*Supporting Information (experimental procedures and spectra data) for*

# Stereoselective Synthesis of *Podophyllum* Lignans Core by Intramolecular Reductive Nickel-catalysis

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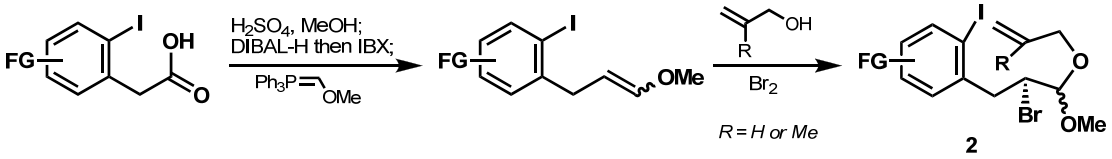
**General Procedure**

For product purification by flash column chromatography, SiliaFlash P60 (particle size: 40~63 μm, pore size 60A) and petroleum ether (bp. 60~90 °C) were used. All solvents were purified and dried by standard techniques and distilled prior to use. All of experiments were conducted under an argon or nitrogen atmosphere in oven-dried or flame-dried glassware with magnetic stirring, unless otherwise specified. Organic extracts were dried over $Na_2SO_4$ or $MgSO_4$, unless otherwise noted. IR spectra were recorded on a *Nicolet* FT-170SX spectrometer. $^1H$ and $^{13}C$ NMR spectra were taken on a *Bruker* AM-400, AM-600 and Varian mercury 300 MHz spectrometer with TMS as an internal standard and $CDCl_3$ as solvent unless otherwise noted. ESI–MS was obtained on *Bruker* esquire 6000 spectrometer. HRMS were determined on a *Bruker Daltonics* APEXII 47e FT-ICR spectrometer with ESI positive ion mode. EI–MS was obtained on GC/MS QP-2010 SE. The X-ray diffraction studies were carried out on a Bruker SMART Apex CCD area detector diffractometer equipped with graphite-monochromated Cu or Mo-Kα radiation source. Melting points were measured on *Kofler* hot stage and are uncorrected.

The following chemicals were purchased and used as received: Zn (99.9%, dust), $NiCl_2$ (99%), $NiCl_2$•DME (97%), crotonic acid (98%), pyridine (99.5%, SuperDry, with molecular sieves), DMA (99.5%, Extra Dry, with molecular sieves), DMF (99.8%, Extra Dry, with molecular sieves), triethyl phosphonoacetate (98%), (*S*)-4-phenyl-2-oxazolidinone (99%), CuBr•$SMe_2$ (99%), TMSOTf (99%), 2,4,4,6-tetrabromo-2,5-cyclohexadienone (97%).

**Preparation of β-Bromo Acetals 2** (*General Procedure A-1*)




To a stirred solution of commercially available or known *o*-iodophenylacetic acids[1] (10 mmol) in MeOH (20 mL) was added conc. $H_2SO_4$ (5 mL) at 0 °C. The mixture was gradually warmed to room temperature, stirred for 10 min, and then was refluxed for 3 h. Finally, the reaction mixture was cooled to room temperature, and the solvent was evaporated in vacuo. The residue was extracted with $CH_2Cl_2$ (3 × 50 mL). The combined organic layers were washed with saturated aqueous $NaHCO_3$ (2 × 20 mL), water (1 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting esters could be used directly for the next reaction without further purification.

To a stirred solution of the corresponding ester (10 mmol) in anhydrous THF (30 mL) was added DIBAL-H (1.0 M in hexanes, 21 mL, 21 mmol, 2.1 equiv) dropwise at −78 °C. The mixture was gradually warmed to room temperature, and stirred further for 6 h. The reaction was quenched with $H_2O$ (20 mL) at 0 °C. The mixture was acidified to pH = 1 with conc. HCl, and extracted EtOAc (3 × 40 mL). The combined organic layers were washed with water (20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting alcohol (ca. 10 mmol) was dissolved in anhydrous EtOAc (40 mL) followed by the addition of IBX (4.200 g, 15 mmol, 1.5 equiv). The mixture was heated to 80 $^oC$ and stirred for 2 h and then cooled to room temperature. The reaction mixture was then filtered through Celite and the filtrate was evaporated to give the expected aldehyde, which could be used directly for the next reaction without further purification.

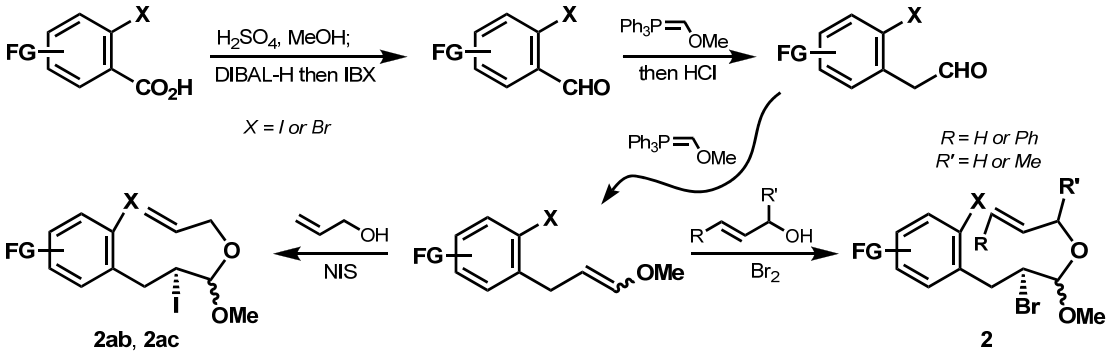
(1) (a) Mei, T.-S.; Wang, D.-H.; Yu, J.-Q. *Org. Lett.* **2010**, *12*, 3140. (b) Qandil, A. M.; Miller, D. W.; Nichols, D. E. *Synthesis* **1999**, 2033.

This step is adapted from a known procedure.[2] *t*-BuOK (98%, 1.257 g, 11 mmol, 1.1 equiv) was added in portions to a suspension of (methoxymethyl)triphenylphosphonium chloride (4.116 g, 12.0 mmol, 1.2 equiv) in THF (30 mL) at 0 ºC. After stirring for 40 min at 0 ºC, a solution of the above 2-(2-iodophenyl)acetaldehyde (ca. 10 mmol) in THF (10 mL) was added dropwise. The resulting mixture was gradually warmed to room temperature, and stirred further for 4 h. The reaction was then quenched by the addition of saturated aqueous $NH_4Cl$ solution (3 mL). The resulting mixture was extracted with EtOAc (3 × 50 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 60 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel to afford the corresponding enol methylether as a colorless oil.

This step is adapted from a known procedure.[3] In a 50 mL round-bottom flask, $Br_2$ (0.09 mL, 1.8 mmol, 1.0 equiv) was dissolved in anhydrous $CH_2Cl_2$ (5 mL) and cooled to −78 °C. To the resulting solution was added the above enol methylether (1.8 mmol) in $CH_2Cl_2$ (5 mL) dropwise over a 2 min period. The mixture was then stirred for 40 min at −78 °C followed by the addition of a solution of allyl alcohol (36 mmol, 20.0 equiv) and *N*,*N*-dimethylaniline (0.5 mL, 3.6 mmol, 2.0 equiv) in $CH_2Cl_2$ (5 mL) dropwise. The resulting mixture was gradually warmed to room temperature, stirred for 9 h, and quenched with saturated aqueous $NaHCO_3$ (2 mL). The reaction mixture was extracted with $CH_2Cl_2$ (3 × 40 mL), and the combined organic layers were washed with HCl (3*N*, 15 mL), water (2 × 15 mL) and brine (15 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 30 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel to afford the corresponding *β*-bromo acetal **2** as a colorless oil.

(2) Jiménez-Núñez, E.; Raducan, M.; Lauterbach, T.; Molawi, K.; Solorio, C. R.; Echavarren, A. M. *Angew. Chem., Int. Ed*. **2009**, *48*, 6152.
(3) Zhang, J.-J.; Yan, C.-S.; Peng, Y.; Luo, Z.-B.; Xu, X.-B.; Wang, Y.-W. *Org. Biomol. Chem.* **2013**, *11*, 2498, and references cited therein.

**Preparation of β-Bromo Acetals 2** (*General Procedure A-2*)




*o*-Iodo( or Bromo)benzaldehydes were prepared according to the corresponding protocol in *General Procedure A-1*.

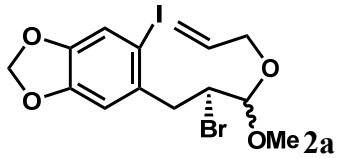
*t*-BuOK (98%, 2.286 g, 20 mmol, 2.0 equiv) was added in portions to a suspension of (methoxymethyl)triphenylphosphonium chloride (7.203 g, 21 mmol, 2.1 equiv) in THF (30 mL) at 0 ºC. After stirring for 40 min at 0 ºC, a solution of the above *o*-iodo( or bromo)benzaldehyde (10 mmol) in THF (15 mL) was added dropwise and the resulting mixture was gradually warmed to room temperature, and stirred for 4 h. The reaction was quenched by addition of saturated aqueous $NH_4Cl$ solution (5 mL). The mixture was extracted with EtOAc (3 × 50 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 60 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel. The resulting enol ether was dissolved in acetone (25 mL) followed by the addition of 2*N* HCl (4 mL) at room temperature. The mixture was heated to 60 $^{o}$C and stirred for 2 h, and then cooled to room temperature. The solvent was evaporated in vacuo, and the residue was extracted with $CH_2Cl_2$ (3 × 40 mL), and the combined organic layers were washed with saturated aqueous $NaHCO_3$ (2 × 20 mL), water (20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting phenylacetaldehyde could be used directly for the next reaction without further purification.

*t*-BuOK (98%, 1.143 g, 10 mmol, 1.0 equiv) was added in portions to a suspension of (methoxymethyl)triphenylphosphonium chloride (4.116 g, 12 mmol, 1.2 equiv) in

THF (25 mL) at 0 ºC. After stirring for 40 min at 0 ºC, a solution of the above 2-(2-iodophenyl)acetaldehyde (10 mmol) in THF (10 mL) was added dropwise and the resulting mixture was gradually warmed to room temperature, and stirred for 4 h. The reaction was quenched by the addition of saturated aqueous $NH_4Cl$ solution (3 mL). The mixture was extracted with EtOAc (3 × 40 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 80 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel to afford the corresponding enol methylether as a colorless oil.

The following synthesis of *β*-bromo acetal **2** was completed according to the corresponding protocol in *General Procedure A-1*.

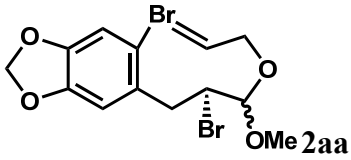
In a 25 mL round-bottom flask, allyl alcohol (2.4 mL, 35 mmol, 50 equiv) was dissolved in anhydrous $CH_2Cl_2$ (5 mL) and cooled to –45 °C. To the stirred solution were added the above enol methylether (0.7 mmol) and $Et_3N$ (0.1 mL, 0.7 mmol, 1.0 equiv), followed by the addition of NIS (99%, 159 mg, 0.7 mmol, 1.0 equiv). The resulting mixture was gradually warmed to room temperature, and stirred for 36 h. The mixture was then extracted with $CH_2Cl_2$ (3 × 20 mL), and the combined organic layers were washed with water (2 × 10 mL) and brine (10 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 25 : 1 → petroleum ether/EtOAc = 5 : 1) on silica gel to afford **2ab** or **2ac**.



**2a**

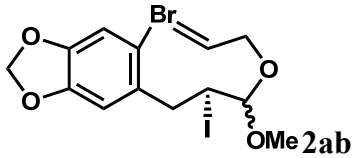
**2a** was prepared as a colorless oil (2.800 g, 59% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.59 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3078, 2898, 2837, 1647, 1619, 1545, 1502, 1477, 1347, 1256, 1228, 1117, 1042, 933, 861, 648 $cm^{-1}$; (*major isomer*) $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.24 (s, 1H),

6.82 (s, 1H), 6.05–5.90 (m, 1H), 5.97 (s, 2H), 5.36 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.24 (dd, *J* = 10.5, 1.2 Hz, 1H), 4.56 (d, *J* = 3.9 Hz, 1H), 4.31–4.23 (m, 2H), 4.17 (dd, *J* = 12.9, 6.0 Hz, 1H), 3.50 (s, 3H), 3.44 (dd, *J* = 14.7, 3.6 Hz, 1H), 3.03 (dd, *J* = 14.7, 10.5 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$):$\delta$ = 148.1, 147.4, 133.9, 133.8, 118.6, 117.7, 111.5, 104.4, 101.6, 87.9, 69.2, 56.0, 53.7, 42.9 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{16}O_4{}^{79}BrINa^+$ $[M+Na]^+$: 476.9169, found: 476.9171.



**2aa**

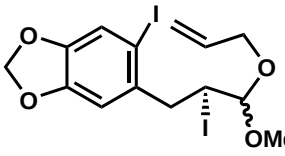
**2aa** was prepared as a yellow oil (1.300 g, 68% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.63 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3078, 2898, 2836, 1647, 1624, 1503, 1479, 1410, 1352, 1231, 1119, 1041, 933, 860, 833, 656 cm$^{-1}$; (*major isomer*) $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.00 (s, 1H), 6.79 (s, 1H), 6.01–5.91 (m, 1H), 5.97 (s, 2H), 5.35 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.23 (dd, *J* = 10.5, 0.9 Hz, 1H), 4.56 (d, *J* = 4.2 Hz, 1H), 4.34–4.22 (m, 2H), 4.15 (ddd, *J* = 12.3, 5.7, 0.9 Hz, 1H), 3.51 (dd, *J* = 14.7, 3.6 Hz, 1H), 3.49 (s, 3H), 2.96 (dd, *J* = 14.7, 10.8 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 147.3, 146.9, 133.8, 130.4, 117.6, 114.5, 112.6, 111.9, 104.3, 101.6, 69.1, 55.7, 53.4, 38.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{16}O_4{}^{79}Br_2Na^+$ $[M+Na]^+$: 428.9308, found: 428.9306.



**2ab**

**2ab** was prepared as a yellow oil (275 mg, 61% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.58 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3079, 2922, 1503, 1648, 1624, 1503, 1478, 1410, 1353, 1248, 1231, 1117, 1040, 933, 860, 654 cm$^{-1}$; (*major isomer*) $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 6.98 (s, 1H), 6.76 (s, 1H), 6.08–5.89 (m, 1H), 5.97 (s, 2H), 5.35 (dd, *J* = 17.2, 1.2 Hz, 1H), 5.23 (d, *J* = 9.2 Hz, 1H), 4.42 (t, *J* = 4.8 Hz, 1H), 4.27 (d, *J* = 4.0 Hz, 1H), 4.17 (dd, *J* = 16.0,

5.2 Hz, 1H), 4.10 (dd, $J$ = 12.4, 5.6 Hz, 1H), 3.44 (s, 3H), 3.38 (dd, $J$ = 14.4, 4.0 Hz, 1H) , 3.05 (dd, $J$ = 14.8, 10.4 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 147.4, 147.0, 133.9, 131.7, 117.6, 114.6, 112.7, 111.6, 104.7, 101.7, 69.1, 55.4, 40.5, 34.2 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{16}O_4{}^{79}BrINa^+$ $[M+Na]^+$: 476.9169, found: 476.9164.

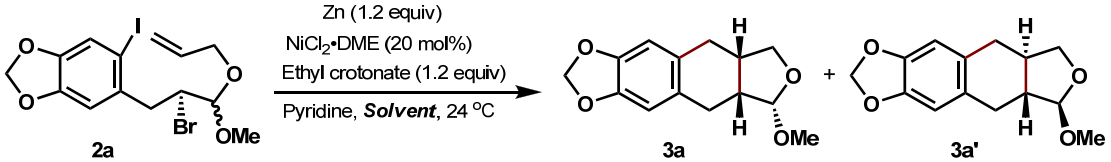


**2ac**

**2ac** was prepared as a yellow oil (281 mg, 60% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.59 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3077, 2900, 1646, 1600, 1502, 1476, 1406, 1385, 1346, 1229, 1115, 1040, 933, 860, 737, 644 cm$^{-1}$; (*major isomer*) $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.23 (s, 1H), 6.79 (s, 1H), 6.00–5.90 (m, 1H), 5.98 (s, 2H), 5.33 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.22 (d, $J$ = 10.0 Hz, 1H), 4.40 (t, $J$ = 4.4 Hz, 1H), 4.29–4.22 (m, 1H), 4.19 (d, $J$ = 4.0 Hz, 1H), 4.11 (dd, $J$ = 12.8, 6.0 Hz, 1H), 3.49 (s, 3H), 3.33 (dd, $J$ = 14.8, 5.6 Hz, 1H), 3.11 (dd, $J$ = 14.8, 10.0 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 148.1, 147.4, 135.2, 133.9, 118.7, 117.6, 111.1, 104.4, 101.6, 87.9, 69.2, 55.4, 44.8, 34.7 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{16}O_4I_2Na^+$ $[M+Na]^+$: 524.9030, found: 524.9029.

## Optimization of Tandem Cyclization

**Table S1. Screening of Solvents**

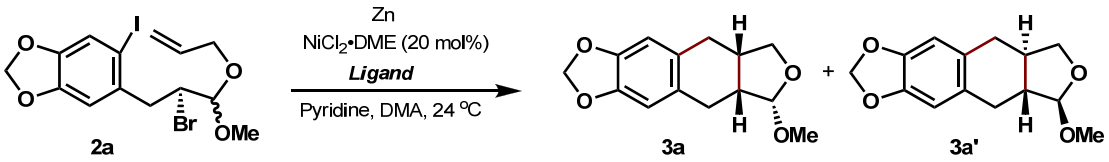



| Entry[a] | ***Solvent*** | **3a**, Yield[b] (%) | **3a′**, Yield[b] (%) | Recovered **2a** (%) |
|---|---|---|---|---|
| 1 | DMPU | 38 | 15 | 29 |
| 2 | MeOH | 24 | 9 | 47 |
| 3 | DMF | 38 | 13 | 37 |
| 4 | $CH_3CN$ | 50 | 24 | 7 |

| | | | | |
|---|---|---|---|---|
| 5 | ***DMA*** | ***56*** | ***28*** | ***3*** |
| 6 | Toluene | 42 | 20 | 21 |

[a] Reaction conducted on 0.6 mmol scale: A mixture of Zn (0.72 mmol), $NiCl_2$•DME (0.12 mmol), ethyl crotonate (0.72 mmol), and pyridine (1.0 mL) were employed for the generation of active $Ni^0$ catalyst at 55 °C; then a solution of **2a** (0.6 mmol) in the indicated solvent (6 mL) was added to the above $Ni^0$ complex dropwise at 24 °C. The resulting mixture was stirred for 3 h and then work up. [b] The isolated yield was shown.

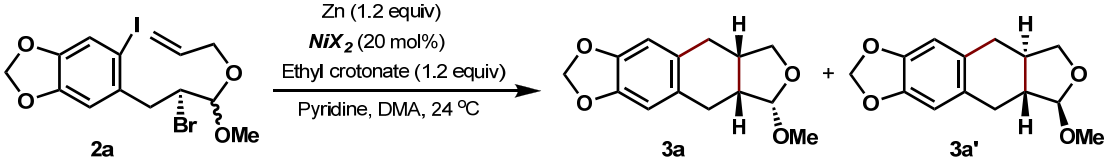
## Table S2. Screening of Ligands




| Entry[a] | ***Ligand*** | **3a**, Yield[b] (%) | **3a′**, Yield[b] (%) | Recovered **2a** (%) |
|---|---|---|---|---|
| 1[c] | 2,2′-bipy | 35 | 18 | 25 |
| 2[c] | 4,4′-di-*tBu*-2,2′-bipy | 29 | 14 | 47 |
| 3[c] | 4,4′-di-OMe-2,2′-bipy | 27 | 13 | 51 |
| 4[c] | 1,10-phen | N.D. | N.D. | 92 |
| 5[c] | 4,7-di-Ph-1,10-phen | N.D. | N.D. | 92 |
| 6[d] | ***EC*** | ***56*** | ***28*** | ***3*** |

[a] Reaction conducted on 0.6 mmol scale: A mixture of Zn, $NiCl_2$•DME (0.12 mmol), ligand, and pyridine (1.0 mL) were employed for the generation of active $Ni^0$ catalyst at 55 °C; then a solution of **2a** (0.6 mmol) in DMA (6 mL) was added to the above $Ni^0$ complex dropwise at 24 °C. The resulting mixture was stirred for 3 h and then work up. [b] The isolated yield was shown. [c] Zn was used with 3 equiv to Ni and *N*-ligand was used with 1.2 equiv to Ni. [d] Zn and ethyl crotonate were used with 6 equiv to Ni.

## Table S3. Optimization of Tandem Cyclization: Screening of Ni Salts

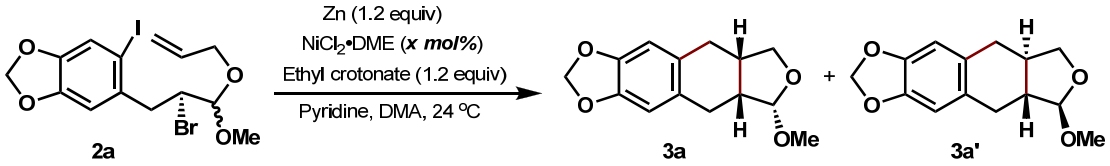



| Entry[a] | ***$NiX_2$*** | **3a**, Yield[b] (%) | **3a′**, Yield[b] (%) | Recovered **2a** (%) |
|---|---|---|---|---|
| 1 | $NiCO_3$ | N.D. | N.D. | 98 |
| 2 | $Ni(OTf)_2$ | N.D. | N.D. | 100 |
| 3 | $Ni(acac)_2$ | N.D. | N.D. | 98 |
| 4 | $NiI_2$ | 25 | 9 | 50 |

| | | | | |
|---|---|---|---|---|
| 5 | $NiCl_2$ | 54 | 26 | 4 |
| 6 | ***$NiCl_2$•DME*** | ***56*** | ***28*** | ***3*** |

[a] Reaction conducted on 0.6 mmol scale: A mixture of Zn (0.72 mmol), $NiX_2$ (0.12 mmol), ethyl crotonate (0.72 mmol), and pyridine (1.0 mL) were employed for the generation of active $Ni^0$ catalyst at 55 °C; then a solution of **2a** (0.6 mmol) in DMA (6 mL) was added to the above $Ni^0$ complex dropwise at 24 °C. The resulting mixture was stirred for 3 h and then work up. [b] The isolated yield was shown. N.D. = No detection.

## Table S4. Investigation of Ni Loading

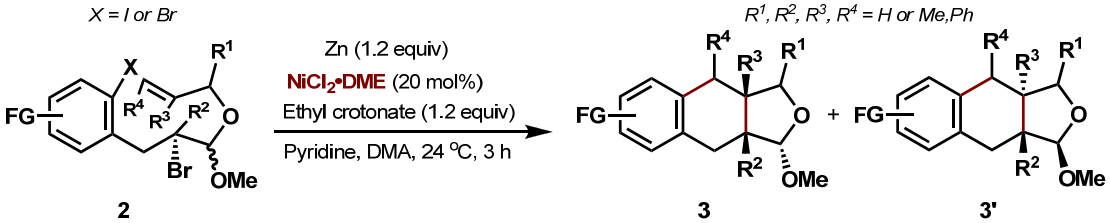



| Entry[a] | ***x mol%*** | Time (h) | **3a**, Yield[b] (%) | **3a′**, Yield[b] (%) | Recovered **2a** (%) |
|---|---|---|---|---|---|
| 1 | 100 | 2 | 57 | 28 | N.D. |
| 2 | 50 | 3 | 56 | 28 | N.D. |
| 3 | 30 | 3 | 56 | 28 | 2 |
| 4 | ***20*** | ***3*** | ***56*** | ***28*** | ***3*** |
| 5 | 20 | 24 | 56 | 28 | 3 |
| 6 | 15 | 24 | 26 | 12 | 55 |
| 7 | 15 | 36 | 26 | 12 | 55 |
| 8 | 15 | 36 | 27 | 12 | 54 |
| 9 | 10 | 36 | 7 | 2 | 74 |

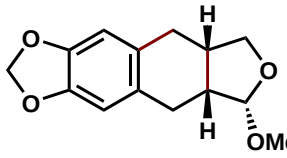
[a] Reaction conducted on 0.6 mmol scale: A mixture of Zn (0.72 mmol), $NiCl_2$•DME (X mmol), ethyl crotonate (0.72 mmol), and pyridine (1.0 mL) were employed for the generation of active $Ni^0$ catalyst at 55 °C; then a solution of **2a** (0.6 mmol) in DMA (6 mL) was added to the above $Ni^0$ complex dropwise at 24 °C. The resulting mixture was stirred for the indicated time and then work up. [b] The isolated yield was shown.

## Stereoselective Synthesis of Tetrahydronaphtho [2, 3-*c*]furans

(*General Procedure B*)



To a stirred slurry of Zn (47 mg, 0.72 mmol, 1.2 equiv) and $NiCl_2$•DME[4] (26.4 mg, 0.12 mmol, 0.2 equiv) in pyridine (1 mL) was added ethyl crotonate (89 $\mu$L，0.72 mmol, 1.2 equiv) at room temperature. The temperature then rose to 55 °C, and stirring (300 r/min) was continued for 15 min. The resulting red-brown complex was cooled to 24 °C, and a solution of $\beta$-bromo acetal **2** (0.6 mmol) in DMA (6 mL) was added dropwise. After stirring for 3 h, the reaction mixture was filtered with a short plug of silica (elution with 20 mL of EtOAc). The filtrate was extracted with EtOAc (2 × 40 mL), and the combined organic layers were washed with water (2 × 10 mL) and brine (10 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated. The crude product was purified by flash column chromatography on silica gel to afford desired **3** and **3′**.



**3a**

**3a** was prepared as a white solid (84 mg, 56% yield) according to *General Procedure B*. $R_f$ = 0.57 (petroleum ether/EtOAc = 4 : 1); Mp. 117–119 °C; IR (film): $\nu_{max}$ = 2954, 2937, 2869, 1501, 1485, 1469, 1452, 1374, 1358, 1304, 1244, 1186, 1159, 1111, 1064, 1045, 1008, 928, 855, 766, 731, 535 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.66 (s, 1H), 6.61 (s, 1H), 5.89 (s, 2H), 4.96 (d, $J$ = 4.8 Hz, 1H), 4.07 (t, $J$ = 7.5 Hz, 1H), 3.56 (t, $J$ = 7.2 Hz, 1H), 3.36 (s, 3H), 2.78 (dd, $J$ = 13.8, 8.1 Hz, 1H), 2.65 (dd, $J$ = 12.3, 8.4 Hz, 1H), 2.58–2.38 (m, 4H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 145.6, 145.3, 132.3, 131.2, 108.3, 108.0, 105.5, 100.5, 70.6, 54.9, 43.2, 38.6, 32.5, 27.2 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{20}O_4N^+$ $[M+NH_4]^+$: 266.1387, found: 266.1390. This product (5 mg) was dissolved in EtOAc (0.6 mL), petroleum ether (1 mL) and hexane (1 mL). After 4 days, colorless single crystals were obtained by slow evaporation of solvent at room temperature.

(4) It could be prepared according to a known procedure, see: Boudier, A.; Breuil, P.-A. R.; Magna, L.; Olivier-Bourbigou, H.; Braunstein, P. *J. Organomet. Chem.* **2012**, *718*, 31. This nickel salt is also available from Strem (No. 93-2801).

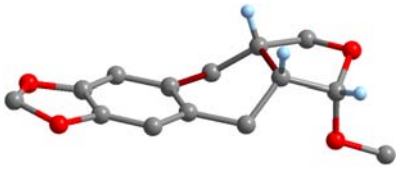
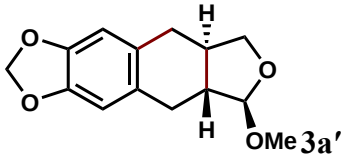


**Table S5**: X-ray crystal data of **3a** (selected H atoms have been omitted for clarity)

| | |
|---|---|
| Empirical formula | $C_{14}H_{16}O_4$ |
| Temperature (K) | 292.9(5) |
| Crystal color | colorless |
| Formula weight | 248.27 |
| Crystal system | Monoclinic |
| Space group | $P2_1/n$ |
| $a$ (Å) | 13.2065(13) |
| $b$ (Å) | 6.4912(5) |
| $c$ (Å) | 14.9358(16) |
| $\alpha$ (°) | 90.00 |
| $\beta$ (°) | 110.261(11) |
| $\gamma$ (°) | 90.00 |
| $V$ (Å $^3$) | 1201.16(19) |
| $Z$ | 4 |
| Density (calculated) (g/cm$^3$) | 1.373 |
| $F$ (000) | 528 |
| $\lambda$ (Å) | 0.71073 |
| Reflections collected | 5484 |
| Independent reflections | 2726 |
| $\theta$ Range for data collection (°) | 3.29—28.56 |
| Index range | $-10 \le h \le 17$<br>$-8 \le k \le 4$<br>$-18 \le l \le 18$ |
| Final $R$ indices [I>2σ($I$)] | $R_1 = 0.0690$, $wR_2 = 0.1882$ |
| Largest difference peak and hole [e Å $^{-3}$] | 0.410, –0.232 |




**3a′**

**3a′** was prepared as a white solid (42 mg, 28% yield) according to *General Procedure B*. $R_f$ = 0.40 (petroleum ether/EtOAc = 4 : 1); Mp. 120–122 °C; IR (film): $\nu_{max}$ = 2921, 2846, 1503, 1483, 1440, 1388, 1226, 1095, 1038, 991, 933, 856, 760, 660 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.59 (s, 1H), 6.56 (s, 1H), 5.90 (s, 2H), 4.85 (d, $J$ = 6.4 Hz, 1H), 4.11 (t, $J$ = 7.6 Hz, 1H), 3.68 (dd, $J$ = 10.4, 7.6 Hz, 1H), 3.49 (s, 3H), 2.98 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.82 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.67 (dd, $J$ = 13.2, 12.8 Hz, 1H), 2.60 (dd, $J$ = 13.6, 12.8 Hz, 1H), 2.16–2.05 (m, 1H), 1.92 (ddd, $J$ = 18.0, 12.4, 5.6 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 146.0 (2C), 128.7, 128.4, 109.8, 109.3, 109.1, 100.8, 71.6, 56.5, 48.2, 41.7, 31.9, 31.4 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{16}O_4Na^+$ $[M+Na]^+$: 271.0941, found: 271.0939. This product was dissolved in EtOAc (0.5 mL), DCM (0.5 mL) and hexane (2 mL). After 5 days, colorless single crystals were obtained by slow evaporation of solvent at room temperature.

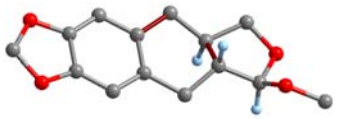
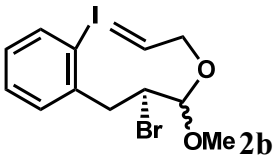


**Table S6**: X-ray crystal data of **3a′** (selected H atoms have been omitted for clarity)

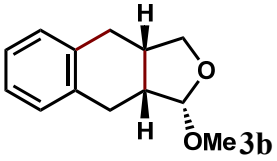
| | |
|---|---|
| Empirical formula | $C_{14}H_{16}O_4$ |
| Temperature (K) | 293(2) |
| Crystal color | colorless |
| Formula weight | 248.27 |
| Crystal system | Monoclinic |
| Space group | $P2_1/n$ |
| $a$ (Å) | 5.0801(7) |
| $b$ (Å) | 17.337(3) |
| $c$ (Å) | 13.987(2) |
| $\alpha$ (°) | 90.00 |
| $\beta$ (°) | 95.513(14) |
| $\gamma$ (°) | 90.00 |
| $V$ (Å $^3$) | 1226.2(3) |
| $Z$ | 4 |
| Density (calculated) (g/$cm^3$) | 1.345 |

| | |
|---|---|
| *F* (000) | 528 |
| $\lambda$ (Å) | 1.54184 |
| Reflections collected | 4114 |
| Independent reflections | 2298 |
| $\theta$ Range for data collection (°) | 4.072—70.780 |
| Index range | $-6 \le h \le 5$<br>$-15 \le k \le 20$<br>$-16 \le l \le 15$ |
| Final *R* indices [I>2σ(*I*)] | $R_1 = 0.0671$, $wR_2 = 0.1855$ |
| Largest difference peak and hole [e Å $^{-3}$] | 0.261, –0.252 |



**2b**

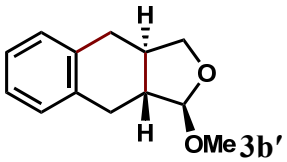
**2b** was prepared as a colorless oil (700 mg, 71% overall yield, dr = 1 : 1) according to *General Procedure A-1*. $R_f$ = 0.67 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3061, 2926, 2854, 1648, 1587, 1563, 1466, 1437, 1348, 1261, 1197, 1126, 1054, 1012, 919, 751, 647 cm$^{-1}$; (*major isomer*) $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.83 (d, *J* = 7.8 Hz, 1H), 7.30 (d, *J* = 4.5 Hz, 2H), 6.96 (dd, *J* = 8.1, 4.2 Hz, 1H), 5.98 (ddd, *J* = 17.1, 10.5, 5.4 Hz, 1H), 5.35 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.24 (dd, *J* = 10.5, 1.2 Hz, 1H), 4.59 (d, *J* = 3.9 Hz, 1H), 4.39–4.35 (m, 1H), 4.31–4.23 (m, 1H), 4.22–4.12 (m, 1H), 3.54 (dd, *J* = 14.7, 3.3, Hz, 1H), 3.51 (s, 3H), 3.13 (dd, *J* = 14.7, 10.5 Hz, 1H) ppm; $^{13}$C NMR (75 MHz, $CDCl_3$): $\delta$ = 140.6, 139.5, 133.8, 131.7, 128.6, 128.0, 117.6, 104.4, 100.4, 69.2, 55.9, 53.3, 43.1 ppm; HRMS (ESI): *m*/*z* calcd for $C_{13}H_{16}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 432.9271, found: 432.9277.



**3b**

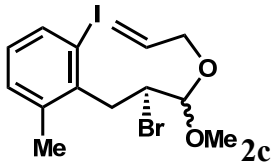
**3b** was prepared as a colorless oil (65 mg, 53% yield) according to *General Procedure B*. $R_f$ = 0.62 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3067, 3019, 2933, 2874, 2830, 1583, 1546, 1488, 1457, 1369, 1225, 1183, 1108, 1070, 1020, 939,

897, 749 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.14–7.08 (m, 4H), 4.98 (d, $J$ = 5.2 Hz, 1H), 4.10 (t, $J$ = 8.0 Hz, 1H), 3.60 (t, $J$ = 8.0 Hz, 1H), 3.37 (s, 3H), 2.88 (dd, $J$ = 14.4, 9.6 Hz, 1H), 2.75 (dd, $J$ = 13.2, 4.8 Hz, 1H), 2.67 (dd, $J$ = 14.4, 6.8 Hz, 1H), 2.57–2.50 (m, 1H), 2.52 (dd, $J$ = 12.8, 10.0 Hz, 1H), 2.47–2.40 (m, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 139.4, 138.5, 127.5, 127.1, 126.1, 125.8, 105.5, 70.8, 54.8, 43.1, 38.4, 32.7, 27.2 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{16}O_2Na^+$ $[M+Na]^+$: 227.1043, found: 227.1046.



**3b′**

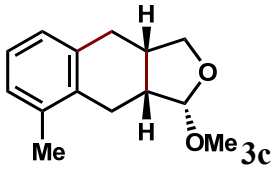
**3b′** was prepared as a white solid (38 mg, 31% yield) according to *General Procedure B*. $R_f$ = 0.50 (petroleum ether/EtOAc = 4 : 1); Mp. 93–94 °C; IR (film): $\nu_{max}$ = 3063, 2923, 2847, 1598, 1491, 1450, 1437, 1398, 1236, 1116, 994, 923, 850, 747, 659 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.14–7.10 (m, 4H), 4.87 (d, $J$ = 6.4 Hz, 1H), 4.13 (dd, $J$ = 7.6, 6.4 Hz, 1H), 3.70 (dd, $J$ = 10.4, 7.6 Hz, 1H), 3.49 (s, 3H), 3.11 (dd, $J$ = 15.6, 4.8 Hz, 1H), 2.94 (dd, $J$ = 15.6, 4.8 Hz, 1H), 2.75 (dd, $J$ = 16.0, 12.8 Hz, 1H), 2.69 (dd, $J$ = 16.0, 10.4 Hz, 1H), 2.20–2.08 (m, 1H), 1.95 (ddd, $J$ = 17.6, 12.0, 5.6 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 135.9, 135.5, 129.9, 129.7, 126.07, 126.05, 109.9, 71.7, 56.5, 48.0, 41.6, 31.8, 31.4 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{16}O_2Na^+$ $[M+Na]^+$: 227.1043, found: 227.1045.



**2c**

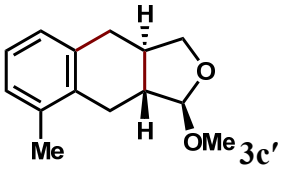
**2c** was prepared as a colorless oil (540 mg, 40% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.74 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3053, 2956, 2928, 2867, 1647, 1587, 1557, 1448, 1349, 1268, 1196, 1129, 1057, 920, 769, 736, 644, 561 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.70 (d, $J$ = 8.0 Hz, 1H), 7.14 (d, $J$ = 7.2 Hz, 1H), 6.82 (t, $J$ = 8.0 Hz, 1H), 6.00–5.90 (m,

1H), 5.33 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.21 (dd, $J$ = 10.8, 1.6 Hz, 1H), 4.62–4.55 (m, 2H), 4.25 (dd, $J$ = 12.8, 5.6 Hz, 1H), 4.15 (dd, $J$ = 12.8, 5.6 Hz, 1H), 3.48 (s, 3H), 3.42 (d, $J$ = 4.8 Hz, 1H), 3.41 (d, $J$ = 7.2 Hz, 1H), 2.46 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 139.2, 139.1, 138.0, 133.9, 130.8, 128.5, 117.4, 104.4, 101.9, 69.3, 55.2, 52.9, 39.3, 21.7 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 446.9427, found: 446.9426.



**3c**

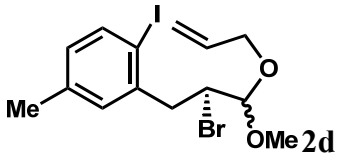
**3c** was prepared as a white solid (65 mg, 50% yield) according to *General Procedure B*. $R_f$ = 0.68 (petroleum ether/EtOAc = 4 : 1); Mp. 103–105 °C; IR (film): $\nu_{max}$ = 3019, 2927, 1591, 1470, 1444, 1371, 1266, 1183, 1116, 1070, 1038, 1012, 939, 773, 736 cm$^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.02 (d, $J$ = 7.6 Hz, 1H), 7.01 (d, $J$ = 5.2 Hz, 1H), 6.94 (dd, $J$ = 8.8, 5.2 Hz, 1H), 4.99 (d, $J$ = 5.2 Hz, 1H), 4.08 (t, $J$ = 8.0 Hz, 1H), 3.57 (t, $J$ = 8.0 Hz, 1H), 3.37 (s, 3H), 2.81 (dd, $J$ = 15.2, 8.0 Hz, 1H), 2.75 (dd, $J$ = 13.6, 5.2 Hz, 1H), 2.69 (dd, $J$ = 15.2, 8.4 Hz, 1H), 2.56–2.48 (m, 1H), 2.52 (dd, $J$ = 13.2, 10.4 Hz, 1H), 2.47–2.41 (m, 1H), 2.31 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 138.5, 137.7, 135.2, 128.2, 125.5, 125.4, 106.1, 71.2, 55.2, 43.2, 38.3, 33.2, 23.1, 19.7 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1195.



**3c′**

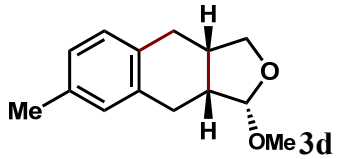
**3c′** was prepared as a white solid (30 mg, 23% yield) according to *General Procedure B*. $R_f$ = 0.59 (petroleum ether/EtOAc = 4 : 1); Mp. 91–93 °C; IR (film): $\nu_{max}$ = 3065, 2923, 2857, 1582, 1465, 1379, 1238, 1186, 1127, 993, 928, 765, 710 cm$^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.07 (d, $J$ = 7.2 Hz, 1H), 7.03 (t, $J$ = 6.8 Hz,

1H), 6.97 (d, $J$ = 7.2 Hz, 1H), 4.91 (d, $J$ = 6.4 Hz, 1H), 4.14 (dd, $J$ = 7.6, 6.4 Hz, 1H), 3.70 (dd, $J$ = 10.4, 7.6 Hz, 1H), 3.51 (s, 3H), 3.06 (dd, $J$ = 16.0, 5.2 Hz, 1H), 2.93 (dd, $J$ = 16.0, 4.8 Hz, 1H), 2.71 (dd, $J$ = 14.8, 12.8 Hz, 1H), 2.48 (dd, $J$ = 16.0, 12.4 Hz, 1H), 2.25 (s, 3H), 2.18–2.06 (m, 1H), 1.95 (ddd, $J$ = 18.4, 12.0, 6.0 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 137.2, 135.5, 134.6, 127.7, 127.4, 125.8, 110.2, 71.8, 56.5, 48.2, 41.1, 32.4, 28.8, 19.7 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1195.



**2d**

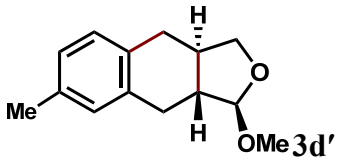
**2d** was prepared as a colorless oil (960 mg, 42% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.76 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3079, 2924, 2867, 2838, 1647, 1595, 1468, 1435, 1348, 1266, 1231, 1196, 1120, 1058, 1011, 925, 808, 738, 705, 645, 558, 451 cm$^{-1}$; (*major isomer*) $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.68 (d, $J$ = 8.0 Hz, 1H), 7.11 (d, $J$ = 1.6 Hz, 1H), 6.77 (dd, $J$ = 8.0, 1.6 Hz, 1H), 6.03–5.91 (m, 1H), 5.36 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.23 (dd, $J$ = 10.4, 1.6 Hz, 1H), 4.56 (d, $J$ = 3.6 Hz, 1H), 4.34 (t, $J$ = 4.0 Hz, 1H), 4.26 (dd, $J$ = 12.8, 5.6 Hz, 1H), 4.17 (dd, $J$ = 12.4, 5.6 Hz, 1H), 3.50 (s, 3H), 3.46 (t, $J$ = 4.0 Hz, 1H), 3.08 (dd, $J$ = 14.4, 10.4 Hz, 1H), 2.29 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 140.3, 139.2, 137.9, 133.9, 132.6, 129.6, 117.6, 104.4, 96.2, 69.2, 55.9, 53.4, 42.9, 20.9 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 446.9427, found: 446.9433.



**3d**

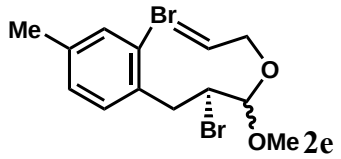
**3d** was prepared as a colorless oil (72 mg, 55% yield) according to *General Procedure B*. $R_f$ = 0.68 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3046, 2928, 2870, 2831, 1618, 1580, 1499, 1448, 1369, 1267, 1183, 1111, 1069, 1020, 940, 902,

815, 738, 704, 666, 563, 442 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.98 (d, $J$ = 8.0 Hz, 1H), 6.97 (s, 1H), 6.93 (d, $J$ = 8.0 Hz, 1H), 4.97 (d, $J$ = 5.2 Hz, 1H), 4.09 (dd, $J$ = 8.0, 7.6 Hz, 1H), 3.60 (dd, $J$ = 8.0, 7.6 Hz, 1H), 3.37 (s, 3H), 2.85 (dd, $J$ = 14.8, 10.0 Hz, 1H), 2.72 (dd, $J$ = 13.2, 4.8 Hz, 1H), 2.62 (dd, $J$ = 14.8, 7.2 Hz, 1H), 2.54–2.46 (m, 1H), 2.47 (dd, $J$ = 13.2, 7.6 Hz, 1H), 2.45–2.38 (m, 1H), 2.31 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 139.2, 135.6, 135.4, 128.3, 126.9, 126.3, 105.4, 70.8, 54.8, 43.2, 38.6, 32.3, 27.1, 21.1 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1203.



**3d′**

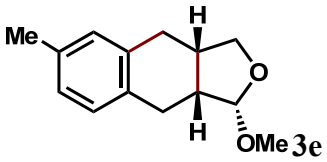
**3d′** was prepared as a white solid (41 mg, 31% yield) according to *General Procedure B*. $R_f$ = 0.56 (petroleum ether/EtOAc = 4 : 1); Mp. 91–93 °C; IR (film): $\nu_{max}$ = 3053, 2957, 2925, 2869, 2854, 1561, 1503, 1462, 1378, 1265, 1159, 1109, 1041, 895, 741, 706 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.00 (d, $J$ = 8.4 Hz, 1H), 6.95 (s, 1H), 6.95 (d, $J$ = 6.4, Hz, 1H), 4.86 (d, $J$ = 6.4 Hz, 1H), 4.12 (dd, $J$ = 7.6, 6.4 Hz, 1H), 3.69 (dd, $J$ = 10.8, 8.0 Hz, 1H), 3.49 (s, 3H), 3.05 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.89 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.71 (dd, $J$ = 16.4, 12.8 Hz, 1H), 2.63 (dd, $J$ = 14.8, 14.4 Hz, 1H), 2.29 (s, 3H), 2.17–2.06 (m, 1H), 1.94 (ddd, $J$ = 17.6, 12.4, 5.6 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 135.7, 135.6, 132.4, 130.4, 129.5, 126.9, 109.9, 71.7, 56.4, 48.1, 41.7, 31.4, 31.3, 20.9 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1205.



**2e**

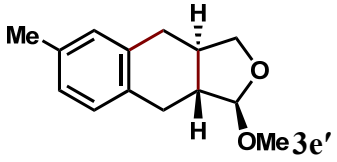
**2e** was prepared as a colorless oil (2.092 g, 51% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.67 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3066, 2924, 2868, 2837, 1647, 1607, 1562, 1492, 1436, 1349, 1266, 1196, 1121,

1056, 1042, 918, 820, 738, 674 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.37 (s, 1H), 7.18 (d, $J$ = 8.0 Hz, 1H), 7.06 (d, $J$ = 8.0 Hz, 1H), 6.01–5.90 (m, 1H), 5.35 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.23 (dd, $J$ = 10.8, 1.6 Hz, 1H), 4.56 (d, $J$ = 4.4 Hz, 1H), 4.37 (dt, $J$ = 10.8, 4.4 Hz, 1H), 4.27–4.22 (m, 1H), 4.18–4.12 (m, 1H), 3.55 (dd, $J$ = 14.4, 3.2 Hz, 1H), 3.49 (s, 3H), 3.05 (dd, $J$ = 10.8, 3.2 Hz, 1H), 2.30 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 138.6, 134.3, 133.9, 133.2, 132.1, 128.0, 124.1, 117.5, 104.5, 69.1, 55.6, 53.3, 38.7, 20.6 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2{}^{79}Br_2Na^+$ $[M+Na]^+$: 398.9566, found: 398.9575.



**3e**

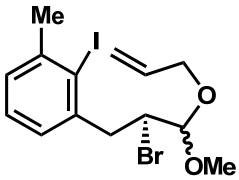
**3e** was prepared as a colorless oil (61 mg, 47% yield) according to *General Procedure B*. $R_f$ = 0.61 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3003, 2927, 2869, 2833, 1618, 1499, 1449, 1369, 1305, 1183, 1111, 1069, 1020, 939, 895, 807, 767, 621, 558 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.03 (d, $J$ = 7.6 Hz, 1H), 6.95 (d, $J$ = 8.0 Hz, 1H), 6.92 (s, 1H), 4.97 (d, $J$ = 5.2 Hz, 1H), 4.09 (dd, $J$ = 8.4, 7.6 Hz, 1H), 3.59 (dd, $J$ = 8.4, 7.6 Hz, 1H), 3.37 (s, 3H), 2.83 (dd, $J$ = 14.8, 10.0 Hz, 1H), 2.70 (dd, $J$ = 13.2, 4.8 Hz, 1H), 2.63 (dd, $J$ = 14.8, 6.8 Hz, 1H), 2.54–2.47 (m, 1H), 2.48 (dd, $J$ = 13.2, 10.8 Hz, 1H), 2.46–2.36 (m, 1H), 2.30 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 138.3, 136.2, 135.2, 127.9, 127.3, 126.7, 105.5, 70.8, 54.8, 43.3, 38.4, 32.6, 26.7, 21.0 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1207.



**3e′**

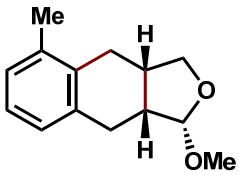
**3e′** was prepared as a white solid (41 mg, 31% yield) according to *General Procedure B*. $R_f$ = 0.51 (petroleum ether/EtOAc = 4 : 1); Mp. 102–103 °C; IR (film): $\nu_{max}$ = 2924, 2855, 1612, 1501, 1441, 1399, 1237, 1184, 1122, 989, 918, 809, 739, 650,

546 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.03 (d, $J$ = 7.6 Hz, 1H), 6.95 (d, $J$ = 8.0 Hz, 1H), 6.93 (s, 1H), 4.85 (d, $J$ = 6.4 Hz, 1H), 4.12 (dd, $J$ = 7.6, 6.8 Hz, 1H), 3.68 (dd, $J$ = 10.8, 8.0 Hz, 1H), 3.49 (s, 3H), 3.06 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.88 (dd, $J$ = 15.6, 4.8 Hz, 1H), 2.70 (dd, $J$ = 15.2, 13.6 Hz, 1H), 2.65 (dd, $J$ = 16.0, 12.0 Hz, 1H), 2.29 (s, 3H), 2.18–2.06 (m, 1H), 1.94 (ddd, $J$ = 17.6, 12.0, 5.6 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 135.6, 135.3, 132.8, 130.2, 129.7, 126.9, 109.9, 71.7, 56.5, 48.2, 41.6, 31.7, 31.0, 20.9 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1205.



**2f**

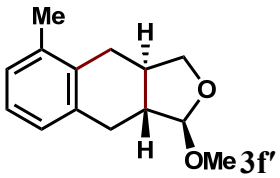
**2f** was prepared as a colorless oil (1.900 g, 45% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.67 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3052, 2976, 2925, 2866, 2835, 1647, 1575, 1460, 1445, 1379, 1349, 1271, 1196, 1126, 1058, 1007, 926, 788, 765, 734, 645 $cm^{-1}$; (*slightly major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.18 (d, $J$ = 7.2 Hz, 1H), 7.14 (d, $J$ = 6.0 Hz, 1H), 7.11 (t, $J$ = 6.8 Hz, 1H), 5.97–5.91 (m, 1H), 5.34 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.22 (dd, $J$ = 12.0, 1.6 Hz, 1H), 4.55 (d, $J$ = 4.4 Hz, 1H), 4.41 (td, $J$ = 4.0, 1.2 Hz, 1H), 4.25 (dd, $J$ = 12.8, 1.6 Hz, 1H), 4.18 (dd, $J$ = 12.8, 6.0 Hz, 1H), 3.58 (t, $J$ = 4.0 Hz, 1H), 3.50 (s, 3H), 3.18 (dd, $J$ = 14.8, 10.4 Hz, 1H), 2.48 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 142.3, 141.3, 133.9, 129.0, 128.3, 127.4, 117.5, 107.7, 104.5, 69.2, 55.9, 53.4, 44.3, 30.0 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{18}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 446.9427, found: 446.9424.



**3f**

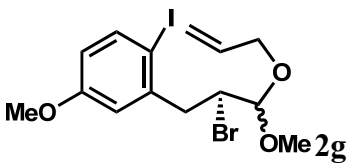
**3f** was prepared as a colorless oil (61 mg, 47% yield) according to *General*

*Procedure B*. $R_f$ = 0.57 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3019, 2934, 2869, 2833, 1592, 1471, 1442, 1370, 1288, 1183, 1115, 1069, 1038, 1012, 969, 942, 773, 740 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.05–6.98 (m, 3H), 4.98 (d, $J$ = 5.2 Hz, 1H), 4.11 (t, $J$ = 8.0 Hz, 1H), 3.62 (t, $J$ = 8.0 Hz, 1H), 3.38 (s, 3H), 2.95 (dd, $J$ = 14.4, 5.2 Hz, 1H), 2.85 (dd, $J$ = 14.8, 10.0 Hz, 1H), 2.66 (dd, $J$ = 14.8, 6.8 Hz, 1H), 2.54–2.45 (m, 1H), 2.44–2.35 (m, 1H), 2.29 (dd, $J$ = 12.8, 12.0 Hz, 1H), 2.29 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 139.3, 136.6, 134.3, 127.5, 125.5, 125.4, 105.7, 70.9, 54.9, 42.9, 38.2, 27.9, 27.5, 19.4 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1196.



**3f′**

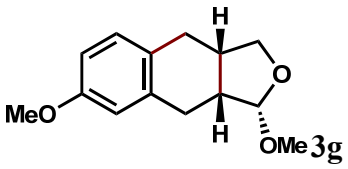
**3f′** was prepared as a colorless oil (41 mg, 31% yield) according to *General Procedure B*. $R_f$ = 0.40 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3061, 2926, 2849, 1582, 1463, 1442, 1399, 1268, 1117, 995, 919, 770, 737, 709, 660 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.08 (d, $J$ = 7.2 Hz, 1H), 7.05 (dd, $J$ = 9.6, 7.6 Hz, 1H), 7.00 (d, $J$ = 7.6 Hz, 1H), 4.87 (d, $J$ = 6.4 Hz, 1H), 4.16 (dd, $J$ = 7.6, 6.8 Hz, 1H), 3.73 (dd, $J$ = 10.4, 7.6 Hz, 1H), 3.50 (s, 3H), 3.10 (dd, $J$ = 16.0, 5.2 Hz, 1H), 2.91 (dd, $J$ = 16.0, 5.2 Hz, 1H), 2.78 (dd, $J$ = 14.8, 13.2 Hz, 1H), 2.41 (dd, $J$ = 16.0, 12.0 Hz, 1H), 2.23 (s, 3H), 2.19–2.07 (m, 1H), 1.93 (ddd, $J$ = 18.4, 12.0, 6.0 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 137.0, 135.9, 134.3, 127.7 (2C), 125.8, 110.0, 71.9, 56.5, 47.5, 41.7, 31.9, 29.1, 19.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1190.



**2g**

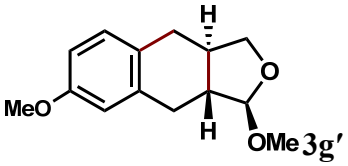
**2g** was prepared as a colorless oil (1.100 g, 67% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.27 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$

= 3078, 2933, 2835, 1646, 1591, 1568, 1468, 1413, 1347, 1238, 1125, 1053, 927, 804, 702, 589 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.67 (d, $J$ = 8.8 Hz, 1H), 6.88 (d, $J$ = 3.2 Hz, 1H), 6.56 (dd, $J$ = 8.8, 2.8 Hz, 1H), 6.02–5.91 (m, 1H), 5.36 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.23 (dd, $J$ = 10.4, 1.6 Hz, 1H), 4.57 (d, $J$ = 4.0 Hz, 1H), 4.37–4.32 (m, 1H), 4.29–4.23 (m, 1H), 4.18 (dd, $J$ = 11.2, 5.6 Hz, 1H), 3.78 (s, 3H), 3.50 (s, 3H), 3.47 (dt, $J$ = 11.2, 4.0 Hz, 1H), 3.07 (dd, $J$ = 14.8, 10.8 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 159.6, 141.7, 139.9, 133.9, 117.7, 117.6, 114.8, 104.5, 88.7, 69.2, 56.0, 55.3, 53.3, 43.1 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{19}O_3{}^{79}BrI^+$ $[M+H]^+$: 440.9557, found: 440.9559.



**3g**

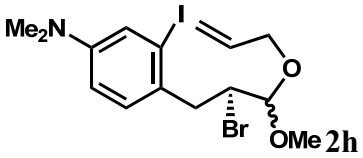
**3g** was prepared as a white solid (72 mg, 51% yield) according to *General Procedure B*. $R_f$ = 0.66 (petroleum ether/EtOAc = 2 : 1); Mp. 81–82 °C; IR (film): $\nu_{max}$ = 2928, 2372, 1584, 1498, 1461, 1365, 1297, 1257, 1114, 1070, 936, 787, 707 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.00 (d, $J$ = 8.0 Hz, 1H), 6.73 (d, $J$ = 2.0 Hz, 1H), 6.66 (dd, $J$ = 8.0, 2.4 Hz, 1H), 4.97 (d, $J$ = 5.2 Hz, 1H), 4.08 (dd, $J$ = 8.4, 7.6 Hz, 1H), 3.78 (s, 3H), 3.59 (dd, $J$ = 8.0, 7.6 Hz, 1H), 3.37 (s, 3H), 2.87 (dd, $J$ = 14.8, 9.6 Hz, 1H), 2.71 (d, $J$ = 8.0 Hz, 1H), 2.63 (dd, $J$ = 14.8, 6.8 Hz, 1H), 2.55–2.47 (m, 1H), 2.45 (dd, $J$ = 9.2, 8.4 Hz, 1H), 2.46–2.38 (m, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 158.1, 140.6, 130.6, 127.7, 113.5, 110.6, 105.4, 70.7, 55.3, 54.8, 43.0, 38.6, 31.8, 27.5 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{22}NO_3^+$ $[M+NH_4]^+$: 252.1594, found: 252.1593.



**3g′**

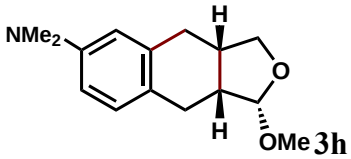
**3g′** was prepared as a white solid (38 mg, 27% yield) according to *General Procedure B*. $R_f$ = 0.51 (petroleum ether/EtOAc = 2 : 1); Mp. 80–81 °C; IR (film):

$\nu_{max}$ = 2923, 2842, 1611, 1501, 1465, 1442, 1302, 1234, 1152, 1117, 1038, 995, 939, 807, 735, 668 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.02 (d, $J$ = 8.4 Hz, 1H), 6.71 (dd, $J$ = 8.4, 2.4 Hz, 1H), 6.67 (d, $J$ = 2.4 Hz, 1H), 4.86 (d, $J$ = 6.4 Hz, 1H), 4.12 (dd, $J$ = 7.6, 6.8 Hz, 1H), 3.78 (s, 3H), 3.69 (dd, $J$ = 10.4, 8.0 Hz, 1H), 3.49 (s, 3H), 3.07 (dd, $J$ = 16.0, 5.2 Hz, 1H), 2.88 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.73 (dd, $J$ = 15.2, 13.2 Hz, 1H), 2.61 (dd, $J$ = 14.4, 12.8 Hz, 1H), 2.18–2.06 (m, 1H), 1.94 (ddd, $J$ = 18.4, 12.8, 6.0 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 157.8, 137.0, 130.4, 127.6, 114.5, 112.3, 109.9, 71.7, 56.5, 55.3, 48.0, 41.9, 31.6, 31.0 ppm; HRMS (ESI): $m/z$ calcd for $C_{14}H_{22}NO_3^+$ $[M+NH_4]^+$: 252.1594, found: 252.1591.



**2h**

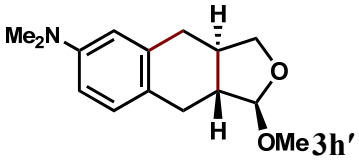
**2h** was prepared as a colorless oil (904 mg, 52% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.50 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3079, 2984, 2925, 2808, 1647, 1601, 1542, 1506, 1443, 1350, 1270, 1222, 1122, 1055, 954, 916, 833, 804, 738, 664 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.15 (d, $J$ = 2.8 Hz, 1H), 7.11 (d, $J$ = 8.8 Hz, 1H), 6.66 (dd, $J$ = 8.8, 2.8 Hz, 1H), 6.04–5.91 (m, 1H), 5.37 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.23 (dd, $J$ = 10.4, 1.2 Hz, 1H), 4.54 (d, $J$ = 4.0 Hz, 1H), 4.34 (dt, $J$ = 10.4, 4.0 Hz, 1H), 4.26 (dd, $J$ = 11.2, 4.0 Hz, 1H), 4.18 (dd, $J$ = 12.8, 6.0 Hz, 1H), 3.49 (s, 3H), 3.42 (dt, $J$ = 14.8, 4.0 Hz, 1H), 3.03 (dd, $J$ = 14.8, 10.4 Hz, 1H), 2.91 (s, 6H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 150.2, 134.0, 131.4, 127.9, 122.8, 117.5, 112.1, 104.3, 101.4, 69.1, 55.7, 54.6, 42.2, 40.3 (2C) ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{22}NO_2{}^{79}BrI^+$ $[M+H]^+$: 453.9873, found: 453.9872.



**3h**

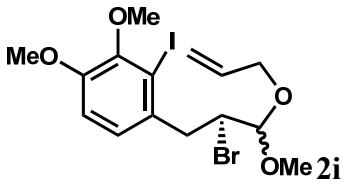
**3h** was prepared as a white solid (77 mg, 52% yield) according to *General*

*Procedure B*. $R_f$ = 0.40 (petroleum ether/EtOAc = 4 : 1); Mp. 54–56 °C; IR (film): $\nu_{max}$ = 2930, 2870, 2836, 1618, 1573, 1510, 1475, 1447, 1347, 1227, 1120, 1068, 1018, 937, 800, 735, 702 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.02 (d, $J$ = 9.2 Hz, 1H), 6.57 (d, $J$ = 3.2 Hz, 1H), 6.56 (dd, $J$ = 6.0, 3.2 Hz, 1H), 4.97 (d, $J$ = 4.8 Hz, 1H), 4.10 (dd, $J$ = 8.4, 7.6 Hz, 1H), 3.61 (t, $J$ = 8.0 Hz, 1H), 3.39 (s, 3H), 2.91 (s, 6H), 2.80 (dd, $J$ = 14.4, 9.6 Hz, 1H), 2.71 (dd, $J$ = 13.2, 5.2 Hz, 1H), 2.59 (dd, $J$ = 14.4, 6.8 Hz, 1H), 2.55–2.48 (m, 1H), 2.51 (dd, $J$ = 12.0, 11.2 Hz, 1H), 2.47–2.40 (m, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 149.3, 139.1, 127.9, 127.6, 112.4, 110.8, 105.6, 70.8, 54.9, 43.5, 41.1 (2C), 38.5, 33.3, 25.9 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{22}NO_2^+$ $[M+H]^+$: 248.1645, found: 248.1646.



**3h′**

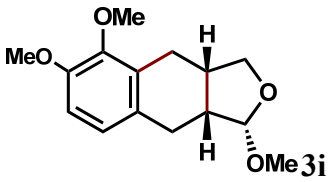
**3h′** was prepared as a white solid (41 mg, 28% yield) according to *General Procedure B*. $R_f$ = 0.30 (petroleum ether/EtOAc = 4 : 1); Mp. 96–99 °C; IR (film): $\nu_{max}$ = 3051, 2923, 2848, 1614, 1564, 1511, 1445, 1353, 1266, 1127, 1060, 995, 920, 838, 801, 738, 704, 651 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.02 (d, $J$ = 8.4 Hz, 1H), 6.61 (dd, $J$ = 8.4, 2.7 Hz, 1H), 6.49 (d, $J$ = 2.1 Hz, 1H), 4.86 (d, $J$ = 6.3 Hz, 1H), 4.12 (dd, $J$ = 7.5, 6.6 Hz, 1H), 3.69 (dd, $J$ = 10.5, 7.8 Hz, 1H), 3.49 (s, 3H), 3.02 (dd, $J$ = 15.3, 5.1 Hz, 1H), 2.90 (s, 6H), 2.89 (dd, $J$ = 15.3, 5.1 Hz, 1H), 2.69 (dd, $J$ = 11.4, 5.4 Hz, 1H), 2.64 (dd, $J$ = 15.6, 5.1 Hz, 1H), 2.21–2.05 (m, 1H), 1.93 (ddd, $J$ = 17.7, 11.7, 5.7 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 149.2, 136.0, 130.3, 124.1, 113.5, 111.7, 110.0, 71.8, 56.5, 48.5, 41.8, 40.9 (2C), 32.3, 30.4 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{22}NO_2^+$ $[M+H]^+$: 248.1645, found: 248.1643.



**2i**

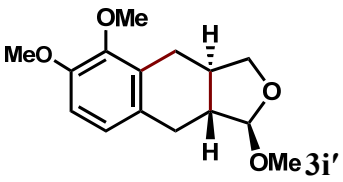
**2i** was prepared as a colorless oil (1.650 g, 69% overall yield, dr = 1 : 1) according

to *General Procedure A-2*. $R_f$ = 0.60 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 3079, 2936, 2836, 1647, 1589, 1482, 1463, 1433, 1396, 1349, 1295, 1270, 1205, 1124, 1031, 934, 809, 799, 737, 645 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.96 (d, $J$ = 8.4 Hz, 1H), 6.77 (d, $J$ = 8.4 Hz, 1H), 5.95–5.83 (m, 1H), 5.29 (dd, $J$ = 17.2, 1.2 Hz, 1H), 5.16 (dd, $J$ = 10.4, 1.2 Hz, 1H), 4.48 (d, $J$ = 4.0 Hz, 1H), 4.30–4.27 (m, 1H), 4.18 (dd, $J$ = 12.8, 5.6 Hz, 1H), 4.10 (dd, $J$ = 14.4, 6.0 Hz, 1H), 3.78 (s, 3H), 3.75 (s, 3H), 3.43 (dd, $J$ = 14.8, 3.6 Hz, 1H), 3.42 (s, 3H), 3.02 (dd, $J$ = 14.8, 10.8 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 151.1, 148.5, 133.8, 133.2, 126.9, 117.5, 111.7, 104.2, 99.2, 69.1, 60.1, 55.8, 55.2, 53.9, 42.6 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{20}O_4{}^{79}BrINa^+$ $[M+Na]^+$: 492.9482, found: 492.9496.



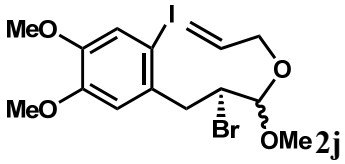
**3i**

**3i** was prepared as a colorless oil (68 mg, 43% yield) according to *General Procedure B*. $R_f$ = 0.55 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 3051, 2938, 2831, 1609, 1584, 1490, 1459, 1426, 1329, 1311, 1267, 1225, 1183, 1115, 1068, 1018, 979, 938, 894, 799, 736, 702. 572, 514 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.86 (d, $J$ = 8.4 Hz, 1H), 6.70 (d, $J$ = 8.0 Hz, 1H), 4.97 (d, $J$ = 5.6 Hz, 1H), 4.11 (t, $J$ = 8.0 Hz, 1H), 3.84 (s, 3H), 3.77 (s, 3H), 3.62 (t, $J$ = 8.0 Hz, 1H), 3.38 (s, 3H), 3.17 (dd, $J$ = 14.4, 5.6 Hz, 1H), 2.79 (dd, $J$ = 14.4, 10.0 Hz, 1H), 2.62 (dd, $J$ = 14.4, 6.8 Hz, 1H), 2.53–2.45 (m, 1H), 2.42–2.31 (m, 1H), 2.23 (dd, $J$ = 14.4, 11.2 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 150.8, 145.8, 132.6, 131.9, 122.6, 109.5, 105.5, 70.8, 60.9, 55.8, 54.8, 43.2, 37.9, 26.5, 25.0 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{20}O_4Na^+$ $[M+Na]^+$: 287.1254, found: 287.1259.



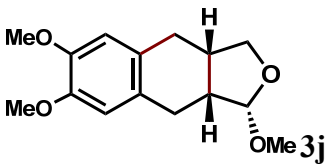
**3i′**

**3i′** was prepared as a colorless oil (35 mg, 22% yield) according to *General Procedure B*. $R_f$ = 0.48 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 3050, 2931, 2843, 1604, 1578, 1515, 1489, 1454, 1420, 1278, 1225, 1116, 1073, 1035, 995, 922, 869, 799, 736, 701, 657 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.86 (d, $J$ = 8.4 Hz, 1H), 6.76 (d, $J$ = 8.4 Hz, 1H), 4.86 (d, $J$ = 6.3 Hz, 1H), 4.15 (dd, $J$ = 7.5, 6.6 Hz, 1H), 3.84(s, 3H), 3.80 (s, 3H), 3.72 (dd, $J$ = 10.5, 7.8 Hz, 1H), 3.49 (s, 3H), 3.16 (dd, $J$ = 16.5, 4.8 Hz, 1H), 3.05 (dd, $J$ = 15.6, 5.1 Hz, 1H), 2.69 (dd, $J$ = 15.0, 12.6 Hz, 1H), 2.41 (dd, $J$ = 16.5, 12.0 Hz, 1H), 2.12–1.99 (m, 1H), 1.91 (ddd, $J$ = 18.0, 12.3, 5.7 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 150.7, 146.9, 130.1, 129.1, 124.8, 110.5, 109.8, 71.9, 60.0, 56.5, 55.8, 47.9, 41.3, 30.9, 26.0 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{20}O_4Na^+$ $[M+Na]^+$: 287.1254, found: 287.1261.



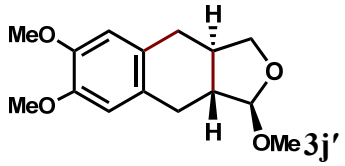
**2j**

**2j** was prepared as a colorless oil (1.325 g, 75% overall yield, dr = 2 : 1) according to *General Procedure A-1*. $R_f$ = 0.61 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 3079, 2962, 2930, 2842, 1647, 1597, 1506, 1462, 1439, 1379, 1257, 1214, 1164, 1123, 1049, 1030, 920, 856, 795 $cm^{-1}$; (*major isomer*) $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.99 (s, 1H), 6.80 (s, 1H), 6.02–5.88 (m, 1H), 5.35 (dd, $J$ = 17.1, 1.5 Hz, 1H), 5.21 (dd, $J$ = 10.5, 0.9 Hz, 1H), 4.54 (d, $J$ = 4.5 Hz, 1H), 4.33 (dt, $J$ = 10.5, 3.9 Hz, 1H), 4.24 (dd, $J$ = 12.6, 5.1 Hz, 1H), 4.14 (dd, $J$ = 12.6, 5.7 Hz, 1H), 3.84 (s, 6H), 3.51 (dd, $J$ = 14.7, 3.6 Hz, 1H), 3.48 (s, 3H), 2.98 (dd, $J$ = 14.7, 10.5 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 148.5, 147.9, 133.8, 129.4, 117.5, 115.4, 115.0, 114.2, 104.4, 69.2, 56.1, 56.0, 55.7, 53.6, 38.7 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{20}O_4{}^{79}BrINa^+$ $[M+Na]^+$: 492.9482, found: 492.9486.



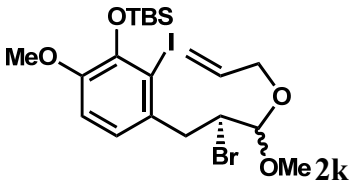
**3j**

**3j** was prepared as a white solid (76 mg, 48% yield) according to *General Procedure B*. $R_f$ = 0.42 (petroleum ether/EtOAc = 2 : 1); Mp. 98–99 °C; IR (film): $\nu_{max}$ = 2934, 2869, 2832, 1611, 1514, 1465, 1453, 1305, 1223, 1193, 1107, 1069, 996, 848, 748 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.69 (s, 1H), 6.65 (s, 1H), 4.97 (d, $J$ = 4.8 Hz, 1H), 4.08 (t, $J$ = 8.0 Hz, 1H), 3.86 (s, 3H), 3.85 (s, 3H), 3.59 (dd, $J$ = 8.4, 7.2 Hz, 1H), 3.37 (s, 3H), 2.82 (dd, $J$ = 14.8, 8.8 Hz, 1H), 2.68 (dd, $J$ = 13.2, 4.4 Hz, 1H), 2.61 (dd, $J$ = 14.8, 7.2 Hz, 1H), 2.56–2.48 (m, 1H), 2.46 (dd, $J$ = 9.6, 3.6 Hz, 1H), 2.46–2.40 (m, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 147.2, 146.8, 130.9, 130.0, 111.5, 111.2, 105.6, 70.8, 56.0 (2C), 54.9. 43.0, 38.3, 32.2, 26.6 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{20}O_4Na^+$ $[M+Na]^+$: 287.1254, found: 287.1255.



**3j′**

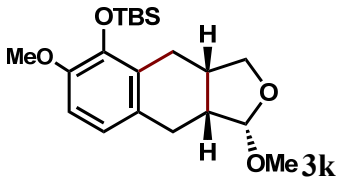
**3j′** was prepared as a colorless oil (40 mg, 25% yield) according to *General Procedure B*. $R_f$ = 0.30 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 2928, 2843, 1611, 1516, 1445, 1398, 1243, 1221, 1190, 1098, 986, 922, 852, 737, 670 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 6.62 (s, 1H), 6.60 (s, 1H), 4.87 (d, $J$ = 6.4 Hz, 1H), 4.13 (dd, $J$ = 7.6, 6.4 Hz, 1H), 3.850 (s, 3H), 3.845 (s, 3H), 3.70 (dd, $J$ = 10.4, 7.6 Hz, 1H), 3.50 (s, 3H), 3.01 (dd, $J$ = 15.6, 5.2 Hz, 1H), 2.84 (dd, $J$ = 15.2, 4.8 Hz, 1H), 2.69 (t, $J$ = 12.4 Hz, 1H), 2.63 (dd, $J$ = 14.0, 12.0 Hz, 1H), 2.18–2.04 (m, 1H), 1.94 (ddd, $J$ = 17.6, 12.0, 5.6 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 147.36, 147.35, 127.7, 127.4, 112.4, 112.2, 109.9, 71.7, 56.5, 55.94, 55.92, 48.2, 41.8, 31.4, 31.0 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{20}O_4Na^+$ $[M+Na]^+$: 287.1254, found: 287.1254.



**2k**

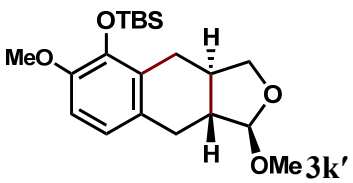
**2k** was prepared as a colorless oil (1.25 g, 51% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.68 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$

= 3081, 2956, 2930, 2896, 2857, 1647, 1586, 1481, 1439, 1361, 1309, 1256, 1125, 1033, 924, 852, 784, 737, 665 $cm^{-1}$; (*major isomer*) $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.87 (d, $J$ = 8.4 Hz, 1H), 6.77 (d, $J$ = 8.4 Hz, 1H), 6.03–5.89 (m, 1H), 5.34 (d, $J$ = 17.1 Hz, 1H), 5.21 (d, $J$ = 10.2 Hz, 1H), 4.51 (d, $J$ = 4.2 Hz, 1H), 4.40 (dt, $J$ = 10.2, 4.2 Hz, 1H), 4.24 (dd, $J$ = 12.6, 6.0 Hz, 1H), 4.13 (dd, $J$ = 12.9, 6.0 Hz, 1H), 3.78 (s, 3H), 3.52 (dd, $J$ = 14.4, 3.6 Hz, 1H), 3.50 (s, 3H), 3.11 (dd, $J$ = 14.4, 9.9 Hz, 1H), 1.05 (s, 9H), 0.26 (s, 6H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 148.0, 145.2, 134.0, 133.5, 123.6, 117.5, 110.6, 104.4, 97.2, 69.2, 55.8, 54.9, 54.0, 43.4, 26.3 (3C), 19.2, –3.1 (2C) ppm; HRMS (ESI): *m*/*z* calcd for $C_{20}H_{32}O_4Si^{79}BrINa^+$ $[M+Na]^+$: 593.0190, found: 593.0200.



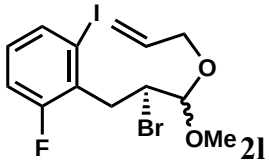
**3k**

**3k** was prepared as a colorless oil (129 mg, 59% yield) according to *General Procedure B*. $R_f$ = 0.57 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 2930, 2858, 2833, 1609, 1585, 1490, 1452, 1361, 1297, 1268, 1227, 1116, 1069, 1010, 925, 841, 783, 687, 651, 573 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.71 (d, $J$ = 8.1 Hz, 1H), 6.63 (d, $J$ = 8.1 Hz, 1H), 4.97 (d, $J$ = 5.1 Hz, 1H), 4.10 (t, $J$ = 8.1 Hz, 1H), 3.76 (s, 3H), 3.61 (t, $J$ = 8.1 Hz, 1H), 3.38 (s, 3H), 3.19 (dd, $J$ = 14.1, 5.4 Hz, 1H), 2.77 (dd, $J$ = 14.1, 9.9 Hz, 1H), 2.59 (dd, $J$ = 14.4, 6.6 Hz, 1H), 2.52–2.41 (m, 1H), 2.39–2.26 (m, 1H), 2.15 (dd, $J$ = 14.1, 10.8 Hz, 1H), 1.00 (s, 9H), 0.16 (s, 3H), 0.13 (s, 3H) ppm; $^{13}C$ NMR (75 MHz, $CDCl_3$): $\delta$ = 148.5, 141.4, 132.5, 129.5, 119.6, 108.7, 105.6, 70.8, 55.0, 54.8, 43.2, 38.0, 26.8, 26.0 (3C), 25.5, 18.8, –4.2 (2C) ppm; HRMS (ESI): *m*/*z* calcd for $C_{20}H_{36}NO_4Si^+$ $[M+NH_4]^+$: 382.2408, found: 382.2409.



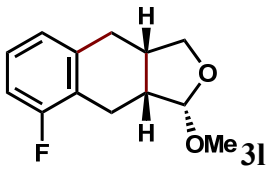
**3k′**

**3k′** was prepared as a colorless oil (68 mg, 31% yield) according to *General Procedure B*. $R_f$ = 0.43 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 2928, 2856, 1586, 1491, 1452, 1364, 1263, 1227, 1102, 1051, 990, 922, 840, 783, 684 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 6.70 (d, $J$ = 8.1 Hz, 1H), 6.64 (d, $J$ = 8.1 Hz, 1H), 4.71 (s, 1H), 4.09 (dd, $J$ = 8.4, 7.5 Hz, 1H), 3.76 (s, 3H), 3.63 (dd, $J$ = 8.7, 3.0 Hz, 1H), 3.33 (s, 3H), 3.01 (dd, $J$ = 14.4, 6.0 Hz, 1H), 2.81 (dd, $J$ = 17.7, 9.9 Hz, 1H), 2.62–2.50 (m, 1H), 2.44 (dd, $J$ = 14.4, 9.3 Hz, 1H), 2.46–2.41 (m, 1H), 2.37 (dd, $J$ = 14.7, 8.7 Hz, 1H), 1.00 (s, 9H), 0.16 (s, 3H), 0.15 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 148.7, 141.8, 130.8, 128.9, 119.5, 110.8, 108.9, 72.4, 55.0, 54.6, 45.6, 36.8, 30.7, 26.03 (3C), 25.99, 18.8, –4.1 (2C) ppm; HRMS (ESI): $m/z$ calcd for $C_{20}H_{36}NO_4Si^+$ $[M+NH_4]^+$: 382.2408, found: 382.2407.

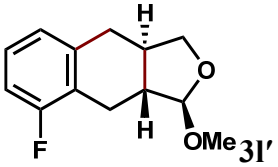


**2l**

**2l** was prepared as a colorless oil (720 mg, 65% overall yield, dr = 2 : 1) according to *General Procedure A-1*. $R_f$ = 0.69 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3080, 2930, 2836, 1647, 1598, 1568, 1451, 1348, 1243, 1130, 1056, 924, 776, 738, 647, 561 $cm^{-1}$; (*one isomer*) $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.63 (d, $J$ = 7.8 Hz, 1H), 7.04 (t, $J$ = 8.7 Hz, 1H), 6.96 (dd, $J$ = 7.8, 5.7 Hz, 1H), 6.03–5.86 (m, 1H), 5.32 (dd, $J$ = 17.1, 1.5 Hz, 1H), 5.20 (dd, $J$ = 10.5, 1.5 Hz, 1H), 4.61 (t, $J$ = 5.7 Hz, 1H), 4.44 (dt, $J$ = 9.6, 5.1 Hz, 1H), 4.24 (dd, $J$ = 12.6, 5.4 Hz, 1H), 4.14 (dd, $J$ = 12.6, 6.9 Hz, 1H), 3.48 (s, 3H), 3.48 (dd, $J$ = 14.1, 5.4 Hz, 1H), 3.39 (dd, $J$ = 14.4, 9.9 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 160.3 (d, $J_{C-F}$ = 250.0 Hz), 135.2 (d, $J_{C-F}$ = 3.0 Hz), 133.8, 129.7 (d, $J_{C-F}$ = 9.0 Hz), 129.1 (d, $J_{C-F}$ = 15.0 Hz), 117.3, 115.5 (d, $J_{C-F}$ = 24.0 Hz), 104.0, 101.2, 68.9, 55.3, 51.4, 36.5 ppm; $^{19}F$ NMR (376 MHz, $CDCl_3$): $\delta$ = –108.88 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{15}O_2F^{79}BrINa^+$ $[M+Na]^+$: 450.9176, found: 450.9172.




**3l** was prepared as a colorless oil (61 mg, 46% yield) according to *General Procedure B* except the use of 30 mol% $NiCl_2$•DME. $R_f$ = 0.62 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3048, 2928, 2873, 1621, 1583, 1470, 1371, 1266, 1245, 1117, 1070, 1032, 999, 940, 893, 780, 739, 703 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.06 (dd, $J$ = 13.6, 7.6 Hz, 1H), 6.88 (d, $J$ = 6.8 Hz, 1H), 6.86 (d, $J$ = 8.4 Hz, 1H), 4.98 (d, $J$ = 5.2 Hz, 1H), 4.10 (dd $J$ = 8.4, 7.6 Hz, 1H), 3.59 (dd, $J$ = 8.0, 7.2 Hz, 1H), 3.36 (s, 3H), 2.97 (dd, $J$ = 15.2, 7.2 Hz, 1H), 2.77 (dd, $J$ = 14.0, 5.2 Hz, 1H), 2.70 (dd, $J$ = 15.2, 8.0 Hz, 1H), 2.55 (dd, $J$ = 14.0, 10.0 Hz, 1H), 2.54–2.40 (m, 2H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 160.0 (d, $J_{C-F}$ = 242.0 Hz), 140.9 (d, $J_{C-F}$ = 5.0 Hz), 126.3 (d, $J_{C-F}$ = 8.0 Hz), 125.5 (d, $J_{C-F}$ = 16.0 Hz), 122.8 (d, $J_{C-F}$ = 3.0 Hz), 112.8 (d, $J_{C-F}$ = 23.0 Hz), 105.6, 70.9, 54.9, 41.9, 37.7, 32.3 (d, $J_{C-F}$ = 3.0 Hz), 18.5 (d, $J_{C-F}$ = 3.0 Hz) ppm; $^{19}F$ NMR (376 MHz, $CDCl_3$): $\delta$ = –121.62 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{15}O_2FNa^+$ $[M+Na]^+$: 245.0948, found: 245.0948.




**3l′** was prepared as a white solid (29 mg, 22% yield) according to *General Procedure B* except the use of 30 mol% $NiCl_2$•DME. $R_f$ = 0.45 (petroleum ether/EtOAc = 4 : 1); Mp. 96–97 °C; IR (film): $\nu_{max}$ = 3066, 2991, 2920, 2851, 1576, 1461, 1400, 1238, 1115, 972, 939, 884, 776, 741, 693, 655 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.10 (dd, $J$ = 13.8, 7.8 Hz, 1H), 6.91 (d, $J$ = 6.9 Hz, 1H), 6.85 (d, $J$ = 8.7 Hz, 1H), 4.90 (d, $J$ = 6.3 Hz, 1H), 4.14 (dd, $J$ = 7.8, 6.6 Hz, 1H), 3.70 (dd, $J$ = 10.5, 7.8 Hz, 1H), 3.50 (s, 3H), 3.25 (dd, $J$ = 15.9, 5.4 Hz, 1H), 2.96 (dd, $J$ = 15.9, 4.5 Hz, 1H), 2.69 (dd, $J$ = 15.6, 12.3 Hz, 1H), 2.52 (dd, $J$ = 15.9, 12.3 Hz, 1H), 2.20–2.04 (m, 1H), 1.90 (ddd, $J$ = 18.0, 12.0, 5.7 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ =

161.4 (d, $J_{C-F}$ = 243.0 Hz), 138.2 (d, $J_{C-F}$ = 5.0 Hz), 127.0 (d, $J_{C-F}$ = 8.0 Hz), 124.9 (d, $J_{C-F}$ = 3.0 Hz), 123.7 (d, $J_{C-F}$ = 18.0 Hz), 112.5 (d, $J_{C-F}$ = 21.0 Hz), 109.9, 71.5, 56.5, 47.4, 41.2, 31.7 (d, $J_{C-F}$ = 2.0 Hz), 24.4 (d, $J_{C-F}$ = 5.0 Hz) ppm; $^{19}$F NMR (376 MHz, $CDCl_3$): $\delta$ = −117.20 ppm; HRMS (ESI): *m*/*z* calcd for $C_{13}H_{15}O_2FNa^+$ $[M+Na]^+$: 245.0948, found: 245.0941. This product (11 mg) was dissolved in $CH_2Cl_2$ (1 mL) and petroleum ether (2 mL). After 5 days, colorless single crystals were obtained by slow evaporation of solvents at room temperature.

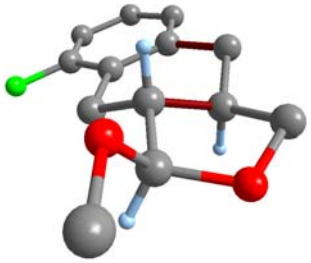
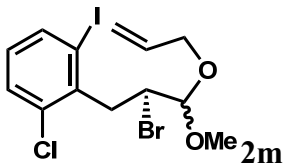


**Table S7**: X-ray crystal data of **3l′** (selected H atoms have been omitted for clarity)

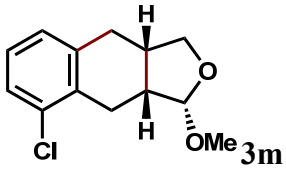
| | |
|---|---|
| Empirical formula | $C_{13}H_{15}FO_2$ |
| Temperature (K) | 273.77(10) |
| Crystal color | colorless |
| Formula weight | 222.25 |
| Crystal system | Triclinic |
| Space group | *P*-1 |
| *a* (Å) | 7.4670(16) |
| *b* (Å) | 8.1131(16) |
| *c* (Å) | 10.193(2) |
| *α* (°) | 107.549(19) |
| *β* (°) | 90.344(18) |
| *γ* (°) | 106.555(18) |
| *V* (Å $^3$) | 561.5(2) |
| *Z* | 2 |
| Density (calculated) (g/cm$^3$) | 1.314 |
| *F* (000) | 236.0 |
| *λ* (Å) | 0.71073 |
| Reflections collected | 3562 |
| Independent reflections | 2209 |

| | |
|---|---|
| $\theta$ Range for data collection (°) | 3.33—26.02 |
| Index range | $-9 \le h \le 8$<br>$-9 \le k \le 10$<br>$-12 \le l \le 12$ |
| Final $R$ indices [I>2σ($I$)] | $R_1 = 0.0550$, $wR_2 = 0.1163$ |
| Largest difference peak and hole [e Å $^{-3}$] | 0.140, –0.180 |



**2m**

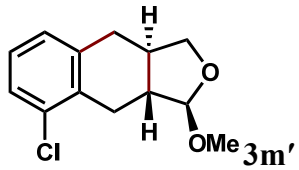
**2m** was prepared as a colorless oil (1.605 g, 68% overall yield, dr = 2 : 1) according to *General Procedure A-1*. $R_f$ = 0.73 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3078, 2986, 2928, 2835, 1647, 1573, 1552, 1428, 1348, 1271, 1202, 1120, 1054, 996, 919, 773, 738, 722, 643, 557 cm$^{-1}$; (*major isomer*) $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.78 (d, $J$ = 8.0 Hz, 1H), 7.36 (d, $J$ = 8.0 Hz, 1H), 6.86 (t, $J$ = 8.0 Hz, 1H), 5.92 (ddd, $J$ = 16.0, 10.8, 5.6 Hz, 1H), 5.31 (dd, $J$ = 17.2, 1.6 Hz, 1H), 5.19 (dd, $J$ = 10.8, 1.6 Hz, 1H), 4.64 (d, $J$ = 5.6 Hz, 1H), 4.63–4.58 (m, 1H), 4.23 (dd, $J$ = 12.8, 5.2 Hz, 1H), 4.14 (dd, $J$ = 13.2, 6.0 Hz, 1H), 3.64–3.60 (m, 2H), 3.48 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 138.8, 138.7, 134.5, 133.9, 130.1, 129.4, 117.2, 104.2, 102.3, 68.9, 54.8, 51.3, 40.9 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{15}O_2{}^{35}Cl^{79}BrINa^+$ $[M+Na]^+$: 466.8881, found: 466.8898.



**3m**

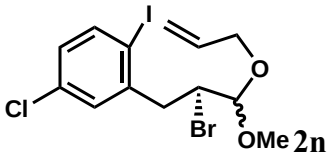
**3m** was prepared as a colorless oil (67 mg, 47% yield) according to *General Procedure B*. $R_f$ = 0.63 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3063, 2932, 2833, 1597, 1570, 1451, 1371, 1308, 1265, 1180, 1144, 1113, 1070, 1022, 973, 938, 902, 873, 826, 776, 737, 657, 569 cm$^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.21 (d, $J$ = 7.6 Hz, 1H), 7.04 (t, $J$ = 7.2 Hz, 1H), 6.99 (d, $J$ = 7.2 Hz, 1H), 4.99 (d, $J$ = 5.2 Hz, 1H), 4.10 (t, $J$ = 8.0 Hz, 1H), 3.59 (dd, $J$ = 8.4, 7.6 Hz, 1H), 3.36 (s, 3H) 3.10 (dd, $J$ =

16.0, 7.6 Hz, 1H), 2.80 (dd, *J* = 8.8, 6.0 Hz, 1H), 2.76 (dd, *J* = 8.8, 5.6 Hz, 1H), 2.58–2.51 (m, 1H), 2.54 (dd, *J* = 13.6, 10.8 Hz, 1H), 2.48–2.38 (m, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 140.5, 136.6, 132.9, 126.9, 126.3, 125.8, 105.6, 70.9, 54.9, 42.3, 37.7, 33.1, 23.5 ppm; HRMS (ESI): *m*/*z* calcd for $C_{13}H_{15}O_2{}^{35}ClNa^+$ $[M+Na]^+$: 261.0653, found: 261.0661.



**3m′**

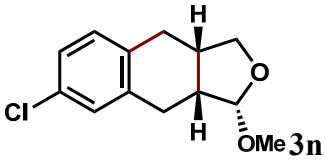
**3m′** was prepared as a white solid (34 mg, 24% yield) according to *General Procedure B*. $R_f$ = 0.55 (petroleum ether/EtOAc = 4 : 1); Mp. 118–119 °C; IR (film): $\nu_{max}$ = 3063, 2933, 2918, 2872, 2844, 1592, 1560, 1441, 1399, 1240, 1188, 1120, 1079, 987, 922, 869, 777, 702, 669, 636, 539, 477 $cm^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.23 (d, *J* = 7.6 Hz, 1H), 7.08 (t, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 7.2 Hz, 1H), 4.92 (d, *J* = 6.4 Hz, 1H), 4.14 (dd, *J* = 7.6, 6.8 Hz, 1H), 3.70 (dd, *J* = 10.4, 7.6 Hz, 1H), 3.51 (s, 3H), 3.31 (dd, *J* = 16.8, 5.6 Hz, 1H), 2.94 (dd, *J* = 16.0, 4.8 Hz, 1H), 2.70 (dd, *J* = 15.6, 12.4 Hz, 1H), 2.55 (dd, *J* = 16.4, 12.4 Hz, 1H), 2.17–2.04 (m, 1H), 1.92 (ddd, *J* = 18.0, 12.0, 6.0 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 138.0, 135.3, 134.1, 128.1, 127.0, 126.9, 109.9, 71.5, 56.6, 48.0, 40.9, 32.3, 29.4 ppm; HRMS (ESI): *m*/*z* calcd for $C_{13}H_{15}O_2{}^{35}ClNa^+$ $[M+Na]^+$: 261.0653, found: 261.0660.



**2n**

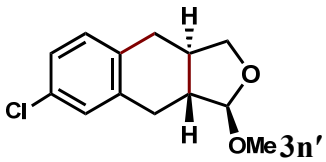
**2n** was prepared as a colorless oil (380 mg, 51% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.73 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 2926, 1638, 1580, 1459, 1385, 1264, 1198, 1121, 1101, 1056, 925, 808, 628 $cm^{-1}$; (*major isomer*) $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.72 (d, *J* = 8.4 Hz, 1H), 7.29 (d, *J* = 2.4 Hz, 1H), 6.95 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.01–5.91 (m, 1H), 5.35 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.23 (d, *J* = 10.4 Hz, 1H), 4.58 (d, *J* = 4.4 Hz, 1H), 4.33–4.22 (m, 2H),

4.19–4.14 (m, 1H), 3.51 (s, 3H), 3.50 (dd, $J$ = 14.8, 8.4 Hz, 1H), 3.09 (dd, $J$ = 14.8, 10.4 Hz, 1H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 142.6, 140.4, 134.2, 133.8, 131.5, 128.8, 117.7, 104.5, 97.3, 69.2, 56.2, 52.6, 42.8 ppm; HRMS (ESI): $m/z$ calcd for $C_{13}H_{16}O_2{}^{35}Cl^{79}BrI^+$ $[M+H]^+$: 444.9061, found: 444.9062.



**3n**

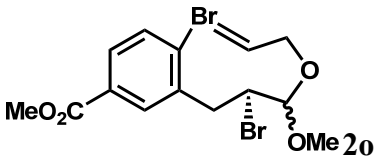
**3n** was prepared as a colorless oil (64 mg, 45% yield) according to *General Procedure B*. $R_f$ = 0.64 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3046, 2981, 2936, 2875, 1598, 1573, 1482, 1444, 1410, 1362, 1252, 1183, 1107, 1068, 990, 899, 818, 743, 683 cm$^{-1}$; $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.13 (s, 1H), 7.08 (dd, $J$ = 8.1, 2.1 Hz, 1H), 7.01 (d, $J$ = 8.1 Hz, 1H), 4.97 (d, $J$ = 4.8 Hz, 1H), 4.09 (dd, $J$ = 8.1, 7.8 Hz, 1H), 3.57 (dd, $J$ = 8.4, 7.2 Hz, 1H), 3.36 (s, 3H), 2.86 (dd, $J$ = 14.7, 8.7 Hz, 1H), 2.73 (dd, $J$ = 12.9, 4.2 Hz, 1H), 2.63 (dd, $J$ =15.0, 6.9 Hz, 1H), 2.57–2.37 (m, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 141.2, 136.8, 131.5, 128.3, 127.5, 125.6, 105.3, 70.6, 54.8, 42.7, 38.2, 32.0, 27.1 ppm; HRMS (ESI): $m/z$ calcd for $C_{12}H_{12}O^{35}Cl^+$ $[M–OMe+H]^+$: 207.0571, found: 207.0568.



**3n′**

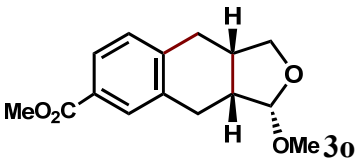
**3n′** was prepared as a colorless oil (36 mg, 25% yield) according to *General Procedure B*. $R_f$ = 0.56 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3049, 2927, 2848, 1597, 1566, 1483, 1441, 1398, 1313, 1236, 1178, 1117, 996, 924, 809, 737, 700, 667 cm$^{-1}$; $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.12 (s, 1H), 7.10 (dd, $J$ = 8.1, 1.8 Hz, 1H), 7.03 (d, $J$ = 8.1 Hz, 1H), 4.86 (d, $J$ = 6.3 Hz, 1H), 4.13 (dd, $J$ = 7.8, 6.3 Hz, 1H), 3.69 (dd, $J$ = 10.5, 7.8 Hz, 1H), 3.49 (s, 3H), 3.07 (dd, $J$ = 16.2, 5.1 Hz, 1H), 2.91 (dd, $J$ = 15.9, 4.8 Hz, 1H), 2.72 (dd, $J$ = 12.9, 8.1 Hz, 1H), 2.60 (dd, $J$ = 9.3, 6.6 Hz, 1H), 2.19–2.04 (m, 1H), 1.93 (ddd, $J$ = 17.7, 12.0, 5.4 Hz, 1H) ppm; $^{13}$C NMR (100 MHz,

$CDCl_3$): $\delta$ = 137.7, 134.0, 131.6, 130.8, 129.5, 126.2, 109.6, 71.5, 56.5, 47.8, 41.5, 31.3, 31.2 ppm; HRMS (ESI): *m*/*z* calcd for $C_{12}H_{12}O^{35}Cl^+$ $[M–OMe+H]^+$: 207.0571, found: 207.0569.



**2o**

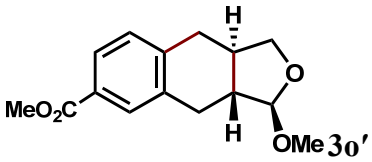
**2o** was prepared as a colorless oil (1.250 g, 51% overall yield, dr = 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.64 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3080, 2951, 2930, 2839, 1724, 1647, 1597, 1574, 1437, 1348, 1293, 1258, 1201, 1111, 1056, 1028, 994, 930, 837, 762, 688, 559 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.97 (d, *J* = 2.0 Hz, 1H), 7.77 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.62 (d, *J* = 8.4 Hz, 1H), 6.01–5.90 (m, 1H), 5.35 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.23 (dd, *J* = 10.4, 1.6 Hz, 1H), 4.60 (d, *J* = 4.4 Hz, 1H), 4.39–4.34 (m, 1H), 4.29–4.22 (m, 1H), 4.18–4.12 (m, 1H), 3.91 (s, 3H), 3.63 (dd, *J* = 14.8, 4.0 Hz, 1H), 3.50 (s, 3H), 3.15 (dd, *J* = 14.8, 10.8 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 166.3, 138.1, 133.8, 133.2 (2C), 133.0, 129.9, 129.3, 117.6, 104.6, 69.1, 55.9, 52.5, 52.3, 38.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{22}NO_4{}^{79}Br_2^+$ $[M+NH_4]^+$: 437.9910, found: 437.9908.



**3o**

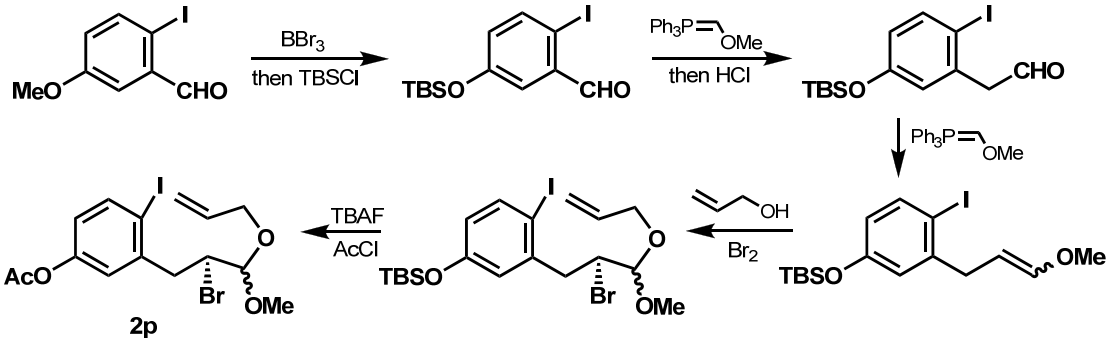
**3o** was prepared as a colorless oil (91 mg, 58% yield) according to *General Procedure B*. $R_f$ = 0.55 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 2947, 2872, 2836, 1720, 1614, 1580, 1438, 1371, 1276, 1194, 1099, 1020, 1001, 938, 925, 843, 764, 674, 555, 461 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.81 (s, 1H), 7.80 (d, *J* = 6.9 Hz, 1H), 7.15 (d, *J* = 8.1, Hz, 1H), 4.99 (d, *J* = 5.1 Hz, 1H), 4.11 (t, *J* = 8.1 Hz, 1H), 3.90 (s, 3H), 3.58 (t, *J* = 8.1 Hz, 1H), 3.36 (s, 3H), 2.91 (dd, *J* = 15.0, 9.3 Hz, 1H), 2.81 (dd, *J* = 13.8, 5.4 Hz, 1H), 2.73 (dd, *J* = 15.0, 7.2 Hz, 1H), 2.58–2.38 (m, 2H), 2.56 (dd, *J* = 14.1, 10.5 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 167.4,

144.0, 139.6, 128.6, 128.1, 127.3, 127.2, 105.4, 70.7, 54.8, 51.9, 42.9, 38.0, 32.8, 27.1 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{22}NO_4^+$ $[M+NH_4]^+$: 280.1543, found: 280.1544.




**3o′** was prepared as a colorless oil (42 mg, 27% yield) according to *General Procedure B*. $R_f$ = 0.45 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3054, 2930, 2847, 1720, 1614, 1571, 1439, 1399, 1382, 1307, 1288, 1238, 1195, 1117, 993, 922, 802, 764, 737, 665, 546, 438 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.82 (s, 1H), 7.78 (d, *J* = 8.1 Hz, 1H), 7.17 (d, *J* = 8.1, Hz, 1H), 4.88 (d, *J* = 6.3 Hz, 1H), 4.14 (t, *J* = 6.9 Hz, 1H), 3.90 (s, 3H), 3.70 (dd, *J* = 10.5, 8.1 Hz, 1H), 3.50 (s, 3H), 3.16 (dd, *J* = 15.6, 4.8 Hz, 1H), 3.00 (dd, *J* = 16.5, 4.8 Hz, 1H), 2.76 (dd, *J* = 16.5, 12.0 Hz, 1H), 2.72 (dd, *J* = 16.2, 12.0 Hz, 1H), 2.23–2.07 (m, 1H), 1.97 (ddd, *J* = 17.7, 11.4, 6.0 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 167.1, 141.1, 136.2, 131.1, 129.7, 128.1, 127.2, 109.6, 71.5, 56.5, 52.0, 48.0, 41.3, 32.1, 31.3 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{22}NO_4^+$ $[M+NH_4]^+$: 280.1543, found: 280.1547.

## Preparation of β-Bromo Acetal 2p




In a 100 mL round-bottom flask, 2-iodo-5-methoxybenzaldehyde (1.310 g, 5 mmol) was dissolved in anhydrous $CH_2Cl_2$ (20 mL) and the resulting solution was cooled to −78 °C, followed by the addition of $BBr_3$ (7.5 mL, 7.5 mmol, 1.5 equiv) dropwise over a 3 min period. The resulting mixture was gradually warmed to room

temperature, stirred for 1.5 h, and cooled to 0 °C again then quenched with saturated aqueous $NaHCO_3$ (5 mL). The reaction mixture was extracted with $CH_2Cl_2$ (3 × 40 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting phenol (ca. 5 mmol) was directly dissolved in anhydrous DMF (15 mL) and the resulting solution was cooled to 0 °C, followed by the addition of imidazole (681 mg, 10 mmol, 2.0 equiv). After 5 min, TBSCl (1.465 g, 10 mmol, 2.0 equiv) was added portionwise. The resulting mixture was gradually warmed to room temperature, and stirred for 45 min. The reaction was cooled to 0 °C again then quenched with saturated aqueous $NaHCO_3$ (2 mL) at 0 °C. The resulting mixture was extracted with $CH_2Cl_2$ (3 × 40 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 30 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel to afford silyl ether (1.575 g, 87% yield) as a colorless oil.

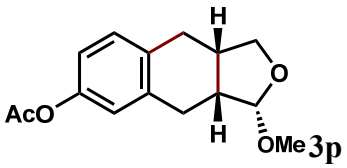
Potassium *tert*-butoxide (98%, 1.143 g, 10 mmol, 2.0 equiv) was added in portions to a suspension of (methoxymethyl)triphenylphosphonium chloride (3.602 g, 10.5 mmol, 2.1 equiv) in THF (20 mL) at 0 ºC. After stirring for 40 min at 0 ºC, a solution of the above silyl ether (1.810 g, 5 mmol) in THF (10 mL) was added dropwise and the resulting mixture was gradually warmed to room temperature, and stirred for 4 h. The reaction was quenched by the addition of saturated aqueous $NH_4Cl$ solution (3 mL). The mixture was extracted with EtOAc (3 × 40 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 60 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel. The resulting enol ether was dissolved in $CH_2Cl_2$ (20 mL) followed by the addition of water (0.5 mL) and TFA (0.8 mL) at room temperature. The mixture was stirred for 24 h, and then extracted with $CH_2Cl_2$ (3 × 30 mL), and the combined organic layers were washed with saturated aqueous $NaHCO_3$ (15 mL), water (1 × 15 mL) and brine (15 mL) respectively, dried over

$Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting phenylacetaldehyde could be used directly for the next reaction without further purification. In a 50 mL round-bottom flask, potassium *tert*-butoxide (98%, 571 mg, 5 mmol, 1.0 equiv) was added in portions to a suspension of (methoxymethyl)triphenylphosphonium chloride (2.058 g, 6 mmol, 1.2 equiv) in THF (20 mL) at 0 ºC. After stirring for 40 min at 0 ºC, a solution of the above phenylacetaldehyde (ca. 5 mmol) in THF (8 mL) was added dropwise. The resulting mixture was gradually warmed to room temperature, and stirred for 4 h. The reaction was then quenched by the addition of saturated aqueous $NH_4Cl$ solution (3 mL). The resulting mixture was extracted with EtOAc (3 × 40 mL), and the combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 60 : 1 → petroleum ether/EtOAc = 10 : 1) on silica gel to afford the desired enol methylether (1.030 g, 51% yield) as a colorless oil.

The following synthesis of the corresponding *β*-bromo acetal as a colorless oil was completed according to the corresponding protocol in *General Procedure A-1*.

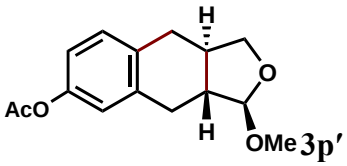
To a stirred solution of the above *β*-bromo acetal (540 mg, 1.0 mmol) in THF (8 mL) was added TBAF (1.0 M in THF, 1.5 mL, 1.5 mmol, 1.5 equiv) at 0 ºC. The mixture was stirred for 1 h at 0 °C. The resultant mixture was extracted with EtOAc (3 × 25 mL), and the combined organic layers were washed with water (2 × 10 mL) and brine (10 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The resulting phenol (ca. 1 mmol) was dissolved directly in THF (5 mL), followed by the addition of $Et_3N$ (0.15 mL, 1.1 mmol, 1.1 equiv) at 0 ºC. After 2 min, AcCl (0.11 mL, 1.5 mmol, 1.5 equiv) was added dropwise, and the resulting mixture was gradually warmed to room temperature, and stirred for 3 h. The resultant mixture was then extracted with EtOAc (3 × 25 mL), and the combined organic layers were washed with water (2 × 10 mL) and brine (10 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 8 : 1 → petroleum

ether/EtOAc = 4 : 1) on silica gel to afford *β*-bromo acetal **2p** (450 mg, 43% overall yield, dr = 1.5 : 1) as a colorless oil. $R_f$ = 0.58 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 2954, 2927, 2854, 1770, 1647, 1593, 1572, 1466, 1436, 1369, 1267, 1201, 1159, 1055, 1011, 921, 815, 738, 702, 676, 597, 558, 459 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.81 (d, $J$ = 8.4 Hz, 1H), 7.06 (d, $J$ = 2.8 Hz, 1H), 6.76 (dd, $J$ = 8.4, 2.8 Hz, 1H), 6.02–5.90 (m, 1H), 5.35 (dd, $J$ = 16.8, 1.6 Hz, 1H), 5.23 (d, $J$ = 10.4 Hz, 1H), 4.57 (d, $J$ = 4.0 Hz, 1H), 4.32 (dt, $J$ = 10.4, 4.0 Hz, 1H), 4.25 (dd, $J$ = 12.0, 5.6 Hz, 1H), 4.17 (dd, $J$ = 12.4, 5.6 Hz, 1H), 3.52 (dd, $J$ = 14.8, 5.2 Hz, 1H), 3.50 (s, 3H), 3.11 (dd, $J$ = 14.8, 10.4 Hz, 1H), 2.29 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 169.0, 150.6, 142.3, 140.2, 133.9, 124.9, 122.1, 117.6, 104.5, 96.0, 69.2, 56.1, 52.8, 43.1, 21.1 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{22}NO_4{}^{79}BrI^+$ $[M+NH_4]^+$: 485.9771, found: 485.9770.



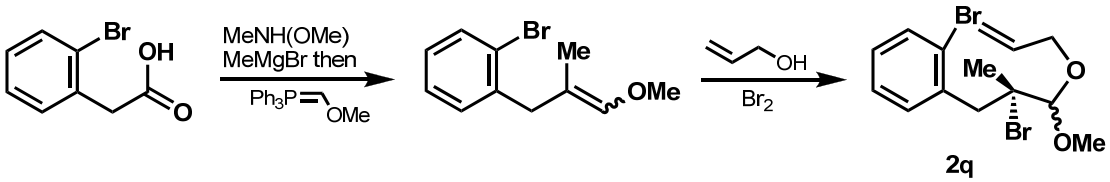
**3p**

**3p** was prepared as a colorless oil (88 mg, 56% yield) according to *General Procedure B*. $R_f$ = 0.48 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 2934, 2872, 2838, 1762, 1614, 1590, 1493, 1469, 1440, 1370, 1290, 1212, 1142, 1107, 1069, 1018, 913, 819, 736, 655, 597, 536, 508, 454 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.08 (d, $J$ = 8.0 Hz, 1H), 6.87 (s, 1H), 6.82 (dd, $J$ = 8.0, 2.0 Hz, 1H), 4.97 (d, $J$ = 5.2 Hz, 1H), 4.10 (t, $J$ = 8.0 Hz, 1H), 3.59 (t, $J$ = 8.0 Hz, 1H), 3.36 (s, 3H), 2.88 (dd, $J$ = 14.8, 9.2 Hz, 1H), 2.75 (dd, $J$ = 12.8, 4.4 Hz, 1H), 2.65 (dd, $J$ = 14.8, 6.8 Hz, 1H), 2.57–2.50 (m, 1H), 2.48 (dd, $J$ = 12.8, 10.0 Hz, 1H), 2.47–2.40 (m, 1H), 2.28 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 169.8, 148.9, 140.8, 136.0, 127.8, 120.6, 118.5, 105.4, 70.7, 54.8, 42.8, 38.3, 32.2, 27.3, 21.1 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{22}NO_4{}^+$ $[M+NH_4]^+$: 280.1543, found: 280.1542.




**3p′** was prepared as a colorless oil (40 mg, 25% yield) according to *General Procedure B*. $R_f$ = 0.39 (petroleum ether/EtOAc = 2 : 1); IR (film): $\nu_{max}$ = 3055, 2927, 2851, 1760, 1612, 1581, 1494, 1442, 1370, 1266, 1209, 1180, 1116, 996, 918, 816, 740, 704, 665, 567, 446 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.11 (d, $J$ = 8.8 Hz, 1H), 6.86 (d, $J$ = 2.8 Hz, 1H), 6.85 (s, 1H), 4.86 (d, $J$ = 6.4 Hz, 1H), 4.13 (dd, $J$ = 7.6, 6.4 Hz, 1H), 3.69 (dd, $J$ = 10.8, 8.0 Hz, 1H), 3.49 (s, 3H), 3.08 (dd, $J$ = 16.4, 5.2 Hz, 1H), 2.93 (dd, $J$ = 16.0, 5.2 Hz, 1H), 2.75 (dd, $J$ = 15.2, 12.8 Hz, 1H), 2.66 (dd, $J$ = 15.6, 12.4 Hz, 1H), 2.28 (s, 3H), 2.19–2.08 (m, 1H), 1.95 (ddd, $J$ = 18.4, 12.4, 6.0 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 169.7, 148.8, 137.3, 133.2, 130.4, 122.4, 119.4, 109.7, 71.6, 56.5, 47.8, 41.6, 31.4 (2C), 21.1 ppm; HRMS (ESI): $m/z$ calcd for $C_{15}H_{22}NO_4^+$ $[M+NH_4]^+$: 280.1543, found: 280.1542.

**Preparation of β-Bromo Acetal 2q**



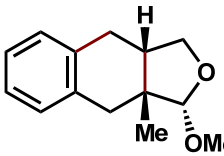

*o*-Bromophenylacetic acid (3.230 g, 15 mmol) were dissolved in $CH_2Cl_2$ (30 mL) followed by the addition of *N*,*N*-carbonyldiimidazole (98%, 2.728 g, 16.5 mmol, 1.1 equiv) at 0 °C. After a good stirring for 30 min, *N*,*O*-dimethylhydroxyamine hydrochloride (98%, 1.782 g, 18 mmol, 1.2 equiv) and $Et_3N$ (6.2 mL, 45 mmol, 3.0 equiv) were successively added at 0 °C. The resulting mixture was slowly warmed to room temperature and stirred for 8 h. The reaction mixture was then quenched by saturated aqueous $NH_4Cl$ (5 mL), and extracted with $CH_2Cl_2$ (3 × 50 mL). The combined organic layers were washed with saturated aqueous $NaHCO_3$ (20 mL), HCl (1*N*, 20 mL), water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash

column chromatography (petroleum ether/EtOAc/$Et_3N$ = 10 : 1 : 0.2 → petroleum ether/EtOAc = 2 : 1 : 0.05) on silica gel to afford the corresponding Weinreb amides as pale yellow oils. The above Weinreb amides (ca. 15 mmol) were then dissolved in THF (30 mL) followed by the addition of methylmagnesium bromide (18 mmol, 1.2 equiv) dropwise via a syringe at −78 °C. The resulting mixture was gradually warmed to 0 ºC, and stirred for 1 h. The reaction was quenched by saturated aqueous $NH_4Cl$ solution (5 mL), and the mixture was extracted with EtOAc (3 × 50 mL). The combined organic layers were washed with water (2 × 20 mL) and brine (20 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 10 : 1 → petroleum ether/EtOAc = 5 : 1) on silica gel to afford the methyl ketone (2.415 g, 76% yield) as a colorless oil.

To a suspension of (methoxymethyl)triphenylphosphonium chloride (2.573 g, 7.5 mmol, 1.5 equiv) in THF (20 mL) was added *n*-BuLi (4.7 mL, 7.5 mmol, 1.5 equiv) dropwise at −78 ºC. The resulting mixture was gradually warmed to room temperature, and stirred for 50 min. The reaction was then cooled to −78 ºC again, followed by the addition of a solution of the above methyl ketone (1.060 g, 5 mmol) in THF (10 mL) dropwise. The resulting mixture was gradually warmed to room temperature, and stirred further for 8 h. The reaction was then quenched by the addition of saturated aqueous $NH_4Cl$ solution (2 mL). The resultant mixture was extracted with EtOAc (3 × 35 mL), and the combined organic layers were washed with water (2 × 15 mL) and brine (15 mL) respectively, dried over $Na_2SO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/EtOAc = 80 : 1 → petroleum ether/EtOAc = 5 : 1) on silica gel to afford enol methylether (420 mg, 35% yield) as a colorless oil and recovered ketone (620mg)

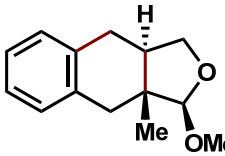
The following synthesis of *β*-bromo acetal **2q** (250 mg, 36% overall yield, dr = 1.8 : 1) as a colorless oil was completed according to the corresponding protocol in *General Procedure A-1*. $R_f$ = 0.60 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3068, 2982, 2930, 2869, 1648, 1595, 1566, 1499, 1472, 1440, 1377, 1345, 1185, 1102,

1056, 1024, 992, 926, 811, 752, 661, 585, 563, 453 $cm^{-1}$; (*one isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.60 (t, $J$ = 8.0 Hz, 1H), 7.57 (d, $J$ = 8.4 Hz, 1H), 7.27 (t, $J$ = 7.6 Hz, 1H), 7.12 (t, $J$ = 8.0 Hz, 1H), 6.04–5.93 (m, 1H), 5.36 (d, $J$ = 17.6 Hz, 1H), 5.23 (d, $J$ = 10.4 Hz, 1H), 4.47 (s, 1H), 4.36 (dd, $J$ = 12.8, 3.6 Hz, 1H), 4.28 (t, $J$ = 6.0 Hz, 1H), 3.62 (s, 3H), 3.56 (d, $J$ = 14.8 Hz, 1H), 3.41 (d, $J$ = 14.4 Hz, 1H), 1.69 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 136.4, 134.0, 133.1, 132.9, 128.4, 126.7 (2C), 117.3, 109.1, 71.7, 71.6, 58.5, 42.7, 25.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2{}^{79}Br_2Na^+$ $[M+Na]^+$: 398.9566, found: 398.9574.



**3q**

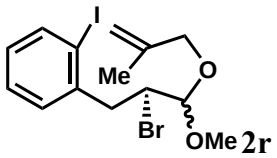
**3q** was prepared as a colorless oil (68 mg, 52% yield) according to *General Procedure B*. $R_f$ = 0.50 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3021, 2956, 2928, 2871, 1604, 1486, 1458, 1381, 1365, 1265, 1191, 1099, 1075, 1021, 990, 940, 795, 741, 705, 589, 453 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.14–7.08 (m, 4H), 4.61 (s, 1H), 4.16 (t, $J$ = 8.4 Hz, 1H), 3.62 (t, $J$ = 8.4 Hz, 1H), 3.37 (s, 3H), 3.14 (d, $J$ = 14.4 Hz, 1H), 2.71 (dd, $J$ = 14.0, 5.6 Hz, 1H), 2.53 (dd, $J$ = 14.0, 10.0 Hz, 1H), 2.32 (d, $J$ = 14.8 Hz, 1H), 1.99–1.91 (m, 1H), 0.99 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 138.9, 137.6, 128.2, 126.9, 126.0, 125.8, 111.5, 71.3, 55.0, 47.6, 46.3, 34.9, 32.8, 28.3 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1203.



**3q′**

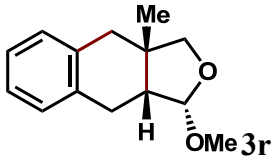
**3q′** was prepared as a colorless oil (35 mg, 27% yield) according to *General Procedure B*. $R_f$ = 0.42 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3054, 2925, 2874, 2848, 1602, 1491, 1465, 1398, 1372, 1266, 1211, 1156, 1120, 1097, 999, 931, 851, 741, 704, 657, 440 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.14–7.10 (m, 4H), 4.74 (s, 1H), 4.04 (t, $J$ = 10.0 Hz, 1H), 3.76 (dd, $J$ = 14.8, 10.0 Hz, 1H), 3.54 (s, 3H),

2.91–2.56 (m, 4H), 2.36–2.24 (m, 1H), 0.86 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 135.4, 134.6, 130.4, 129.6, 126.2, 125.9, 112.6, 69.2, 57.6, 42.7, 41.8, 39.6, 27.4, 10.4 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1205.



**2r**

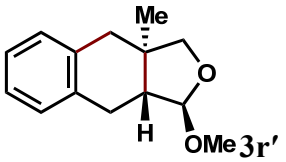
**2r** was prepared as a colorless oil (1.160 g, 78% overall yield, dr = 2 : 1) according to *General Procedure A-1*. $R_f$ = 0.63 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3053, 2927, 2862, 1656, 1587, 1563, 1467, 1438, 1374, 1349, 1265, 1196, 1127, 1074, 1012, 910, 740, 704, 647, 553, 443 cm$^{-1}$; (*major isomer*) $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.83 (d, *J* = 7.8 Hz, 1H), 7.30 (d, *J* = 4.5 Hz, 2H), 6.96 (dd, *J* = 8.4, 4.5 Hz, 1H), 5.07 (s, 1H), 4.95 (s, 1H), 4.60 (d, *J* = 4.2 Hz, 1H), 4.38 (dt, *J* = 10.8, 3.6 Hz, 1H), 4.16 (dd, *J* = 12.3, 6.6 Hz, 1H), 4.06 (dd, *J* = 12.3, 8.4 Hz, 1H), 3.57 (dd, *J* = 6.6, 4.2 Hz, 1H), 3.52 (s, 3H), 3.13 (dd, *J* = 14.7, 10.8 Hz, 1H), 1.82 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 141.3, 140.7, 139.6, 131.7, 128.6, 128.0, 113.0, 104.5, 100.4, 72.2, 56.1, 53.4, 43.1, 19.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 446.9427, found: 446.9434.



**3r**

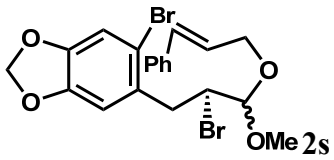
**3r** was prepared as a colorless oil (73 mg, 56% yield) according to *General Procedure B*. $R_f$ = 0.55 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3020, 2954, 2924, 2869, 2832, 1607, 1585, 1489, 1458, 1379, 1361, 1310, 1264, 1186, 1113, 1043, 1025, 943, 895, 751, 740, 664, 569, 450 cm$^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.15–7.06 (m, 4H), 5.04 (d, *J* = 6.0 Hz, 1H), 3.70 (d, *J* = 8.4 Hz, 1H), 3.63 (d, *J* = 8.4 Hz, 1H), 3.35 (s, 3H), 2.83 (dd, *J* = 14.8, 8.8 Hz, 1H), 2.69 (d, *J* = 14.0 Hz, 1H), 2.63 (dd, *J* = 14.8, 6.8 Hz, 1H), 2.49 (d, *J* = 14.0 Hz, 1H), 2.03 (dt, *J* = 8.4, 6.8 Hz, 1H), 0.96 (s, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 138.5, 137.8, 127.8, 127.3, 126.1,

125.6, 106.4, 77.3, 55.0, 50.5, 43.2, 39.4, 28.5, 27.6 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1202.



**3r′**

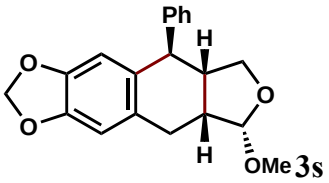
**3r′** was prepared as a white solid (37 mg, 28% yield) according to *General Procedure B*. $R_f$ = 0.45 (petroleum ether/EtOAc = 4 : 1); Mp. 102–103 °C; IR (film): $\nu_{max}$ = 3051, 2962, 2926, 2856, 1615, 1503, 1444, 1399, 1266, 1238, 1196, 1120, 1086, 994, 972, 913, 818, 739, 706, 664, 559, 445 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.16–7.07 (m, 4H), 4.87 (d, *J* = 7.2 Hz, 1H), 3.86 (d, *J* = 7.5 Hz, 1H), 3.79 (d, *J* = 7.5 Hz, 1H), 3.50 (s, 3H), 2.98 (dd, *J* = 16.2, 5.4 Hz, 1H), 2.81 (dd, *J* = 15.6, 10.2 Hz, 1H), 2.70 (d, *J* = 12.9 Hz, 1H), 2.65 (d, *J* = 15.6 Hz, 1H), 2.04 (ddd, *J* = 18.6, 12.9, 6.0 Hz, 1H), 0.97 (s, 3H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 135.2, 135.1, 130.3, 129.8, 126.2, 125.9, 108.6, 78.7, 56.6, 49.7, 41.0, 39.9, 26.7, 17.4 ppm; HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$: 241.1199, found: 241.1204.



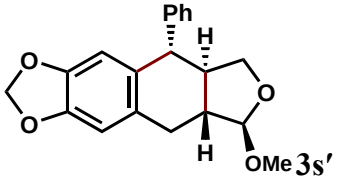
**2s**

**2s** was prepared as a colorless oil (750 mg, 60% overall yield, dr = 2 : 1) according to *General Procedure A-2*. $R_f$ = 0.55 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3025, 2926, 2903, 1678, 1625, 1599, 1503, 1478, 1449, 1410, 1353, 1232, 1119, 1070, 1039, 967, 935, 861, 738, 693, 656, 537, 439 $cm^{-1}$; (*major isomer*) $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 7.40 (d, *J* = 7.6 Hz, 2H), 7.32 (t, *J* = 8.0 Hz, 2H), 7.25 (t, *J* = 7.6 Hz, 1H), 6.99 (s, 1H), 6.80 (s, 1H), 6.66 (d, *J* = 15.6 Hz, 1H), 6.32 (dt, *J* = 16.0, 6.0 Hz, 1H), 5.95 (s, 1H), 5.94 (s, 1H), 4.61 (t, *J* = 4.0 Hz, 1H), 4.41 (dd, *J* = 12.0, 6.0 Hz, 1H), 4.36–4.32 (m, 1H), 4.31 (dd, *J* = 12.8, 6.4 Hz, 1H), 3.53 (dd, *J* = 15.2, 3.6 Hz, 1H), 3.51 (s, 3H), 2.99 (dd, *J* = 14.8, 10.4 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 147.4, 147.0, 136.5, 132.9, 130.6, 128.6 (2C), 127.8, 126.5 (2C), 125.0,

114.7, 112.7, 111.9, 104.4, 101.7, 68.8, 55.8, 53.4, 39.1 ppm; HRMS (ESI): *m*/*z* calcd for $C_{20}H_{20}O_4{}^{79}Br_2Na^+$ $[M+Na]^+$: 504.9621, found: 504.9629.




**3s** was prepared as a colorless oil (99 mg, 51% yield) according to *General Procedure B*. $R_f$ = 0.48 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3027, 2927, 1672, 1602, 1501, 1481, 1450, 1361, 1288, 1254, 1149, 1113, 1044, 1014, 936, 871, 751, 702, 599, 546, 439 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ = 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 (d, *J* = 7.2 Hz, 1H), 7.16 (d, *J* = 6.9 Hz, 2H), 6.64 (s, 1H), 5.98 (s, 1H), 5.78 (s, 1H), 5.76 (s, 1H), 4.93 (d, *J* = 4.8 Hz, 1H), 3.74 (t, *J* = 8.4 Hz, 1H), 3.59 (d, *J* = 10.8 Hz, 1H), 3.48 (t, *J* = 8.4 Hz, 1H), 3.33 (s, 3H), 2.91 (dd, *J* = 14.1, 9.9 Hz, 1H), 2.72–2.50 (m, 2H), 2.63 (dd, *J* = 13.2, 6.9 Hz, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 145.5, 145.4, 141.0, 135.4, 132.1, 129.2 (2C), 128.8 (2C), 127.0, 108.1, 107.3, 105.4, 100.6, 70.2, 54.8, 48.7, 44.8, 43.5, 27.5 ppm; HRMS (ESI): *m*/*z* calcd for $C_{20}H_{20}O_4Na^+$ $[M+Na]^+$: 347.1254, found: 347.1258.




**3s′** was prepared as a white solid (47 mg, 24% yield) according to *General Procedure B*. $R_f$ = 0.40 (petroleum ether/EtOAc = 4 : 1); Mp. 198–200 °C; IR (film): $\nu_{max}$ = 3029, 2959, 2909, 2848, 1599, 1488, 1375, 1242, 1117, 1036, 991, 929, 868, 748, 703, 646, 606, 568, 424 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ =7.24 (t, *J* = 7.2 Hz, 2H), 7.18 (d, *J* = 5.6 Hz, 1H), 7.03 (d, *J* = 7.2 Hz, 2H), 6.55 (s, 1H), 6.14 (s, 1H), 5.78 (s, 2H), 4.81 (d, *J* = 6.0 Hz, 1H), 3.74 (d, *J* = 10.8 Hz, 1H), 3.65 (d, *J* = 7.2 Hz, 1H), 3.64 (d, *J* = 9.6 Hz, 1H), 3.41 (s, 3H), 2.99 (dd, *J* = 15.6, 4.8 Hz, 1H), 2.78 (t, *J* = 14.0 Hz, 1H), 2.25–2.15 (m, 1H), 2.06 (ddd, *J* = 18.0, 12.0, 5.6 Hz, 1H) ppm; $^{13}C$

NMR (100 MHz, $CDCl_3$): $\delta$ = 146.1 (2C), 144.2, 132.7, 129.5, 128.7 (2C), 128.4 (2C), 126.9, 110.0, 109.4, 108.8, 100.9, 71.1, 56.5, 49.9, 49.7, 47.9, 32.1 ppm; HRMS (ESI): *m*/*z* calcd for $C_{20}H_{20}O_4Na^+$ $[M+Na]^+$: 347.1254, found: 347.1258. This product (8.4 mg) was dissolved in EtOAc (1 mL) and petroleum ether (2 mL). After a week, colorless single crystals were obtained by slow evaporation of solvents at room temperature.

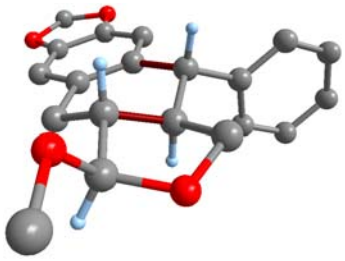
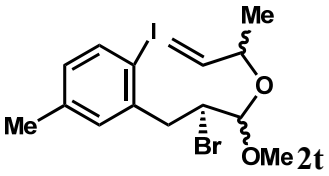


**Table S8**: X-ray crystal data of **3s′** (selected H atoms have been omitted for clarity)

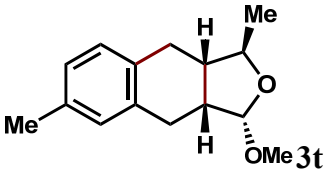
| | |
|---|---|
| Empirical formula | $C_{20}H_{20}O_4$ |
| Temperature (K) | 294.06(10) |
| Crystal color | colorless |
| Formula weight | 324.36 |
| Crystal system | Triclinic |
| Space group | *P*-1 |
| *a* (Å) | 6.4202(14) |
| *b* (Å) | 8.678(2) |
| *c* (Å) | 15.259(4) |
| *α* (°) | 77.58(2) |
| *β* (°) | 82.191(19) |
| *γ* (°) | 85.69(2) |
| *V* (Å $^3$) | 821.6(3) |
| *Z* | 2 |
| Density (calculated) (g/cm$^3$) | 1.311 |
| *F* (000) | 344.0 |
| *λ* (Å) | 0.71073 |
| Reflections collected | 5016 |
| Independent reflections | 3189 |
| *θ* Range for data collection (°) | 3.26—26.02 |

| | |
|---|---|
| Index range | $-7 \le h \le 7$<br>$-10 \le k \le 10$<br>$-16 \le l \le 18$ |
| Final *R* indices [I>2σ(*I*)] | $R_1 = 0.0637$, $wR_2 = 0.1343$ |
| Largest difference peak and hole [e Å $^{-3}$] | 0.189, –0.244 |



**2t**

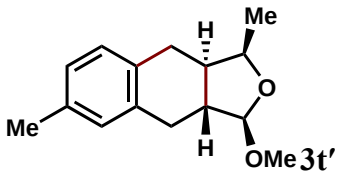
**2t** was prepared as a colorless oil (530 mg, 43% overall yield, dr = 1.5 : 2 : 1 : 1) according to *General Procedure A-2*. $R_f$ = 0.55 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3078, 2977, 2927, 2834, 1642, 1595, 1468, 1444, 1371, 1318, 1265, 1230, 1194, 1059, 994, 928, 807, 706, 673, 572, 451 cm$^{-1}$; (*major isomer*) $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.67 (d, $J$ = 8.1 Hz, 1H), 7.11 (s, 1H), 6.76 (d, $J$ = 8.1 Hz, 1H), 5.92–5.71 (m, 1H), 5.24 (d, $J$ = 18.0 Hz, 1H), 5.18 (d, $J$ = 9.6 Hz, 1H), 4.60 (d, $J$ = 3.6 Hz, 1H), 4.36–4.21 (m, 2H), 3.54–4.48 (m, 1H), 3.47 (s, 3H), 3.11 (dd, $J$ = 12.0, 6.9 Hz, 1H), 2.29 (s, 3H), 1.34 (d, $J$ = 6.0 Hz, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 140.4, 139.5, 139.1, 137.7, 132.5, 129.5, 117.0, 102.3, 96.2, 75.5, 55.1, 54.0, 42.6, 21.5, 20.9 ppm; HRMS (ESI): *m/z* calcd for $C_{15}H_{20}O_2{}^{79}BrINa^+$ $[M+Na]^+$: 460.9584, found: 460.9594.



**3t**

**3t** was prepared as a colorless oil (67 mg, 48% yield) according to *General Procedure B*. $R_f$ = 0.48 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 2926, 1618, 1500, 1451, 1384, 1316, 1183, 1116, 1094, 1074, 1025, 977, 902, 854, 812, 594, 572, 441 cm$^{-1}$; $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 6.99 (d, $J$ = 7.6 Hz, 1H), 6.96 (s, 1H), 6.93 (d, $J$ = 7.2 Hz, 1H), 4.98 (d, $J$ = 4.8 Hz, 1H), 3.90–3.83 (m, 1H), 3.38 (s, 3H), 2.86–2.79 (m, 1H), 2.72 (dd, $J$ = 14.4, 6.0 Hz, 1H), 2.63–2.54 (m, 2H), 2.42 (dd, $J$ = 13.6, 10.8 Hz, 1H), 2.31 (s, 3H), 1.97–1.88 (m, 1H), 1.33 (d, $J$ = 6.0 Hz, 3H) ppm;

$^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 139.5, 135.6, 135.4, 128.2, 126.9, 126.3, 105.2, 77.8, 54.8, 46.3, 44.1, 31.4, 27.6, 21.1, 19.3 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{20}O_2Na^+$ [M+Na]$^+$: 255.1356, found: 255.1359.




**3t′** was prepared as a colorless oil (31 mg, 22% yield) according to *General Procedure B*. $R_f$ = 0.39 (petroleum ether/EtOAc = 4 : 1); IR (film): $\nu_{max}$ = 3050, 2959, 2925, 2870, 1616, 1502, 1459, 1443, 1401, 1377, 1326, 1266, 1188, 1114, 1060, 1031, 981, 963, 810, 739, 705, 440 cm$^{-1}$; $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ = 7.01 (d, *J* = 8.4 Hz, 1H), 6.95 (s, 1H), 6.94 (d, *J* = 8.4 Hz, 1H), 4.87 (d, *J* = 6.3 Hz, 1H), 3.95 (dq, *J* = 9.6, 6.0 Hz, 1H), 3.50 (s, 3H), 3.05 (dd, *J* = 15.9, 5.4 Hz, 1H), 2.84 (dd, *J* = 15.6, 5.1 Hz, 1H), 2.71 (dd, *J* = 15.6, 12.6 Hz, 1H), 2.60 (dd, *J* = 14.7, 12.9 Hz, 1H), 2.29 (s, 3H), 2.04 (ddd, *J* = 18.0, 12.0, 5.7 Hz, 1H), 1.68–1.55 (m, 1H), 1.33 (d, *J* = 6.0 Hz, 3H) ppm; $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 135.7, 135.6, 132.4, 130.4, 129.5, 126.9, 109.1, 78.8, 56.5, 48.8, 48.4, 31.7, 30.9, 20.9, 18.8 ppm; HRMS (ESI): *m*/*z* calcd for $C_{15}H_{20}O_2Na^+$ [M+Na]$^+$: 255.1356, found: 255.1357.

*Supporting Information (spectra copies) for*

# Stereoselective Synthesis of *Podophyllum* Lignans Core by Intramolecular Reductive Nickel-catalysis

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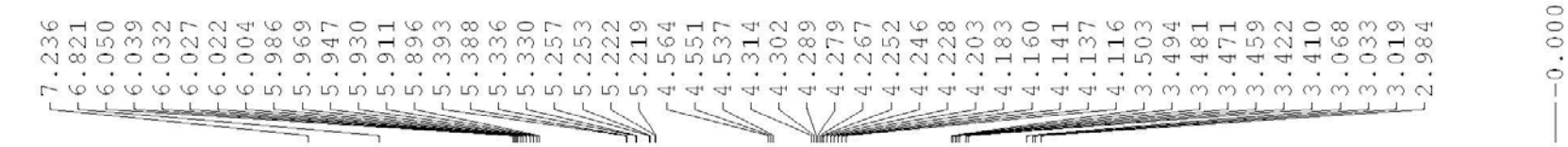
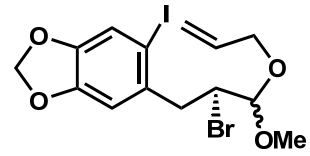



$^1$H NMR (300 MHz, $CDCl_3$)




**2a**

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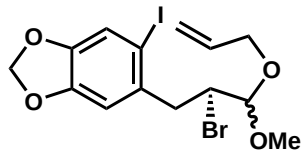
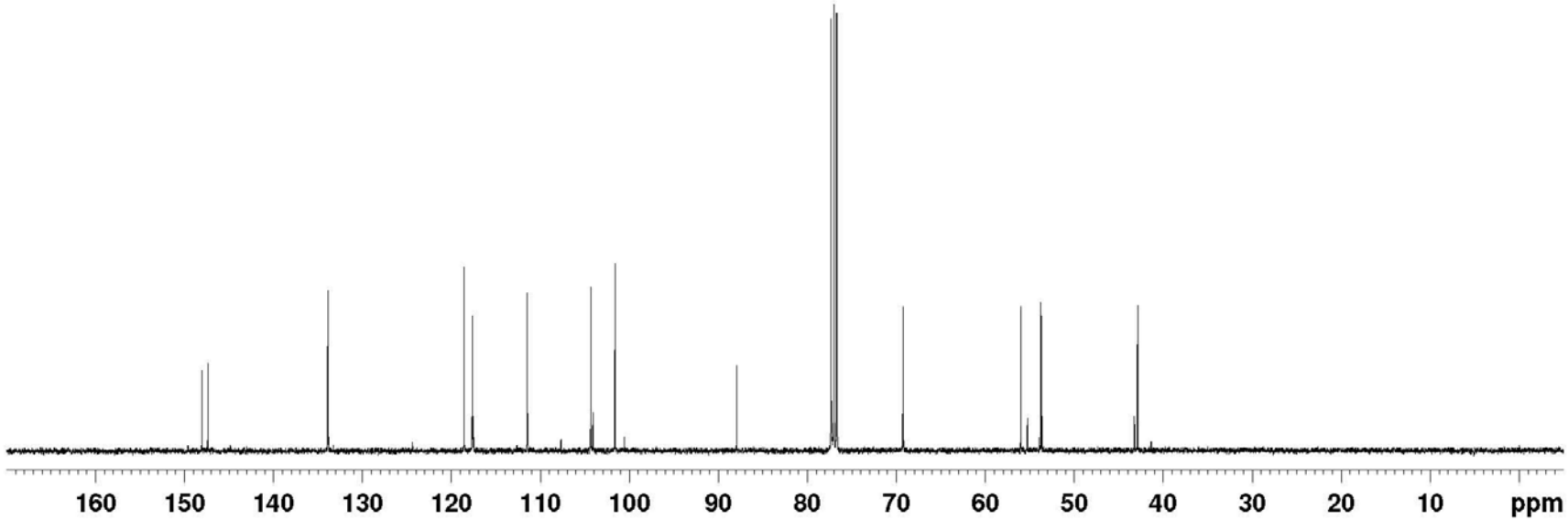
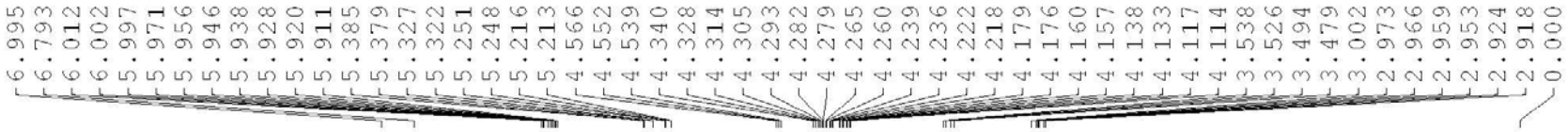
133.82
118.57
117.65
117.54
111.50
111.42
104.35
104.09
101.60
87.92
77.32
77.00
76.68
69.33
69.19
55.98
55.24
53.71
53.61
43.21
42.86

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

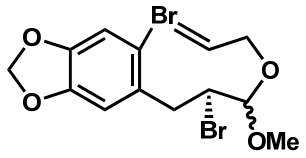



**2a**

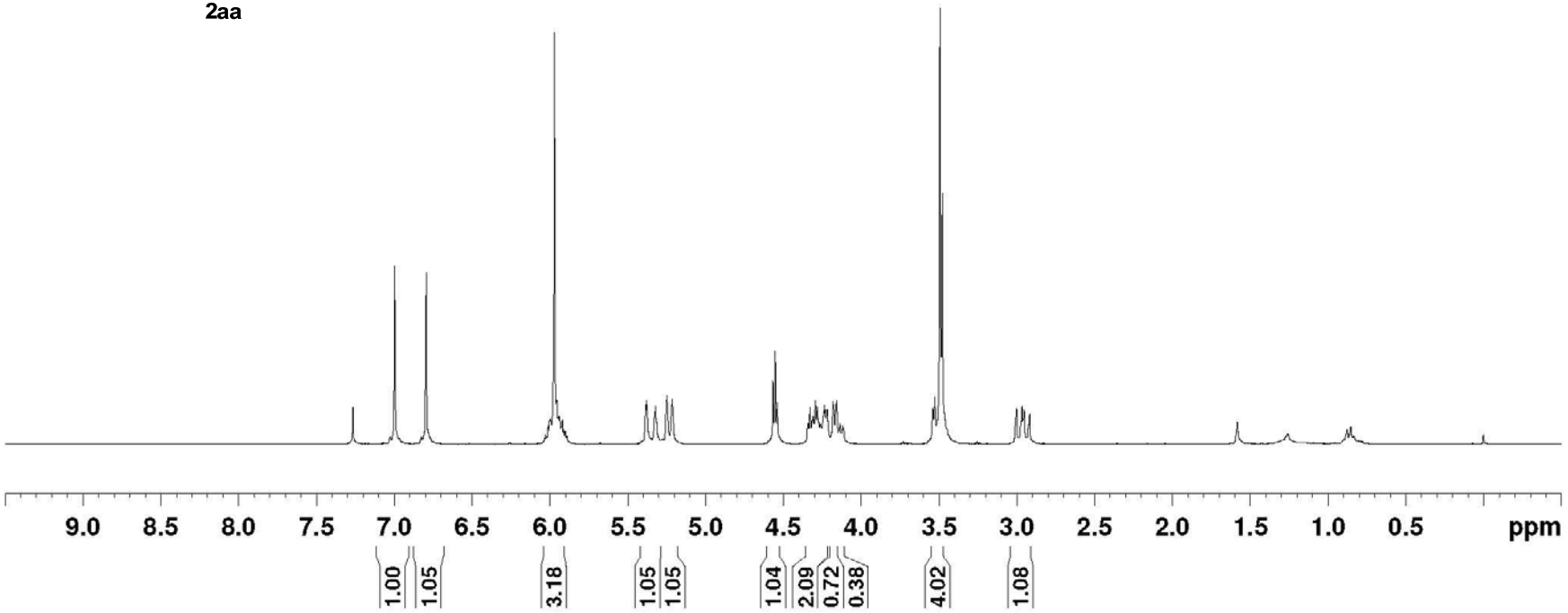


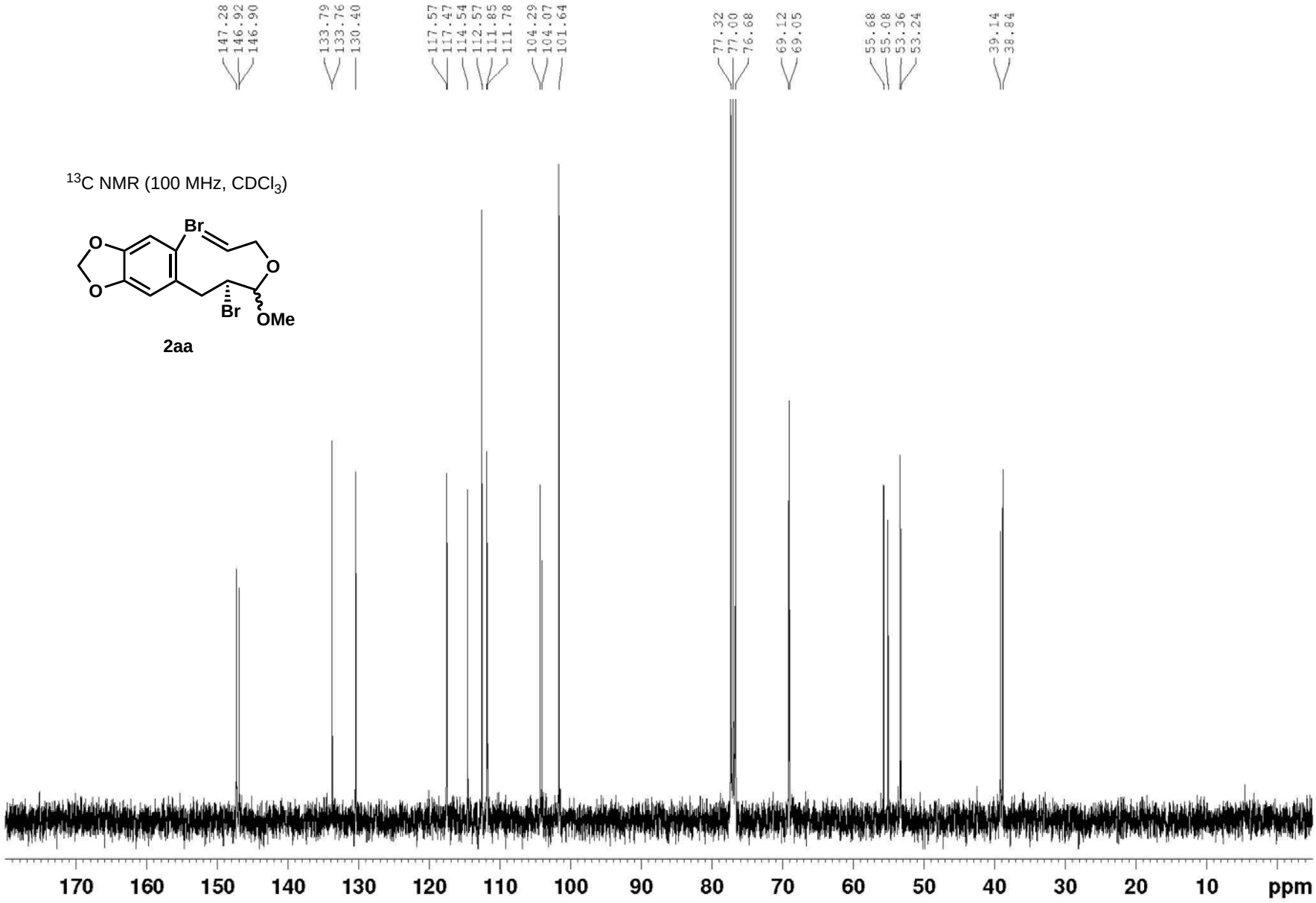



$^1$H NMR (300 MHz, $CDCl_3$)




**2aa**

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133.79
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117.47
114.54
112.57
111.85
111.78
104.29
104.07
101.64
77.32
77.00
76.68
69.12
69.05
55.68
55.08
53.36
53.24
39.14
38.84
$^{13}$C NMR (100 MHz, $CDCl_3$)
Br
O
O
O
Br
OMe
2aa
170
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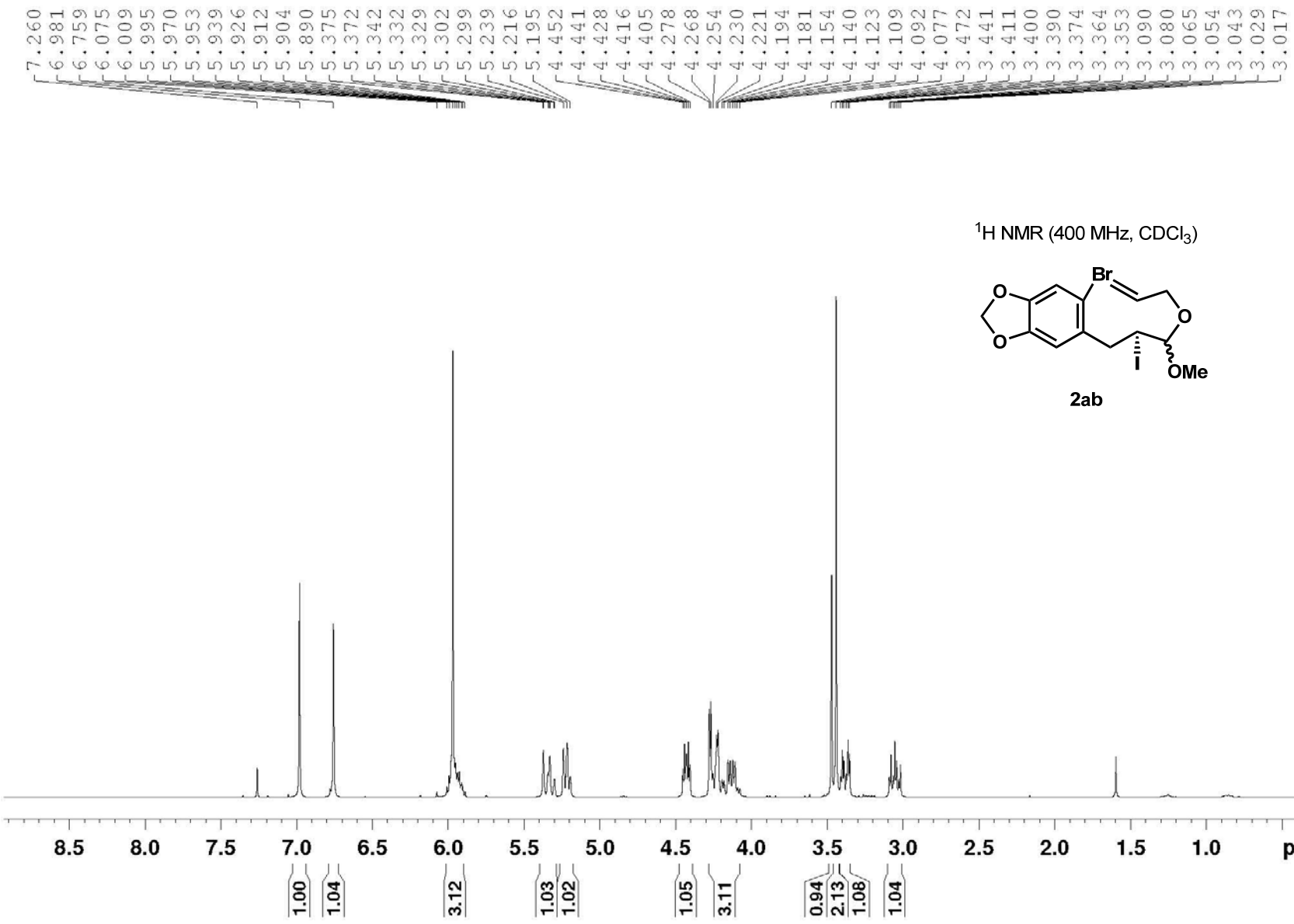
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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6.759
6.075
6.009
5.995
5.970
5.953
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5.904
5.890
5.375
5.372
5.342
5.332
5.329
5.302
5.299
5.239
5.216
5.195
4.452
4.441
4.428
4.416
4.405
4.278
4.268
4.254
4.230
4.221
4.194
4.181
4.154
4.140
4.123
4.109
4.092
4.077
3.472
3.441
3.411
3.400
3.390
3.374
3.364
3.353
3.090
3.080
3.065
3.054
3.043
3.029
3.017
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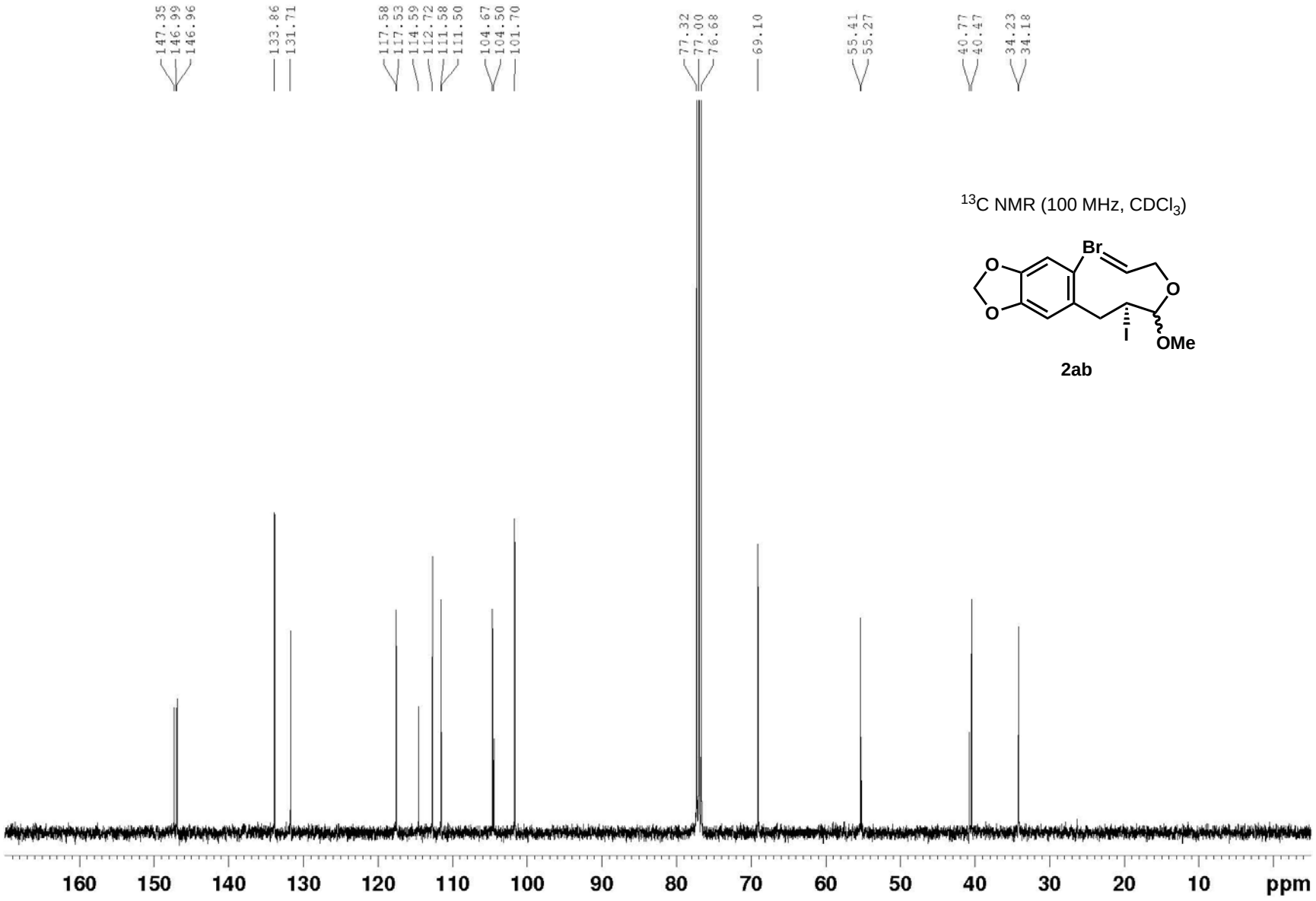
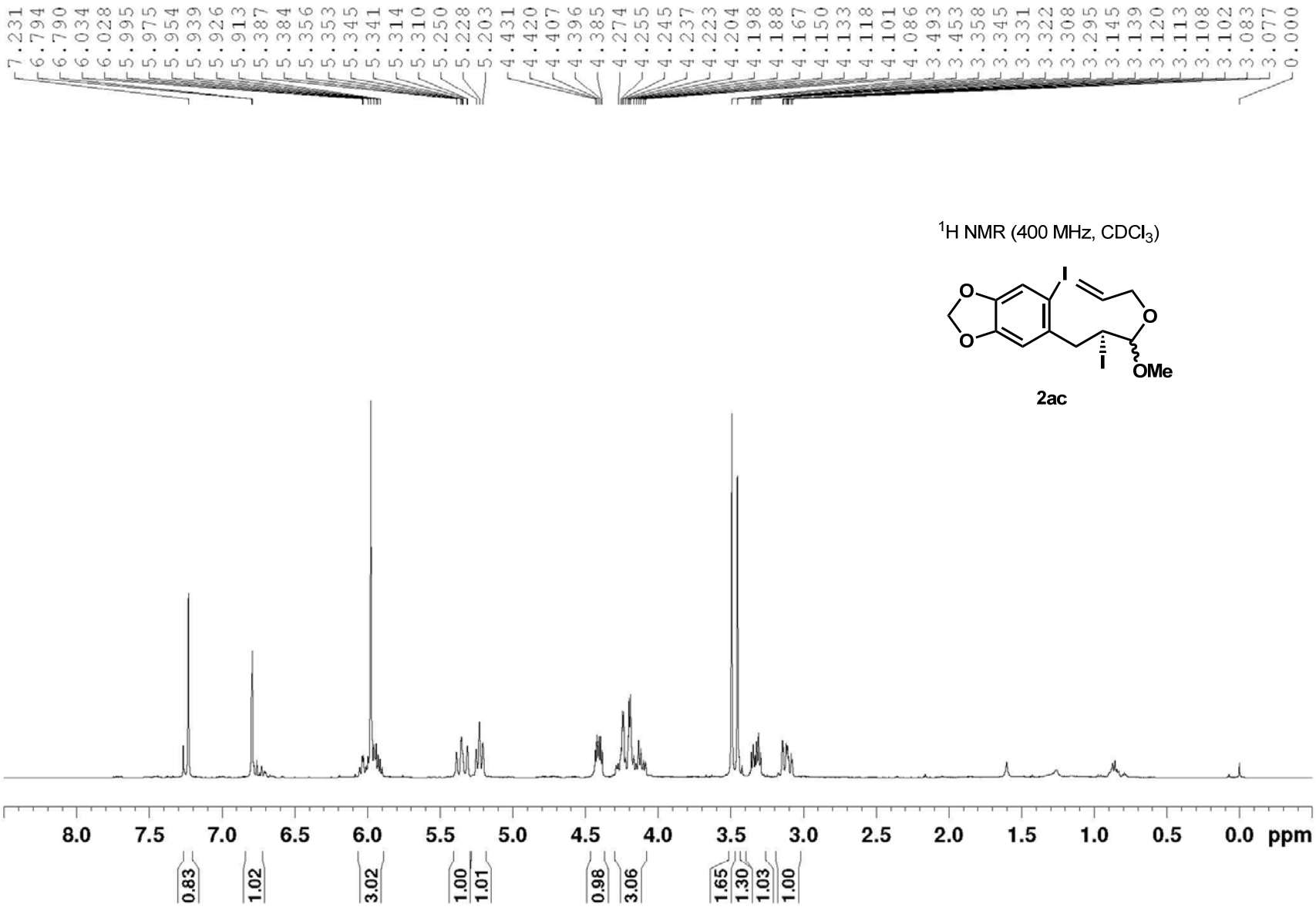
Br
O
O
O
I
OMe
2ab
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm
1.00
1.04
3.12
1.03
1.02
1.05
3.11
0.94
2.13
1.08
1.04




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




**2ab**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6.028
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5.975
5.954
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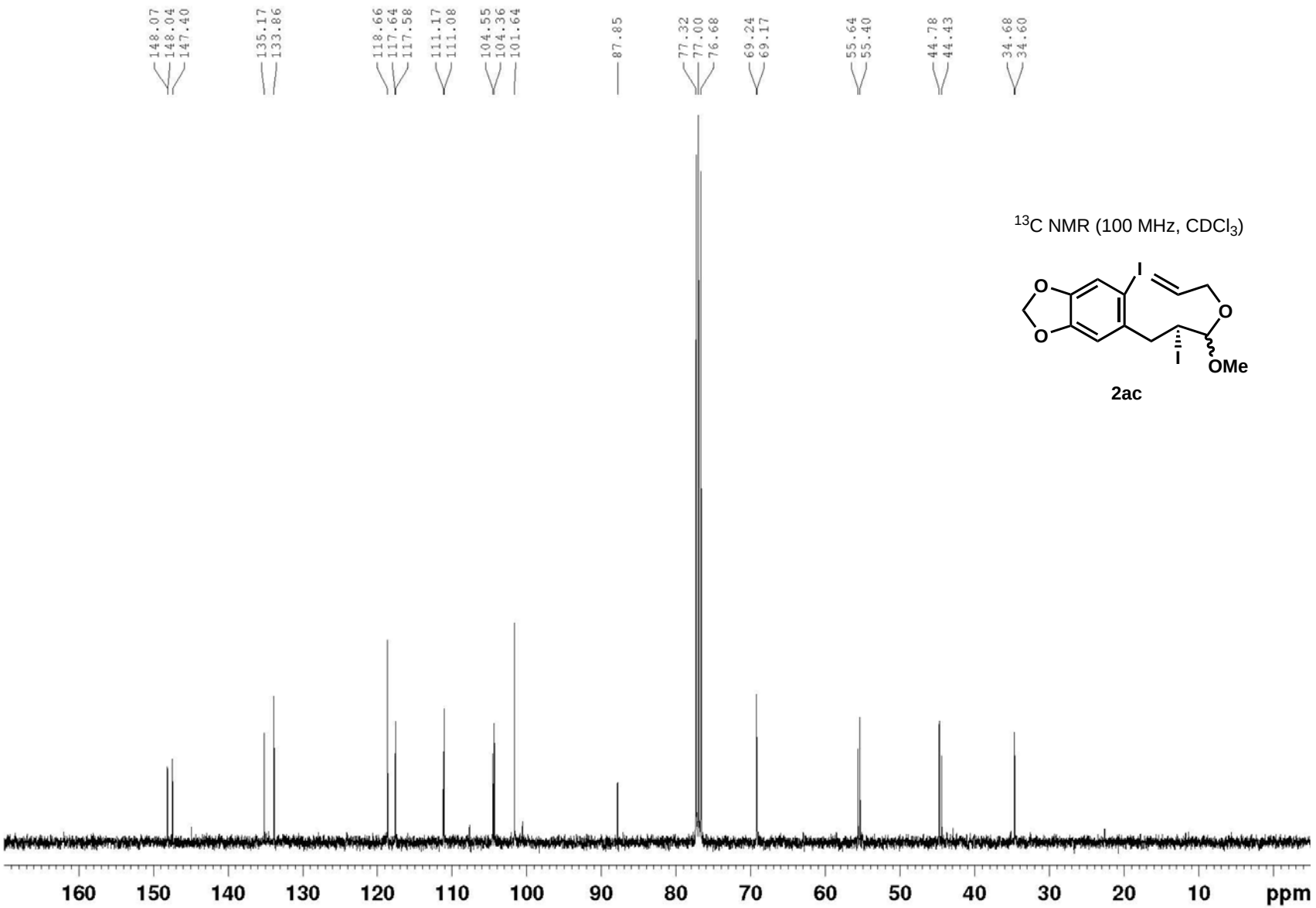
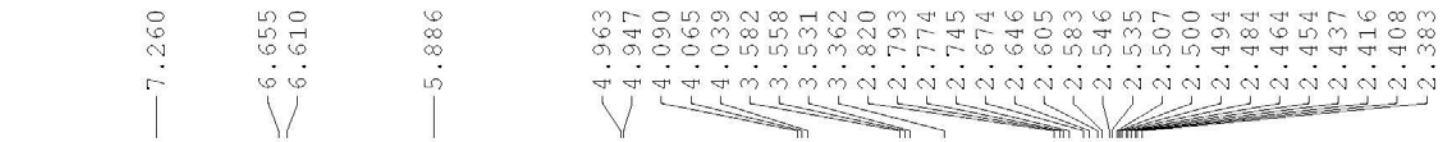
4.396
4.385
4.274
4.255
4.245
4.237
4.223
4.204
4.198
4.188
4.167
4.150
4.133
4.118
4.101
4.086
3.493
3.453
3.358
3.345
3.331
3.322
3.308
3.295
3.145
3.139
3.120
3.113
3.108
3.102
3.083
3.077
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
O
O
O
I
I
OMe
2ac
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.83
1.02
3.02
1.00
1.01
0.98
3.06
1.65
1.30
1.03
1.00



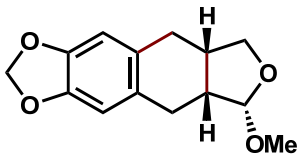

$^{13}C$ NMR (100 MHz, $CDCl_3$)



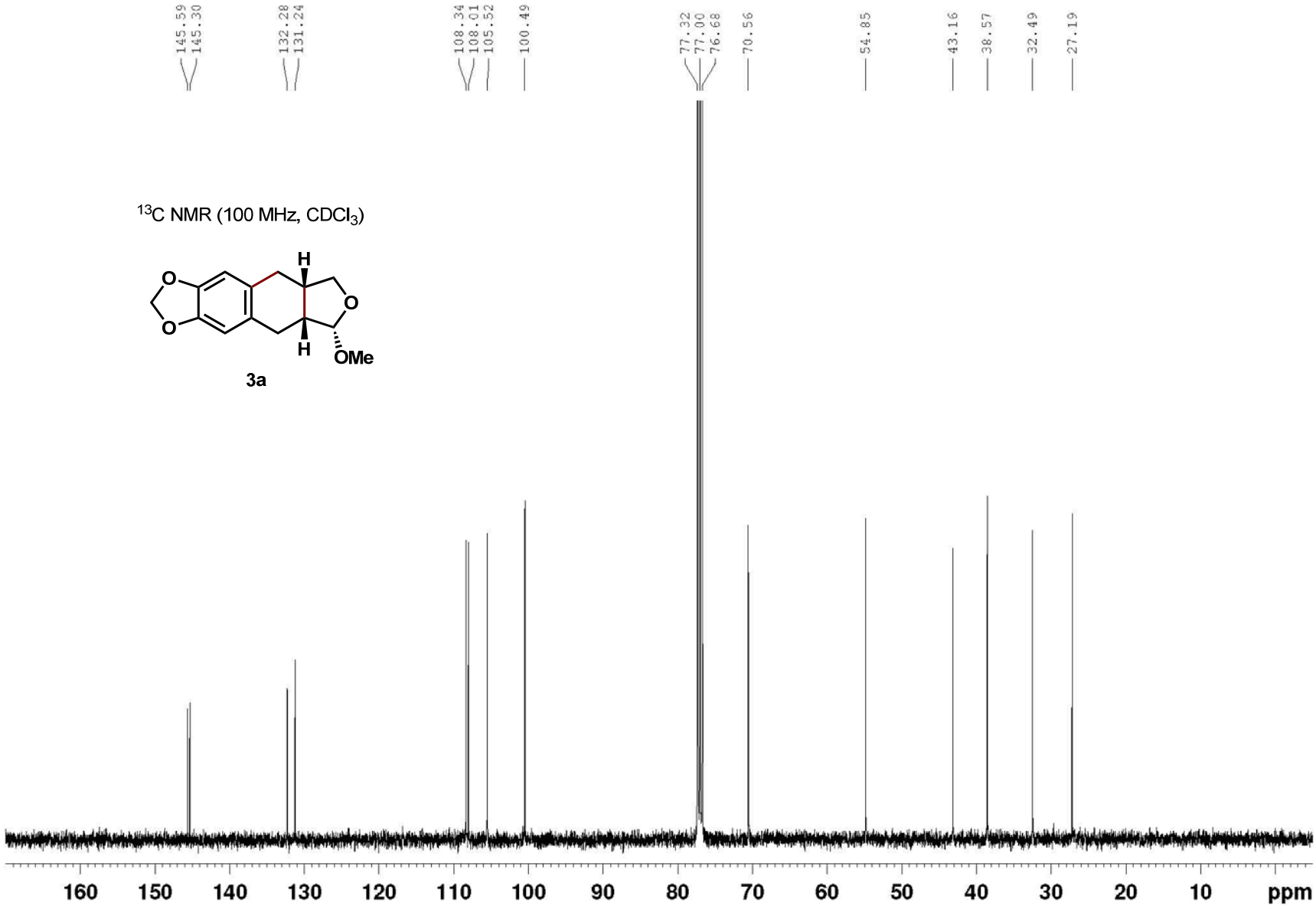

**2ac**

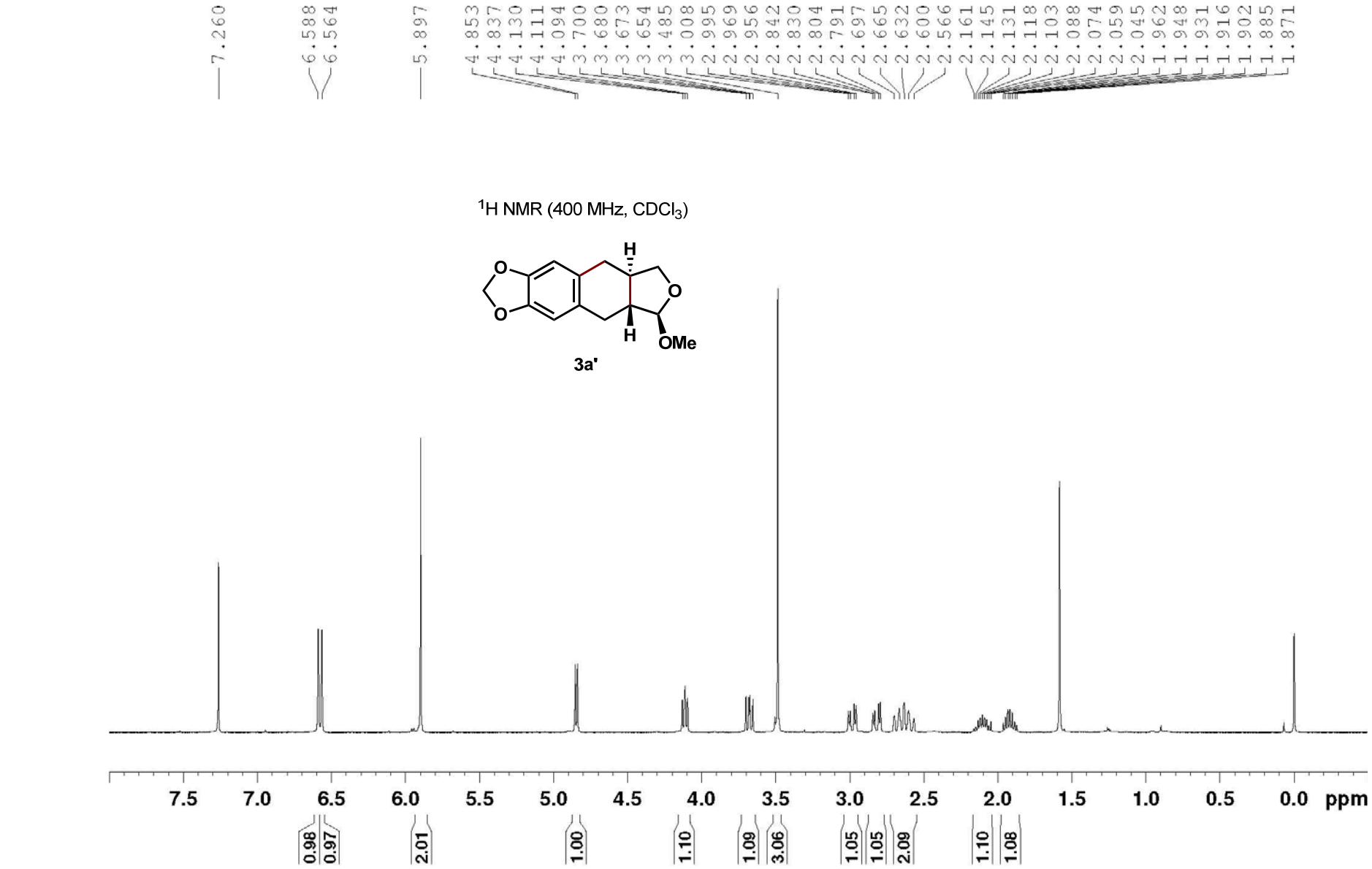


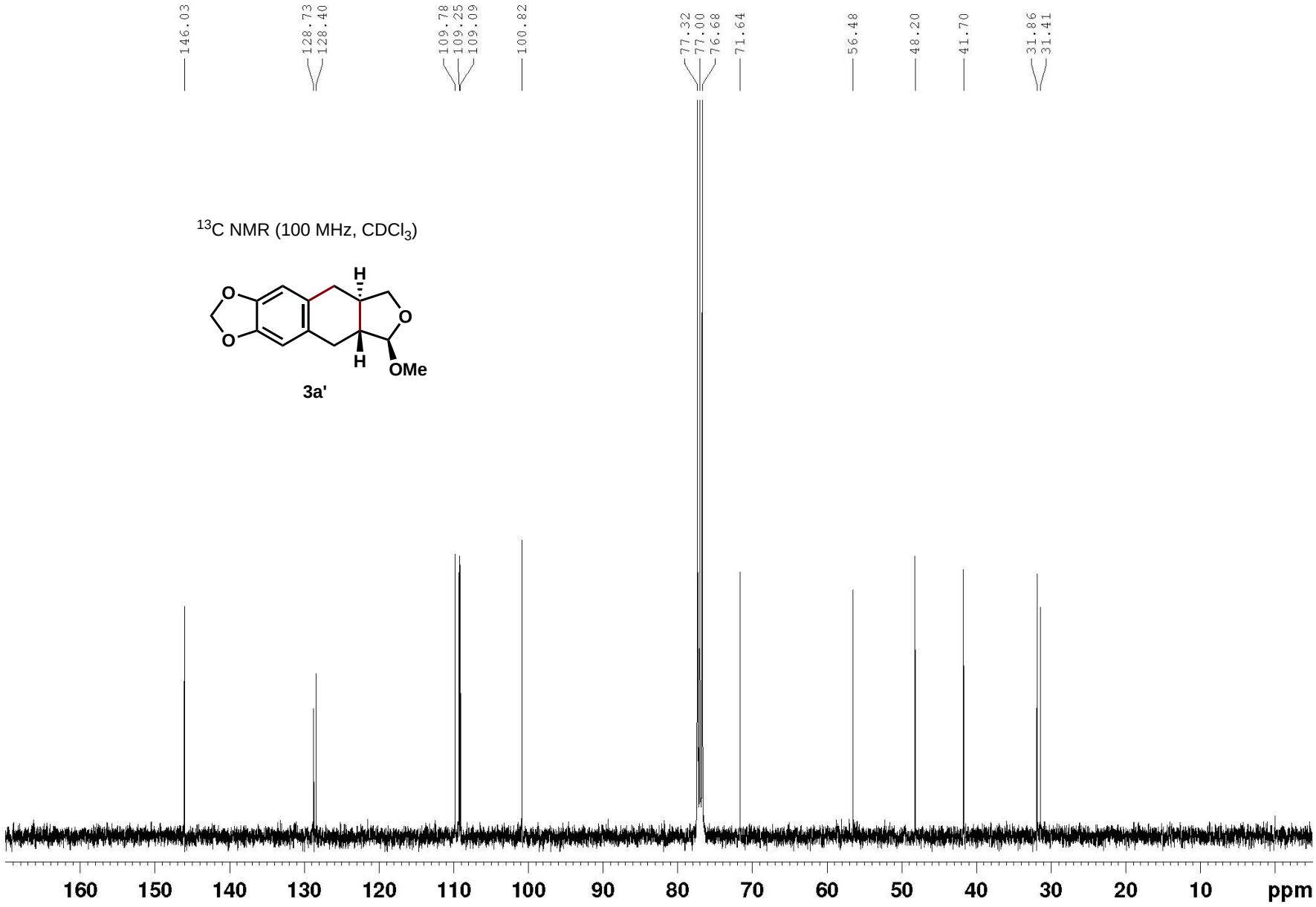

$^1$H NMR (300 MHz, $CDCl_3$)




**3a**


145.59
145.30
132.28
131.24
108.34
108.01
105.52
100.49
77.32
77.00
76.68
70.56
54.85
43.16
38.57
32.49
27.19
$^{13}$C NMR (100 MHz, CDCl$_3$)
O
O
H
O
H
OMe
3a
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

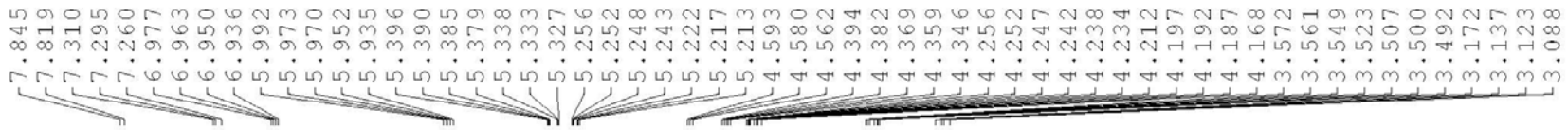

7.260
6.588
6.564
5.897
4.853
4.837
4.130
4.111
4.094
3.700
3.680
3.673
3.654
3.485
3.008
2.995
2.969
2.956
2.842
2.830
2.804
2.791
2.697
2.665
2.632
2.600
2.566
2.161
2.145
2.131
2.118
2.103
2.088
2.074
2.059
2.045
1.962
1.948
1.931
1.916
1.902
1.885
1.871
$^1$H NMR (400 MHz, $CDCl_3$)
O
O
O
H
H
OMe
3a'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.98
0.97
2.01
1.00
1.10
1.09
3.06
1.05
1.05
2.09
1.10
1.08



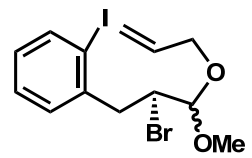

$^{13}$C NMR (100 MHz, $CDCl_3$)



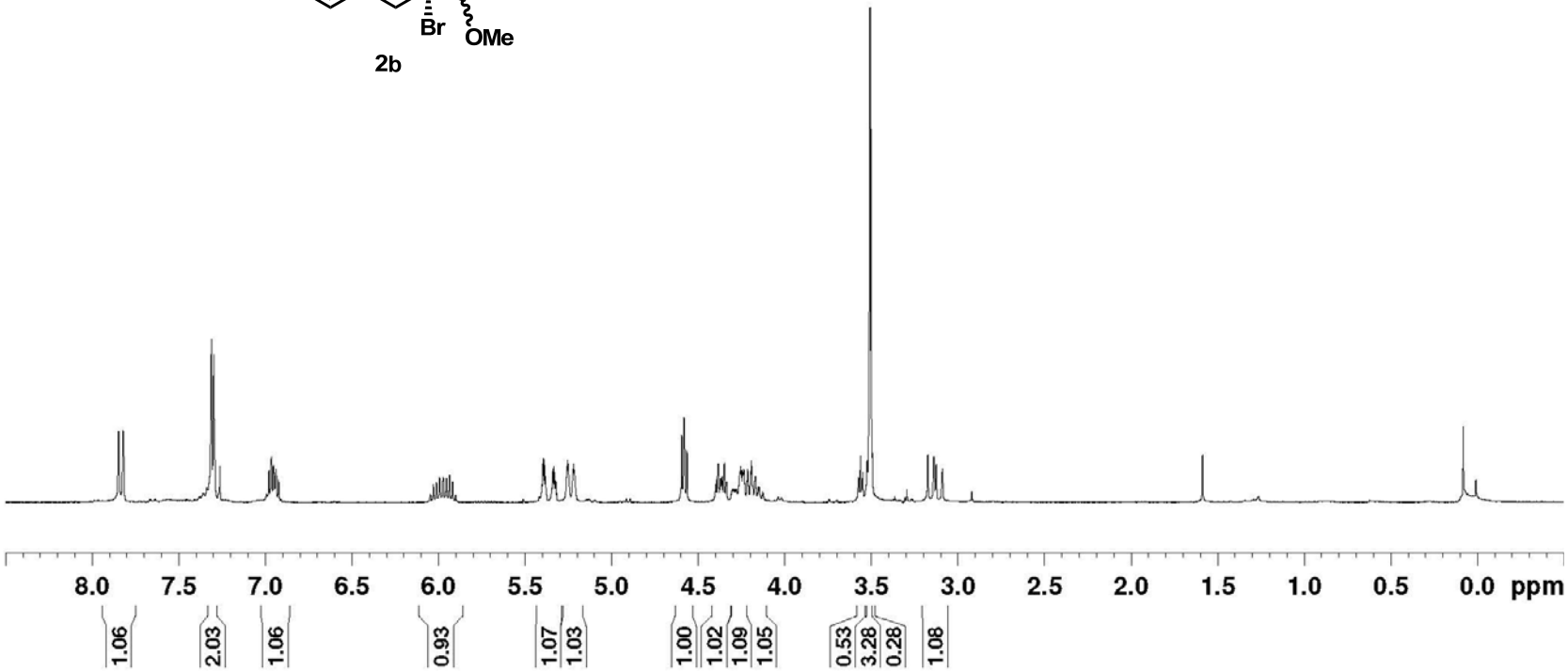

**3a'**




$^1$H NMR (300 MHz, $CDCl_3$)

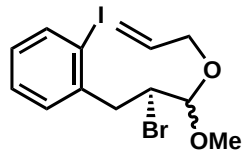



**2b**

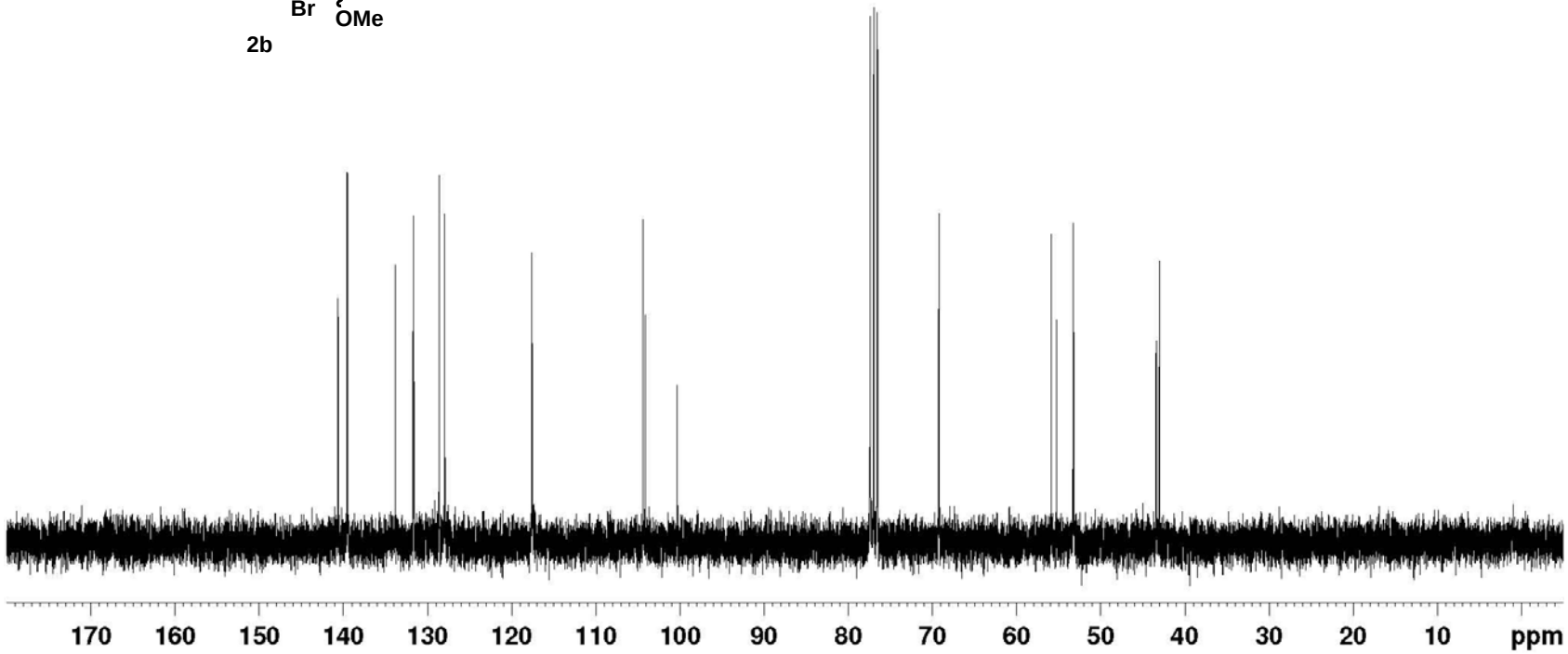


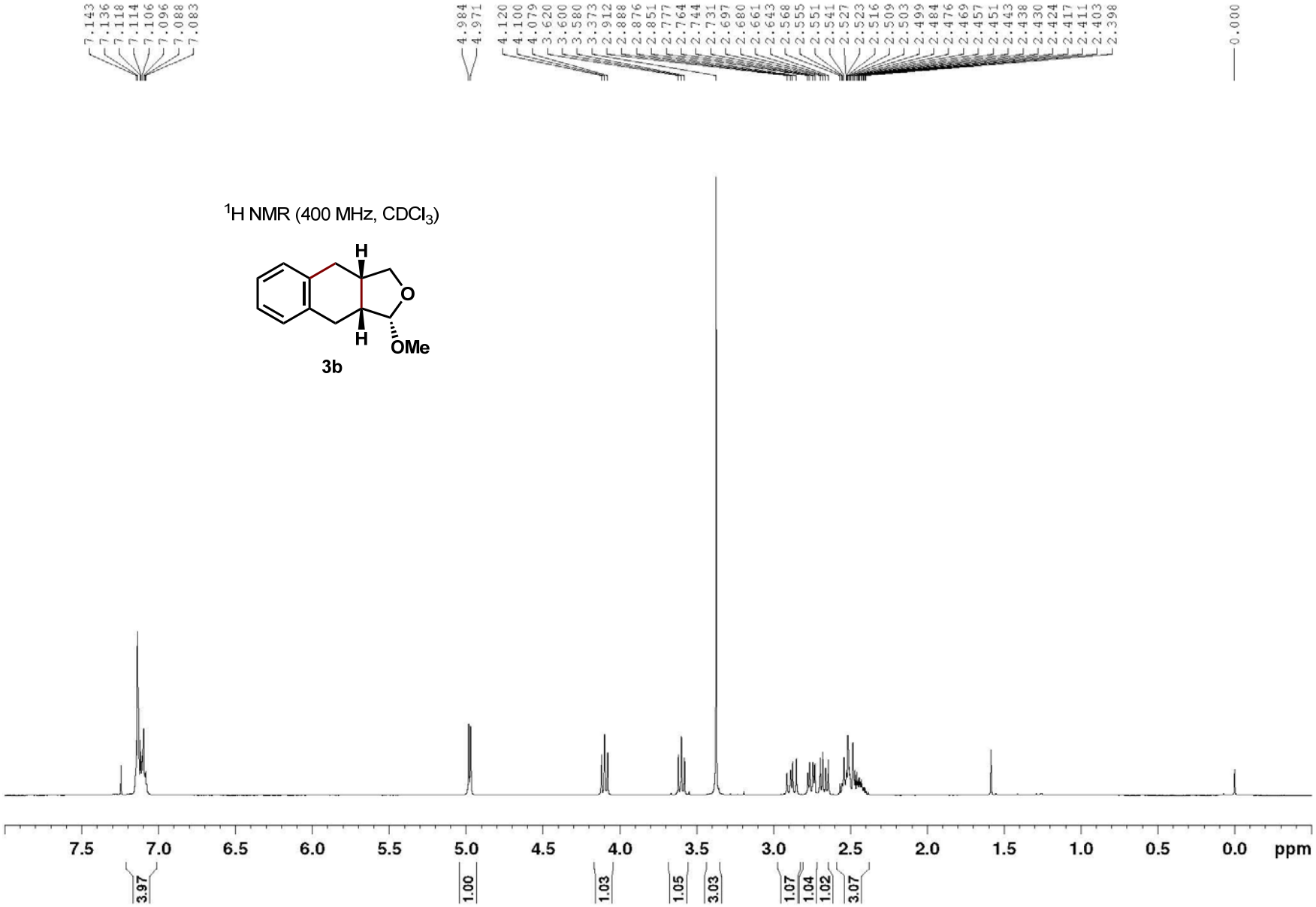
140.64
139.54
133.84
131.72
131.65
128.64
127.98
127.95
117.64
117.55
104.42
104.13
100.35
77.42
77.00
76.58
69.31
69.21
55.93
55.26
53.30
53.20
43.41
43.05

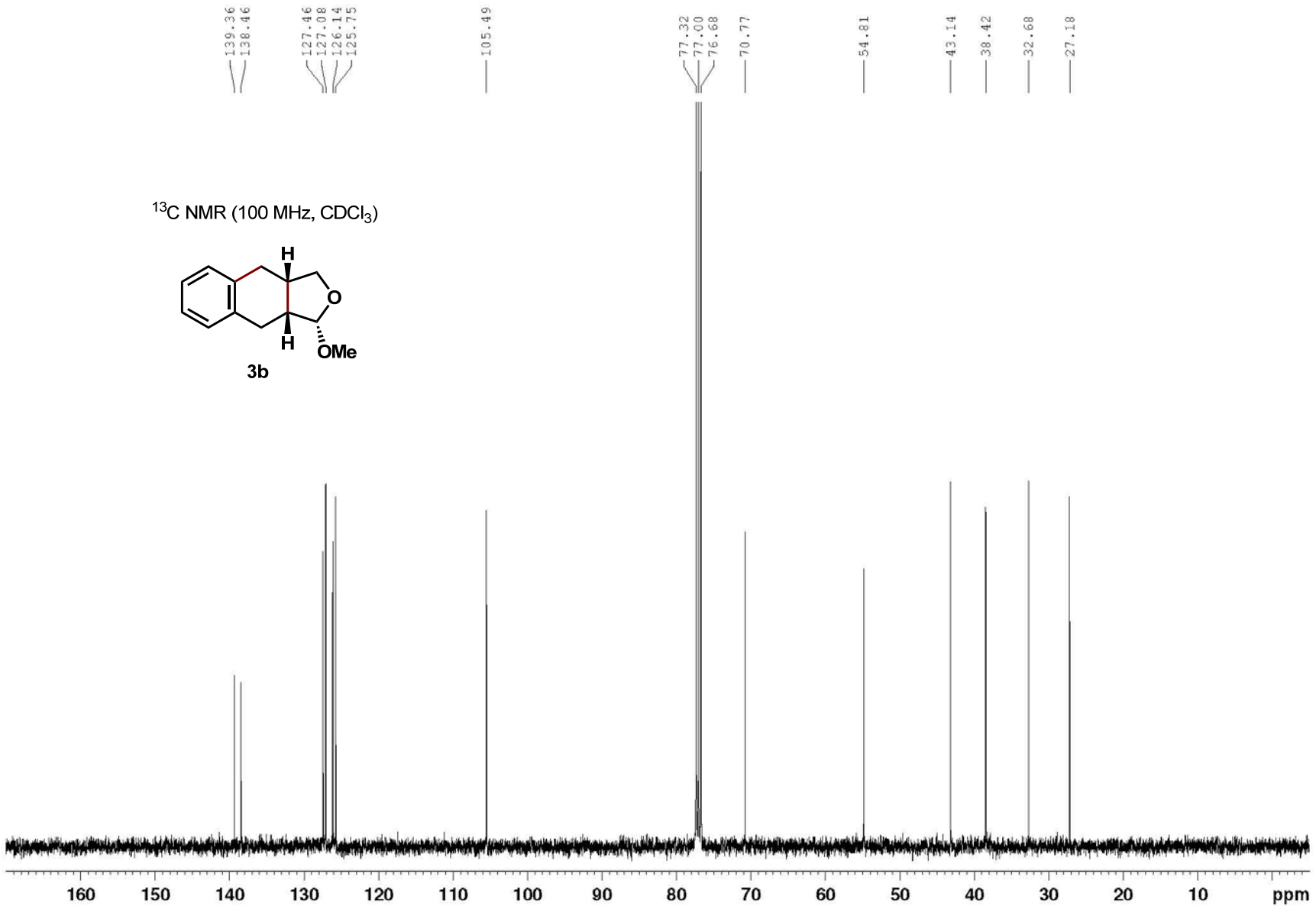
$^{13}$C NMR (75 MHz, $CDCl_3$)

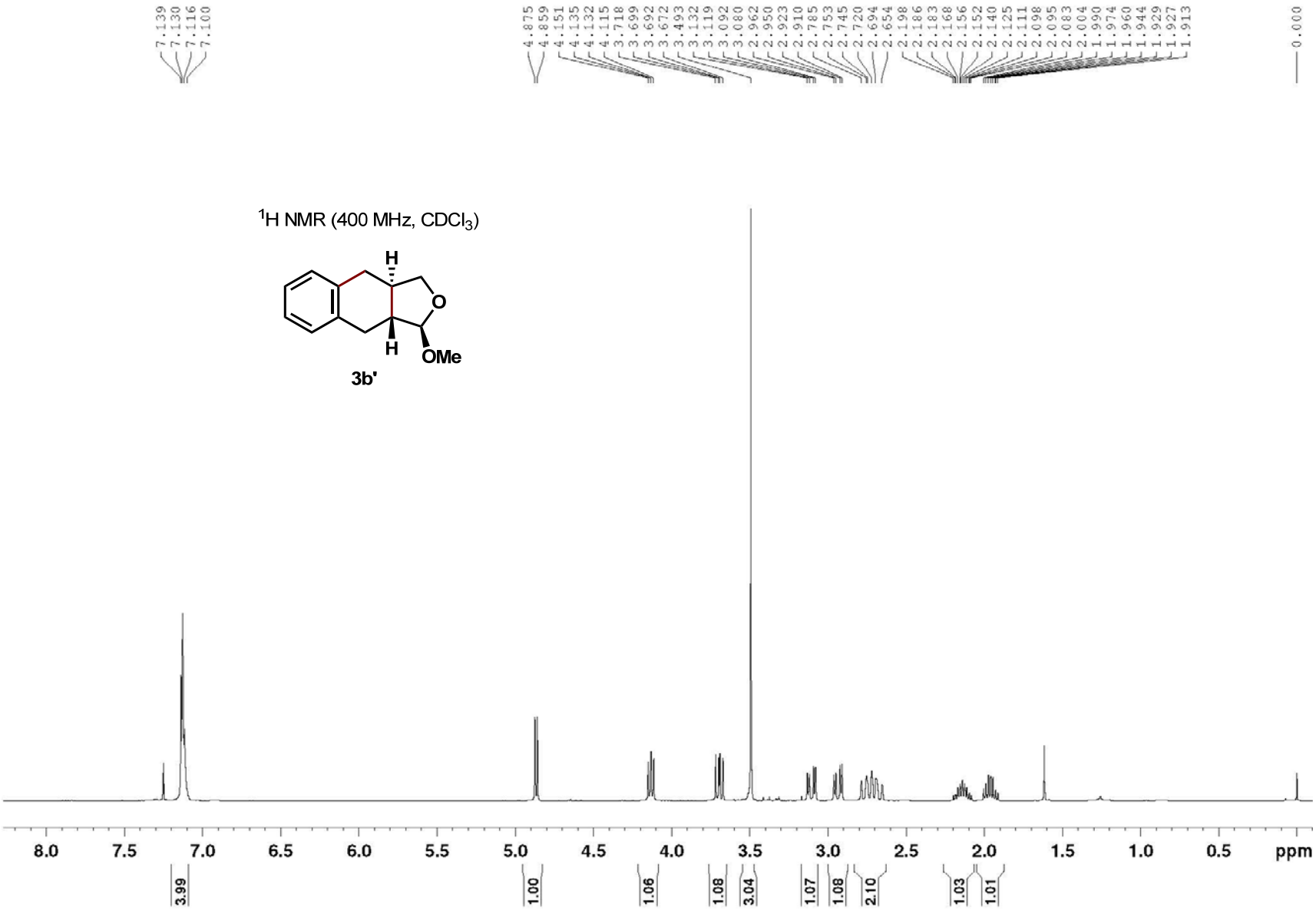


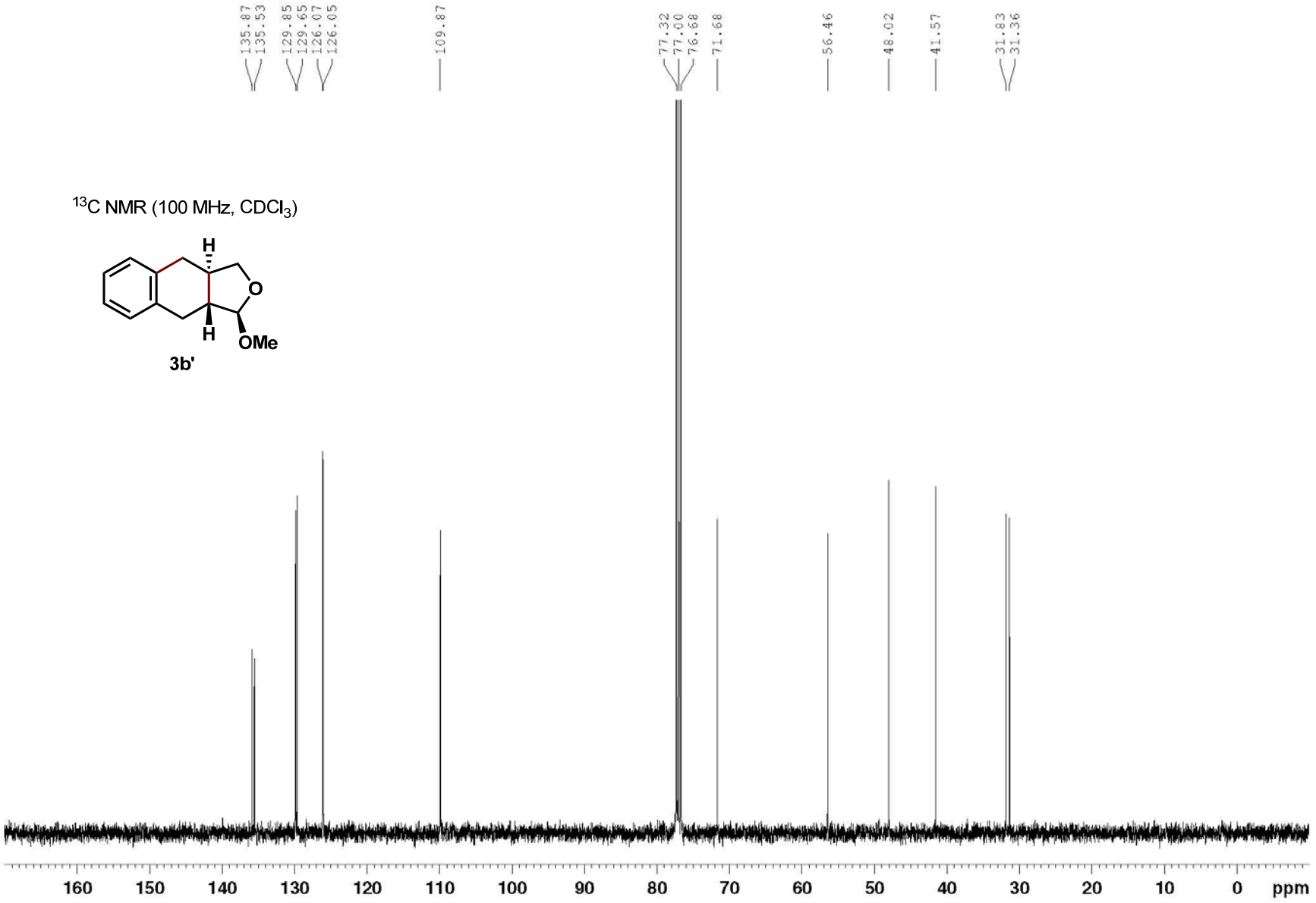

**2b**

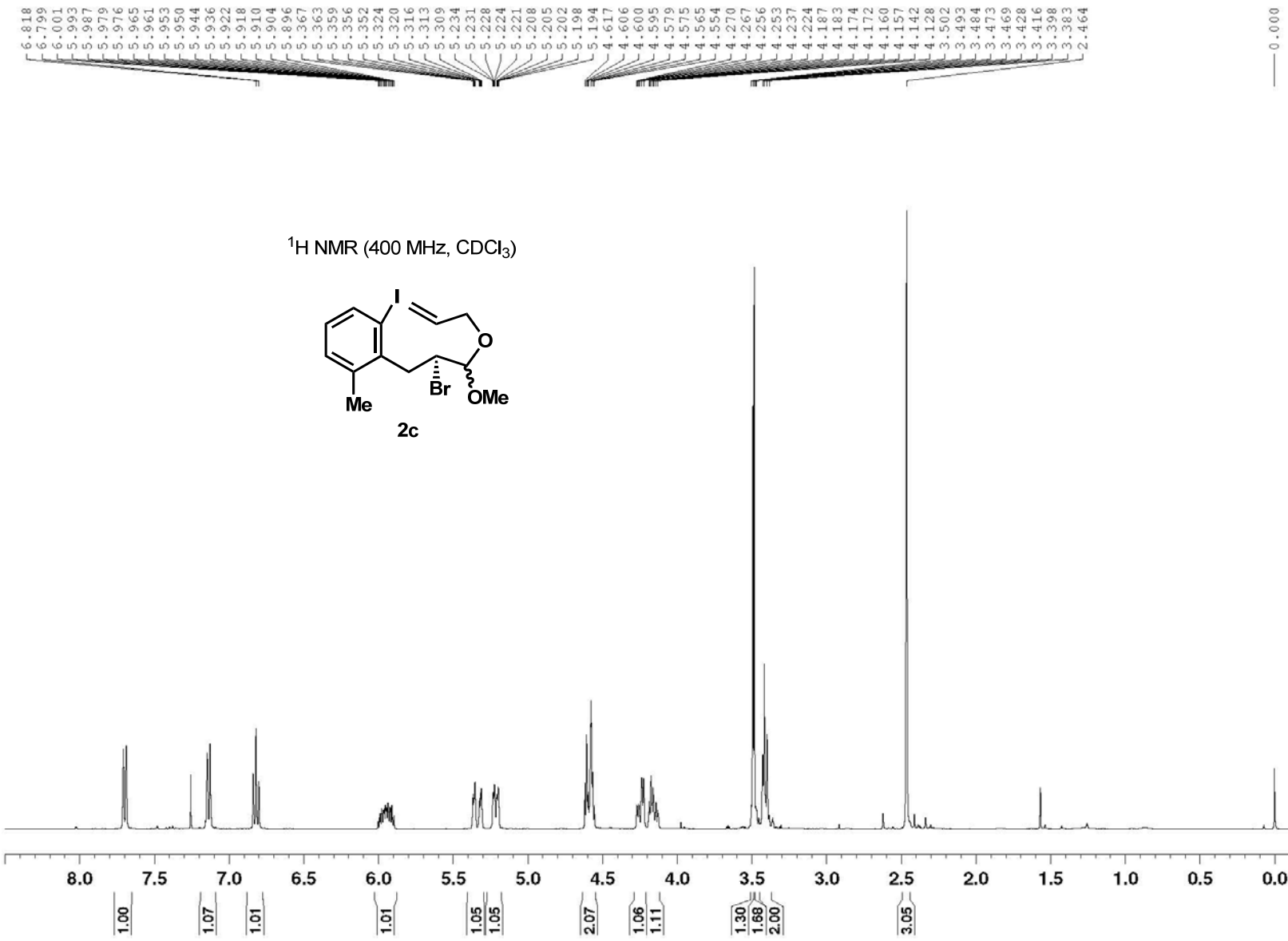


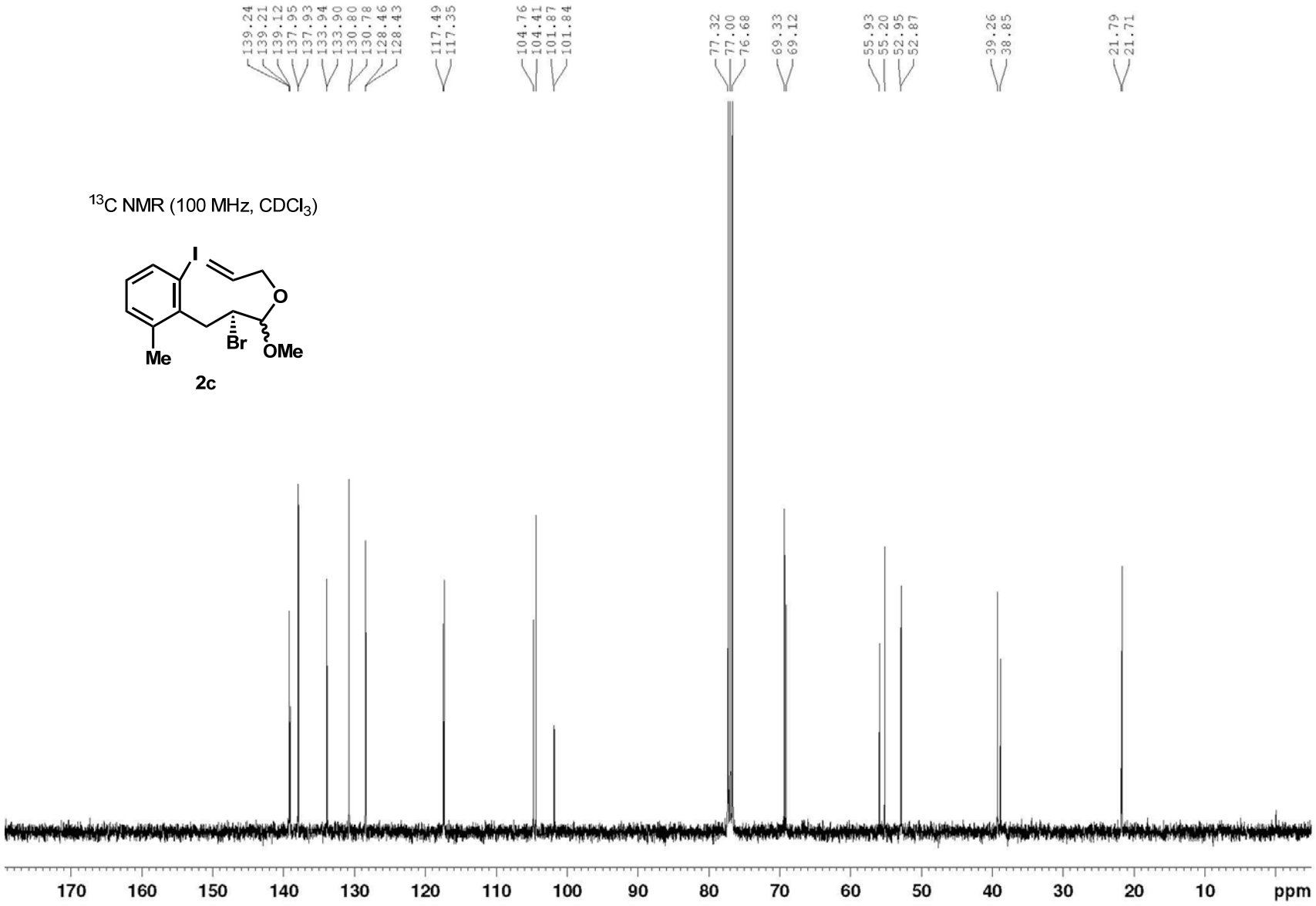

7.143
7.136
7.118
7.114
7.106
7.096
7.088
7.083
4.984
4.971
4.120
4.100
4.079
3.620
3.600
3.580
3.373
2.912
2.888
2.876
2.851
2.777
2.764
2.744
2.731
2.697
2.680
2.661
2.643
2.568
2.555
2.551
2.541
2.527
2.523
2.516
2.509
2.503
2.499
2.484
2.476
2.469
2.457
2.451
2.443
2.438
2.430
2.424
2.417
2.411
2.403
2.398
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
OMe
3b
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.97
1.00
1.03
1.05
3.03
1.07
1.04
1.02
3.07


139.36
138.46
127.46
127.08
126.14
125.75
105.49
77.32
77.00
76.68
70.77
54.81
43.14
38.42
32.68
27.18
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
H
OMe
3b
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.139
7.130
7.116
7.100
4.875
4.859
4.151
4.135
4.132
4.115
3.718
3.699
3.692
3.672
3.493
3.132
3.119
3.092
3.080
2.962
2.950
2.923
2.910
2.785
2.753
2.745
2.720
2.694
2.654
2.198
2.186
2.183
2.168
2.156
2.152
2.140
2.125
2.111
2.098
2.095
2.083
2.004
1.990
1.974
1.960
1.944
1.929
1.927
1.913
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
OMe
3b'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
3.99
1.00
1.06
1.08
3.04
1.07
1.08
2.10
1.03
1.01


135.87
135.53
129.85
129.65
126.07
126.05
109.87
77.32
77.00
76.68
71.68
56.46
48.02
41.57
31.83
31.36
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
H
OMe
3b'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

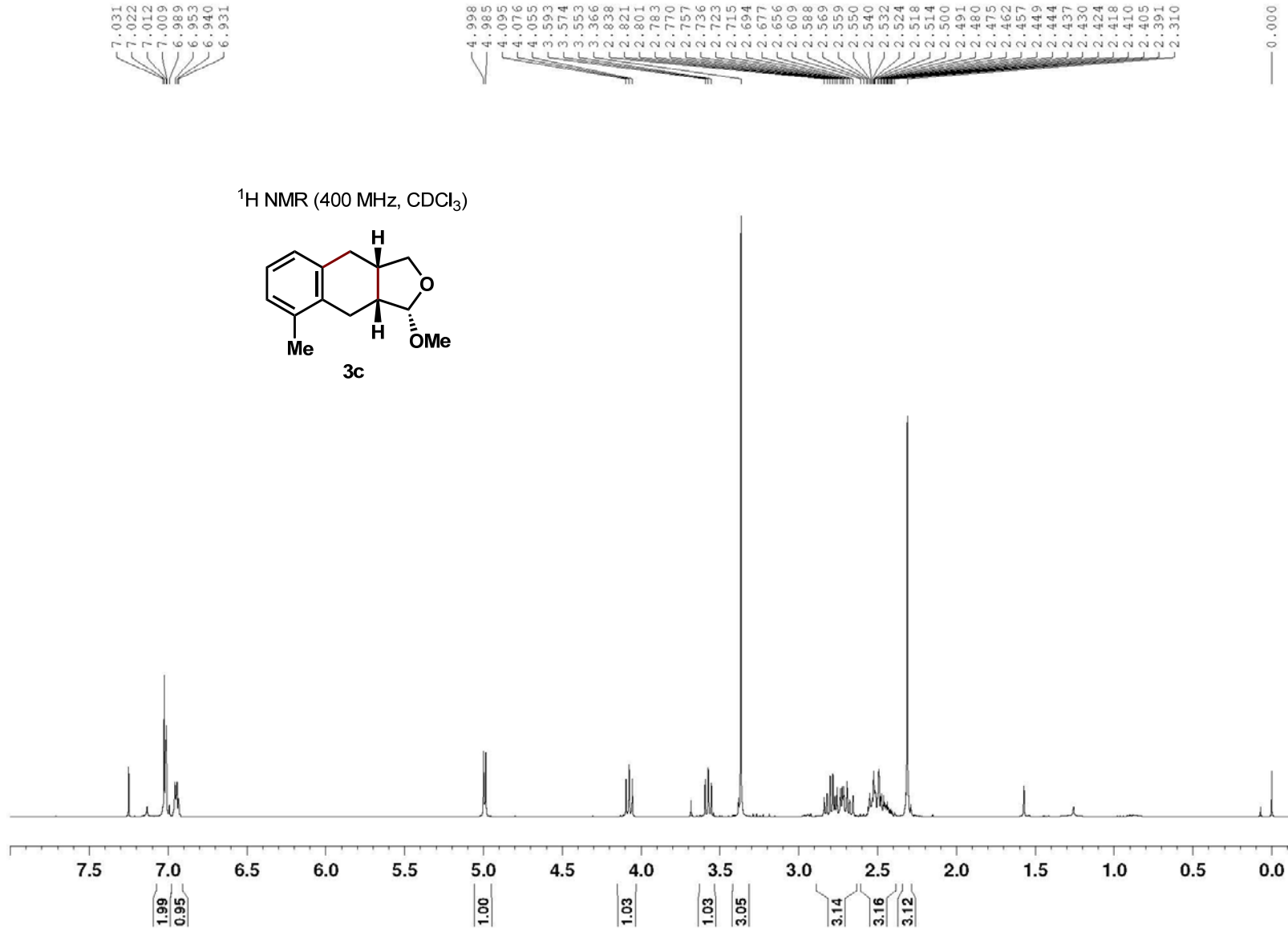

6.818
6.799
6.001
5.993
5.987
5.979
5.976
5.965
5.961
5.953
5.950
5.944
5.936
5.922
5.918
5.910
5.904
5.896
5.367
5.363
5.359
5.356
5.352
5.324
5.320
5.316
5.313
5.309
5.234
5.231
5.228
5.224
5.221
5.208
5.205
5.202
5.198
5.194
4.617
4.606
4.600
4.595
4.579
4.575
4.565
4.554
4.270
4.267
4.256
4.253
4.237
4.224
4.187
4.183
4.174
4.172
4.160
4.157
4.142
4.128
3.502
3.493
3.484
3.473
3.469
3.428
3.416
3.398
3.383
2.464
0.000
$^1$H NMR (400 MHz, $CDCl_3$)
I
O
Br
OMe
Me
2c
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.07
1.01
1.01
1.05
1.05
2.07
1.06
1.11
1.30
1.68
2.00
3.05

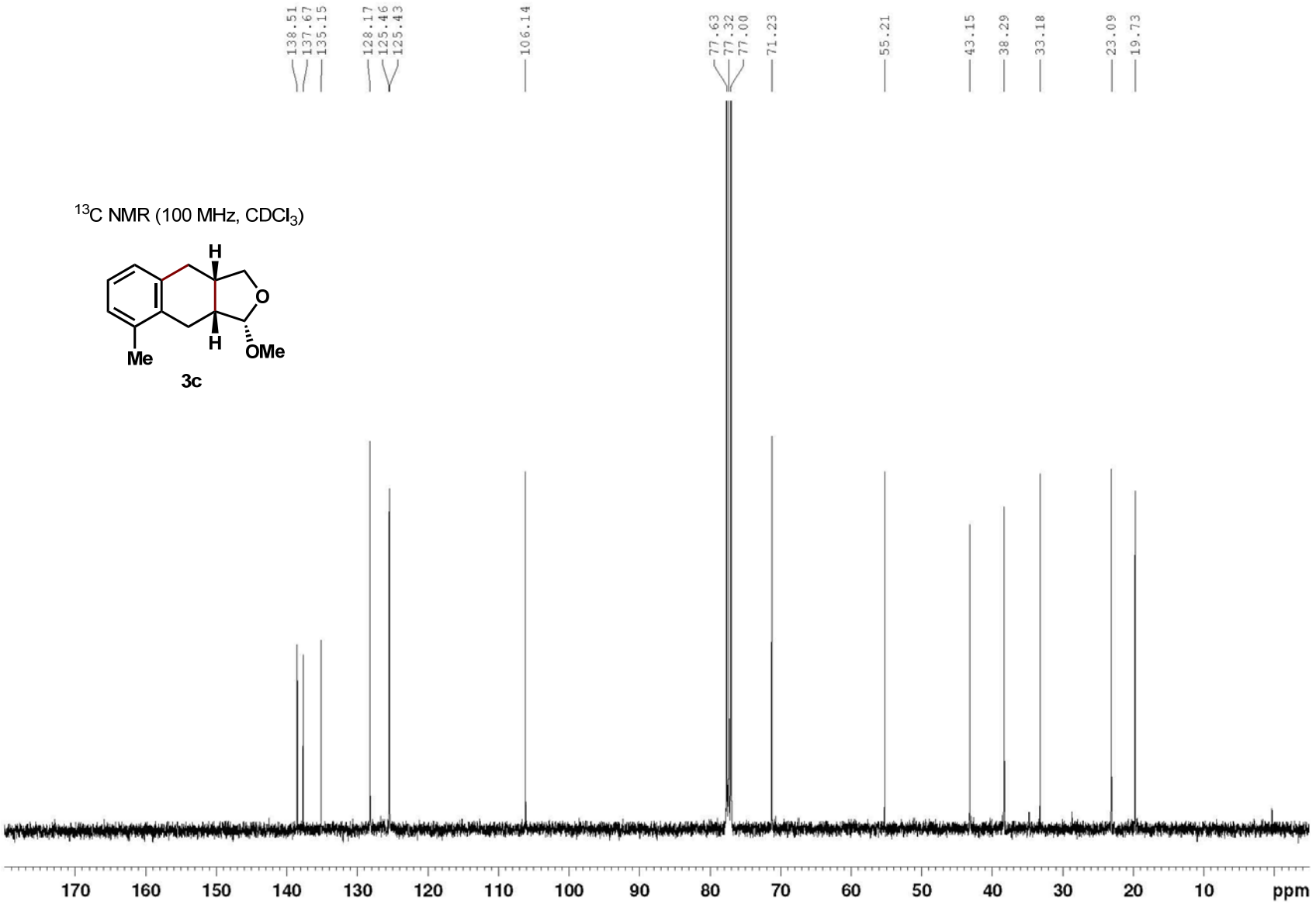


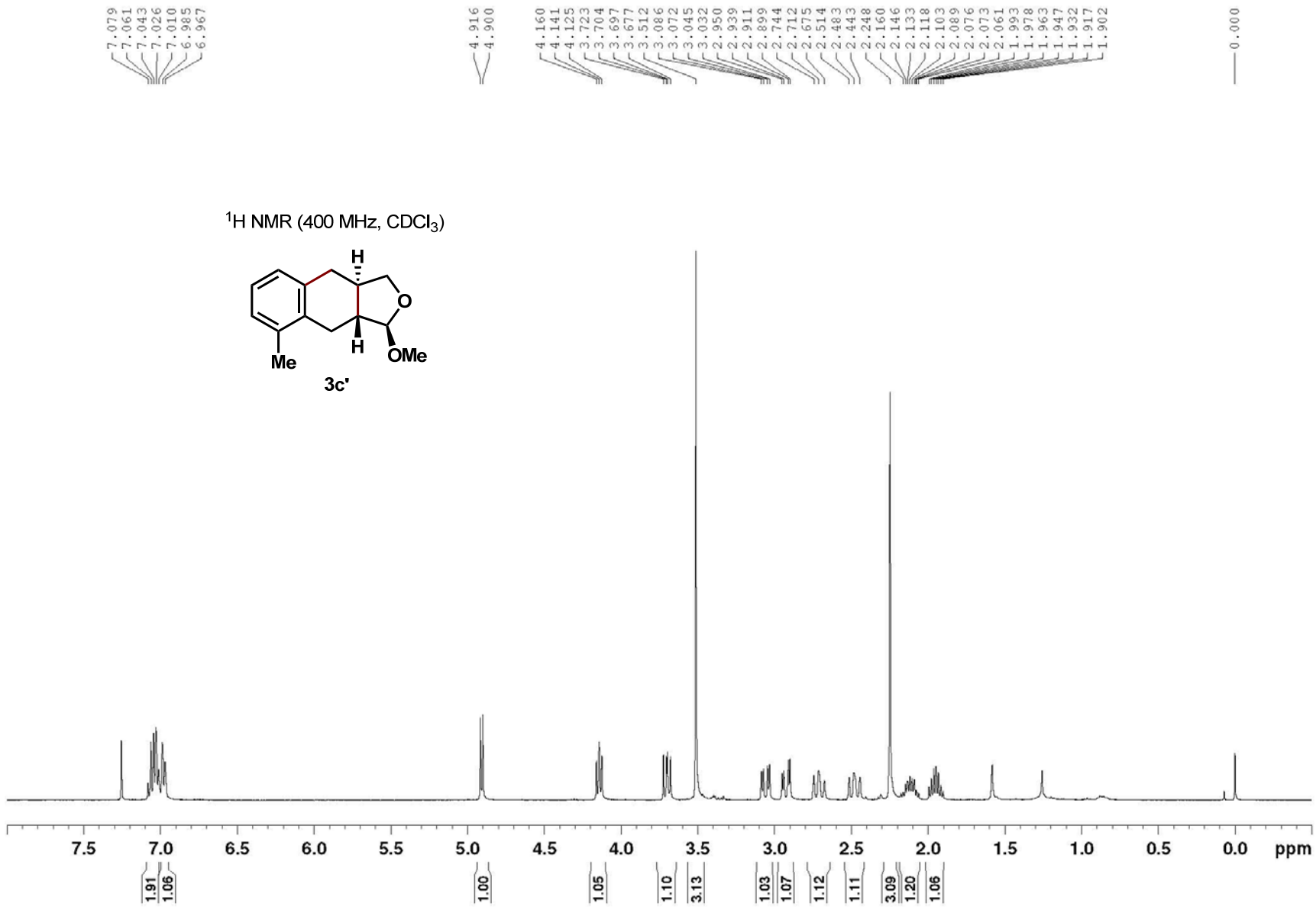

$^{13}$C NMR (100 MHz, $CDCl_3$)

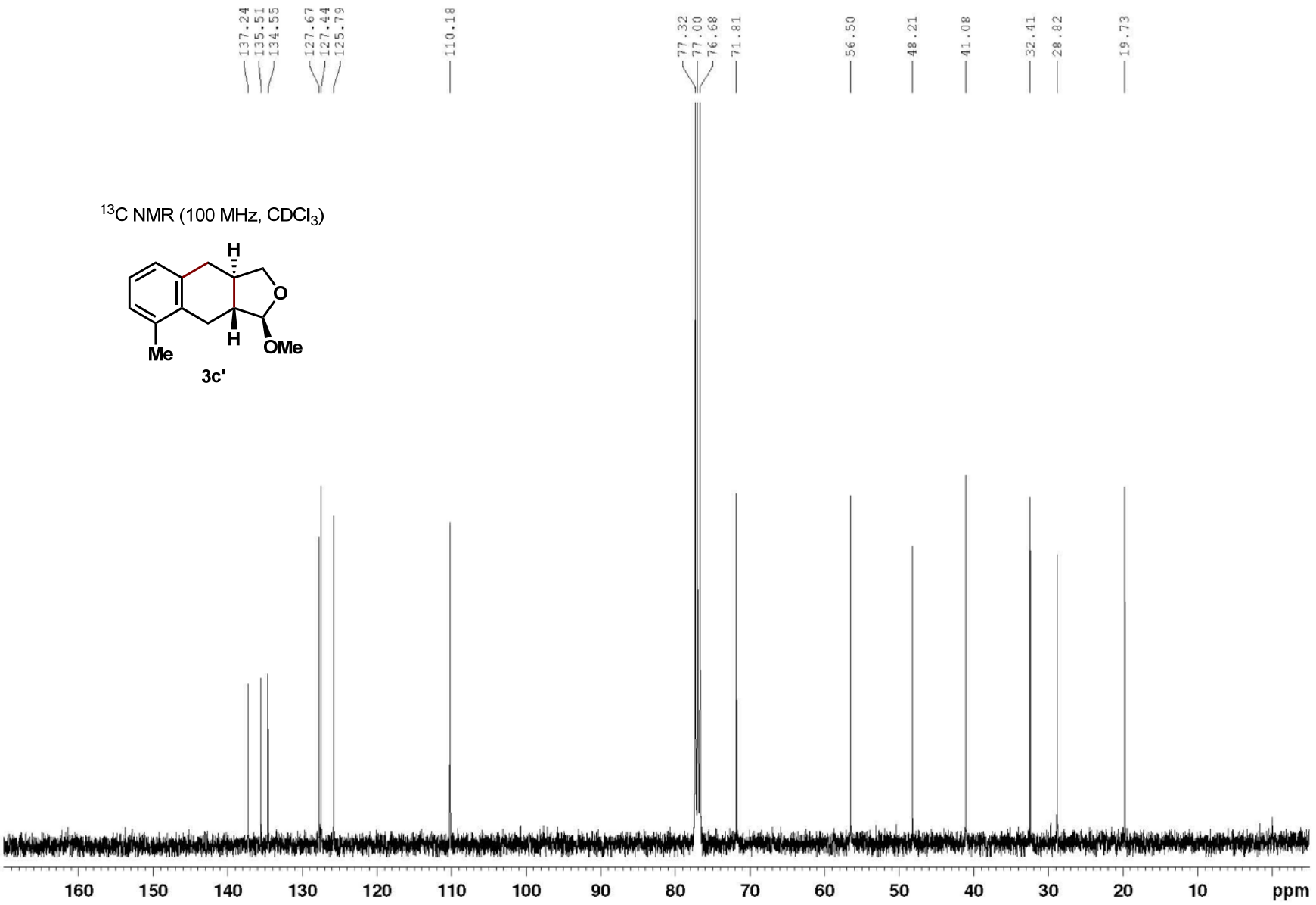



**2c**


7.031
7.022
7.012
7.009
6.989
6.953
6.940
6.931
4.998
4.985
4.095
4.076
4.055
3.593
3.574
3.553
3.366
2.838
2.821
2.801
2.783
2.770
2.757
2.736
2.723
2.715
2.694
2.677
2.656
2.609
2.588
2.569
2.559
2.550
2.540
2.532
2.524
2.518
2.514
2.500
2.491
2.480
2.475
2.462
2.457
2.449
2.444
2.437
2.430
2.424
2.418
2.410
2.405
2.391
2.310
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
Me
OMe
3c
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.99
0.95
1.00
1.03
1.03
3.05
3.14
3.16
3.12


138.51
137.67
135.15
128.17
125.46
125.43
106.14
77.63
77.32
77.00
71.23
55.21
43.15
38.29
33.18
23.09
19.73
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
H
Me
OMe
3c
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

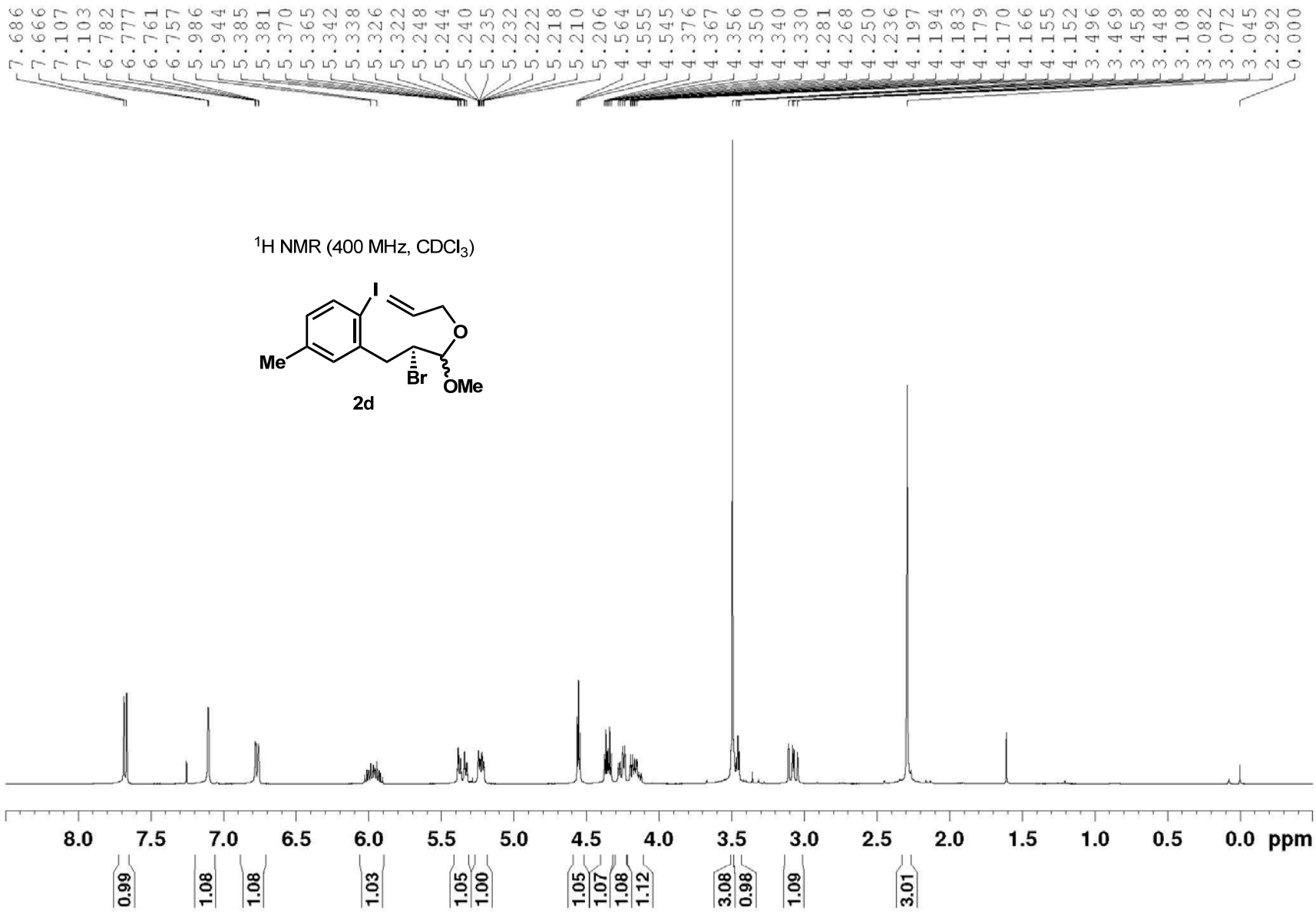

7.079
7.061
7.043
7.026
7.010
6.985
6.967
4.916
4.900
4.160
4.141
4.125
3.723
3.704
3.697
3.677
3.512
3.086
3.072
3.045
3.032
2.950
2.939
2.911
2.899
2.744
2.712
2.675
2.514
2.483
2.443
2.248
2.160
2.146
2.133
2.118
2.103
2.089
2.076
2.073
2.061
1.993
1.978
1.963
1.947
1.932
1.917
1.902
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
OMe
Me
3c'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.91
1.06
1.00
1.05
1.10
3.13
1.03
1.07
1.12
1.11
3.09
1.20
1.06

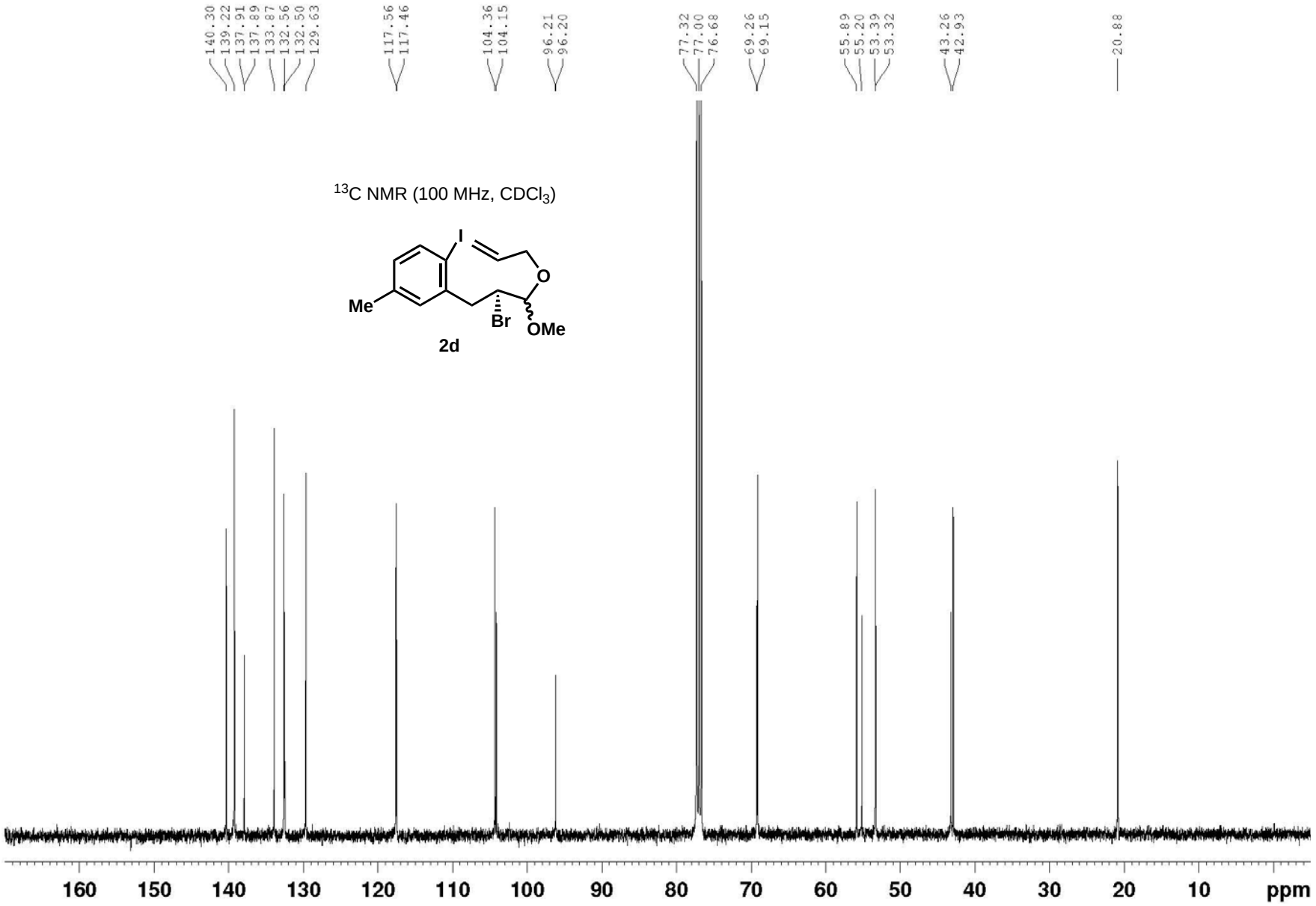



$^{13}$C NMR (100 MHz, $CDCl_3$)




**3c'**

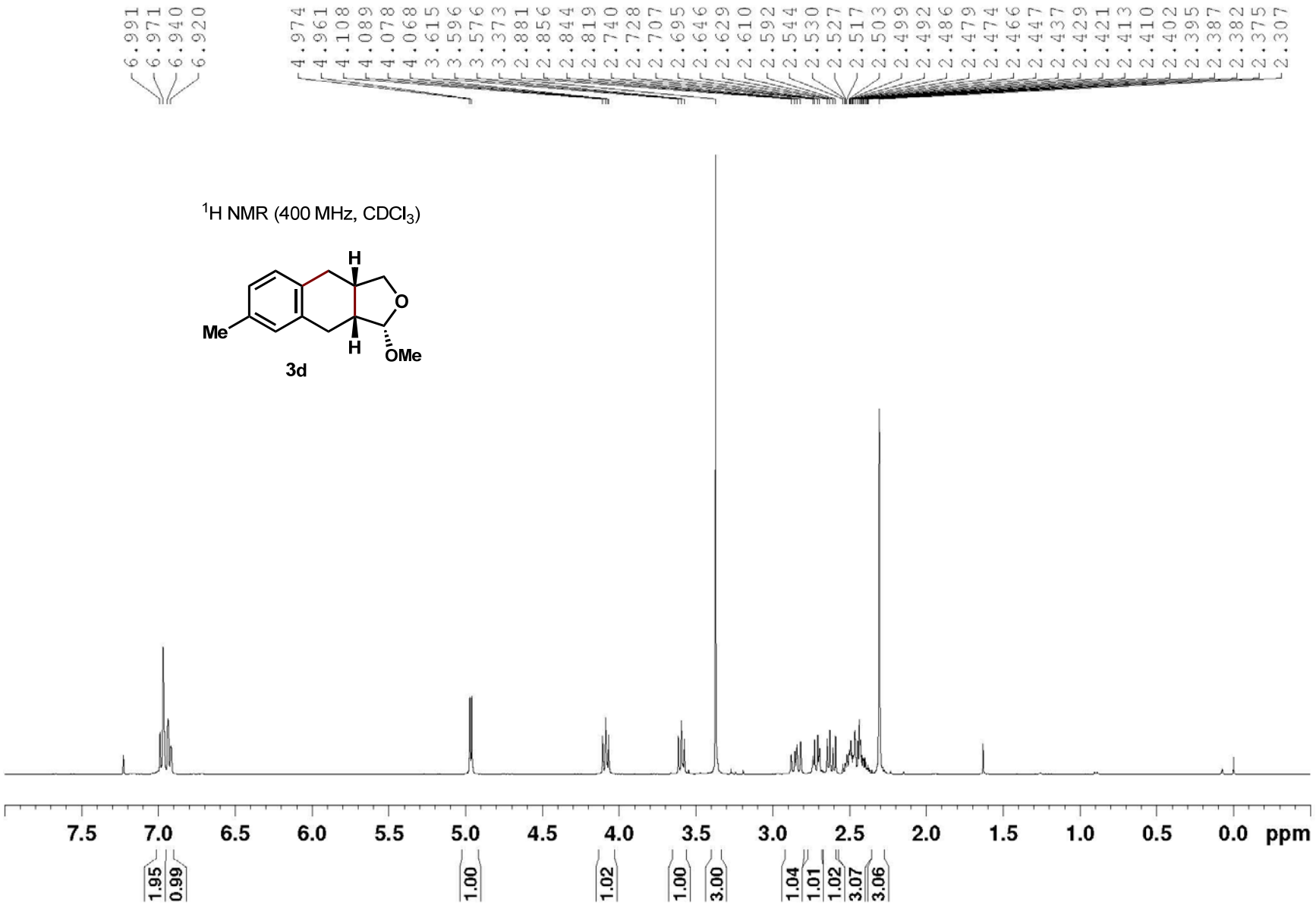

7.686
7.666
7.107
7.103
6.782
6.777
6.761
6.757
5.986
5.944
5.385
5.381
5.370
5.365
5.342
5.338
5.326
5.322
5.248
5.244
5.240
5.235
5.232
5.222
5.218
5.210
5.206
4.564
4.555
4.545
4.376
4.367
4.356
4.350
4.340
4.330
4.281
4.268
4.250
4.236
4.197
4.194
4.183
4.179
4.170
4.166
4.155
4.152
3.496
3.469
3.458
3.448
3.108
3.082
3.072
3.045
2.292
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
I
O
Me
Br
OMe
2d
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.99
1.08
1.08
1.03
1.05
1.00
1.05
1.07
1.08
1.12
3.08
0.98
1.09
3.01



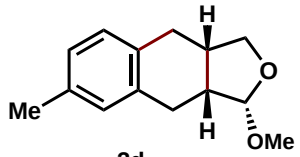

$^{13}$C NMR (100 MHz, $CDCl_3$)



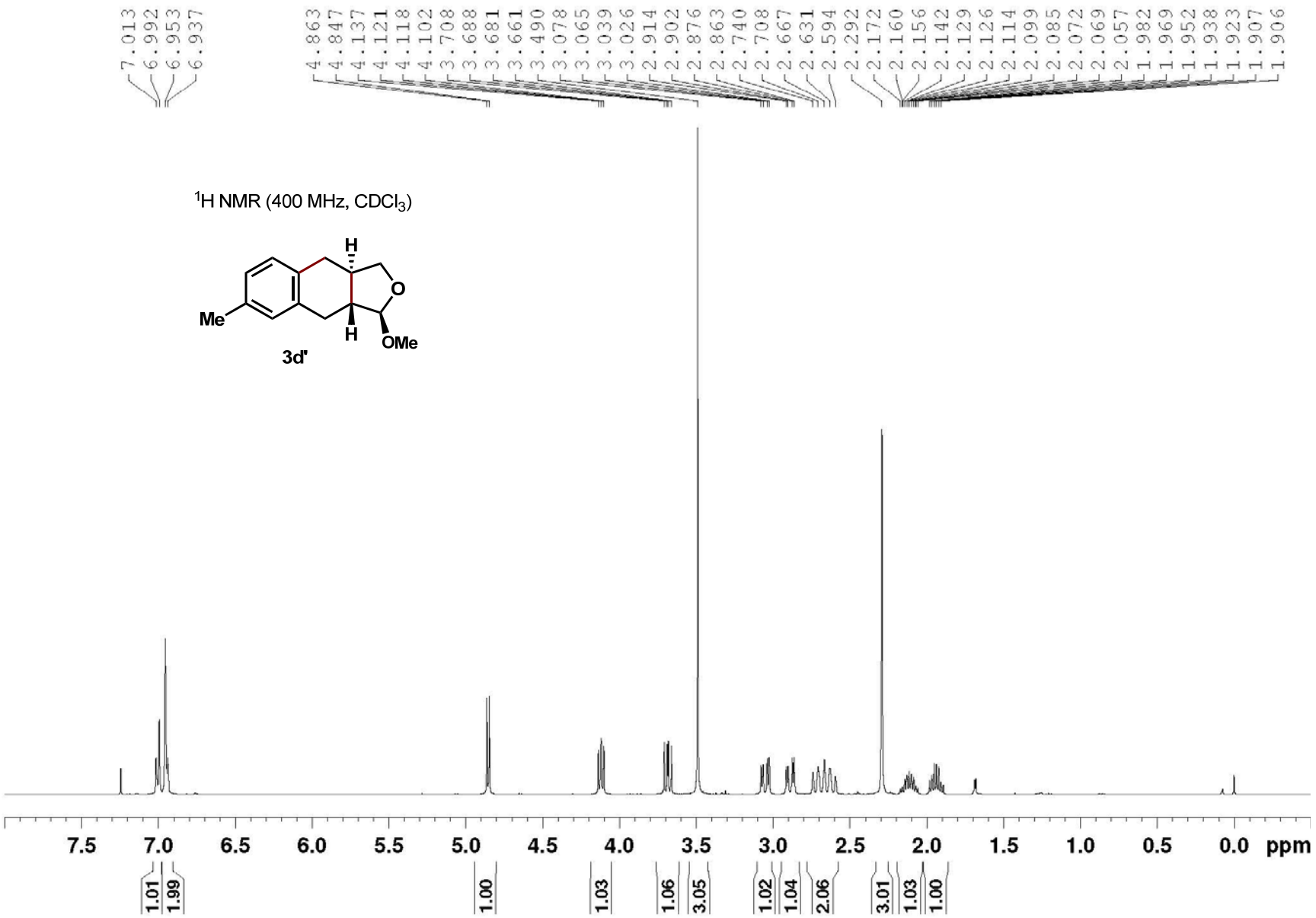

**2d**

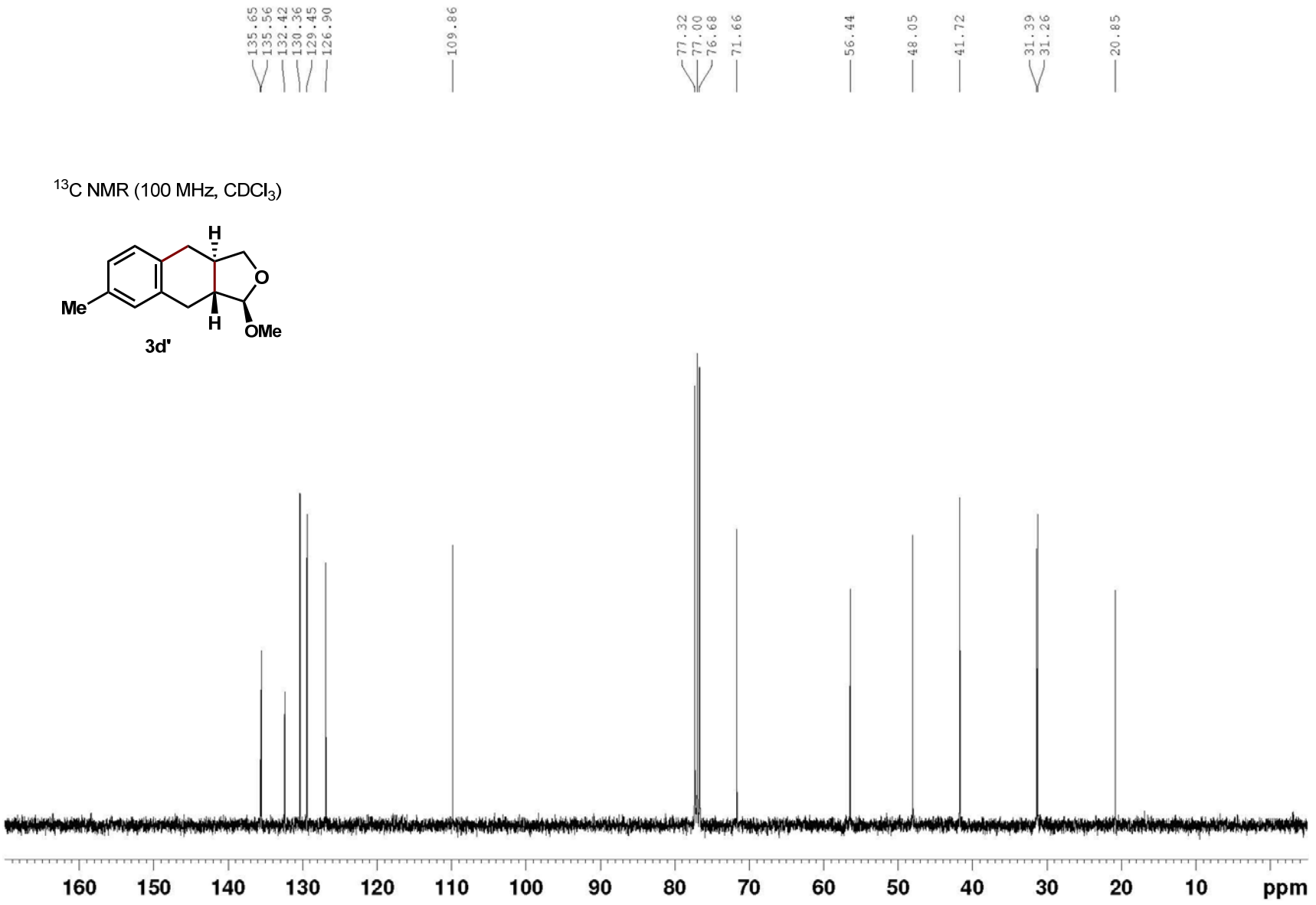

6.991
6.971
6.940
6.920
4.974
4.961
4.108
4.089
4.078
4.068
3.615
3.596
3.576
3.373
2.881
2.856
2.844
2.819
2.740
2.728
2.707
2.695
2.646
2.629
2.610
2.592
2.544
2.530
2.527
2.517
2.503
2.499
2.492
2.486
2.479
2.474
2.466
2.447
2.437
2.429
2.421
2.413
2.410
2.402
2.395
2.387
2.382
2.375
2.307
$^1$H NMR (400 MHz, $CDCl_3$)
H
O
Me
H
OMe
3d
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.95
0.99
1.00
1.02
1.00
3.00
1.04
1.01
1.02
3.07
3.06

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




**3d**


7.013
6.992
6.953
6.937
4.863
4.847
4.137
4.121
4.118
4.102
3.708
3.688
3.681
3.661
3.490
3.078
3.065
3.039
3.026
2.914
2.902
2.876
2.863
2.740
2.708
2.667
2.631
2.594
2.292
2.172
2.160
2.156
2.142
2.129
2.126
2.114
2.099
2.085
2.072
2.069
2.057
1.982
1.969
1.952
1.938
1.923
1.907
1.906
1H NMR (400 MHz, CDCl3)
H
O
Me
H
OMe
3d'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.01
1.99
1.00
1.03
1.06
3.05
1.02
1.04
2.06
3.01
1.03
1.00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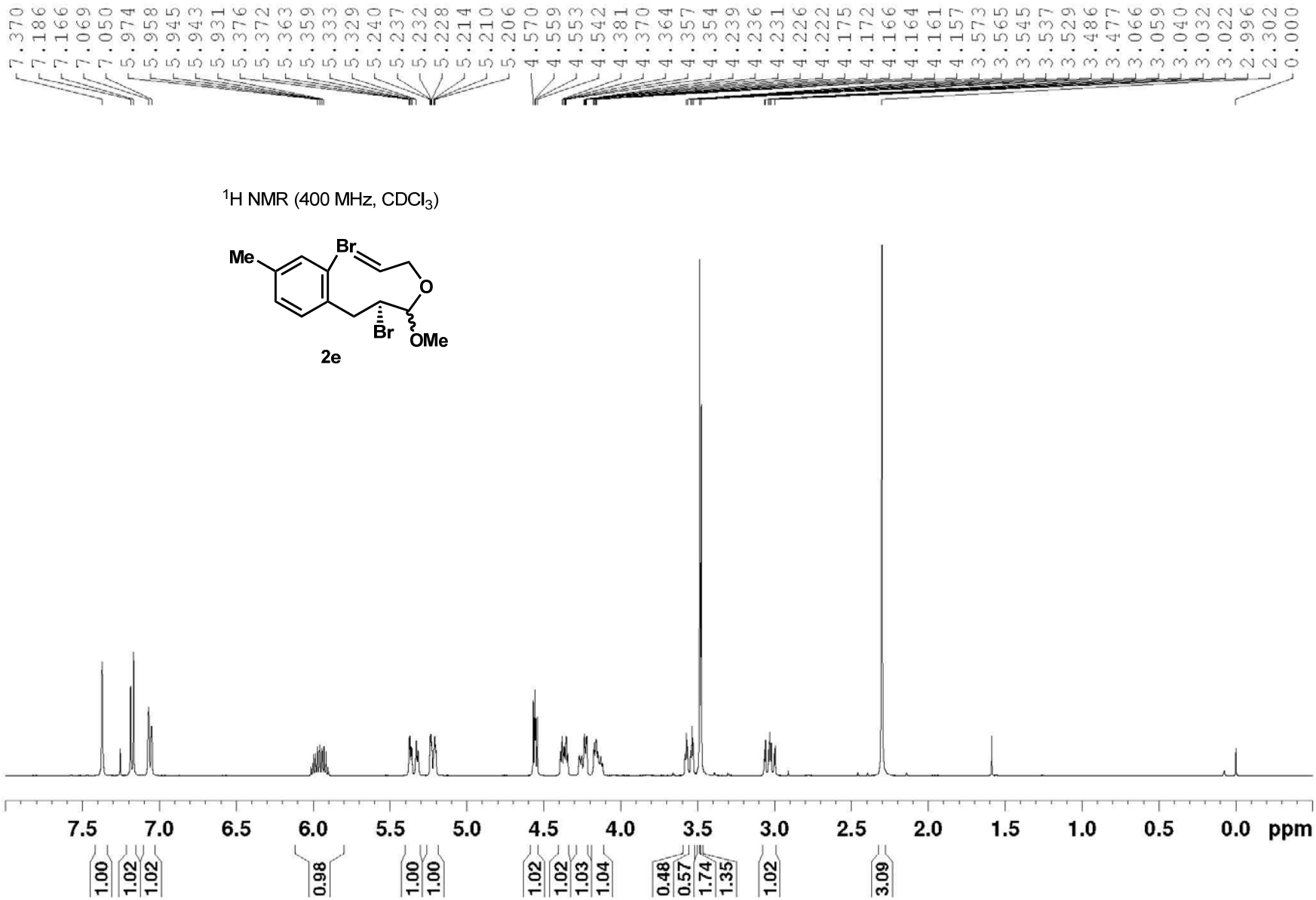
135.56
132.42
130.36
129.45
126.90
109.86
77.32
77.00
76.68
71.66
56.44
48.05
41.72
31.39
31.26
20.85
$^{13}$C NMR (100 MHz, $CDCl_3$)
H
O
Me
H
OMe
3d'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.166
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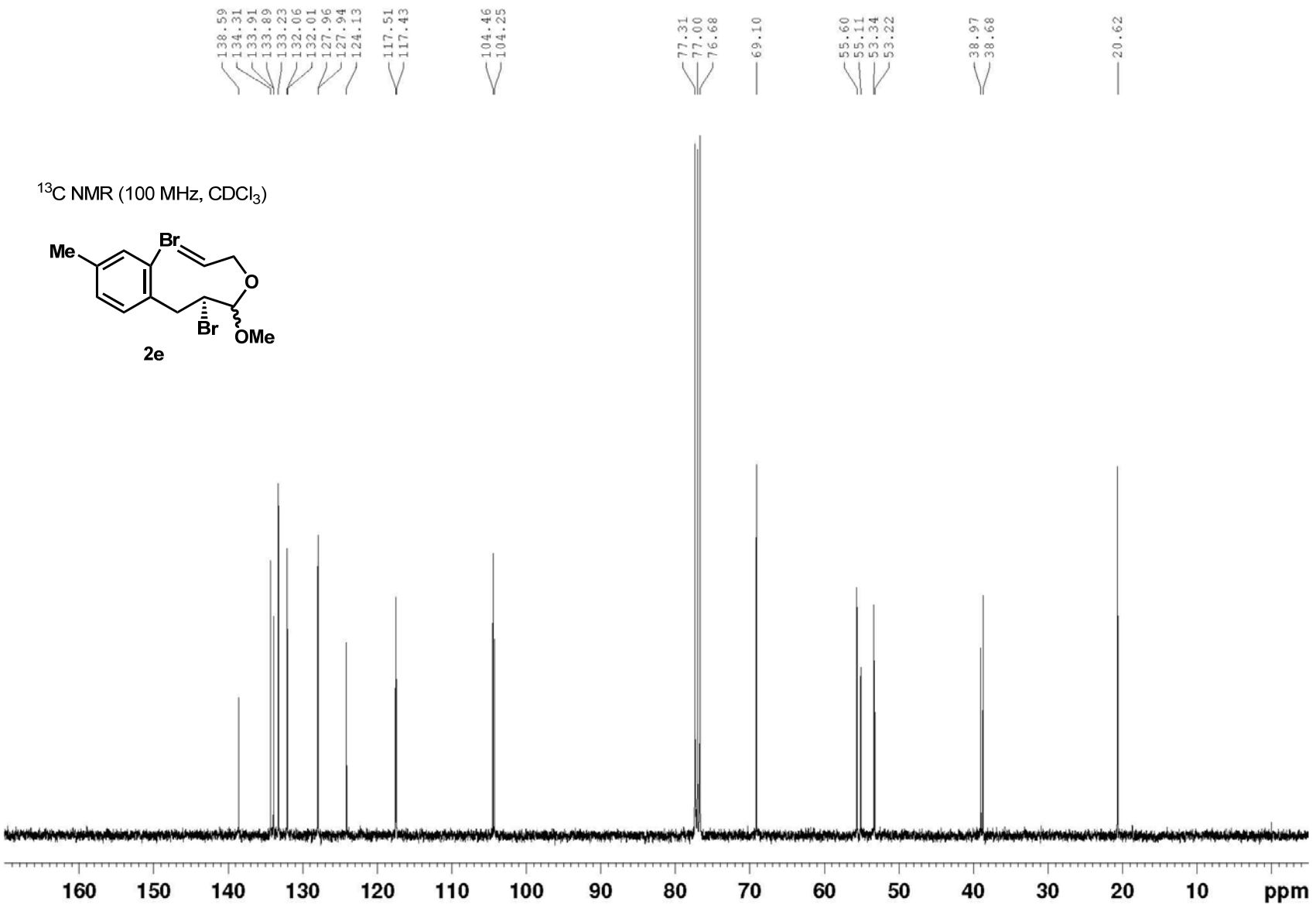
7.050
5.974
5.958
5.945
5.943
5.931
5.376
5.372
5.363
5.359
5.333
5.329
5.240
5.237
5.232
5.228
5.214
5.210
5.206
4.570
4.559
4.553
4.542
4.381
4.370
4.364
4.357
4.354
4.239
4.236
4.231
4.226
4.222
4.175
4.172
4.166
4.164
4.161
4.157
3.573
3.565
3.545
3.537
3.529
3.486
3.477
3.066
3.059
3.040
3.032
3.022
2.996
2.302
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
Me
Br
O
Br
OMe
2e
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.02
1.02
0.98
1.00
1.00
1.02
1.02
1.03
1.04
0.48
0.57
1.74
1.35
1.02
3.09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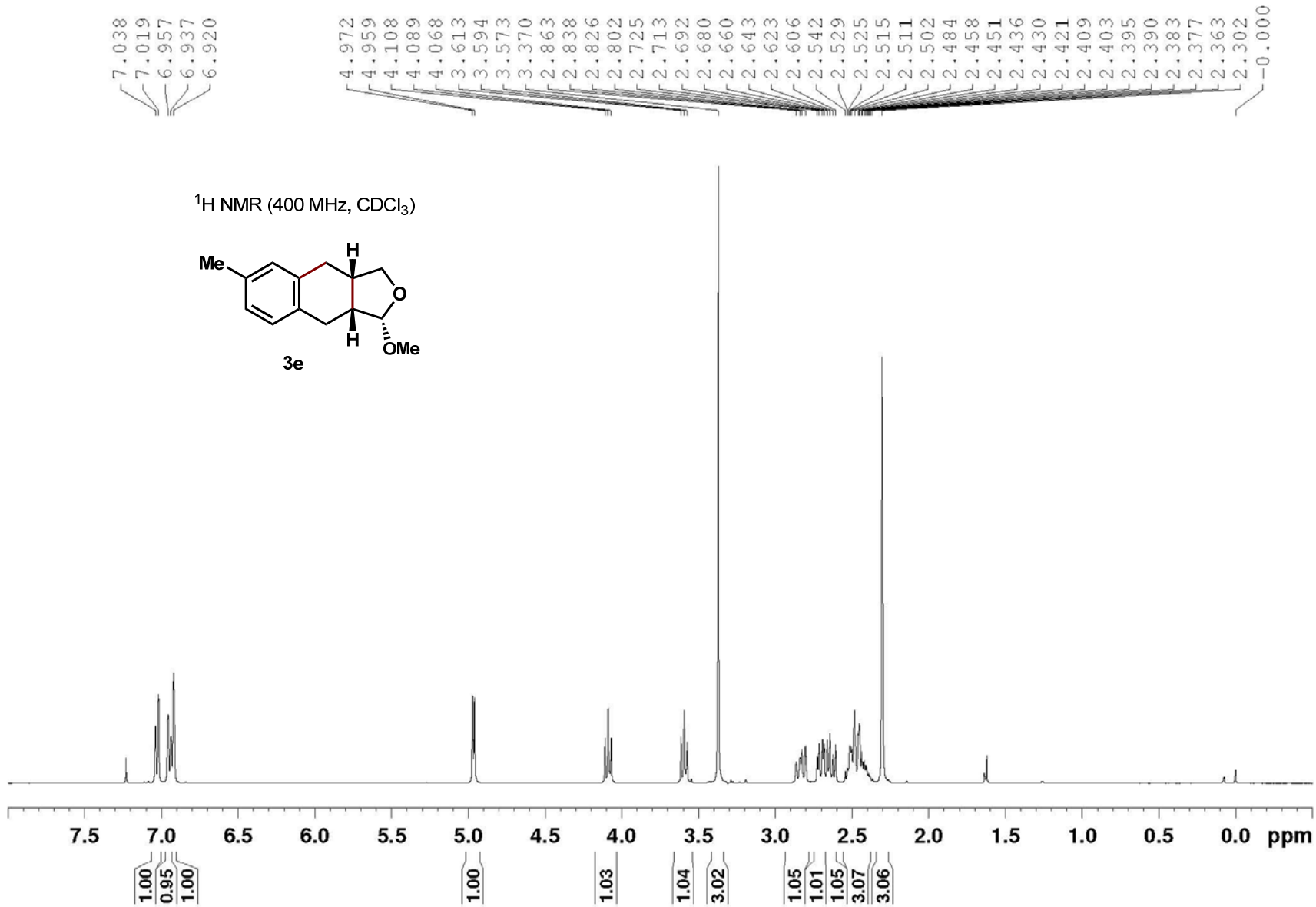
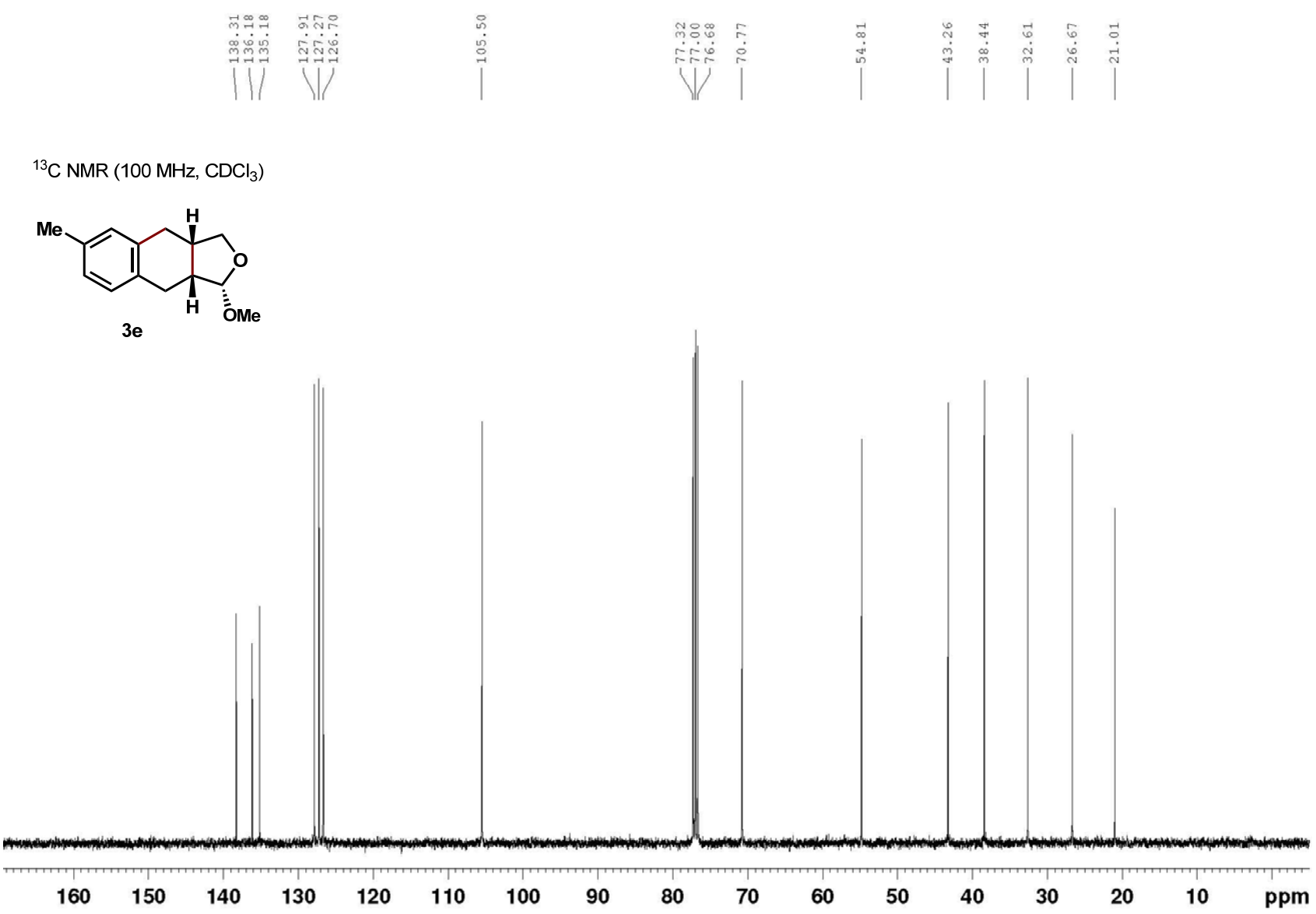
134.31
133.91
133.89
133.23
132.06
132.01
127.96
127.94
124.13
117.51
117.43
104.46
104.25
77.31
77.00
76.68
69.10
55.60
55.11
53.34
53.22
38.97
38.68
20.62
$^{13}$C NMR (100 MHz, $CDCl_3$)
Me
Br
O
Br
OMe
2e
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.038
7.019
6.957
6.937
6.920
4.972
4.959
4.108
4.089
4.068
3.613
3.594
3.573
3.370
2.863
2.838
2.826
2.802
2.725
2.713
2.692
2.680
2.660
2.643
2.623
2.606
2.542
2.529
2.525
2.515
2.511
2.502
2.484
2.458
2.451
2.436
2.430
2.421
2.409
2.403
2.395
2.390
2.383
2.377
2.363
2.302
0.000
1H NMR (400 MHz, CDCl3)
Me
H
O
H
OMe
3e
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
0.95
1.00
1.00
1.03
1.04
3.02
1.05
1.01
1.05
3.07
3.06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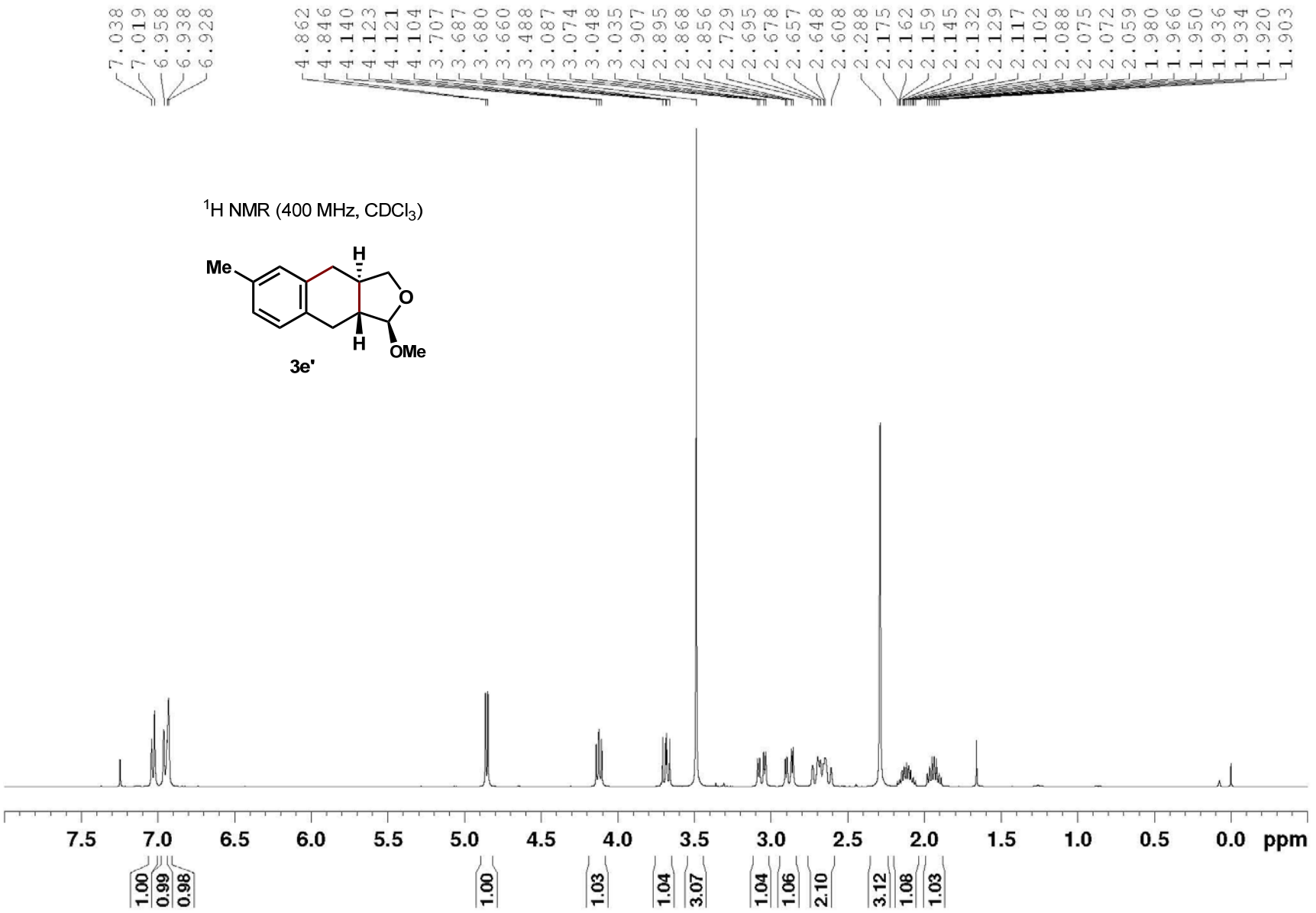
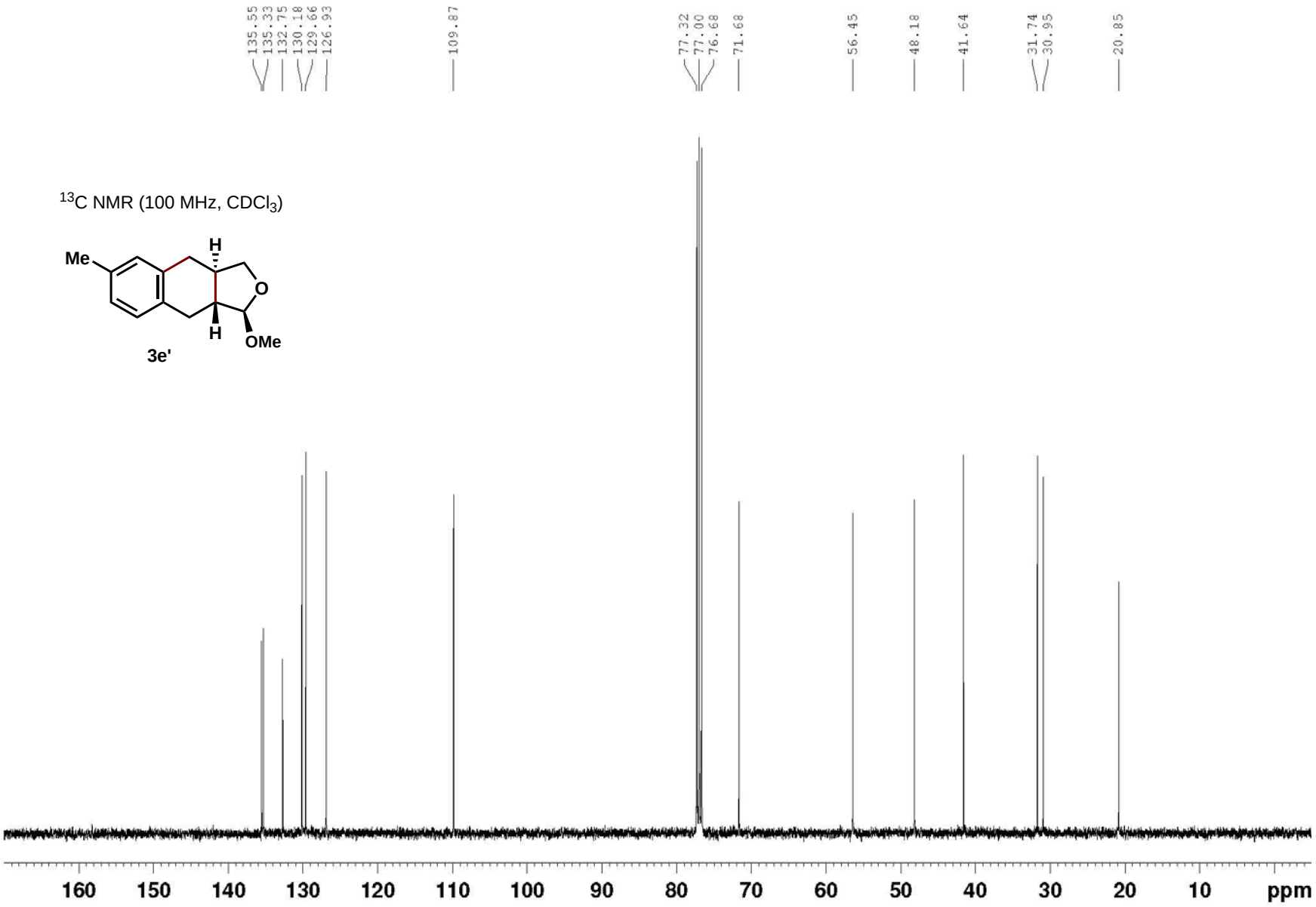
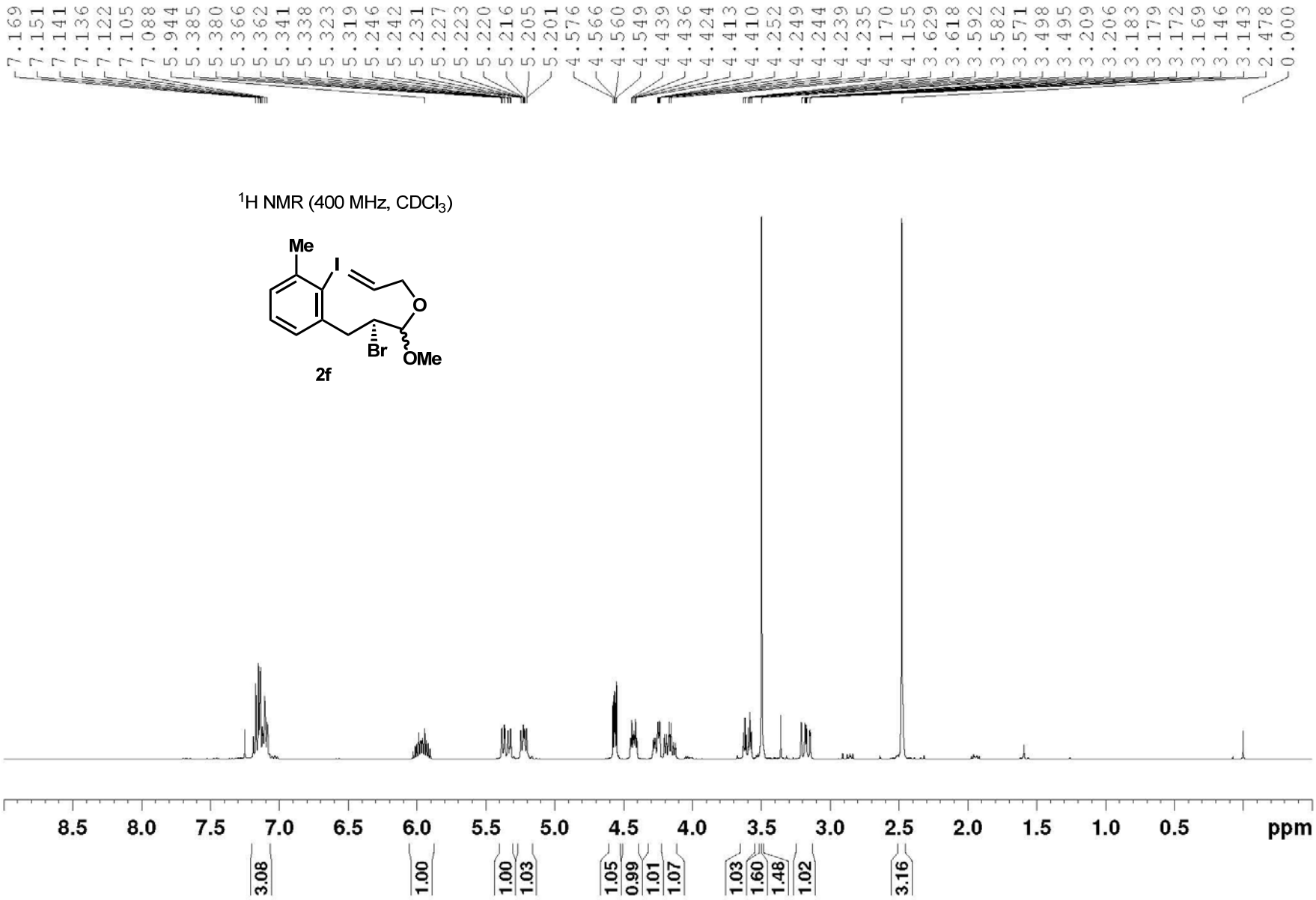
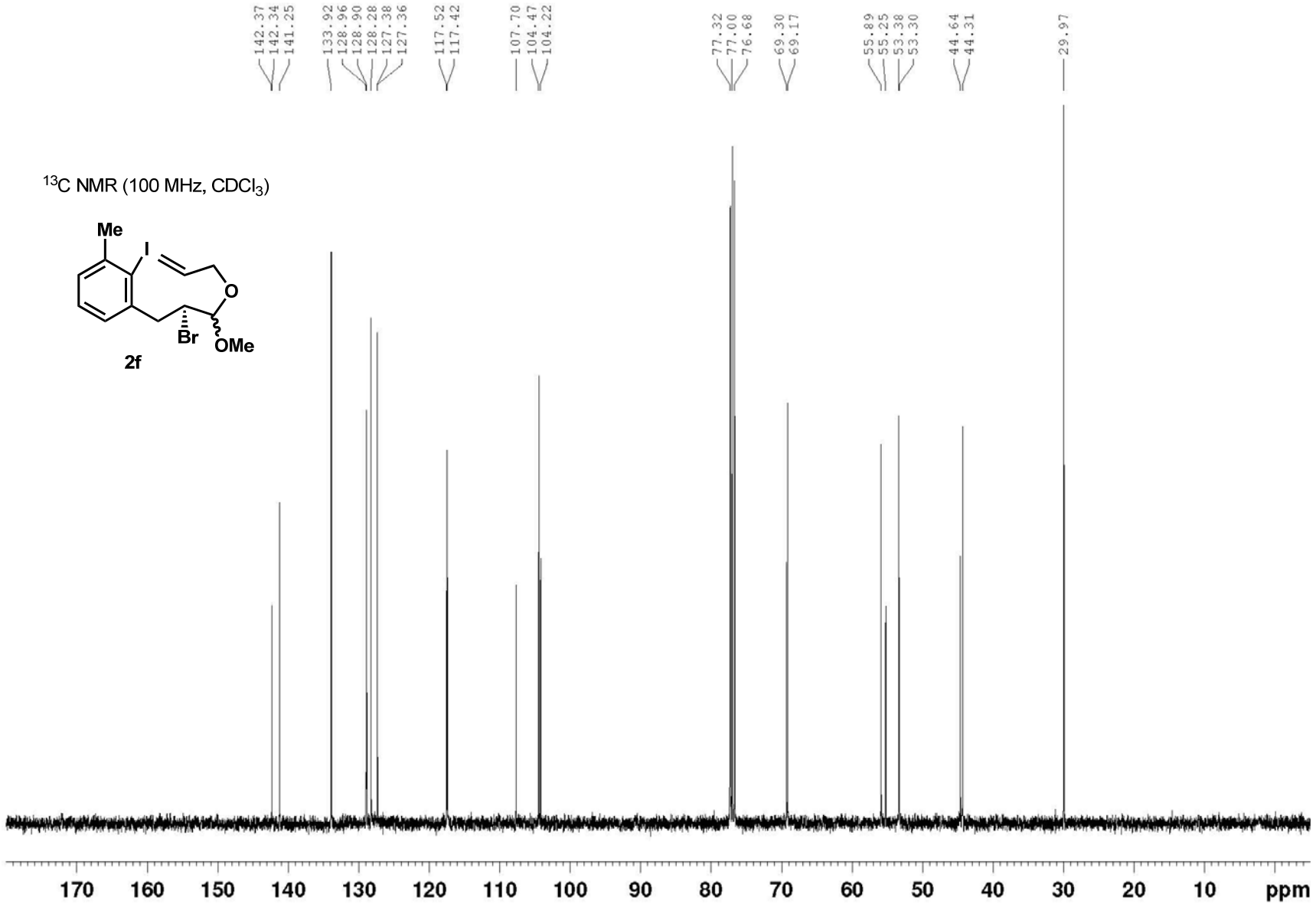
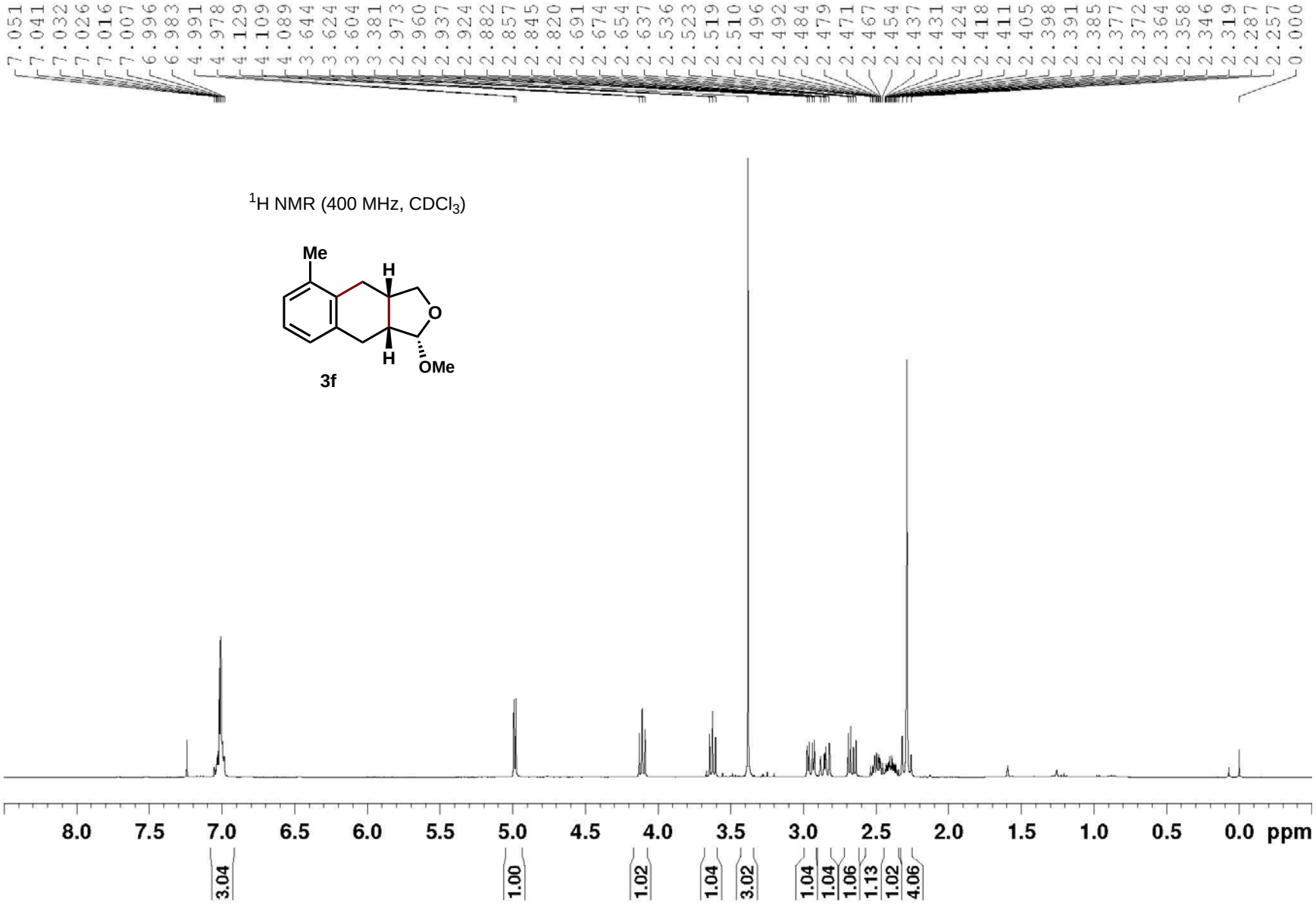
136.18
135.18
127.91
127.27
126.70
105.50
77.32
77.00
76.68
70.77
54.81
43.26
38.44
32.61
26.67
21.01
$^{13}$C NMR (100 MHz, CDCl$_3$)
Me
H
O
H
OMe
3e
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

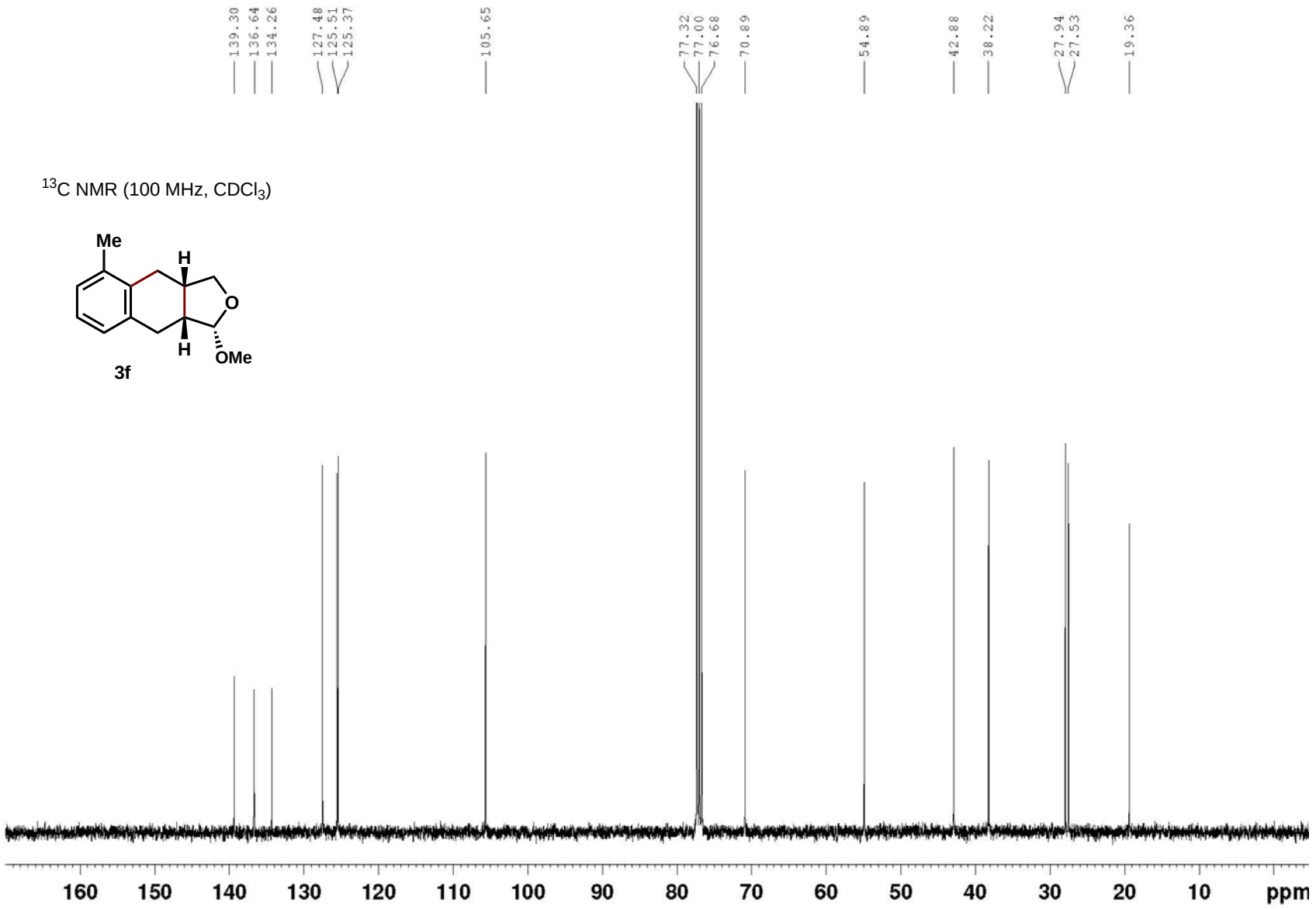

7.038
7.019
6.958
6.938
6.928
4.862
4.846
4.140
4.123
4.121
4.104
3.707
3.687
3.680
3.660
3.488
3.087
3.074
3.048
3.035
2.907
2.895
2.868
2.856
2.729
2.695
2.678
2.657
2.648
2.608
2.288
2.175
2.162
2.159
2.145
2.132
2.129
2.117
2.102
2.088
2.075
2.072
2.059
1.980
1.966
1.950
1.936
1.934
1.920
1.903
1H NMR (400 MHz, CDCl3)
Me
H
O
H
OMe
3e'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
0.99
0.98
1.00
1.03
1.04
3.07
1.04
1.06
2.10
3.12
1.08
1.03


135.55
135.33
132.75
130.18
129.66
126.93
109.87
77.32
77.00
76.68
71.68
56.45
48.18
41.64
31.74
30.95
20.85
$^{13}$C NMR (100 MHz, $CDCl_3$)
Me
H
O
H
OMe
3e'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.169
7.151
7.141
7.136
7.122
7.105
7.088
5.944
5.385
5.380
5.366
5.362
5.341
5.338
5.323
5.319
5.246
5.242
5.231
5.227
5.223
5.220
5.216
5.205
5.201
4.576
4.566
4.560
4.549
4.439
4.436
4.424
4.413
4.410
4.252
4.249
4.244
4.239
4.235
4.170
4.155
3.629
3.618
3.592
3.582
3.571
3.498
3.495
3.209
3.206
3.183
3.179
3.172
3.169
3.146
3.143
2.478
0.000
1H NMR (400 MHz, CDCl3)
Me
I
O
Br
OMe
2f
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
3.08
1.00
1.00
1.03
1.05
0.99
1.01
1.07
1.03
1.60
1.48
1.02
3.16


142.37
142.34
141.25
133.92
128.96
128.90
128.28
127.38
127.36
117.52
117.42
107.70
104.47
104.22
77.32
77.00
76.68
69.30
69.17
55.89
55.25
53.38
53.30
44.64
44.31
29.97
$^{13}$C NMR (100 MHz, $CDCl_3$)
Me
I
O
Br
OMe
2f
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

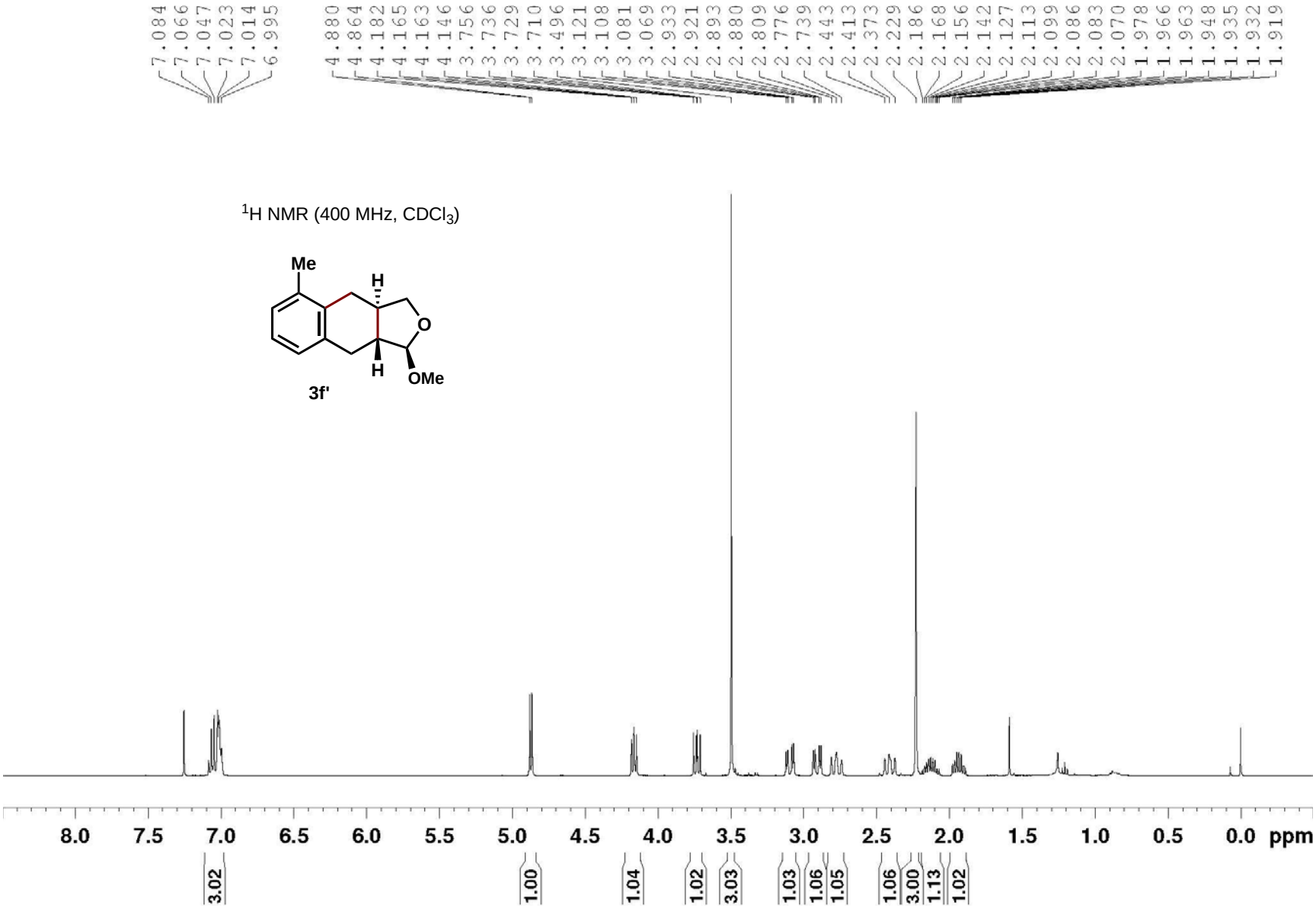

7.051
7.041
7.032
7.026
7.016
7.007
6.996
6.983
4.991
4.978
4.129
4.109
4.089
3.644
3.624
3.604
3.381
2.973
2.960
2.937
2.924
2.882
2.857
2.845
2.820
2.691
2.674
2.654
2.637
2.536
2.523
2.519
2.510
2.496
2.492
2.484
2.479
2.471
2.467
2.454
2.437
2.431
2.424
2.418
2.411
2.405
2.398
2.391
2.385
2.377
2.372
2.364
2.358
2.346
2.319
2.287
2.257
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
Me
H
O
H
OMe
3f
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.04
1.00
1.02
1.04
3.02
1.04
1.04
1.06
1.13
1.02
4.06




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




**3f**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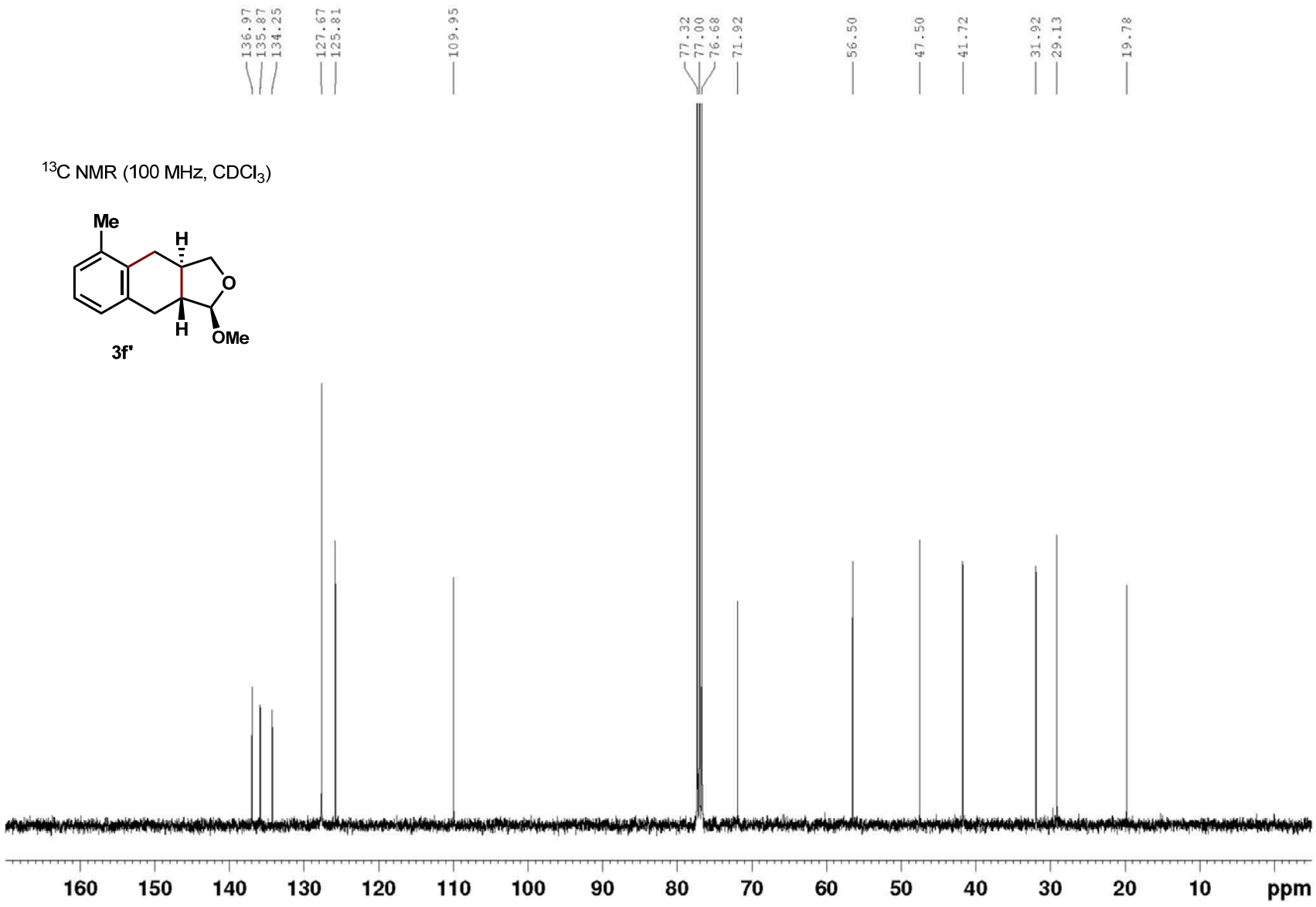
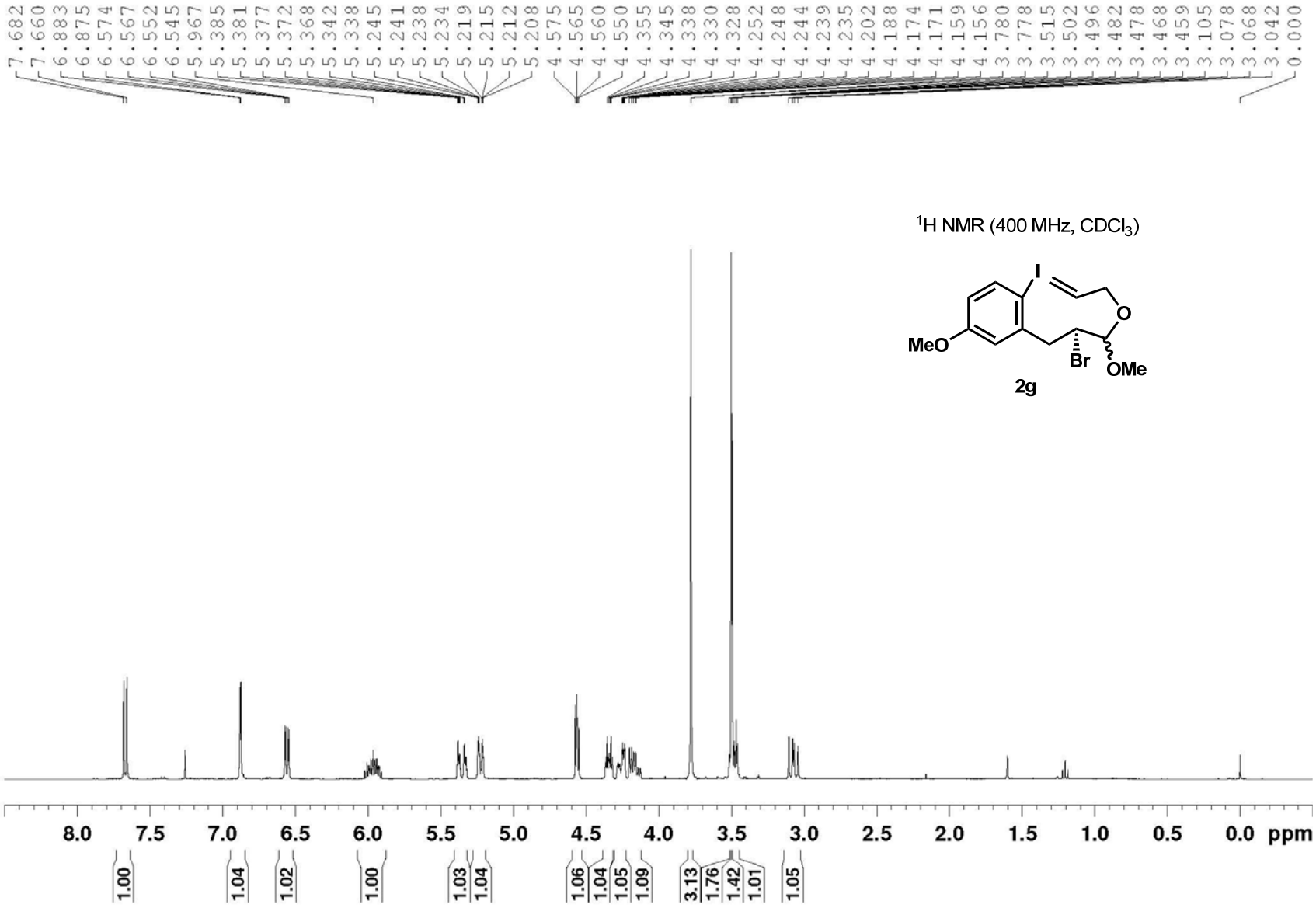
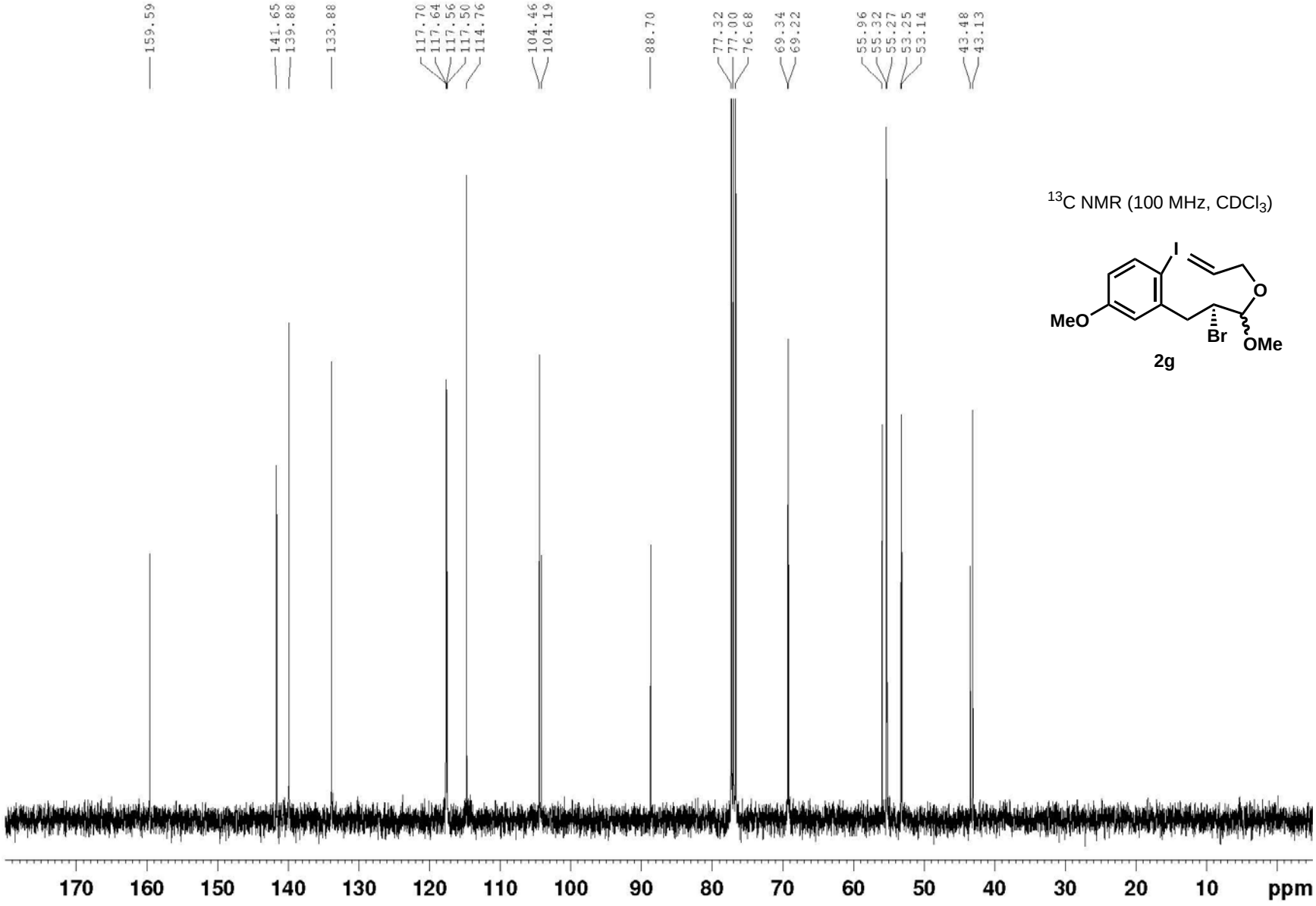
7.066
7.047
7.023
7.014
6.995
4.880
4.864
4.182
4.165
4.163
4.146
3.756
3.736
3.729
3.710
3.496
3.121
3.108
3.081
3.069
2.933
2.921
2.893
2.880
2.809
2.776
2.739
2.443
2.413
2.373
2.229
2.186
2.168
2.156
2.142
2.127
2.113
2.099
2.086
2.083
2.070
1.978
1.966
1.963
1.948
1.935
1.932
1.919
$^1$H NMR (400 MHz, CDCl$_3$)
Me
H
O
H
OMe
3f'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.02
1.00
1.04
1.02
3.03
1.03
1.06
1.05
1.06
3.00
1.13
1.02


136.97
135.87
134.25
127.67
125.81
109.95
77.32
77.00
76.68
71.92
56.50
47.50
41.72
31.92
29.13
19.78
$^{13}$C NMR (100 MHz, CDCl$_3$)
Me
H
O
H
OMe
3f'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

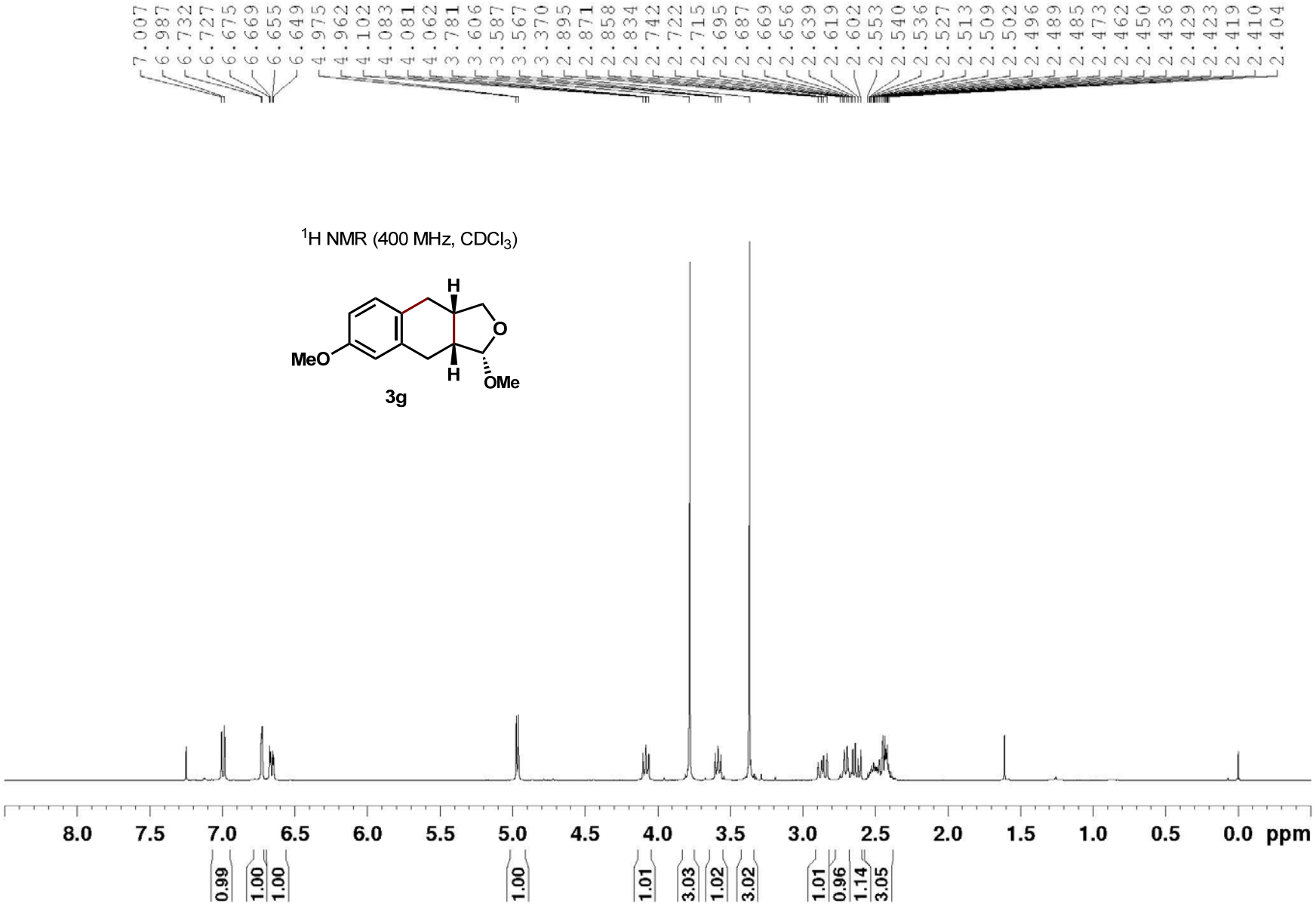

7.682
7.660
6.883
6.875
6.574
6.567
6.552
6.545
5.967
5.385
5.381
5.377
5.372
5.368
5.342
5.338
5.245
5.241
5.238
5.234
5.219
5.215
5.212
5.208
4.575
4.565
4.560
4.550
4.355
4.345
4.338
4.330
4.328
4.252
4.248
4.244
4.239
4.235
4.202
4.188
4.174
4.171
4.159
4.156
3.780
3.778
3.515
3.502
3.496
3.482
3.478
3.468
3.459
3.105
3.078
3.068
3.042
0.000
1H NMR (400 MHz, CDCl3)
I
O
MeO
Br
OMe
2g
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.04
1.02
1.00
1.03
1.04
1.06
1.04
1.05
1.09
3.13
1.76
1.42
1.01
1.05

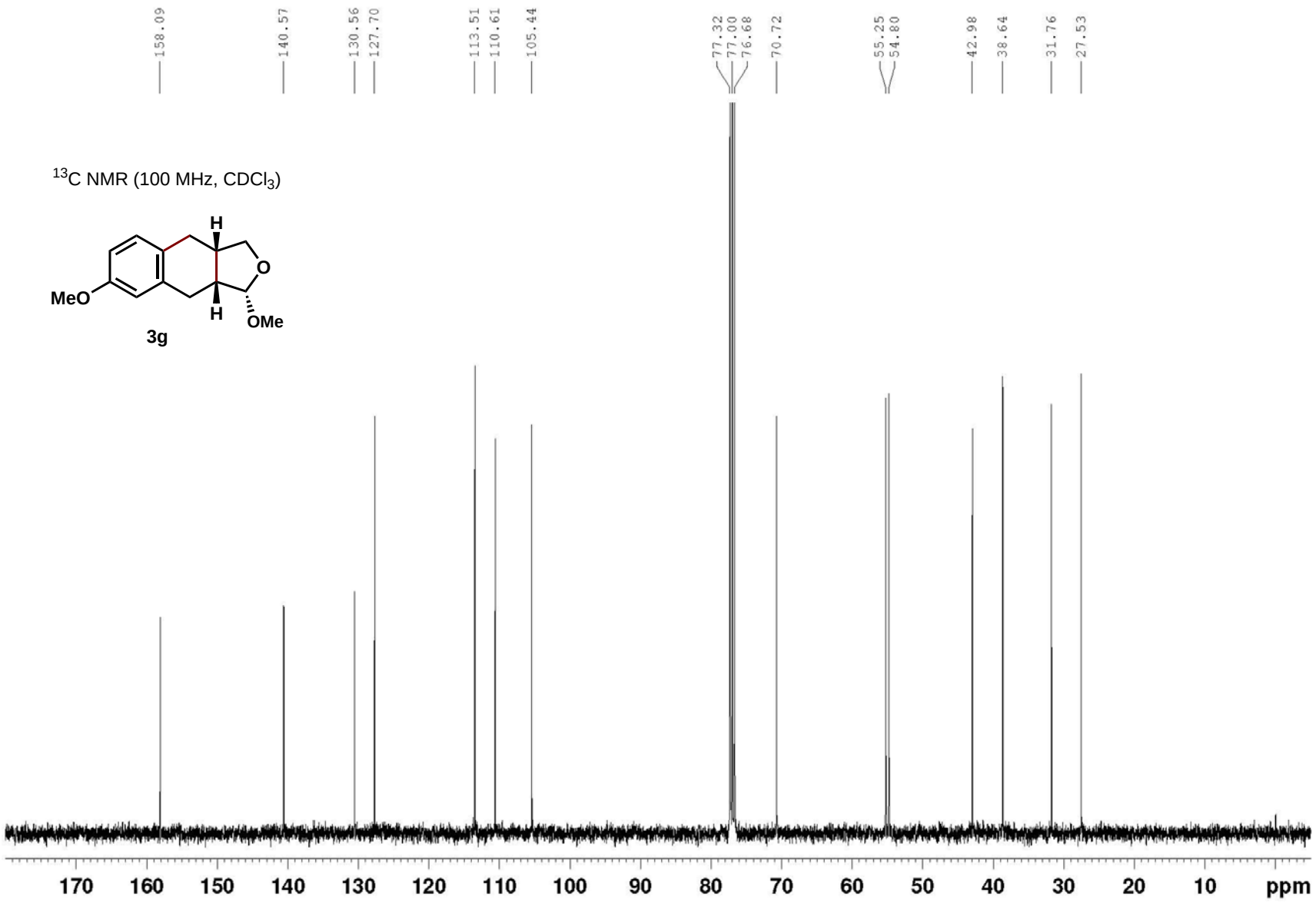


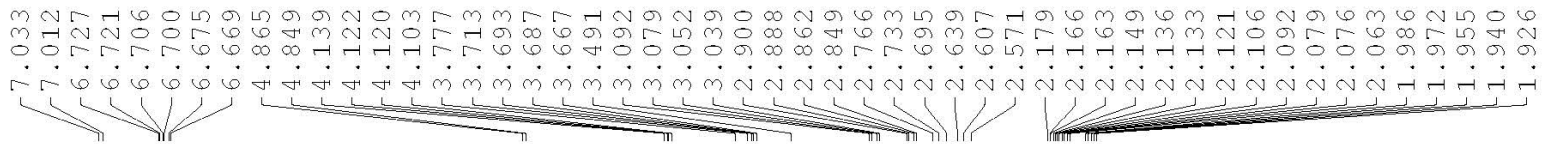

$^{13}$C NMR (100 MHz, $CDCl_3$)



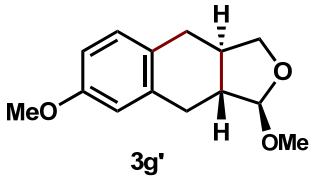

**2g**


7.007
6.987
6.732
6.727
6.675
6.669
6.655
6.649
4.975
4.962
4.102
4.083
4.081
4.062
3.781
3.606
3.587
3.567
3.370
2.895
2.871
2.858
2.834
2.742
2.722
2.715
2.695
2.687
2.669
2.656
2.639
2.619
2.602
2.553
2.540
2.536
2.527
2.513
2.509
2.502
2.496
2.489
2.485
2.473
2.462
2.450
2.436
2.429
2.423
2.419
2.410
2.404
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
MeO
H
OMe
3g
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.99
1.00
1.00
1.00
1.01
3.03
1.02
3.02
1.01
0.96
1.14
3.05

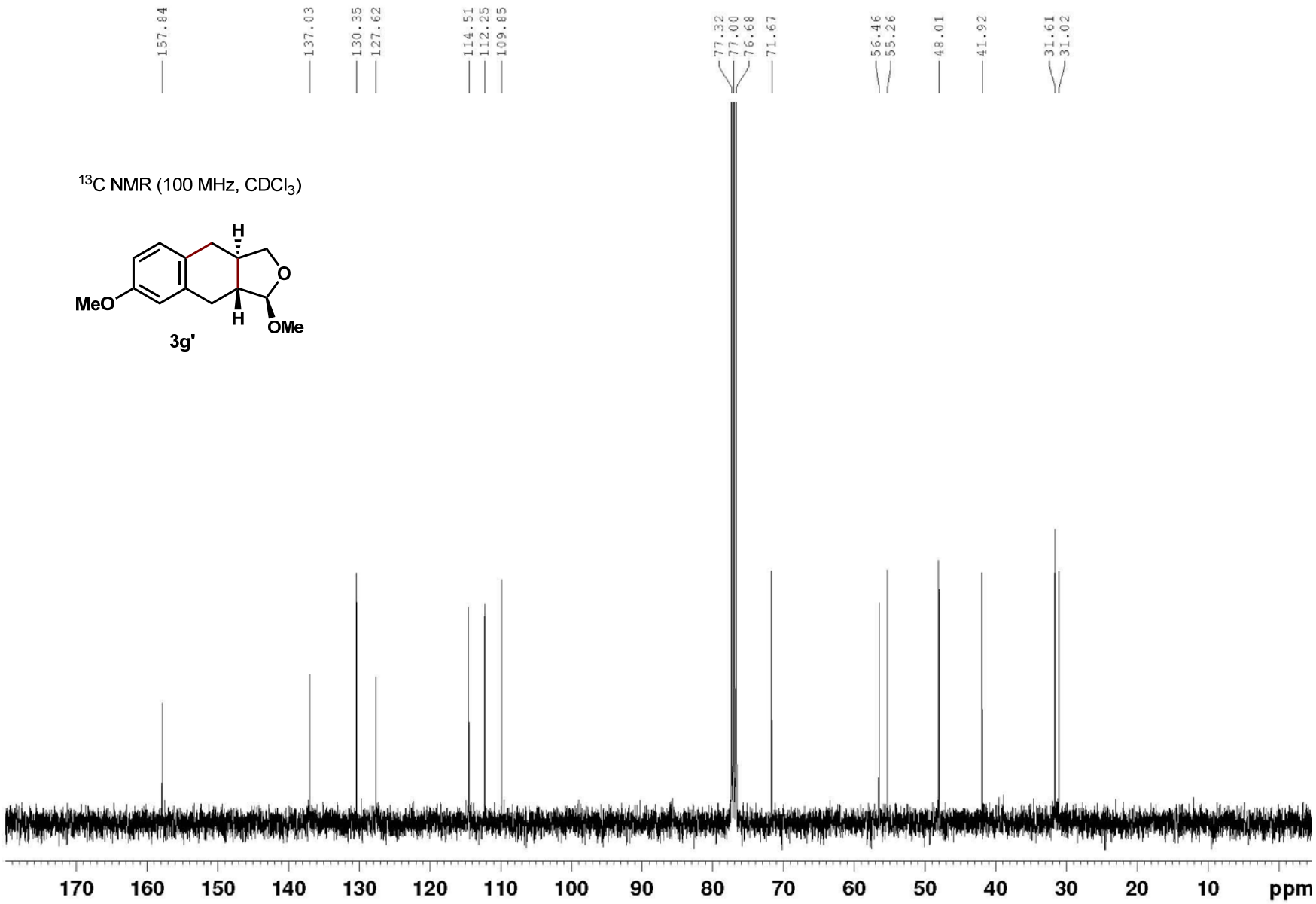

158.09
140.57
130.56
127.70
113.51
110.61
105.44
77.32
77.00
76.68
70.72
55.25
54.80
42.98
38.64
31.76
27.53
$^{13}$C NMR (100 MHz, $CDCl_3$)
H
O
MeO
H
OMe
3g
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

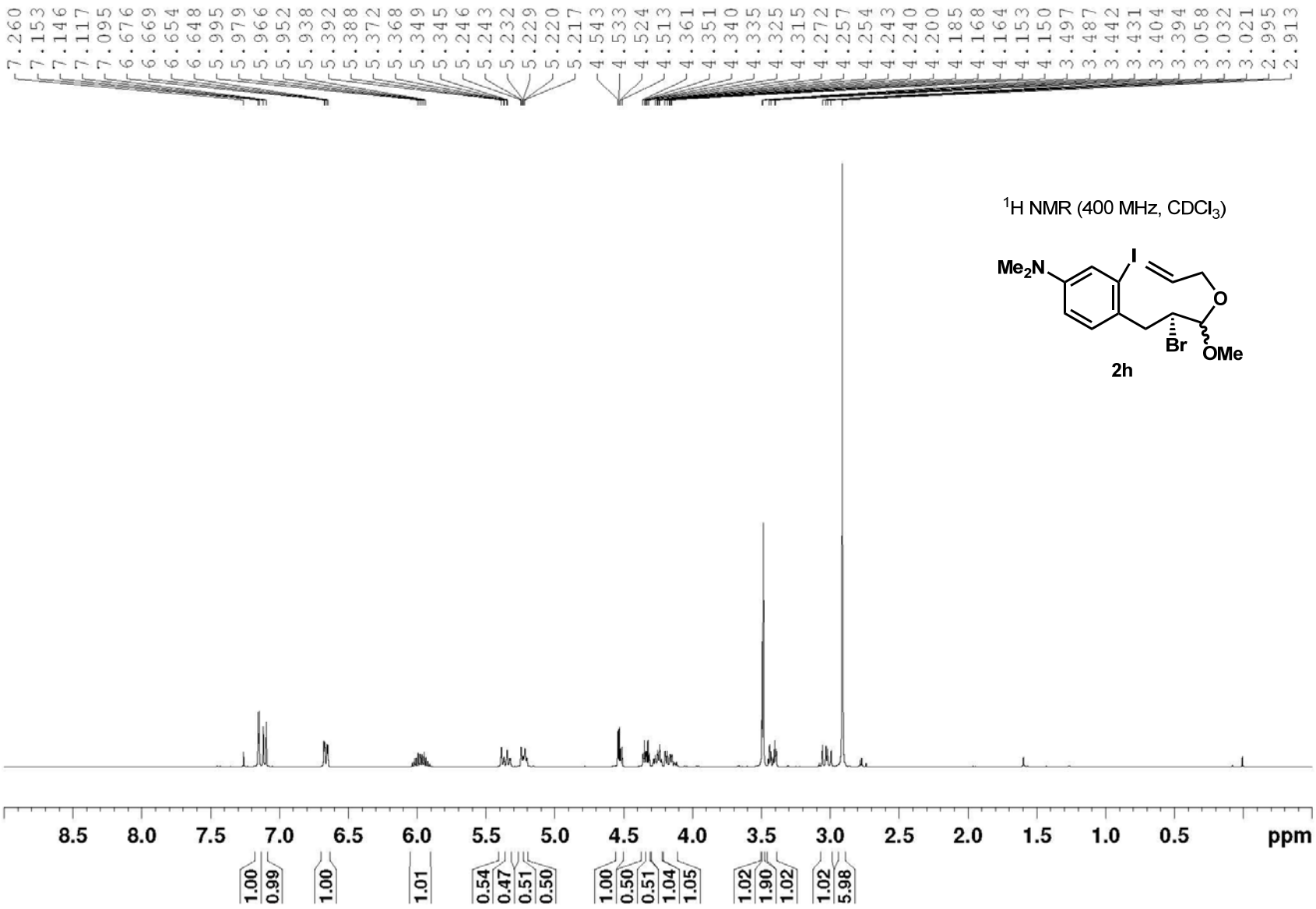


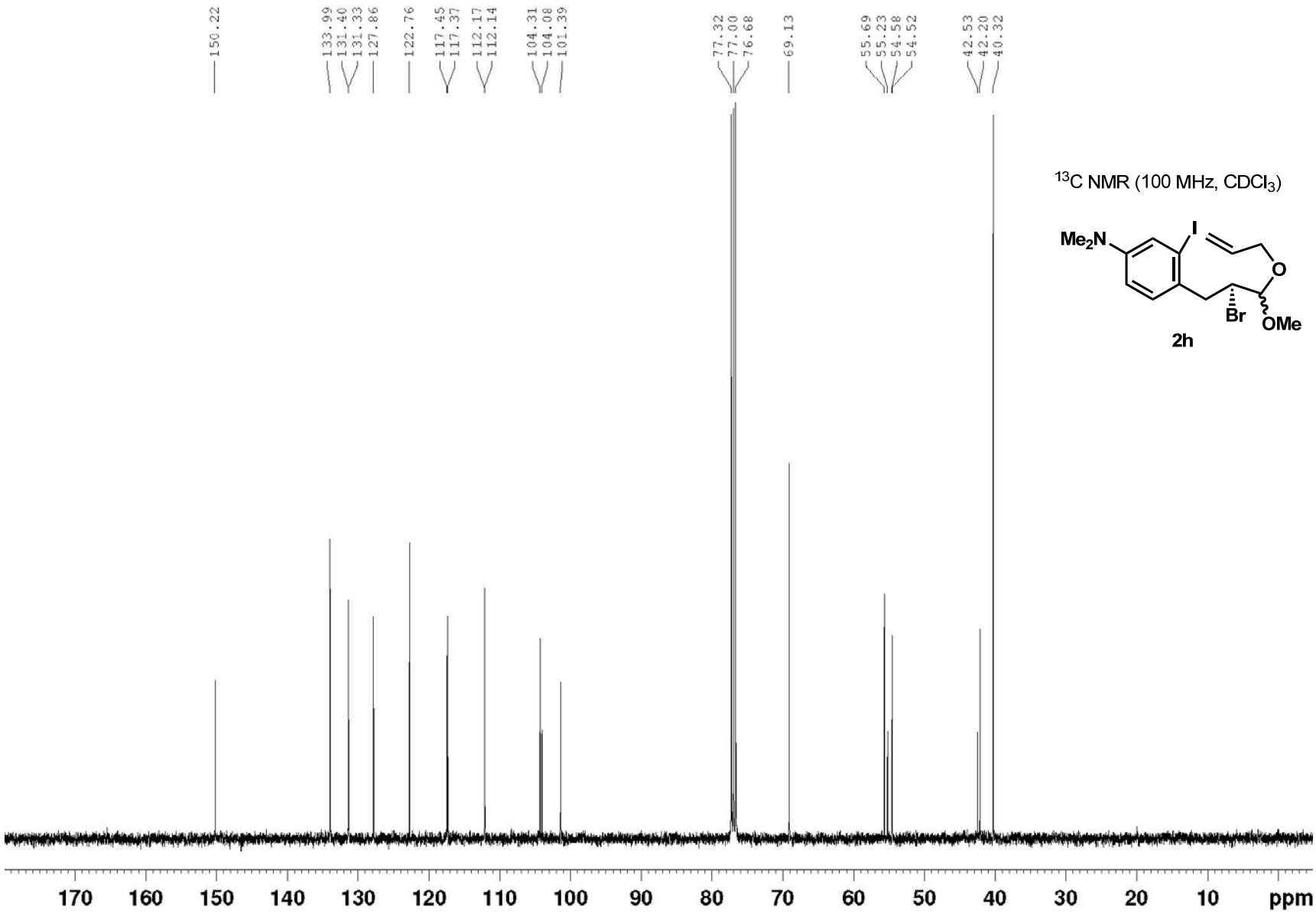

$^1$H NMR (400 MHz, $CDCl_3$)




**3g'**


157.84
137.03
130.35
127.62
114.51
112.25
109.85
77.32
77.00
76.68
71.67
56.46
55.26
48.01
41.92
31.61
31.02
$^{13}$C NMR (100 MHz, CDCl$_3$)
MeO
H
O
H
OMe
3g'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

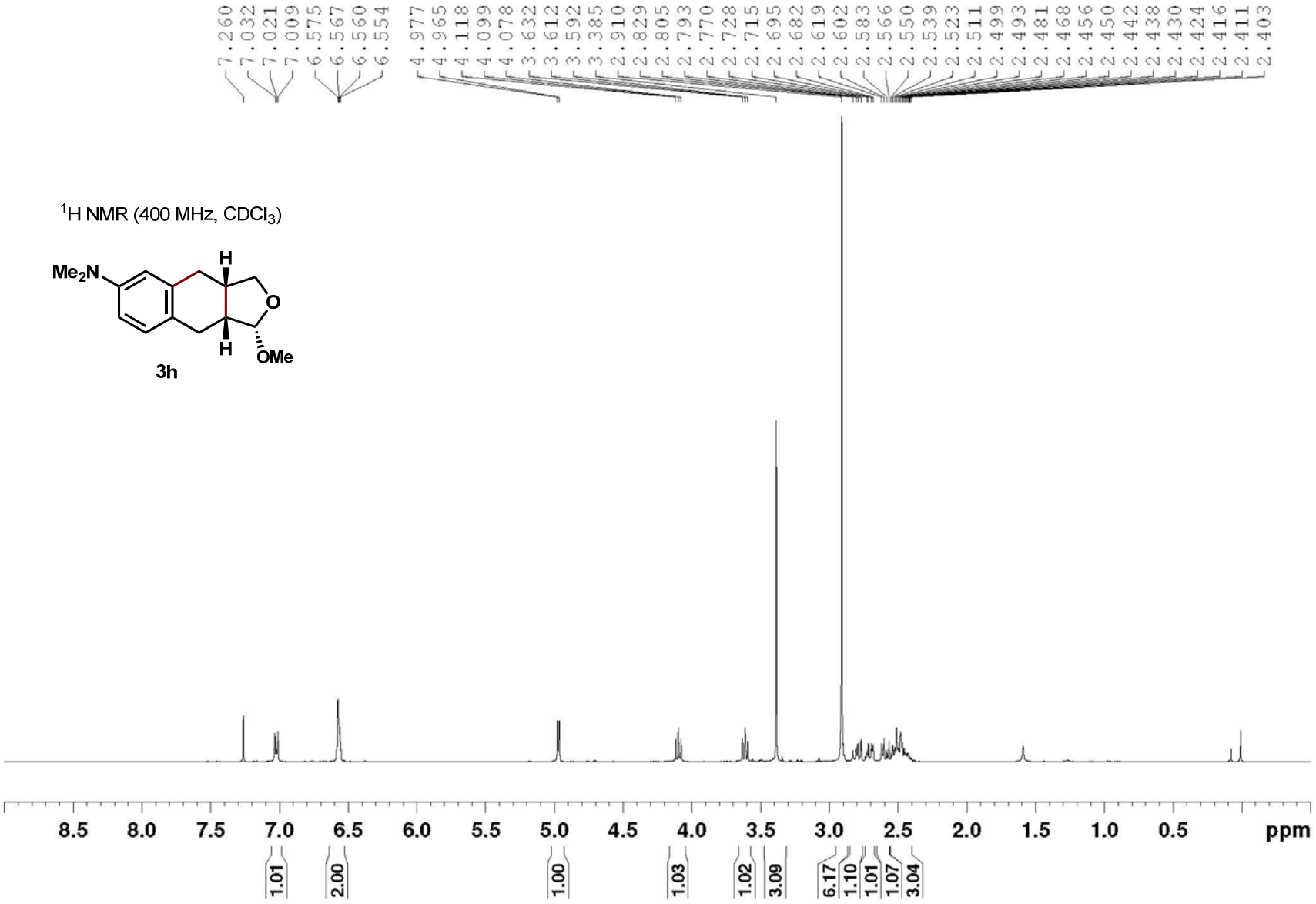

7.260
7.153
7.146
7.117
7.095
6.676
6.669
6.654
6.648
5.995
5.979
5.966
5.952
5.938
5.392
5.388
5.372
5.368
5.349
5.345
5.246
5.243
5.232
5.229
5.220
5.217
4.543
4.533
4.524
4.513
4.361
4.351
4.340
4.335
4.325
4.315
4.272
4.257
4.254
4.243
4.240
4.200
4.185
4.168
4.164
4.153
4.150
3.497
3.487
3.442
3.431
3.404
3.394
3.058
3.032
3.021
2.995
2.913
$^1$H NMR (400 MHz, CDCl$_3$)
Me$_2$N
I
O
Br
OMe
2h
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
0.99
1.00
1.01
0.54
0.47
0.51
0.50
1.00
0.50
0.51
1.04
1.05
1.02
1.90
1.02
1.02
5.98

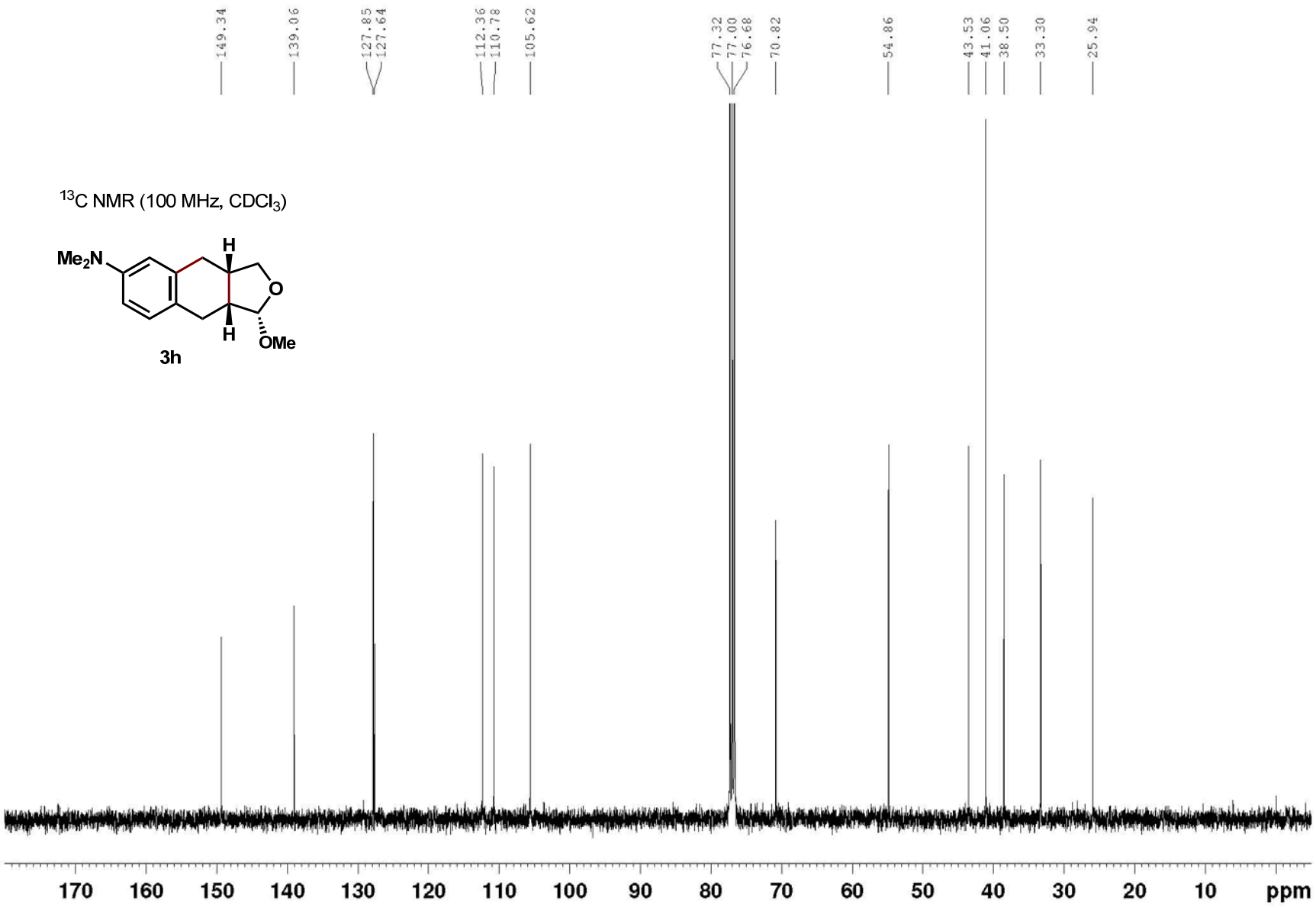


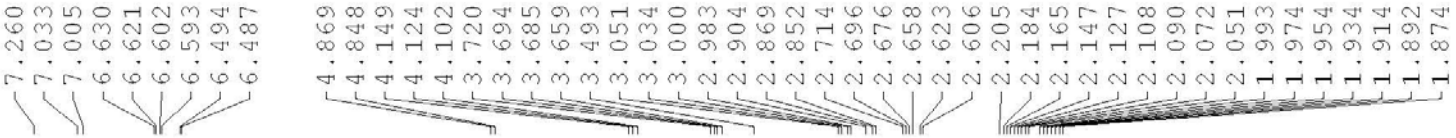

$^{13}C$ NMR (100 MHz, $CDCl_3$)



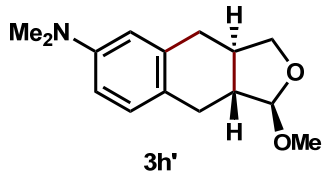

**2h**


7.260
7.032
7.021
7.009
6.575
6.567
6.560
6.554
4.977
4.965
4.118
4.099
4.078
3.632
3.612
3.592
3.385
2.910
2.829
2.805
2.793
2.770
2.728
2.715
2.695
2.682
2.619
2.602
2.583
2.566
2.550
2.539
2.523
2.511
2.499
2.493
2.481
2.468
2.456
2.450
2.442
2.438
2.430
2.424
2.416
2.411
2.403
$^1$H NMR (400 MHz, $CDCl_3$)
$Me_2N$
H
O
H
OMe
3h
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.01
2.00
1.00
1.03
1.02
3.09
6.17
1.10
1.01
1.07
3.04

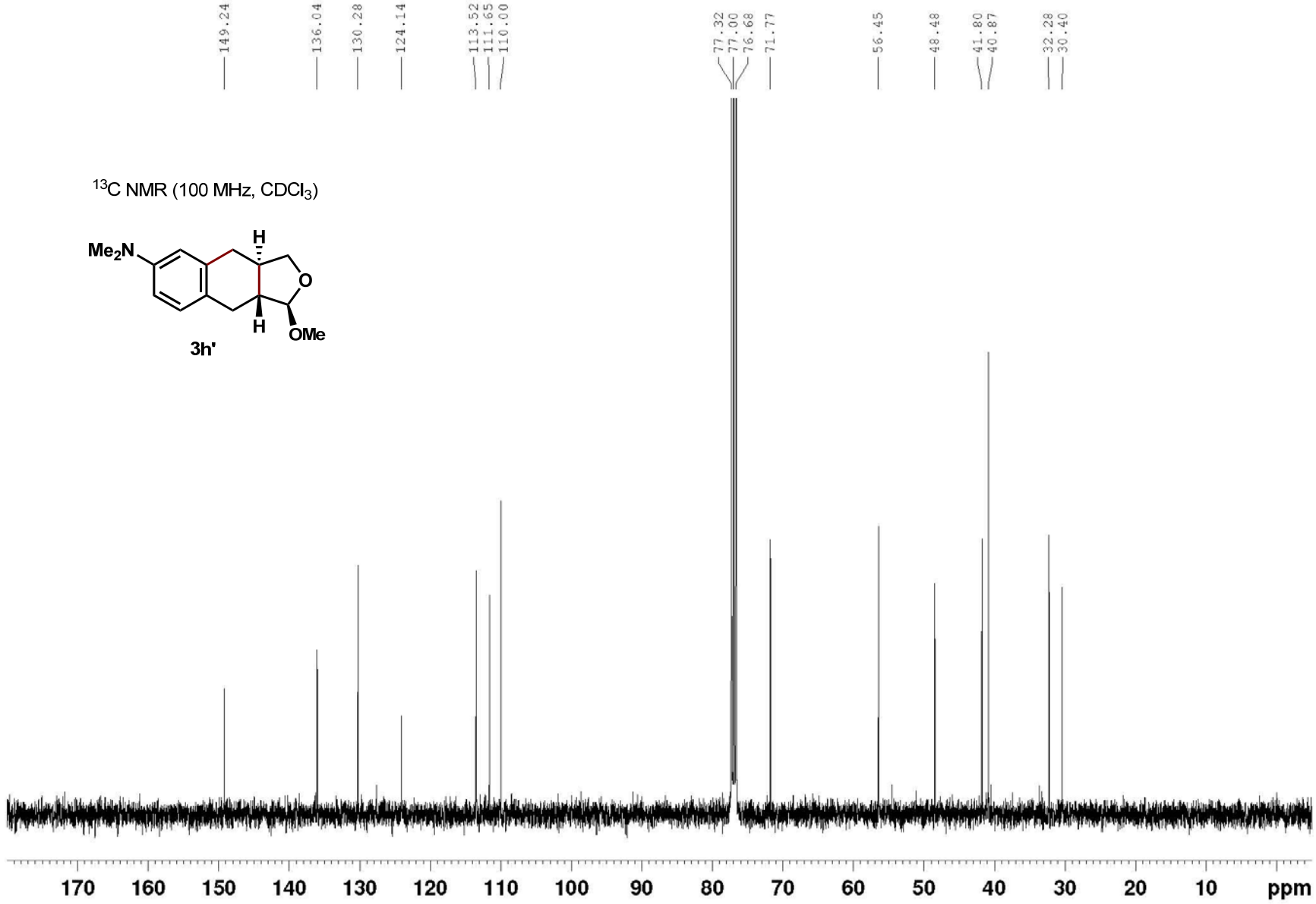

149.34
139.06
127.85
127.64
112.36
110.78
105.62
77.32
77.00
76.68
70.82
54.86
43.53
41.06
38.50
33.30
25.94
$^{13}$C NMR (100 MHz, $CDCl_3$)
$Me_2N$
H
O
H
OMe
3h
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

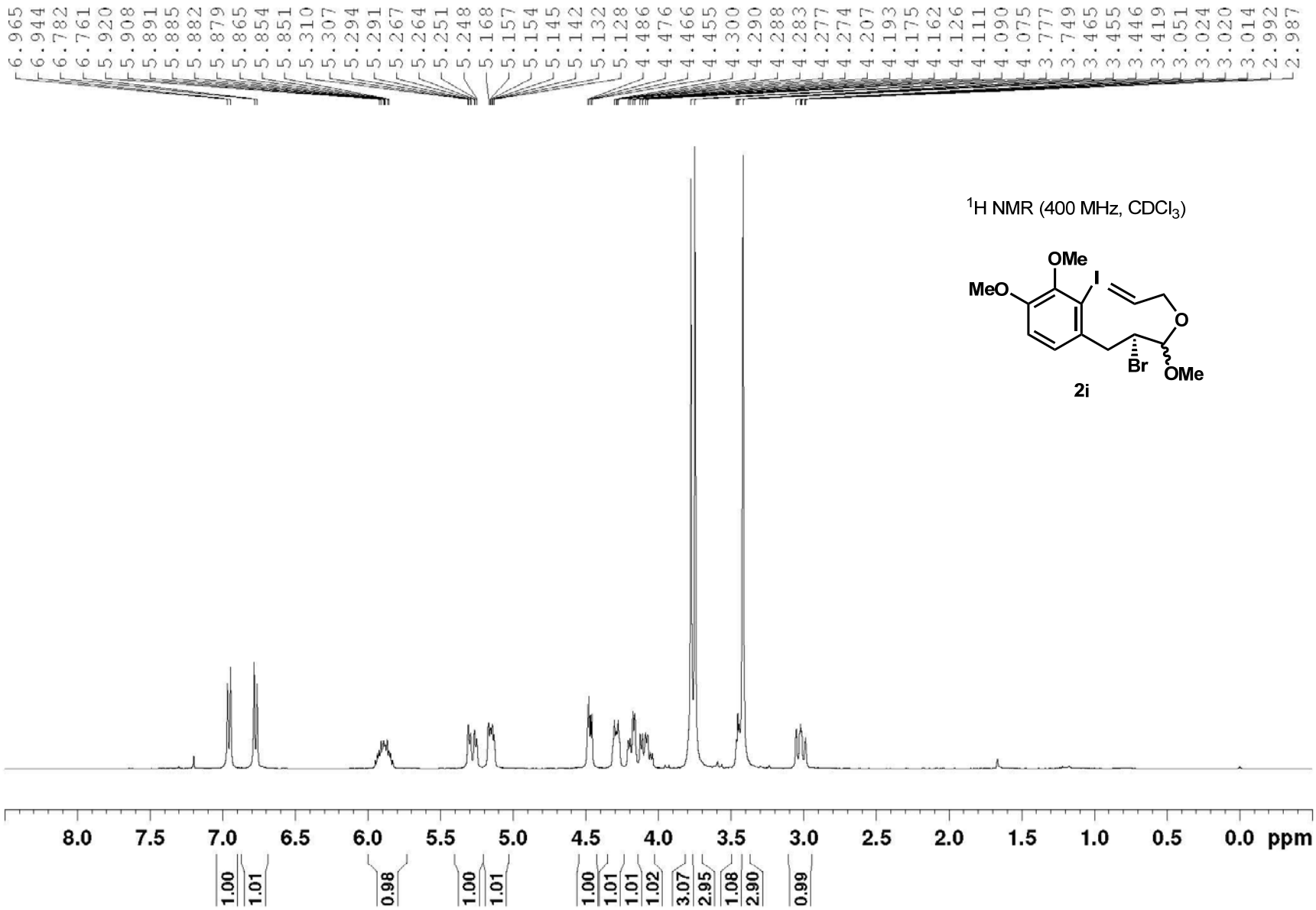


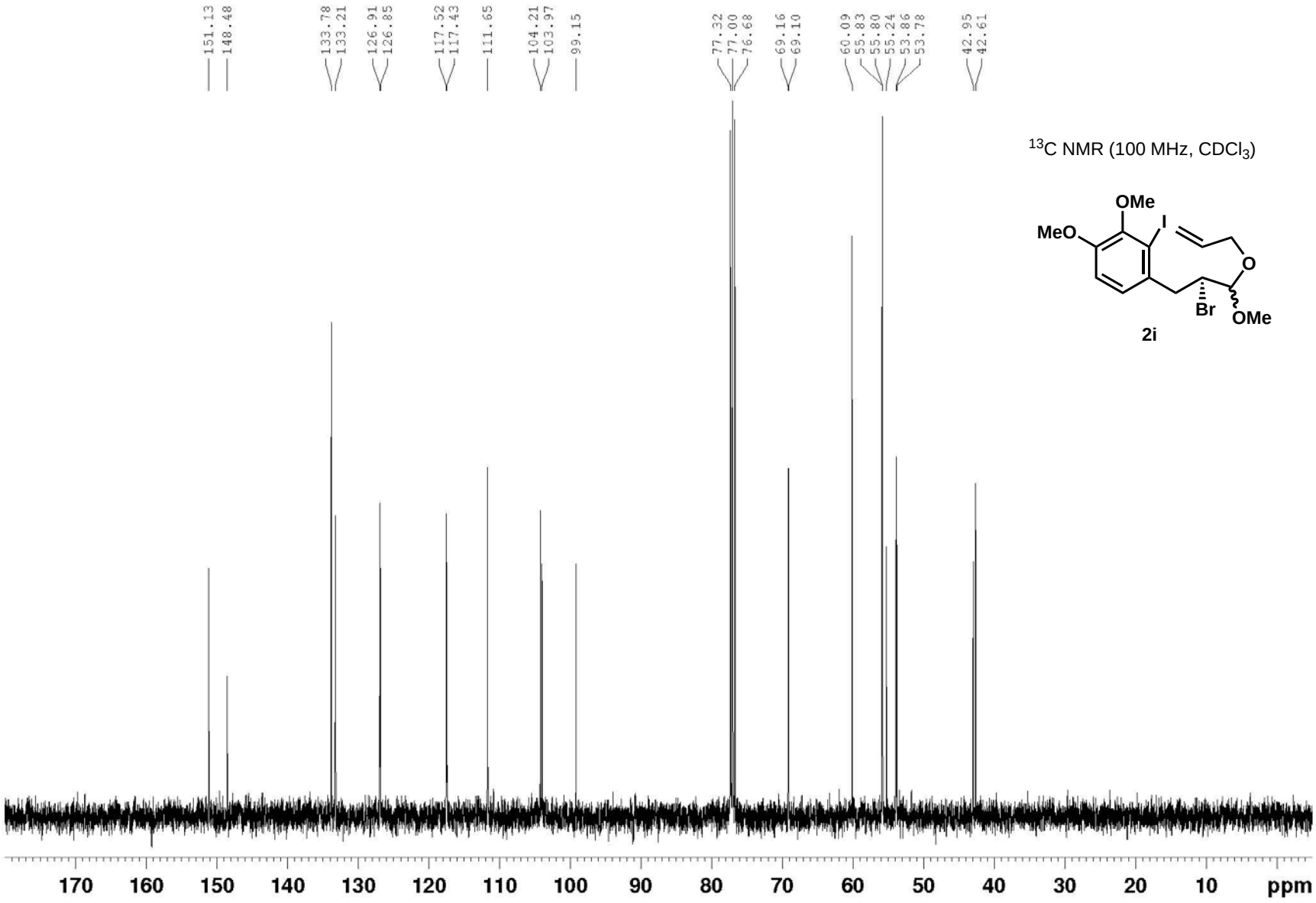

$^1$H NMR (300 MHz, $CDCl_3$)




3h'


149.24
136.04
130.28
124.14
113.52
111.65
110.00
77.32
77.00
76.68
71.77
56.45
48.48
41.80
40.87
32.28
30.40
$^{13}$C NMR (100 MHz, $CDCl_3$)
$Me_2N$
H
O
H
OMe
3h'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

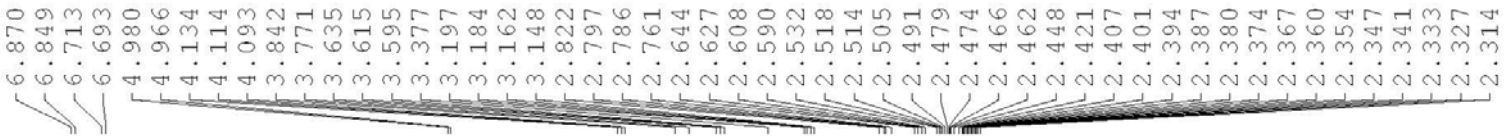

6.965
6.944
6.782
6.761
5.920
5.908
5.891
5.885
5.882
5.879
5.865
5.854
5.851
5.310
5.307
5.294
5.291
5.267
5.264
5.251
5.248
5.168
5.157
5.154
5.145
5.142
5.132
5.128
4.486
4.476
4.466
4.455
4.300
4.290
4.288
4.283
4.277
4.274
4.207
4.193
4.175
4.162
4.126
4.111
4.090
4.075
3.777
3.749
3.465
3.455
3.446
3.419
3.051
3.024
3.020
3.014
2.992
2.987
$^1$H NMR (400 MHz, $CDCl_3$)
OMe
MeO
I
O
Br
OMe
2i
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.01
0.98
1.00
1.01
1.00
1.01
1.01
1.02
3.07
2.95
1.08
2.90
0.99



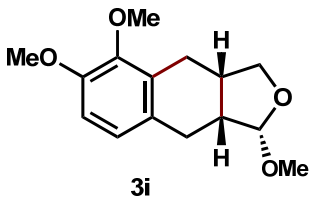

$^{13}$C NMR (100 MHz, $CDCl_3$)



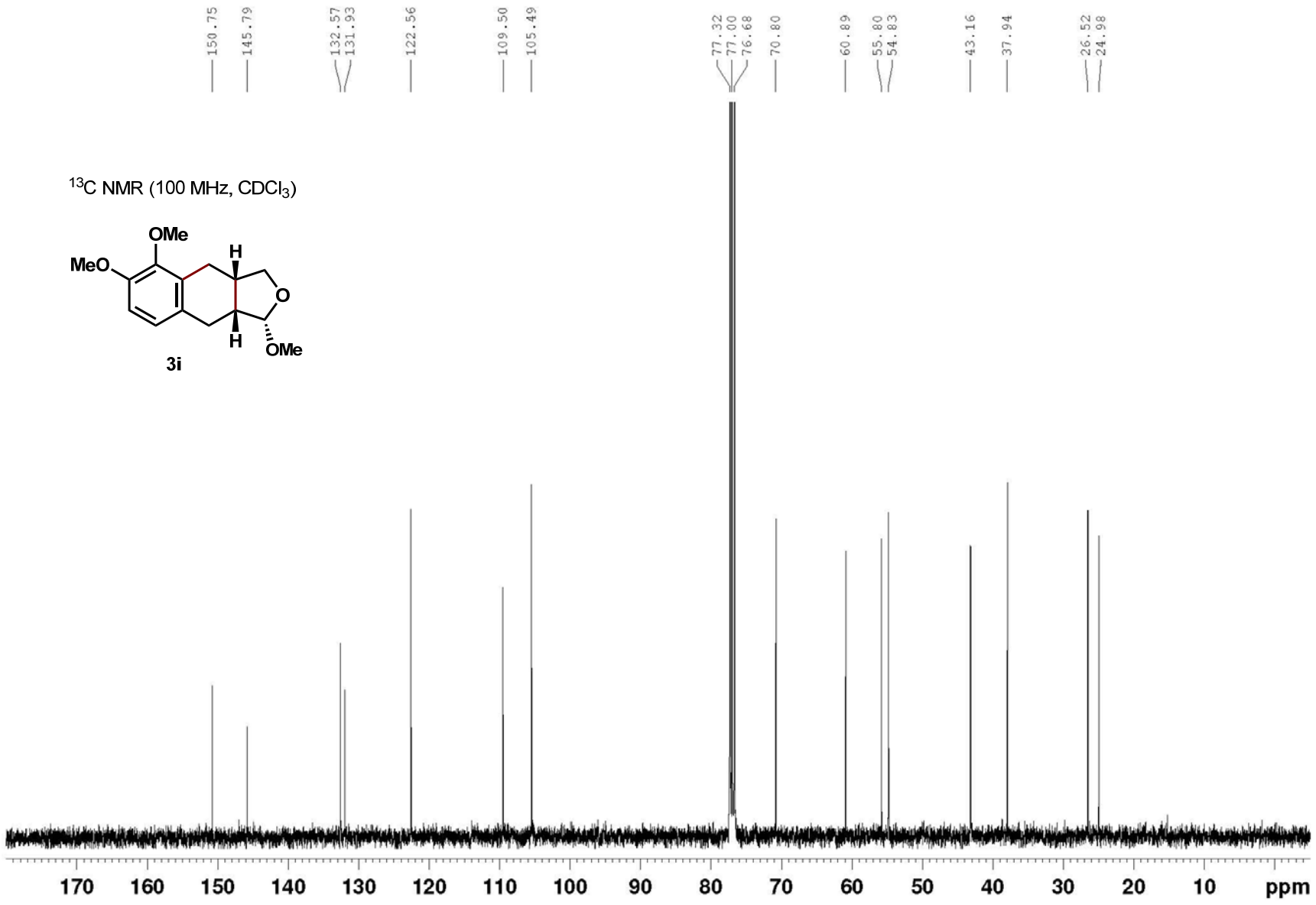

**2i**

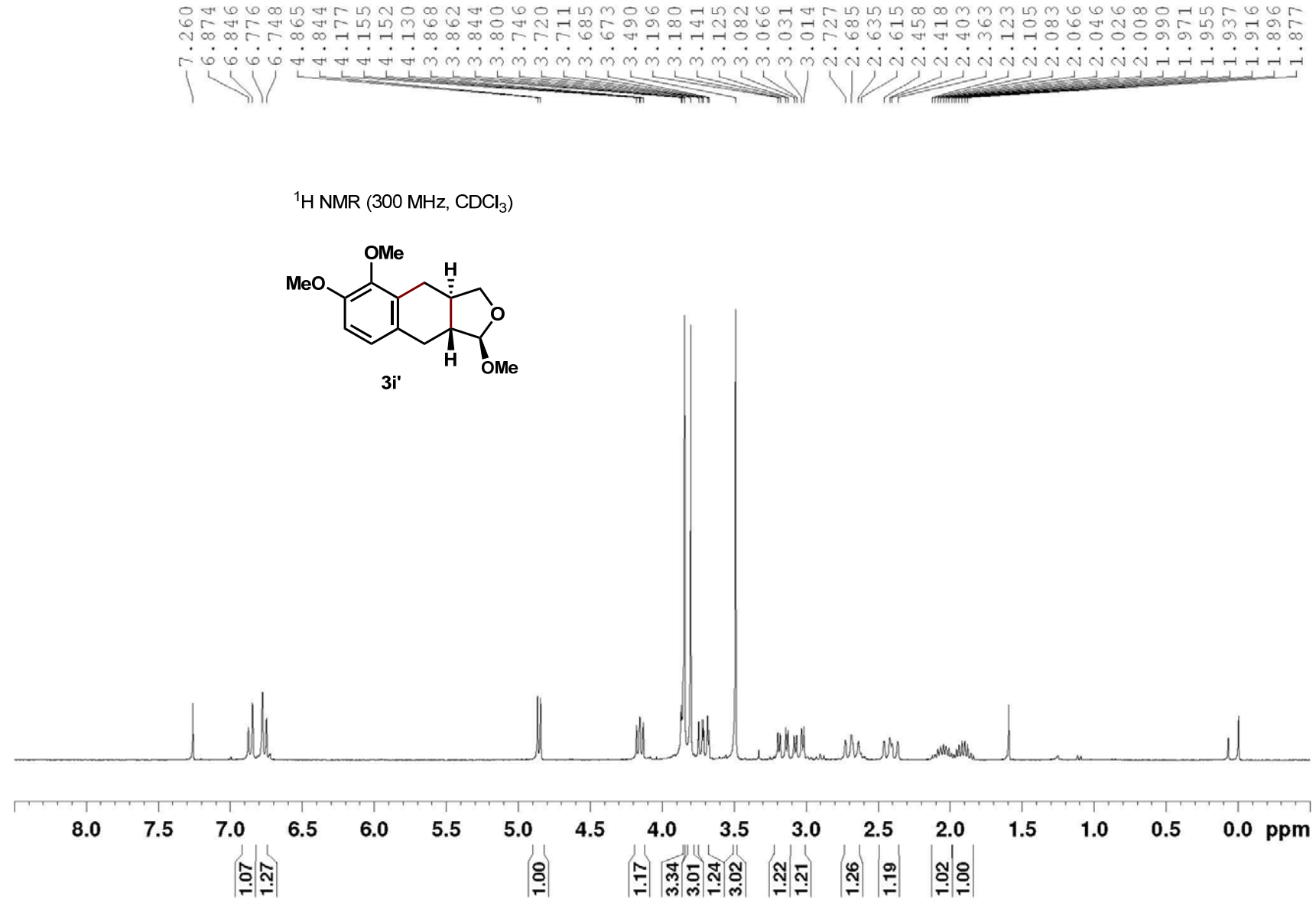


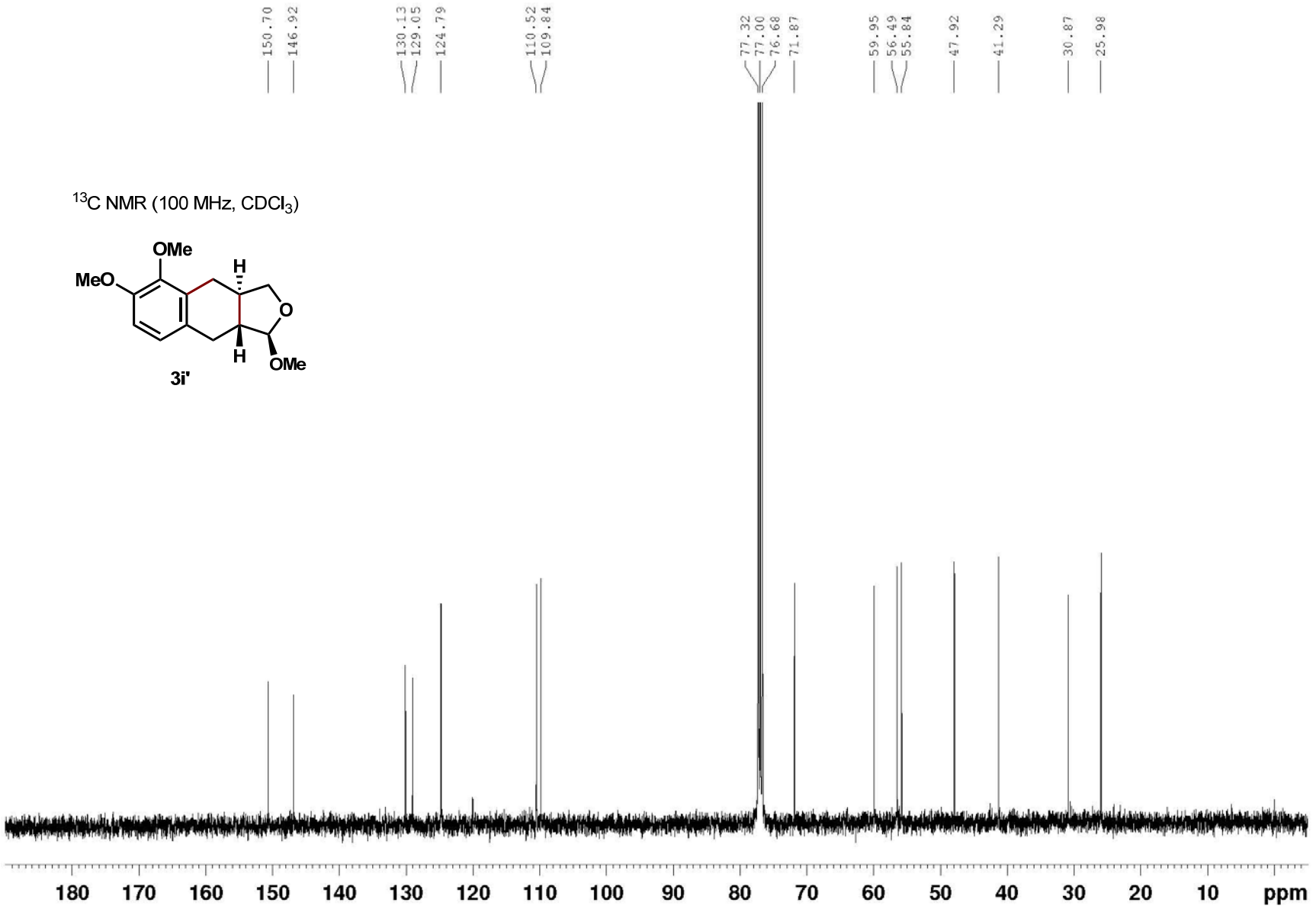

$^1$H NMR (400 MHz, $CDCl_3$)

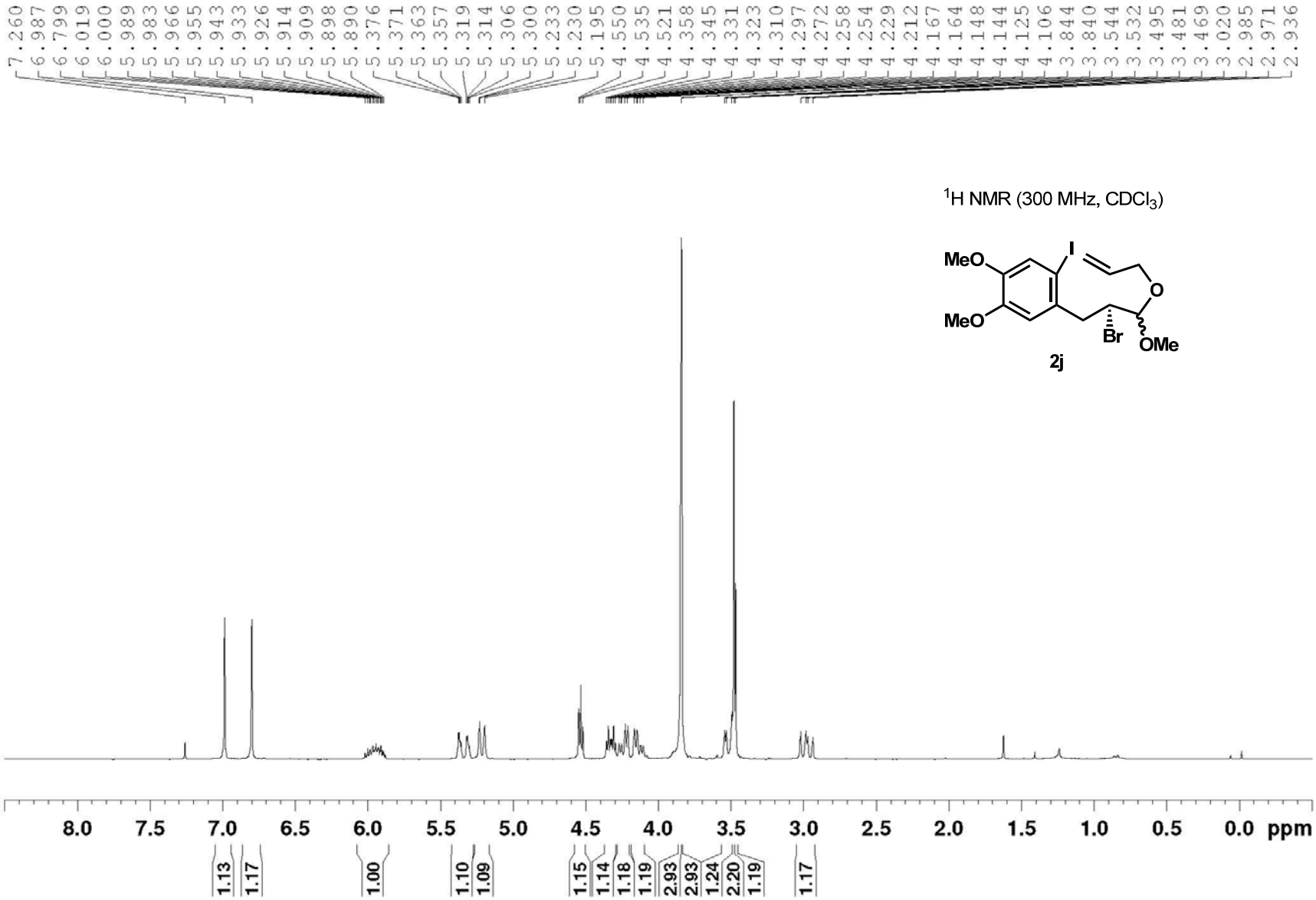


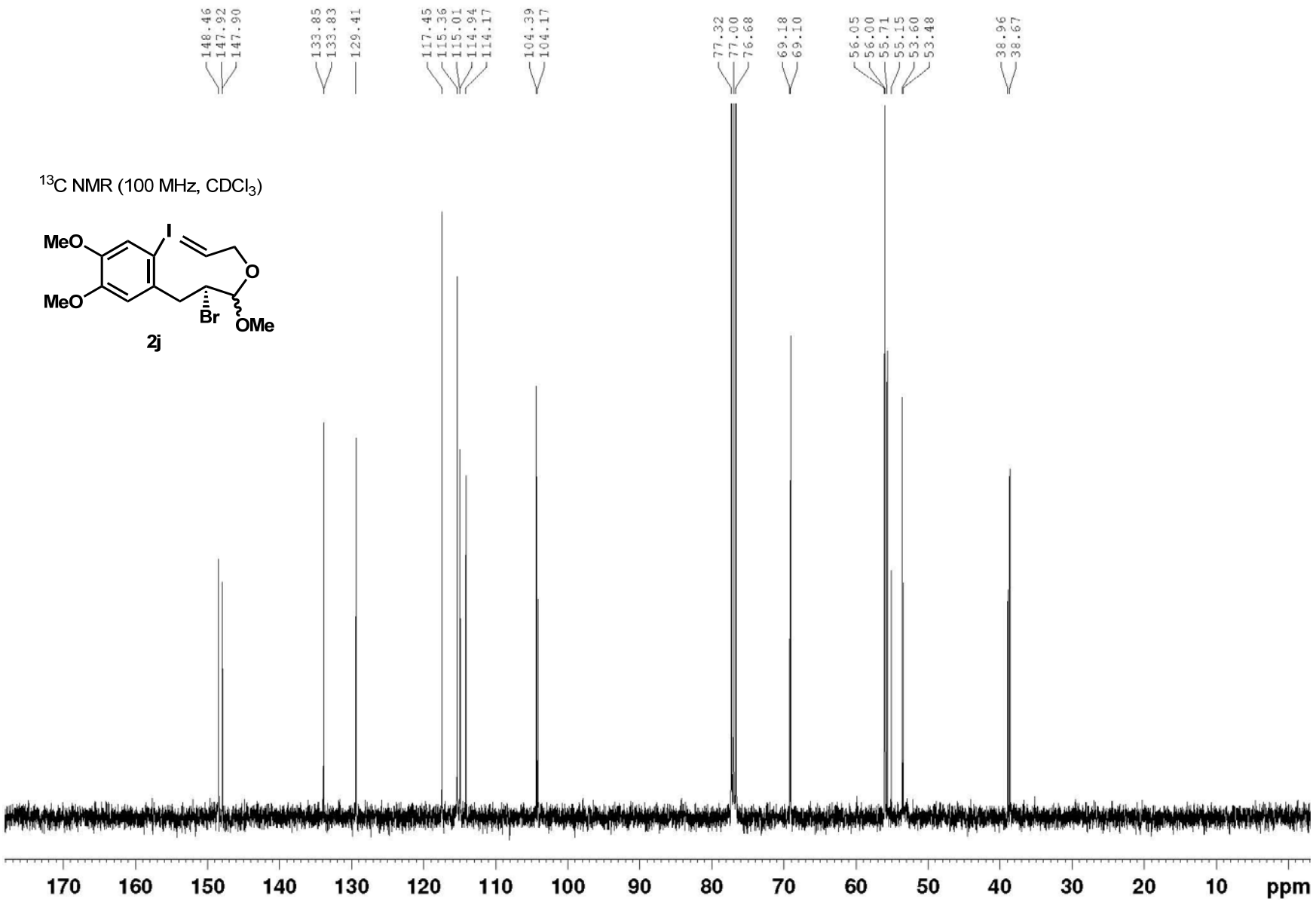

**3i**

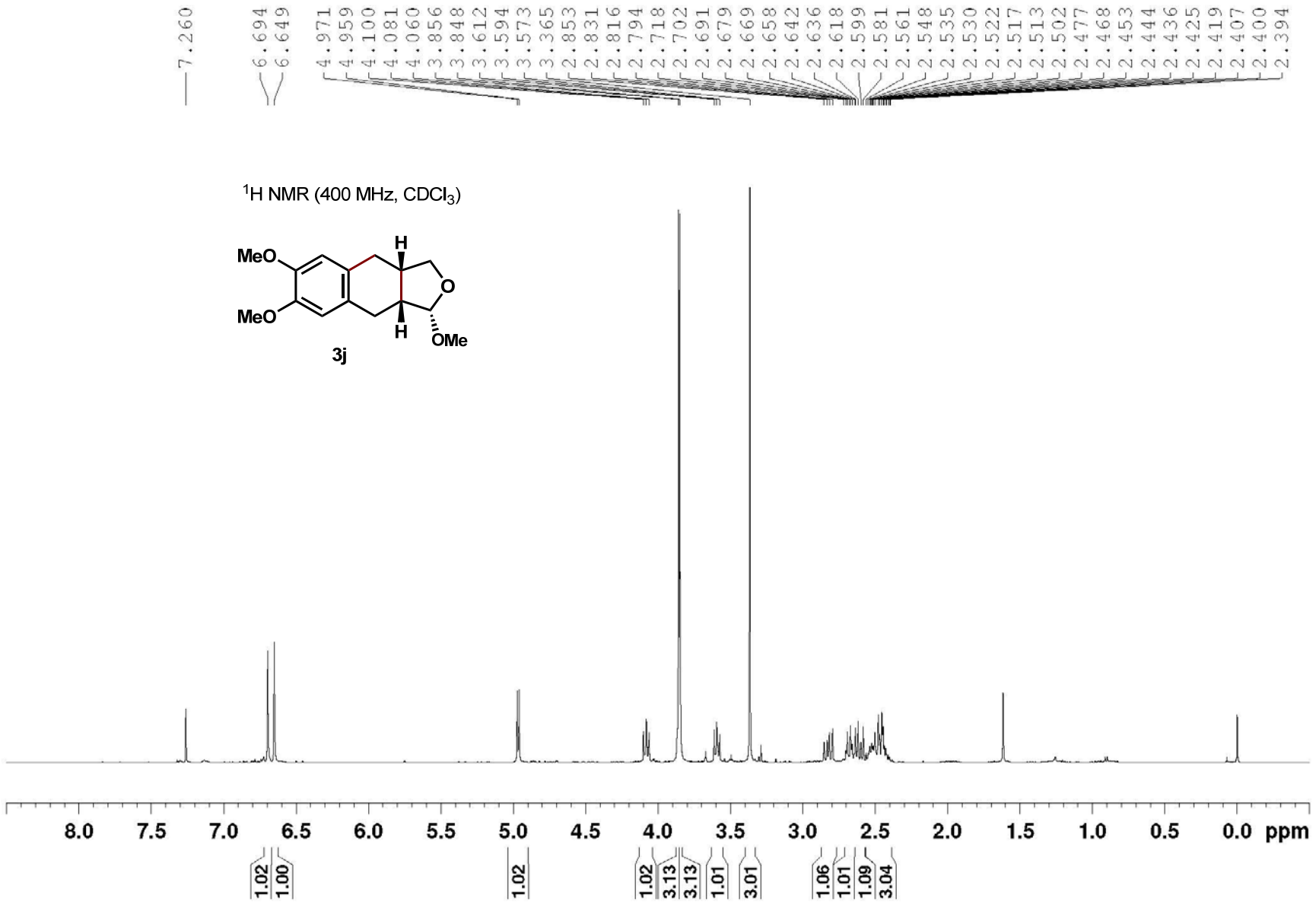

150.75
145.79
132.57
131.93
122.56
109.50
105.49
77.32
77.00
76.68
70.80
60.89
55.80
54.83
43.16
37.94
26.52
24.98
$^{13}$C NMR (100 MHz, $CDCl_3$)
OMe
MeO
H
O
H
OMe
3i
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

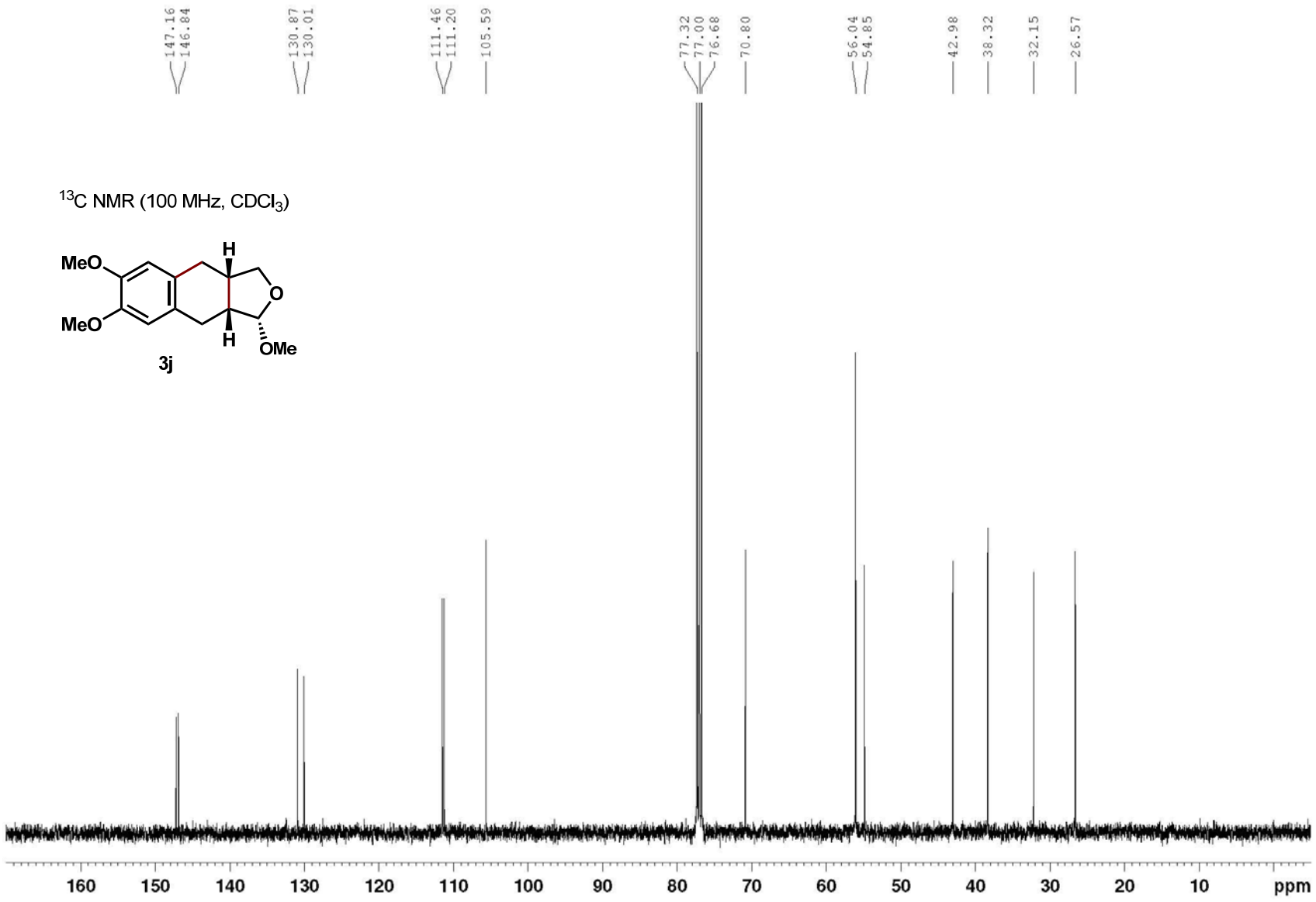

7.260
6.874
6.846
6.776
6.748
4.865
4.844
4.177
4.155
4.152
4.130
3.868
3.862
3.844
3.800
3.746
3.720
3.711
3.685
3.673
3.490
3.196
3.180
3.141
3.125
3.082
3.066
3.031
3.014
2.727
2.685
2.635
2.615
2.458
2.418
2.403
2.363
2.123
2.105
2.083
2.066
2.046
2.026
2.008
1.990
1.971
1.955
1.937
1.916
1.896
1.877
$^1$H NMR (300 MHz, CDCl$_3$)
OMe
MeO
H
O
H
OMe
3i'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.07
1.27
1.00
1.17
3.34
3.01
1.24
3.02
1.22
1.21
1.26
1.19
1.02
1.00

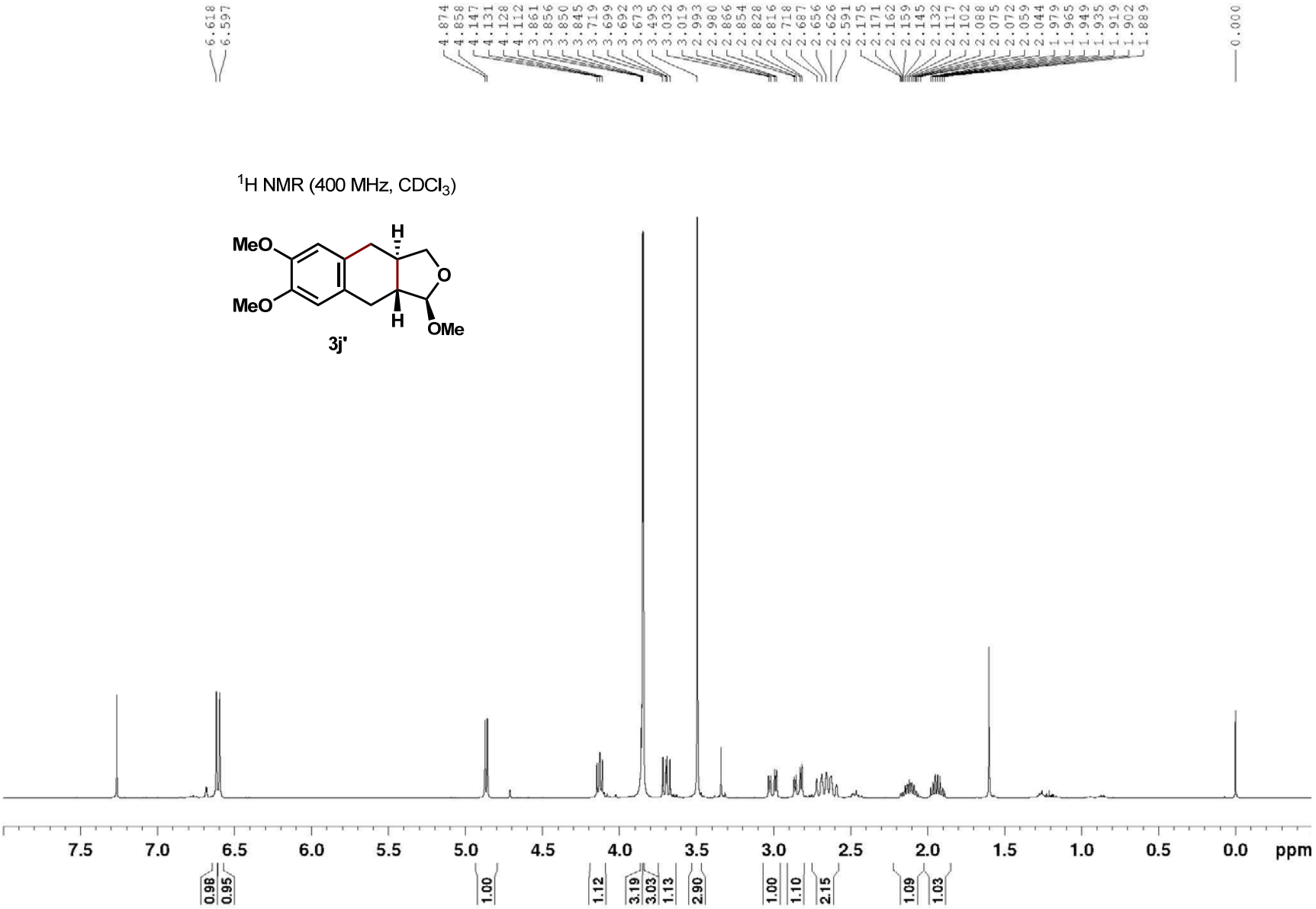

150.70
146.92
130.13
129.05
124.79
110.52
109.84
77.32
77.00
76.68
71.87
59.95
56.49
55.84
47.92
41.29
30.87
25.98
$^{13}$C NMR (100 MHz, $CDCl_3$)
OMe
MeO
H
O
H
OMe
3i'
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

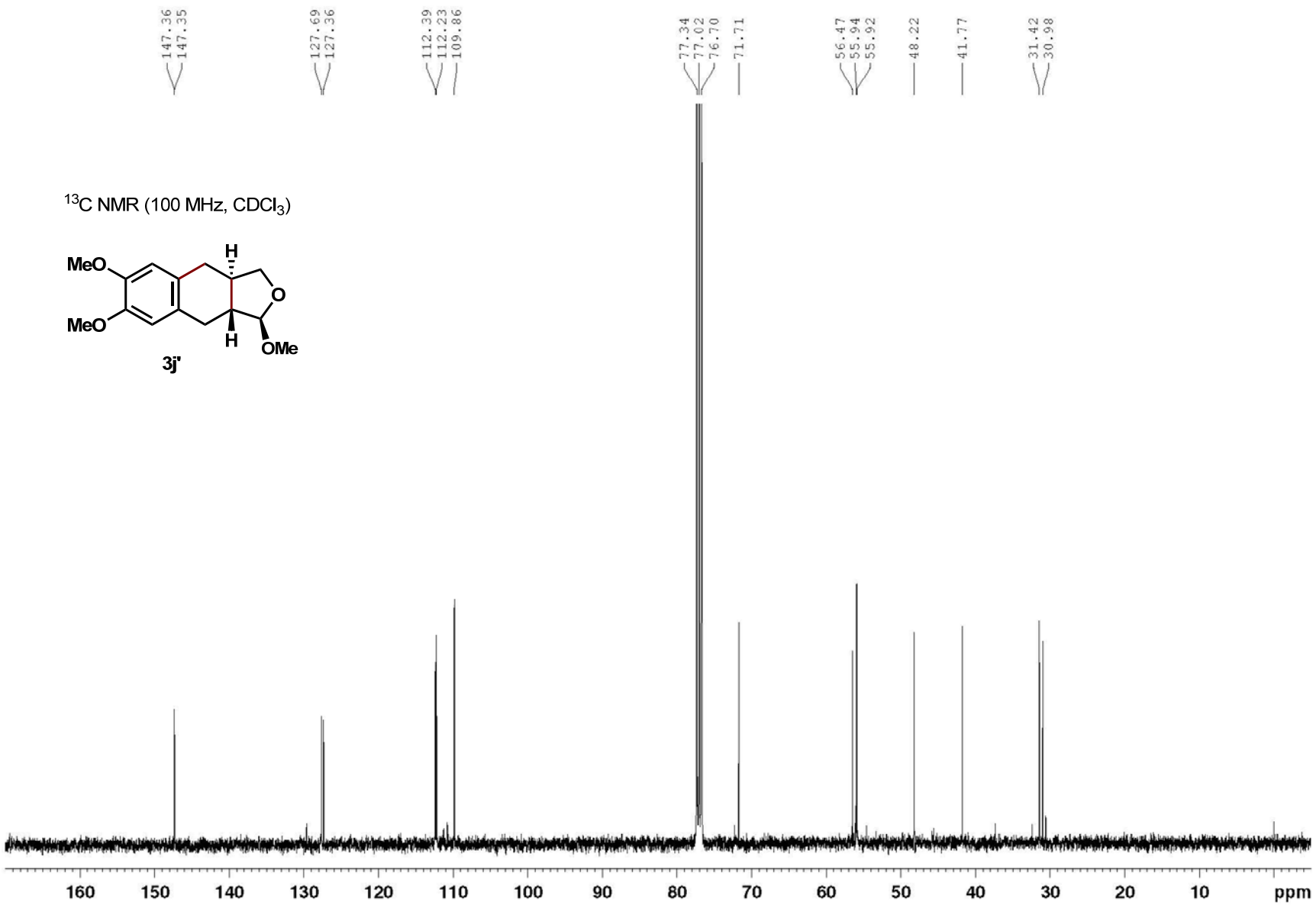

7.260
6.987
6.799
6.019
6.000
5.989
5.983
5.966
5.955
5.943
5.933
5.926
5.914
5.909
5.898
5.890
5.376
5.371
5.363
5.357
5.319
5.314
5.306
5.300
5.233
5.230
5.195
4.550
4.535
4.521
4.358
4.345
4.331
4.323
4.310
4.297
4.272
4.258
4.254
4.229
4.212
4.167
4.164
4.148
4.144
4.125
4.106
3.844
3.840
3.544
3.532
3.495
3.481
3.469
3.020
2.985
2.971
2.936
1H NMR (300 MHz, CDCl3)
MeO
MeO
I
O
Br
OMe
2j
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0 ppm
1.13
1.17
1.00
1.10
1.09
1.15
1.14
1.18
1.19
2.93
2.93
1.24
2.20
1.19
1.17

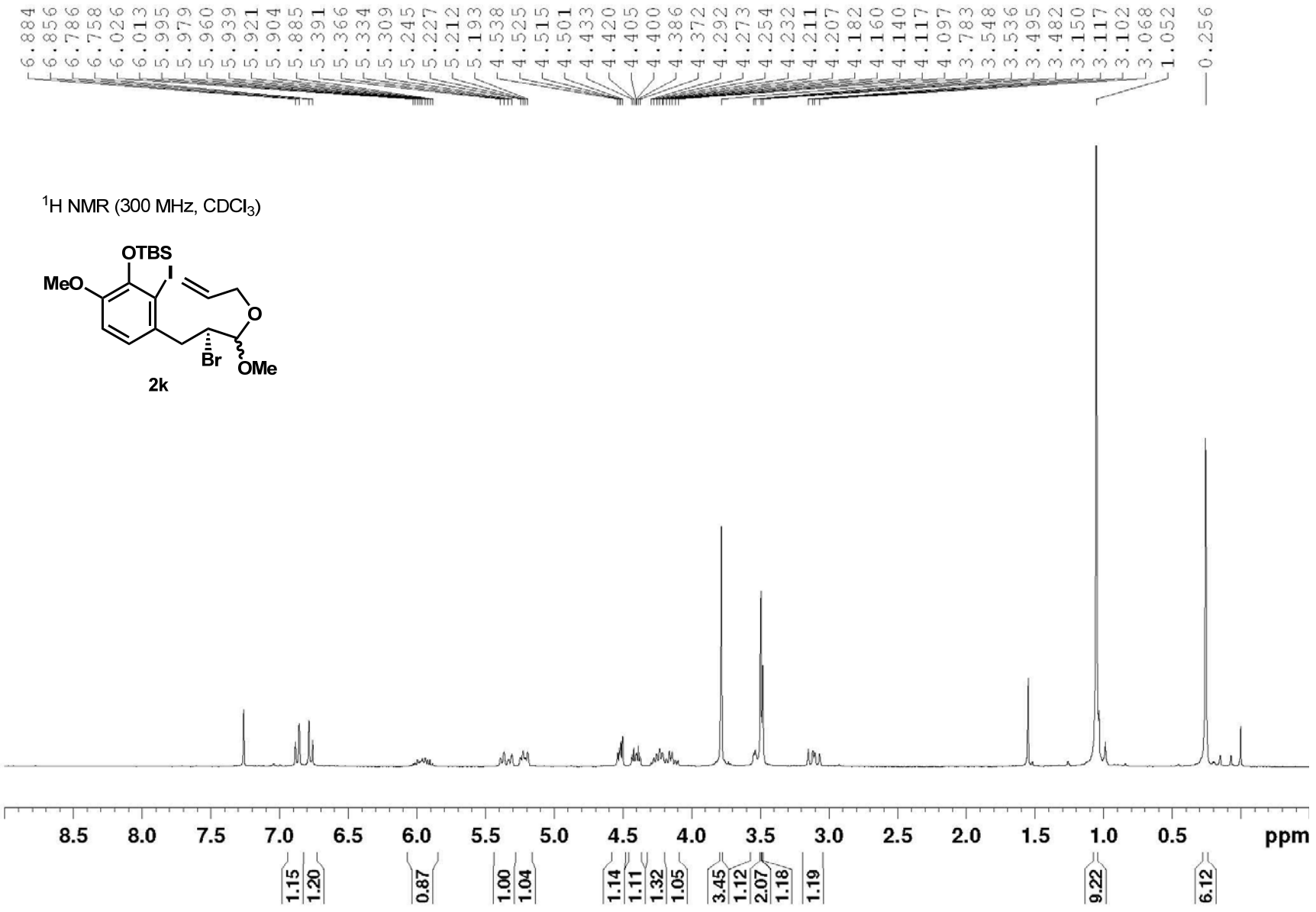

148.46
147.92
147.90
133.85
133.83
129.41
117.45
115.36
115.01
114.94
114.17
104.39
104.17
77.32
77.00
76.68
69.18
69.10
56.05
56.00
55.71
55.15
53.60
53.48
38.96
38.67
$^{13}$C NMR (100 MHz, $CDCl_3$)
MeO
MeO
I
O
Br
OMe
2j
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

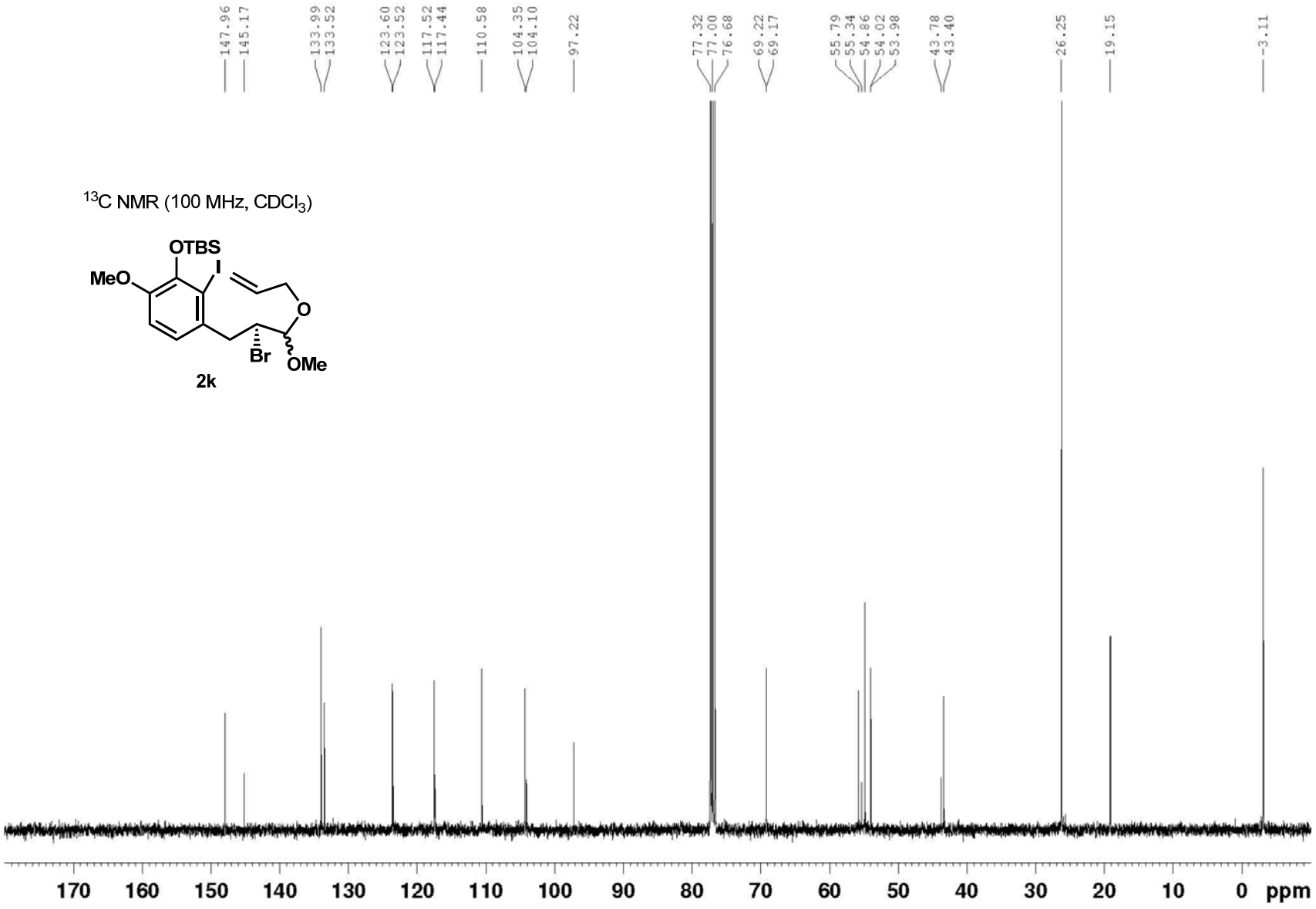

7.260
6.694
6.649
4.971
4.959
4.100
4.081
4.060
3.856
3.848
3.612
3.594
3.573
3.365
2.853
2.831
2.816
2.794
2.718
2.702
2.691
2.679
2.669
2.658
2.642
2.636
2.618
2.599
2.581
2.561
2.548
2.535
2.530
2.522
2.517
2.513
2.502
2.477
2.468
2.453
2.444
2.436
2.425
2.419
2.407
2.400
2.394
$^1$H NMR (400 MHz, CDCl$_3$)
MeO
MeO
H
O
H
OMe
3j
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.02
1.00
1.02
1.02
3.13
3.13
1.01
3.01
1.06
1.01
1.09
3.04


147.16
146.84
130.87
130.01
111.46
111.20
105.59
77.32
77.00
76.68
70.80
56.04
54.85
42.98
38.32
32.15
26.57
$^{13}$C NMR (100 MHz, CDCl$_3$)
MeO
MeO
H
H
O
OMe
3j
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


6.618
6.597
4.874
4.858
4.147
4.131
4.128
4.112
3.861
3.856
3.850
3.845
3.719
3.699
3.692
3.673
3.495
3.032
3.019
2.993
2.980
2.866
2.854
2.828
2.816
2.718
2.687
2.656
2.626
2.591
2.175
2.171
2.162
2.159
2.145
2.132
2.117
2.102
2.088
2.075
2.072
2.059
2.044
1.979
1.965
1.949
1.935
1.919
1.902
1.889
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
MeO
MeO
H
O
H
OMe
3j'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.98
0.95
1.00
1.12
3.19
3.03
1.13
2.90
1.00
1.10
2.15
1.09
1.03


147.36
147.35
127.69
127.36
112.39
112.23
109.86
77.34
77.02
76.70
71.71
56.47
55.94
55.92
48.22
41.77
31.42
30.98
$^{13}$C NMR (100 MHz, $CDCl_3$)
MeO
MeO
H
O
H
OMe
3j'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

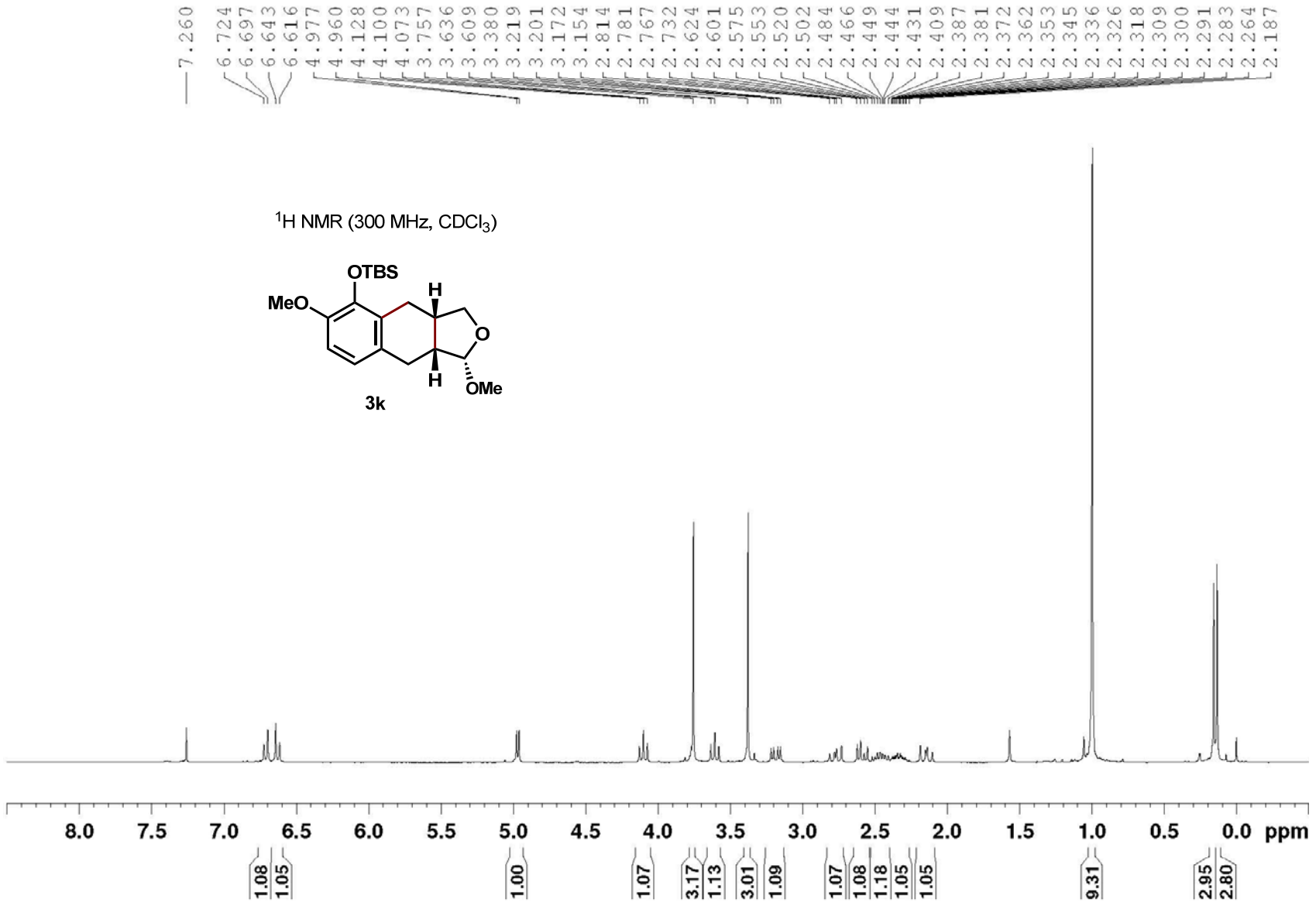

6.884
6.856
6.786
6.758
6.026
6.013
5.995
5.979
5.960
5.939
5.921
5.904
5.885
5.391
5.366
5.334
5.309
5.245
5.227
5.212
5.193
4.538
4.525
4.515
4.501
4.433
4.420
4.405
4.400
4.386
4.372
4.292
4.273
4.254
4.232
4.211
4.207
4.182
4.160
4.140
4.117
4.097
3.783
3.548
3.536
3.495
3.482
3.150
3.117
3.102
3.068
1.052
0.256
1H NMR (300 MHz, CDCl3)
OTBS
I
MeO
O
Br
OMe
2k
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.15
1.20
0.87
1.00
1.04
1.14
1.11
1.32
1.05
3.45
1.12
2.07
1.18
1.19
9.22
6.12




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

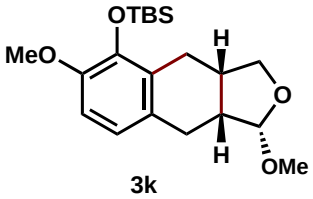



**2k**

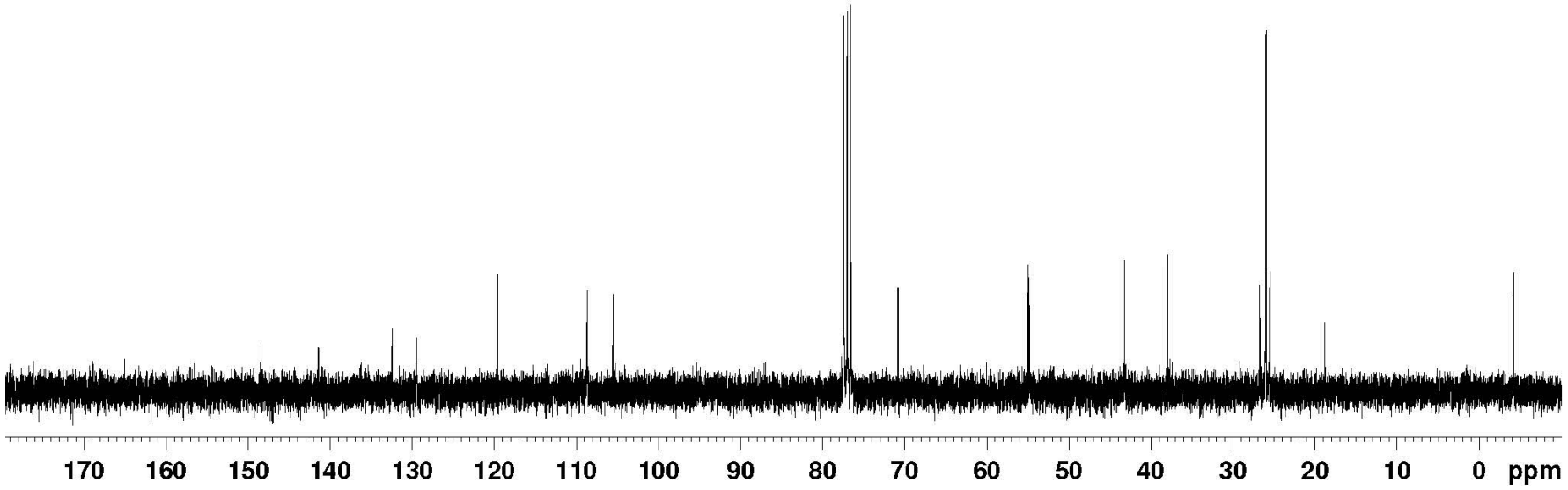

7.260
6.724
6.697
6.643
6.616
4.977
4.960
4.128
4.100
4.073
3.757
3.636
3.609
3.380
3.219
3.201
3.172
3.154
2.814
2.781
2.767
2.732
2.624
2.601
2.575
2.553
2.520
2.502
2.484
2.466
2.449
2.444
2.431
2.409
2.387
2.381
2.372
2.362
2.353
2.345
2.336
2.326
2.318
2.309
2.300
2.291
2.283
2.264
2.187
$^1$H NMR (300 MHz, CDCl$_3$)
OTBS
MeO
H
O
H
OMe
3k
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.08
1.05
1.00
1.07
3.17
1.13
3.01
1.09
1.07
1.08
1.18
1.05
1.05
9.31
2.95
2.80

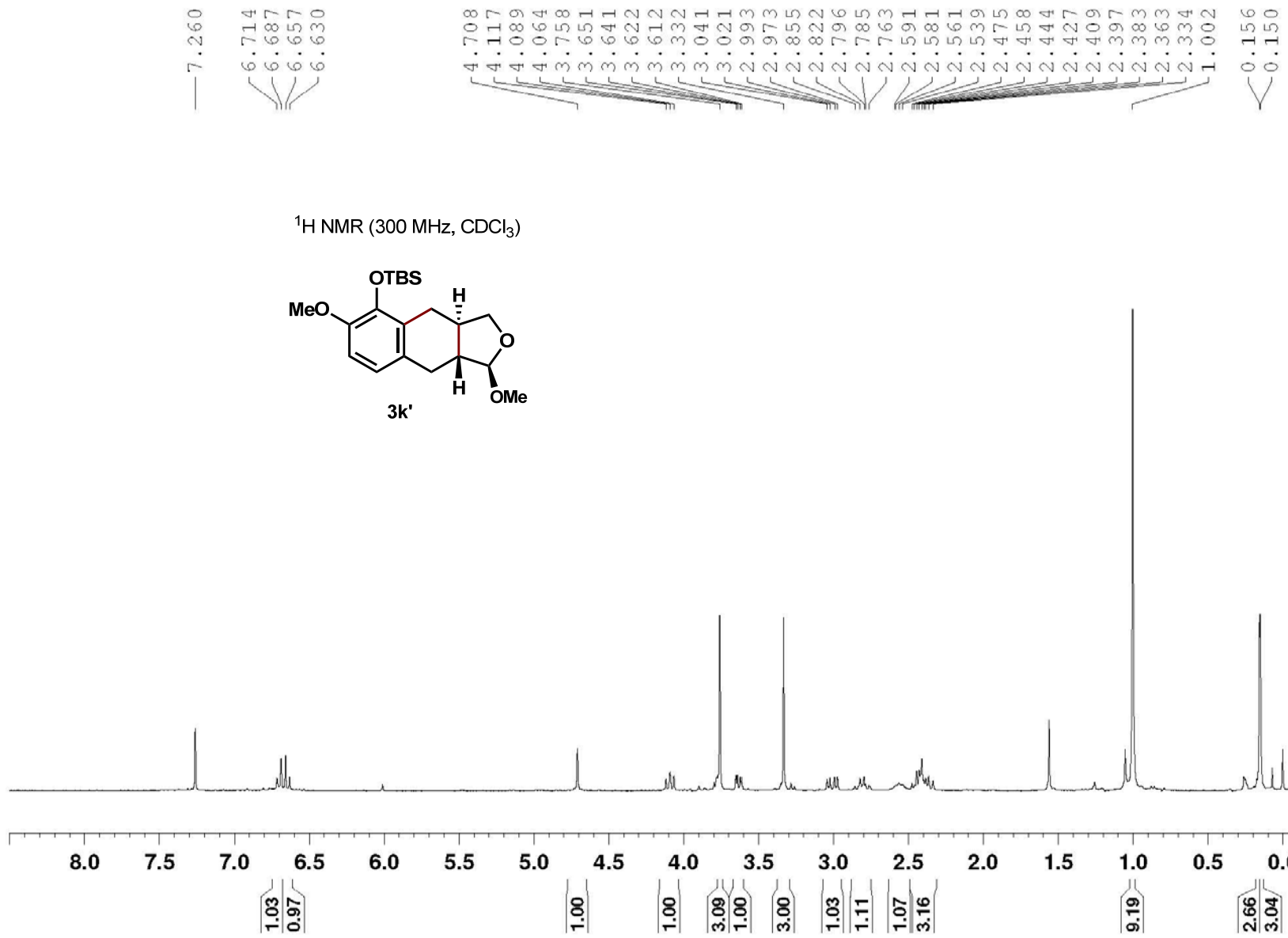
148.45
141.43
132.47
129.48
119.61
108.69
105.55
77.43
77.00
76.58
70.84
55.00
54.84
43.24
38.01
26.75
26.00
25.52
18.79
4.16

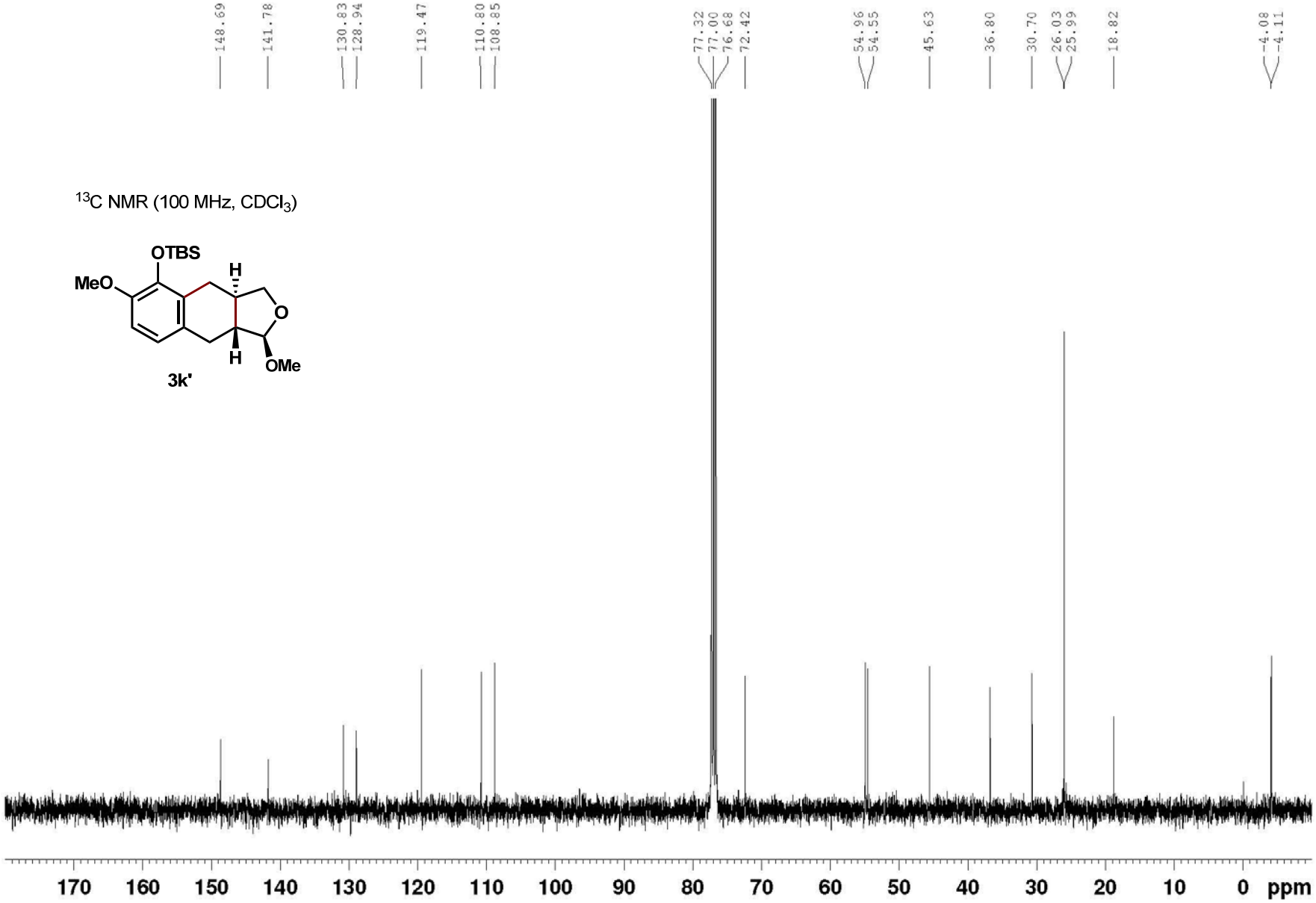
$^{13}$C NMR (75 MHz, $CDCl_3$)

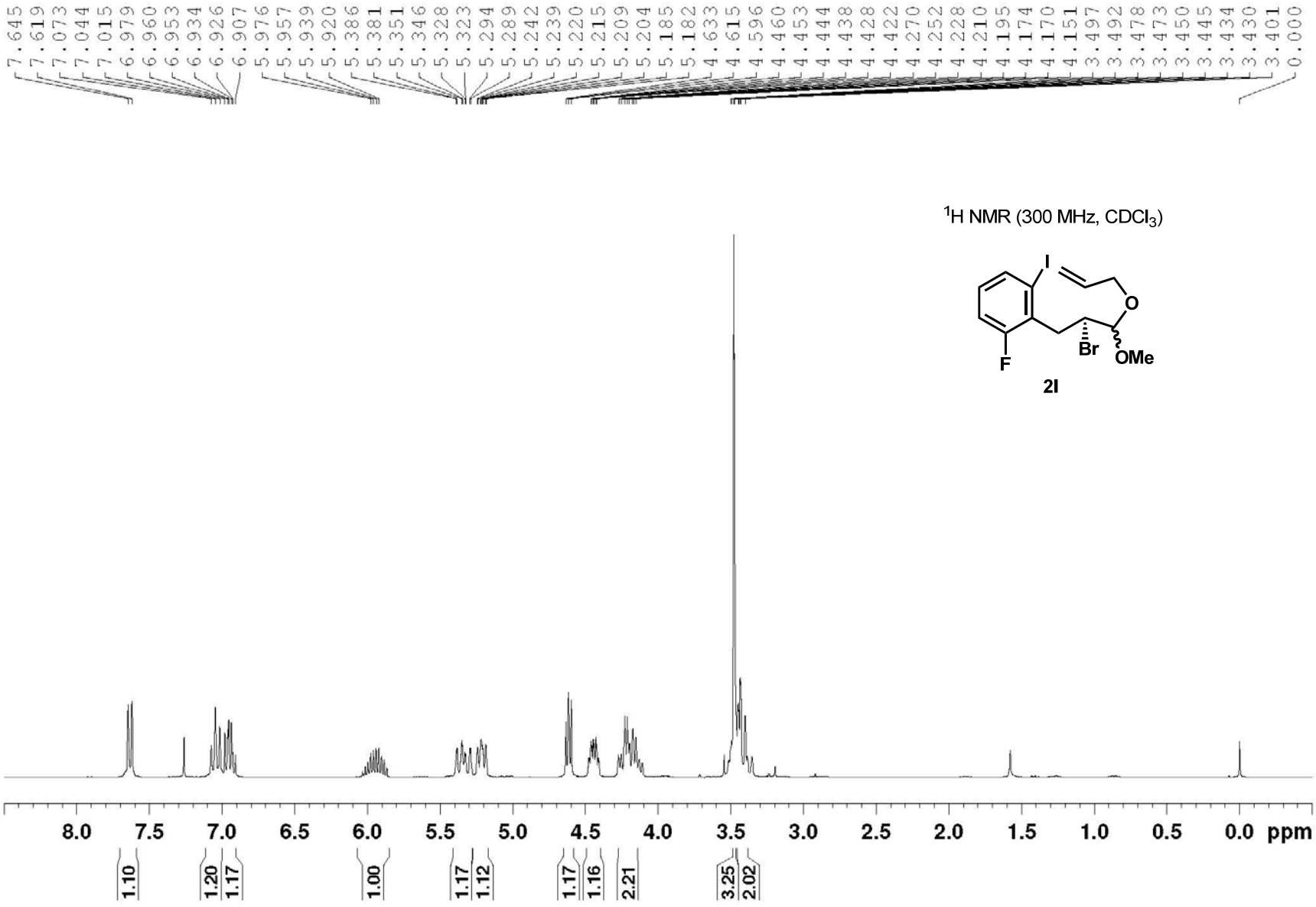


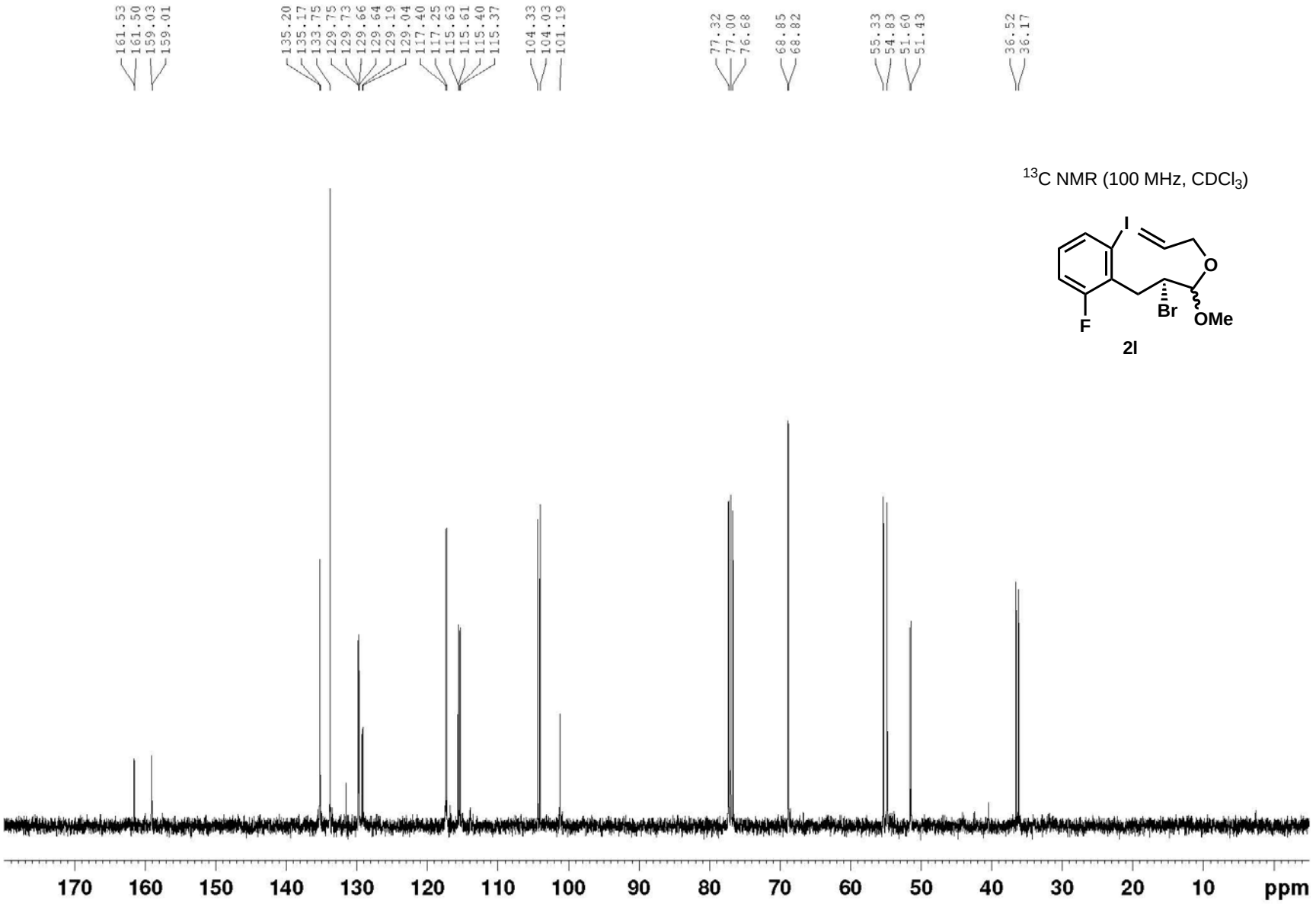

**3k**




7.260
6.714
6.687
6.657
6.630
4.708
4.117
4.089
4.064
3.758
3.651
3.641
3.622
3.612
3.332
3.041
3.021
2.993
2.973
2.855
2.822
2.796
2.785
2.763
2.591
2.581
2.561
2.539
2.475
2.458
2.444
2.427
2.409
2.397
2.383
2.363
2.334
1.002
0.156
0.150
$^1$H NMR (300 MHz, $CDCl_3$)
OTBS
MeO
H
O
H
OMe
3k'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.03
0.97
1.00
1.00
3.09
1.00
3.00
1.03
1.11
1.07
3.16
9.19
2.66
3.04


148.69
141.78
130.83
128.94
119.47
110.80
108.85
77.32
77.00
76.68
72.42
54.96
54.55
45.63
36.80
30.70
26.03
25.99
18.82
-4.08
-4.11
$^{13}$C NMR (100 MHz, $CDCl_3$)
OTBS
MeO
H
O
H
OMe
3k'
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

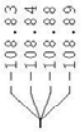

7.645
7.619
7.073
7.044
7.015
6.979
6.960
6.953
6.934
6.926
6.907
5.976
5.957
5.939
5.920
5.386
5.381
5.351
5.346
5.328
5.323
5.294
5.289
5.242
5.239
5.220
5.215
5.209
5.204
5.185
5.182
4.633
4.615
4.596
4.460
4.453
4.444
4.438
4.428
4.422
4.270
4.252
4.228
4.210
4.195
4.174
4.170
4.151
3.497
3.492
3.478
3.473
3.450
3.445
3.434
3.430
3.401
0.000
1H NMR (300 MHz, CDCl3)
I
O
Br
OMe
F
2l
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.10
1.20
1.17
1.00
1.17
1.12
1.17
1.16
2.21
3.25
2.02



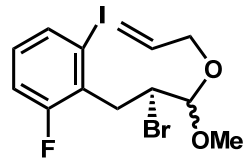

$^{13}$C NMR (100 MHz, $CDCl_3$)



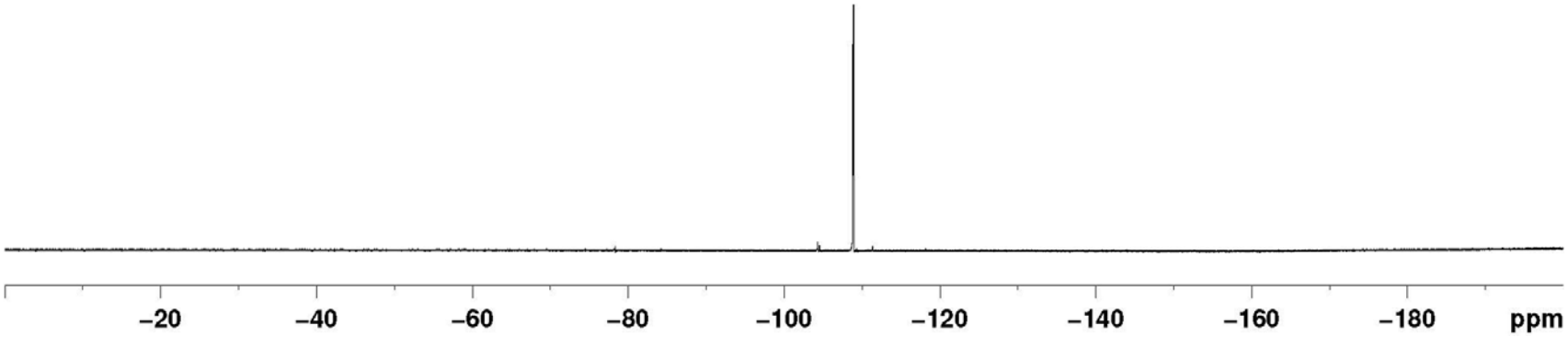

**2l**

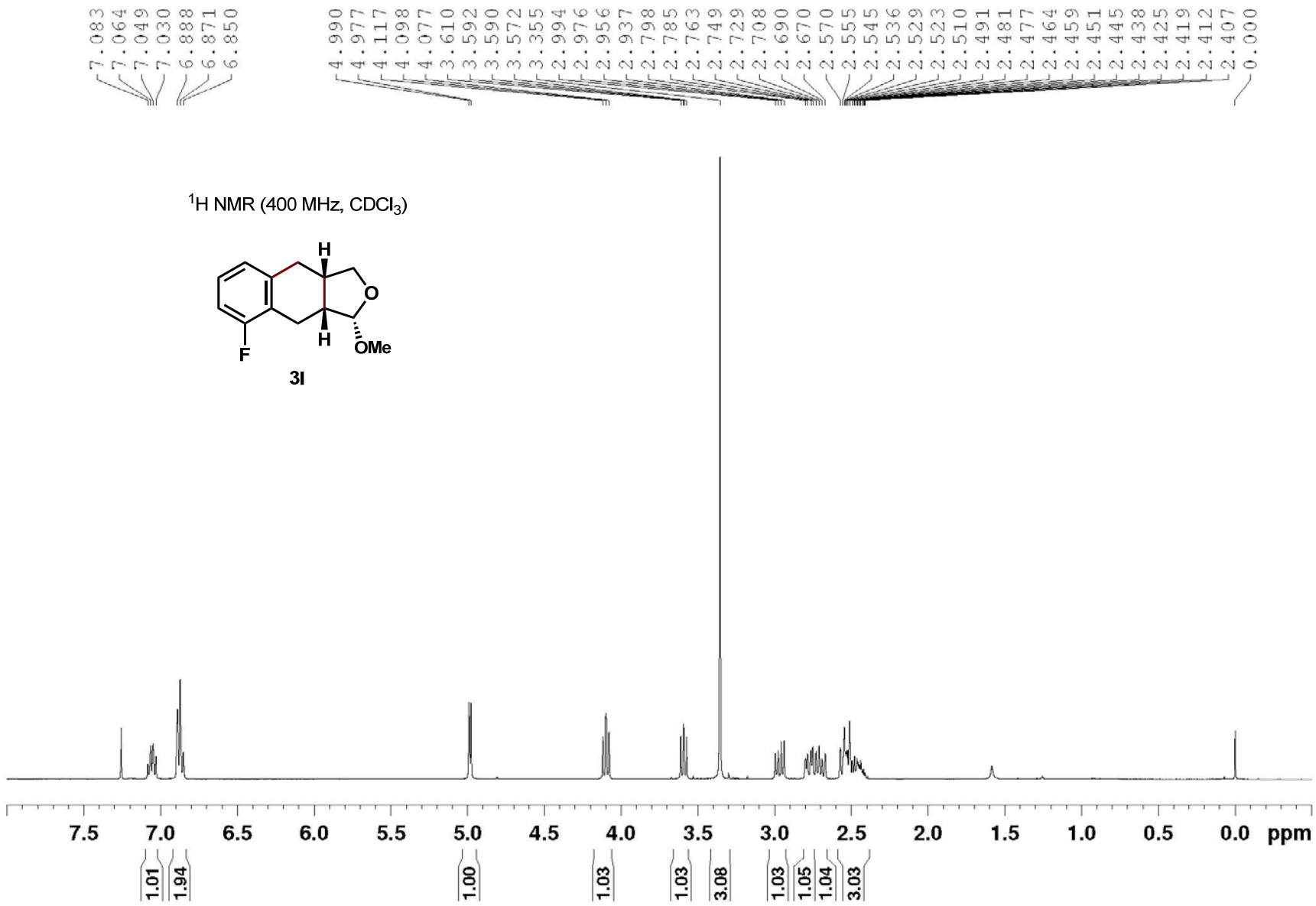


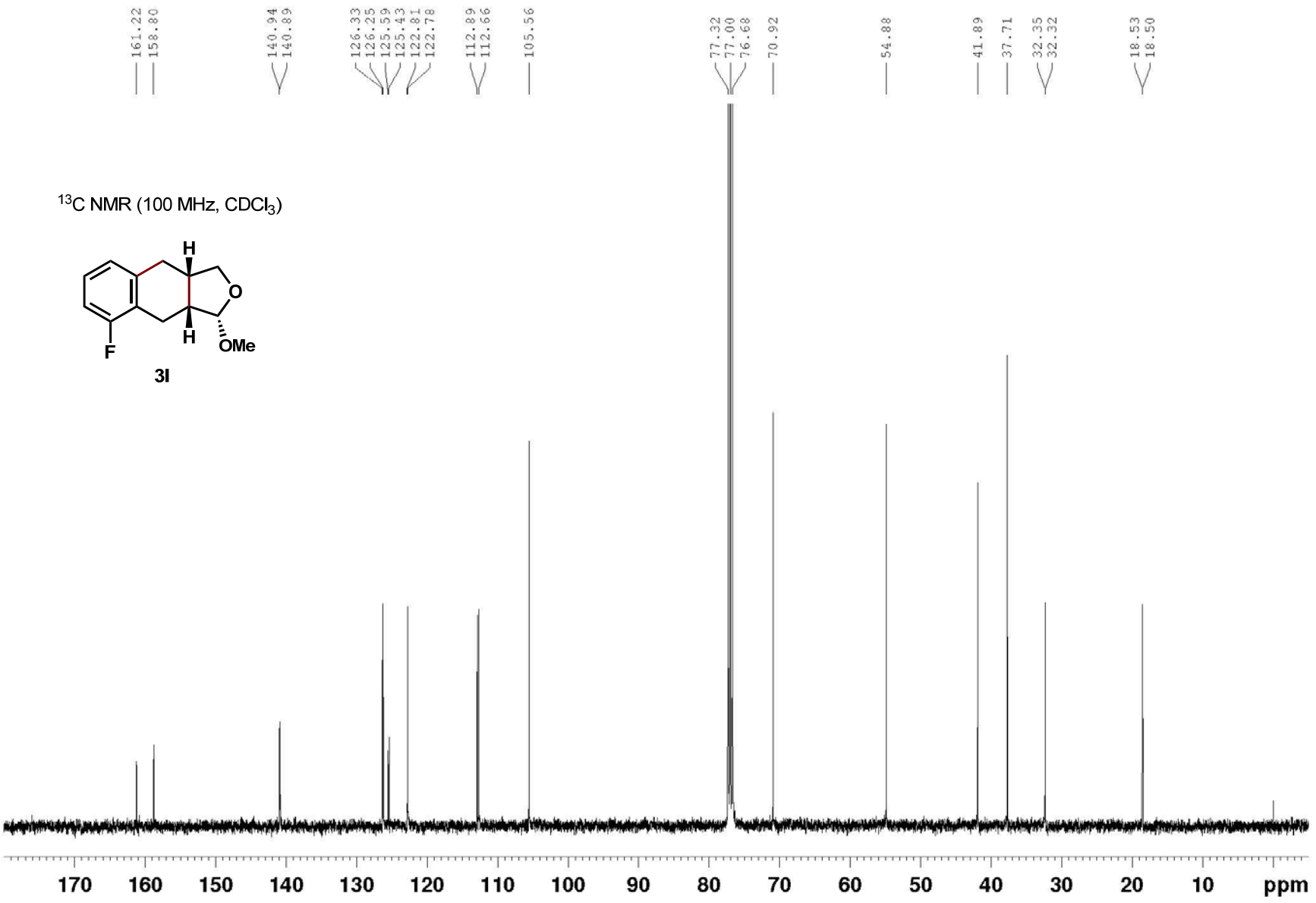

$^{19}$F NMR (376 MHz, $CDCl_3$)

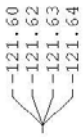



**2l**

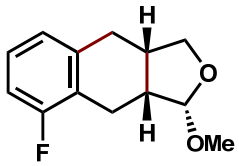



7.083
7.064
7.049
7.030
6.888
6.871
6.850
4.990
4.977
4.117
4.098
4.077
3.610
3.592
3.590
3.572
3.355
2.994
2.976
2.956
2.937
2.798
2.785
2.763
2.749
2.729
2.708
2.690
2.670
2.570
2.555
2.545
2.536
2.529
2.523
2.510
2.491
2.481
2.477
2.464
2.459
2.451
2.445
2.438
2.425
2.419
2.412
2.407
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
F
OMe
3l
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.01
1.94
1.00
1.03
1.03
3.08
1.03
1.05
1.04
3.03

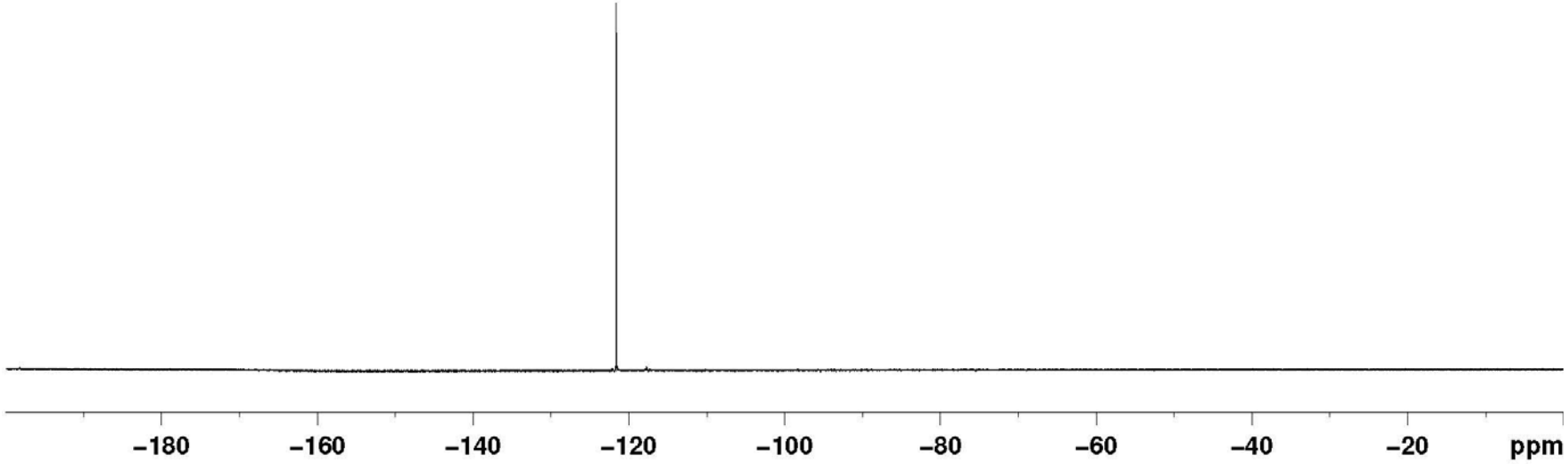

161.22
158.80
140.94
140.89
126.33
126.25
125.59
125.43
122.81
122.78
112.89
112.66
105.56
77.32
77.00
76.68
70.92
54.88
41.89
37.71
32.35
32.32
18.53
18.50
$^{13}$C NMR (100 MHz, $CDCl_3$)
H
O
H
OMe
F
3l
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

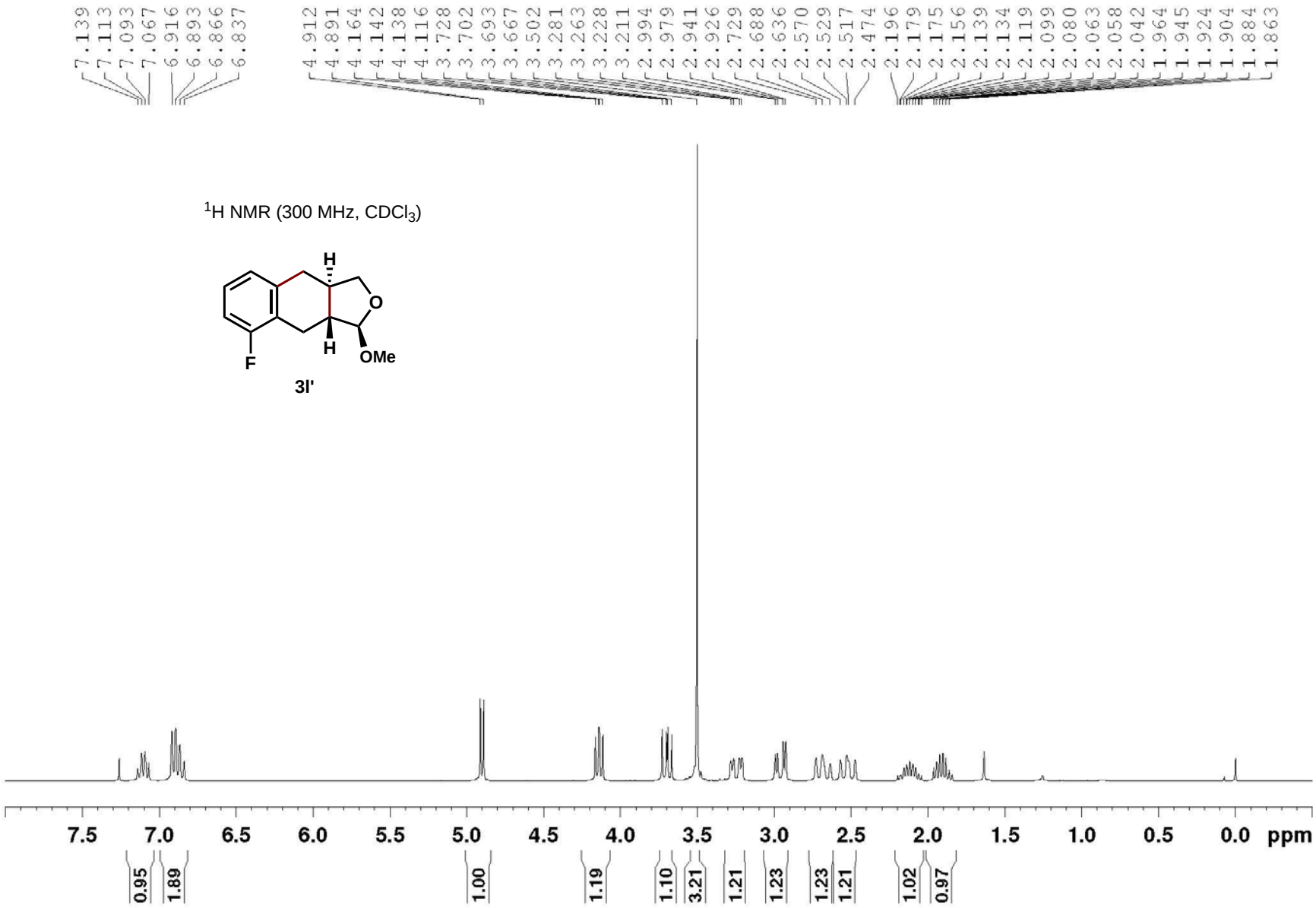


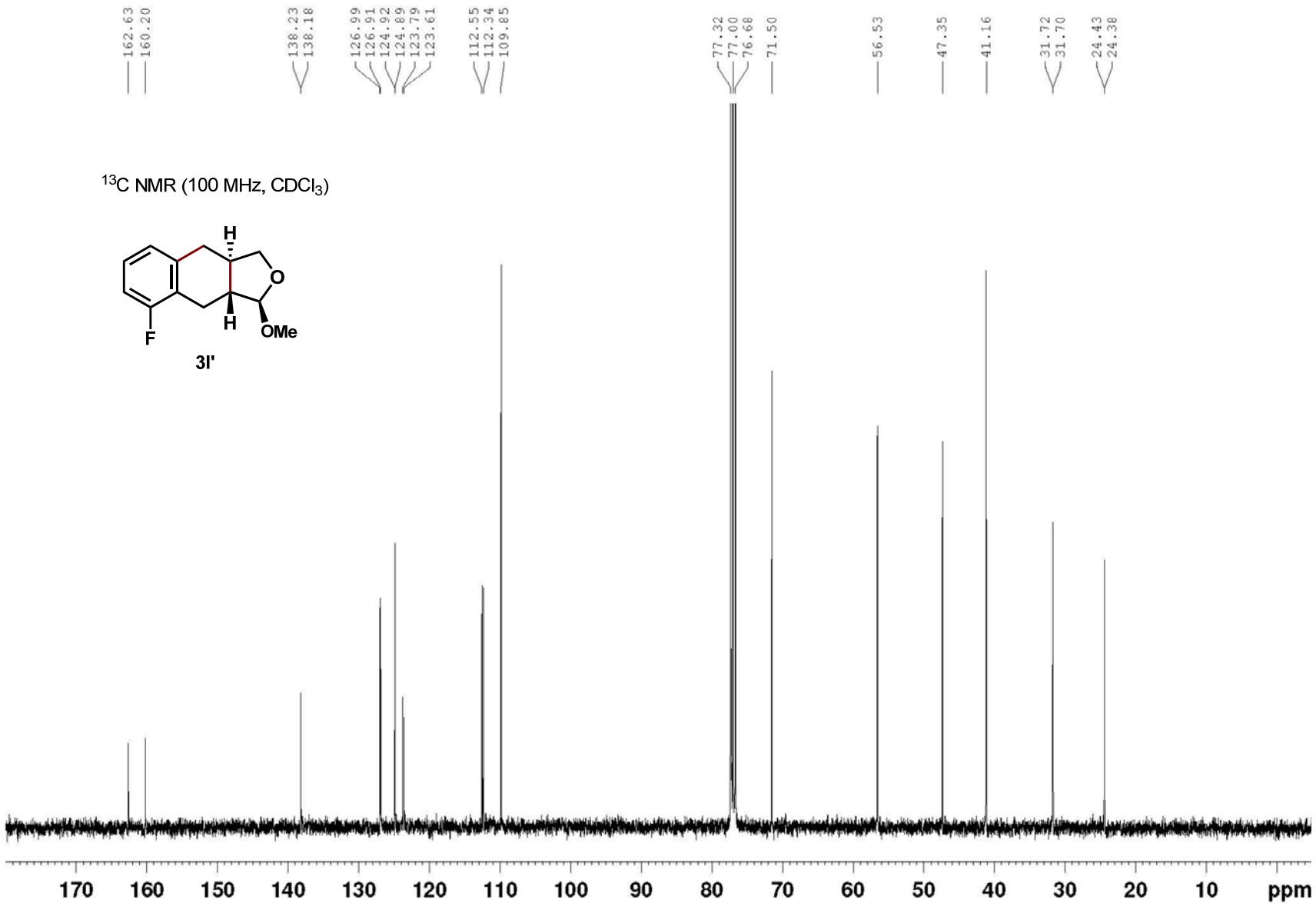

$^{19}$F NMR (376 MHz, $CDCl_3$)



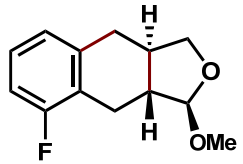

**3l**



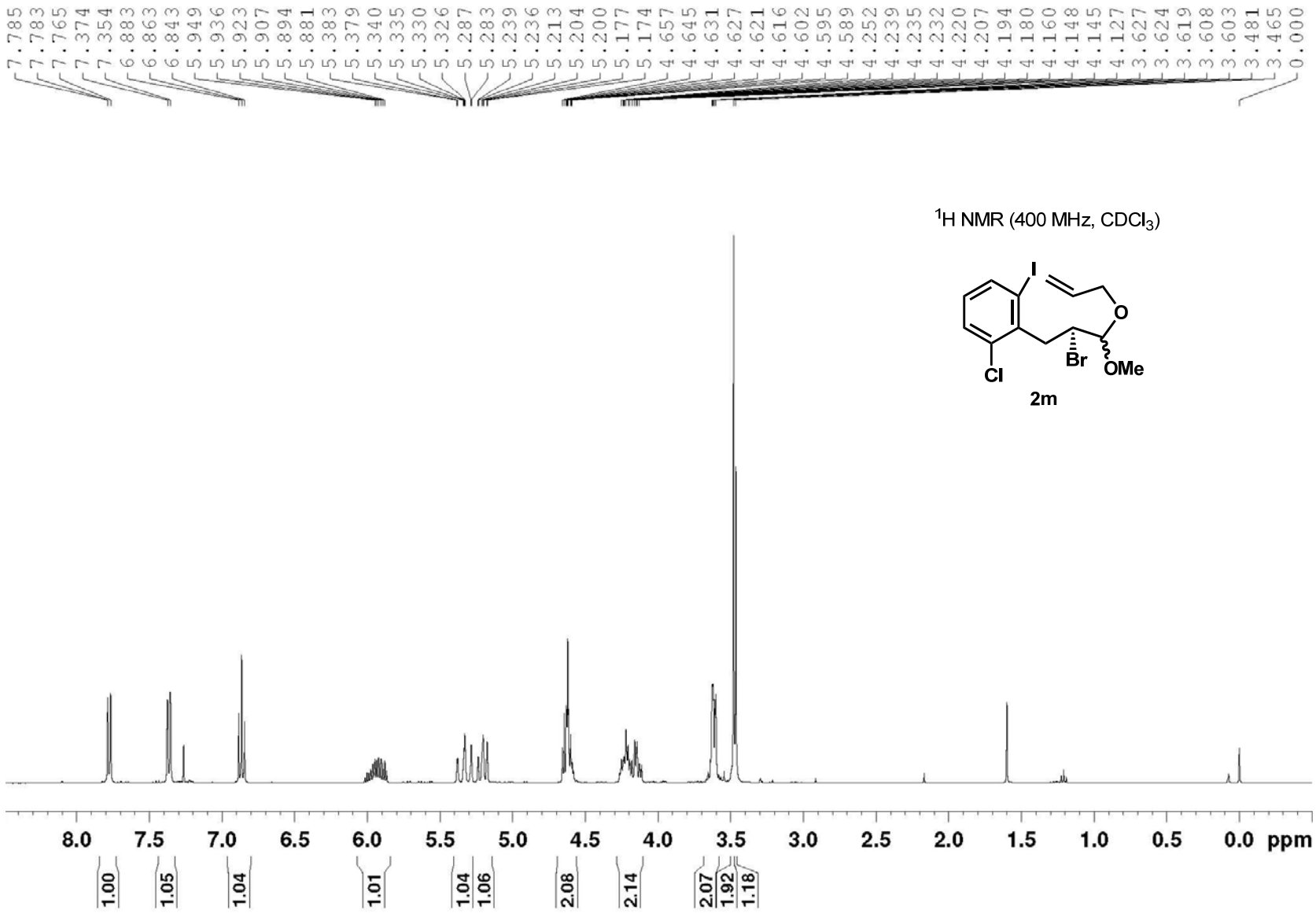

7.139
7.113
7.093
7.067
6.916
6.893
6.866
6.837
4.912
4.891
4.164
4.142
4.138
4.116
3.728
3.702
3.693
3.667
3.502
3.281
3.263
3.228
3.211
2.994
2.979
2.941
2.926
2.729
2.688
2.636
2.570
2.529
2.517
2.474
2.196
2.179
2.175
2.156
2.139
2.134
2.119
2.099
2.080
2.063
2.058
2.042
1.964
1.945
1.924
1.904
1.884
1.863
$^1$H NMR (300 MHz, $CDCl_3$)
H
O
H
OMe
F
3l'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.95
1.89
1.00
1.19
1.10
3.21
1.21
1.23
1.23
1.21
1.02
0.97

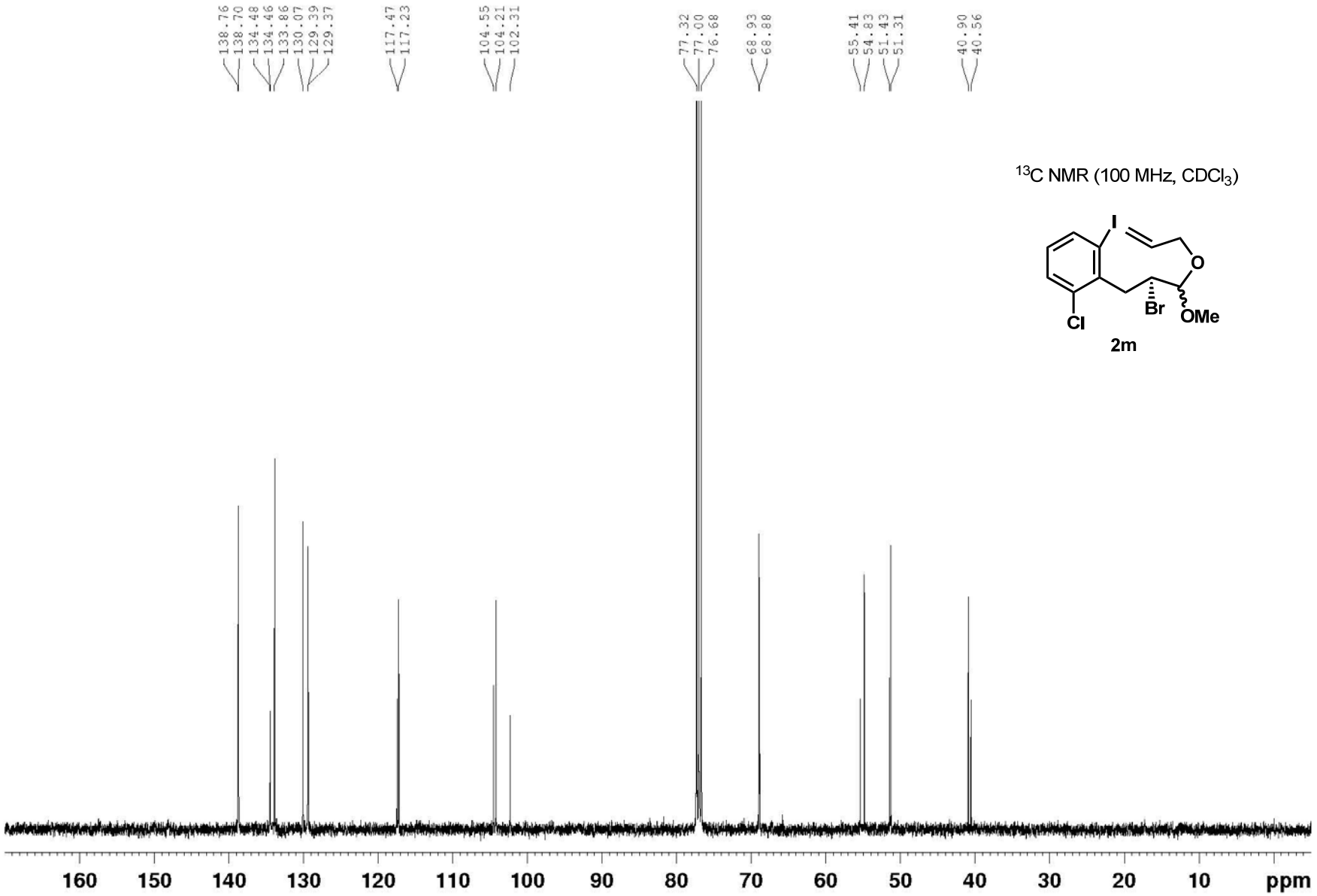

162.63
160.20
138.23
138.18
126.99
126.91
124.92
124.89
123.79
123.61
112.55
112.34
109.85
77.32
77.00
76.68
71.50
56.53
47.35
41.16
31.72
31.70
24.43
24.38
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
H
F
OMe
3l'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

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




**3l'**

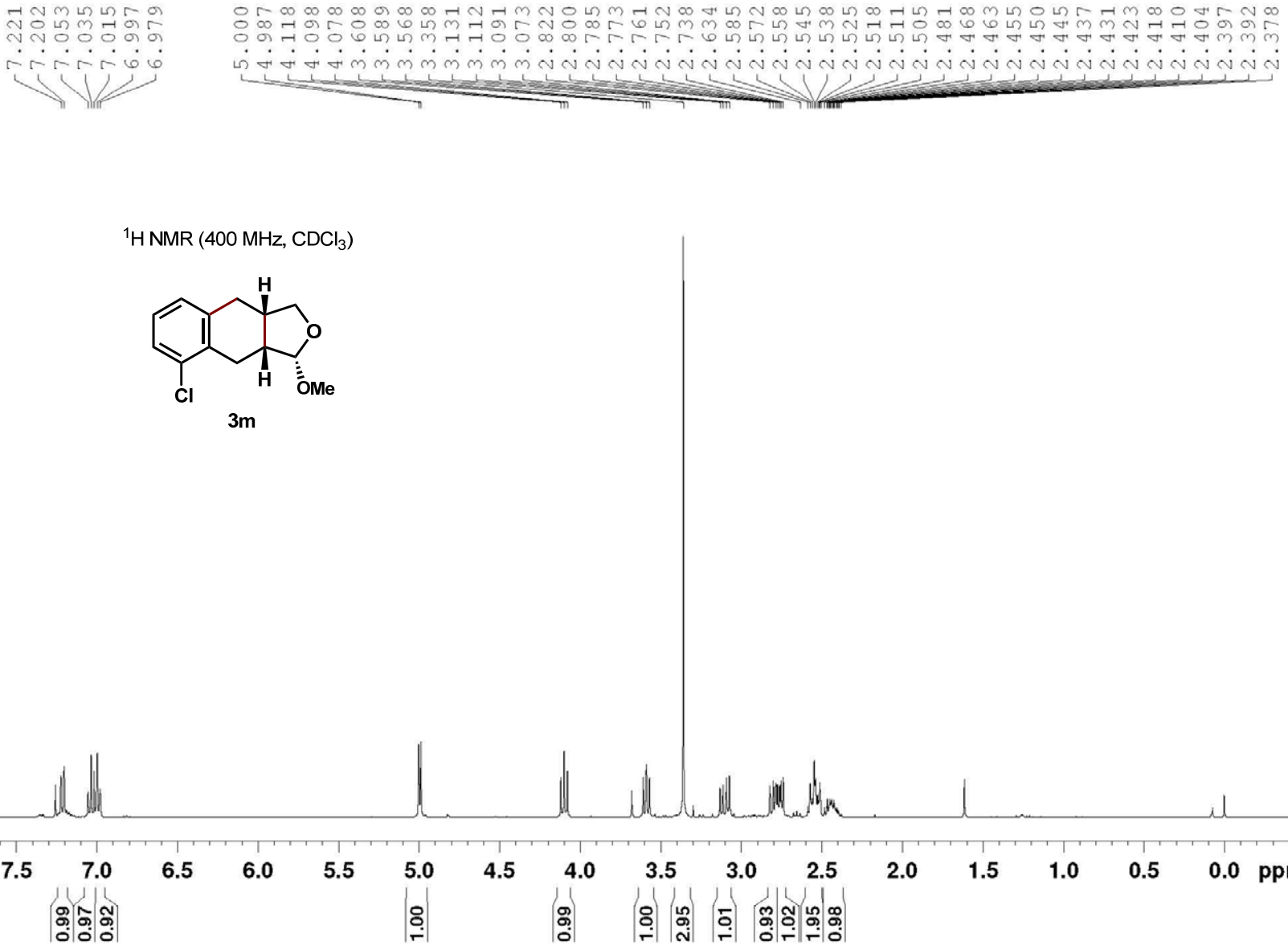

7.785
7.783
7.765
7.374
7.354
6.883
6.863
6.843
5.949
5.936
5.923
5.907
5.894
5.881
5.383
5.379
5.340
5.335
5.330
5.326
5.287
5.283
5.239
5.236
5.213
5.204
5.200
5.177
5.174
4.657
4.645
4.631
4.627
4.621
4.616
4.602
4.595
4.589
4.252
4.239
4.235
4.232
4.220
4.207
4.194
4.180
4.160
4.148
4.145
4.127
3.627
3.624
3.619
3.608
3.603
3.481
3.465
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
I
O
Br
OMe
Cl
2m
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.05
1.04
1.01
1.04
1.06
2.08
2.14
2.07
1.92
1.18

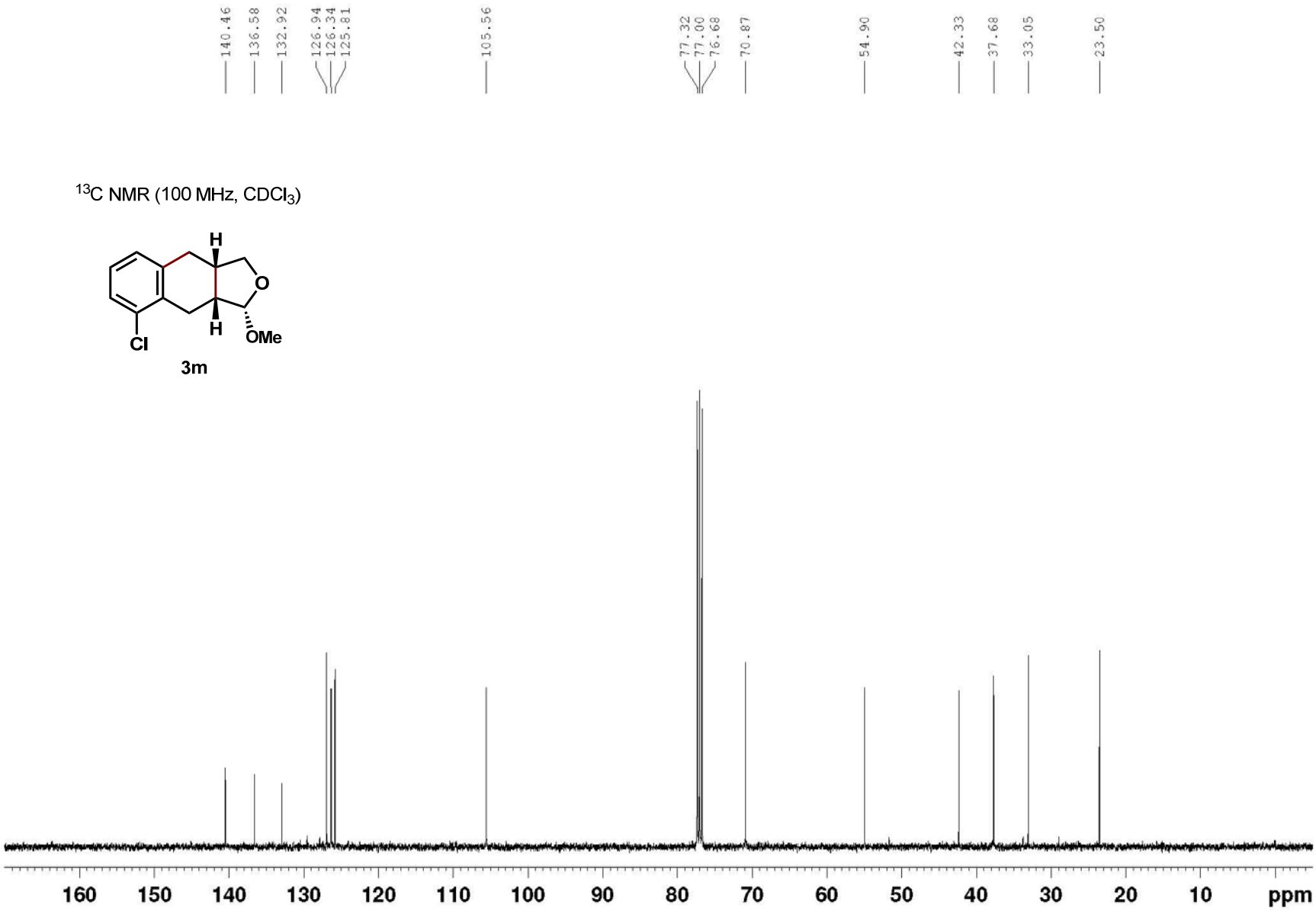



$^{13}$C NMR (100 MHz, $CDCl_3$)




**2m**

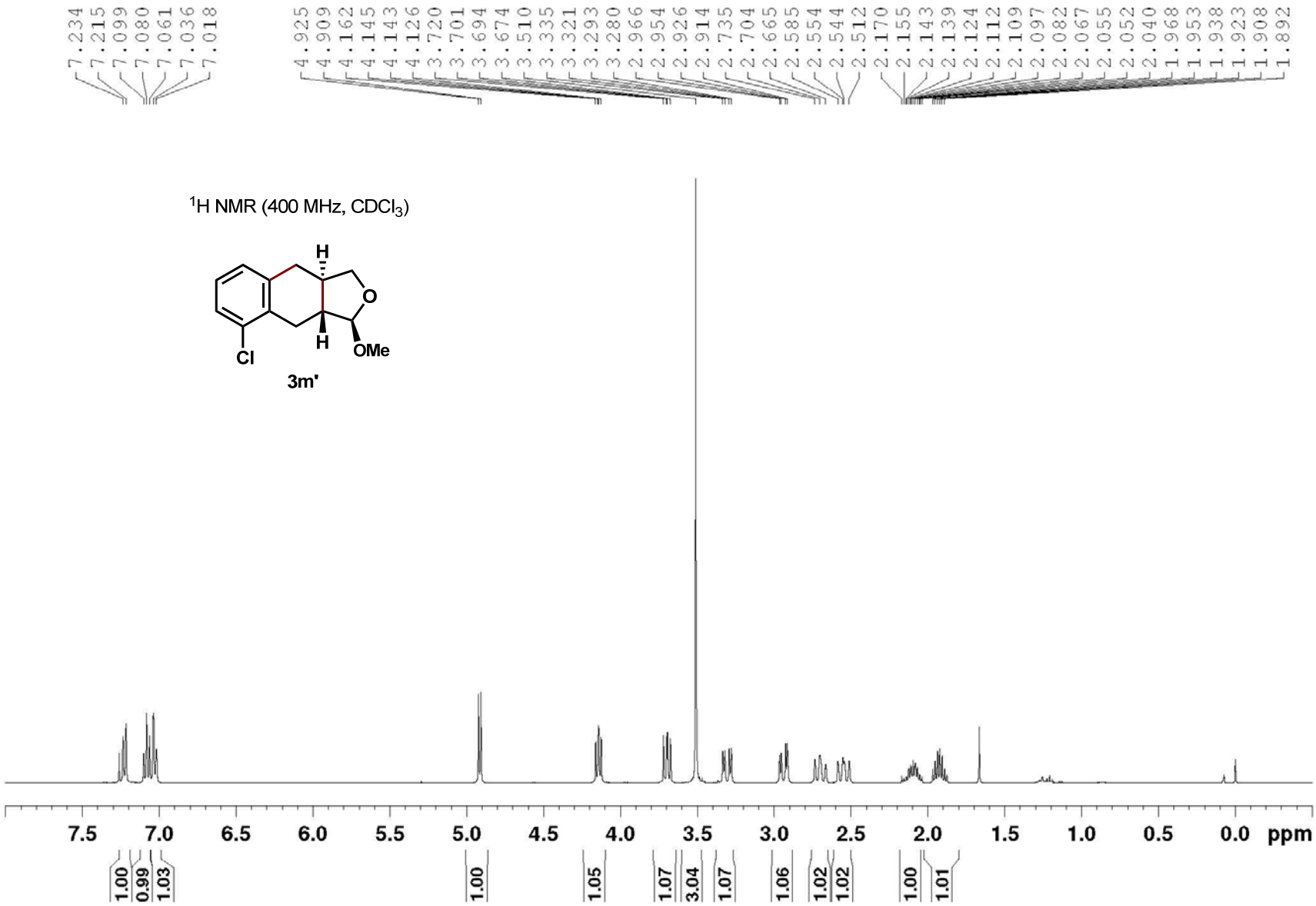

7.221
7.202
7.053
7.035
7.015
6.997
6.979
5.000
4.987
4.118
4.098
4.078
3.608
3.589
3.568
3.358
3.131
3.112
3.091
3.073
2.822
2.800
2.785
2.773
2.761
2.752
2.738
2.634
2.585
2.572
2.558
2.545
2.538
2.525
2.518
2.511
2.505
2.481
2.468
2.463
2.455
2.450
2.445
2.437
2.431
2.423
2.418
2.410
2.404
2.397
2.392
2.378
$^1$H NMR (400 MHz, CDCl$_3$)
H
O
H
OMe
Cl
3m
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.99
0.97
0.92
1.00
0.99
1.00
2.95
1.01
0.93
1.02
1.95
0.98

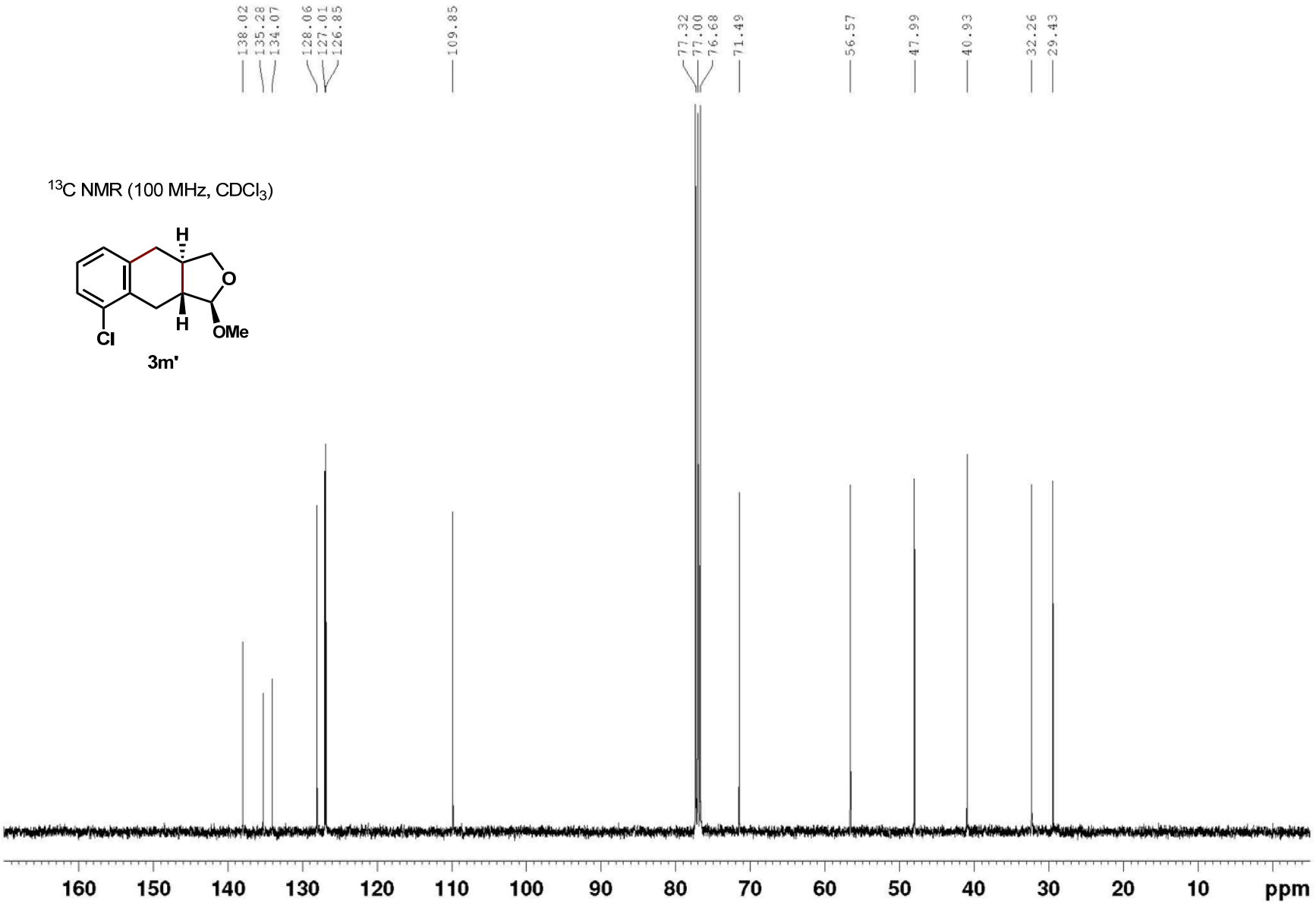


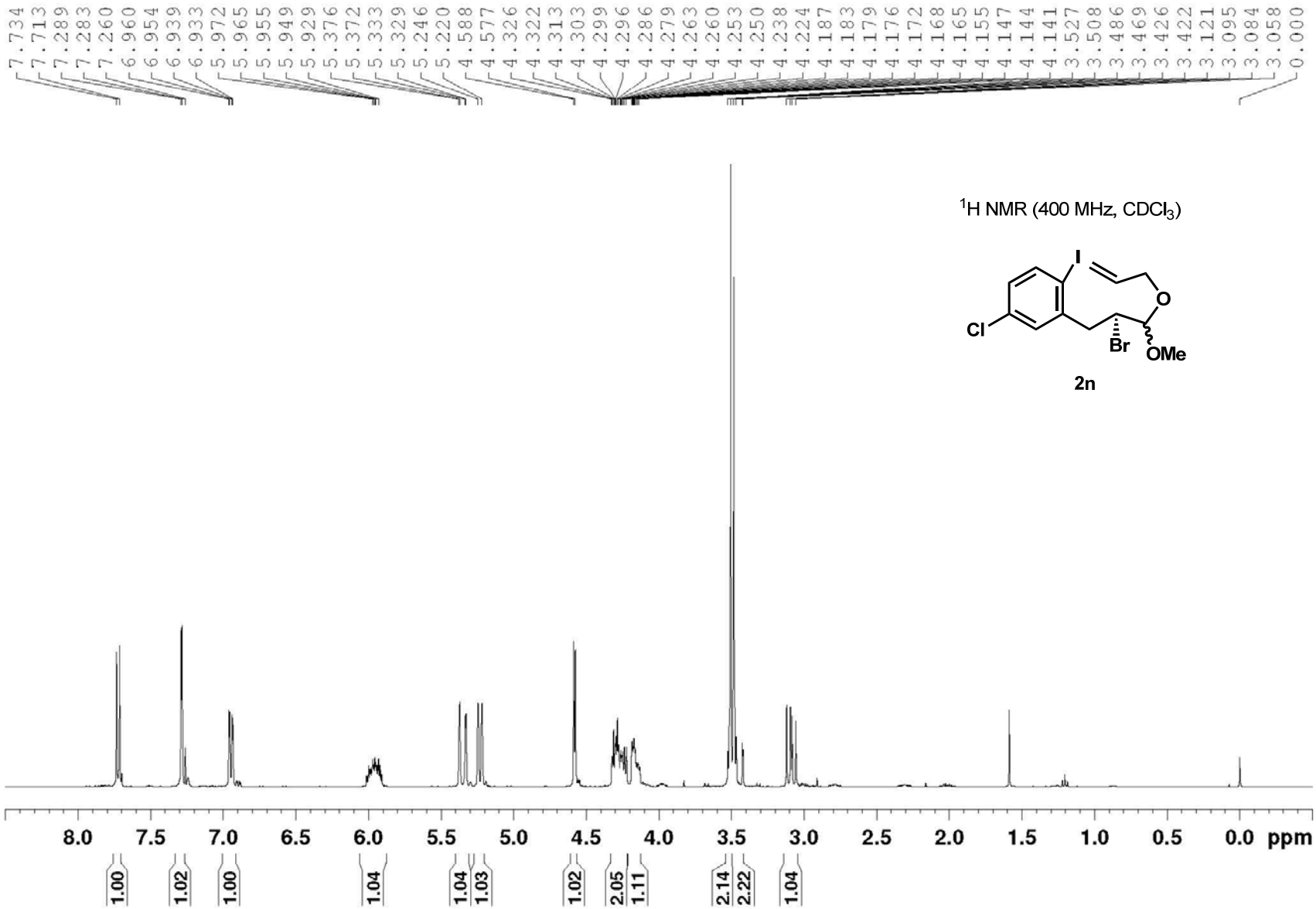

$^{13}$C NMR (100 MHz, $CDCl_3$)

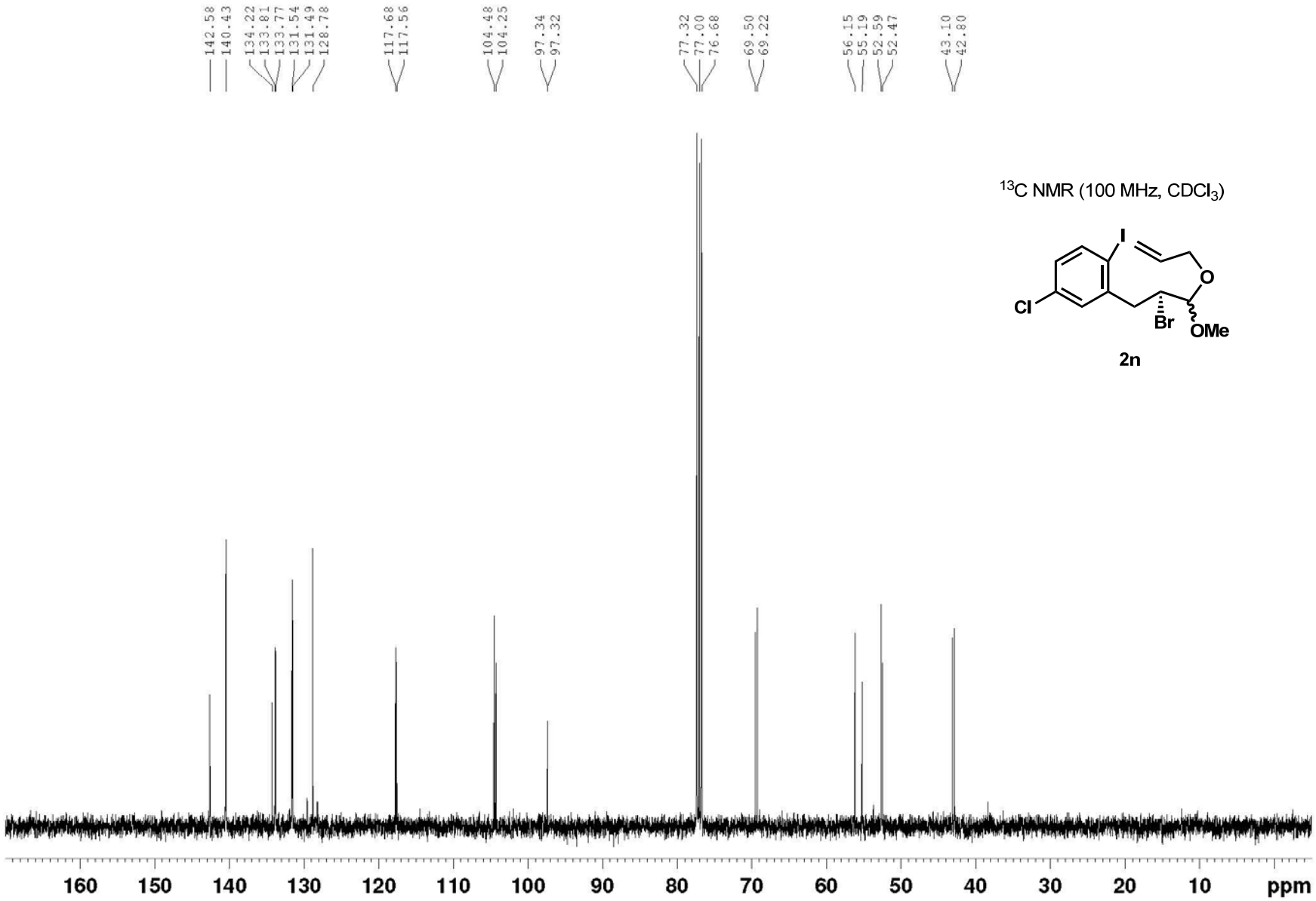



**3m**


7.234
7.215
7.099
7.080
7.061
7.036
7.018
4.925
4.909
4.162
4.145
4.143
4.126
3.720
3.701
3.694
3.674
3.510
3.335
3.321
3.293
3.280
2.966
2.954
2.926
2.914
2.735
2.704
2.665
2.585
2.554
2.544
2.512
2.170
2.155
2.143
2.139
2.124
2.112
2.109
2.097
2.082
2.067
2.055
2.052
2.040
1.968
1.953
1.938
1.923
1.908
1.892
1H NMR (400 MHz, CDCl3)
H
O
H
OMe
Cl
3m'
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
0.99
1.03
1.00
1.05
1.07
3.04
1.07
1.06
1.02
1.02
1.00
1.01


138.02
135.28
134.07
128.06
127.01
126.85
109.85
77.32
77.00
76.68
71.49
56.57
47.99
40.93
32.26
29.43
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
H
OMe
Cl
3m'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

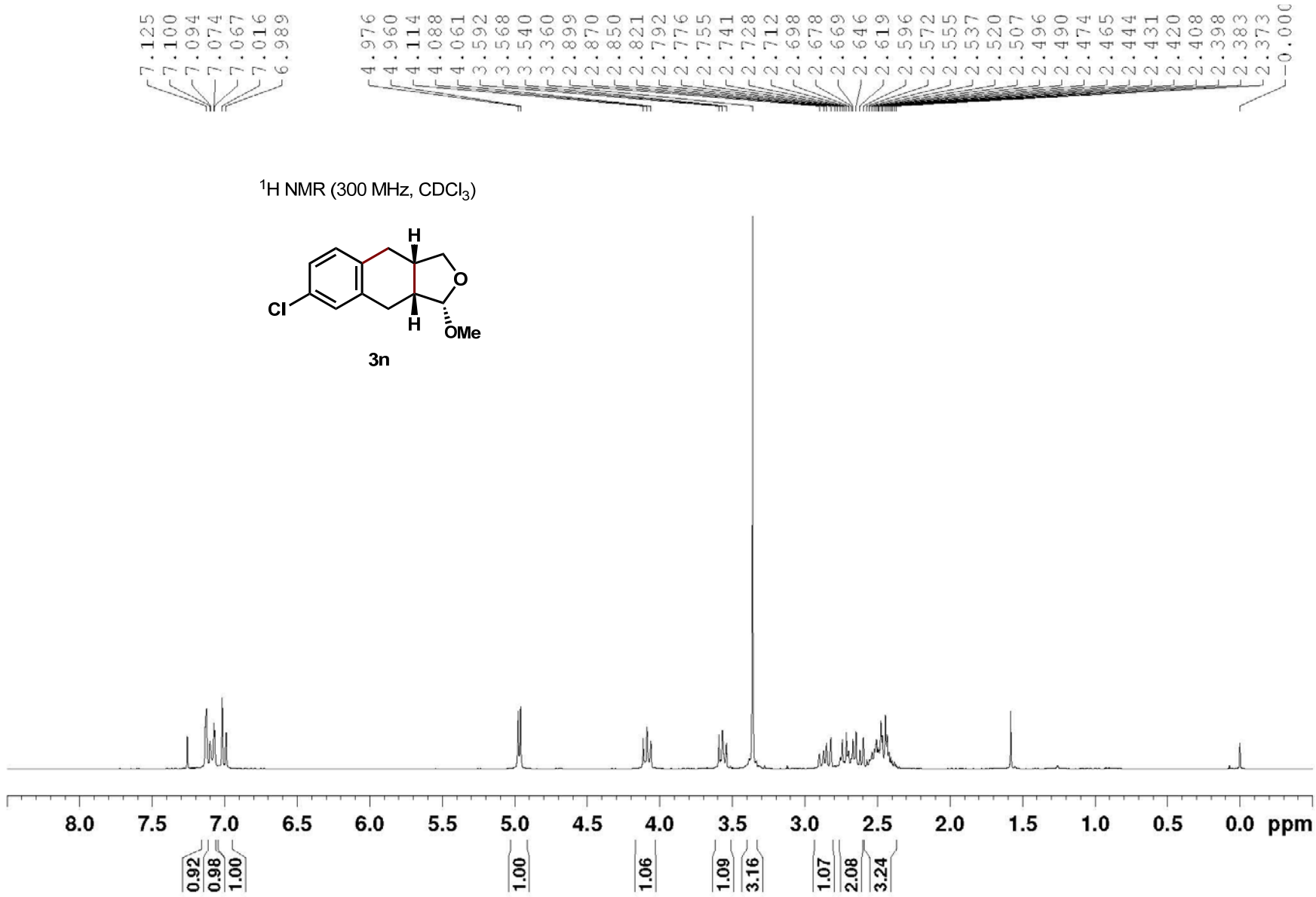

7.734
7.713
7.289
7.283
7.260
6.960
6.954
6.939
6.933
5.972
5.965
5.955
5.949
5.929
5.376
5.372
5.333
5.329
5.246
5.220
4.588
4.577
4.326
4.322
4.313
4.303
4.299
4.296
4.286
4.279
4.263
4.260
4.253
4.250
4.238
4.224
4.187
4.183
4.179
4.176
4.172
4.168
4.165
4.155
4.147
4.144
4.141
3.527
3.508
3.486
3.469
3.426
3.422
3.121
3.095
3.084
3.058
0.000
1H NMR (400 MHz, CDCl3)
I
O
Cl
Br
OMe
2n
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.02
1.00
1.04
1.04
1.03
1.02
2.05
1.11
2.14
2.22
1.04

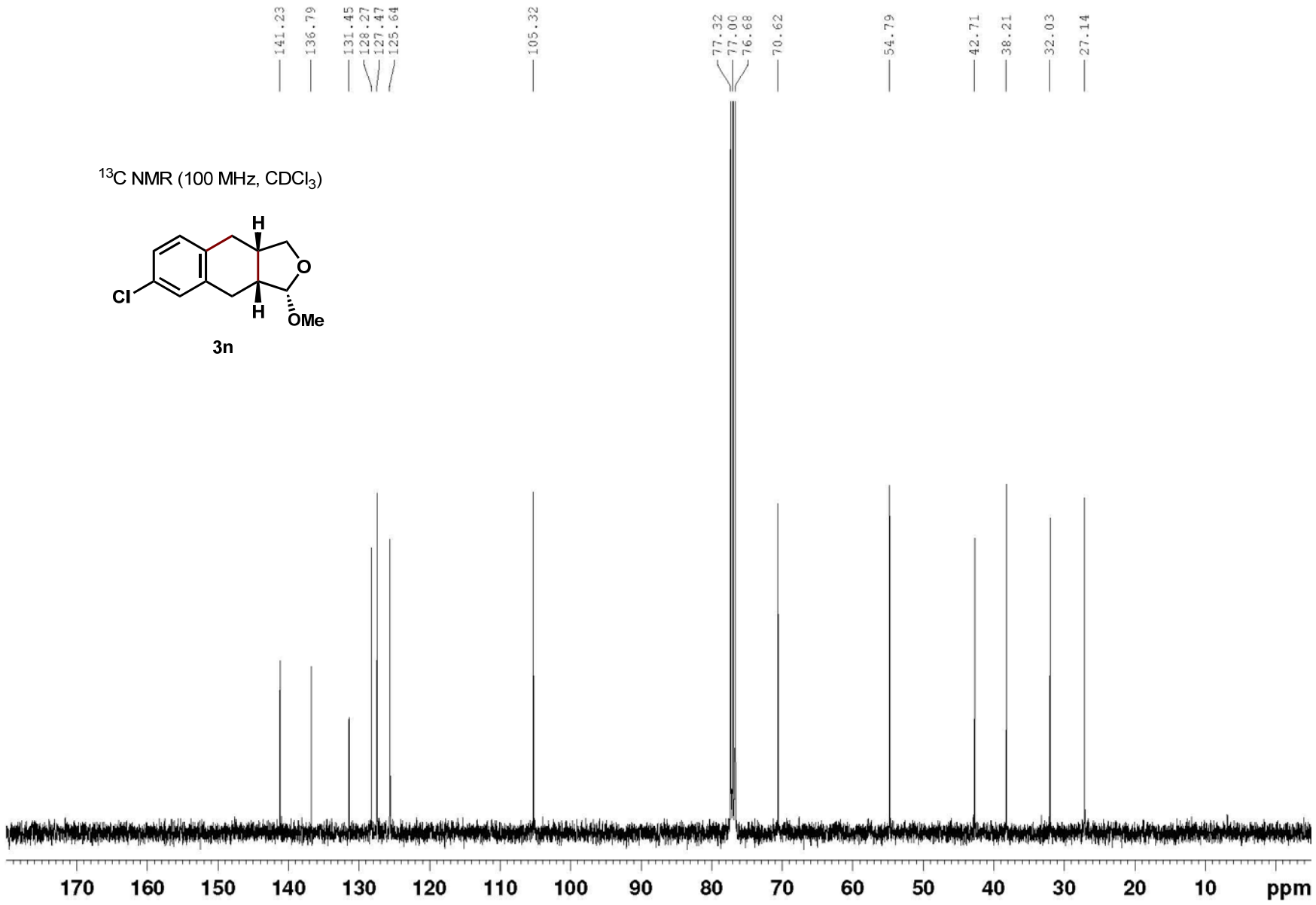


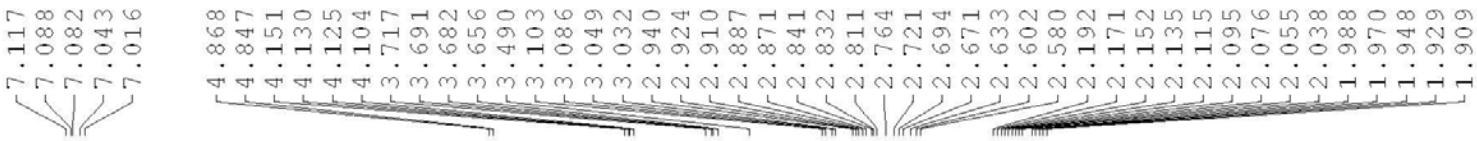

$^{13}$C NMR (100 MHz, $CDCl_3$)



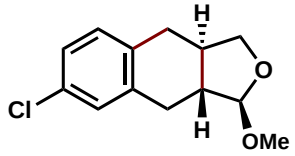

**2n**


7.125
7.100
7.094
7.074
7.067
7.016
6.989
4.976
4.960
4.114
4.088
4.061
3.592
3.568
3.540
3.360
2.899
2.870
2.850
2.821
2.792
2.776
2.755
2.741
2.728
2.712
2.698
2.678
2.669
2.646
2.619
2.596
2.572
2.555
2.537
2.520
2.507
2.496
2.490
2.474
2.465
2.444
2.431
2.420
2.408
2.398
2.383
2.373
0.000
$^1$H NMR (300 MHz, CDCl$_3$)
H
O
Cl
H
OMe
3n
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.92
0.98
1.00
1.00
1.06
1.09
3.16
1.07
2.08
3.24

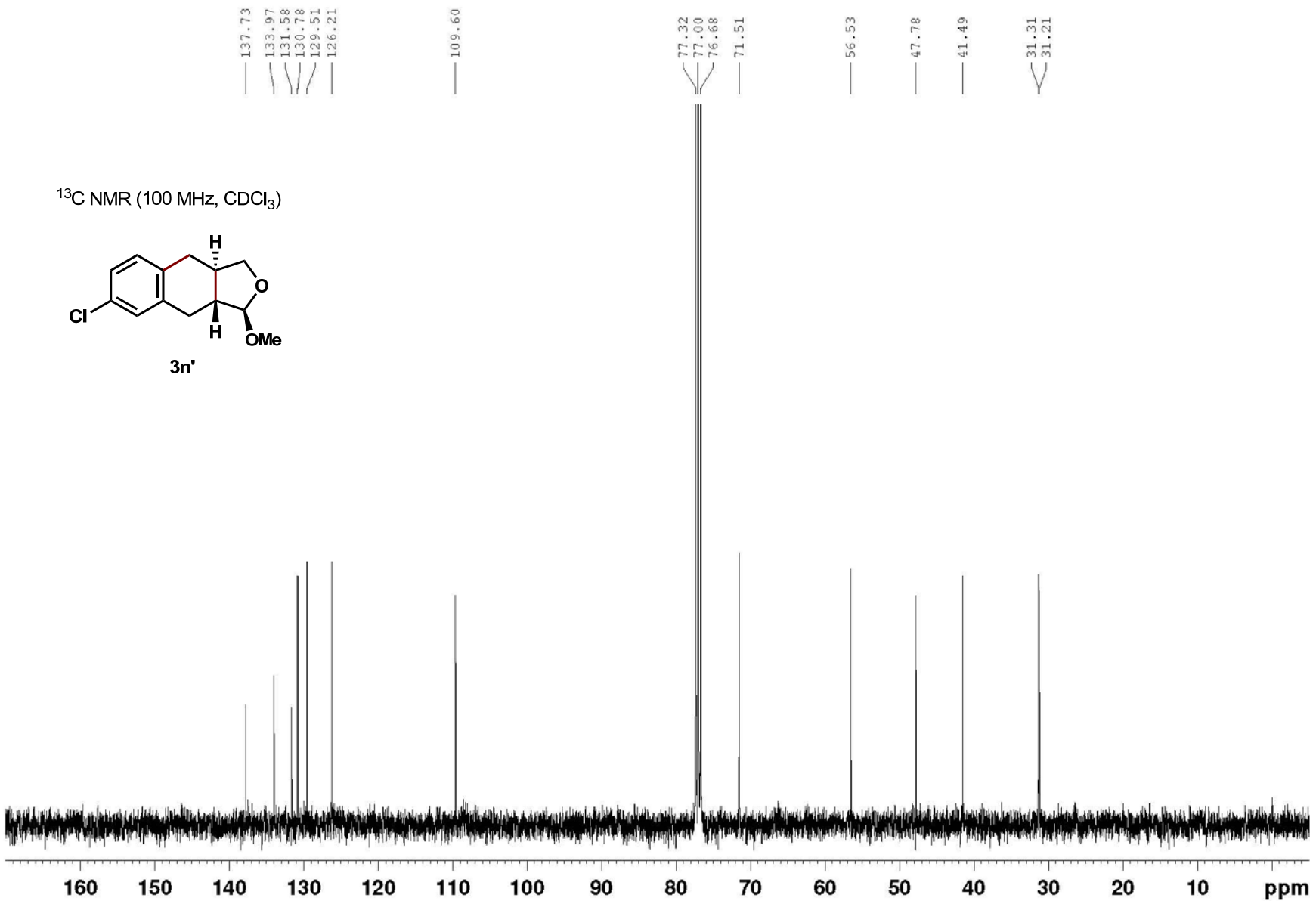

141.23
136.79
131.45
128.27
127.47
125.64
105.32
77.32
77.00
76.68
70.62
54.79
42.71
38.21
32.03
27.14
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
Cl
H
OMe
3n
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

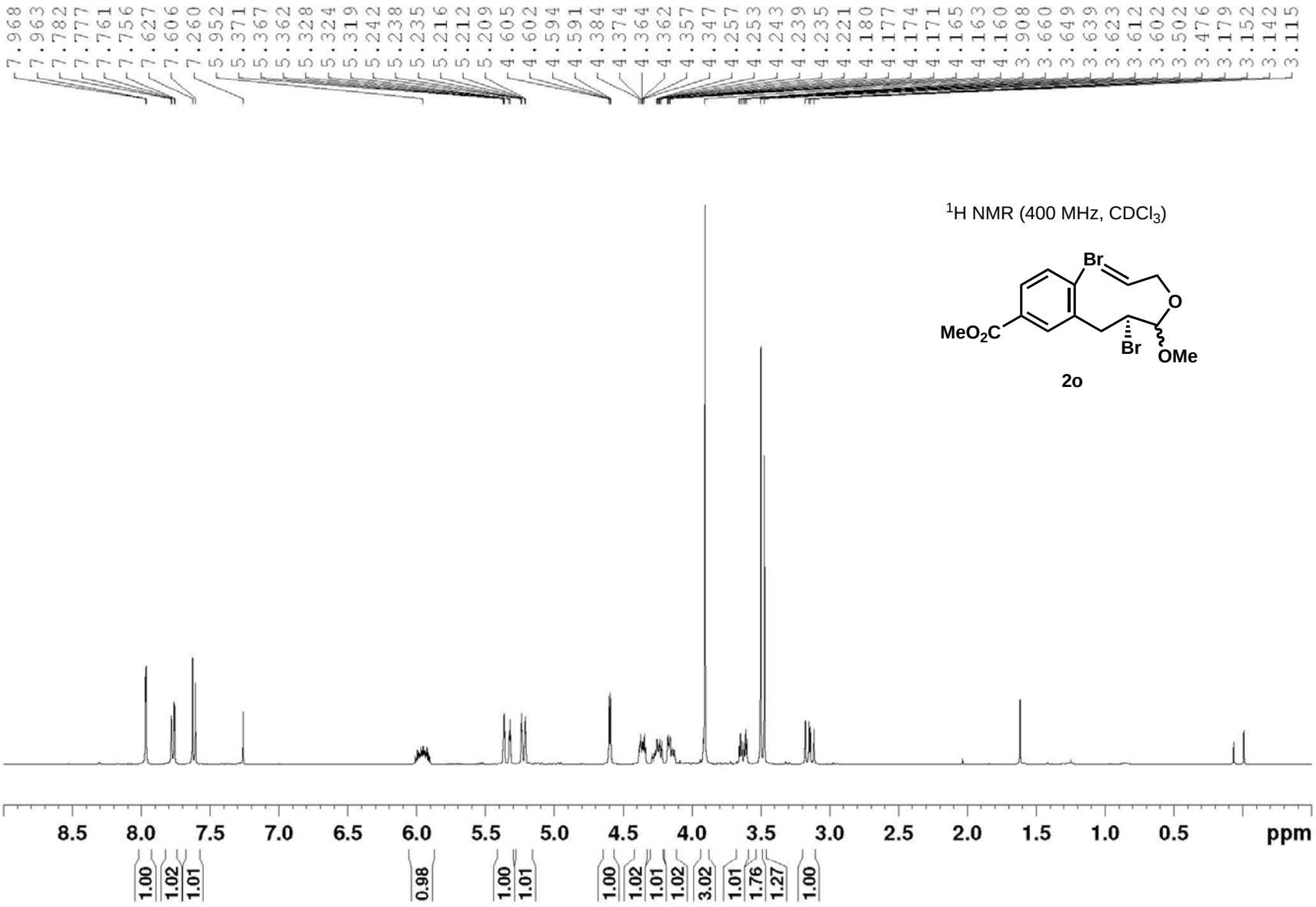


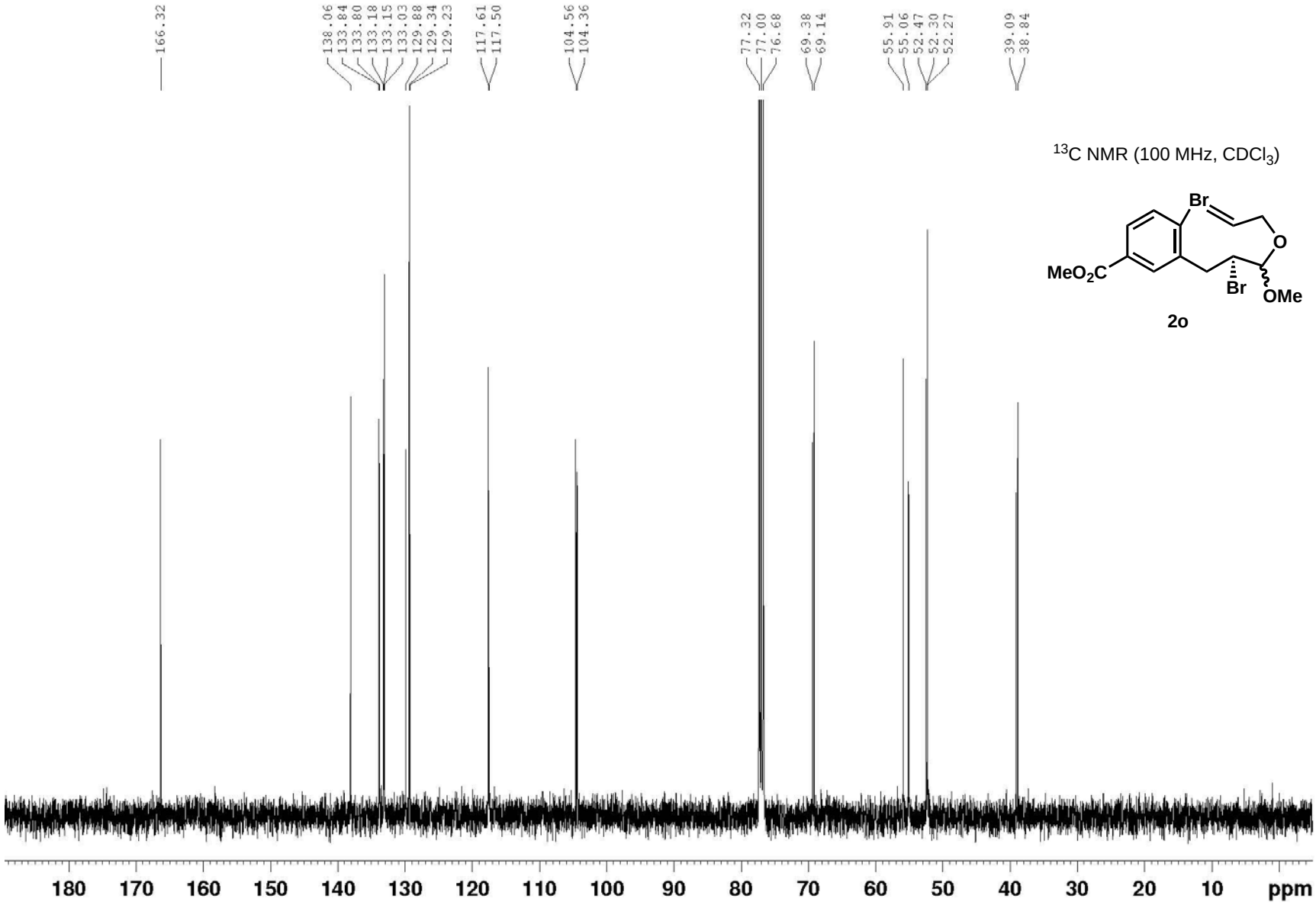

$^1$H NMR (300 MHz, $CDCl_3$)




**3n'**


137.73
133.97
131.58
130.78
129.51
126.21
109.60
77.32
77.00
76.68
71.51
56.53
47.78
41.49
31.31
31.21
$^{13}$C NMR (100 MHz, $CDCl_3$)
H
O
Cl
H
OMe
3n'
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

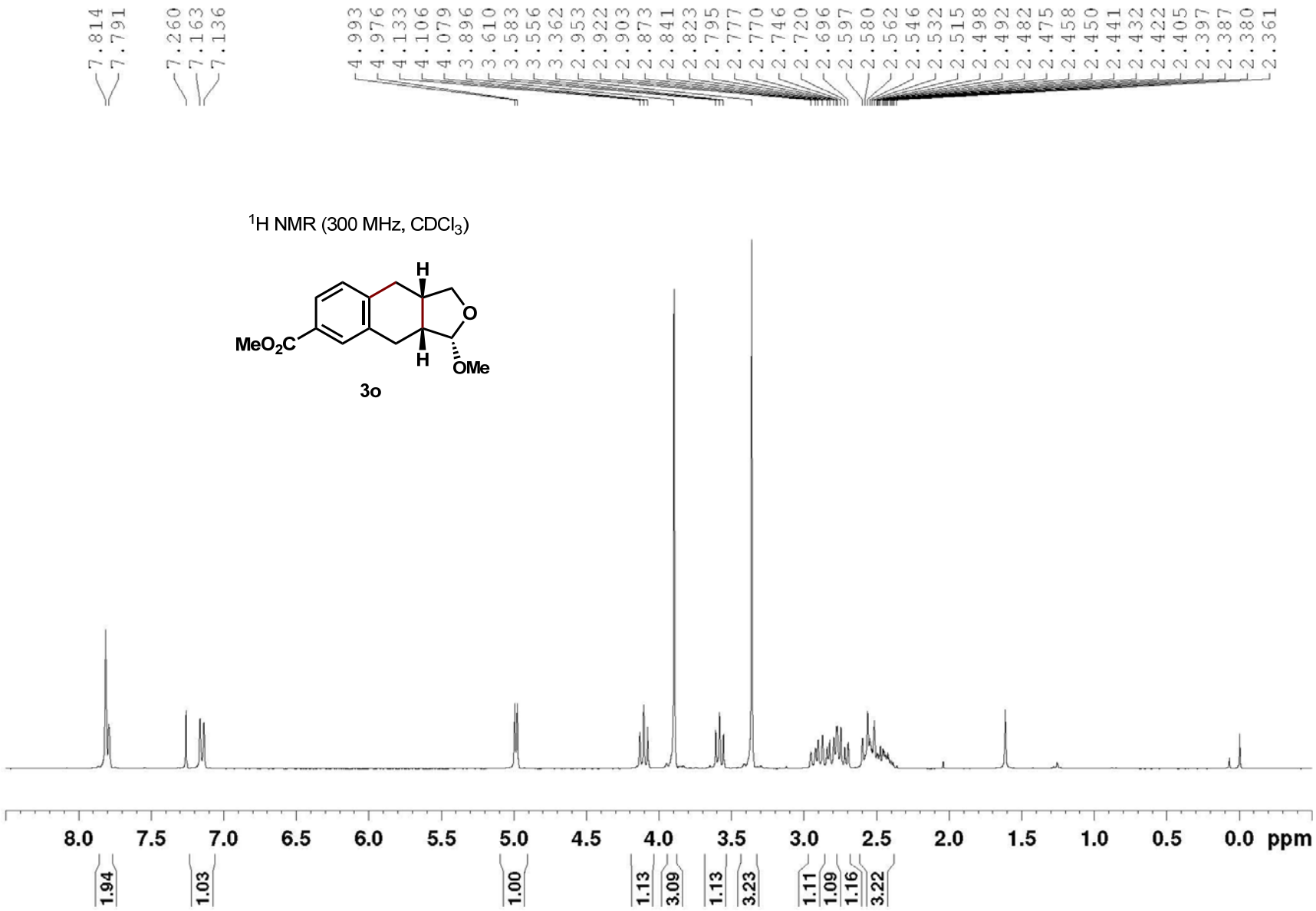

7.968
7.963
7.782
7.777
7.761
7.756
7.627
7.606
7.260
5.952
5.371
5.367
5.362
5.328
5.324
5.319
5.242
5.238
5.235
5.216
5.212
5.209
4.605
4.602
4.594
4.591
4.384
4.374
4.364
4.362
4.357
4.347
4.257
4.253
4.243
4.239
4.235
4.221
4.180
4.177
4.174
4.171
4.165
4.163
4.160
3.908
3.660
3.649
3.639
3.623
3.612
3.602
3.502
3.476
3.179
3.152
3.142
3.115
1H NMR (400 MHz, CDCl3)
Br
O
MeO2C
Br
OMe
2o
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
1.02
1.01
0.98
1.00
1.01
1.00
1.02
1.01
1.02
3.02
1.01
1.76
1.27
1.00

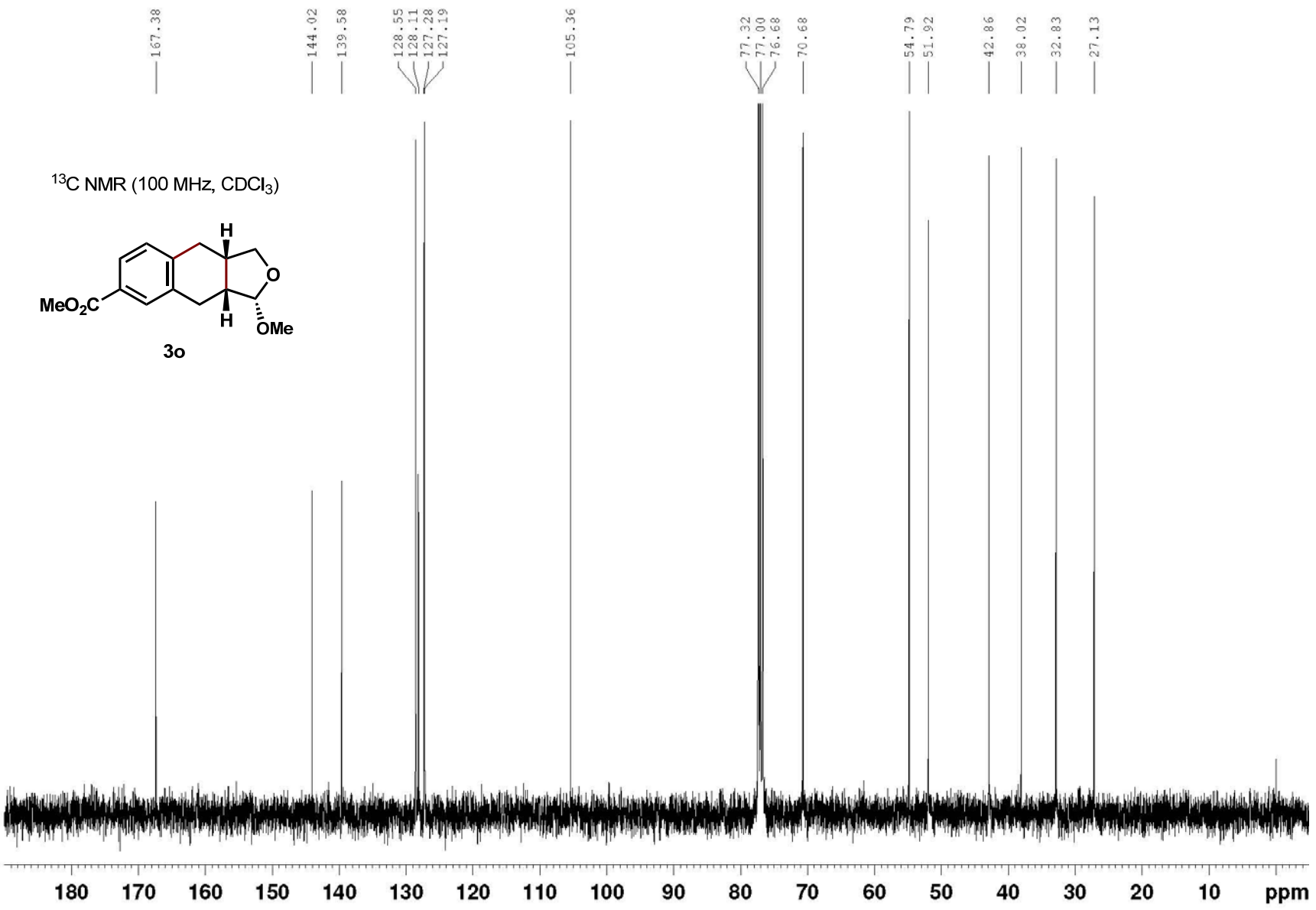


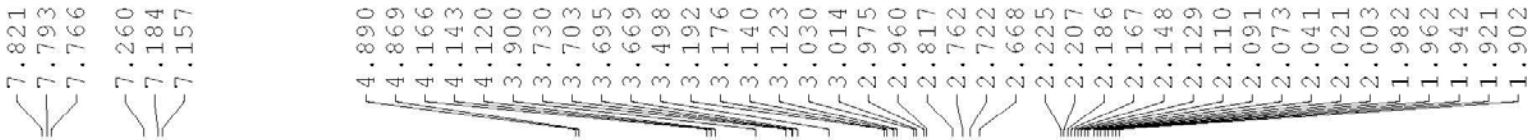

$^{13}$C NMR (100 MHz, $CDCl_3$)



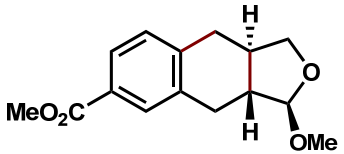

**2o**


7.814
7.791
7.260
7.163
7.136
4.993
4.976
4.133
4.106
4.079
3.896
3.610
3.583
3.556
3.362
2.953
2.922
2.903
2.873
2.841
2.823
2.795
2.777
2.770
2.746
2.720
2.696
2.597
2.580
2.562
2.546
2.532
2.515
2.498
2.492
2.482
2.475
2.458
2.450
2.441
2.432
2.422
2.405
2.397
2.387
2.380
2.361
$^1$H NMR (300 MHz, $CDCl_3$)
H
O
$MeO_2C$
H
OMe
3o
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.94
1.03
1.00
1.13
3.09
1.13
3.23
1.11
1.09
1.16
3.22

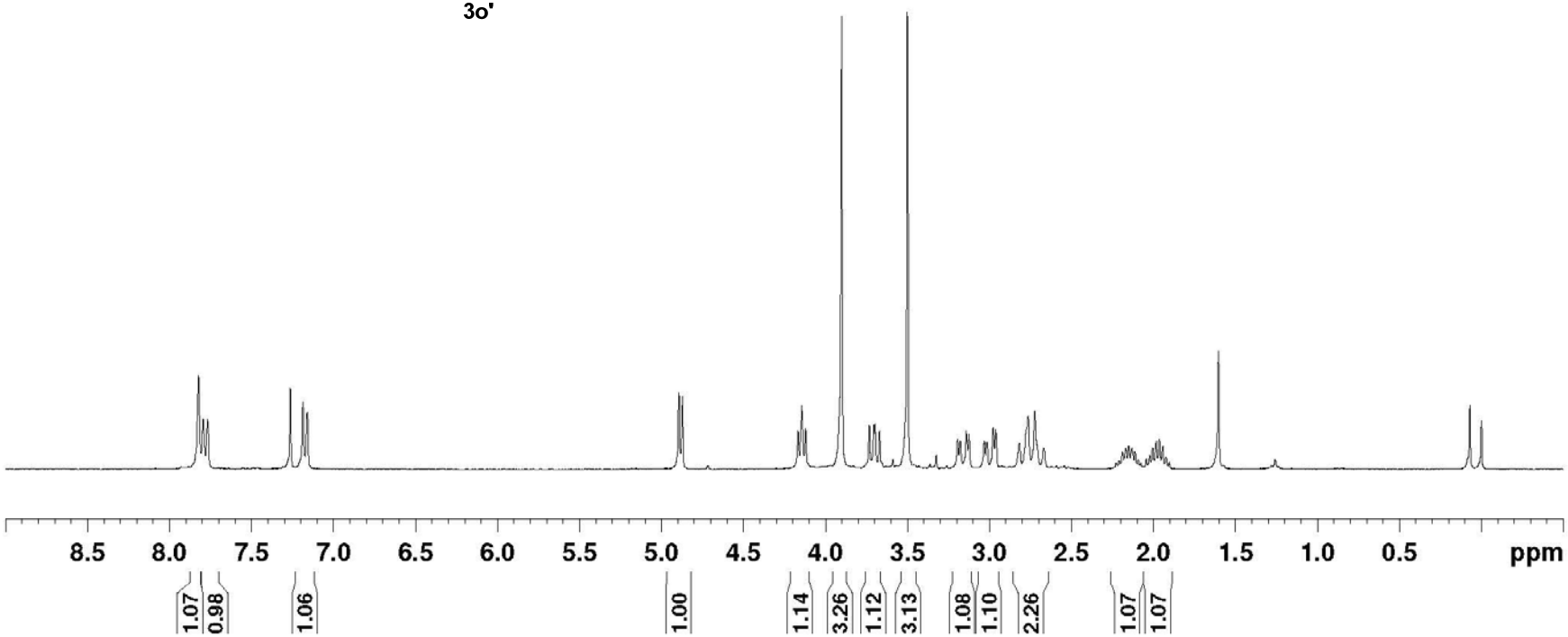

167.38
144.02
139.58
128.55
128.11
127.28
127.19
105.36
77.32
77.00
76.68
70.68
54.79
51.92
42.86
38.02
32.83
27.13
$^{13}$C NMR (100 MHz, CDCl$_3$)
MeO$_2$C
H
O
H
OMe
3o
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

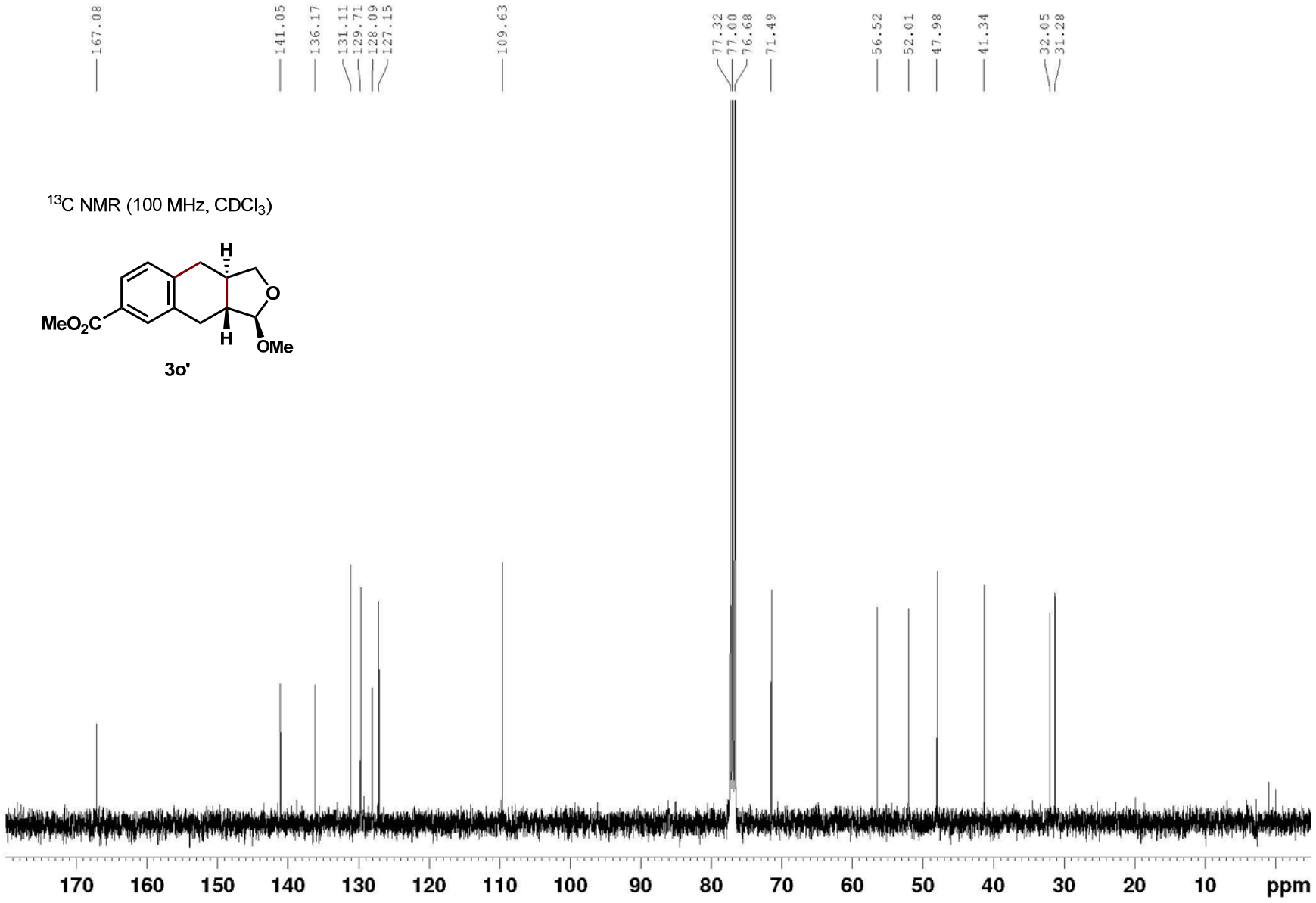


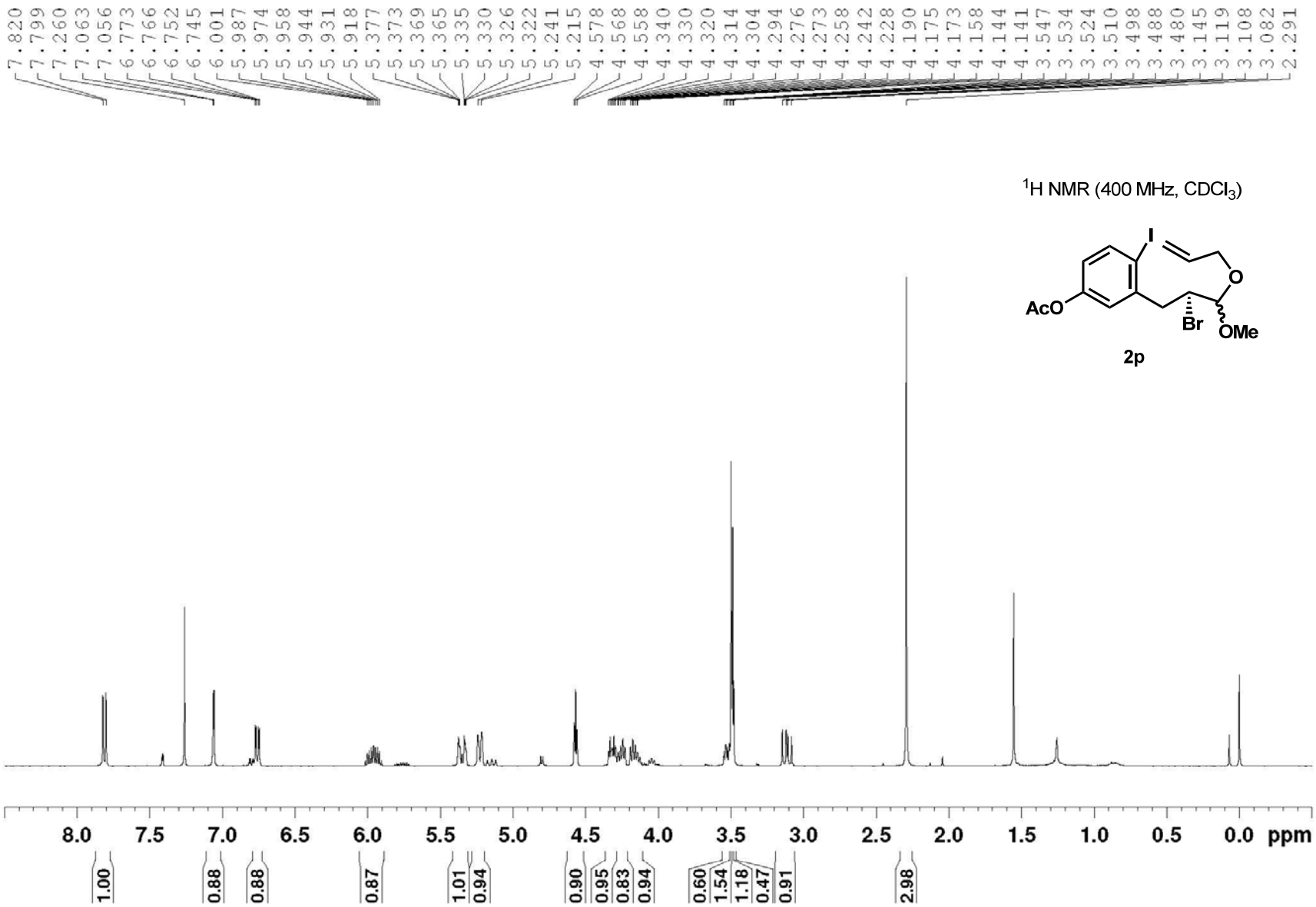

$^1$H NMR (300 MHz, $CDCl_3$)

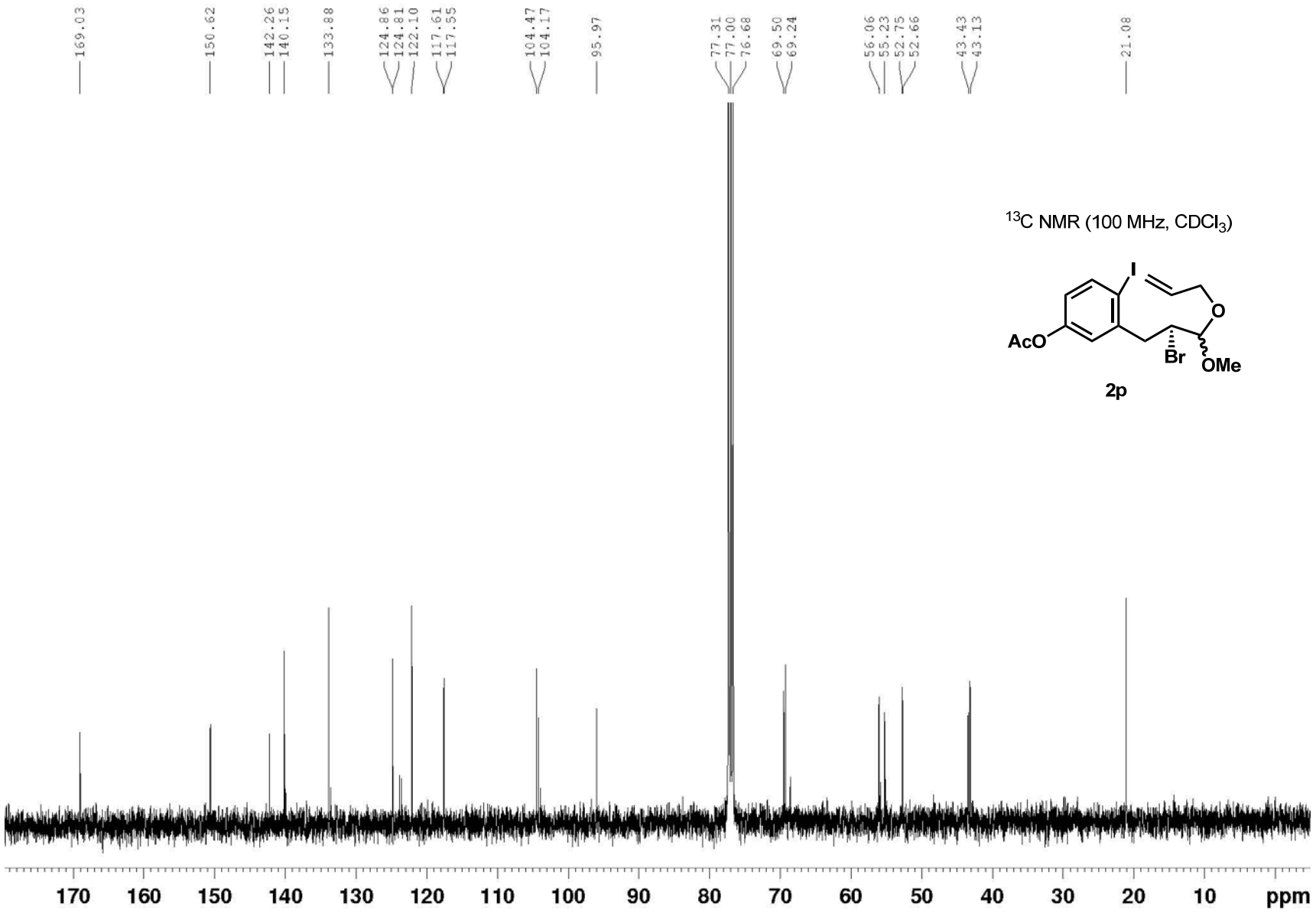



**3o'**




167.08
141.05
136.17
131.11
129.71
128.09
127.15
109.63
77.32
77.00
76.68
71.49
56.52
52.01
47.98
41.34
32.05
31.28
13C NMR (100 MHz, CDCl3)
MeO2C
H
O
H
OMe
3o'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

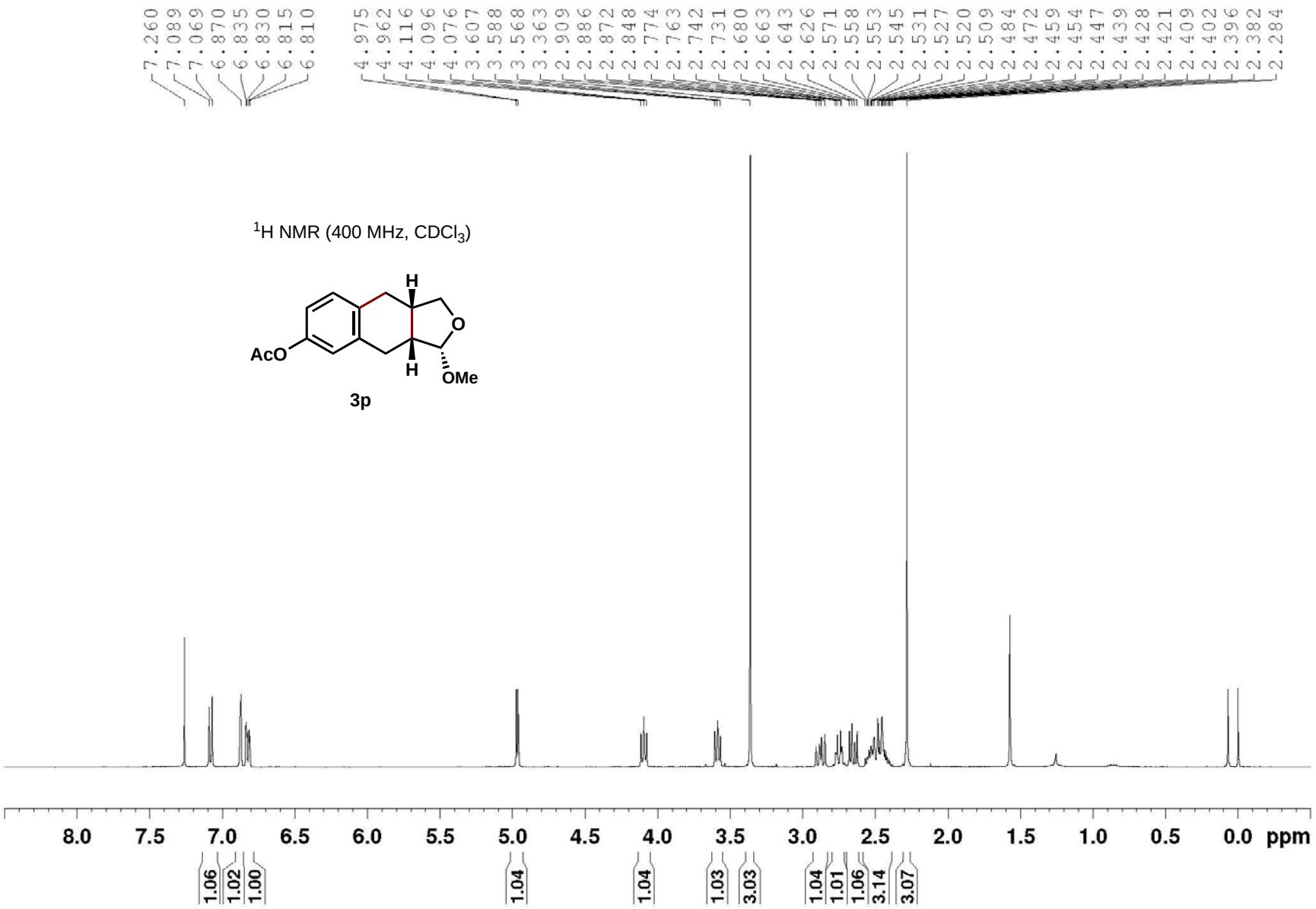

7.820
7.799
7.260
7.063
7.056
6.773
6.766
6.752
6.745
6.001
5.987
5.974
5.958
5.944
5.931
5.918
5.377
5.373
5.369
5.365
5.335
5.330
5.326
5.322
5.241
5.215
4.578
4.568
4.558
4.340
4.330
4.320
4.314
4.304
4.294
4.276
4.273
4.258
4.242
4.228
4.190
4.175
4.173
4.158
4.144
4.141
3.547
3.534
3.524
3.510
3.498
3.488
3.480
3.145
3.119
3.108
3.082
2.291
1H NMR (400 MHz, CDCl3)
I
O
AcO
Br
OMe
2p
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
0.88
0.88
0.87
1.01
0.94
0.90
0.95
0.83
0.94
0.60
1.54
1.18
0.47
0.91
2.98

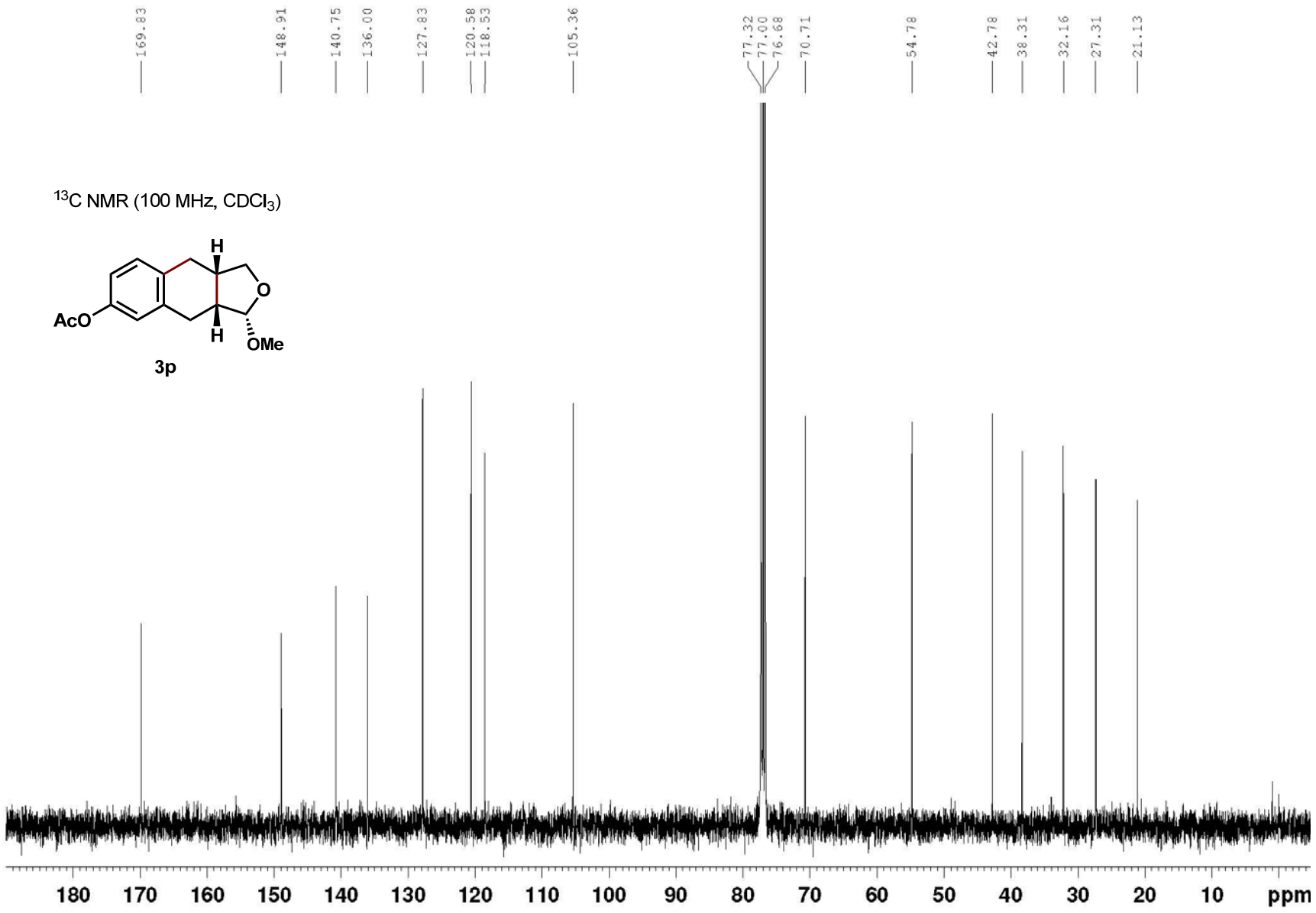


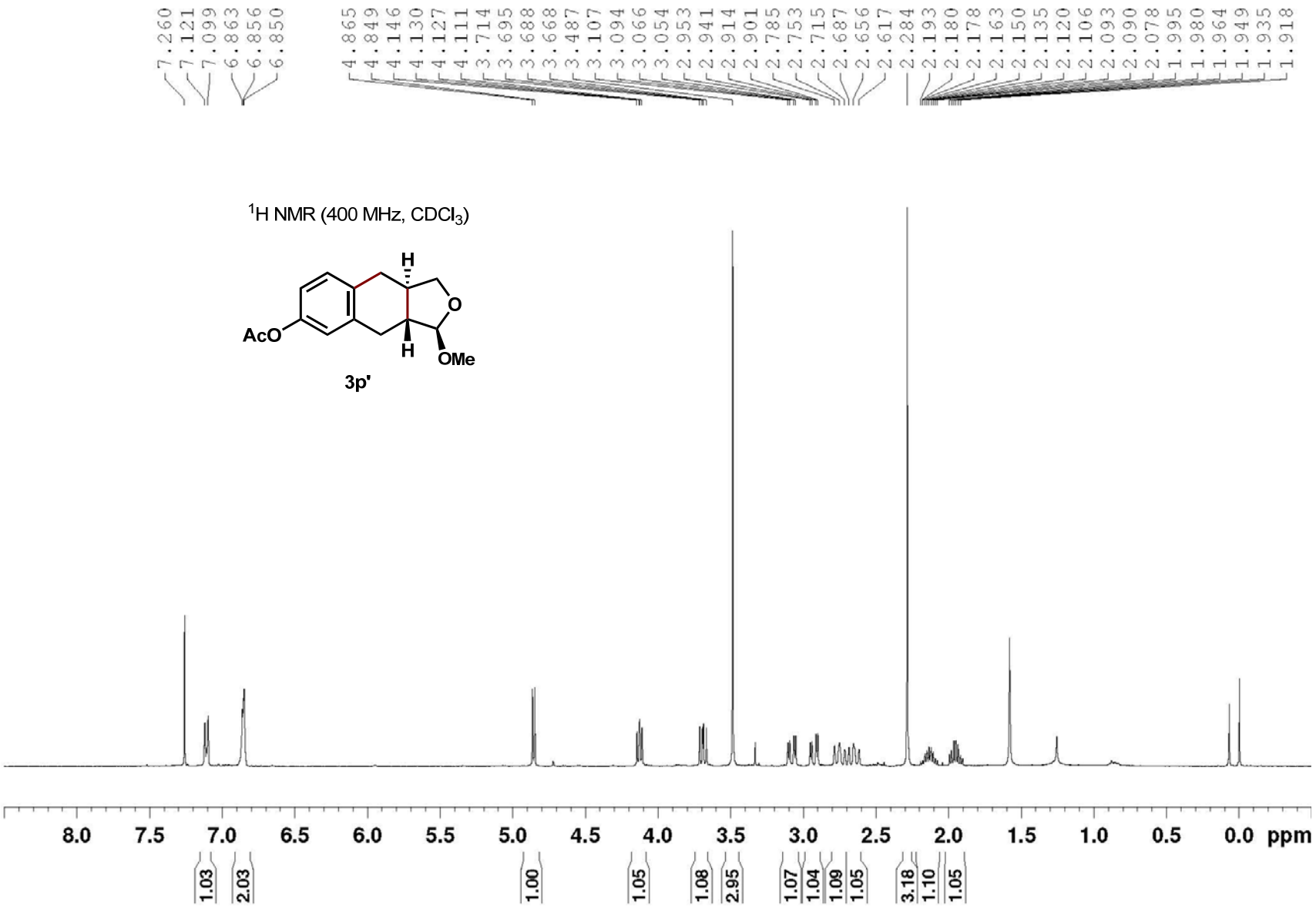

$^{13}$C NMR (100 MHz, $CDCl_3$)

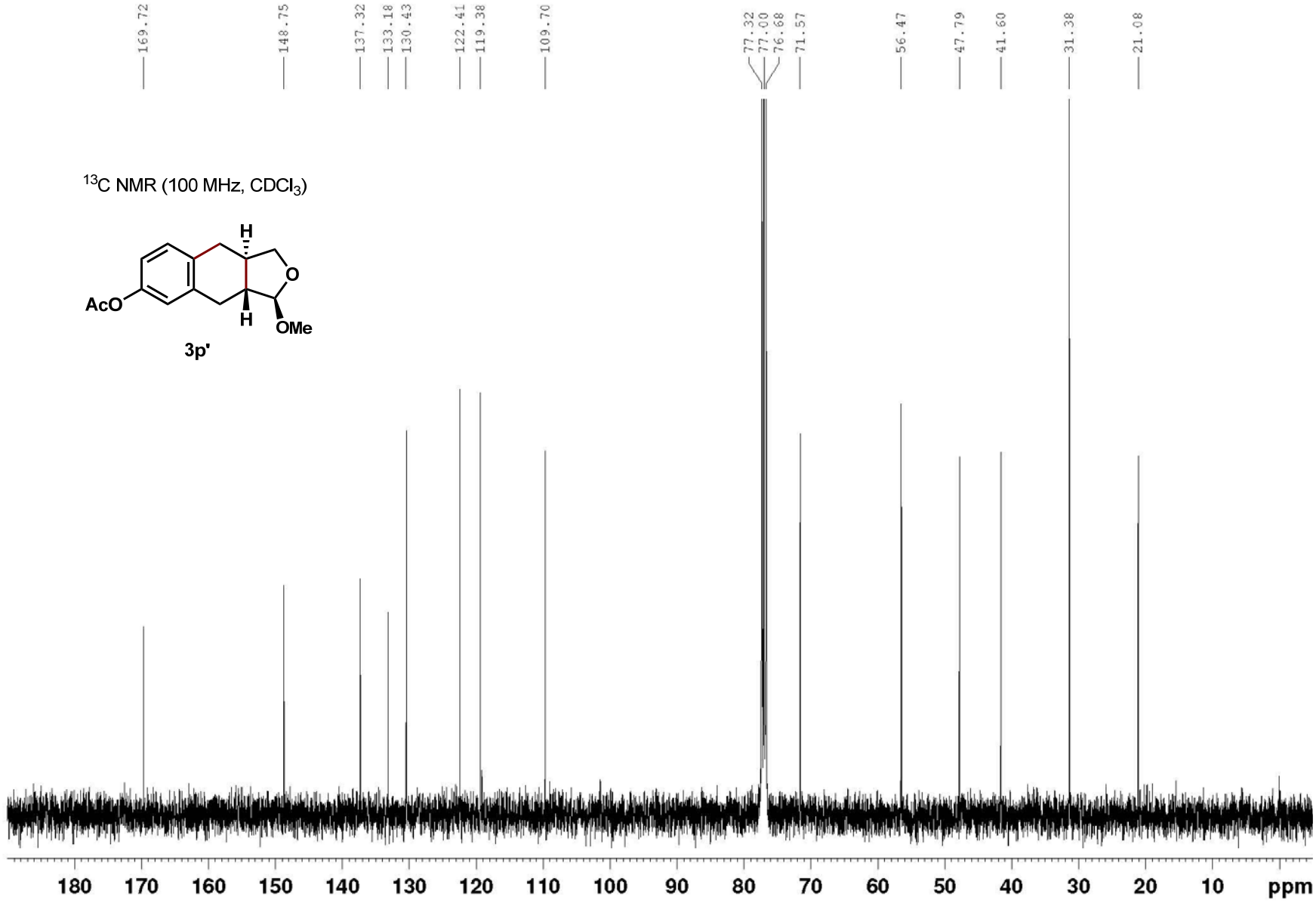


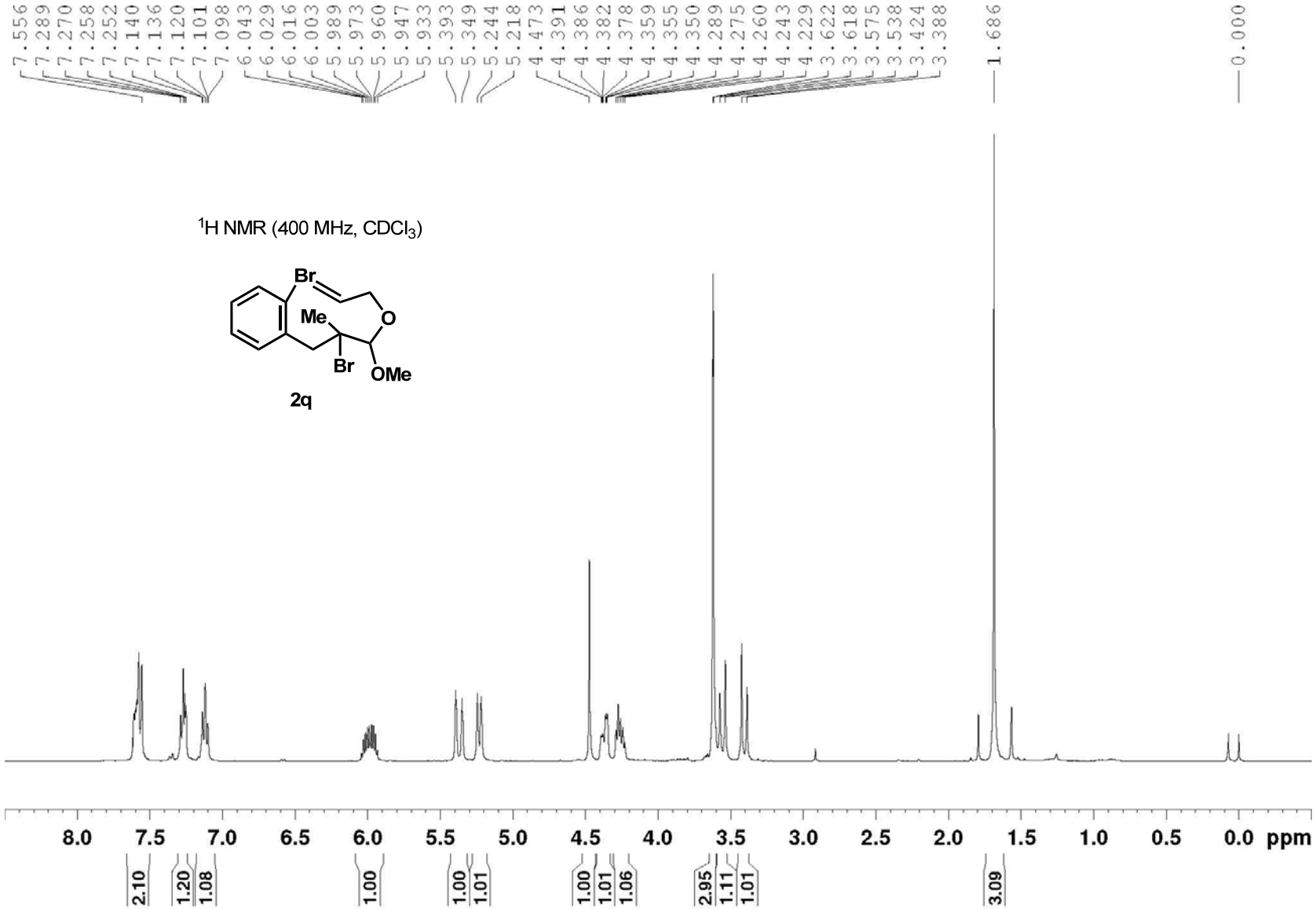

**2p**

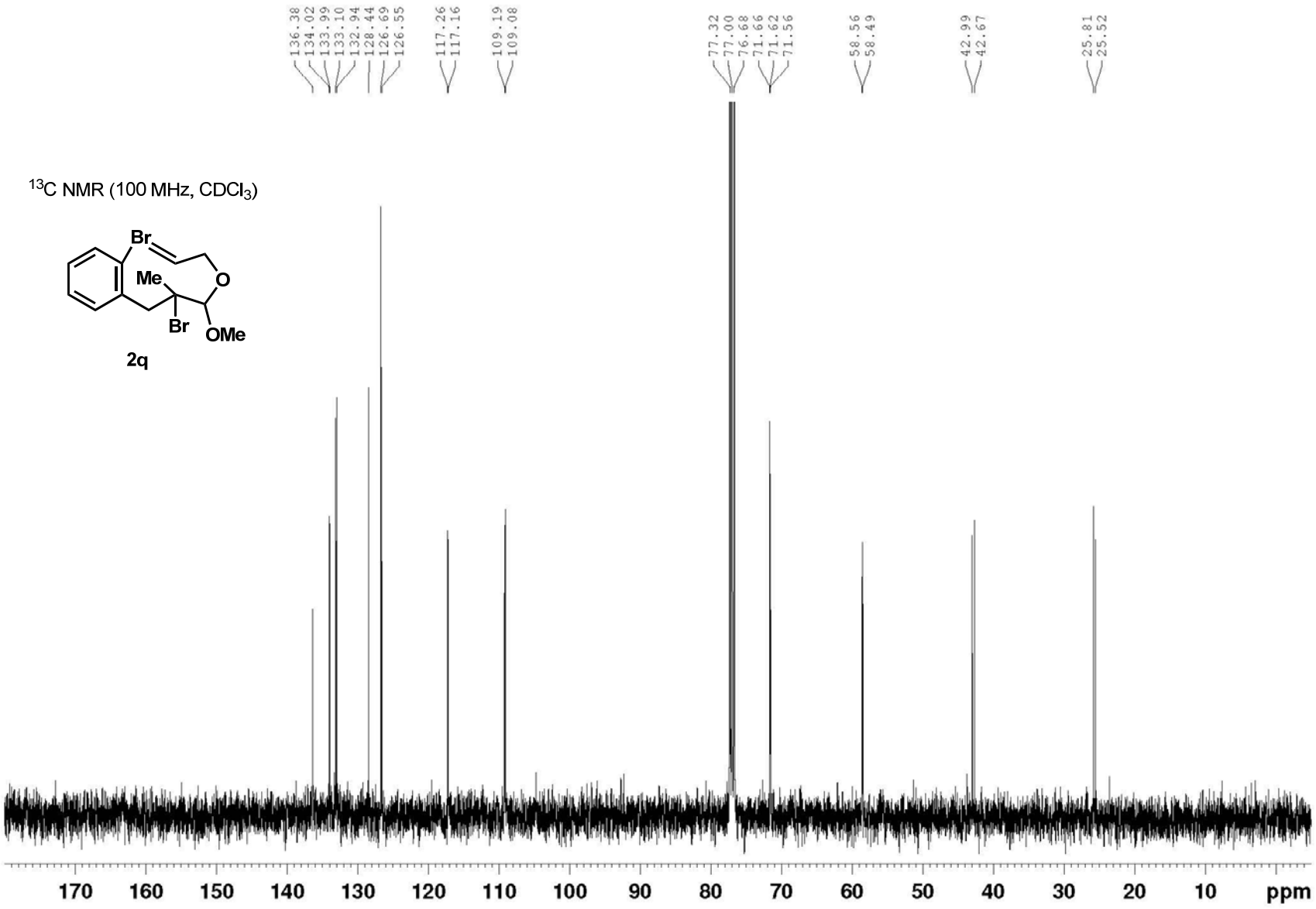

7.260
7.089
7.069
6.870
6.835
6.830
6.815
6.810
4.975
4.962
4.116
4.096
4.076
3.607
3.588
3.568
3.363
2.909
2.886
2.872
2.848
2.774
2.763
2.742
2.731
2.680
2.663
2.643
2.626
2.571
2.558
2.553
2.545
2.531
2.527
2.520
2.509
2.484
2.472
2.459
2.454
2.447
2.439
2.428
2.421
2.409
2.402
2.396
2.382
2.284
$^1$H NMR (400 MHz, $CDCl_3$)
H
O
AcO
H
OMe
3p
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.06
1.02
1.00
1.04
1.04
1.03
3.03
1.04
1.01
1.06
3.14
3.07

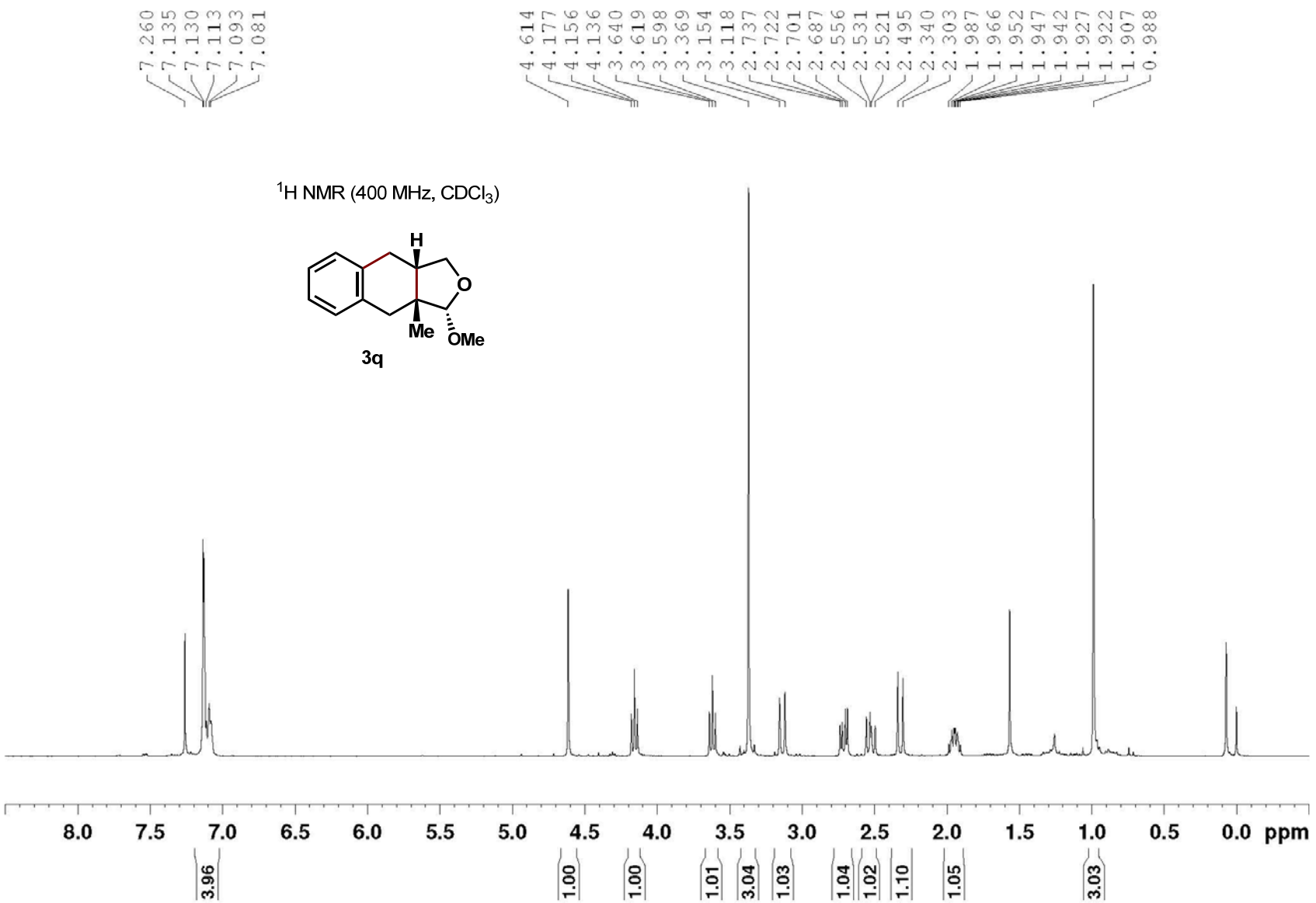

169.83
148.91
140.75
136.00
127.83
120.58
118.53
105.36
77.32
77.00
76.68
70.71
54.78
42.78
38.31
32.16
27.31
21.13
13C NMR (100 MHz, CDCl3)
H
O
AcO
H
OMe
3p
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

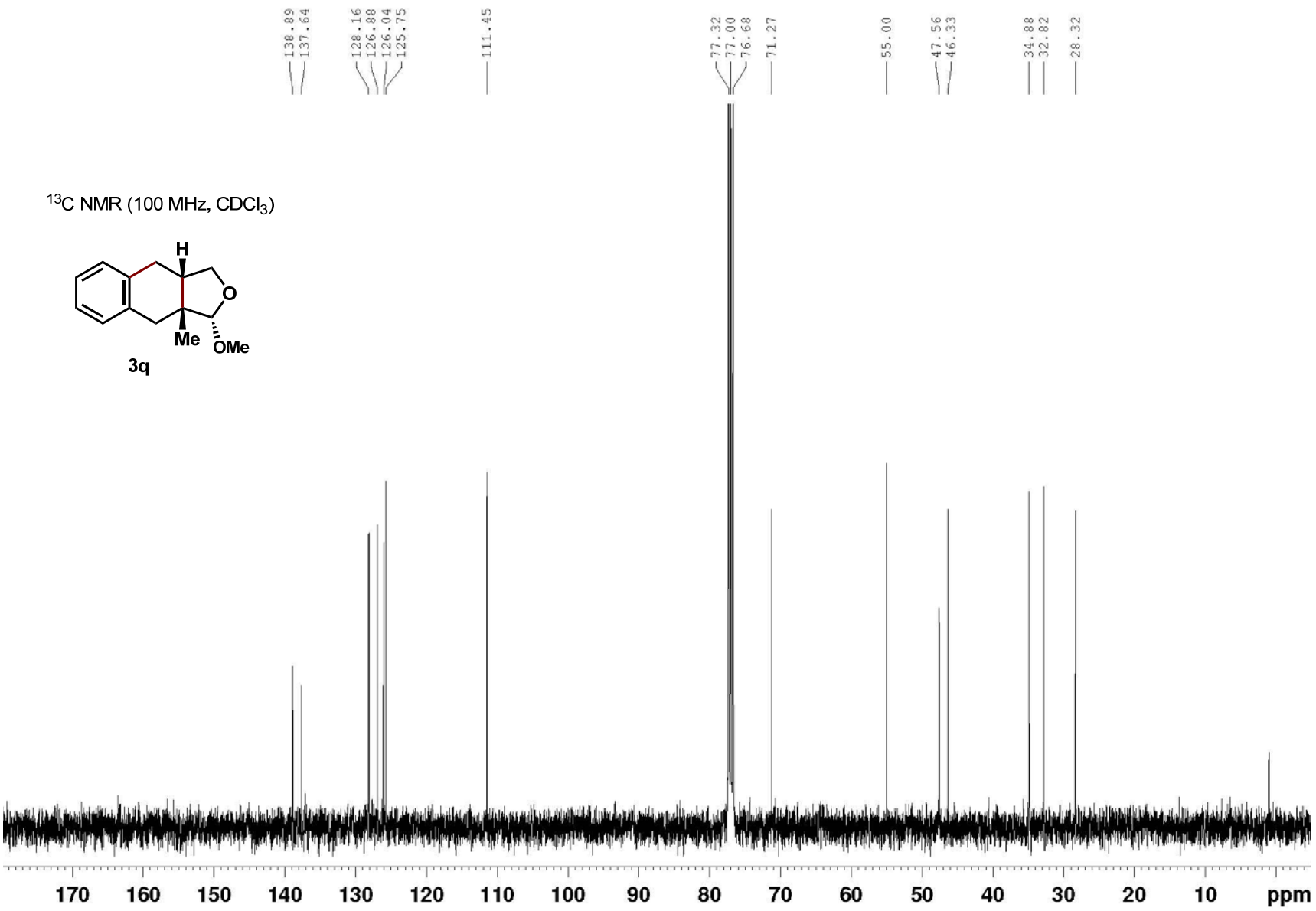

7.260
7.121
7.099
6.863
6.856
6.850
4.865
4.849
4.146
4.130
4.127
4.111
3.714
3.695
3.688
3.668
3.487
3.107
3.094
3.066
3.054
2.953
2.941
2.914
2.901
2.785
2.753
2.715
2.687
2.656
2.617
2.284
2.193
2.180
2.178
2.163
2.150
2.135
2.120
2.106
2.093
2.090
2.078
1.995
1.980
1.964
1.949
1.935
1.918
$^1$H NMR (400 MHz, CDCl$_3$)
AcO
H
O
H
OMe
3p'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.03
2.03
1.00
1.05
1.08
2.95
1.07
1.04
1.09
1.05
3.18
1.10
1.05

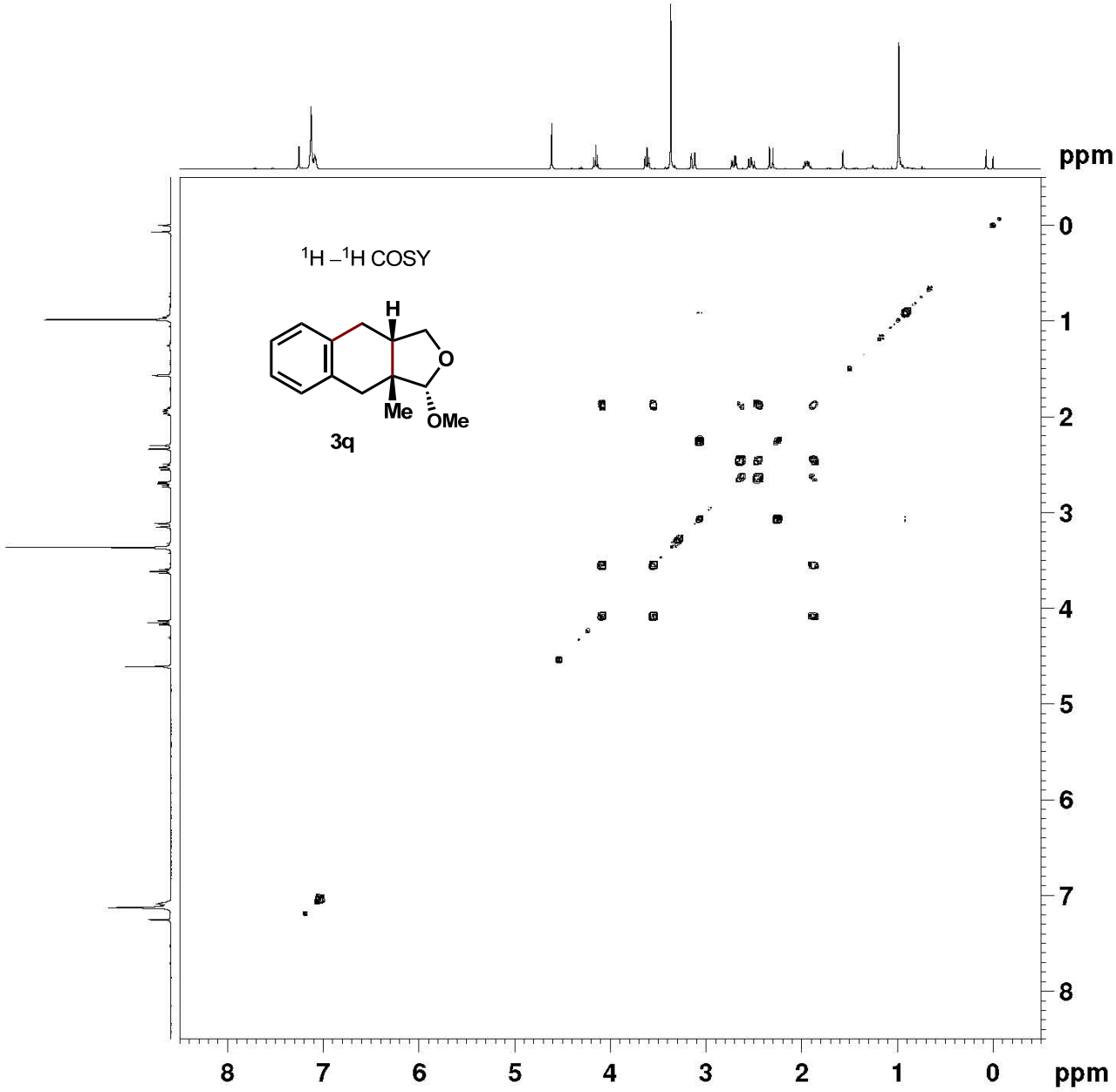

169.72
148.75
137.32
133.18
130.43
122.41
119.38
109.70
77.32
77.00
76.68
71.57
56.47
47.79
41.60
31.38
21.08
$^{13}$C NMR (100 MHz, CDCl$_3$)
AcO
H
O
H
OMe
3p'
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

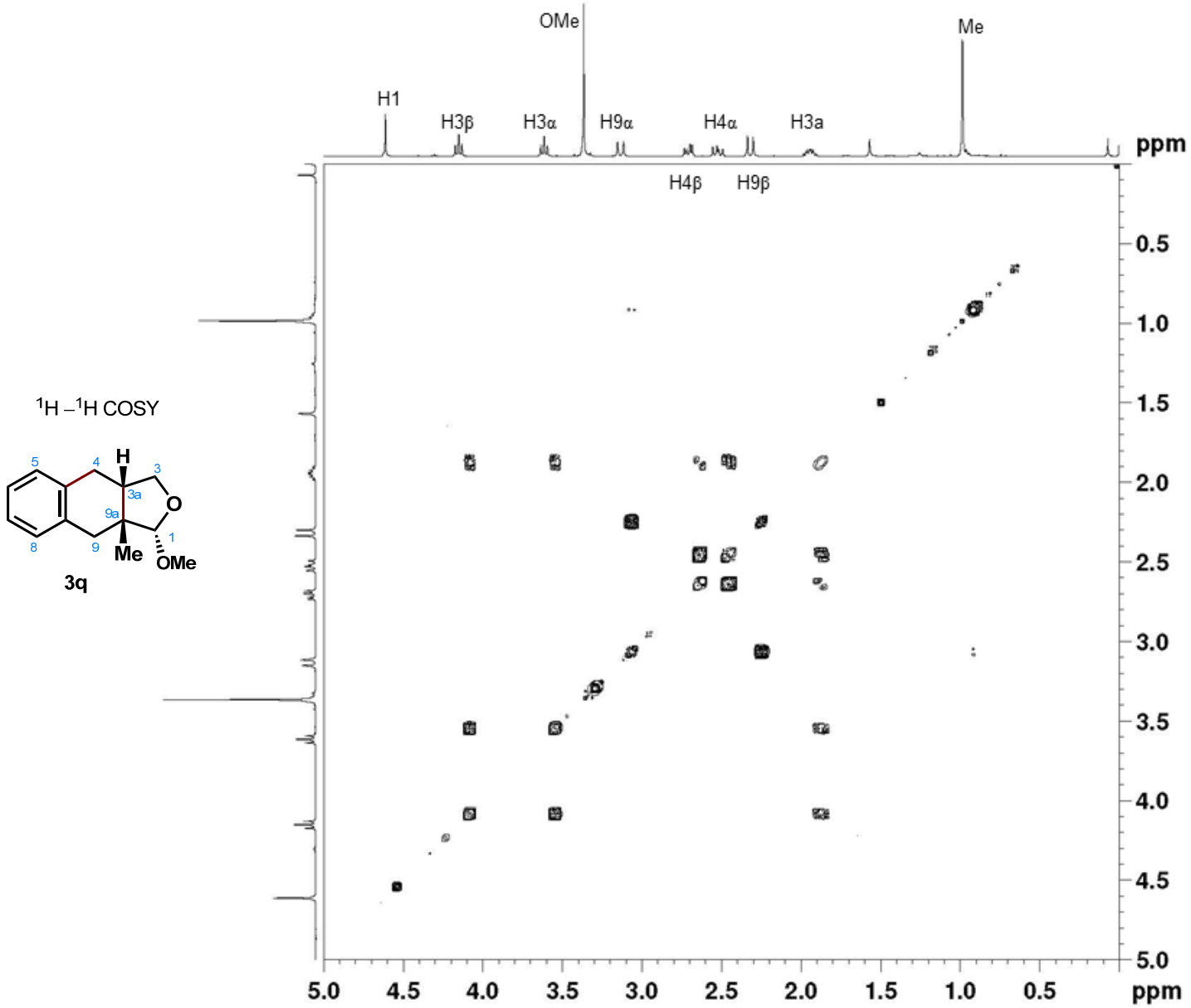

7.556
7.289
7.270
7.258
7.252
7.140
7.136
7.120
7.101
7.098
6.043
6.029
6.016
6.003
5.989
5.973
5.960
5.947
5.933
5.393
5.349
5.244
5.218
4.473
4.391
4.386
4.382
4.378
4.359
4.355
4.350
4.289
4.275
4.260
4.243
4.229
3.622
3.618
3.575
3.538
3.424
3.388
1.686
0.000
$^1$H NMR (400 MHz, $CDCl_3$)
Br
Me
O
Br
OMe
2q
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0 ppm
2.10
1.20
1.08
1.00
1.00
1.01
1.00
1.01
1.06
2.95
1.11
1.01
3.09


136.38
134.02
133.99
133.10
132.94
128.44
126.69
126.55
117.26
117.16
109.19
109.08
77.32
77.00
76.68
71.66
71.62
71.56
58.56
58.49
42.99
42.67
25.81
25.52
$^{13}$C NMR (100 MHz, CDCl$_3$)
Br
Me
O
Br
OMe
2q
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.260
7.135
7.130
7.113
7.093
7.081
4.614
4.177
4.156
4.136
3.640
3.619
3.598
3.369
3.154
3.118
2.737
2.722
2.701
2.687
2.556
2.531
2.521
2.495
2.340
2.303
1.987
1.966
1.952
1.947
1.942
1.927
1.922
1.907
0.988
$^1$H NMR (400 MHz, $CDCl_3$)
H
O
Me
OMe
3q
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.96
1.00
1.00
1.01
3.04
1.03
1.04
1.02
1.10
1.05
3.03


138.89
137.64
128.16
126.88
126.04
125.75
111.45
77.32
77.00
76.68
71.27
55.00
47.56
46.33
34.88
32.82
28.32
$^{13}$C NMR (100 MHz, CDCl$_3$)
H
O
Me
OMe
3q
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

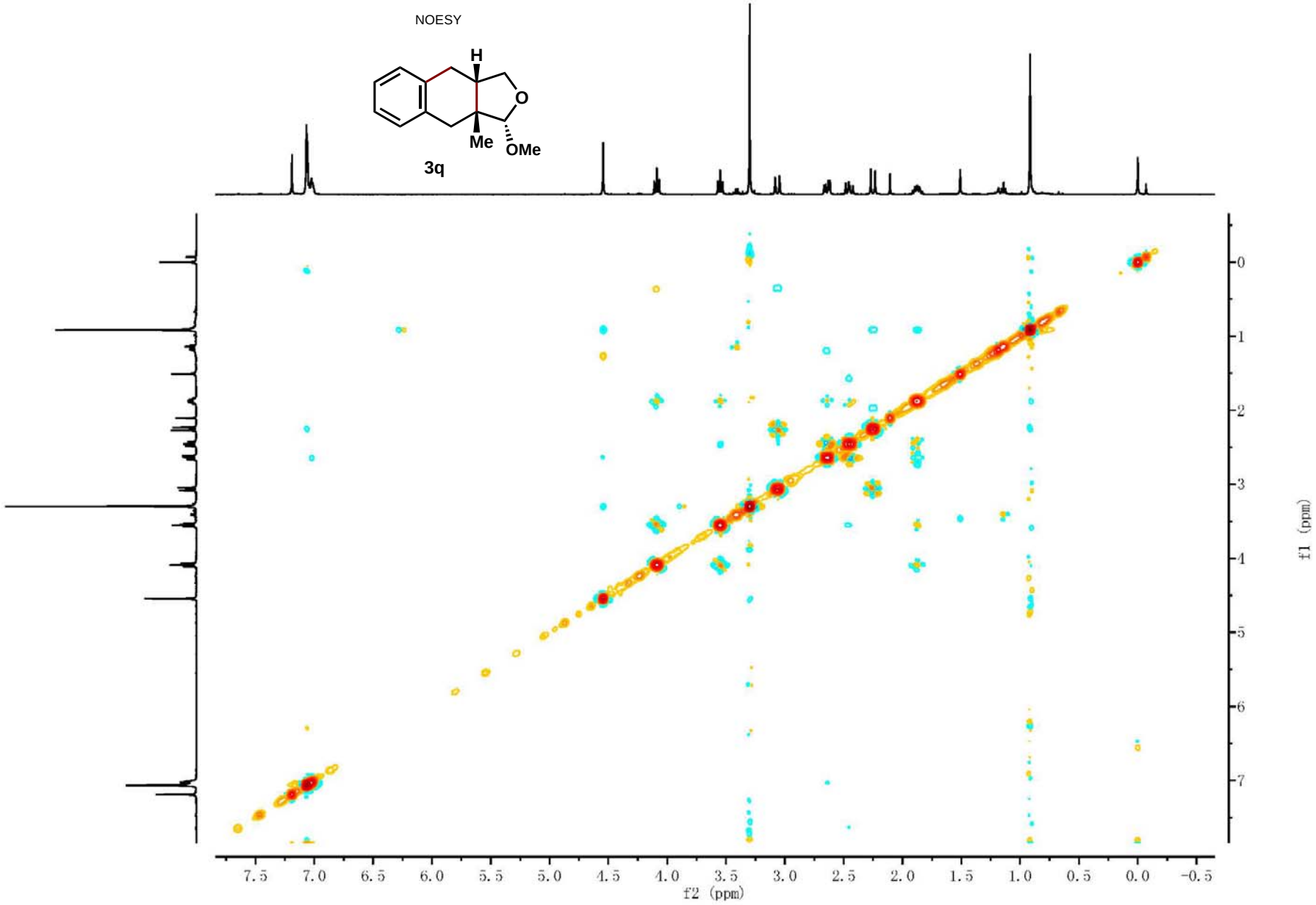

$^1$H –$^1$H COSY
H
O
Me
OMe
3q
ppm
0
1
2
3
4
5
6
7
8
8
7
6
5
4
3
2
1
0
ppm

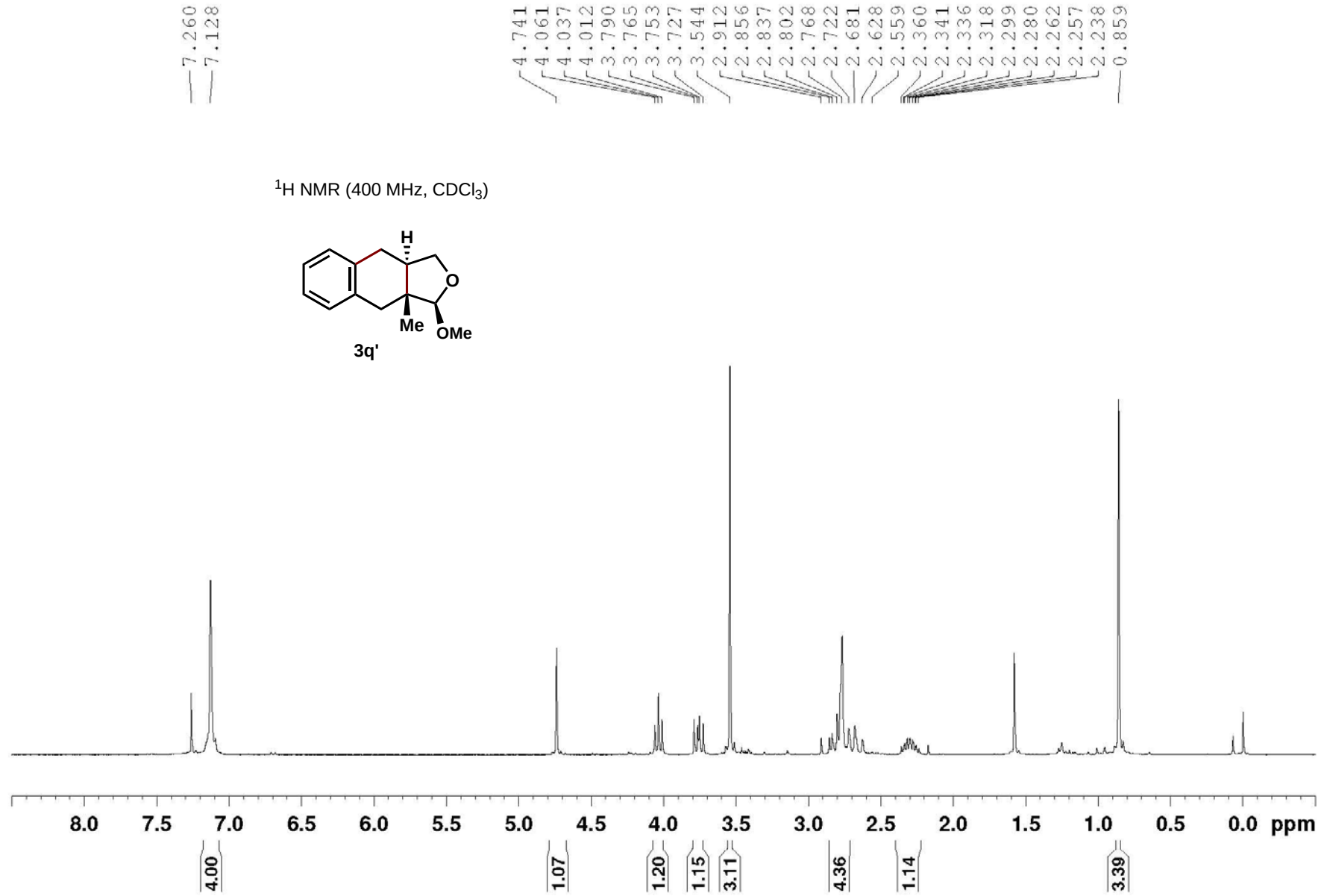

OMe
Me
H1
H3β
H3α
H9α
H4α
H3a
H4β
H9β
ppm
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm

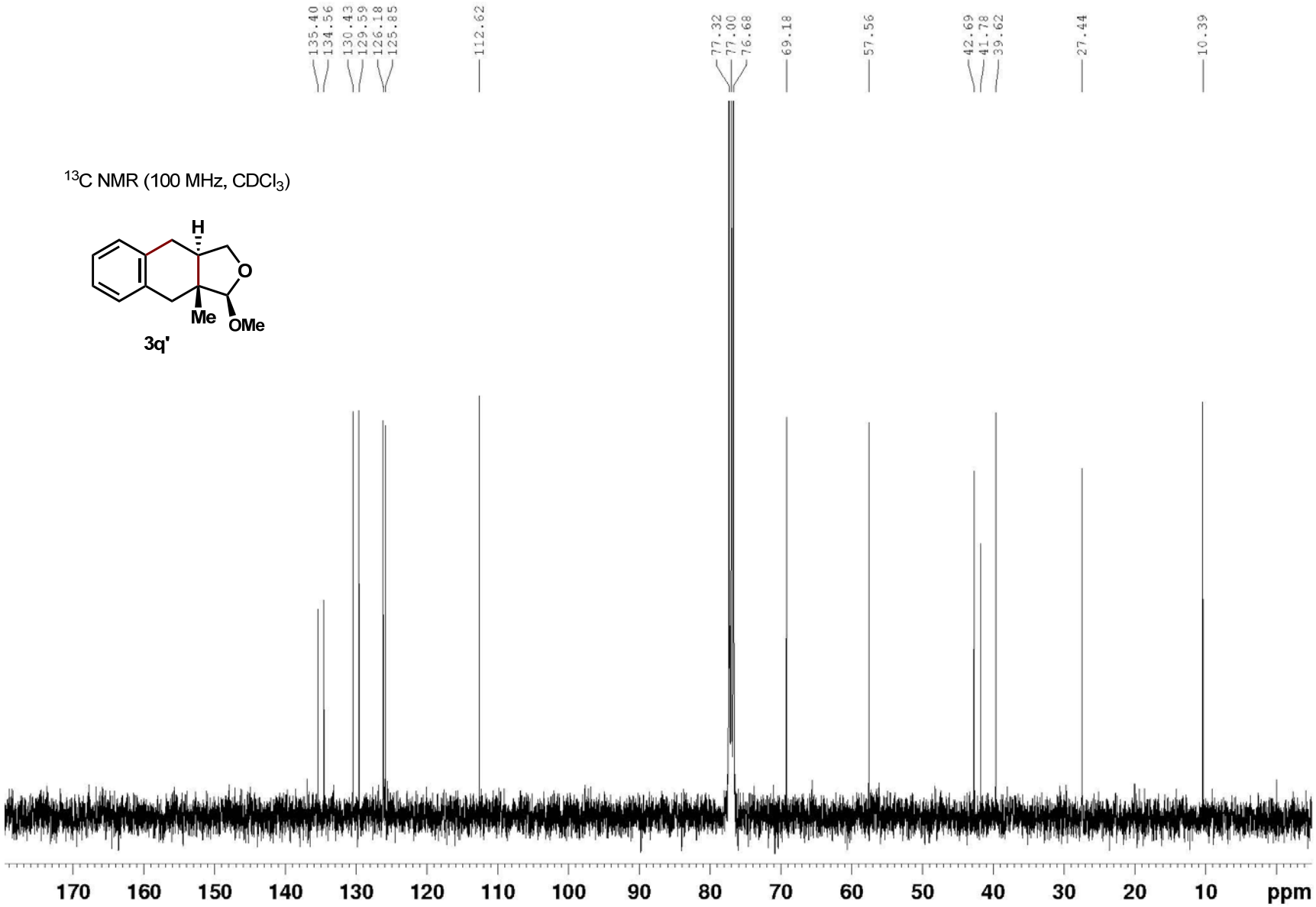
$^1$H –$^1$H COSY

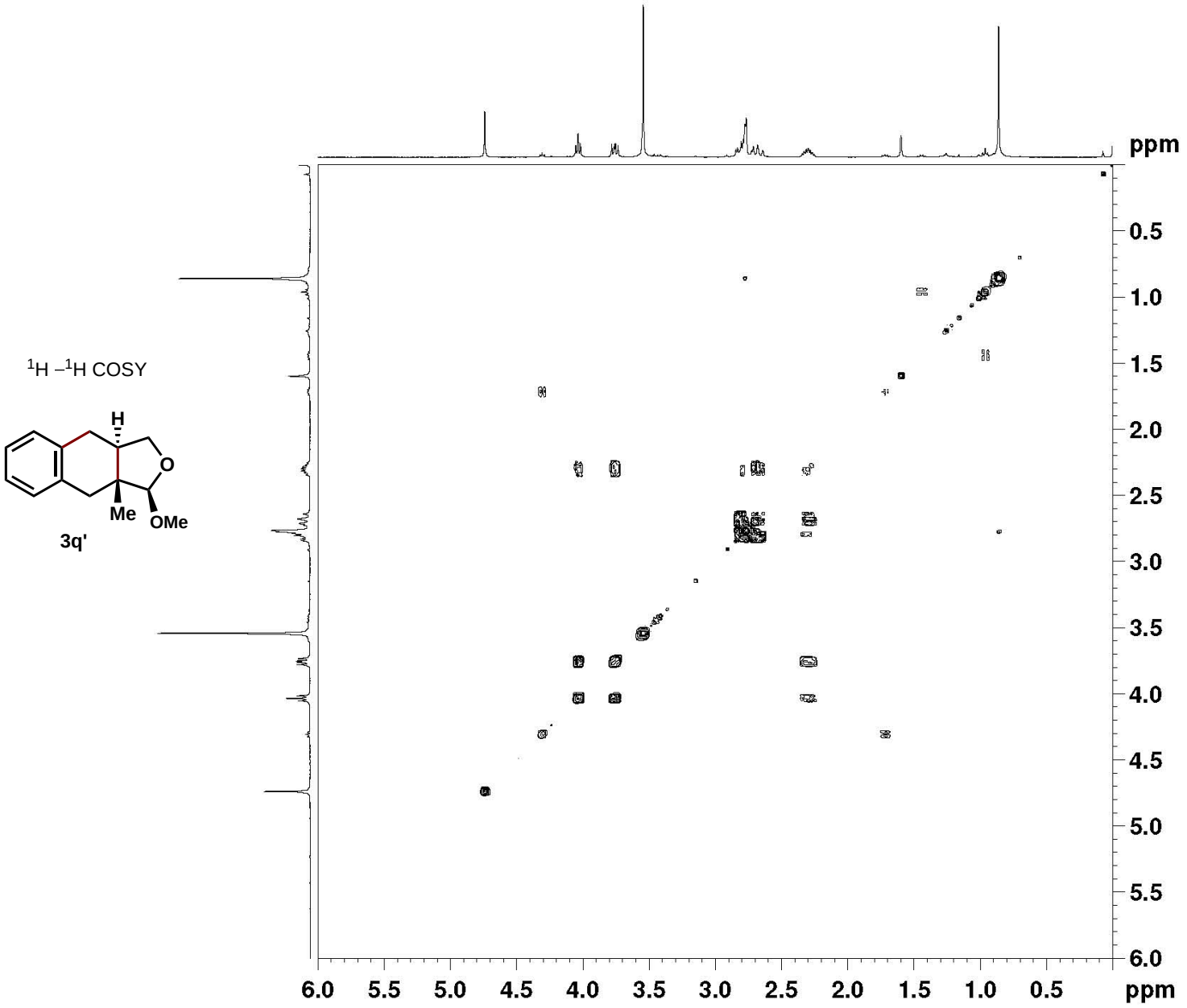

5
4
H
3
3a
O
9a
1
8
9
Me
OMe

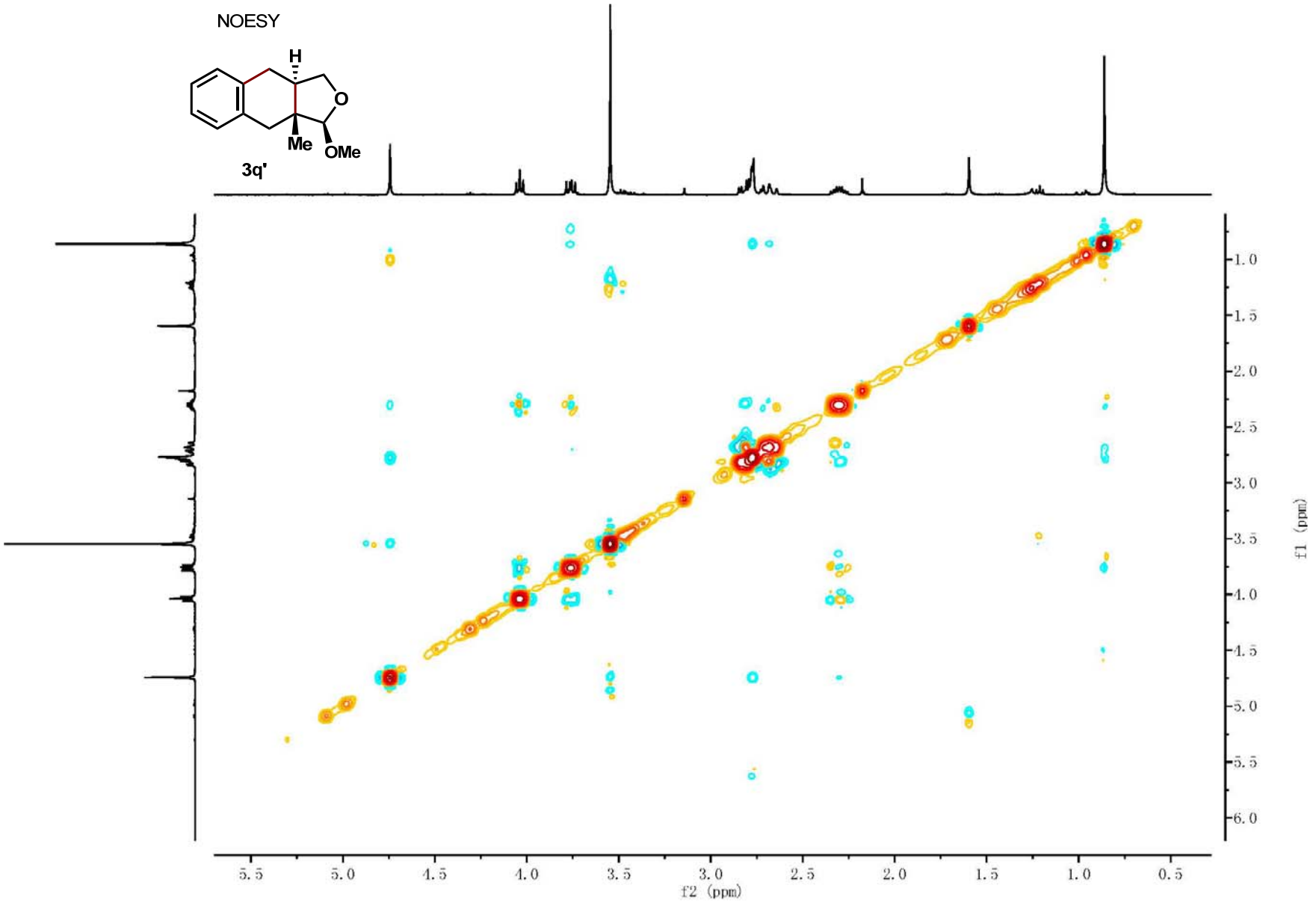
**3q**

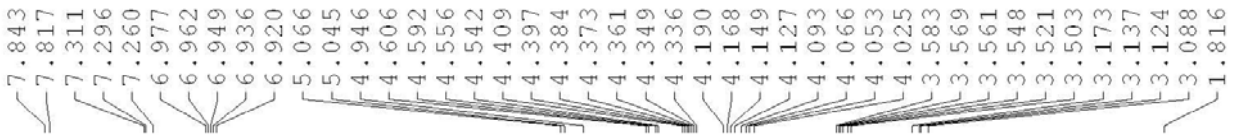

NOESY
H
O
Me
OMe
3q
f2 (ppm)
f1 (ppm)


7.260
7.128
4.741
4.061
4.037
4.012
3.790
3.765
3.753
3.727
3.544
2.912
2.856
2.837
2.802
2.768
2.722
2.681
2.628
2.559
2.360
2.341
2.336
2.318
2.299
2.280
2.262
2.257
2.238
0.859
$^1$H NMR (400 MHz, $CDCl_3$)
H
O
Me
OMe
3q'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
4.00
1.07
1.20
1.15
3.11
4.36
1.14
3.39

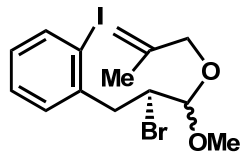

135.40
134.56
130.43
129.59
126.18
125.85
112.62
77.32
77.00
76.68
69.18
57.56
42.69
41.78
39.62
27.44
10.39
$^{13}$C NMR (100 MHz, $CDCl_3$)
H
O
Me
OMe
3q'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


$^1$H –$^1$H COSY
H
O
Me
OMe
3q'
ppm
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm

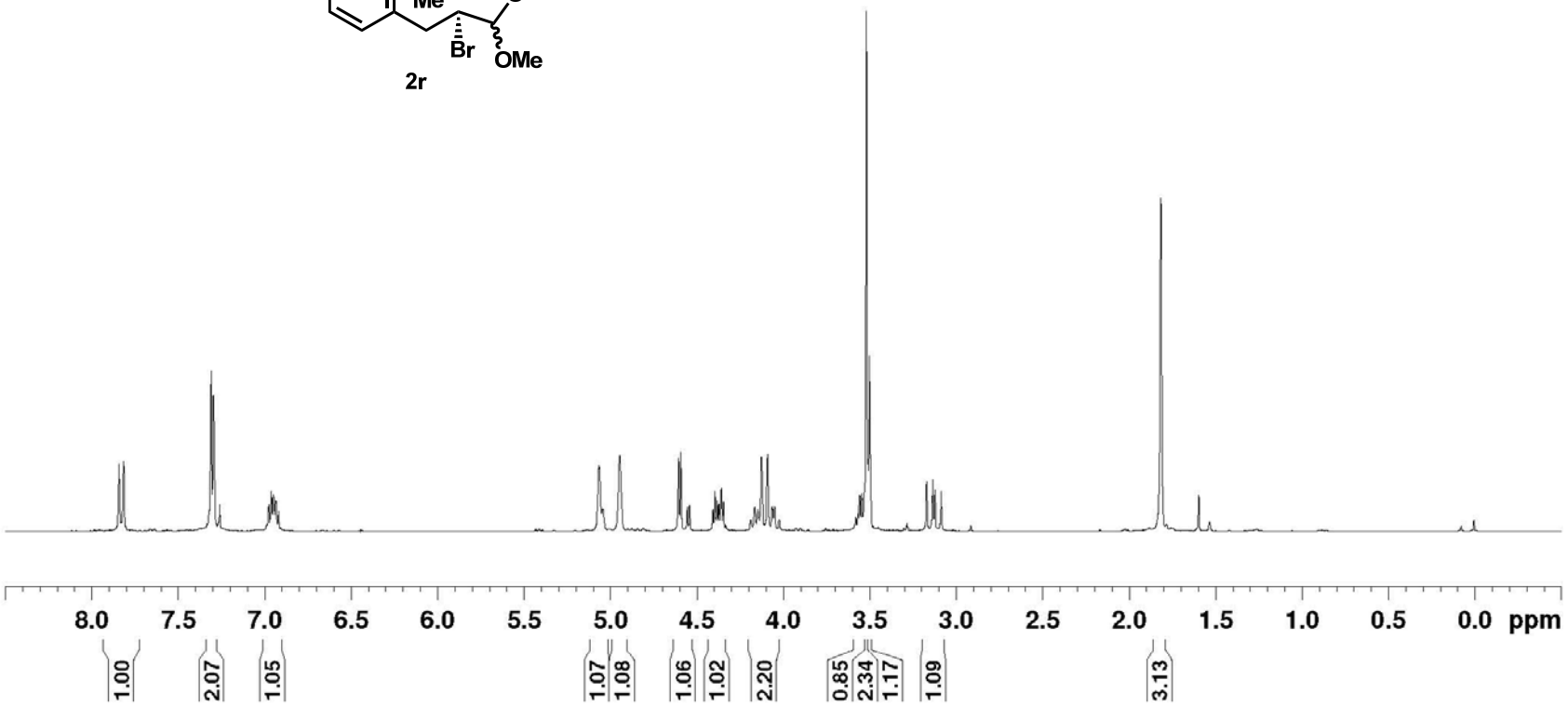

NOESY
H
O
Me
OMe
3q'
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
f1 (ppm)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)

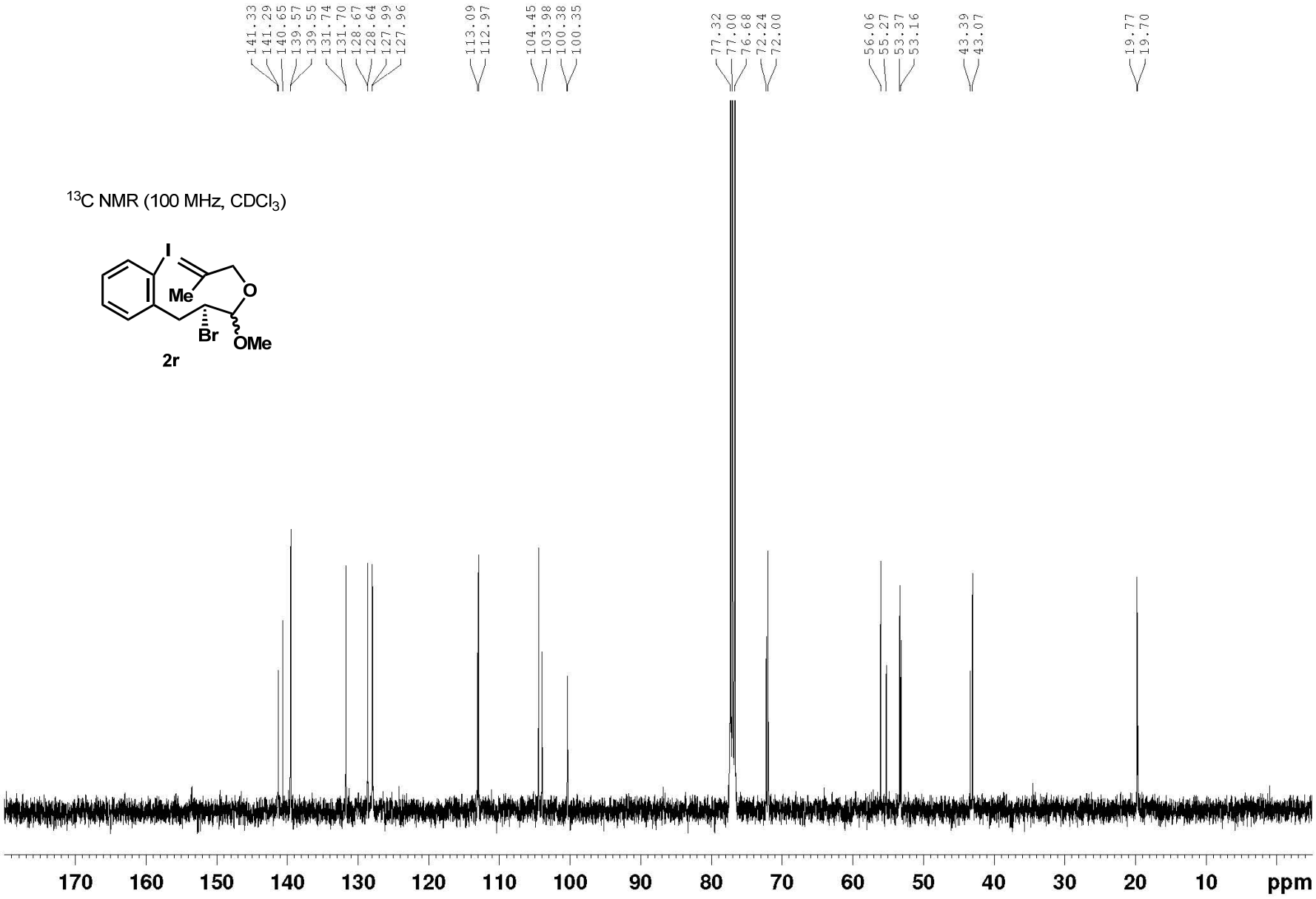


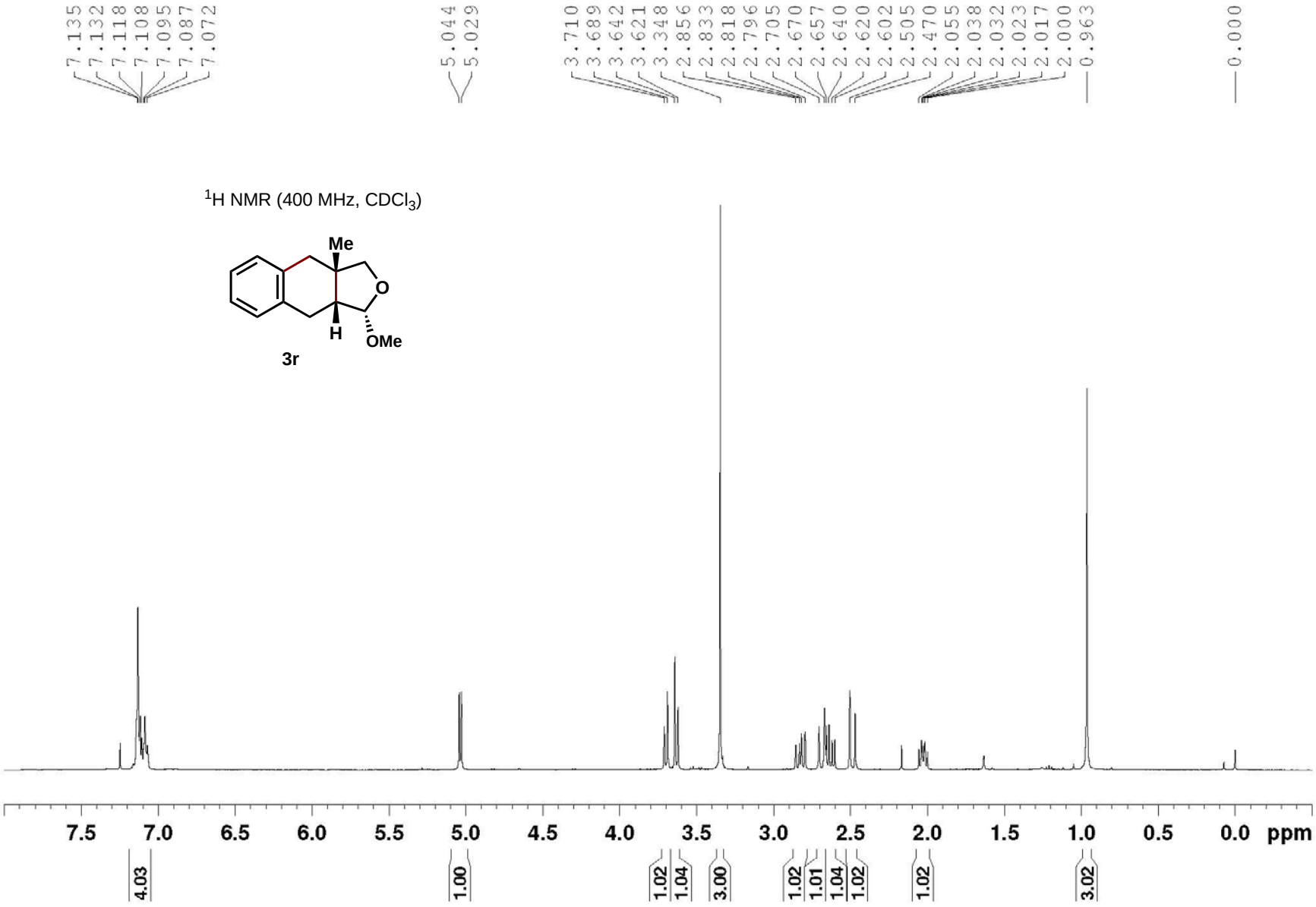

$^1$H NMR (400 MHz, $CDCl_3$)

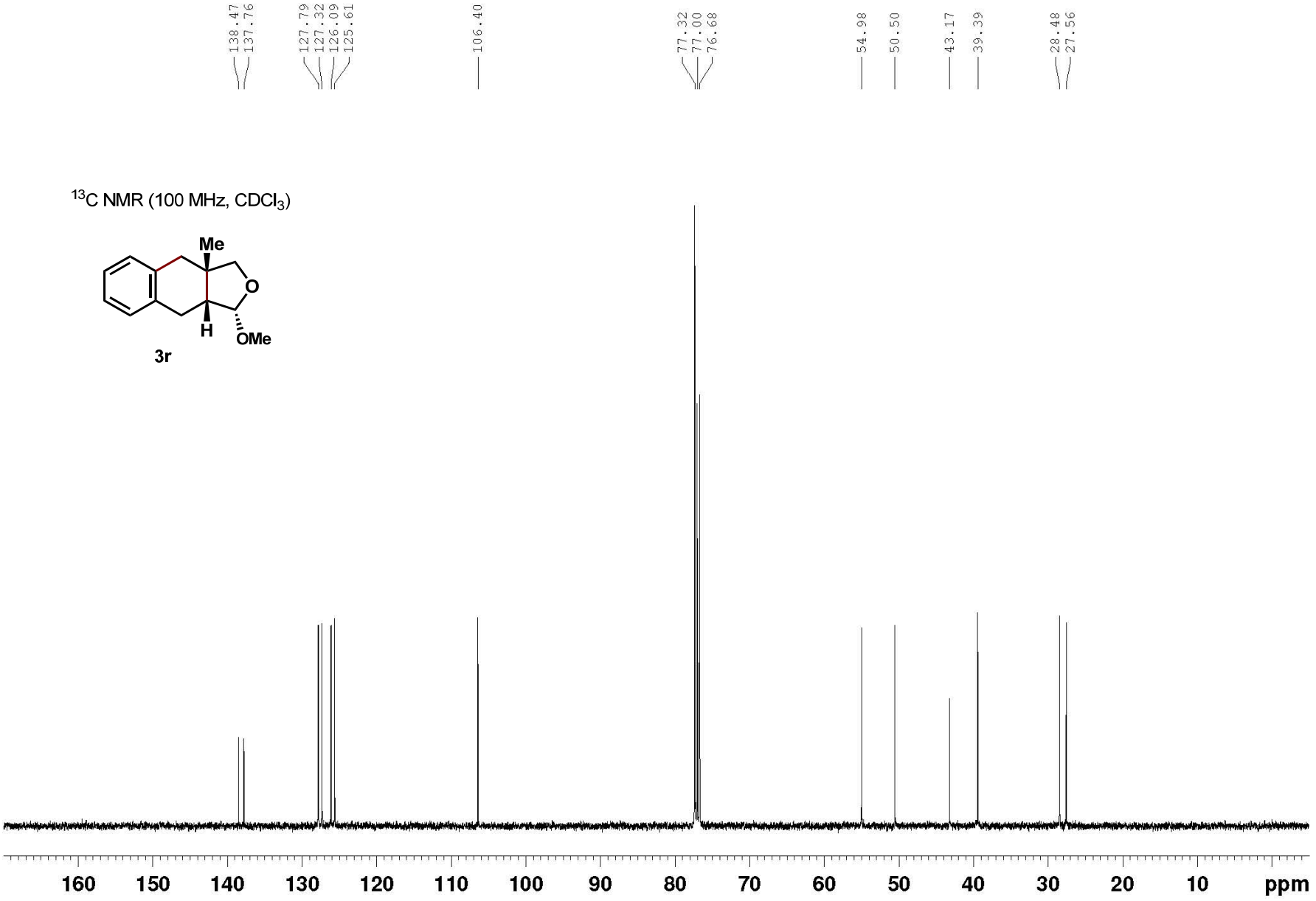


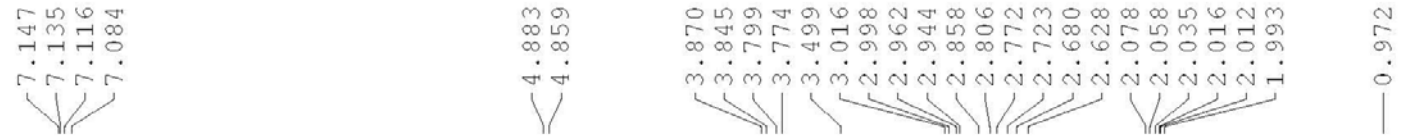

2r



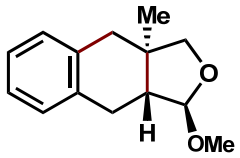

141.33
141.29
140.65
139.57
139.55
131.74
131.70
128.67
128.64
127.99
127.96
113.09
112.97
104.45
103.98
100.38
100.35
77.32
77.00
76.68
72.24
72.00
56.06
55.27
53.37
53.16
43.39
43.07
19.77
19.70
$^{13}$C NMR (100 MHz, $CDCl_3$)
I
Me
O
Br
OMe
2r
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.135
7.132
7.118
7.108
7.095
7.087
7.072
5.044
5.029
3.710
3.689
3.642
3.621
3.348
2.856
2.833
2.818
2.796
2.705
2.670
2.657
2.640
2.620
2.602
2.505
2.470
2.055
2.038
2.032
2.023
2.017
2.000
0.963
0.000
$^1$H NMR (400 MHz, $CDCl_3$)
Me
O
H
OMe
3r
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
4.03
1.00
1.02
1.04
3.00
1.02
1.01
1.04
1.02
1.02
3.02

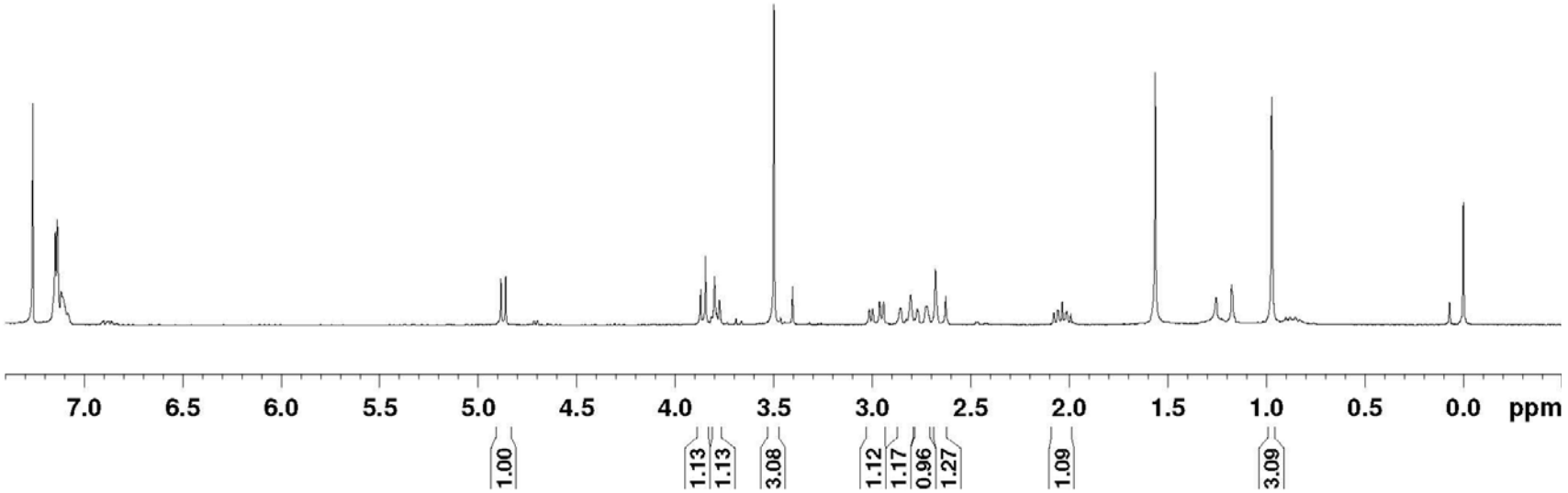

138.47
137.76
127.79
127.32
126.09
125.61
106.40
77.32
77.00
76.68
54.98
50.50
43.17
39.39
28.48
27.56
$^{13}$C NMR (100 MHz, CDCl$_3$)
Me
O
H
OMe
3r
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm



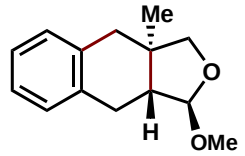

$^1$H NMR (300 MHz, $CDCl_3$)



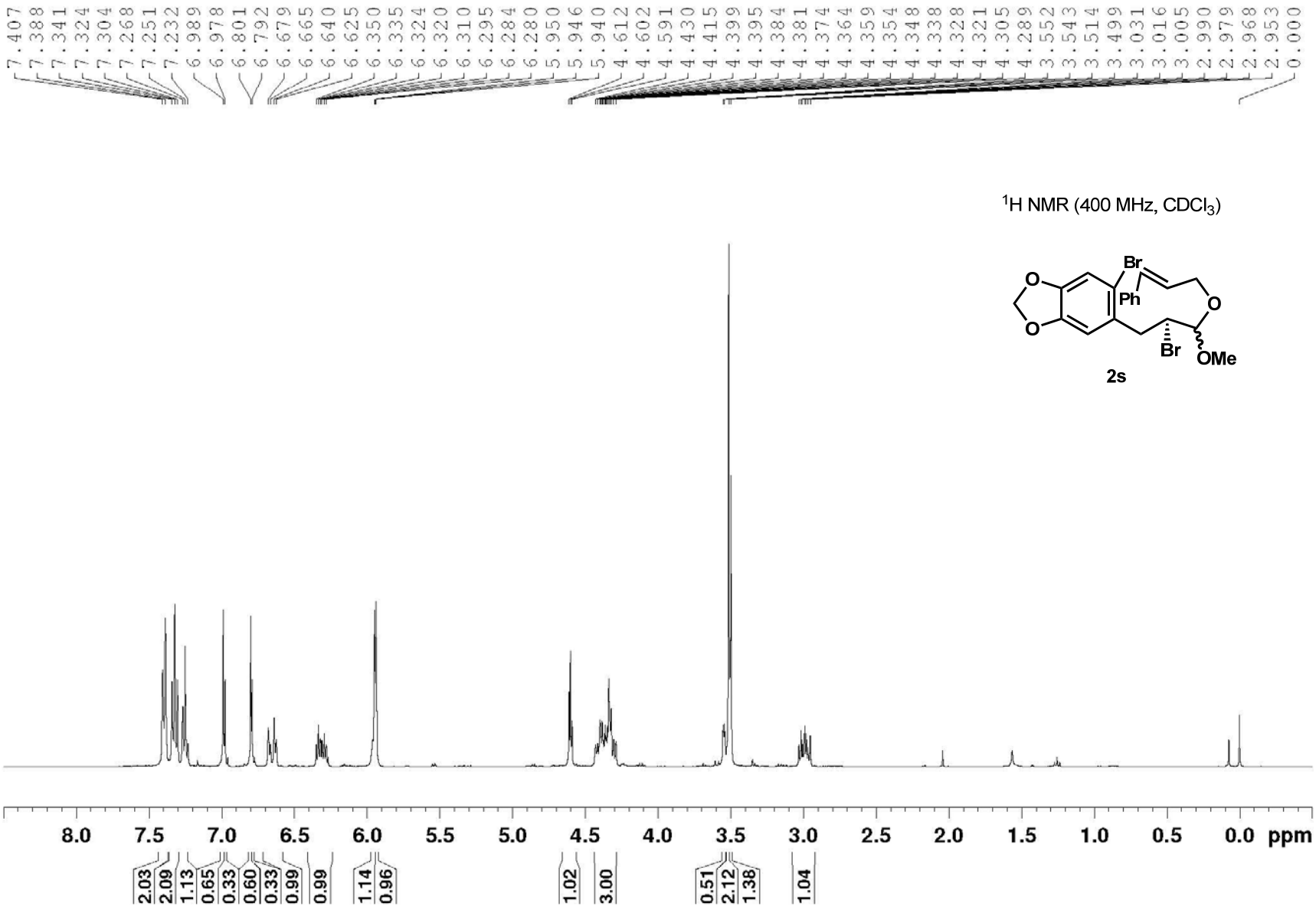

**3r'**

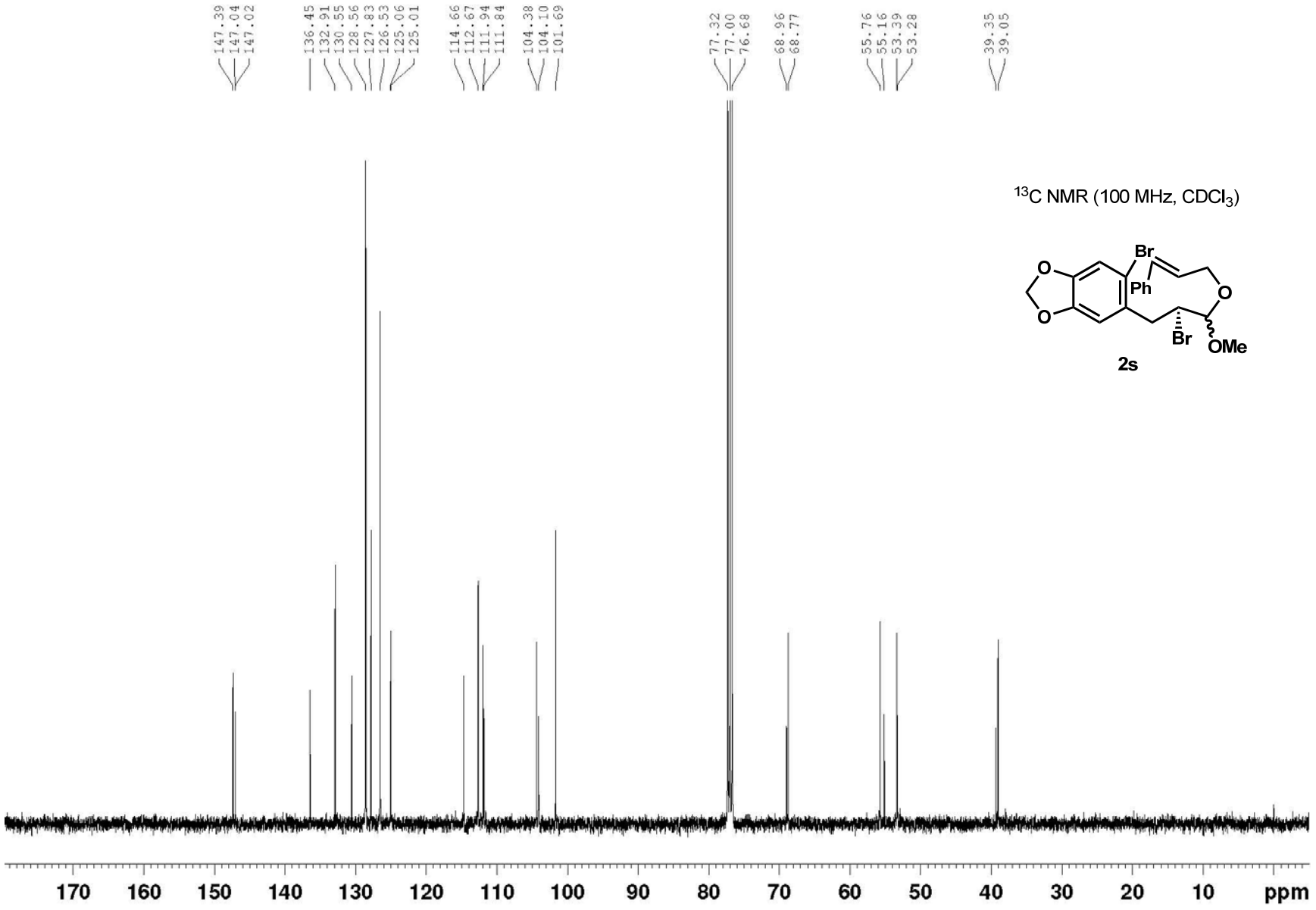


$^{13}$C NMR (100 MHz, $CDCl_3$)




**3r'**

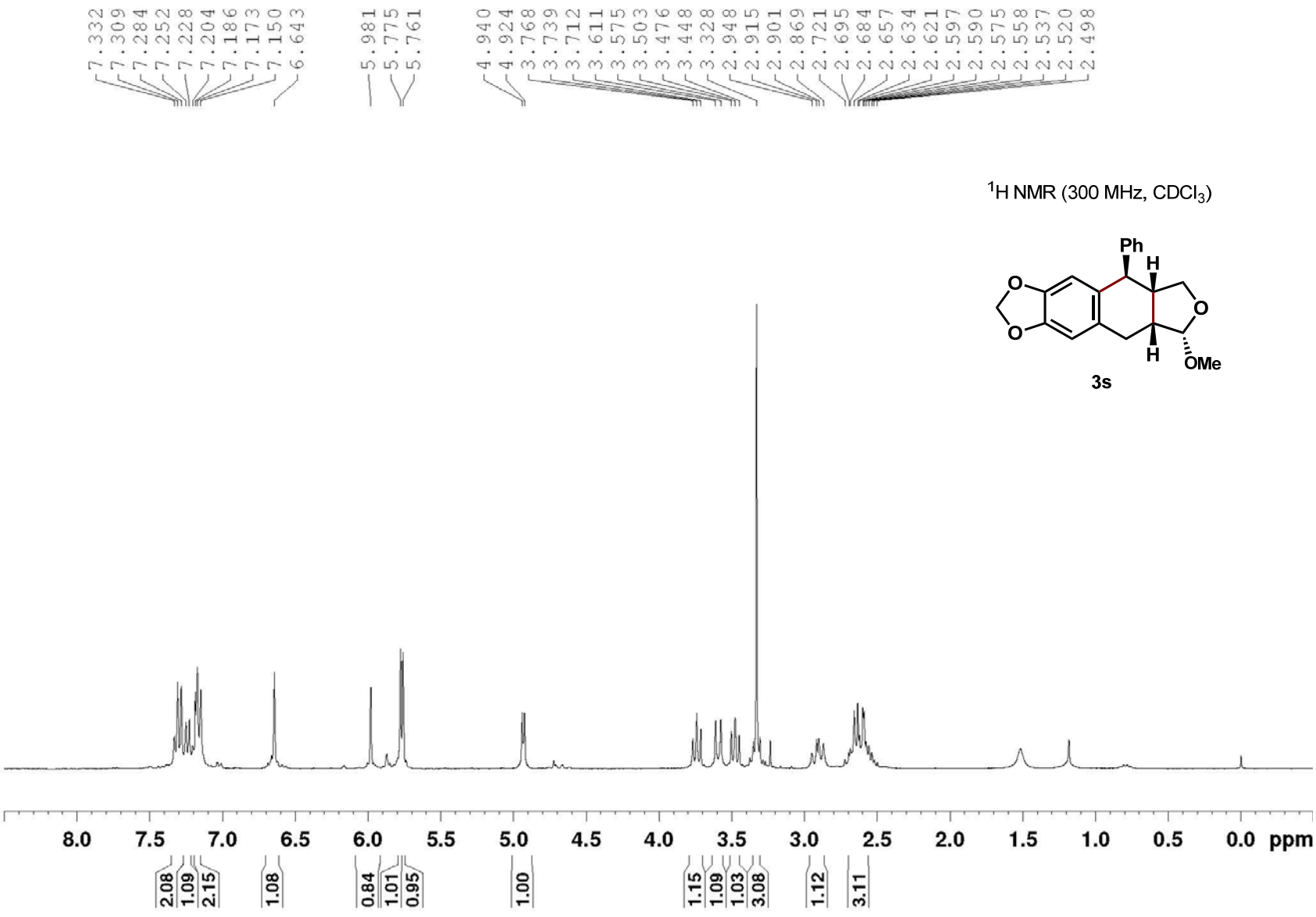

7.407
7.388
7.341
7.324
7.304
7.268
7.251
7.232
6.989
6.978
6.801
6.792
6.679
6.665
6.640
6.625
6.350
6.335
6.324
6.320
6.310
6.295
6.284
6.280
5.950
5.946
5.940
4.612
4.602
4.591
4.430
4.415
4.399
4.395
4.384
4.381
4.374
4.364
4.359
4.354
4.348
4.338
4.328
4.321
4.305
4.289
3.552
3.543
3.514
3.499
3.031
3.016
3.005
2.990
2.979
2.968
2.953
0.000
1H NMR (400 MHz, CDCl3)
Br
O
Ph
O
O
Br
OMe
2s
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.03
2.09
1.13
0.65
0.33
0.60
0.33
0.99
0.99
1.14
0.96
1.02
3.00
0.51
2.12
1.38
1.04

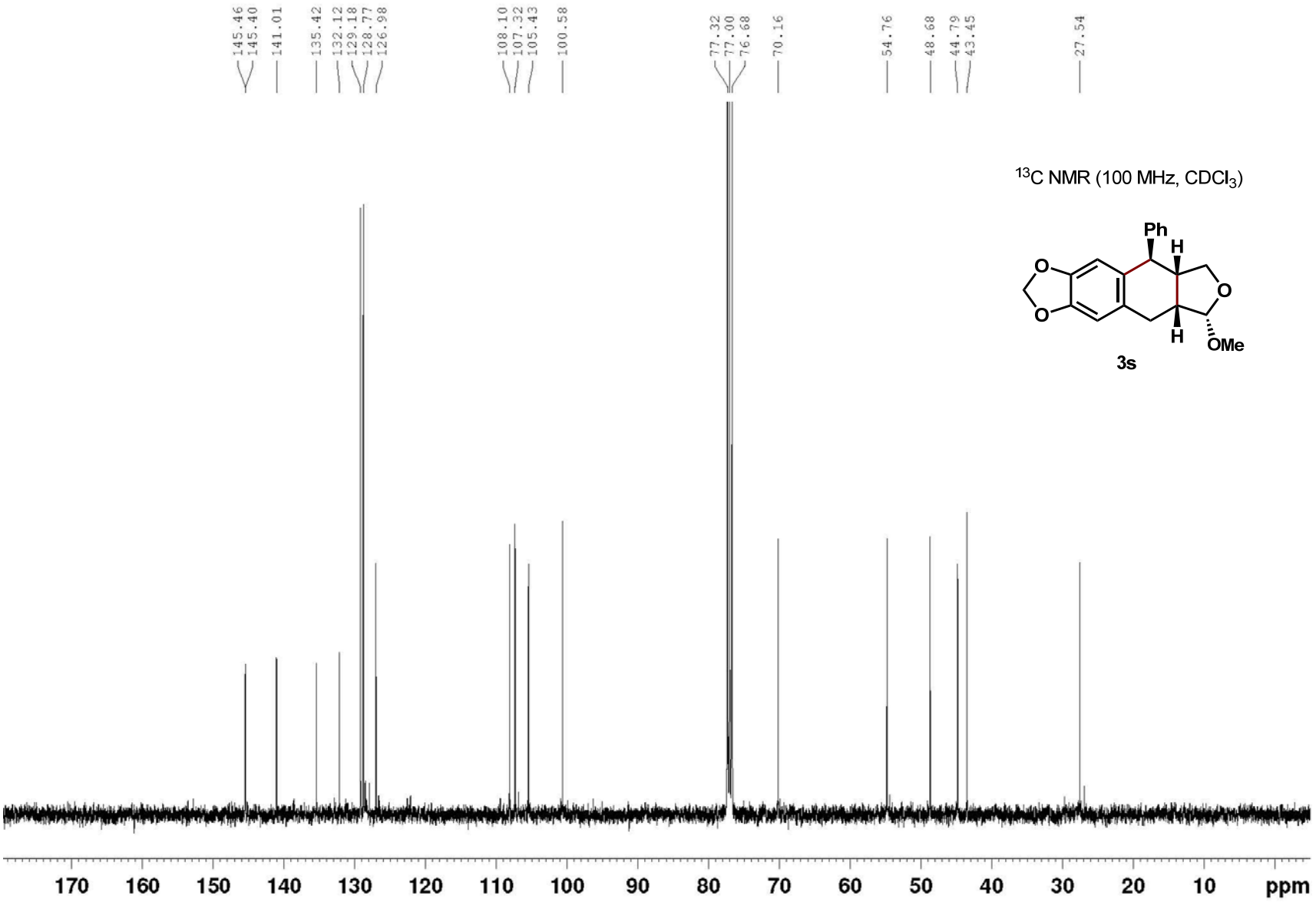



$^{13}$C NMR (100 MHz, $CDCl_3$)

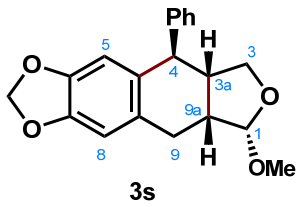



**2s**

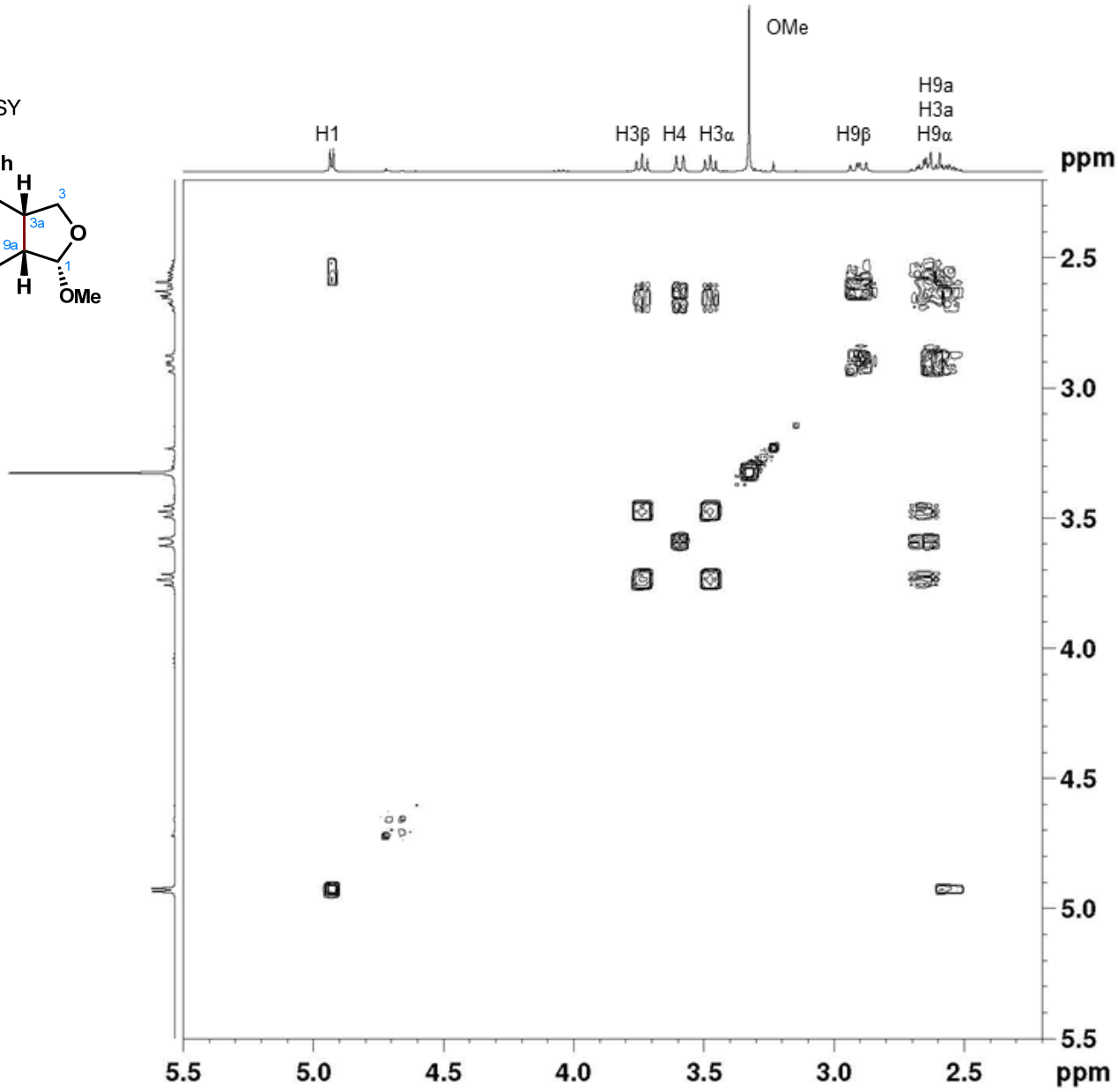

7.332
7.309
7.284
7.252
7.228
7.204
7.186
7.173
7.150
6.643
5.981
5.775
5.761
4.940
4.924
3.768
3.739
3.712
3.611
3.575
3.503
3.476
3.448
3.328
2.948
2.915
2.901
2.869
2.721
2.695
2.684
2.657
2.634
2.621
2.597
2.590
2.575
2.558
2.537
2.520
2.498
$^1$H NMR (300 MHz, $CDCl_3$)
Ph
H
O
O
O
H
OMe
3s
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.08
1.09
2.15
1.08
0.84
1.01
0.95
1.00
1.15
1.09
1.03
3.08
1.12
3.11

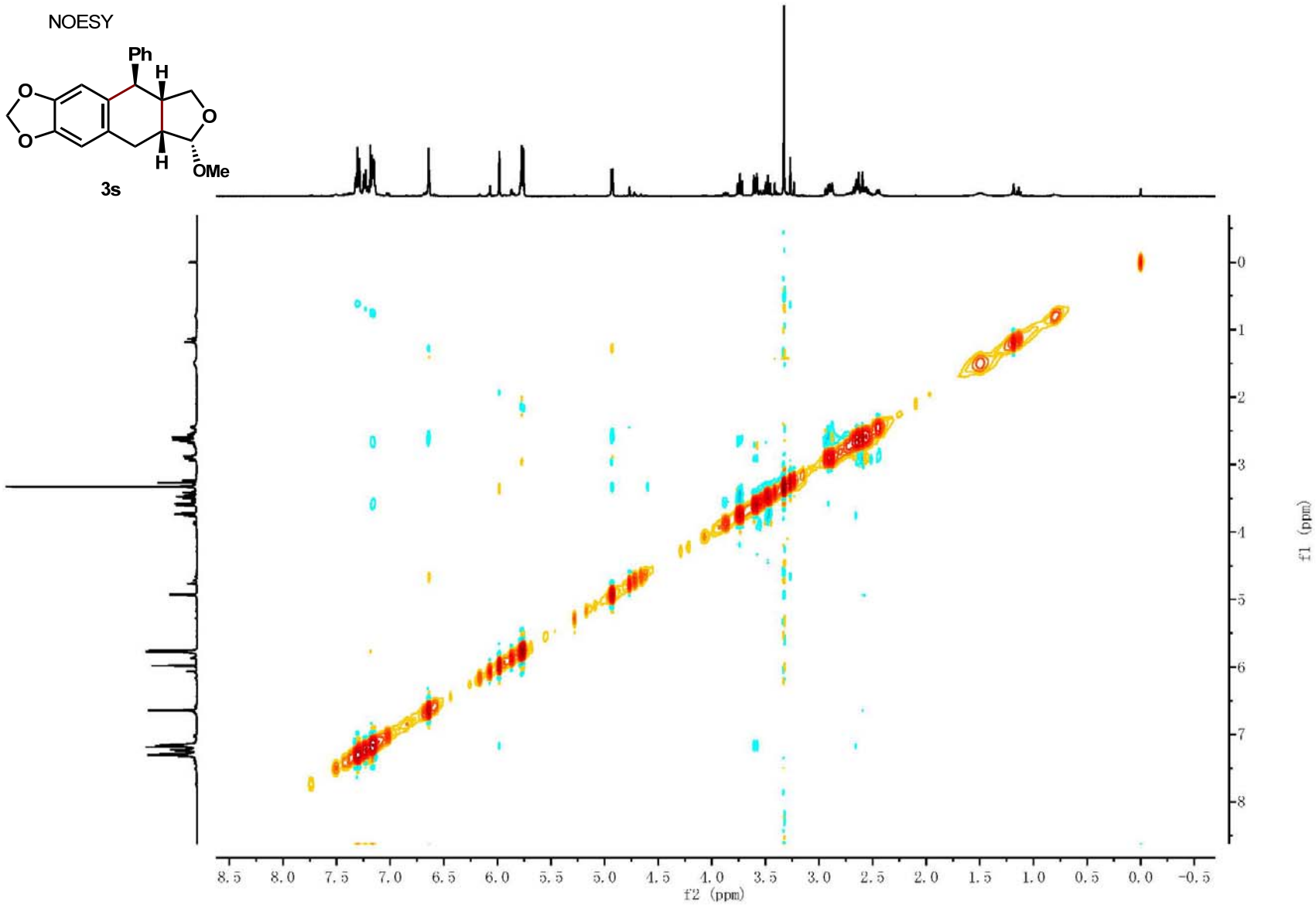

145.46
145.40
141.01
135.42
132.12
129.18
128.77
126.98
108.10
107.32
105.43
100.58
77.32
77.00
76.68
70.16
54.76
48.68
44.79
43.45
27.54
$^{13}$C NMR (100 MHz, CDCl$_3$)
Ph
H
O
O
O
H
OMe
3s
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

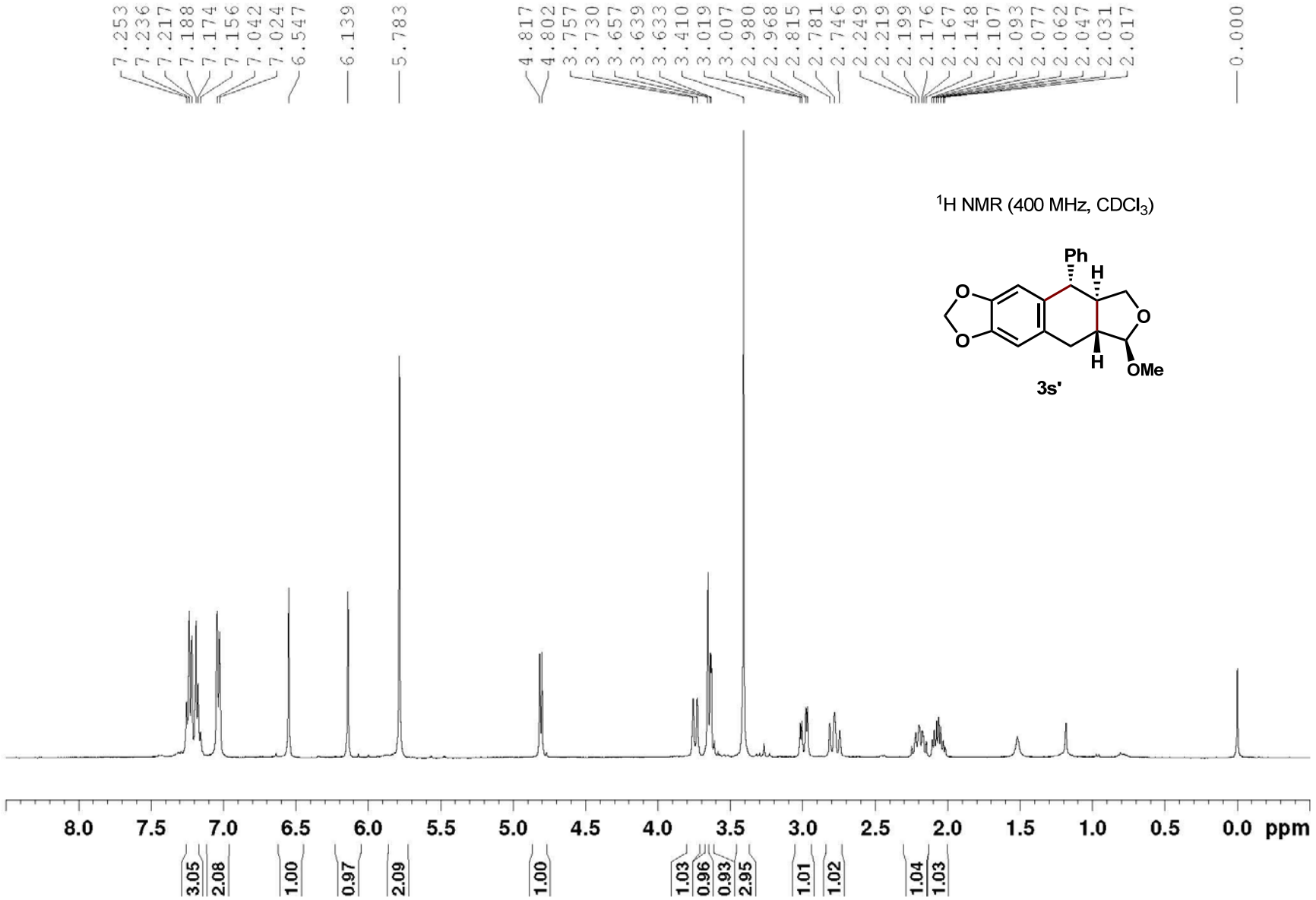
$^1$H –$^1$H COSY

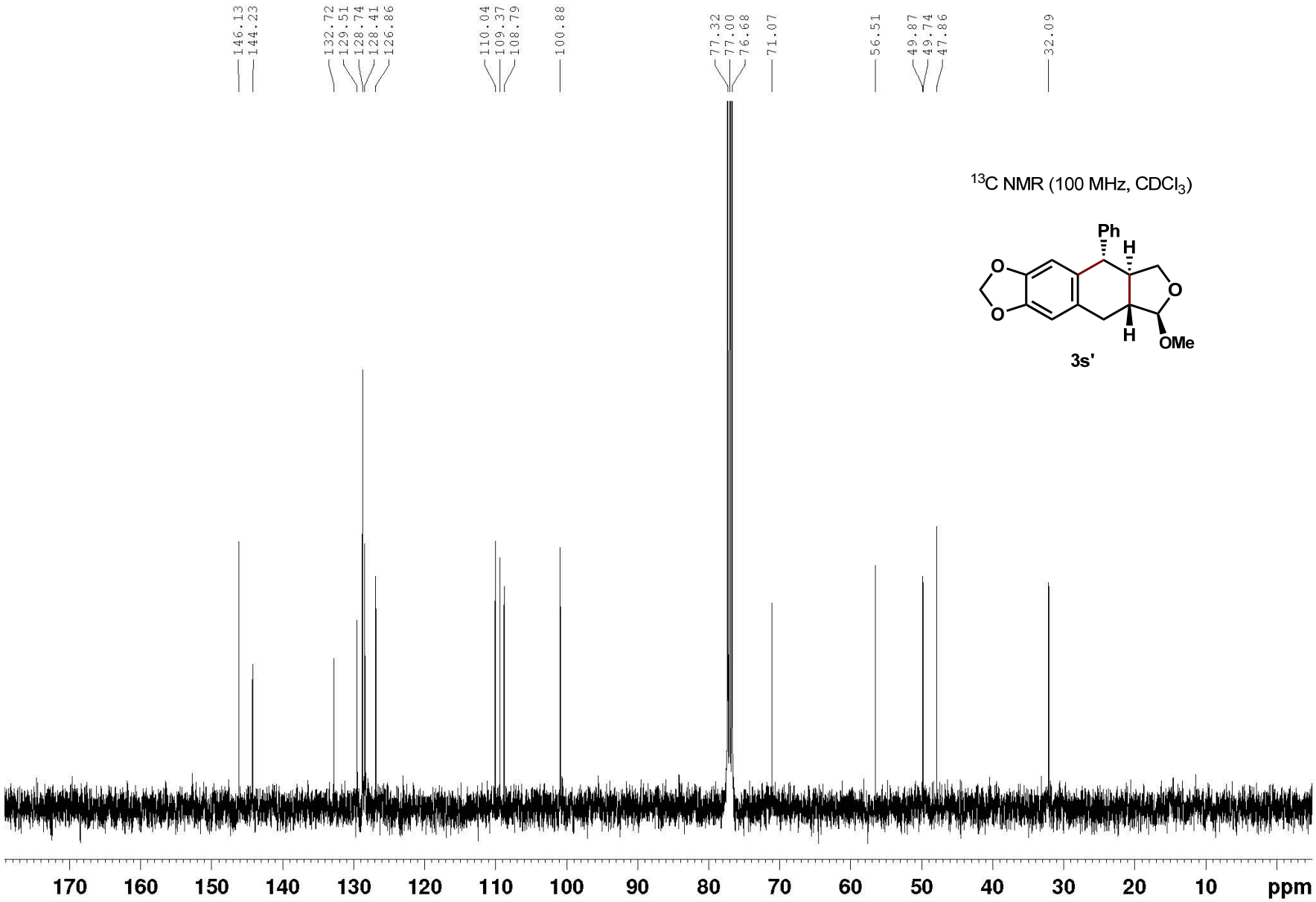

Ph
H
5
4
3
3a
9a
O
O
O
1
8
9
H
OMe

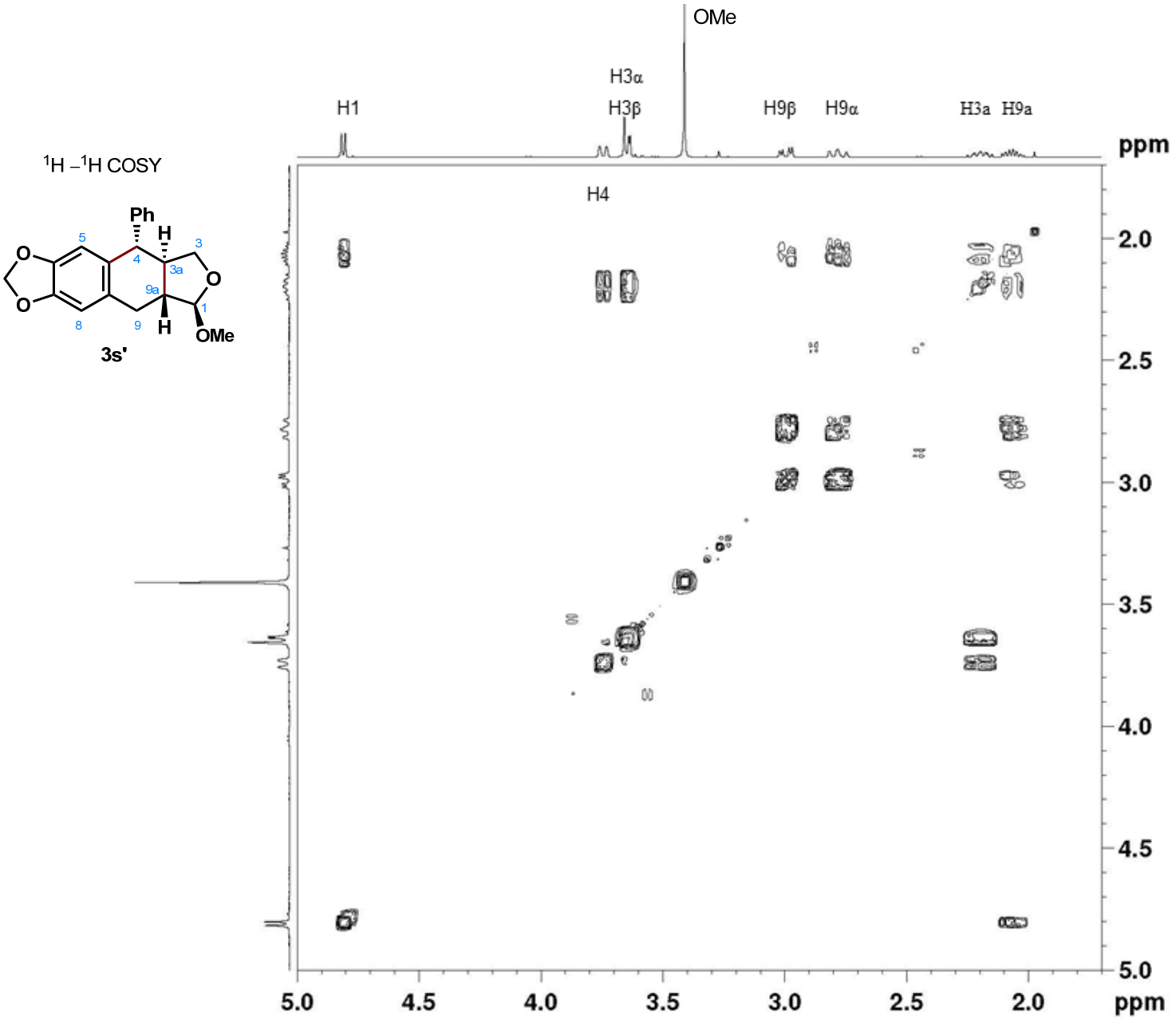
**3s**

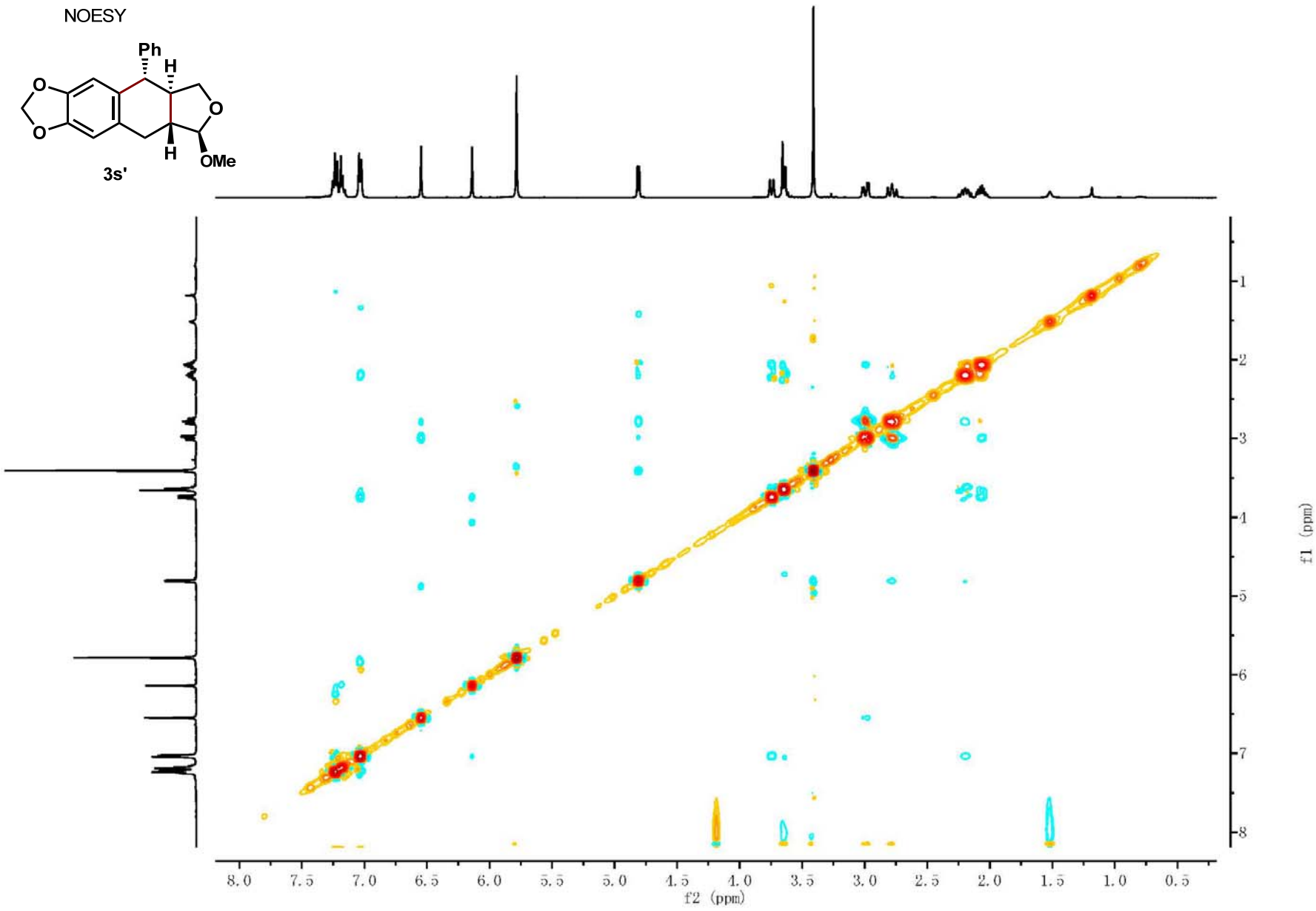

OMe
H9a
H3a
H9α
H1
H3β
H4
H3α
H9β
ppm
2.5
3.0
3.5
4.0
4.5
5.0
5.5
5.5
5.0
4.5
4.0
3.5
3.0
2.5
ppm

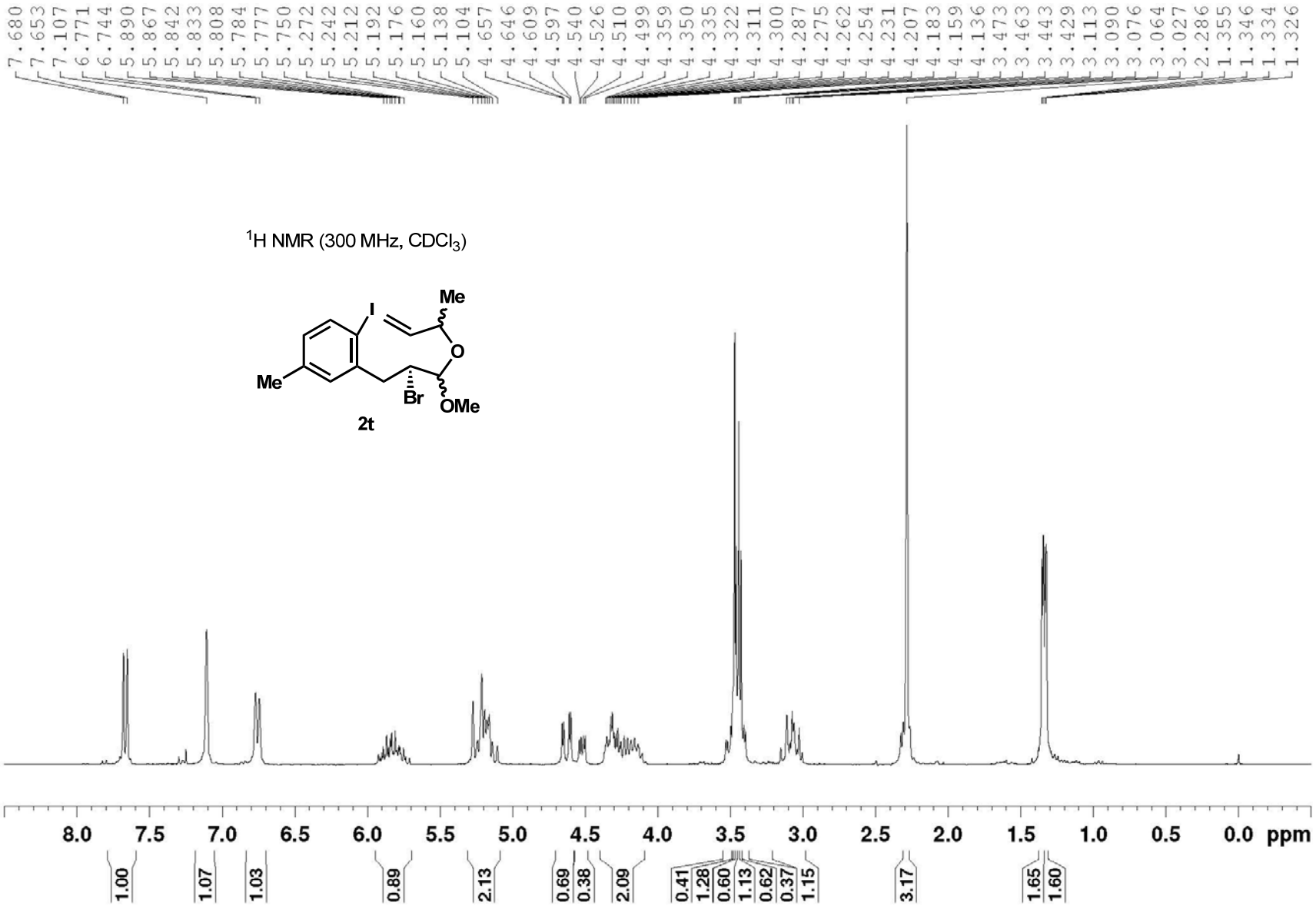

NOESY
Ph
H
O
O
O
H
OMe
3s
f2 (ppm)
f1 (ppm)

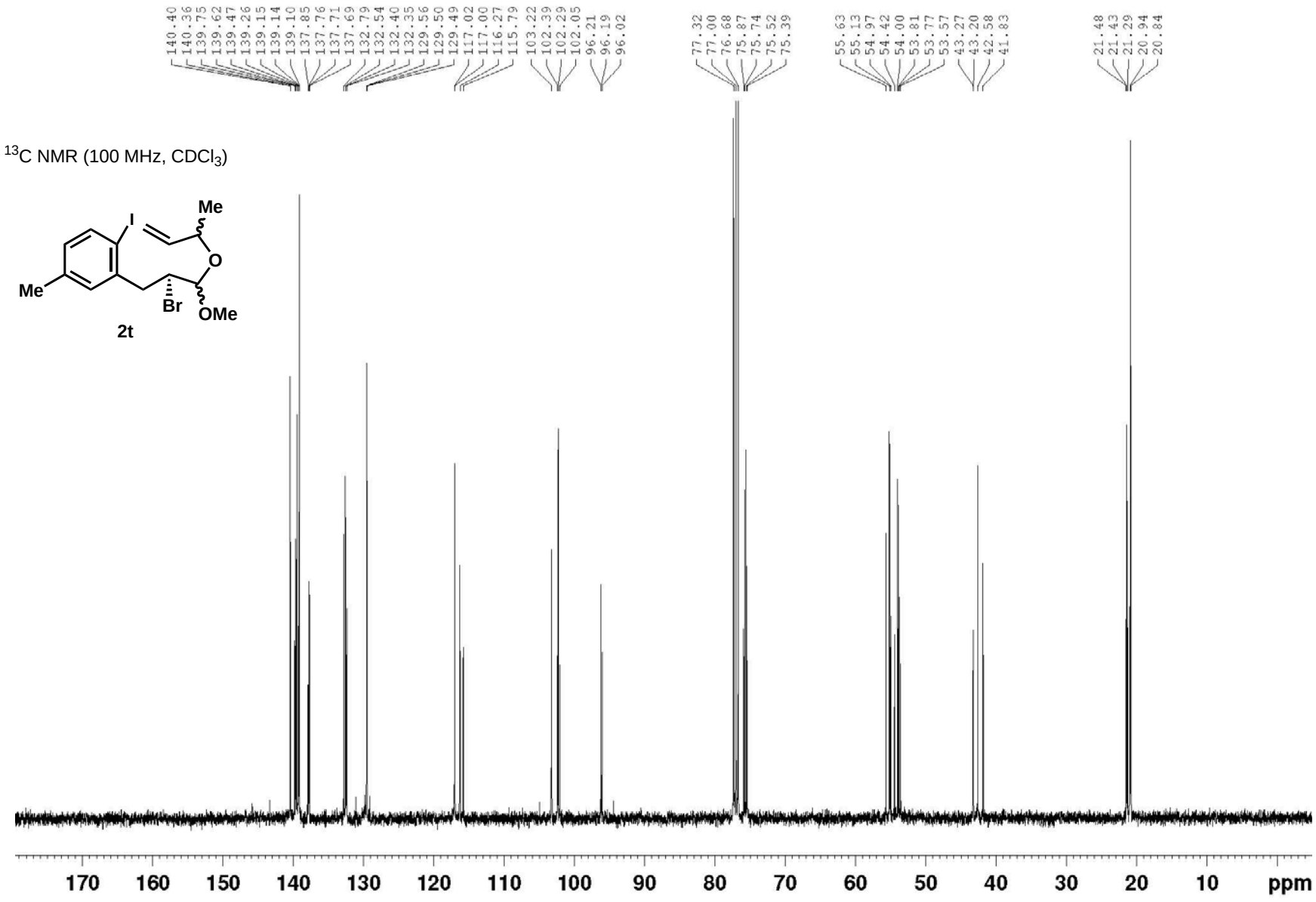

7.253
7.236
7.217
7.188
7.174
7.156
7.042
7.024
6.547
6.139
5.783
4.817
4.802
3.757
3.730
3.657
3.639
3.633
3.410
3.019
3.007
2.980
2.968
2.815
2.781
2.746
2.249
2.219
2.199
2.176
2.167
2.148
2.107
2.093
2.077
2.062
2.047
2.031
2.017
0.000
$^1$H NMR (400 MHz, CDCl$_3$)
Ph
H
O
O
O
H
OMe
3s'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.05
2.08
1.00
0.97
2.09
1.00
1.03
0.96
0.93
2.95
1.01
1.02
1.04
1.03

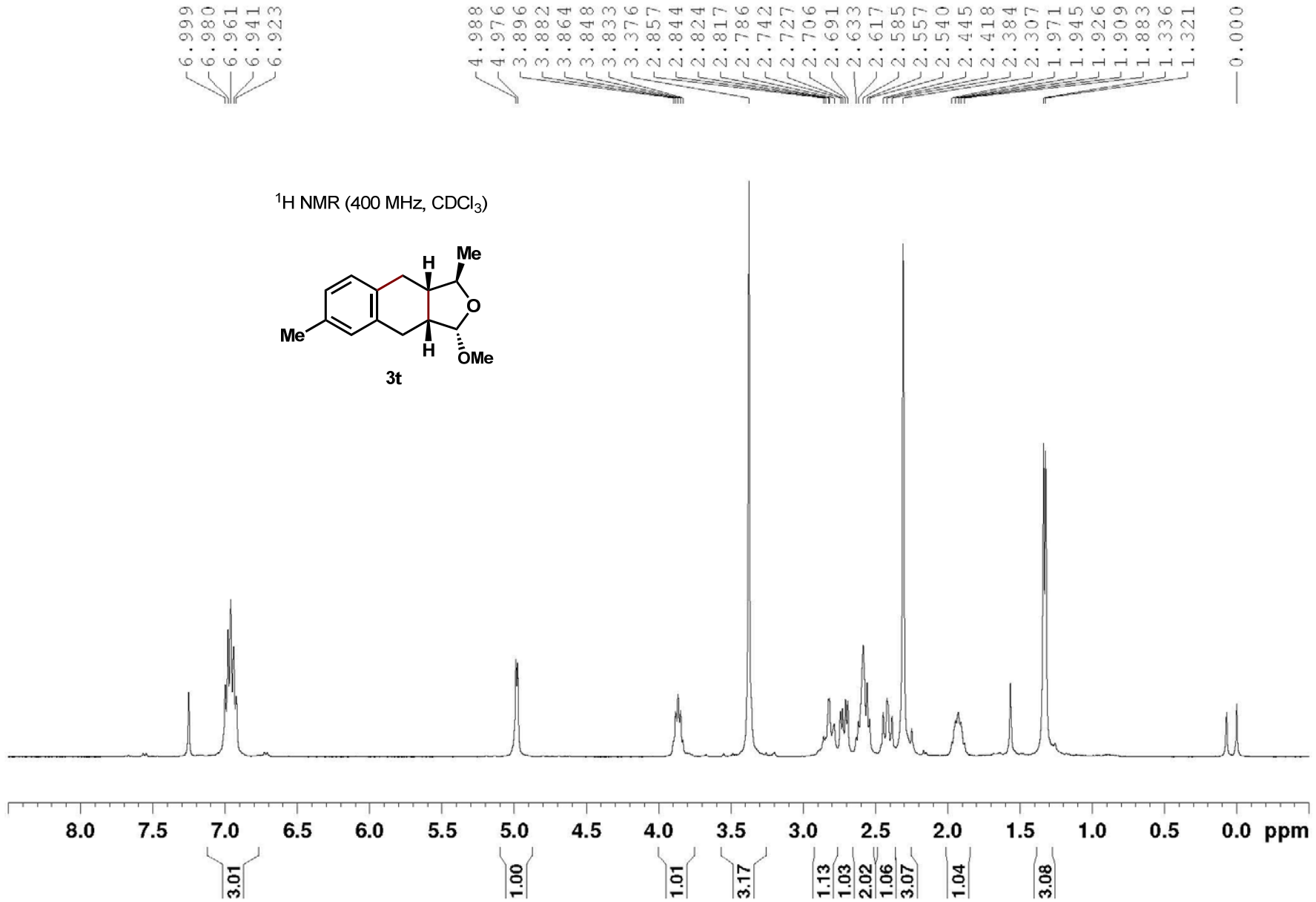

146.13
144.23
132.72
129.51
128.74
128.41
126.86
110.04
109.37
108.79
100.88
77.32
77.00
76.68
71.07
56.51
49.87
49.74
47.86
32.09
$^{13}$C NMR (100 MHz, $CDCl_3$)
Ph
H
O
O
O
H
OMe
3s'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

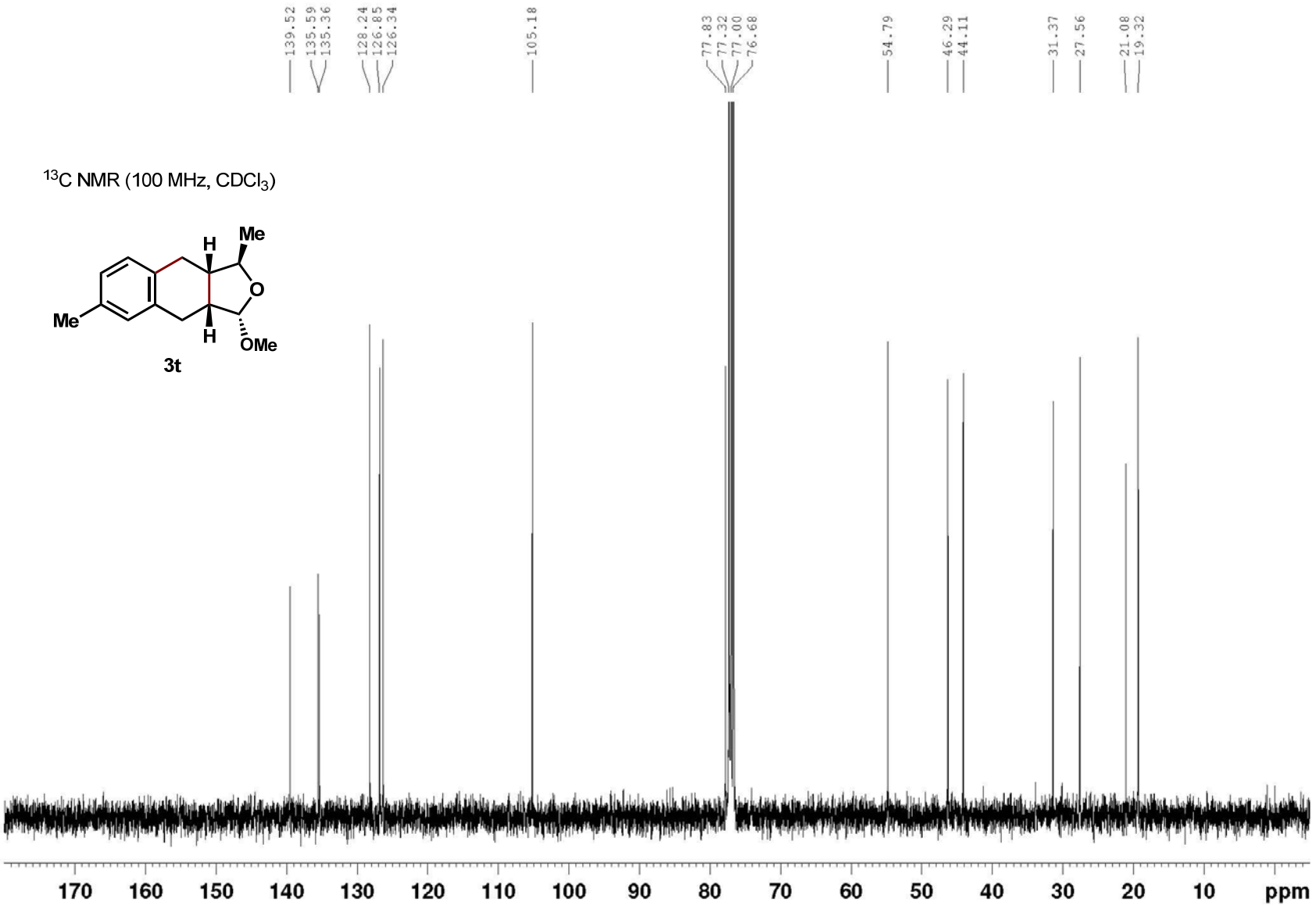

$^1$H –$^1$H COSY
Ph
H
5
4
3
3a
9a
1
8
9
H
OMe
3s'
OMe
H3α
H1
H3β
H9β
H9α
H3a
H9a
H4
ppm
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
ppm


NOESY
Ph
H
O
O
O
H
OMe
3s'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
1
2
3
4
5
6
7
8
f1 (ppm)

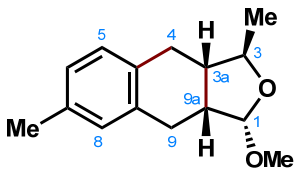

7.680
7.653
7.107
6.771
6.744
5.890
5.867
5.842
5.833
5.808
5.784
5.777
5.750
5.272
5.242
5.212
5.192
5.176
5.160
5.138
5.104
4.657
4.646
4.609
4.597
4.540
4.526
4.510
4.499
4.359
4.350
4.335
4.322
4.311
4.300
4.287
4.275
4.262
4.254
4.231
4.207
4.183
4.159
4.136
3.473
3.463
3.443
3.429
3.113
3.090
3.076
3.064
3.027
2.286
1.355
1.346
1.334
1.326
$^1$H NMR (300 MHz, CDCl$_3$)
Me
I
O
Me
Br
OMe
2t
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.07
1.03
0.89
2.13
0.69
0.38
2.09
0.41
1.28
0.60
1.13
0.62
0.37
1.15
3.17
1.65
1.60


140.40
140.36
139.75
139.62
139.47
139.26
139.15
139.14
139.10
137.85
137.76
137.71
137.69
132.79
132.54
132.40
132.35
129.56
129.50
129.49
117.02
117.00
116.27
115.79
103.22
102.39
102.29
102.05
96.21
96.19
96.02
77.32
77.00
76.68
75.87
75.74
75.52
75.39
55.63
55.13
54.97
54.42
54.00
53.81
53.77
53.57
43.27
43.20
42.58
41.83
21.48
21.43
21.29
20.94
20.84
$^{13}$C NMR (100 MHz, CDCl$_3$)
Me
I
O
Me
Br
OMe
2t
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

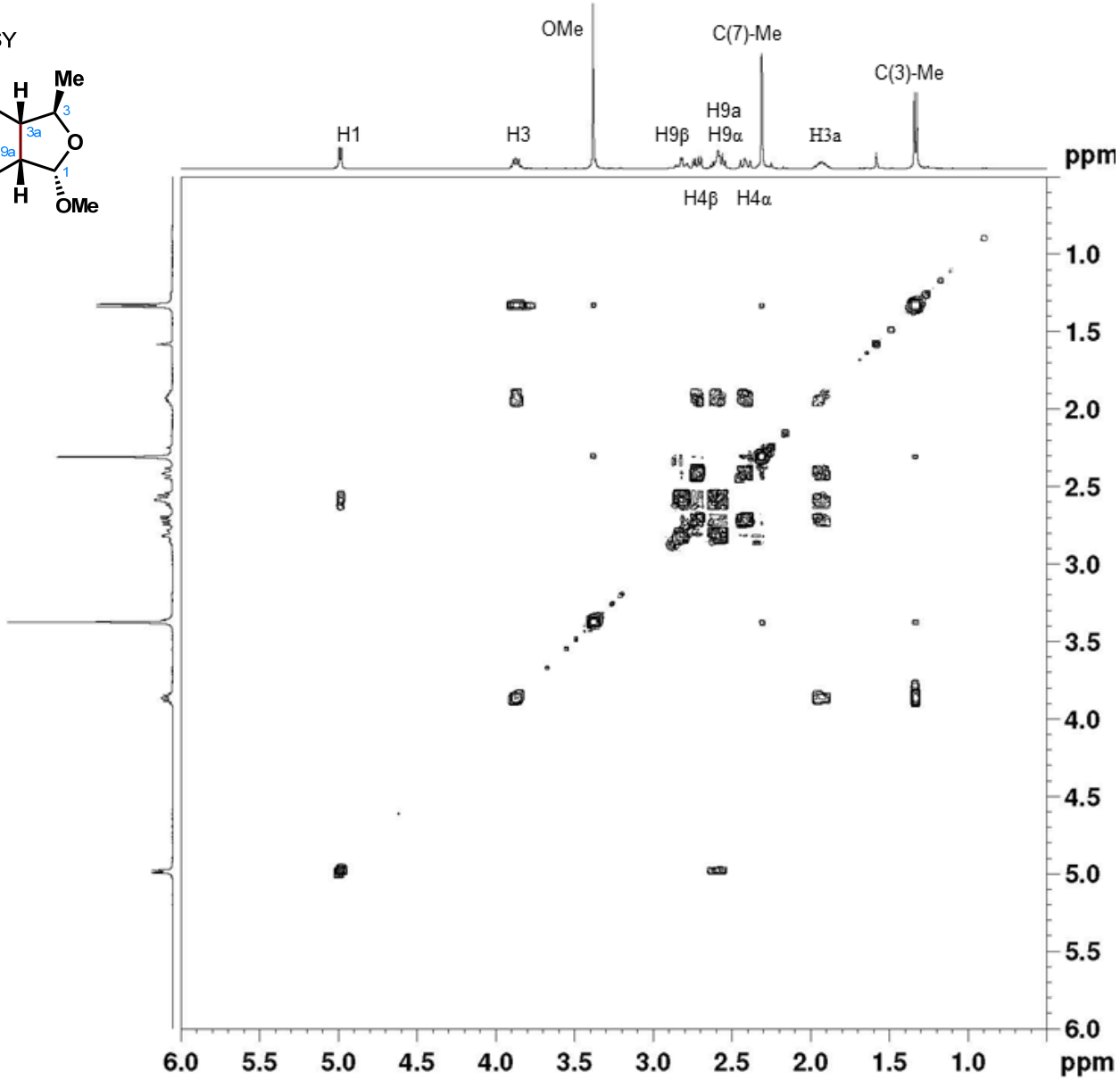

6.999
6.980
6.961
6.941
6.923
4.988
4.976
3.896
3.882
3.864
3.848
3.833
3.376
2.857
2.844
2.824
2.817
2.786
2.742
2.727
2.706
2.691
2.633
2.617
2.585
2.557
2.540
2.445
2.418
2.384
2.307
1.971
1.945
1.926
1.909
1.883
1.336
1.321
0.000
$^1$H NMR (400 MHz, $CDCl_3$)
Me
H
O
Me
H
OMe
3t
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.01
1.00
1.01
3.17
1.13
1.03
2.02
1.06
3.07
1.04
3.08

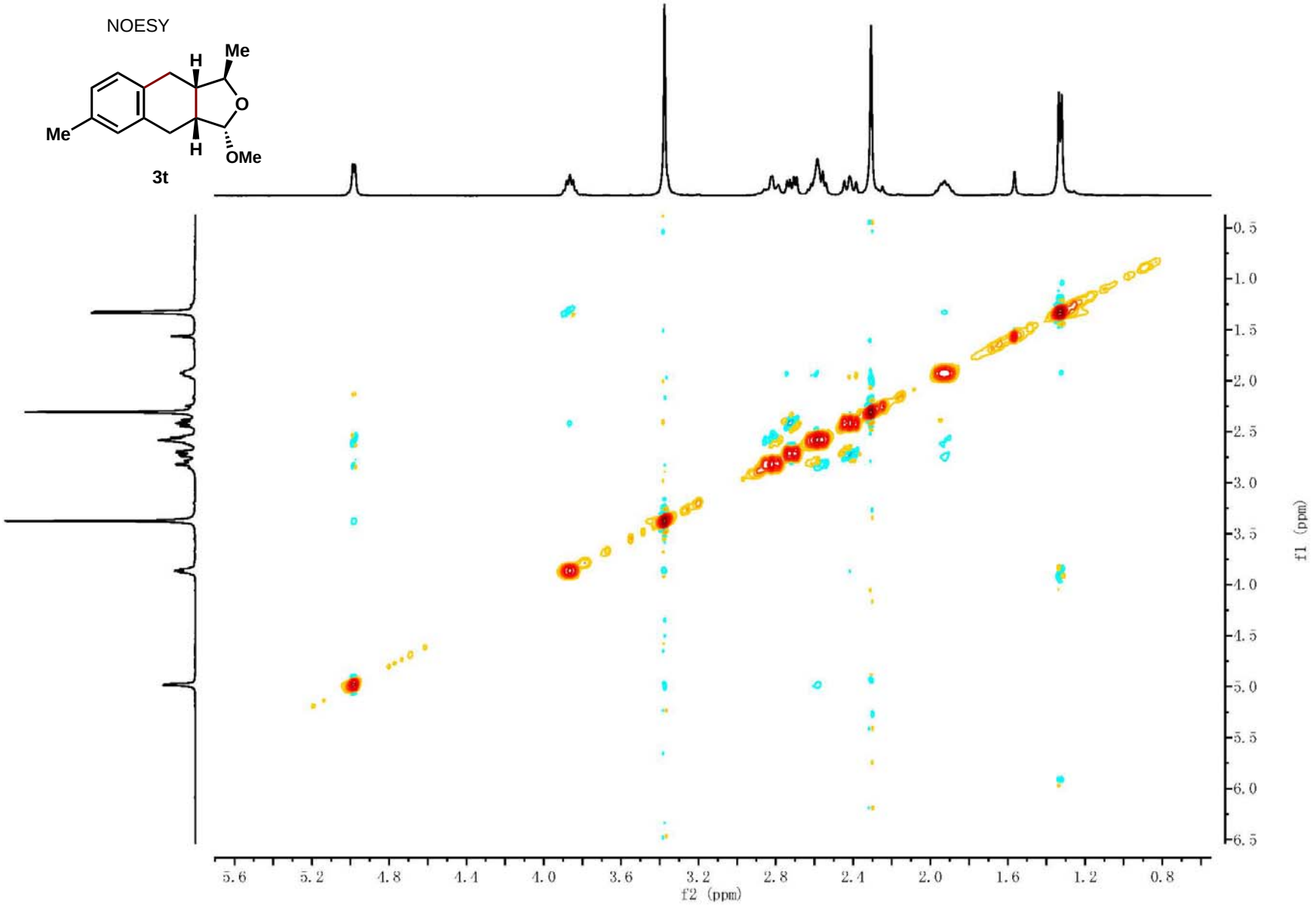

139.52
135.59
135.36
128.24
126.85
126.34
105.18
77.83
77.32
77.00
76.68
54.79
46.29
44.11
31.37
27.56
21.08
19.32
$^{13}$C NMR (100 MHz, $CDCl_3$)
Me
H
O
Me
H
OMe
3t
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

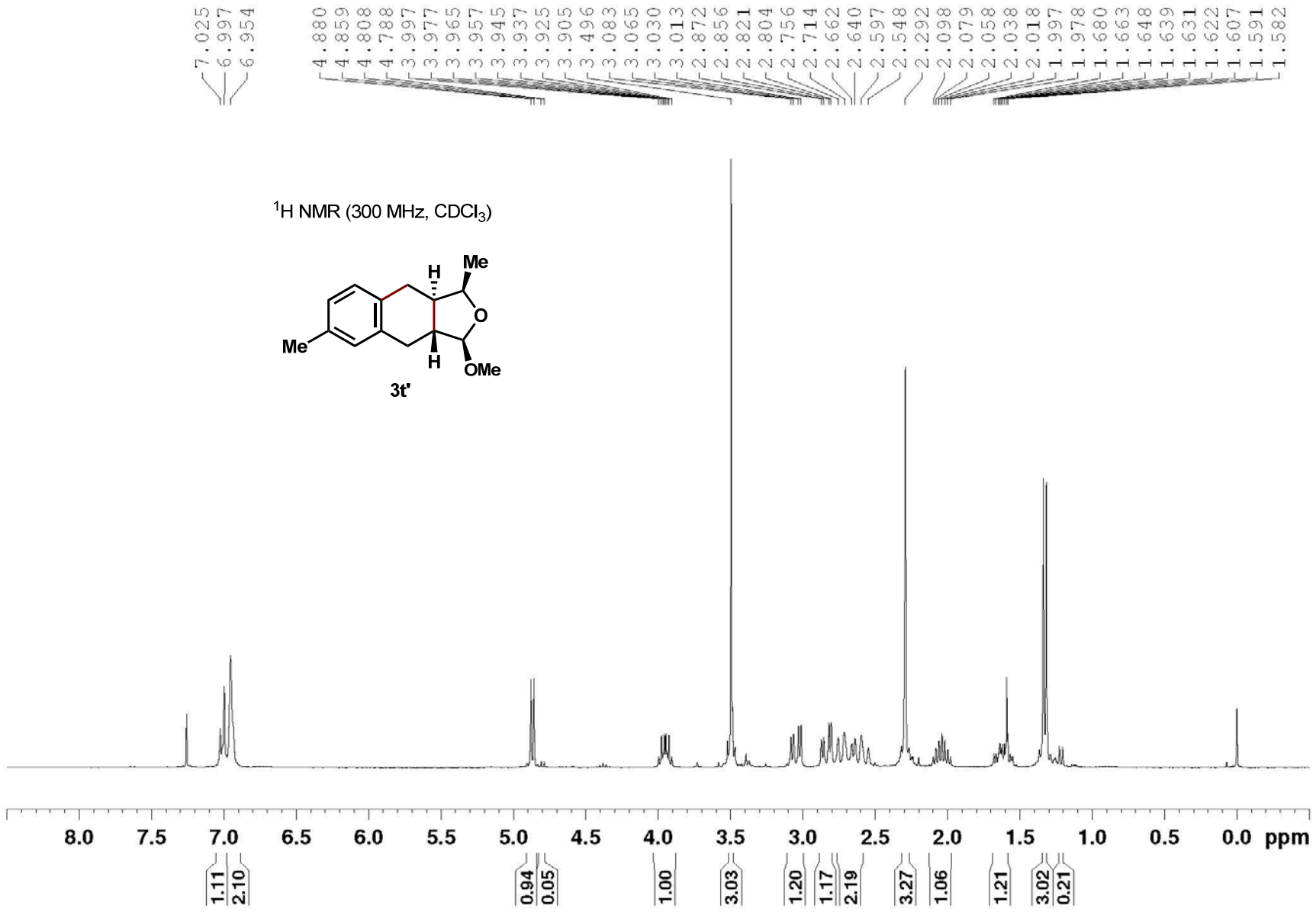
$^1$H –$^1$H COSY

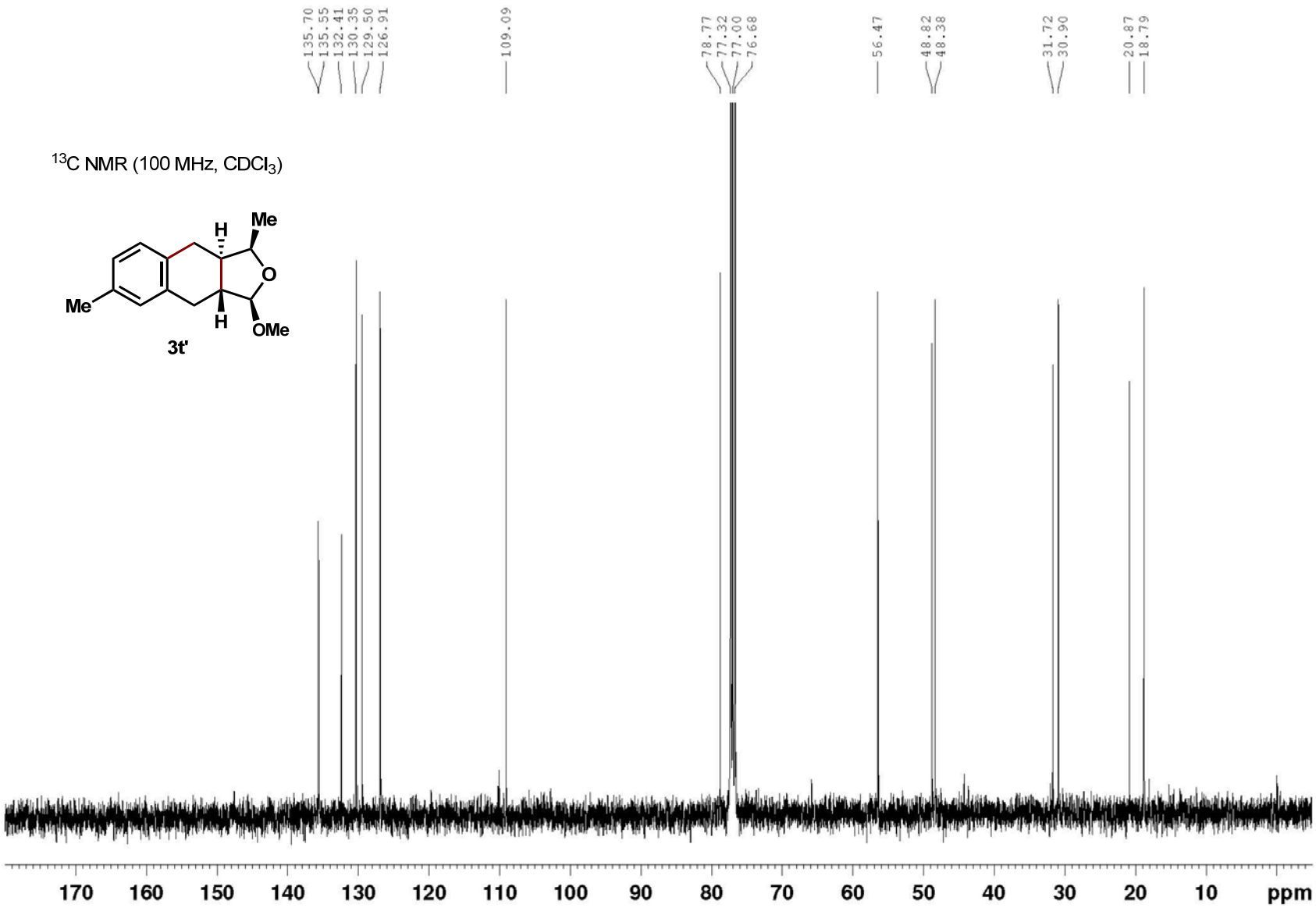

Me
H
5
4
3
3a
9a
O
1
Me
8
9
H
OMe

**3t**

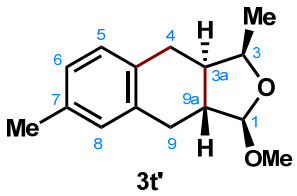

OMe
C(7)-Me
C(3)-Me
H9a
H1
H3
H9β
H9α
H3a
ppm
H4β
H4α
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm


NOESY
H
Me
O
Me
H
OMe
3t
f2 (ppm)
f1 (ppm)

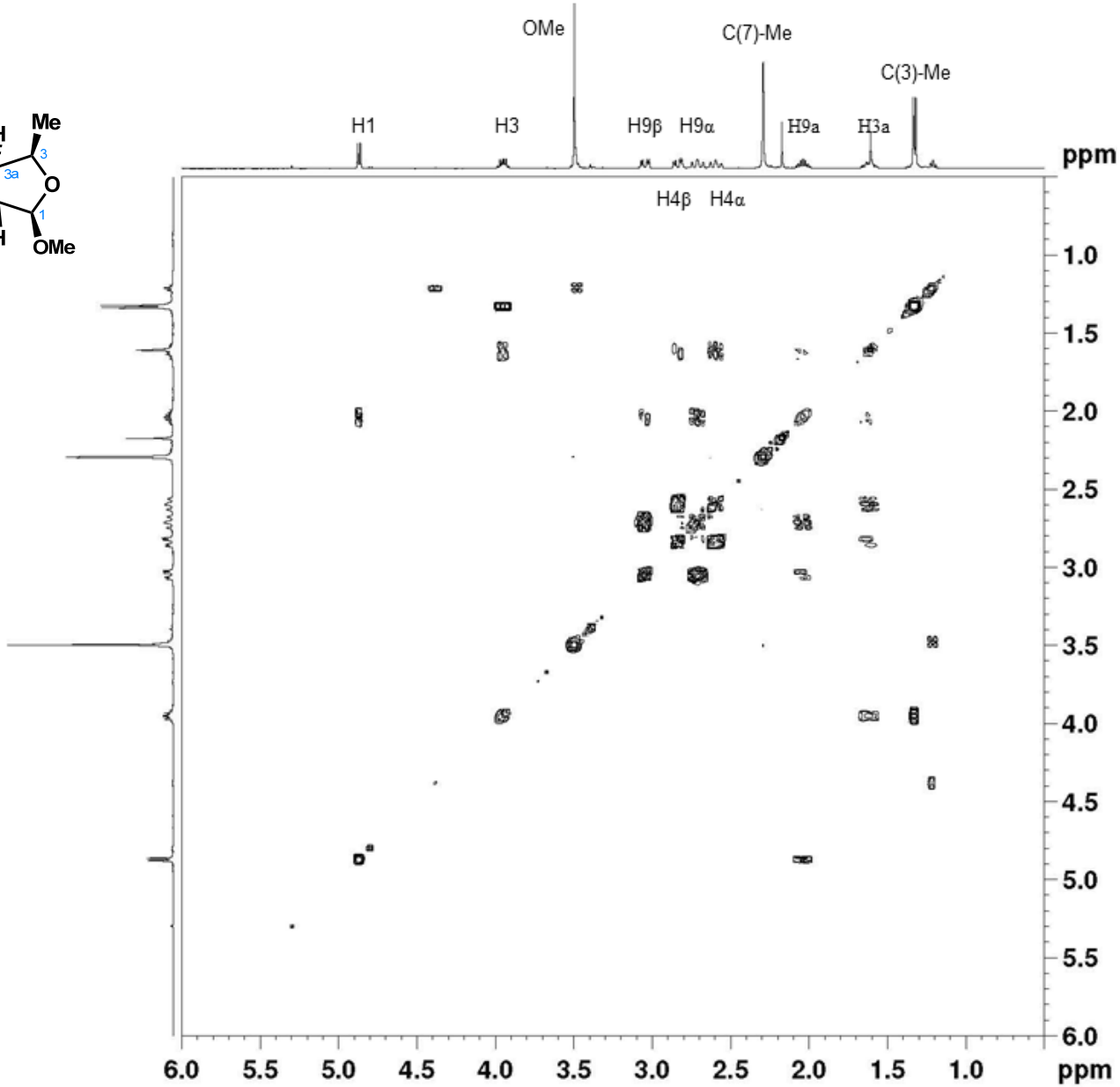

7.025
6.997
6.954
4.880
4.859
4.808
4.788
3.997
3.977
3.965
3.957
3.945
3.937
3.925
3.905
3.496
3.083
3.065
3.030
3.013
2.872
2.856
2.821
2.804
2.756
2.714
2.662
2.640
2.597
2.548
2.292
2.098
2.079
2.058
2.038
2.018
1.997
1.978
1.680
1.663
1.648
1.639
1.631
1.622
1.607
1.591
1.582
$^1$H NMR (300 MHz, CDCl$_3$)
Me
H
O
Me
H
OMe
3t'
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.11
2.10
0.94
0.05
1.00
3.03
1.20
1.17
2.19
3.27
1.06
1.21
3.02
0.21

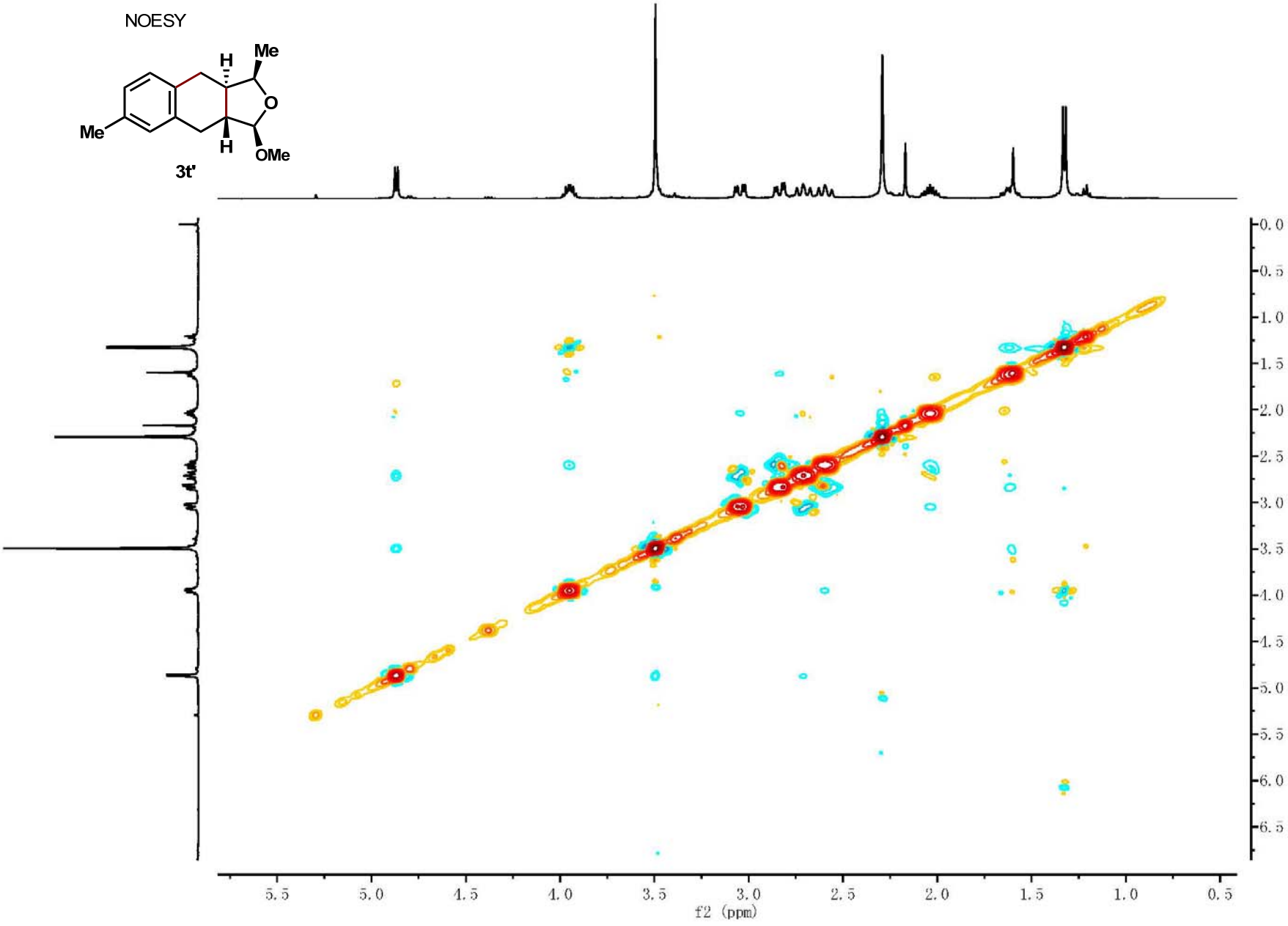

135.70
135.55
132.41
130.35
129.50
126.91
109.09
78.77
77.32
77.00
76.68
56.47
48.82
48.38
31.72
30.90
20.87
18.79
$^{13}$C NMR (100 MHz, CDCl$_3$)
Me
H
O
Me
H
OMe
3t'
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

$^1$H –$^1$H COSY


Me
H
5
4
3
6
3a
O
7
9a
1
Me
8
9
H
OMe

**3t'**


OMe
C(7)-Me
C(3)-Me
H1
H3
H9β
H9α
H9a
H3a
H4β
H4α
ppm
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm


NOESY
Me
H
O
Me
H
OMe
3t'
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)