SUPPLEMENTARY INFORMATION

Enabling Nucleophilic Substitution Reactions of Activated Alkyl Fluorides Through Hydrogen-Bonding

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General information

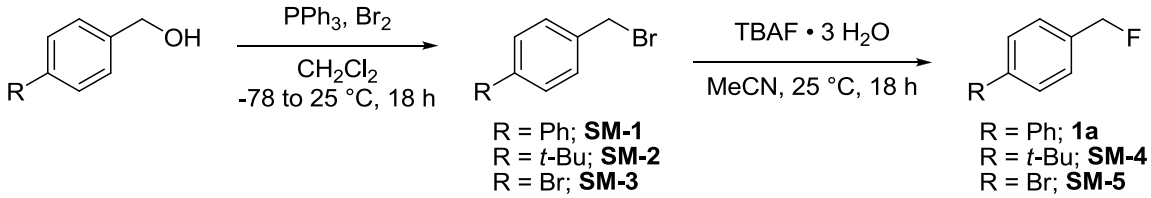
Unless otherwise noted, all commercial reagents were used without further purification. Dichloromethane, toluene, ether, tetrahydrofuran and acetonitrile were purified using a Vacuum Atmospheres Inc. Solvant Purification System. Thin-layer chromatography (TLC) analysis of reaction mixtures was performed using Silicyle silica gel 60Å F254 TLC plates, and visualized under UV or by staining with ceric ammonium molybdate or $KMnO_4$. Flash column chromatography was carried out on Silicycle Silica Gel 60 Å, 230 X 400 mesh. High-resolution mass spectra were obtained on a LC/MS-TOF Agilent 6210 using either electrospray ionization (ESI) or atmospheric pressure photoionization (APPI). Nuclear magnetic resonance (NMR) spectra were recorded using Agilent DD2 500 and Varian Inova 400 spectrometers. ^{1}H and ^{13}C chemical shifts are reported in ppm downfield of tetramethylsilane and referenced to tetramethylsilane or residual solvent peaks. For ^{19}F NMR, $CFCl_3$ is used as the external standard. Coupling constants (*J*) are measured in hertz (Hz). Multiplicities are reported using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad resonance. Infrared spectra were recorded using a Thermo Scientific Nicolet 380 FT-IR spectrometer. Melting points were recorded on a Stanford ResearchSystem OptiMelt capillary melting point apparatus and are uncorrected.

Materials and methods

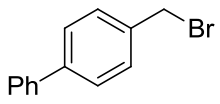
4-(chloromethyl)biphenyl (**1b**)[1] and 2-fluoro-1-methylene-1,2,3,4-tetrahydronaphthalene (**SM-8**)[2] were prepared according to literature protocols.

Synthesis of fluorinated substrates

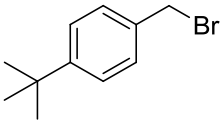
Synthesis of fluorides **1a**, **SM-4** and **SM-5**:



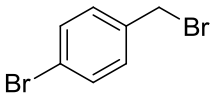
General procedure for the bromination of benzylic alchohols (Procedure A): To a stirred solution of triphenylphosphine (1.05 equiv.) in anhydrous dichloromethane (0.45 M substrate concentration) was added bromine (1.1 equiv.) dropwise at 0 °C. The resulting solution was stirred for 30 min at room temperature then cooled to – 78 °C, at which point a solution of alcohol (1 equiv.) in anhydrous dichloromethane was added. The reaction mixture was stirred 18 h at room temperature. The reaction was quenched with an aqueous solution of $Na_2S_2O_3$ (0.95 M) and $NaHCO_3$ (1.19 M) and extracted with CH_2Cl_2 (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. The crude reaction mixture is then triturated with minimum hexanes (2x), which is then removed *in vacuo* to afford the benzylic bromides.



4-(bromomethyl)-1,1'-biphenyl (SM-1). Following general procedure A on a 9 mmol scale of commercially available 4-biphenylmethanol, the product (2.16 g, 97%) was obtained as a white powder. Spectral data were identical to those of the product obtained from a commercial source (Aldrich).

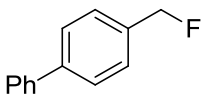


1-(bromomethyl)-4-*tert*-butylbenzene (SM-2). Following general procedure A on a 8.31 mmol scale of 4-*tert*-butylbenzyl alcohol[3] afforded the product (1.90 g, 99%) as a colorless oil. Spectral data were identical to those previously reported.[4]

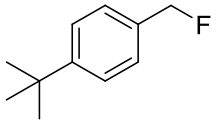


1-bromo-4-(bromomethyl)benzene (SM-3). Following general procedure A on a 8 mmol scale of 4-bromobenzyl alcohol, the product (1.77 g, 89%) was obtained as a crystalline solid. Spectral data were identical to those previously reported.[4]

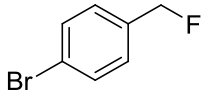
General procedure for the fluorination of benzylic bromides (Procedure B): To a stirred solution of the benzylic bromide (1 equiv.) in anhydrous acetronitrile (0.5 M) was added tetrabutylamonium fluoride trihydrate (2 equiv.) at room temperature. The reaction mixture was stirred 18 h at room temperature. The reaction was quenched with water and extracted with Et_2O (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and concentrated in vacuum. Column chromatography followed.



4-(fluoromethyl)-1,1'-biphenyl (1a). Following general procedure B on a 4 mmol scale of **SM-1**, the desired product (540 mg, 72%) was isolated as a white solid by flash chromatography using hexane/ethyl acetate (98/2). Spectral data were identical to those previously reported.[5]

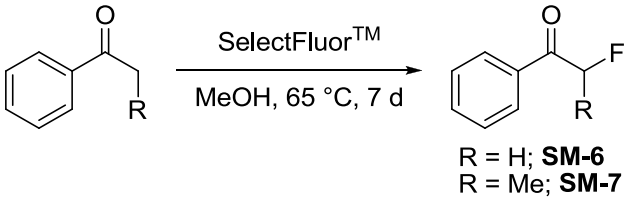


1-*tert*-butyl-4-(fluoromethyl)benzene (SM-4). Following general procedure B on a 4.4 mmol scale of **SM-2**, the product (400 mg, 54%) was obtained as a colorless oil by flash chromatography using hexane/ethyl acetate (98/2). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.33 (s, 9H), 5.35 (d, *J* = 48.1 Hz, 2H), 7.33 (d, *J* = 6.7 Hz, 2H), 7.43 (d, *J* = 8.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 31.4 (d, *J* = 0.6 Hz), 34.8 (d, *J* = 0.1 Hz), 84.6 (d, *J* = 164.3 Hz), 125.7 (d, *J* = 1.7 Hz), 127.7 (d, *J* = 5.4 Hz), 133.4 (d, *J* = 16.9 Hz), 152.0 (d, *J* = 3.3 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -204.4 (t, *J* = 48.2 Hz); IR (ATR, ZnSe) ν = 2962, 2901, 1364, 1108, 970, 851, 834, 810, 671; HRMS-APPI calcd for $C_{11}H_{15}$ $[M-F]^{*+}$ 147.1168, found 147.1162.



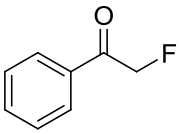
1-bromo-4-(fluoromethyl)benzene (SM-5). Following general procedure B on a 2.64 mmol scale of **SM-3**, the product (188 mg, 49%) was obtained as a colorless solid by flash chromatography using hexane/ethyl acetate (98/2). Spectral data were identical to those previously reported.[5]

General procedure for the α-fluorination of ketones (Procedure C):

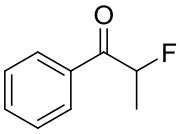


To a stirred solution of the ketone in methanol (0.2 M) is added SelectFluor™ (2 equiv.) and the mixture is refluxed for 7 days, upon which methanol is evaporated under vacuum.

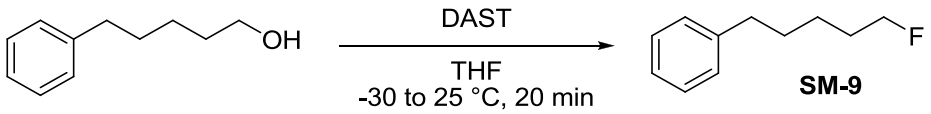
The resulting mixture is dissolved in dichloromethane, insoluble material is filtered off and this organic phase is washed with H_2O and brine, dried over $MgSO_4$ and concentrated *in vacuo*.



2-fluoro-1-phenylethanone (SM-6). Following general procedure C on a 8.32 mmol scale of acetophenone, the product (510 mg, 49%) was isolated as a colorless oil after flash chromatography using hexanes/ ethyl acetate (90/10). Spectral data were identical to those previously reported.[6]

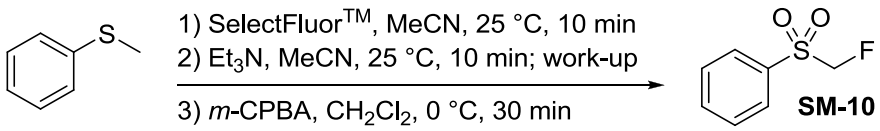


2-fluoro-1-phenylpropan-1-one (SM-7). Following general procedure C on a 5.96 mmol scale of propiophenone, the product (523 mg, 58%) was isolated as a colorless oil after column chromatography using hexanes/ ethyl acetate/acetone (96/2/2). ^{1}H, ^{13}C, ^{19}F NMR,[7] HRMS[7] and IR[8] data were in accordance with those previously reported.



(5-fluoropentyl)benzene (SM-9). In a round-bottomed flask, 5-phenyl-1-pentanol (200 mg, 1.22 mmol, 1 equiv.) was dissolved in 3.25 mL of THF and cooled to -30 °C.

Diethylaminosulfur trifluoride (DAST, 192 μL, 1.45 mmol, 1.2 equiv.) was added quickly and the reaction mixture was allowed to reach room temperature over 20 minutes. The mixture was then cooled back to -30 °C, at which point methanol (1 mL) was slowly added. After removal of volatiles under reduced pressure, an aqueous phase was extracted with CH_2Cl_2 (3x). The combined organic fractions were washed with H_2O and brine, dried over $MgSO_4$ and concentrated *in vacuo*. After flash chromatography (100% hexanes), the desired product (63 mg, 31%) was obtained as a colorless oil. Spectral data were identical to those previously reported.[9]



(Fluoromethylsulfonyl)benzene (SM-10). To a stirred solution of SelectFluor™ (3.5 g, 9.88 mmol, 1.25 equiv.) in acetonitrile (40 mL) in a round-bottomed flask was added dropwise a solution of thioanisole (981 mg, 7.91 mmol, 1 equiv.) in 4 mL acetonitrile. After 10 minutes at room temperature, triethylamine (1.37 mL, 9.88 mmol, 1.25 equiv.) was added and the mixture was allowed to stir for another 10 minutes. The reaction mixture was diluted with water then extracted with dichloromethane (3x), the combined organic extracts were dried over Na_2SO_4. The dichloromethane solution containing a crude product was cooled at 0 °C, *m*-CPBA (3.41 g, 15.2 mmol (77%), 1.9 equiv.) was added and the reaction mixture was allowed to stir for 30 minutes at 0 °C. After a solution of sodium sulfite was added and the reaction allowed to warm to room

temperature over 2 hours, the organic phase was washed with a saturated solution of $NaHCO_3$, dried over $MgSO_4$, filtered and evaporated under reduced pressure. The desired product (286 mg, 21%) was isolated as a creamy white solid after flash chromatography using hexanes/ ethyl acetate (75/25). Spectral data were identical to those previously reported.[10]

Nucleophilic substitution reactions

General procedures:

General procedure D:

To a stirred solution of alkyl fluoride (0.21 mmol) in isopropyl alcohol/water (1:1) (420 μL) in a small glass vessel was added the amine (0.63 mmol, 3 equiv.) at room temperature. The mixture reaction was stirred for 18 h at 70 °C. The reaction was quenched with an aqueous solution of Na_2CO_3 (1M) and extracted with Et_2O (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. The desired product was then purified by flash chromatography if necessary.

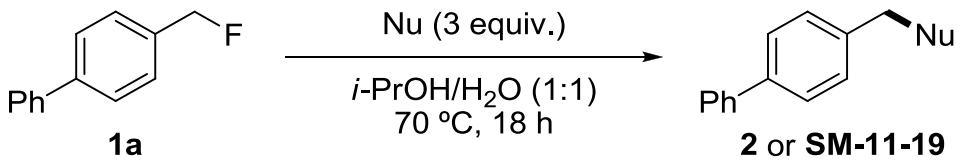
General procedure E:

To a stirred solution of alkyl fluoride (0.21 mmol) and an amine hydrochloride, thiol or phenol (0.63 mmol, 3 equiv.) in isopropyl alcohol/water (1:1) (420 μL) was added DBU or NaOH (0.63 mmol, 3 equiv.) at room temperature. The reaction mixture was stirred for 18 h at 70 °C. The reaction was quenched with an aqueous solution of Na_2CO_3 (1 M) and extracted with Et_2O (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. Column chromatography followed when necessary.

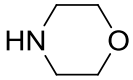
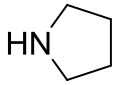
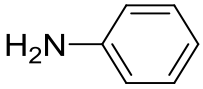
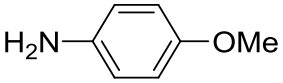
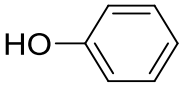
General procedure F:

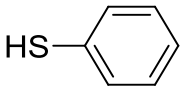
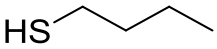
To a stirred solution of alkyl fluoride (1 equiv.) in isopropyl alcohol/water (1:1) (c = 0.5M) in a small glass vessel was added the amine (3 equiv.) at room temperature. The mixture reaction was stirred for 48 h at 90 °C. The reaction was quenched with an aqueous solution of Na_2CO_3 (1M) and extracted with CH_2Cl_2 (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. The desired product was then purified by flash chromatography if necessary.

Table S1. S_N2 reaction of 4-phenylbenzyl fluoride (**1a**) with *N*-, *O*-, *S*- and *C*-nucleophiles.

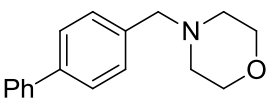


1a **2** or **SM-11-19**

Entry	Nu	Product	Yield [%][b]
1		**2**	96
2		**SM-11**	98
3		**SM-12**	73
4[c]		**SM-13**	97
5[d]		**SM-14**	77
6[d]		**SM-15**	96
7[e]		**SM-16**	36

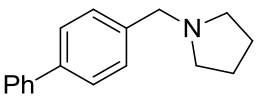
8		**SM-17**	88
9		**SM-18**	64
10[f]	n-$Bu_4N^+CN^-$	**SM-19**	13

[b] Yields after purification by flash chromatography. [c] 3 equiv. of DBU was also added. [d] Reaction was performed at 90 °C for 48 h. [e] 3 equiv. of NaOH was also added. [f] 10 equiv. of the n-$Bu_4N^+CN^-$ was used.



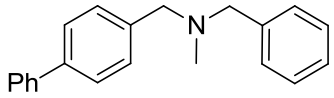
4-([1,1'-biphenyl]-4-ylmethyl)morpholine (2). Following general procedure D with 0.21 mmol of **1a** and 0.63 mmol of freshly distilled morpholine, the desired product (49 mg, 96%) was isolated by flash chromatography as a brown oil using hexanes/ethyl acetate (70/30). Spectral data were identical to those previously reported.[5]

The synthesis of the title compound was also achieved using a modified protocol: To a stirred mixture of benzylic chloride **1b** or benzylic bromide **SM-1** (0.25 mmol, 50 mg for **1b**) in DMF (0.5 M, 0.5 mL) in a glass vessel was added morpholine (0.75 mmol, 3 equiv., 65 μL). The reaction mixture was then allowed to stir for 4 hours at 70 °C at which point it was treated according to the work-up procedure of Procedure D. Conversion was complete for both reactions and flash chromatography allowed the isolation of 90-95% yield of **2**.

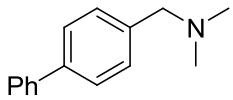


1-([1,1'-biphenyl]-4-ylmethyl)pyrrolidine (SM-11). Following general procedure D with 0.21 mmol of **1a** and 0.63 mmol of freshly distilled pyrrolidine, the desired product (49 mg, 98 %) was obtained pure following

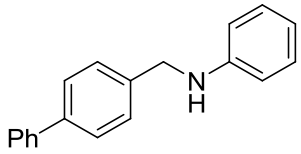
work-up as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.79 (br s, 4H), 2.53 (br s, 4H), 3.64 (s, 2H), 7.36 (t, *J* = 7.3 Hz , 1H), 7.42-7.47 (m, 4H), 7.53 (d, *J* = 8.0 Hz, 2H), 7.58 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 23.6, 54.3, 60.5, 127.1, 127.18, 127.24, 128.8, 129.5, 138.5, 140.0, 141.2; IR (ATR, ZnSe) ν = 2963, 2791, 1602, 1487, 1459, 1409, 761, 729, 696 cm^{-1}; HRMS-ESI calcd for $C_{17}H_{20}N$ $[M+H]^+$ 238.1590, found 238.1593.



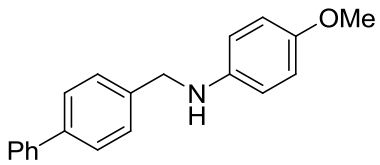
***N*-benzyl-1-(biphenyl-4-yl)-N-methylmethanamine (SM-12).** Following general procedure D with 0.21 mmol of **1a** and 0.63 mmol of *N*-benzylmethylamine, the desired product (44 mg, 73 %) was isolated as a colorless oil by flash chromatography using hexanes/acetone (90/10). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.22 (s, 3H), 3.55 (s, 2H), 3.56 (s, 2H), 7.23-7.27 (m,1H), 7.33 (t, *J* = 7.4 Hz, 3H), 7.37-7.44 (m, 6H), 7.54-7.60 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 42.4, 61.6, 62.0, 127.09, 127.11, 127.2, 127.3, 128.4, 128.9, 129.1, 129.5, 138.6, 139.4, 140.0, 141.2; IR (ATR, ZnSe) ν = 3027, 2785, 1601, 1487, 1452, 1407, 1132, 1020, 1008, 868, 758, 733, 695 cm^{-1}; HRMS-ESI calcd for $C_{21}H_{21}N$ $[M+H]^+$ 288.1747, found 288.1752.



1-(biphenyl-4-yl)-*N*,*N*-dimethylmethanamine (SM-13). Following general procedure E with 0.21 mmol of **1a** and 0.63 mmol of *N*,*N*-dimethylamine hydrochloride and DBU, the desired product (43 mg, 97%) was obtained as a yellowish solid after column chromatography using hexanes/acetone (95/5). Spectral data were identical to those previously reported.[11]

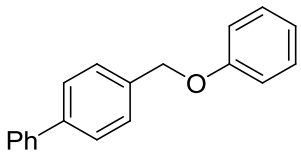


***N*-(biphenyl-4-ylmethyl)aniline (SM-14).** This product was recovered using general procedure D with 0.21 mmol of **1a** and 0.63 mmol of aniline and heating at 90 °C for 48 h after all reactants were mixed. After column chromatography using hexanes/ethyl acetate (95/5), the product (46 mg, 77%) was recovered as a white solid. m.p. 87-89 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 4.07 (br s, 1H), 4.37 (s, 2H), 6.66 (d, *J* = 8.0 Hz, 2H), 6.73 (t, *J* = 7.3 Hz, 1H), 7.19 (t, *J* = 7.8 Hz, 2H), 7.34 (t, *J* = 7.3 Hz, 1H), 7.41-7.45 (m, 4H), 7.56-7.59 (m, 4H) ; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 48.1, 113.0, 117.8, 127.2, 127.4, 127.5, 128.0, 128.9, 129.4, 138.7, 140.3, 141.0, 148.3; IR (ATR, ZnSe) ν = 3376, 3028, 2921, 2842, 1597, 1500, 1485, 1459, 1405 cm^{-1}; HRMS-ESI calcd for $C_{19}H_{17}N$ $[M+H]^+$ 260.1434, found 260.1437.

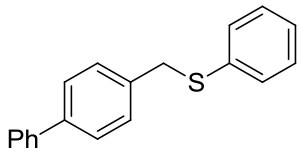


***N*-(biphenyl-4-ylmethyl)-4-methoxyaniline (SM-15).** Following general procedure D with 0.21 mmol of **1a** and 0.63 mmol of *p*-anisidine and heating at 90 °C for 48 h after all reactants were mixed, the desired product (61 mg, 96%) was isolated as a beige solid by flash chromatography using hexanes/acetone (85/15). m.p. 133-135 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 3.74 (s, 3H), 3.79 (br s, 1H), 4.32 (s, 2H), 6.62 (d, *J* = 8.9 Hz, 2H), 6.79 (d, *J* = 8.9 Hz, 2H), 7.33 (t, *J* = 7.2 Hz, 1H), 7.41-7.44 (m, 4H), 7.55-7.59 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 49.1, 55.9, 114.3, 115.1, 127.2, 127.4, 127.5, 128.1, 128.9, 138.9, 140.3, 141.0, 142.5, 152.4; IR (neat) ν = 3350, 3029, 2997, 2928, 2835, 2706,

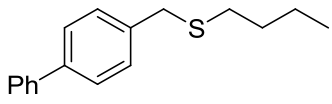
2561, 1604, 1578, 1510, 1456, 1440, 1408, 1288, 1256, 1180, 1034, 971, 907, 831, 764, 753, 726, 697 cm^{-1}; HRMS-ESI calcd for $C_{20}H_{19}NO$ $[M+H]^+$ 290.1539, found 290.1548.



4-(phenoxymethyl)biphenyl (SM-16). Following general procedure E on a 0.27 mmol scale of **1a** and using 3 equiv. of phenol and NaOH, the product (25 mg, 36%) was obtained as a white solid after flash chromatography using hexanes/acetone (99.5/0.5). Spectral data were identical to those previously reported.[5]

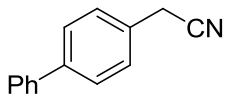


([1,1'-biphenyl]-4-ylmethyl)(phenyl)sulfane (SM-17). Following general procedure E with benzenethiol, the desired product (51 mg, 88%) was isolated as a white crystalline solid by flash chromatography using hexanes/ethyl acetate (98/2). m.p. 122-126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.15 (s, 2H), 7.18 (t, *J* = 7.2 Hz, 1H), 7.22-7.36 (m, 7H), 7.42 (t, *J* = 7.4 Hz, 2H), 7.51 (d, *J* = 8.1 Hz, 2H), 7.56 (d, *J* = 7.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.9, 126.5, 127.2, 127.3, 127.4, 128.9, 129.0, 129.4, 130.0, 136.5, 136.7, 140.2, 140.9; IR (ATR, ZnSe) ν = 3056, 2922, 1581, 1476, 1406, 1088, 848, 733, 684 cm^{-1}; HRMS-APPI calcd for $C_{19}H_{16}S$ $[M^*]^+$ 276.0977, found 276.0967.



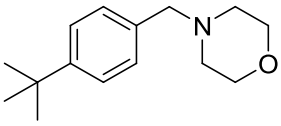
(biphenyl-4-ylmethyl)(butyl)sulfane (SM-18). Following general procedure E with 1-butanethiol, the desired product (35 mg, 64%) was isolated as a colorless oil by flash chromatography using hexanes/ethyl

acetate (99/1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, *J* = 7.3 Hz, 3H), 1.34-1.44 (m, 2H), 1.53-1.61 (m, 2H), 2.46 (t, *J* = 7.4 Hz, 2H), 3.75 (s, 2H), 7.32-7.45 (m, 5H), 7.53-7.59 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 13.8, 22.2, 31.3, 31.5, 36.1, 127.2, 127.3, 127.4, 128.9, 129.4, 137.9, 139.9, 141.0; IR (ATR, ZnSe) ν = 2955, 2927, 2870, 1486, 1008, 765, 735, 695 cm^{-1}; HRMS-APPI calcd for $C_{17}H_{20}S$ $[M^{*}]^{+}$ 256.1280, found 256.1290.

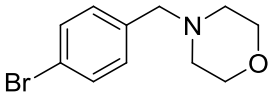


2-(biphenyl-4-yl)acetonitrile (SM-19): To a stirred solution of **1a** (0.21 mmol) in isopropyl alcohol/water (1:1) (420 μL) in a small glass vessel was added the tetrabutylammonium cyanide (564 mg, 2.10 mmol, 10 equiv.) at room temperature. The mixture reaction was stirred for 18 h at 70 °C. The reaction was quenched with an aqueous solution of Na_2CO_3 (1M) and extracted with Et_2O (3x). The combined organic extracts were washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. The desired product (5 mg, 13%) was then isolated as a white solid by flash chromatography using hexanes/ethyl acetate (90/10). Spectral data were identical to those previously reported.[12]

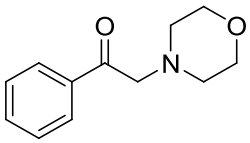
Other molecules synthesised by nucleophilic substitution reactions



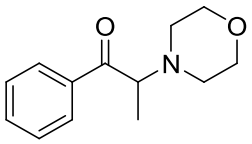
4-(4-*tert*-butylbenzyl)morpholine (SM-20): Following general procedure D on a 0.30 mmol scale of **SM-4** and 0.90 mmol of morpholine, the product (53 mg, 76%) was obtained as a yellow oil after flash chromatography (70/30 hexanes/ethyl acetate). Spectral data were identical to those previously reported.[13]



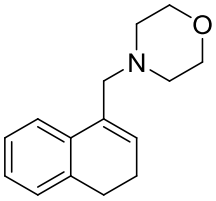
4-(4-bromobenzyl)morpholine (SM-21): Following the general procedure D on a 0.21 mmol scale of **SM-5** and 0.63 mmol of morpholine, the product (52 mg, 97%) was obtained pure after work-up as a white crystalline solid. Spectral data were identical to those previously reported.[14]



2-morpholino-1-phenylethanone (SM-22). Following general procedure F but heating at 80°C, on a 0.51 mmol scale of **SM-6**, the product (95 mg, 91%) was isolated as a slightly yellow oil after work-up. To prevent any form of decomposition, the work-up was perfromed using water only and no sodium carbonate; moreover no chromatography could be done on this product as it yielded novel impurities. Spectral data were identical to those previously reported.[15]



2-morpholino-1-phenylpropan-1-one (SM-23). Following general procedure F on a 0.43 mmol scale of **SM-7**, the product (30 mg, 32%) was recovered as a slightly orange oil after flash chromatography using dichloromethane/methanol (98/2). Spectral data were identical to those previously reported.[16]



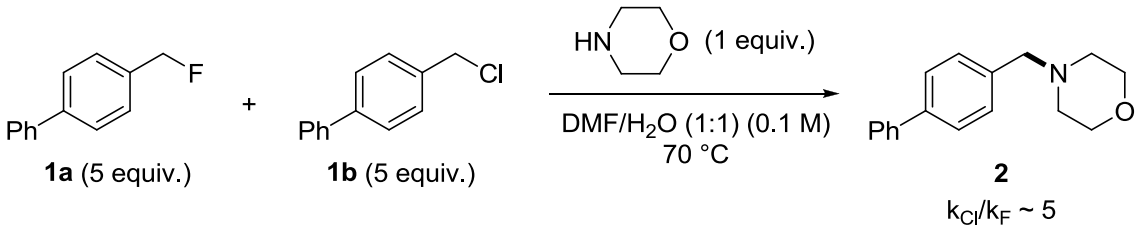
4-((3,4-dihydronaphthalen-1-yl)methyl)morpholine (SM-24). Following general procedure F on a 0.41 mmol scale of **SM-8**, the product (48 mg, 51%) was obtained as a brown oil by flash chromatography using hexanes/ethyl acetate (85/15). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.27-2.32 (m, 2H), 2.46 (br s, 4H), 2.75 (t, *J* = 8.0 Hz, 2H), 3.28 (s, 2H), 3.69 (t, *J* = 4.6 Hz, 4H), 5.97 (t, *J* = 4.0 Hz, 1H), 7.11-7.22 (m, 3H), 7.57 (d, *J* = 7.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 23.3, 28.3, 53.7, 62.3, 67.3, 124.0, 126.4, 126.9, 127.4, 129.0, 132.5, 134.7, 136.5; IR (ZnSe) ν = 2929, 2085, 1452, 1115, 1003, 865, 760, 733; HRMS-ESI calcd for $C_{15}H_{19}NO$ $[M+H]^+$ 230.1539, found 230.1546.

Attempted reactions of substrates **SM-9** and **SM-10**

Following general procedure F on a 0.26 mmol scale of **SM-9**, no conversion could be observed in the crude reaction mixture by NMR.

Following general procedure F on a 0.31 mmol scale of **SM-10**, no conversion could be observed in the crude reaction mixture by NMR.

Kinetic competition experiment



In a small glass vessel, **1a** (93 mg, 0.5 mmol, 5 equiv.) and **1b** (101 mg, 0.5 mmol, 5 equiv.) were dissolved in DMF:H_2O (1:1) (2 mL) under argon. Morpholine (9 µL, 0.1 mmol, 1 equiv.) was then added with a micro-syringe and the reaction mixture was heated at 70 °C for 5 hours. Fluorene (83 mg, 0.5 mmol) was added to the reaction mixture, which was then diluted with an aqueous solution of Na_2CO_3 (1M) and extracted with 5 x Et_2O. The combined organic extracts were washed with 4 x H_2O and finally with brine. The organic phase was dried over $MgSO_4$, filtered and concentrated under vacuum. At this point, ^{1}H NMR analysis of the crude mixture yielded k_{Cl}/k_F of about 5 using the following information:

1- The crude mixture contained 5 products, all easily identifiable : Internal standard fluorene (δ 3.92 ppm, 2H), unreacted benzylic fluoride **1a** (5.45 ppm, d, 1.88H), unreacted benzylic chloride **1b** (4.66 ppm, 1.16H), 4-biphenylmethanol (4.77 ppm, 0.31H) and desired amine **2** (3.56 ppm, 0.284H)
2- Independent experiments demonstrated that under our conditions, **1b** could not be converted to **1a** and that only **1b** could yield 4-biphenylmethanol.
3- Considering the above statements, we calculate that 73% of starting **1b** and 94% of **1a** remain after the reaction, for a k_{Cl}/k_F of approximately 5.

^{1}H NMR Spectra of Known Compounds

Figure S1: ^{1}H NMR spectrum of compound 1a.

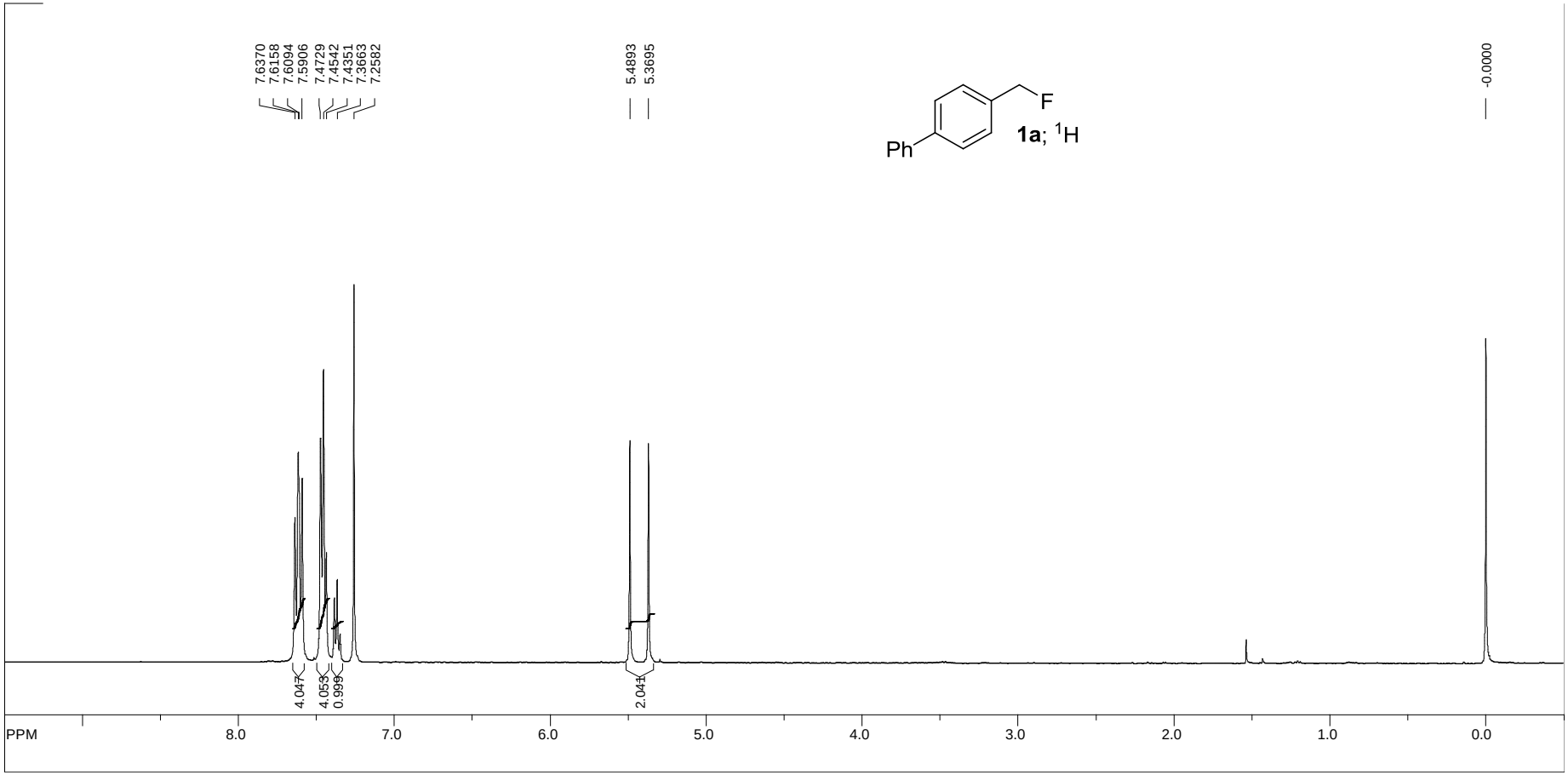


Figure S2: ^{1}H NMR spectrum of compound 1b.

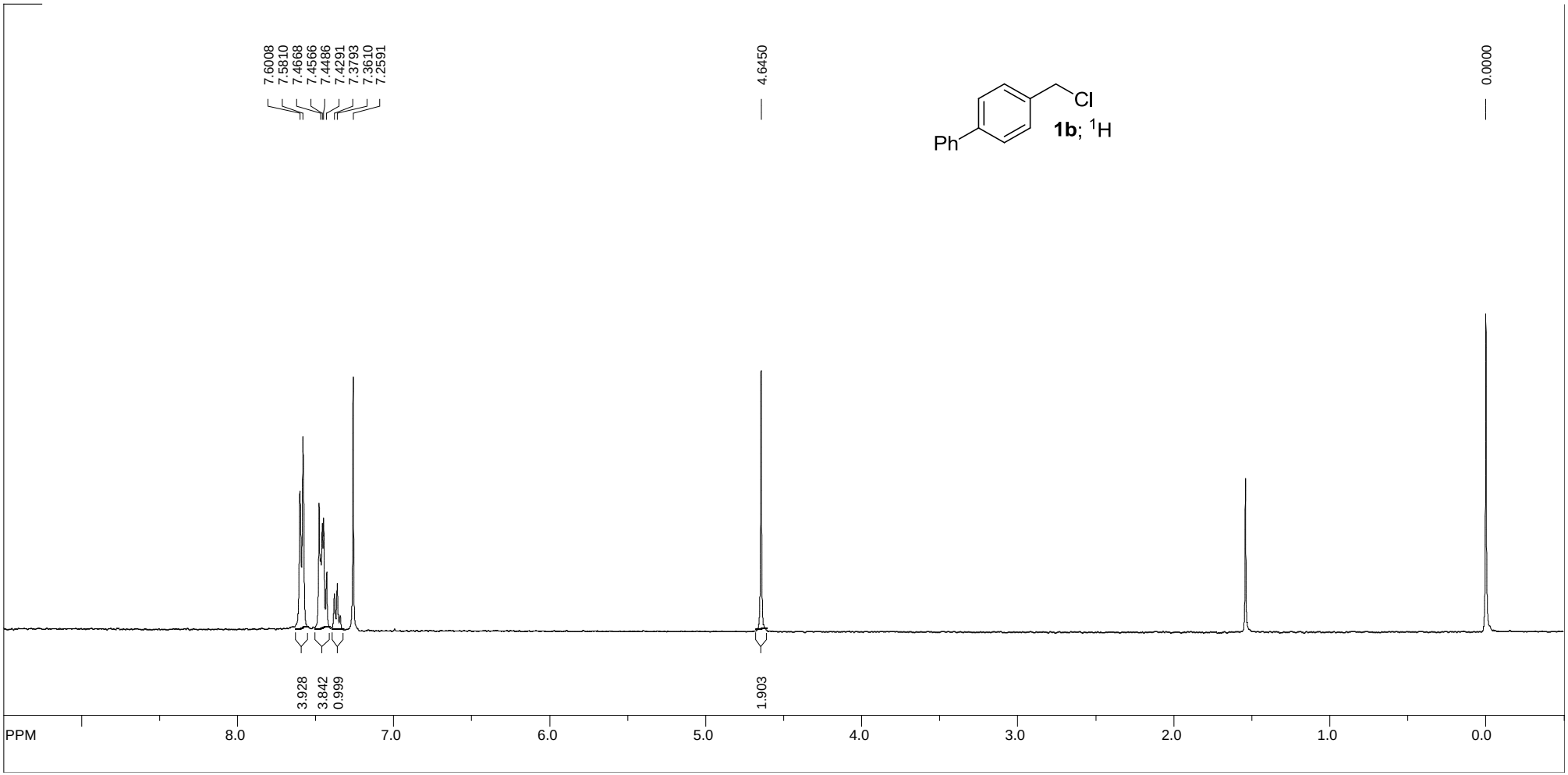


Figure S3: ^{1}H NMR spectrum of compound 2.

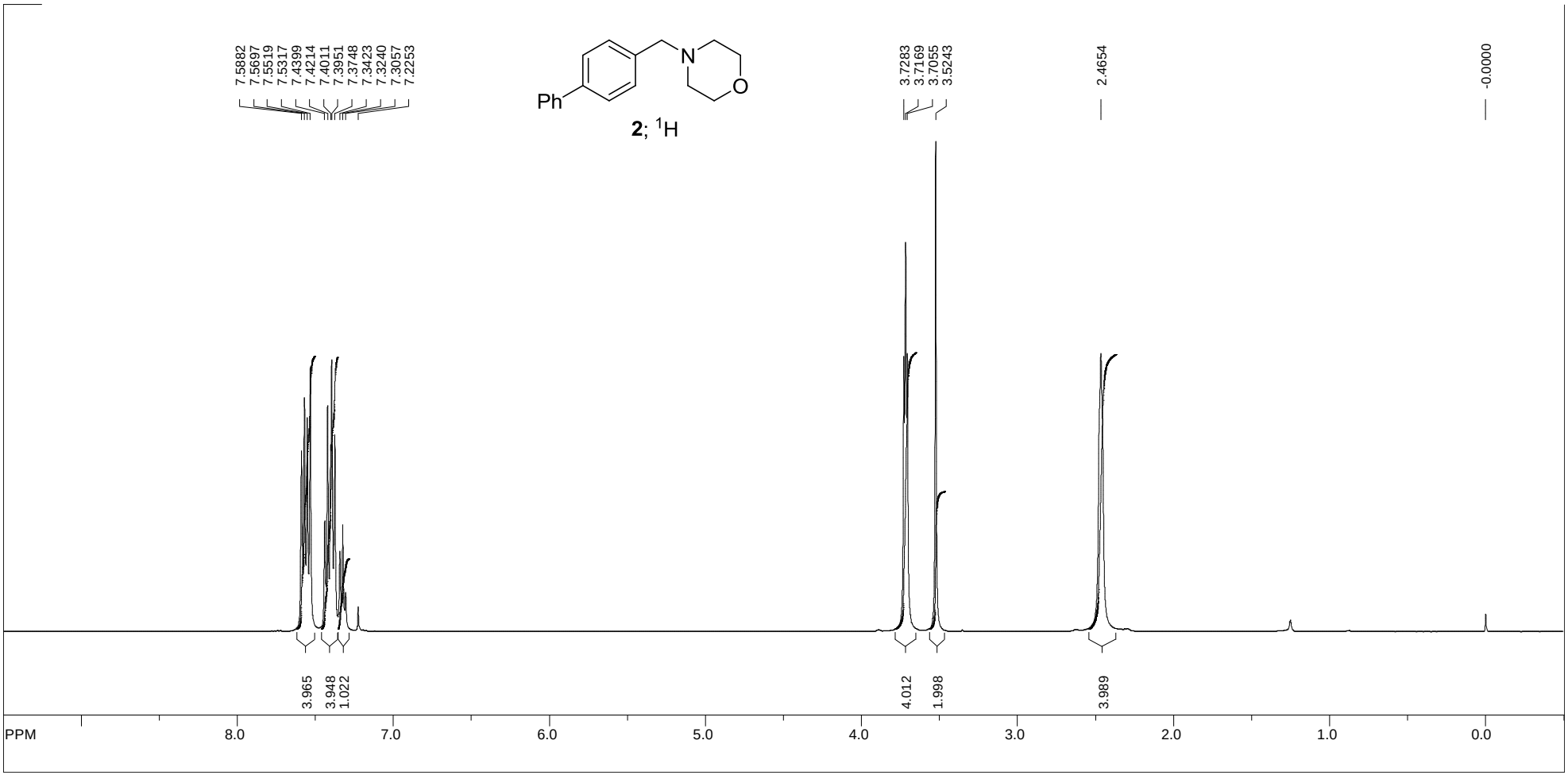


Figure S4: ^{1}H NMR spectrum of compound SM-1.

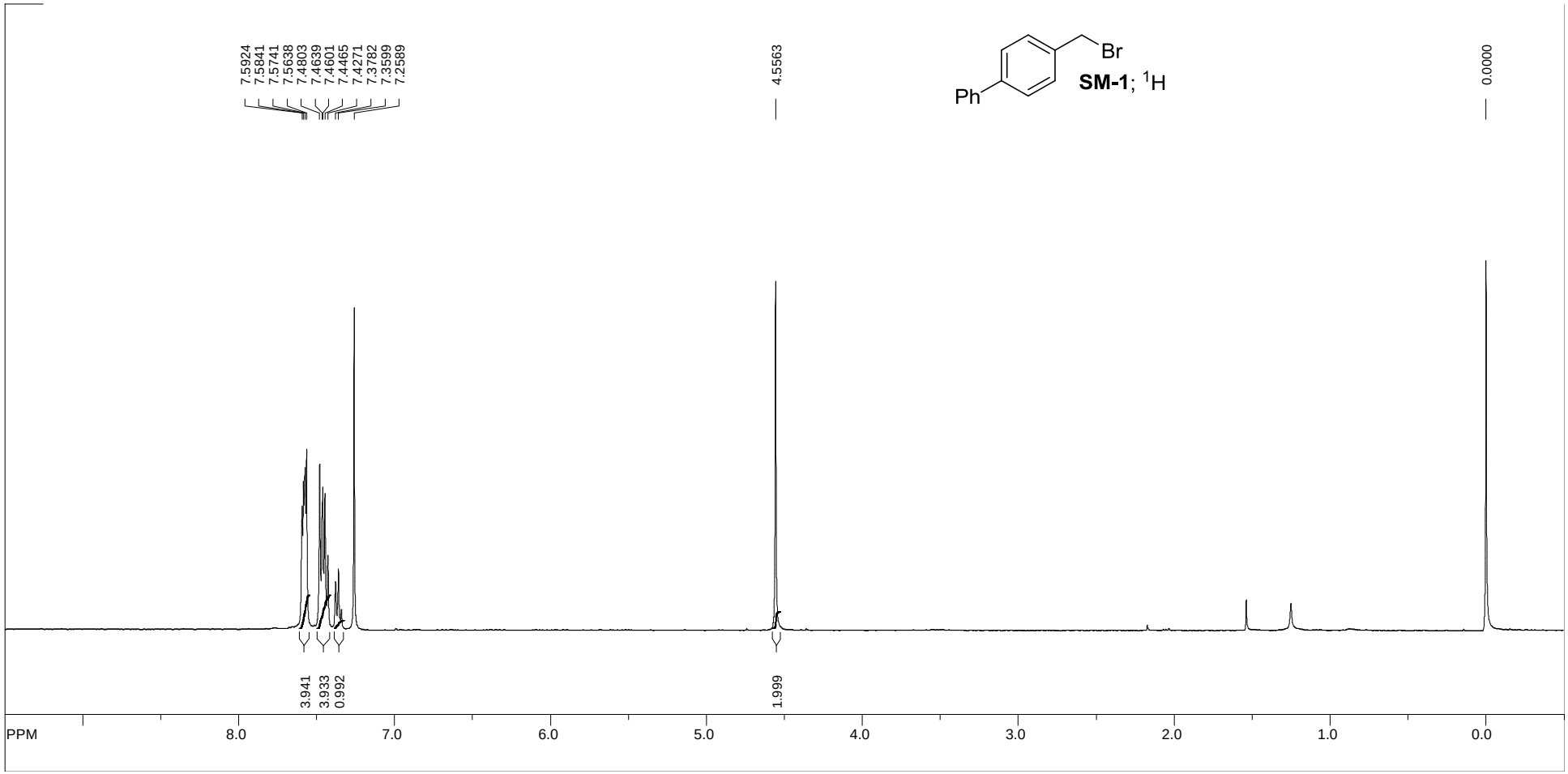


Figure S5: ^{1}H NMR spectrum of compound SM-2.

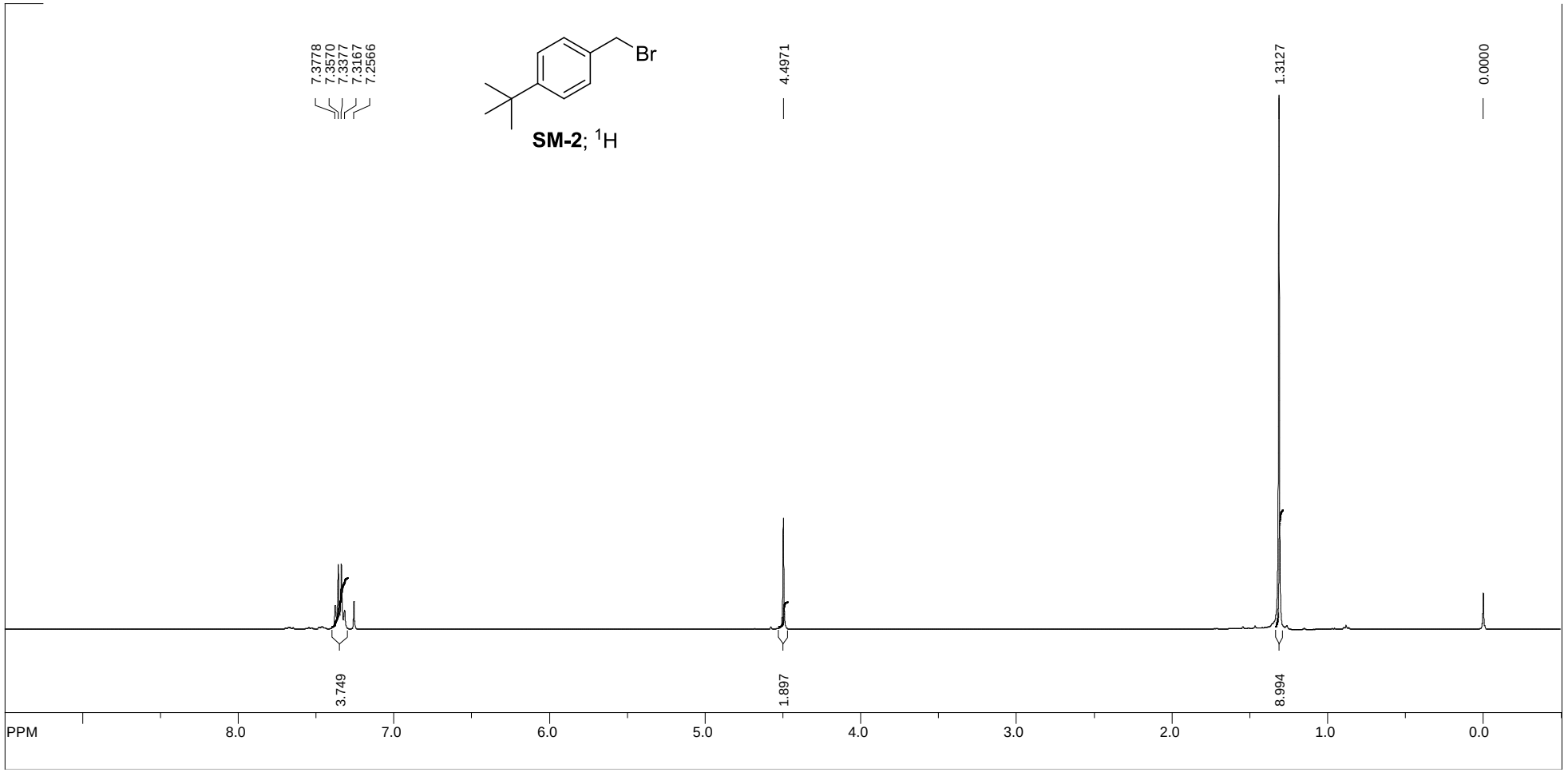


Figure S6: ^{1}H NMR spectrum of compound SM-3.

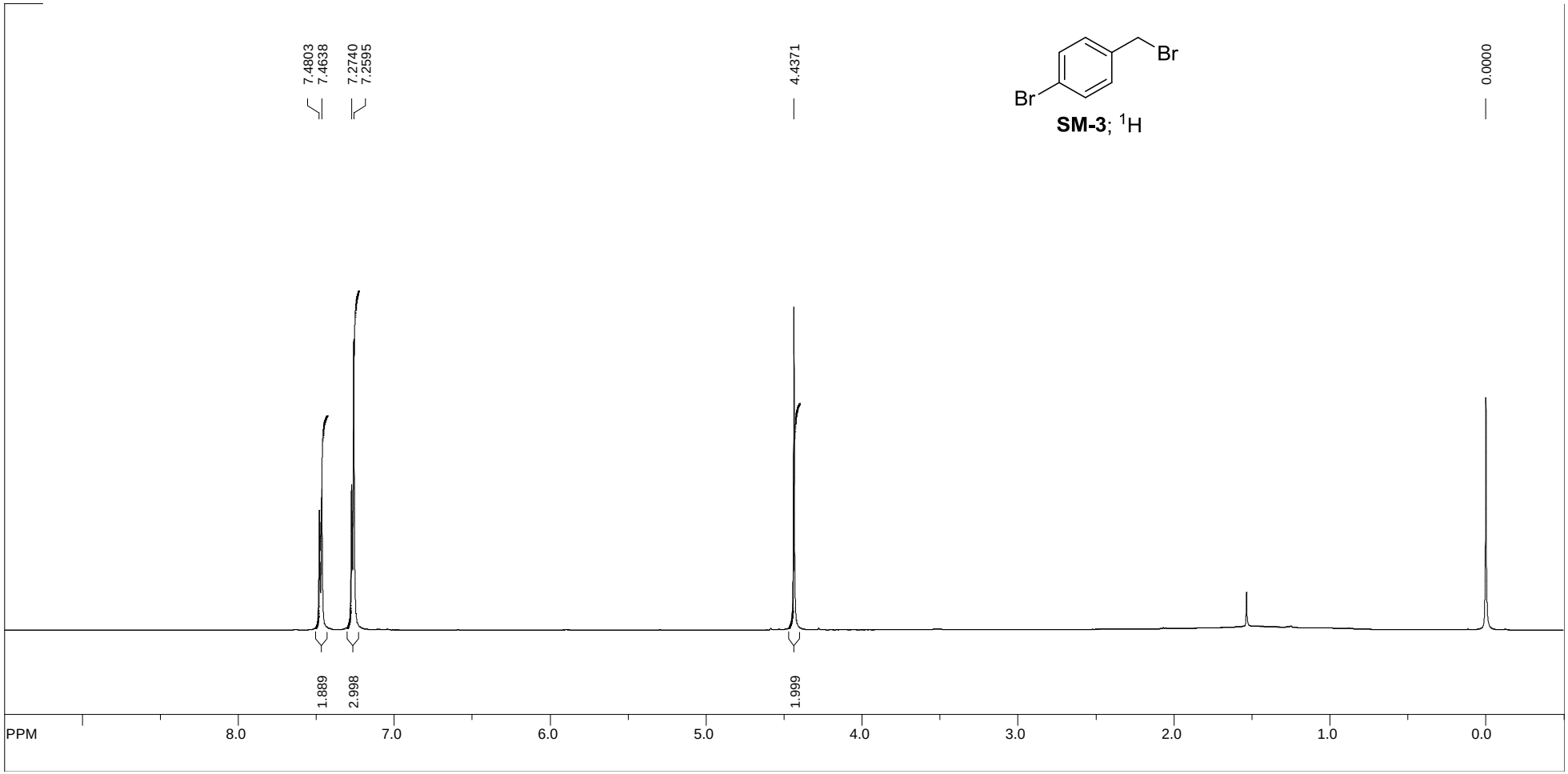


Figure S7: ^{1}H NMR spectrum of compound SM-5.

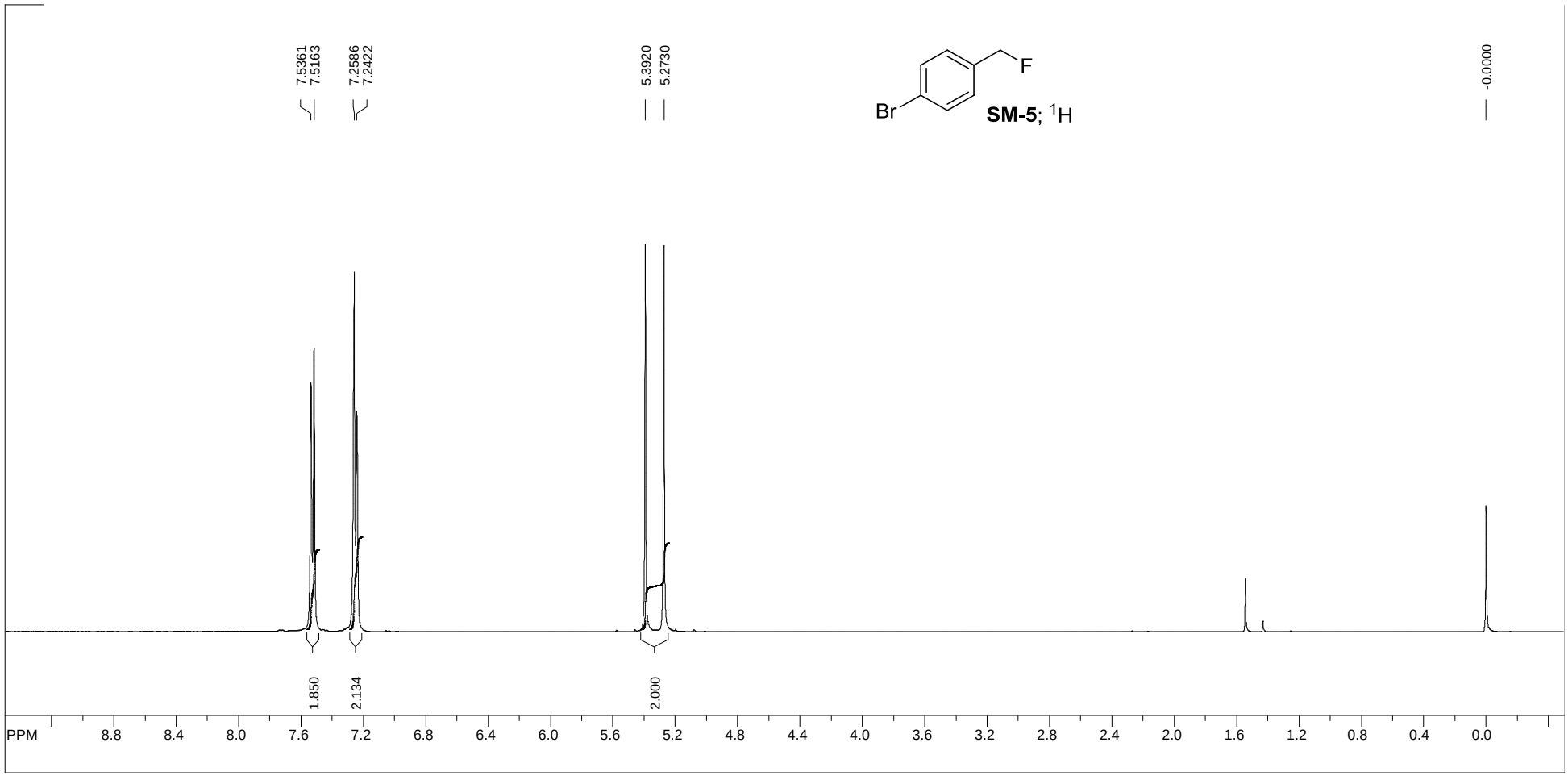


Figure S8: ^{1}H NMR spectrum of compound SM-6.

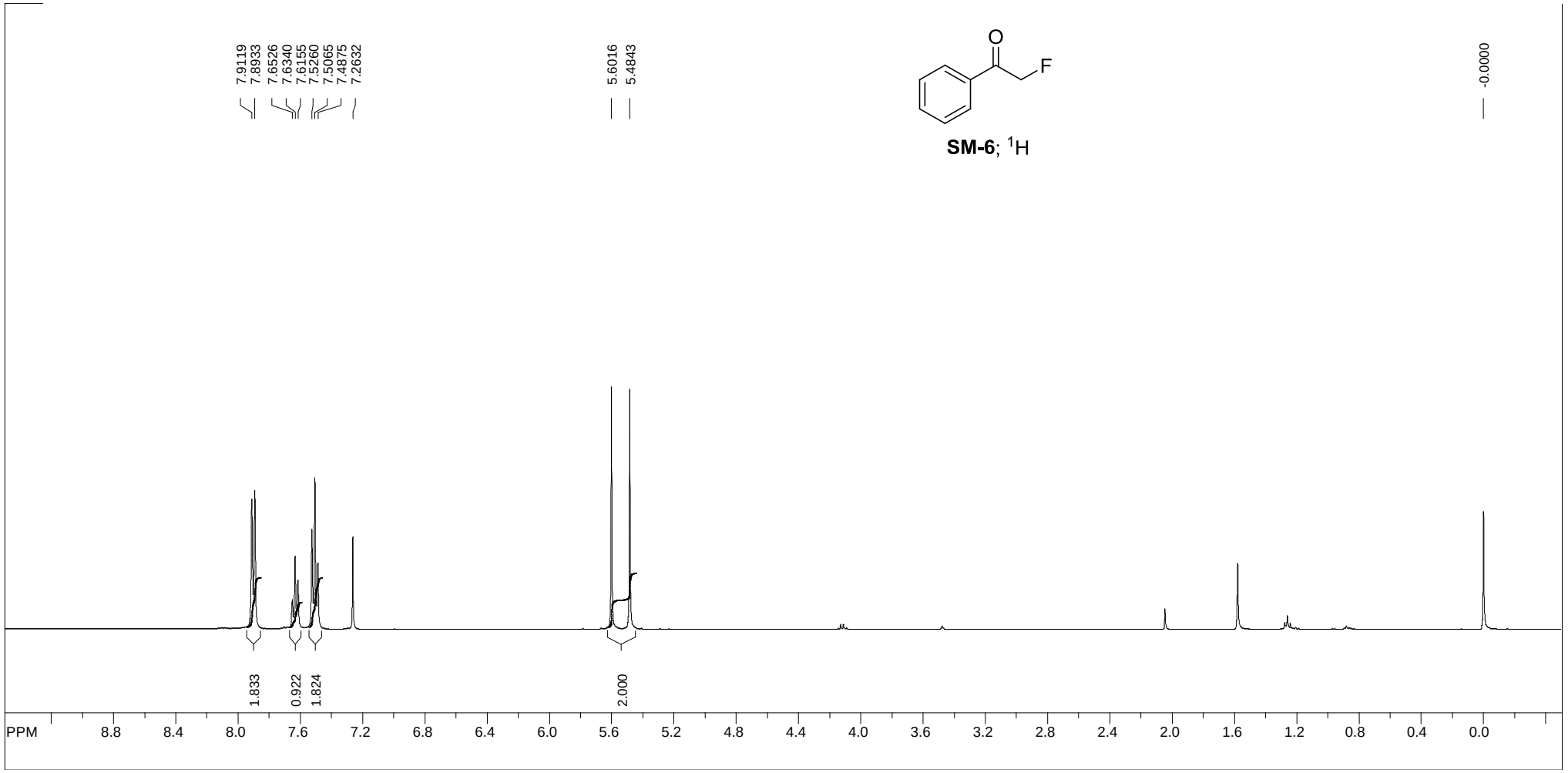


Figure S9: ^{1}H NMR spectrum of compound SM-7.

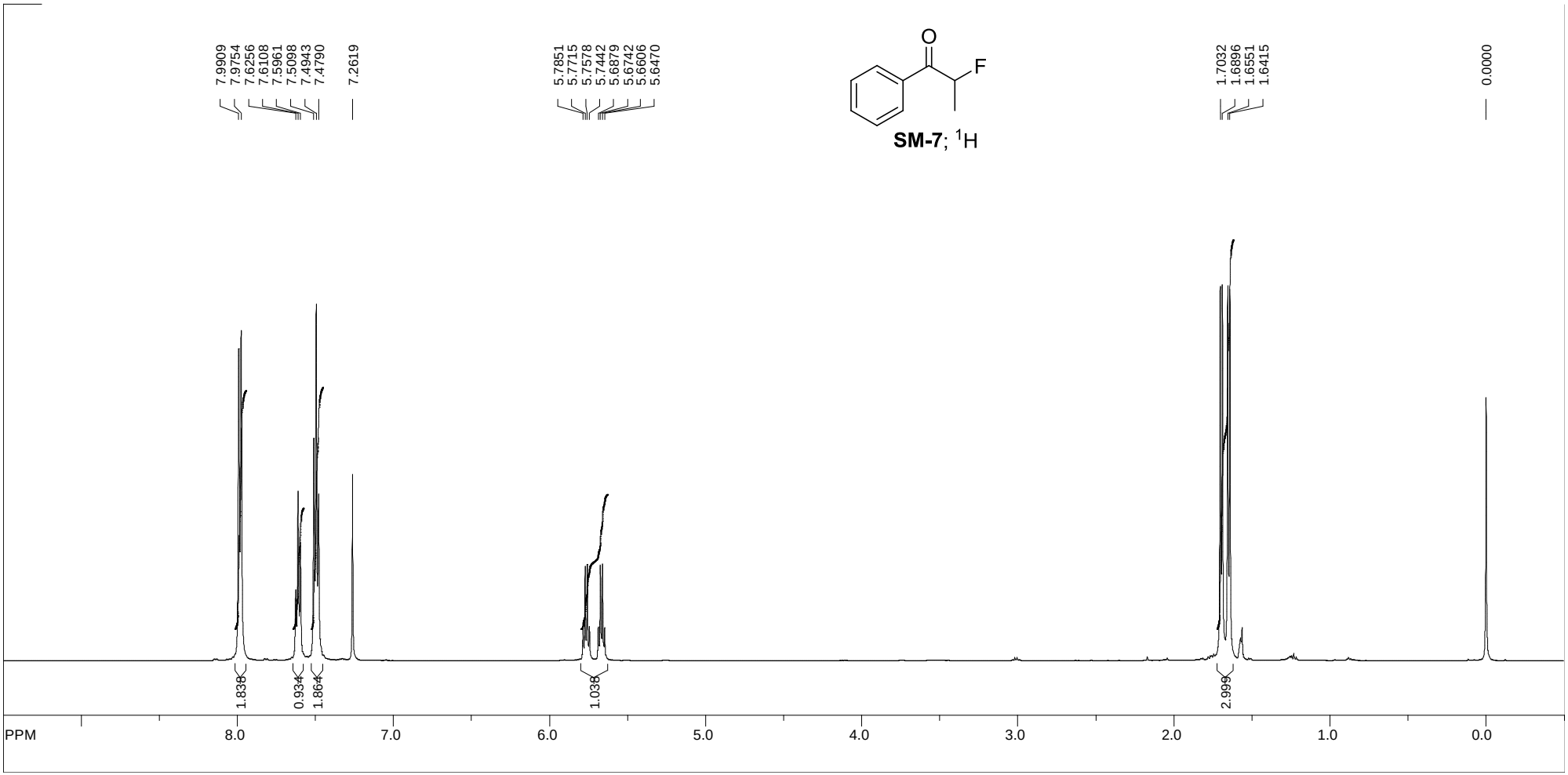


Figure S10: ^{1}H NMR spectrum of compound SM-8.

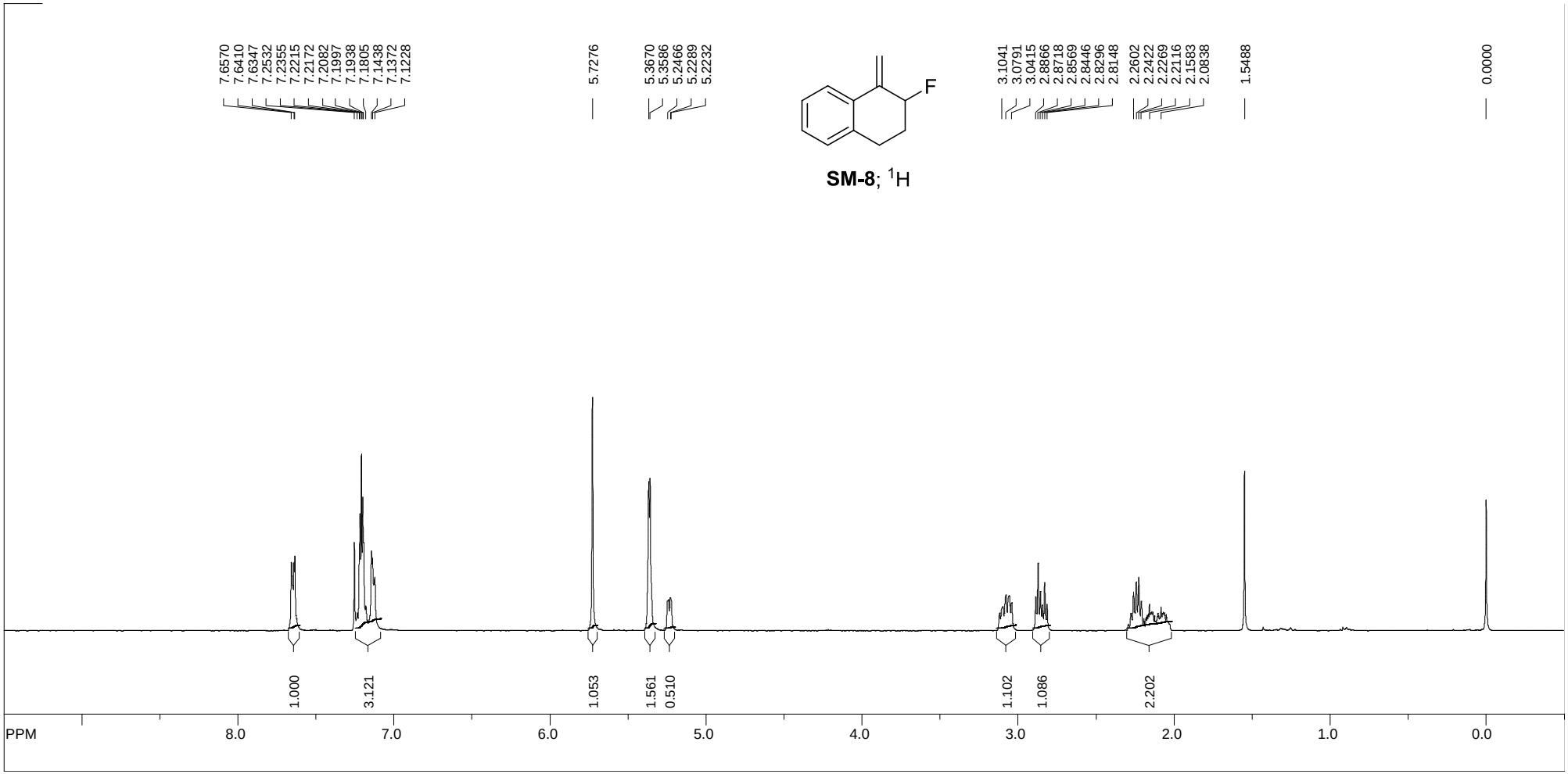


Figure S11: ^{1}H NMR spectrum of compound SM-9.

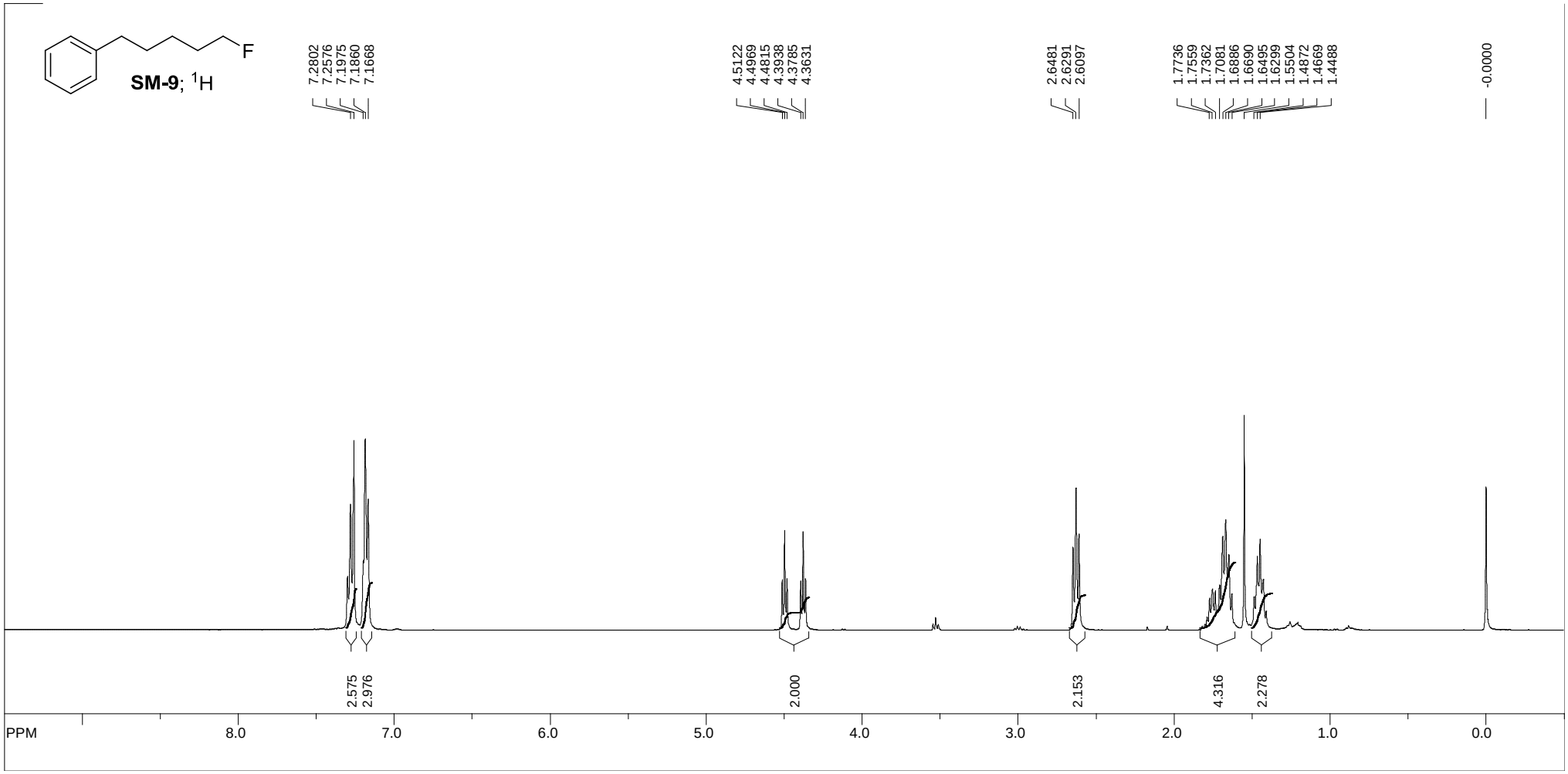


Figure S12: ^{1}H NMR spectrum of compound SM-10.

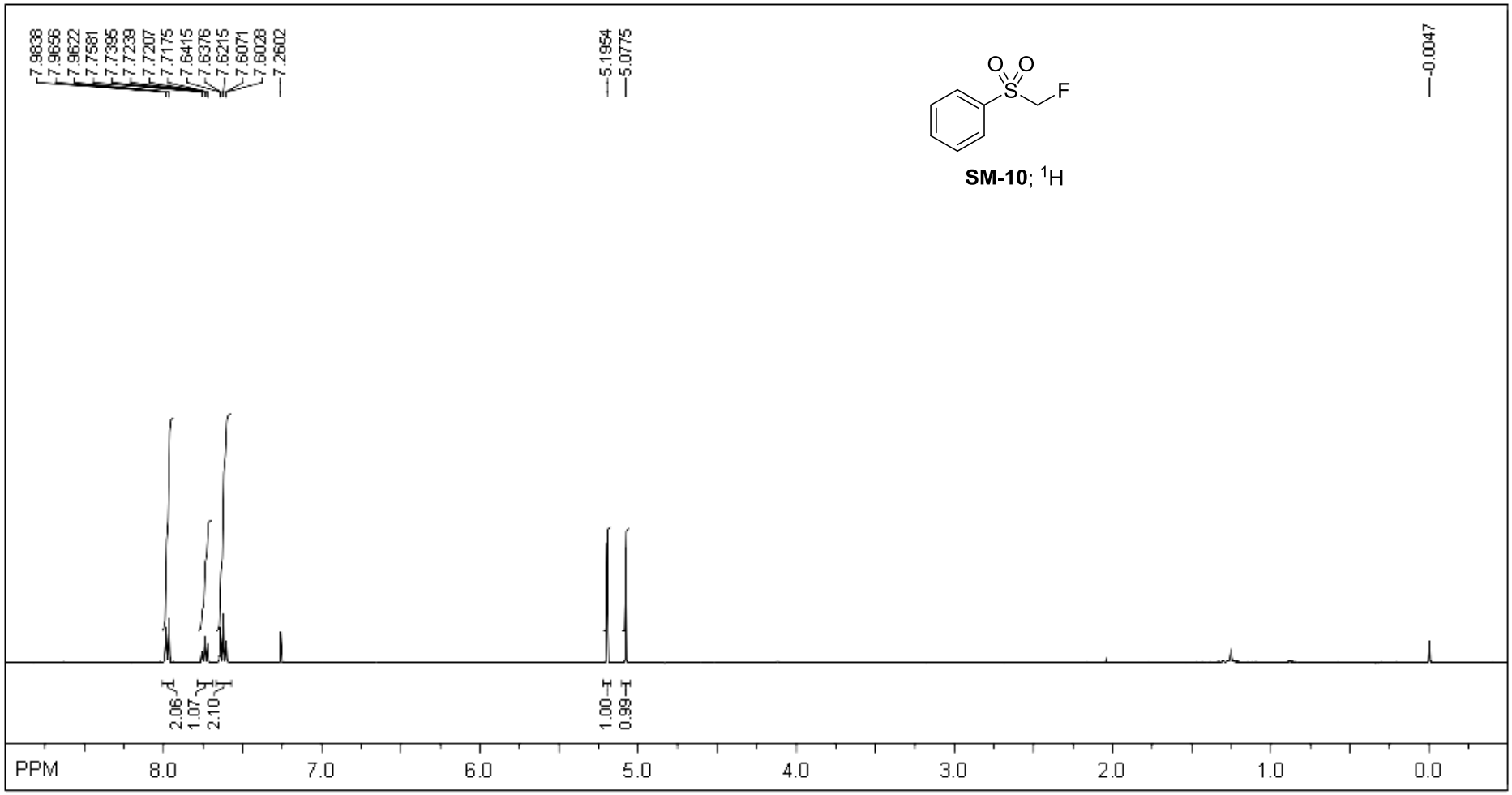


Figure S13: ^{1}H NMR spectrum of compound SM-13.

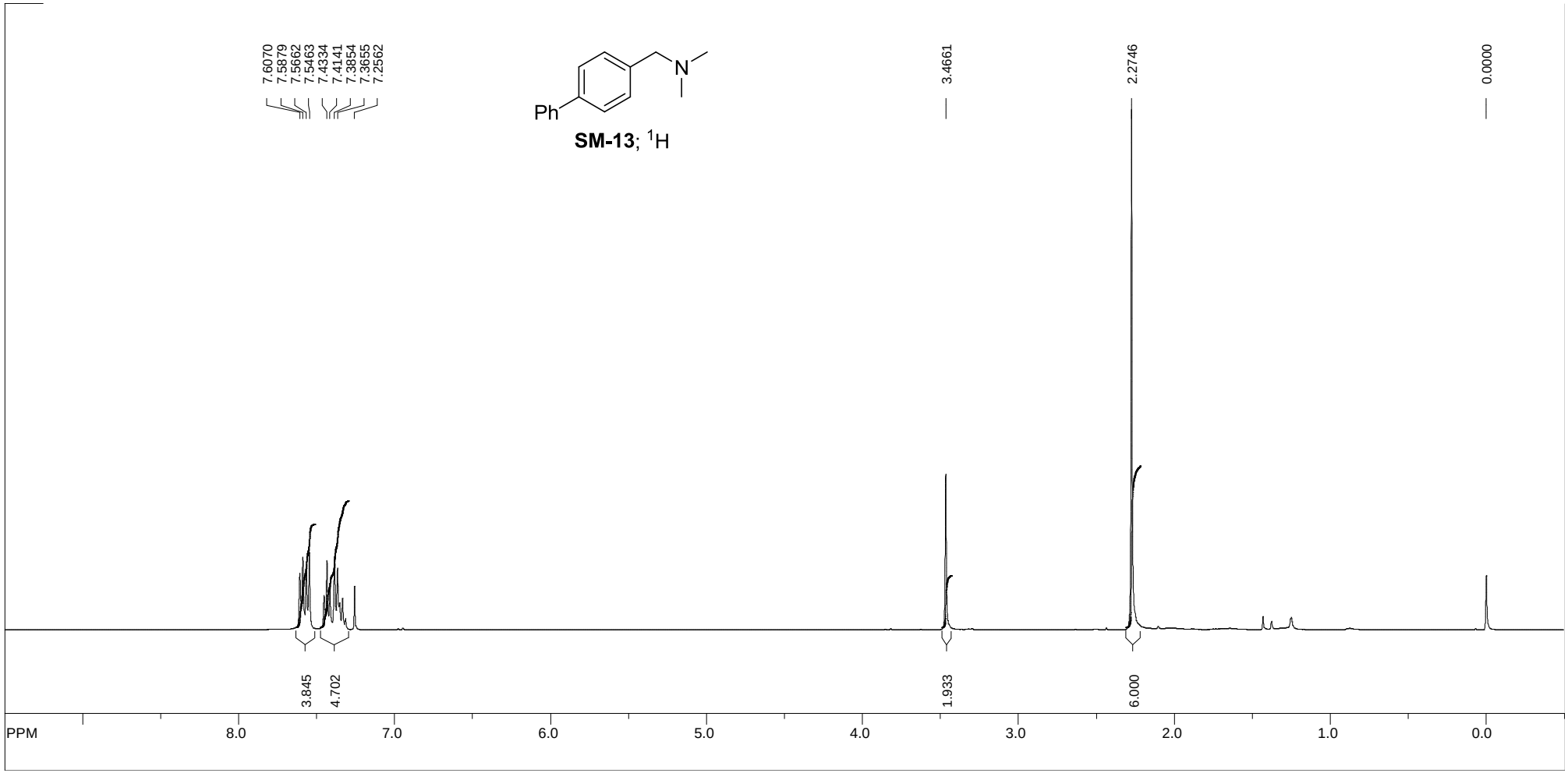


Figure S14: ^{1}H NMR spectrum of compound SM-16.

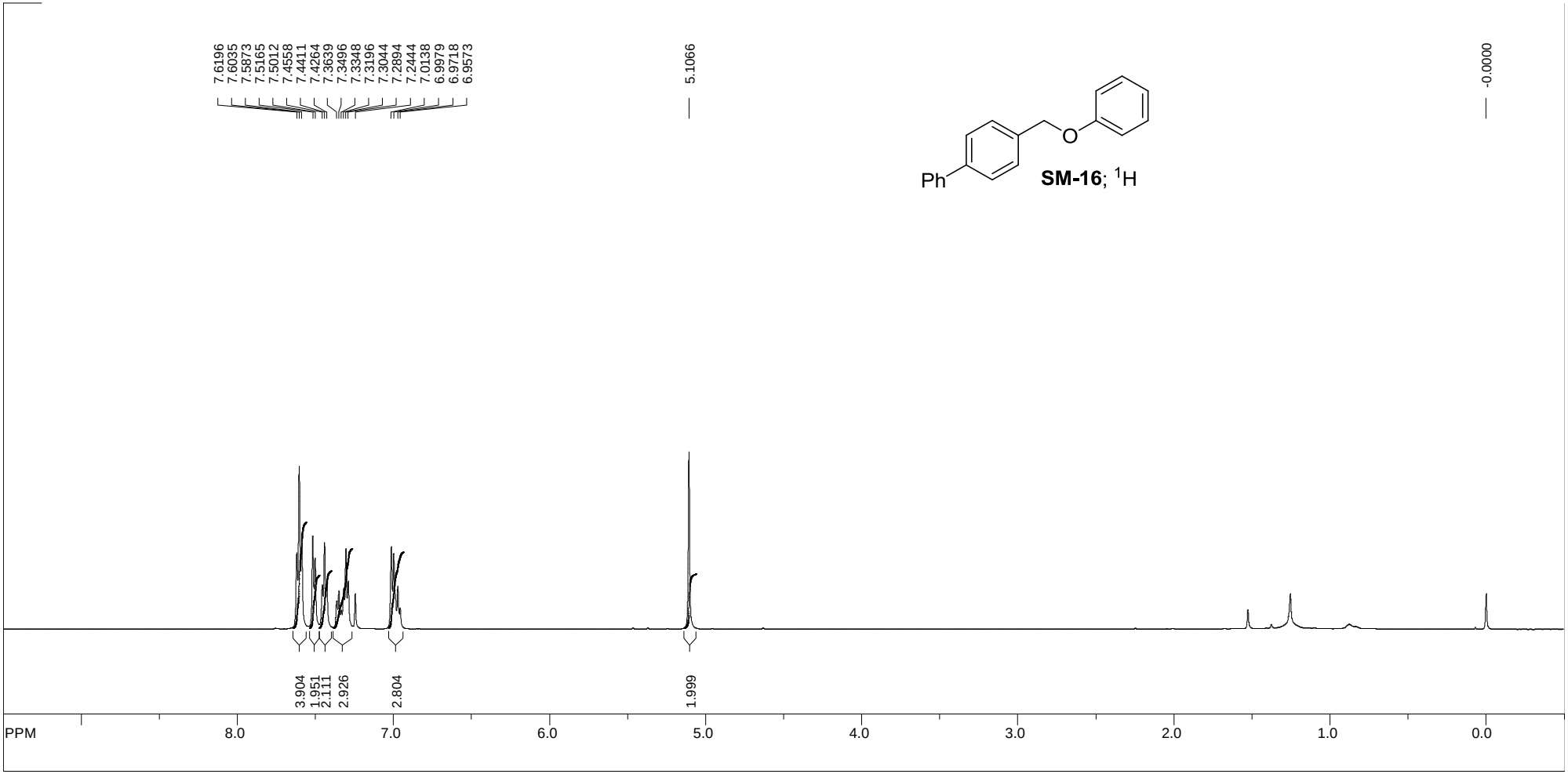


Figure S15: ^{1}H NMR spectrum of compound SM-19.

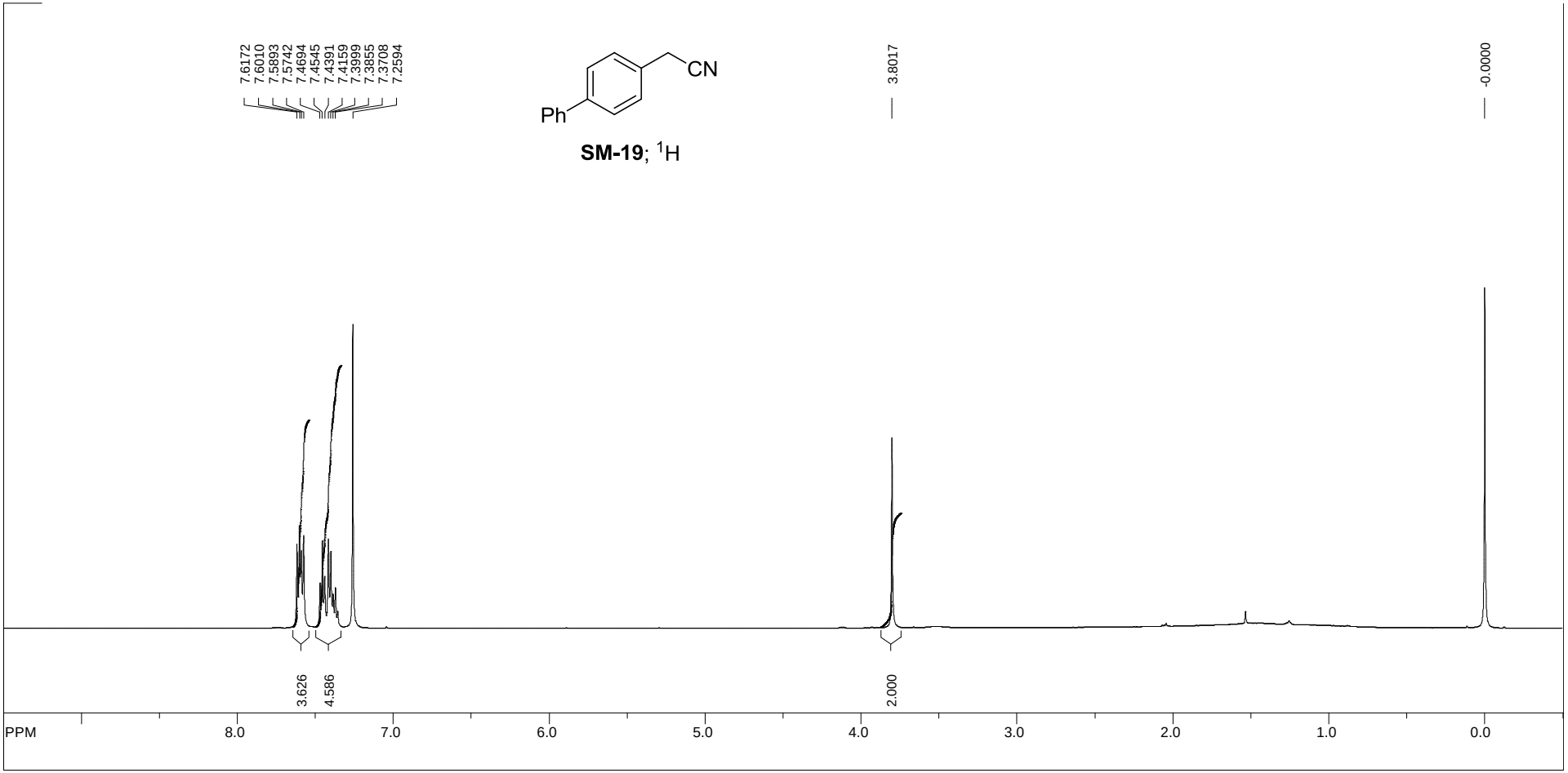


Figure S16: ^{1}H NMR spectrum of compound SM-20.

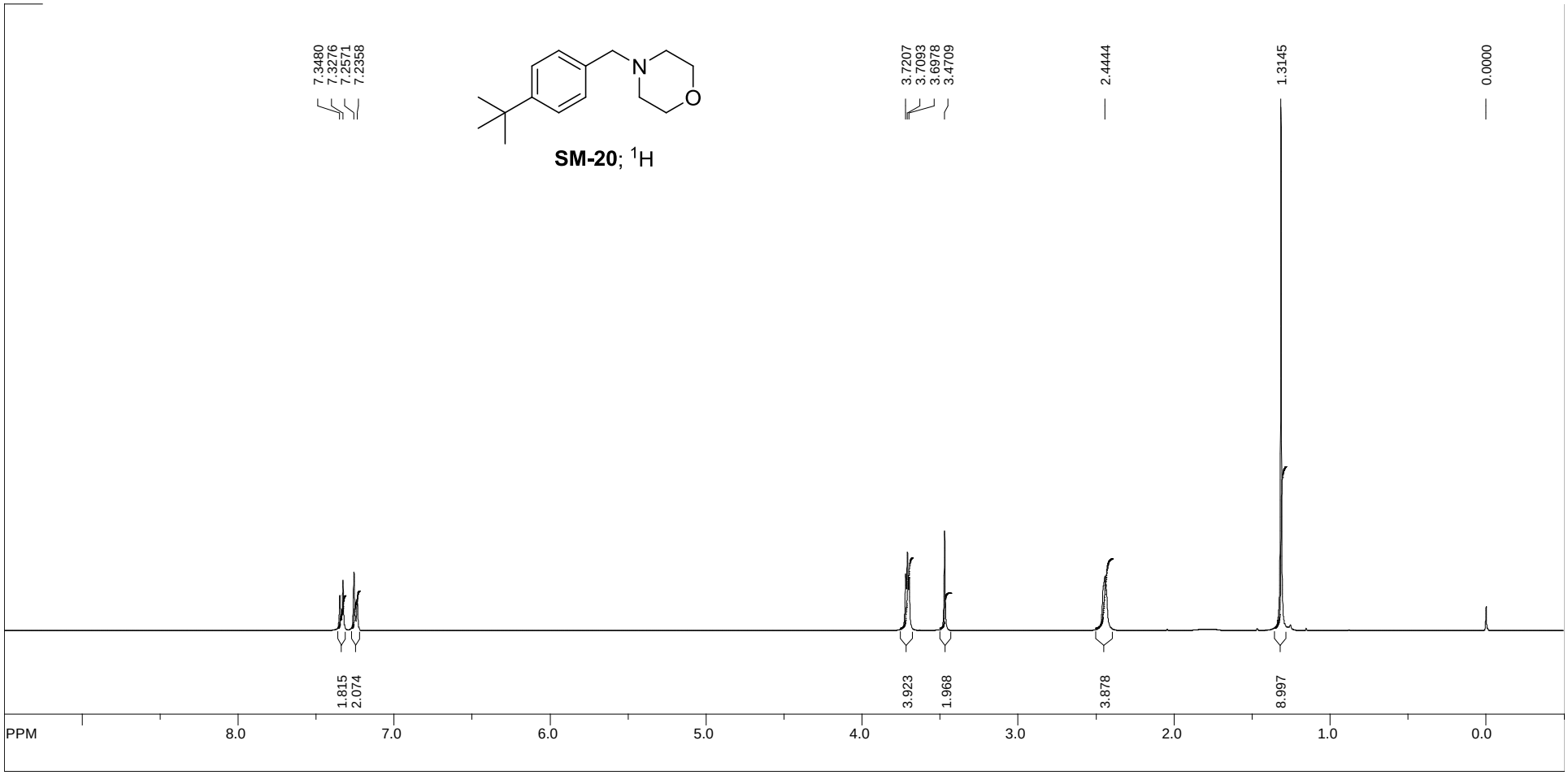


Figure S17: ^{1}H NMR spectrum of compound SM-21.

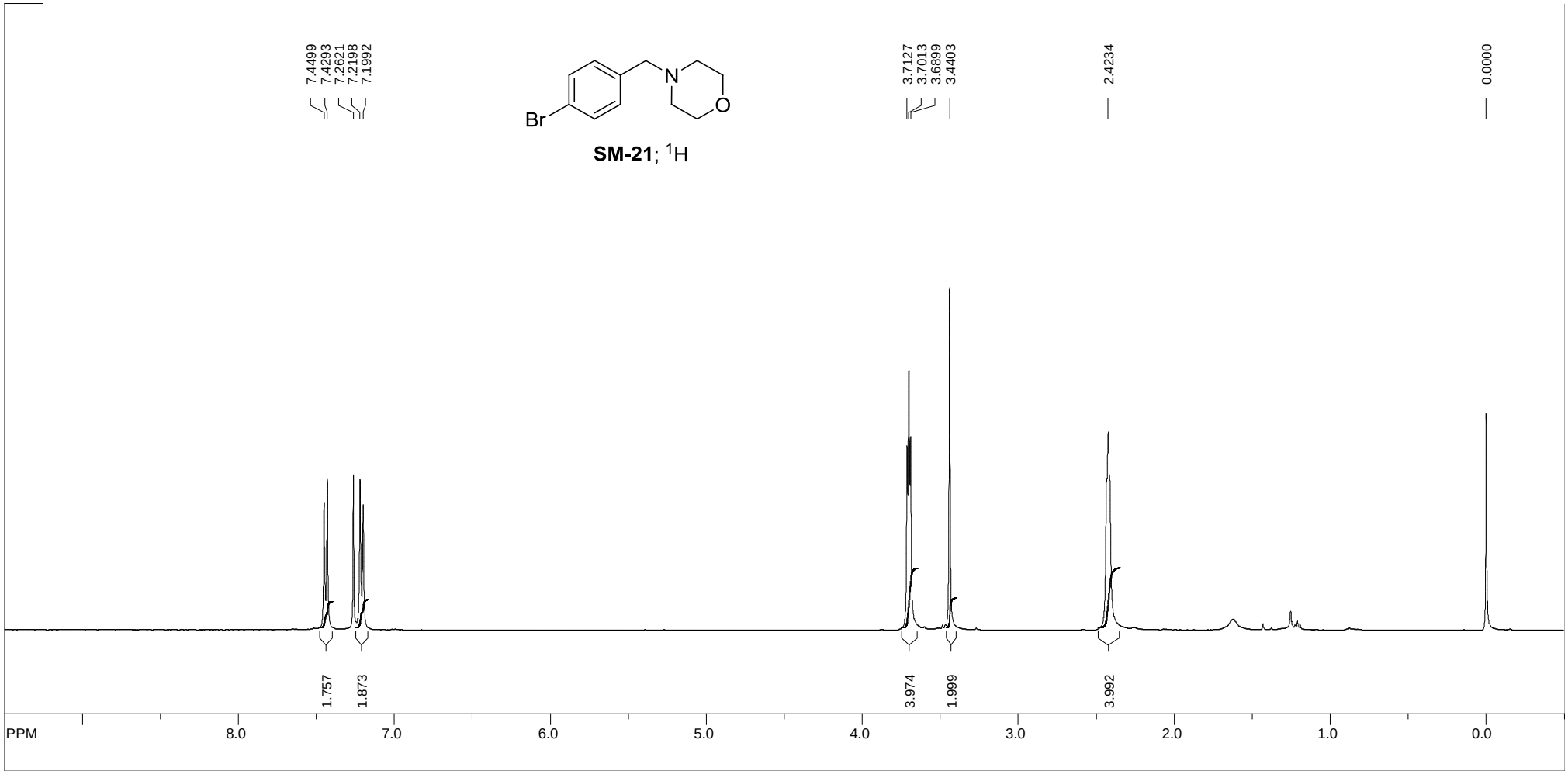


Figure S18: ^{1}H NMR spectrum of compound SM-22.

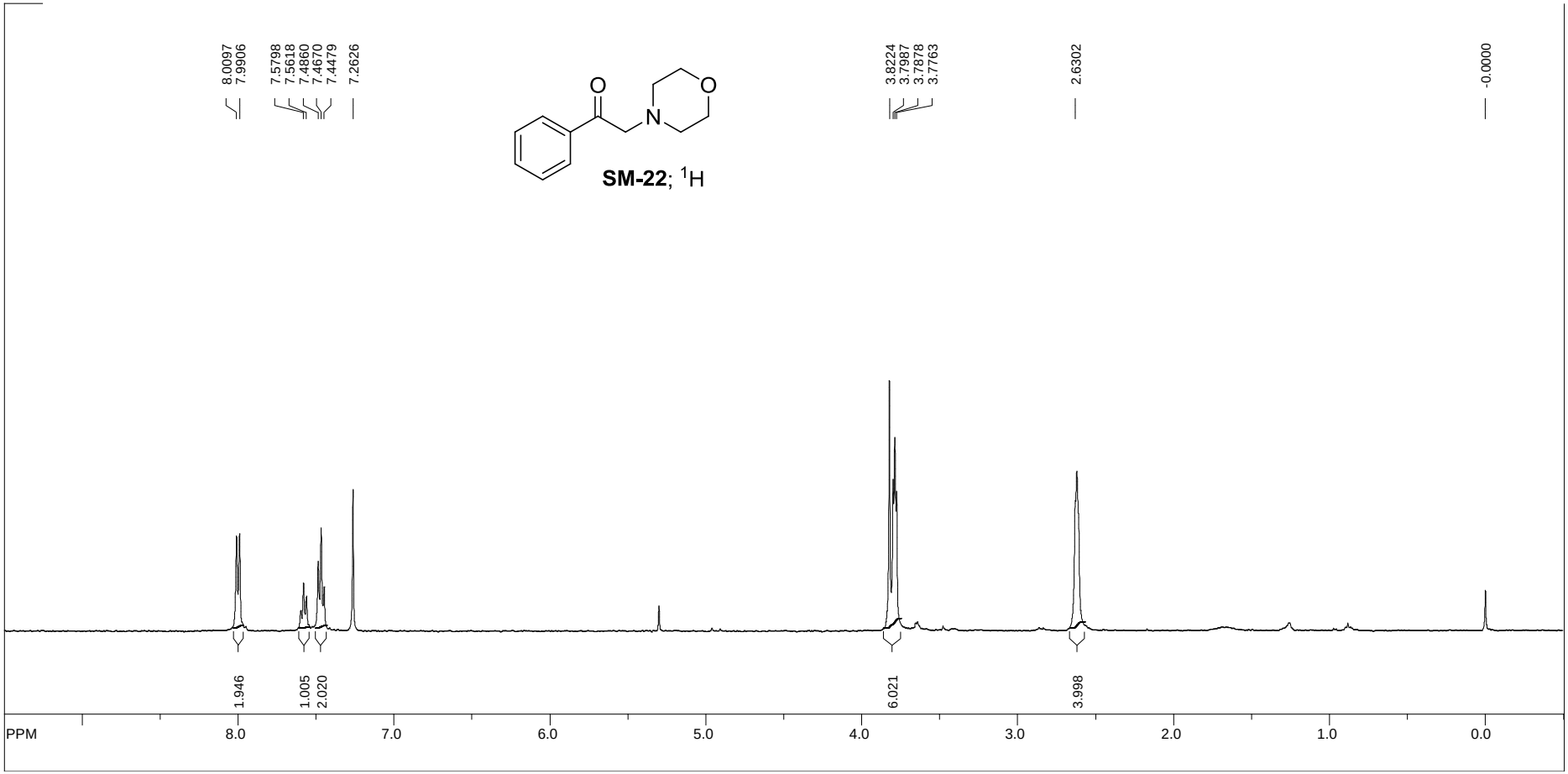
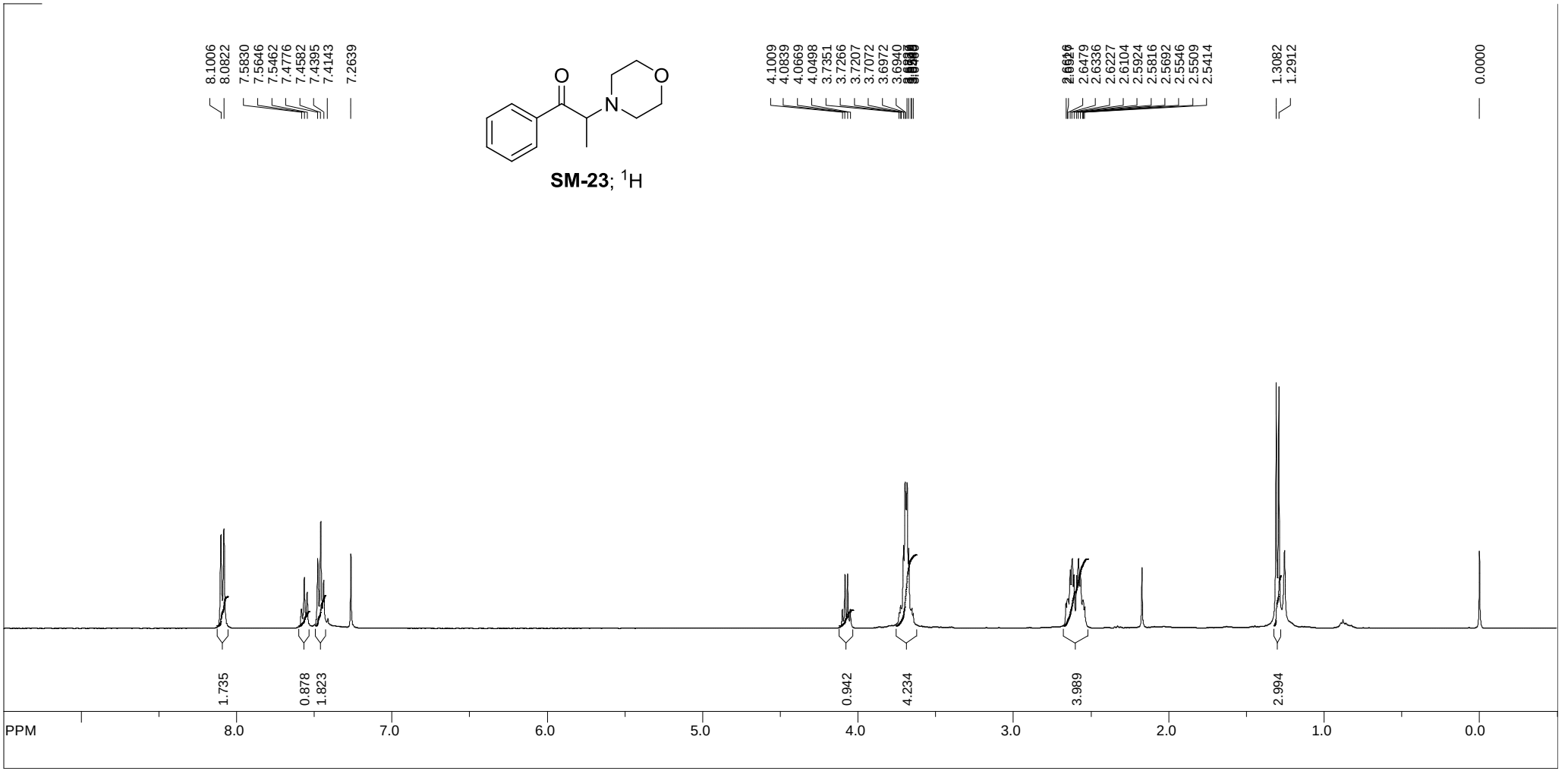


Figure S19: ^{1}H NMR spectrum of compound SM-23.



NMR Spectra of Novel Compounds

Figure S1: ^{1}H NMR spectrum of compound SM-4.

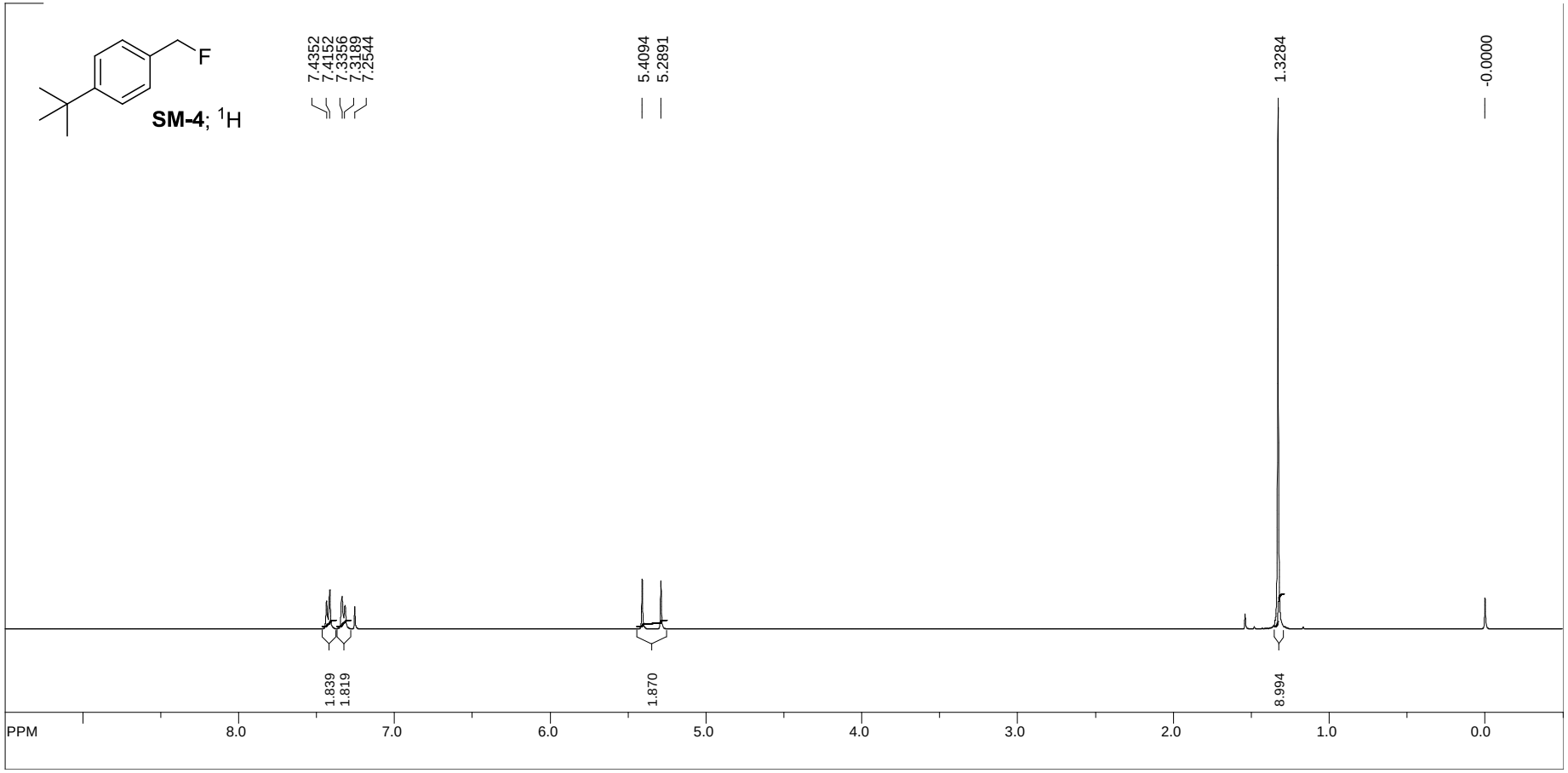


Figure S2: ^{13}C NMR spectrum of compound SM-4.

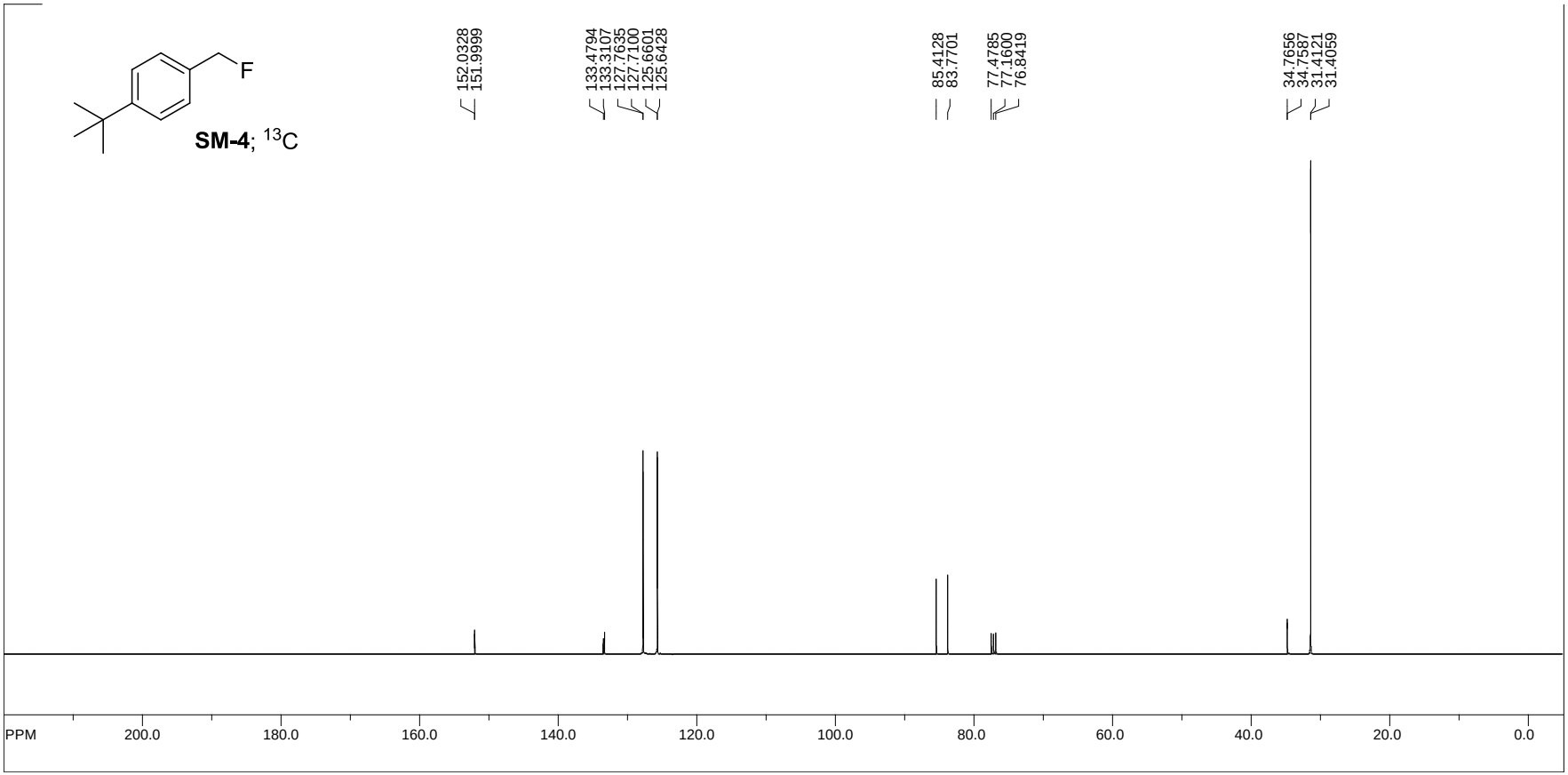


Figure S3: ^{19}F NMR spectrum of compound SM-4.

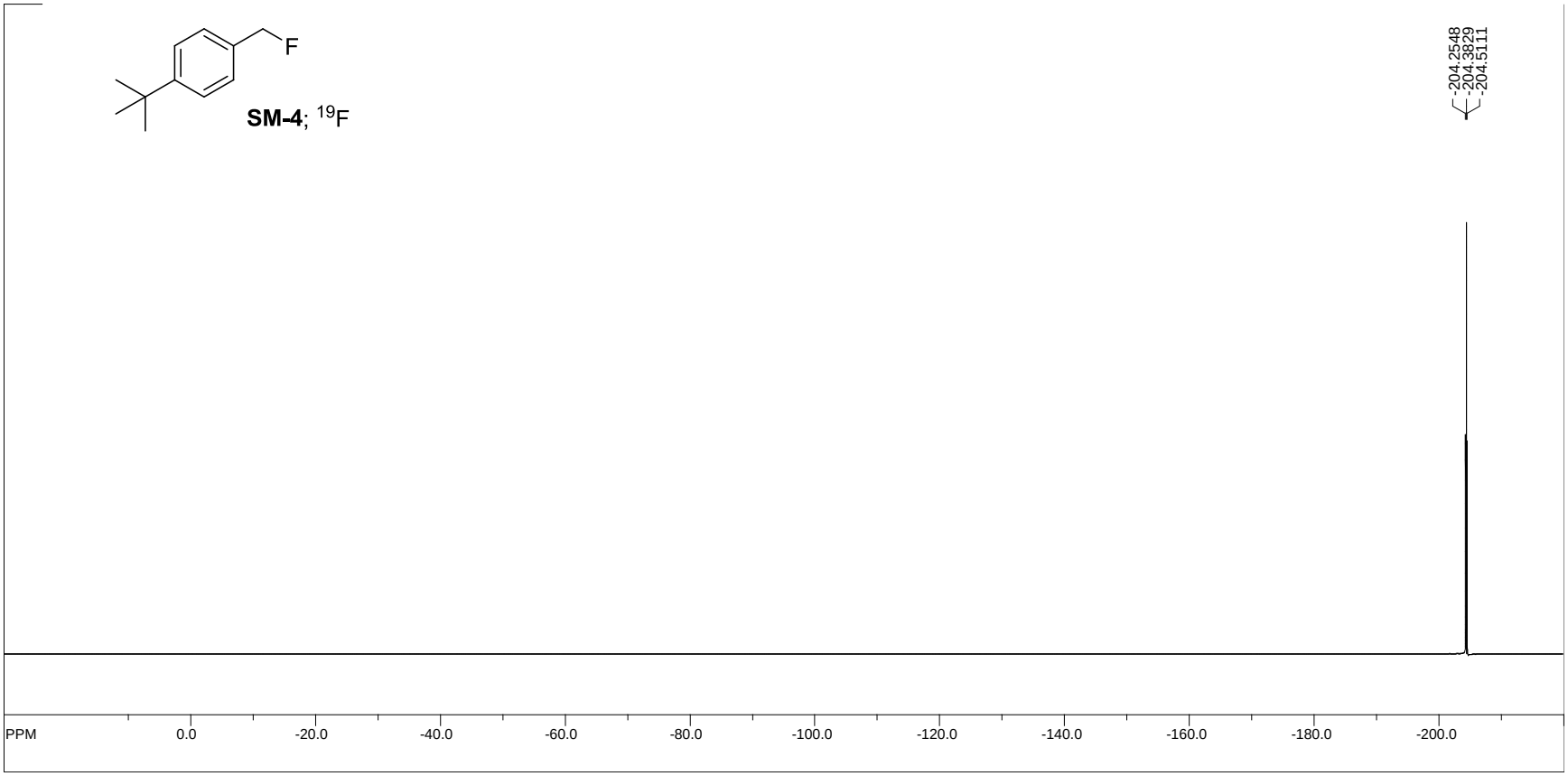


Figure S4: ^{1}H NMR spectrum of compound SM-11.

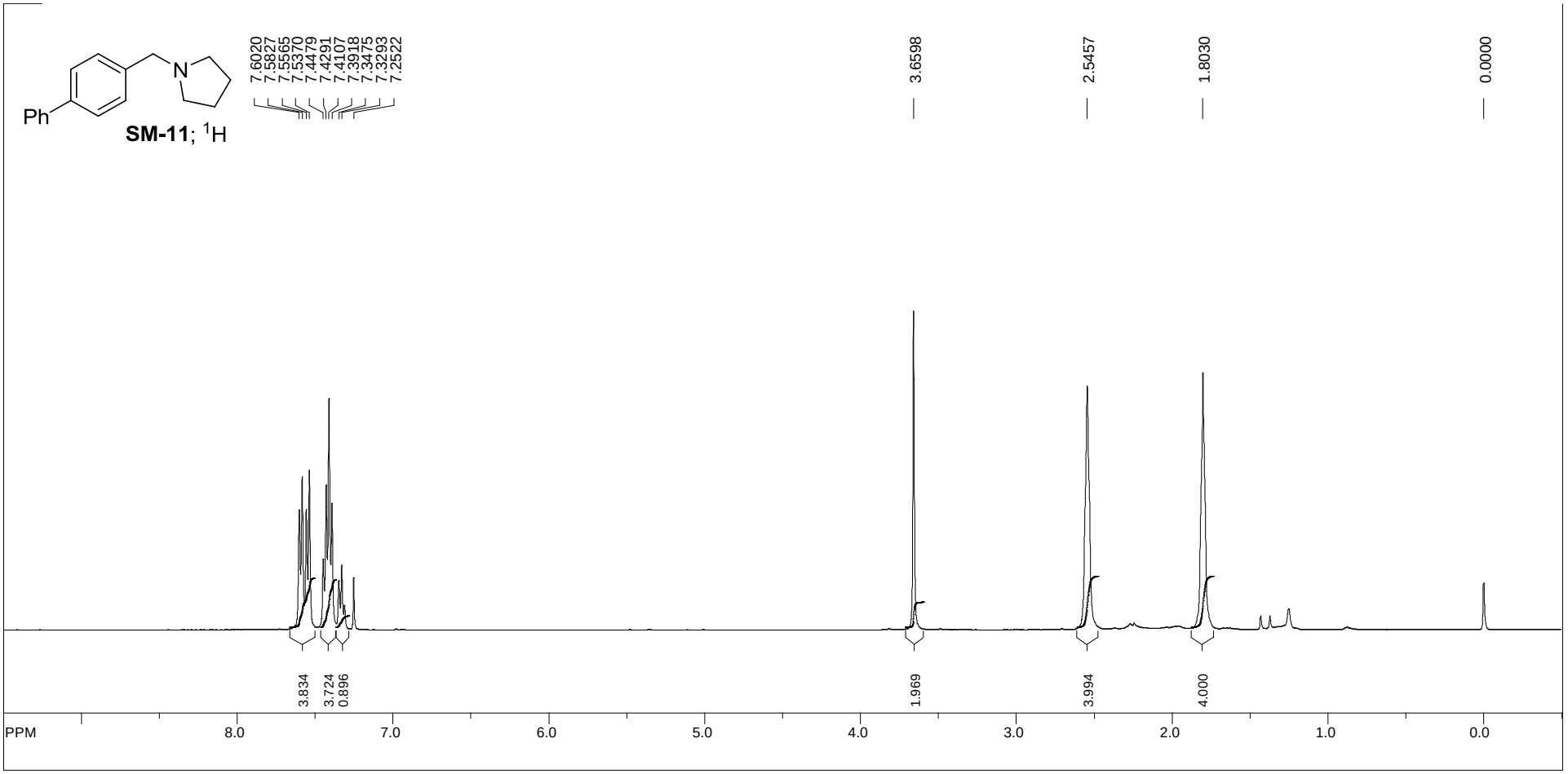


Figure S5: ^{13}C NMR spectrum of compound SM-11.

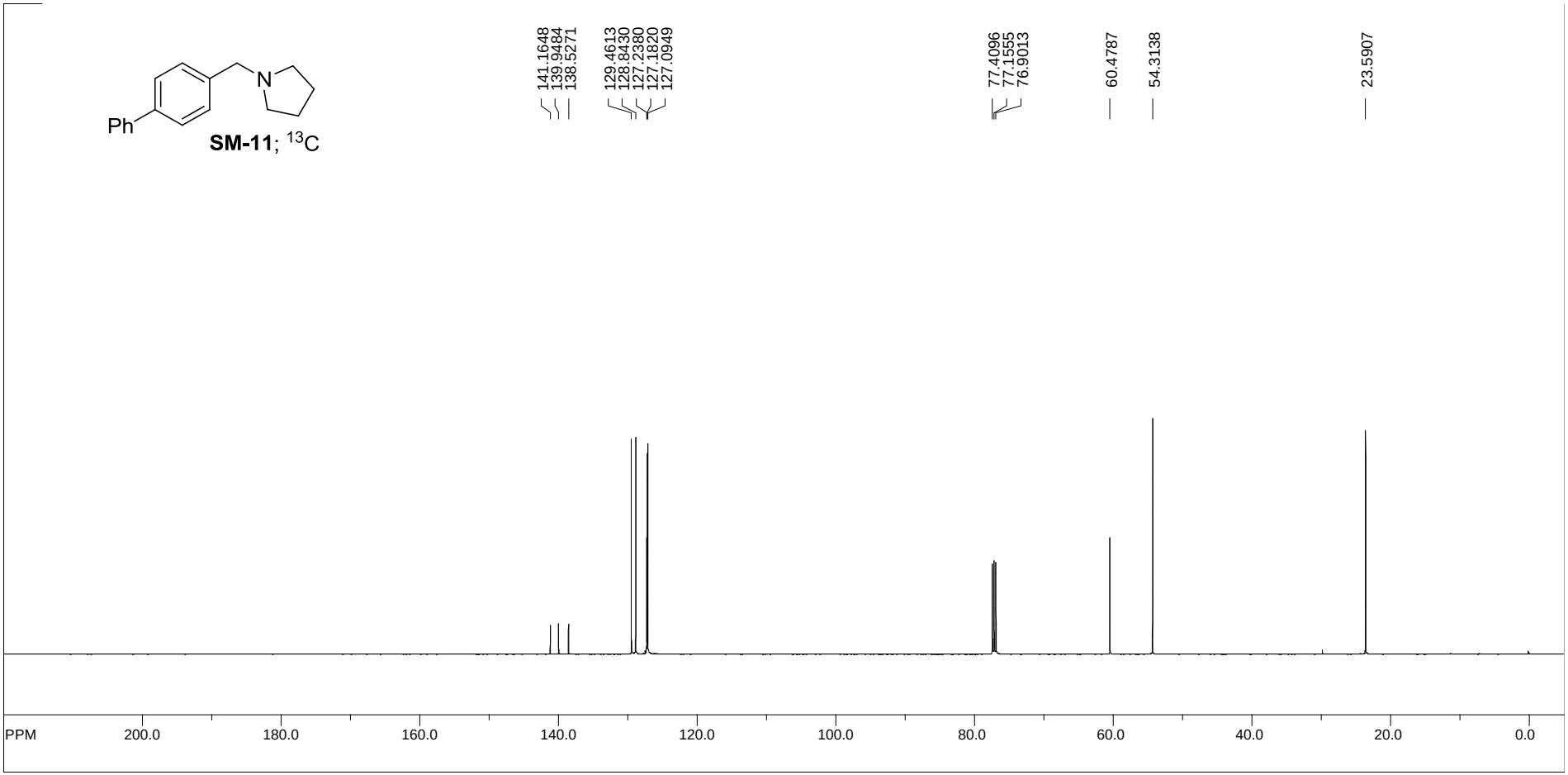


Figure S6: ^{1}H NMR spectrum of compound SM-12.

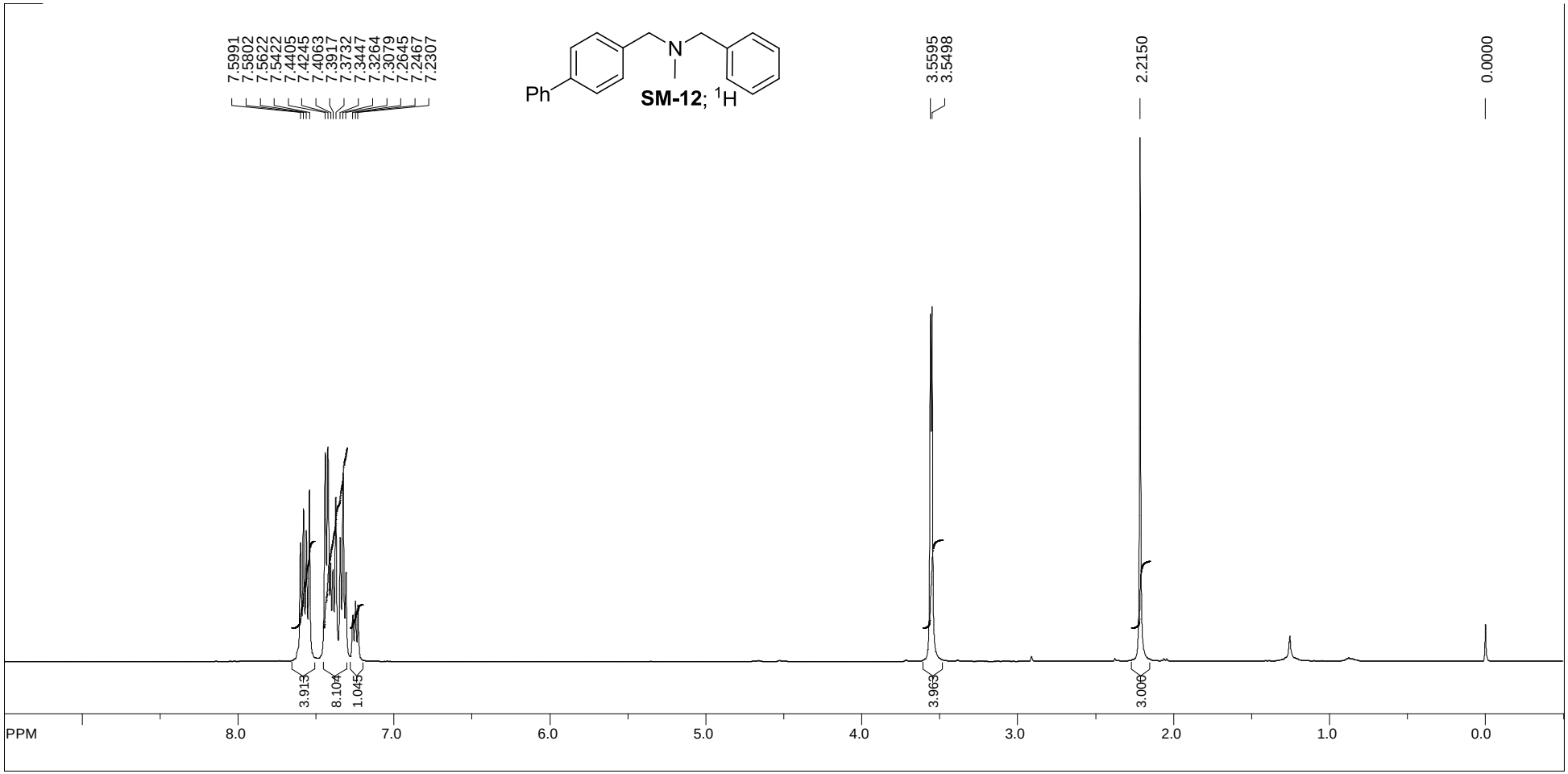


Figure S7: ^{13}C NMR spectrum of compound SM-12.

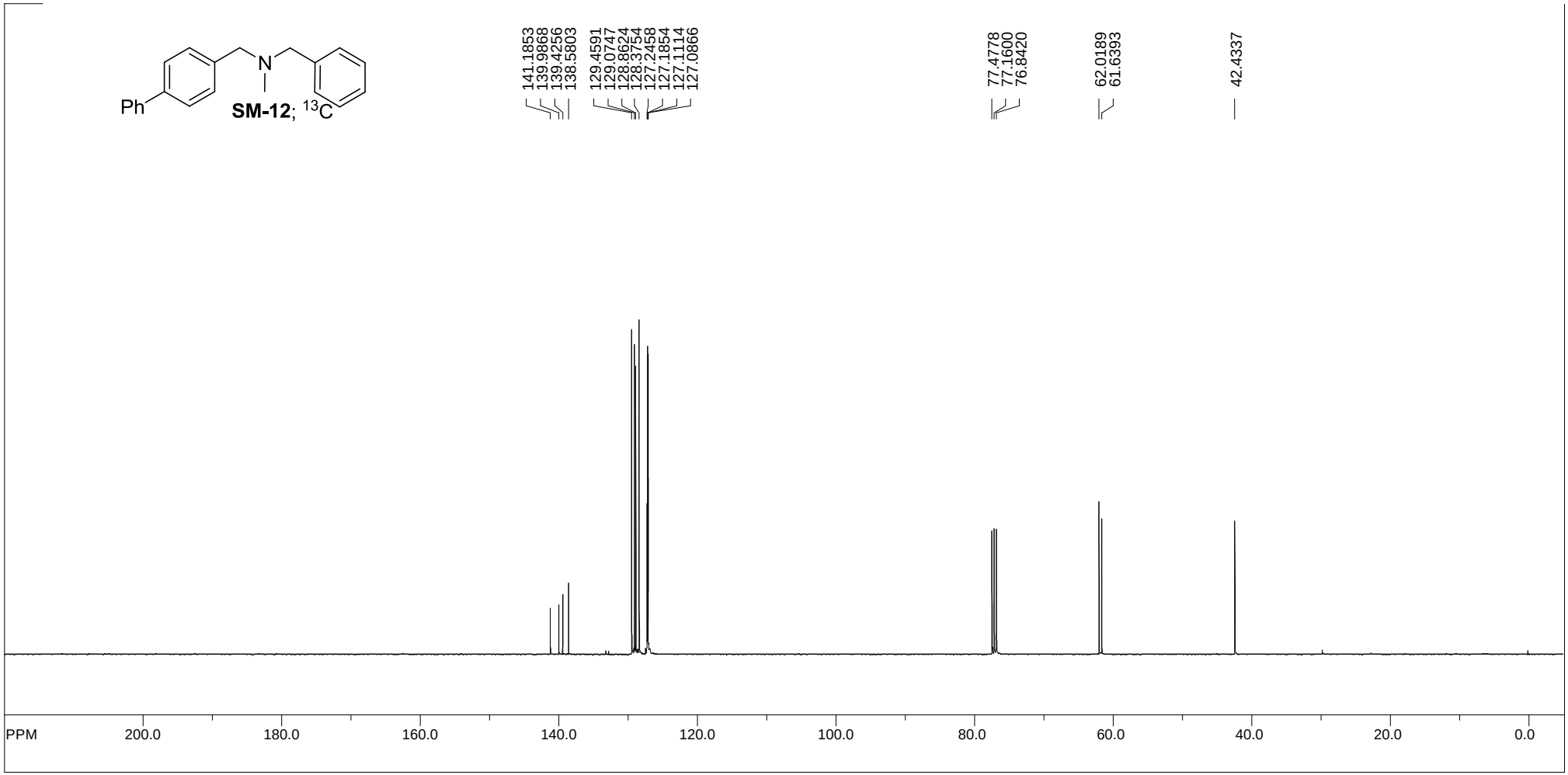


Figure S8: ^{1}H NMR spectrum of compound SM-14.

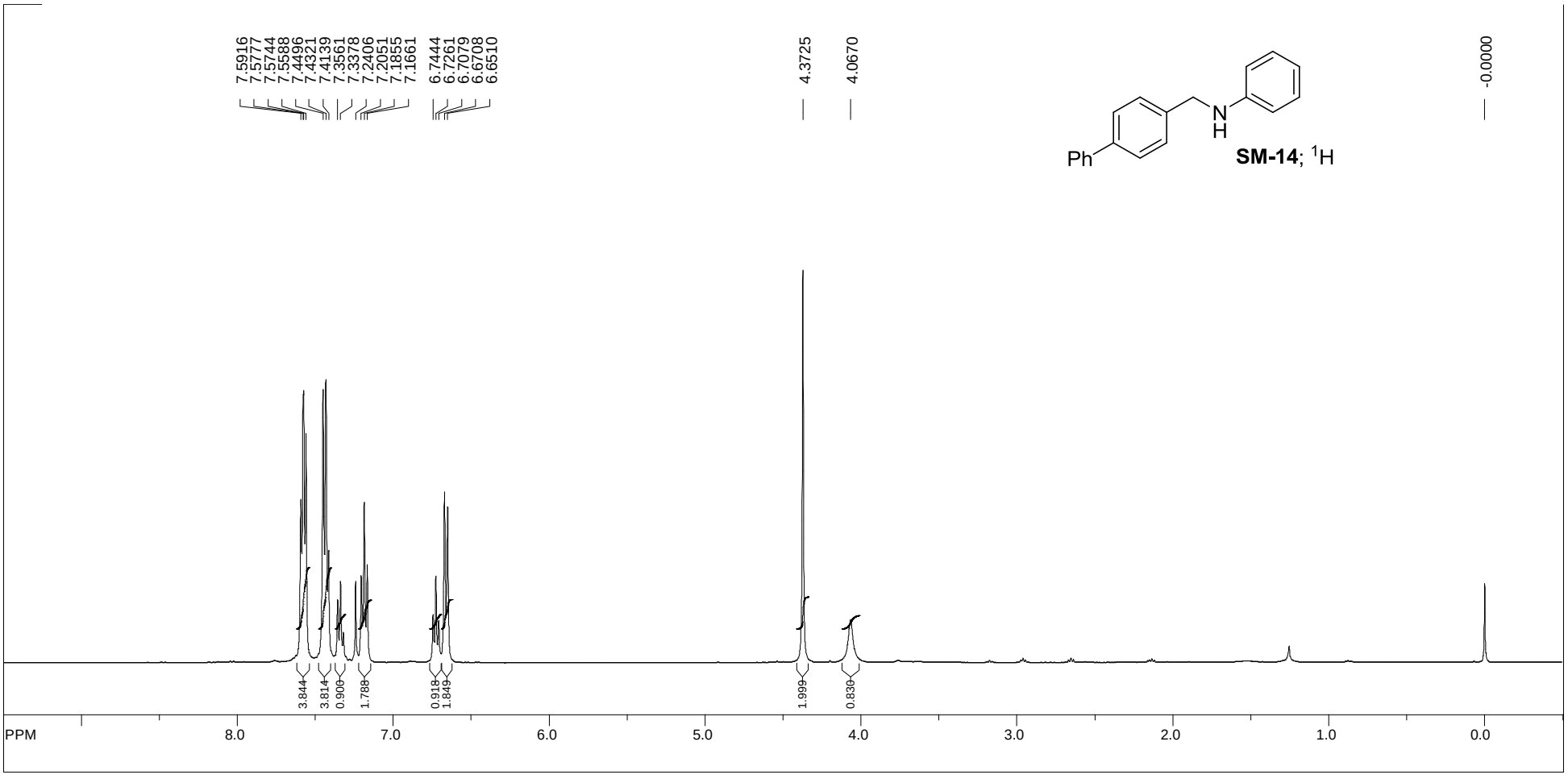


Figure S9: ^{13}C NMR spectrum of compound SM-14.

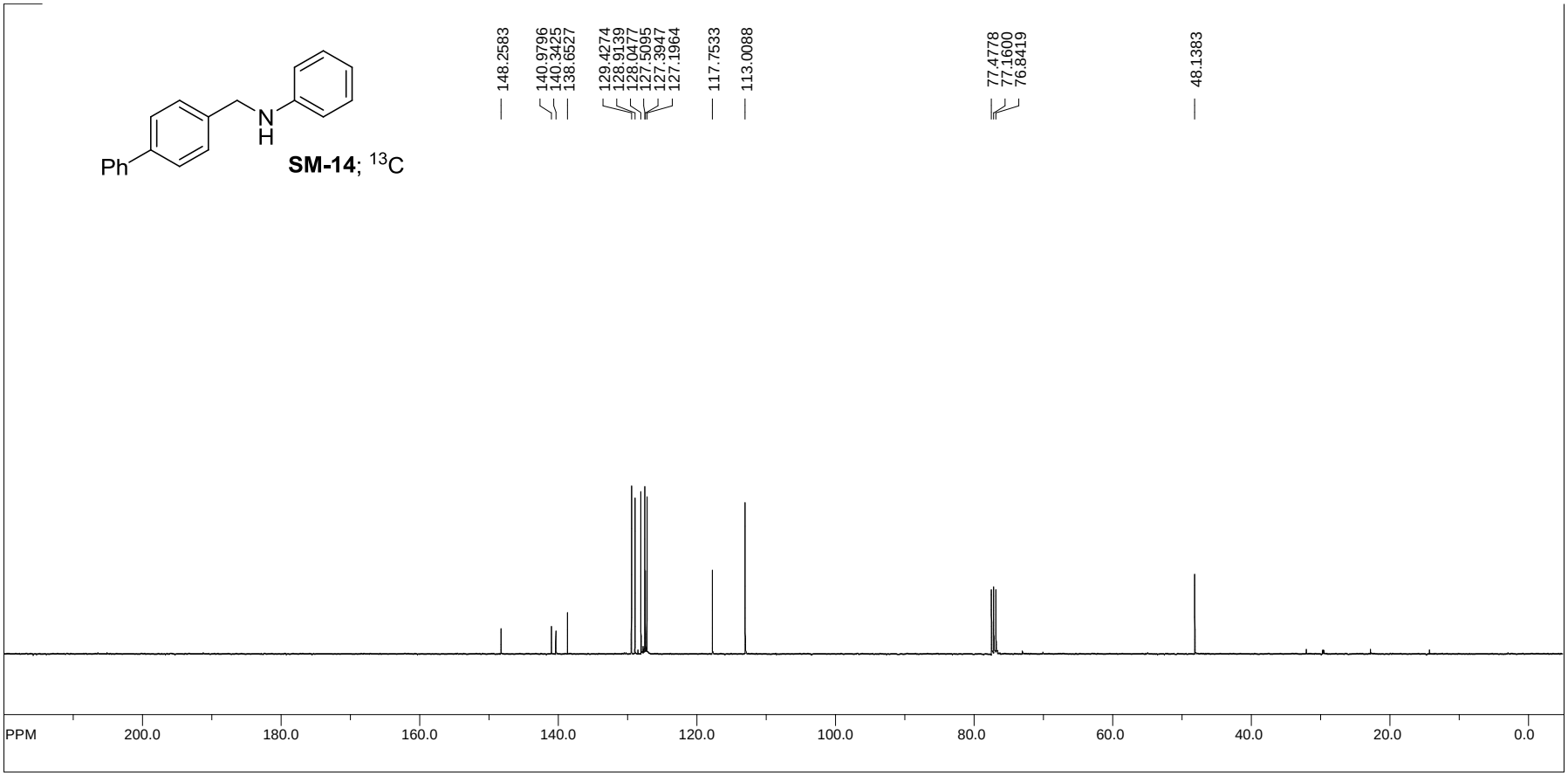


Figure S10: ^{1}H NMR spectrum of compound SM-15.

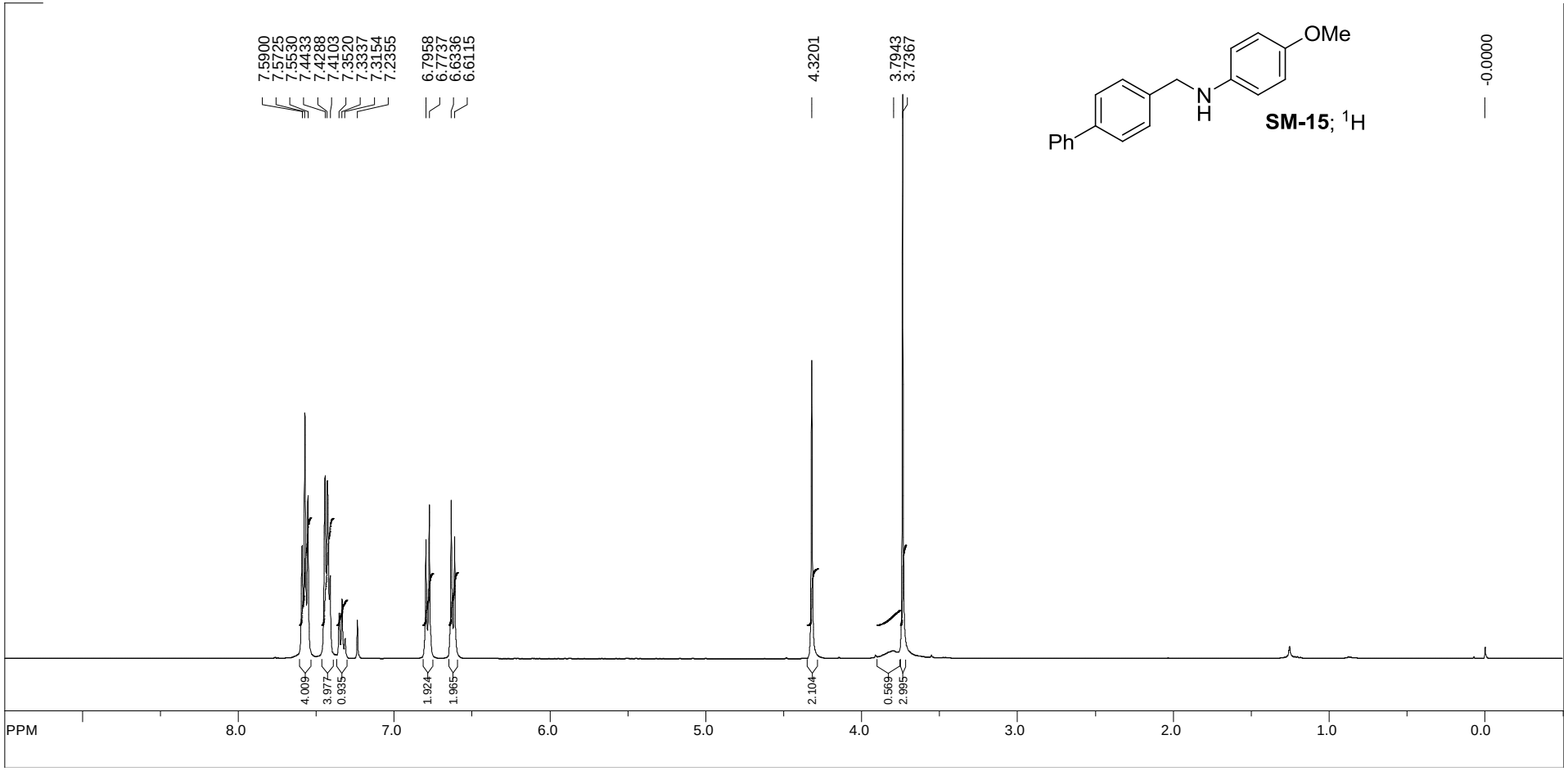


Figure S11: ^{13}C NMR spectrum of compound SM-15.

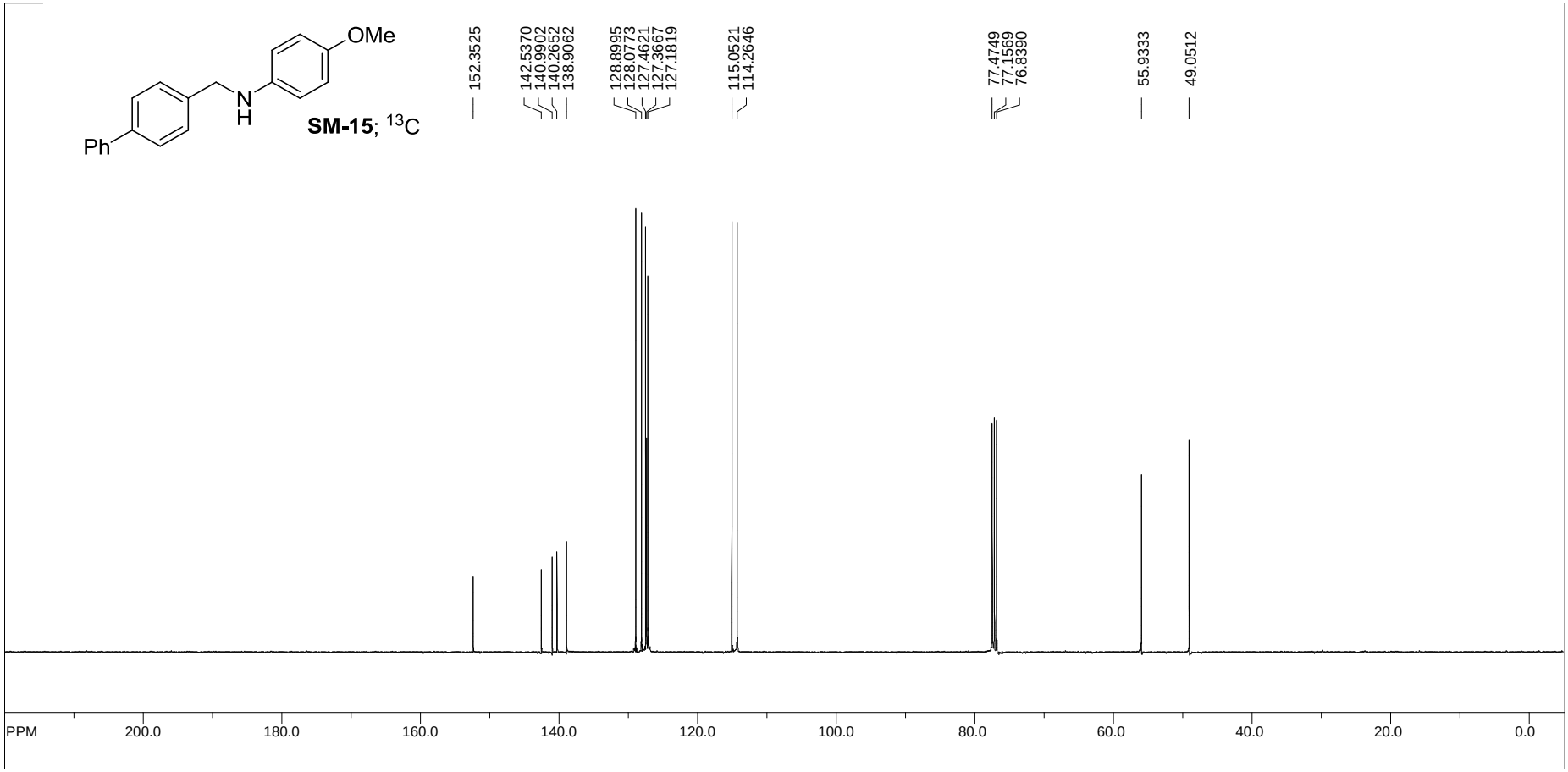


Figure S12: ^{1}H NMR spectrum of compound SM-17.

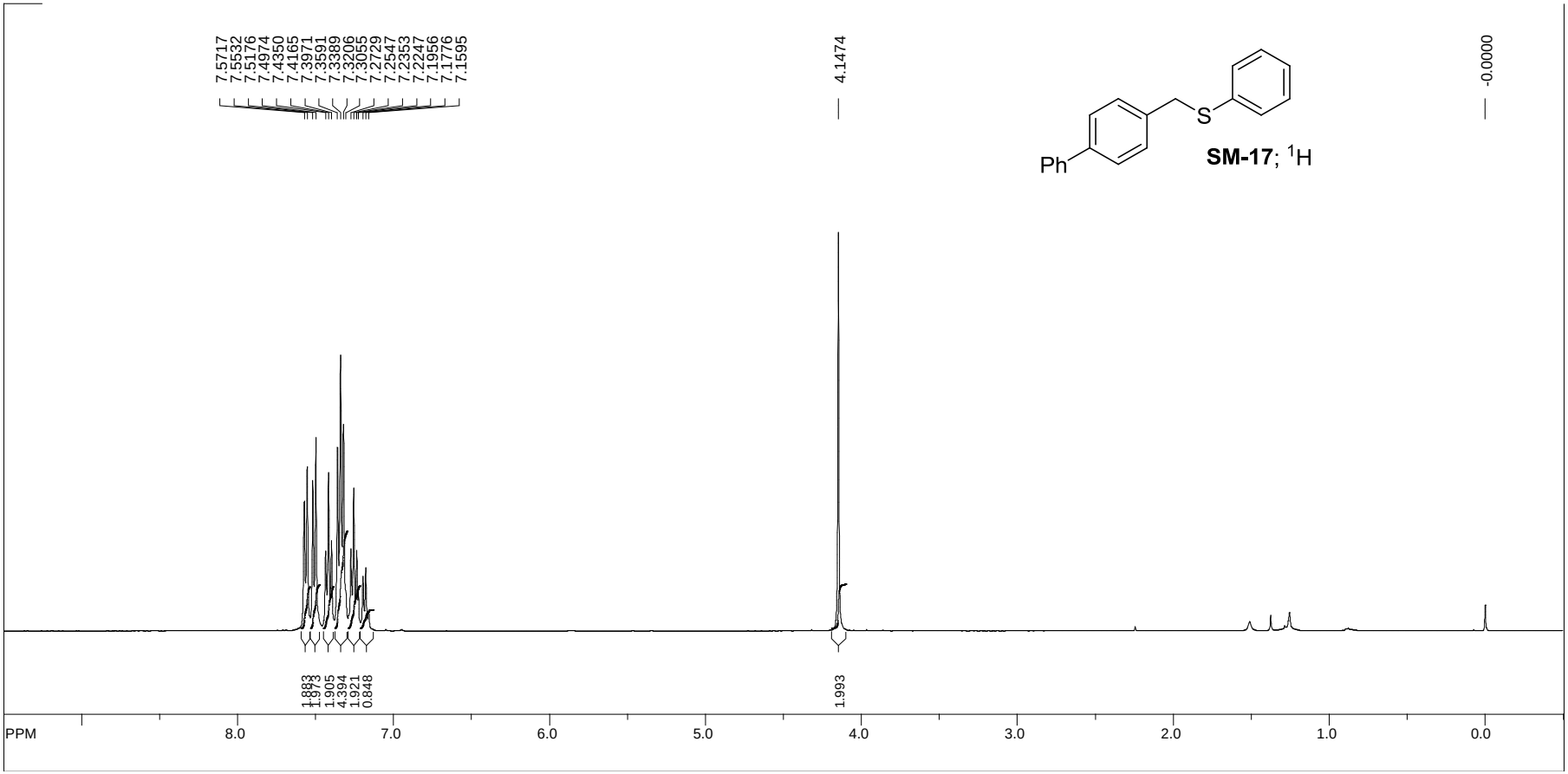


Figure S13: ^{13}C NMR spectrum of compound SM-17.

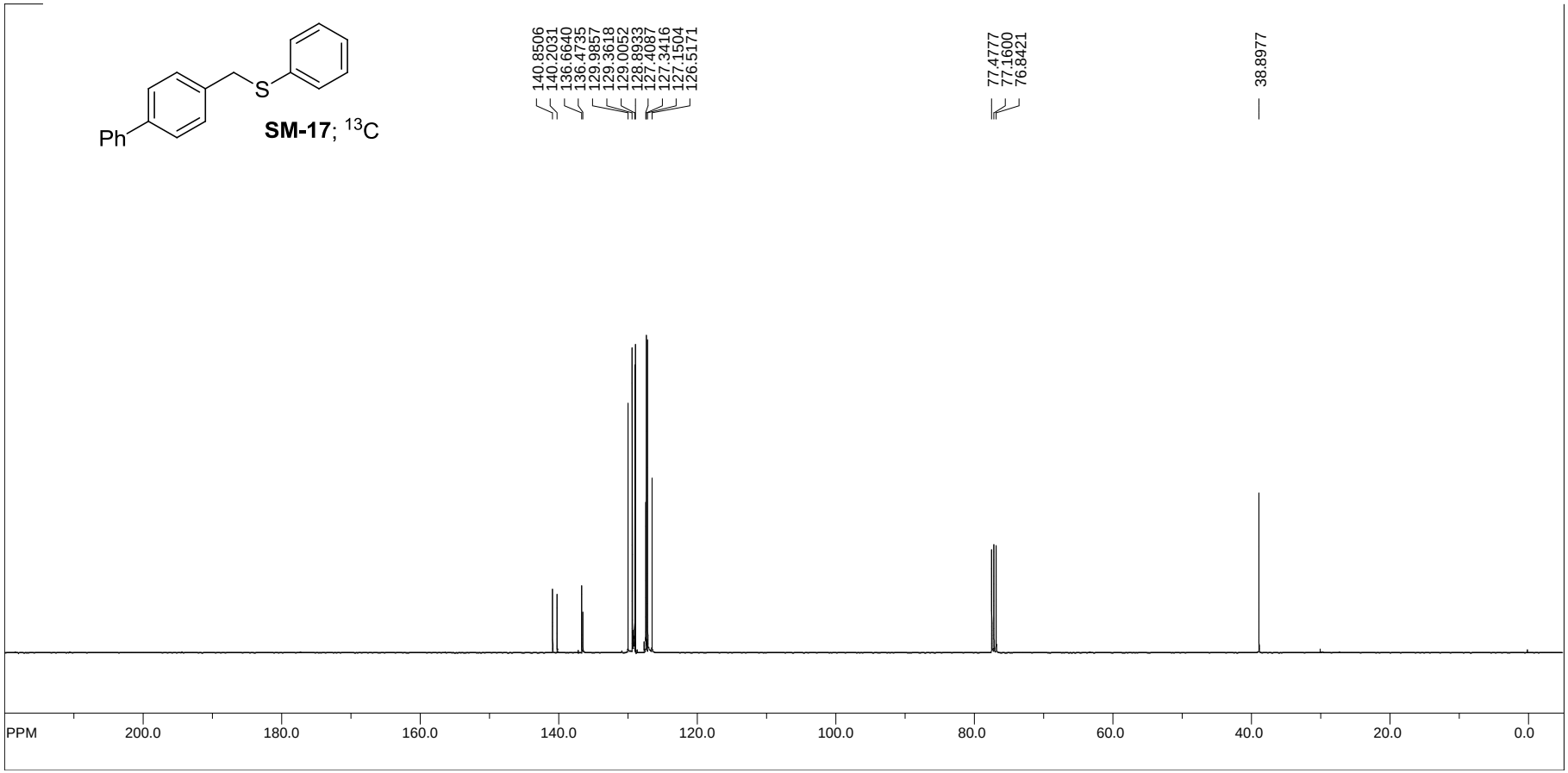


Figure S14: ^{1}H NMR spectrum of compound SM-18.

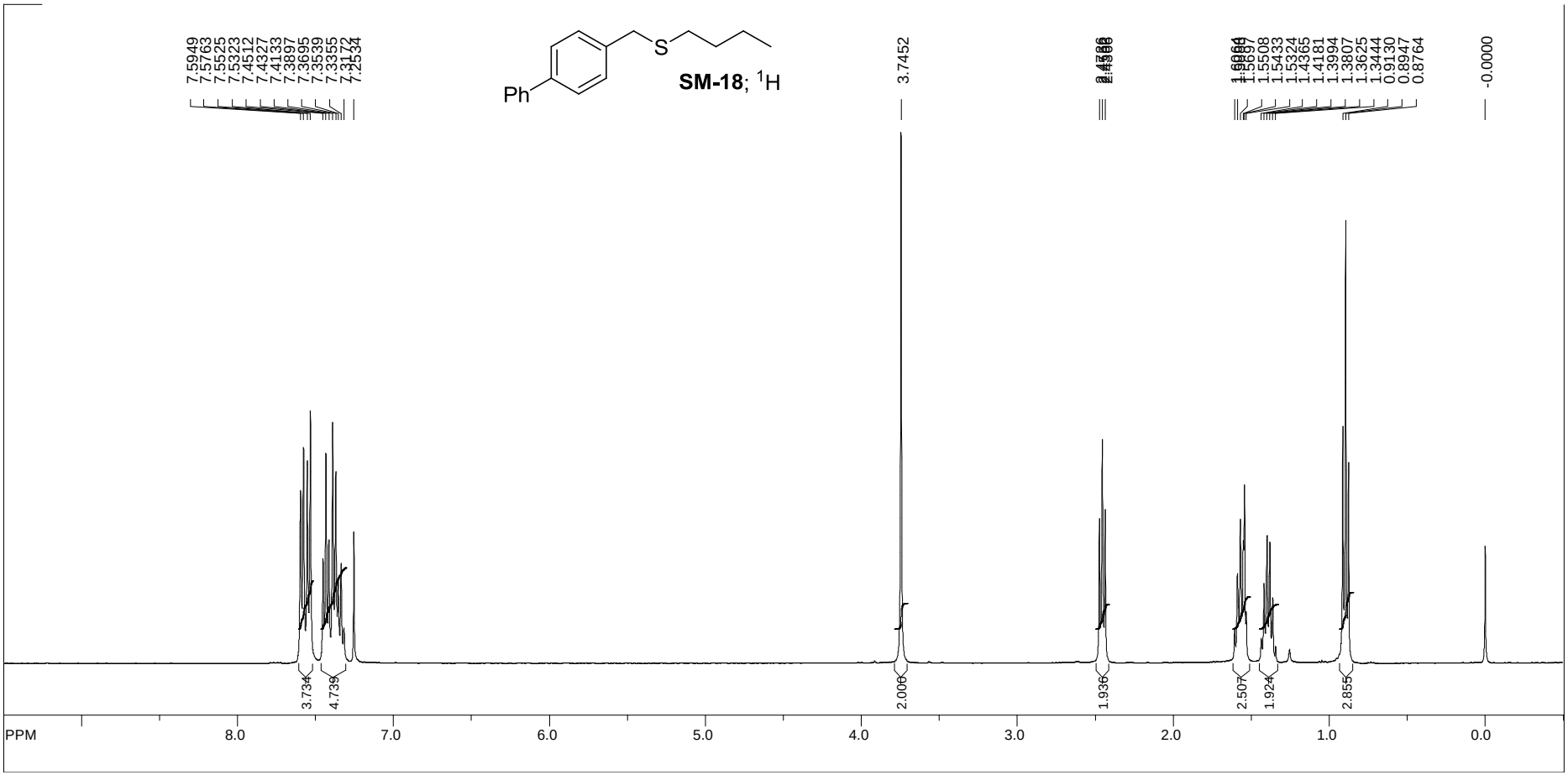


Figure S15: ^{13}C NMR spectrum of compound SM-18.

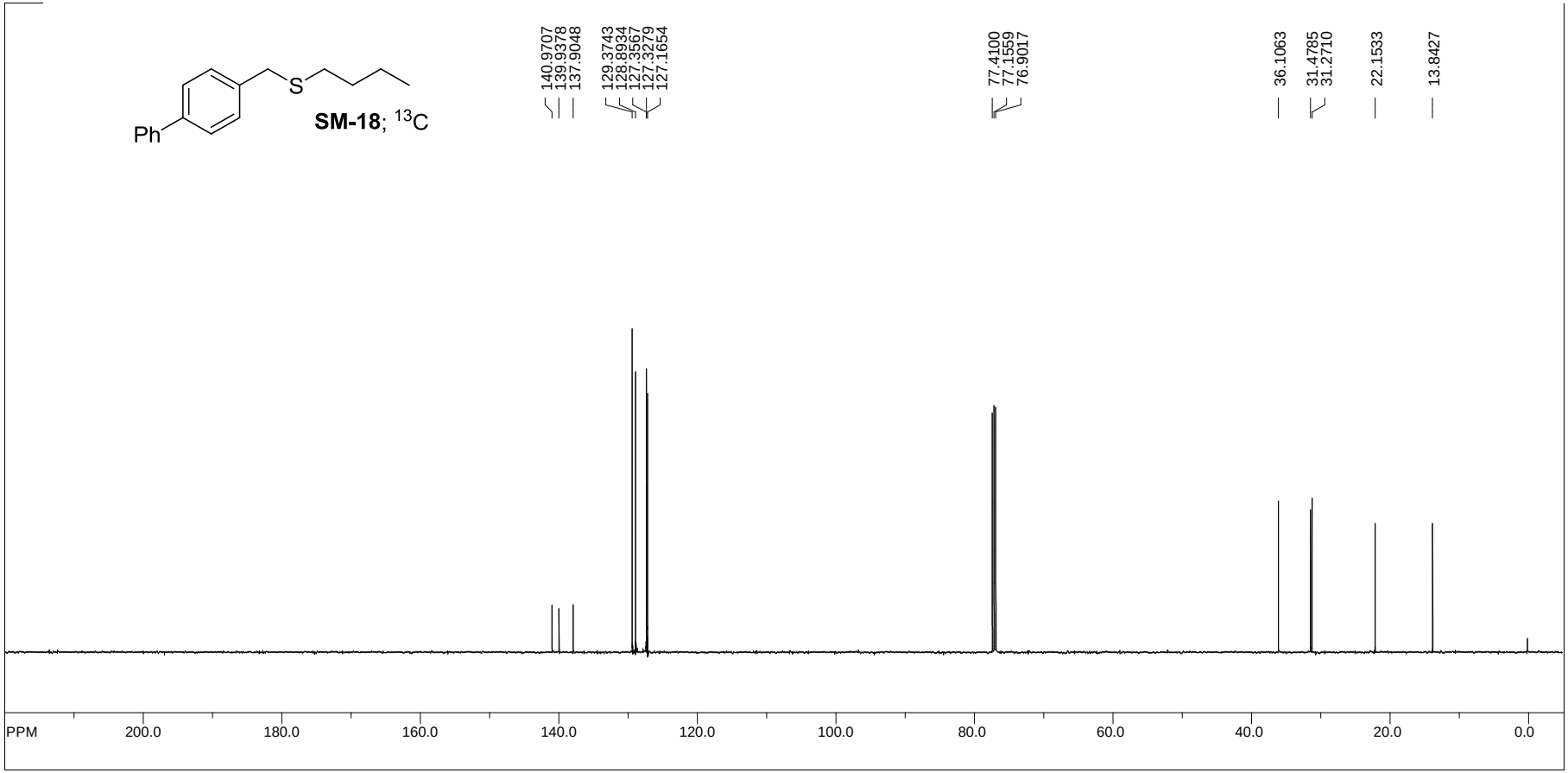


Figure S16: ^{1}H NMR spectrum of compound SM-24.

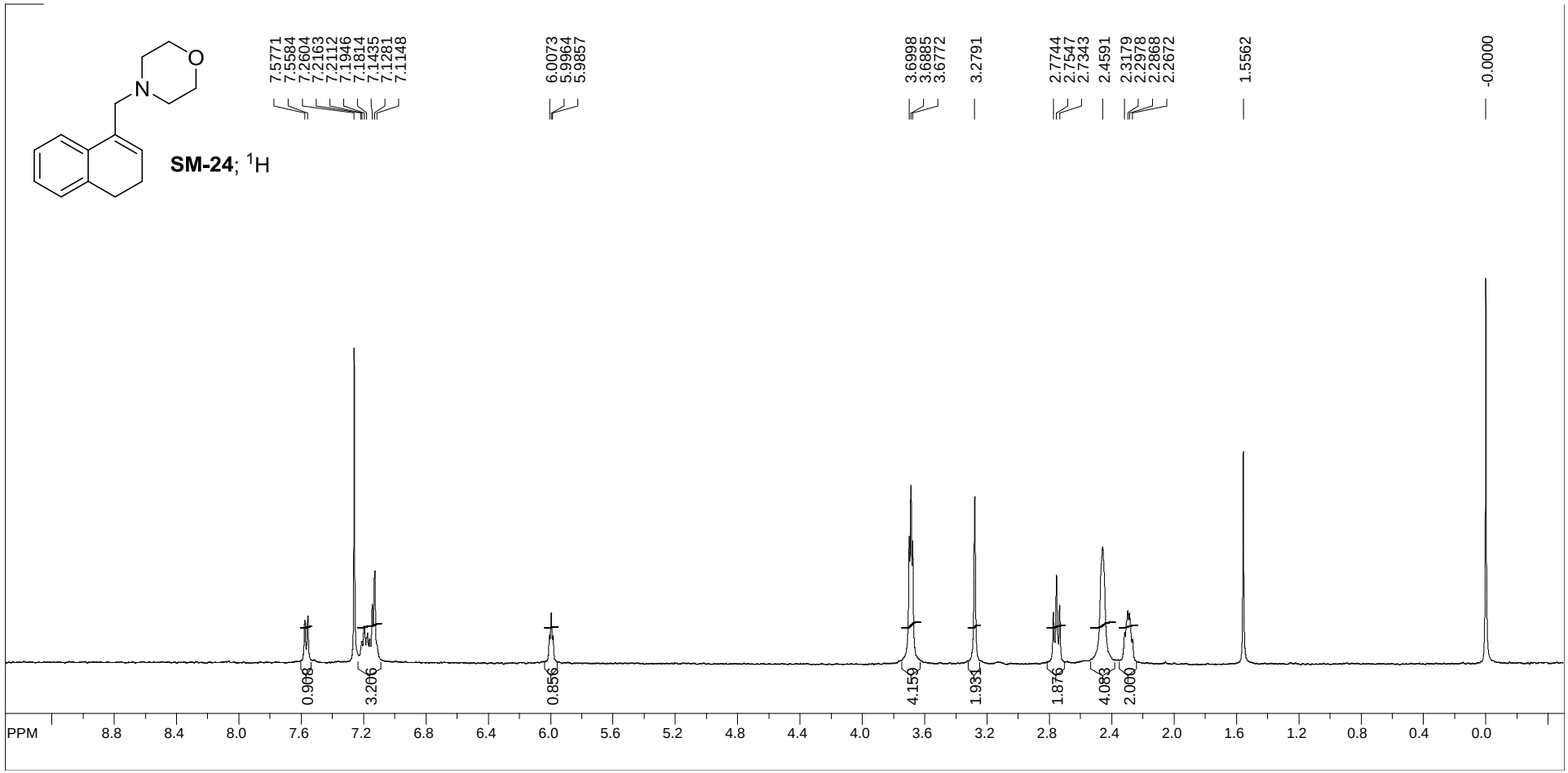
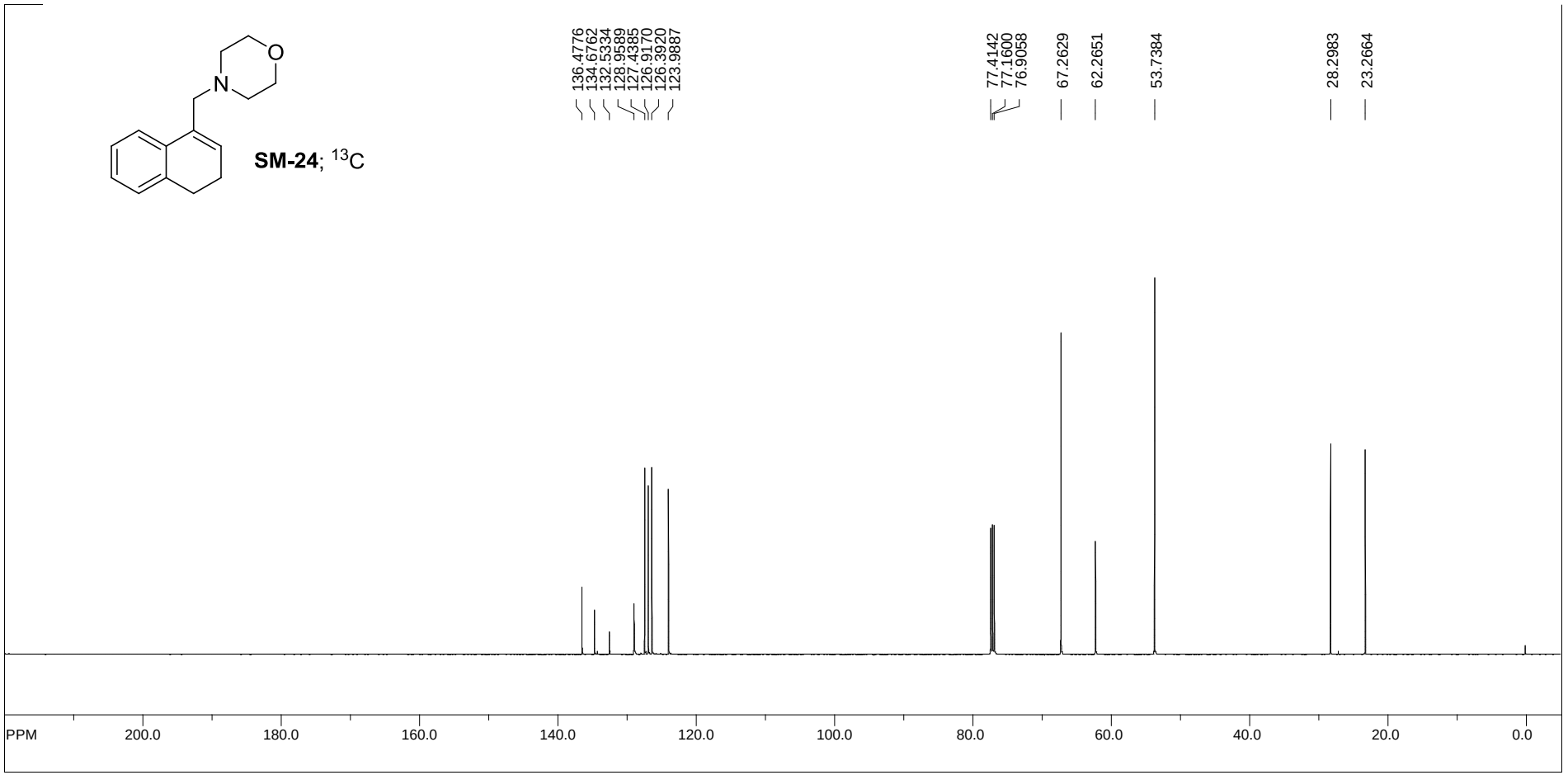


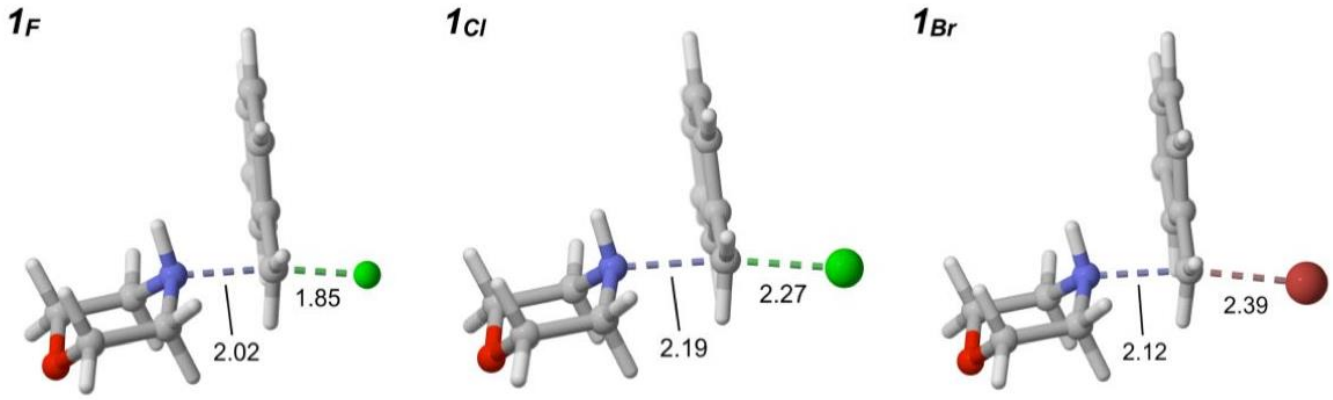
Figure S17: ^{13}C NMR spectrum of compound SM-24.



COMPUTATIONAL DETAILS

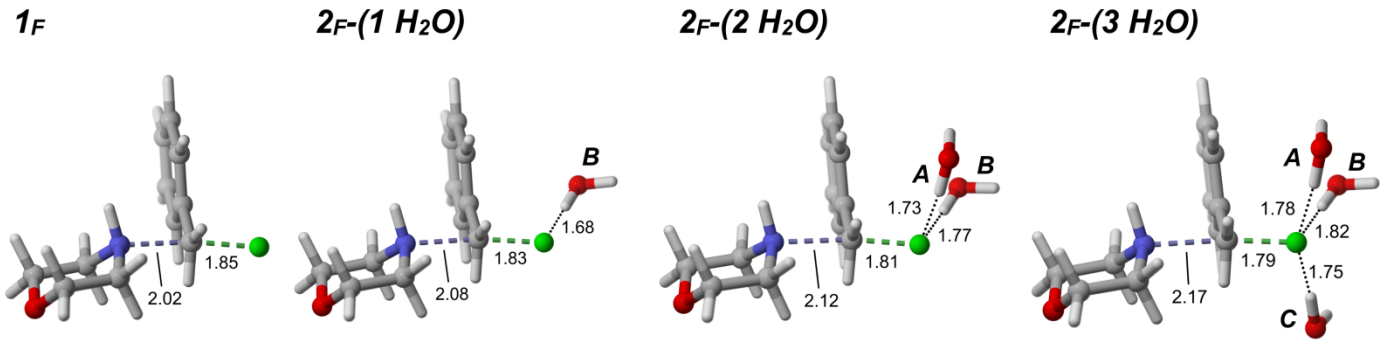
All calculations were performed with the Gaussian 09 package.[17] All the structures reported were fully optimized including SMD equilibrium solvation model[18] for the specified solvent with the M06-2X hybrid density functional[19] in combination with the 6-31+G(d,p) basis set for all atoms. A fine grid density was used for numerical integration in the calculations. Harmonic vibrational frequencies were computed for all optimized structures to verify that they were either minima, possessing zero imaginary frequencies, or transition structures, possessing a single imaginary frequency relevant to the reaction coordinate. BSSE corrected energies were obtained using the counterpoise correction method.[20] Thermodynamic corrections are unscaled and based on the vibrational analyses and temperature of 298 K. Multiple conformational isomers were optimized for transition structures involving water molecule(s) and resulted in only very small energy differences. The most relevant structures are presented.

Table S1: Implicit (SMD) Solvation Free Energies (kcal/mol) Comparison



	i-PrOH			H_2O			DMF		
	ΔG_{solv}	ΔG_{solv}	$\Delta\Delta G_{solv}$	ΔG_{solv}	ΔG_{solv}	$\Delta\Delta G_{solv}$	ΔG_{solv}	ΔG_{solv}	$\Delta\Delta G_{solv}$
$TS^{\ddagger}$	BnX	$(TS^{\ddagger})$		BnX	$(TS^{\ddagger})$		BnX	$(TS^{\ddagger})$	
1_F	-8.0	-30.2	-22.2	-3.8	-24.9	-21.1	-8.0	-29.6	-21.6
1_{Cl}	-8.7	-24.7	-16.0	-3.9	-18.5	-14.6	-8.6	-23.8	-15.2
1_{Br}	-8.7	-22.9	-14.2	-3.8	-16.8	-13.0	-8.6	-22.0	-13.4

Table S2: Effect of water molecules on the stabilization of the transition structure of S_N2 reaction with BnF.



TS	ΔH‡	ΔE_{dist} BnX	ΔE_{int} H_2O_A	ΔE_{int} H_2O_B	ΔE_{int} H_2O_C	F···O_A (Å)	F···O_B (Å)	F···O_C (Å)	F-H-O_A (°)	F-H-O_B (°)	F-H-O_C (°)
1_F	22.4	39.6	-	-	-	-	-	-	-	-	-
2_F-(1 H_2O)	16.8	36.1	-	-11.1	-	-	2.66	-	-	180	-
2_F-(2 H_2O)	12.3	33.7	-11.1	-10.0	-	2.71	2.74	-	175	173	-
2_F-(3 H_2O)	8.8	31.6	-9.2	-8.7	-8.6	2.75	2.79	2.73	173	176	175

Energies reported in kcal/mol

Table S3: Computed Energies (Electronic energies (**E**) and enthalpies (H_{298}) reported in Hartree)

Filename	Structure	Method	E	H_{298}
	Starting materials			
BnBr_opt_SMDiPrOH	BnBr (solv. iPrOH)	A (iPrOH)	-2842.664930	-2842.536599
	BnBr (gas phase from iPrOH)	B (iPrOH)	-2842.651083	
BnBr_opt_SMDH2O	BnBr (solv. H_2O)	A (H_2O)	-2842.657169	-2842.528898
	BnBr (gas phase from H_2O)	B (H_2O)	-2842.651079	
BnBr_opt_SMDDMF	BnBr (solv. DMF)	A (DMF)	-2842.664714	-2842.536415
	BnBr (gas phase from DMF)	B (DMF)	-2842.651082	
BnCl_opt_SMDiPrOH	BnCl (solv. iPrOH)	A (iPrOH)	-731.031370	-730.902828
	BnCl (gas phase from iPrOH)	B (iPrOH)	-731.017568	
BnCl_opt_SMDH2O	BnCl (solv. H_2O)	A (H_2O)	-731.023742	-730.895232
	BnCl (gas phase from H_2O)	B (H_2O)	-731.017554	
BnCl_opt_SMDDMF	BnCl (solv. DMF)	A (DMF)	-731.031218	-730.902706
	BnCl (gas phase from DMF)	B (DMF)	-731.017568	
BnF_opt_SMDiPrOH	BnF (solv. iPrOH)	A (iPrOH)	-370.668856	-370.540006
	BnF (gas phase from iPrOH)	B (iPrOH)	-370.656087	
BnF_opt_SMDH2O	BnF (solv. H_2O)	A (H_2O)	-370.662144	-370.533323
	BnF (gas phase from H_2O)	B (H_2O)	-370.656069	
BnF_opt_SMDDMF	BnF (solv. DMF)	A (DMF)	-370.668816	-370.539991
	BnF (gas phase from DMF)	B (DMF)	-370.656087	
Morpholine_opt_SMDiPrOH	Morpholine (solv. iPrOH)	A (iPrOH)	-287.696499	-287.553636
	Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.682589	
H2O_opt_SMDiPrOH	H_2O (solv. iPrOH)	A (iPrOH)	-76.408591	-76.383470
	H_2O (gas phase from iPrOH)	B (iPrOH)	-76.394929	
	Benzyl fluoride-water adduct			
BnF_H2O_adduct_opt_SMDiPrOH	BnF-H_2O adduct (solv. iPrOH)	A (iPrOH)	-447.080322	-446.923196
	BnF-H_2O adduct (gas phase from iPrOH)	B (iPrOH)	-447.058904	
	BnF-H_2O adduct (gas phase from iPrOH) - BSSE corrected*	B (iPrOH)	-447.058326	
BnF_H2O_adduct_BnF	BnF-H_2O adduct - BnF (gas phase from iPrOH)	B (iPrOH)	-370.655908	
BnF_H2O_adduct_H2O	BnF-H_2O adduct - H_2O (gas phase from iPrOH)	B (iPrOH)	-76.394928	
	Transition structures and analysis for BnBr			
	No water molecule			
TS_SN2_1Br_opt_SMDiPrOH	TS S_N2 1_{Br} (solv. iPrOH)	A (iPrOH)	-3130.346860	-3130.074239
	TS S_N2 1_{Br} (gas phase from iPrOH)	B (iPrOH)	-3130.310347	
TS_SN2_1Br_opt_SMDiPrOH_BnBr	TS S_N2 1_{Br} - BnBr (gas phase from iPrOH)	B (iPrOH)	-2842.616849	
TS_SN2_1Br_opt_SMDiPrOH_Morpholine	TS S_N2 1_{Br} - Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.681008	
TS_SN2_1Br_opt_SMDH2O	TS S_N2 1_{Br} (solv. H_2O)	A (H_2O)	-3130.337537	-3130.064723
	TS S_N2 1_{Br} (gas phase from H_2O)	B (H_2O)	-3130.310834	
TS_SN2_1Br_opt_SMDDMF	TS S_N2 1_{Br} (solv. DMF)	A (DMF)	-3130.346022	-3130.073596
	TS S_N2 1_{Br} (gas phase from DMF)	B (DMF)	-3130.310885	
	1 water molecule			
TS_SN2_2Br_1H2O_opt_SMDiPrOH	TS S_N2 $2_{Br(1\ H2O)}$ (solv. iPrOH)	A (iPrOH)	-3206.763688	-3206.463870
	TS S_N2 $2_{Br(1\ H2O)}$ (gas phase from iPrOH)	B (iPrOH)	-3206.719719	
	TS S_N2 $2_{Br(1\ H2O)}$ (gas phase from iPrOH) - BSSE corrected*	B (iPrOH)	-3206.717436	
TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr	TS S_N2 $2_{Br(1\ H2O)}$ - BnBr (gas phase from iPrOH)	B (iPrOH)	-2842.620266	
TS_SN2_2Br_1H2O_opt_SMDiPrOH_Morpholine	TS S_N2 $2_{Br(1\ H2O)}$ - Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.681045	
TS_SN2_2Br_1H2O_opt_SMDiPrOH_H2O	TS S_N2 $2_{Br(1\ H2O)}$ - H_2O (gas phase from iPrOH)	B (iPrOH)	-76.394834	
TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr_Morpholine	TS S_N2 $2_{Br(1\ H2O)}$ - BnBr+Morpholine (gas phase from iPrOH)	B (iPrOH)	-3130.312476	
TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr_H2O	TS S_N2 $2_{Br(1\ H2O)}$ - BnBr+H_2O (gas phase from iPrOH)	B (iPrOH)	-2919.025947	
	Transition structures and analysis for BnCl			
	No water molecule			
TS_SN2_1Cl_opt_SMDiPrOH	TS S_N2 1_{Cl} (solv. iPrOH)	A (iPrOH)	-1018.709341	-1018.437193
	TS S_N2 1_{Cl} (gas phase from iPrOH)	B (iPrOH)	-1018.669973	
TS_SN2_1Cl_opt_SMDiPrOH_BnCl	TS S_N2 1_{Cl} - BnCl (gas phase from iPrOH)	B (iPrOH)	-730.981237	
TS_SN2_1Cl_opt_SMDiPrOH_Morpholine	TS S_N2 1_{Cl} - Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.681068	
TS_SN2_1Cl_opt_SMDH2O	TS S_N2 1_{Cl} (solv. H_2O)	A (H_2O)	-1018.700225	-1018.427983
	TS S_N2 1_{Cl} (gas phase from H_2O)	B (H_2O)	-1018.670713	
TS_SN2_1Cl_opt_SMDDMF	TS S_N2 1_{Cl} (solv. DMF)	A (DMF)	-1018.708713	-1018.436722
	TS S_N2 1_{Cl} (gas phase from DMF)	B (DMF)	-1018.670726	
	1 water molecule			
TS_SN2_2Cl_1H2O_opt_SMDiPrOH	TS S_N2 $2_{Cl(1\ H2O)}$ (solv. iPrOH)	A (iPrOH)	-1095.124090	-1094.824844
	TS S_N2 $2_{Cl(1\ H2O)}$ (gas phase from iPrOH)	B (iPrOH)	-1095.078787	
	TS S_N2 $2_{Cl(1\ H2O)}$ (gas phase from iPrOH) - BSSE corrected*	B (iPrOH)	-1095.077774	
TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl	TS S_N2 $2_{Cl(1\ H2O)}$ - BnCl (gas phase from iPrOH)	B (iPrOH)	-730.983685	
TS_SN2_2Cl_1H2O_opt_SMDiPrOH_Morpholine	TS S_N2 $2_{Cl(1\ H2O)}$ - Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.681086	
TS_SN2_2Cl_1H2O_opt_SMDiPrOH_H2O	TS S_N2 $2_{Cl(1\ H2O)}$ - H_2O (gas phase from iPrOH)	B (iPrOH)	-76.394838	
TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl_Morpholine	TS S_N2 $2_{Cl(1\ H2O)}$ - BnCl+Morpholine (gas phase from iPrOH)	B (iPrOH)	-1018.671748	
TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl_H2O	TS S_N2 $2_{Cl(1\ H2O)}$ - BnCl+H_2O (gas phase from iPrOH)	B (iPrOH)	-807.388441	

Table S3: Computed Energies (Electronic energies (**E**) and enthalpies (H_{298}) reported in Hartree), contd.

	Transition structures and analysis for BnF			
	No water molecule			
TS_SN2_1F_opt_SMDiPrOH	TS S_N2 1_F (solv. iPrOH)	A (iPrOH)	-658.331252	-658.057985
	TS S_N2 1_F (gas phase from iPrOH)	B (iPrOH)	-658.283195	
TS_SN2_1F_opt_SMDiPrOH_BnF	TS S_N2 1_F - BnF (gas phase from iPrOH)	B (iPrOH)	-370.592924	
TS_SN2_1F_opt_SMDiPrOH_Morpholine	TS S_N2 1_F - Morpholine (gas phase from IPrOH)	B (IPrOH)	-287.680947	
TS_SN2_1F_opt_SMDH2O	TS S_N2 1_F (solv. H_2O)	A (H_2O)	-658.323905	-658.050465
	TS S_N2 1_F (gas phase from H_2O)	B (H_2O)	-658.284246	
TS_SN2_1F_opt_SMDDMF	TS S_N2 1_F (solv. DMF)	A (DMF)	-658.331252	-658.058094
	TS S_N2 1_F (gas phase from DMF)	B (DMF)	-658.284096	
	1 water molecule			
TS_SN2_2F_1H2O_opt_SMDiPrOH	TS S_N2 $2_{F(1\ H2O)}$ (solv. IPrOH)	A (IPrOH)	-734.750743	-734.450365
	TS S_N2 $2_{F(1\ H2O)}$ (gas phase from iPrOH)	B (iPrOH)	-734.700321	
	TS S_N2 $2_{F(1\ H2O)}$ (gas phase from iPrOH) - BSSE corrected*	B (iPrOH)	-734.699092	
TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF	TS S_N2 $2_{F(1\ H2O)}$ - BnF (gas phase from IPrOH)	B (IPrOH)	-370.598583	
TS_SN2_2F_1H2O_opt_SMDiPrOH_Morpholine	TS S_N2 $2_{F(1\ H2O)}$ - Morpholine (gas phase from iPrOH)	B (iPrOH)	-287.680993	
TS_SN2_2F_1H2O_opt_SMDiPrOH_H2O	TS S_N2 $2_{F(1\ H2O)}$ - H_2O (gas phase from iPrOH)	B (iPrOH)	-76.394532	
TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF_Morpholine	TS S_N2 $2_{F(1\ H2O)}$ - BnF+Morpholine (gas phase from iPrOH)	B (iPrOH)	-658.286851	
TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF_H2O	TS S_N2 $2_{F(1\ H2O)}$ - BnF+H_2O (gas phase from iPrOH)	B (iPrOH)	-447.007674	
	2 water molecules			
TS_SN2_2F_2H2O_opt_SMDiPrOH	TS S_N2 $2_{F2\ H2O)}$ (solv. IPrOH)	A (IPrOH)	-811.168760	-810.841000
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from iPrOH)	B (iPrOH)	-811.116551	
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from iPrOH) - BSSE corrected ($H2O_A$)*	B (iPrOH)	-811.114910	
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from IPrOH) - BSSE corrected ($H2O_B$)*	B (IPrOH)	-811.114924	
TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF	TS S_N2 $2_{F2\ H2O)}$ - BnF (gas phase from IPrOH)	B (IPrOH)	-370.602380	
TS_SN2_2F_2H2O_opt_SMDiPrOH_H2O_A	TS S_N2 $2_{F2\ H2O)}$ - H_2O_A (gas phase from iPrOH)	B (iPrOH)	-76.394690	
TS_SN2_2F_2H2O_opt_SMDiPrOH_H2O_B	TS S_N2 $2_{F2\ H2O)}$ - H_2O_B (gas phase from IPrOH)	B (IPrOH)	-76.394741	
TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF_Morpho_H2O_B	TS S_N2 $2_{F2\ H2O)}$ - BnF+Morpholine+H_2O_B (gas phase from IPrOH)	B (IPrOH)	-734.702475	
TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A	TS S_N2 $2_{F2\ H2O)}$ - BnF+Morpholine+H_2O_A (gas phase from iPrOH)	B (iPrOH)	-734.704240	
	3 water molecules			
TS_SN2_2F_3H2O_opt_SMDiPrOH	TS S_N2 $2_{F3\ H2O)}$ (solv. iPrOH)	A (iPrOH)	-887.584968	-887.229957
	TS S_N2 $2_{F3\ H2O)}$ (gas phase from iPrOH)	B (iPrOH)	-887.527916	
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from iPrOH) - BSSE corrected ($H2O_A$)*	B (iPrOH)	-887.526235	
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from iPrOH) - BSSE corrected ($H2O_B$)*	B (iPrOH)	-887.526090	
	TS S_N2 $2_{F2\ H2O)}$ (gas phase from iPrOH) - BSSE corrected ($H2O_C$)*	B (iPrOH)	-887.526458	
TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF	TS S_N2 $2_{F3\ H2O)}$ - BnF (gas phase from IPrOH)	B (IPrOH)	-370.605679	
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_A	TS S_N2 $2_{F3\ H2O)}$ - H_2O_A (gas phase from iPrOH)	B (IPrOH)	-76.394779	
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_B	TS S_N2 $2_{F3\ H2O)}$ - H_2O_B (gas phase from iPrOH)	B (IPrOH)	-76.394820	
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_C	TS S_N2 $2_{F3\ H2O)}$ - H_2O_C (gas phase from IPrOH)	B (IPrOH)	-76.394780	
TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_B_H2O_C	TS S_N2 $2_{F2\ H2O)}$ - BnF+Morpholine+H_2O_C+$H2O_B$ (gas phase from iPrOH)	B (IPrOH)	-811.116784	
TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A_H2O_C	TS S_N2 $2_{F2\ H2O)}$ - BnF+Morpholine+H_2O_C+$H2O_A$ (gas phase from iPrOH)	B (IPrOH)	-811.117464	
TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A_H2O_B	TS S_N2 $2_{F2\ H2O)}$ - BnF+Morpholine+H_2O_B+$H2O_A$ (gas phase from IPrOH)	B (IPrOH)	-811.117895	

Methods

A (**solvent**) : M06-2X(SMD/**solvent**)/6-31+G(d,p)

B (**solvent**) : M06-2X(gas phase)/6-31+G(d,p)//M06-2X(SMD/**solvent**)/6-31+G(d,p)

BSSE corrected* : SCF corrected using the counterpoise method for the water-complex interaction

Table S4: Cartesians coordinates for computed structures

BnBr_opt_SMDiPrOH

H	-1.254877	-1.494200	0.891902
C	-0.775587	-1.093791	0.000000
H	-1.254877	-1.494200	-0.891902
C	-0.723703	0.396602	0.000000
C	-0.755660	3.192923	0.000000
C	-0.727896	1.101157	-1.207553
C	-0.727896	1.101157	1.207553
C	-0.745571	2.494466	1.208469
C	-0.745571	2.494466	-1.208469
H	-0.731105	0.554783	-2.148113
H	-0.731105	0.554783	2.148113
H	-0.758187	3.034942	2.150385
H	-0.758187	3.034942	-2.150385
H	-0.775478	4.278932	0.000000
Br	1.041996	-1.873254	0.000000

SCF energy: -2842.664930450
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
No imaginary frequency
Zero-point correction: 0.120484
Enthalpy correction: 0.128331
Free energy correction: 0.087488

BnBr_opt_SMDH2O

H	-1.253536	-1.494363	0.892513
C	-0.776370	-1.093655	0.000000
H	-1.253536	-1.494363	-0.892513
C	-0.725848	0.396430	0.000000
C	-0.753557	3.192467	0.000000
C	-0.729847	1.100496	-1.207645
C	-0.729847	1.100496	1.207645
C	-0.745045	2.493970	1.208647
C	-0.745045	2.493970	-1.208647
H	-0.734950	0.552892	-2.146963
H	-0.734950	0.552892	2.146963
H	-0.757167	3.034576	2.149959
H	-0.757167	3.034576	-2.149959
H	-0.771421	4.278005	0.000000
Br	1.044585	-1.864679	0.000000

SCF energy: -2842.657168590
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
No imaginary frequency
Zero-point correction: 0.120378
Enthalpy correction: 0.128271
Free energy correction: 0.087246

BnBr_opt_SMDDMF

H	-1.254402	-1.494539	0.892001

```
   C      -0.775542      -1.094075       0.000000
   H      -1.254402      -1.494539      -0.892001
   C      -0.724350       0.396504       0.000000
   C      -0.754994       3.193149       0.000000
   C      -0.728509       1.101044      -1.207655
   C      -0.728509       1.101044       1.207655
   C      -0.745395       2.494561       1.208625
   C      -0.745395       2.494561      -1.208625
   H      -0.732295       0.554366      -2.147838
   H      -0.732295       0.554366       2.147838
   H      -0.757890       3.034913       2.150430
   H      -0.757890       3.034913      -2.150430
   H      -0.774493       4.278981       0.000000
  Br       1.042656      -1.871542       0.000000
---------------------------------------------------
SCF energy: -2842.664713500
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.120445
    Enthalpy correction:        0.128299
    Free energy correction:     0.087435
---------------------------------------------------

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BnCl_opt_SMDiPrOH
---------------------------------------------------
   H      -0.898315      -2.056207       0.892760
   C      -0.427790      -1.645823       0.000000
   H      -0.898315      -2.056207      -0.892760
   C      -0.431266      -0.148855       0.000000
   C      -0.422848       2.648488       0.000000
   C      -0.428645       0.555968      -1.207729
   C      -0.428645       0.555968       1.207729
   C      -0.424818       1.949901       1.208251
   C      -0.424818       1.949901      -1.208251
   H      -0.430875       0.008410      -2.147438
   H      -0.430875       0.008410       2.147438
   H      -0.426778       2.490505       2.150147
   H      -0.426778       2.490505      -2.150147
   H      -0.422481       3.734654       0.000000
  Cl       1.276242      -2.302499       0.000000
---------------------------------------------------
SCF energy: -731.031370165
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.120739
    Enthalpy correction:        0.128542
    Free energy correction:     0.088370
---------------------------------------------------

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BnCl_opt_SMDH2O
---------------------------------------------------
   H      -0.898002      -2.054404       0.893433
   C      -0.428755      -1.645254       0.000000
   H      -0.898002      -2.054404      -0.893433
   C      -0.430989      -0.148885       0.000000
   C      -0.422183       2.648145       0.000000
   C      -0.428297       0.555389      -1.207772
   C      -0.428297       0.555389       1.207772
```

C	-0.424245	1.949467	1.208364
C	-0.424245	1.949467	-1.208364
H	-0.432184	0.007018	-2.146527
H	-0.432184	0.007018	2.146527
H	-0.427012	2.489966	2.149799
H	-0.427012	2.489966	-2.149799
H	-0.422264	3.733833	0.000000
Cl	1.276668	-2.299590	0.000000

SCF energy: -731.023742088
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
No imaginary frequency
Zero-point correction: 0.120666
Enthalpy correction: 0.128510
Free energy correction: 0.088119

BnCl_opt_SMDDMF

H	-0.898315	-2.056207	0.892760
C	-0.427790	-1.645823	0.000000
H	-0.898315	-2.056207	-0.892760
C	-0.431266	-0.148855	0.000000
C	-0.422848	2.648488	0.000000
C	-0.428645	0.555968	-1.207729
C	-0.428645	0.555968	1.207729
C	-0.424818	1.949901	1.208251
C	-0.424818	1.949901	-1.208251
H	-0.430875	0.008410	-2.147438
H	-0.430875	0.008410	2.147438
H	-0.426778	2.490505	2.150147
H	-0.426778	2.490505	-2.150147
H	-0.422481	3.734654	0.000000
Cl	1.276242	-2.302499	0.000000

SCF energy: -731.031217564
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
No imaginary frequency
Zero-point correction: 0.120705
Enthalpy correction: 0.128512
Free energy correction: 0.088337

BnF_opt_SMDiPrOH

H	-0.833057	-2.081305	0.896463
C	-0.372402	-1.660556	0.000000
H	-0.833057	-2.081305	-0.896463
C	-0.412959	-0.161919	0.000000
C	-0.415171	2.634509	0.000000
C	-0.414567	0.542753	-1.207665
C	-0.414567	0.542753	1.207665
C	-0.414905	1.936927	1.208854
C	-0.414905	1.936927	-1.208854
H	-0.418532	-0.004524	-2.147415
H	-0.418532	-0.004524	2.147415
H	-0.419419	2.478400	2.150213
H	-0.419419	2.478400	-2.150213

```
   H      -0.419264       3.720750       0.000000
   F       0.973751      -2.094167       0.000000
-----------------------------------------------------
SCF energy: -370.668856357
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.122108
    Enthalpy correction:        0.128850
    Free energy correction:     0.091930
-----------------------------------------------------

-----------------------------------------------------
BnF_opt_SMDH2O
-----------------------------------------------------
   H      -0.832277      -2.080247       0.896771
   C      -0.372936      -1.660010       0.000000
   H      -0.832277      -2.080247      -0.896771
   C      -0.413338      -0.162012       0.000000
   C      -0.414242       2.634171       0.000000
   C      -0.415005       0.542227      -1.207720
   C      -0.415005       0.542227       1.207720
   C      -0.414562       1.936532       1.208970
   C      -0.414562       1.936532      -1.208970
   H      -0.420395      -0.005793      -2.146569
   H      -0.420395      -0.005793       2.146569
   H      -0.419324       2.477996       2.149829
   H      -0.419324       2.477996      -2.149829
   H      -0.417987       3.719940       0.000000
   F       0.974625      -2.090399       0.000000
-----------------------------------------------------
SCF energy: -370.662144339
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.122058
    Enthalpy correction:        0.128821
    Free energy correction:     0.091854
-----------------------------------------------------

-----------------------------------------------------
BnF_opt_SMDDMF
-----------------------------------------------------
   H      -0.833057      -2.081305       0.896463
   C      -0.372402      -1.660556       0.000000
   H      -0.833057      -2.081305      -0.896463
   C      -0.412959      -0.161919       0.000000
   C      -0.415171       2.634509       0.000000
   C      -0.414567       0.542753      -1.207665
   C      -0.414567       0.542753       1.207665
   C      -0.414905       1.936927       1.208854
   C      -0.414905       1.936927      -1.208854
   H      -0.418532      -0.004524      -2.147415
   H      -0.418532      -0.004524       2.147415
   H      -0.419419       2.478400       2.150213
   H      -0.419419       2.478400      -2.150213
   H      -0.419264       3.720750       0.000000
   F       0.973751      -2.094167       0.000000
-----------------------------------------------------
SCF energy: -370.668816076
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
```

```
    Zero-point correction:      0.122079
    Enthalpy correction:        0.128825
    Free energy correction:     0.091896
-----------------------------------------------------

-----------------------------------------------------
H2O_opt_SMDiPrOH
-----------------------------------------------------
   O       3.945874      -1.425656      -2.318180
   H       4.625486      -2.045596      -2.611865
   H       3.383367      -1.936938      -1.722987
-----------------------------------------------------
SCF energy: -76.408590503
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.021341
    Enthalpy correction:        0.025121
    Free energy correction:     0.003033
-----------------------------------------------------

-----------------------------------------------------
Morpholine_opt_SMDiPrOH
-----------------------------------------------------
   H       1.403570       0.832418      -1.630001
   H       2.555606       2.558786      -0.327463
   H       0.276477       1.486961      -0.415728
   C       1.187294       0.895789      -0.549770
   C       2.348819       1.591852       0.137594
   O       3.542284       0.821302       0.024033
   H       2.117137       1.748970       1.202103
   H       2.494434      -1.368960      -1.158695
   N       1.005280      -0.426509       0.051264
   C       2.230416      -1.213563      -0.098548
   C       3.371020      -0.478273       0.582809
   H       4.316995      -1.006945       0.441830
   H       2.095881      -2.193245       0.369453
   H       3.169104      -0.387780       1.660910
   H       0.235685      -0.905597      -0.409001
-----------------------------------------------------
SCF energy: -287.696498996
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
    No imaginary frequency
    Zero-point correction:      0.136712
    Enthalpy correction:        0.142863
    Free energy correction:     0.108348
-----------------------------------------------------

-----------------------------------------------------
BnF_H2O_adduct_opt_SMDiPrOH
-----------------------------------------------------
   H       0.040091       0.019288      -0.006792
   C       0.013772       0.022653       1.080440
   C      -0.068430       0.017794       3.869590
   C       0.057891      -1.190904       1.774686
   C      -0.066470       1.227654       1.775987
   C      -0.108372       1.225192       3.171476
   C       0.015079      -1.186737       3.171861
   H      -0.102057       2.166767       1.231839
   H      -0.176095       2.163823       3.713794
   H       0.045418      -2.130359       3.711281
```

H	-0.104474	0.014339	4.954991
C	0.183249	-2.482071	1.025668
H	-0.318390	-2.448743	0.056380
H	-0.171684	-3.332575	1.611438
F	1.555559	-2.730640	0.750143
H	1.559348	-4.564925	-0.017520
O	1.058571	-5.359636	-0.250660
H	1.704955	-5.970462	-0.626335

SCF energy: -447.080321657
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
No imaginary frequency
Zero-point correction: 0.145576
Enthalpy correction: 0.157126
Free energy correction: 0.107558

BnF_H2O_adduct_BnF

H	-0.388805	1.377647	3.232865
H	-0.238913	-0.767051	1.989155
C	-0.352761	1.381102	2.147464
C	-0.269252	0.176571	1.449735
H	-0.460426	3.527131	1.991668
H	-0.456015	-1.969267	-0.110688
C	-0.392703	2.588500	1.449350
F	1.271228	-1.367332	-0.971983
C	-0.226440	0.172404	0.052560
C	-0.101082	-1.118763	-0.696458
C	-0.350801	2.590962	0.053861
C	-0.270559	1.385961	-0.641686
H	-0.602721	-1.085435	-1.665746
H	-0.386388	3.530075	-0.490287
H	-0.244240	1.382596	-1.728918

SCF energy: -370.655907763
M06-2X(gas phase)/6-31+G(d,p) Single point

BnF_H2O_adduct_H2O

H	1.275017	-3.201617	-1.739646
H	1.420624	-4.607154	-2.348461
O	0.774240	-3.996328	-1.972786

SCF energy: -76.394927733
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1Br_opt_SMDDMF

H	-0.010902	-2.186790	-0.680112
C	0.737991	-1.579222	-0.195654
H	0.911881	-1.700817	0.864091
C	1.411362	-0.498495	-0.939107

C	2.608001	1.628868	-2.303022
C	2.386167	0.281702	-0.309512
C	1.034270	-0.206024	-2.253871
C	1.633952	0.851543	-2.934150
C	2.982614	1.341360	-0.988705
H	2.679105	0.052686	0.712388
H	0.267572	-0.806755	-2.738032
H	1.339448	1.073235	-3.955714
H	3.738841	1.943897	-0.494229
H	3.073816	2.453728	-2.833901
N	-0.921460	-0.371337	0.387487
H	-1.259684	0.082574	-0.462814
C	-0.547123	0.635343	1.383938
H	-0.011512	0.120737	2.191939
H	0.129372	1.361588	0.924294
C	-1.774956	1.338263	1.948519
H	-1.493292	2.012250	2.761208
H	-2.266970	1.924762	1.156315
O	-2.694487	0.399068	2.487331
C	-3.123536	-0.523491	1.496594
H	-3.822453	-1.210251	1.980406
H	-3.654064	0.014036	0.694648
C	-1.939939	-1.284556	0.913515
H	-2.272104	-1.950722	0.111888
Br	2.326240	-3.307148	-0.623337
H	-1.468149	-1.890028	1.697598

SCF energy: -3130.346021700
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -479 cm-1
Zero-point correction: 0.258181
Enthalpy correction: 0.272426
Free energy correction: 0.215789

TS_SN2_1Br_opt_SMDH2O

H	-0.012603	-2.198150	-0.692713
C	0.731818	-1.589735	-0.202608
H	0.898154	-1.712325	0.858337
C	1.406612	-0.503695	-0.936949
C	2.603367	1.637023	-2.278640
C	2.381063	0.269760	-0.298999
C	1.027533	-0.196394	-2.247373
C	1.628129	0.867374	-2.917227
C	2.977904	1.335861	-0.967307
H	2.671861	0.031158	0.721146
H	0.257992	-0.790117	-2.735042
H	1.332145	1.100463	-3.935496
H	3.733558	1.933640	-0.466902
H	3.069144	2.466980	-2.800939
N	-0.928634	-0.382158	0.371119
H	-1.282432	0.062389	-0.477948
C	-0.542465	0.637555	1.349430
H	0.006592	0.135725	2.156256
H	0.125273	1.360118	0.872114
C	-1.761180	1.349182	1.919440
H	-1.472004	2.032432	2.720705
H	-2.268313	1.919519	1.127202

O	-2.676204	0.412414	2.483507
C	-3.116357	-0.527332	1.506522
H	-3.809530	-1.206341	2.007519
H	-3.651143	0.004446	0.705471
C	-1.934893	-1.290974	0.926428
H	-2.273210	-1.975639	0.143703
Br	2.328492	-3.304378	-0.626829
H	-1.450669	-1.878798	1.716073

SCF energy: -3130.337537110
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -482 cm-1
Zero-point correction: 0.258649
Enthalpy correction: 0.272814
Free energy correction: 0.216557

TS_SN2_1Br_opt_SMDiPrOH

H	-0.015202	-2.190197	-0.691004
C	0.728274	-1.579947	-0.201713
H	0.906352	-1.712305	0.856070
C	1.407275	-0.498842	-0.939278
C	2.610967	1.635082	-2.286527
C	2.386684	0.271590	-0.304838
C	1.029538	-0.193248	-2.250791
C	1.632852	0.867493	-2.922803
C	2.986600	1.334351	-0.975579
H	2.681846	0.031851	0.714009
H	0.261097	-0.787367	-2.740552
H	1.338489	1.098622	-3.942405
H	3.747102	1.928550	-0.477399
H	3.079965	2.462195	-2.811245
N	-0.925424	-0.381342	0.382037
H	-1.273123	0.060471	-0.470949
C	-0.547737	0.640707	1.361947
H	-0.005624	0.140020	2.174323
H	0.123355	1.363113	0.888497
C	-1.772808	1.349070	1.924151
H	-1.488985	2.033088	2.727507
H	-2.275249	1.922010	1.129465
O	-2.686770	0.411680	2.482223
C	-3.119997	-0.529741	1.507651
H	-3.811207	-1.211473	2.009035
H	-3.659075	-0.004179	0.704250
C	-1.935315	-1.291970	0.929760
H	-2.269782	-1.973974	0.142418
Br	2.321553	-3.313259	-0.638933
H	-1.455651	-1.882046	1.720672

SCF energy: -3130.346860090
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -478 cm-1
Zero-point correction: 0.258403
Enthalpy correction: 0.272621
Free energy correction: 0.216080

TS_SN2_1Br_opt_SMDiPrOH_BnBr

H	3.747102	1.928550	-0.477399
H	3.079965	2.462195	-2.811245
C	2.986600	1.334351	-0.975579
H	2.681846	0.031851	0.714009
C	2.610967	1.635082	-2.286527
C	2.386684	0.271590	-0.304838
C	1.632852	0.867493	-2.922803
C	1.407275	-0.498842	-0.939278
H	1.338489	1.098622	-3.942405
H	0.906352	-1.712305	0.856070
C	1.029538	-0.193248	-2.250791
C	0.728274	-1.579947	-0.201713
Br	2.321553	-3.313259	-0.638933
H	0.261097	-0.787367	-2.740552
H	-0.015202	-2.190197	-0.691004

SCF energy: -2842.616849260
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1Br_opt_SMDiPrOH_Morpholine

N	-0.925424	-0.381342	0.382037
H	-1.273123	0.060471	-0.470949
C	-0.547737	0.640707	1.361947
H	-0.005624	0.140020	2.174323
H	0.123355	1.363113	0.888497
C	-1.772808	1.349070	1.924151
H	-1.488985	2.033088	2.727507
H	-2.275249	1.922010	1.129465
O	-2.686770	0.411680	2.482223
C	-3.119997	-0.529741	1.507651
H	-3.811207	-1.211473	2.009035
H	-3.659075	-0.004179	0.704250
C	-1.935315	-1.291970	0.929760
H	-2.269782	-1.973974	0.142418
H	-1.455651	-1.882046	1.720672

SCF energy: -287.681007580
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1Cl_opt_SMDDMF

H	-0.043230	2.161416	-0.035526
C	-0.868580	1.588192	0.362809
H	-1.035174	1.581664	1.429683
C	-1.586023	0.636223	-0.502441
C	-2.887833	-1.223176	-2.134786
C	-2.459944	-0.302025	0.057988
C	-1.368873	0.639131	-1.884918
C	-2.019175	-0.286127	-2.698204
C	-3.107162	-1.229573	-0.755565
H	-2.626691	-0.303094	1.132588
H	-0.692395	1.371732	-2.318538
H	-1.847100	-0.278734	-3.770344

H	-3.782708	-1.956755	-0.315078
H	-3.393221	-1.945695	-2.768652
N	0.707346	0.137156	0.880752
H	0.237063	-0.582724	1.431701
C	1.676310	0.855743	1.714087
H	2.011900	1.735316	1.150457
H	1.179498	1.197680	2.626881
C	2.877257	-0.016670	2.056021
H	3.637826	0.563209	2.584923
H	2.562037	-0.855019	2.697755
O	3.486104	-0.521524	0.876688
C	2.568074	-1.297777	0.120783
H	3.103707	-1.654893	-0.762338
H	2.243791	-2.168059	0.713626
C	1.354475	-0.470504	-0.284617
H	0.629230	-1.096852	-0.812721
Cl	-2.222578	3.380703	0.161992
H	1.666071	0.341036	-0.955004

SCF energy: -1018.708713460
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -502 cm-1
Zero-point correction: 0.257683
Enthalpy correction: 0.271991
Free energy correction: 0.215564

TS_SN2_1Cl_opt_SMDH2O

H	-0.028350	2.152798	-0.041805
C	-0.861299	1.591184	0.357200
H	-1.033597	1.593783	1.422931
C	-1.581832	0.637638	-0.503810
C	-2.886290	-1.227026	-2.126877
C	-2.455959	-0.297061	0.061568
C	-1.364616	0.634120	-1.886082
C	-2.016337	-0.293924	-2.694884
C	-3.104756	-1.227428	-0.747506
H	-2.618365	-0.294367	1.136574
H	-0.685685	1.362713	-2.322067
H	-1.844323	-0.292189	-3.766738
H	-3.779800	-1.952481	-0.303511
H	-3.392338	-1.951741	-2.757175
N	0.699893	0.130564	0.886740
H	0.230624	-0.595699	1.429695
C	1.664810	0.846624	1.726098
H	1.992954	1.736137	1.173969
H	1.168422	1.173366	2.644368
C	2.871589	-0.018834	2.059586
H	3.629919	0.559709	2.591672
H	2.565448	-0.870303	2.685481
O	3.483191	-0.507424	0.868499
C	2.565147	-1.287940	0.107076
H	3.101513	-1.633718	-0.779286
H	2.252121	-2.160281	0.700134
C	1.347419	-0.462586	-0.285116
H	0.625609	-1.090289	-0.816012
Cl	-2.196567	3.389591	0.130797
H	1.651457	0.355060	-0.951519

SCF energy: -1018.700225380
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -506 cm-1
Zero-point correction: 0.257904
Enthalpy correction: 0.272242
Free energy correction: 0.215649

TS_SN2_1Cl_opt_SMDiPrOH

H	-0.039976	2.156501	-0.030123
C	-0.862313	1.578277	0.367223
H	-1.037255	1.579562	1.432714
C	-1.582805	0.631748	-0.500986
C	-2.887396	-1.220242	-2.139410
C	-2.461810	-0.303923	0.055596
C	-1.362901	0.636354	-1.883004
C	-2.014439	-0.285198	-2.699196
C	-3.110385	-1.227747	-0.760944
H	-2.634055	-0.305024	1.129399
H	-0.684854	1.368664	-2.314750
H	-1.840644	-0.275821	-3.771125
H	-3.790817	-1.952265	-0.323376
H	-3.394296	-1.939610	-2.775792
N	0.704318	0.134735	0.887516
H	0.235637	-0.583843	1.441555
C	1.675662	0.857062	1.715466
H	2.005340	1.738192	1.150777
H	1.183376	1.197931	2.631156
C	2.881904	-0.008838	2.053063
H	3.644844	0.575602	2.573137
H	2.578484	-0.849326	2.696462
O	3.484510	-0.514227	0.867623
C	2.563576	-1.299168	0.119197
H	3.096233	-1.655918	-0.765721
H	2.250335	-2.167538	0.719471
C	1.346284	-0.475384	-0.279810
H	0.619980	-1.105338	-0.802093
Cl	-2.219478	3.380937	0.161239
H	1.652943	0.333845	-0.955264

SCF energy: -1018.709341120
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -503 cm-1
Zero-point correction: 0.257827
Enthalpy correction: 0.272148
Free energy correction: 0.215622

TS_SN2_1Cl_opt_SMDiPrOH_BnCl

H	-1.840644	-0.275821	-3.771125
H	-3.394296	-1.939610	-2.775792
C	-2.014439	-0.285198	-2.699196
C	-2.887396	-1.220242	-2.139410
H	-0.684854	1.368664	-2.314750
C	-1.362901	0.636354	-1.883004

C	-3.110385	-1.227747	-0.760944
H	-3.790817	-1.952265	-0.323376
C	-1.582805	0.631748	-0.500986
C	-2.461810	-0.303923	0.055596
H	-0.039976	2.156501	-0.030123
C	-0.862313	1.578277	0.367223
Cl	-2.219478	3.380937	0.161239
H	-2.634055	-0.305024	1.129399
H	-1.037255	1.579562	1.432714

SCF energy: -730.981237414
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1Cl_opt_SMDiPrOH_Morpholine

N	0.704318	0.134735	0.887516
H	0.235637	-0.583843	1.441555
C	1.675662	0.857062	1.715466
H	2.005340	1.738192	1.150777
H	1.183376	1.197931	2.631156
C	2.881904	-0.008838	2.053063
H	3.644844	0.575602	2.573137
H	2.578484	-0.849326	2.696462
O	3.484510	-0.514227	0.867623
C	2.563576	-1.299168	0.119197
H	3.096233	-1.655918	-0.765721
H	2.250335	-2.167538	0.719471
C	1.346284	-0.475384	-0.279810
H	0.619980	-1.105338	-0.802093
H	1.652943	0.333845	-0.955264

SCF energy: -287.681067895
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1F_opt_SMDDMF

H	0.677025	1.205576	-1.571538
C	-0.069299	1.480723	-0.838621
H	0.129187	2.287396	-0.147418
C	-1.348201	0.736693	-0.759598
C	-3.758942	-0.676183	-0.601052
C	-2.230442	0.964495	0.301270
C	-1.680483	-0.202661	-1.741009
C	-2.881681	-0.905754	-1.662646
C	-3.431241	0.260572	0.380801
H	-1.972001	1.693989	1.065383
H	-0.996156	-0.377124	-2.567744
H	-3.133217	-1.632461	-2.429495
H	-4.111363	0.443608	1.207433
H	-4.694389	-1.224339	-0.539818
F	-0.696311	2.736190	-2.034559
N	0.934286	0.286333	0.457907
H	0.395690	0.277120	1.326951
C	2.239553	0.921363	0.688935
H	2.705202	1.082120	-0.291042
H	2.081194	1.893414	1.164732

C	3.139302	0.046220	1.549999
H	4.136475	0.485531	1.629826
H	2.713281	-0.049174	2.561346
O	3.294930	-1.241357	0.973038
C	2.040081	-1.891192	0.837949
H	2.232678	-2.870346	0.392937
H	1.590397	-2.038081	1.832773
C	1.094854	-1.085378	-0.042822
H	0.114612	-1.567853	-0.085296
H	1.497476	-1.018159	-1.061346

SCF energy: -658.331251668
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -640 cm-1
Zero-point correction: 0.259374
Enthalpy correction: 0.273158
Free energy correction: 0.218751

TS_SN2_1F_opt_SMDH2O

H	0.682308	1.214364	-1.567735
C	-0.068074	1.490605	-0.839350
H	0.127331	2.295860	-0.145832
C	-1.343660	0.741025	-0.762460
C	-3.743683	-0.688120	-0.602376
C	-2.221712	0.956046	0.304153
C	-1.673508	-0.194252	-1.748405
C	-2.869609	-0.905815	-1.669103
C	-3.417603	0.244030	0.384409
H	-1.961220	1.679365	1.073115
H	-0.989969	-0.360538	-2.577183
H	-3.119433	-1.630333	-2.438108
H	-4.094621	0.416679	1.215399
H	-4.674626	-1.243156	-0.540035
F	-0.694268	2.740914	-2.035534
N	0.929639	0.295640	0.462582
H	0.396032	0.290495	1.334672
C	2.240842	0.921025	0.682033
H	2.701818	1.074464	-0.301164
H	2.094580	1.896148	1.154792
C	3.139450	0.046515	1.542470
H	4.140540	0.476473	1.613989
H	2.717635	-0.049447	2.553950
O	3.281503	-1.248613	0.966478
C	2.015588	-1.890620	0.844804
H	2.197248	-2.873553	0.405303
H	1.577500	-2.021072	1.845449
C	1.076214	-1.078606	-0.034235
H	0.092281	-1.553724	-0.069599
H	1.473975	-1.020517	-1.055204

SCF energy: -658.323905085
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -641 cm-1
Zero-point correction: 0.259699
Enthalpy correction: 0.273440
Free energy correction: 0.219255

TS_SN2_1F_opt_SMDiPrOH

H	0.679039	1.210601	-1.566189
C	-0.065950	1.478483	-0.829345
H	0.126977	2.291164	-0.143574
C	-1.345945	0.735657	-0.756938
C	-3.754232	-0.682404	-0.607235
C	-2.228432	0.954897	0.305282
C	-1.677340	-0.197192	-1.744656
C	-2.877160	-0.902736	-1.670818
C	-3.427942	0.248327	0.380503
H	-1.973245	1.681548	1.073312
H	-0.994268	-0.363590	-2.574118
H	-3.128256	-1.623662	-2.443380
H	-4.108752	0.425663	1.207932
H	-4.689031	-1.232239	-0.549672
F	-0.696242	2.737687	-2.032698
N	0.933363	0.292797	0.461357
H	0.399113	0.289367	1.333158
C	2.243781	0.921834	0.681903
H	2.705343	1.075142	-0.301146
H	2.094516	1.897595	1.153202
C	3.144469	0.048446	1.542542
H	4.145530	0.480394	1.610864
H	2.727246	-0.043115	2.557267
O	3.287482	-1.245053	0.969817
C	2.026507	-1.890545	0.846289
H	2.212968	-2.872334	0.404870
H	1.586091	-2.028597	1.845814
C	1.083523	-1.082678	-0.033583
H	0.100471	-1.560011	-0.069590
H	1.482875	-1.024165	-1.053897

SCF energy: -658.331251643
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -639 cm-1
Zero-point correction: 0.259423
Enthalpy correction: 0.273267
Free energy correction: 0.218141

TS_SN2_1F_opt_SMDiPrOH_BnF

H	-4.689448	-1.232948	-0.549581
H	-4.109169	0.424954	1.208023
C	-3.754649	-0.683113	-0.607144
C	-3.428359	0.247618	0.380594
H	-3.128673	-1.624371	-2.443289
C	-2.877577	-0.903445	-1.670727
C	-2.228849	0.954188	0.305373
H	-1.973662	1.680839	1.073403
C	-1.677757	-0.197901	-1.744565
C	-1.346362	0.734948	-0.756847
H	-0.994685	-0.364299	-2.574027
C	-0.066367	1.477774	-0.829254
H	0.126560	2.290455	-0.143483
F	-0.696659	2.736978	-2.032607

H	0.678622	1.209892	-1.566098

SCF energy: -370.592923892
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_1F_opt_SMDiPrOH_Morpholine

H	0.100054	-1.560720	-0.069499
H	1.585674	-2.029306	1.845905
H	2.212551	-2.873043	0.404961
H	0.398696	0.288658	1.333249
C	1.083106	-1.083387	-0.033492
C	2.026090	-1.891254	0.846380
N	0.932946	0.292088	0.461448
H	1.482458	-1.024874	-1.053806
H	2.726829	-0.043824	2.557358
O	3.287065	-1.245762	0.969908
C	3.144052	0.047737	1.542633
C	2.243364	0.921125	0.681994
H	2.094099	1.896886	1.153293
H	2.704926	1.074433	-0.301055
H	4.145113	0.479685	1.610955

SCF energy: -287.680947062
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Br_1H2O_opt_SMDiPrOH

H	-4.286859	0.666157	0.933702
H	-4.446053	-0.471081	2.299522
H	-2.906689	-1.336723	0.477027
C	-3.751138	0.180251	1.763938
H	-1.894990	0.652799	-0.245201
H	-0.275788	-0.326186	-2.450872
H	-2.900956	2.606318	1.258575
C	-2.568925	-0.615630	1.227338
H	0.807721	1.520013	-3.709359
O	-3.314143	1.169517	2.688392
H	-0.613858	-1.611009	-0.348121
N	-1.554593	0.259327	0.633694
C	-2.398408	2.074088	2.081067
C	0.475661	0.297525	-1.971811
C	1.081153	1.336336	-2.674496
H	-2.093101	-1.166432	2.048638
C	-1.176138	1.333982	1.554312
H	-2.112087	2.798077	2.847794
C	0.140946	-1.001339	0.125147
H	-0.506263	2.029585	1.040380
C	0.826710	0.054727	-0.639847
H	0.278272	-1.071925	1.195326
C	2.038090	2.139835	-2.050651
H	-0.631330	0.880054	2.392215
H	2.511254	2.947815	-2.600718
C	1.788213	0.858029	-0.018220
C	2.392497	1.896566	-0.722276
H	2.064288	0.663824	1.015722

H	3.140044	2.516521	-0.236234
H	3.171131	-1.499921	-1.683750
O	3.740709	-0.988124	-2.284393
H	4.420848	-1.607266	-2.578745
Br	1.711354	-2.744043	-0.200514

SCF energy: -3206.763687860
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -468 cm-1
Zero-point correction: 0.282195
Enthalpy correction: 0.299818
Free energy correction: 0.236147

TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr

H	-0.068442	-0.763812	-2.486253
H	-0.406512	-2.048635	-0.383502
H	1.015067	1.082387	-3.744740
C	0.683007	-0.140101	-2.007192
C	0.348292	-1.438965	0.089766
C	1.288499	0.898710	-2.709877
Br	1.918700	-3.181669	-0.235895
C	1.034056	-0.382899	-0.675228
H	0.485618	-1.509551	1.159945
C	2.245436	1.702209	-2.086032
H	2.718600	2.510189	-2.636099
C	1.995559	0.420403	-0.053601
C	2.599843	1.458940	-0.757657
H	2.271634	0.226198	0.980341
H	3.347390	2.078895	-0.271615

SCF energy: -2842.620265600
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr_H2O

H	-0.068442	-0.763812	-2.486253
H	-0.406512	-2.048635	-0.383502
H	1.015067	1.082387	-3.744740
C	0.683007	-0.140101	-2.007192
C	0.348292	-1.438965	0.089766
C	1.288499	0.898710	-2.709877
Br	1.918700	-3.181669	-0.235895
C	1.034056	-0.382899	-0.675228
H	0.485618	-1.509551	1.159945
H	3.378477	-1.937547	-1.719131
O	3.948055	-1.425750	-2.319774
H	4.628194	-2.044892	-2.614126
C	2.245436	1.702209	-2.086032
H	2.718600	2.510189	-2.636099
C	1.995559	0.420403	-0.053601
C	2.599843	1.458940	-0.757657
H	2.271634	0.226198	0.980341
H	3.347390	2.078895	-0.271615

SCF energy: -2919.025947220

M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Br_1H2O_opt_SMDiPrOH_BnBr_Morpholine

H	-2.699343	-1.774349	0.441646
H	-4.079513	0.228531	0.898321
H	-4.238707	-0.908707	2.264141
H	-0.068442	-0.763812	-2.486253
C	-3.543792	-0.257375	1.728557
C	-2.361579	-1.053256	1.191957
H	-0.406512	-2.048635	-0.383502
H	-1.687644	0.215173	-0.280582
H	1.015067	1.082387	-3.744740
H	-1.885755	-1.604058	2.013257
C	0.683007	-0.140101	-2.007192
N	-1.347247	-0.178299	0.598313
O	-3.106797	0.731891	2.653011
C	0.348292	-1.438965	0.089766
H	-2.693610	2.168692	1.223194
C	1.288499	0.898710	-2.709877
Br	1.918700	-3.181669	-0.235895
C	1.034056	-0.382899	-0.675228
C	-2.191062	1.636462	2.045686
H	0.485618	-1.509551	1.159945
C	-0.968792	0.896356	1.518931
H	-0.298917	1.591959	1.004999
C	2.245436	1.702209	-2.086032
H	-0.423984	0.442428	2.356834
H	-1.904741	2.360451	2.812413
H	2.718600	2.510189	-2.636099
C	1.995559	0.420403	-0.053601
C	2.599843	1.458940	-0.757657
H	2.271634	0.226198	0.980341
H	3.347390	2.078895	-0.271615

SCF energy: -3130.312476270
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Br_1H2O_opt_SMDiPrOH_H2O

H	3.378477	-1.937547	-1.719131
O	3.948055	-1.425750	-2.319774
H	4.628194	-2.044892	-2.614126

SCF energy: -76.394834104
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Br_1H2O_opt_SMDiPrOH_Morpholine

H	-2.699343	-1.774349	0.441646
H	-4.079513	0.228531	0.898321
H	-4.238707	-0.908707	2.264141
C	-3.543792	-0.257375	1.728557
C	-2.361579	-1.053256	1.191957

H	-1.687644	0.215173	-0.280582
H	-1.885755	-1.604058	2.013257
N	-1.347247	-0.178299	0.598313
O	-3.106797	0.731891	2.653011
H	-2.693610	2.168692	1.223194
C	-2.191062	1.636462	2.045686
C	-0.968792	0.896356	1.518931
H	-0.298917	1.591959	1.004999
H	-0.423984	0.442428	2.356834
H	-1.904741	2.360451	2.812413

SCF energy: -287.681044755
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Cl_1H2O_opt_SMDiPrOH

H	3.642629	-2.408456	-0.660301
H	2.239170	-0.397025	-0.914924
O	4.021106	-1.244046	0.958978
H	2.581061	1.040599	1.161955
H	-0.090290	0.653449	-2.330305
H	4.171522	-0.120502	2.643117
C	3.099467	-2.025362	0.207086
H	0.518784	1.481861	-0.050649
C	1.904989	-1.187041	-0.229711
C	3.406416	-0.700688	2.121336
H	-1.227992	-1.017844	-3.771360
C	2.223676	0.179983	1.741279
C	-0.779488	-0.066578	-1.895360
H	1.176974	-1.813708	-0.753895
H	2.758249	-2.876374	0.816956
N	1.253766	-0.543784	0.913941
C	-1.419901	-1.003644	-2.702657
C	-0.321227	0.925141	0.341187
H	3.073285	-1.520317	2.776966
H	1.722632	0.552812	2.639710
C	-1.025517	-0.040530	-0.517847
H	-0.498019	0.930760	1.406565
H	0.767866	-1.244833	1.475417
C	-2.308390	-1.920643	-2.138039
H	-2.808552	-2.650397	-2.767876
C	-1.921735	-0.957392	0.043463
C	-2.559072	-1.895901	-0.764544
H	-2.115293	-0.931839	1.113355
H	-3.253602	-2.605574	-0.324925
Cl	-1.656742	2.714098	0.094146
H	-3.220000	1.667838	-1.274365
O	-3.917240	1.270410	-1.823467
H	-4.690583	1.833115	-1.689259

SCF energy: -1095.124090270
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -487 cm-1
Zero-point correction: 0.281277
Enthalpy correction: 0.299246
Free energy correction: 0.235079

TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl

H	-1.371869	-0.535347	-3.645480
H	-0.234167	1.135946	-2.204425
C	-1.563778	-0.521147	-2.576777
C	-0.923365	0.415919	-1.769480
H	-2.952429	-2.167900	-2.641996
C	-2.452267	-1.438146	-2.012159
H	0.374907	1.964358	0.075231
C	-1.169394	0.441967	-0.391967
Cl	-1.800619	3.196595	0.220026
C	-0.465104	1.407638	0.467067
C	-2.702949	-1.413404	-0.638664
C	-2.065612	-0.474895	0.169343
H	-0.641896	1.413257	1.532445
H	-3.397479	-2.123077	-0.199045
H	-2.259170	-0.449342	1.239235

SCF energy: -730.983685413
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl_H2O

H	-1.371869	-0.535347	-3.645480
H	-0.234167	1.135946	-2.204425
C	-1.563778	-0.521147	-2.576777
C	-0.923365	0.415919	-1.769480
H	-2.952429	-2.167900	-2.641996
C	-2.452267	-1.438146	-2.012159
H	0.374907	1.964358	0.075231
O	-4.061117	1.752907	-1.697587
H	-3.363877	2.150335	-1.148485
H	-4.834460	2.315612	-1.563379
C	-1.169394	0.441967	-0.391967
Cl	-1.800619	3.196595	0.220026
C	-0.465104	1.407638	0.467067
C	-2.702949	-1.413404	-0.638664
C	-2.065612	-0.474895	0.169343
H	-0.641896	1.413257	1.532445
H	-3.397479	-2.123077	-0.199045
H	-2.259170	-0.449342	1.239235

SCF energy: -807.388441413
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Cl_1H2O_opt_SMDiPrOH_BnCl_Morpholine

H	-1.371869	-0.535347	-3.645480
H	-0.234167	1.135946	-2.204425
C	-1.563778	-0.521147	-2.576777
H	2.095293	0.085472	-0.789044
H	3.498752	-1.925959	-0.534421
C	-0.923365	0.415919	-1.769480
H	-2.952429	-2.167900	-2.641996
H	1.033097	-1.331211	-0.628015

C	1.761112	-0.704544	-0.103831
C	-2.452267	-1.438146	-2.012159
C	2.955590	-1.542865	0.332966
H	0.374907	1.964358	0.075231
O	3.877229	-0.761549	1.084858
H	2.437184	1.523096	1.287835
C	-1.169394	0.441967	-0.391967
Cl	-1.800619	3.196595	0.220026
C	-0.465104	1.407638	0.467067
H	2.614372	-2.393877	0.942836
N	1.109889	-0.061287	1.039821
C	2.079799	0.662480	1.867159
C	-2.702949	-1.413404	-0.638664
C	3.262539	-0.218191	2.247216
H	4.027645	0.361995	2.768997
C	-2.065612	-0.474895	0.169343
H	-0.641896	1.413257	1.532445
H	0.623989	-0.762336	1.601297
H	-3.397479	-2.123077	-0.199045
H	1.578755	1.035309	2.765590
H	2.929408	-1.037820	2.902846
H	-2.259170	-0.449342	1.239235

SCF energy: -1018.671748060
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Cl_1H2O_opt_SMDiPrOH_H2O

O	-4.061117	1.752907	-1.697587
H	-3.363877	2.150335	-1.148485
H	-4.834460	2.315612	-1.563379

SCF energy: -76.394837710
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2Cl_1H2O_opt_SMDiPrOH_Morpholine

H	2.095293	0.085472	-0.789044
H	3.498752	-1.925959	-0.534421
H	1.033097	-1.331211	-0.628015
C	1.761112	-0.704544	-0.103831
C	2.955590	-1.542865	0.332966
O	3.877229	-0.761549	1.084858
H	2.437184	1.523096	1.287835
H	2.614372	-2.393877	0.942836
N	1.109889	-0.061287	1.039821
C	2.079799	0.662480	1.867159
C	3.262539	-0.218191	2.247216
H	4.027645	0.361995	2.768997
H	0.623989	-0.762336	1.601297
H	1.578755	1.035309	2.765590
H	2.929408	-1.037820	2.902846

SCF energy: -287.681086340
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_1H2O_opt_SMDiPrOH

H	3.809616	-2.360401	-0.749412
H	2.433823	-0.312296	-0.817782
O	4.085631	-1.425512	1.032143
H	0.049171	0.661647	-2.242764
H	2.637810	0.825670	1.444260
C	3.213721	-2.089456	0.125379
C	2.054570	-1.187139	-0.274391
H	0.748889	1.327401	0.061935
H	4.122422	-0.542788	2.860425
H	1.362662	-1.728938	-0.925228
H	-1.287376	-0.768722	-3.769196
C	3.395002	-1.038863	2.213605
C	-0.683820	-0.033150	-1.839732
C	2.243922	-0.100137	1.881480
H	2.831171	-3.009670	0.593633
N	1.325953	-0.697615	0.902636
C	-1.437458	-0.834195	-2.695603
C	-0.084302	0.756095	0.448185
H	3.016127	-1.936102	2.727015
H	1.685384	0.153912	2.787242
C	-0.873814	-0.108554	-0.456475
H	-0.290214	0.764629	1.509001
H	0.812638	-1.468953	1.334358
C	-2.385574	-1.715537	-2.173705
H	-2.974835	-2.338072	-2.840593
C	-1.827012	-0.989954	0.062473
C	-2.579510	-1.792110	-0.793402
H	-1.981267	-1.042299	1.137821
H	-3.320414	-2.472739	-0.384398
F	-1.147759	2.228319	0.258164
H	-2.529287	2.044246	-0.679970
O	-3.335118	1.940521	-1.234025
H	-3.937653	2.638616	-0.950387

SCF energy: -734.750743331
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -623 cm-1
Zero-point correction: 0.283201
Enthalpy correction: 0.300378
Free energy correction: 0.235231

TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF

H	-0.228196	1.166258	-2.198906
H	-1.564743	-0.264112	-3.725338
C	-0.961187	0.471461	-1.795874
C	-1.714825	-0.329585	-2.651745
H	0.471522	1.832012	0.105793
F	-1.425126	2.732930	0.302022
C	-0.361669	1.260706	0.492043
C	-1.151181	0.396057	-0.412617
C	-2.662941	-1.210927	-2.129847
H	-3.252202	-1.833462	-2.796735
H	-0.567581	1.269240	1.552859

C	-2.104379	-0.485344	0.106331
C	-2.856877	-1.287500	-0.749544
H	-2.258634	-0.537689	1.181679
H	-3.597781	-1.968129	-0.340540

SCF energy: -370.598583322
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF_H2O

H	-0.228196	1.166258	-2.198906
H	-1.564743	-0.264112	-3.725338
C	-0.961187	0.471461	-1.795874
C	-1.714825	-0.329585	-2.651745
H	0.471522	1.832012	0.105793
F	-1.425126	2.732930	0.302022
H	-2.806654	2.548857	-0.636112
O	-3.612485	2.445132	-1.190167
C	-0.361669	1.260706	0.492043
C	-1.151181	0.396057	-0.412617
C	-2.662941	-1.210927	-2.129847
H	-3.252202	-1.833462	-2.796735
H	-4.215020	3.143226	-0.906529
H	-0.567581	1.269240	1.552859
C	-2.104379	-0.485344	0.106331
C	-2.856877	-1.287500	-0.749544
H	-2.258634	-0.537689	1.181679
H	-3.597781	-1.968129	-0.340540

SCF energy: -447.007673538
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_1H2O_opt_SMDiPrOH_BnF_Morpholine

H	-0.228196	1.166258	-2.198906
H	-1.564743	-0.264112	-3.725338
H	2.156456	0.192315	-0.773924
H	3.532249	-1.855791	-0.705554
C	-0.961187	0.471461	-1.795874
C	-1.714825	-0.329585	-2.651745
H	0.471522	1.832012	0.105793
C	1.777203	-0.682529	-0.230533
O	3.808264	-0.920902	1.076001
C	2.936354	-1.584846	0.169237
H	1.085295	-1.224328	-0.881370
H	2.360443	1.330281	1.488118
F	-1.425126	2.732930	0.302022
C	-0.361669	1.260706	0.492043
H	2.553804	-2.505060	0.637491
C	-1.151181	0.396057	-0.412617
C	-2.662941	-1.210927	-2.129847
H	3.845055	-0.038178	2.904283
H	-3.252202	-1.833462	-2.796735
N	1.048586	-0.193005	0.946494
C	1.966555	0.404474	1.925338
C	3.117635	-0.534253	2.257463

H	-0.567581	1.269240	1.552859
H	0.535271	-0.964343	1.378216
H	1.408017	0.658523	2.831100
H	2.738760	-1.431492	2.770873
C	-2.104379	-0.485344	0.106331
C	-2.856877	-1.287500	-0.749544
H	-2.258634	-0.537689	1.181679
H	-3.597781	-1.968129	-0.340540

SCF energy: -658.286850987
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_1H2O_opt_SMDiPrOH_H2O

H	-2.806654	2.548857	-0.636112
O	-3.612485	2.445132	-1.190167
H	-4.215020	3.143226	-0.906529

SCF energy: -76.394531640
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_1H2O_opt_SMDiPrOH_Morpholine

H	2.156456	0.192315	-0.773924
H	3.532249	-1.855791	-0.705554
C	1.777203	-0.682529	-0.230533
O	3.808264	-0.920902	1.076001
C	2.936354	-1.584846	0.169237
H	1.085295	-1.224328	-0.881370
H	2.360443	1.330281	1.488118
H	2.553804	-2.505060	0.637491
H	3.845055	-0.038178	2.904283
N	1.048586	-0.193005	0.946494
C	1.966555	0.404474	1.925338
C	3.117635	-0.534253	2.257463
H	0.535271	-0.964343	1.378216
H	1.408017	0.658523	2.831100
H	2.738760	-1.431492	2.770873

SCF energy: -287.680992886
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_2H2O_opt_SMDiPrOH

H	3.649861	-2.551115	-0.760143
C	3.131352	-2.202455	0.136168
H	2.367565	-0.445143	-0.855699
O	4.096931	-1.534781	0.939742
H	2.741387	-3.075011	0.683086
H	-1.335579	-0.639260	-3.673366
H	1.226666	-1.808668	-0.799454
C	1.989174	-1.266095	-0.233038
H	0.042270	0.773877	-2.166325
C	-1.462950	-0.710264	-2.597263

C	-0.687034	0.081397	-1.752776
C	3.514317	-1.044961	2.141430
H	4.310570	-0.550544	2.702908
H	-3.009755	-2.206173	-2.717976
H	3.132216	-1.890146	2.734643
H	2.791589	0.808312	1.315586
N	1.373466	-0.673944	0.959850
C	-2.403676	-1.590328	-2.060013
H	0.816473	1.389275	0.128846
C	2.386635	-0.069861	1.833858
H	0.856862	-1.391775	1.472086
C	-0.848770	-0.002688	-0.366405
C	-0.034622	0.851210	0.523818
C	-2.567783	-1.676754	-0.676213
H	1.907791	0.263400	2.759411
C	-1.793207	-0.884235	0.168856
H	-3.300537	-2.359415	-0.256153
F	-1.052537	2.337817	0.359728
H	-0.205521	0.842136	1.591554
H	-2.455740	2.159438	-0.698625
O	-3.298873	2.037441	-1.177243
H	-1.917761	-0.948384	1.247385
H	-3.821403	2.824832	-0.979958
H	-2.257098	2.033180	1.564533
O	-2.937056	1.779189	2.220551
H	-3.620289	1.328217	1.708202

SCF energy: -811.168759744
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -606 cm-1
Zero-point correction: 0.307188
Enthalpy correction: 0.327760
Free energy correction: 0.257450

TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF

H	0.005466	1.051996	-2.316925
H	-1.372383	-0.361141	-3.823966
C	-0.723838	0.359516	-1.903376
C	-1.499754	-0.432145	-2.747863
H	0.779669	1.667394	-0.021754
F	-1.089341	2.615936	0.209128
C	-0.071426	1.129329	0.373218
C	-0.885574	0.275431	-0.517005
C	-2.440480	-1.312209	-2.210613
H	-3.046559	-1.928054	-2.868576
H	-0.242325	1.120255	1.440954
C	-1.830011	-0.606116	0.018256
C	-2.604587	-1.398635	-0.826813
H	-1.954565	-0.670265	1.096785
H	-3.337341	-2.081296	-0.406753

SCF energy: -370.602379868
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A

H	-1.372383	-0.361141	-3.823966
H	-3.046559	-1.928054	-2.868576
C	-1.499754	-0.432145	-2.747863
H	3.613057	-2.272996	-0.910743
H	0.005466	1.051996	-2.316925
C	-2.440480	-1.312209	-2.210613
H	2.330761	-0.167024	-1.006299
C	-0.723838	0.359516	-1.903376
H	1.189862	-1.530549	-0.950054
C	3.094548	-1.924336	-0.014432
C	1.952370	-0.987976	-0.383638
H	2.704583	-2.796892	0.532486
O	4.060127	-1.256662	0.789142
C	-2.604587	-1.398635	-0.826813
C	-0.885574	0.275431	-0.517005
H	-3.337341	-2.081296	-0.406753
H	0.779669	1.667394	-0.021754
N	1.336662	-0.395825	0.809250
C	-1.830011	-0.606116	0.018256
C	-0.071426	1.129329	0.373218
H	2.754785	1.086431	1.164986
H	0.820058	-1.113656	1.321486
C	3.477513	-0.766842	1.990830
F	-1.089341	2.615936	0.209128
C	2.349831	0.208258	1.683258
H	4.273766	-0.272425	2.552308
H	3.095412	-1.612027	2.584043
H	-1.954565	-0.670265	1.096785
H	-0.242325	1.120255	1.440954
H	1.870987	0.541519	2.608811
H	-2.293902	2.311299	1.413933
H	-3.657093	1.606336	1.557602
O	-2.973860	2.057308	2.069951

SCF energy: -734.704240357
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_2H2O_opt_SMDiPrOH_BnF_Morpho_H2O_B

H	3.613057	-2.272996	-0.910743
C	3.094548	-1.924336	-0.014432
H	2.330761	-0.167024	-1.006299
O	4.060127	-1.256662	0.789142
H	2.704583	-2.796892	0.532486
H	-1.372383	-0.361141	-3.823966
H	1.189862	-1.530549	-0.950054
C	1.952370	-0.987976	-0.383638
H	0.005466	1.051996	-2.316925
C	-1.499754	-0.432145	-2.747863
C	-0.723838	0.359516	-1.903376
C	3.477513	-0.766842	1.990830
H	4.273766	-0.272425	2.552308
H	-3.046559	-1.928054	-2.868576
H	3.095412	-1.612027	2.584043
H	2.754785	1.086431	1.164986
N	1.336662	-0.395825	0.809250
C	-2.440480	-1.312209	-2.210613

H	0.779669	1.667394	-0.021754
C	2.349831	0.208258	1.683258
H	0.820058	-1.113656	1.321486
C	-0.885574	0.275431	-0.517005
C	-0.071426	1.129329	0.373218
C	-2.604587	-1.398635	-0.826813
H	1.870987	0.541519	2.608811
C	-1.830011	-0.606116	0.018256
H	-3.337341	-2.081296	-0.406753
H	-0.242325	1.120255	1.440954
H	-2.492544	2.437557	-0.849225
O	-3.335677	2.315560	-1.327843
H	-1.954565	-0.670265	1.096785
H	-3.858207	3.102951	-1.130558
F	-1.089341	2.615936	0.209128

SCF energy: -734.702475401
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_2H2O_opt_SMDiPrOH_H2O_A

H	-2.293902	2.311299	1.413933
H	-3.657093	1.606336	1.557602
O	-2.973860	2.057308	2.069951

SCF energy: -76.394689520
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_2H2O_opt_SMDiPrOH_H2O_B

O	-3.335677	2.315560	-1.327843
H	-2.492544	2.437557	-0.849225
H	-3.858207	3.102951	-1.130558

SCF energy: -76.394740684
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_3H2O_opt_SMDiPrOH

H	0.530902	2.725540	-0.118691
C	-0.335414	2.213951	0.280740
H	-0.487265	2.197241	1.351227
C	-1.154265	1.355885	-0.598209
C	-2.728346	-0.231974	-2.271592
C	-2.120687	0.504865	-0.052220
C	-0.977456	1.407443	-1.984705
C	-1.764409	0.615929	-2.819209
C	-2.904970	-0.287903	-0.887584
H	-2.254065	0.465073	1.026334
H	-0.224899	2.069829	-2.405793
H	-1.625657	0.660142	-3.895291
H	-3.654548	-0.947323	-0.460286
H	-3.342389	-0.847988	-2.921948
N	1.088099	0.642489	0.723139

H	0.571773	-0.051666	1.266820
C	2.133787	1.249473	1.554607
H	2.544598	2.103909	1.002263
H	1.685608	1.618959	2.481824
C	3.249526	0.260775	1.862348
H	4.068269	0.752844	2.392821
H	2.865024	-0.561582	2.485575
O	3.794590	-0.270145	0.660225
C	2.798224	-0.938805	-0.104633
H	3.289512	-1.316657	-1.004520
H	2.407168	-1.791985	0.471309
C	1.662875	0.008658	-0.467915
H	0.877217	-0.534554	-1.001480
F	-1.331827	3.698715	0.129155
H	2.039787	0.805722	-1.121896
O	-0.222847	5.025230	-1.979352
O	-3.279565	3.157560	1.989710
O	-3.623575	3.377964	-1.436580
H	-2.582950	3.418414	1.359456
H	-3.940550	2.701054	1.453282
H	-2.800781	3.473001	-0.924315
H	-4.143615	4.165262	-1.231025
H	-0.650294	4.594003	-1.215647
H	-0.849528	4.934978	-2.708211

SCF energy: -887.584968268
M06-2X(SMD,solvent)/6-31+G(d,p) optimization
1 imaginary frequency: -588 cm-1
Zero-point correction: 0.330548
Enthalpy correction: 0.355011
Free energy correction: 0.270828

TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF

H	0.067228	0.725616	-2.171940
H	0.823029	1.381327	0.115162
F	-1.039700	2.354502	0.363008
H	-1.333530	-0.684072	-3.661438
C	-0.685329	0.063230	-1.750852
C	-0.043287	0.869738	0.514593
C	-1.472282	-0.728285	-2.585356
C	-0.862138	0.011672	-0.364356
H	-0.195138	0.853028	1.585080
C	-2.436219	-1.576188	-2.037739
C	-1.828560	-0.839349	0.181633
H	-3.050262	-2.192202	-2.688095
C	-2.612843	-1.632117	-0.653731
H	-1.961938	-0.879141	1.260187
H	-3.362421	-2.291537	-0.226433

SCF energy: -370.605679412
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A_H2O_B

H	0.823029	1.381327	0.115162

C	-0.043287	0.869738	0.514593
H	-0.195138	0.853028	1.585080
C	-0.862138	0.011672	-0.364356
C	-2.436219	-1.576188	-2.037739
C	-1.828560	-0.839349	0.181633
C	-0.685329	0.063230	-1.750852
C	-1.472282	-0.728285	-2.585356
C	-2.612843	-1.632117	-0.653731
H	-1.961938	-0.879141	1.260187
H	0.067228	0.725616	-2.171940
H	-1.333530	-0.684072	-3.661438
H	-3.362421	-2.291537	-0.226433
H	-3.050262	-2.192202	-2.688095
N	1.380226	-0.701725	0.956992
H	0.863900	-1.395880	1.500673
C	2.425914	-0.094741	1.788460
H	2.836725	0.759696	1.236116
H	1.977735	0.274746	2.715677
C	3.541653	-1.083439	2.096201
H	4.360396	-0.591370	2.626674
H	3.157151	-1.905796	2.719428
O	4.086717	-1.614359	0.894078
C	3.090351	-2.283019	0.129220
H	3.581639	-2.660871	-0.770667
H	2.699295	-3.136199	0.705162
C	1.955002	-1.335556	-0.234062
H	1.169344	-1.878768	-0.767627
H	2.331914	-0.538492	-0.888043
O	-2.987438	1.813347	2.223563
O	-3.331448	2.033751	-1.202727
H	-2.290823	2.074201	1.593309
H	-3.648423	1.356841	1.687135
H	-2.508654	2.128788	-0.690462
H	-3.851488	2.821049	-0.997172
F	-1.039700	2.354502	0.363008

SCF energy: -811.117894892
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_A_H2O_C

H	0.823029	1.381327	0.115162
C	-0.043287	0.869738	0.514593
H	-0.195138	0.853028	1.585080
C	-0.862138	0.011672	-0.364356
C	-2.436219	-1.576188	-2.037739
C	-1.828560	-0.839349	0.181633
C	-0.685329	0.063230	-1.750852
C	-1.472282	-0.728285	-2.585356
C	-2.612843	-1.632117	-0.653731
H	-1.961938	-0.879141	1.260187
H	0.067228	0.725616	-2.171940
H	-1.333530	-0.684072	-3.661438
H	-3.362421	-2.291537	-0.226433
H	-3.050262	-2.192202	-2.688095
N	1.380226	-0.701725	0.956992
H	0.863900	-1.395880	1.500673
C	2.425914	-0.094741	1.788460

H	2.836725	0.759696	1.236116
H	1.977735	0.274746	2.715677
C	3.541653	-1.083439	2.096201
H	4.360396	-0.591370	2.626674
H	3.157151	-1.905796	2.719428
O	4.086717	-1.614359	0.894078
C	3.090351	-2.283019	0.129220
H	3.581639	-2.660871	-0.770667
H	2.699295	-3.136199	0.705162
C	1.955002	-1.335556	-0.234062
H	1.169344	-1.878768	-0.767627
H	2.331914	-0.538492	-0.888043
O	0.069280	3.681017	-1.745499
O	-2.987438	1.813347	2.223563
H	-2.290823	2.074201	1.593309
H	-3.648423	1.356841	1.687135
H	-0.358167	3.249790	-0.981794
H	-0.557401	3.590765	-2.474358
F	-1.039700	2.354502	0.363008

SCF energy: -811.117463583
M06-2X(gas phase)/6-31+G(d,p) Single point

TS_SN2_2F_3H2O_opt_SMDiPrOH_BnF_Morpho_H2O_B_H2O_C

H	0.823029	1.381327	0.115162
C	-0.043287	0.869738	0.514593
H	-0.195138	0.853028	1.585080
C	-0.862138	0.011672	-0.364356
C	-2.436219	-1.576188	-2.037739
C	-1.828560	-0.839349	0.181633
C	-0.685329	0.063230	-1.750852
C	-1.472282	-0.728285	-2.585356
C	-2.612843	-1.632117	-0.653731
H	-1.961938	-0.879141	1.260187
H	0.067228	0.725616	-2.171940
H	-1.333530	-0.684072	-3.661438
H	-3.362421	-2.291537	-0.226433
H	-3.050262	-2.192202	-2.688095
N	1.380226	-0.701725	0.956992
H	0.863900	-1.395880	1.500673
C	2.425914	-0.094741	1.788460
H	2.836725	0.759696	1.236116
H	1.977735	0.274746	2.715677
C	3.541653	-1.083439	2.096201
H	4.360396	-0.591370	2.626674
H	3.157151	-1.905796	2.719428
O	4.086717	-1.614359	0.894078
C	3.090351	-2.283019	0.129220
H	3.581639	-2.660871	-0.770667
H	2.699295	-3.136199	0.705162
C	1.955002	-1.335556	-0.234062
H	1.169344	-1.878768	-0.767627
H	2.331914	-0.538492	-0.888043
O	0.069280	3.681017	-1.745499
O	-3.331448	2.033751	-1.202727
H	-2.508654	2.128788	-0.690462
H	-3.851488	2.821049	-0.997172

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   H      -0.358167       3.249790      -0.981794
   H      -0.557401       3.590765      -2.474358
   F      -1.039700       2.354502       0.363008
-----------------------------------------------------
SCF energy: -811.116784026
M06-2X(gas phase)/6-31+G(d,p) Single point
-----------------------------------------------------

-----------------------------------------------------
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_A
-----------------------------------------------------
   H      -2.290823       2.074201       1.593309
   O      -2.987438       1.813347       2.223563
   H      -3.648423       1.356841       1.687135
-----------------------------------------------------
SCF energy: -76.394779003
M06-2X(gas phase)/6-31+G(d,p) Single point
-----------------------------------------------------

-----------------------------------------------------
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_B
-----------------------------------------------------
   H      -2.508654       2.128788      -0.690462
   H      -3.851488       2.821049      -0.997172
   O      -3.331448       2.033751      -1.202727
-----------------------------------------------------
SCF energy: -76.394820170
M06-2X(gas phase)/6-31+G(d,p) Single point
-----------------------------------------------------

-----------------------------------------------------
TS_SN2_2F_3H2O_opt_SMDiPrOH_H2O_C
-----------------------------------------------------
   O       0.069280       3.681017      -1.745499
   H      -0.557401       3.590765      -2.474358
   H      -0.358167       3.249790      -0.981794
-----------------------------------------------------
SCF energy: -76.394780342
M06-2X(gas phase)/6-31+G(d,p) Single point
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