

# Facile Synthesis of Saponins Containing 2,3-Branched Oligosaccharides by Using Partially Protected Glycosyl Donors

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**General Methods.** Optical rotations were determined at 20 °C with an automatic polarimeter. <sup>1</sup>H, <sup>13</sup>C NMR and <sup>1</sup>H-<sup>13</sup>C COSY spectra were recorded at 400 MHz in CDCl<sub>3</sub> or pyridine-*d*<sub>6</sub>. Chemical shifts are given in ppm downfield from internal Me<sub>4</sub>Si. Mass spectra were measured using MALTI-TOF-MS with dihydroxybenzoic acid (DHB) as matrix. Thin layer chromatography (TLC) was performed on silica gel HF<sub>254</sub> with detection by charring with 30% (v/v) H<sub>2</sub>SO<sub>4</sub> in MeOH or in some cases by a UV detector.

**Isopropyl 4,6-di-*O*-benzylidene-1-thio-β-D-galactopyranoside (3).**

To a solution of isopropyl 1-thio-β-D-galactopyranoside (2.0 g, 8.40 mmol) and PhCH(OMe)<sub>2</sub> (1.54 g, 10.1 mmol) in DMF (10 mL) at 0 °C was added catalytic amount of camphorsulfonic acid (CSA) until the pH of the solution reached pH 2-3. The reaction mixture was stirred at rt overnight, neutralized with triethylamine, diluted with ethyl acetate (100 mL), then washed with brine, dried over anhydrous MgSO<sub>4</sub>, and concentrated. Column chromatography of the crude product on a silica gel column (1:1 petroleum ether/EtOAc) gave **3** as a white solid (2.24 g, 82%); [α]<sup>20</sup><sub>D</sub> -62° (*c* 1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 1.34, 1.38 (2 d, 2×3 H, *J* = 6.9 Hz), 3.24-3.32 (m, 1 H), 3.53 (d, 1 H, *J* = 1.2 Hz), 3.68 (dd, 1 H, *J* = 9.3, 3.6 Hz), 3.77 (t, 1 H, *J* = 9.3 Hz), 4.02 (d, 1 H, *J* = 12.5 Hz), 4.24 (br s, 1 H), 4.33 (d, 1 H, *J* = 12.5 Hz), 4.40 (d, 1 H, *J* = 9.3 Hz), 5.53 (s, 1 H), 7.35-7.51 (m, 5 H). Anal. Calcd for C<sub>16</sub>H<sub>22</sub>O<sub>5</sub>S: C, 58.87; H, 6.79%. Found: C, 58.72; H, 6.85%.

**Isopropyl 3-*O*-fluorenylmethoxycarbonyl-4,6-di-*O*-benzylidene-1-thio-β-D-galactopyranoside (4).**

To a solution of compound **3** (2.15 g, 6.60 mmol) in pyridine (15 mL) at 0 °C was added FmocCl (2.05 g, 7.92 mmol) and catalytic amount of DMAP (60 mg). The reaction mixture was stirred at rt for 16 h, then co-evaporated with toluene under diminished pressure to remove pyridine. The residue was purified on a silica gel column with 4:1 petroleum ether/EtOAc as the eluent to afford **4** as a white solid (3.15 g, 87%); [α]<sup>20</sup><sub>D</sub> +31° (*c* 1.8, CHCl<sub>3</sub>); <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 1.36, 1.39 (2 d, 2×3 H, *J* = 6.9 Hz), 3.45-3.35 (m, 1 H), 3.53

(d, 1 H,  $J = 1.0$  Hz), 4.02 (dd, 1 H,  $J = 12.5, 1.7$  Hz), 4.12 (t, 1 H,  $J = 9.6$  Hz), 4.29 (t, 1 H,  $J = 7.6$  Hz), 4.34 (dd, 1 H,  $J = 12.5, 1.5$  Hz), 4.43-4.46 (m, 3 H), 4.49 (d, 1 H,  $J = 9.6$  Hz), 4.77 (dd, 1 H,  $J = 9.6, 3.5$  Hz), 5.50 (s, 1 H), 7.21-7.76 (m, 13 H). Anal. Calcd for  $C_{31}H_{32}O_7S$ : C, 67.86; H, 5.88%. Found: C, 67.99; H, 5.80%.

**Diosgenyl 3-*O*-fluorenylmethoxycarbonyl-4,6-di-*O*-benzylidene- $\beta$ -D-galactopyranoside (5).**

To a solution of compound **4** (1.1 g, 2.01 mmol) and diosgenin (833 mg, 2.01 mmol) in anhydrous  $CH_2Cl_2$  (10 mL), NIS (497 mg, 2.21 mmol) and catalytic amount of TMSOTf (36  $\mu$ L, 0.2 mmol) were added at  $-42$  °C under a  $N_2$  protection. The mixture was stirred under these conditions for 45 min, at the end of which time TLC indicated the reaction was complete. The reaction mixture was neutralized with  $Et_3N$  and concentrated to dryness. The residue was subject to column chromatography on a silica gel column with 5:1 petroleum ether/EtOAc as the eluent to give **5** as a white solid (1.34 g, 75%);  $[\alpha]_D^{20} -34^\circ$  ( $c$  1.3,  $CHCl_3$ ); Selected  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  0.79 (d, 6 H,  $J = 6.2$  Hz), 0.89-0.96 (m, 2 H), 0.97 (d, 3 H,  $J = 6.9$  Hz), 1.03 (s, 3 H), 1.04-2.38 (m, 22 H), 3.37 (t, 1 H,  $J = 10.9$  Hz), 3.46-3.50 (m, 2 H), 3.55-3.66 (m, 1 H), 4.04-4.09 (m, 2 H), 4.27-4.34 (m, 2 H), 4.35-4.50 (m, 5 H), 4.75 (dd, 1 H,  $J = 10.2, 3.7$  Hz), 5.34 (br d, 1 H,  $J = 5.6$  Hz), 5.51 (s, 1 H), 7.42-8.11 (13 H, *Ph*). Anal. Calcd for  $C_{55}H_{66}O_{10}$ : C, 74.47; H, 7.50%. Found: C, 74.69; H, 7.41%.

**Diosgenyl 2,3,4-tri-*O*-acetyl- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-3-*O*-fluorenylmethoxy-carbonyl-4,6-di-*O*-benzylidene- $\beta$ -D-galactopyranoside (6).**

To a mixture of compound **5** (443 mg, 0.50 mmol) and fully acetylated rhamnose imidate **9** (222 mg, 0.51 mmol) in anhydrous  $CH_2Cl_2$  (5 mL) at  $0$  °C was added TMSOTf (9  $\mu$ L, 0.05 mmol) under a  $N_2$  protection. The reaction mixture was stirred for 1 h, at the end of which time TLC indicated the completion of the reaction. The reaction was neutralized with  $Et_3N$ , concentrated, and subjected to a silica gel column with 4:1 petroleum ether/EtOAc as the eluent to give **6** as a white solid (510 mg, 88%);  $[\alpha]_D^{20} -74^\circ$  ( $c$  0.25,  $CHCl_3$ ); Selected  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  0.79 (d, 6 H,  $J = 4.3$  Hz), 0.95 (d, 3 H,  $J = 5.9$  Hz), 1.03 (s, 3 H), 1.23 (d,

3 H,  $J = 6.2$  Hz), 1.96, 2.01, 2.02 (3 s, 3×3 H), 3.38 (t, 1 H,  $J = 10.9$  Hz), 3.45-3.50 (m, 2 H), 3.61-3.72 (m, 1 H), 4.06 (d, 1 H,  $J = 11.7$  Hz), 4.17 (dd, 1 H,  $J = 9.9, 7.6$  Hz), 4.24-4.39 (m, 3 H), 4.40-4.45 (m, 2 H), 4.49-4.58 (m, 2 H), 4.61 (d, 1 H,  $J = 7.6$  Hz), 4.83 (dd, 1 H,  $J = 9.9, 3.6$  Hz), 5.08 (t, 1 H,  $J = 9.9$  Hz), 5.16 (d, 1 H,  $J = 1.4$  Hz), 5.25-5.30 (m, 2 H), 5.39 (d, 1 H,  $J = 5.0$  Hz), 5.50 (s, 1 H), 7.20-7.76 (m, 13 H). Anal. Calcd for C<sub>67</sub>H<sub>82</sub>O<sub>17</sub>: C, 69.41; H, 7.13%. Found: C, 69.63; H, 7.09%.

**Diosgenyl 2,3,4-tri-*O*-acetyl- $\alpha$ -L-rhamnopyranosyl-(1→2)-4,6-di-*O*-benzylidene- $\beta$ -D-galactopyranoside (7).**

To a solution of compound **6** (430 mg, 0.37 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (5 mL) was added triethylamine (1 mL, 7.2 mmol). The reaction mixture was stirred at rt for 2 h, concentrated to dryness under reduced pressure. Purification of the residue on a silica gel column (3:2 petroleum ether/EtOAc) furnished **7** as a foam (333 mg, 96%);  $[\alpha]^{20}_{\text{D}} -95^{\circ}$  ( $c$  0.75, CHCl<sub>3</sub>); Selected <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  0.79 (d, 6 H,  $J = 5.0$  Hz), 0.97 (d, 3 H,  $J = 6.9$  Hz), 1.07 (s, 3 H), 1.21 (d, 3 H,  $J = 6.2$  Hz), 1.98, 2.00, 2.12 (3 s, 3×3 H), 3.37 (t, 1 H,  $J = 10.9$  Hz), 3.45-3.50 (m, 2 H), 3.58-3.67 (m, 1 H), 3.75-3.85 (m, 2 H), 4.07 (d, 1 H,  $J = 12.3$  Hz), 4.16 (d, 1 H,  $J = 2.4$  Hz), 4.31 (d, 1 H,  $J = 12.4$  Hz), 4.41 (q, 1 H,  $J = 7.5$  Hz), 4.47-4.54 (m, 2 H), 5.07 (t, 1 H,  $J = 10.0$  Hz), 5.28 (dd, 1 H,  $J = 10.0, 3.4$  Hz), 5.32 (d, 1 H,  $J = 1.6$  Hz), 5.36 (dd, 1 H,  $J = 3.4, 1.6$  Hz), 5.39 (d, 1 H,  $J = 5.0$  Hz), 5.54 (s, 1 H), 7.36-7.51 (m, 5 H). Anal. Calcd for C<sub>52</sub>H<sub>72</sub>O<sub>15</sub>: C, 66.65; H, 7.74%. Found: C, 66.93; H, 7.67%.

**Isopropyl 2,3,4,6-tetra-*O*-benzoyl- $\beta$ -D-glucopyranosyl-(1→3)-4,6-di-*O*-benzylidene-1-thio- $\beta$ -D-galactopyranoside (12).**

To a mixture of compound **3** (326 mg, 1.0 mmol), fully benzoylated glucose imidate **10** (760 mg, 1.02 mmol), and 4 Å MS (150 mg) in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (6 mL) at 0 °C was added TMSOTf (18  $\mu$ L, 0.1 mmol) under a N<sub>2</sub> protection. The reaction mixture was stirred for 1 h, neutralized with Et<sub>3</sub>N, and filtered. The filtrates were concentrated, and the residue was subjected to a silica gel column with 4:1 petroleum ether/EtOAc as the eluent to afford **12** as a foam (776 mg, 86%);  $[\alpha]^{20}_{\text{D}} -87^{\circ}$  ( $c$  0.25, CHCl<sub>3</sub>); <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  1.25, 1.31 (2 d, 2×3 H,  $J = 6.9$  Hz), 3.14-3.21 (m, 1 H), 3.27 (br s, 1 H), 3.75 (dd, 1 H,  $J = 9.4, 3.2$

Hz), 3.83 (dd, 1 H,  $J = 11.8, 1.3$  Hz), 3.90 (t, 1 H,  $J = 9.4$  Hz), 4.16-4.24 (m, 2 H), 4.25 (d, 1 H,  $J = 3.2$  Hz), 4.33 (d, 1 H,  $J = 9.4$  Hz), 4.54 (dd, 1 H,  $J = 12.2, 5.7$  Hz), 4.68 (dd, 1 H,  $J = 12.2, 2.8$  Hz), 5.39 (s, 1 H), 5.40 (d, 1 H,  $J = 7.8$  Hz), 5.58 (t, 1 H,  $J = 9.6, 7.8$  Hz), 5.68 (t, 1 H,  $J = 9.6$  Hz), 5.92 (t, 1 H,  $J = 9.6$  Hz), 7.25-7.94 (m, 25 H). Anal. Calcd for  $C_{50}H_{48}O_{14}S$ : C, 66.36; H, 5.35%. Found: C, 66.57; H, 5.28%.

**Isopropyl 2,3,4,6-tetra-*O*-benzoyl- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-2-*O*-acetyl-4,6-di-*O*-benzylidene-1-thio- $\beta$ -D-galactopyranoside (12a).**

To a solution of compound **12** (54 mg, 0.06 mmol) in pyridine (1 mL) was added  $Ac_2O$  (0.5 mL). The reaction mixture was stirred at rt for 3 h, then co-evaporated with toluene under diminished pressure to remove pyridine, and purified the residue by silica-gel column chromatography (2:1 petroleum ether–EtOAc) to give quantitative yield of **12a** as a syrup;  $[\alpha]^{20}_D +9^\circ$  ( $c$  0.5,  $CHCl_3$ );  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  1.15, 1.33 (2 d, 2 $\times$ 3 H,  $J = 6.9$  Hz), 1.49 (s, 3 H), 3.15-3.27 (m, 2 H), 3.70-3.79 (m, 2 H), 4.09-4.21 (m, 2 H), 4.32-4.37 (m, 2 H), 4.56 (dd, 1 H,  $J = 12.2, 5.1$  Hz), 4.73 (dd, 1 H,  $J = 12.2, 2.9$  Hz), 5.08 (d, 1 H,  $J = 7.6$  Hz), 5.31 (t, 1 H,  $J = 9.6$  Hz), 5.39 (s, 1 H), 5.52 (dd, 1 H,  $J = 9.6, 7.6$  Hz), 5.68 (t, 1 H,  $J = 9.6$  Hz), 5.92 (t, 1 H,  $J = 9.6$  Hz), 7.25-7.94 (m, 25 H). Anal. Calcd for  $C_{52}H_{50}O_{15}S$ : C, 65.95; H, 5.32%. Found: C, 66.13; H, 5.38%.

**Diosgenyl 2,3,4,6-tetra-*O*-benzoyl- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-4,6-di-*O*-benzylidene- $\beta$ -D-galactopyranoside (13).**

To a solution of compound **12** (452 mg, 0.50 mmol) and diosgenin (207 mg, 0.50 mmol) in anhydrous dichloromethane (8 mL), NIS (124 mg, 0.55 mmol) and catalytic amount of TMSOTf (11  $\mu$ L, 0.06 mmol) were added at  $-42^\circ C$  under a  $N_2$  protection. The reaction mixture was stirred under these conditions for 45 min, at the end of which time TLC indicated the completion of the reaction. The mixture was then neutralized with  $Et_3N$ , and concentrated. The residue was subject to column chromatography on a silica gel column with 3:1 petroleum ether/EtOAc as the eluent to give **13** as a white solid (391 mg, 63%);  $[\alpha]^{20}_D -24^\circ$  ( $c$  1,  $CHCl_3$ ); Selected  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  0.79 (d, 6 H,  $J = 6.3$  Hz), 0.97 (d, 3 H,  $J = 6.9$  Hz), 1.00 (s, 3 H), 3.23 (br s, 1 H), 3.37 (t, 1 H,  $J = 10.9$  Hz), 3.45-3.57 (m, 2 H),

3.74 (dd, 1 H,  $J = 9.6, 3.3$  Hz), 3.81-3.88 (m, 2 H), 4.15-4.22 (m, 3 H), 4.33 (d, 1 H,  $J = 7.6$  Hz), 4.39 (q, 1 H,  $J = 7.5$  Hz), 4.53 (dd, 1 H,  $J = 12.2, 5.3$  Hz), 4.68 (dd, 1 H,  $J = 12.2, 3.0$  Hz), 5.32 (d, 1 H,  $J = 5.0$  Hz), 5.38 (d, 1 H,  $J = 7.9$  Hz), 5.40 (s, 1 H), 5.57 (dd, 1 H,  $J = 9.6, 7.9$  Hz), 5.69 (t, 1 H,  $J = 9.6$  Hz), 5.91 (t, 1 H,  $J = 9.6$  Hz), 7.25-8.05 (m, 25 H). Anal. Calcd for  $C_{74}H_{82}O_{17}$ : C, 71.48; H, 6.65%. Found: C, 71.69; H, 6.48%.

**Diosgenyl 2,3,4,6-tetra-*O*-benzoyl- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-[2,3,4-tri-*O*-acetyl- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)]-4,6-di-*O*-benzylidene- $\beta$ -D-galactopyranoside (8).**

The mixture of compound **13** (323 mg, 0.26 mmol) and fully acetylated rhamnose imidate **9** (126 mg, 0.29 mmol) was dissolved in anhydrous  $CH_2Cl_2$  (4 mL). To the solution was added TMSOTf (5.5  $\mu$ L, 0.03 mmol) at 0 °C under a  $N_2$  protection. The reaction mixture was stirred for 1.5 h, neutralized with  $Et_3N$ , and concentrated to dryness. Purification of the residue by silica-gel column chromatography with 3:1 petroleum ether/EtOAc as the eluent to afford **8** as a foam (329 mg, 84%);  $[\alpha]_D^{20} -44^\circ$  ( $c$  1,  $CHCl_3$ ); Selected  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  0.79 (d, 6 H,  $J = 6.3$  Hz), 0.97 (d, 3 H,  $J = 6.9$  Hz), 1.01 (s, 3 H), 1.10 (d, 3 H,  $J = 5.9$  Hz), 2.02 (s, 3 H), 2.08 (s, 6 H), 3.20 (br s, 1 H), 3.38 (t, 1 H,  $J = 10.9$  Hz), 3.45-3.62 (m, 2 H), 3.91-4.06 (m, 2 H), 4.07 (dd, 1 H,  $J = 9.6, 3.6$  Hz), 4.18-4.22 (m, 2 H), 4.25-4.30 (m, 1 H), 4.37 (d, 1 H,  $J = 7.7$  Hz), 4.39-4.47 (m, 2 H), 4.56 (dd, 1 H,  $J = 12.3, 4.2$  Hz), 4.73 (dd, 1 H,  $J = 12.2, 3.3$  Hz), 5.06 (t, 1 H,  $J = 10.0$  Hz), 5.23 (br s, 1 H), 5.27 (d, 1 H,  $J = 7.8$  Hz), 5.34 (dd, 1 H,  $J = 10.0, 3.6$  Hz), 5.36-3.91 (m, 3 H), 5.55 (dd, 1 H,  $J = 9.4, 7.8$  Hz), 5.78 (t, 1 H,  $J = 9.4$  Hz), 5.91 (t, 1 H,  $J = 9.4$  Hz), 7.20-8.09 (m, 25 H); Selected  $^{13}C$  NMR ( $CDCl_3$ ):  $\delta$  14.5, 16.2, 17.1 (2 C), 19.2, 20.8 (3 C), 28.8, 29.4, 30.2, 31.3, 31.4, 31.8, 32.1, 36.9, 37.2, 38.2, 39.7, 40.2, 41.6, 50.1, 56.2, 56.5, 62.1, 62.6, 66.2, 66.3, 66.8, 68.9, 69.0, 69.7, 70.1, 71.4, 72.2, 72.4, 72.9, 73.0, 75.8, 76.9, 77.6, 80.8, 96.8 (C-1<sup>II</sup>), 98.9 (C-1<sup>I</sup>), 99.1 (C-1<sup>III</sup>), 100.4, 109.2, 121.6, 140.5, 165.2, 165.4, 165.5, 165.9, 169.98, 170.05, 170.4. Anal. Calcd for  $C_{86}H_{98}O_{24}$ : C, 68.15; H, 6.52%. Found: C, 68.41; H, 6.46%.

**Diosgenyl  $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-[ $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)]- $\beta$ -D-galactopyranoside (1).**

A solution of compound **8** (256 mg, 0.17 mmol) in 80% AcOH (20 mL) was stirred at 70

°C for 3 h. The solvent was removed under reduced pressure to give a residue, which was dissolved in a solution of MeOH-CH<sub>2</sub>Cl<sub>2</sub> (2:1, 9 mL). To the above solution was added aqueous 1 N NaOH until pH 9-10 was reached. The reaction mixture was stirred at rt for 6 h, then neutralized with Amberlite IR-120 (H<sup>+</sup>). The solvents were filtered, and the filtrate was concentrated. The residue was subjected to a silica gel column with CH<sub>2</sub>Cl<sub>2</sub>/MeOH (5:2) as the eluent to give **1** as a white solid (122 mg, 81%); Selected <sup>1</sup>H NMR (pyridine-*d*<sub>6</sub>): δ 0.69 (d, 3 H, *J* = 5.1 Hz), 0.86 (s, 3 H), 1.04 (s, 3 H), 1.13 (d, 3 H, *J* = 6.9 Hz), 1.69 (d, 3 H, *J* = 6.1 Hz), 3.49-3.60 (m, 2 H), 3.92-4.04 (m, 4 H), 4.18-4.26 (m, 3 H), 4.27-4.40 (m, 4 H), 4.47 (dd, 1 H, *J* = 11.8, 2.2 Hz), 4.52 (q, 1 H, *J* = 7.5 Hz), 4.60 (dd, 1 H, *J* = 9.2, 3.2 Hz), 4.68 (t, 1 H, *J* = 8.0 Hz), 4.80 (d, 1 H, *J* = 2.4 Hz), 4.90-4.92 (m, 2 H), 4.94 (d, 1 H, *J* = 7.9 Hz), 5.20 (d, 1 H, *J* = 7.8 Hz), 5.32 (d, 1 H, *J* = 4.2 Hz), 6.30 (s, 1 H). MALDITOF-MS found for C<sub>45</sub>H<sub>72</sub>O<sub>17</sub>: 907.5 [M + Na]<sup>+</sup>. Anal. Calcd for C<sub>45</sub>H<sub>72</sub>O<sub>17</sub>: C, 61.07; H, 8.20%. Found: C, 60.92; H, 8.32%.

#### **General procedure for preparation of compounds 16, 19, 24 and 27.**

To a mixture of glycosyl acceptor (0.10 mmol), glycosyl donor (0.1 mmol), and 4 Å MS in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (3 mL) at 0 °C was added TMSOTf (2 µL, 0.01 mmol) under a N<sub>2</sub> protection. The reaction mixture was stirred for 2 h, at the end of which time TLC indicated glycosyl donor was completely consumed. The reaction mixture was neutralized with Et<sub>3</sub>N, and filtered. The filtrates were concentrated, and the crude product was then dissolved in pyridine-acetic anhydride (1.5 mL, v/v 2:1). The resulting mixture was stirred at rt for 2 h, then co-evaporated with toluene under reduced pressure to remove pyridine. Purification of the residue by silica-gel column chromatography (3:1~2:1 petroleum ether–EtOAc) gave desired products.

#### **Isopropyl 2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl-(1→2)-3-*O*-acetyl-4,6-di-*O*-bezyldiene-1-thio-β-D-galactopyranoside (16)**

Yield: 54%; [α]<sup>20</sup><sub>D</sub> -23° (*c* 0.5, CHCl<sub>3</sub>); <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 1.30, 1.37 (2 d, 2×3 H, *J* = 6.9 Hz), 2.00, 2.01, 2.03, 2.16 (4 s, 4×3 H), 3.27-3.40 (m, 2 H), 3.48 (br s, 1 H), 3.99 (dd, 1 H, *J* = 12.5, 1.6 Hz), 4.16 (t, 1 H, *J* = 9.6 Hz), 4.25 (dd, 1 H, *J* = 12.1, 5.1 Hz), 4.31 (dd, 1 H, *J*



= 12.5, 1.3 Hz), 4.34 (d, 1 H,  $J = 3.5$  Hz), 4.52 (d, 1 H,  $J = 9.6$  Hz), 4.83 (d, 1 H,  $J = 6.9$  Hz), 4.93 (dd, 1 H,  $J = 9.6, 3.5$  Hz), 4.96 (dd, 1 H,  $J = 8.7, 6.9$  Hz), 4.98-5.04 (m, 1 H), 5.10 (t, 1 H,  $J = 8.7$  Hz), 5.46 (s, 1 H), 7.36-7.52 (m, 5 H). Anal. Calcd for  $C_{29}H_{38}O_{13}S$ : C, 55.58; H, 6.11%. Found: C, 55.26; H, 6.21%.

**Isopropyl 2,3,4-tri-*O*-benzoyl- $\beta$ -D-xylopyranosyl-(1 $\rightarrow$ 2)-3-*O*-acetyl-4,6-di-*O*-benzylidene-1-thio- $\beta$ -D-galactopyranoside (19).**

Yield: 65%;  $[\alpha]_D^{20} -38^\circ$  ( $c$  0.75,  $CHCl_3$ );  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  1.35, 1.44 (2 d,  $2 \times 3$  H,  $J = 6.9$  Hz), 1.99 (s, 3 H), 3.38-3.45 (m, 1 H), 3.48 (br s, 1 H), 3.84 (dd, 1 H,  $J = 12.9, 4.2$  Hz), 3.98 (dd, 1 H,  $J = 12.4, 1.4$  Hz), 4.28-4.35 (m, 2 H), 4.40 (d, 1 H,  $J = 3.4$  Hz), 4.58 (d, 1 H,  $J = 9.6$  Hz), 4.86 (dd, 1 H,  $J = 9.5, 3.4$  Hz), 4.90 (dd, 1 H,  $J = 12.9, 3.4$  Hz), 5.28 (d, 1 H,  $J = 3.9$  Hz), 5.29-5.35 (m, 2 H), 5.58 (s, 1 H), 5.68 (t, 1 H,  $J = 5.7$  Hz), 7.27-8.09 (m, 20 H). Anal. Calcd for  $C_{44}H_{44}O_{13}S$ : C, 65.01; H, 5.46%. Found: C, 65.36; H, 5.38%.

**Isopropyl 2,3,4,6-tetra-*O*-benzoyl- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-2-*O*-chloroacetyl-4,6-di-*O*-benzylidene-1-thio- $\beta$ -D-glucopyranoside (24).**

Yield: 83%;  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  1.23, 1.25 (2 d,  $2 \times 3$  H,  $J = 6.9$  Hz), 3.09-3.12 (m, 1 H), 3.46-3.52 (m, 1 H), 3.69-3.89 (m, 5 H), 4.10 (t, 1 H,  $J = 9.1$  Hz), 4.27 (dd, 1 H,  $J = 12.1, 4.2$  Hz), 4.31 (d, 1 H,  $J = 10.5, 4.9$  Hz), 4.47 (dd, 1 H,  $J = 12.1, 3.4$  Hz), 4.51 (d, 1 H,  $J = 10.2$  Hz), 5.07 (t, 1 H,  $J = 9.1$  Hz), 5.10 (d, 1 H,  $J = 7.8$  Hz), 5.47 (dd, 1 H,  $J = 9.6, 7.8$  Hz), 5.61 (s, 1 H), 5.65 (t, 1 H,  $J = 9.6$  Hz), 5.82 (t, 1 H,  $J = 9.6$  Hz), 7.36-7.52 (m, 5 H). Anal. Calcd for  $C_{52}H_{49}ClO_{15}S$ : C, 63.64; H, 5.03%. Found: C, 63.91; H, 4.95%.

**Diosgenyl 2,3,4-tri-*O*-acetyl- $\beta$ -D-xylopyranosyl-(1 $\rightarrow$ 2)-3-*O*-acetyl-4,6-di-*O*-benzylidene-1-thio- $\beta$ -D-galactopyranoside (27).**

Yield: 51%;  $[\alpha]_D^{20} -242^\circ$  ( $c$  0.25,  $CHCl_3$ ); Selected  $^1H$  NMR ( $CDCl_3$ ):  $\delta$  0.79 (d, 6 H,  $J = 6.1$  Hz), 0.97 (d, 3 H,  $J = 6.9$  Hz), 1.03 (s, 3 H), 2.00, 2.02, 2.07, 2.11 (4 s,  $4 \times 3$  H), 3.34-3.50 (m, 4 H), 3.53-3.61 (m, 1 H), 4.01 (dd, 1 H,  $J = 11.4, 1.4$  Hz), 4.07 (dd, 1 H,  $J = 10.1, 7.7$  Hz), 4.23-4.33 (m, 3 H), 4.40 (q, 1 H,  $J = 7.4$  Hz), 4.53 (d, 1 H,  $J = 7.7$  Hz), 4.82-4.98 (m, 4 H), 5.09 (t, 1 H,  $J = 7.9$  Hz), 5.34 (br d, 1 H,  $J = 5.3$  Hz), 5.46 (s, 1 H),

7.34-7.50 (m, 5 H). Anal. Calcd for C<sub>53</sub>H<sub>72</sub>O<sub>16</sub>: C, 65.96; H, 7.52%. Found: C, 66.28; H, 7.55%.

**Diosgenyl 4,6-di-*O*-benzylidene-1-thio-β-D-galactopyranoside (25).**

To a solution of compound **5** (150 mg, 0.17 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (3 mL) was added triethylamine (0.5 mL, 3.6 mmol). The reaction mixture was stirred at rt for 2 h, concentrated to dryness under diminished pressure. Purification of the residue on a silica gel column (1:1 petroleum ether/EtOAc) furnished **25** as a white solid (108 mg, 97%);  $[\alpha]_D^{20}$  -133° (*c* 0.5, CHCl<sub>3</sub>); <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 0.78-0.80 (m, 6 H), 0.89-0.96 (m, 2 H), 0.97 (d, 3 H, *J* = 6.9 Hz), 1.03 (s, 3 H), 1.04-2.38 (m, 22 H), 3.37 (t, 1 H, *J* = 10.9 Hz), 3.46-3.50 (m, 2 H), 3.58-3.66 (m, 1 H), 3.67-3.75 (m, 2 H), 4.07 (dd, 1 H, *J* = 12.5, 1.5 Hz), 4.20 (d, 1 H, *J* = 2.6 Hz), 4.31 (dd, 1 H, *J* = 12.5, 1.0 Hz), 4.02-4.45 (m, 2 H), 5.36 (d, 1 H, *J* = 5.1 Hz), 5.54 (s, 1 H), 7.35-7.52 (m, 5 H). Anal. Calcd for C<sub>40</sub>H<sub>56</sub>O<sub>8</sub>: C, 72.26; H, 8.49%. Found: C, 72.41; H, 8.38%.

**Diosgenyl 2,3,4-tri-*O*-benzoyl-β-D-xylopyranosyl-(1→3)-[2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl-(1→2)]-4,6-di-*O*-benzylidene-β-D-galactopyranoside (28).**

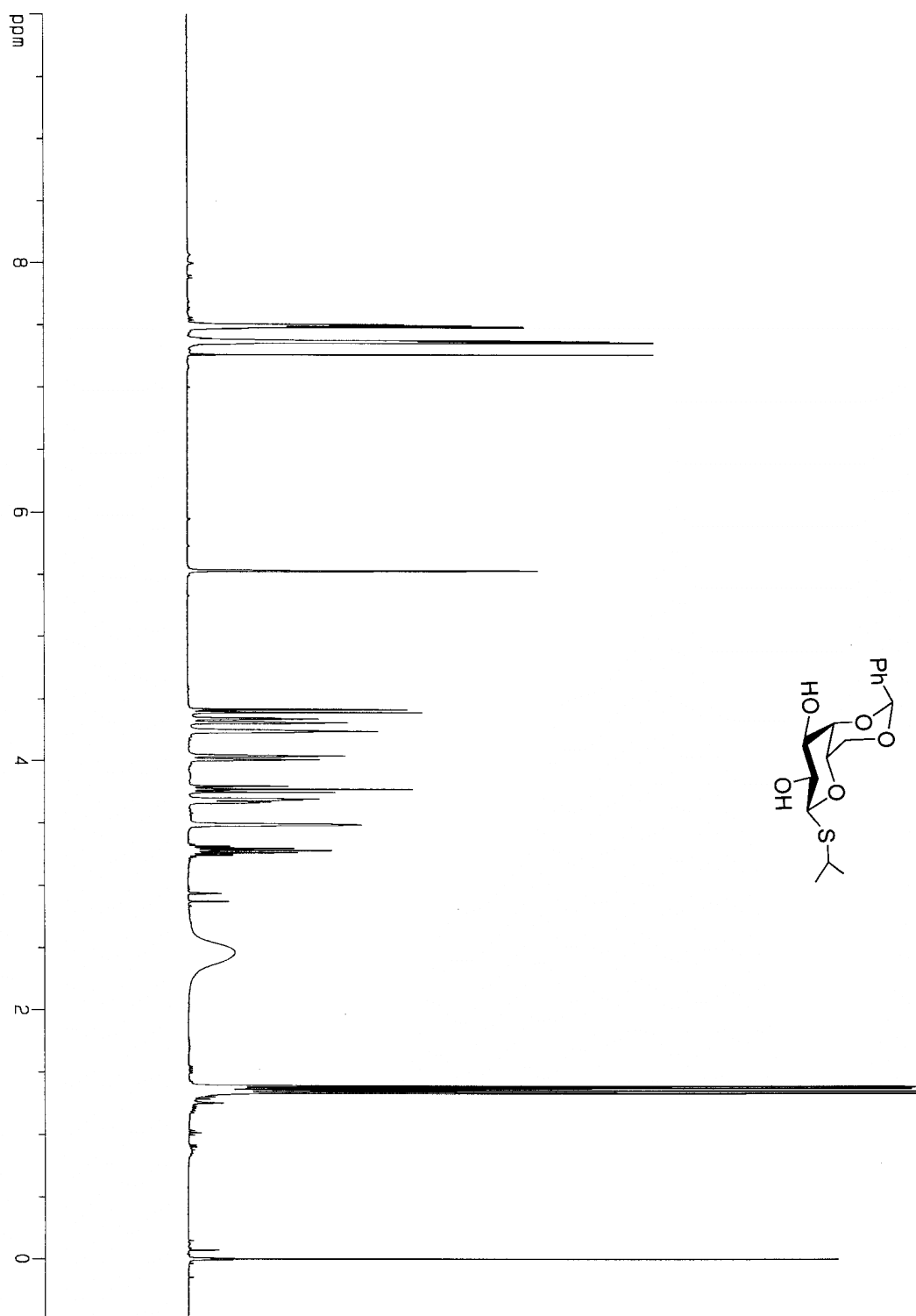
The mixture of compound **7** (206 mg, 0.22 mmol) and fully benzoylated xylose imidate **17** (150 mg, 0.25 mmol) was dissolved in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (4 mL). To the solution was added TMSOTf (5 μL, 0.03 mmol) at 0 °C under a N<sub>2</sub> protection. The reaction mixture was stirred for 2 h, neutralized with Et<sub>3</sub>N, and concentrated to dryness. The residue was subjected to a silica gel column with 3:1 petroleum ether/EtOAc as the eluent to give **28** as a foam (238 mg, 78%);  $[\alpha]_D^{20}$  -102° (*c* 0.5, CHCl<sub>3</sub>); Selected <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 0.78 (d, 6 H, *J* = 4.9 Hz), 0.96 (d, 3 H, *J* = 6.9 Hz), 1.02 (s, 3 H), 1.10 (d, 3 H, *J* = 6.1 Hz), 1.87, 1.94, 2.03 (3 s, 3×3 H), 3.36 (t, 1 H, *J* = 10.9 Hz), 3.40-3.48 (m, 2 H), 3.54-3.62 (m, 1 H), 3.85 (dd, 1 H, *J* = 12.9, 1.1 Hz), 3.91 (dd, 1 H, *J* = 9.6, 3.5 Hz), 4.06-4.414 (m, 2 H), 4.31 (dd, 1 H, *J* = 11.9, 1.0 Hz), 4.40 (q, 1 H, *J* = 8.0 Hz), 4.46 (d, 1 H, *J* = 3.5 Hz), 4.47-4.53 (m, 1 H), 4.57 (d, 1 H, *J* = 7.7 Hz), 4.69 (dd, 1 H, *J* = 12.9, 2.1 Hz), 4.97 (t, 1 H, *J* = 9.9 Hz), 5.07 (d, 1 H, *J* = 3.0 Hz), 5.20 (d, 1 H, *J* = 1.1 Hz), 5.24-5.30 (m, 3 H), 5.29 (dd, 1 H, *J* = 3.3, 1.1 Hz), 5.38 (d, 1 H, *J* = 5.1 Hz), 5.53 (s, 1 H), 5.64 (t, 1 H, *J* = 3.2 Hz), 7.08-8.06

(m, 20 H); Selected  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ):  $\delta$  14.5, 16.2, 17.1, 17.1, 19.3, 20.5, 20.76, 20.80 (2 C), 28.8, 29.4, 30.2, 31.35, 31.38, 31.8, 32.1, 36.9, 37.2, 38.2, 39.7, 40.2, 41.6, 50.1, 56.4, 58.8, 62.1, 65.9, 66.2, 66.3, 66.8, 67.0, 68.3, 69.0, 69.2, 69.9, 71.5, 71.8, 75.9, 77.9, 80.8, 83.5, 97.1 (C-1<sup>II</sup>), 99.0 (C-1<sup>I</sup>), 100.0 (C-1<sup>III</sup>), 100.8, 109.2, 121.8, 140.4, 164.6, 165.0, 165.5, 169.9 (2 C), 170.0. Anal. Calcd for  $\text{C}_{78}\text{H}_{92}\text{O}_{22}$ : C, 67.81; H, 6.71%. Found: C, 67.66; H, 6.84%.

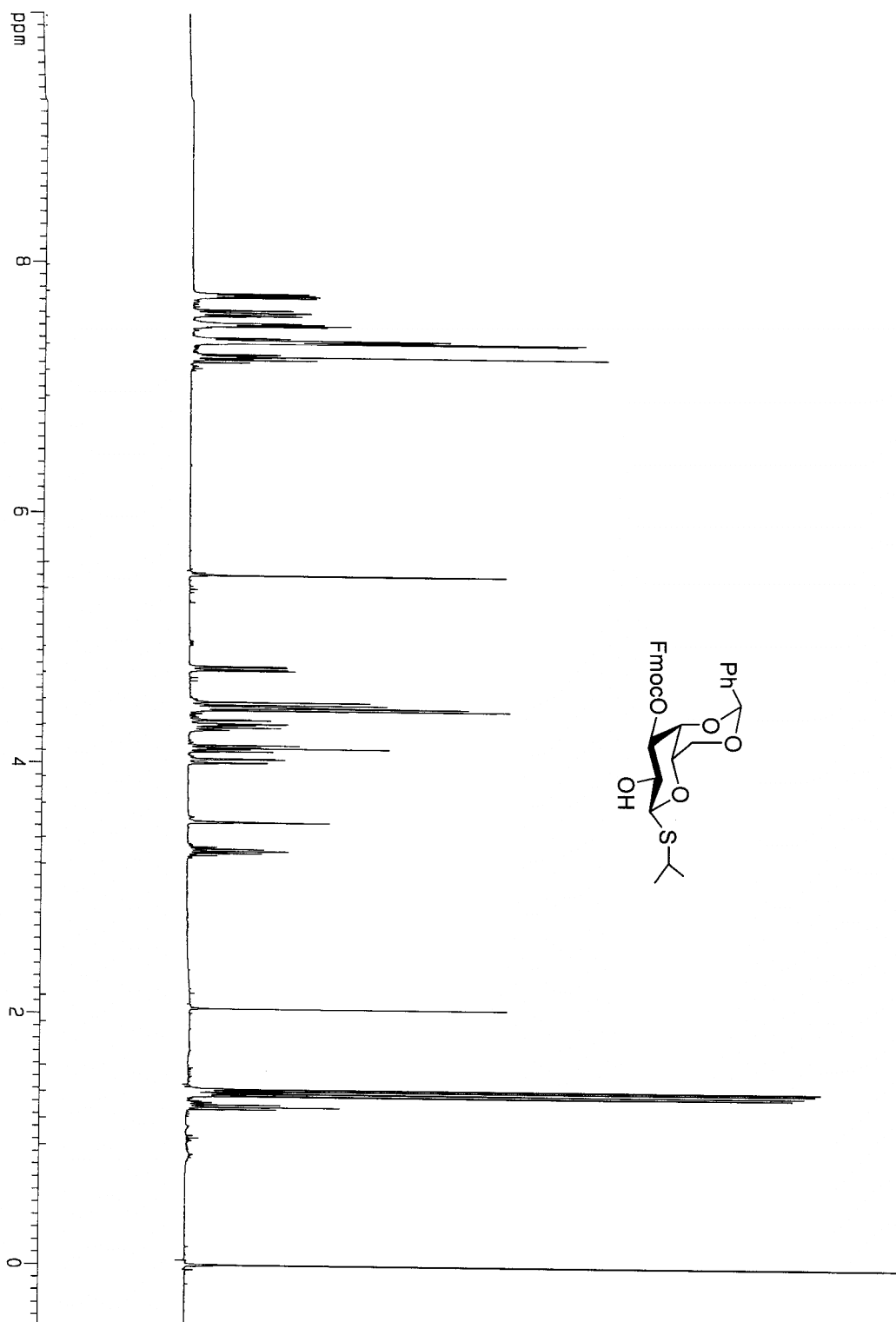
**Diosgenyl  $\beta$ -D-xylopyranosyl-(1 $\rightarrow$ 3)-[ $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)]- $\beta$ -D-galactopyranoside (2).**

A solution of compound **28** (183 mg, 0.133 mmol) in 80% AcOH (15 mL) was stirred at 70  $^{\circ}\text{C}$  for 2 h. The solvent was removed under reduced pressure to give a residue, which was dissolved in a solution of MeOH- $\text{CH}_2\text{Cl}_2$  (2:1, 6 mL). To the above solution was added aqueous 1 N NaOH until pH 9-10 was attained. The reaction mixture was stirred at rt for 6 h, then neutralized with Amberlite IR-120 ( $\text{H}^+$ ). The solvents were filtered, and the filtrates were concentrated. The residue was subjected to a silica gel column with  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (3:1) as the eluent to give **2** as a white solid (96 mg, 85%); Selected  $^1\text{H}$  NMR (pyridine- $d_6$ ):  $\delta$  0.69 (d, 3 H,  $J = 5.3$  Hz), 0.87 (s, 3 H), 1.05 (s, 3 H), 1.13 (d, 3 H,  $J = 6.9$  Hz), 1.69 (d, 3 H,  $J = 6.1$  Hz), 3.49-3.68 (m, 3 H), 3.91 (t, 1 H,  $J = 8.0$  Hz), 3.98-4.04 (m, 1 H), 4.06-4.15 (m, 3 H), 4.20-4.32 (m, 3 H), 4.38-4.43 (m, 2 H), 4.53 (q, 1 H,  $J = 7.3$  Hz), 4.60 (dd, 1 H,  $J = 9.2, 3.3$  Hz), 4.73 (t, 1 H,  $J = 7.9$  Hz), 4.80 (d, 1 H,  $J = 2.5$  Hz), 4.90 (d, 1 H,  $J = 1.8$  Hz), 4.93 (dd, 1 H,  $J = 9.6, 3.2$  Hz), 4.99 (d, 1 H,  $J = 7.7$  Hz), 5.05 (d, 1 H,  $J = 7.5$  Hz), 5.31 (d, 1 H,  $J = 4.7$  Hz), 6.29 (s, 1 H). MALDITOF-MS found for  $\text{C}_{44}\text{H}_{70}\text{O}_{16}$ : 877.2  $[\text{M} + \text{Na}]^+$ . Anal. Calcd for  $\text{C}_{44}\text{H}_{70}\text{O}_{16}$ : C, 61.81; H, 8.25%. Found: C, 62.03; H, 8.07%.

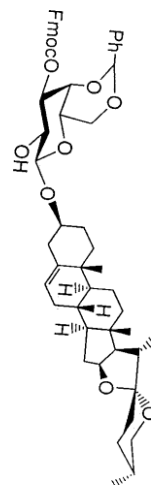
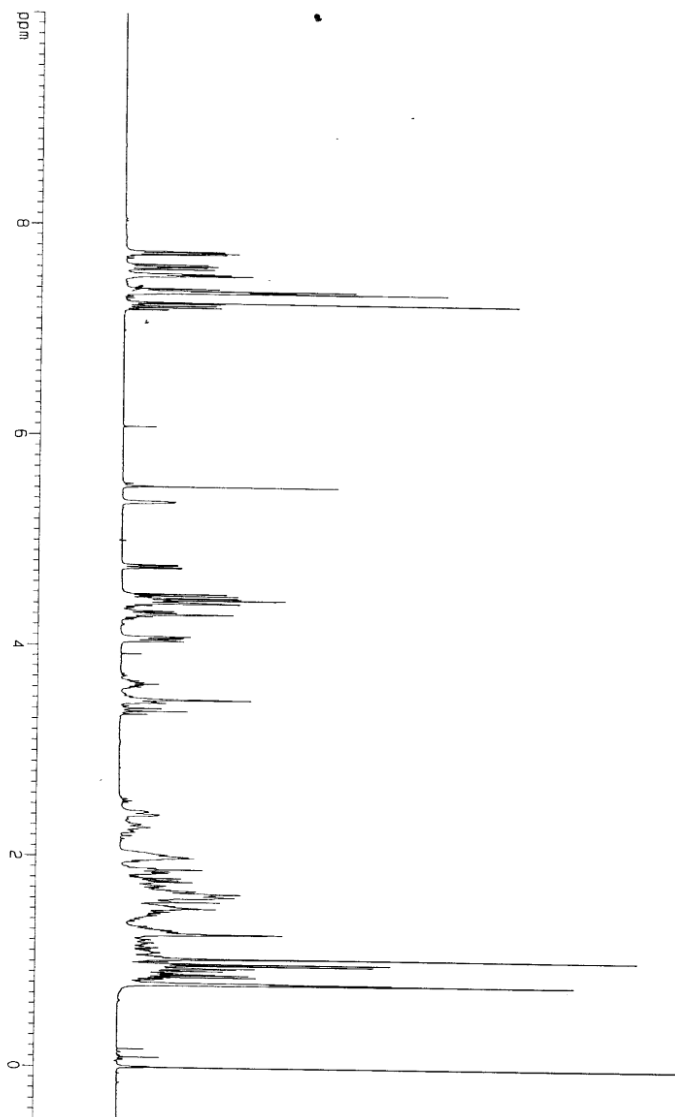
$^1\text{H}$  NMR Spectra of Compound 3



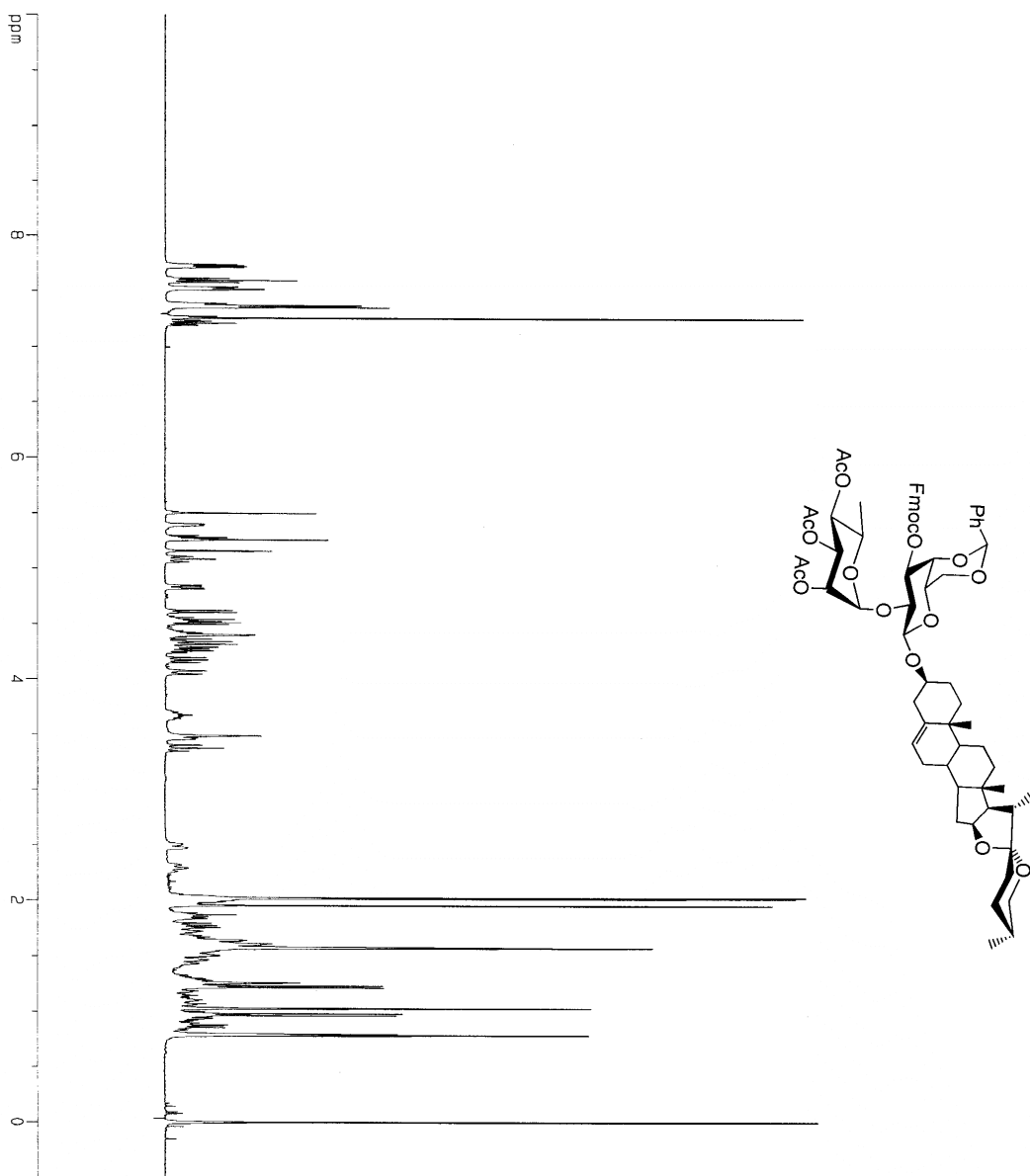
<sup>1</sup>H NMR Spectra of Compound 4



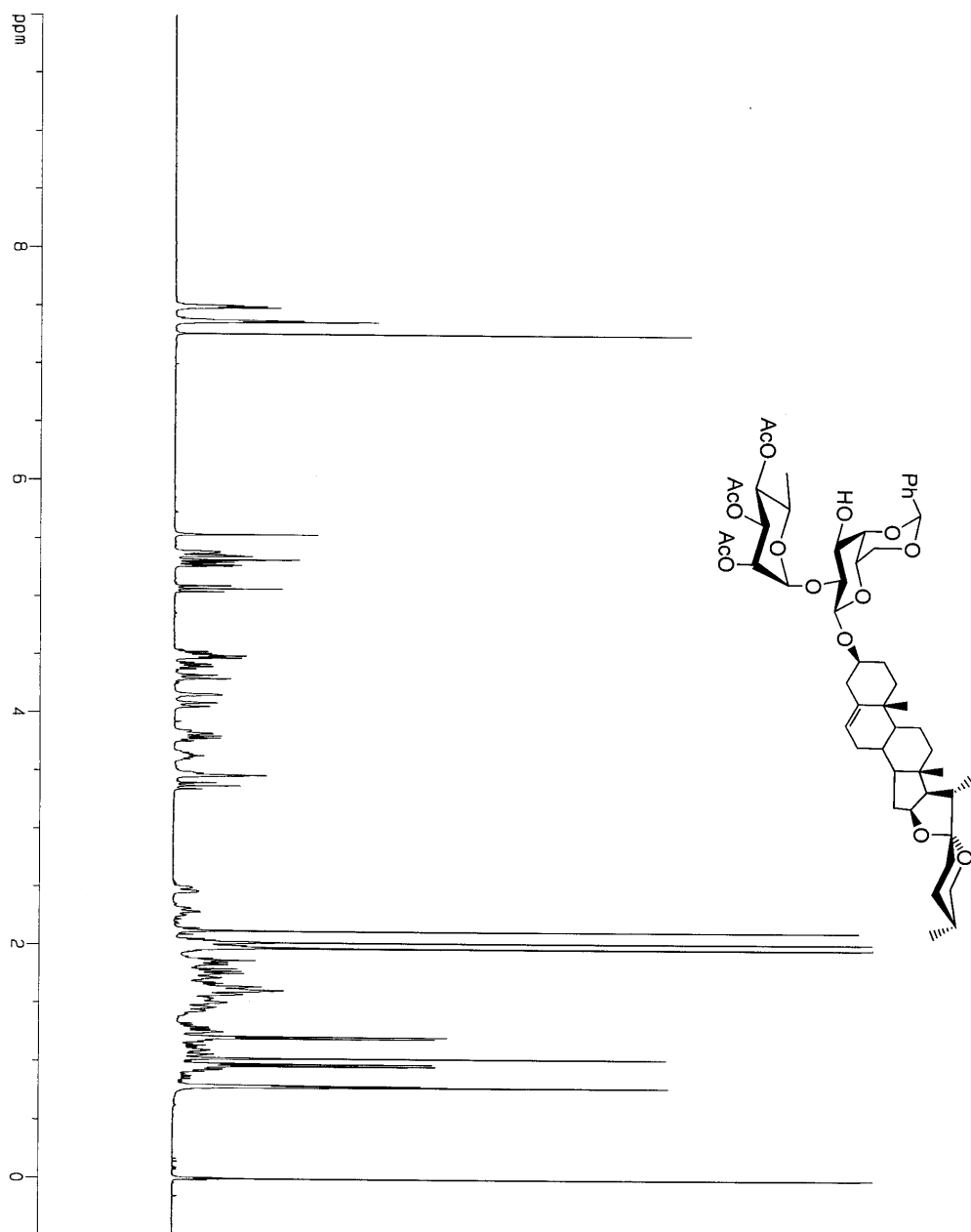
<sup>1</sup>H NMR Spectra of Compound 5



# $^1\text{H}$ NMR Spectra of Compound 6

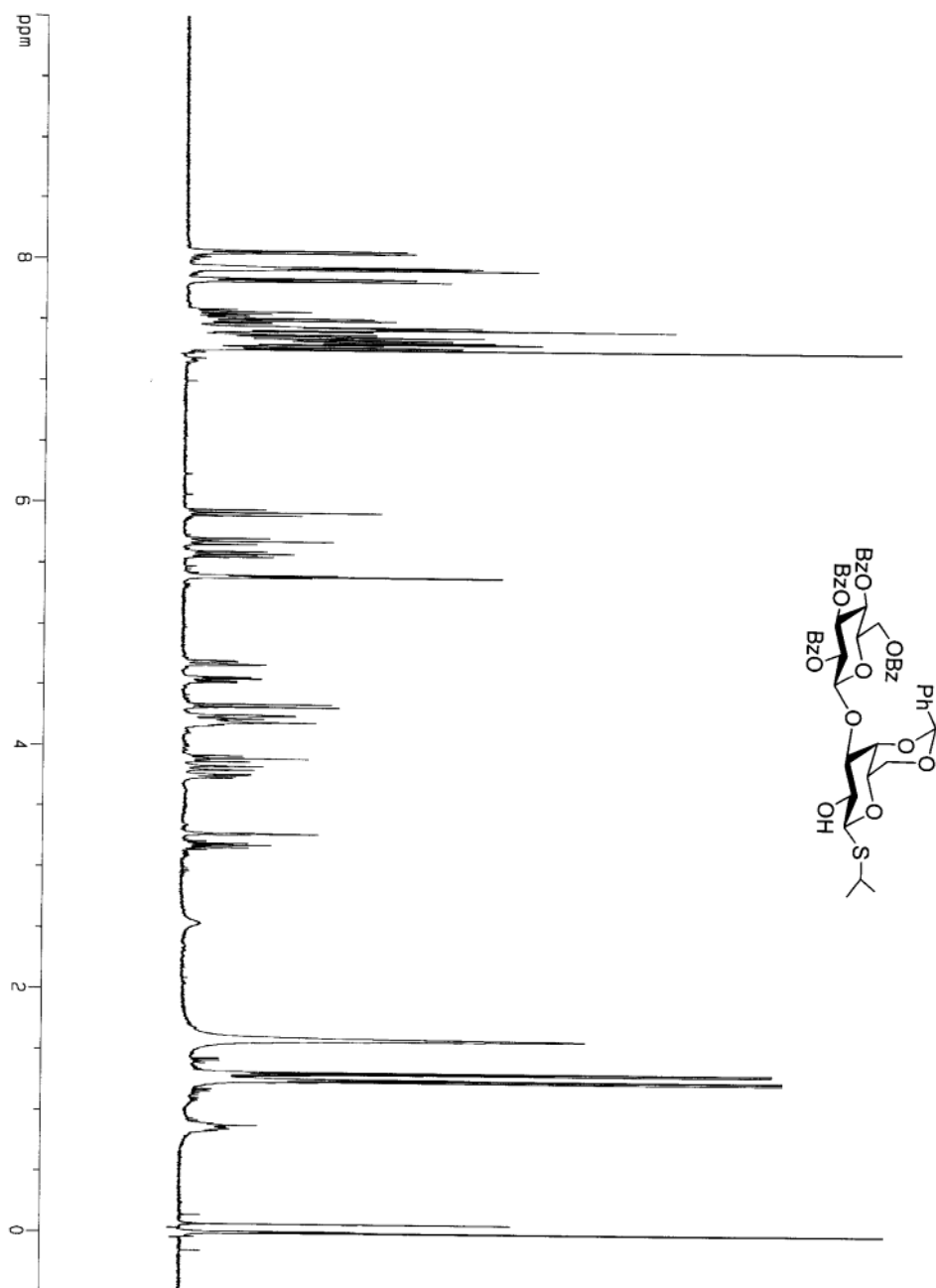


$^1\text{H}$  NMR Spectra of Compound 7

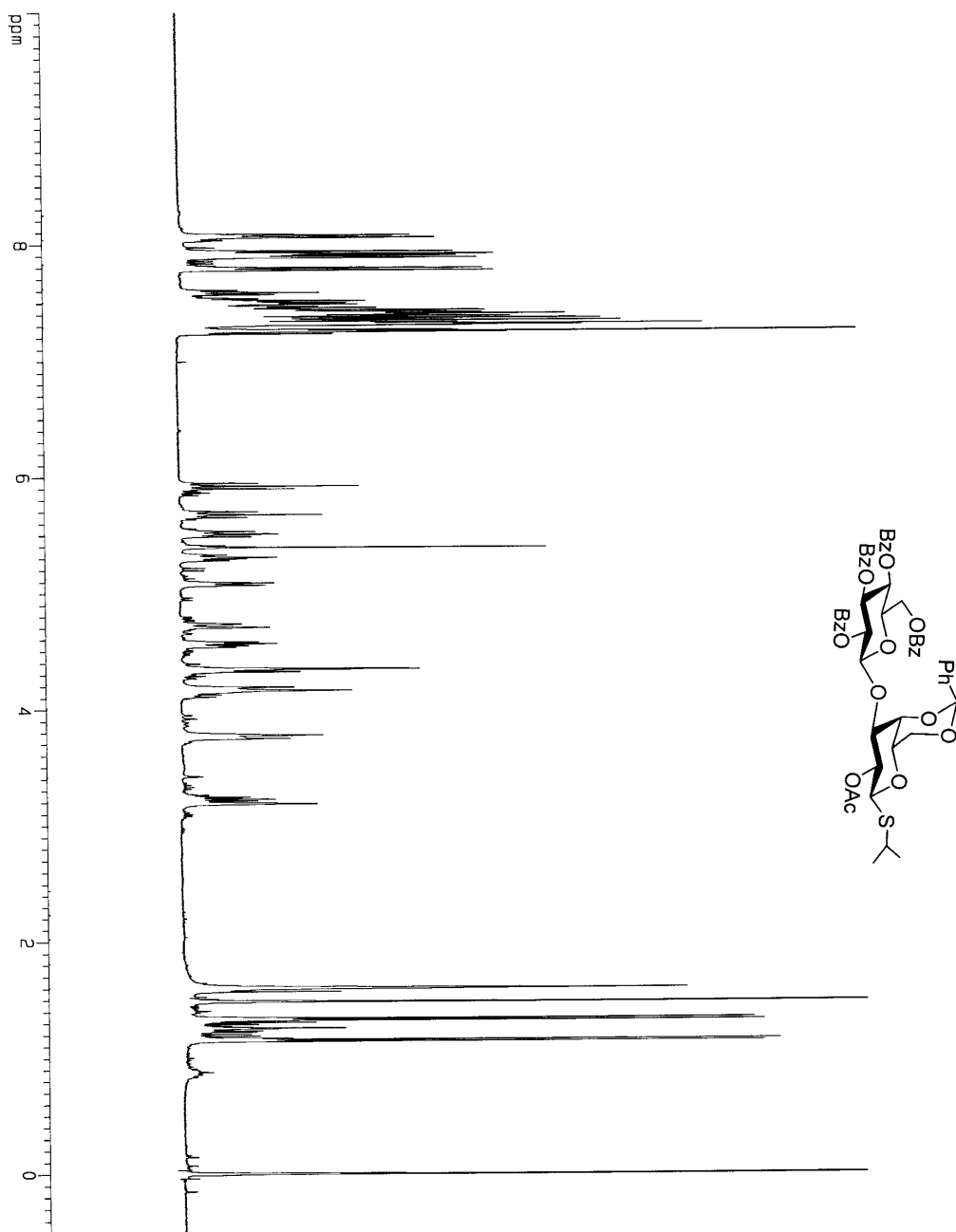




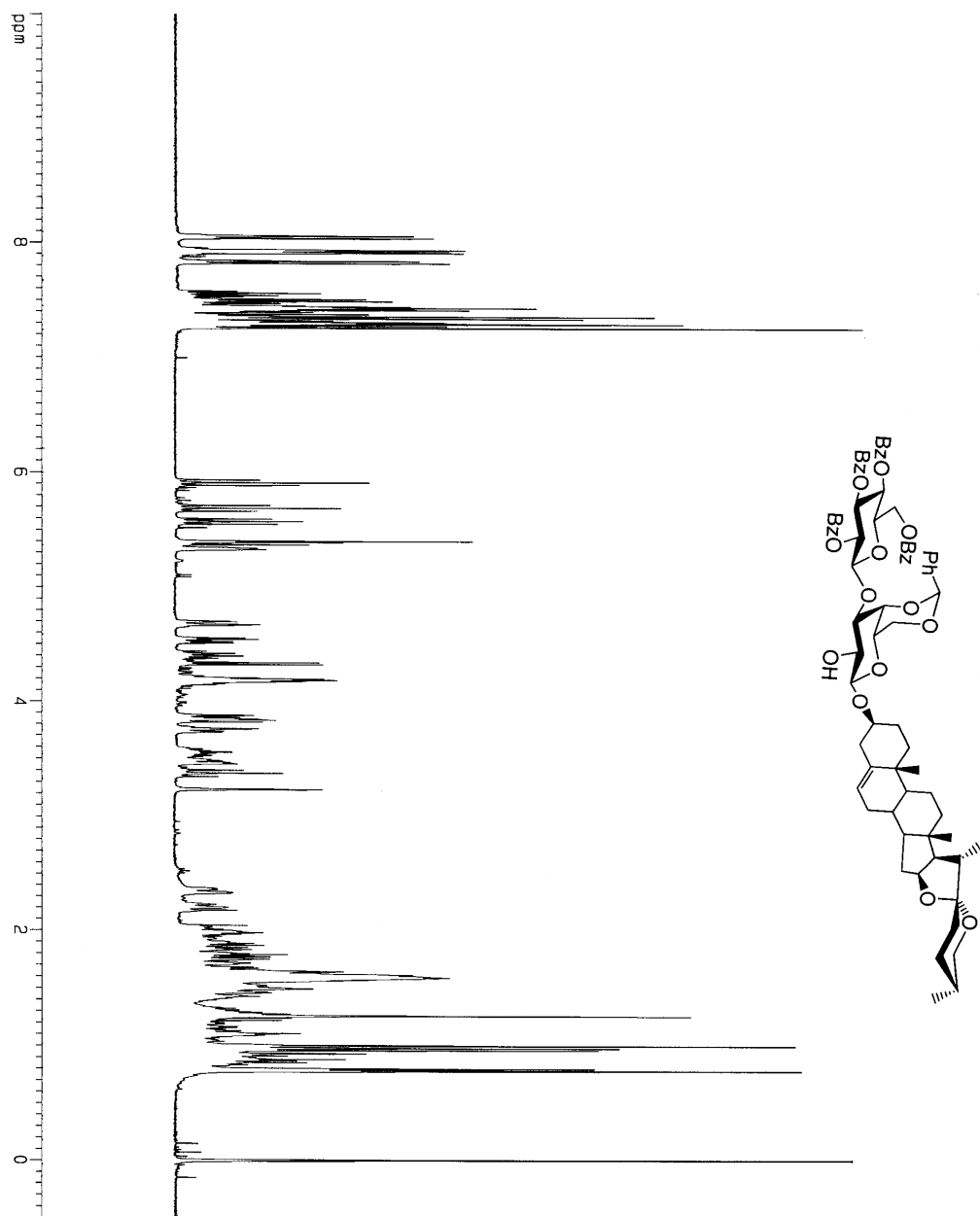
# $^1\text{H}$ NMR Spectra of Compound 12



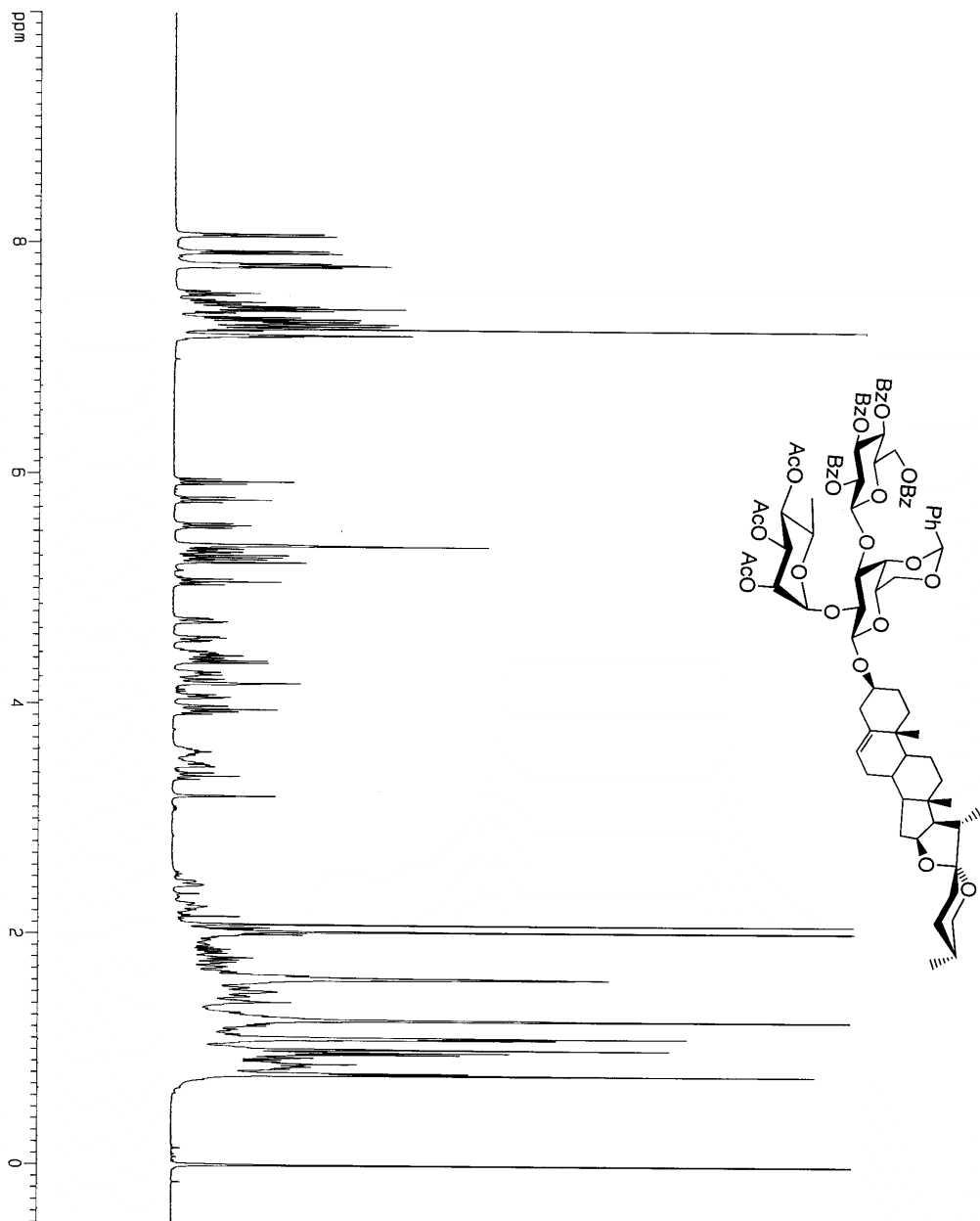
# <sup>1</sup>H NMR Spectra of Compound 12a



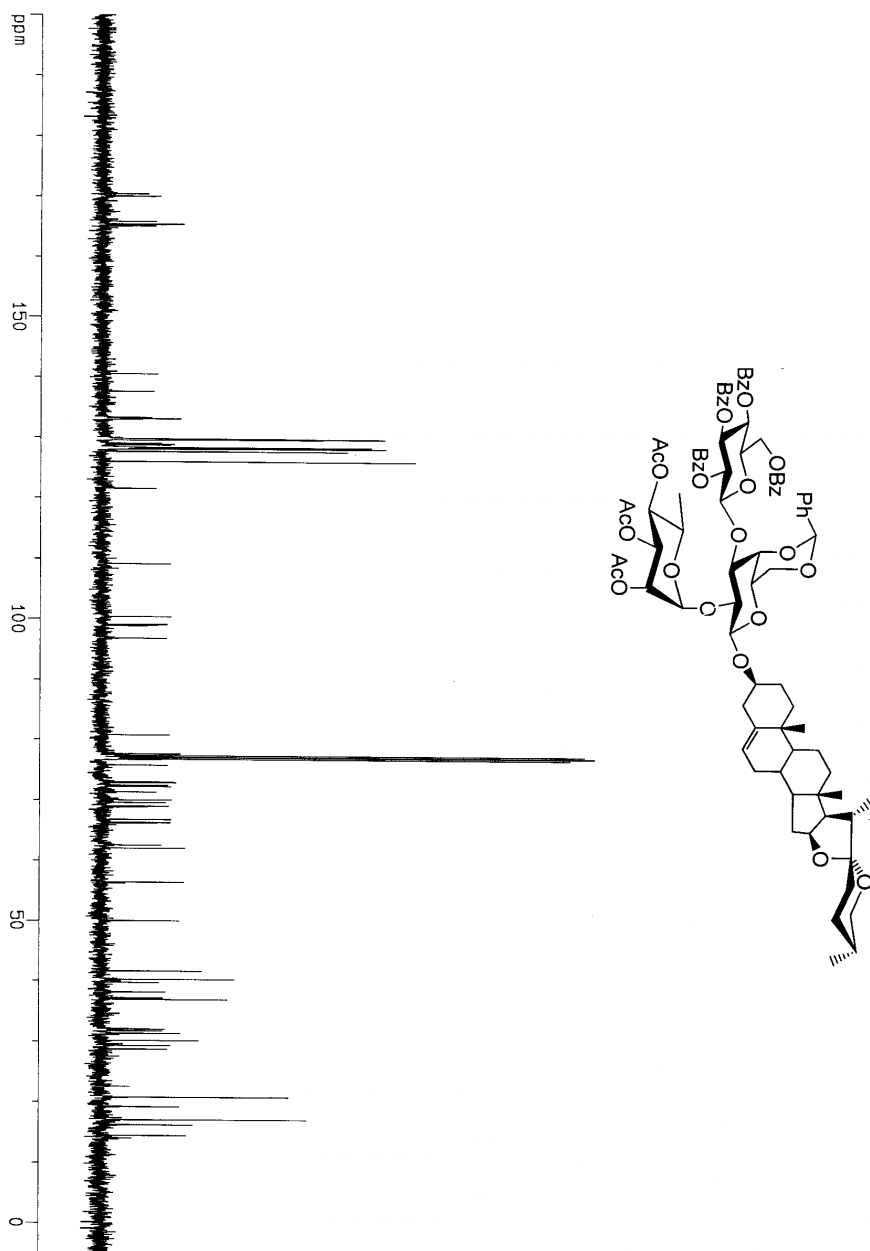
# $^1\text{H}$ NMR Spectra of Compound 13



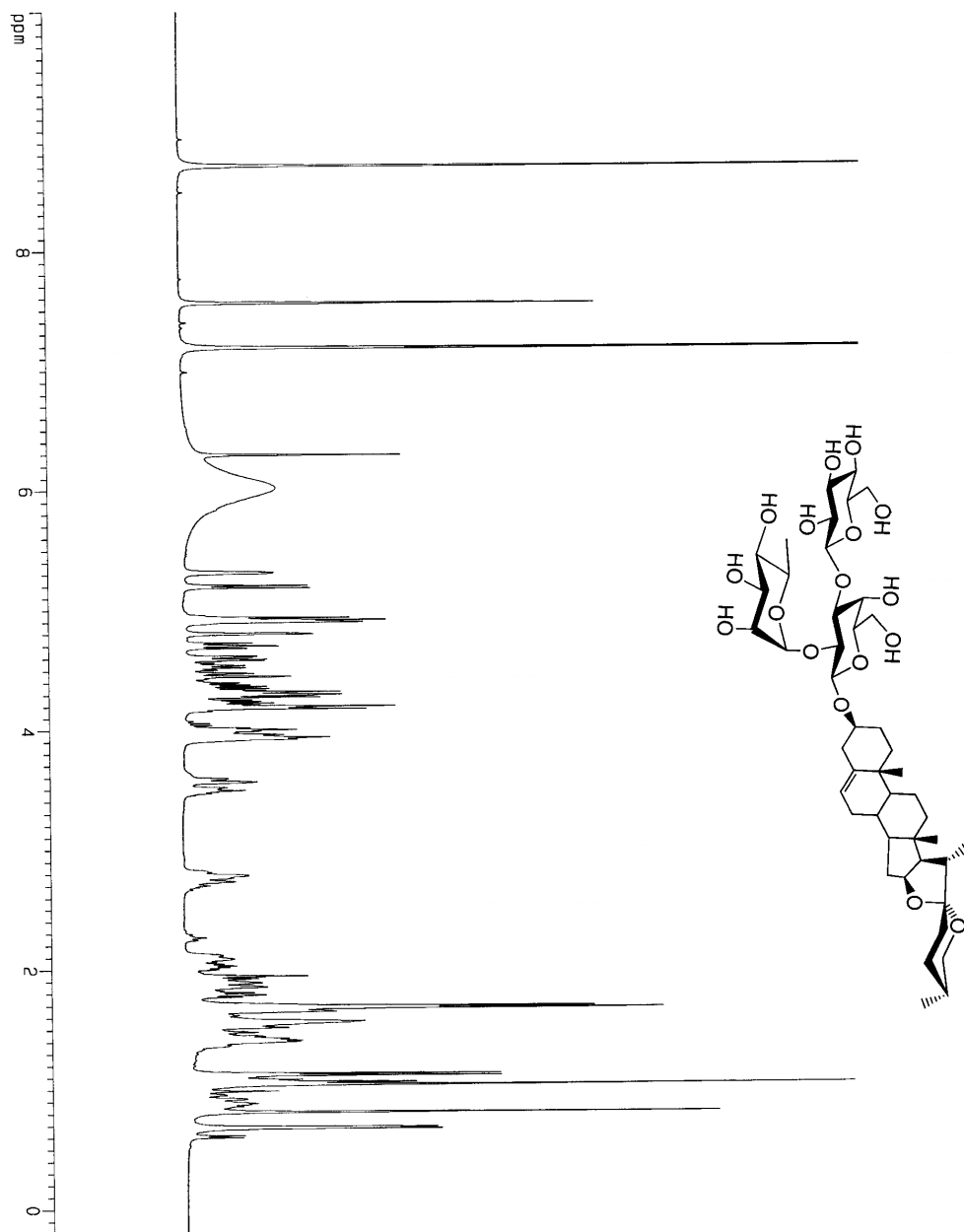
# <sup>1</sup>H NMR Spectra of Compound 8



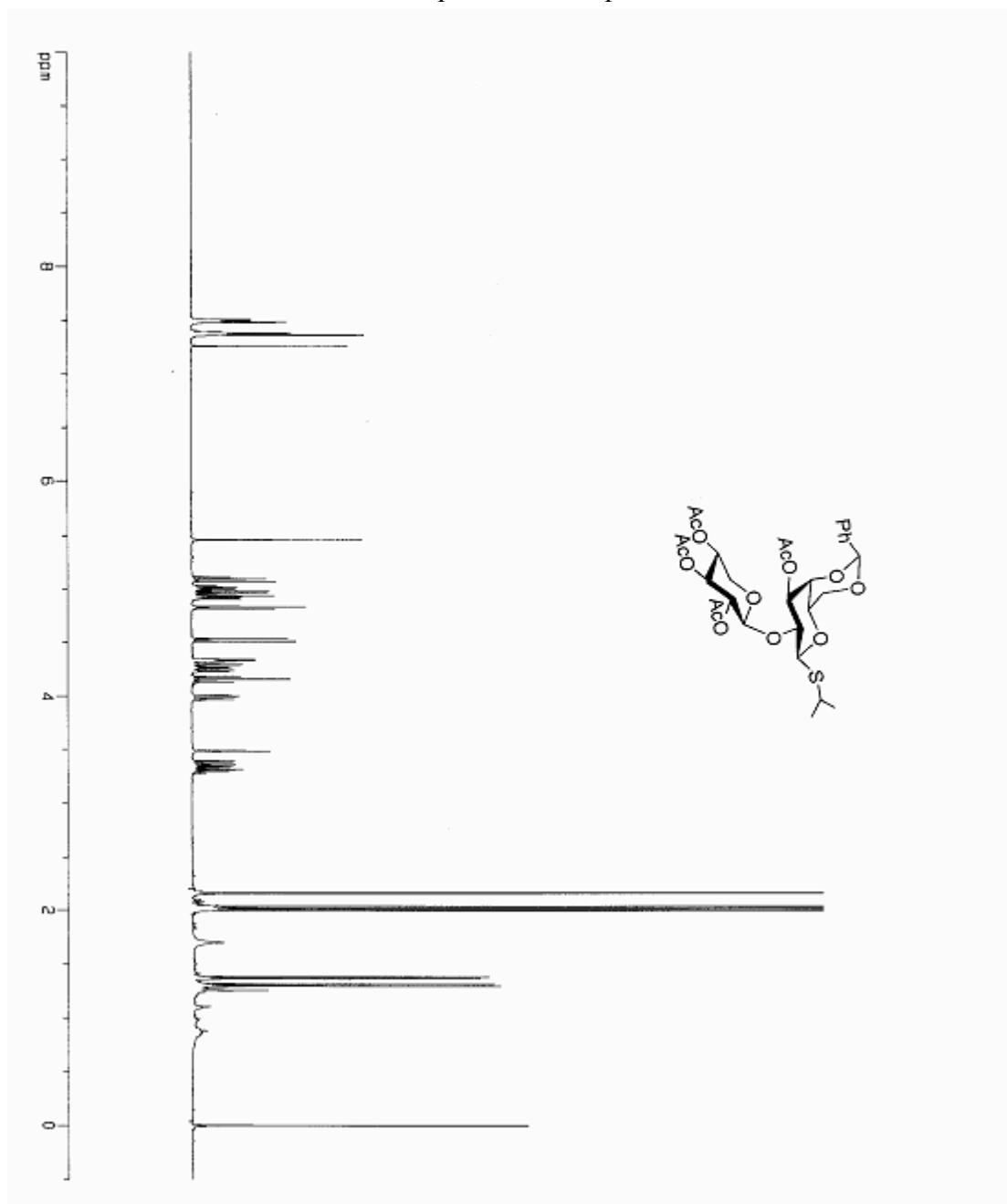
<sup>13</sup>C NMR Spectra of Compound 8



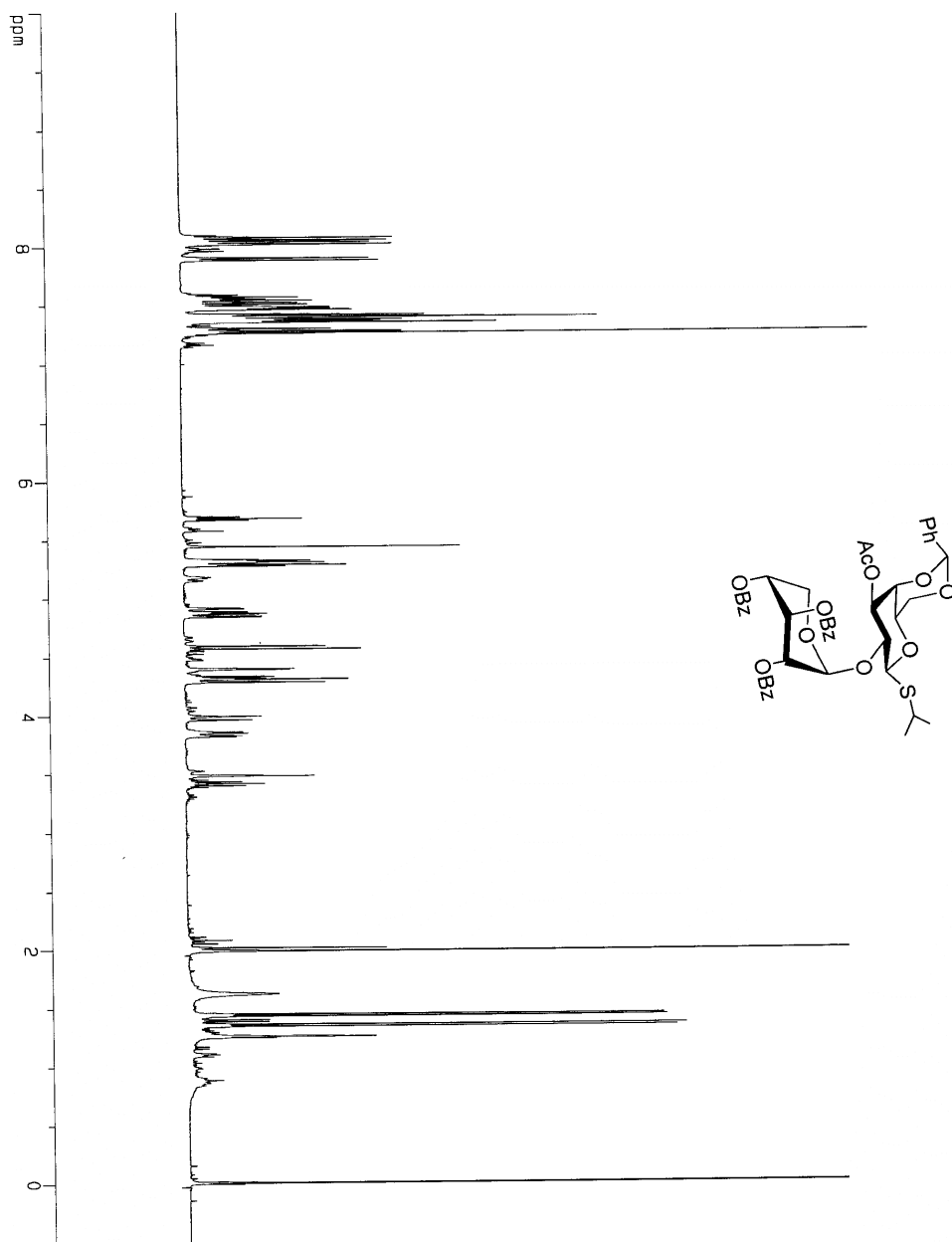
# $^1\text{H}$ NMR Spectra of Compound 1



# <sup>1</sup>H NMR Spectra of Compound 16

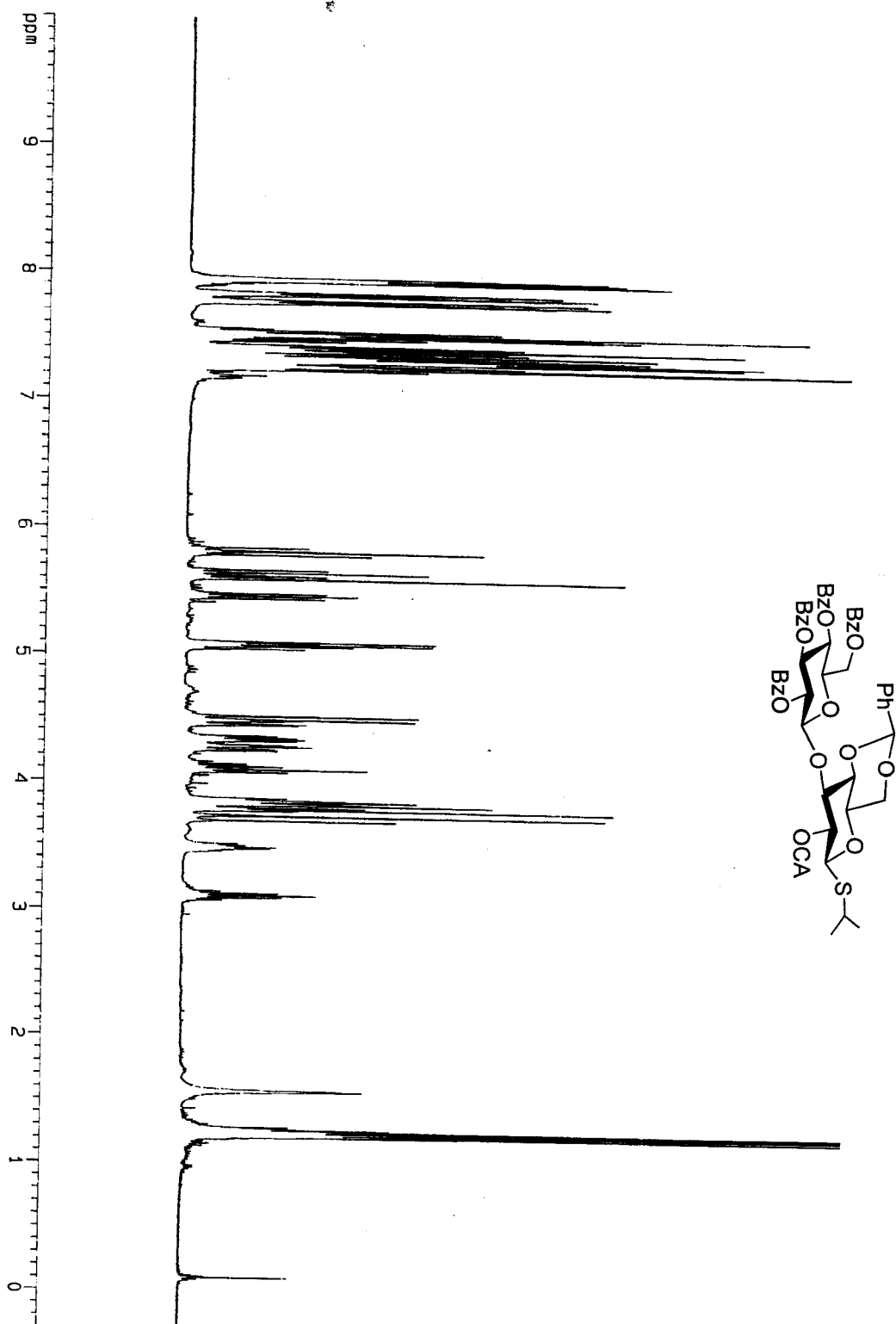


# <sup>1</sup>H NMR Spectra of Compound 19

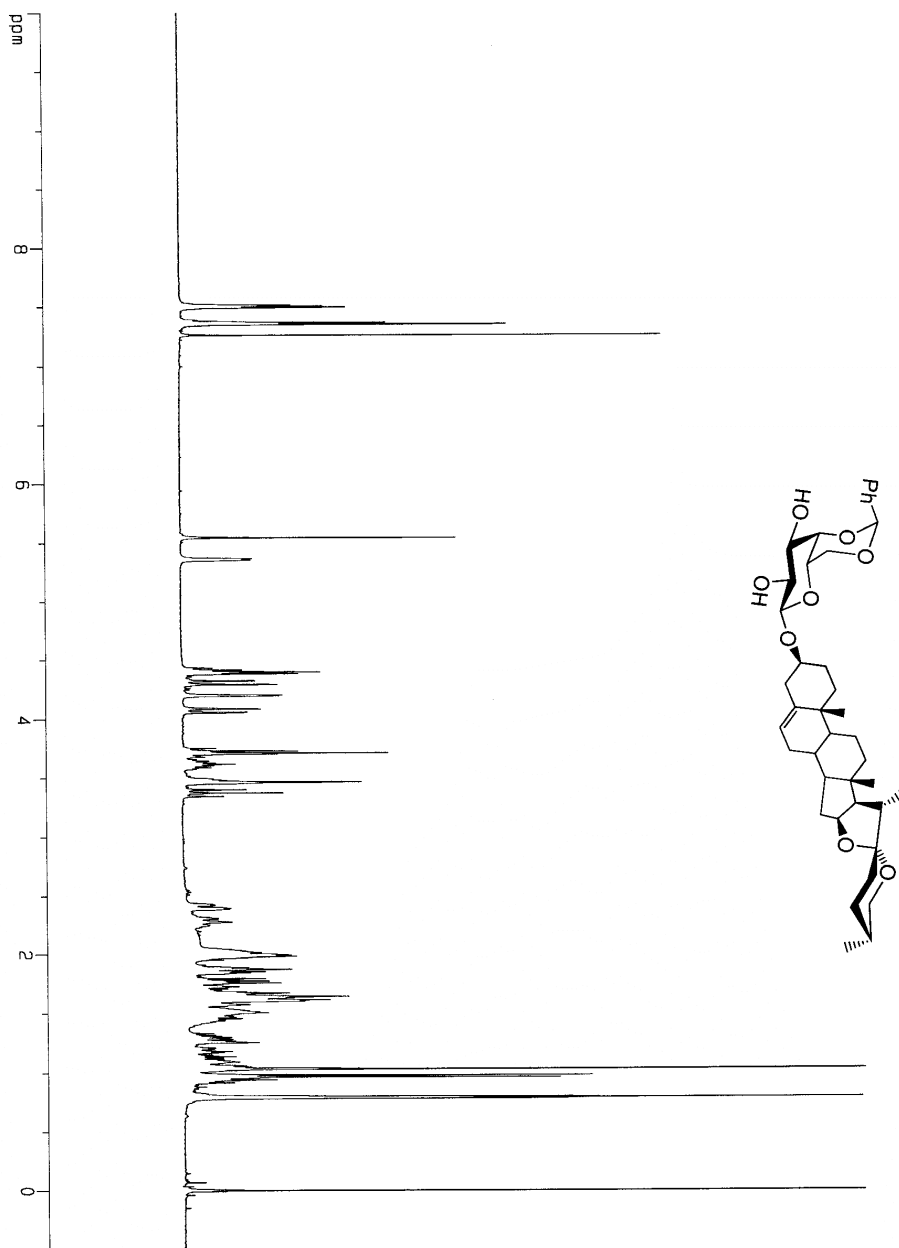




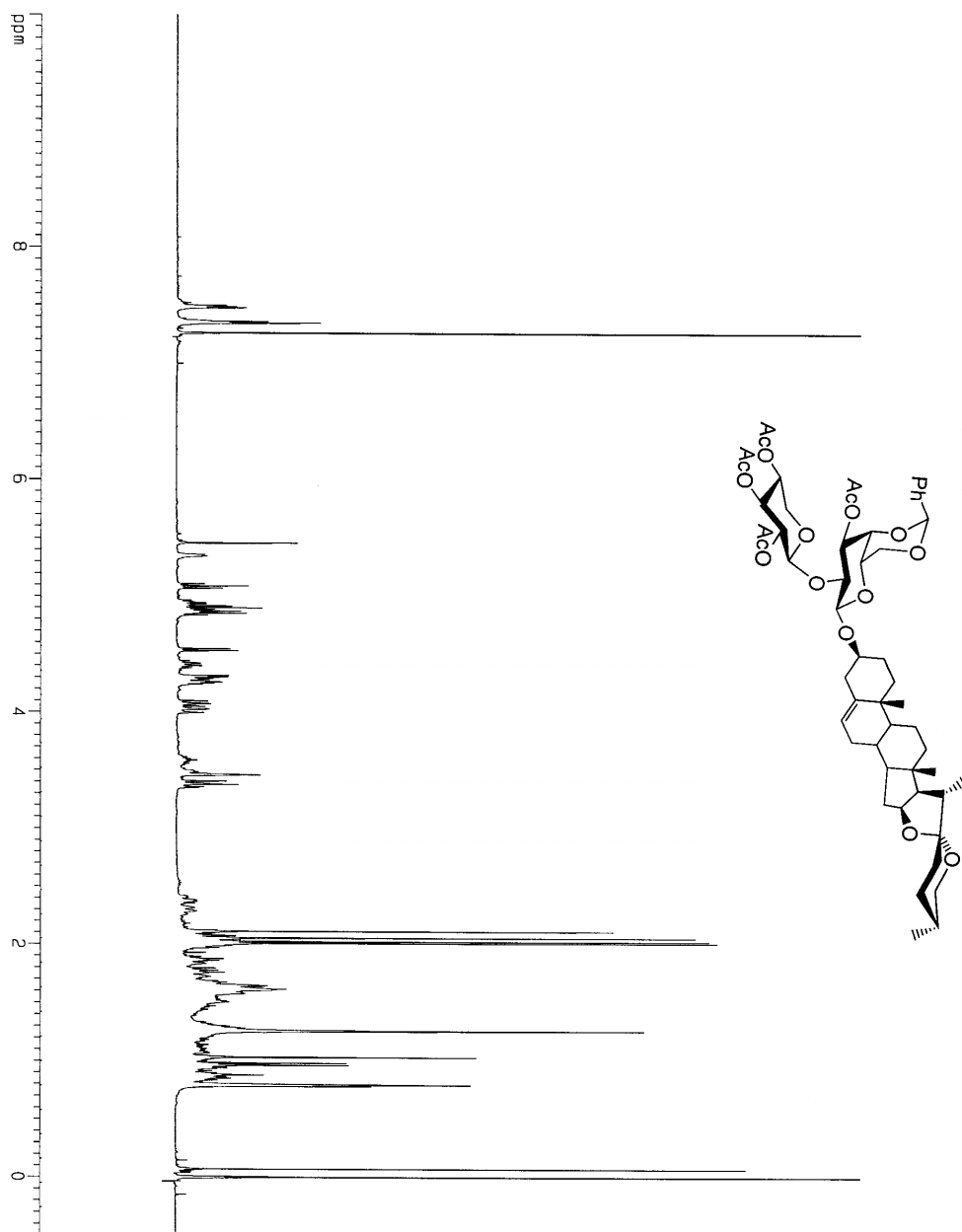
<sup>1</sup>H NMR Spectra of Compound 24



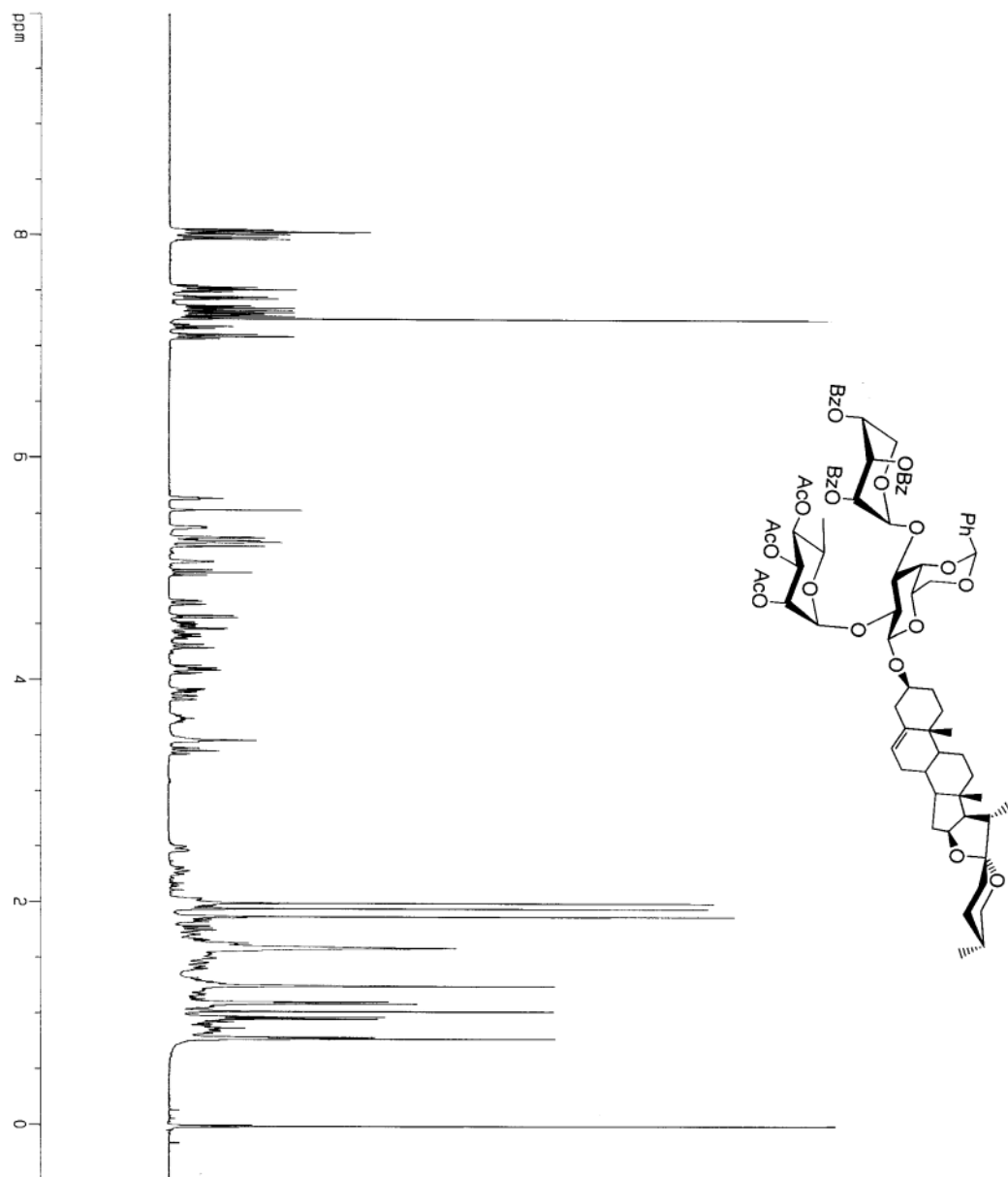
$^1\text{H}$  NMR Spectra of Compound 25



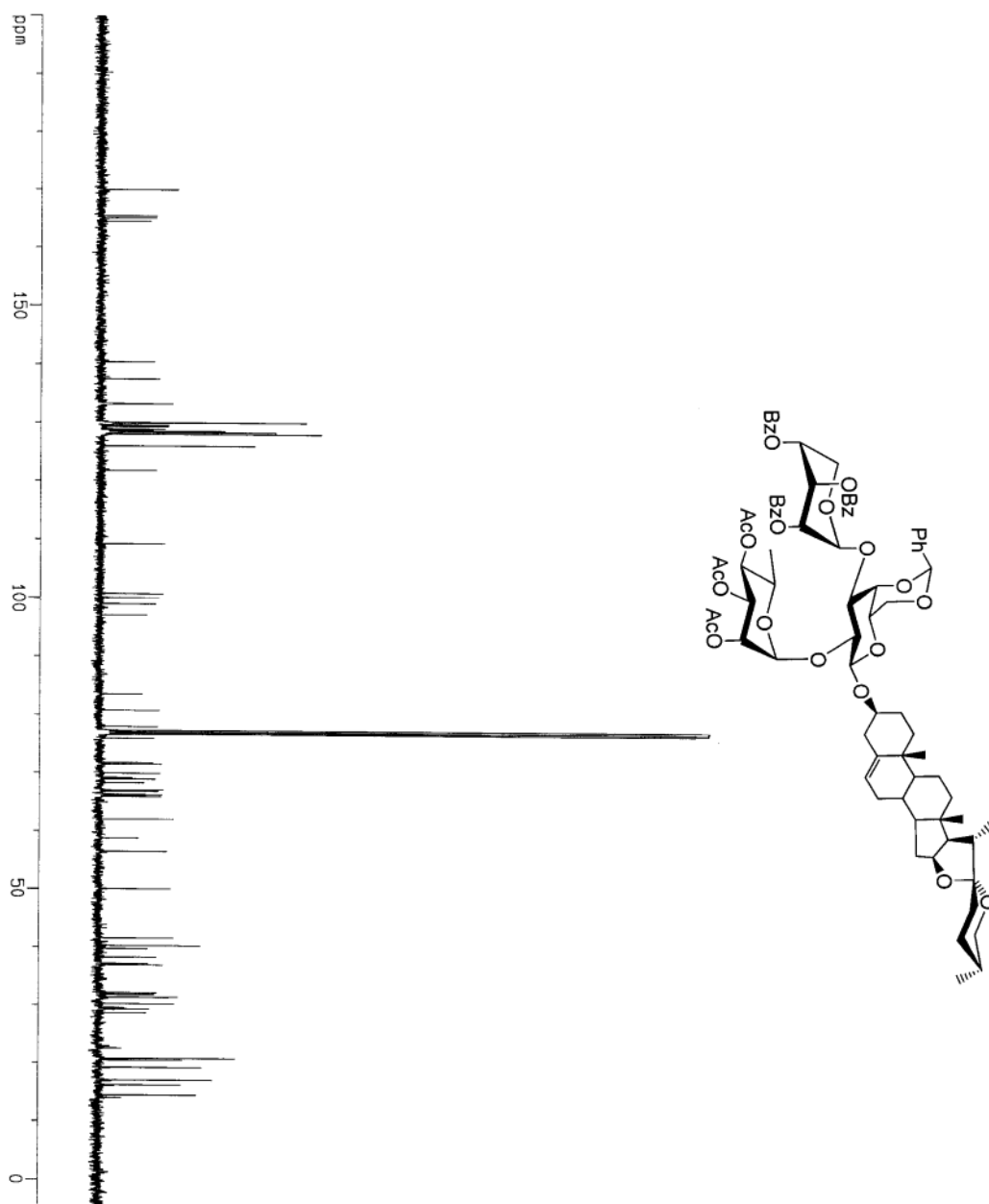
<sup>1</sup>H NMR Spectra of Compound 27



<sup>1</sup>H NMR Spectra of Compound 28



$^{13}\text{C}$  NMR Spectra of Compound **28**



# <sup>1</sup>H NMR Spectra of Compound 2

