

# SUPPORTING INFORMATION

## **Stereoselective Synthesis of Sugar Fused $\beta$ -Disubstituted $\gamma$ -butyro-lactones: C-Spiro-glycosides from 1,2-Cyclopropane-carboxylated Sugars**

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**General Methods:** All reactions are performed in oven-dried apparatus. Reaction mixtures were stirred magnetically unless otherwise stated. All the products were characterised by using NMR. Commercial grade solvents were distilled prior to use. Dichloromethane, dimethyl formamide and methanol were initially dried and stored over 4 Å<sup>0</sup> molecular sieves. <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded over 500 MHz or 400 MHz and 125 MHz or 100 MHz respectively. Coupling constants are reported in Hz. CDCl<sub>3</sub> (0.03% TMS) was used for recording NMR spectra.

### General Procedures and Data

#### General experimental procedure for the preparation of 1,2-cyclopropanecarboxylates:

To a stirred suspension of glucal (1.0 mmol) and Rh<sub>2</sub>(OAc)<sub>4</sub> (0.02 mmol) in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (2 mL) was added dropwise, over a period of 1 h, a solution of methyl diazoacetate (3 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (10 mL). After cessation of the nitrogen evolution (5-10 min), the reaction mixture was concentrated in *vacuo* and the remaining residue was purified by silica gel column chromatography (eluent: 10-30% EtOAc in light petroleum) to give the desired 1,2-cyclopropanecarboxylate adduct.

#### General experimental procedure for NBS mediated ring opening of 1,2-cyclopropanecarboxylate:

To a stirred solution of 1,2-cyclopropanecarboxylate (0.5 mmol) in 1,4-dioxane:water (5 mL (2:1)) was added *N*-bromosuccinimide (0.6 mmol) and the stirring was continued until the reaction mixture showed the absence of starting material on TLC. The reaction mixture was then concentrated to half its volume in *vacuo* and extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 x 10 mL). The combined extracts were dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>, filtered and concentrated. Purification by column chromatography over silica gel using EtOAc:hexane provided the bromohydrin as colorless gum in 65-81% yield.

#### General experimental procedure for the K<sub>2</sub>CO<sub>3</sub> mediated one-pot reaction:

To a stirred solution of bromohydrin (0.25 mmol) in CH<sub>3</sub>OH (2 mL) under nitrogen was added K<sub>2</sub>CO<sub>3</sub> (0.50 mmol) at 25 °C. The reaction mixture was stirred for a period of 6 h. CH<sub>3</sub>OH was evaporated, and the reaction mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub> (20 mL) and washed with 1% HCl (10 mL) and water (10 mL). The organic layer was

dried over anhydrous Na<sub>2</sub>SO<sub>4</sub> and concentrated. Column chromatography of the crude product with EtOAc : hexane afforded the pure spirocyclic lactol as a colorless gum in 72-92% yield.

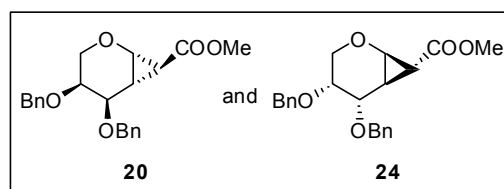
### General experimental procedure for dehydroxylation:

To a stirred solution of spiro lactol (0.2 mmol) in CH<sub>2</sub>Cl<sub>2</sub> at 0 °C was added triethylsilane (0.8 mmol) and trifluoroacetic acid (0.4 mmol) dropwise respectively and continued stirring while allowing the reaction to 25 °C. After completion of reaction (2-3 h) solvent was evaporated and the crude product was purified by column chromatography over silicagel using EtOAc:hexane to afford pure spiro lactone in 88-94% yield.

### Compound 20 and Compound 24: <sup>1</sup>H NMR

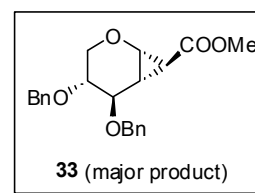
(CDCl<sub>3</sub>, 400 MHz): δ 7.26-7.43 (m, 10H), 4.79 (s, 2H), 4.60 (s, 2H), 4.09 (s, 1H), 3.97 (d, 1H, *J* = 6.8 Hz), 3.86 (dd, 1H, *J* = 5.2 Hz,

*J* = 6.4 Hz), 3.67 (s, 3H), 3.54 (dd, 1H, *J* = 3.2 Hz, *J* = 10.4 Hz), 3.43-3.47 (m, 1H), 2.10 (t, 1H, *J* = 6.4 Hz), 1.60 (d, 1H, *J* = 6.4 Hz). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 171.5, 138.0, 137.8, 128.3, 128.2, 128.1, 127.7, 127.6, 127.5, 127.4, 127.3, 73.4, 72.0, 71.2, 70.9, 62.9, 58.3, 51.7, 26.6, 25.4. Low-resolution MS (EI): *m/z*: 368 (M<sup>+</sup>).

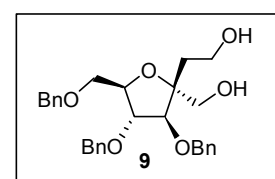


**Compound 33** (major diastereomer): <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.29-7.39 (m, 10H), 4.68 (d, 1H, *J* = 12 Hz), 4.60 (d, 1H, *J* = 12 Hz), 4.58 (d, 1H, *J* = 12 Hz), 4.51 (d, 1H, *J* = 12 Hz), 4.01 (dd, 1H, *J* = 1.6 Hz, *J* = 7.2 Hz), 3.95 (d, 1H, *J* = 2

Hz), 3.75 (dd, 1H, *J* = 1.6 Hz, *J* = 12 Hz), 3.69 (s, 3H), 3.49-3.50 (m, 1H), 2.30 (dd, 1H, *J* = 2 Hz, *J* = 6.4 Hz), 1.93 (dd, 1H, *J* = 6.4 Hz, *J* = 7.2 Hz). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 172.5, 137.7, 128.5, 128.4, 127.9, 127.8, 127.7, 74.4, 71.6, 70.9, 70.4, 62.3, 58.7, 51.8, 24.4, 23.9. Low-resolution MS (EI): *m/z*: 368 (M<sup>+</sup>).



**Compound 9:** <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.26-7.29 (m, 15H), 4.51-4.62 (m, 6H), 4.12-4.17 (m, 2H), 4.04-4.07 (m, 1H), 3.76-3.85 (m, 2H), 3.54-3.69 (m, 4H), 1.99 (ddd, 1H, *J* =

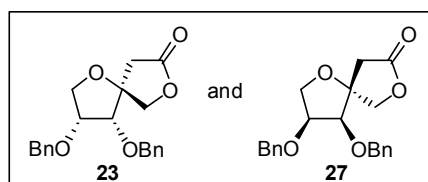




(m, 1H), 3.89 (d, 1H,  $J = 2.8$  Hz), 3.77 (dd, 1H,  $J = 2.8$  Hz,  $J = 4$  Hz), 2.99 (d, 1H,  $J = 18$  Hz), 2.64 (d, 1H,  $J = 18$  Hz), 1.33 (d, 3H,  $J = 6.4$  Hz).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  175.0, 137.3, 137.0, 128.7, 128.6, 128.2, 128.1, 127.8, 129.6, 127.5, 87.4, 86.9, 84.9, 78.8, 75.9, 72.2, 72.1, 36.2, 20.2. Low-resolution MS (EI):  $m/z$ : 369 ( $\text{M}^+ + 1$ ).

**Compound 23 and Compound 27:**  $^1\text{H}$  NMR

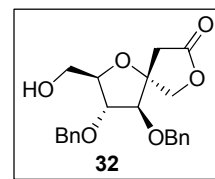
( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.31-7.38 (m, 10H), 4.77 (d, 1H,  $J = 12$  Hz), 4.64 (d, 1H,  $J = 12$  Hz), 4.56 (d, 1H,  $J = 12$  Hz), 4.51 (d, 1H,  $J = 12$  Hz), 4.24 (d,



1H,  $J = 10$  Hz), 4.16 (d, 1H,  $J = 10$  Hz), 4.07 (ddd, 1H,  $J = 1.2$  Hz,  $J = 5.6$  Hz,  $J = 10$  Hz), 4.02 (d, 1H,  $J = 1.2$  Hz), 3.98 (dd, 1H,  $J = 4$  Hz,  $J = 10.8$  Hz), 3.72 (d, 1H,  $J = 4.4$  Hz), 3.22 (d, 1H,  $J = 18.4$  Hz), 2.51 (d, 1H,  $J = 18.4$  Hz).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  176.0, 137.5, 136.9, 128.6, 128.5, 128.3, 127.9, 129.8, 127.6, 84.7, 79.4, 75.3, 74.9, 72.5, 71.8, 70.6, 36.0. Low-resolution MS (EI):  $m/z$ : 355 ( $\text{M}^+ + 1$ ).

**Compound 32** (major Diastereomer):  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400

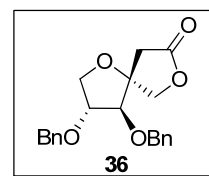
MHz):  $\delta$  7.28-7.42 (m, 10H), 4.69 (d, 1H,  $J = 11.2$  Hz), 4.57 (s, 1H), 4.56 (s, 1H), 4.46 (d, 1H,  $J = 11.2$  Hz), 4.35 (d, 1H,  $J = 10$  Hz), 4.21 (d, 1H,  $J = 10$  Hz), 4.16 (dd, 1H,  $J = 3.6$  Hz,  $J = 7.6$



Hz), 4.12 (dd, 1H,  $J = 2.0$  Hz,  $J = 3.6$  Hz), 3.89 (d, 1H,  $J = 2.0$  Hz), 3.74-3.77 (m, 1H), 3.64-3.67 (m, 1H), 2.95 (d, 1H,  $J = 18.2$  Hz), 2.67 (d, 1H,  $J = 18.2$  Hz), 2.06 (bs, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  174.7, 137.0, 136.6, 128.8, 128.7, 128.4, 128.3, 128.0, 127.7, 87.8, 83.9, 89.9, 82.1, 75.3, 72.4, 72.0, 62.8, 35.7. Low-resolution MS (EI):  $m/z$ : 384 ( $\text{M}^+$ ).

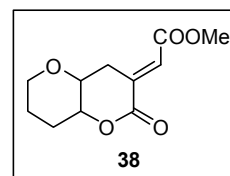
**Compound 36** (major diastereomer):  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):

$\delta$  7.32-7.44 (m, 10H), 4.71 (d, 1H,  $J = 12$  Hz), 4.58 (d, 1H,  $J = 11.6$  Hz), 4.56 (d, 1H,  $J = 12$  Hz), 4.51 (d, 1H,  $J = 12$  Hz), 4.35 (d, 1H,  $J = 6.0$  Hz), 4.25 (d, 1H,  $J = 6.0$  Hz), 4.15-4.18 (m, 1H), 4.09



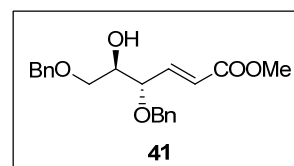
(dd, 1H,  $J = 4.4$  Hz,  $J = 10.0$  Hz), 4.00 (bs, 1H), 3.92 (bs, 1H), 3.00 (d, 1H,  $J = 18.0$  Hz), 2.61 (d, 1H,  $J = 18.0$  Hz).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  175.0, 137.2, 137.0, 128.7, 128.6, 128.3, 127.8, 127.6, 87.3, 84.2, 81.7, 76.0, 72.4, 71.8, 70.9, 35.1. Low-resolution MS (EI):  $m/z$ : 355 ( $\text{M}^+ + 1$ ).

**Compound 38:**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz):  $\delta$  6.97 (dd, 1H,  $J = 1.5$  Hz,  $J = 2.5$  Hz), 4.45 (s, 1H), 3.91 (dd, 1H,  $J = 4.5$  Hz,  $J = 11.5$  Hz), 3.70-3.74 (m, 4H), 3.47-3.57 (m, 2H), 2.81 (dt, 1H,  $J = 3.5$  Hz,  $J = 19.0$  Hz), 2.15 (d, 1H,  $J = 14.5$  Hz), 1.90-1.95



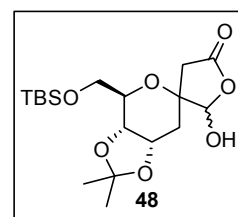
(dt, 1H,  $J = 4.5$  Hz,  $J = 13$  Hz), 1.70-1.77 (m, 1H), 1.36 (d, 1H,  $J = 12$  Hz).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 125 MHz):  $\delta$  165.6, 164.4, 138.4, 129.0, 74.7, 69.3, 68.0, 51.7, 31.8, 28.2, 19.0. Low-resolution MS (EI):  $m/z$ : 226 ( $\text{M}^+$ ).

**Compound 41:**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.26-7.35 (m, 10H), 6.97 (dd, 1H,  $J = 6.8$  Hz,  $J = 16.4$  Hz), 6.09 (d, 1H,  $J = 15.6$  Hz), 4.62 (d, 1H,  $J = 11.6$  Hz), 4.52 (s, 2H), 4.40 (d, 1H,  $J = 11.6$  Hz), 4.09 (t, 1H,  $J = 6$  Hz), 3.91 (m, 1H), 3.76

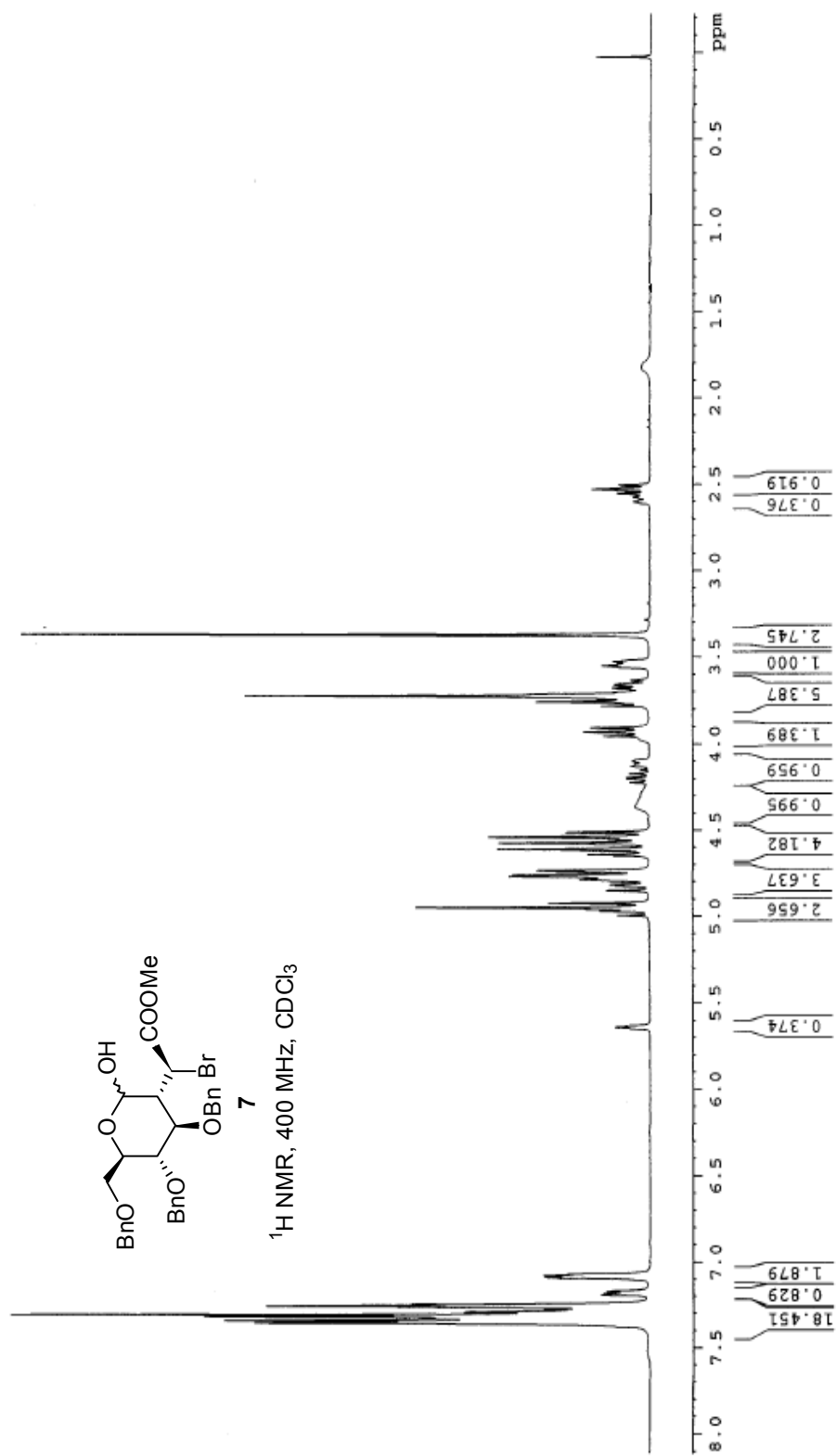


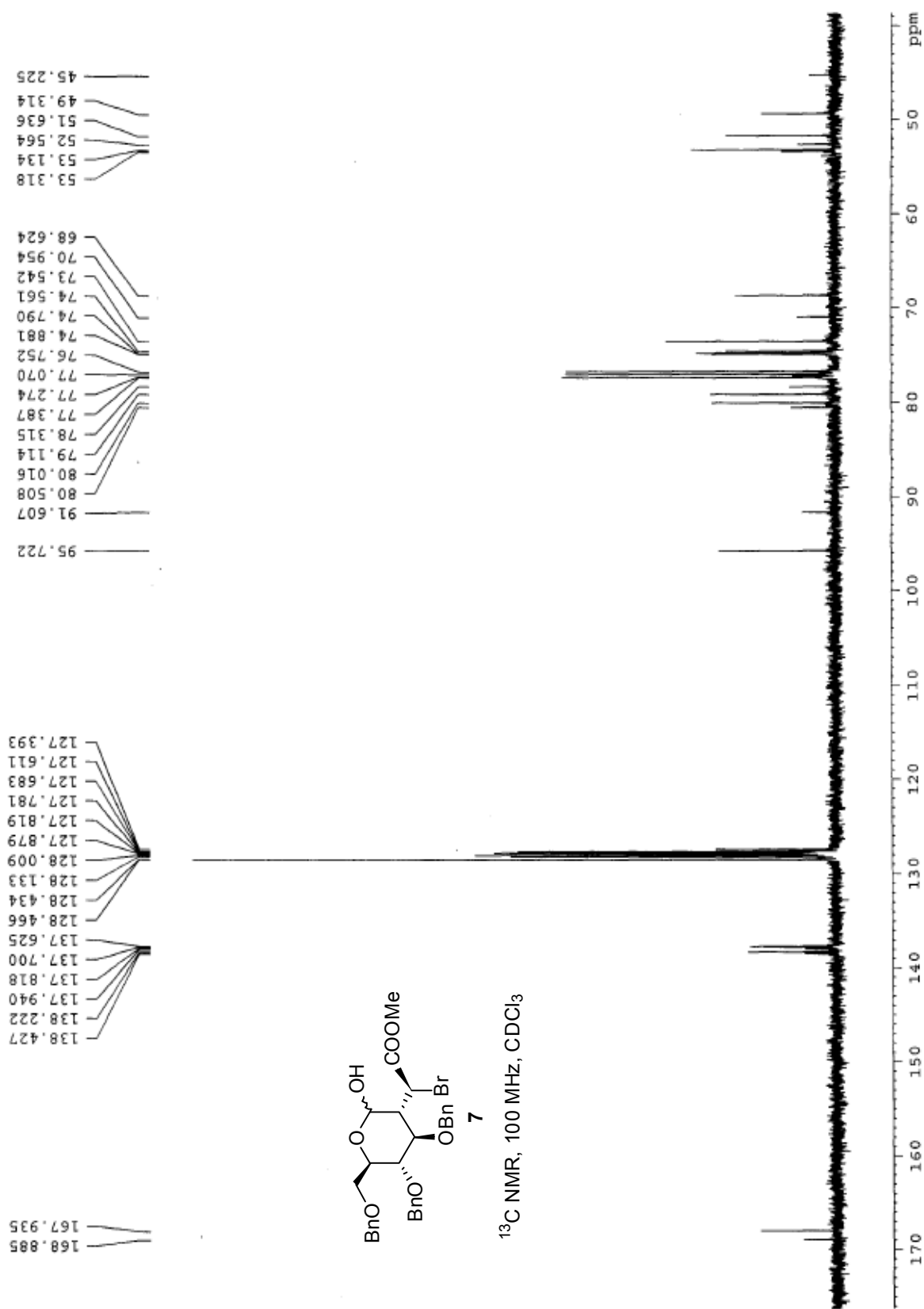
(s, 3H), 3.59 (d, 2H,  $J = 4.8$  Hz), 2.43 (bs, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  166.2, 144.9, 137.7, 137.6, 128.4, 127.8, 123.8, 78.6, 73.5, 72.2, 71.6, 70.3, 51.7. Low-resolution MS (EI):  $m/z$ : 357 ( $\text{M}^+ + 1$ ).

**Compound 48** (major diastereomer):  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  5.49 (bs, 1H), 4.43-4.45 (m, 1H), 4.18 (dd, 1H,  $J = 6.0$  Hz,  $J = 8.4$  Hz), 3.88 (dd, 1H,  $J = 2$  Hz,  $J = 11.2$  Hz), 3.80 (dd, 1H,  $J = 4.0$  Hz,  $J = 11.2$  Hz), 3.62-3.65 (m, 1H), 3.02 (d, 1H,  $J = 18.0$  Hz), 2.65 (d, 1H,  $J = 18$  Hz), 2.14-2.21 (m, 2H), 1.37 (s, 3H),

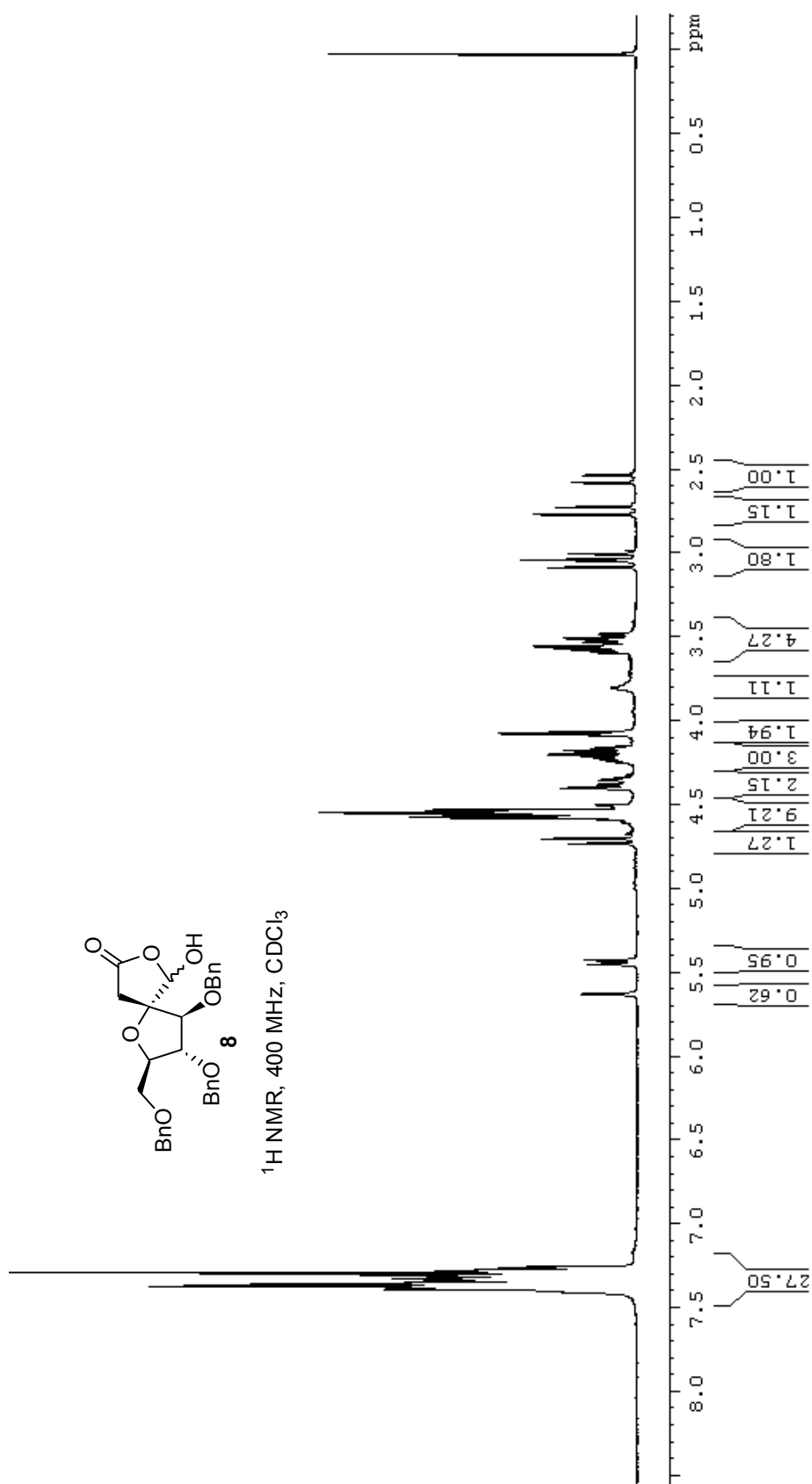


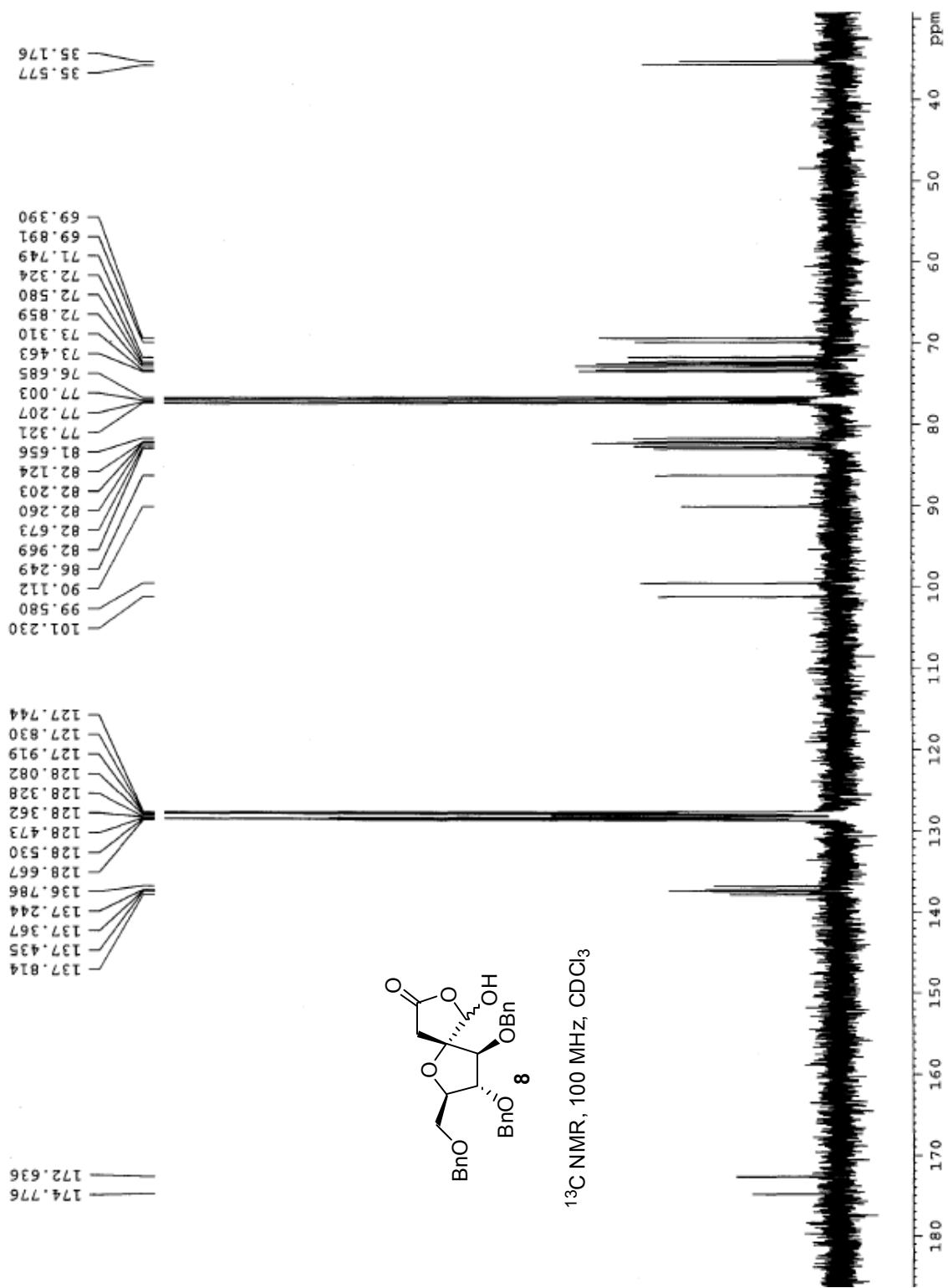
1.27 (s, 3H), 0.93 (s, 9H), 0.10 (s, 6H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  171.7, 109.5, 102.2, 76.0, 73.7, 70.0, 69.5, 62.6, 40.4, 31.6, 27.7, 25.8, 25.3, 18.3, -5.2, -5.3. Low-resolution MS (EI):  $m/z$ : 388 ( $\text{M}^+$ ).

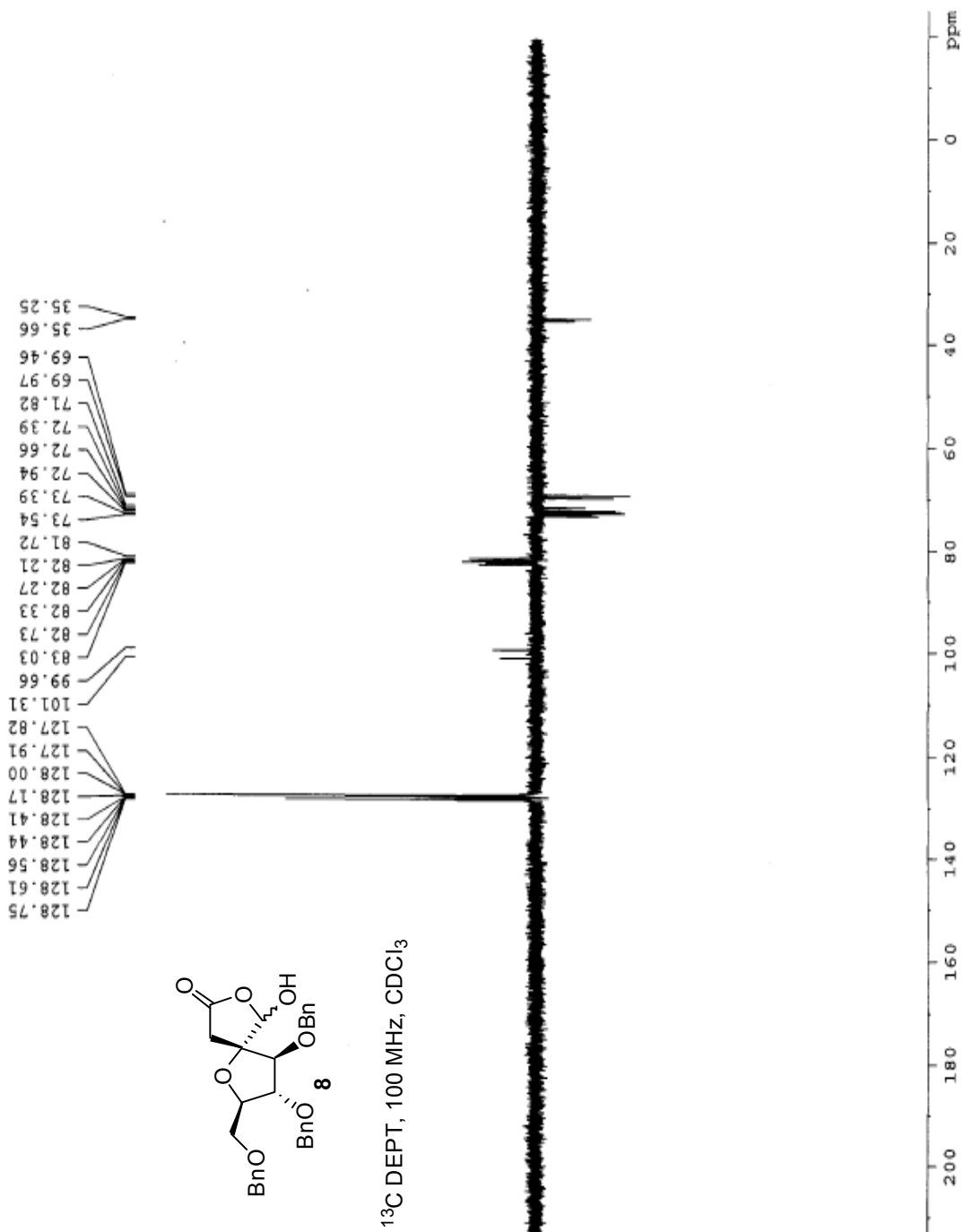


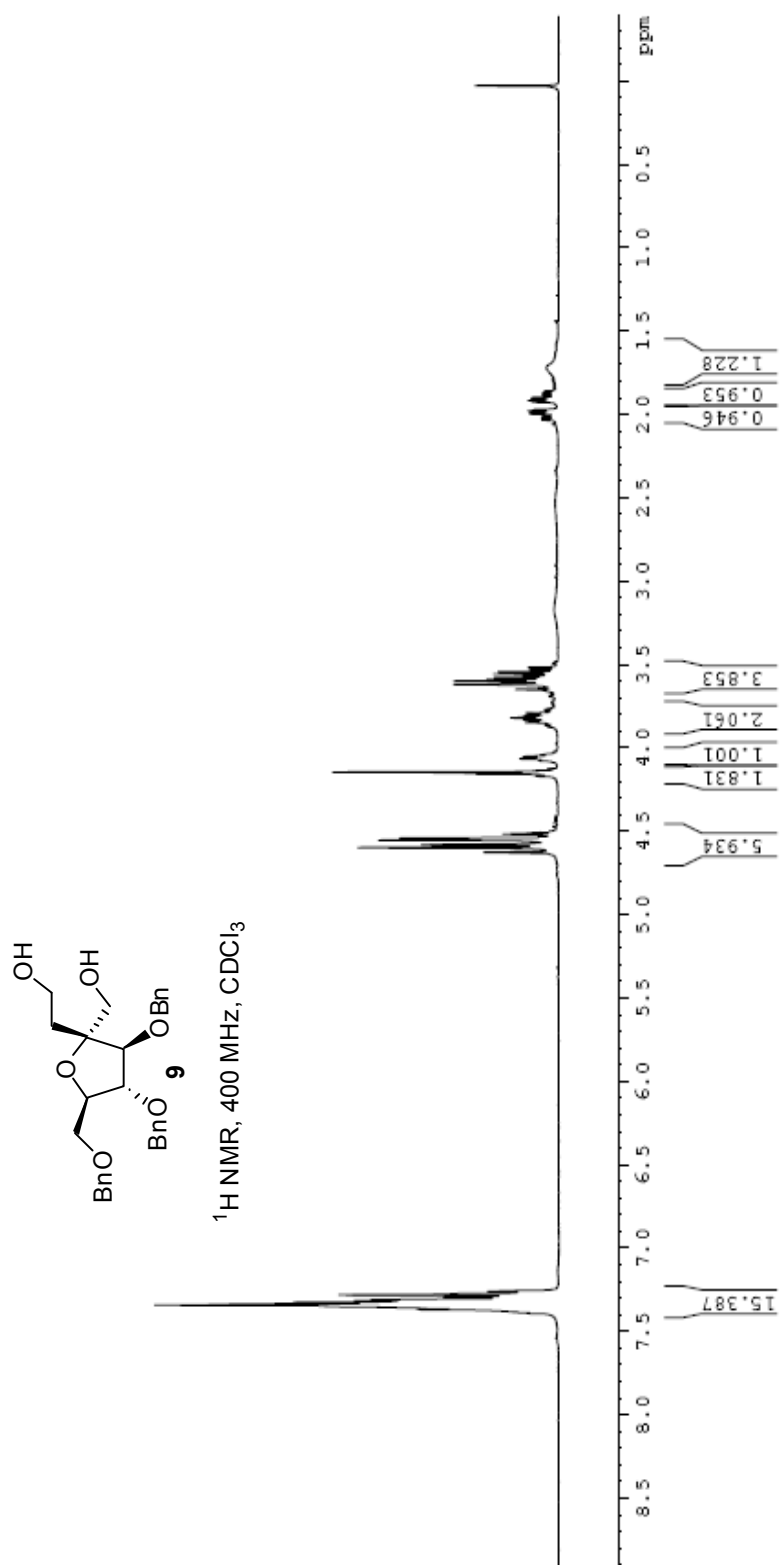


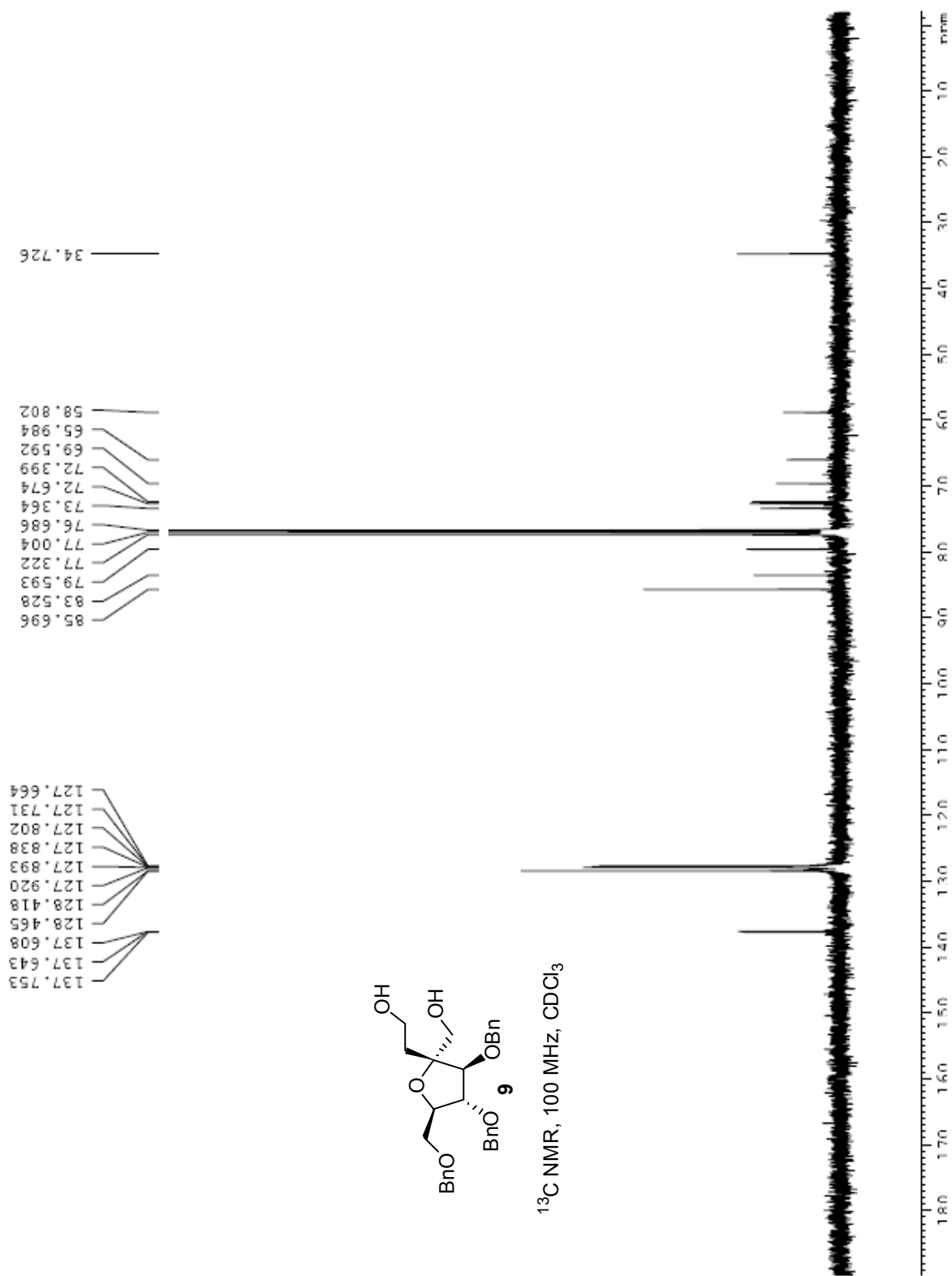


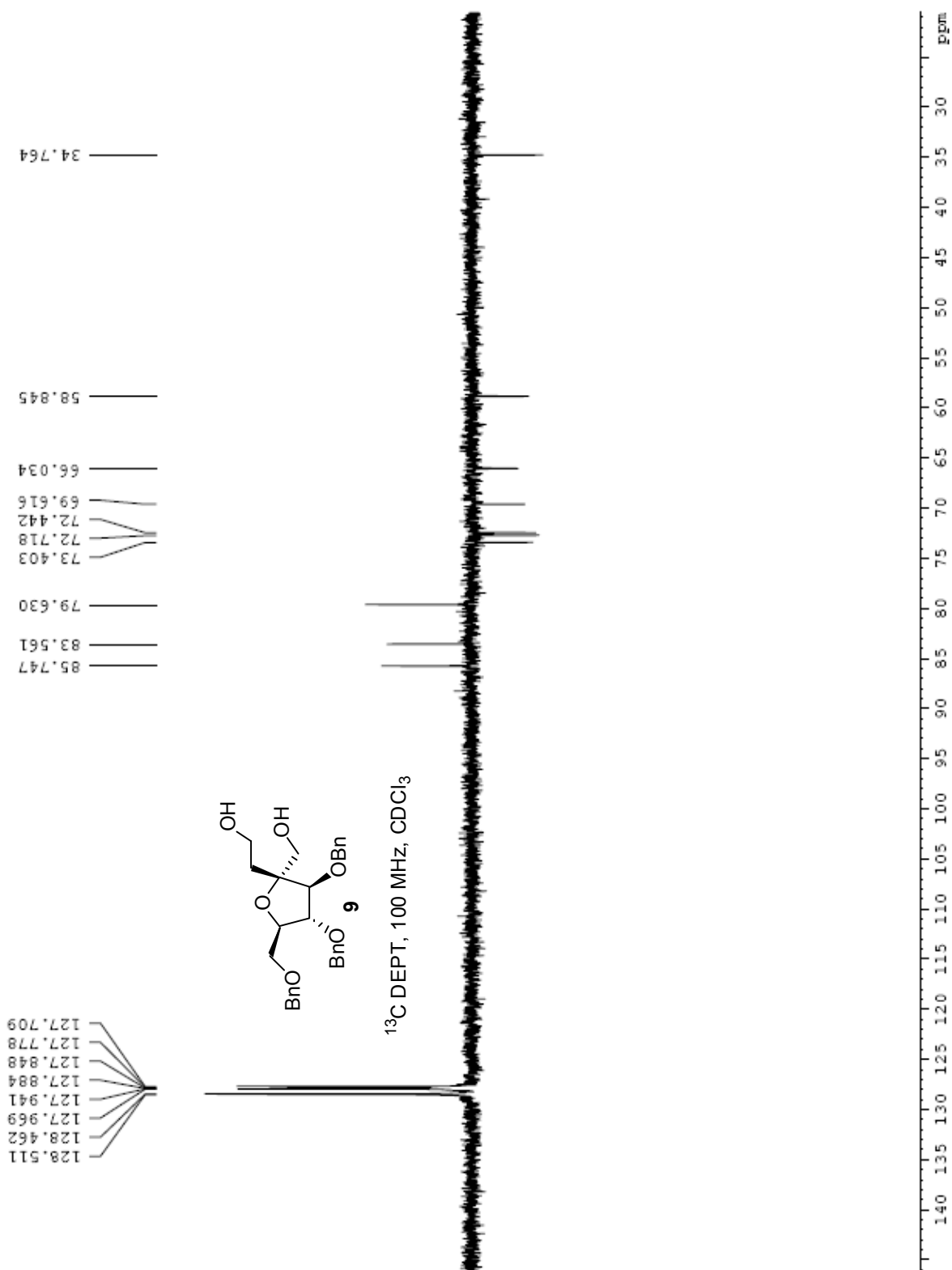




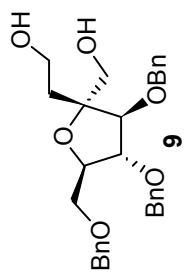
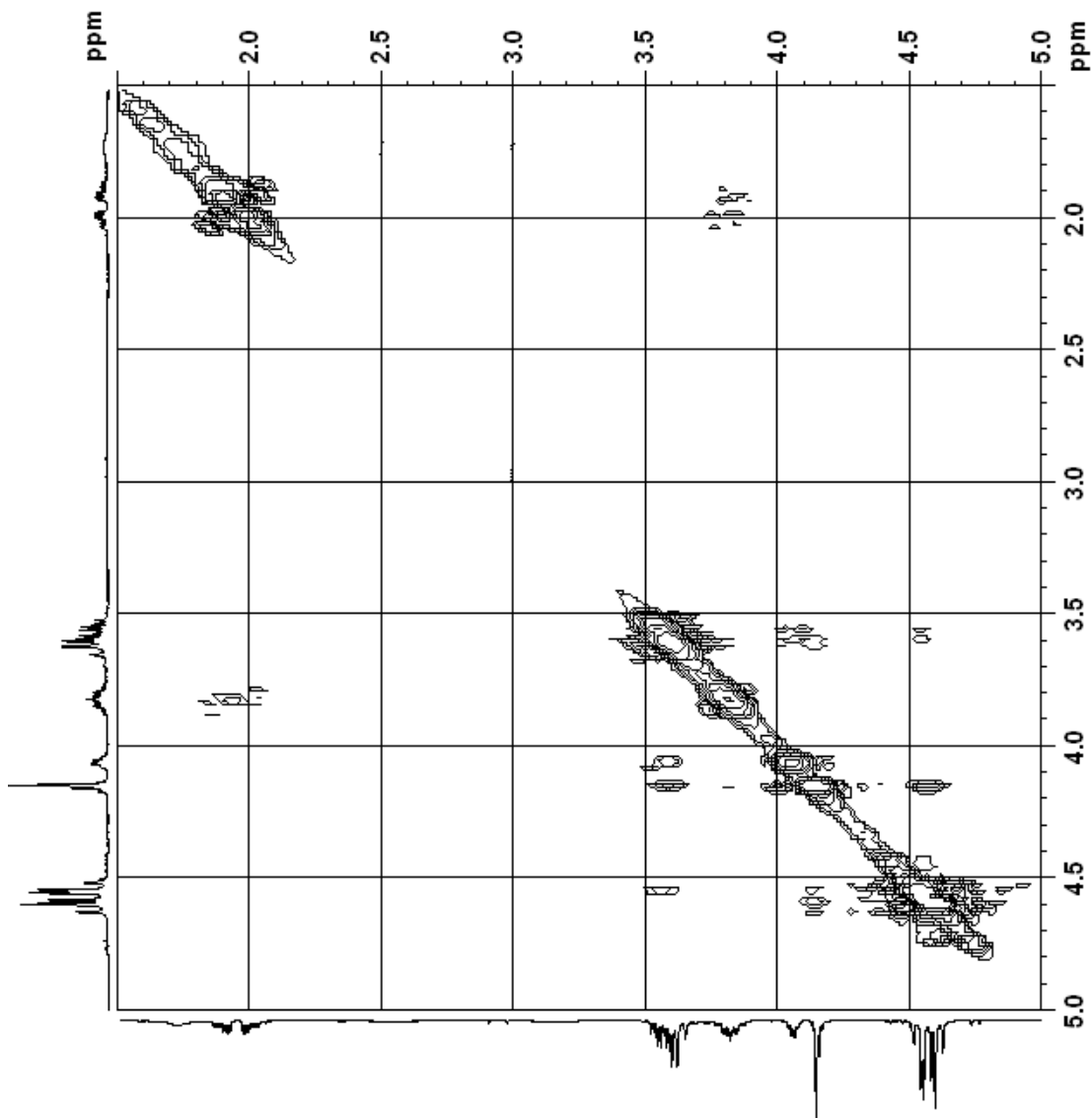






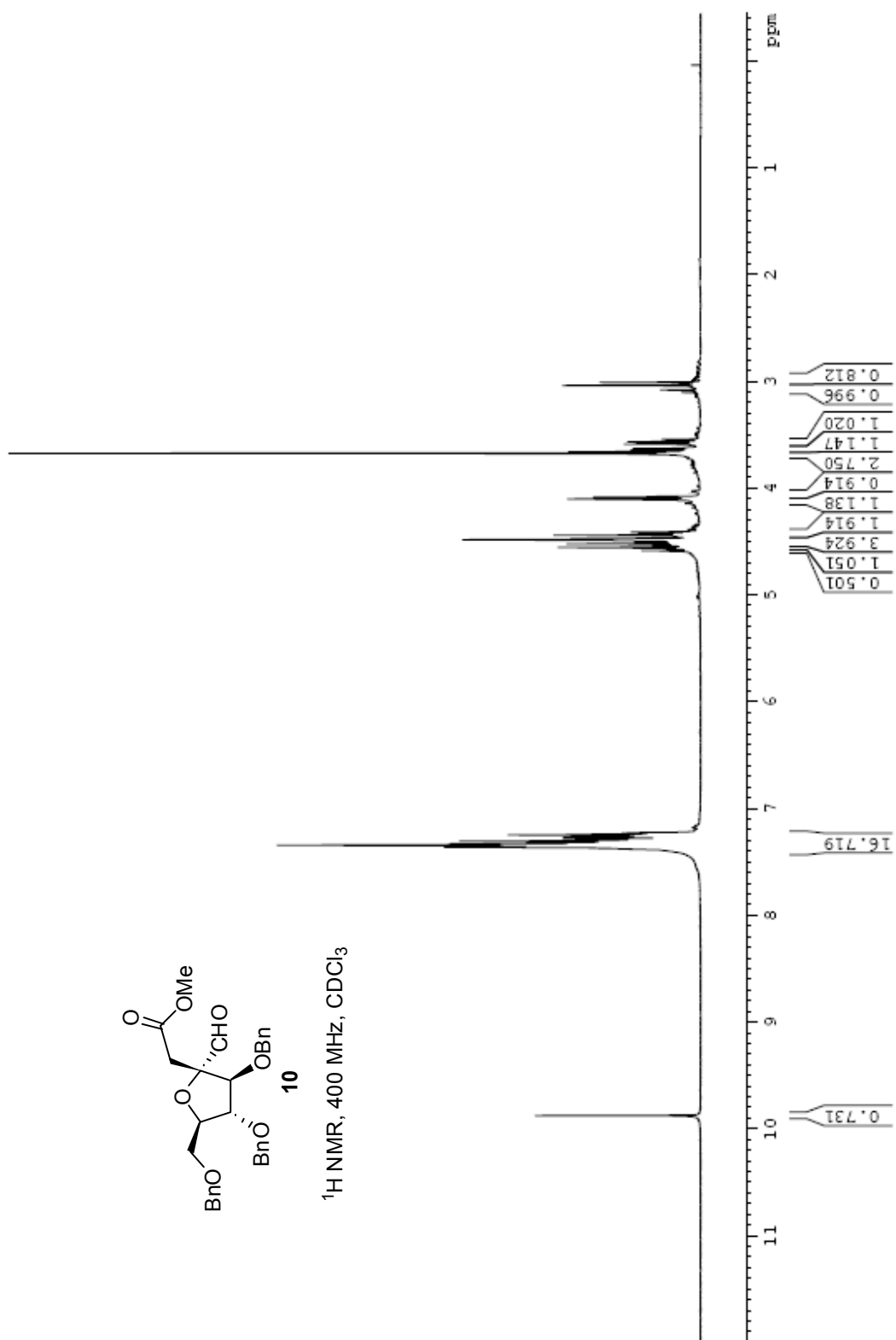


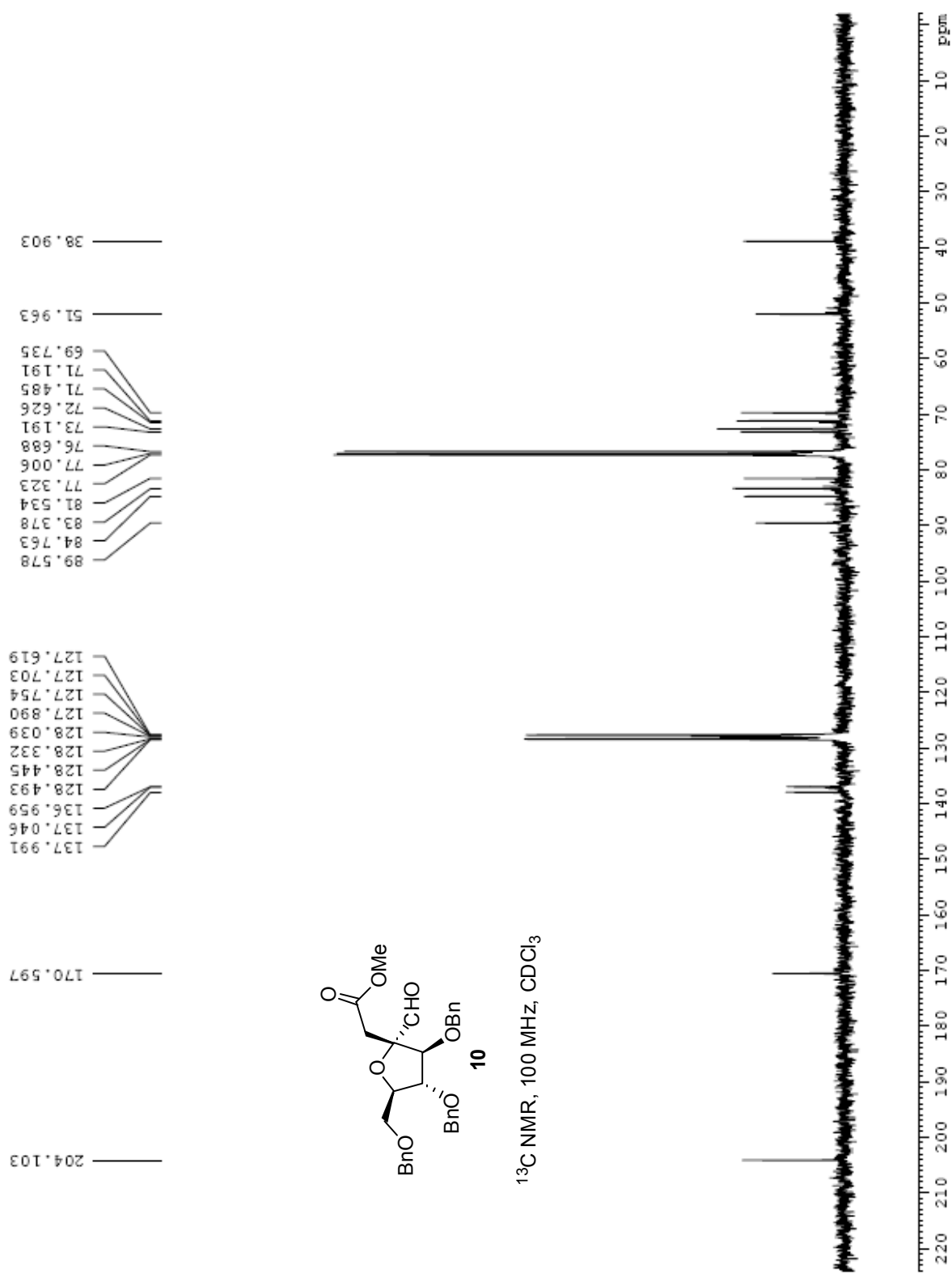


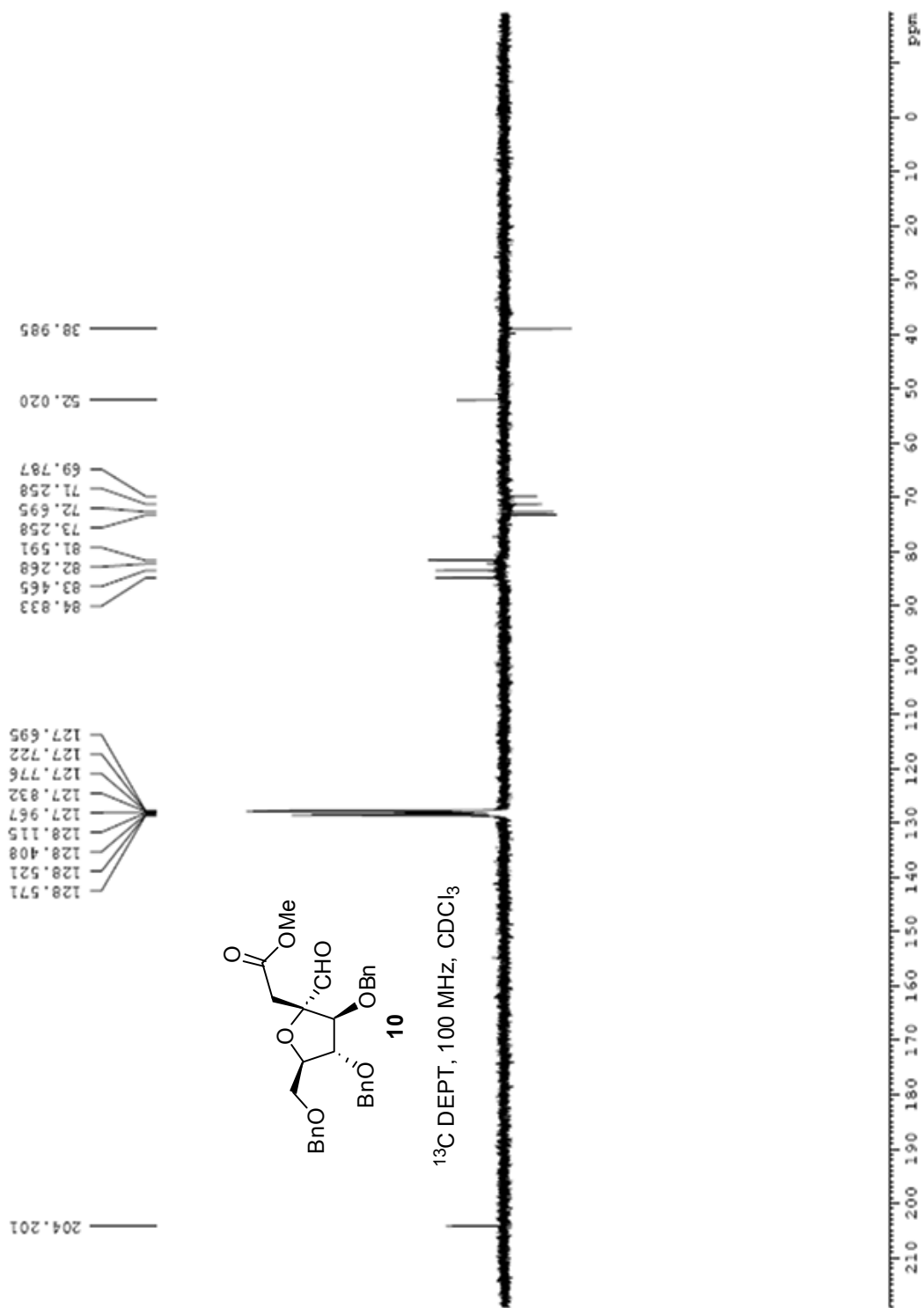


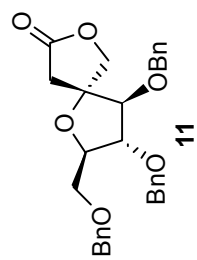
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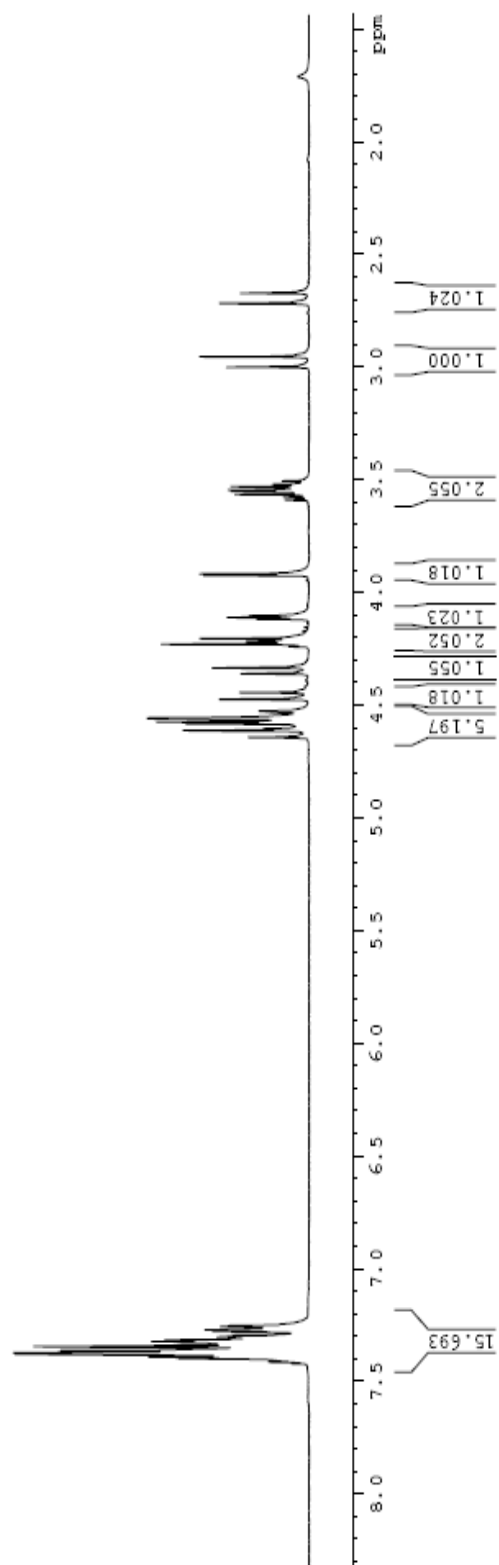


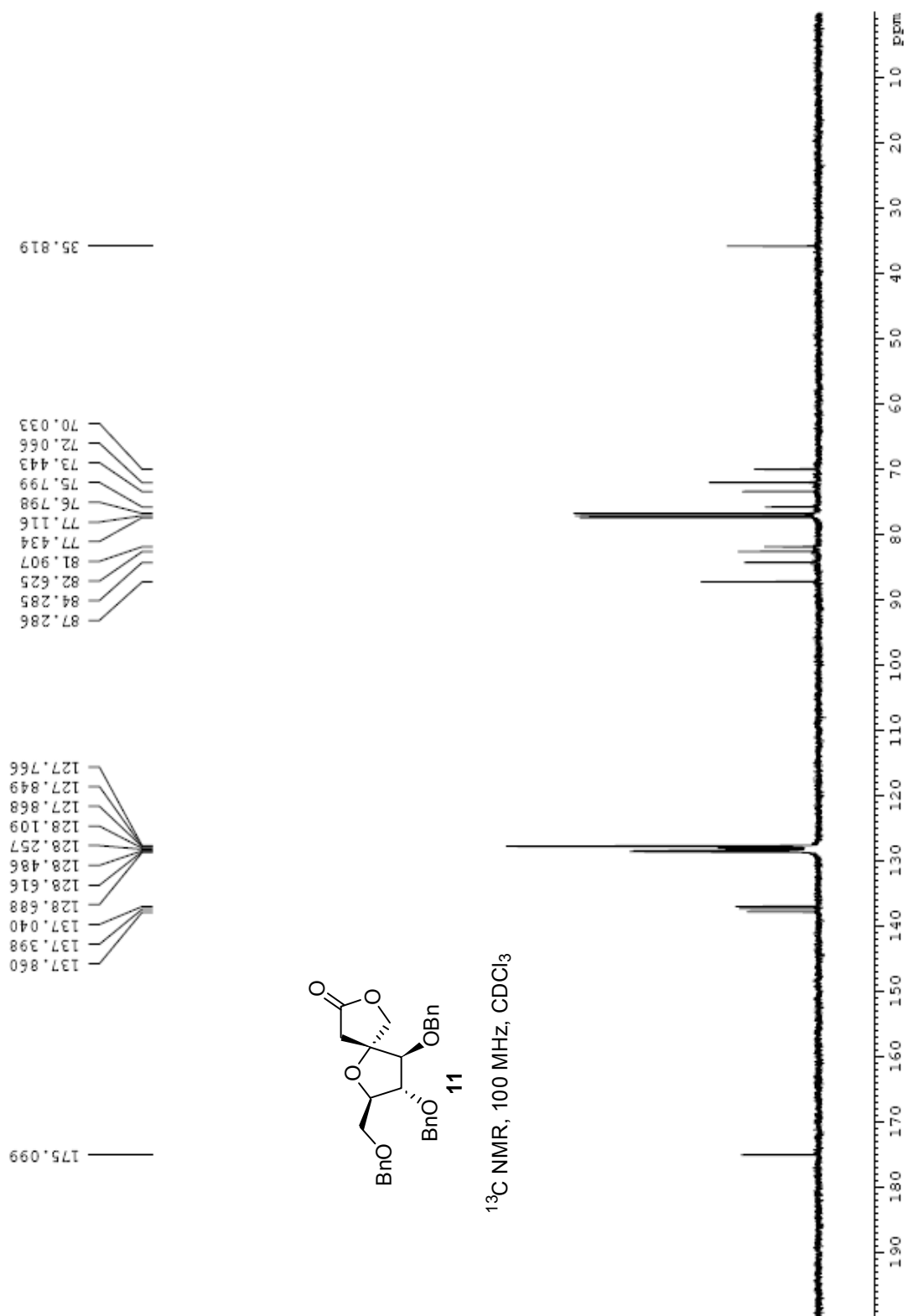


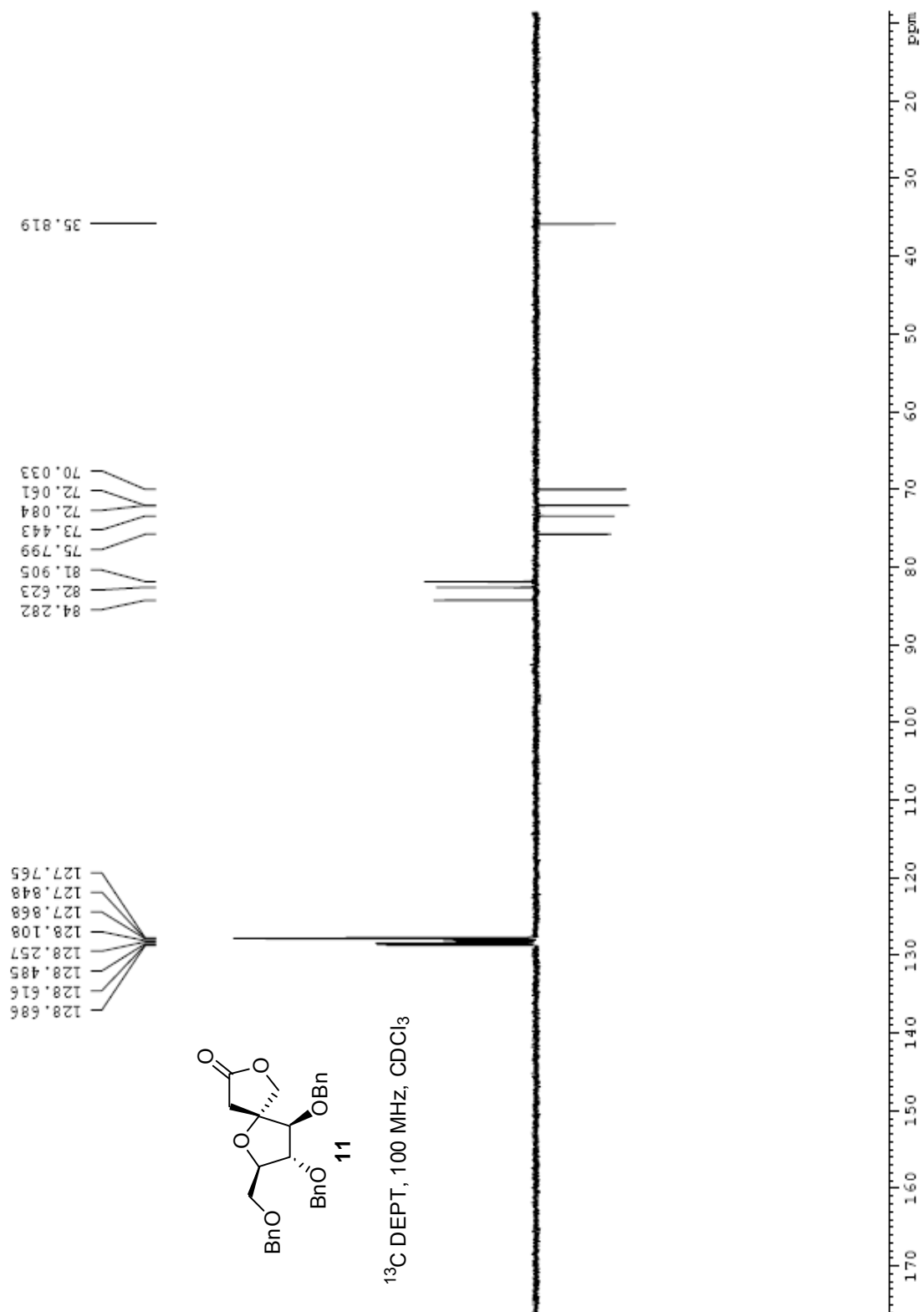


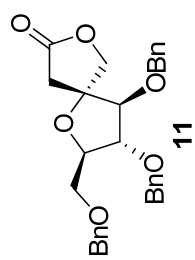
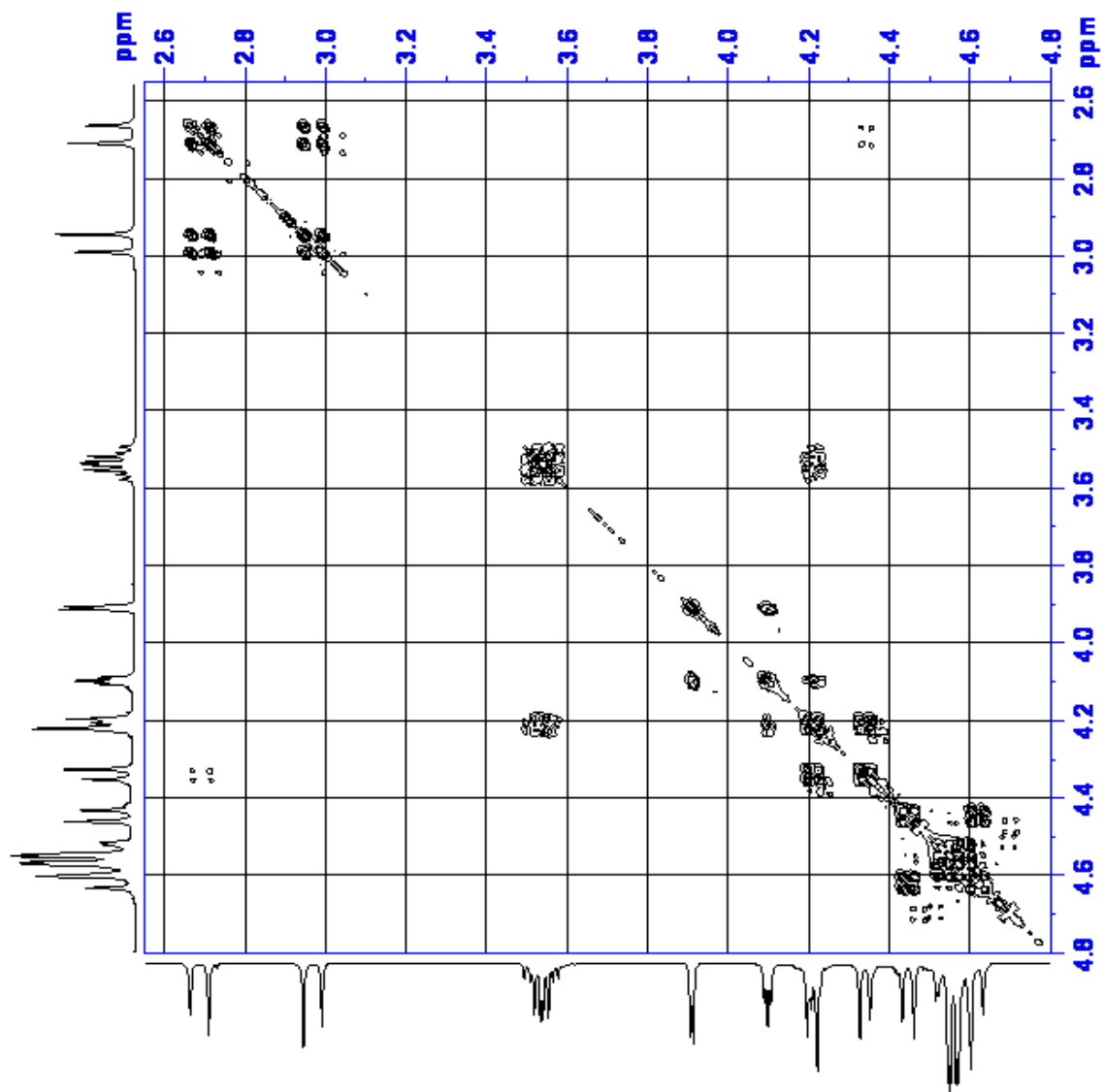


<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>

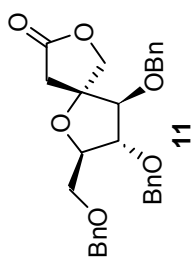
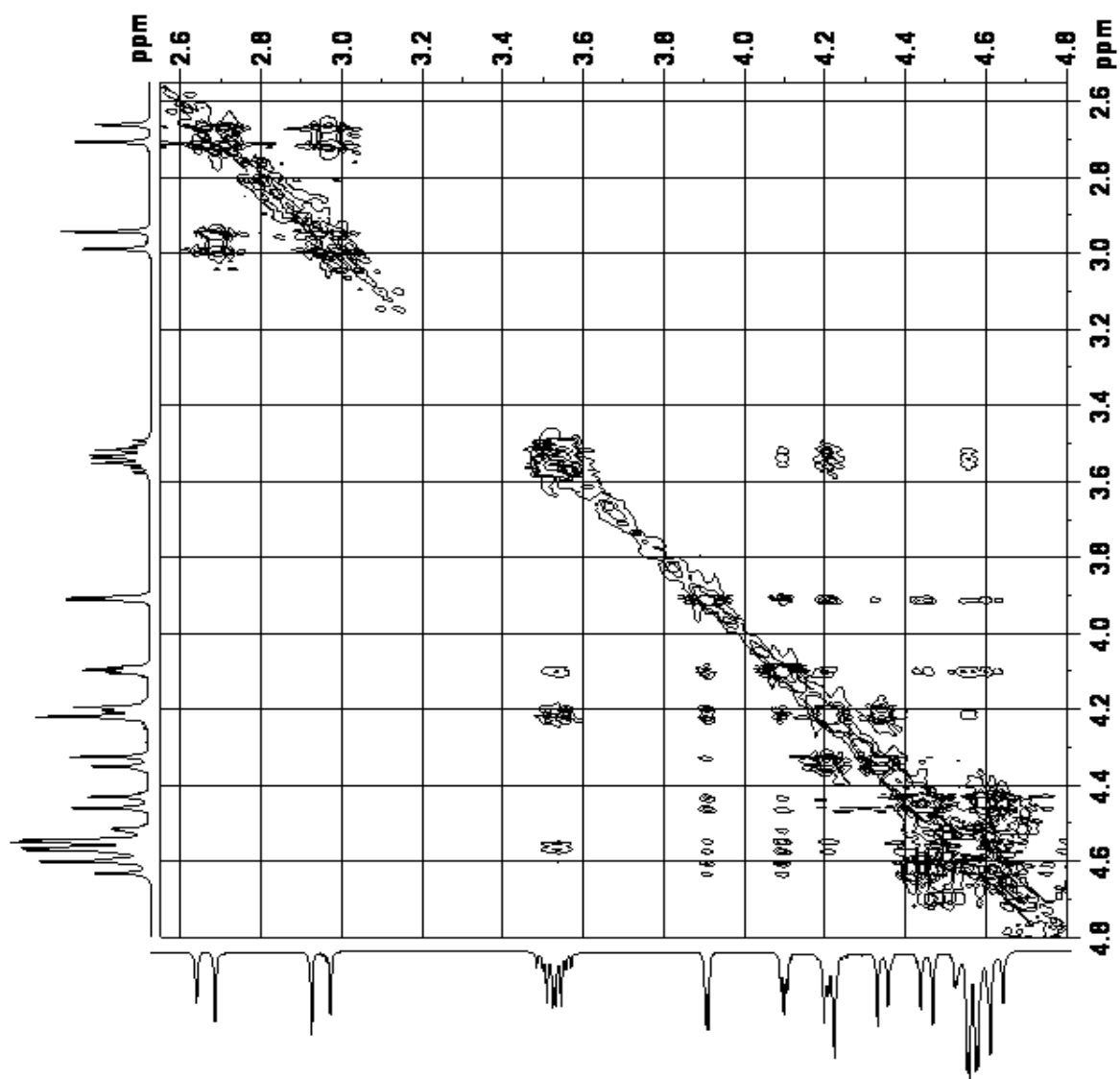






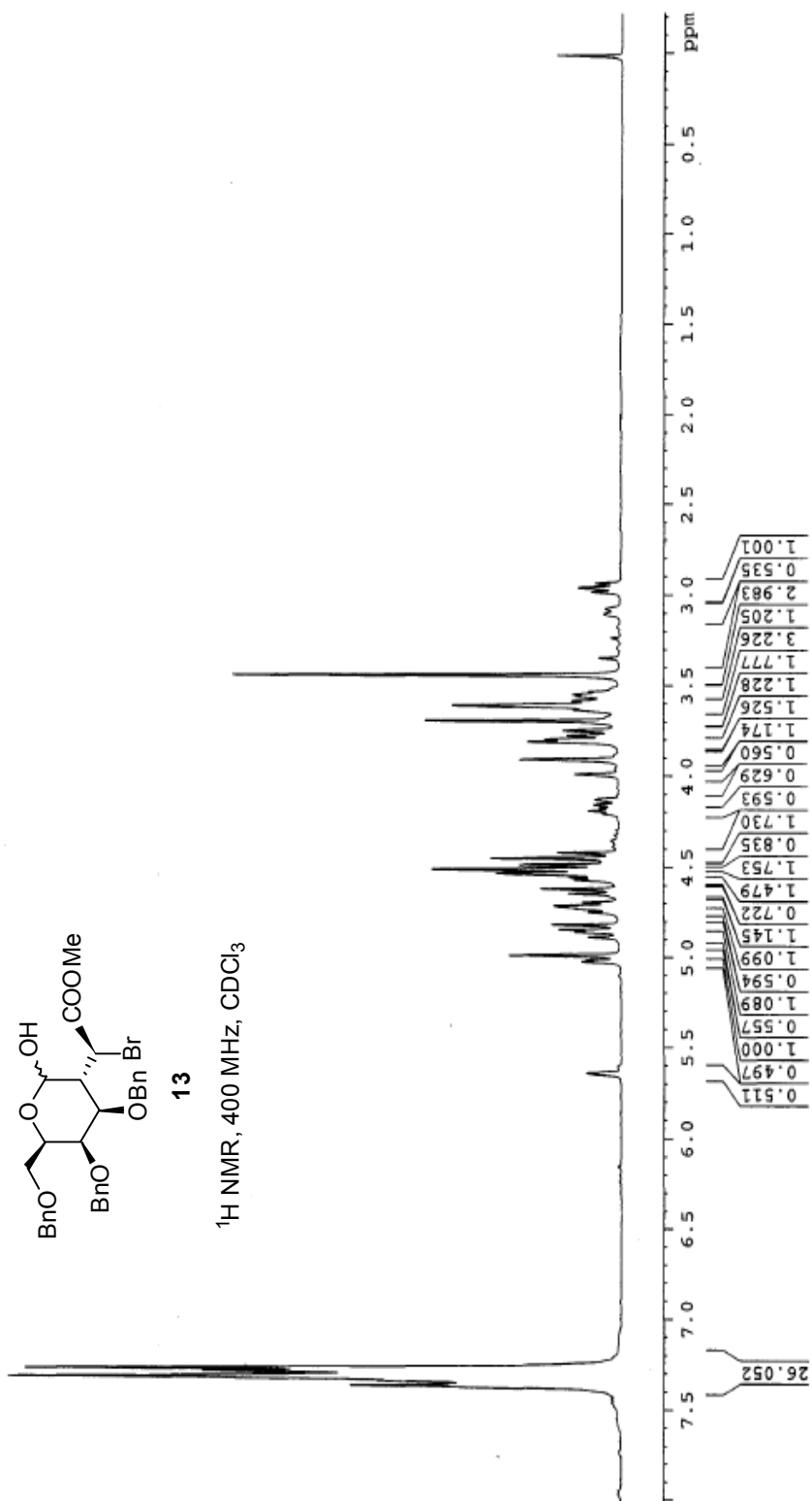


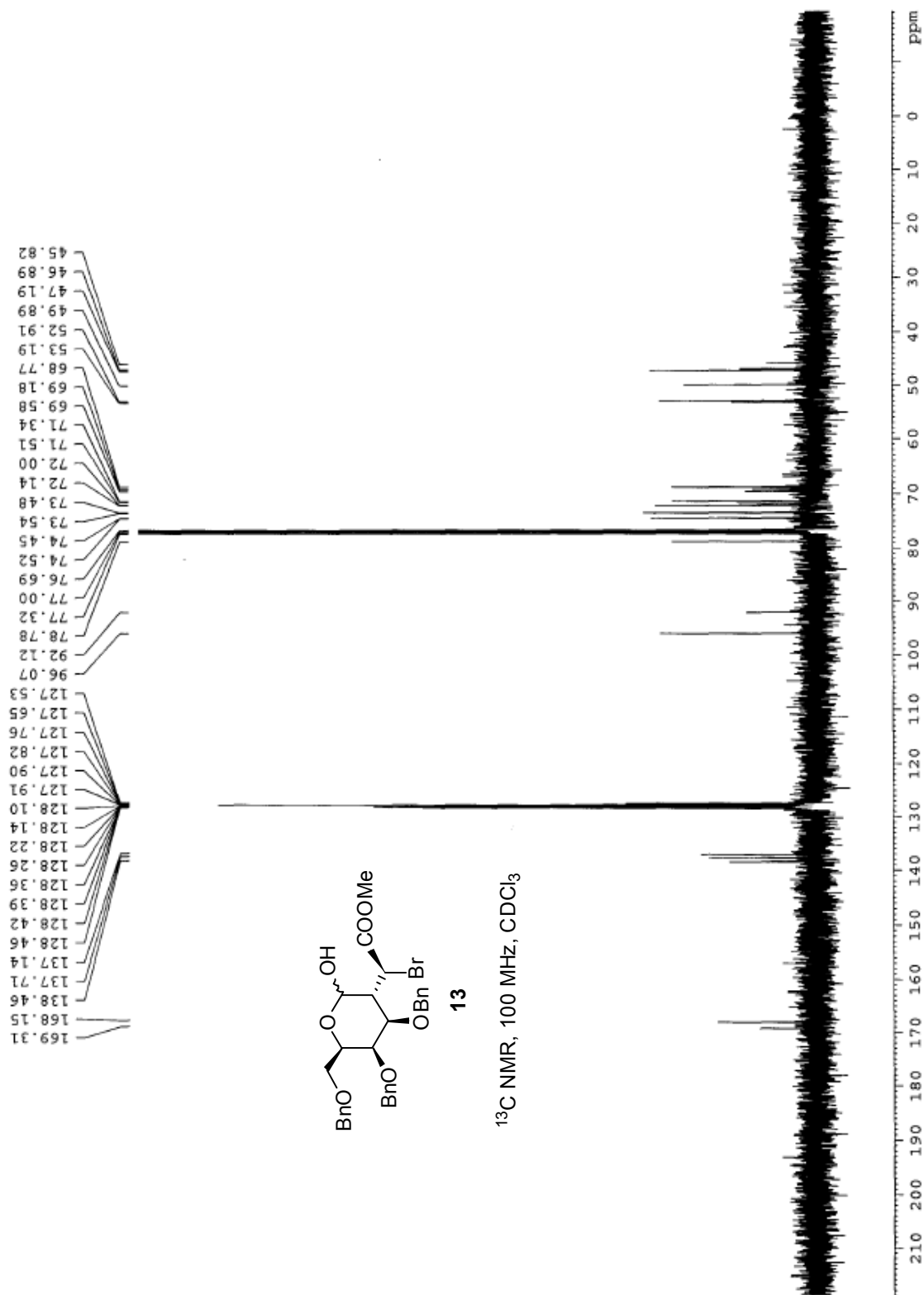
$^1\text{H}$ - $^1\text{H}$  COSY, 400 MHz,  $\text{CDCl}_3$

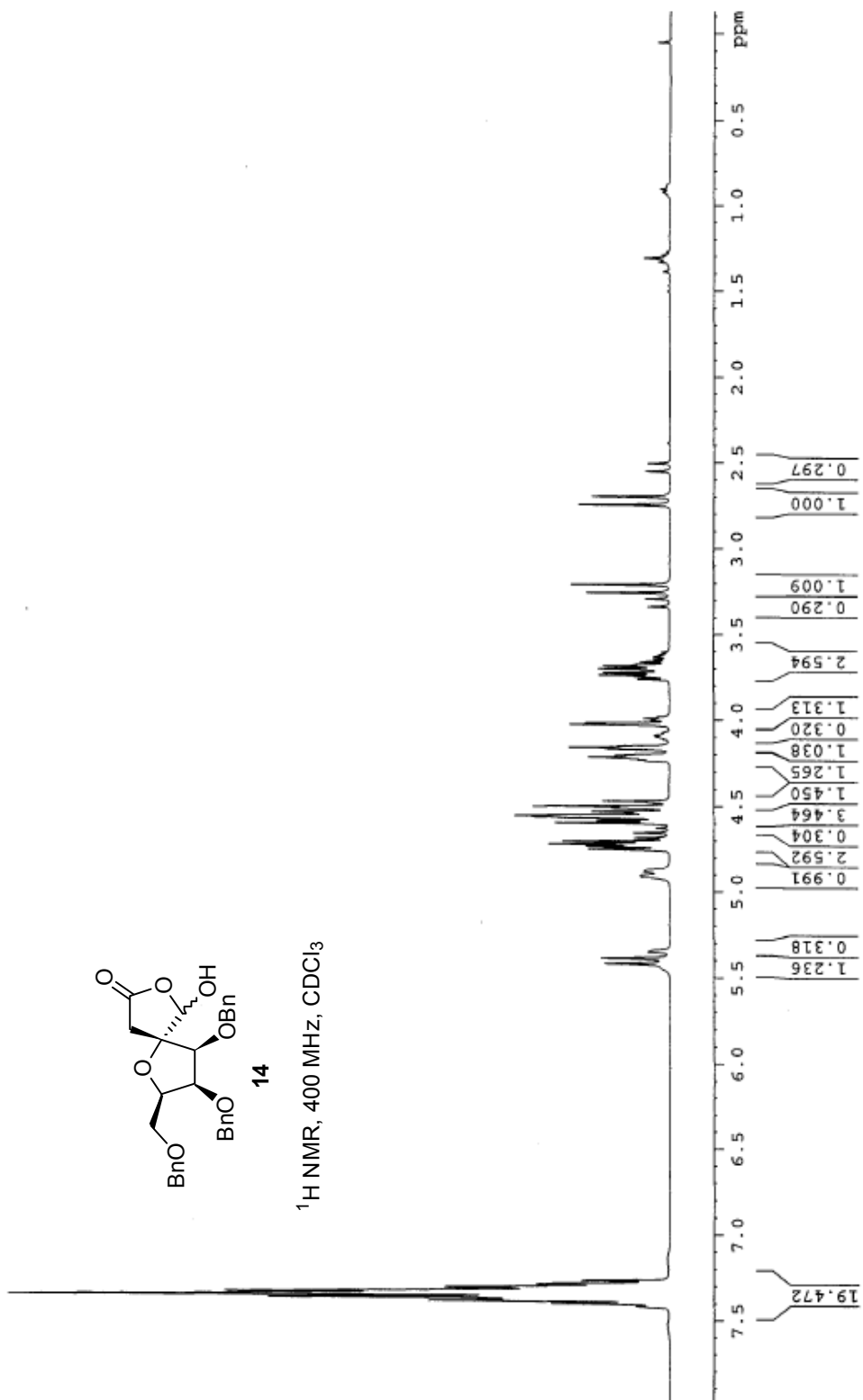


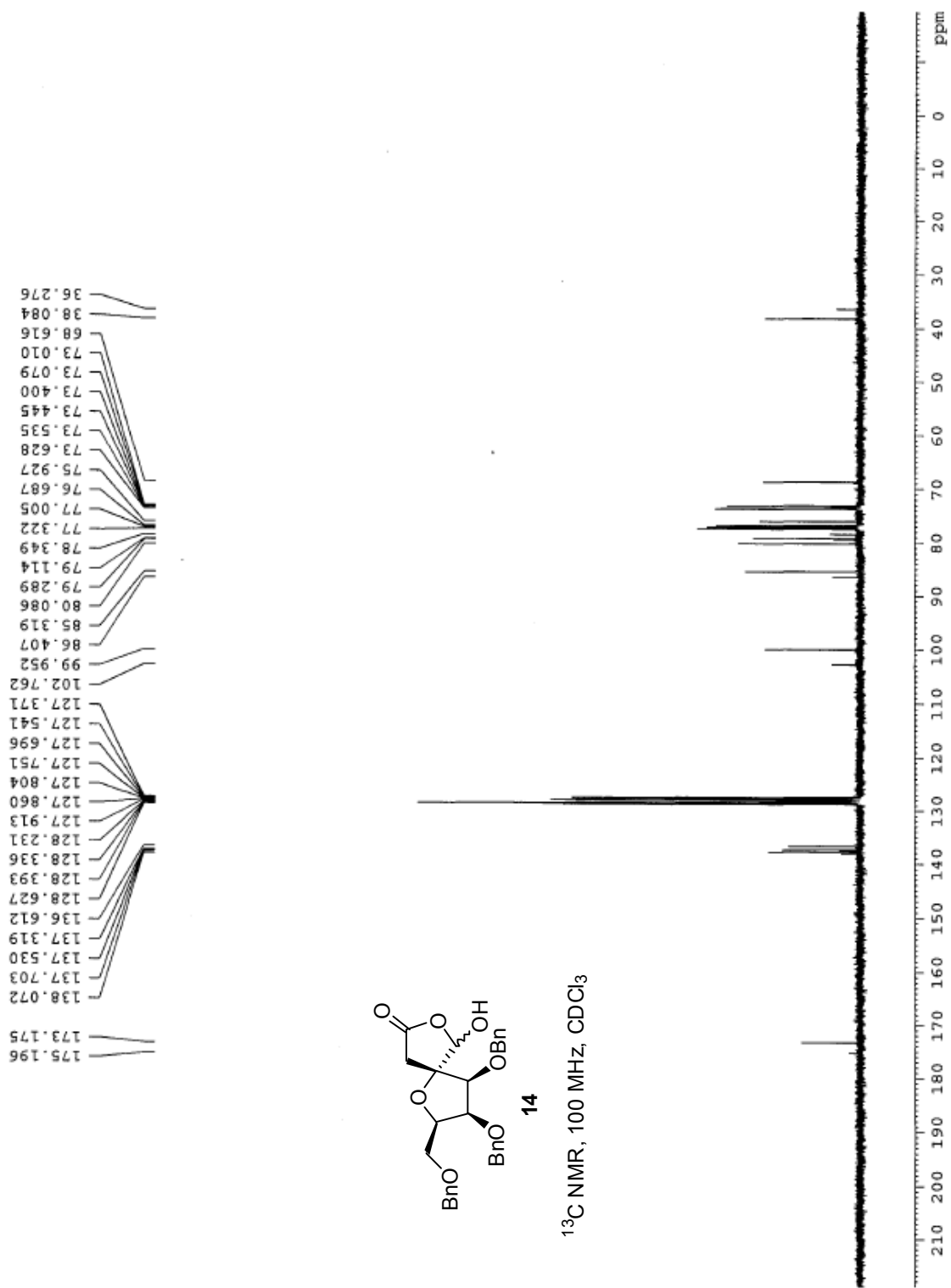
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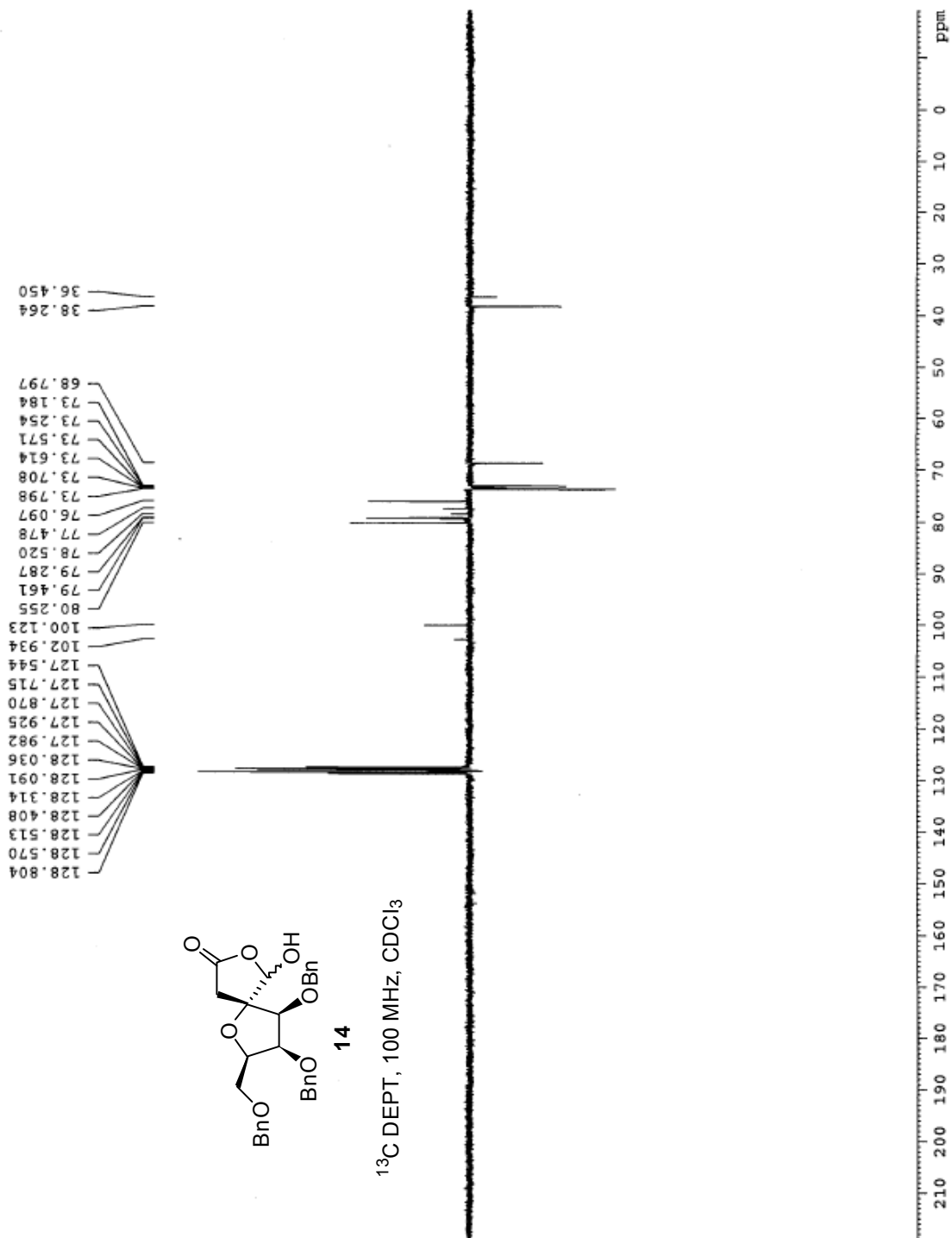


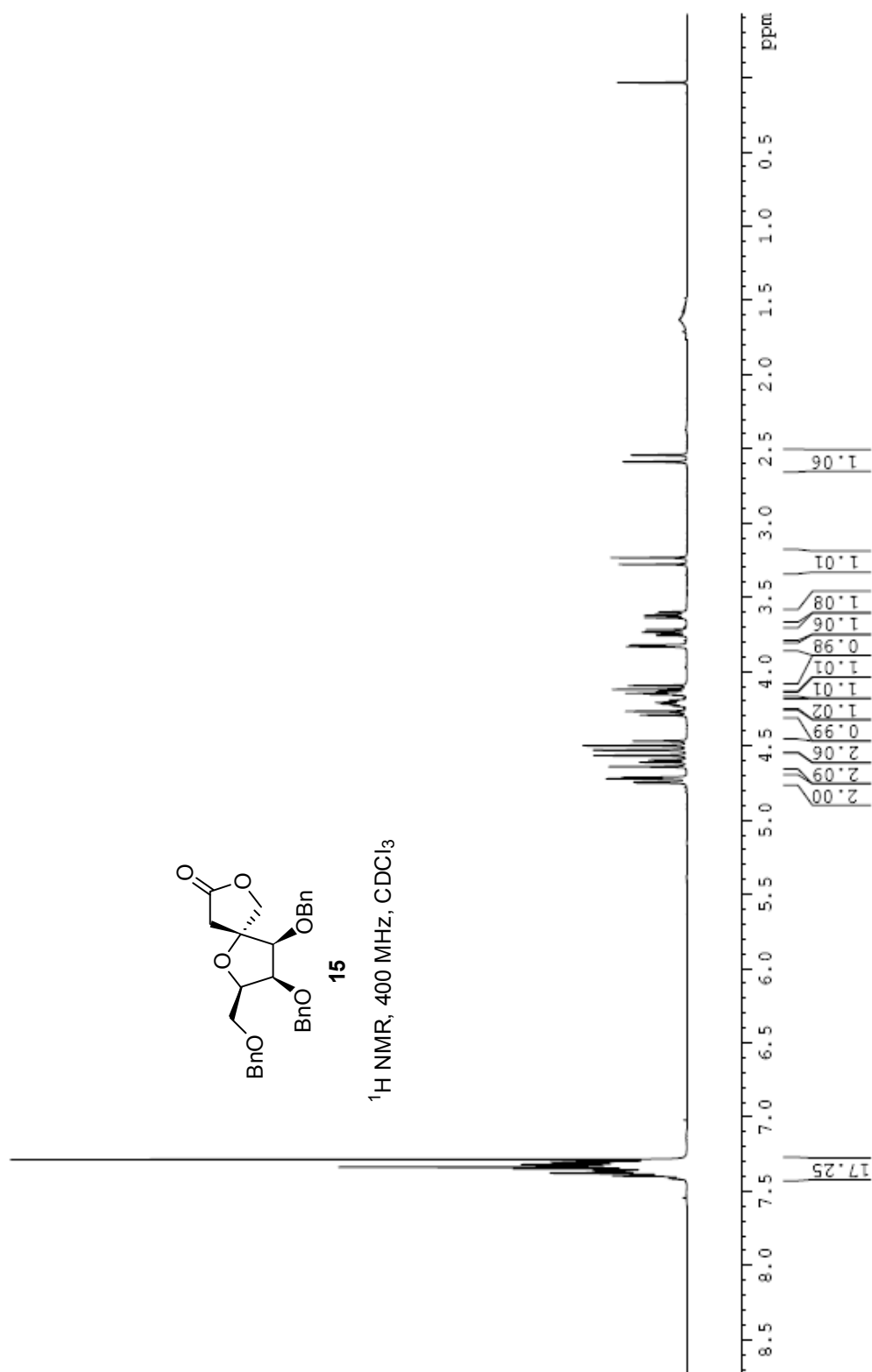


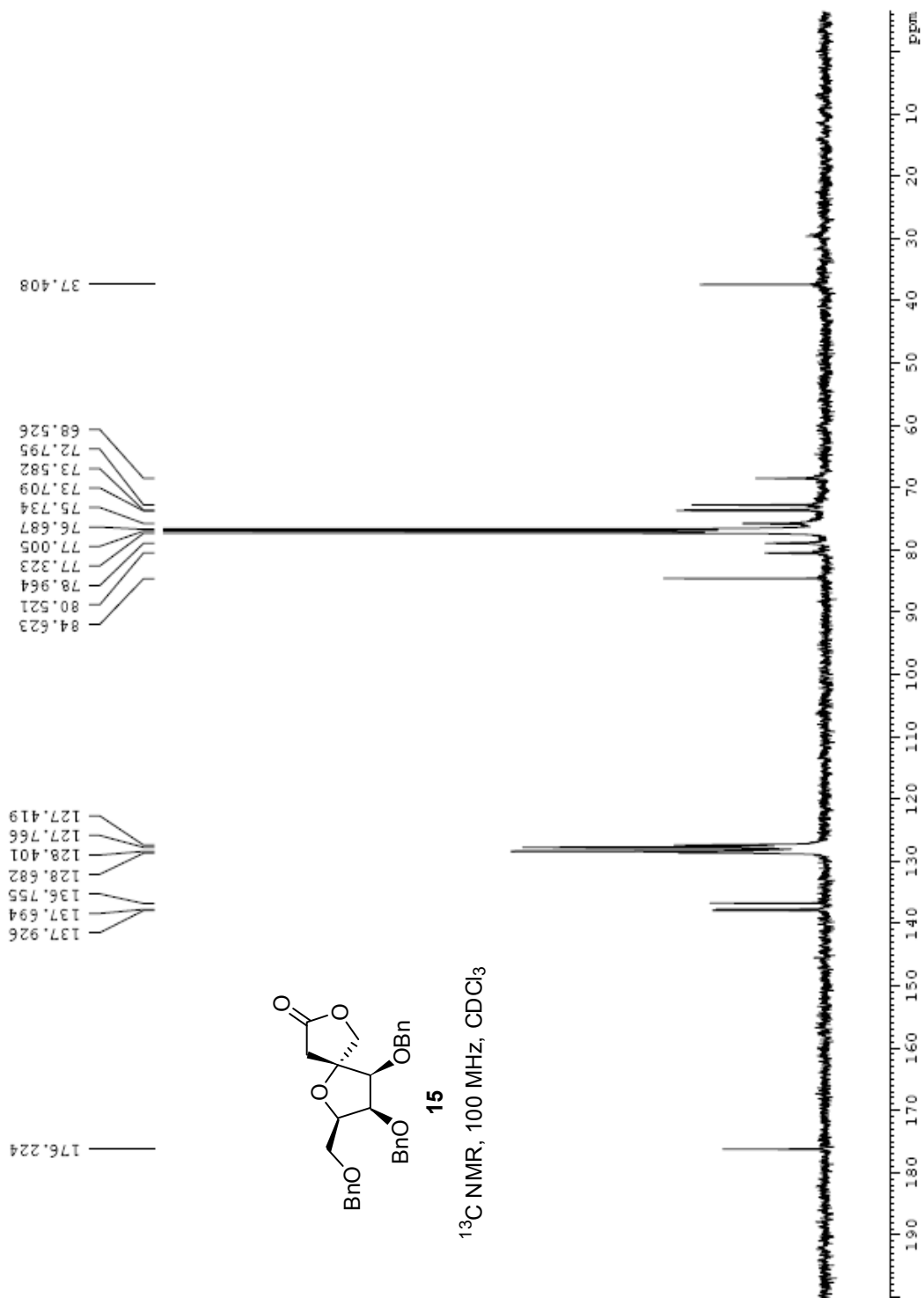


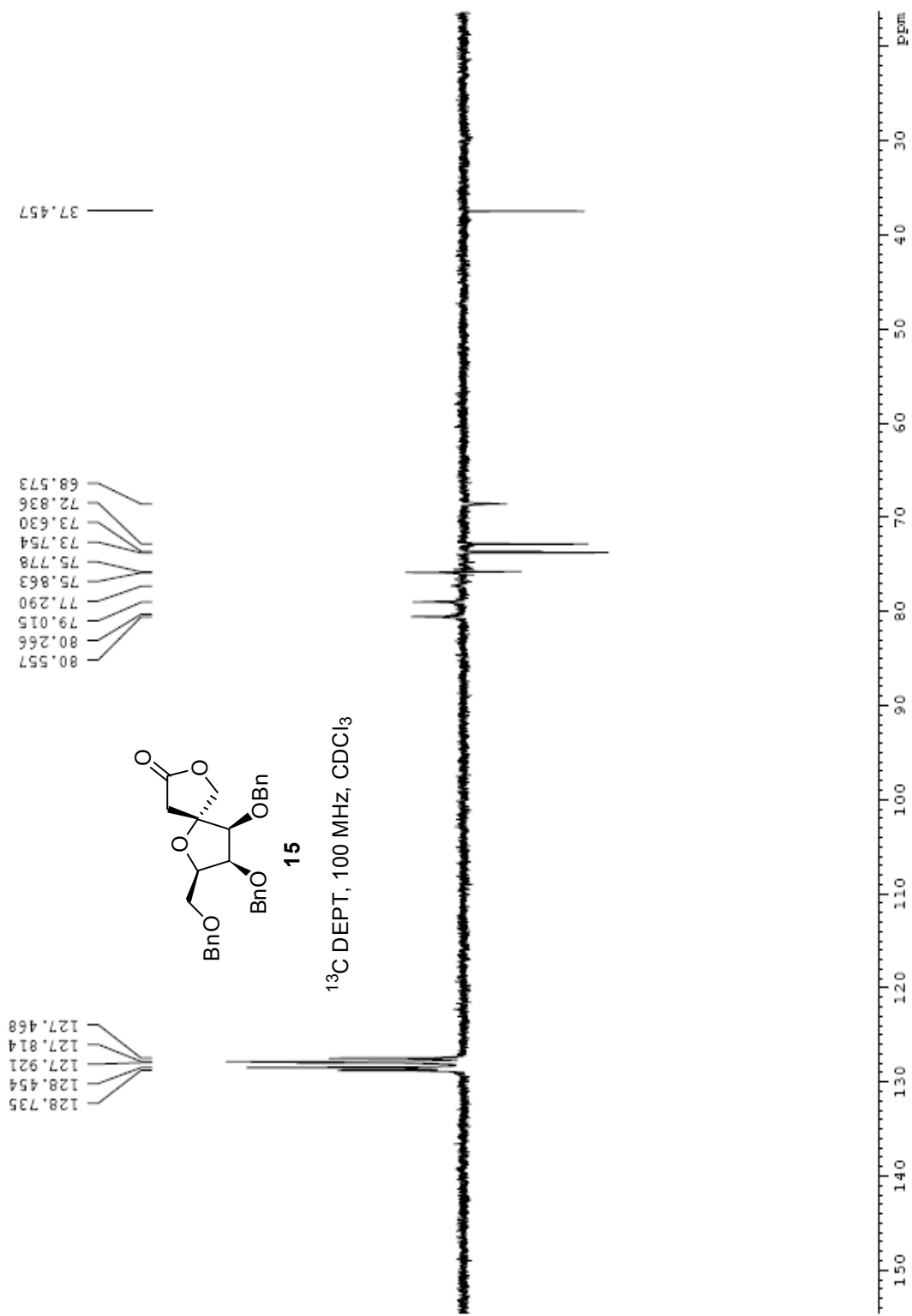




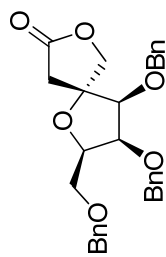
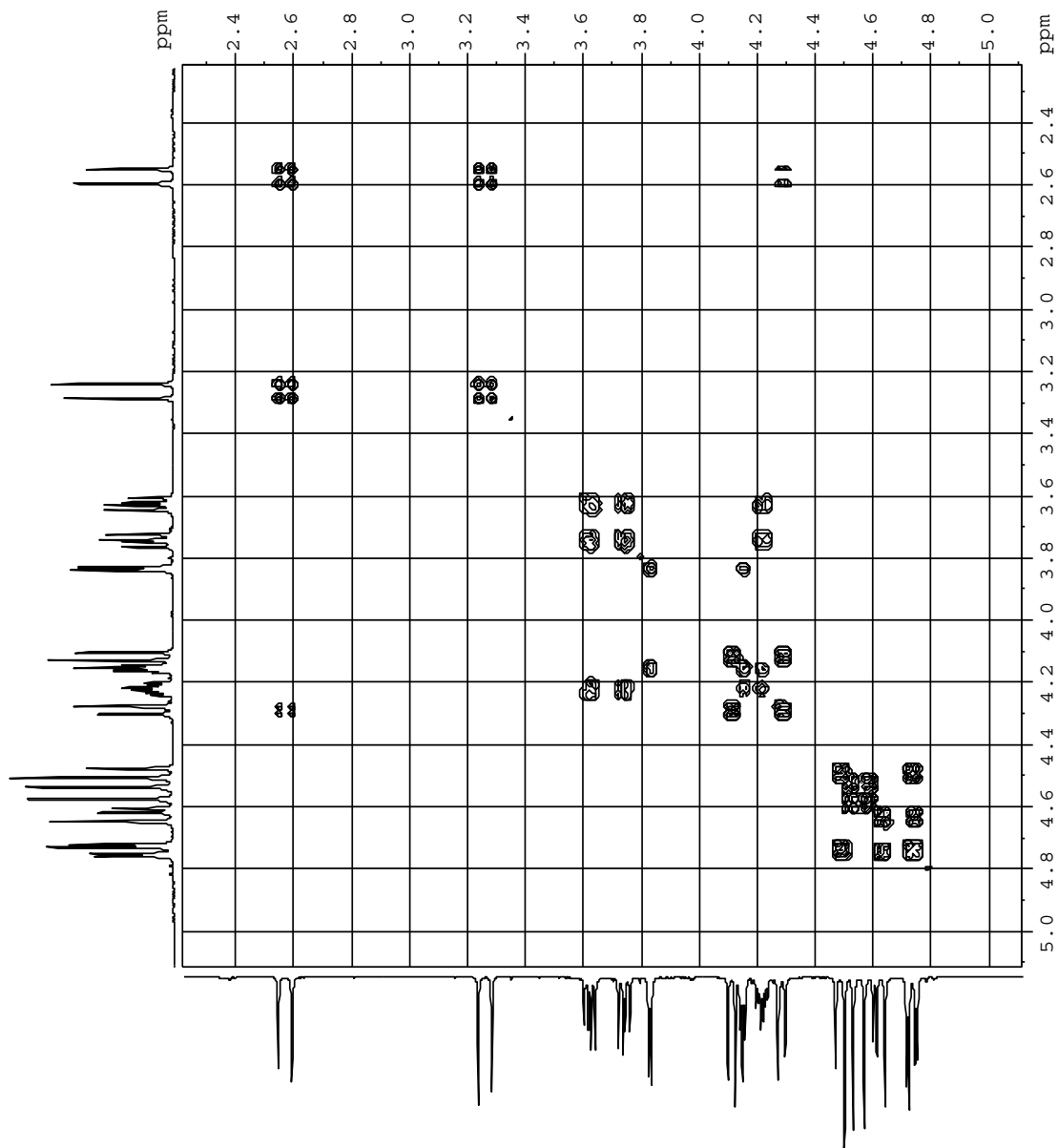






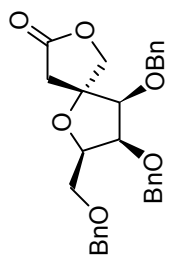
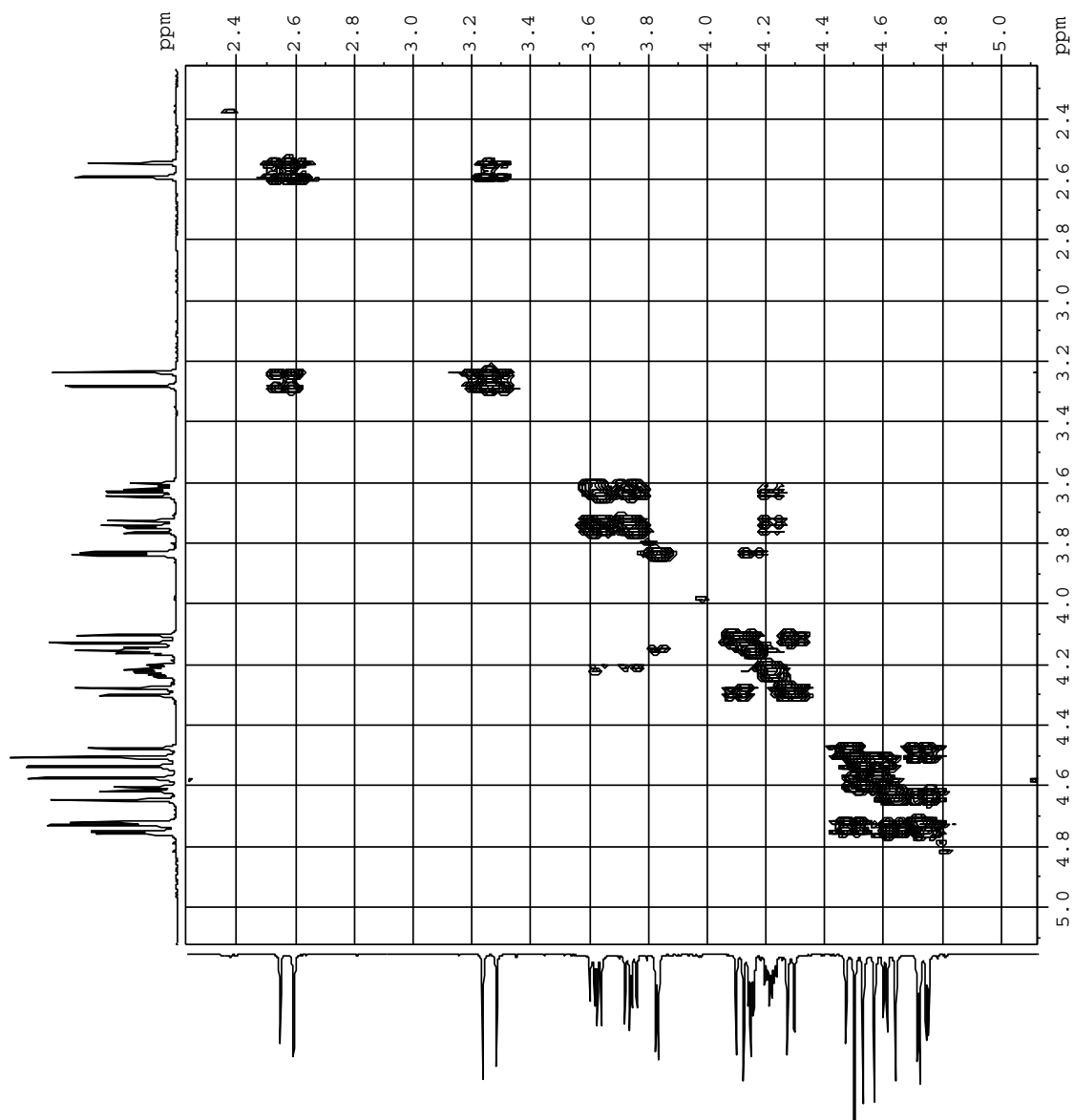






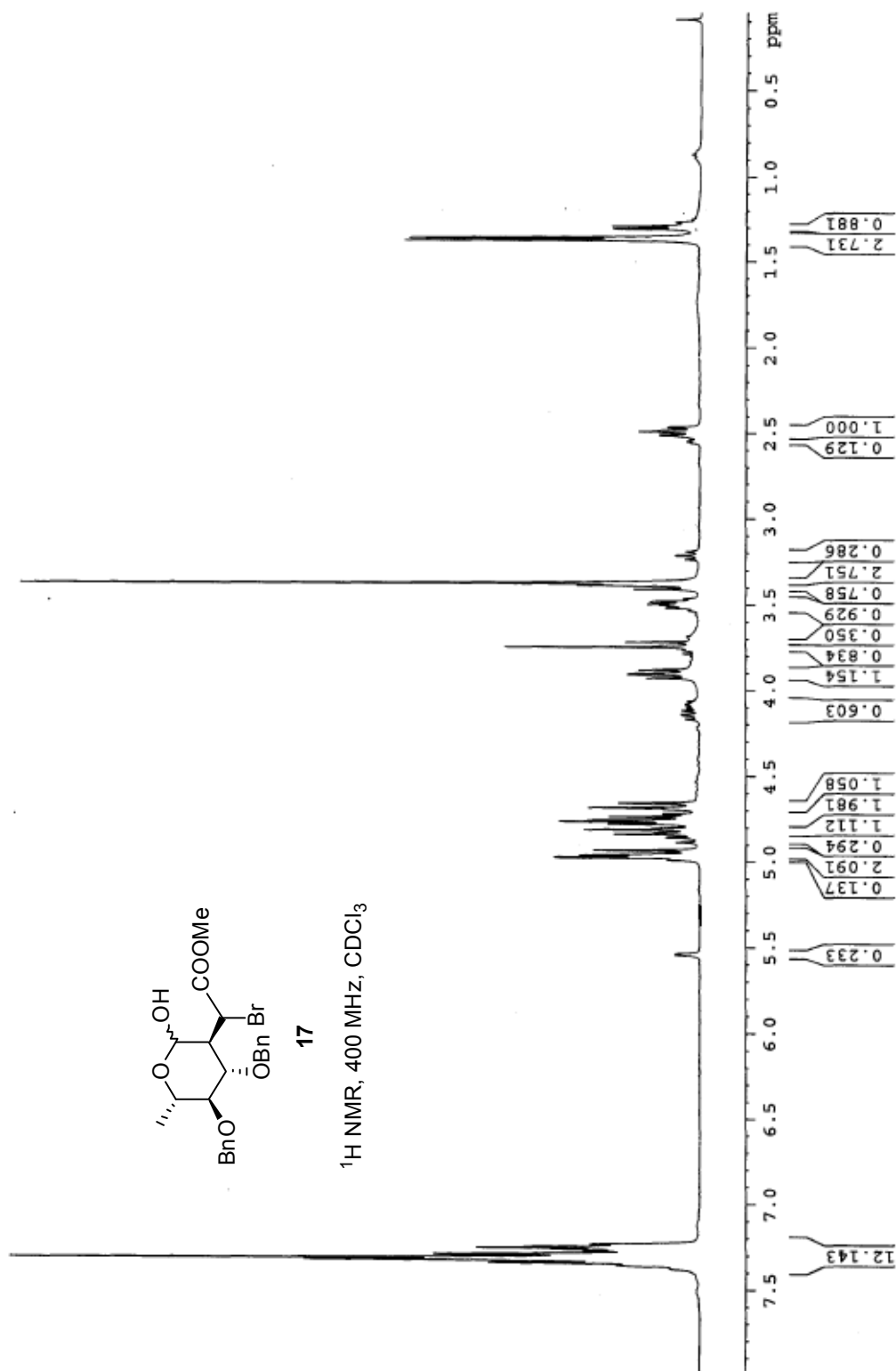
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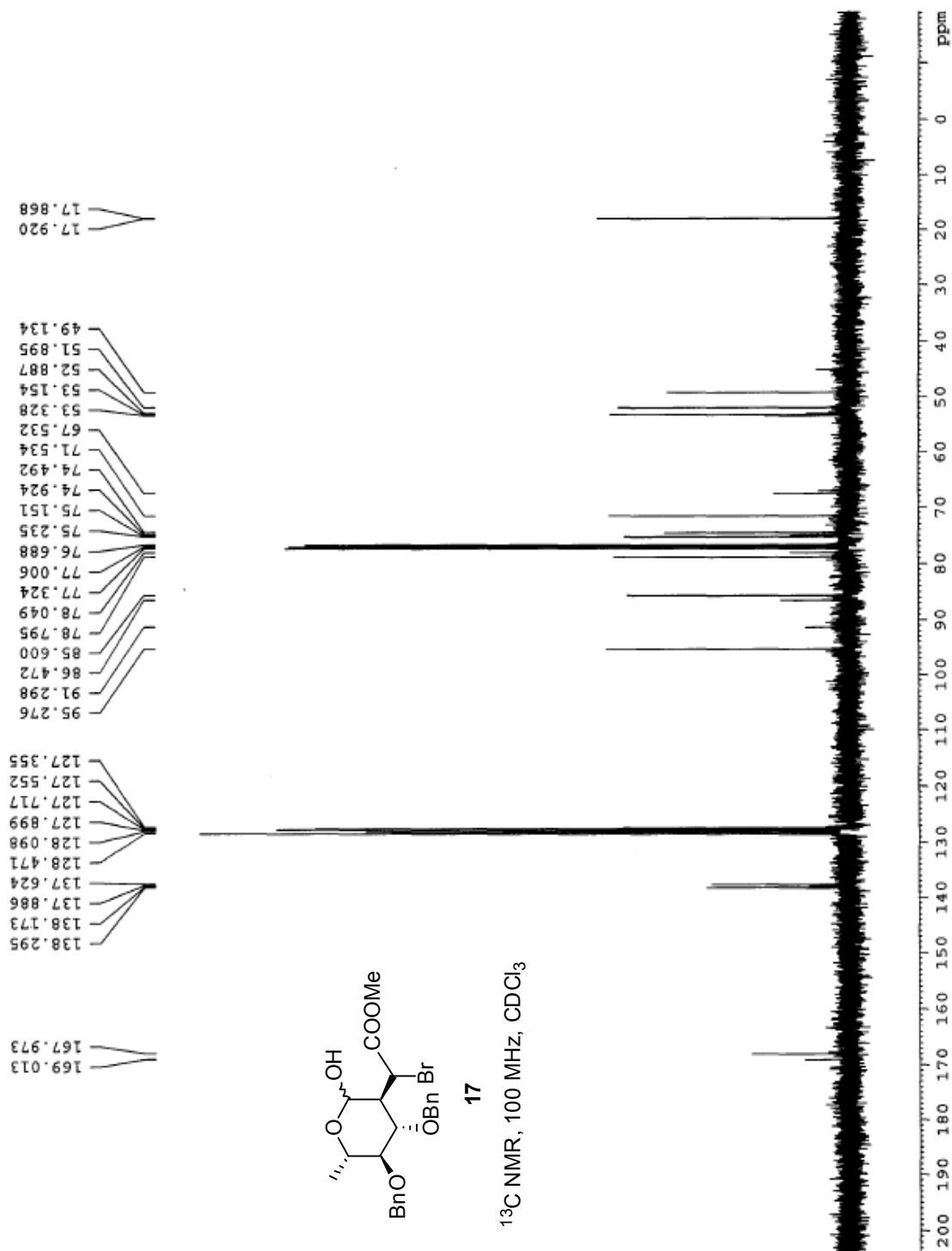
<sup>1</sup>H-<sup>1</sup>H COSY, 400 MHz, CDCl<sub>3</sub>

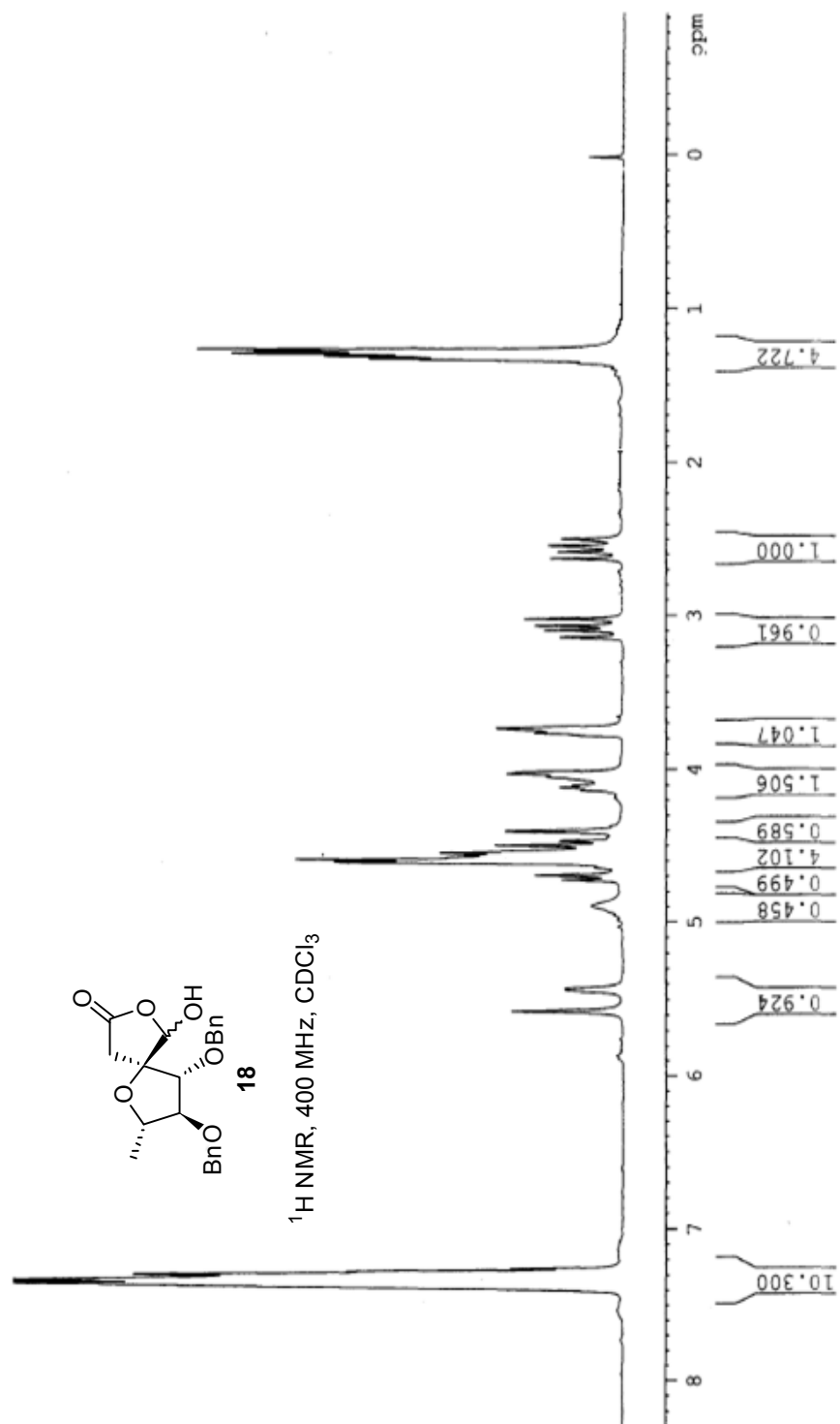


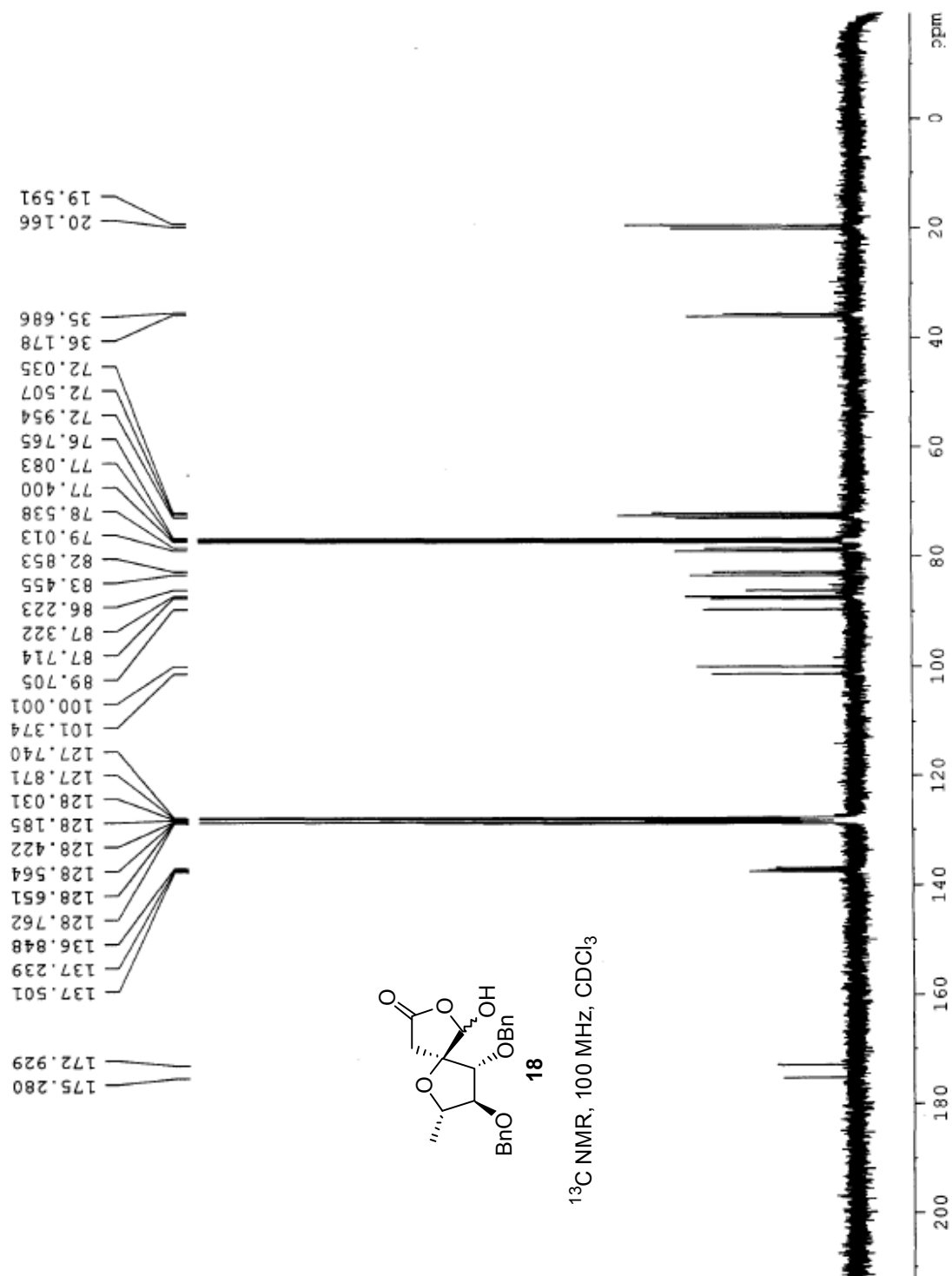
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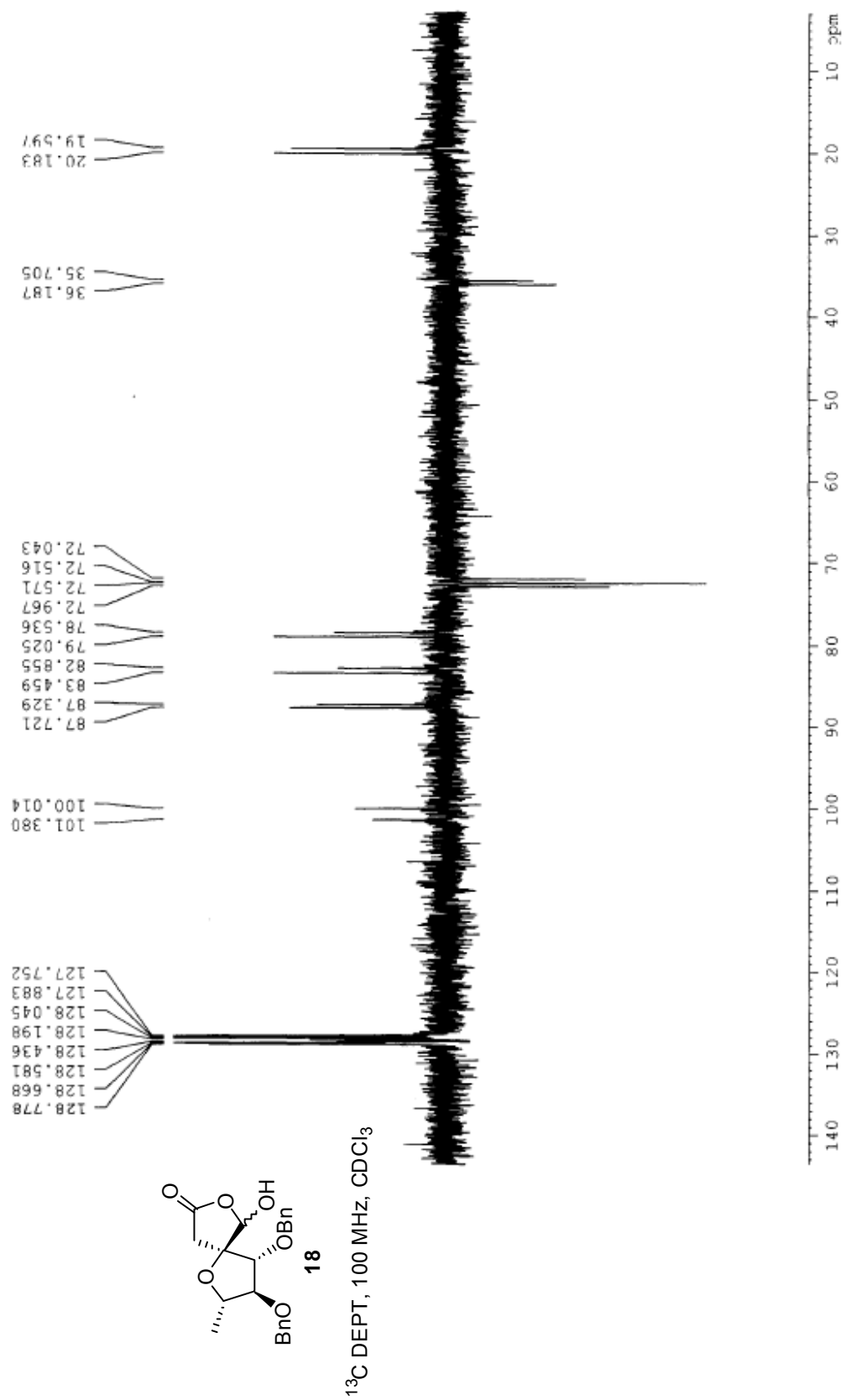
NOESY, 400 MHz, CDCl<sub>3</sub>

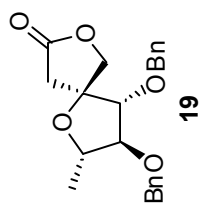




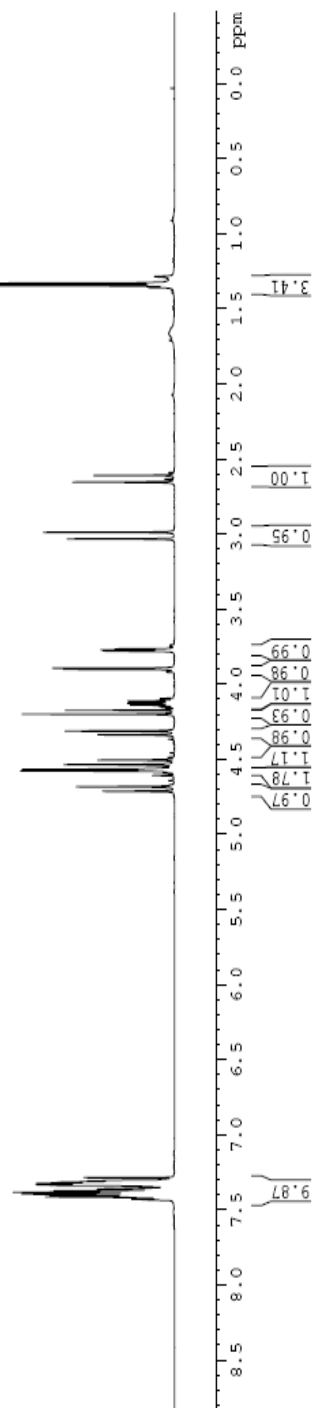




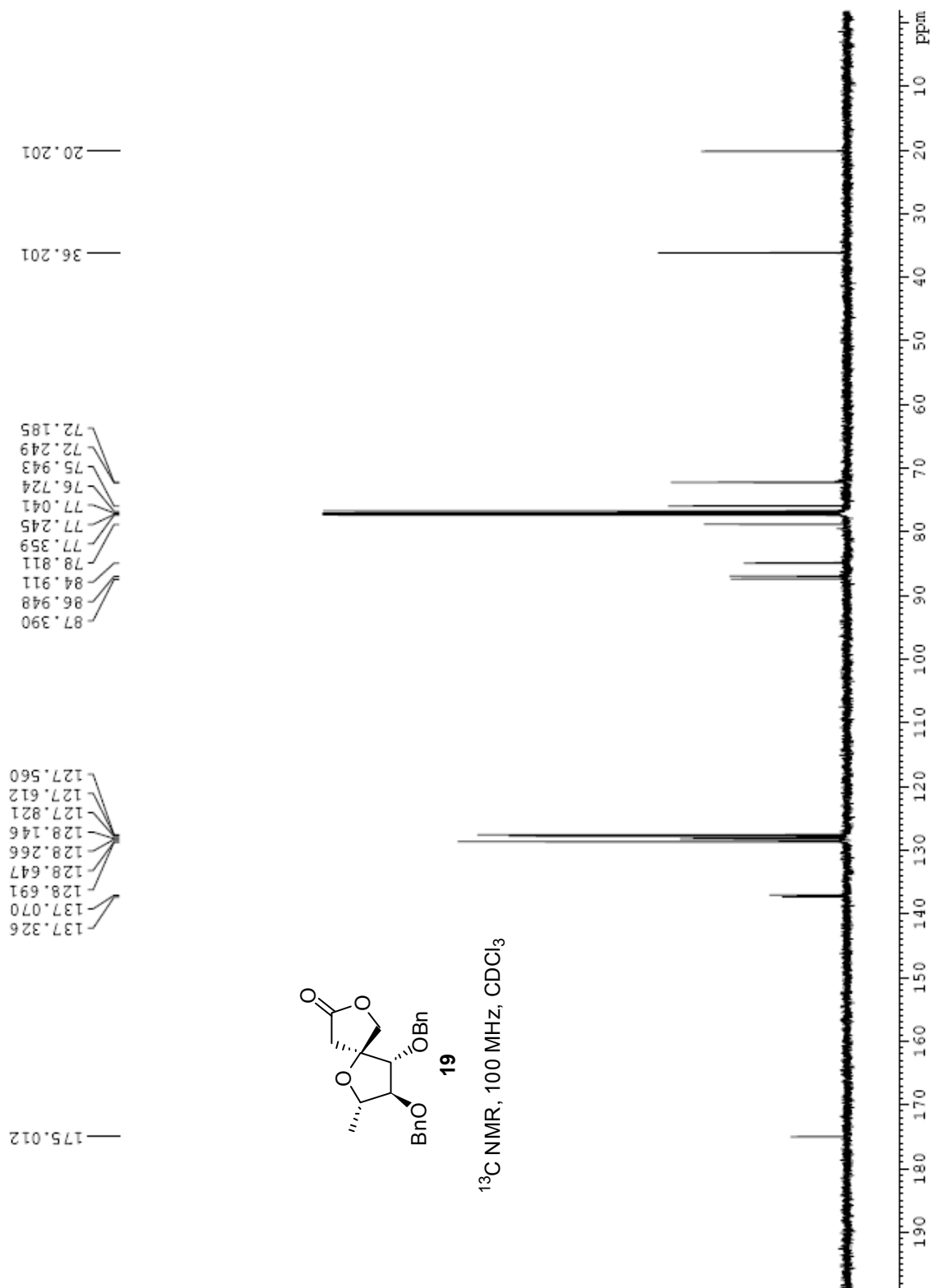


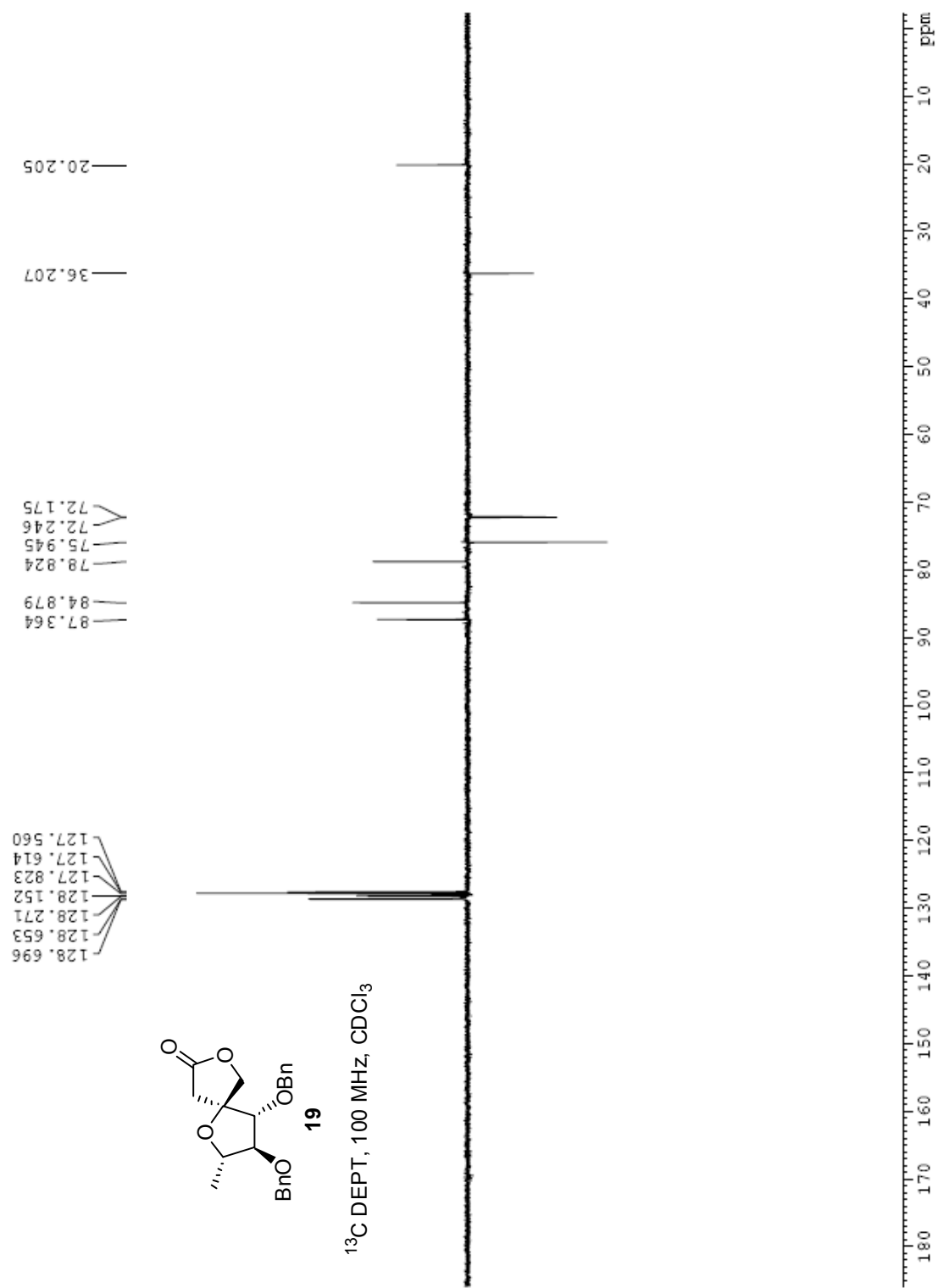


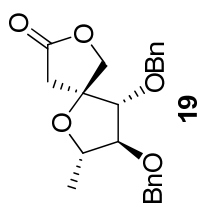
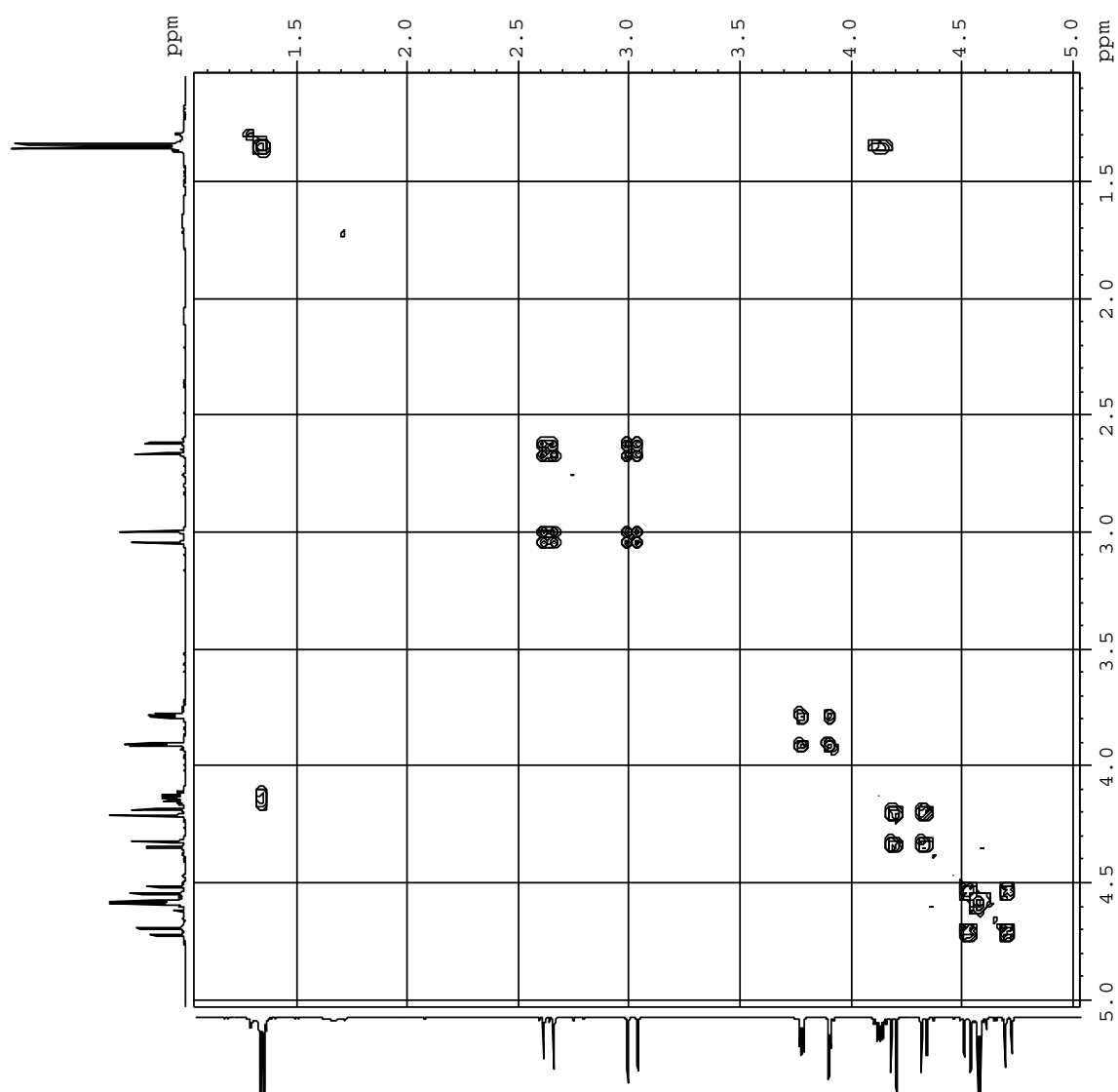
$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$



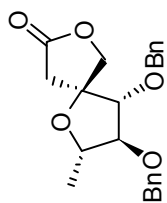




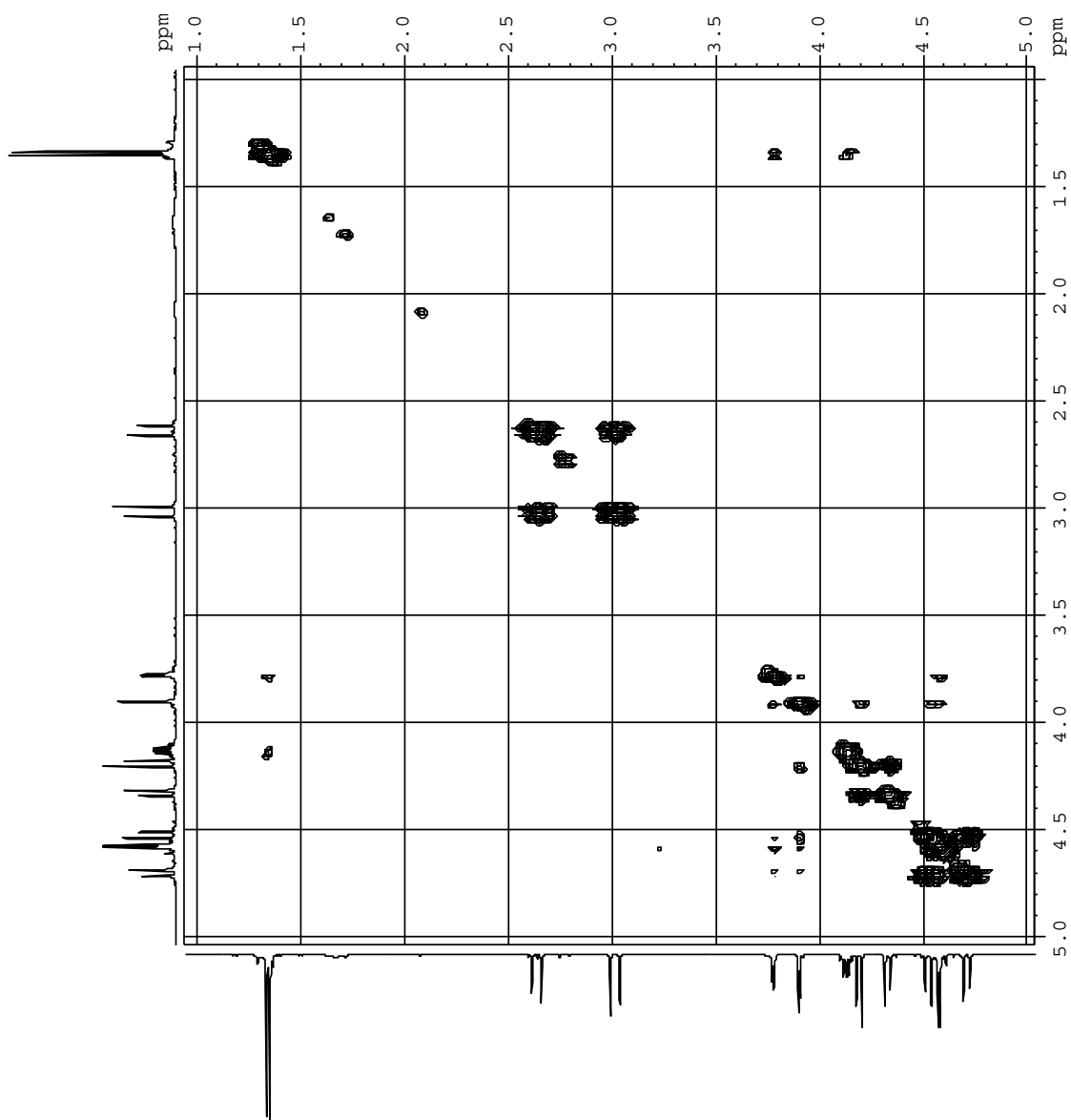


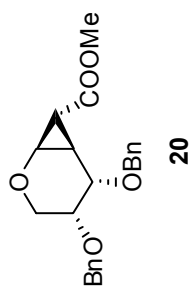


$^1\text{H}$ - $^1\text{H}$  COSY, 400 MHz,  $\text{CDCl}_3$



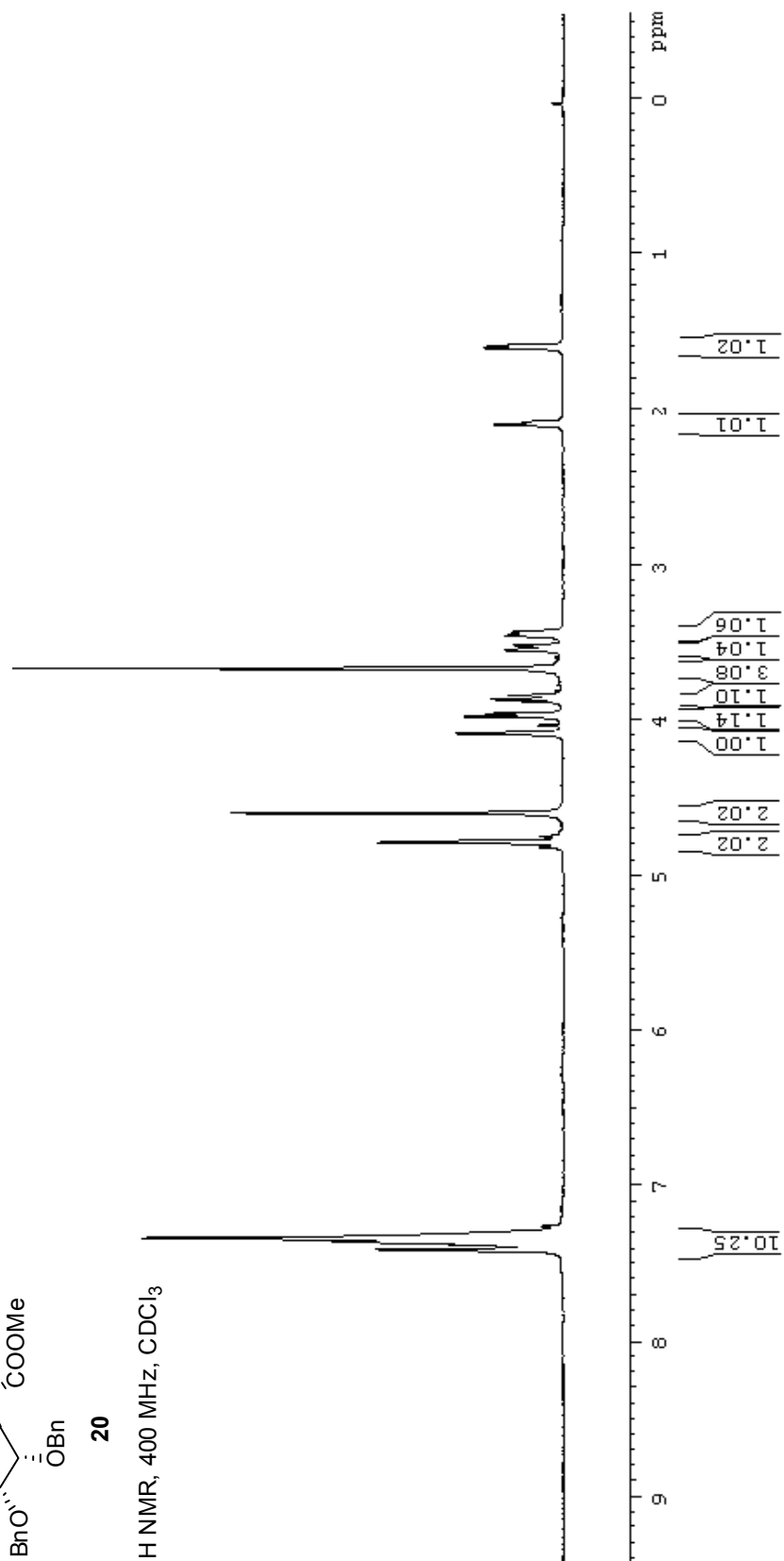
NOESY, 400 MHz, CDCl<sub>3</sub>

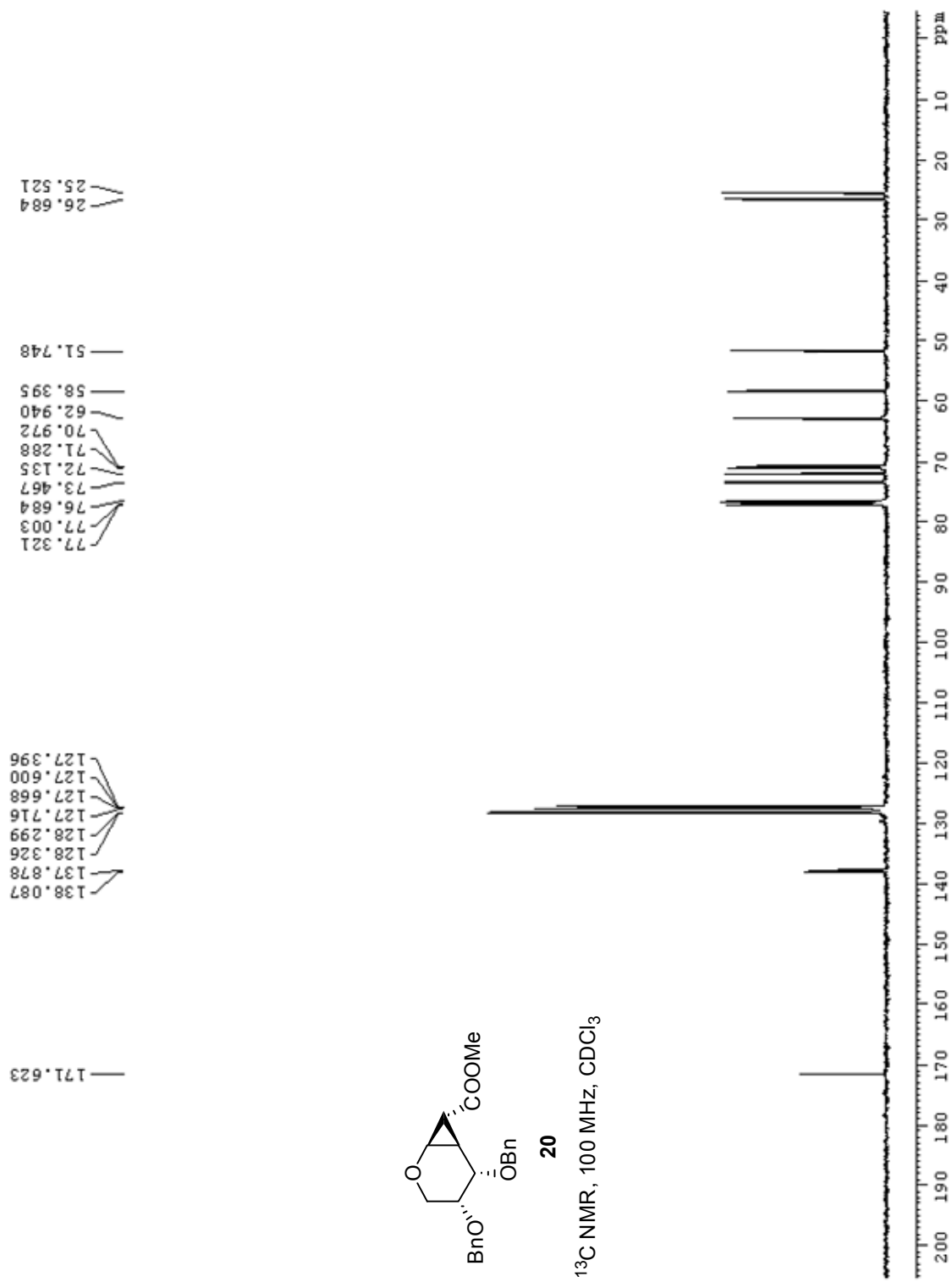


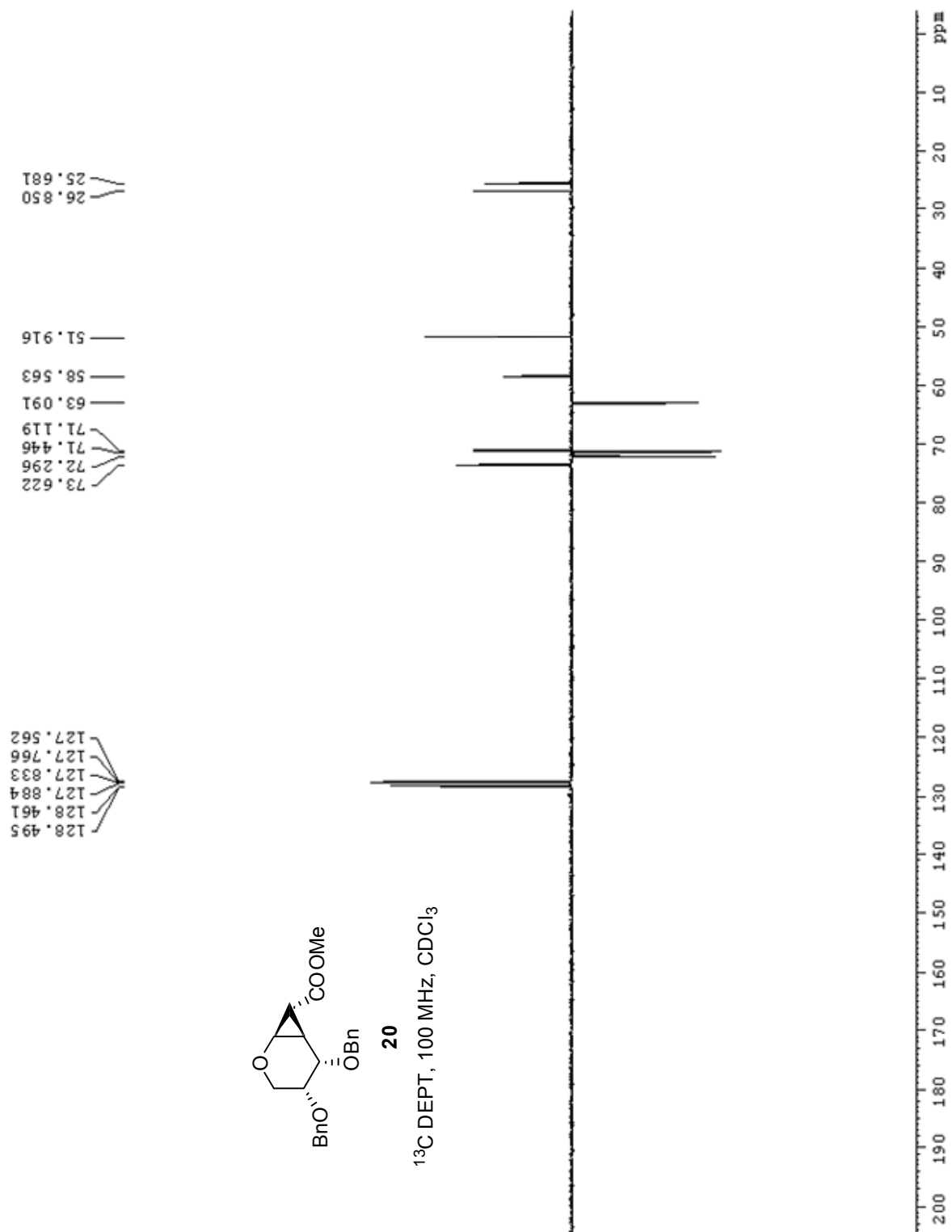


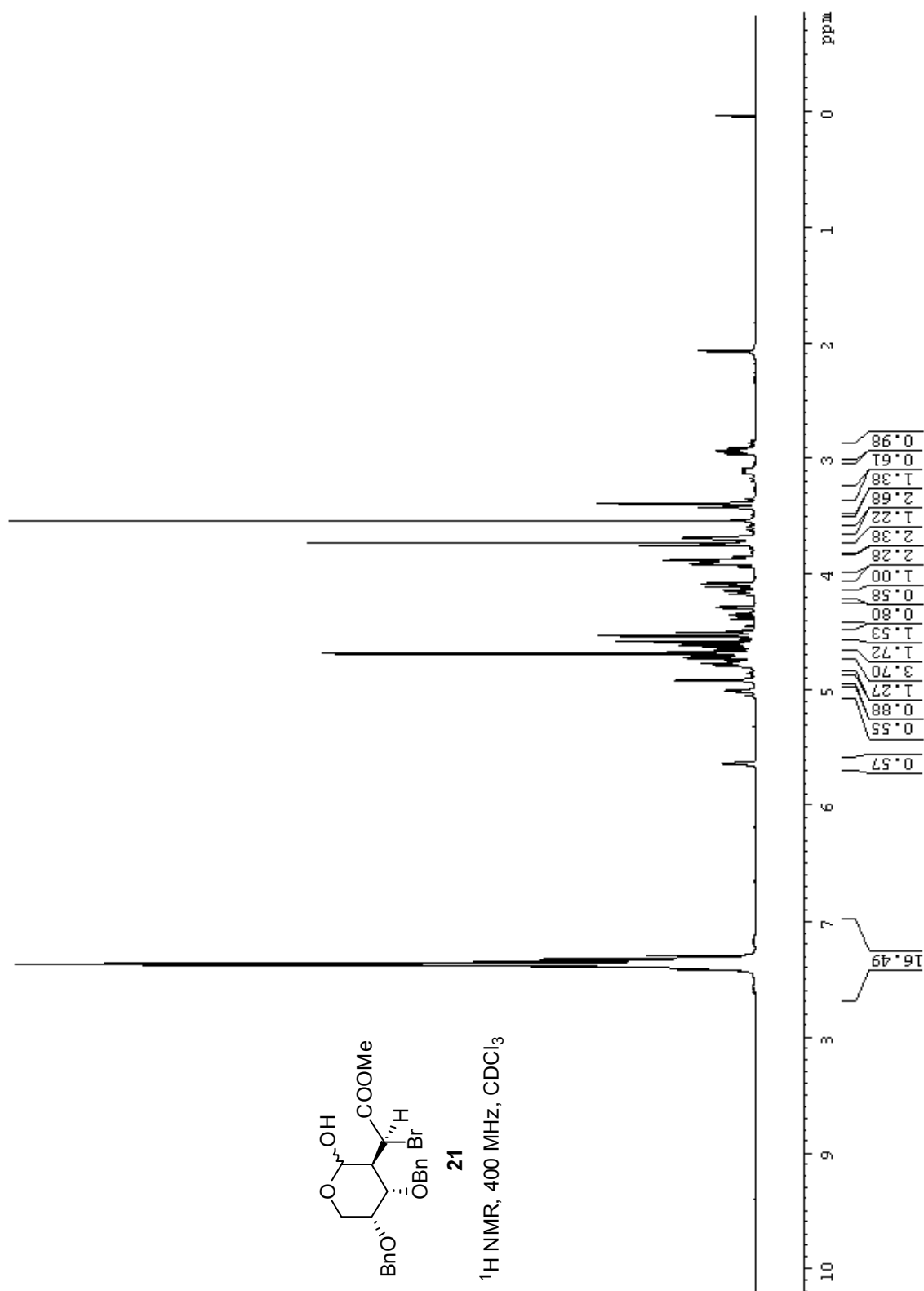
**20**

$^1\text{H NMR}$ , 400 MHz,  $\text{CDCl}_3$

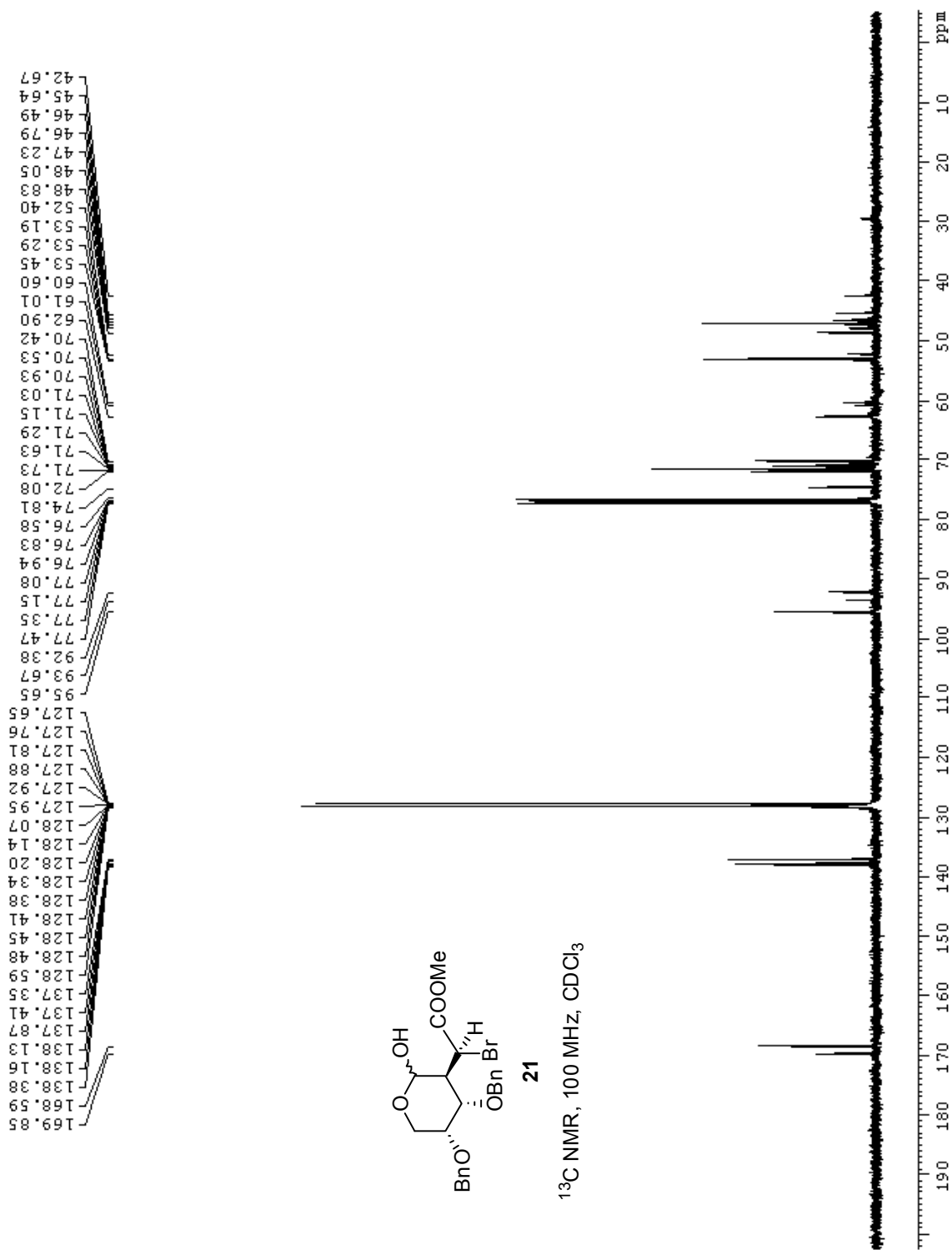


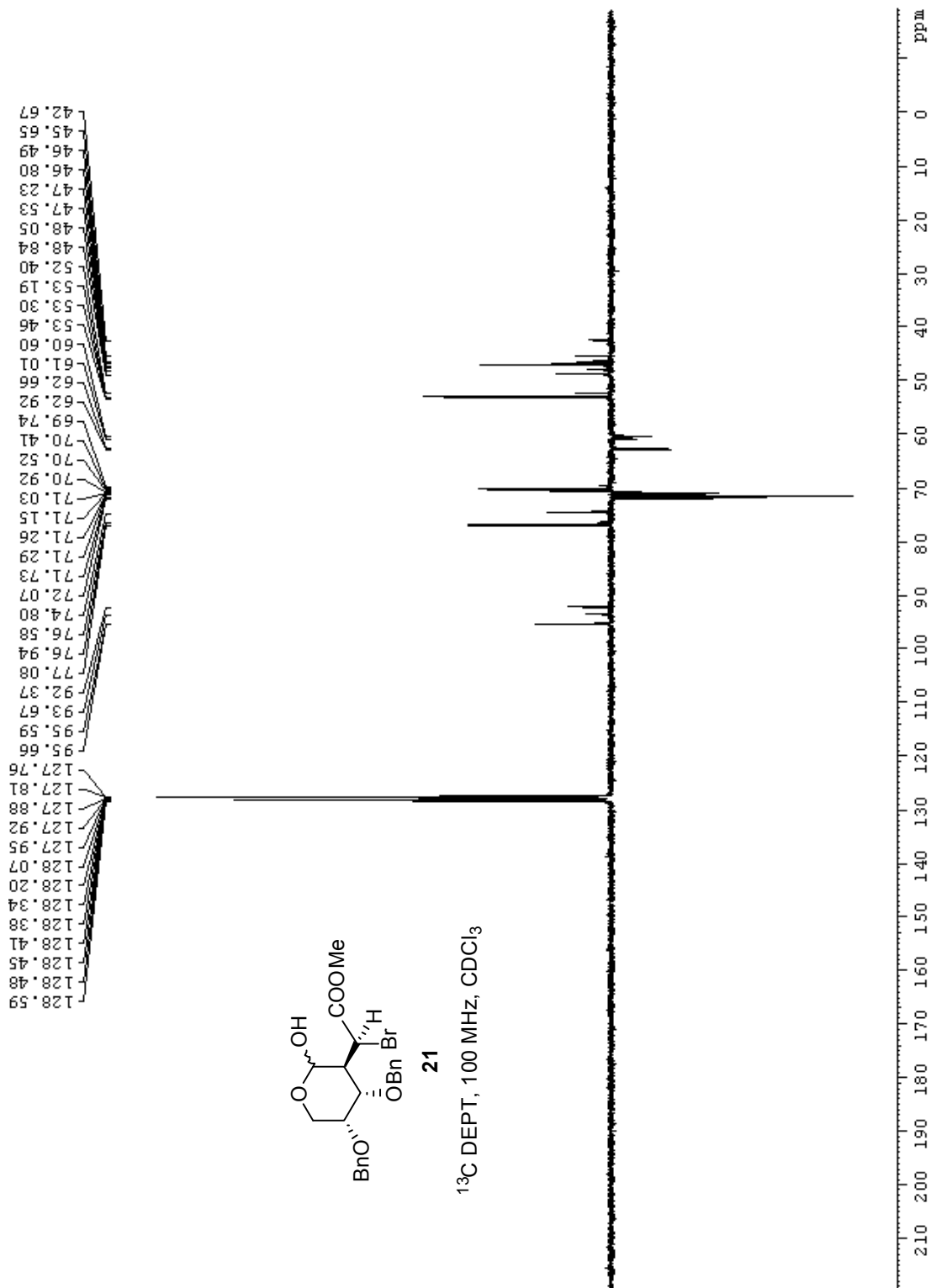


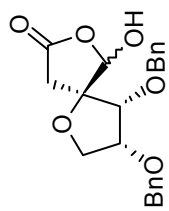




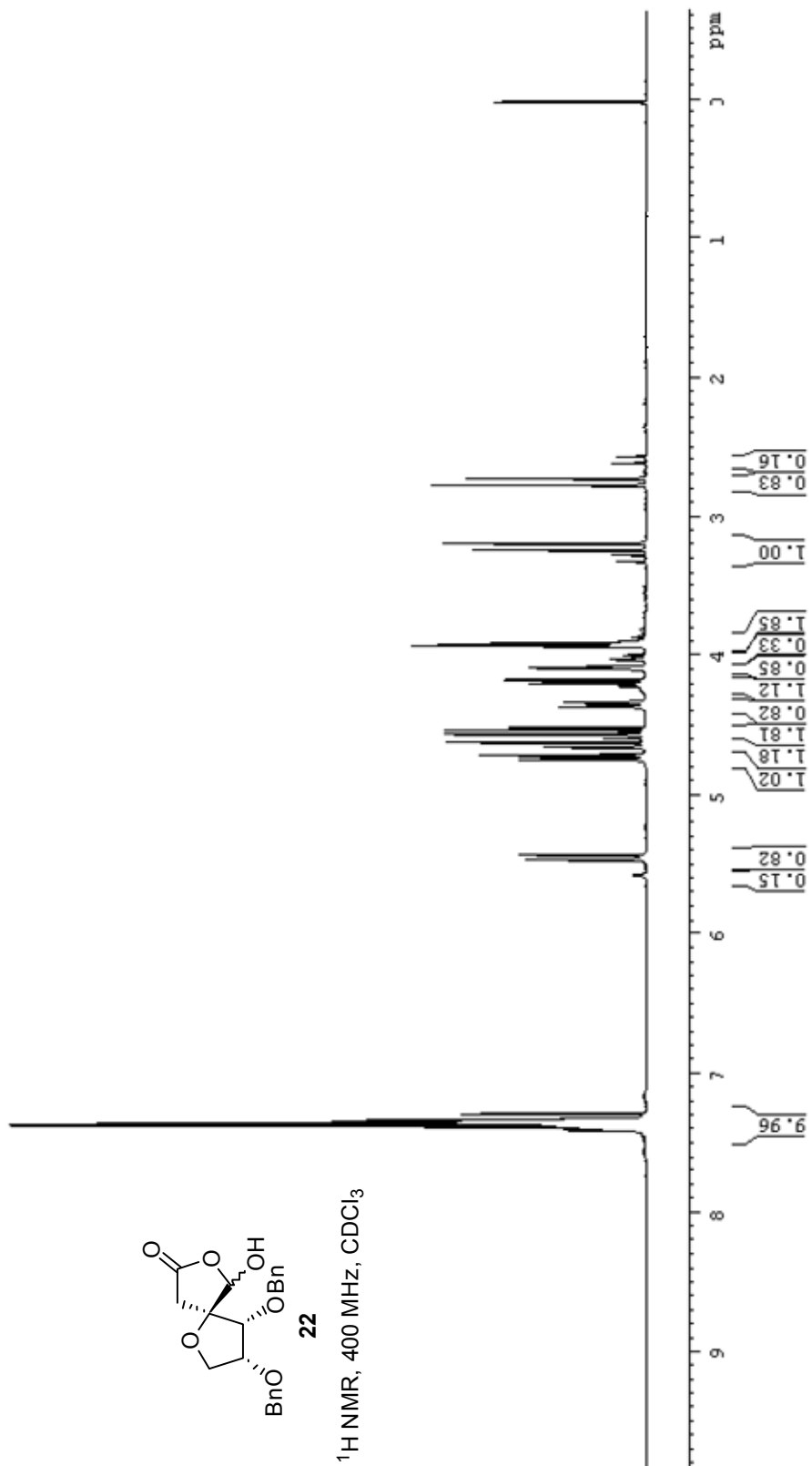


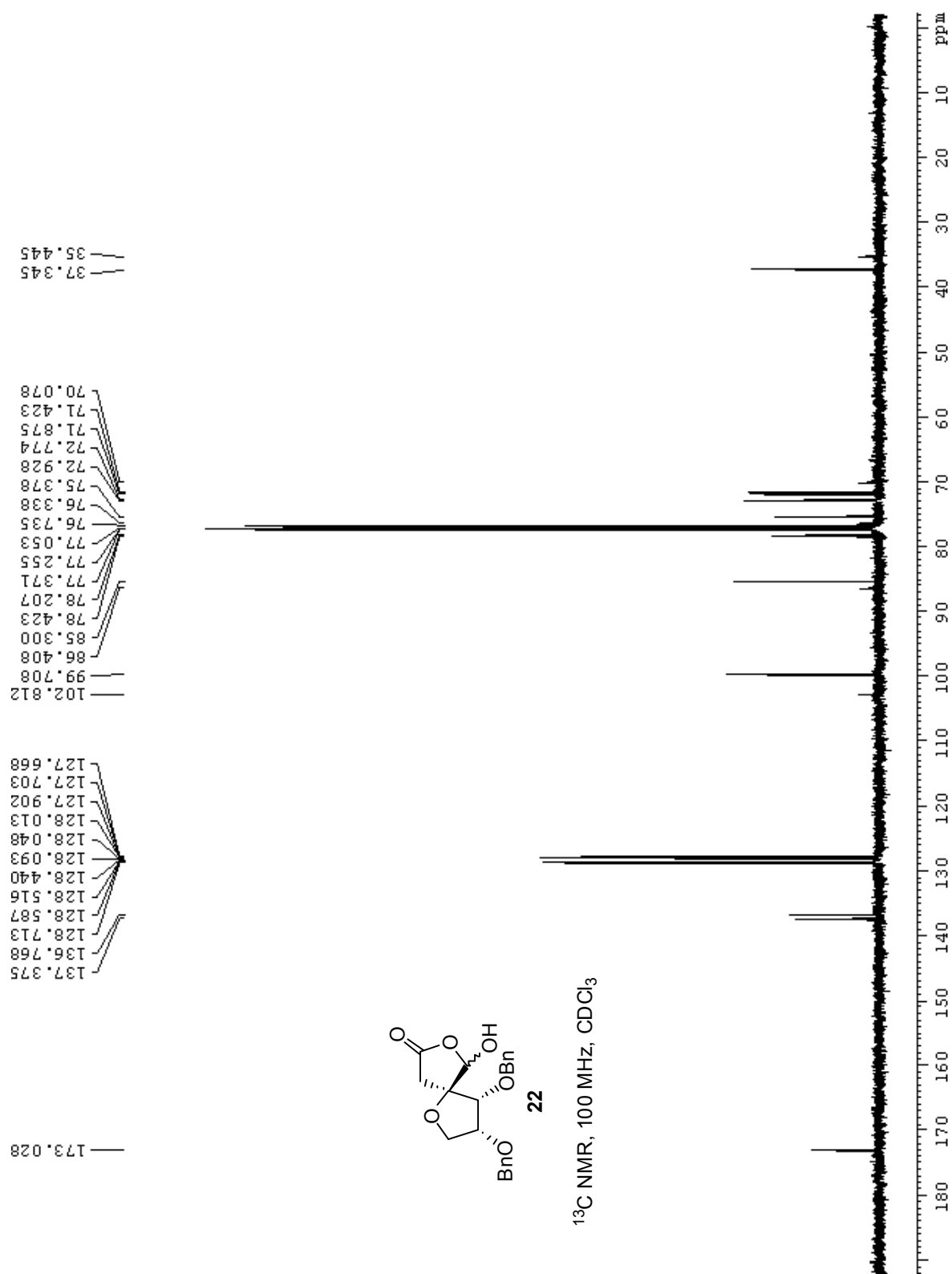


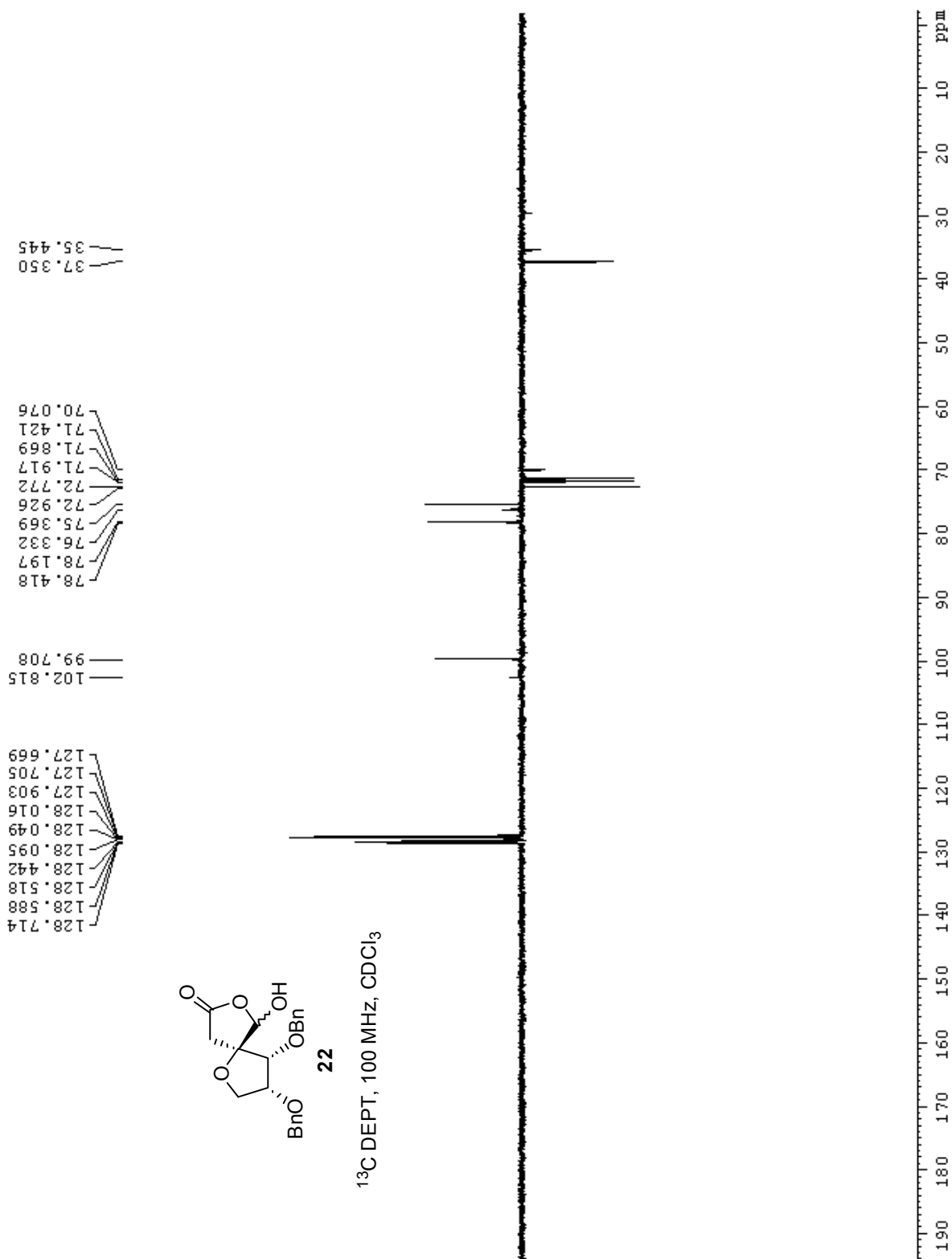


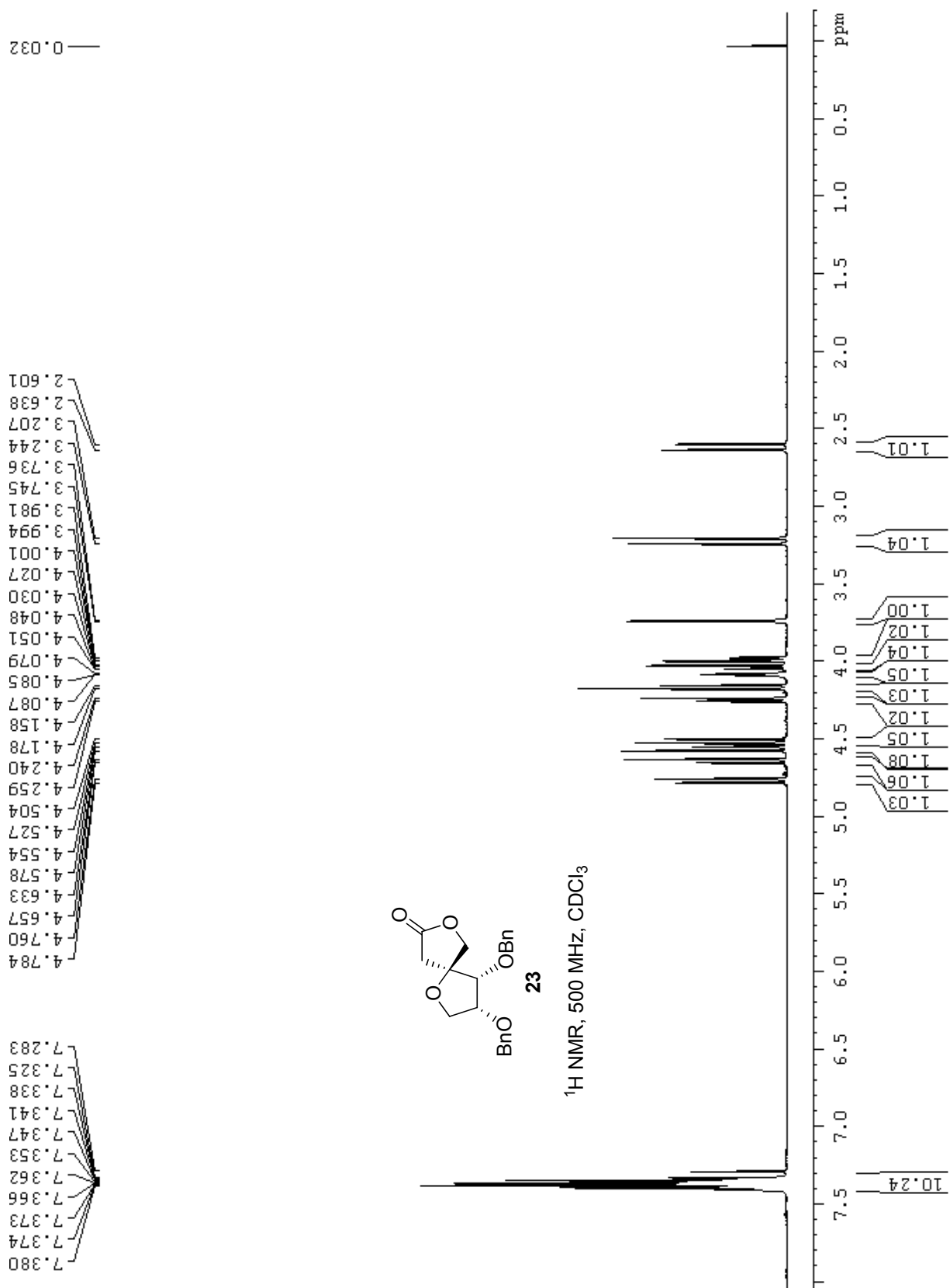


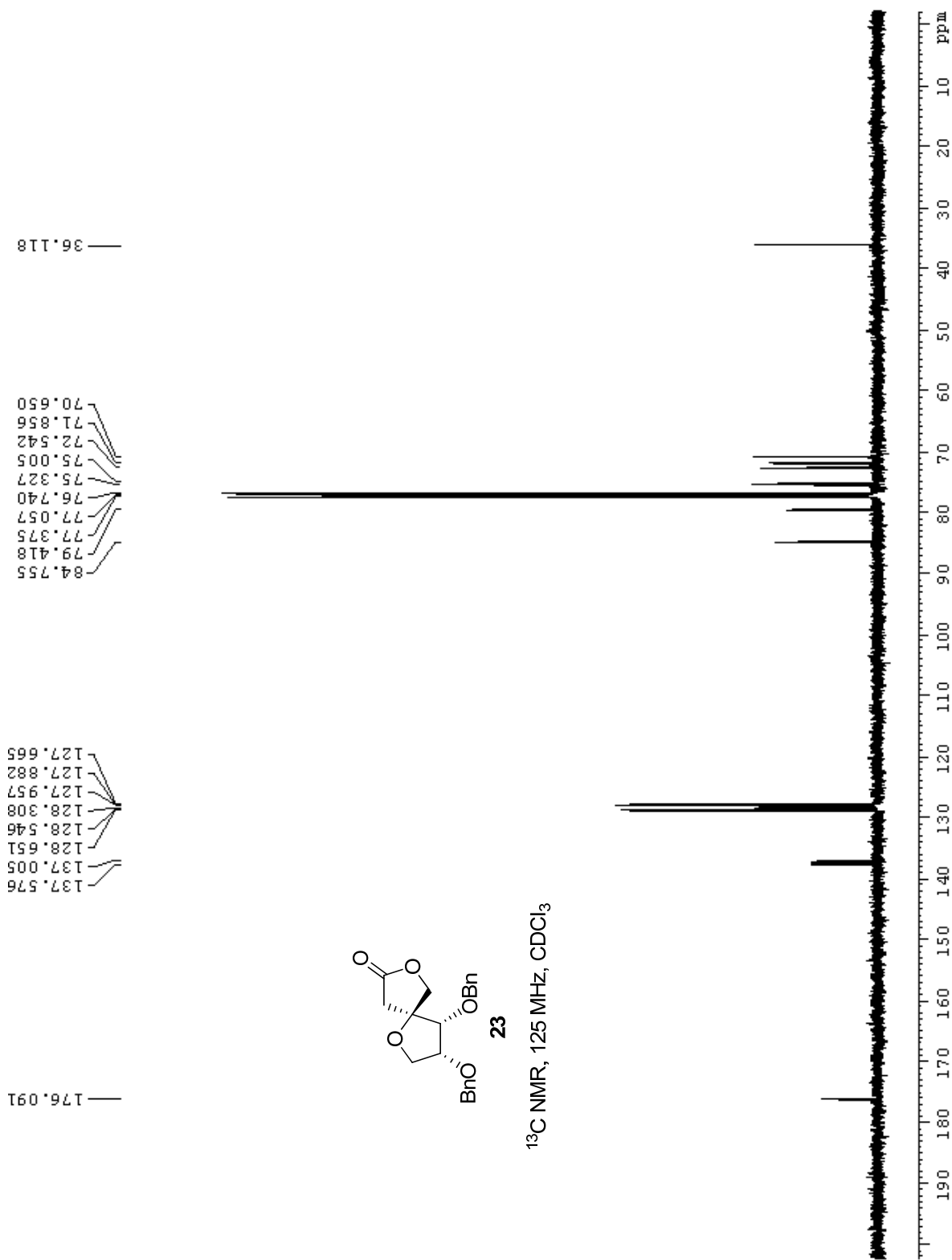
<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>

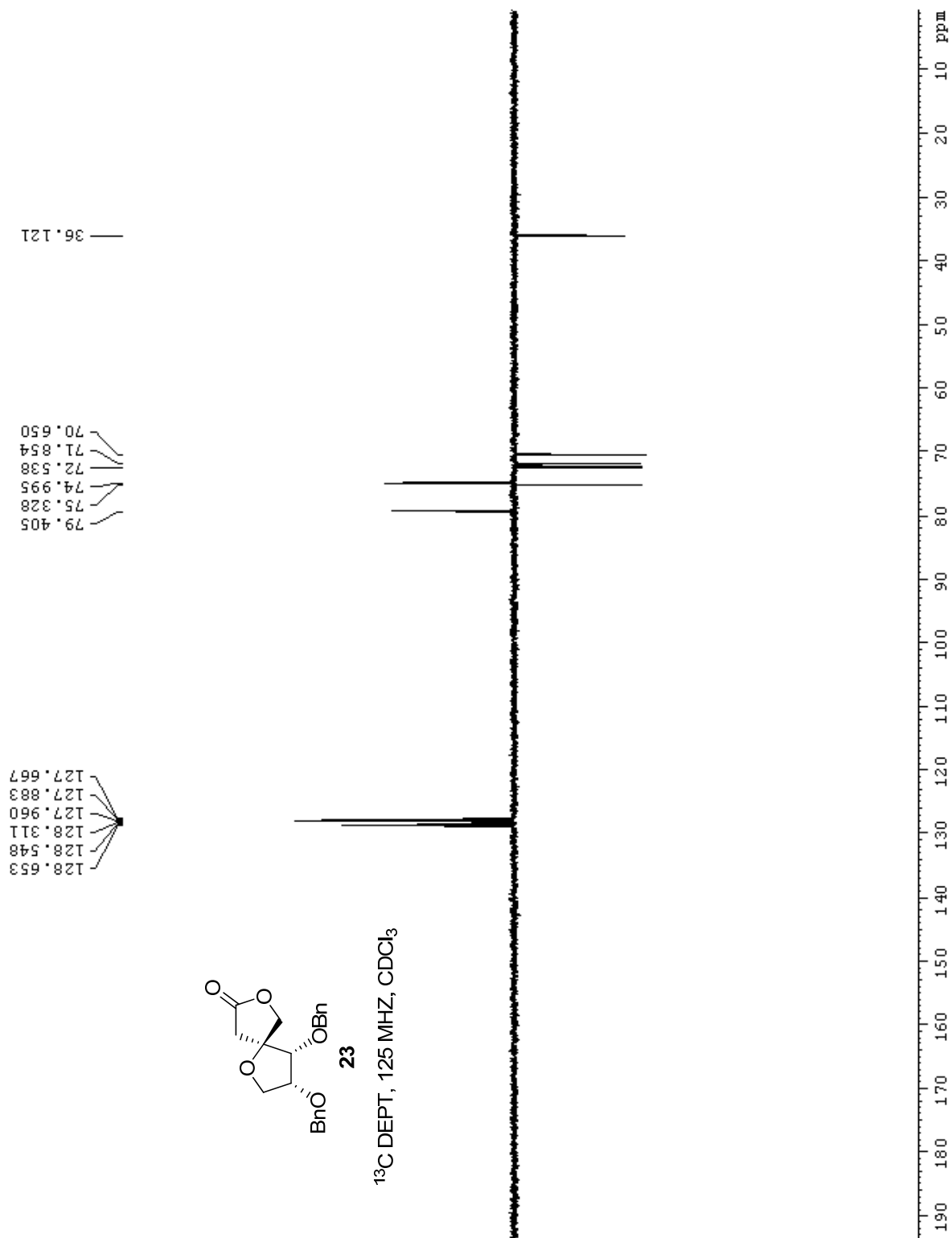




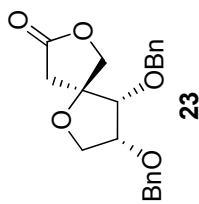
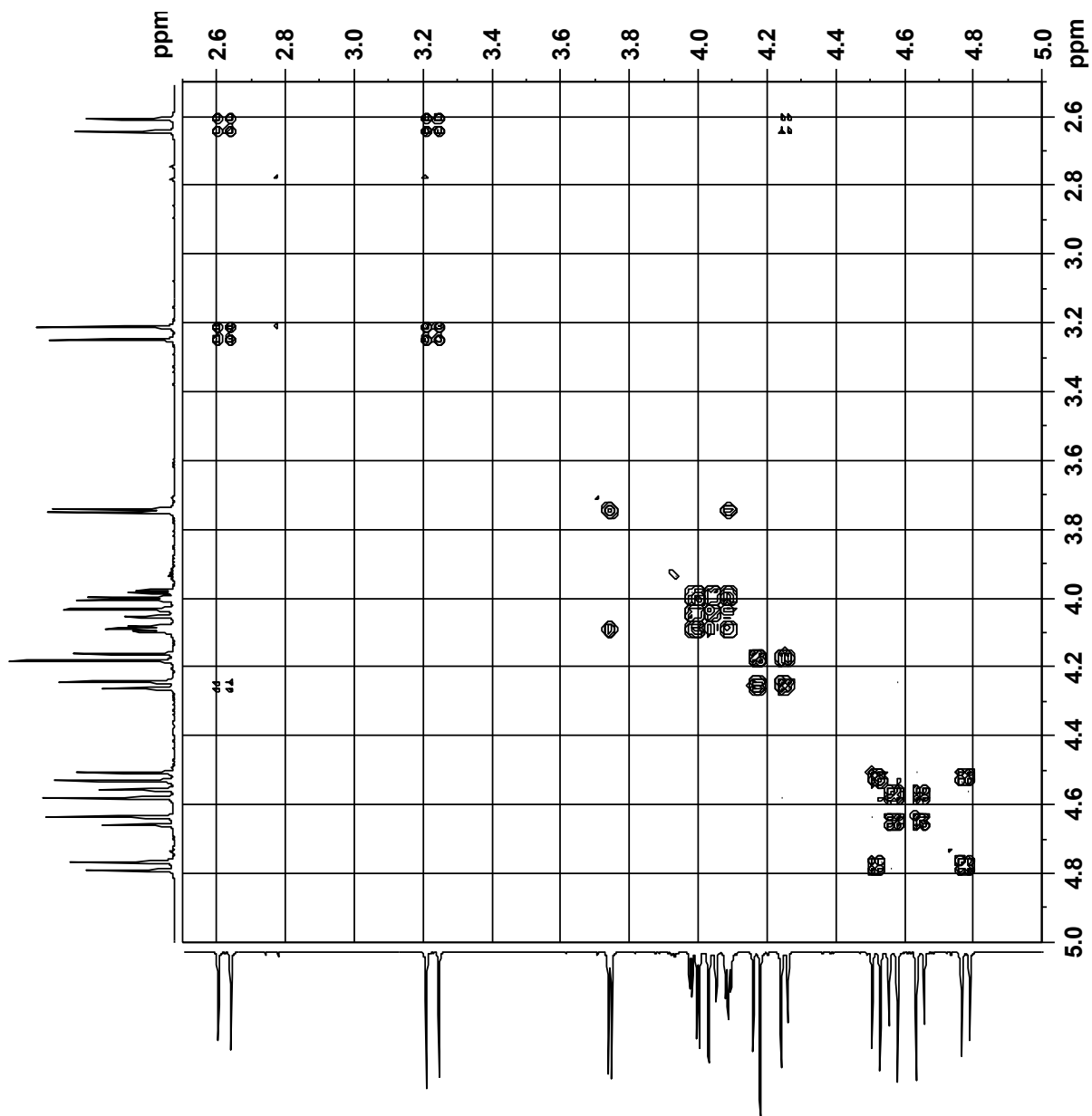






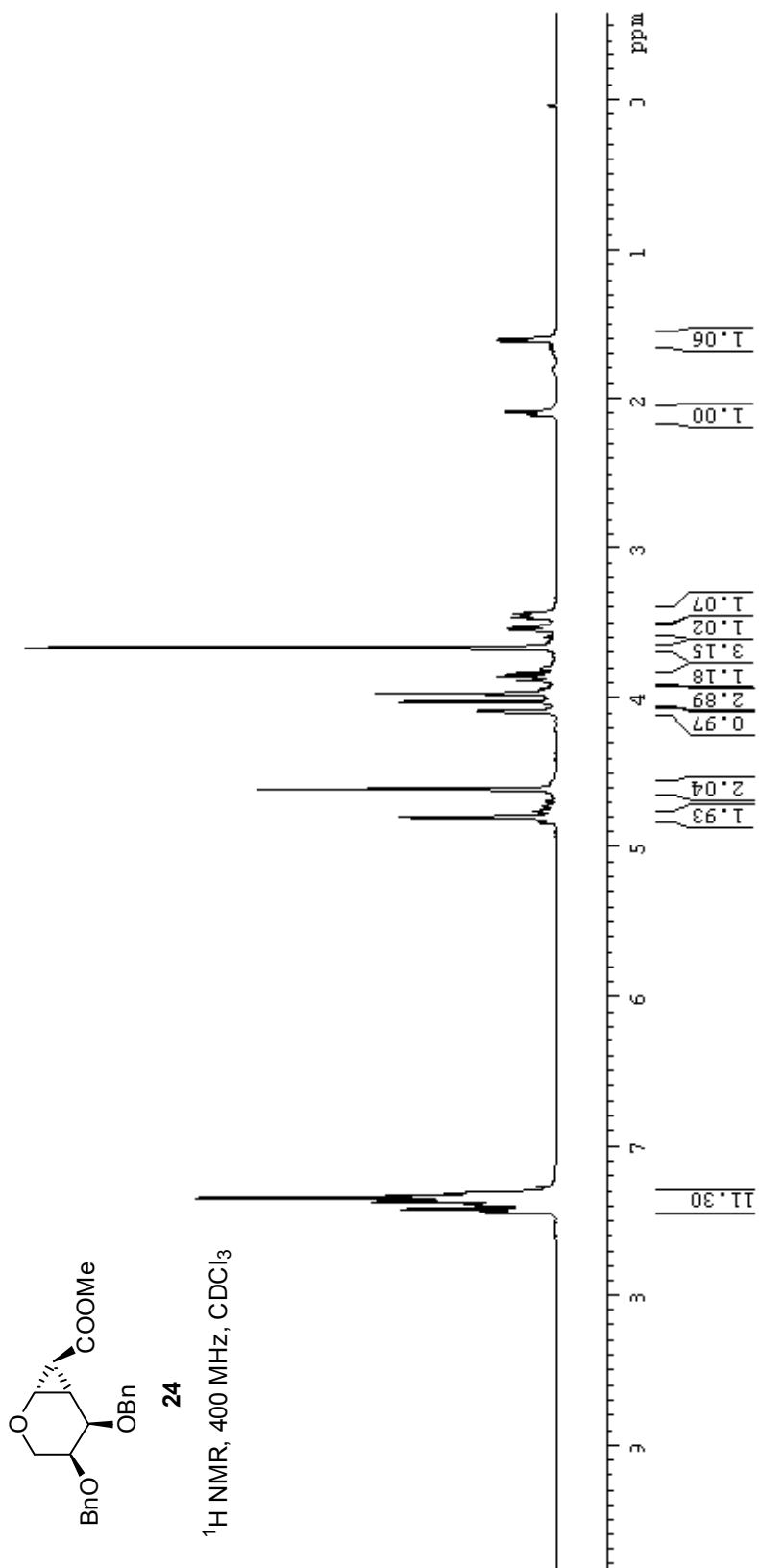


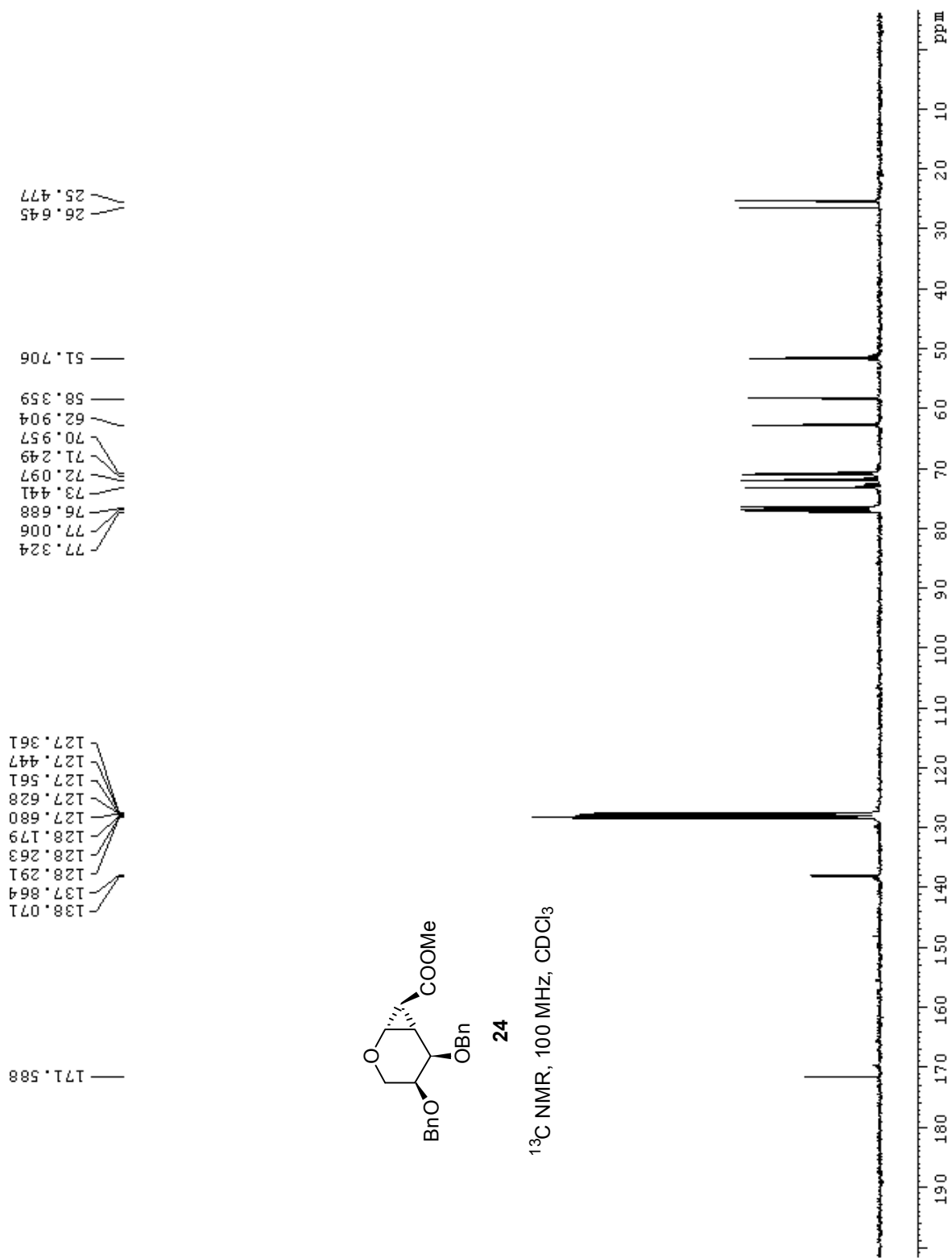


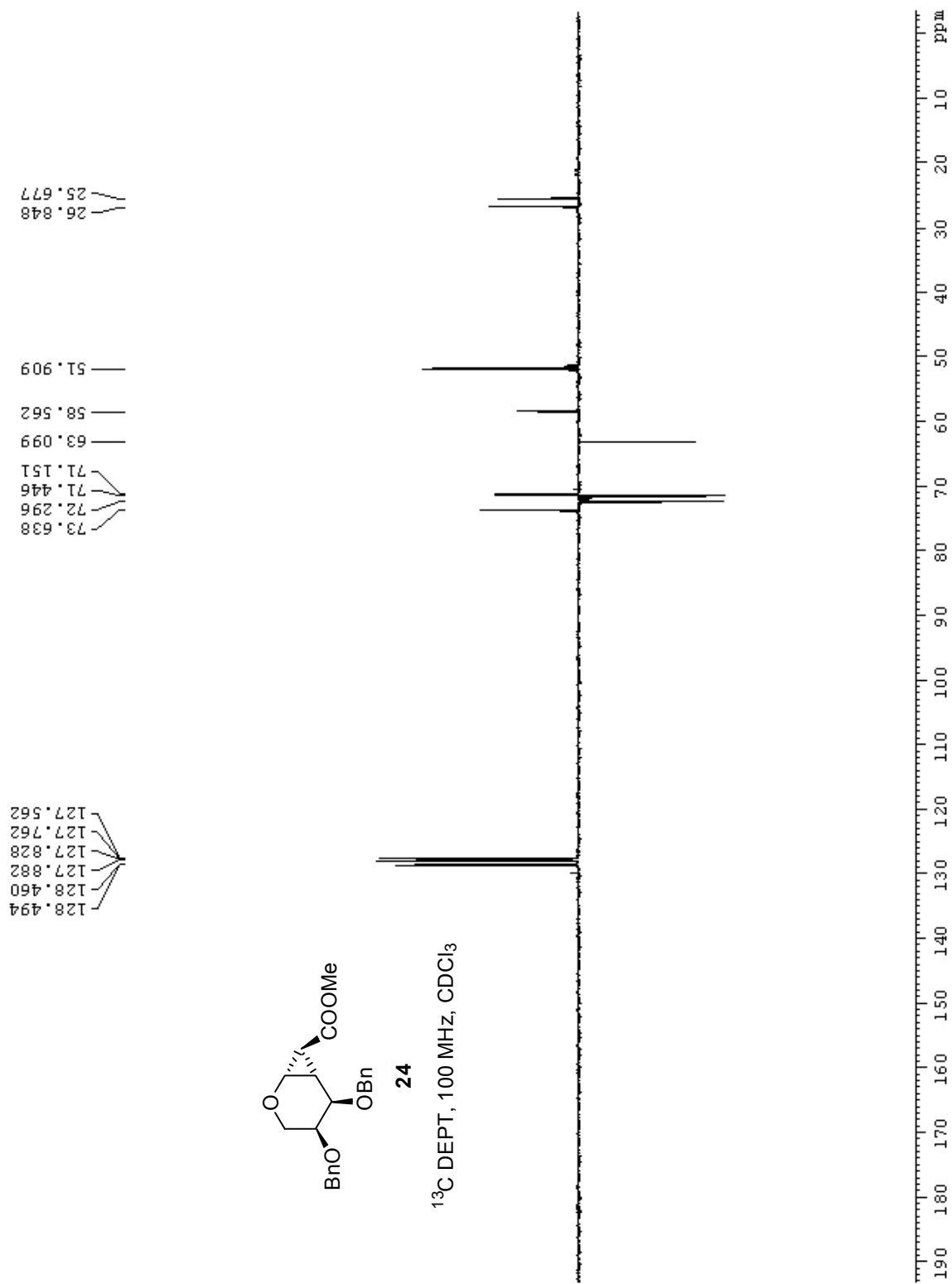


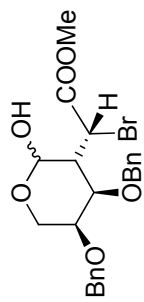
$^1\text{H}$ - $^1\text{H}$  COSY, 500 MHz,  $\text{CDCl}_3$





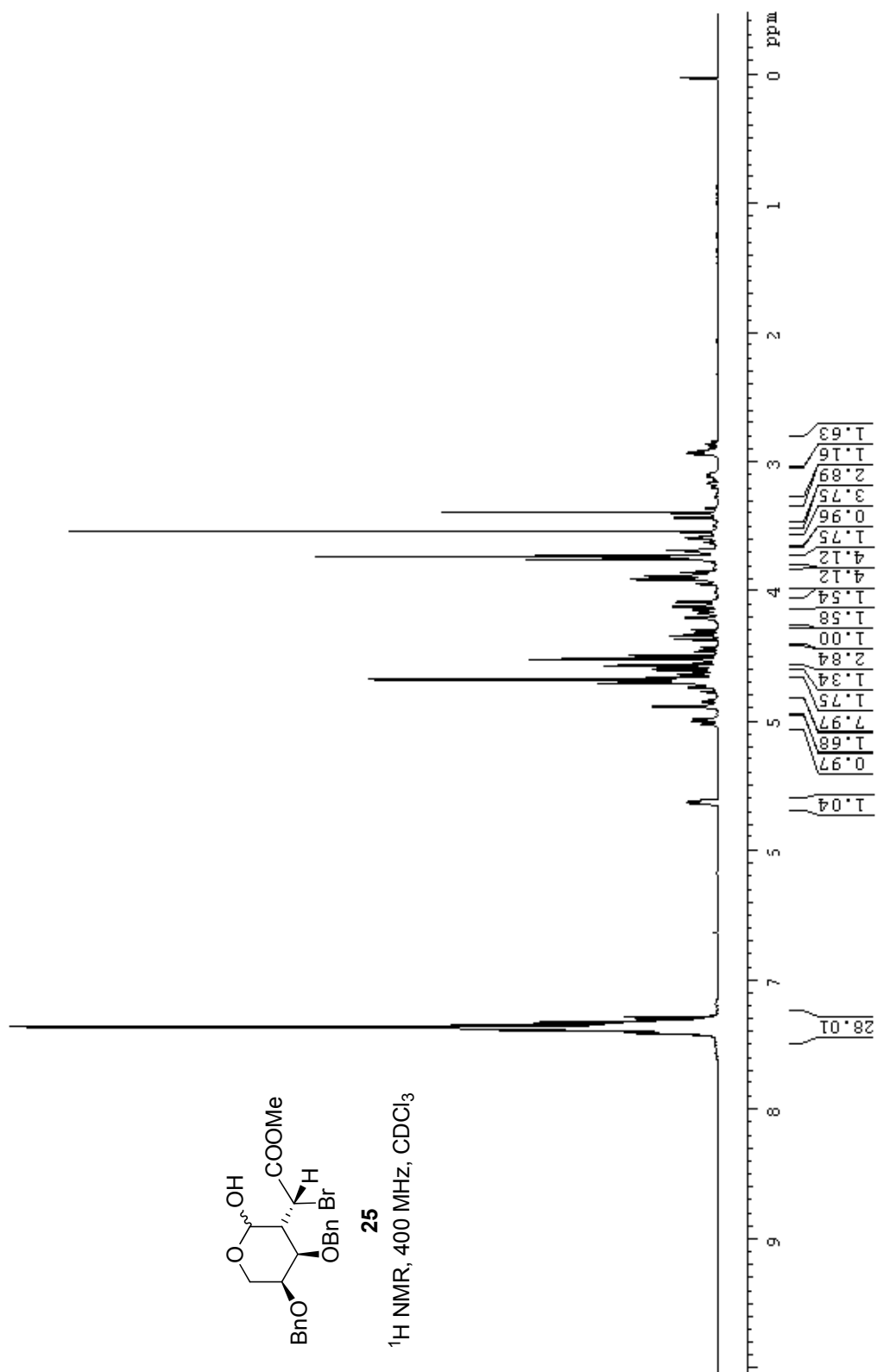


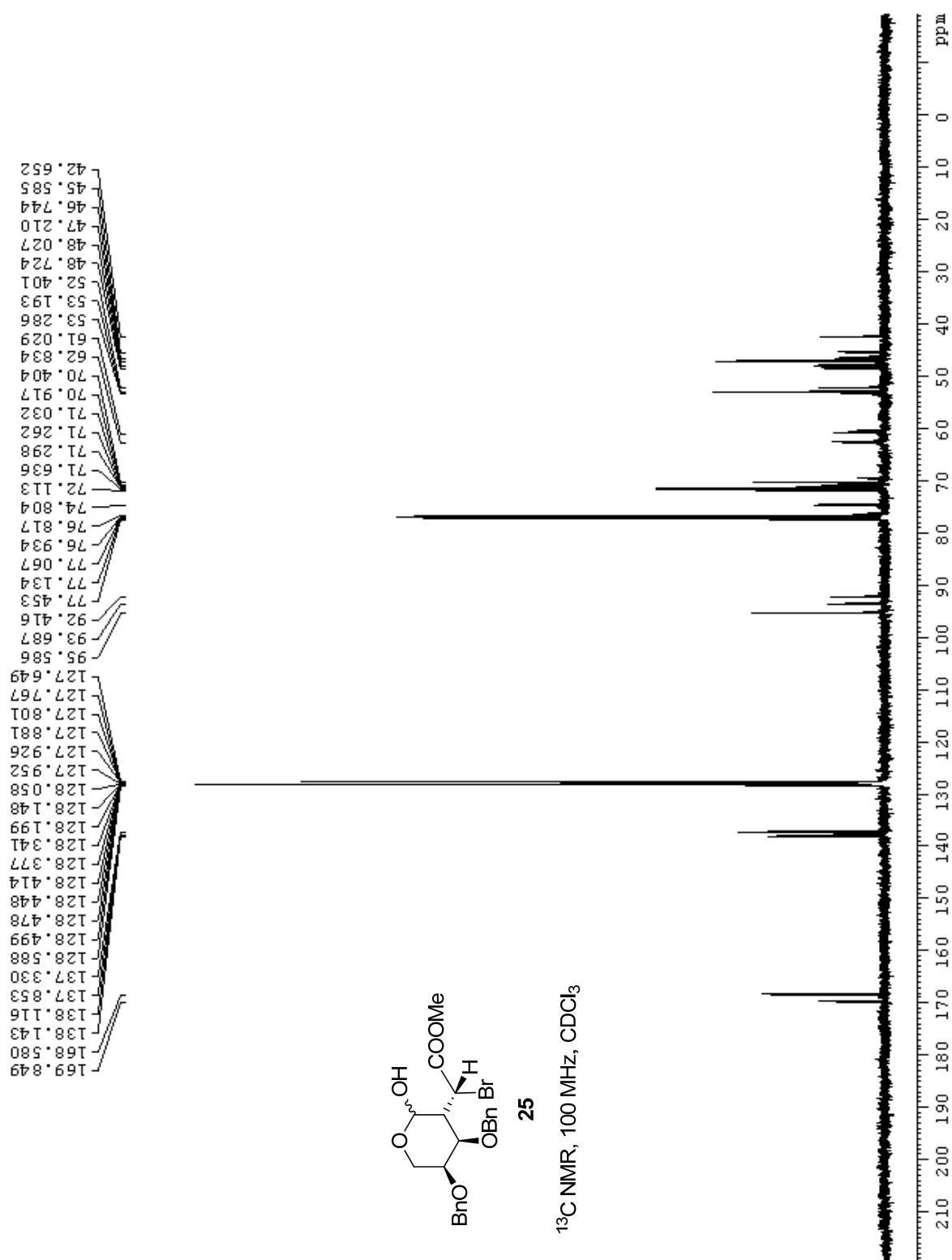


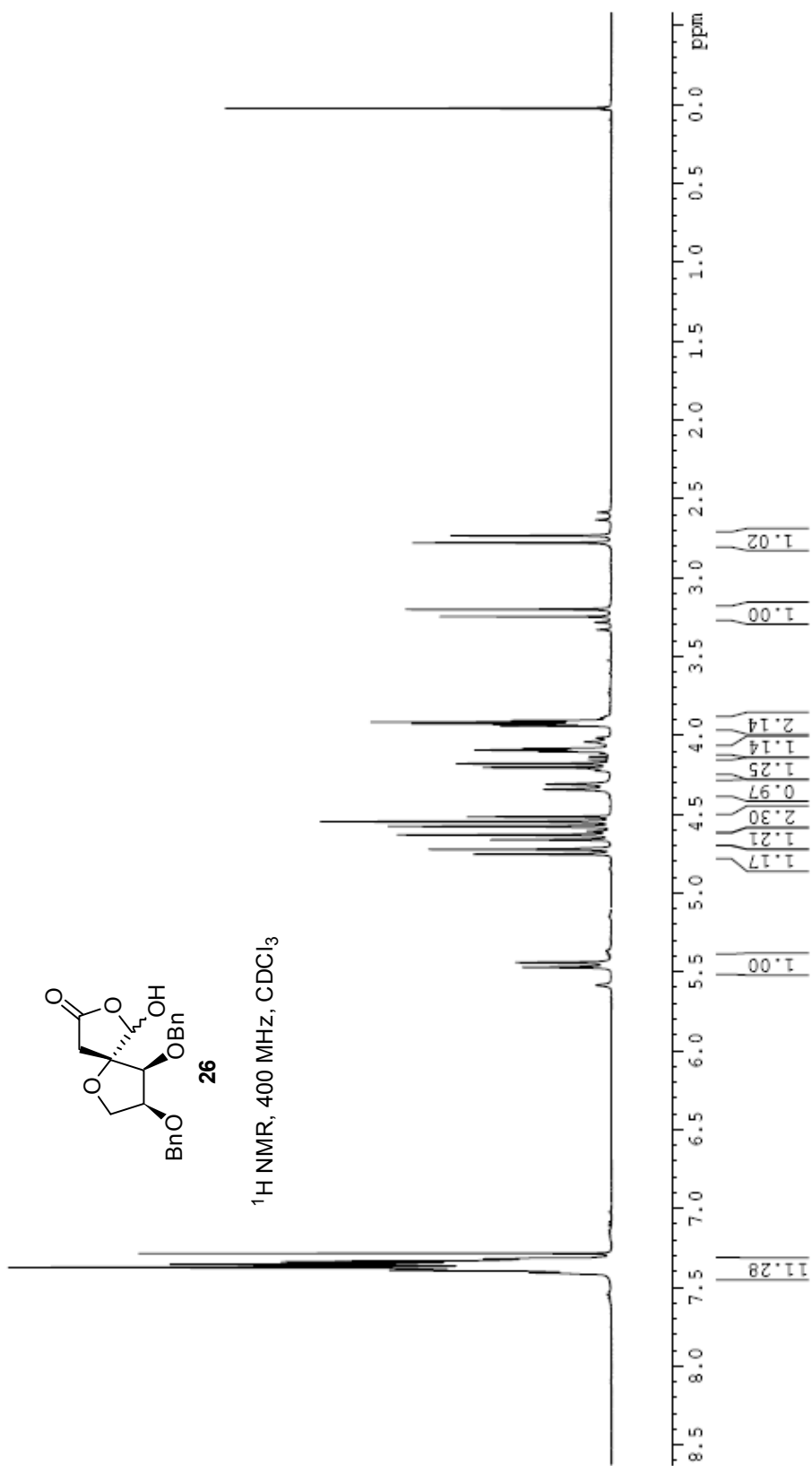


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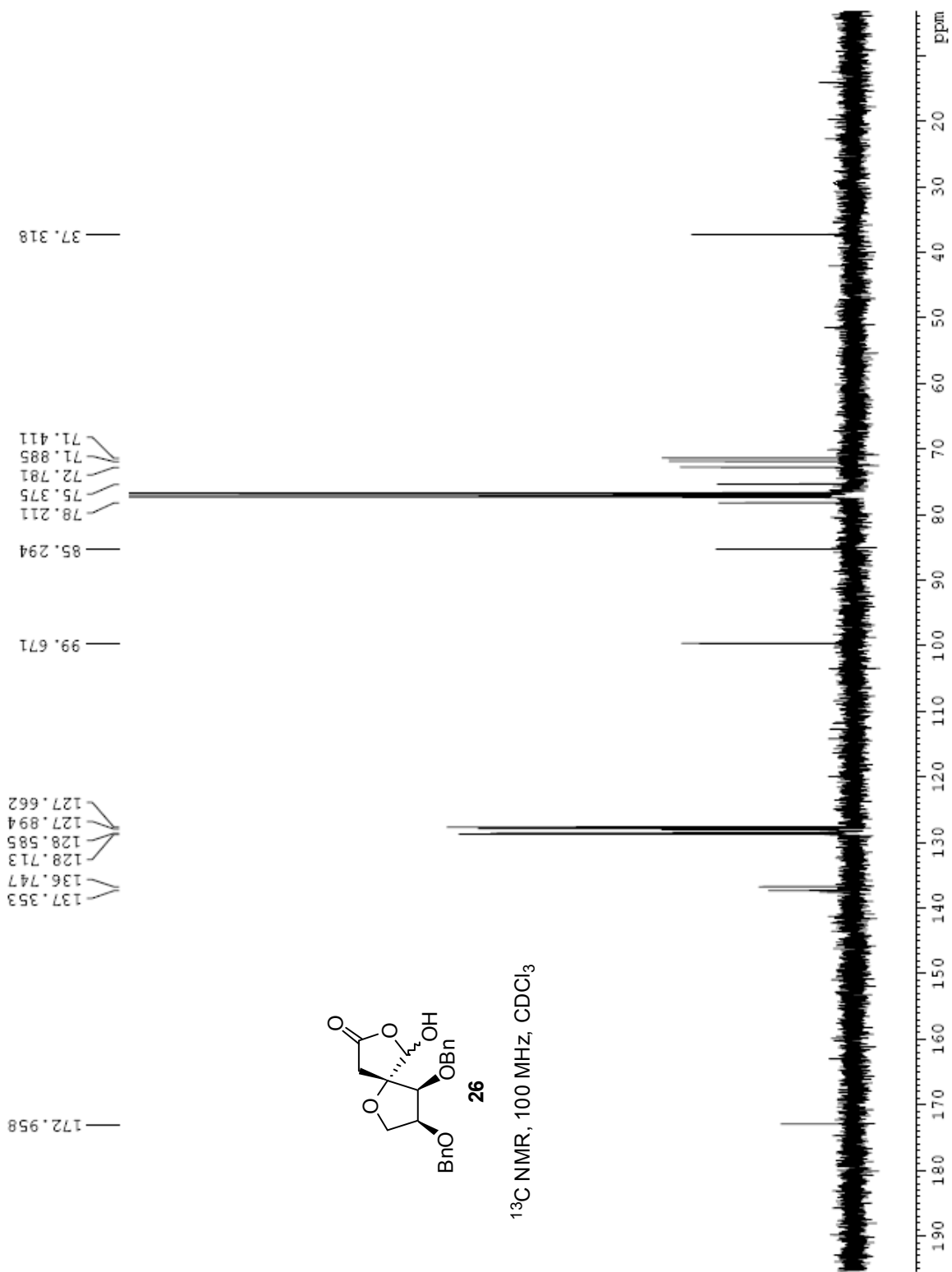
<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>

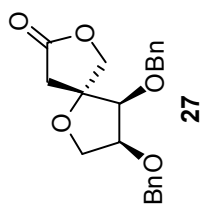




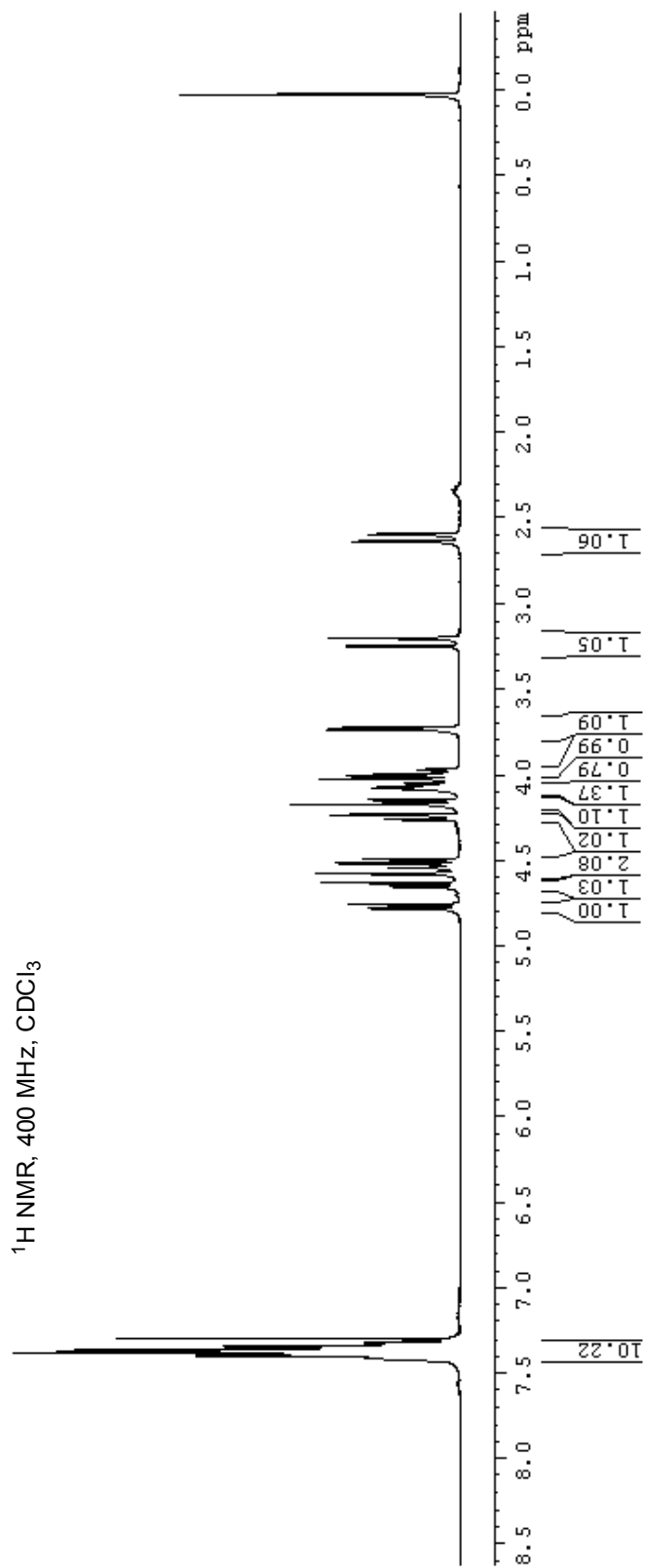


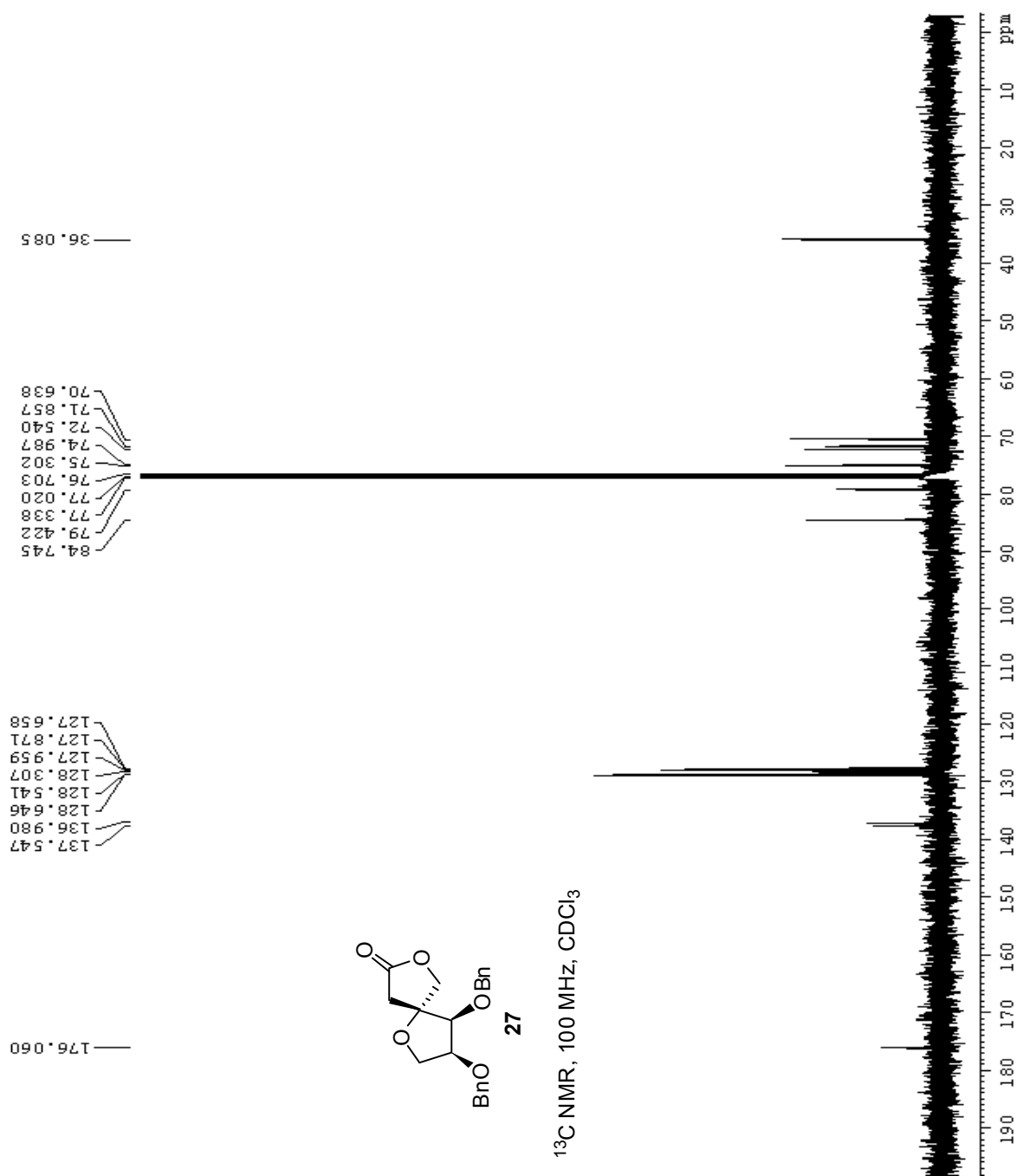


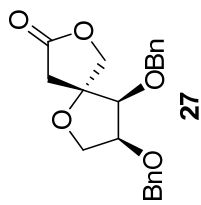
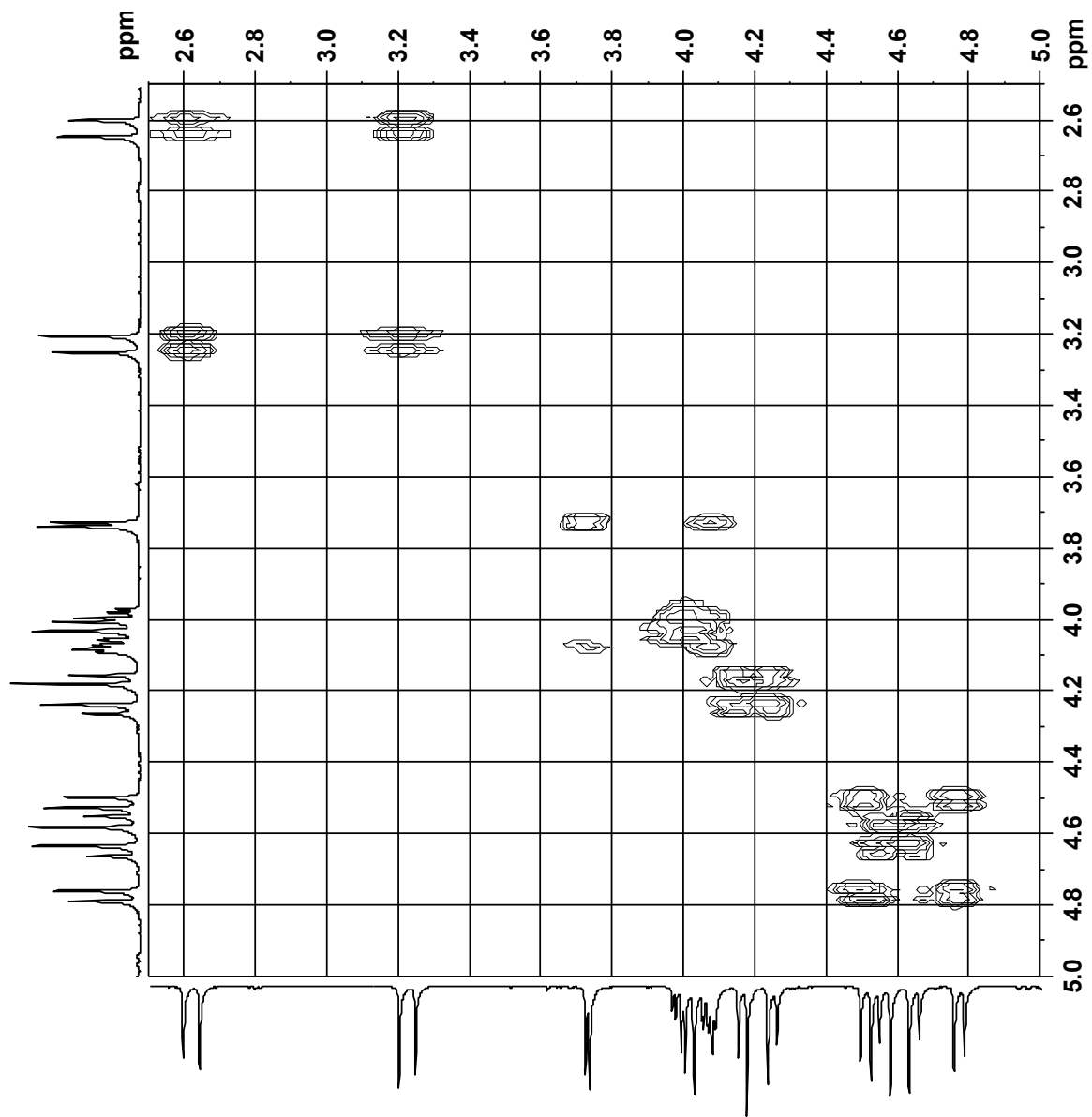




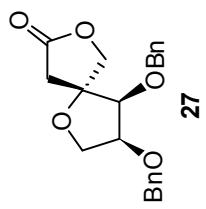
$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$



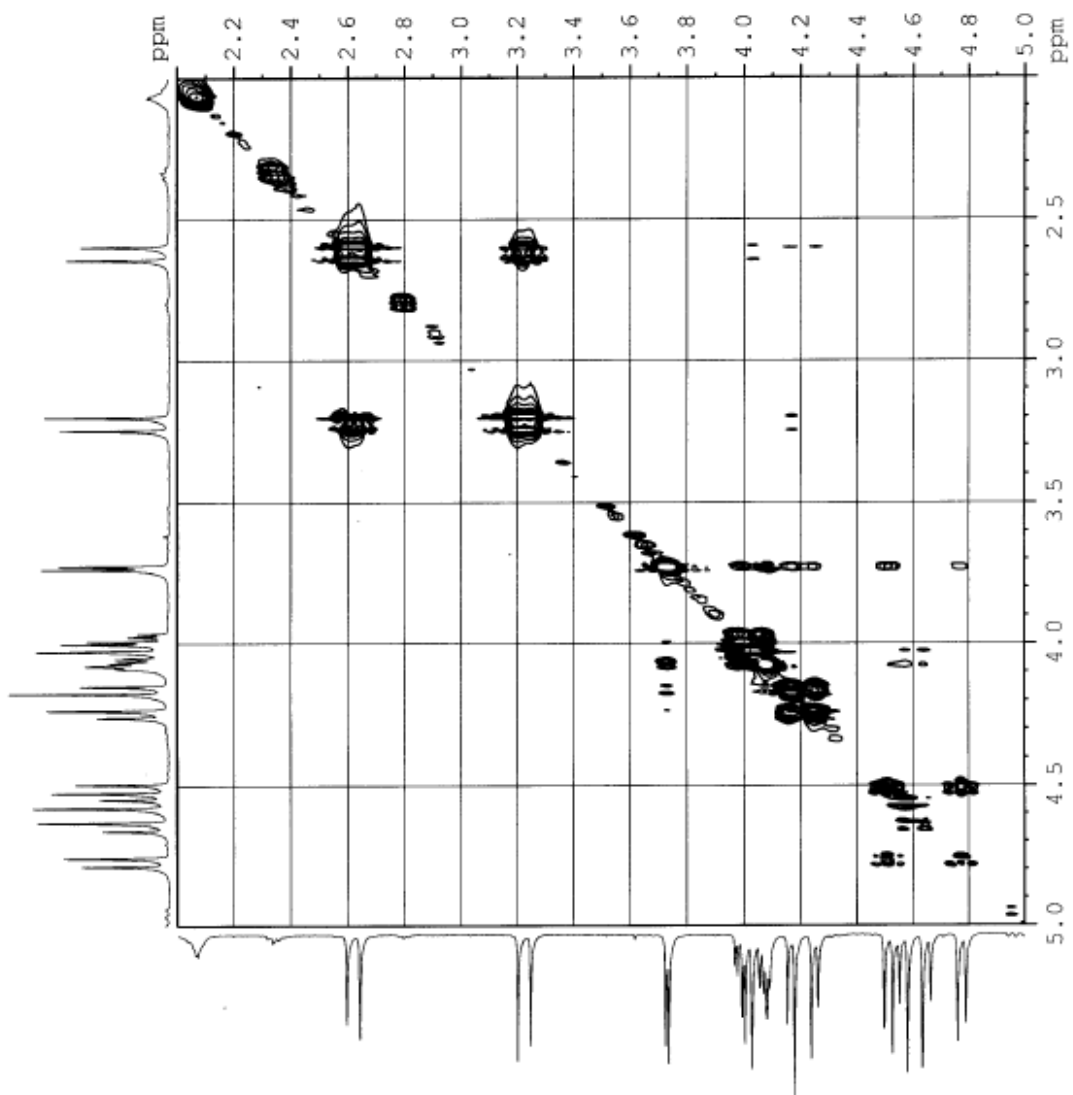




$^1\text{H}$ - $^1\text{H}$  COSY, 400 MHz,  $\text{CDCl}_3$

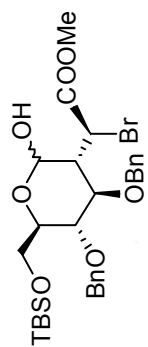


NOESY, 400 MHz, CDCl<sub>3</sub>



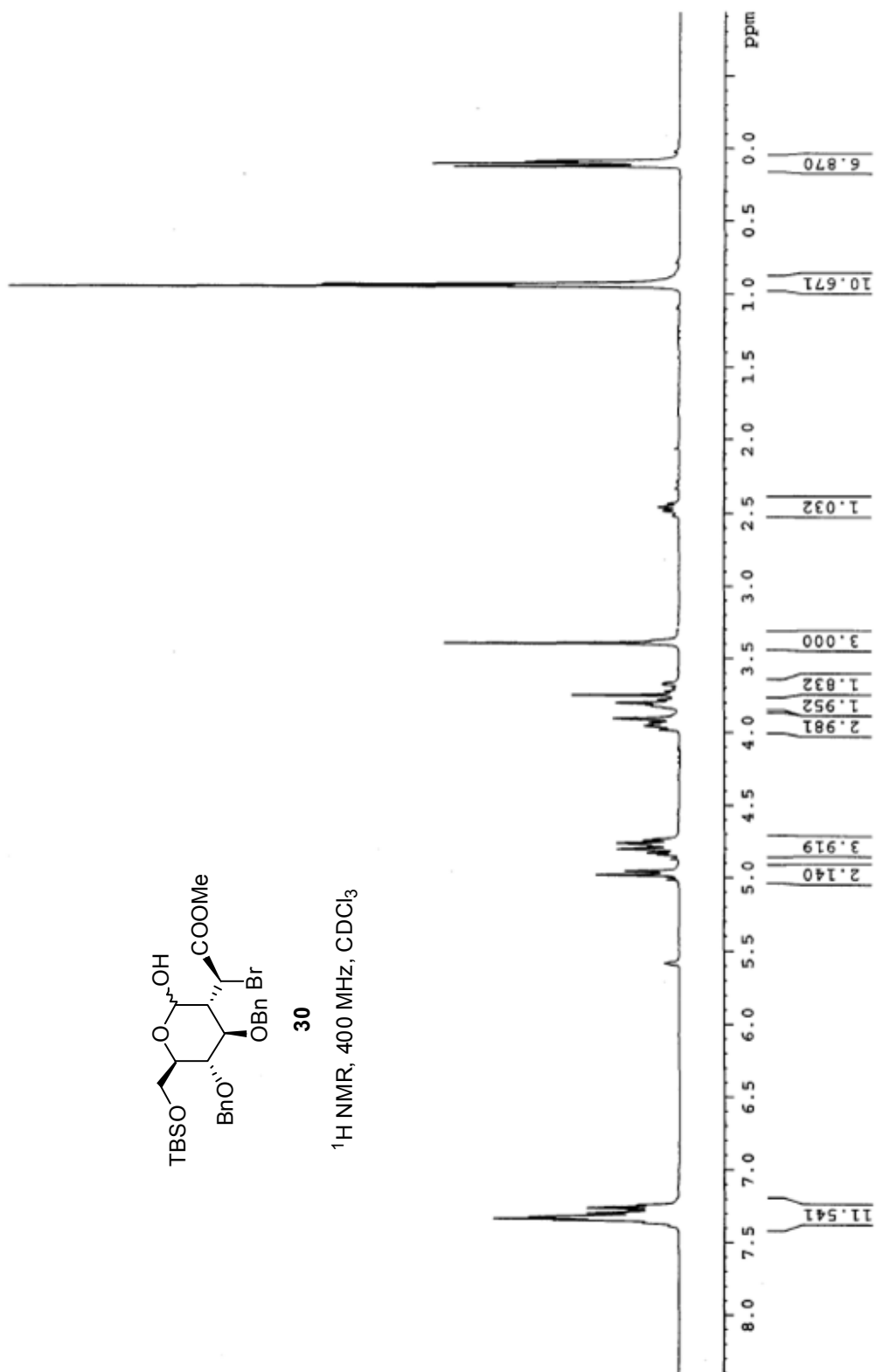




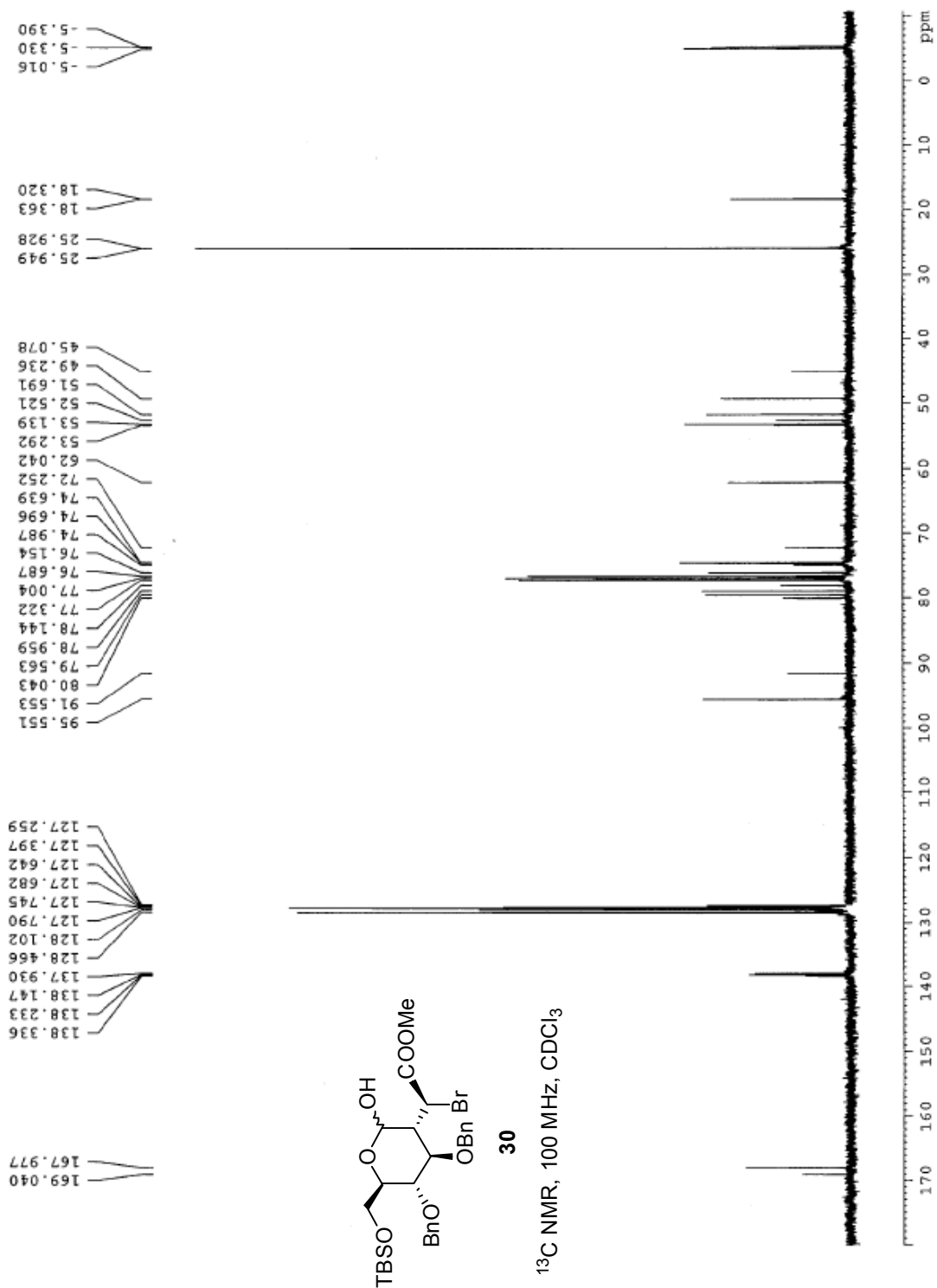


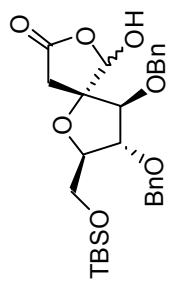
30

$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$



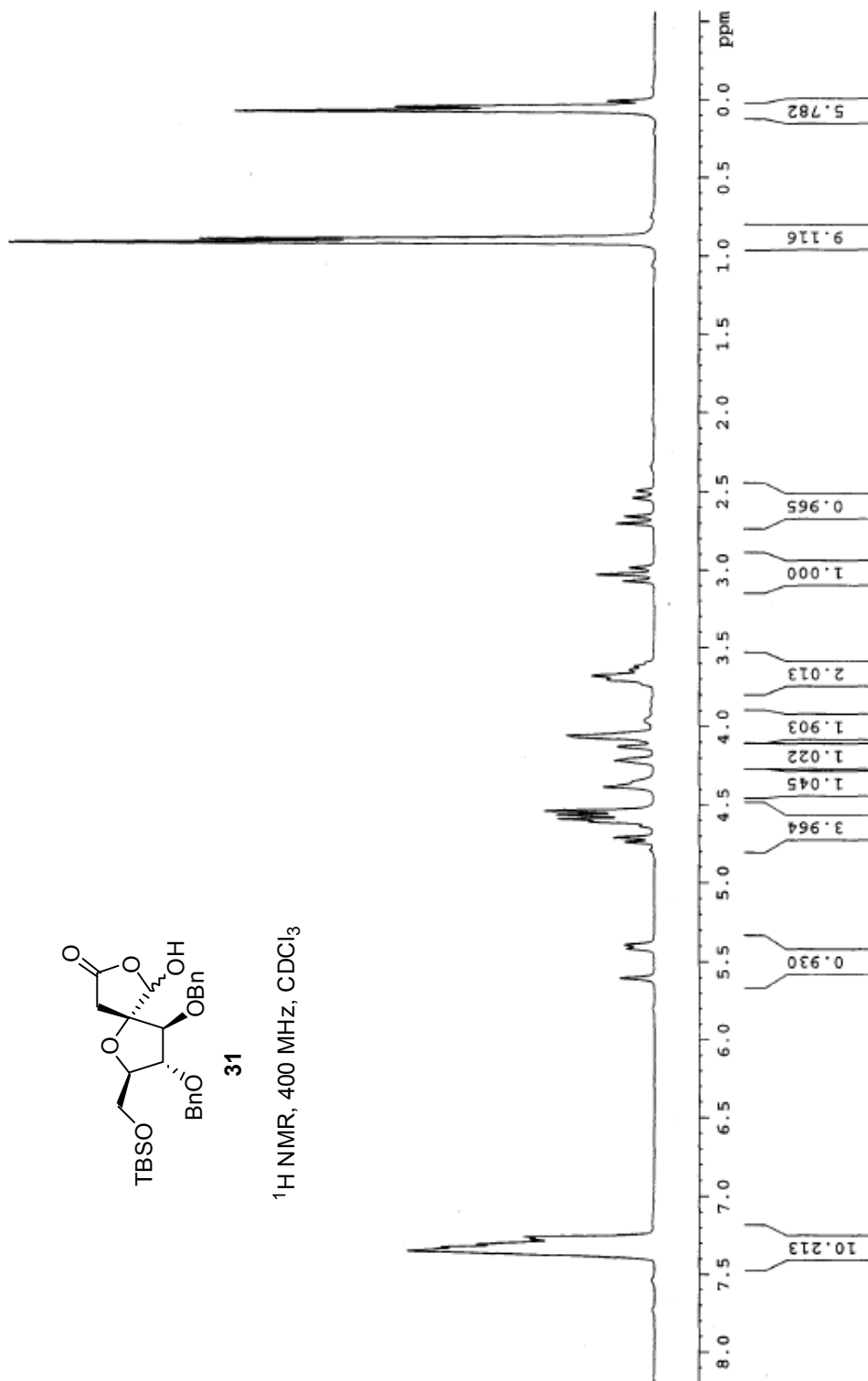


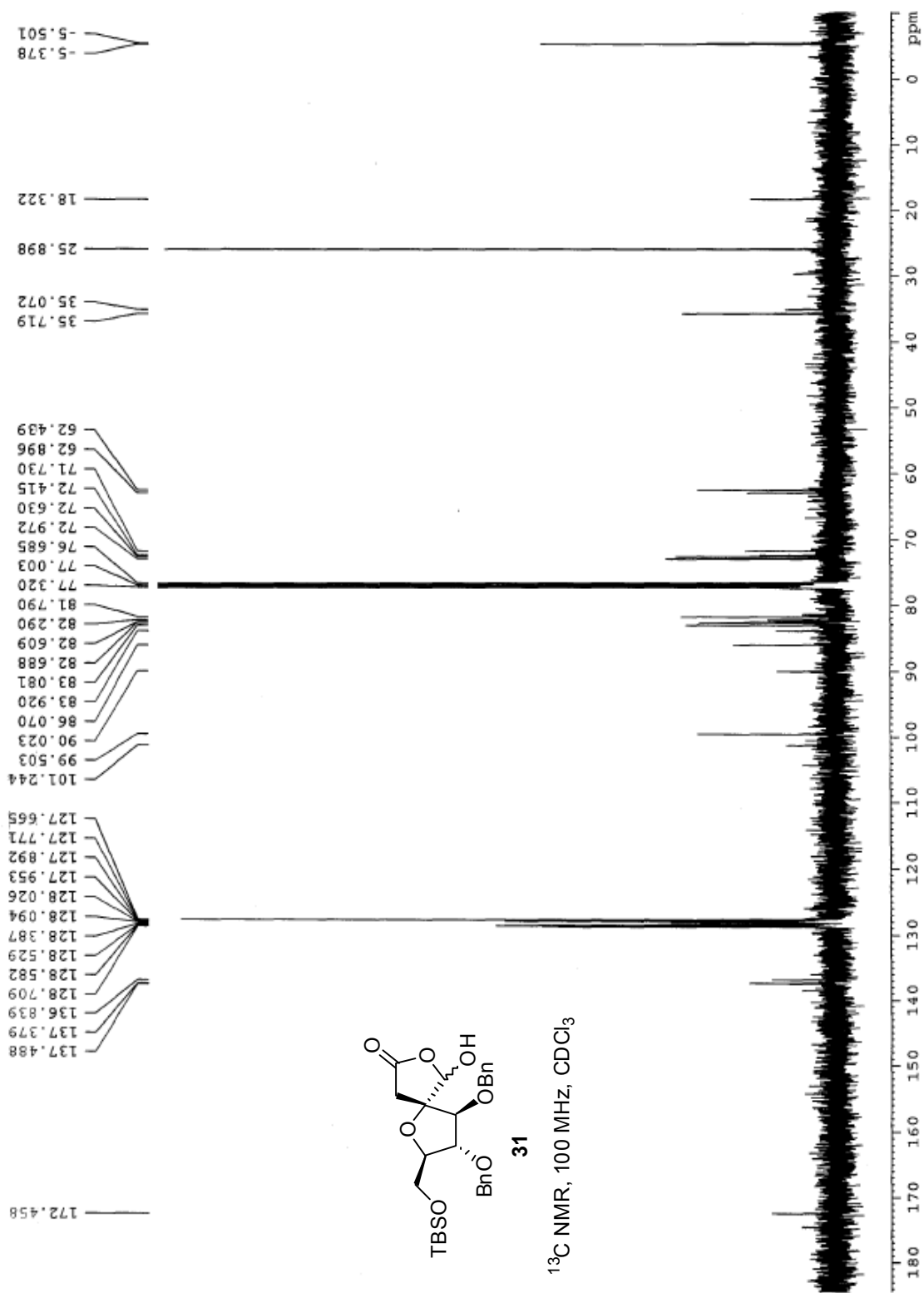


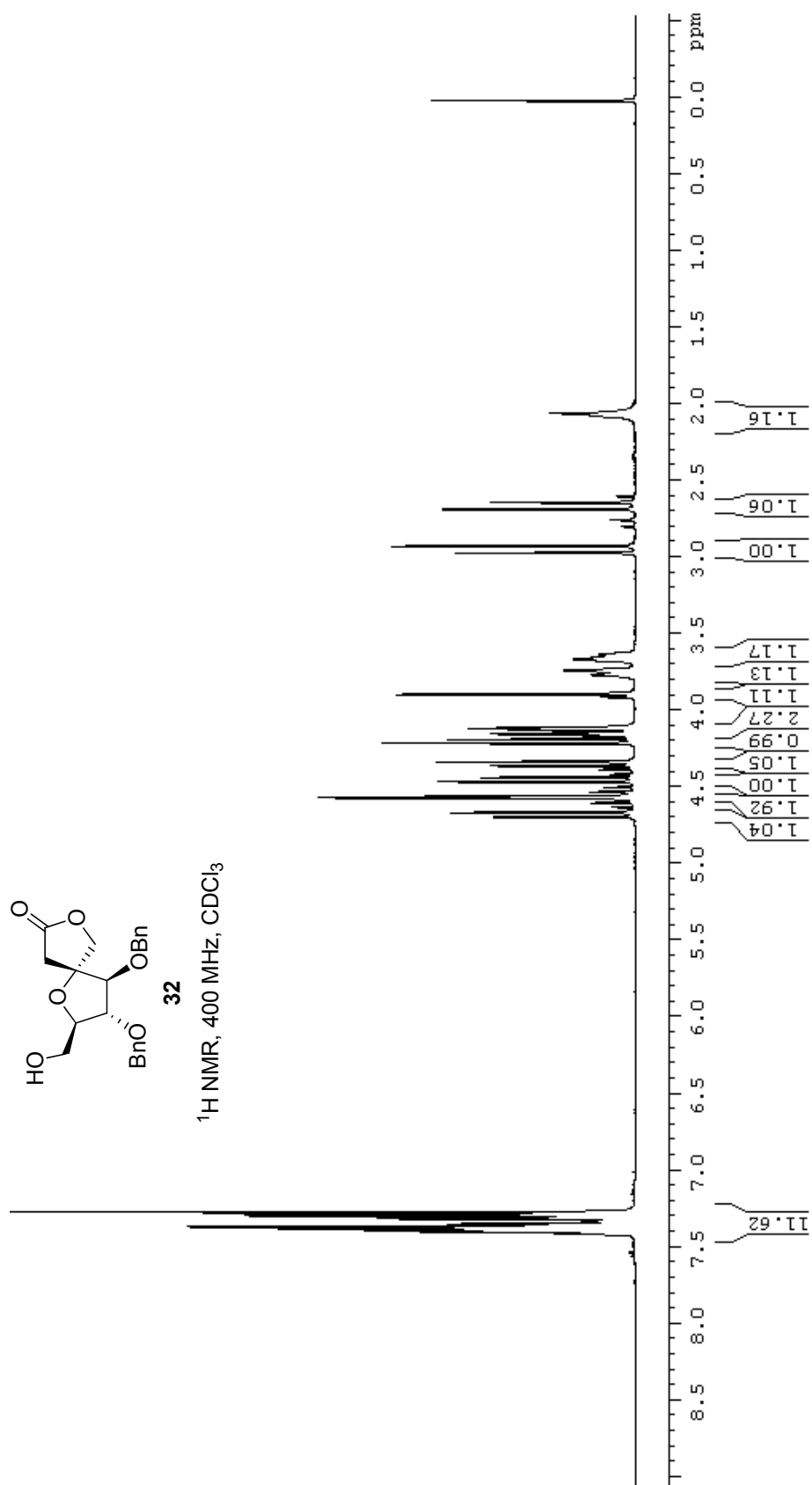


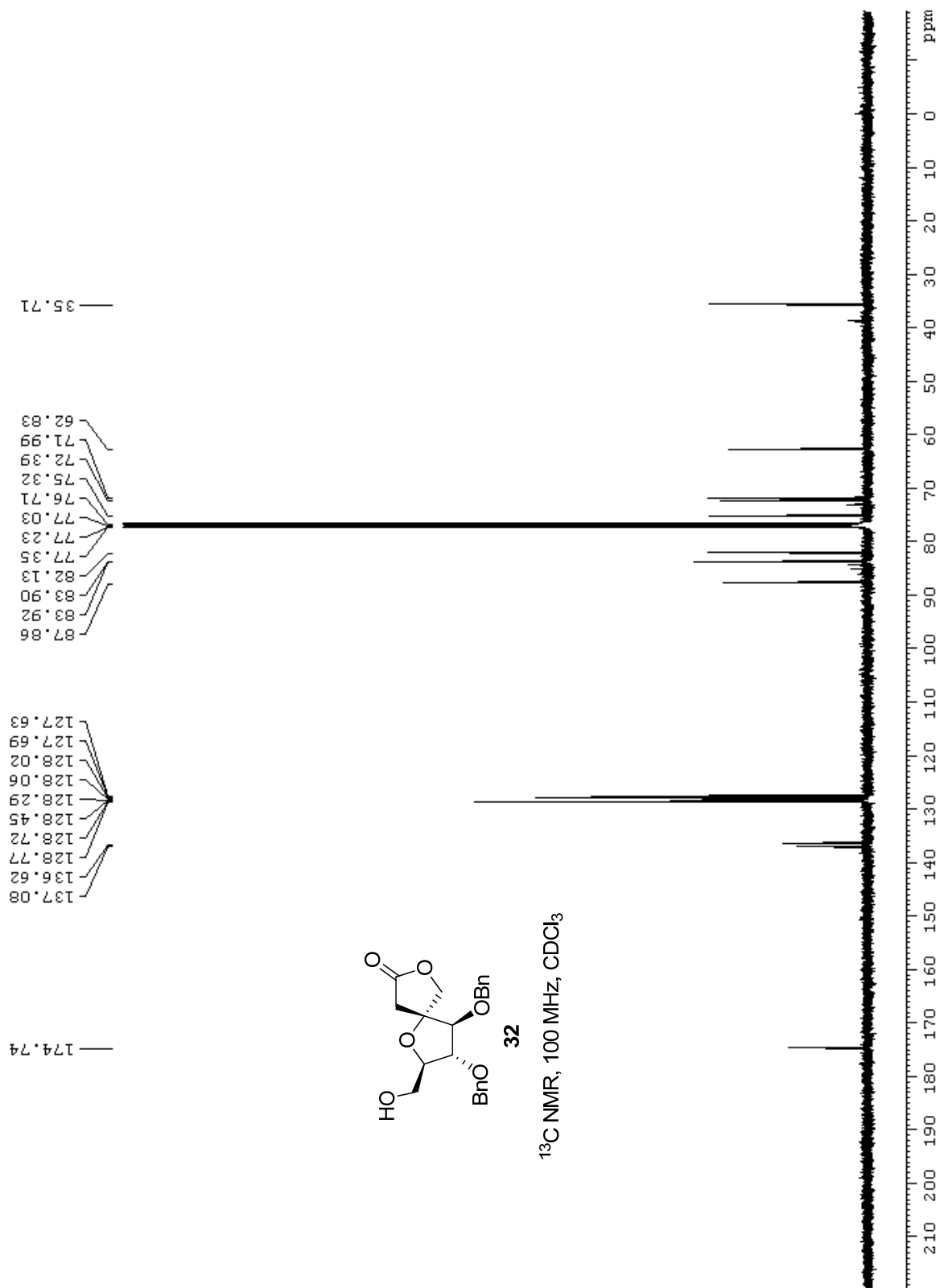
31

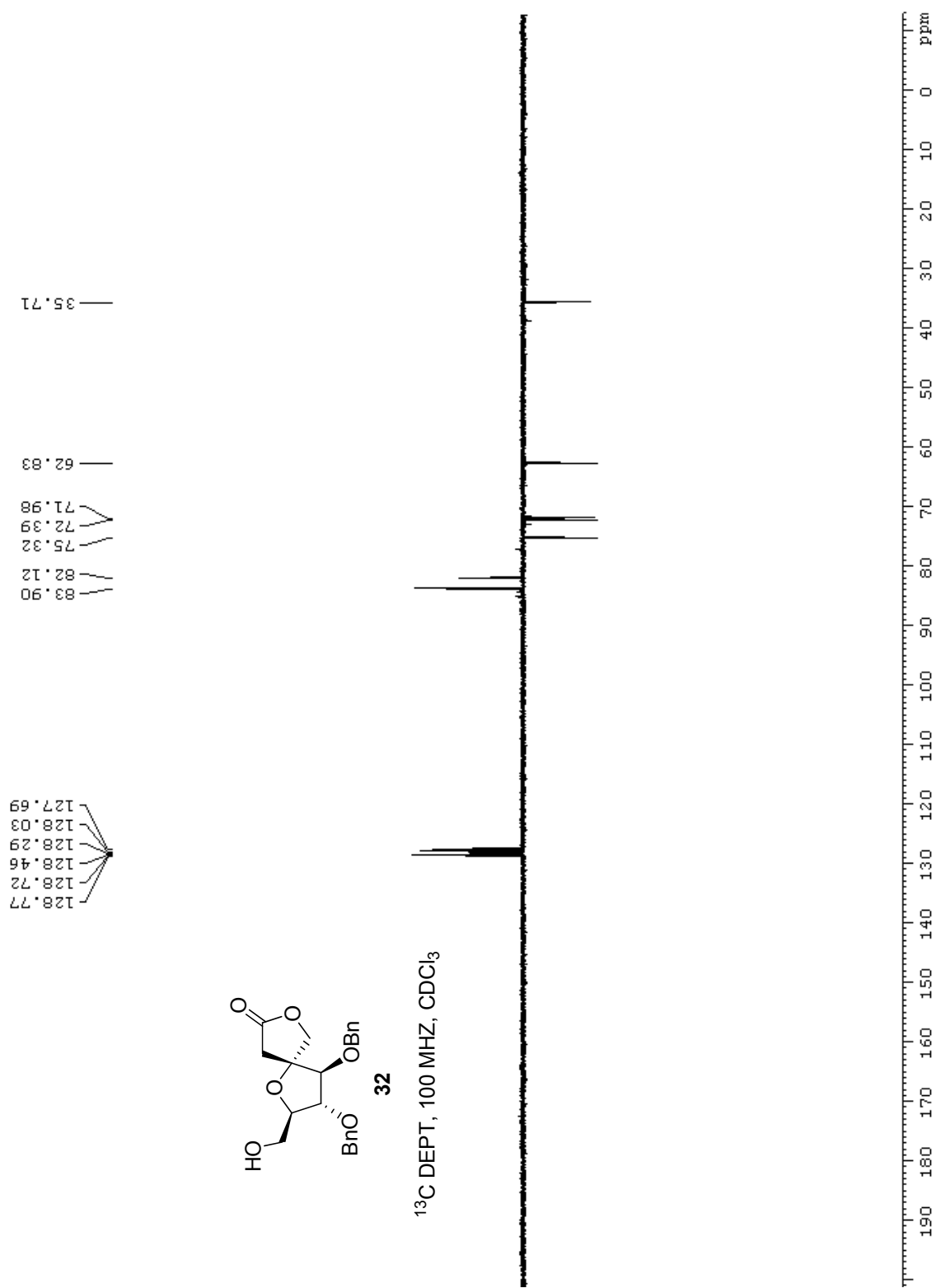
$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$

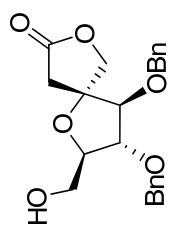
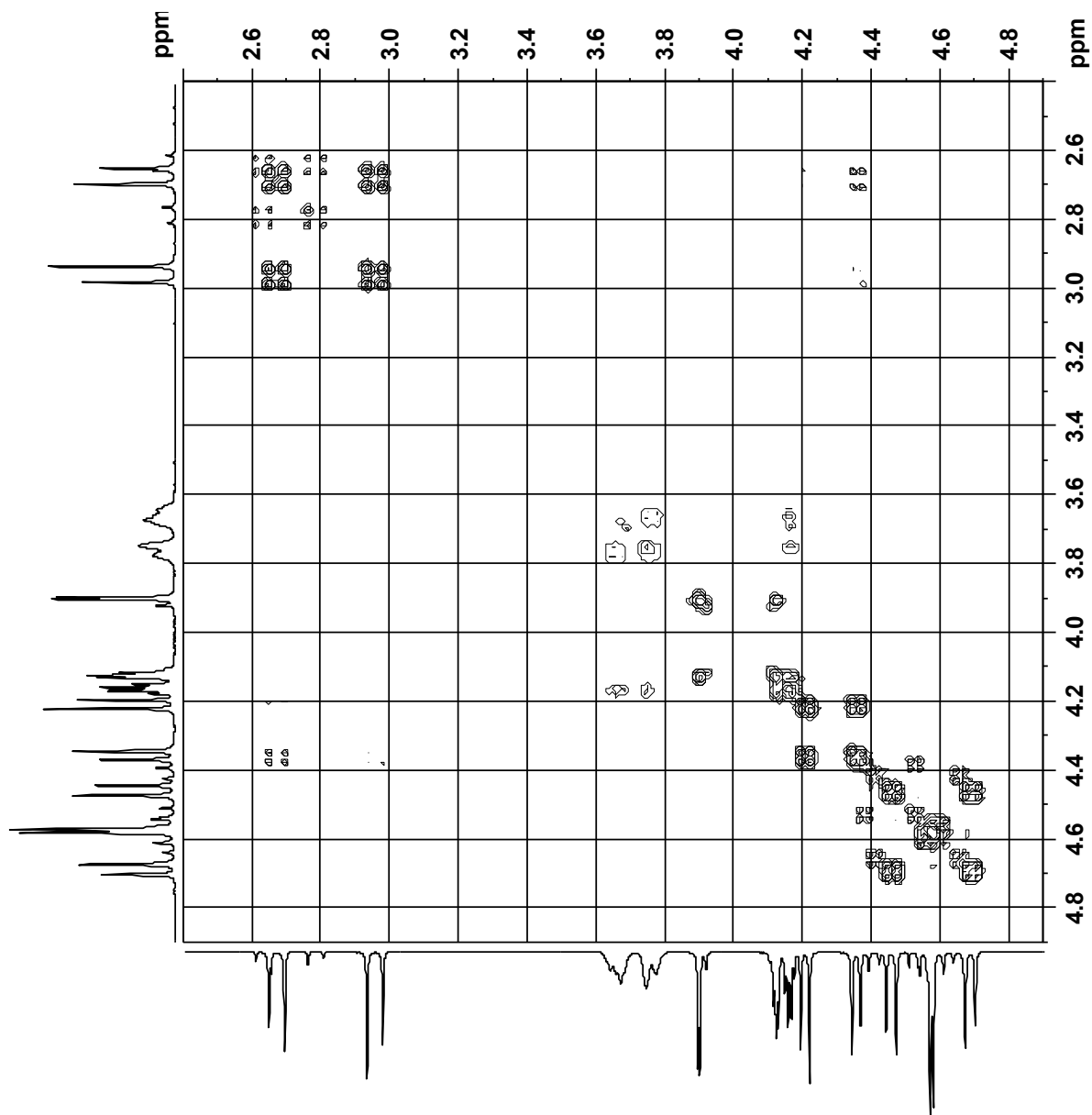






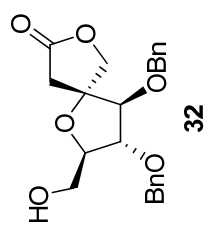
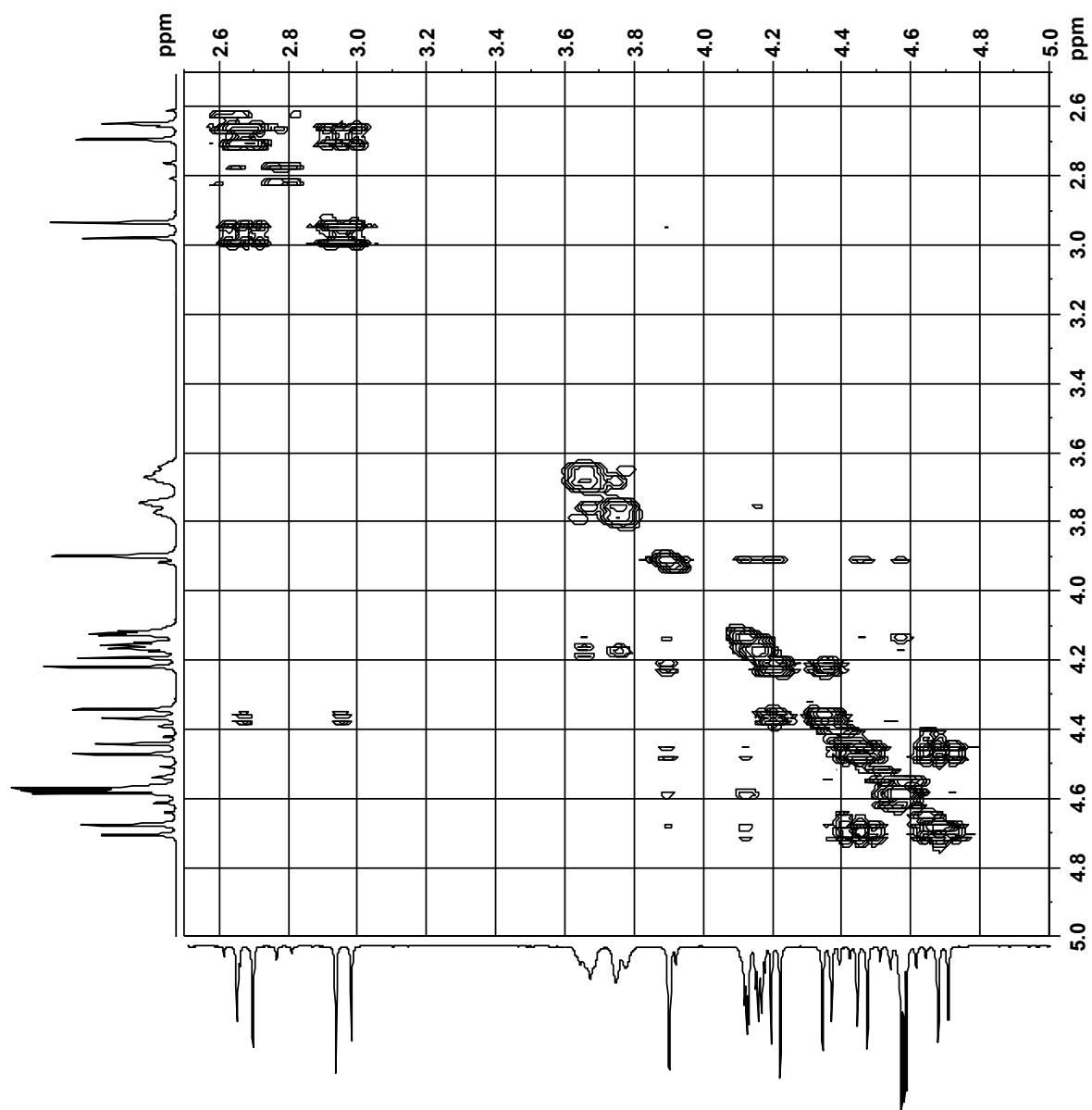






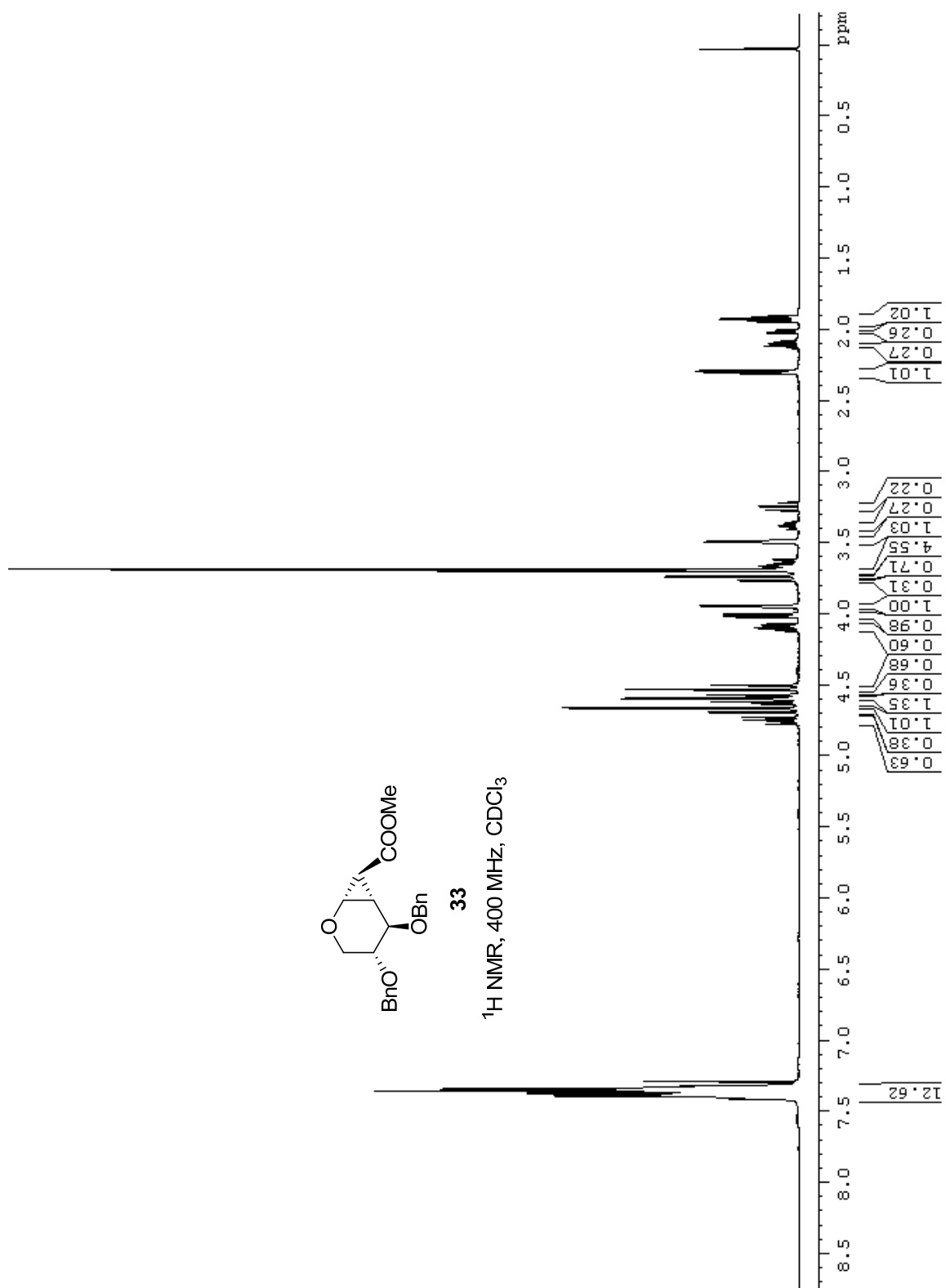
**32**

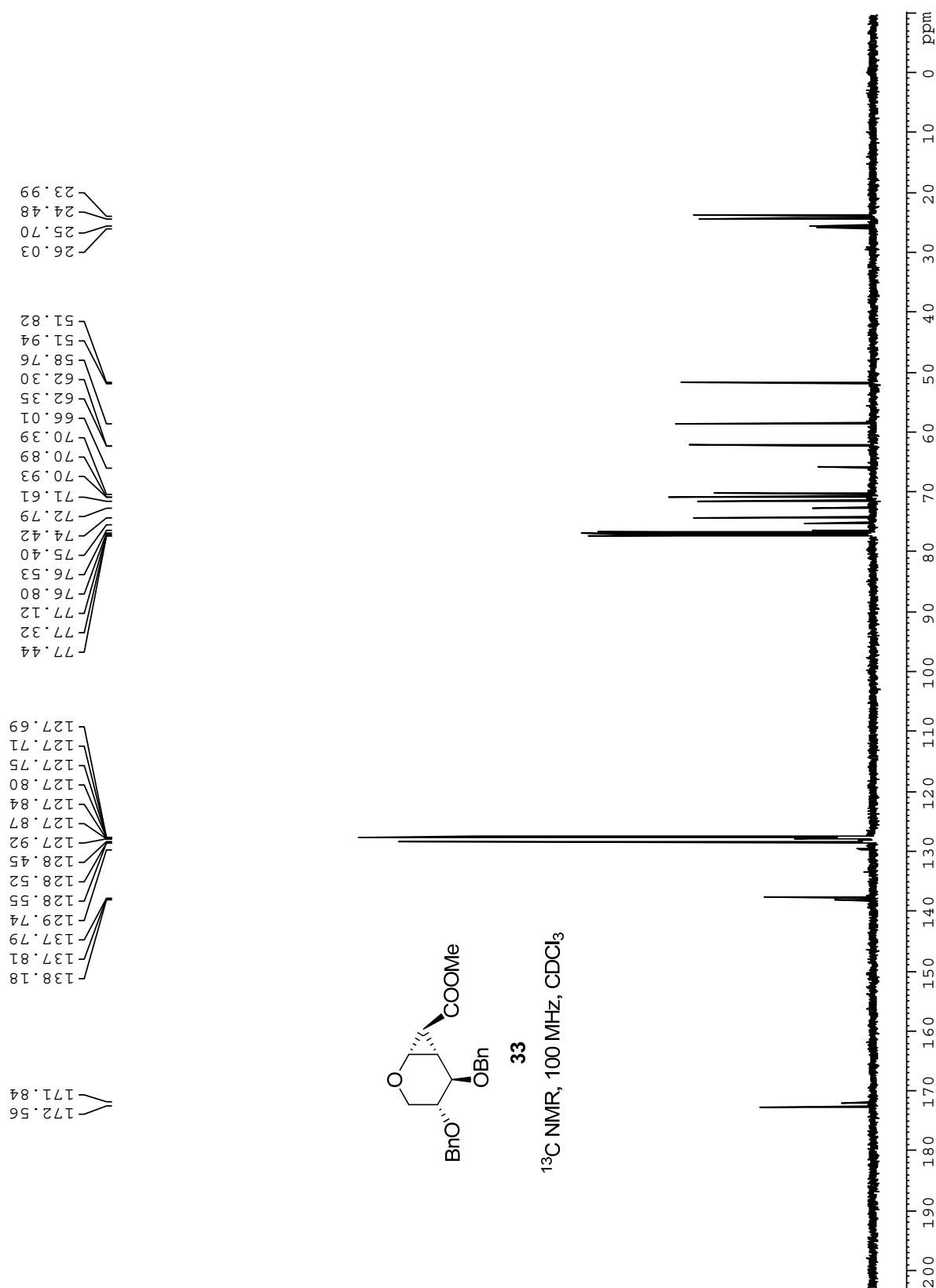
$^1\text{H}$ - $^1\text{H}$  COSY, 400 MHz,  $\text{CDCl}_3$

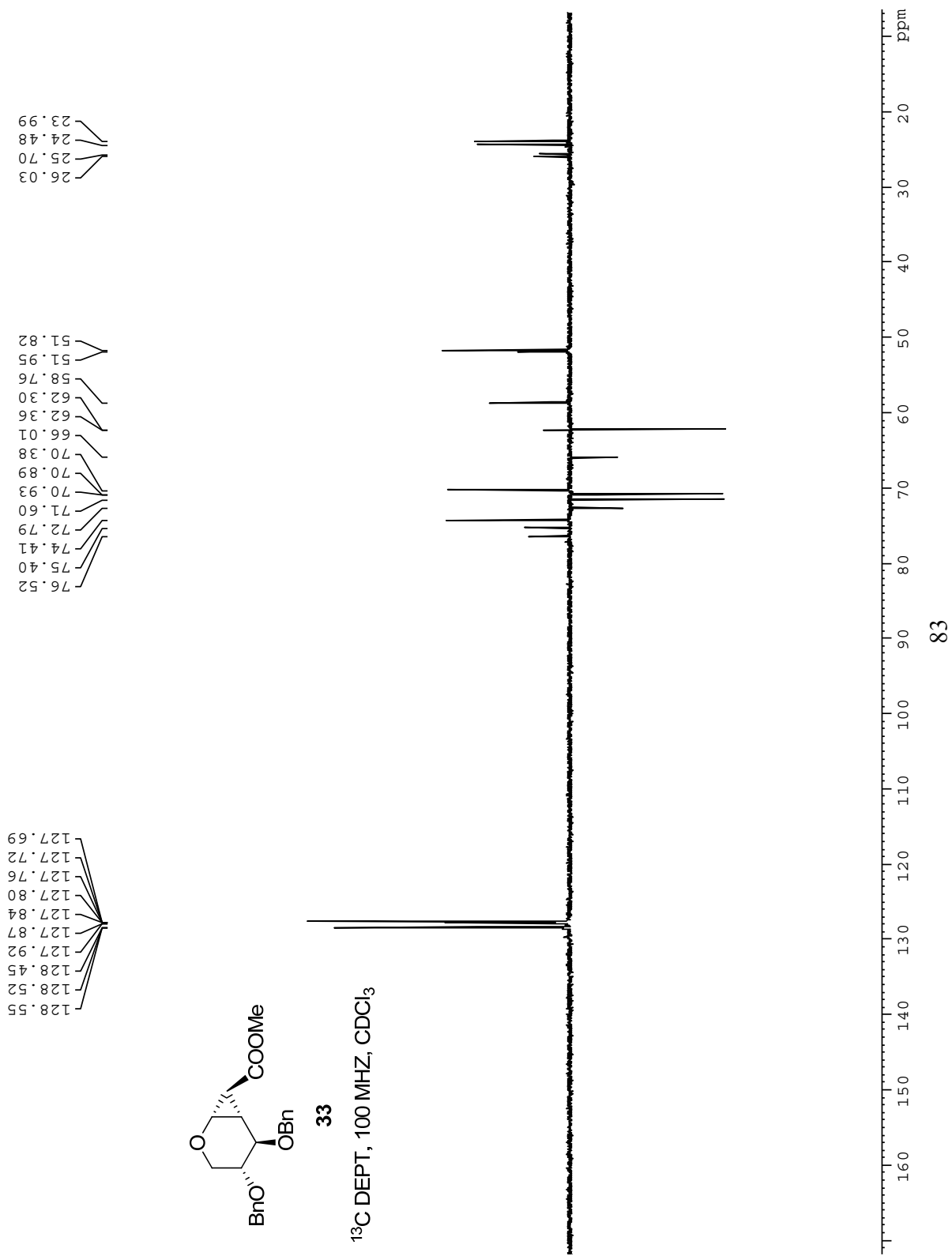


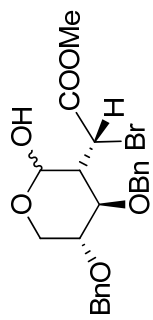
NOESY, 400 MHz, CDCl<sub>3</sub>





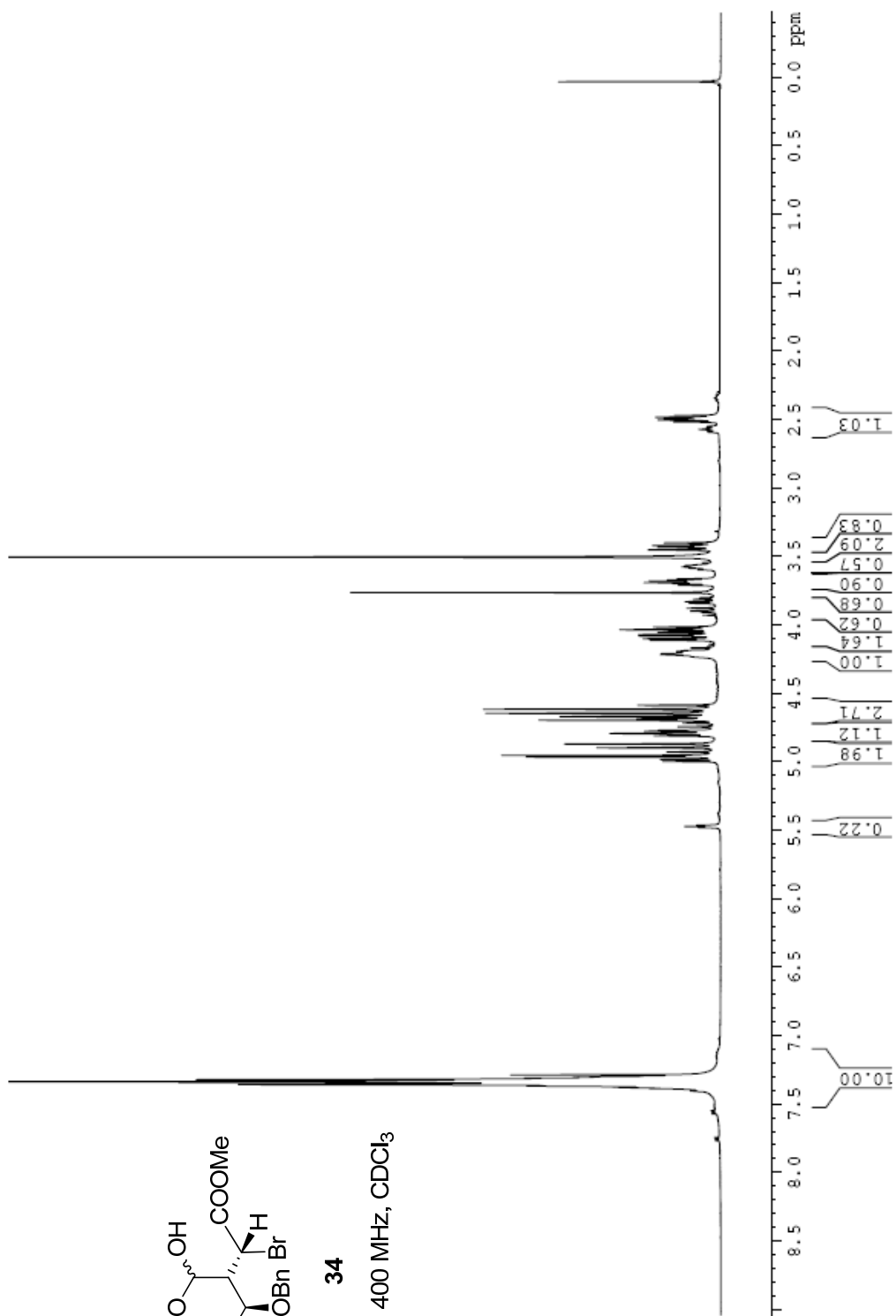


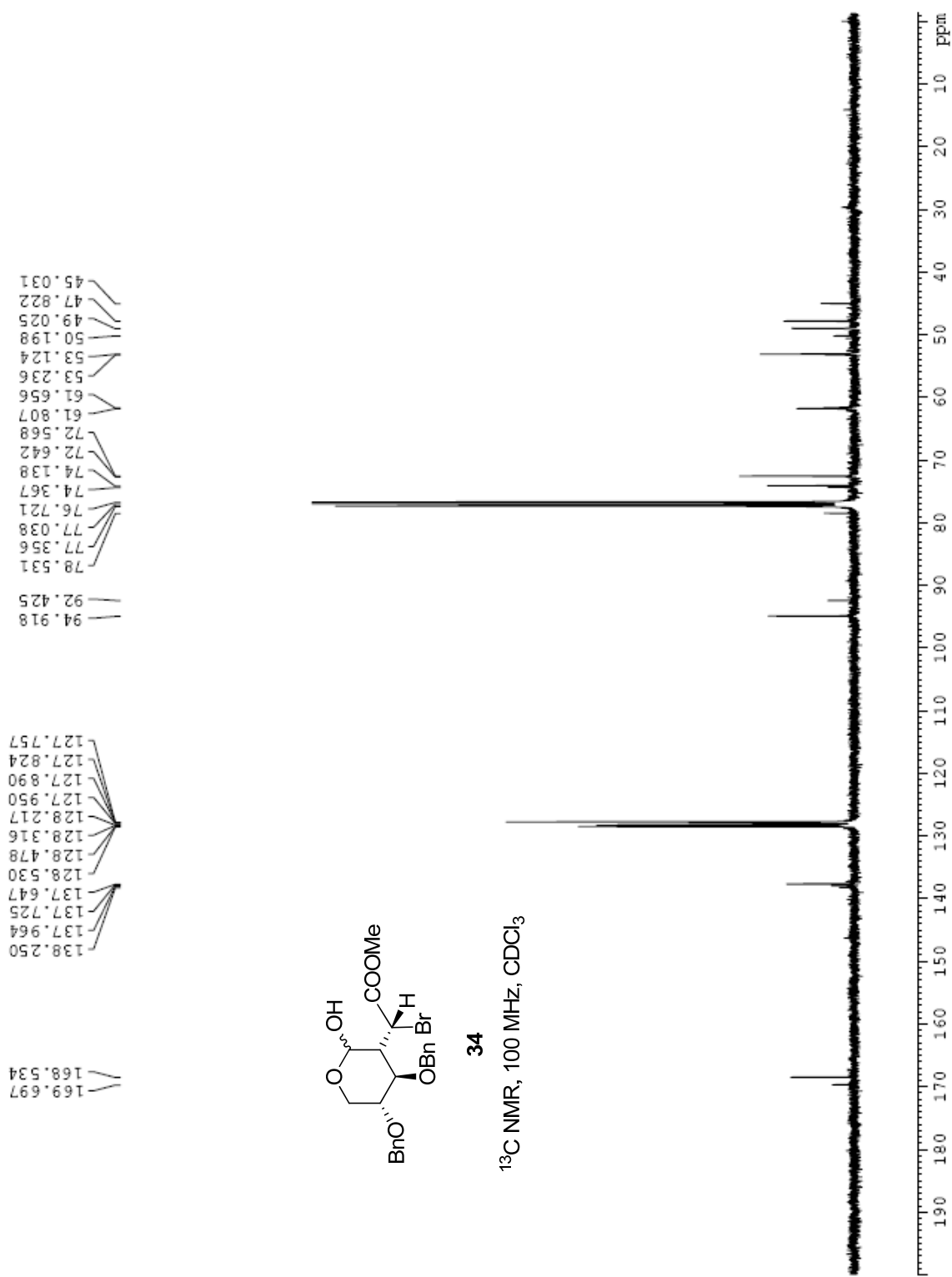


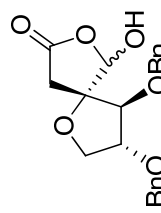


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<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>

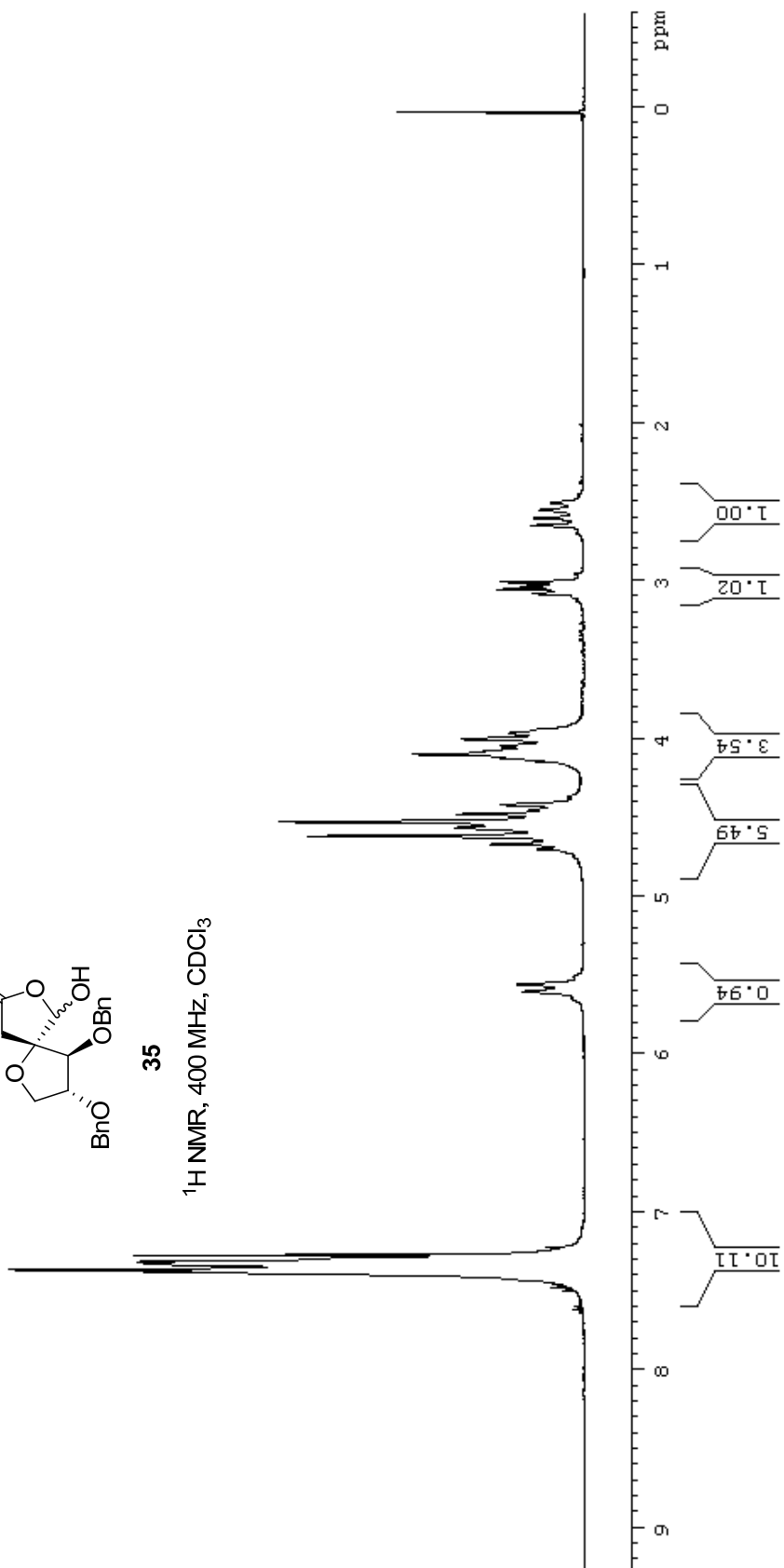


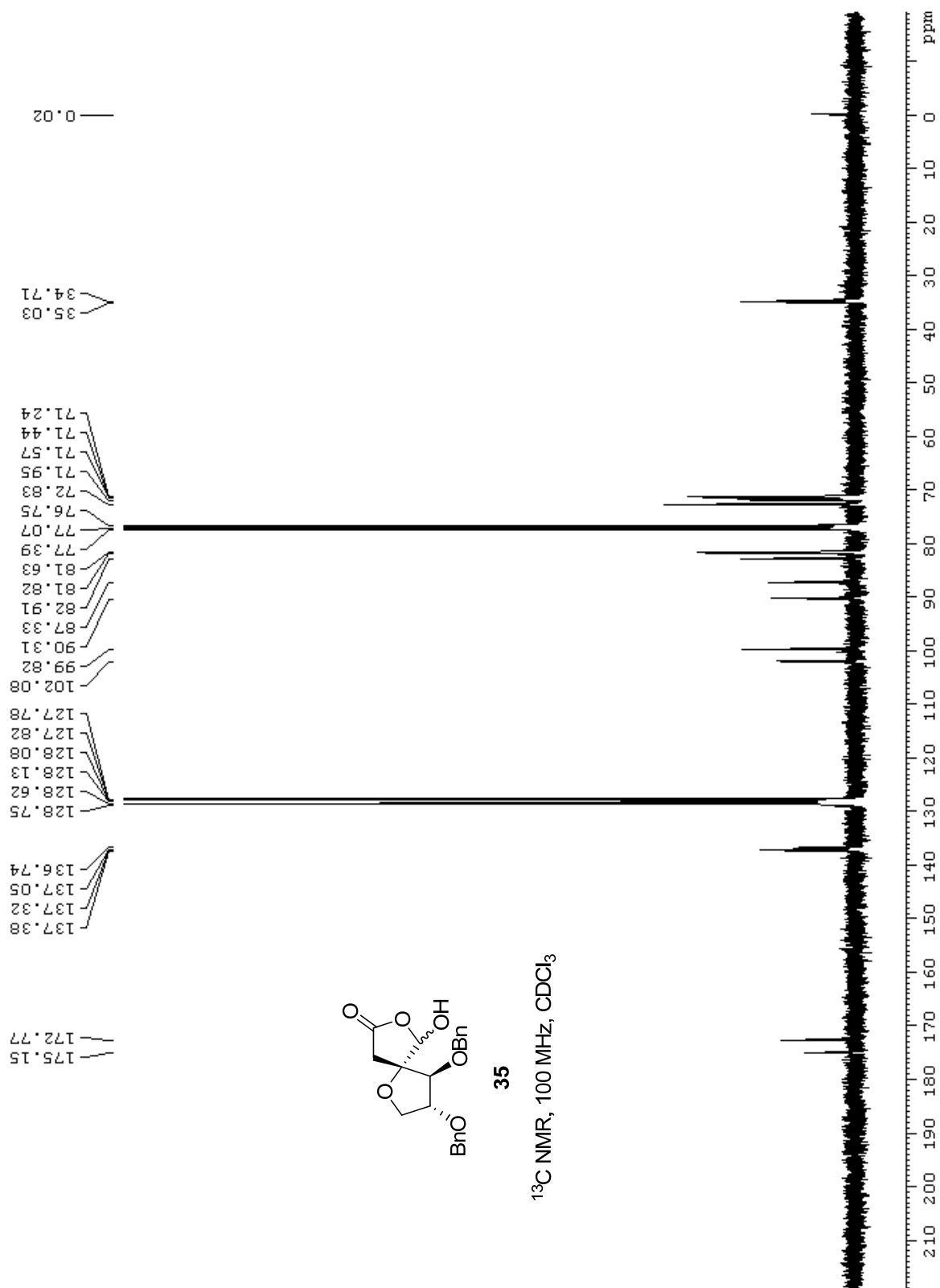


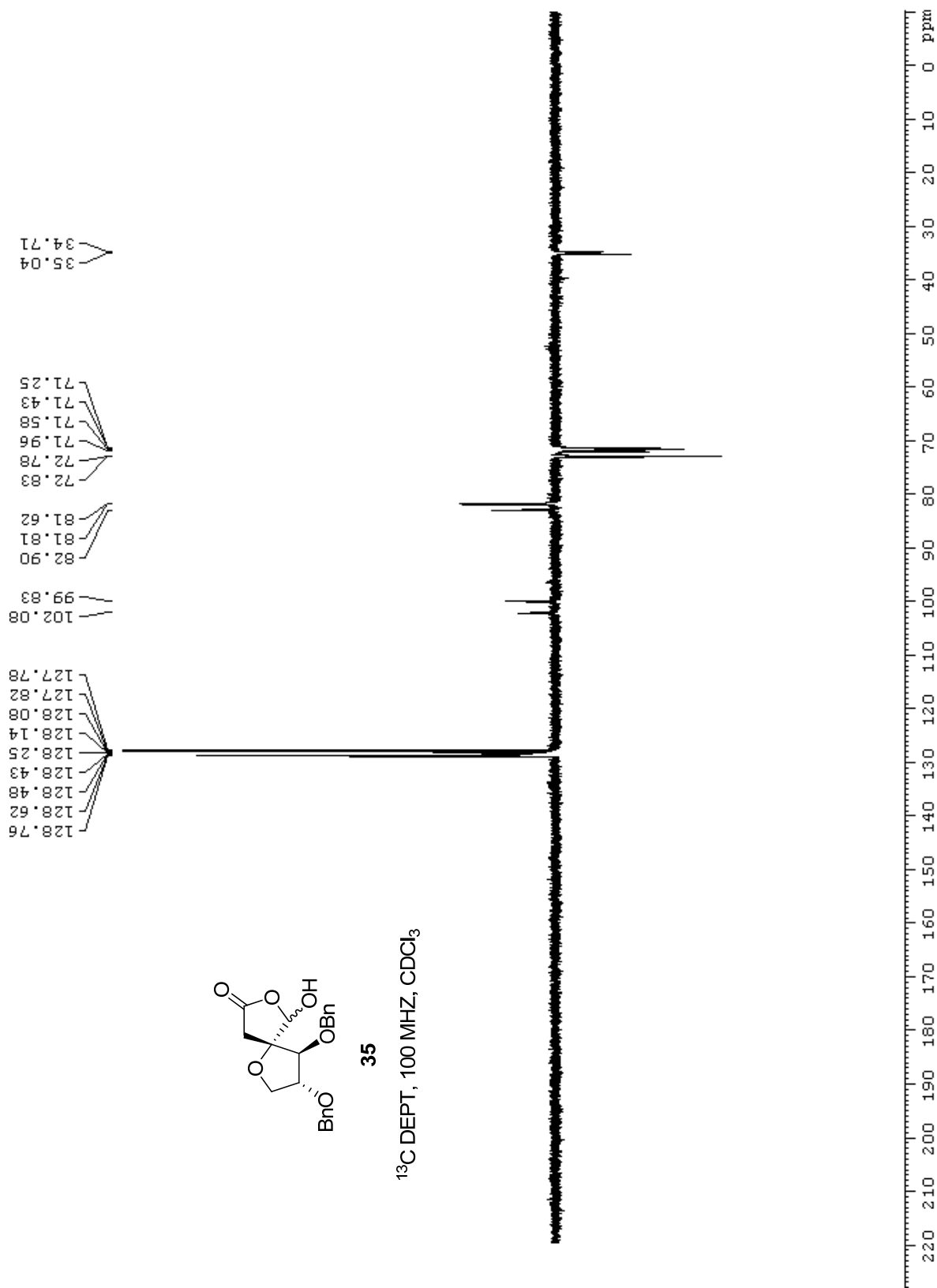


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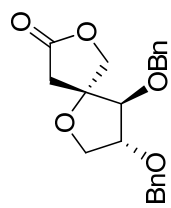
<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>





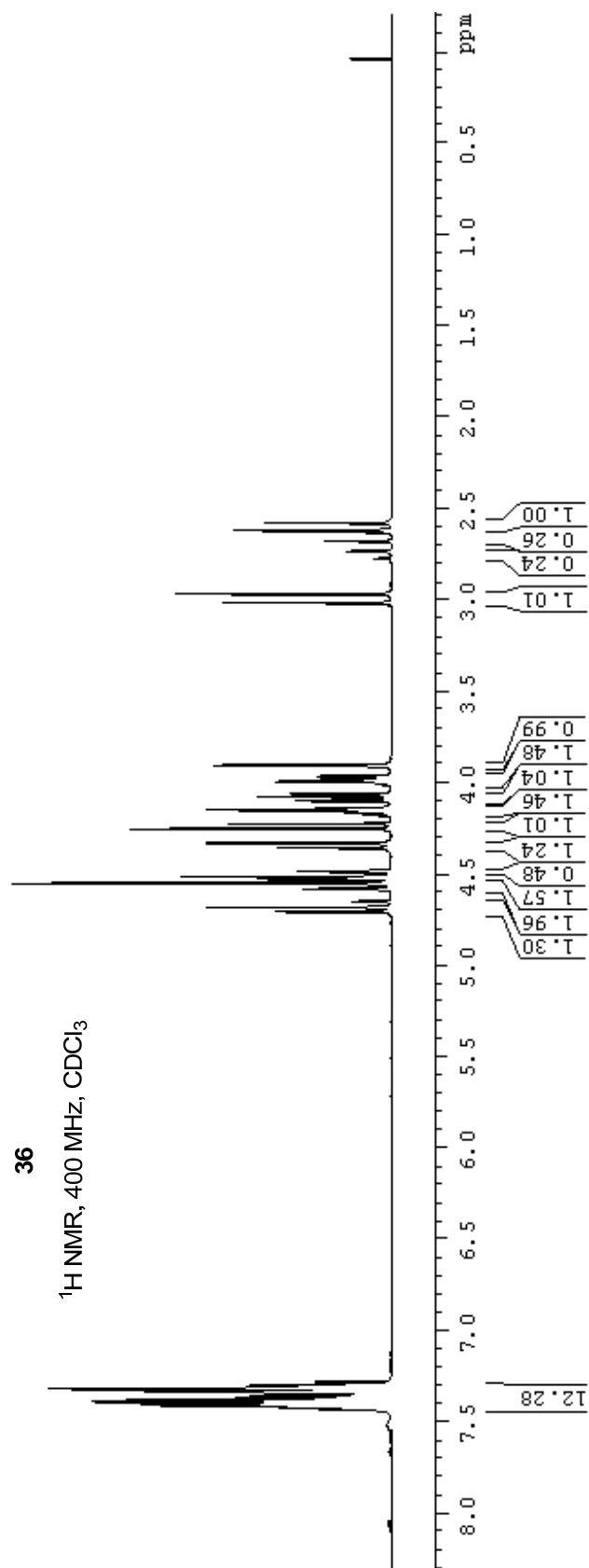


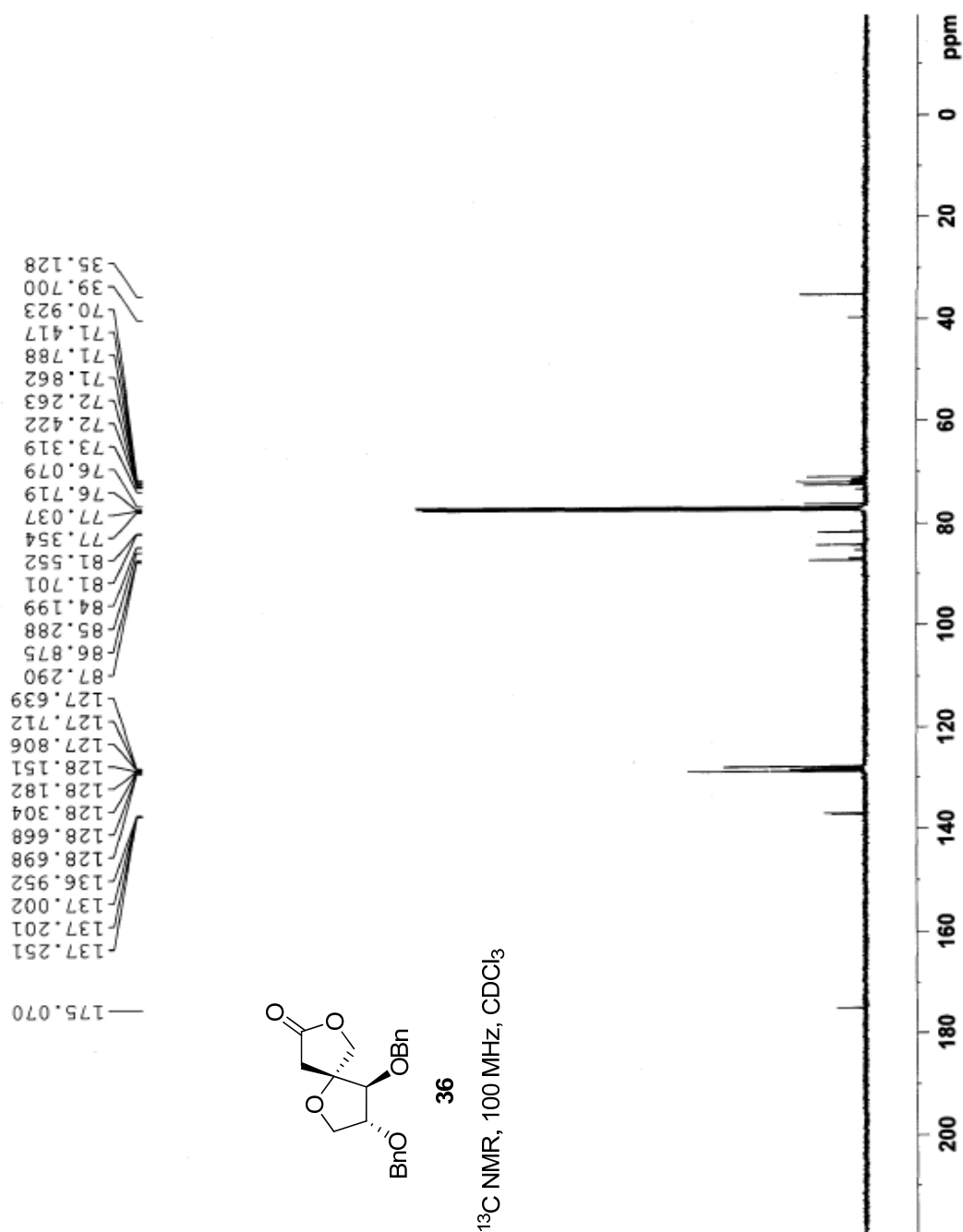


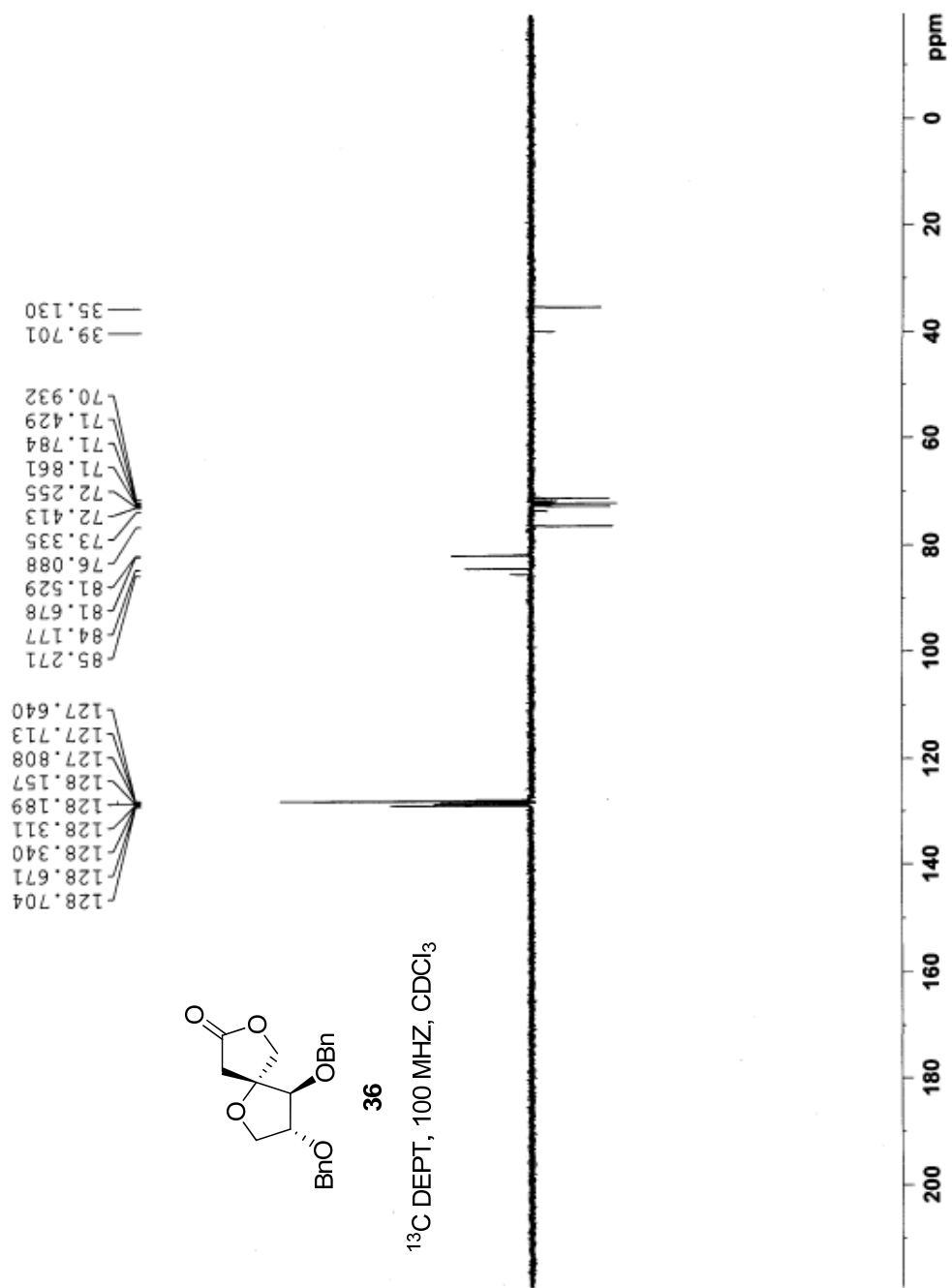


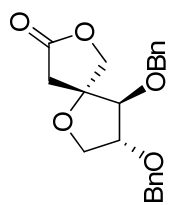
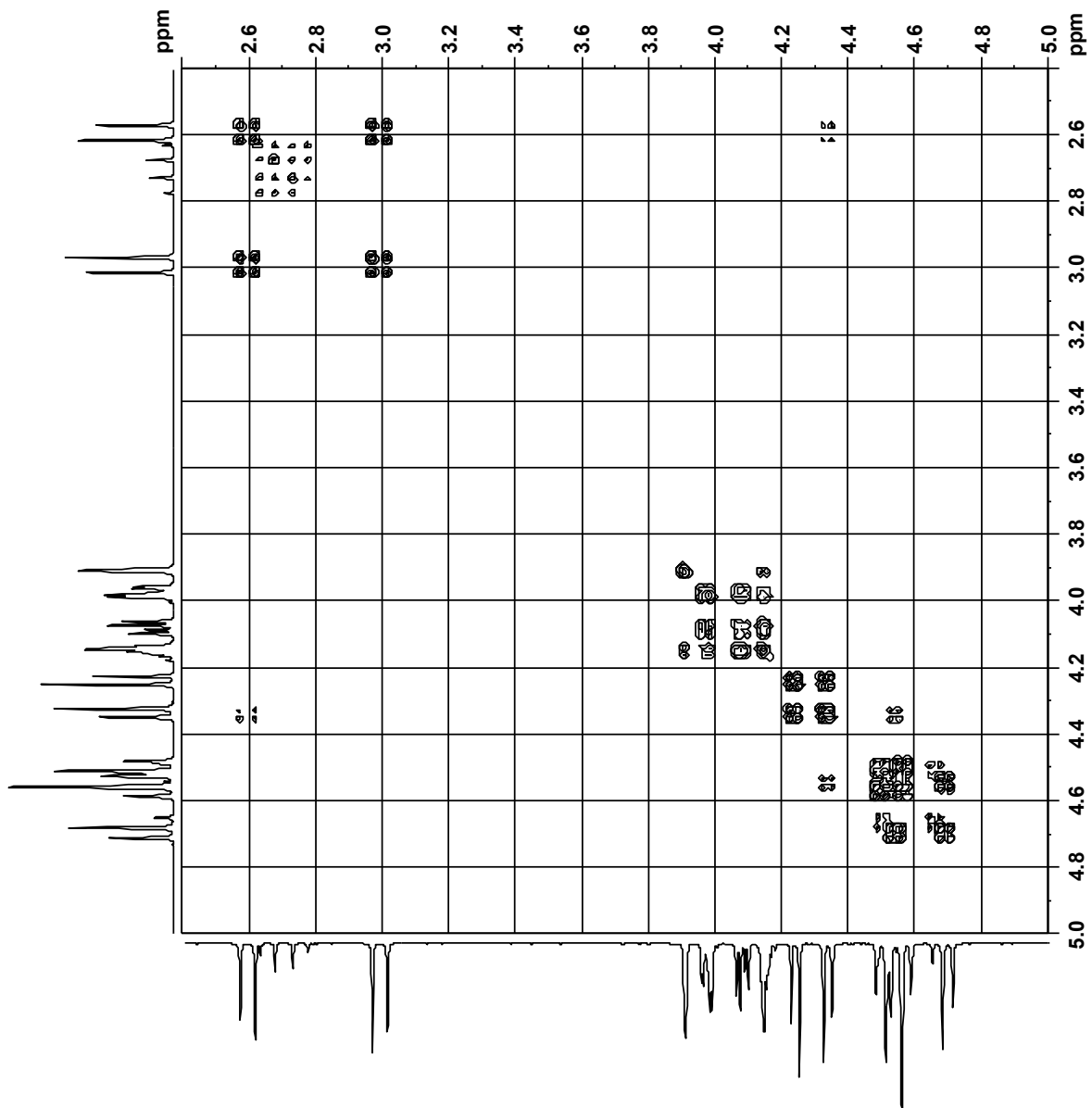
36

$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$









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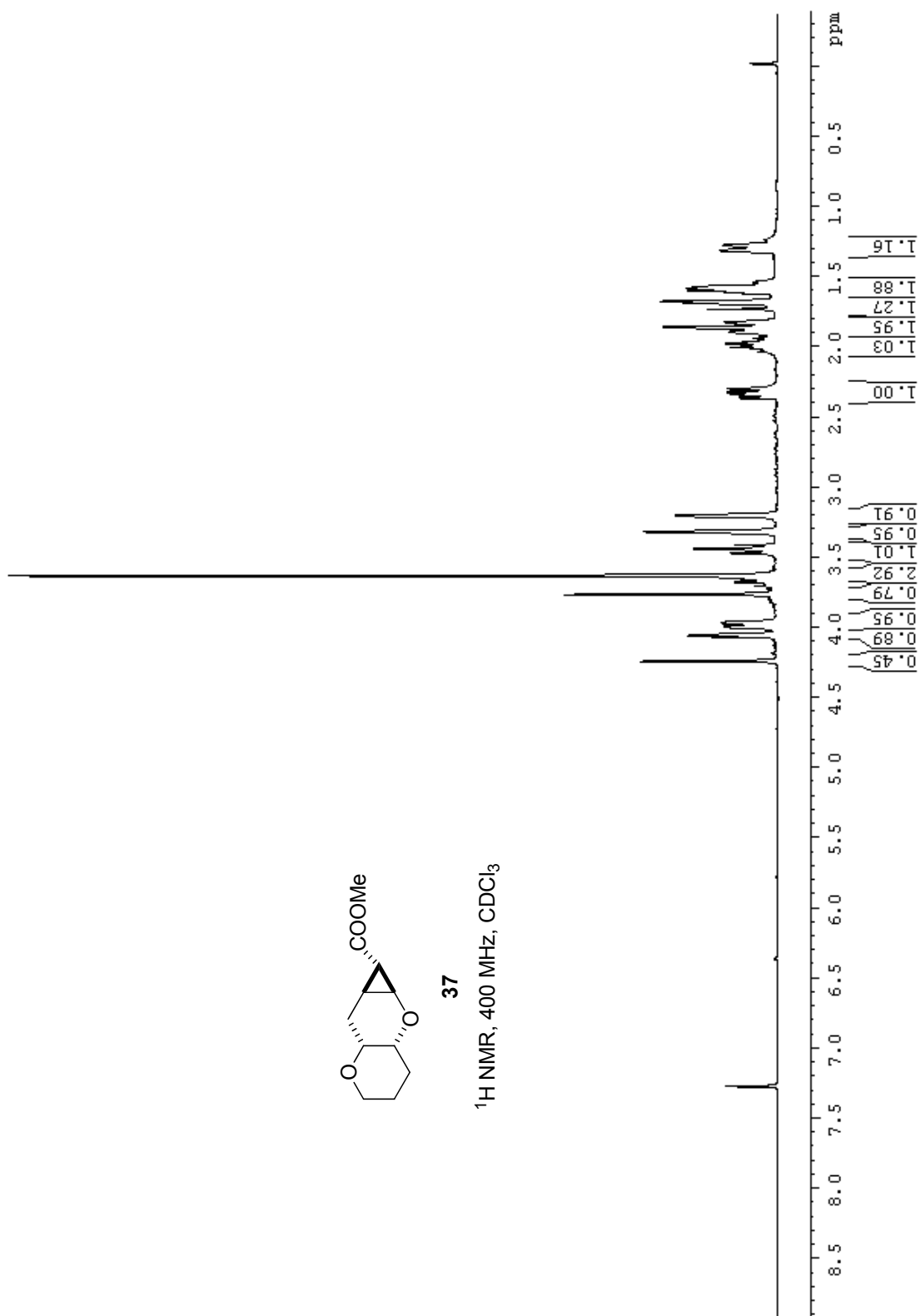
$^1\text{H}-^1\text{H}$  COSY, 400 MHz,  $\text{CDCl}_3$





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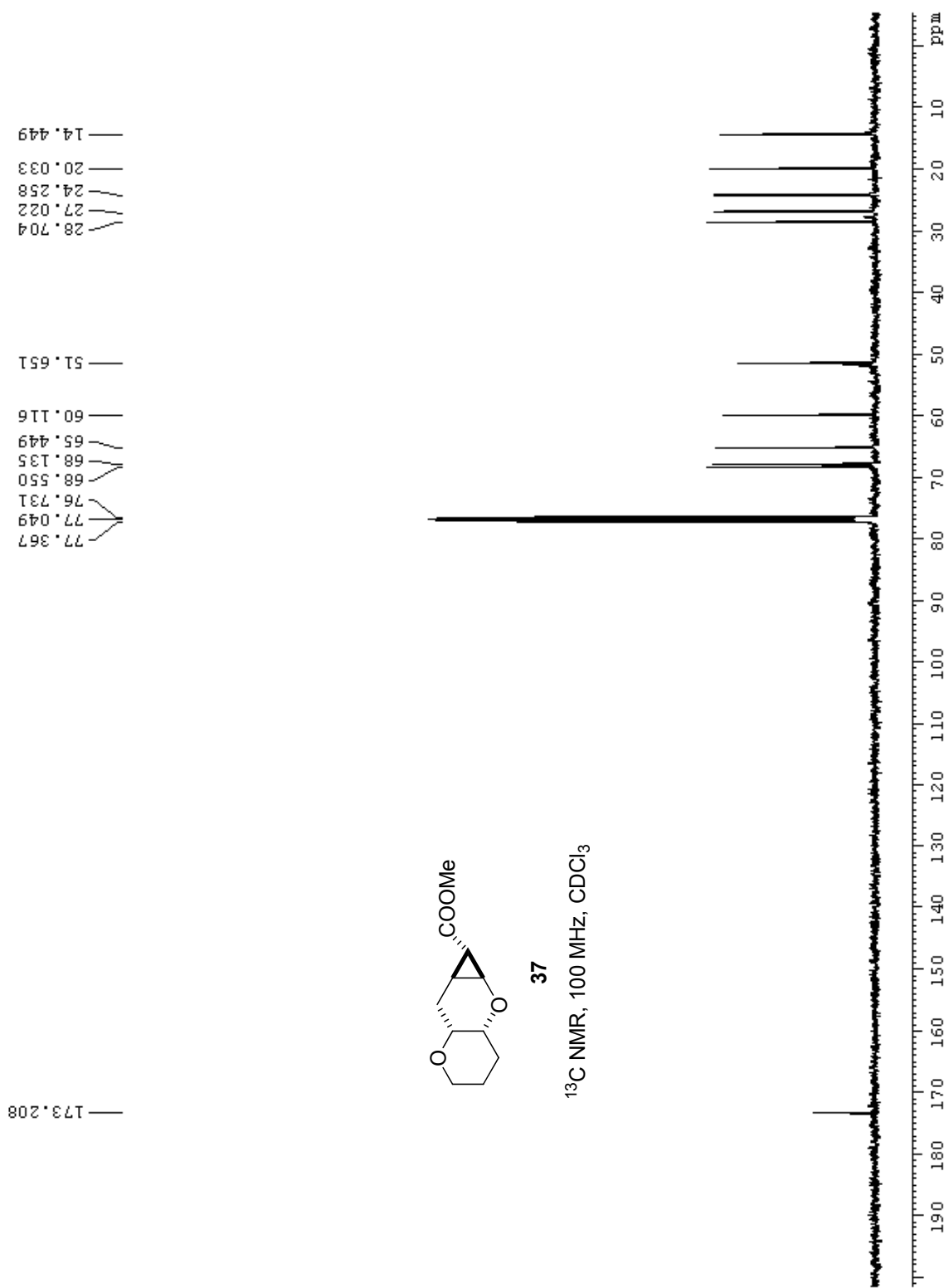
<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>





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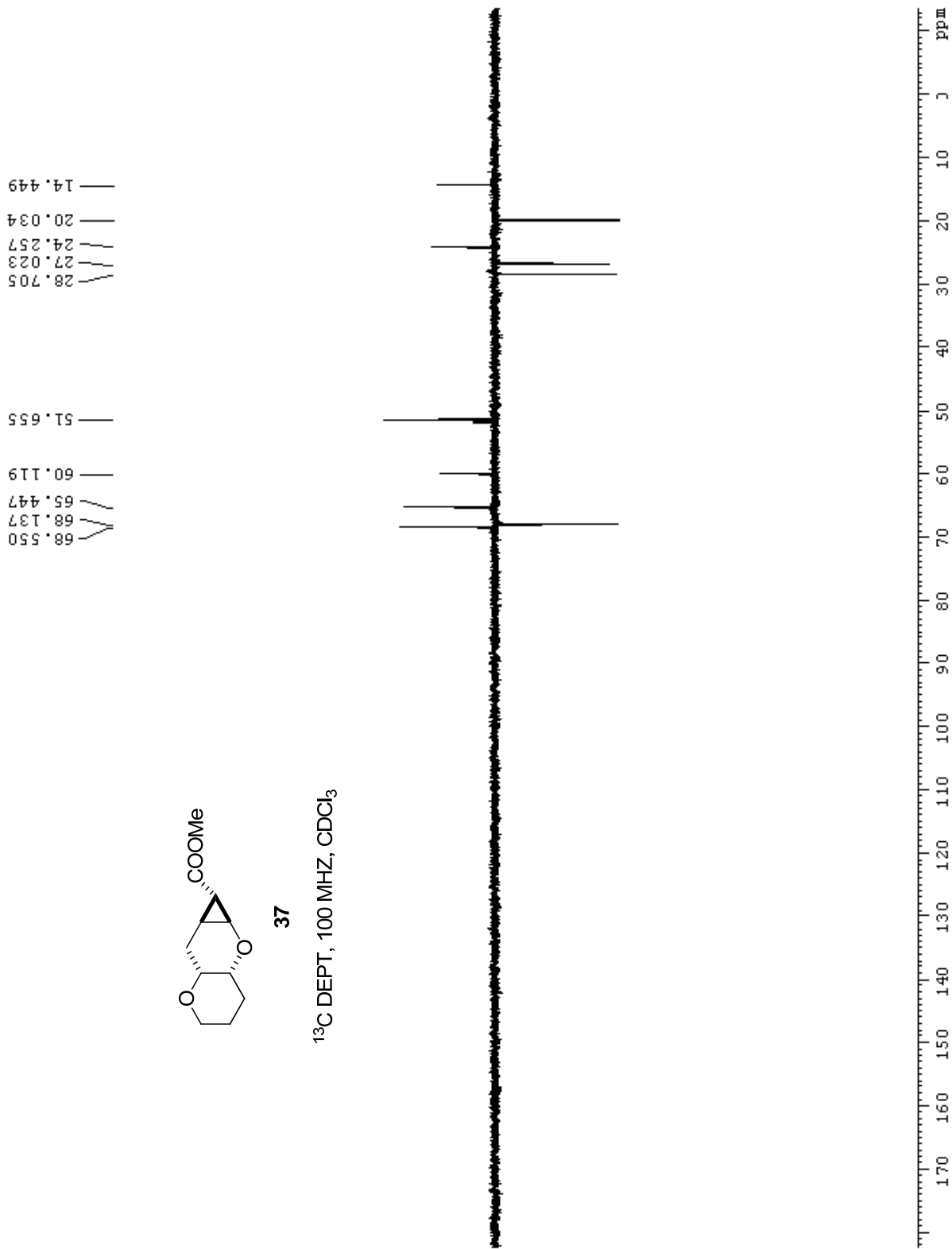
$^{13}\text{C}$  NMR, 100 MHz,  $\text{CDCl}_3$



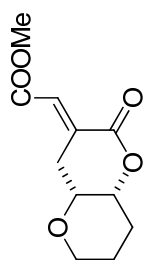


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$^{13}\text{C}$  DEPT, 100 MHz,  $\text{CDCl}_3$

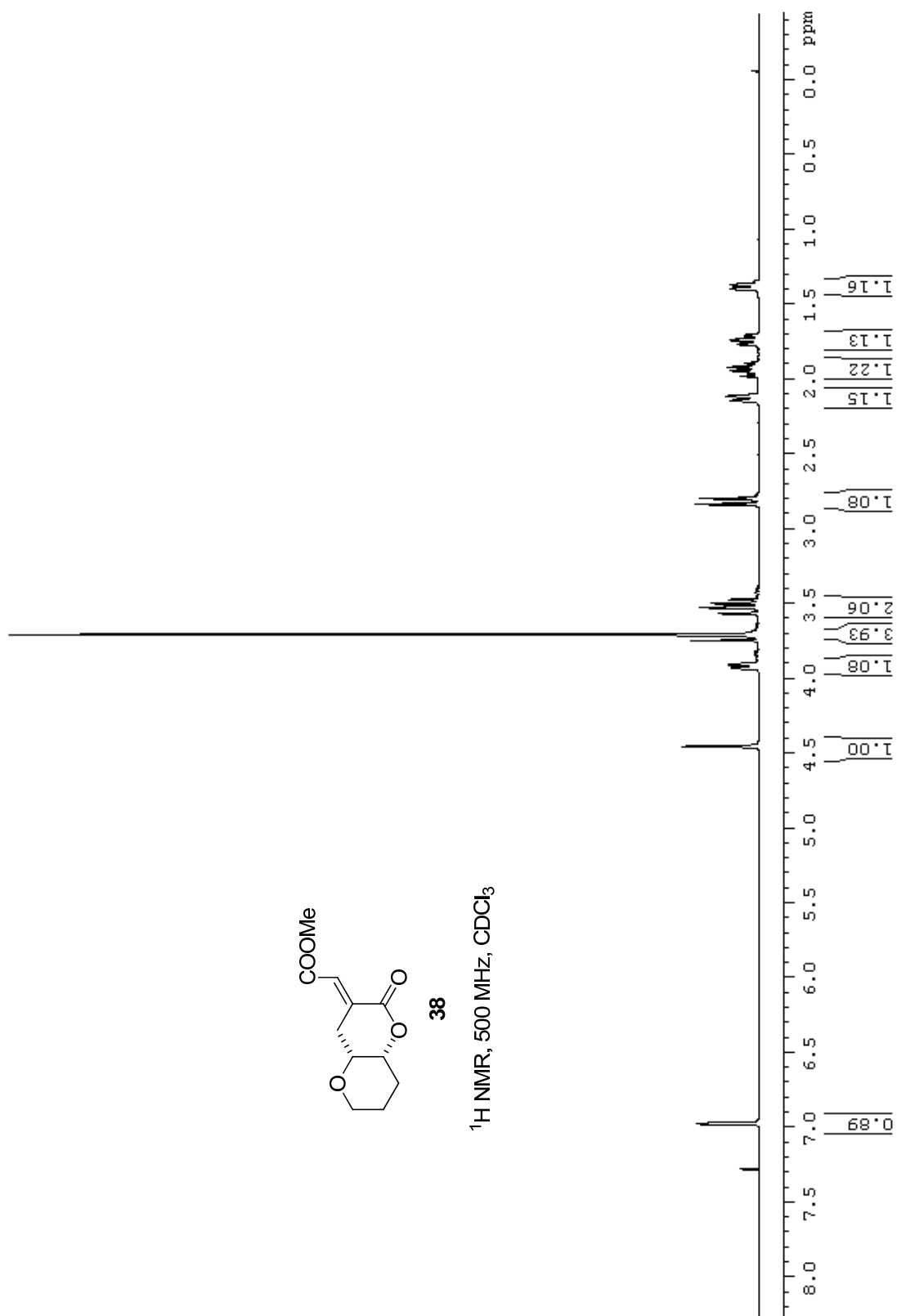


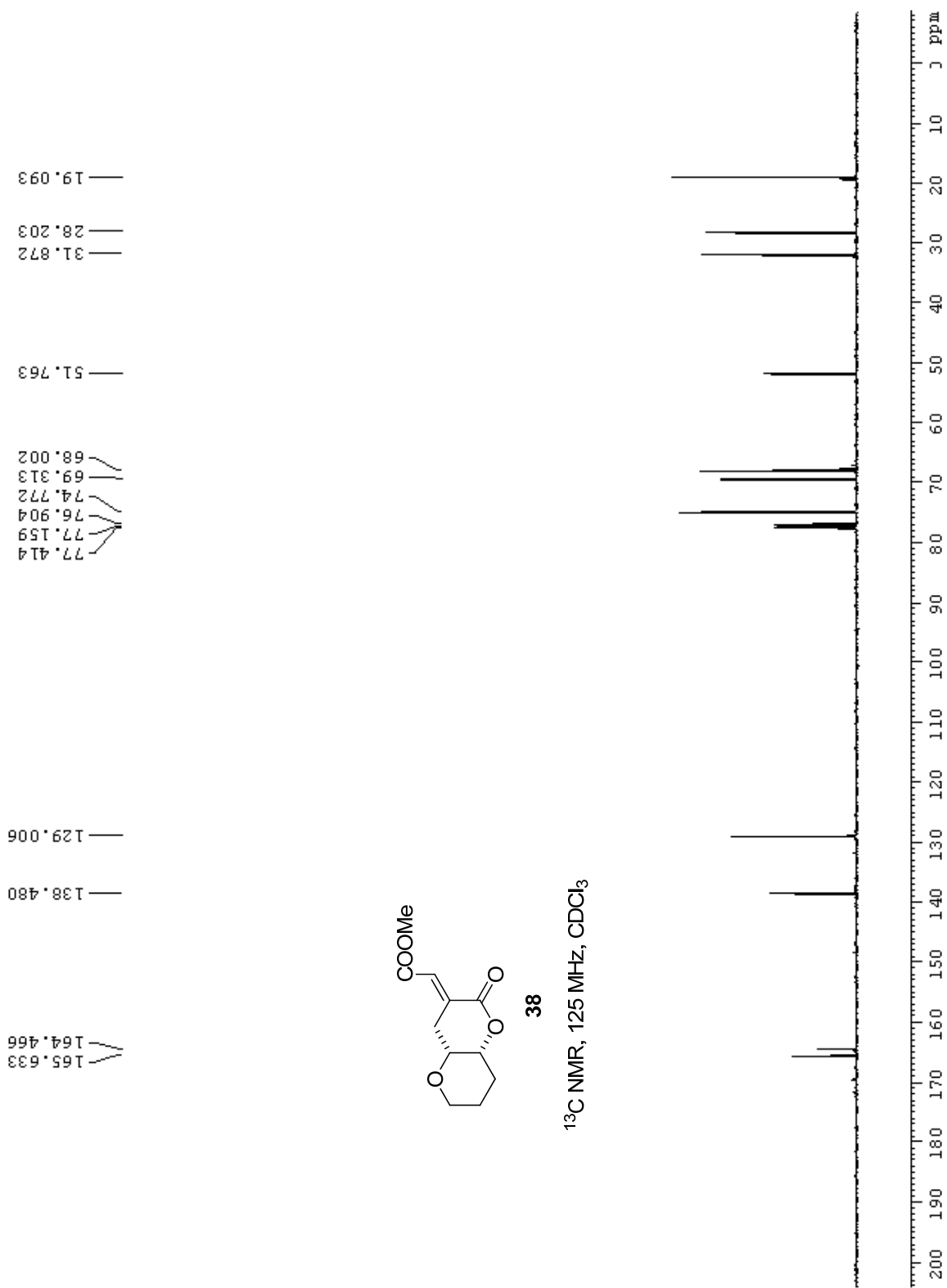


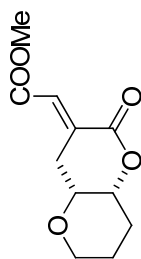


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<sup>1</sup>H NMR, 500 MHz, CDCl<sub>3</sub>

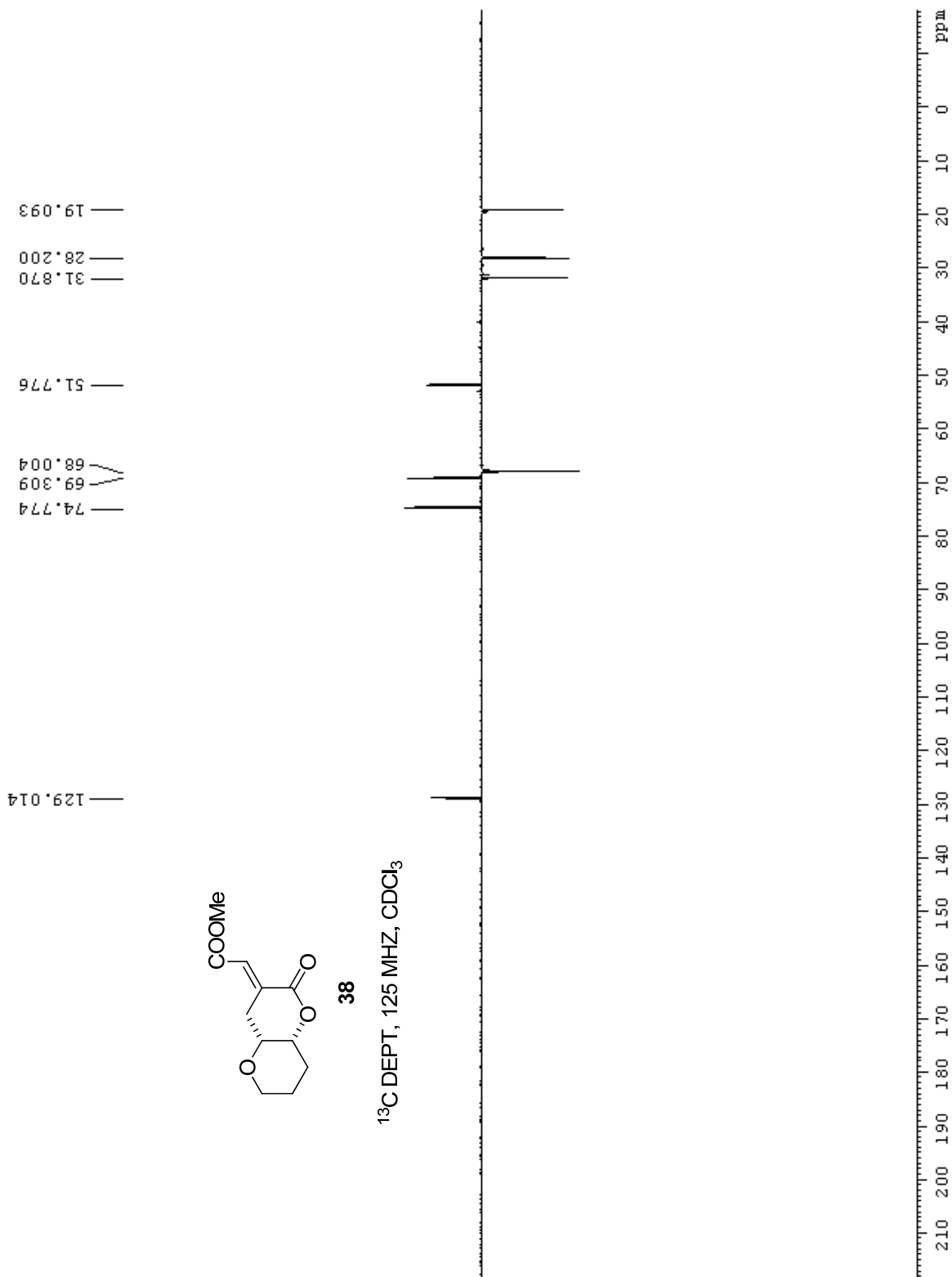


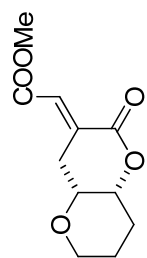
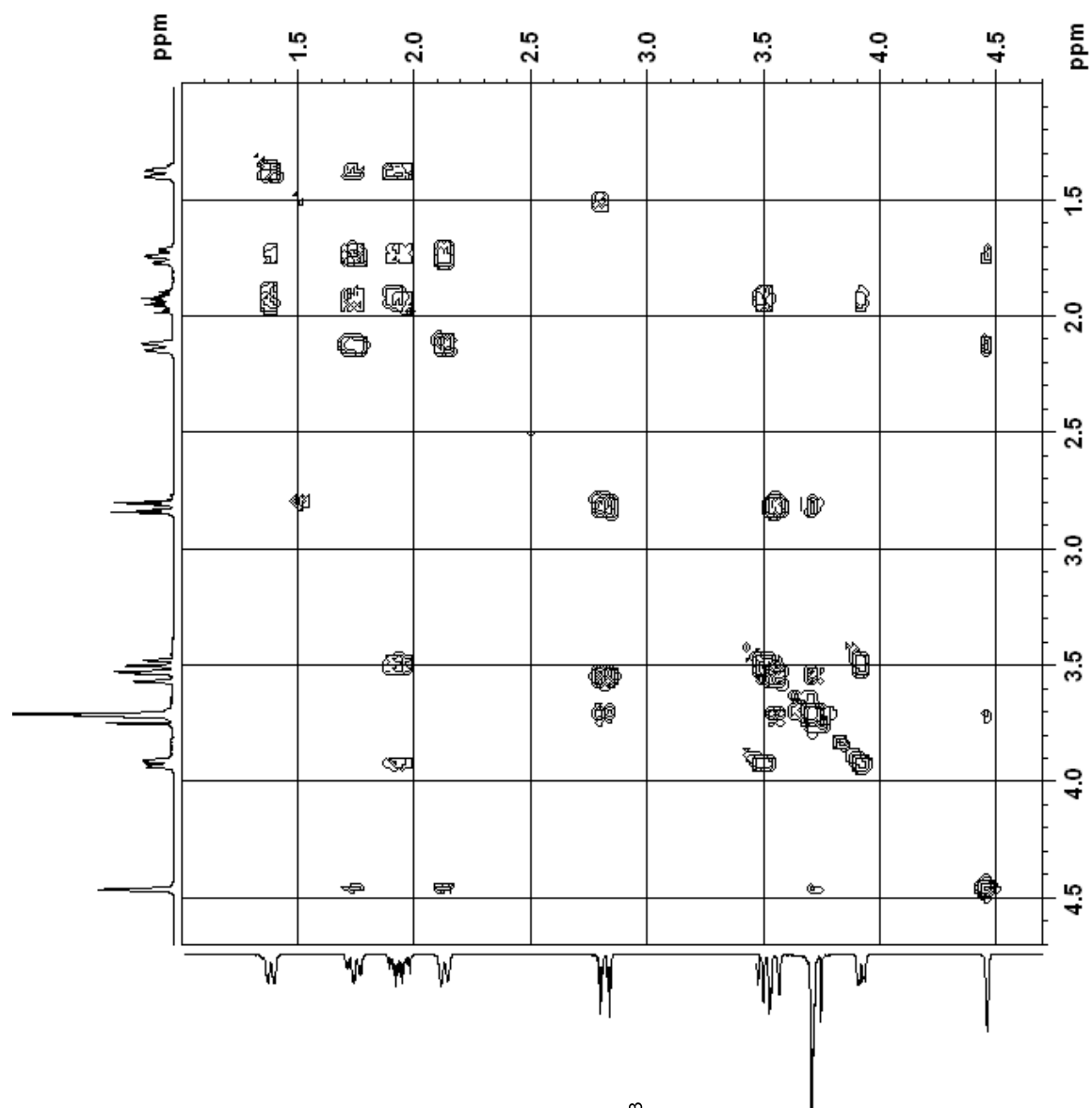




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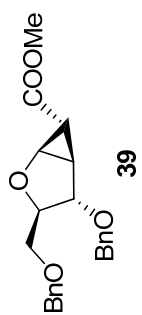
$^{13}\text{C}$  DEPT, 125 MHz,  $\text{CDCl}_3$



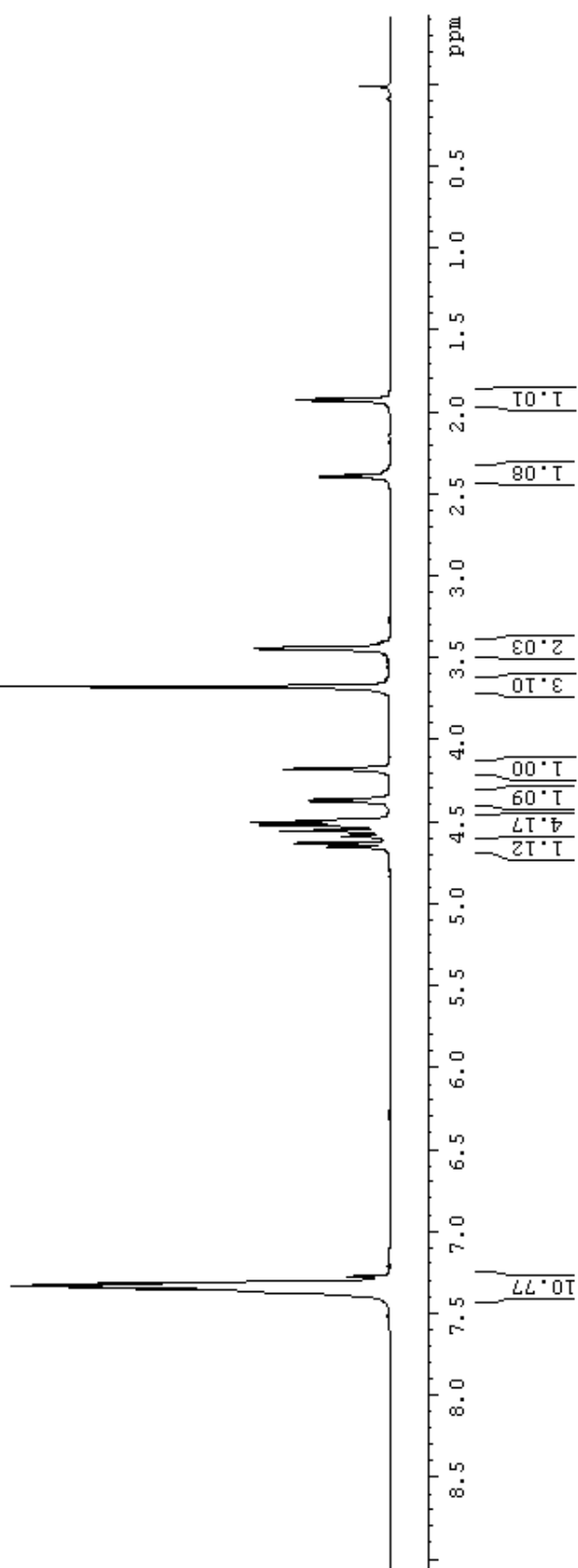


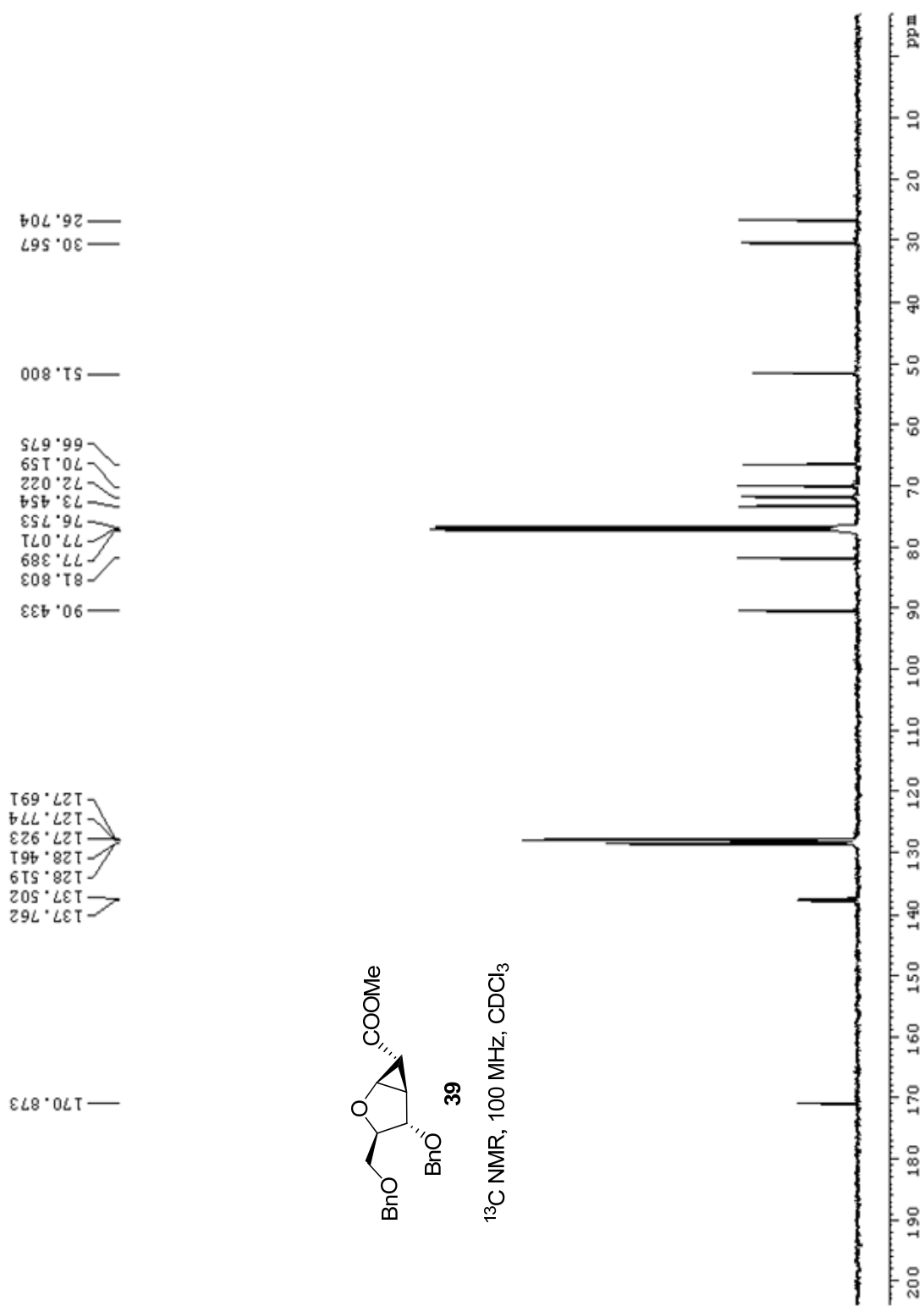
**38**

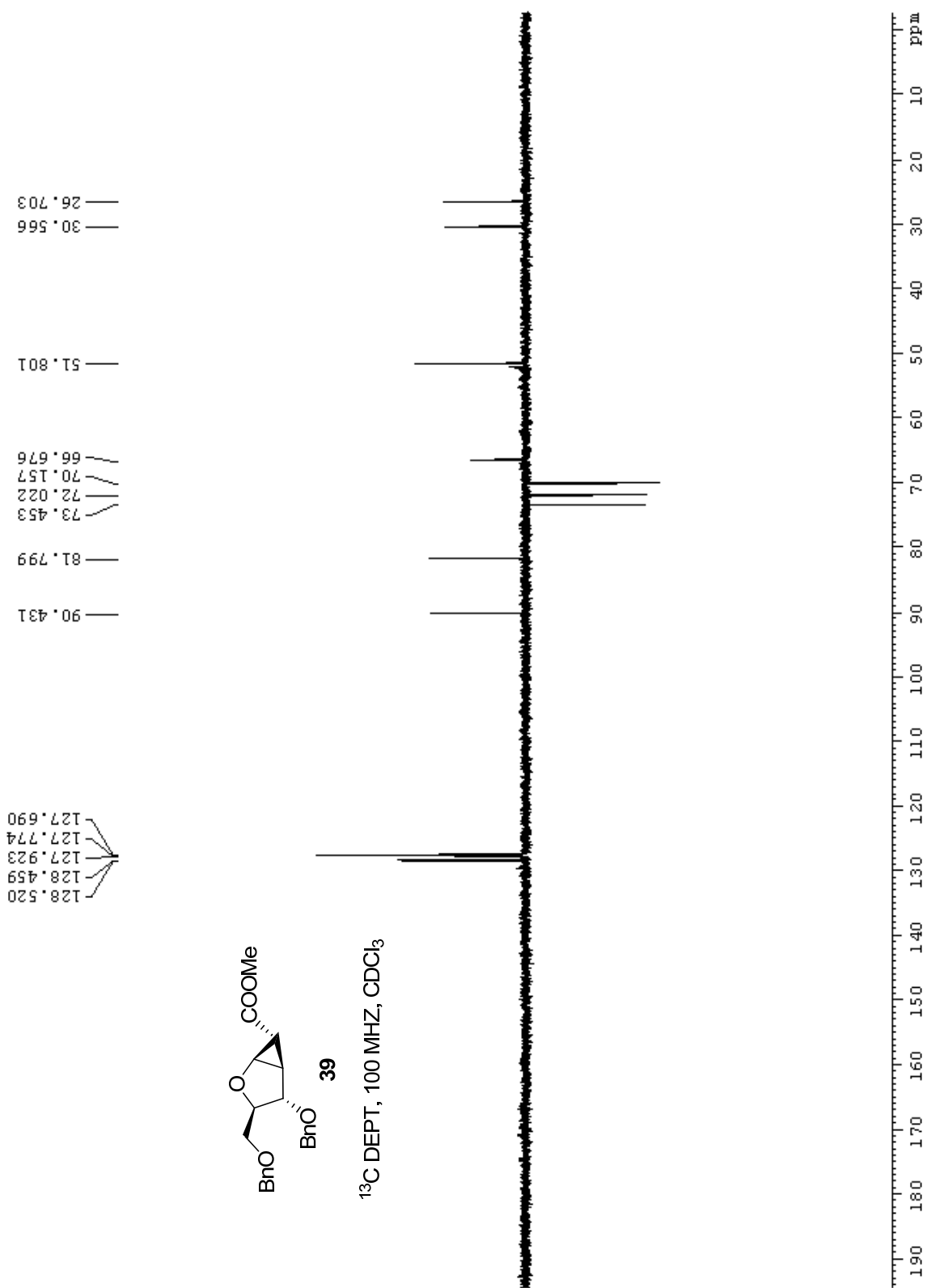
$^1\text{H}$ - $^1\text{H}$  COSY, 500 MHz,  $\text{CDCl}_3$

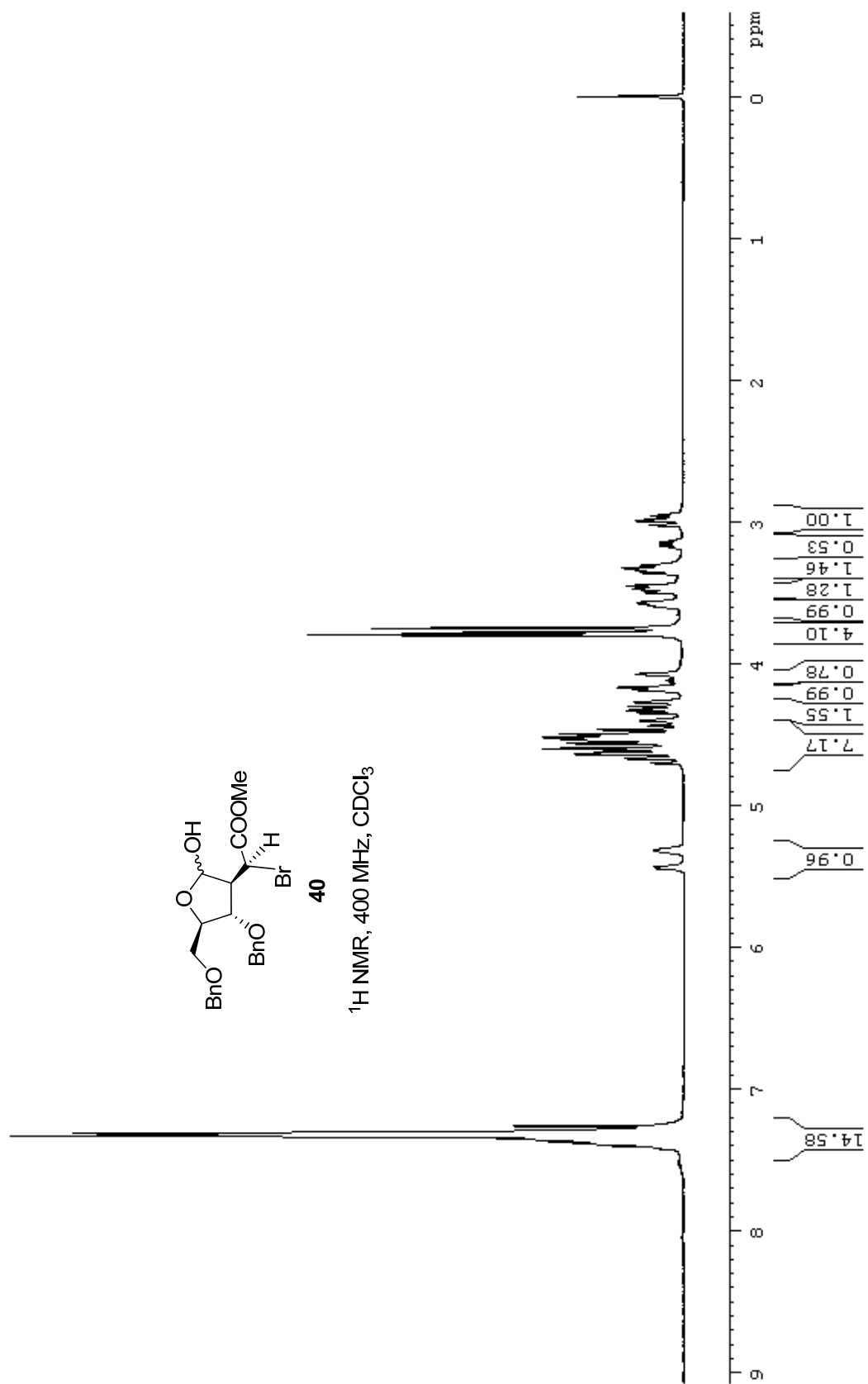


<sup>1</sup>H NMR, 400 MHz, CDCl<sub>3</sub>

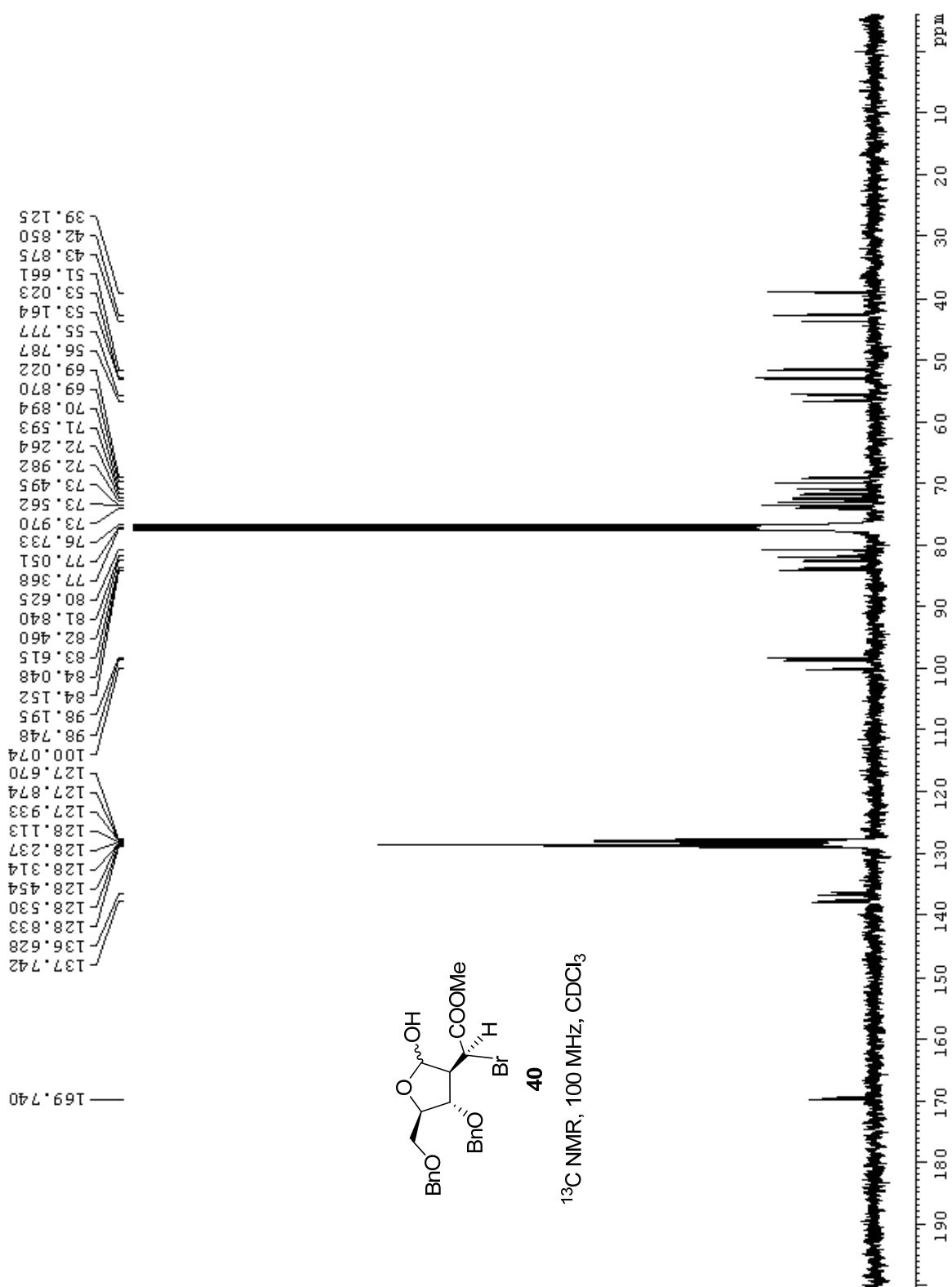


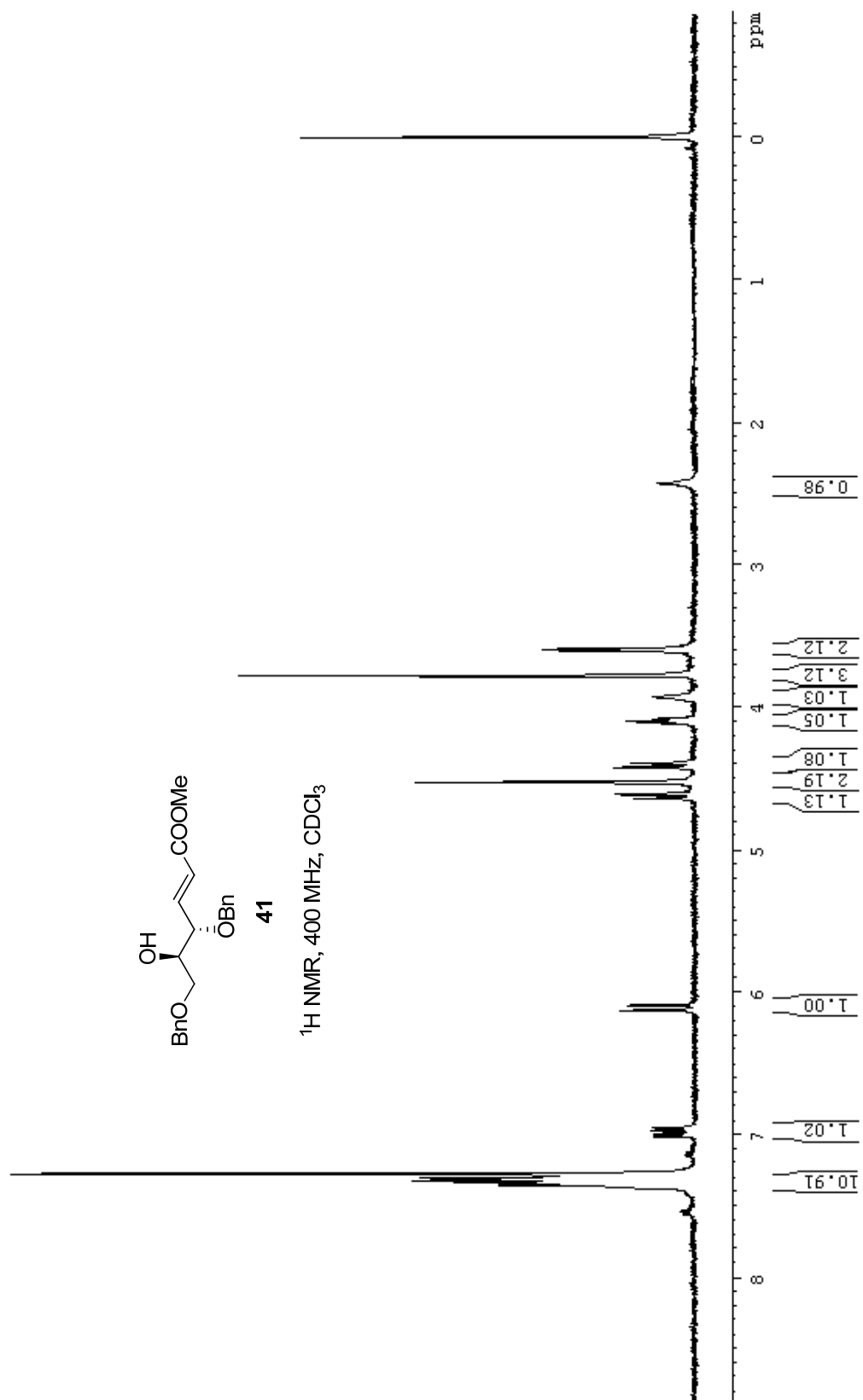


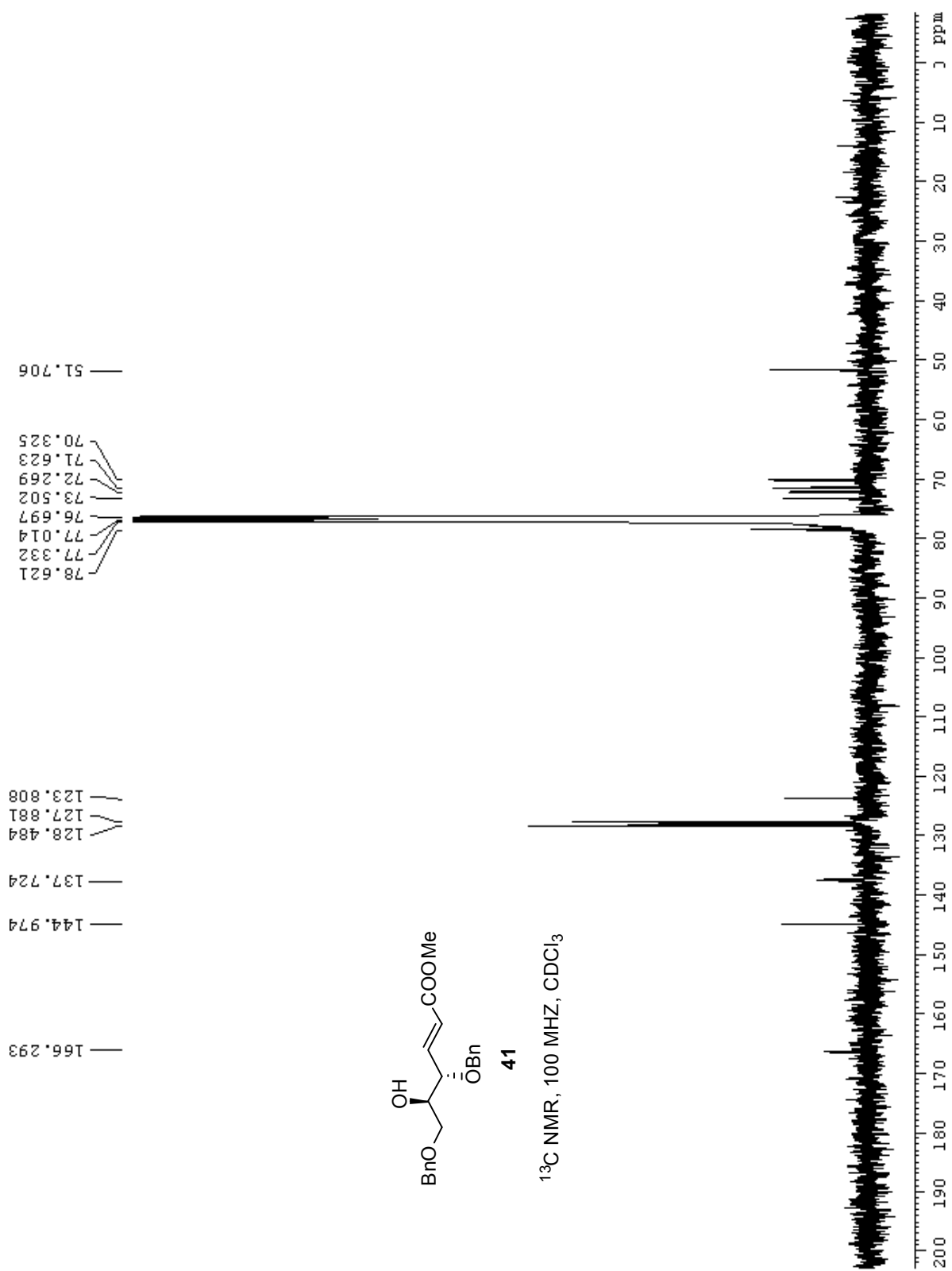


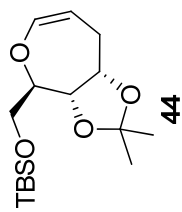




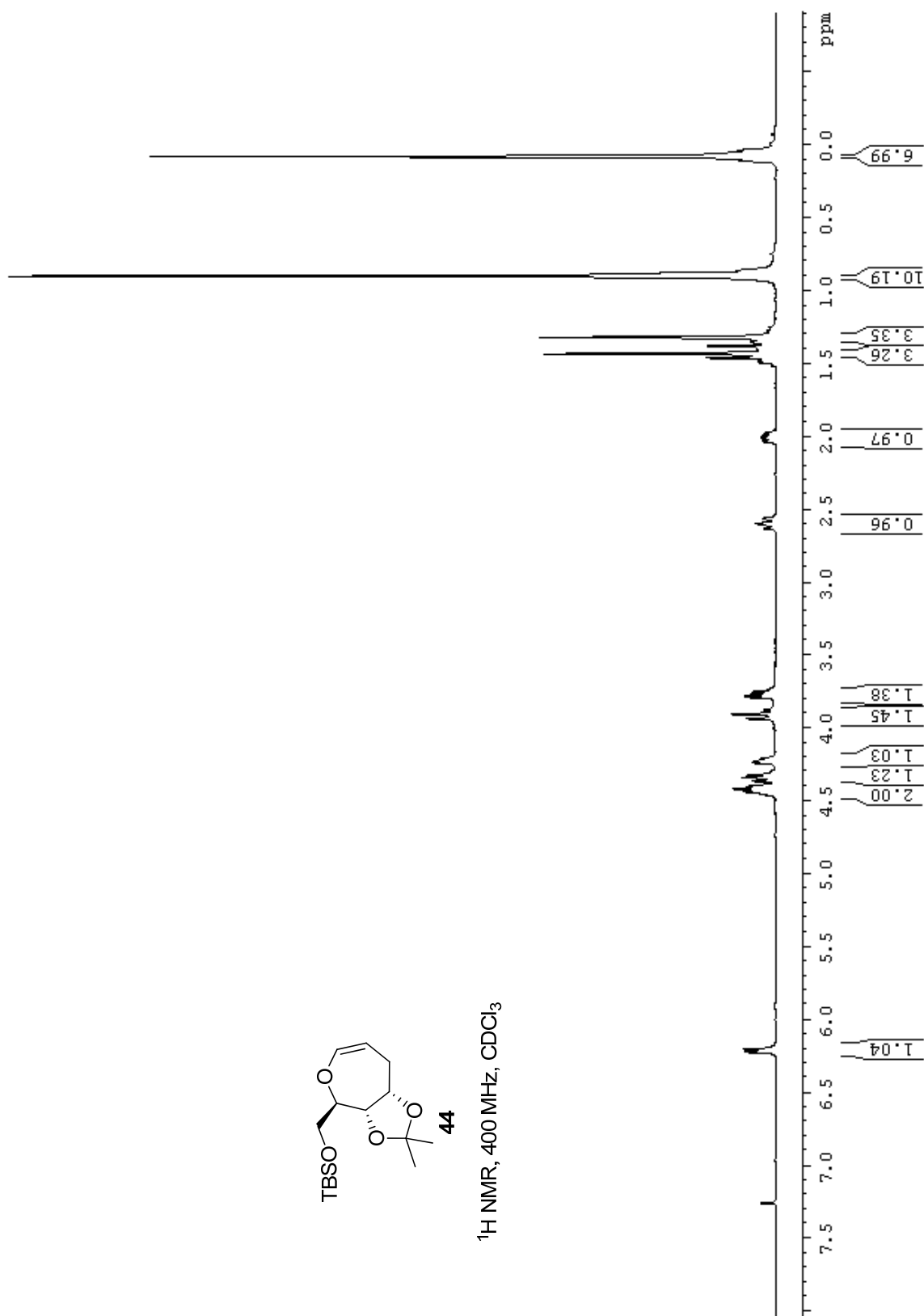


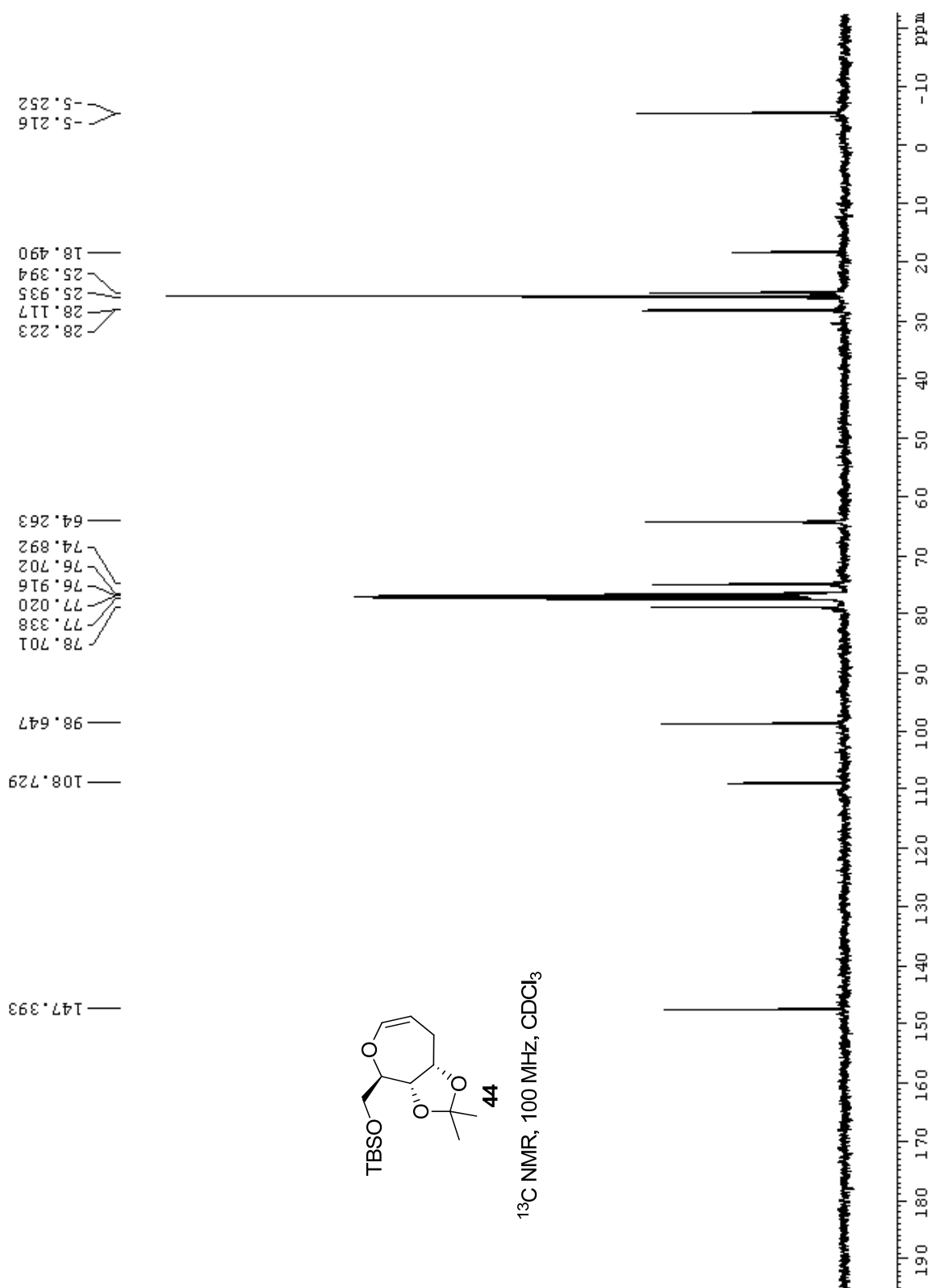


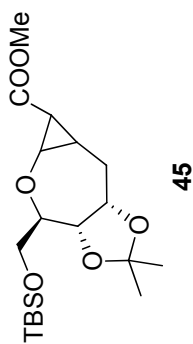




$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$

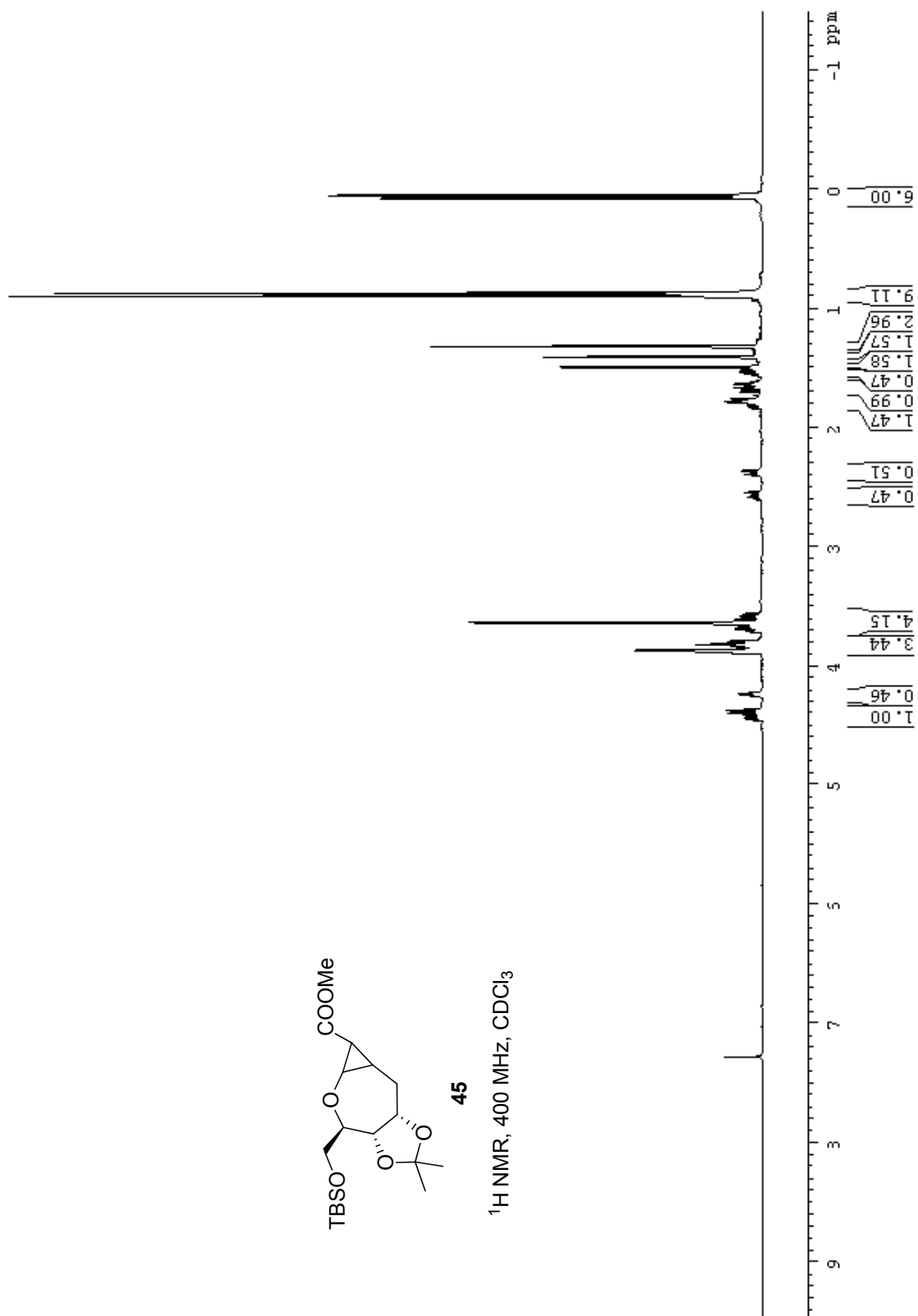


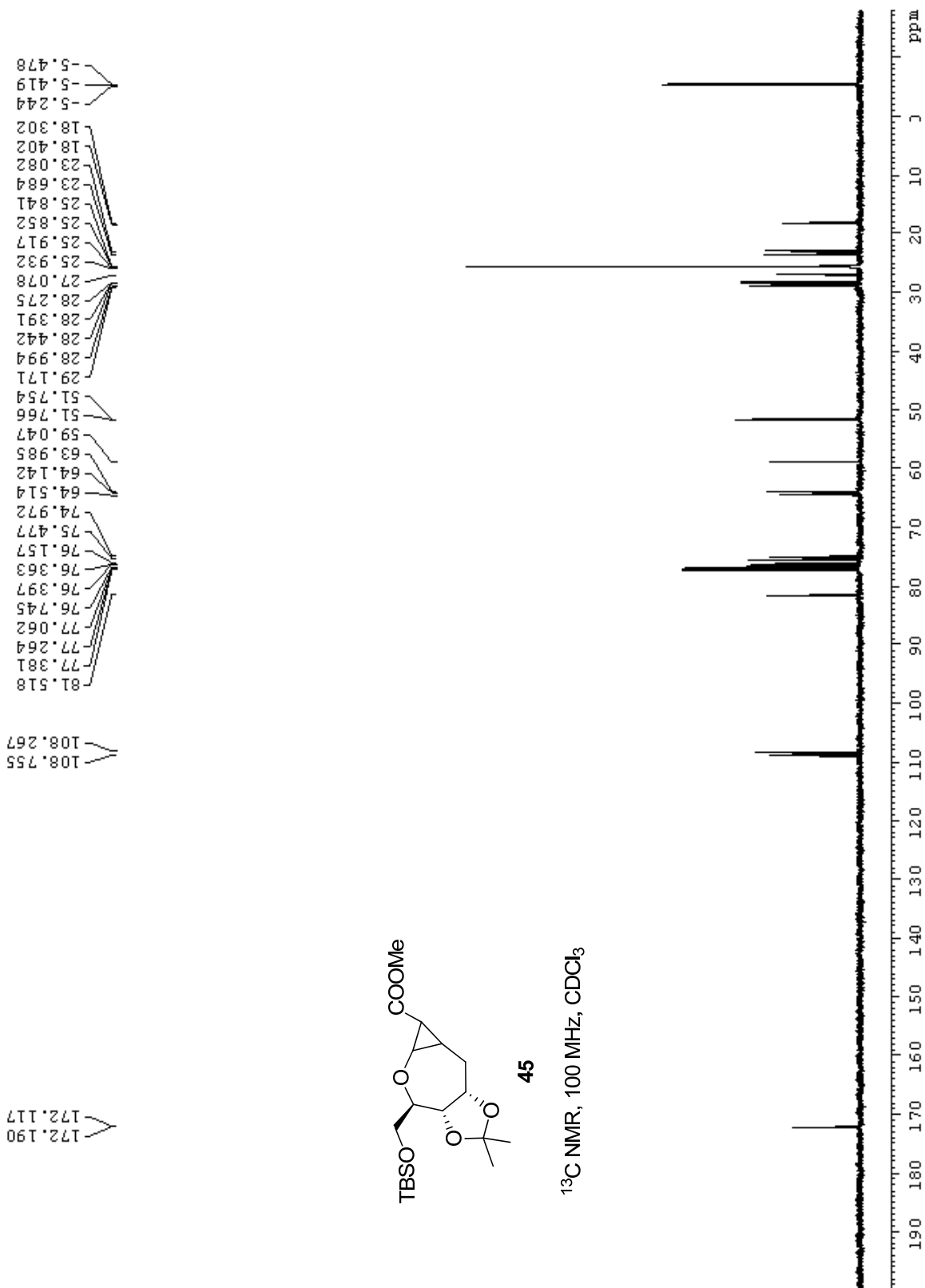


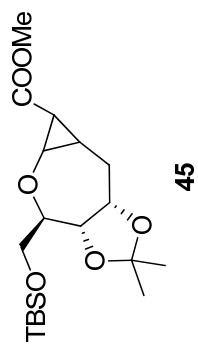


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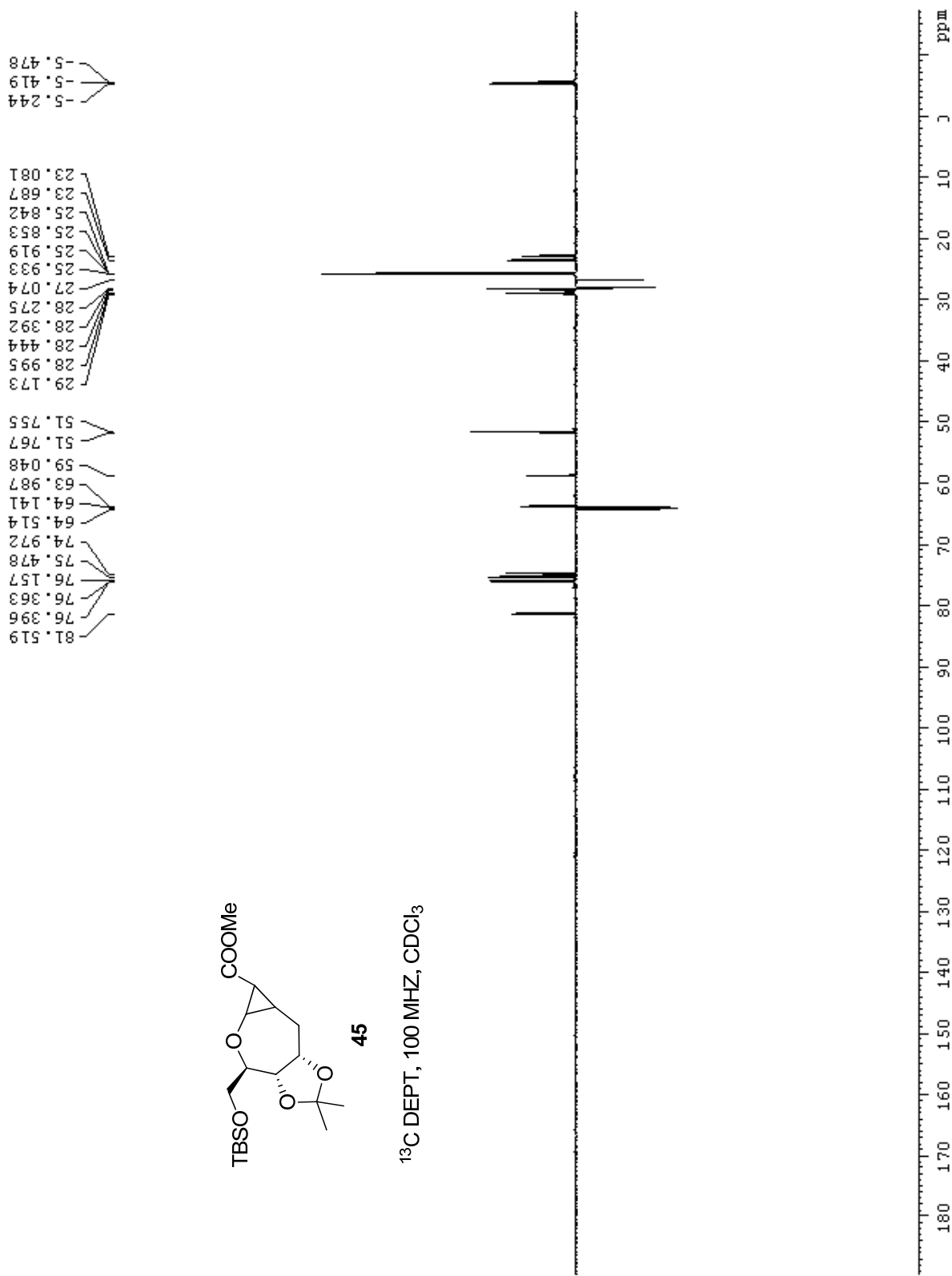
$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$



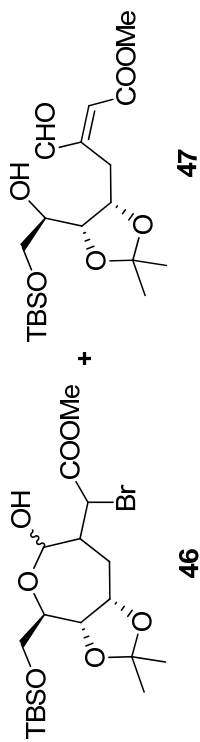




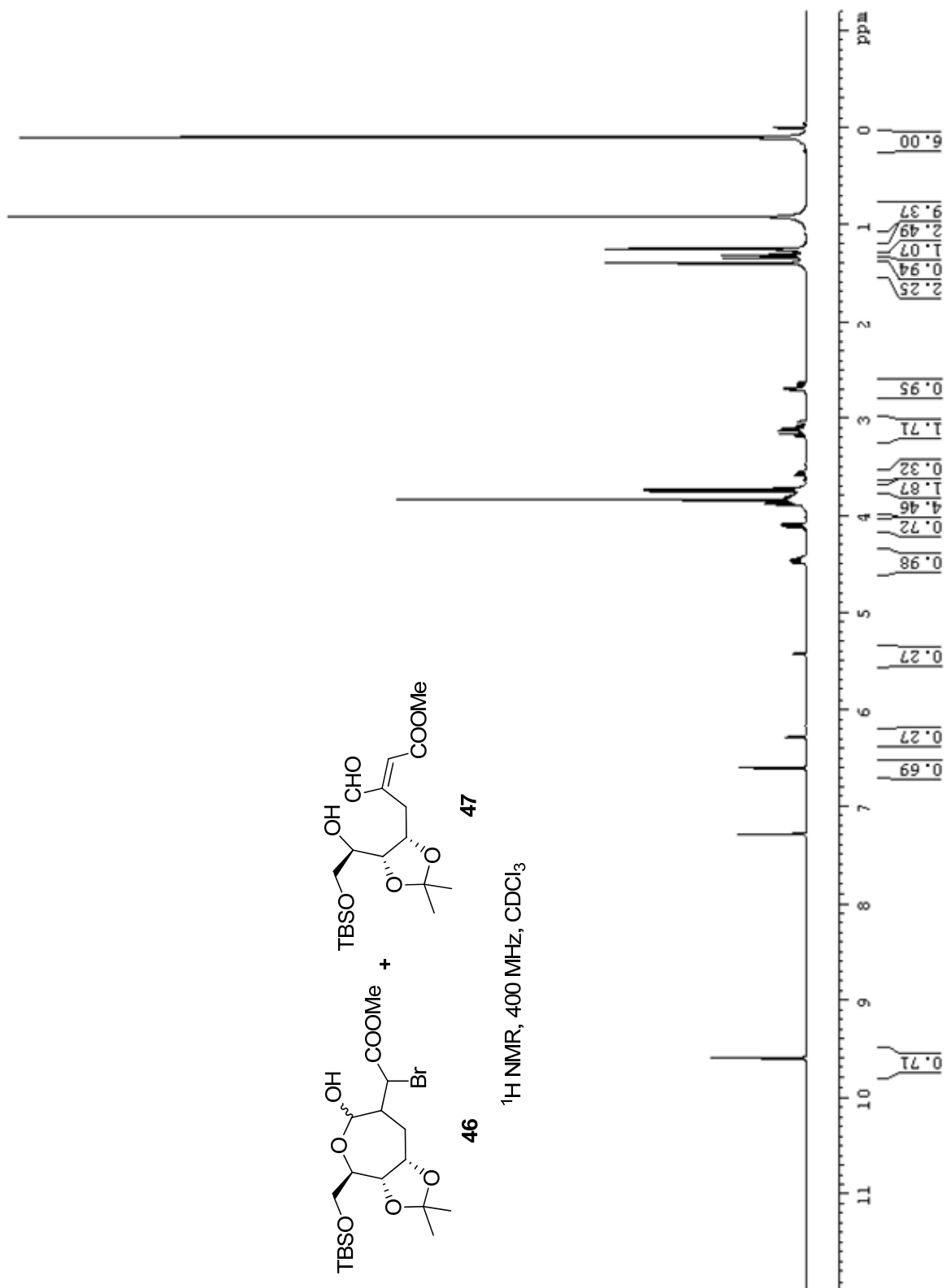
<sup>13</sup>C DEPT, 100 MHz, CDCl<sub>3</sub>

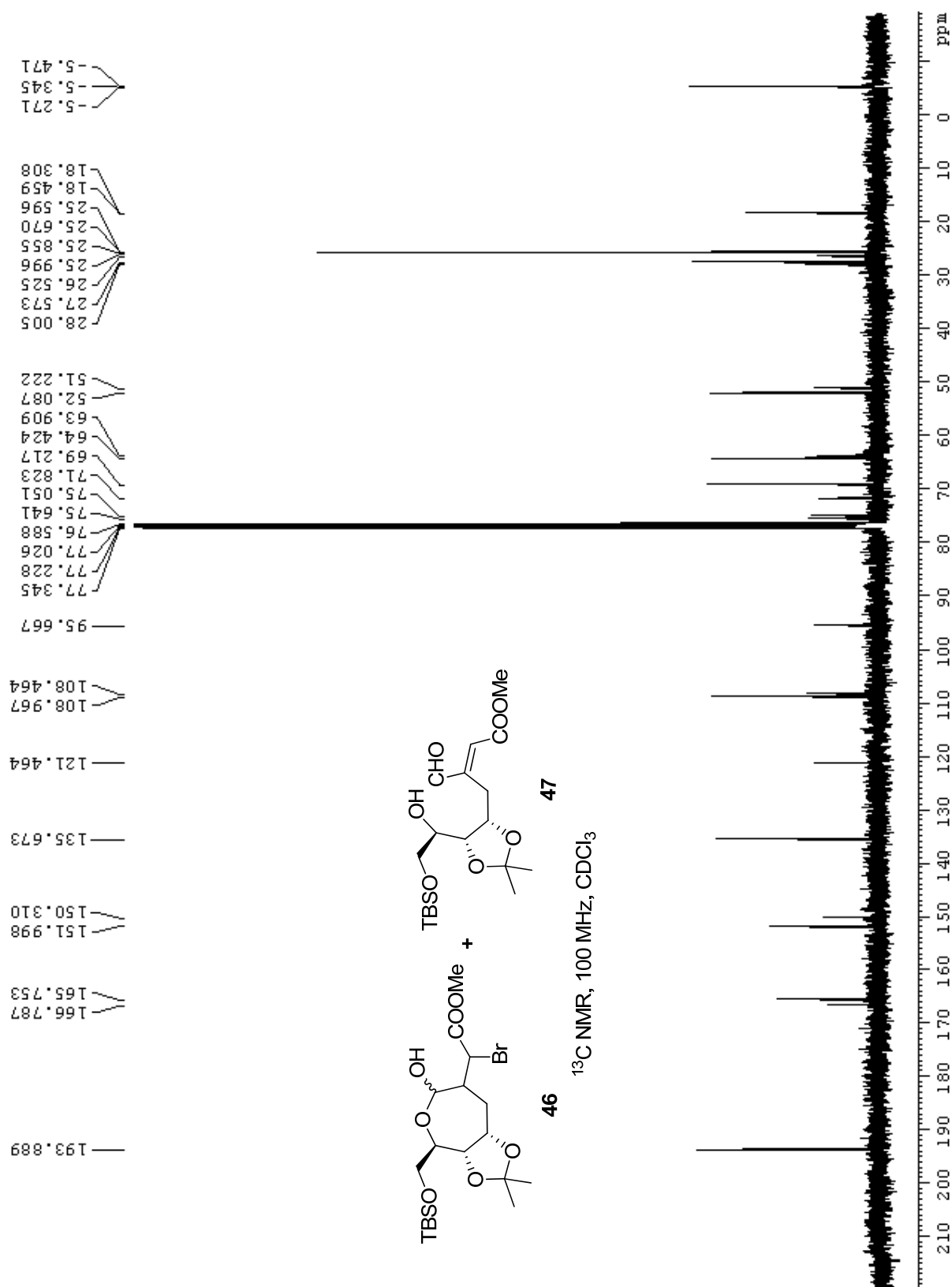


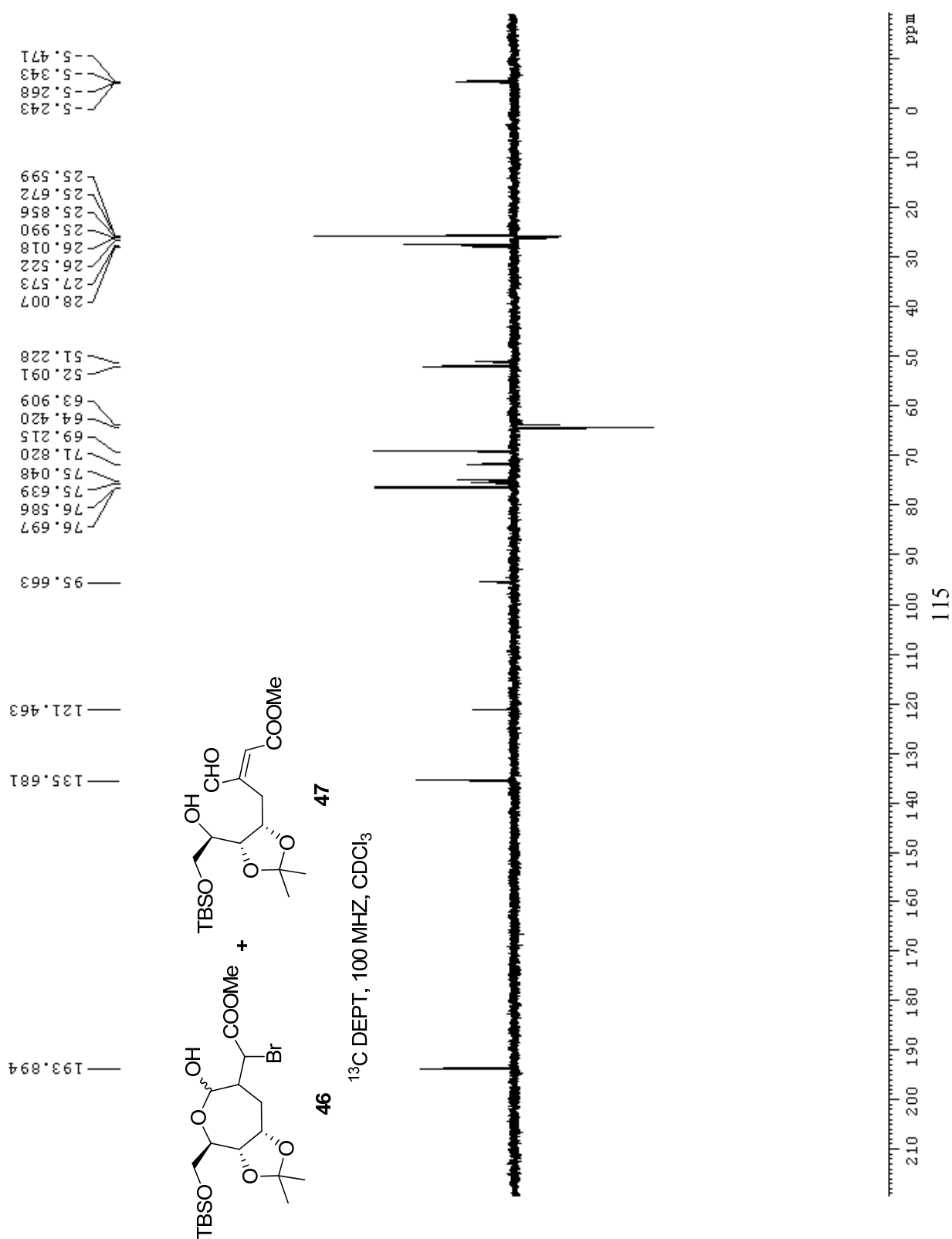


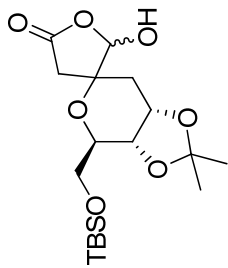


$^1\text{H NMR}$ , 400 MHz,  $\text{CDCl}_3$



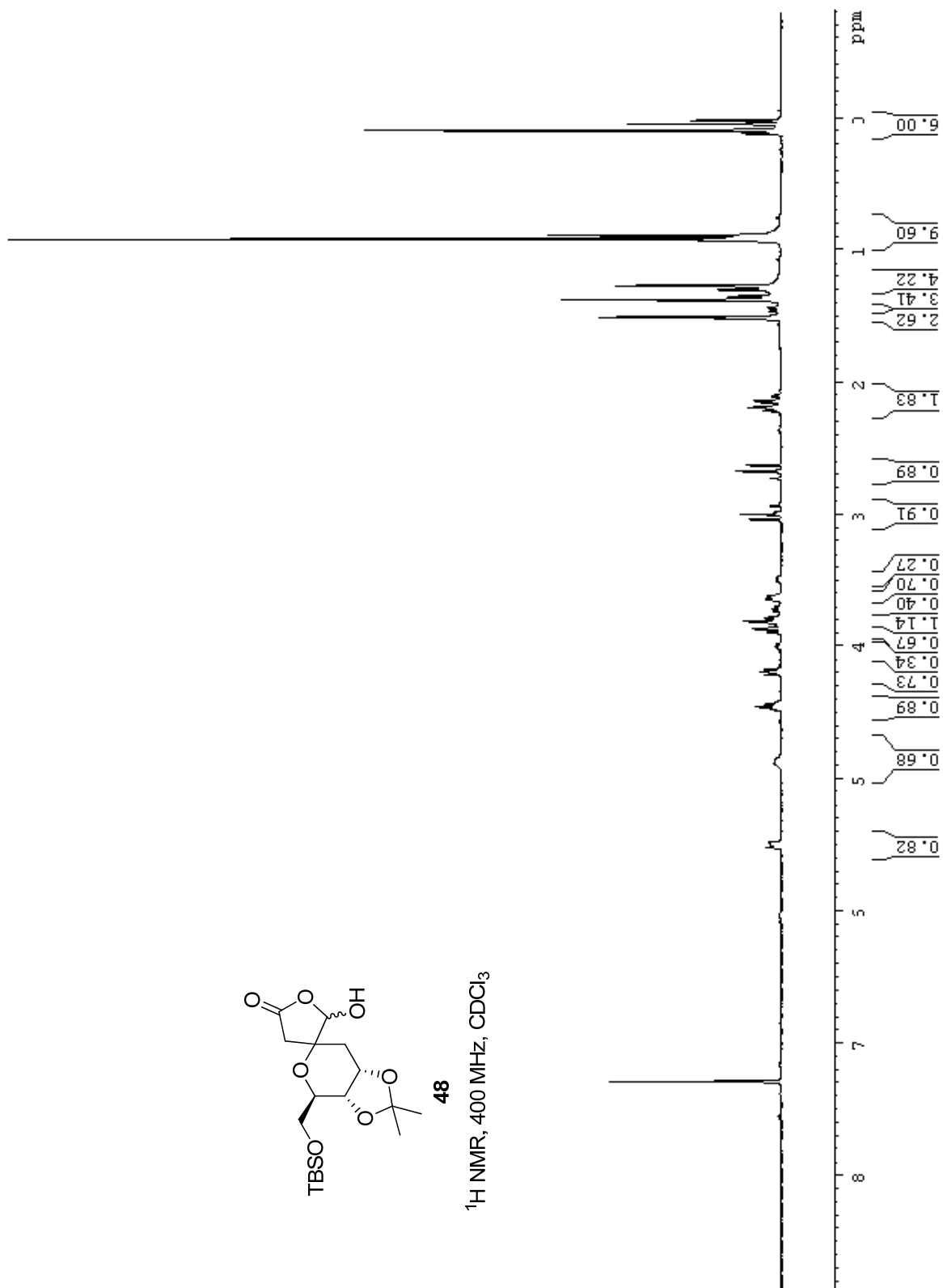


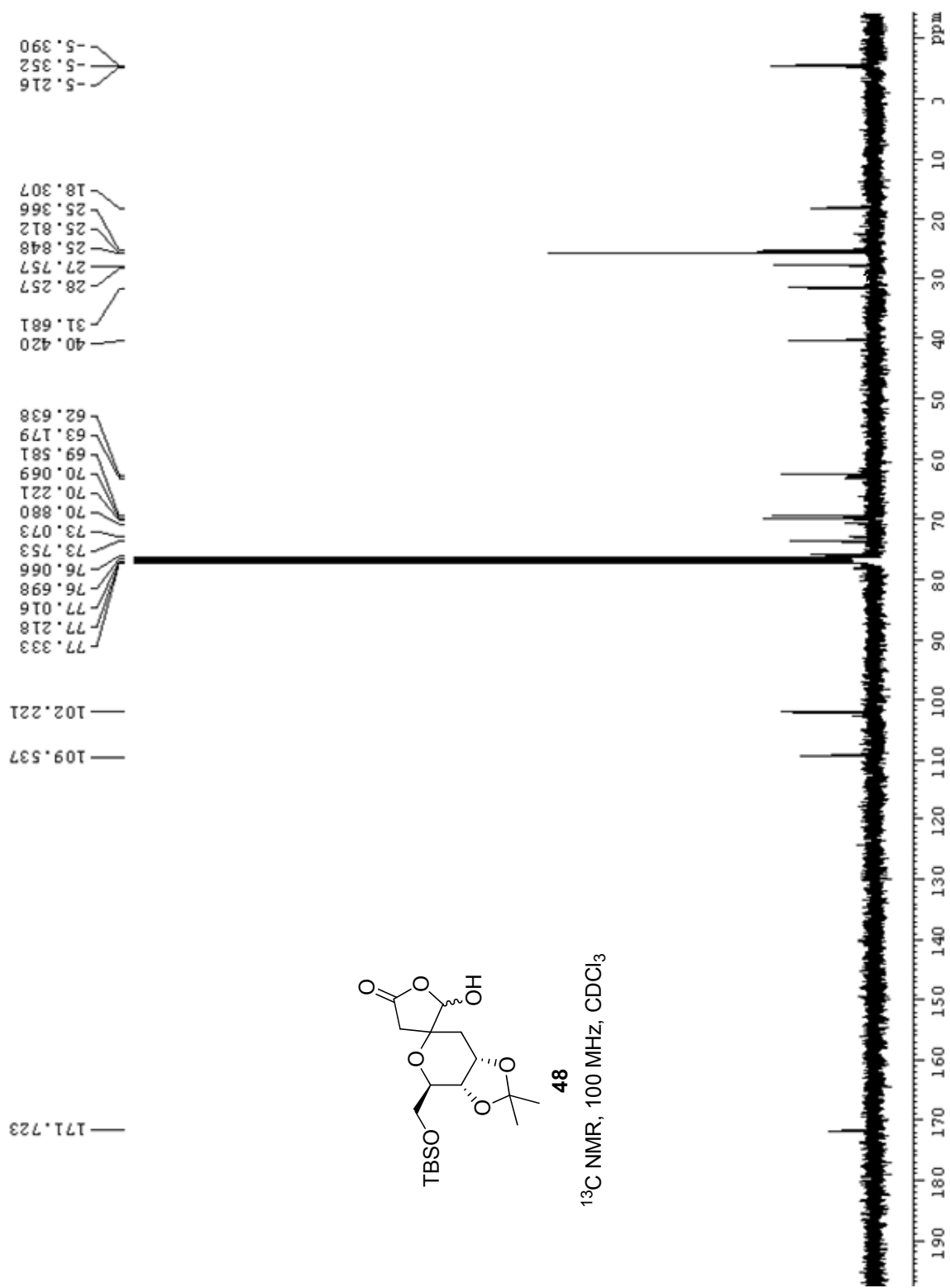


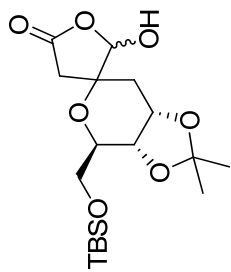


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$^1\text{H}$  NMR, 400 MHz,  $\text{CDCl}_3$







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$^{13}\text{C}$  DEPT, 100 MHz,  $\text{CDCl}_3$

