New Oxidative Tools for the Functionalization of the Cephalostatin North 1 Hemisphere

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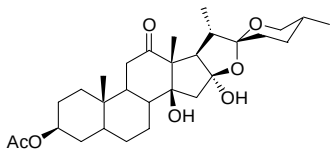
Supporting Information

General. All reactions were carried out under nitrogen unless otherwise indicated. Toluene, acetonitrile (CH_3CN), and methylene chloride (CH_2Cl_2) were dried and distilled from calcium hydride (CaH_2). Diethyl ether and tetrahydrofuran (THF) were distilled from benzophenone ketyl. Pyridine and dimethylformamide (DMF) was dried by distillation from calcium hydride (CaH_2). Cyclohexane, acetone, and methanol were spectra-grade. All work-up, wash, recrystalization, and chromatographic solvents were distilled. Sodium sulfate (Na_2SO_4) was anhydrous.

Thin layer chromatography (TLC) was used to monitor the progress of reactions by co-spotting with the starting materials. *p*-Anisaldehyde (1350 mL absolute ethanol, 50 mL concentrated H_2SO_4, 37 mL *p*-anisaldehyde) was utilized as a common TLC visualizing solution.

Flash chromatographic purifications were performed using silica gel (230-400 mesh). ^1H NMR and ^{13}C NMR data were recorded on General Electric QE-300 (300 MHz) in chloroform-d_1 as a solvent and are described in parts per million (ppm) from the residual chloroform (7.24ppm and 77.0ppm).

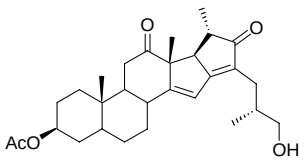
Peak multiplicates in ^1H NMR spectra are abbreviated as s (singlet), t (triplet), m (multiplet), br (broad), and bs (broad singlet). Mass spectra were performed by the Purdue University campus wide mass spectrometry facility.



18

Diol 18. 150 mL of freshly prepared DMDO solution was added to a solution of tertiary alcohol **17** (18.5 g, 0.0379 mol) in CH_2Cl_2 (50 mL) at room temperature. The resulting homogeneous solution was stirred at room temperature until potassium iodide starch paper shows no DMDO left. The reaction mixture was dried over Na_2SO_4 and filtered. The solvent was removed *in vacuo* and another 150 mL of freshly prepared

DMDO solution was added at room temperature.[1] Total 750 mL of DMDO solution (~ 2.2 eq.) was continuously added in the same way. After 7 days, all the starting material was consumed. The resulting reaction mixture was dried over Na_2SO_4 and was evaporated under reduced pressure. Flash column chromatography (EtOAc/n-Hx = 1:2) gave 15.7 g (0.0311 mol, 82%) of diol **18** as a white solid (M.P. 179 – 180 ^oC, toluene); ^1H NMR (300 MHz, $CDCl_3$) δ 4.60-4.65 (m, 1H), 3.44-3.60 (m, 3H), 3.21 (d, *J* = 8.5 Hz, 1H), 2.24-2.44 (m, 3H), 2.02-2.21 (m, 2H), 1.94 (s, 3H), 1.17 (s, 3H), 1.00 (d, *J* = 6.9 Hz), 0.87 (s, 3H), 0.80 (d, *J* = 6.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 211.9, 170.2, 113.1, 107.2, 86.1, 72.8, 67.6, 61.7, 58.2, 46.4, 46.3, 44.1, 43.4, 39.1, 36.6, 36.2, 35.8, 33.6, 31.6, 29.8, 28.2, 27.8, 27.2, 26.9, 21.1, 16.8, 14.5, 14.2, 11.6; HRMS (EI) for $C_{29}H_{44}O_7$ $[M]^+$ calcd. 504.3087, found 504.3068.

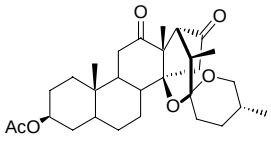


19

Dienone 19. To a solution of hemiketal **18** (20 mg, 0.0396 mmol) in CH_2Cl_2 (0.5 mL) was added $BF_3.OEt_2$ (10.5 μL, 2.1 eq.) at 0 ^oC. The reaction was stirred for 8 h. The reaction was diluted with EtOAc and washed with sat. $NaHCO_3$, dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The crude residue was purified by flash chromatography (EtOAc/n-Hexane = 1:2) to give dienone **19** (5 mg, 0.0107 mmol, 27%) along with isomeric spiroketal **20** (8 mg, 0.0160 mmol, 40%); ^1H NMR (300 MHz, $CDCl_3$) δ 6.27 (s, 1H), 4.65-4.78 (m, 1H), 3.47 (br, 1H), 3.39 (dd, *J* = 11.7, 5.4 Hz, 1H), 3.10-3.18 (m, 2H), 2.59-2.67 (m, 1H), 2.44-2.58 (m, 3H), 2.28-2.37 (m, 1H), 2.15-2.22 (m, 2H), 2.06 (s, 3H), 1.35 (d, *J* = 7.5 Hz, 3H), 1.17 (s, 3H), 0.99 (s, 3H), 0.82 (d, *J* = 7.5 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 213.4, 211.2, 176.9, 171.3, 170.5, 128.7, 118.4, 72.8, 65.8, 61.9, 58.0, 51.5, 43.6, 43.5, 38.0, 36.3, 36.0, 35.3, 33.6, 31.5, 29.4, 27.4, 27.1,

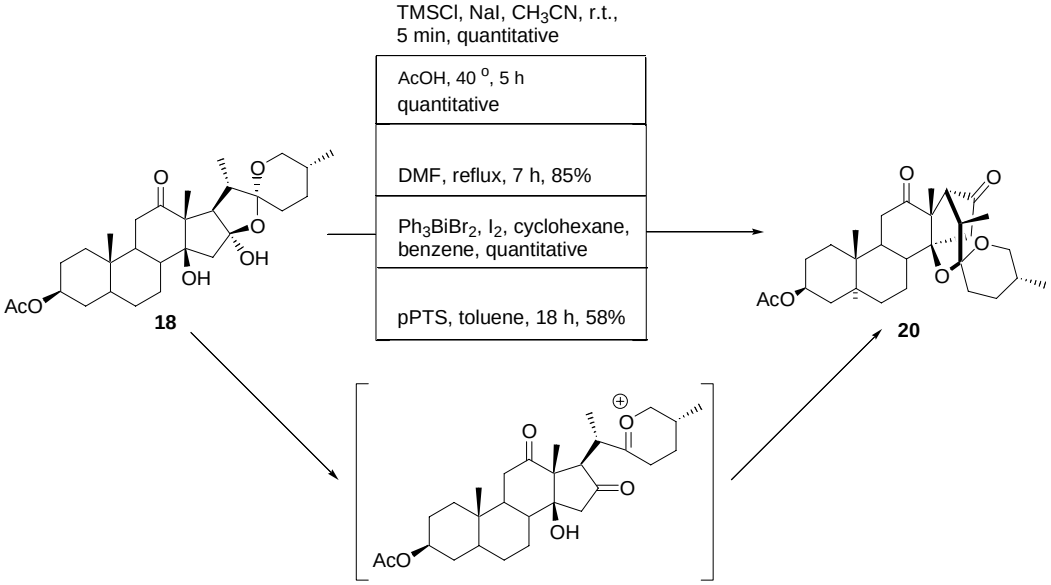
[1] Adam, W.; Bialas, J.; Hadjiarapoglou, L. *Chem. Ber.* **1991**, *124*, 124.

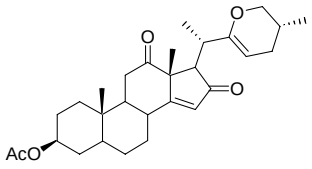
26.0, 21.7, 21.3, 16.1, 14.0, 11.6; HRMS (EI) for $C_{29}H_{40}O_5$ $[M]^+$ calcd. 468.2876, found 468.2875.



20

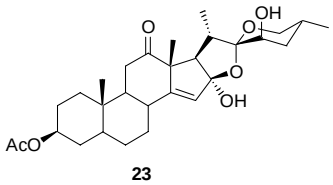
Isomeric Spiroketal 20. To a solution of diol **18** (52.4 mg, 0.1038 mmol) in CH_2Cl_2 (3 mL) was added acetic acid (1 mL) and the reaction was stirred at room temperature for 8 h. The resulting reaction mixture was diluted with EtOAc and washed with sat. $NaHCO_3$, dried over Na_2SO_4. The solvent was removed under reduced pressure, and the crude product was filtered through a silica gel pad to provide isomeric spiroketal **20** (51.9 mg, 0.1037 mmol, > 99%, M.P. 155-157 ^oC, toluene); ^1H NMR (300 MHz, $CDCl_3$) δ 4.61-4.72 (m, 1H), 3.34-3.38 (m, 1H), 3.19-3.26 (m, 1H), 2.44-2.62 (m, 3H), 2.02-2.29 (m, 4H), 2.00 (s, 3H), 1.27 (s, 3H), 0.99 (d, *J* = 6.9 Hz, 3H), 0.95 (s, 3H), 0.76 (d, *J* = 5.9, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 212.5, 211.7, 170.5, 97.7, 83.9, 72.9, 66.7, 57.4, 54.5, 47.2, 44.6, 41.6, 39.4, 36.9, 36.3, 36.0, 33.8, 31.5, 29.7, 28.0, 27.6, 27.4, 27.1, 21.3, 17.2, 14.4, 14.1, 13.7, 11.8; HRMS (EI) for $C_{29}H_{42}O_6$ $[M]^+$ calcd. 486.2981, found 486.2972; Isomeric spiroketal **20** can be easily obtained from various reaction conditions.





21

Vinyl Ether 21. To a solution of diol **18** (3.01 g, 0.006 mol) in toluene (15 mL) was added pyridine (9.65 mL, 20 eq.) at room temperature.[2] The solution was cooled to – 50 ^{o}C, then $SOCl_2$ (1.74 mL, 4 eq.) was added. The reaction was stirred for 40 min. The resulting reaction mixture was washed with sat. $NaHCO_3$, dried over Na_2SO_4, and evaporated under reduced pressure. Flash column chromatography with EtOAc/n-Hexane = 1:5 gave vinyl ether **21** (2.16 g, 0.0046 mol, 77%); ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.70 (d, *J* = 1.4 Hz, 1H), 4.59-4.68 (m, 1H), 4.44-4.47 (m, 1H), 3.84-3.89 (m, 1H), 3.39-3.45 (m, 1H), 3.11 (d, *J* = 6.1 Hz, 1H), 2.66-2.74 (m, 1H), 2.47-2.62 (m, 2H), 2.36 (dd, *J* = 14.2, 4.0 Hz, 1H), 1.98 (s, 3H), 1.48 (s, 3H), 1.25 (d, *J* = 7.2 Hz, 3H), 0.94 (s, 3H), 0.87 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 210.0, 206.0, 182.5, 170.3, 156.2, 125.5, 94.7, 72.8, 71.3, 62.8, 52.6, 52.3, 43.6, 37.0, 36.9, 36.5, 36.2, 35.4, 33.6, 29.3, 28.9, 27.4, 27.1, 26.9, 21.6, 21.3, 19.8, 17.2, 11.6; HRMS (EI) for $C_{29}H_{40}O_5$ $[M]^+$ calcd. 468.2876, found 468.2854.

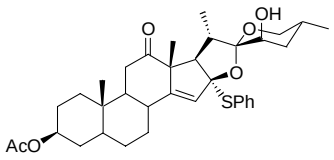


23

Hemiketal 23. To a solution of vinyl ether **21** (2.89 g, 0.0062 mol) in CH_2Cl_2 (20 mL) was added dropwise DMDO (90 mL, ~1.5 eq.) at – 50 ^{o}C. The reaction was stirred for 30 min. After 30 min., the reaction mixture was evaporated *in vacuo* at room temperature to give hemiketal **23** (3.08 g, 0.0061 mol, > 99%) as a unstable white solid

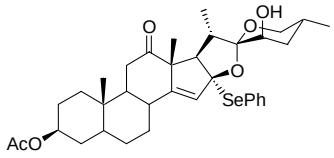
[2] LaCour, T. G.; Guo, C.; Bhandaru, S.; Boyd, M. R.; Fuchs, P.L. *J. Am. Chem. Soc.* **1998**, 120, 692.

(decomposed at 80 ^{o}C); ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.38 (d, *J* = 1.7 Hz, 1H), 4.59-4.70 (m, 1H), 3.62 (d, *J* = 8.5 Hz, 1H), 3.49-3.57 (m, 1H), 3.22 (s, 1H), 3.08 (d, *J* = 7.9 Hz, 1H), 2.41-2.54 (m, 2H), 2.35 (dd, *J* = 14.9, 4.9 Hz, 1H), 2.17-2.27 (m, 1H), 1.99 (s, 3H), 1.24 (s, 3H), 1.23 (d, *J* = 6.9 Hz, 3H), 0.91 (s, 3H), 0.82 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 210.6, 170.5, 155.6, 121.5, 116.6, 107.9, 72.9, 70.9, 67.4, 62.0, 59.3, 52.5, 43.8, 37.1, 36.2, 36.1, 36.0, 33.9, 33.6, 29.1, 27.7, 27.1, 23.9, 21.3, 21.1, 16.7, 15.7, 11.6; HRMS (ESI) for $C_{29}H_{42}O_7$ $[M]^+$ calcd. 502.2931, found 502.2935.



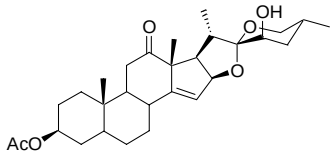
24

Sulfide 24. To a solution of hemiketal **23** (24.3 mg, 0.0503 mmol) in CH_2Cl_2 (0.5 mL) was added benzenethiol (7.8 μL, 1.5 eq.). The solution was cooled to – 40 ^{o}C, stirred, and $BF_3.OEt_2$ (0.3 μL, 5 mol%) was added to the reaction mixture. After 30 min., the reaction was diluted with EtOAc, quenched with sat. $NaHCO_3$, dried over Na_2SO_4, and filtered. The filtrate was evaporated under reduced pressure, and separated by flash column chromatography (EtOAc/n-Hexane = 1:2) to provide sulfide **24** (21.2 mg, 0.0356 mmol, 71%); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.45-7.49 (m, 2H), 7.22-7.27 (m, 3H), 5.26 (d, *J* = 0.6 Hz, 1H), 4.62-4.71 (m, 1H), 3.63-3.79 (m, 2H), 3.58 (bs, 1H), 2.07-2.38 (m, 3H), 2.02 (s, 3H), 1.28 (d, *J* = 6.9 Hz, 3H), 1.22 (s, 3H), 0.85 (d, *J* = 6.9 Hz, 3H), 0.84 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 209.6, 170.6, 151.7, 135.7, 133.5, 128.6, 128.1, 123.9, 107.8, 103.6, 73.0, 71.5, 67.6, 62.2, 59.1, 52.2, 44.4, 43.9, 36.8, 36.5, 36.1, 35.9, 33.7, 33.6, 29.2, 27.6, 27.1, 24.1, 21.4, 20.9, 16.9, 15.6, 11.6; HRMS (ESI) for $C_{35}H_{46}O_6SNa$ $[M+Na]^+$ calcd. 617.2913, found 617.2914.



25

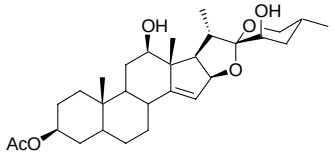
Selenide 25. To a solution of hemiketal **23** (59.3 mg, 0.1180 mmol) in CH_2Cl_2 (2 mL) was added benzeneselenol (13.8 μL, 1.1 eq.) at room temperature. The reaction was cooled to – 30 ^oC, and $BF_3.OEt_2$ (1.5 μL, 10 mol%) was added. After 20 min., the reaction was quenched with sat. $NaHCO_3$, dried over Na_2CO_3, filtered, and evaporated under reduced pressure. Flash column chromatography (EtOAc/n-Hexane = 1:2) gave selenide **25** (32.6 mg, 0.0508 mmol, 43%); ^1H NMR (300 MHz, $CDCl_3$) δ 7.57-7.60 (m, 2H), 7.26-7.36 (m, 3H), 5.37 (s, 1H), 4.64-4.73 (m, 1H), 7.80 (d, *J* = 9.2 Hz, 1H), 3.67-3.74 (m, 2H), 3.59-3.63 (m, 1H), 2.11-2.36 (m, 3H), 2.06 (s, 3H), 1.32 (d, *J* = 6.9 Hz, 3H), 1.22 (s, 3H), 0.89 (d, *J* = 6.4 Hz, 3H), 0.85 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 209.8, 170.6, 151.6, 137.9, 129.5, 128.7, 128.3, 124.9, 108.0, 99.7, 73.0, 71.5, 67.7, 62.2, 60.4, 51.6, 44.3, 43.8, 36.7, 36.4, 36.0, 35.7, 33.7, 33.4, 29.2, 27.6, 27.1, 24.0, 21.4, 21.3, 16.9, 15.7, 11.5; HRMS (ESI) for $C_{35}H_{46}O_6SeNa$ $[M+Na]^+$ calcd. 665.2357, found 665.2368.



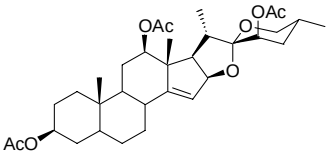
26

Compound 26. PhSeH (0.15 mL, 2.5 eq.) was added to a solution of lactol **23** (288.0 mg, 0.5729 mmol) in CH_2Cl_2 (6 mL) at – 30 ^oC, then $BF_3.OEt_2$ (7.3 μL, 10 mol%) was added. The reaction was stirred with irradiation by a sun lamp (275W RS-M) for 2 h. The reaction mixture was washed with sat. $NaHCO_3$, dried over Na_2SO_4, and evaporated under reduced pressure. Flash column chromatography (EtOAc/n-Hexane = 1:2) gave compound **26** (230.9 mg, 0.4745 mmol, 83%). Additionally, compound **26** can be obtained from selenide **25**. To a solution of selenide **25** (30.1 mg, 0.0469 mmol) in CH_2Cl_2 (1 mL) was added PhSeH (5.5 μL, 1.1 eq.) at – 30 ^oC, and a sun lamp was turned

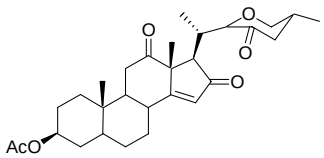
on. After stirred for 2 h, the reaction was quenched with H_2O and EtOAc, dried over Na_2SO_4, and evaporated under reduced pressure. Flash column chromatography (EtOAc/n-Hexane = 1:2) provided compound **26** (19.9 mg, 0.0408 mmol, 87%) as a white solid (M.P. 245 – 246 ^oC, EtOAc/n-Hx); ^1H NMR (300 MHz, $CDCl_3$) δ 5.38-5.39 (m, 1H), 4.76 (dd, *J* = 7.9, 2.1 Hz, 1H), 4.59-4.70 (m, 1H), 3.41-3.60 (m, 3H), 3.20 (t, *J* = 7.9 Hz, 1H), 2.41-2.57 (m, 2H), 2.32 (dd, *J* = 14.8, 4.6 Hz, 1H), 2.02-2.17 (m, 1H), 2.00 (s, 3H), 1.28 (s, 3H), 1.18 (d, *J* = 6.9 Hz, 3H), 0.92 (s, 3H), 0.79 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 211.4, 170.6, 156.0, 120.3, 106.5, 84.2, 73.1, 71.2, 66.6, 62.5, 53.2, 51.6, 44.0, 43.4, 37.3, 36.5, 36.2, 34.3, 33.7, 29.4, 27.8, 27.2, 24.2, 21.8, 21.4, 16.8, 15.5, 11.7; HRMS (EI) for $C_{29}H_{42}O_6$ $[M]^+$ calcd. 486.2981, found 486.2993.



Diol 45. To a mixture of compound **26** (1.03 g, 2.12 mmol) and $NaBH_4$ (96.3 mg, 1.2 eq.) was added 15 mL of CH_2Cl_2 and 15 mL of MeOH at – 78 ^oC. After stirred for 9 h, the reaction was quenched with H_2O and EtOAc, then washed with sat. NaCl and EtOAc (3 x 80 mL). The combined organic layers were dried over Na_2SO_4, and evaporated under reduced pressure to afford diol as a white solid (M. P. 184 – 185 ^oC, EtOAc) without silica gel column chromatography (1.02 g, 2.10 mmol, 99% with the C12-α: -β = 1:20); ^1H NMR (300 MHz, $CDCl_3$) δ 5.33 (m, 1H), 4.84 (dd, *J* = 8.1, 2.1 Hz, 1H), 4.57-4.68 (m, 1H), 3.59 (bs, 1H), 3.41-3.53 (m, 2H), 3.12 (dd, *J* = 11.1, 4.6 Hz, 1H), 2.39 (t, *J* = 8.1 Hz, 1H), 2.03-2.14 (m, 1H), 1.98 (s, 3H), 1.16 (d, *J* = 6.7 Hz, 3H), 0.97 (s, 3H), 0.84 (s, 3H), 0.78 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 158.4, 118.8, 106.0, 84.9, 79.4, 73.3, 71.2, 66.6, 57.9, 53.0, 52.3, 44.3, 43.8, 36.6, 36.5, 35.8, 33.9, 33.7, 29.8, 29.5, 28.1, 27.3, 24.2, 21.4, 16.8, 15.7, 14.0, 12.0; HRMS (EI) for $C_{29}H_{44}O_6$ $[M]^+$ calcd. 488.3138, found 488.3134.



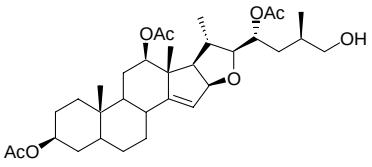
Triacetate 46. Ac_2O (59.4 μL, 3 eq.) was added to the solution of diol **45** (107.3 mg, 0.2196 mmol), DMAP (2.7 mg, 10 mol%), and pyridine (0.2 mL, 12 eq.) in CH_2Cl_2 (2 mL) at 0 ^oC. The reaction was stirred for 8 h at room temperature, quenched with sat. $NaHCO_3$ and EtOAc. The resulting solution was washed with sat. NaCl, dried over Na_2SO_4, and filtered. The filtrate was evaporated *in vacuo* to provide triacetate (125.8 mg, 0.2196 mmol, >99%) as a white solid (M. P. 173 – 174 ^oC, EtOAc); ^1H NMR (300 MHz, $CDCl_3$) δ 5.35 (s, 1H), 4.82-4.86 (m, 2H), 4.58-4.67 (m, 1H), 4.34 (dd, *J* = 11.2, 4.4 Hz, 1H), 3.41-3.57 (m, 2H), 2.26 (t, *J* = 8.0 Hz, 1H), 2.08 (s, 3H), 2.01 (s, 3H), 1.98 (s, 3H), 1.02 (s, 3H), 1.00 (d, *J* = 7.5 Hz, 3H), 0.84 (s, 3H), 0.76 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.5, 170.5, 170.1, 157.2, 119.6, 104.7, 84.9, 80.9, 73.2, 72.4, 66.7, 58.0, 51.9, 51.6, 44.2, 43.3, 36.5, 35.9, 34.0, 33.9, 33.7, 29.4, 28.0, 27.2, 26.5, 24.6, 21.3, 21.2, 21.2, 16.6, 15.3, 14.9, 11.9; HRMS (EI) for $C_{33}H_{48}O_8$ $[M]^+$ calcd. 573.3427, found 573.3432.



28

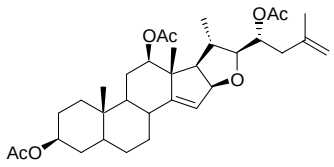
Compound 28. To a solution of sulfide **24** (27.6 mg, 0.0464 mmol) in CH_2Cl_2 (1 mL) was added *m*-CPBA (11.4 mg, 1.0 eq.) at room temperature. After 10 minutes, sat. $NaHCO_3$ was added and the reaction was washed with sat. NaCl, extracted with EtOAc (3 x 20 mL). The combined organic layers were dried over Na_2SO_4, filtered, and evaporated under reduced pressure. Flash column chromatography (EtOAc/*n*-Hexane = 1:2) gave compound **28** (13.6 mg, 0.0281 mmol, 60%) as a white solid (M.P. 125 – 126 ^oC, EtOAc); ^1H NMR (300 MHz, $CDCl_3$) δ 5.70 (d, *J* = 1.5 Hz, 1H), 4.81 (d, *J* = 3.4 Hz, 1H), 4.60-4.71 (m, 1H), 4.0 (ddd, *J* = 11.4, 4.5, 2.3 Hz, 1H), 3.38 (t, *J* = 11.1, 1H), 3.13 (d, *J* = 9.0, 1H), 2.74-2.80 (m, 1H), 2.52-2.64 (m, 3H), 2.23-2.43 (m, 2H), 2.02-2.14 (m,

2H), 2.00 (s, 3H), 1.54 (s, 3H), 0.96 (s, 3H), 0.93 (d, *J* = 6.9 Hz, 3H), 0.92 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 210.0, 208.7, 206.8, 183.7, 170.5, 125.3, 83.3, 72.8, 63.2, 52.5, 51.8, 47.1, 43.6, 37.4, 36.6, 36.2, 35.5, 33.6, 33.2, 31.0, 29.3, 27.5, 27.1, 22.4, 21.3, 17.2, 14.6, 11.6; HRMS (ESI) for $C_{29}H_{40}O_6Na$ $[M+Na]^+$ calcd. 507.2723, found 507.2723.



29

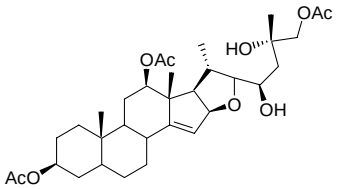
Alcohol 29. To a solution of triacetate **46** (35.0 mg, 0.0611 mmol) and Et_3SiH (87.8 μL, 9 eq.) was added $BF_3.OEt_2$ (69.7 μL, 9 eq.) at 0 °C. The reaction was stirred for 36 h at room temperature, quenched with sat. $NaHCO_3$/EtOAc, washed with sat. NaCl, and dried over Na_2SO_4. Solvent was removed *in vacuo* and flash silica gel column chromatography (EtOAc/ *n*-Hexane = 1:1) provided alcohol **29** (33.7 mg, 0.0586 mmol, 96%) as a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.34 (s, 1H), 5.04-5.10 (m, 1H), 4.72 (dd, *J* = 7.9, 1.5 Hz, 1H), 4.56-4.67 (m, 1H), 4.38 (dd, *J* = 11.3, 4.4 Hz, 1H), 3.40-3.43 (m, 3H), 2.01 (s, 3H), 2.00 (s, 3H), 1.96 (s, 3H), 1.03 (s, 3H), 0.97 (d, *J* = 6.4 Hz, 3H), 0.87 (d, *J* = 6.7 Hz, 3H), 0.82 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 170.5, 157.3, 119.7, 88.0, 86.5, 81.0, 73.2, 72.3, 68.3, 59.9, 51.8, 51.7, 44.1, 37.5, 36.5, 35.8, 34.0, 33.7, 33.6, 32.1, 29.4, 27.9, 27.2, 26.5, 21.3, 21.2, 21.2, 18.0, 16.3, 16.0, 11.9; HRMS (ESI) for $C_{33}H_{50}O_8$ $[M]^+$ calcd. 575.3584, found 575.3586.



30

Olefin 30. To a solution of alcohol **29** (776.7 mg, 1.3561 mmol), Ph_3P (889.3 mg, 2.5 eq.) ,and imidazole (468.4 mg, 5 eq.) in Et_2O (20 mL) and CH_3CN (2 mL) was added

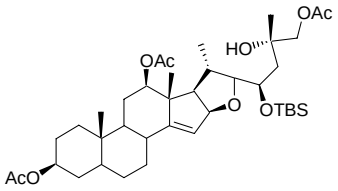
I_2 (1.03 g, 3 eq.) at 0 ^oC. The reaction was stirred at room temperature for 2.5 h. sat. $Na_2S_2O_3$ and EtOAc were used to quench the reaction. The resulting colorless solution was washed with sat. NaCl, dried over Na_2SO_4, and filtered. The filtrate was evaporated under reduced pressure. The resulting colorless oil was further treated with DBU (0.4 mL, 2 eq.) in CH_3CN (20 mL) at reflux for 3 h. The reaction was evaporated under reduced pressure to give yellow oil. Flash column chromatography (EtOAc/ *n*-Hexane = 1:6) provided olefin **30** (626.6 mg, 1.1256 mmol, 83% in 2 steps) as a colorless oil; ^1H NMR (300 MHz, $CDCl_3$) δ 5.38 (s, 1H), 5.14 (dd, *J* = 11.2, 6.5 Hz, 1H), 4.73-4.77 (m, 2H), 4.68 (s, 1H), 4.60-4.66 (m, 1H), 4.40 (dd, *J* = 11.4, 4.6 Hz, 1H), 3.43 (dd, *J* = 8.8, 4.5 Hz, 1H), 2.30 (d, *J* = 6.4 Hz, 1H), 2.02 (s, 3H), 1.99 (s, 3H), 1.98 (s, 3H), 1.70 (s, 3H), 1.05 (s, 3H), 1.00 (d, *J* = 6.4 Hz, 3H), 0.84 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.5, 170.4, 157.2, 141.7, 119.8, 113.1, 87.7, 86.5, 81.0, 73.2, 72.2, 59.9, 51.8, 51.7, 44.1, 38.8, 37.6, 36.5, 35.8, 34.0, 33.7, 29.5, 28.0, 27.2, 26.5, 22.4, 21.3, 21.2, 21.1, 18.0, 16.0, 11.9; HRMS (ESI) for $C_{33}H_{48}O_7$ $[M]^+$ calcd. 557.3478, found 557.3457.



31

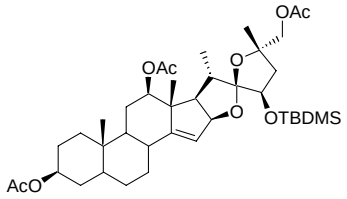
Acetate 31. To a stirred solution of $(DHQ)_2PHAL$ (33.6 mg, 0.1 eq.), $K_3Fe(CN)_6$ (425.6 mg, 3 eq.), K_2CO_3 (178.7 mg, 3 eq.), and $K_2OsO_4.2H_2O$ (2.2 mg, 0.014 eq.) in *t*-BuOH (2.5 mL) and H_2O (2.5 mL) was added a solution of olefin **30** (239.9 mg, 0.4309 mmol) in *t*-BuOH at 0 ^oC. The reaction was stirred at 0 ^oC for 17 h. After 17 h, Na_2SO_3 was added and stirred for additional 1 h at room temperature. The product mixture was extracted with CH_2Cl_2 and H_2O three times. The combined organic layers were dried over Na_2SO_4, filtered, and evaporated under reduced pressure. The resulting colorless oil was filtered through a silica gel pad (3 cm), and the solvent was removed *in vacuo*. The filtrate was further treated with K_2CO_3 (300 mg) in THF (2 mL) and H_2O (2 mL) at room temperature for 3 h. The reaction was extracted with EtOAc, dried over Na_2SO_4, filtered, and evaporated under reduced pressure. Flash column chromatography (EtOAc/ *n*-

Hexane = 1:1) gave acetate **31** (176.4 mg, 0.3091 mmol, 72% in 2 steps, C25-***S***:-***R*** = 7.8:1 based on the ^{1}HNMR integration of C22 of compound **32**) as a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.34 (s, 1H), 4.77-4.79 (m, 1H), 4.61-4.68 (m, 1H), 4.40 (dd, *J* = 11.4, 4.5 Hz, 1H), 4.03-4.09 (m, 2H), 3.61 (s, 1H), 3.32 (dd, *J* = 7.9, 3.7 Hz, 1H), 2.80 (d, *J* = 2.0 Hz, 1H), 2.12-2.20 (m, 2H), 2.05 (s, 3H), 2.04 (s, 3H), 1.99 (s, 3H), 1.23 (s, 3H), 1.07 (s, 3H), 1.03 (d, *J* = 6.1 Hz, 3H), 0.85 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 170.6, 157.8, 119.5, 89.7, 86.4, 81.1, 73.2, 71.5, 69.6, 60.7, 52.1, 51.7, 44.2, 40.0, 36.5, 35.9, 35.1, 34.1, 33.7, 29.7, 29.5, 28.0, 27.2, 26.6, 26.4, 21.4, 21.2, 20.9, 19.1, 16.2, 11.9; HRMS (ESI) for $C_{33}H_{50}O_9$ $[M]^+$ calcd. 590.3455, found 590.3449.

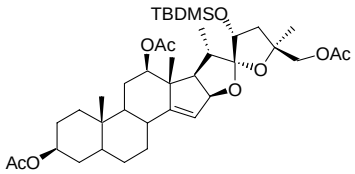


32

Compound 32. TBDMSOTf (13.2 μL, 1.2 eq.) was added to a solution of acetate **31** (28.3 mg, 0.0479 mmol) and TEA (33.4 μL, 5.0 eq.) in CH_2Cl_2 (1 mL) at 0 ^{o}C. After stirred for 4 h at 0 ^{o}C, the reaction was quenched by sat. $NaHCO_3$, extracted with EtOAc, washed with sat. NaCl, dried over Na_2SO_4, and evaporated under reduced pressure. Flash column chromatography (EtOAc/ *n*-Hexane = 1:8) provided compound **32** (26.3 mg, 0.0373 mmol, 78%); ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.35-5.37 (m, 1H), 4.73 (dd, *J* = 7.8, 2.1 Hz, 1H), 4.58-4.69 (m, 2H), 4.41 (dd, *J* = 11.4, 4.6 Hz, 1H), 3.86-4.02 (m, 3H), 3.39 (d, *J* = 8.6, 5.4 Hz, 1H), 2.05-2.12 (m, 1H), 2.04 (s, 3H), 2.02 (s, 3H), 1.97 (s, 3H), 1.18 (s, 3H), 1.05 (s, 3H), 1.01 (d, *J* = 6.7 Hz, 3H), 0.86 (s, 9H), 0.83 (s, 3H), 0.07 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 170.5, 170.4, 157.8, 119.4, 90.6, 86.5, 80.9, 73.2, 71.5, 71.3, 69.9, 60.1, 51.7, 51.6, 44.1, 43.0, 38.2, 36.5, 35.8, 34.1, 33.7, 29.6, 29.4, 27.9, 27.2, 26.5, 25.8, 25.7, 25.3, 21.3, 21.1, 20.9, 18.7, 17.9, 16.2, 11.9, -4.0, -4.4; HRMS (ESI) for $C_{39}H_{64}O_9SiNa$ $[M+Na]^+$ calcd. 727.4217, found 727.4209.



33



34

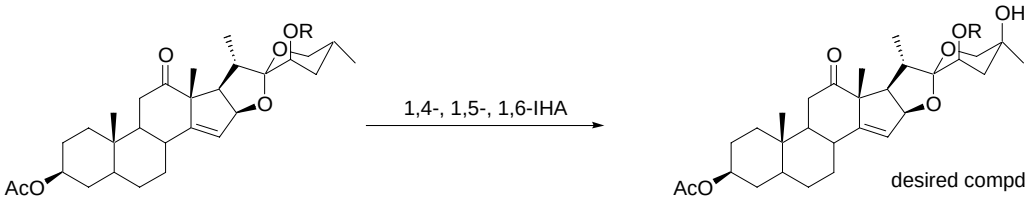
Compound 33, compound 34. A solution of compound **32** (26.5 mg, 0.0376 mmol), $PhI(OAc)_2$ (31.5 mg, 2.6 eq.), and I_2 (21.0 mg, 2.2 eq.) in cyclohexane (2 mL) was placed in a Rayonet photoreactor (Model RPR-100, 300 nm). After 2 h of irradiation, the reaction was quenched with aq. $Na_2S_2O_3$ and Et_2O, dried over Na_2SO_4, and evaporated under reduced pressure. Flash column chromatography (EtOAc/ *n*-Hexane = 1:5) gave compound **33** (16.9 mg, 0.0240 mmol, 75% borsm), **34** (1.4 mg, 0.0020 mmol, 6% borsm), along with unreacted **32** (3.9 mg, 15% recovered).

Compound 33. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.34, 4.91-4.94 (m, 1H), 4.59-4.69 (m, 1H), 4.37 (dd, *J* = 11.3, 4.6 Hz, 1H), 4.19 (d, *J* = 4.3 Hz, 1H), 3.99-4.09 (m, 2H), 2.20-2.29 (m, 1H), 2.05 (s, 3H), 2.02 (s, 3H), 1.98 (s, 3H), 1.31 (s, 3H), 1.04 (s, 3H), 0.83-0.87 (m, 15H), 0.03 (s, 3H), 0.02 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 170.5, 170.4, 157.4, 119.8, 118.4, 84.8, 81.9, 81.0, 79.1, 73.2, 70.3, 57.7, 51.8, 51.6, 44.2, 42.9, 39.3, 36.5, 35.9, 34.1, 33.7, 29.7, 29.5, 28.0, 27.2, 26.5, 26.0, 25.7, 21.4, 21.2, 20.9, 17.9, 15.8, 15.7, 11.9, -4.8, -4.9; HRMS (ESI) for $C_{39}H_{62}O_9SiNa$ $[M+Na]^+$ calcd. 725.4061, found 725.4052.

Compound 34. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.37 (s, 1H), 4.99-5.01 (m, 1H), 4.60-4.68 (m, 1H), 4.33 (dd, *J* = 11.2, 4.6 Hz, 1H), 4.17-4.23 (m, 1H), 3.95-4.15 (m 1H), 2.15-2.31 (m, 2H), 2.05 (s, 3H), 2.01 (s, 3H), 1.92 (s, 3H), 1.08 (s, 3H), 1.04 (s, 3H), 1.01 (d, *J* = 4.1 Hz, 1H), 0.83 (s, 9H), 0.82 (d, *J* = 3.0 Hz, 3H), 0.04 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.9, 170.6, 170.3, 153.4, 122.2, 115.5, 85.0, 80.0, 78.9, 73.3, 71.8, 70.9, 54.4, 52.4, 51.7, 44.3, 39.9, 39.5, 36.4, 36.0, 33.8, 33.7, 29.7, 29.3, 28.1, 27.3, 26.4, 25.7, 24.8, 21.4, 21.1, 21.0, 17.8, 14.8, 13.6, 11.9, -4.0, -5.0; HRMS (ESI) for $C_{39}H_{62}O_9SiNa$ $[M+Na]^+$ calcd. 725.4061, found 725.4069.

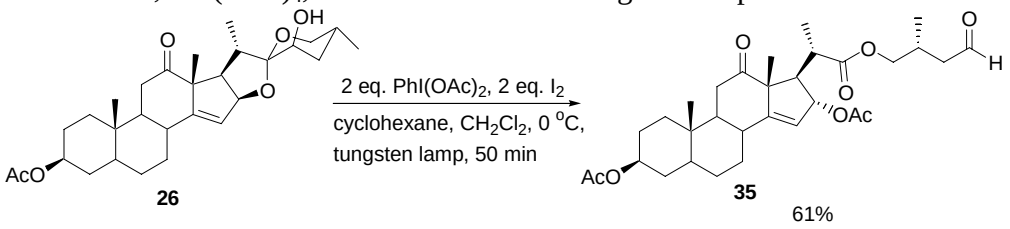
Survey of methods for axial C-23 alcohol-directed oxygenation of unactivated C-25 position.

With C-23 axial OH group at our hand, it was expected to have several chances to introduce the hydroxy group at C-25 in a desired stereochemistry without ring opening.



a. 1,4-Hydrogen abstraction

Alkoxy radical is one of the strongest hydrogen abstractors. Several attempts using, Suarez condition,[3] $Pb(OAc)_4$,[4] Selectfluor^{TM}[5] with tungsten lamp were not successful.

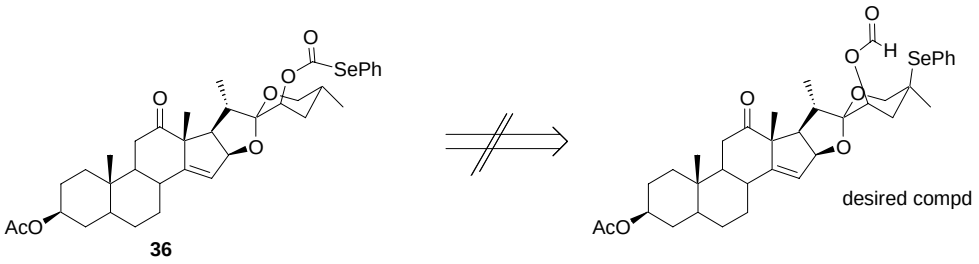


In the cases of $Pb(OAc)_4$, I_2, tungsten lamp, and Selectfluor^{TM}, MeCN, reflux, the S.M. decomposed

b. 1,5-Hydrogen abstraction

Carbonyl radical from selenoester might be another acceptable choice for our hydrogen abstraction attempts. Selenoester can be obtained from triphosgen followed by benzene selenol.[6]

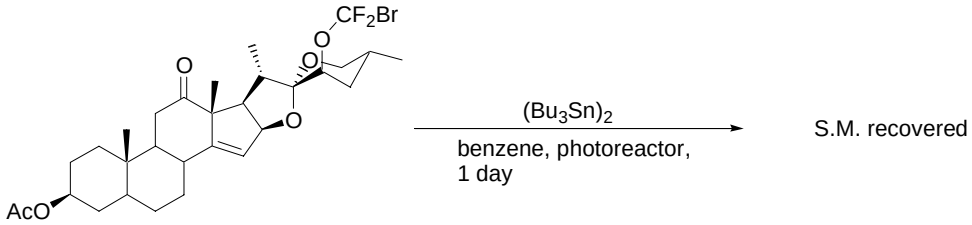
[3] Carmen Betancor, Raimundo Freire, Ines Perez-Martin, Thierry Prange, Ernesto Suarez *Org. Lett.* **2002**, *4*, 1295.
[4] Heusler, L., Kalvoda, I. *Angew. Chem. Int. Ed.* **1964**, *3*, 525.
[5] R. Eric Banks, Nicolas J. Lawrence, Mohammed K. Besheesh, Allan L. Popplewell, Robin G. Pritchard *Chem. Commun.* **1996**, 1629.
[6] Dale L. Boger, Robert J. Mathvin K. *J. Org. Chem.* **1992**, *57*, 4696.



36

Reaction #	Conditions	Results
110-1-342	uv lamp/benzene	Major portion S.M, Some decomposed spots
110-1-339	AIBN/Bu_3SnH/benzene/reflux	Major portions at the origin and less than 10% 23-OH compd
110-1-344	ACN/Bu_3SnH/toluene/reflux	10% of 23-OH compd, S.M. 36% recovered, the others at origin
110-1-345	$Bu_3SnSnBu_3$/benzene/tungsten lamp then uv lamp	small amount of unknown compd, the others at origin
110-1-347	$Ph_3SnSnPh_3$/benzene/uv lamp	28% S.M. recovered, the others

Treatments with various radical initiators with a uv lamp didn't give any traces of desired product but gave selenoester itself or decomposed material.
Instead of selenoester, treatment of bromodifluoromethylether compound **37** gave only starting compound.

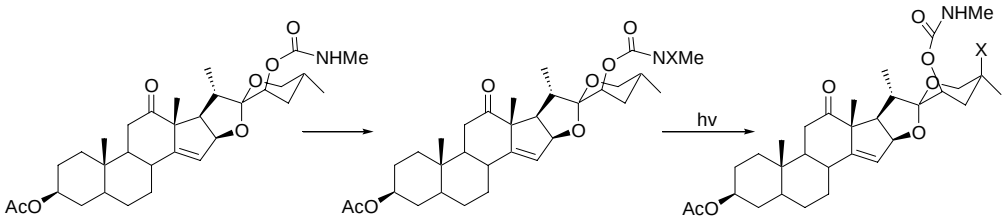


37

c. 1,6-Hydrogen abstraction

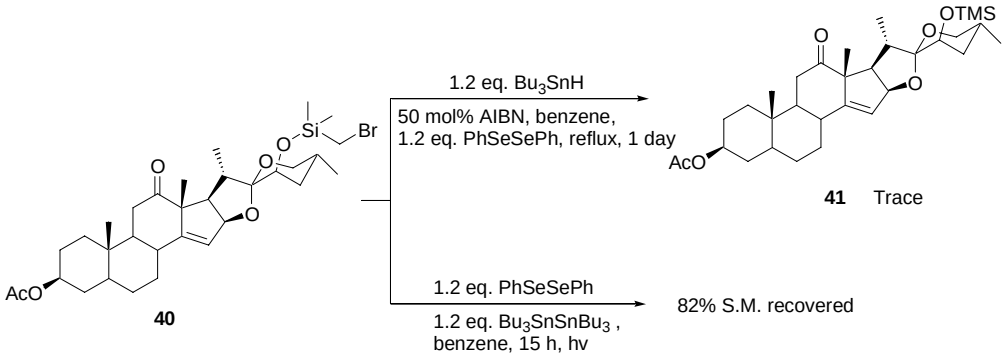
Hofmann-Loeffler-Freytag type reaction has many examples which successfully functionalized a C-H bond in a cyclic compound.[7] However, its application on our compound was not successful.

[7] Patrick F. Dicks, Stephen A. Glover, andre Goosen, Cedric W. McCleland *Tetrahedron*, **1987**, *43*, 923.



Reaction #	Conditions	Results
110-1-333(X=Br)	$AcOBr/CCl_4$/r.t./3 h	decomposed in NMR tube, bromine attacks double bond
110-1-348(X=NO)	hv/benzene	N.R.

Bromomethyldimethylsilyl group is assumed to have the ability to abstract hydrogen also. Using Bu_3SnH, AIBN provided only TMS protected compound, whereas from ditin reagent, starting compound was recovered.



Using Bu_3SnH, AIBN provided only TMS protected compound, whereas from ditin reagent, starting compound was recovered.

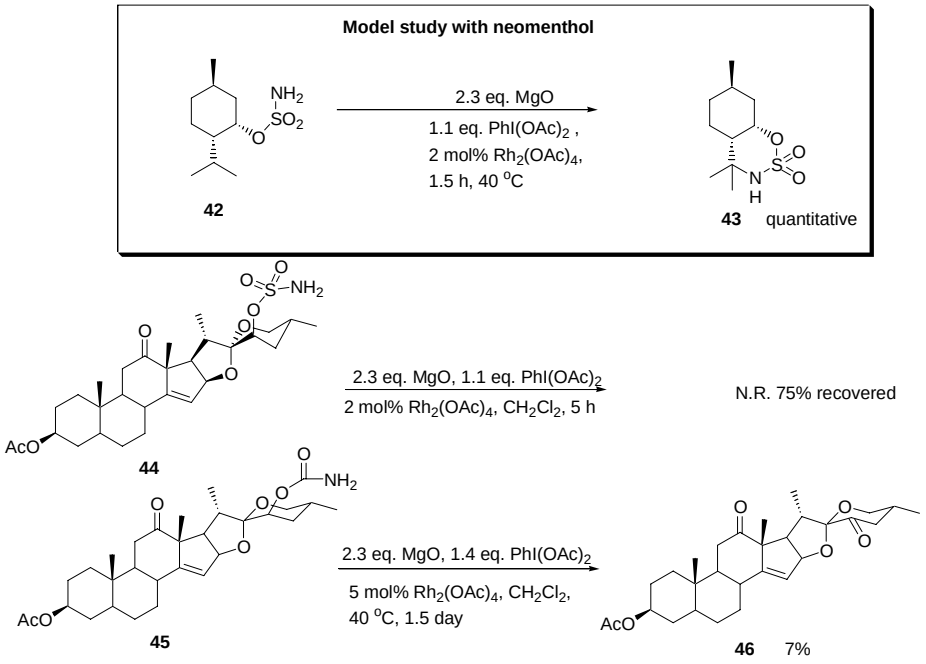
d. C-H insertions using nitrene chemistry

Although none of our attempts using radical chemistry were successful, activation at C-25 using nitrene chemistry was a possibility.

As our model study, neomenthol, which has a sulfamoyl group, was successfully transformed to the desired product.[8] However, application on our compound provided no

[8] (a) Christine G. Espino, Paul M. Wehn, Jessica Chow, J. Du Bois, *J. Am. Chem. Soc.* **2001**, *123*, 6935. (b) Christine G. Espino, J. Du Bois, *Angew. Chem. Int. Ed.* **2001**, *40*, 598. (c) Paul M. Wehn, J. Du Bois, *J. Am. Chem. Soc.* **2002**, 124, 12950. (d) J. J. Fleming, K. W. Fiori, J. Du Bois, *J. Am. Chem. Soc.* **2003**, 125, 2028.

evidence of desired product. From the carbamate **45**, only C-23 ketone compound was separated in only 7% yield.



Further investigation of an alternative route toward dienyl ether 27

As an alternative toward dienyl ether **27**, we investigated another possibility on conversion of 2-bromophenyl sulfide **47**[9] to dienyl ether **27** via intramolecular hydrogen abstraction. However, 2-bromophenyl sulfide **47** was decomposed under the condition with 1.5 eq. BuSnH, 0.3 eq. AIBN in benzene under reflux.

[9] 2-Bromophenyl sulfide **47** can be easily obtained from the same reaction condition as sulfide **24**, selenide **25** (10 mol% $BF_3.OEt_2$, 1.5 eq. 2-bromobenzenethiol in CH_2Cl_2 at – 40 °C for 20 min., 32%), followed by acyl protection using 1.2 eq. Ac_2O, 5 eq. pyridine in CH_2Cl_2 .

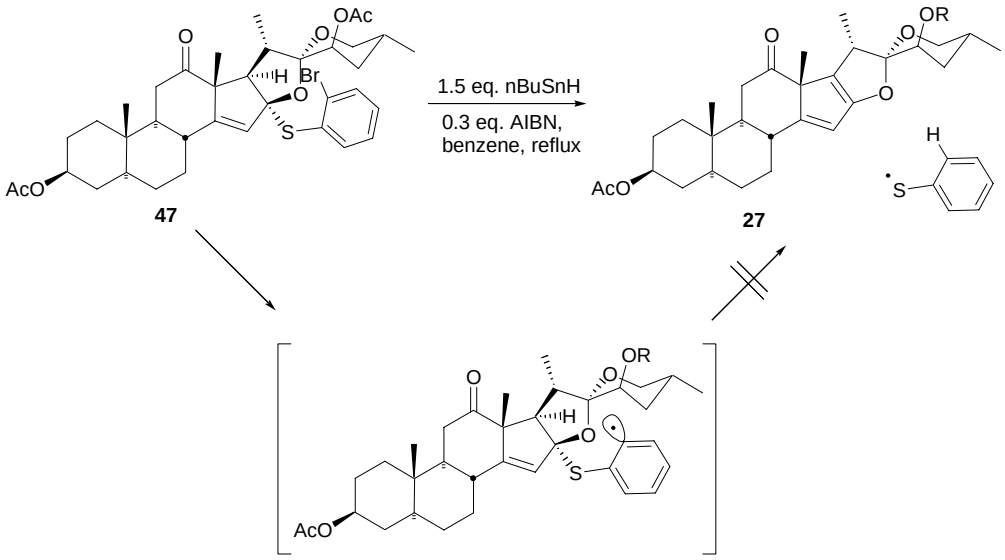
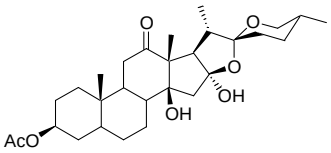
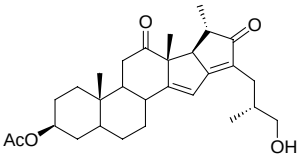
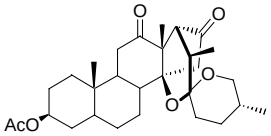
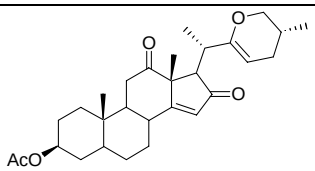
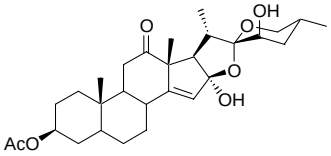
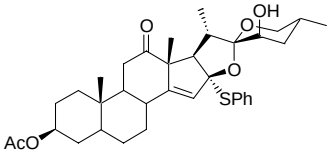
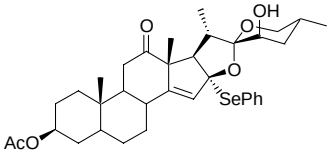
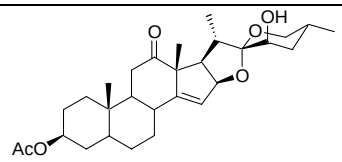
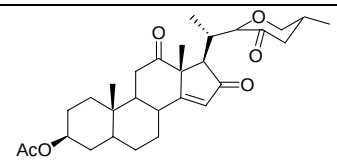
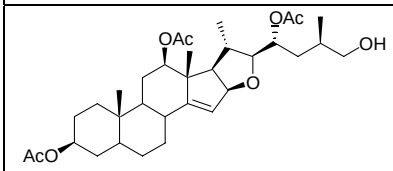
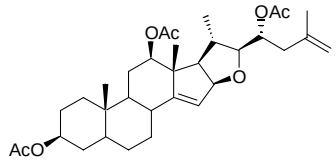
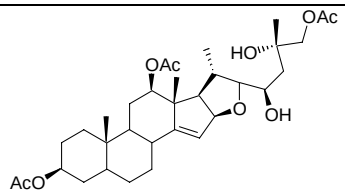
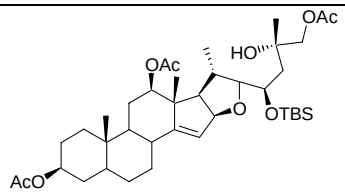
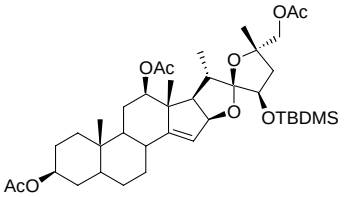

OAc
O
O
H
Br
O
S
AcO
47
1.5 eq. nBuSnH
0.3 eq. AIBN,
benzene, reflux
OR
O
O
O
H
S
AcO
27
OR
O
O
H
O
S
AcO

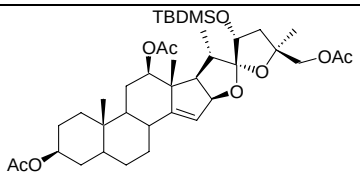
Table 1. ^{13}CNMR peak assignment table for key intermediates.

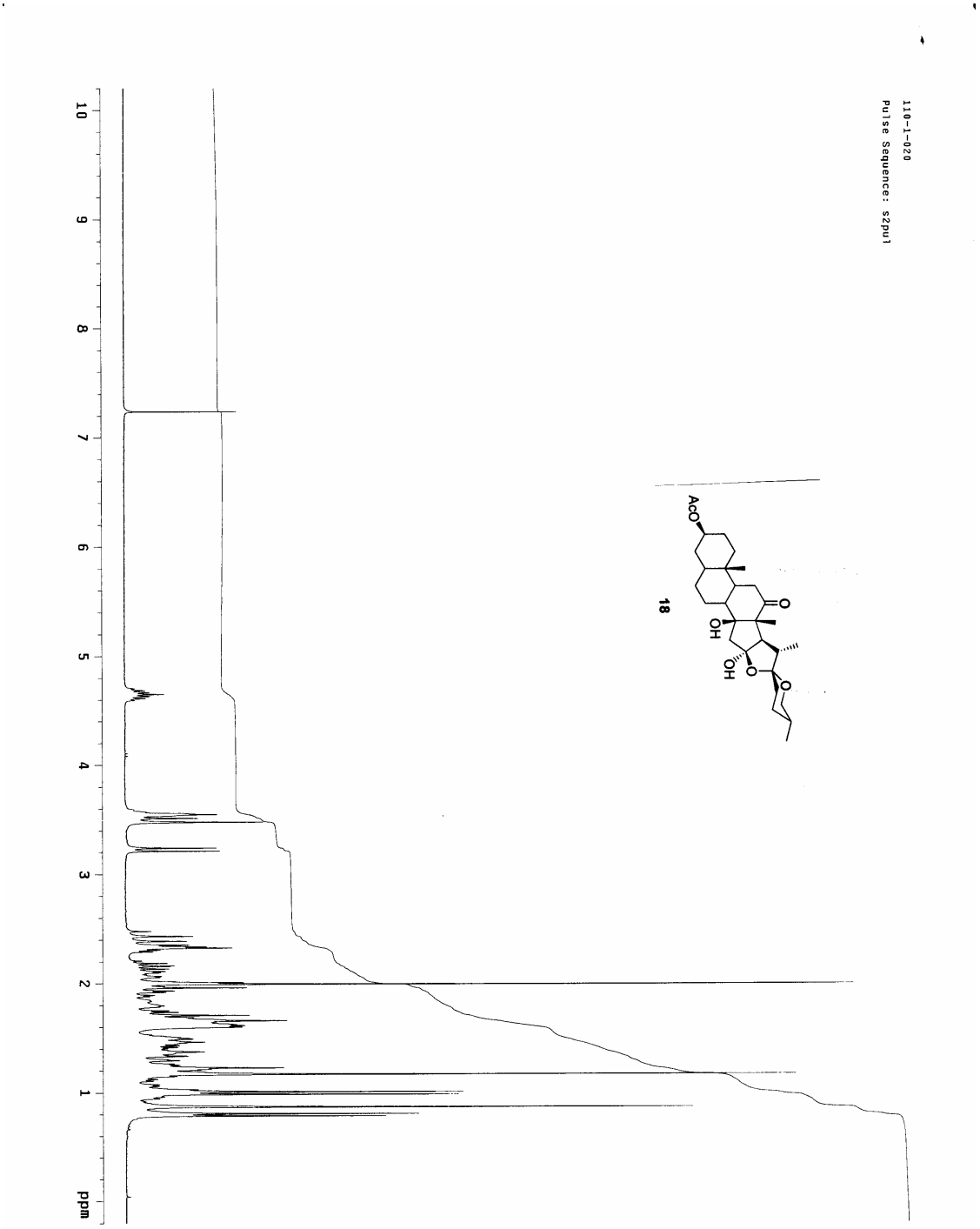
compd. / position	**18**	**20**	**21**	**23**	**24**	**25**	**26**	**29**	**30**	**31**	**32**	**33**	**34**
1	36.2	36.3	36.2	36.2	36.1	36.0	36.2	35.8	35.8	35.9	35.8	35.9	36.0
2	26.9	27.1	27.1	27.1	27.1	27.1	27.2	27.2	27.2	27.2	27.2	27.2	27.3
3	72.8	72.9	72.8	72.9	73.0	73.0	73.1	73.2	73.2	73.2	73.2	73.2	73.3
4	33.6	33.8	33.6	33.6	33.6	33.4	33.7	33.7	33.7	33.7	33.7	33.7	33.7
5	44.1	44.6	43.6	43.8	43.9	43.8	44.0	44.1	44.1	44.2	44.1	44.2	44.3
6	27.8	27.6	27.4	27.7	27.6	27.6	27.8	27.9	28.0	28.0	27.9	28.0	28.1
7	27.2	27.4	28.9	29.1	29.2	29.2	29.4	29.4	29.5	29.5	29.4	29.7	29.7
8	39.1	39.4	37.0	37.1	33.7	33.7	34.3	34.0	34.0	34.1	34.1	34.1	33.8
9	46.4	47.2	52.3	52.5	52.2	51.6	53.2	51.8	51.8	51.7	51.6	51.6	51.7
10	35.8	36.0	36.5	36.1	36.5	36.4	36.5	36.5	36.5	36.5	36.5	36.5	36.4
11	36.6	36.9	36.9	37.1	36.8	36.7	37.3	26.5	26.5	26.6	26.5	26.5	26.4
12	211.9	212.5	206.0	210.6	209.6	209.8	211.4	81.0	81.0	81.1	80.9	81.0	78.9
13	61.7	57.4	62.8	62.0	62.2	62.2	62.5	59.9	59.9	60.7	60.1	57.7	54.4
14	86.1	83.9	182.5	155.6	151.7	151.6	156.0	157.3	157.2	157.8	157.8	157.4	153.4
15	43.4	41.6	125.5	121.5	123.9	124.9	120.3	119.7	119.8	119.5	119.4	119.8	122.2
16	113.1	211.7	210.0	116.6	103.6	99.7	84.2	86.5	86.5	86.4	86.5	84.8	85.0
17	58.2	54.5	52.6	59.3	59.1	60.4	51.6	51.7	51.7	52.1	51.7	51.8	52.4
18	14.5	14.4	19.8	21.1	20.9	21.3	21.8	16.0	16.0	16.2	16.2	15.7	13.6
19	11.6	11.8	11.6	11.6	11.6	11.5	11.7	11.9	11.9	11.9	11.9	11.9	11.9
20	46.3	47.2	35.4	43.8	44.4	44.3	43.4	37.5	37.6	40.0	38.2	39.3	39.9
21	14.2	13.7	21.3	15.7	15.6	15.7	15.5	16.3	18.0	19.1	18.7	15.8	14.8
22	107.2	97.7	156.2	107.9	107.8	108.0	106.5	88.0	87.7	89.7	90.6	118.4	115.5
23	31.6	33.8	94.7	70.9	71.5	71.5	71.2	72.3	72.2	69.6	71.5	79.1	71.8
24	28.2	28.0	29.3	36.0	35.9	35.7	36.2	33.6	38.8	35.1	43.0	42.9	39.5
25	29.8	29.7	26.9	33.9	24.1	24.0	24.2	32.1	141.7	69.6	71.3	81.9	80.0
26	67.6	66.7	71.3	67.4	67.6	67.7	66.6	68.3	113.1	71.5	69.9	70.3	70.9
27	16.8	17.2	17.2	16.7	16.9	16.9	16.8	18.0	22.4	26.4	25.3	26.0	24.8

Table 2. Characterization Check List

compound	^{1}HNMR	^{13}CNMR	LRMS	HRMS	others
 **18**	O	O	O	O	X-ray M.P. 179 – 180 ^{o}C (toluene)
 **19**	O	O	O	O	
 **20**	O	O	O	O	X-ray M.P. 155 – 157 ^{o}C (toluene)
 **21**	O	O	O	O	
 **23**	O	O	O	O	
 **24**	O	O	O	O	
 **25**	O	O	O	O	

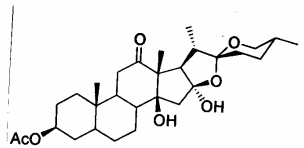
 **26**	O	O	O	O	X-ray M.P. 245 – 246 °C (EtOAc/n-Hx)
 **28**	O	O	O	O	M.P. 225 – 226 °C (EtOAc)
 **29**	O	O	O	O	
 **30**	O	O	O	O	
 **31**	O	O	O	O	
 **32**	O	O	O	O	
 **33**	O	O	O	O	

 **34**	O	O	O	O	

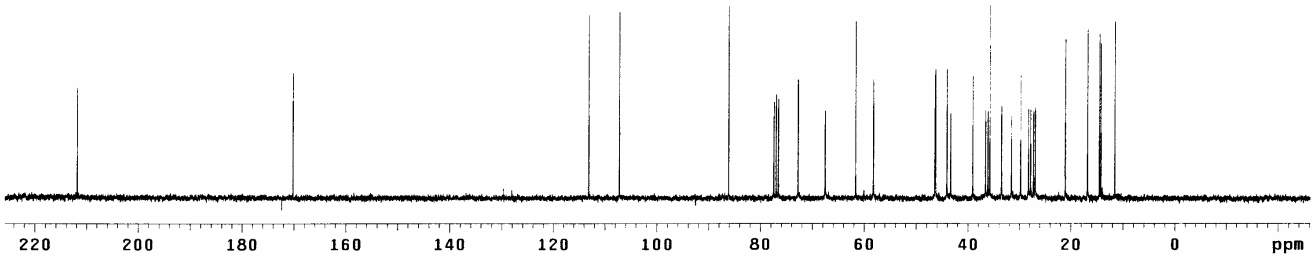

110-1-020
Pulse Sequence: s2pul
AcO
OH
OH
O
O
O
18
10
9
8
7
6
5
4
3
2
1
ppm

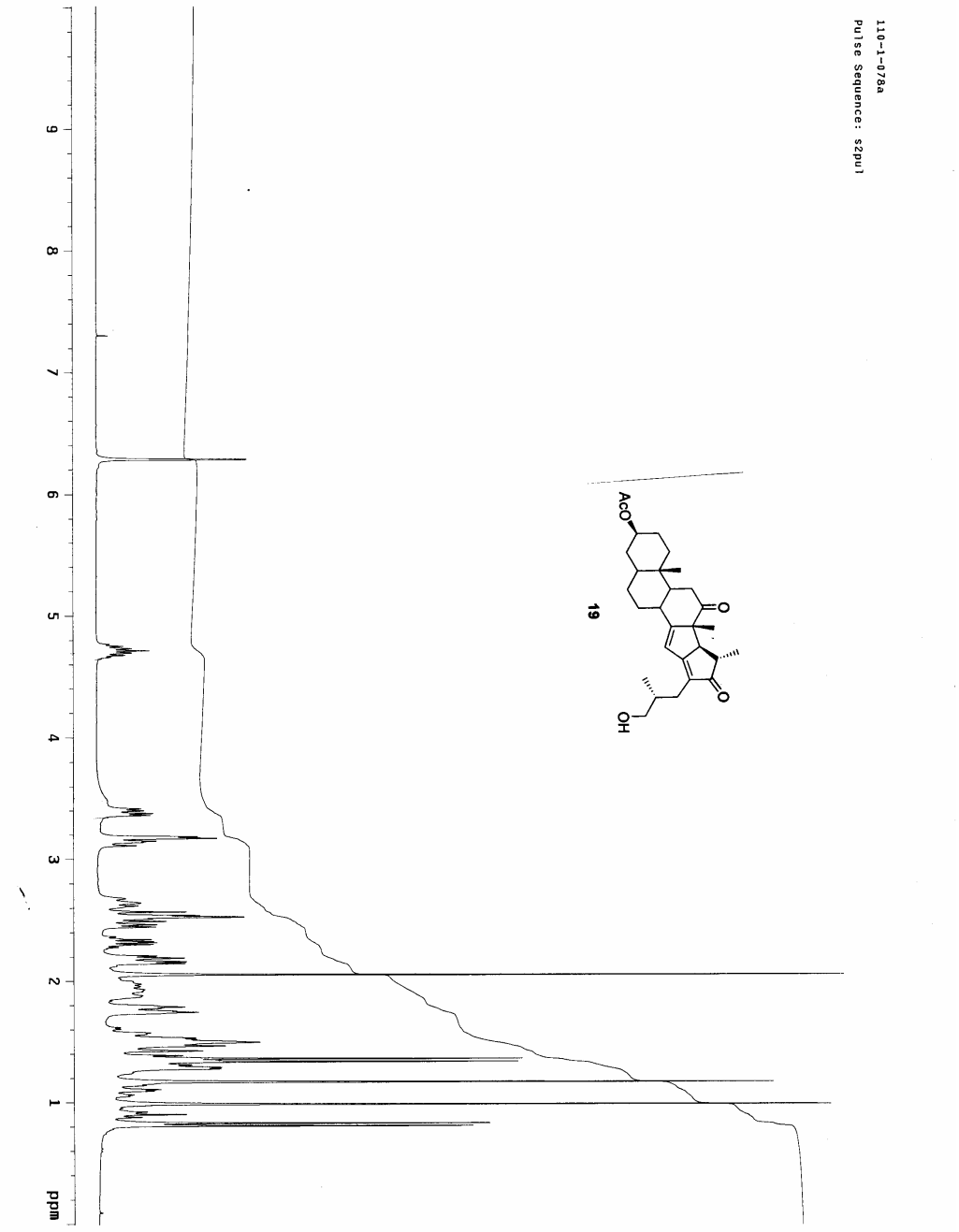
110-1-020

Pulse Sequence: s2pul



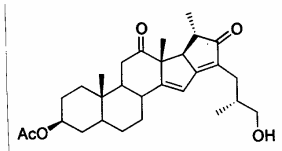
18



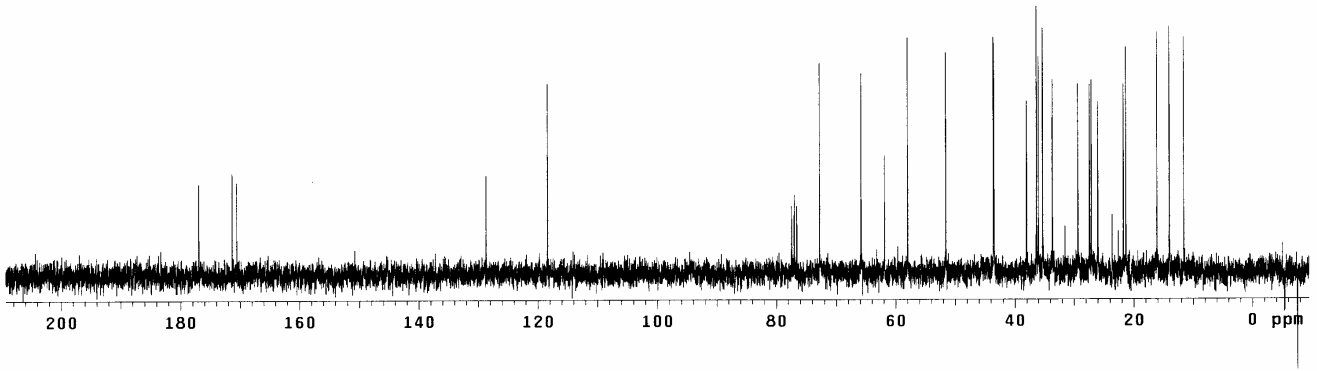

110-1-078a
Pulse Sequence: s2pul
AcO
O
O
OH
19
9
8
7
6
5
4
3
2
1
ppm

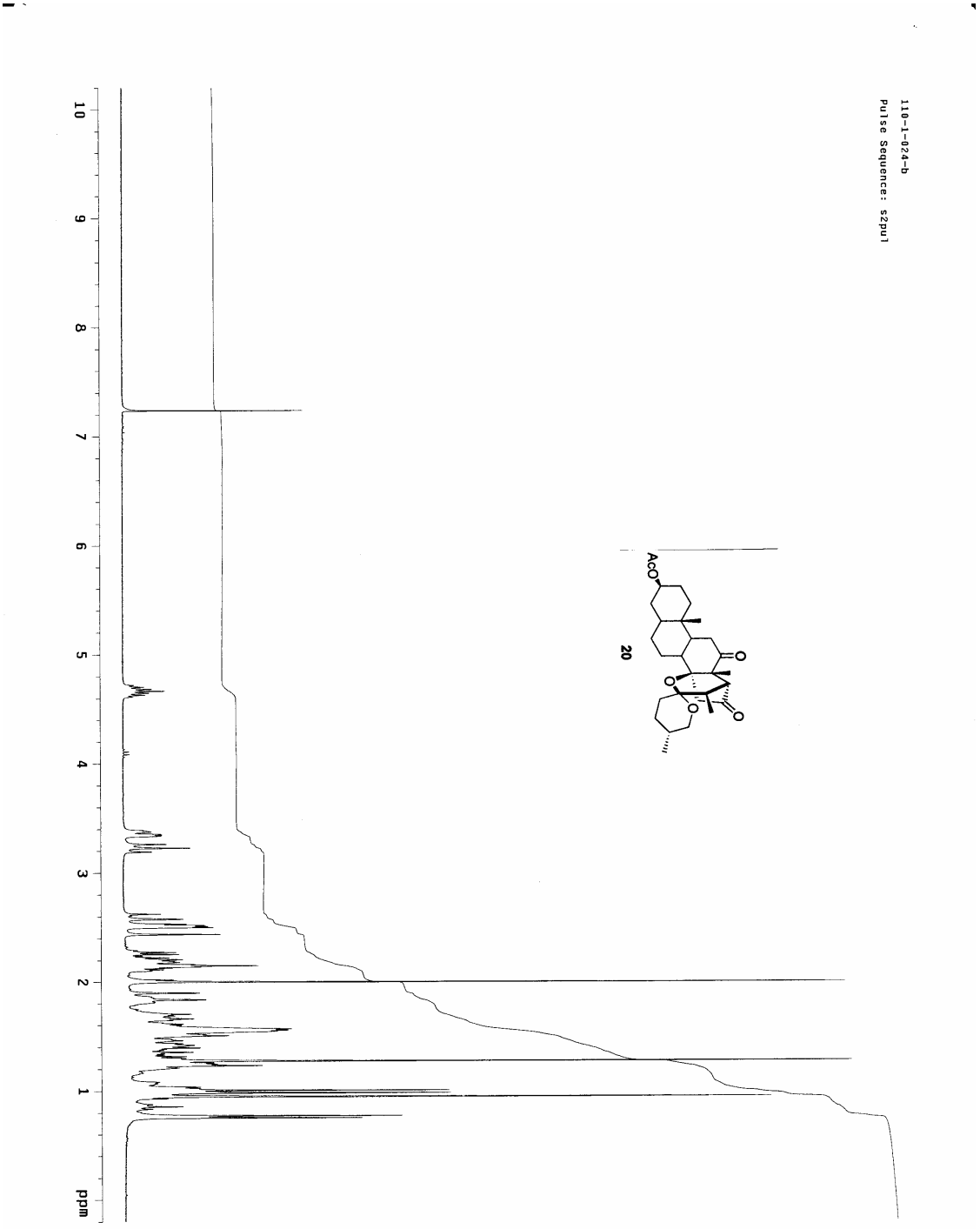
110-1-078a

Pulse Sequence: s2pul



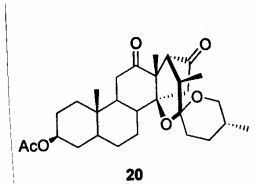
19



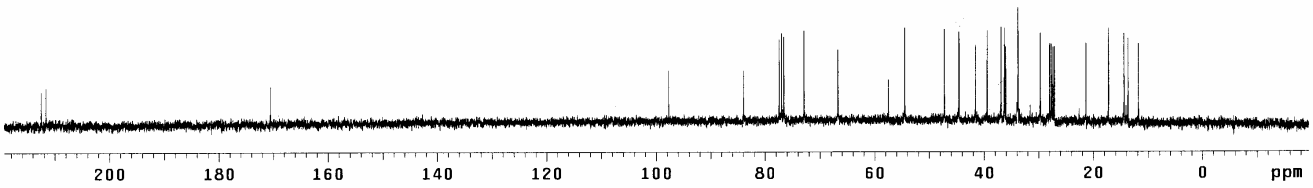

110-1-024-b
Pulse Sequence: s2pul
AcO
O
O
O
O
20
10
9
8
7
6
5
4
3
2
1
ppm

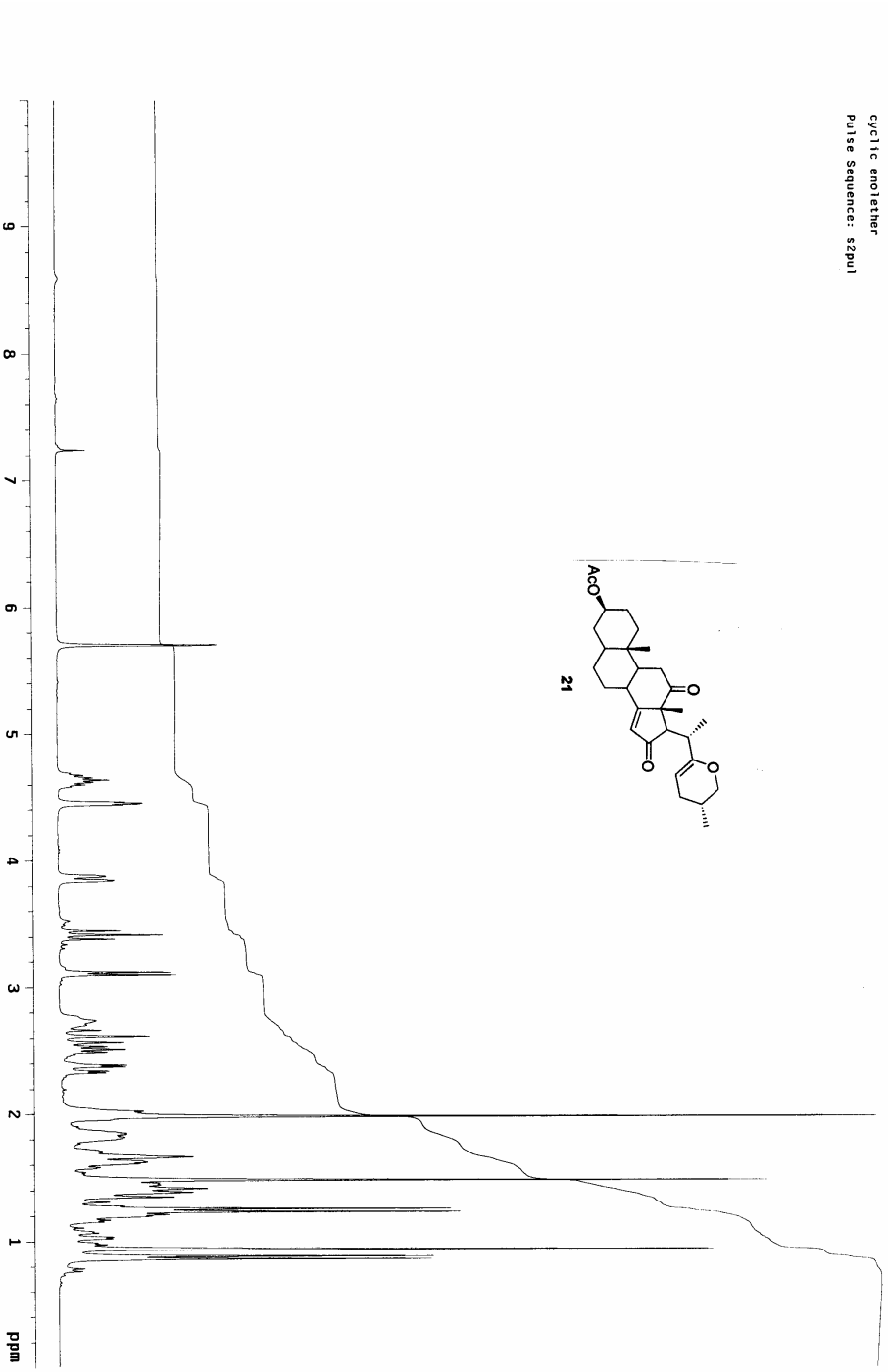
C-111-024
Pulse Sequence: s2pul

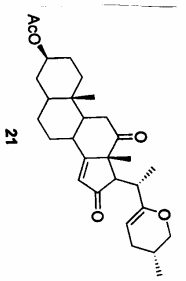
INDEX	FREQUENCY	PPM	HEIGHT
1	16030.188	212.532	6.7
2	15964.261	211.657	7.4
3	12862.416	170.533	7.6
4	7370.732	97.723	10.7
5	6330.741	83.934	10.6
6	5839.588	77.422	16.6
7	5807.174	76.993	17.8
8	5775.309	76.570	17.1
9	5498.967	72.906	18.3
10	5033.635	66.737	14.6
11	4332.616	57.443	8.9
12	4108.466	54.471	18.8
13	3561.825	47.223	18.6
14	3362.397	44.579	18.0
15	3134.401	41.557	15.5
16	2973.979	39.430	18.3
17	2784.440	36.917	19.0
18	2738.292	36.305	18.8
19	2718.514	36.043	15.2
20	2548.753	33.792	22.7
21	2378.992	31.541	4.0
22	2238.898	29.684	17.8
23	2108.144	27.950	15.8
24	2084.520	27.637	15.7
25	2064.193	27.367	15.1
26	2044.415	27.105	15.2
27	1609.299	21.336	15.9
28	1299.994	17.236	18.8
29	1086.831	14.409	17.7
30	1062.109	14.082	3.8
31	1032.991	13.696	16.8
32	889.601	11.795	15.8



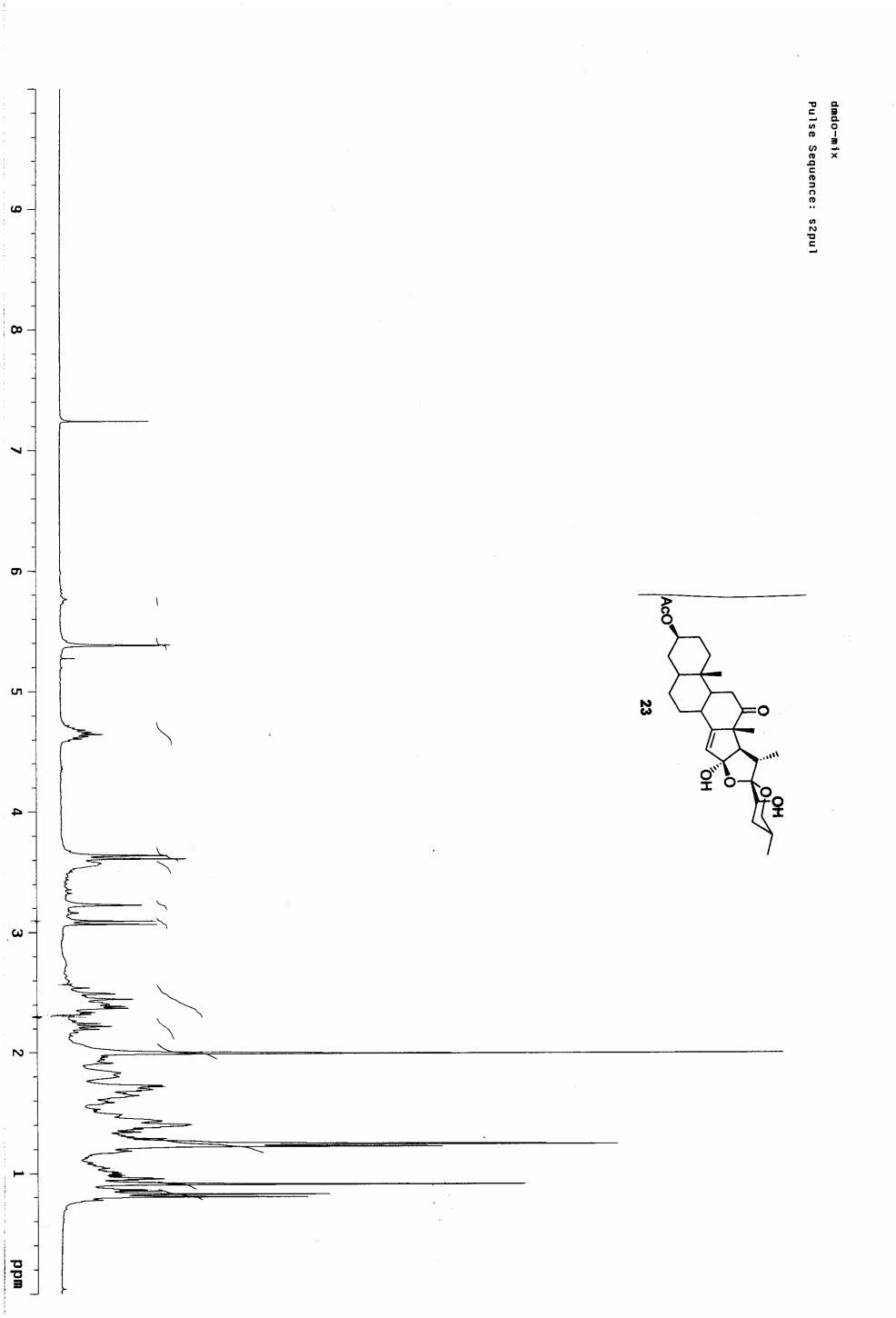
20




cyclic enolether
Pulse Sequence: s2pul
AcO
O
O
O
21
9
8
7
6
5
4
3
2
1
ppm

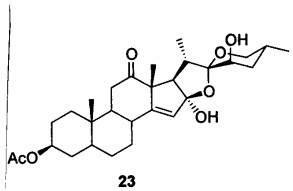


21

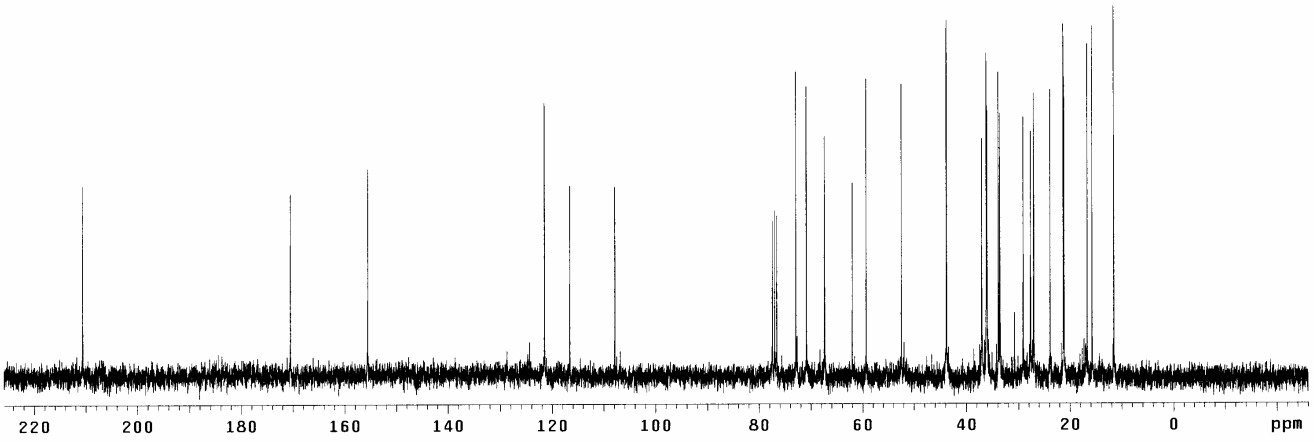

dmdo-mix
Pulse Sequence: s2pul
AcO
O
OH
O
OH
23
9
8
7
6
5
4
3
2
1
ppm

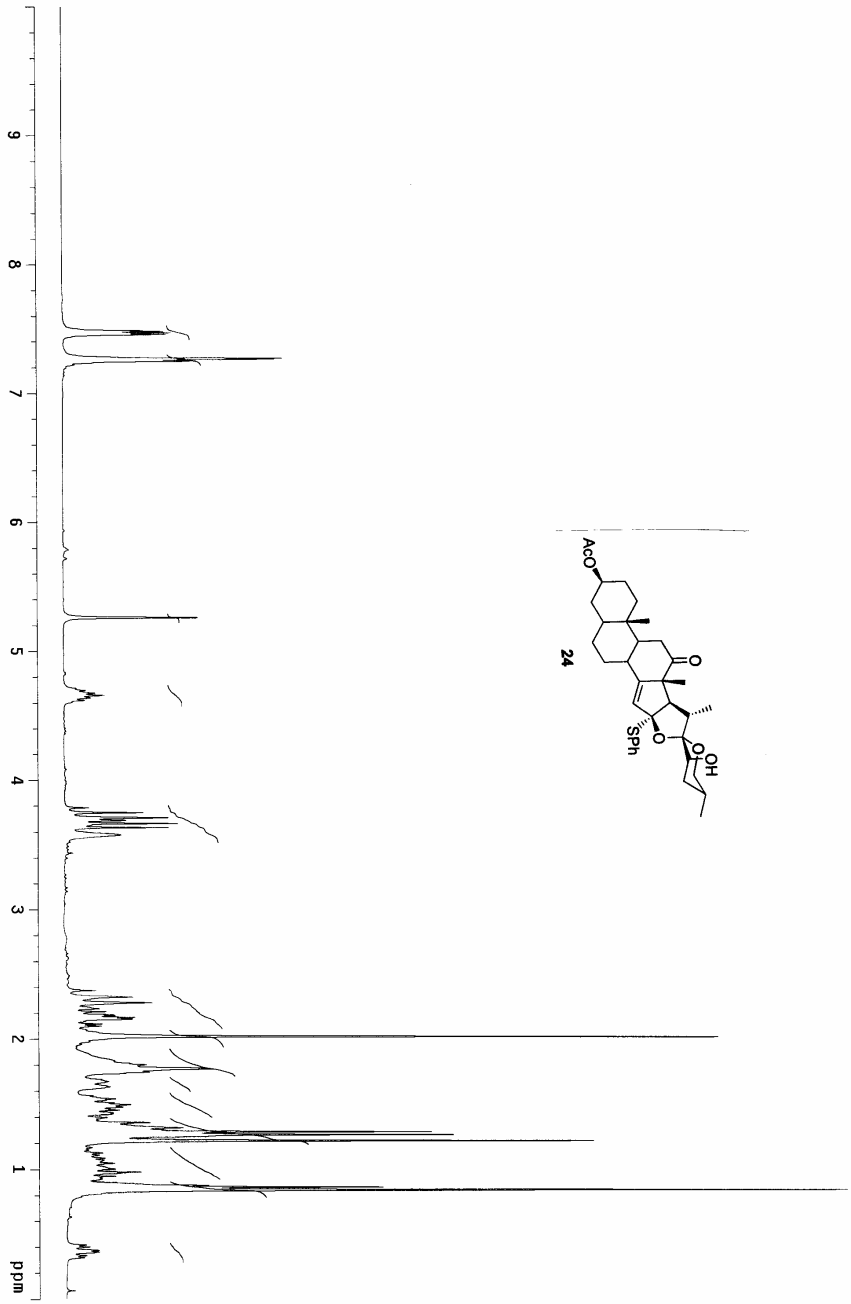
dmdo-crude

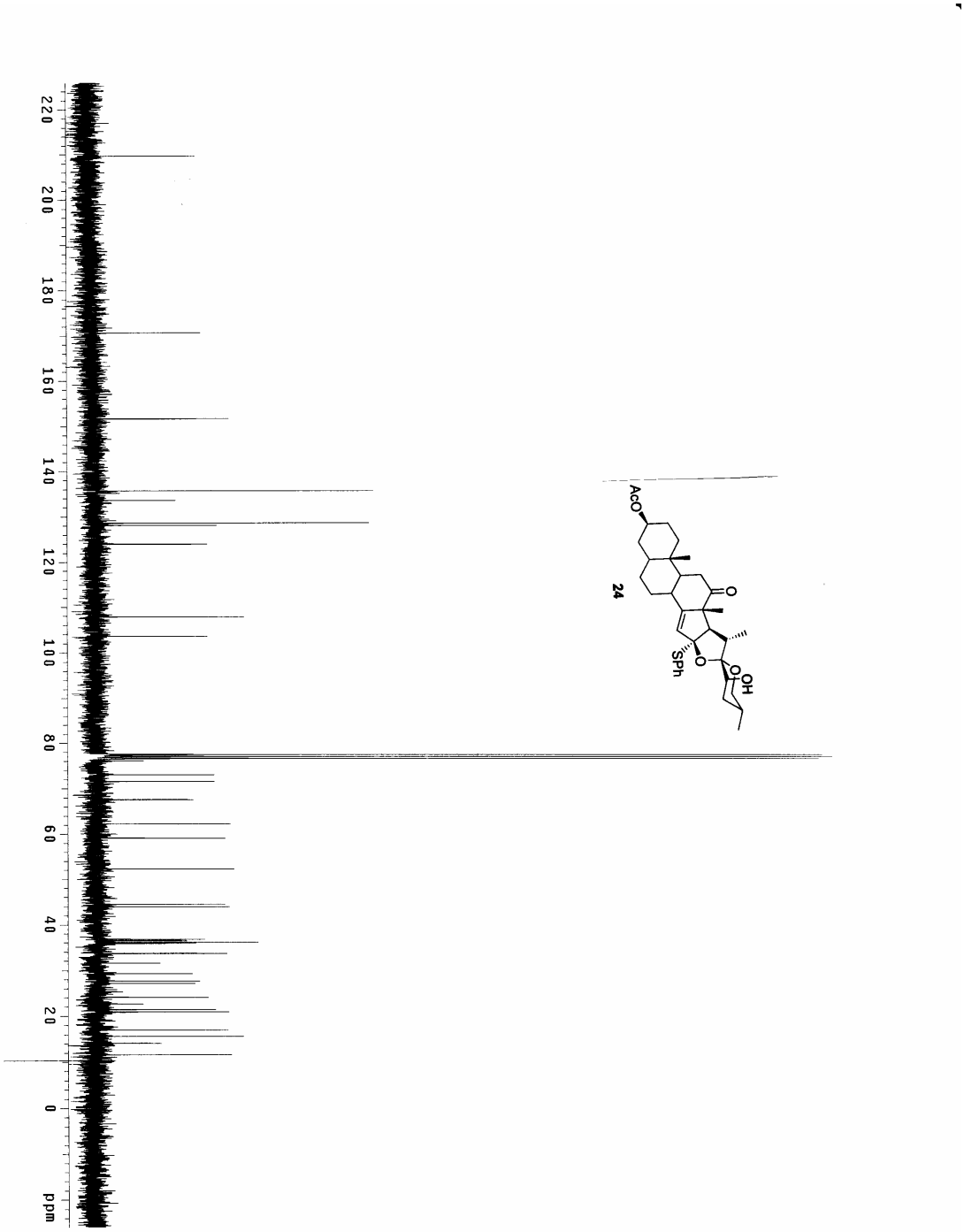
Pulse Sequence: s2pul

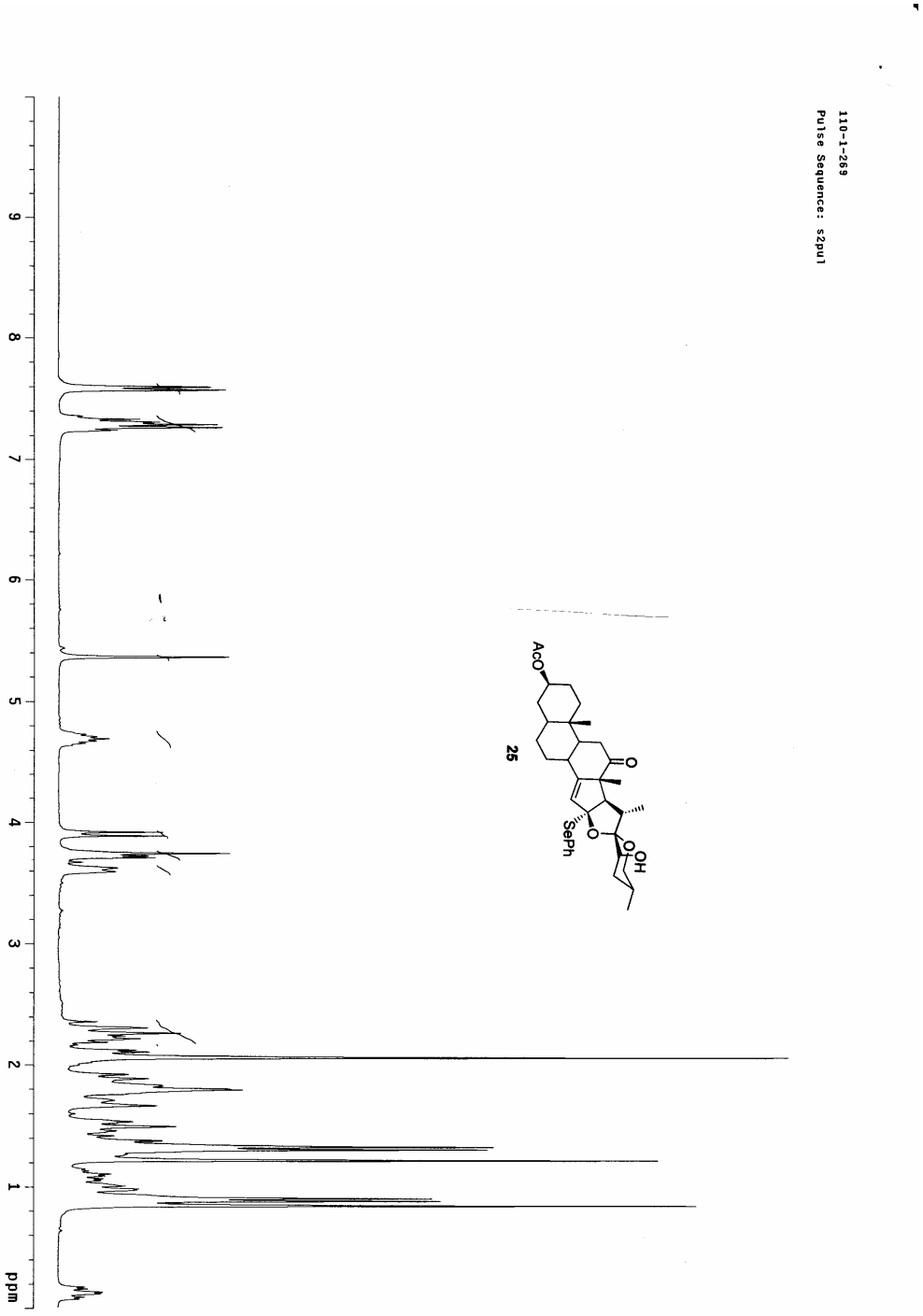


23



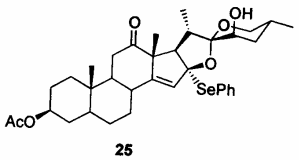

9
8
7
6
5
4
3
2
1
ppm
AcO
O
SPh
O
OH
O
24


220
200
180
160
140
120
100
80
60
40
20
0
ppm
AcO
O
SPh
O
O
OH
24

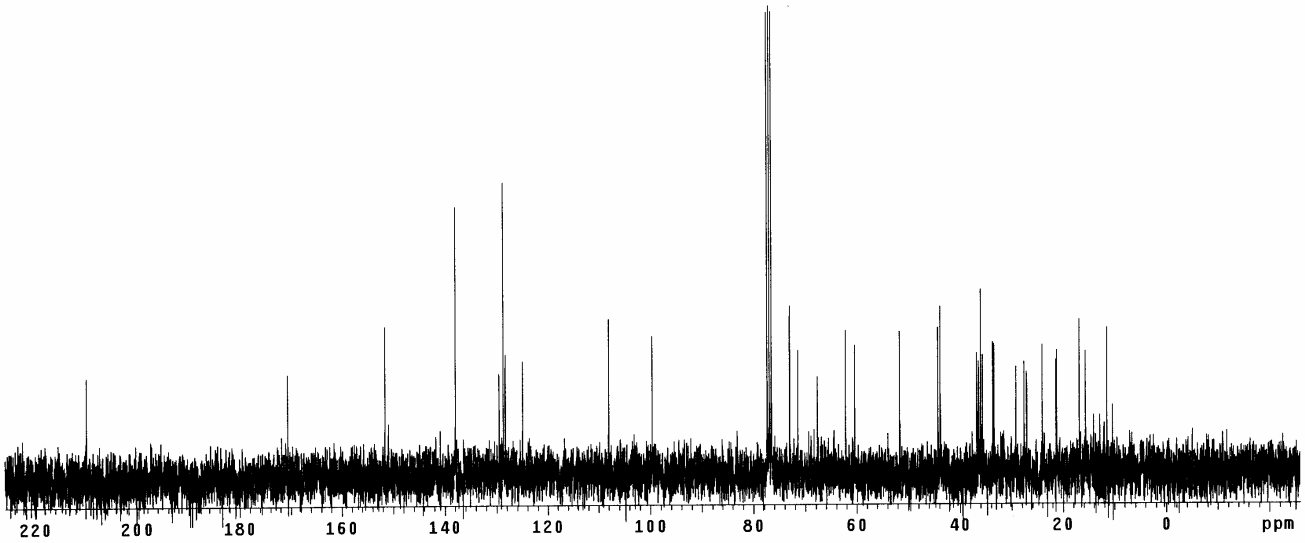

110-1-269
Pulse Sequence: s2pul
AcO
O
SePh
O
OH
25
9
8
7
6
5
4
3
2
1
ppm

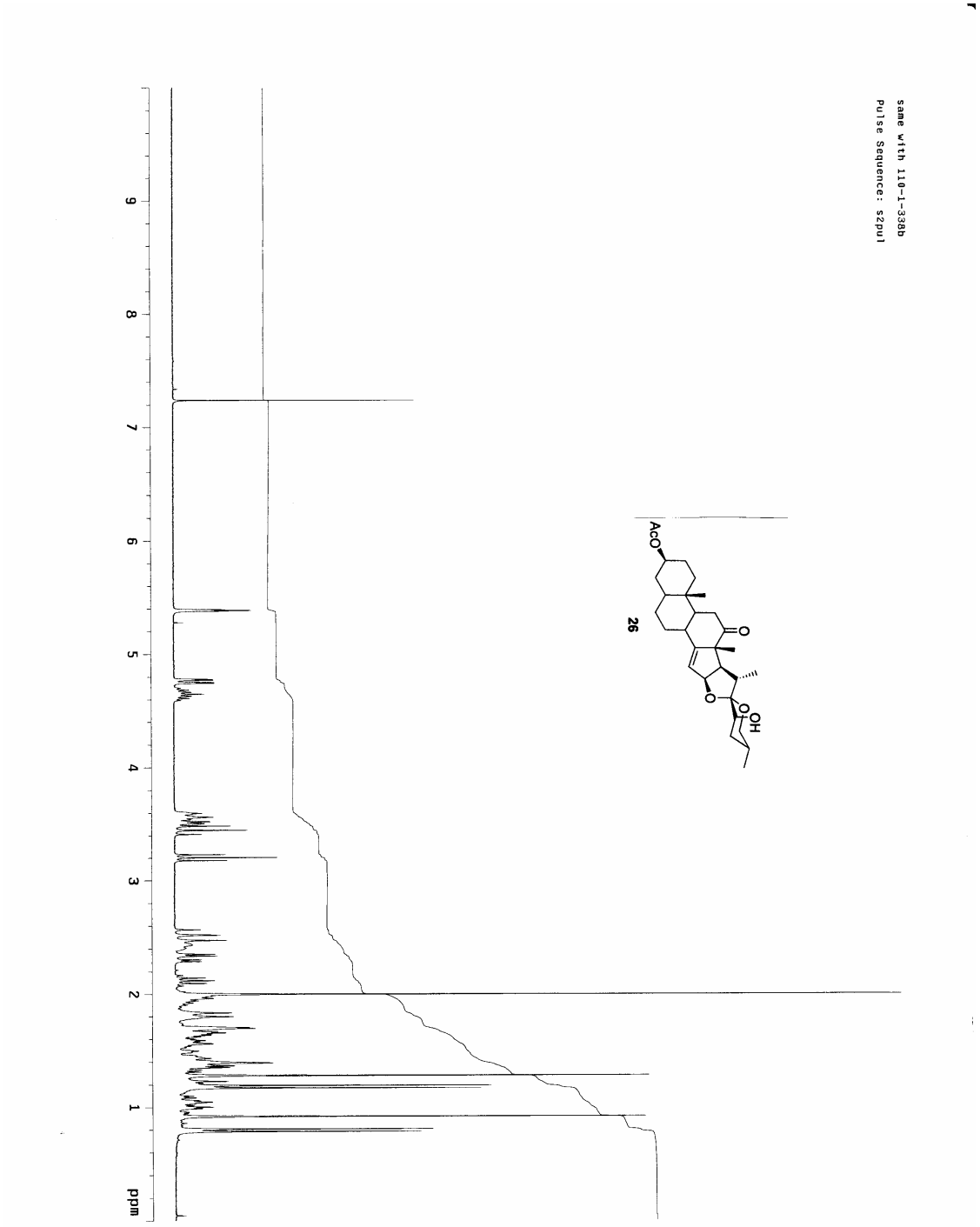
110-1-269

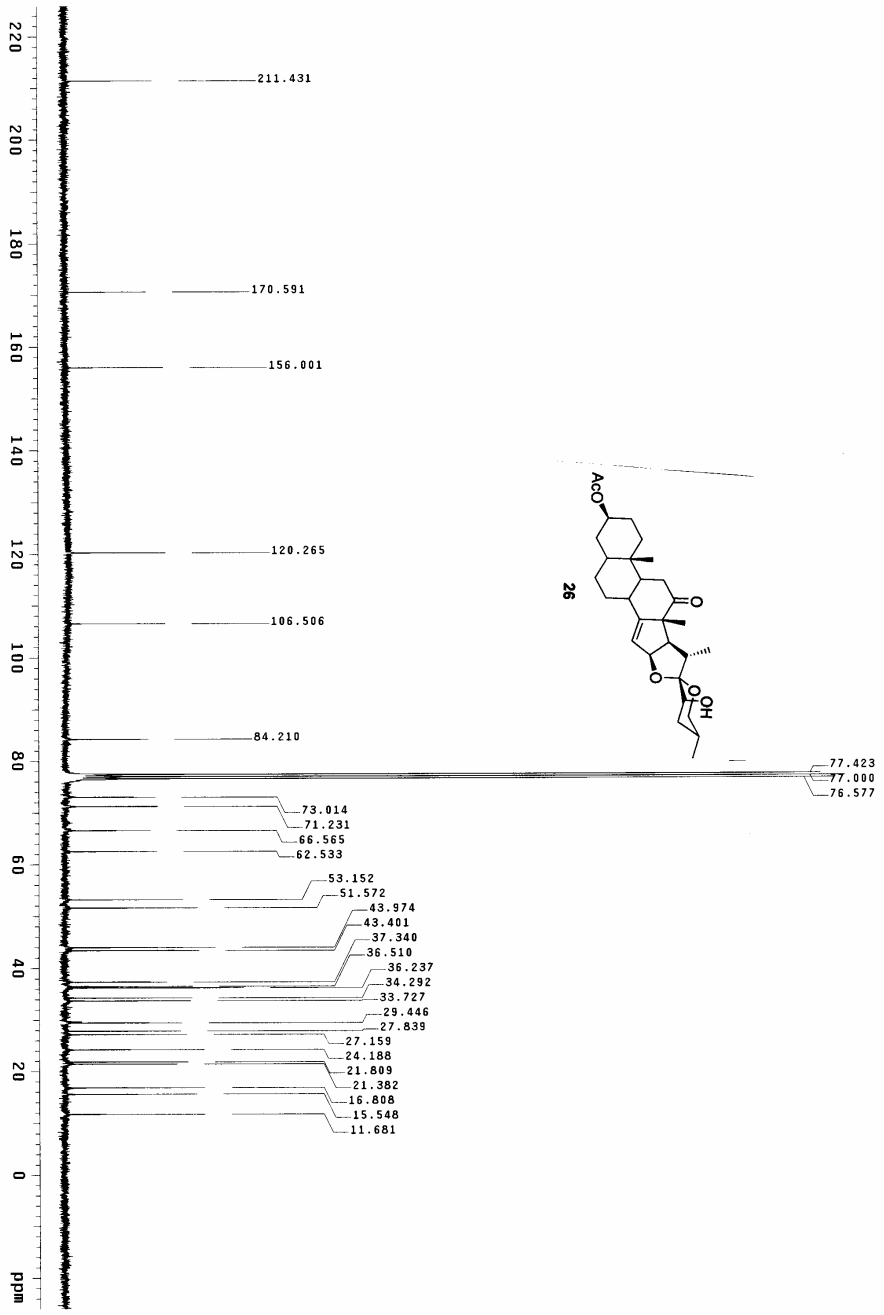
Pulse Sequence: s2pul

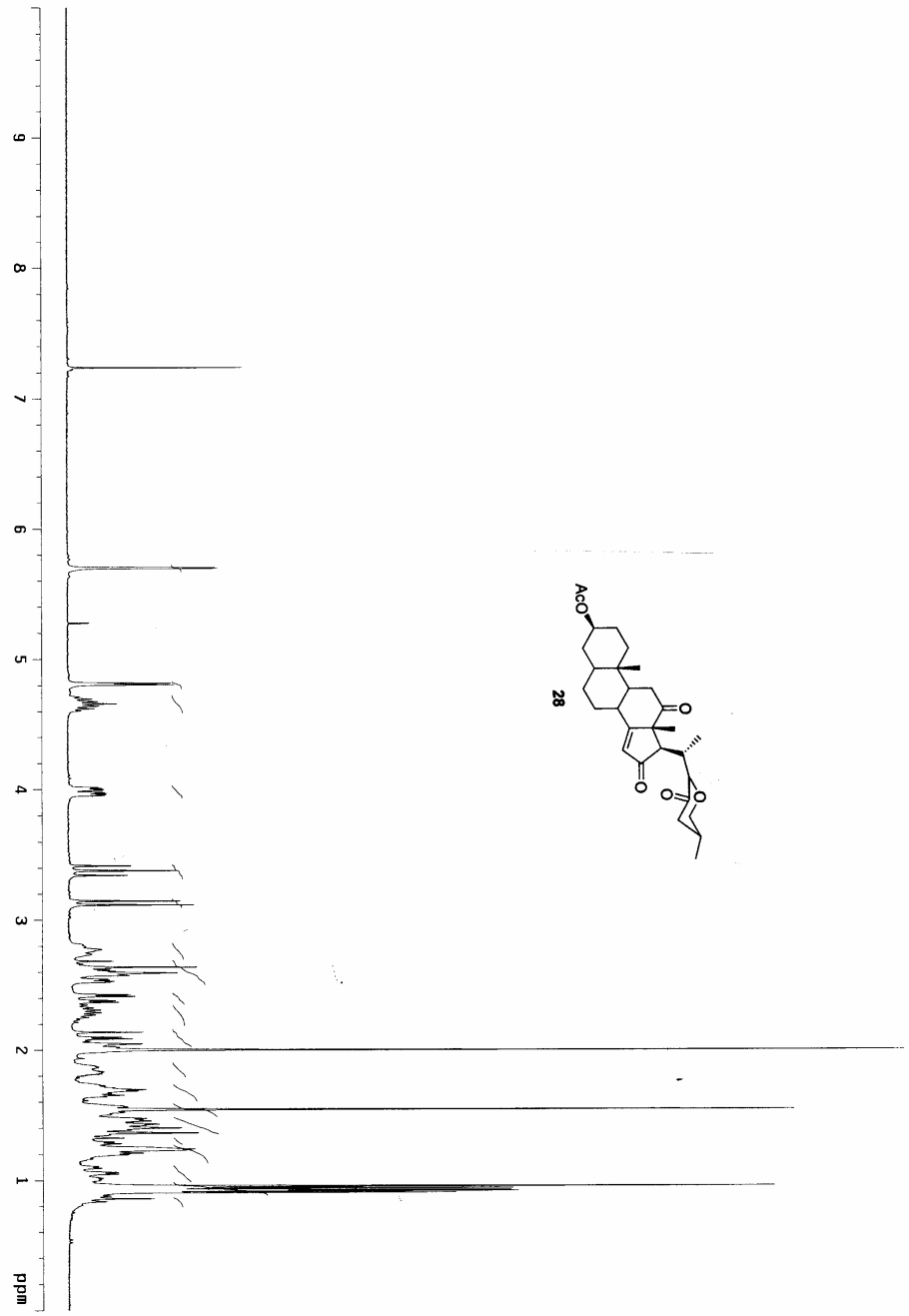


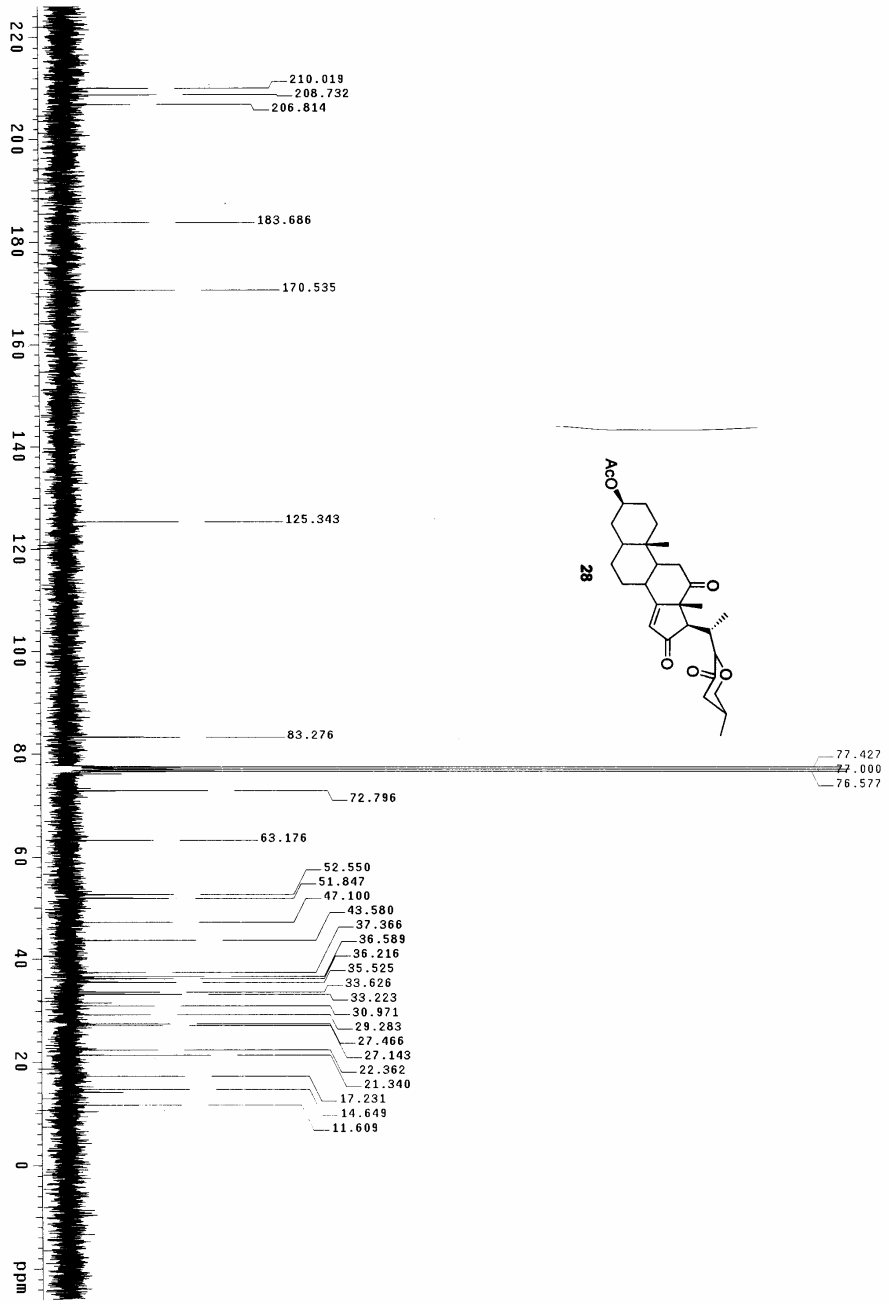
25

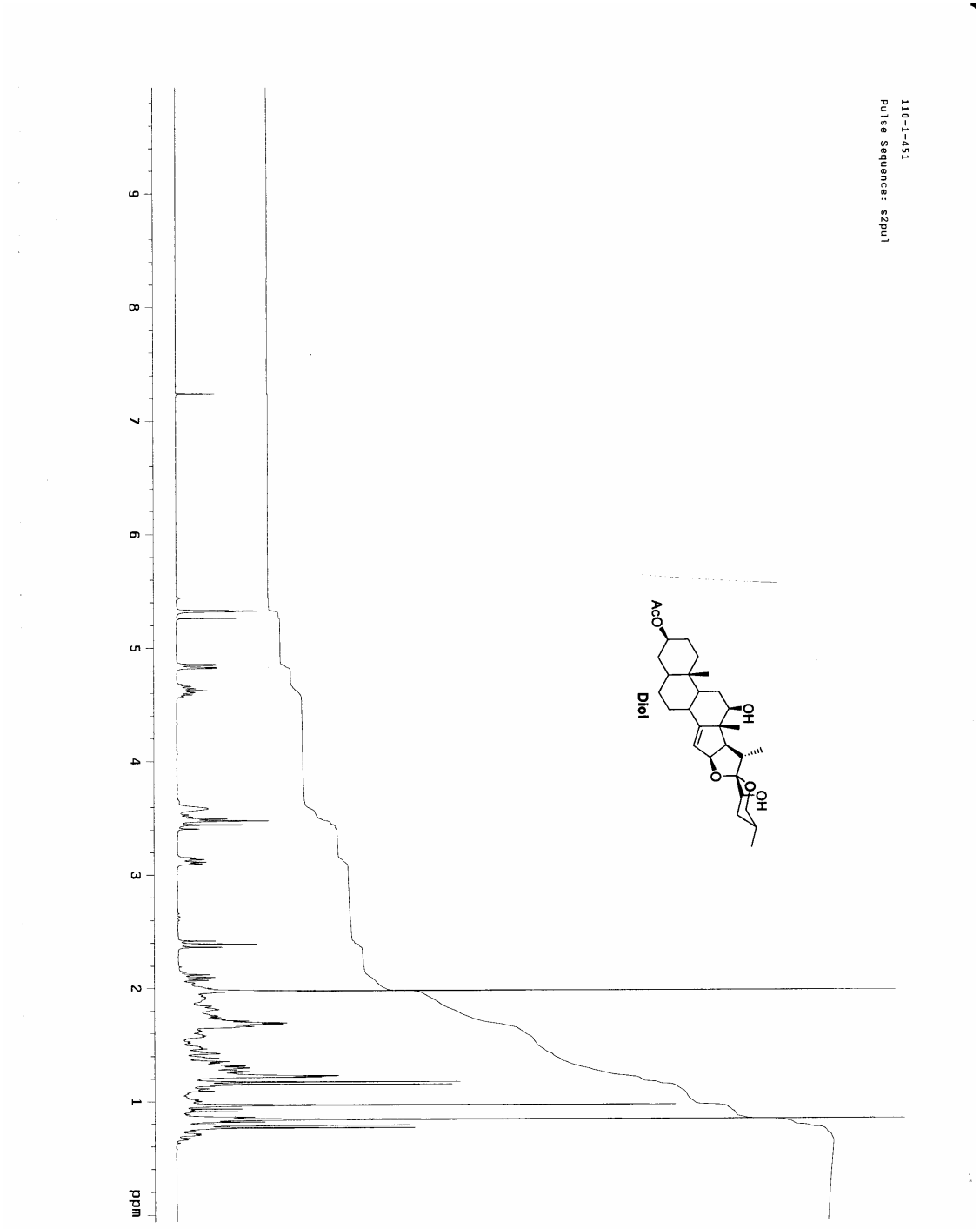


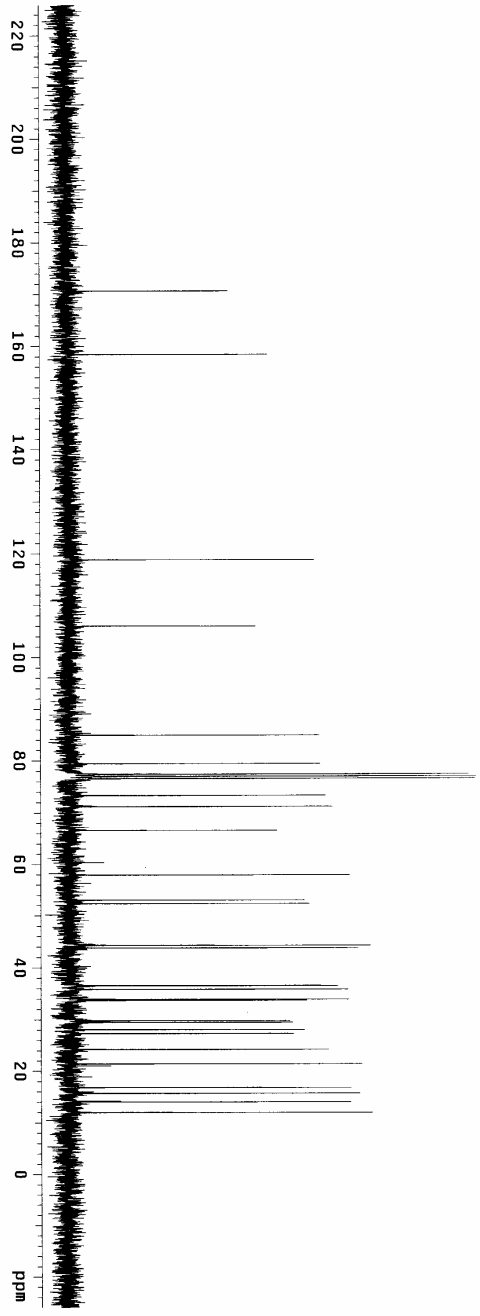

same with 110-1-338b
Pulse Sequence: s2pul
AcO
O
O
O
OH
26
9
8
7
6
5
4
3
2
1
ppm

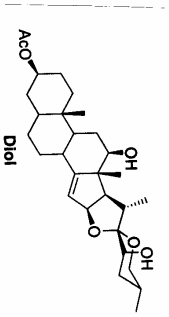

211.431
170.591
156.001
120.265
106.506
84.210
77.423
77.000
76.577
73.014
71.231
66.565
62.533
53.152
51.572
43.974
43.401
37.340
36.510
36.237
34.292
33.727
29.446
27.839
27.159
24.188
21.809
21.382
16.808
15.548
11.681
ppm
AcO
OH
O
O
O
26

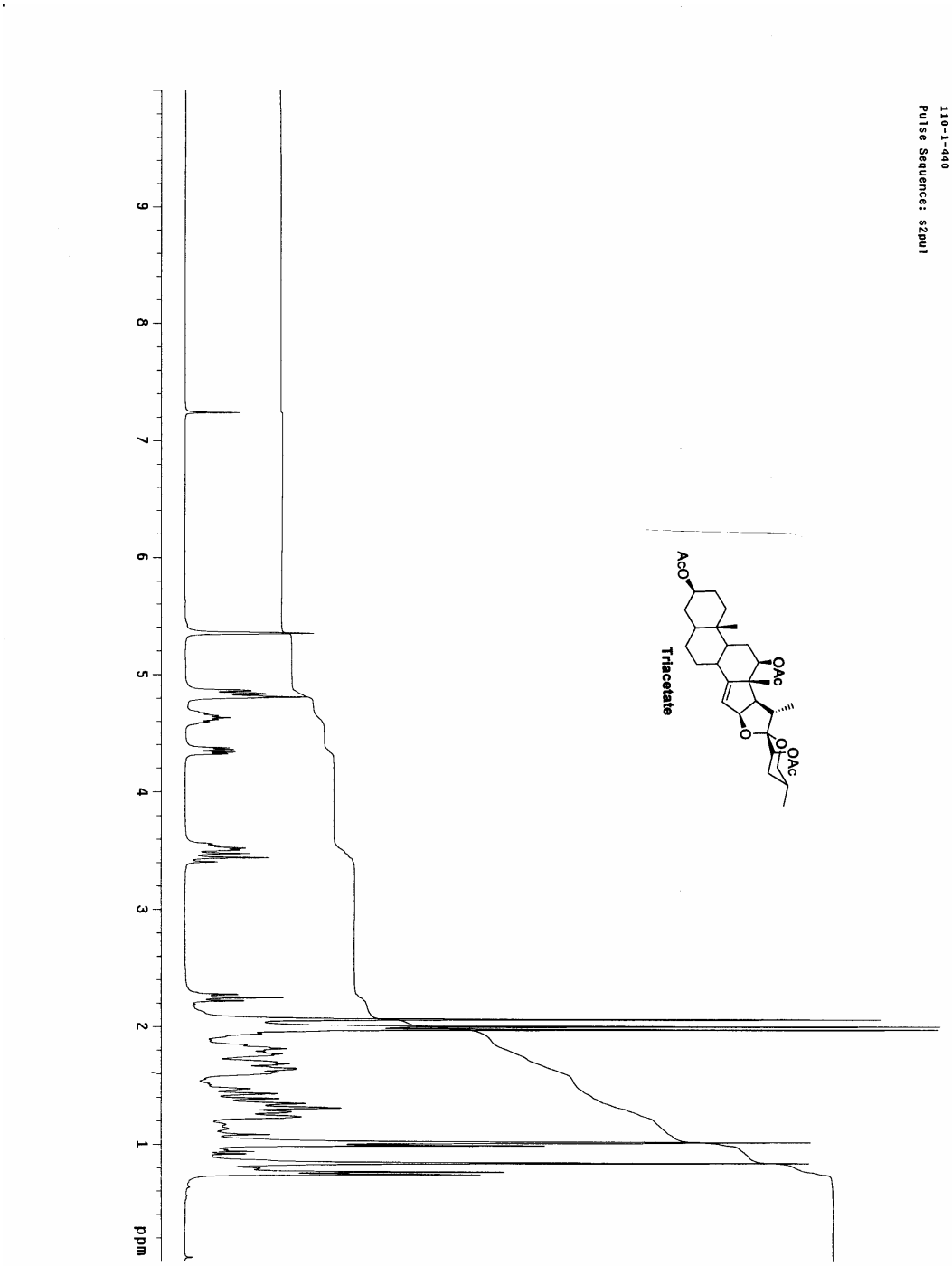

AcO
O
O
O
O
O
28
9
8
7
6
5
4
3
2
1
ppm

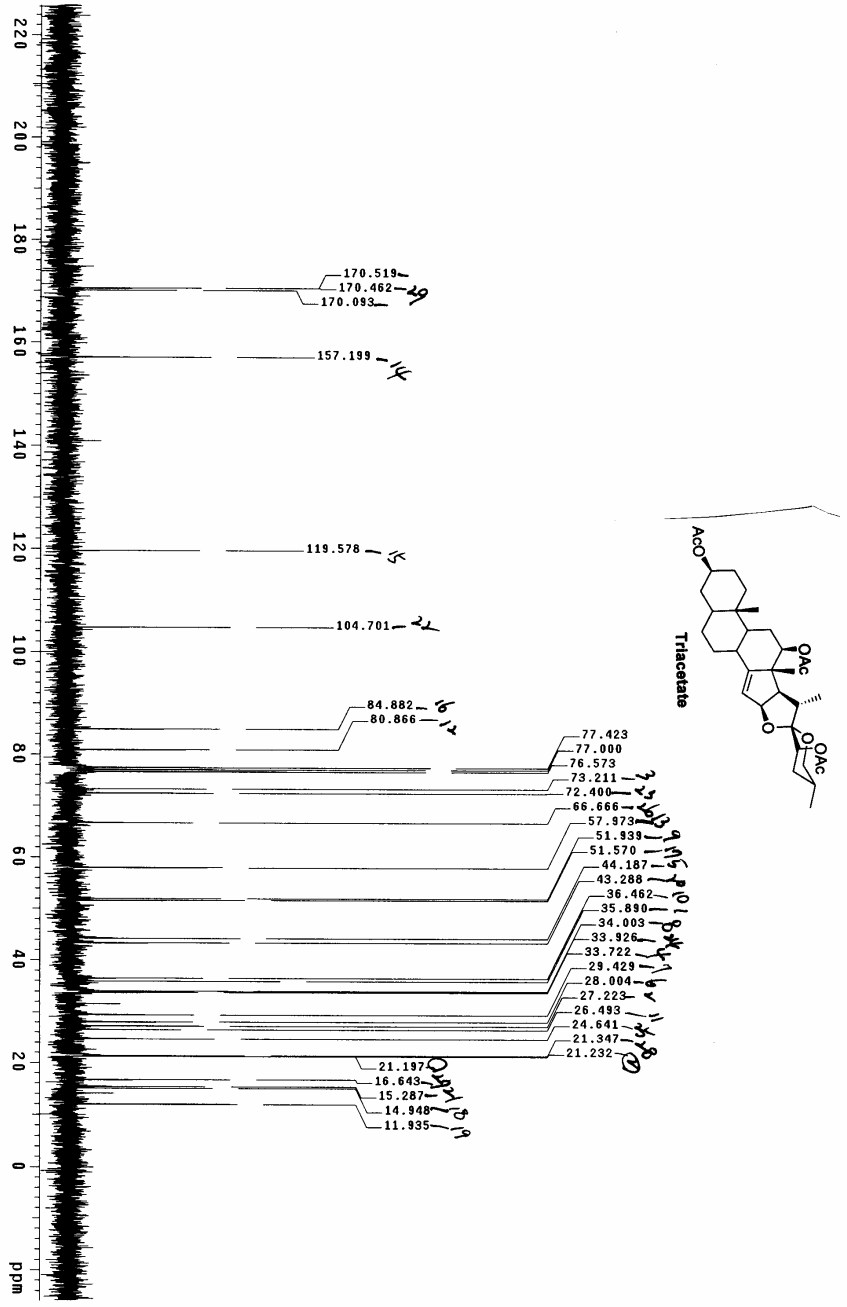

210.019
208.732
206.814
183.686
170.535
125.343
83.276
77.427
77.000
76.577
72.796
63.176
52.550
51.847
47.100
43.580
37.366
36.589
36.216
35.525
33.626
33.223
30.971
29.283
27.466
27.143
22.362
21.340
17.231
14.649
11.609
ppm
AcO
28

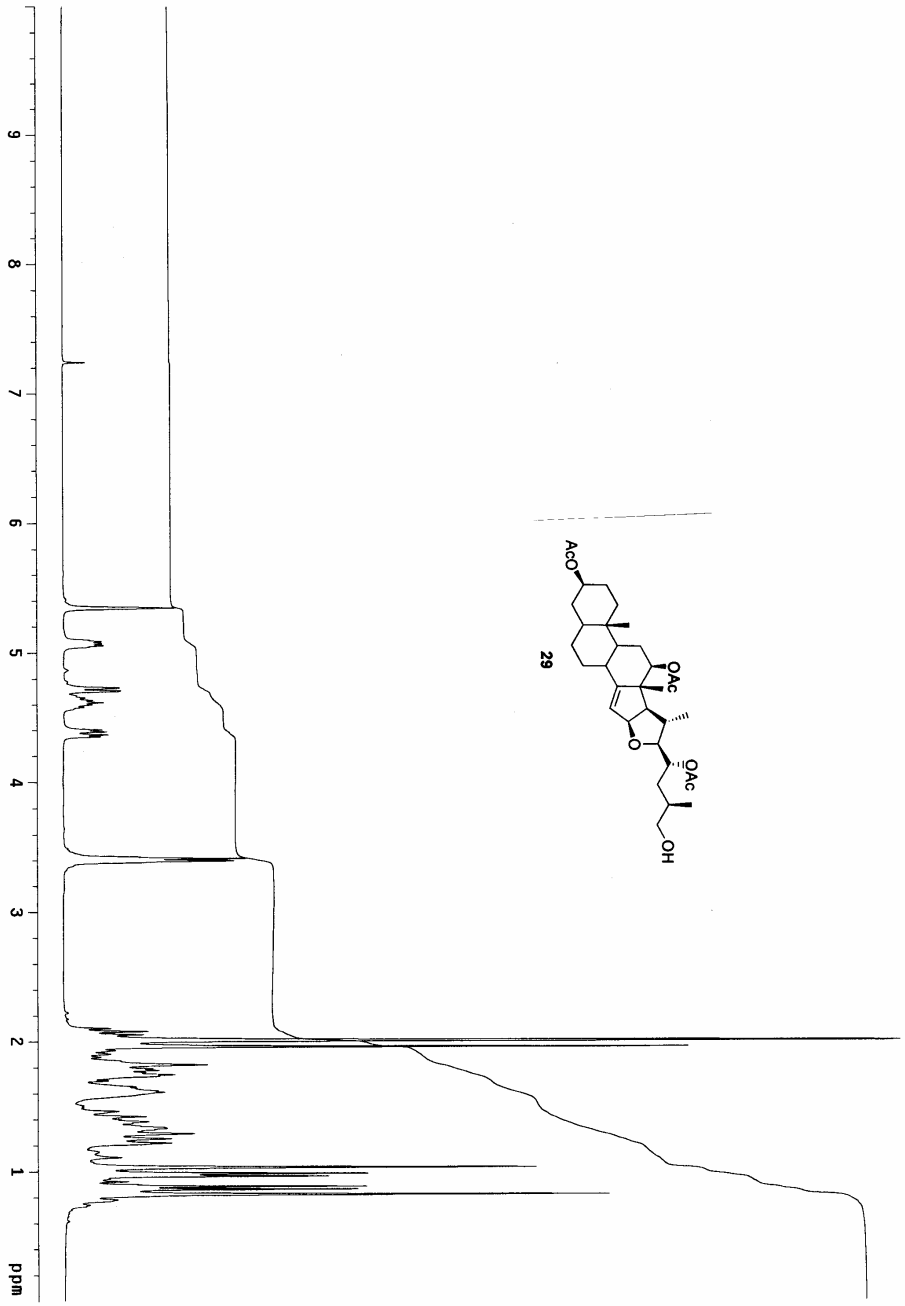

110-1-451
Pulse Sequence: s2pul
AcO
OH
OH
O
O
Diol
9
8
7
6
5
4
3
2
1
ppm

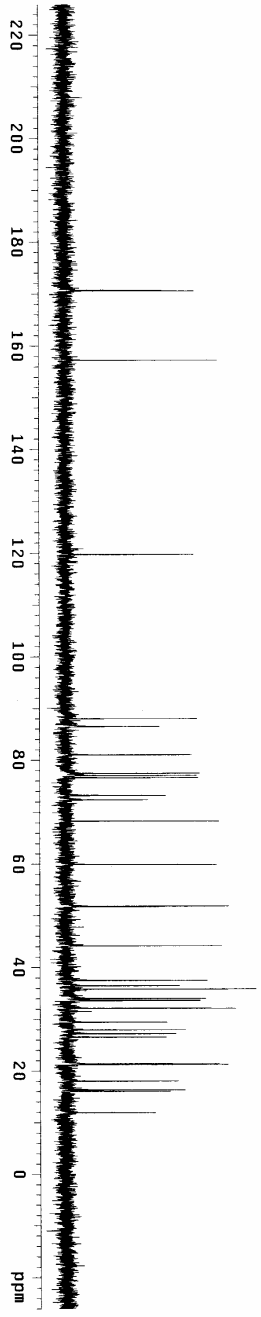

220
200
180
160
140
120
100
80
60
40
20
0
ppm

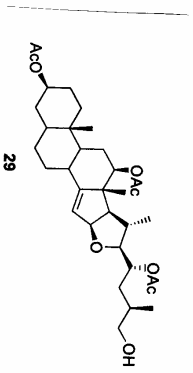

AcO
OH
O
OH
Diol


110-1-440
Pulse Sequence: s2pul
AcO
OAc
OAc
O
O
Triacetate
9
8
7
6
5
4
3
2
1
ppm

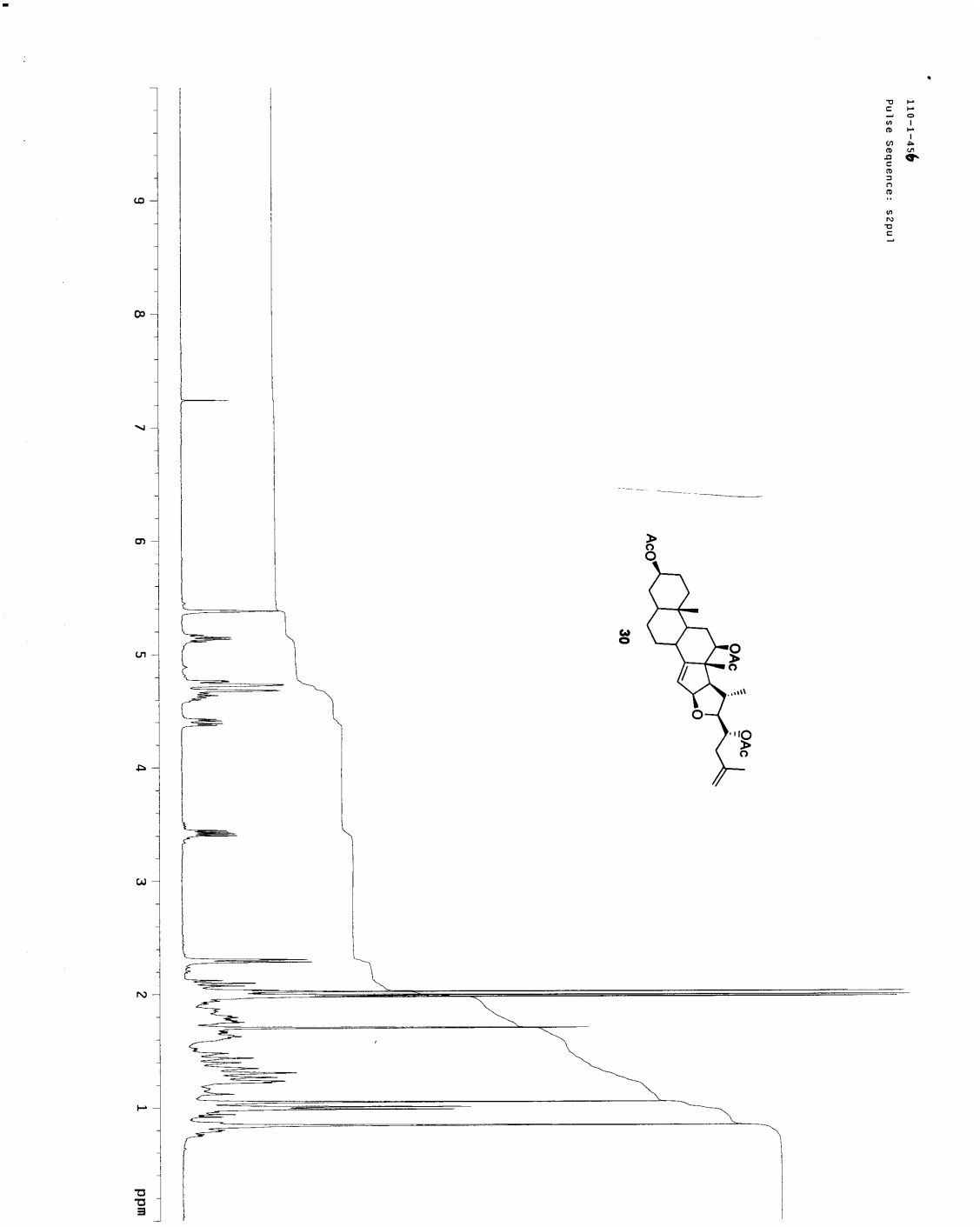

170.519
170.462
170.093
157.199
119.578
104.701
84.882
80.866
77.423
77.000
76.573
73.211
72.400
66.666
57.973
51.939
51.570
44.187
43.288
36.462
35.890
34.003
33.926
33.722
29.429
28.004
27.223
26.493
24.641
21.347
21.232
21.197
16.643
15.287
14.948
11.935
ppm
AcO
OAc
OAc
O
O
Triacetate


AcO
OAc
OAc
OH
O
29
9
8
7
6
5
4
3
2
1
ppm



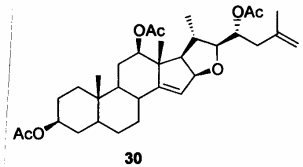


29

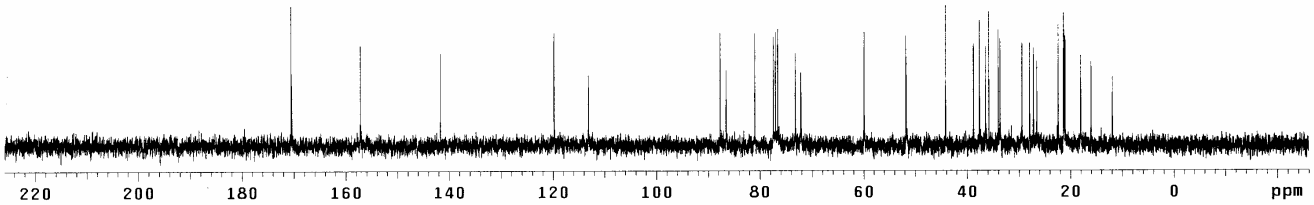

110-1-45
Pulse Sequence: s2pul
AcO
OAc
OAc
O
30
9
8
7
6
5
4
3
2
1
ppm

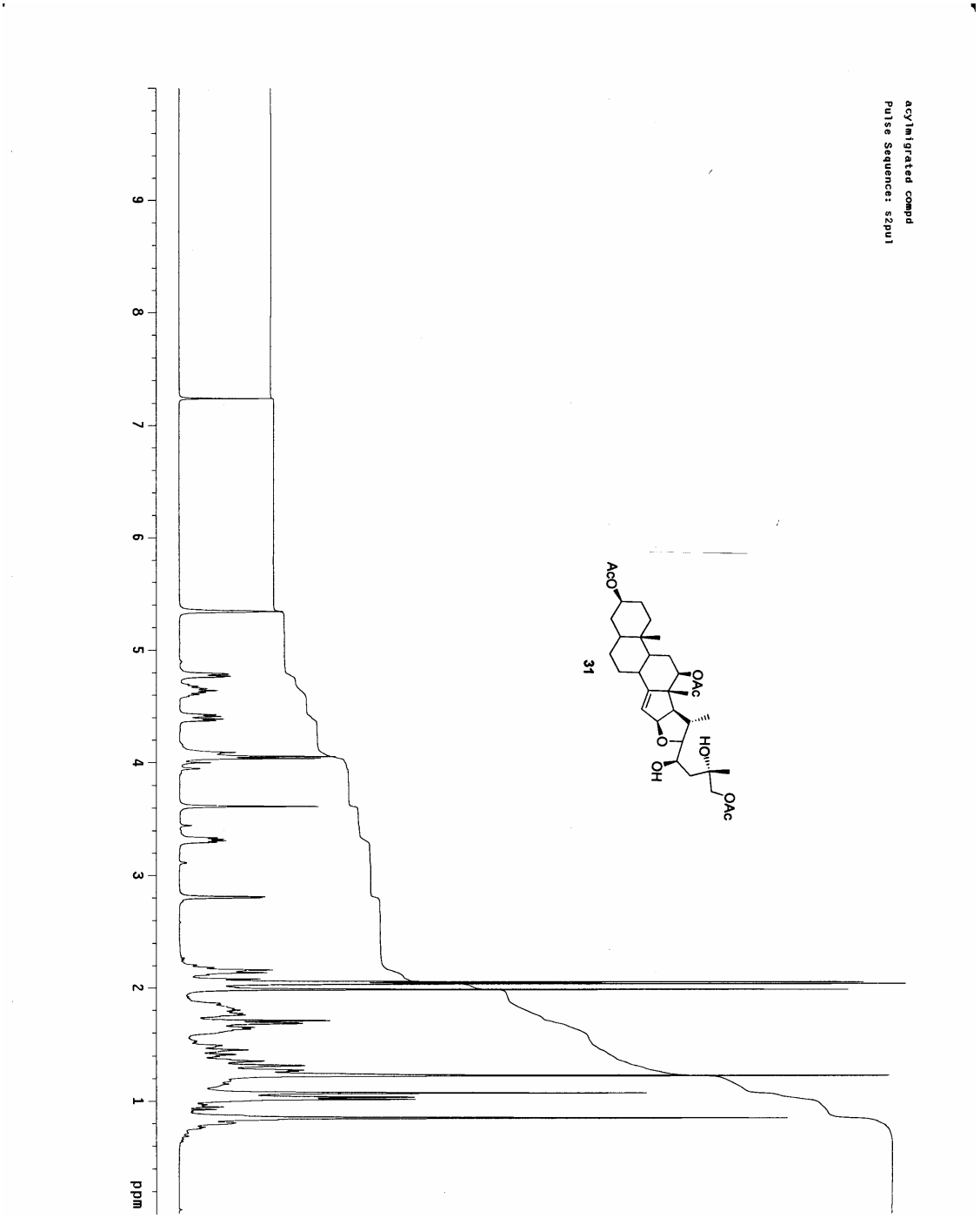
110-1-452

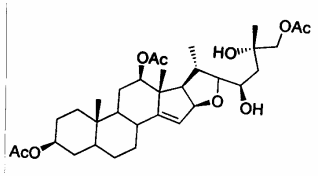
Pulse Sequence: s2pul



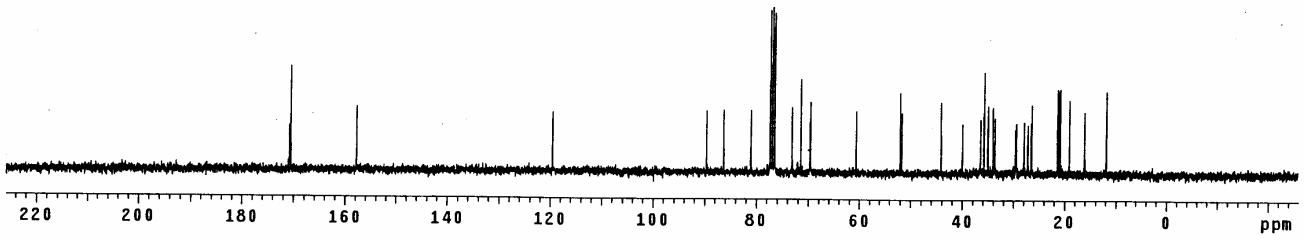
30



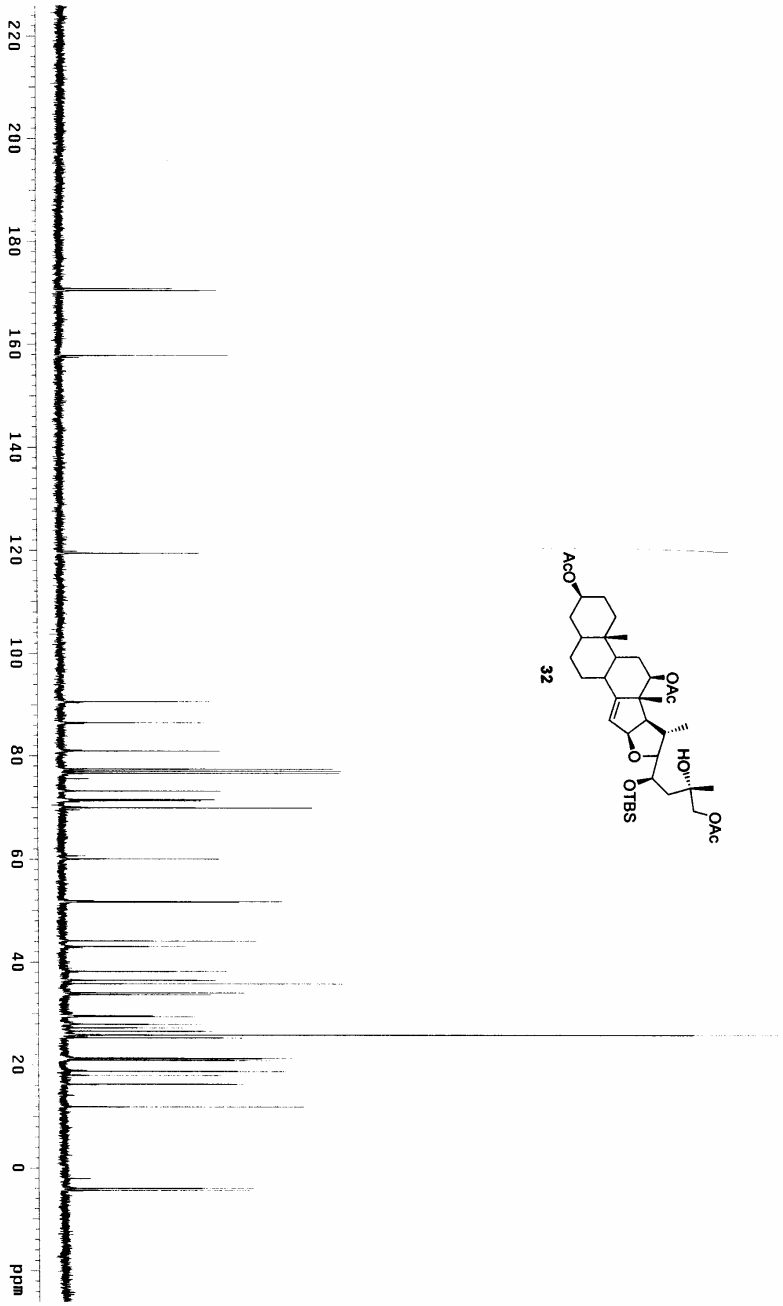

acylmigrated compd
Pulse Sequence: s2pul
AcO
OAc
HO
O
OH
OAc
31
9
8
7
6
5
4
3
2
1
ppm

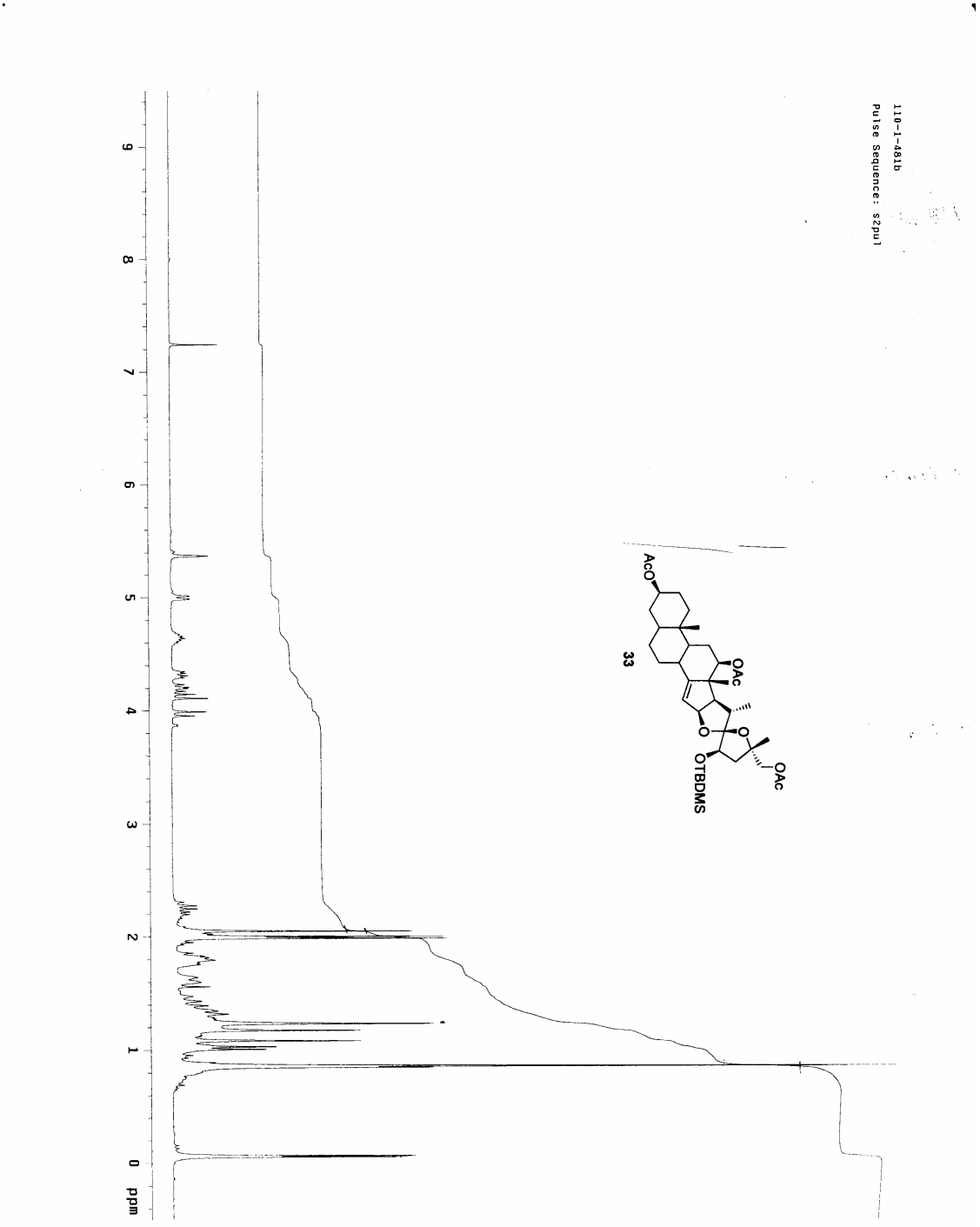


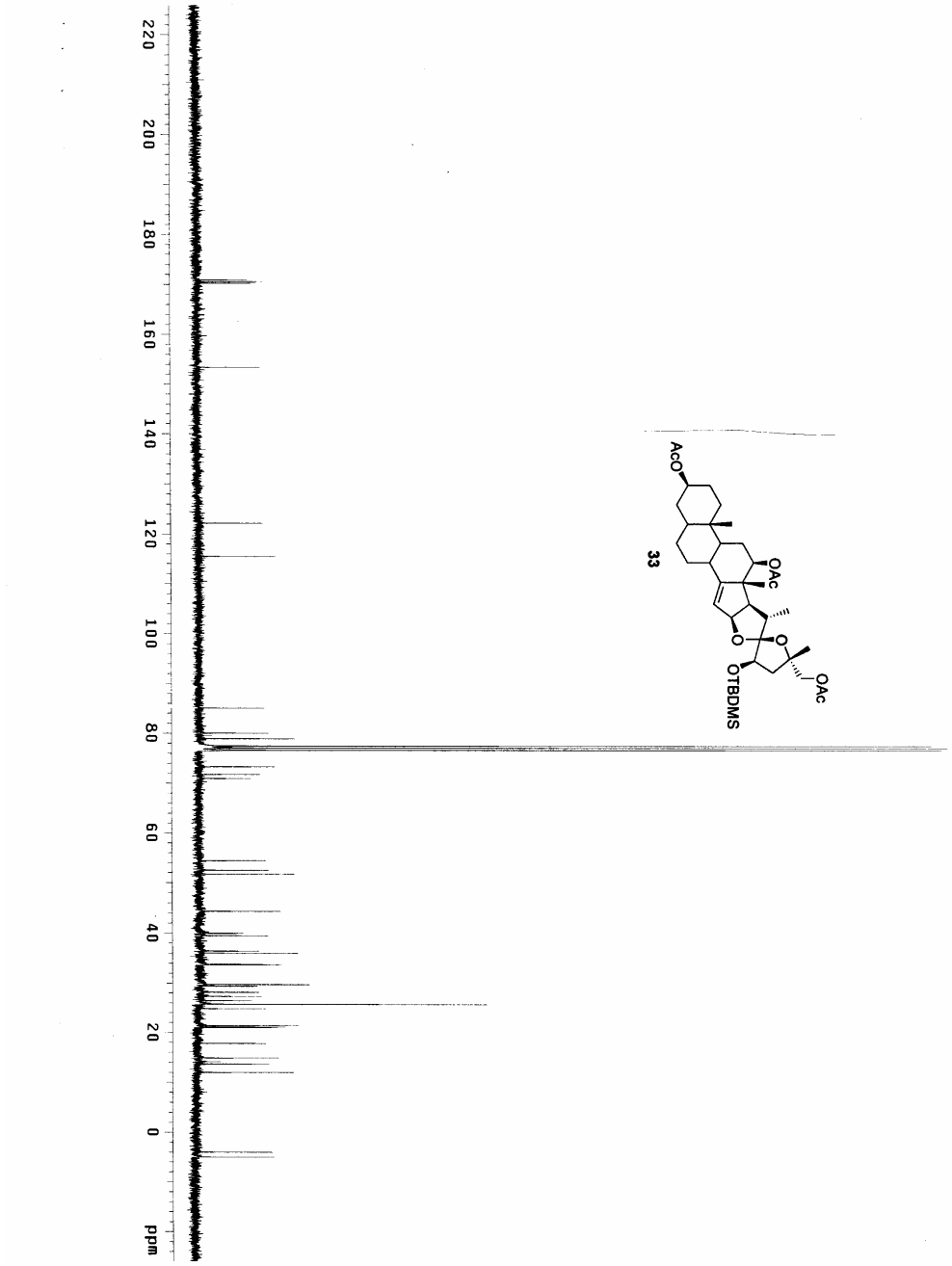
31




110-1-474
Pulse Sequence: s2pul
AcO
OAc
HO
OAc
O
OTBS
32
9
8
7
6
5
4
3
2
1
ppm


110-1-474
Pulse Sequence: s2pul
AcO
OAc
HO
OTBS
OAc
O
32
220
200
180
160
140
120
100
80
60
40
20
0
ppm

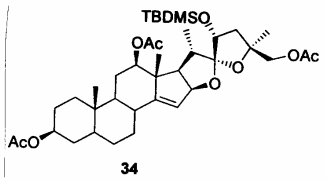

110-1-481b
Pulse Sequence: s2pul
AcO
OAc
OTBDMS
OAc
33
9
8
7
6
5
4
3
2
1
0 ppm


110-1-481b
Pulse Sequence: s2pul
AcO
OAc
OTBDMS
OAc
33
220
200
180
160
140
120
100
80
60
40
20
0
ppm

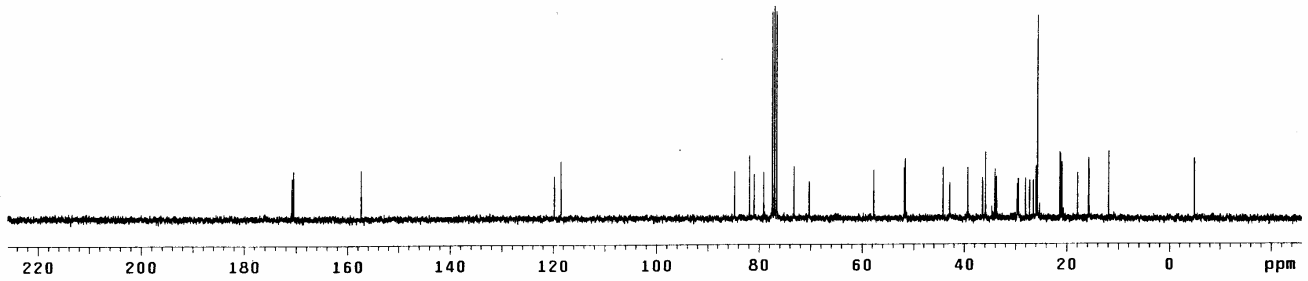

110-1-481c
Pulse Sequence: s2pul
AcO
OAc
TBDMSO
O
O
OAc
34
9
8
7
6
5
4
3
2
1
0
ppm

110-1-481c

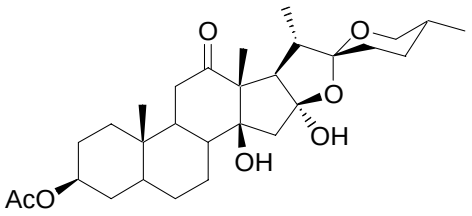
Pulse Sequence: s2pul



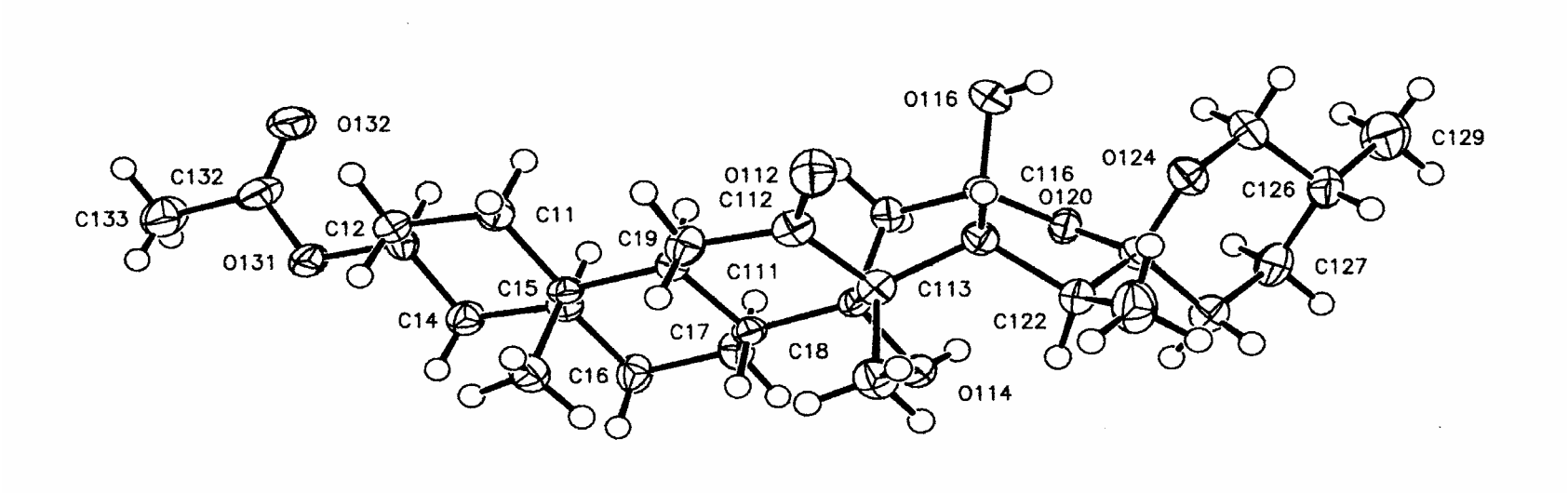
34



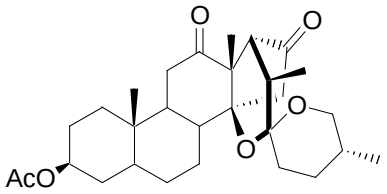
X-ray structure of diol **18**



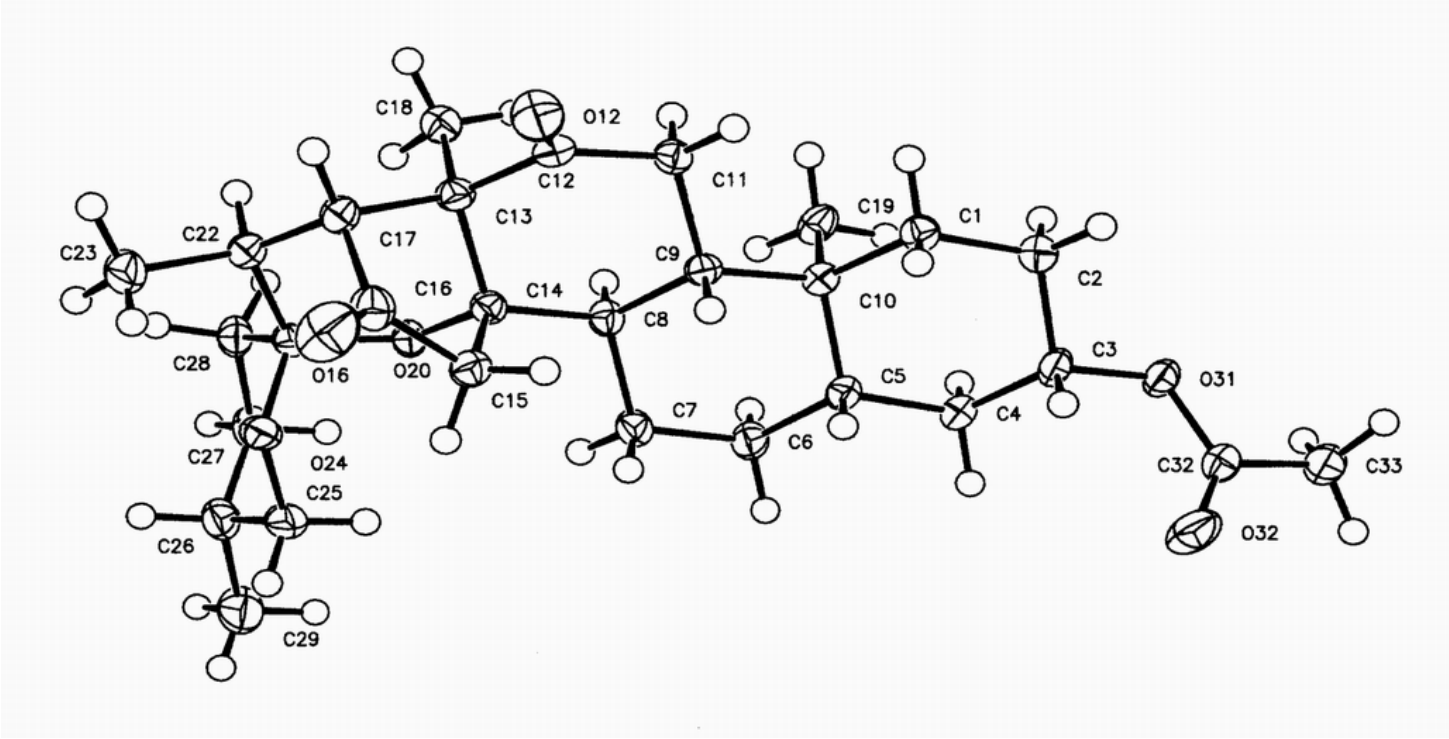
18



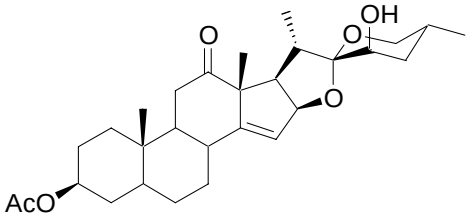
X-ray structure of isomeric spiroketal **20**



20



X-ray structure of compound **26**



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