Supporting information for

Copper-Catalyzed Ring-Opening Radical Trifluoromethylation of Cycloalkanone Oximes

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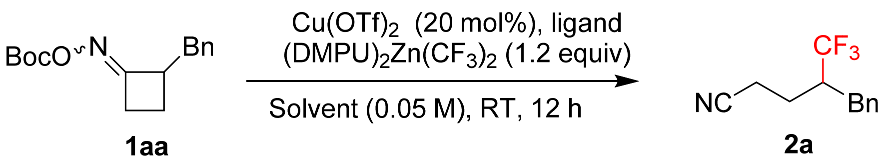
1. Complete references 4a and 4b.

Reference 4a: Blondiaux, N.; Moune, M.; Desroses, M.; Frita, R.; Flipo, M.; Mathys, V.; Soetaert, K.; Kiass, M.; Delorme, V.; Djaout, K.; Trebosc, V.; Kemmer, C.; Wintjens, R.; Wohlkonig, A.; Antoine, R.; Huot, L.; Hot, D.; Coscolla, M.; Feldmann, J.; Gagneux, S.; Locht, C.; Brodin, P.; Gitzinger, M.; Deprez, B.; Willand, N.; Baulard, A. R. *Science* **2017**, *355*, 1206–1211.

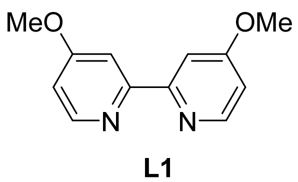
Reference 4b: Flipo, M.; Desroses, M.; Lecat-Guillet, N.; Villemagne, B.; Blondiaux, N.; Leroux, F.; Piveteau, C.; Mathys, V.; Flament, M.-P.; Siepmann, J.; Villeret, V.; Wohlkonig, A.; Wintjens, R.; Soror, S. H.; Christophe, T.; Jeon, H. K.; Locht, C.; Brodin, P.; Deprez, B.; Baulard, A. R.; Willand, N. *J. Med. Chem.* **2012**, *55*, 68–83.

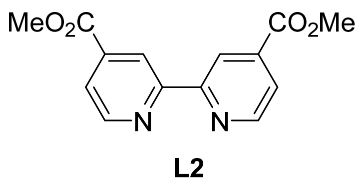
2. Table S1 Optimization of conditions for the synthesis of 2a[a].

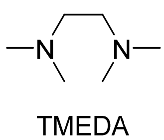


Entry	Ligand	Solvent	Yield (%)[b]
1	bpy	DCM	77
2	**L1**	DCM	71
3	**L2**	DCM	72
4	TMEDA	DCM	22
5	bpy	PhCl	61
6	bpy	PhCl/DCM (3:1)	67
7	bpy	PhCl/DCM (1:1)	66
8	bpy	PhCl/DCM (1:3)	66
9	bpy	MeCN	24

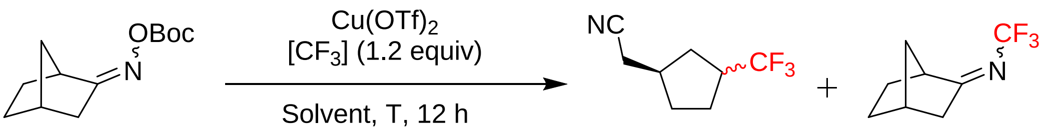
[a] Reagents and conditions: **1aa** (0.20 mmol), $Cu(OTf)_2$ (0.04 mmol), ligand (0.044 mmol), $(DMPU)_2Zn(CF3)_2$ (0.24 mmol), Solvent (4.0 mL), RT, 12 h. [b] Isolated yield based on **1aa**.







3. Table S2 Optimization of conditions for the synthesis of 5b[a].



Entry	$Cu(OTf)_2$ (mol %)	$[CF_3]$	Solvent	T/°C	Yield (%)[b]	
					5b	**5ba**
1	20	$(DMPU)_2Zn(CF_3)_2$ bpy (22 mol%)	DCM	rt	0	78
2	20	$(DMPU)_2Zn(CF_3)_2$ bpy (22 mol%)	DCM	40	0	80
3	20	$(DMPU)_2Zn(CF_3)_2$ bpy (22 mol%)	PhCl	40	0	32
4	20	$(bpy)Zn(CF_3)_2$	DCM	40	6	62
5	20	$(bpy)Zn(CF_3)_2$	DCM	rt	0	11
6	10	$(bpy)Zn(CF_3)_2$	DCM	40	20	34
7	5	$(bpy)Zn(CF_3)_2$	DCM	40	28	14
8	5	$(bpy)Zn(CF_3)_2$	DCE	60	45	8
9	**5**	**$(bpy)Zn(CF_3)_2$**	**DCE**	**70**	**48**	**6**
10	10	$(bpy)Zn(CF_3)_2$	DCE	70	32	20

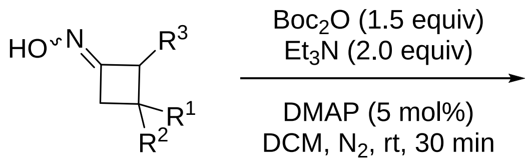
[a] Reagents and conditions: **4b** (0.20 mmol), $Cu(OTf)_2$, $[CF_3]$ (0.24 mmol), solvent (4.0 mL), 12 h. [b] ^{19}F NMR yield with benzyl 4-fluorobenzoate as an internal standard based on **4b**.

4. Synthesis and characterization of substrates.

The following substrates were known compounds:

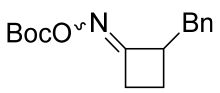
2-Benzylcyclobutan-1-one *O*-benzoyl oxime (**1ac**),[1a] 2-benzylcyclobutan-1-one oxime (**1ae**).[1a]

Typical procedure for the *O-tert*-butoxycarbonylation of oximes.

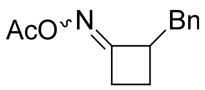


To the mixture of cyclobutanone oximes (1.0 equiv) prepared by conventional methods, [1] triethylamine (2.0 equiv), DMAP (5.0 mol %) and dichloromethane (0.5 M) in a flask was added di-*tert*-butyl dicarbonate (1.5 equiv) slowly at room temperature. The mixture was stirred at room temperature for 30 minutes. Water was then added to quench the reaction. The resulting mixture was extracted with dichloromethane for three times. The organic phases were combined and dried over anhydrous Na_2SO_4. After the removal of solvent under reduced pressure, the crude product was purified by column chromatography on silica gel with ethyl acetate/petroleum ether as the eluent to give the *O*-(*tert*-butoxycarbonyl) oximes.

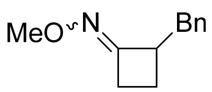
Characterization of new substrates



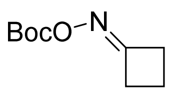
2-Benzylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1aa). This compound was prepared from 2-benzylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 435 mg (79%). Mixture of two isomers (70:30 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22-7.29 (m, 2H), 7.12-7.21 (m, 3H), 3.50-3.67 (m, 1H), 3.12-3.27 (m, 1H), 2.70-2.91 (m, 3H), 1.93-2.10 (m, 1H), 1.64-1.81 (m, 1H), 1.50 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2/168.5, 152.2, 138.5/138.2, 128.7/128.6, 128.3, 126.2, 83.2/83.1, 46.2/45.9, 37.7/36.4, 28.7/28.2, 27.6, 20.4/19.0; IR (neat): *v* (cm^{-1}) 2981, 2933, 1770, 1454, 1370, 1271, 1243, 1151, 1049, 838, 756, 701; ESI-MS: (*m/z*) 298.2 (M^++Na); HRMS calcd for $C_{16}H_{22}NO_3$ (M+H): 276.1594, found 276.1592.



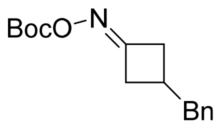
2-Benzylcyclobutan-1-one *O*-acetyl oxime (1ab). This compound was prepared from 2-benzylcyclobutan-1-one oxime according to the conventional method.[2] Yield: 308 mg (71%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (t, *J* = 7.2 Hz, 2H), 7.13-7.20 (m, 3H), 3.52-3.62 (m, 1H), 3.16 (dd, *J* = 14.0, 4.8 Hz, 1H), 2.76-2.93 (m, 3H), 2.00-2.12 (m, 4H), 1.71-1.81 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 168.6, 138.4, 128.6, 128.3, 126.2, 46.0, 37.6, 28.9, 20.3, 19.3; IR (neat): *v* (cm^{-1}) 3027, 2934, 1767, 1497, 1454, 1366, 1252, 1210, 1001, 948, 911, 855, 752, 705; ESI-MS: (*m/z*) 240.1 (M^++Na); HRMS calcd for $C_{13}H_{16}NO_2$ (M+H): 218.1176, found 218.1175.



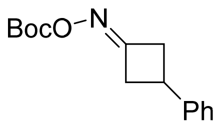
2-Benzylcyclobutan-1-one *O*-methyl oxime (1ad). This compound was prepared from 2-benzylcyclobutan-1-one oxime according to the conventional method.[3] Yield: 200 mg (53%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.17-7.30 (m, 5H), 3.84 (s, 3H), 3.41-3.51 (m, 1H), 3.10 (dd, *J* = 14.4, 4.8 Hz, 1H), 2.70-2.88 (m, 3H), 1.99-2.10 (m, 1H), 1.68-1.79 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 139.3, 128.8, 128.3, 126.2, 61.5, 46.0, 38.4, 28.0, 21.0; IR (neat): *v* (cm^{-1}) 3027, 2936, 2898, 1498, 1465, 1453, 1152, 1045, 861, 751, 702; ESI-MS: (*m/z*) 190.2 (M^++H); HRMS calcd for $C_{12}H_{16}NO$ (M+H): 190.1226, found 190.1227.



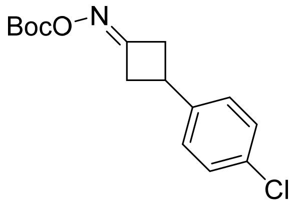
Cyclobutanone *O*-(*tert*-butoxycarbonyl) oxime (1b). This compound was prepared from cyclobutanone oxime according to the typical procedure indicated above. Yield: 330 mg (89%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.91 (t, J = 8.4 Hz, 4H), 1.88-1.98 (m, 2H), 1.40 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 151.9, 82.9, 31.4, 31.2, 27.3, 13.9; IR (neat): v (cm^{-1}) 2980, 2935, 1770, 1370, 1273, 1244, 1152, 1049, 1022, 835, 757; ESI-MS: (*m/z*) 186.2 (M^++H); HRMS calcd for $C_9H_{15}NNaO_3$ (M+Na): 208.0944, found 208.0944.



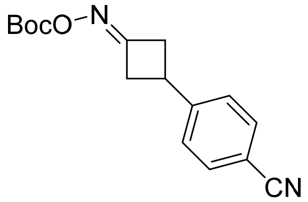
3-Benzylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1c). This compound was prepared from 3-benzylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 457 mg (83%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29 (t, J = 7.2 Hz, 2H), 7.22 (t, J = 7.2 Hz, 1H), 7.14 (d, J = 6.8 Hz, 2H), 3.06-3.17 (m, 2H), 2.82 (d, J = 6.8 Hz, 2H), 2.64-2.76 (m, 3H), 1.52 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.7, 152.3, 139.4, 128.6, 128.5, 126.4, 83.5, 41.7, 37.1, 36.9, 29.3, 27.8; IR (neat): ν (cm^{-1}) 2979, 2931, 1769, 1496, 1454, 1395, 1369, 1271, 1246, 1153, 1050, 1021, 834, 755, 700; ESI-MS: (*m/z*) 573.8 (2M^++Na); HRMS calcd for $C_{32}H_{42}N_2NaO_6$ (2M+Na): 573.2935, found 573.2930.



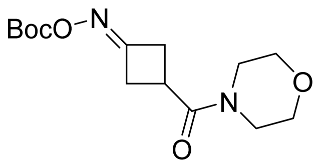
3-Phenylcyclobutanone *O*-(*tert*-butoxycarbonyl) oxime (1d). This compound was prepared from 3-phenylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 465 mg (89%). White solid, m.p.: 81-83 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.37 (m, 2H), 7.24-7.26 (m, 3H), 3.42-3.69 (m, 3H), 3.08-3.19 (m, 2H), 1.54 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.8, 152.2, 143.1, 128.7, 126.8, 126.3, 83.6, 39.4, 39.3, 32.5, 27.7; IR (KBr): ν (cm^{-1}) 2980, 2937, 1771, 1370, 1271, 1252, 1152, 1050, 1023, 835, 755, 699; ESI-MS: (*m/z*) 545.3 (2M^++Na); HRMS calcd for $C_{30}H_{38}N_2NaO_6$ [2M+Na]: 545.2622, found 545.2620.



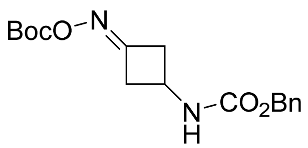
3-(4-Chlorophenyl)cyclobutanone *O*-(*tert*-butoxycarbonyl) oxime (1e). This compound was prepared from 3-(4-chlorophenyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 508 mg (86%). White solid, m.p.: 70-72 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (d, J = 8.8 Hz, 2H), 7.17 (d, J = 8.8 Hz, 2H), 3.43-3.65 (m, 3H), 3.02-3.14 (m, 2H), 1.54 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.2, 152.1, 141.6, 132.6, 128.8, 127.7, 83.7, 39.3, 31.9, 27.7; IR (KBr): ν (cm^{-1}) 2981, 2933, 1770, 1696, 1493, 1396, 1370, 1271, 1252, 1153, 1093, 1050, 1014, 835, 757; ESI-MS: (*m/z*) 341.2 (M^++HCOOH); HRMS calcd for $C_{15}H_{18}ClNNaO_3$ (M+Na): 318.0867, found 318.0866.



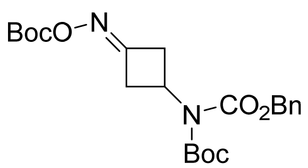
4-(3-(((*tert*-Butoxycarbonyl)oxy)imino)cyclobutyl)benzonitrile (1f). This compound was prepared from 4-(3-(hydroxyimino)cyclobutyl)benzonitrile according to the typical procedure indicated above. Yield: 481 mg (84%). White solid, m.p.: 122-124 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64 (d, J = 8.8 Hz, 2H), 7.36 (d, J = 8.4 Hz, 2H), 3.65-3.74 (m, 1H), 3.44-3.61 (m, 2H), 3.07-3.19 (m, 2H), 1.54 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.3, 152.1, 148.5, 132.6, 127.3, 118.6, 110.9, 83.9, 39.1, 32.6, 27.7; IR (KBr): ν (cm^{-1}) 2982, 2937, 2227, 1769, 1608, 1396, 1370, 1273, 1252, 1152, 1050, 1019, 832, 756, 558; ESI-MS: (*m/z*) 595.3 ($2M^+$+Na); HRMS calcd for $C_{16}H_{18}N_2NaO_3$ (M+Na): 309.1210, found 309.1212.



***tert*-Butoxy(((3-(morpholine-4-carbonyl)cyclobutylidene)amino)oxy)methanone (1g).** This compound was prepared from (3-(hydroxyimino)cyclobutyl)(morpholino)-methanone according to the typical procedure indicated above. Yield: 465 mg (78%). White solid, m.p.: 105-107 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.60-3.70 (m, 6H), 3.15-3.43 (m, 7H), 1.52 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.3, 162.0, 152.0, 83.7, 66.8, 66.5, 45.6, 42.4, 35.1, 35.0, 29.5, 27.7; IR (KBr): ν (cm^{-1}) 2980, 2932, 2858, 1767, 1650, 1437, 1396, 1272, 1155, 1116, 1051, 1020, 1000, 837; ESI-MS: (*m/z*) 316.2 (M^{+}+NH_4); HRMS calcd for $C_{14}H_{22}N_2NaO_5$ (M+Na): 321.1421, found 321.1419.

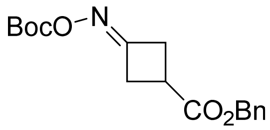


Benzyl (3-(((*tert*-butoxycarbonyl)oxy)imino)cyclobutyl)carbamate (1h). This compound was prepared from benzyl (3-(hydroxyimino)cyclobutyl)carbamate according to the typical procedure indicated above. Yield: 475 mg (71%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.26 (br, 5H), 5.86 (br, 1H), 5.01 (s, 2H), 4.14-4.25 (m, 1H), 3.17-3.36 (m, 2H), 2.83-2.97 (m, 2H), 1.45 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.8, 155.8, 152.2, 136.2, 128.6, 128.2, 128.1, 83.7, 66.8, 40.2, 40.0, 39.8, 27.7; IR (neat): ν (cm^{-1}) 3341, 3045, 2981, 2936, 1699, 1538, 1456, 1395, 1371, 1256, 1153, 1069, 1012, 913, 834, 779, 748, 698; ESI-MS: (*m/z*) 691.3 ($2M^{+}$+Na); HRMS calcd for $C_{34}H_{44}N_4NaO_{10}$ (2M+Na): 691.2950, found 691.2939.

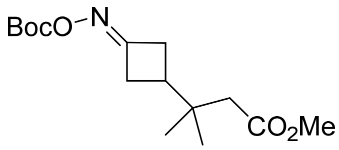


Benzyl (3-(((*tert*-butoxycarbonyl)oxy)imino)cyclobutyl)(*tert*-butoxycarbonyl)-carbamate (1i). This compound was prepared from benzyl (3-(hydroxyimino)-cyclobutyl)(*tert*-butoxycarbonyl)carbamate according to the typical procedure indicated above. Yield: 590 mg (68%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ

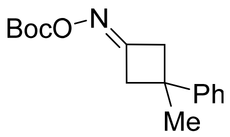
7.31-7.39 (m, 5H), 5.21 (AB, J = 12.0 Hz, 2H), 4.70-4.80 (m, 1H), 3.24-3.45 (m, 4H), 1.52 (s, 9H), 1.43 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.2, 153.6, 152.1, 151.7, 135.0, 128.6, 128.5, 84.0, 83.6, 68.9, 44.9, 39.1, 38.9, 27.9, 27.7; IR (neat): ν (cm^{-1}) 2981, 2942, 1771, 1748, 1705, 1395, 1370, 1341, 1245, 1152, 1107, 837, 755; ESI-MS: (*m/z*) 891.4 ($2M^+$+Na); HRMS calcd for $C_{44}H_{60}N_4NaO_{14}$ (2M+Na): 891.3998, found 891.3985.



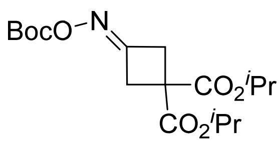
Benzyl 3-(((*tert*-butoxycarbonyl)oxy)imino)cyclobutanecarboxylate (1j). This compound was prepared from benzyl benzyl 3-(hydroxyimino)cyclobutane-1-carboxylate according to the typical procedure indicated above. Yield: 472 mg (74%). White solid, m.p.: 66-68 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31-7.40 (m, 5H), 5.16 (s, 2H), 3.19-3.36 (m, 5H), 1.53 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.0, 161.9, 151.9, 135.4, 128.6, 128.5, 128.3, 83.7, 67.0, 35.6, 35.4, 31.0, 27.7; IR (KBr): ν (cm^{-1}) 2989, 2942, 1772, 1735, 1370, 1271, 1252, 1152, 1049, 1018, 836, 755, 698; ESI-MS: (*m/z*) 342.1 (M^++Na); HRMS calcd for $C_{17}H_{21}NNaO_5$ (M+Na): 342.1312, found 342.1309.



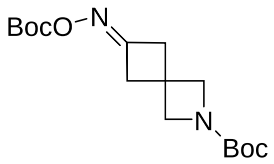
Methyl 3-(3-(((*tert*-butoxycarbonyl)oxy)imino)cyclobutyl)-3-methylbutanoate (1k). This compound was prepared from methyl 3-(3-(hydroxyimino)cyclobutyl)-3-methylbutanoate according to the typical procedure indicated above. Yield: 490 mg (82%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.52 (s, 3H), 2.76-2.90 (m, 2H), 2.60-2.72 (m, 2H), 2.31-2.40 (m, 1H), 2.06 (s, 2H), 1.40 (s, 9H), 0.87 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.6, 163.3, 151.8, 82.9, 51.0, 44.0, 37.1, 33.9, 32.2, 32.0, 27.3, 22.7, 22.6; IR (neat): *ν* (cm^{-1}) 2976, 1771, 1736, 1370, 1272, 1246, 1155, 1051, 1014, 835; ESI-MS: (*m/z*) 322.2 (M^++Na); HRMS calcd for $C_{15}H_{26}NO_5$ (M+H): 300.1805, found 300.1805.



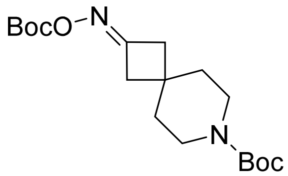
3-Methyl-3-phenylcyclobutanone *O*-(*tert*-butoxycarbonyl) oxime (1l). This compound was prepared from 3-methyl-3-phenylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 479 mg (87%). White solid, m.p.: 74-76 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.38 (m, 2H), 7.21-7.26 (m, 3H), 3.35 (dt, *J* = 2.8, 16.4 Hz, 2H), 3.06-3.19 (m, 2H), 1.54 (s, 9H), 1.53 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.9, 152.2, 148.0, 128.6, 126.3, 125.0, 83.5, 44.6, 44.5, 37.8, 30.7, 27.7; IR (KBr): ν (cm^{-1}) 2979, 2926, 1772, 1695, 1395, 1370, 1270, 1250, 1153, 1049, 1020, 834, 760, 701; ESI-MS: (*m/z*) 573.3 ($2M^+$+Na); HRMS calcd for $C_{32}H_{42}N_2NaO_6$ (2M+Na): 573.2935, found 573.2931.



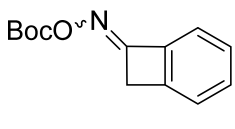
Diisopropyl 3-(((*tert*-butoxycarbonyl)oxy)imino)cyclobutane-1,1-dicarboxylate (1m). This compound was prepared from diisopropyl 3-(hydroxyimino)cyclobutane-1,1-dicarboxylate according to the typical procedure. Yield: 586 mg (82%). White solid, m.p.: 84.5-86 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.02-5.14 (m, 2H), 3.51 (s, 4H), 1.52 (s, 9H), 1.25 (d, *J* = 6.0 Hz, 12H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2, 159.6, 151.8, 83.9, 70.0, 46.8, 39.6, 39.3, 27.7, 21.5; IR (KBr): ν (cm^{-1}) 2983, 2938, 1777, 1731, 1468, 1457, 1372, 1269, 1250, 1156, 1107, 1049, 1016, 917, 876, 840; ESI-MS: (*m/z*) 380.2 (M^++Na); HRMS calcd for $C_{17}H_{31}N_2O_7$ ($M+NH_4$): 375.2126, found 375.2129.



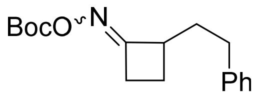
***tert*-Butyl 6-(((*tert*-butoxycarbonyl)oxy)imino)-2-azaspiro[3.3]heptane-2-carboxylate (1n)**. This compound was prepared from *tert*-butyl 6-(hydroxyimino)-2-azaspiro[3.3]heptane-2-carboxylate according to the typical procedure indicated above. Yield: 476 mg (73%). White solid, m.p.: 137-139 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.01 (AB, *J* = 8.8 Hz, 4H), 3.20 (d, *J* = 5.6 Hz, 4H), 1.52 (s, 9H), 1.43 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.2, 155.9, 152.0, 83.8, 79.8, 42.6, 42.5, 31.6, 28.3, 27.7; IR (KBr): ν (cm^{-1}) 2978, 2934, 2876, 1771, 1703, 1395, 1369, 1272, 1249, 1153, 834; ESI-MS: (*m/z*) 675.4 (2M^{+}+Na); HRMS calcd for $C_{32}H_{52}N_4NaO_{10}$ (2M+Na): 675.3576, found 675.3559.



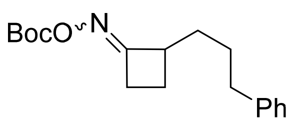
***tert*-Butyl 2-(((*tert*-butoxycarbonyl)oxy)imino)-7-azaspiro[3.5]nonane-7-carboxylate (1o)**. This compound was prepared from *tert*-butyl 2-(hydroxyimino)-7-azaspiro[3.5]nonane-7-carboxylate according to the typical procedure indicated above. Yield: 468 mg (66%). White solid, m.p.: 87-89 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.27-3.41 (m, 4H), 2.75 (s, 4H), 1.57-1.63 (m, 4H), 1.51 (s, 9H), 1.44 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.7, 154.7, 152.1, 83.5, 79.6, 41.6, 41.5, 36.2, 33.2, 28.4, 27.7; IR (KBr): ν (cm^{-1}) 2978, 2921, 1771, 1693, 1421, 1368, 1270, 1247, 1156, 1049, 1019, 835; ESI-MS: (*m/z*) 731.4 (2M^{+}+Na); HRMS calcd for $C_{36}H_{60}N_4NaO_{10}$ (2M+Na): 731.4202, found 731.4194.



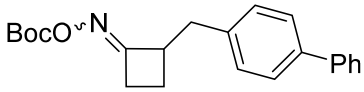
Bicyclo[4.2.0]octa-1,3,5-trien-7-one *O*-(*tert*-butoxycarbonyl) oxime (1p). This compound was prepared from bicyclo[4.2.0]octa-1,3,5-trien-7-one oxime according to the typical procedure indicated above. Yield: 401 mg (86%). Mixture of two isomers (60:40 determined by ^{1}H NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21-7.49 (m, 4H), 3.92 (s, 0.8H), 3.88 (s, 1.2H), 1.51 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9/156.2, 152.1/152.0, 145.5/144.4, 139.2/138.0, 133.1/132.7, 128.5/128.4, 123.6/123.1, 123.0/120.9, 83.6/83.3, 39.8/39.4, 27.5; IR (neat): *ν* (cm^{-1}) 2981, 2933, 1774, 1686, 1370, 1269, 1245, 1153, 1002, 840, 757; ESI-MS: (*m/z*) 234.1 (M^{+}+H); HRMS calcd for $C_{13}H_{16}NO_3$ (M+H): 234.1125, found 234.1123.



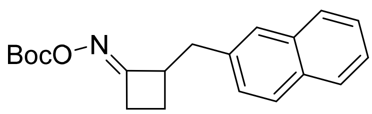
2-Phenethylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1q). This compound was prepared from 2-phenethylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 468 mg (81%). Mixture of two isomers (75:25 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12-7.29 (m, 5H), 3.19-3.58 (m, 1H), 2.79-3.01 (m, 2H), 2.58-2.72 (m, 2H), 2.04-2.27 (m, 2H), 1.81-1.93 (m, 1H), 1.61-1.74 (m, 1H), 1.50 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1/169.0, 152.3, 141.4/141.2, 128.4, 128.3, 125.9, 83.2, 45.7/44.6, 33.8, 33.0/32.9, 28.9/28.6, 27.7, 20.9/19.9; IR (neat): *ν* (cm^{-1}) 2981, 2933, 1770, 1455, 1370, 1271, 1244, 1152, 1049, 1019, 834, 752, 700; ESI-MS: (*m/z*) 312.2 (M^{+}+Na); HRMS calcd for $C_{17}H_{23}NNaO_3$ (M+Na): 312.1570, found 312.1569.



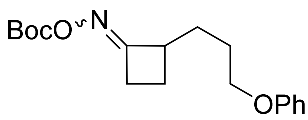
2-(3-Phenylpropyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1r). This compound was prepared from 2-(3-phenylpropyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 485 mg (80%). Mixture of two isomers (60:40 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21-7.28 (m, 2H), 7.12-7.19 (m, 3H), 3.22-3.38 (m, 1H), 2.79-2.99 (m, 2H), 2.53-2.66 (m, 2H), 2.04-2.17 (m, 1H), 1.88-1.98 (m, 0.4H), 1.55-1.84 (m, 4.6H), 1.50 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1/169.2, 152.2, 142.0/141.8, 128.2, 128.1, 125.6, 83.1/83.0, 45.7/45.1, 35.5/35.4, 31.6/30.8, 28.8/28.5, 28.4/28.3, 27.6, 20.7/19.8; IR (neat): ν (cm^{-1}) 2980, 2934, 1770, 1369, 1271, 1243, 1152, 835, 751; ESI-MS: (*m/z*) 304.3 (M^++H); HRMS calcd for $C_{18}H_{26}NO_3$ (M+H): 304.1907, found 304.1907.



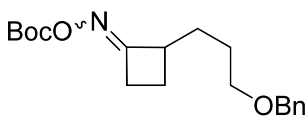
2-([1,1'-Biphenyl]-4-ylmethyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1s). This compound was prepared from 2-([1,1'-biphenyl]-4-ylmethyl)-cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 534 mg (76%). Mixture of two isomers (60:40 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48-7.59 (m, 4H), 7.37-7.44 (m, 2H), 7.27-7.34 (m, 1H), 7.20-7.27 (m, 2H), 3.53-3.72 (m, 1H), 3.17-3.33 (m, 1H), 2.72-3.00 (m, 3H), 1.94-2.13 (m, 1H), 1.67-1.84 (m, 1H), 1.51-1.56 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0/168.3, 152.0, 140.5/140.4, 138.9, 137.4/137.2, 129.0/128.9, 128.4, 126.8, 126.7, 126.6/126.5, 83.0/82.9, 46.0/45.7, 37.1/35.9, 28.6/28.1, 27.4, 20.3/18.9; IR (neat): ν (cm^{-1}) 2981, 2933, 1767, 1487, 1370, 1271, 1159, 1049, 1017, 912, 835, 760, 735, 699; ESI-MS: (*m/z*) 374.2 (M^++Na); HRMS calcd for $C_{22}H_{25}NNaO_3$ (M+Na): 374.1727, found 374.1725.



2-(Naphthalen-2-ylmethyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1t). This compound was prepared from 2-([1,1'-biphenyl]-4-ylmethyl)- cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 267 mg (41%). Colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75-7.82 (m, 3H), 7.64 (s, 1H), 7.41-7.49 (m, 2H), 7.34 (dd, J = 8.0, 1.5 Hz, 1H), 3.66-3.75 (m, 1H), 3.37 (dd, J = 14.0, 5.0 Hz, 1H), 3.01-3.07 (m, 1H), 2.85-3.00 (m, 2H), 2.05-2.14 (m, 1H), 1.80-1.89 (m, 1H), 1.56 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.4, 152.4, 136.2, 133.5, 132.2, 128.1, 127.6, 127.5, 127.3, 127.1, 126.0, 125.4, 83.4, 46.0, 38.0, 29.0, 27.8, 20.6; IR (neat): *v* (cm^{-1}) 2980, 2933, 1769, 1369, 1271, 1242, 1151, 1017, 830, 754; ESI-MS: (*m/z*) 348.2 (M^++Na); HRMS calcd for $C_{20}H_{24}NO_3$ (M+H): 326.1751, found 326.1744.

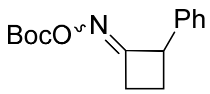


2-(3-Phenoxypropyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1u). This compound was prepared from 2-(3-phenoxypropyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 530 mg (83%). Mixture of two isomers (70:30 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.17-7.25 (m, 2H), 6.79-6.90 (m, 3H), 3.84-3.93 (m, 2H), 3.23-3.37 (m, 1H), 2.77-2.98 (m, 2H), 1.97-2.17 (m, 1.3H), 1.59-1.93 (m, 4.7H), 1.44-1.50 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6/168.7, 158.6, 152.0, 129.0, 120.3/120.2, 114.0, 82.8, 66.9/66.8, 45.3/44.6, 28.6, 28.5/28.3, 27.5/27.4, 26.4/26.3, 20.6/19.6; IR (neat): *v* (cm^{-1}) 2980, 2935, 1770, 1600, 1497, 1370, 1271, 1245, 1152, 1049, 1019, 834, 756, 693; ESI-MS: (*m/z*) 320.2 (M^++H); HRMS calcd for $C_{18}H_{26}NO_4$ (M+H): 320.1856, found 320.1854.

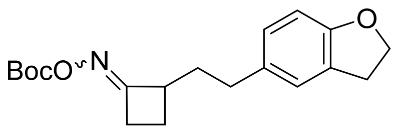


2-(3-(Benzyloxy)propyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1v). This compound was prepared from 2-(3-(benzyloxy)propyl)cyclobutan-1-one oxime according to the typical procedure. Yield: 520 mg (78%). Mixture of two isomers (75:25 determined by ^{1}H NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19-7.32 (m, 5H), 4.45 (s, 0.5H), 4.44 (s, 1.5H), 3.39-3.48 (m, 2H), 3.20-3.33 (m, 1H), 2.77-2.98 (m, 2H), 2.04-2.16 (m, 1H), 1.93-1.99 (m, 0.25H), 1.75-1.86 (m, 0.75H), 1.57-1.73 (m, 4H), 1.46-1.49 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.9/169.0, 152.1, 138.3, 128.1, 127.4, 127.3/127.2, 83.0/82.9, 72.6, 69.6, 45.5/44.9, 28.8/28.7, 28.7/28.4, 27.7/27.5, 26.9/26.8, 20.7/19.6; IR (neat): *v* (cm^{-1}) 2980, 2935, 2858, 1770, 1455, 1369, 1270, 1244, 1152, 1101, 1019, 835, 739, 689; ESI-MS: (*m/z*)

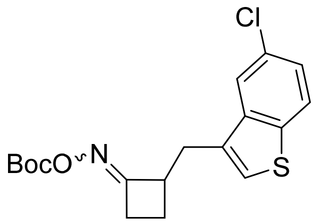
334.2 (M^++H); HRMS calcd for $C_{19}H_{28}NO_4$ (M+H): 334.2013, found 334.2011.



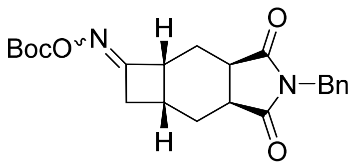
2-Phenylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (2w). This compound was prepared from 2-phenylcyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 460 mg (88%). Mixture of two isomers in 80:20 ratio determined by ^{13}C NMR. Colorless oil.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27-7.34 (m, 2H), 7.19-7.25 (m, 3H), 4.48-4.55 (m, 1H), 3.11-3.21 (m, 1H), 2.98-3.08 (m, 1H), 2.47-2.58 (m, 1H), 2.03-2.13 (m, 1H), 1.40 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5/167.4, 152.2/152.1, 138.9, 128.7/128.6, 127.1/127.0, 126.8, 83.5/83.2, 50.4/49.3, 29.6/29.4, 27.7/27.6, 23.8/23.2; IR (neat): *v* (cm^{-1}) 2980, 1768, 1369, 1270, 1242, 1151, 1048, 1020, 836, 758, 698; ESI-MS: (*m/z*) 284.1 (M^++Na); HRMS calcd for $C_{15}H_{20}NO_3$ (M+H): 262.1438, found 262.1437.



2-(2-(2,3-Dihydrobenzofuran-5-yl)ethyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1x). This compound was prepared from 2-(2-(2,3-dihydrobenzofuran-5-yl)-ethyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 477 mg (72%). Mixture of two isomers (92:8 determined by ^{1}H NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.00-7.05 (m, 1H), 6.87-6.95 (m, 1H), 6.66-6.72 (m, 1H), 4.50-4.59 (m, 2H), 3.21-3.38 (m, 1H), 3.17 (t, J = 8.4 Hz, 2H), 2.83-3.05 (m, 2H), 2.54-2.69 (m, 2H), 2.03-2.21 (m, 2H), 1.80-1.92 (m, 1H), 1.64-1.75 (m, 1H), 1.53 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 158.3, 152.4, 133.3, 127.8, 127.0, 124.9, 108.9, 83.3, 71.1, 44.6, 34.3, 32.4, 29.8, 29.0, 27.8, 21.0; IR (neat): *v* (cm^{-1}) 2979, 2932, 1769, 1492, 1369, 1271, 1244, 1153, 1050, 1020, 983, 833; ESI-MS: (*m/z*) 332.2 (M^++H); HRMS calcd for $C_{19}H_{26}NO_4$ (M+H): 332.1856, found 332.1854.

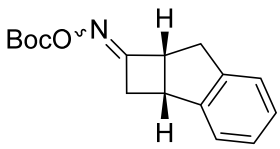


2-((5-Chlorobenzo[*b*]thiophen-3-yl)methyl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1y). This compound was prepared from 2-((5-chlorobenzo[*b*]thiophen-3-yl)methyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 556 mg (76%). Mixture of two isomers (83:17 determined by ^{1}H NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67-7.74 (m, 2H), 7.13-7.30 (m, 2H), 3.66-3.76 (m, 1H), 3.46 (dd, *J* = 15.2, 4.8 Hz, 0.2H), 3.32 (dd, *J* = 15.2, 4.8 Hz, 0.8H), 2.85-3.08 (m, 3H), 2.08-2.21 (m,1H), 1.67-1.81 (m, 1H), 1.52 (br, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 152.2, 140.1/140.0, 138.3, 132.5, 130.5, 124.7, 124.4, 124.1/123.7, 121.2, 83.5/83.4, 44.8/44.2, 30.5/29.7, 29.1/28.5, 27.7, 21.1/20.3; IR (neat): *v* (cm^{-1}) 2981, ,2933, 1768, 1424, 1394, 1272, 1245, 1153, 1077, 1019, 834; ESI-MS: (*m/z*) 404.1 (M^++K); HRMS calcd for $C_{18}H_{24}ClN_2O_3S$ (M+NH_4): 383.1191, found 383.1189.

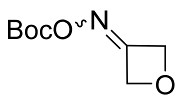


2-Benzyl-5-(((*tert*-butoxycarbonyl)oxy)imino)octahydro-1*H*-cyclobuta[*f*]isoindole -1,3(2*H*)-dione (1z). This compound was prepared from 2-((5-chlorobenzo[*b*]thiophen-3-yl)methyl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 518 mg (65%). Mixture of two isomers (67:33 determined by ^{13}C NMR). White solid, m.p.: 62-64 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20-7.34 (m, 5H), 4.56-4.66 (m, 2H), 2.92-3.22 (m, 4H), 2.60-2.74 (m, 1H), 2.01-2.31 (m, 4H), 1.68-1.81 (m, 1H), 1.48 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 179.1, 178.9/178.8, 167.5/166.7, 152.1/152.0, 135.8, 128.7, 128.6, 128.1, 83.8/83.7, 42.5, 40.4/39.8, 37.1, 36.9/36.7, 35.8/35.4, 27.7, 25.0, 23.7/23.0, 21.8/21.0;

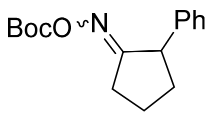
IR (KBr): ν (cm^{-1}) 2980, 2939, 1770, 1700, 1457, 1431, 1397, 1370, 1344, 1247, 1153, 1018, 835, 736, 703; ESI-MS: (*m/z*) 819.3 ($2M^+$+Na); HRMS calcd for $C_{44}H_{52}N_4NaO_{10}$ (2M+Na): 819.3576, found 819.3573.



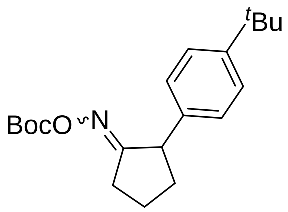
(*cis*)-2,2a,7,7a-Tetrahydro-1*H*-cyclobuta[*a*]inden-1-one *O*-(*tert*-butoxycarbonyl) oxime (1za). This compound was prepared from (*cis*)-2,2a,7,7a-tetrahydro-1*H*-cyclobuta[*a*]inden-1-one oxime according to the typical procedure indicated above. Yield: 470 mg (86%). Mixture of two isomers (75:25 determined by ^{1}H NMR). White solid, m.p.: 116-118 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19-7.26 (m, 4H), 4.01-4.09 (m, 1H), 3.89-3.99 (m, 1H), 3.36-3.52 (m, 2H), 3.21-3.33 (m, 1H), 2.90 (dt, *J* = 17.6, 3.2 Hz, 0.75H), 2.80 (dt, *J* = 17.6, 3.2 Hz, 0.25H), 1.54 (s, 2.3H), 1.49 (s, 6.7H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 169.4/168.4, 152.2, 144.2/144.1, 143.1/142.8, 127.5/127.4, 127.3, 125.3/125.0, 124.9/124.7, 83.5/83.4, 47.7/47.6, 40.4/39.7, 39.9/39.5, 36.8/35.3, 27.7; IR (KBr): ν (cm^{-1}) 2979, 1771, 1477, 1458, 1370, 1249, 1152, 1048, 1021, 835, 757; ESI-MS: (*m/z*) 569.3 ($2M^+$+Na); HRMS calcd for $C_{16}H_{19}NNaO_3$ (M+Na): 296.1257, found 296.1258.



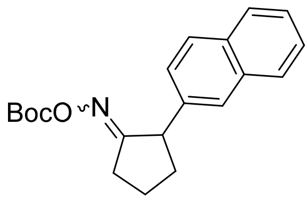
Oxetan-3-one *O*-(*tert*-butoxycarbonyl) oxime (1zb). This compound was prepared from oxetan-3-one oxime according to the typical procedure indicated above. Yield: 325 mg (87%). White solid, m.p.: 87-89 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.35 (s, 4H), 1.53 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.7, 151.3, 84.4, 78.4, 78.1, 27.6; IR (KBr): *ν* (cm^{-1}) 3009, 2976, 2934, 1781, 1432, 1371, 1278, 1250, 1169, 956, 772; ESI-MS: (*m/z*) 205.2 (M^++NH_4); HRMS calcd for $C_8H_{13}NNaO_4$ (M+Na): 210.0737, found 210.0736.



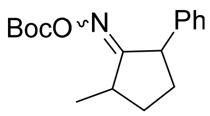
2-Phenylcyclopentanone *O*-(*tert*-butoxycarbonyl) oxime (1-3a). This compound was prepared from 2-phenylcyclopentan-1-one oxime according to the typical procedure indicated above. Yield: 501 mg (91%). Mixture of two isomers (80:20 determined by ^{1}H NMR). White solid, 49.6-51.5 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.14-7.33 (m, 5H), 3.94 (t, *J* = 7.2 Hz, 1H), 2.60-2.88 (m, 2H), 2.20-2.34 (m, 1H), 1.72-2.03 (m, 3H), 1.52/1.18 (2s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 175.2/174.8, 152.1/152.0, 140.6/140.5, 128.5, 127.8/127.2, 126.7/126.3, 83.2/82.8, 49.0/47.2, 35.5/34.8, 32.1/29.6, 27.8/27.6, 23.2/22.5; IR (KBr): ν (cm^{-1}) 3040, 2984, 1770, 1369, 1247, 1152, 1050, 1022, 832, 752; ESI-MS: (*m/z*) 573.3 ($2M^{+}$+Na); HRMS calcd for $C_{16}H_{22}NO_3$ (M+H): 276.1594, found 276.1595.



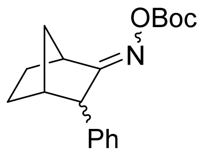
2-(4-(*tert*-Butyl)phenyl)cyclopentan-1-one *O*-(tert-butoxycarbonyl) oxime (1-3b) This compound was prepared from 2-(4-(*tert*-butyl)phenyl)cyclopentan-1-one oxime according to the typical procedure indicated above. Yield: 484 mg (73%). Mixture of two isomers (94:6 determined by ^{1}H NMR). White solid, m.p.: 96-98 ^{o}C. The major isomer has: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 8.4 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 3.91 (t, *J* = 7.6 Hz, 1H), 2.76-2.86 (m, 1H), 2.59-2.75 (m, 1H), 2.17-2.29 (m, 1H), 1.89-2.02 (m, 2H), 1.71-1.84 (m, 1H), 1.52 (s, 9H), 1.29 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.4, 152.1, 149.3, 137.2, 127.4, 125.4, 125.3, 83.1, 48.5, 34.5, 34.3, 31.3, 29.6, 27.7, 22.4; IR (KBr): *v* (cm^{-1}) 2964, 1771, 1476, 1368, 1268, 1154, 1049, 1021, 832; ESI-MS: (*m/z*) 354.2 (M^{+}+Na); HRMS calcd for $C_{20}H_{33}N_2O_3$ ($M+NH_4$): 349.2486, found 349.2489.



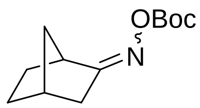
2-(Naphthalen-2-yl)cyclopentanone *O*-(*tert*-butoxycarbonyl) oxime (1-3c). This compound was prepared from 2-(naphthalen-2-yl)cyclopentan-1-one oxime according to the typical procedure indicated above. Yield: 527 mg (81%). White solid, 128-130 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.81 (m, 3H), 7.67 (s, 1H), 7.37-7.47 (m, 3H); 4.11 (t, J = 8.0 Hz, 1H), 2.81-2.92 (m, 1H), 2.66-2.77 (m, 1H), 2.27-2.37 (m, 1H), 1.93-2.14 (m, 2H), 1.77-1.90 (m, 1H), 1.51 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.3, 152.2, 138.0, 133.4, 132.4, 128.4, 127.8, 127.6, 126.4, 126.2, 126.1, 125.7, 83.3, 49.2, 34.6, 29.7, 27.8, 22.6; IR (KBr): ν (cm^{-1}) 3054, 2977, 1770, 1369, 1247, 1152, 1049, 1021, 832, 749; ESI-MS: (*m/z*) 673.3 (2M^{+}+Na); HRMS calcd for $C_{20}H_{23}NNaO_3$ (M+Na): 348.1570, found 348.1569.



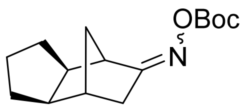
2-Methyl-5-phenylcyclopentan-1-one *O*-(*tert*-butoxycarbonyl) oxime (1-3d). This compound was prepared from 2-methyl-5-phenylcyclopentan-1-one oxime according to the typical procedure indicated above. Yield: 445 mg (77%). Mixture of four isomers. White solid, m.p.: 65-67 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08-7.31 (m, 5H), 4.18-4.25 (m, 0.2H), 4.07 (t, J = 8.8 Hz, 0.4H), 3.91 (t, J = 7.6 Hz, 0.4H), 3.11-3.27 (m, 0.4H), 2.85-2.99 (m, 0.6H), 1.22-2.37 (m, 16H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.9/177.8/177.5/177.3, 152.2/152.1/152.0/151.8, 141.8/141.0/140.7/140.4, 128.5/128.4/127.2/127.1, 128.1/127.8, 126.6/126.5/126.1, 83.0/83.0/82.8/82.6, 49.2/49.1/47.8/47.6, 40.2/38.7/36.7/36.4, 33.7/33.4/33.1, 32.6/32.4/31.5/31.4, 27.7/27.5, 17.9/17.6/16.8/16.2; IR (KBr): *v* (cm^{-1}) 2975, 2934, 2873, 1770, 1495, 1453, 1369, 1269, 1246, 1153, 1053, 1014, 838, 755, 699; DART-MS: (*m/z*) 290.2 (M^{+}+H); HRMS calcd for $C_{17}H_{24}NO_3$ (M+H): 290.1751, found 290.1750.



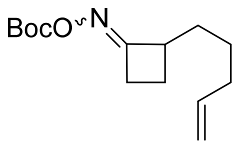
3-Phenylbicyclo[2.2.1]heptan-2-one *O*-(*tert*-butoxycarbonyl) oxime (4a). This compound was prepared from 3-phenylbicyclo[2.2.1]heptan-2-one oxime according to the typical procedure indicated above. Yield: 428 mg (71%). Mixture of four isomers. White solid, m.p.: 87-89 ^oC. ^1H NMR (400 MHz, $CDCl_3$) δ 7.20-7.27 (m, 3H), 7.12-7.19 (m, 1H), 6.97-7.08 (m, 1H), 3.89-3.97 (m, 0.5H), 3.74-3.79 (m, 0.5H), 3.54-3.65 (m, 0.5H), 3.13-3.19 (m, 0.5H), 2.54-2.62 (m, 0.6H), 2.36-2.41 (m, 0.4H), 1.45-1.89 (m, 8H), 1.11-1.39 (m, 7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9/174.8/173.8/173.7, 152.3/152.1, 139.7/138.1/137.7/137.1, 128.2/128.1, 128.0/127.8, 127.6/127.5, 126.5/126.3/126.2, 83.1/83.0/82.8/82.7, 53.8/53.4/52.2/51.2, 45.5/44.2/43.6, 42.8/42.6, 41.6/40.4/38.8/38.1, 34.8/34.7, 28.1/27.7/27.3/26.6, 27.5/27.4, 25.3/25.1/22.3/21.7; IR (KBr): v (cm^{-1}) 2974, 2877, 1767, 1497, 1451, 1369, 1248, 1155, 1050, 1020, 829, 753, 741, 700; ESI-MS: (*m/z*) 302.2 (M^++H); HRMS calcd for $C_{18}H_{24}NO_3$ (M+H): 302.1751, found 302.1750.



Bicyclo[2.2.1]heptan-2-one *O*-(*tert*-butoxycarbonyl) oxime (4b). This compound was prepared from bicyclo[2.2.1]heptan-2-one oxime according to the typical procedure indicated above. Yield: 351 mg (78%). Mixture of two isomers in 90:10 ratio determined by ^1H NMR. Colorless oil. ^1H NMR (400 MHz, $CDCl_3$) δ 3.43 (br, 0.1H), 2.97 (d, J = 4.0 Hz, 0.9H), 2.44 (br, 1H), 2.22-2.31 (m, 1H), 2.03-2.16 (m, 1H), 21.54-1.75 (m, 2H), 1.31-1.49 (m, 12H), 1.19-1.29 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.8, 152.2, 82.7, 42.4/40.3, 38.6/38.1, 37.2/36.0, 35.1, 27.5, 27.2/26.8, 26.3/25.7; IR (neat): v (cm^{-1}) 2975, 2878, 1770, 1369, 1251, 1154, 1053, 1022, 854, 829, 753; ESI-MS: (*m/z*) 264.1 (M^++K); HRMS calcd for $C_{12}H_{20}NO_3$ (M+H): 226.1438, found 226.1437.



Octahydro-5*H*-4,7-methanoinden-5-one *O*-(*tert*-butoxycarbonyl) oxime (4c). This compound was prepared from octahydro-5*H*-4,7-methanoinden-5-one oxime according to the typical procedure indicated above. Yield: 450 mg (85%). Mixture of two isomers (84:16 determined by ^{1}H NMR). White solid, m.p.: 36-38 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.28 (s, 0.16H), 2.81 (s, 0.84H), 2.34 (dd, *J* = 18.0, 4.0 Hz, 1H), 2.25 (br, 1H), 1.86-2.18 (m, 5H), 1.59-1.75 (m, 2H), 1.50 (br, 9H), 1.19-1.34 (m, 2H), 0.93-1.10 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.7, 152.5, 83.1, 46.8, 46.6/46.5, 44.5, 43.4, 39.6, 36.7/35.8, 32.7, 32.2/32.1, 31.5/31.3, 27.7/27.6; IR (KBr): ν (cm^{-1}) 2951, 2864, 1770, 1369, 1292, 1246, 1155, 1051, 844, 826, 748; ESI-MS: (*m/z*) 553.3 (2M^{+}+Na); HRMS calcd for $C_{30}H_{46}N_2NaO_6$ (2M+Na): 553.3248, found 553.3243.



2-(Pent-4-en-1-yl)cyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (6). This compound was prepared from 2-(pent-4-en-1-yl)cyclobutan-1-one oxime according to the typical procedure indicated above. Yield: 339 mg (67%). Mixture of two isomers (65:35 determined by ^{13}C NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.68-5.83 (m, 1H), 4.87-5.04 (m, 2H), 3.20-3.36 (m, 1H), 2.78-3.00 (m, 2H), 1.97-2.19 (m, 3H), 1.31-1.93 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.2/169.4, 152.3, 138.3, 114.7/114.6, 83.2/83.1, 45.7/45.2, 33.4, 31.6/30.5, 28.9/28.6, 27.6, 26.0/25.9, 20.8/19.8; IR (neat): *v* (cm^{-1}) 3081, 2980, 2933, 2859, 1771, 1370, 1243, 1153, 1049, 1019, 913, 836; ESI-MS: (*m/z*) 254.2 (M^{+}+H); HRMS calcd for $C_{14}H_{24}NO_3$ (M+H): 254.1751, found 254.1750.

Preparation of (bpy)Zn(CF_3)$_2$.

This compound was prepared from $(DMPU)_2Zn(CF_3)_2$ in 95% yield according to the conventional method.[4] $(DMPU)_2Zn(CF_3)_2$ (4.60 g, 10 mmol) was added to an oven-dried 100 mL two-neck round-bottomed flask quipped with a magnetic stir bar in a grovebox. The contents were then evacuated and backfilled three times with nitrogen. Anhydrous dichloromethane (20.0 mL) was added and stirred for 10 minutes to dissolve the $(DMPU)_2Zn(CF_3)_2$. Next, 2,2'-bipyridine (bpy) (1.64 g, 10.5 mol) was added and stirred for another 30 minutes. Anhydrous Et_2O (40.0 mL) was added slowly into the flask and stirred for 5 minutes. The solid obtained was washed with Et_2O (20.0 mL) three times under nitrogen and dried under vacuum to give $(bpy)Zn(CF_3)_2$. Yield: 3.42 g (95%). Yellow solid, m.p.: 69-72 ^{o}C (dec.). ^{1}H NMR (400 MHz, CD_3CN) δ 8.79 (d, J = 4.4 Hz, 2H), 8.47 (d, J = 8.0 Hz, 2H), 8.25 (t, J = 7.6 Hz, 2H), 7.75 (t, J = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, DMF-d_7) δ 152.4, 150.5, 147.7 (qq, J = 358.9, 4.3 Hz), 141.7, 127.6, 123.5; ^{19}F NMR (376 MHz, CD_3CN) δ -42.8 (s, 6F); IR (KBr): v (cm^{-1}) 3117, 1663, 1610, 1600, 1479, 1446, 1320, 1251, 1137, 1028, 967, 947, 772; DART-MS: (m/z) 239.0 (M^+-C_2F_5); HRMS calcd for $C_{10}H_8FN_2Zn$ (M-C_2F_5): 238.9957, found 238.9958.

5. Synthesis and characterization of products.

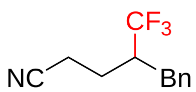
Typical Procedure for the Trifluoromethylation of Cycloalkanone Oximes.

$Cu(OTf)_2$ (14.5 mg, 0.04 mmol), bpy (6.9 mg, 0.044 mmol) and $(DMPU)_2Zn(CF_3)_2$ (110.3 mg, 0.24 mmol) were added to an oven-dried 10 mL schlenk tube equipped with a stir bar in a grovebox. 2-Benzylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (55.1 mg, 0.2 mmol) was then added into the schlenk tube followed by the addition of anhydrous dichloromethane (4.0 mL) under nitrogen atmosphere. The mixture was stirred at room temperature for 12 h. The resulting mixture was filtered through a short plug of silica gel (rinsed with ethyl acetate). After the removal of solvents under reduced pressure, the crude product was purified by column chromatography on silica gel with ethyl acetate/petroleum ether (1:30, v:v) as the eluent to give the pure product 4-benzyl-5,5,5-trifluoropentanenitrile (**2a**) as a colorless oil. Yield: 35.0 mg (77%).

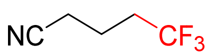
Example at 1 mmol scale.

$Cu(OTf)_2$ (72.5 mg, 0.20 mmol), bpy (34.5 mg, 0.22 mmol) and $(DMPU)_2Zn(CF_3)_2$ (552 mg, 1.2 mmol) were added to an oven-dried 50 mL schlenk tube equipped with a stir bar in a grovebox. 2-Benzylcyclobutan-1-one *O*-(*tert*-butoxycarbonyl) oxime (275 mg, 1.0 mmol) was then added into the schlenk tube followed by the addition of anhydrous dichloromethane (20 mL) under nitrogen atmosphere. The mixture was stirred at room temperature for 12 h. The resulting mixture was filtered through a short plug of silica gel (rinsed with ethyl acetate). After the removal of solvents under reduced pressure, the crude product was purified by column chromatography on silica gel with ethyl acetate/petroleum ether (1:30, v:v) as the eluent to give the pure product 4-benzyl-5,5,5-trifluoropentanenitrile (**2a**) as a colorless oil. Yield: 170 mg (75%).

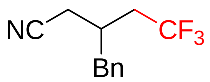
Characterization of all products.



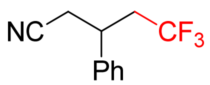
4-Benzyl-5,5,5-trifluoropentanenitrile (2a). Yield: 35 mg (77%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (t, *J* = 7.6 Hz, 2H), 7.26-7.30 (m, 1H), 7.20 (d, *J* = 7.2 Hz, 2H), 3.13-3.21 (m, 1H), 2.51-2.61 (m, 2H), 2.31 (t, *J* = 7.2 Hz, 2H), 1.76-1.97 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 136.7, 128.9, 128.8, 127.5 (q, *J* = 279.0 Hz), 127.2, 118.4, 43.5 (q, *J* = 25.3 Hz), 33.9 (q, *J* = 2.7 Hz), 23.5 (q, *J* = 1.5 Hz), 15.2; ^{19}F NMR (376 MHz, $CDCl_3$) δ -70.3 (d, *J* = 8.3 Hz, 3F); IR (neat): *v* (cm^{-1}) 3031, 2947, 2259, 1498, 1455, 1393, 1257, 1153, 1116, 1083, 1001, 743, 701; EI-MS: *m/z* (rel intensity) 227 (M^+, 1), 191 (3), 175 (3), 149 (8), 137 (15), 121 (12), 95 (15), 81 (55), 69 (100); HRMS calcd for $C_{12}H_{12}F_3N$ (M): 227.0922, found 227.0925.



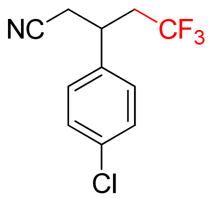
5,5,5-Trifluoropentanenitrile (2b). This compound was obtained in 80% yield based on ^{19}F NMR with 1-chloro-4-fluorobenzene as the internal standard and characterized in reaction solution: ^{19}F NMR (376 MHz, CH_2Cl_2) δ -66.6 (t, *J* = 10.9 Hz, 3F). EI-MS: *m/z* (rel intensity) 136.0 (M^+-H, 1), 117 (32), 109 (6), 97 (17), 77 (78), 69 (31), 64 (53), 51 (17), 41 (100); HRMS calcd for $C_5H_5F_3N$ (M-H): 136.0374, found 136.0373.



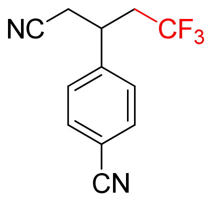
3-Benzyl-5,5,5-trifluoropentanenitrile (2c). Yield: 32 mg (70%). Colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.33 (t, *J* = 7.2 Hz, 2H), 7.26 (t, *J* = 7.2 Hz, 1H), 7.18 (d, *J* = 7.2 Hz, 2H), 2.87 (dd, *J* = 13.6, 5.6 Hz, 1H), 2.74 (dd, *J* = 13.6, 8.0 Hz, 1H), 2.21-2.51 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.1, 129.0, 127.3, 126.3 (q, *J* = 275.3 Hz), 117.2, 39.6, 36.7 (q, *J* = 28.0 Hz), 31.8, 21.0 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -63.4 (t, *J* = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 3030, 2932, 2860, 2251, 1498, 1455, 1391, 1286, 1255, 1144, 1109, 1042, 989, 746, 702; EI-MS: *m/z* (rel intensity) 227 (M^+, 17), 186 (3), 147 (5), 117 (4), 115 (5), 92 (9), 91 (100), 65 (8); HRMS calcd for $C_{12}H_{12}F_3N$ (M): 227.0922, found 227.0929.



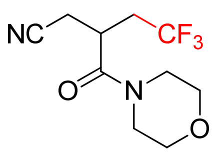
5,5,5-Trifluoro-3-phenylpentanenitrile (2d). Yield: 32 mg (75%). Colorless oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.23-7.44 (m, 5H), 3.30-3.39 (m, 1H), 2.50-2.77 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.7, 129.3, 128.3, 126.9, 125.9 (q, *J* = 275.4 Hz), 117.3, 38.4 (q, *J* = 29.2 Hz), 36.2 (q, *J* = 2.7 Hz), 24.8 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -64.0 (t, *J* = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 3041, 2255, 1456, 1387, 1289, 1259, 1142, 1118, 1076, 763, 701; EI-MS: *m/z* (rel intensity) 213 (M^+, 35), 173 (87), 133 (14), 130 (12), 109 (100), 103 (15), 77 (19), 51 (13); HRMS calcd for $C_{11}H_{10}F_3N$ (M): 213.0765, found 213.0770.



3-(4-Chlorophenyl)-5,5,5-trifluoropentanenitrile (2e). Yield: 42 mg (84%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36 (d, J = 8.8 Hz, 2H), 7.21 (d, J = 8.8 Hz, 2H), 3.30-3.39 (m, 1H), 2.49-2.77 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.0, 134.2, 129.5, 128.3, 125.7 (q, J = 276.3 Hz), 117.0, 38.3 (q, J = 28.9 Hz), 35.7 (q, J = 2.7 Hz), 24.7 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -63.9 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2942, 2255, 1494, 1388, 1291, 1260, 1144, 1119, 1097, 1015, 825; EI-MS: *m/z* (rel intensity) 247 (M^+, 6), 209 (36), 207 (100), 143 (35), 131 (56), 130 (20), 128 (19), 115 (18), 91 (70); HRMS calcd for $C_{11}H_9ClF_3N$ (M): 247.0376, found 247.0382.

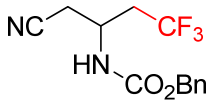


4-(1-Cyano-4,4,4-trifluorobutan-2-yl)benzonitrile (2f). Yield: 39 mg (83%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, J = 8.4 Hz, 2H), 7.41 (d, J = 8.4 Hz, 2H), 3.39-3.48 (m, 1H), 2.54-2.79 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.6, 133.1, 127.9, 125.5 (q, J = 276.3 Hz), 118.1, 116.6, 112.6, 38.0 (q, J = 28.9 Hz), 36.3 (q, J = 2.7 Hz), 24.5; ^{19}F NMR (376 MHz, $CDCl_3$): δ -63.8 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2933, 2235, 2230, 1610, 1507, 1422, 1389, 1260, 1144, 1102, 831, 616, 575, 560; EI-MS: *m/z* (rel intensity) 238 (M^+, 30), 221 (4), 199 (12), 198 (84), 155 (9), 134 (100), 128 (10), 73 (10); HRMS calcd for $C_{12}H_9F_3N_2$ (M): 238.0718, found 238.0723.

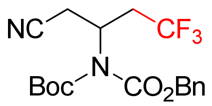


5,5,5-Trifluoro-3-(morpholine-4-carbonyl)pentanenitrile (2g). Yield: 44 mg (89%).

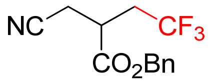
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.50-3.80 (m, 8H), 3.32-3.41 (m, 1H), 2.57-2.80 (m, 3H), 2.25-2.40 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.9, 125.6 (q, J = 275.3 Hz), 116.9, 66.7, 66.4, 46.6, 42.9, 36.3 (q, J = 28.9 Hz), 31.8, 21.1; ^{19}F NMR (376 MHz, $CDCl_3$): δ -64.8 (t, J =10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2923, 2861, 2255, 1652, 1456, 1263, 1149, 1113, 1040, 905, 846; ESI-MS: (*m/z*) 251.1 (M^{+}+H); HRMS calcd for $C_{10}H_{14}F_3N_2O_2$ (M+H): 251.1002, found 251.1002.



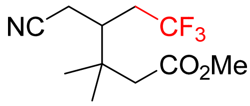
Benzyl (1-cyano-4,4,4-trifluorobutan-2-yl)carbamate (2h). Yield: 39 mg (69%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29-7.39 (m, 5H), 5.29 (d, J = 8 Hz, 1H), 5.10 (s, 2H), 4.16-4.28 (m, 1H), 2.83 (dd, J = 5.2, 16.8 Hz, 1H), 2.72 (dd, J = 5.2, 16.8 Hz, 1H), 2.36-2.65 (m, 2H), ; ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.3, 135.7, 128.7, 128.5, 128.1, 125.2 (q, J = 275.3 Hz), 116.4, 67.4, 43.3, 36.9 (q, J = 27.9 Hz), 23.5; ^{19}F NMR (376 MHz, $CDCl_3$): δ -63.6 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 3331, 3032, 2959, 2255, 1705, 1538, 1337, 1264, 1173, 1138, 1066, 740, 698; ESI-MS: (*m/z*) 285.1 (M^{+}-H); HRMS calcd for $C_{13}H_{14}F_3N_2O_2$ (M+H): 287.1002, found 287.1003.



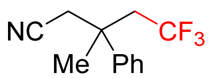
Benzyl (1-cyano-4,4,4-trifluorobutan-2-yl)(*tert*-butoxycarbonyl)carbamate (2i). Yield: 64 mg (83%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30-7.42 (m, 5H), 5.23 (s, 2H), 4.97-5.08 (m, 1H), 3.09 (dd, J = 16.8, 8.8 Hz, 1H), 2.82-2.98 (m, 1H), 2.78 (dd, J = 16.8, 6.4 Hz, 1H), 2.37-2.57 (m, 1H), 1.40 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5, 151.5, 134.7, 128.7, 128.6, 128.4, 125.3 (q, J = 275.3 Hz), 116.3, 84.8, 69.3, 48.2 (q, J = 3.0 Hz), 35.7 (q, J = 28.0 Hz), 27.7, 21.9; ^{19}F NMR (376 MHz, $CDCl_3$): δ -64.8 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2983, 2259, 1744, 1706, 1394, 1372, 1343, 1245, 1156, 1096, 751, 698; ESI-MS: (*m/z*) 409.2 (M^{+}+Na); HRMS calcd for $C_{18}H_{25}F_3N_3O_4$ (M+NH$_4$): 404.1792, found 404.1791.



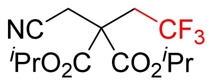
Benzyl 2-(cyanomethyl)-4,4,4-trifluorobutanoate (2j). Yield: 41 mg (76%). Colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.32-7.41 (m, 5H), 5.20 (s, 2H), 3.02-3.11 (m, 1H), 2.70-2.86 (m, 3H), 2.42-2.57 (m, 1H); ^{13}C NMR (100 MHz, CDCl$_3$): δ 170.0, 134.6, 128.9, 128.8, 128.6, 125.6 (q, J = 275.3 Hz), 116.3, 68.2, 36.2, 34.3 (q, J = 28.9 Hz), 19.3; ^{19}F NMR (376 MHz, CDCl$_3$): δ -64.3 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 3037, 2959, 2264, 1743, 1391, 1258, 1186, 1150, 1116, 751, 698; EI-MS: *m/z* (rel intensity) 271 (M$^+$, 12), 240 (12), 227 (9), 207 (13), 187 (28), 173 (14), 131 (31), 108 (26), 103 (16), 91 (100), 77 (20); HRMS calcd for $C_{13}H_{12}F_3NO_2$ (M+H): 271.0820, found 271.0829.



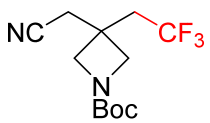
Methyl 4-(cyanomethyl)-6,6,6-trifluoro-3,3-dimethylhexanoate (2k). Yield: 37 mg (74%). Colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$) δ 3.68 (s, 3H), 2.64 (d, J = 4.8 Hz, 2H), 2.19-2.43 (m, 5H), 1.14 (s, 3H), 1.11 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 171.3, 126.7 (q, J = 275.6 Hz), 118.3, 51.6, 44.1, 36.4 (q, J = 1.6 Hz), 36.3, 33.2 (q, J = 28.3 Hz), 25.1, 24.8, 17.8; ^{19}F NMR (376 MHz, CDCl$_3$) δ -64.1 (t, J = 9.8 Hz, 3F); IR (neat): *ν* (cm^{-1}) 2958, 2251, 1734, 1470, 1438, 1259, 1218, 1141, 1014; EI-MS: *m/z* (rel intensity) 251 (M$^+$, 1), 220 (22), 204 (7), 178 (34), 158 (16), 115 (25), 83 (17), 73 (100), 59 (21); HRMS calcd for $C_{10}H_{13}F_3NO_2$ (M-CH$_3$): 236.0898, found 236.0902.



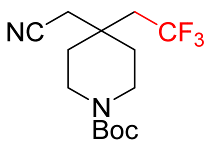
5,5,5-Trifluoro-3-methyl-3-phenylpentanenitrile (2l). Yield: 41 mg (90%). Colorless oil. ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.26-7.42 (m, 5H), 2.82 (AB, J = 16.8 Hz, 2H), 2.55-2.76 (m, 2H), 1.67 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): δ 142.4, 128.9, 127.6, 125.7 (q, J = 277.2 Hz), 125.2, 117.2, 44.1 (q, J = 26.2 Hz), 37.9, 30.8, 25.4; ^{19}F NMR (376 MHz, $CDCl_3$): δ -59.7 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2985, 2259, 1447, 1375, 1260, 1172, 1122, 1099, 1051, 767, 700; EI-MS: *m/z* (rel intensity) 227 (M^+, 20), 188 (11), 187 (100), 147 (15), 123 (42), 115 (10), 103 (18), 91 (15), 77 (15); HRMS calcd for $C_{12}H_{12}F_3N$ (M): 227.0922, found 227.0921.



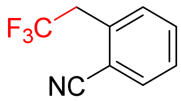
Diisopropyl 2-(cyanomethyl)-2-(2,2,2-trifluoroethyl)malonate (2m). Yield: 40 mg (65%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.05-5.16 (m, 2H), 3.12 (s, 2H), 3.03 (q, J = 10.8 Hz, 2H), 1.27 (t, J = 5.6 Hz, 12H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 125.2 (q, J = 276.2 Hz), 115.5, 71.5, 52.1, 36.0 (q, J = 28.9 Hz), 21.6, 21.3, 21.2; ^{19}F NMR (376 MHz, $CDCl_3$): δ -61.4 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2987, 2251, 1740, 1379, 1304, 1267, 1237, 1209, 1177, 1148, 1100, 1048; ESI-MS: (*m/z*) 332.1 (M^++Na); HRMS calcd for $C_{13}H_{19}F_3NO_4$ (M+H): 310.1261, found 310.1263.



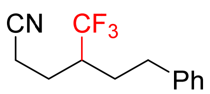
***tert*-Butyl 3-(cyanomethyl)-3-(2,2,2-trifluoroethyl)azetidine-1-carboxylate (2n)**. Yield: 51 mg (92%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.89 (d, J = 9.2 Hz, 2H), 3.79 (d, J = 9.2 Hz, 2H), 2.83 (s, 2H), 2.64 (q, J = 10.8 Hz, 2H), 1.43 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.9, 125.6 (q, J = 276.2 Hz), 116.2, 80.6, 58.2, 39.4 (q, J = 28.0 Hz), 32.3, 28.3, 25.7; ^{19}F NMR (376 MHz, $CDCl_3$): δ -62.0 (t, J = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2979, 2892, 2255, 1705, 1396, 1369, 1256, 1233, 1149, 1122, 1063, 1032, 862, 774; ESI-MS: (*m/z*) 296.2 (M^++NH_4); HRMS calcd for $C_{12}H_{17}F_3N_2NaO_2$ (M+Na): 301.1134, found 301.1135.



***tert*-Butyl 4-(cyanomethyl)-4-(2,2,2-trifluoroethyl)piperidine-1-carboxylate (2o)**. Yield: 54 mg (88%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.36-3.52 (m, 4H), 2.59 (s, 2H), 2.37 (q, *J* = 11.6 Hz, 2H), 1.56-1.75 (m, 4H), 1.45 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.6, 126.2 (q, *J* = 277.2 Hz), 116.6, 80.2, 39.3 (q, *J* = 27.9 Hz), 34.4, 33.0, 28.4, 26.2; ^{19}F NMR (376 MHz, $CDCl_3$): δ -59.3 (t, *J* = 10.9 Hz, 3F); IR (neat): ν (cm^{-1}) 2978, 2935, 2251, 1694, 1423, 1384, 1368, 1263, 1155, 1098, 976; ESI-MS: (*m/z*) 329.2 (M^++Na); HRMS calcd for $C_{14}H_{22}F_3N_2O_2$ (M+H): 307.1628, found 307.1628.

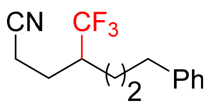


2-(2,2,2-Trifluoroethyl)benzonitrile (2p). Yield: 26 mg (70%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.0 Hz, 1H), 7.62 (t, *J* = 7.2 Hz, 1H), 7.44-7.55 (m, 2H), 3.66 (q, *J* = 10.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.6 (q, *J* = 2.7 Hz), 133.2, 133.0, 131.4, 128.9, 125.0 (q, *J* = 276.1 Hz), 117.2, 114.4, 38.5 (q, *J* = 31.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -65.4 (t, *J* = 9.8 Hz, 3F); IR (neat): *v* (cm^{-1}) 2229, 1363, 1255, 1145, 1118, 1072, 912, 765, 655; EI-MS: *m/z* (rel intensity) 185 (M^+, 38), 166 (7), 134 (2), 116 (100), 107 (2), 89 (17), 75 (3), 63 (6), 51 (2); HRMS calcd for $C_9H_6F_3N$ (M): 185.0452, found 185.0446.

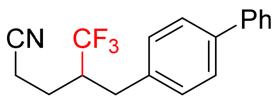


6-Phenyl-4-(trifluoromethyl)hexanenitrile (2q). Yield: 38 mg (78%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (t, *J* = 7.6 Hz, 2H), 7.24 (d, *J* = 7.2 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 2H), 2.67-2.81 (m, 2H), 2.44 (t, *J* = 7.6 Hz, 2H), 2.19-2.31 (m, 1H), 1.96-2.07 (m, 2H), 1.84-1.94 (m, 1H), 1.68-1.78 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.2, 128.7, 128.3, 127.8 (q, *J* = 279.2 Hz), 126.5, 118.6, 41.1 (q, *J* = 25.3 Hz), 32.7, 29.4, 24.1, 15.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.7 (d, *J* = 9.4 Hz, 3F); IR (neat): *v* (cm^{-1}) 3029, 2949, 2255, 1497, 1455, 1395, 1260, 1151, 1116, 1002, 751, 701; EI-MS: *m/z* (rel intensity) 241 (M^+, 24), 172 (9), 144 (15), 105 (6), 91 (100), 77

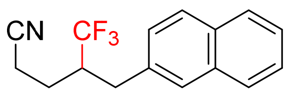
(7), 65 (10), 51 (5); HRMS calcd for $C_{13}H_{14}F_3N$ (M): 241.1078, found 241.1075.



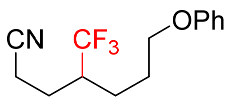
7-Phenyl-4-(trifluoromethyl)heptanenitrile (2r). Yield: 25 mg (50%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (t, J = 7.6 Hz, 2H), 7.16-7.24 (m, 3H), 2.61-2.70 (m, 2H), 2.42 (t, J = 7.2 Hz, 2H), 2.18-2.31 (m, 1H), 1.65-2.10 (m, 5H), 1.41-1.53 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.2, 128.5, 128.3, 127.8 (q, J = 279.8 Hz), 126.1, 118.6, 41.5 (q, J = 25.6 Hz), 35.5, 28.2, 27.0, 23.9 (q, J = 2.5 Hz), 15.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.8 (d, J = 9.4 Hz, 3F); IR (neat): v (cm^{-1}) 3032, 2948, 2259, 1454, 1396, 1261, 1149, 1116, 1029, 750, 700; EI-MS: *m/z* (rel intensity) 255 (M^+, 21), 227 (4), 158 (8), 144 (4), 105 (6), 91 (100), 82 (5), 77 (5), 51 (3); HRMS calcd for $C_{14}H_{16}F_3N$ (M): 255.1235, found 255.1242.



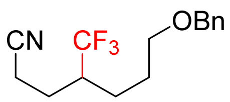
4-([1,1'-Biphenyl]-4-ylmethyl)-5,5,5-trifluoropentanenitrile (2s). Yield: 46 mg (76%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55-7.61 (m, 4H), 7.41-7.47 (m, 2H), 7.32-7.37 (m, 1H), 7.23-7.28 (m, 2H), 3.14-3.23 (m, 1H), 2.54-2.65 (m, 2H), 2.34 (t, J = 7.6 Hz, 2H), 1.78-1.97 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.4, 140.1, 135.7, 129.3, 128.8, 127.6, 127.5 (q, J = 279.7), 127.4, 127.0, 118.5, 43.5 (q, J =25.5 Hz), 33.6 (q, J = 2.4 Hz), 23.5, 15.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -70.1 (d, J = 6.8 Hz, 3F); IR (neat): v (cm^{-1}) 3041, 2942, 2259, 1487, 1393, 1255, 1155, 1109, 1008, 760, 698; ESI-MS: (*m/z*) 326.1 (M^++Na); HRMS calcd for $C_{18}H_{20}F_3N_2$ ($M+NH_4$): 321.1573, found 321.1570.



5,5,5-Trifluoro-4-(naphthalen-2-ylmethyl)pentanenitrile (2t). Yield: 40 mg (72%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79-7.88 (m, 3H), 7.66 (s, 1H), 7.46-7.54 (m, 2H), 7.32 (dd, J = 8.4, 2.0 Hz, 1H), 3.29-3.37 (m, 1H), 2.62-2.78 (m, 2H), 2.32 (t, J = 7.2 Hz, 2H), 1.80-2.01 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.1, 133.4, 132.4, 128.9, 127.8, 127.7, 127.6 (q, J = 279.8 Hz), 127.5, 126.6, 126.5, 126.0, 118.4, 43.4 (q, J = 25.5 Hz), 34.2 (q, J = 3.3 Hz), 23.6, 15.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -70.1 (d, J = 7.9 Hz, 3F); IR (neat): v (cm^{-1}) 3067, 2950, 2259, 1456, 1394, 1256, 1152, 1113, 1007, 816, 751; ESI-MS: (m/z) 295.2 (M^++NH_4); HRMS calcd for $C_{16}H_{15}F_3N$ (M+H): 278.1151, found 278.1149.

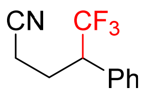


7-Phenoxy-4-(trifluoromethyl)heptanenitrile (2u). Yield: 41 mg (75%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (t, J = 7.6 Hz, 2H), 6.96 (t, J = 7.6 Hz, 1H), 6.89 (d, J = 8.4 Hz, 2H), 3.99 (t, J = 5.2 Hz, 2H), 2.51 (t, J = 7.2 Hz, 2H), 2.28-2.40 (m, 1H), 1.98-2.08 (m, 1H), 1.85-1.95 (m, 4H), 1.62-1.74 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 129.5, 127.8 (q, J = 278.9 Hz), 120.9, 118.6, 114.4, 66.9, 41.4 (q, J = 26.4 Hz), 26.3, 24.4, 24.0, 15.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.9 (d, J = 9.8 Hz, 3F); IR (neat): v (cm^{-1}) 2951, 2879, 2251, 1600, 1586, 1497, 1473, 1396, 1245, 1158, 1125, 755, 692; ESI-MS: (m/z) 289.2 (M^++NH_4); HRMS calcd for $C_{14}H_{20}F_3N_2O$ (M+NH_4): 289.1522, found 289.1520.

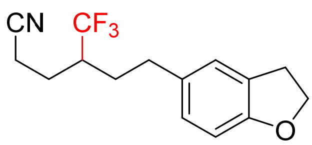


7-(Benzyloxy)-4-(trifluoromethyl)heptanenitrile (2v). Yield: 36 mg (63%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27-7.39 (m, 5H), 4.50 (s, 2H), 3.50 (t, J = 5.6 Hz, 2H), 2.45 (t, J = 6.8 Hz, 2H), 2.20-2.32 (m, 1H), 1.92-2.02 (m, 1H), 1.67-1.89 (m, 4H), 1.51-1.60 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.2, 128.4, 127.8 (q, J = 279.0 Hz), 127.7, 118.7, 73.1, 69.4, 41.4 (q, J = 25.6 Hz), 26.6, 24.4, 24.0, 15.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.9 (d, J = 9.4 Hz, 3F); IR (neat): v (cm^{-1}) 2948, 2861, 2251, 1455, 1397, 1361, 1262, 1209, 1159, 1125, 738, 699; ESI-MS: (m/z) 303.2 (M^++NH_4); HRMS calcd for $C_{15}H_{22}F_3N_2O$ (M+NH_4): 303.1679, found

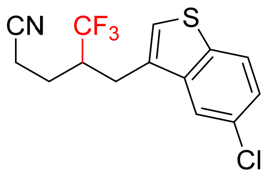
303.1678.



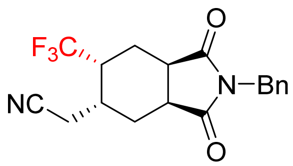
5,5,5-Trifluoro-4-phenylpentanenitrile (2w). Yield: 33 mg (78%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.44 (m, 3H), 7.28-7.33 (m, 2H), 3.38-3.50 (m, 1H), 2.32-2.45 (m, 2H), 2.07-2.25 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 132.3 (q, J = 1.6 Hz), 129.2, 129.0, 128.8, 126.2 (q, J = 278.3 Hz), 118.2, 48.8 (q, J = 27.2 Hz), 24.9 (q, J = 2.6 Hz), 14.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.7 (d, J = 7.9 Hz, 3F); IR (neat): v (cm^{-1}) 3045, 2963, 2255, 1457, 1377, 1325, 1260, 1157, 1114, 1016, 768, 704; EI-MS: *m/z* (rel intensity) 213 (M^+, 100), 159 (75), 144 (63), 140 (65), 117 (26), 109 (91), 91 (43), 77 (18), 54 (68); HRMS calcd for $C_{11}H_{10}F_3N$ (M): 213.0765, found 213.0762.



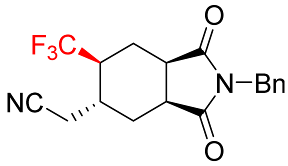
6-(2,3-Dihydrobenzofuran-5-yl)-4-(trifluoromethyl)hexanenitrile (2x). Yield: 37 mg (65%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.02 (s, 1H), 6.91 (d, J = 8.0 Hz, 1H), 6.72 (d, J = 8.0 Hz, 1H), 4.56 (t, J = 8.4 Hz, 2H), 3.19 (t, J = 8.8 Hz, 2H), 2.58-2.73 (m, 2H), 2.44 (t, J = 7.6 Hz, 2H), 2.19-2.31 (m, 1H), 1.83-2.05 (m, 3H), 1.61-1.73 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.7, 132.1, 127.8 (q, J = 279.0 Hz), 127.7, 127.4, 124.8, 118.6, 109.2, 71.2, 40.9 (q, J = 25.6 Hz), 32.1, 29.8, 29.7, 24.0 (q, J = 2.5 Hz), 15.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.7 (d, J = 9.8 Hz, 3F); IR (neat): v (cm^{-1}) 2956, 2251, 1611, 1492, 1395, 1245, 1151, 1113, 983, 944, 819; ESI-MS: (*m/z*) 301.2 (M^++NH_4); HRMS calcd for $C_{15}H_{17}F_3NO$ (M+H): 284.1257, found 284.1255.



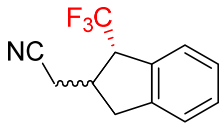
4-((5-Chlorobenzo[b]thiophen-3-yl)methyl)-5,5,5-trifluoropentanenitrile (2y). Yield: 46 mg (73%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, J = 8.4 Hz, 1H), 7.66 (d, J = 2.0 Hz, 1H), 7.36 (dd, J = 8.4, 1.6 Hz, 1H), 7.35 (s, 1H), 3.28 (dd, J = 14.8, 3.2 Hz, 1H), 2.82-2.90 (m, 1H), 2.63-2.77 (m, 1H), 2.30-2.46 (m, 2H), 1.94-2.05 (m, 1H), 1.82-1.93 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.4, 138.7, 131.0, 130.5, 127.4 (q, J = 279.3 Hz), 125.9, 125.3, 124.2, 120.8, 118.4, 41.8 (q, J = 25.7 Hz), 26.9 (q, J = 3.2 Hz), 24.1 (q, J = 2.1 Hz), 15.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -70.2 (d, J = 8.3 Hz, 3F); IR (neat): v (cm^{-1}) 3097, 2955, 2251, 1590, 1453, 1424, 1394, 1253, 1156, 1118, 1078, 1000, 866, 834, 804; ESI-MS: (*m/z*) 316.0 (M^+-H); HRMS calcd for $C_{14}H_{10}ClF_3NS$ (M-H): 316.0180, found 316.0180.



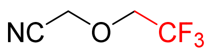
2-(2-Benzyl-1,3-dioxo-6-(trifluoromethyl)octahydro-1*H*-isoindol-5-yl)acetonitrile (*cis*-2z). Yield: 13 mg (18%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.26-7.37 (m, 5H), 4.64 (s, 2H), 3.00-3.10 (m, 2H), 2.55 (dd, J = 17.0, 6.4 Hz, 1H), 2.36-2.45 (m, 2H), 2.07-2.26 (m, 3H), 1.96-2.05 (m, 1H), 1.82-1.92 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.4, 177.2, 135.5, 128.8, 128.7, 128.2, 126.7 (q, J = 279.8 Hz), 117.2, 42.6, 39.2 (q, J = 26.2 Hz), 37.3, 37.0, 29.7, 26.8, 20.4, 18.6 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -65.8 (d, J = 9.4 Hz, 3F); IR (neat): ν (cm^{-1}) 2955, 2255, 1782, 1708, 1499, 1431, 1396, 1350, 1265, 1160, 1121, 966, 707; ESI-MS: (*m/z*) 373.1 (M^++Na); HRMS calcd for $C_{18}H_{18}O_2N_2F_3$ (M+H): 351.1315, found 351.1318.



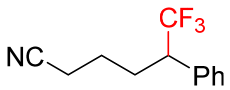
2-(2-Benzyl-1,3-dioxo-6-(trifluoromethyl)octahydro-1*H*-isoindol-5-yl)acetonitrile (*trans*-2z). Yield: 41 mg (59%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27-7.38 (m, 5H), 4.64 (s, 2H), 3.04-3.13 (m, 1H), 2.92-3.02 (m, 1H), 2.48-2.67 (m, 2H), 2.35-2.44 (m, 1H), 1.94-2.26 (m, 4H), 1.40-1.51 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.4, 177.3, 135.4, 128.7, 128.6, 128.1, 126.7 (q, J = 278.6 Hz), 117.0, 42.5, 41.5 (q, J = 26.2 Hz), 37.8, 37.1, 28.8, 25.9, 22.9, 22.8 (q, J = 3.0 Hz) ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -70.6 (d, J = 8.3 Hz, 3F); IR (neat): ν (cm^{-1}) 3069, 3040, 2948, 2254, 1777, 1705, 1431, 1396, 1343, 1257, 1173, 1118, 736, 703; ESI-MS: (*m/z*) 373.1 (M^++Na); HRMS calcd for $C_{18}H_{18}F_3N_2O_2$ (M+H): 351.1315, found 351.1318. The stereochemistry was further confirmed by 2D NMR experiments.



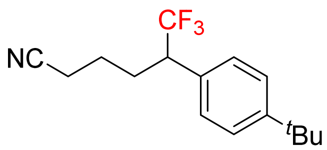
2-(2-(Trifluoromethyl)-2,3-dihydro-1*H*-inden-1-yl)acetonitrile (2za). Yield: 38 mg (84%). Mixture of two isomers (*trans:cis* = 94:6 determined by ^{1}H NMR). Colorless oil. The *trans* isomer: ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22-7.34 (m, 4H), 3.70 (q, J = 6.0 Hz, 1H), 3.30 (dd, J = 16.4, 9.6 Hz, 1H), 3.14 (dd, J = 16.4, 7.6 Hz, 1H), 2.82-3.06 (m, 2H), 2.80 (dd, J = 17.2, 6.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.2, 140.1, 128.6, 127.7, 127.5 (q, J = 276.3 Hz), 124.9, 123.5, 117.3, 47.7 (q, J = 27.1 Hz), 41.7 (q, J = 7.1 Hz), 31.9 (q, J = 10.7 Hz), 22.5; ^{19}F NMR (376 MHz, $CDCl_3$): δ -70.5 (d, J = 7.9 Hz, 3F); IR (neat): ν (cm^{-1}) 3032, 2946, 2251, 1460, 1393, 1270, 1156, 1112, 960, 749; EI-MS: *m/z* (rel intensity) 225 (M^+, 26), 207 (10), 185 (100), 165 (36), 145 (13), 131 (21), 115 (33), 91 (36); HRMS calcd for $C_{12}H_{10}F_3N$ (M): 225.0765, found 225.0772. The stereochemistry was further confirmed by 2D NMR experiments.



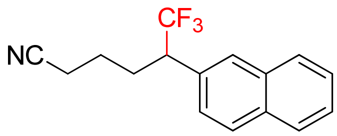
2-(2,2,2-Trifluoroethoxy)acetonitrile (2zb). This compound was obtained in 40% yield based on the ^{19}F NMR with benzyl 4-fluorobenzoate as the internal standard and characterized in reaction solution: ^{19}F NMR (376 MHz, CH_2Cl_2) δ -74.5 (t, J = 7.9 Hz, 3F). EI-MS: *m/z* (rel intensity) 139.0 (M^+, 7), 120 (8), 93 (15), 83 (21), 70 (100), 58 (20), 43 (45); HRMS calcd for $C_4H_4F_3NO$ (M): 139.0245, found 139.0241.



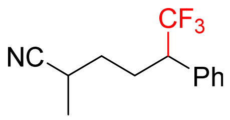
6,6,6-Trifluoro-5-phenylhexanenitrile (3a). Yield: 36 mg (80%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23-7.40 (m, 5H), 3.19-3.28 (m, 1H), 2.28 (t, J = 7.2 Hz, 2H), 2.09-2.20 (m, 1H), 1.95-2.07 (m, 1H), 1.44-1.64 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 133.7, 128.9, 128.8, 128.5, 126.5 (q, J = 278.6 Hz), 118.9, 49.6 (q, J = 27.4 Hz), 27.8 (q, J = 2.3 Hz), 22.8, 16.9; ^{19}F NMR (376 MHz, $CDCl_3$): δ -69.8 (d, J = 9.8 Hz, 3F); IR (neat): ν (cm^{-1}) 3040, 2951, 2243, 1457, 1259, 1174, 1152, 1114, 761, 704; EI-MS: *m/z* (rel intensity) 227 (M^+, 88), 207 (41), 187 (9), 159 (100), 117 (71), 109 (93), 91 (58), 54 (27); HRMS calcd for $C_{12}H_{12}F_3N$ (M): 227.0922, found 227.0928.



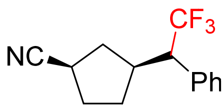
5-(4-(*tert*-Butyl)phenyl)-6,6,6-trifluorohexanenitrile (3b). Yield: 45 mg (80%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 (d, J = 8.0 Hz, 2H), 7.19 (d, J = 8.0 Hz, 2H), 3.15-3.28 (m, 1H), 2.31 (t, J = 6.8 Hz, 2H), 2.09-2.20 (m, 1H), 1.95-2.07 (m, 1H), 1.50-1.62 (m, 2H), 1.32 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.5, 130.6, 128.4, 126.6 (q, J = 278.3 Hz), 125.9, 119.0, 49.1 (q, J = 26.9 Hz), 34.6, 31.3, 27.9, 22.9, 17.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.9 (d, J = 9.8 Hz, 3F); IR (neat): *ν* (cm^{-1}) 2964, 2257, 1516, 1462, 1364, 1259, 1174, 1153, 1111, 827; EI-MS: *m/z* (rel intensity) 283 (M^+, 25), 267 (5), 248 (3), 214 (100), 181 (25), 165 (6), 152 (17), 107 (10), 91 (5), 69 (6); HRMS calcd for $C_{16}H_{20}F_3N$ (M): 283.1548, found 283.1549.



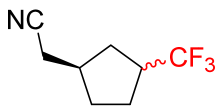
6,6,6-Trifluoro-5-(naphthalen-2-yl)hexanenitrile (3c). Yield: 49 mg (88%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81-7.91 (m, 3H), 7.75 (s, 1H), 7.49-7.56 (m, 2H), 7.41 (d, J = 8.8 Hz, 1H), 3.37-3.51 (m, 1H), 2.07-2.36 (m, 4H), 1.47-1.69 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 133.3, 133.2, 131.1, 128.9, 128.7, 127.9, 127.7, 126.7, 126.6 (q, J = 278.0 Hz), 125.7, 118.9, 49.7 (q, J = 26.2 Hz), 27.8 (q, J = 1.8 Hz), 22.9, 17.0 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -69.5 (d, J = 8.3 Hz, 3F); IR (neat): ν (cm^{-1}) 3061, 2968, 2255, 1508, 1260, 1151, 1113, 819, 751; EI-MS: *m/z* (rel intensity) 277 (M^+, 1), 247 (2), 209 (17), 194 (5), 170 (11), 117 (100), 115 (46), 91 (17); HRMS calcd for $C_{16}H_{14}F_3N$ (M): 277.1078, found 277.1080.



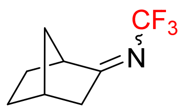
6,6,6-Trifluoro-2-methyl-5-phenylhexanenitrile (3d). Yield: 33 mg (68%). Mixture of two isomers (50:50 determined by ^{1}H NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.40 (m, 3H), 7.21-7.30 (m, 2H), 3.15-3.29 (m, 1H), 2.45-2.62 (m, 1H), 2.16-2.29 (m, 0.5H), 2.05-2.16 (m, 1H), 1.89-2.02 (m, 0.5H), 1.31-1.61 (m, 2H), 1.24 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.9/133.7, 128.9, 128.8, 128.5, 126.5 (q, J = 278.7 Hz), 122.3/122.1, 49.8 (q, J = 26.6 Hz)/49.6 (q, J = 26.5 Hz), 31.3/31.2, 26.3 (q, J = 2.3 Hz)/26.2 (q, J = 2.3 Hz), 25.4/25.3, 17.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -69.8 (d, J = 9.8 Hz, 1.5F), -69.9 (d, J = 8.3 Hz, 1.5F); IR (neat): *v* (cm^{-1}) 3040, 2984, 2944, 2240, 1496, 1457, 1259, 1161, 1112, 762, 704; EI-MS: *m/z* (rel intensity) 241 (M^+, 82), 226 (13), 221 (22), 200 (15), 172 (37), 159 (79), 117 (60), 109 (100), 91 (60), 68 (97); HRMS calcd for $C_{13}H_{14}F_3N$ (M): 241.1078, found 241.1081.



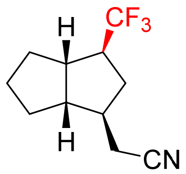
3-(2,2,2-Trifluoro-1-phenylethyl)cyclopentane-1-carbonitrile (5a). Yield: 28 mg (55%). Mixture of two diastereoisomers in 50:50 ratio determined by ^{1}H NMR. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.38 (m, 3H), 7.18-7.26 (m, 2H), 3.05-3.17 (m, 1H), 2.78-2.89 (m, 0.5 H), 2.68-2.73 (m, 0.5H), 2.40-2.56 (m, 1.5H), 2.02-2.21 (m, 1.5H), 1.62-1.95 (m, 2.5H), 1.46-1.58 (m, 0.5H), 1.21-1.43 (m, 1H), ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.7, 128.9, 128.8/128.7, 128.4/128.3, 126.6 (q, J = 279.2 Hz), 122.8/122.7, 54.8 (q, J = 25.3 Hz)/54.7 (q, J = 26.2 Hz), 40.5/40.3, 36.8/36.7, 30.7, 30.5/30.4, 29.0, 27.6, 26.2; ^{19}F NMR (376 MHz, $CDCl_3$) δ -66.5 (d, J = 9.4 Hz, 1.5F), -66.6 (d, J = 8.3 Hz, 1.5F); IR (neat): v (cm^{-1}) 3045, 2976, 2883, 2239, 1498, 1455, 1358, 1321, 1256, 1148, 1111, 1079, 872, 762, 705, 636; EI-MS: *m/z* (rel intensity) 253 (M^+, 51), 233 (10), 212 (5), 184 (5), 159 (100), 140 (42), 135 (21), 115 (23), 109 (62), 91 (52), 67 (69); HRMS calcd for $C_{14}H_{14}F_3N$ (M): 253.1078, found 253.1071.



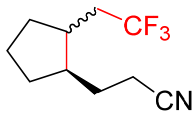
2-(3-(Trifluoromethyl)cyclopentyl)acetonitrile (5b). This compound was obtained in 48% yield (based on the ^{19}F NMR with benzyl 4-fluorobenzoate as the internal standard) as a mixture of two isomers (50:50 determined by ^{19}F NMR). Characterization in reaction solution: ^{19}F NMR (376 MHz, $ClCH_2CH_2Cl$) δ -71.6 (d, J = 9.4 Hz, 1.5F)/71.8 (d, J = 9.4 Hz, 1.5F). EI-MS: *m/z* (rel intensity) 176 (M^+, 2), 137 (13), 117 (100), 108 (10), 97 (38), 77 (15), 67 (9), 41 (34); HRMS calcd for $C_8H_{10}F_3N$ (M): 176.0687, found 176.0693.



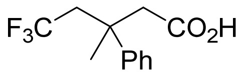
***N*-(Trifluoromethyl)bicyclo[2.2.1]heptan-2-imine (5ba).** This compound was obtained in 78% yield (based on the ^{19}F NMR with 1-chloro-4-fluorobenzene as the internal standard). Mixture of two isomers (70:30 determined by ^{19}F NMR). ^{19}F NMR (376 MHz, CH_2Cl_2) δ -56.8 (s, 1F), -58.6 (s, 2F). EI-MS: *m/z*(rel intensity) 177 (M^+, 35), 162 (16), 148 (16), 122 (11), 92 (24), 66 (100), 53 (14), 39 (22); HRMS calcd for $C_8H_{10}F_3N$ (M): 177.0765, found 177.0762.



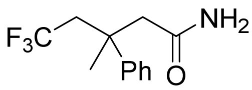
2-(3-(Trifluoromethyl)octahydropentalen-1-yl)acetonitrile (5c). Yield: 16 mg (45%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.61-2.72 (m, 1H), 2.38-2.52 (m, 2H), 2.08-2.31 (m, 3H), 1.44-1.86 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 127.6 (q, J = 275.1 Hz), 118.3, 49.6 (q, J = 26.7 Hz), 49.2, 44.0, 42.4, 34.2, 32.7, 31.5, 25.2, 21.5 ; ^{19}F NMR (376 MHz, $CDCl_3$): δ -70.7 (d, J = 8.3 Hz, 3F); IR (neat): ν (cm^{-1}) 2950, 2870, 2251, 1397, 1267, 1155, 1106, 1077; EI-MS: *m/z* (rel intensity) 217 (M^+, 2), 200 (6), 177 (19), 149 (11) 135 (12), 130 (13), 94 (11), 84 (21), 71 (28), 56 (100); HRMS calcd for $C_{11}H_{14}F_3N$ (M): 217.1078, found 217.1083. The stereochemistry was confirmed by 2D NMR experiments.



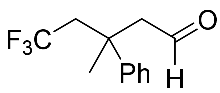
2-(2,2,2-Trifluoroethyl)cyclopentyl)propanenitrile (7). Yield: 25 mg (61%). Mixture of two isomers (80:20 determined by ^{19}F NMR). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.15-2.47 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 127.2 (q, J = 275.9 Hz), 119.5, 44.5/41.2, 39.4/36.4 (q, J = 1.4 Hz), 38.2 (q, J = 27.8 Hz)/33.7 (q, J = 27.0 Hz), 32.5/30.0, 30.7/28.9, 30.0/25.0, 23.5/21.8, 16.1/15.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -64.4 (t, J = 9.8 Hz, 2.4F), -64.6 (t, J = 10.9 Hz, 0.6F); IR (neat): *v* (cm^{-1}) 2956, 2877, 2246, 1457, 1438, 1388, 1352, 1260, 1140, 1097, 1053, 750; EI-MS: *m/z* (rel intensity) 204 (M^+-H, 4), 177 (14), 165 (8), 122 (25), 109 (9), 95 (54), 82 (54), 67 (25), 55 (100); HRMS calcd for $C_{10}H_{13}F_3N$ (M-H): 204.1000, found 204.0994.



5,5,5-Trifluoro-3-methyl-3-phenylpentanoic acid (8a). This compound was prepared from 5,5,5-trifluoro-3-methyl-3-phenylpentanenitrile according to the conventional method. Yield: 42 mg (85%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.37 (m, 4H), 7.20-7.28 (m, 1H), 2.60-2.87 (m, 4H), 1.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.9, 144.7, 128.5, 126.8, 126.3 (q, J = 277.2 Hz), 125.4, 45.3, 43.9 (q, J = 26.4 Hz), 37.6, 25.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.3 (t, J = 10.9 Hz, 3F); IR (neat): v (cm^{-1}) 2955, 1711, 1446, 1370, 1260, 1120, 1074, 1051, 699; ESI-MS: (m/z) 245.0 (M^+-H); HRMS calcd for $C_{12}H_{12}F_3O_2$ (M-H): 245.0795, found 245.0796.

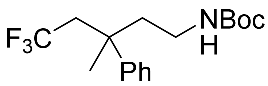


5,5,5-Trifluoro-3-methyl-3-phenylpentanamide (8b). This compound was prepared from 5,5,5-trifluoro-3-methyl-3-phenylpentanenitrile according to the conventional method.[5] Yield: 43 mg (87%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31-7.38 (m, 4H), 7.21-7.27 (m, 1H), 5.38 (br, 1H), 4.92 (br, 1H), 2.75 (q, J = 10.8 Hz, 2H), 2.60 (AB, J = 14.4 Hz, 2H), 1.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 144.5, 128.7, 126.9, 126.3 (q, J = 277.9 Hz), 125.6, 48.9, 44.2 (q, J = 25.8 Hz), 38.1, 23.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.0 (t, J = 10.9 Hz, 3F); IR (neat): v (cm^{-1}) 3469, 3338, 3193, 2953, 1667, 1604, 1368, 1260, 1168, 1115, 1095, 1048, 766, 700; ESI-MS: (m/z) 268.1 (M^++Na); HRMS calcd for $C_{12}H_{14}F_3NNaO$ (M+Na): 268.0920, found 268.0921.



5,5,5-Trifluoro-3-methyl-3-phenylpentanal (8c). This compound was prepared from 5,5,5-trifluoro-3-methyl-3-phenylpentanenitrile according to the conventional method. Yield: 28 mg (62%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.47 (s, 1H), 7.32-7.39

(m, 4H), 7.22-7.28 (m, 1H), 2.98 (d, J = 16.4 Hz, 1H), 2.77 (d, J = 16.4 Hz, 1H), 2.60 (q, J = 10.8 Hz, 2H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.9, 144.1, 128.8, 127.0, 126.1 (q, J = 278.0 Hz), 125.6, 53.9, 45.5 (q, J = 26.4 Hz), 37.4, 25.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.4 (t, J = 10.9 Hz, 3F); IR (neat): v (cm^{-1}) 3062, 2954, 1721, 1498, 1370, 1263, 1174, 1121, 1098, 765, 700; ESI-MS: (m/z) 229.0 (M^+-H); HRMS calcd for $C_{12}H_{12}F_3O$ (M-H): 229.0846, found 229.0843.



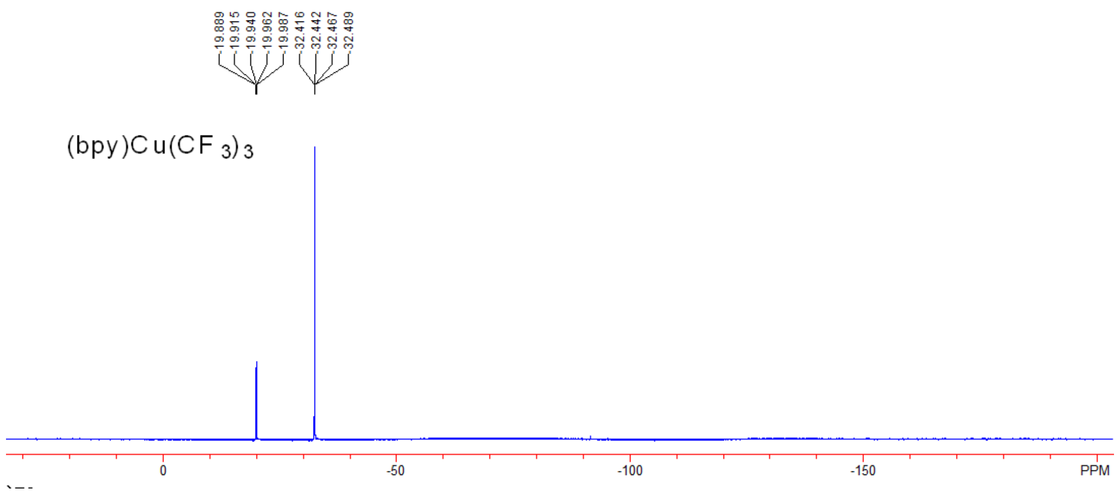
***tert*-Butyl (5,5,5-trifluoro-3-methyl-3-phenylpentyl)carbamate (8d).** This compound was prepared from 5,5,5-trifluoro-3-methyl-3-phenylpentanenitrile according to the conventional method.[6] Yield: 54 mg (81%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.36 (m, 4H), 7.19-7.25 (m, 1H), 4.30 (br, 1H), 3.03 (br, 1H), 2.72 (br, 1H), 2.35-2.62 (m, 2H), 1.97-2.07 (m, 1H), 1.84-1.93 (m, 1H), 1.54 (s, 3H), 1.40 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.7, 144.5, 128.5, 126.5, 126.3 (q, J = 277.9 Hz), 125.7, 79.2, 46.2 (q, J = 25.9 Hz), 42.6, 37.9, 36.4, 28.3, 23.2; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.0 (t, J = 12.4 Hz, 3F); IR (neat): v (cm^{-1}) 3363, 2978, 1709, 1512, 1501, 1367, 1261, 1173, 1120, 764, 700; ESI-MS: (m/z) 354.2 (M^++Na); HRMS calcd for $C_{17}H_{24}F_3NNaO_2$ (M+Na): 354.1651, found 354.1653.

6. Mechanistic experiments.

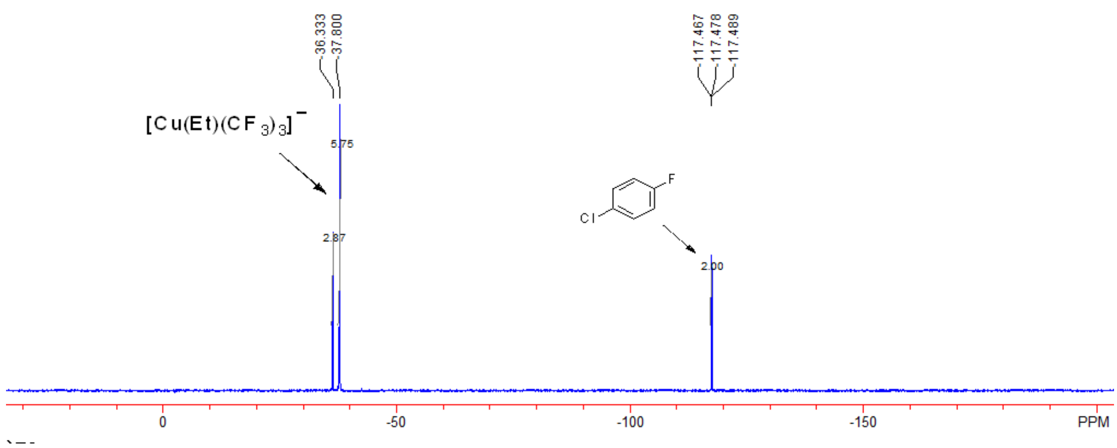
(1) Synthesis and characterization of products 9. [7]

(bpy)Cu(CF_3)$_3$ (42.7 mg, 0.1 mmol) was added to an oven-dried 10 mL schlenk tube equipped with a stir bar under nitrogen atmosphere. The schlenk tube was placed into an ice bath. 1-Chloro-4-fluorobenzene (26.1 mg, 0.2 mmol) and anhydrous DMF (2.0 mL) were then added to the tube successively at 0 °C and the mixture was stirred for 10 minutes. Diethylzinc (0.15 mL, 0.15 mmol, 1 M solution in hexane) was then added slowly into the tube under nitrogen and the resulting mixture was stirred for another 3 h. The $[Cu(Et)(CF_3)_3]^-$ anion (**9**) was thus obtained in 96% yield based on ^{19}F NMR

^{19}F NMR (376 MHz, DMF) of $(bpy)Cu(CF_3)_3$:

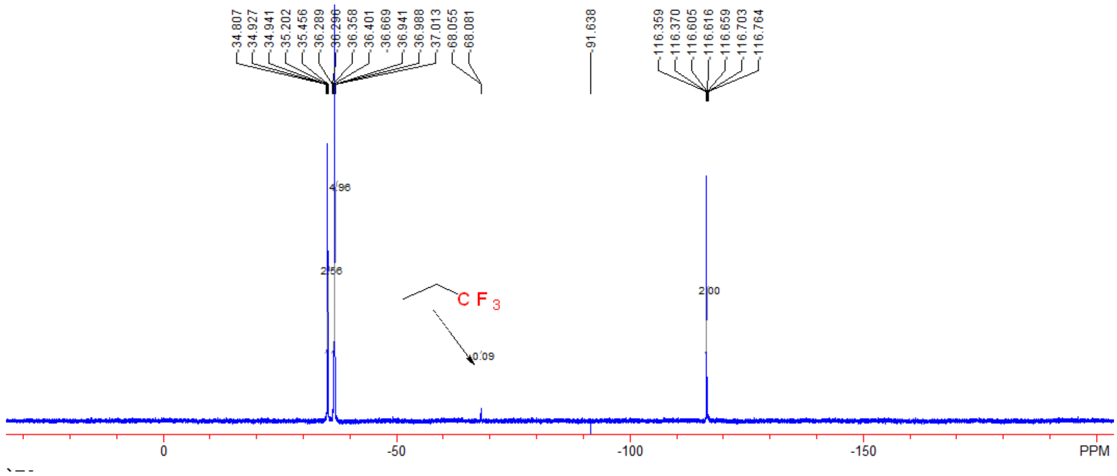


^{19}F NMR (376 MHz, DMF) of the reaction mixture:

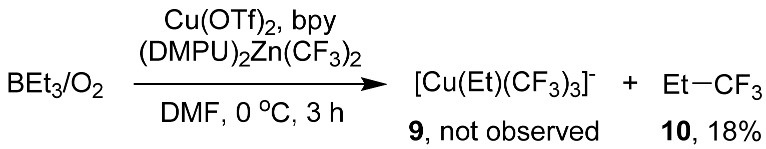


The decomposition of **9** in the reaction mixture above was also conducted at room temperature for 3 h. $EtCF_3$ (**10**) was observed in only about 3% yield while 85% **9** remained unchanged.

^{19}F NMR (376 MHz, DMF) of the decomposed reaction mixture:

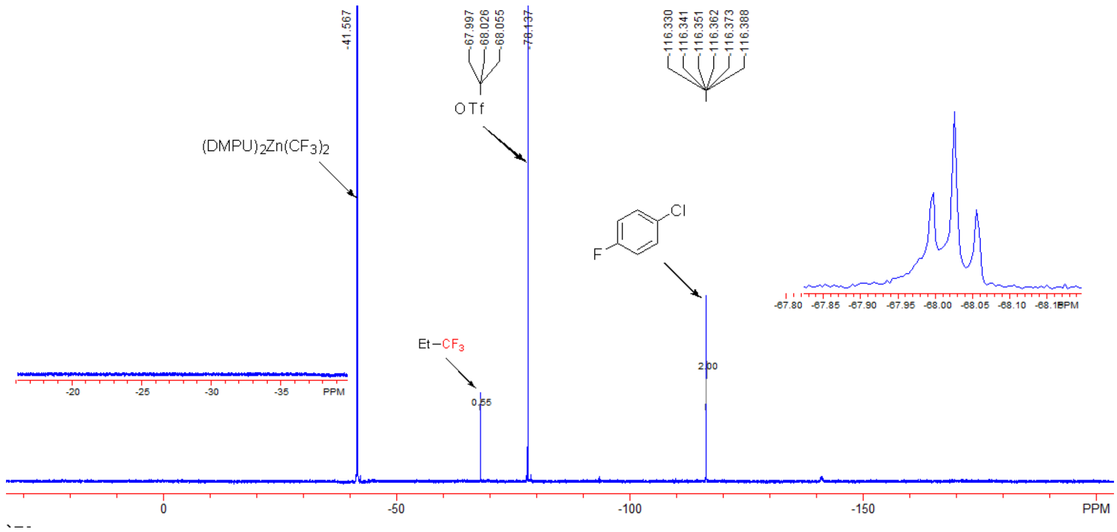


(2) Probing the identity of the species responsible for the trifluoromethylation of alkyl radicals.



$Cu(OTf)_2$ (36.2 mg, 0.1 mmol), bpy (15.6 mg, 0.1 mmol) and $(DMPU)_2Zn(CF_3)_2$ (137.9 mg, 0.3 mmol) were added to an oven-dried 10 mL schlenk tube equipped with a stir bar in a grovebox under nitrogen atmosphere. E_3B (0.2 mL, 0.2 mmol, 1 M solution in THF) was then added in the tube under nitrogen. Anhydrous DMF (2.0 mL) was added into the tube quickly and then air (50 mL) was added by a syringe. After 3 h, 1-chloro-4-fluorobenzene (26.1 mg, 0.2 mmol) was added for ^{19}F NMR analysis.

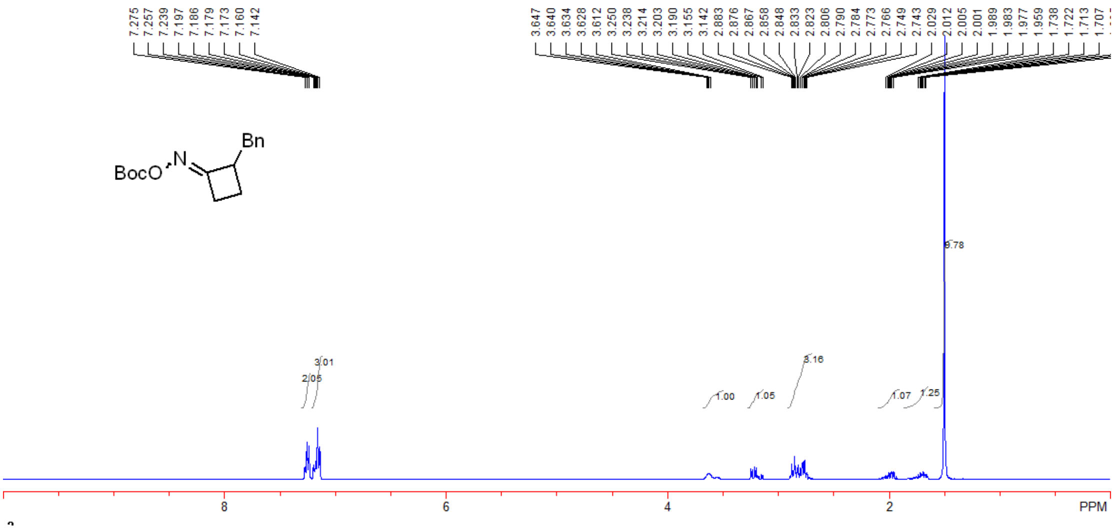
^{19}F NMR (376 MHz, DMF) of the reaction mixture:



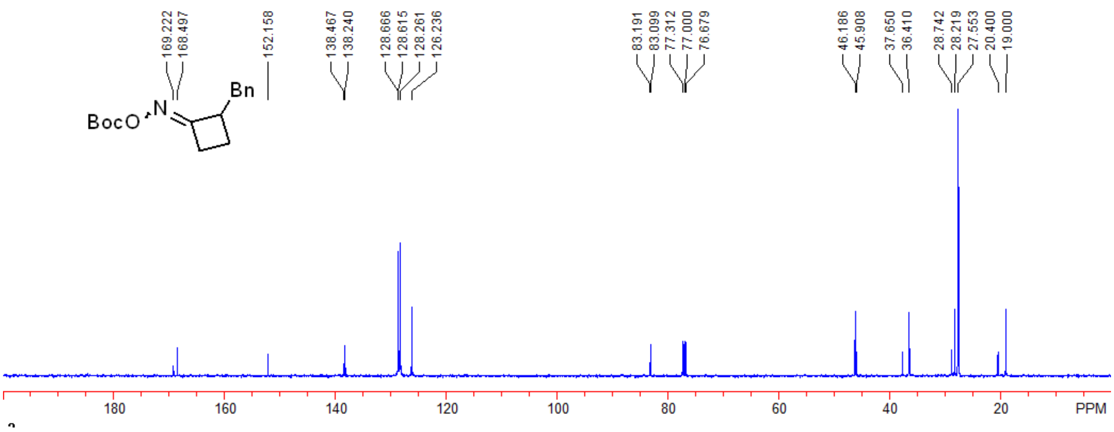
7. ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra of new substrates.

Compound 1aa

^{1}H NMR (400 MHz, $CDCl_3$):

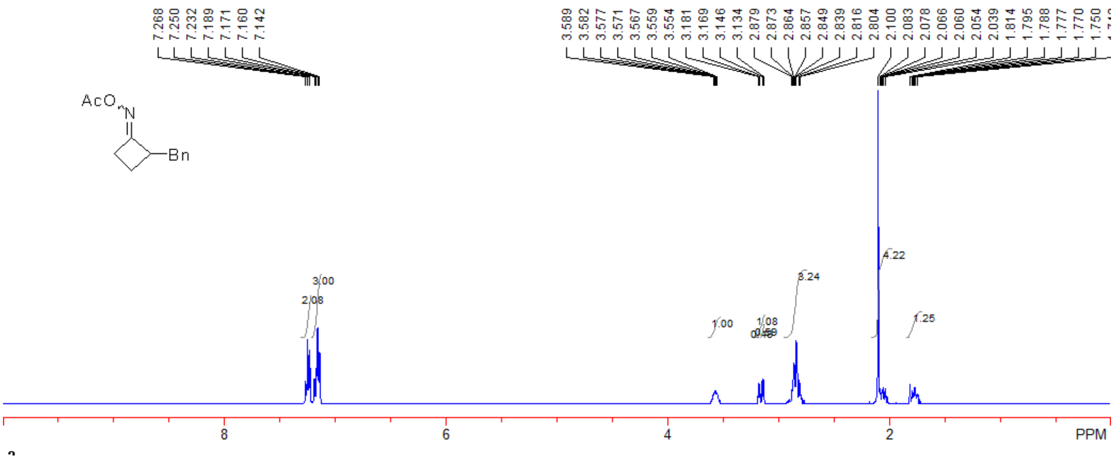


^{13}C NMR (100 MHz, $CDCl_3$):

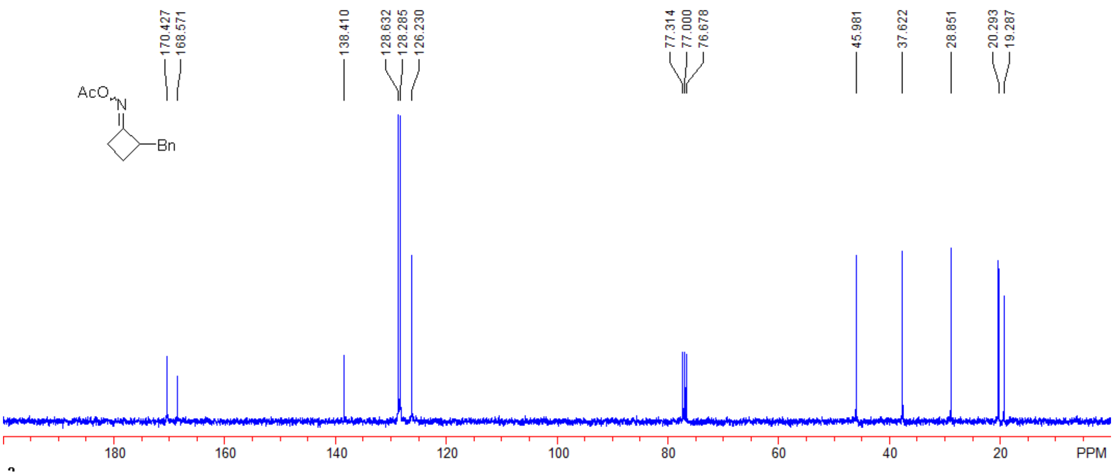


Compound 1ab

^{1}H NMR (400 MHz, $CDCl_3$):

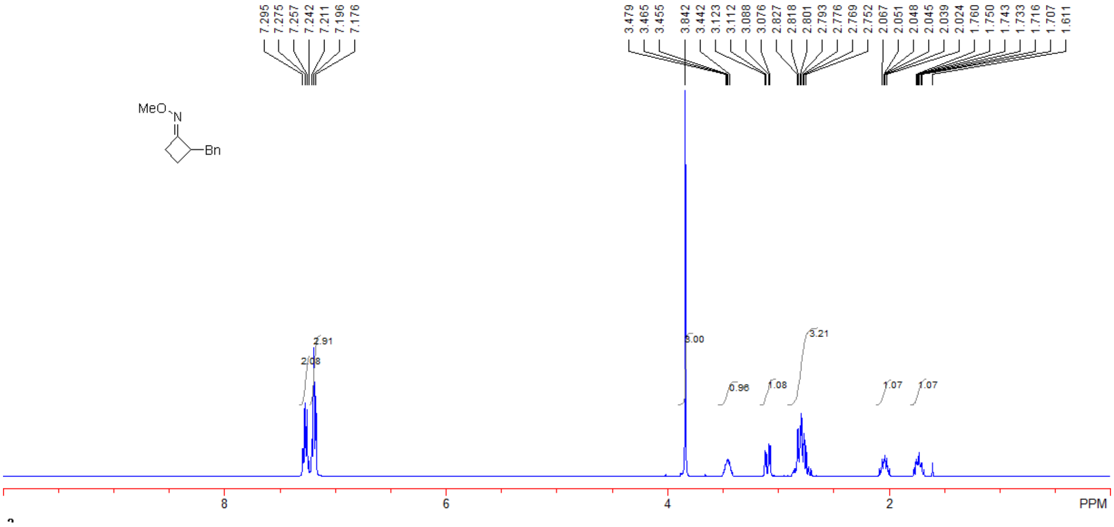


^{13}C NMR (100 MHz, $CDCl_3$):

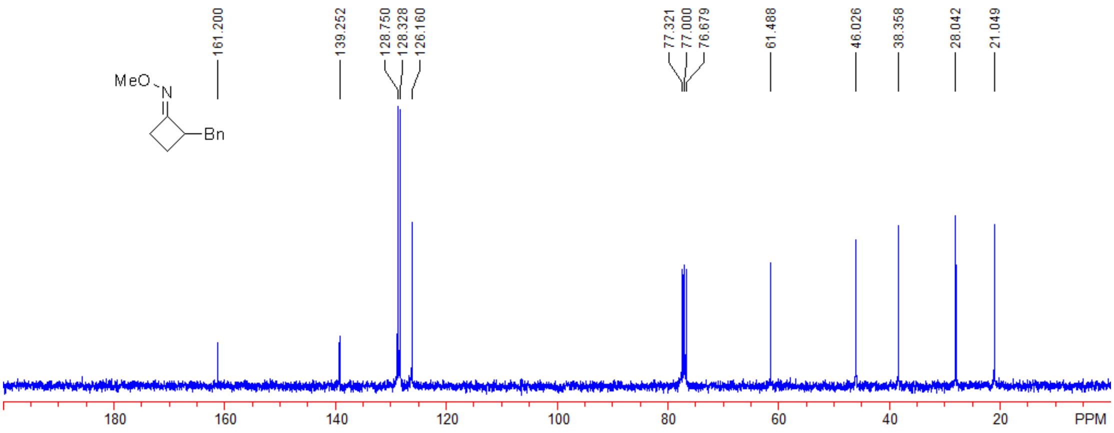


Compound 1ad

^{1}H NMR (400 MHz, $CDCl_3$):

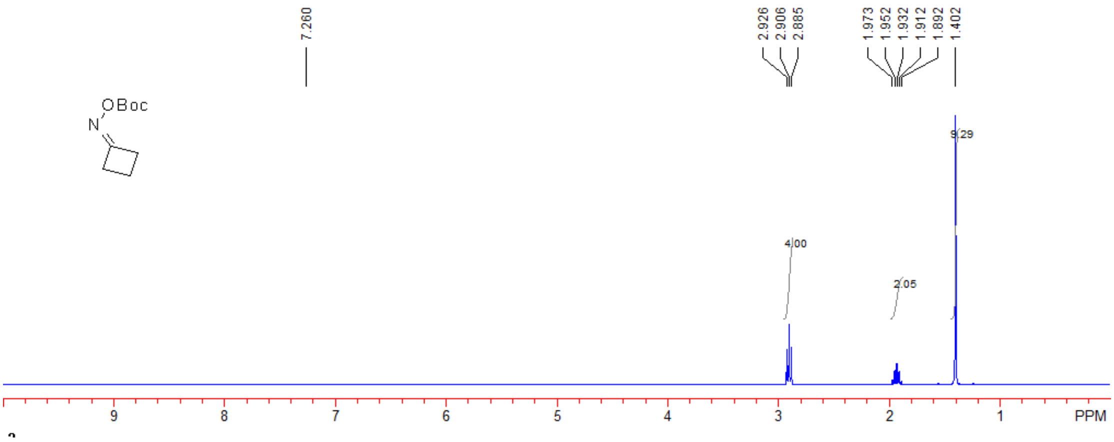


^{13}C NMR (100 MHz, $CDCl_3$):

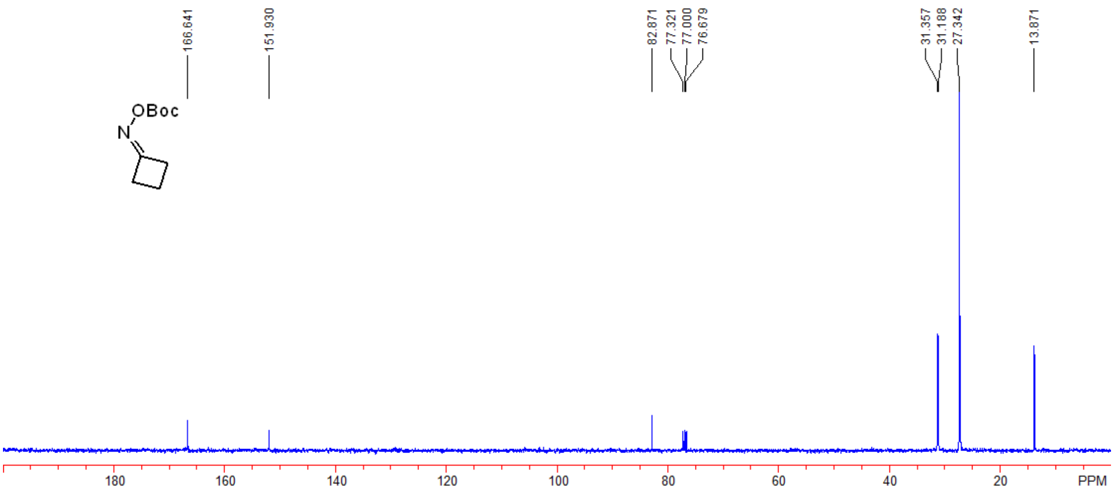


Compound 1b

^1H NMR (400 MHz, $CDCl_3$):

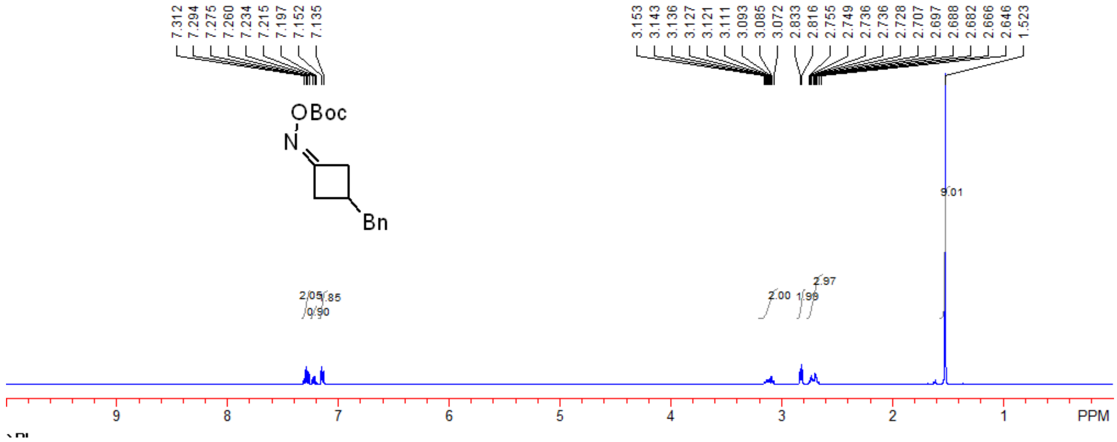


^{13}C NMR (100 MHz, $CDCl_3$):

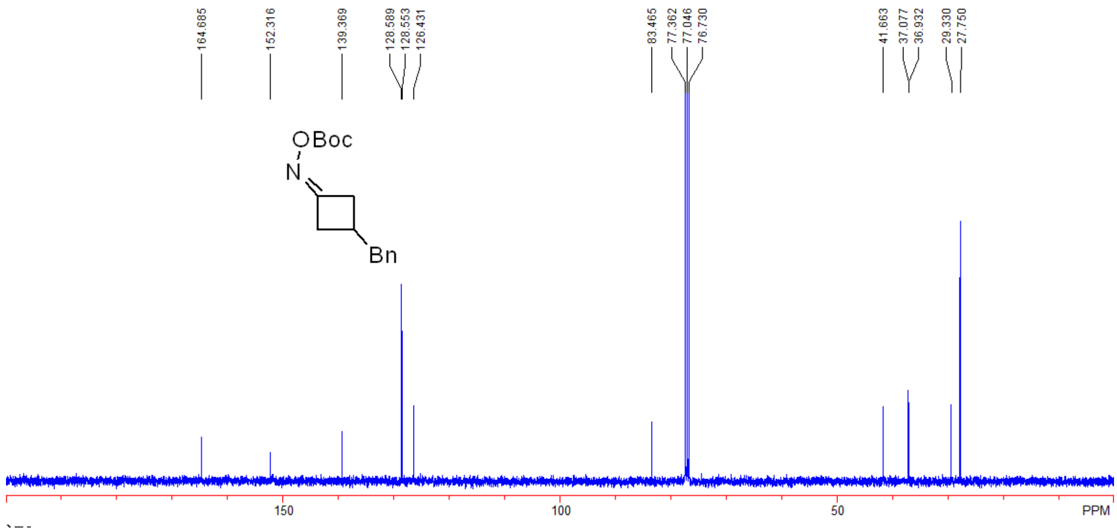


Compound 1c

^{1}H NMR (400 MHz, $CDCl_3$):

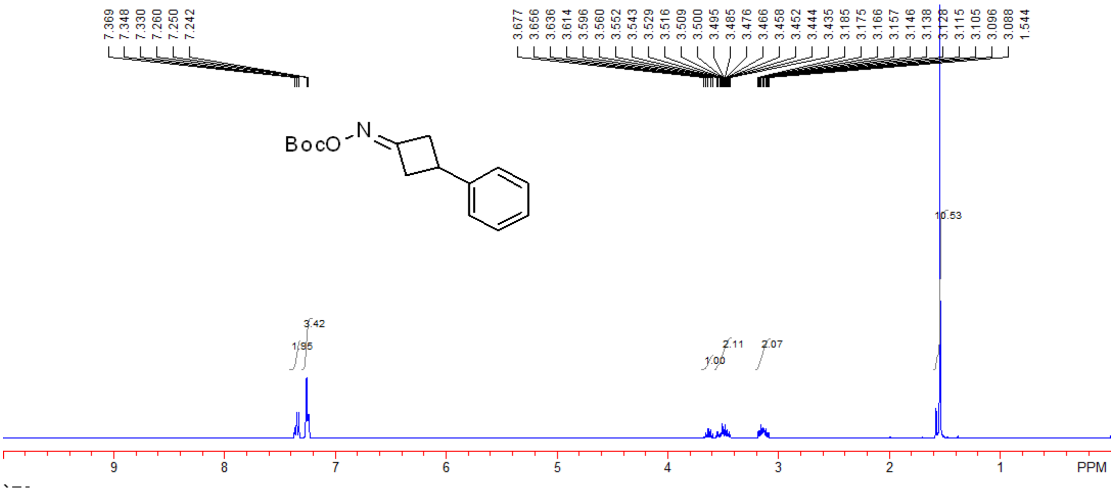


^{13}C NMR (100 MHz, $CDCl_3$):

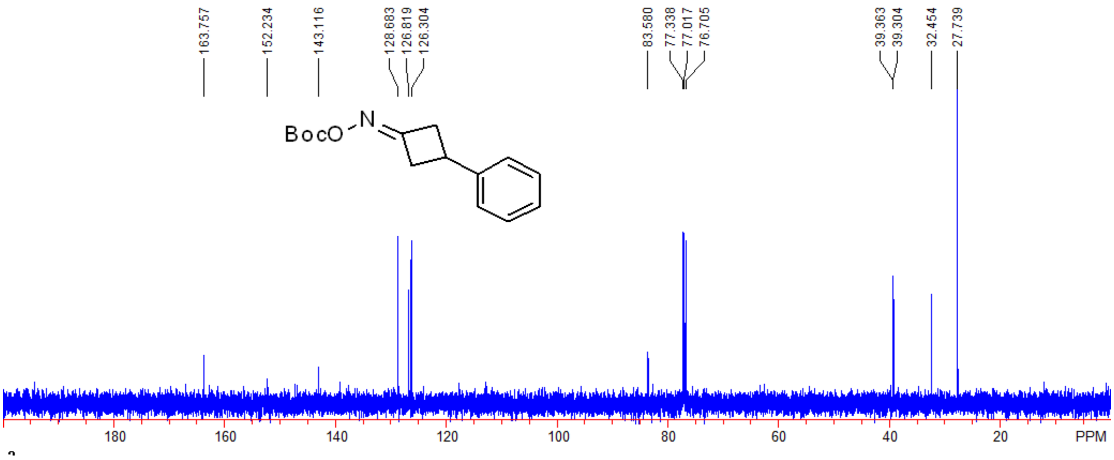


Compound 1d

^{1}H NMR (400 MHz, $CDCl_3$):

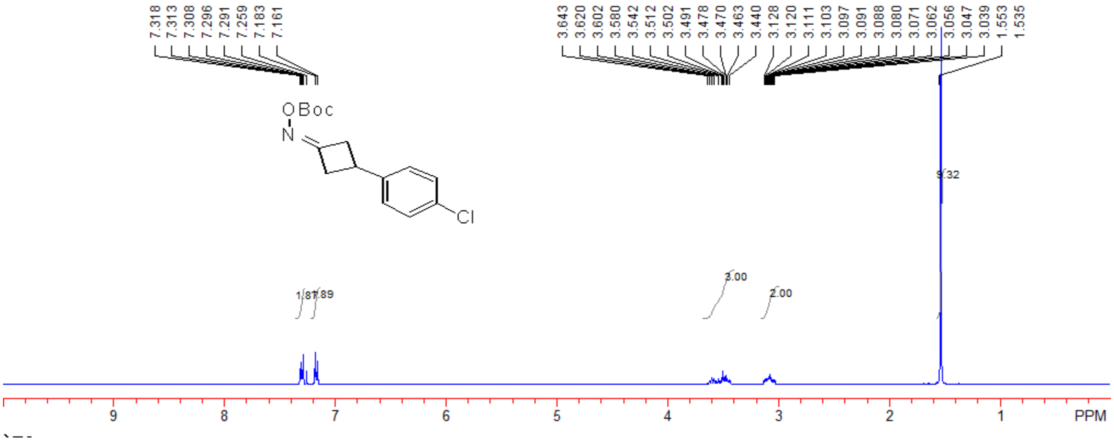


^{13}C NMR (100 MHz, $CDCl_3$):

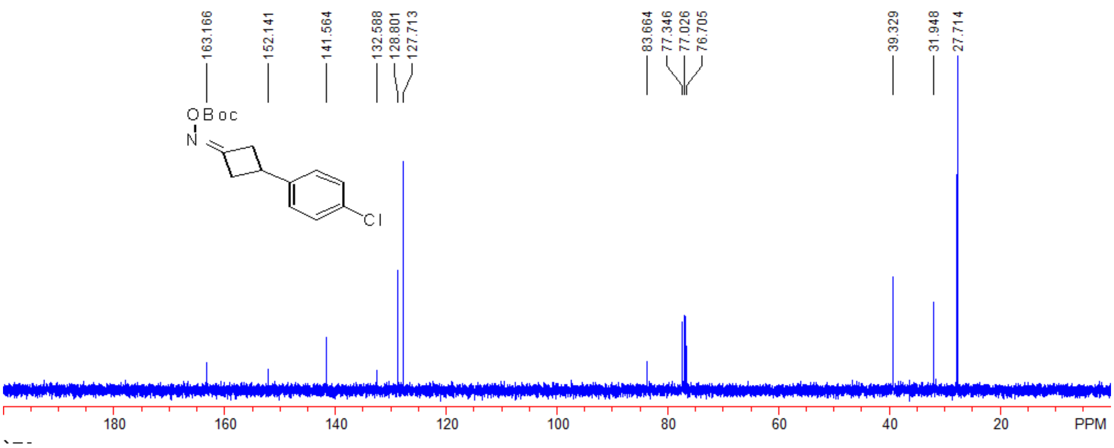


Compound 1e

^{1}H NMR (400 MHz, $CDCl_3$):

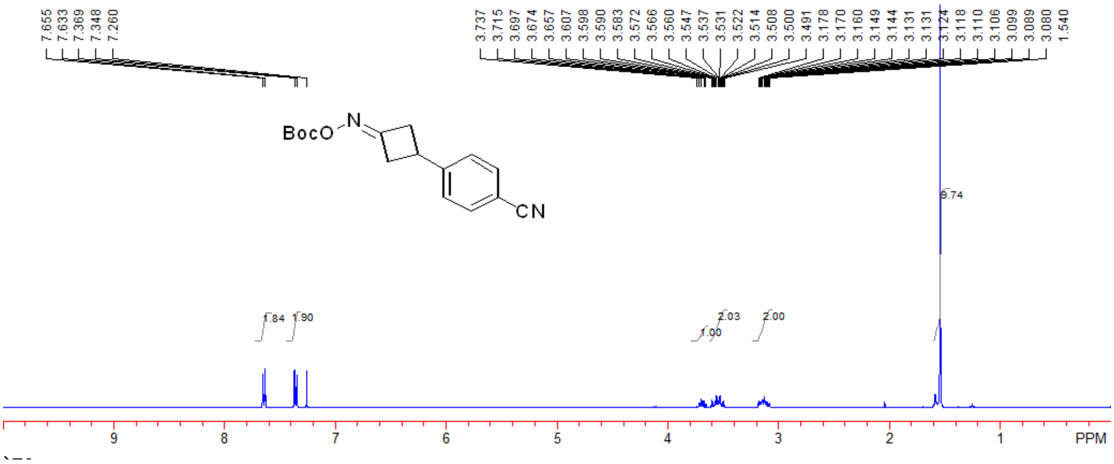


^{13}C NMR (100 MHz, $CDCl_3$):

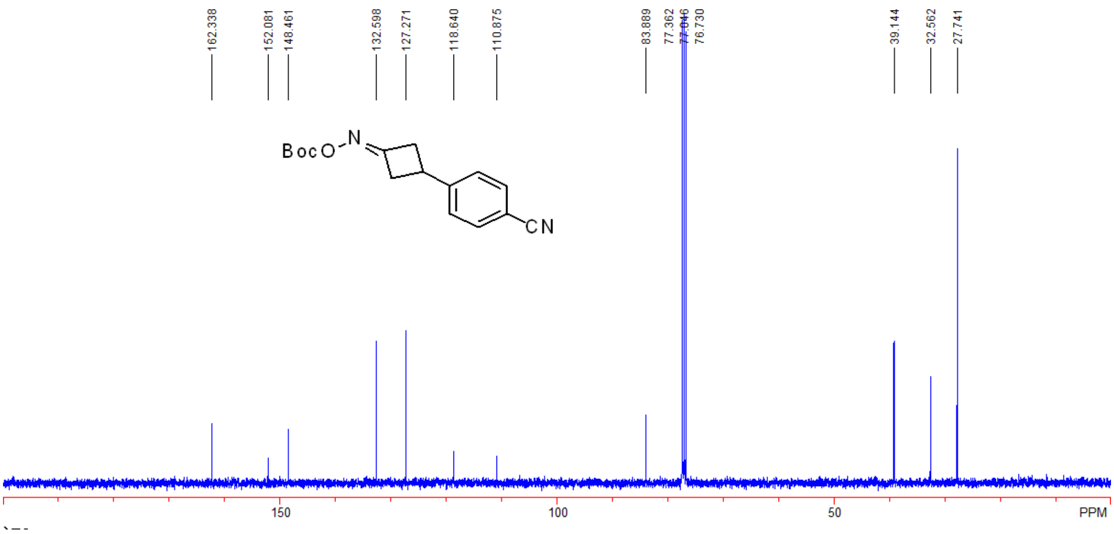


Compound 1f

^1H NMR (400 MHz, $CDCl_3$):

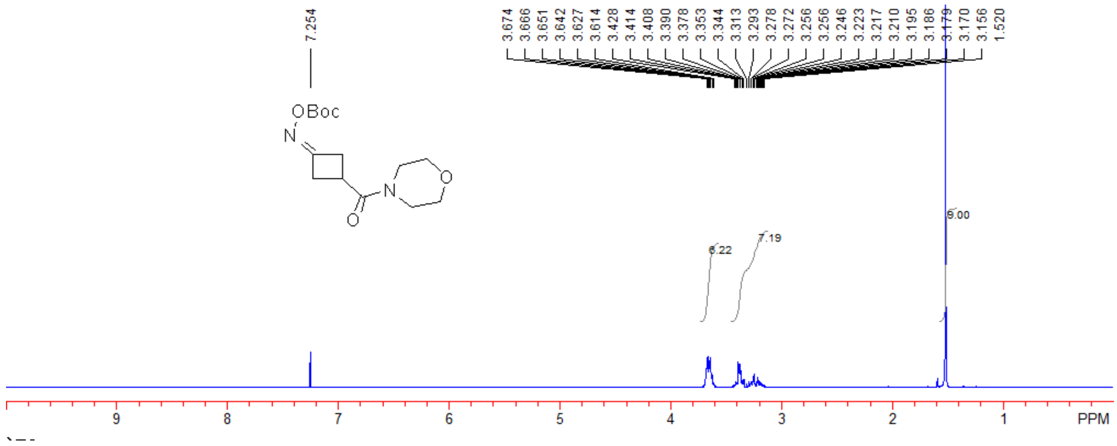


^{13}C NMR (100 MHz, $CDCl_3$):

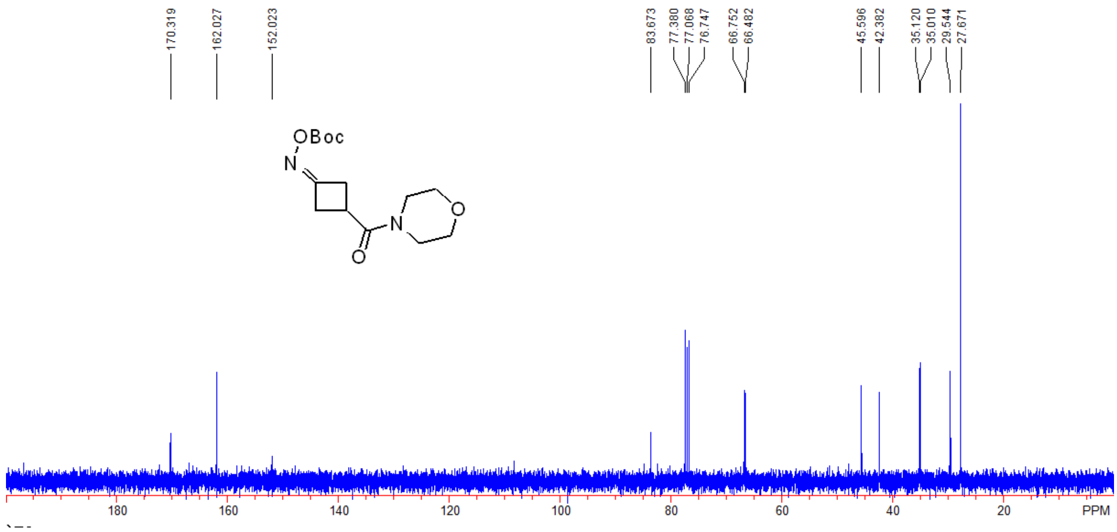


Compound 1g

^{1}H NMR (400 MHz, $CDCl_3$):

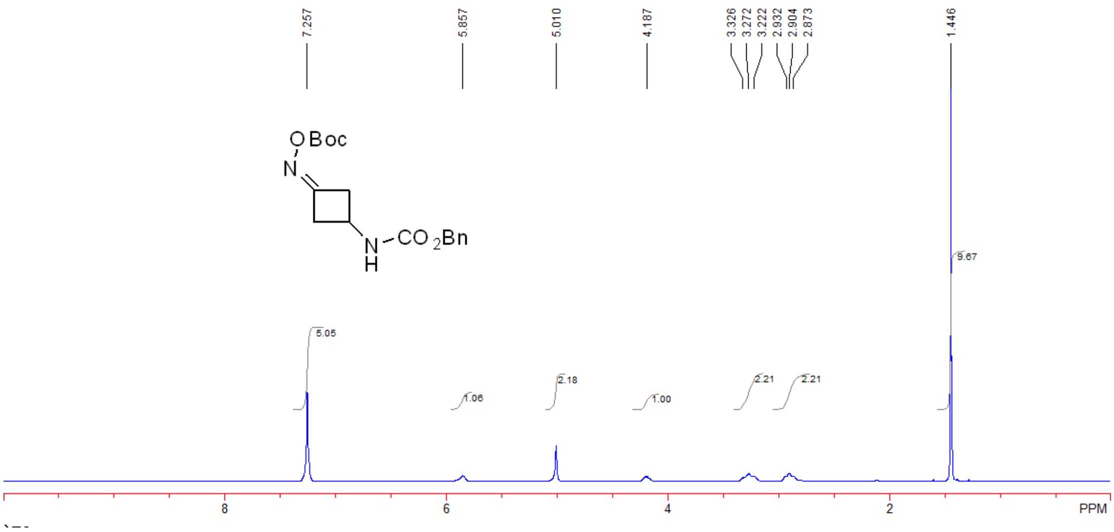


^{13}C NMR (100 MHz, $CDCl_3$):

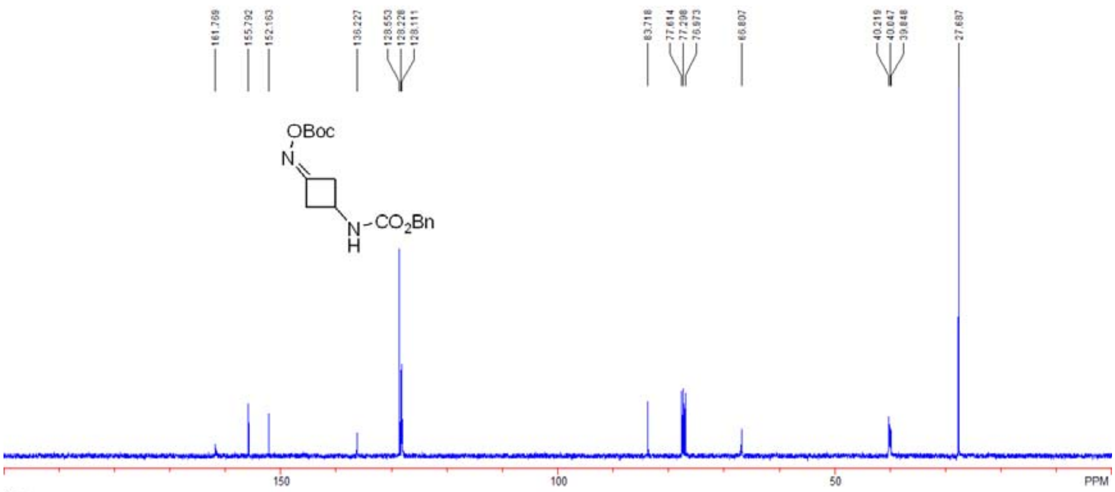


Compound 1h

^{1}H NMR (400 MHz, $CDCl_3$):

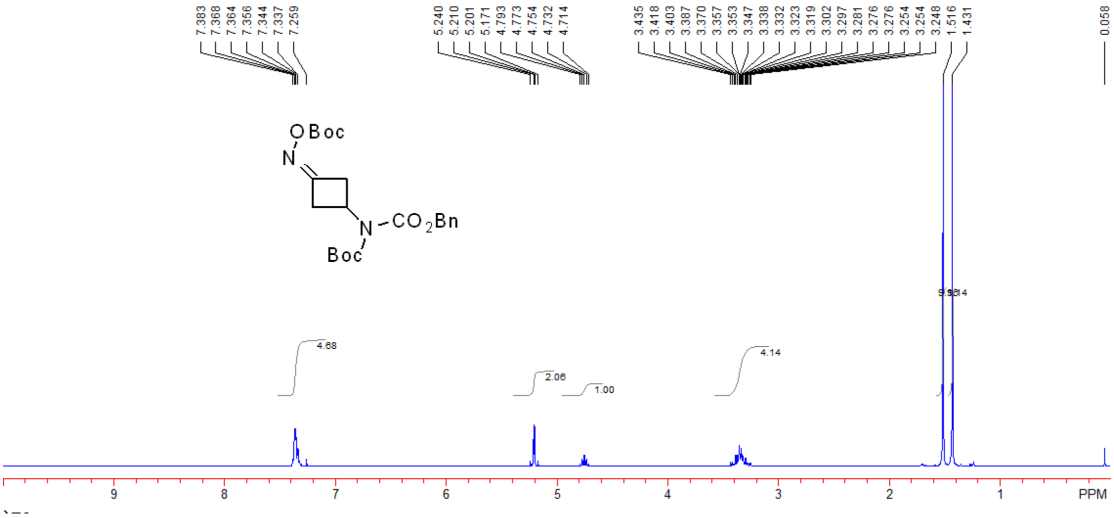


^{13}C NMR (100 MHz, $CDCl_3$):

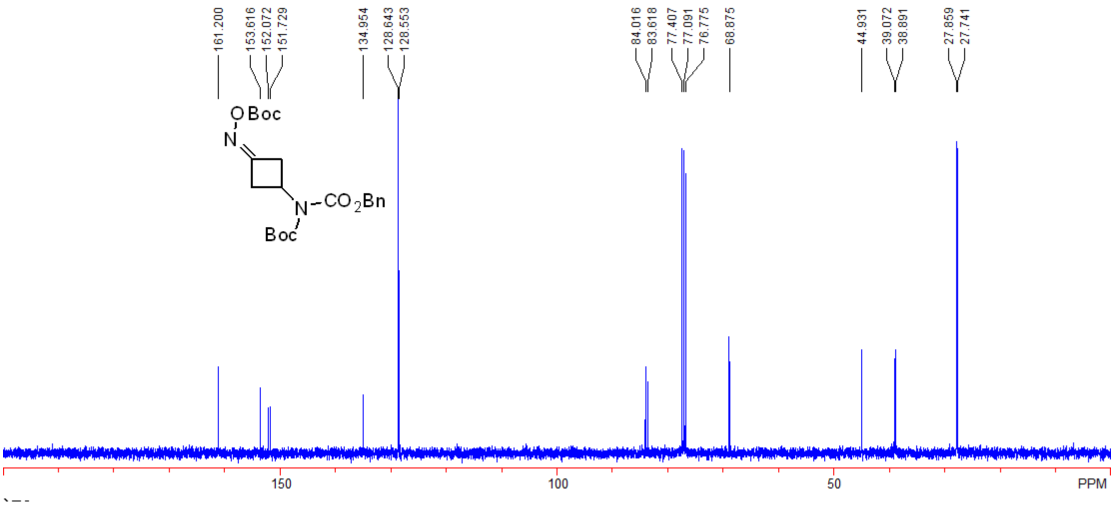


Compound 1i

^{1}H NMR (400 MHz, $CDCl_3$):

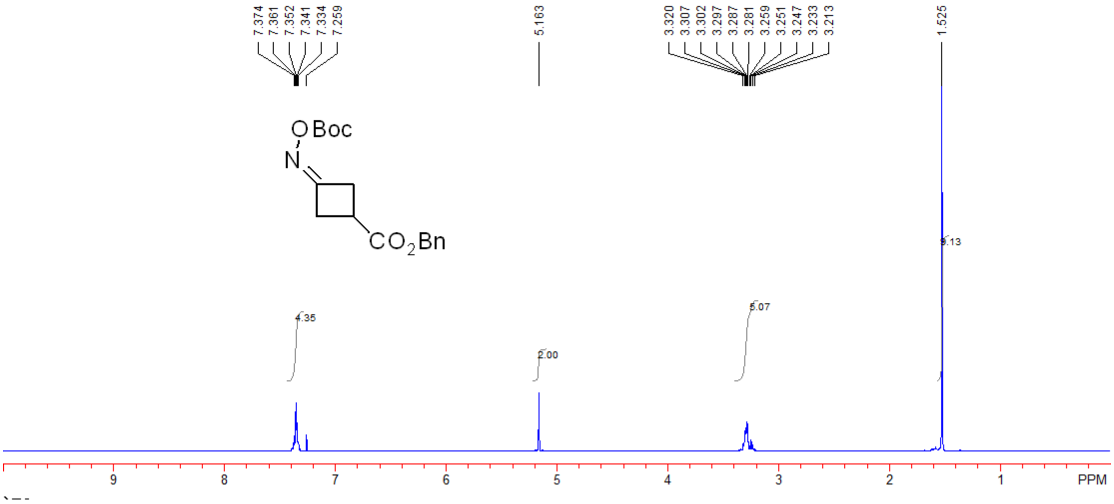


^{13}C NMR (100 MHz, $CDCl_3$):

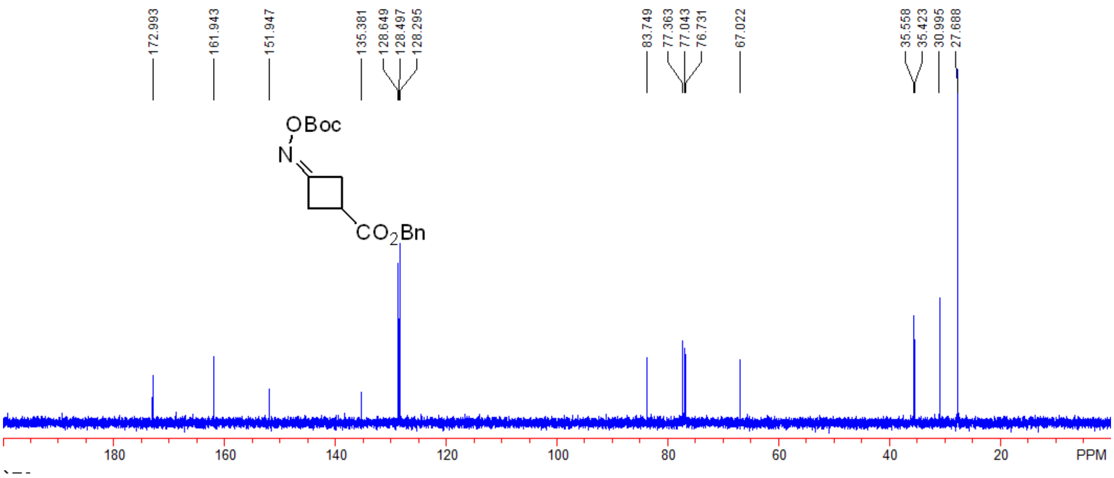


Compound 1j

^{1}H NMR (400 MHz, $CDCl_3$):

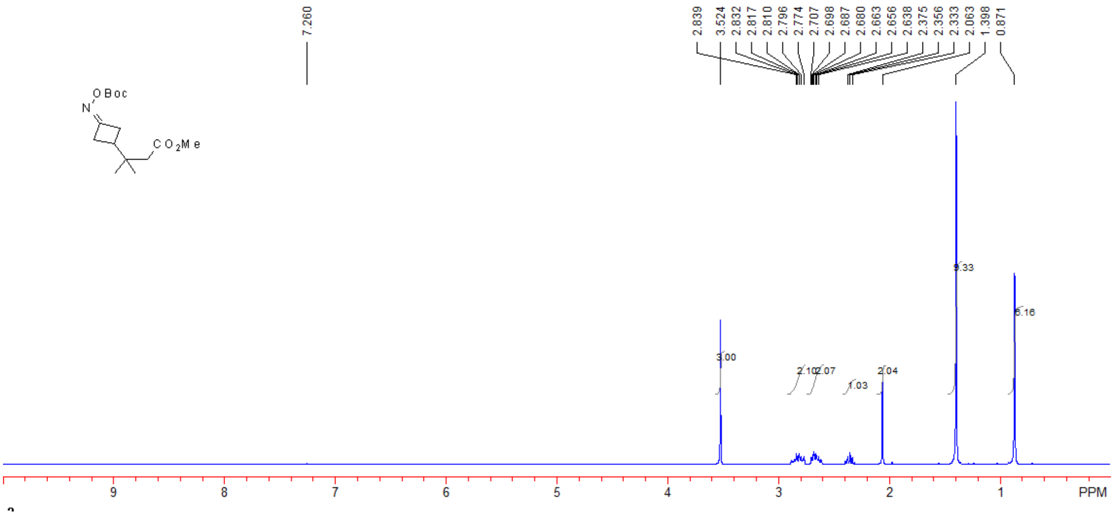


^{13}C NMR (100 MHz, $CDCl_3$):

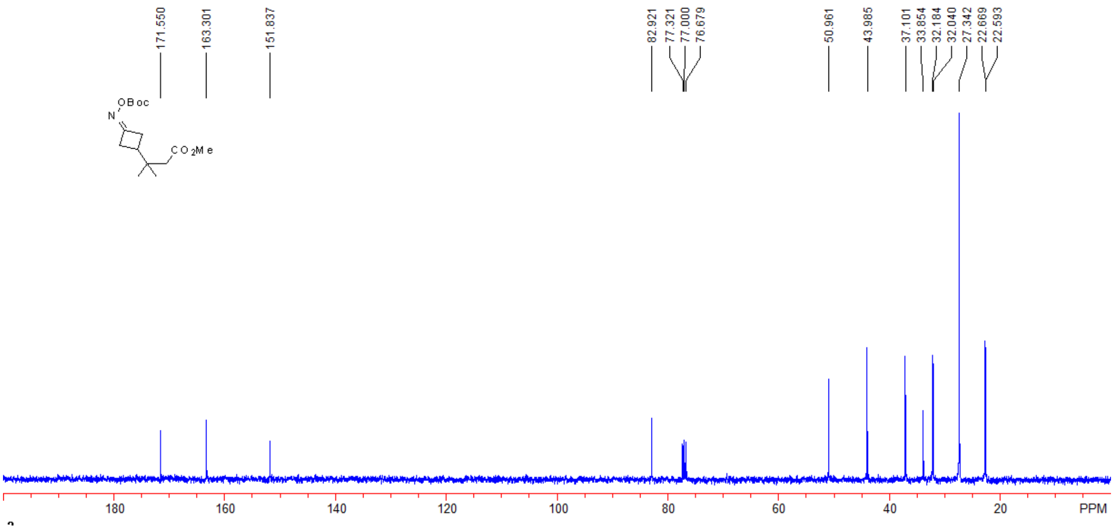


Compound 1k

^{1}H NMR (400 MHz, $CDCl_3$):

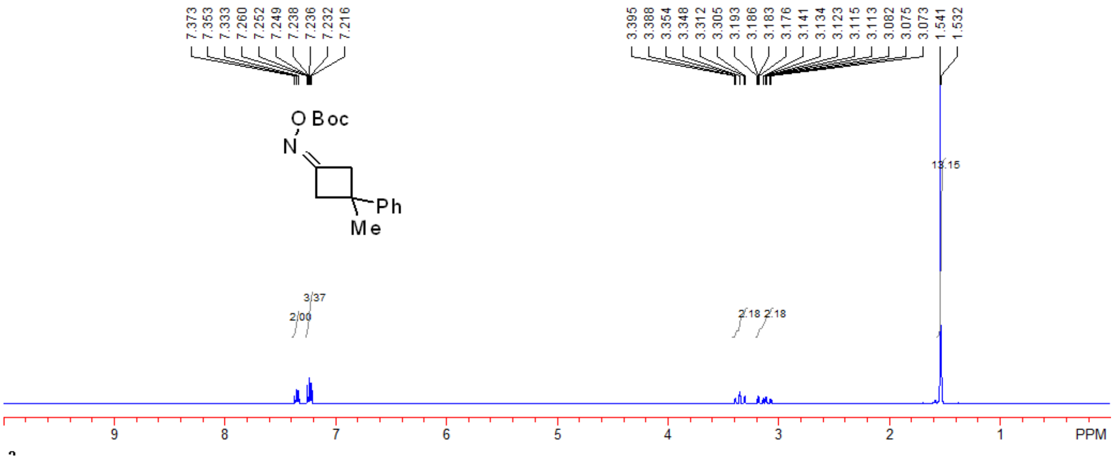


^{13}C NMR (100 MHz, $CDCl_3$):

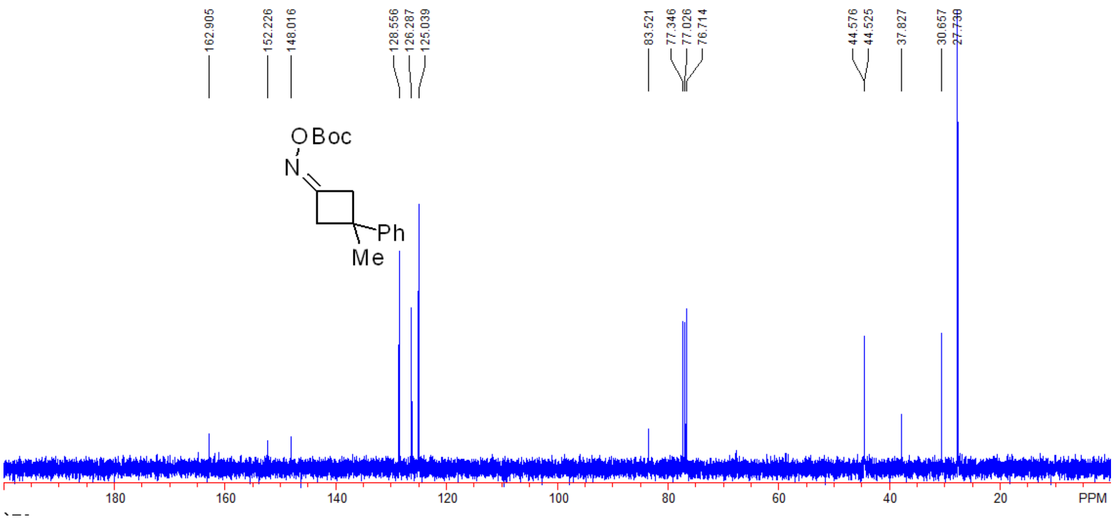


Compound 1l

^{1}H NMR (400 MHz, $CDCl_3$):

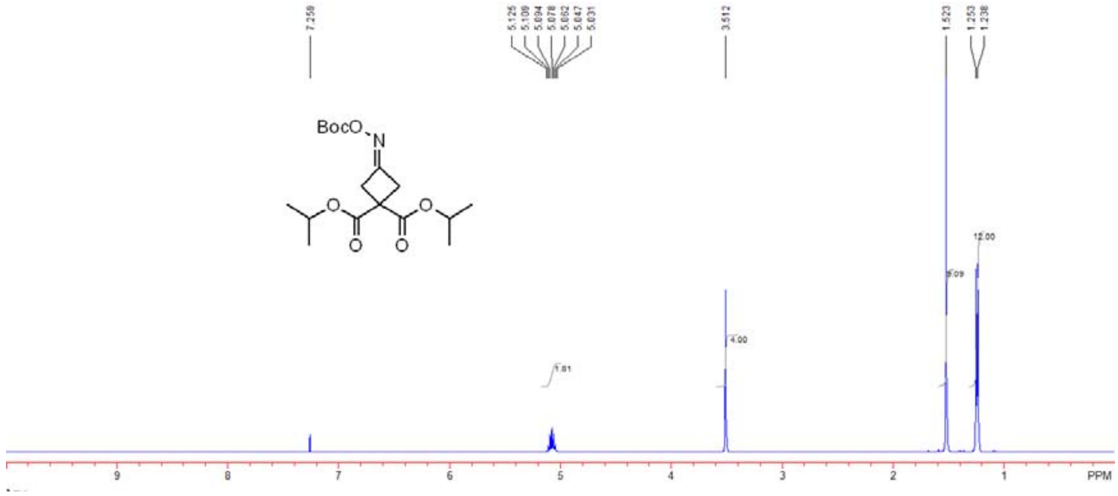


^{13}C NMR (100 MHz, $CDCl_3$):

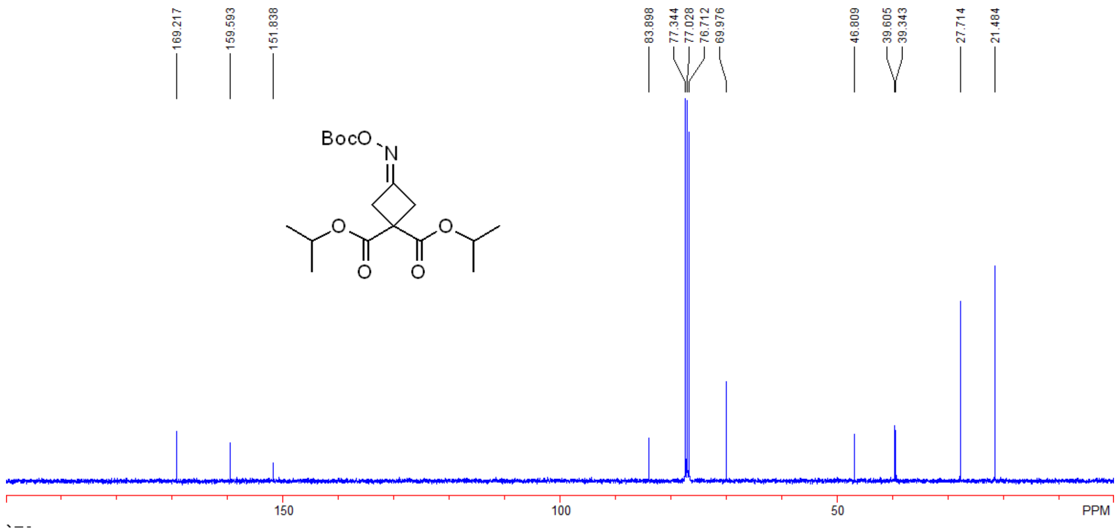


Compound 1m

^{1}H NMR (400 MHz, CDCl$_3$):

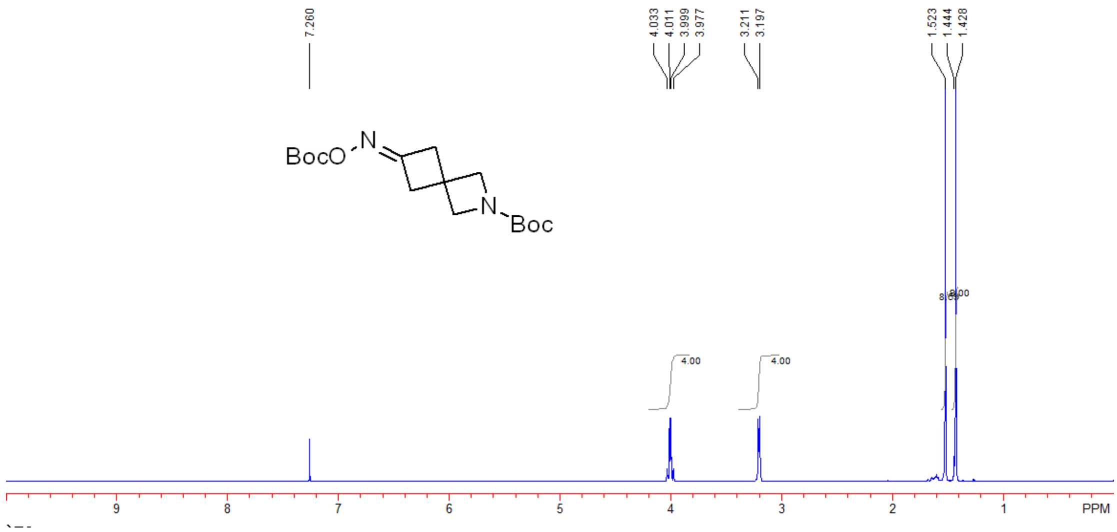


^{13}C NMR (100 MHz, CDCl$_3$):

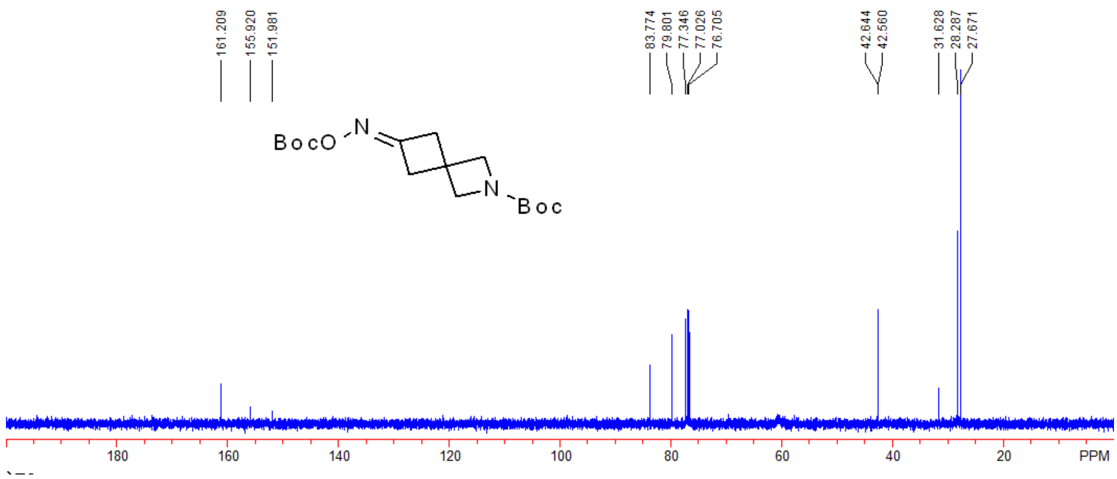


Compound 1n

^{1}H NMR (400 MHz, $CDCl_3$):

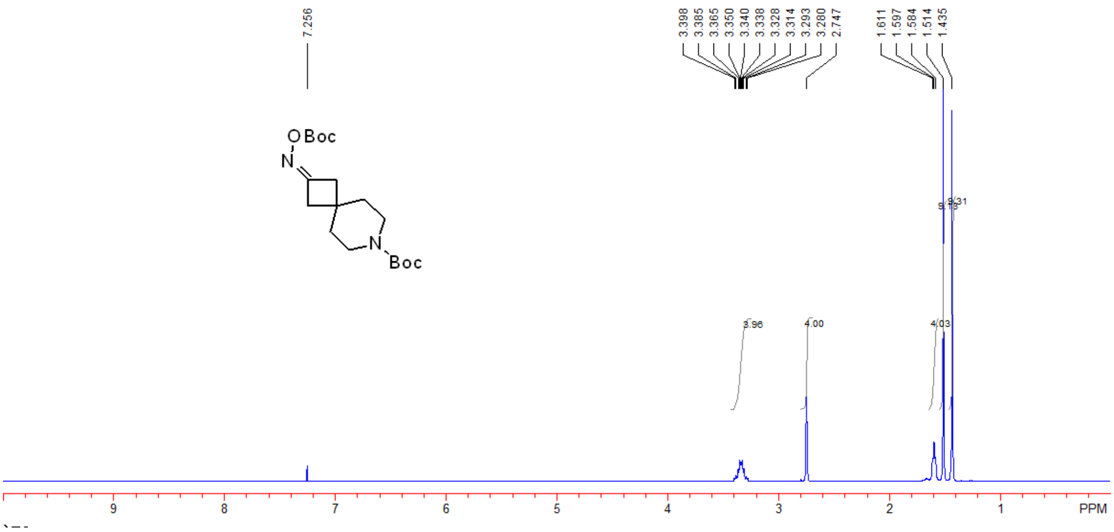


^{13}C NMR (100 MHz, $CDCl_3$):

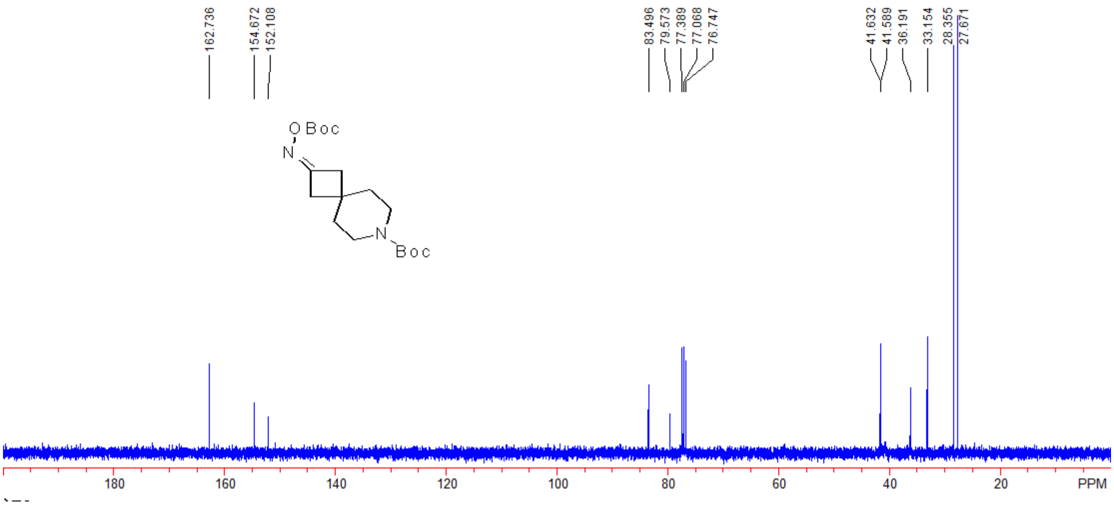


Compound 1o

[1]H NMR (400 MHz, $CDCl_3$):

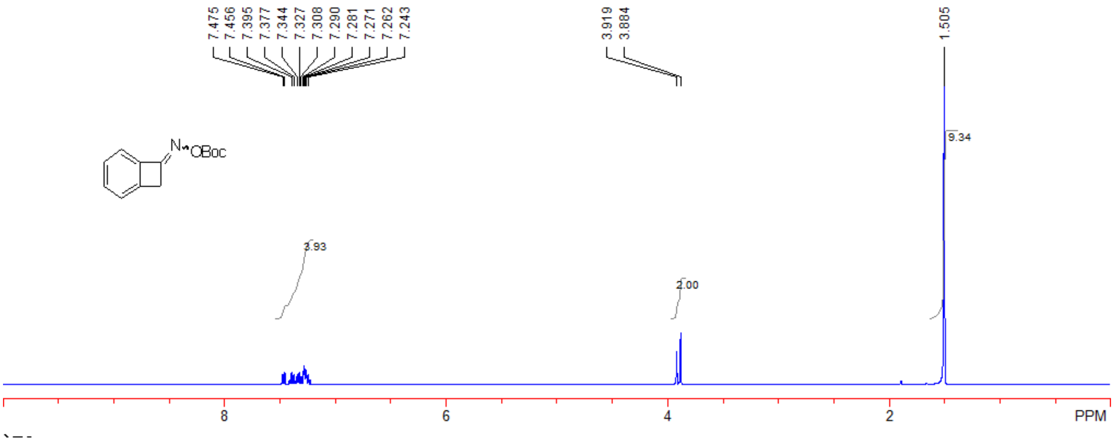


[13]C NMR (100 MHz, $CDCl_3$):

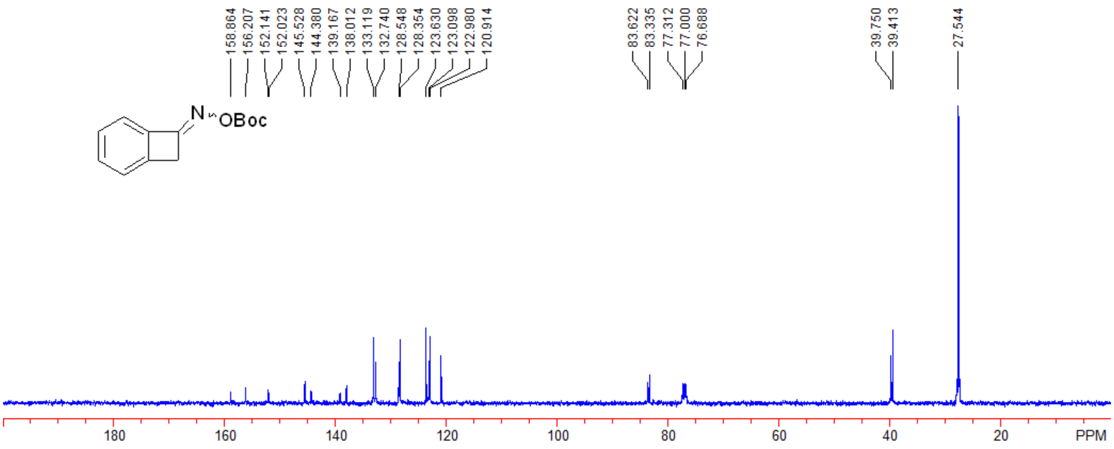


Compound 1p

^{1}H NMR (400 MHz, $CDCl_3$):

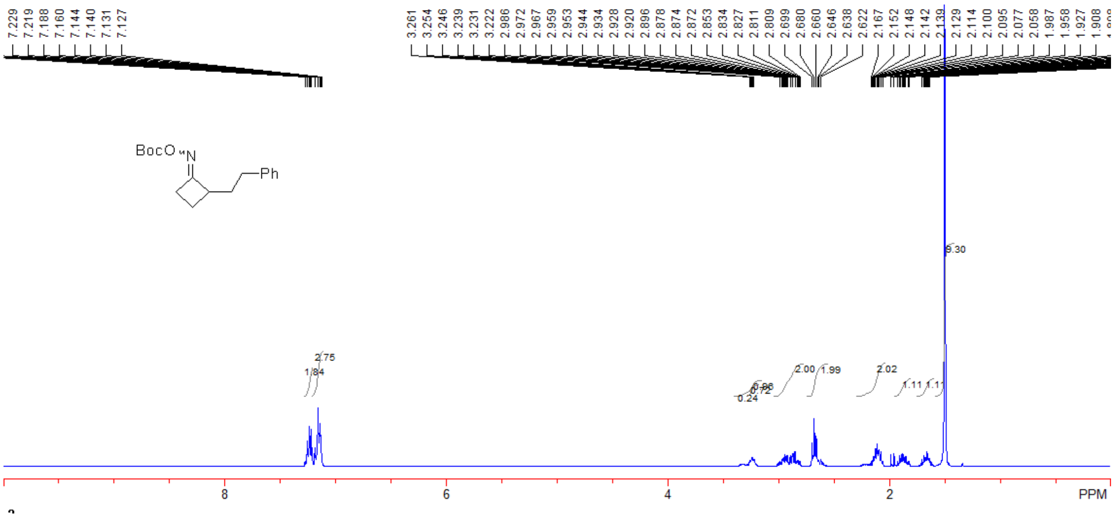


^{13}C NMR (100 MHz, $CDCl_3$):

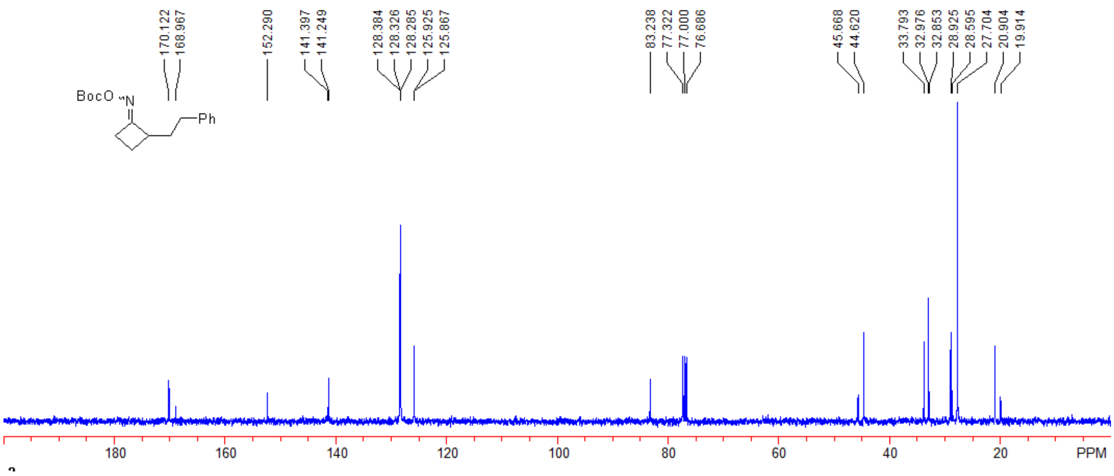


Compound 1q

^{1}H NMR (400 MHz, $CDCl_3$):

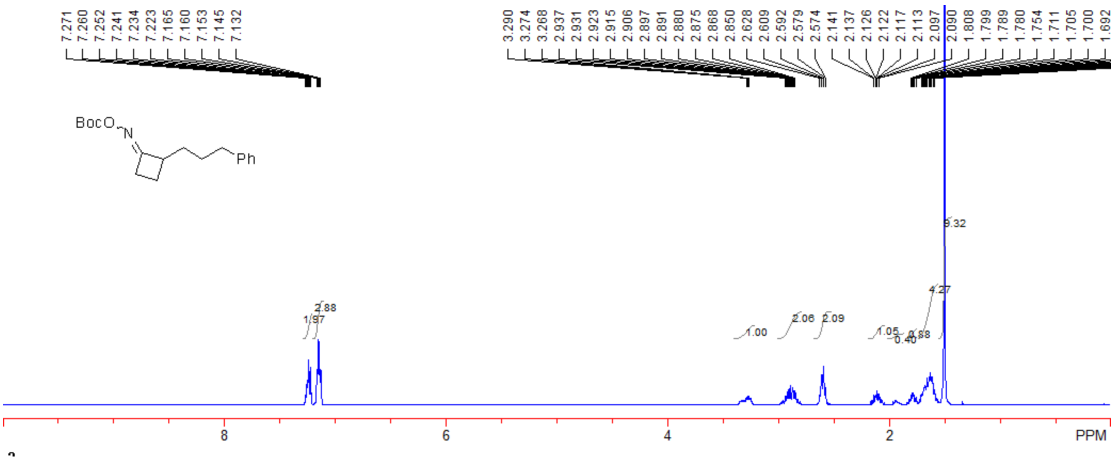


^{13}C NMR (100 MHz, $CDCl_3$):

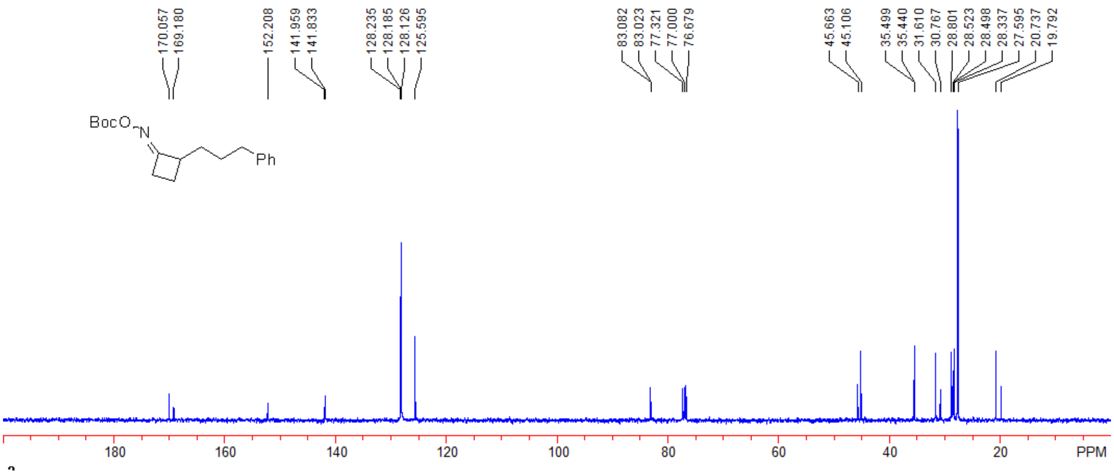


Compound 1r

^{1}H NMR (400 MHz, $CDCl_3$):

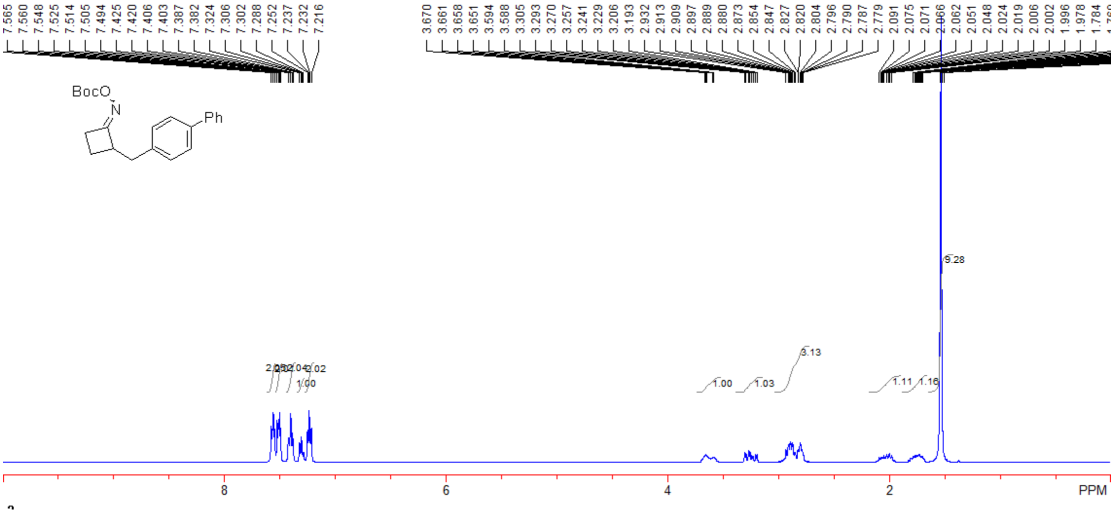


^{13}C NMR (100 MHz, $CDCl_3$):

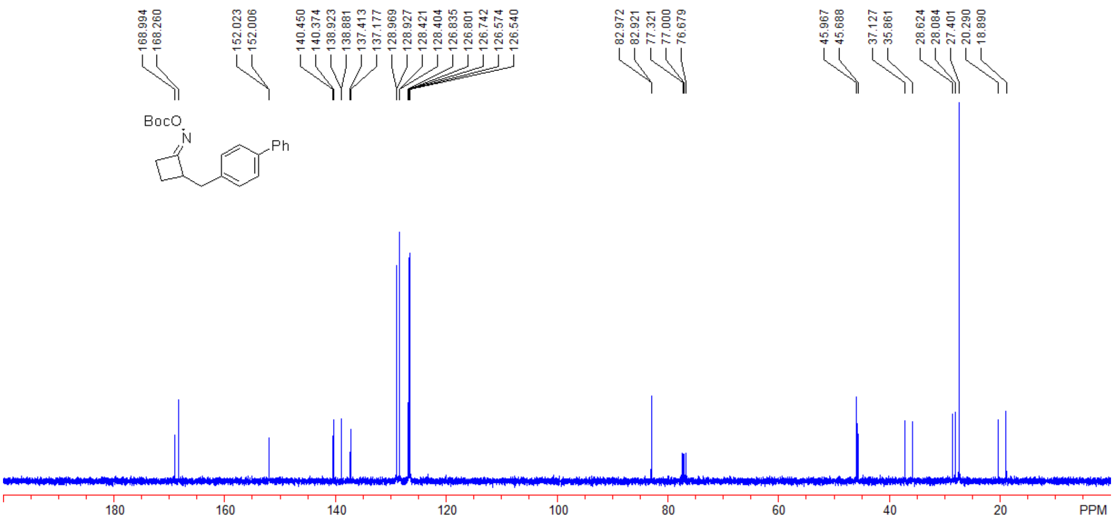


Compound 1s

^{1}H NMR (400 MHz, $CDCl_3$):

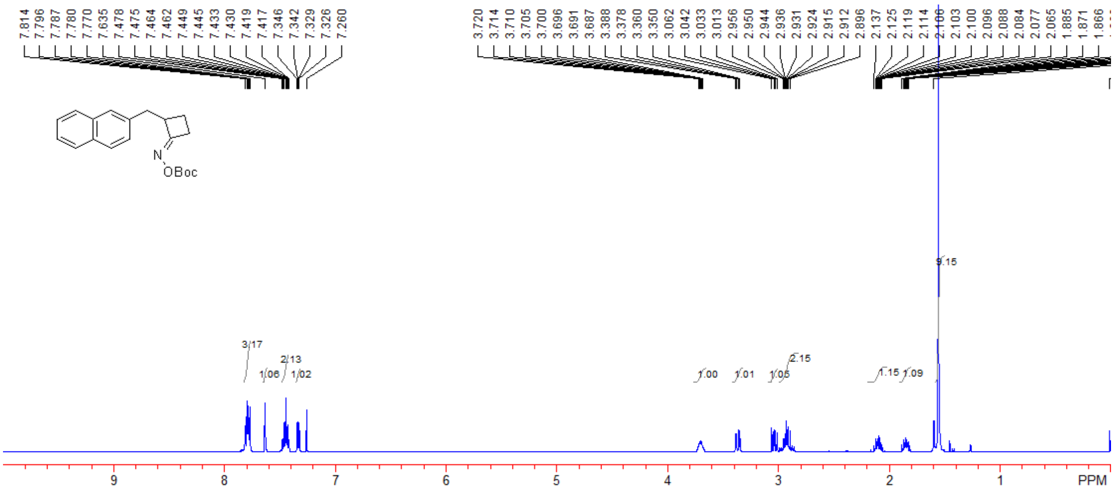


^{13}C NMR (100 MHz, $CDCl_3$):

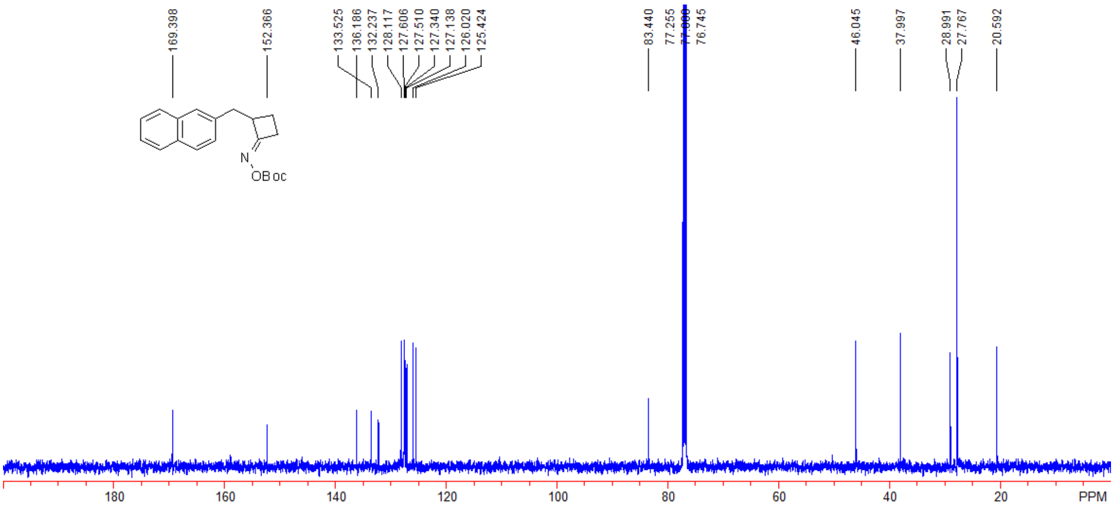


Compound 1t

[1]H NMR (500 MHz, $CDCl_3$):

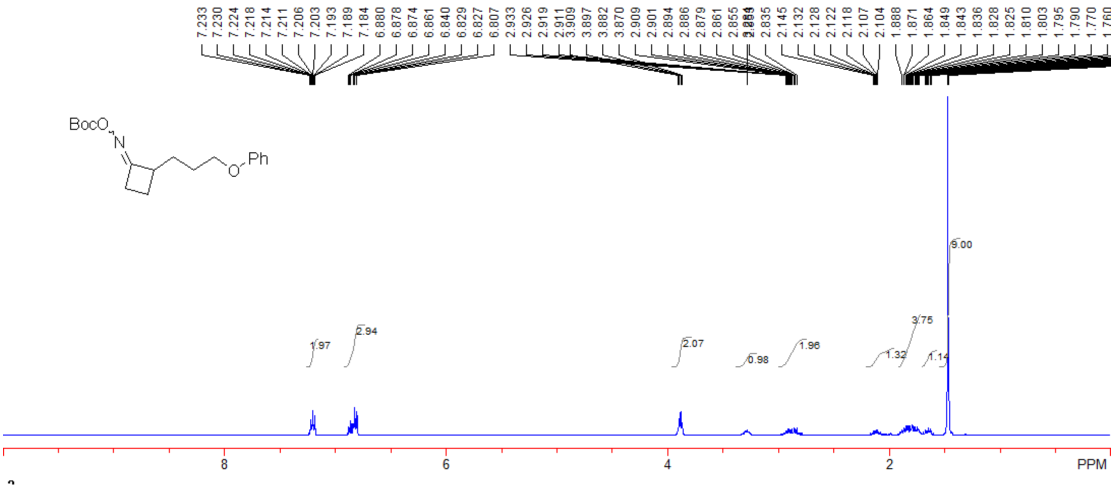


[13]C NMR (125 MHz, $CDCl_3$):

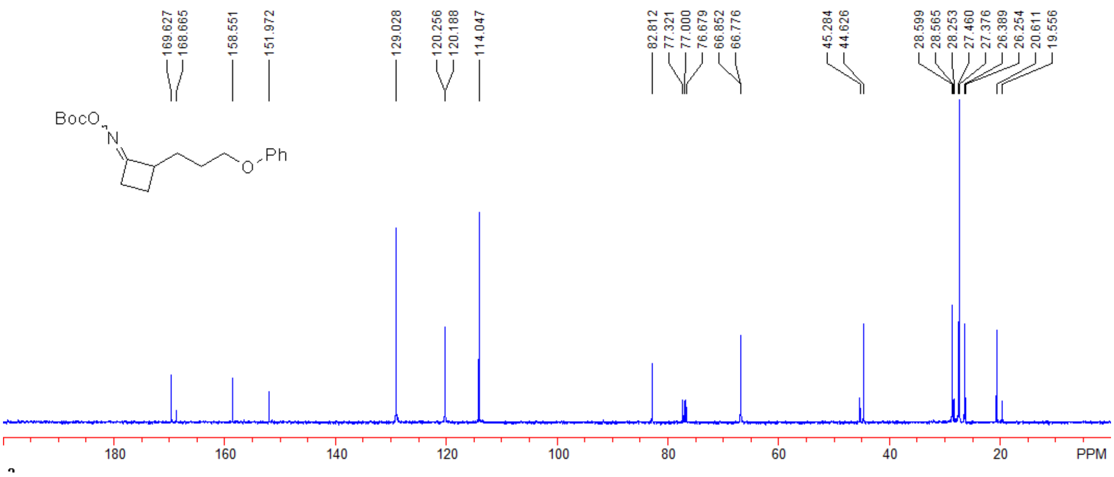


Compound 1u

^{1}H NMR (400 MHz, $CDCl_3$):

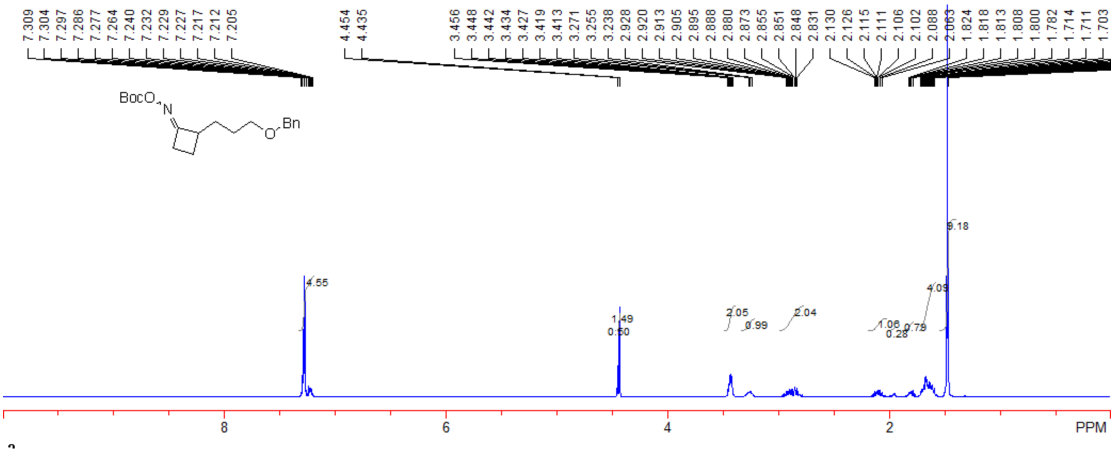


^{13}C NMR (100 MHz, $CDCl_3$):

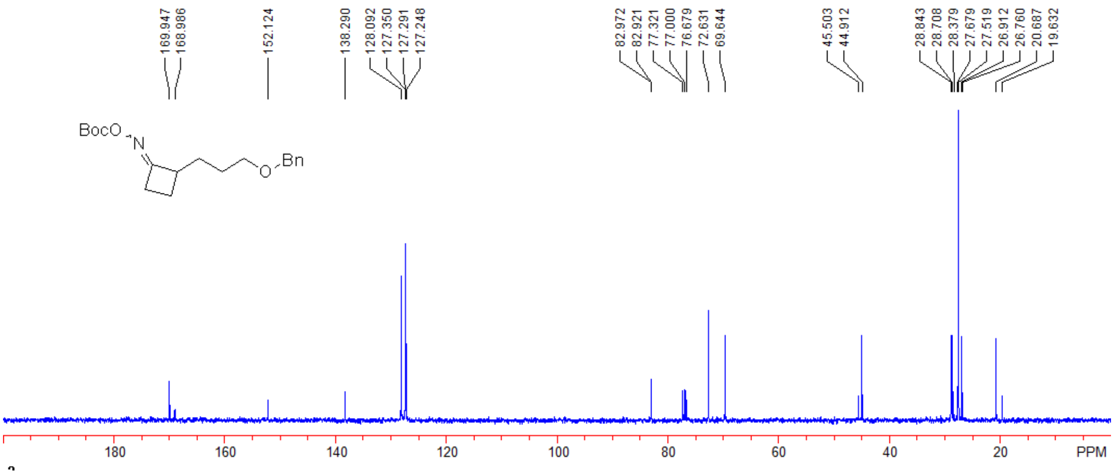


Compound 1v

^{1}H NMR (400 MHz, $CDCl_3$):

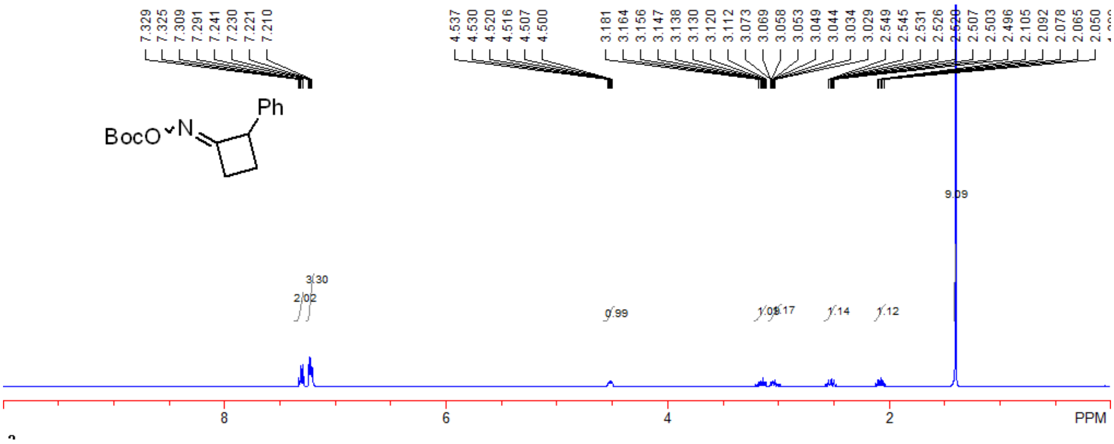


^{13}C NMR (100 MHz, $CDCl_3$):

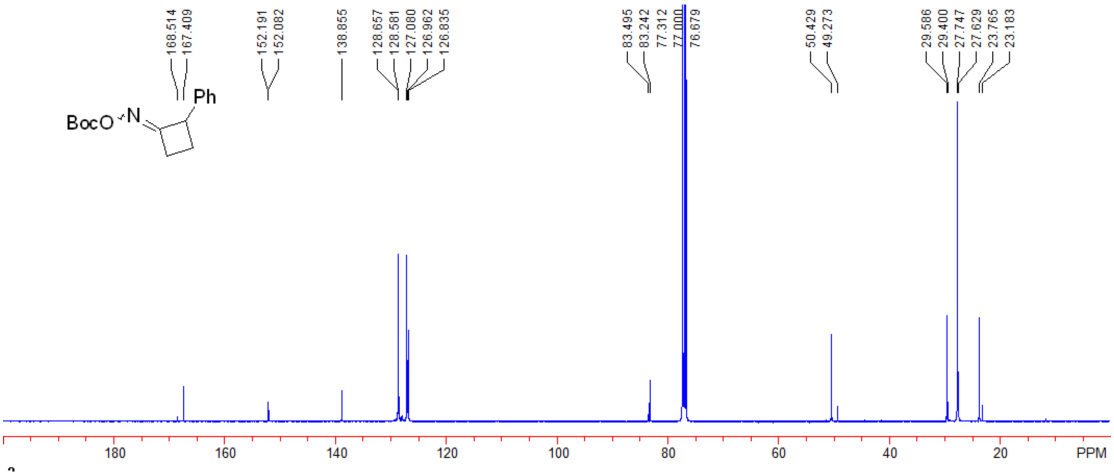


Compound 1w

[1]H NMR (400 MHz, $CDCl_3$):

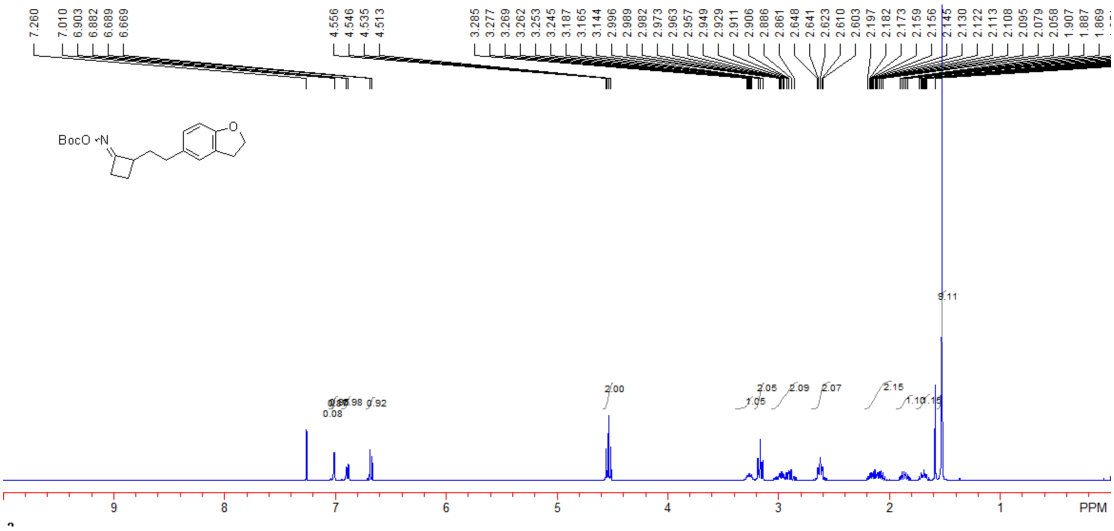


[13]C NMR (100 MHz, $CDCl_3$):

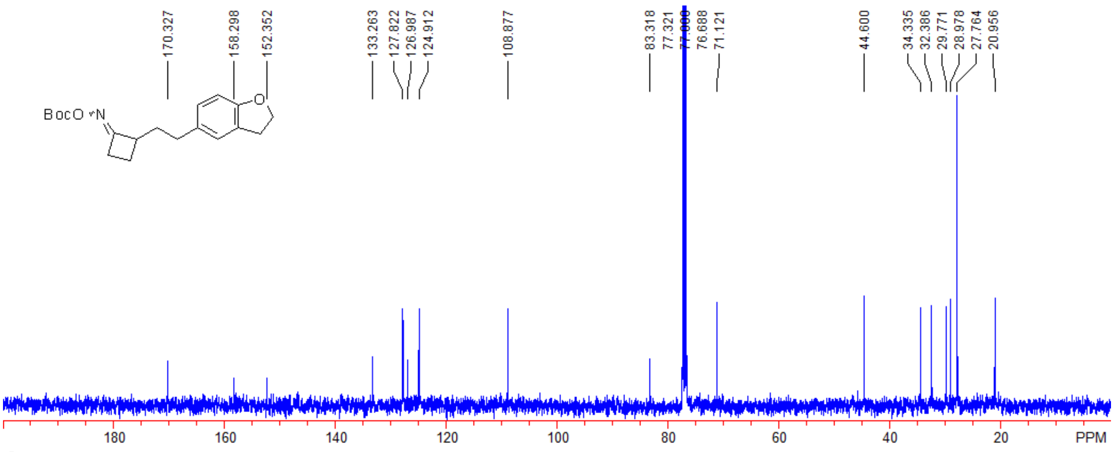


Compound 1x

^{1}H NMR (400 MHz, $CDCl_3$):

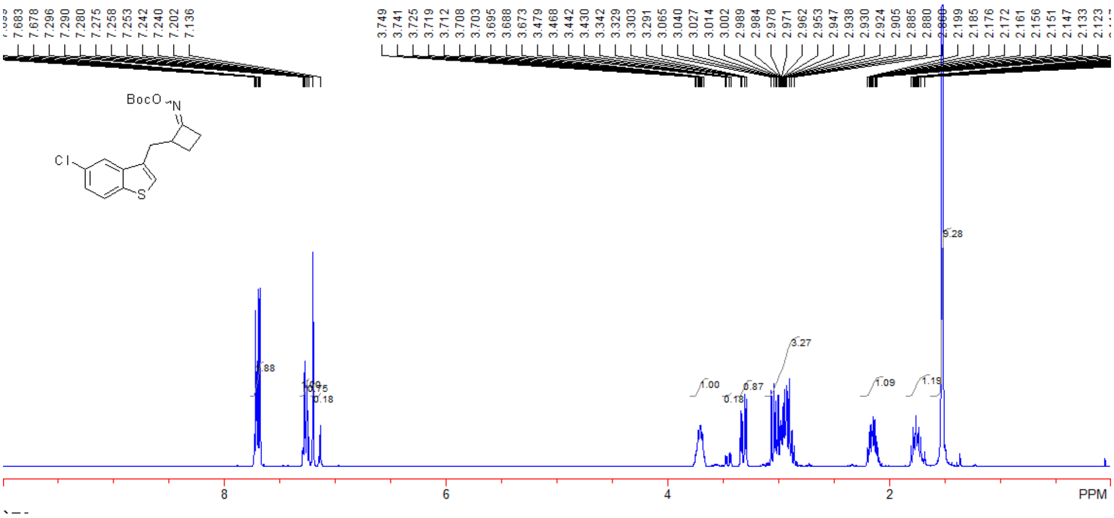


^{13}C NMR (100 MHz, $CDCl_3$):

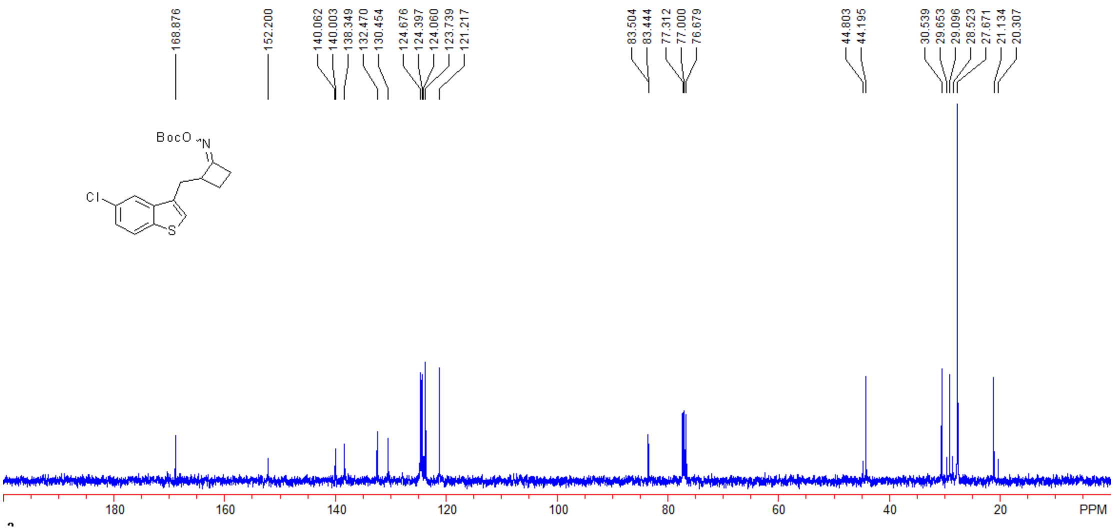


Compound 1y

^{1}H NMR (400 MHz, $CDCl_3$):

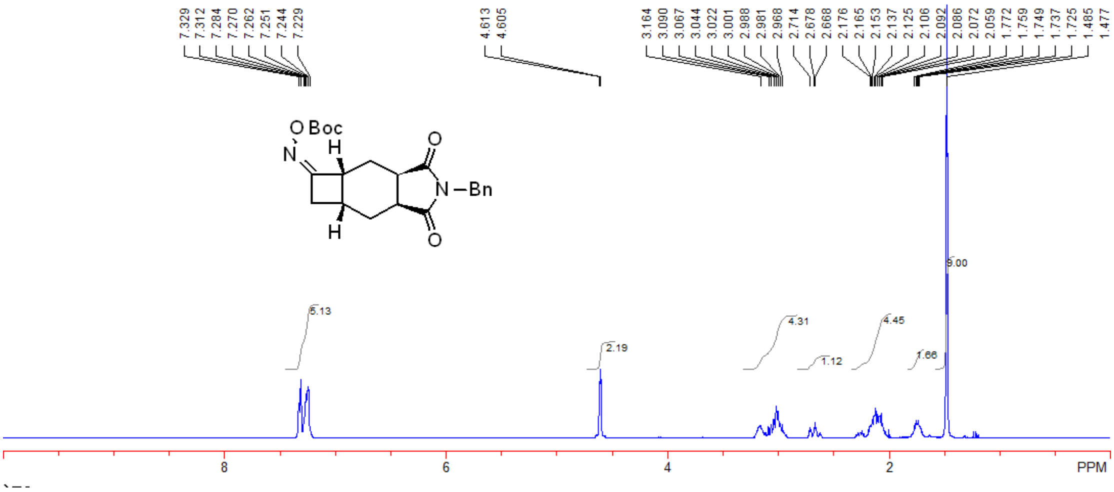


^{13}C NMR (100 MHz, $CDCl_3$):

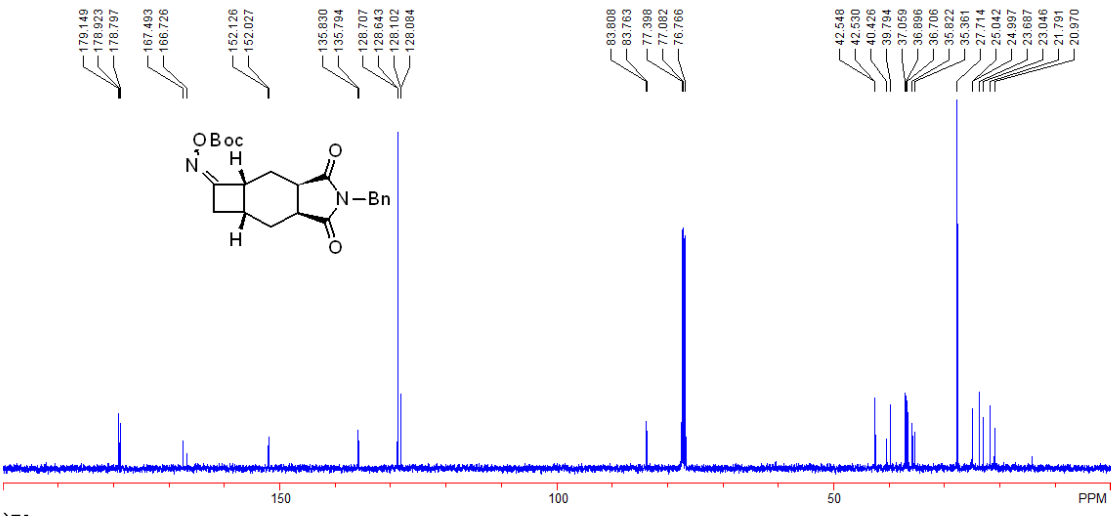


Compound 1z

^{1}H NMR (400 MHz, $CDCl_3$):

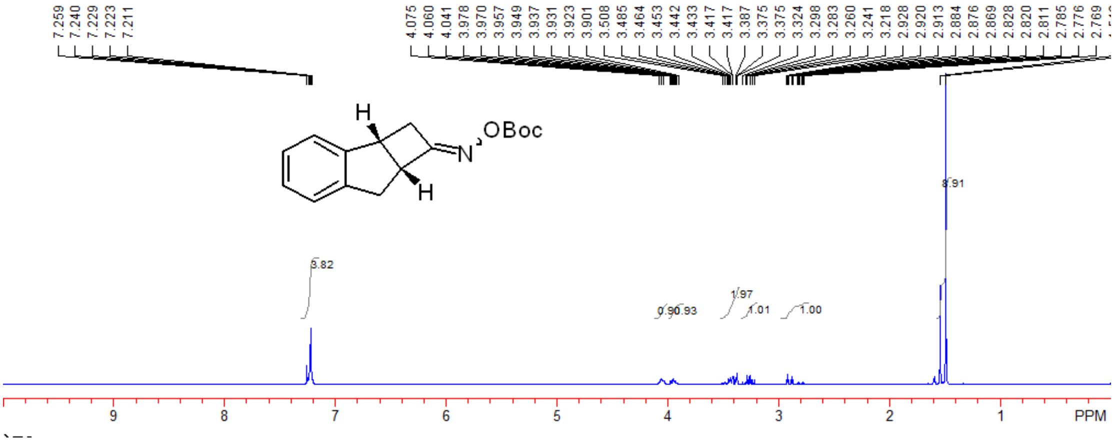


^{13}C NMR (100 MHz, $CDCl_3$):

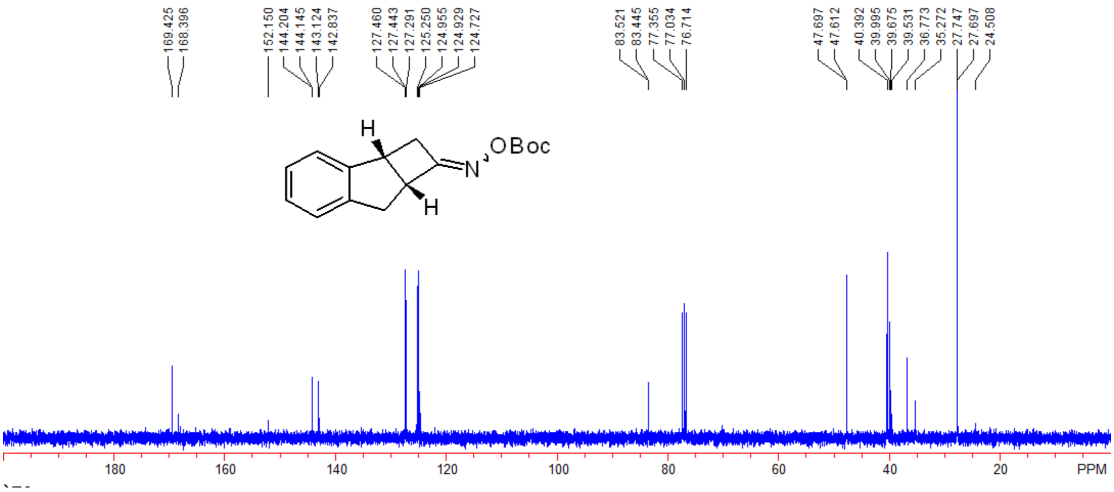


Compound 1za

^{1}H NMR (400 MHz, $CDCl_3$):

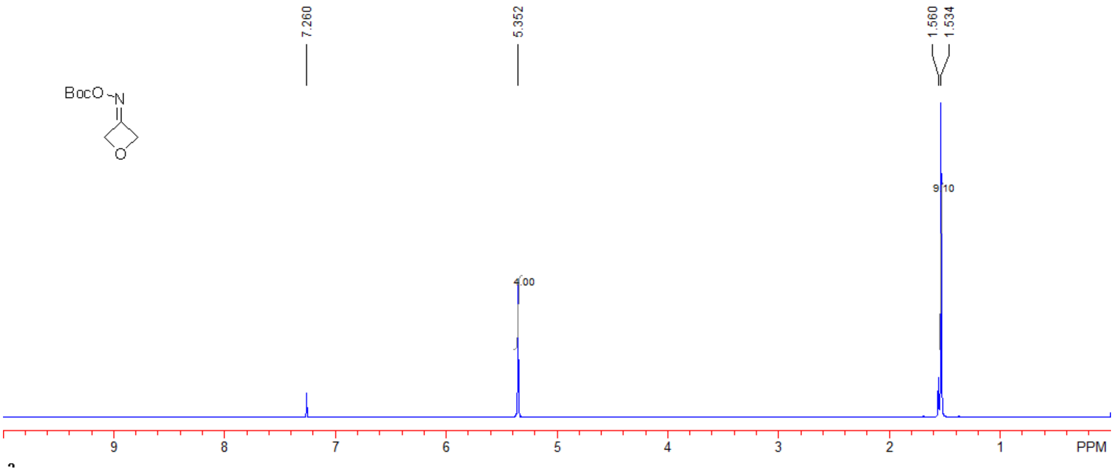


^{13}C NMR (100 MHz, $CDCl_3$):

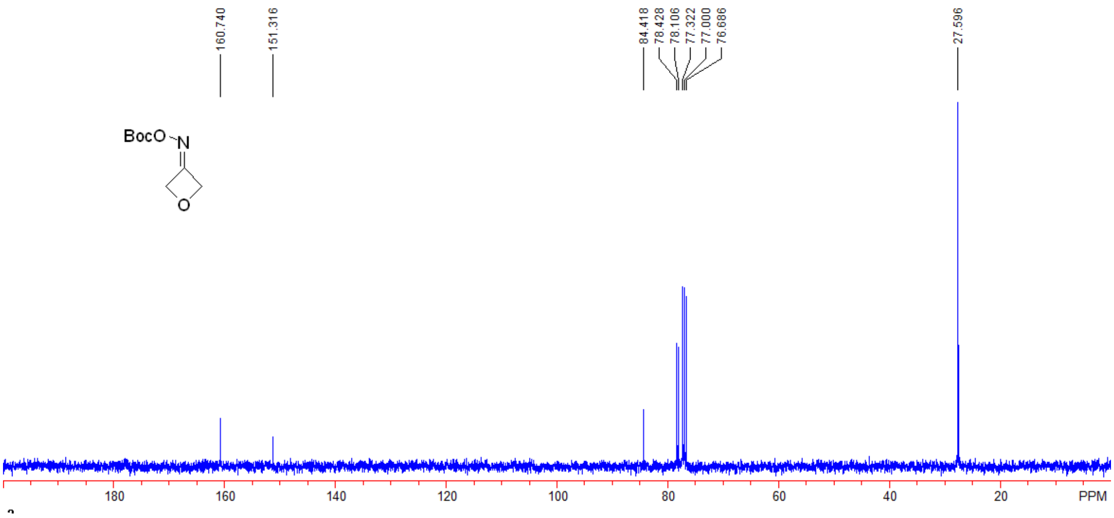


Compound 1zb

^{1}H NMR (400 MHz, $CDCl_3$):

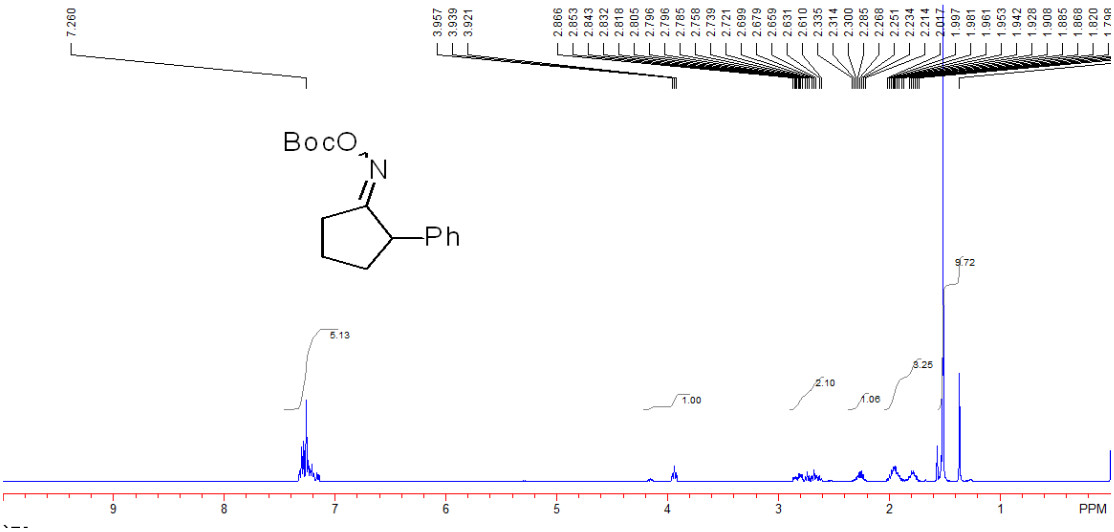


^{13}C NMR (100 MHz, $CDCl_3$):

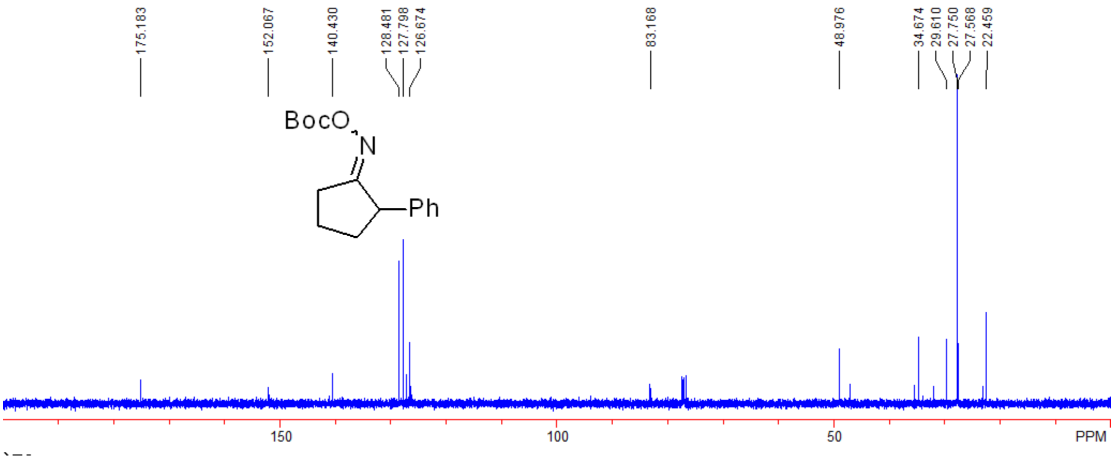


Compound 1-3a

^{1}H NMR (400 MHz, $CDCl_3$):

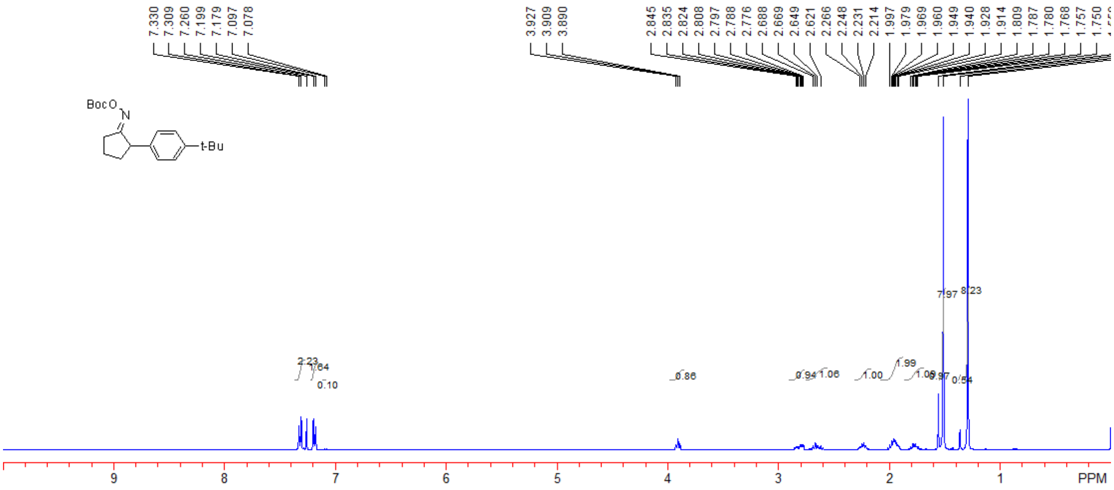


^{13}C NMR (100 MHz, $CDCl_3$):

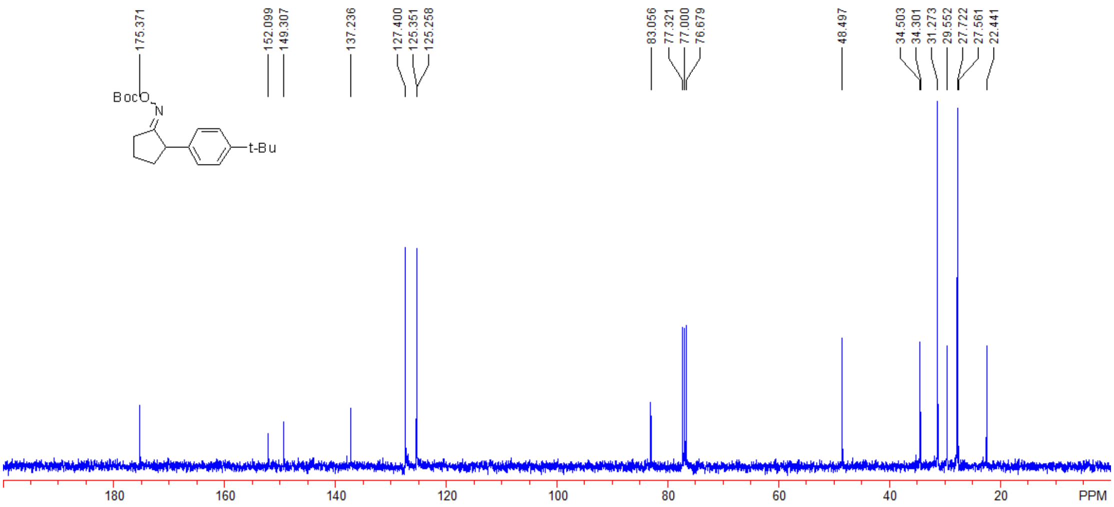


Compound 1-3b

^{1}H NMR (400 MHz, $CDCl_3$):

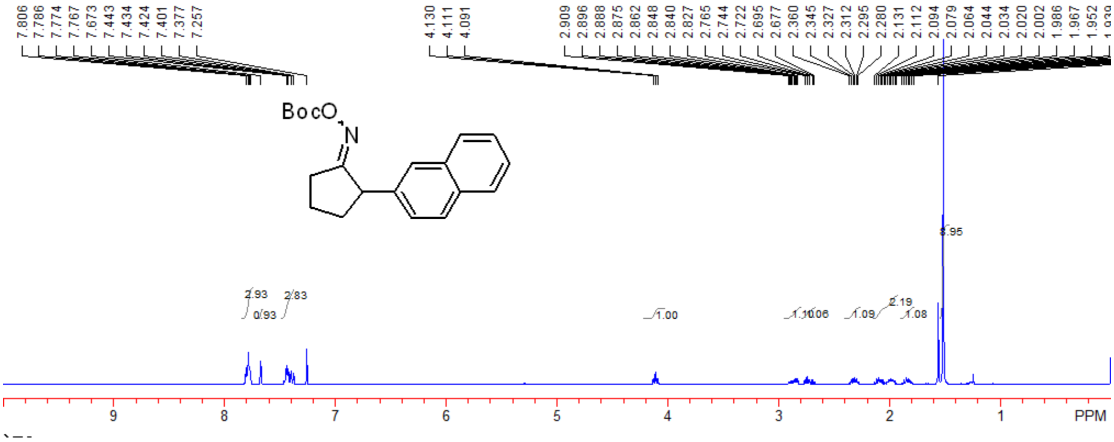


^{13}C NMR (100 MHz, $CDCl_3$):

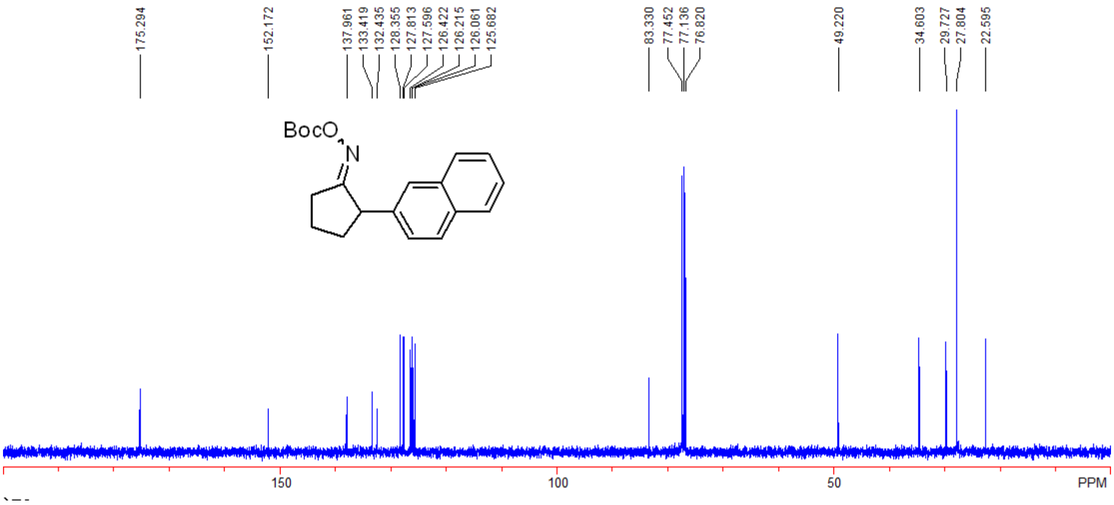


Compound 1-3c

^{1}H NMR (400 MHz, $CDCl_3$):

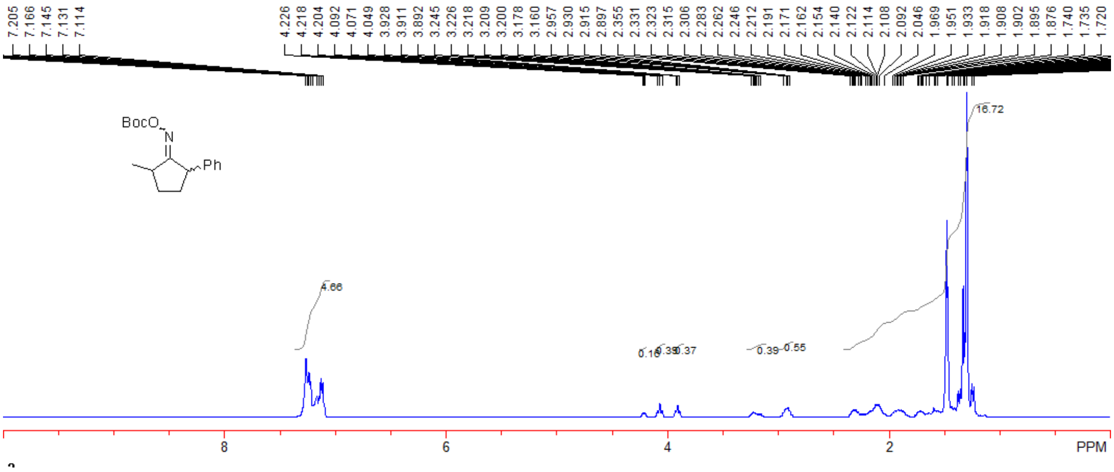


^{13}C NMR (100 MHz, $CDCl_3$):

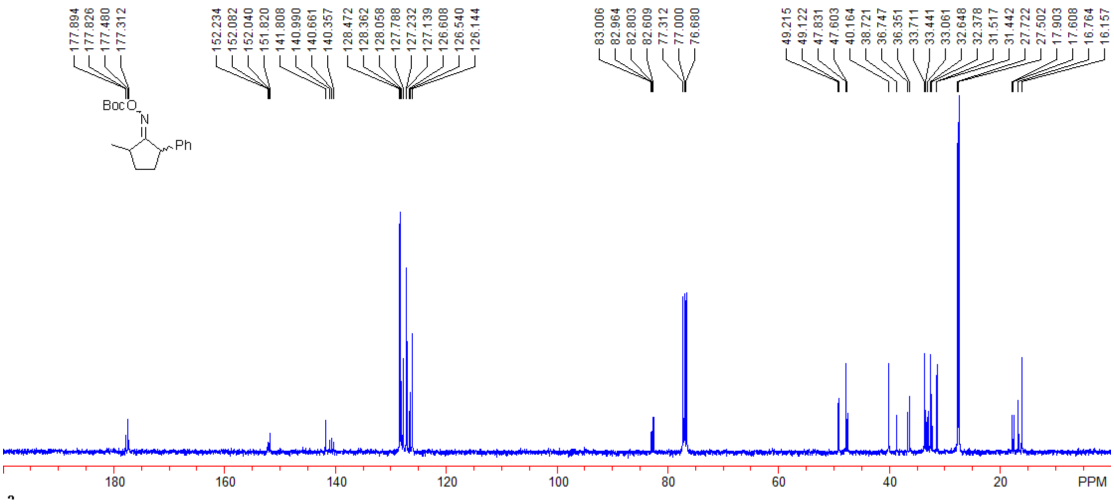


Compound 1-3d

^{1}H NMR (400 MHz, $CDCl_3$):

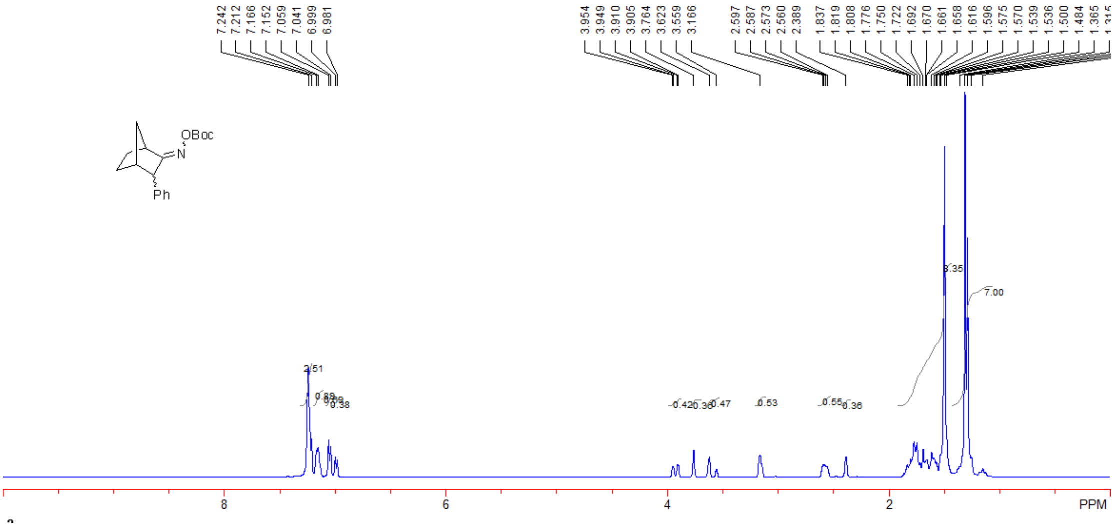


^{13}C NMR (100 MHz, $CDCl_3$):

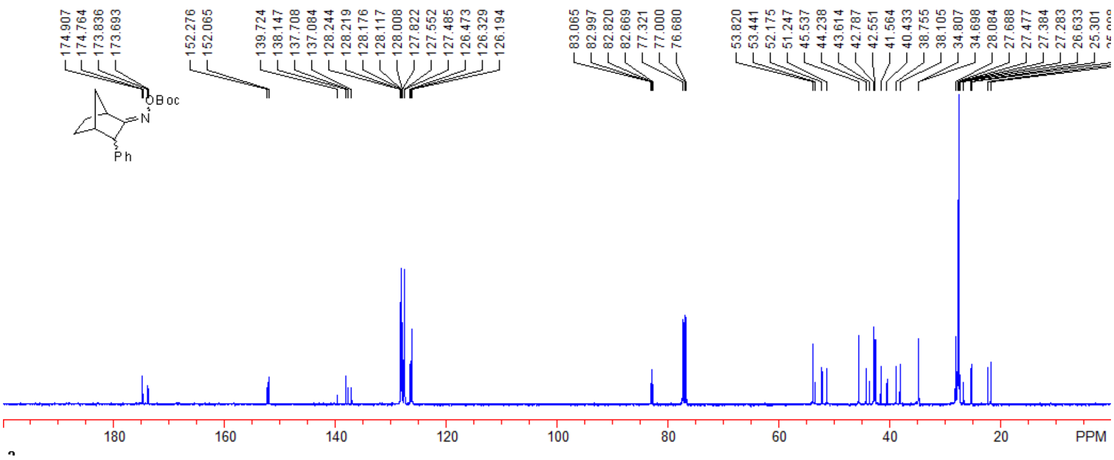


Compound 4a

^{1}H NMR (400 MHz, $CDCl_3$):

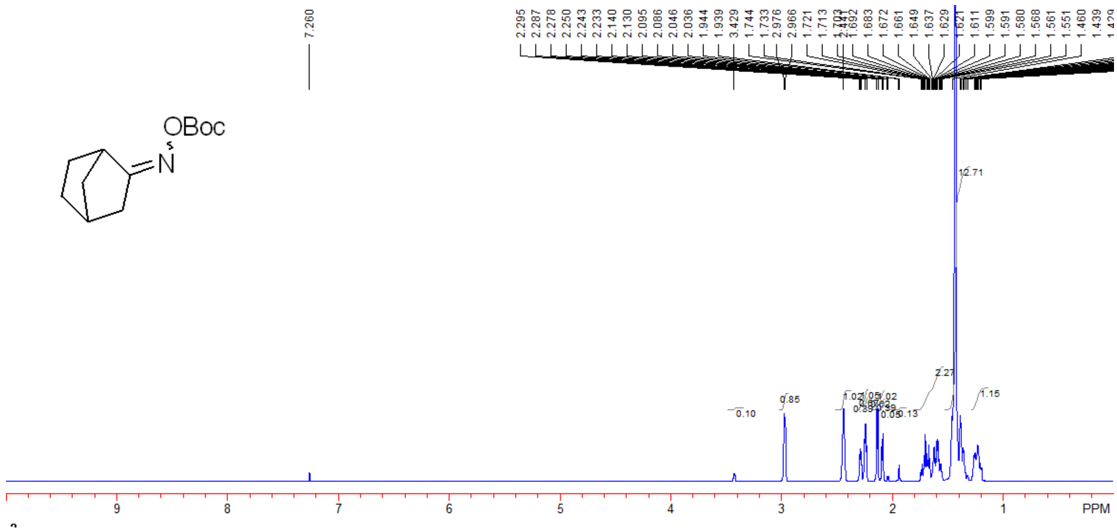


^{13}C NMR (100 MHz, $CDCl_3$):

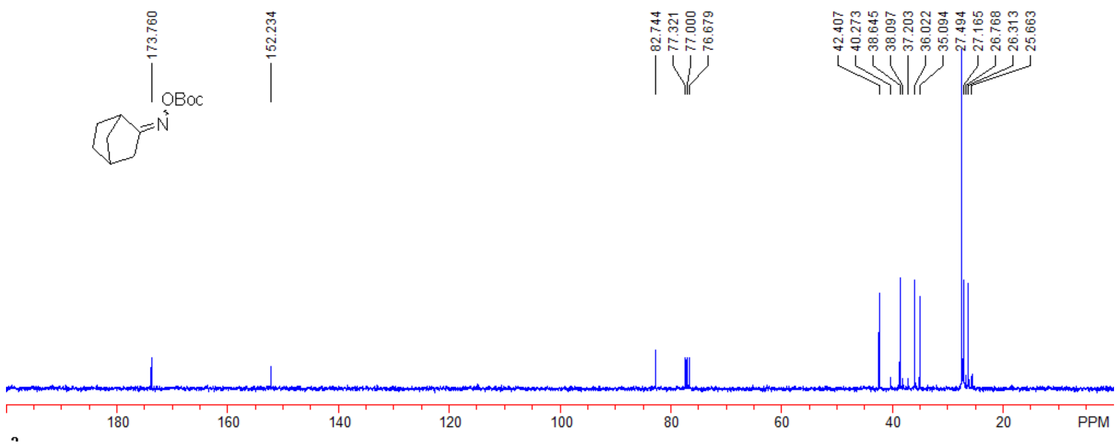


Compound 4b

^{1}H NMR (400 MHz, $CDCl_3$):

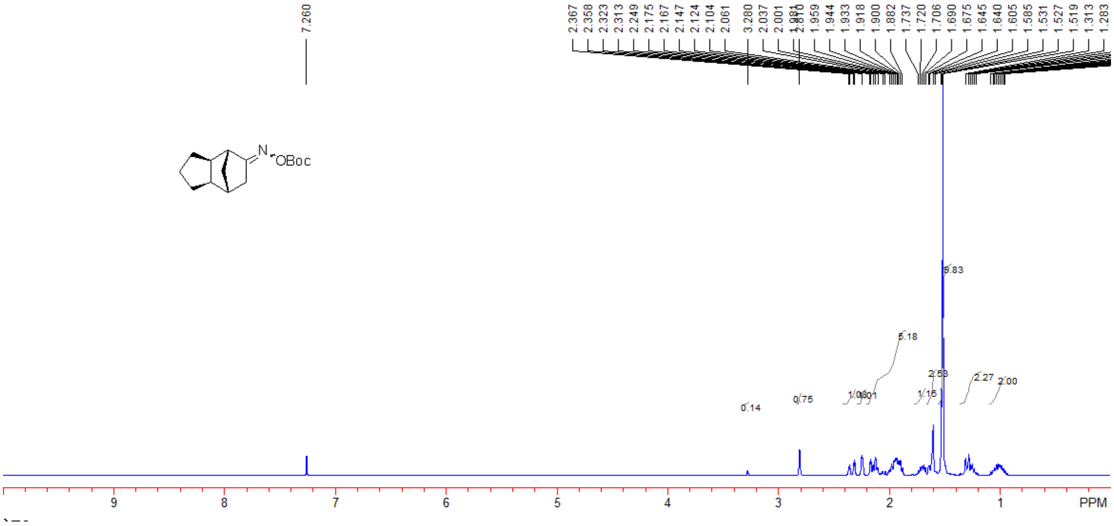


^{13}C NMR (100 MHz, $CDCl_3$):

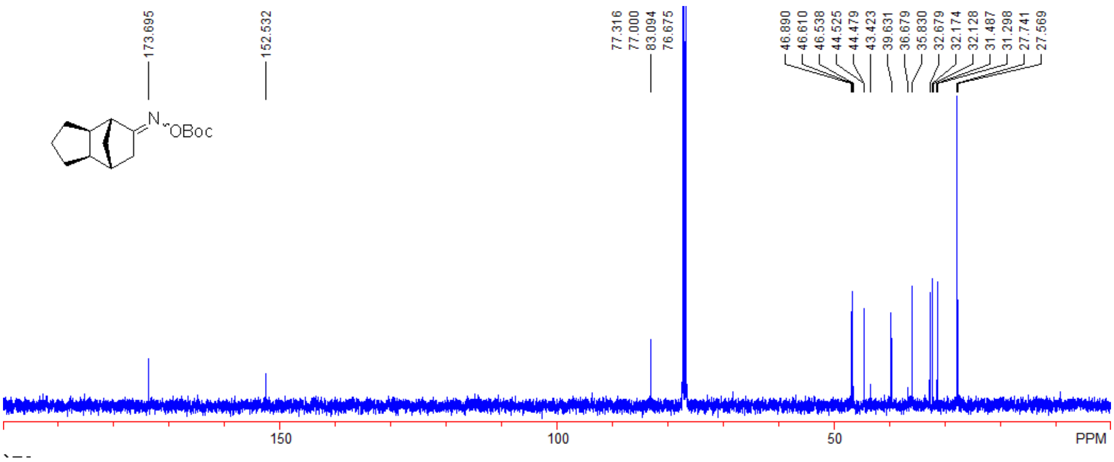


Compound 4c

^{1}H NMR (400 MHz, $CDCl_3$):

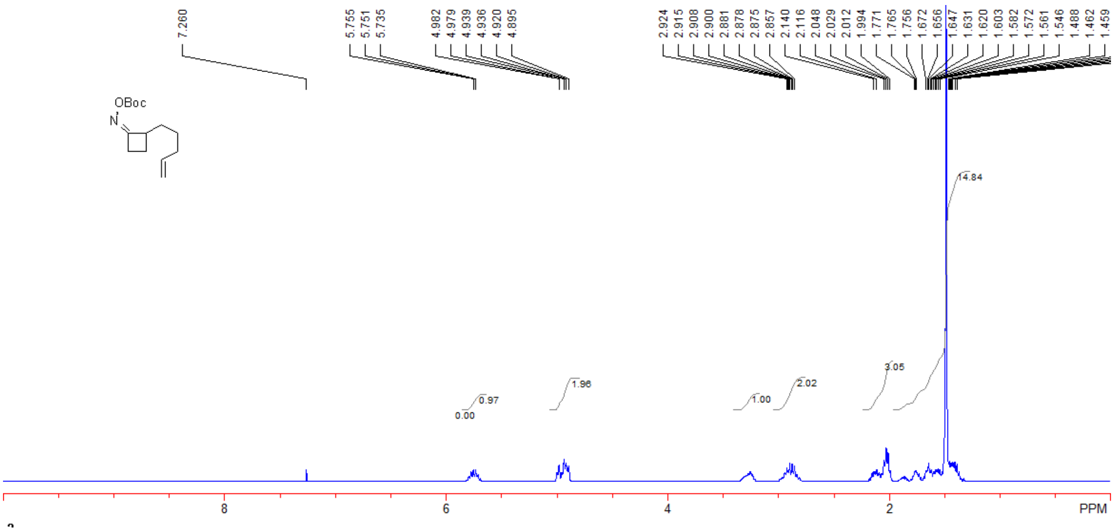


^{13}C NMR (100 MHz, $CDCl_3$):

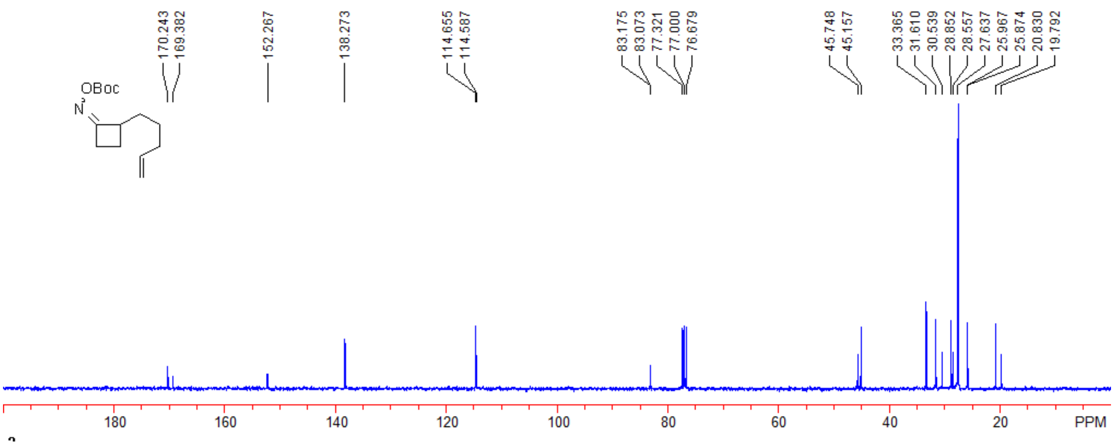


Compound 6

^{1}H NMR (400 MHz, $CDCl_3$):

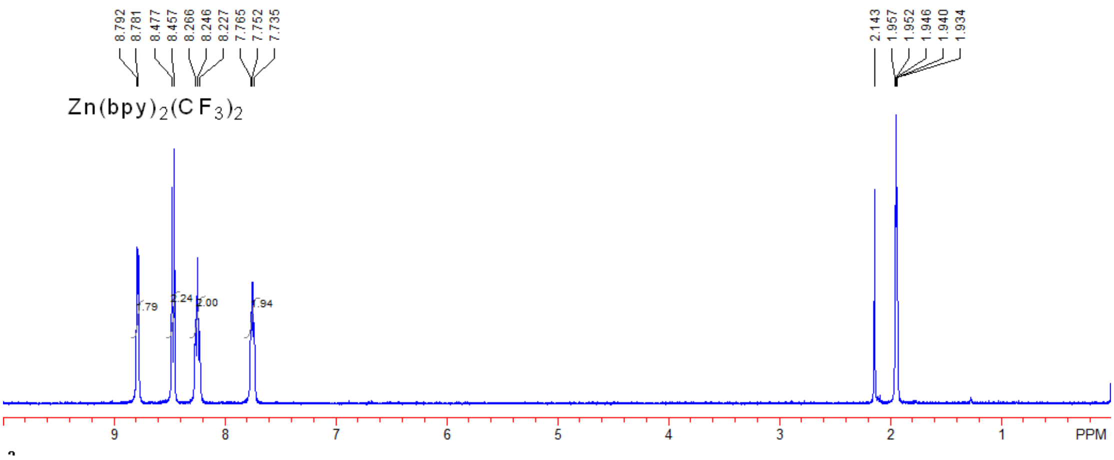


^{13}C NMR (100 MHz, $CDCl_3$):

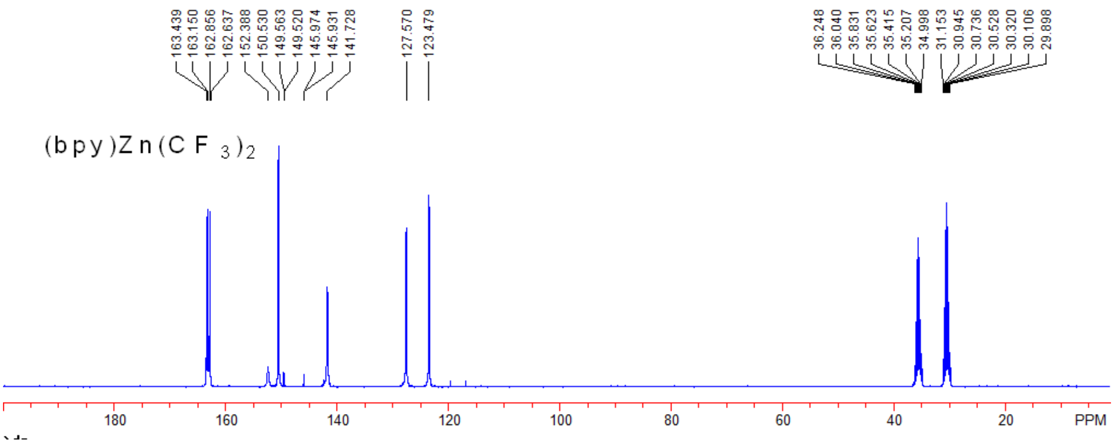


(bpy)Zn(CF_3)$_2$

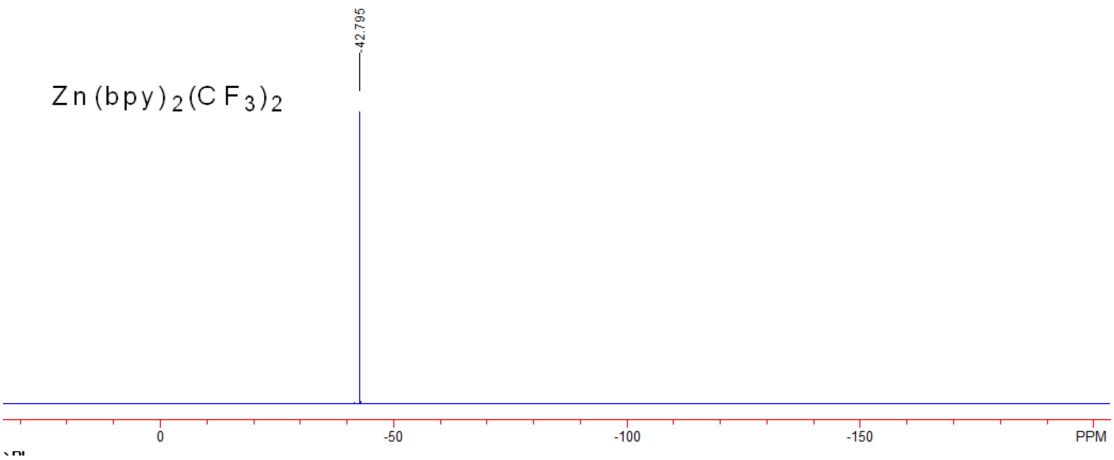
^{1}H NMR (400 MHz, CD_3CN):



^{13}C NMR (100 MHz, DMF-d_7):



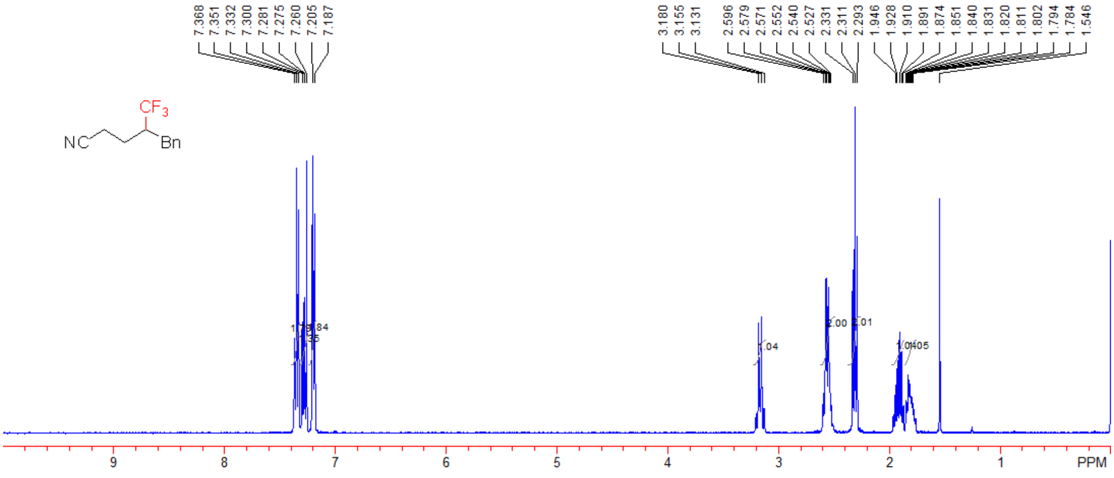
^{19}F NMR (376 MHz, CD_3CN):



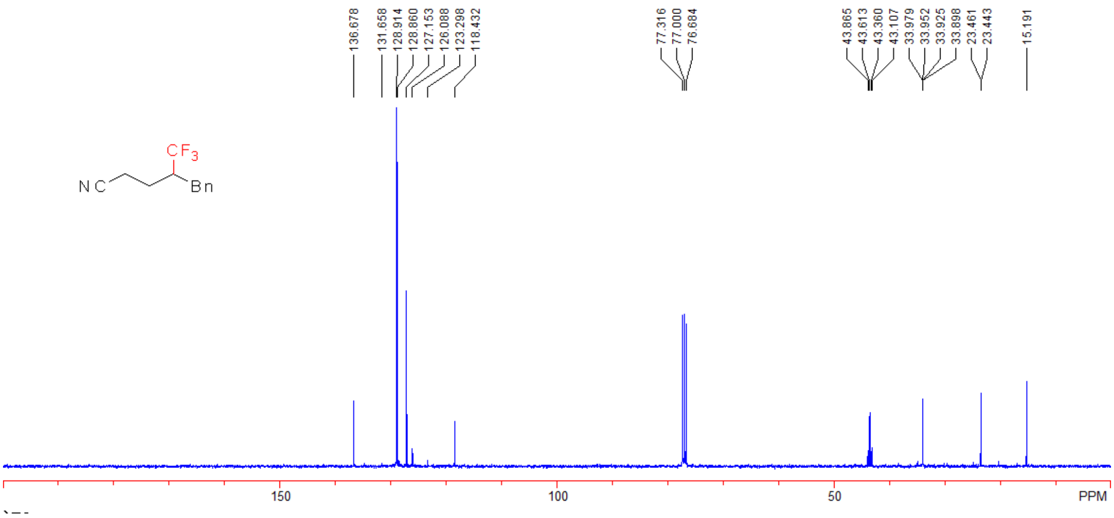
8. ^{1}H, ^{13}C and ^{19}F NMR spectra of all products.

Compound 2a

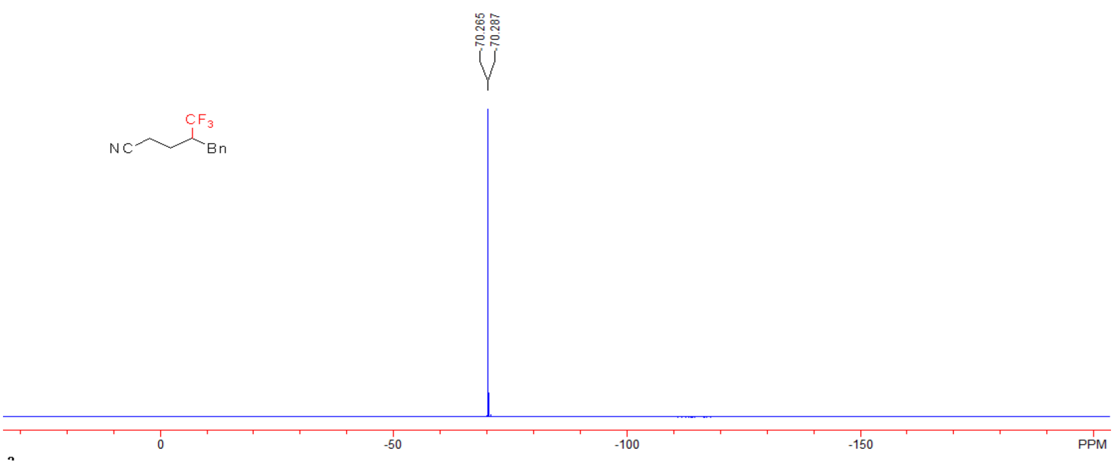
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

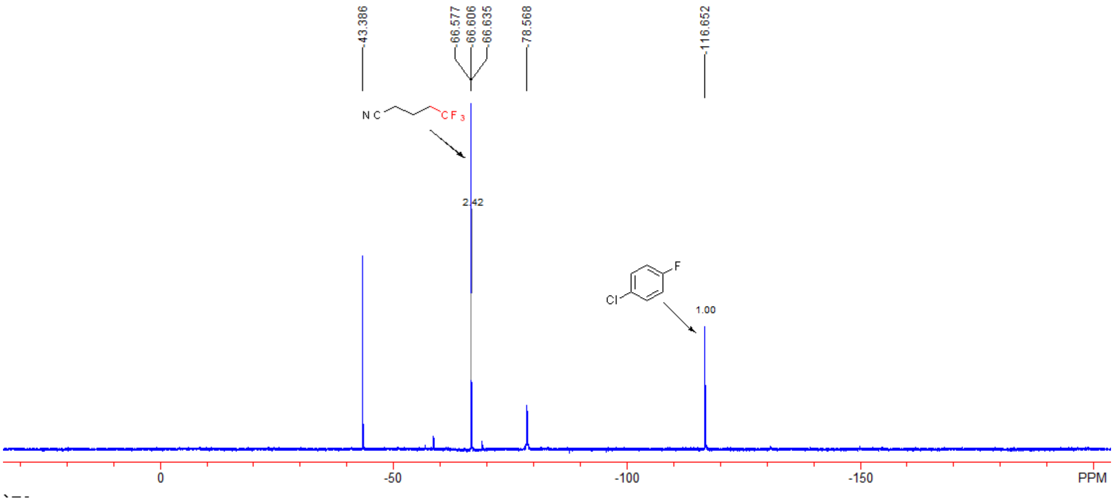


^{19}F NMR (376 MHz, $CDCl_3$):



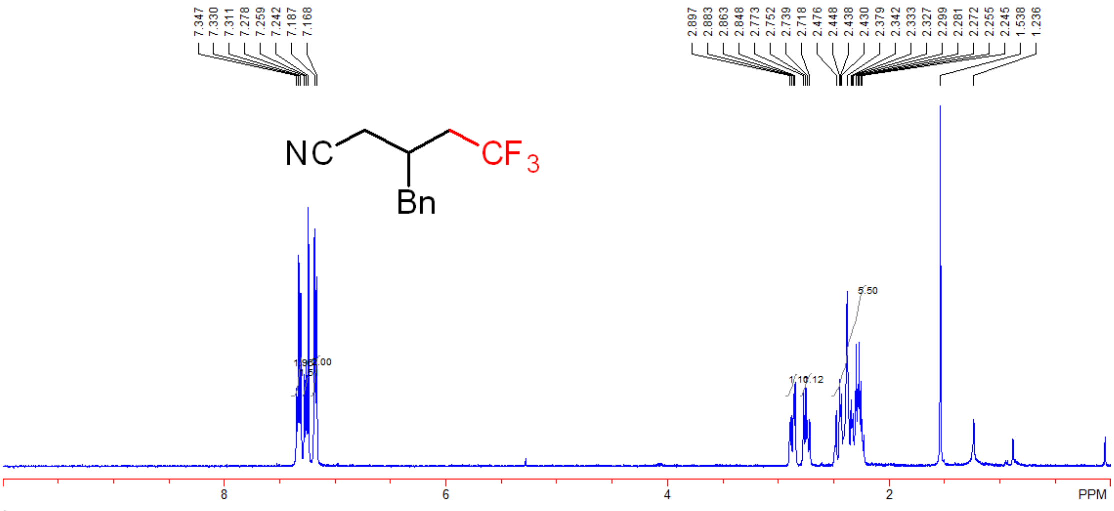
Compound 2b

^{19}F NMR (376 MHz, DCM):

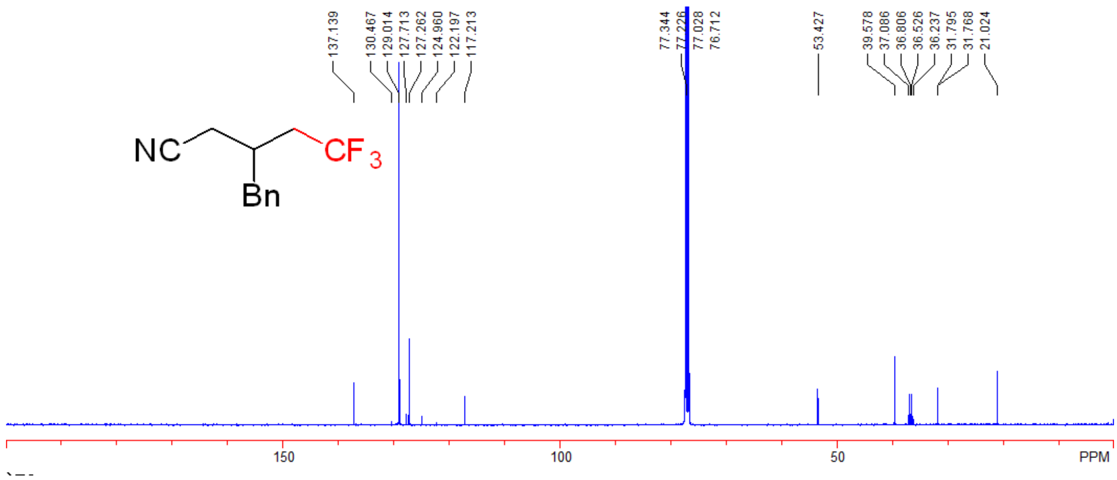


Compound 2c

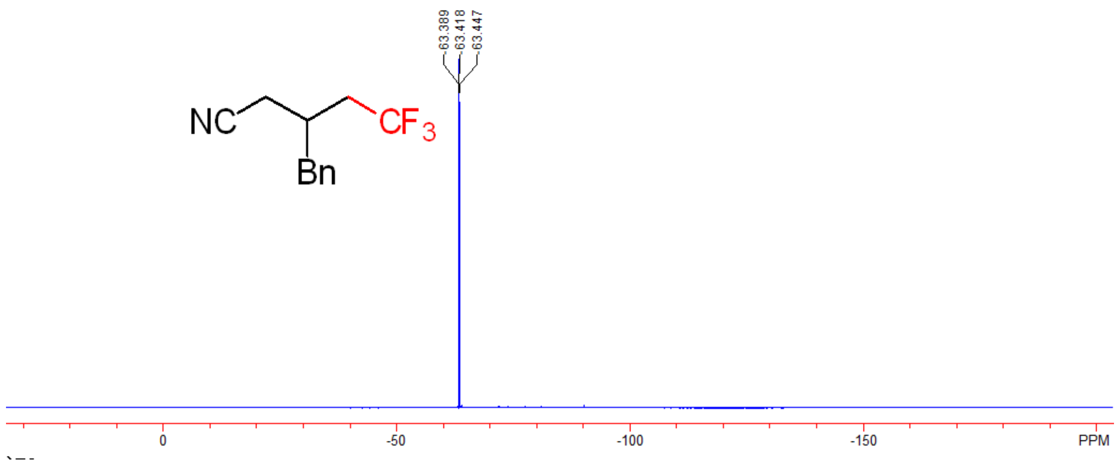
^{1}H NMR (400 MHz, CDCl$_3$):



^{13}C NMR (100 MHz, CDCl$_3$):

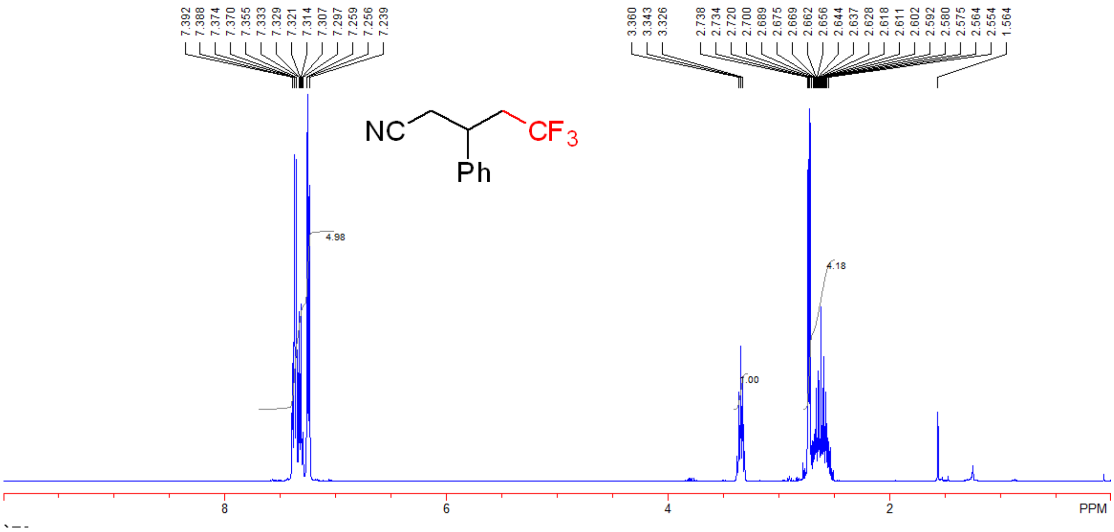


^{19}F NMR (376 MHz, CDCl$_3$):

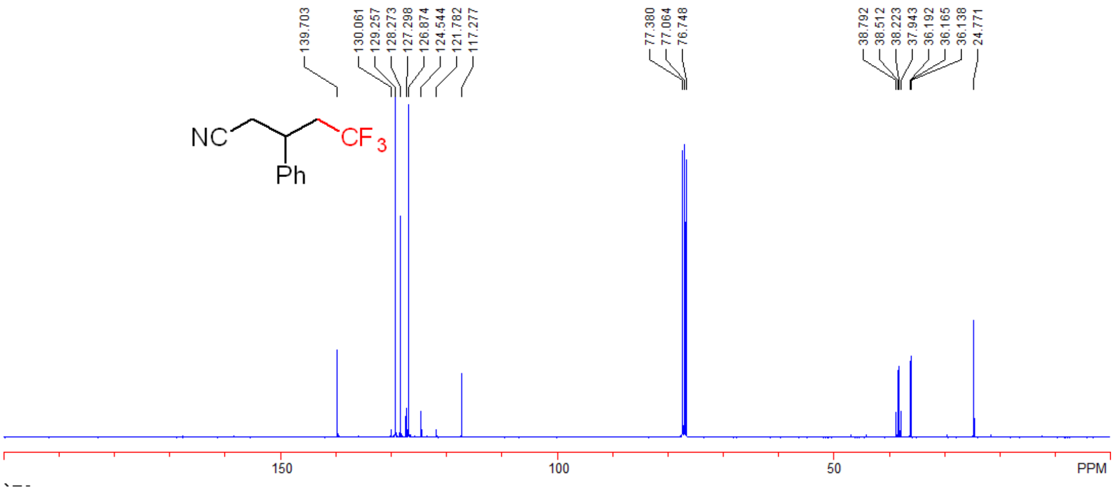


Compound 2d

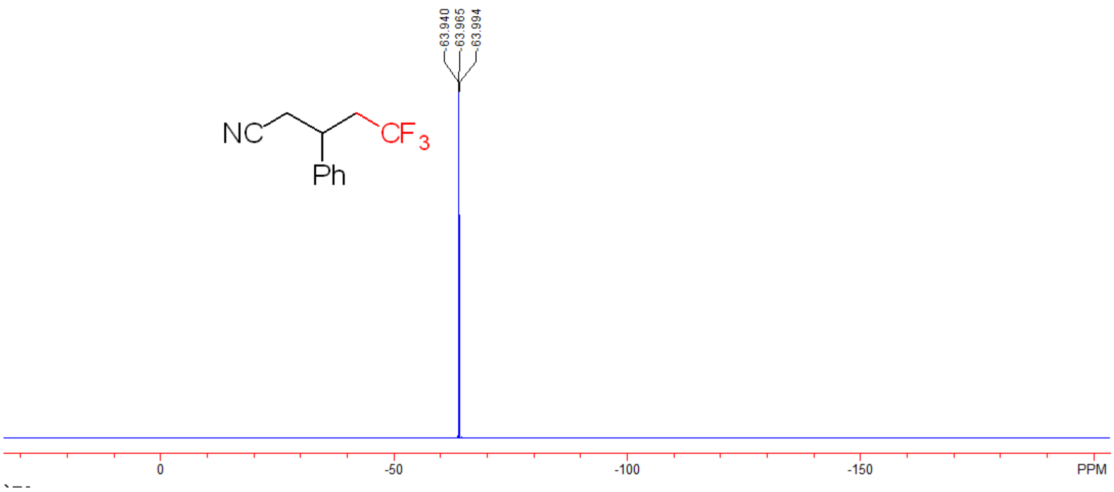
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

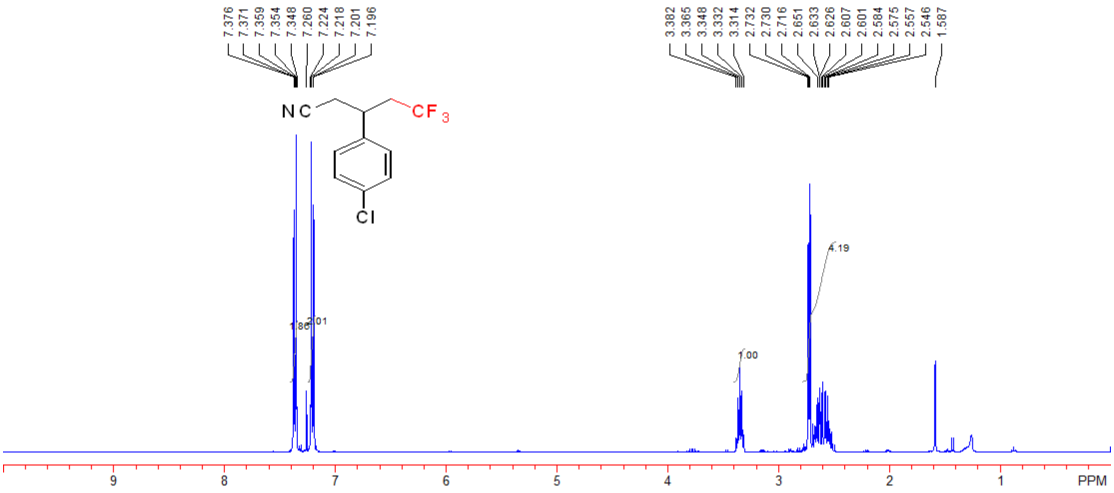


^{19}F NMR (376 MHz, $CDCl_3$):

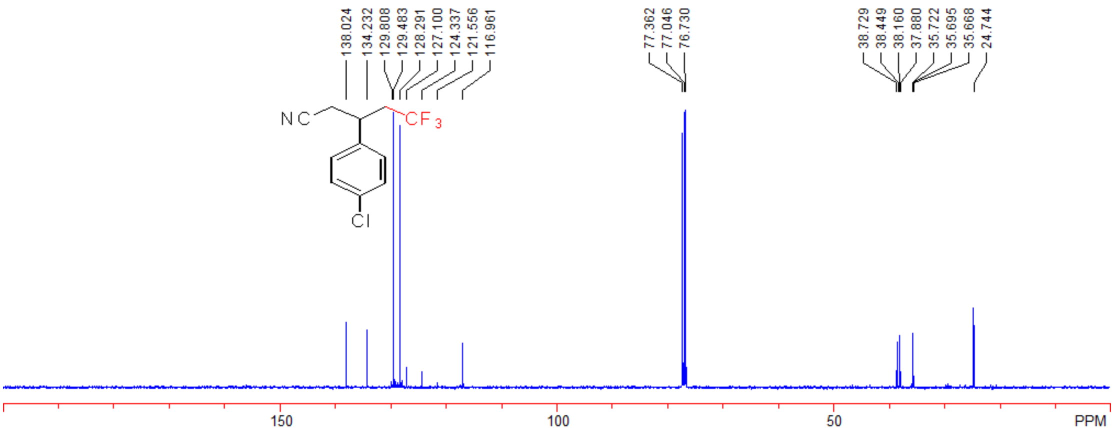


Compound 2e

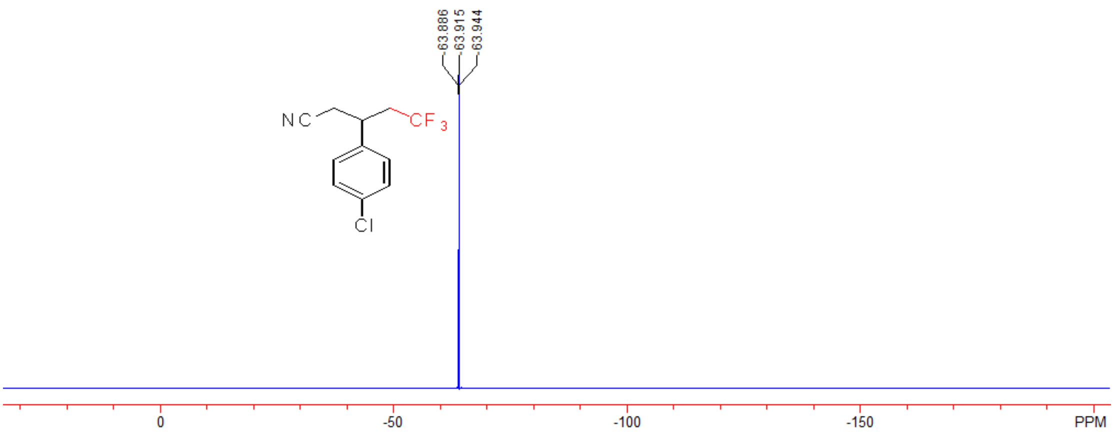
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

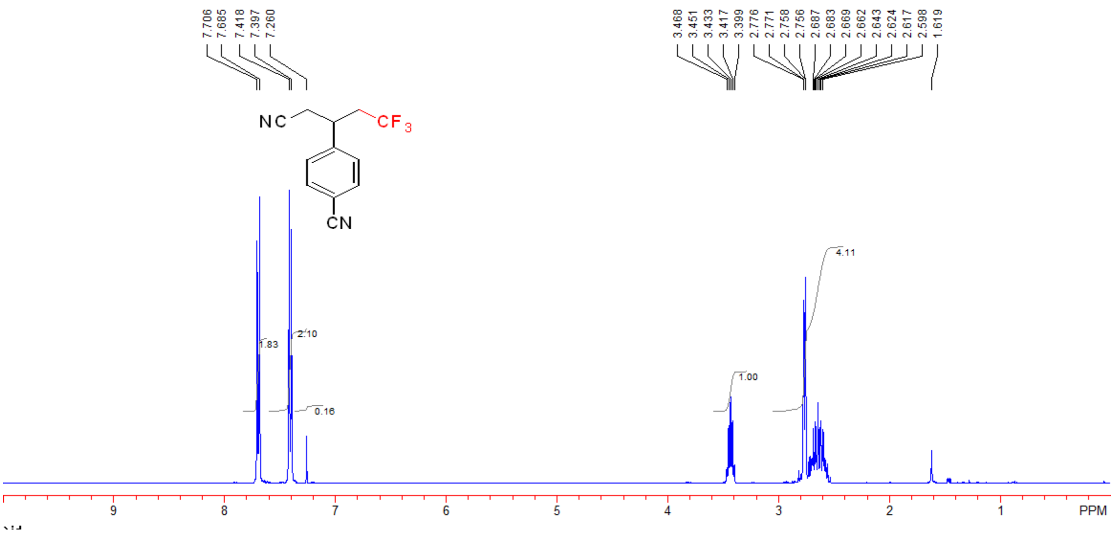


^{19}F NMR (376 MHz, $CDCl_3$):

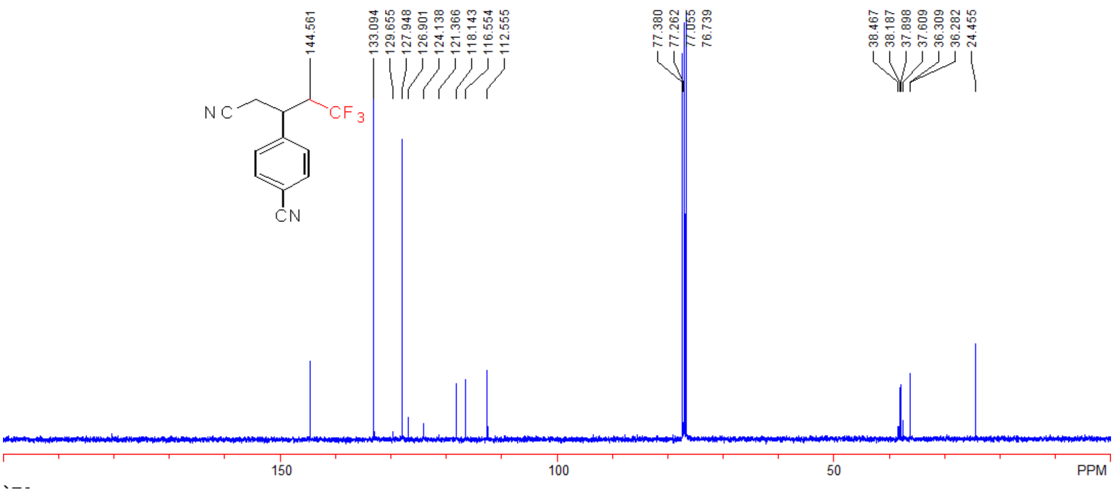


Compound 2f

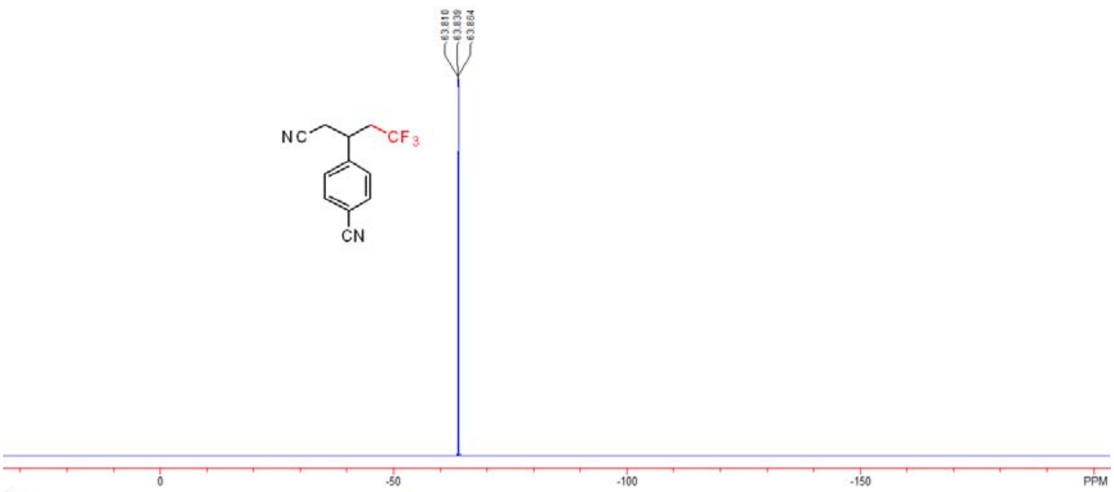
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

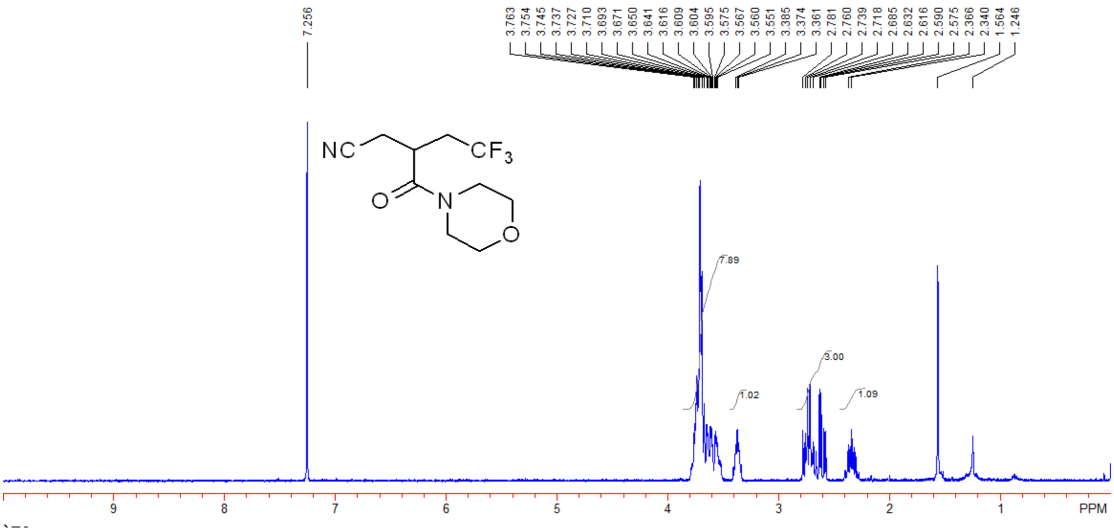


^{19}F NMR (376 MHz, $CDCl_3$):

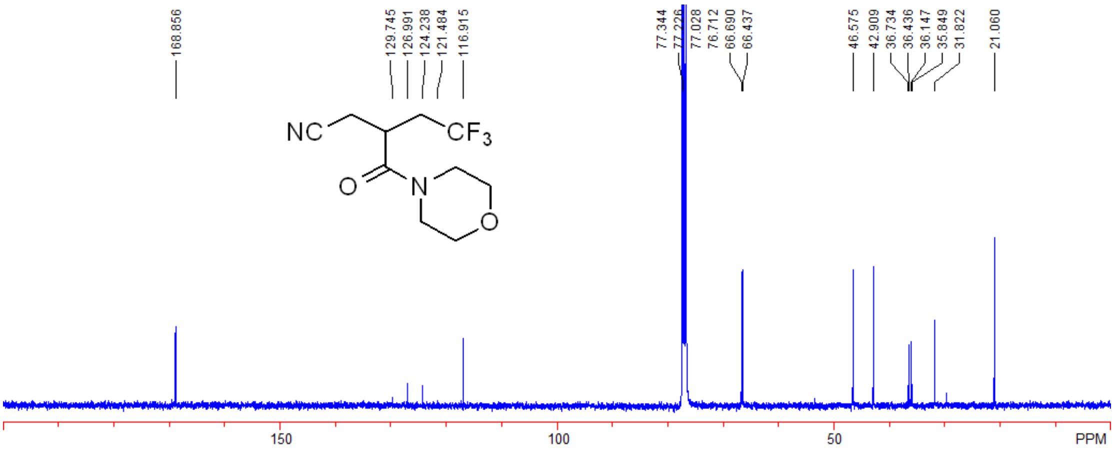


Compound 2g

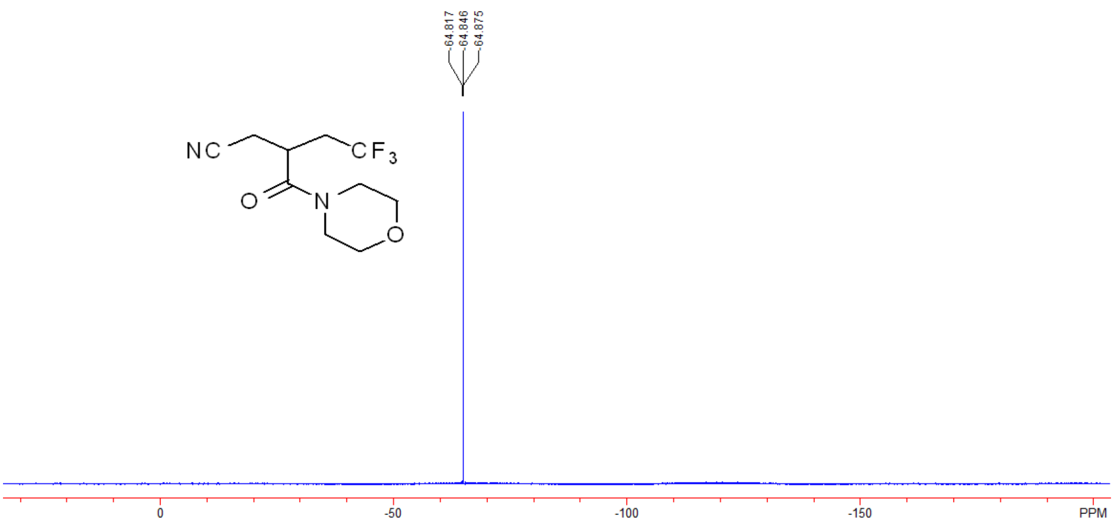
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

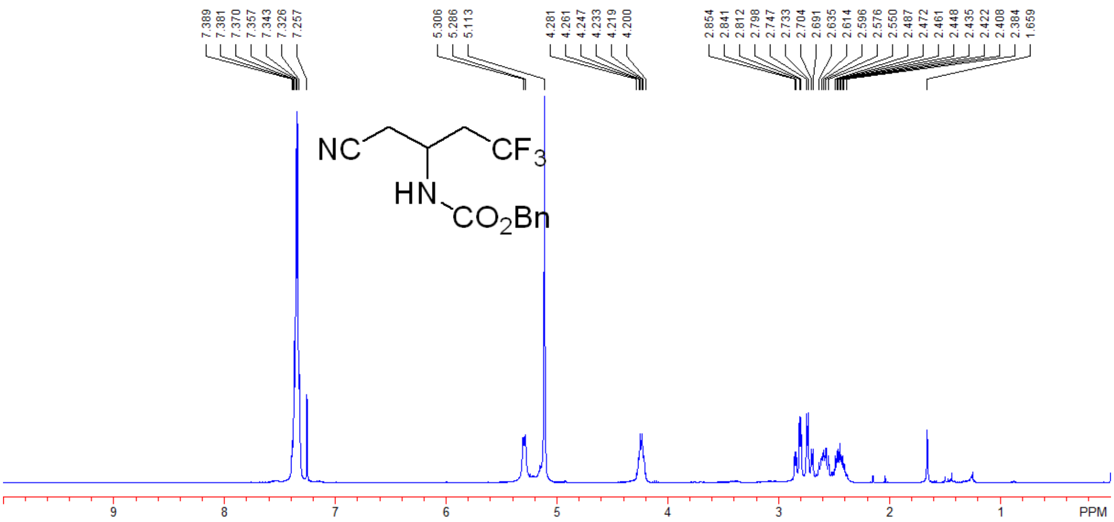


^{19}F NMR (376 MHz, $CDCl_3$):

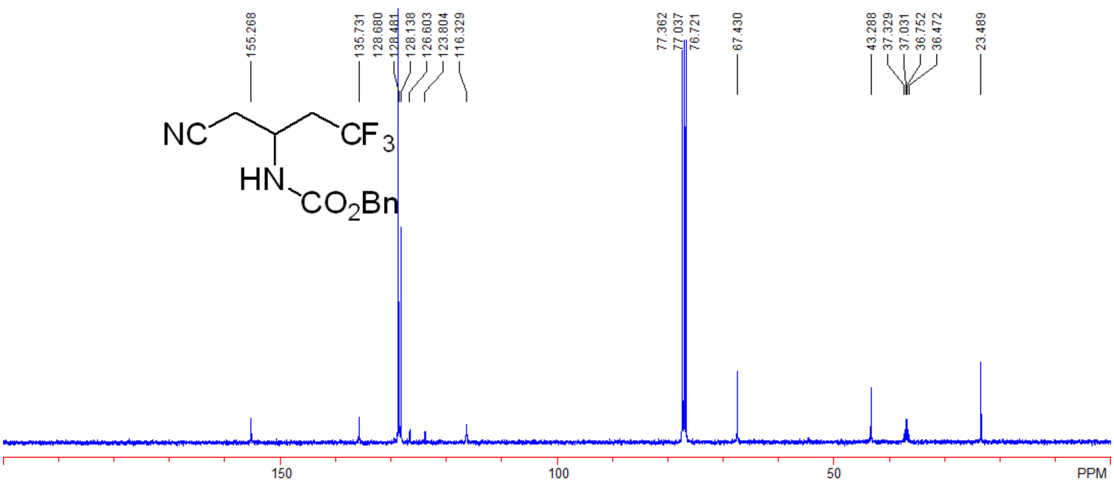


Compound 2h

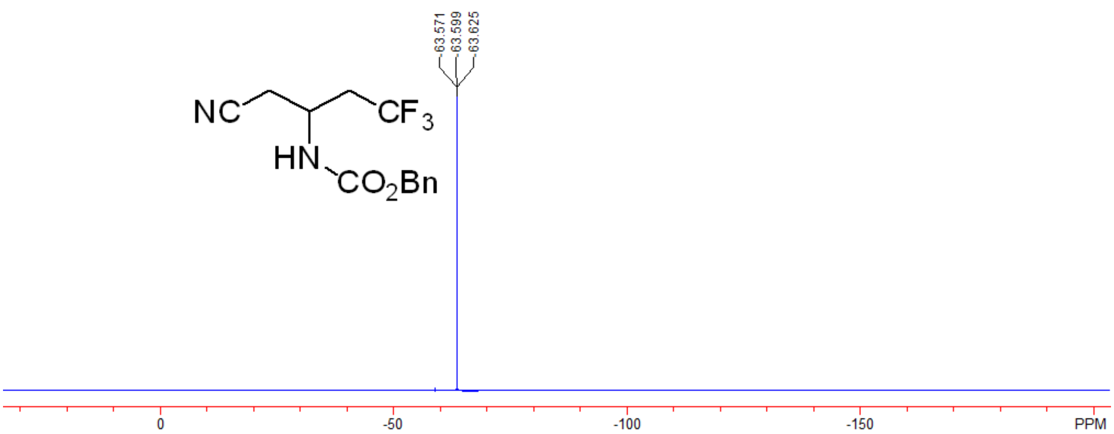
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

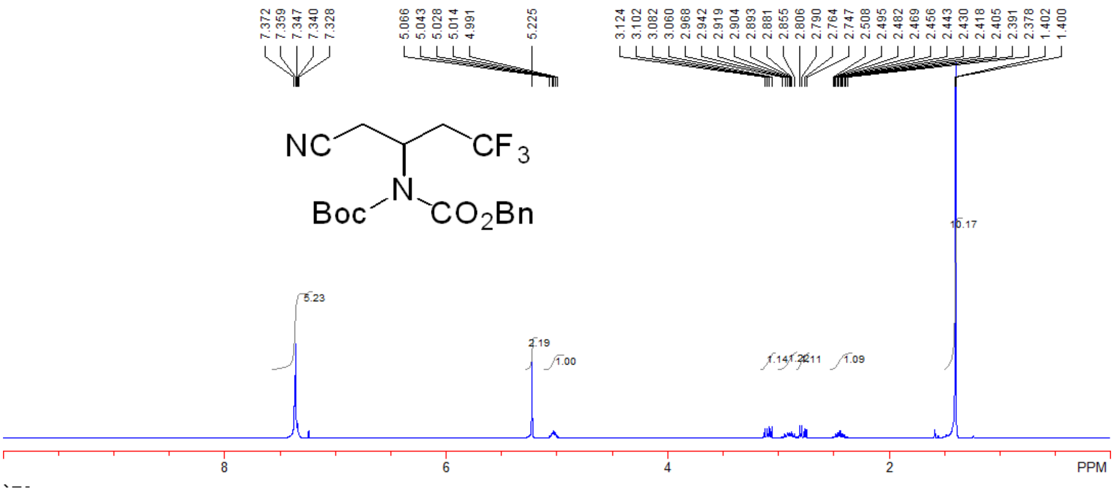


^{19}F NMR (376 MHz, $CDCl_3$):

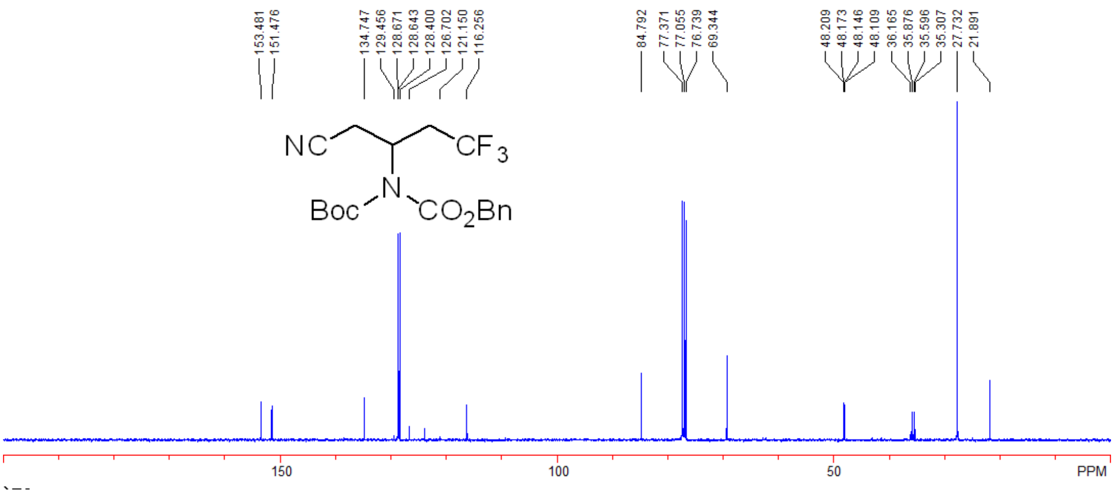


Compound 2i

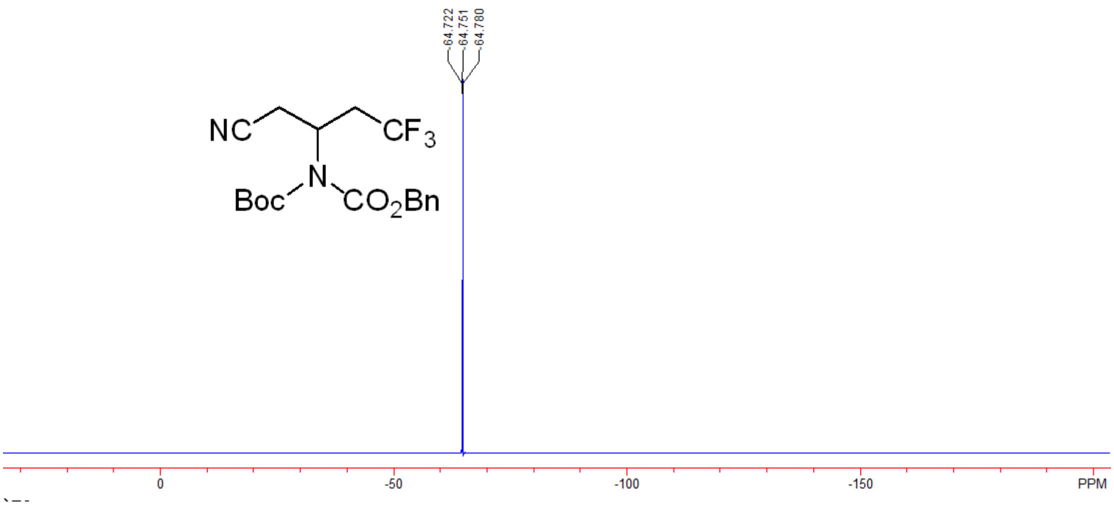
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

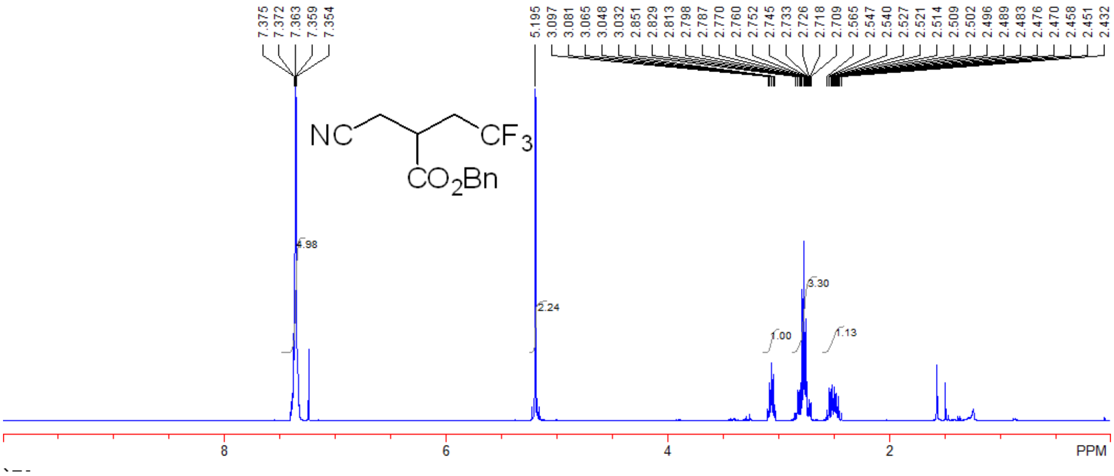


^{19}F NMR (376 MHz, $CDCl_3$):

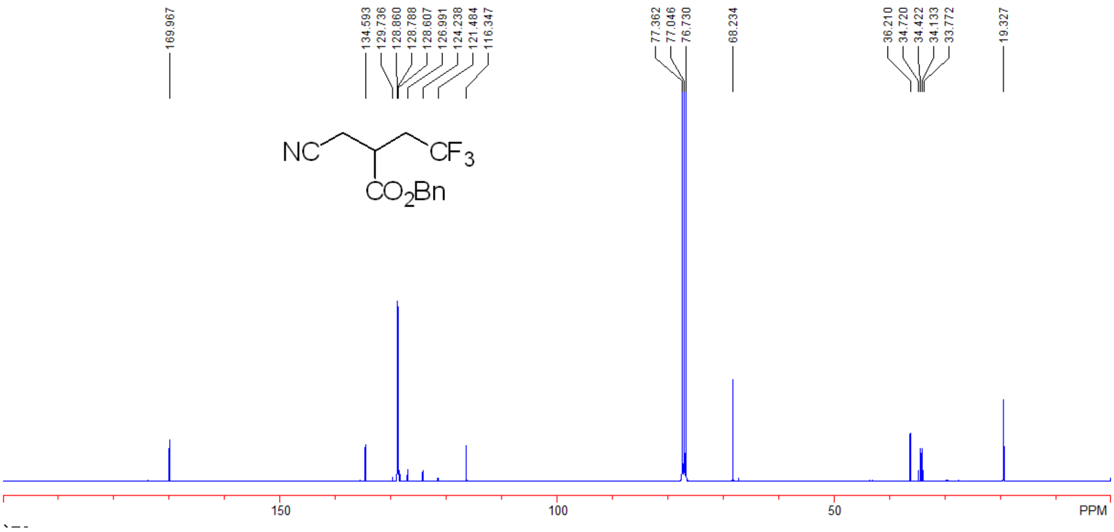


Compound 2j

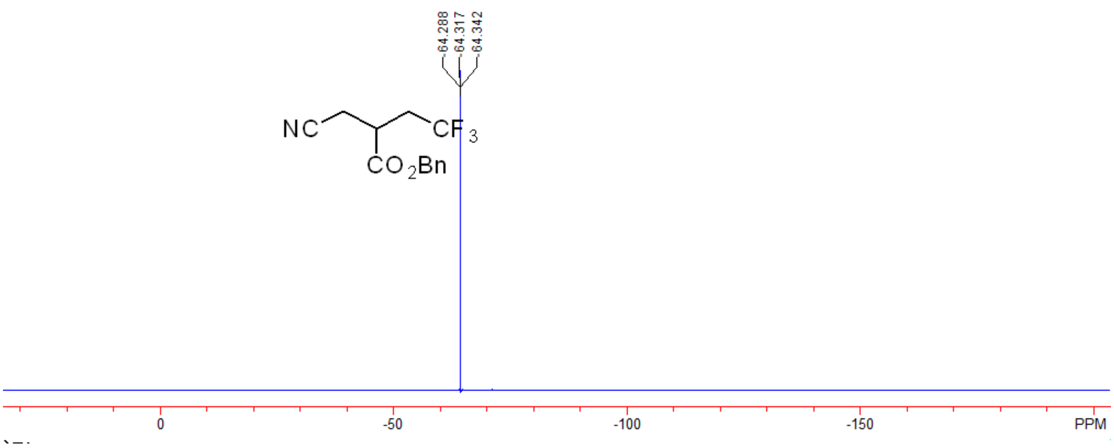
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

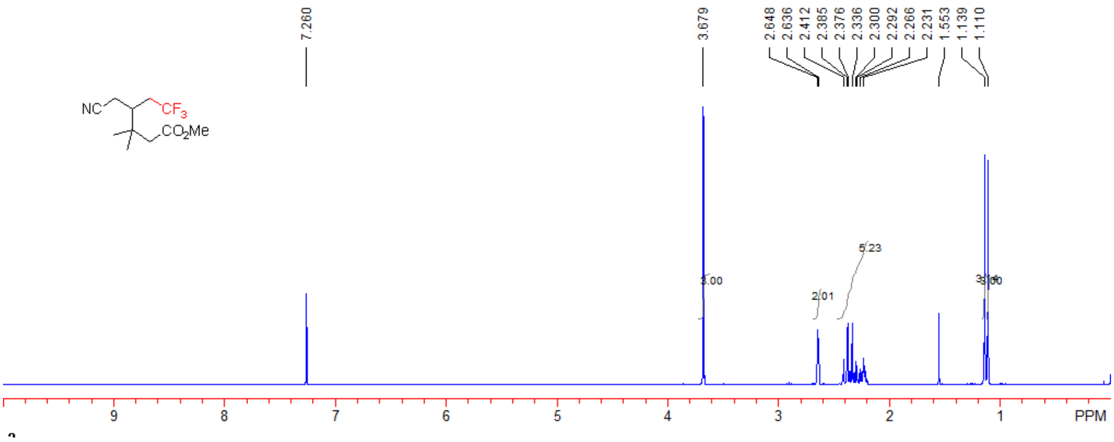


^{19}F NMR (376 MHz, $CDCl_3$):

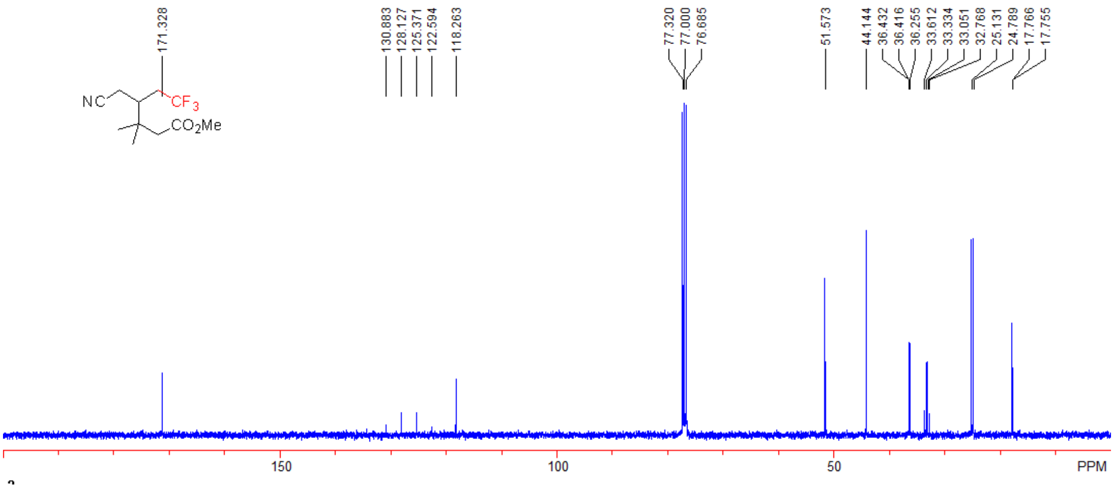


Compound 2k

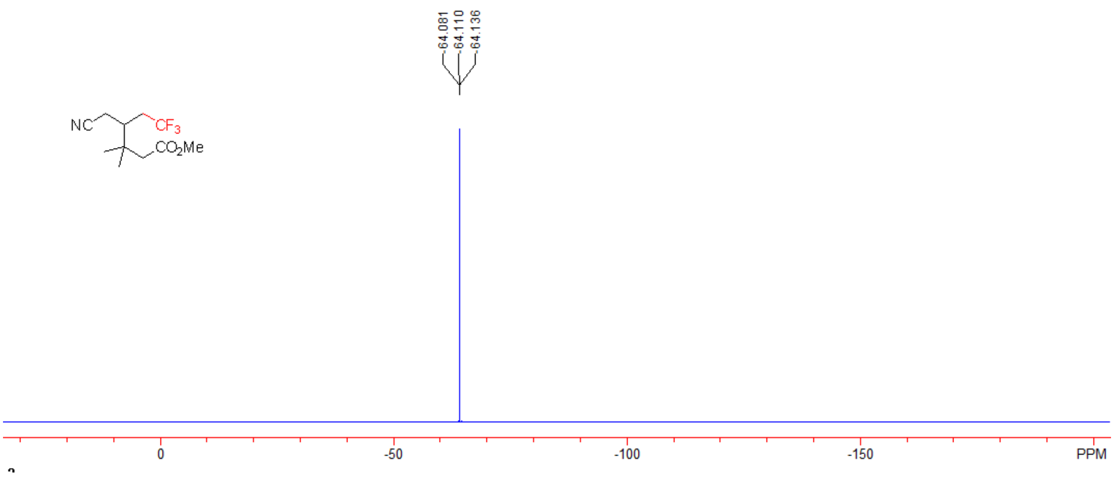
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

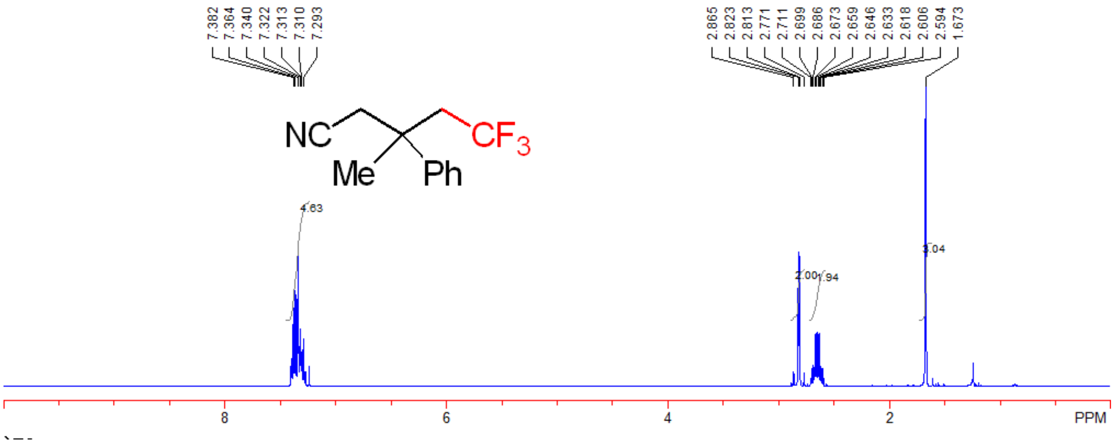


^{19}F NMR (376 MHz, $CDCl_3$):

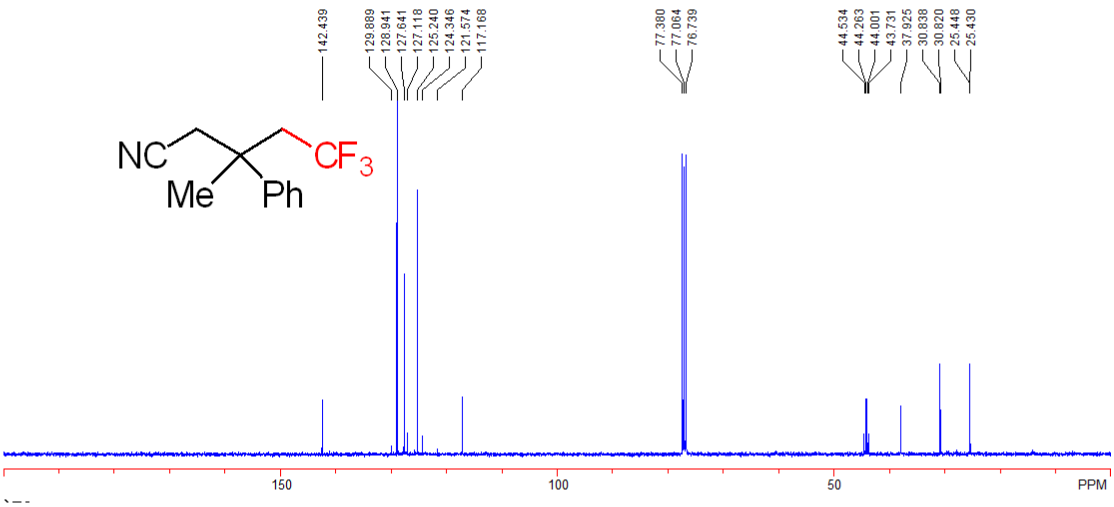


Compound 2l

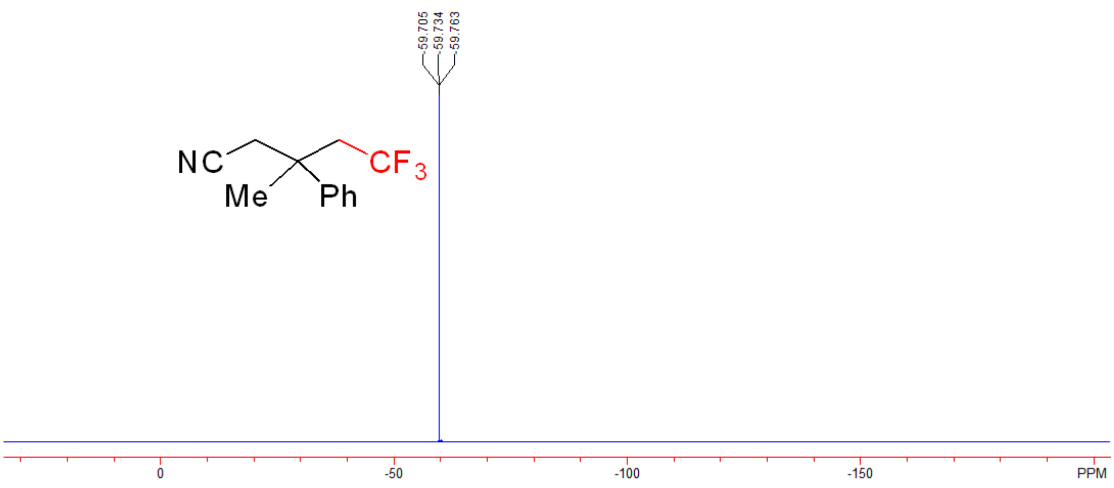
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

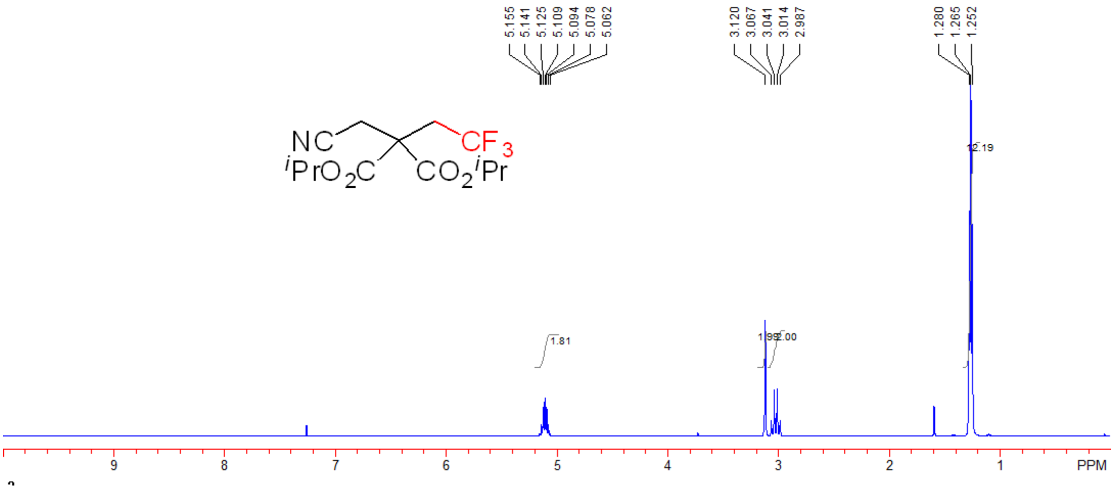


^{19}F NMR (376 MHz, $CDCl_3$):

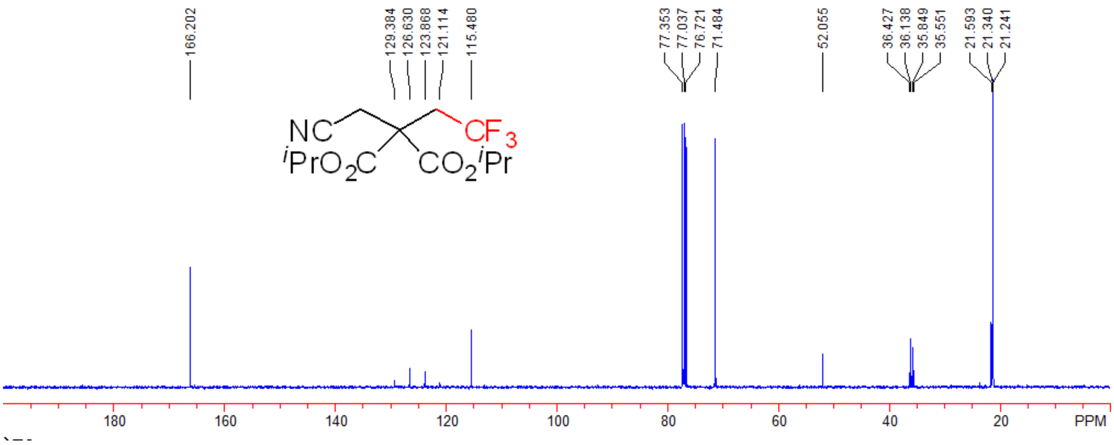


Compound 2m

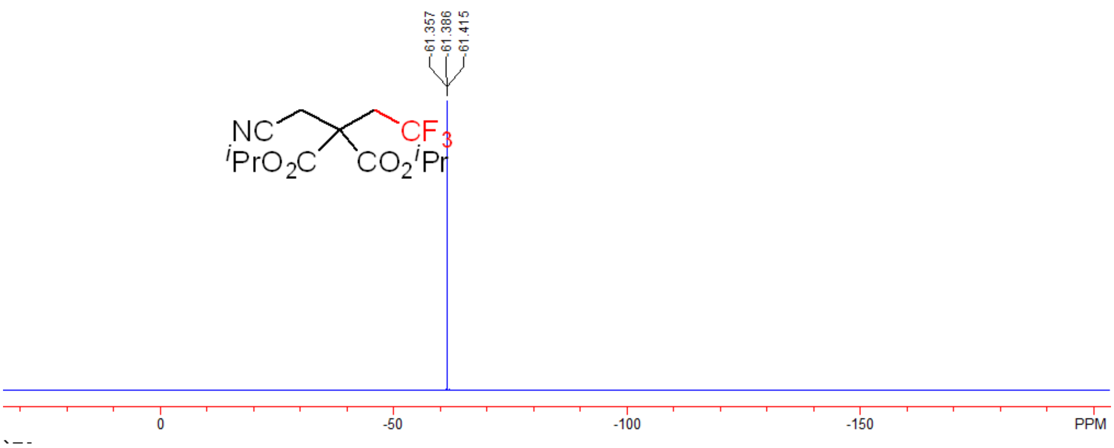
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

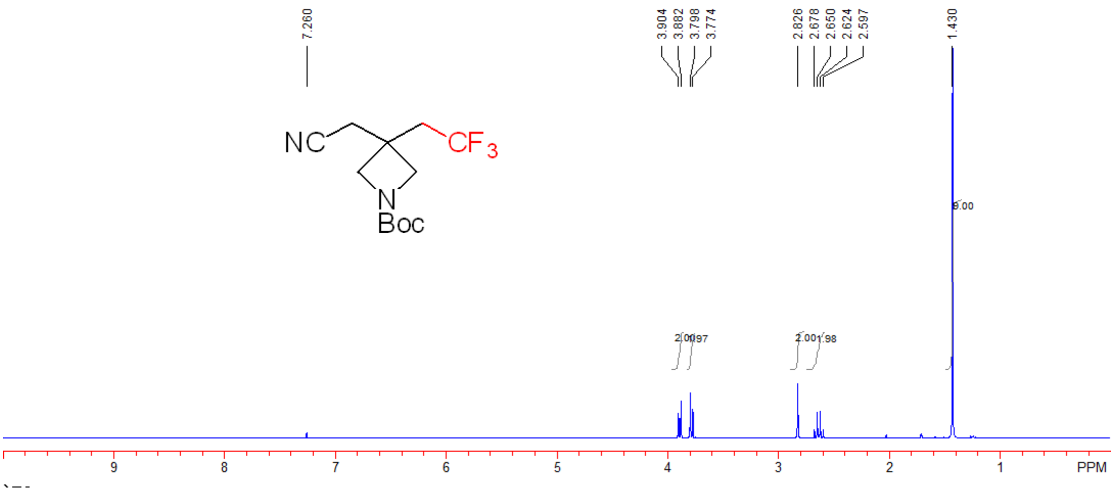


^{19}F NMR (376 MHz, $CDCl_3$):

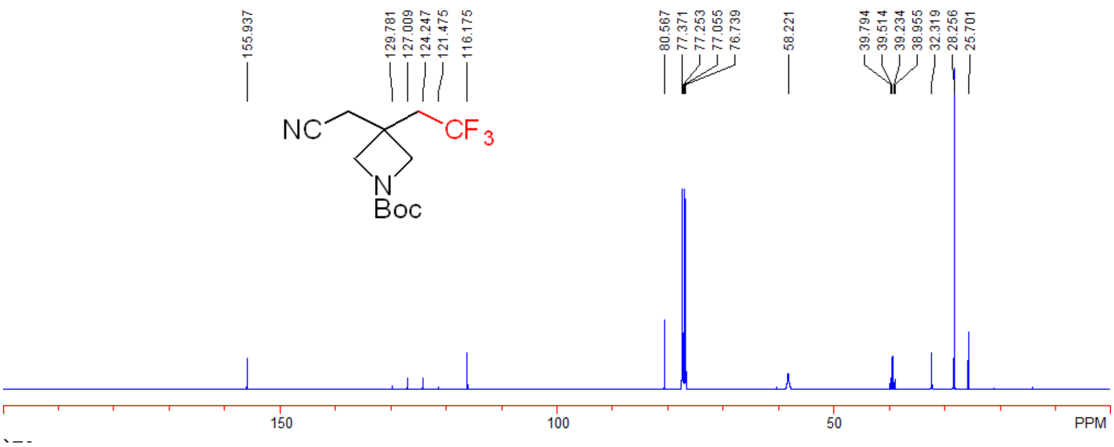


Compound 2n

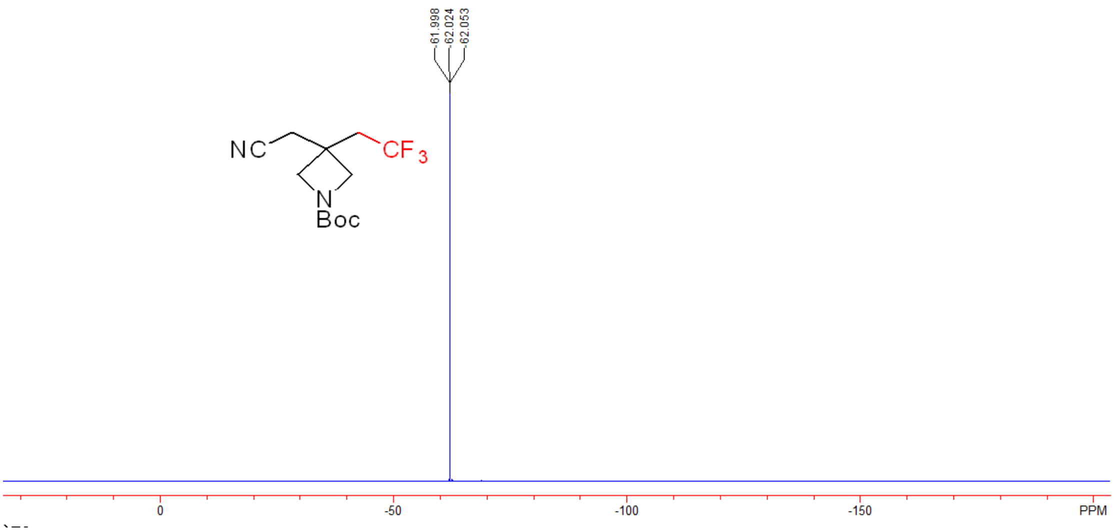
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

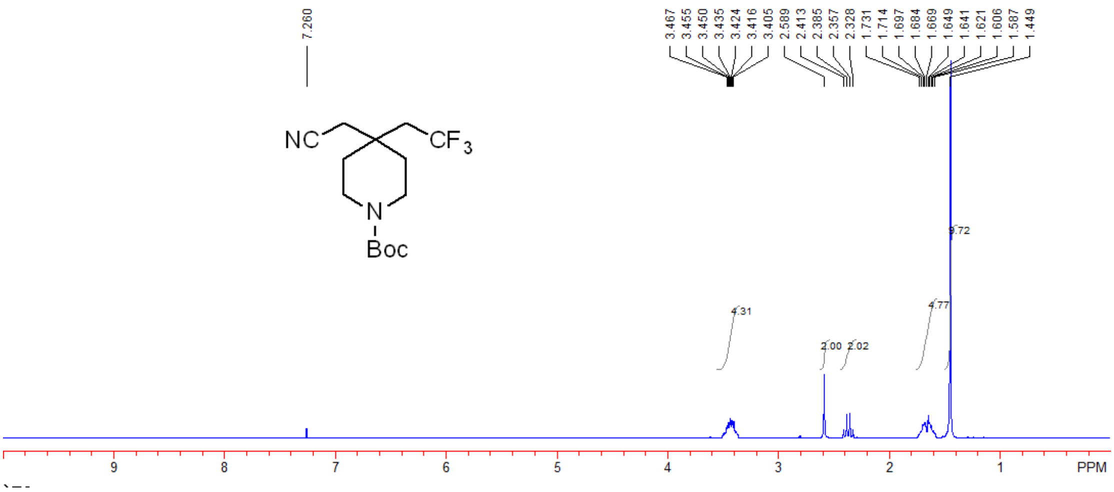


^{19}F NMR (376 MHz, $CDCl_3$):

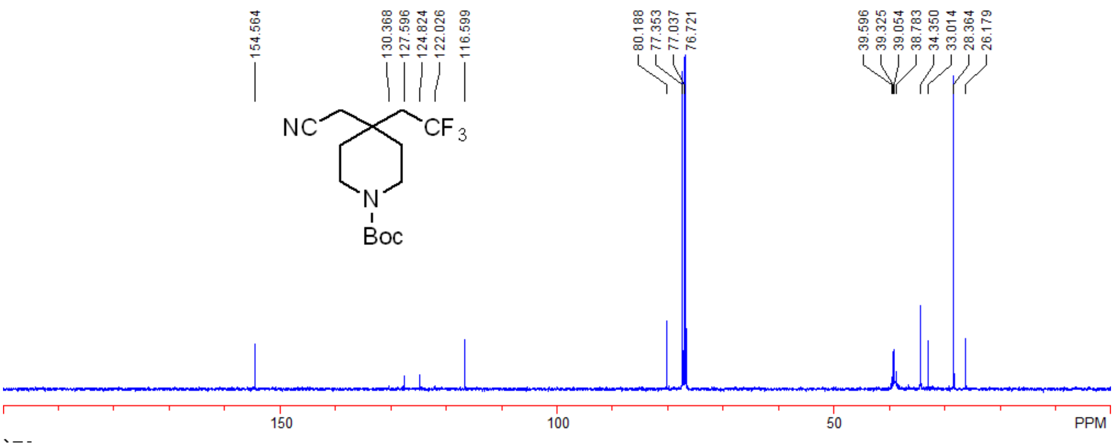


Compound 2o

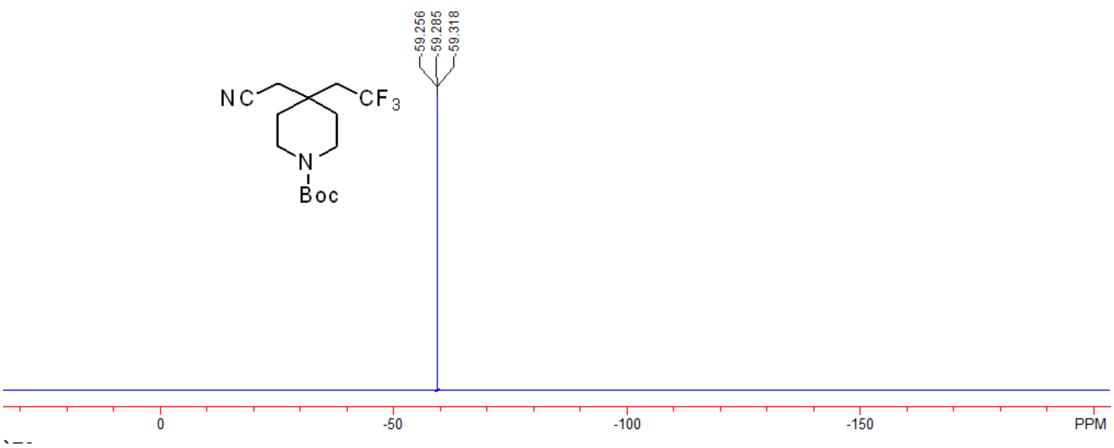
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

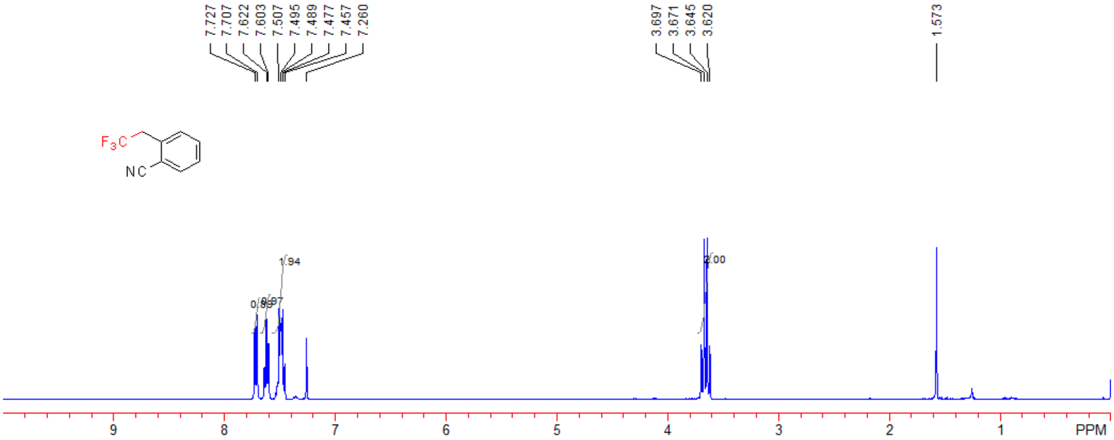


^{19}F NMR (376 MHz, $CDCl_3$):

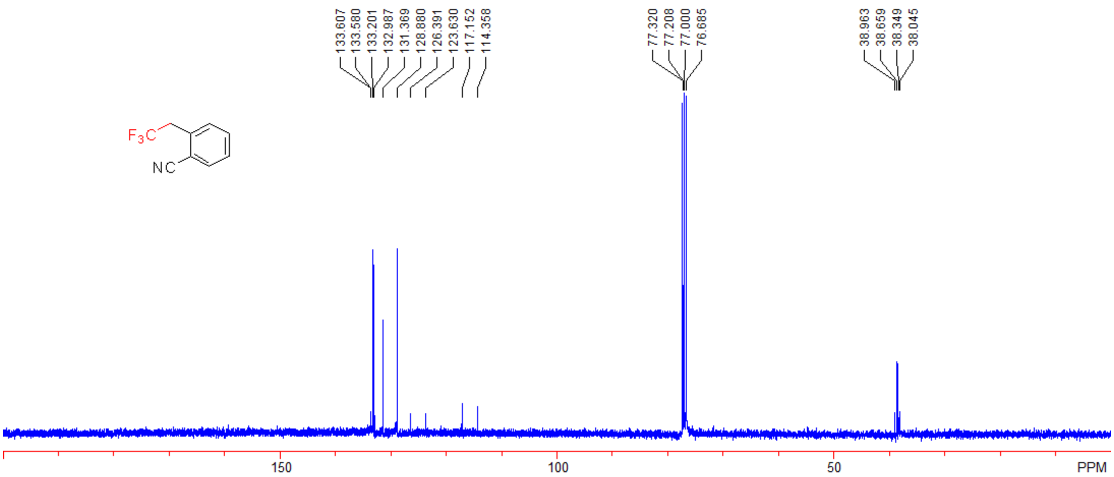


Compound 2p

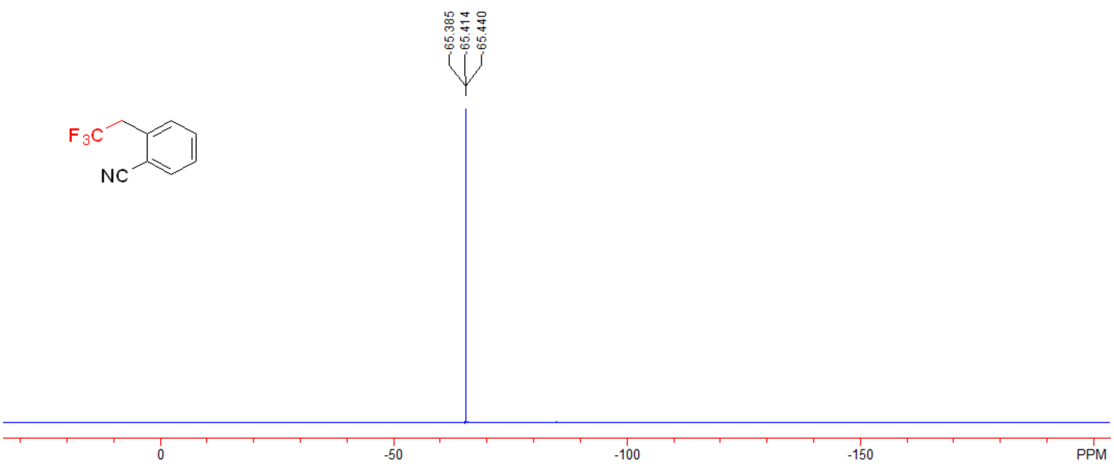
^1H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

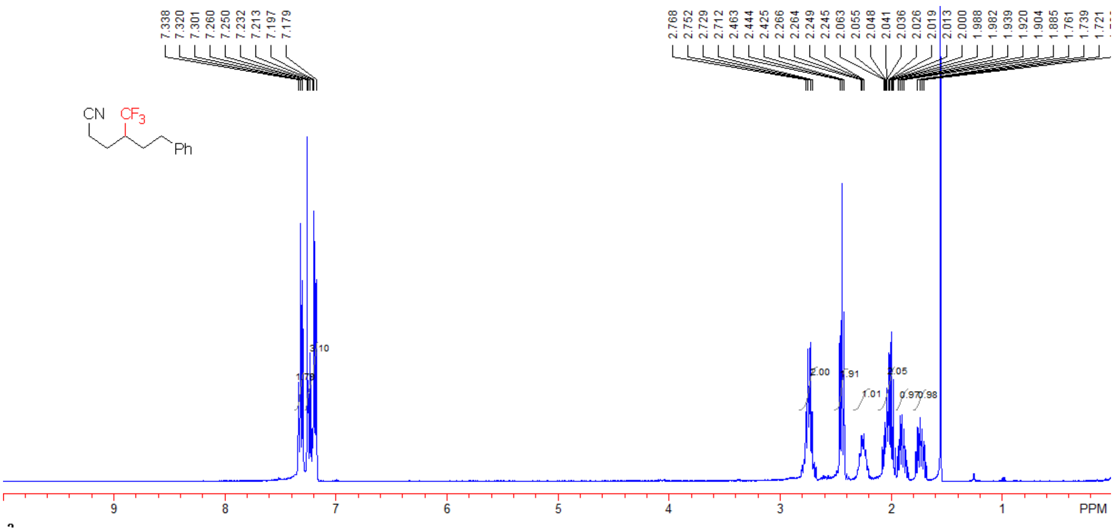


^{19}F NMR (376 MHz, $CDCl_3$):

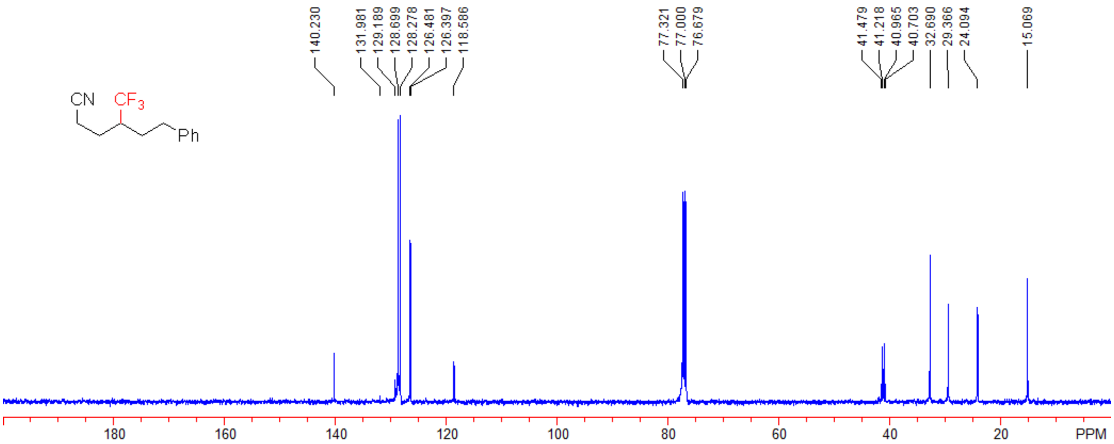


Compound 2q

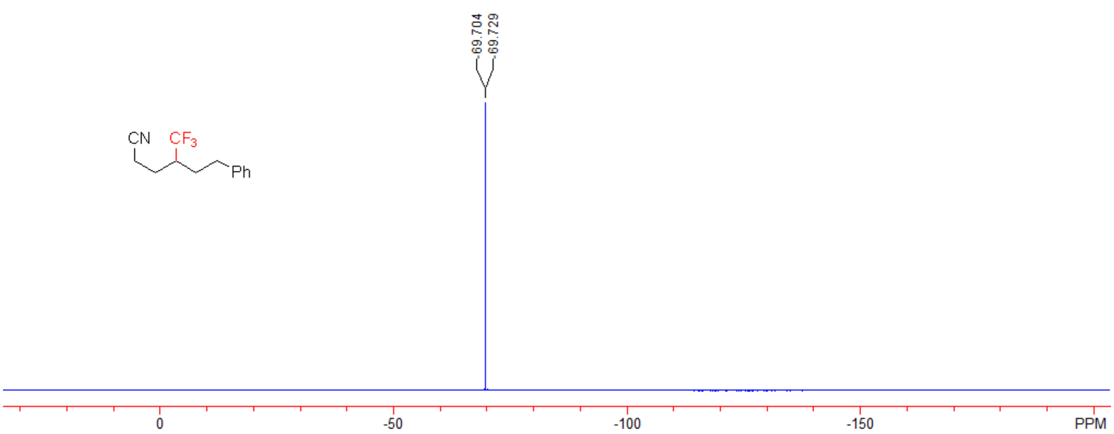
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

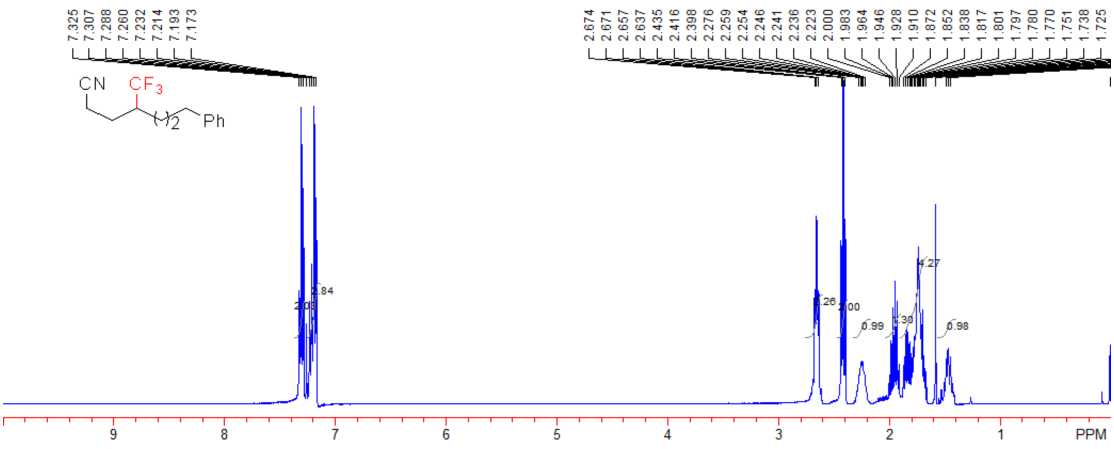


^{19}F NMR (376 MHz, $CDCl_3$):

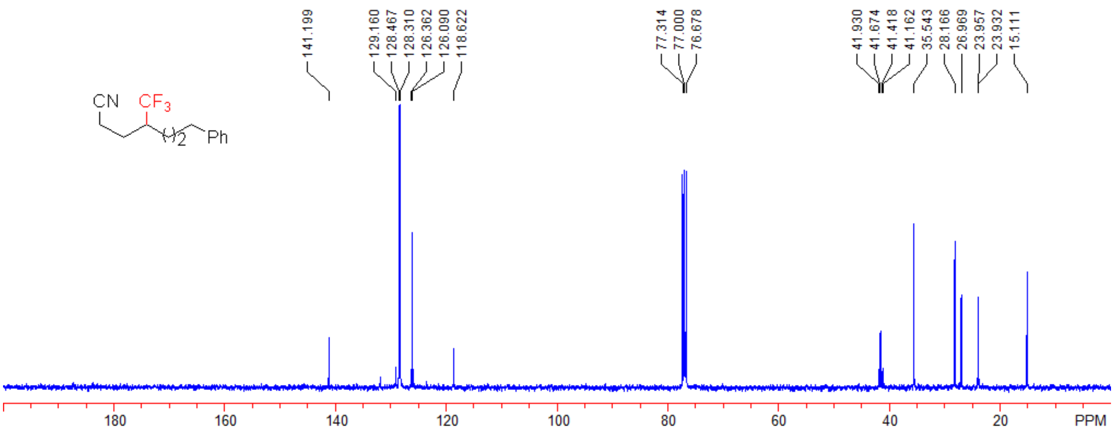


Compound 2r

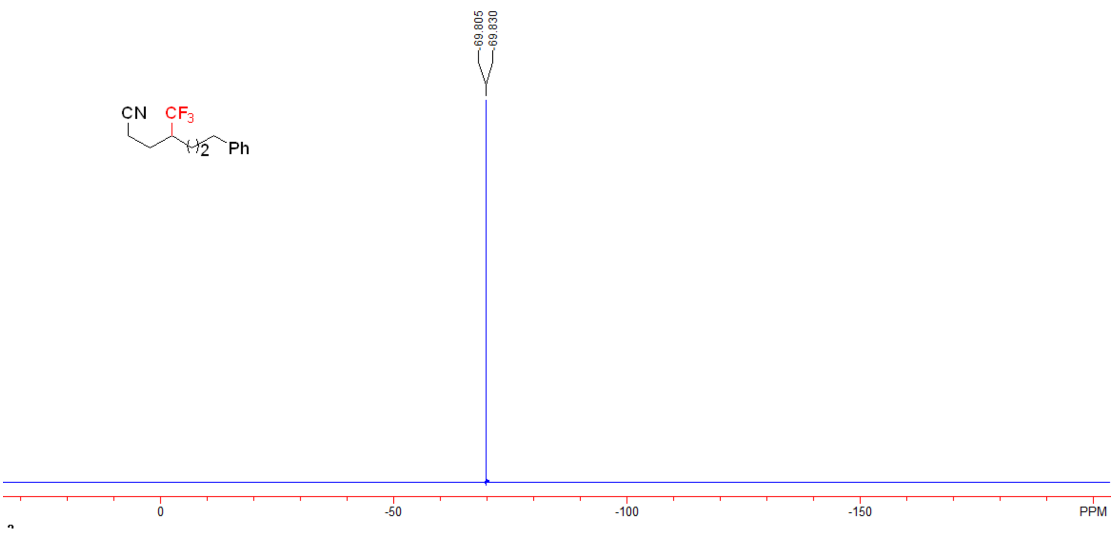
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

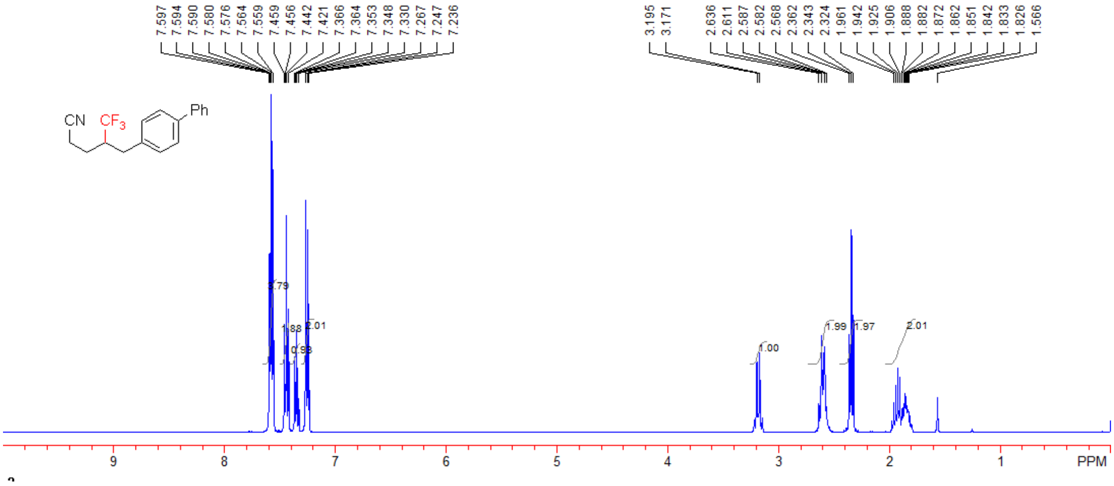


^{19}F NMR (376 MHz, $CDCl_3$):

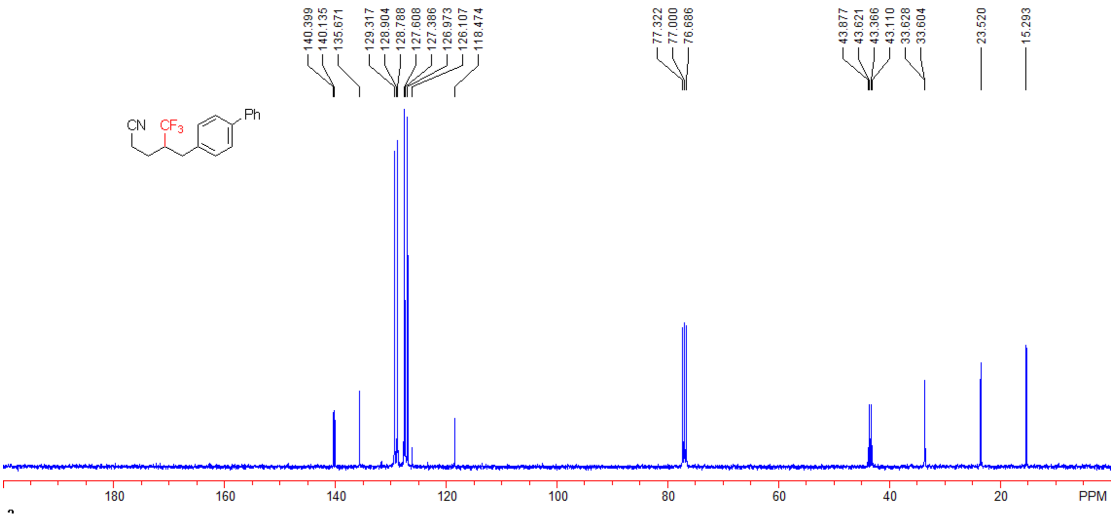


Compound 2s

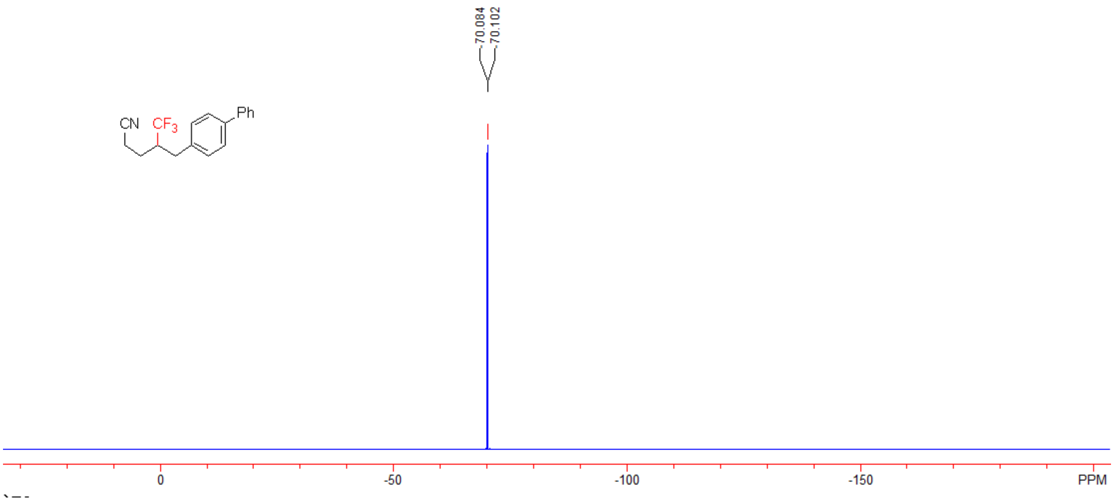
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

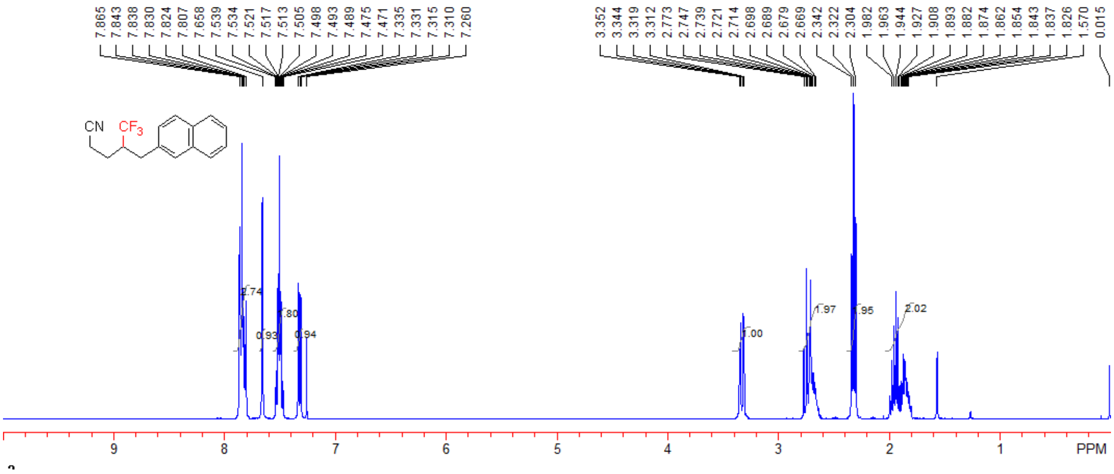


^{19}F NMR (376 MHz, $CDCl_3$):

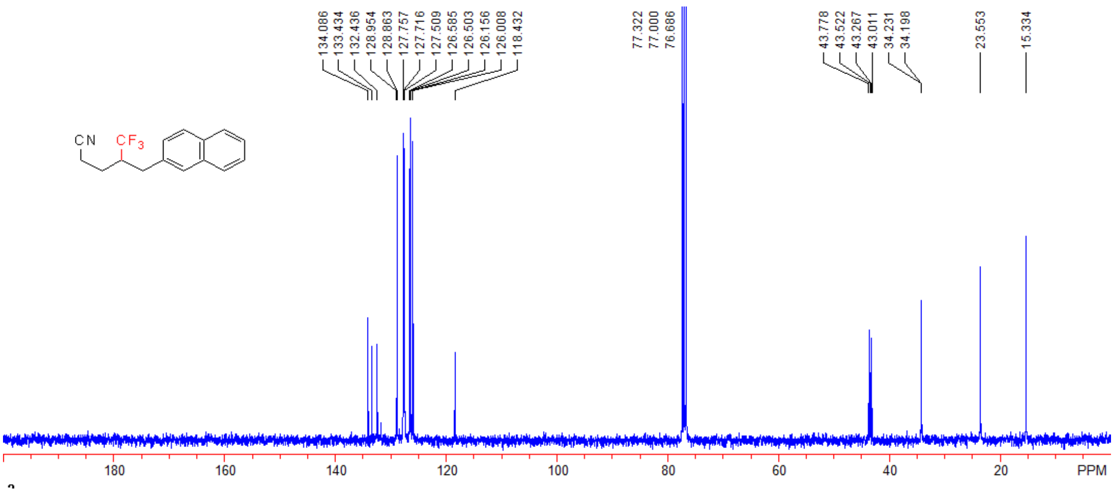


Compound 2t

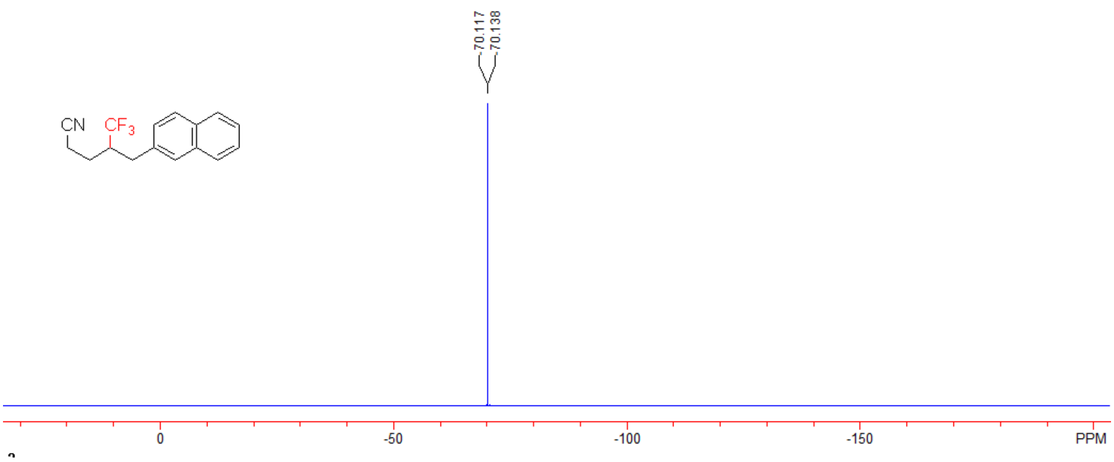
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

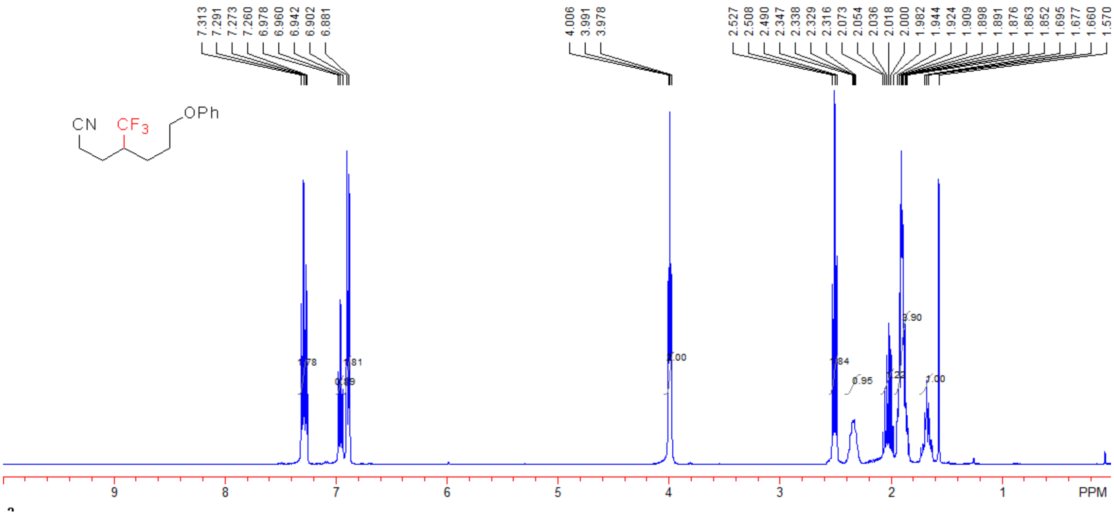


^{19}F NMR (376 MHz, $CDCl_3$):

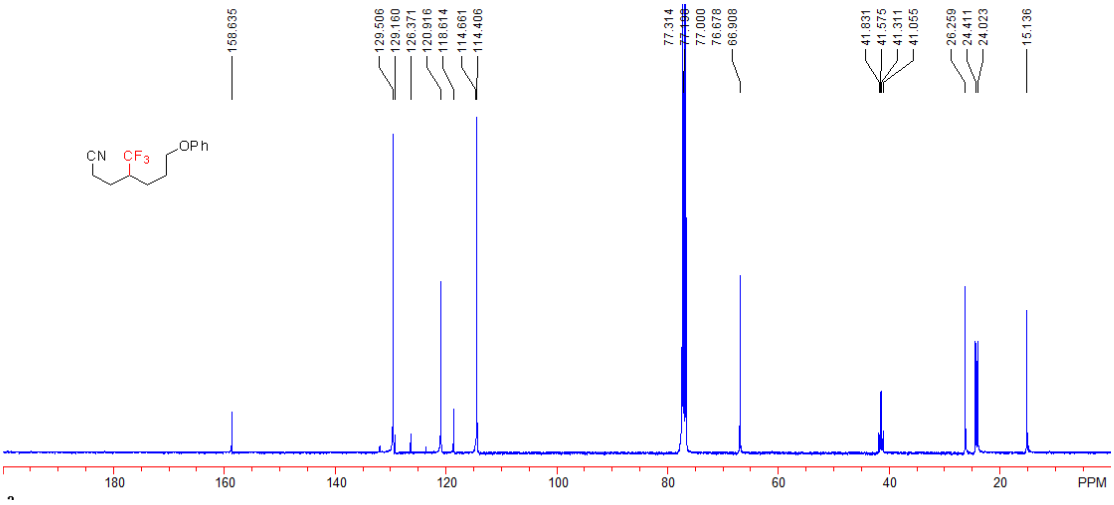


Compound 2u

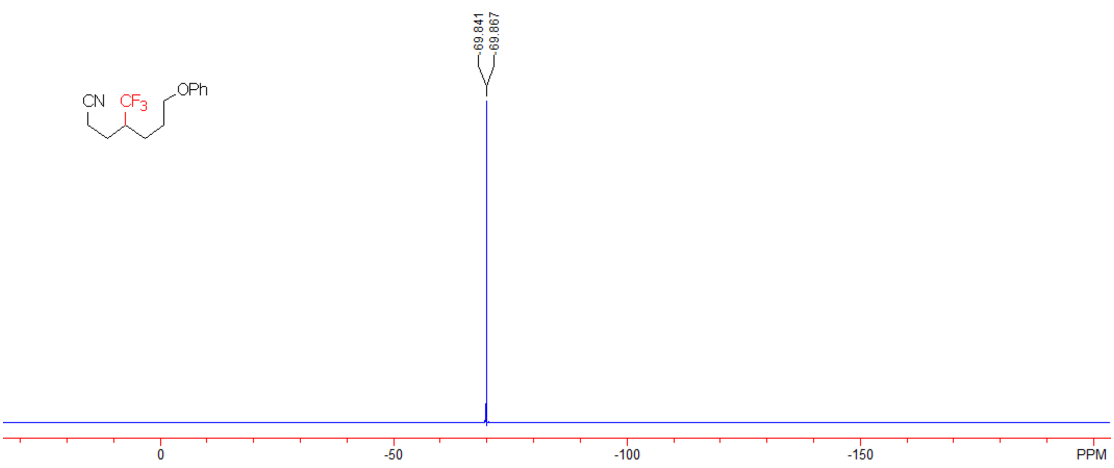
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

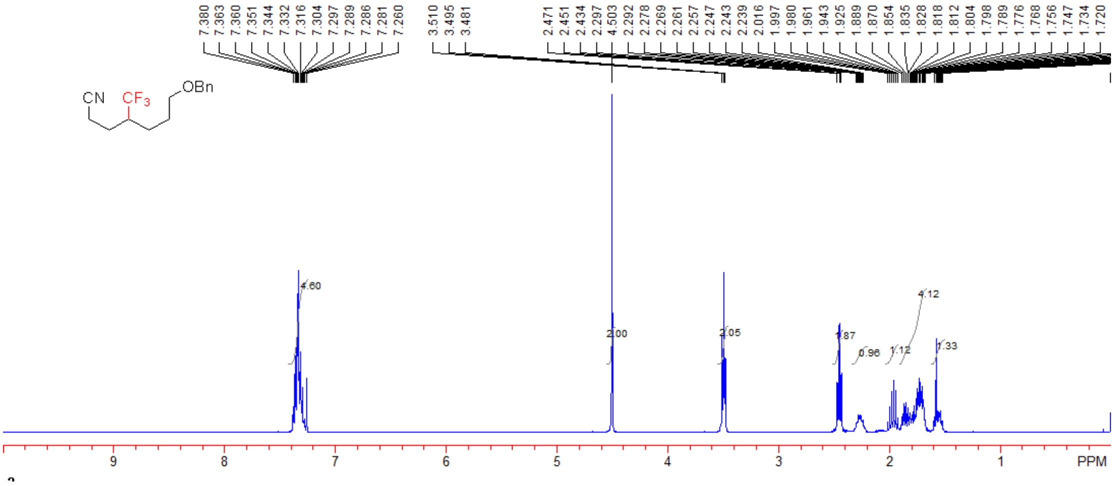


^{19}F NMR (376 MHz, $CDCl_3$):

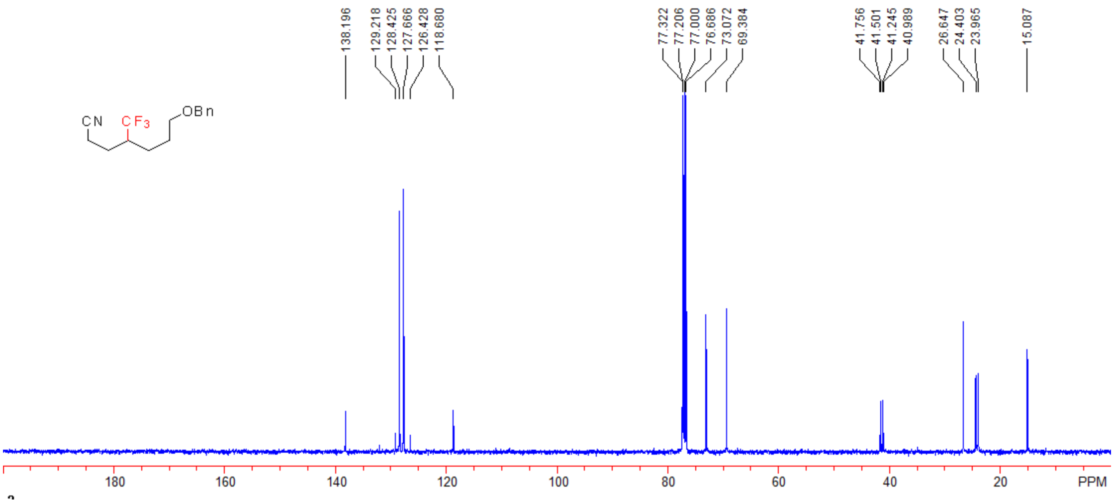


Compound 2v

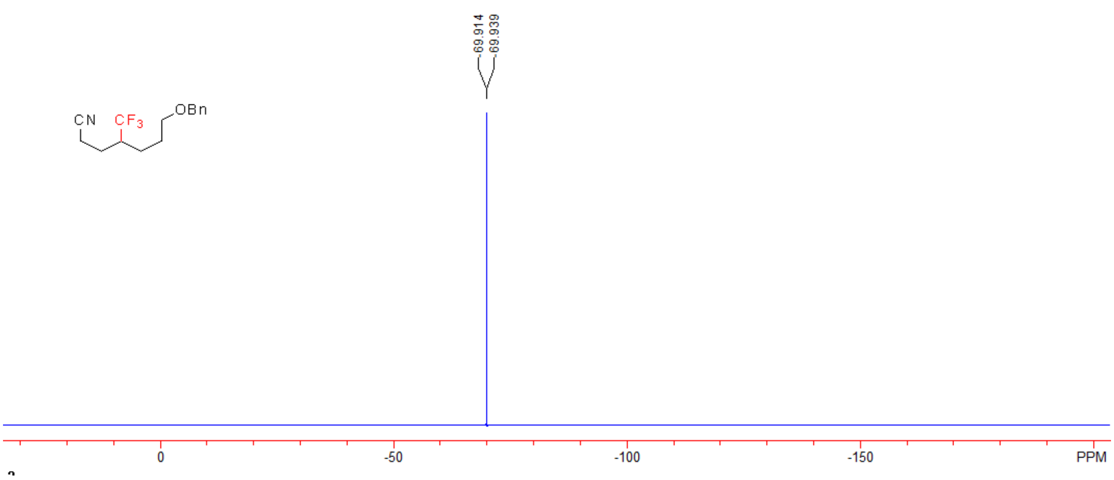
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

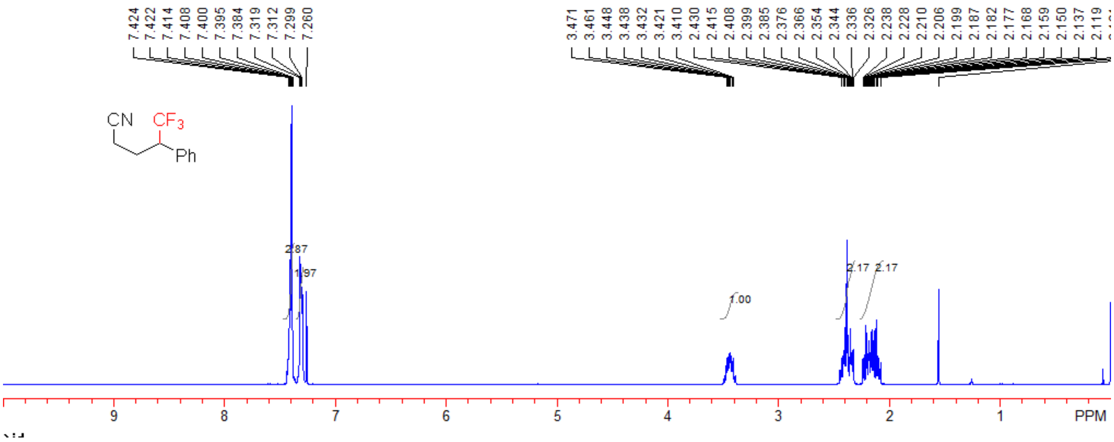


^{19}F NMR (376 MHz, $CDCl_3$):

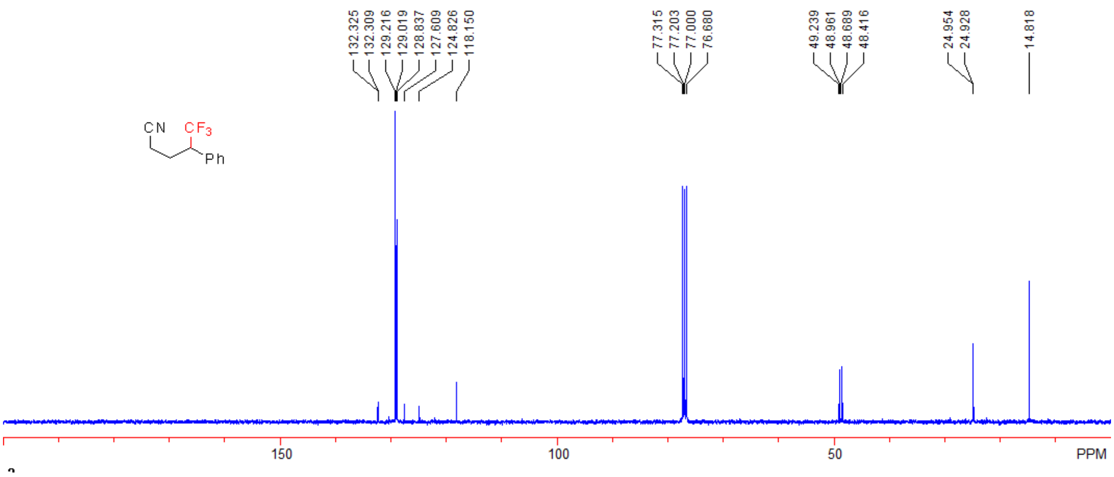


Compound 2w

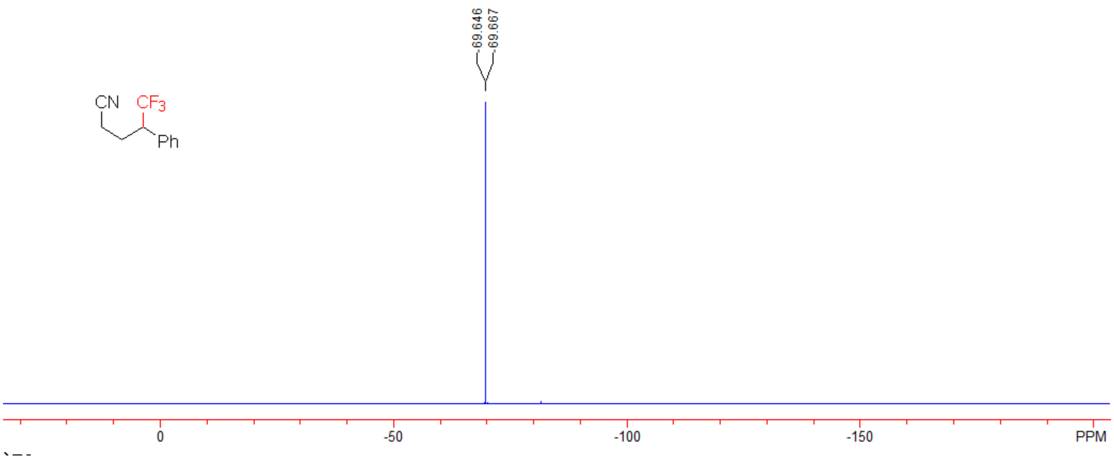
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

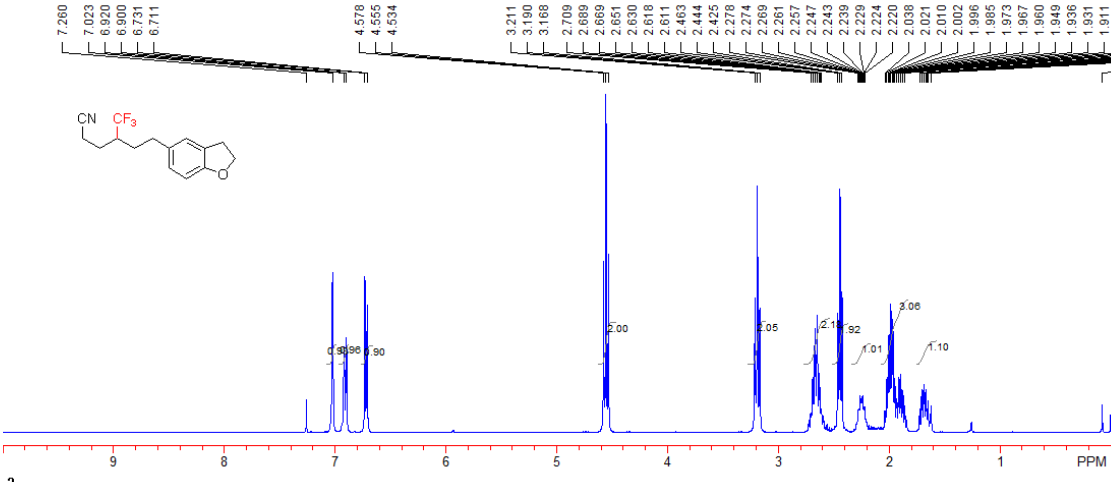


^{19}F NMR (376 MHz, $CDCl_3$):

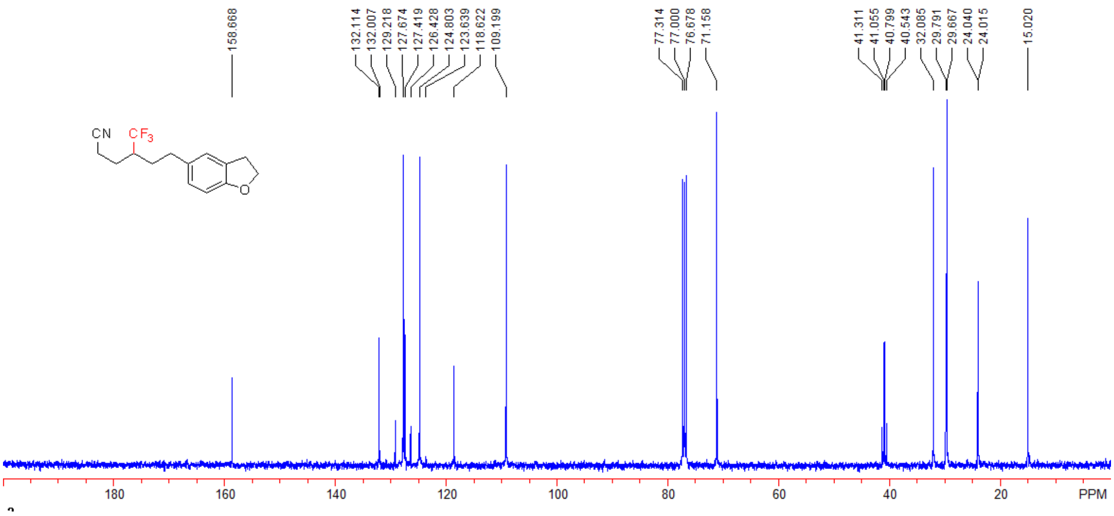


Compound 2x

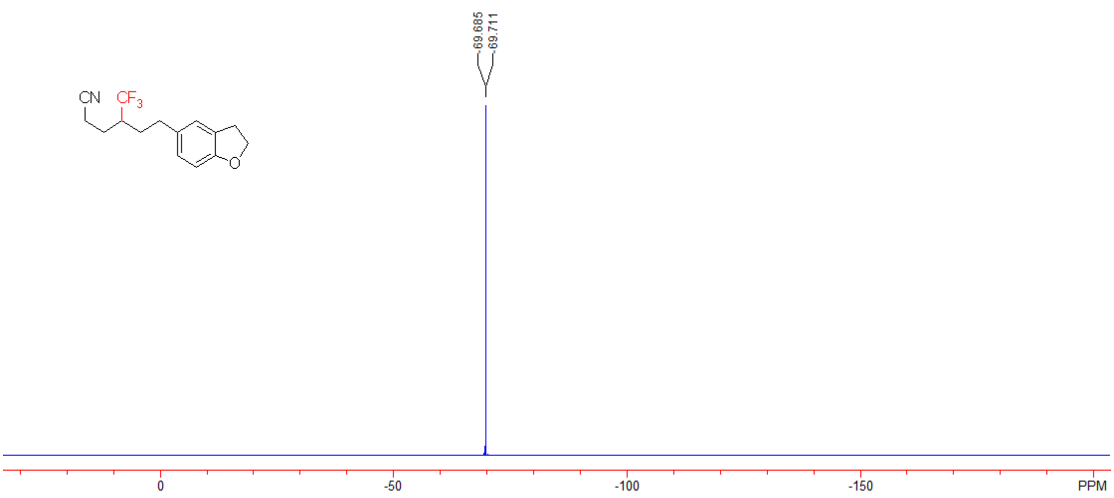
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

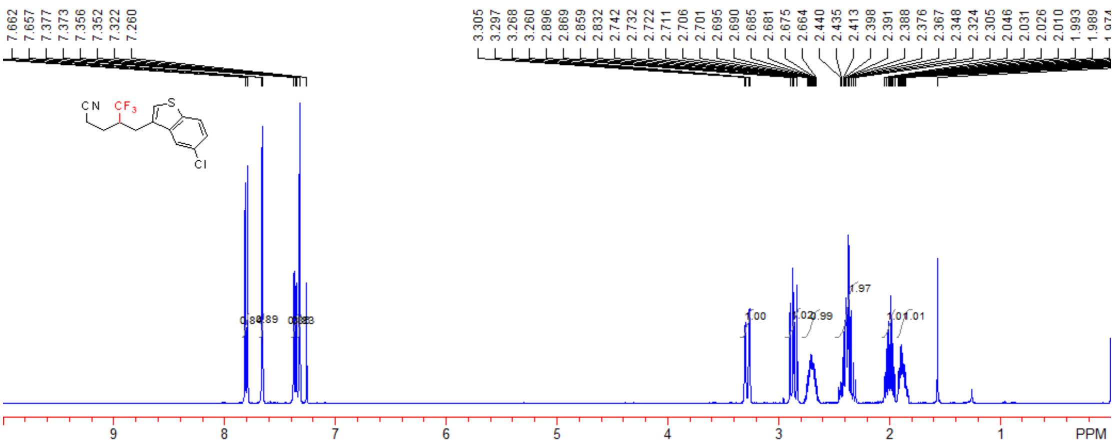


^{19}F NMR (376 MHz, $CDCl_3$):

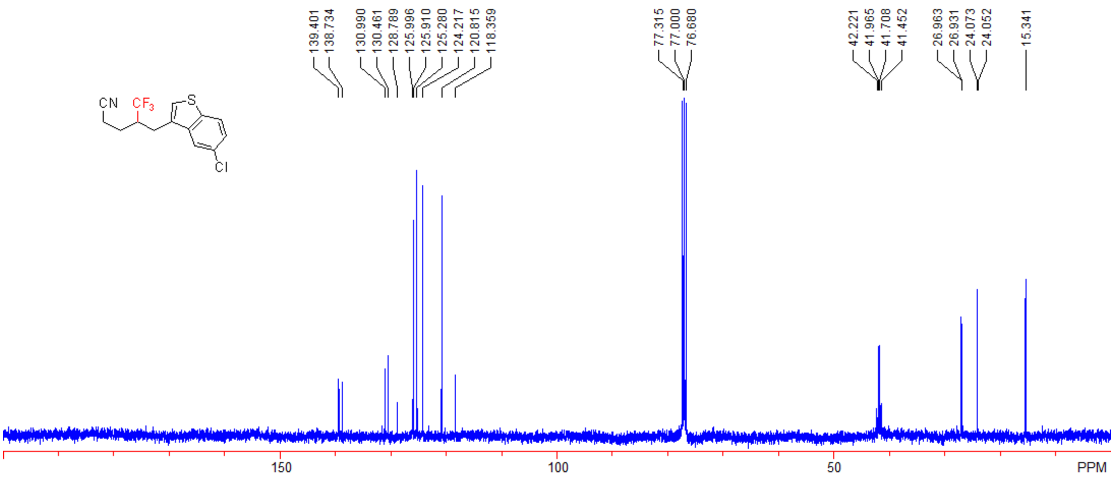


Compound 2y

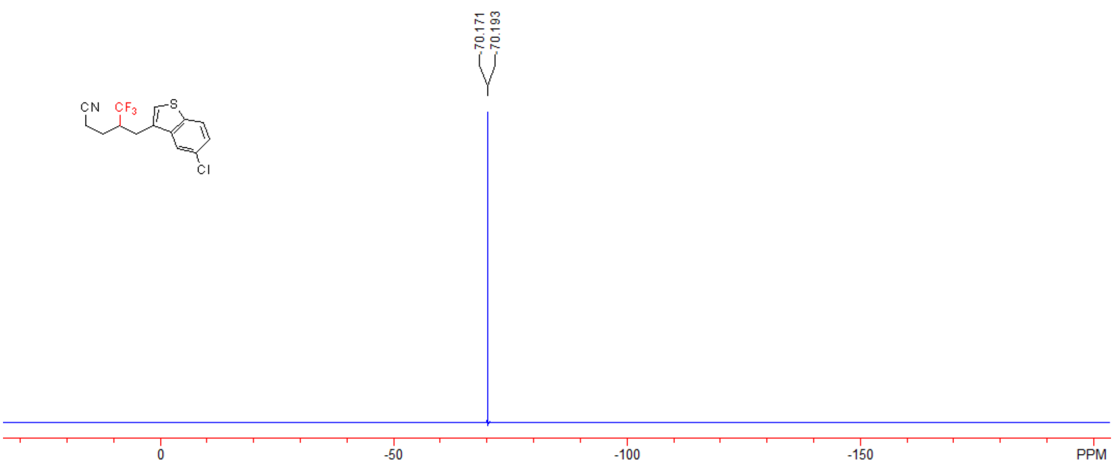
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

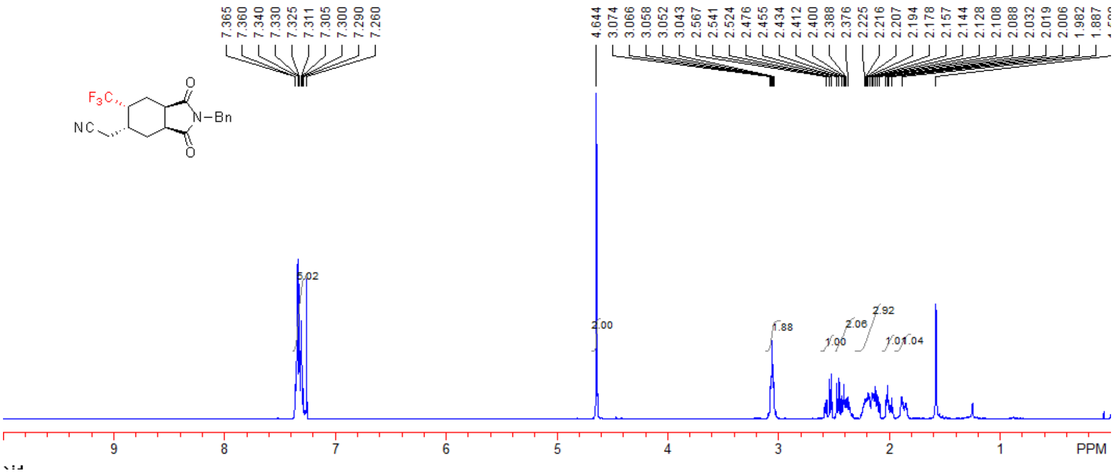


^{19}F NMR (376 MHz, $CDCl_3$):

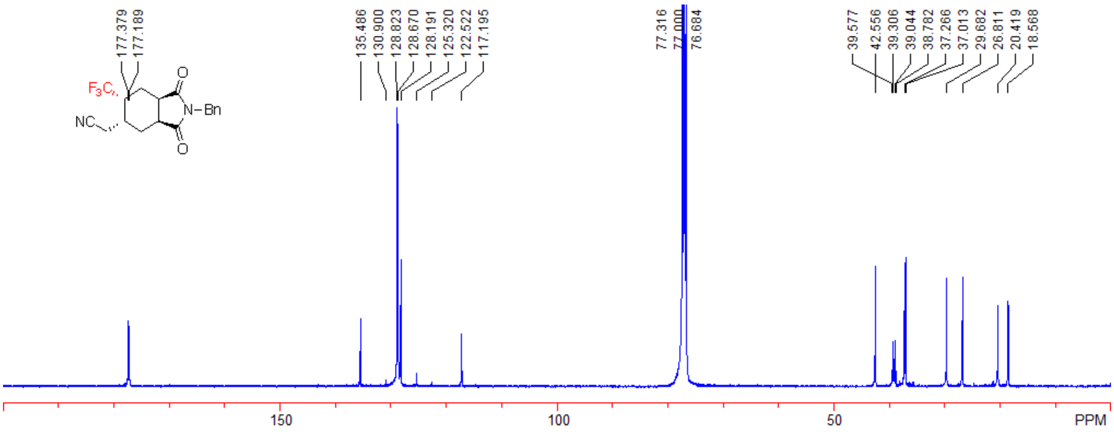


Compound cis-2z

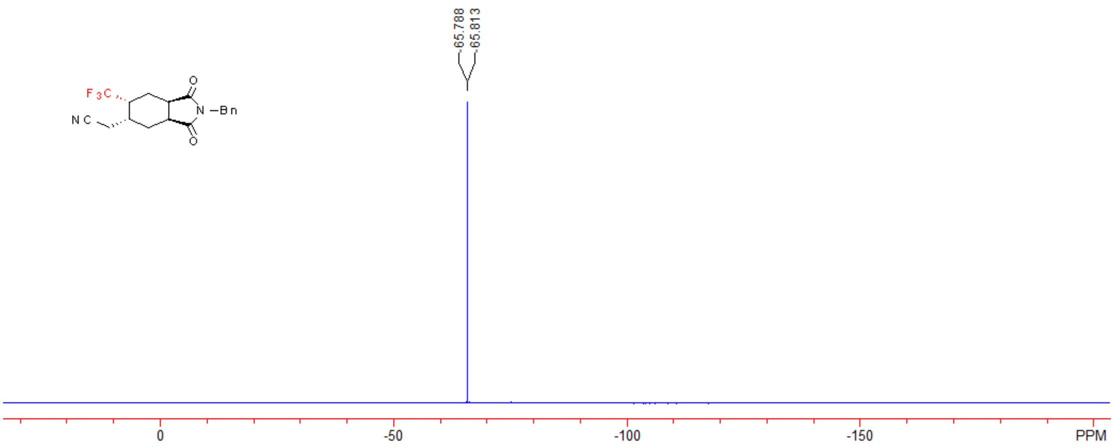
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

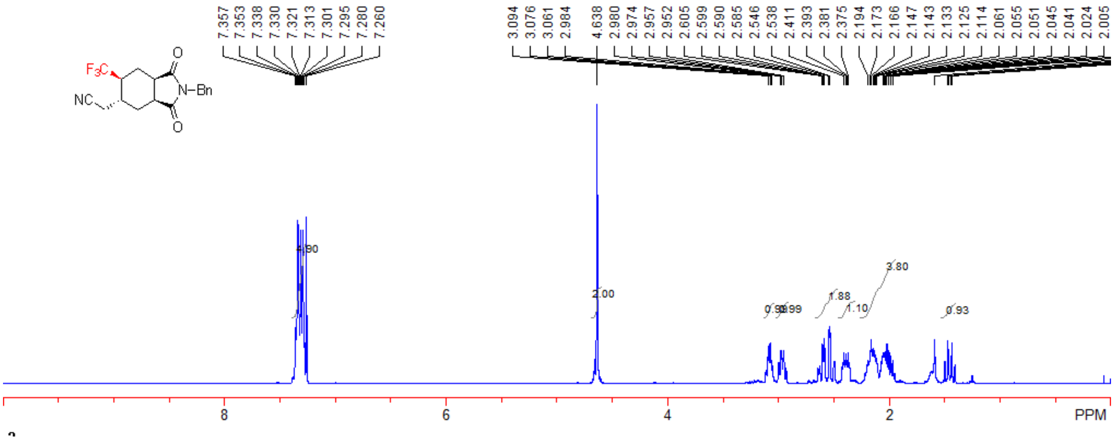


^{19}F NMR (376 MHz, $CDCl_3$):

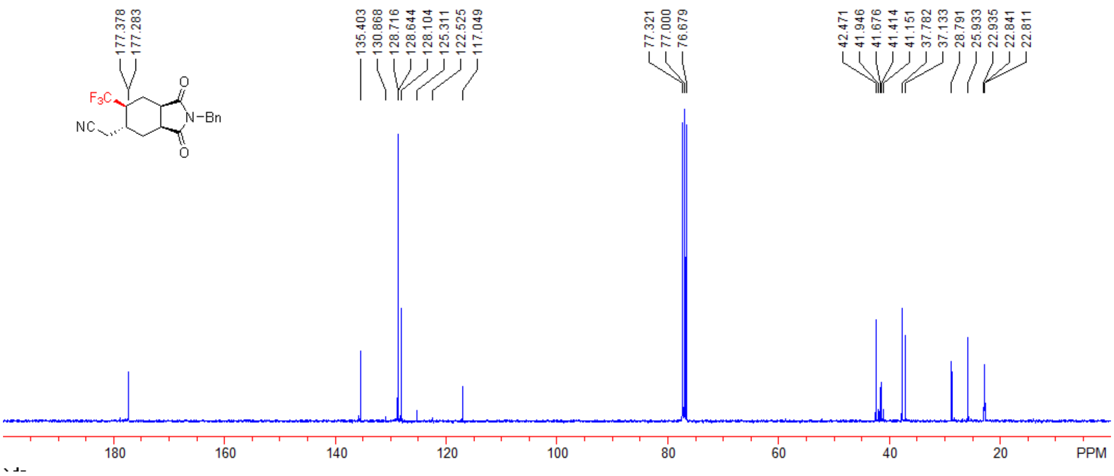


Compound trans-2z

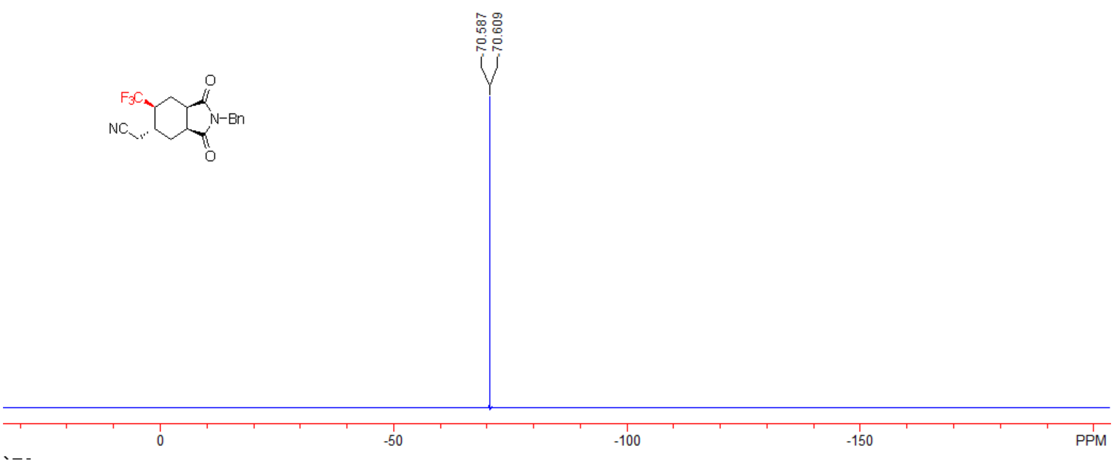
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

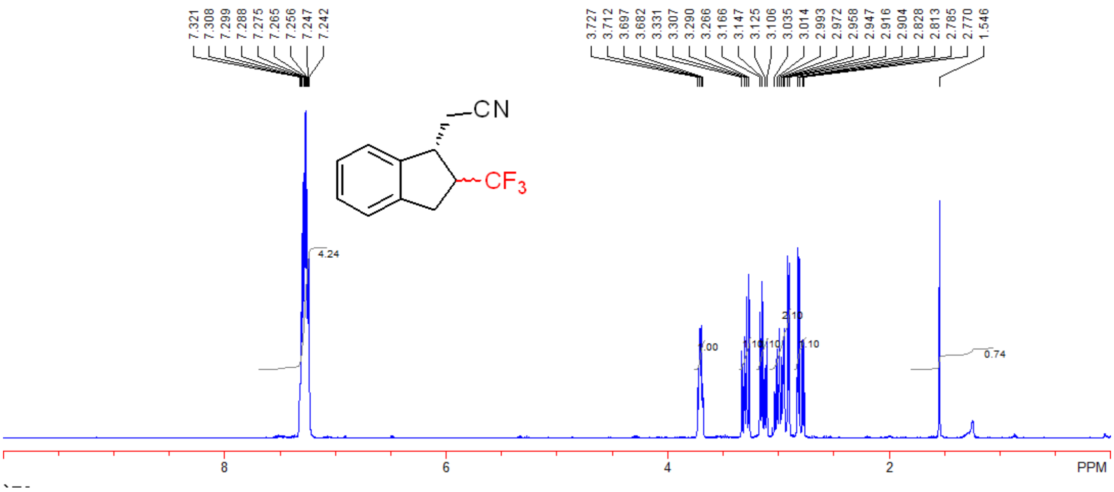


^{19}F NMR (376 MHz, $CDCl_3$):

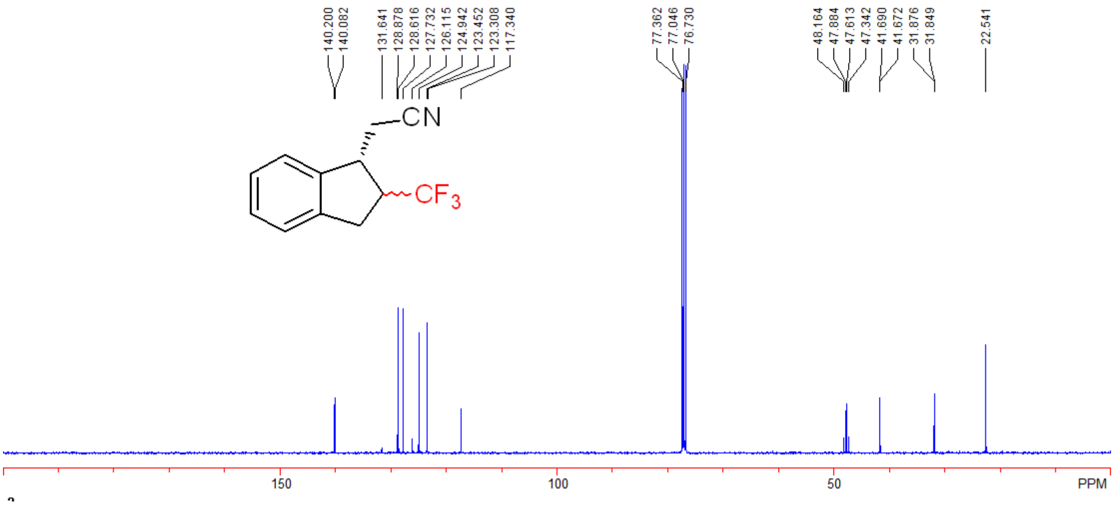


Compound 2za

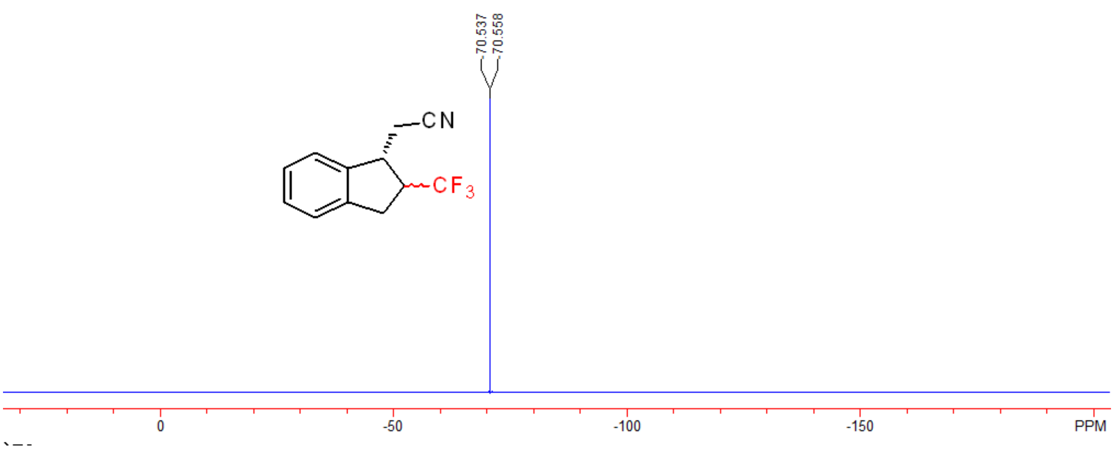
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

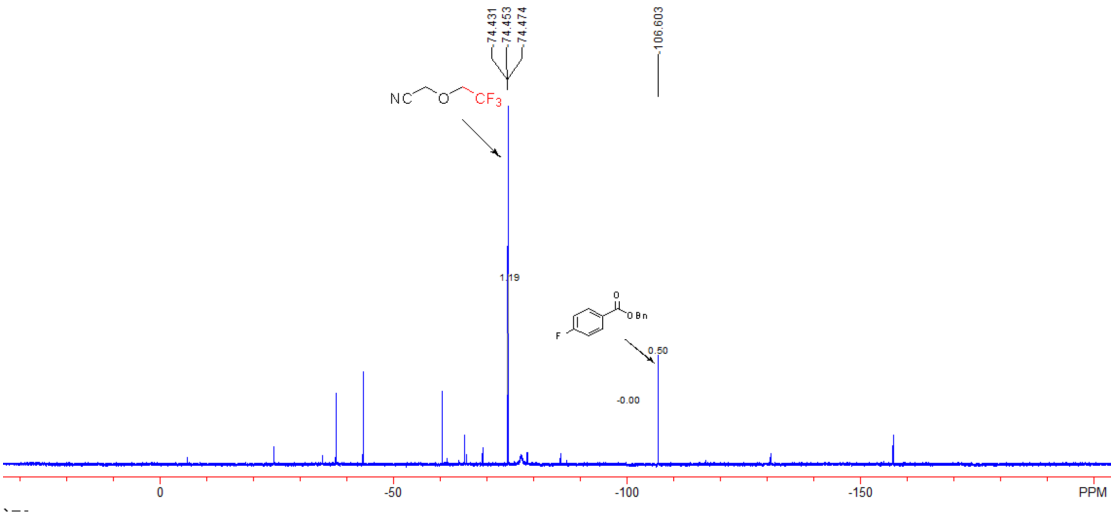


^{19}F NMR (376 MHz, $CDCl_3$):



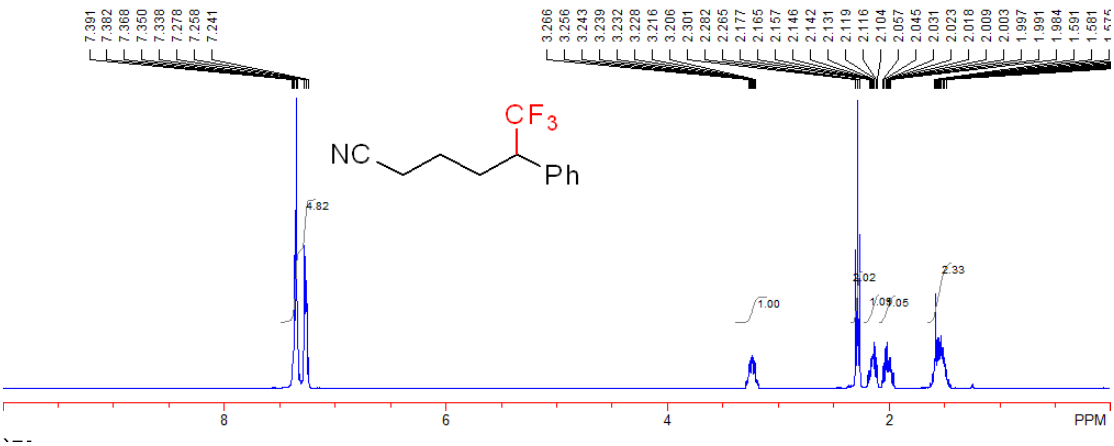
Compound 2zb

^{19}F NMR (376 MHz, DCM):

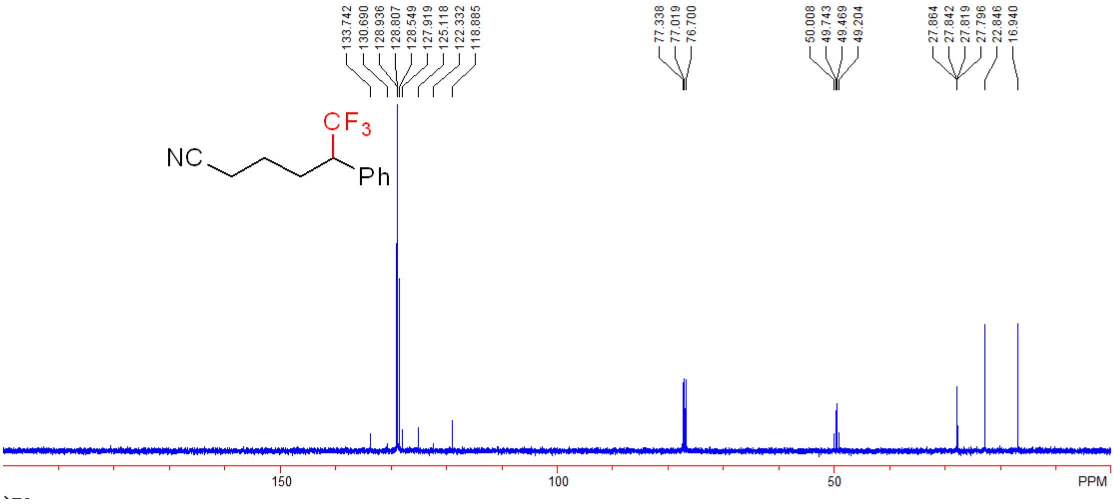


Compound 3a

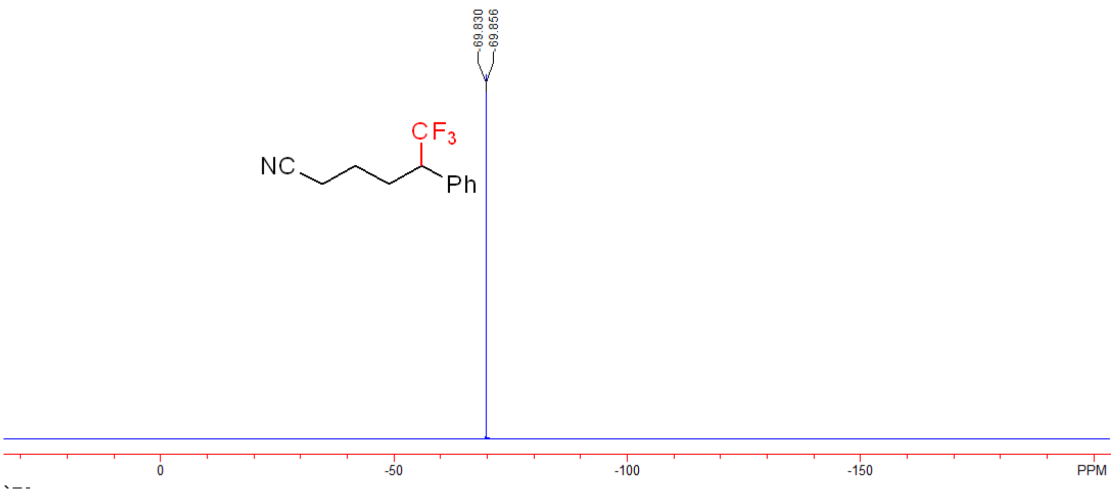
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

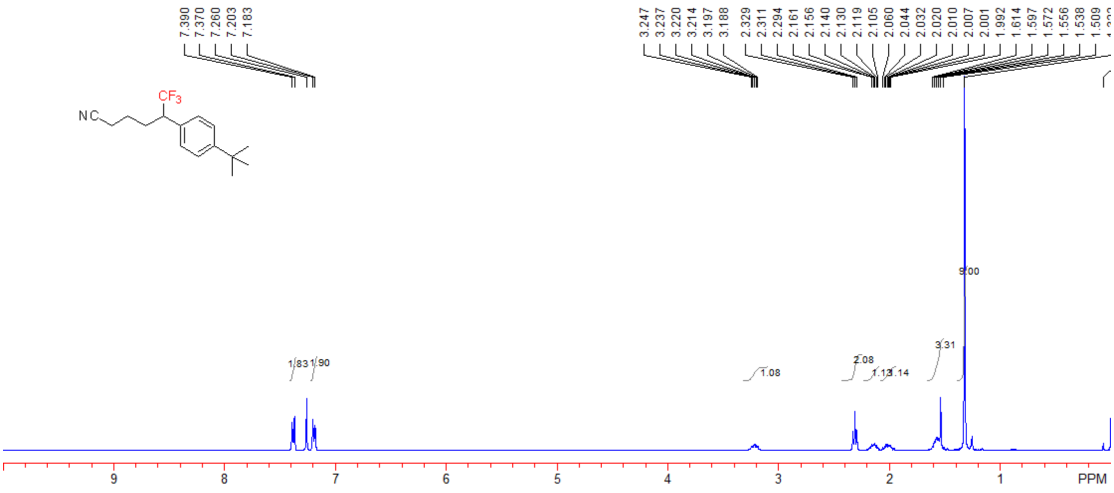


^{19}F NMR (376 MHz, $CDCl_3$):

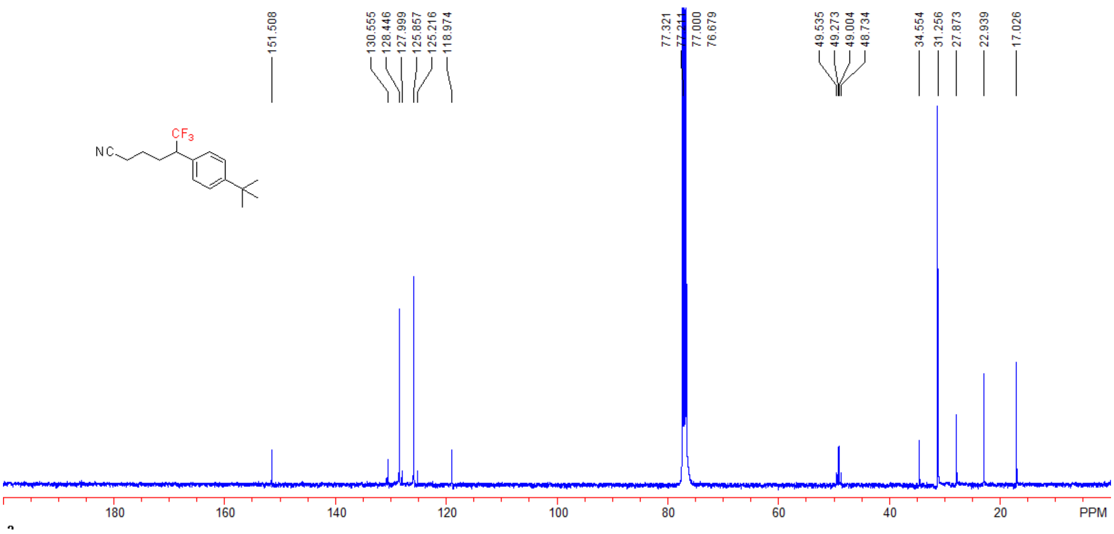


Compound 3b

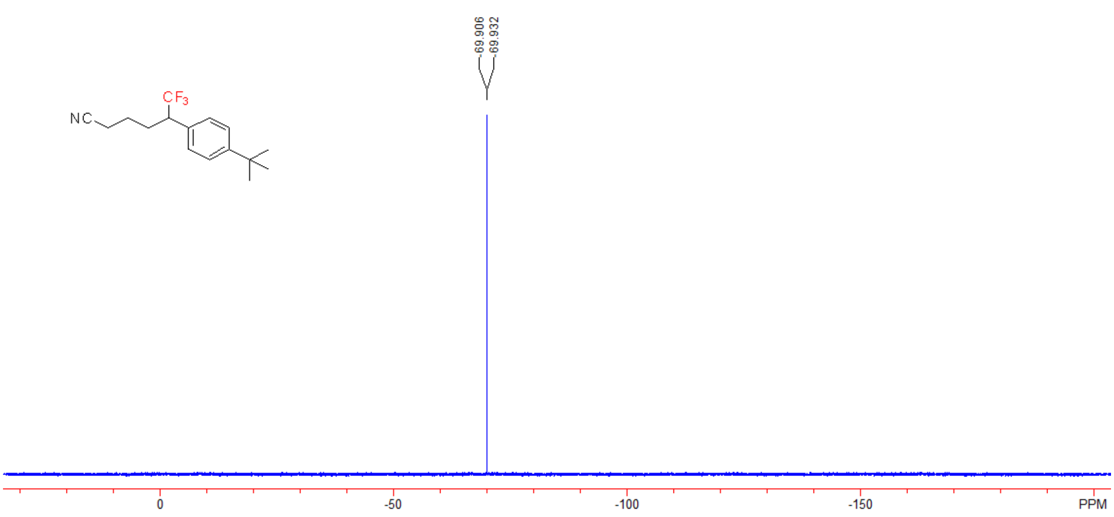
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

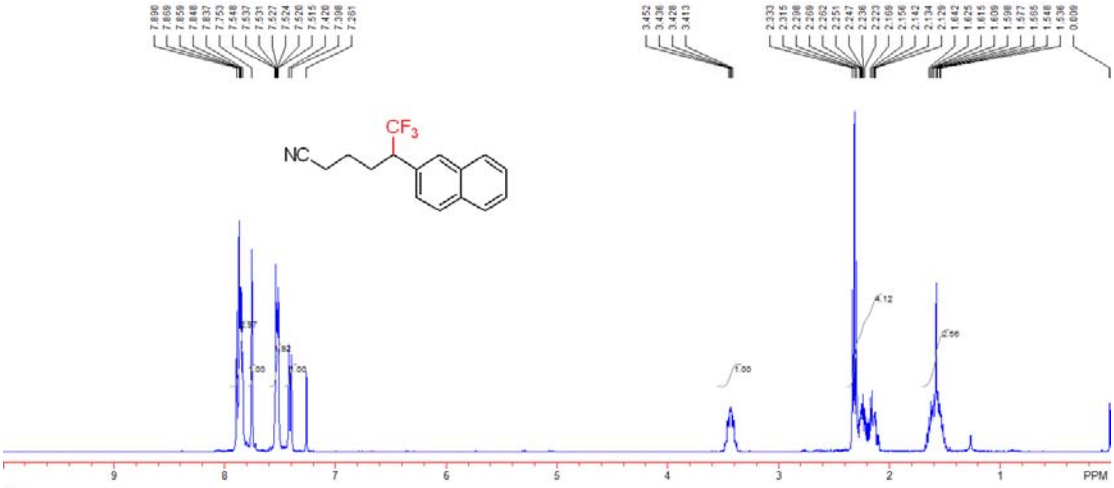


^{19}F NMR (376 MHz, $CDCl_3$):

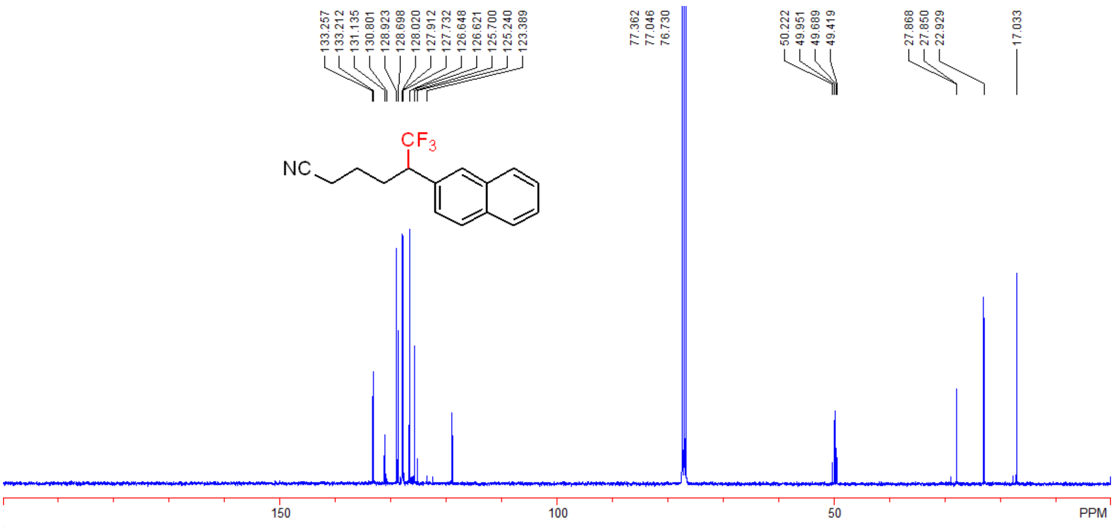


Compound 3c

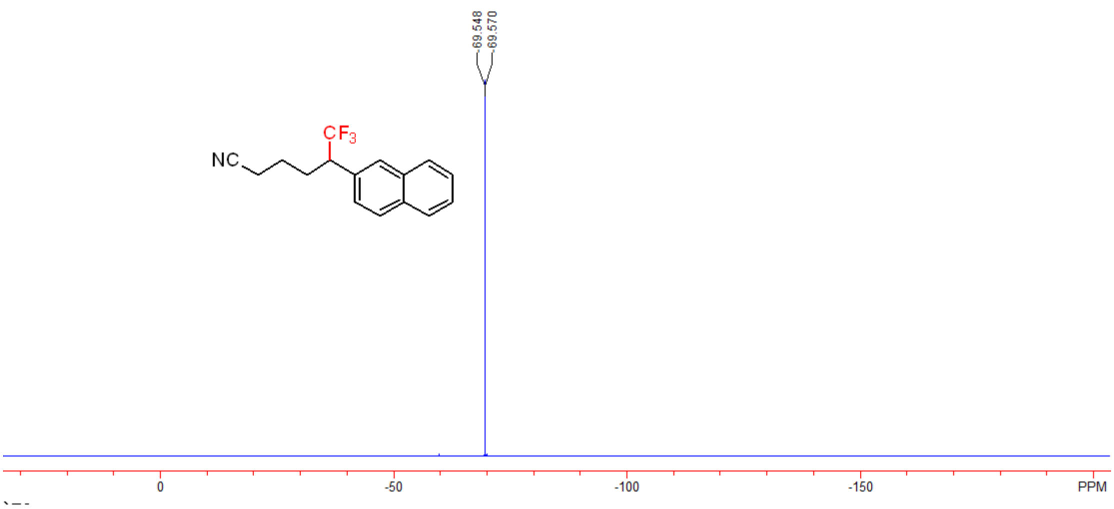
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

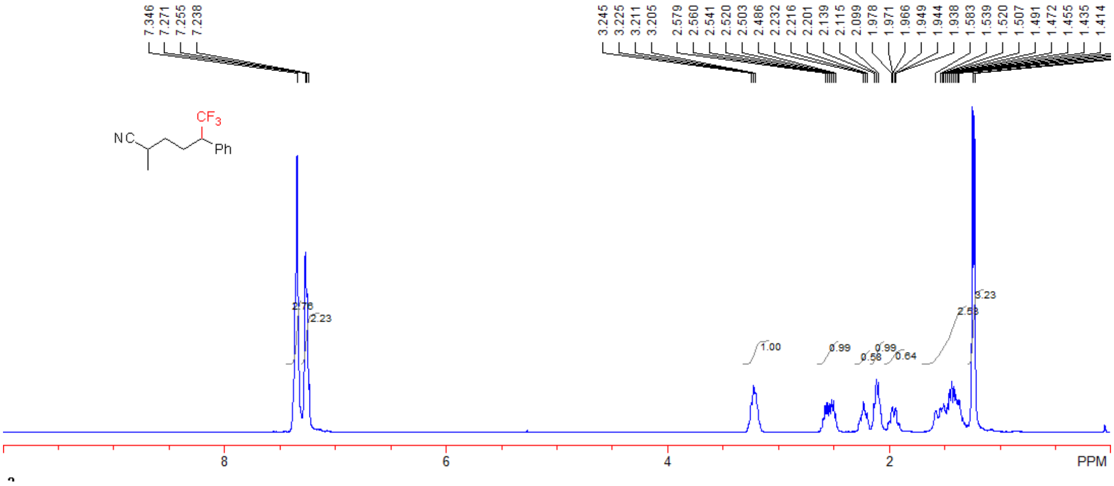


^{19}F NMR (376 MHz, $CDCl_3$):

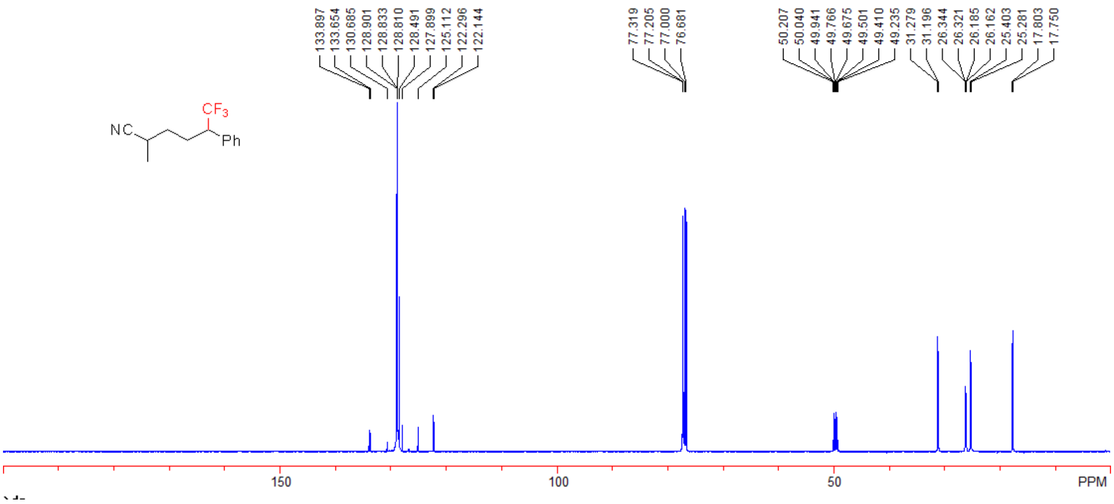


Compound 3d

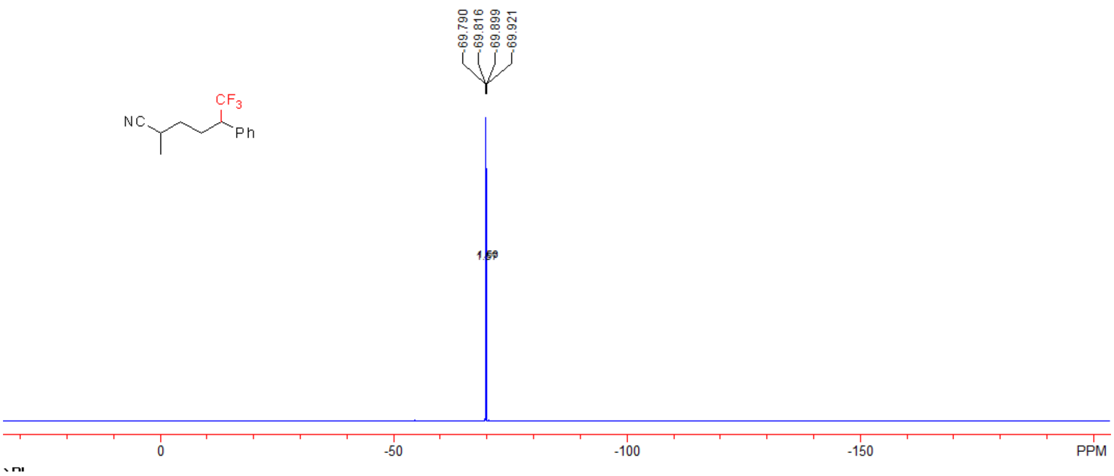
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

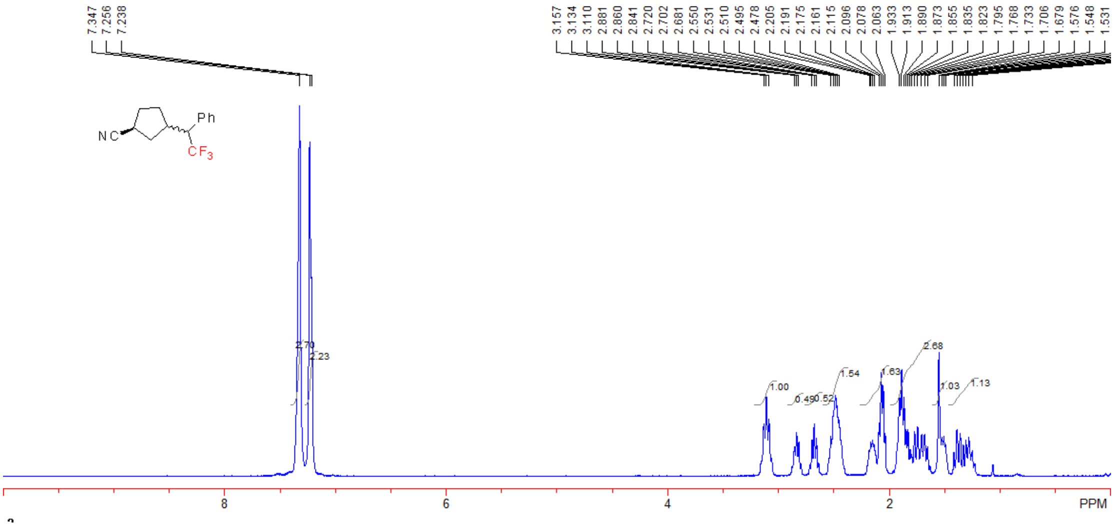


^{19}F NMR (376 MHz, $CDCl_3$):

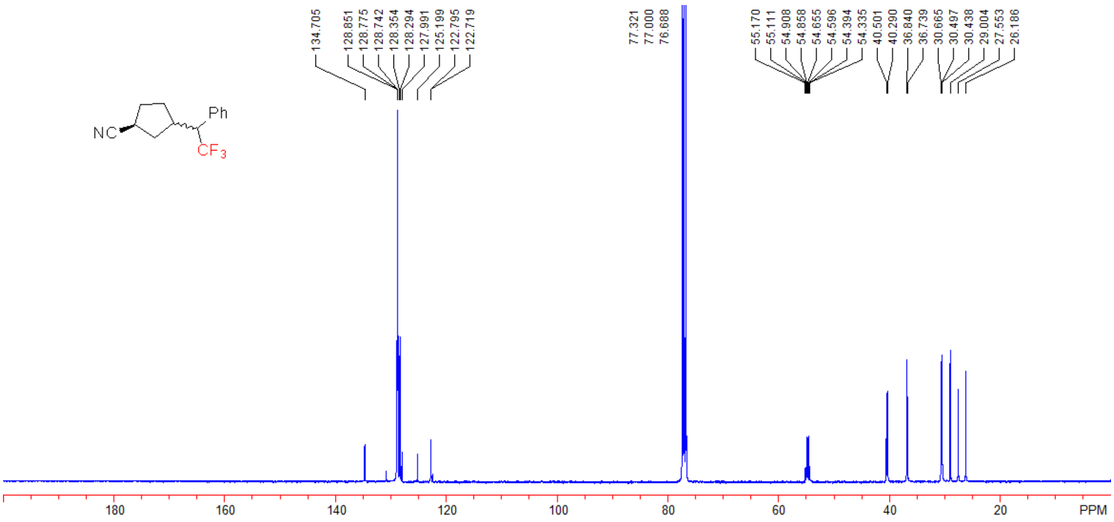


Compound 5a

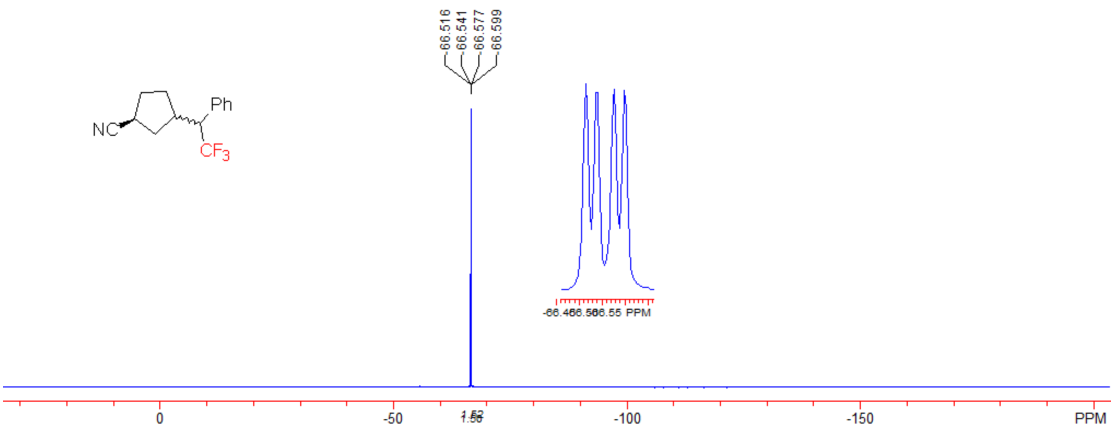
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

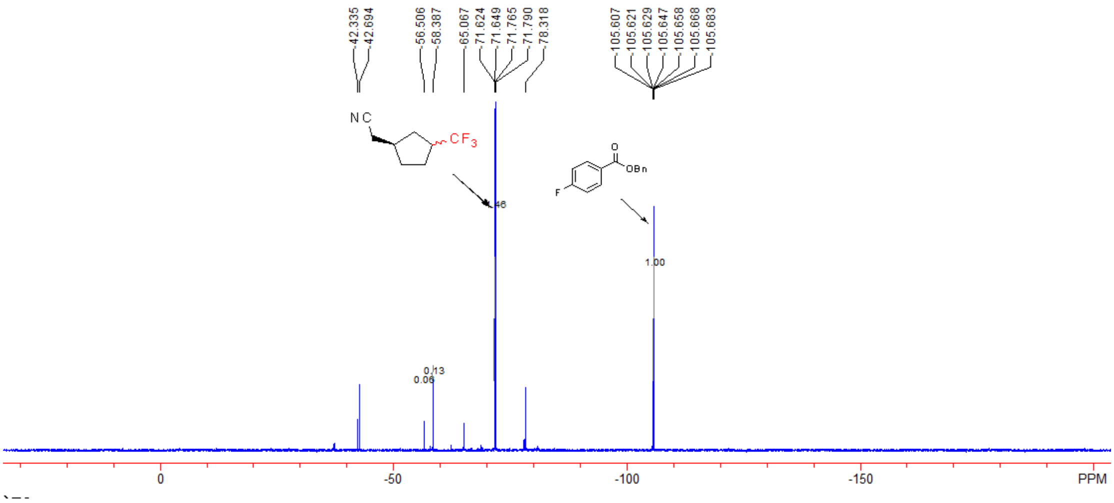


^{19}F NMR (376 MHz, $CDCl_3$):



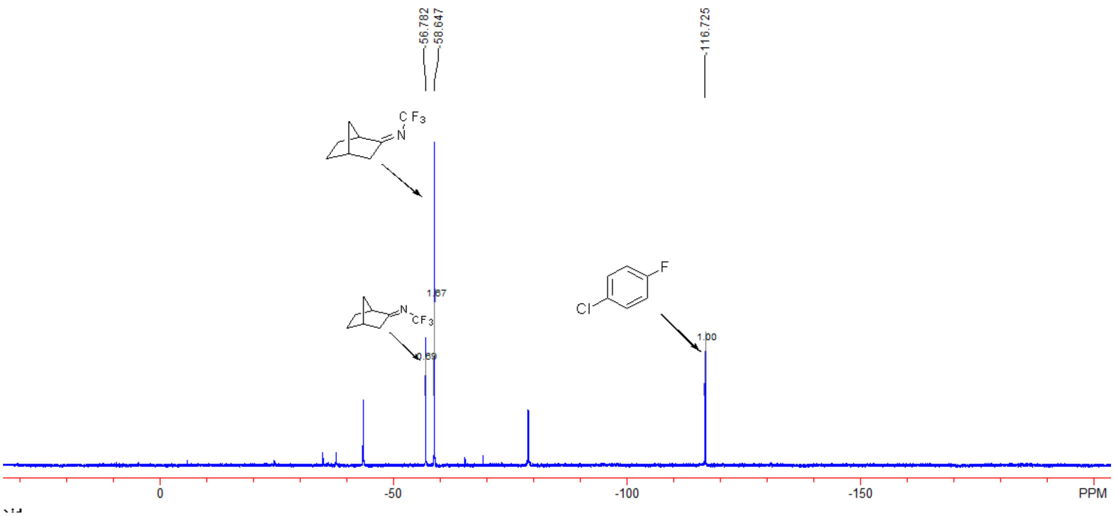
Compound 5b

^{19}F NMR (376 MHz, $CDCl_3$):



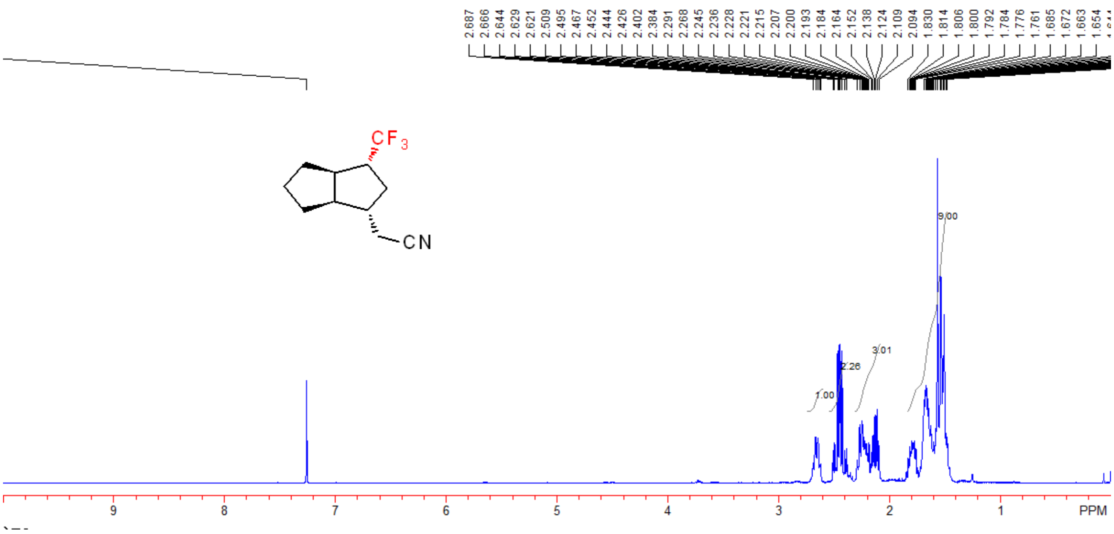
Compound 5ba

^{19}F NMR (376 MHz, CH_2Cl_2):

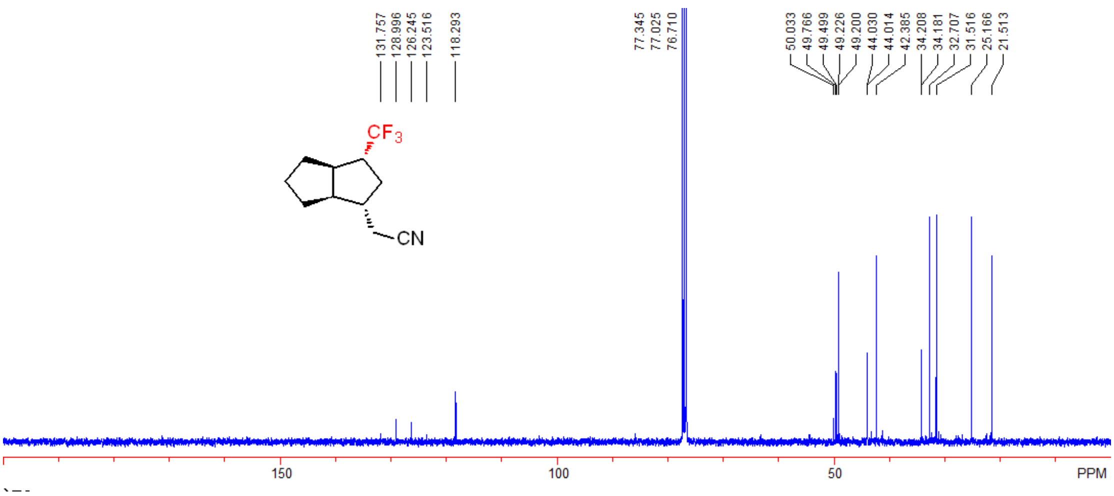


Compound 5c

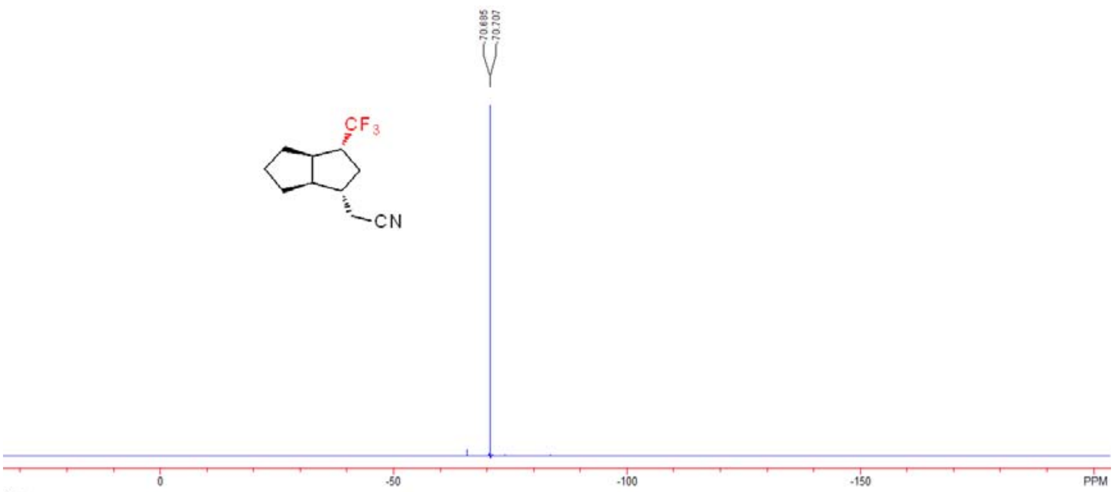
[1]H NMR (400 MHz, $CDCl_3$):



[13]C NMR (100 MHz, $CDCl_3$):

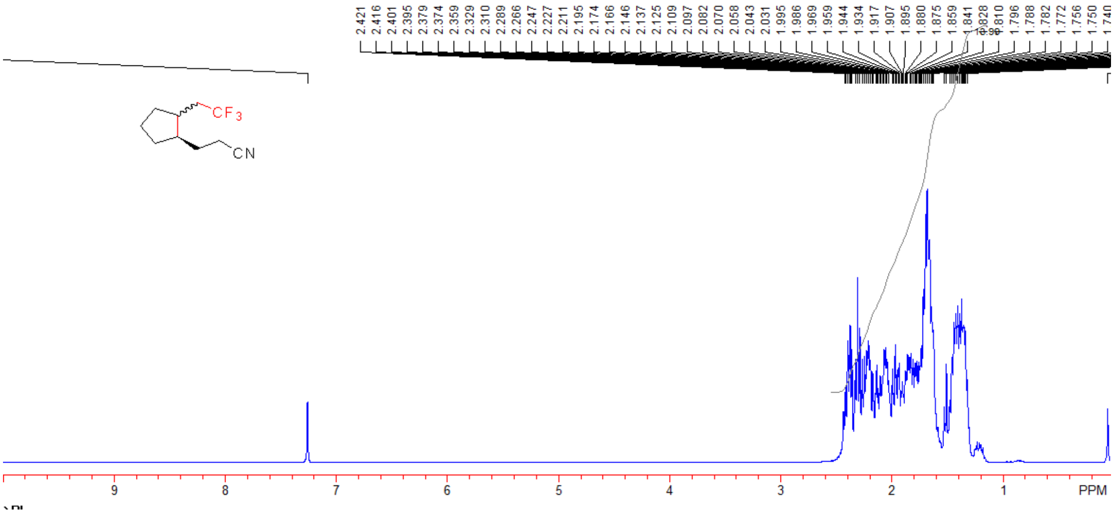


[19]F NMR (376 MHz, $CDCl_3$):

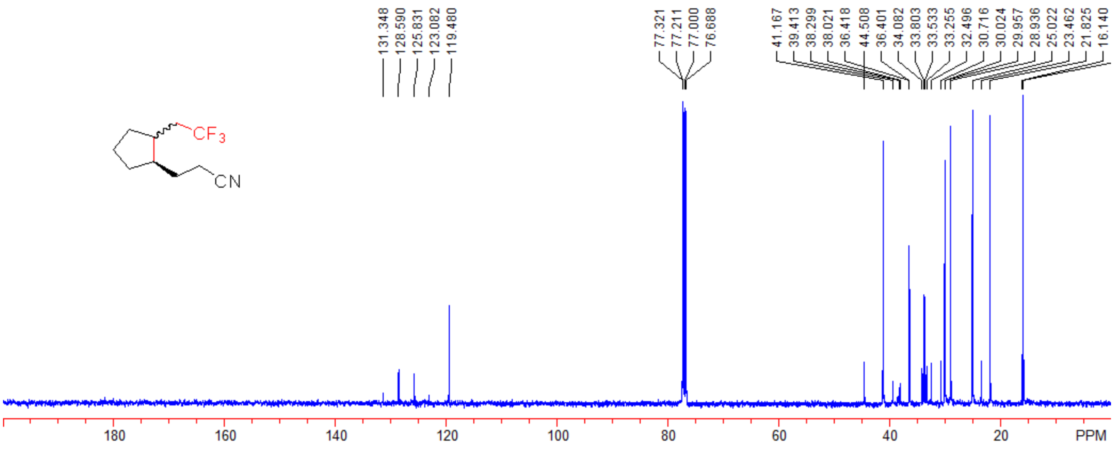


Compound 7

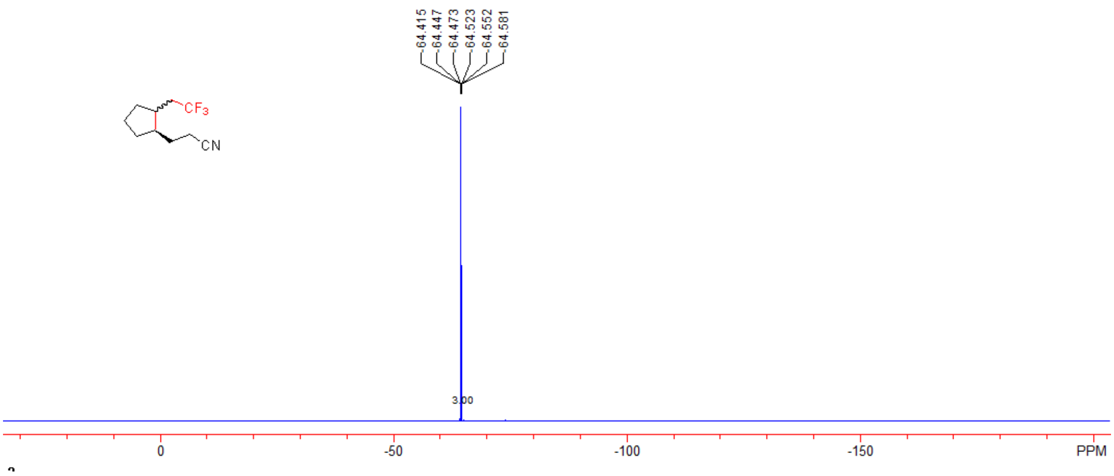
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

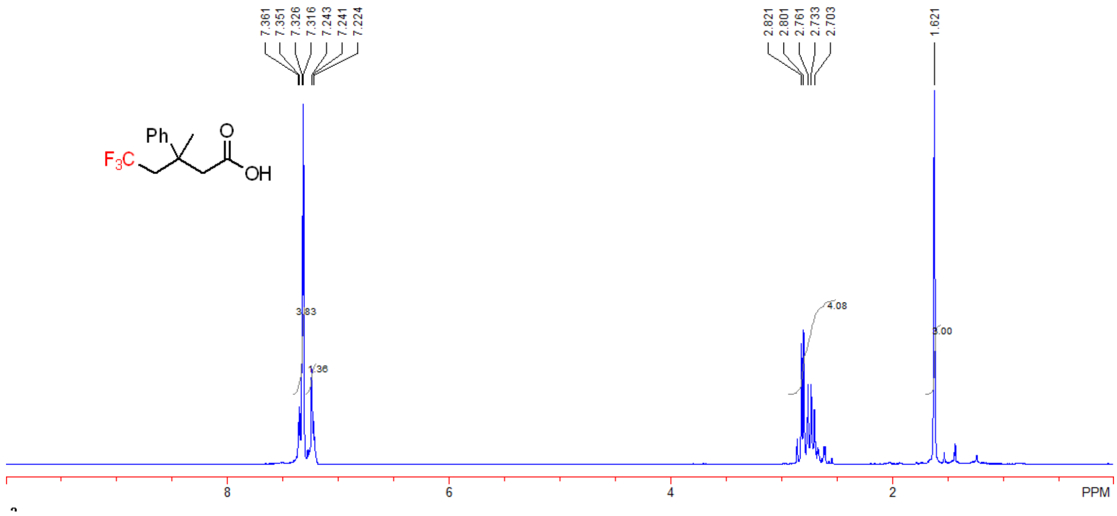


^{19}F NMR (376 MHz, $CDCl_3$):

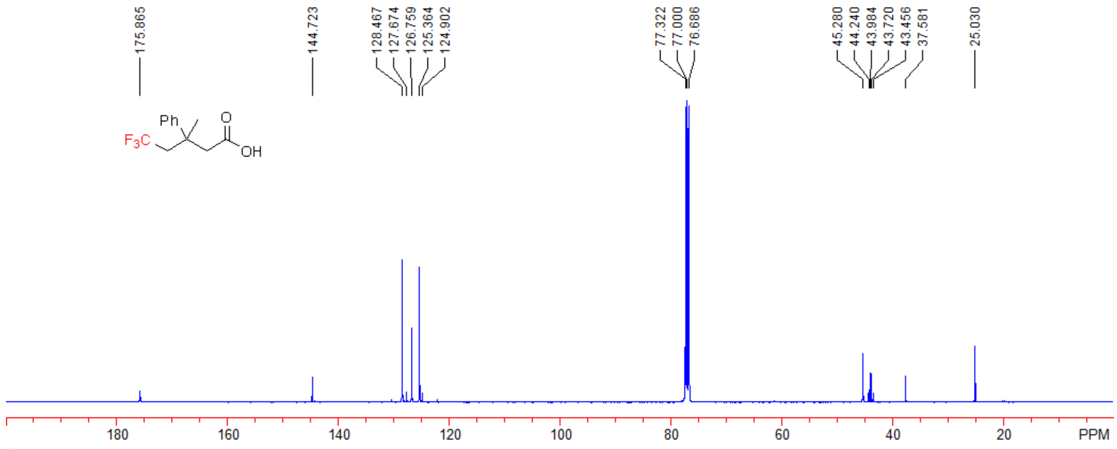


Compound 8a

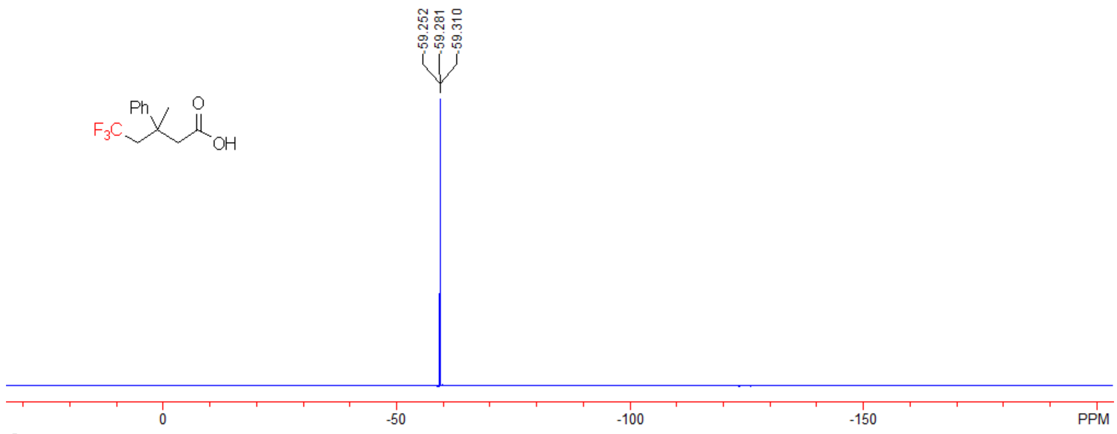
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

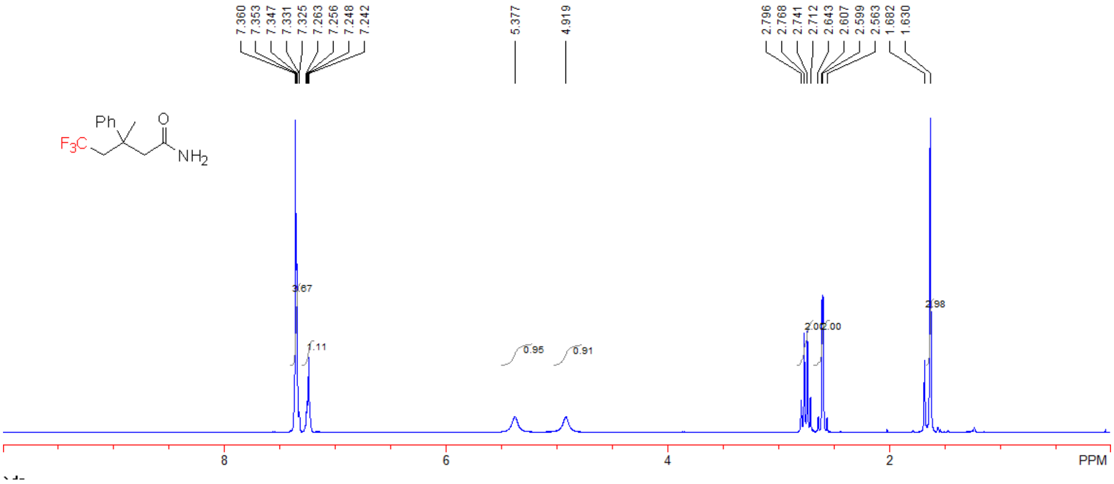


^{19}F NMR (376 MHz, $CDCl_3$):

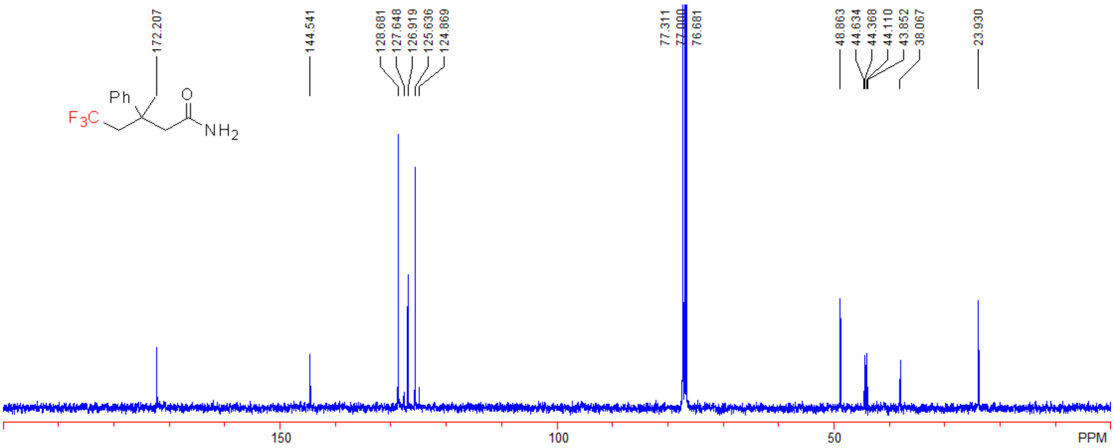


Compound 8b

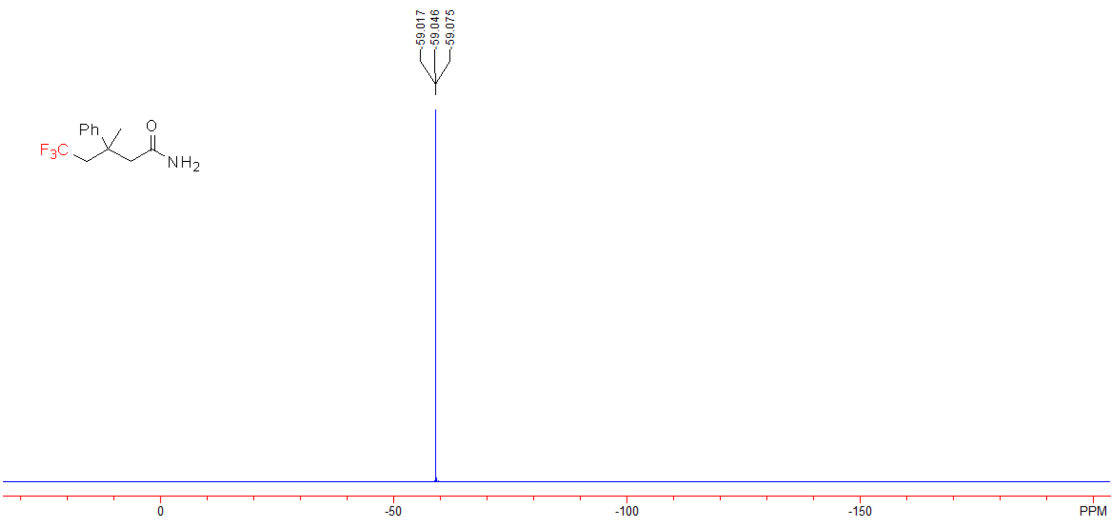
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

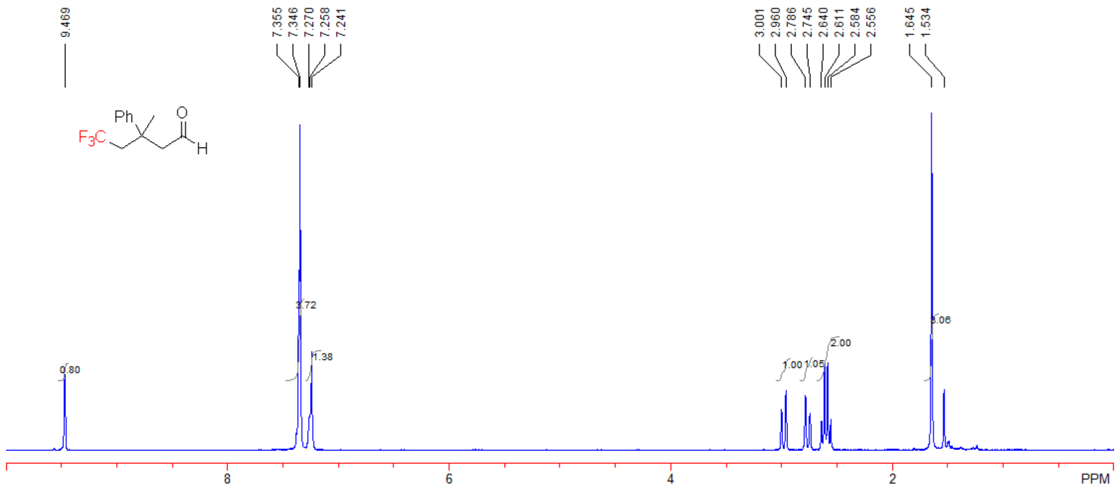


^{19}F NMR (376 MHz, $CDCl_3$):

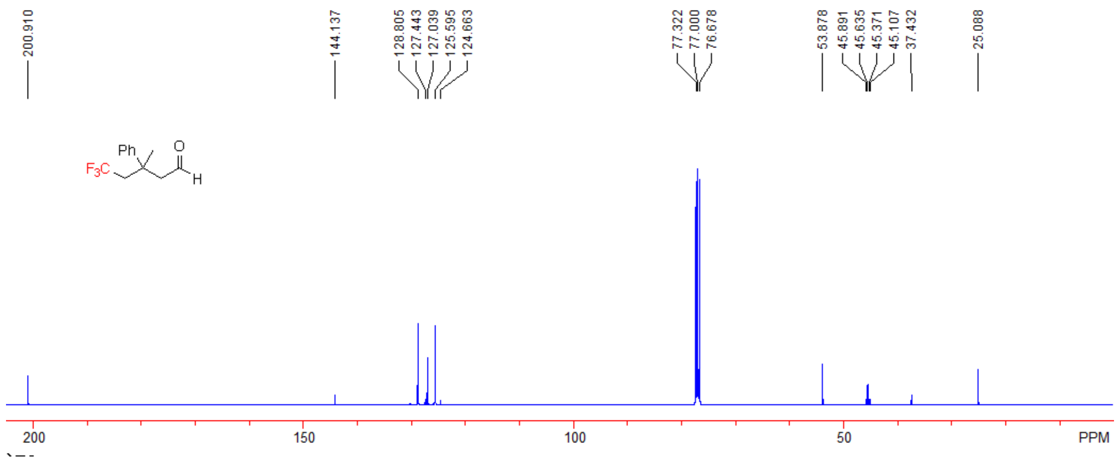


Compound 8c

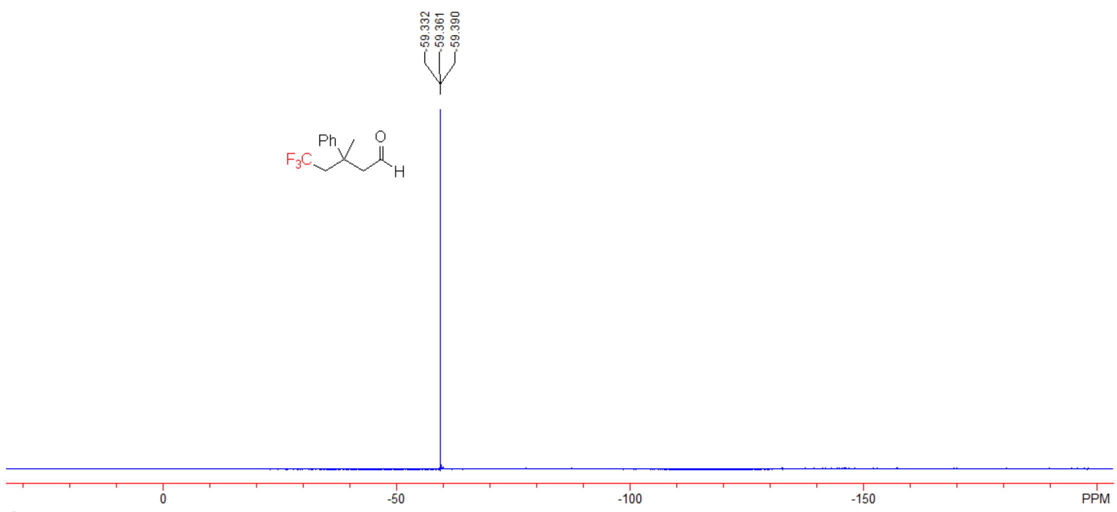
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):

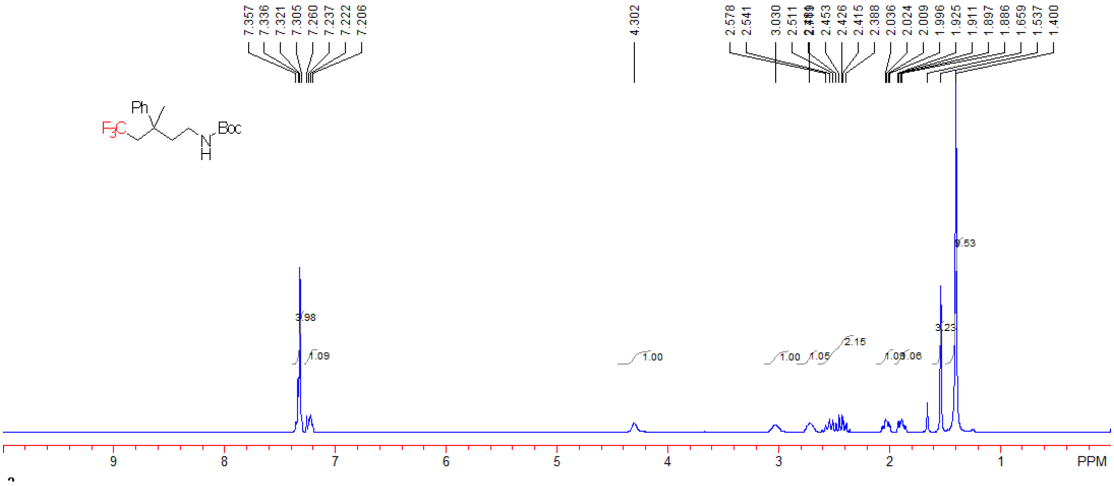


^{19}F NMR (376 MHz, $CDCl_3$):

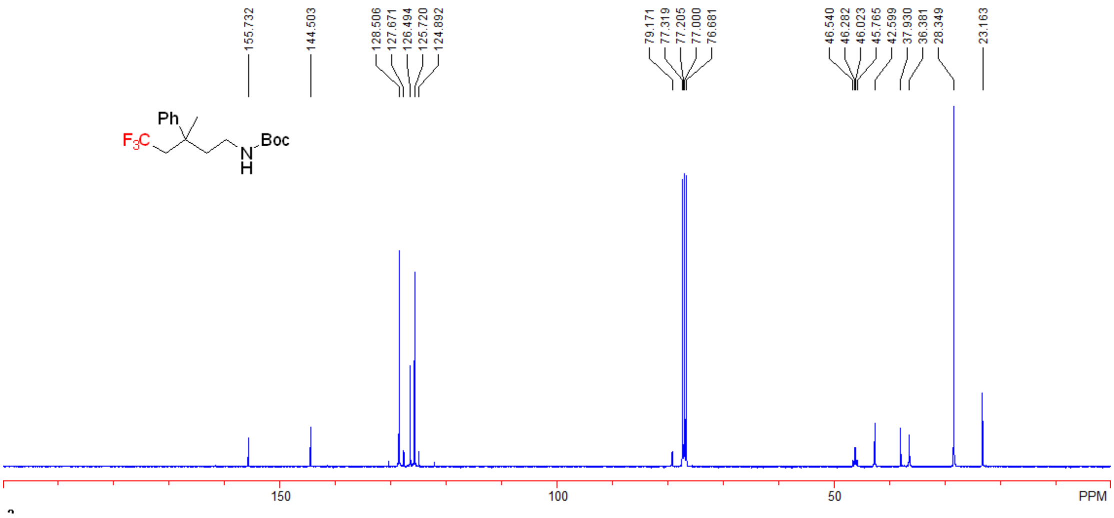


Compound 8d

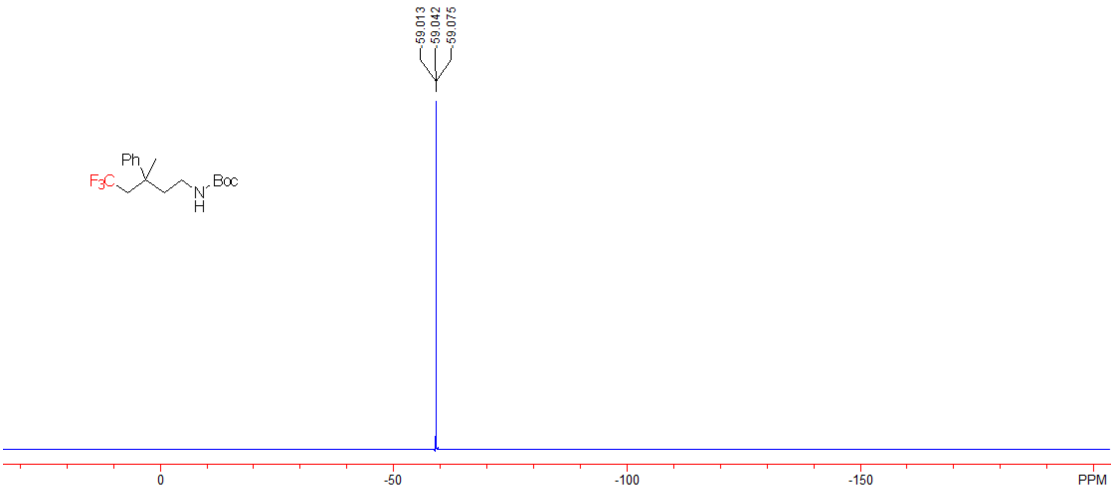
^{1}H NMR (400 MHz, $CDCl_3$):



^{13}C NMR (100 MHz, $CDCl_3$):



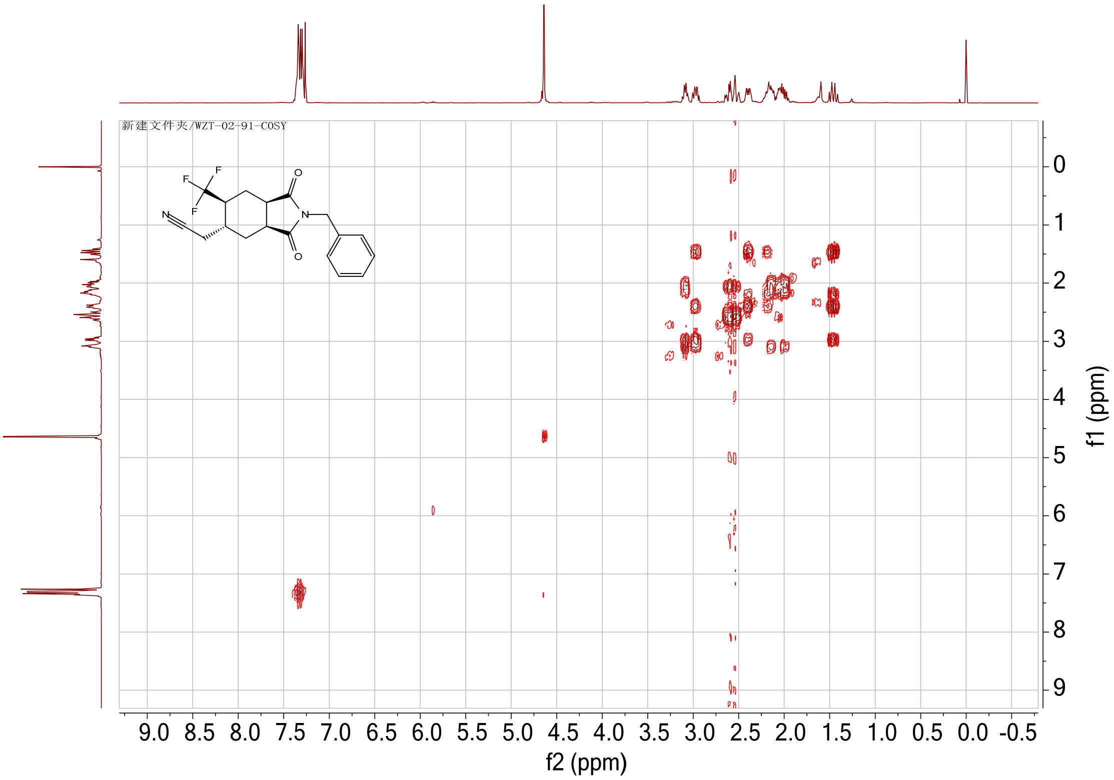
^{19}F NMR (376 MHz, $CDCl_3$):



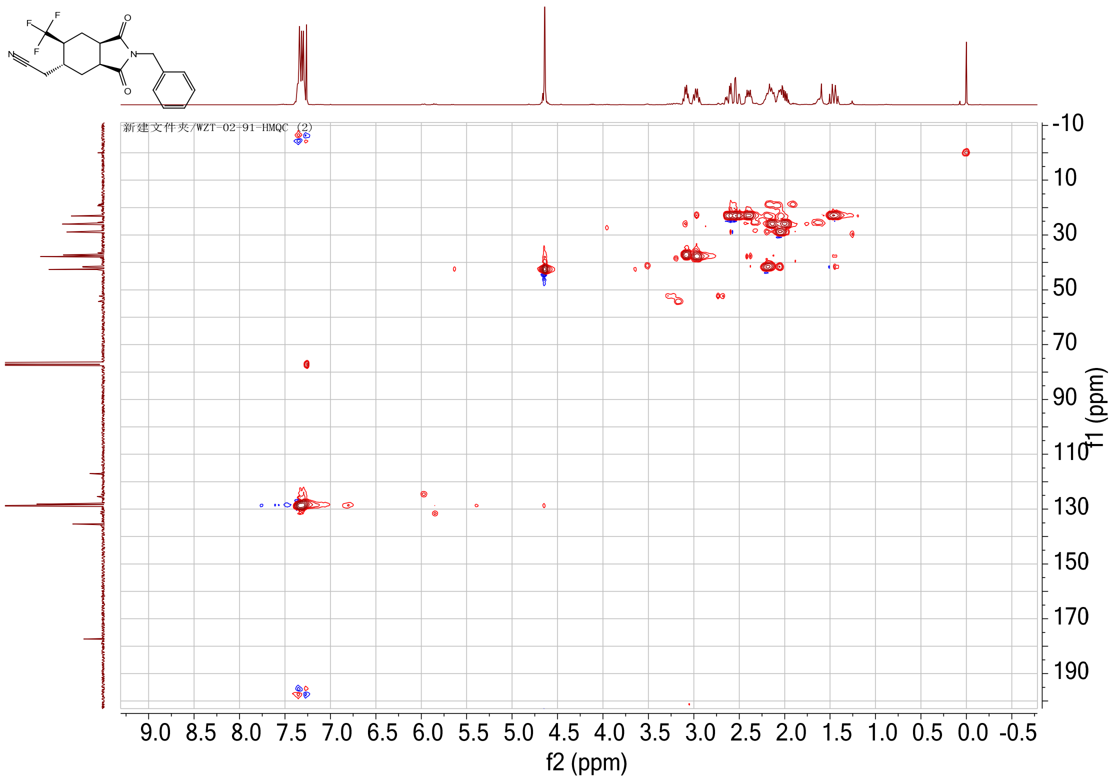
9. 2D NMR spectra of compounds 2z, 2za and 5c.

Compound 2z

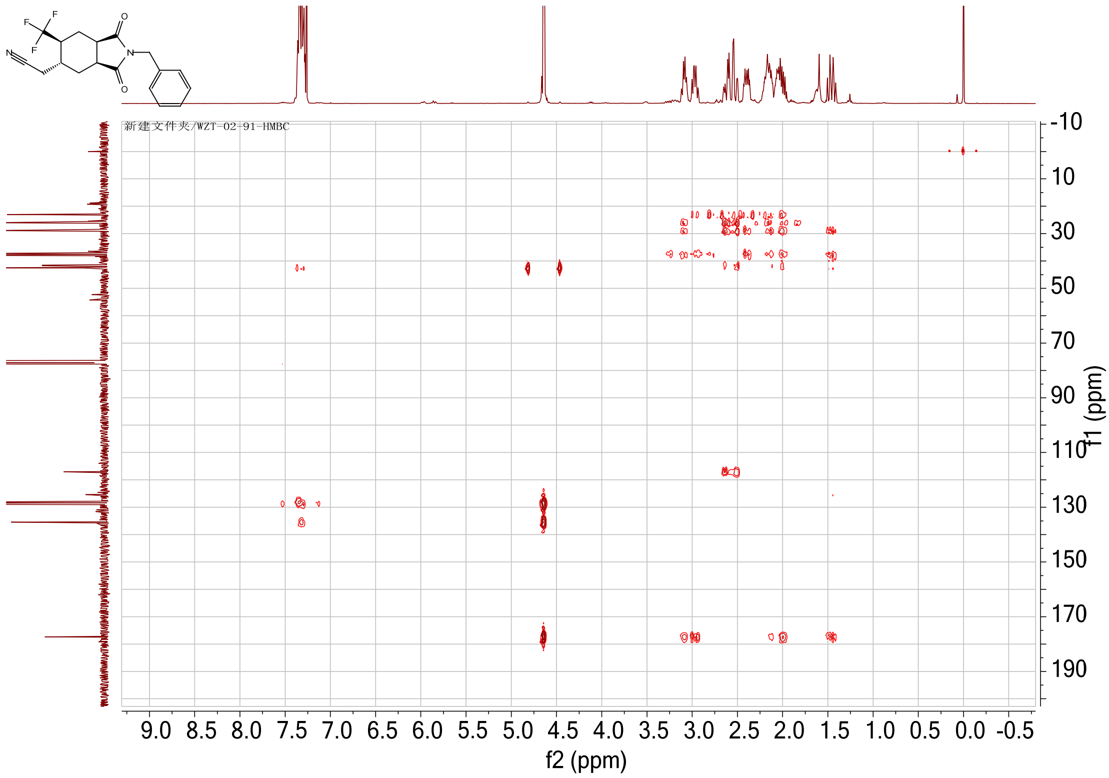
COSY (400 MHz, $CDCl_3$):



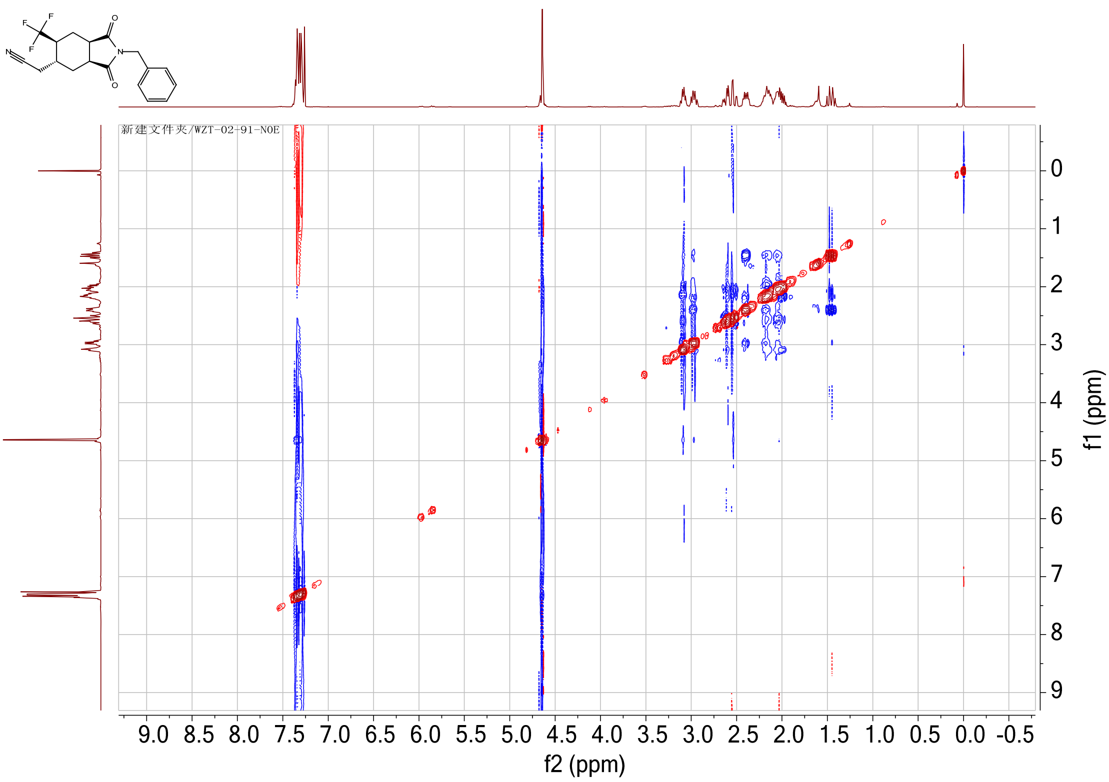
HMQC (400 MHz, $CDCl_3$):



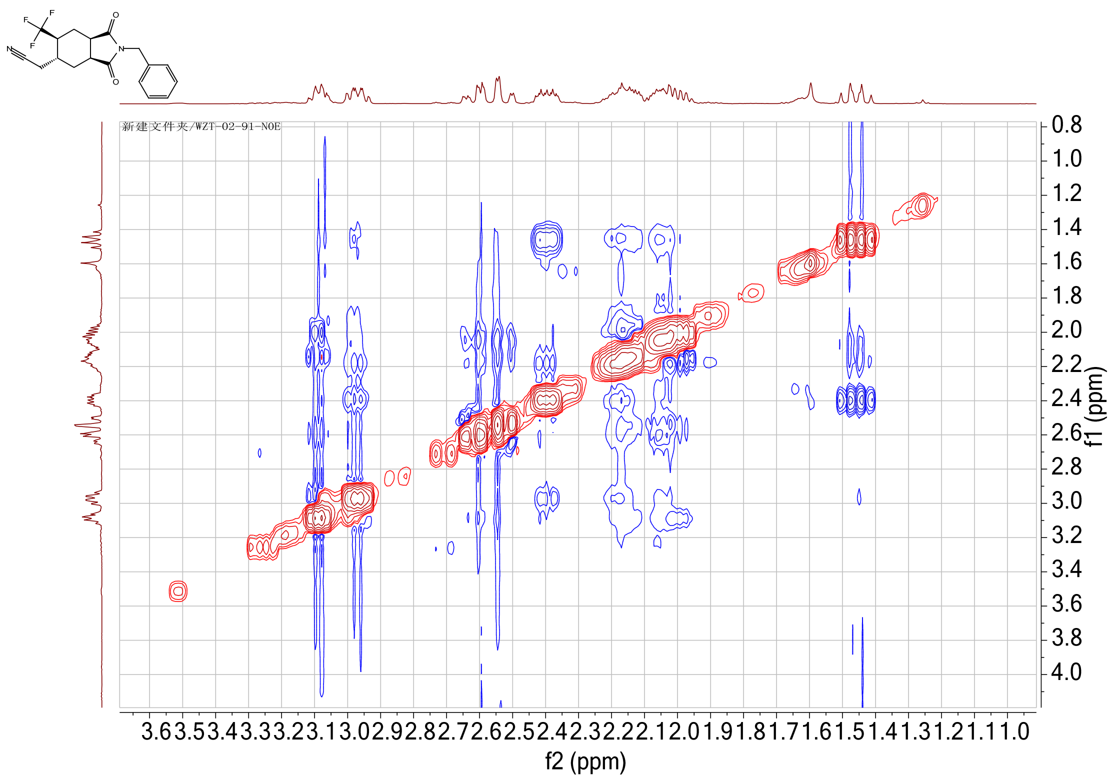
HMBC (400 MHz, CDCl3):



NOESY (400 MHz, CDCl3):

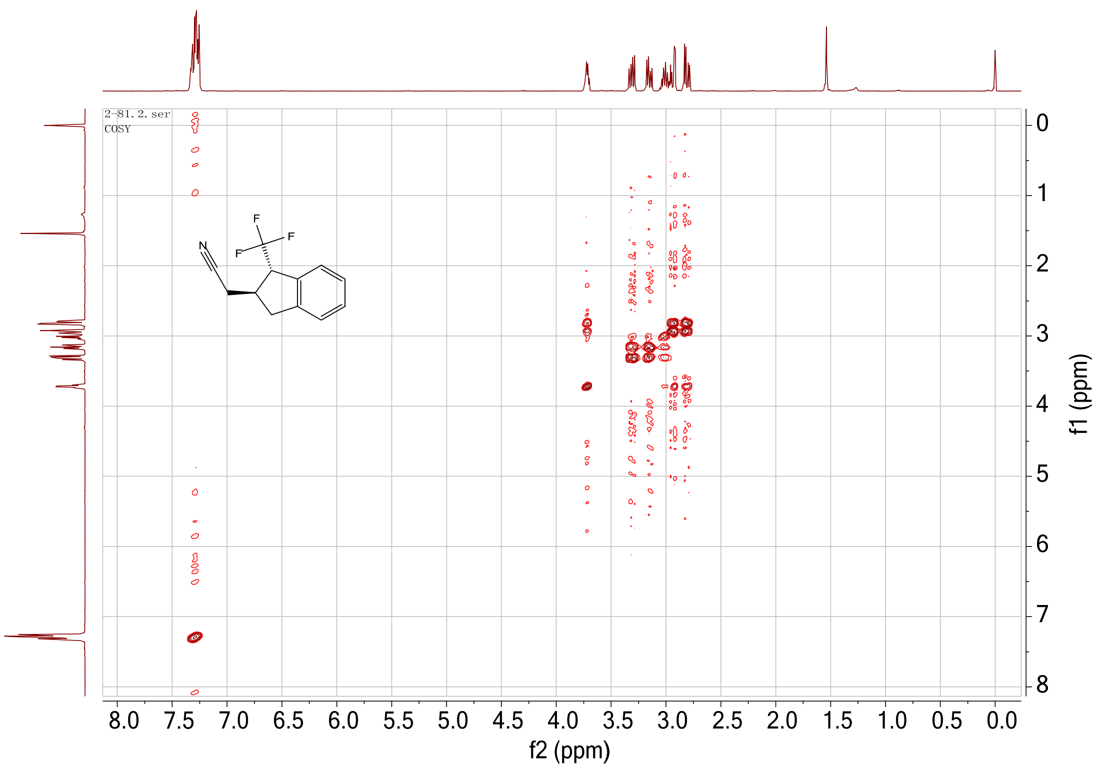


NOESY (400 MHz, $CDCl_3$):

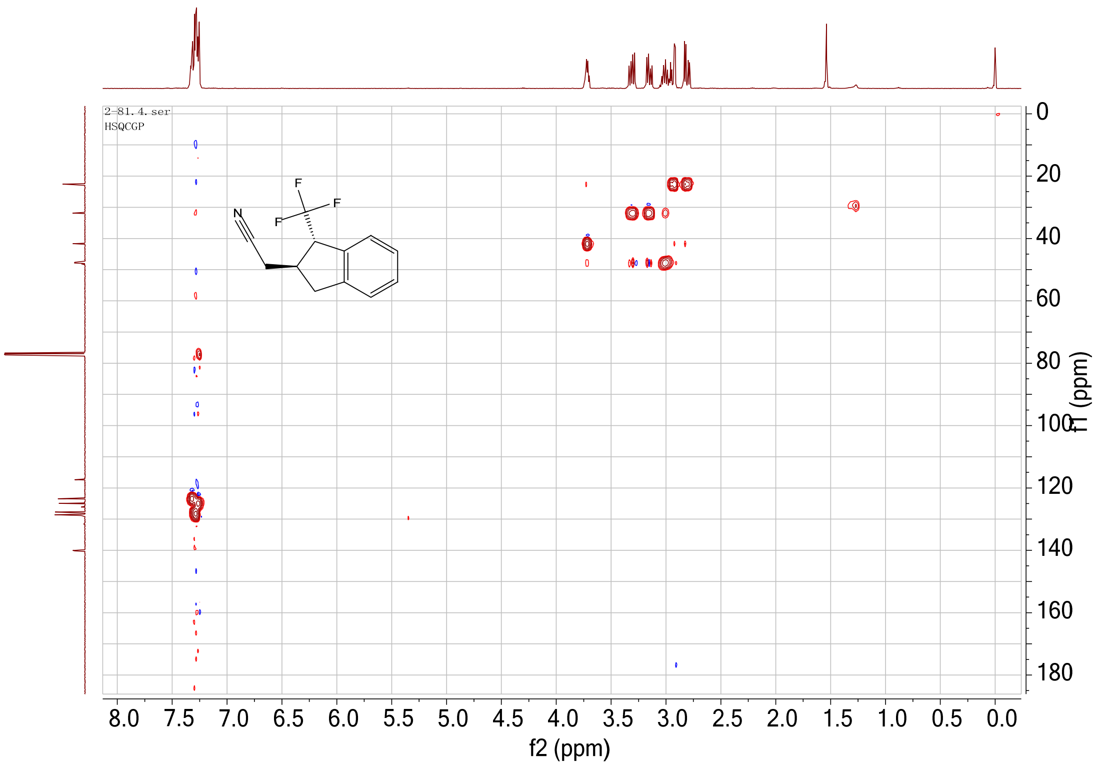


Compound 2za

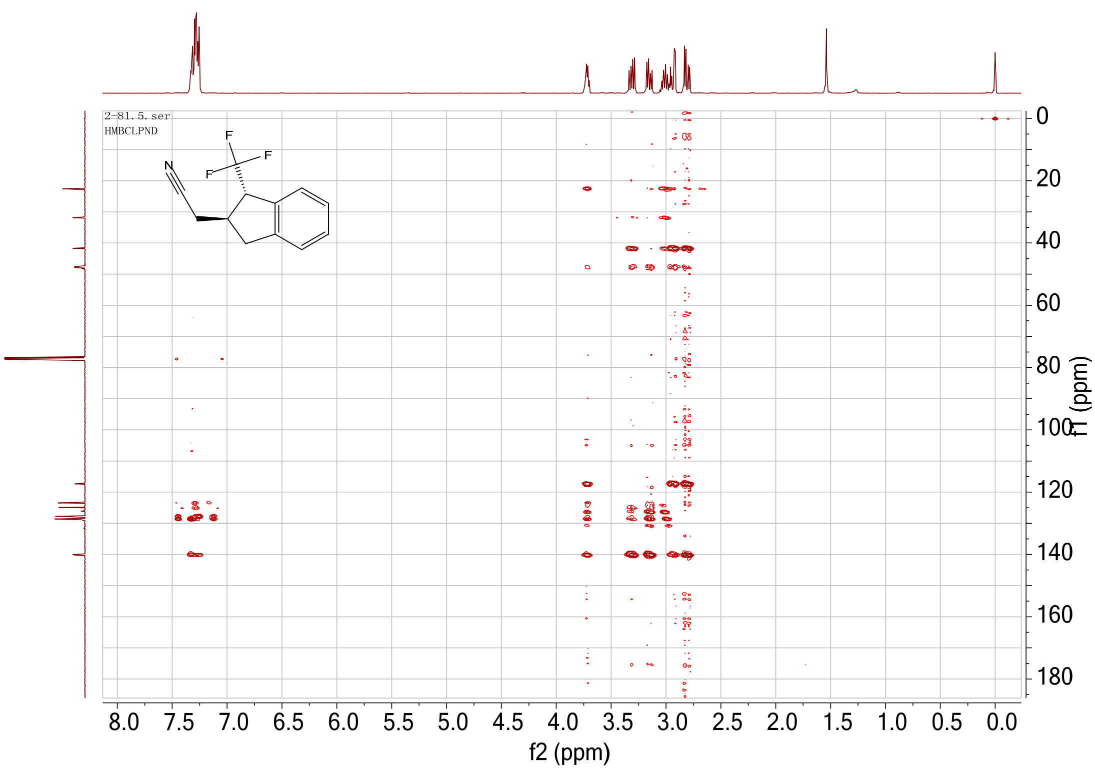
COSY (500 MHz, $CDCl_3$):



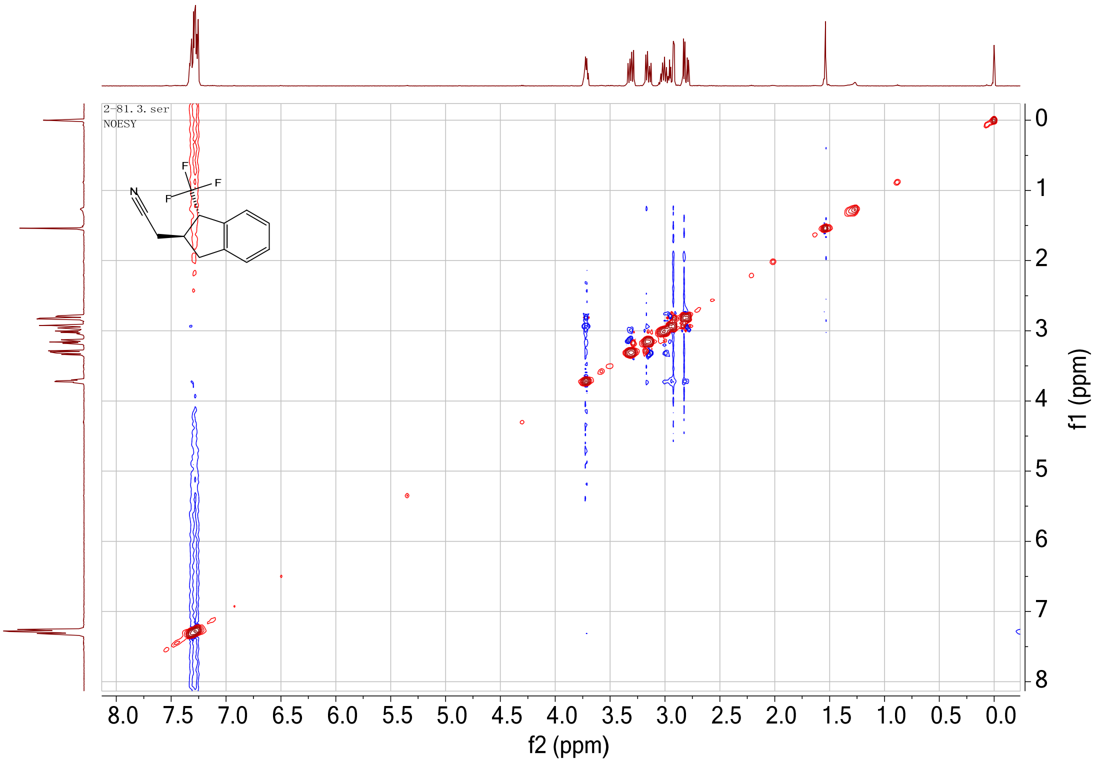
HMQC (500 MHz, $CDCl_3$):



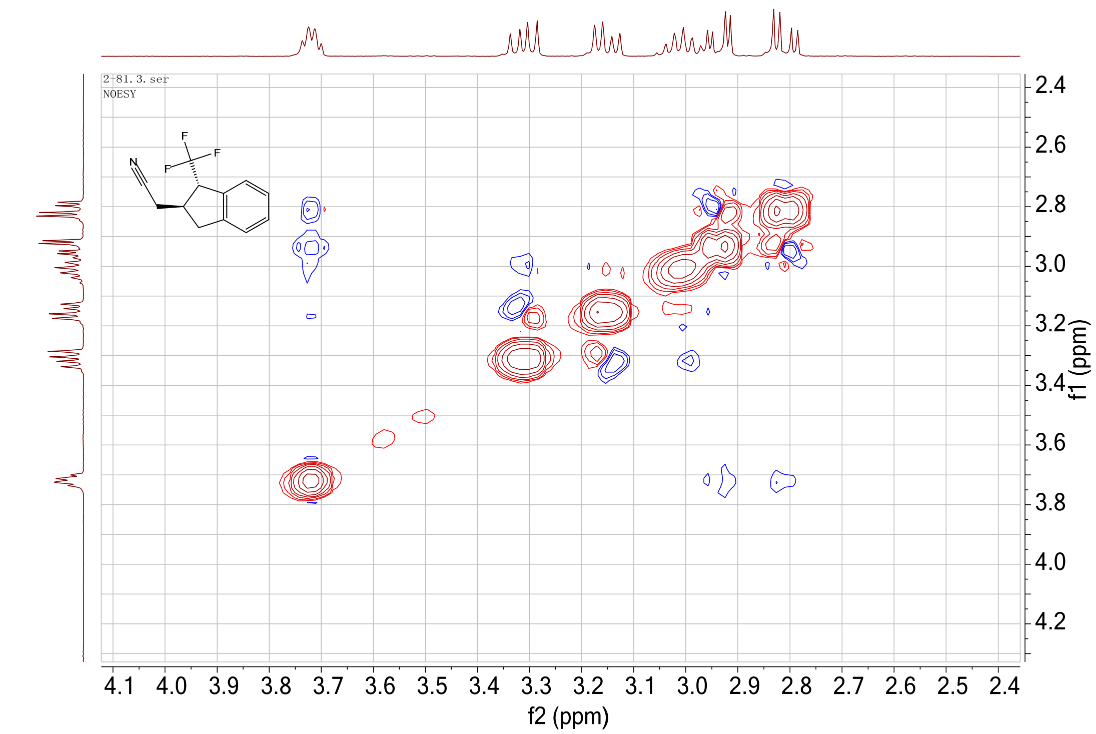
HMBC (500 MHz, $CDCl_3$):



NOESY (500 MHz, CDCl3):

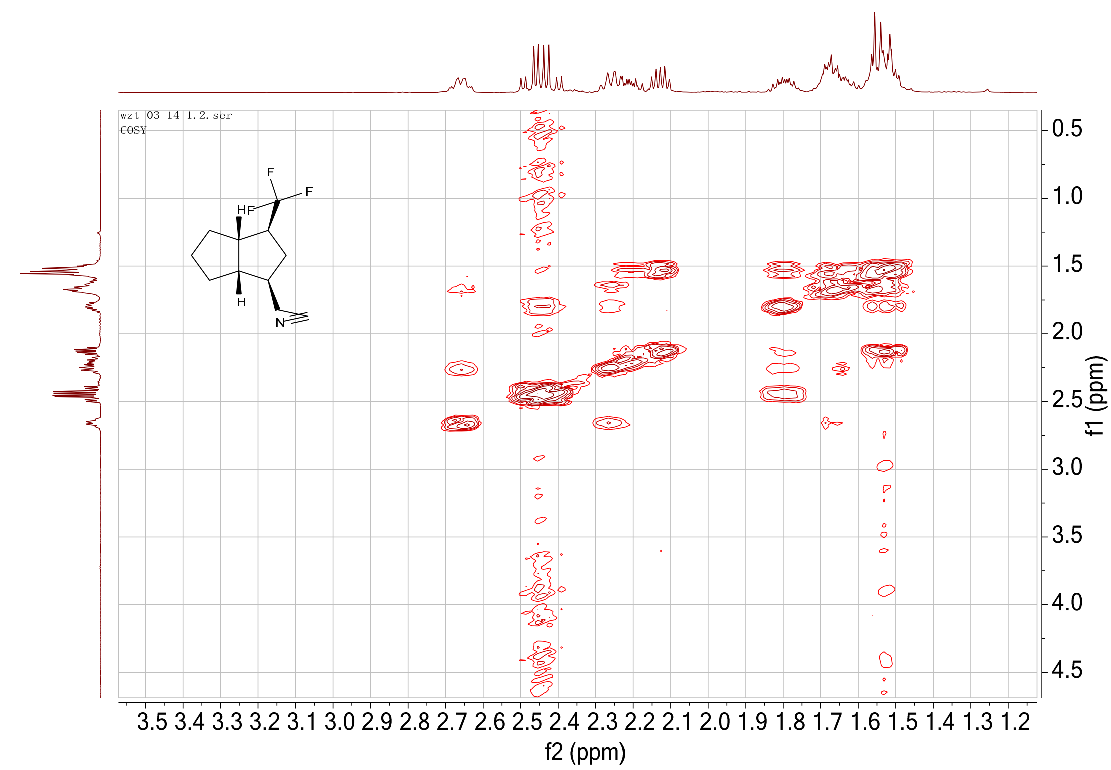


NOESY (500 MHz, CDCl3):

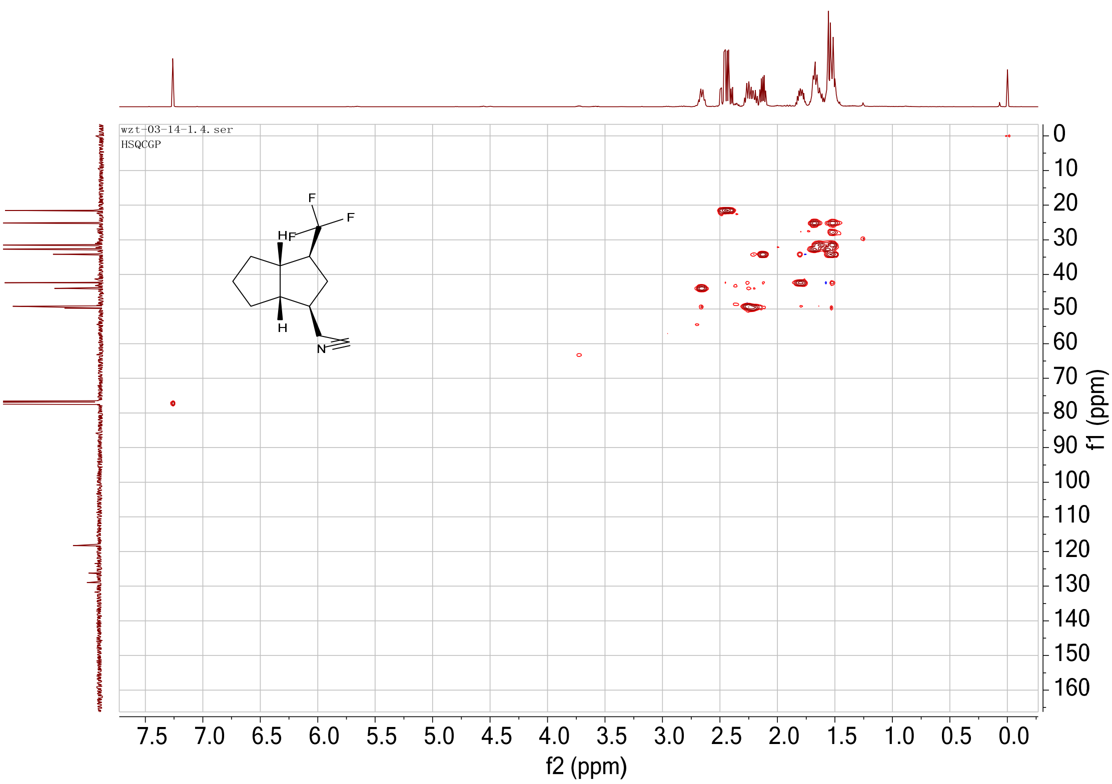


Compound 5c

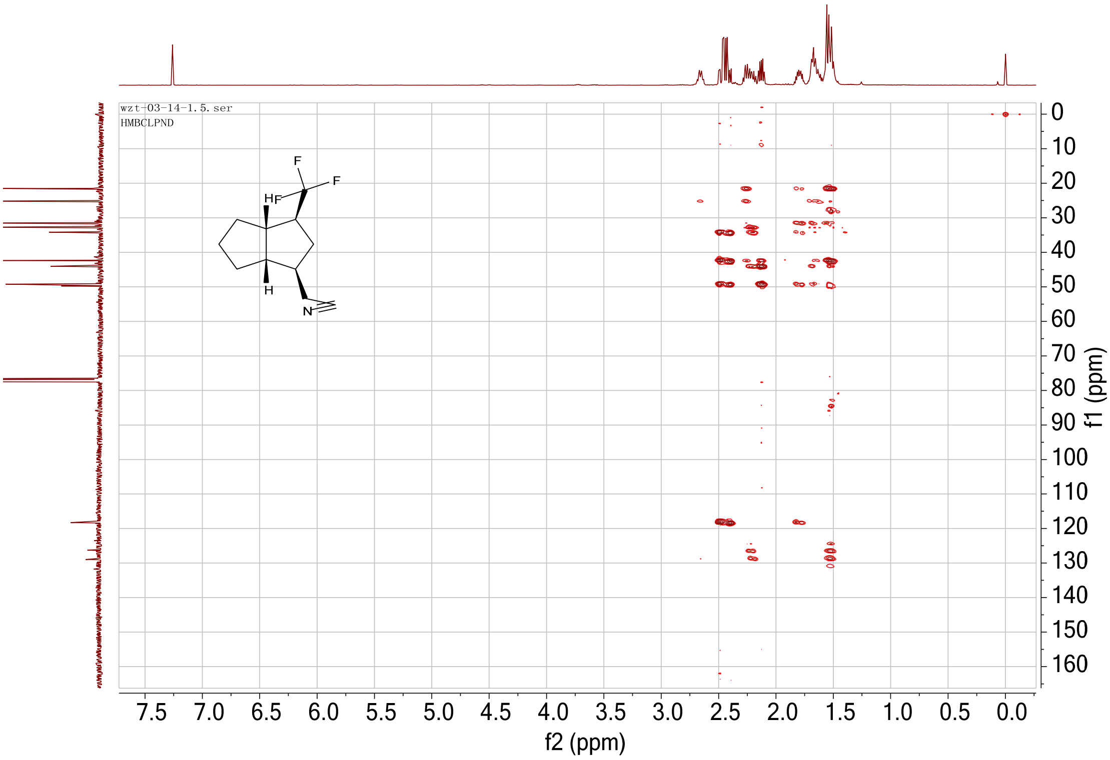
COSY (500 MHz, $CDCl_3$):



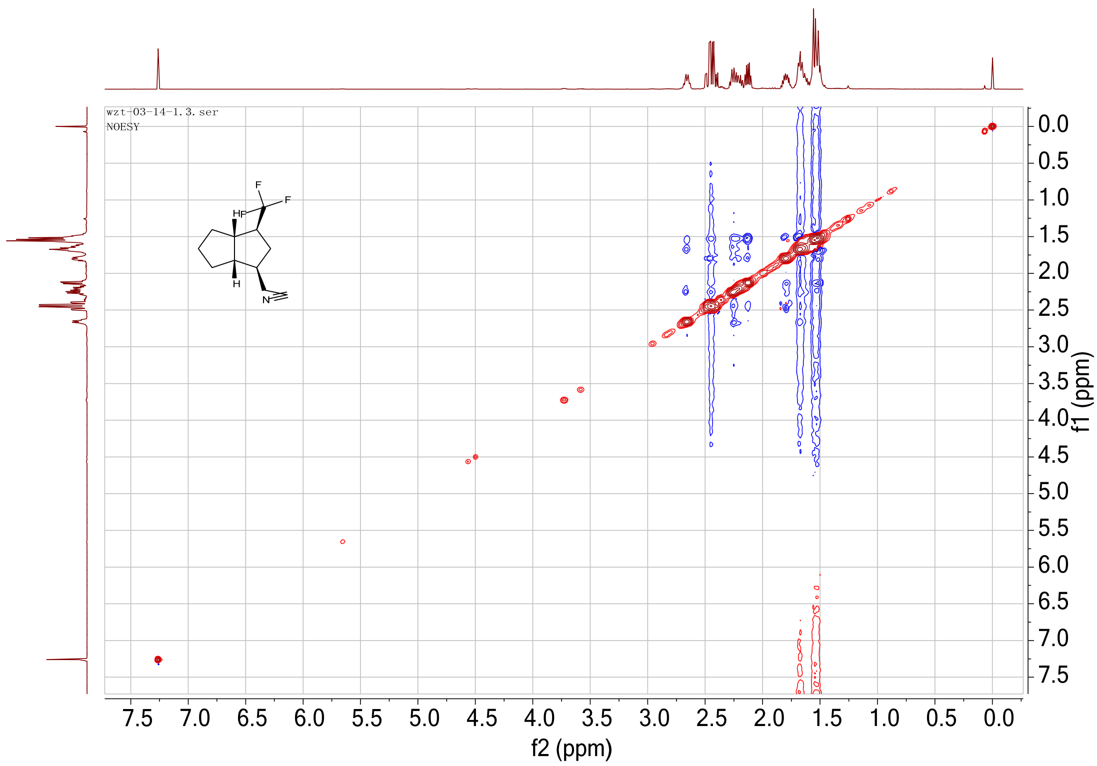
HMQC (500 MHz, $CDCl_3$):



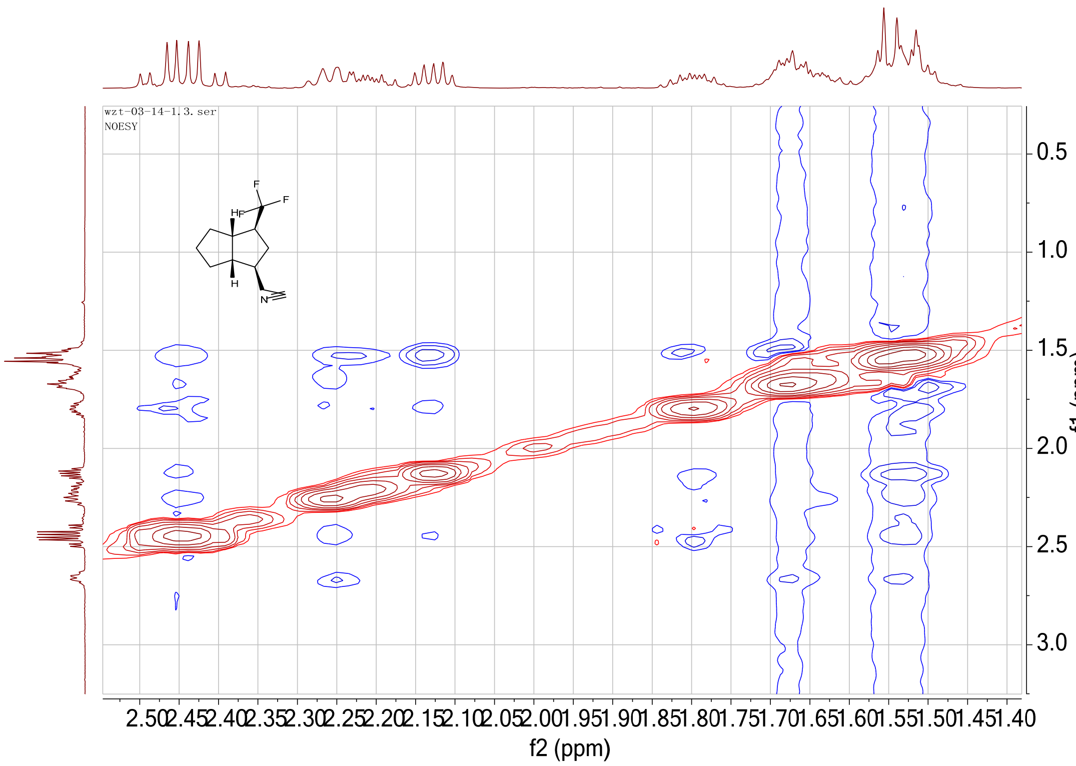
HMBC (500 MHz, $CDCl_3$):



NOESY (500 MHz, $CDCl_3$):



NOESY (500 MHz, $CDCl_3$):



10. References.

1. (a) Zhao, B,; Shi, Z. *Angew. Chem., Int. Ed.* **2017**, *56*, 12727-12731; *Angew. Chem.* **2017**, *129*, 12901-12905. (b) Yang, K.; Yang, Z.; Dang, Q.; Bai, X. *Eur. J. Org. Chem.* **2015**, *2015*, 4344-4347. (c) Mino, T.; Masuda, S.; Nishio, M.; Yamashita, M. *J. Org. Chem.* **1997**, *62*, 2633-2635. (d) Xu, Y.; Su, T.; Huang, Z.; Dong, G. *Angew. Chem., Int. Ed.* **2016**, *55*, 2559-2563; *Angew. Chem.* **2016**, *128*, 2605-2609.
2. Yang, H.-B.; Selander, N. *Chem. –Eur. J.* **2017**, *23*, 1779-1783.
3. Chu, Y.; Shan, Z.; Liu, D.; Sun, N. *J. Org. Chem.* **2006**, *71*, 3998-4001.
4. Aikawa, K.; Nakamura, Y.; Yokota, Y.; Toya, W.; Mikami, K. *Chem. –Eur. J.* **2015**, *21*, 96-100.
5. Erdelmeier, I.; Tailhan-Lomont, C.; Yadan, J.-C. *J. Org. Chem.* **2000**, *65*, 8152-8157.
6. Zhang, W.; Wang, F.; McCann, S. D.; Wang, D.; Chen, P.; Stahl, S. S.; Liu, G. *Science* **2016**, *353*, 1014-1018.
7. Tan, X.; Liu, Z.; Shen, H.; Zhang, P.; Zhang, Z.; Li, C. *J. Am. Chem. Soc.* **2017**, *139*, 12430-12433.