Divergent De Novo Synthesis of All Eight Stereoisomers of 2,3,6-Trideoxyhexopyranosides and Their Oligomers

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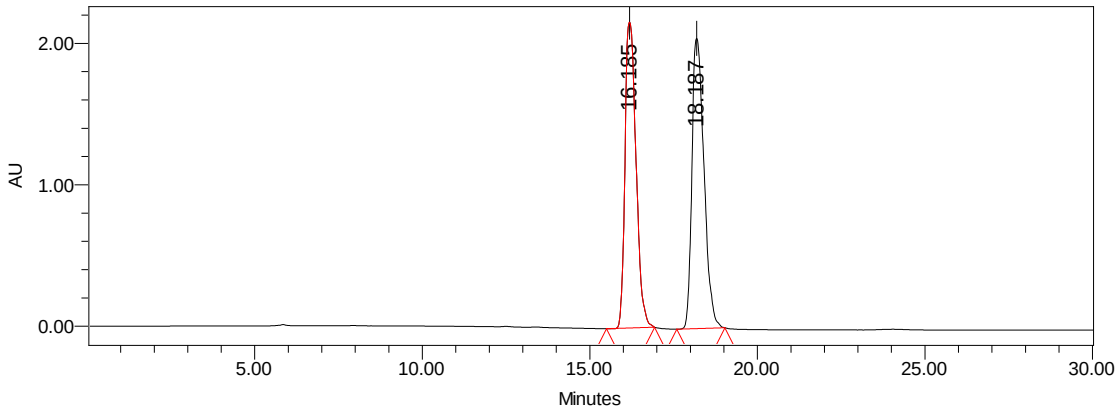
General Remarks

All reactions in non-aqueous media were conducted under a positive pressure of dry argon in glassware that had been oven dried prior to use unless noted otherwise. Anhydrous solutions were transferred via an oven dried syringe or cannula. All solvents were dried prior to use unless noted otherwise. Thin layer chromatography was performed using precoated silica gel plates (SILICYCLE inc. 60, F254). Flash column chromatography was performed with silica gel (Silicycle, 40-63 μm). Infrared spectra (IR) were obtained on a Bruker Equinox 55 Spectrophotometer. ^{1}H and ^{13}C nuclear magnetic resonance spectra (NMR) were obtained on a Varian Unity-Inova 400 MHz or 500 MHz recorded in ppm (δ) downfield of TMS (δ=0) in $CDCl_3$ unless noted otherwise. Signal splitting patterns were described as singlet (s), doublet (d), triplet(t), quartet (q), quintet (quint), or multiplet (m), with coupling constants (*J*) in hertz. High resolution mass spectra (HRMS) were performed by Analytical Instrument Center at the School of Pharmacy on an Electron Spray Injection (ESI) mass spectrometer.

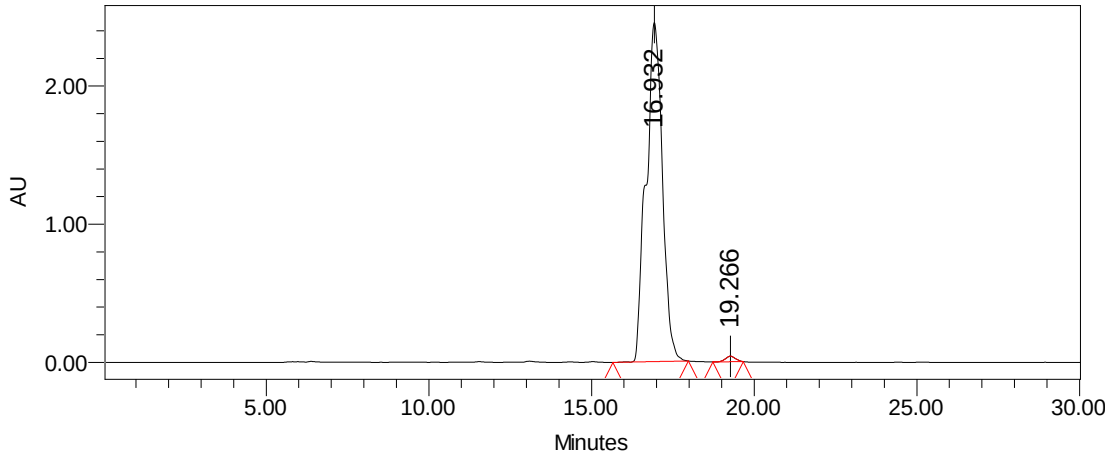
Chiral alcohols **10** and **ent-10** and dihydropyranone substrates **12**, **13**, **ent-12**, and **ent-13** were prepared according to literature procedures as discussed in the manuscript. Their spectral data are identical to literature. For ent-**10**, $[\alpha]_D^{22}$= +20.1 (*c* = 1.2, CH_2Cl_2), literature $[\alpha]_D^{25}$= +21 (*c* = 1.0, CH_2Cl_2) in S. A. Borisova, S. R. Guppi, H. J. Kim, B. Wu, J. H. Penn, H.-W. Liu, G. A. O'Doherty, *Org. Lett.* **2010**, *12*, 5150. For **10**, $[\alpha]_D^{22}$= -19.4 (*c* = 1.0, CH_2Cl_2), literature $[\alpha]_D^{20}$= -20.1 (*c* = 1.0, CH_2Cl_2) in M. Shan, Y. Xing, G. A. O'Doherty, *J. Org. Chem.* **2009**, *74*, 5961.

Racemic **10**:



	Retention Time	% Area
1	16.2	49.1
2	18.2	50.9

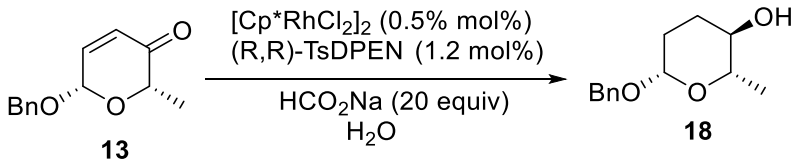
Enantio-enriched **10**:



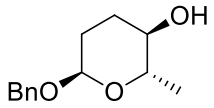
	Retention Time	% Area
1	16.9	99
2	19.3	1.0

General procedures for the rhodium-catalyzed divergent reduction:

Dihydropyranone substrates **12**, **13**, **ent-12**, and **ent-13** were reduced to the corresponding 2,3,6-trideoxypyranosides according to the following scheme.

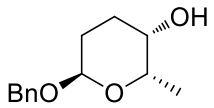


A stirred solution of $[Cp^*RhCl_2]_2$ (0.6 mg, 0.5 %) and (R,R)-TsDPEN (0.9 mg, 1.2 %) in 2 mL of water was heated in a 20 mL vial to 40 °C for 1 h and subsequently cooled to ambient temperature. To this solution was added sodium formate (272 mg, 20.0 equiv) and **13** (43.6 mg, 0.2 mmol) sequentially. After heating the vial to 40 °C for 6 h, the reaction was cooled to ambient temperature. The aqueous solution was extracted with ether (4 x 5 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 50 % EtOAc/Hex) afforded **18** (31.5 mg, 0.14 mmol, 71 % yield) as a colorless oil. The other seven products were prepared according to the same method with different substrates or ligand.



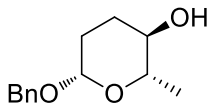
(2S, 3R, 6R)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (16)

39.5 mg, 89%. Colorless oil.$[\alpha]_D^{22}$= -76.9 (*c* = 1.0, $CHCl_3$) ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.36-7.26 (m, 5H), 4.84-4.83 (m, 1H), 4.71 (d, *J* = 12.0 Hz, 1H), 4.48 (d, *J* = 12.0 Hz, 1H), 3.65 (dq, *J* = 6.4, 6.0 Hz, 1H), 3.33-3.25 (m, 1H), 1.91-1.77 (m, 4H), 1.43 (d, *J* = 5.6 Hz, 1H), 1.27 (d, *J* = 6.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.4, 128.6, 128.0 127.8, 95.7, 72.4, 69.9, 68.8, 29.9, 27.9, 18.2. IR (neat) ν 3014, 2933, 2902, 1455, 1348, 1216, 1044, 982. HRMS (ESI) m/z calcd for $C_{13}H_{18}O_3$ $(M+Na)^+$ 245.1148, found 245.1149. The spectra data are in accordance with the following reference: M. Shan, Y. Xing, G. A. O'Doherty, *J. Org. Chem.* **2009**, *74*, 5961.



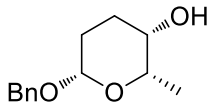
(2S, 3S, 6R)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (17)

38.1 mg, 86%. Colorless oil.$[\alpha]_D^{22}$= -86.8 (*c* = 0.53, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 7.36-7.26 (m, 5H), 4.90 (d, *J* = 3.5 Hz, 1H), 4.70 (d, *J* = 12.0 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.02 (q, *J* = 6.7 Hz, 1H), 3.59-3.58 (m, 1H), 2.07-2.03 (m, 1H), 2.00-1.94 (m, 1H), 1.82-1.75 (m, 2H), 1.62-1.57 (m, 1H), 1.19 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 138.4, 128.6, 128.0 127.8, 96.7, 69.1, 67.7, 66.5, 26.1, 23.6, 17.4. IR (neat) ν 3019, 2936, 2905, 1454, 1215, 1078, 982. HRMS (ESI) m/z calcd for $C_{13}H_{18}O_3$ $(M+Na)^+$ 245.1148, found 245.1146.



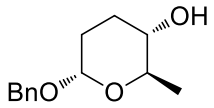
(2S, 3R, 6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (18)

31.5 mg, 71%. Colorless oil.$[\alpha]_D^{22}$= +74.2 (*c* = 1.0, $CHCl_3$) ^1H NMR (500 MHz, $CDCl_3$, TMS): δ 7.36-7.26 (m, 5H), 4.89 (d, *J* = 12.0 Hz, 1H), 4.59 (d, *J* = 12.0 Hz, 1H), 4.52 (dd, *J* = 9.5, 2.0 Hz, 1H), 3.31-3.28 (m, 2H), 2.08-2.04 (m, 1H), 1.92-1.89 (m, 1H), 1.68-1.65 (m, 1H), 1.47-1.44 (m, 2H), 1.35 (d, *J* = 6.0 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 138.0, 128.6, 128.2, 127.9, 100.6, 76.0, 71.9, 70.4, 31.3, 30.9, 18.3. IR (neat) ν 3031, 2936, 2902, 1453, 1351, 1047, 982. HRMS (ESI) m/z calcd for $C_{13}H_{18}O_3$ $(M+Na)^+$ 245.1148, found 245.1154.



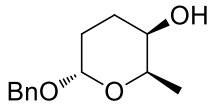
(2S, 3S, 6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (19)

32.4 mg, 73%. Colorless oil.$[\alpha]_D^{22}$= +79.1 (*c* = 0.64, $CHCl_3$) ^1H NMR (400 MHz, $CDCl_3$, TMS): δ 7.36-7.26 (m, 5H), 4.91 (d, *J* = 12.0 Hz, 1H), 4.61 (d, *J* = 12.4 Hz, 1H), 4.51 (d, *J* = 9.2 Hz, 1H), 3.60 (q, *J* = 6.4 Hz, 1H), 3.49 (d, *J* = 9.2 Hz, 1H), 2.03-1.97 (m, 2H), 1.74-1.60 (m, 3H), 1.29 (d, *J* = 6.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 138.0, 128.6, 128.2, 127.9, 101.1, 74.2, 70.1, 67.0, 29.9, 25.6, 17.4. IR (neat) ν 2936, 2868, 1453, 1363, 1215, 1168, 1059, 982. HRMS (ESI) m/z calcd for $C_{13}H_{18}O_3$ $(M+Na)^+$ 245.1148, found 245.1147.



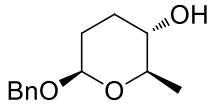
(2R, 3S, 6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (ent-16)

37.3 mg, 84%. Colorless oil.$[\alpha]_D^{22}$= +73.5 (*c* = 1.0, $CHCl_3$). The spectral data of **ent-16** are identical to **16**.



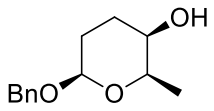
(2R, 3R, 6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (ent-17)

35.0 mg, 79%. Colorless oil.$[\alpha]_D^{22}$= +84.6 (*c* = 1.0, $CHCl_3$). The spectral data of **ent-17** are identical to **17**.



(2R, 3S, 6R)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (ent-18)

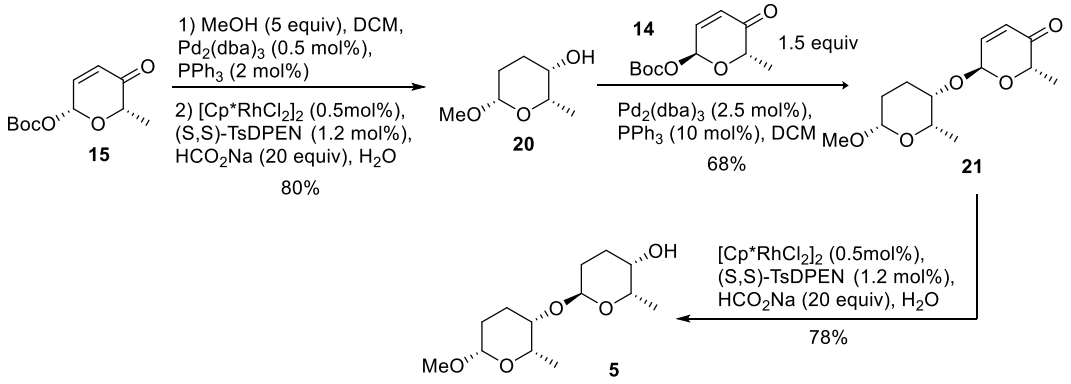
36.9 mg, 83%. Colorless oil.$[\alpha]_D^{22}$= -71.0 (*c* = 1.0, $CHCl_3$). The spectral data of **ent-18** are identical to **18**.

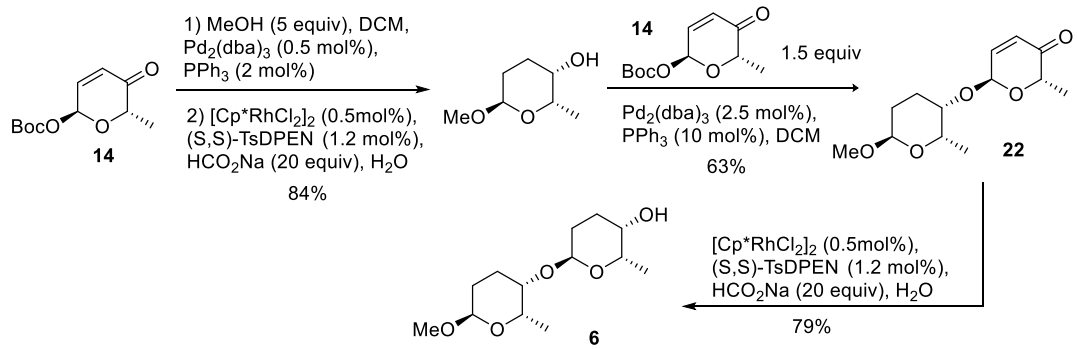


(2R, 3R, 6R)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-ol (ent-19)

35.0 mg, 79%. Colorless oil.$[\alpha]_D^{22}$= -76.0 (*c* = 1.0, $CHCl_3$). The spectral data of **ent-19** are identical to **19**.

General procedures for the synthesis of β- and α-narbosine B 5 and 6:

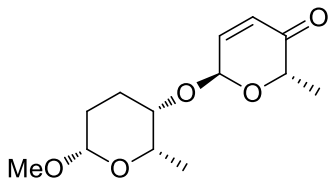




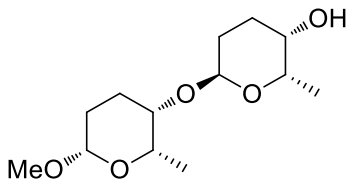
To a stirred solution of carbonate **15** (114 mg, 0.5 mmol, 1.00 equiv) and methanol (0.10 mL, 2.5 mmol, 5.0 equiv) in 5 mL of DCM at 0 °C in a 20 mL vial was sequentially added triphenylphosphine (2.6 mg, 0.01 mmol, 2.0 mol%) and $Pd_2(dba)_3$ (2.3 mg, 0.025 mmol, 0.5 mol%). Then the solution was warmed to ambient temperature and stirred for 2 h. The solution turned colors from dark red to green and was concentrated carefully under reduced pressure. The product was very volatile and used in next step without purification. A stirred solution of $[Cp^*RhCl_2]_2$ (1.5 mg, 0.5 mol%) and (S,S)-TsDPEN (2.3 mg, 1.2 mol%) in 5 mL of water was heated in a 20 mL vial to 40 °C for 1 h and cooled to ambient temperature. To this solution was added sodium formate (680 mg, 20.0 equiv) and crude allylic alkylation product (~0.5 mmol) sequentially. After heating the vial to 40 °C for another 6 h, the reaction was cooled to ambient temperature. The product was extracted with ether (4 x 10 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 100 % ether) afforded product **20** (58.4 mg, 0.4 mmol, 80 % yield) as a colorless oil.

To a stirred solution of **20** (58.4 mg, 0.4 mmol, 1.00 equiv) and carbonate **14** (137 mg, 0.6 mmol, 1.5 equiv) in 4 mL of DCM at 0 °C in a 20 mL vial under argon protection was sequentially added triphenylphosphine (10.4 mg, 0.04 mmol, 10 mol%) and $Pd_2(dba)_3$ (9.2 mg, 0.01 mmol, 2.5 mol%). Then the solution was warmed to ambient temperature and stirred for 6 h. The solution turned colors from dark red to green and was concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 10 % EtOAc/Hex) afforded product **21** (69 mg, 0.27 mmol, 68 % yield) as a colorless oil.

A stirred solution of $[Cp^*RhCl_2]_2$ (0.3 mg, 0.5 %) and (R,R)-TsDPEN (0.5 mg, 1.2 %) in 1 mL of water was heated in a 20 mL vial to 40 °C for 1 h and cooled to ambient temperature. To this solution was added sodium formate (136 mg, 20.0 equiv) and **21** (25.6 mg, 0.1 mmol) sequentially. After heating the vial to 40 °C for another 6 h, the reaction was cooled to ambient temperature. The product was extracted with ether (4 x 5 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 50 % EtOAc/Hex) afforded **5** (20 mg, 0.078 mmol, 78 % yield) as white solid.
The other isomeric α-narbosine B was prepared according to similar procedures by starting from **14**.

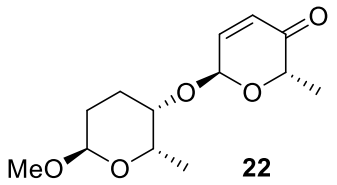


(2S,6R)-6-(((2S,3S,6S)-6-methoxy-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyl-2H-pyran-3(6H)-one (21)
69 mg, 68%. Colorless oil.$[\alpha]_D^{22}$= +99.1 (*c* = 0.23, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 6.85 (dd, *J* = 10.0, 3.5 Hz, 1H), 6.06 (d, *J* = 10.0 Hz, 1H), 5.23 (d, *J* = 3.5 Hz, 1H), 4.59 (q, *J* = 6.5 Hz, 1H), 4.38-4.35 (m, 1H), 3.63 (dq, *J* = 6.0, 1.0 Hz, 1H), 3.55-3.54 (m, 1H), 3.48 (s, 3H), 2.16-2.14 (m, 1H), 1.75-1.68 (m, 3H), 1.36 (d, *J* = 6.5 Hz, 3H), 1.29 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 197.1, 143.4, 127.4, 103.0, 95.6, 75.9, 73.4, 70.7, 56.3, 28.8, 26.3, 17.4, 15.3. IR (neat) ν 3020, 2358, 1761, 1518, 1476, 1036, 1022, 929. HRMS (ESI) m/z calcd for $C_{13}H_{20}O_5$ $(M+Na)^+$ 279.1202, found 279.1201.



(2S,3S,6S)-6-(((2S,3S,6S)-6-methoxy-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-ol. (5)
20 mg, 78%. White solid, mp = 75-77°C. $[\alpha]_D^{22}$= -22.9 (*c* = 0.21, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 4.82 (d, *J* = 4.0 Hz, 1H), 4.35 (dd, *J* = 9.5, 2.0 Hz, 1H), 4.06 (q, *J* = 6.5 Hz,

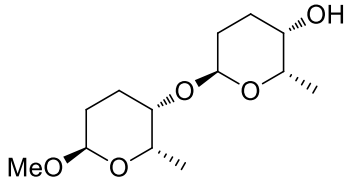
1H), 3.58 (dq, *J* = 6.5, 1.5 Hz, 2H), 3.50 (s, 3H), 3.40-3.39 (m, 1H), 2.10-2.03 (m, 2H), 1.93-1.91 (m, 1H), 1.78-1.73 (m, 2H),1.72-1.70 (m, 1H), 1.69-1.63 (m, 2H), 1.43 (s, 1H), 1.25 (d, *J* = 6.5 Hz, 3H), 1.16 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 103.2, 100.0, 74.5, 73.8, 67.8, 67.0, 56.4, 28.8, 26.6, 26.1, 23.8, 17.42, 17.37. IR (neat) ν 2937, 1448, 1216, 1117, 1088, 1074, 1022, 982. HRMS (ESI) m/z calcd for $C_{13}H_{24}O_5$ $(M+Na)^+$ 283.1515, found 283.1512. Natural products **5** and **6** was isolated as a mixture in the original isolation paper (T. Henkel, S. Breidingmack, A. Zeeck, S. Grabley, P. E. Hammann, K. Hutter, G. Till, R. Thiericke, J. Wink, *Liebigs Ann. Chem.* **1991**, 575.) By comparing the spectra data of the mixture of **5** and **6** in the above isolation paper and the spectra data of **6** from Trost (B. M. Trost; Y. H. Rhee. *J. Am. Chem. Soc*, **2002**, *124*, 2528.), our spectra data for **5** are in accordance with data from the isolation paper.



22

(2S,6R)-6-(((2S,3S,6R)-6-methoxy-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyl-2H-pyran-3(6H)-one (22)

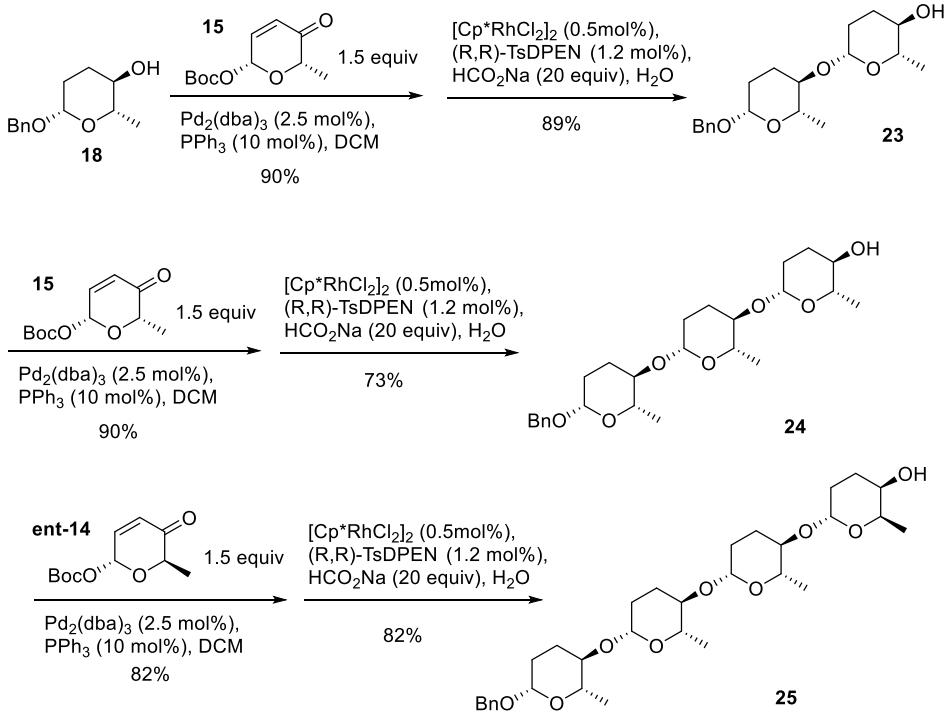
68 mg, 63%. Colorless oil.$[\alpha]_D^{22}$= -18.6 (*c* = 0.3, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 6.88 (dd, *J* = 10.5, 3.5 Hz, 1H), 6.09 (d, *J* = 10.0 Hz, 1H), 5.23 (d, *J* = 3.5 Hz, 1H), 4.72 (d, *J* = 3.0 Hz, 1H), 4.59 (q, *J* = 7.0 Hz, 1H), 3.94 (dq, *J* = 6.5, 1.0 Hz, 1H), 3.61 (s, 1H), 3.36 (s, 3H), 2.08-2.04 (m, 1H), 2.00-1.95 (m, 1H), 1.92-1.87 (m, 1H), 1.59-1.56 (m, 1H), 1.38 (d, *J* = 7.0 Hz, 3H), 1.21 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 197.1, 143.3, 127.6, 98.4, 95.6, 76.9, 70.8, 65.9, 55.0, 24.9, 24.5, 17.4, 15.4. IR (neat) ν 2912, 2364, 1702, 1475, 1103, 1017. HRMS (ESI) m/z calcd for $C_{13}H_{20}O_5$ $(M+Na)^+$ 279.1202, found 279.1199.



(2S,3S,6S)-6-(((2S,3S,6R)-6-methoxy-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-ol. (6)

21 mg, 79%. White solid, mp = 79-81°C. $[\alpha]_D^{22}$= -106.8 (*c* = 0.35, $CHCl_3$), literature (see below) $[\alpha]_D$ = -103.5 (*c* = 0.59, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 4.82 (d, *J* = 3.5 Hz, 1H), 4.72 (s, 1H), 4.05 (q, *J* = 6.5 Hz, 1H), 3.86 (dq, *J* = 6.5, 1.0 Hz, 1H), 3.60-3.58 (m, 1H), 3.48-3.47 (m, 1H), 3.36 (s, 3H), 2.10-1.91 (m, 4H), 1.79-1.68 (m, 3H),1.59-1.54 (m, 2H), 1.16 (d, *J* = 7.0 Hz, 3H), 1.15 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 99.6, 98.2, 74.9, 67.5, 66.7, 66.1, 54.6, 26.0, 24.5, 24.4, 23.6, 17.2, 17.1. All spectral data are in accordance with literature: B. M. Trost; Y. H. Rhee. *J. Am. Chem. Soc*, **2002**, *124*, 2528.

General procedures for the synthesis of tetrasaccharide:



To a stirred solution of carbonate **15** (69 mg, 0.3 mmol, 1.5 equiv) and alcohol **18** (45.6 mg, 0.2 mmol, 1.0 equiv) in 2 mL of DCM at 0 °C in a 20 mL vial under argon protection was sequentially added triphenylphosphine (5.2 mg, 10.0 %) and $Pd_2(dba)_3$ (4.6 mg, 2.5 %). Then the solution was warmed to ambient temperature and stirred for 6 h. The solution turned color from dark red to green and was concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 10 % EtOAc/Hex) afforded enone product (60.0 mg, 0.18 mmol, 90 % yield) as a colorless oil.

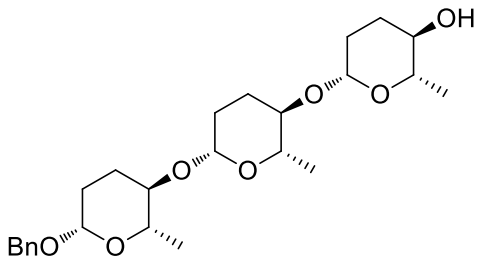
A stirred solution of $[Cp^*RhCl_2]_2$ (0.6 mg, 0.5 %) and (R,R)-TsDPEN (0.8 mg, 1.2 %) in 2 mL of water was heated in a 20 mL vial to 40 °C for 1 h and cooled to ambient temperature. To this solution was added sodium formate (245 mg, 20.0 equiv) and the above enone (0.18 mmol). After heating the vial to 40 °C for another 6 h, the reaction was cooled to ambient temperature. The product was extracted with ether (4 x 5 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 50 % EtOAc/Hex) afforded **23** (54.0 mg, 0.16 mmol, 89 % yield) as a colorless oil.

To a stirred solution of carbonate **15** (55 mg, 0.24 mmol, 1.5 equiv) and alcohol **23** (54.0 mg, 0.16 mmol, 1.0 equiv) in 2 mL of DCM at 0 °C in a 20 mL vial under argon protection was sequentially added triphenylphosphine (4.2 mg, 10.0 %) and $Pd_2(dba)_3$ (3.7 mg, 2.5 %). The solution was warmed to ambient temperature and stirred for 6 h. The solution turned color from dark red to green and was concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 10 % EtOAc/Hex) afforded enone product (64.2 mg, 0.15 mmol, 90 % yield) as a colorless oil.

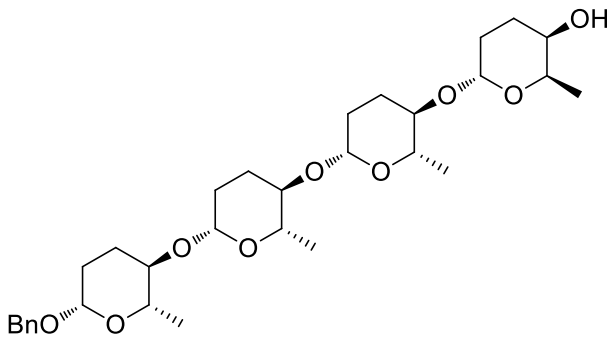
A stirred solution of $[Cp^*RhCl_2]_2$ (0.5 mg, 0.5 %) and (R,R)-TsDPEN (0.7 mg, 1.2 %) in 2 mL of water was heated in a 20 mL vial to 40 °C for 1 h and then cooled to ambient temperature. To this solution was added sodium formate (204 mg, 20.0 equiv) and the above enone (0.15 mmol). After heating the vial to 40 °C for 6 h, the reaction was cooled to ambient temperature. The product was extracted with ether (4 x 5 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 50 % EtOAc/Hex) afforded **24** (49.3 mg, 0.11 mmol, 73 % yield) as a white solid.

To a stirred solution of carbonate **ent-14** (28 mg, 0.12 mmol, 1.5 equiv) and alcohol **24** (36.0 mg, 0.08 mmol, 1.0 equiv) in 1 mL of DCM at 0 °C in a 20 mL vial under argon protection was sequentially added triphenylphosphine (2.1 mg, 10.0 %) and $Pd_2(dba)_3$ (2.9 mg, 2.5 %). Then the solution was warmed to ambient temperature and stirred for 6 h. The solution turned color from dark red to green and was concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 10 % EtOAc/Hex) afforded enone product (36.7 mg, 0.07 mmol, 82 % yield) as a yellow oil.

A stirred solution of $[Cp^*RhCl_2]_2$ (0.2 mg, 0.5 %) and (R,R)-TsDPEN (0.3 mg, 1.2 %) in 1 mL of water was heated in a 20 mL vial to 40 °C for 1 hour and then cooled to ambient temperature. To this solution was added sodium formate (96 mg, 20.0 equiv) and the above enone (0.07 mmol) sequentially. After heating the vial to 40 °C for 6 h, the reaction was cooled to ambient temperature. The product was extracted with ether (4 x 3 mL), dried over sodium sulfate, filtered, and concentrated under reduced pressure. Purification by flash chromatography (gradient elution, 50 % EtOAc/Hex) afforded **25** (32.3 mg, 0.06 mmol, 82 % yield) as a yellow oil.



(2S,3R,6R)-6-(((2S,3R,6R)-6-(((2S,3R,6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-ol (24) 49.3 mg, 73%. White solid, mp = 49-50°C. $[\alpha]_D^{22}$= +14.0 (*c* = 0.89, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 7.35-7.26 (m, 5H), 4.88 (d, *J* = 12.0 Hz, 1H), 4.56 (d, *J* = 12.0 Hz, 1H), 4.51-4.45 (m, 3H), 3.39-3.34 (m, 2H), 3.28-3.26 (m, 2H), 3.22-3.17 (m, 2H), 2.24-2.20 (m, 2H), 2.05-2.03 (m, 1H),1.89-1.84 (m, 3H), 1.62-1.53 (m, 4H), 1.40-1.36 (m, 3H), 1.29 (d, *J* = 6.0 Hz, 3H), 1.29 (d, *J* = 6.0 Hz, 3H), 1.24 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.1, 128.6, 128.2, 127.9, 103.32, 103.26, 100.7, 80.4, 80.3, 76.0, 74.7, 71.6, 70.4, 31.5, 31.2, 30.9, 30.3, 30.1, 18.531, 18.495, 18.4. IR (neat) ν 3014, 2974, 2934, 2873, 1456, 1401, 1216, 1165, 1130, 1059, 984. HRMS (ESI) m/z calcd for $C_{25}H_{38}O_7$ $(M+Na)^+$ 473.2509, found 473.2517.



(2R,3R,6R)-6-(((2S,3R,6R)-6-(((2S,3R,6R)-6-(((2S,3R,6S)-6-(benzyloxy)-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-yl)oxy)-2-methyltetrahydro-2H-pyran-3-ol (25)

32.3 mg, 82%. Yellow oil. $[\alpha]_D^{22}$= +34.6 (*c* = 0.93, $CHCl_3$) ^{1}H NMR (500 MHz, $CDCl_3$, TMS): δ 7.35-7.26 (m, 5H), 4.89-4.86 (m, 2H), 4.57 (d, *J* = 12.0 Hz, 1H), 4.50-4.45 (m, 3H), 4.02 (q, *J* = 7.0 Hz, 1H), 3.57-3.56 (m, 1H), 3.39-3.32 (m, 3H),3.21-3.14 (m, 3H), 2.24-2.20 (m, 2H),2.13-2.11 (m, 1H), 1.96-1.91 (m, 2H), 1.87-1.73 (m, 6H), 1.64-1.52 (m, 6H), 1.29 (d, *J* = 6.0 Hz, 3H), 1.24 (d, *J* = 6.0 Hz, 3H), 1.23 (d, *J* = 6.0 Hz, 3H), 1.15 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.1, 128.6, 128.2, 127.9, 103.30, 103.27, 100.7, 99.5, 80.4, 80.2, 79.3, 74.9, 74.7, 70.4, 67.7, 66.7, 31.2, 31.1, 30.9, 30.3, 30.1, 29.9, 26.1, 24.1, 18.6, 18.533, 18.503, 17.3. IR (neat) ν 3020, 2905, 1475, 1421, 1215, 1115, 1017, 960. HRMS (ESI) m/z calcd for $C_{31}H_{48}O_9$ $(M+Na)^+$ 587.3190, found 587.3194.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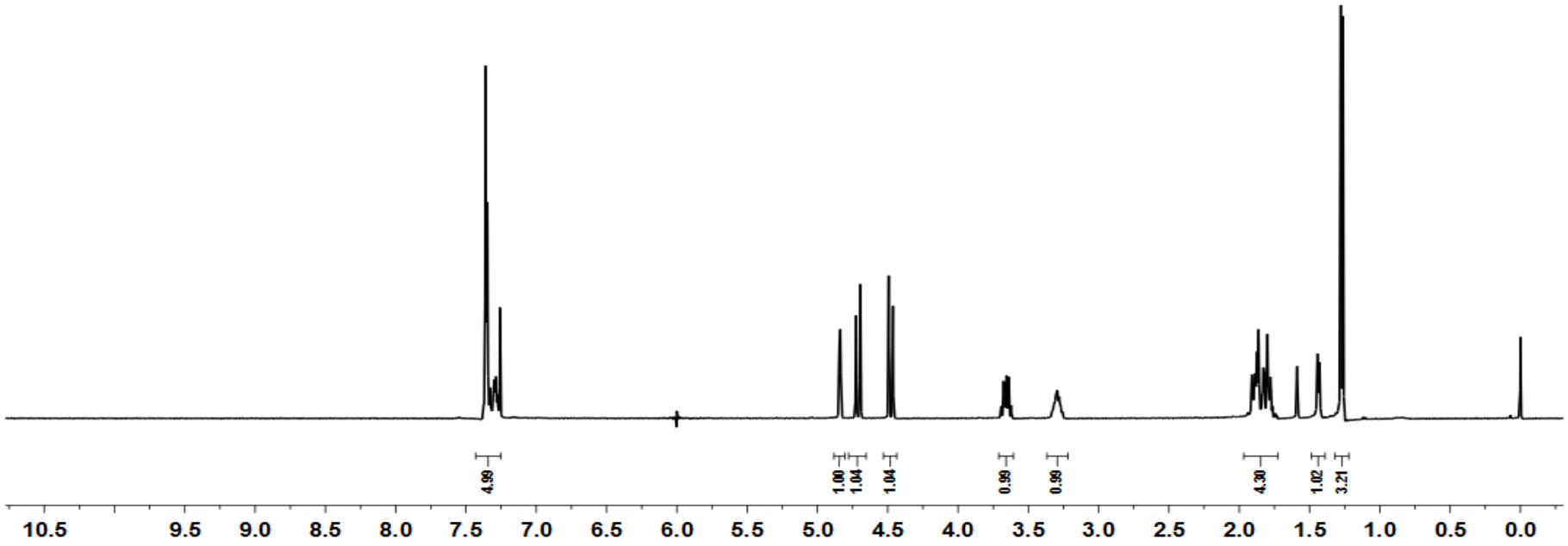
O

16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8.0
7.5
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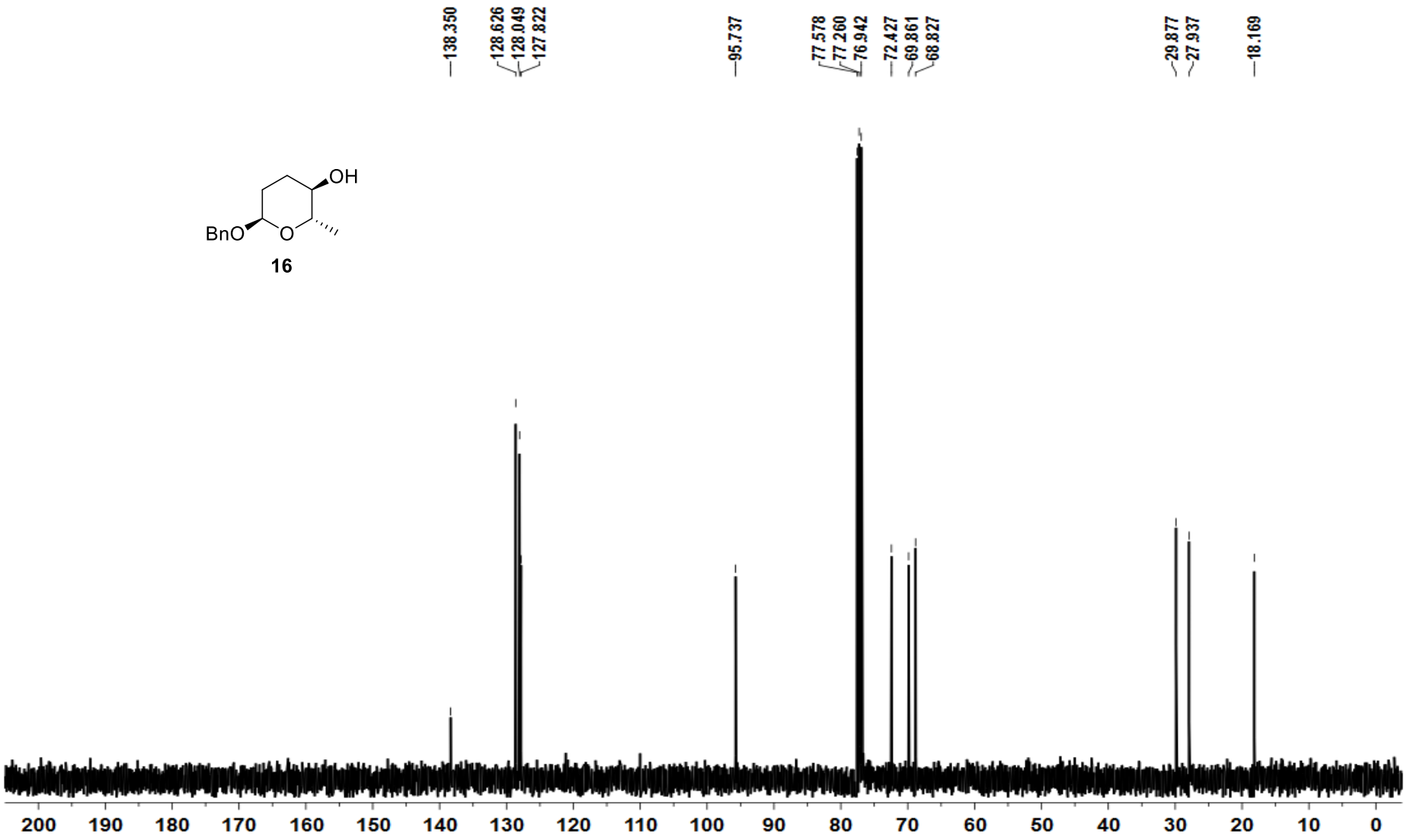
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27.937
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O
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10
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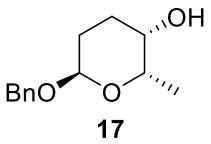
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BnO
O

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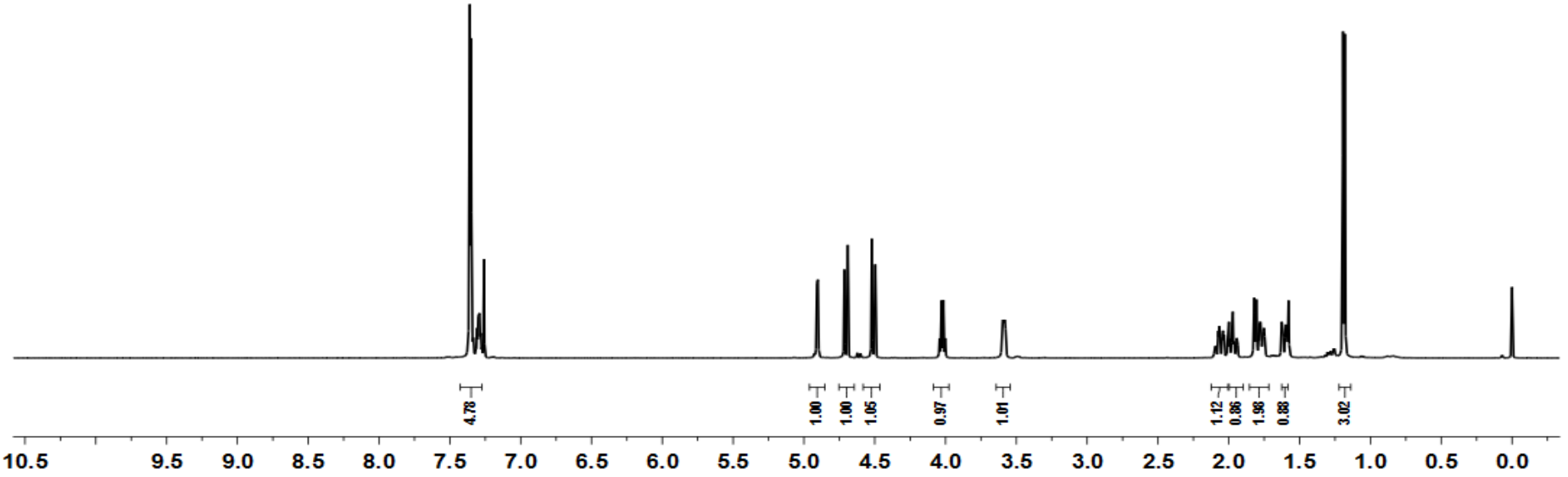
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8.5
8.0
7.5
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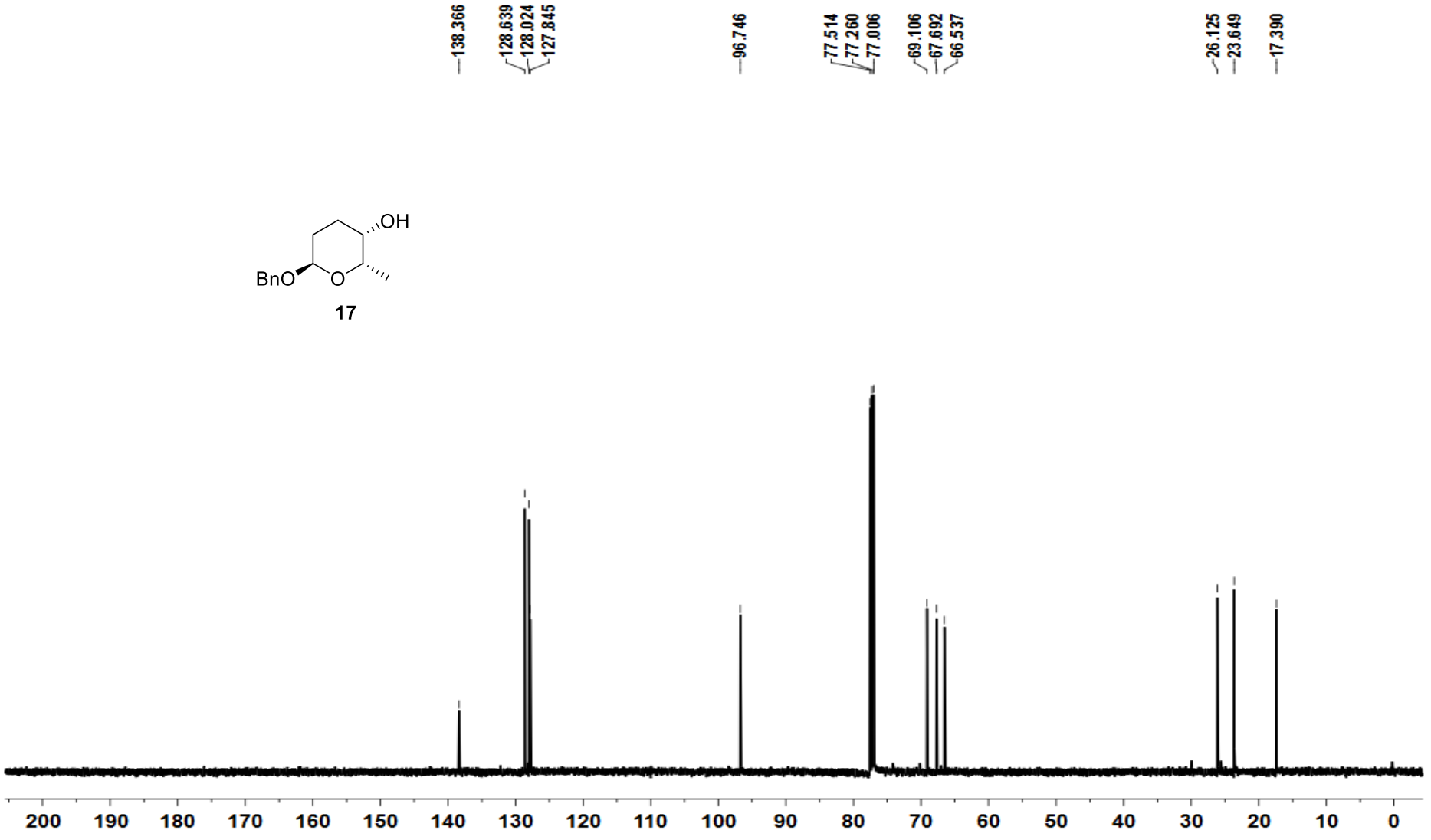
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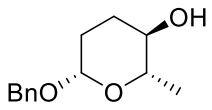
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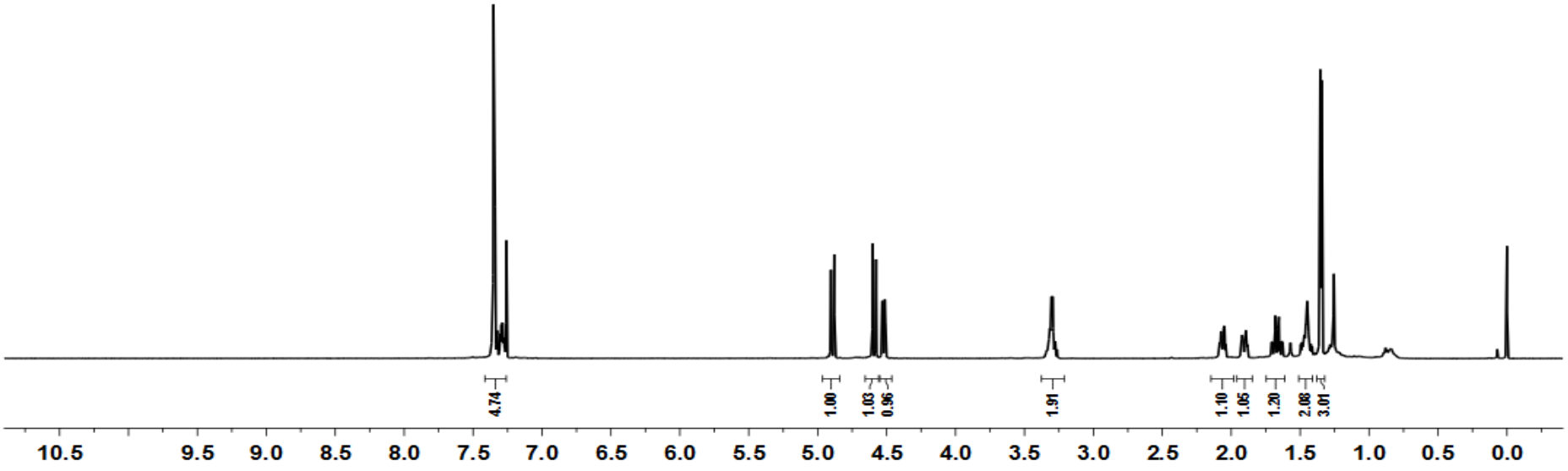
BnO
O

18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7.5
7.0
6.5
6.0
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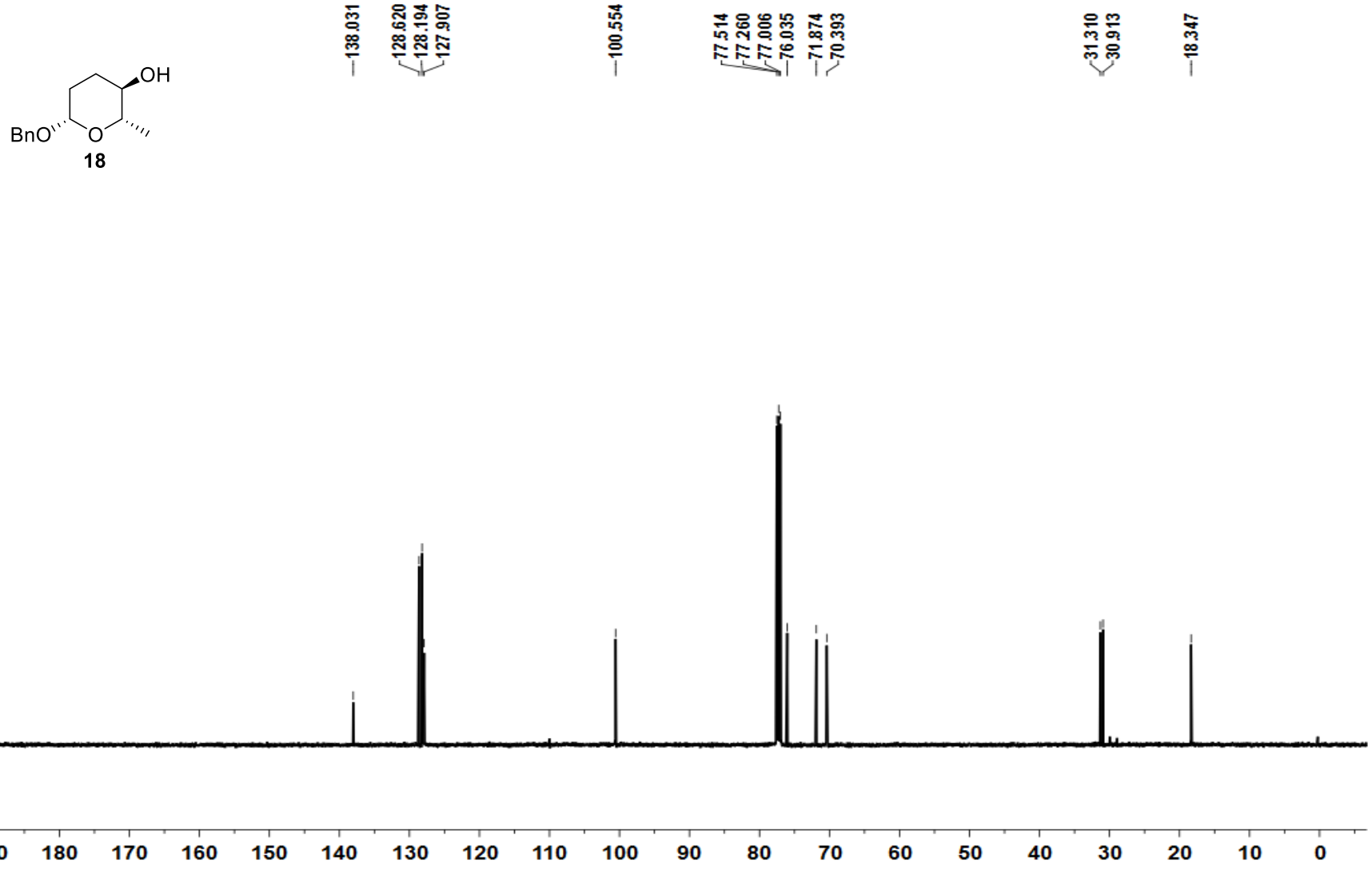
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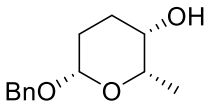
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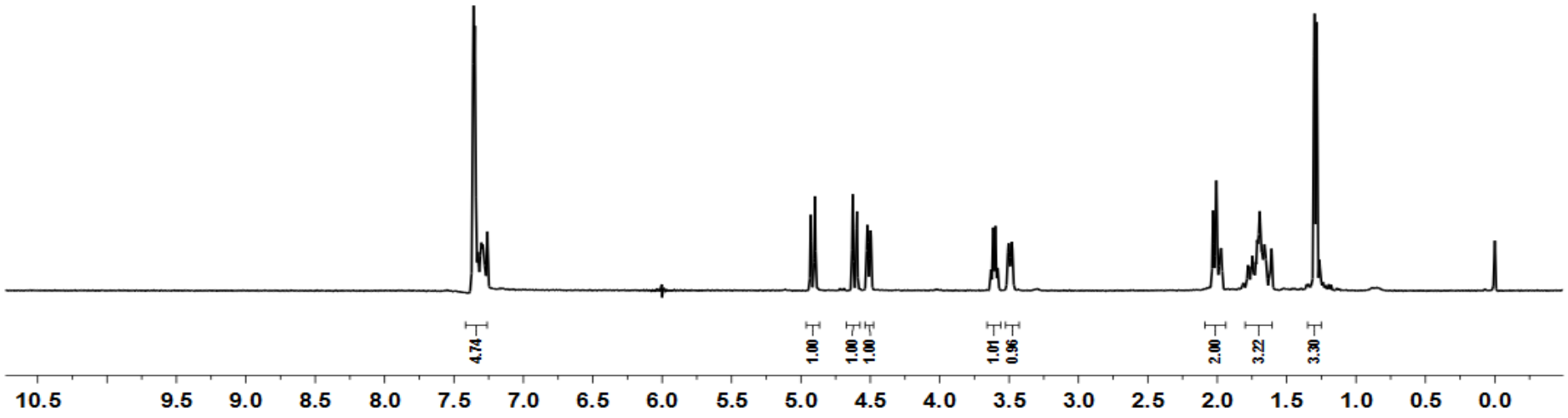
BnO
O

19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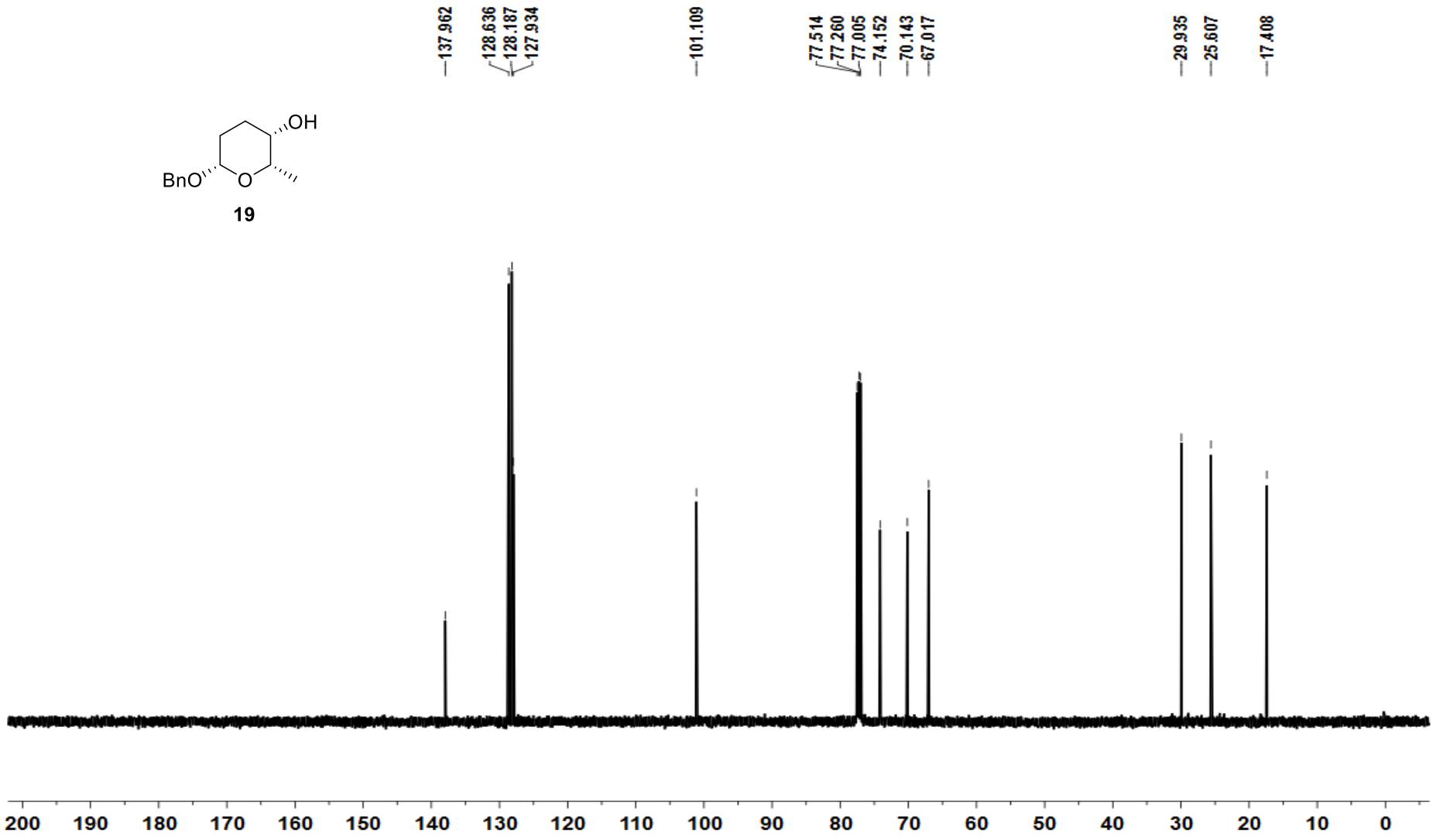
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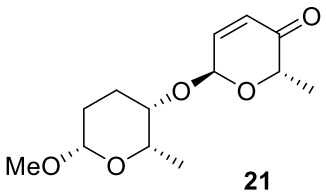
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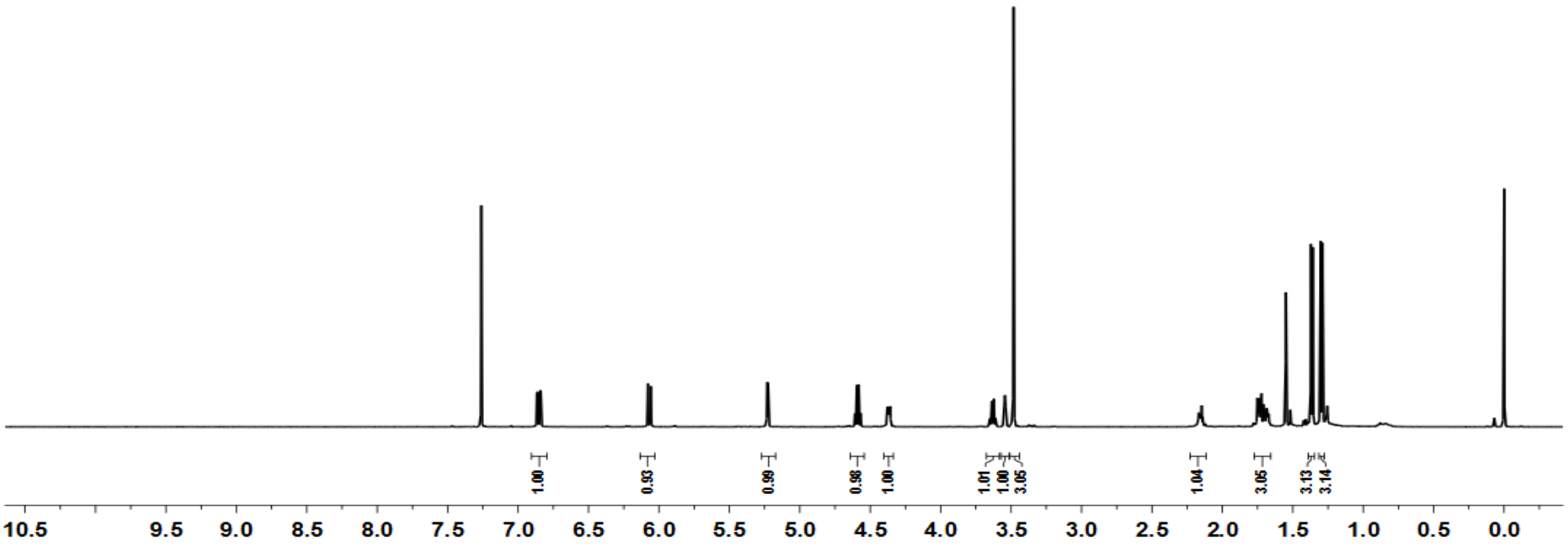
O
MeO
O

21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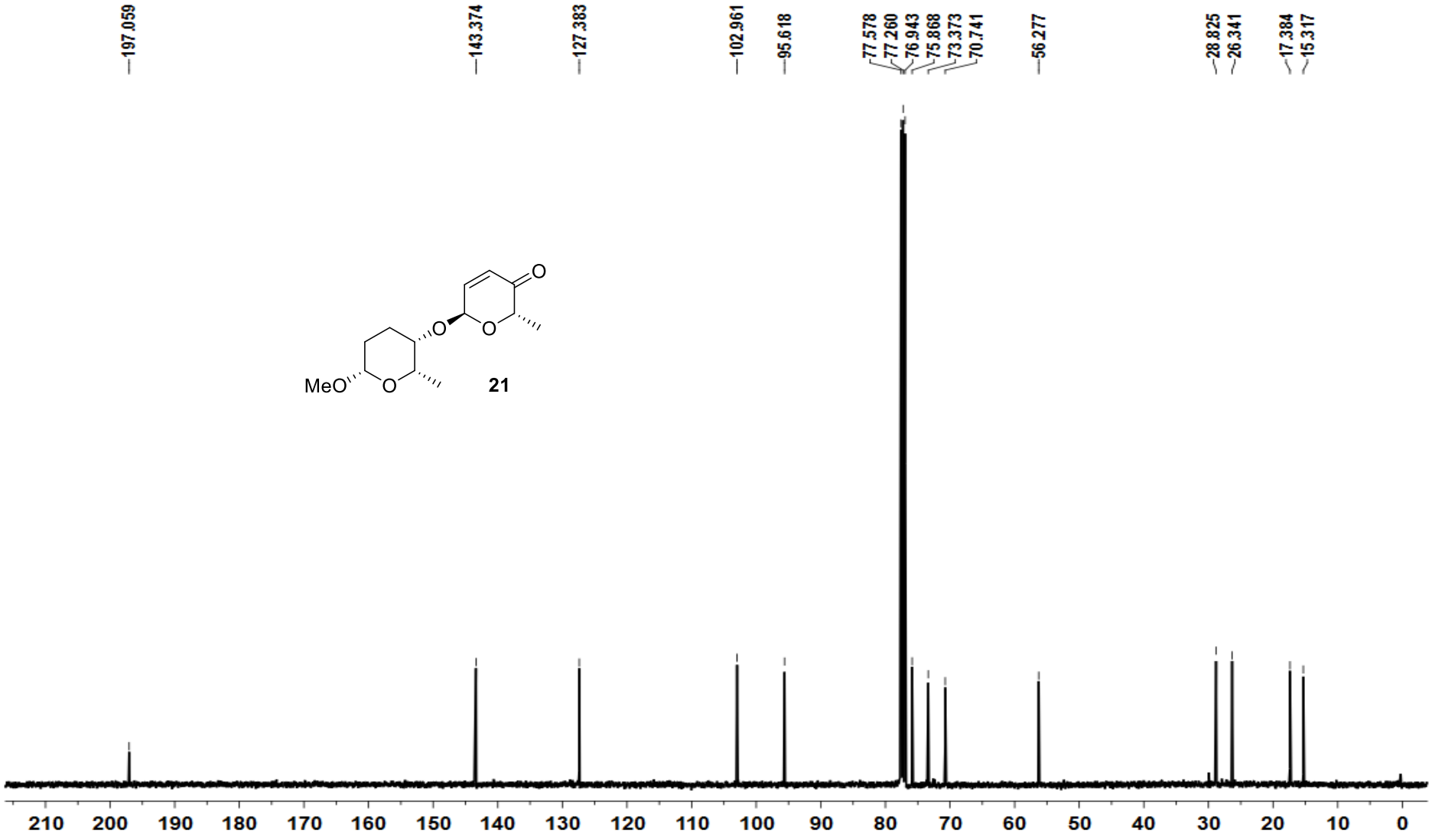
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15.317
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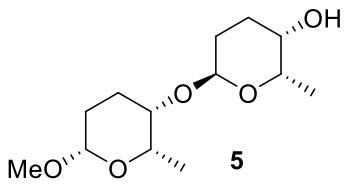
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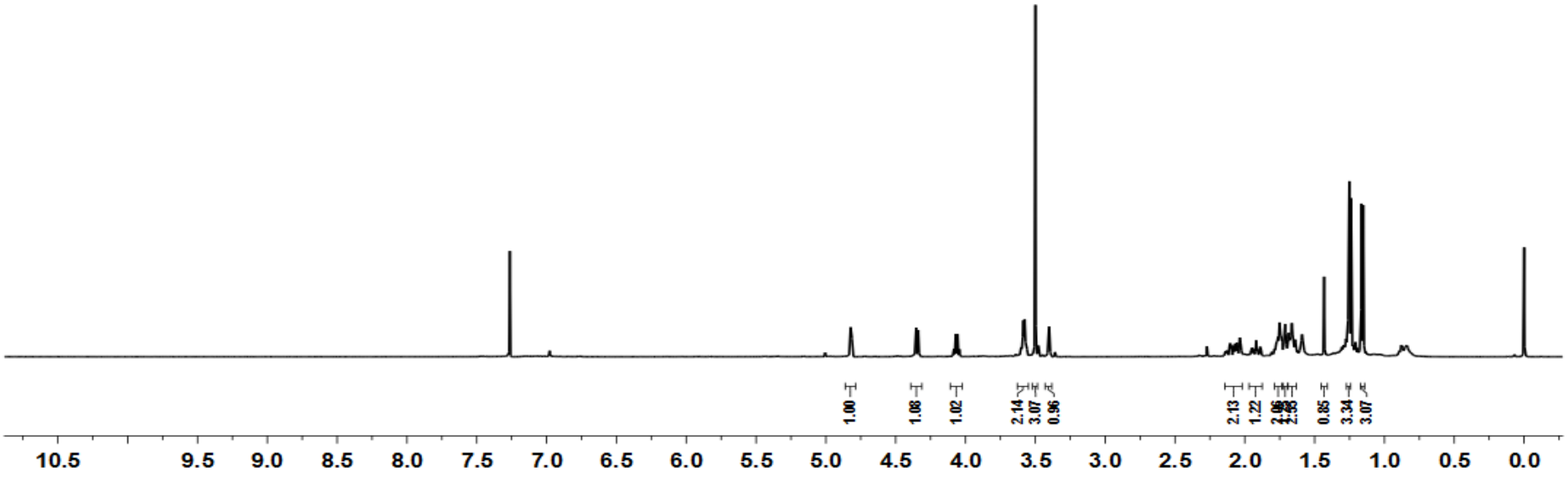
MeO
O

5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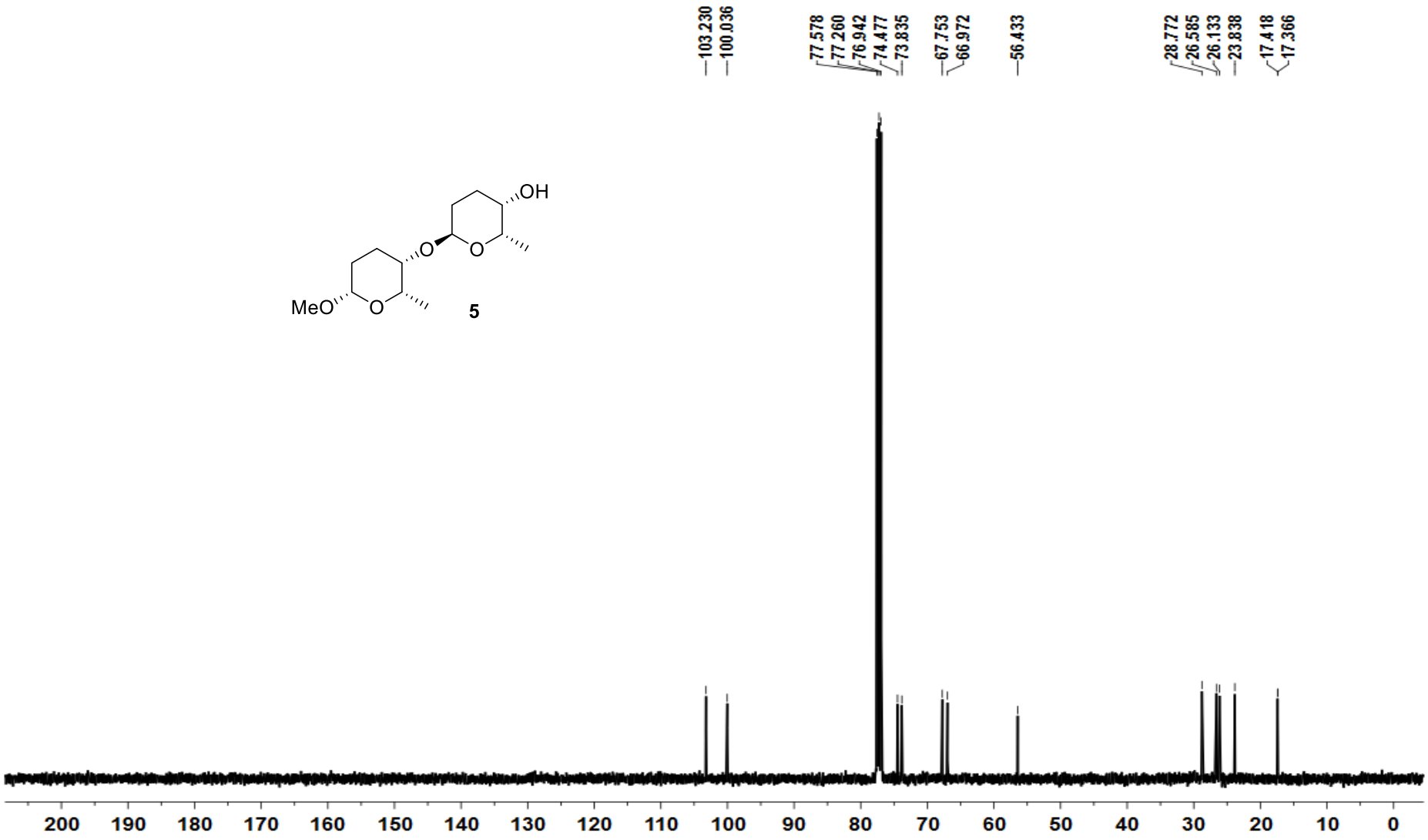
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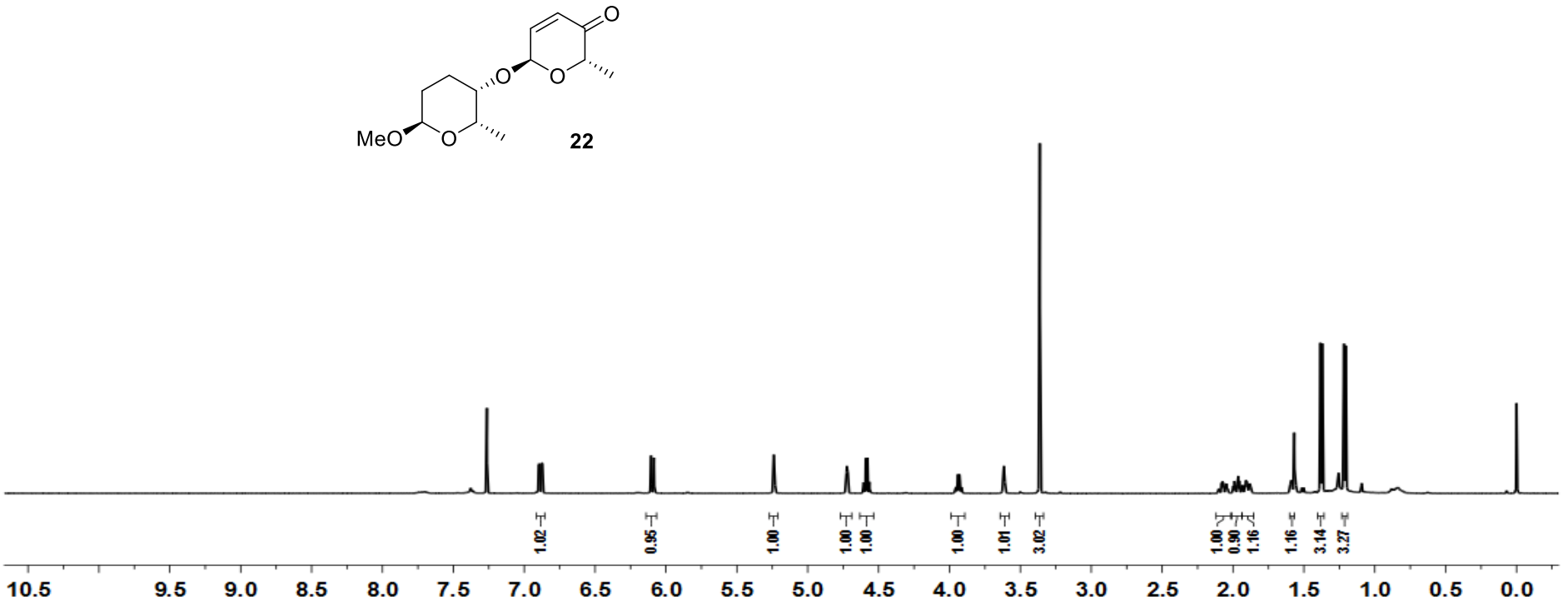
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3.14
3.27
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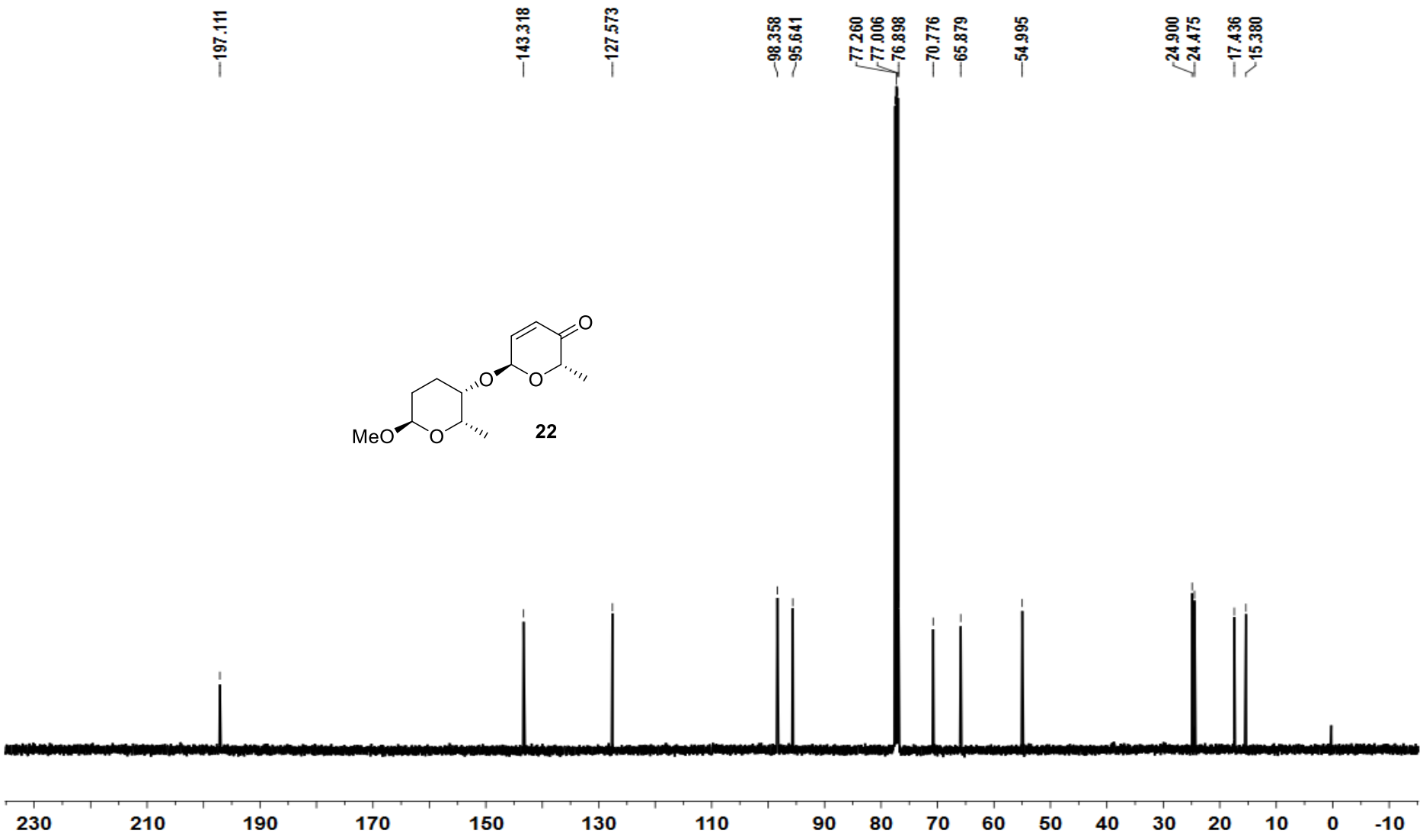
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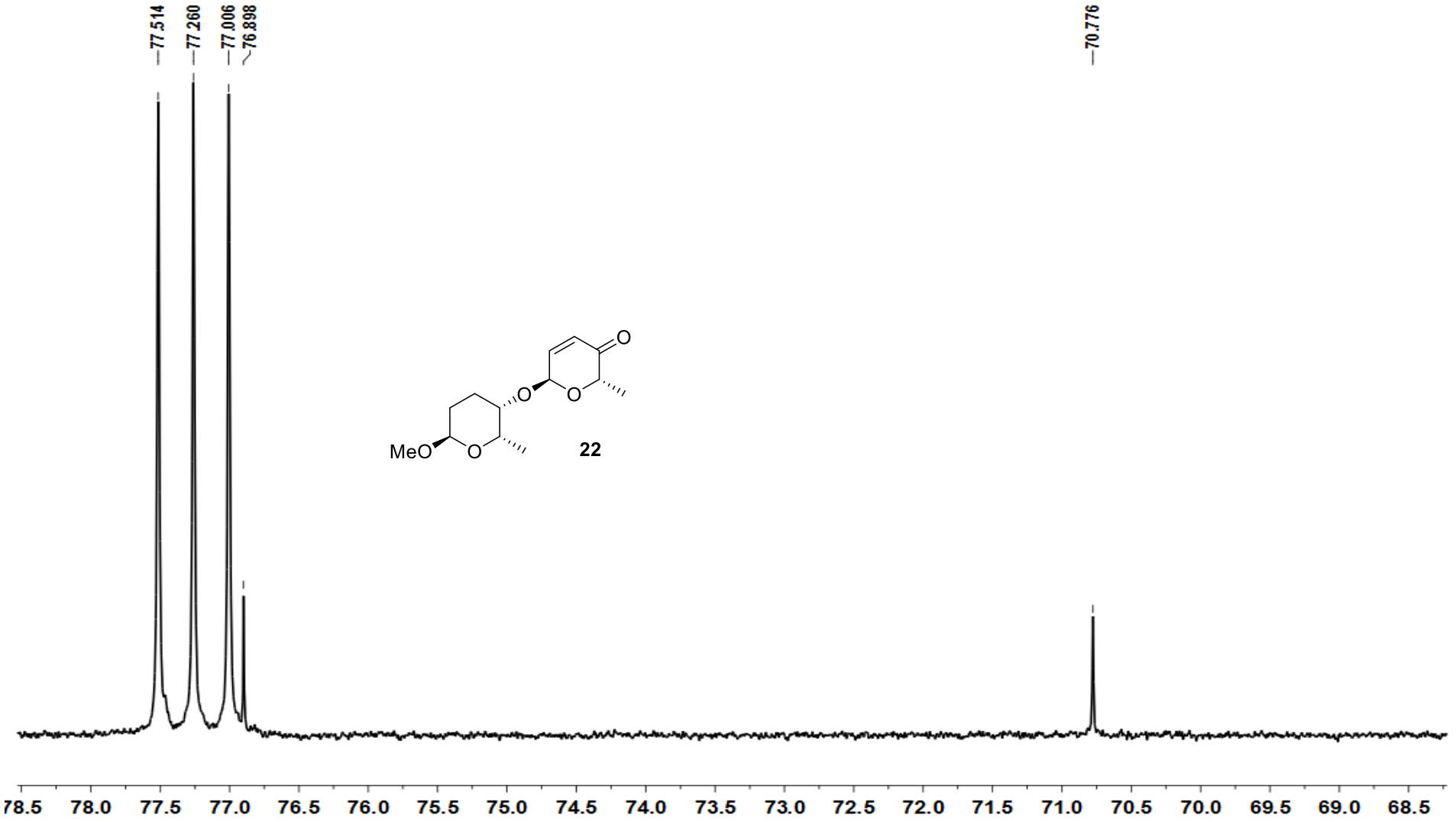
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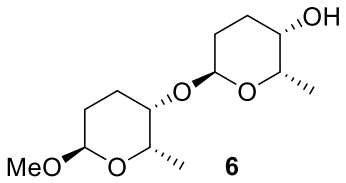
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MeO
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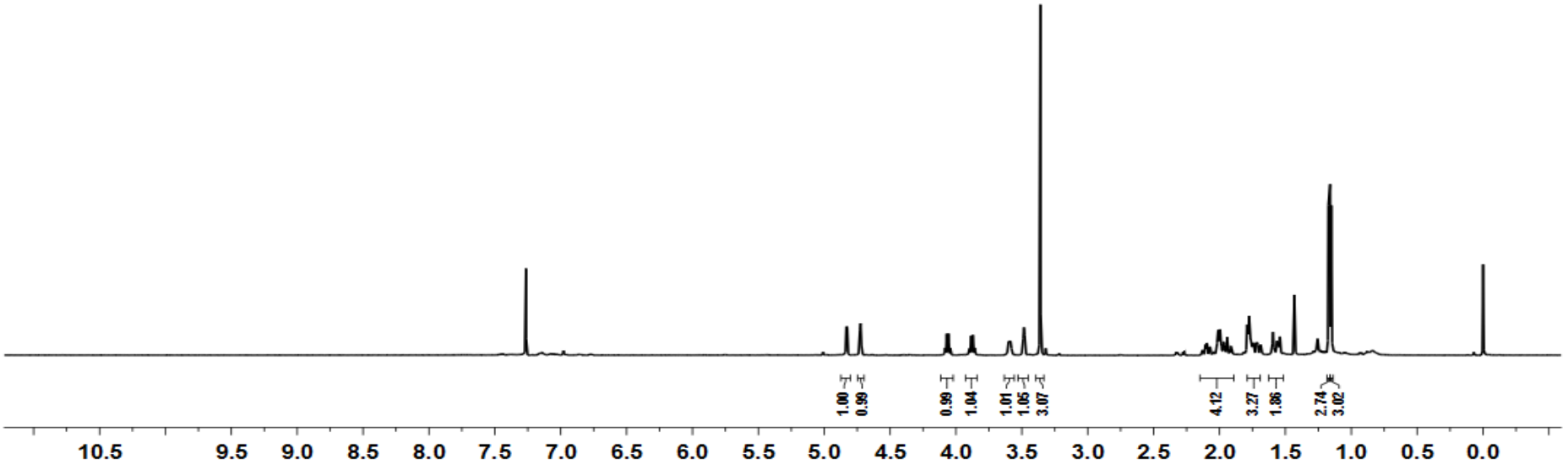
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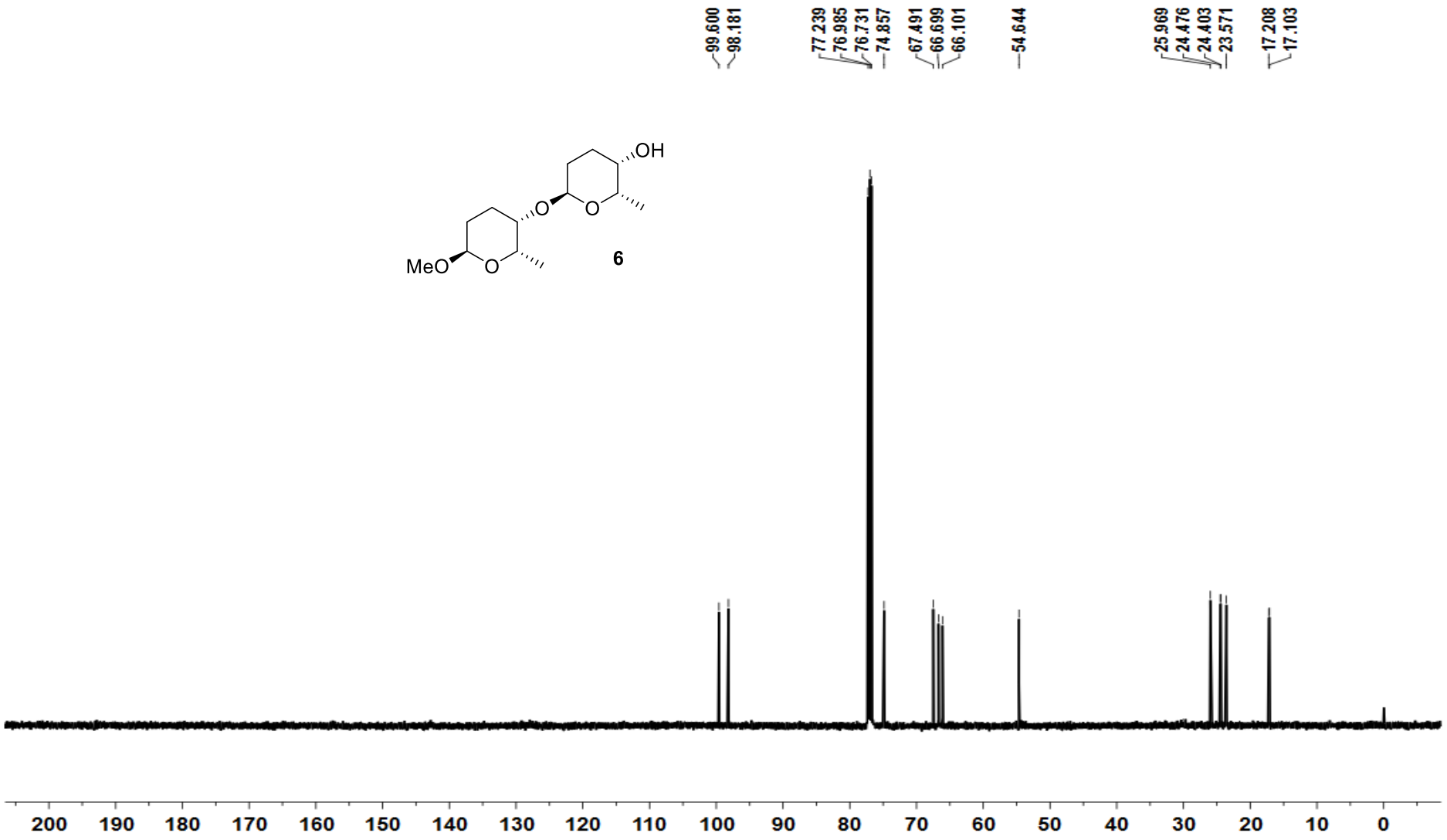
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24.403
23.571
17.208
17.103
OH
O
O
MeO
O
6
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150
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130
120
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90
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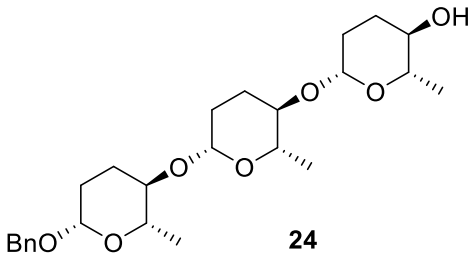
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BnO
O

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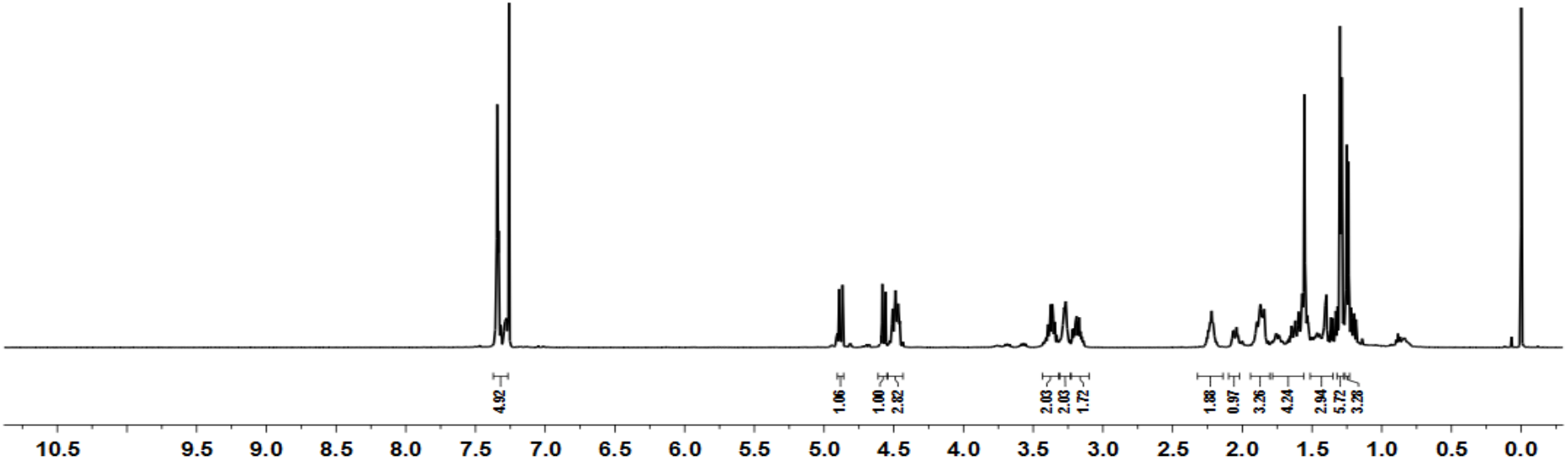
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5.72
3.28
10.5
9.5
9.0
8.5
8.0
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6.0
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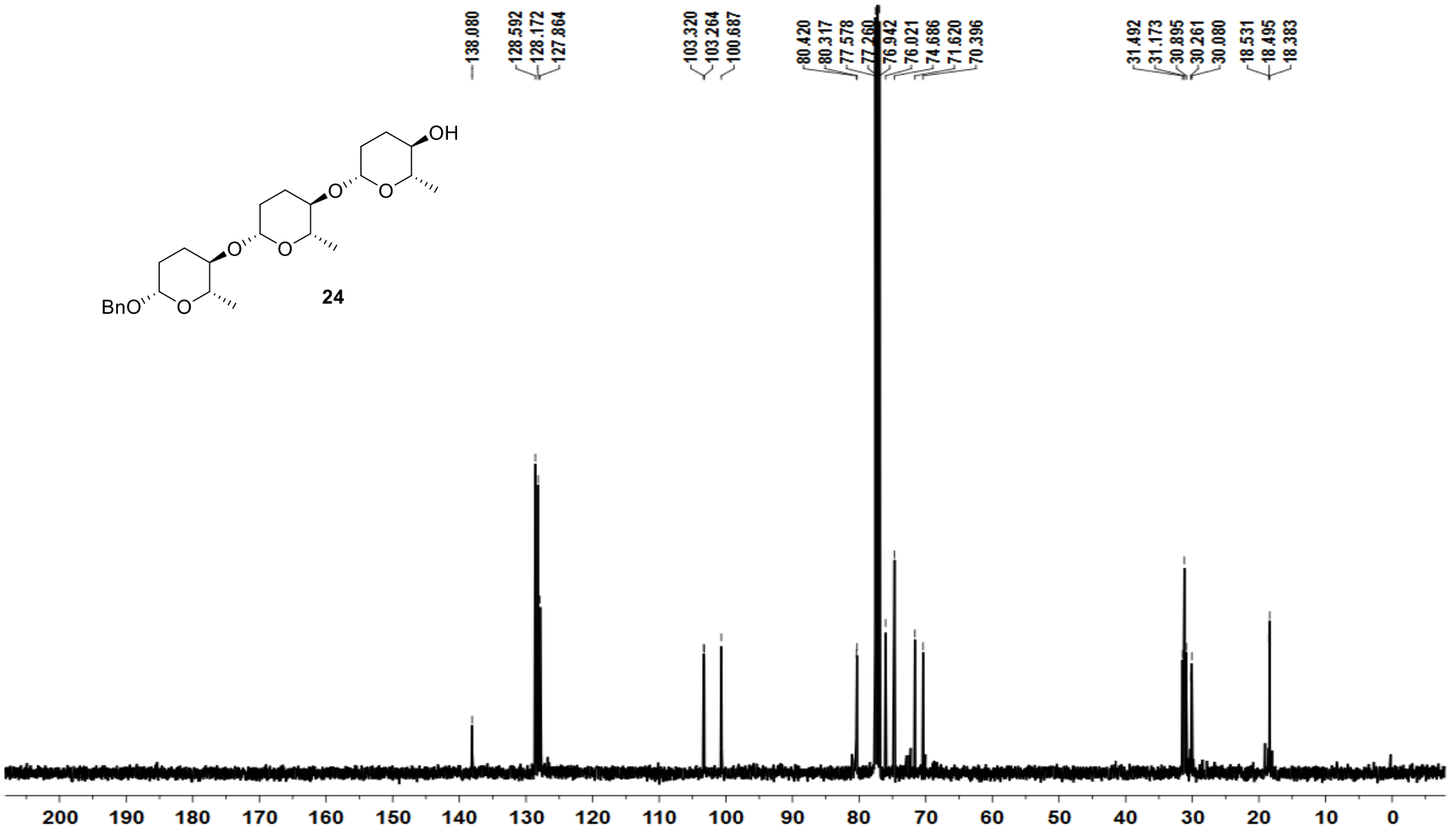
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77.260
76.942
76.021
74.686
71.620
70.396
31.492
31.173
30.895
30.261
30.080
18.531
18.495
18.383
OH
O
O
O
O
BnO
24
200
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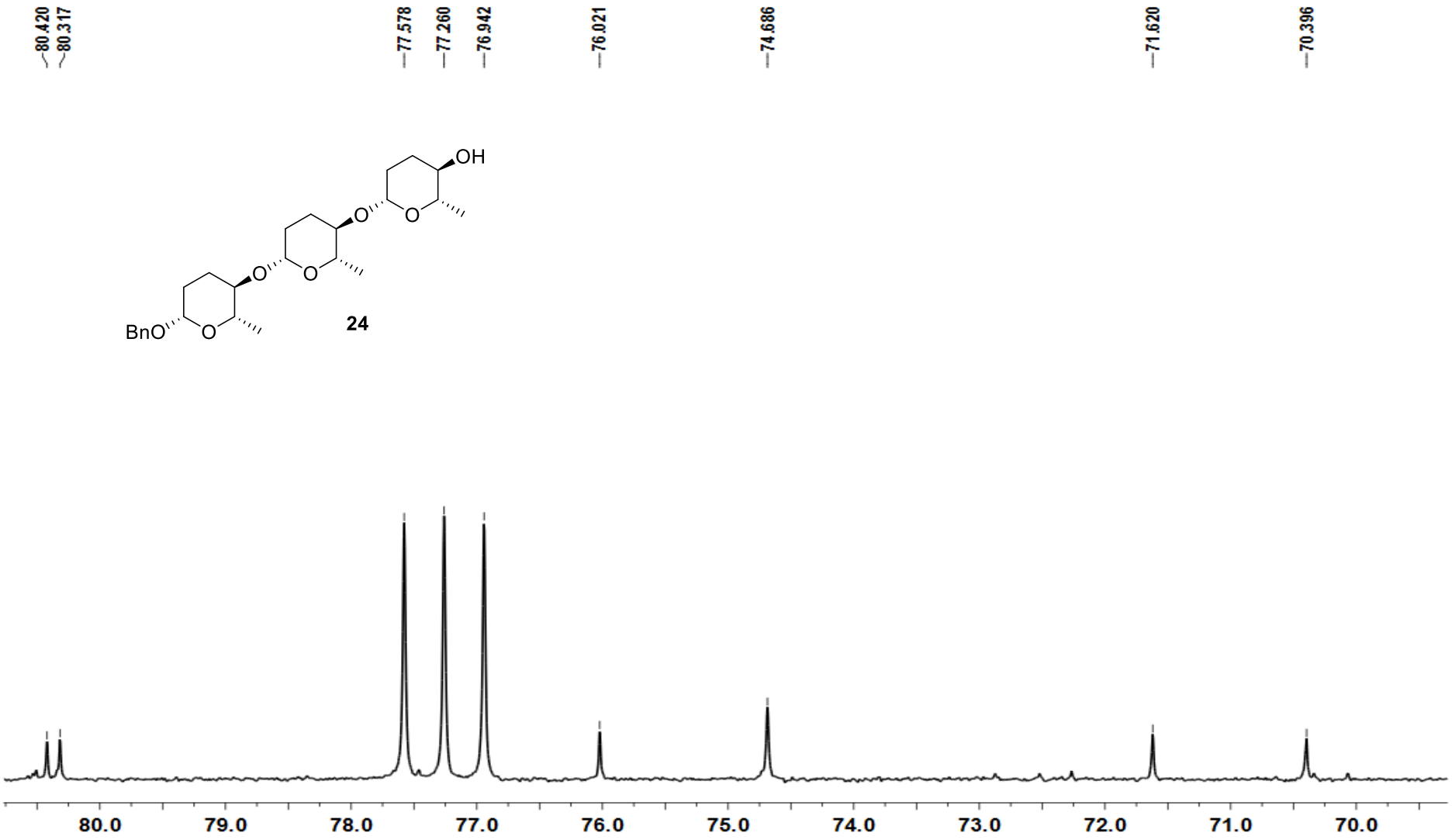
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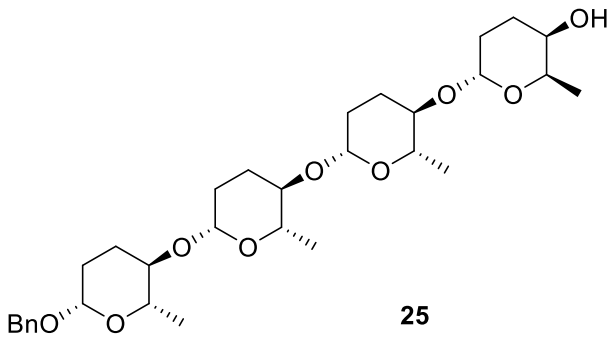
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BnO
O

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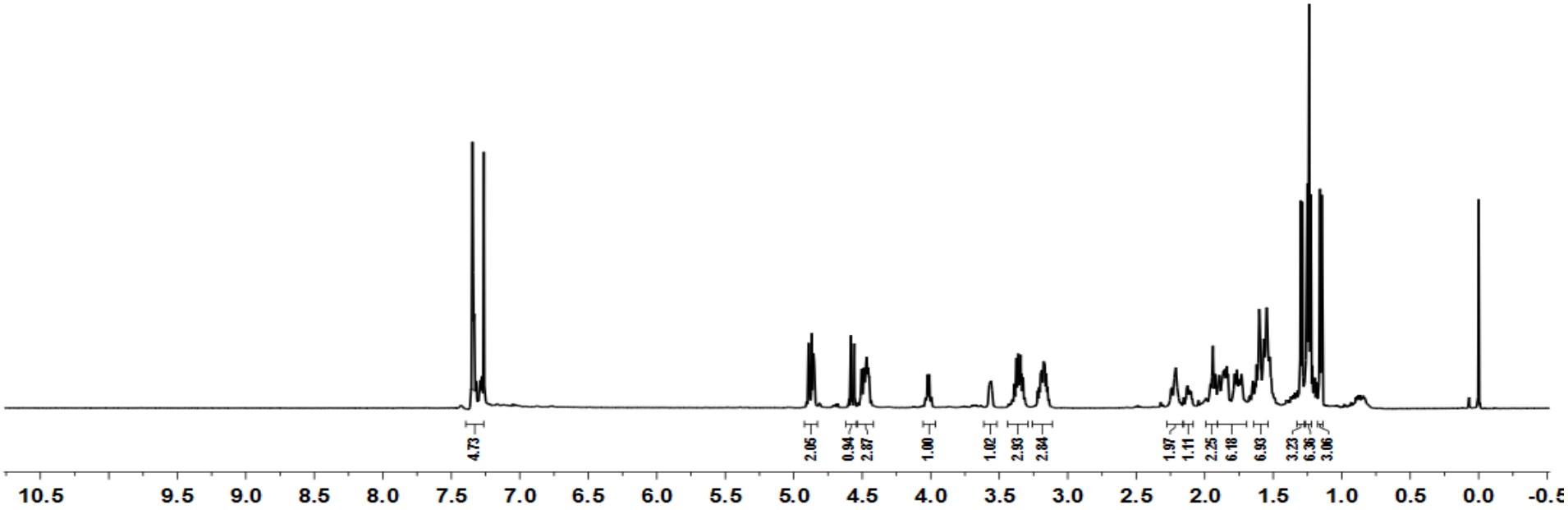
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6.93
3.23
6.36
3.06
10.5
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9.0
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8.0
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7.0
6.5
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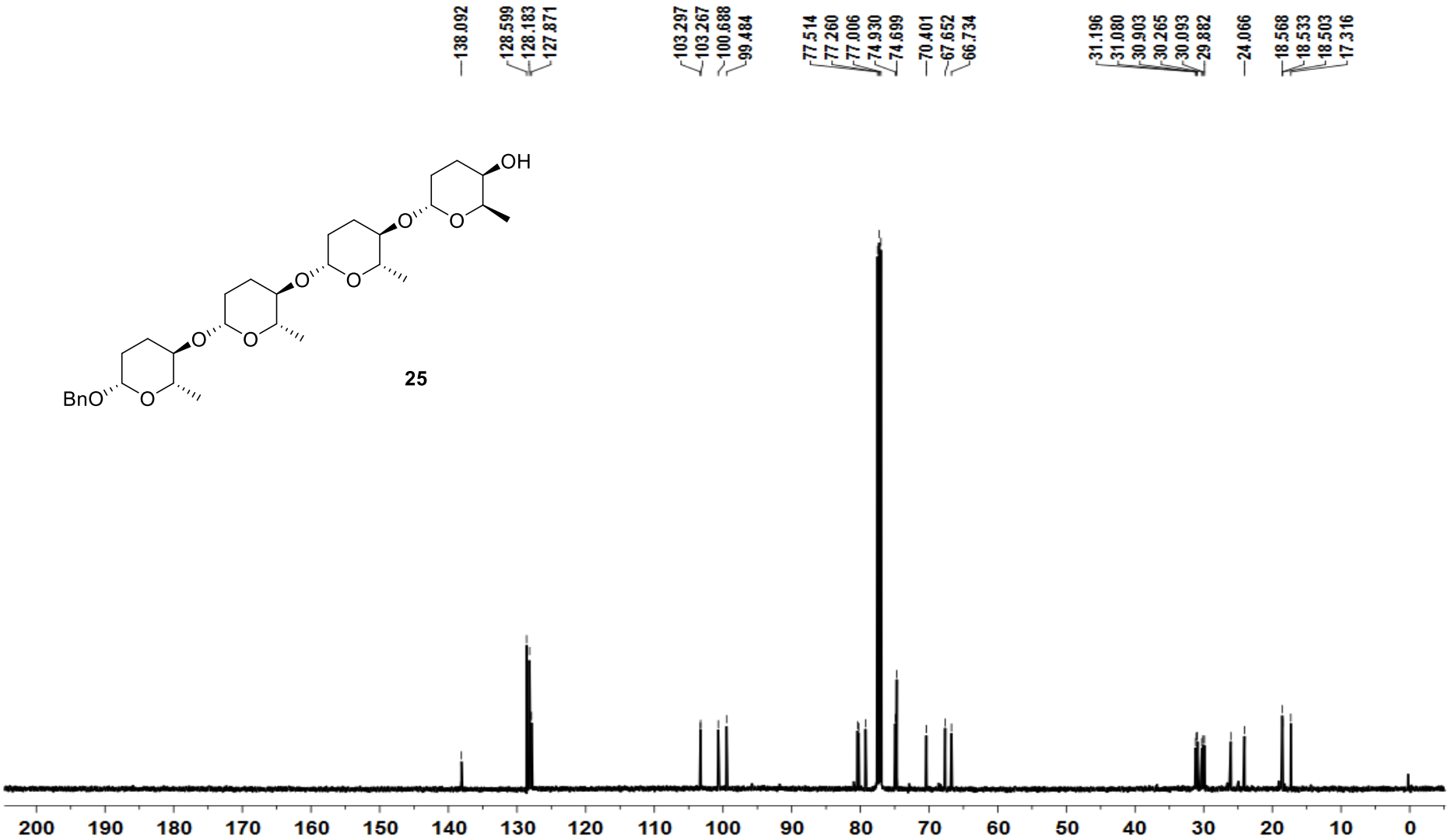
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30.093
29.882
24.066
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18.533
18.503
17.316
OH
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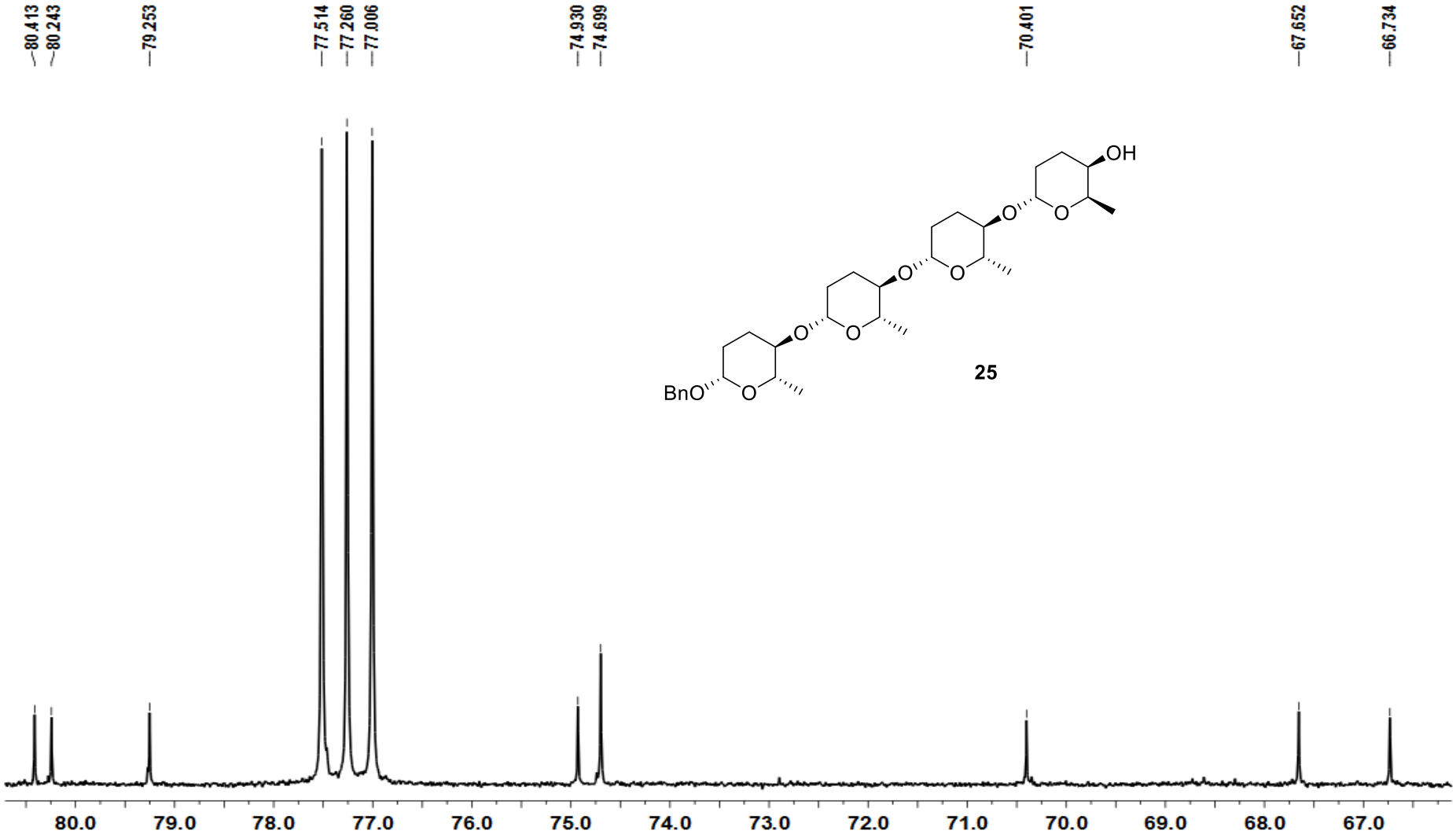
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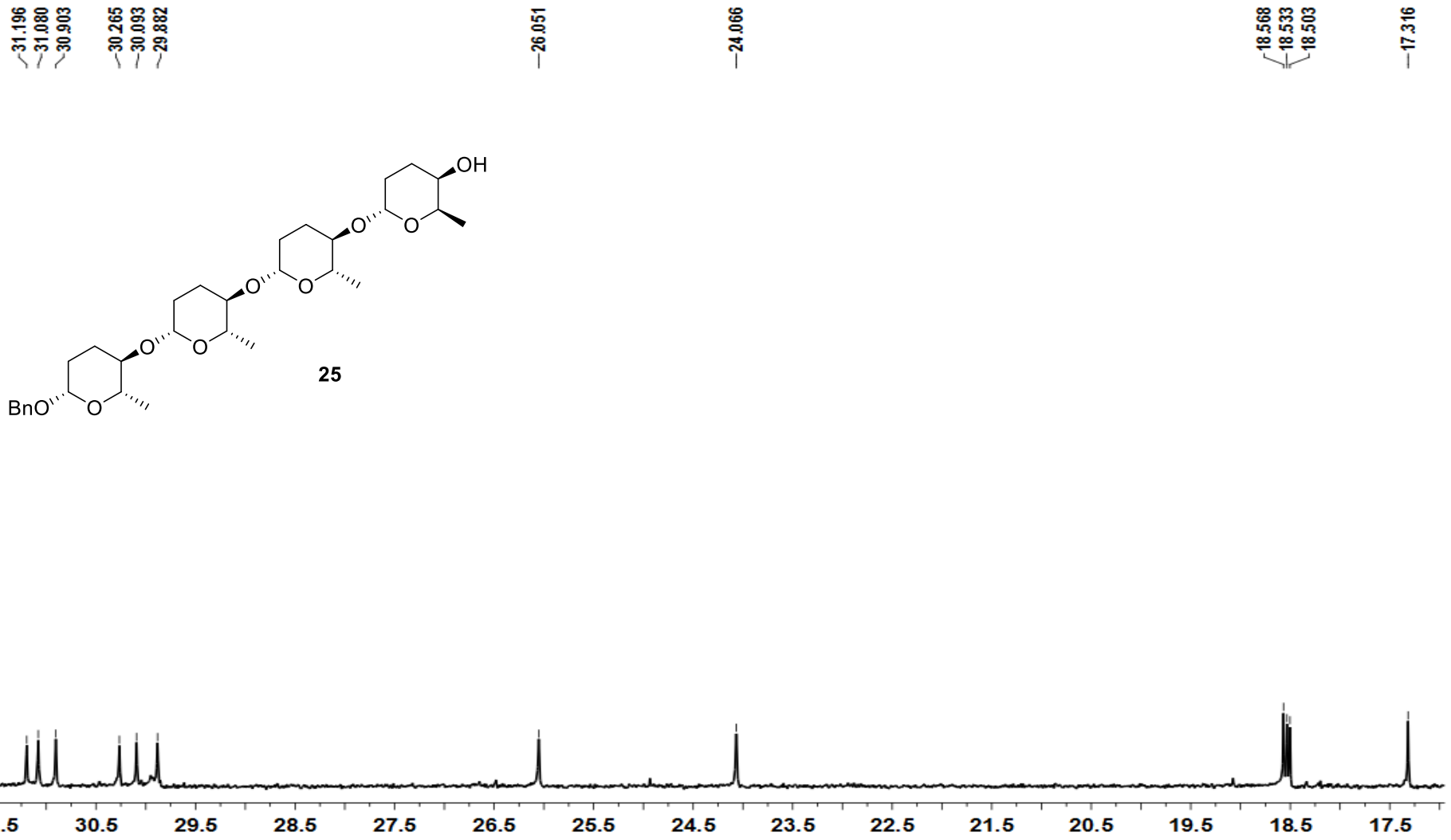
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