Electronic Supplementary Information

Direct Benzylic Polychlorination of (Poly)Azines with N-Chlorosuccinimide

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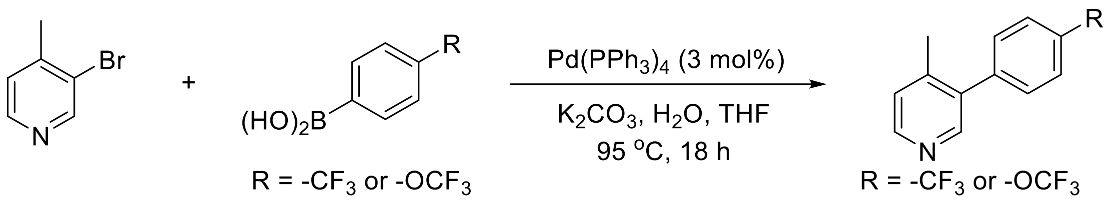
1. General Information

All reactions were carried out with standard Schlenk techniques under argon or in an argon-filled glove box. NCS was purchased from TCI and used without purification. **1r**, **1s**, **1aa**, **1ab**, **1ac** and **1ad** were synthesized according to the reported procedure. Other commercially available chemicals were purchased from Acros, Sigma-Aldrich, J&K, Alfa Aesar, Bidepharm, Heowns and Innochem Chemical Companies and used as received. Anhydrous CH_3CN was purchased from J&K and used as received (water < 30 ppm, J&KSeal). Analytical thin-layer chromatography (TLC) was performed on silica gel 60 F_{254} aluminum sheets from Qingdao Haiyang Chemical Co., Ltd. Flash chromatography was performed on silica gel (200–300 mesh, Qingdao Haiyang Chemical Co., Ltd).

^{1}H, ^{13}C, and ^{19}F NMR spectra were recorded in $CDCl_3$ on a Bruker AVANCE Avance III 400 instrument. Chemical shifts are reported in parts per million (ppm) and are referenced to the residual solvent resonance as the internal standard ($CDCl_3$: 7.26 ppm for ^{1}H NMR, and 77.16 ppm for $^{13}C\{^{1}H\}$ NMR). Data are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q =quartet, m = multiplet), coupling constants (Hz) and integration. Infrared spectra were recorded on a Thermo Scientific™ Nicolet™ iS50 FTIR. High-resolution mass spectra (HRMS) were recorded on the Thermo Quest Finnigan LCQDECA system equipped with an ESI ionization source and a TOF detector mass spectrometer and Thermo Scientific™ Q Exactive™ UHMR combined Quadrupole Orbitrap™ mass spectrometer equipped with an ESI ionization source.

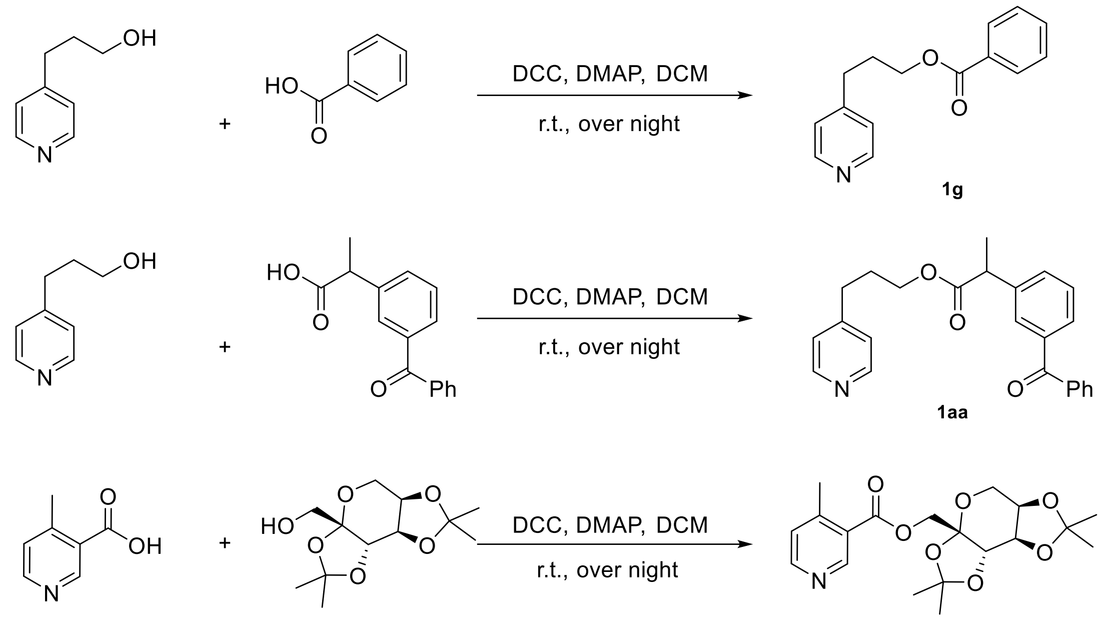
Preparation of starting materials

1.1 Synthesis of 3-aryl-4-methyl pyridines



General procedure A: To a 100 mL round-bottomed flask equipped with a magnetic stir bar, 4-trifluoro-methylphenylboronic acid or 4-trifluoromethoxyphenylboronic acid (3 mmol, 1.0 equiv.), $Pd(PPh_3)_4$ (0.09 mmol, 104.0 mg) and K_2CO_3 (7.02 mmol, 72.0 mg) were weighed in turn, then ventilated with argon three times. Then 3-bromo-4-methylpyridine (3 mmol, 516.1 mg), THF (7.6 mL) and distilled water (3.9 mL) were added under argon. The resulting mixture was refluxed at 95 °C for 18 h and cooled to room temperature, then diluted with H_2O and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layer was washed with brine (3 × 20 mL), dried over Na_2SO_4 and then concentrated in vacuo. The crude product was purified by column chromatography (silica gel, PE/EA = 10:1 → 5:1) to obtain the desired product.

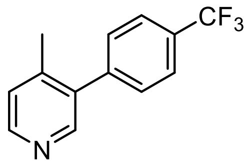
1.2 Synthesis of 4-substituted pyridines decorated with ester groups



1ab

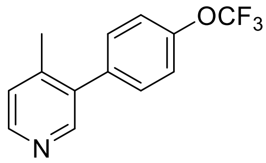
General procedure B: To a 100 mL round-bottomed flask equipped with a magnetic stir bar, the corresponding carboxylic acid (3 mmol, 1.0 equiv.), 3-(pyridin-4-yl)propan-1-ol (3 mmol, 1.0 equiv.), dicyclohexylcarbodiimide (DCC, 3.6 mmol, 1.2 equiv), DMAP (4-dimethylaminepyridine) (0.15 mmol, 0.05 equiv.) were combined in dry DCM (20 mL) and the reaction mixture was allowed to stir at room temperature overnight. Then, the white precipitate was filtered off, and the solution was concentrated by evaporation of the solvent, followed by column chromatography (silica gel, PE/EA = 10:1 → 5:1) to obtain the desired products.

1.3 Characterization Data of starting materials



1r
$C_{13}H_{10}F_3N$

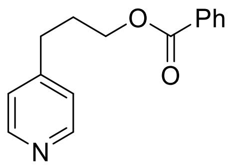
1r, yellow oil, 372.5 mg, 52% yield (prepared according to general procedure A). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.50 (d, J = 5.0 Hz, 1H), 8.43 (s, 1H), 7.72 (d, J = 8.0 Hz, 2H), 7.45 (d, J = 8.0 Hz, 2H), 7.22 (d, J = 5.0 Hz, 1H), 2.29 (s, 3H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 149.8, 149.2, 144.5, 141.8, 136.6, 130.2, 129.8, 125.6 (q, J = 3.8 Hz), 125.4, 124.2 (d, J = 272.1 Hz), 19.8 ppm. **^{19}F NMR** (376 MHz, $CDCl_3$): δ -62.59 ppm. **IR** (film): 3050, 1618, 1592, 1321, 1217, 1163, 1107, 1004, 847, 822 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_{11}F_3N^+$ $[M+H]^+$ 238.0838; found 238.0839.



1s

$C_{13}H_{10}F_3NO$

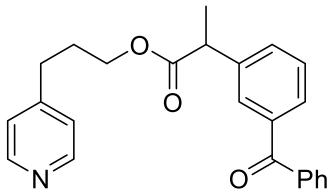
1s, yellow oil, 638.5 mg, 84% yield (prepared according to general procedure A). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.45 (d, *J* = 5.0 Hz, 1H), 8.41 (s, 1H), 7.36 – 7.27 (m, 4H), 7.18 (d, *J* = 5.0 Hz, 1H), 2.27 (s, 3H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 150.0, 148.9, 144.6, 136.7, 136.5, 130.8, 125.3, 120.6 (q, *J* = 257.4 Hz), 121.0, 19.9 ppm. **^{19}F NMR** (376 MHz, $CDCl_3$): δ -57.82 ppm. **IR** (film): 3050, 1592, 1509, 1481, 1252, 1208, 1161, 1004, 871, 699 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_{11}F_3NO^+$ $[M+H]^+$ 254.0787; found 254.0788.



1g

$C_{15}H_{15}NO_2$

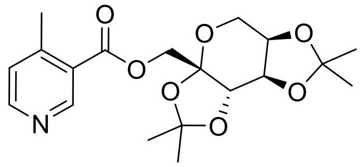
1g, colorless liquid, 506.7 mg, 70% yield (prepared according to general procedure B). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.53 – 8.45 (m, 2H), 8.03 – 7.95 (m, 2H), 7.58 – 7.51 (m, 1H), 7.44 – 7.40 (m, 2H), 7.16 – 7.11 (m, 2H), 4.33 (t, *J* = 6.4 Hz, 2H), 2.81 – 2.74 (m, 2H), 2.17 – 2.05 (m, 2H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 166.5, 150.3, 149.8, 133.1, 130.2, 129.6, 128.5, 124.0, 64.0, 31.8, 29.3 ppm. **IR** (film): 2955, 1713, 1601, 1451, 1268, 1112, 1026, 709 cm^{-1}. **HRMS** (ESI): calculated for $C_{15}H_{16}NO_2^+$ $[M+H]^+$ 242.1176; found 242.1179.



1aa

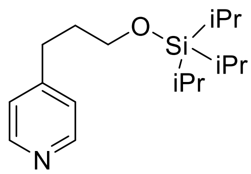
$C_{24}H_{23}NO_3$

1aa, colorless oil, 560.2 mg, 50% yield (prepared according to general procedure B). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.50 – 8.44 (s, 2H), 7.80 – 7.76 (m, 3H), 7.69 – 4.66 (m, 1H), 7.63 – 7.53 (m, 2H), 7.46 (m, 3H), 7.01 (d, *J* = 4.9 Hz, 2H), 4.09 (t, *J* = 6.4 Hz, 2H), 3.80 (q, *J* = 7.2 Hz, 1H), 2.56 (t, *J* = 7.7 Hz, 2H), 1.95 – 1.88 (m, 2H), 1.55 (d, *J* = 7.2 Hz, 3H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 196.6, 174.1, 150.1, 149.9, 141.1, 138.1, 137.6, 132.7, 131.6, 130.2, 129.3, 129.2, 128.7, 128.5, 124.0, 63.9, 45.6, 31.5, 29.2, 18.4 ppm. **IR** (film): 2935, 2159, 2036, 1731, 1659, 1601, 1447, 1282, 1176, 722 cm^{-1}. **HRMS** (ESI): calculated for $C_{24}H_{24}NO_3^+$ $[M+H]^+$ 374.1751; found 374.1755.



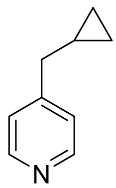
1ab
$C_{19}H_{25}NO_7$

1ab, colorless oil, 690.8 mg, 61% yield (prepared according to general procedure B). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 9.11 (s, 1H), 8.56 (d, *J* = 5.0 Hz, 1H), 7.20 (d, *J* = 5.0 Hz, 1H), 4.69 (d, *J* = 11.8 Hz, 1H), 4.64 (dd, *J* = 7.9, 2.6 Hz, 1H), 4.44 (d, *J* = 2.6 Hz, 1H), 4.32 (d, *J* = 11.8 Hz, 1H), 4.26 (dd, *J* = 7.9, 1.8 Hz, 1H), 3.96 (dd, *J* = 13.0, 1.9 Hz, 1H), 3.80 (d, *J* = 13.0 Hz, 1H), 2.64 (s, 3H), 1.55 (s, 3H), 1.43 (s, 3H), 1.37 (s, 3H), 1.35 (s, 3H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 165.4, 152.4, 151.4, 149.9, 126.5, 125.8, 109.3, 109.0, 101.6, 70.9, 70.8, 70.2, 65.8, 61.5, 26.6, 25.9, 25.6, 24.1, 21.2 ppm. **IR** (film): 2989, 2935, 1729, 1591, 1375, 1277, 1251, 1208, 1107, 1069, 888 cm^{-1}. **HRMS** (ESI): calculated for $C_{19}H_{26}NO_7^+$ $[M+H]^+$ 380.1704; found 380.1707.



1h
$C_{17}H_{31}NOSi$

1h, yellow oil, 879.8 mg, 60% yield (prepared according to a procedure by Humbeck[1], 5 mmol scale). Spectra were consistent with that previously reported. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.52 – 8.37 (m, 2H), 7.17 – 7.06 (m, 2H), 3.70 (t, *J* = 6.1 Hz, 2H), 2.79 – 2.57 (m, 2H), 1.91 – 1.75 (m, 2H), 1.08 – 1.02 (m, 21H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.5, 149.8, 124.1, 62.3, 33.6, 31.6, 18.1, 12.1 ppm.



1z
$C_9H_{11}N$

1z, yellow oil, 792.9 mg, 29% yield (prepared according to a procedure by Keiichi[2], 20.4 mmol scale). Spectra were consistent with that previously reported. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.44 – 8.39 (m, 2H), 7.13 – 7.09 (m, 2H), 2.45 (d, *J* = 7.0 Hz, 2H), 0.95 – 0.85 (m, 1H), 0.54 – 0.44 (m, 2H), 0.17 – 0.11 (m, 2H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.1, 149.7, 123.8, 39.6, 10.8, 4.8 ppm.

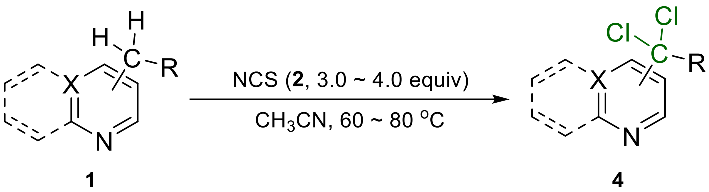
2. Experimental Details for the benzylic Polychlorination of (Poly)Azines with NCS

2.1 Optimization Studies

General procedure: To an oven-dried 10mL Schlenk tube equipped with a magnetic stir bar, NCS (26.7/53.4/80.2 mg, 0.2/0.4/0.6 mmol, 1.0/2.0/3.0 equiv.) was weighed, and ventilated with argon three times. Then **1a** (21.4 mg, 0.2 mmol, 1.0 equiv.) and CH_3CN (0.5 mL) were added under argon. The resulting mixture was stirred at varied temperature for 6 h. After the indicated time, benzyl ether (39.8 mg, 0.2 mmol, 1.0 equiv.) was added to the reaction mixture then an aliquot (approximately 50 µL) of the reaction solution was then directly transferred to an NMR tube and $CDCl_3$ was added. The yield was determined by ^{1}H NMR analysis based on the integration of the targeted product and internal standard.

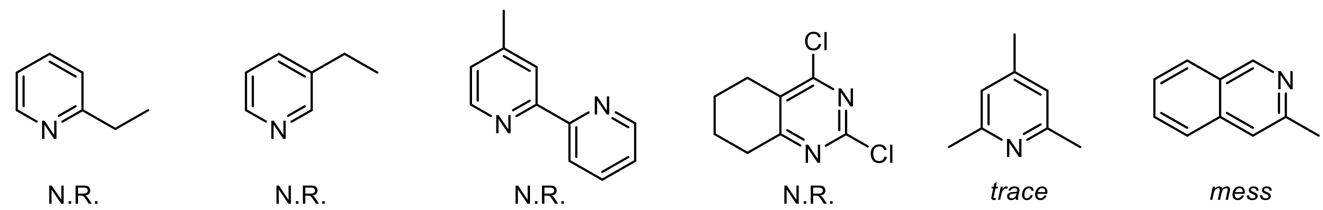
2.2 General Procedure for Benzylic Polychlorination of (Poly)Azines with NCS

2.2.1 Synthetic Procedure



General procedure C: To an oven-dried 10mL Schlenk tube equipped with a magnetic stir bar, NCS (0.6 or 0.8 mmol, 53.4 or 80.2 mg, 3.0 or 4.0 equiv.) was weighed, and ventilated with argon three times. Then **1** (0.2 mmol, 1.0 equiv.) and CH_3CN (0.5 mL) were added under argon. The resulting mixture was stirred at 60°C or 80°C. The reaction was monitored by TLC. After cooling to room temperature, the reaction mixture was concentrated in vacuo and purified by preparative TLC on silica gel to afford the polychlorination products.

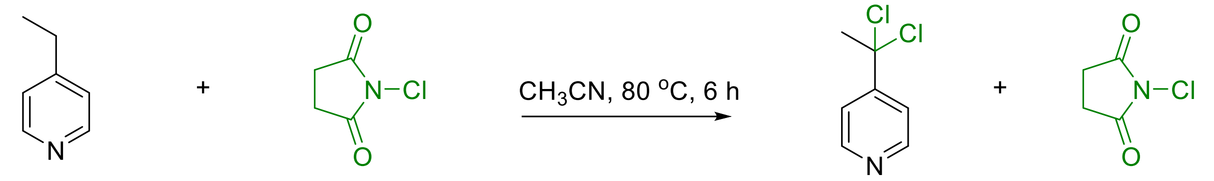
2.2.2 Unsuccessful Examples



Scheme S1. Unsuccessful examples.

2.3 5 mmol-Scale Synthesis

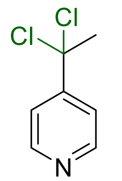
2.3.1 Synthetic Procedure



1a (5 mmol) **2** **4a**, 63% **2'**, 86%

To an oven-dried 100mL round-bottom flask equipped with a magnetic stir bar, NCS (2.003 g, 15 mmol) was weighed, and ventilated with argon three times. Then **1a** (535.8 mg, 5 mmol) and CH_3CN (12.5 mL) were added under argon. The resulting mixture was stirred at 80 °C for 6 h. After cooling to room temperature, the reaction mixture was concentrated under reduced pressure, and diethyl ether (30 mL) was added to the crude product. The obtained suspension was filtered and the soild was collected and drained to afford succinimide **2'** in 86% yield (1.272 g). The diethyl ether organic phase was washed with water (30×3 mL) and dried over anhydrous sodium sulfate. Removal of the solvent furnished pure dichlorination product **4a** (551.2 mg, 63%) as yellow oil.

2.3.2 Characterization data of 4-(1,1-dichloroethyl)pyridine (**4a**)



4a
$C_7H_7Cl_2N$

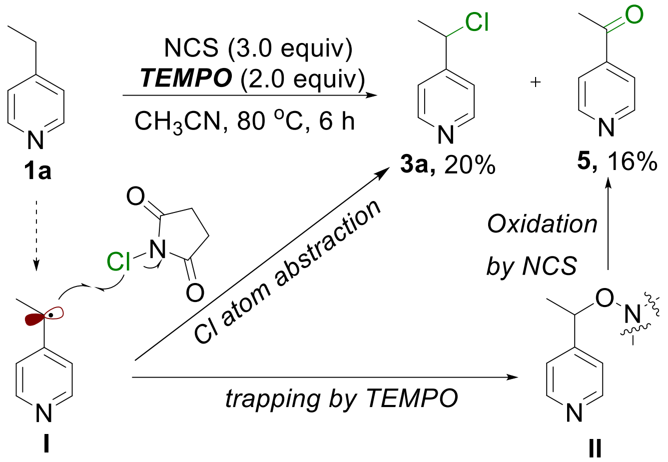
^{1}H NMR (400 MHz, $CDCl_3$):δ 8.68 (d, *J* = 5.2 Hz, 2H), 7.68 – 7.51 (m, 2H), 2.50 (s, 3H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 152.4, 150.4, 120.0, 85.8, 38.6 ppm. **IR** (film): 3044, 2929, 1590, 1406, 1229, 1065, 1051, 821, 743, 682, 625 cm^{-1}. **HRMS** (ESI): calculated for $C_7H_8Cl_2N^+$ $[M+H]^+$ 176.0028; found 176.0026.

2.4 Experimental Studies on the Reaction Mechanism

2.4.1 Radical trapping experiment

(a) Radical trapping experiment by TEMPO

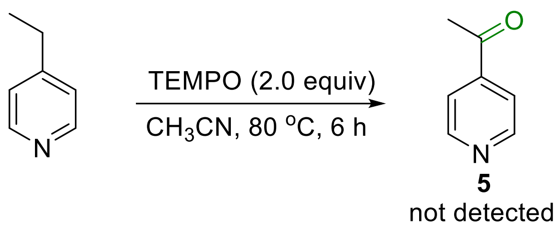
Experimental procedure: To an oven-dried 10mL Schlenk tube equipped with a magnetic stir bar, NCS (80.2 mg, 0.6 mmol, 3.0 equiv.) and TEMPO (62.5 mg, 0.4 mmol, 2.0 equiv.) was weighed, and ventilated with argon three times. Then **1a** (21.4 mg, 0.2 mmol, 1.0 equiv.) and CH_3CN (0.5 mL) were added under argon. The resulting mixture was stirred at 80 °C for 6 h. After cooling to room temperature, the reaction mixture was concentrated in vacuo, and purified by preparative TLC on silica gel (PE/EA = 5:1)to only afford the monochlorination product **3a** in 20% yield and benzyl oxidation product ketone **5** in 16% yield.

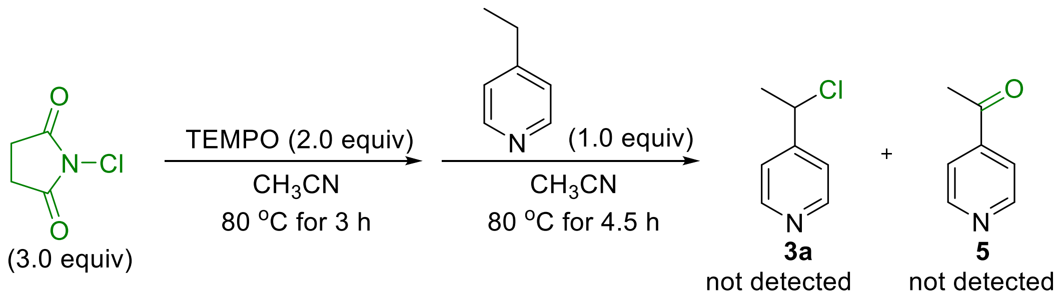


Scheme S2. Radical trapping experiment by TEMPO.

When 2.0 equivalents of 2,2,6,6-tetramethyl-piperidinyl-1-oxide (TEMPO) was subjected to the standard reaction of 4-ethyl pyridine **1a**, the double C–Cl bonds formation reaction was completely suppressed, and instead, the benzylic C–H oxidation product 1-(pyridin-4-yl)ethan-1-one **5** and monochlorinated product **3a** were isolated in 16% and 20% yields, respectively. The formation of ketone **5** and monochlorinated product **3a** suggests the formation of benzylic radical specie **I**, which further undergoes radical trapping reaction with TEMPO and oxidation reaction with NCS to generate the ketone product **5** (**I** → **II** → **5**),[3] or proceeds through halogen atom transfer reaction (XAT)[4] with NCS to deliver the chlorinated product **3a** (**I** → **3a**).

(b) Other control experiments





The reaction between TEMPO and 4-ethyl pyridine in the absence of NCS was performed, but it did not produce oxidative product 1-(pyridine-4-yl)ethan-1-one. NMR analysis on the reaction mixture showed that most of the 4-ethyl pyridine was retained in the presence of TEMPO. Previous studies by Song et al[5] have shown that the reaction of NCS and TEMPO would produce oxoammonium species, which is a potent ionic electrophile. However, when we subjected 4-ethyl pyridine to the premixed solution of TEMPO and NCS (stirred at 80 ºC for 3 hours), no ketone product or monochlorination product was detected. This result suggests that the ketone formation may be through a radical mechanism involving the trapping of benzylic radical with TEMPO rather than through the ionic mechanism via the electrophilic oxidation by the oxoammonium species generated from the reaction of TEMPO and NCS.

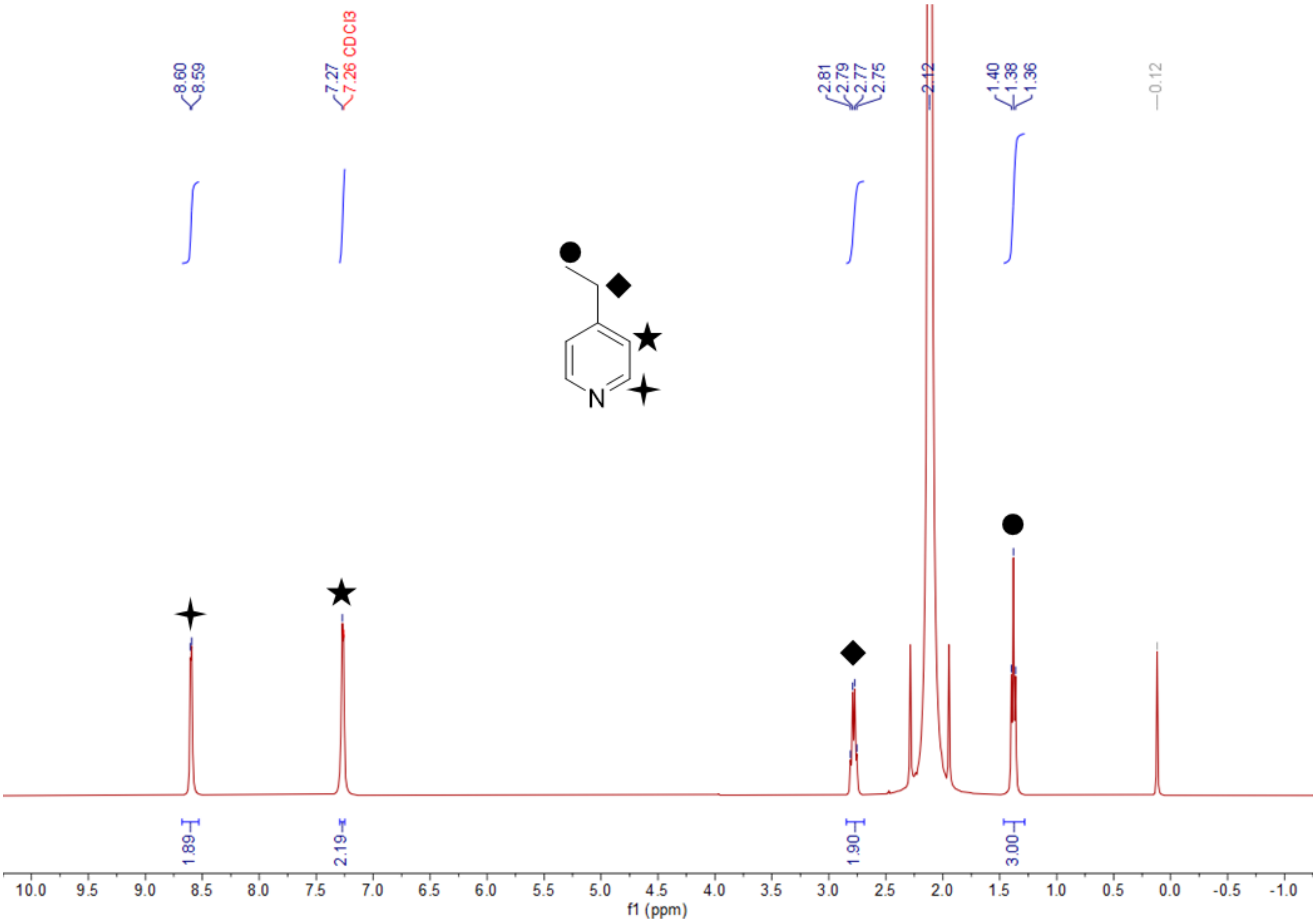


Figure S1. ^{1}H NMR spectroscopy of reaction mixture of 4-ethyl pyridine **1a** and TEMPO.

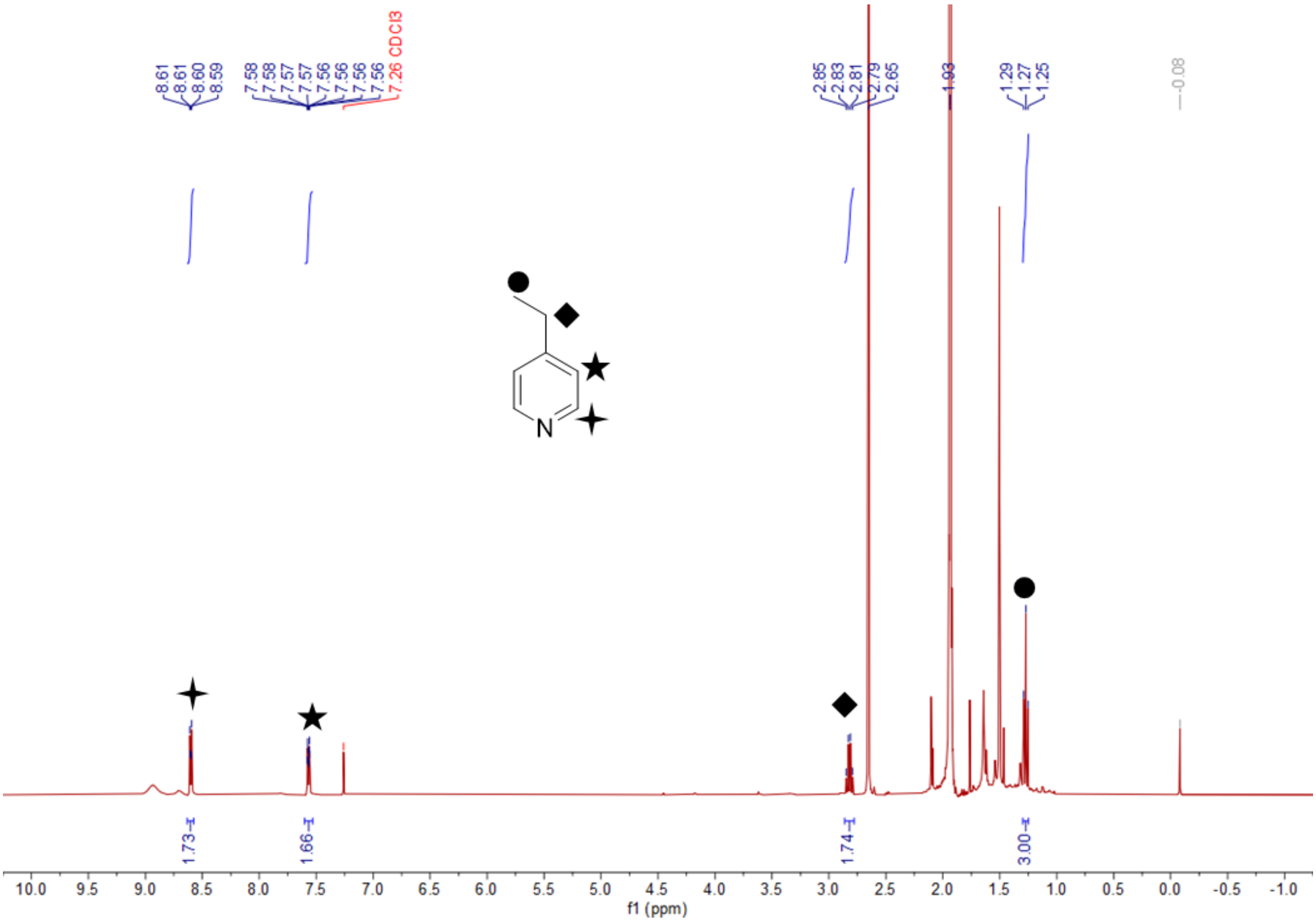
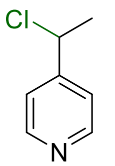


Figure S2. ^{1}H NMR spectroscopy of reaction mixture of 4-ethyl pyridine **1a** and the premixed solution of TEMPO and NCS.

2.4.2 Characterization data of 4-(1-chloroethyl)pyridine (**3a**)

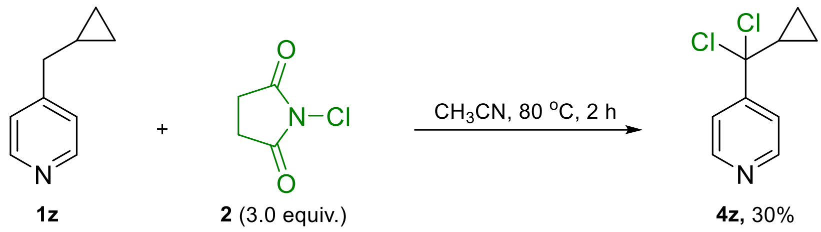


3a

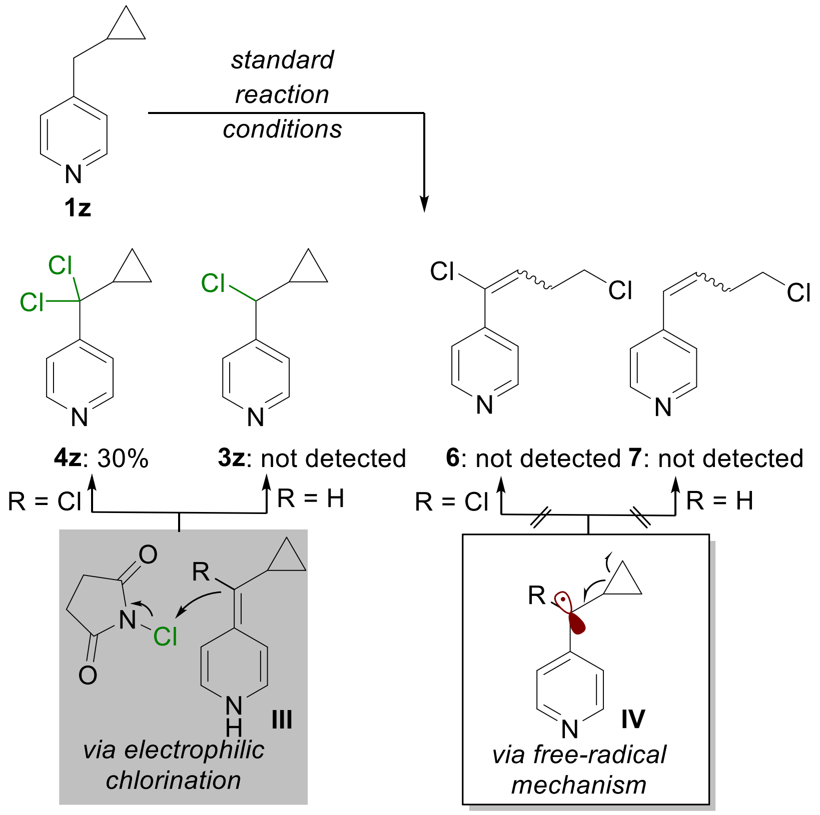
C_7H_8ClN

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.69 – 8.55 (m, 2H), 7.37 – 7.30 (m, 2H), 5.00 (q, *J* = 6.8 Hz, 1H), 1.83 (d, *J* = 6.8 Hz, 3H) ppm. **$^{13}C\{^{1}H\}$ NMR** (101 MHz, $CDCl_3$): δ 151.4, 150.3, 121.5, 56.6, 26.2 ppm. **IR** (film): 2928, 1599, 1415, 908, 822, 730 cm^{-1}. **HRMS** (ESI): calculated for $C_7H_9ClN^+[M+H]^+$ 142.0418; found 142.0414.

2.4.3 Radical clock experiment



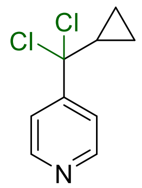
Experimental procedure: To an oven-dried 10mL Schlenk tube equipped with a magnetic stir bar, NCS (80.2 mg, 0.6 mmol, 3.0 equiv.) was weighed, and ventilated with argon three times. Then **1z** (26.6 mg, 0.2 mmol, 1.0 equiv.) and CH_3CN (0.5 mL) were added under argon. The resulting mixture was stirred at 80 °C for 2 h. After cooling to the room temperature, the reaction mixture was concentrated in vacuo, and purified by column chromatography (silica gel, PE/Acetone = 100:1→50:1) to afford the dichlorinated product **4z** in 30% yield.



Scheme S3. Radical clock experiment.

The radical clock experiment with 4-(cyclopropylmethyl)-pyridine **1z** did not give a radical ring-opening product **6** or **7** (via **IV** → **6** or **7**), but only afforded the 1,1-dichlorinated product **4z** in 30% yield The formation of the normally dichlorinated product would be due to the generation of an electron-rich 4-(cyclopropylmethylene)-1,4-dihydropyridine intermediate **III**, which subsequently undergoes electrophilic chlorination reaction followed by rearomatization reaction leading to the formation of **4z**.

2.4.4 Characterization data of 4-(dichloro(cyclopropyl)methyl)pyridine (**4a**)

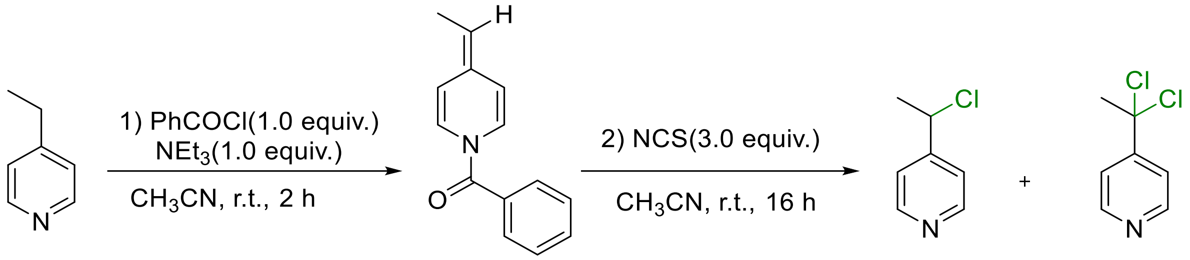


4z

$C_9H_9Cl_2N$

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.70 – 8.63 (m, 2H), 7.73 – 7.62 (m, 2H), 1.89 – 1.82 (m, 1H), 1.00 – 0.95 (m, 2H), 0.90 – 0.84 (m, 2H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 152.5, 150.1, 120.9, 92.1, 29.8, 27.1, 5.8 ppm. **IR** (film): 3016, 2926, 1594, 1404, 1224, 754, 633 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_{10}Cl_2N^+$ $[M+H]^+$ 202.0185; found 202.0183.

2.4.5 Experimental verification of the involvement of dihydropyridine intermediate



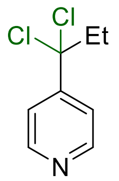
1a **8** **3a**, trace **4a**, 48%

Experimental procedure: In an argon-filled glove box, an oven-dried 10 mL Schlenk tube was charged **1a** (21.4 mg, 0.2 mmol, 1.0 equiv.), benzoyl chloride (28.1 mg, 0.2 mmol, 1.0 equiv.), NEt_3 (20.2 mg, 0.2 mmol, 1.0 equiv.) and CH_3CN (0.5 mL). The resulting mixture was first pre-stirred for two hours at room temperature and then NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), which was dissolved in 0.5 mL CH_3CN) was added to the reaction solution. The resulting mixture was stirred at room temperature for another 16 h and then concentrated in vacuo, further purification by chromatography on silica gel (PE/EA = 50:1→5:1) affords dichlorination product **4a** as the major product in 48% yield. This control experiment indicates that this polychlorination process may involve the generation of methylene-1,4-dihydropyridine intermediate.[6]

Therefore, from these control experiments, both the radical and ionic pathways are possible in the benzylic polychlorination.

3. Spectroscopic Characterization Data of the Polychlorination Products

3.1 4-(1,1-dichloropropyl)pyridine (**4b**)

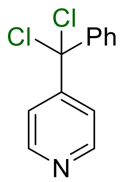


4b

$C_8H_9Cl_2N$

Prepared according to general procedure C from **1b** (24.2 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4b** as yellow oil (30.5 mg, 80% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.75 – 8.58 (m, 2H), 7.68 – 7.50 (m, 2H), 2.54 (q, *J* = 7.1 Hz, 2H), 1.08 (t, *J* = 7.2 Hz, 3H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 151.3, 150.3, 120.8, 91.8, 43.5, 10.2 ppm. **IR** (film): 3044, 2981, 2940, 1590, 1405, 1325, 1223, 1073, 809, 633, 559 cm^{-1}. **HRMS** (ESI): calculated for $C_8H_{10}Cl_2N^+$ $[M+H]^+$ 190.0185; found 190.0183.

3.2 4-(dichloro(phenyl)methyl)pyridine (**4c**)

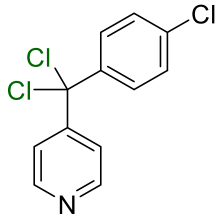


4c

$C_{12}H_9Cl_2N$

Prepared according to general procedure C from **1c** (33.8 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4c** as yellow oil (37.7 mg, 79% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.61 – 8.52 (m, 2H), 7.54 – 7.47 (m, 2H), 7.45 – 7.40 (m, 2H), 7.36 – 7.25 (m, 3H) ppm.**^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 152.4, 150.2, 142.6, 129.6, 128.5, 127.2, 121.6, 89.6 ppm. **IR** (film): 3038, 1588, 1446, 1410, 1326, 1167, 787, 692, 652, 617 cm^{-1}. **HRMS** (ESI): calculated for $C_{12}H_{10}Cl_2N^+$ $[M+H]^+$ 238.0185; found 238.0182.

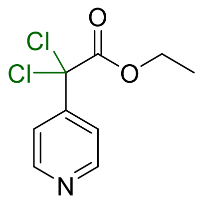
3.3 4-(dichloro(4-chlorophenyl)methyl)pyridine (**4d**)



4d
$C_{12}H_8Cl_3N$

Prepared according to general procedure C from **1d** (40.7 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4d** as yellow oil (43.9 mg, 81% yield).**^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.73 – 8.55 (m, 2H), 7.53 – 7.46 (m, 4H), 7.38 – 7.32 (m, 2H).**^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 151.9, 150.3, 141.2, 135.9, 128.7, 121.5, 88.8 ppm. **IR** (film): 3043, 1589, 1488, 1411, 1093, 1013, 806, 770, 730, 624 cm^{-1}. **HRMS** (ESI): calculated for $C_{12}H_9Cl_3N^+$ $[M+H]^+$ 271.9795; found 271.9792.

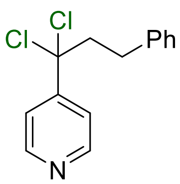
3.4 Ethyl 2,2-dichloro-2-(pyridin-4-yl)acetate (**4e**)



4e
$C_9H_9Cl_2NO_2$

Prepared according to general procedure C from **1e** (33.0 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4e** as yellow oil (37.3 mg, 80% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.75 – 8.67 (m, 2H), 7.64 – 7.58 (m, 2H), 4.32 (q, *J* = 7.1 Hz, 2H), 1.29 (t, *J* = 7.1 Hz, 3H).**^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 165.0, 150.3, 147.3, 121.0, 82.7, 64.9, 13.8 ppm. **IR** (film): 2983, 1746, 1592, 1410, 1231, 1017, 758, 609 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_{10}Cl_2NO_2^+$ $[M+H]^+$ 234.0083; found 234.0081.

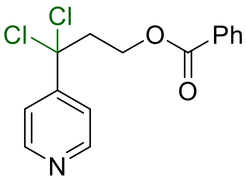
3.5 4-(1,1-dichloro-3-phenylpropyl)pyridine (**4f**)



4f
$C_{14}H_{13}Cl_2N$

Prepared according to general procedure C from **1f** (39.5 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4f** as yellow oil (38.8 mg, 73% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.74 – 8.59 (m, 2H), 7.69 – 7.60 (m, 2H), 7.32 – 7.26 (m, 2H), 7.24 – 7.18 (m, 1H), 7.18 – 7.13 (m, 2H), 2.91 – 2.84 (m, 2H), 2.83 – 2.76 (m, 2H). **$^{13}C\{^1H\}$ NMR** (101 MHz, $CDCl_3$): δ 151.2, 150.4, 139.6, 128.8, 128.5, 126.6, 120.7, 90.2, 51.8, 32.1 ppm. **IR** (film): 3062, 3027, 2934, 1591, 1497, 1405, 1009, 752, 698 cm^{-1}. **HRMS** (ESI): calculated for $C_{14}H_{14}Cl_2N^+$ $[M+H]^+$ 266.0498; found 266.0498.

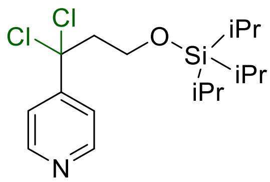
3.6 3,3-dichloro-3-(pyridin-4-yl)propyl benzoate (**4g**)



4g
$C_{15}H_{13}Cl_2NO_2$

Prepared according to general procedure C from **1g** (48.3 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4g** as yellow solid (42.6 mg, 69% yield). mp 65 – 66 °C. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.70 – 8.63 (m, 2H), 7.84 – 7.78 (m, 2H), 7.68 – 7.63 (m, 2H), 7.58 – 7.51 (m, 1H), 7.43 – 7.36 (m, 2H), 4.58 (t, *J* = 6.6 Hz, 2H), 3.08 (t, *J* = 6.6 Hz, 2H). **$^{13}C\{^1H\}$ NMR** (101 MHz, $CDCl_3$): δ 166.3, 150.9, 150.5, 133.4, 129.6, 129.6, 128.5, 120.6, 88.0, 61.2, 48.4 ppm. **IR** (film): 3043, 1716, 1590, 1407, 1267, 1111, 1026, 707, 632 cm^{-1}. **HRMS** (ESI): calculated for $C_{15}H_{14}Cl_2NO_2^+$ $[M+H]^+$ 310.0396; found 310.0395.

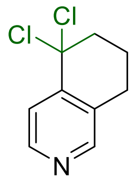
3.7 4-(1,1-dichloro-3-((triisopropylsilyl)oxy)propyl)pyridine (**4h**)



4h
$C_{17}H_{29}Cl_2NOSi$

Prepared according to General Procedure C from **1h** (58.7 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4h** as yellow oil (46.3 mg, 64% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.67 (d, *J* = 6.1 Hz, 2H), 7.65 – 7.61 (m, 2H), 3.94 (t, *J* = 7.0 Hz, 2H), 2.85 (t, *J* = 7.0 Hz, 2H), 1.03 – 0.98 (m, 21H) ppm. **$^{13}C\{^1H\}$ NMR** (101 MHz, $CDCl_3$) δ 151.5, 150.3, 120.6, 88.3, 60.3, 52.1, 18.1, 12.0 ppm. **IR** (film): 2942, 2889, 2865, 1591, 1462, 1407, 1106, 1069, 881, 781, 680, 632 cm^{-1}. **HRMS** (ESI): calculated for $C_{17}H_{30}Cl_2NOSi^+$ $[M+H]^+$ 362.1468; found 362.1472.

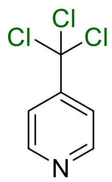
3.8 5,5-dichloro-5,6,7,8-tetrahydroisoquinoline (**4i**)



4i
$C_9H_9Cl_2N$

Prepared according to general procedure C from **1i** (26.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4i** as yellow oil (26.4 mg, 65% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.50 (d, *J* = 5.3 Hz, 1H), 8.39 (s, 1H), 7.73 (d, *J* = 5.4 Hz, 1H), 2.85 (t, *J* = 6.4 Hz, 2H), 2.82 – 2.76 (m, 2H), 2.16 – 2.04 (m, 2H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 151.0, 148.2, 147.3, 129.1, 122.3, 85.6, 45.7, 25.8, 20.5. **IR** (film): 3022, 2942, 2873, 1588, 1442, 1409, 1230, 1085, 844, 783, 642 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_{10}Cl_2N^+$ $[M+H]^+$ 202.0185; found 202.0185.

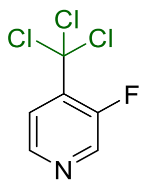
3.9 4-(trichloromethyl)pyridine (**4j**)



4j
$C_6H_4Cl_3N$

Prepared according to general procedure C from **1j** (18.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4j** as yellow oil (31.4 mg, 81% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.84 – 8.67 (m, 2H), 7.89 – 7.70 (m, 2H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 151.9, 150.7, 119.5, 95.6 ppm. **IR** (film): 3045, 1582, 1409, 1192, 807, 751, 722 cm^{-1}. **HRMS** (ESI): calculated for $C_6H_5Cl_3N^+$ $[M+H]^+$ 195.9482; found 195.9477.

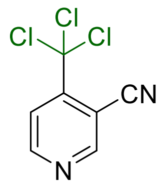
3.10 3-fluoro-4-(trichloromethyl)pyridine (**4k**)



4k
$C_6H_3Cl_3FN$

Prepared according to general procedure C from **1k** (22.2 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4k** as yellow oil (25.8 mg, 60% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.60 (d, *J* = 3.2 Hz, 1H), 8.54 (d, *J* = 5.2 Hz, 1H), 7.81 (dd, *J* = 6.9, 5.1 Hz, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 155.2 (d, *J* = 269.1 Hz), 146.1 (d, *J* = 6.3 Hz), 140.4 (d, *J* = 25.0 Hz), 138.2, 119.9, 90.8 ppm. **^{19}F{^{1}H} NMR** (376 MHz, $CDCl_3$) δ -119.96 ppm. **IR** (film): 3052, 1560, 1411, 1289, 1220, 1200, 1068, 802, 776, 716, 629, 559 cm^{-1}. **HRMS** (ESI): calculated for $C_6H_4Cl_3FN^+$ $[M+H]^+$ 213.9388; found 213.9388.

3.11 4-(trichloromethyl)nicotinonitrile (**4l**)

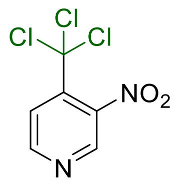


4l

$C_7H_3Cl_3N_2$

Prepared according to general procedure C from **1l** (23.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 10:1) to afford **4l** as white solid (37.5 mg, 85% yield). m.p. 81 – 82 °C. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 9.05 (s, 1H), 8.94 (d, *J* = 5.4 Hz, 1H), 8.03 (d, *J* = 5.4 Hz, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 155.7, 154.1, 152.4, 119.2, 114.7, 107.5, 92.6 ppm. **IR** (film): 3030, 1575, 1467, 1394, 1196, 1152, 906, 758, 762, 724, 698, 647, 623 cm^{-1}. **HRMS** (ESI): calculated for $C_7H_4Cl_3N_2^+$ $[M+H]^+$ 220.9435; found 220.9430.

3.12 3-nitro-4-(trichloromethyl)pyridine (**4m**)

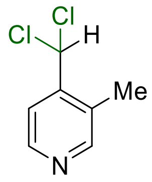


4m

$C_6H_3Cl_3N_2O_2$

Prepared according to general procedure C from **1m** (27.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 10:1) to afford **4m** as yellow solid (40.0 mg, 83% yield). m.p. 79 – 80 °C. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.93 (d, *J* = 5.4 Hz, 1H), 8.90 (s, 1H), 8.10 (d, *J* = 5.4 Hz, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 153.4, 146.2, 143.4, 142.1, 121.2, 91.2 ppm. **IR** (film): 1588, 1533, 1358, 1208, 844, 782, 737, 632 cm^{-1}. **HRMS** (ESI): calculated for $C_6H_4Cl_3N_2O_2^+$ $[M+H]^+$ 240.9333; found 240.9335

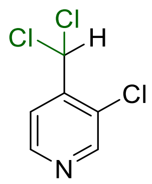
3.13 4-(dichloromethyl)-3-methylpyridine (**4n**)



4n
$C_7H_7Cl_2N$

Prepared according to general procedure C from **1n** (21.4 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 10:1) to afford **4n** as yellow oil (24.9 mg, 71% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.56 (d, *J* = 5.2 Hz, 1H), 8.46 (s, 1H), 7.63 (d, *J* = 5.1 Hz, 1H), 6.81 (s, 1H), 2.43 (s, 3H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 152.0, 148.8, 145.9, 128.9, 120.5, 67.7, 15.7 ppm. **IR** (film): 2981, 1594, 1403, 1224, 905, 764, 728, 648 cm^{-1}. **HRMS** (ESI): calculated for $C_7H_8Cl_2N^+$ $[M+H]^+$ 176.0028; found 176.0029.

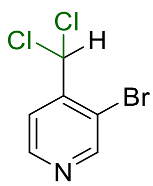
3.14 3-chloro-4-(dichloromethyl)pyridine (**4o**)



4o
$C_6H_4Cl_3N$

Prepared according to general procedure C from **1o** (24.5 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4o** as yellow oil (22.5 mg, 57% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.67 – 8.58 (m, 2H), 7.81 (d, *J* = 5.1 Hz, 1H), 7.02 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 150.1, 149.1, 145.3, 128.3, 122.3, 66.1 ppm. **IR** (film): 3047, 1580, 1397, 1219, 1096, 1035, 769, 717, 692, 603 cm^{-1}. **HRMS** (ESI): calculated for $C_6H_5Cl_3N^+$ $[M+H]^+$ 195.9482; found 195.9482.

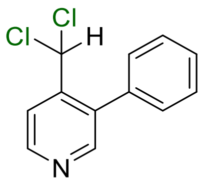
3.15 3-bromo-4-(dichloromethyl)pyridine (**4p**)



4p
$C_6H_4BrCl_2N$

Prepared according to general procedure C from **1p** (34.4 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4p** as yellow oil (31.9 mg, 66% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.75 (s, 1H), 8.64 (d, *J* = 5.1 Hz, 1H), 7.82 (d, *J* = 5.1 Hz, 1H), 6.98 (s, 1H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 152.6, 149.6, 147.0, 122.8, 118.7, 68.7 ppm. **IR** (film): 3044, 1576, 1396, 1217, 1087, 1018, 764, 703, 685, 595 cm^{-1}. **HRMS** (ESI): calculated for $C_6H_5BrC_{l2}N^+$ $[M+H]^+$ 239.8977; found 239.8973.

3.16 4-(dichloromethyl)-3-phenylpyridine (**4q**)

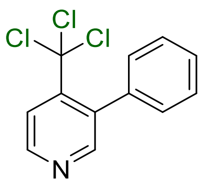


4q

$C_{12}H_9Cl_2N$

Prepared according to general procedure C from **1q** (33.8 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 °C. Purification by preparative TLC (PE/EA = 20:1) to afford **4q** as yellow oil (27.3 mg, 67% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.74 (d, *J* = 5.3 Hz, 1H), 8.55 (s, 1H), 7.87 (d, *J* = 5.3 Hz, 1H), 7.56 – 7.45 (m, 3H), 7.42 – 7.34 (m, 2H), 6.65 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 150.9, 149.9, 145.9, 135.2, 133.4, 129.4, 129.1, 128.9, 121.5, 67.4 ppm. **IR** (film): 3027, 1587, 1444, 1398, 1219, 1006, 852, 758, 697, 587 cm^{-1}. **HRMS** (ESI): calculated for $C_{12}H_{10}Cl_2N^+$ $[M+H]^+$ 238.0185; found 238.0185.

3.17 3-phenyl-4-(trichloromethyl)pyridine (**4q'**)

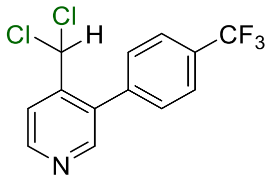


4q'

$C_{12}H_8Cl_3N$

Prepared according to general procedure C from **1q'** (33.8 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4q'** as yellow oil (31.3 mg, 57% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.74 (d, *J* = 5.5 Hz, 1H), 8.51 (s, 1H), 8.04 (d, *J* = 5.5 Hz, 1H), 7.39 – 7.44 (m, 5H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 154.0, 149.6, 145.0, 137.5, 135.0, 130.5, 128.3, 127.8, 119.7, 95.5 ppm. **IR** (film): 3030, 1575, 1467, 1394, 1196, 905, 786, 725, 699, 647 cm^{-1}. **HRMS** (ESI): calculated for $C_{12}H_9Cl_3N^+$ $[M+H]^+$ 271.9795; found 271.9798.

3.18 4-(dichloromethyl)-3-(4-(trifluoromethyl)phenyl)pyridine (**4r**)

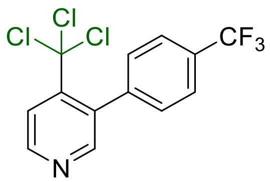


4r

$C_{13}H_8Cl_2F_3N$

Prepared according to general procedure C from **1r** (47.4 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 °C. Purification by preparative TLC (PE/EA = 20:1) to afford **4r** as yellow oil (23.4 mg, 38% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.79 (d, *J* = 5.3 Hz, 1H), 8.54 (s, 1H), 7.90 (d, *J* = 5.3 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 2H), 7.53 (d, *J* = 7.9 Hz, 2H), 6.55 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 150.7, 150.6, 146.0, 138.9, 132.1, 131.3 (q, *J* = 33.1 Hz), 129.9, 126.2 (q, *J* = 3.7 Hz), 124.0 (q, *J* = 272.3 Hz), 121.6, 67.0 ppm. **^{19}F{^{1}H} NMR** (376 MHz, $CDCl_3$) δ -62.76 ppm. **IR** (film): 3043, 1620, 1320, 1165, 1124, 1066, 856, 783, 707, 598 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_9Cl_2F_3N^+$ [M+H]$^+$ 306.0059; found 306.0057.

3.19 4-(trichloromethyl)-3-(4-(trifluoromethyl)phenyl)pyridine (**4r'**)

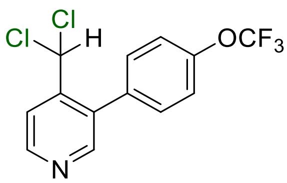


4r'

$C_{13}H_7Cl_3F_3N$

Prepared according to general procedure C from **1r'** (47.4 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4r'** as yellow oil (32.1 mg, 47% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.79 (d, *J* = 5.5 Hz, 1H), 8.48 (s, 1H), 8.07 (d, *J* = 5.5 Hz, 1H), 7.69 (d, *J* = 8.1 Hz, 2H), 7.55 (d, *J* = 8.1 Hz, 2H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 153.5, 150.3, 148.1, 141.3, 133.6, 131.0, 130.4, 124.9 (q, *J* = 3.8 Hz), 124.1 (q, *J* = 272.4 Hz), 119.8, 95.2 ppm. **^{19}F{^{1}H} NMR** (376 MHz, $CDCl_3$) δ -62.61 ppm. **IR** (film): 2927, 1618, 1321, 1165, 1124, 1067, 841, 785, 727, 634 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_8Cl_3F_3N^+$ [M+H]$^+$ 339.9669; found 339.9666.

3.20 4-(dichloromethyl)-3-(4-(trifluoromethoxy)phenyl)pyridine (**4s**)

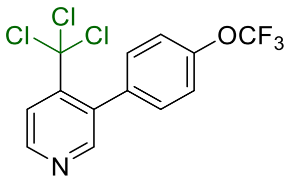


4s

$C_{13}H_8Cl_2F_3NO$

Prepared according to general procedure C from **1s** (50.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 ºC. Purification by preparative TLC (PE/EA = 20:1) to afford **4s** as yellow oil (23.1 mg, 36% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.77 (d, *J* = 5.4 Hz, 1H), 8.53 (s, 1H), 7.89 (d, *J* = 5.3 Hz, 1H), 7.46 – 7.41 (m, 2H), 7.41 – 7.35 (m, 2H), 6.59 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 150.8, 150.4, 149.8, 146.0, 133.8, 132.1, 131.0, 121.9, 121.6, 120.6 (q, *J* = 258.2 Hz), 67.1 ppm. **^{19}F{^{1}H} NMR** (376 MHz, $CDCl_3$) δ -57.74 ppm. **IR** (film): 2927, 1511, 1397, 1254, 1212, 1165, 1003, 858, 784, 708, 596 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_9Cl_2F_3NO^+$ [M+H]$^+$ 322.0008; found 322.0008.

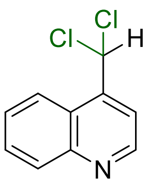
3.21 4-(trichloromethyl)-3-(4-(trifluoromethoxy)phenyl)pyridine (**4s’**)



4s'
$C_{13}H_7Cl_3F_3NO$

Prepared according to general procedure C from **1s’** (50.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 20:1) to afford **4s’** as yellow oil (30.9 mg, 43% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.77 (d, *J* = 5.3 Hz, 1H), 8.50 (s, 1H), 8.06 (d, *J* = 5.5 Hz, 1H), 7.49 – 7.40 (m, 2H), 7.32 – 7.24 (m, 2H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 153.8, 150.1, 149.3 (q, *J* = 1.8 Hz), 148.2, 136.0, 133.7, 132.1, 120.6 (q, *J* = 257.7 Hz), 120.2, 119.8, 95.3 ppm. **^{19}F{^{1}H} NMR** (376 MHz, $CDCl_3$) δ -57.75 ppm. **IR** (film): 2928, 1576, 1471, 1251, 1208, 1161, 1003, 799, 785, 727, 629 cm^{-1}. **HRMS** (ESI): calculated for $C_{13}H_8Cl_3F_3NO^+$ [M+H]$^+$ 355.9618; found 355.9617.

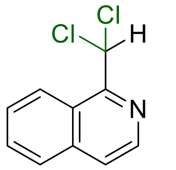
3.22 4-(dichloromethyl)quinoline (**4t**)



4t
$C_{10}H_7Cl_2N$

Prepared according to general procedure C from **1t** (28.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 ºC. Purification by preparative TLC (PE/EA = 50:1) to afford **4t** as colorless oil (19.3 mg, 46% yield). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 9.00 (d, *J* = 4.5 Hz, 1H), 8.24 – 8.16 (m, 2H), 7.83 – 7.74 (m, 2H), 7.70 – 7.64 (m, 1H), 7.33 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 150.3, 148.9, 143.5, 130.8, 130.0, 127.7, 123.6, 123.0, 118.6, 68.0 ppm. Spectra were consistent with that previously reported.[7] **IR** (film): 2979, 1594, 1507, 1239, 1213, 760, 727, 631, 605 cm^{-1}. **HRMS** (ESI): calculated for $C_{10}H_8Cl_2N^+$ [M+H]$^+$ 212.0028; found 212.0025.

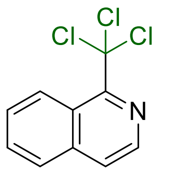
3.23 1-(dichloromethyl)isoquinoline (**4u**)



4u
$C_{10}H_7Cl_2N$

Prepared according to general procedure C from **1u** (28.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 °C. Purification by preparative TLC (PE/EA = 100:1) to afford **4u** as yellow solid (37.7 mg, 89% yield). m.p. 57 – 58 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.65 (d, *J* = 8.2 Hz, 1H), 8.46 (d, *J* = 5.6 Hz, 1H), δ 7.89 (d, *J* = 7.5 Hz, 1H), 7.78 – 7.66 (m, 3H), 7.30 (s, 1H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 155.0, 140.9, 137.5, 130.7, 127.9, 127.9, 125.4, 124.5, 123.3, 71.5 ppm. Spectra were consistent with that previously reported.[8] **IR** (film): 3056, 1625, 1499, 1379, 1347, 896, 749, 650 cm^{-1}. **HRMS** (ESI): calculated for $C_{10}H_8Cl_2N^+$ [M+H]$^+$ 212.0028; found 212.0025.

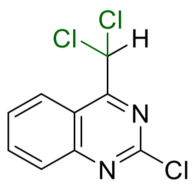
3.24 1-(trichloromethyl)isoquinoline (**4u'**)



4u'
$C_{10}H_6Cl_3N$

Prepared according to general procedure C from **1u'** (28.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (106.8 mg, 0.8 mmol, 4.0 equiv.). Purification by preparative TLC (PE/EA = 50:1) to afford **4u'** as yellow oil (23.3 mg, 47% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.87 (dd, *J* = 8.7, 1.1 Hz, 1H), 8.53 (d, *J* = 5.5 Hz, 1H), 7.94 (dd, *J* = 8.0, 2.0 Hz, 1H), 7.81 – 7.67 (m, 3H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 154.1, 139.1, 138.3, 130.5, 128.1, 127.6, 127.3, 124.5, 123.4, 98.4 ppm. Spectra were consistent with that previously reported.[9] **IR** (film): 3056, 2926, 1584, 1499, 1369, 1329, 896, 815, 801, 759, 652, 642 cm^{-1}. **HRMS** (ESI): calculated for $C_{10}H_7Cl_3N^+$ [M+H]$^+$ 245.9639; found 245.9639.

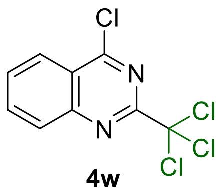
3.25 2-chloro-4-(dichloromethyl)quinazoline (**4v**)



4v
$C_9H_5Cl_3N_2$

Prepared according to general procedure C from **1v** (35.7 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 50:1) to afford **4v** as white solid (46.2 mg, 93% yield). m.p. 125 – 126 °C.**^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.67 – 8.61 (m, 1H), 8.10 – 8.04 (m, 1H), 8.03 – 7.96 (m, 1H), 7.78 – 7.72 (m, 1H), 7.03 (s, 1H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$): δ 166.2, 155.7, 154.0, 135.8, 129.0, 128.6, 125.5, 119.0, 69.3 ppm. **IR** (film): 3065, 2987, 1544, 1304, 1174, 809, 775, 637 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_6Cl_3N_2^+$ $[M+H]^+$ 246.9591; found 246.9589

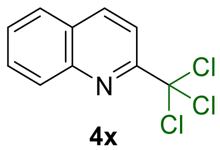
3.26 4-chloro-2-(trichloromethyl)quinazoline (**4w**)



4w
$C_9H_4Cl_4N_2$

Prepared according to general procedure C from **1w** (35.7 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 50:1) to afford **4w** as white solid (37.6 mg, 67% yield). mp 122 – 124 °C.**^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.35 – 8.30 (m, 1H), 8.22 – 8.17 (m, 1H), 8.10 – 8.03 (m, 1H), 7.88 – 7.81 (m, 1H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 164.1, 159.9, 150.2, 136.1, 130.8, 129.8, 126.1, 123.0, 96.0 ppm. Spectra were consistent with that previously reported.[10] **IR** (film): 3068, 1553, 1480, 1346, 1292, 824, 730, 682 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_5Cl_4N_2^+$ $[M+H]^+$ 280.9201; found 280.9201.

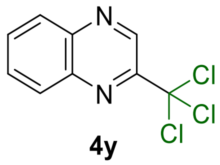
3.27 2-(trichloromethyl)quinoline (**4x**)



4x
$C_{10}H_6Cl_3N$

Prepared according to general procedure C from **1x** (28.6 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 °C. Purification by preparative TLC (PE/EA = 100:1) to afford **4x** as yellow oil (34.4 mg, 81% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.29 (d, *J* = 8.7 Hz, 1H), 8.21 (d, *J* = 8.5 Hz, 1H), 8.07 (d, *J* = 8.8 Hz, 1H), 7.86 (d, *J* = 8.2 Hz, 1H), 7.83 – 7.76 (m, 1H), 7.66 – 7.61 (m, 1H) ppm.**^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 157.4, 145.9, 138.1, 130.7, 130.3, 128.5, 128.0, 127.5, 117.5, 98.2 ppm. Spectra were consistent with that previously reported.[11] **IR** (film): 3062, 1594, 1500, 1425, 1300, 916, 822, 767, 659 cm^{-1}. **HRMS** (ESI): calculated for $C_{10}H_7Cl_3N^+$ $[M+H]^+$ 245.9639; found 245.9633.

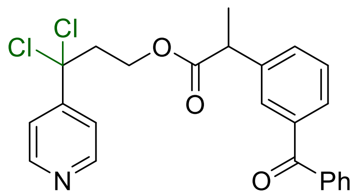
3.28 2-(trichloromethyl)quinoxaline (**4y**)



4y
$C_9H_5Cl_3N_2$

Prepared according to general procedure C from **1y** (28.8 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.), performed at 60 °C. Purification by preparative TLC (PE/EA = 20:1) to afford **4y** as yellow oil (42.3 mg, 85% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.51 (s, 1H), 8.23 – 8.15 (m, 2H), 7.87 (m, 2H) ppm. **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 152.4, 142.3, 142.2, 139.4, 132.0, 131.5, 130.2, 129.2, 96.0 ppm. Spectra were consistent with that previously reported.[12] **IR** (film): 3065, 1490, 1368, 983, 915, 820, 795, 769, 658 cm^{-1}. **HRMS** (ESI): calculated for $C_9H_6Cl_3N_2^+$ [M+H]$^+$ 246.9591; found 246.9591.

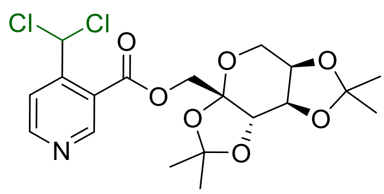
3.29 3,3-dichloro-3-(pyridin-4-yl)propyl 2-(3-benzoylphenyl)propanoate (**4aa**)



4aa
$C_{24}H_{21}Cl_2NO_3$

Prepared according to general procedure C from **1aa** (74.7 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4aa** as yellow oil (64.4 mg, 73% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.67 (d, *J* = 5.3 Hz, 2H), 7.81 – 7.76 (m, 2H), 7.70 – 7.63 (m, 2H), 7.62 – 7.56 (m, 3H), 7.51 – 7.39 (m, 4H), 4.40 – 4.24 (m, 2H), 3.62 (q, *J* = 7.2 Hz, 1H), 2.89 – 2.83 (m, 2H), 1.46 (d, *J* = 7.2 Hz, 3H). **^{13}C{^{1}H} NMR** (101 MHz, $CDCl_3$) δ 196.5, 173.8, 150.8, 150.5, 140.5, 138.1, 137.6, 132.7, 131.5, 130.2, 129.3, 129.2, 128.7, 128.5, 120.5, 87.7, 61.3, 47.9, 45.3, 18.5 ppm. **IR** (film): 2976, 1733, 1655, 1594, 1447, 1407, 1281, 1161, 1072, 816, 719, 642 cm^{-1}. **HRMS** (ESI): calculated for $C_{24}H_{22}Cl_2NO_3^+$ [M+H]$^+$ 422.0971; found 442.0971.

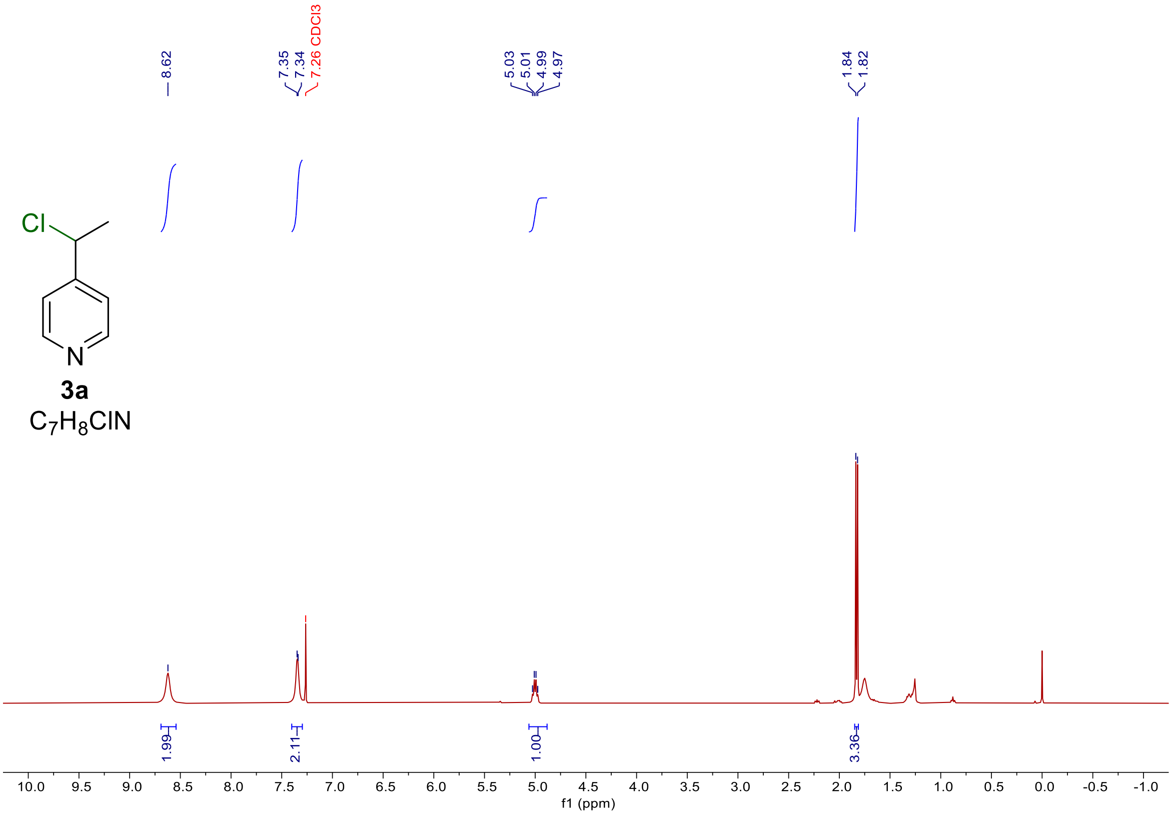
3.30 ((3aS,5aR,8aR,8bS)-2,2,7,7-tetramethyltetrahydro-3aH-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-3a-yl)methyl 4-(dichloromethyl)nicotinate (**4ab)**



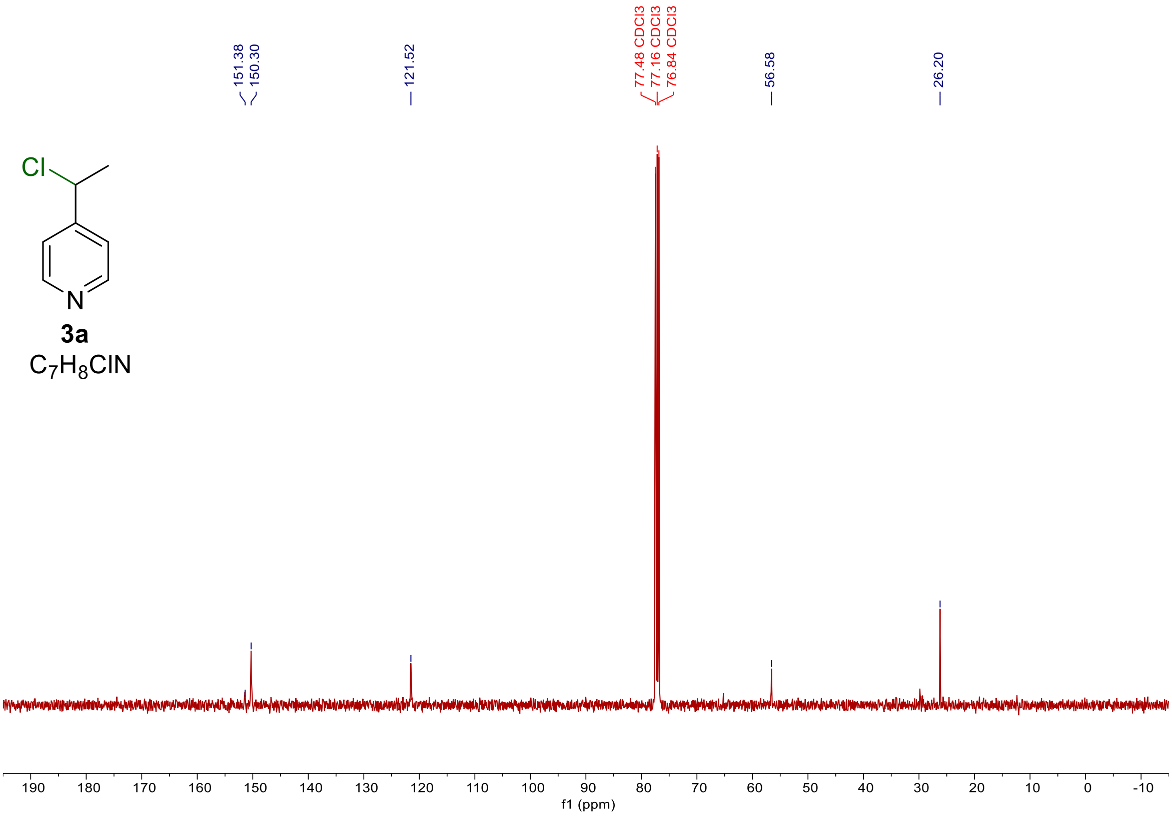
4ab
$C_{19}H_{23}Cl_2NO_7$

Prepared according to general procedure C from **1ab** (75.9 mg, 0.2 mmol, 1.0 equiv.) and NCS (80.2 mg, 0.6 mmol, 3.0 equiv.). Purification by preparative TLC (PE/EA = 5:1) to afford **4ab** as yellow oil (47.1 mg, 53% yield). ^{1}**H NMR** (400 MHz, $CDCl_3$): δ 9.23 (s, 1H), 8.88 (d, *J* = 5.3 Hz, 1H), 7.99 (d, *J* = 5.3 Hz, 1H), 7.95 (s, 1H), 4.74 (d, *J* = 11.7 Hz, 1H), 4.64 (dd, *J* = 7.9, 2.6 Hz, 1H), 4.43 (d, *J* = 2.7 Hz, 1H), 4.38 (d, *J* = 11.7 Hz, 1H), 4.26 (dd, *J* = 7.9, 1.8 Hz, 1H), 3.95 (dd, *J* = 13.0, 2.0 Hz, 1H), 3.84 – 3.78 (m, 1H), 1.56 (s, 3H), 1.40 (s, 3H), 1.36 (s, 3H), 1.34 (s, 3H).^{13}**C{^{1}H} NMR** (101 MHz, $CDCl_3$):δ 164.4, 154.3, 151.6, 149.9, 122.4, 121.2, 109.4, 109.1, 101.5, 71.1, 70.8, 70.2, 67.0, 66.1, 61.6, 26.5, 25.9, 25.5, 24.1 ppm. **IR** (film): 2990, 2937, 1727, 1587, 1375, 1283, 1107, 1069, 889, 734 cm^{-1}. **HRMS** (ESI): calculated for $C_{19}H_{24}Cl_2NO_7^+$ $[M+H]^+$ 448.0924; found 448.0914.

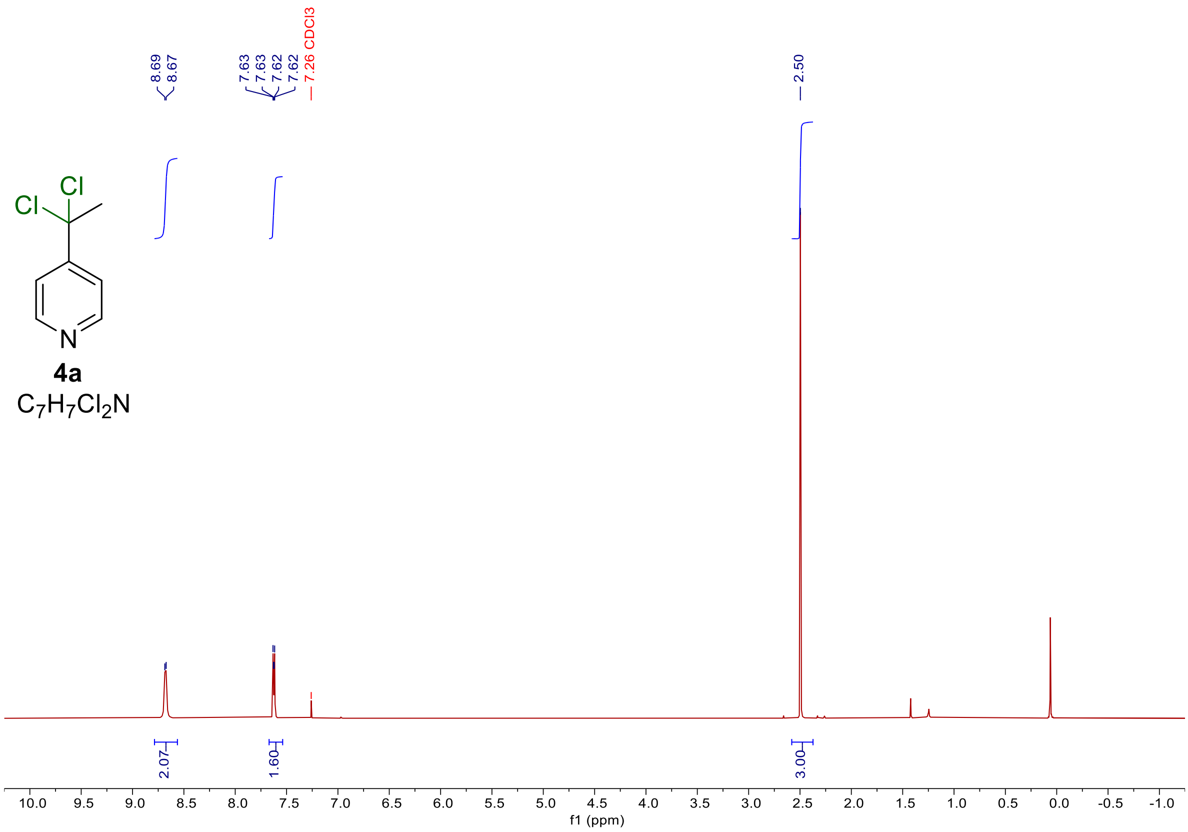
4. NMR Spectrum



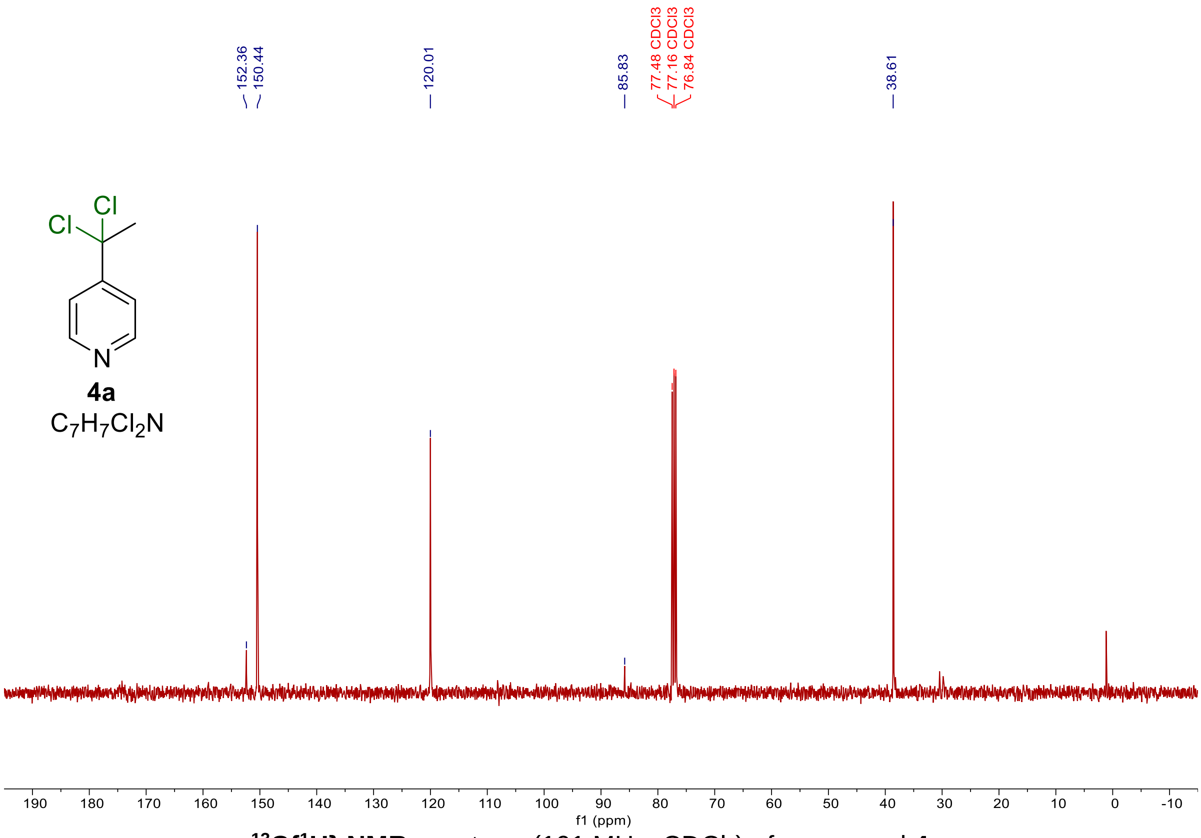
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **3a**.



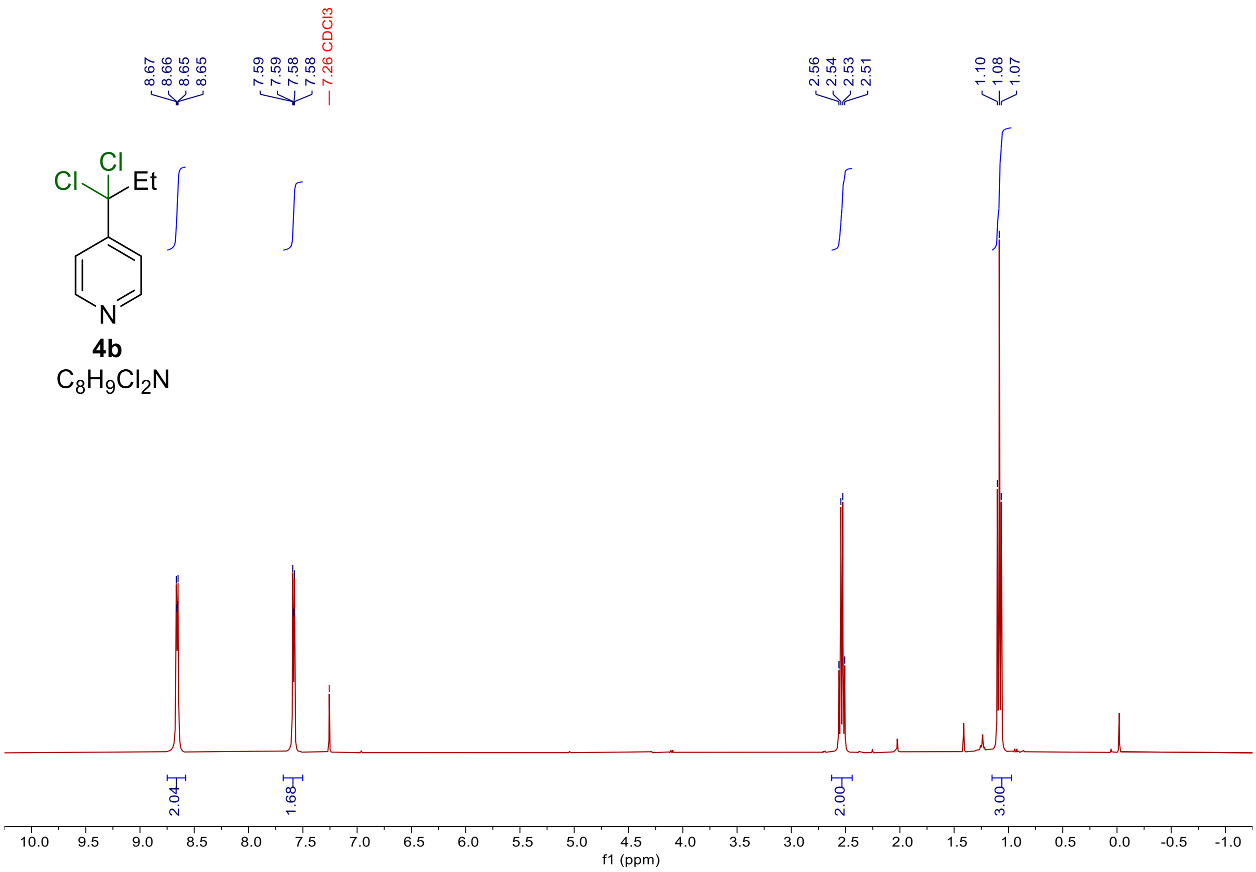
$^{13}C\{^1H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **3a**.



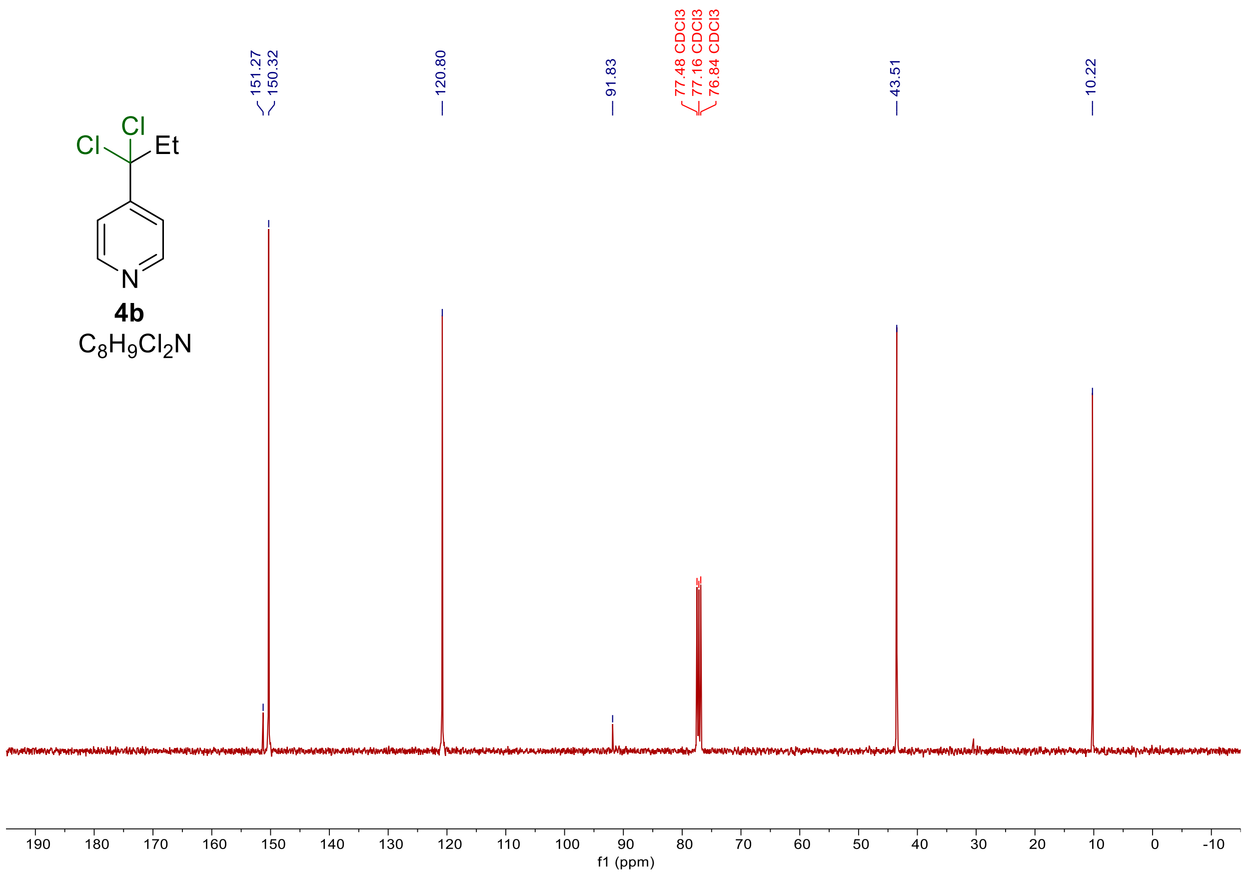
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4a.**



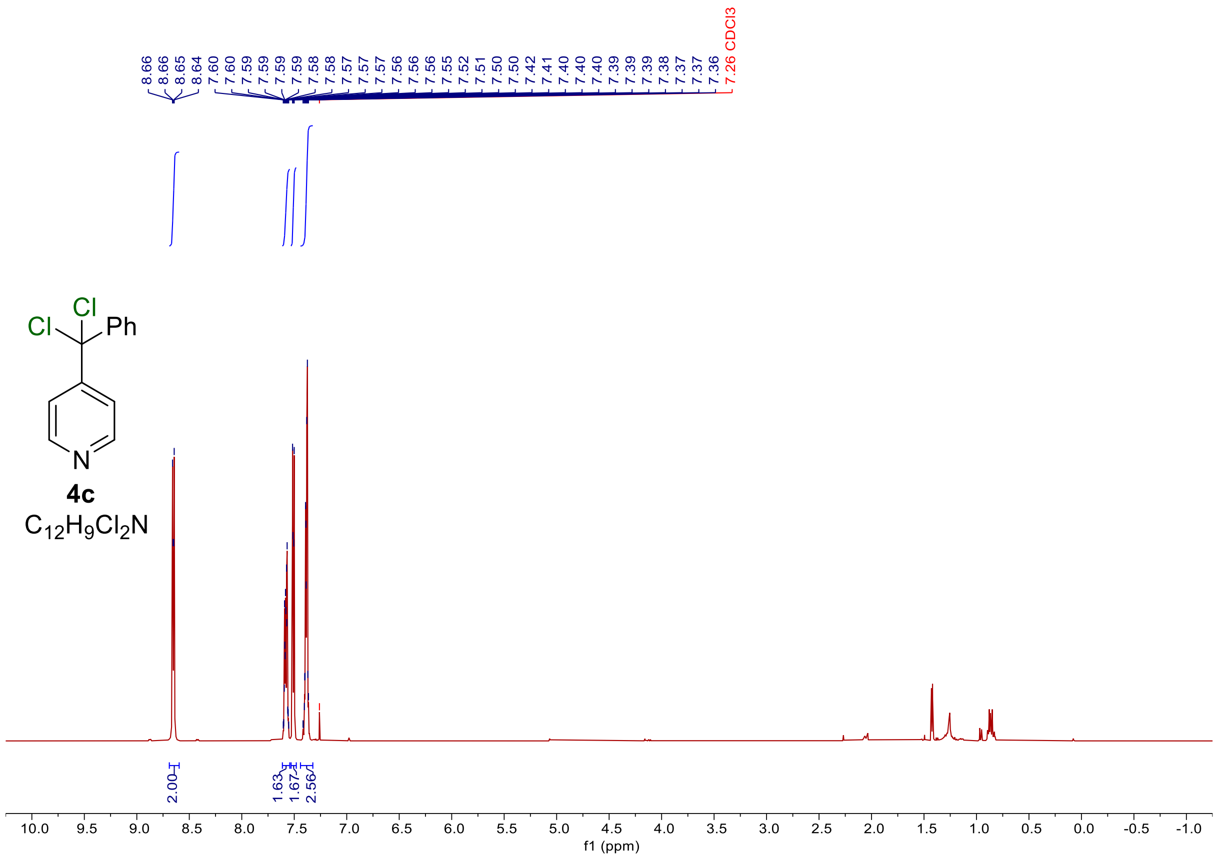
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4a.**



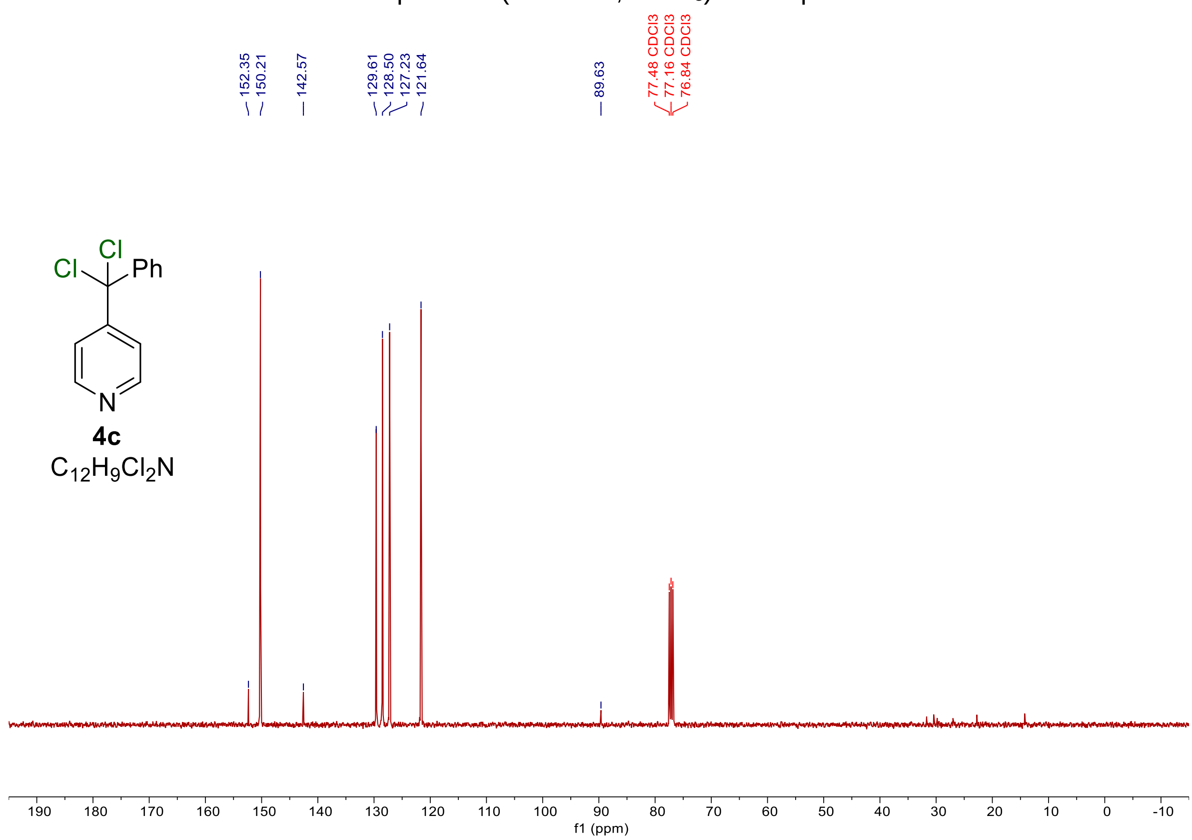
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4b.**



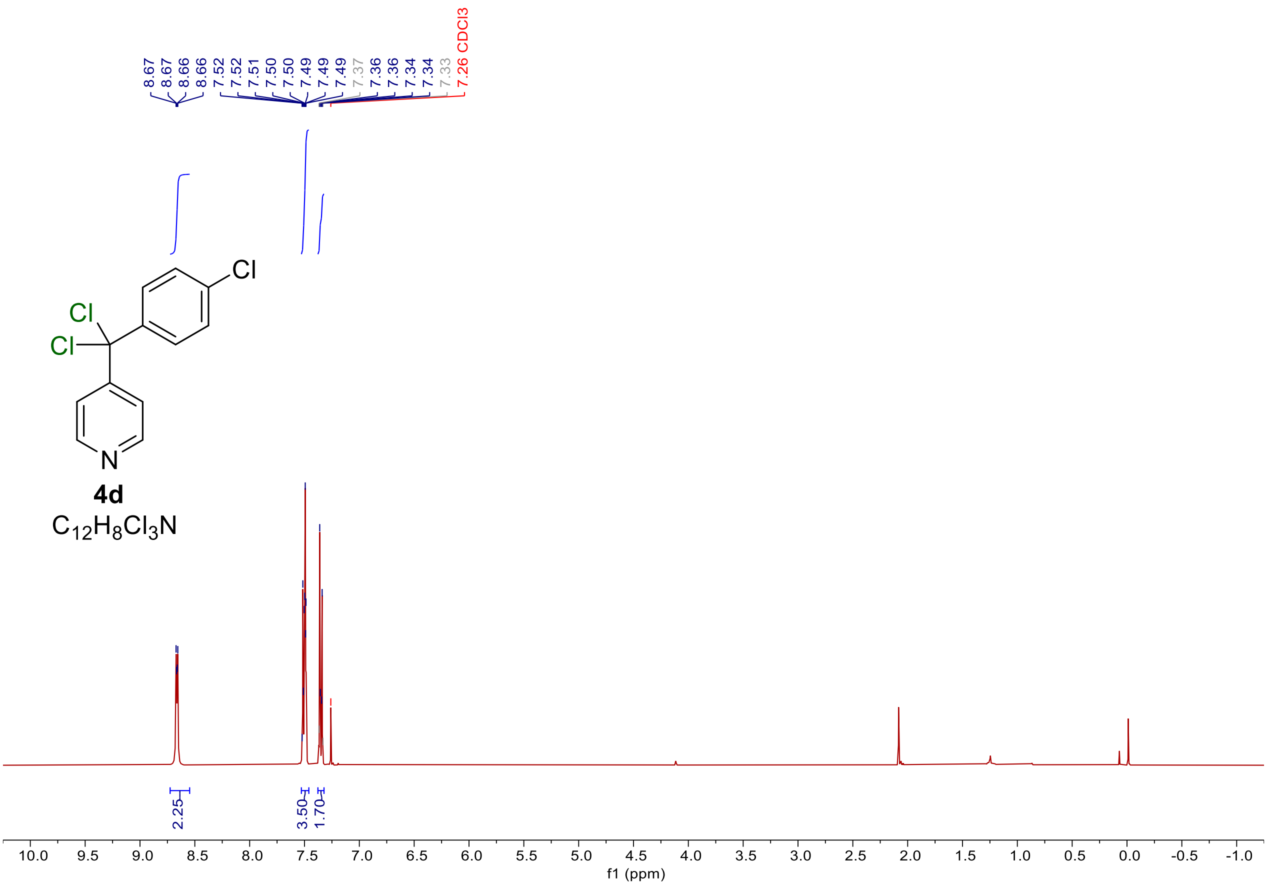
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4b.**



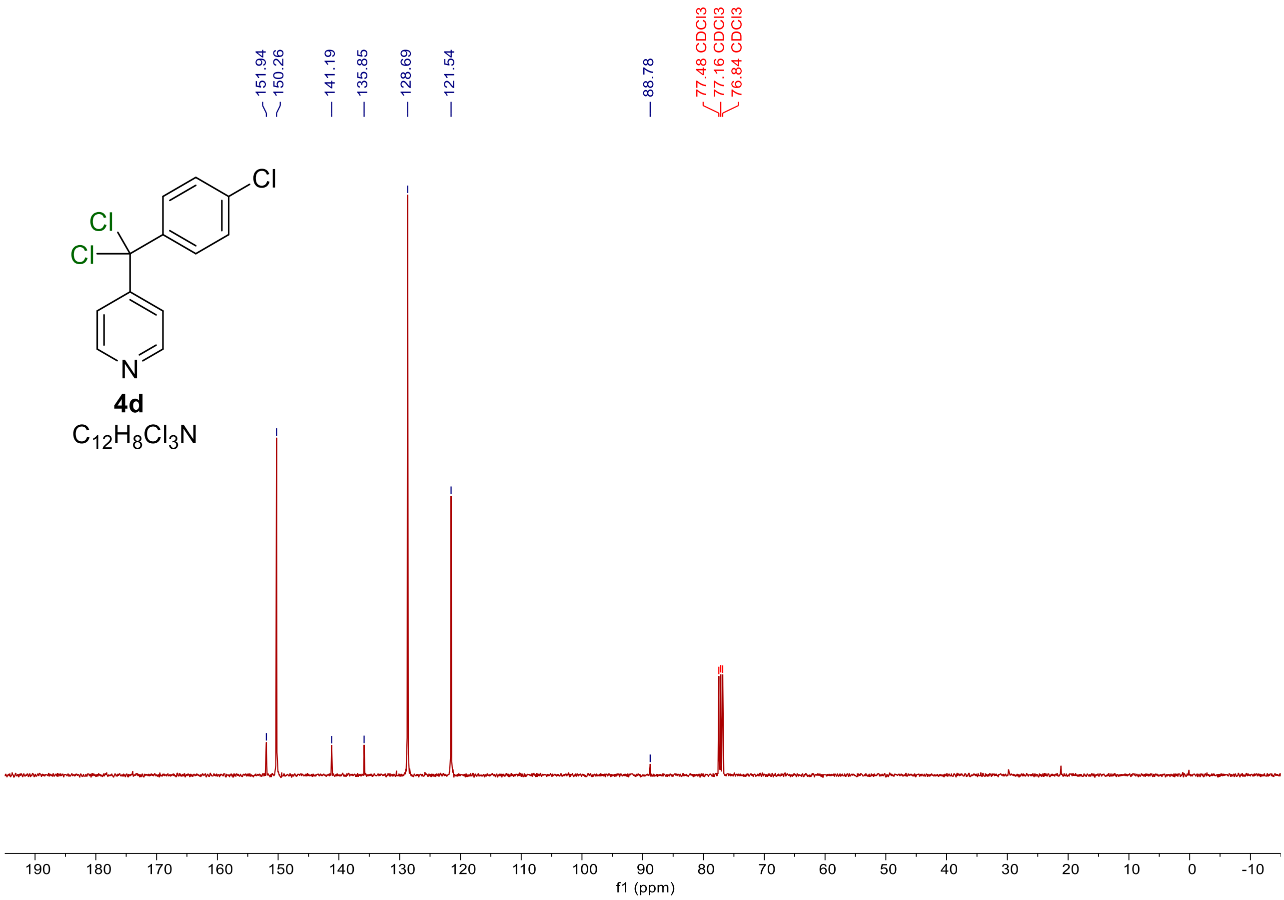
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4c**.



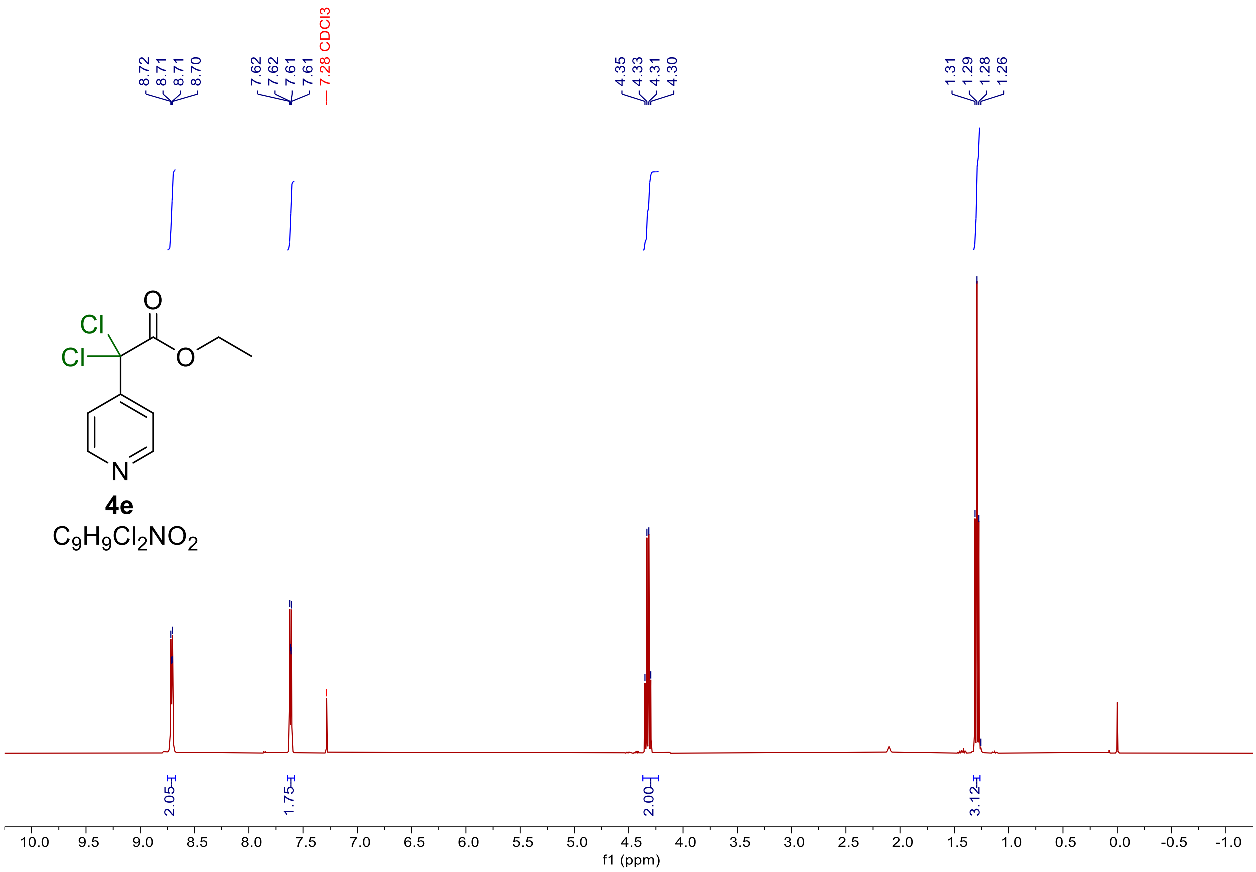
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4c**.



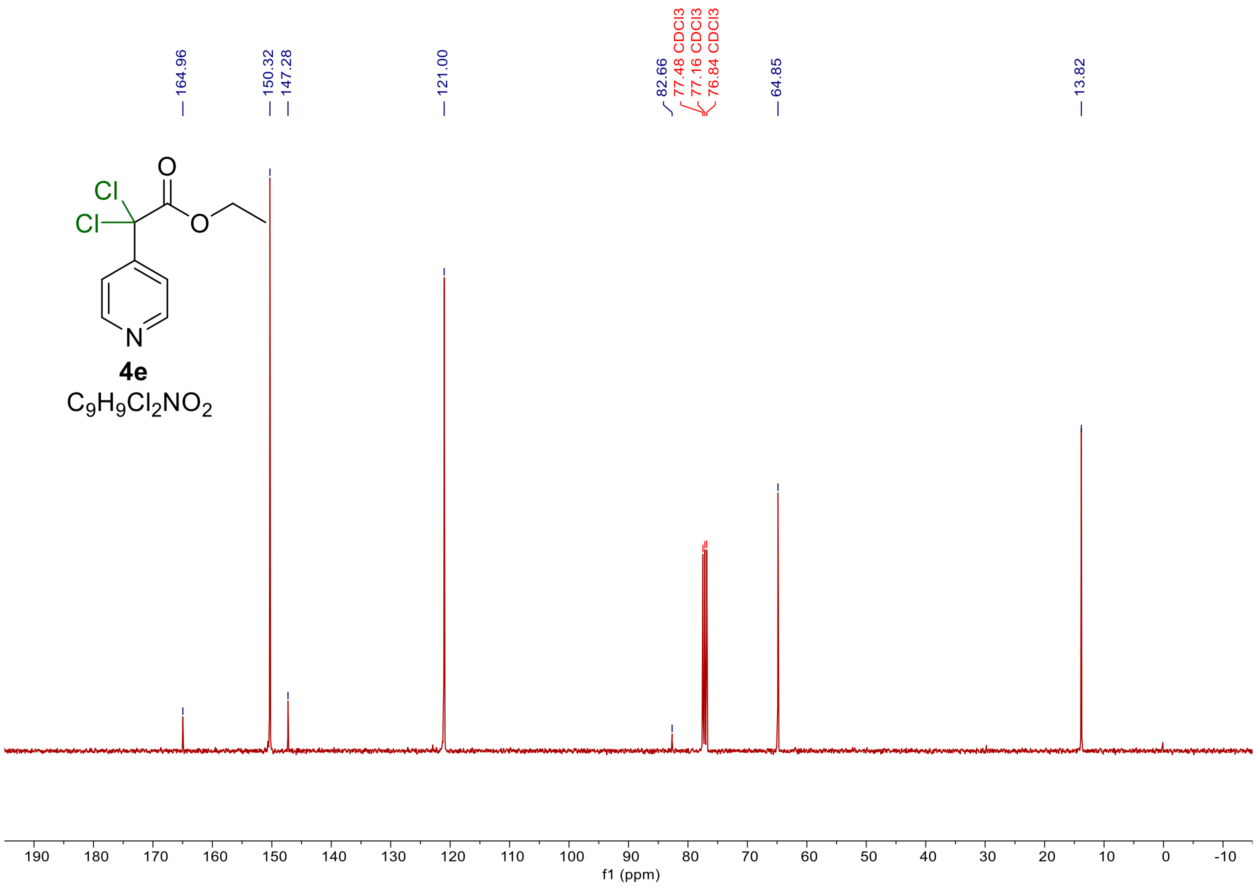
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4d**.



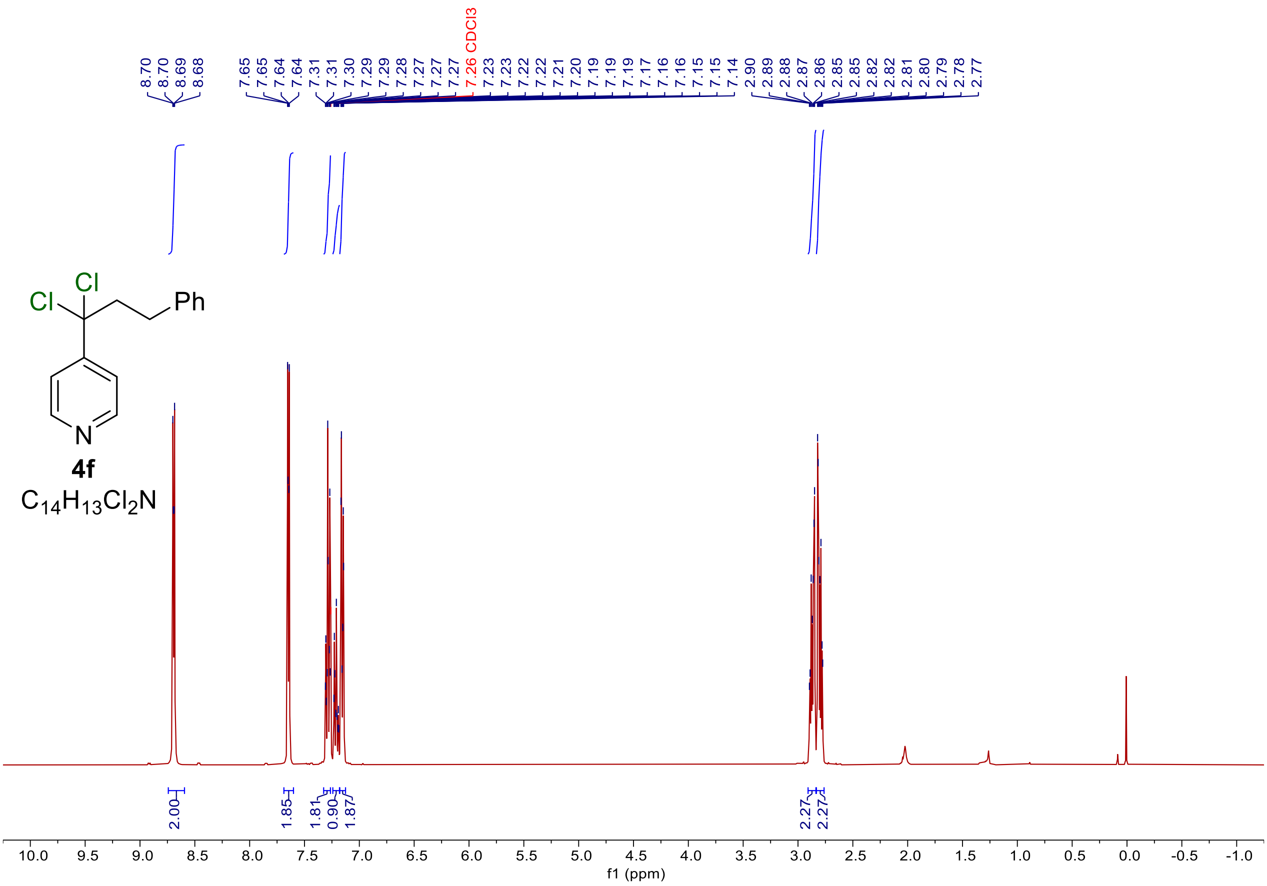
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4d**.



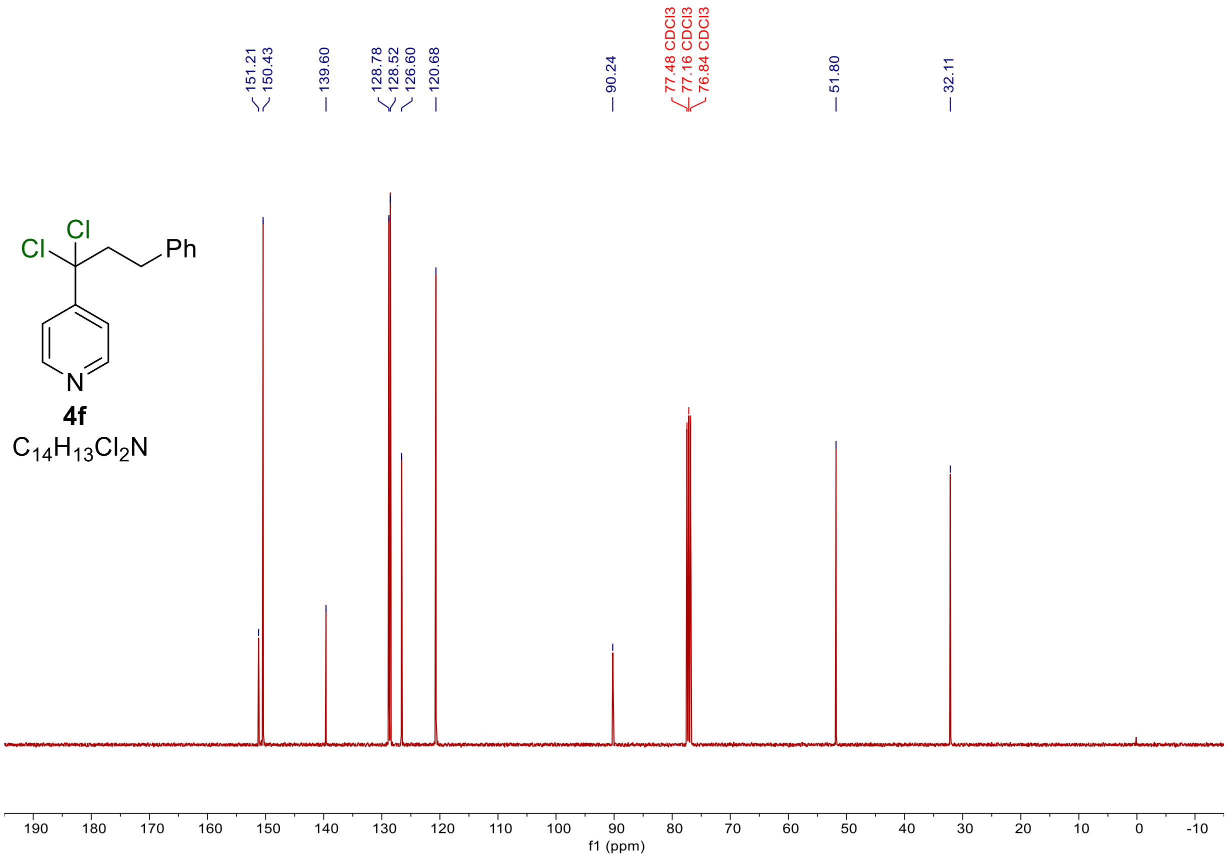
[1]**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4e**.



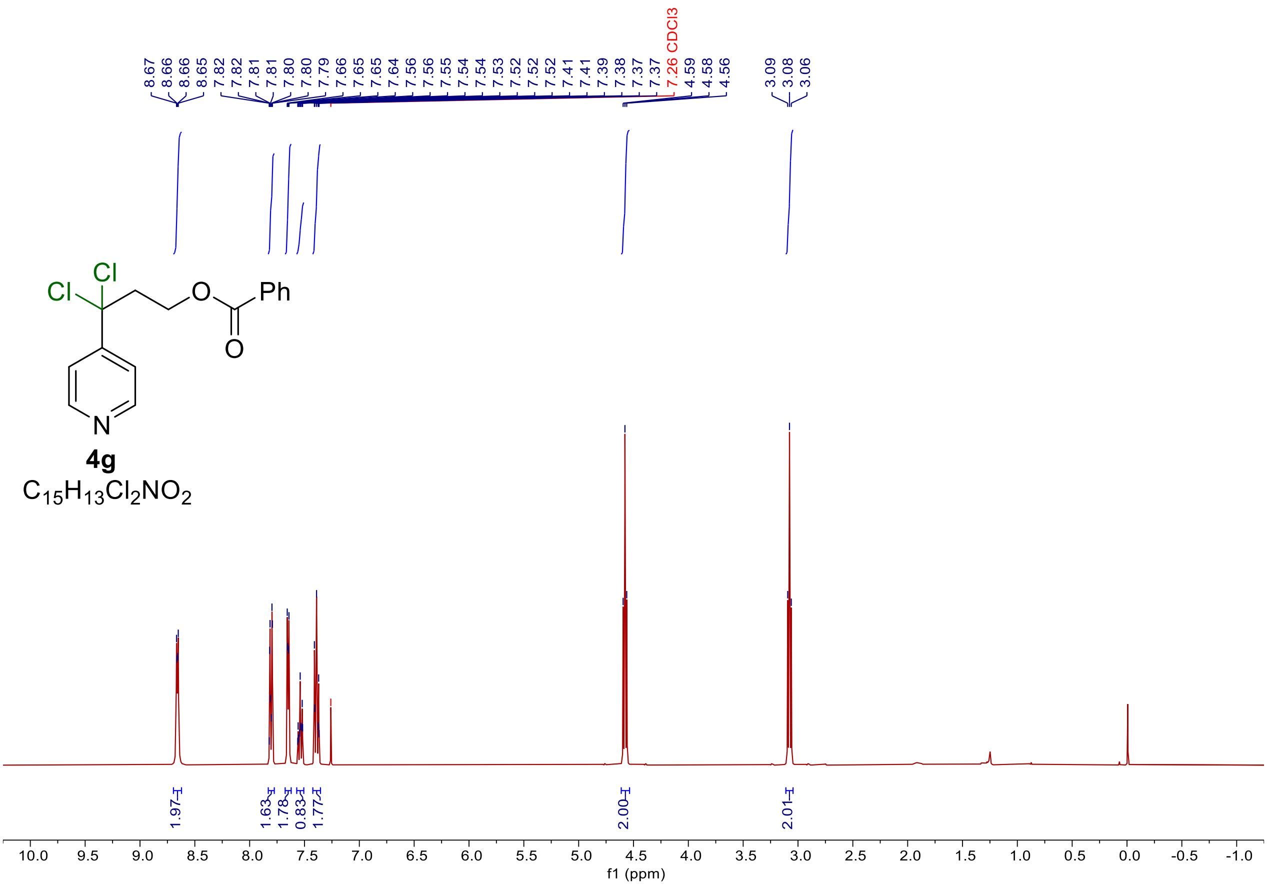
[13]**C{[1]H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4e**.



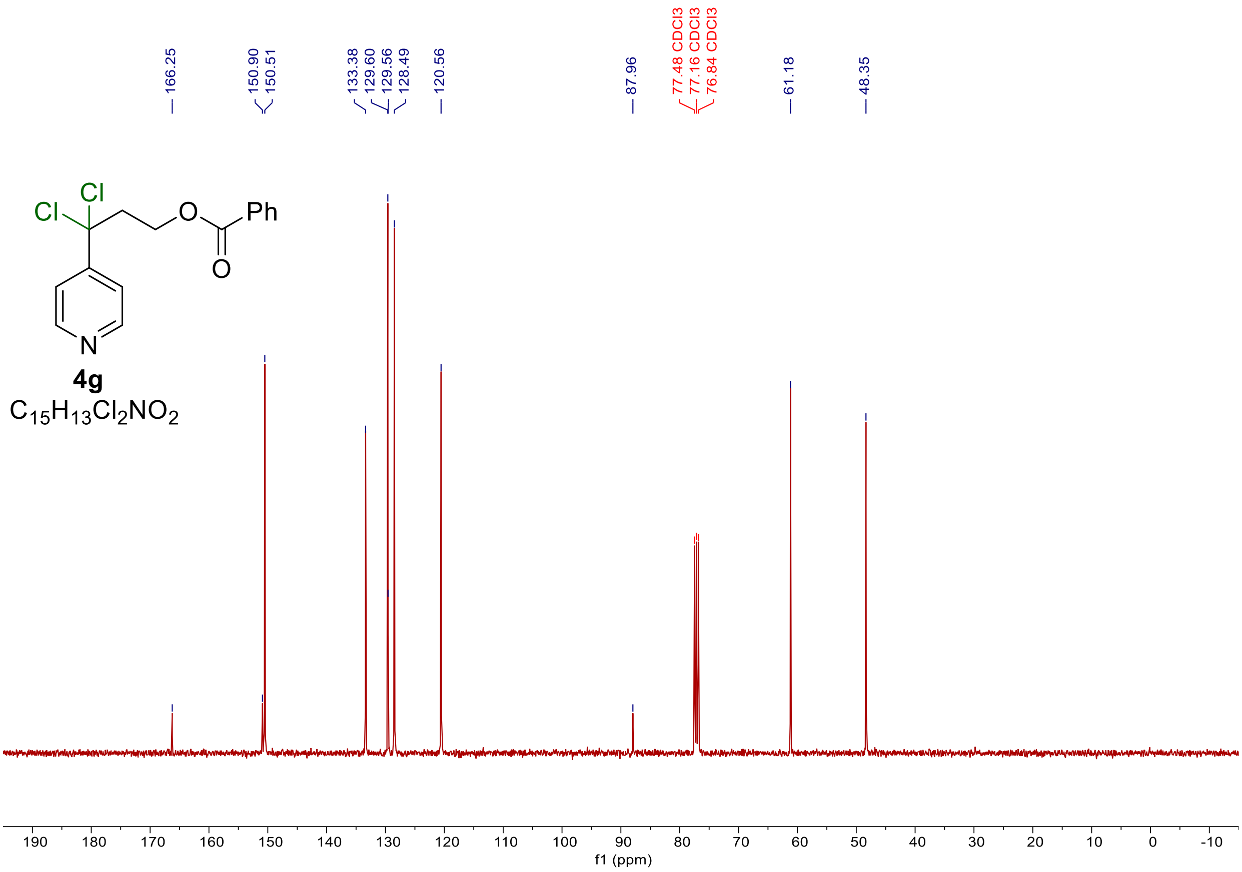
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4f**.



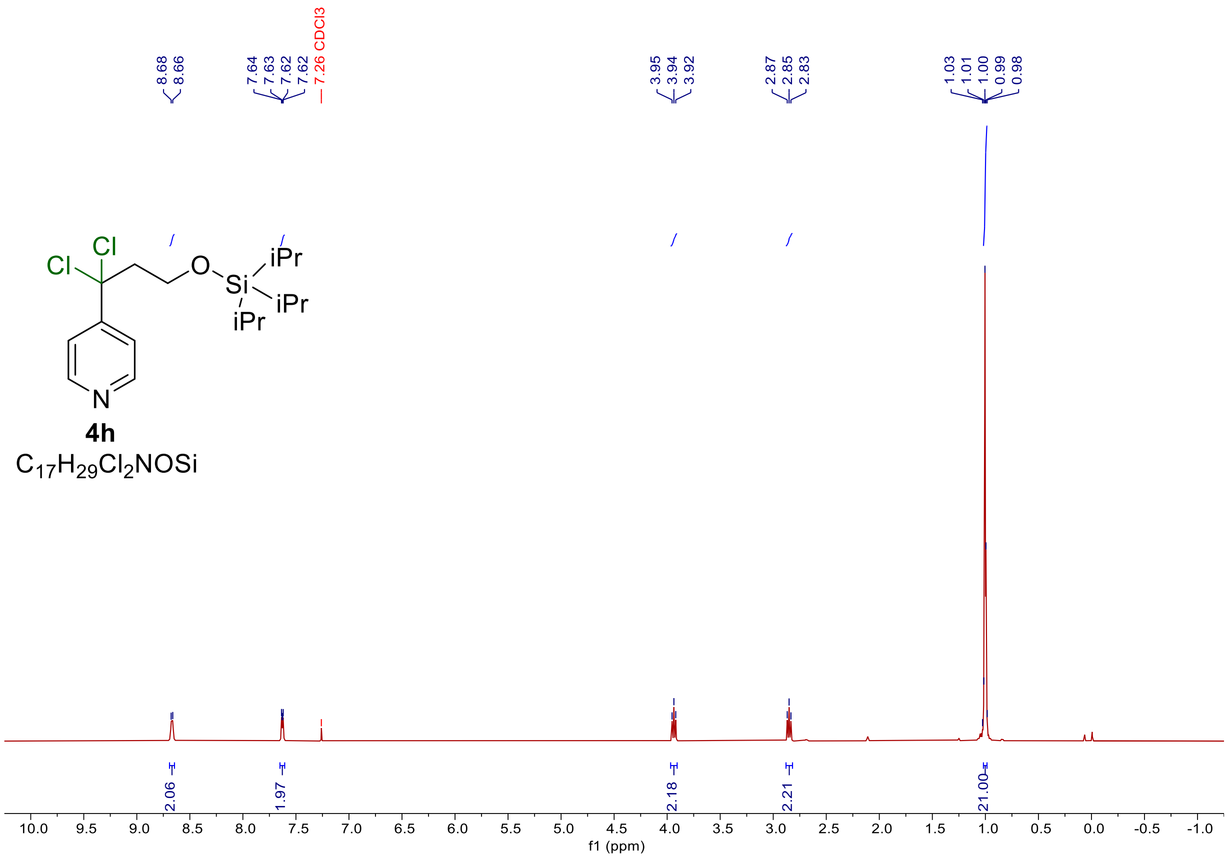
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4f**..



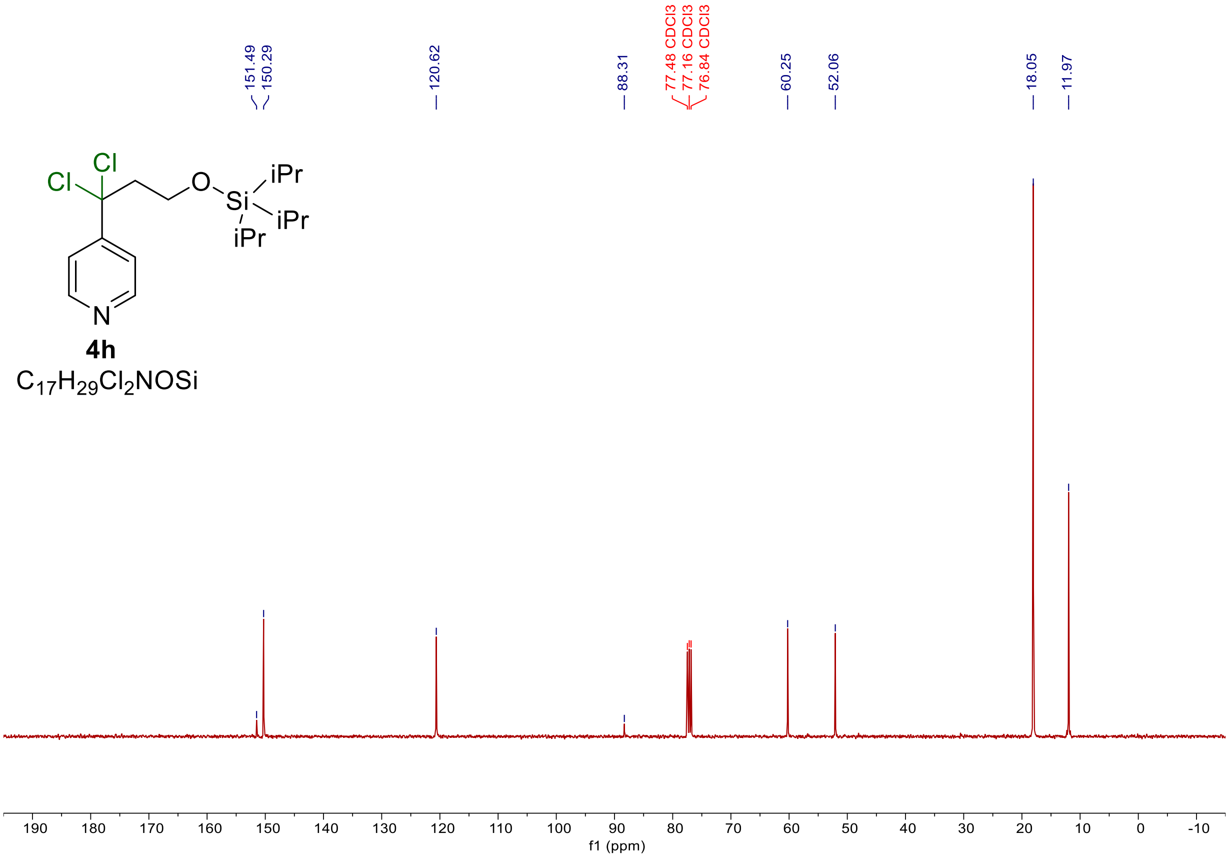
[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **4g**.



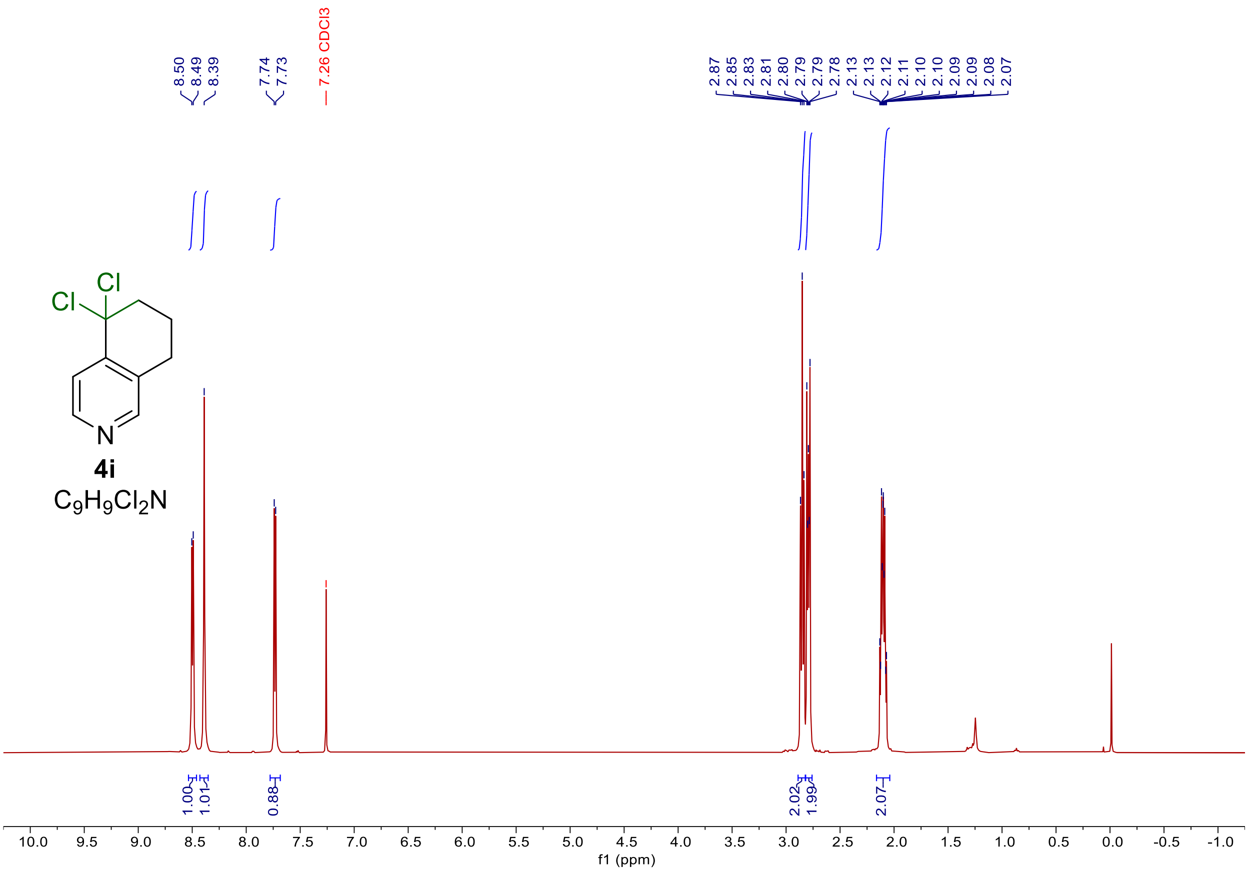
[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4g**.



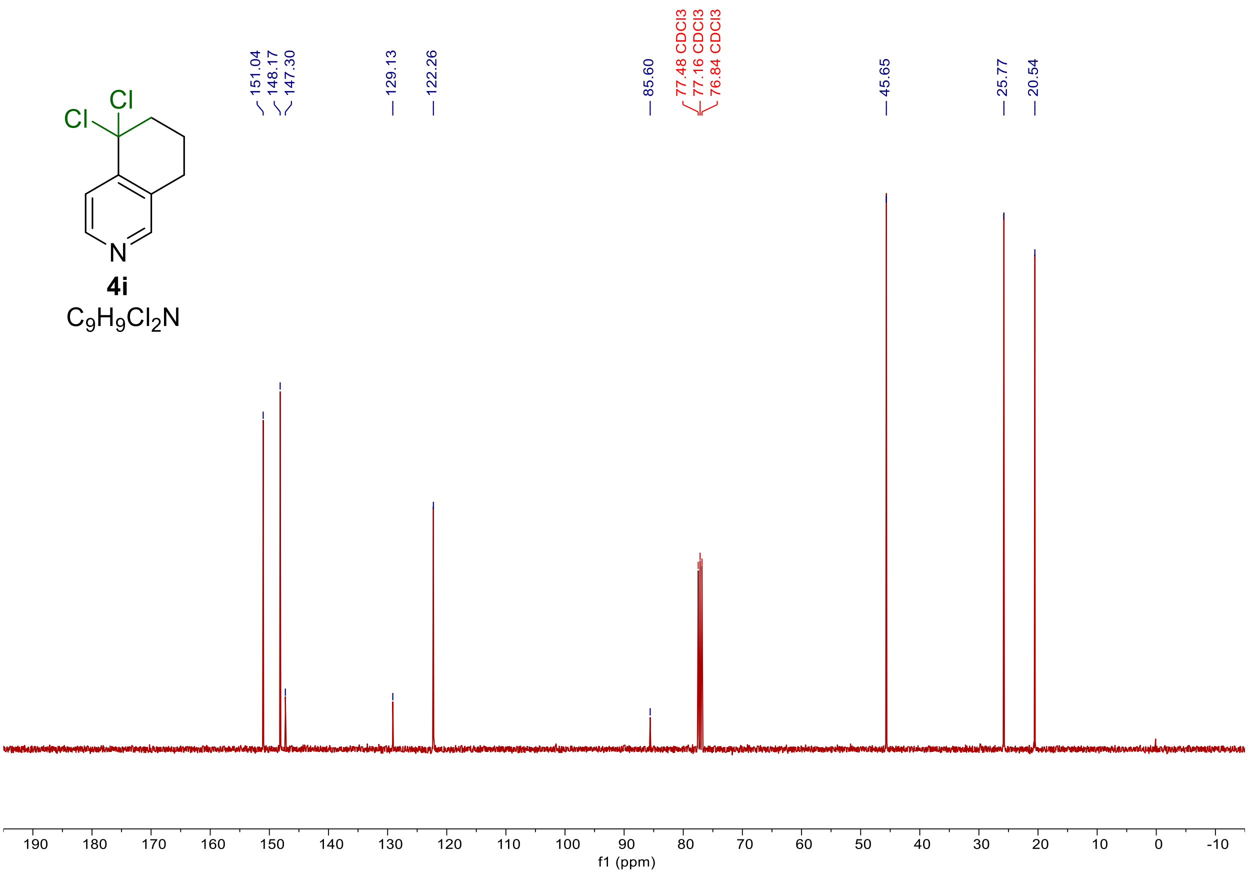
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4h.**



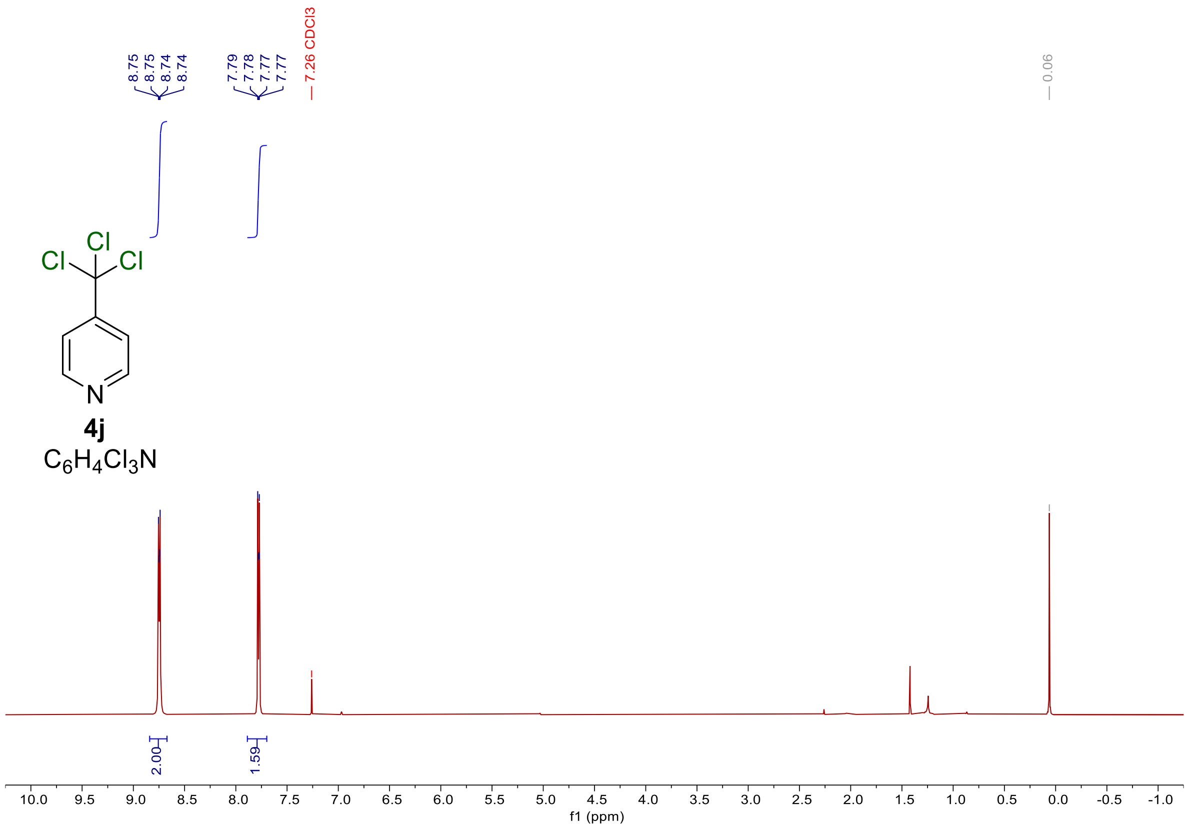
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4h.**



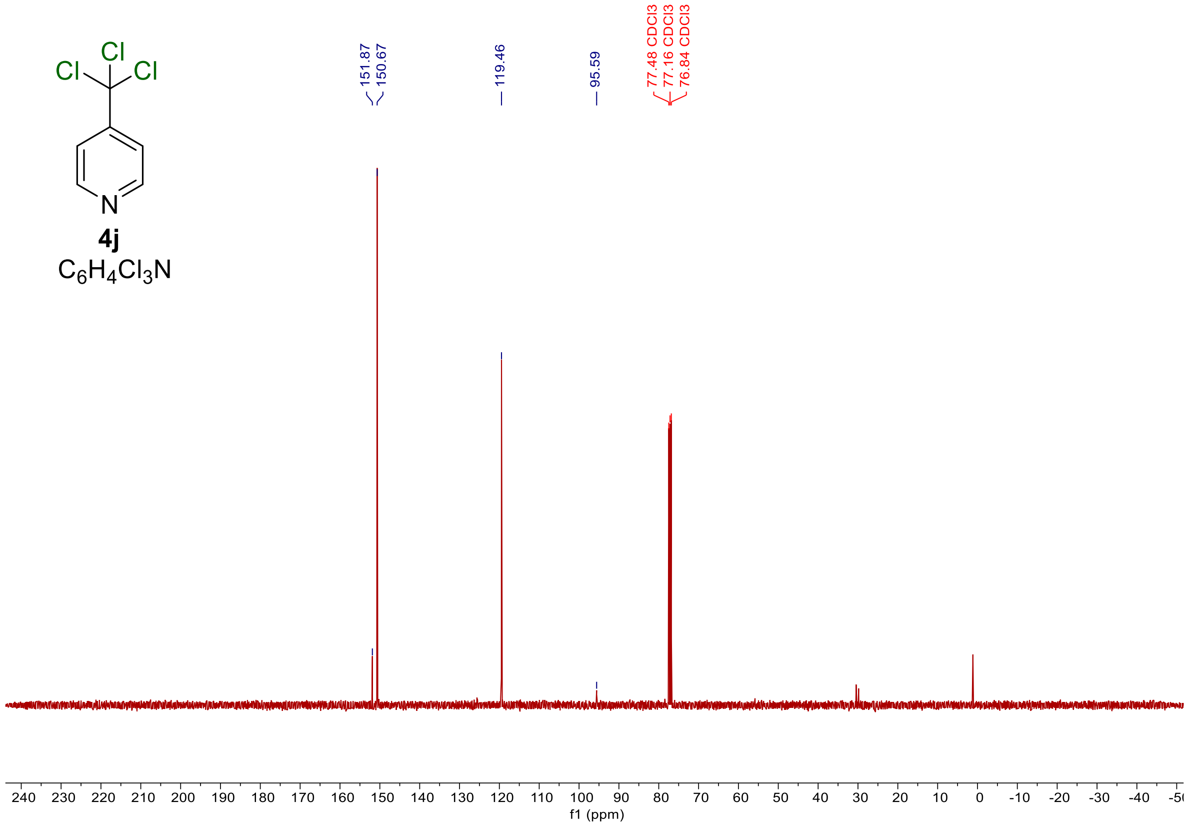
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4i**.



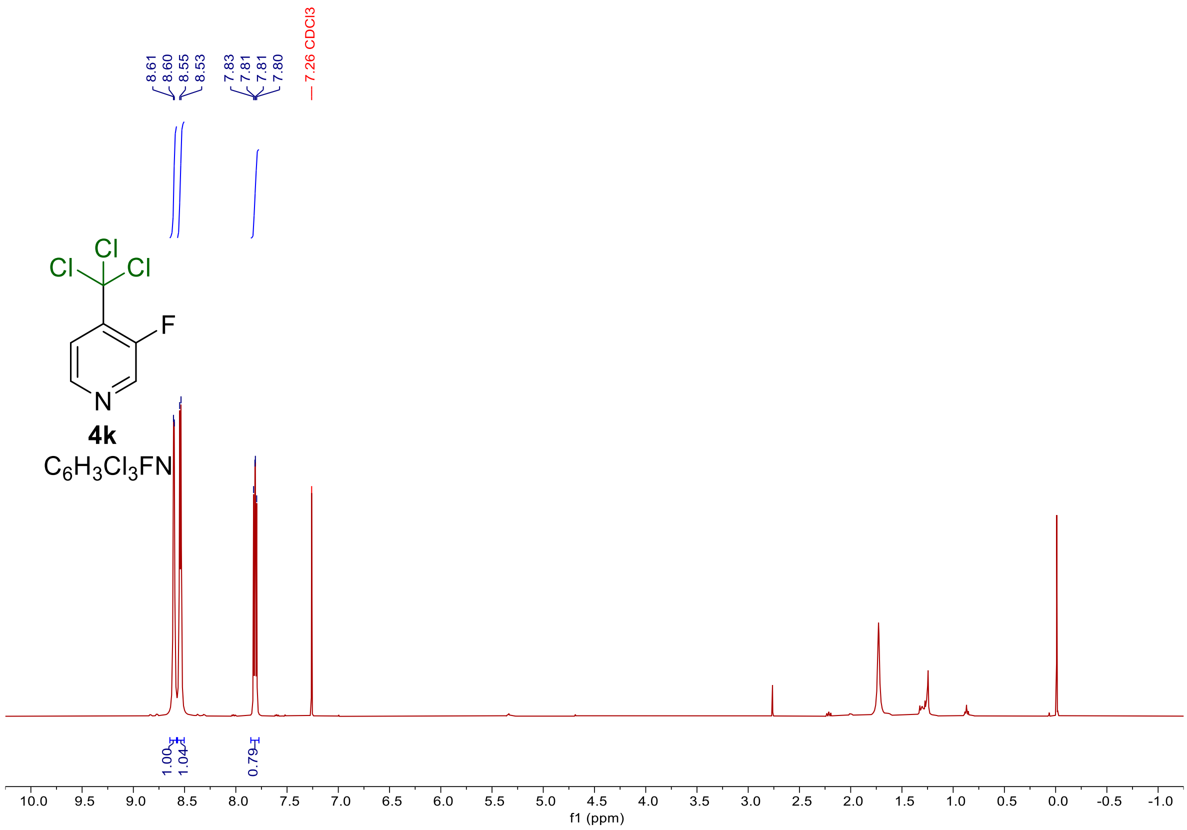
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4i**.



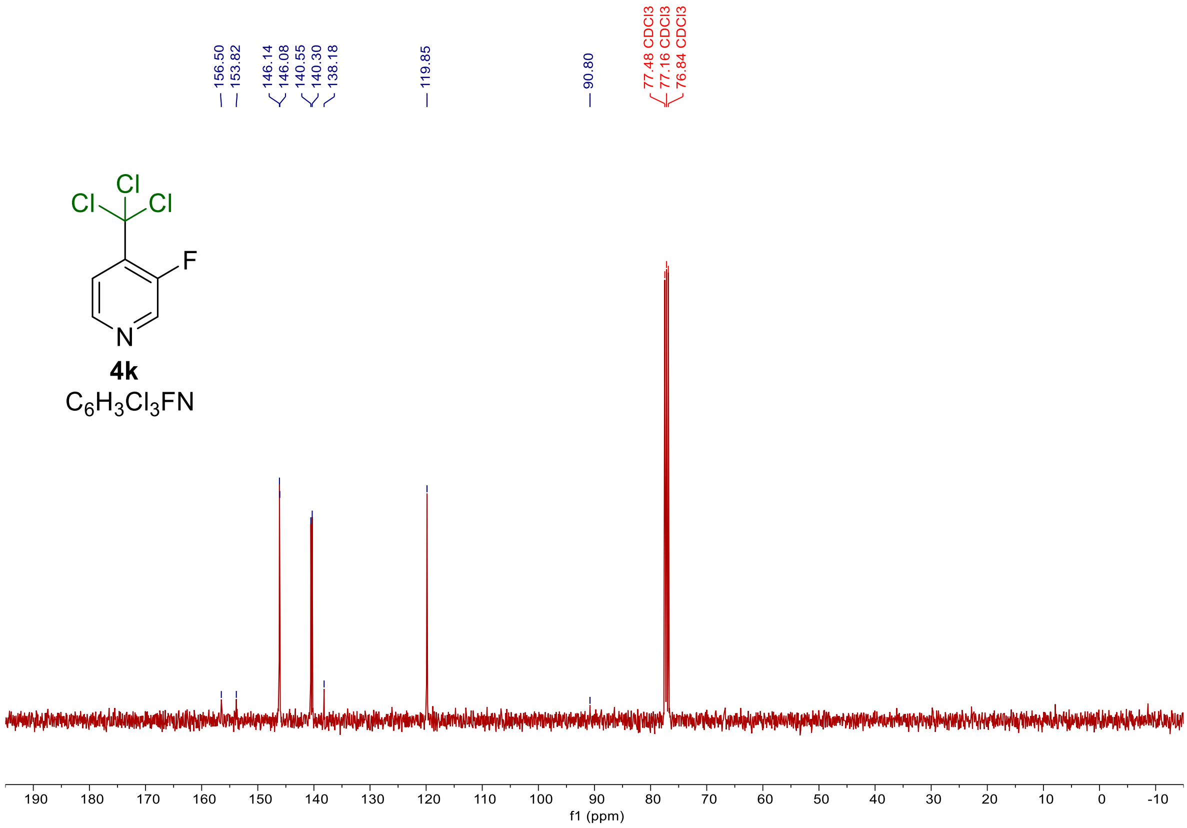
¹H NMR spectrum (400 MHz, $CDCl_3$) of compound **4j.**



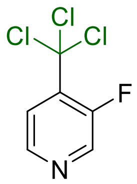
¹³C{¹H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4j.**



[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **4k**.

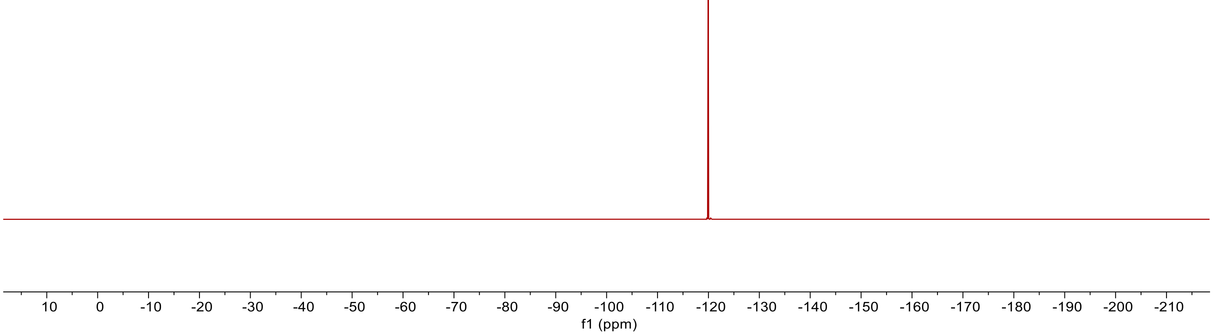


[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4k**.

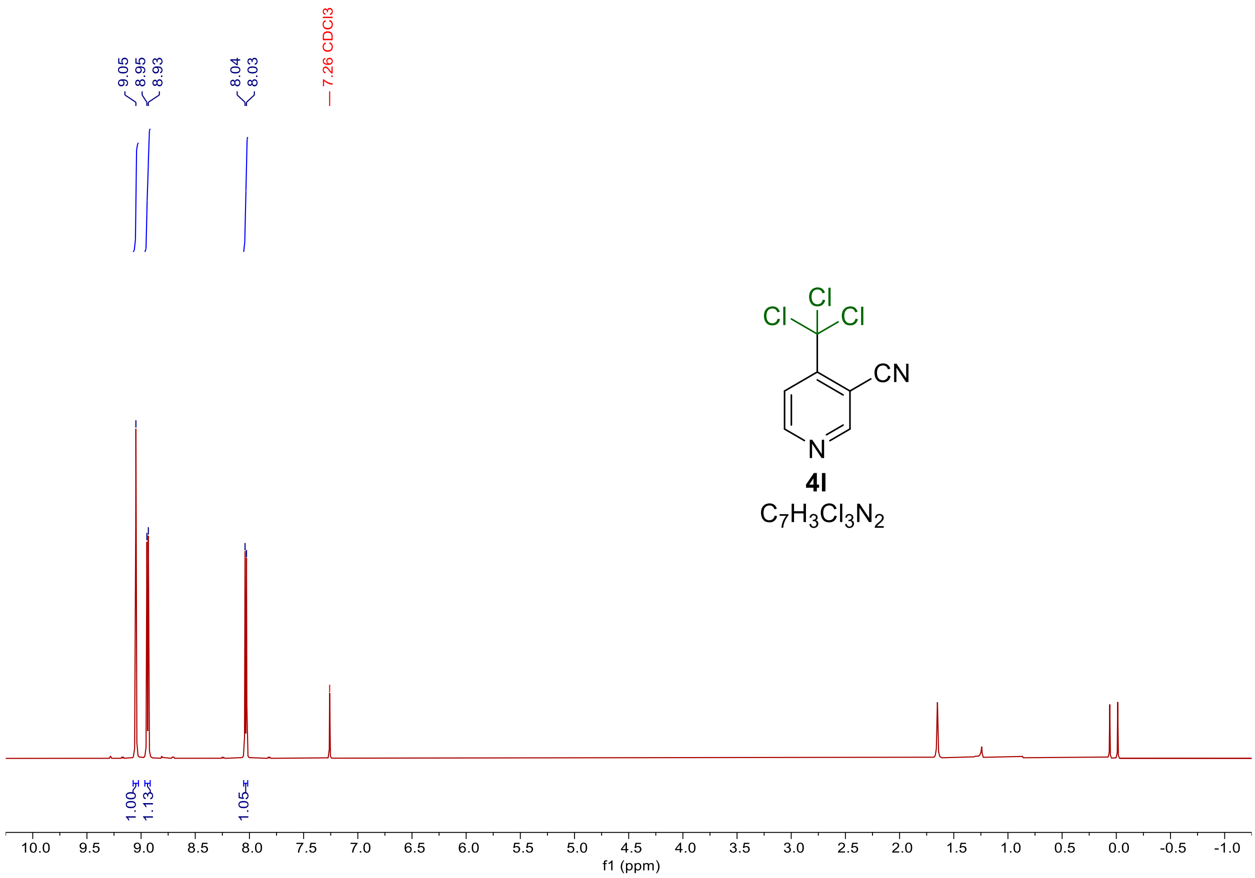


4k

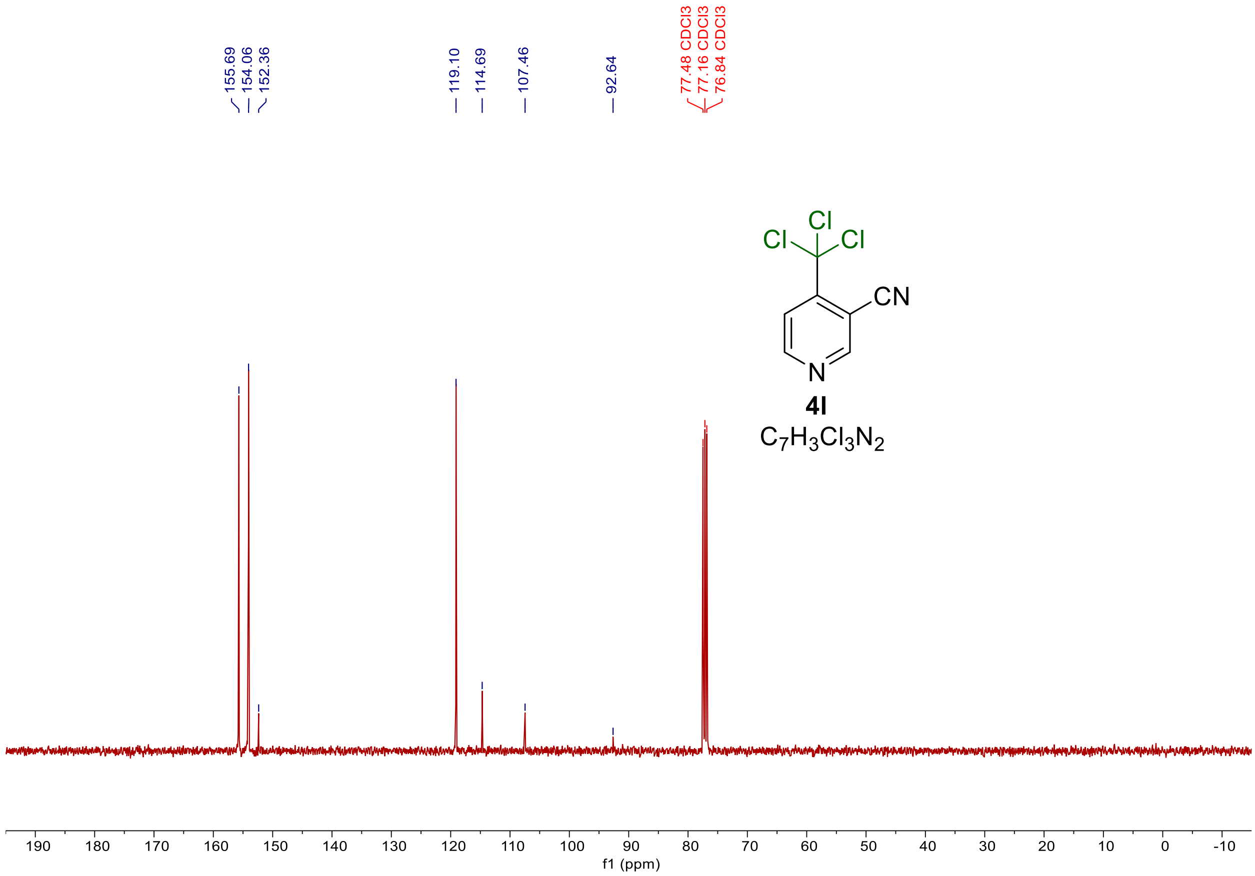
$C_6H_3Cl_3FN$



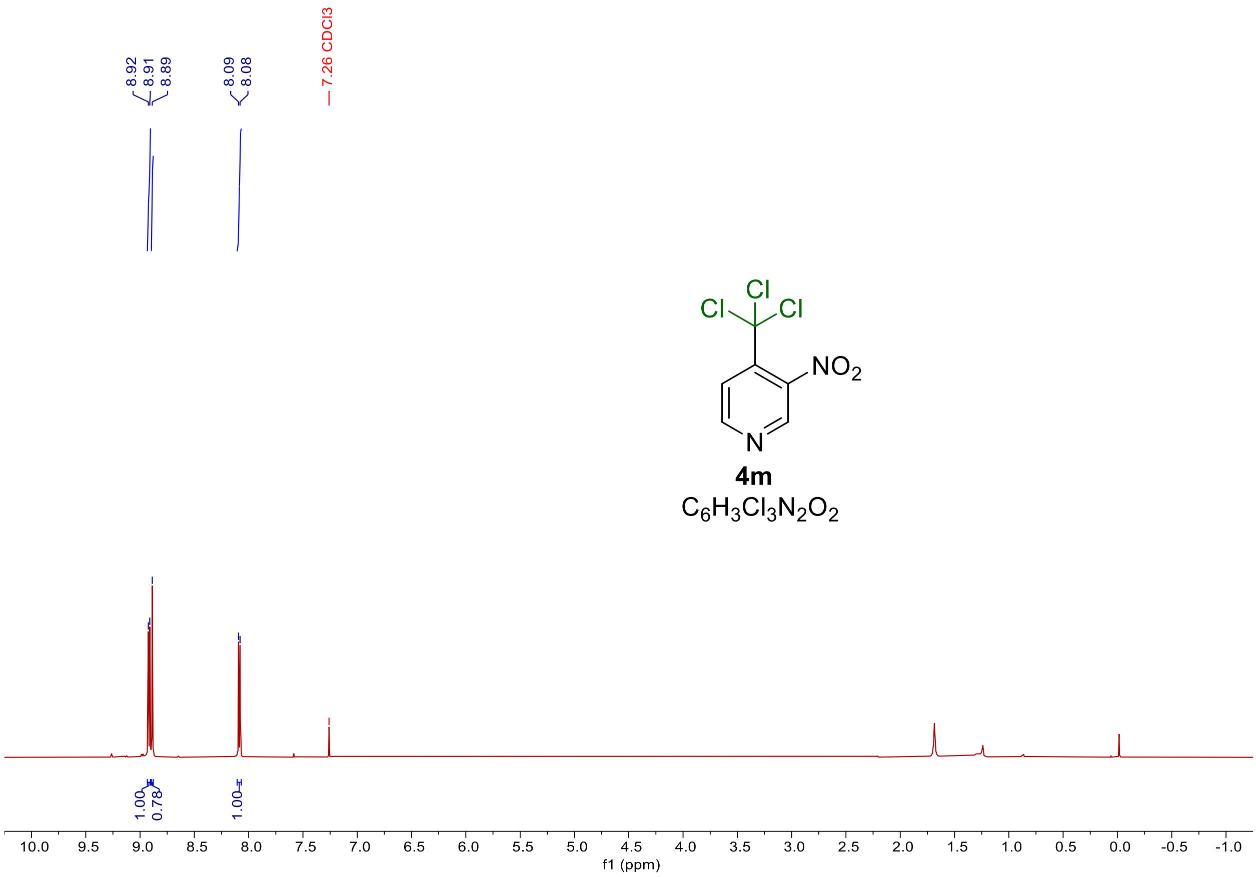
^{19}F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



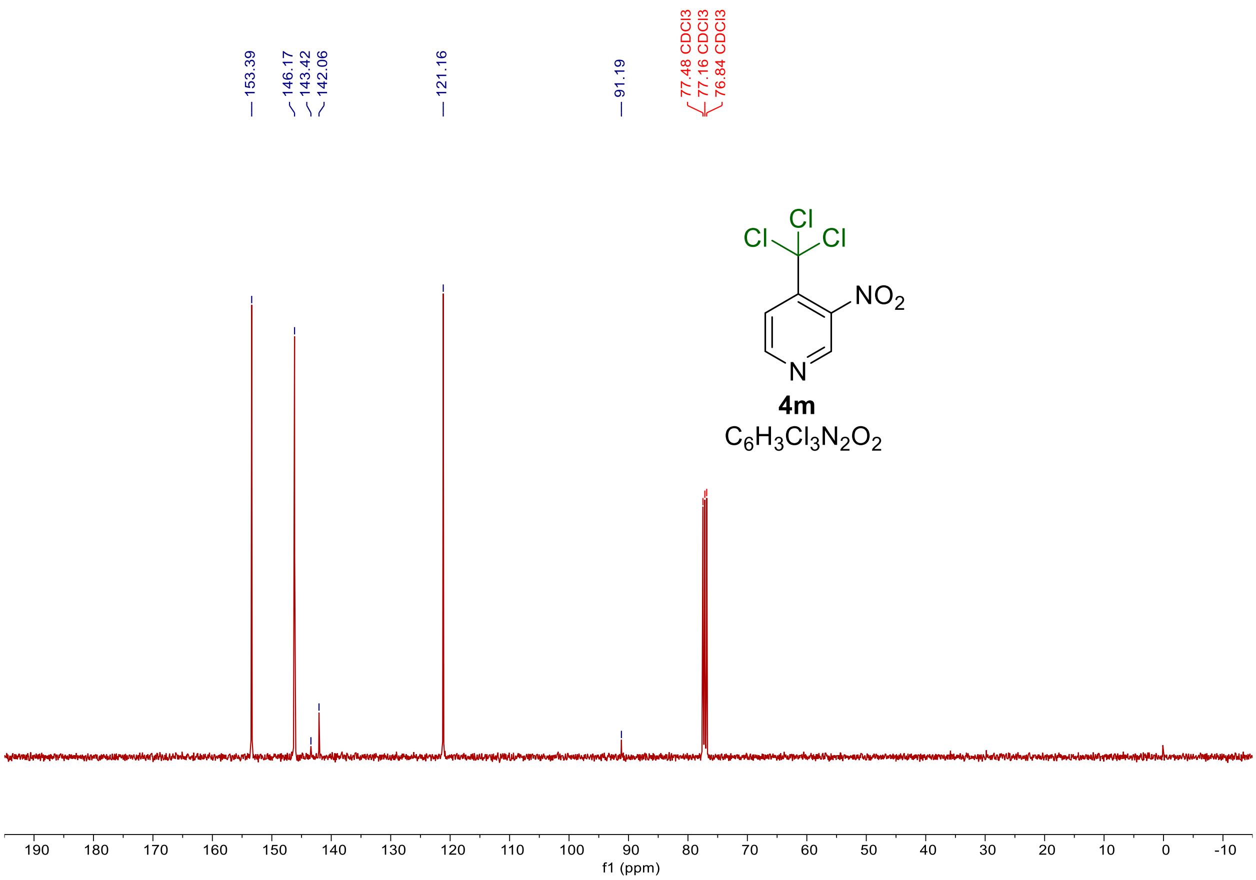
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4l**.



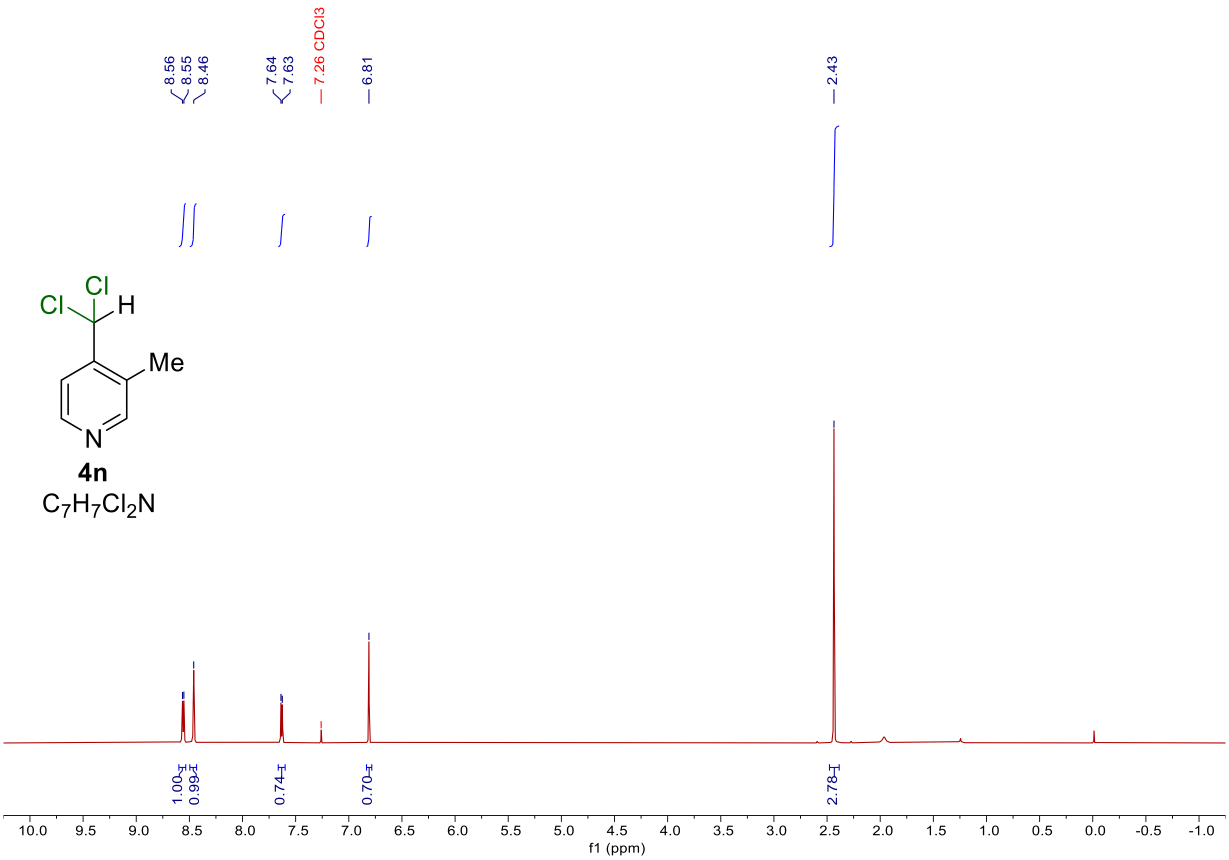
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4l**.



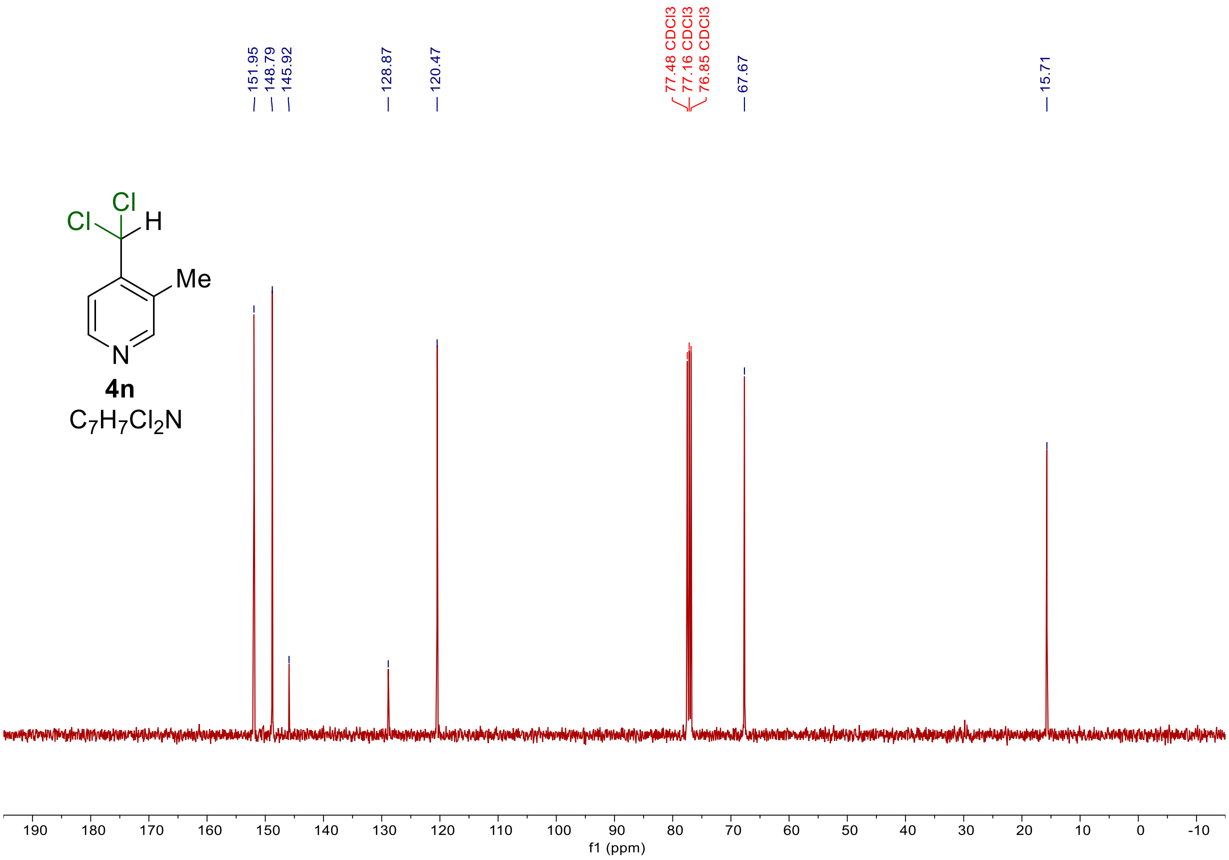
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4m**.



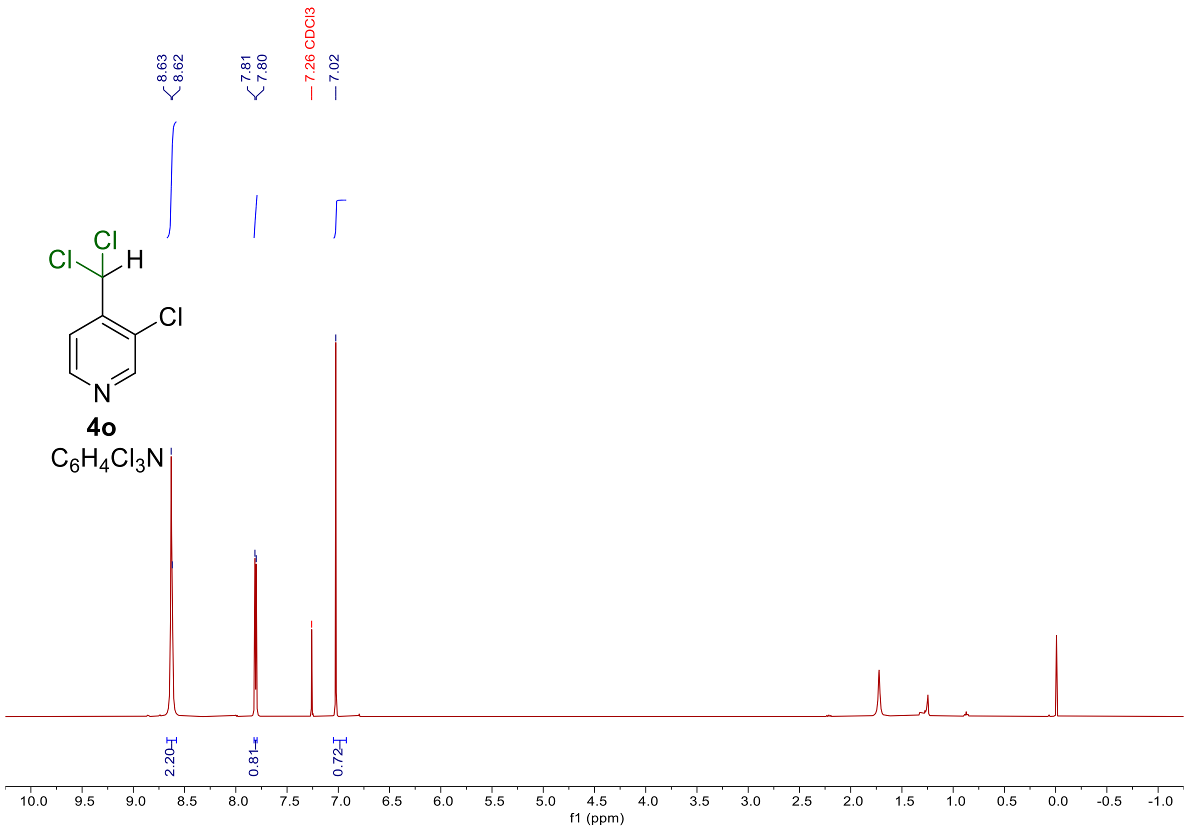
$^{13}C\{^1H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4m**.



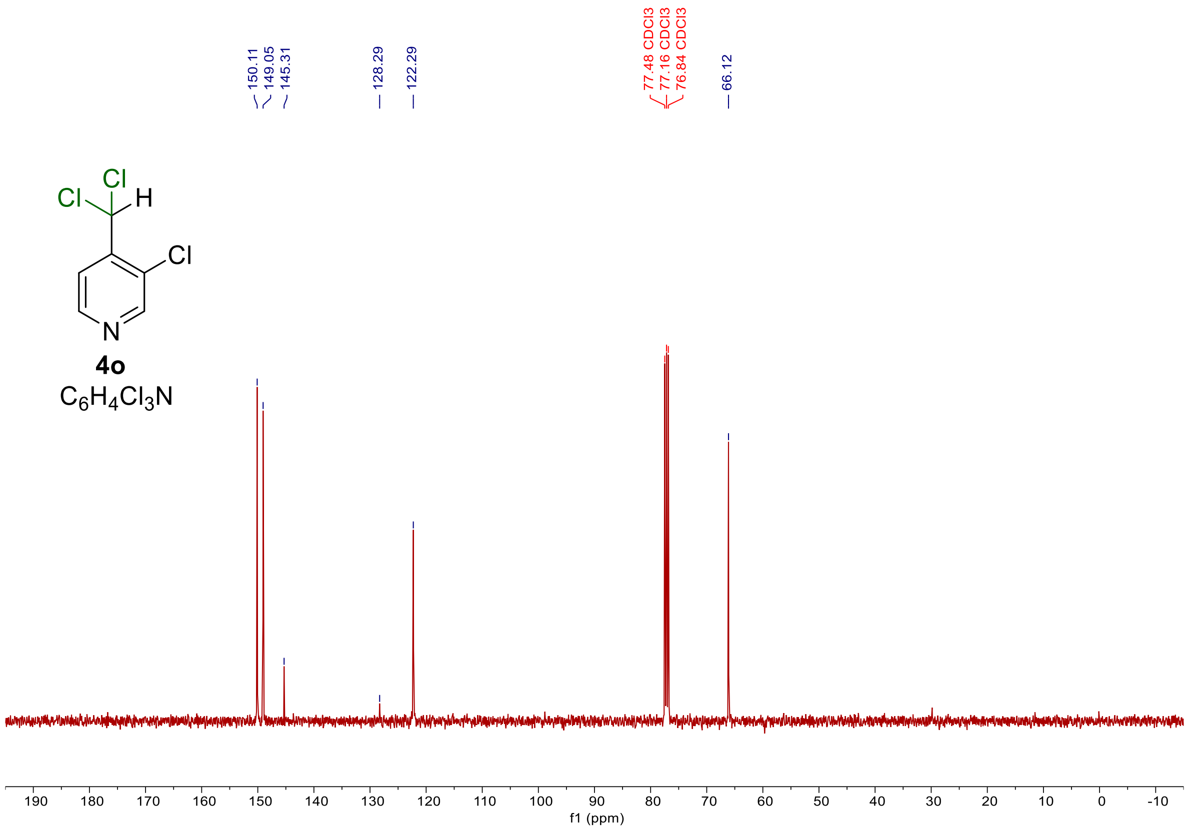
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4n.**



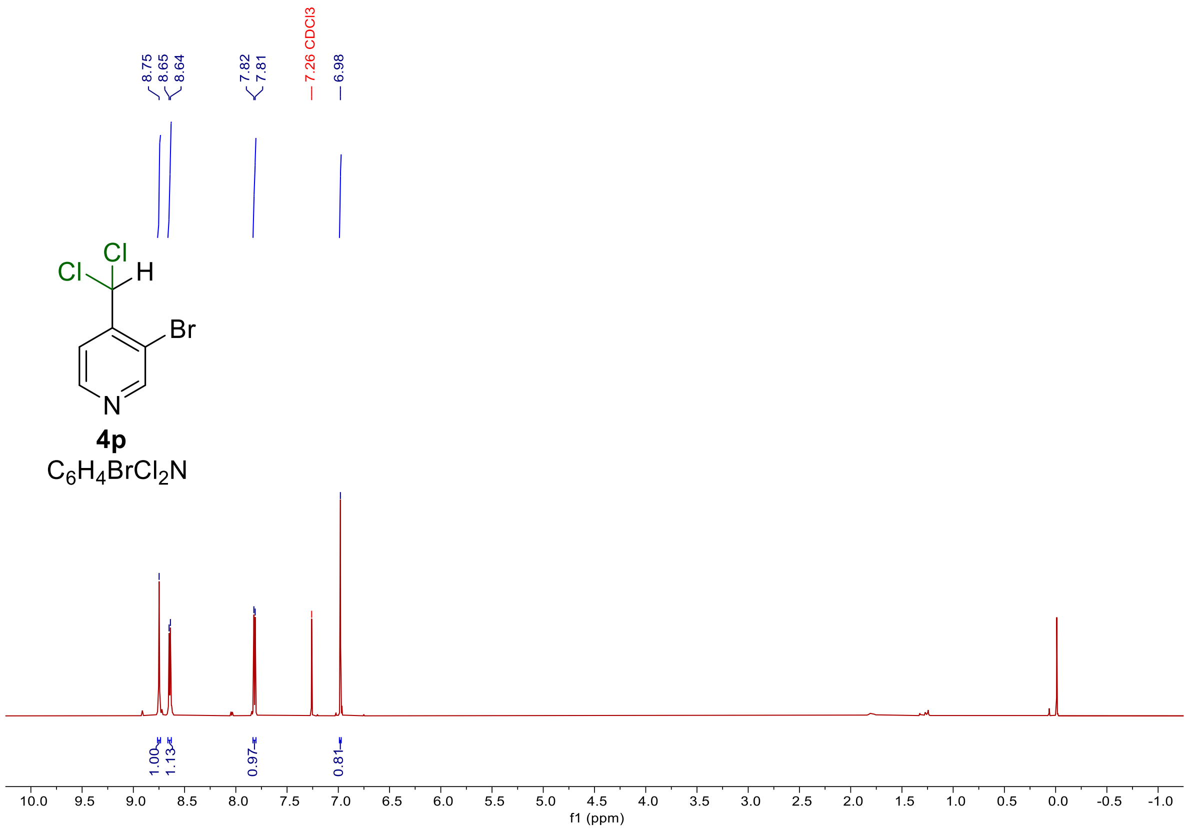
$^{13}C\{^1H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4n.**



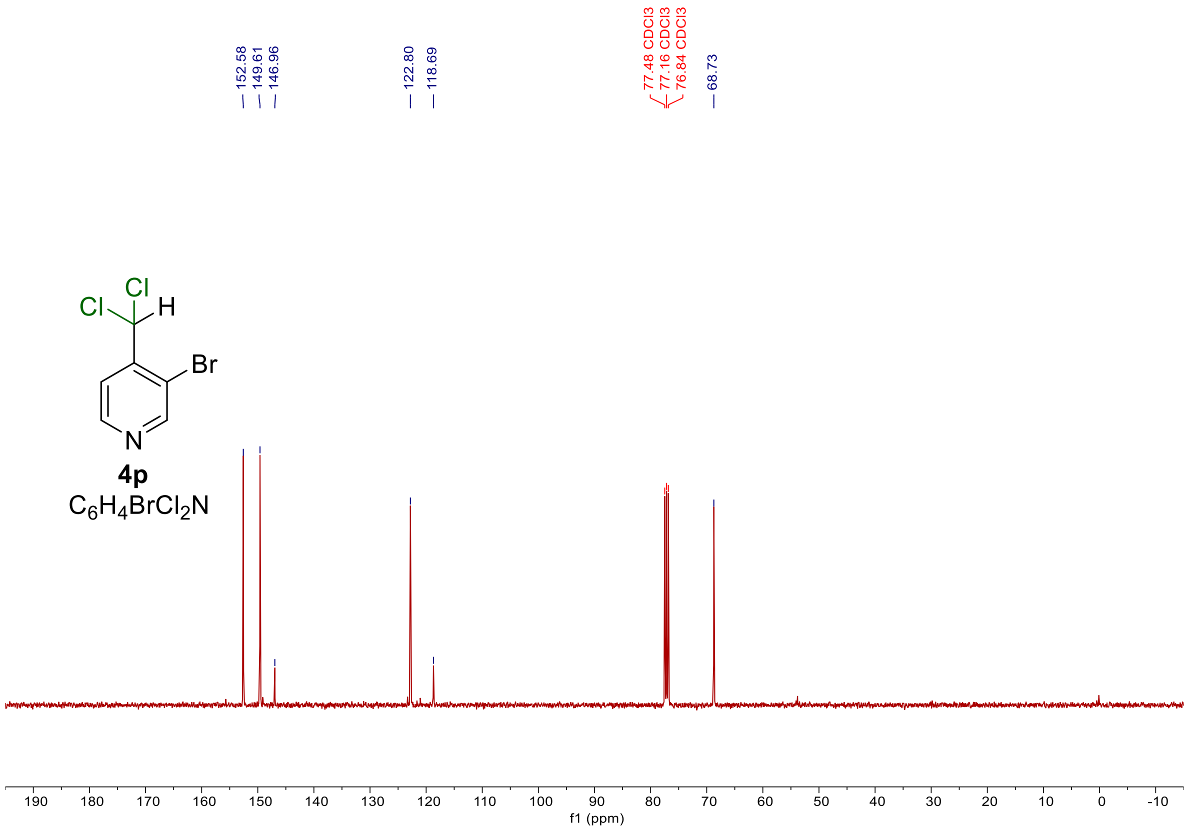
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4o**.



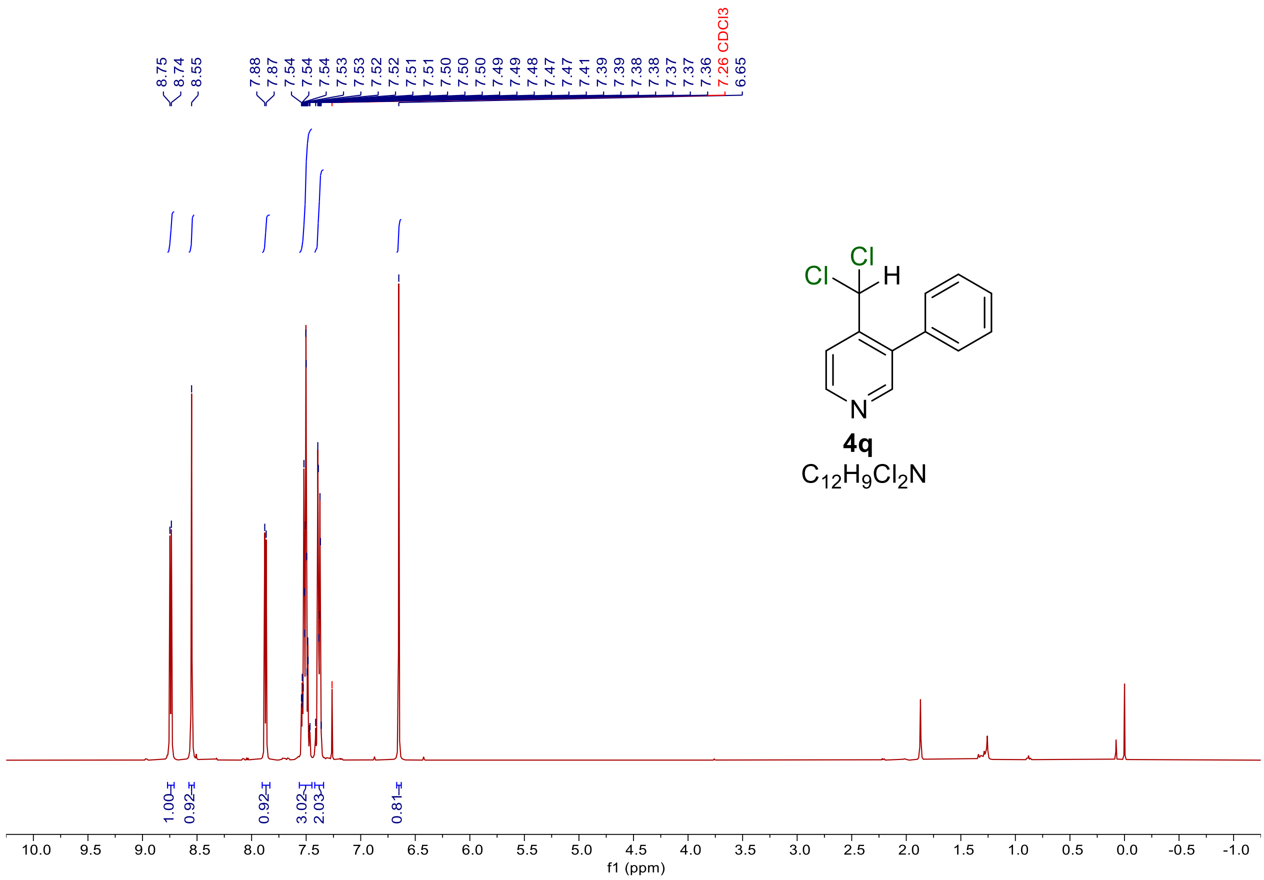
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4o**.



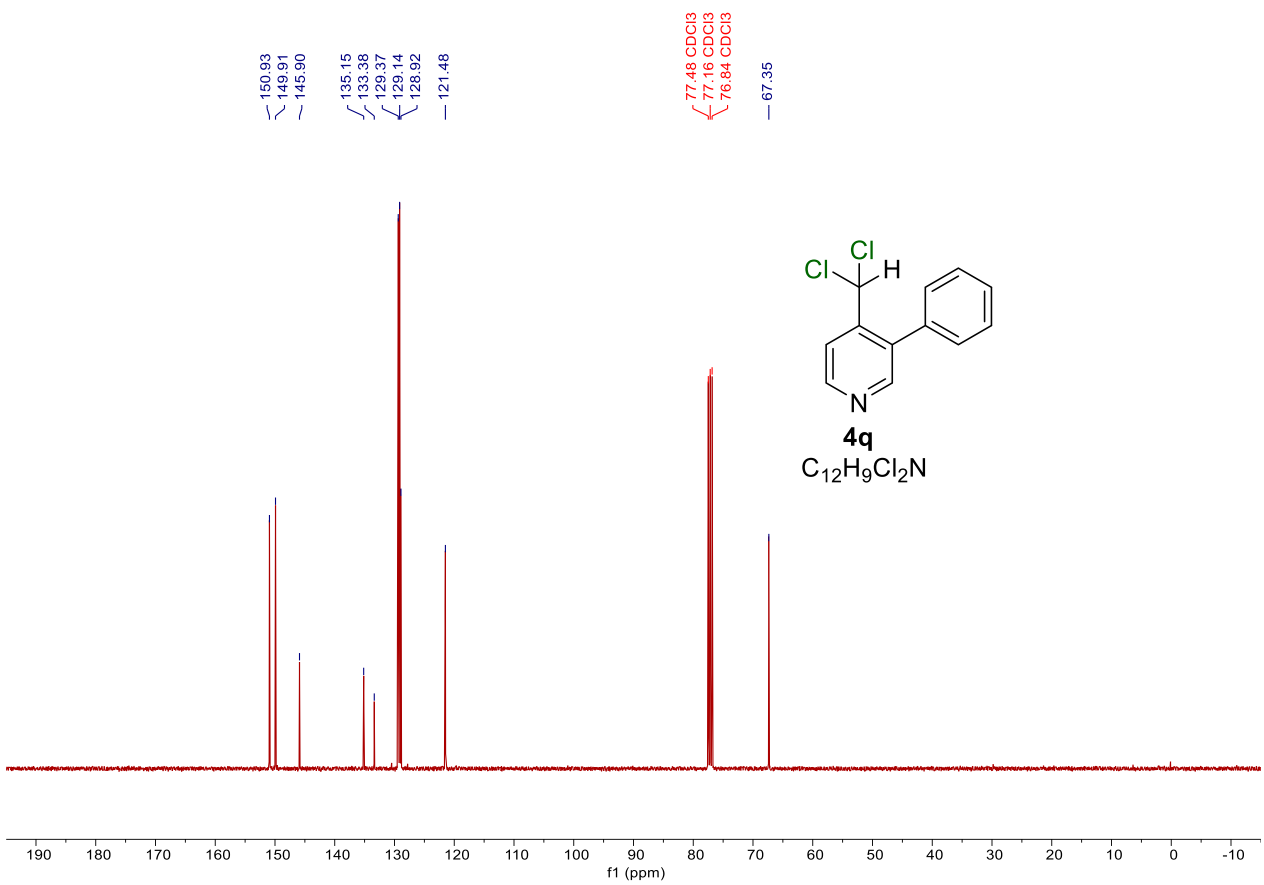
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4p**.



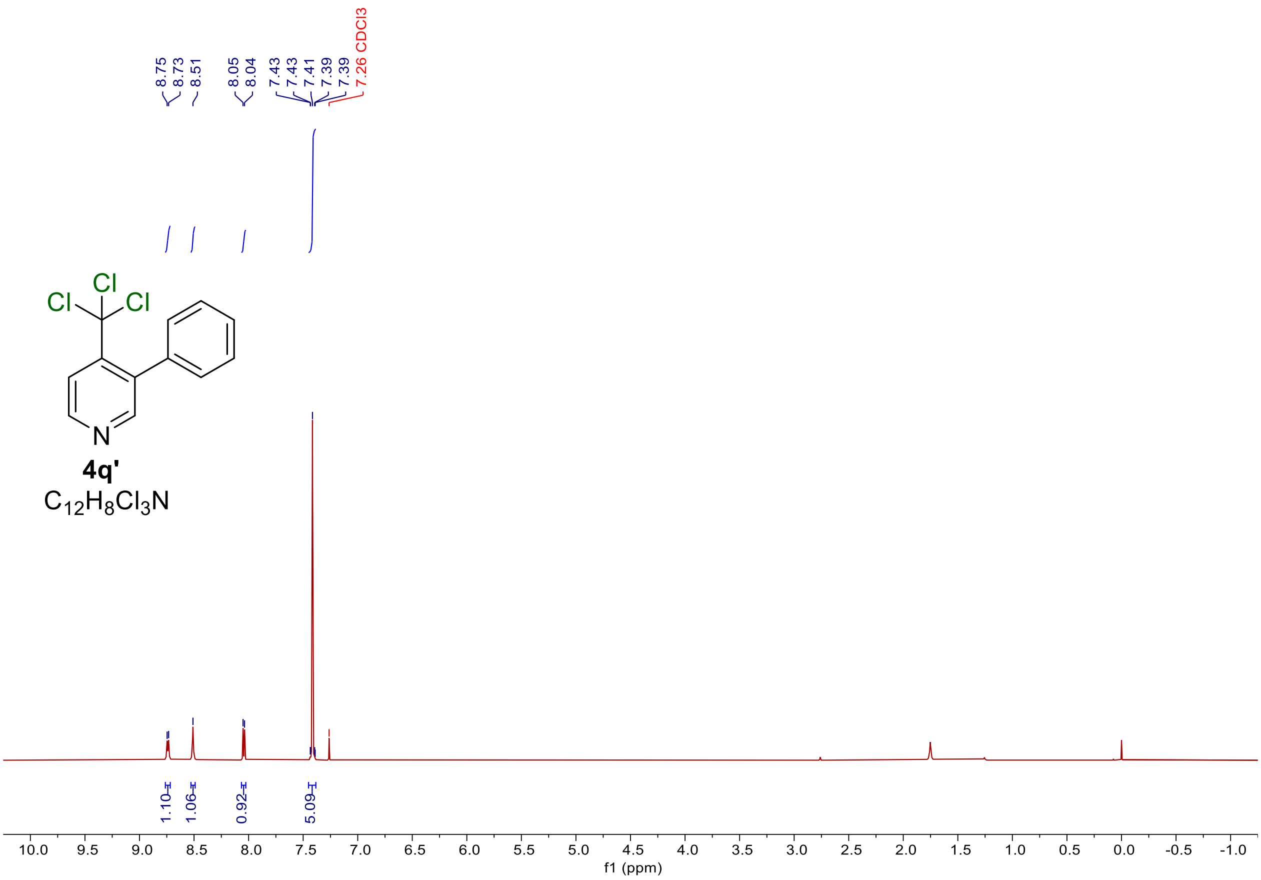
$^{13}C\{^{1}H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4p**.



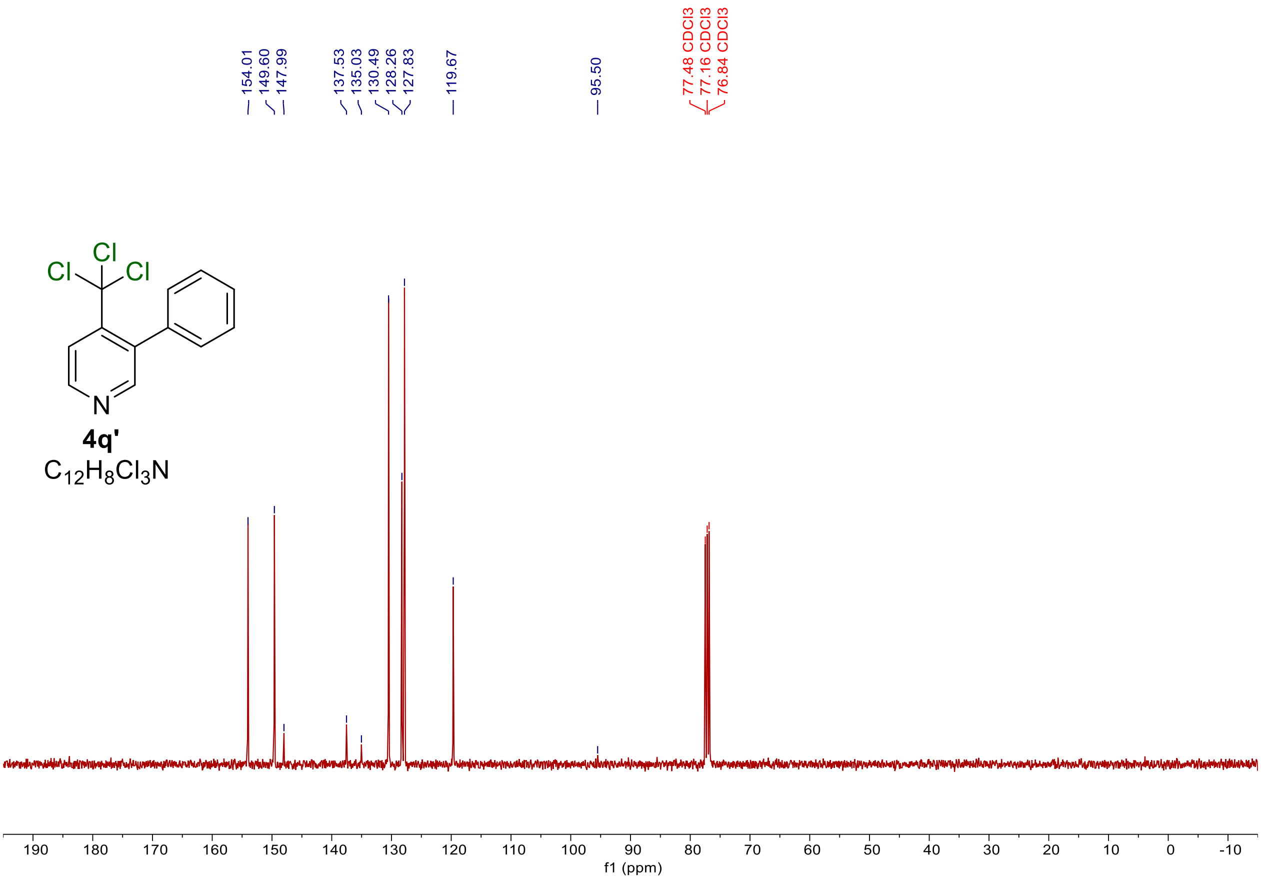
[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **4q**.



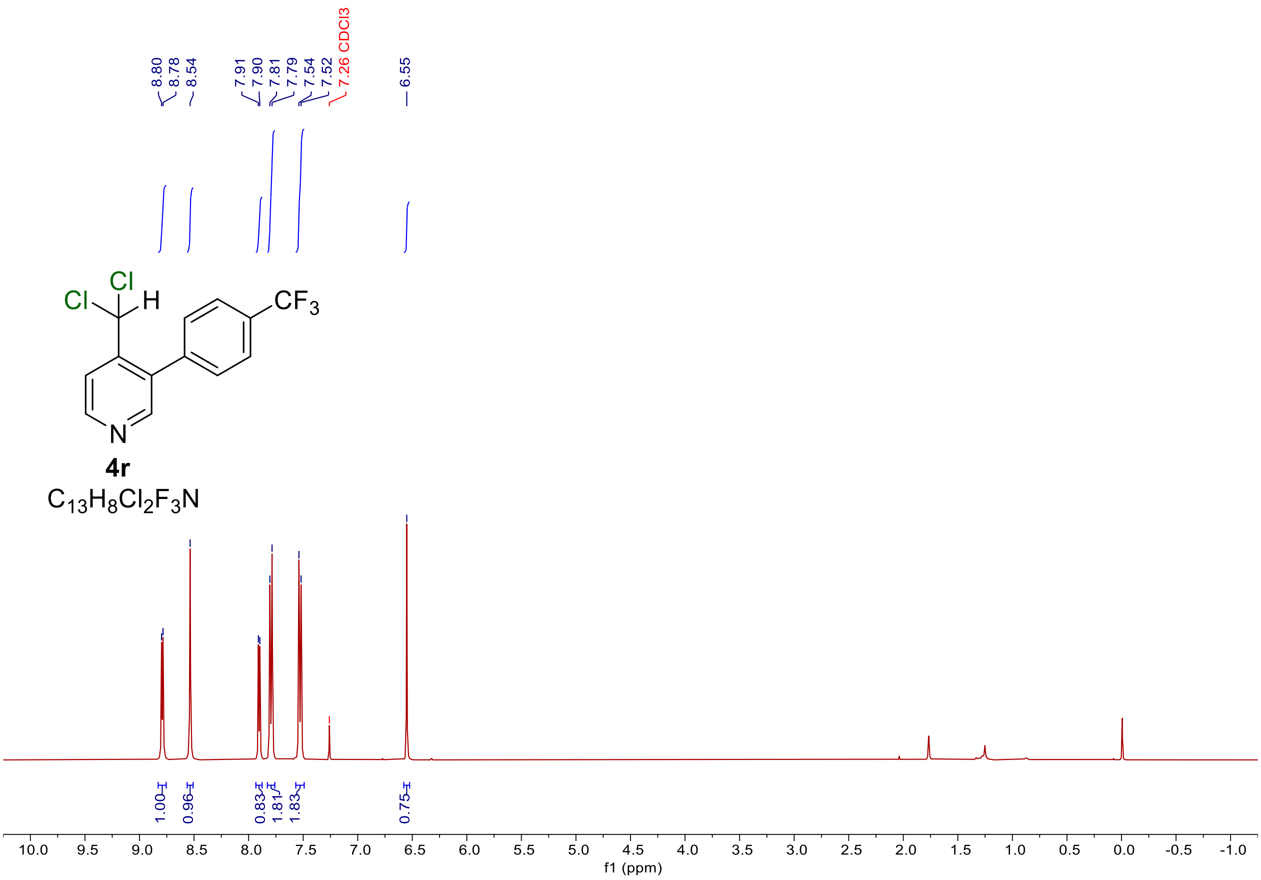
[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4q**.



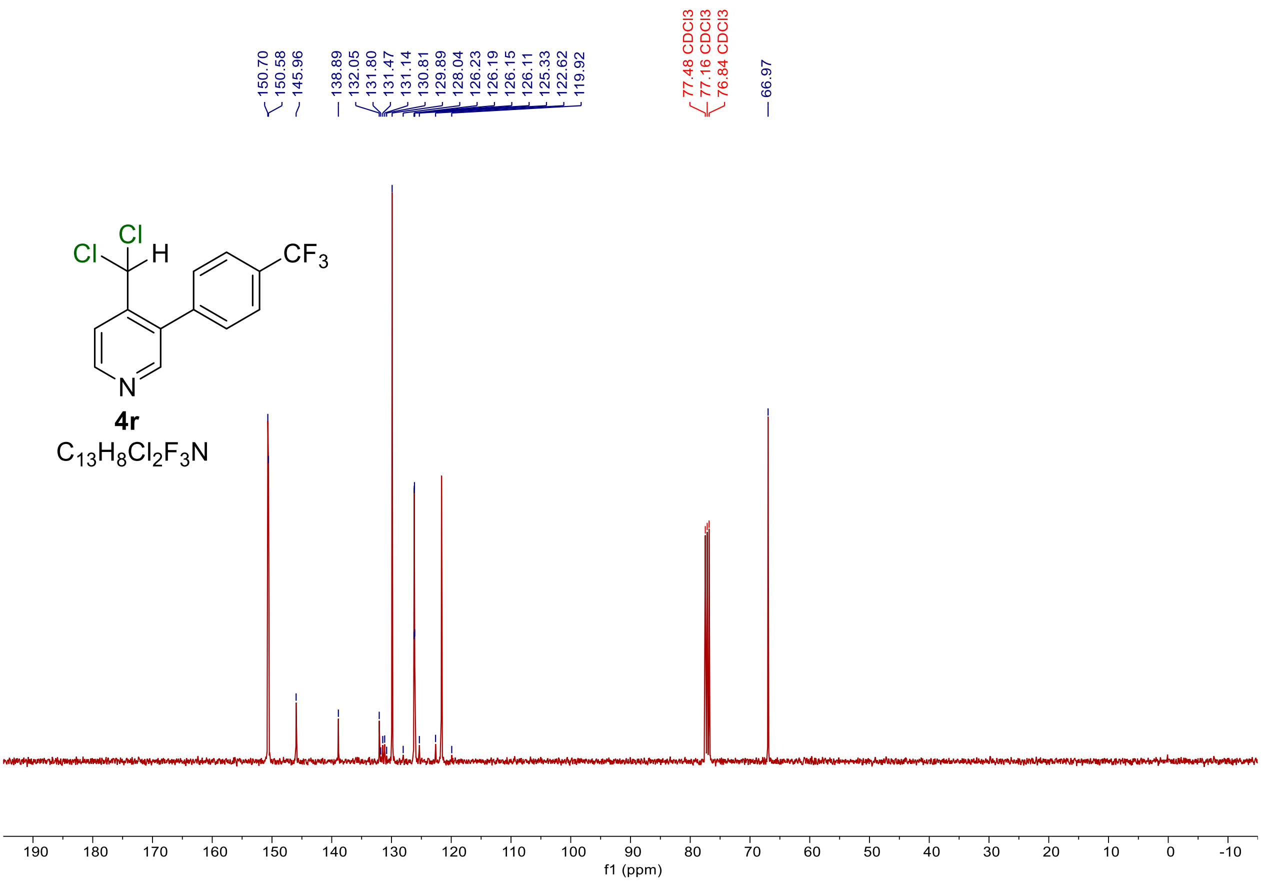
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4q'**.



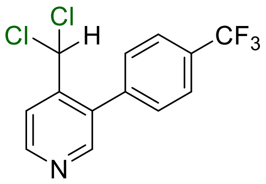
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4q'**.



^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4r**.

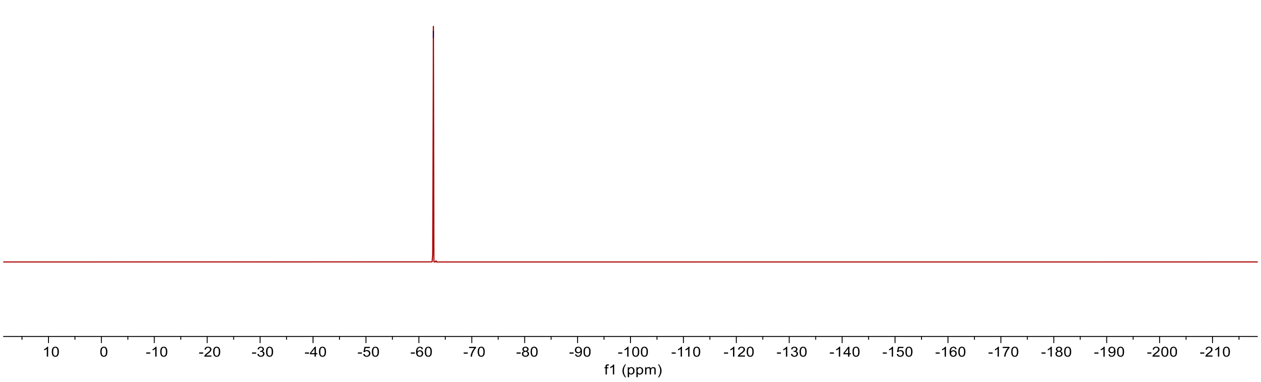


^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4r**.

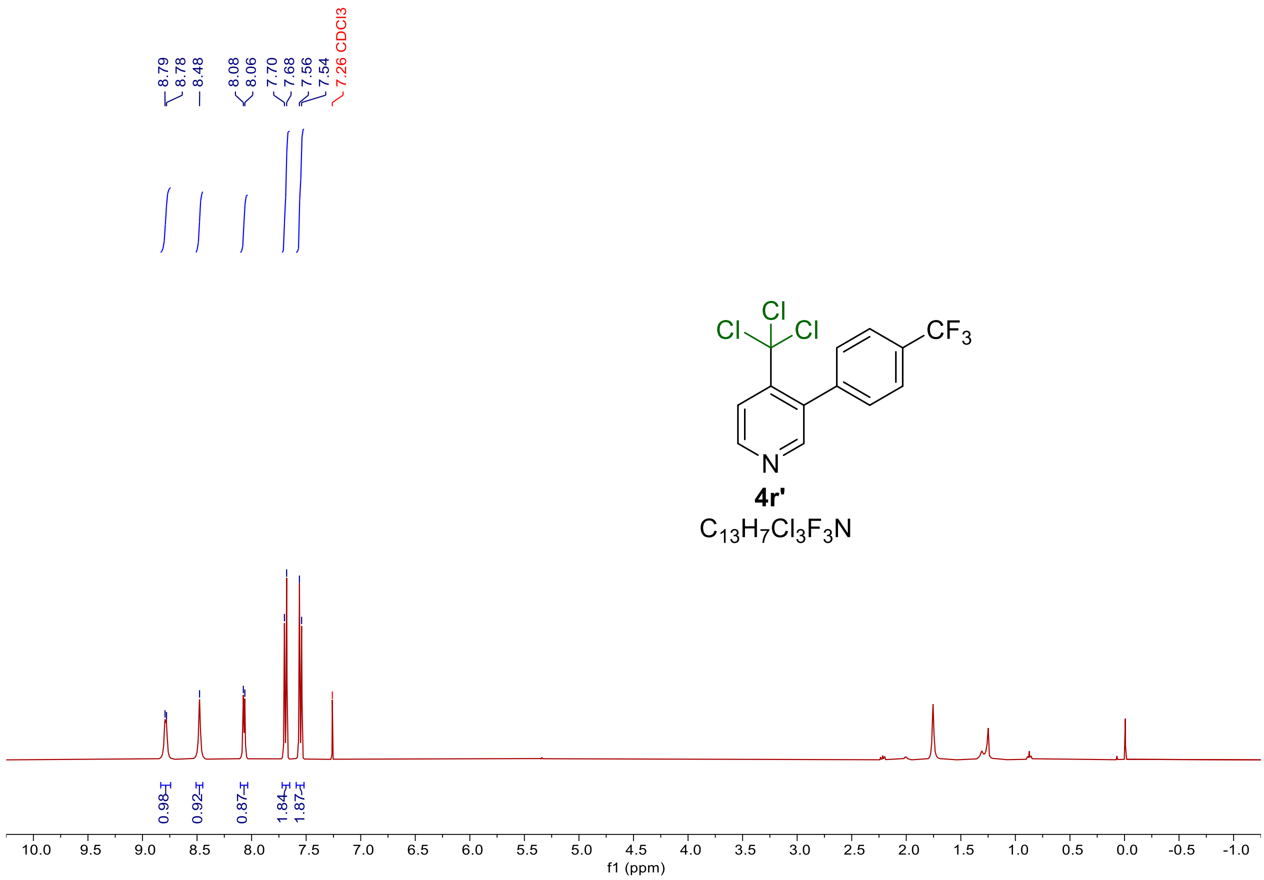


4r

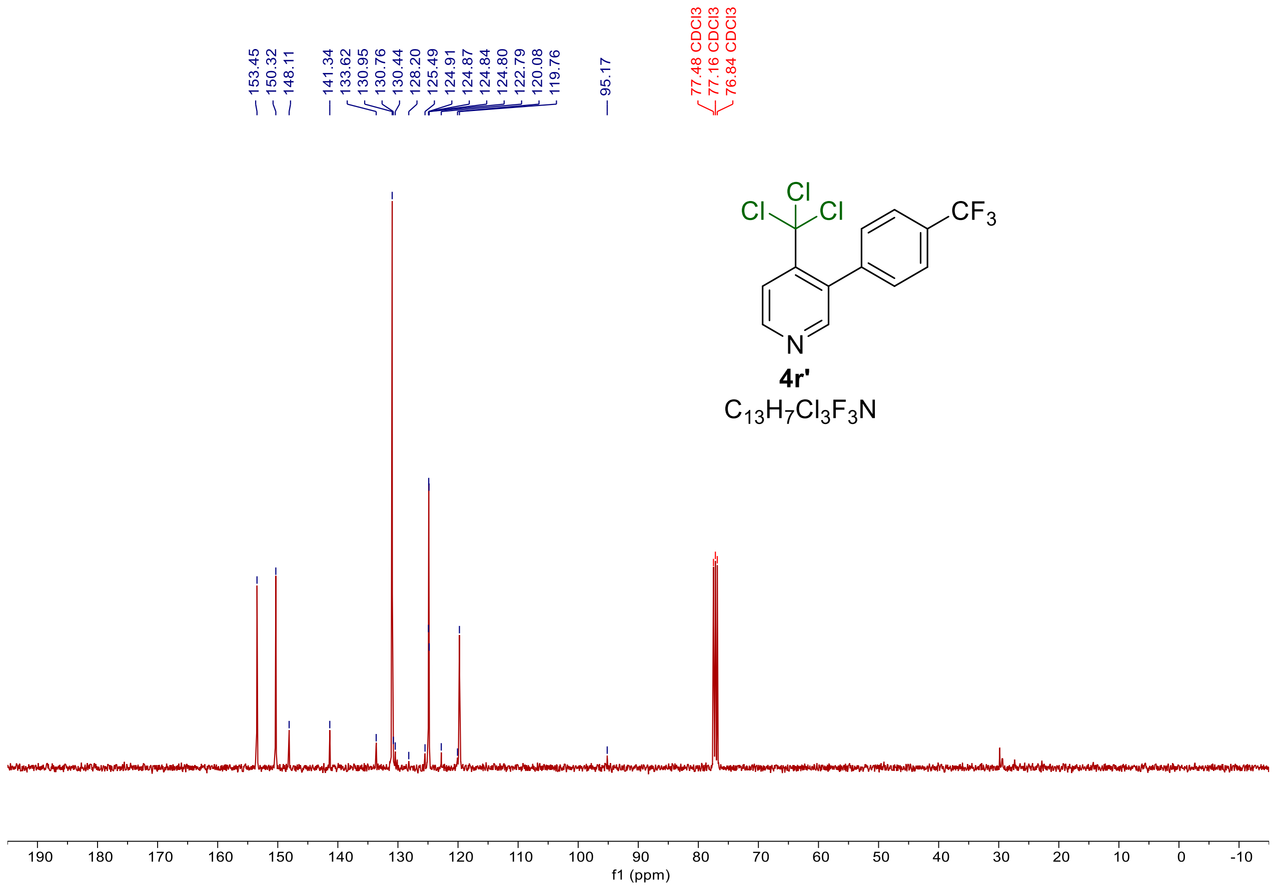
$C_{13}H_8Cl_2F_3N$



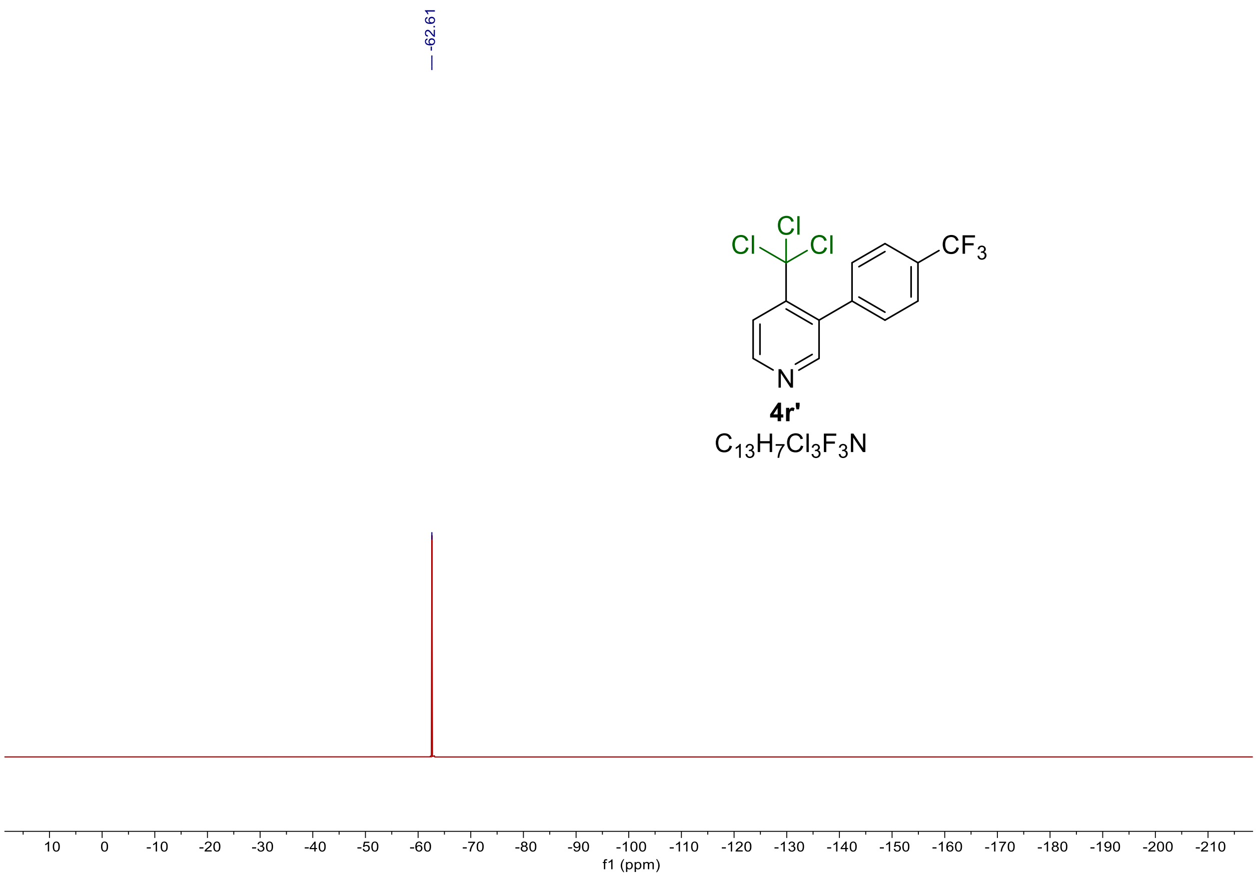
[19]F NMR spectrum (376 MHz, $CDCl_3$) of compound **4r**.



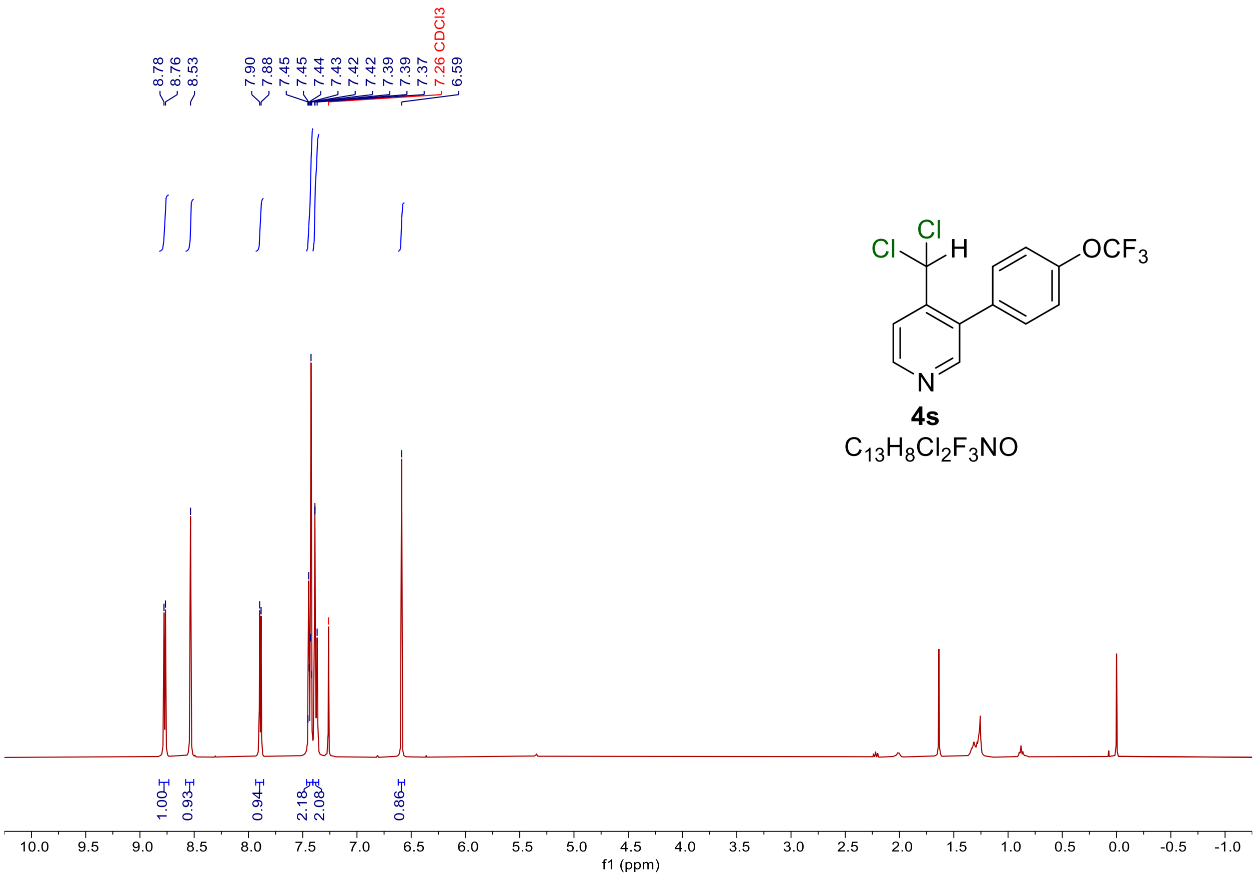
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4r’**.



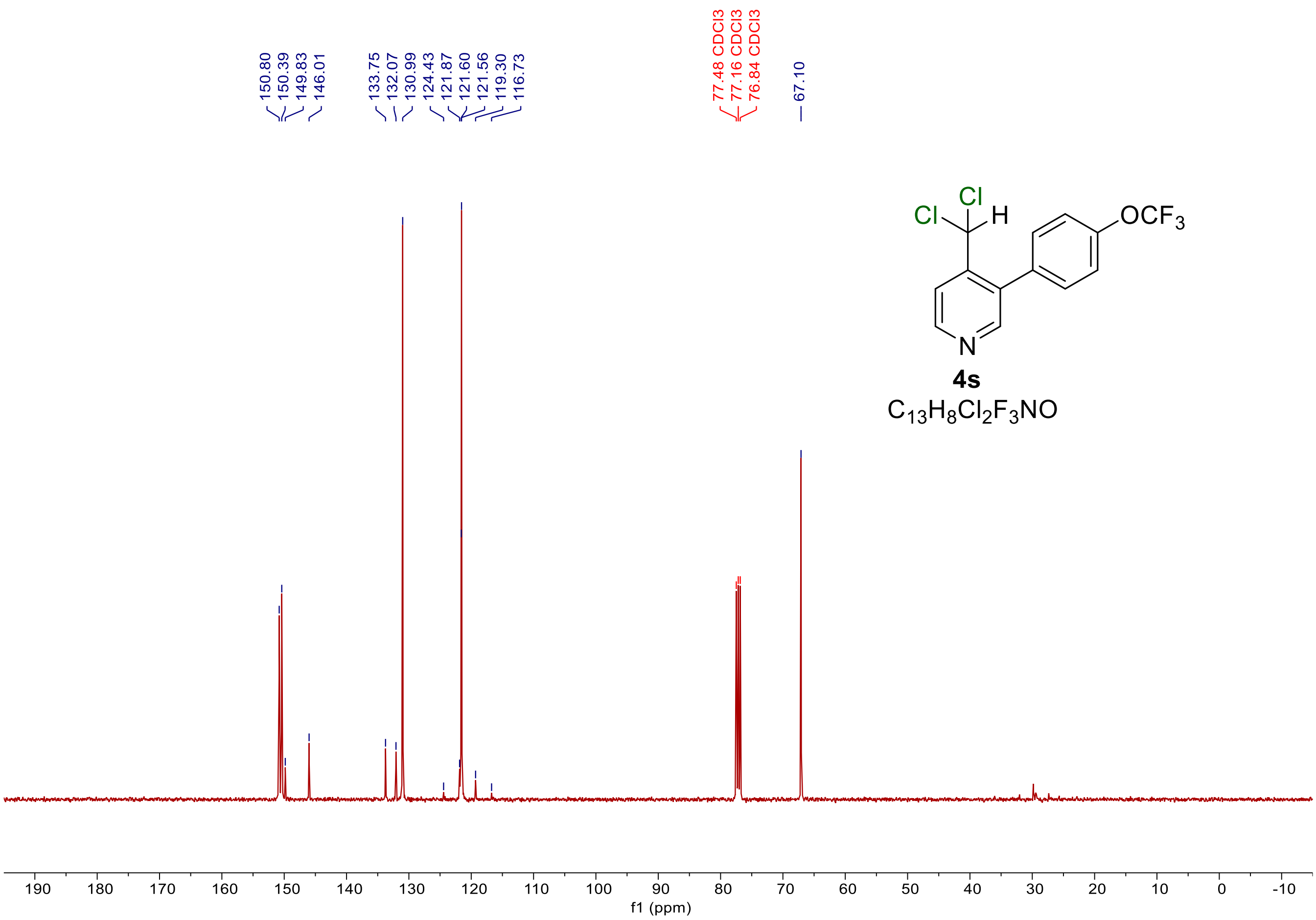
$^{13}C\{^1H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4r’**.



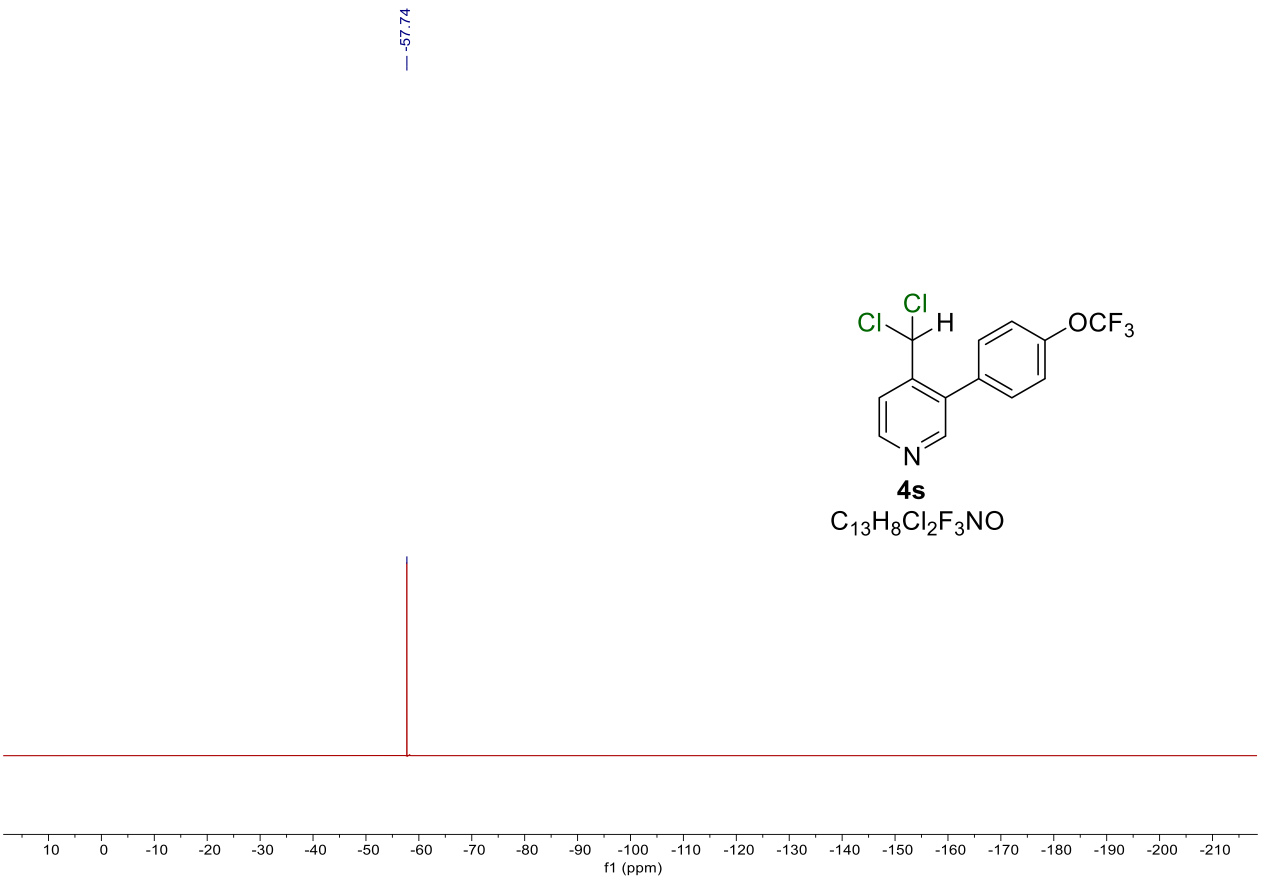
19F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



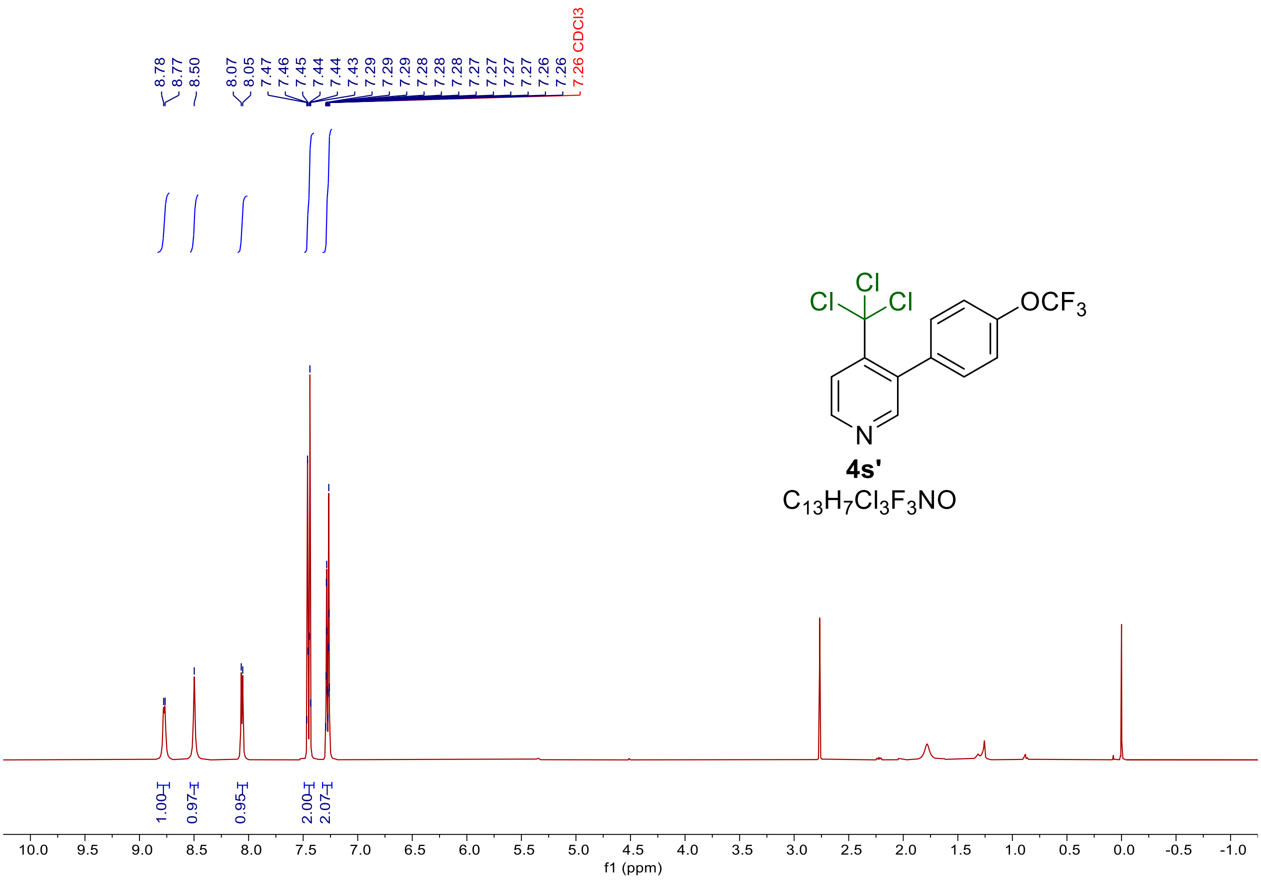
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4s**.



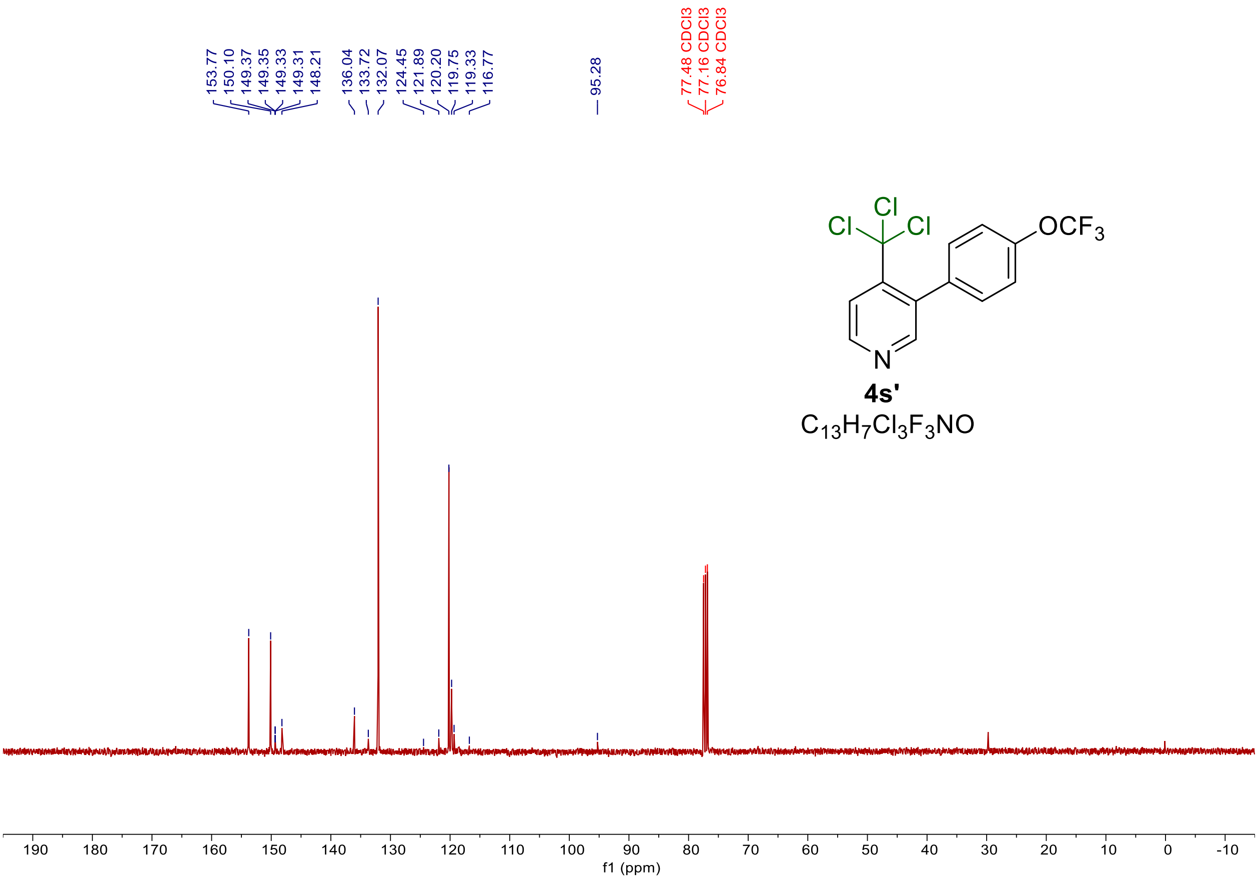
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4s.**



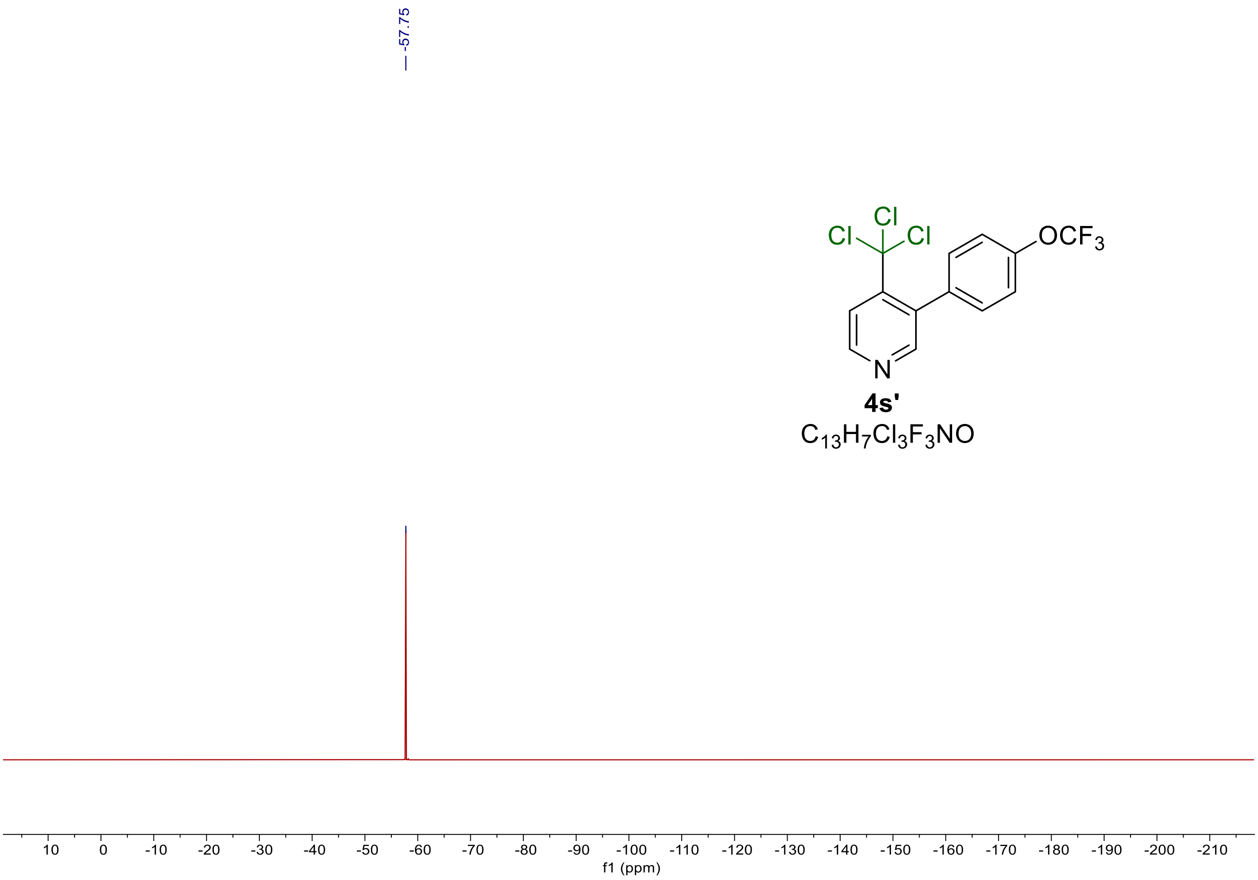
^{19}F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4s'**.



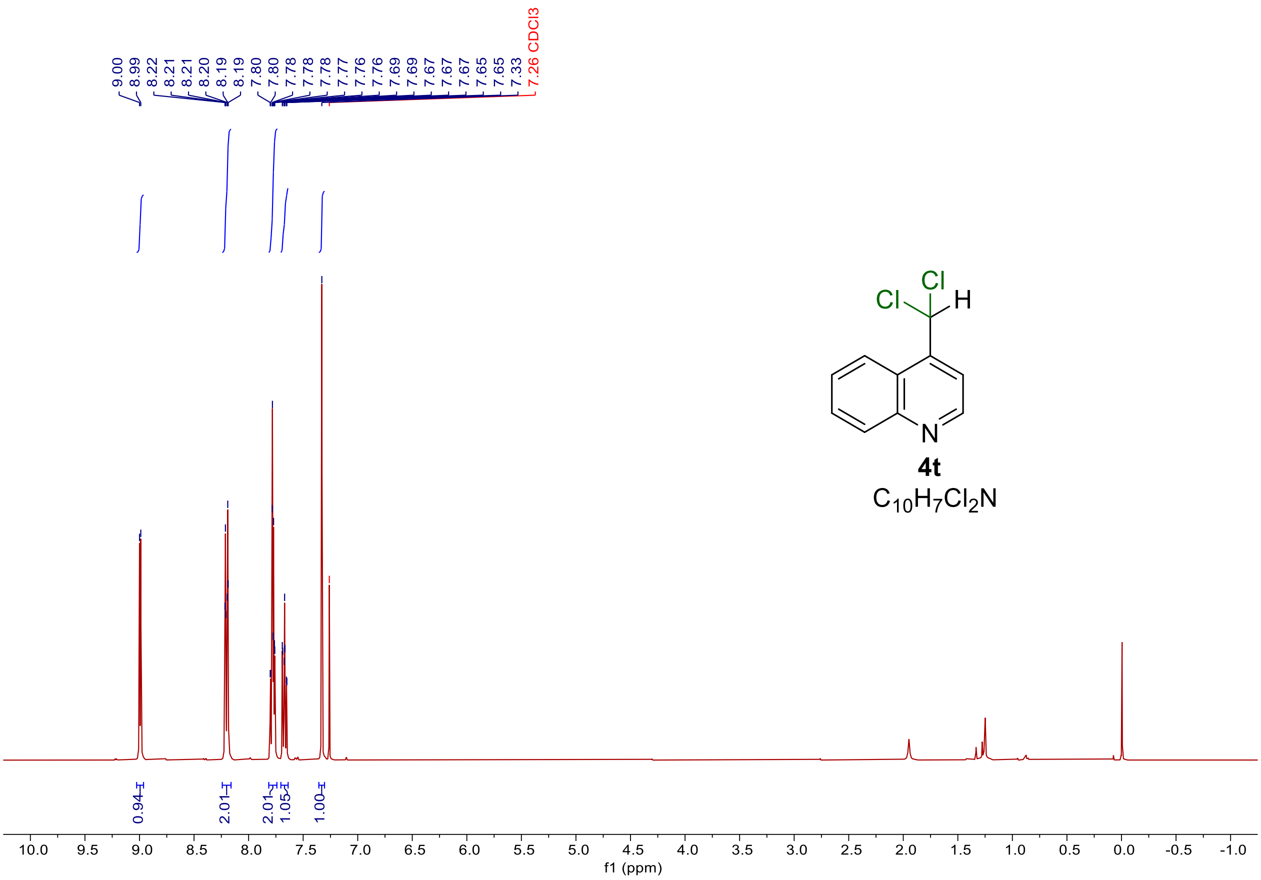
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4s'**.



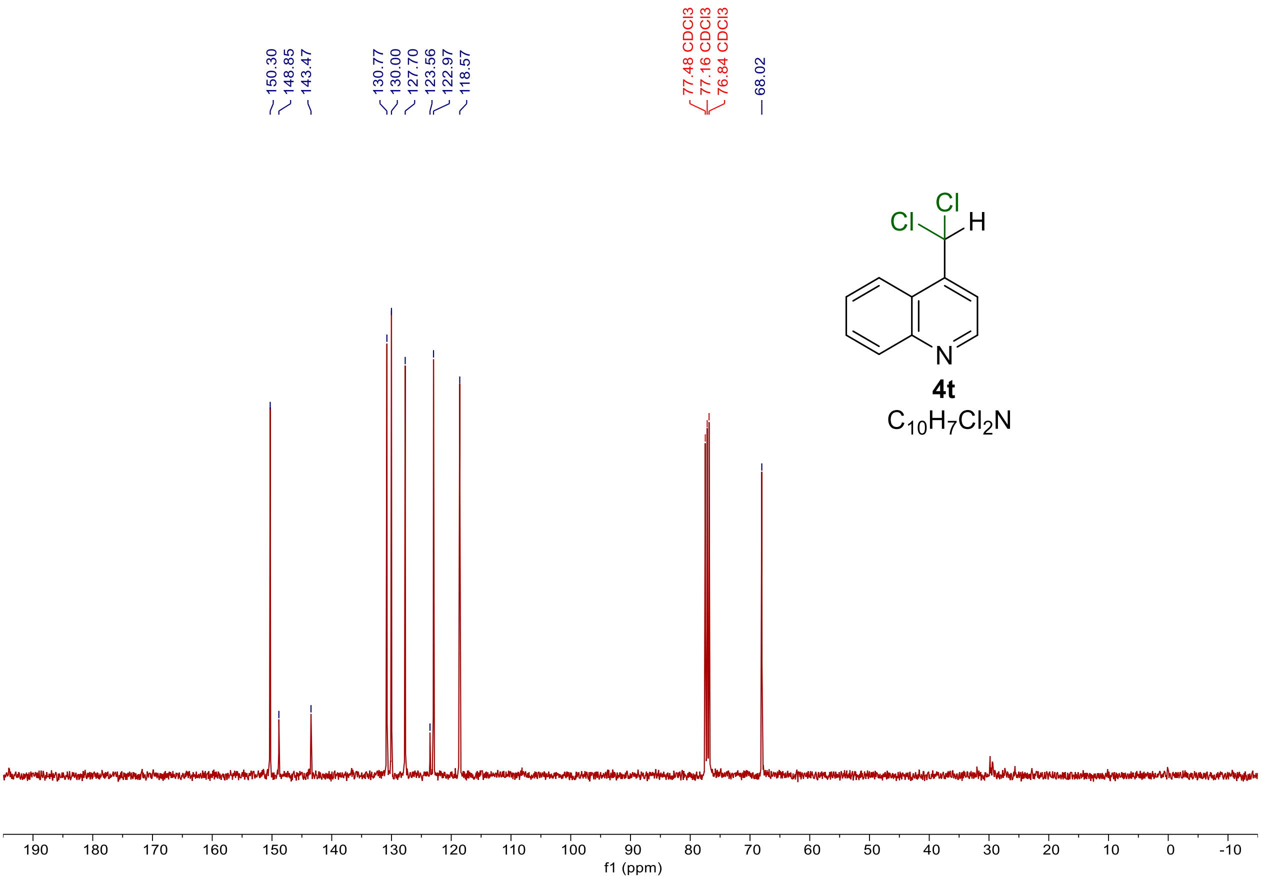
4s'

$C_{13}H_7Cl_3F_3NO$

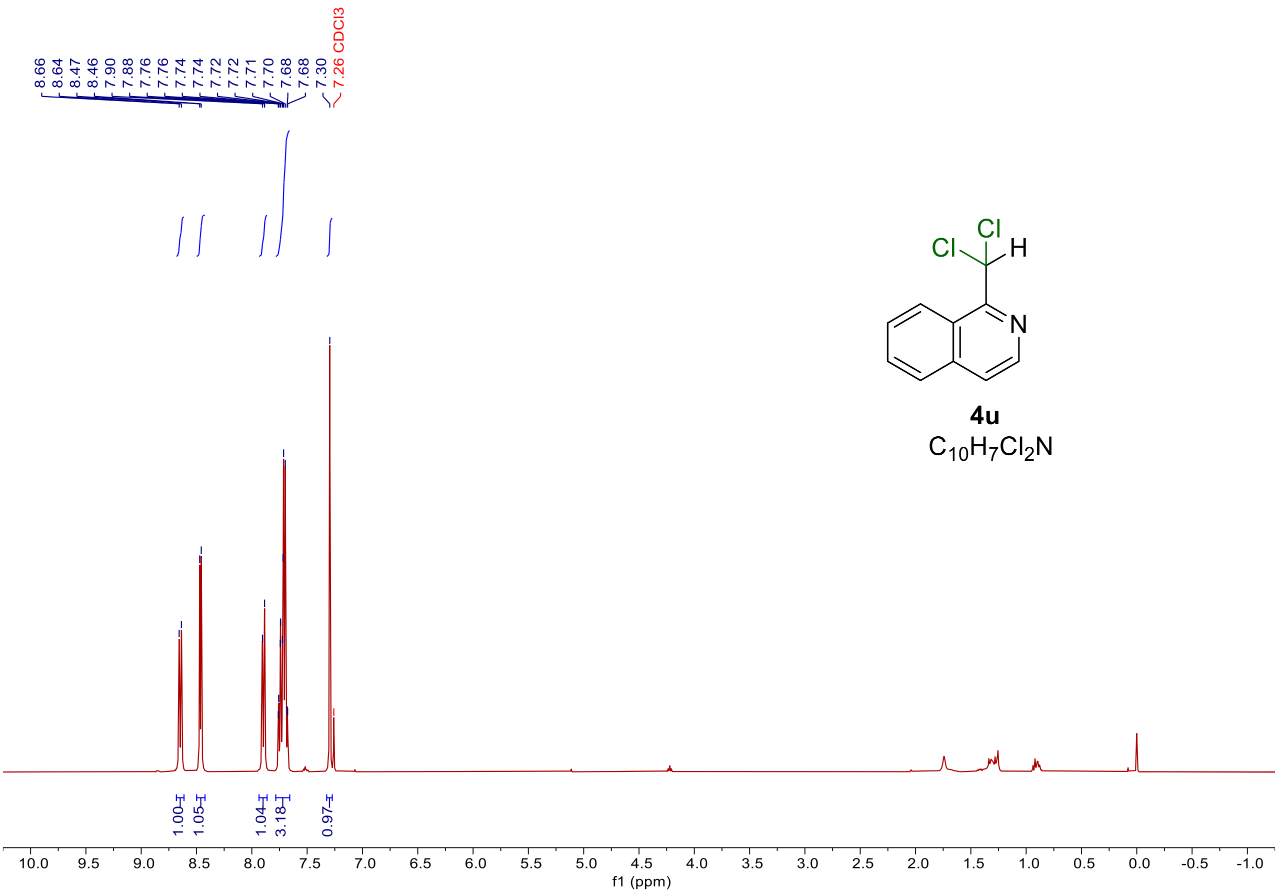
^{19}F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



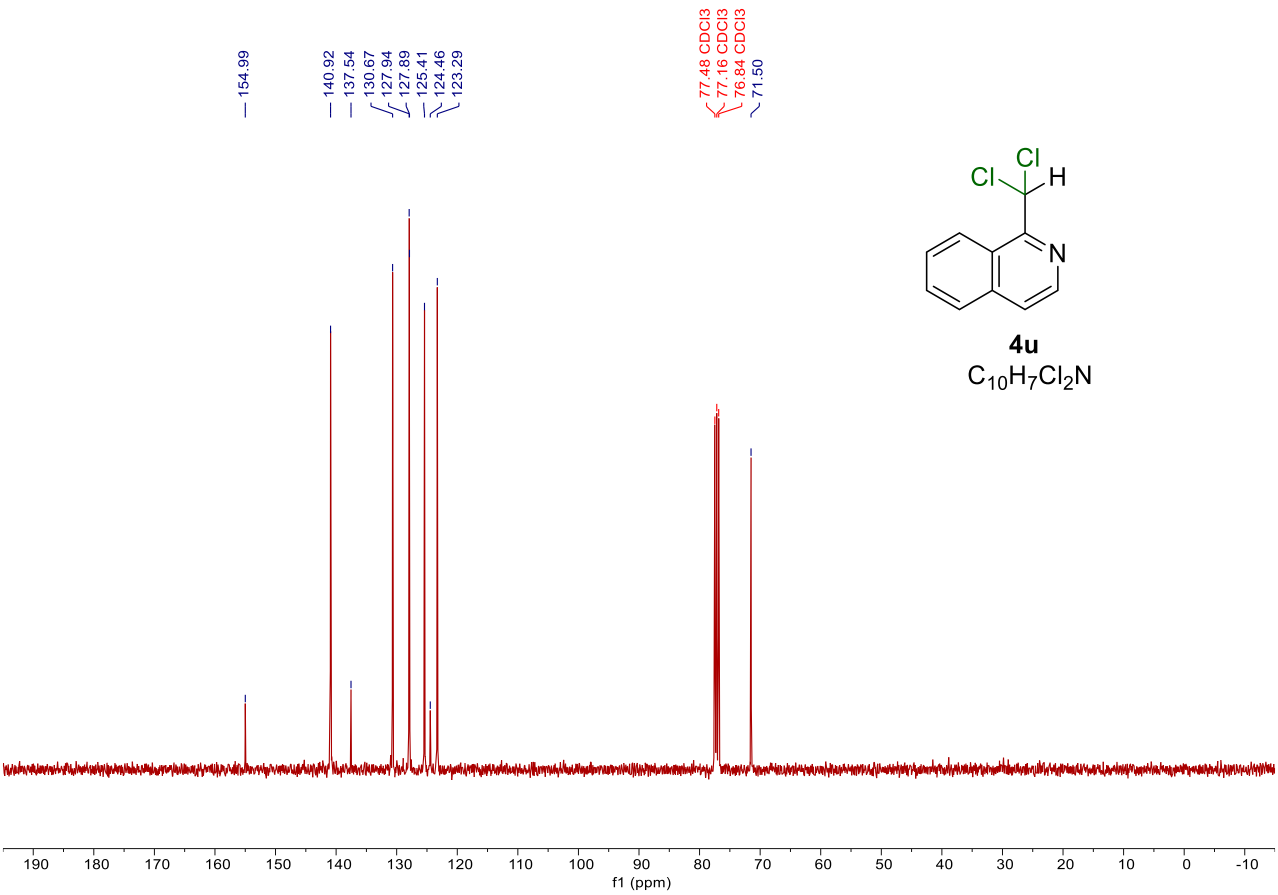
¹H NMR spectrum (400 MHz, CDCl₃) of compound **4t.**



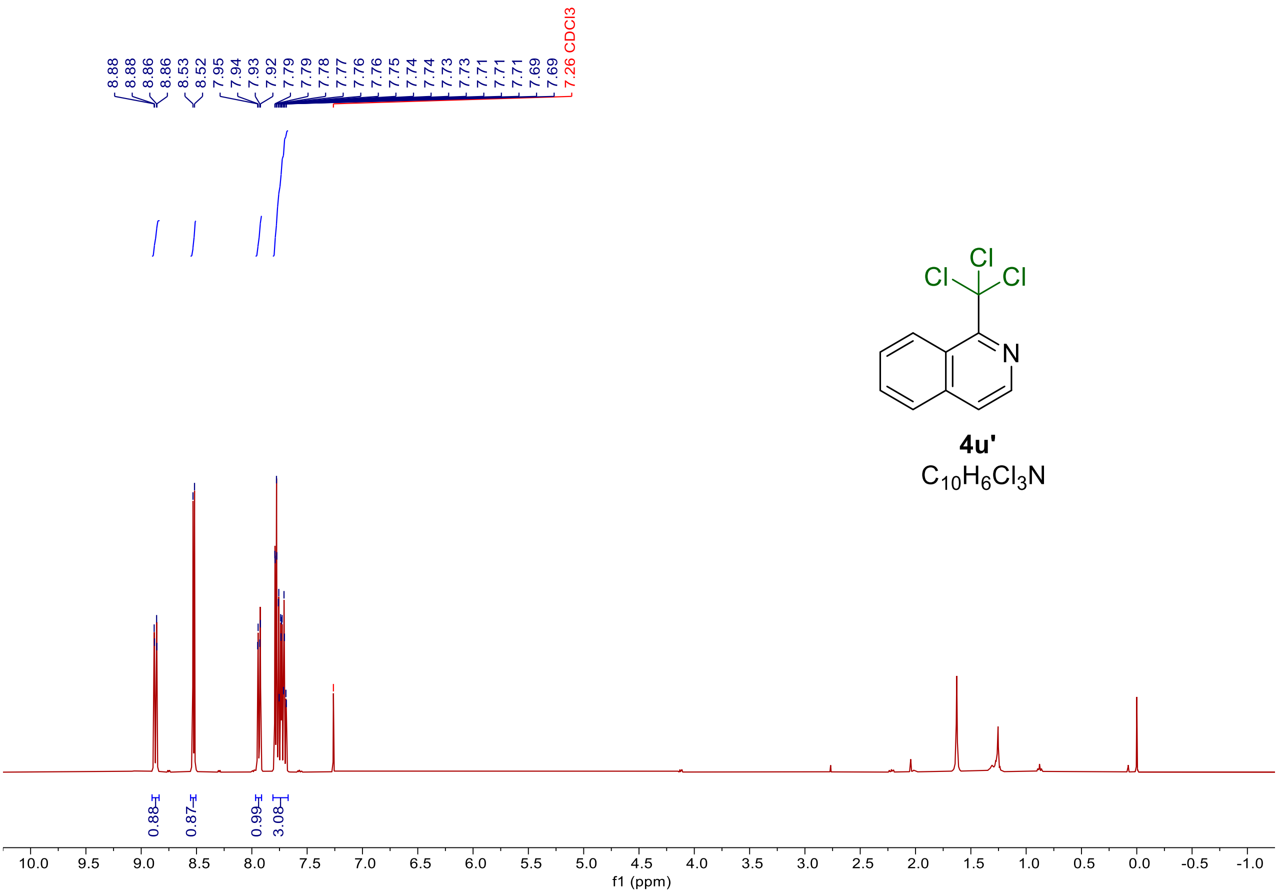
^{13}C{^{1}H} NMR spectrum (101 MHz, CDCl₃) of compound **4t.**



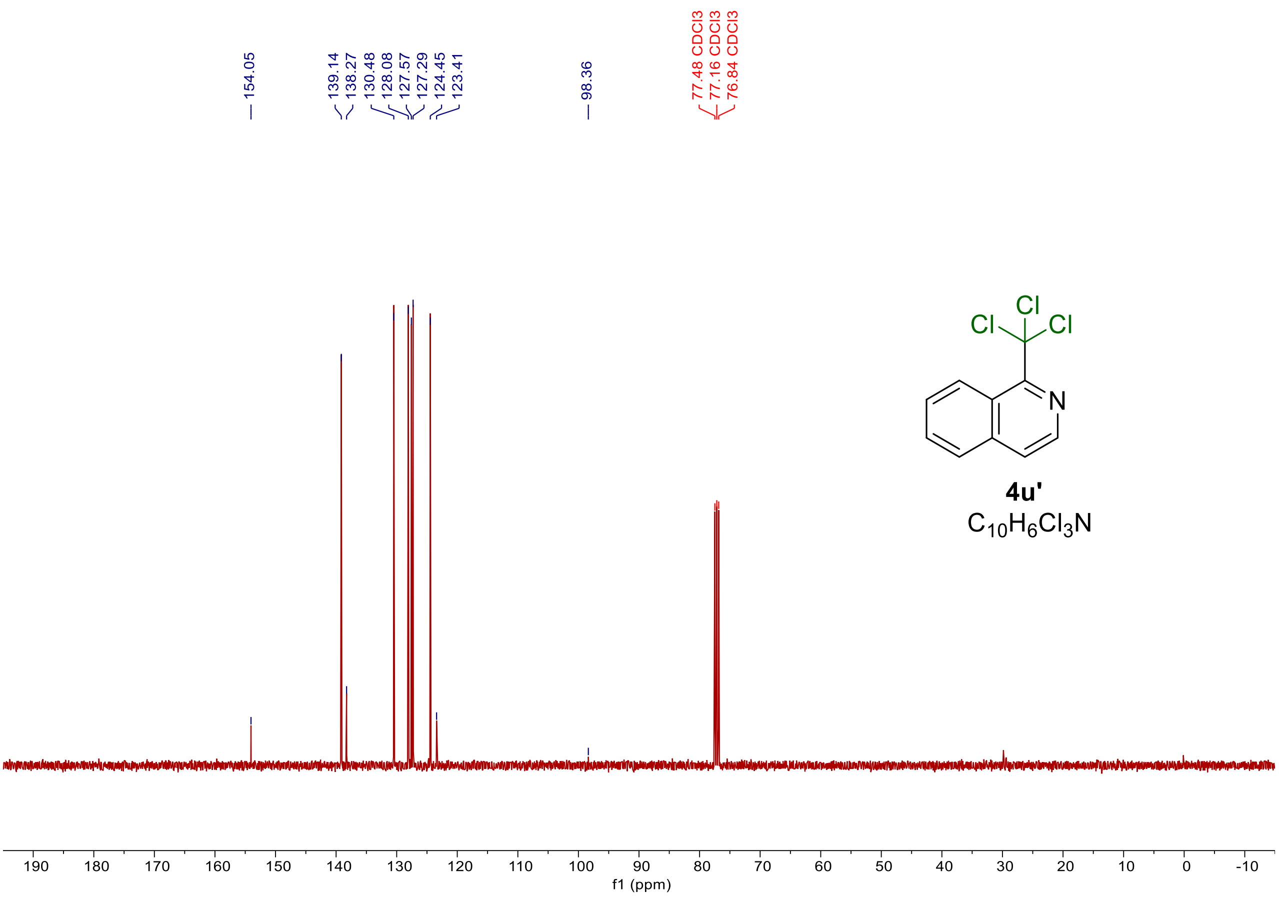
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4u**.



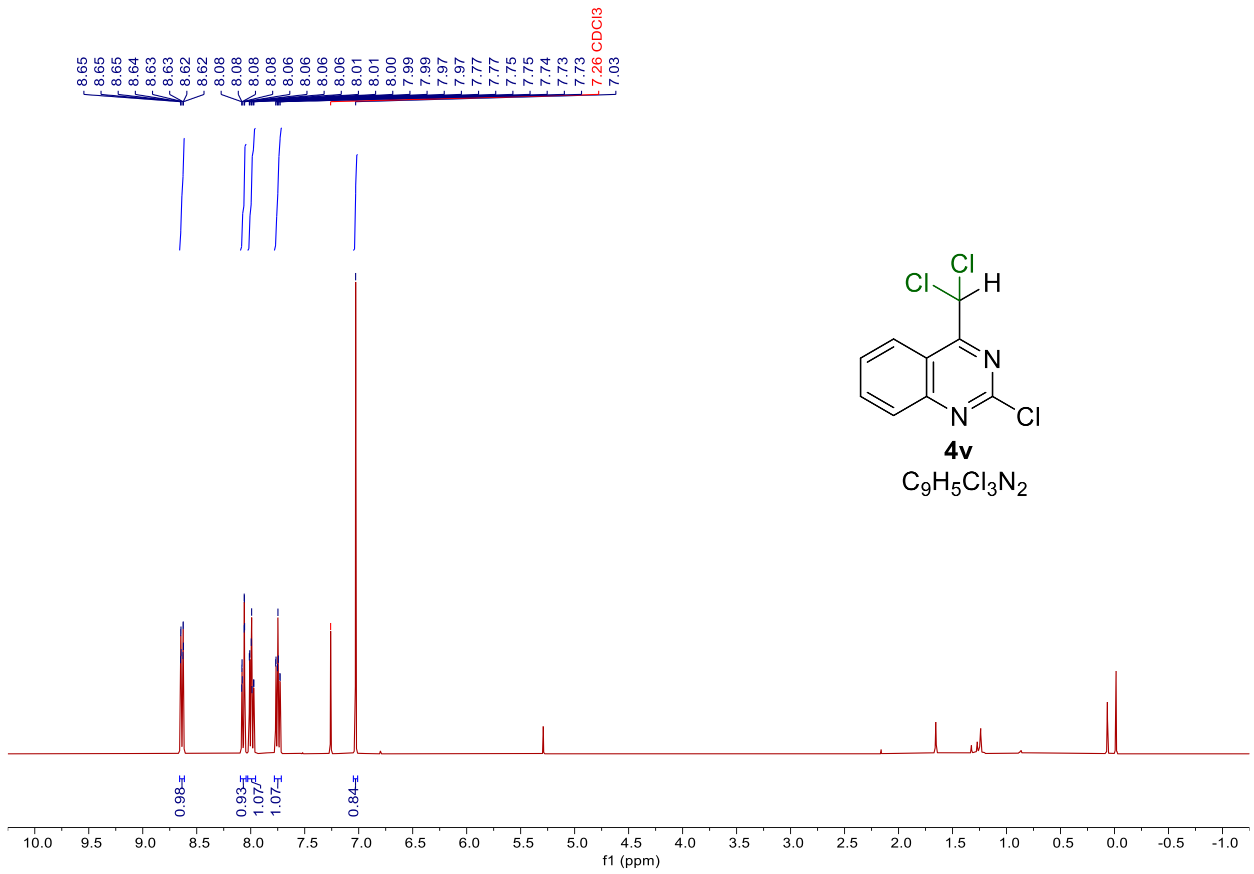
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4u**.



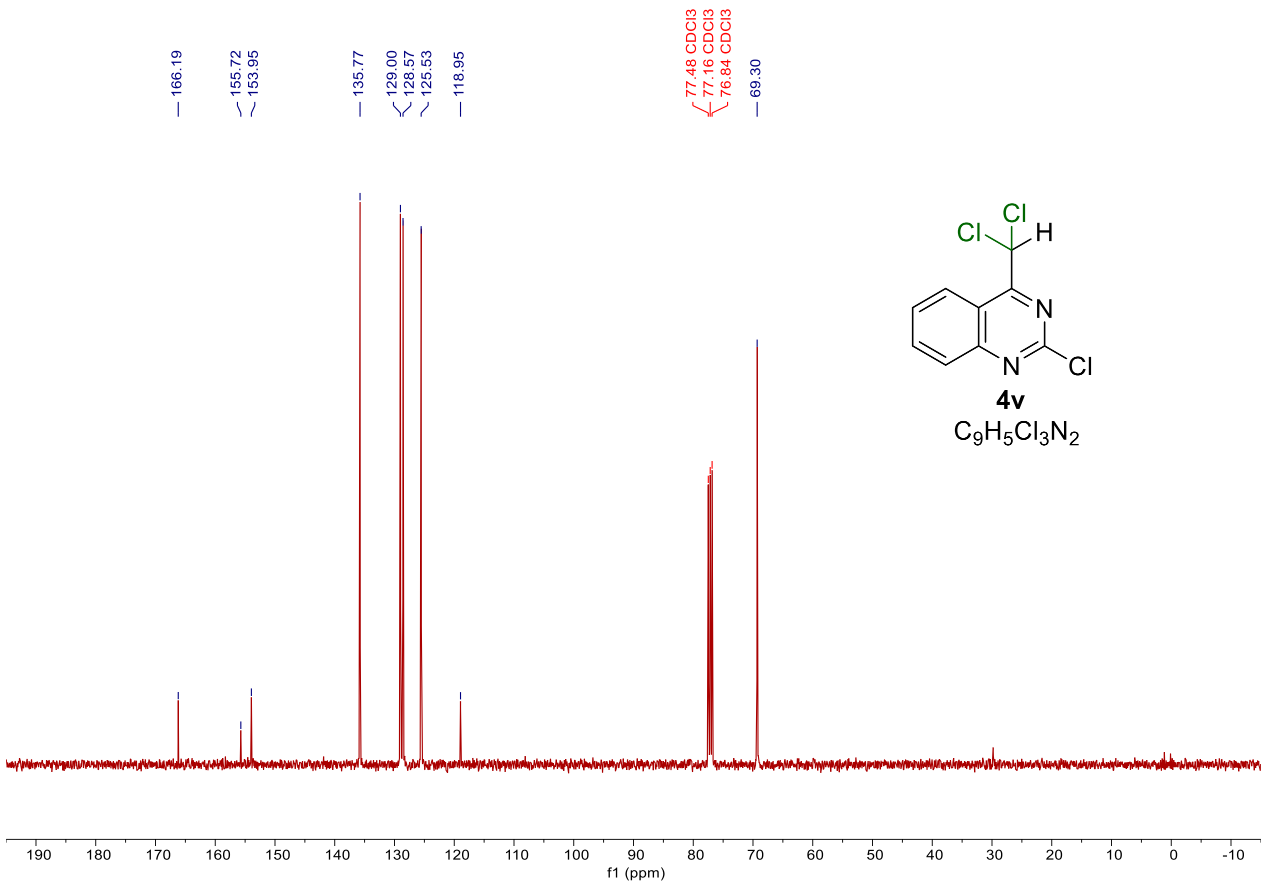
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4u'**.



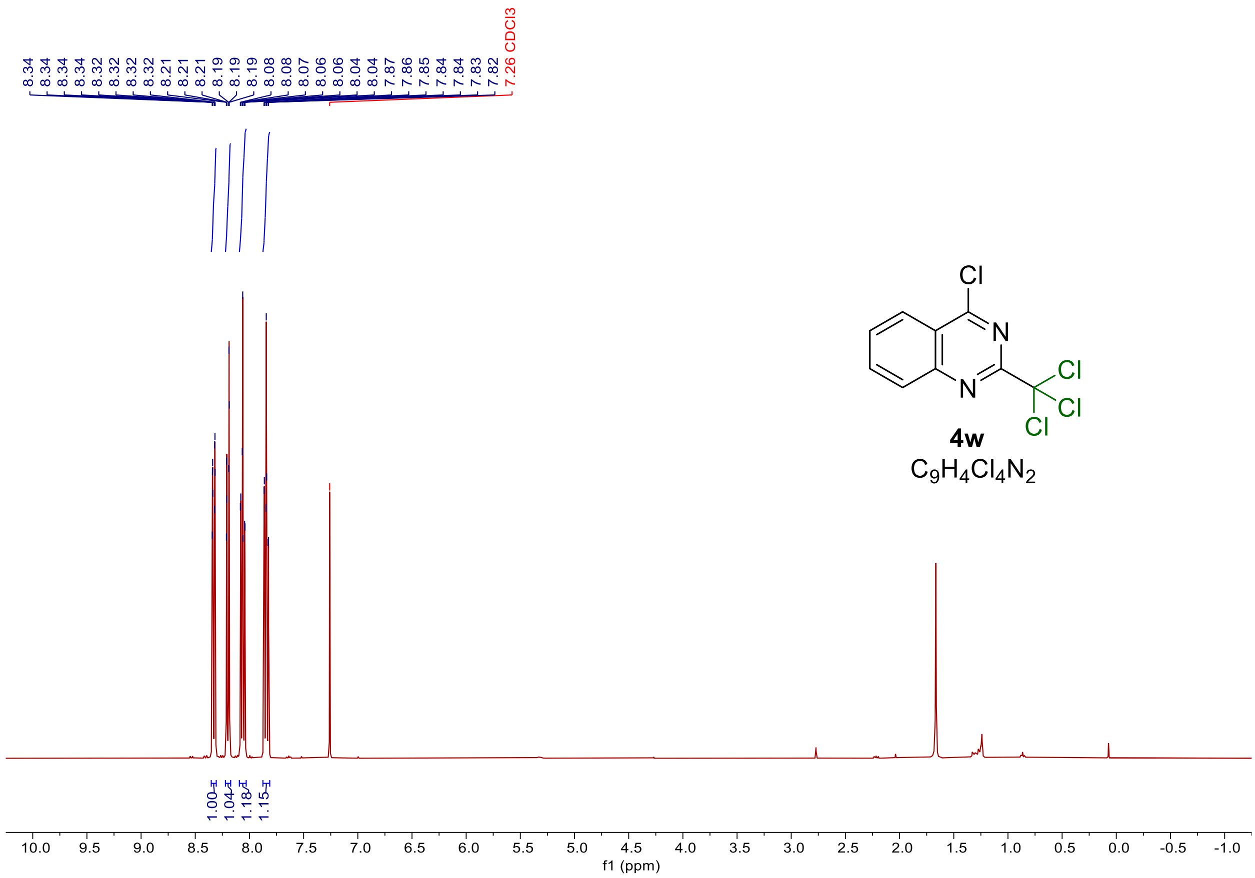
$^{13}C\{^1H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4u'**.



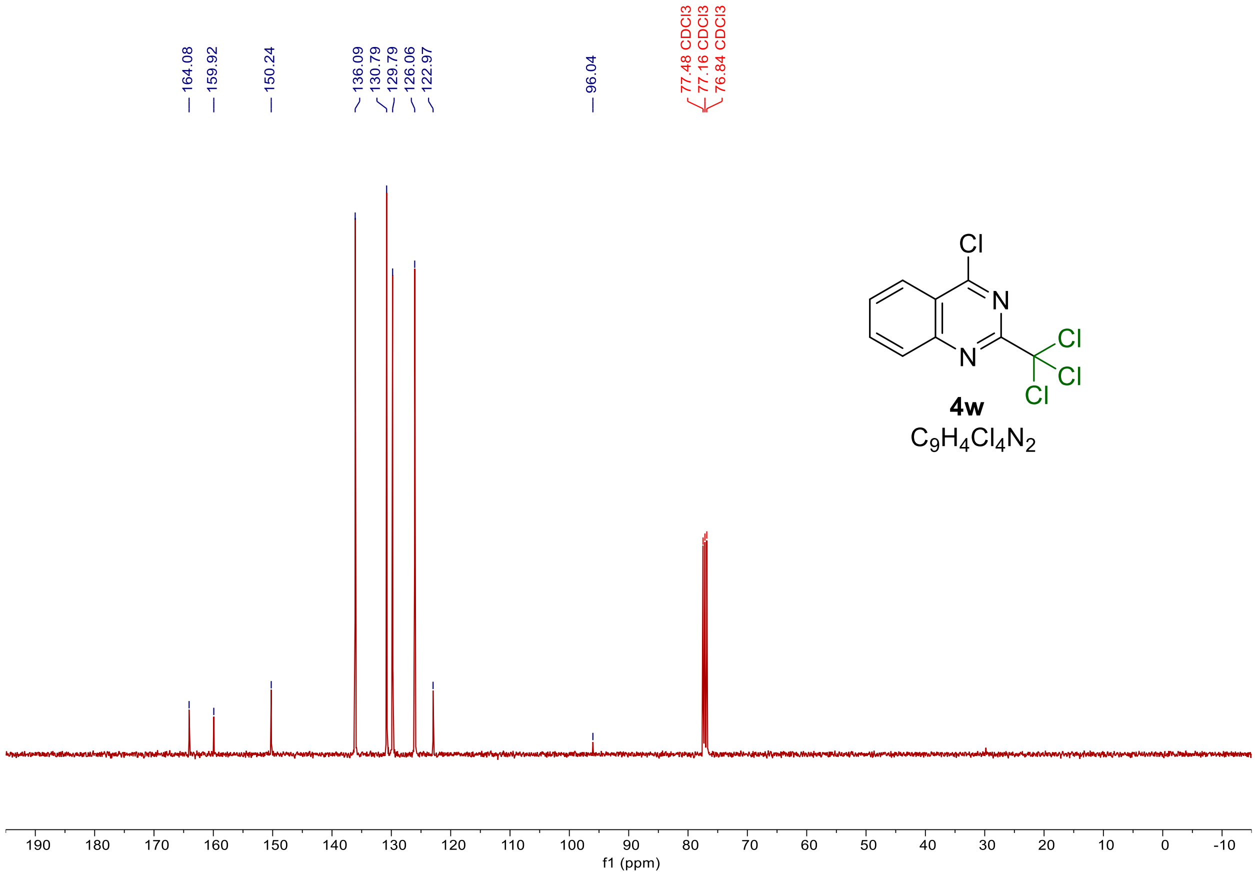
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4v**.



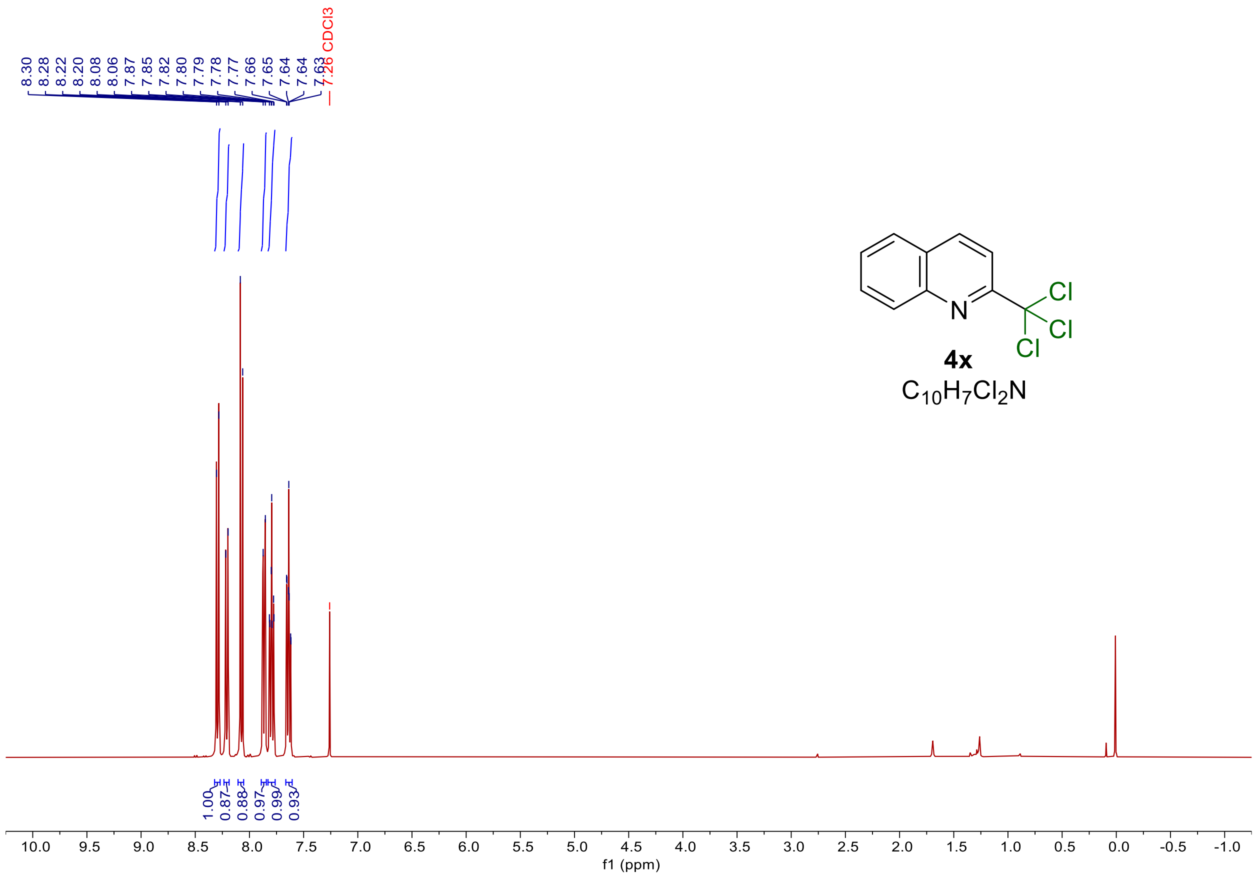
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4v**.



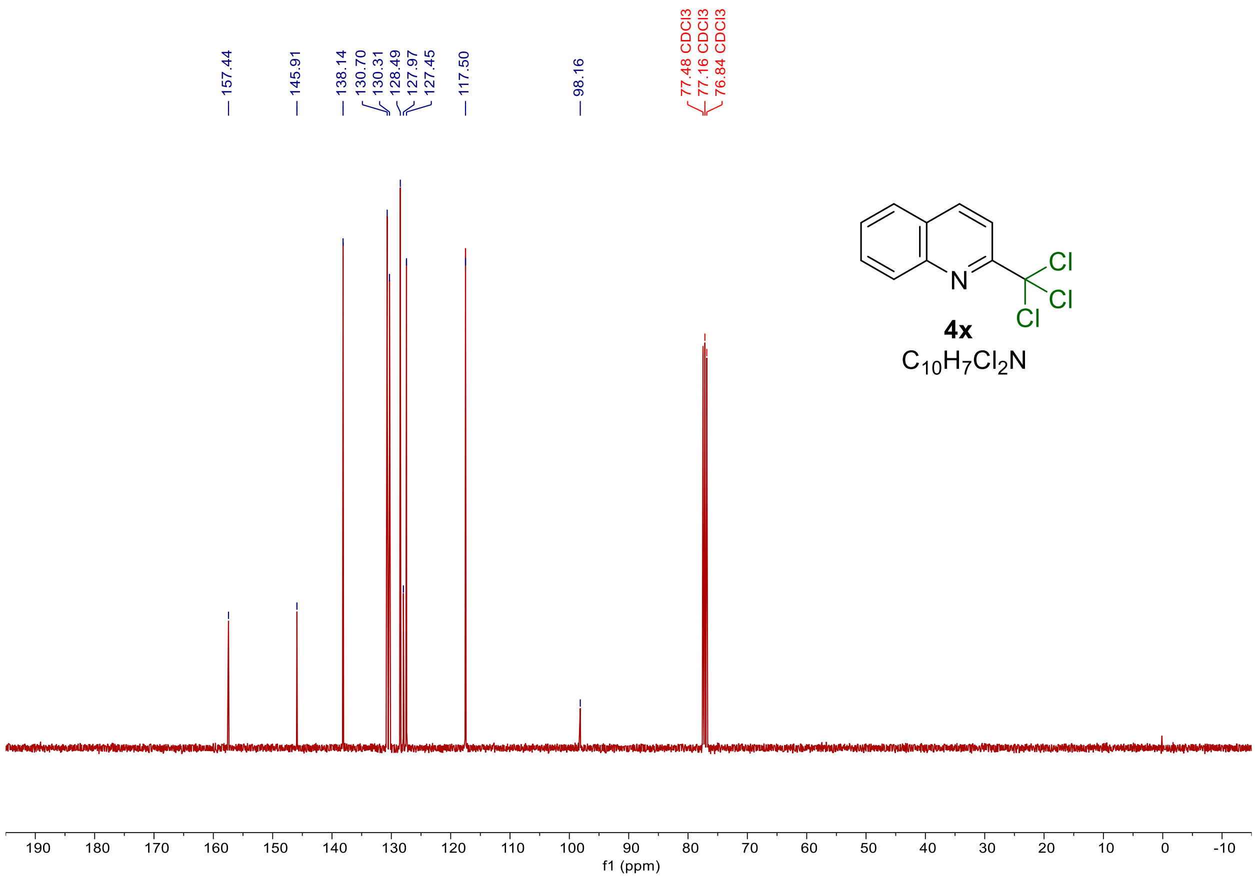
1H NMR spectrum (400 MHz, CDCl3) of compound **4w**.



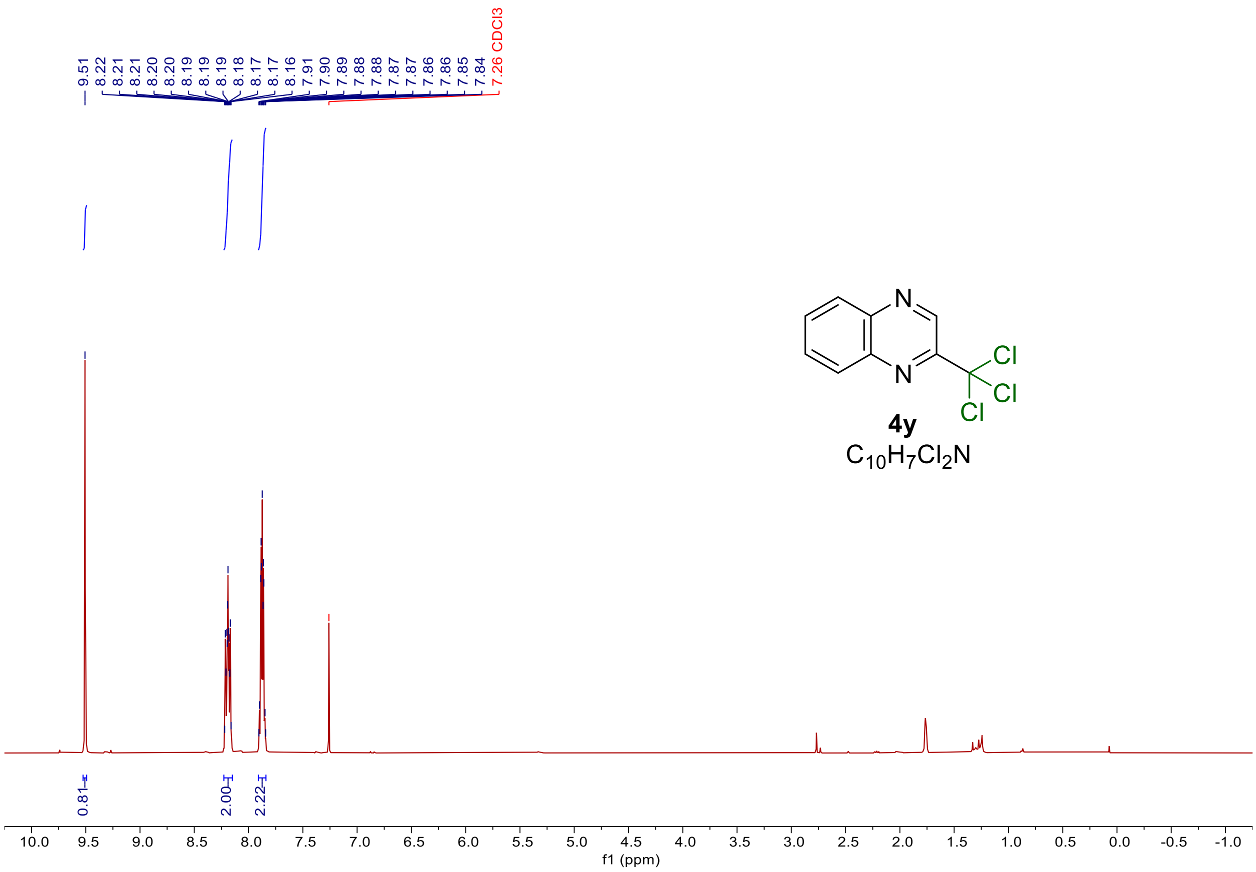
13C{1H} NMR spectrum (101 MHz, CDCl3) of compound **4w**.



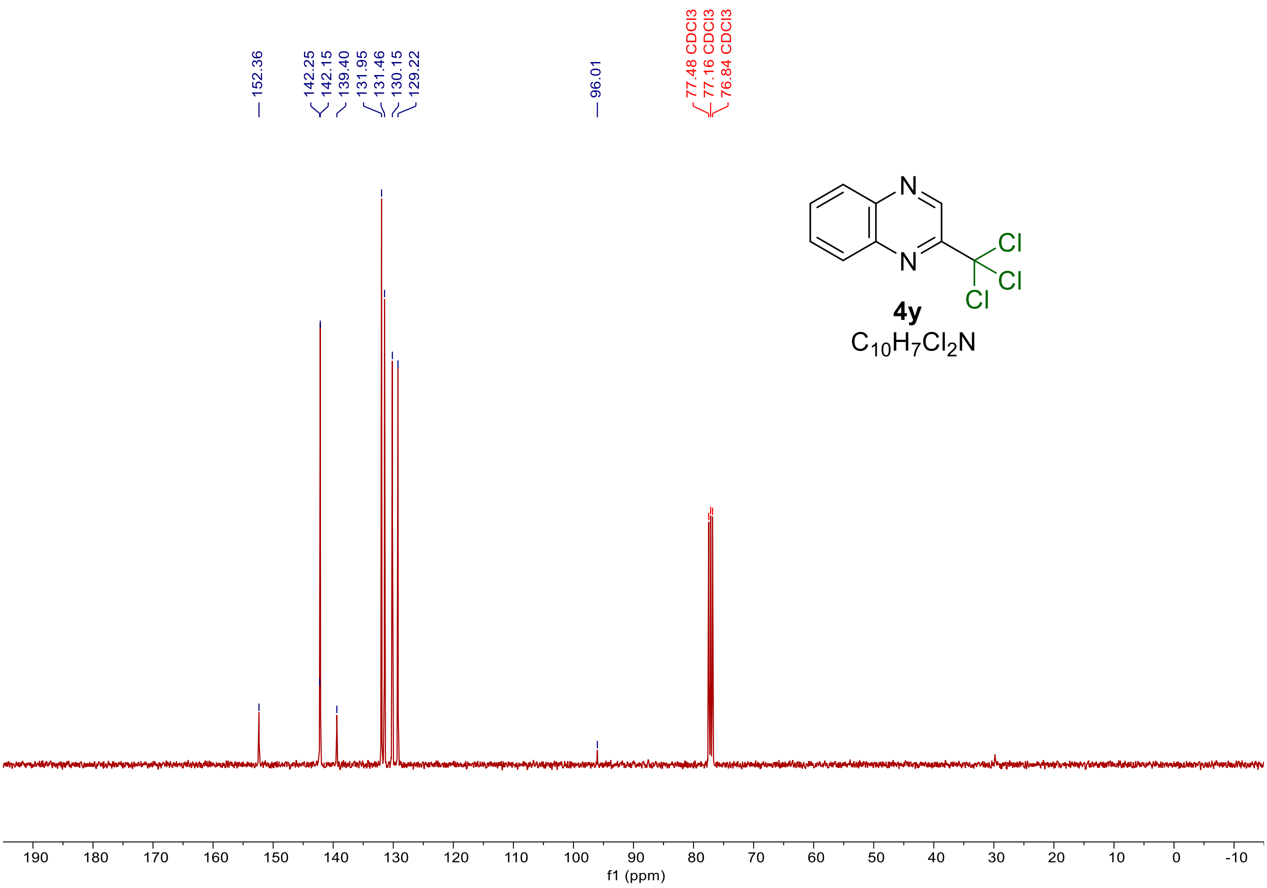
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4x**.



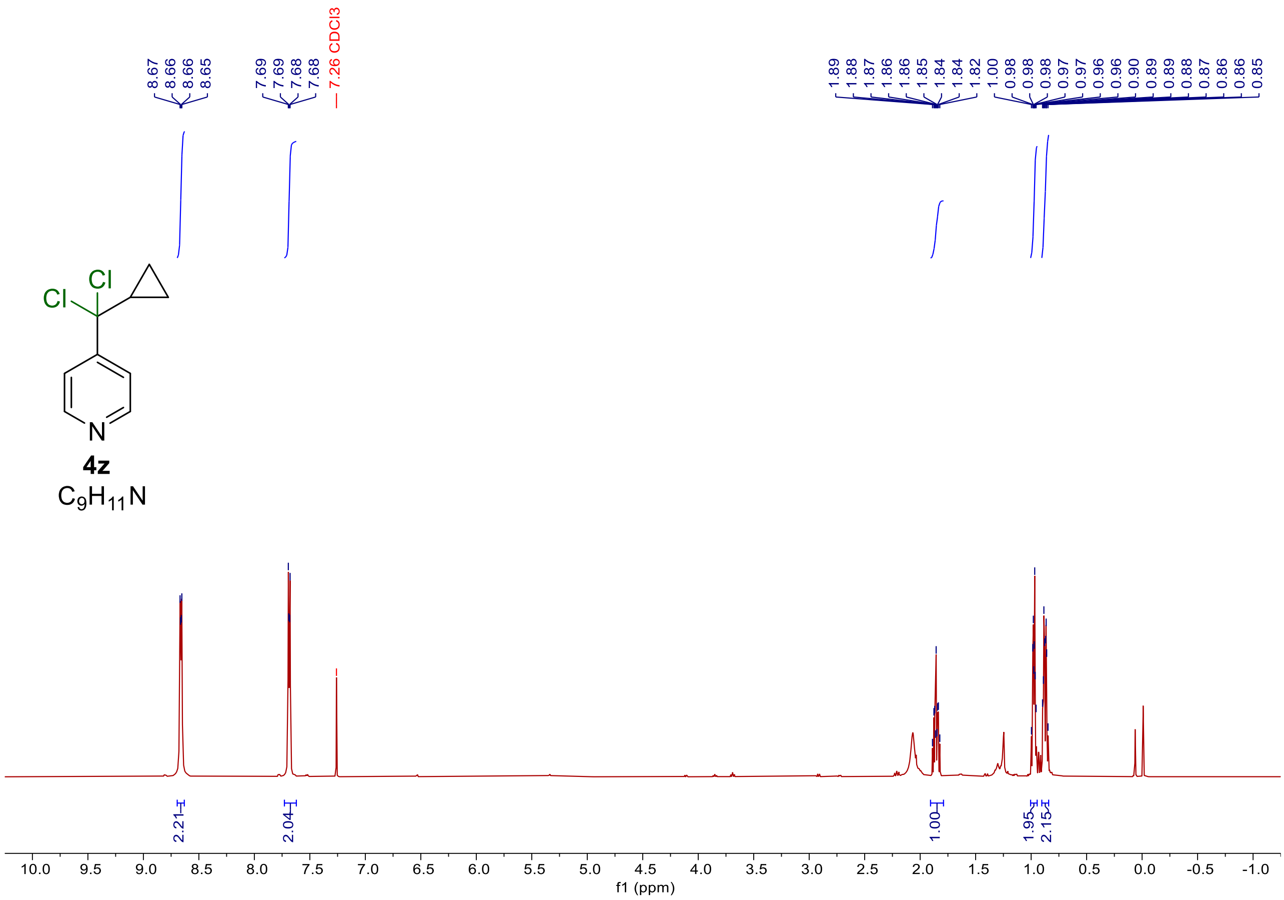
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4x.**



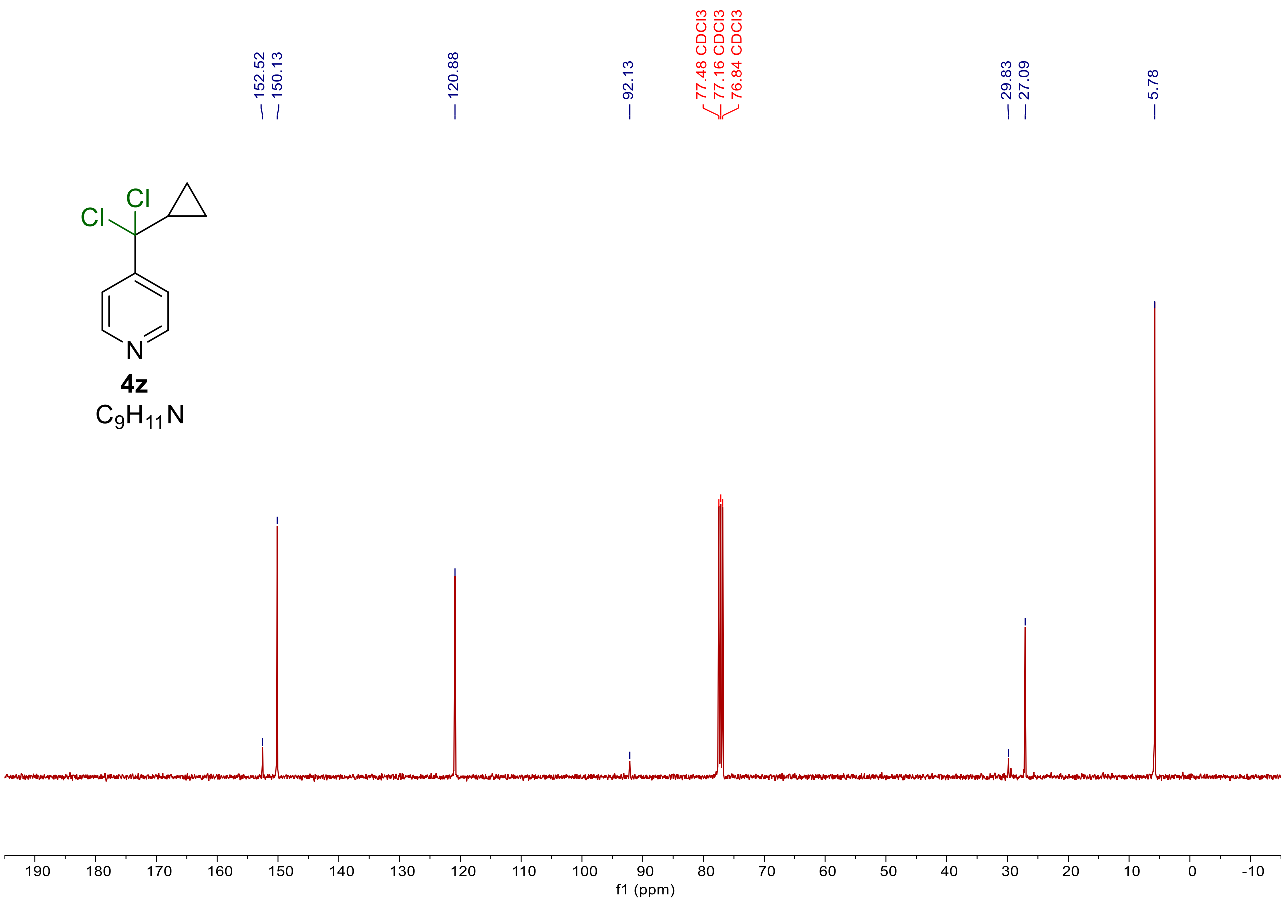
[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **4y.**



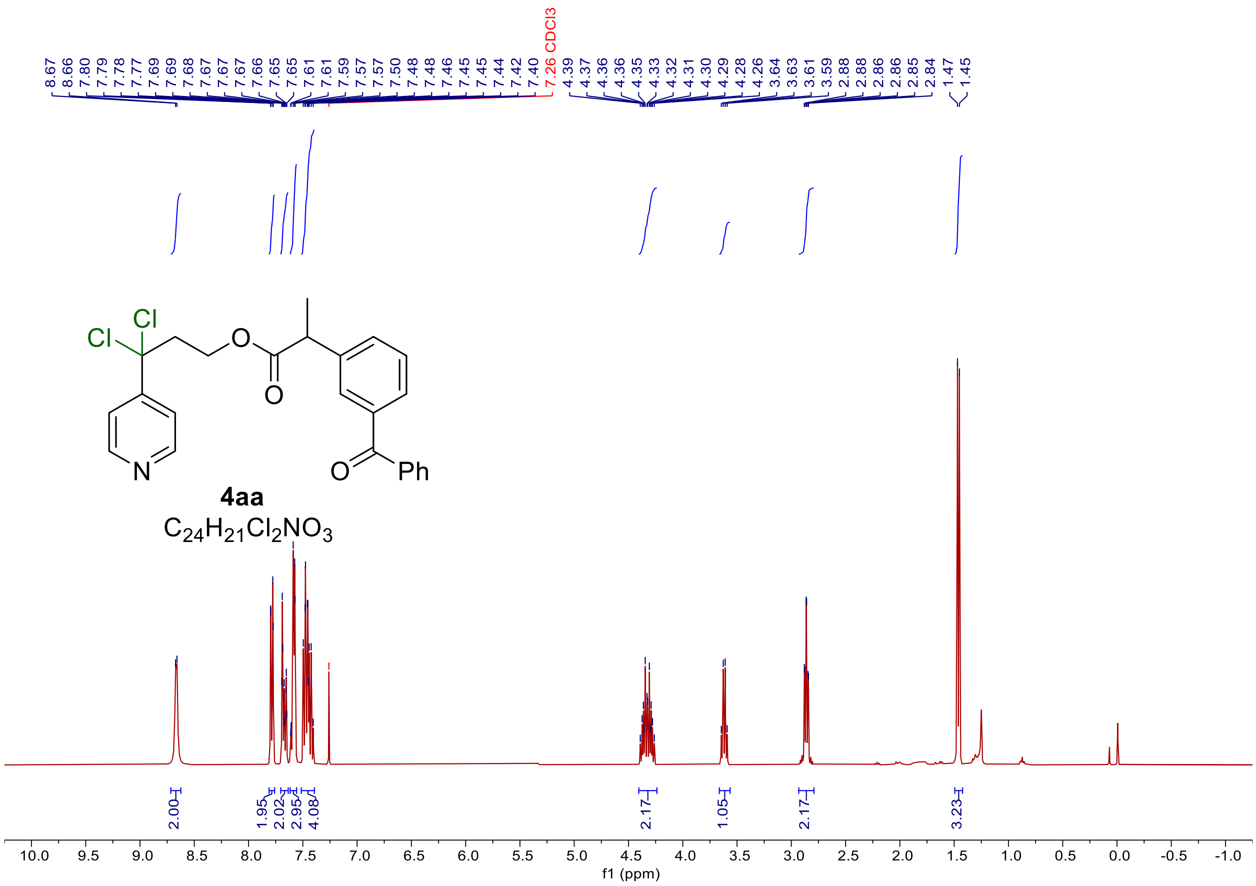
[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **4y.**



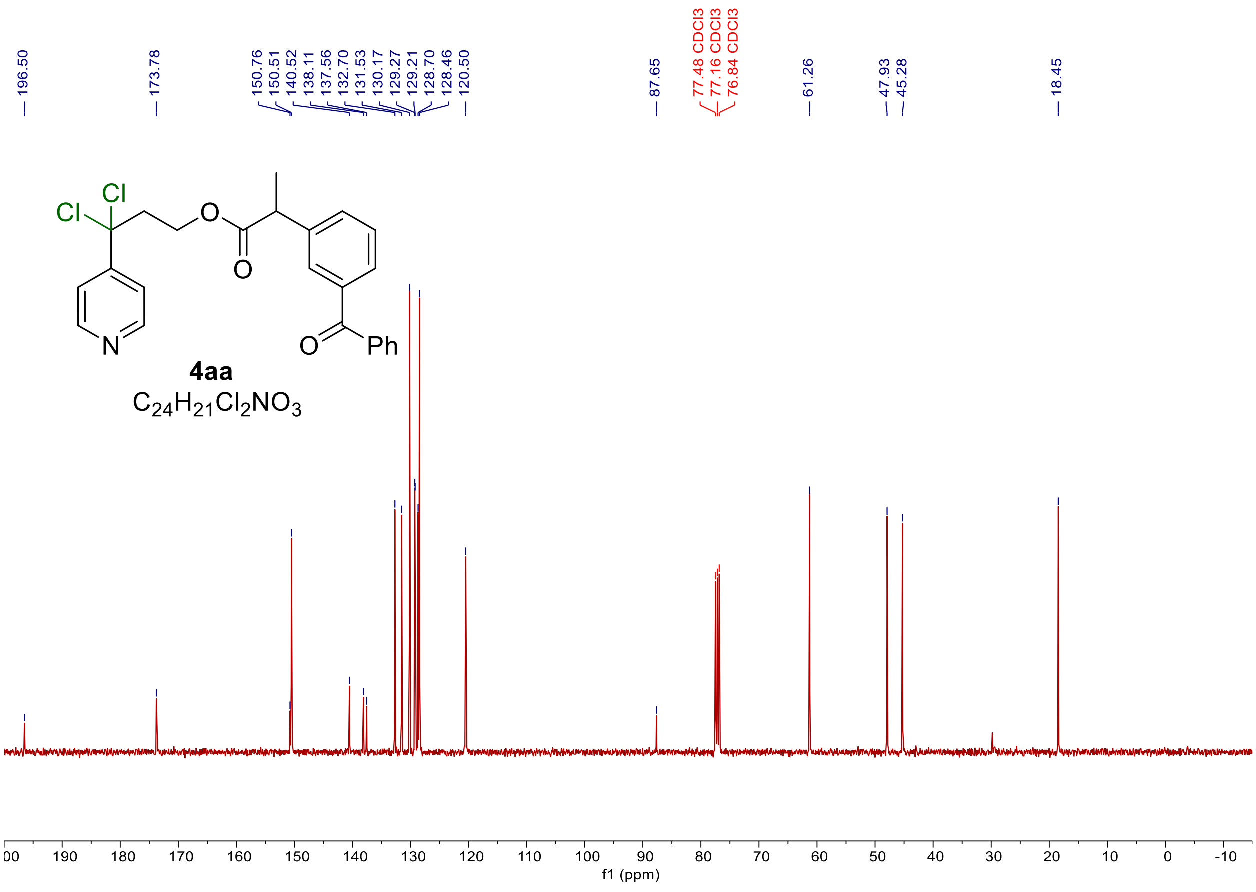
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **4z**.



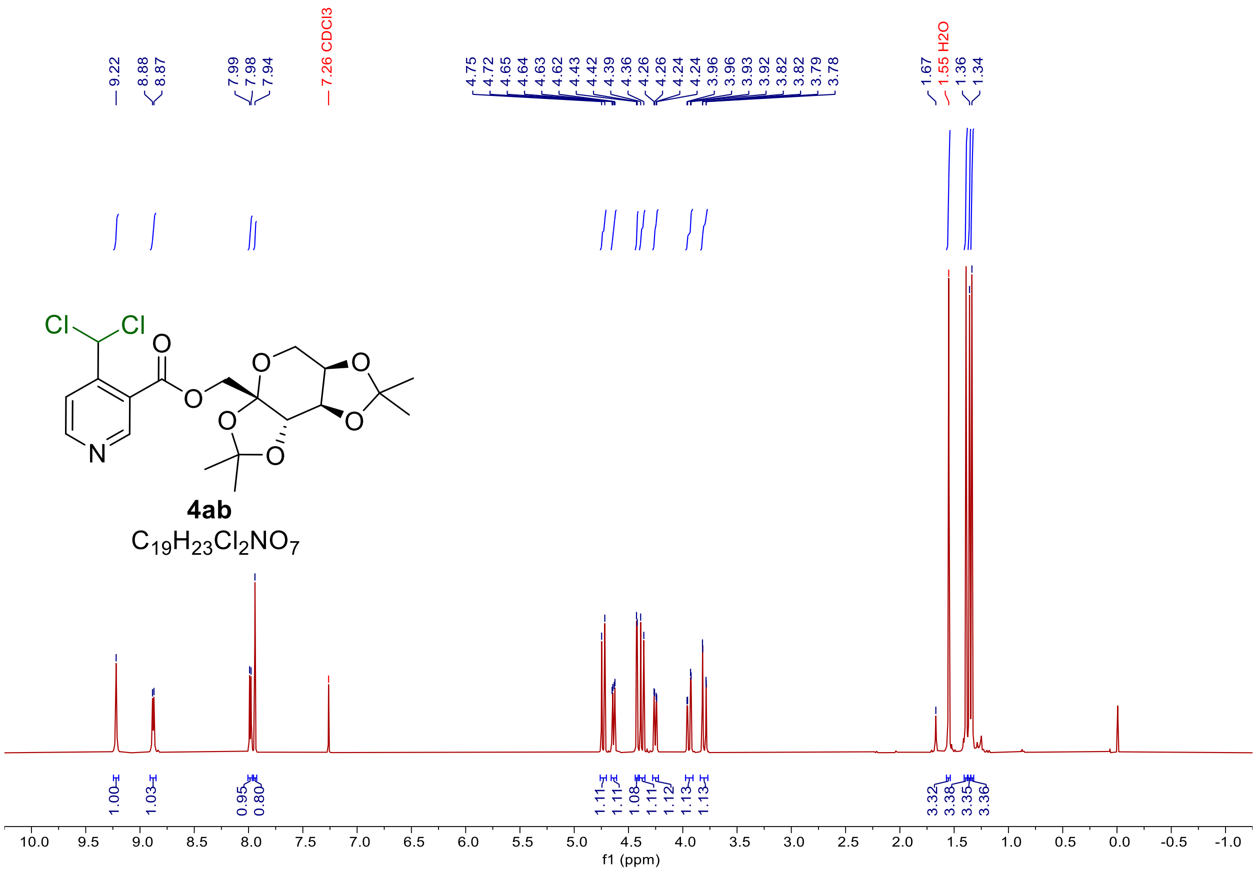
$^{13}C\{^{1}H\}$ NMR spectrum (101 MHz, $CDCl_3$) of compound **4z**.



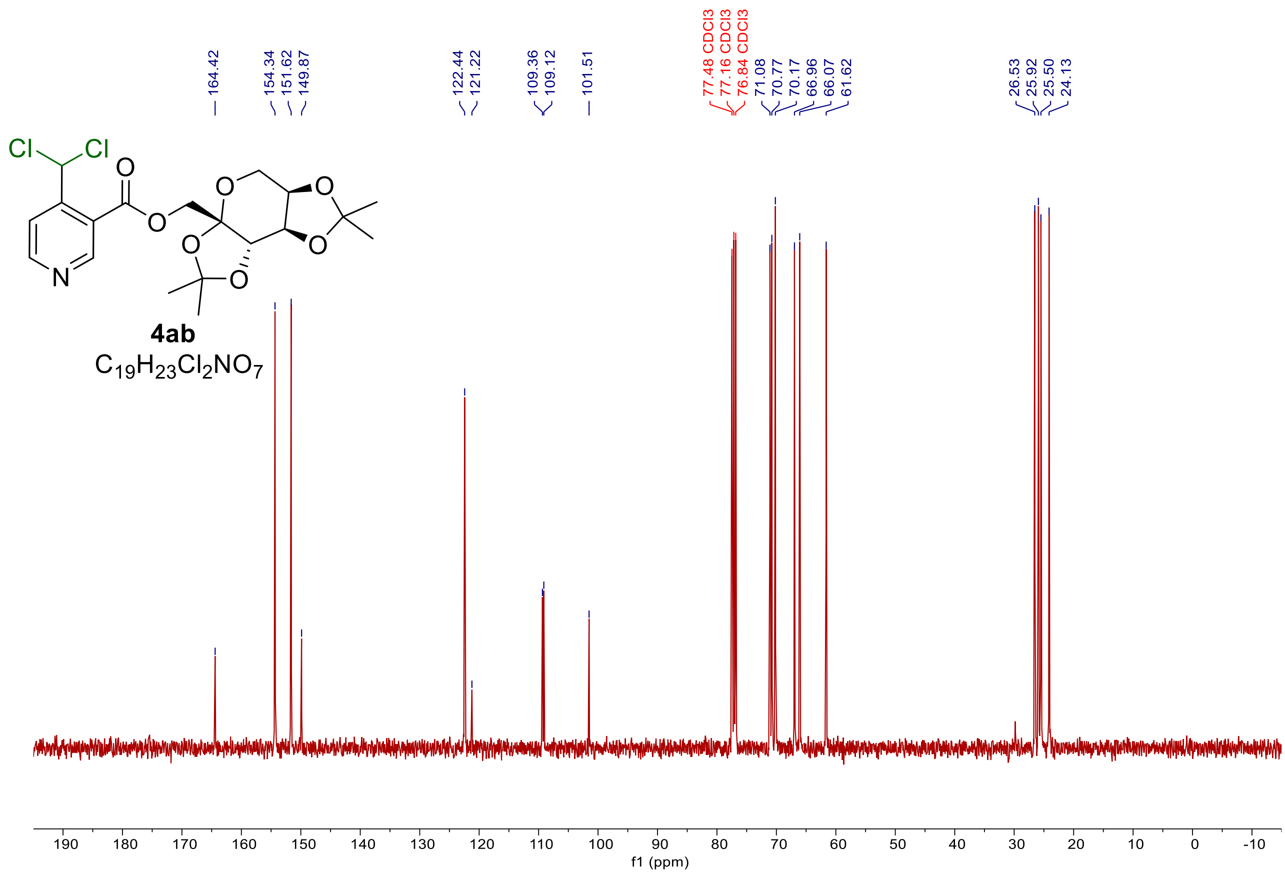
^{1}**H NMR** spectrum (400 MHz, CDCl₃) of compound **4aa**.



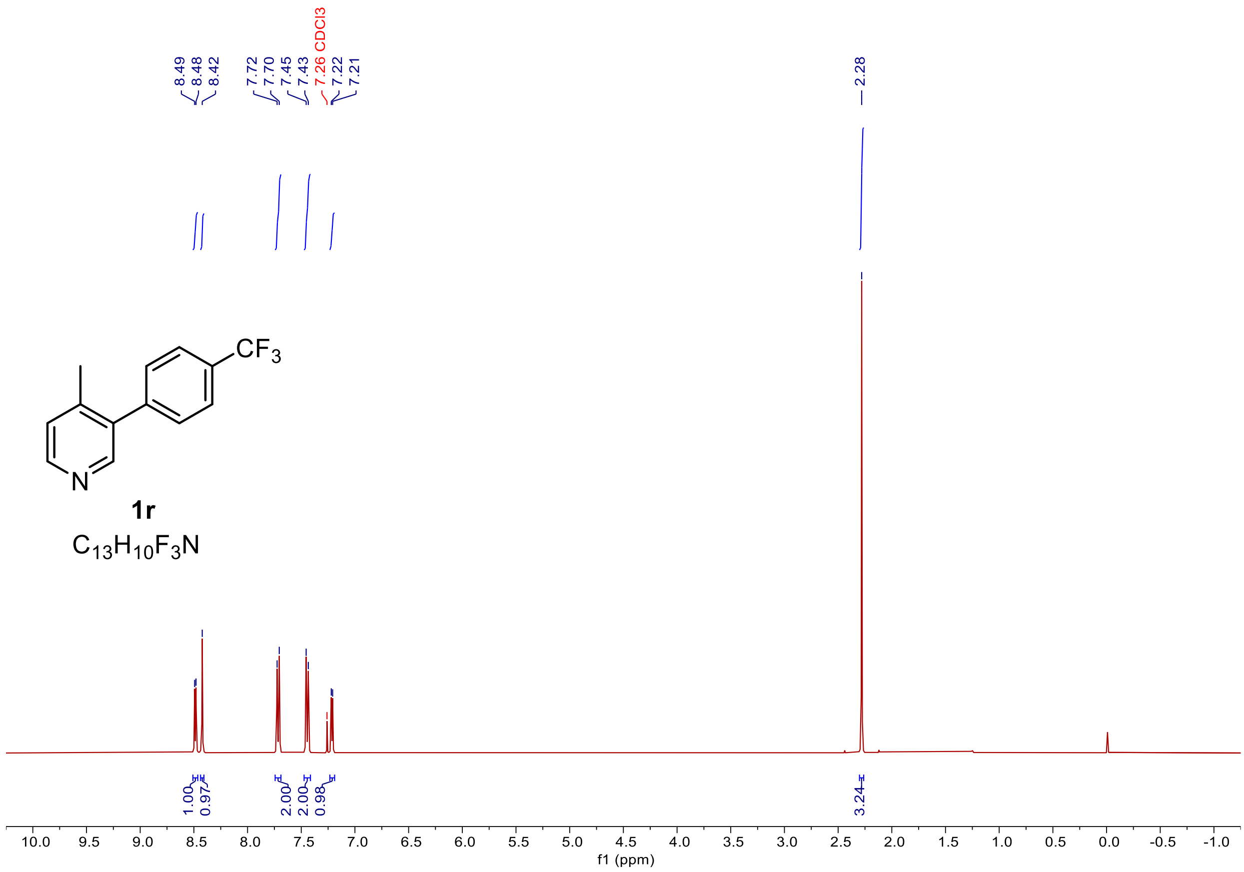
^{13}**C{^{1}H} NMR** spectrum (101 MHz, CDCl₃) of compound **4aa**.



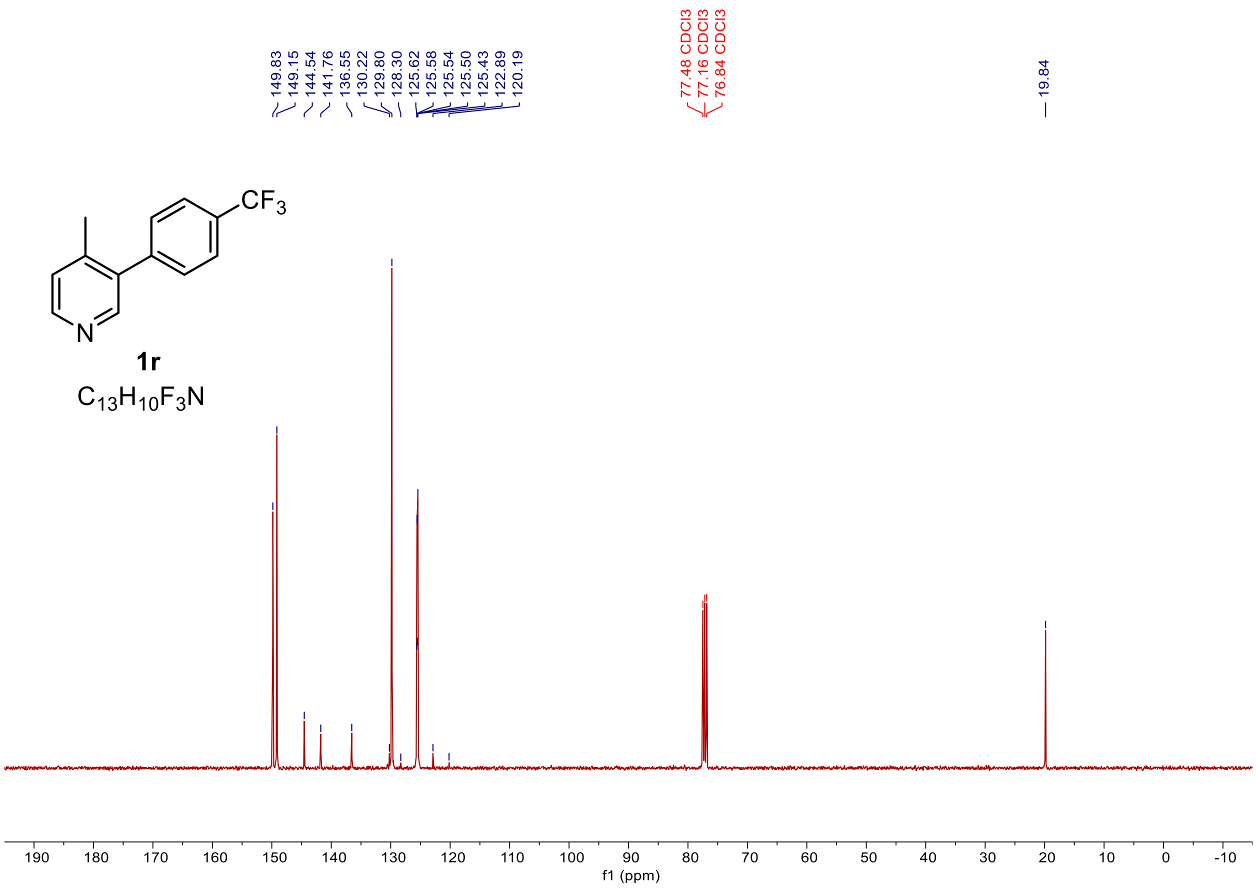
^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **4ab**.



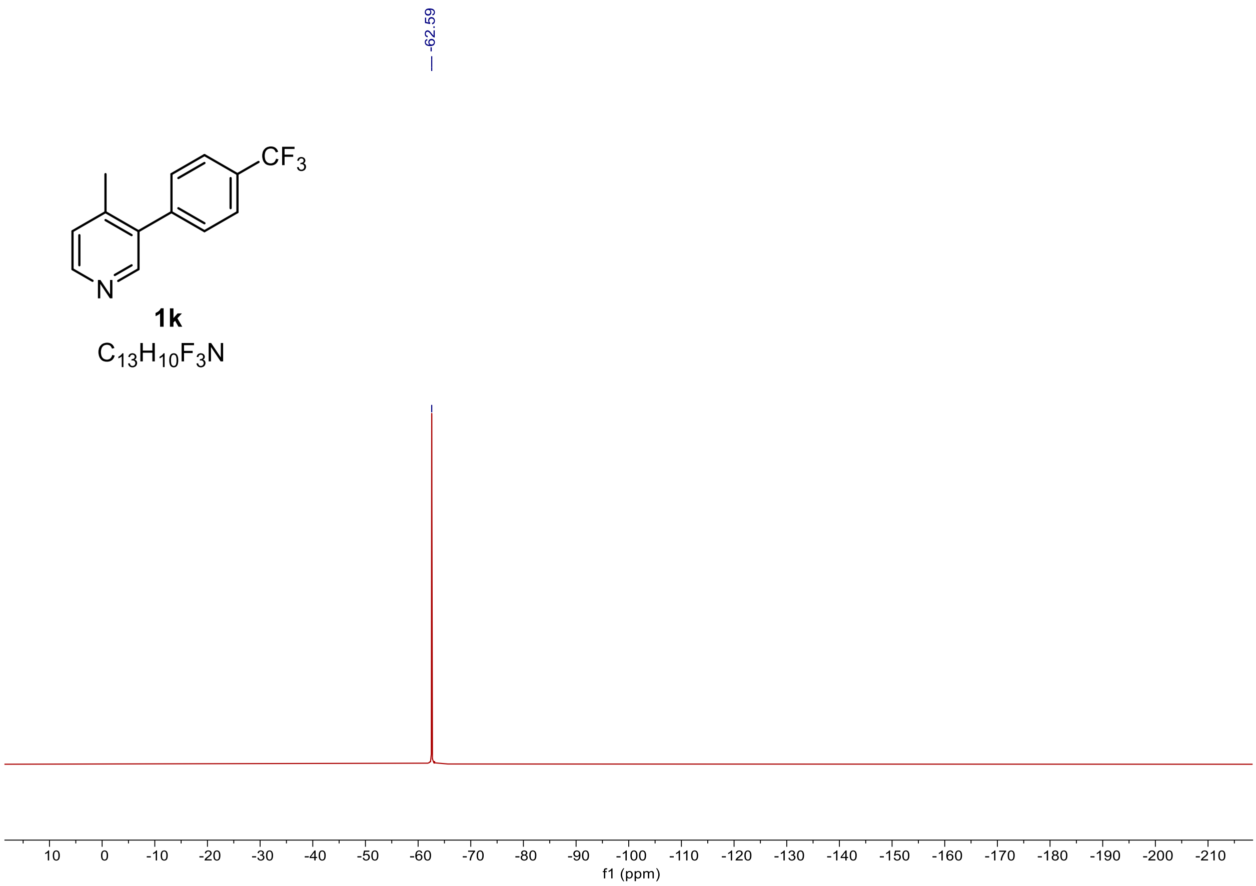
^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **4ab**.



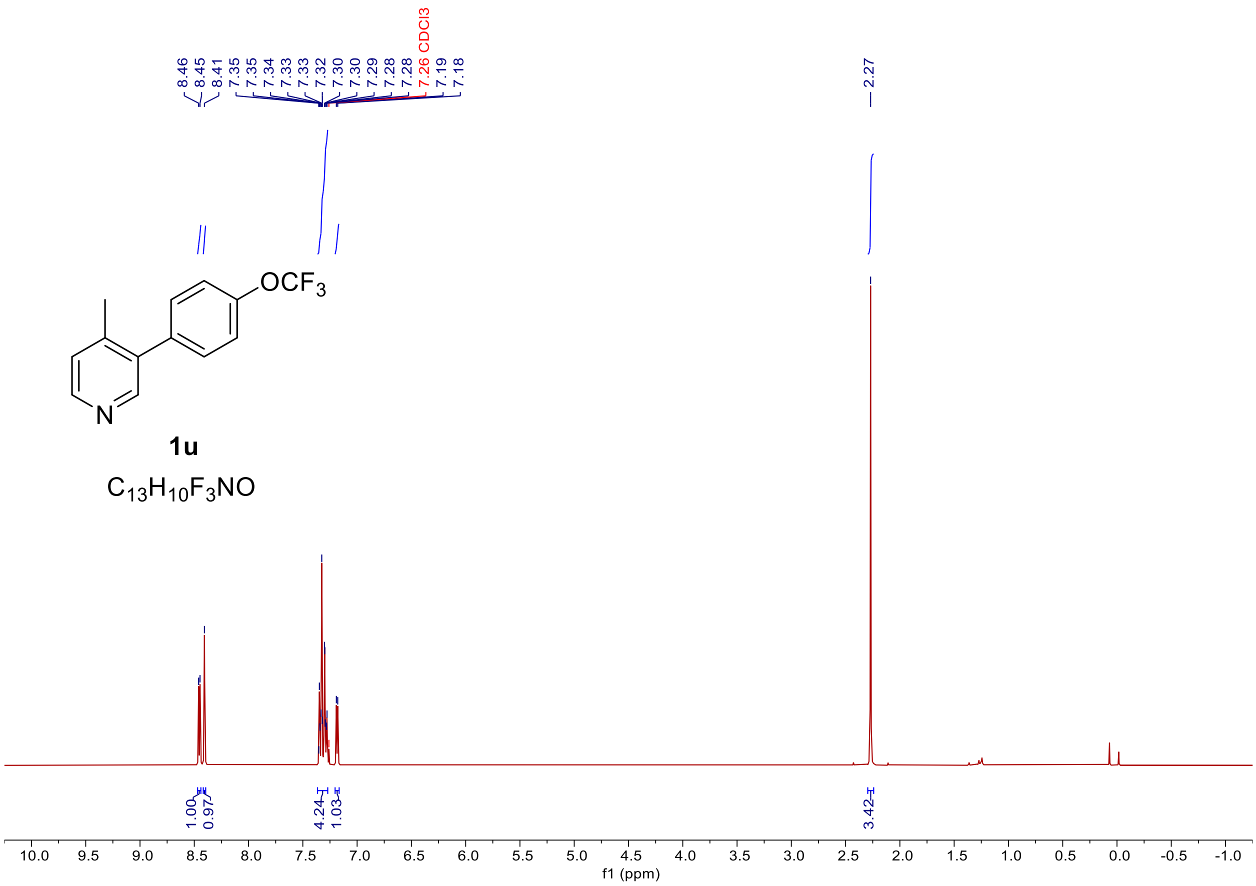
[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **1r**.



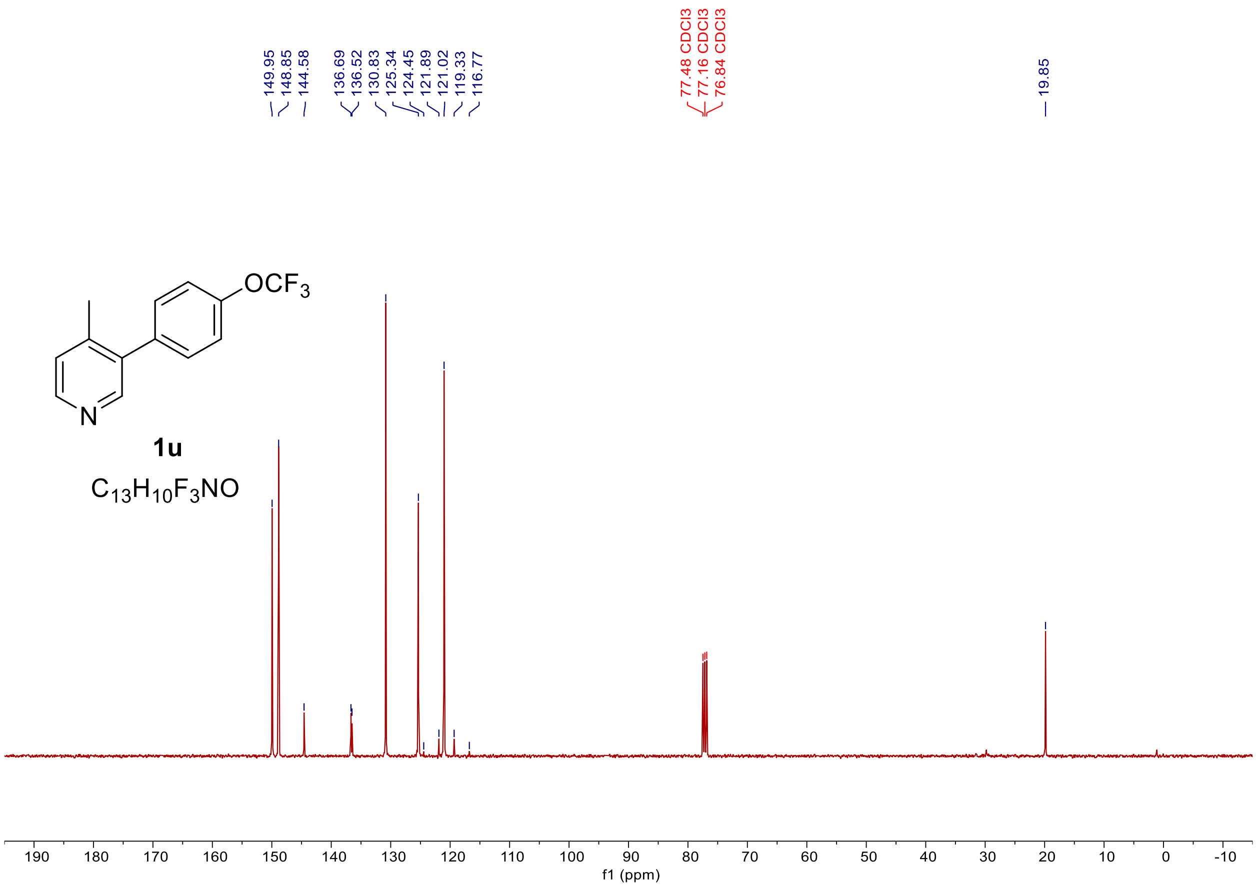
[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **1r**.



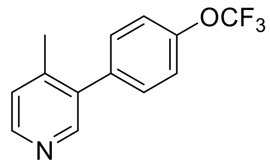
^{19}F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



^{1}**H NMR** spectrum (400 MHz, $CDCl_3$) of compound **1u**.

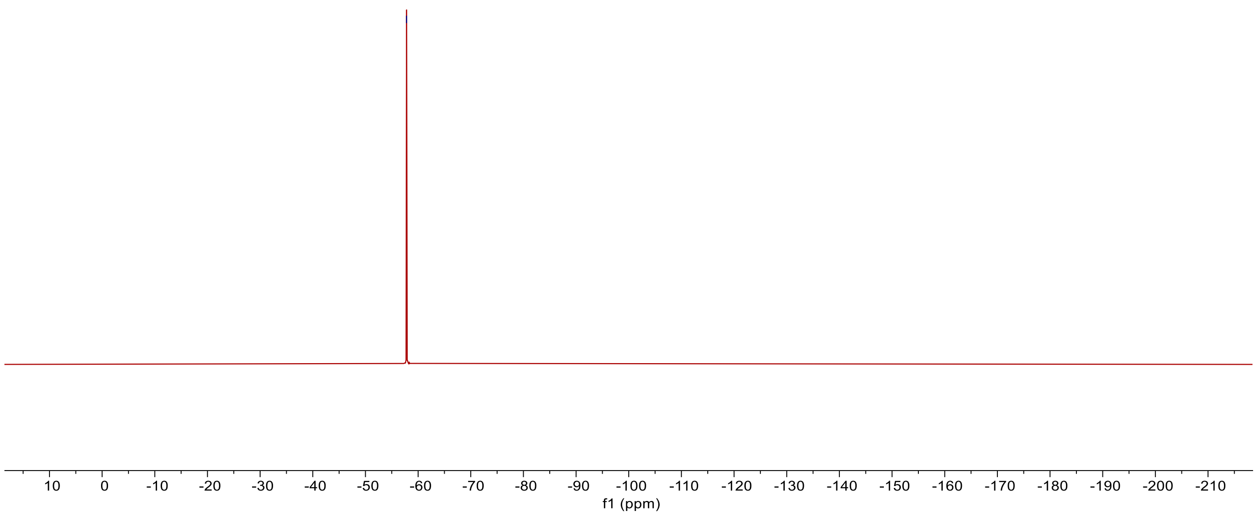


^{13}**C{^{1}H} NMR** spectrum (101 MHz, $CDCl_3$) of compound **1u**.

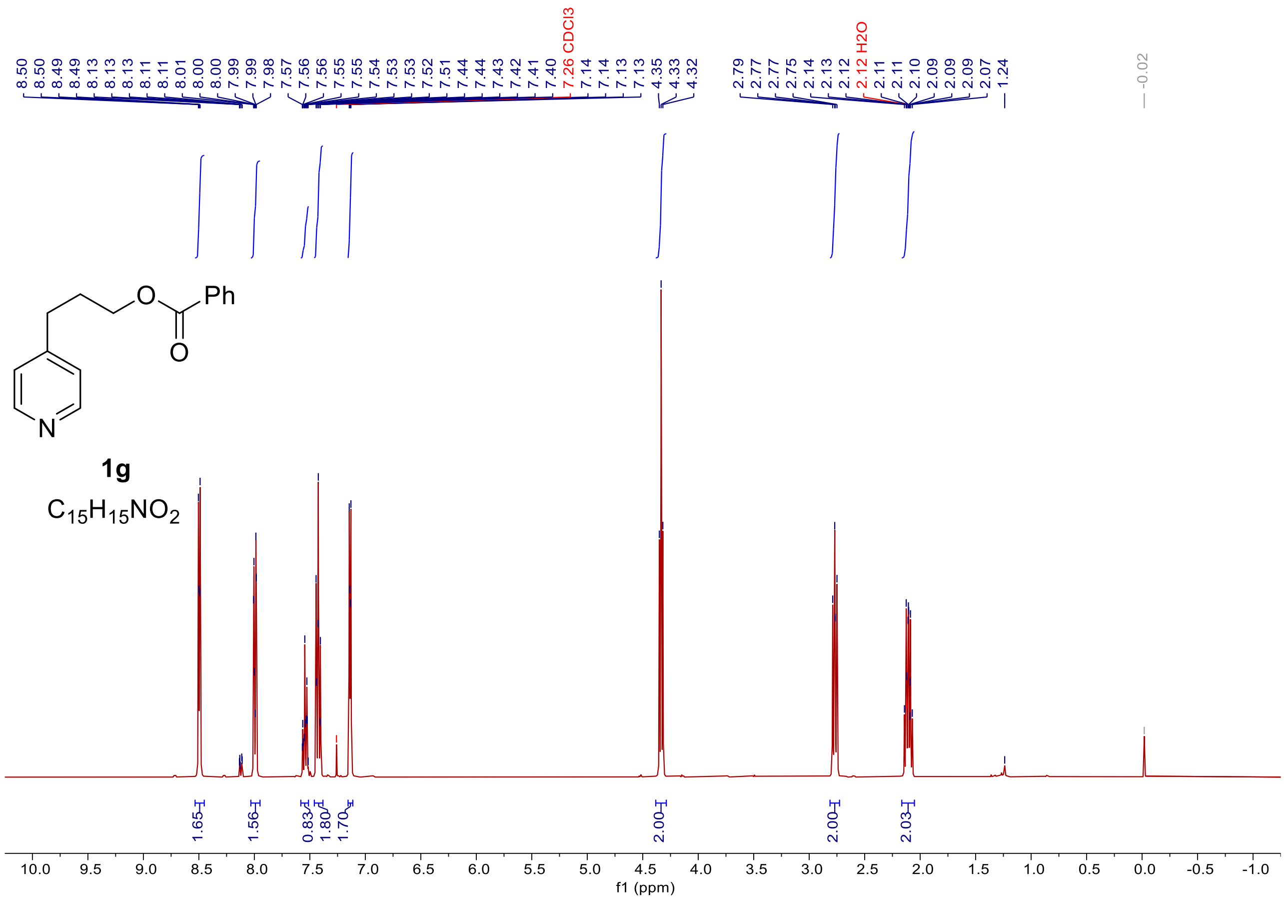


1u

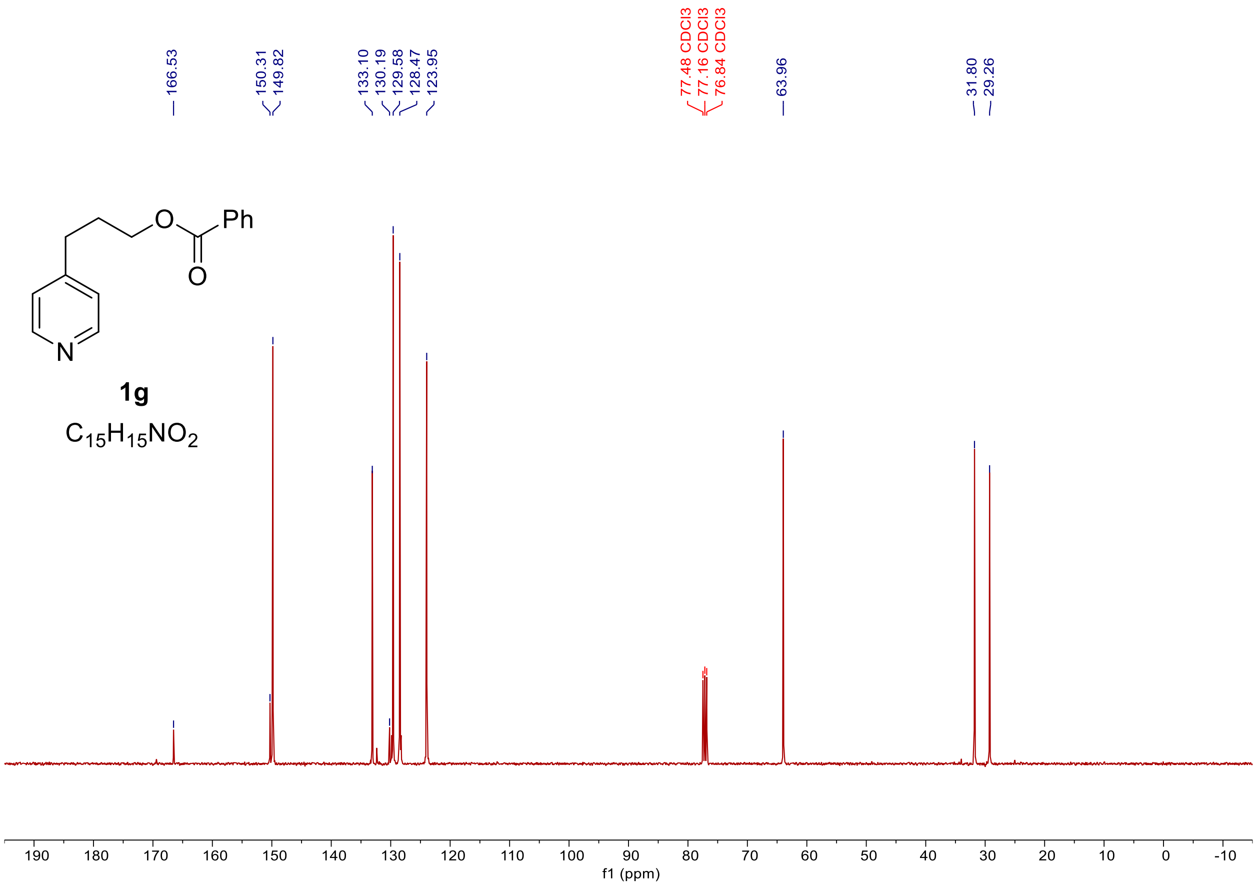
$C_{13}H_{10}F_3NO$



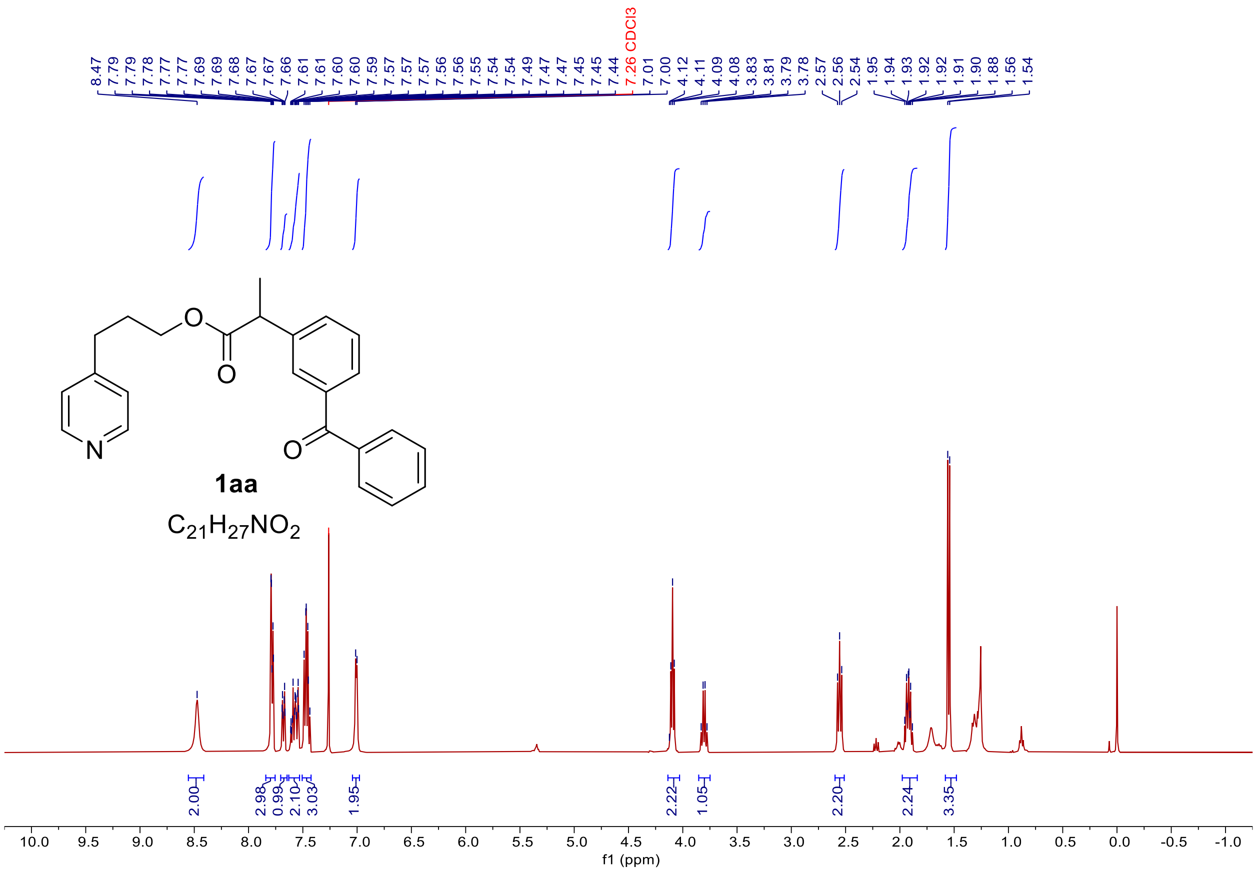
^{19}F NMR spectrum (376 MHz, $CDCl_3$) of compound **4k**.



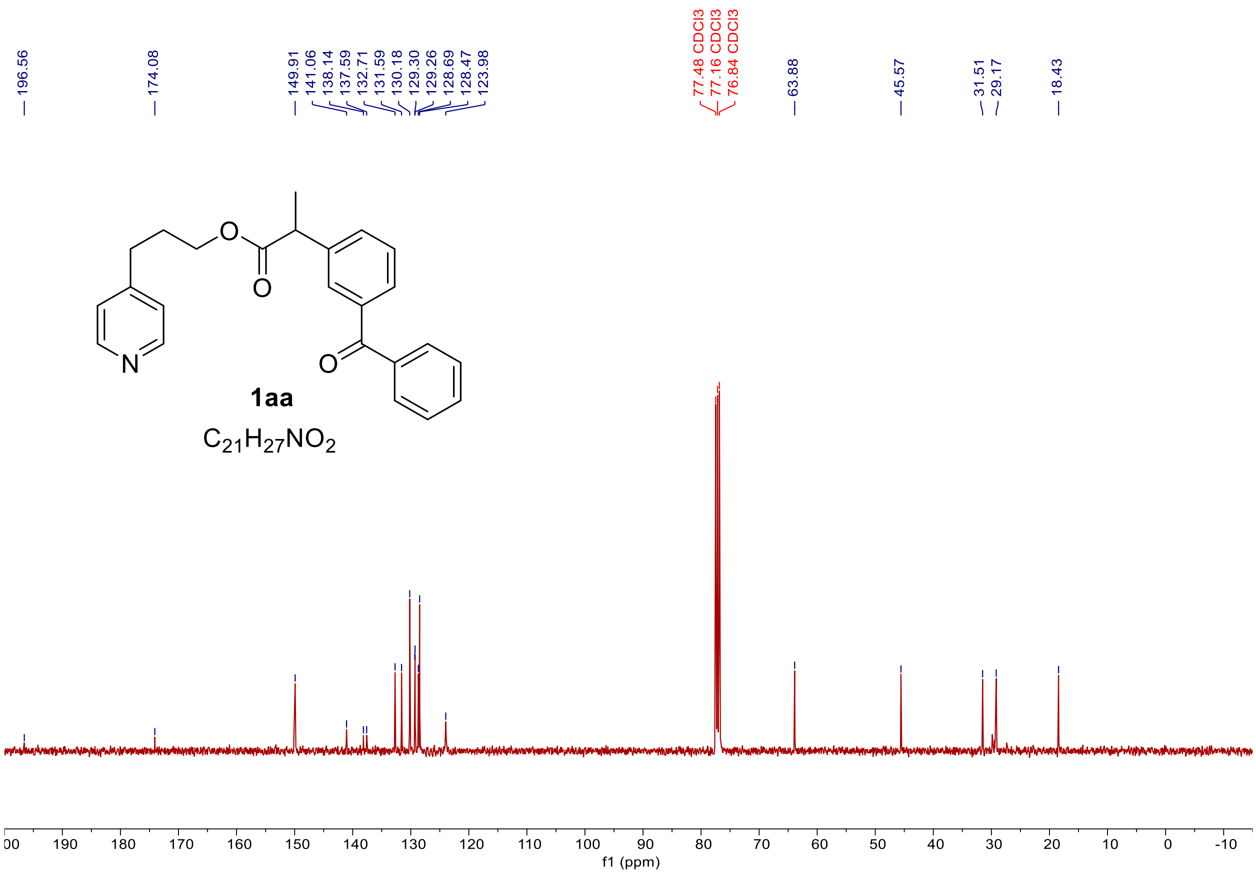
^{1}H NMR spectrum (400 MHz, $CDCl_3$) of compound **1g**.



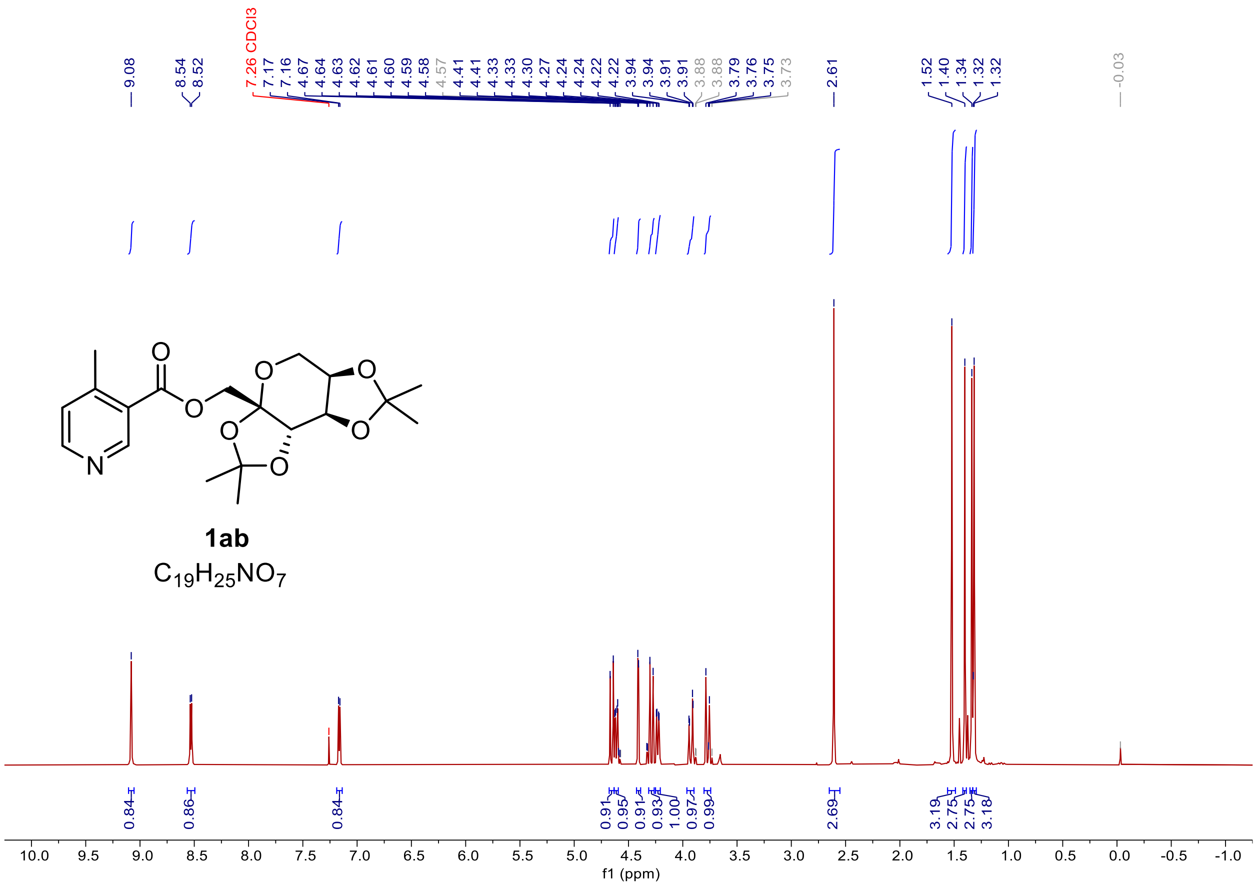
^{13}C{^{1}H} NMR spectrum (101 MHz, $CDCl_3$) of compound **1g**.



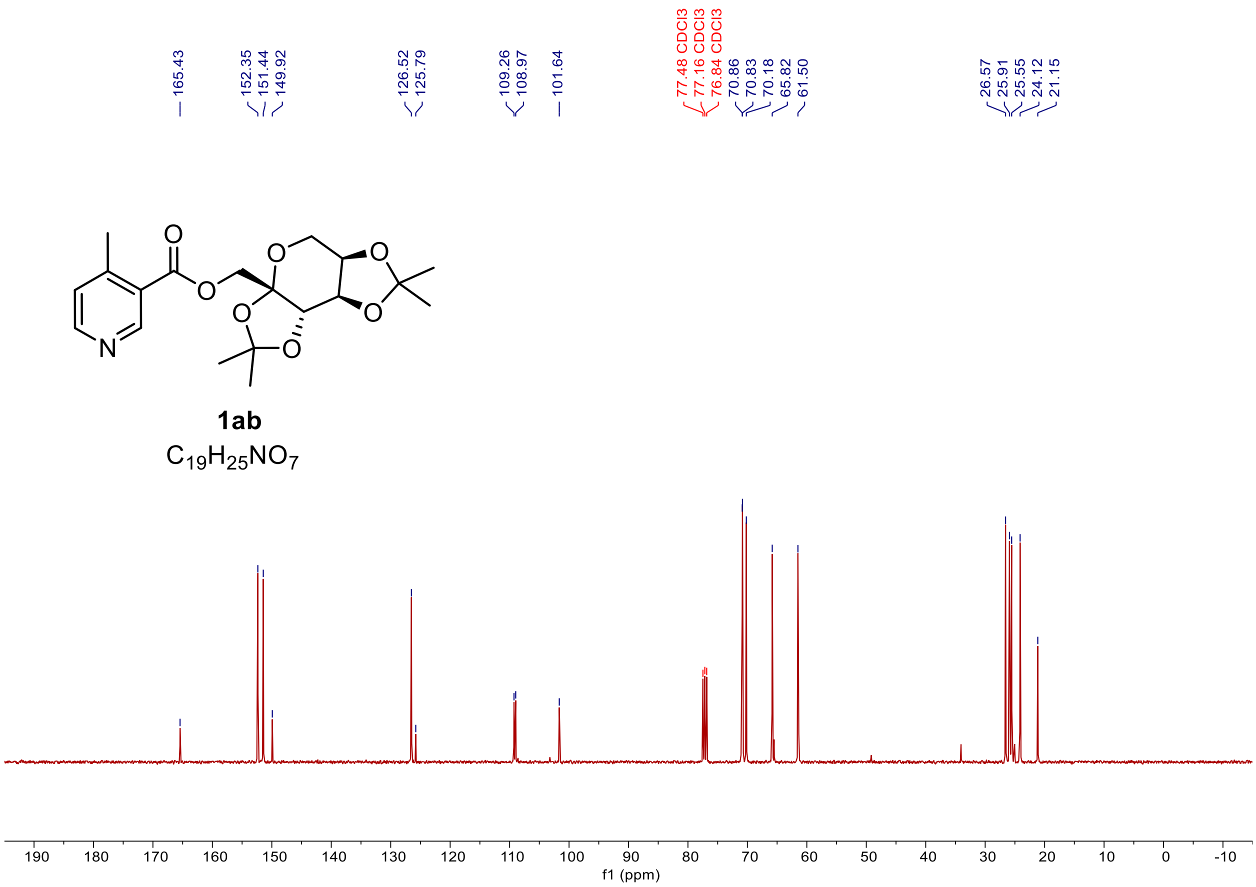
[1]H NMR spectrum (400 MHz, $CDCl_3$) of compound **1aa**.



[13]C{[1]H} NMR spectrum (101 MHz, $CDCl_3$) of compound **1aa**.



¹H NMR spectrum (400 MHz, $CDCl_3$) of compound **1ab**.

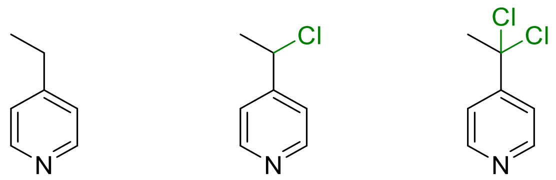


¹³C{¹H} NMR spectrum (101 MHz, $CDCl_3$) of compound **1ab**.

5. Computational information

5.1 Computational details of log*P*

Geometry optimizations and frequency calculations were performed by the dispersion-corrected functional B3LYP-D3[13] with the 6-31G(d) basis set using Gaussian 16.[14] Two polarity descriptors, molecular polarity index (*MPI)* and polarizability(α), were calculated at the B3LYP-D3/def2-SVPD level by Multiwfn[15] software. Three hydrogen bonds descriptors, the numbers of hydrogen bonding donor (N^{D}_{HB}) and acceptors (N^{A}_{HB}, $N^{A}_{HB\text{-}F}$), were generated by RDKit. Solvation effects were considered by the solvation model based on density (SMD).[16]



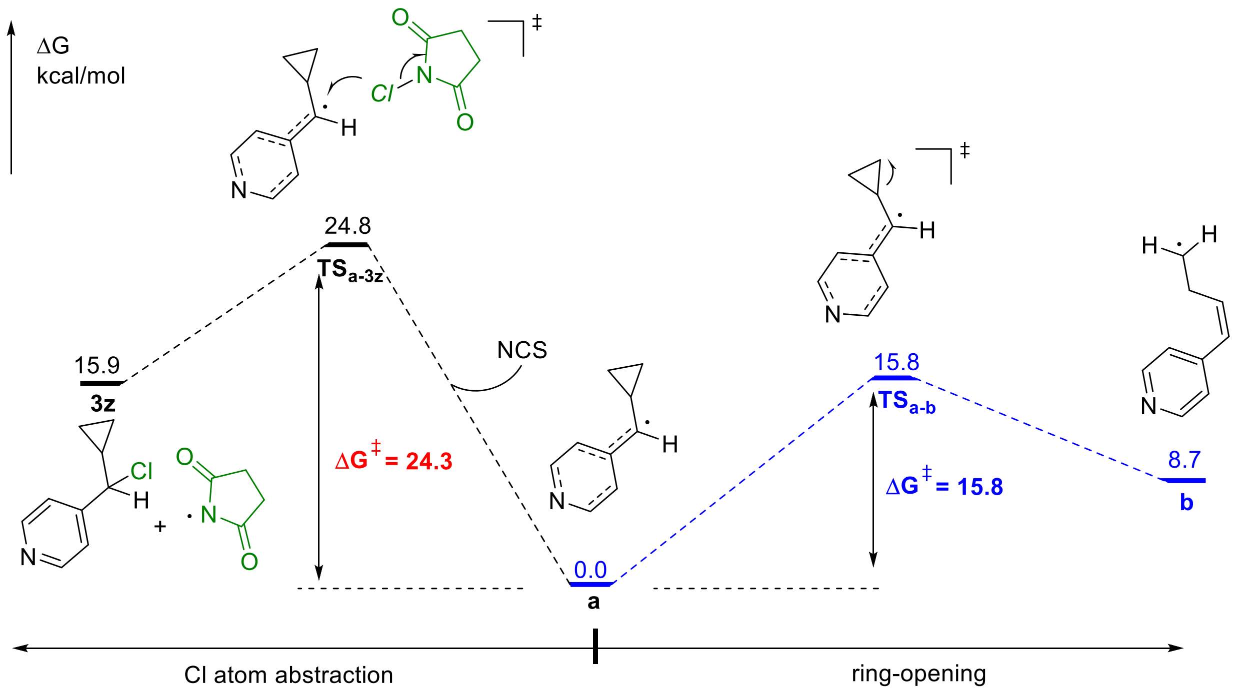
	1a	**3a**	4a
log*P*	1.75	1.46	1.93

Table S1. Calculation of log*P*.

Substrates	N^{D}_{HB}	N^{A}_{HB}	$N^{A}_{HB\text{-}F}$	*MPI*	α	log*P*
1a	1	0	0	17.88	149.57	1.75
3a	1	0	0	14.98	167.86	1.46
4a	1	0	0	16.09	129.01	1.93

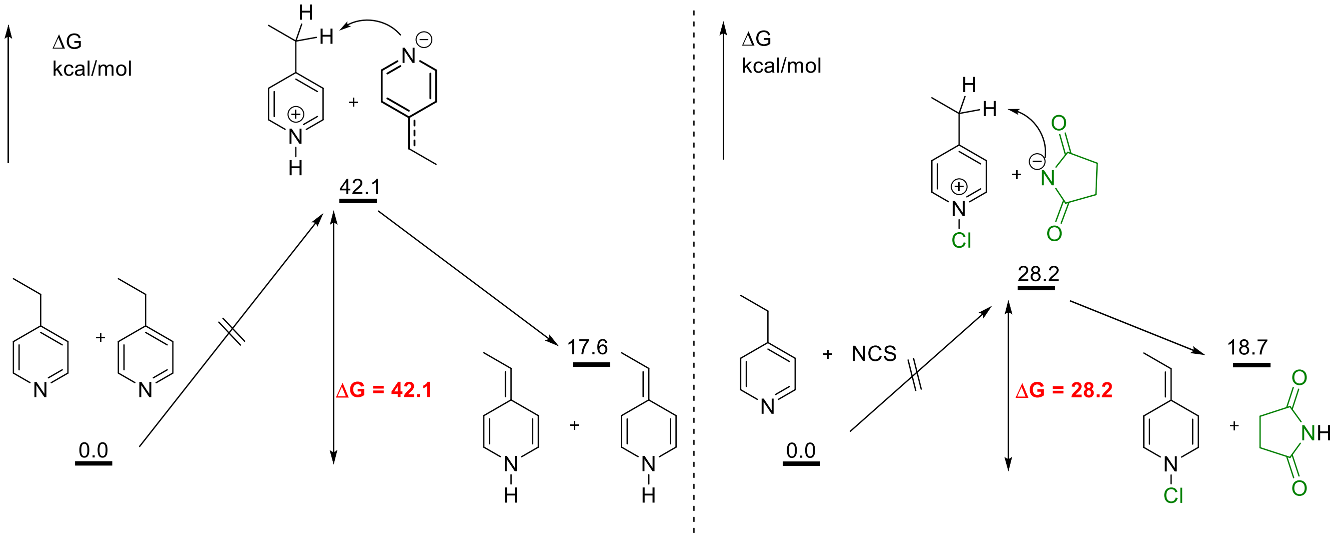
5.2 Computational studies on the reaction of cyclopropylmethyl radical

Geometry optimizations and frequency calculations were performed at the (U)M06-2X[17]/ 6-311G(d,p) level using Gaussian 16.[14] To get more accurate energies, single point energies were computed at the (U)M06-2X/cc-pVTZ for all the species. Solvation effects were considered by the solvation model based on density (SMD)[13] with acetonitrile as the solvent.



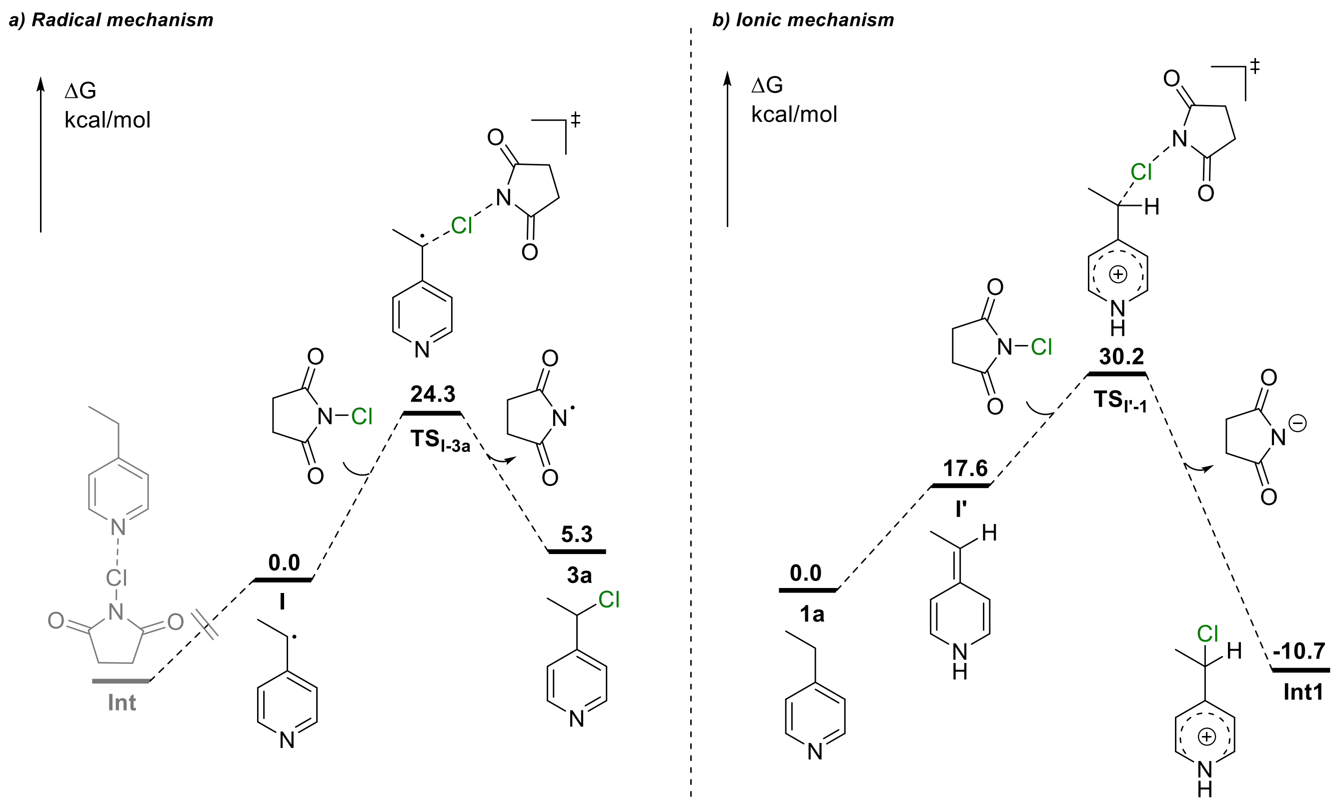
Scheme S4. Computational comparison between the ring-opening and Cl atom transfer process.

We have performed some additional computations to investigate the fidelity of using 4-(cyclopropylmethyl)pyridine as a radical probe. The activation barrier for the ring-opening reaction of pyridine-4-yl stabilized cyclopropylmethyl radical is predicted to be 15.8 kcal/mol, which is much lower than the Cl atom transfer event between cyclopropylmethyl radical and NCS ($\Delta G^{\ddagger}$ = 24.8 kcal/mol). No observation of the related ring-opening product reveals that the radical process is less possible for the chlorination reaction with 4-(cyclopropylmethyl)pyridine.



Scheme S5. Computational analysis on the generation of 1,4-dihydropyridine intermediate

Although previous studies have shown that azine benzylic C-H could be deprotonated, known processes are generally promoted by strong acids or bases. Our theoretical calculations suggest that the basicity of 4-ethyl pyridine is not strong enough to promote its tautomerization into the proposed 1,4-dihydropyridine intermediate, the formation of dihydrogen pyridine intermediate is endergonic by 17.6 kcal/mol. The ionic pathway proceeding through the chlorination of N-chlorinated dihydrogen azine intermediate was also investigated. Our calculations show that the initial formation of 4-ethylpyridine•Cl+ species through the transfer Cl^+ from NCS to N atom of 4-ethyl pyridine is endergonic 28.2 kcal/mol, which is highly thermodynamically unfavorable. Besides, the formation of N-chlorinated dihydrogen azine is endergonic by 18.7 kcal/mol (with the deprotonation of benzylic C-H bond by the succinimide anion). Due to the mechanistic complexity, we currently cannot determine which species is related to the formation of chlorinated product.



Scheme S6. Computational analysis on the possible pathway involved in the benzylic chlorination of 4-ethyl pyridine.

From calculations, we didn't get the reasonable pathways of the generation of pyridine dearomatization intermediate or benzylic radical. Although it is not clear how pyridine dearomatization intermediate and benzylic radical were generated, our computational results show that once they were formed, they could easily react with NCS through electrophilic chlorination or a halogen atom transfer (XAT) to afford the chlorination products. For the radical pathway, benzylic radical **I** may be generated through either a stepwise electron transfer/deprotonation pathway or a concerted proton-coupled electron-transfer (PCET) pathway.[18] Then the benzylic radical **I** could abstract the Cl atom of NCS to provide the chlorinated product **3a** with a barrier of 24.3 kcal/mol (relative to **I**). To the ionic pathway, methylene-1,4-dihydropyridine intermediate **I'** may be generated through the deprotonation/isomerization of **1a.** The intermediate **I'** could react with NCS through electrophilic chlorination with a barrier of 30.2 kcal/mol (relative to **1a**). Therefore, both the radical and ionic pathways are possible according to the DFT calculation.

5.3 Cartesian Coordinates of the Optimized Structures

NCS

M06-2X/6-311G(d,p) Electronic E: -820.188466 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -820.138980 a.u.

M06-2X/cc-pVTZ Electronic E: -820.241716 a.u.

C	9.5499561149	-7.5284400504	-3.6514586826
C	10.0503996823	-6.0818749783	-3.5849991695
H	9.7527694277	-8.0058136057	-4.6107713813

H	9.9588499340	-8.1606161594	-2.8630355960
H	10.7175090779	-5.9006913153	-2.7417389821
H	10.5569787912	-5.7604954406	-4.4952682054
N	7.7343157262	-6.1036177239	-3.3416366214
C	8.8214526571	-5.2222807903	-3.3998101939
C	8.0511289677	-7.4616815647	-3.4721115997
O	8.7319460637	-4.0318185067	-3.3108945713
O	7.2482687090	-8.3491742454	-3.4421423732
Cl	6.1502531483	-5.5648512792	-3.1284277335

Succinimide-radical

M06-2X/6-311G(d,p) Electronic E: -359.930435 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -359.885294 a.u.

M06-2X/cc-pVTZ Electronic E: -359.971128 a.u.

C	9.5643154466	-7.5305868771	-3.6645737406
C	10.0696706160	-6.0876463230	-3.5664691831
H	9.7254084424	-7.9771887306	-4.6466406235
H	9.9916321778	-8.1953005275	-2.9130079435
H	10.6982476658	-5.9197070126	-2.6899138044
H	10.6100617634	-5.7442437620	-4.4479423949
N	7.7495473333	-6.1132689691	-2.9950269685
C	8.8057902848	-5.2624793898	-3.4080299883
C	8.0686006803	-7.4217844671	-3.4339383853
O	8.6587424793	-4.0818444677	-3.5717983726
O	7.2315591105	-8.2724544736	-3.5765265950

Succinimide-anion

M06-2X/6-311G(d,p) Electronic E: -360.146781 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -360.097533 a.u.

M06-2X/cc-pVTZ Electronic E: -360.193981 a.u.

C	9.5496361145	-7.5197258696	-3.6144786636
C	10.0142647699	-6.0755163505	-3.5436861257
H	9.9011897079	-8.0561889922	-4.4982337367
H	9.8134339295	-8.1165721406	-2.7390864258
H	10.5413009971	-5.8236155215	-2.6210676664
H	10.6468321179	-5.7695177741	-4.3793785612
N	7.6107241492	-6.0944795796	-3.6759124806
C	8.6966297470	-5.2819637300	-3.5969480128

C	8.0178518894	-7.3903170720	-3.6879667481
O	8.6795869343	-4.0559201534	-3.5673867924
O	7.2890883533	-8.3748025865	-3.7500959866

I

M06-2X/6-311G(d,p) Electronic E: -326.209125 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -326.109587 a.u.

M06-2X/cc-pVTZ Electronic E: -326.244988 a.u.

C	8.0501225516	-1.3805059040	-5.2513741769
C	9.3795722202	-1.0917416901	-5.0126413035
C	8.9675556145	-0.5442935956	-2.8361633876
C	7.6145926589	-0.8054150868	-2.9620928949
C	7.1054839579	-1.2427754790	-4.2071953426
H	7.7310353106	-1.7113097584	-6.2333585711
H	10.1077735053	-1.1965801045	-5.8114231799
H	9.3637510975	-0.2081280185	-1.8823952359
H	6.9604647903	-0.6723775624	-2.1089041245
N	9.8575678414	-0.6772327439	-3.8289156625
C	5.7332224848	-1.5312387155	-4.4154226125
H	5.4365693388	-1.8584279533	-5.4054993045
C	4.7005390363	-1.4055399965	-3.3510249921
H	4.6444578800	-0.3786589026	-2.9698469998
H	3.7157268446	-1.6846546799	-3.7236591874
H	4.9355398771	-2.0436113990	-2.4906241345

$TS_{I\text{-}3a}$

M06-2X/6-311G(d,p) Electronic E: -1146.379607 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -1146.212099 a.u.

M06-2X/cc-pVTZ Electronic E: -1146.466468 a.u.

C	8.2281801847	-1.0068297467	-4.6260506995
C	9.2805411890	-0.1516879632	-4.3361556986
C	8.3612571285	0.4390858527	-2.3304120161
C	7.2631681057	-0.3880914369	-2.5215325211
C	7.1825783064	-1.1330424621	-3.7033316808
H	8.2145525287	-1.5676083767	-5.5537648296
H	10.0982058641	-0.0359415544	-5.0401723966
H	8.4419507537	1.0299753460	-1.4237241804
H	6.4921916311	-0.4414995124	-1.7632428622

N	9.3587097864	0.5647311938	-3.2104575614
C	6.0556498947	-2.0202068844	-4.0032046294
H	5.9955981033	-2.3099222527	-5.0482366265
C	7.4426069948	-8.0673174243	-2.7395007266
C	6.7079157353	-7.7223113708	-1.4409703976
H	8.4488653732	-8.4550728918	-2.5774268013
H	6.9006644066	-8.7748626941	-3.3679266307
H	5.7541323277	-8.2396591476	-1.3326961772
H	7.3018618913	-7.9104386622	-0.5459075066
N	7.0081775151	-5.7776496397	-2.6904717643
C	6.4286776199	-6.2269319393	-1.5206842169
C	7.5570873734	-6.7525134925	-3.5003917741
O	5.8283493525	-5.5536916194	-0.7235917914
O	8.0369047506	-6.5805423294	-4.5906122154
Cl	6.8029094248	-3.8908046629	-3.2897951647
C	4.7473091492	-1.8605305461	-3.3015518006
H	4.0564615350	-2.6494382999	-3.5967339650
H	4.8558297912	-1.8666979141	-2.2163777976
H	4.3160372833	-0.8965995690	-3.5976435678

3a

M06-2X/6-311G(d,p) Electronic E: -786.462639 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -786.359530 a.u.

M06-2X/cc-pVTZ Electronic E: -786.506605 a.u.

C	8.0405702462	-1.6653824929	-5.0718028451
C	9.3902410711	-1.5242845802	-4.7615086676
C	8.9245655199	-0.2066235557	-2.9609631573
C	7.5577413892	-0.2887205147	-3.1831468353
C	7.0983165844	-1.0361820739	-4.2667583373
H	7.7355413677	-2.2575605133	-5.9268723904
H	10.1418163368	-2.0084591841	-5.3773886381
H	9.3053171788	0.3717337360	-2.1250504472
H	6.8687390143	0.2290977621	-2.5254127068
N	9.8380431451	-0.8106271655	-3.7288849088
C	4.8677114233	-1.8372023824	-3.3928599950
H	4.9554286622	-1.2343627658	-2.4872922632
H	3.8134436076	-1.9506368965	-3.6473369536
H	5.2900070138	-2.8261873333	-3.1971116824

C	5.6275274566	-1.2059233967	-4.5430160801
H	5.4893746910	-1.7727886399	-5.4610950475
Cl	4.8982151421	0.4329817769	-4.9157807143

1a

M06-2X/6-311G(d,p) Electronic E: -326.857286 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -326.743283 a.u.

M06-2X/cc-pVTZ Electronic E: -326.892669 a.u.

C	3.1717611213	-2.7563143475	0.1192270379
C	4.5573447591	-2.7700043696	0.2549297906
C	5.2669476031	-1.5782140227	0.1286896974
C	4.5201282136	-0.4257467461	-0.1319336698
C	3.1423181768	-0.5137022568	-0.2504334286
N	2.4586798412	-1.6580220890	-0.1290748780
H	2.6116723578	-3.6817525250	0.2165824984
H	5.0601076278	-3.7075868970	0.4567636900
H	5.0124928077	0.5344980355	-0.2419220751
H	2.5554880951	0.3771161058	-0.4532600629
C	6.7684491657	-1.4865957370	0.2598246118
H	7.1569450811	-1.0356949924	-0.6590386460
H	6.9903675016	-0.7712626331	1.0584124943
C	7.4829143566	-2.8038494568	0.5322899540
H	7.3113831496	-3.5242792202	-0.2712900121
H	8.5585825655	-2.6363238835	0.6085468764
H	7.1460435762	-3.2541679645	1.4692311217

I’

M06-2X/6-311G(d,p) Electronic E: -326.827979 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -326.714197 a.u.

M06-2X/cc-pVTZ Electronic E: -326.864385 a.u.

C	4.0845418183	-2.0956358572	-0.1573559358
C	5.1712620685	-1.7327315076	0.5544687872
C	6.0498196059	-0.6425900098	0.1151077514
C	5.6127108042	-0.0216084462	-1.1403305654
C	4.5143551714	-0.4352891971	-1.7998936241
N	3.7385363301	-1.4682274080	-1.3272004653
H	3.4277094798	-2.8978975511	0.1535395881
H	5.3805427531	-2.2721073558	1.4683708106

H	6.1920288648	0.7966274552	-1.5520369234
H	4.1820969155	0.0141834213	-2.7265674936
C	7.1577190286	-0.2203618671	0.7672310984
H	7.7111947381	0.6028148816	0.3207323516
C	7.7074249289	-0.7698422069	2.0511922661
H	7.1236800131	-1.6079078353	2.4344323670
H	8.7382390561	-1.1195058297	1.9254024968
H	7.7347137314	-0.0042849693	2.8350394036
H	2.9217518022	-1.7640973270	-1.8390593332

TS$_{I'-1}$

M06-2X/6-311G(d,p) Electronic E: -1147.017447 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -1146.835805 a.u.

M06-2X/cc-pVTZ Electronic E: -1147.104409 a.u.

C	9.2242436193	-3.8440424897	-9.2223176965
C	8.5585558598	-2.5337684322	-9.6422281992
H	8.8165015217	-4.7186904057	-9.7306238766
H	10.3060084606	-3.8458380975	-9.3606542067
H	9.2649529865	-1.7867191205	-10.0063050008
H	7.7832251360	-2.6630400867	-10.3982293222
N	8.1720300492	-2.8881638063	-7.3551997223
C	7.9082006829	-1.9975789630	-8.3747016261
C	8.9297980806	-3.9761142916	-7.7348658419
O	7.2734144353	-0.9767651231	-8.2673466952
O	9.2872460196	-4.8692299890	-7.0059447909
Cl	7.5865780331	-2.6295397876	-5.5802167337
C	4.1625417978	-4.6731930448	-3.3138562220
C	5.4276490033	-4.2075120843	-3.1370281029
C	5.7520392962	-2.8337281462	-3.4091387877
C	4.6514628297	-2.0182253752	-3.8474565167
C	3.4096807719	-2.5402520026	-4.0056398259
N	3.1692303185	-3.8553348822	-3.7454133461
H	3.8797485404	-5.6991055730	-3.1199503275
H	6.1852706744	-4.8931252330	-2.7823376547
H	4.8142219319	-0.9693782877	-4.0631312556
H	2.5589900848	-1.9594828628	-4.3352322919
C	7.0476262177	-2.3263877728	-3.3229598984
H	7.1375473966	-1.2449964008	-3.3573724698

C	8.1692783889	-3.0888407098	-2.6687907543
H	9.1177946433	-2.5711547506	-2.8236047316
H	8.0215079644	-3.1949121401	-1.5871943085
H	8.2760624771	-4.0937760991	-3.0872861341
H	2.2345953785	-4.2249590521	-3.8631129102

Int1

M06-2X/6-311G(d,p) Electronic E: -786.915984 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -786.799000 a.u.

M06-2X/cc-pVTZ Electronic E: -786.960174 a.u.

C	3.1100417875	-3.8964638417	-3.3814803574
C	3.1170243352	-4.1357708410	-2.0231663726
C	3.9842524257	-3.4133909041	-1.2065667182
C	4.8301086301	-2.4606551377	-1.7800412115
C	4.7904897730	-2.2564357395	-3.1392384029
N	3.9384800841	-2.9748724533	-3.8892738498
H	2.4691014850	-4.4129366343	-4.0820193429
H	2.4500555965	-4.8806427715	-1.6093336373
H	5.5200266641	-1.8826620634	-1.1785504887
H	5.4097818935	-1.5401024016	-3.6601166878
C	3.9619890802	-3.6325747235	0.2842168265
C	3.5335234853	-2.3934800296	1.0473815110
H	3.5127705805	-2.6022858553	2.1171585222
H	4.2113589958	-1.5598195167	0.8555635353
H	2.5280020373	-2.1128189053	0.7242348701
Cl	5.6245313149	-4.1468159100	0.8196644895
H	3.3210119268	-4.4792209313	0.5173620279
H	3.9213097445	-2.8087830002	-4.8948255136

a

M06-2X/6-311G(d,p) Electronic E: -403.590617 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -403.458433 a.u.

M06-2X/cc-pVTZ Electronic E: -403.634708 a.u.

C	7.9371504173	-0.9847120408	-5.2932517098
C	9.2965892012	-0.8400006144	-5.1027032426
C	9.0768947925	-0.8880441408	-2.8342421677
C	7.7040402013	-1.0352914592	-2.9055879037
C	7.0738441099	-1.0885362764	-4.1735719897

H	7.5292145710	-1.0178209443	-6.2972087741
H	9.9561439687	-0.7600747195	-5.9618447955
H	9.5600874511	-0.8470344238	-1.8623014990
H	7.1327350002	-1.1094732690	-1.9891819180
N	9.8872147571	-0.7888220742	-3.8980252154
C	5.6785610953	-1.2352264114	-4.3623499469
C	4.6756428771	-1.3419901617	-3.3136886325
C	3.2937133868	-0.7578819134	-3.5769003236
C	3.4656189825	-2.2346139892	-3.5618356420
H	5.0144881157	-1.2916209497	-2.2876069146
H	3.1500688412	-0.2721310269	-4.5338526441
H	2.8038115692	-0.2872917414	-2.7344305019
H	3.0958856977	-2.7885416176	-2.7087710530
H	3.4403379229	-2.7597564790	-4.5083250042
H	5.3176413315	-1.2718669675	-5.3868033516

$TS_{a\text{-}3z}$

M06-2X/6-311G(d,p) Electronic E: -1223.760719 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -1223.561060 a.u.

M06-2X/cc-pVTZ Electronic E: -1223.854926 a.u.

C	7.8477205631	-1.2637820424	-5.3491205482
C	9.0305106526	-0.5659121467	-5.5462186577
C	9.0663227105	0.1545297536	-3.3801096096
C	7.8833702897	-0.5048307678	-3.0773748970
C	7.2456890820	-1.2326755530	-4.0871474888
H	7.3957971031	-1.8207319919	-6.1618470839
H	9.5095609484	-0.5712740710	-6.5199215057
H	9.5776004806	0.7268805013	-2.6128414781
H	7.4808358747	-0.4499194710	-2.0739677580
N	9.6405880438	0.1347563444	-4.5865375008
C	5.9832969593	-1.9554936109	-3.8759961746
C	5.0381847702	-1.5641402700	-2.8352349627
C	3.7385953685	-0.9205666357	-3.3259179701
C	3.7217993044	-2.2935704660	-2.7545101038
H	5.4444084904	-1.1752173693	-1.9113994180
H	3.6227411425	-0.8093082762	-4.3962514143
H	3.3729090112	-0.0985184613	-2.7249416282
H	3.3153971564	-2.4342107307	-1.7617295210

H	3.5930822127	-3.1247540286	-3.4375161999
H	5.5212864517	-2.3145455884	-4.7926936008
C	7.7578479401	-7.9955294520	-2.5090734745
C	6.4374343012	-7.8856591227	-1.7419290719
H	8.6061927743	-8.2631880469	-1.8784375991
H	7.7158276737	-8.6986050450	-3.3418619217
H	5.6570094898	-8.5451052653	-2.1226708141
H	6.5448508575	-8.0659064857	-0.6716006141
N	6.9659207733	-5.8072735789	-2.6565733963
C	5.9804720115	-6.4440691700	-1.9358508516
C	8.0076467820	-6.6038784559	-3.0810014115
O	4.9583566647	-5.9480694558	-1.5331652023
O	8.9348559328	-6.2582472380	-3.7678292630
Cl	6.7397231832	-3.8678888019	-3.2381458587

3z

M06-2X/6-311G(d,p) Electronic E: -1223.779154 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -1223.578605 a.u.

M06-2X/cc-pVTZ Electronic E: -1223.870009 a.u.

C	8.2604824322	-1.4130089094	-5.0389738569
C	8.8604748205	-0.2895279484	-5.6002206594
C	8.2823821248	1.0119181861	-3.8195739851
C	7.6560668852	-0.0461309249	-3.1765805253
C	7.6415048965	-1.2927536478	-3.8001522715
H	8.2797845045	-2.3632361225	-5.5605969618
H	9.3498087454	-0.3611582861	-6.5665951313
H	8.3067035613	1.9924405625	-3.3547145809
H	7.1956604078	0.1039537355	-2.2066890955
N	8.8780547880	0.9066564407	-5.0123390884
C	6.9602453390	-2.4835527831	-3.1801781671
C	5.5372459861	-2.2433964607	-2.7806231499
C	4.4877455121	-2.4902085294	-3.8313147188
C	4.6169313622	-3.4208824959	-2.6583599964
H	5.3750459666	-1.4114548279	-2.1055015960
H	4.8287303739	-2.8495946112	-4.7951217297
H	3.6441792234	-1.8134190364	-3.8604550466
H	3.8577494287	-3.3845890188	-1.8881917920
H	5.0379116239	-4.4024589627	-2.8458679095

H	7.0285095620	-3.3368078175	-3.8533672519
C	6.2248642575	-7.1613879960	-3.2569017287
C	5.7037816850	-7.1984002536	-1.8132829302
H	6.6664764921	-8.1068025060	-3.5752667674
H	5.4729205014	-6.8673350924	-3.9894890404
H	4.6637318334	-6.8839744260	-1.7187314988
H	5.8130238432	-8.1746654743	-1.3397722981
N	7.6667844340	-5.8986861533	-1.8969523112
C	6.5674021812	-6.1921569586	-1.0642269708
C	7.3155506402	-6.0997966577	-3.2412146366
O	6.3982507670	-5.7416874269	0.0329009413
O	7.8225428126	-5.5438038366	-4.1780262204
Cl	7.9352880082	-3.0107967606	-1.7130370248

$TS_{a\text{-}b}$

M06-2X/6-311G(d,p) Electronic E: -403.562618 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -403.433001 a.u.

M06-2X/cc-pVTZ Electronic E: -403.606926 a.u.

C	7.9962123934	-1.1405254314	-5.2894949062
C	9.3279683185	-0.8146680968	-5.0869594600
C	9.0290811849	-0.6372757485	-2.8398290581
C	7.6840115328	-0.9533226187	-2.9323016481
C	7.1219451007	-1.2237621578	-4.1930117276
H	7.6327563526	-1.3316666844	-6.2929826570
H	10.0031968562	-0.7517347673	-5.9354358793
H	9.4650486040	-0.4276139463	-1.8673203704
H	7.0848159820	-0.9790261533	-2.0304696863
N	9.8612864752	-0.5635943970	-3.8865177360
C	5.7296207165	-1.5740372994	-4.4036620128
C	4.8112320493	-1.7956524037	-3.4163048748
C	3.1581096575	-0.6259304655	-3.3924452034
C	3.3647073669	-2.0628452958	-3.6754070878
H	5.1110732623	-1.7856338217	-2.3738796419
H	3.2292038910	0.0974356038	-4.1924011615
H	3.0057128116	-0.2766871634	-2.3805068134
H	2.9048205903	-2.7410288719	-2.9603890132
H	3.1601101648	-2.3532297024	-4.7039888041
H	5.4087696897	-1.6599305784	-5.4391782582

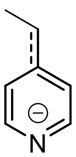
b

M06-2X/6-311G(d,p) Electronic E: -403.572312 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -403.444673 a.u.

M06-2X/cc-pVTZ Electronic E: -403.616322 a.u.

C	7.9857195648	-1.8564835590	-3.9455434357
C	9.3556454686	-1.6625807900	-4.0301343097
C	9.1071200937	0.5025978727	-4.6819728984
C	7.7221413087	0.4103037730	-4.6275438649
C	7.1243955714	-0.7948421743	-4.2485677198
H	7.6057512655	-2.8261659909	-3.6486953026
H	10.0309046553	-2.4801127802	-3.7963737004
H	9.5769667024	1.4368279862	-4.9746737593
H	7.1115237250	1.2706576380	-4.8771510764
N	9.9282459485	-0.5080662792	-4.3903470616
C	5.6568847472	-0.8869025485	-4.1895353780
C	4.9547503483	-1.9587149898	-3.8140333890
C	3.0153973614	-2.1487451448	-2.3135797407
C	3.4484021180	-1.9896634940	-3.7358113406
H	5.4607383050	-2.8704934281	-3.5040642304
H	3.0493701063	-1.2967372108	-1.6459419783
H	2.8779764833	-3.1328138342	-1.8838917391
H	3.0771315982	-2.8264181800	-4.3354528857
H	3.0504837827	-1.0633012577	-4.1600707210
H	5.1234138457	0.0149414916	-4.4831526483



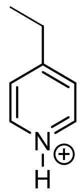
M06-2X/6-311G(d,p) Electronic E: -326.329168 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -326.229829 a.u.

M06-2X/cc-pVTZ Electronic E: -326.367364 a.u.

C	5.7318041765	-2.7591146223	-4.2570390104
C	6.9057064593	-2.9229046142	-3.5713642928
C	7.1567199620	-2.2208675559	-2.3245642264
C	6.0389734036	-1.3711162153	-1.9496744562
C	4.9114783189	-1.2985251085	-2.7331907876
N	4.6949758377	-1.9620906769	-3.8898256625

H	5.5897455053	-3.3080564580	-5.1875505062
H	7.6639962159	-3.5924959913	-3.9681426740
H	6.0841106991	-0.7815734757	-1.0399483496
H	4.0978813882	-0.6482624442	-2.4110575853
C	8.3058354571	-2.3428792213	-1.5891653681
H	9.0891535029	-3.0042224037	-1.9483264145
C	8.5310894527	-1.6012651325	-0.2971711768
H	9.5079612156	-1.8441077749	0.1282086260
H	8.5008504081	-0.5079838949	-0.4155509844
H	7.7823889969	-1.8393614103	0.4728588689

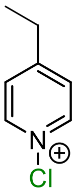


M06-2X/6-311G(d,p) Electronic E: -327.315078 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -327.186930 a.u.

M06-2X/cc-pVTZ Electronic E: -327.350286 a.u.

H	0.9224254558	-1.0338794140	-3.9724617631
C	2.0467451363	-0.9409384957	-2.2801109918
C	3.1285977643	-1.4584923428	-1.6006372562
C	3.8809875862	-2.4878606182	-2.1717901471
C	3.4997912864	-2.9618709626	-3.4353463871
C	2.4152117955	-2.4184643803	-4.0783482218
N	1.7241024893	-1.4292374164	-3.4849487305
H	1.4231654164	-0.1448893048	-1.8980019781
H	3.3717087049	-1.0503832655	-0.6295759280
H	4.0546641824	-3.7579783077	-3.9154447473
H	2.0673857073	-2.7351513868	-5.0513595793
C	5.0712418763	-3.1014335766	-1.4876017670
H	4.8691376364	-4.1734481618	-1.3917580898
H	5.9172764134	-3.0207097237	-2.1778351238
C	5.4320420694	-2.5073442696	-0.1336636832
H	4.6152140934	-2.6216475853	0.5827292098
H	6.3071804457	-3.0180146499	0.2700950504
H	5.6701599405	-1.4442021383	-0.2159058661

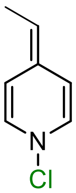


M06-2X/6-311G(d,p) Electronic E: -786.846472 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -786.731763 a.u.

M06-2X/cc-pVTZ Electronic E: -786.895859 a.u.

Cl	7.1888454004	-6.3820456071	-1.2426984870
C	6.5696429982	-4.6175349339	-3.0927832505
C	6.8665172542	-3.6946597568	-4.0694059487
C	8.1948602991	-3.4127341919	-4.3963782300
C	9.1982501304	-4.1028140464	-3.7026002902
C	8.8793144568	-5.0186485483	-2.7341952110
N	7.5760106032	-5.2466950541	-2.4574998755
H	5.5619305784	-4.8756302554	-2.7963649003
H	6.0392305923	-3.2033549439	-4.5628066139
H	10.2448049395	-3.9249388884	-3.9166128826
H	9.6096433842	-5.5789942959	-2.1668358074
C	8.5835619415	-2.4133032900	-5.4461986696
H	9.2552907730	-1.6928440432	-4.9676588994
H	9.1973685016	-2.9445169056	-6.1815215418
C	7.4302829335	-1.6954370990	-6.1311661241
H	6.8283084656	-1.1339053494	-5.4129765048
H	7.8224820190	-0.9909622435	-6.8654721311
H	6.7771057290	-2.3980685473	-6.6536286322



M06-2X/6-311G(d,p) Electronic E: -786.372559 a.u.

M06-2X/6-311G(d,p) Gibbs free E: -786.272554 a.u.

M06-2X/cc-pVTZ Electronic E: -786.421712 a.u.

Cl	7.2938329362	-6.8236907114	-1.7226587000
C	6.5340035988	-4.6651259804	-3.0489460481
C	6.7577552088	-3.7982626861	-4.0456386572
C	8.1127839497	-3.3990725151	-4.4347300331
C	9.1632302386	-4.0922898111	-3.6853628412

C	8.8915977293	-4.9504751624	-2.6953110525
N	7.5748419192	-5.1798045471	-2.2628785840
H	5.5412498145	-4.9682679177	-2.7429998044
H	5.8950416586	-3.3831943739	-4.5500986013
H	10.2012281521	-3.8861531145	-3.9202245039
H	9.6552887527	-5.4599251954	-2.1227930045
C	8.4121061584	-2.4934745319	-5.3874187051
H	9.4671395662	-2.3063792237	-5.5743565203
C	7.4465629114	-1.7173717858	-6.2274023501
H	7.6953526012	-0.6520937258	-6.2093268982
H	7.5001701453	-2.0321356255	-7.2754796626
H	6.4130176591	-1.8268640922	-5.8984840334

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