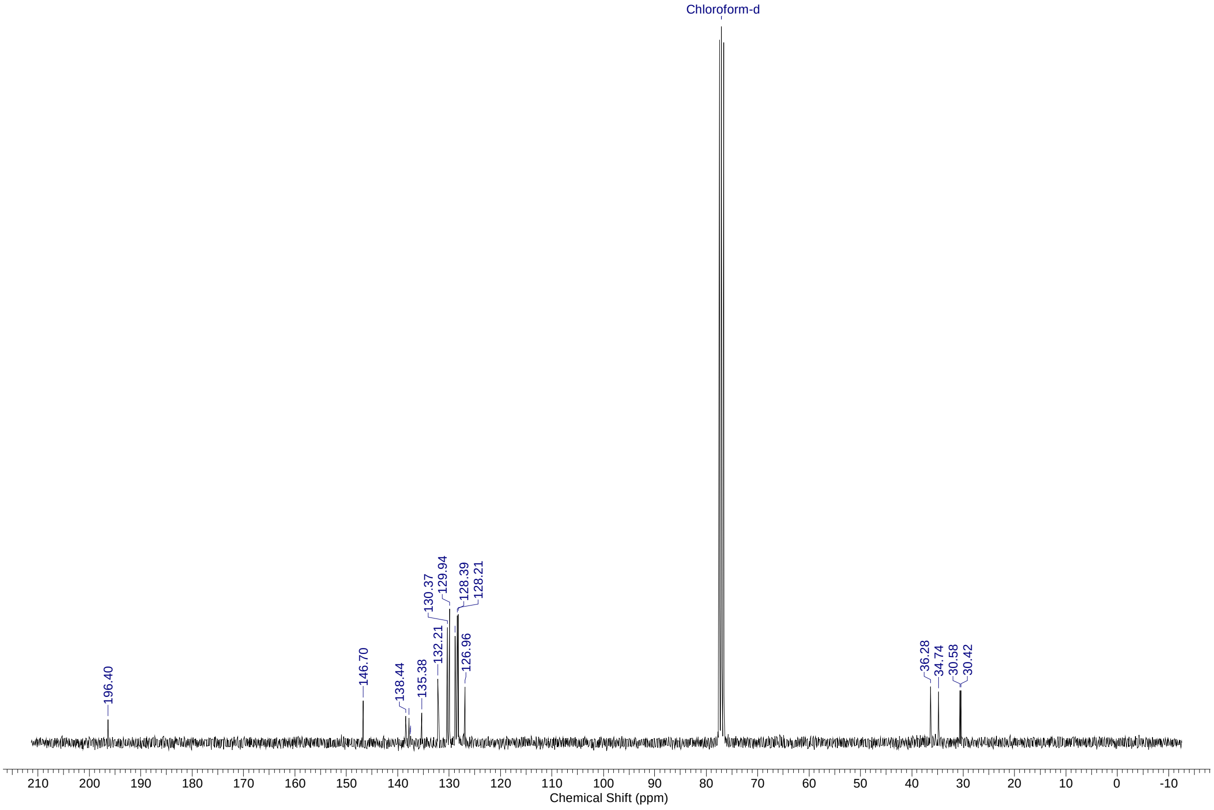
1.95
1.92
1.90
1.87
1.85
3.99
7.70
1.95
2.00
1.97
2.02
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5 -1.0
Chemical Shift (ppm)


Chloroform-d
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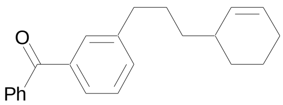
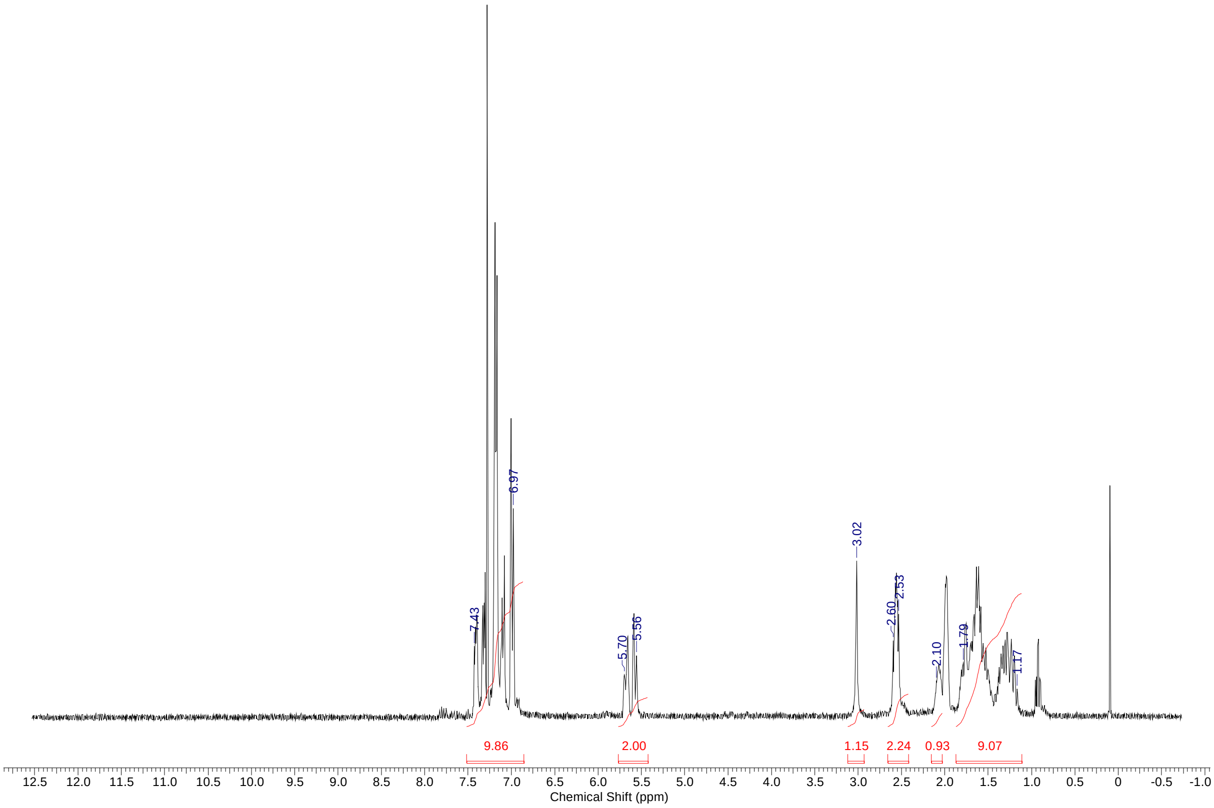
146.70
138.44
135.38
132.21
130.37
129.94
128.39
128.21
126.96
36.28
34.74
30.58
30.42
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
Chemical Shift (ppm)

Compound 3k


O
Ph


7.43
6.97
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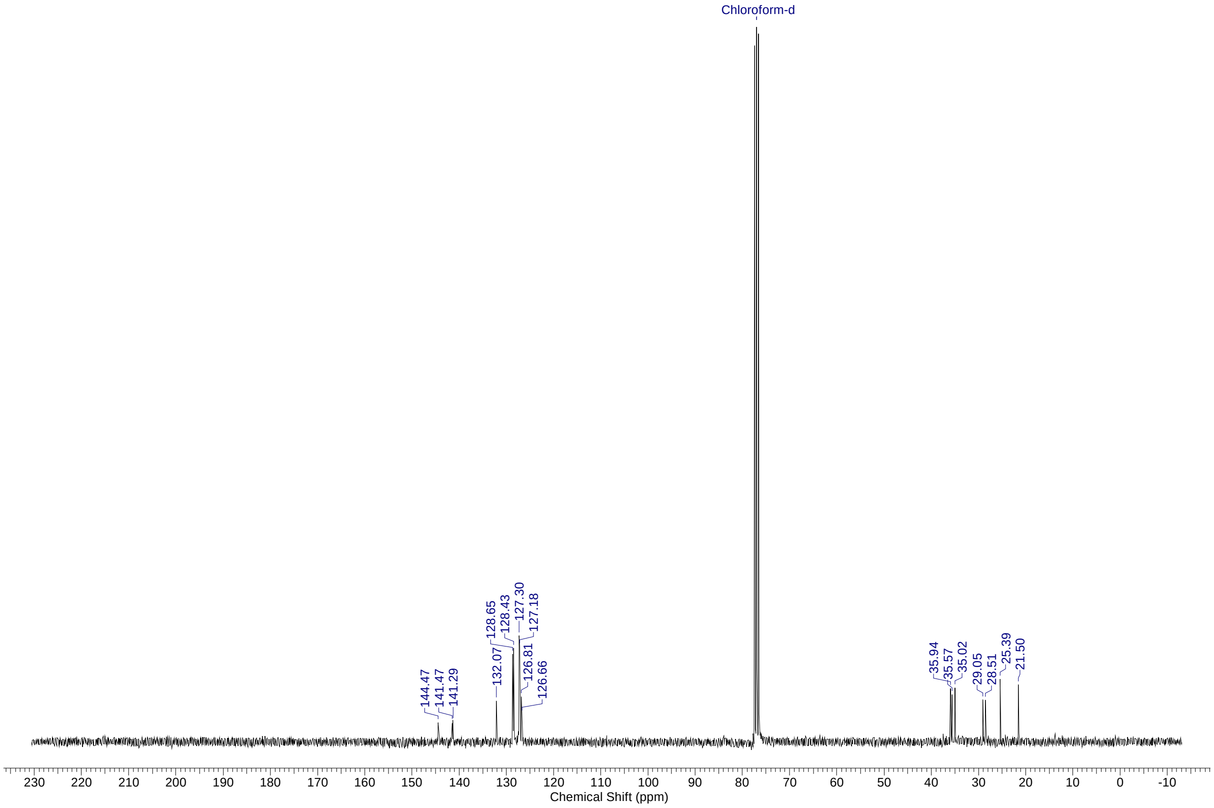
5.56
3.02
2.60
2.53
2.10
1.79
1.17
9.86
2.00
1.15
2.24
0.93
9.07
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0
Chemical Shift (ppm)


Chloroform-d
144.47
141.47
141.29
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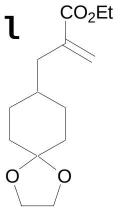
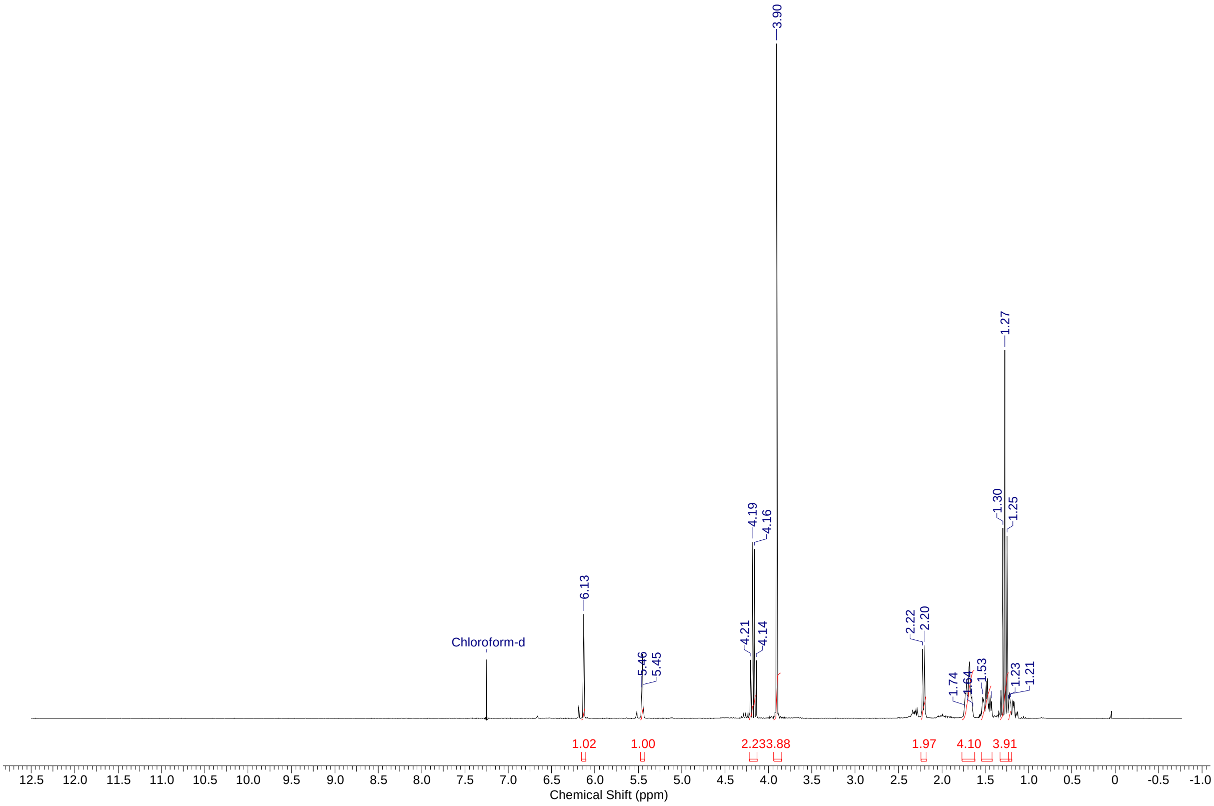
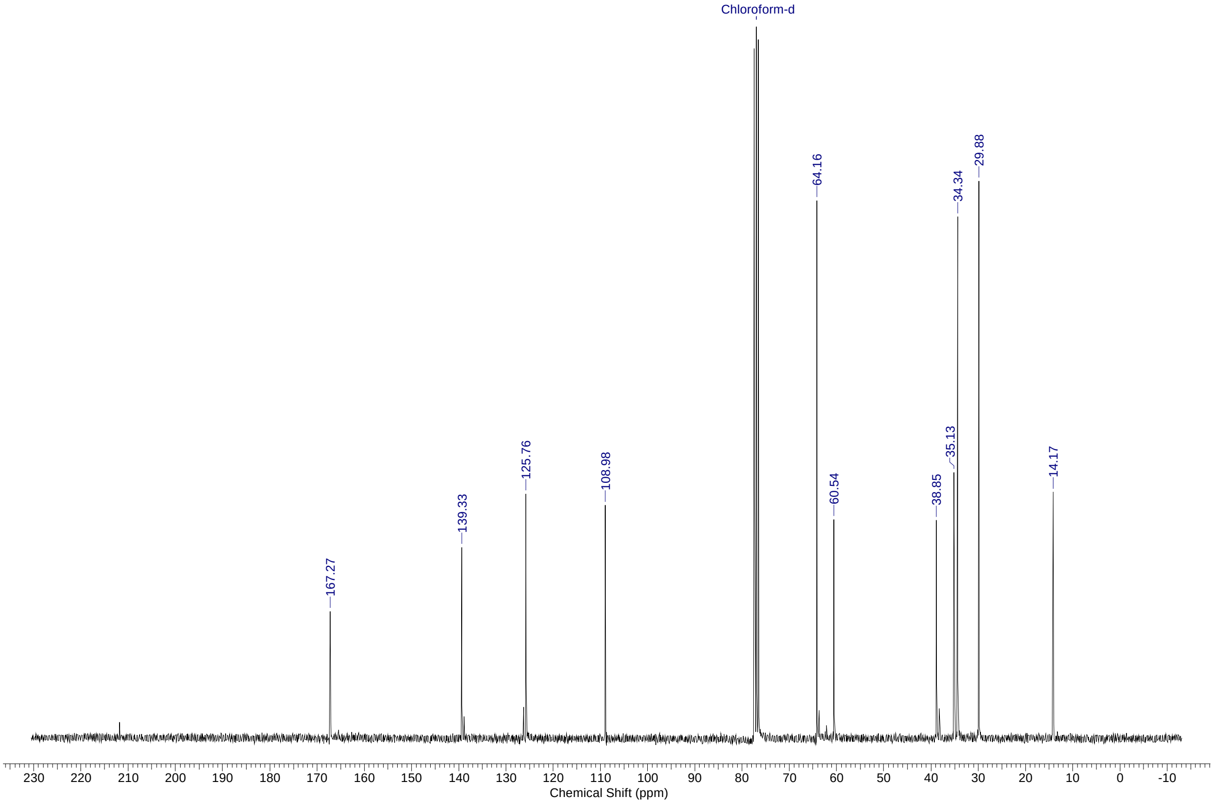
128.65
128.43
127.30
127.18
126.81
126.66
35.94
35.57
35.02
29.05
28.51
25.39
21.50
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
Chemical Shift (ppm)

Compound 3l


CO2Et
O
O


3.90
1.27
1.30
1.25
4.19
4.16
6.13
4.21
4.14
2.22
2.20
Chloroform-d
5.46
5.45
1.74
1.64
1.53
1.23
1.21
1.02
1.00
2.23
3.88
1.97
4.10
3.91
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5 -1.0
Chemical Shift (ppm)


Chloroform-d
64.16
29.88
34.34
35.13
125.76
108.98
14.17
60.54
38.85
139.33
167.27
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
Chemical Shift (ppm)