

Supporting Information

Remote C(sp³)-H Cyanation and Deuteration of Amides via Photoredox Catalysis

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1. General information

^1H NMR (400 MHz), ^{13}C NMR (100 MHz) and ^{19}F NMR (376 MHz) spectra were recorded on a Quantum-I Plus 400 NMR spectrometer with CDCl_3 as solvent and tetramethylsilane (TMS) as the internal standard. Chemical shifts were reported in parts per million (ppm, δ scale) downfield from TMS at 0.00 ppm and referenced to CDCl_3 at 7.26 ppm (for ^1H NMR) and 77.16 ppm (for ^{13}C NMR). HR-MS spectra were recorded on a Waters Xevo G2QTOF/UPLC mass spectrometer using electrospray ionization. EPR experiments were conducted using Bruker Elexsys E580 Spectrometer. All commercially available reagents and solvents were purchased from Energy Chemical and Adamas-beta® and used as received unless otherwise specified.

2. Photochemical reaction setup

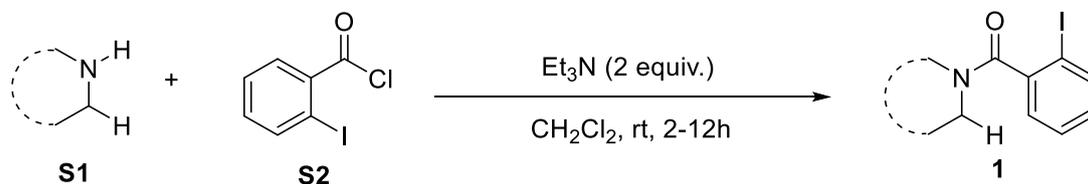


Figure S1: Reaction setup

3. General procedures for synthesis of substrates

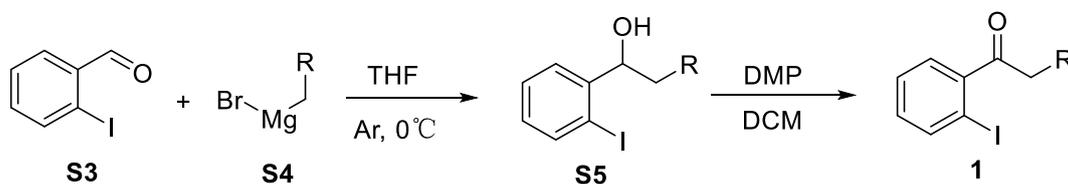
3.1 Synthesis of substrates

General synthetic procedures A:



An oven-dried 20 mL reaction vial, equipped with a magnetic stir bar, was charged with 2-iodobenzoyl chloride (2.0 mmol) under an inert nitrogen atmosphere in a glovebox and sealed with a septum-capped open-top closure. To this mixture were sequentially added the amine substrate (2.5 mmol) and anhydrous dichloromethane (DCM, 10 mL). The reaction was initiated by the dropwise addition of triethylamine (Et_3N , 3.0 mmol;) under continuous stirring. Upon completion of the reaction, the mixture was quenched with water, and the aqueous layer was extracted with DCM (3×5 mL). The combined organic extracts were washed with brine, dried over anhydrous sodium sulfate (Na_2SO_4), and concentrated in vacuo. The crude residue was purified by flash column chromatography (hexane/ethyl acetate gradient) to afford the desired tethered amine products in high purity.

General synthetic procedures B:

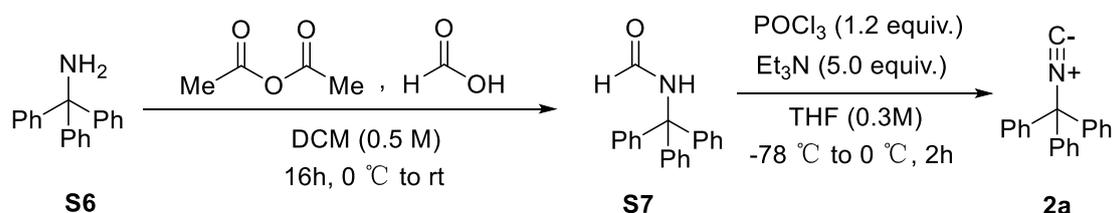


A three-neck round-bottom flask was flame-dried under vacuum and purged with nitrogen prior to use. The flask was charged with 2-iodobenzaldehyde (5 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (THF, 20 mL) under a positive pressure of nitrogen. The reaction vessel was immersed in an ice-water bath to maintain the internal temperature at 0 °C. The corresponding Grignard reagent (1.5 equiv) was introduced dropwise via syringe pump over 30 minutes while maintaining rigorous temperature

control. The resulting heterogeneous mixture was stirred vigorously at 0 °C for 2 hours, with reaction progress monitored by thin-layer chromatography (TLC). The reaction was quenched by careful addition of saturated aqueous ammonium chloride (NH₄Cl) solution. The aqueous layer was extracted with ethyl acetate (3 × 30 mL), and the combined organic extracts were washed with brine (50 mL), dried over anhydrous sodium sulfate (Na₂SO₄), and filtered. The solvent was removed under reduced pressure using a rotary evaporator, and the crude product was purified by flash column chromatography on silica gel using a gradient elution system to afford the desired secondary benzylic alcohol as a colorless oil.

In a separate flame-dried round-bottom flask, a solution of alcohol **3** (1.0 equiv) in anhydrous dichloromethane (DCM, 0.1 M) was prepared under nitrogen atmosphere. The solution was cooled to 0 °C in an ice-water bath, and Dess-Martin periodinane (DMP, 1.5 equiv) was added portionwise over 5 minutes. The cooling bath was removed, and the reaction mixture was allowed to warm gradually to room temperature (25 °C) with continuous stirring. Reaction completion was confirmed by TLC analysis after 2 hours. The mixture was filtered through a pad of Celite®, washing thoroughly with ethyl acetate (3 × 20 mL). The combined filtrates were concentrated under reduced pressure, and the resulting residue was purified by flash column chromatography on silica gel (230-400 mesh) using a mixture of petroleum ether and ethyl acetate (10:1 to 5:1 gradient) as eluent to yield the target 1-(o-iodoaryl)alkan-1-one as a pale yellow crystalline solid.

General synthetic procedures C:

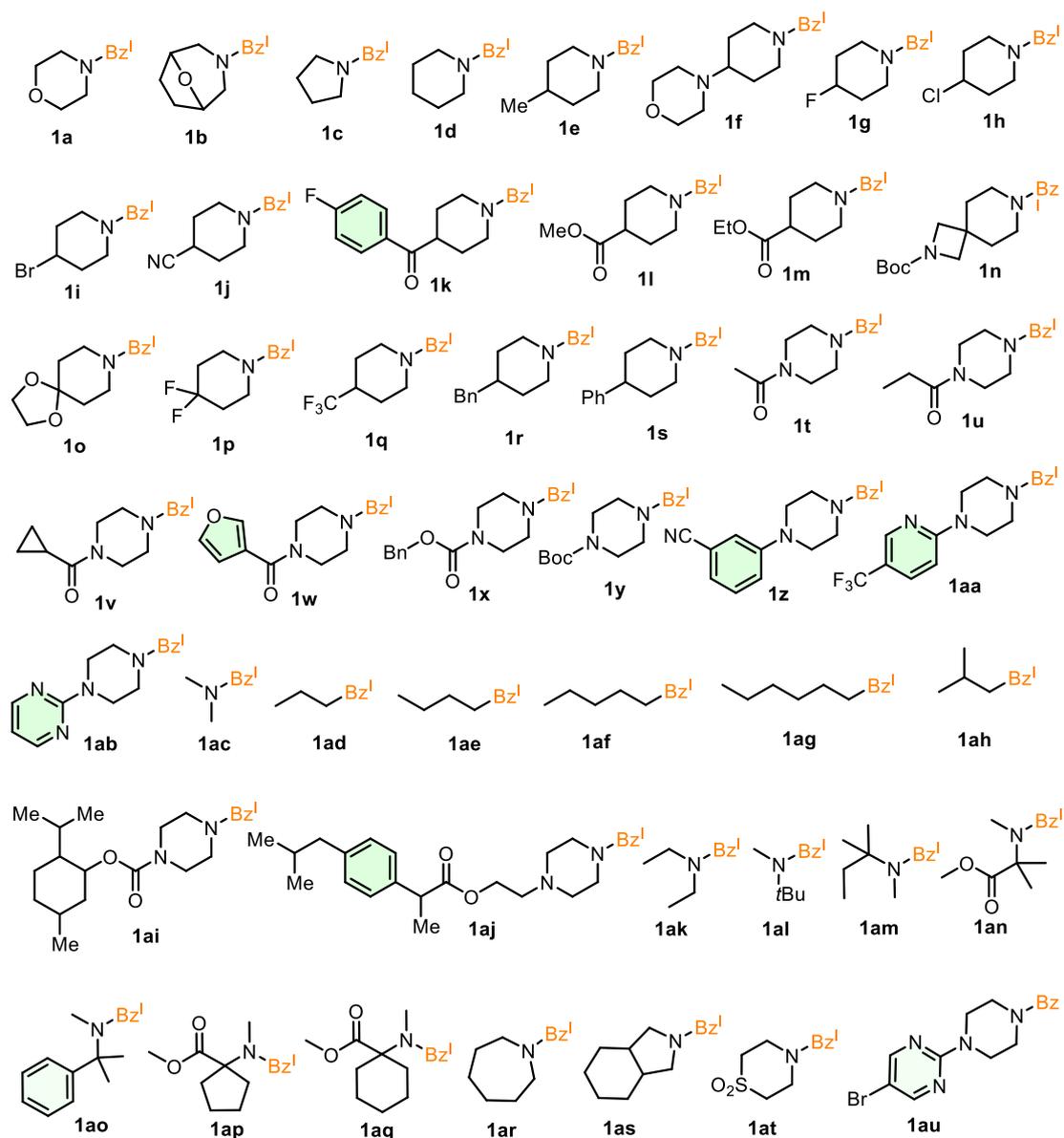


Acetic formic anhydride was prepared by stirring acetic anhydride (27.3 mL, 289.2 mmol, 2.5 equiv.) and formic acid (10.9 mL, 289.2 mmol, 2.5 equiv.) at 55 °C for 2 h. This reagent was added dropwise to a solution of triphenylmethanamine **S6** (30.0 g,

115.7 mmol, 1.0 equiv.) in dry DCM (231.0 mL, 0.5 M) at 0 °C. After stirring at 0 °C for 15 min, the reaction was warmed to room temperature and stirred for 16 h. The mixture was quenched with cold water and extracted with DCM (×3). The combined organic layers were dried (Na₂SO₄), concentrated, and used directly as crude **S7** without purification.

A solution of **S7** (33.3 g, 115.7 mmol) in anhydrous THF (290 mL) was cooled to -78°C under N₂. Et₃N (80.6 mL, 578.5 mmol) was added, followed by dropwise addition of POCl₃ (12.9 mL, 138.8 mmol) in THF (92 mL). The reaction was stirred at -78°C for 1 h, warmed to 0°C (1 h), then quenched with ice-water. Standard workup (Et₂O extraction, Na₂SO₄ drying, concentration) afforded the crude product, which was purified by flash chromatography (SiO₂, 0→2% EtOAc/cyclohexane) to yield **2a** (23.4 g, 76%) as a white solid (R_f = 0.60 in 9:1 cyclohexane/EtOAc).

The following substrates were synthesized through **general procedure A and B**



Examples of unsuccessful substrates

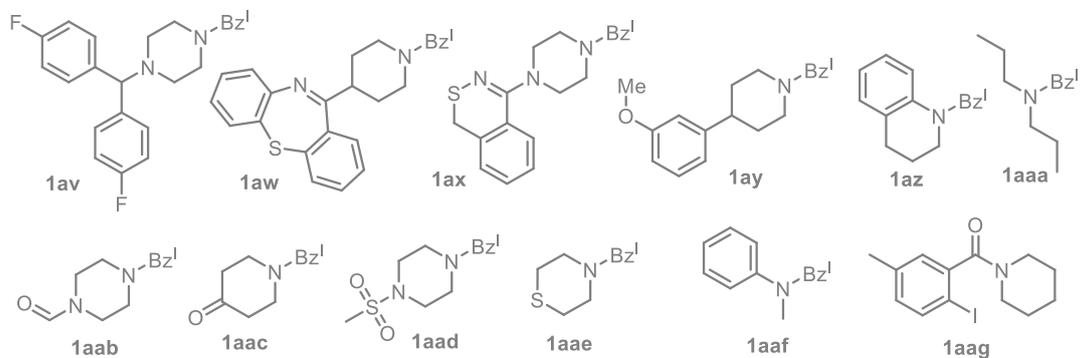
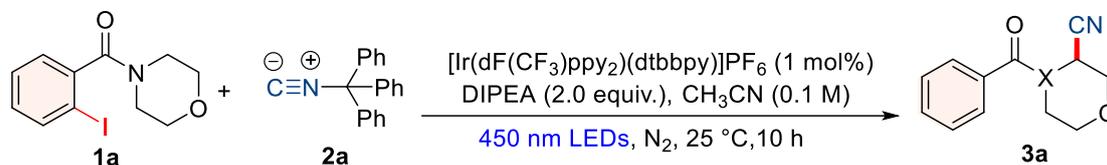


Figure S1. Starting materials prepared according to general procedure A and B

NMR data are consistent with reported literature.¹⁻⁴

4. Optimization of the reaction conditions

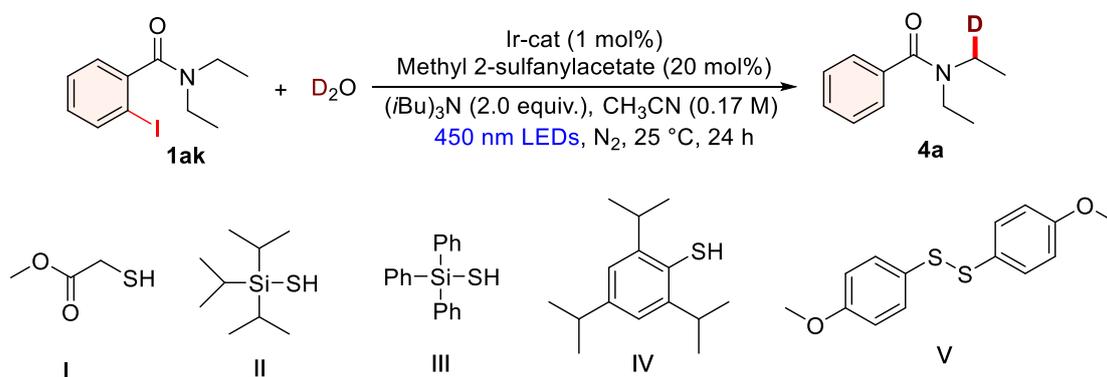
Table S1. Optimization of Remote C(sp³)-H Cyanation^a



Entry	Catalyst	Solvent	Base	Yield ^b
1	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	DIPEA	81%
2	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Et ₃ N	N.D.
3	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Bn ₃ N	N.D.
4	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Me ₃ N	N.D.
5	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(tBu) ₃ N	N.D.
6	[Ir(ppy) ₂ (dtbbpy)]PF ₆	MeCN	DIPEA	35%
7	Ir(ppy) ₃	MeCN	DIPEA	51%
8	4CzIPN	MeCN	DIPEA	< 5%
9	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	DMF	DIPEA	37%
10	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	DCM	DIPEA	22%
11	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	EtOAc	DIPEA	61%
12	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	THF	DIPEA	29%
13 ^c	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	DIPEA	N.D.
14	-	MeCN	DIPEA	N.D.
15	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	-	N.D.

^a reaction conditions: (2-iodophenyl)(morpholino)methanone (0.2 mmol, 1.0 equiv.), (isocyanomethanetriyl)tribenzene (0.4 mmol, 0.4 equiv.), Catalyst (0.02 mmol, 0.1 equiv.), Base (0.4 mmol, 2 equiv.), Solvent (2 ml, 0.1 M), 25 °C, blue light, N₂ atmosphere, 10 h. ^b Yields are of isolated products after chromatographic purification. ^c The reaction was performed in the dark. DIPEA = *N,N*-diethylpropan-2-amine. N.D. = Not detected.

Table S2. Optimization of Remote C(sp³)-H Deuteration^a

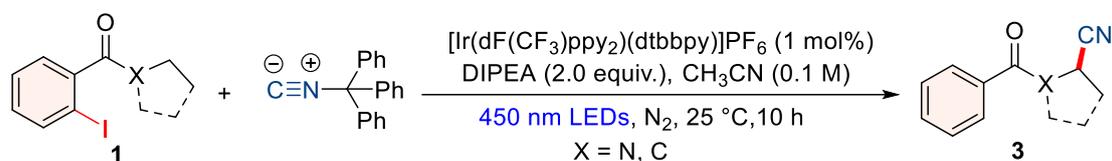


Entry	Catalyst	Solvent	Base	R-SH	Yield ^b	D-inc
1	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	I	91%	94%
2	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	DIPEA	I	82%	81%
3	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Et ₃ N	I	83%	76%
4	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Me ₃ N	I	62%	67%

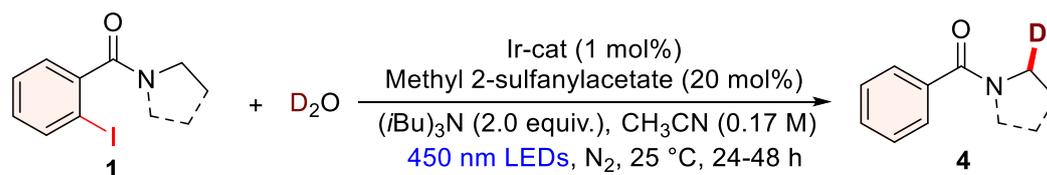
5	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	Bn ₃ N	I	59%	54%
6	Ir(ppy) ₃	MeCN	(<i>i</i> Bu) ₃ N	I	65%	71%
7	4CzIPN	MeCN	(<i>i</i> Bu) ₃ N	I	77%	46%
8	[Ir(ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	I	88%	86%
9	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	DCM	(<i>i</i> Bu) ₃ N	I	64%	73%
10	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	DMF	(<i>i</i> Bu) ₃ N	I	61%	66%
11	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	EtOAc	(<i>i</i> Bu) ₃ N	I	Trace	-
12	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	THF	(<i>i</i> Bu) ₃ N	I	Trace	-
13	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	II	N.D.	-
14	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	III	N.D.	-
15	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	IV	N.D.	-
16	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	V	N.D.	-
17	-	MeCN	(<i>i</i> Bu) ₃ N	I	N.D.	-
18	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	-	I	N.D.	-
19	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	-	N.D.	-
20 ^c	[Ir(dF(CF ₃)ppy) ₂ (dtbbpy)]PF ₆	MeCN	(<i>i</i> Bu) ₃ N	I	N.D.	-

^a reaction conditions: *N,N*-diethyl-2-iodobenzamide (0.2 mmol, 1.0 equiv.), D₂O (0.8mL), Catalyst (0.02 mmol, 0.1 equiv.), Base (0.4mmol, 2 equiv.), Thioalcohol (20 mol%), Solvent (1.2 ml, 0.17 M), 25 °C, blue light, N₂ atmosphere, 24 h. ^b Yields are of isolated products after chromatographic purification. ^c The reaction was performed in the dark. N.D. = Not detected.

5. General procedures for Remote C(sp³)-H Cyanation and Deuteration



General procedure 1: To a 8 mL glass bottles equipped with a magnetic stir bar, 2-iodobenzoyl protected amine (0.2 mmol, 1.0 equiv.), (isocyanomethanetriyl)tribenzene (0.24 mmol, 1.2 equiv.), DIPEA (0.4 mmol, 2 equiv.) Ir catalyst (1 mol%) and CH₃CN (2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 10 hours. After the reaction was finished (monitored by TLC), the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel.

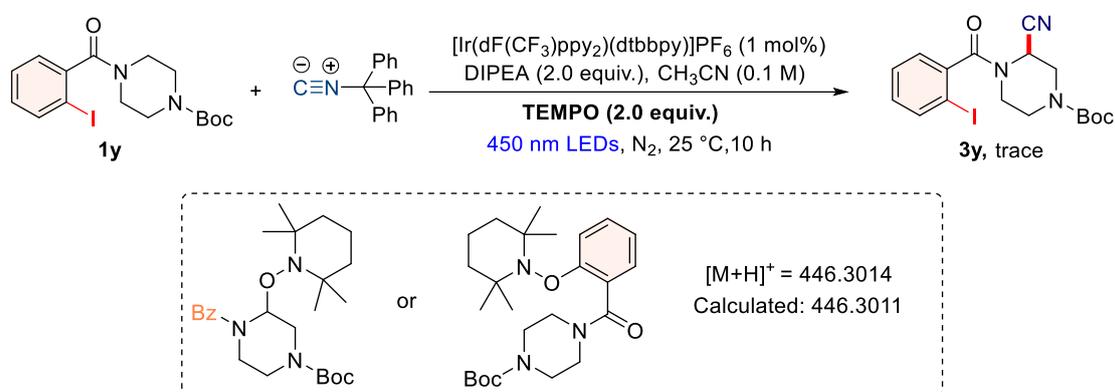


General procedure 2: To a 8 mL glass bottles equipped with a magnetic stir bar, 2-iodobenzoyl protected amine (0.2 mmol, 1.0 equiv.), D₂O (0.8mL), Ir catalyst (1 mol%),

(*i*Bu)₃N (0.4 mmol, 2 equiv.), methyl 2-mercaptoacetate (20 mol%) and CH₃CN (1.2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 24-48 hours. After the reaction was finished (monitored by GC-MS), the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel.

6. Mechanistic studies

6.1 Radical scavenging experiments with TEMPO



Follow **General procedure 1**, To a 8 mL glass bottles equipped with a magnetic stir bar, 2-iodobenzoyl protected amine (0.2 mmol, 1.0 equiv.), (isocyanomethanetriyl)tribenzene (0.24 mmol, 1.2 equiv.), DIPEA (0.4 mmol, 2 equiv.), TEMPO (0.4 mmol, 2.0 equiv.), Ir catalyst (1 mol%) and CH₃CN (2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 10 hours. The reaction was monitored by GC-MS. No product **3y** was observed.

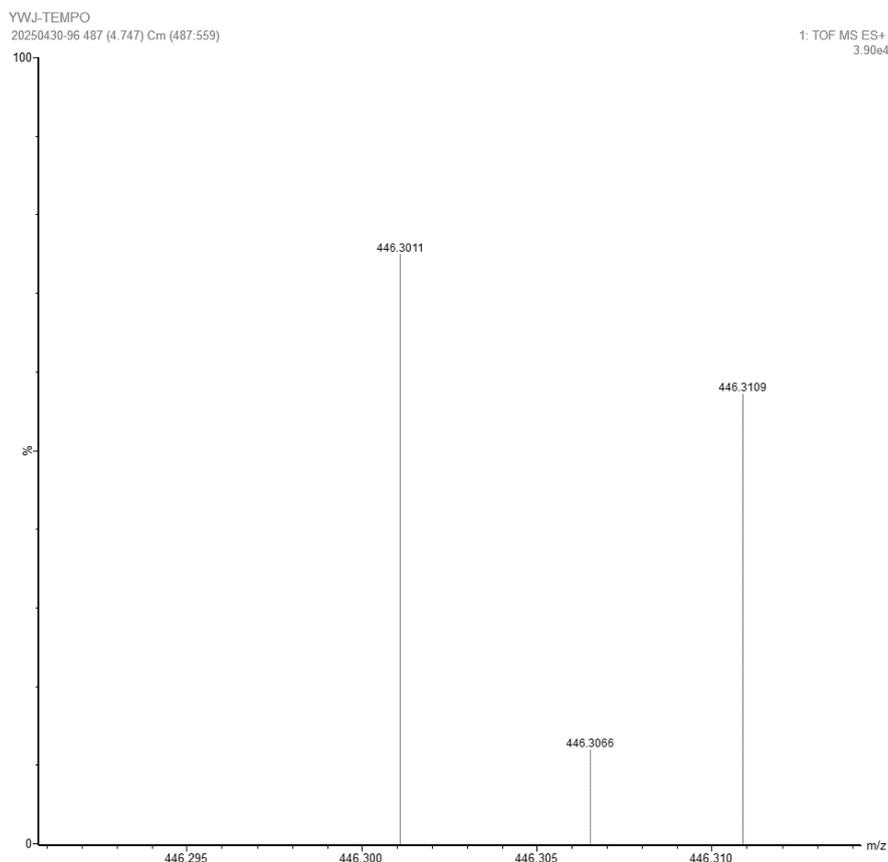
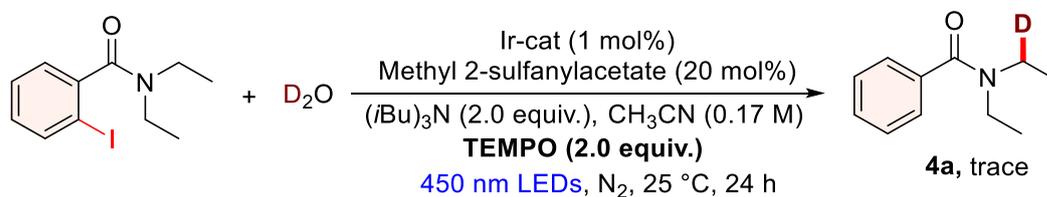
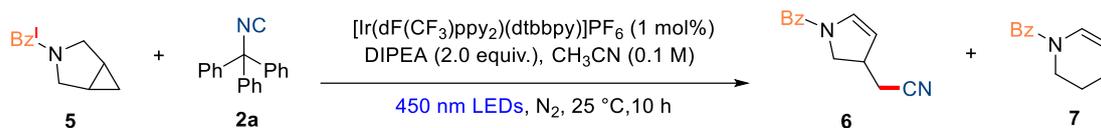


Figure S2 HRMS of TEMPO trapped adducts



Follow **General procedure 2**, to a 8 mL glass bottles equipped with a magnetic stir bar, *N,N*-diethyl-2-iodobenzamide (0.2 mmol, 1.0 equiv.), D_2O (0.8 mL), Ir catalyst (1 mol%), $(iBu)_3N$ (0.4 mmol, 2 equiv.), TEMPO (0.4 mmol, 2.0 equiv.), methyl 2-mercaptoacetate (20 mol%) and CH_3CN (1.2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 24 hours. The reaction was monitored by GC-MS No product **4a** was observed.

6.2 Radical clock experiments



Follow **General procedure 1**, To a 8 mL glass bottles equipped with a magnetic stir bar, (3-azabicyclo[3.1.0]hexan-3-yl)(2-iodophenyl)methanone (0.2 mmol, 1.0 equiv.), (isocyanomethyl)triphenylborane (0.24 mmol, 1.2 equiv.), DIPEA (0.4 mmol, 2 equiv.), TEMPO (0.4 mmol, 2.0 equiv.) Ir catalyst (1 mol%) and CH_3CN (2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 10 hours. The reaction was monitored by GC-MS. Product **6** and **7** can be observed.

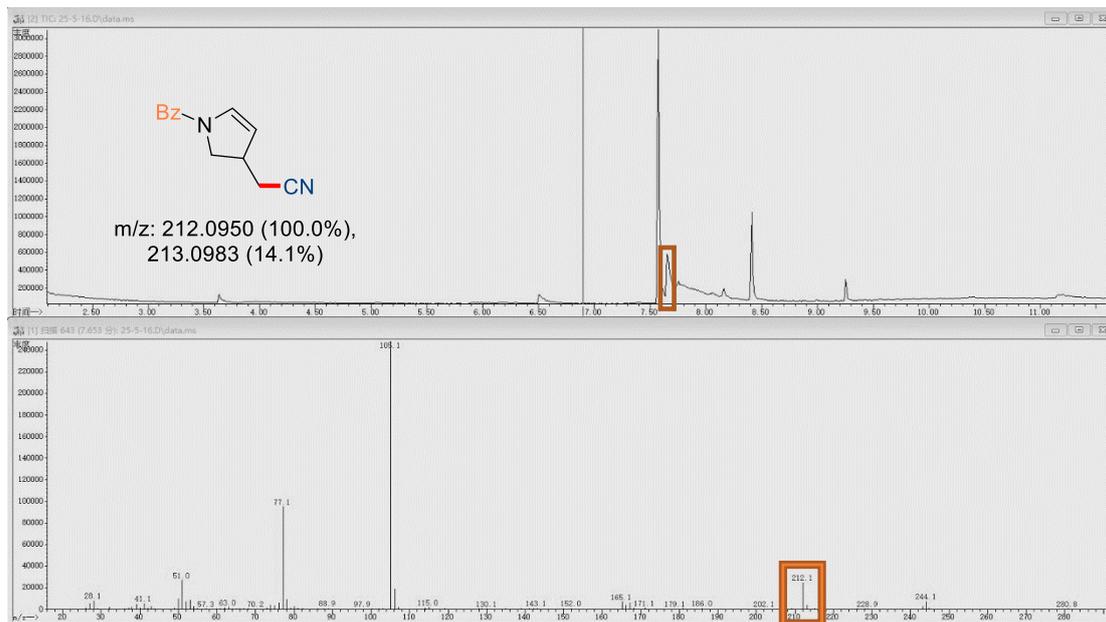
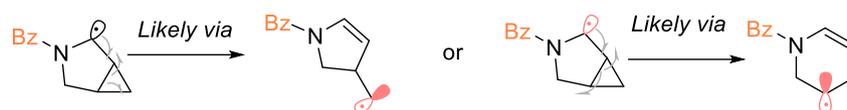


Figure S3 GC-MS of radical clock experiments (product **6**)

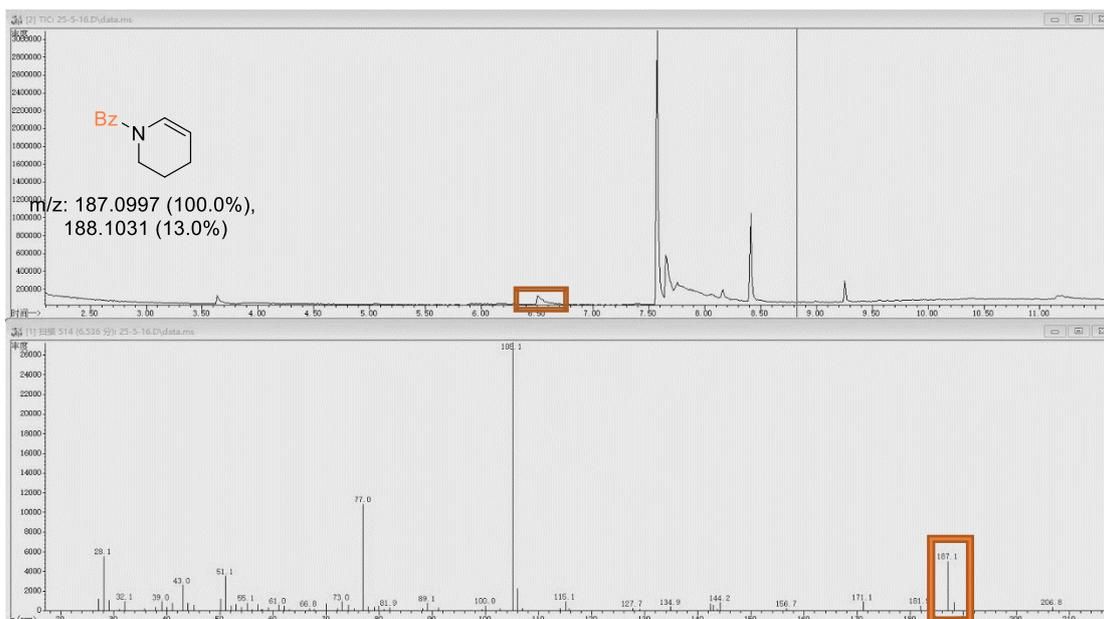
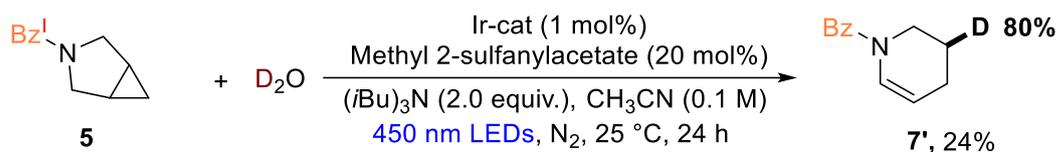


Figure S4 GC-MS of radical clock experiments (product **7**)



Follow **General procedure 2**, to a 8 mL glass bottles equipped with a magnetic stir bar, (3-azabicyclo[3.1.0]hexan-3-yl)(2-iodophenyl)methanone (0.2 mmol, 1.0 equiv.), D₂O (0.8 mL), Ir catalyst (1 mol%), (iBu)₃N (0.4 mmol, 2 equiv.), methyl 2-mercaptoacetate (20 mol%) and CH₃CN (1.2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 24 hours. After the reaction was finished (monitored by GC-MS), the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel.

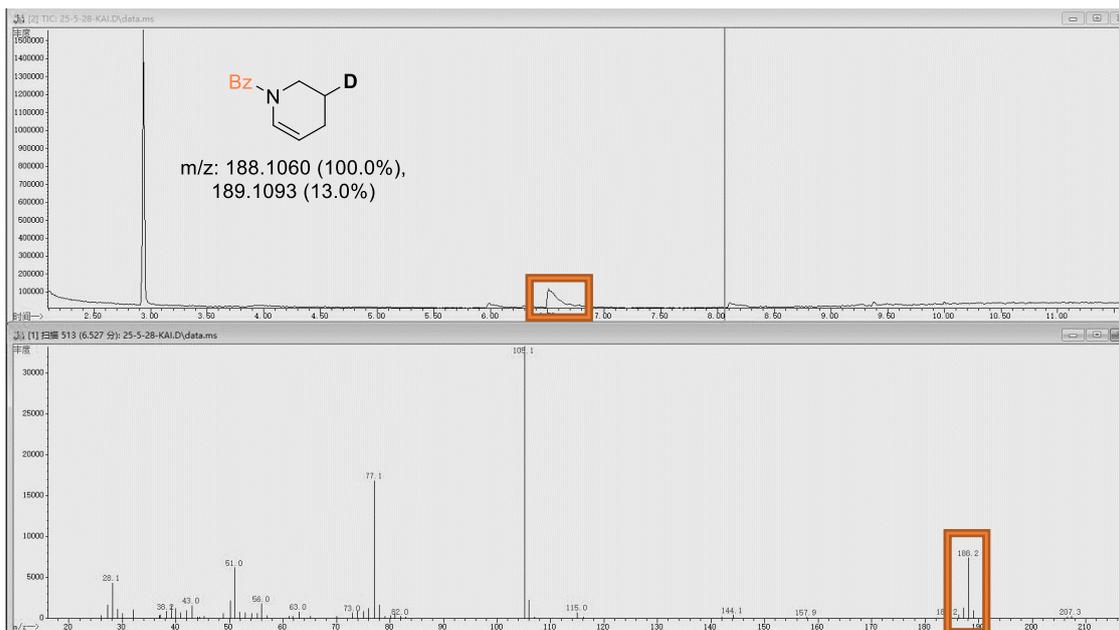
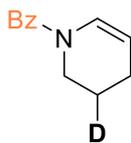


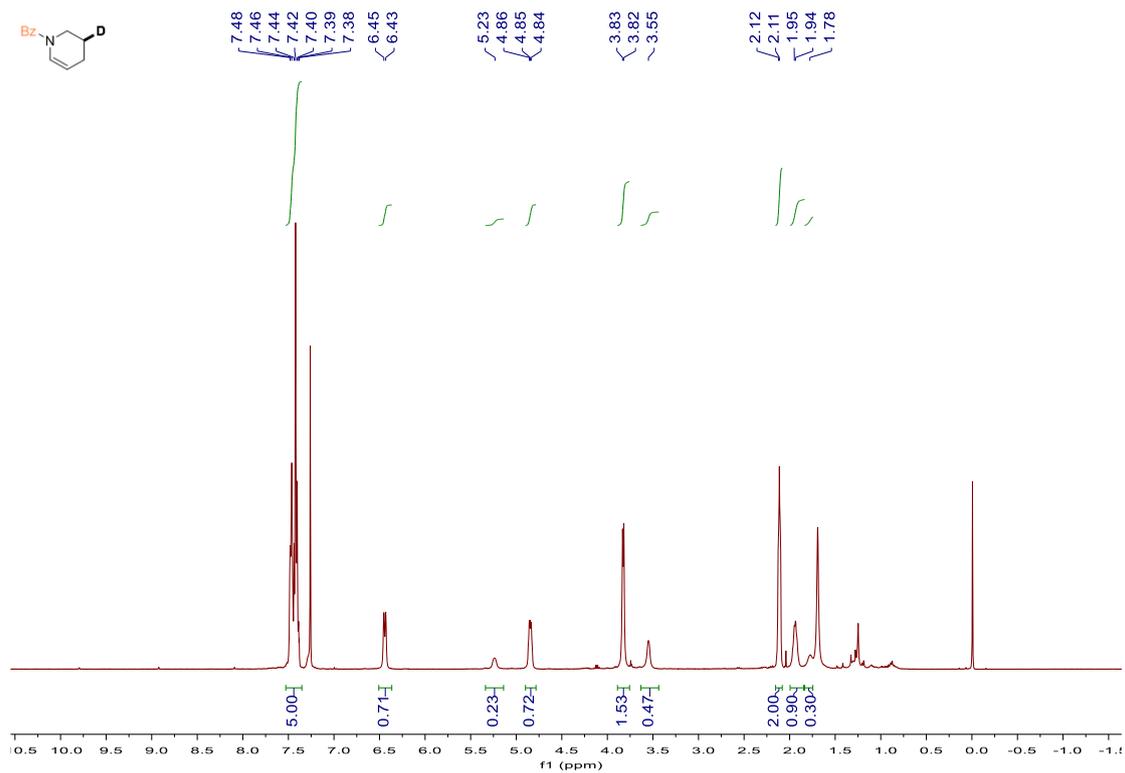
Figure S3 GC-MS of radical clock experiments (product 7')



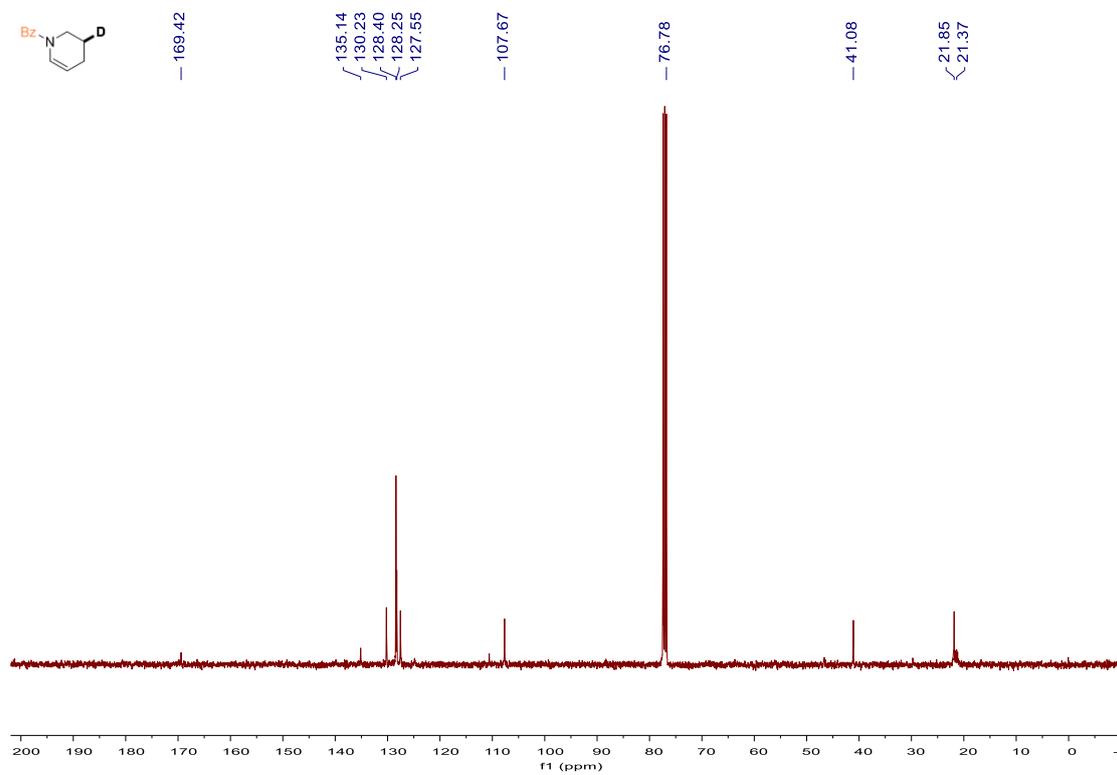
(3,4-dihydropyridin-1(2H)-yl-3-d)(phenyl)methanone (7'):

^1H NMR (400 MHz, CDCl_3) δ 7.52 - 7.37 (m, 5H), 7.29 - 6.44 (d, $J = 8.2$ Hz, 1H), 5.23 - 4.84 (m, 1H), 3.92-3.49 (d, $J = 5.4$ Hz, 2H), 2.17 - 2.06 (m, 2H), 2.01 - 1.75 (m, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 169.4 135.1, 130.2, 128.4, 128.2, 127.5, 107.6, 76.8, 41.1, 21.9, 21.4.

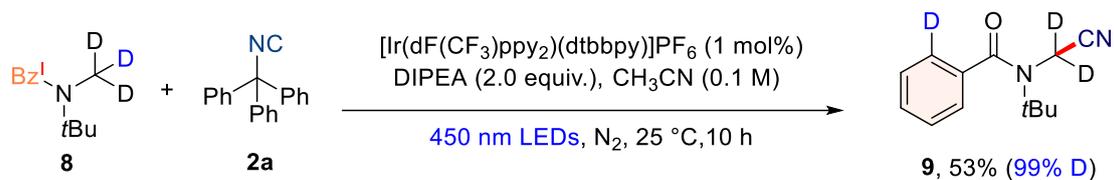
^1H NMR spectrum (100 MHz, CDCl_3 , 23 °C) of 7'



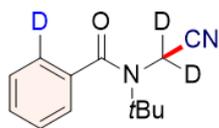
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of 7'



6.3 Deuterium labeling experiments



Follow **General procedure 1**, to a 8 mL glass bottles equipped with a magnetic stir bar, *N*-(tert-butyl)-2-iodo-*N*-(methyl-d₃)benzamide (0.2 mmol, 1.0 equiv.), (isocyanomethanetriyl)tribenzene (0.24 mmol, 1.2 equiv.), DIPEA (0.4 mmol, 2 equiv.), Ir catalyst (1 mol%) and CH_3CN (2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under blue LEDs and irradiated for 10 hours. After the reaction was finished (monitored by TLC), the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel.



N-(tert-butyl)-*N*-(cyanomethyl-d₂)benzamide-2-d (**9**):

^1H NMR (400 MHz, Chloroform-*d*) δ 7.55 – 7.36 (m, 4H), 1.61 (s, 9H). ^{13}C NMR (101 MHz, CDCl_3) δ 173.2, 137.1, 130.5, 130.0, 126.6, 117.5, 58.5, 28.2.

6.3 Cyclic voltammetry

Substrate redox potentials were determined using CV with the following method in (Figure S4). Cyclic voltammetry experiments were performed on a CHI 760E potentiometer and a Glass Carbon electrode as the working electrode. The auxiliary electrode was a platinum sheet. All potentials are referenced against the SCE (Saturated Calomel Electrode) redox couple. reference. Samples were prepared with 0.01 mmol of substrate **1a** in 10 mL of 0.1 M tetrabutylammonium tetrafluoroborate (nBu_4NBF_4) in dry, degassed NMP.

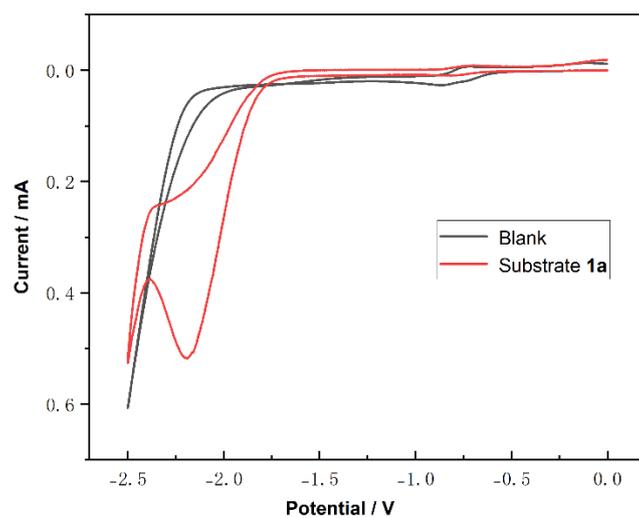
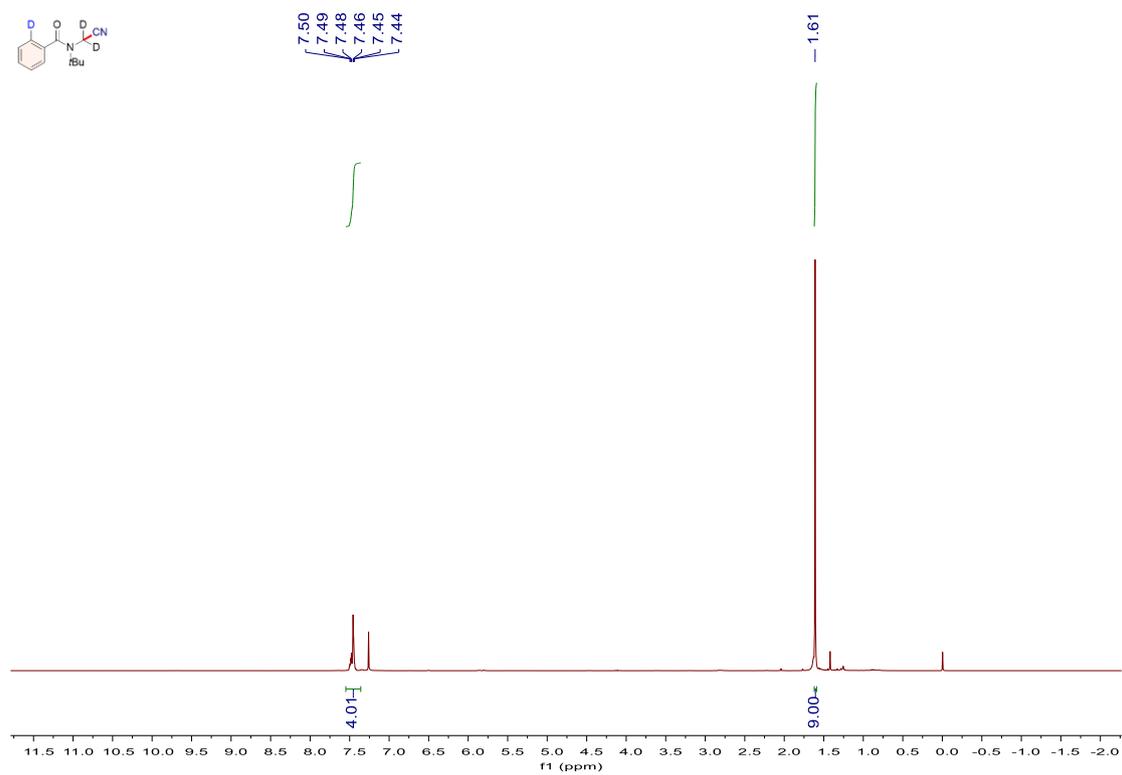


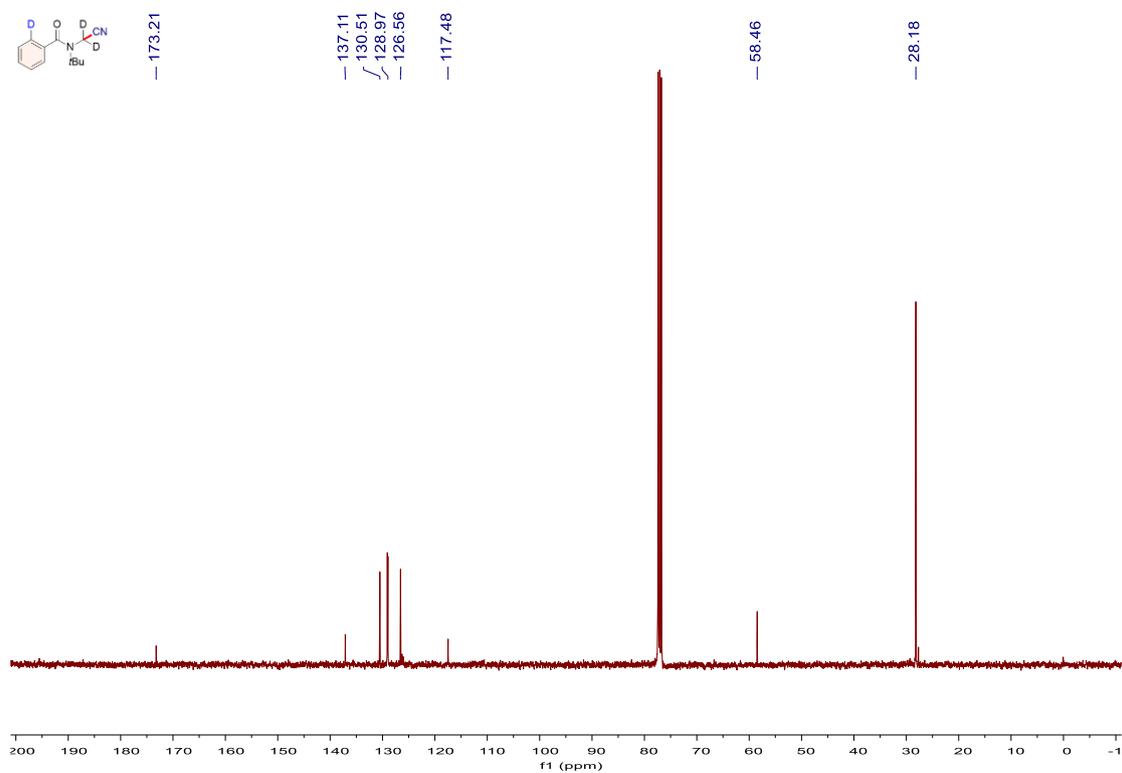
Figure S4 Cyclic voltammetry (IUPAC convention) studies of **1a**

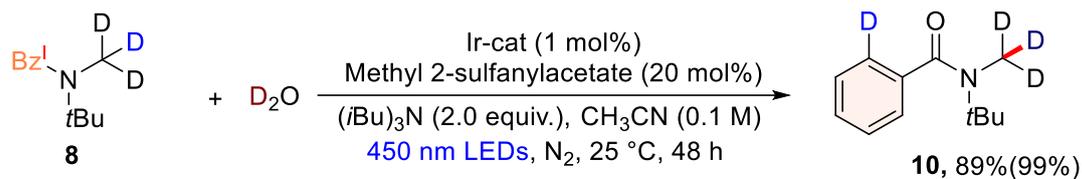
In figure S4: The $E_{p1/2}$ values of (2-iodophenyl)(morpholino)methanone (**1a**) were measured and determined as -2.20 V.

^1H NMR spectrum (100 MHz, CDCl_3 , 23 $^\circ\text{C}$) of **9**



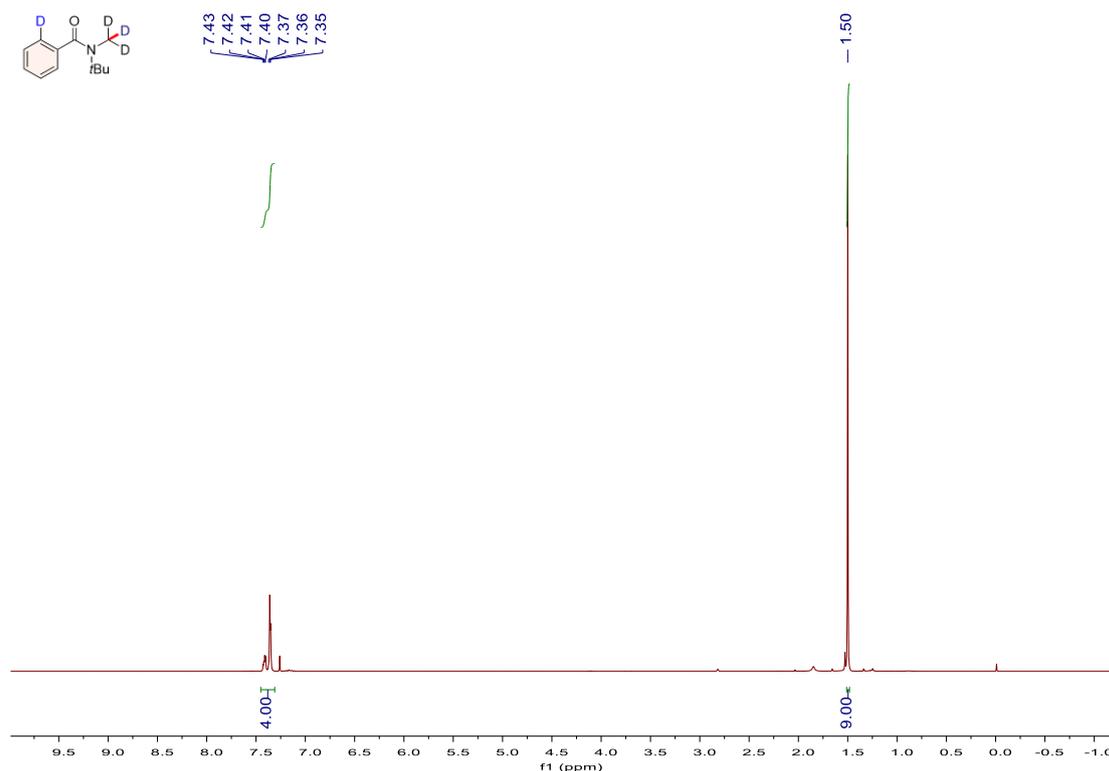
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 $^\circ\text{C}$) of **9**



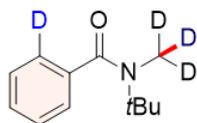
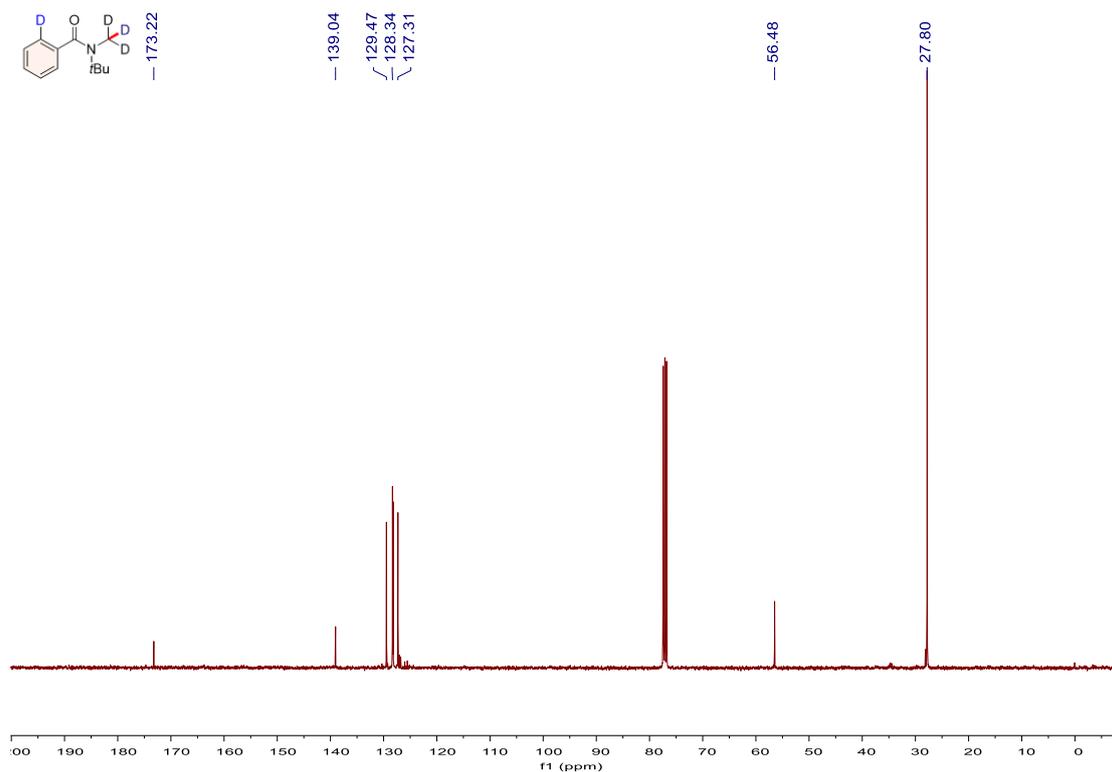


Follow **General procedure 2** to a 8 mL glass bottles equipped with a magnetic stir bar, *N*-(tert-butyl)-2-iodo-*N*-(methyl- d_3)benzamide (0.2 mmol, 1.0 equiv.), D_2O (0.8 mL), Ir catalyst (1 mol%), $(iBu)_3N$ (0.4 mmol, 2 equiv.), methyl 2-mercaptoacetate (20 mol%) and CH_3CN (1.2 mL) were added. The resulting mixture was stirred in nitrogen atmosphere under a blue LEDs and irradiated for 24-48 hours. After the reaction was finished (monitored by TLC), the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel.

1H NMR spectrum (100 MHz, $CDCl_3$, 23 °C) of **10**



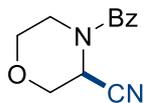
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **10**



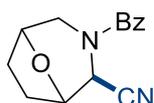
***N*-(tert-butyl)-*N*-(methyl-d₃)benzamide-2-d (**10**):**

^1H NMR (400 MHz, CDCl_3) δ 7.45 – 7.31 (m, 4H), 1.50 (s, 9H). ^{13}C NMR (101 MHz, CDCl_3) δ 173.2, 139.0, 129.5, 128.3, 127.3, 56.5, 27.8.

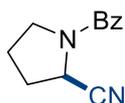
7. Characterization of the products



4-benzoylmorpholine-3-carbonitrile (3a): Followed the general procedure 1 with (2-iodophenyl)(morpholino)methanone (63.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 35.9 mg of the title compound (Colorless oil); 83% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 – 7.37 (m, 4.1 Hz, 5H), 5.46 (s, 1H), 4.14 (d, J = 12.1 Hz, 1H), 4.03 – 3.89 (m, 1H), 3.85 – 3.61 (m, 2H), 3.52 (d, J = 8.4 Hz, 2H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 133.2, 131.1, 129.0, 127.4, 116.3, 67.9, 66.8, 42.6. **HRMS (ESI)** calcd $\text{C}_{12}\text{H}_{13}\text{N}_2\text{O}_2^+$ $[\text{M} + \text{H}]^+$: 217.0972, found: 217.0971.

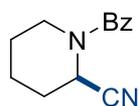


3-benzoyl-8-oxa-3-azabicyclo[3.2.1]octane-2-carbonitrile (3b): Followed the general procedure 1 with (8-oxa-3-azabicyclo[3.2.1]octan-3-yl)(2-iodophenyl)methanone (68.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 31.9 mg of the title compound (Colorless oil); 66% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.61 – 7.34 (m, 5H), 5.41 (s, 1H), 4.68 – 4.29 (m, 2H), 3.84 – 3.25 (m, 2H), 2.11 – 1.63 (m, 4H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 171.6, 133.5, 130.93, 129.0, 127.2, 116.3, 75.2, 51.6, 46.7, 27.2, 26.7. **HRMS (ESI)** calcd $\text{C}_{14}\text{H}_{14}\text{N}_2\text{O}_2\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 265.0947, found: 265.0946.

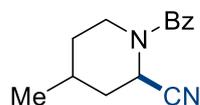


1-benzoylpyrrolidine-2-carbonitrile (3c): Followed the general procedure 1 with (2-iodophenyl)(pyrrolidin-1-yl)methanone (60.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 22.0 mg of the title compound (Colorless oil); 55% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 (d, J = 7.2 Hz, 2H),

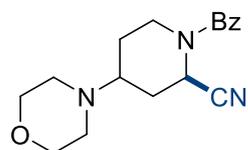
7.51 – 7.36 (m, 3H), 4.91 (s, 1H), 3.83 – 3.47 (m, 2H), 2.39 – 1.95 (m, 4H). ^{13}C NMR (101 MHz, CDCl_3) δ 169.9, 135.1, 130.9, 128.5, 127.5, 118.7, 49.5, 46.9, 30.4, 25.6. HRMS (ESI) calcd $\text{C}_{12}\text{H}_{13}\text{N}_2\text{O}^+$ $[\text{M} + \text{H}]^+$: 202.1022, found: 202.1026.



1-benzoylpiperidine-2-carbonitrile (3d): Followed the general procedure 1 with (2-iodophenyl)(piperidin-1-yl)methanone (63.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 20.9 mg of the title compound (Colorless oil); 49% yield; ^1H NMR (400 MHz, CDCl_3) δ 7.63 – 7.31 (m, 5H), 5.81 (s, 1H), 3.81 (s, 1H), 3.23 (s, 1H), 2.01 (d, J = 11.2 Hz, 1H), 1.89 (t, J = 3.6 Hz, 1H), 1.87 – 1.81 (m, 1H), 1.81 – 1.64 (m, 2H), 1.55 – 1.40 (m, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.8, 134.3, 130.6, 128.8, 127.1, 117.5, 45.5, 42.2, 28.6, 25.2, 20.7. HRMS (ESI) calcd $\text{C}_{12}\text{H}_{12}\text{N}_2\text{ONa}^+$ $[\text{M} + \text{Na}]^+$: 237.0998, found: 237.0995.

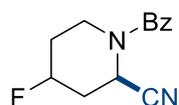


1-benzoyl-4-methylpiperidine-2-carbonitrile (3e): Followed the general procedure 1 with (2-iodophenyl)(4-methylpiperidin-1-yl)methanone (65.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 9: 1) to give 33.3 mg of the title compound (Colorless oil); 73% yield; ^1H NMR (400 MHz, CDCl_3) δ 7.57 – 7.34 (m, 5H), 5.85 (s, 1H), 4.06 – 2.99 (m, 2H), 2.11 – 1.92 (m, 2H), 1.70 (d, J = 14.8 Hz, 1H), 1.44 (d, J = 14.8 Hz, 1H), 1.22 – 1.06 (m, 1H), 1.02 (d, J = 6.4 Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.7, 134.3, 130.6, 128.8, 127.2, 117.7, 45.3, 36.3, 33.7, 27.7, 21.4. HRMS (ESI) calcd $\text{C}_{14}\text{H}_{17}\text{N}_2\text{O}^+$ $[\text{M} + \text{H}]^+$: 229.1335, found: 229.1337.

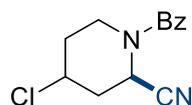


1-benzoyl-4-morpholinopiperidine-2-carbonitrile (3f): Followed the general

procedure 1 with (2-iodophenyl)(4-morpholinopiperidin-1-yl)methanone (80.1 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 1: 1) to give 32.9 mg of the title compound (Colorless oil); 55% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 – 7.30 (m, 5H), 5.89 (s, 1H), 4.12 - 3.80 (m, 1H), 3.70 (t, $J = 4.4$ Hz, 4H), 3.28 (s, 1H), 2.89 – 2.76 (m, 1H), 2.55 (t, $J = 4.5$ Hz, 4H), 2.29 – 2.11 (m, 1H), 1.94 – 1.69 (m, 2H), 1.51 – 1.35 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 134.0, 131.0, 129.0, 127.4, 117.4, 67.4, 58.6, 49.7, 42.1, 31.2, 28.0. **HRMS (ESI)** calcd $\text{C}_{17}\text{H}_{22}\text{N}_3\text{O}_2^+$ $[\text{M} + \text{H}]^+$: 300.1707, found: 300.1712.

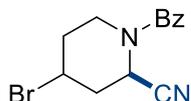


1-benzoyl-4-fluoropiperidine-2-carbonitrile (3g): Followed the general procedure 1 with (4-fluoropiperidin-1-yl)(2-iodophenyl)methanone (66.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 20.5 mg of the title compound (Colorless oil); 44% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.58 – 7.39 (m, 5H), 5.78 (s, 1H), 5.11 – 4.88 (m, 1H), 4.37 – 3.86 (m, 1H), 3.31 (t, $J = 13.8$ Hz, 1H), 2.49 (d, $J = 13.1$ Hz, 1H), 2.27 – 2.14 (m, 1H), 2.00 – 1.86 (m, 1H), 1.77 – 1.65 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.6, 133.4, 131.1, 129.0, 127.2, 116.6, 87.6, 85.8, 41.9, 34.4, 34.2, 32.0, 31.8. $^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -176.82 – -178.63 (m). **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{14}\text{FN}_2\text{O}^+$ $[\text{M} + \text{H}]^+$: 233.1085, found: 233.1089.

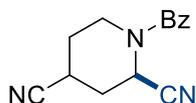


1-benzoyl-4-chloropiperidine-2-carbonitrile (3h): Followed the general procedure 1 with (4-chloropiperidin-1-yl)(2-iodophenyl)methanone (69.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 36.7 mg of the title compound (Colorless oil); 74% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 – 7.34 (m, 5H), 5.76 (s, 1H), 4.35 – 4.23 (m, 1H), 4.22 – 3.81 (m, 1H), 3.31 (t, $J = 13.2$ Hz, 1H), 2.52 (d, $J = 13.6$ Hz, 1H), 2.24 (d, $J = 13.4$ Hz, 1H), 2.12 – 2.00 (m, 1H), 1.86 – 1.73 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.6, 133.4, 131.1, 129.0, 127.2, 116.5, 52.1, 43.7, 42.8, 38.1, 35.9. **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{14}\text{ClN}_2\text{O}^+$ $[\text{M} + \text{H}]^+$:

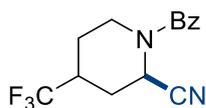
249.0789, found: 249.0791.



1-benzoyl-4-bromopiperidine-2-carbonitrile (3i): Followed the general procedure 1 with (4-bromopiperidin-1-yl)(2-iodophenyl)methanone (78.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 35.1 mg of the title compound (Colorless oil); 60% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 – 7.32 (m, 5H), 5.75 (s, 1H), 4.42 – 4.28 (m, 1H), 4.28 - 3.74 (m, 1H), 3.44 – 3.16 (m, 1H), 2.61 (d, J = 13.6 Hz, 1H), 2.33 (d, J = 13.2 Hz, 1H), 2.28 – 2.14 (m, 1H), 2.07 – 1.87 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 133.3, 131.1, 129.0, 127.2, 116.5, 45.7, 43.0, 41.6, 38.8, 36.6. **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{13}\text{BrN}_2\text{ONa}^+$ $[\text{M} + \text{Na}]^+$: 315.0103, found: 315.0105.

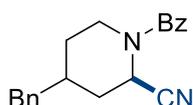


1-benzoylpiperidine-2,4-dicarbonitrile (3j): Followed the general procedure 1 with 1-(2-iodobenzoyl)piperidine-4-carbonitrile (68.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 33.46 mg of the title compound (Colorless oil); 70% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.65 – 7.36 (m, 5H), 5.76 (s, 1H), 4.08 (s, 1H), 3.26 (t, J = 13.8 Hz, 1H), 3.14 – 3.01 (m, 1H), 2.41 (d, J = 13.9 Hz, 1H), 2.22 – 2.02 (m, 2H), 1.87 – 1.74 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 133.1, 131.3, 129.1, 127.3, 119.6, 116.0, 43.1, 41.9, 31.4, 24.2. **HRMS (ESI)** calcd $\text{C}_{14}\text{H}_{14}\text{N}_3\text{O}^+$ $[\text{M} + \text{H}]^+$: 240.1131, found: 240.1135.

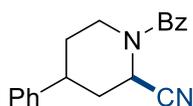


1-benzoyl-4-(trifluoromethyl)piperidine-2-carbonitrile (3k): Followed the general procedure 1 with (2-iodophenyl)(4-(trifluoromethyl)piperidin-1-yl)methanone (76.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 6: 1)

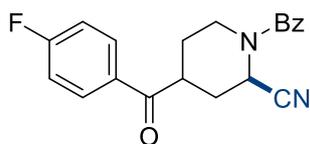
to give 35.5 mg of the title compound (Colorless oil); 63% yield; **¹H NMR (400 MHz, CDCl₃)** δ 7.58 – 7.38 (m, 5H), 5.89 (s, 1H), 4.05 (s, 1H), 3.37 – 3.21 (m, 1H), 2.77 – 2.61 (m, 1H), 2.33 – 2.18 (m, 1H), 2.03 – 1.92 (m, 1H), 1.91 – 1.79 (m, 1H), 1.65 – 1.49 (m, 1H). **¹³C NMR (101 MHz, CDCl₃)** δ 170.7, 133.4, 131.1, 129.0, 127.2, 116.5, 43.7, 41.2, 38.1, 37.7, 37.5, 37.2, 27.6, 24.3. **¹⁹F NMR (376 MHz, CDCl₃)** δ -73.67, -73.69. **HRMS (ESI)** calcd C₁₄H₁₄F₃N₂O⁺ [M + H]⁺: 283.1053, found: 283.1056.



1-benzoyl-4-benzylpiperidine-2-carbonitrile (3l): Followed the general procedure 1 with (4-benzylpiperidin-1-yl)(2-iodophenyl)methanone (81.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 40.1 mg of the title compound (Colorless oil); 66% yield; **¹H NMR (400 MHz, CDCl₃)** δ 7.50 – 7.38 (m, 5H), 7.30 (d, *J* = 7.4 Hz, 2H), 7.25 – 7.19 (m, 1H), 7.14 (d, *J* = 7.4 Hz, 2H), 5.85 (s, 1H), 3.83 (s, 1H), 3.22 (s, 1H), 2.68 – 2.53 (m, 2H), 2.27 – 2.12 (m, 1H), 2.11 – 1.94 (m, 1H), 1.71 (s, 1H), 1.52 (s, 1H), 1.26 – 1.12 (m, 1H). **¹³C NMR (101 MHz, CDCl₃)** δ 170.6, 138.6, 134.2, 130.7, 129.1, 128.8, 128.6, 127.2, 126.6, 117.5, 45.2, 42.4, 34.5, 31.5. **HRMS (ESI)** calcd C₂₀H₂₁N₂O⁺ [M + H]⁺: 306.1601, found: 306.1602.



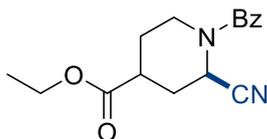
1-benzoyl-4-phenylpiperidine-2-carbonitrile (3m): Followed the general procedure 1 with (2-iodophenyl)(4-phenylpiperidin-1-yl)methanone (78.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 24.9 mg of the title compound (Colorless oil); 43% yield; **¹H NMR (400 MHz, CDCl₃)** δ 7.48 (s, 5H), 7.28 - 7.32 (m, 2H), 7.29 – 7.21 (m, 3H), 5.98 (s, 1H), 4.00 (s, 1H), 3.44 (s, 1H), 3.23 – 3.11 (m, 1H), 2.22 (s, 1H), 2.09 – 1.87 (m, 2H), 1.78 – 1.65 (m, 1H). **¹³C NMR (101 MHz, CDCl₃)** δ 170.8, 143.1, 134.1, 130.8, 128.9, 127.2, 126.8, 117.4, 38.9, 35.5, 32.8. **HRMS (ESI)** calcd C₁₉H₁₉N₂O⁺ [M + H]⁺: 291.1492, found: 291.1490.



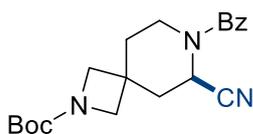
1-benzoyl-4-(4-fluorobenzoyl)piperidine-2-carbonitrile (3n): Followed the general procedure 1 with (4-(4-fluorobenzoyl)piperidin-1-yl)(2-iodophenyl)methanone (87.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 28.2 mg of the title compound (Colorless oil); 42% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.10 – 7.95 (m, 2H), 7.54 – 7.36 (m, 5H), 7.18 (t, J = 8.5 Hz, 2H), 5.92 (s, 1H), 4.27 – 3.90 (m, 1H), 3.90 – 3.79 (m, 1H), 3.42 (s, 1H), 2.20 (s, 1H), 2.13 – 2.02 (m, 1H), 1.84 – 1.67 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 198.4, 170.7, 167.5, 164.9, 133.8, 131.5, 131.4, 131.2, 131.1, 130.9, 128.9, 127.2, 117.2, 116.4, 116.2, 44.15, 42.1, 40.1, 31.2, 28.4. $^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -103.55 (t, J = 6.7 Hz). **HRMS (ESI)** calcd $\text{C}_{20}\text{H}_{17}\text{FN}_2\text{O}_2$ $[\text{M} + \text{H}]^+$: 337.1347, found: 337.1345.



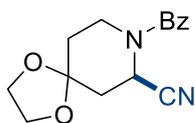
methyl 1-benzoyl-2-cyanopiperidine-4-carboxylate (3o): Followed the general procedure 1 with methyl 1-(2-iodobenzoyl)piperidine-4-carboxylate (74.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 39.2 mg of the title compound (Colorless oil); 72% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.57 – 7.32 (m, 5H), 5.86 (s, 1H), 3.96 (s, 1H), 3.71 (d, J = 1.1 Hz, 3H), 3.27 (s, 1H), 2.97 – 2.82 (m, 1H), 2.39 – 2.26 (m, 1H), 2.04 (d, J = 13.5 Hz, 1H), 1.98 – 1.86 (m, 1H), 1.70 – 1.54 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 173.4., 170.7, 133.8, 130.9, 128.9, 127.2, 116.8, 52.3, 44.3, 41.6, 38.0, 30.7, 27.9. **HRMS (ESI)** calcd $\text{C}_{15}\text{H}_{17}\text{N}_2\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 273.1234, found: 273.1238.



ethyl-1-benzoyl-2-cyanopiperidine-4-carboxylate (3p): Followed the general procedure 1 with ethyl 1-(2-iodobenzoyl)piperidine-4-carboxylate (77.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 46.3 mg of the title compound (Colorless oil); 81% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.61 – 7.35 (m, 5H), 5.86 (s, 1H), 4.25 – 4.13 (m, 2H), 3.98 (s, 1H), 3.28 (s, 1H), 2.96 – 2.83 (m, 1H), 2.39 – 2.26 (m, 1H), 2.05 (d, $J = 13.2$ Hz, 1H), 2.00 – 1.87 (m, 1H), 1.65 – 1.56 (m, 1H), 1.27 (t, $J = 7.1$ Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 172.9, 170.7, 133.8, 130.9, 128.9, 127.2, 116.9, 61.2, 38.1, 30.7, 27.9, 14.2. **HRMS (ESI)** calcd $\text{C}_{16}\text{H}_{19}\text{N}_2\text{O}_3^+ [\text{M} + \text{H}]^+$: 287.1390, found: 287.1395.

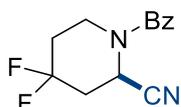


tert-butyl-7-benzoyl-6-cyano-2,7-diazaspiro[3.5]nonane-2-carboxylate (3q): Followed the general procedure 1 with tert-butyl 7-(2-iodobenzoyl)-2,7-diazaspiro[3.5]nonane-2-carboxylate (91.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 51.8 mg of the title compound (Colorless oil); 73% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.58 – 7.32 (m, 5H), 5.75 (s, 1H), 4.22 (d, $J = 9.0$ Hz, 1H), 3.83 (d, $J = 9.0$ Hz, 2H), 3.69 (d, $J = 8.5$ Hz, 1H), 3.61 (d, $J = 8.5$ Hz, 1H), 3.27 (s, 1H), 2.32 (d, $J = 14.2$ Hz, 1H), 2.02 (d, $J = 13.5$ Hz, 1H), 1.96 – 1.85 (m, 1H), 1.74 – 1.62 (m, 1H), 1.43 (s, 9H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 156.3, 133.7, 131.0, 128.9, 127.2, 117.3, 80.0, 59.6, 58.4, 41.5, 40.1, 36.2, 35.2, 32.5, 28.4. **HRMS (ESI)** calcd $\text{C}_{20}\text{H}_{25}\text{N}_3\text{O}_3\text{Na}^+ [\text{M} + \text{Na}]^+$: 378.1788, found: 378.1788.



8-benzoyl-1,4-dioxaspiro[4.5]decane-7-carbonitrile (3r): Followed the

general procedure 1 with (2-iodophenyl)(1,4-dioxo-8-azaspiro[4.5]decan-8-yl)methanone (74.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 31.8 mg of the title compound (Colorless oil); 57% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.60 – 7.31 (m, 5H), 5.82 (s, 1H), 4.20 – 3.80 (m, 5H), 3.53 (s, 1H), 2.15 – 1.93 (m, 2H), 1.81 – 1.70 (m, 2H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.6, 133.9, 130.8, 128.9, 127.2, 117.4, 105.2, 65.0, 64.8, 43.2, 41.3, 36.3, 35.1. **HRMS (ESI)** calcd $\text{C}_{15}\text{H}_{16}\text{N}_2\text{O}_3\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 295.1053, found: 295.1045.

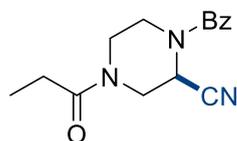


1-benzoyl-4,4-difluoropiperidine-2-carbonitrile (3s): Followed the general procedure 1 with (4,4-difluoropiperidin-1-yl)(2-iodophenyl)methanone (70.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 6: 1) to give 43.0 mg of the title compound (Colorless oil); 86% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.71 – 7.38 (m, 5H), 5.89 (s, 1H), 4.45 – 3.85 (m, 1H), 3.55 (t, $J = 13.8$ Hz, 1H), 2.54 (t, $J = 12.9$ Hz, 1H), 2.39 – 2.17 (m, 2H), 2.12 – 1.87 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.6, 133.0, 131.4, 129.1, 127.3, 122.1, 119.7, 119.6, 117.2, 116.1, 41.2, 40.6, 36.1, 35.9, 35.6, 34.1, 33.9, 33.6. $^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -89.55 – -90.88 (m), -99.06 – -101.24 (m). **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{13}\text{F}_2\text{N}_2\text{O}^+$ $[\text{M} + \text{H}]^+$: 251.0990, found: 251.0995.

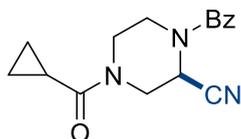


4-acetyl-1-benzoylpiperazine-2-carbonitrile (3t): Followed the general procedure 1 with 1-(4-(2-iodobenzoyl)piperazin-1-yl)ethan-1-one (71.6 mg, 0.2 mmol) and purified using flash chromatography (DCM : MeOH= 25: 1) to give 36.5 mg of the title compound (Colorless oil); 71% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.62 – 7.35 (m, 5H), 5.97 – 5.26 (m, 1H), 5.03 – 4.62 (m, 1H), 4.11 (t, $J = 10.6$ Hz, 1H), 3.84 (d, $J = 13.5$ Hz, 1H), 3.55 – 3.13 (m, 2H), 2.95 – 2.58 (m, 1H), 2.28 – 2.10 (m, 3H). $^{13}\text{C NMR}$

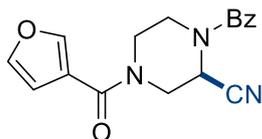
(101 MHz, CDCl₃) δ 170.9, 169.3, 133.0, 131.3, 129.0, 127.4, 115.8, 48.4, 45.7, 43.2, 41.1, 21.2, 21.1. **HRMS (ESI)** calcd C₁₄H₁₅N₃O₂Na⁺ [M + Na]⁺: 280.1056, found: 280.1066.



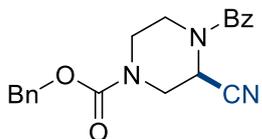
1-benzoyl-4-propionylpiperazine-2-carbonitrile (3u) : Followed the general procedure 1 with 1-(4-(2-iodobenzoyl)piperazin-1-yl)propan-1-one (74.4 mg, 0.2 mmol) and purified using flash chromatography (DCM : MeOH= 25: 1) to give 36.3 mg of the title compound (Colorless oil); 67% yield; **¹H NMR (400 MHz, CDCl₃)** δ 7.62 – 7.35 (m, 5H), 5.65 (s, 1H), 5.02 – 4.64 (m, 1H), 4.18 (d, *J* = 13.8 Hz, 1H), 3.89 (s, 1H), 3.51 – 3.09 (m, 2H), 2.94 – 2.60 (m, 1H), 2.58 – 2.32 (m, 2H), 1.19 (t, *J* = 7.4 Hz, 3H). **¹³C NMR (101 MHz, CDCl₃)** δ 172.7, 170.6, 133.1, 131.3, 129.0, 127.4, 115.8, 47.4, 44.9, 43.4, 41.3, 26.2, 9.3. **HRMS (ESI)** calcd C₁₅H₁₈N₃O₂⁺ [M + H]⁺: 272.1394, found: 272.1391.



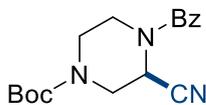
1-benzoyl-4-(cyclopropanecarbonyl)piperazine-2-carbonitrile (3v): Followed the general procedure 1 with (4-(cyclopropanecarbonyl)piperazin-1-yl)(2-iodophenyl) methanone (76.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 2: 1) to give 24.3 mg of the title compound (Colorless oil); 43% yield; **¹H NMR (400 MHz, CDCl₃)** δ 7.59 – 7.34 (m, 5H), 5.65 (s, 1H), 4.98 – 4.12 (m, 2H), 3.89 (s, 1H), 3.38 (s, 2H), 3.07 – 2.56 (m, 1H), 1.06 (s, 2H), 0.92 – 0.78 (m, 2H).. **¹³C NMR (101 MHz, CDCl₃)** δ 172.8, 170.8, 133.2, 131.3, 129.0, 127.4, 115.9, 47.7, 44.7, 42.0, 11.2, 8.4, 8.1. **HRMS (ESI)** calcd C₁₆H₁₇N₃O₂Na⁺ [M + Na]⁺: 306.1213, found: 306.1209.



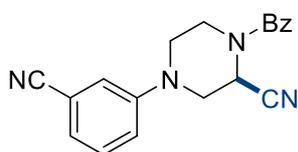
1-benzoyl-4-(furan-3-carbonyl)piperazine-2-carbonitrile (3w): Followed the general procedure 1 with (4-(furan-3-carbonyl)piperazin-1-yl)(2-iodophenyl) methanone (82.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 2: 1) to give 32.7 mg of the title compound (Colorless oil); 53% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.55 – 7.51 (m, 1H), 7.51 – 7.43 (m, 5H), 7.19 (d, $J = 3.5$ Hz, 1H), 6.56 – 6.42 (m, 1H), 5.51 (s, 1H), 4.98 (d, $J = 14.1$ Hz, 1H), 4.67 (d, $J = 13.6$ Hz, 1H), 4.24 – 3.72 (m, 1H), 3.50 (s, 1H), 3.41 – 3.27 (m, 1H), 3.03 (s, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.8, 159.4, 147.0, 144.5, 133.1, 131.3, 129.1, 127.4, 118.6, 115.7, 111.9, 46.9, 44.1. **HRMS (ESI)** calcd $\text{C}_{17}\text{H}_{15}\text{N}_3\text{O}_3\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 322.1006, found: 322.1013.



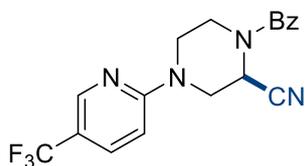
benzyl 4-benzoyl-3-cyanopiperazine-1-carboxylate (3x): Followed the general procedure 1 with benzyl 4-(2-iodobenzoyl)piperazine-1-carboxylate (90.0mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 50.3 mg of the title compound (Colorless oil); 72% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.58 – 7.41 (m, 5H), 7.36 (s, 5H), 5.61 (s, 1H), 5.19 (s, 2H), 4.48 (s, 1H), 4.33 – 4.06 (m, 1H), 3.86 (s, 1H), 3.40 (s, 1H), 3.17 (s, 1H), 3.02 – 2.79 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.8, 154.9, 135.9, 133.2, 131.2, 129.0, 128.7, 128.5, 128.2, 127.4, 115.9, 68.2, 46.2, 44.7, 43.5, 42.0. **HRMS (ESI)** calcd $\text{C}_{20}\text{H}_{19}\text{N}_3\text{O}_3\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 372.1319, found: 372.1311.



tert-butyl-4-benzoyl-3-cyanopiperazine-1-carboxylate (3y): Followed the general procedure 1 with tert-butyl 4-(2-iodobenzoyl)piperazine-1-carboxylate (83.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 6: 1) to give 47.3 mg of the title compound (Colorless oil); 75% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.52 – 7.31 (m, 5H), 5.43 (s, 1H), 4.55 – 4.00 (m, 2H), 3.80 (s, 1H), 3.43 – 3.28 (m, 1H), 3.12 (s, 1H), 2.80 (s, 1H), 1.48 (s, 9H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.8, 154.0, 133.4, 131.1, 129.0, 127.3, 116.0, 81.5, 46.3, 45.1, 43.8, 42.8, 28.3. **HRMS (ESI)** calcd $\text{C}_{17}\text{H}_{13}\text{N}_3\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 316.1656, found: 316.1653.

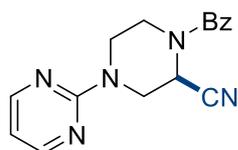


1-benzoyl-4-(3-cyanophenyl)piperazine-2-carbonitrile (3z): Followed the general procedure 1 with 3-(4-(2-iodobenzoyl)piperazin-1-yl)benzotrile (83.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 26.5 mg of the title compound (Colorless oil); 42% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.64 – 7.43 (m, 5H), 7.40 (t, $J = 7.9$ Hz, 1H), 7.27 – 7.23 (m, 1H), 7.19 (d, $J = 11.4$ Hz, 2H), 5.71 (s, 1H), 4.08 (s, 1H), 3.87 (d, $J = 12.1$ Hz, 1H), 3.69 – 3.51 (m, 2H), 3.17 – 3.05 (m, 1H), 2.95 – 2.80 (m, 1H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 150.5, 133.3, 131.2, 130.4, 129.0, 127.4, 125.1, 122.1, 120.3, 118.8, 116.5, 113.5, 52.1, 48.9, 44.8, 42.5. **HRMS (ESI)** calcd $\text{C}_{19}\text{H}_{16}\text{N}_4\text{ONa}^+$ $[\text{M} + \text{Na}]^+$: 339.1216, found: 339.1215.

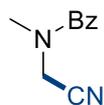


1-benzoyl-4-(6-(trifluoromethyl)pyridin-3-yl)piperazine-2-carbonitrile (3aa): Followed the general procedure 1 with (2-iodophenyl)(4-(5-(trifluoromethyl)pyridin-2-yl)piperazin-1-yl)methanone (92.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 6: 1) to give 43.9 mg of the title compound (Colorless oil); 61% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.44 (s, 1H), 7.72 (d, $J = 8.8$

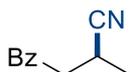
Hz, 1H), 7.61 – 7.40 (m, 5H), 6.75 (d, $J = 8.9$ Hz, 1H), 5.71 (s, 1H), 4.87 (d, $J = 13.7$ Hz, 1H), 4.33 (d, $J = 12.9$ Hz, 1H), 4.02 (s, 1H), 3.54 (s, 1H), 3.25 (d, $J = 13.0$ Hz, 1H), 3.03 (t, $J = 11.8$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.8, 159.7, 145.8, 135.2, 133.3, 131.2, 129.0, 127.4, 125.6, 122.9, 116.3, 106.3, 46.7, 44.7. ^{19}F NMR (376 MHz, CDCl_3) δ -61.34. HRMS (ESI) calcd $\text{C}_{18}\text{H}_{16}\text{F}_3\text{N}_4\text{O}^+$ $[\text{M} + \text{H}]^+$: 361.1271, found: 361.1270.



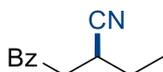
1-benzoyl-4-(pyrimidin-2-yl)piperazine-2-carbonitrile (3ab): Followed the general procedure 1 with (2-iodophenyl)(4-(pyrimidin-2-yl)piperazin-1-yl)methanone (78.8mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 6: 1) to give 49.8 mg of the title compound (Colorless oil); 85% yield; ^1H NMR (400 MHz, CDCl_3) δ 8.35 (d, $J = 4.7$ Hz, 2H), 7.48 (s, 5H), 6.62 (t, $J = 4.7$ Hz, 1H), 5.74 (s, 1H), 5.24 (d, $J = 13.5$ Hz, 1H), 4.83 (d, $J = 12.5$ Hz, 1H), 3.93 (s, 1H), 3.55 – 3.38 (m, 1H), 3.20 (d, $J = 13.2$ Hz, 1H), 2.96 (t, $J = 12.5$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.8, 161.3, 157.9, 133.6, 131.1, 129.0, 127.4, 116.4, 111.7, 45.6, 44.7, 43.3, 42.2. HRMS (ESI) calcd $\text{C}_{16}\text{H}_{16}\text{N}_5\text{O}^+$ $[\text{M} + \text{H}]^+$: 294.1349, found: 294.1345.



N-(cyanomethyl)-N-methylbenzamide (3ac): Followed the general procedure 1 with 2-iodo-*N,N*-dimethylbenzamide (54.9 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 12.2 mg of the title compound (Colorless oil); 35% yield; ^1H NMR (400 MHz, CDCl_3) δ 7.46 (s, 5H), 4.47 (s, 2H), 3.15 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.7, 133.9, 130.8, 128.8, 127.4, 115.2, 37.4, 35.5. HRMS (ESI) calcd $\text{C}_{10}\text{H}_{10}\text{N}_2\text{ONa}^+$ $[\text{M} + \text{Na}]^+$: 197.0685, found: 197.0683.



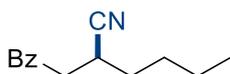
2-methyl-4-oxo-4-phenylbutanenitrile (3ad): Followed the general procedure 1 with 2-iodo-*N,N*-dimethylbenzamide (54.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 20: 1) to give 24.6 mg of the title compound (Colorless oil); 71% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.95 (d, $J = 7.5$ Hz, 2H), 7.61 (t, $J = 7.4$ Hz, 1H), 7.49 (t, $J = 7.7$ Hz, 2H), 3.51 – 3.28 (m, 2H), 3.27 – 3.11 (m, 1H), 1.43 (d, $J = 6.8$ Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 195.2, 135.9, 133.9, 128.9, 128.1, 122.7, 42.3, 20.6, 18.0. **HRMS (ESI)** calcd $\text{C}_{10}\text{H}_{10}\text{NONa}^+$ $[\text{M} + \text{Na}]^+$: 196.0733, found: 196.0726.



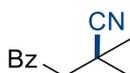
2-ethyl-4-oxo-4-phenylbutanenitrile (3ae): Followed the general procedure 1 with 1-(2-iodophenyl)pentan-1-one (57.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 20: 1) to give 13.8 mg of the title compound (Colorless oil); 37% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.04 – 7.90 (m, 2H), 7.61 (t, $J = 7.4$ Hz, 1H), 7.49 (t, $J = 7.6$ Hz, 2H), 3.46 – 3.33 (m, 1H), 3.30 – 3.17 (m, 2H), 1.83 – 1.66 (m, 2H), 1.16 (t, $J = 7.4$ Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 195.4, 136.0, 133.9, 128.9, 128.1, 121.8, 76.8, 40.5, 28.0, 25.4, 11.6. **HRMS (ESI)** calcd $\text{C}_{12}\text{H}_{13}\text{NONa}^+$ $[\text{M} + \text{Na}]^+$: 210.0889, found: 210.0886.



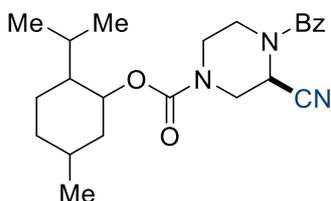
2-(2-oxo-2-phenylethyl)pentanenitrile (3af): Followed the general procedure 1 with 1-(2-iodophenyl)hexan-1-one (60.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 20: 1) to give 17.8 mg of the title compound (Colorless oil); 44% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.95 (d, $J = 7.7$ Hz, 2H), 7.61 (t, $J = 7.4$ Hz, 1H), 7.49 (t, $J = 7.6$ Hz, 2H), 3.48 - 3.35 (m, 1H), 3.35 – 3.16 (m, 2H), 1.72 – 1.64 (m, 2H), 1.62 – 1.51 (m, 2H), 0.99 (t, $J = 6.6$ Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 195.4, 136.0, 133.9, 128.9, 128.1, 122.0, 40.9, 34.1, 26.2, 20.5, 13.5. **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{16}\text{NO}^+$ $[\text{M} + \text{H}]^+$: 202.1226, found: 202.1222.



2-(2-oxo-2-phenylethyl)hexanenitrile (3ag): Followed the general procedure 1 with 1-(2-iodophenyl)heptan-1-one (63.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 20: 1) to give 24.8 mg of the title compound (Colorless oil); 56% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.00 – 7.90 (m, 2H), 7.61 (t, J = 7.4 Hz, 1H), 7.49 (t, J = 7.6 Hz, 2H), 3.46 – 3.33 (m, 1H), 3.32 – 3.17 (m, 2H), 1.72 – 1.64 (m, 2H), 1.59 – 1.45 (m, 2H), 1.45 – 1.32 (m, 2H), 0.94 (t, J = 7.3 Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 195.4, 136.0, 133.9, 128.9, 128.1, 122.0, 40.9, 31.8, 29.3, 26.4, 22.2, 13.8. **HRMS (ESI)** calcd $\text{C}_{14}\text{H}_{18}\text{NO}^+$ $[\text{M} + \text{H}]^+$: 216.1383, found: 216.1383.

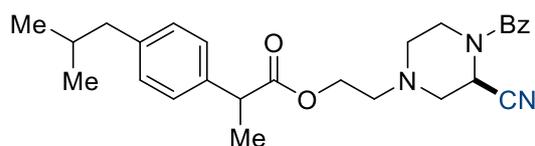


2,2-dimethyl-4-oxo-4-phenylbutanenitrile (3ah): Followed the general procedure 1 with 1-(2-iodophenyl)-3-methylbutan-1-one (57.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 20: 1) to give 16.8 mg of the title compound (Colorless oil); 43% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.95 (d, J = 7.6 Hz, 2H), 7.60 (t, J = 7.3 Hz, 1H), 7.48 (t, J = 7.6 Hz, 2H), 3.25 (s, 2H), 1.54 (s, 6H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 195.2, 136.5, 133.7, 128.8, 128.0, 124.6, 47.5, 29.7, 27.0. **HRMS (ESI)** calcd $\text{C}_{12}\text{H}_{14}\text{NO}^+$ $[\text{M} + \text{H}]^+$: 188.1070, found: 188.1065.



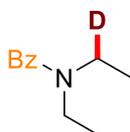
2-isopropyl-5-methylcyclohexyl-4-benzoyl-3-cyanopiperazine-1-carboxylate (3ai): Followed the general procedure 1 with 2-isopropyl-5-methylcyclohexyl 4-(2-iodobenzoyl)piperazine-1-carboxylate (99.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 54.8 mg of the title compound (Colorless oil); 69% yield; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.59 – 7.31 (m, 5H), 4.61

(m, 1H), 4.46 (s, 1H), 4.23 (s, 1H), 3.82 (s, 1H), 3.48 – 3.32 (m, 1H), 3.23 – 3.00 (m, 1H), 2.97 – 2.74 (m, 1H), 2.06 (s, 1H), 1.92 – 1.77 (m, 1H), 1.68 (s, 1H), 1.54 – 1.32 (m, 2H), 1.11 – 0.83 (m, 9H), 0.78 (d, $J = 5.3$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.7, 154.7, 133.3, 131.1, 129.0, 127.3, 115.8, 75.8, 47.4, 45.8, 43.4, 41.5, 34.3, 31.4, 26.6, 23.8, 22.1, 20.8, 16.7. HRMS (ESI) calcd $\text{C}_{21}\text{H}_{32}\text{N}_3\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 398.2438, found: 398.2438.



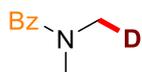
2-(4-benzoyl-3-cyanopiperazin-1-yl)ethyl 2-(4-isobutylphenyl)propanoate (3aj):

Followed the general procedure 1 with 2-(4-(2-iodobenzoyl)piperazin-1-yl)ethyl 2-(4-isobutylphenyl)propanoate (99.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 63.5 mg of the title compound (Colorless oil); 71% yield; ^1H NMR (400 MHz, CDCl_3) δ 7.55 – 7.34 (m, 5H), 7.23 – 7.13 (m, 2H), 7.12 – 7.04 (m, 2H), 5.52 (s, 1H), 4.30 – 4.14 (m, 2H), 3.75 – 3.65 (m, 1H), 3.33 (s, 1H), 2.93 (s, 1H), 2.76 – 2.55 (m, 3H), 2.44 – 2.34 (m, 2H), 2.27 (d, $J = 11.6$ Hz, 1H), 2.15 – 2.00 (m, 1H), 1.95 – 1.63 (m, 2H), 1.50 (d, $J = 7.2$ Hz, 3H), 0.91 – 0.83 (m, 6H). ^{13}C NMR (101 MHz, CDCl_3) δ 174.4, 170.4, 140.7, 137.7, 133.8, 130.8, 129.4, 128.9, 127.4, 116.9, 62.0, 55.9, 54.6, 54.4, 52.2, 52.1, 45.2, 45.0, 30.2, 22.4, 18.2. HRMS (ESI) calcd $\text{C}_{27}\text{H}_{34}\text{N}_3\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 448.2595, found: 448.2595.

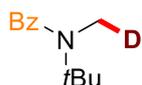


***N*-ethyl-*N*-(ethyl-1-d)benzamide (4a):** Followed the general procedure 2 with *N,N*-diethyl-2-iodobenzamide (60.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 4: 1) to give 33.1 mg of the title compound (Colorless oil); 93% yield and D-incorporation 94%; ^1H NMR (400 MHz, CDCl_3) δ 7.37 (s, 5H), 3.59 – 3.18 (m, 3H), 1.25 (s, 3H), 1.10 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.4, 137.3,

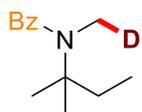
129.2, 128.5, 126.3, 43.3, 39.3, 14.3, 12.9. **HRMS (ESI)** calcd $C_{11}H_{15}DNO^+$ $[M + H]^+$: 179.1289, found: 179.1284.



***N*-methyl-*N*-(methyl-d)benzamide (4b)**: Followed the general procedure 2 with 2-iodo-*N,N*-dimethylbenzamide (54.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 18.3 mg of the title compound (Colorless oil); 61% yield and D-incorporation 92%; **1H NMR (400 MHz, $CDCl_3$)** δ 7.42 (s, 5H), 3.17 - 2.97 (m, 5H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 171.7, 136.4, 129.6, 128.4, 127.1, 39.6, 35.8. **HRMS (ESI)** calcd $C_9H_{11}DNO^+$ $[M + H]^+$: 151.0976, found: 151.0976.

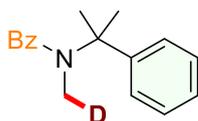


***N*-(tert-butyl)-*N*-(methyl-d)benzamide (4c)**: Followed the general procedure 2 with *N*-(tert-butyl)-2-iodo-*N*-methylbenzamide (63.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 10: 1) to give 36.8 mg of the title compound (Colorless oil); 95% yield and D-incorporation 92%; **1H NMR (400 MHz, $CDCl_3$)** δ 7.50 – 7.33 (m, 5H), 2.90 – 2.86 (m, 2H), 1.54 (s, 9H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 173.2, 139.2, 129.5, 128.3, 127.3, 56.5, 35.2, 35.0, 27.8. **HRMS (ESI)** calcd $C_{12}H_{17}DNO^+$ $[M + H]^+$: 193.1446, found: 193.1445.

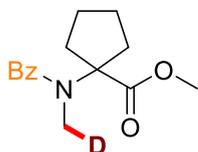


***N*-(methyl-d)-*N*-(tert-pentyl)benzamide (4d)**: Followed the general procedure 2 with 2-iodo-*N*-methyl-*N*-(tert-pentyl)benzamide (66.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 32.7 mg of the title compound (Colorless oil); 79% yield and D-incorporation 93%; **1H NMR (400 MHz, $CDCl_3$)** δ 7.38 (m, 5H), 2.85 – 2.81 (m, 2H), 2.02 (q, $J = 7.5$ Hz, 2H), 1.44 (s, 6H), 0.92

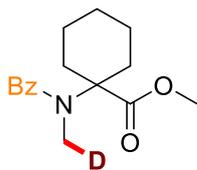
(t, $J = 7.5$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 173.1, 139.3, 129.4, 128.4, 127.2, 59.4, 35.5, 32.1, 26.0, 8.8. HRMS (ESI) calcd $\text{C}_{13}\text{H}_{19}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 207.1602, found: 207.1605.



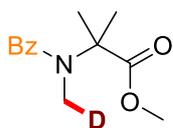
***N*-(methyl-d)-*N*-(2-phenylpropan-2-yl)benzamide (4e)**: Followed the general procedure 2 with 2-iodo-*N*-methyl-*N*-(2-phenylpropan-2-yl)benzamide (75.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 8: 1) to give 32.5 mg of the title compound (Colorless oil); 64% yield and D-incorporation 95%; ^1H NMR (400 MHz, CDCl_3) δ 7.50 – 7.42 (m, 4H), 7.40 – 7.29 (m, 5H), 7.23 – 7.19 (m, 1H), 2.94 – 2.90 (m, 2H), 1.81 (s, 6H). ^{13}C NMR (101 MHz, CDCl_3) δ 172.7, 148.1, 138.4, 129.8, 128.4, 127.5, 126.3, 124.5, 61.4, 36.2, 35.8, 27.5. HRMS (ESI) calcd $\text{C}_{17}\text{H}_{19}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 255.1602, found: 255.1604.



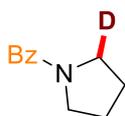
methyl 1-(*N*-(methyl-d)benzamido)cyclopentane-1-carboxylate (4f): Followed the general procedure 2 with methyl 1-(2-iodo-*N*-methylbenzamido)cyclopentane-1-carboxylate (77.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 42.4 mg of the title compound (Colorless oil); 81% yield and D-incorporation 92%; ^1H NMR (400 MHz, CDCl_3) δ 7.53 – 7.32 (m, 5H), 3.72 (s, 3H), 3.03 (d, $J = 5.9$ Hz, 2H), 2.50 – 2.38 (m, 2H), 2.09 – 1.99 (m, 2H), 1.87 – 1.78 (m, 2H), 1.78 – 1.68 (m, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 174.9, 173.2, 136.8, 123.0, 128.4, 127.5, 71.3, 52.3, 35.8, 35.5, 35.3, 24.5. HRMS (ESI) calcd $\text{C}_{15}\text{H}_{19}\text{DNO}_3^+$ $[\text{M} + \text{H}]^+$: 263.1500, found: 263.1504.



methyl 1-(*N*-(methyl-d)benzamido)cyclohexane-1-carboxylate (4g): Followed the general procedure 2 with methyl 1-(2-iodo-*N*-methylbenzamido)cyclohexane-1-carboxylate (80.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 41.4 mg of the title compound (Colorless oil); 75% yield and D-incorporation 93%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.58 – 7.31 (m, 5H), 3.73 (s, 3H), 3.01 (d, J = 5.9 Hz, 2H), 2.26 – 2.15 (m, 2H), 1.98 – 1.87 (m, 2H), 1.79 – 1.69 (m, 2H), 1.51 (m, 4H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 174.4, 172.9, 137.2, 129.9, 128., 127.5, 63.9, 52.0, 34.7, 34.5, 31.6, 25.5, 22.6. **HRMS (ESI)** calcd $\text{C}_{16}\text{H}_{20}\text{DNO}_3\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 299.1476, found: 299.1470.

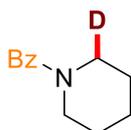


methyl 2-methyl-2-(*N*-(methyl-d)benzamido)propanoate (4h): Followed the general procedure 2 with methyl 2-(2-iodo-*N*-methylbenzamido)-2-methylpropanoate (72.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 45.3 mg of the title compound (Colorless oil); 96% yield and D-incorporation 92%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.50 – 7.32 (m, 5H), 3.71 (s, 3H), 2.96 – 2.93 (m, 2H), 1.53 (s, 6H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 224.7, 174.7, 171.9, 136.5, 129.9, 128.4, 127.3, 60.8, 52.4, 33.5, 33.1, 23.0. **HRMS (ESI)** calcd $\text{C}_{12}\text{H}_{14}\text{DNO}_3^+$ $[\text{M} + \text{H}]^+$: 237.4344, found: 237.4346.



phenyl(pyrrolidin-1-yl-2-d)methanone (4i): Followed the general procedure 2 with (2-iodophenyl)(pyrrolidin-1-yl)methanone (60.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 28.5 mg of the title

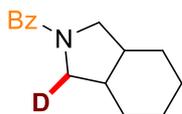
compound (Colorless oil); 81% yield and D-incorporation 90%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.56 – 7.43 (m, 2H), 7.37 (d, $J = 4.9$ Hz, 3H), 3.66 – 3.58 (m, 2H), 3.43 – 3.36 (m, 2H), 2.00 – 1.89 (m, 2H), 1.89 – 1.79 (m, 2H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 169.8, 137.3, 129.8, 128.3, 127.1, 49.7, 46.2, 26.4, 24.5. **HRMS (ESI)** calcd $\text{C}_{11}\text{H}_{13}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 177.1133, found: 177.1138.



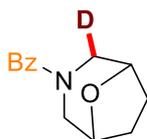
phenyl(piperidin-1-yl-2-d)methanone (4j): Followed the general procedure 2 with (2-iodophenyl)(piperidin-1-yl)methanone (63.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 37.2 mg of the title compound (Colorless oil); 98% yield and D-incorporation 91%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.39 (s, 5H), 3.70 (s, 2H), 3.34 (s, 1H), 1.68 (s, 4H), 1.52 (s, 2H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.4, 136.5, 129.4, 128.4, 126.8, 48.8, 43.1, 26.6, 25.7, 24.6. **HRMS (ESI)** calcd $\text{C}_{12}\text{H}_{15}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 191.1289, found: 191.1294.



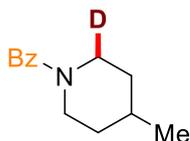
(azepan-1-yl-2-d)(phenyl)methanone (4k): Followed the general procedure 2 with azepan-1-yl(2-iodophenyl)methanone (65.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 7: 1) to give 39.2 mg of the title compound (Colorless oil); 96% yield and D-incorporation 94%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.41 (s, 5H), 3.70 (m, 2H), 3.39 (t, $J = 5.4$ Hz, 2H), 1.87 (q, $J = 5.6$ Hz, 2H), 1.71 – 1.58 (m, 6H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 171.7, 137.4, 129.1, 128.4, 126.5, 49.8, 46.4, 29.6, 27.9, 27.3, 26.5. **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{17}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 205.1446, found: 205.1449.



(octahydro-2H-isoindol-2-yl-1-d)(phenyl)methanone (4l): Followed the general procedure 2 with (2-iodophenyl)(octahydro-2H-isoindol-2-yl)methanone (71.0 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 4: 1) to give 41.9 mg of the title compound (Colorless oil); 91% yield and D-incorporation 91%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.62 – 7.47 (m, 2H), 7.47 – 7.34 (m, 3H), 3.66 – 3.55 (m, 2H), 3.49 – 3.43 (m, 1H), 3.33 – 3.26 (m, 1H), 2.40 – 2.29 (m, 1H), 2.24 – 2.14 (m, 1H), 1.72 – 1.62 (m, 1H), 1.62 – 1.48 (m, 4H), 1.47 – 1.33 (m, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.5, 137.2, 129.8, 128.3, 127.1, 53.8, 49.9, 37.9, 36.0, 25.8, 25.6, 23.0, 22.4. **HRMS (ESI)** calcd $\text{C}_{15}\text{H}_{18}\text{DNO}^+$ $[\text{M} + \text{Na}]^+$: 271.1163, found: 271.1166.

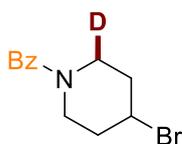


(8-oxa-3-azabicyclo[3.2.1]octan-3-yl-2-d)(phenyl)methanone (4m): Followed the general procedure 2 with (8-oxa-3-azabicyclo[3.2.1]octan-3-yl)(2-iodophenyl)methanone (68.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 2: 1) to give 41.4 mg of the title compound (Colorless oil); 78% yield and D-incorporation 95%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.51 – 7.29 (m, 5H), 4.54 – 4.10 (m, 3H), 3.47 – 3.08 (m, 2H), 1.92 (s, 4H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 171.8, 135.7, 129.7, 128.7, 127.0, 74.3, 73.7, 53.7, 53.1, 47.9, 47.3, 27.5, 27.3 **HRMS (ESI)** calcd $\text{C}_{13}\text{H}_{14}\text{DNO}_2\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 241.1058, found: 241.1055.

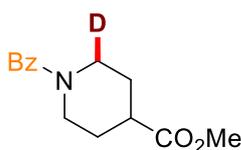


(4-methylpiperidin-1-yl-2-d)(phenyl)methanone (4n): Followed the general procedure 2 with (2-iodophenyl)(4-methylpiperidin-1-yl)methanone (65.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give

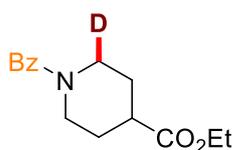
38.7 mg of the title compound (Colorless oil); 95% yield and D-incorporation 93%; ^1H NMR (400 MHz, CDCl_3) δ 7.37 (s, 5H), 4.74 – 4.58 (m, 1H), 3.69 (d, $J = 9.8$ Hz, 1H), 3.03 – 2.70 (m, 1H), 1.98 – 1.45 (m, 4H), 1.08 (s, 1H), 0.96 (d, $J = 6.5$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.4, 136.6, 129.4, 128.5, 126.9, 48.1, 47.6, 42.5, 42.2, 34.8, 33.9, 31.2, 21.8. HRMS (ESI) calcd $\text{C}_{13}\text{H}_{17}\text{DNO}^+$ $[\text{M} + \text{H}]^+$: 205.1446, found: 205.1448.



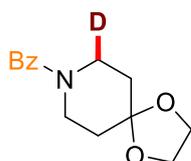
(4-bromopiperidin-1-yl-2-d)(phenyl)methanone(4o): Followed the general procedure 2 with (4-bromopiperidin-1-yl)(2-iodophenyl)methanone (78.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 31.6 mg of the title compound (Colorless oil); 59% yield and D-incorporation 91%; ^1H NMR (400 MHz, CDCl_3) δ 7.50 – 7.32 (m, 5H), 4.52 – 4.38 (m, 1H), 4.08 – 3.58 (m, 2H), 3.35 (s, 1H), 2.29 – 1.86 (m, 4H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.6, 135.7, 129.9, 128.6, 126.9, 49.0, 45.8, 40.2, 36.1, 35.3. HRMS (ESI) calcd $\text{C}_{12}\text{H}_{13}\text{DBrNONa}^+$ $[\text{M} + \text{Na}]^+$: 291.0214, found: 291.0216.



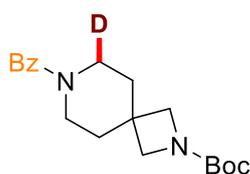
methyl 1-benzoylpiperidine-4-carboxylate-2-d (4p): Followed the general procedure 2 with methyl 1-(2-iodobenzoyl)piperidine-4-carboxylate (74.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 43.6 mg of the title compound (Colorless oil); 88% yield and D-incorporation 95%; ^1H NMR (400 MHz, CDCl_3) δ 7.50 – 7.29 (m, 5H), 4.49 (s, 1H), 3.69 (s, 4H), 3.18 – 2.91 (m, 1H), 2.63 – 2.53 (m, 1H), 1.99 (s, 2H), 1.72 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 174.7, 170.5, 136.0, 129.7, 128.6, 126.9, 52.0, 46.9, 41.5, 41.0, 28.5, 28.0. HRMS (ESI) calcd $\text{C}_{14}\text{H}_{17}\text{DNO}_3^+$ $[\text{M} + \text{H}]^+$: 249.1344, found: 249.1346.



ethyl-1-benzoylpiperidine-4-carboxylate-2-d (4q): Followed the general procedure 2 with ethyl 1-(2-iodobenzoyl)piperidine-4-carboxylate (77.4mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 44.0 mg of the title compound (Colorless oil); 58% yield and D-incorporation 99%; **¹H NMR (400 MHz, CDCl₃)** δ 7.47 – 7.32 (m, 5H), 4.50 (s, 1H), 4.18 – 4.10 (m, 2H), 3.71 (s, 1H), 3.03 (s, 1H), 2.59 – 2.50 (m, 1H), 2.00 (s, 1H), 1.85 – 1.52 (m, 3H), 1.25 (t, *J* = 7.1 Hz, 3H). **¹³C NMR (101 MHz, CDCl₃)** δ 174.3, 170.5, 136.1, 129.7, 128.6, 126.9, 60.7, 47.0, 41.5, 41.1, 28.5, 28.0, 14.3. **HRMS (ESI)** calcd C₁₅H₁₉DNO₃⁺ [M + H]⁺: 263.1500, found: 263.1496.



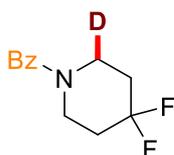
phenyl(1,4-dioxa-8-azaspiro[4.5]decan-8-yl-7-d)methanone (4r): Followed the general procedure 2 with (2-iodophenyl) (1,4-dioxa-8-azaspiro[4.5]decan-8-yl) methanone (74.6 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 47.1 mg of the title compound (Colorless oil); 95% yield and D-incorporation 95%; **¹H NMR (400 MHz, CDCl₃)** δ 7.38 (s, 5H), 3.97 (s, 6H), 3.47 (s, 1H), 1.86 - 1.57 (m, 4H). **¹³C NMR (101 MHz, CDCl₃)** δ 170.5, 136.0, 129.7, 128.6, 126.9, 107.0, 64.6, 45.7, 40.3, 35.6, 34.8. **HRMS (ESI)** calcd C₁₄H₁₇DNO₃⁺ [M + H]⁺: 249.1344, found: 249.1348.



tert-butyl 7-benzoyl-2,7-diazaspiro[3.5]nonane-2-carboxylate-6-d (4s): Followed the general procedure 2 with tert-butyl 7-(2-iodobenzoyl)-2,7-diazaspiro[3.5]nonane-2-carboxylate (77.4mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 1: 1) to give 74.6 mg of the title compound (Colorless oil); 72% yield and D-incorporation 94%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.45 – 7.30 (m, 5H), 3.76 – 3.24 (m, 7H), 1.88 – 1.62 (m, 4H), 1.42 (s, 9H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.6, 156.4, 135.9, 129.8, 128.6, 126.9, 79.7, 59.2, 44.9, 39.3, 35.1, 33.8, 28.4. **HRMS (ESI)** calcd $\text{C}_{19}\text{H}_{26}\text{DN}_2\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 332.2079, found: 332.2083.

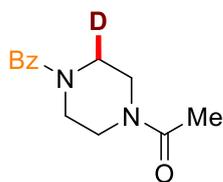


(1,1-dioxidothiomorpholino-3-d)(phenyl)methanone (4t): Followed the general procedure 2 with (1,1-dioxidothiomorpholino)(2-iodophenyl)methanone (72.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 2: 1) to give 35.0 mg of the title compound (white solid); 73% yield and D-incorporation 99%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.45 (m, 5H), 4.05 (s, 3H), 3.05 (s, 4H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 171.1, 134.0, 130.8, 129.0, 127.0, 52.1, 52.0, 45.3, 41.1. **HRMS (ESI)** calcd $\text{C}_{11}\text{H}_{13}\text{DNO}_3\text{S}^+$ $[\text{M} + \text{H}]^+$: 241.0572, found: 241.0563.

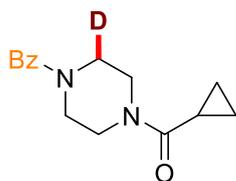


(4,4-difluoropiperidin-1-yl-2-d)(phenyl)methanone (4u): Followed the general procedure 2 with (4,4-difluoropiperidin-1-yl)(2-iodophenyl)methanone (70.1 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 25.8 mg of the title compound (Colorless oil); 57% yield and D-incorporation 95%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.52 – 7.30 (m, 5H), 3.97 – 3.44 (m, 3H), 2.20 – 1.86 (m, 4H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 135.3, 130.2, 128.7, 126.9, 124.0, 121.6, 119.2, 44.4, 39.1, 34.5, 33.8. $^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -97.82. **HRMS (ESI)**

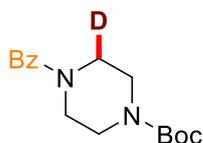
calcd $C_{12}H_{13}DF_2NO^+$ $[M + H]^+$: 249.0920, found: 249.0911.



1-(4-benzoylpiperazin-1-yl-3-d)ethan-1-one (4v): Followed the general procedure 2 with 1-(4-(2-iodobenzoyl)piperazin-1-yl)ethan-1-one (71.6 mg, 0.2 mmol) and purified using flash chromatography (DCM : MeOH= 25: 1) to give 39.1 mg of the title compound (Colorless oil); 84% yield and D-incorporation 94%; 1H NMR (400 MHz, $CDCl_3$) δ 7.51 – 7.32 (m, 5H), 3.85 – 3.30 (m, 7H), 2.12 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 169.3, 135.2, 130.2, 128.7, 127.1, 47.6, 46.2, 42.2, 41.6, 21.5. HRMS (ESI) calcd $C_{13}H_{16}DN_2O_2^+$ $[M + H]^+$: 234.1347, found: 234.1345.

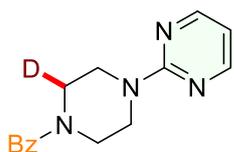


(4-benzoylpiperazin-1-yl-3-d)(cyclopropyl)methanone (4w): Followed the general procedure 2 with (4-(cyclopropanecarbonyl)piperazin-1-yl)(2-iodophenyl)methanone (76.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 1: 1) to give 34.2 mg of the title compound (Colorless oil); 66% yield and D-incorporation 93%; 1H NMR (400 MHz, $CDCl_3$) δ 7.60 – 7.31 (m, 5H), 3.92 – 3.37 (m, 7H), 1.89 (s, 1H), 1.05 – 0.97 (m, 2H), 0.84 – 0.75 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.6, 170.9, 130.3, 128.8, 127.3, 47.6, 45.5, 42.3, 11.2, 7.9. HRMS (ESI) calcd $C_{15}H_{18}DN_2O_2^+$ $[M + H]^+$: 260.1504, found: 260.1500.

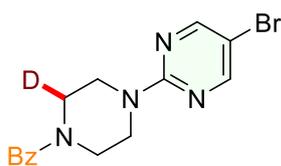


tert-butyl 4-benzoylpiperazine-1-carboxylate-3-d (4x): Followed the general

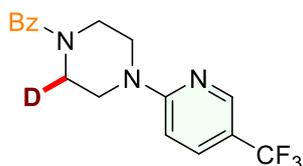
procedure 2 with tert-butyl 4-(2-iodobenzoyl)piperazine-1-carboxylate (83.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 47.7 mg of the title compound (Colorless oil); 82% yield and D-incorporation 96%; ^1H NMR (400 MHz, CDCl_3) δ 7.47 – 7.34 (m, 5H), 3.80 – 3.29 (m, 7H), 1.46 (s, 9H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.7, 154.6, 135.5, 123.0, 128.7, 127.1, 80.4, 43.5, 28.4. HRMS (ESI) calcd $\text{C}_{16}\text{H}_{22}\text{DN}_2\text{O}_3^+$ $[\text{M} + \text{H}]^+$: 292.1766, found: 292.1762.



phenyl(4-(pyrimidin-2-yl)piperazin-1-yl-2-d)methanone (4y): Followed the general procedure 2 with (2-iodophenyl)(4-(pyrimidin-2-yl)piperazin-1-yl)methanone (78.8 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 43.2 mg of the title compound (Colorless oil); 82% yield and D-incorporation 97%; ^1H NMR (400 MHz, CDCl_3) δ 8.32 (d, $J = 4.7$ Hz, 2H), 7.43 (s, 5H), 6.54 (t, $J = 4.7$ Hz, 1H), 4.07 – 3.40 (m, 7H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.7, 161.6, 157.8, 135.7, 129.9, 128.6, 127.2, 110.6, 47.7, 44.1, 43.5. HRMS (ESI) calcd $\text{C}_{15}\text{H}_{16}\text{DN}_4\text{O}^+$ $[\text{M} + \text{H}]^+$: 270.1460, found: 270.1465.

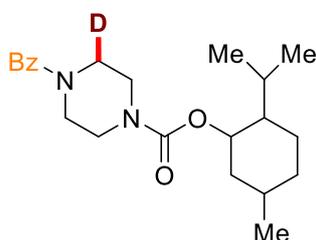


(4-(5-bromopyrimidin-2-yl)piperazin-1-yl-2-d)(phenyl)methanone (4z): Followed the general procedure 2 with (4-(5-bromopyrimidin-2-yl)piperazin-1-yl)(2-iodophenyl)methanone (94.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 54.8 mg of the title compound (Colorless oil); 79% yield and D-incorporation 93%; ^1H NMR (400 MHz, CDCl_3) δ 8.30 (s, 2H), 7.42 (s, 5H), 3.98 – 3.40 (m, 7H). ^{13}C NMR (101 MHz, CDCl_3) δ 170.7, 159.8, 158.1, 135.5, 130.0, 128.7, 127.2, 106.6, 47.3, 44.1, 43.8, 41.9. HRMS (ESI) calcd $\text{C}_{15}\text{H}_{15}\text{DBrN}_4\text{O}^+$ $[\text{M} + \text{H}]^+$: 348.0565, found: 348.0566.



phenyl(4-(5-(trifluoromethyl)pyridin-2-yl)piperazin-1-yl-2-d)methanone (4aa):

Followed the general procedure 2 with (2-iodophenyl)(4-(5-(trifluoromethyl)pyridin-2-yl)piperazin-1-yl)methanone (92.2 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 3: 1) to give 63.8 mg of the title compound (Colorless oil); 95% yield and D-incorporation 94%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.39 (s, 1H), 7.65 (d, $J = 8.7$ Hz, 1H), 7.42 (s, 5H), 6.65 (d, $J = 9.0$ Hz, 1H), 4.02 – 3.40 (m, 7H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 160.2, 145.8, 135.4, 134.8, 130.1, 128.7, 127.2, 125.8, 123.2, 116.4, 116.1, 115.8, 115.5, 105.9, 47.2, 44.8, 44.7, 41.8. $^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -61.15. **HRMS (ESI)** calcd $\text{C}_{17}\text{H}_{16}\text{DF}_3\text{N}_3\text{O}^+$ $[\text{M} + \text{H}]^+$: 337.1381, found: 337.1381.



2-isopropyl-5-methylcyclohexyl-4-benzoylpiperazine-1-carboxylate-3-d (4ab):

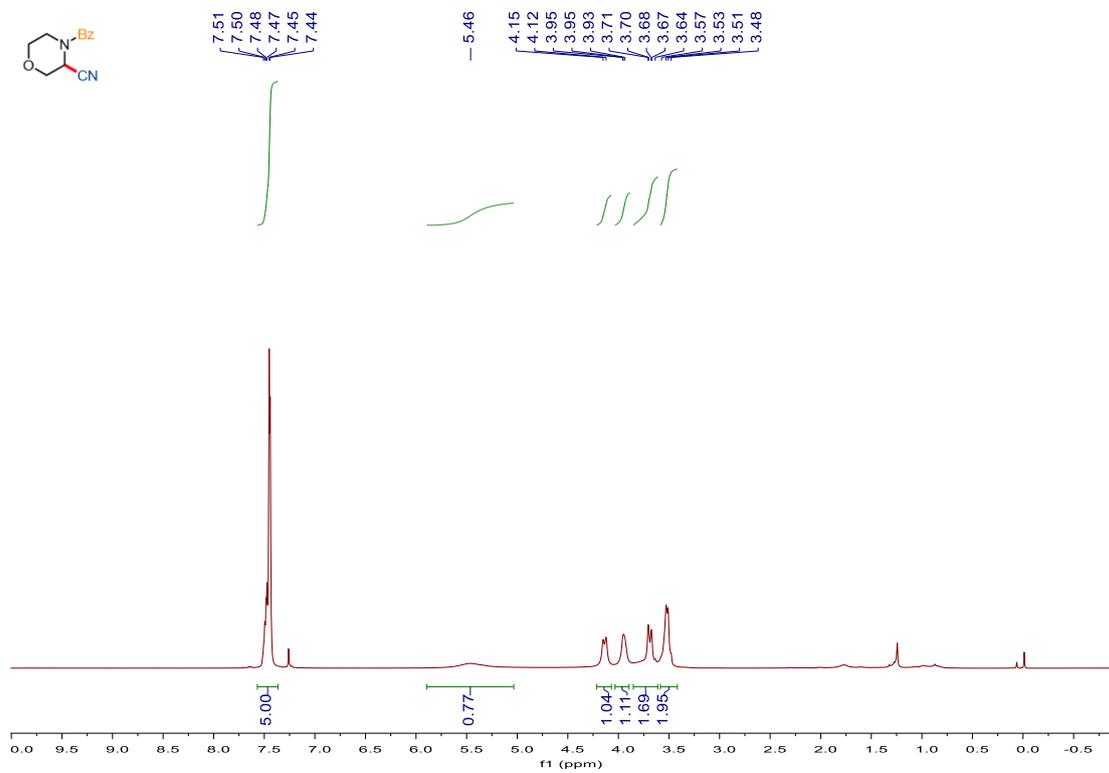
Followed the general procedure 2 with 2-isopropyl-5-methylcyclohexyl 4-(2-iodobenzoyl)piperazine-1-carboxylate (94.4 mg, 0.2 mmol) and purified using flash chromatography (petroleum ether : EA= 5: 1) to give 64.9 mg of the title compound (Colorless oil); 87% yield and D-incorporation 96%; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.51 – 7.31 (m, 5H), 4.65 – 4.51 (m, 1H), 3.80 – 3.29 (m, 7H), 2.04 (d, $J = 13.0$ Hz, 1H), 1.93 – 1.81 (m, 1H), 1.66 (d, $J = 11.0$ Hz, 2H), 1.55 – 1.29 (m, 2H), 1.12 – 0.82 (m, 9H), 0.77 (d, $J = 6.9$ Hz, 3H). $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ 170.7, 155.2, 135.4, 130.0, 128.7, 127.1, 75.8, 47.4, 43.9, 43.7, 41.5, 34.3, 31.4, 26.6, 23.7, 22.1, 20.8, 16.7. **HRMS (ESI)** calcd $\text{C}_{22}\text{H}_{31}\text{DN}_2\text{O}_3\text{Na}^+$ $[\text{M} + \text{Na}]^+$: 396.2368, found: 396.2370.

Reference:

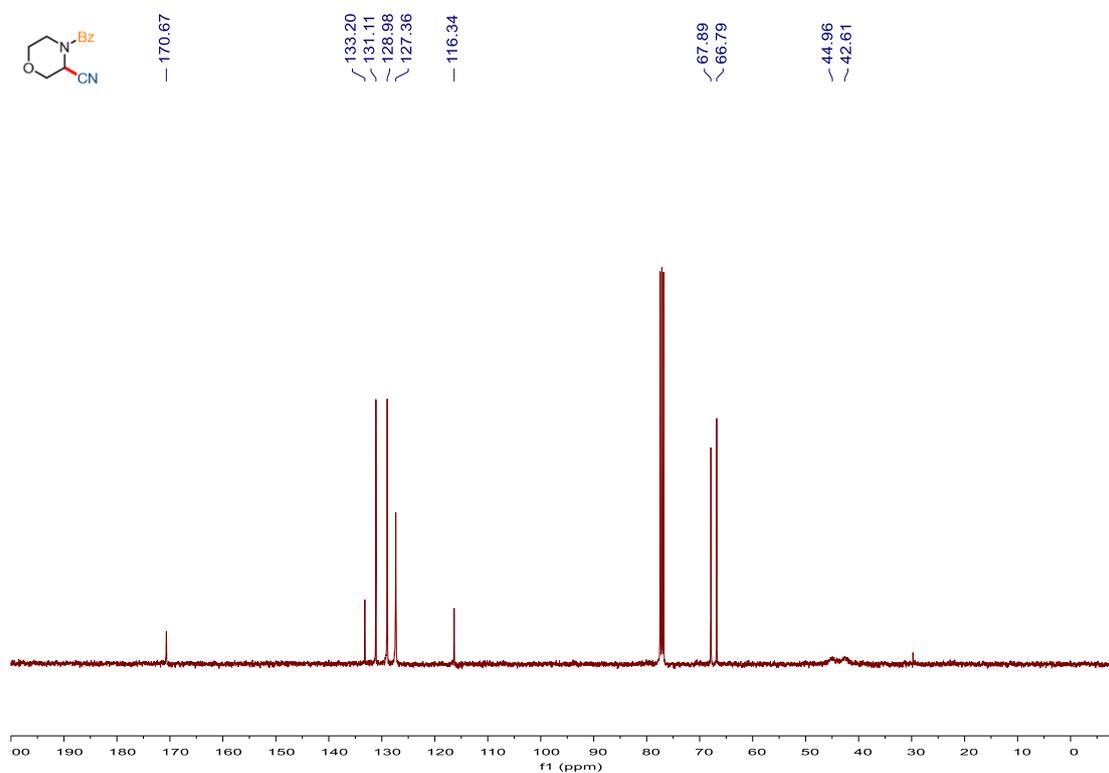
1. S. Sarkar, S. Wagulde, X. Jia, V. Gevorgyan, *Chem.* **2022**, 8, 3096–3108.
2. Z. Lei, W. Zhang and J. Wu, *ACS Catal.* **2023**, 13, 16105-16113.
3. G. Xu, L. Zeng, Liang, M. Hu, F. Sun, J. Li, *Org. Chem. Front.* **2025**,12, 2586-2591.
4. I. Quirós, M.Martín, C. Pérez-Sánchez, T. Rigotti, M. Tortosa, *Chem. Sci.* **2024**,15, 14188-14194.

8. NMR Spectra for the substrates and products

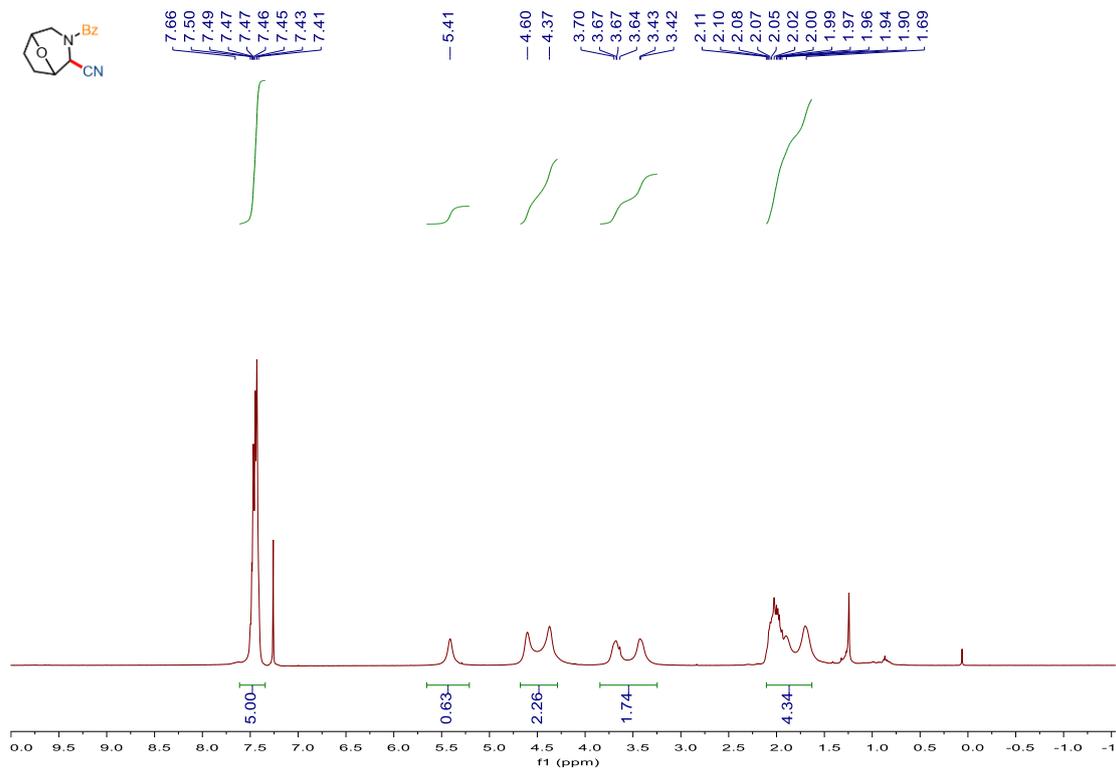
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3a**



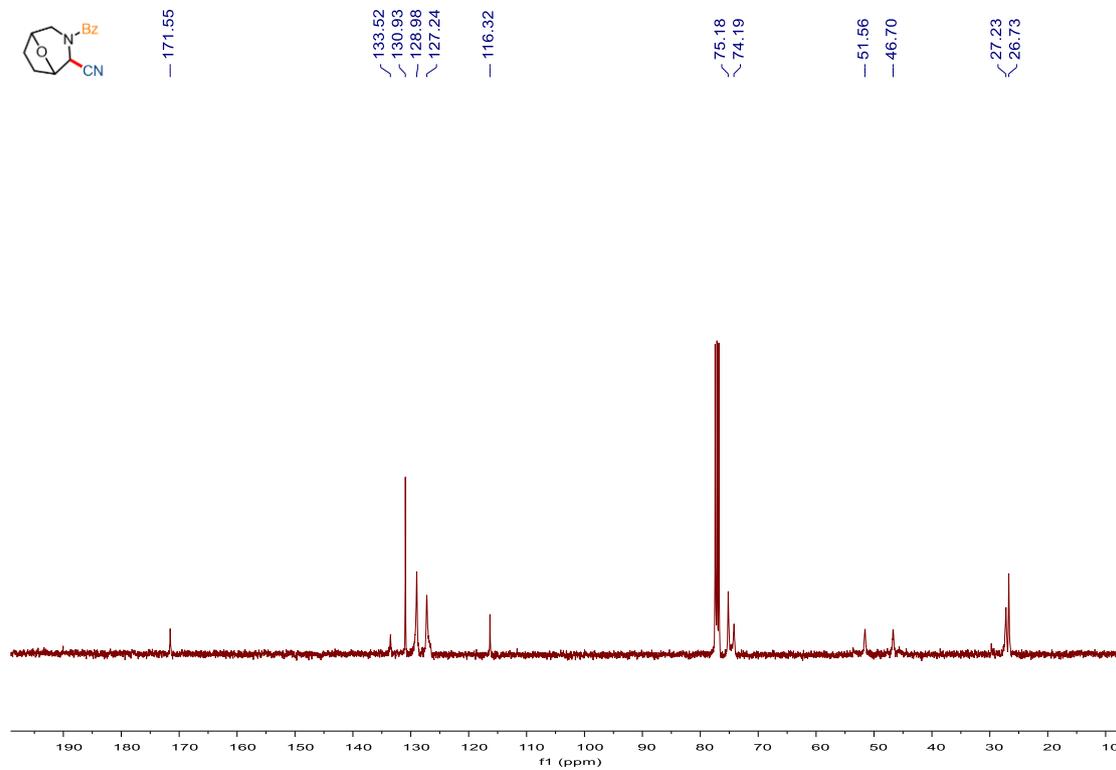
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3a**



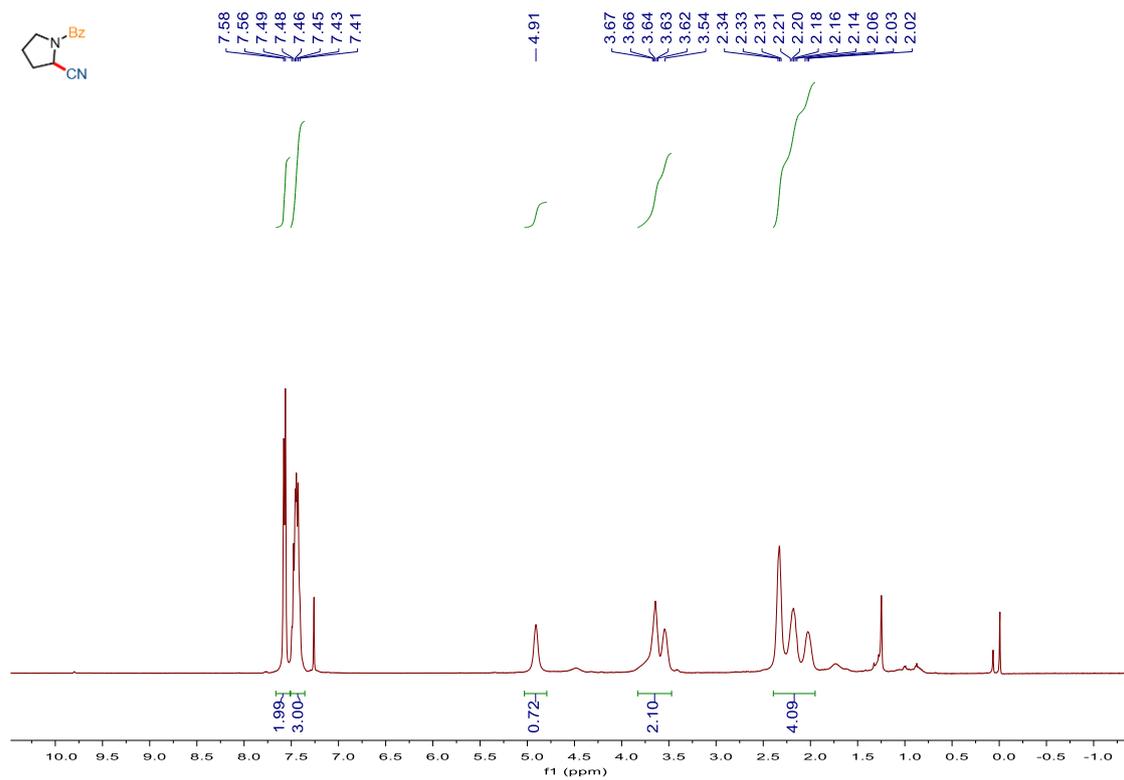
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3b**



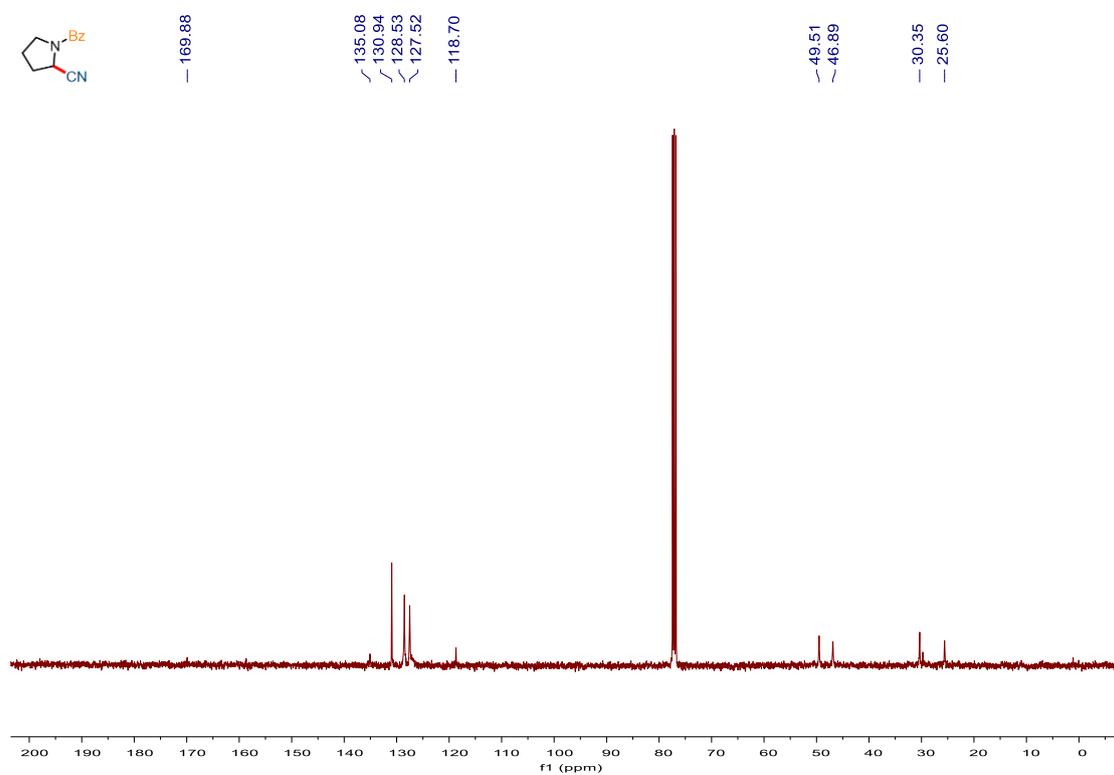
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3b**



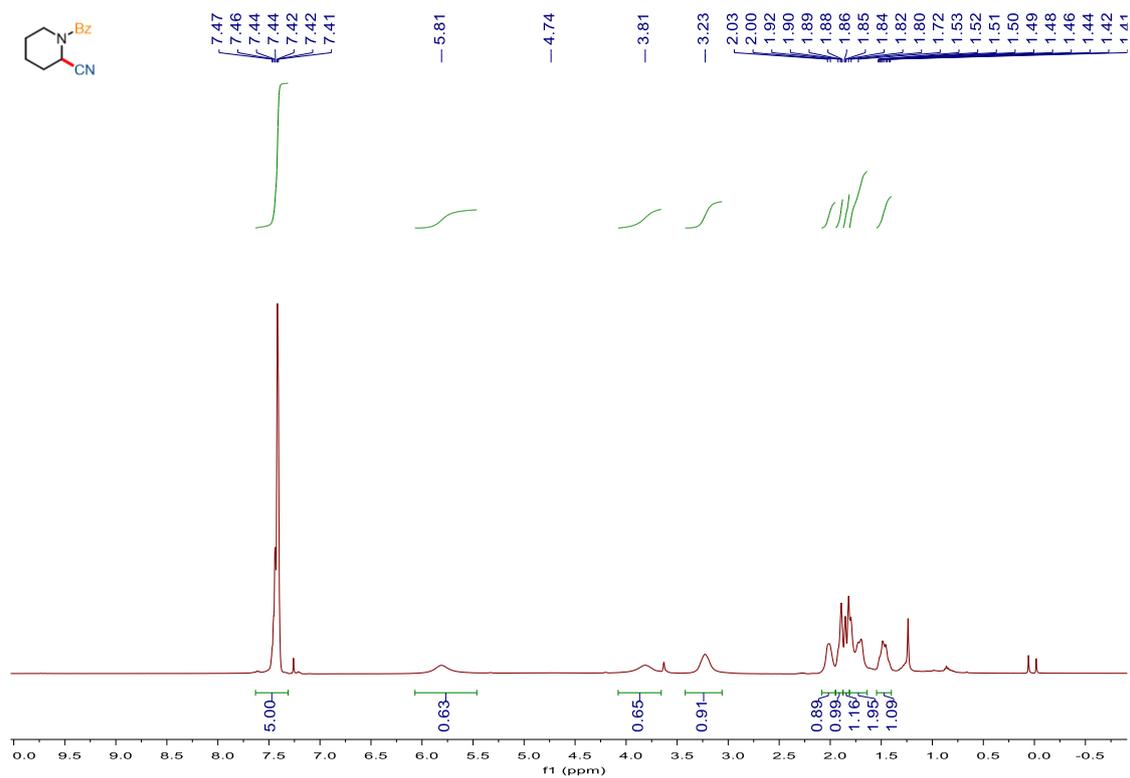
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3c**



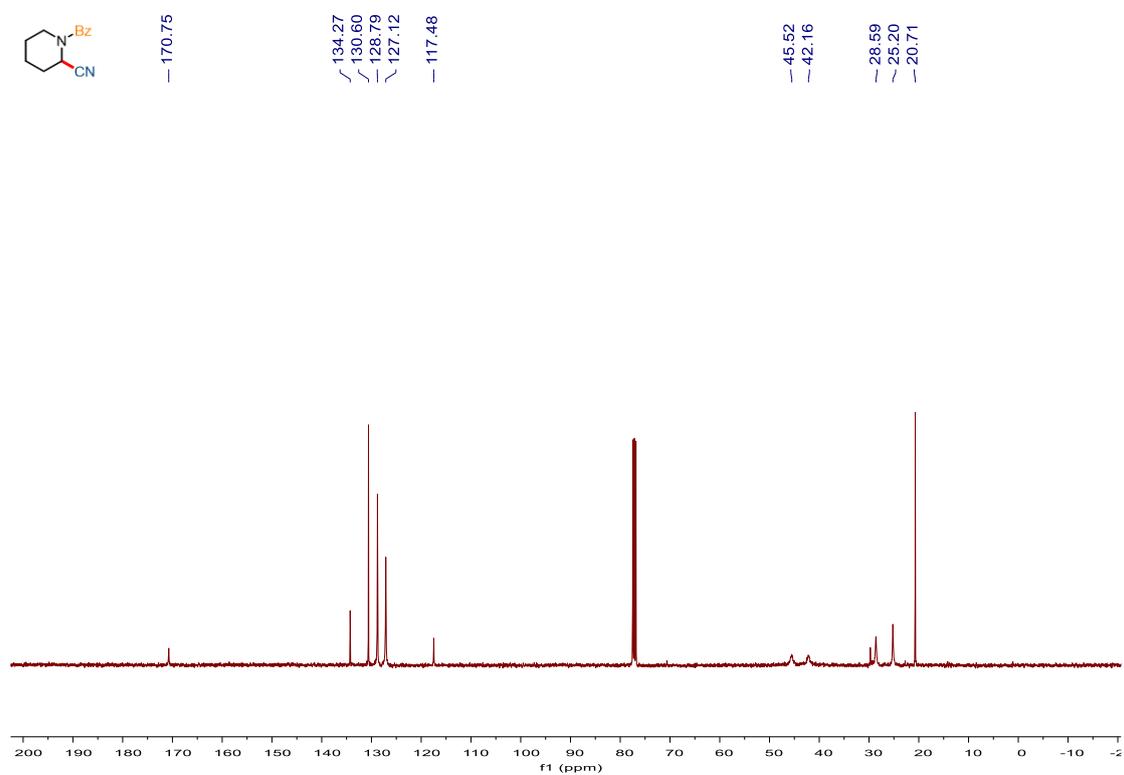
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3c**



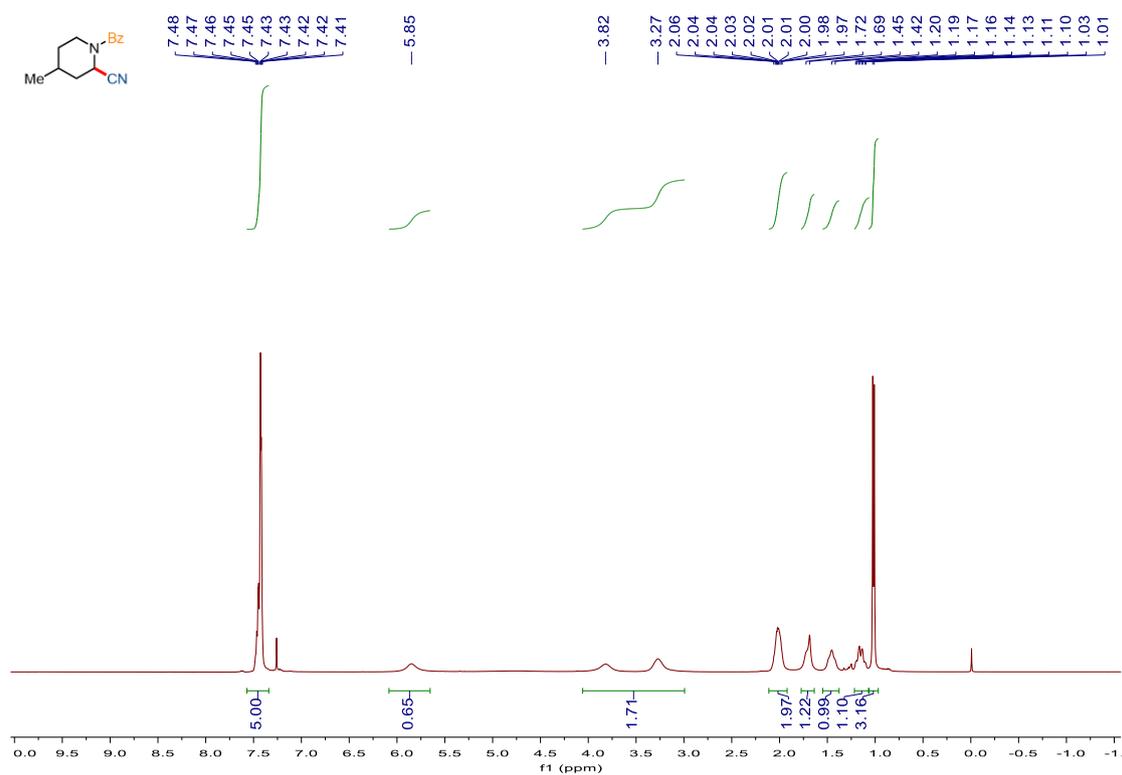
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3d**



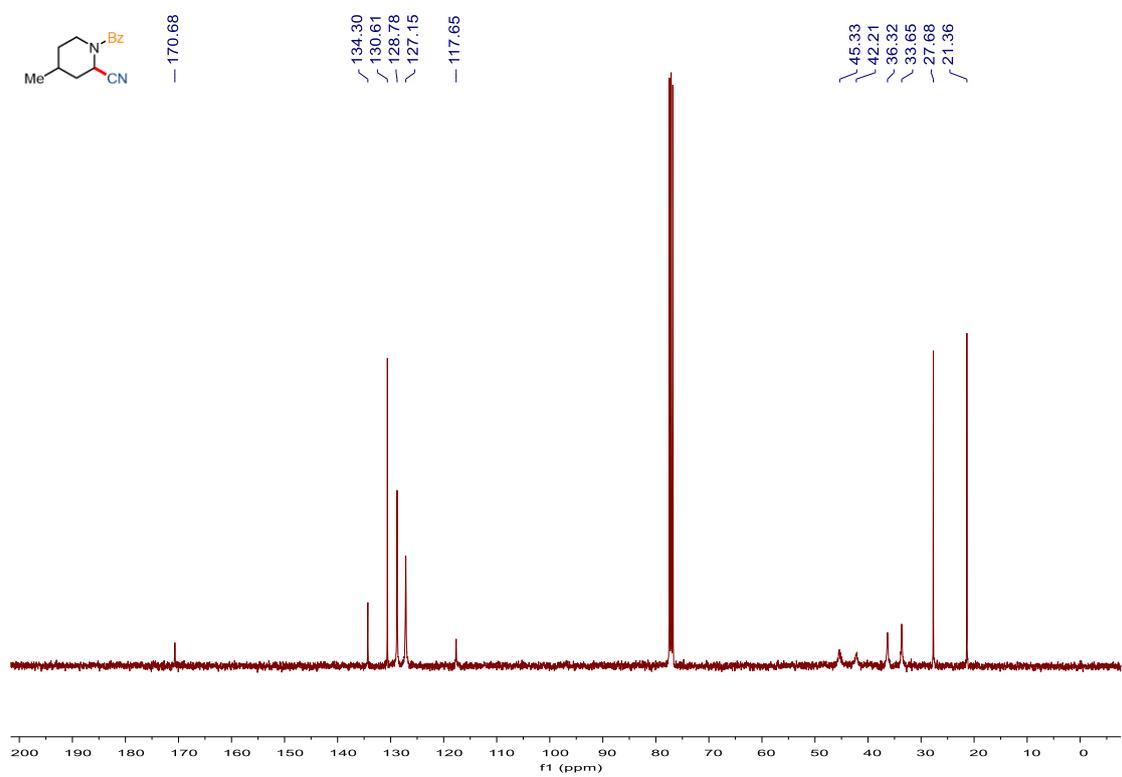
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3d**



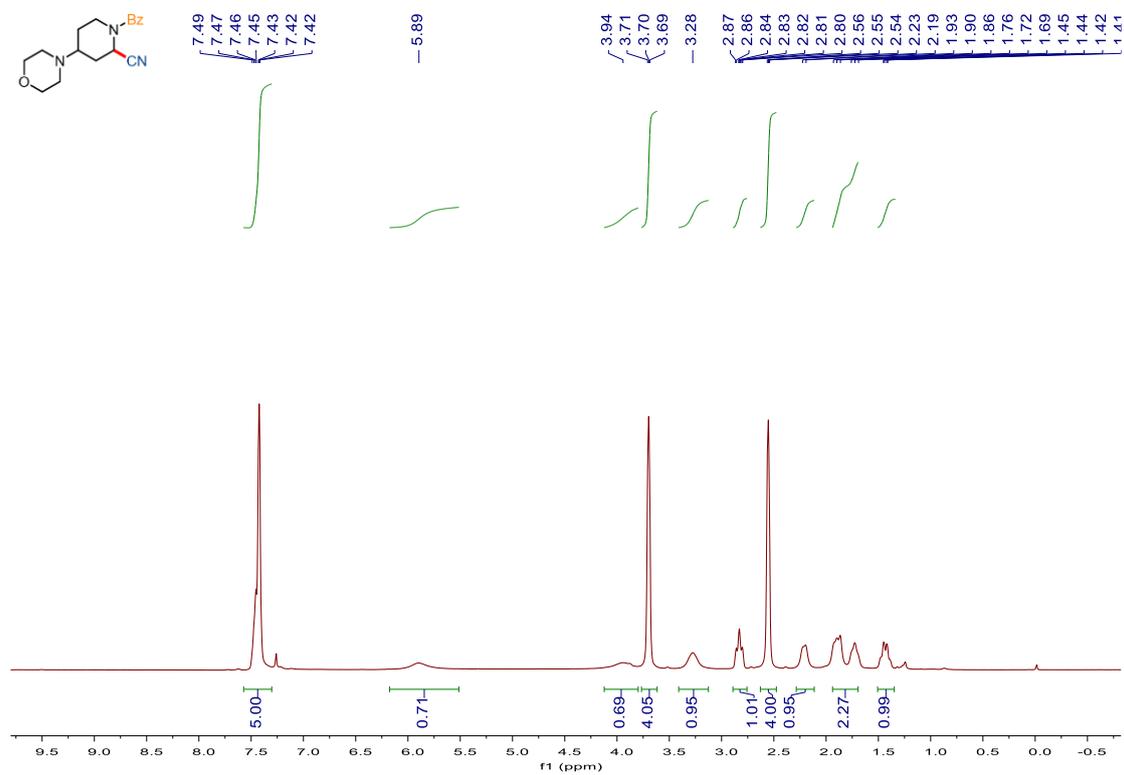
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3e**



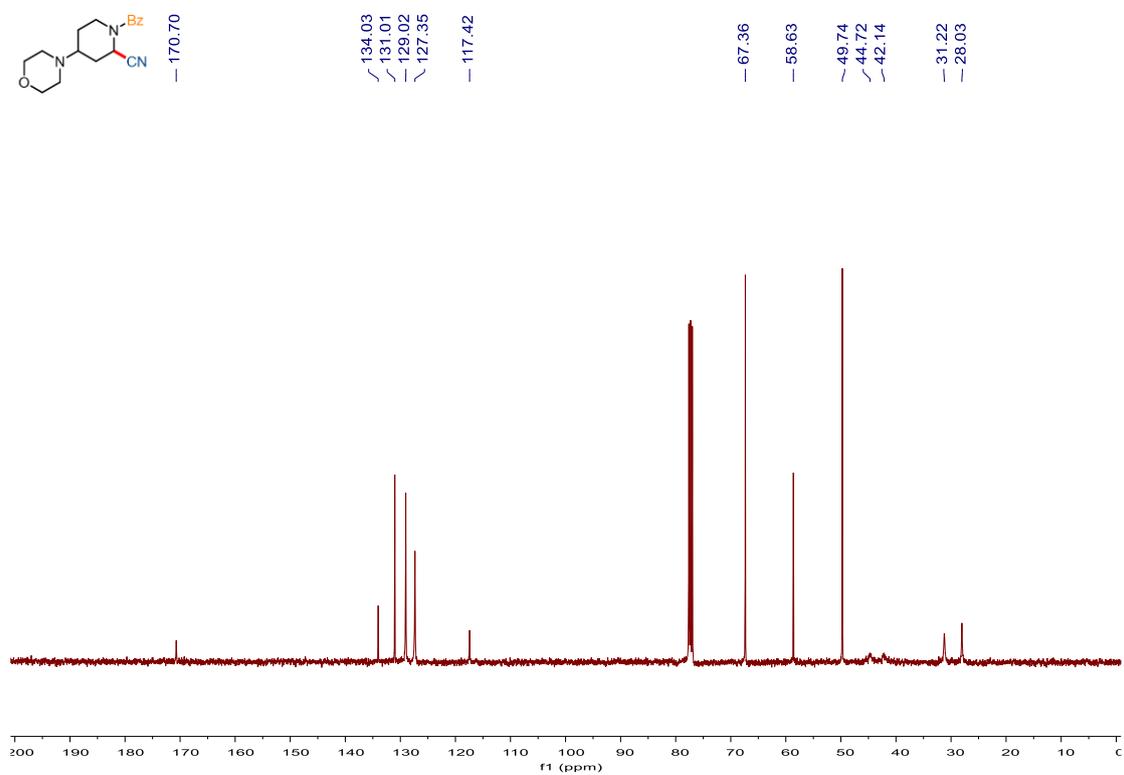
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3e**



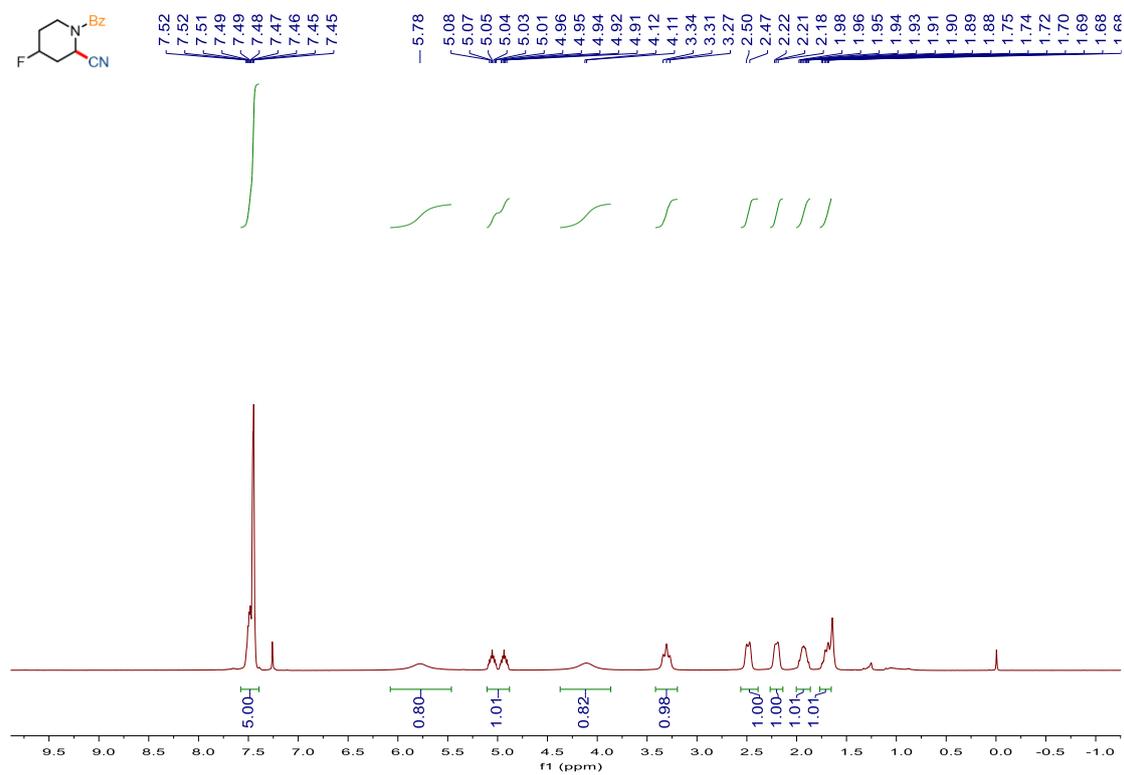
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3f**



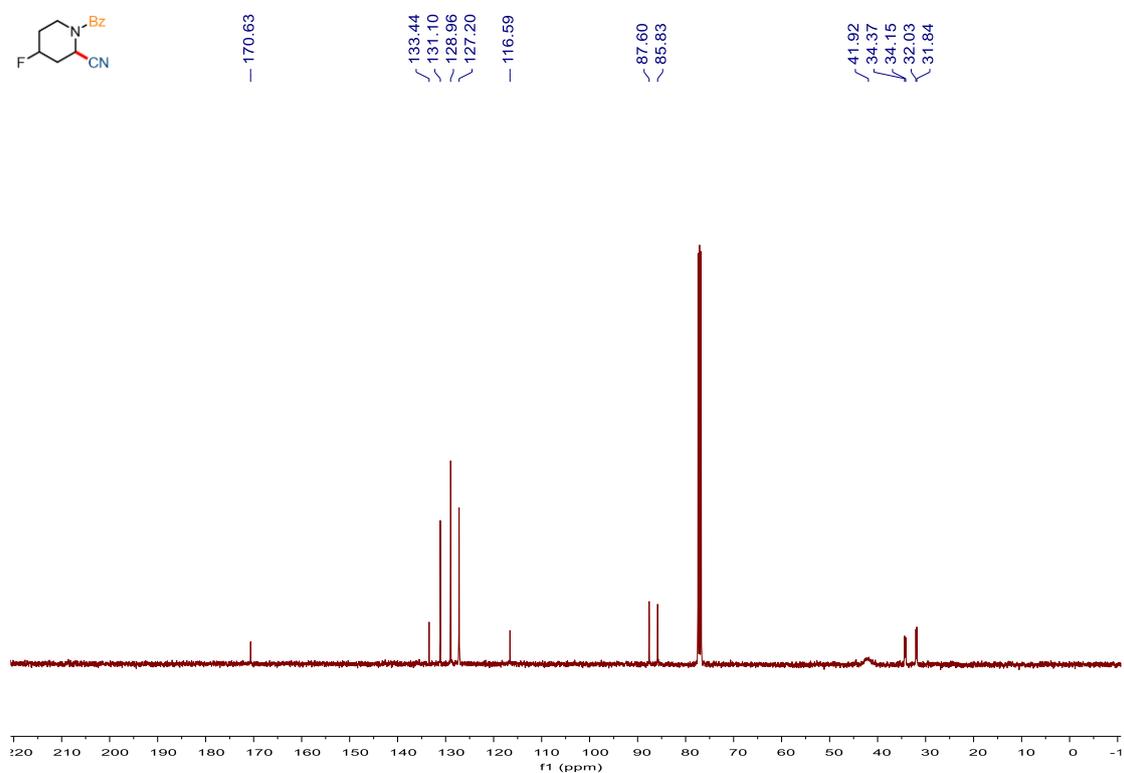
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3f**



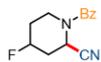
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3g**



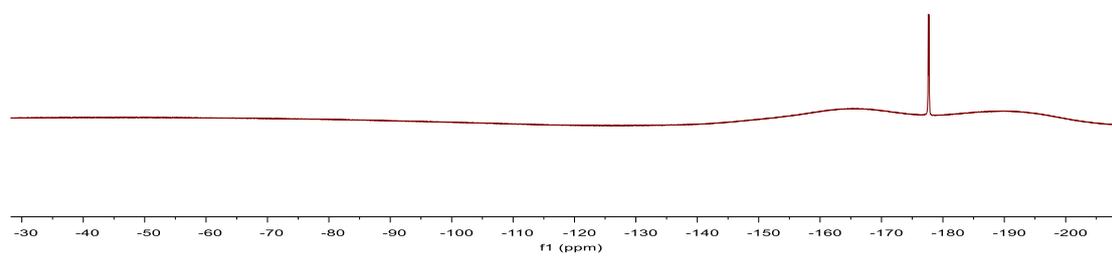
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3g**



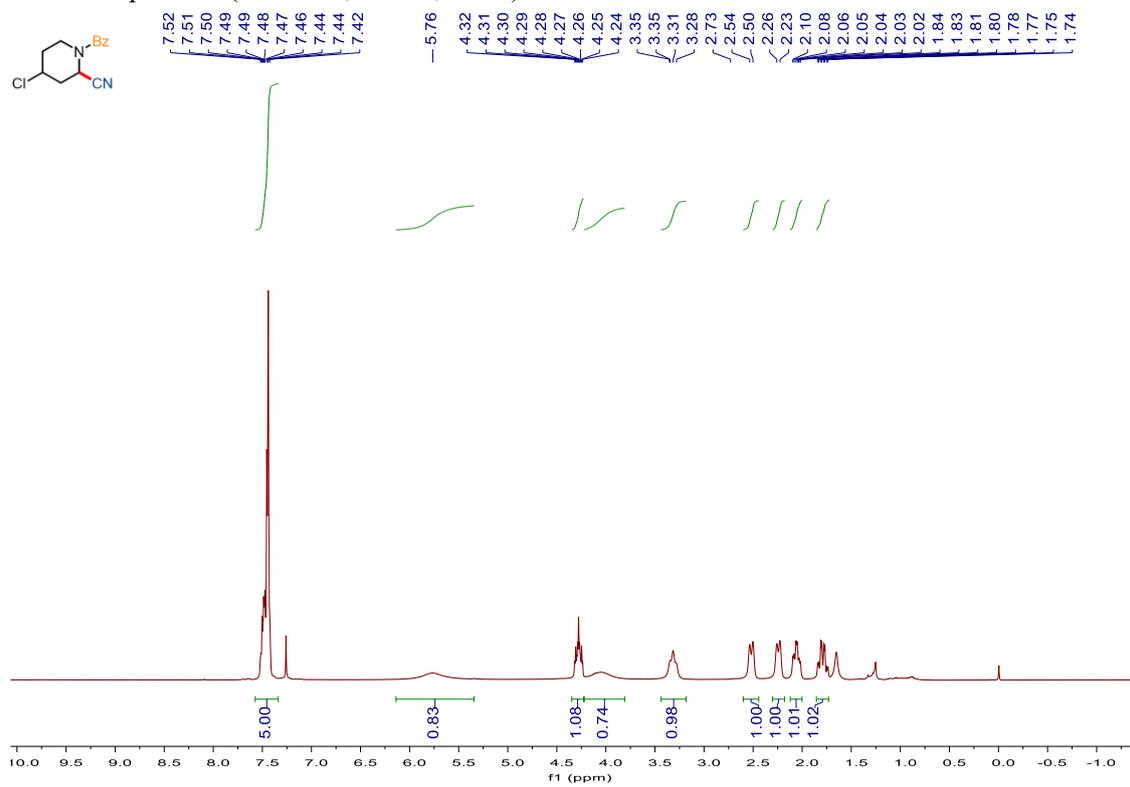
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 $^\circ\text{C}$) of **3g**



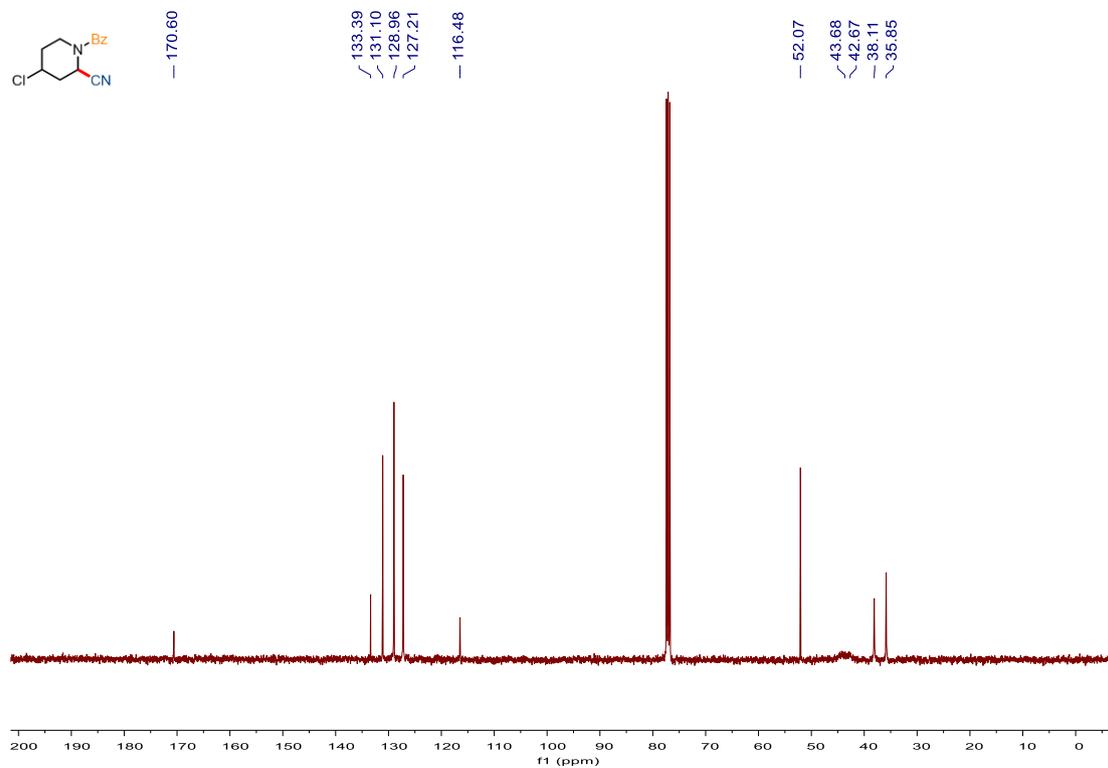
δ -177.62
 δ -177.74



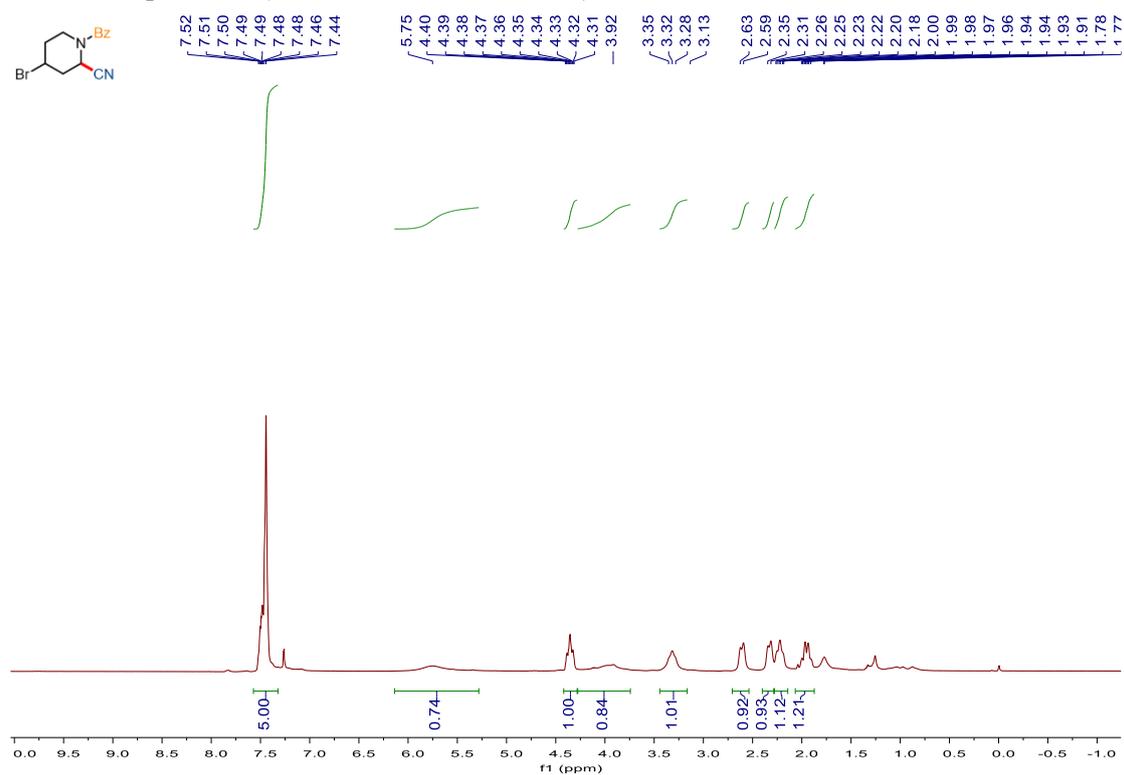
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3h**



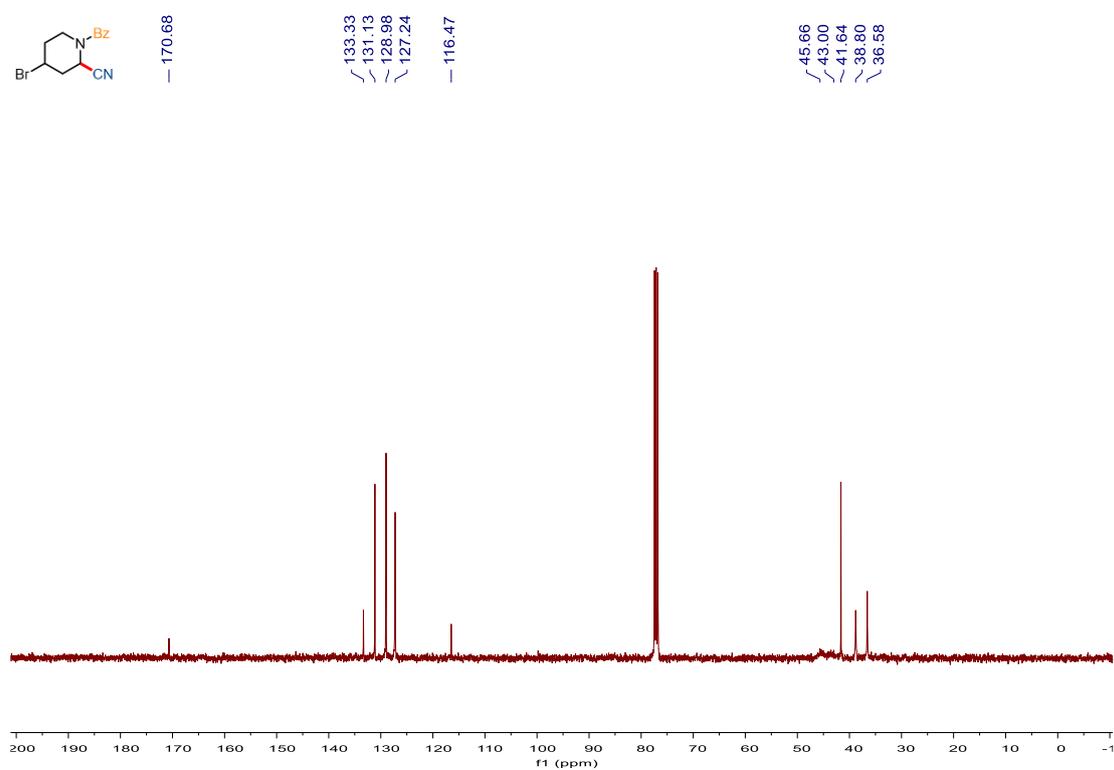
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3h**



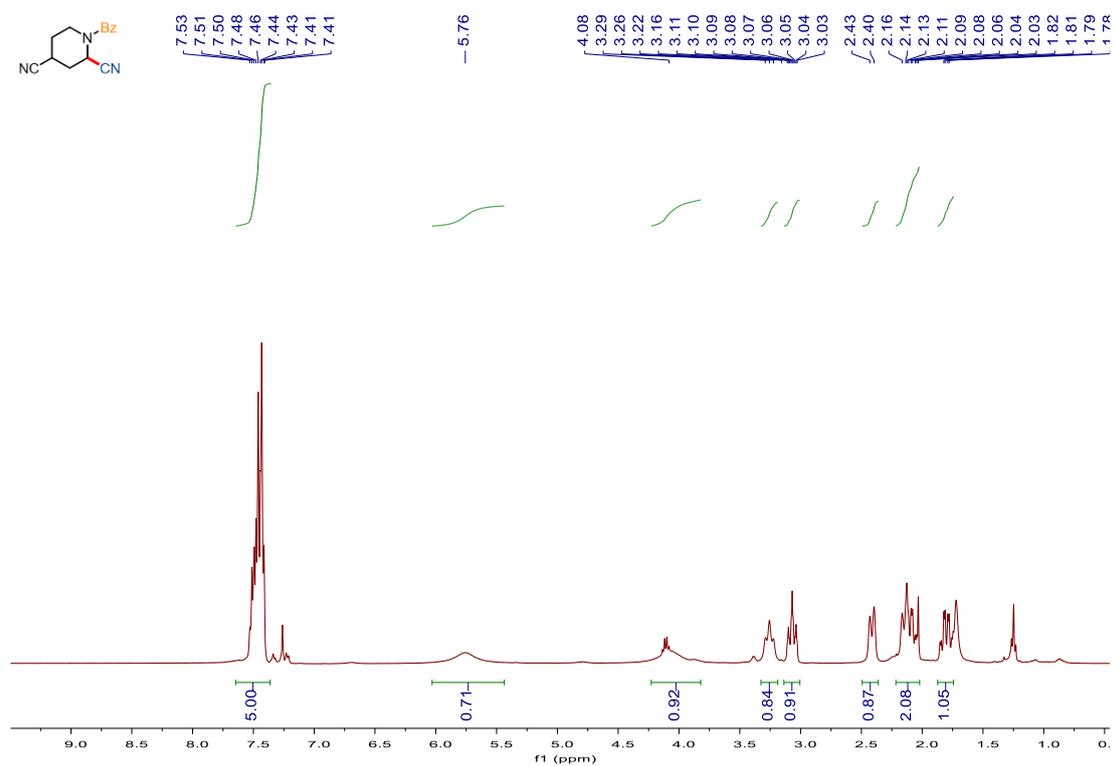
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3i**



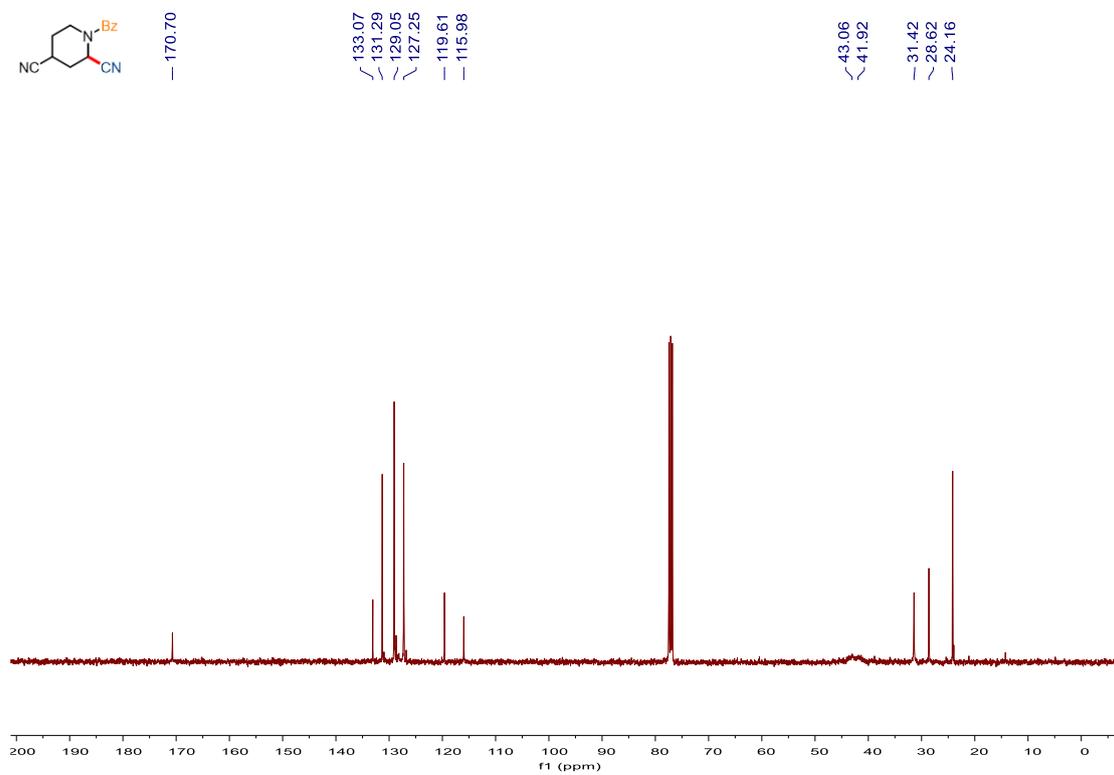
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3i**



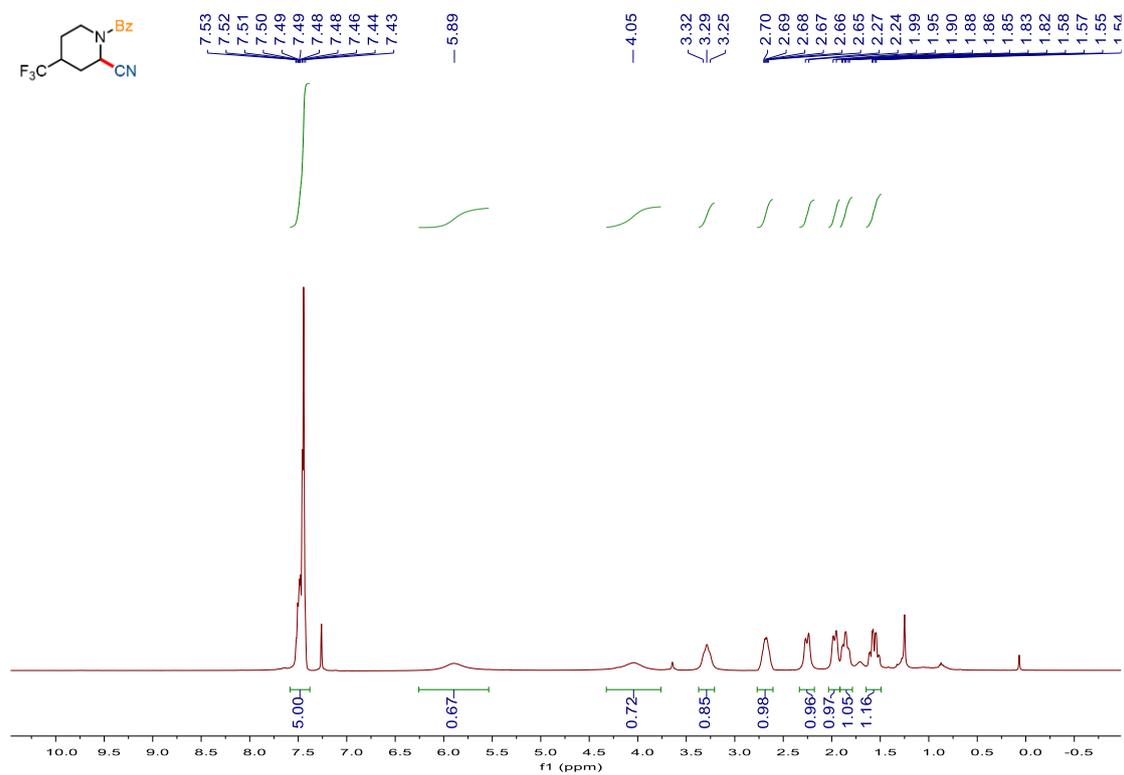
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3j**



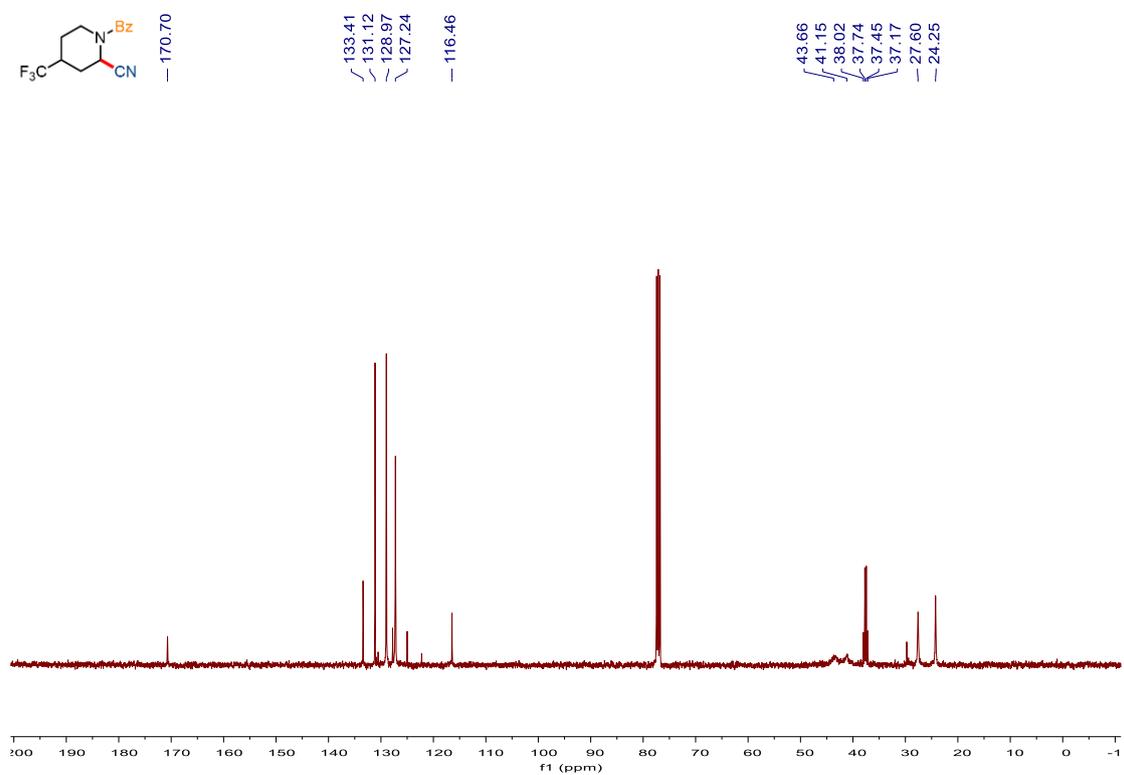
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3j**



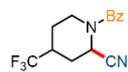
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3k**



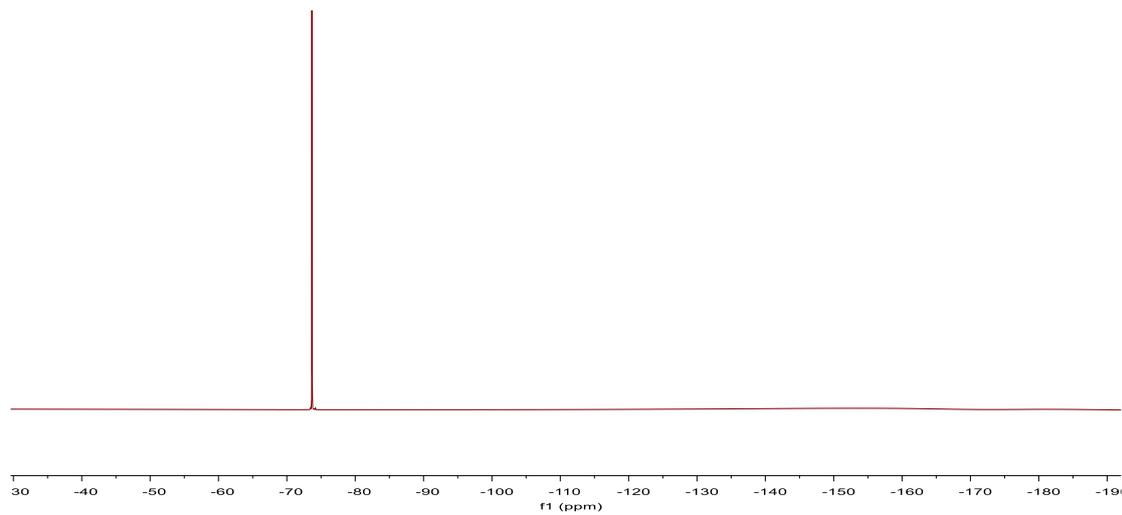
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3k**



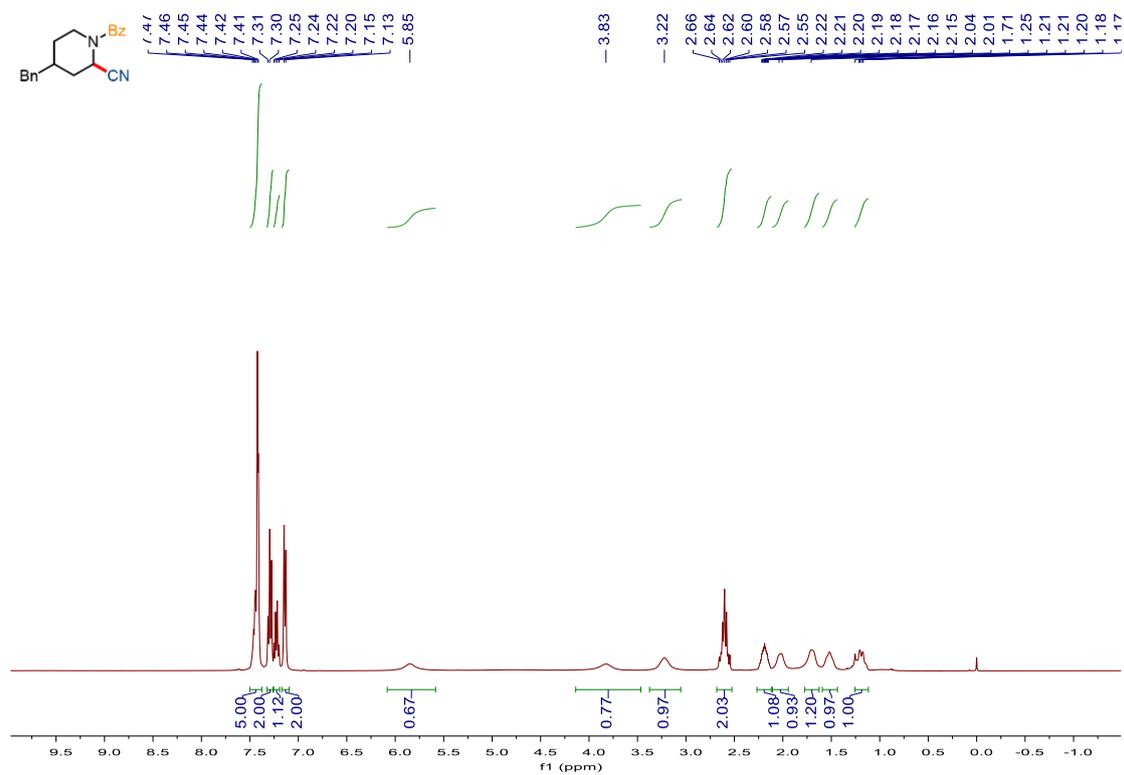
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **3k**



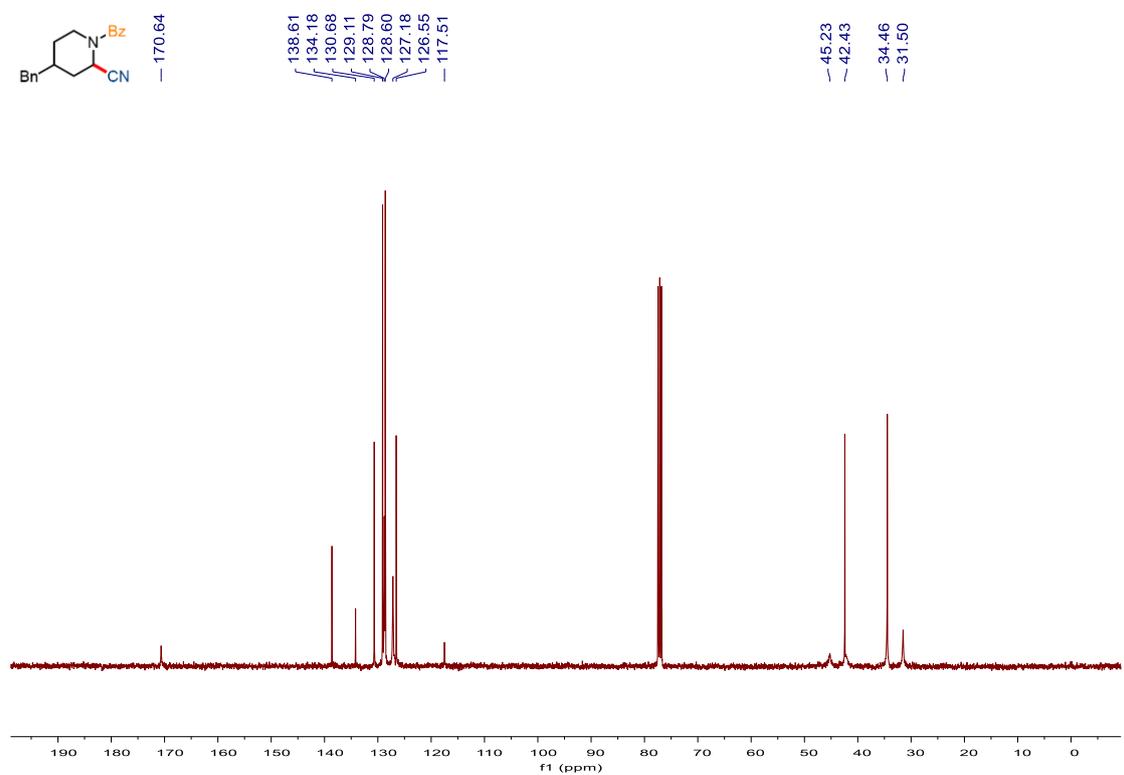
δ -73.67
 δ -73.69



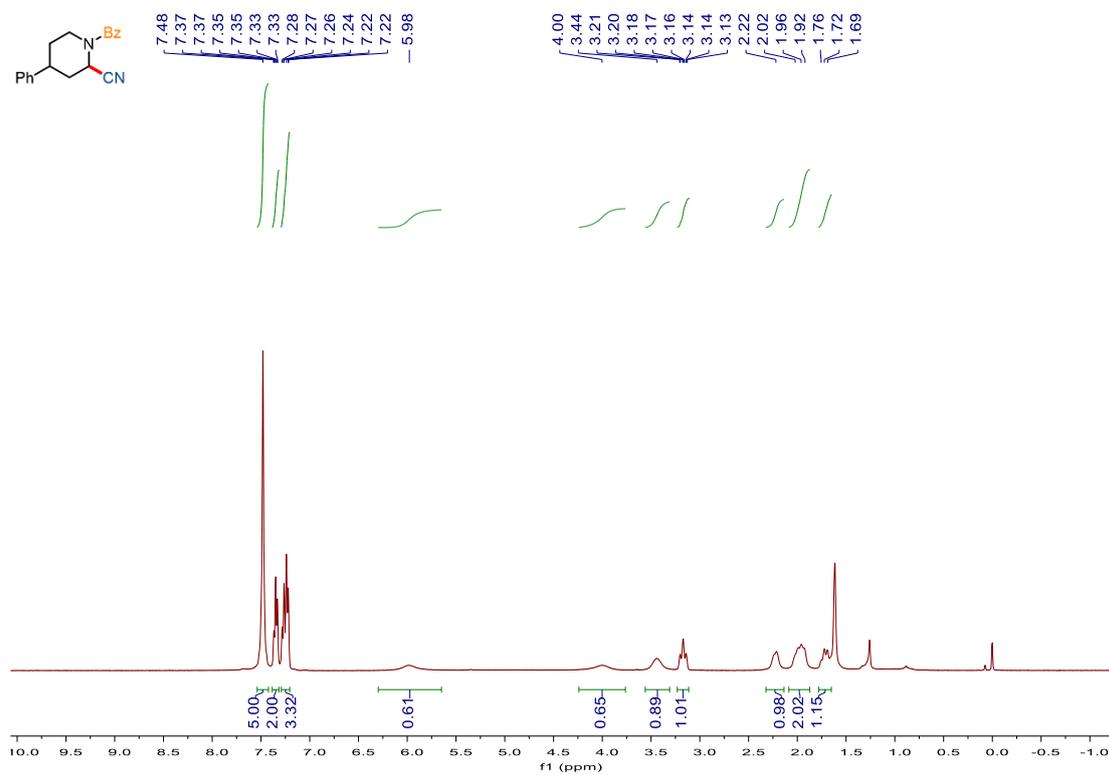
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **31**



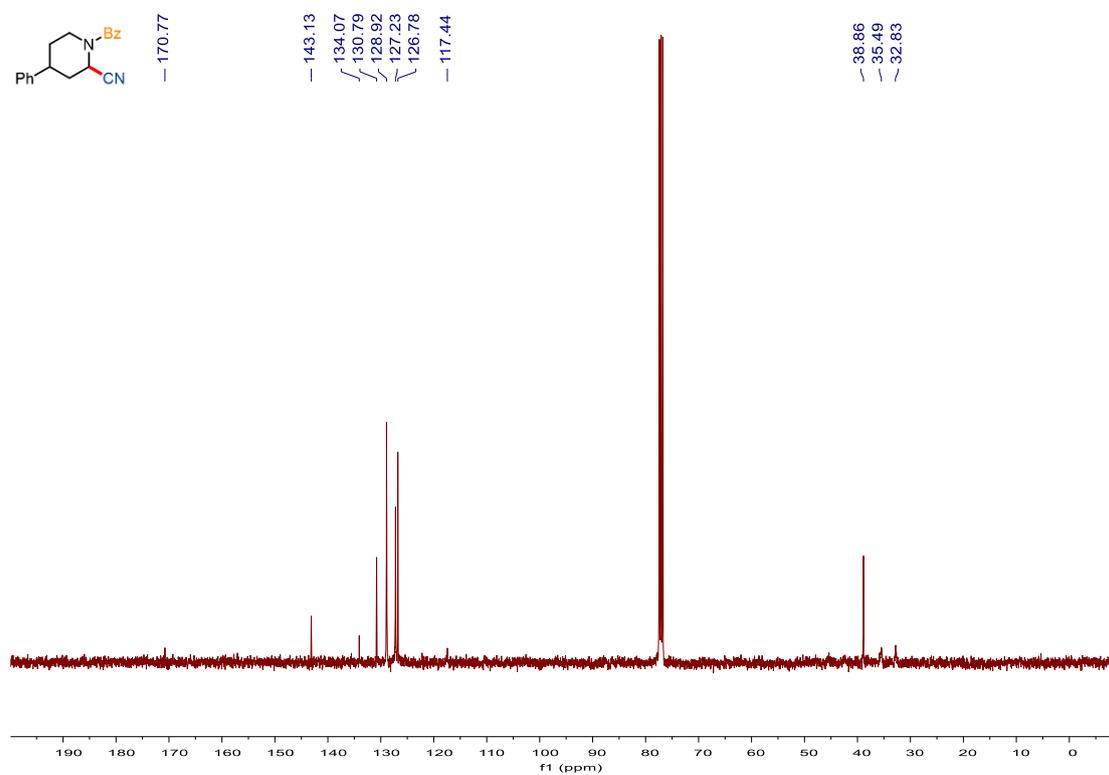
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **31**



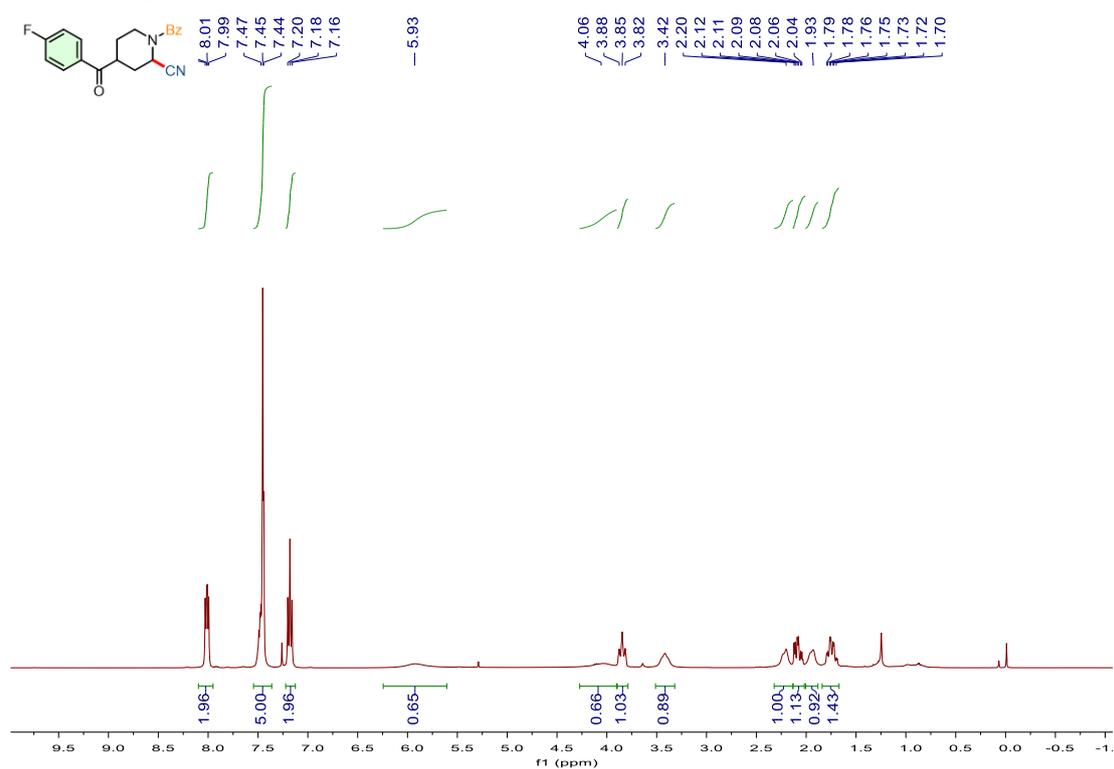
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3m**



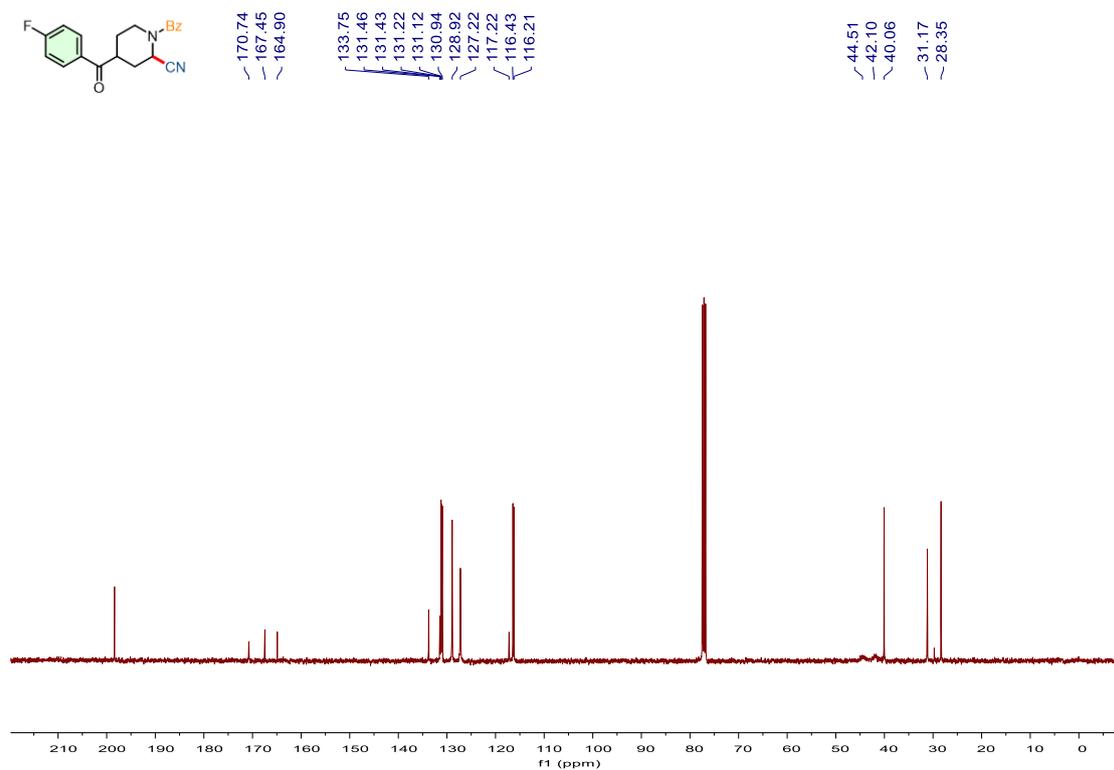
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3m**



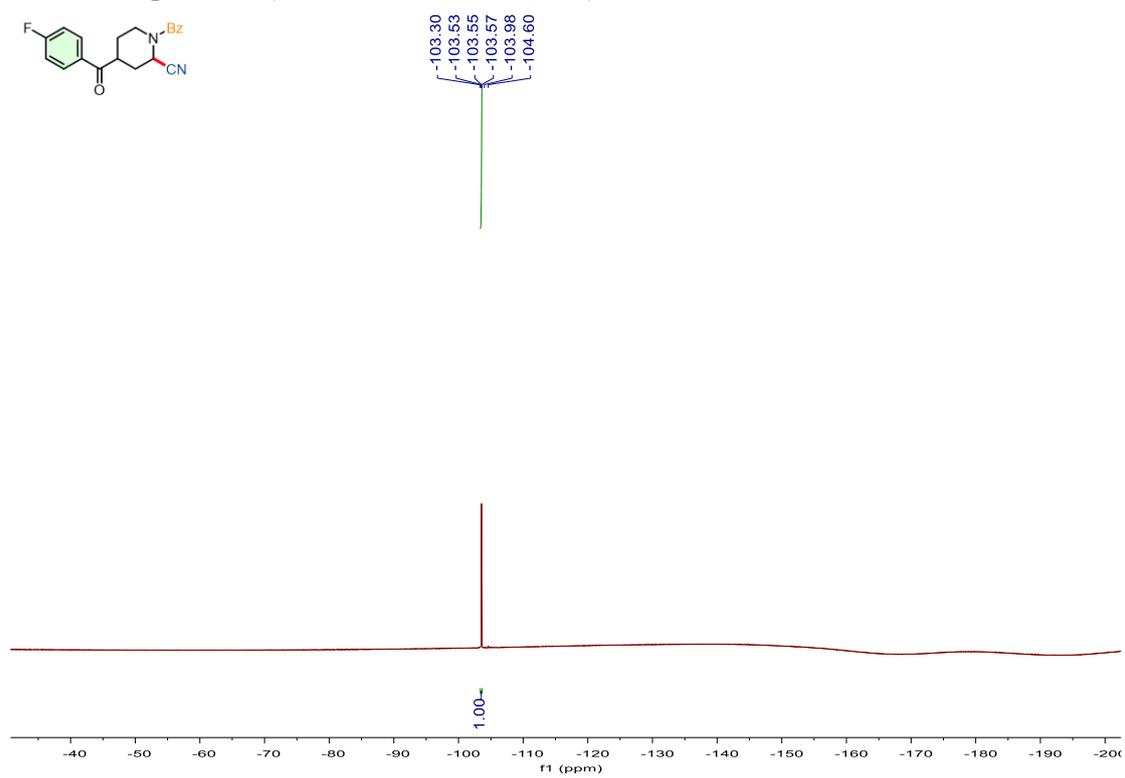
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3n**



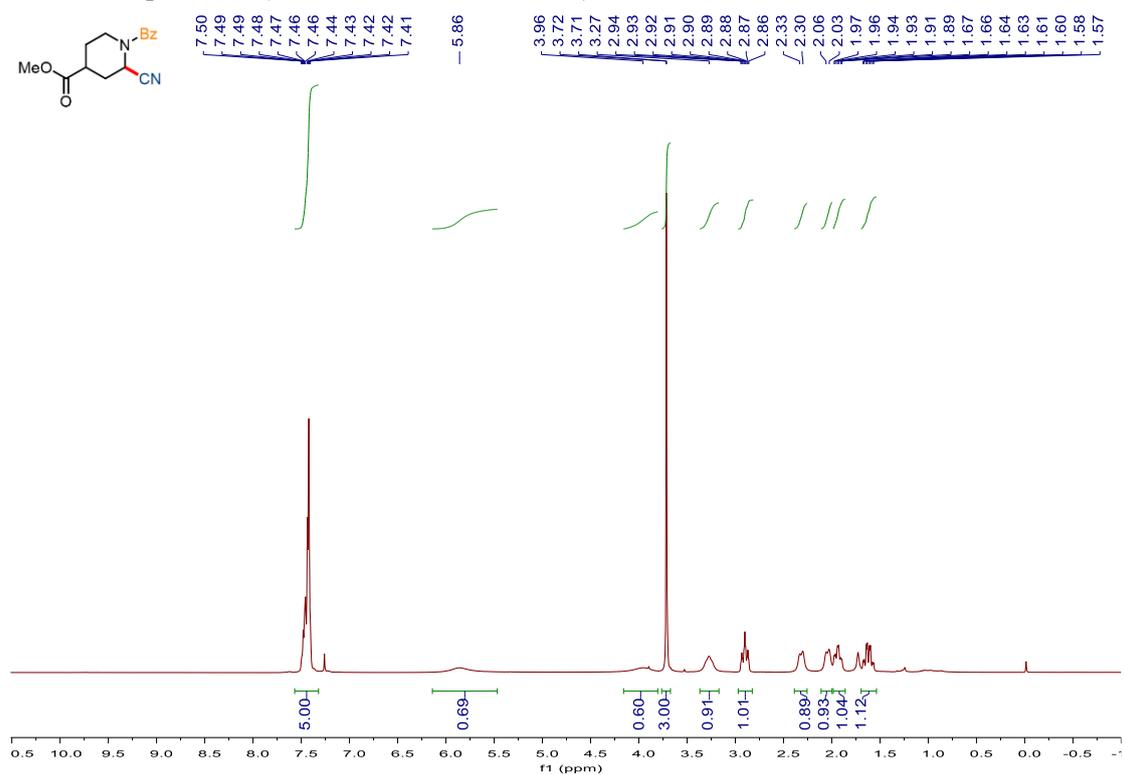
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3n**



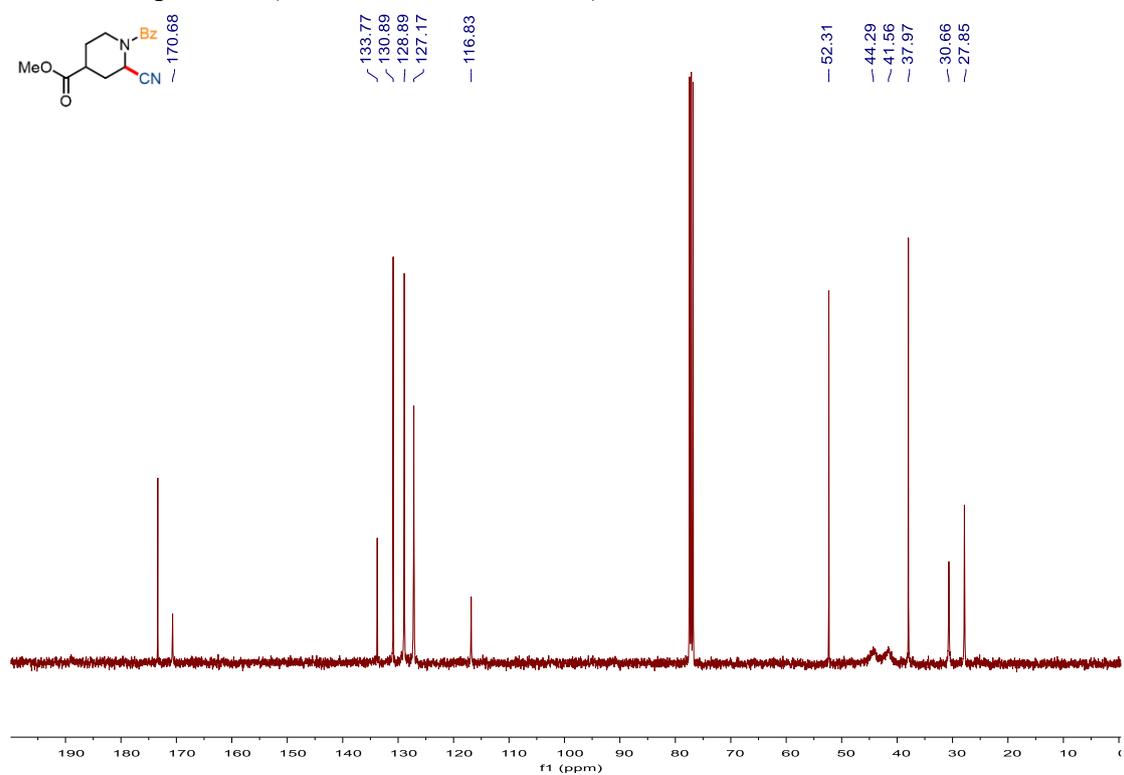
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **3n**



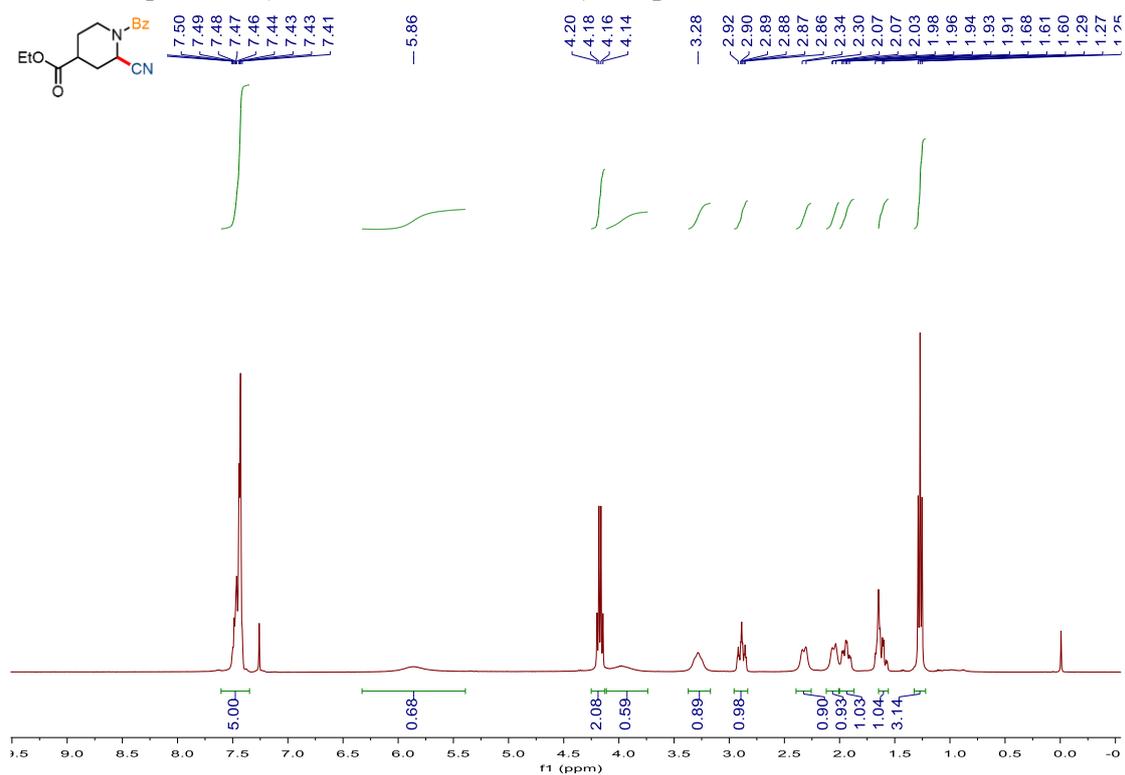
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **30**



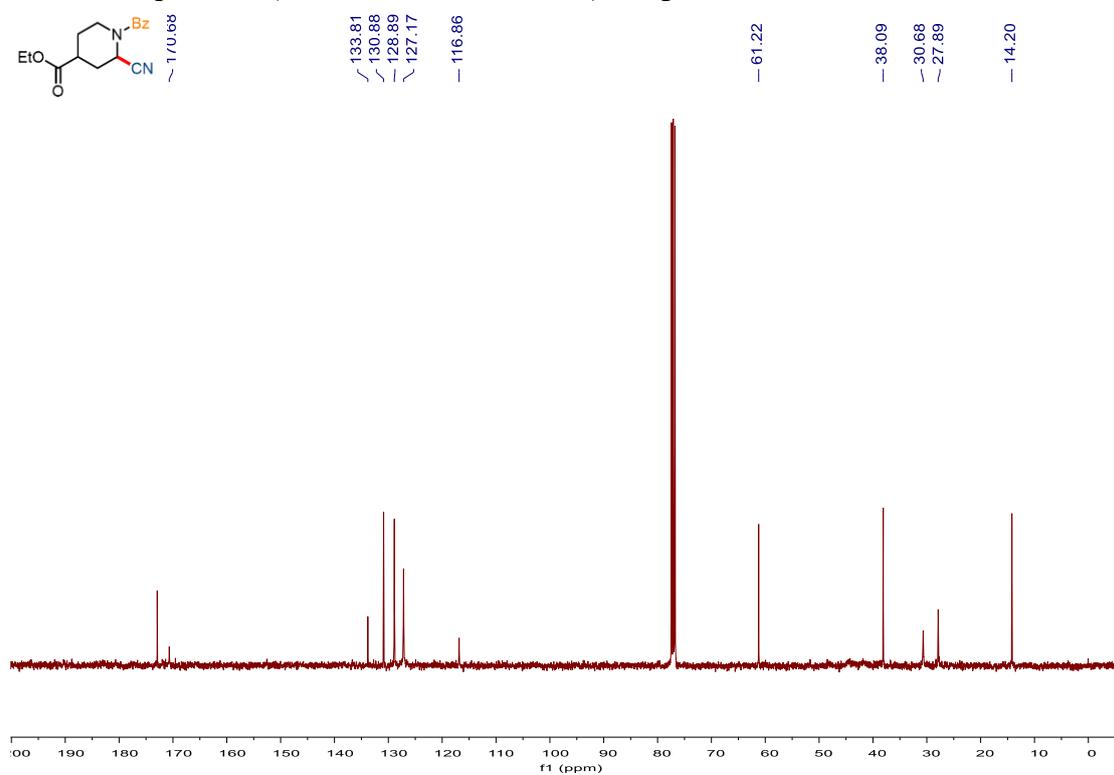
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **30**



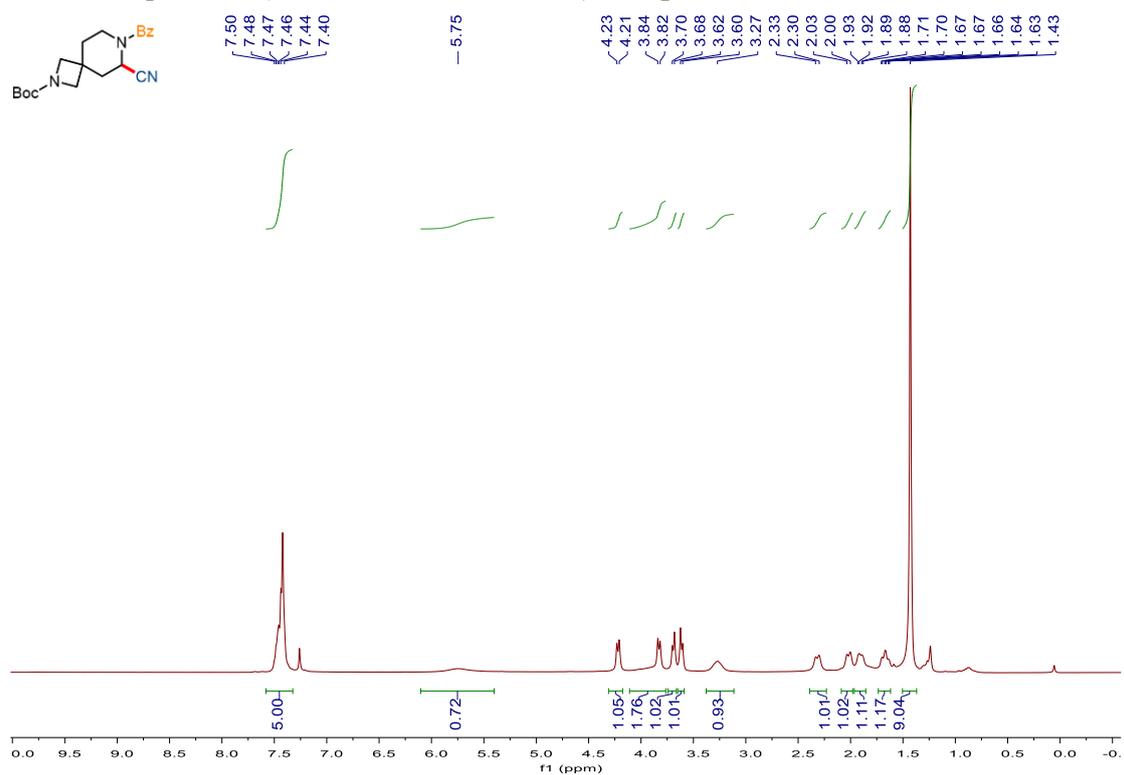
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3p**



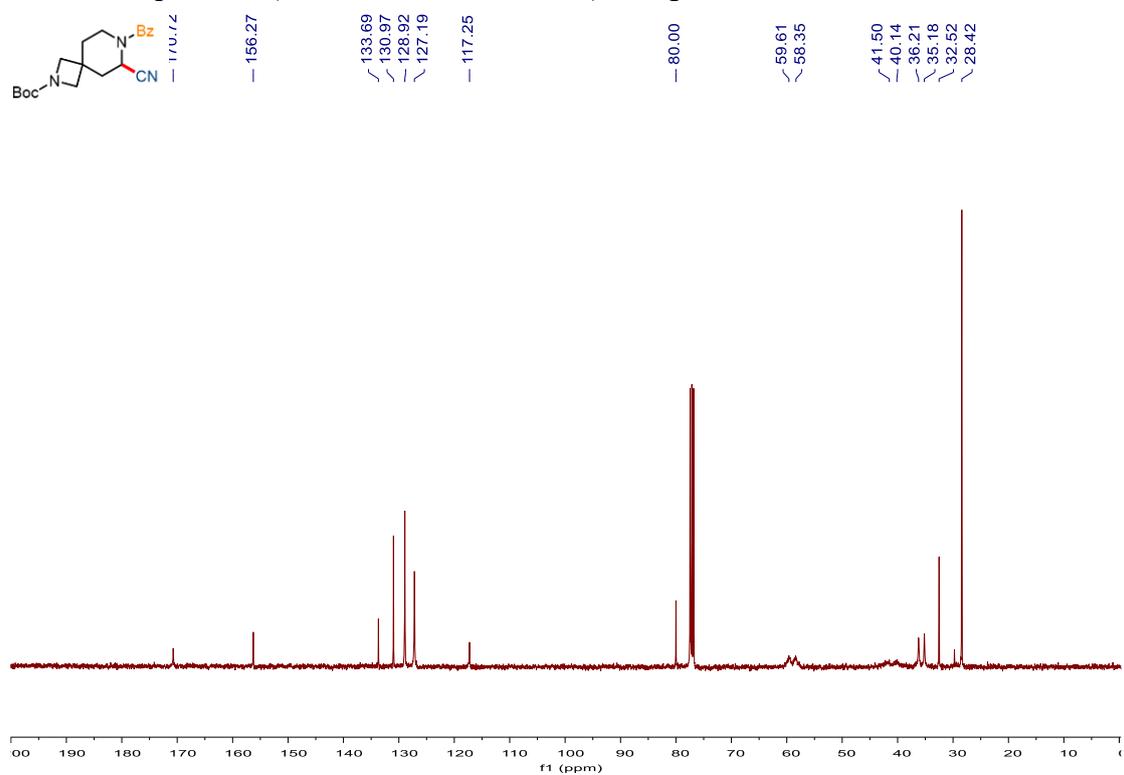
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3p**



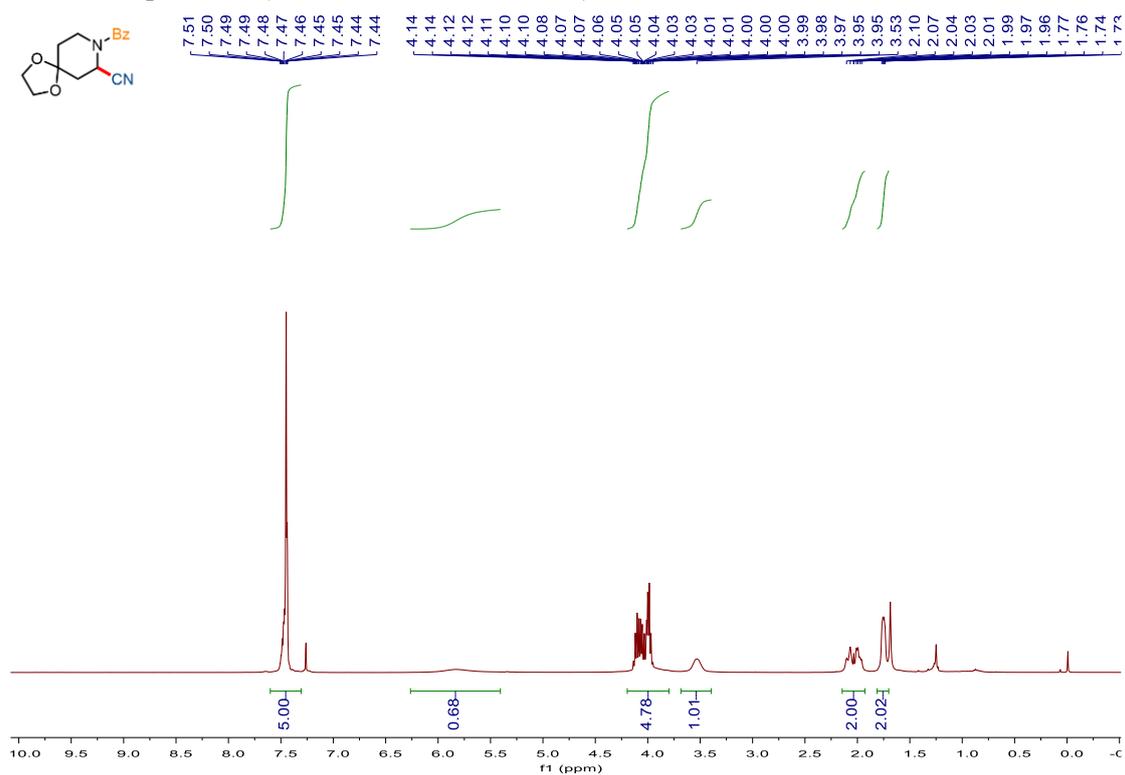
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3q**



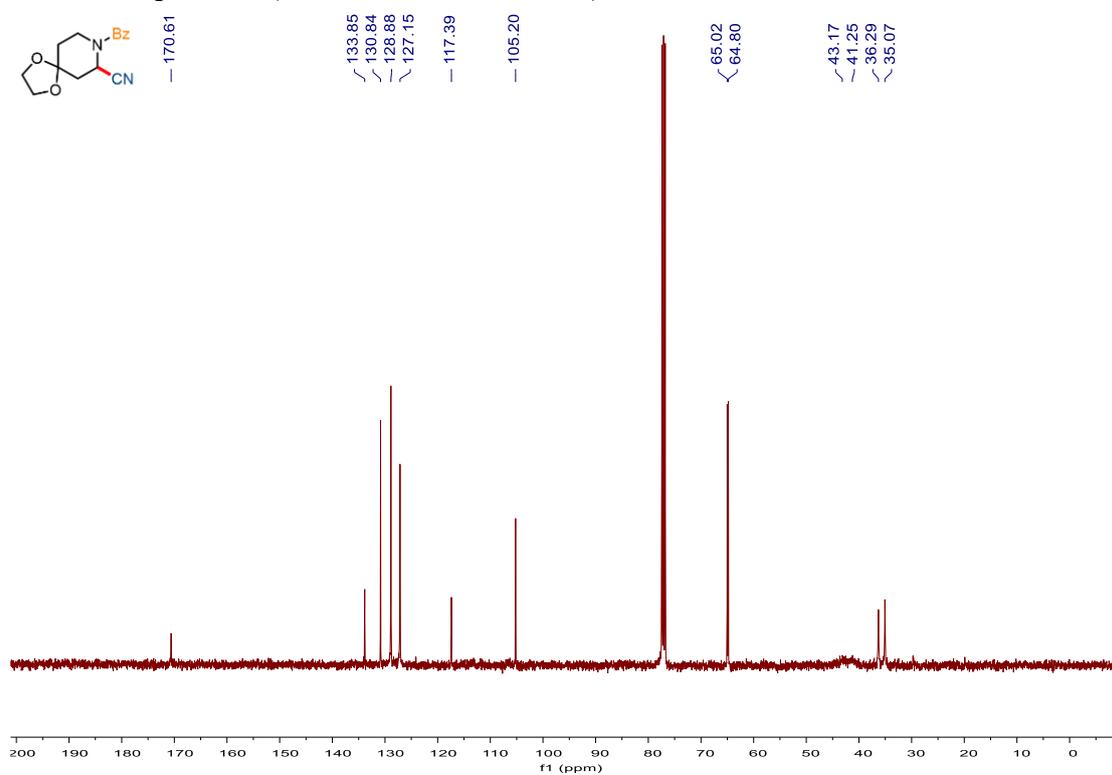
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3q**



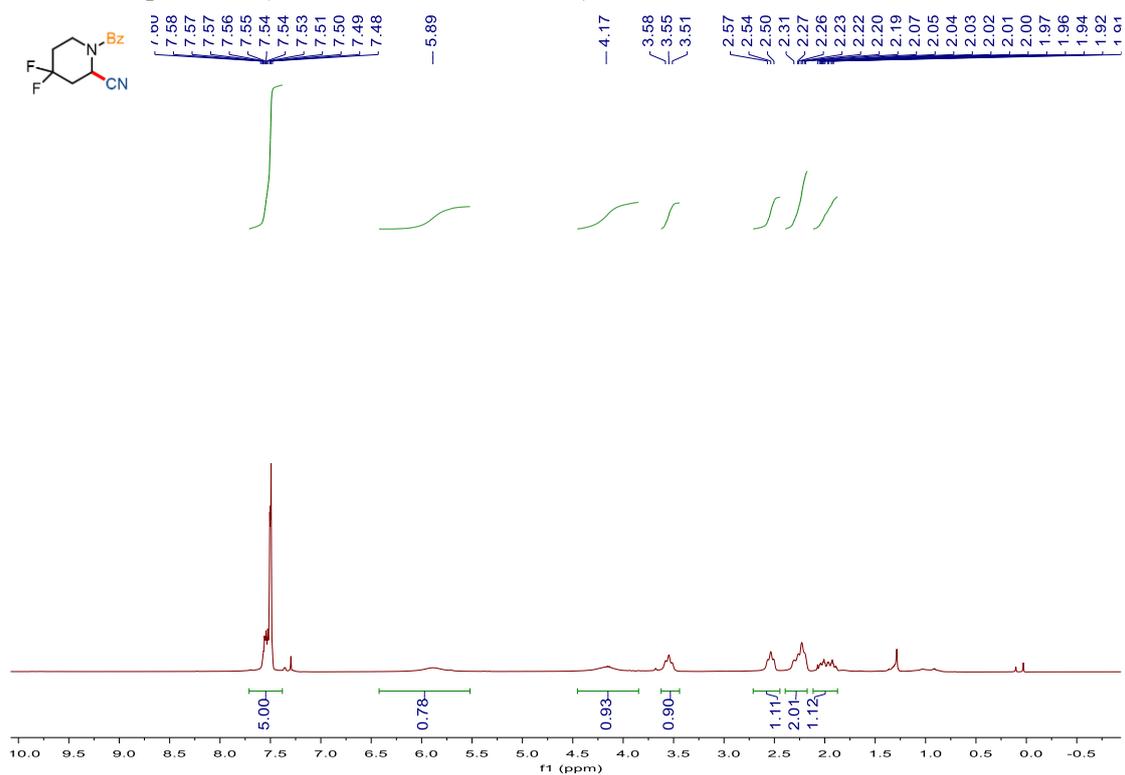
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3r**



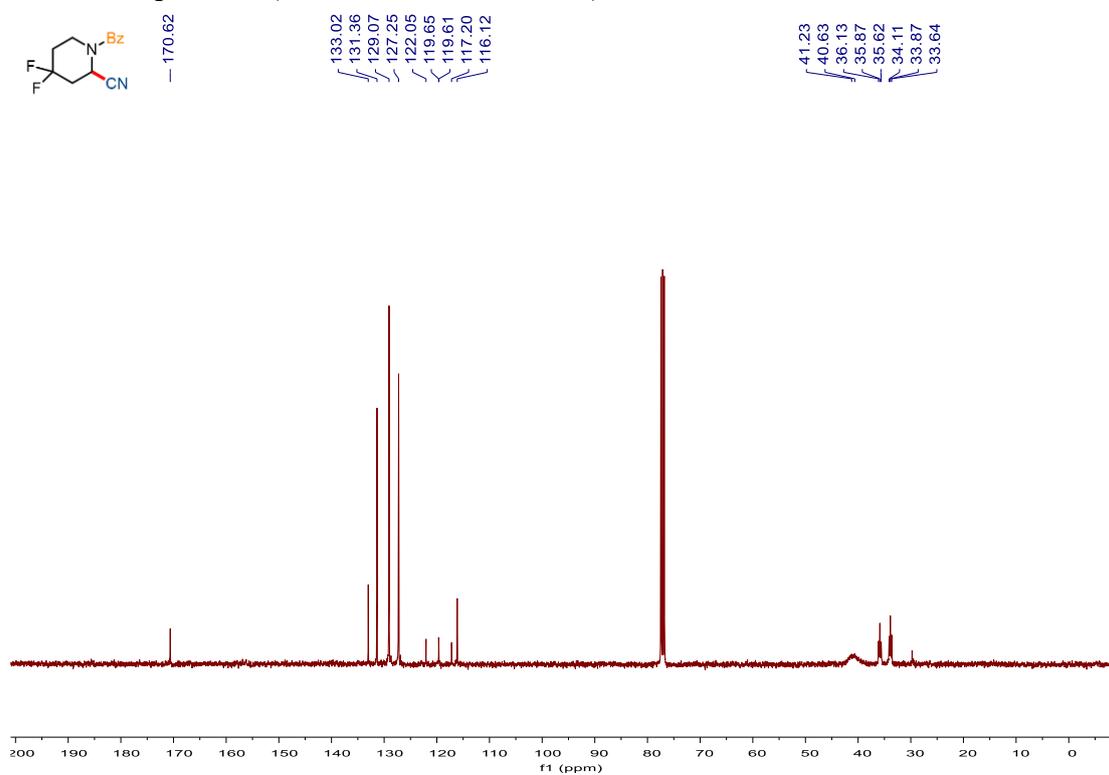
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3r**



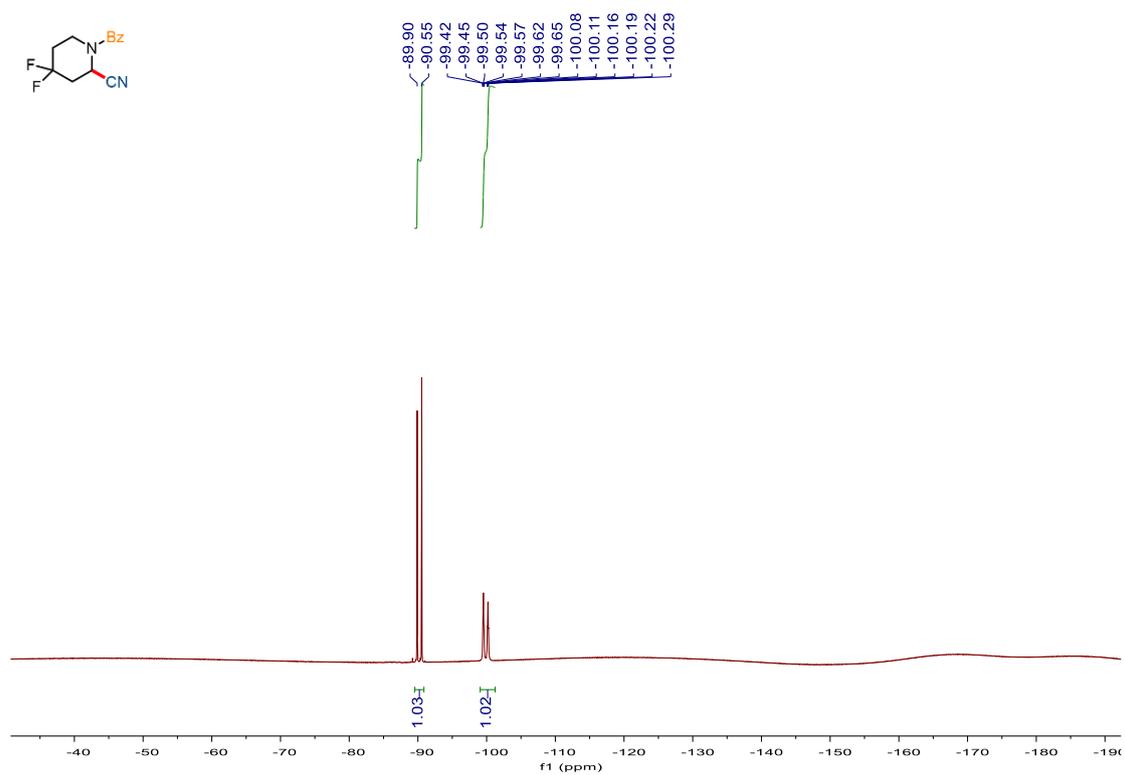
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3s**



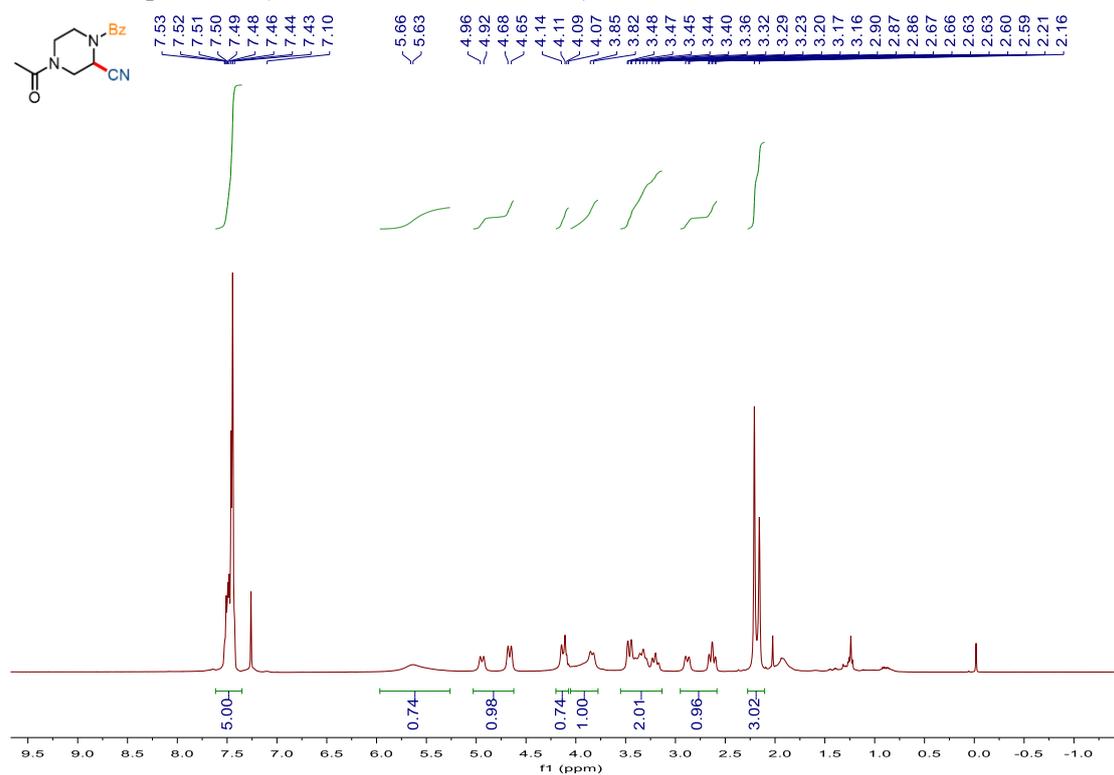
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3s**



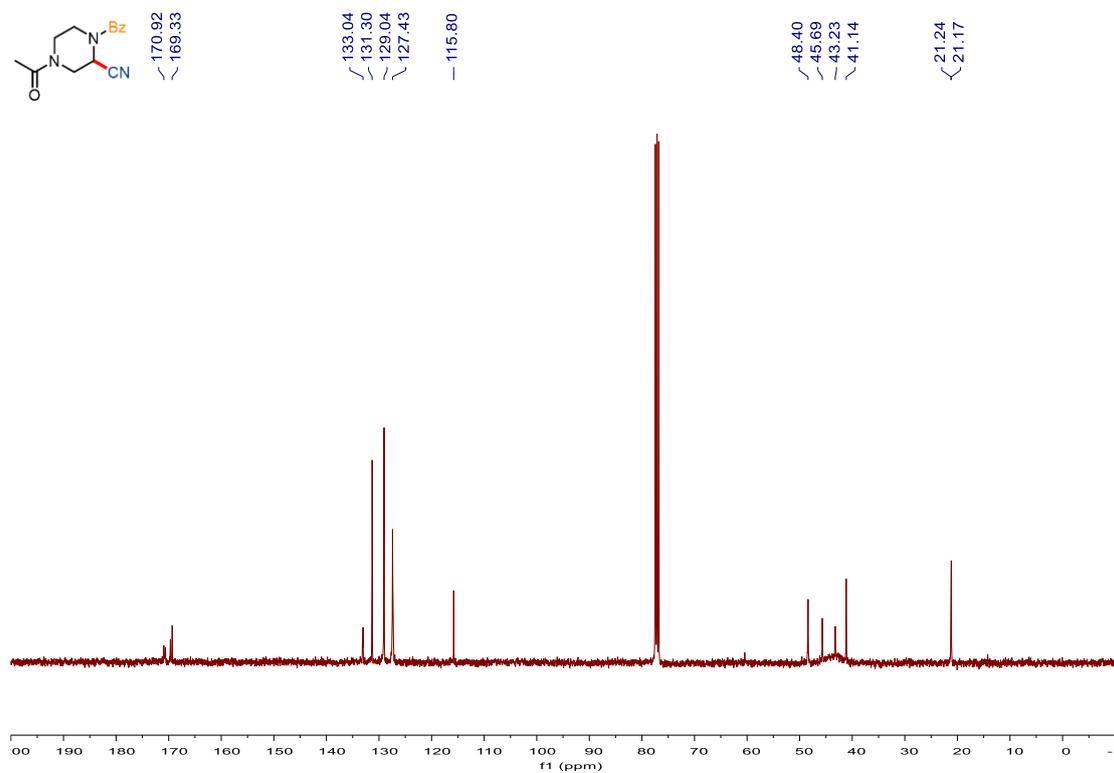
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **3s**



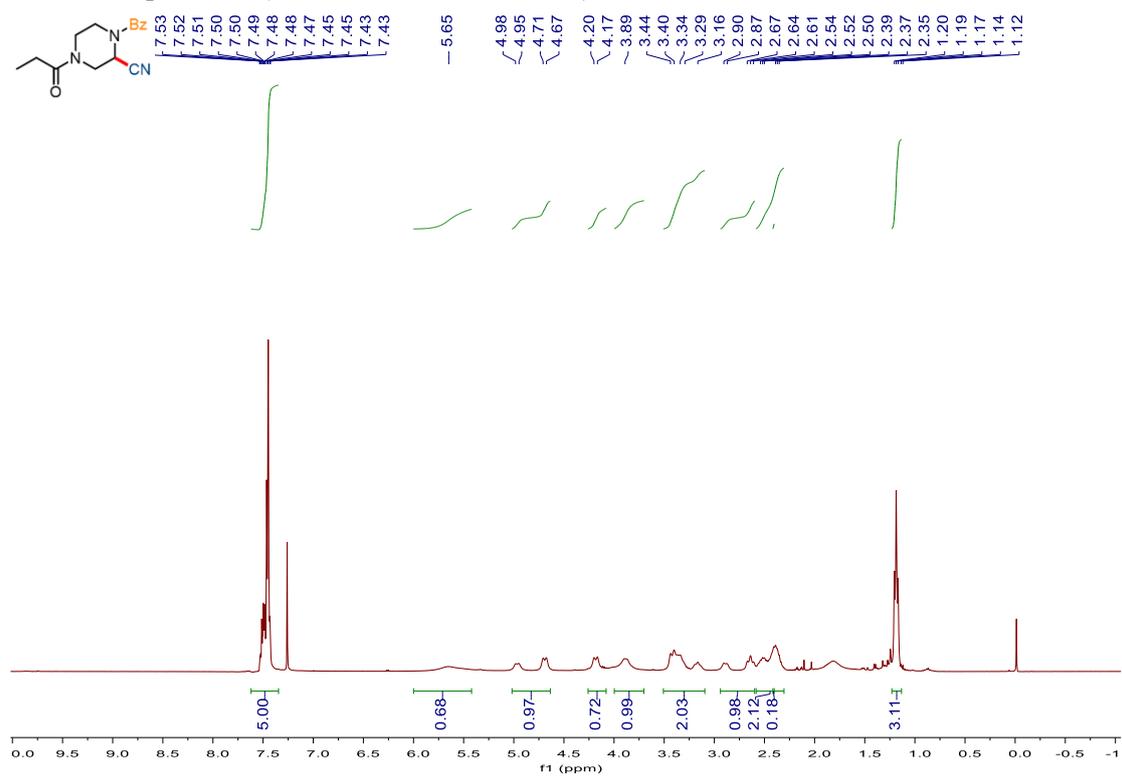
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3t**



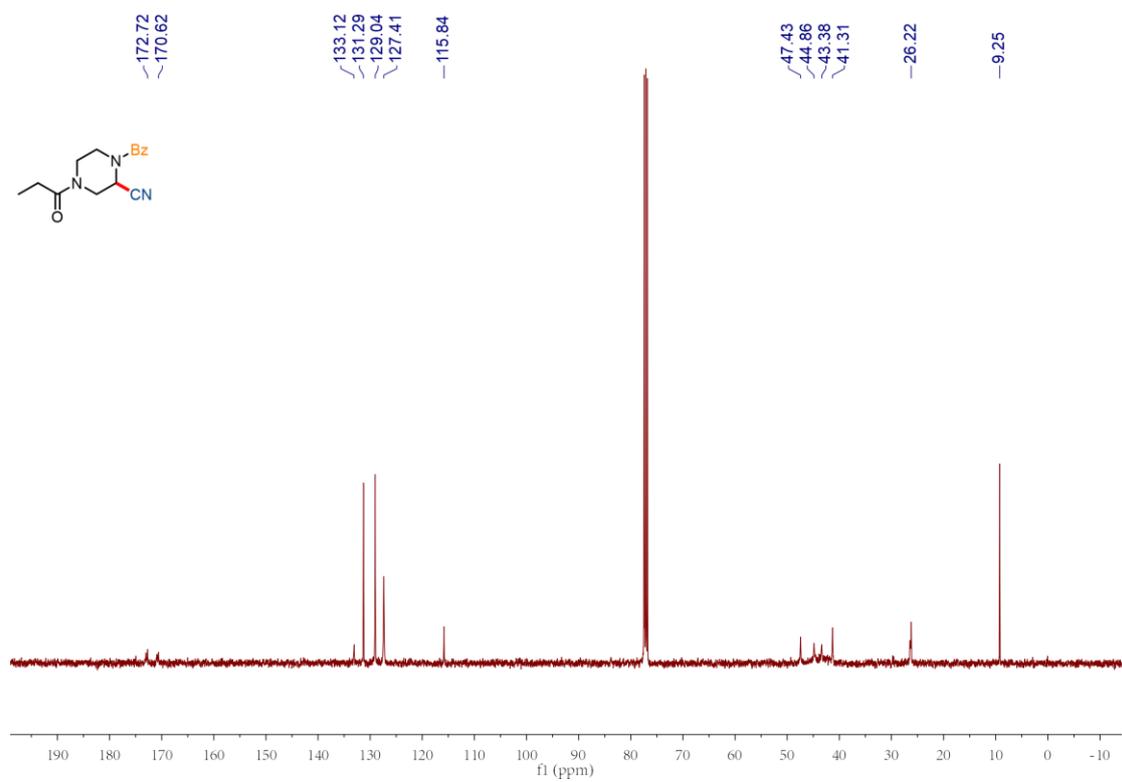
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3t**



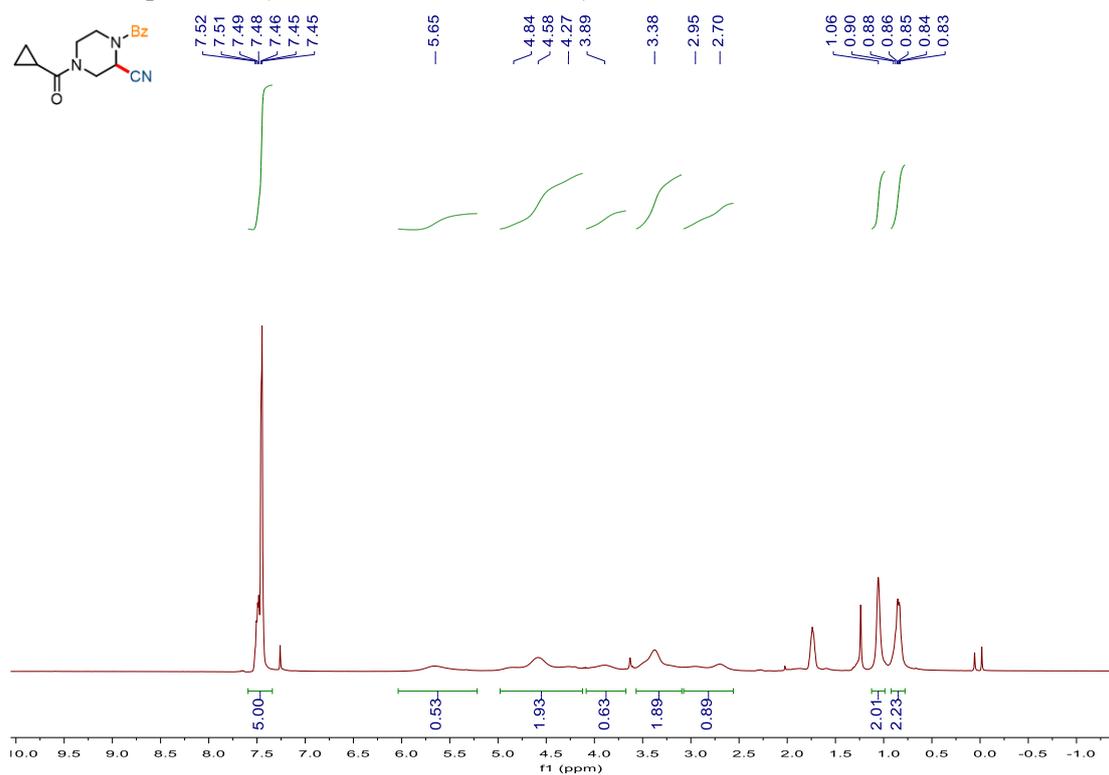
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3u**



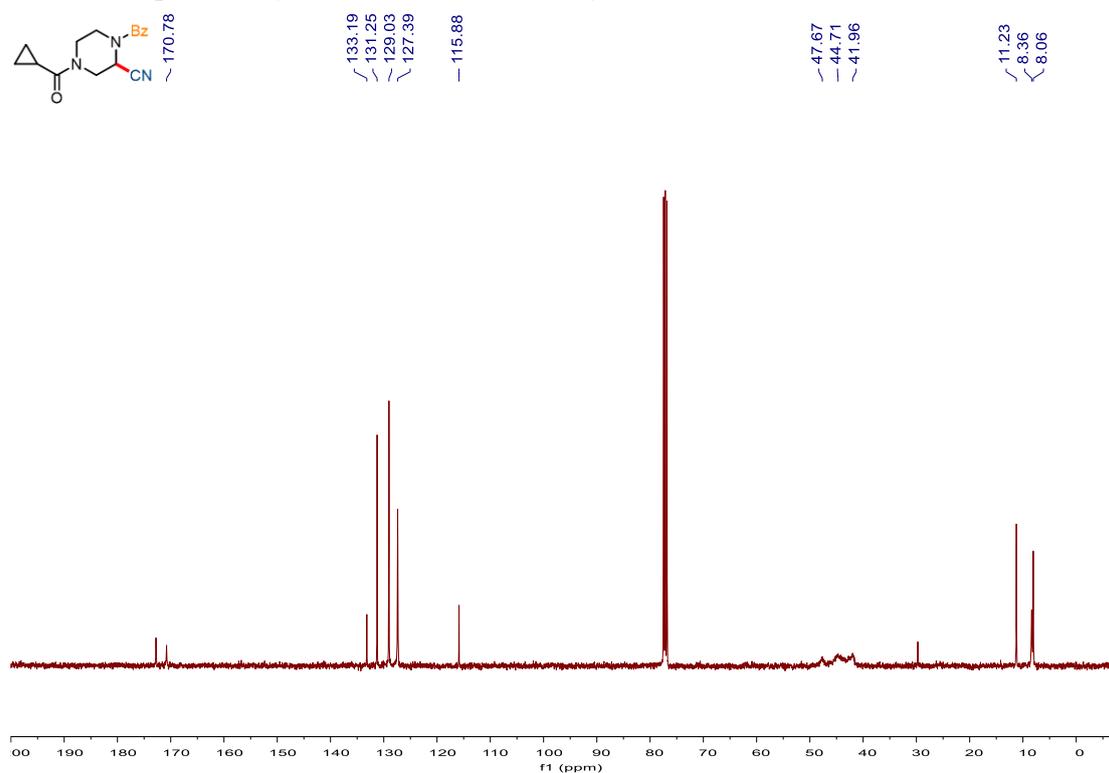
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3u**



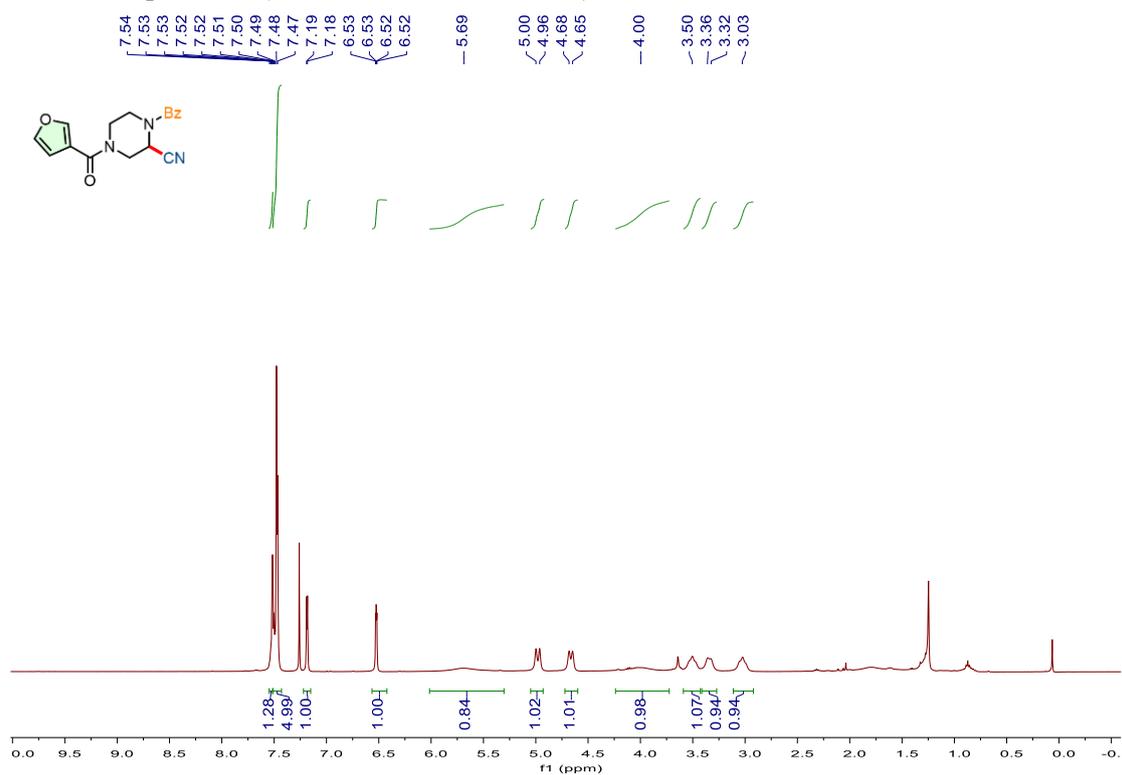
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3v**



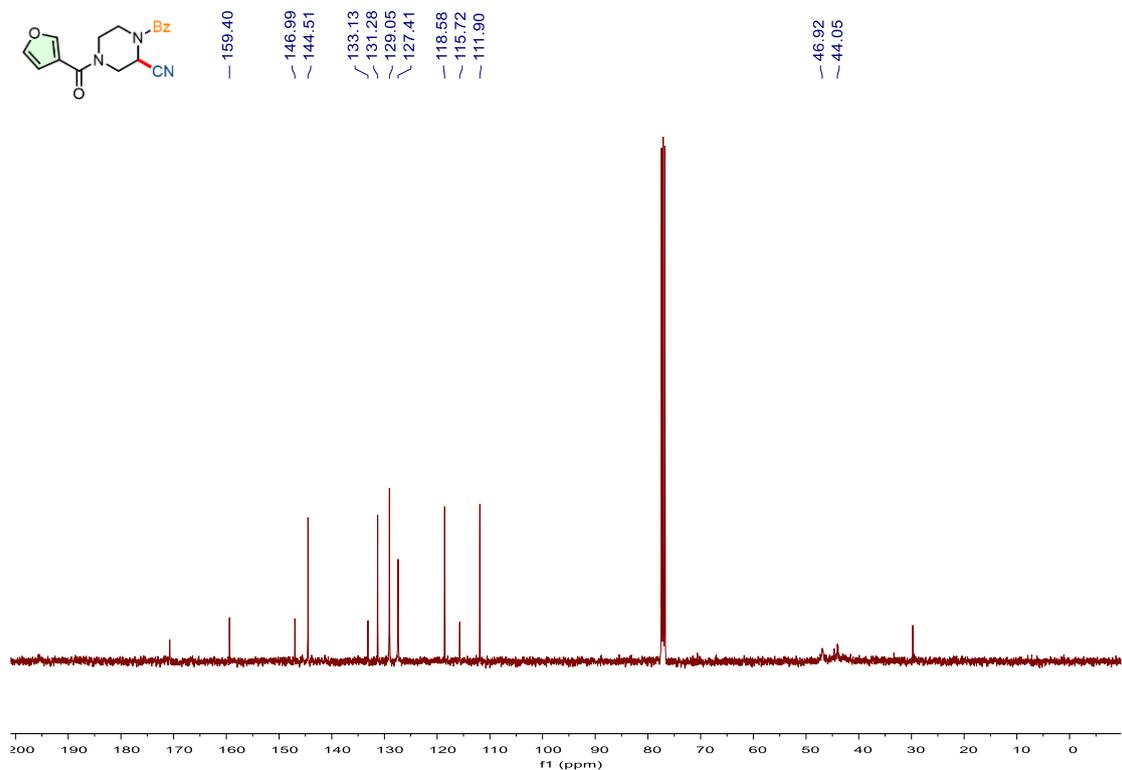
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3v**



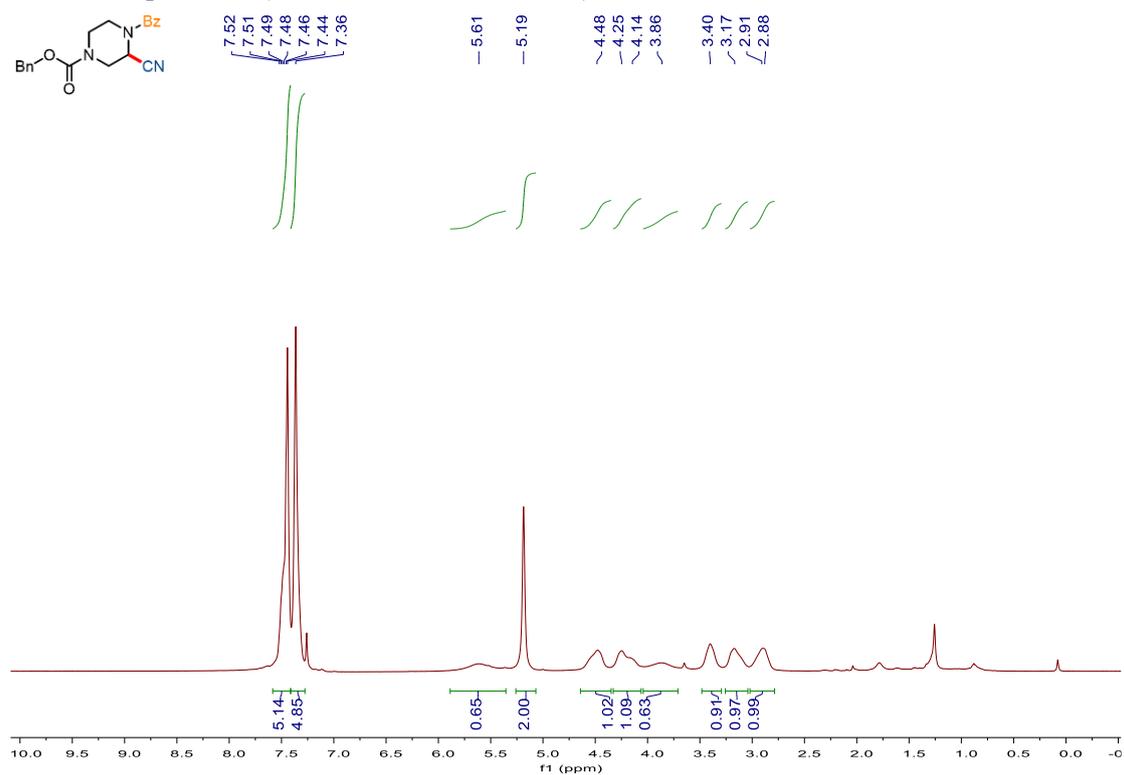
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3w**



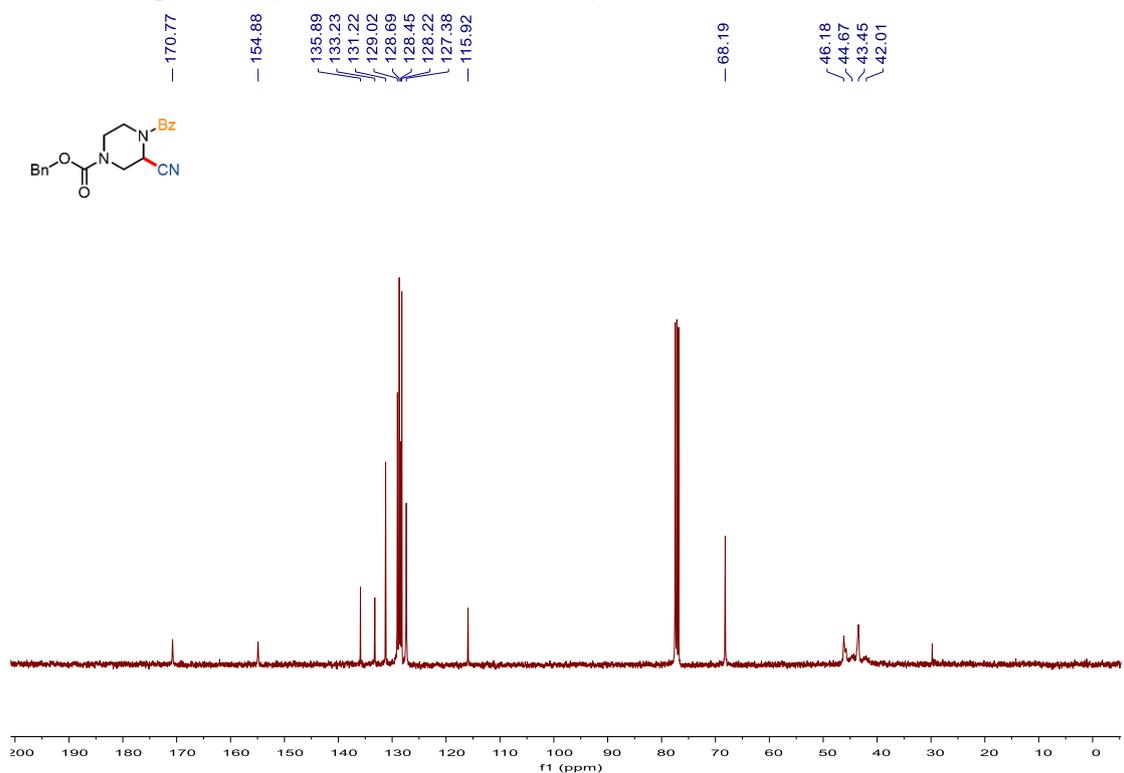
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3w**



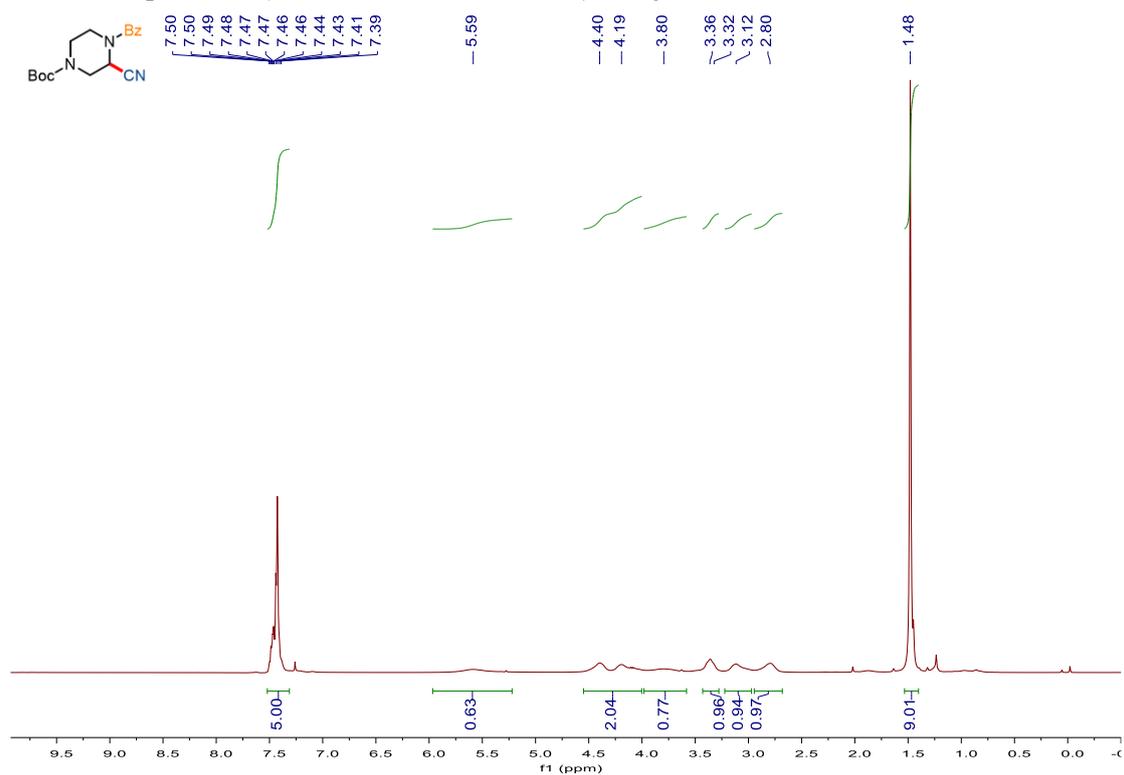
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3x**



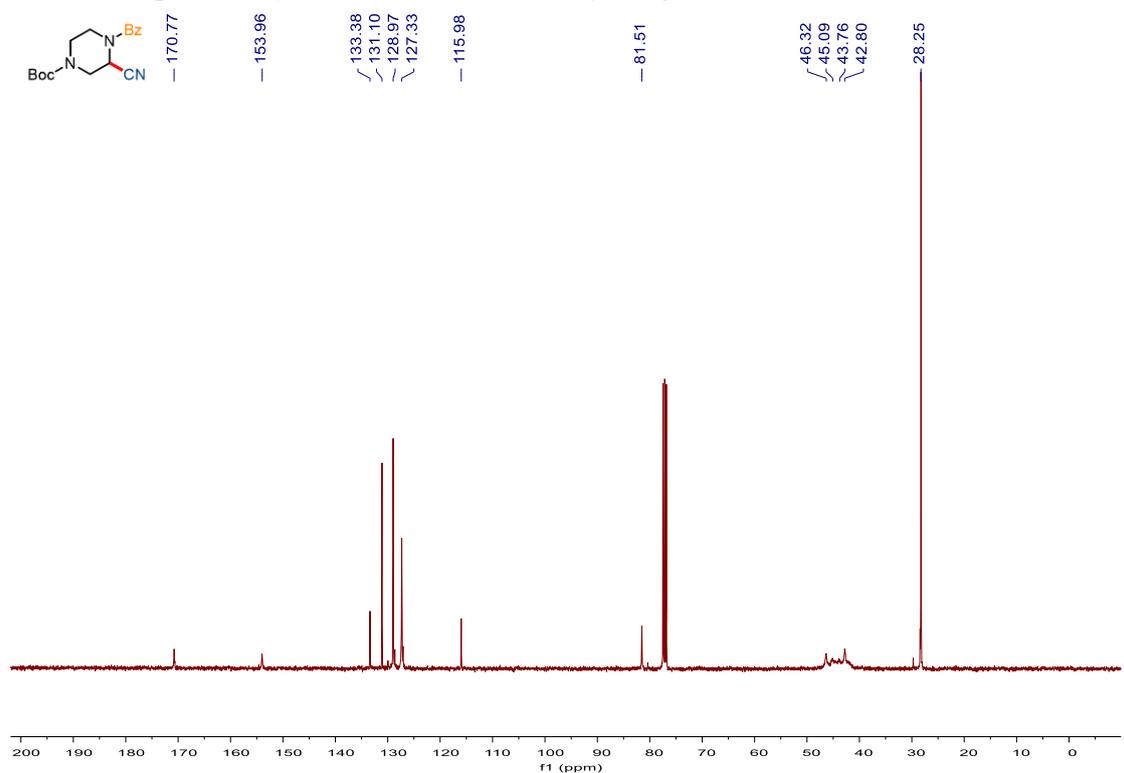
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3x**



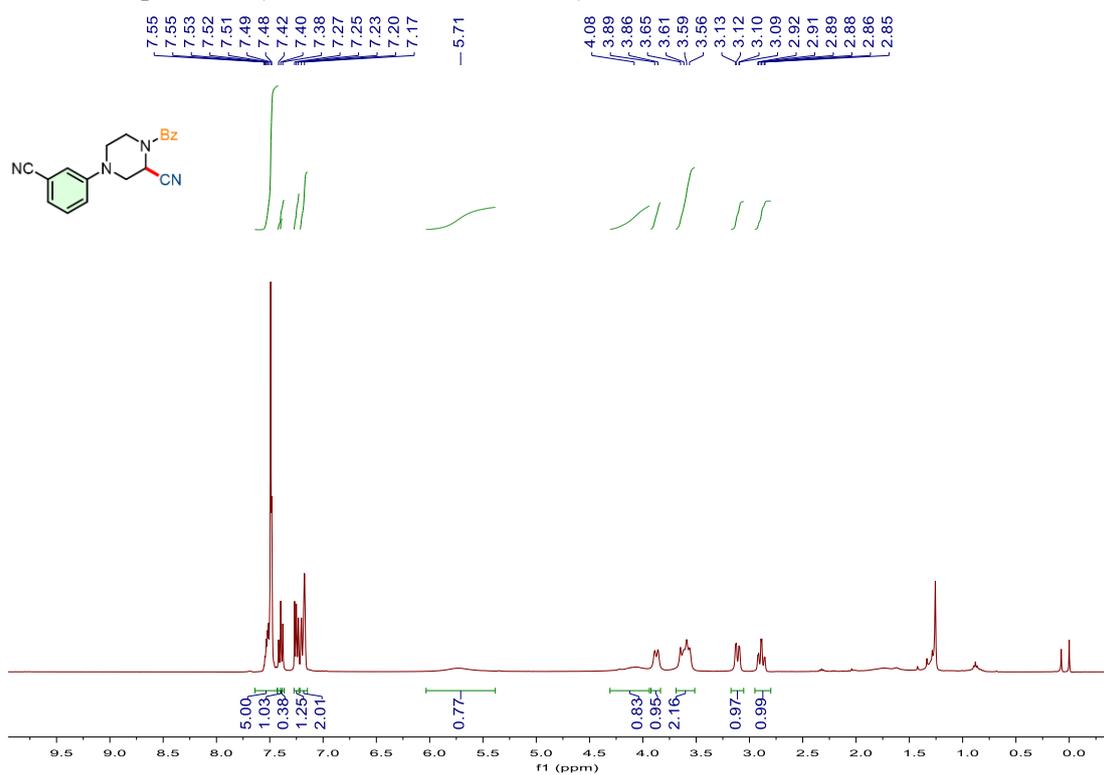
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3y**



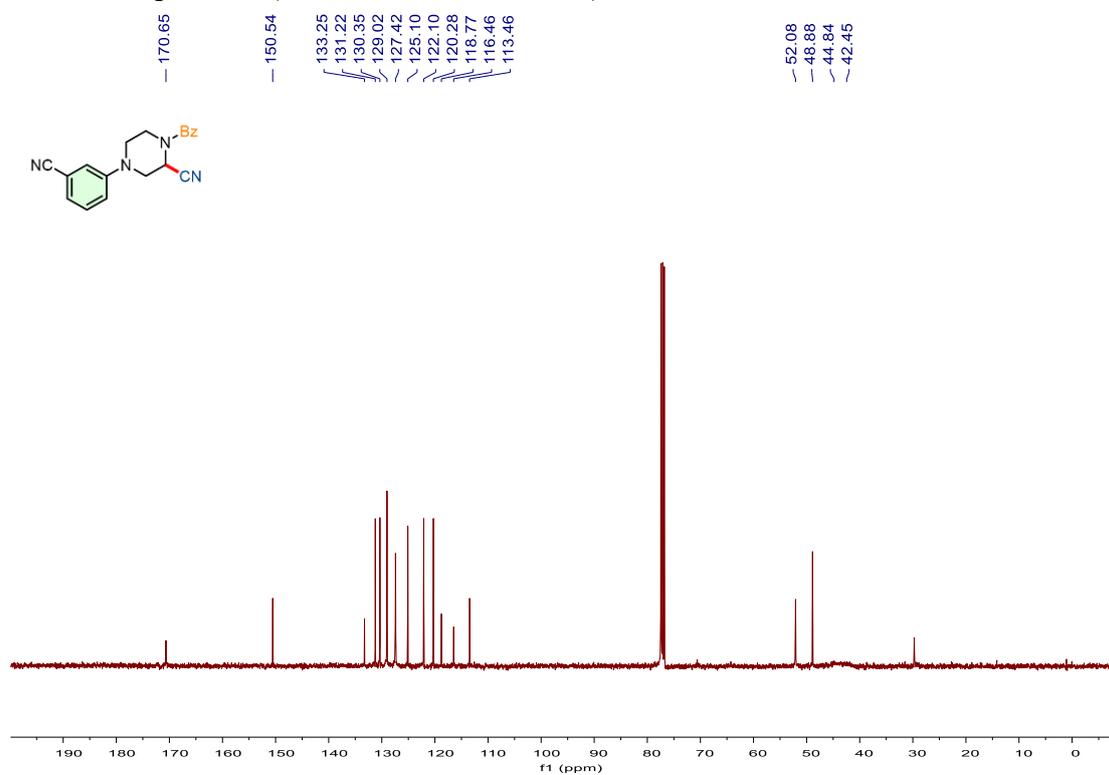
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3y**



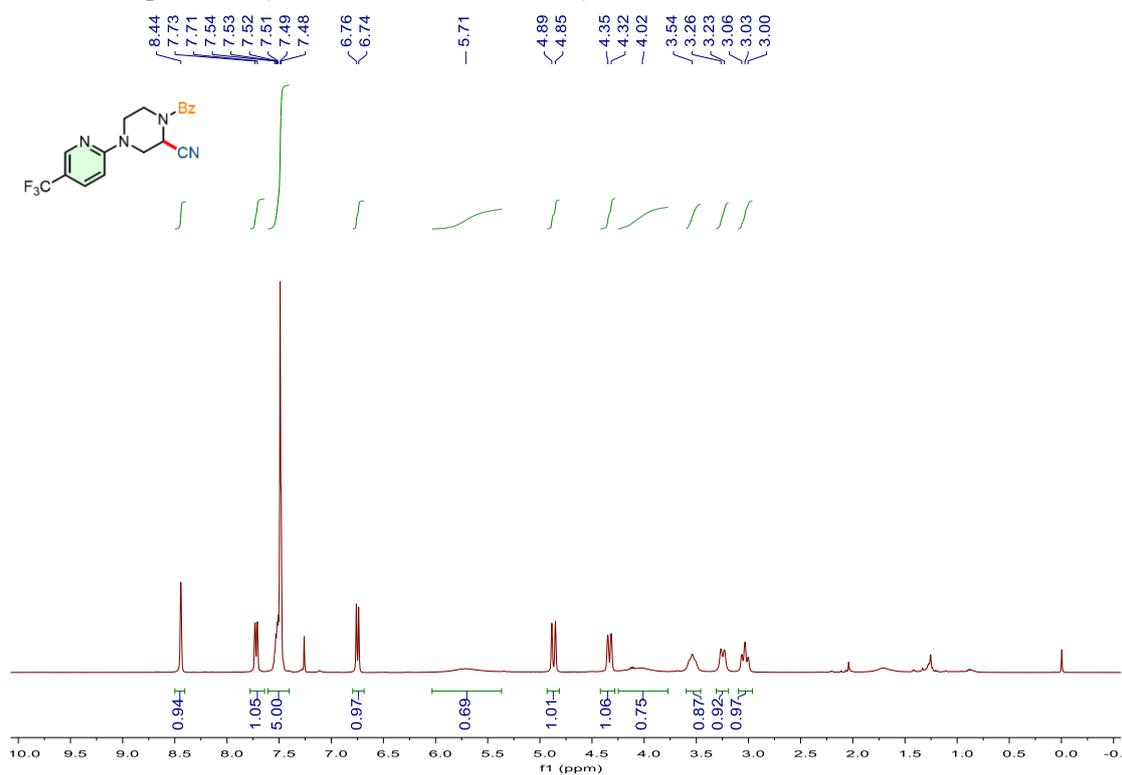
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3z**



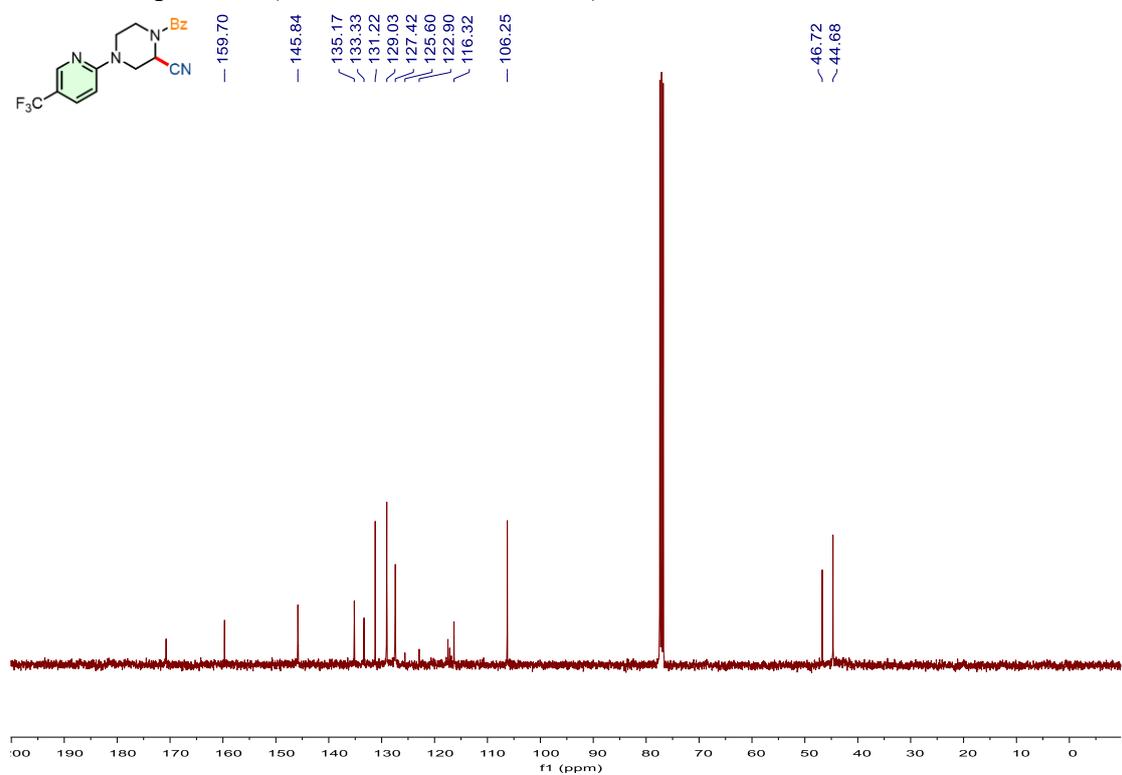
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3z**



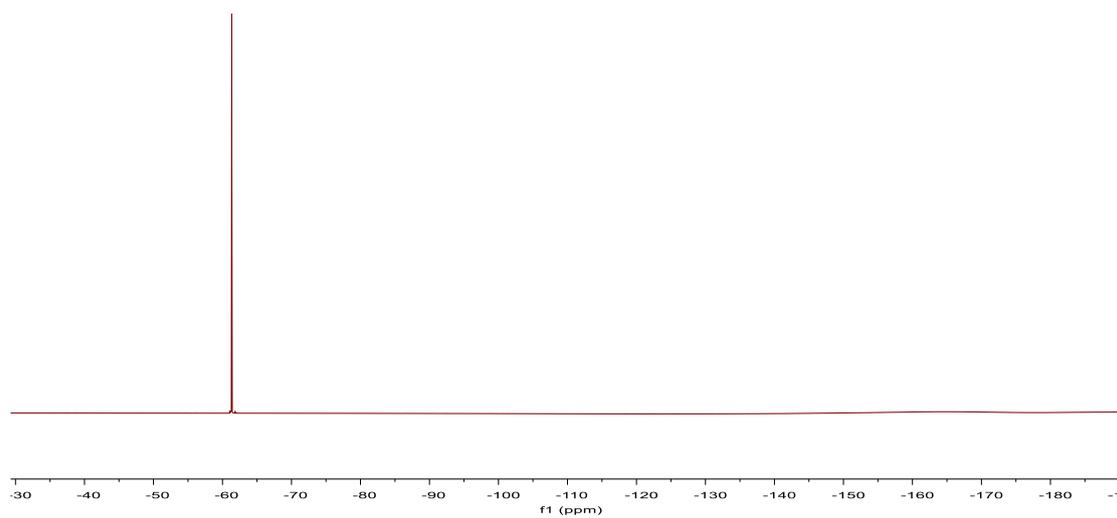
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3aa**



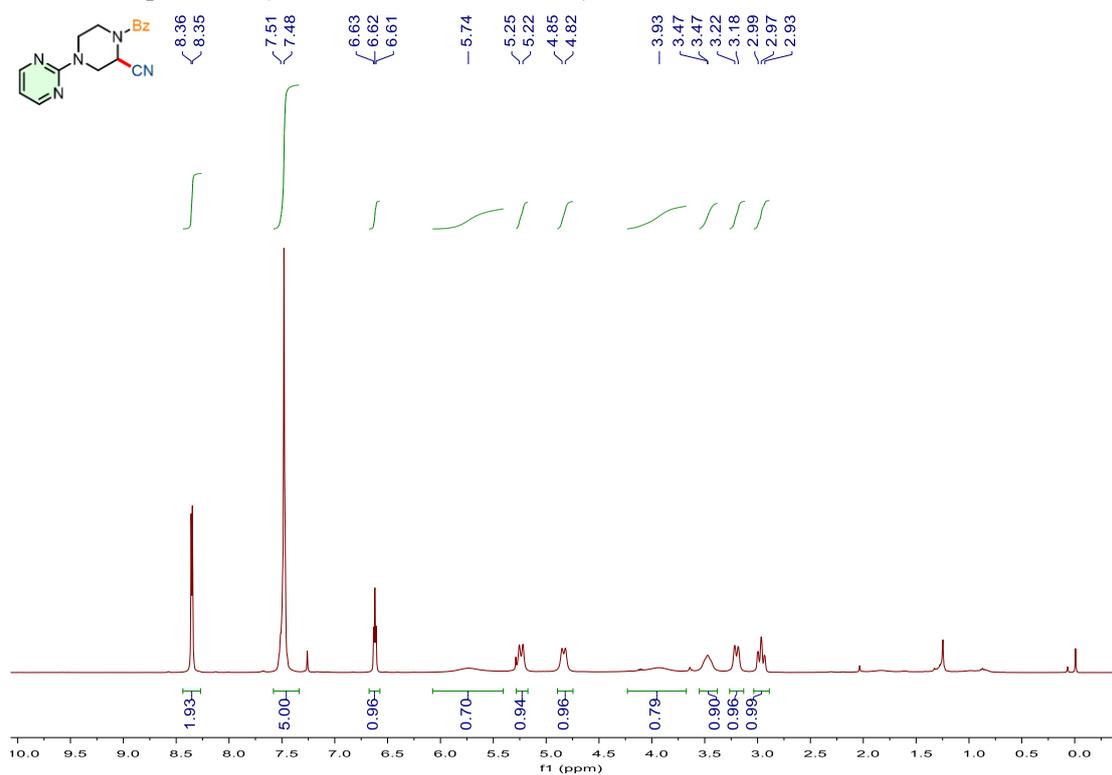
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3aa**



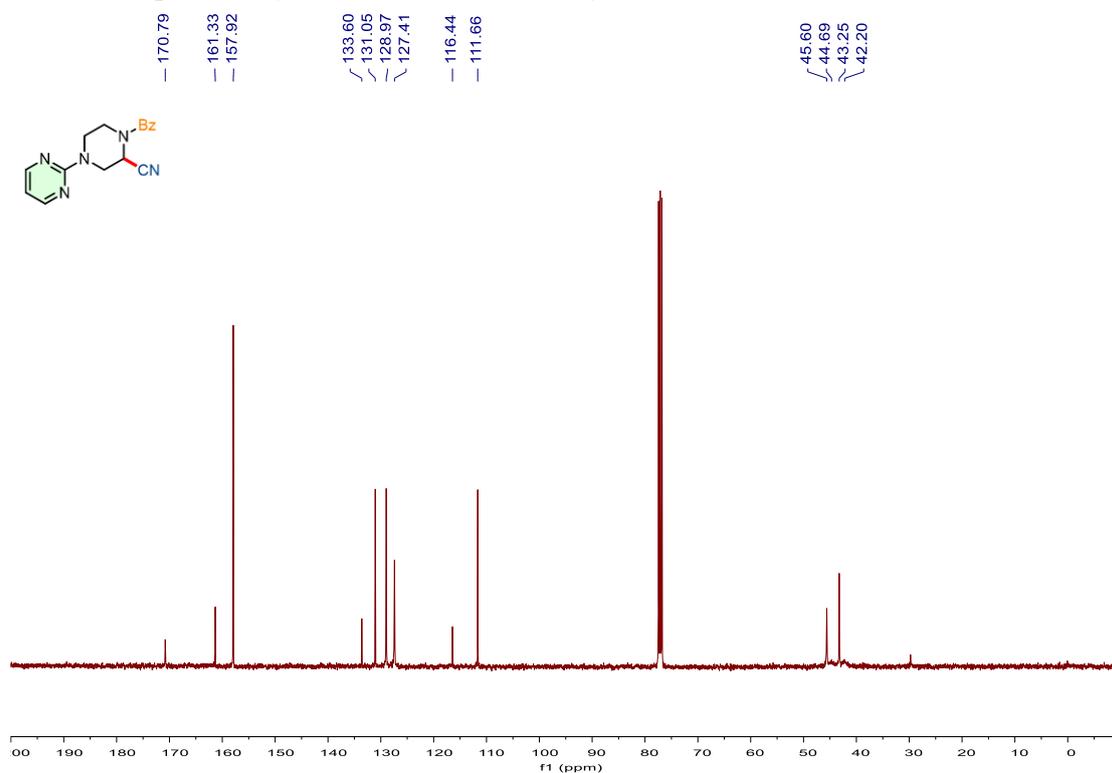
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **3aa**



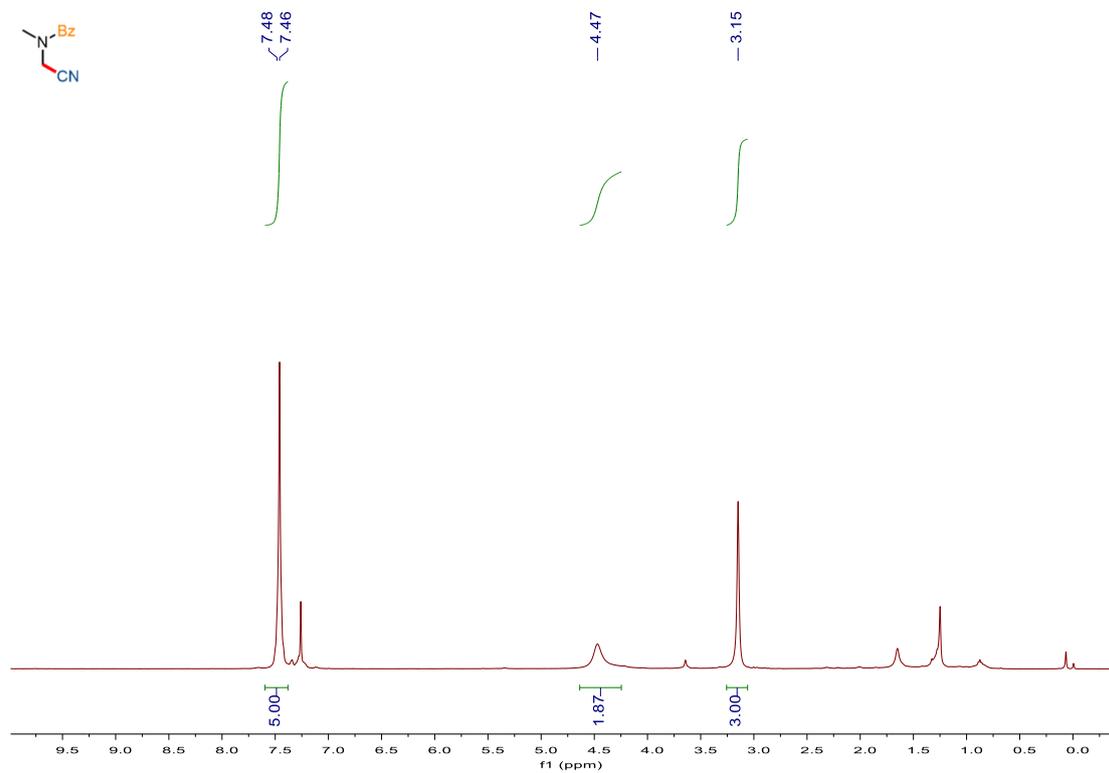
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3ab**



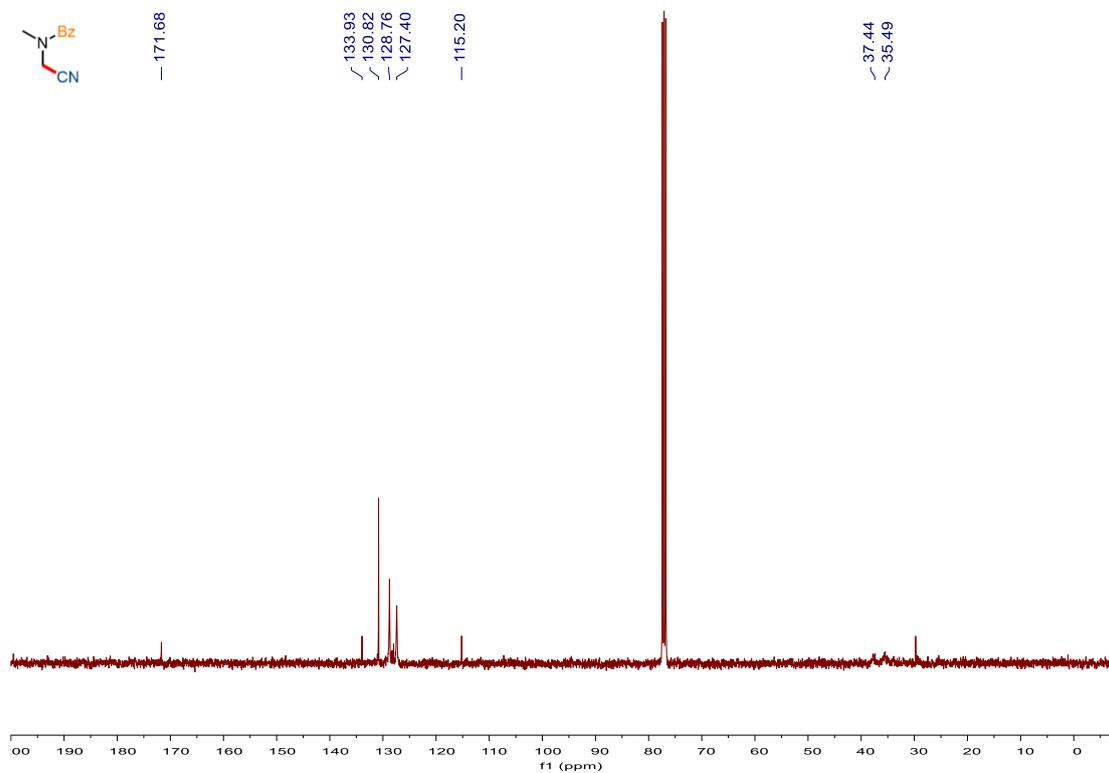
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3ab**



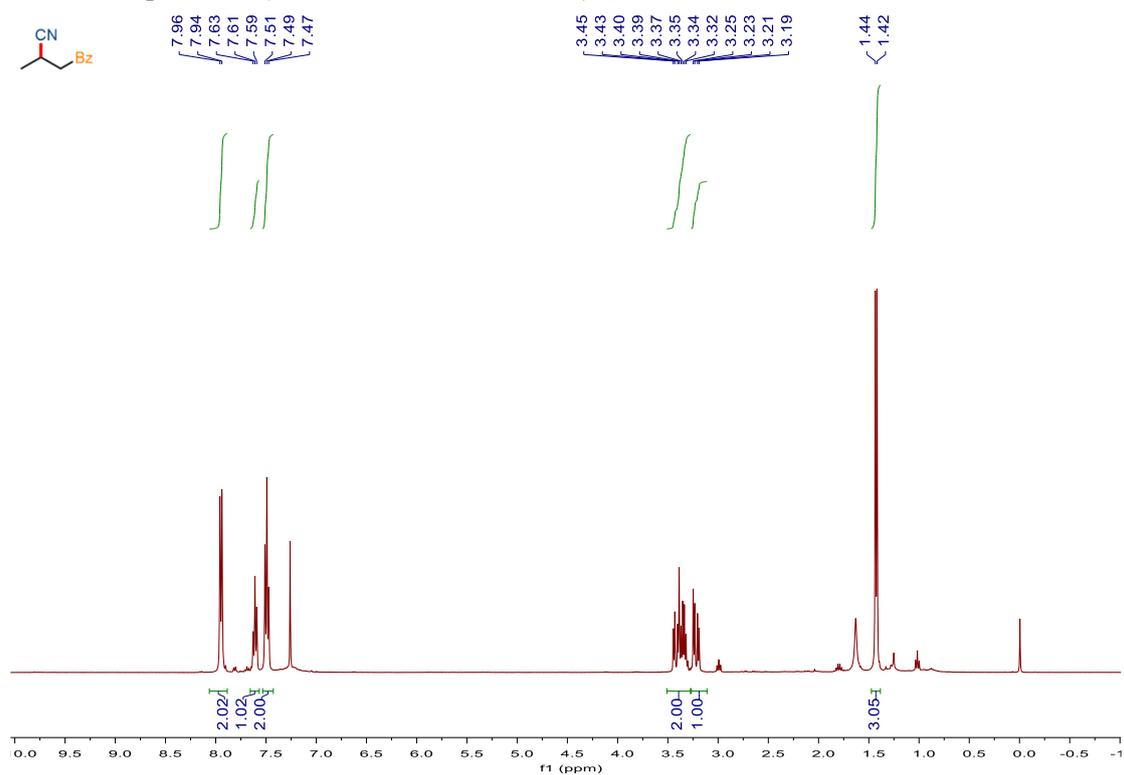
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3ac**



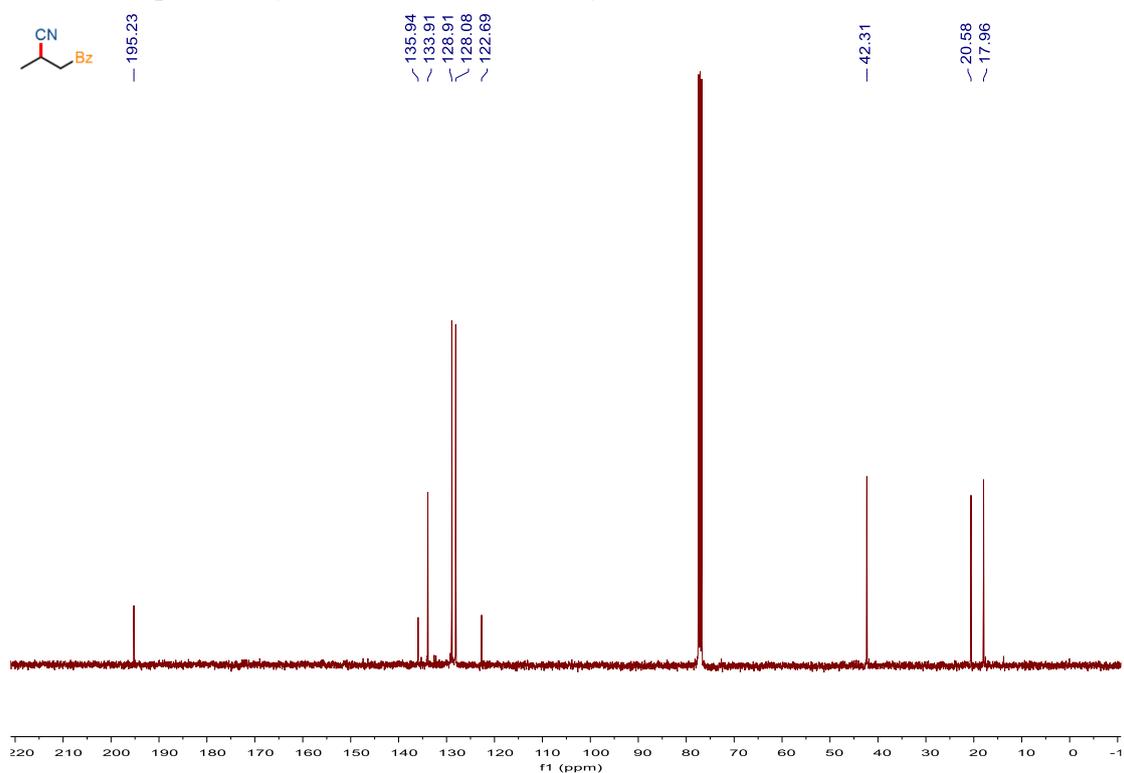
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3ac**



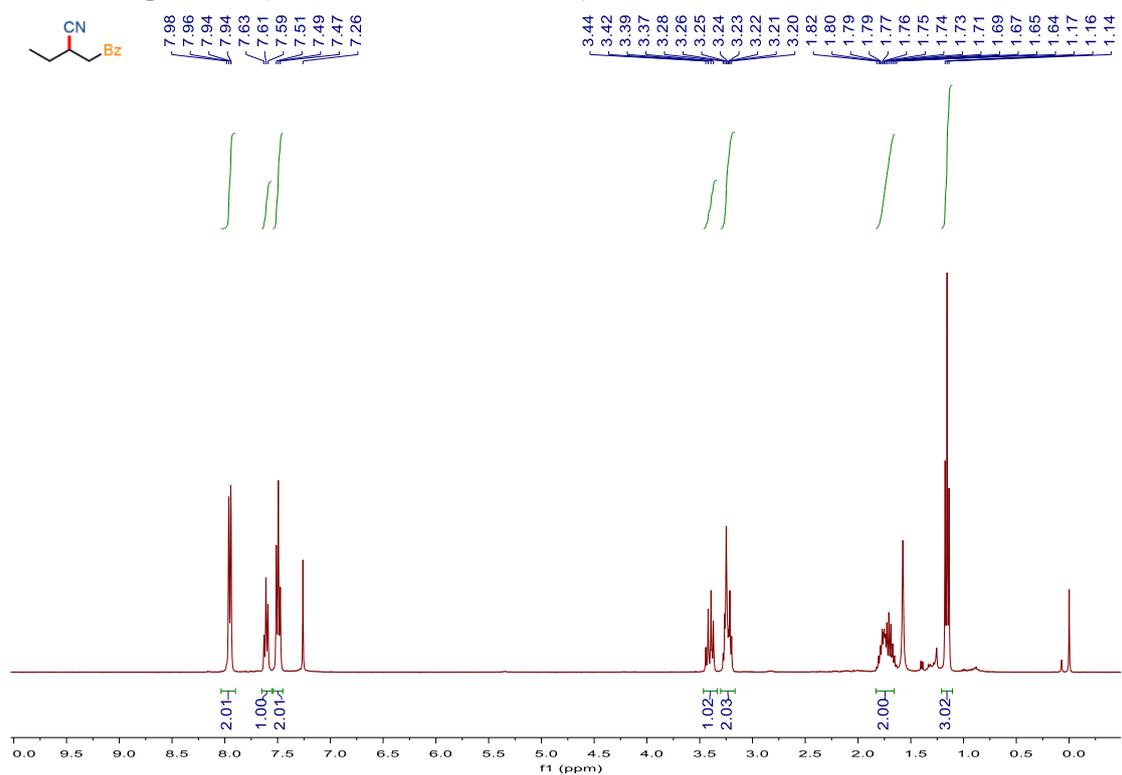
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3ad**



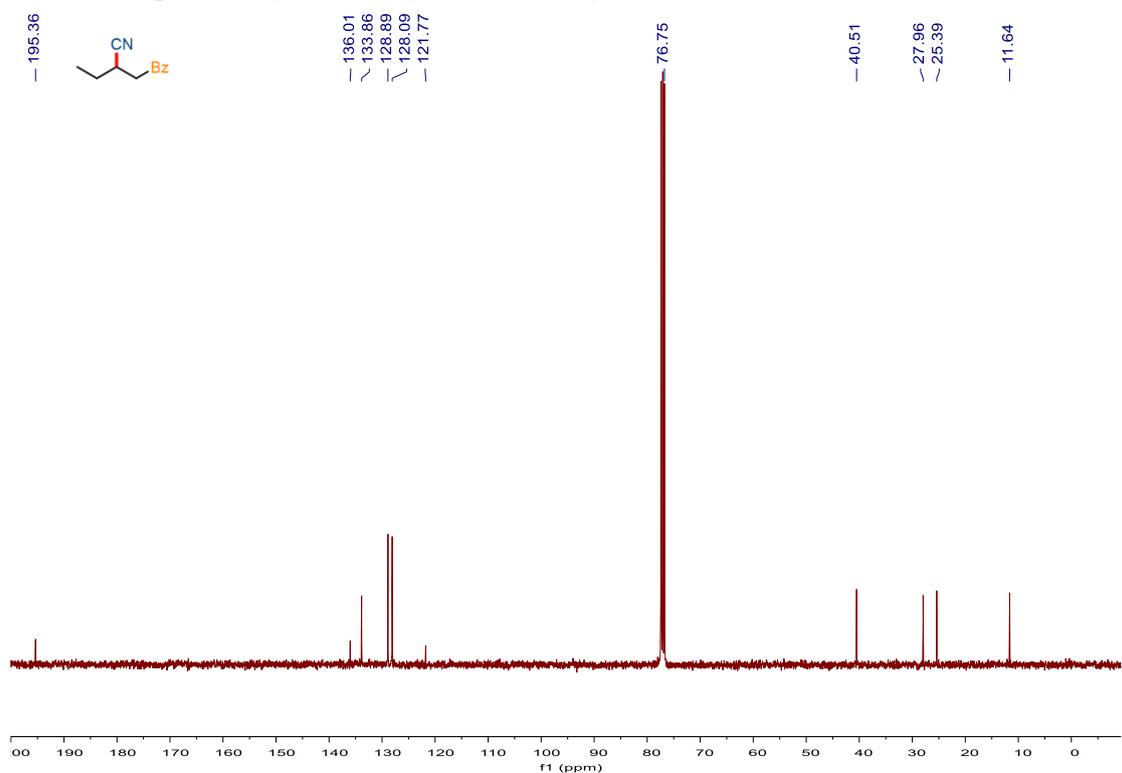
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3ad**



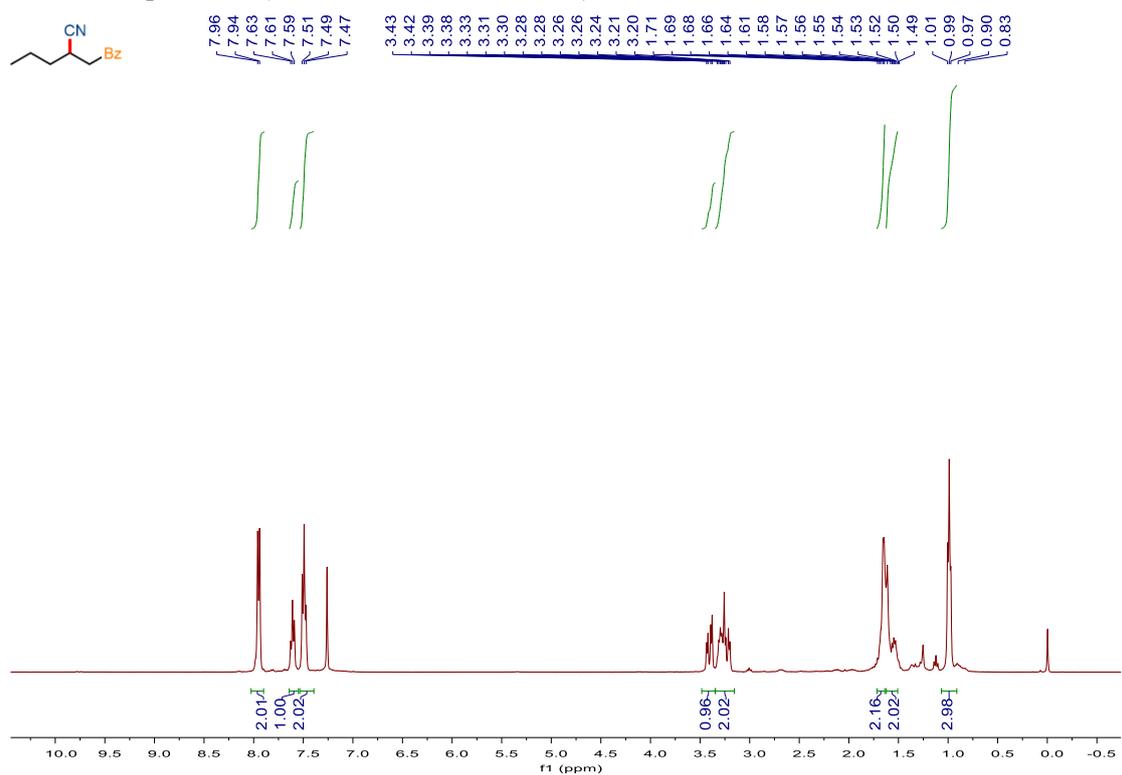
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **3ae**



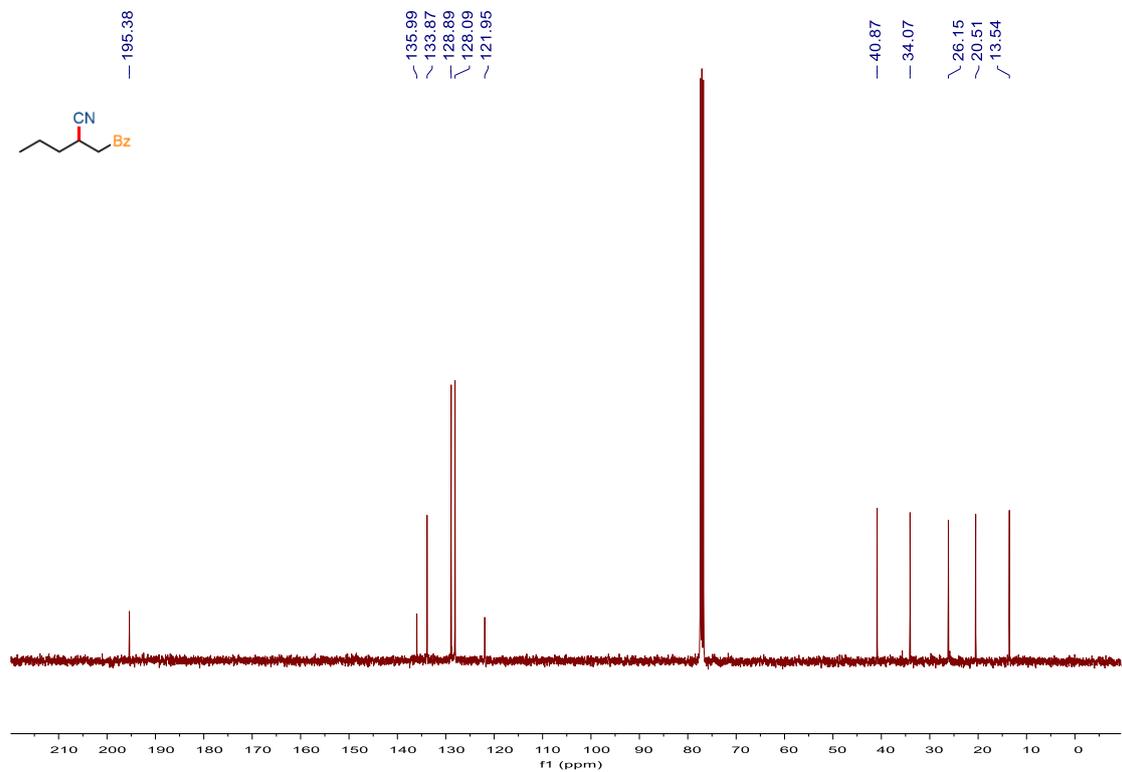
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **3ae**



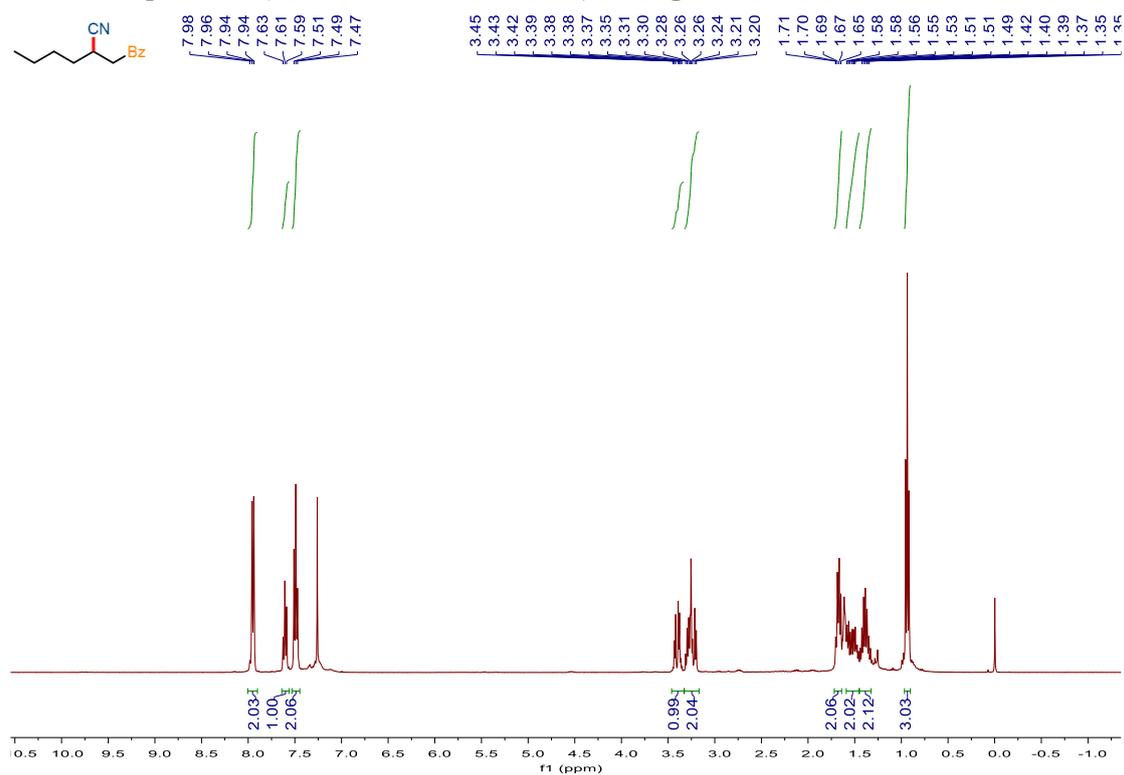
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3af**



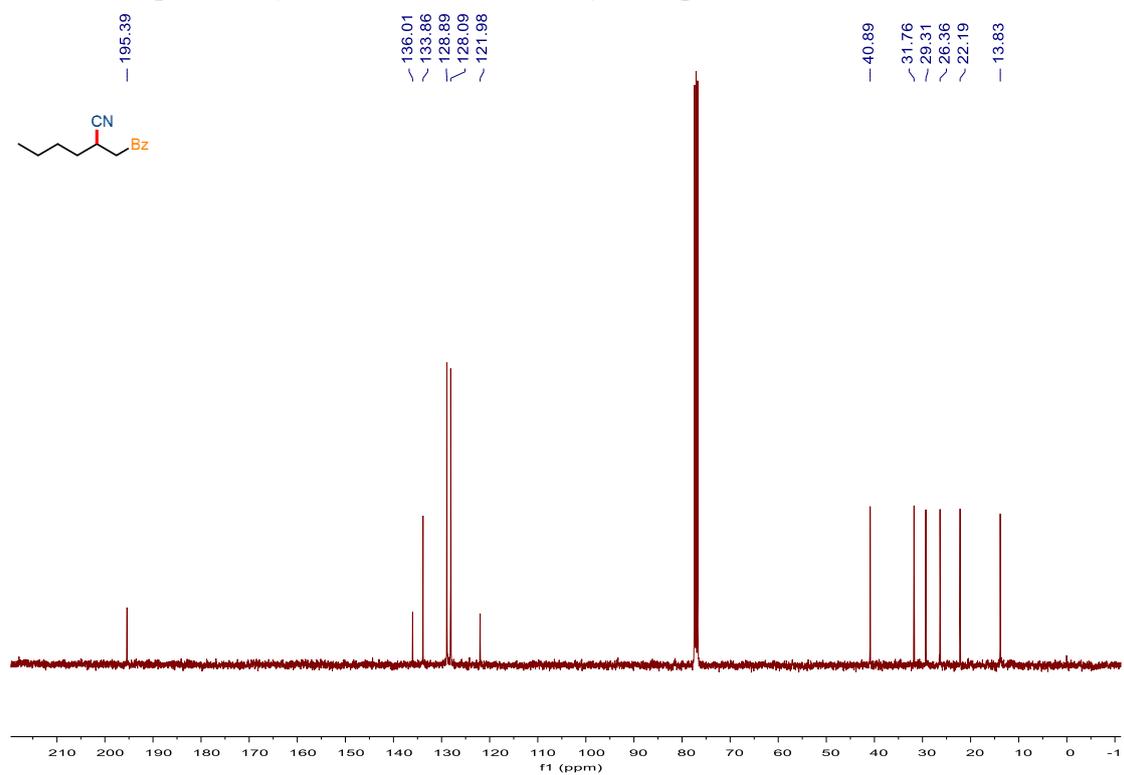
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3af**



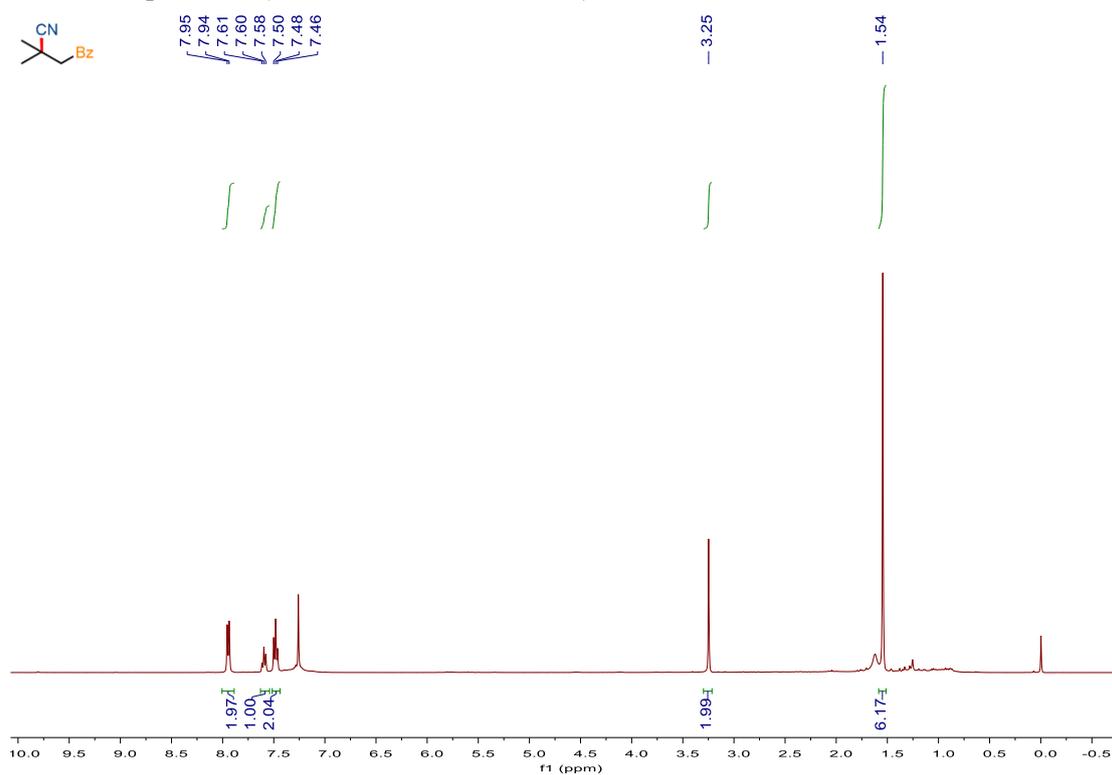
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3ag**



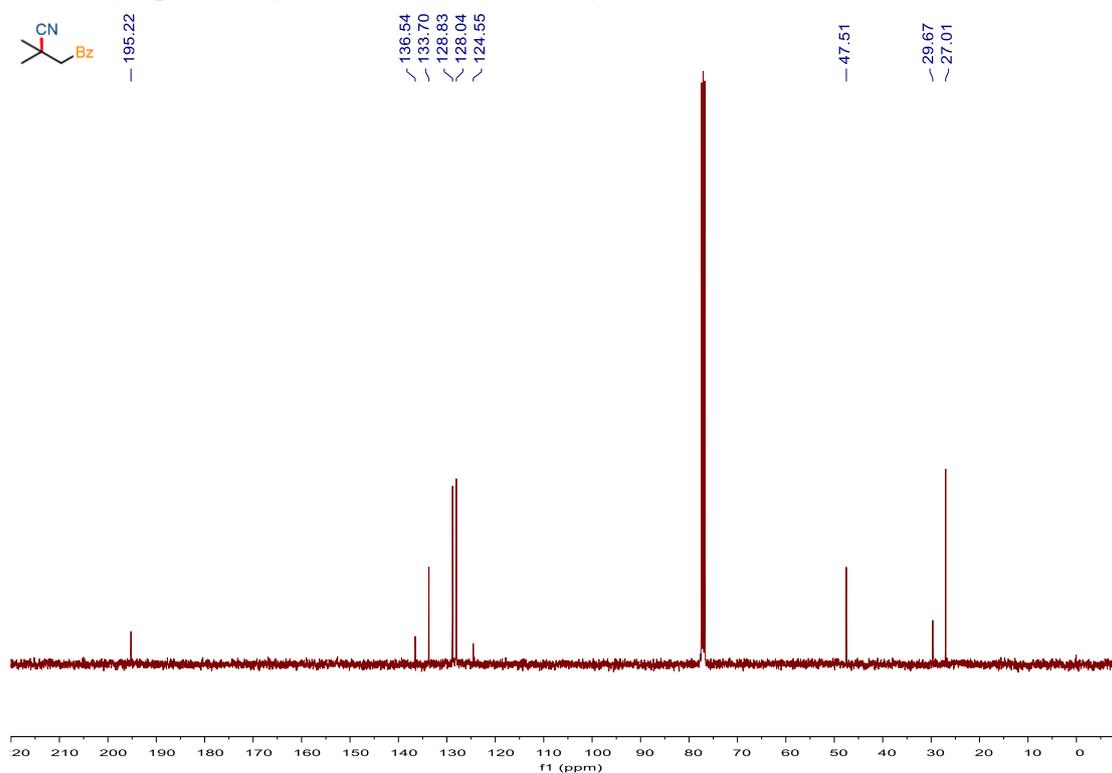
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3ag**



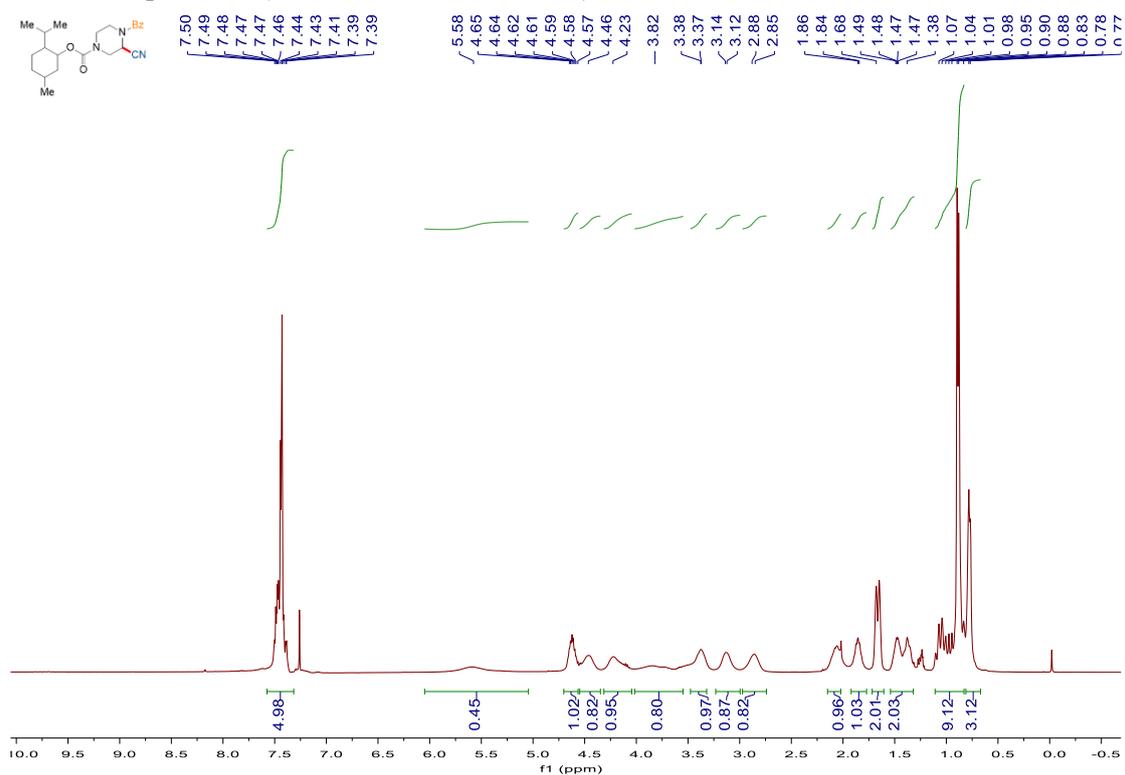
^1H NMR spectrum (400 MHz, CDCl_3 , 23 $^\circ\text{C}$) of **3ah**



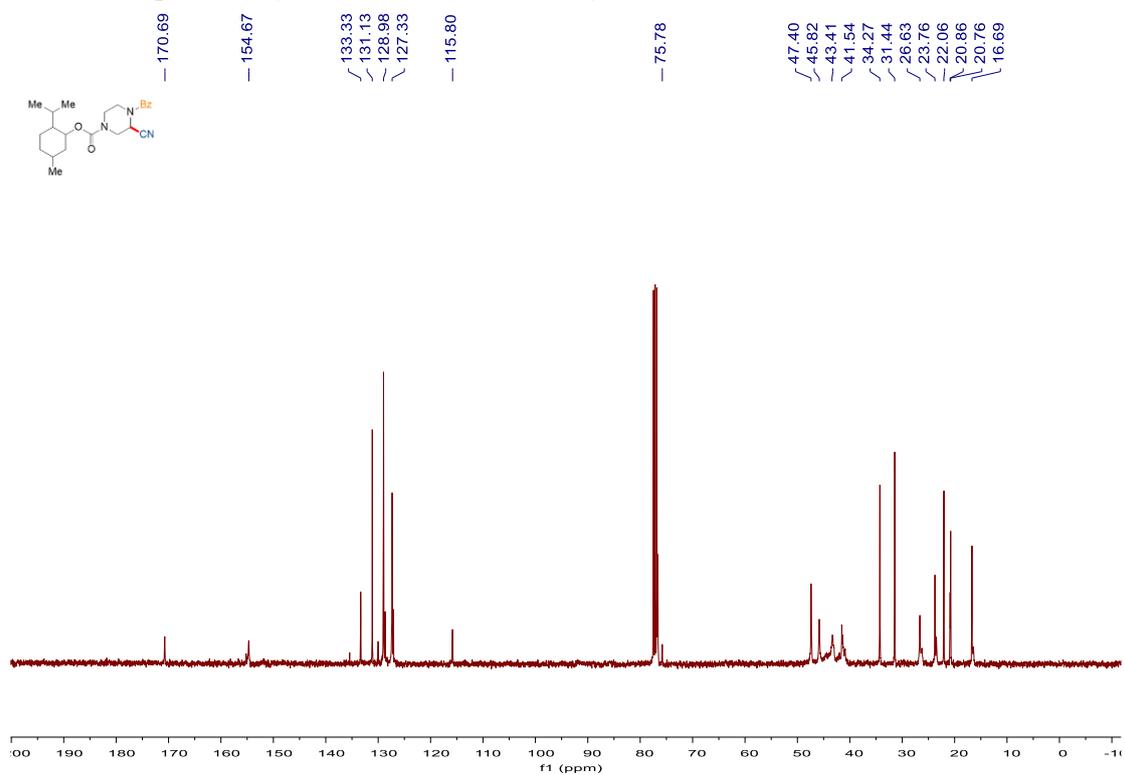
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 $^\circ\text{C}$) of **3ah**



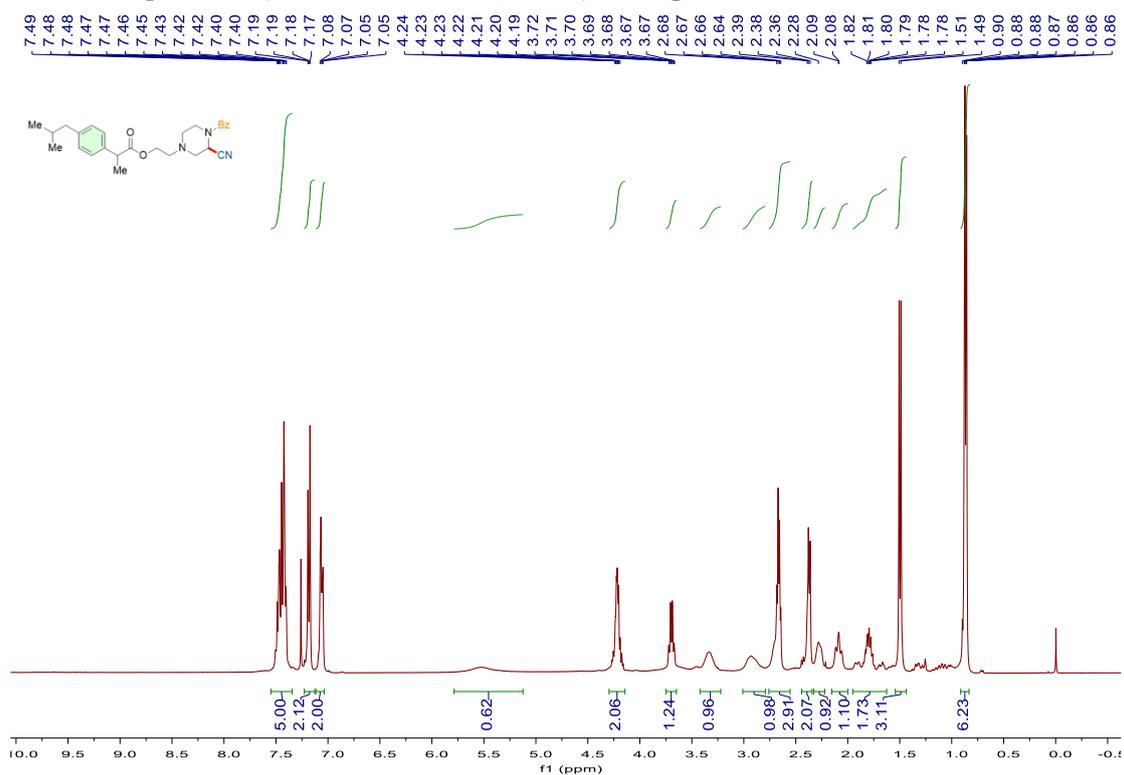
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3ai**



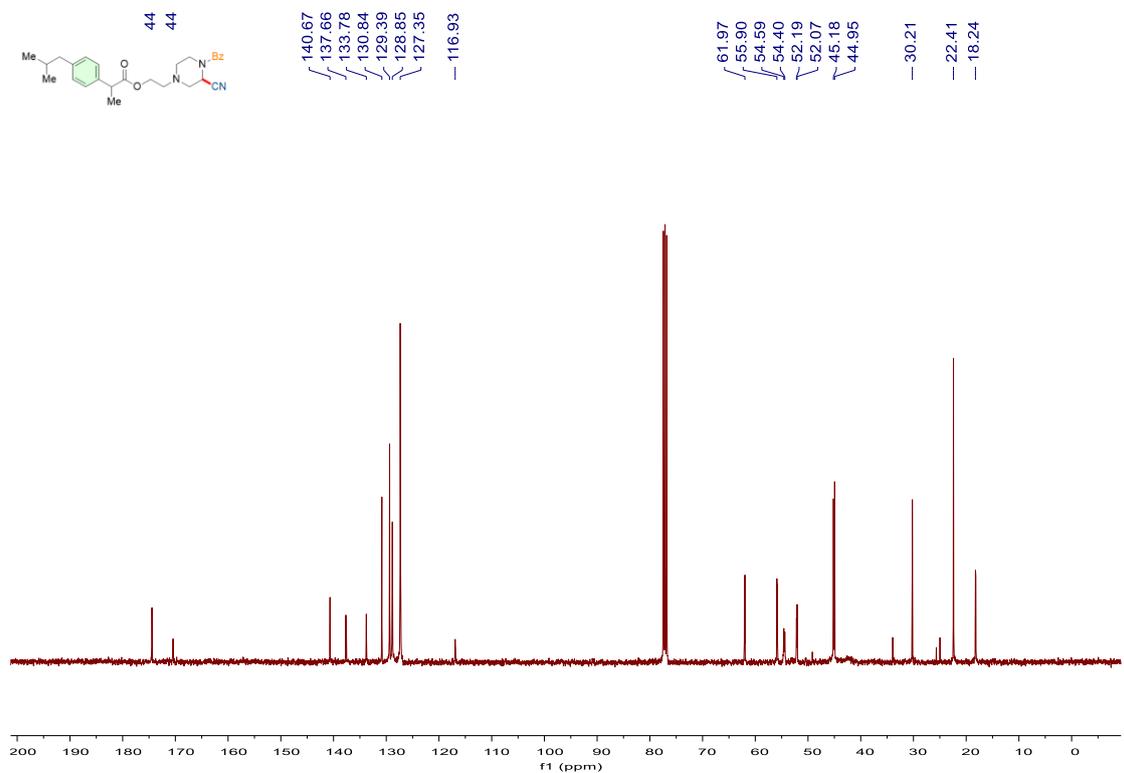
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3ai**



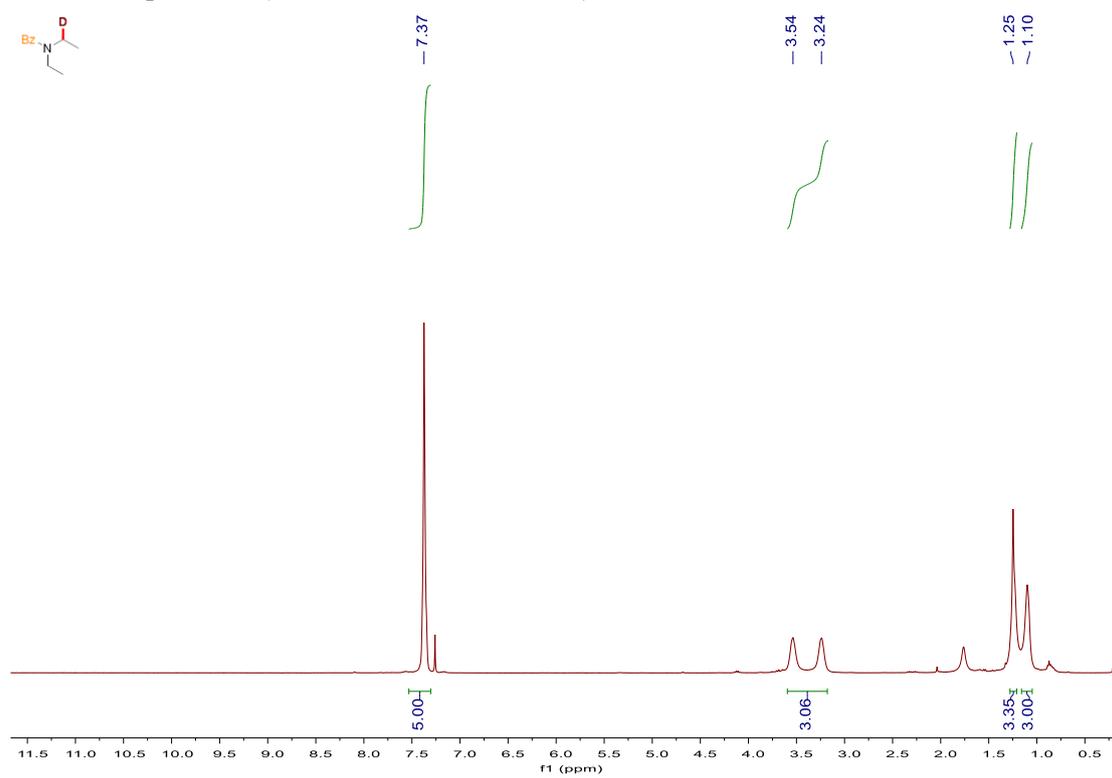
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **3ag**



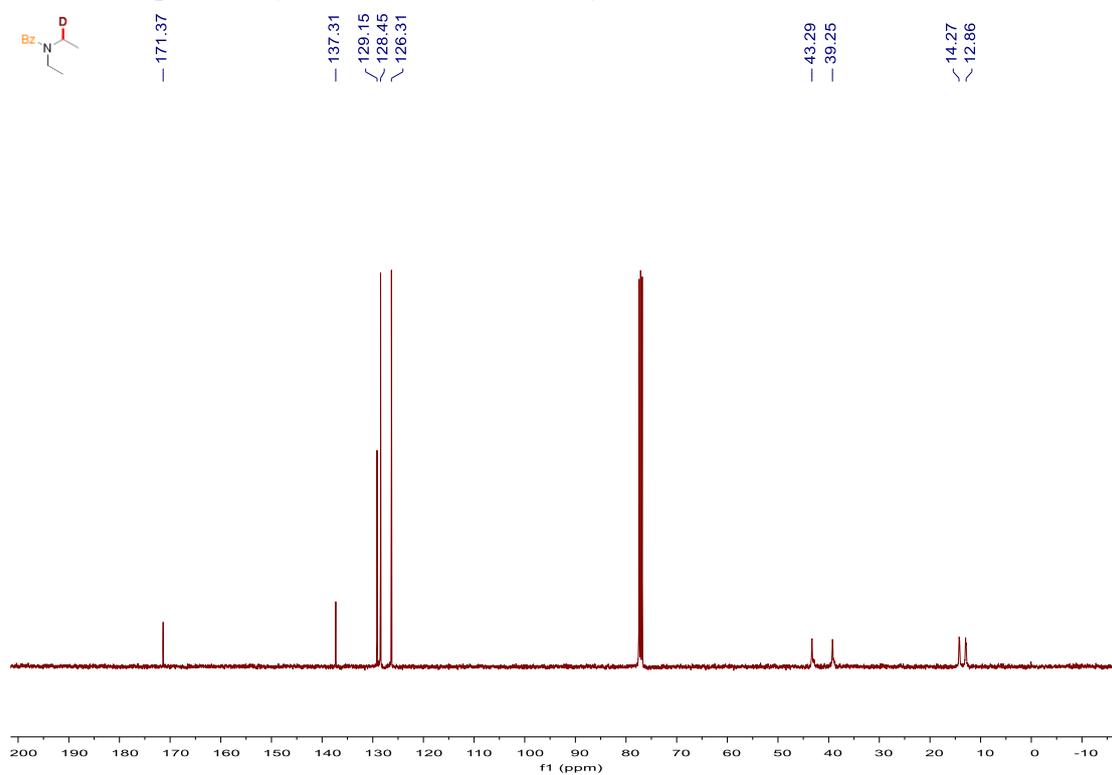
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **3ag**



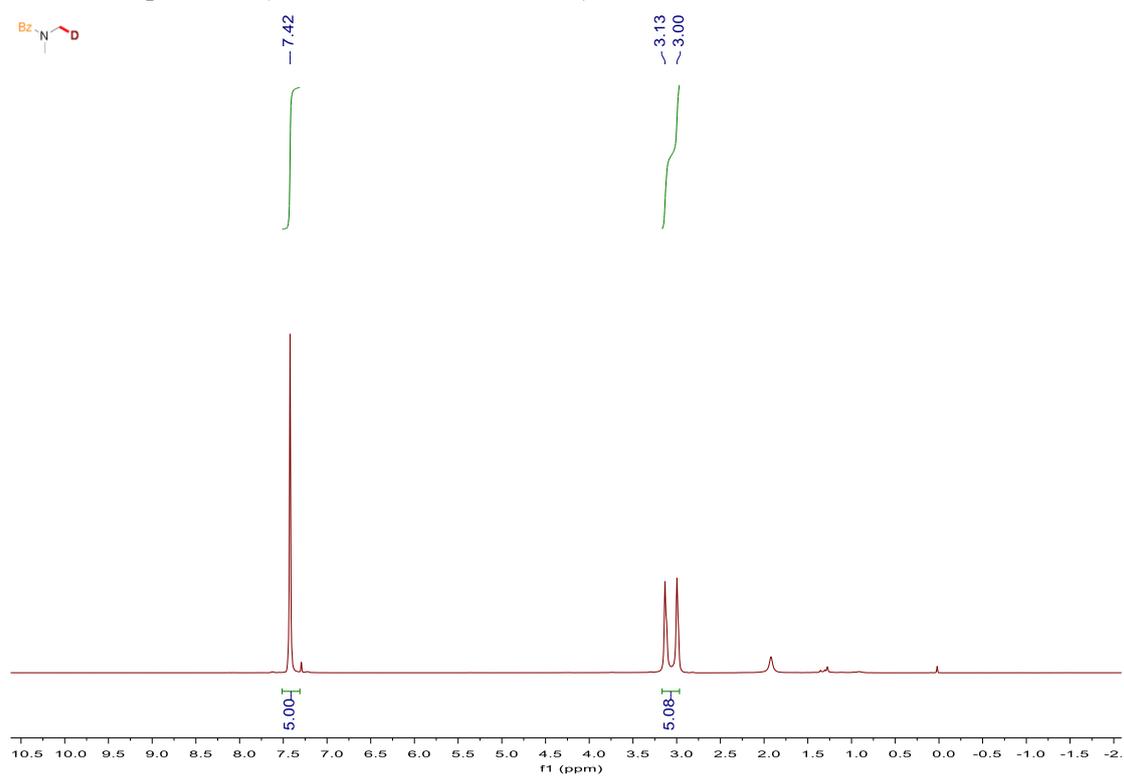
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4a**



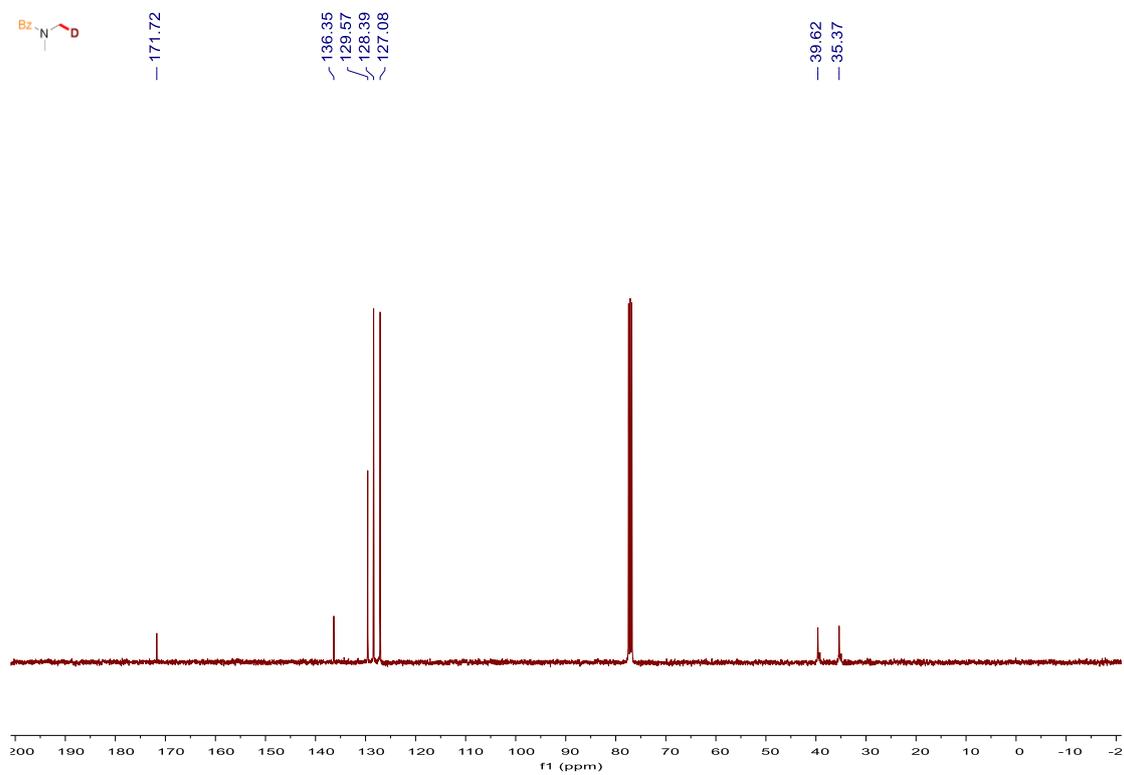
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4a**



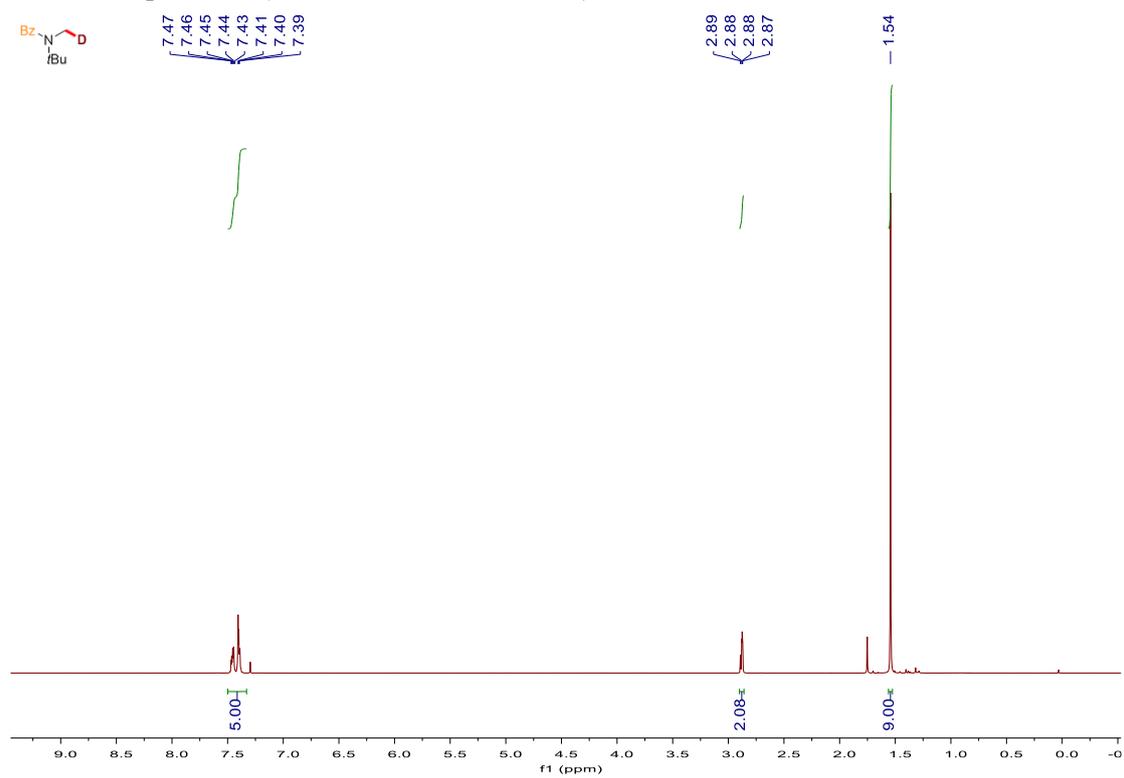
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4b**



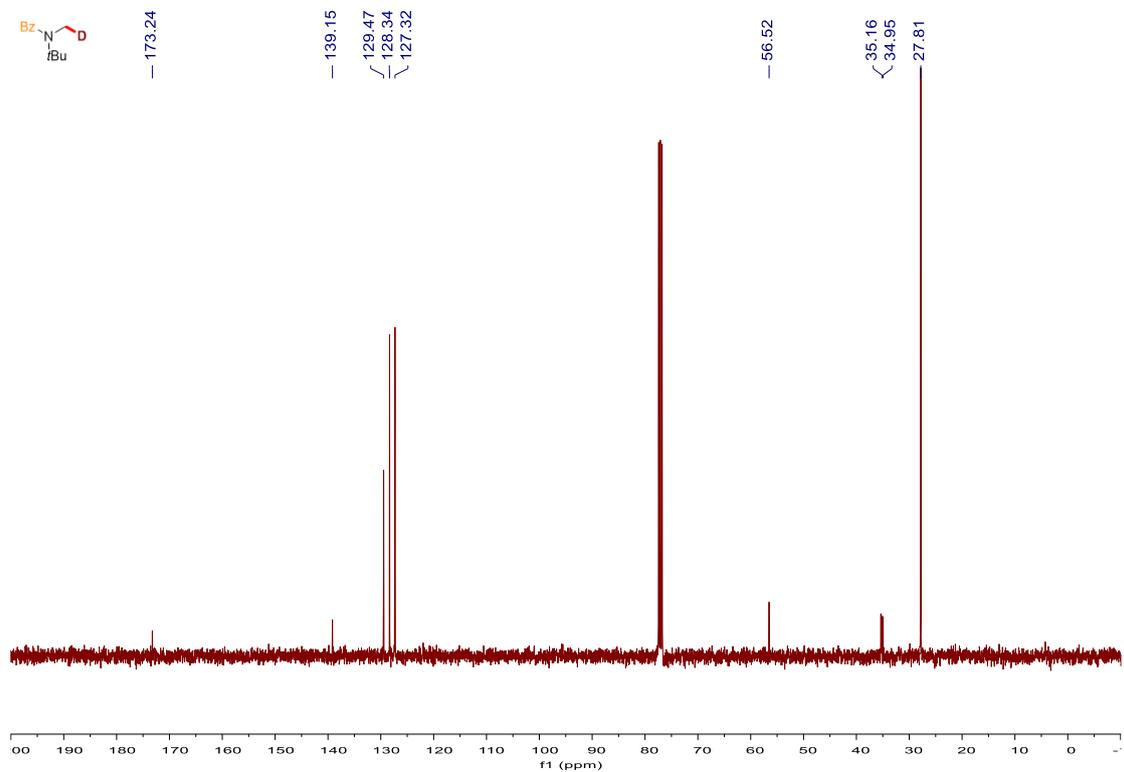
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4b**



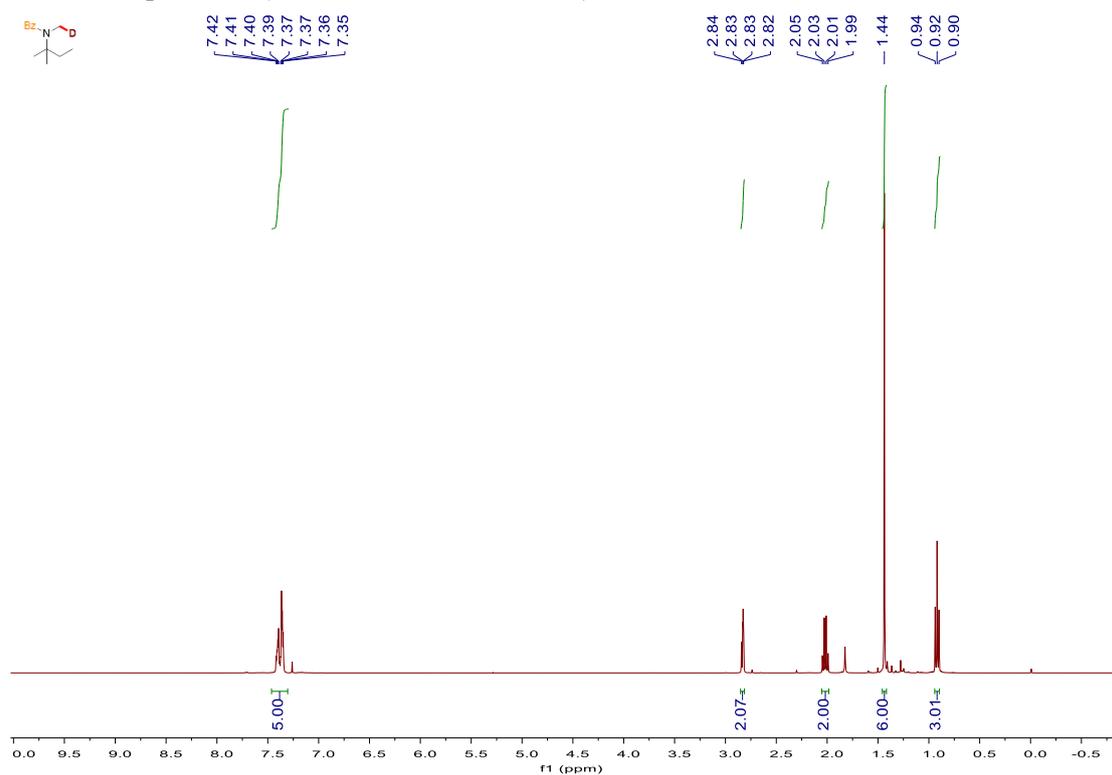
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4c**



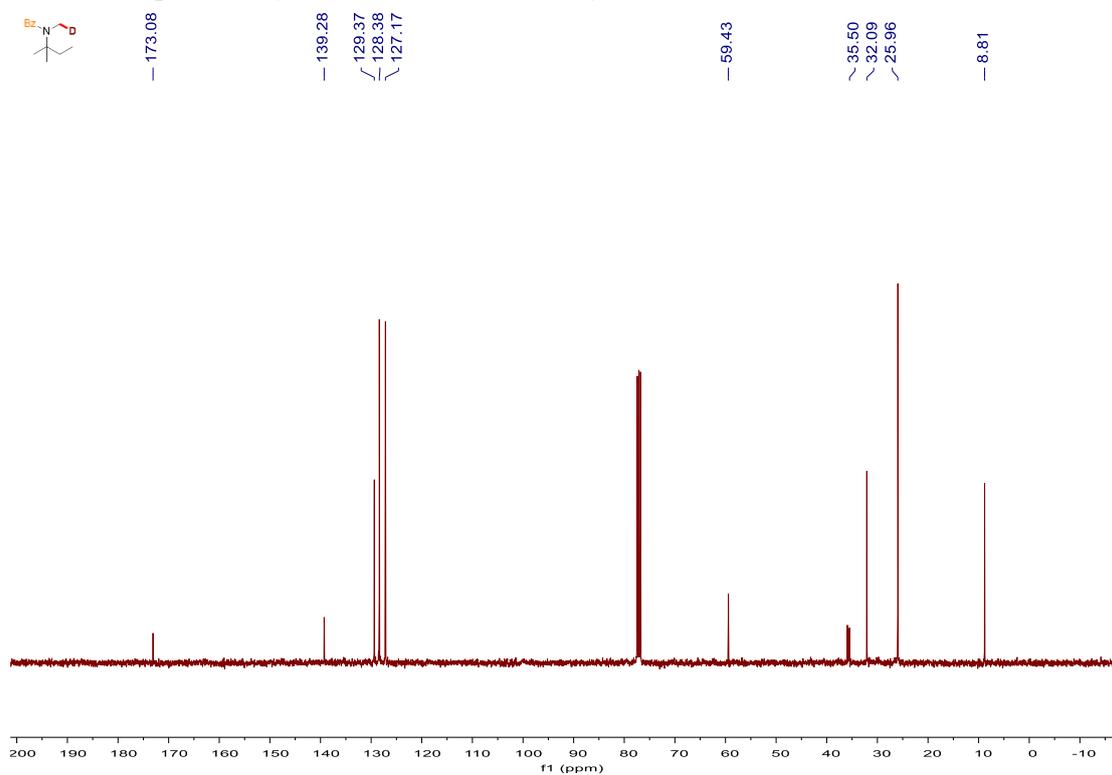
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4c**



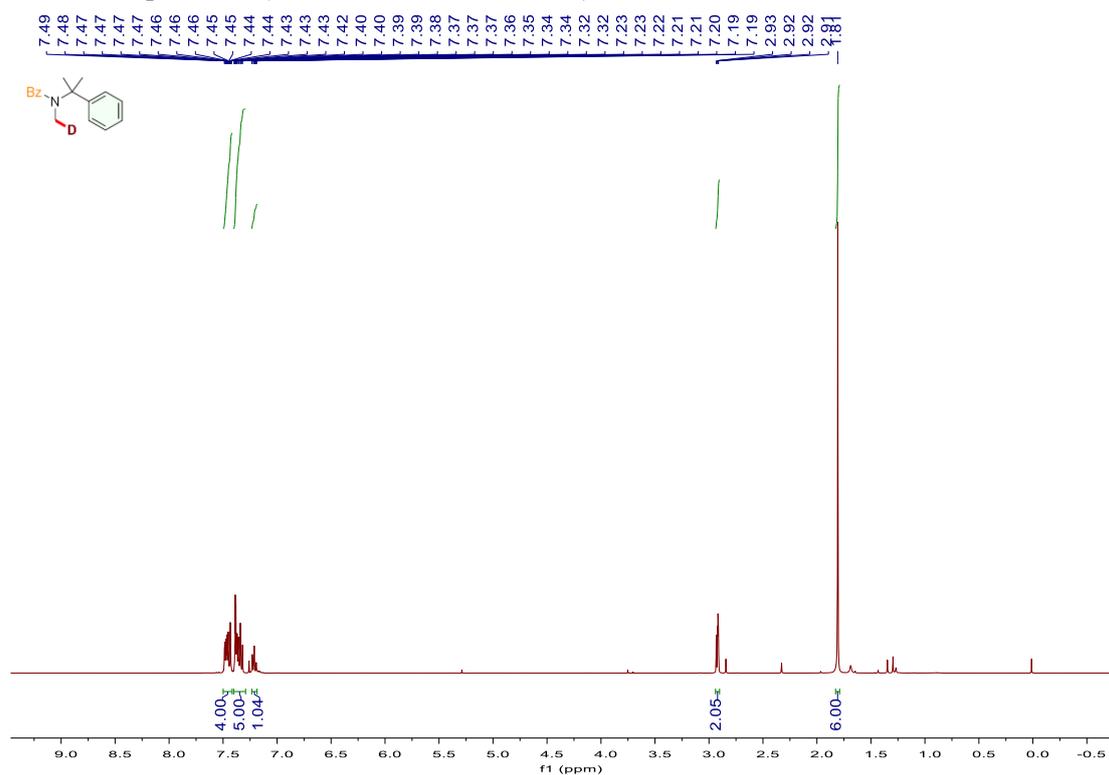
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4d**



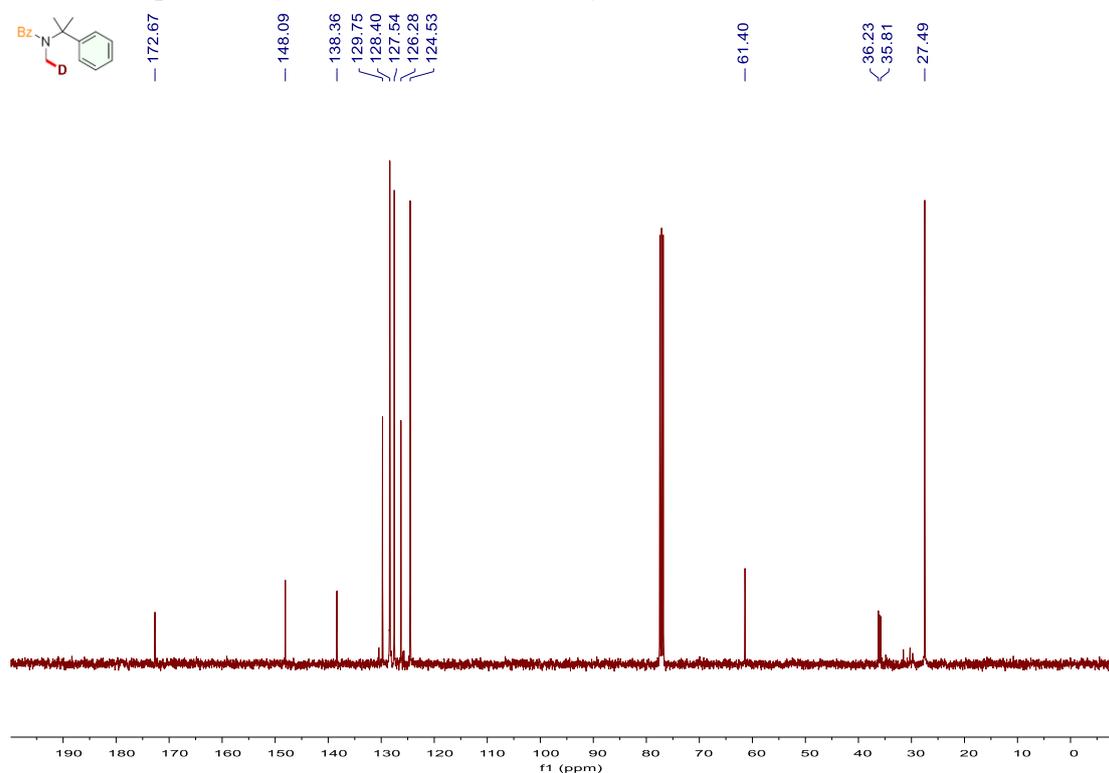
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4d**



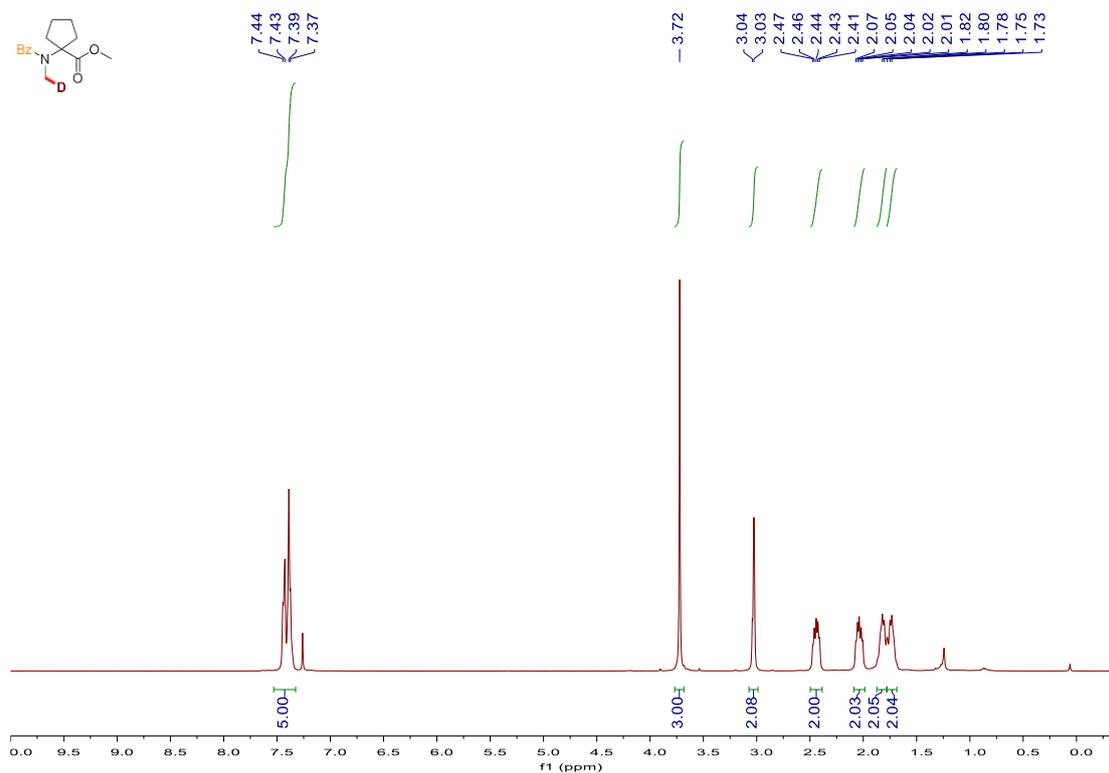
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4e**



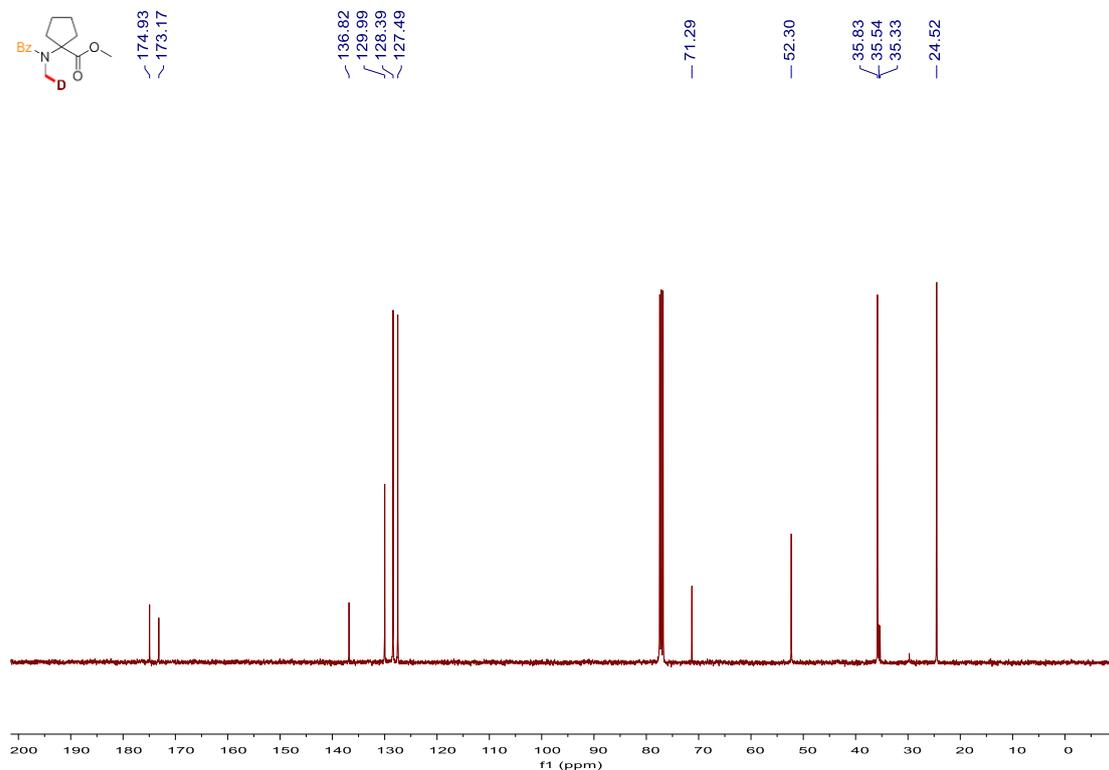
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4e**



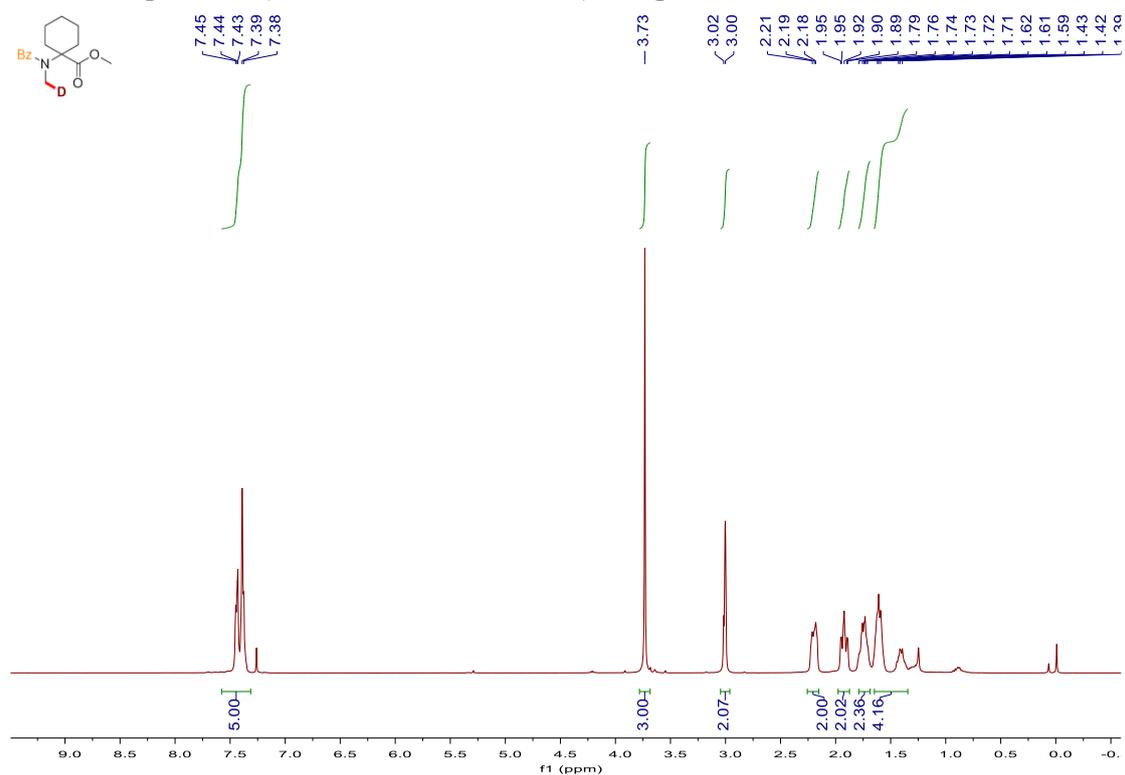
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4f**



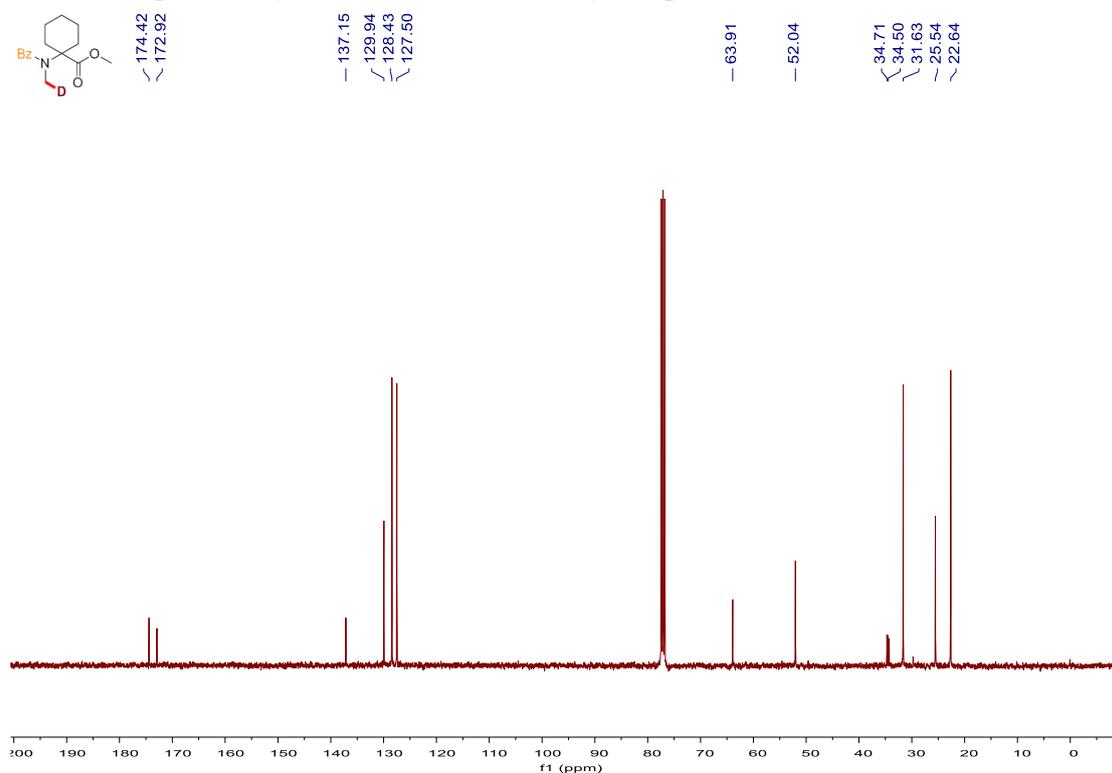
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4f**



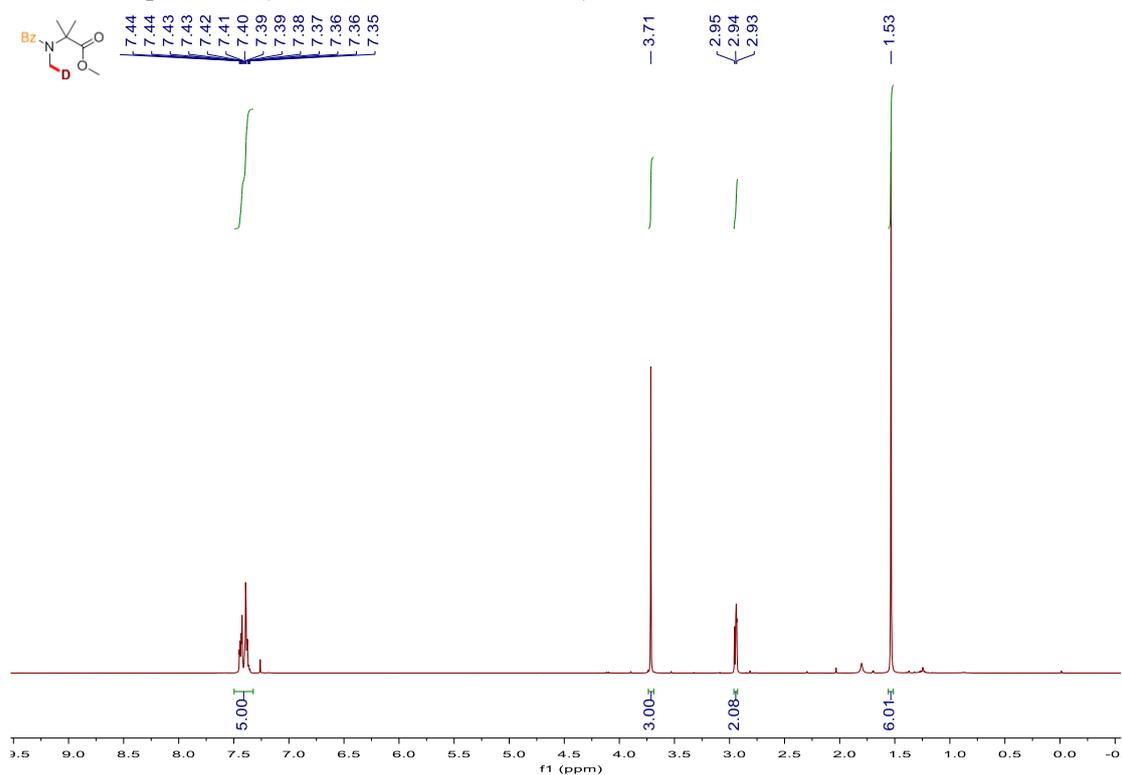
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4g**



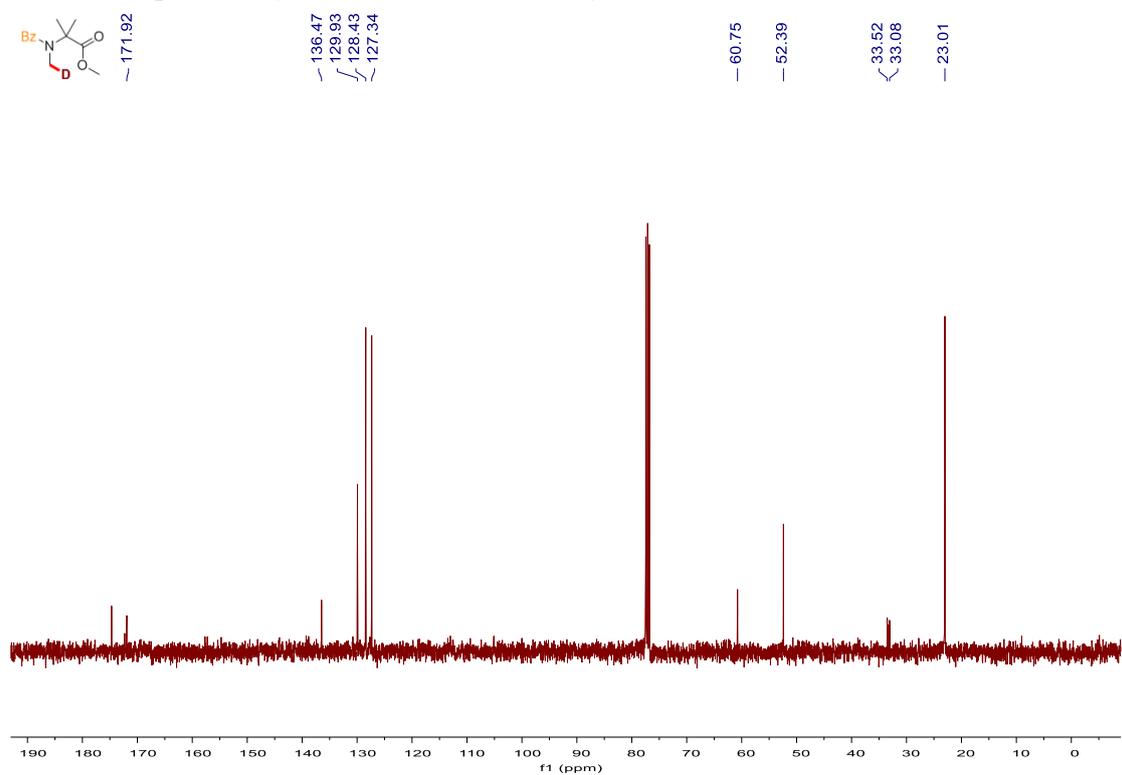
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4g**



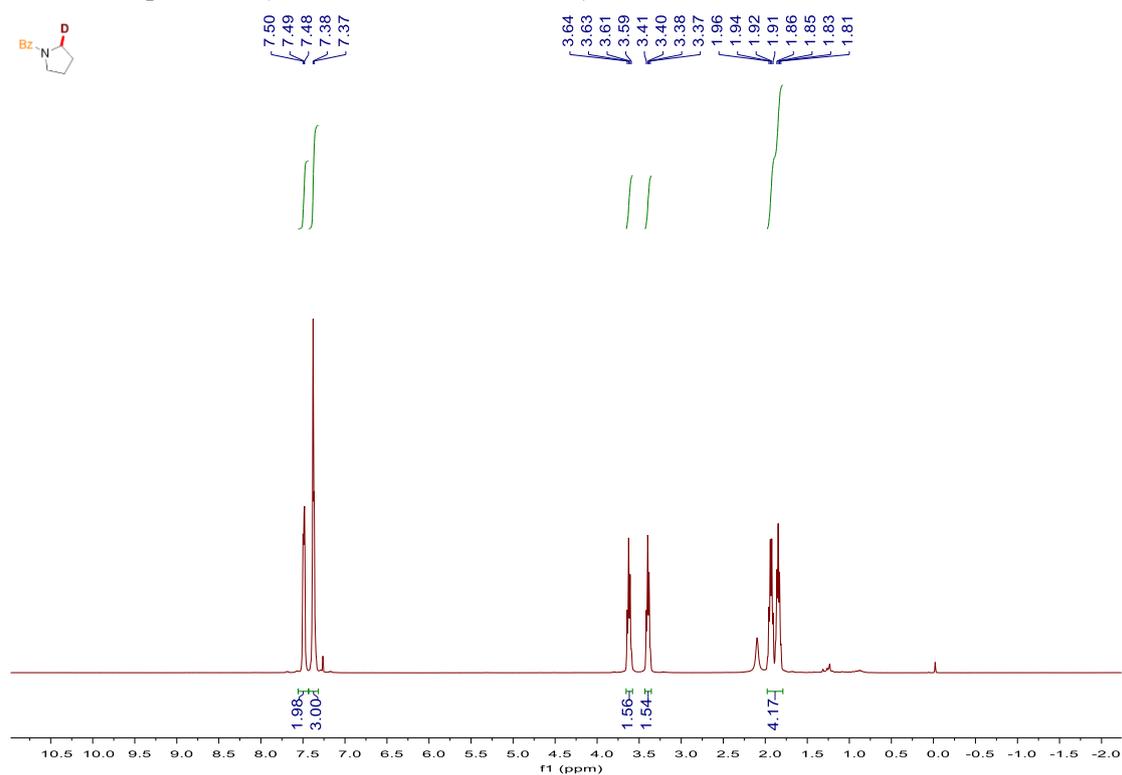
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4h**



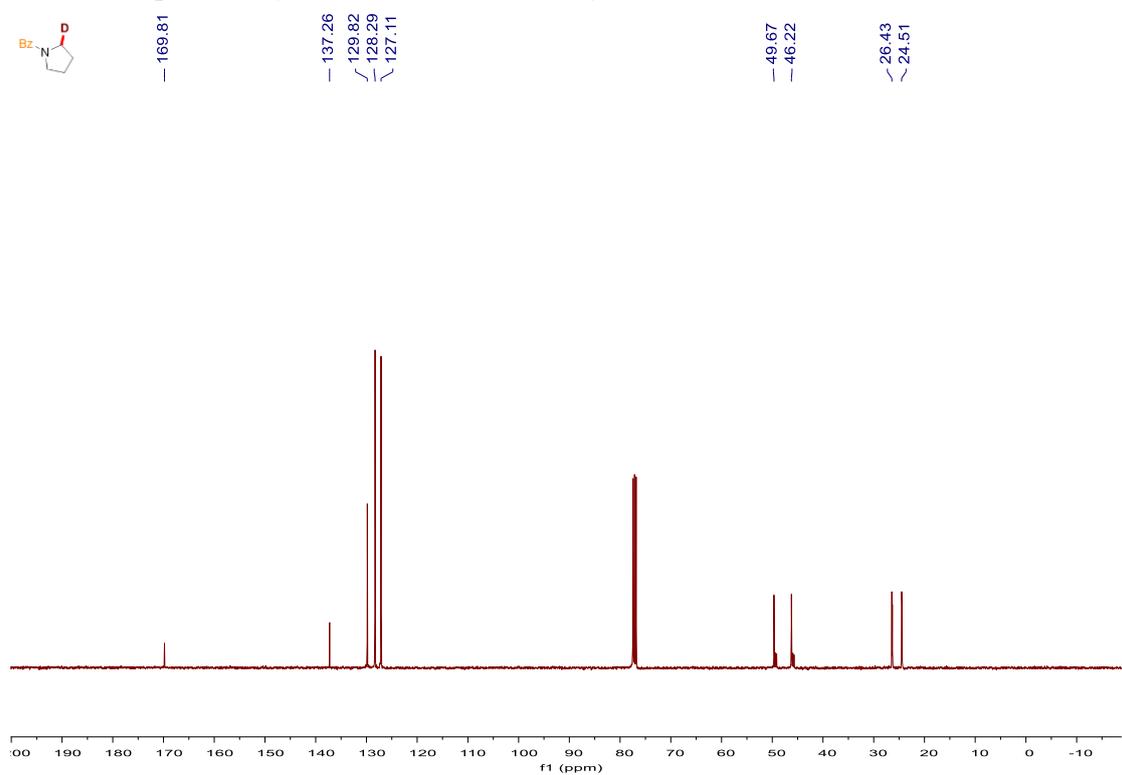
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4h**



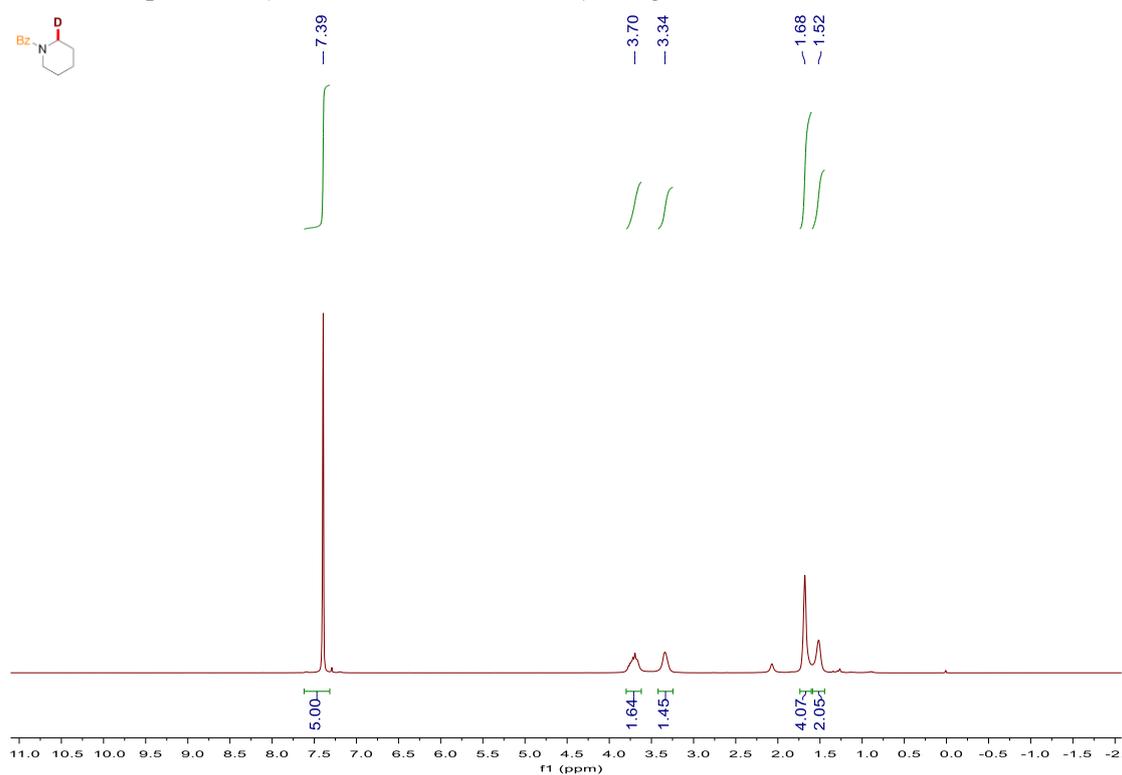
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4i**



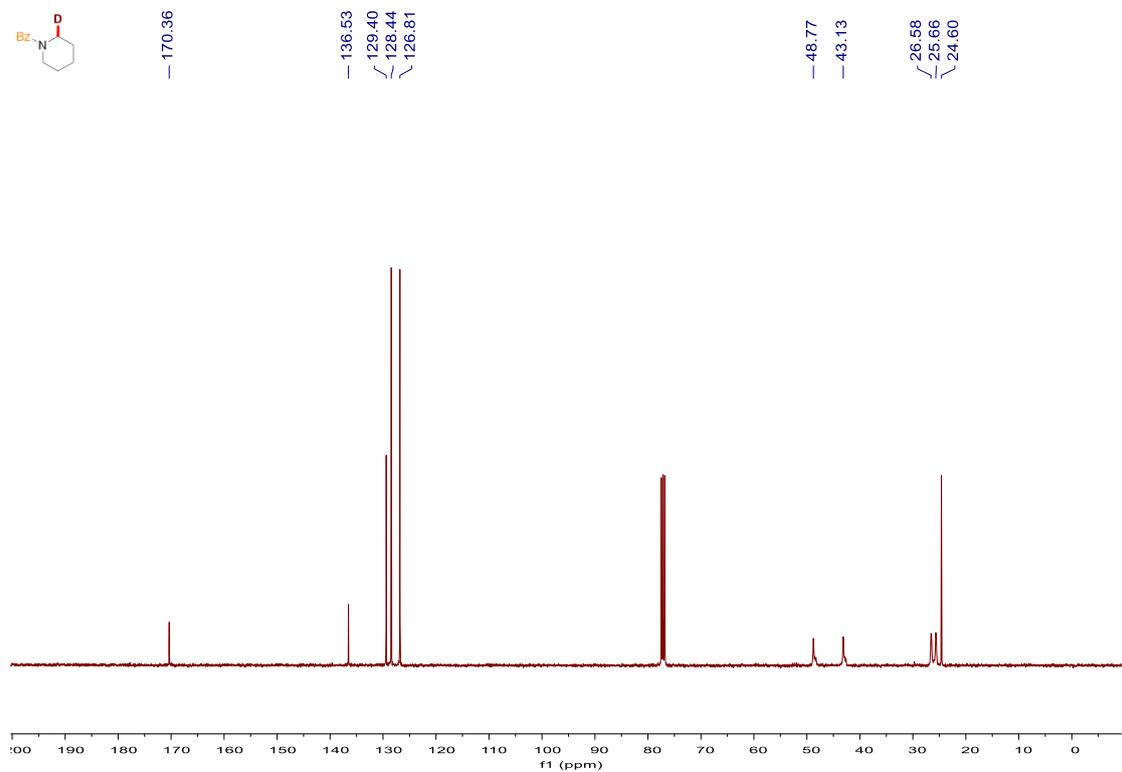
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4i**



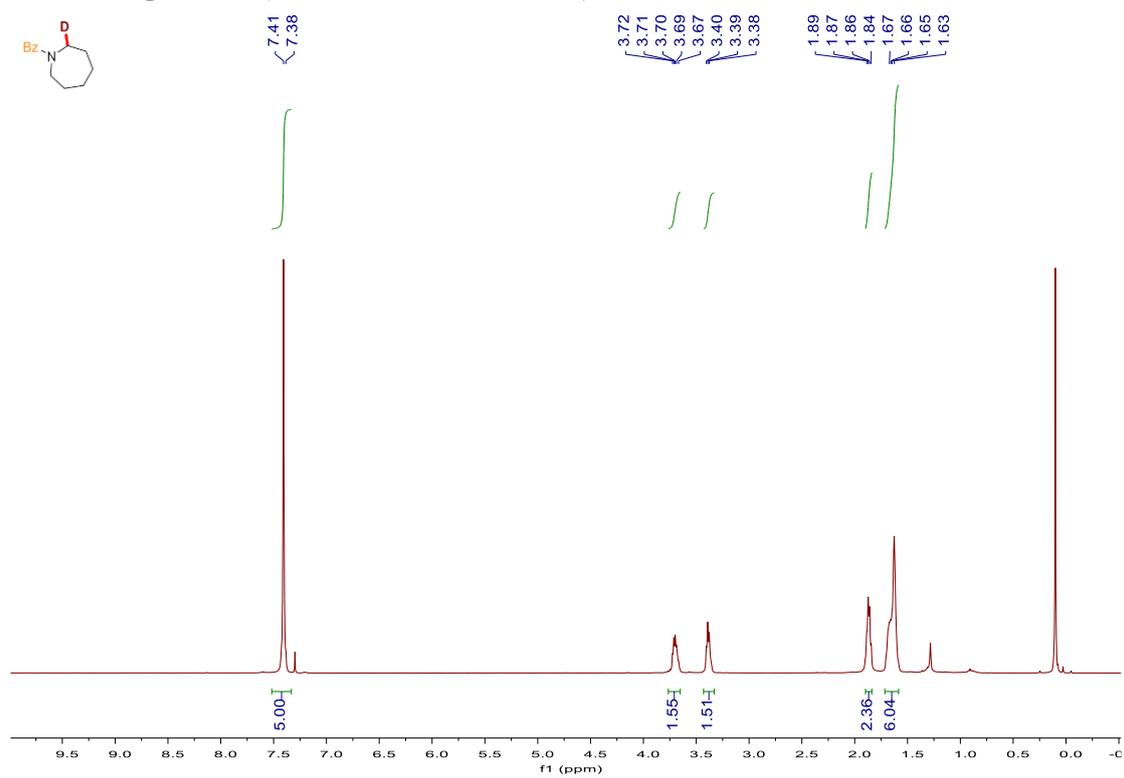
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4j**



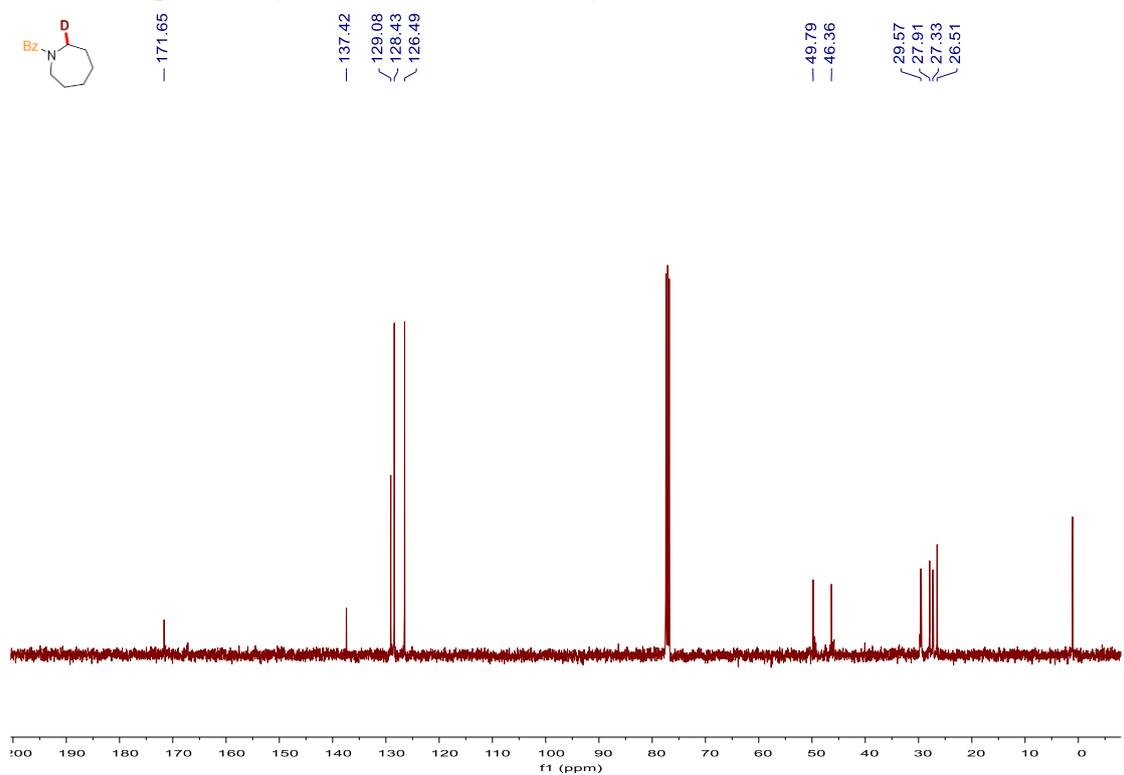
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4j**



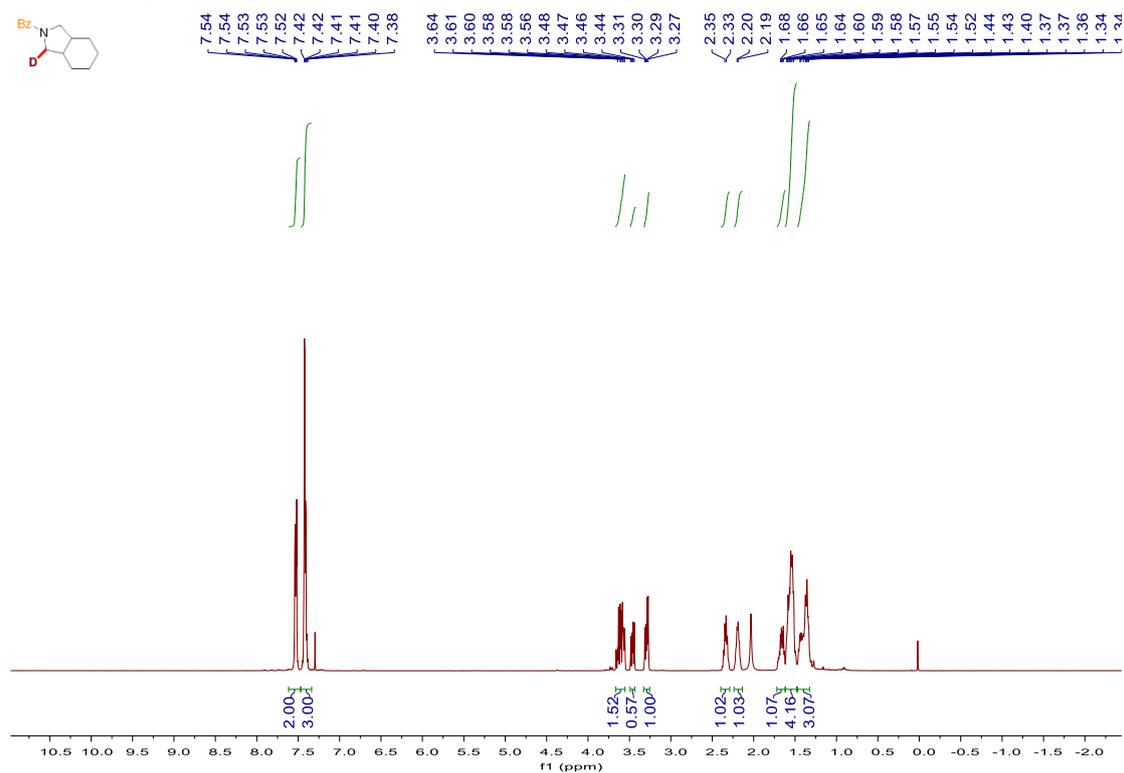
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4k**



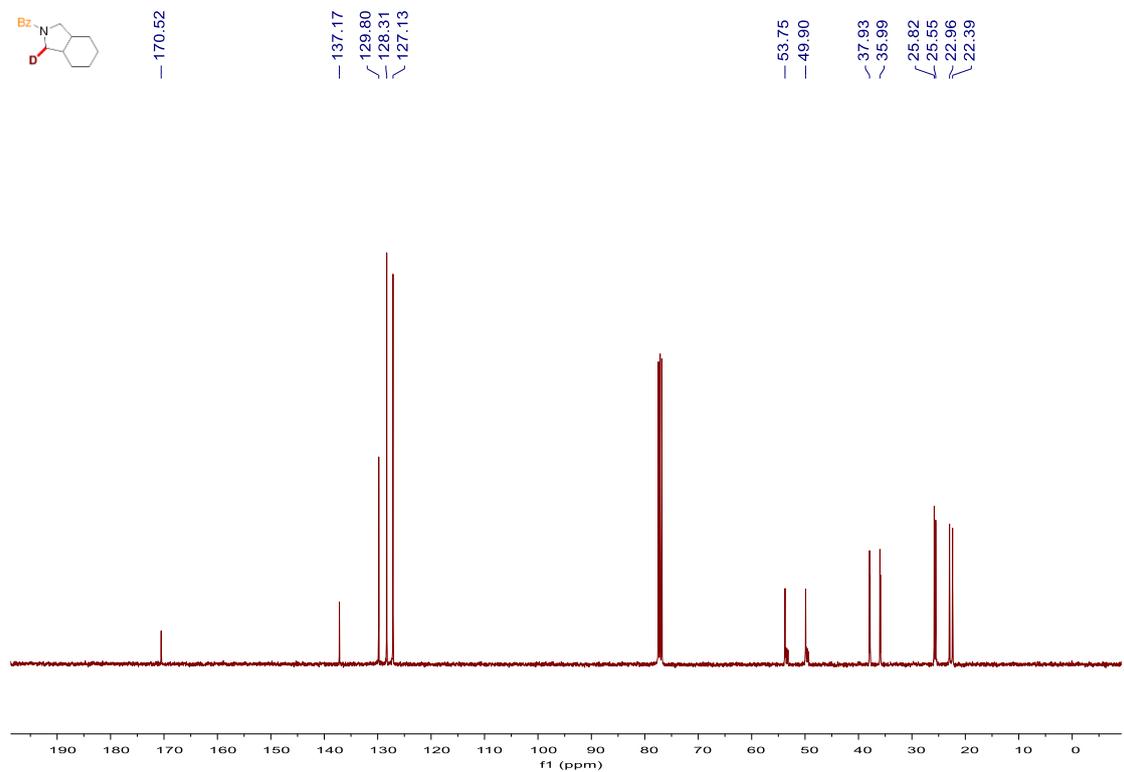
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4k**



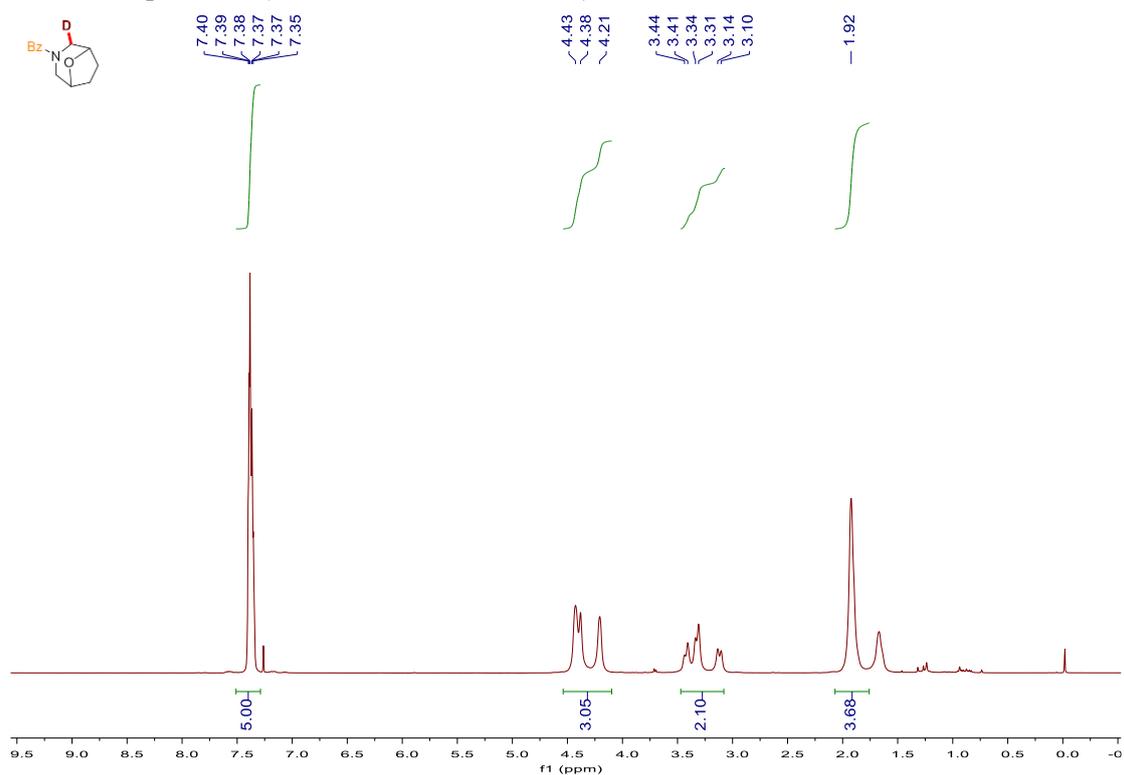
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4I**



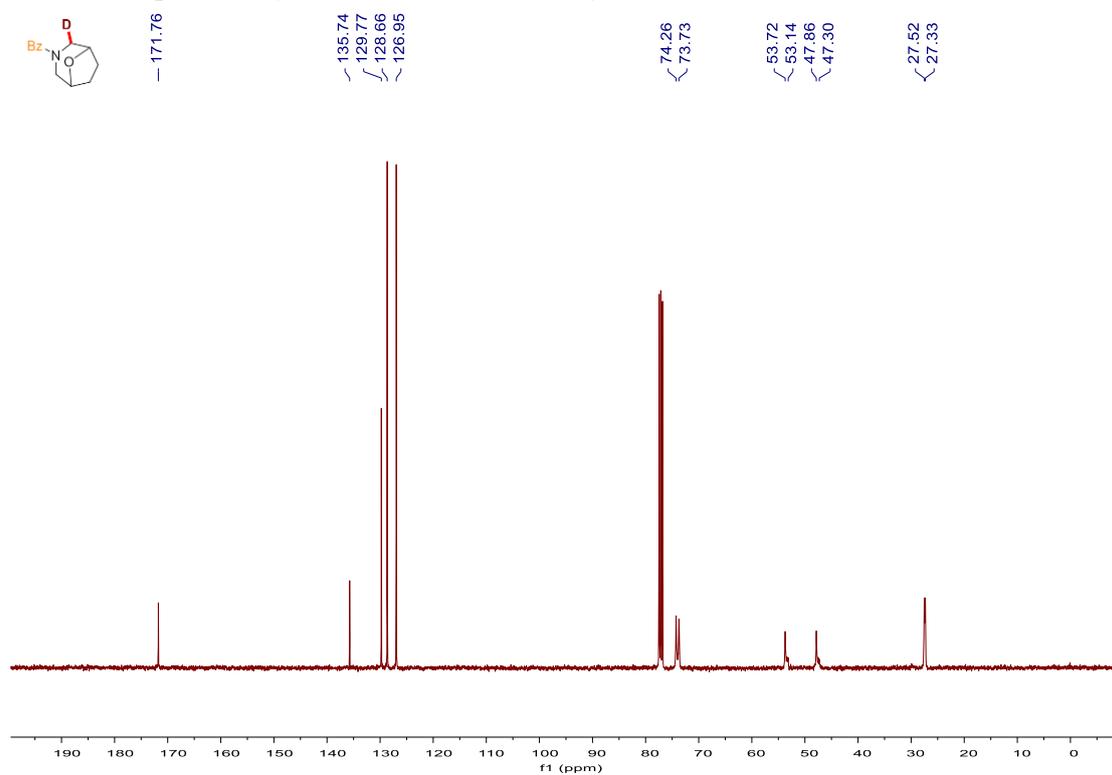
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4I**



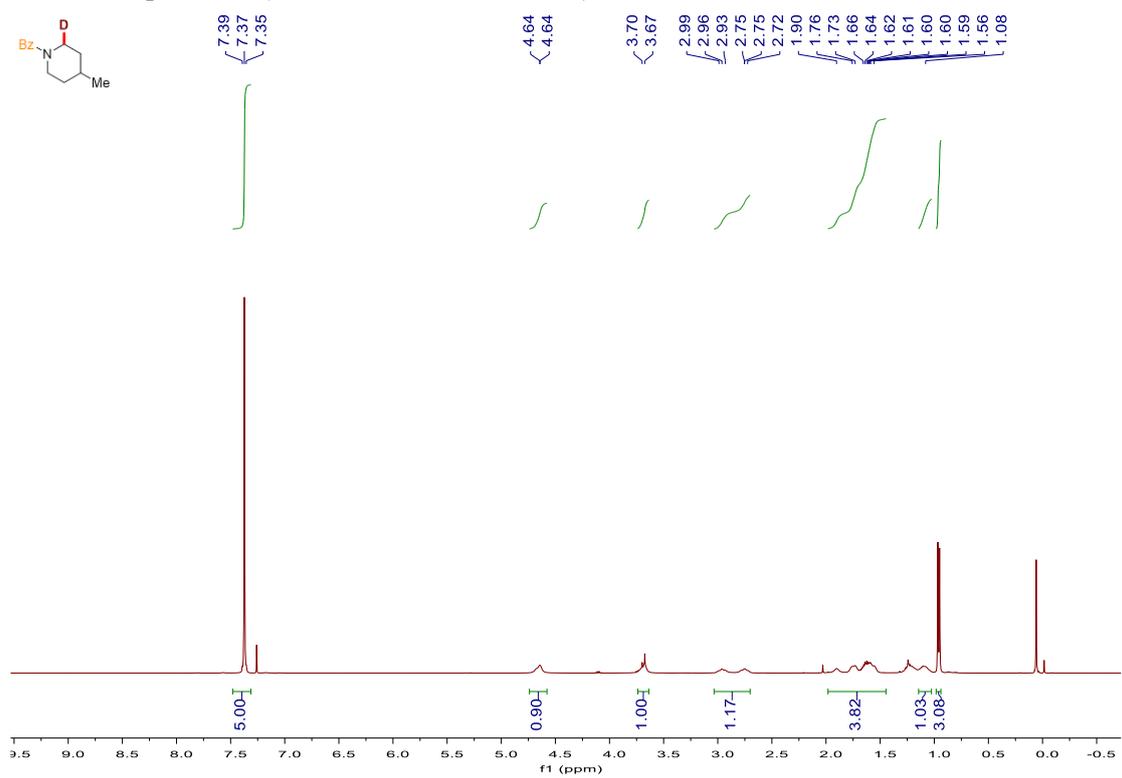
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4m**



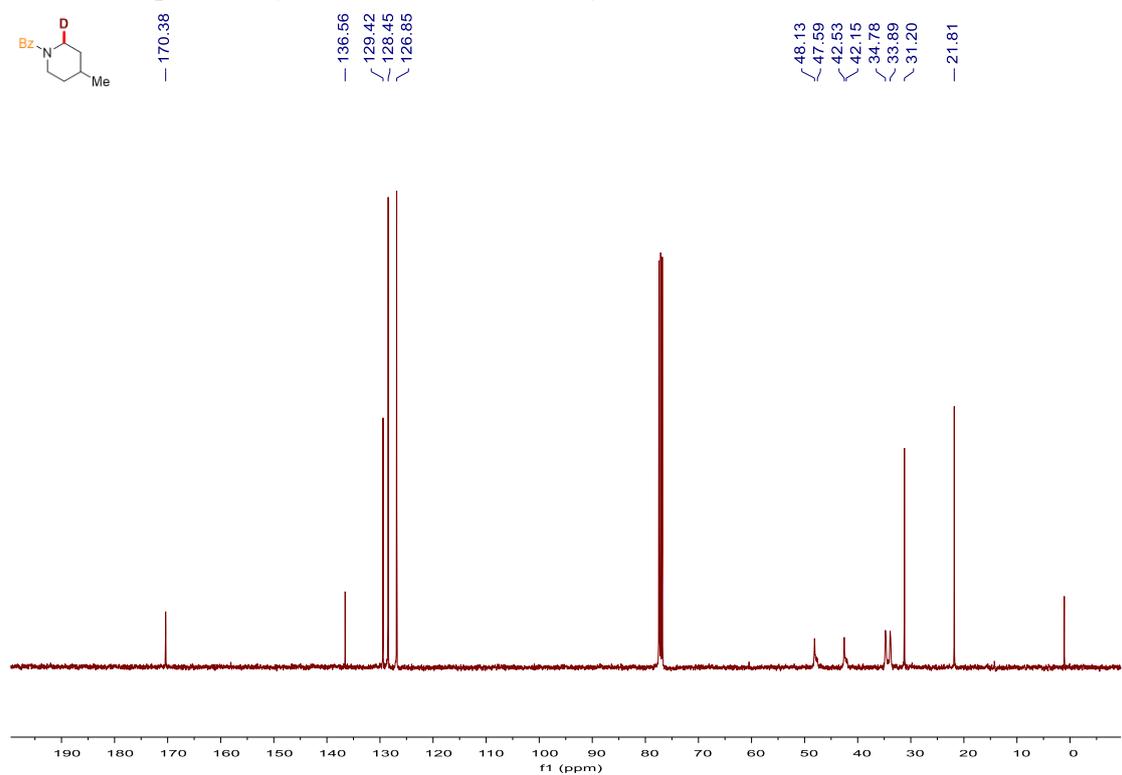
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4m**



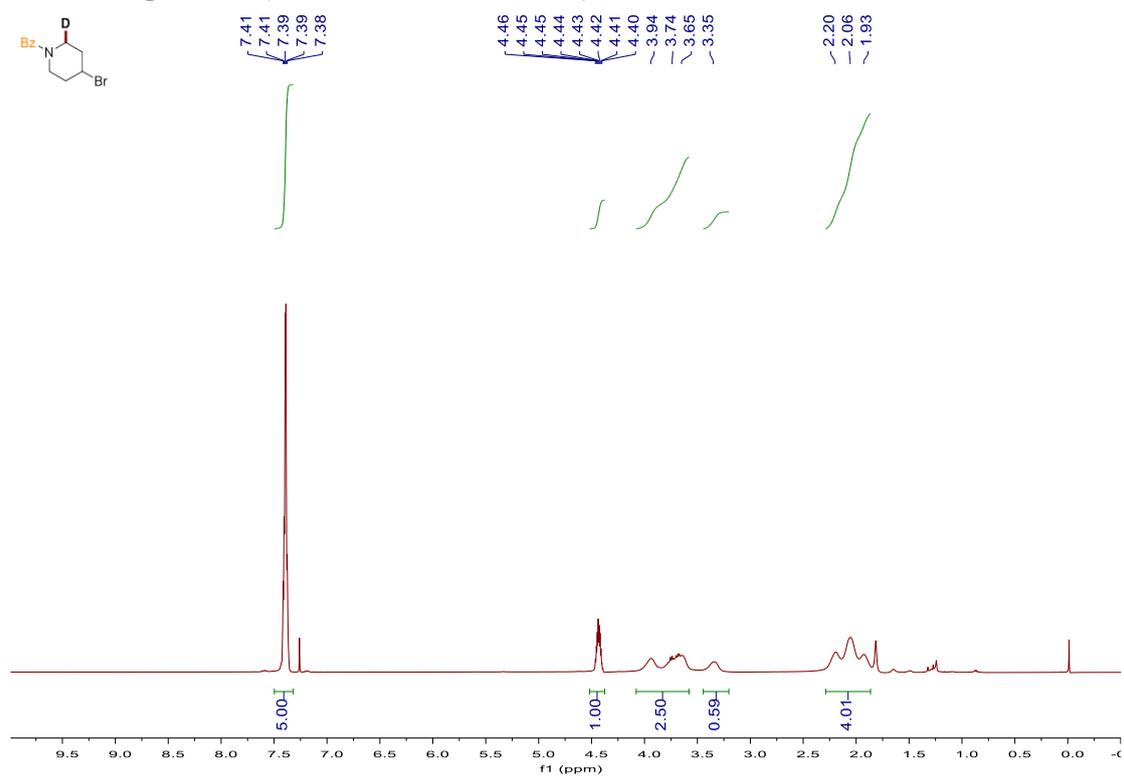
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4n**



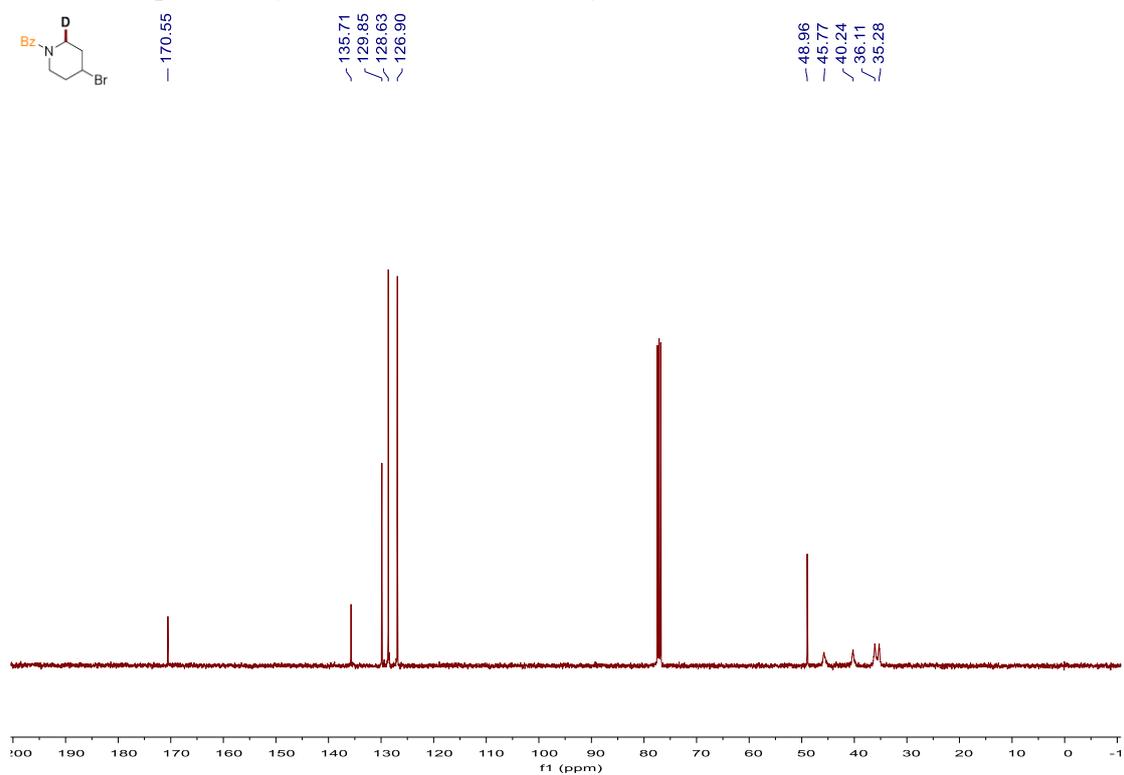
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4n**



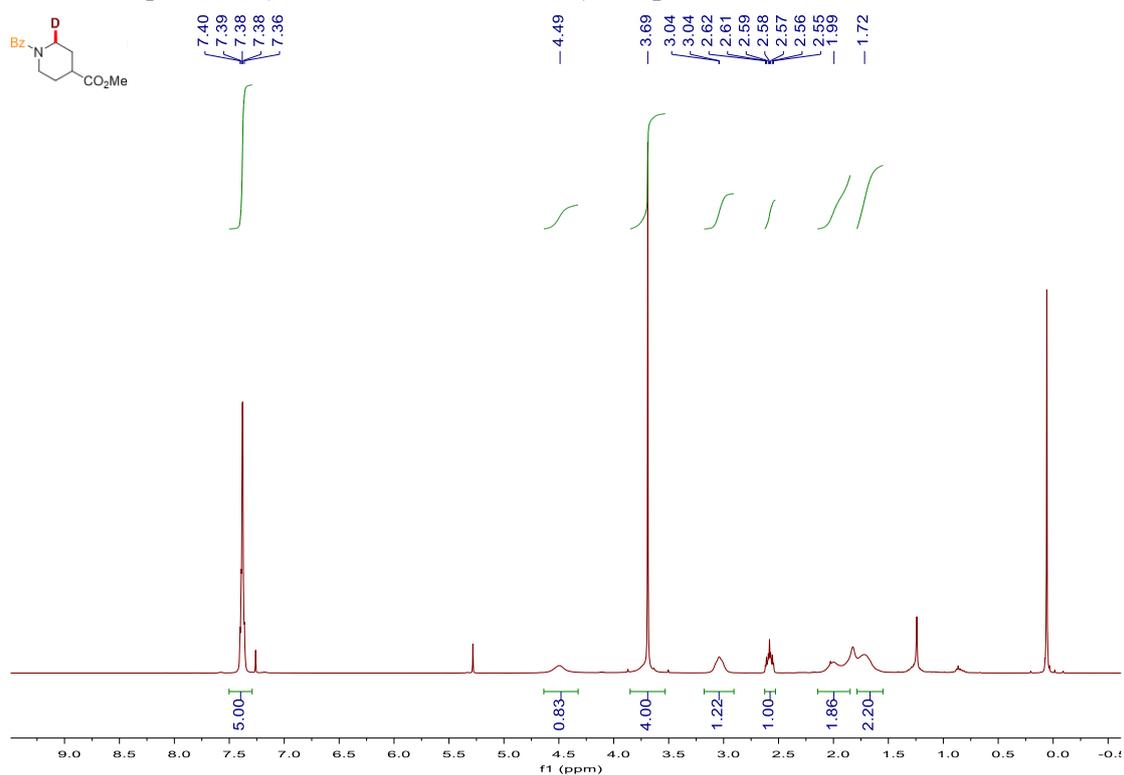
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4o**



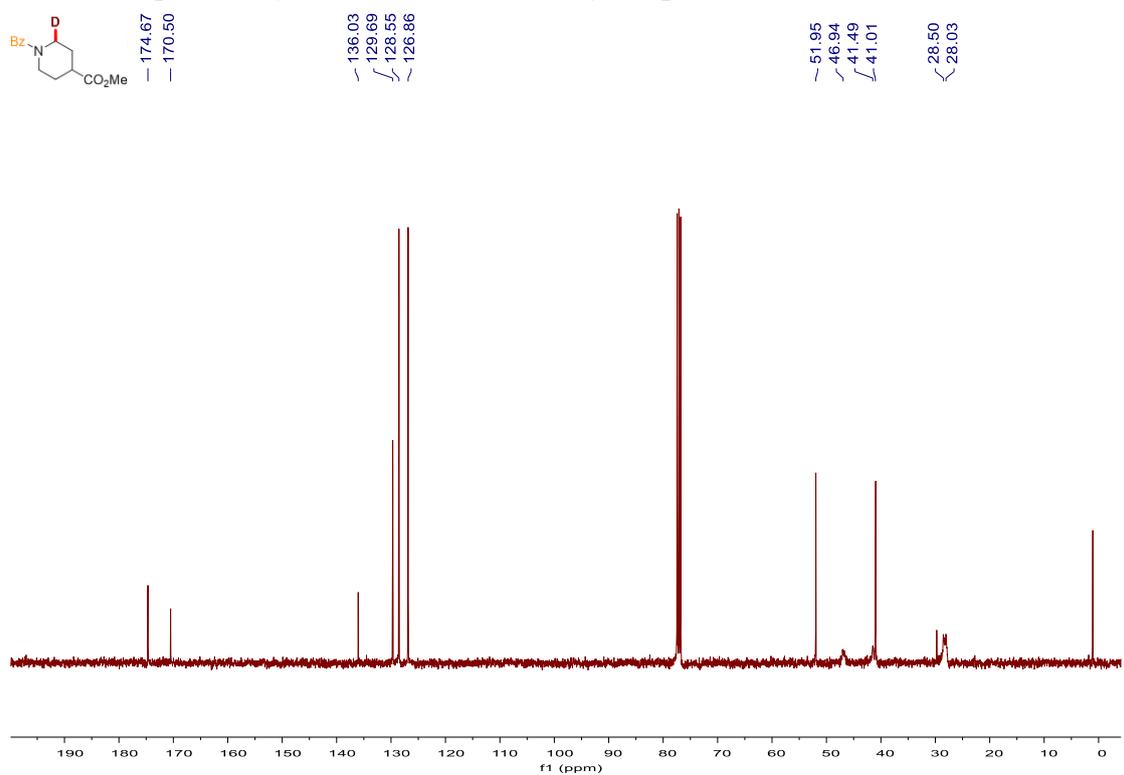
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4o**



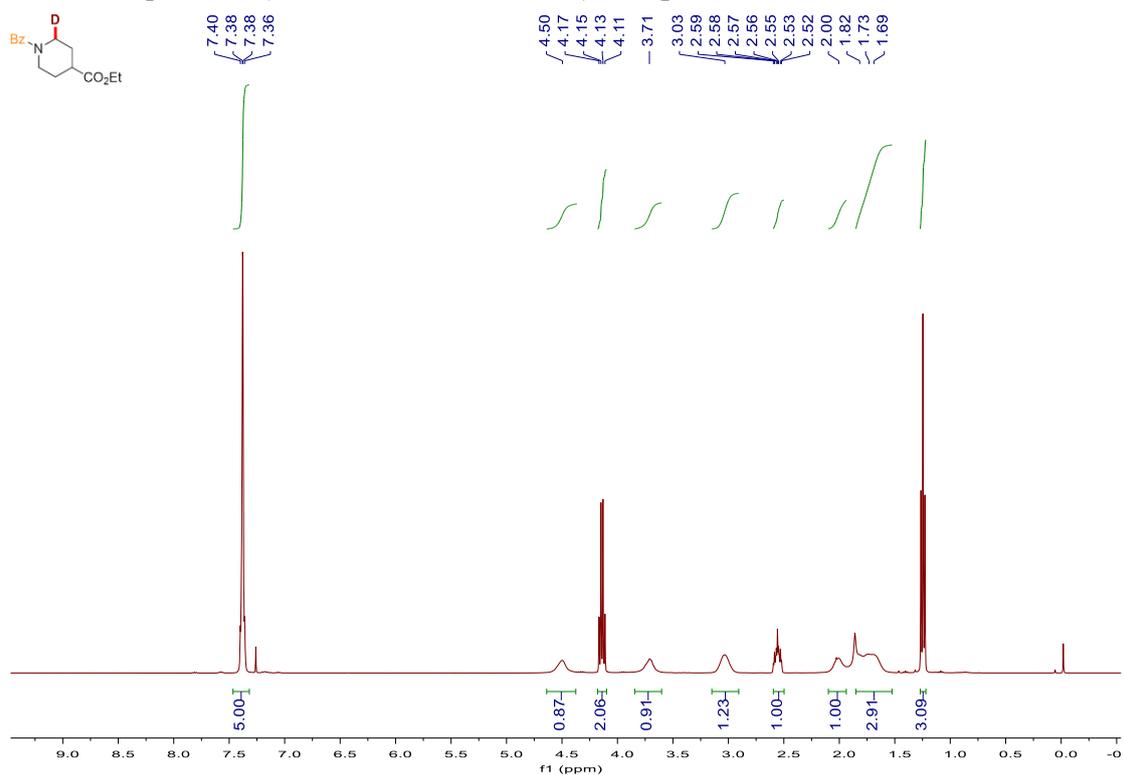
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4p**



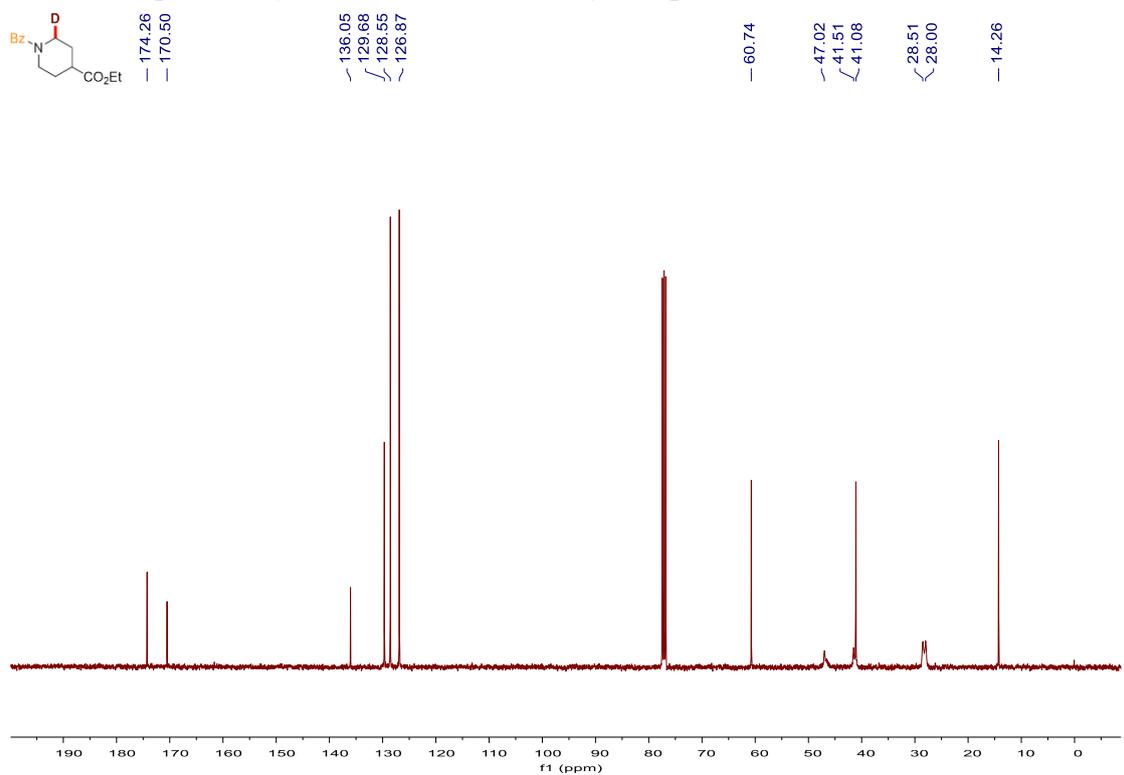
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4p**



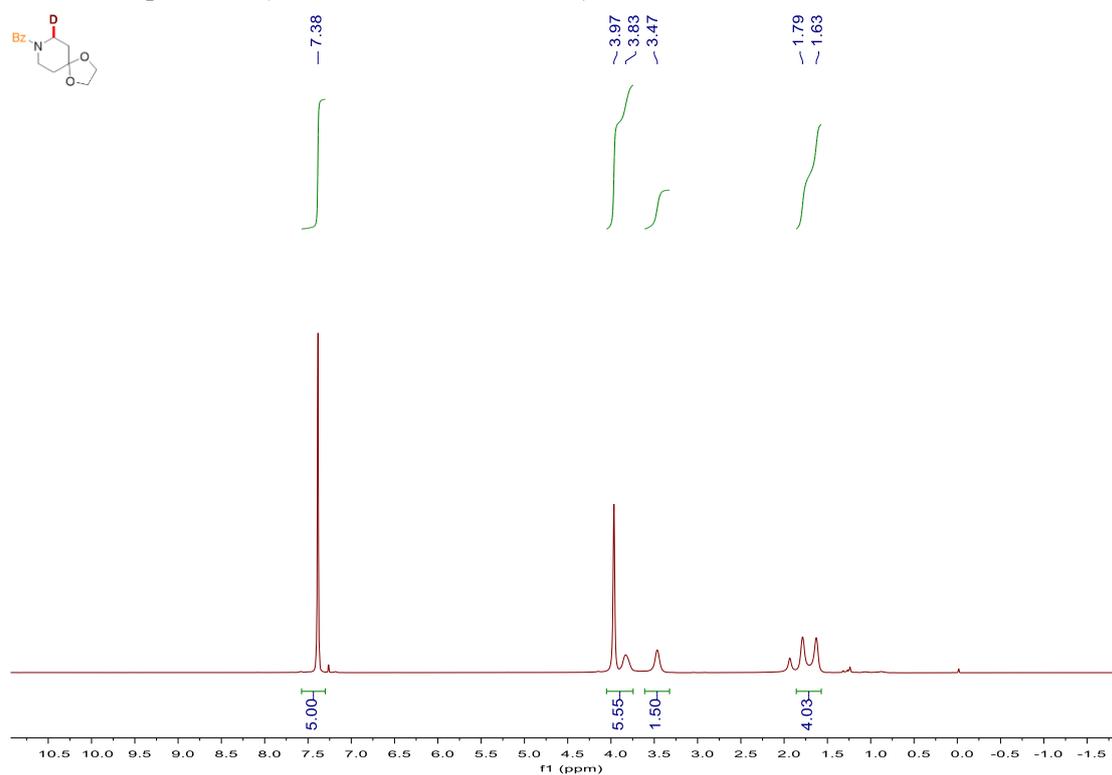
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4q**



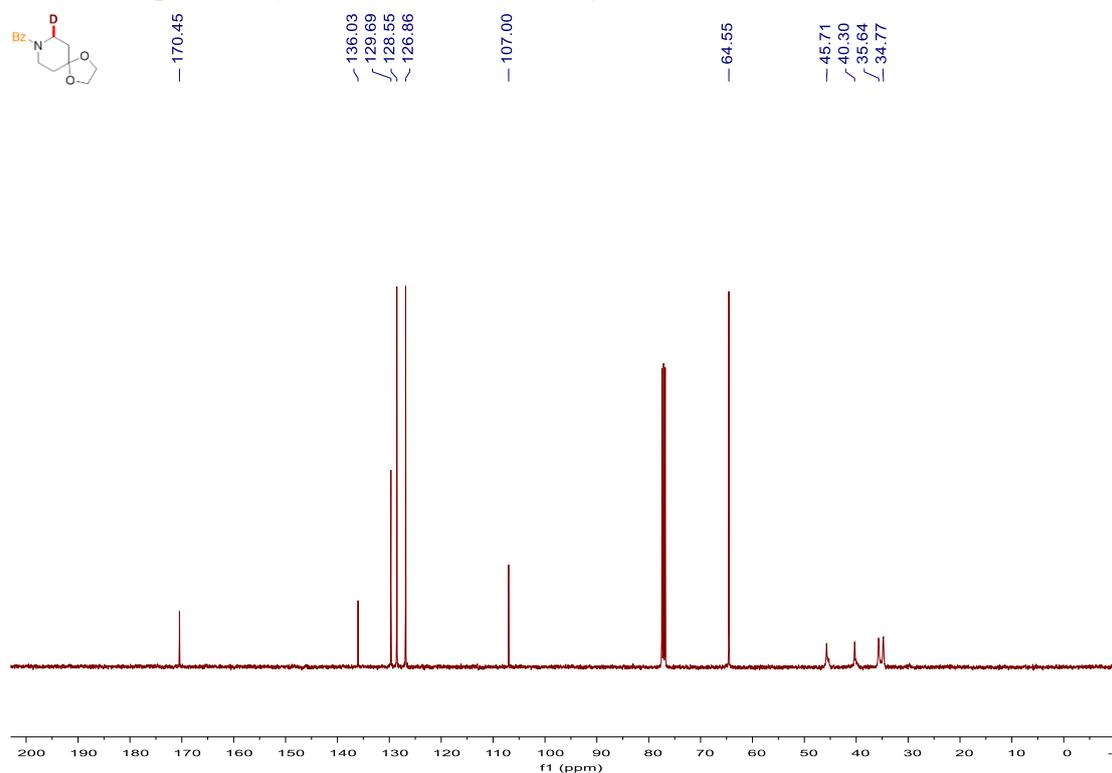
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4q**



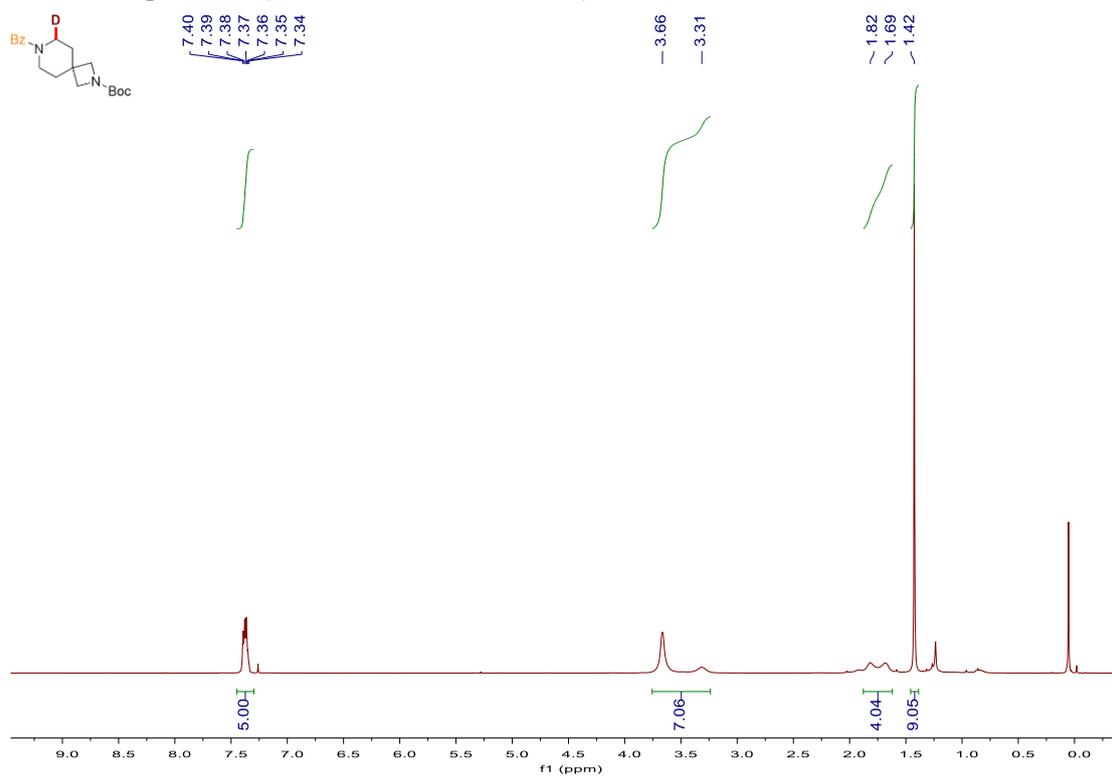
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4r**



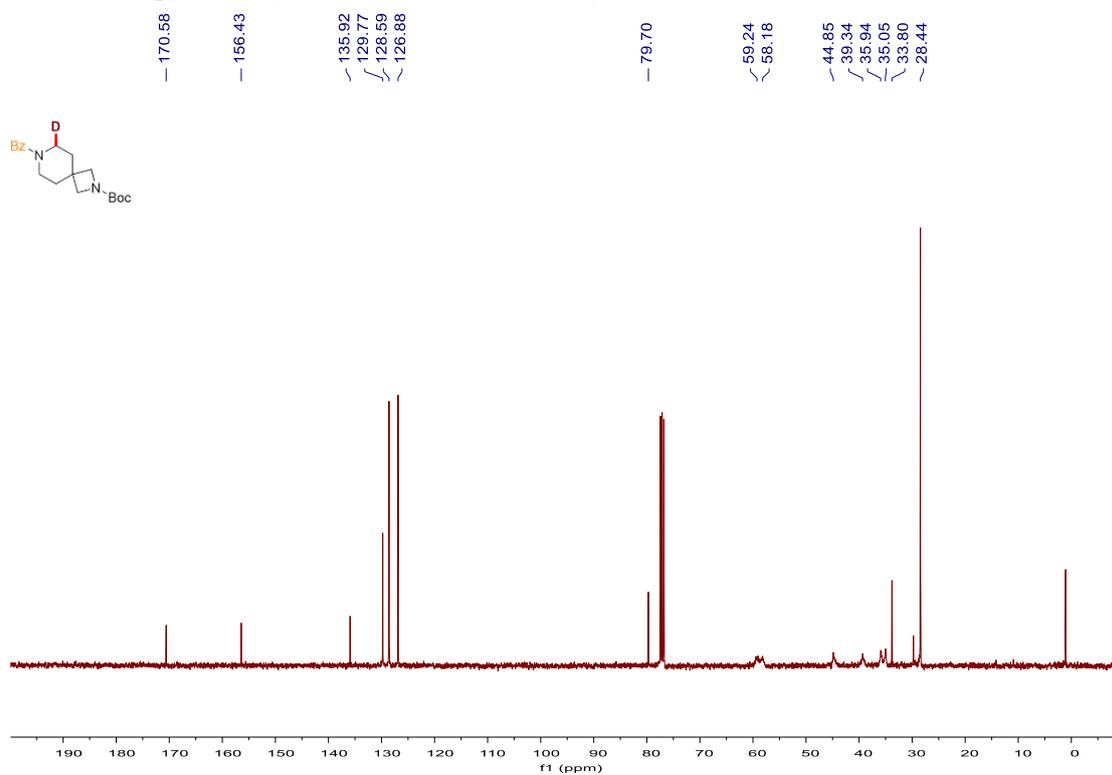
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4r**



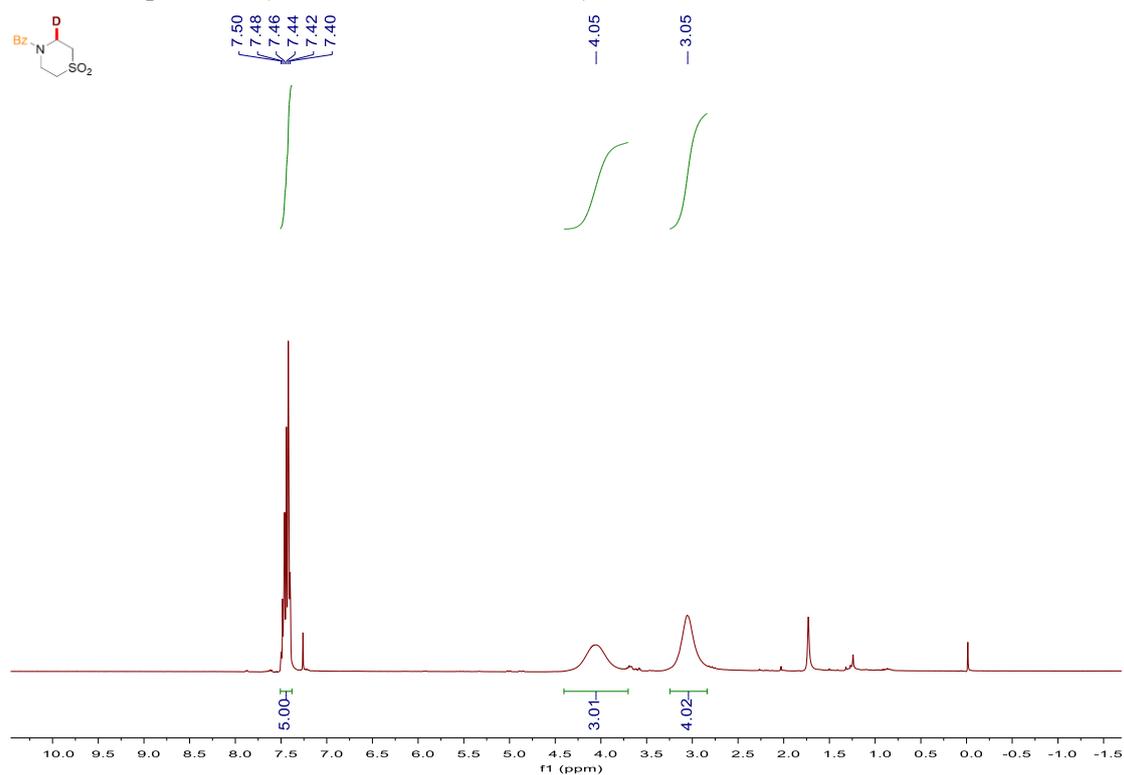
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4s**



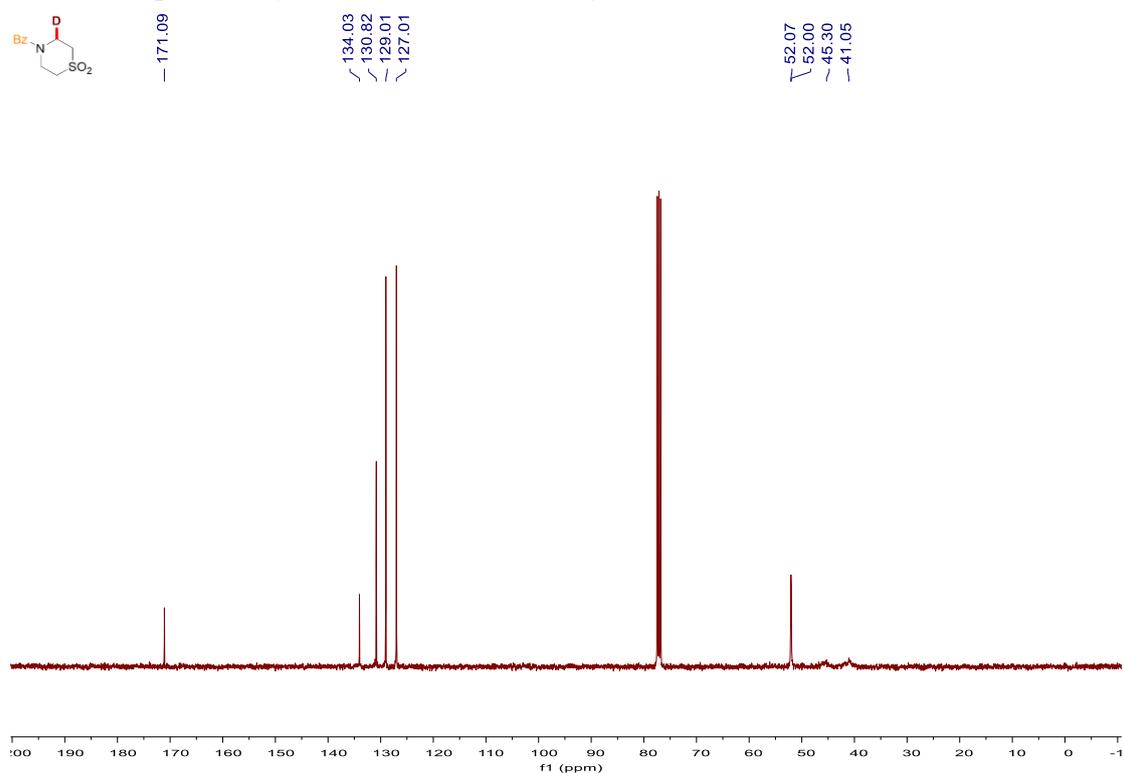
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4s**



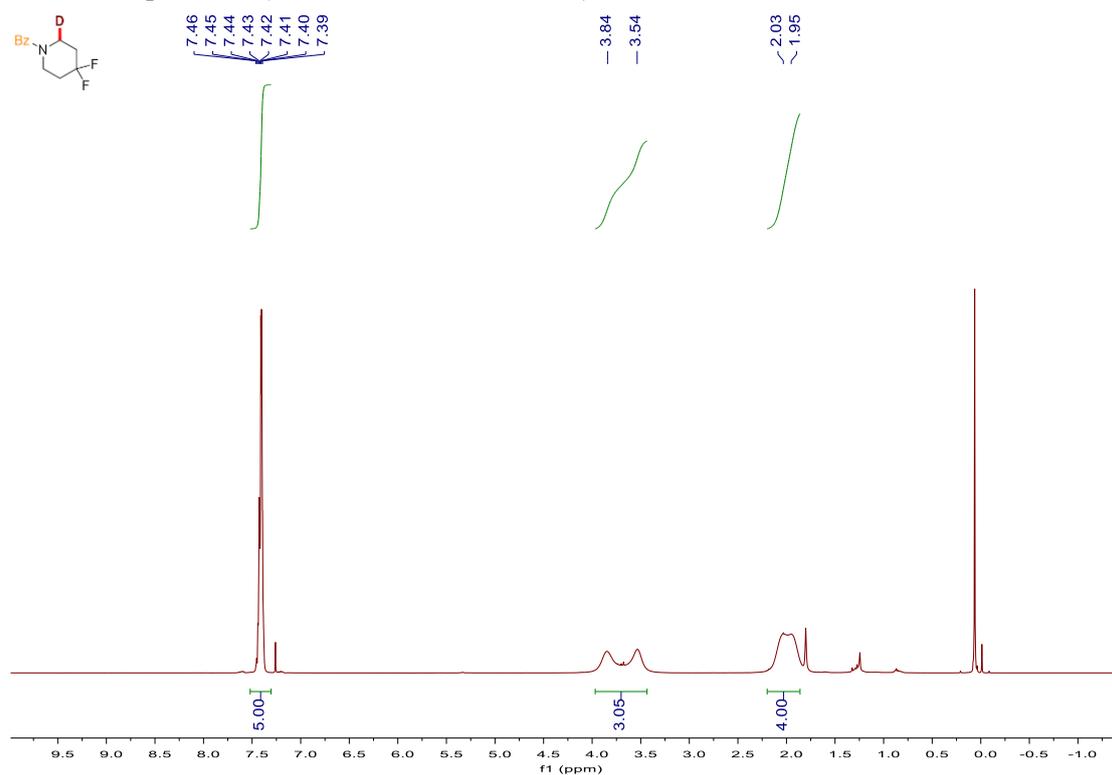
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4t**



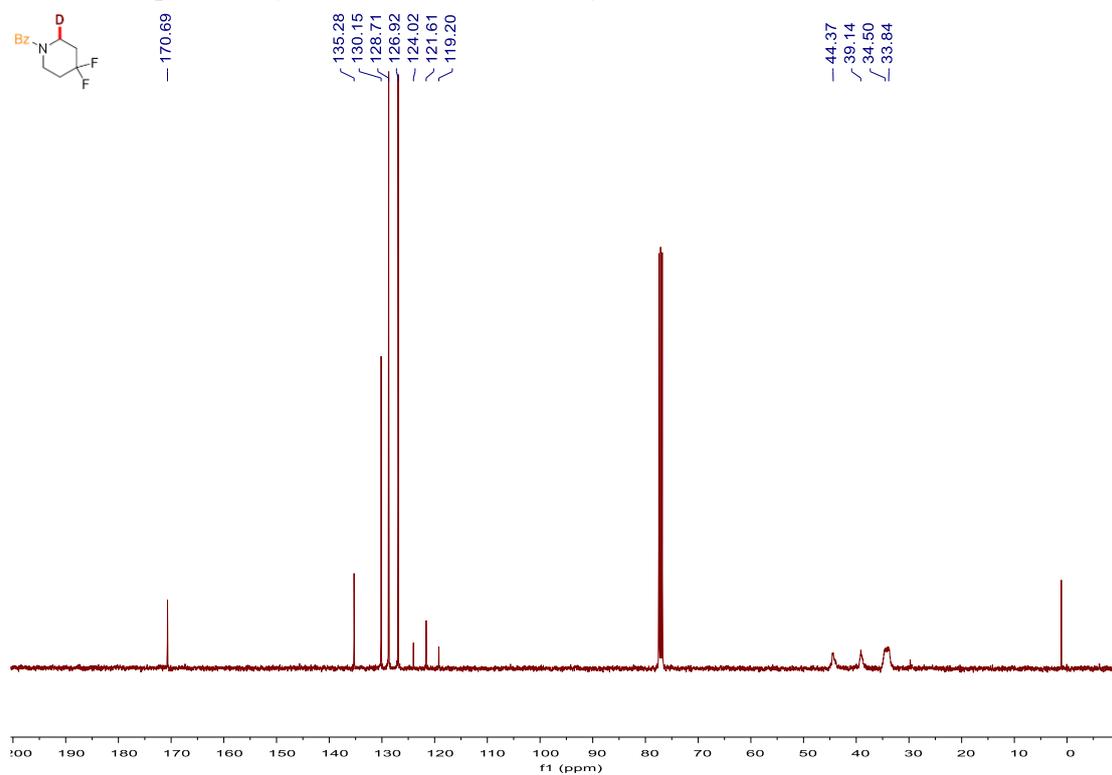
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4t**



^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4u**



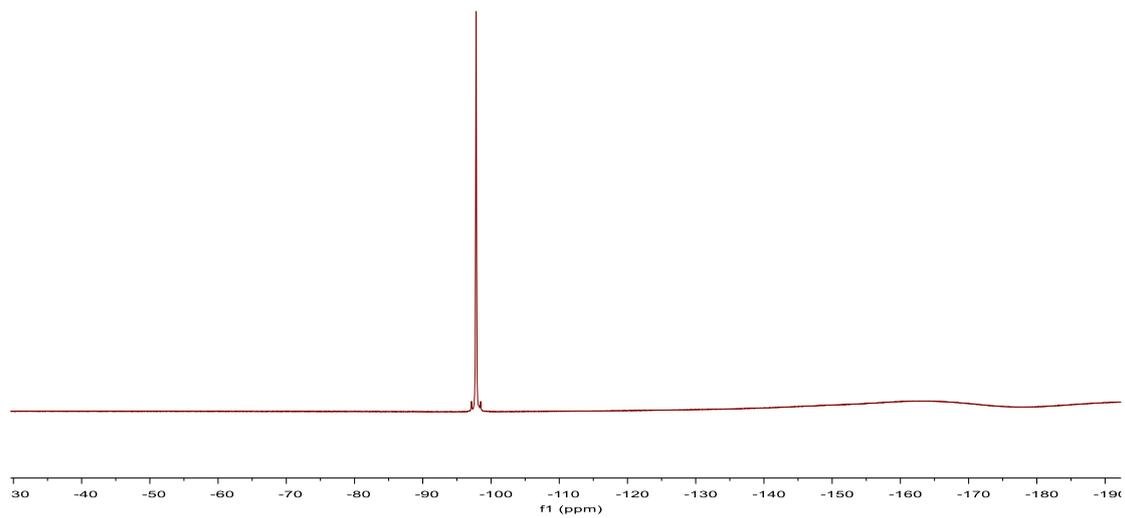
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4u**



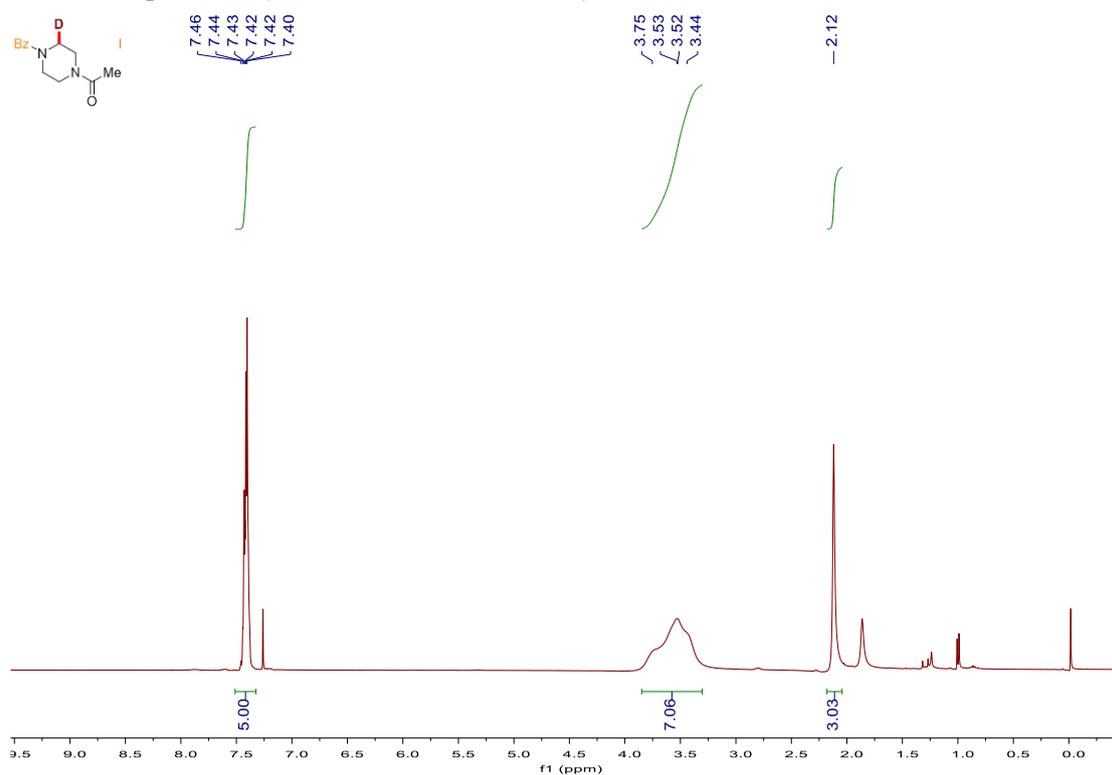
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **4u**



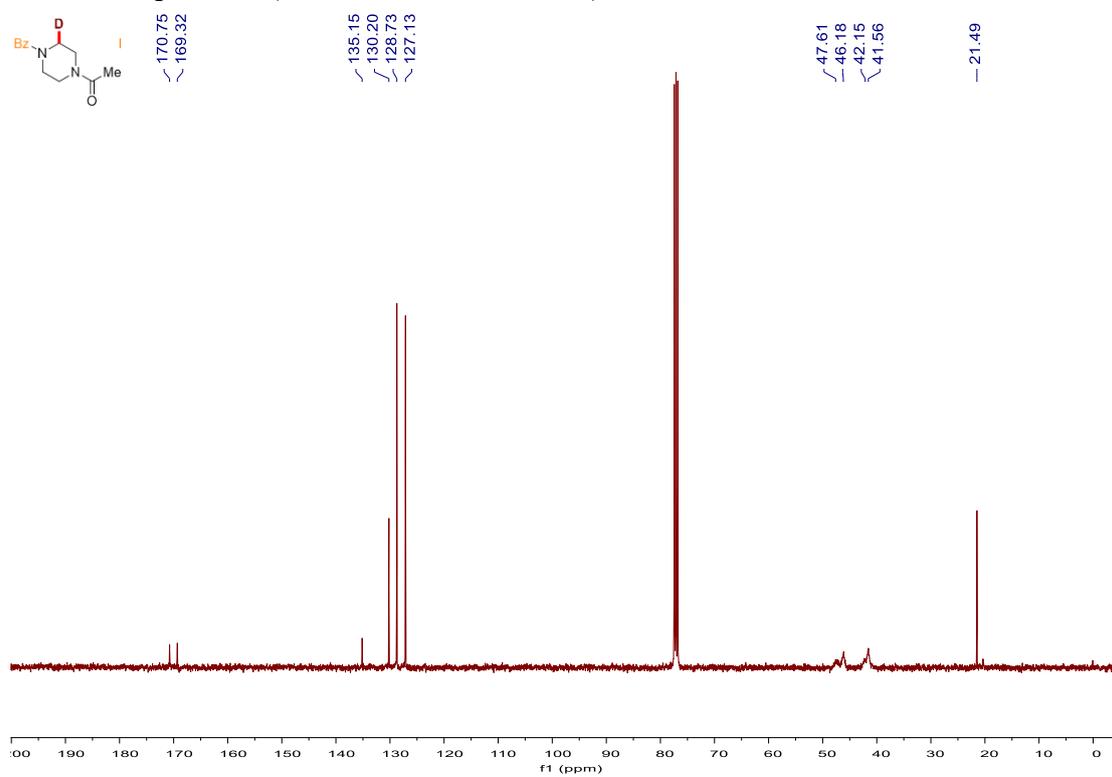
-97.82



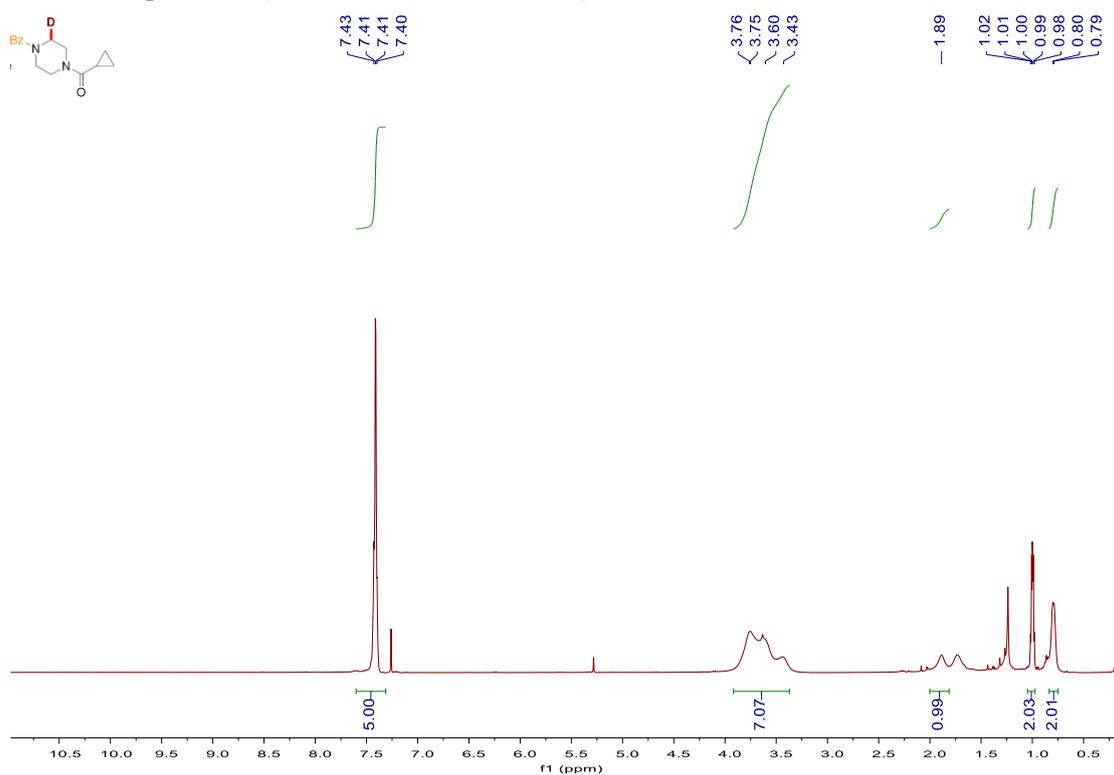
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4v**



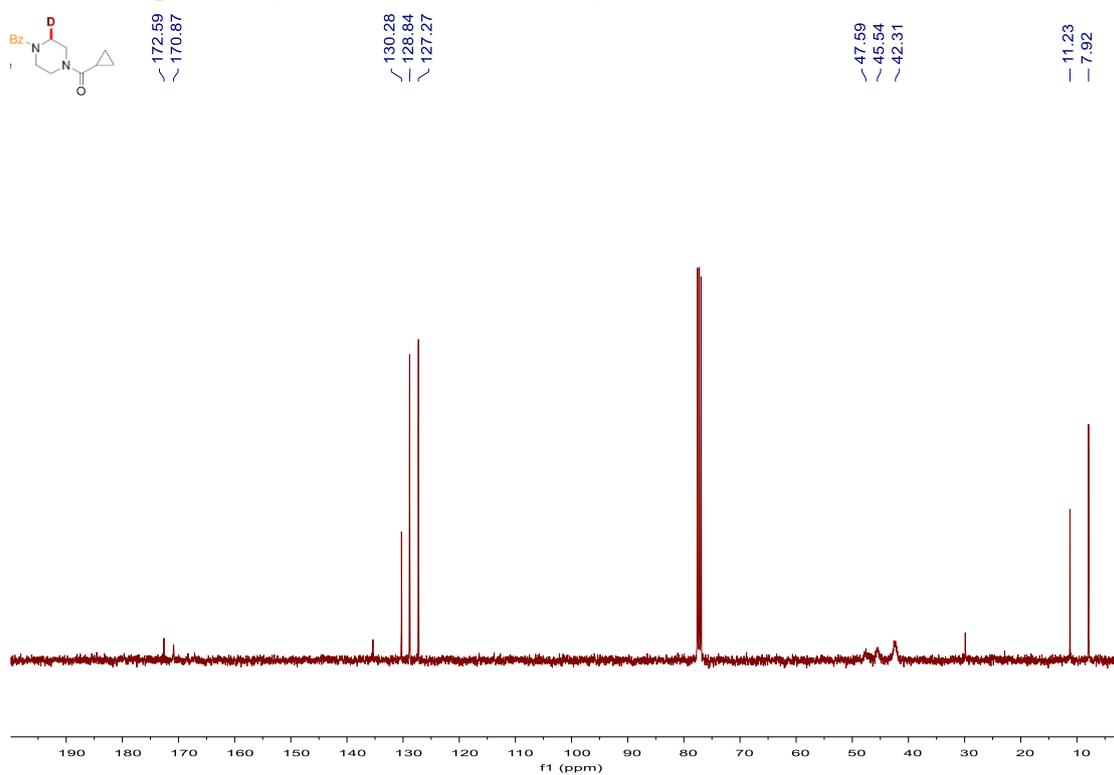
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4v**



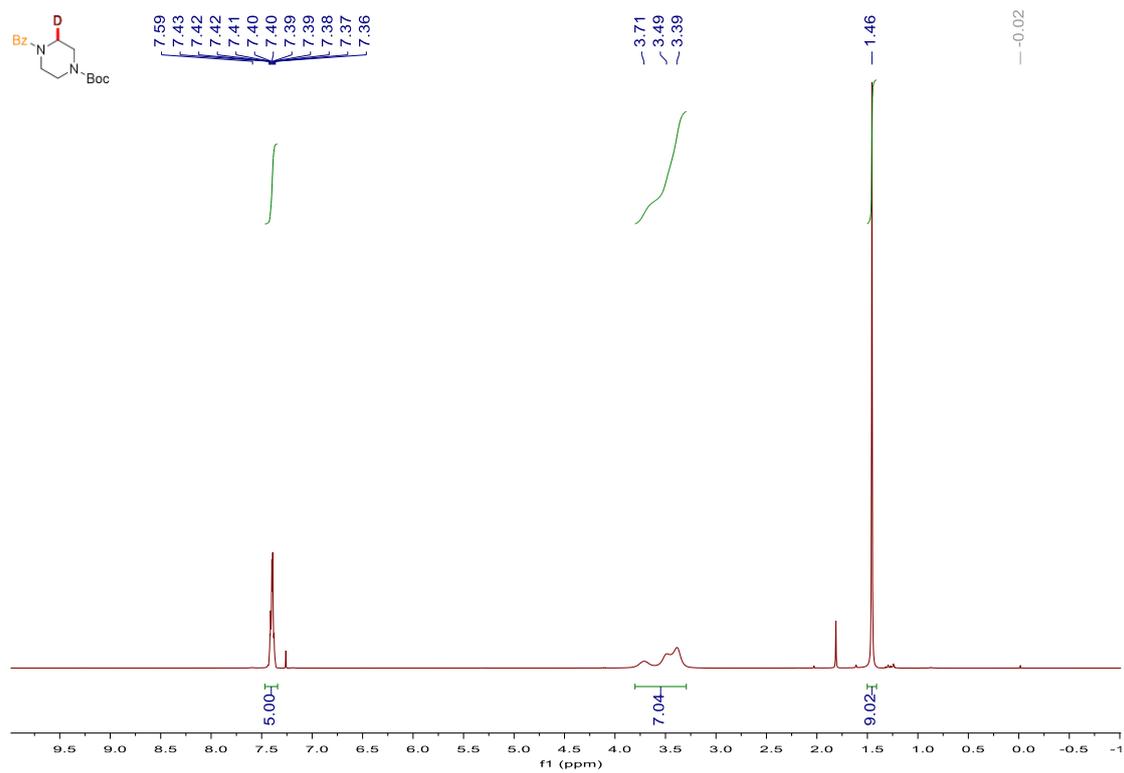
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4w**



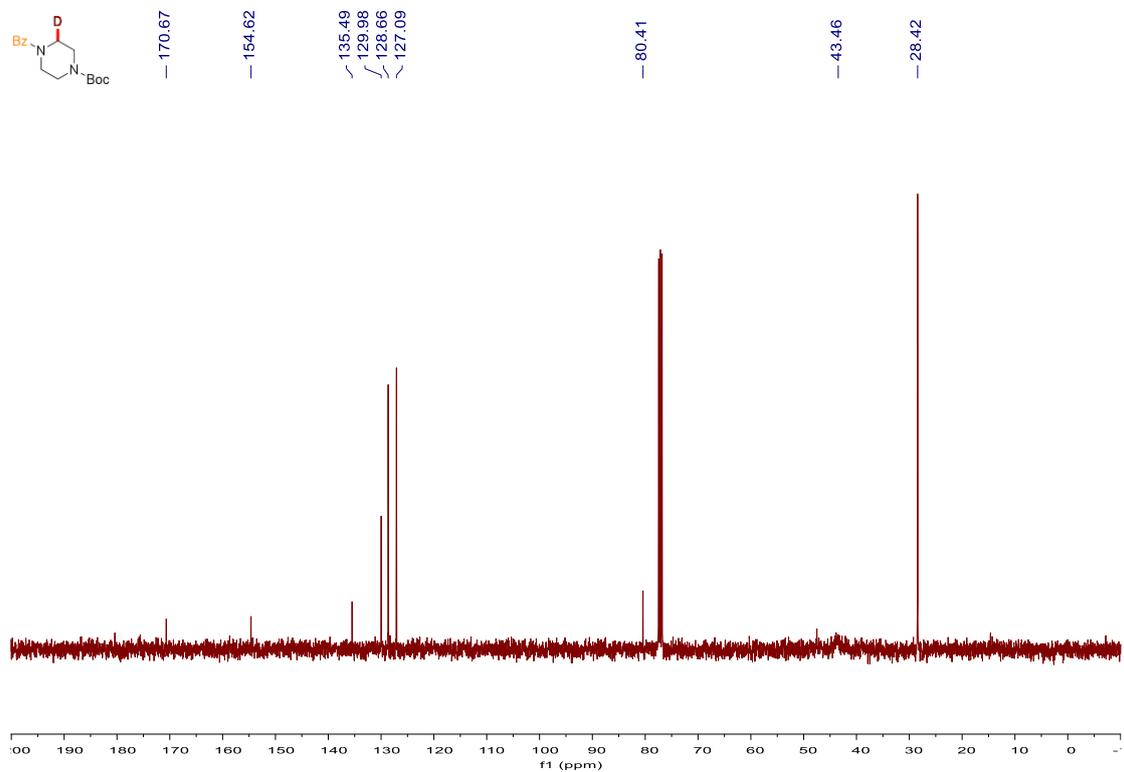
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4w**



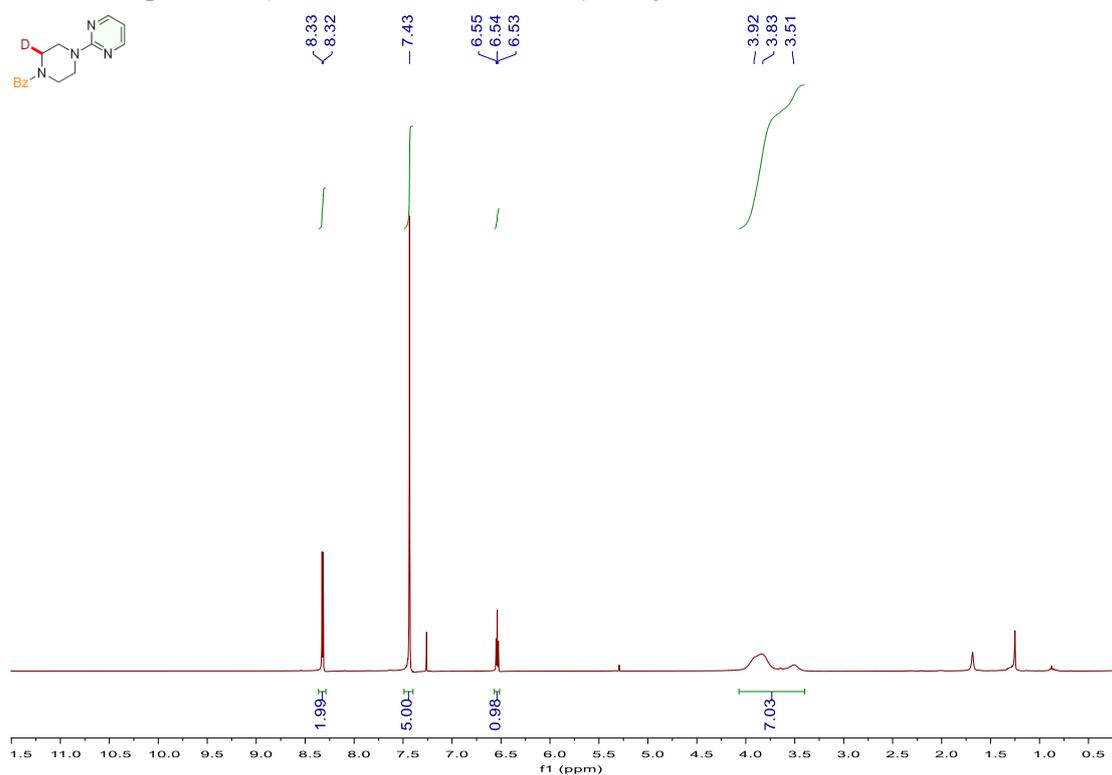
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4x**



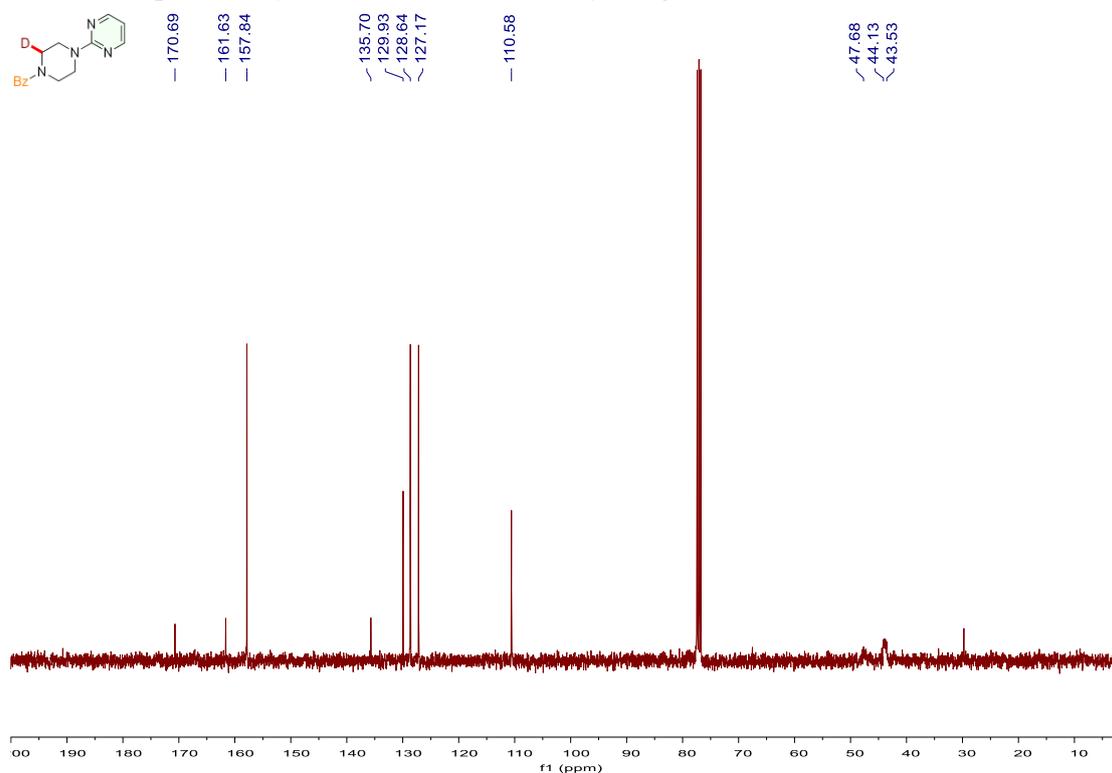
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4x**



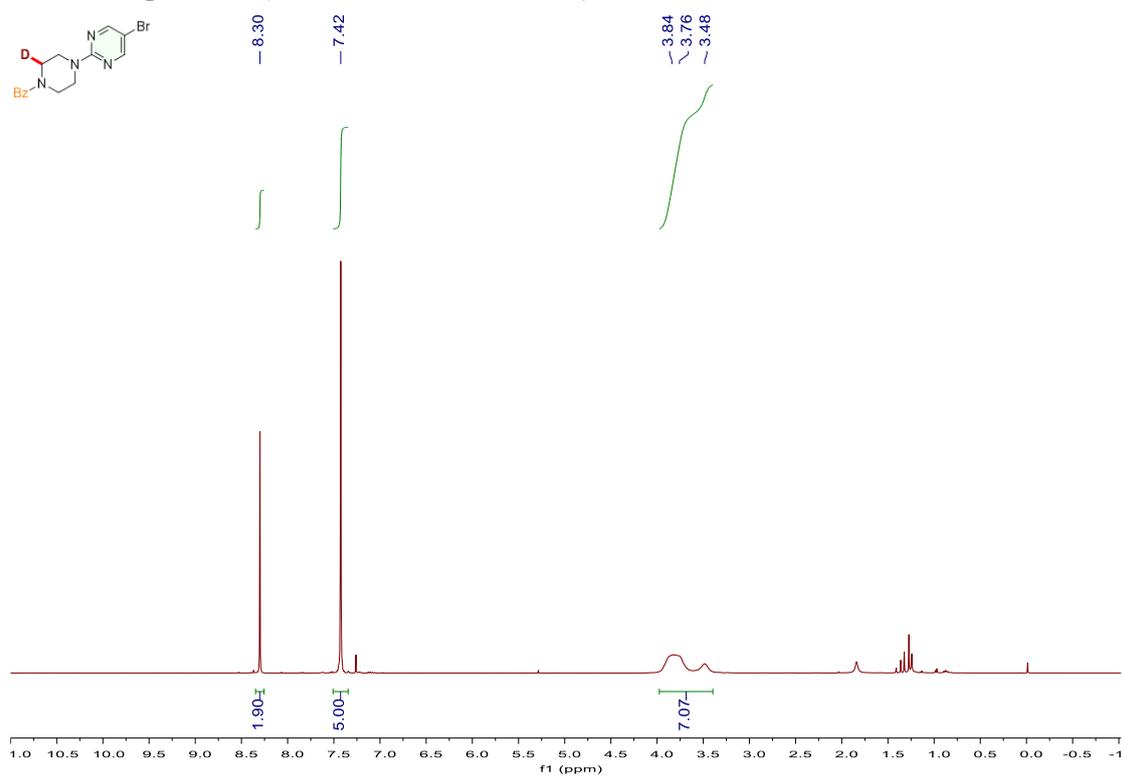
^1H NMR spectrum (400 MHz, CDCl_3 , 23 °C) of **4y**



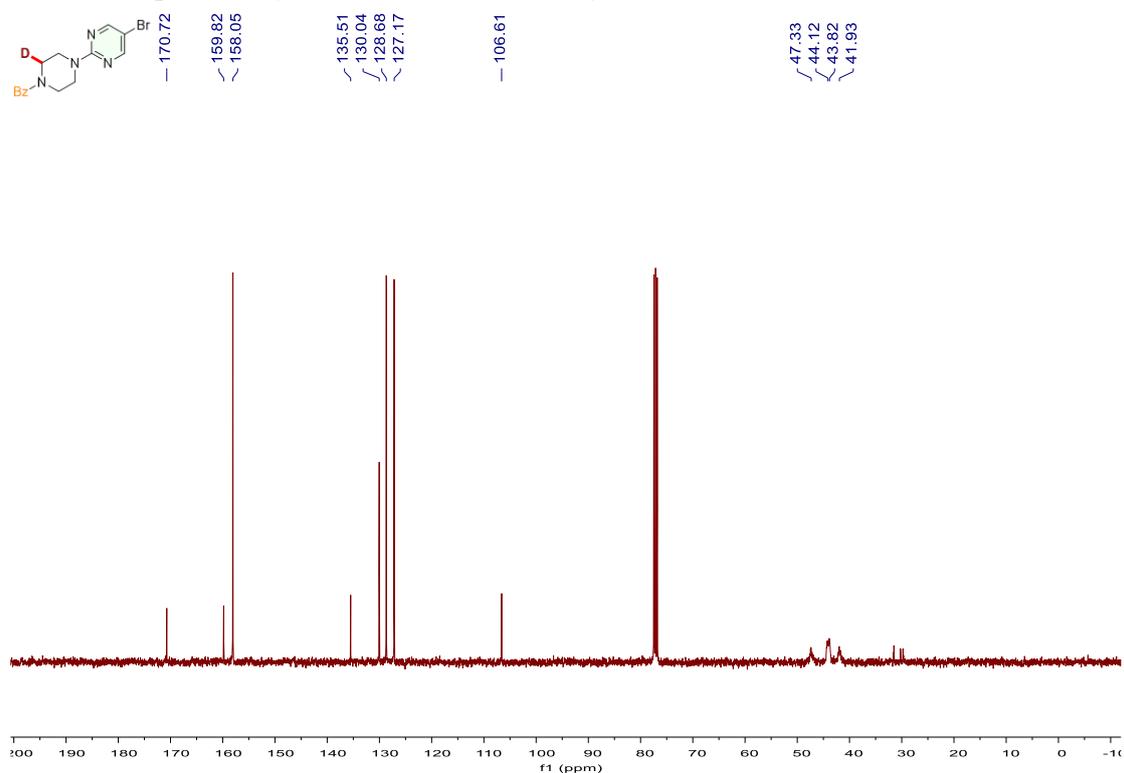
^{13}C NMR spectrum (100 MHz, CDCl_3 , 23 °C) of **4y**



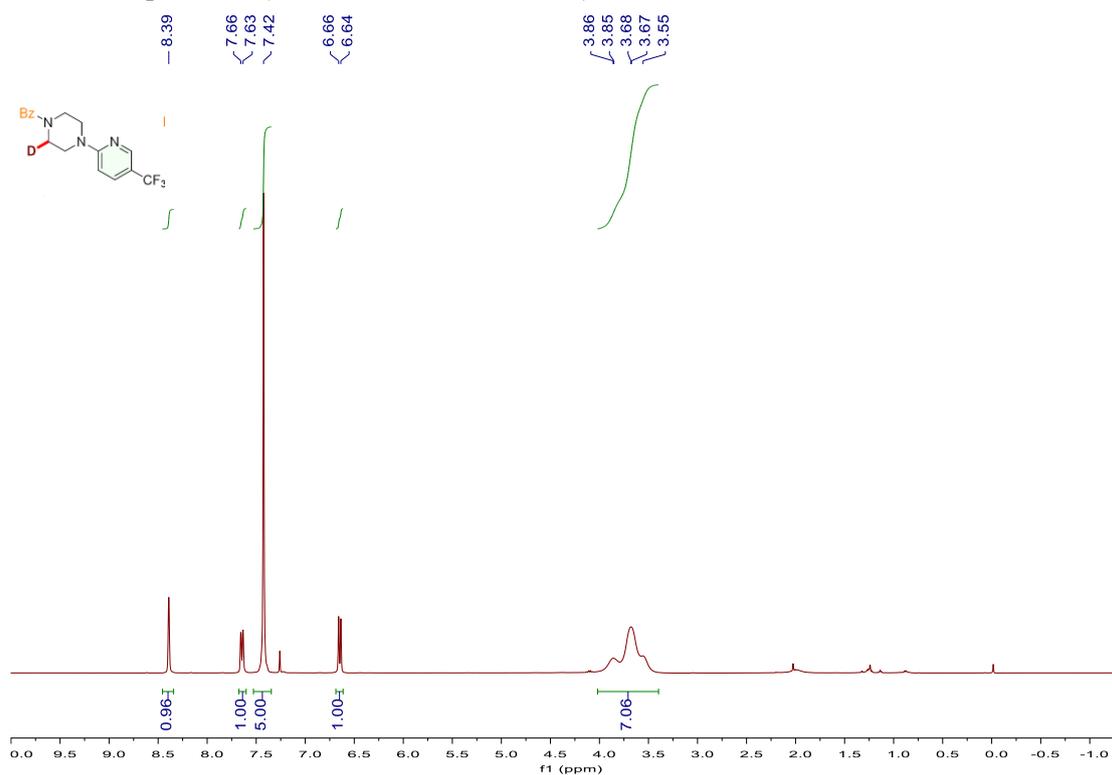
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4z**



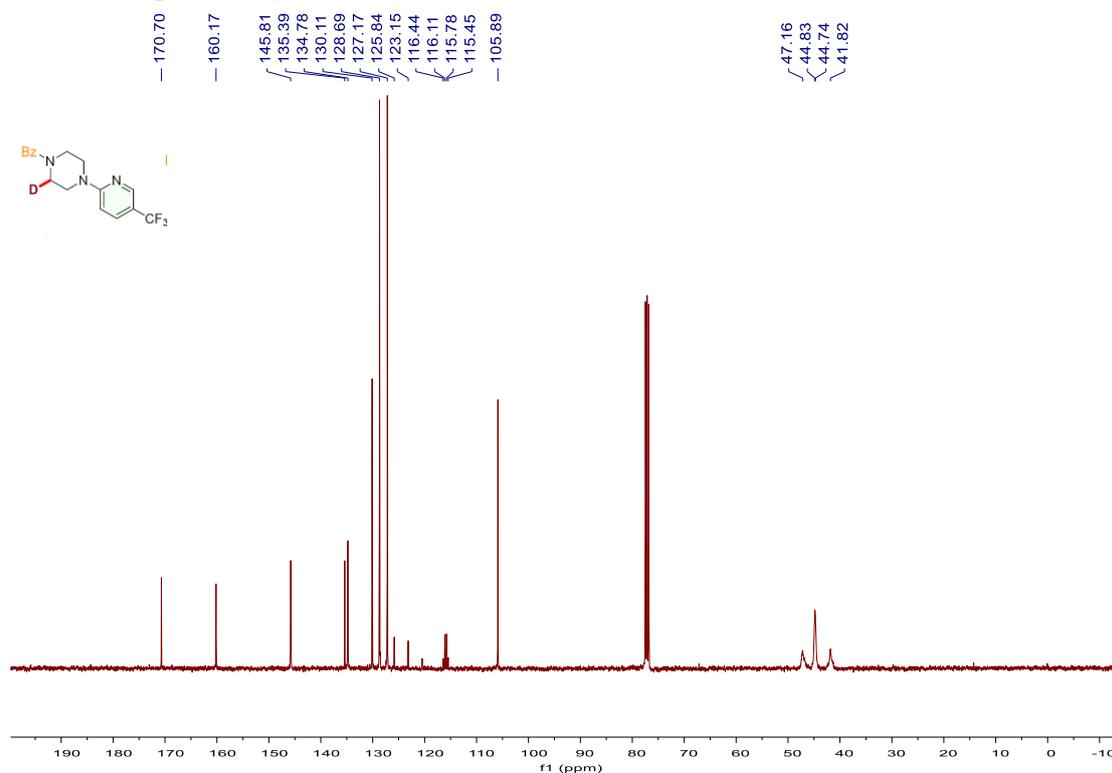
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4z**



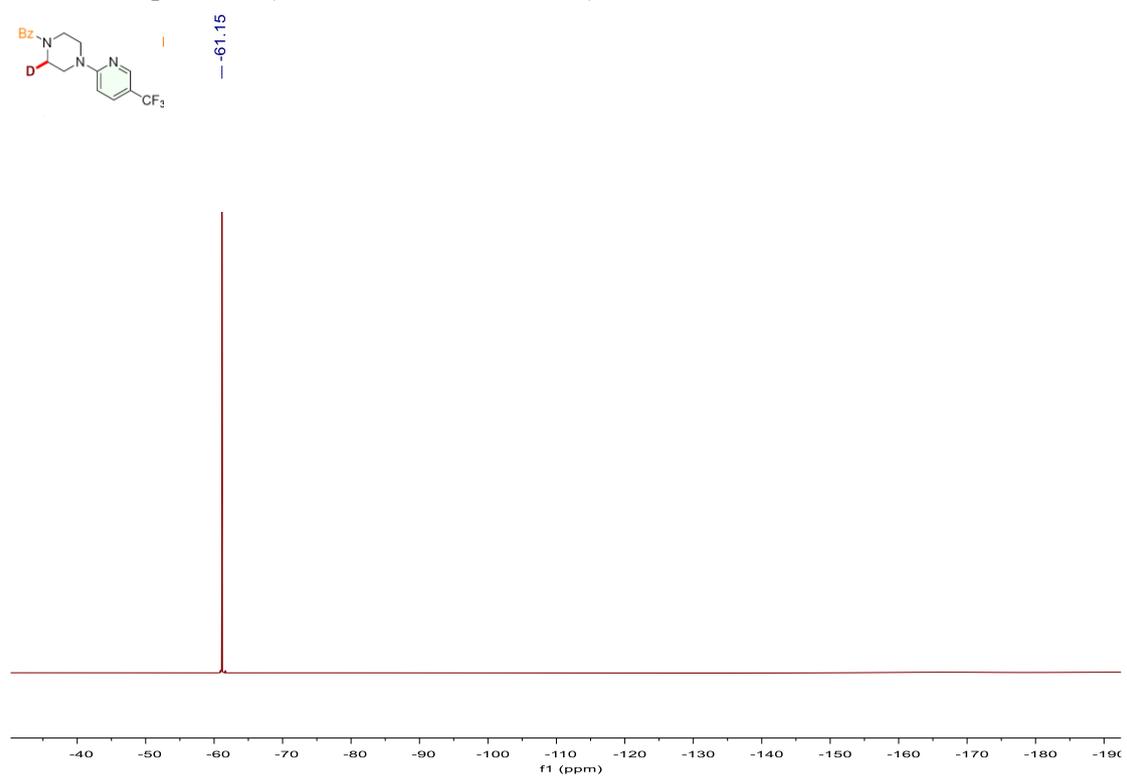
¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4aa**



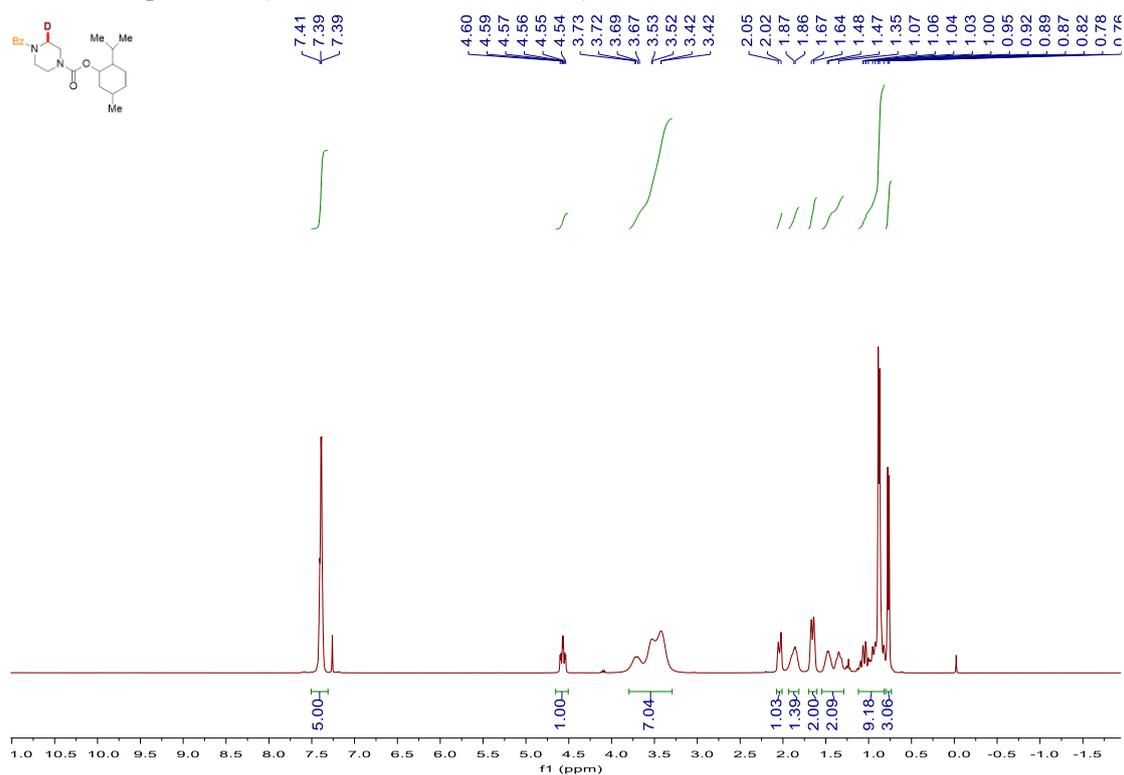
¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4aa**



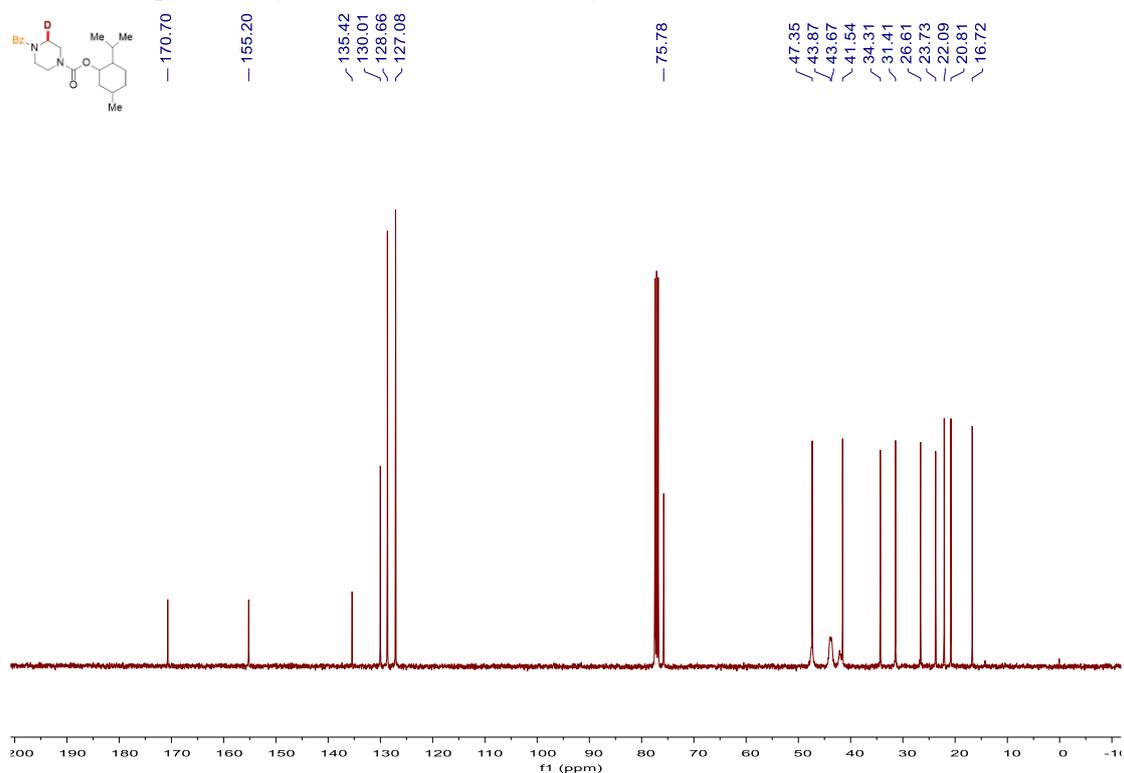
^{19}F NMR spectrum (376 MHz, CDCl_3 , 23 °C) of **4aa**



¹H NMR spectrum (400 MHz, CDCl₃, 23 °C) of **4ab**

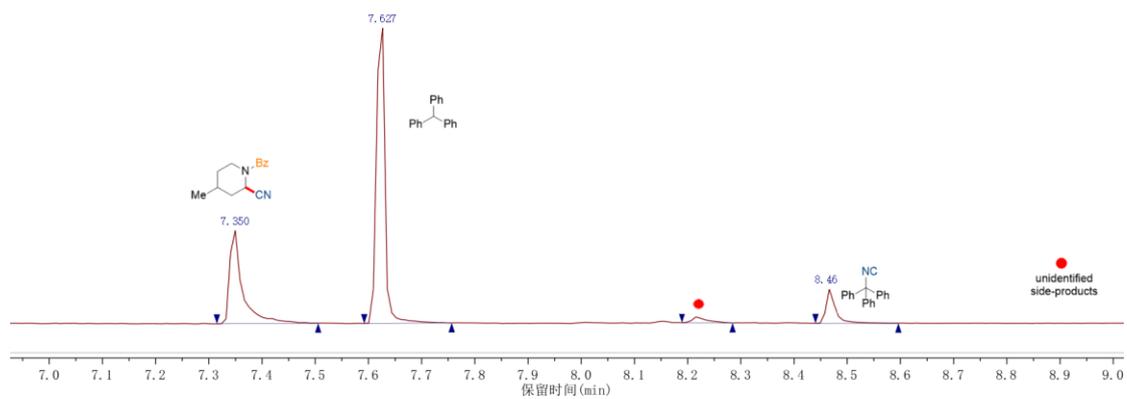


¹³C NMR spectrum (100 MHz, CDCl₃, 23 °C) of **4ab**

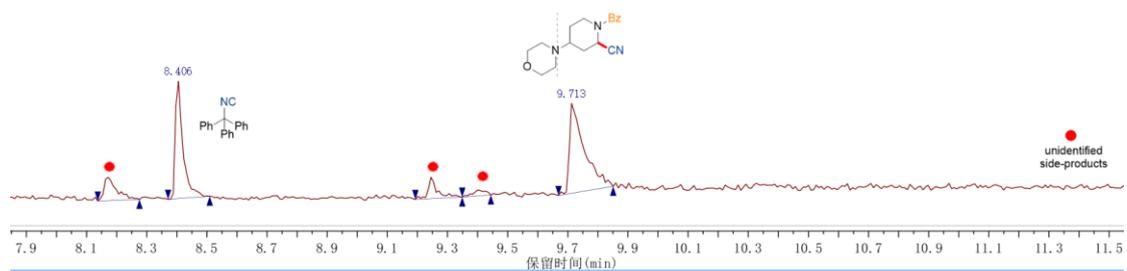


9. GC Data

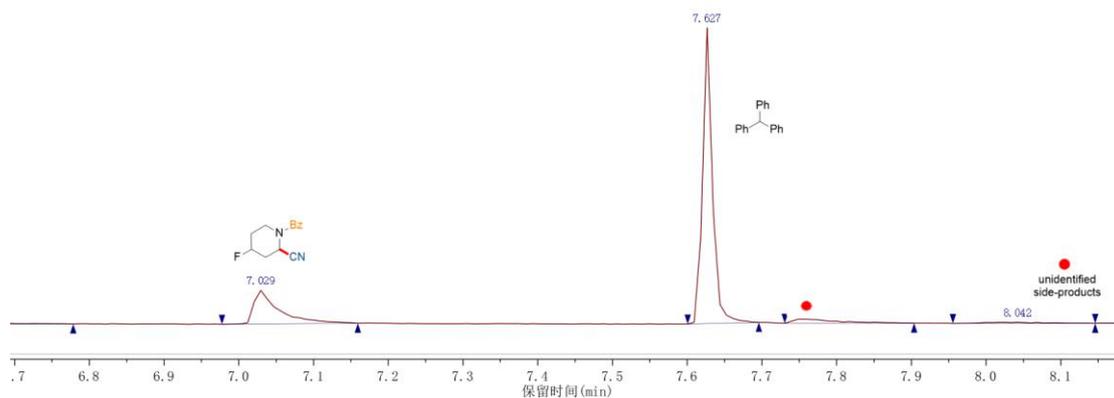
GC-MS of reaction solution of compound **3e**



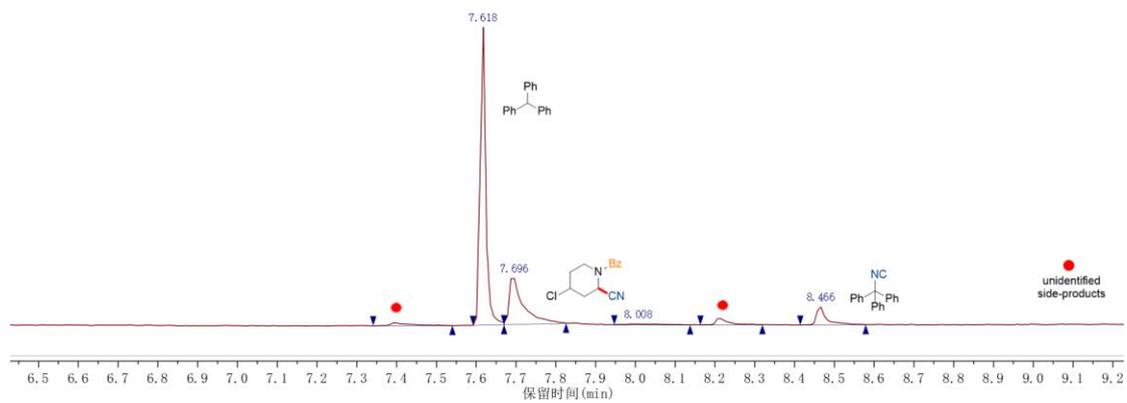
GC-MS of reaction solution of compound **3f**



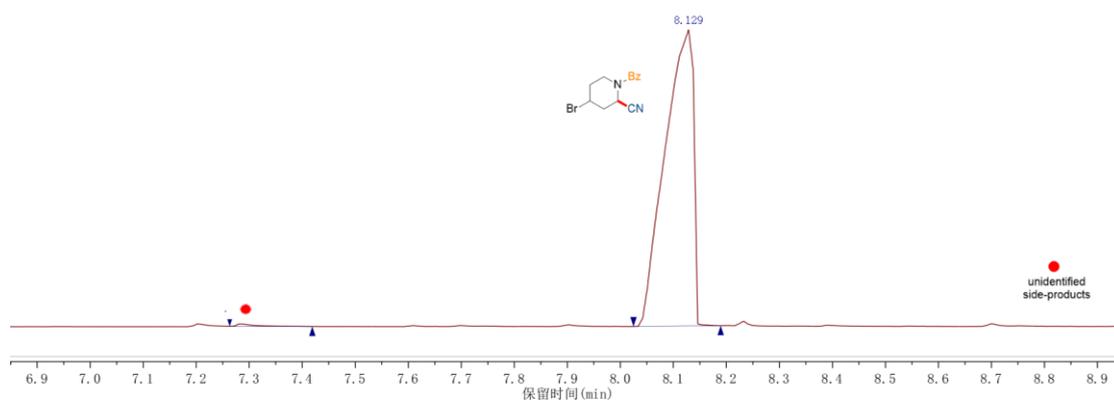
GC-MS of reaction solution of compound **3g**



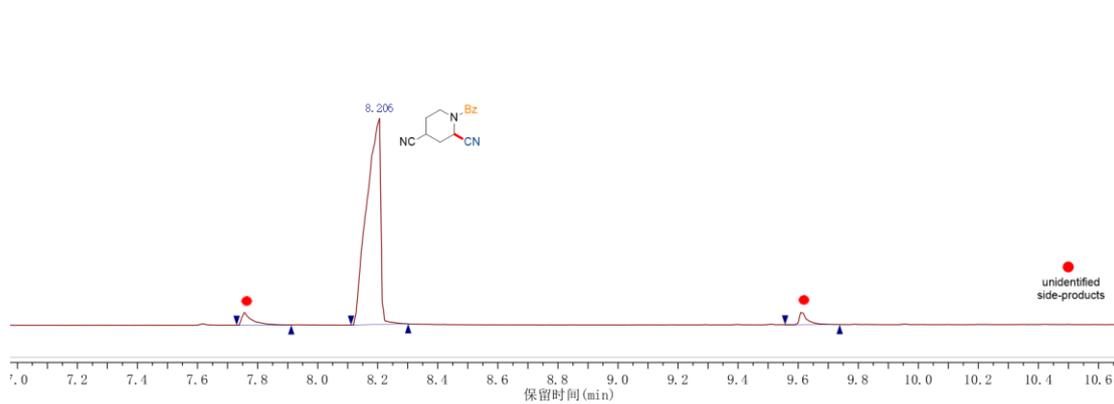
GC-MS of reaction solution of compound **3h**



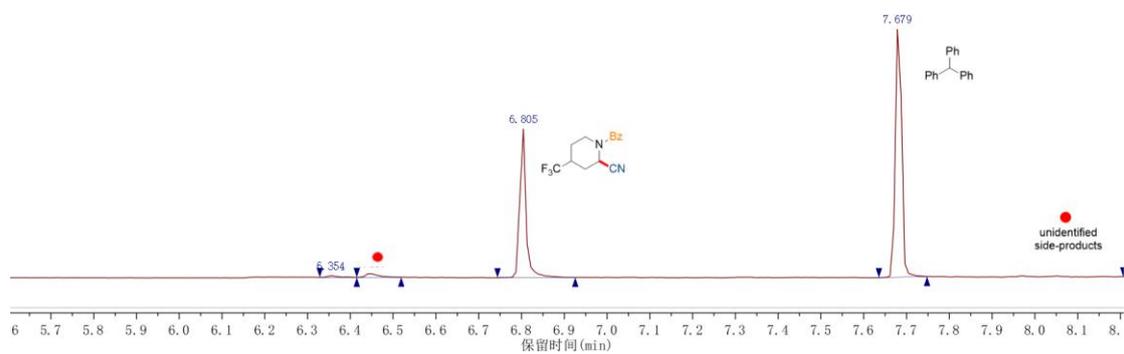
GC-MS of compound **3i**



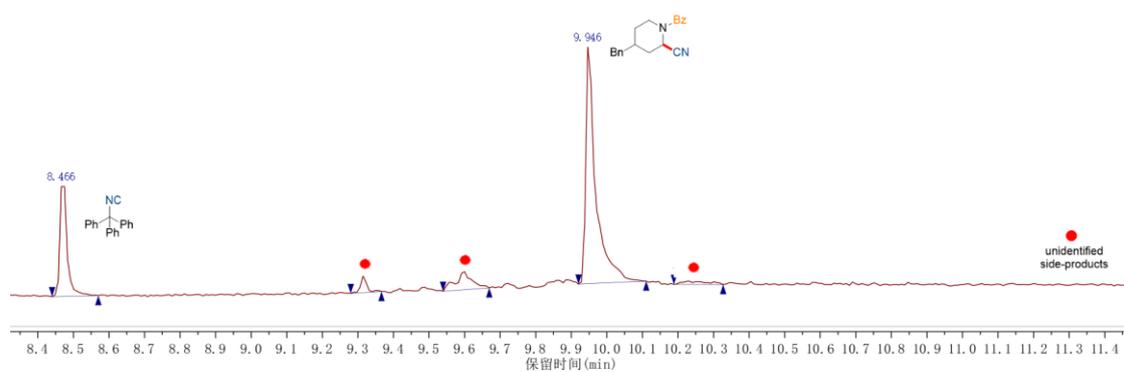
GC-MS of compound **3j**



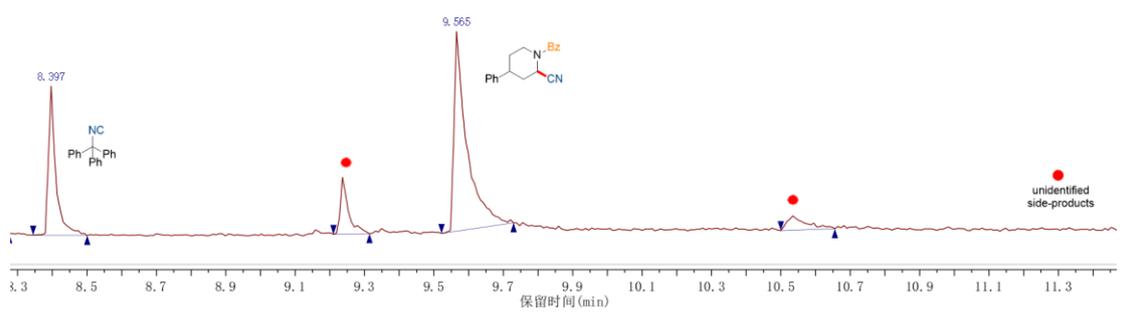
GC-MS of reaction solution of compound **3k**



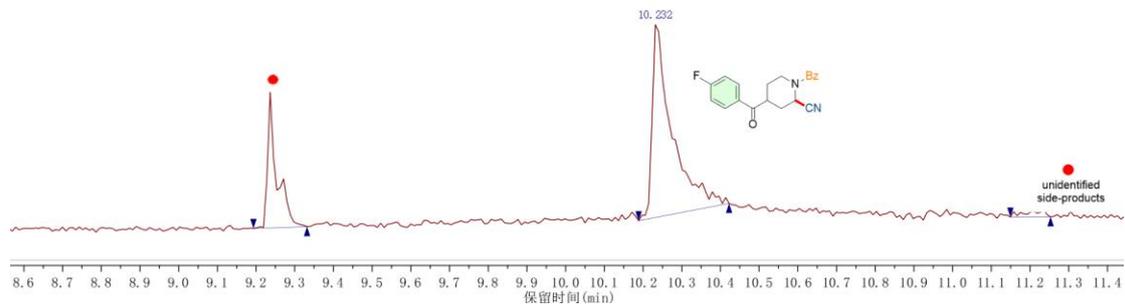
GC-MS of reaction solution of compound **3l**



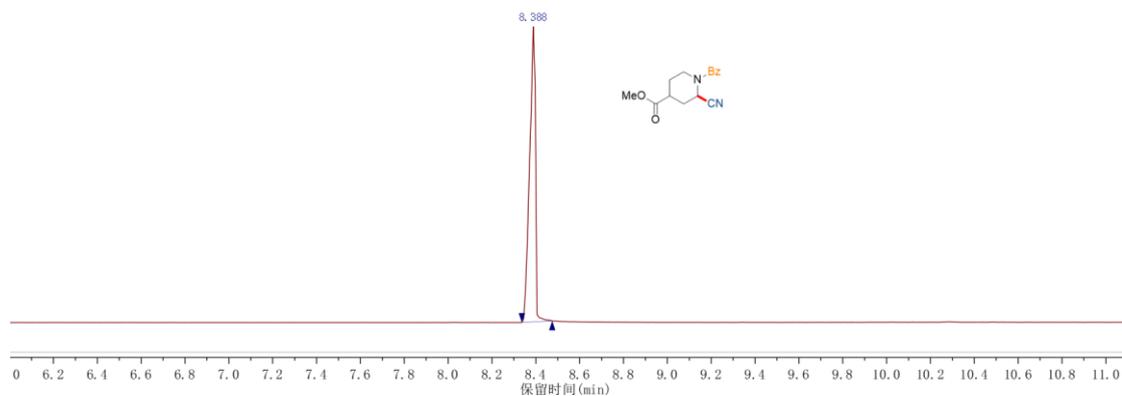
GC-MS of reaction solution of compound **3m**



GC-MS of reaction solution of compound **3n**



GC-MS of compound **3o**



GC-MS of reaction solution of compound **3p**

