Supplementary Material (ESI) for Green Chemistry

Supporting Information

A Mild and Environmentally Benign Method for the Synthesis of Glycals in PEG-600/H_2O

Jinzhong Zhao[1,2], Shanqiao Wei[1], Xiaofeng Ma[1] and Huawu Shao[*,1]

[1]Natural Products Research Center, Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, 610041, China

[2]Shanxi Agriculture University, Taigu Shanxi, 030801, China

Graduate School of Chinese Academy of Sciences, China

[*]Correspondence author: E-mail: *shaohw@cib.ac.cn*
Fax: (+86) 28-85222753

Contents Page No.

General: Reactions were monitored by thin layer chromatography using silica gel HSGF254 plates. Flash chromatography was performed using silica gel HG/T2354-92. ^{1}H NMR and ^{13}C NMR (600 and 150 MHz, respectively) spectra were recorded in $CDCl_3$. ^{1}H NMR chemical shifts are reported in ppm (δ) relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard ($CDCl_3$, δ 7.26 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet), integration and coupling constants (Hz). ^{13}C NMR chemical shifts are reported in ppm from tetramethylsilane (TMS) with the solvent resonance as the internal standard ($CDCl_3$, δ 77.0 ppm). ESI-HRMS spectra were recorded on BioTOF Q. Optical rotations were acquired on a Perkin Elmer-341 Digital Polarimeter. Glycals **2**, **16-22** and **24-27** are known compounds and their ^{1}H NMR data matched the literature data.[1]

General Procedure for the Synthesis of glycopyranosyl bromide.[1a]

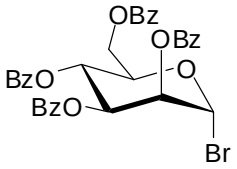
General Procedure for the Synthesis of glycals

To a solution of glycopyranosyl bromide (1 mmol) in PEG-600/H_2O (1:1, 6.0 mL) were added zinc dust (2.0 mmol), followed by stirring at room temperature. TLC indicated that the reaction was complete. Upon completion of the reaction, inorganic salts and excessive zinc dust were removed by filtration. The filtrate was extracted with EtOAc. The combined organic layers are dried (sodium sulfate) and concentrated in vacuo and the residue was purified by silica gel flash column chromatography to afford the pure glycal.

The multi-gram scale preparation of glycals 3,4,6-tri-*O*-acetyl-D-glucal (2)

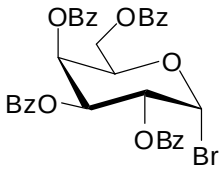
To a suspension of glycopyranosyl bromide (20.6 g, 50 mmol) in PEG-600/H_2O (1:1, 400 mL) were added zinc dust (6.5 g, 100 mmol) at room temperature. The reaction mixture was stirred at room temperature and monitored by TLC. Upon completion of the reaction, inorganic salts and excessive zinc dust were removed by filtration. The filtrate was extracted with EtOAc. The combined organic layers are dried (sodium sulfate) and concentrated in vacuo and the residue was purified by silica gel flash column chromatography to afford glucal **2** (10.9 g, 80%).

2,3,4,6-Tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (5)



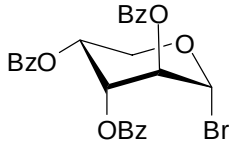
^{1}H NMR ($CDCl_3$): δ_H 4.52 (dd, 1H, J = 12.4, 3.7), 4.66 (m, 1H), 4.74 (dd, 1H, J = 12.4, 2.3), 5.91 (dd, 1H, J = 2.9, 1.6), 6.24 (dd, 1H, J = 10.1, 10.1), 6.29 (dd, 2H, J = 10.3, 3.3), 6.59 (d, 1H, J = 1.0), 7.28 (d, 2H, J = 7.6), 7.37-7.45 (m, 7H), 7.53 (m, 1H), 7.57-7.62 (m, 2H), 7.84 (dd, 2H, J = 8.2, 1.0), 7.98 (dd, 2H, J = 8.2, 1.0), 8.03 (dd, 2H, J = 8.2, 1.1), 8.10 (dd, 2H, J = 8.2, 1.2).

2,3,4,6-Tetra-*O*-benzoyl-α-D-galactopyranosyl bromide (6)



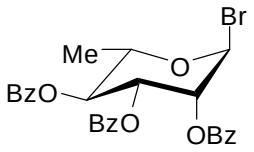
^{1}H NMR (CD_3COCD_3): δ_H 4.60 (dd, 1H, J = 11.6, 5.8), 4.69 (dd, 1H, J = 11.6, 6.7), 5.15 (dd, 1H, J = 6.3, 6.1), 5.83 (dd, 1H, J = 10.4, 4.0), 6.12 (dd, 1H, J = 10.3, 3.2), 6.27 (d, 1H, J = 2.7), 7.23 (d, 1H, J = 4.0), 7.30 (dd, 2H, J = 8.0, 7.6), 7.42-7.51 (m, 5H), 7.56 (dd, 2H, J = 7.9, 7.6), 7.58-7.61 (m, 2H), 7.69 (dd, 1H, J = 7.6, 7.4), 7.79-7.81 (m, 2H), 7.98-8.01 (m, 4H), 8.12-8.13 (m, 2H).

2,3,4-Tri-*O*-benzoyl-α-D-arabinosyl bromide (7)



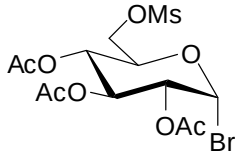
^{1}H NMR ($CDCl_3$): δ_H 4.23 (dd, 1H, J = 13.5, 1.7), 4.47 (d, 1H, J = 12.2), 5.71(dd, 1H, J = 10.6, 3.9), 5.83 (m, 1H), 6.00 (dd, 1H, J = 10.4, 3.4), 6.93 (d, 1H, J = 3.9), 7.29 (dd, 2H, J = 8.0, 7.6), 7.41 (dd, 2H, J = 8.0, 7.6), 7.45-7.51 (m, 3H), 7.54 (dd, 1H, J = 7.4, 7.4), 7.62 (dd, 1H, J = 7.4, 7.4), 7.85 (d, 2H, J = 8.0), 8.02 (d, 2H, J = 8.0), 8.09 (d, 2H, J = 7.9).

2,3,4-Tri-*O*-benzoyl-α-L-rhamnosyl bromide (8)



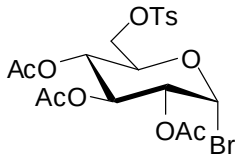
^{1}H NMR ($CDCl_3$): δ_H 1.43 (d, 3H, J = 6.1), 4.44 (m, 1H), 5.78 (dd, 1H, J = 12.0, 12.0), 5.89 (m, 1H), 6.21 (dd, 1H, J = 10.3, 3.3), 6.56 (s, 1H), 7.24-7.26 (m, 2H), 7.38-7.43 (m, 3H), 7.48-7.54 (m, 3H), 7.61 (dd, 1H, J = 7.4, 7.4), 7.83 (d, 2H, J = 7.4), 8.00 (d, 2H, J = 7.4), 8.09 (d, 2H, J = 7.3).

2,3,4-Tri-*O*-acetyl-6-*O*-mesyl-α-D-glucopyranosyl bromide (9)



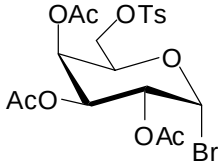
^{1}H NMR ($CDCl_3$): δ_H 2.04 (s, 3H), 2.08 (s, 3H), 2.10 (s, 3H), 3.06 (s, 3H), 4.30-4.83 (m, 3H), 4.84 (dd, 1H, J = 9.8, 3.9), 5.16 (dd, 1H, J = 9.7, 9.7), 5.56 (dd, 1H, J = 9.8, 9.7), 6.62 (d, 1H, J = 4.0).

2,3,4-Tri-*O*-acetyl-6-*O*-tosyl-α-D-glucopyranosyl bromide (10)



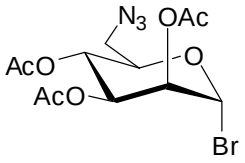
^{1}H NMR ($CDCl_3$): δ_H 2.00 (s, 3H), 2.02 (s, 3H), 2.08 (s, 3H), 2.46 (s, 3H), 4.14-4.19 (m, 2H), 4.72 (dd, 1H, J = 10.2, 4.0), 5.09 (dd, 1H, J = 10.4, 9.4), 5.49 (dd, 1H, J = 9.6, 9.6), 6.48 (d, 1H, J = 4.0).

2,3,4-Tri-*O*-acetyl-6-*O*-tosyl-α-D-galactopyranosyl bromide (11)



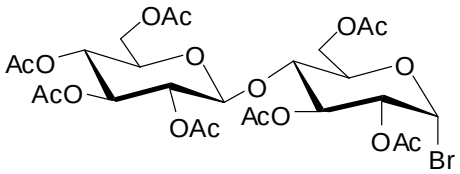
^{1}H NMR ($CDCl_3$): δ_H 1.99 (s, 3H), 2.08 (s, 3H), 2.09 (s, 3H), 2.46 (s, 3H), 4.05-4.12 (m, 2H), 4.43 (dd, 1H, J = 6.3, 6.1), 4.99 (dd, 1H, J = 10.7, 4.0), 5.34 (dd, 1H, J = 10.5, 3.2), 5.47 (d, 1H, J = 3.1), 6.60 (d, 1H, J = 4.0), 7.36 (d, 2H, J = 8.0), 7.77 (d, 2H, J = 8.2).

2,3,4-Tri-*O*-acetyl-6-deoxy-6-azido-α-D-mannopyranosyl bromide (12)

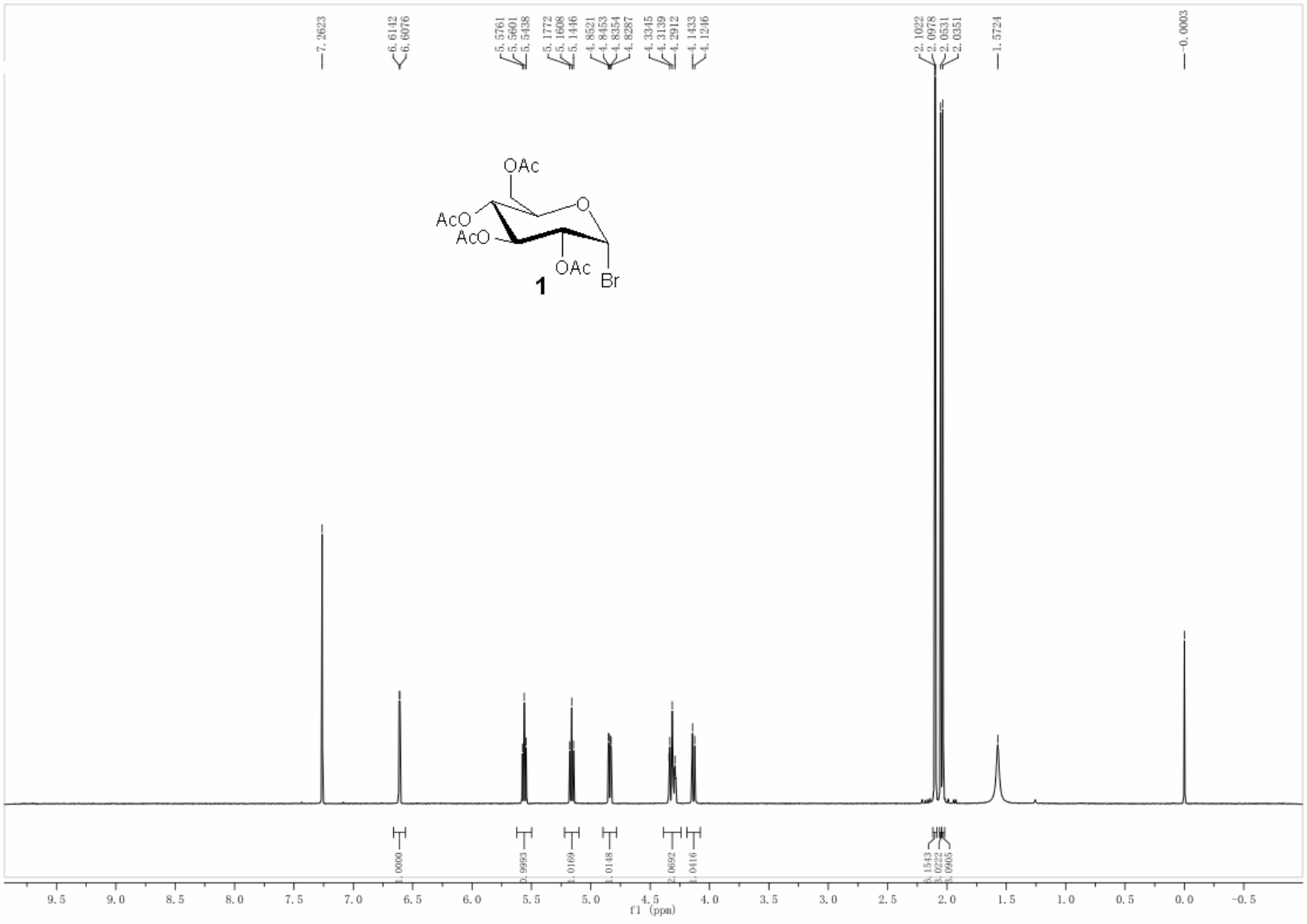


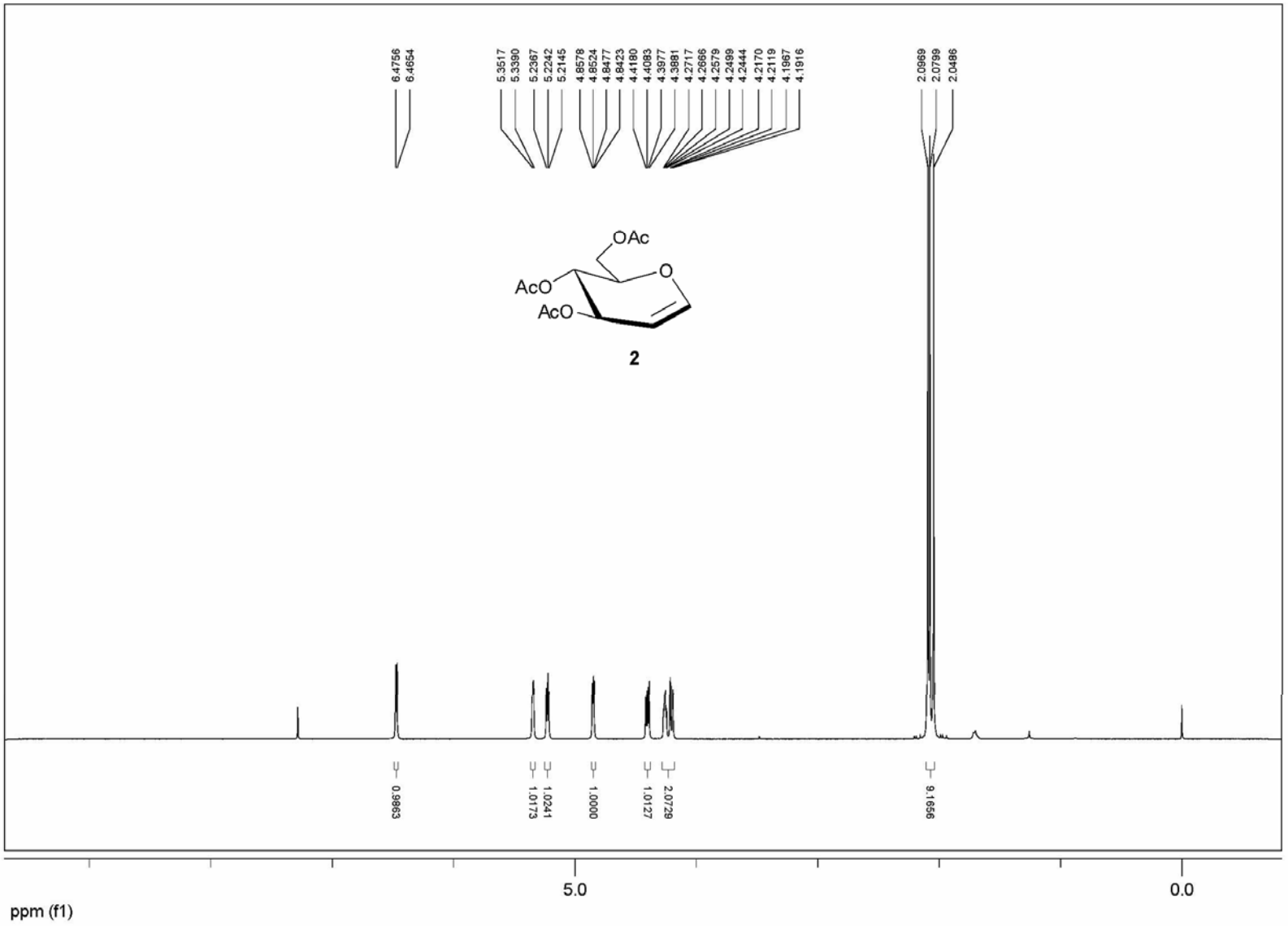
^{1}H NMR (CD_3COCD_3): δ_H 1.95 (s, 3H), 2.08 (s, 3H), 2.11 (s, 3H), 3.60 (dd, 1H, J = 11.6, 5.8), 3.71 (dd, 1H, J = 11.8, 2.3), 4.25 (m, 1H), 5.36 (dd, 1H, J = 10.1, 10.1), 5.43 (m, 1H), 5.63 (dd, 1H, J = 10.1, 3.5), 6.11 (s, 1H).

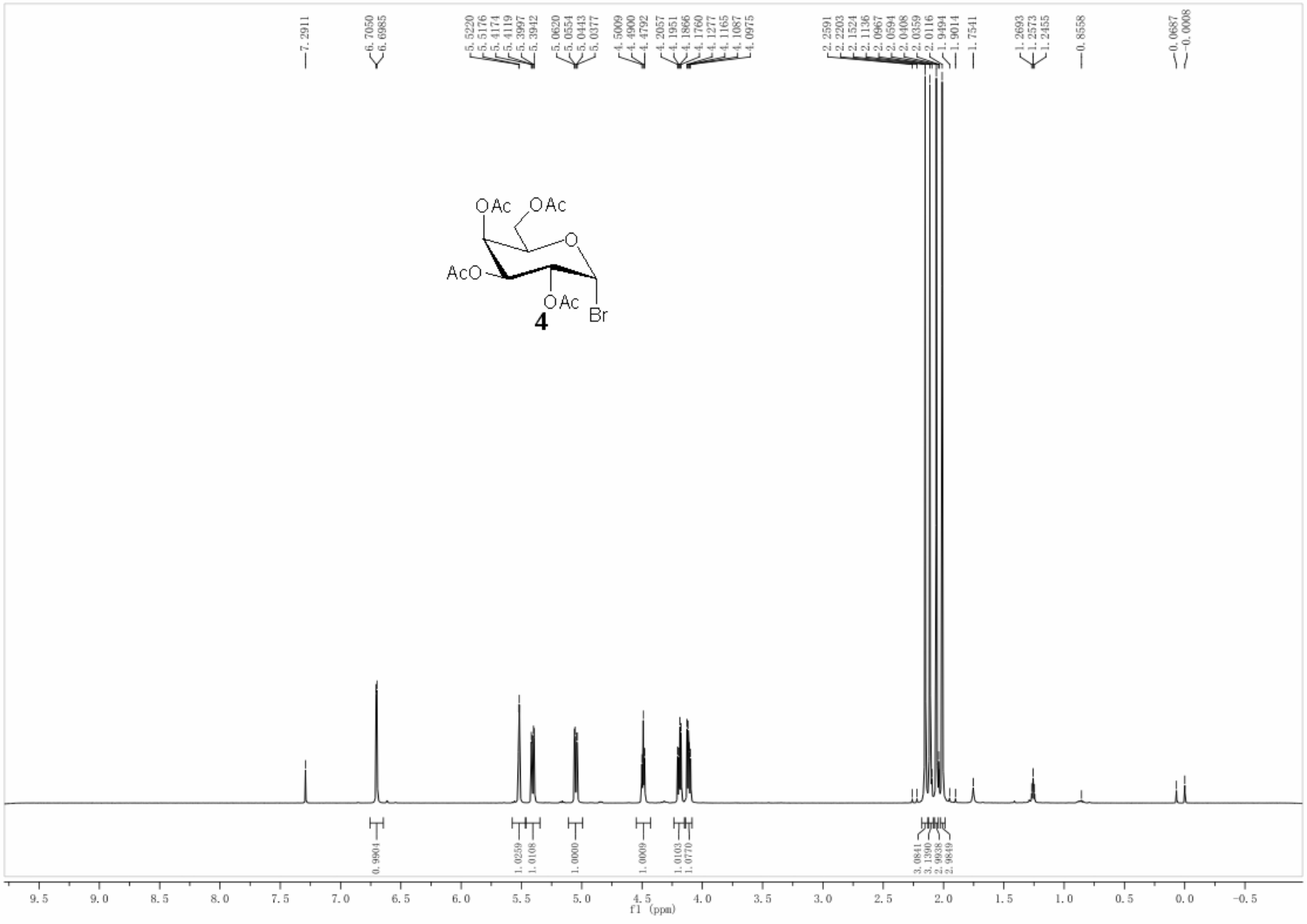
2,3,6,2',3',4',6'-hepta-*O*-acetyl-α-D-cellobiosyl bromide (13)

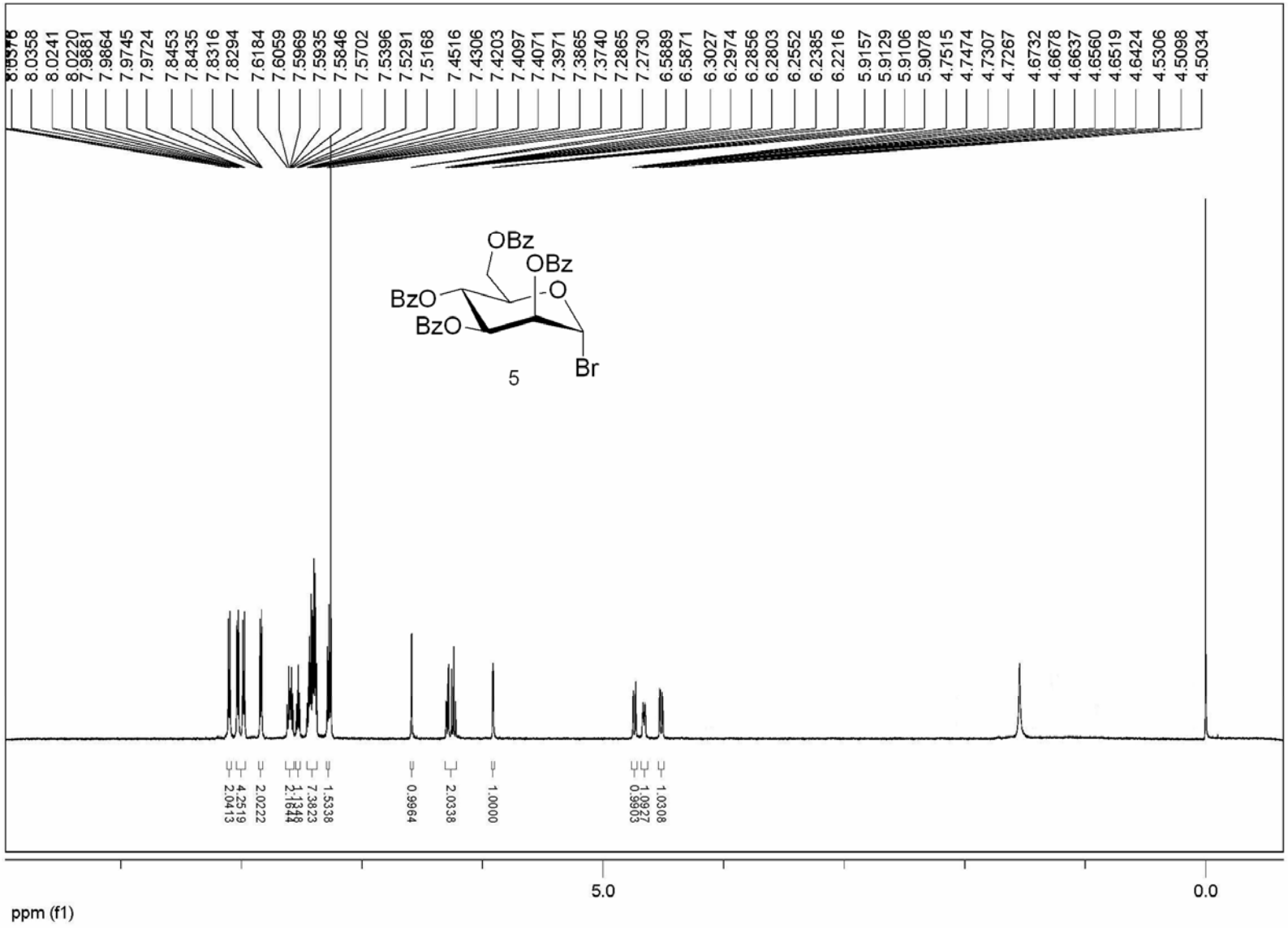


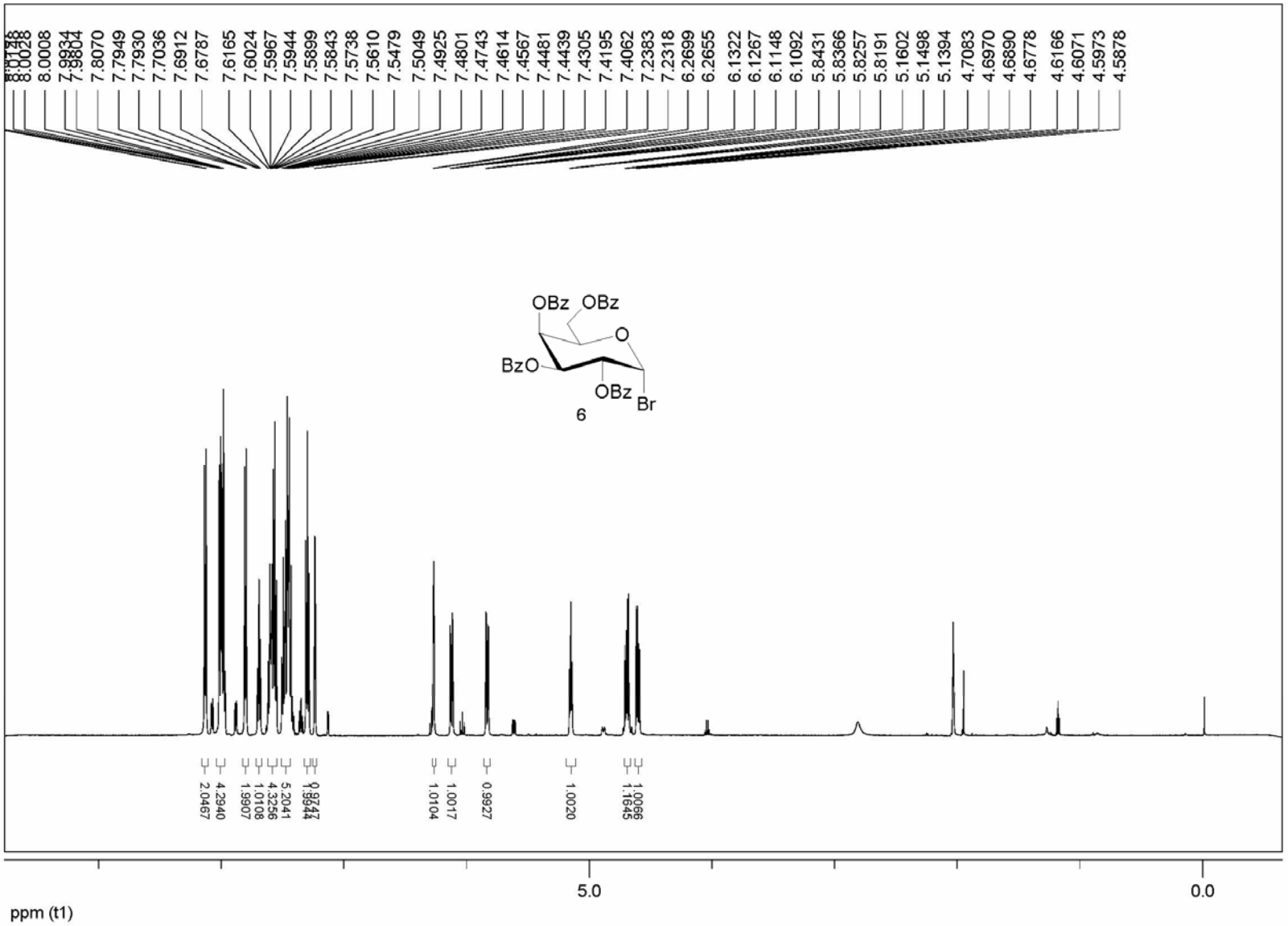
^{1}H NMR ($CDCl_3$): δ_H 1.99 (s, 3H), 2.01 (s, 3H), 2.04 (s, 3H), 2.05 (s, 3H), 2.09 (s, 6H), 2.14 (s, 3H), 3.68 (m, 1H), 3.84 (dd, 1H, J = 9.6, 9.5), 4.06 (d, 1H, J = 12.4), 4.17-4.21 (m, 2H), 4.36 (dd, 1H, J = 12.4, 4.6), 4.53 (d, 1H, J = 10.6), 4.56 (d, 1H, J = 7.9), 4.77 (dd, 1H, J = 9.8, 3.9), 4.94 (dd, 1H, J = 9.2, 7.9), 5.08 (dd, 1H, J = 9.7, 9.7), 5.16 (dd, 1H, J = 9.5, 9.2), 5.54 (dd, 1H, J = 9.9, 9.7), 6.53 (d, 1H, J = 5.8).

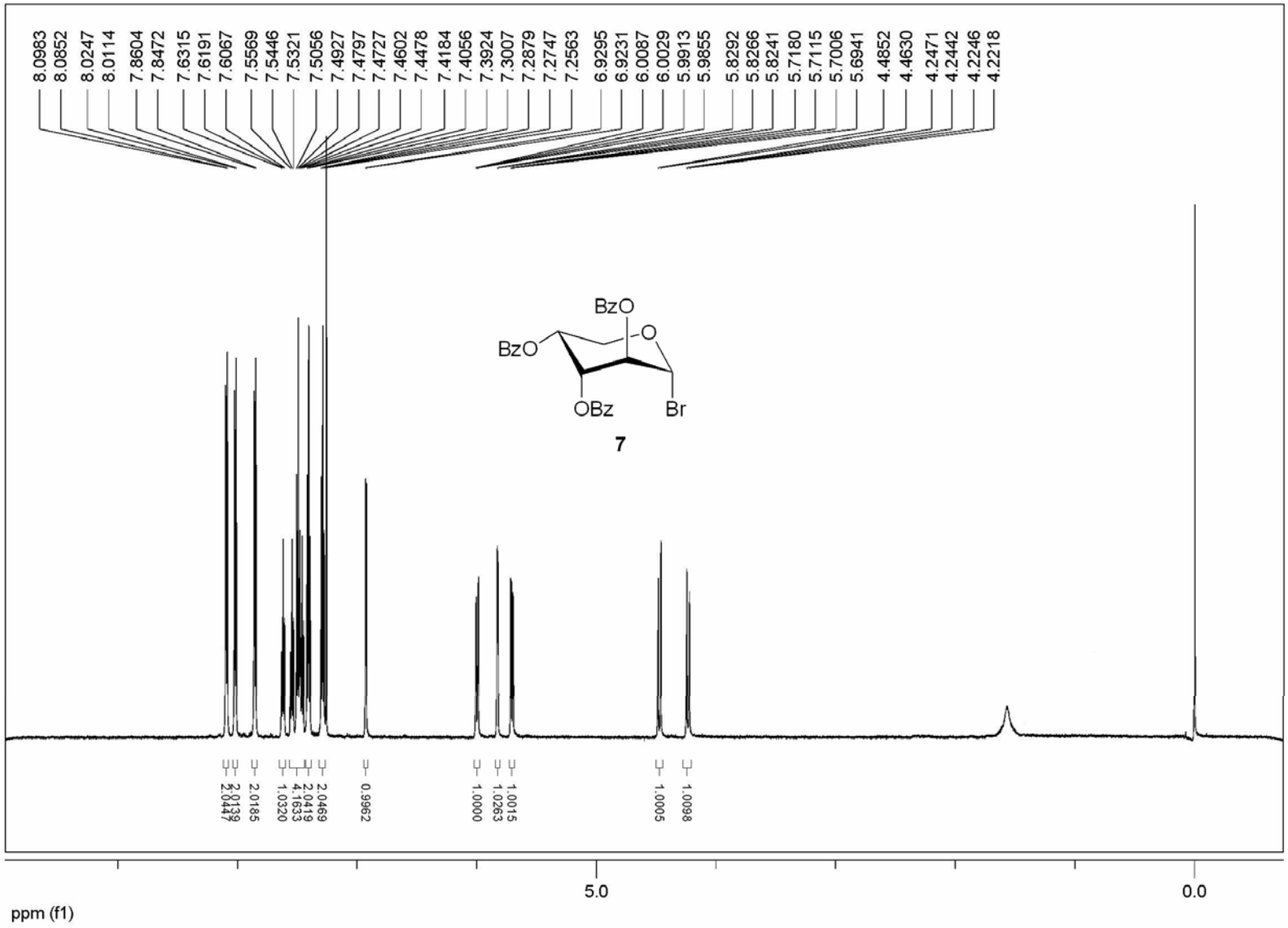


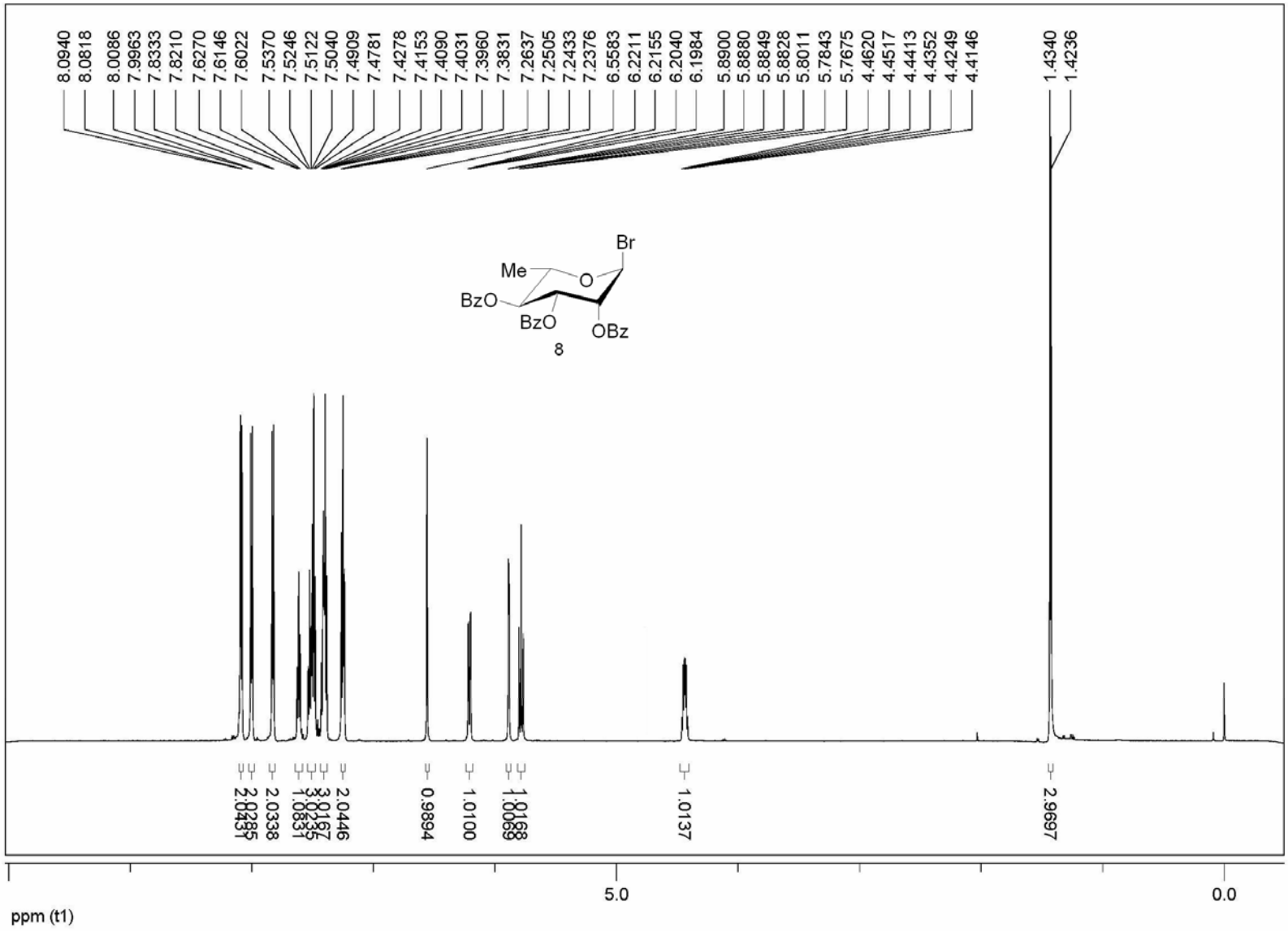


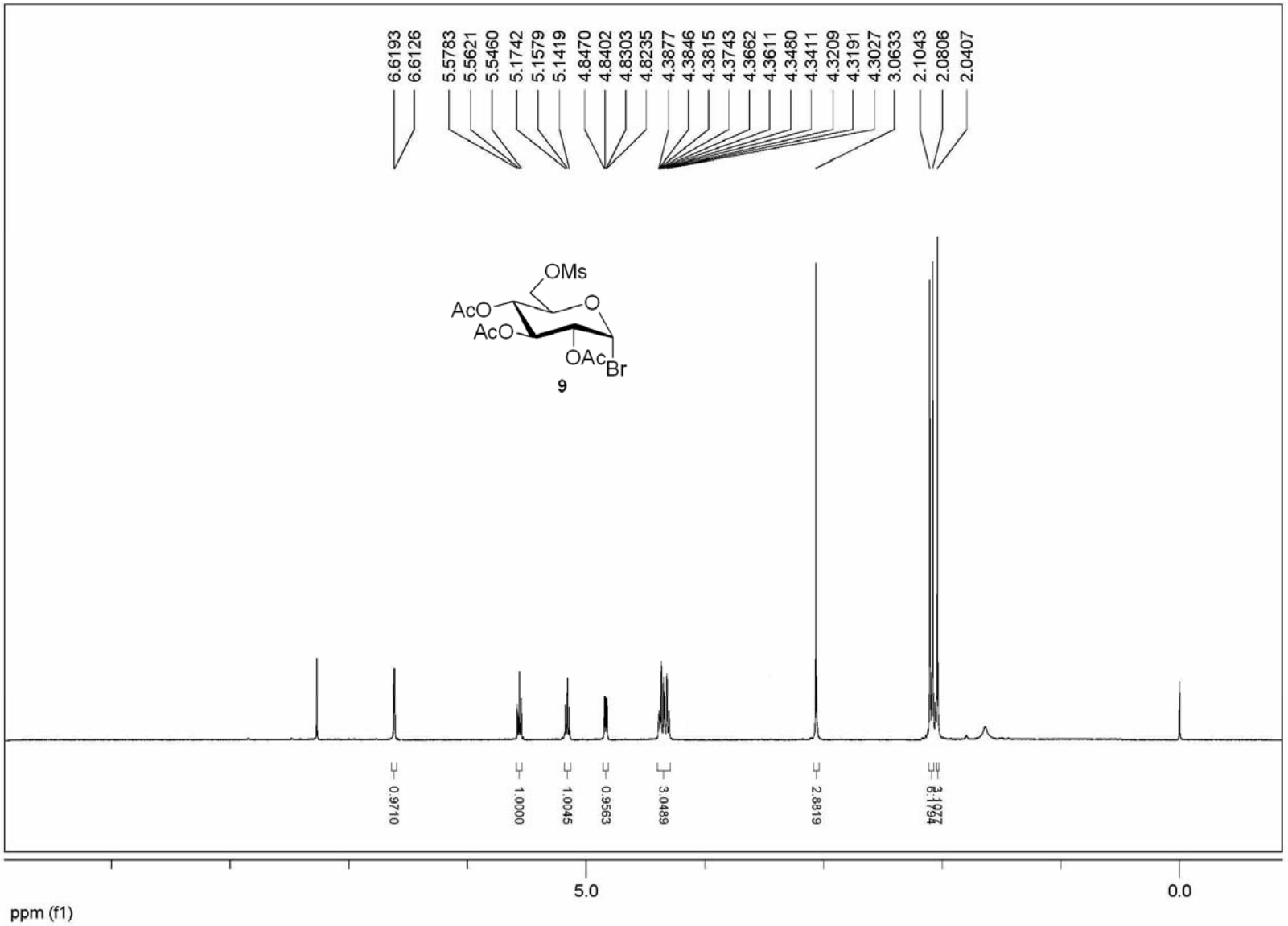


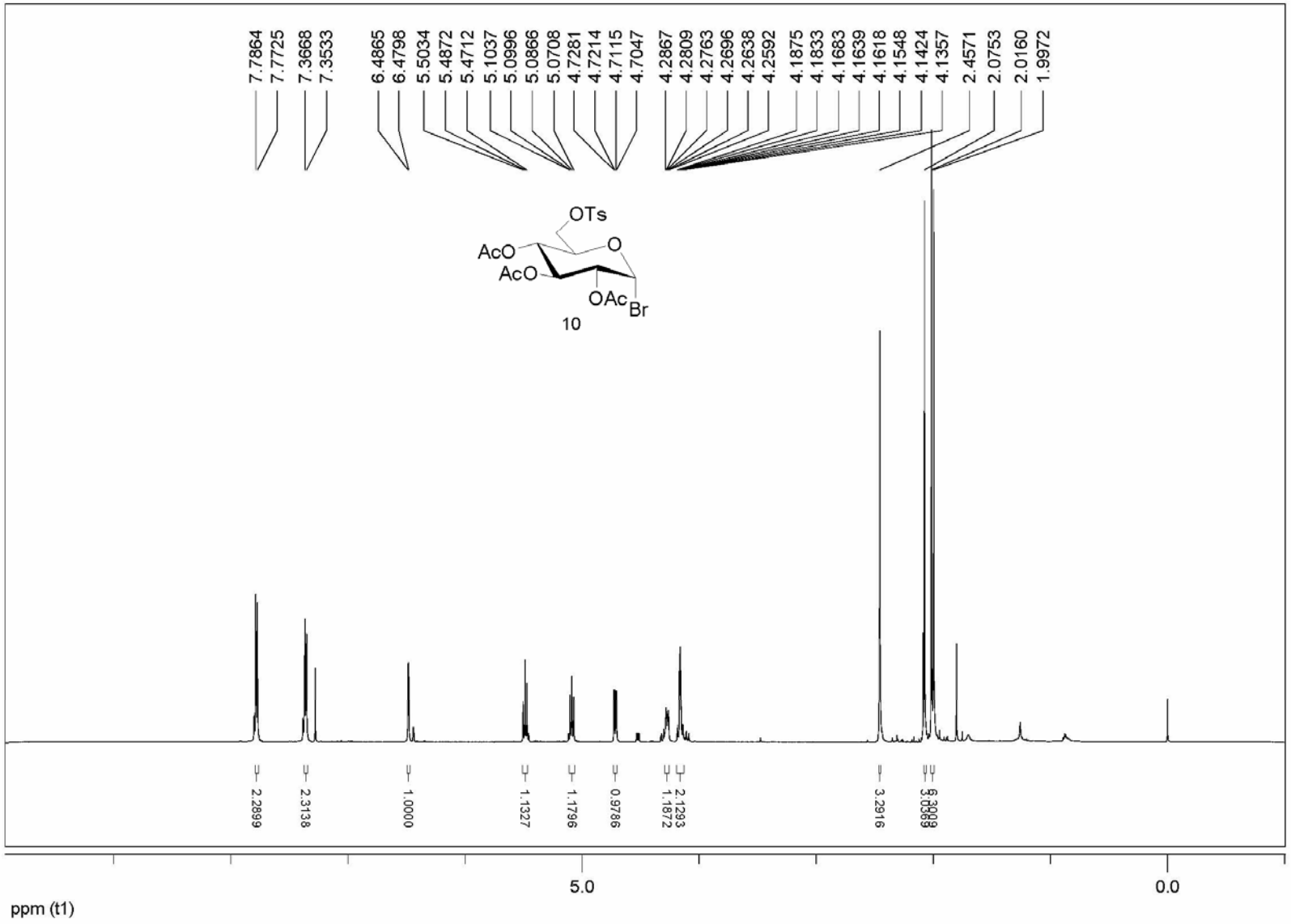


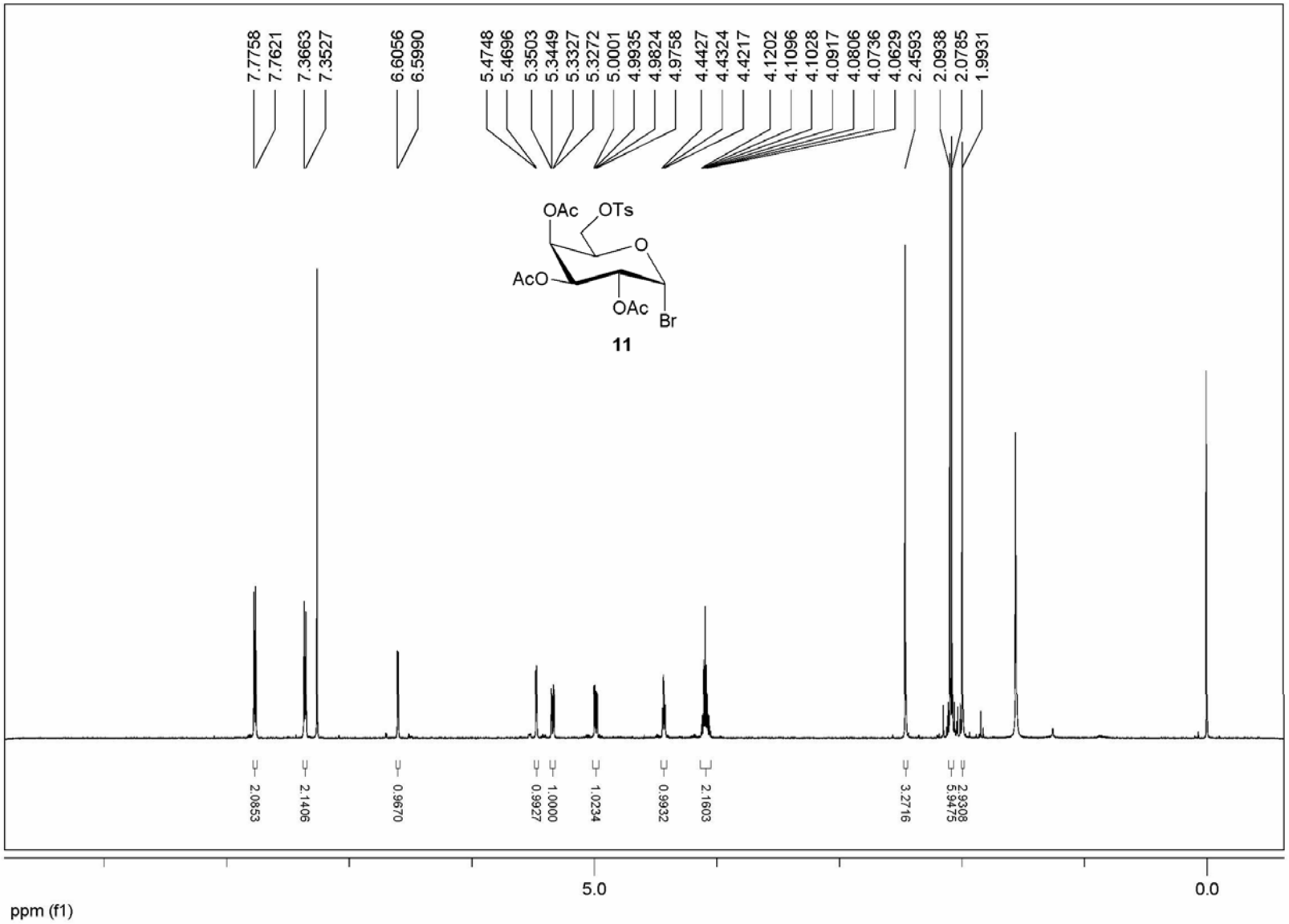


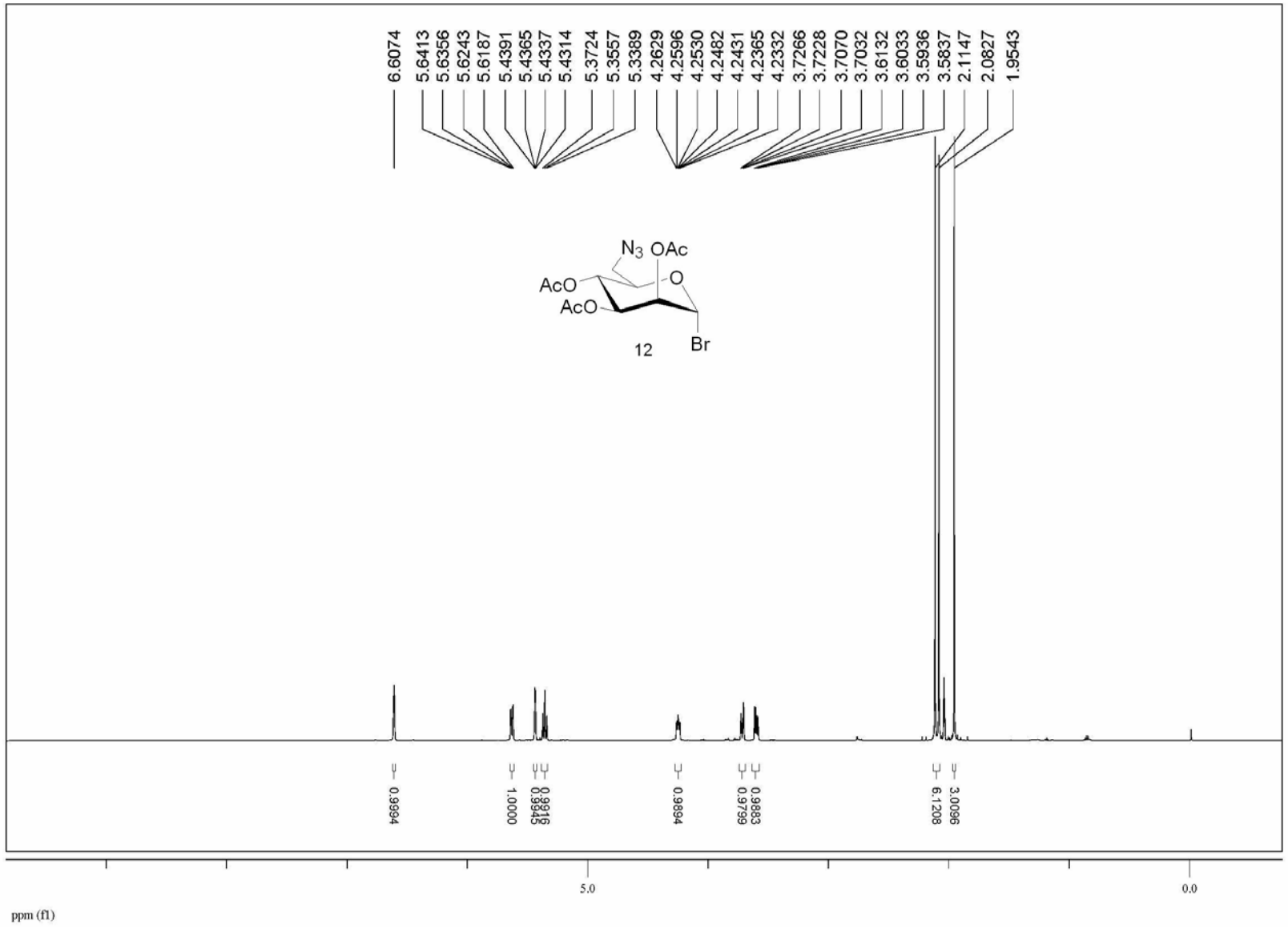


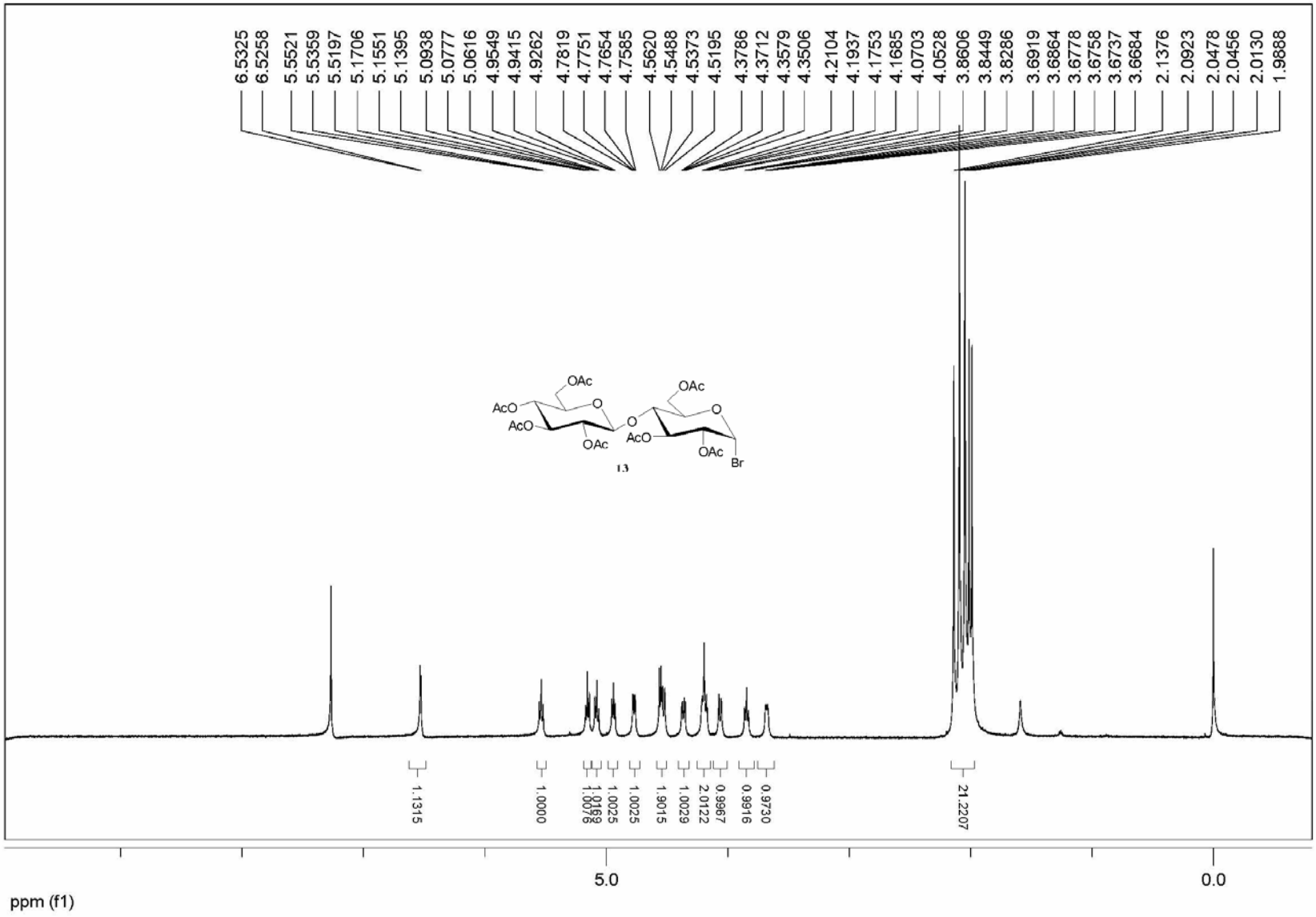


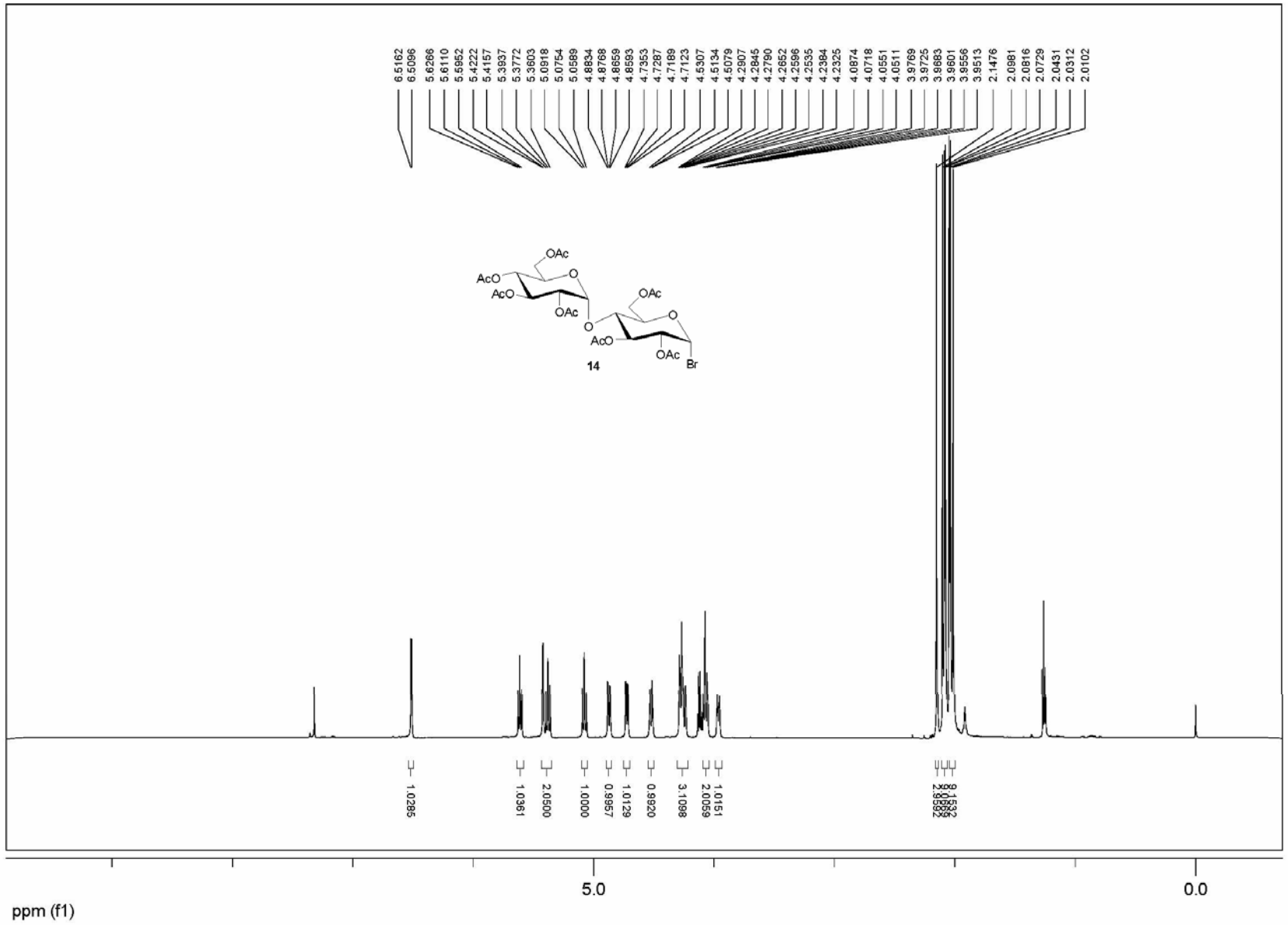


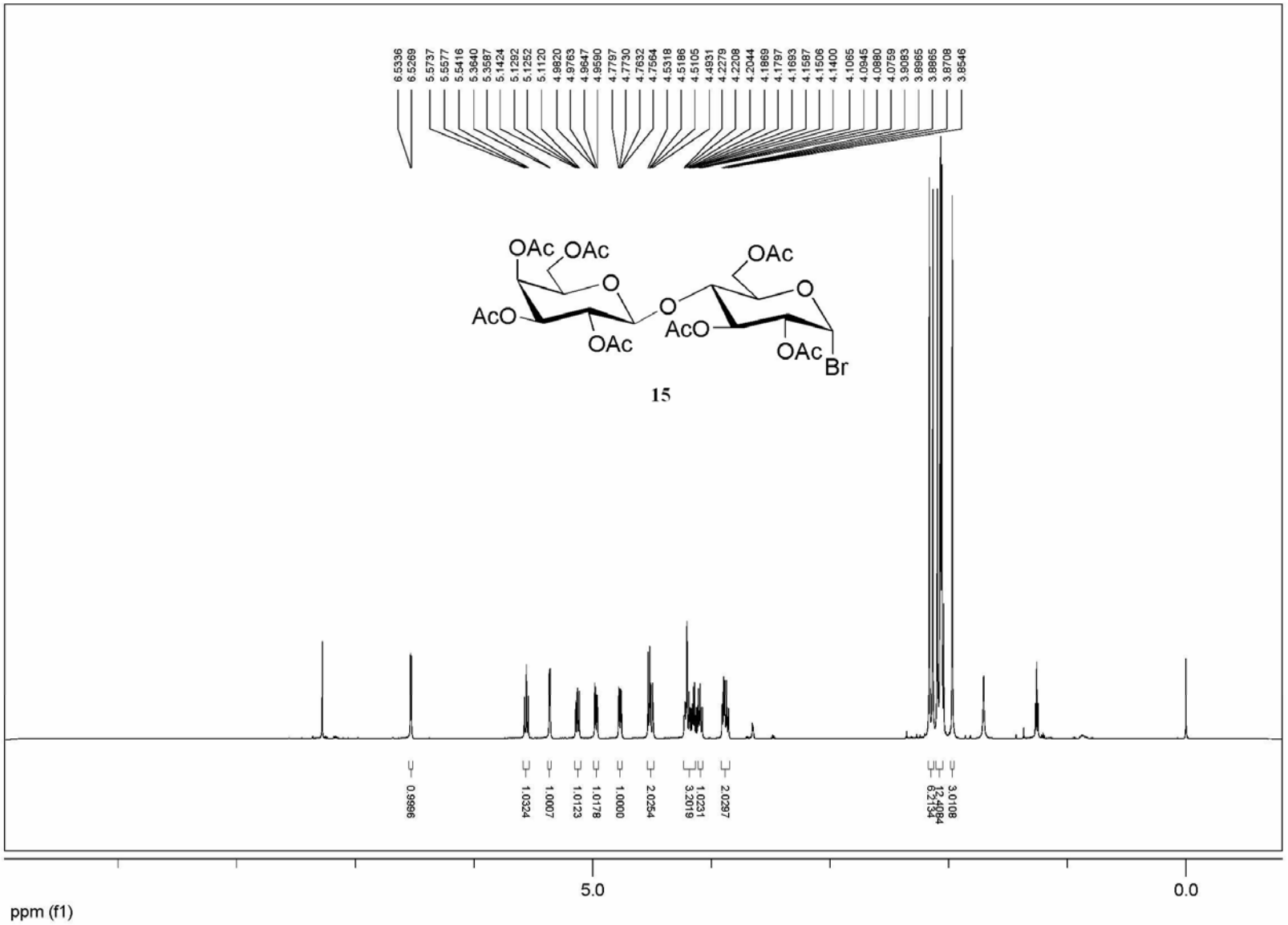


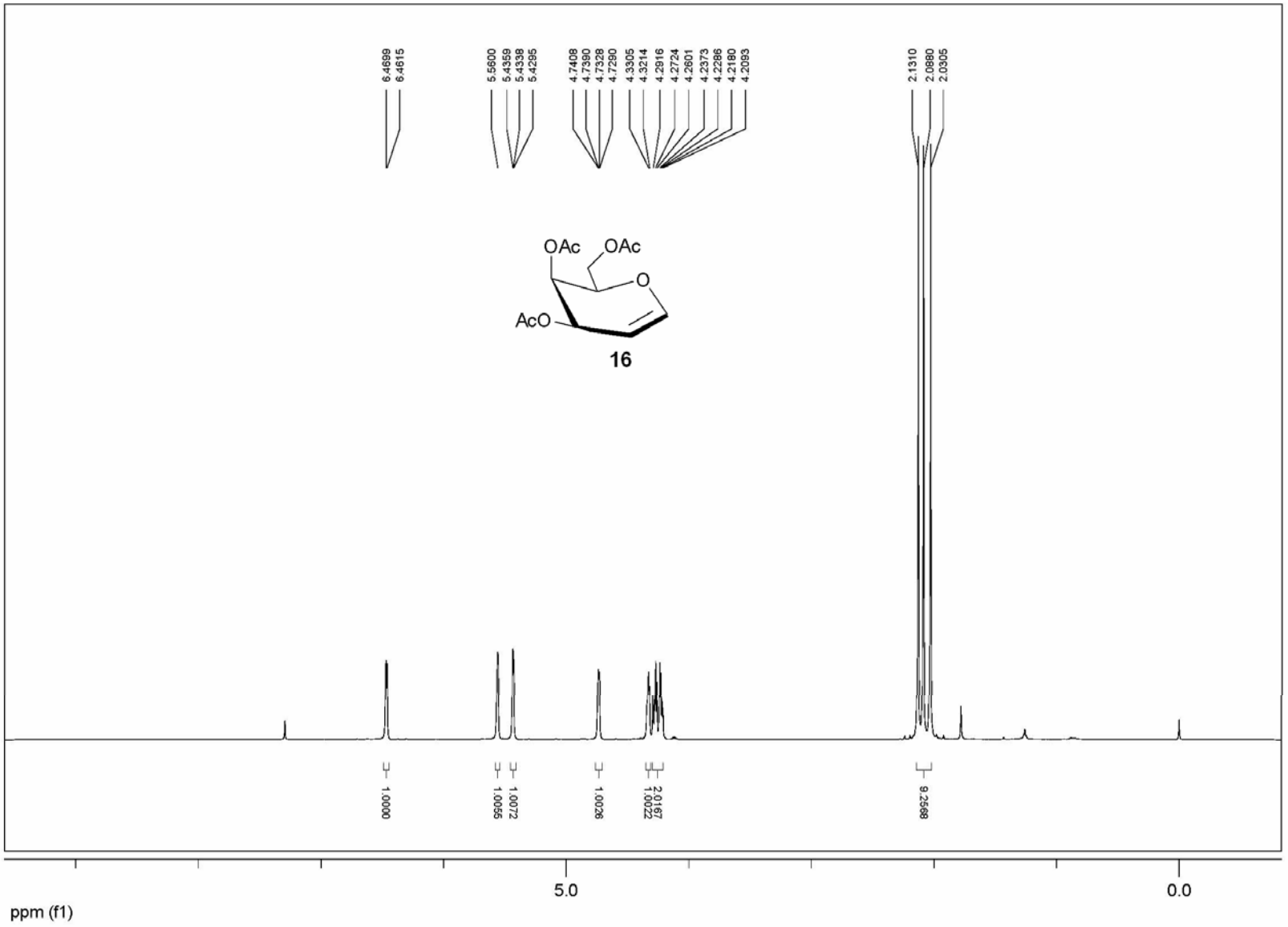


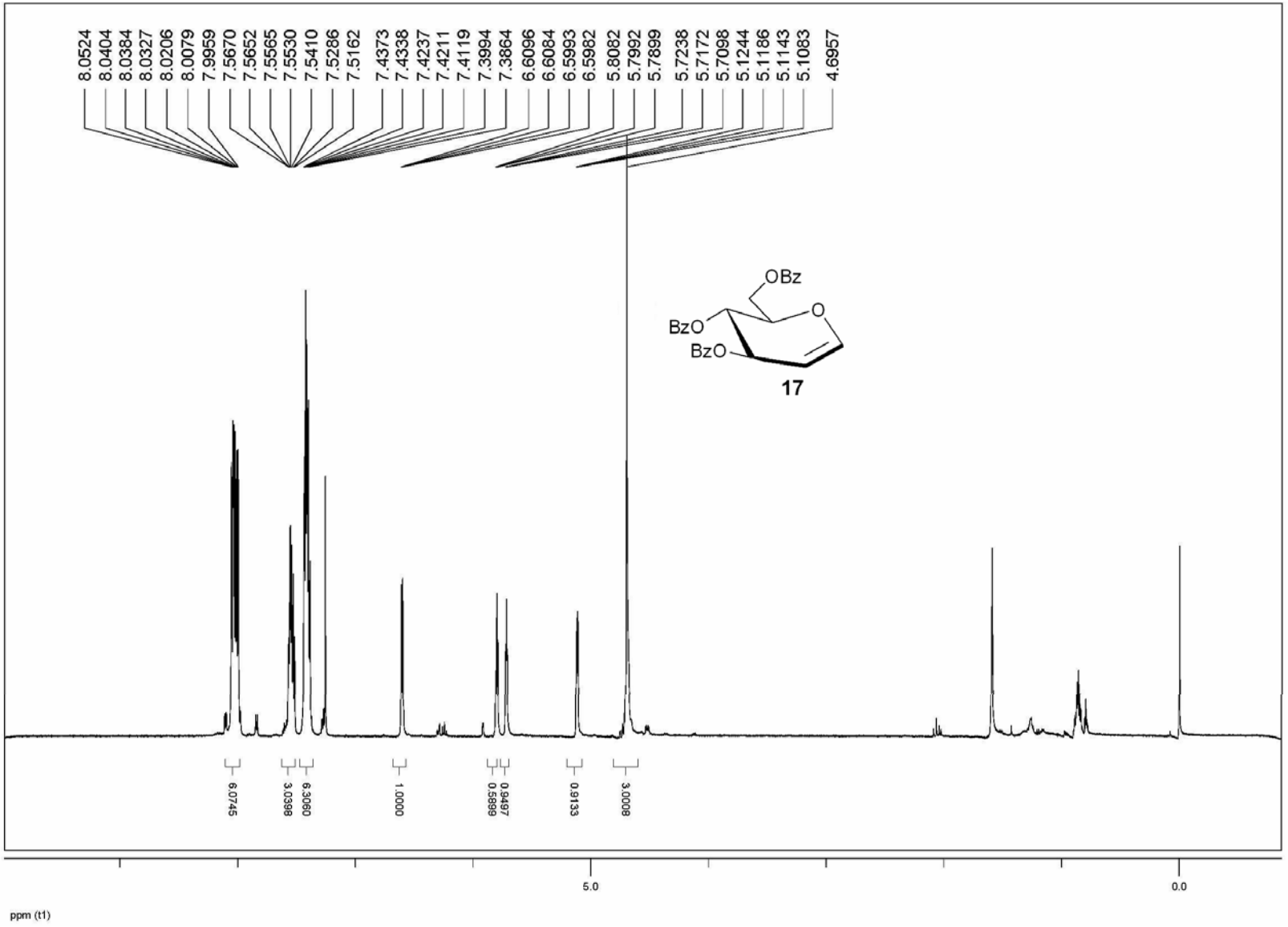


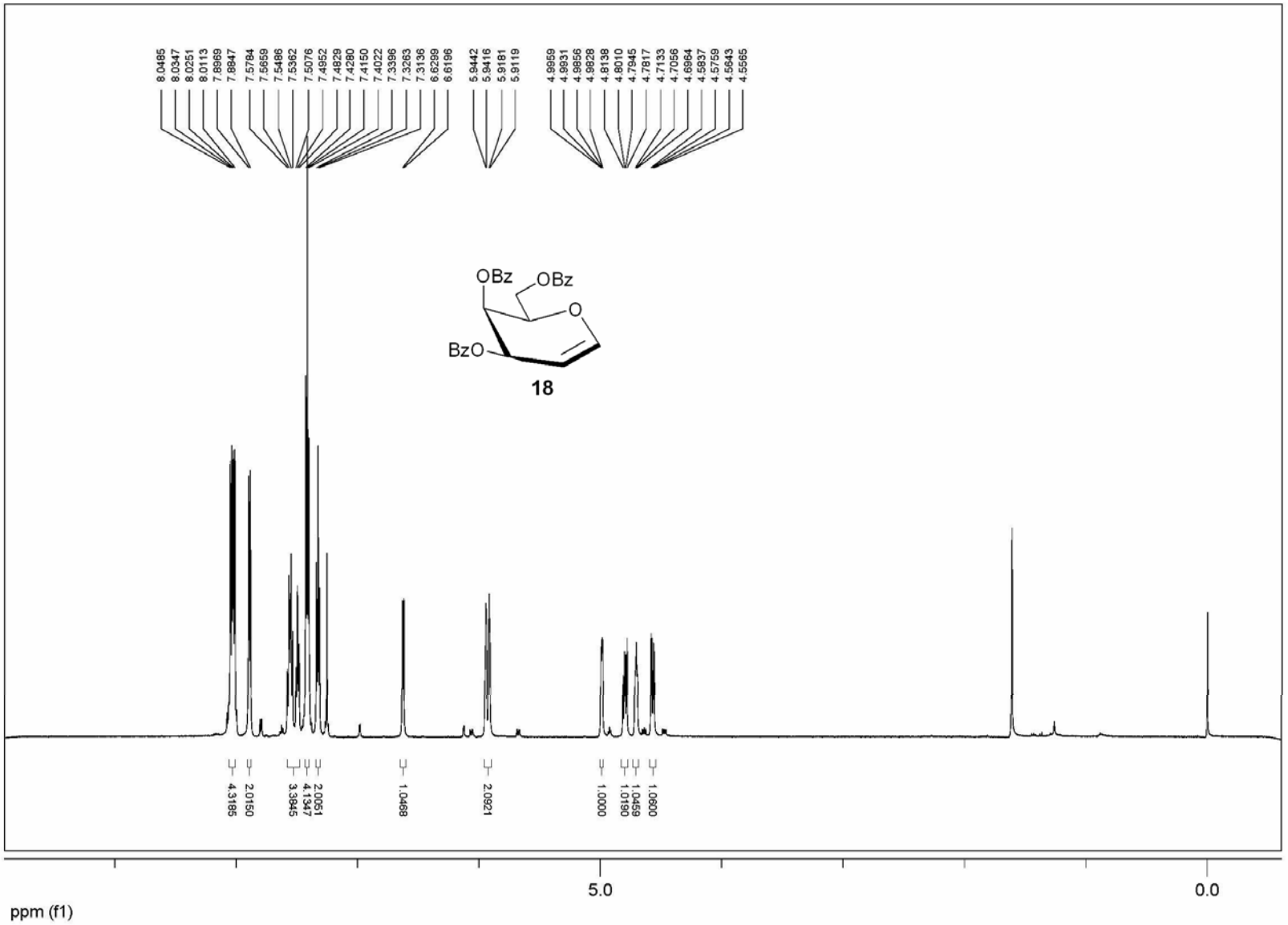


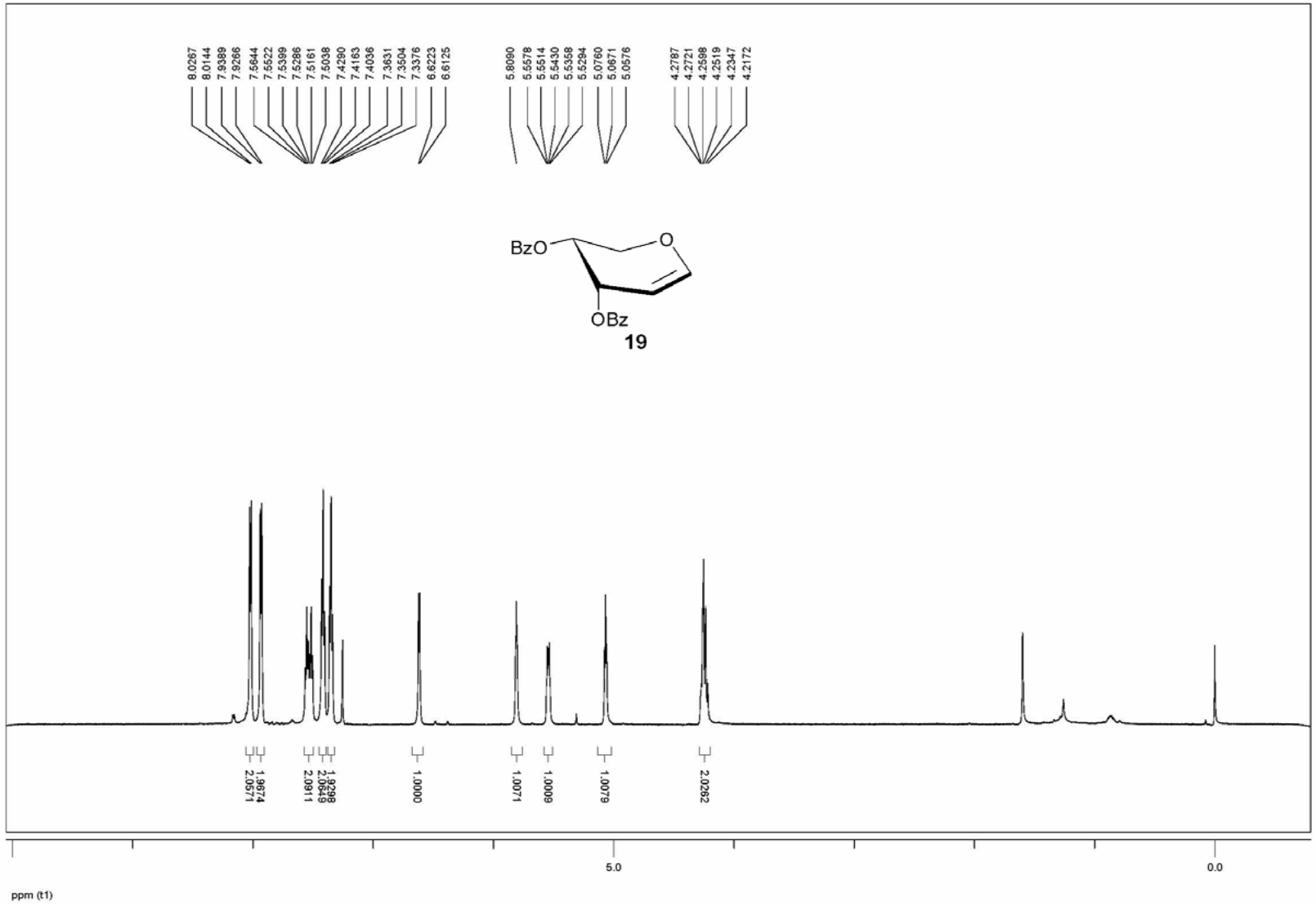


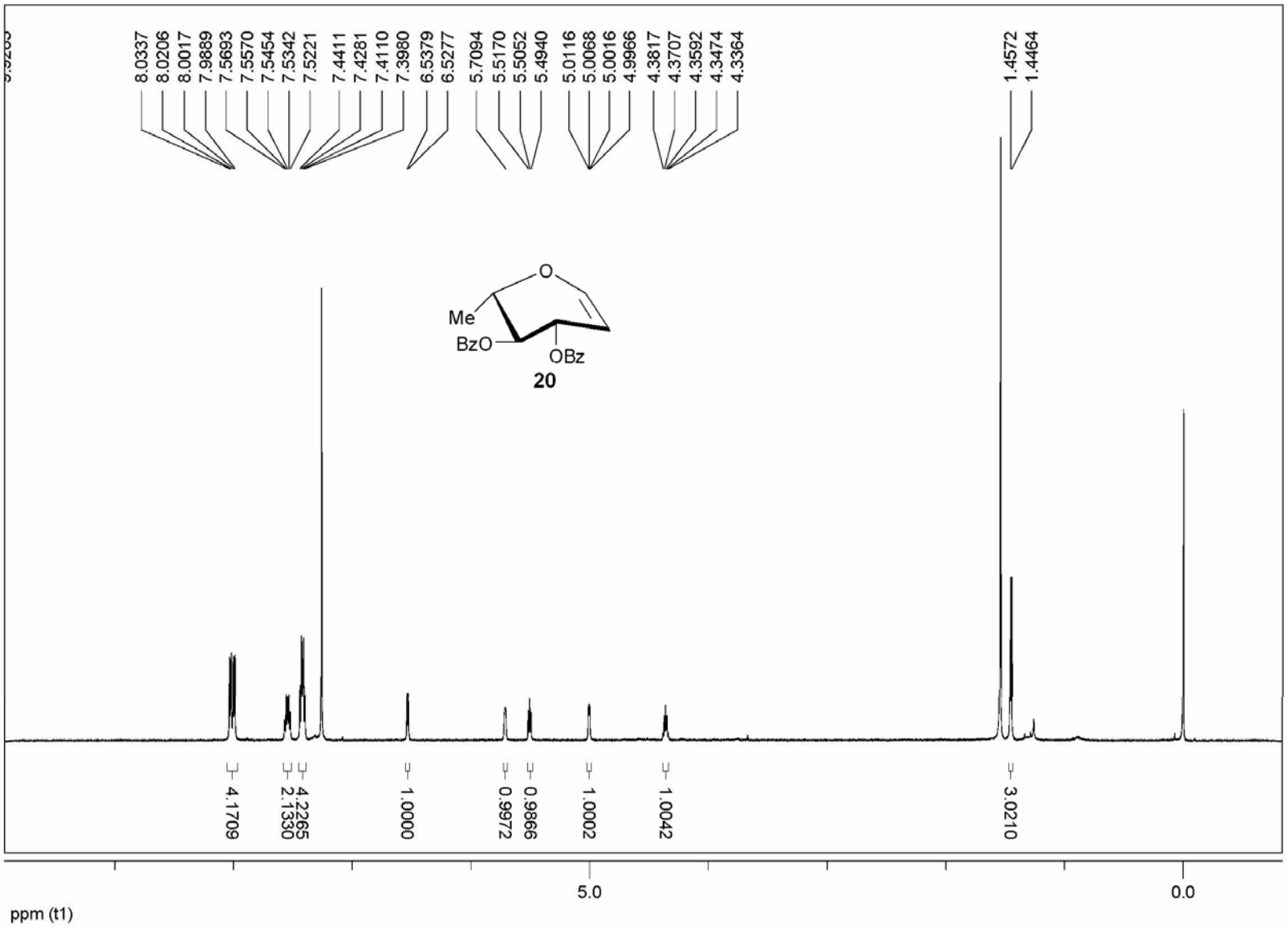


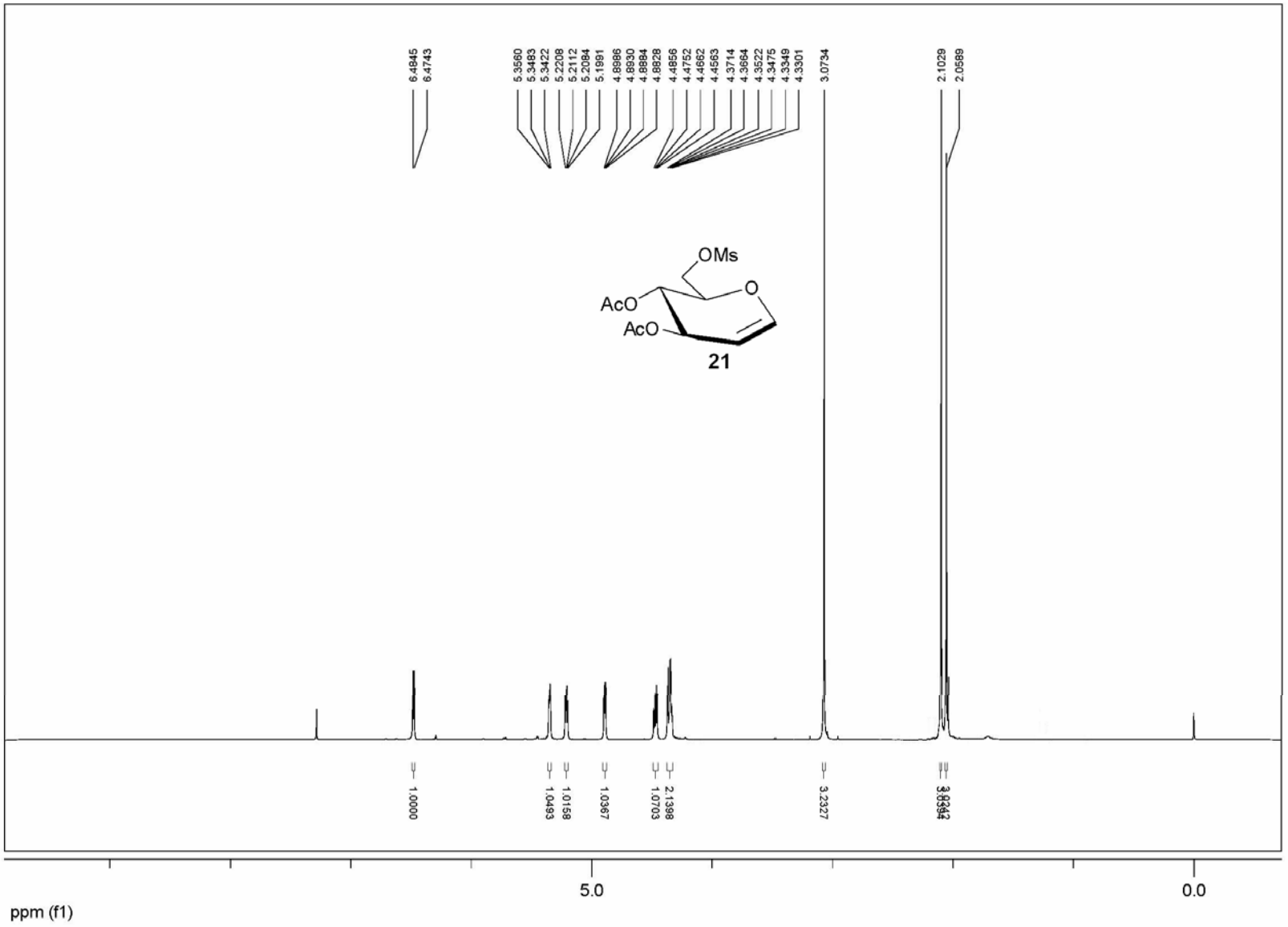


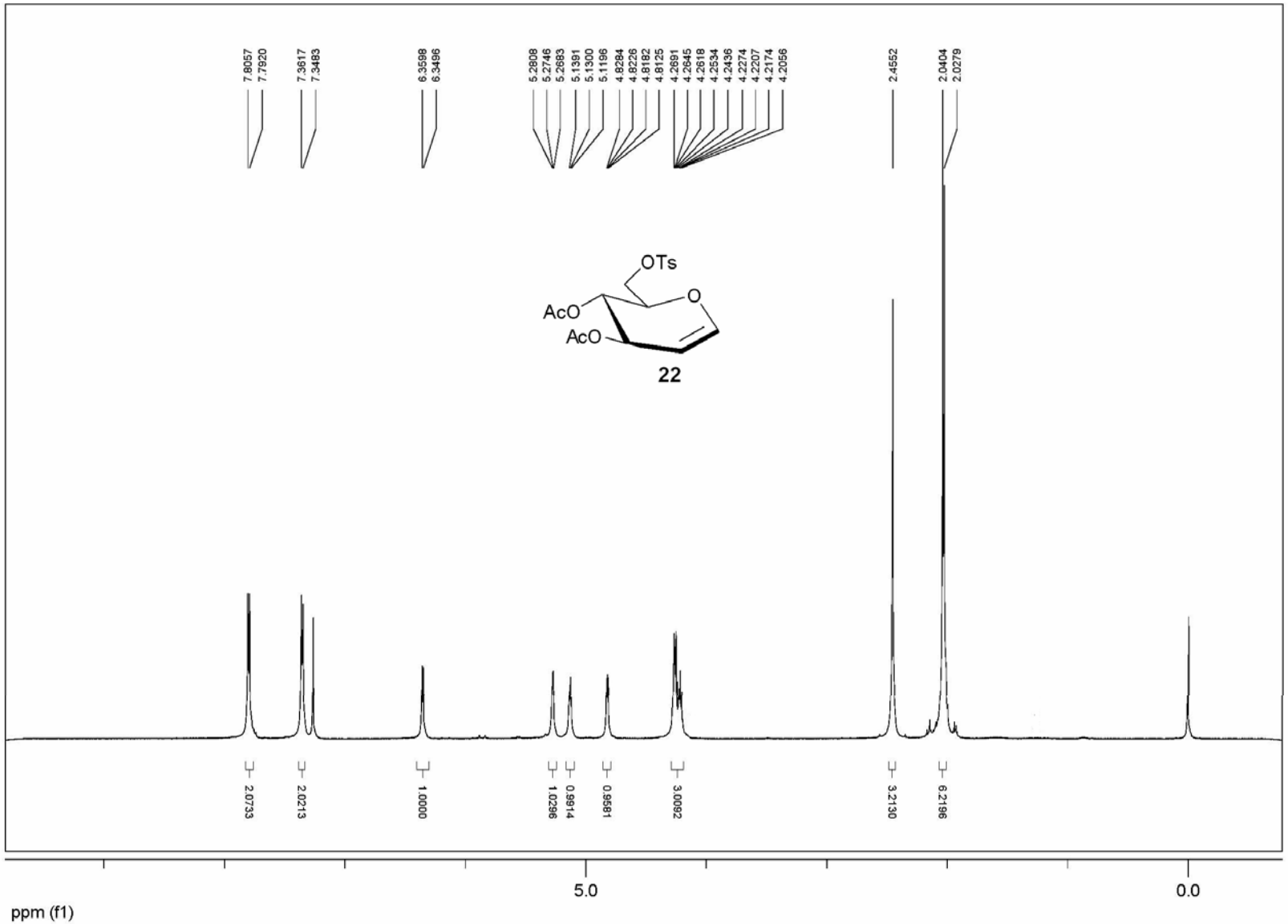


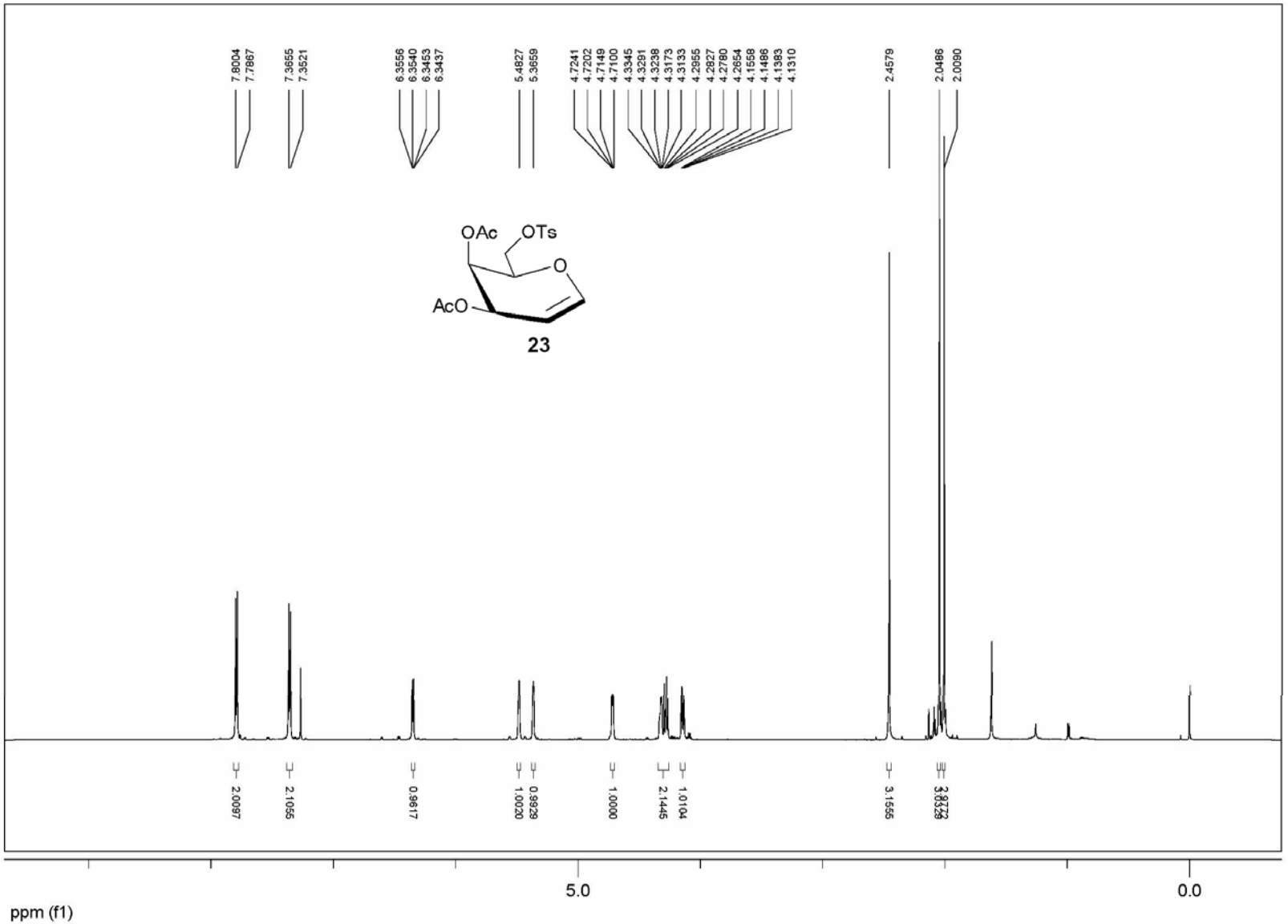


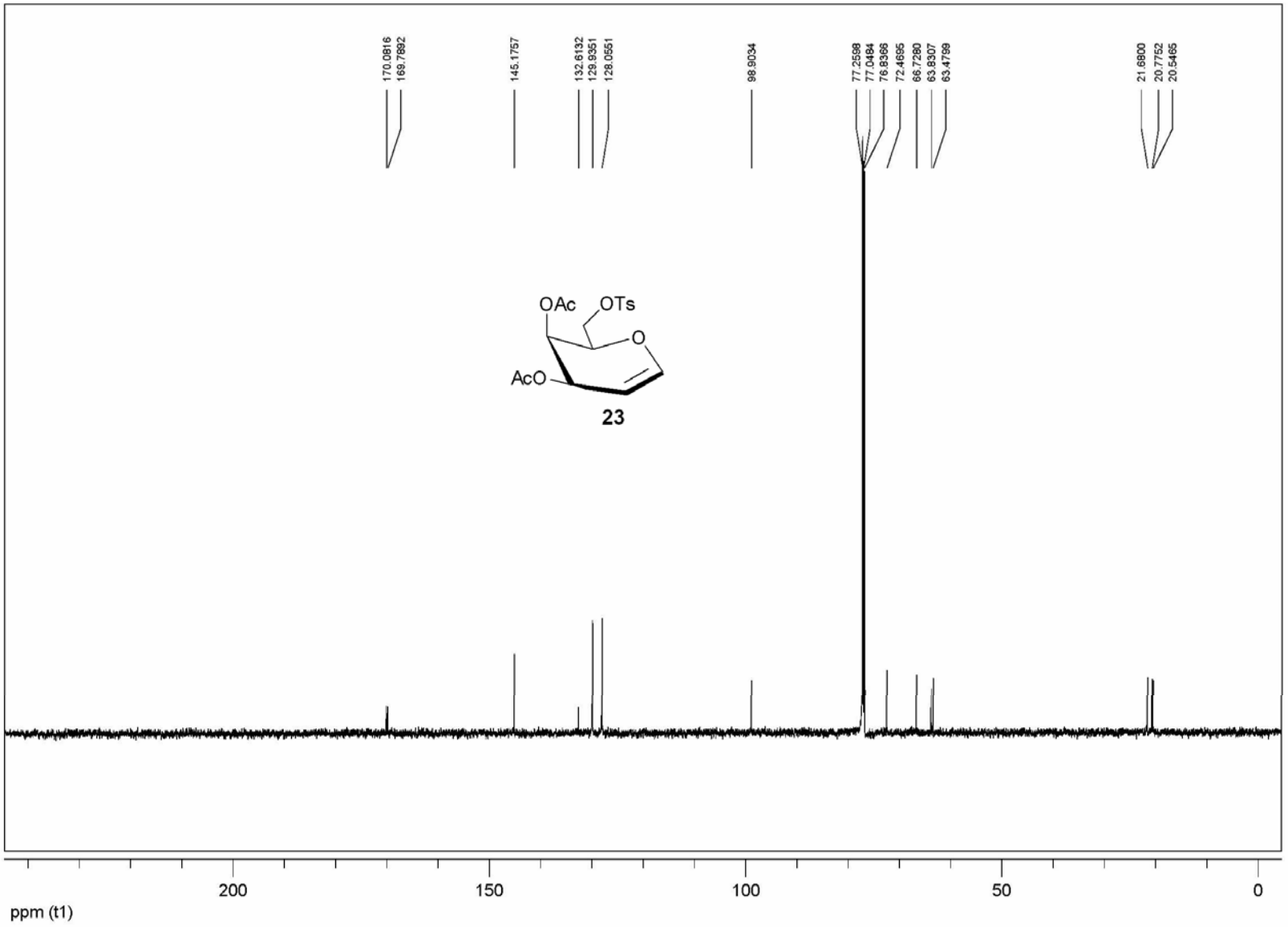


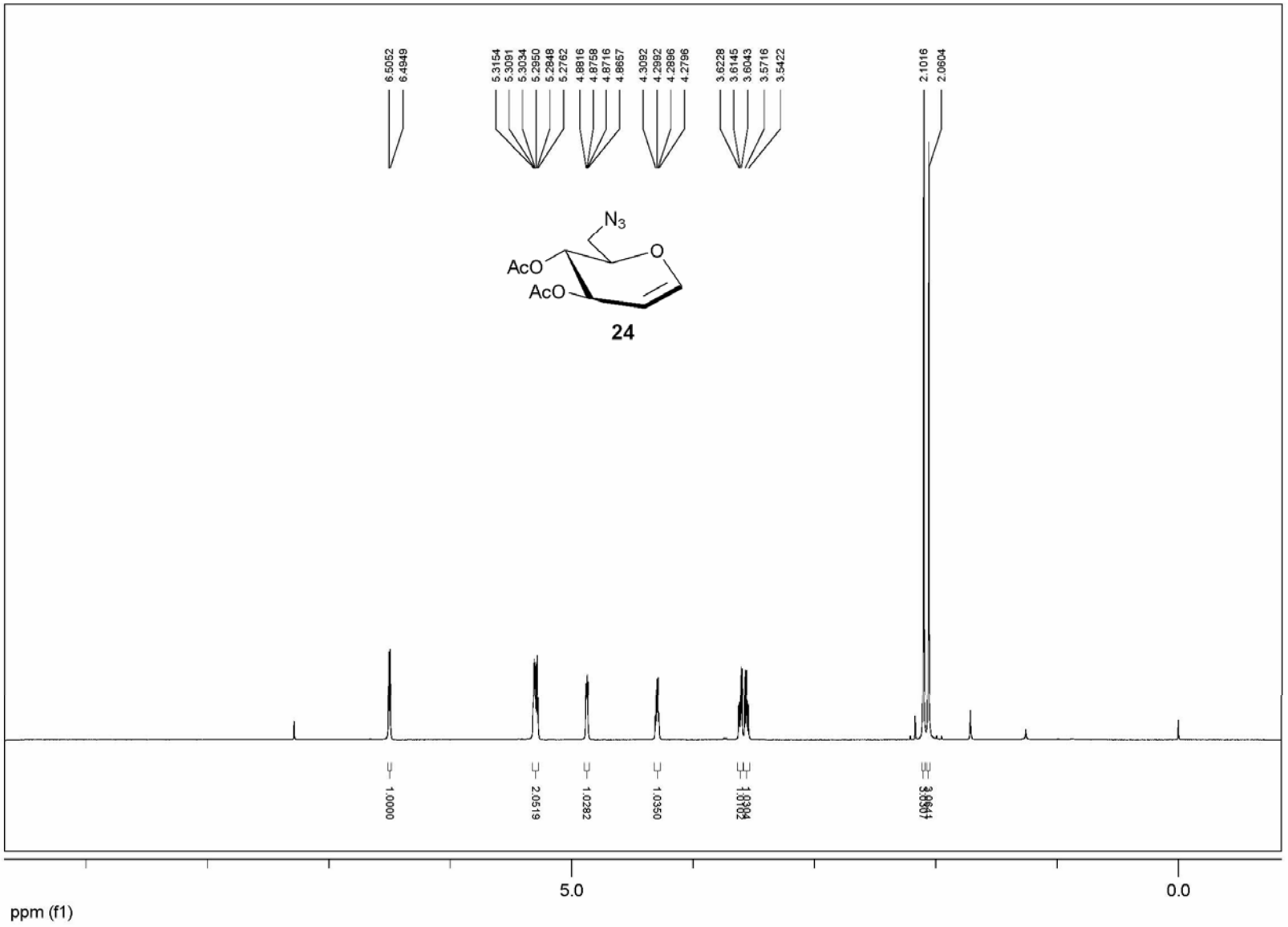


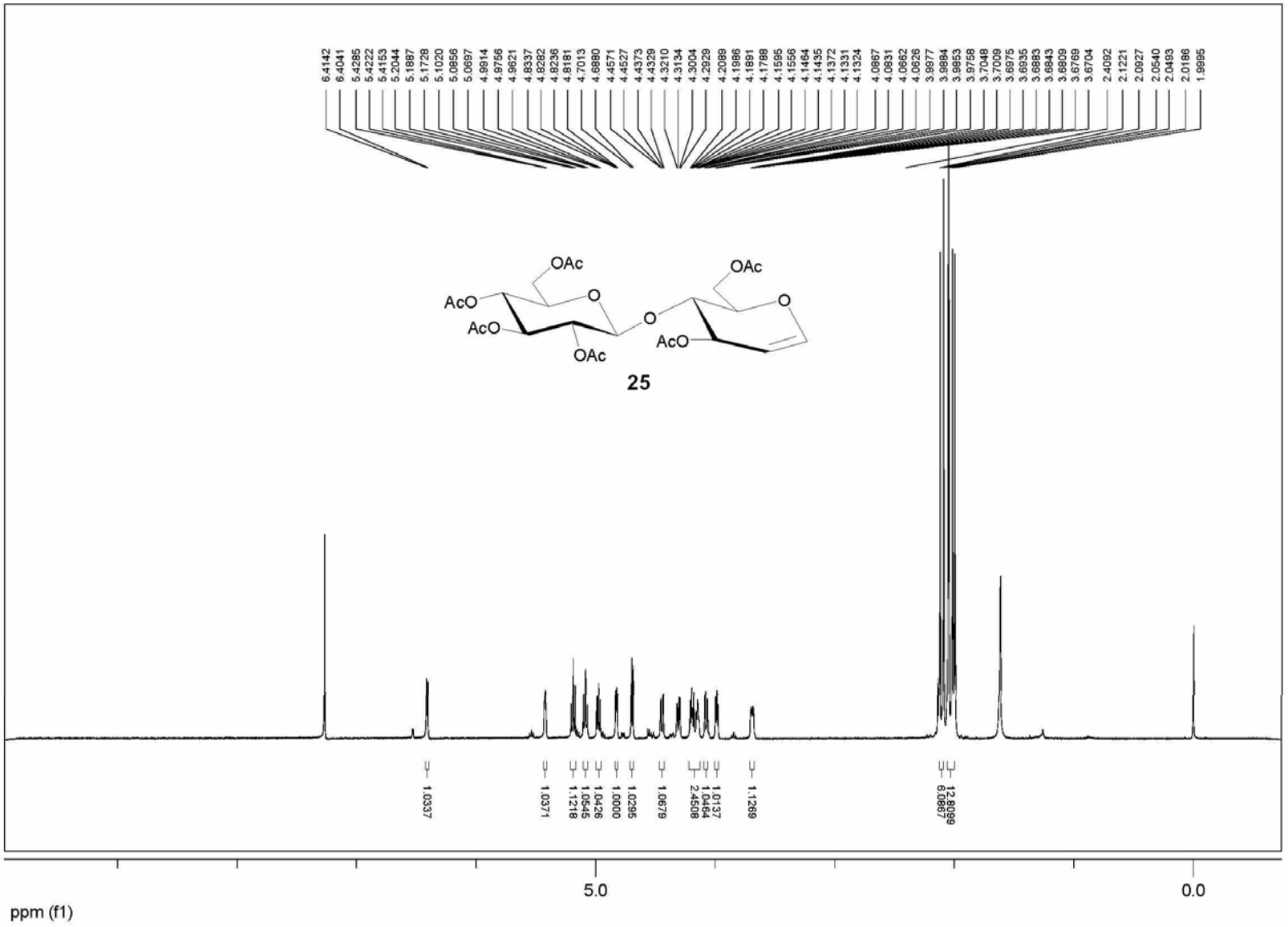


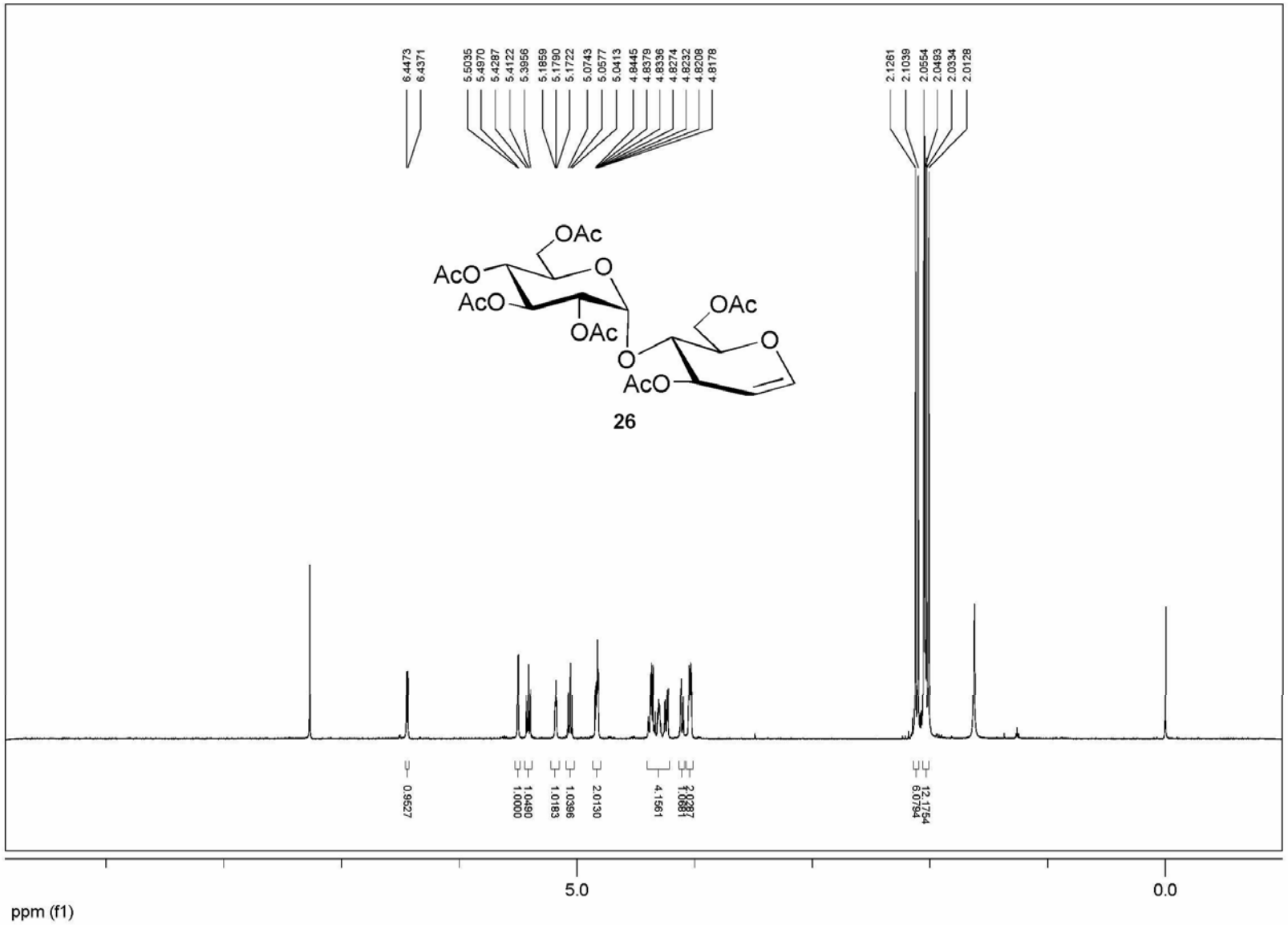


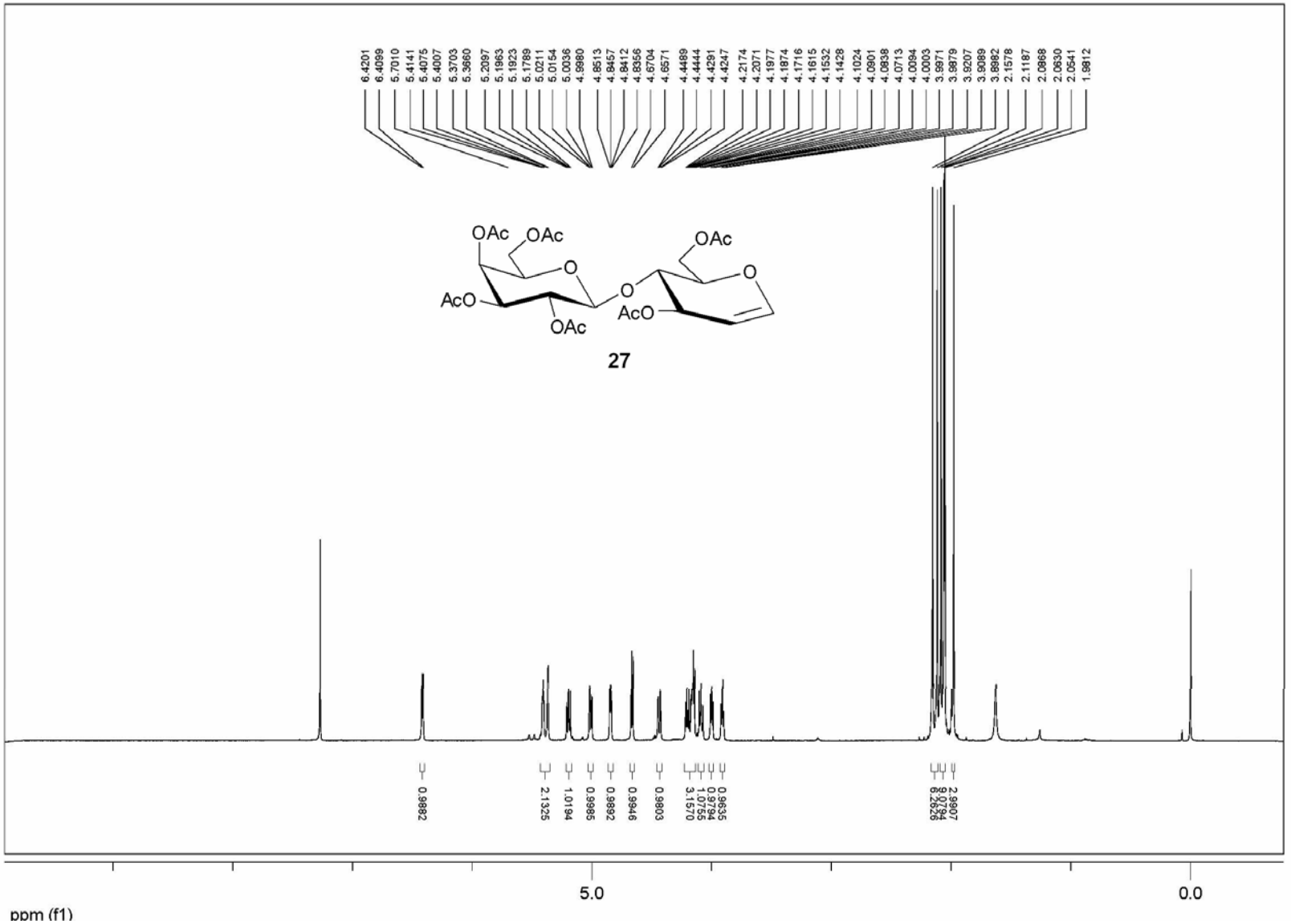

7.8004
7.7867
7.3655
7.3521
6.3556
6.3540
6.3453
6.3437
5.4827
5.3659
4.7241
4.7202
4.7149
4.7100
4.3345
4.3291
4.3238
4.3173
4.3133
4.2955
4.2827
4.2780
4.2654
4.1558
4.1486
4.1383
4.1310
2.4579
2.0486
2.0090
OAc
OTs
O
AcO
23
2.0097
2.1055
0.9617
1.0020
0.8929
1.0000
2.1445
1.0104
3.1555
5.0
0.0
ppm (f1)











Reference

[1] (a) Hunsen, M.; Long, D. A.; D'Ardenne, C. R.; Smith, A. L. *Carbohydr. Res.* **2005**, *340*, 2670-2674. (b) Cavallaro, C. L., Schwartz, J. *J. Org. Chem.* **1995**, *60*, 7055-7057. (c) Pollon, J. H. P.; Llewellyn, G.; Williams, J. M. *Synthesis* **1989**, 758-759. (d) Hansen, T.; Daasbjerg, K.; Skrydstrup, T. *Tetrahedron Lett.* **2000**, *41*, 8645-8649. (e) Boutureira, O.; Rodríguez, M. A.; Matheu, M. I.; Díaz , Y.; Castillón, S. *Org. Lett.* **2006**, *8*, 673-675. (f) Torii, S.; Inokuchi, T.; Masatsugu, Y. *Bull. Chem. Soc. Jpn.* **1985**,*58*, 3629-3630. (g) Maki, T.; Tejima, S. *Chem. Pharm. Bull.* **1967**, *15*, 1367-1372. (h) Mitchell, S. A.; Pratt, M. R.; Hruby, V. J.; Polt, R. *J. Org. Chem.* **2001**, *66*, 2327-2342.