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Supplementary Information

Synthesis of Alkylseleno-Carbohydrates and Evaluation of their Antioxidant Properties

Jaqueline P. Vargas,[a] Lucimar M. Pinto,[b] Lucielli Savegnago*,[b] and Diogo S. Lüdtke*,[a]

[a]Instituto de Química, Universidade Federal do Rio Grande do Sul (UFRGS), Av. Bento Gonçalves 9500, 91501-970 Porto Alegre-RS, Brazil

[b]Grupo de Pesquisa em Neurobiotecnologia (GPN), CDTec, Universidade Federal de Pelotas (UFPel), 96160-000 Pelotas-RS, Brazil

Experimental

Chemistry

General procedures

^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectra were recorded at 300 and 75 MHz, respectively with tetramethylsilane as internal standard. Column chromatography was performed using silica gel (230-400 mesh) following the methods described by Still. Thin layer chromatography (TLC) was performed using silica gel GF254, 0.25 mm thickness. For visualization, TLC plates were either placed under ultraviolet light or stained with iodine vapour or acidic vanillin. Tetrahydrofuran (THF) was dried over sodium benzophenone ketyl and distilled prior to use. Dichloromethane was distilled from phosphorus pentoxide. All other solvents were used as purchased unless otherwise noted.

General procedure for the synthesis of **5**-**7**

Under an argon atmosphere, sodium borohydride (2.5 equiv.) was added to a solution of the dialkyldiselenide (1.0 mmol) in THF (7.5 mL). Ethanol (2.5 mL) was then added dropwise and the clear solution formed was stirred at room temperature for 10 min. After this time, a solution of the appropriate tosylate (1.5 mmol in 1 mL THF) was added dropwise. After stirring under reflux for the time indicated in table 1, the reaction mixture was quenched with aqueous saturated NH_4Cl (10 mL) and extracted with CH_2Cl_2 (3 × 25 mL). The combined organic layers were dried with $MgSO_4$, filtered and concentrated. The crude product was purified by flash chromatography first eluting with hexanes and then with a mixture of hexanes/ethyl acetate.

Compound **5a**

Yield 65%; white solid; purified using hexane:EtOAc 80:20; $[\alpha]_D^{20}$ = −54 (*c* 1.0, AcOEt); m.p. 62 °C; IR (film) ν_{max}/cm^{-1} 3398, 2922, 1372, 1217, 1089, 1014, 817; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.93 (d, 1H, *J* 3.7 Hz, CH), 4.53 (d, 1H, *J* 3,7 Hz, CH), 4.34 (ddd, 1H, *J* 9.0, 5.3, 2.5 Hz, CH), 4.27 (dd, 1H, *J* 5.3, 2.5 Hz, CH), 2.82 (dq, 2H, *J* 12.0, 7.3 Hz, CH_2), 2.69-2.60 (m, 2H, CH_2), 1.72-1.62 (m, 2H, CH_2), 1.50 (s, 3H, CH_3), 1.43-1.27 (m, 10H, 5 × CH_2), 1.31 (s, 3H, CH_3), 0.88 (t, 3H, *J* 6.7 Hz, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 111.5, 104.7, 85.0, 80.1, 75.0, 31.7, 30.5, 29.7, 29.0, 28.9, 26.6, 26.0, 24.9, 22.5, 19.9, 13.9; HRMS-ESI *m/z* calcd. for $C_{16}H_{30}O_4Se + Na^+$: 389.1202; found: 389.1206.

Compound **5b**

Yield 53%; white solid; purified using hexane:EtOAc 80:20; $[\alpha]_D^{20}$ = −42 (*c* 1.0, AcOEt); m.p. 65 °C; IR (film) ν_{max}/cm^{-1} 3398, 2922, 1376, 1225, 1089, 1014, 817; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.93 (d, 1H, *J* 3.8 Hz, CH), 4.53 (d, 1H, *J* 3.8 Hz, CH), 4.35 (ddd, 1H, *J* 9.2, 5.6, 2.6 Hz, CH), 4.27 (dd, 1H, *J* 5.6, 2.6 Hz, CH), 2.82 (dq, 2H, *J* 12.1, 7.4 Hz, CH_2), 2.67-2.62 (m, 2H, CH_2), 1.71-1.58 (m, 2H, CH_2), 1.50 (s, 3H, CH_3), 1.39-1.26 (m, 14H, 7 × CH_2), 0.88 (t, 3H, *J* 6.7 Hz, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 111.6, 104.8, 85.1, 80.0, 75.3, 31.8, 30.5, 29.8, 29.5, 29.4, 29.3, 29.1, 26.7, 26.1, 25.1, 22.6, 20.0, 14.1; HRMS-ESI *m/z* calcd. for $C_{18}H_{34}O_4Se + Na^+$: 417.1515; found: 417.1523.

*e-mail: luciellisavegnago@yahoo.com.br; dsludtke@iq.ufrgs.br

Compound **6a**

Yield 66%; pale yellow oil; purified using hexane:EtOAc 97.5:2.5; $[\alpha]_D^{20} = -76$ (*c* 1.0, AcOEt); IR (film) ν_{max}/cm^{-1} 2930, 1376, 1210, 1111, 878; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.98 (s, 1H, CH), 4.71 (d, 1H, *J* 5.9 Hz, CH), 4.61 (d, 1H, *J* 5.9 Hz, CH), 4.29 (dd, 1H, *J* 10.1, 6.0 Hz, CH), 3.35 (s, 3H, CH_3), 2.79 (dd, 1H, *J* 12.5, 6.0 Hz, CH_a), 2.63-2.55 (m, 3H, CH_2, CH_b), 1.71-1.60 (m, 2H, CH_2), 1.48 (s, 3H, CH_3), 1.41-1.27 (m, 10H, 5 × CH_2), 1.32 (s, 3H, CH_3), 0.88 (t, *J* 6.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 112.2, 109.4, 86.7, 85.3, 83.5, 54.8, 31.7, 30.4, 29.8, 29.1, 29.0, 27.1, 26.3, 24.8, 24.2, 22.5, 14.0; HRMS-ESI *m/z* calcd. for $C_{17}H_{32}O_4Se + Na^+$: 403.1358; found: 403.1402.

Compound **6b**

Yield 60%; pale yellow oil; purified using hexane:EtOAc 95:5; $[\alpha]_D^{20} = -72$ (*c* 1.0, AcOEt); IR (film) ν_{max}/cm^{-1} 2933, 1368, 1208, 1096, 872; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.98 (s, 1H, CH), 4.71 (d, 1H, *J* 5.9 Hz, CH), 4.61 (d, 1H, *J* 5.9 Hz, CH), 4.29 (dd, 1H, *J* 10.1, 6.0 Hz, CH), 3.35 (s, 3H, CH_3), 2.80 (dd, 1H, *J* 12.5, 6.0 Hz, CH_a), 2.59 (m, 3H, CH_2, CH_b), 1.66 (m, 2H, CH), 1.48 (s, 3H, CH_3), 1.42-1.26 (m, 14H, 7 × CH_2), 1.32 (s, 3H, CH_3), 0.88 (t, *J* 6.7 Hz, 3H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 112.2, 109.4, 86.7, 85.3, 83.5, 54.8, 31.8, 30.4, 29.8, 29.47, 29.44, 29.2, 29.0, 27.1, 26.3, 24.8, 24.2, 22.6, 14.0; HRMS-ESI *m/z* calcd. for $C_{19}H_{36}O_4Se + Na^+$: 408.1779; found: 408.1779.

Compound **7a**

Yield 51%; orange oil; purified using hexane:EtOAc 95:5; $[\alpha]_D^{20} = -66$ (*c* 1.0, AcOEt); IR (film) ν_{max}/cm^{-1} 2922, 1383, 1210, 1066, 999; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.53 (d, 1H, *J* 5.0 Hz, CH), 4.61 (dd, 1H, *J* 7.9, 2.4 Hz, CH), 4.39 (dd, 1H, *J* 7.9, 1.8 Hz, CH), 4.30 (dd, 1H, *J* 5.0, 2.4 Hz, CH), 3.89 (td, 1H, *J* 7.3, 1.7 Hz, CH), 2.77-2.74 (m, 2H, CH_2), 2.63-2.58 (m, 2H, CH_2), 1.71-1.61 (m, 2H, CH_2), 1.53 (s, 3H, CH_3), 1.45 (s, 3H, CH_3), 1.38-1.26 (m, 14H, 7 × CH_2), 1.35 (s, 3H, CH_3), 1.33 (s, 3H, CH_3), 0.88 (t, 3H, *J* 6.7 Hz, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 108.9, 108.3, 96.5, 71.5, 70.8, 70.4, 68.0, 31.6, 30.5, 29.8, 29.0, 28.9, 25.9, 25.8, 24.7, 24.5, 24.3, 22.6, 22.5, 13.9; HRMS-ESI *m/z* calcd. for $C_{20}H_{36}O_5Se + Na^+$: 436.1728; found: 436.1744.

Compound **7b**

Yield 50%; yellow oil; purified using hexane:EtOAc 95:5; $[\alpha]_D^{20} = -62$ (*c* 1.0, AcOEt); IR (film) ν_{max}/cm^{-1} 2925, 1384, 1208, 1064, 992; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.53 (d, 1H, *J* 5.0 Hz, CH), 4.62 (dd, 1H, *J* 7.9, 2.4 Hz, CH), 4.39 (dd, 1H, *J* 7.9, 1.8 Hz, CH), 4.30 (dd, 1H, *J* 5.0, 2.4 Hz, CH), 3.89 (td, 1H, *J* 7.3, 1.7 Hz, CH), 2.78-2.75 (m, 2H, CH_2), 2.64-2.59 (m, 2H, CH_2), 1.71-1.61 (m, 2H, CH_2), 1.53 (s, 3H, CH_3), 1.45 (s, 3H, CH_3), 1.38-1.26 (m, 10H, 5 × CH_2), 1.35 (s, 3H, CH_3), 1.33 (s, 3H, CH_3), 0.88 (t, *J* 6.7 Hz, 3H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 109.0, 108.4, 96.6, 71.6, 70.9, 70.4, 68.1, 31.8, 30.6, 29.9, 29.49, 29.46, 29.2, 29.0, 26.0, 25.9, 24.8, 24.7, 24.3, 22.8, 22.6, 14.0.

General procedure for the synthesis of **8** and **10**

In a round bottomed flask, the appropriate selenocarbohydrate (0.5 mmol) was stirred in an aqueous solution of trifluoracetic acid (50% v/v, 10 mL) for 1 h at room temperature. After this time, the reaction mixture was concentrated in vacuum, co-evaporated with toluene (3 × 10 mL) and the residue dissolved in a MeOH (10 mL), in the presence of a catalytic amount of sulfuric acid, and stirred for additional 24 h, at room temperature. Following this time, the mixture was neutralized by the addition of solid sodium bicarbonate. The mixture was filtered and the solvents evaporated to afford the product.

Compound **8a**

Yield 95%; yellow oil; mixture of anomers (1.0:0.66); IR (film) ν_{max}/cm^{-1} 3421, 2925, 1456, 1208, 1112, 1024; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.99 (d, 0.46H, *J* 4.5 Hz, CH_β), 4.85 (s, 0.7H, CH_α), 4.51 (ddd, 0.7H, *J* 7.9, 6.9, 4.1 Hz, CH), 4.36 (ddd, 0.46H, *J* 7.4, 6.5, 5.1 Hz, CH), 4.24 (dd, 0.7H, *J* 4.5, 3.7 Hz, CH), 4.20 (s, 0.7H, CH), 4.13 (dd, 0.46H, *J* 4.1, 3.5 Hz, CH), 4.07 (d, 0.46H, *J* 4.6 Hz, CH), 3.49 (s, 1.38H, $CH_{3\alpha}$) 3.38 (s, 2.1H, $CH_{3\beta}$), 2.82 (m, 4H, 2 × CH_2), 2.64 (m, 4H, 2 × CH_2), 1.67 (m, 4H, 2 × CH_2), 1.30 (m, 20H, 2 × 5 × CH_2), 0.88 (t, 6H, *J* 6.8 Hz, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 108.5, 101.7, 83.5, 79.6, 78.6, 78.5, 77.0, 76.2, 55.8, 55.1, 31.7, 30.6, 30.5, 29.87, 29.82, 29.12, 29.10, 29.06, 29.03, 24.91, 24.87, 22.65, 22.56, 21.9, 14.0.

Compound **8b**

Yield 95%; yellow oil; mixture of anomers (1.0:0.63); IR (film) ν_{max}/cm^{-1} 3421, 2926, 1463, 1192, 1120, 1016; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.99 (d, 0.5H, *J* 4.6 Hz, CH_b), 4.85 (s, 0.8H, CH_a), 4.51 (ddd, 0.8H, *J* 8.1, 6.8, 4.1 Hz, CH), 4.36 (ddd, 0.5H, *J* 7.4, 6.5, 4.9 Hz, CH), 4.24 (dd, 0.8H, *J* 4.5, 3.7 Hz, CH), 4.21 (s, 0.8H, CH), 4.13 (dd, 0.5H, *J* 4.1, 3.5 Hz, CH), 4.07 (d, 0.5H, *J* 4.6 Hz, CH), 3.49 (s, 1.5H, CH_{3a}) 3.38 (s, 2.4H, CH_{3b}), 2.82 (m, 4H, 2 × CH_2), 2.64 (m, 4H, 2 × CH_2), 1.67 (m, 4H, 2 × CH_2), 1.32 (m, 28H, 2 × 7 × CH_2), 0.88 (t, 6H, *J* 6.8 Hz, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 108.5, 101.7, 83.6, 79.6, 78.6, 78.5, 77.1, 76.2, 55.8, 55.1, 31.8, 30.6, 30.5, 29.90, 29.85, 29.51, 29.49, 29.47, 29.25, 29.13, 29.10, 24.94, 24.90, 22.66, 22.62, 21.9, 14.0.

Compound **10a**

Yield 95%; yellow oil; mixture of anomers (1.0:0.55); IR (film) ν_{max}/cm^{-1} 3381, 2917, 1472, 1104, 1032; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.86 (s, 1.30H, CH_a), 4.77 (d, 0.7H, *J* 4.6 Hz, CH_b), 4.17 (dd, 0.7H, *J* 7.6 Hz, 6.8, CH), 4.11 (dd, 2 × 0.7H, *J* 3.1, 1.4 Hz, CH), 4.05 (d, 0.7H, *J* 4.7 Hz, CH), 4.04 (d, 1.3H, *J* 5.5 Hz, CH), 3.99 (s, 1.3H), 3.91 (dd, 1.3H, *J* 7.2, 3.4 Hz, CH), 3.87 (ddd, 1.3H, *J* 7.6, 6.8, 1.1 Hz, CH), 3.45 (s, 3 × 0.7H, CH_{3a}), 3.36 (s, 3 × 1.3H, CH_{3b}), 2.79 (d, 2H, *J* 6.8 Hz, 2 × CH), 2.71 (m, 2H, 2 × CH), 2.57 (dt, 4H, *J* 7.4, 1.6 Hz, 2 × CH_2), 1.63 (m, 4H, 2 × CH_2), 1.30 (m, 20H, 2 × 5 × CH_2), 0.85 (t, 6H, *J* 6.7 Hz, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 109.0, 102.1, 86.7, 83.0, 79.5, 78.4, 77.8, 75.1, 70.3, 69.6, 56.0, 54.9, 31.74, 31.72, 30.5, 29.85, 29.84, 29.12, 29.11, 29.06, 29.04, 27.95, 27.45, 24.94, 24.63, 22.5, 14.0.

Compound **10b**

Yield 95%; yellow oil; mixture of anomers (1.0:0.43); IR (film) ν_{max}/cm^{-1} 3377, 2925, 1463, 1104, 1016; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.89 (s, 1.0H, CH_a), 4.81 (d, 0.7H, *J* 4.7 Hz, CH_b), 4.18 (dd, 0.7H, *J* 7.6, 7.0 Hz, CH), 4.12 (dd, 2 × 0.7H, *J* 2.1, *J* 1.6 Hz, CH), 4.07 (m, 1.0H + 0.7H, CH), 3.99 (s, 1.0H, CH), 3.94 (dd, 1H, *J* 6.8, 3.5 Hz, CH), 3.88 (ddd, 1H, *J* 7.7, 6.1, 1.3 Hz, CH), 3.48 (s, 3 × 0.7H,CH_{3a}), 3.38 (s, 3 × 1H, CH_{3b}), 2.82 (d, 2H, *J* 6.1 Hz, 2 × CH), 2.73 (m, 2H, 2 × CH), 2.58 (m, 2H, 2 × CH), 1.65 (m, 4H, 2 × CH_2), 1.29 (m, 28H, 2 × 7 × CH_2), 0.87 (t, 6H, *J* 6.7 Hz, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 109.3, 102.2, 87.7, 83.2, 78.9, 78.7, 78.0, 75.7, 70.5, 69.3, 56.1, 54.9, 31.8, 30.52, 30.50, 29.89, 29.86, 29.54, 29.52, 29.49, 29.28, 29.14, 29.11, 28.4, 27.5, 24.97, 24.49, 22.6, 14.1.

General procedure for the synthesis of **9**

In a round bottomed flask, alkylselenoneoglycoconjugate (0.5 mmol) was stirred in a solution of MeOH (10.0 mL) with HCl (1.0 mL) for 5 h under reflux. After this time, the solution was neutralized with $NaHCO_3$, filtered and concentrated to afford the product

Compound **9a**

Yield 80%; orange oil; mixture of anomers (1.0:0.32); IR (film) ν_{max}/cm^{-1} 3392, 2922, 1467, 1116, 1021; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.92 (d, 0.33H, *J* 4.7 Hz, CH_b), 4.82 (s, 1.05H, CH_a), 4.16 (m, 2 × 0.33 + 1.05H, CH), 4.07 (m, 2 × 1.05 + 0.33H, CH), 3.47 (s, 0.99H, CH_{3a}), 3.36 (s, 3.15H, CH_{3b}), 2.79 (m, 4H, 2 × CH_2), 2.65 (m, 4H, 2 × CH_2), 1.66 (m, 4H, 2 × CH_2), 1.32 (m, 20H, 2 × 5 × CH_2), 0.88 (t, 6H, *J* 6.7 Hz, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 108.0, 102.6, 83.9, 82.6, 75.5, 75.3, 73.2, 71.4, 55.3, 55.0, 31.7, 30.42, 30.41, 29.80, 29.74, 29.06, 29.05, 28.99, 28.97, 27.5, 26.2, 25.1, 24.6, 22.5, 13.9; HRMS-ESI *m/z* calcd. for $C_{14}H_{28}O_4Se + Na^+$: 363.1045; found: 363.1046.

Compound **9b**

Yield 80%; yellow oil; mixture of anomers (1.0:0.38); IR (film) ν_{max}/cm^{-1} 3405, 2925, 1463, 1128, 1032; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.94 (d, 0.36H, *J* 4.5 Hz, CH_b), 4.82 (s, 0.94H, CH_a), 4.16 (m, 2 × 0.36 + 0.94H, CH), 4.08 (m, 2 × 0.94 + 0.36H, CH), 3.48 (s, 1.08H, CH_{3a}), 3.37 (s, 2.82H, CH_{3b}), 2.82 (m, 4H, 2 × CH_2), 2.64 (m, 4H, 2 × CH_2), 1.66 (m, 4H, 2 × CH_2), 1.30 (m, 20H, 2 × 5 × CH_2), 0.88 (t, *J* 6.8 Hz, 6H, 2 × CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 108.0, 102.6, 83.9, 82.3, 75.8, 75.6, 73.5, 71.3, 55.5, 55.1, 31.8, 30.5, 29.86, 29.84, 29.66, 29.51, 29.48, 29.46, 29.26, 29.10, 29.06, 27.6, 26.2, 25.2, 24.7, 22.6, 14.1; HRMS-ESI *m/z* calcd. for $C_{16}H_{32}O_4Se + Na^+$: 391.1358; found: 391.1410.

Antioxidant assays

To determine if seleno-carbohydrates **5b**, **8a**, **8b** and **10b** present *in vitro* antioxidant activity, we evaluated: DPPH, ABTS, hydroxyl radical and nitric oxide scavenging activity, the ferric ion (Fe^{3+}) reducing antioxidant power (FRAP) and superoxido dismutase (SOD)-like activity. All compounds were dissolved in dimethyl sulfoxide (DMSO). The stable radical DPPH has been widely used for determining the hydrogen- or electron-donating capacity of pure anti-oxidant compounds, plant and fruit extracts and food materials. The scavenging activity of compounds **5b**, **8a**, **8b** and **10b** was determined in accordance with the method of Choi *et al.*[1] with some modifications.

The ABTS method is based on the ability of anti-oxidants to quench the long-lived ABTS radical cation, a blue/green chromophore with characteristic absorption at 734 nm. The ABTS radical scavenging activity was determined according to the method described by Re *et al.*[2] with some modifications. Different concentrations of compounds (**5b**, **8a**, **8b**, **10b**) were mixed with the $ABTS^+$ solution, and the decrease in the absorbance at 734 nm was recorded.

The hydroxyl radical scavenging activities of compounds were determined according to the method described by Smirnoff *et al.*,[3] with some modifications. The scavenging effect of compounds on nitric oxide was measured according to the method of Marcocci *et al.*[4] with a slight modification. The results are expressed as percentages of radical inhibition (I%) compared to the respective control values, as calculated from the following equation: $I\% = [(A_C - A_S/A_C) \times 100]$, in which A_C is the

absorbance of the control reaction mixture excluding the test compound and A_S is the absorbance of the test compound in different concentrations.

SOD-like activity of compounds was determined as described by Marklund and Marklund.[5] Briefly, Tris-HCl buffer (pH 8.5) and 24 mmol L^{-1} pyrogallol were added to the sample solution during 60 min at 37 °C. Sample activities are expressed as the auto-oxidation inhibition rate (%) of pyrogallol *vs.* the control sample (sample without compounds). The FRAP assay was carried out as described by Stratil *et al.*[6] with slight modifications. This method is based on the principle of increase in the absorbance of the reaction mixture. Increase in absorbance indicates increase in the antioxidant activity. Thus, different concentrations of compounds **5b**, **8a**, **8b** and **10b** and FRAP reagent were added to each sample, and the mixture was incubated at 37 °C for 40 min in the dark. The absorbance of the resulting solution was measured at 593 nm with a spectrophotometer.

The results are presented as means ± standard deviation (SD). Statistical analysis was performed using a one-way analysis of variance (ANOVA) followed by Newman-Keuls multiple comparison tests when appropriate. All tests were performed in duplicate and repeated at least three times. The IC_{50} values (concentration of sample required to scavenge 50% free radical) were calculated from the graph of scavenging effect percentage against compound concentration. Differences were considered statistically significant at a p value of 0.05.

NMR spectra

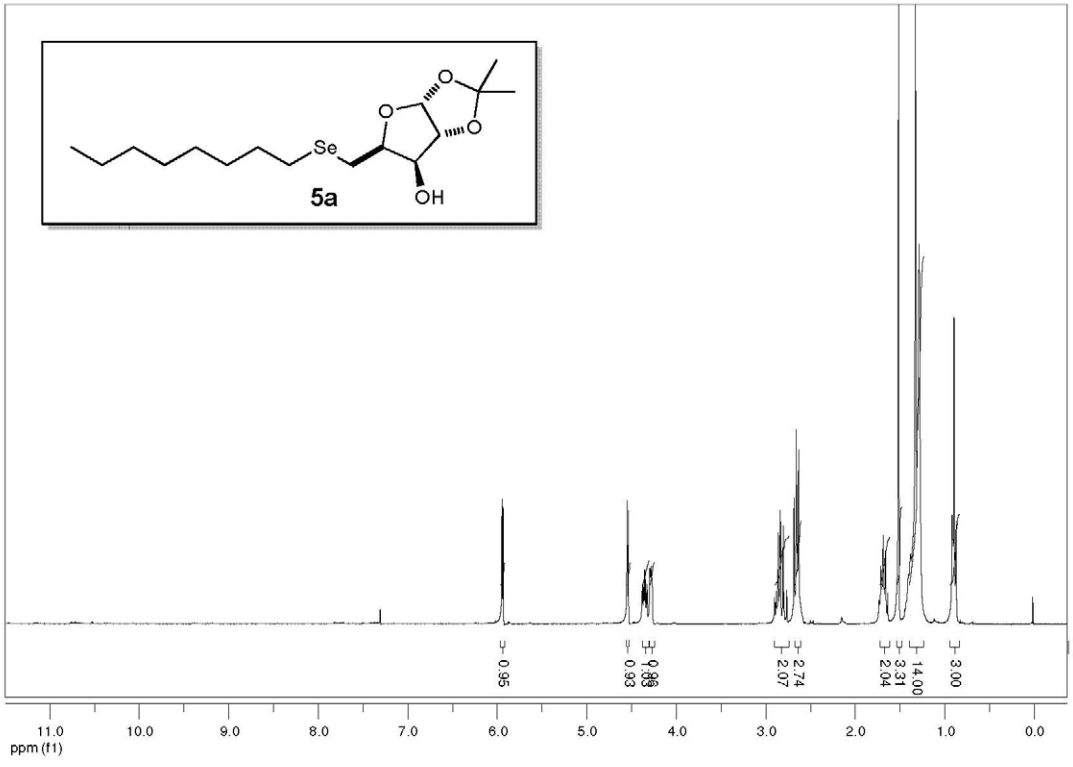

Figure S1. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **5a**.

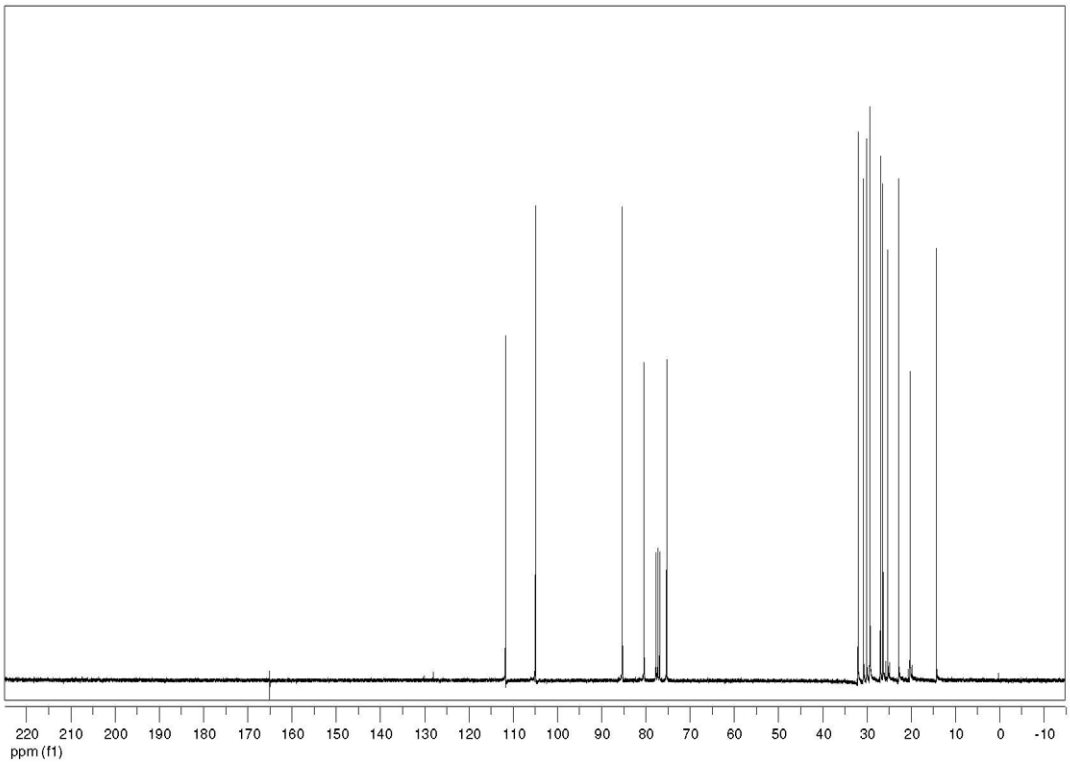

Figure S2. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **5a**.

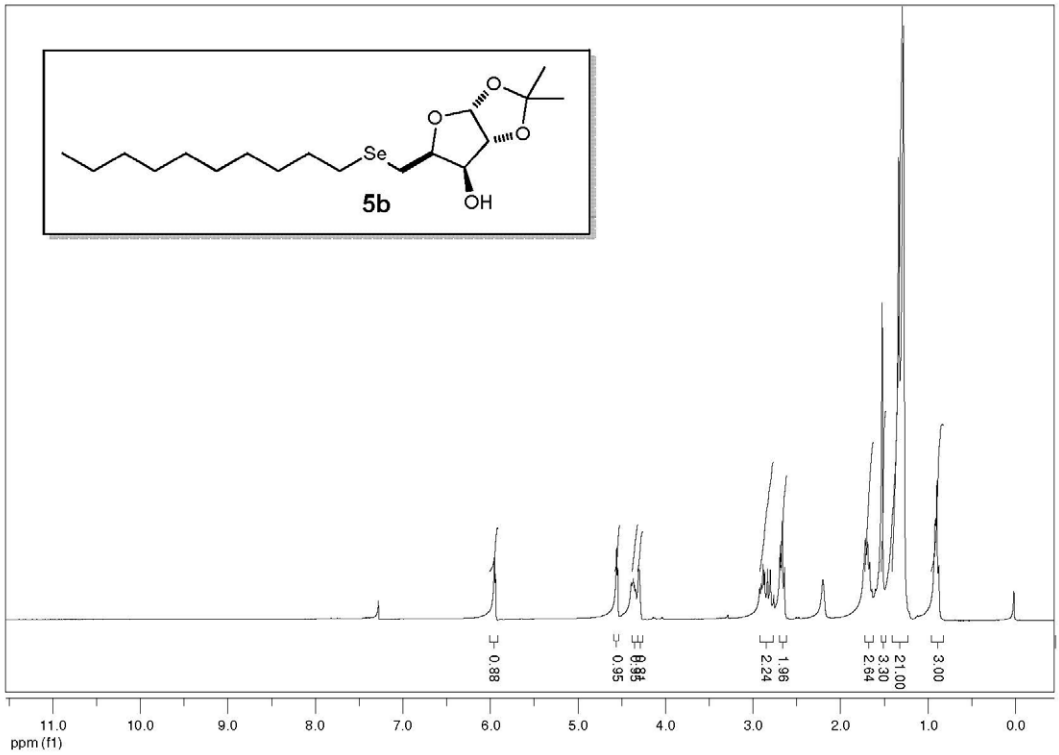

Figure S3. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **5b**.

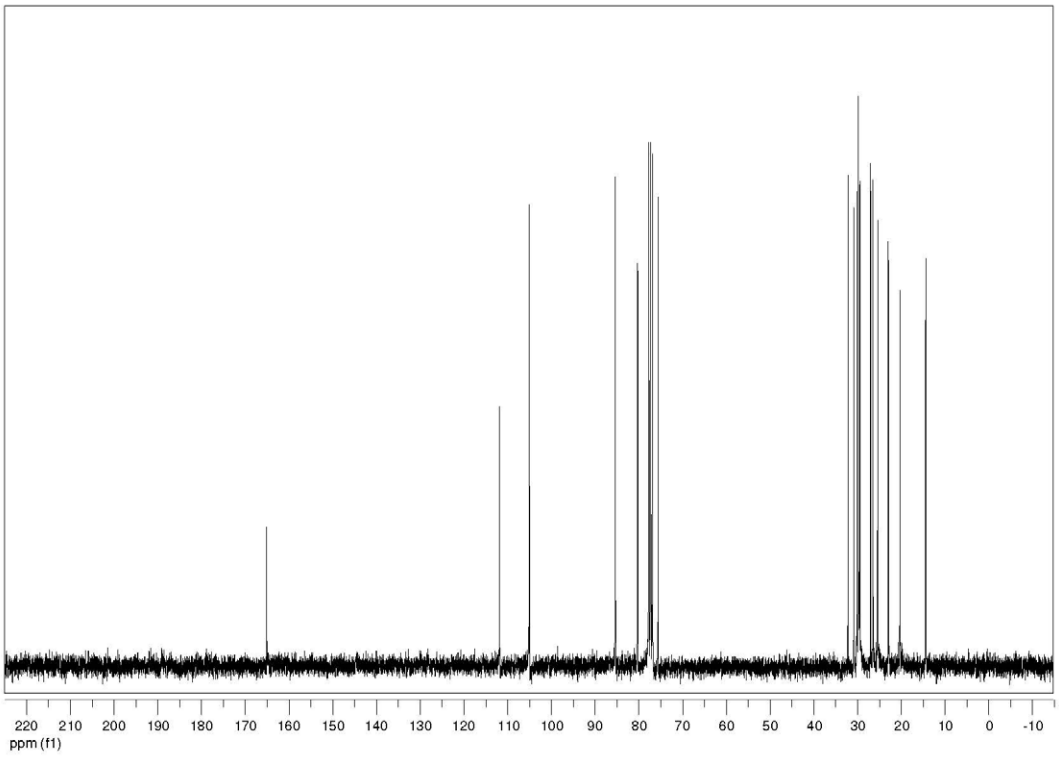

Figure S4. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **5b**.

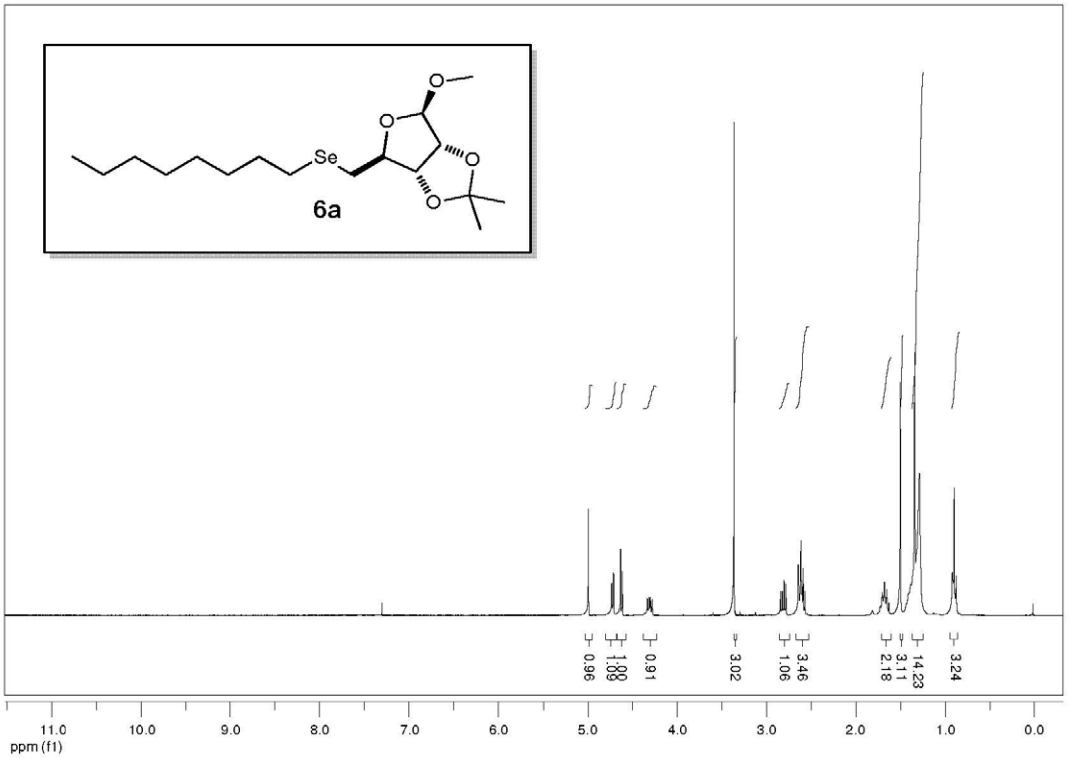

Figure S5. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **6a**.

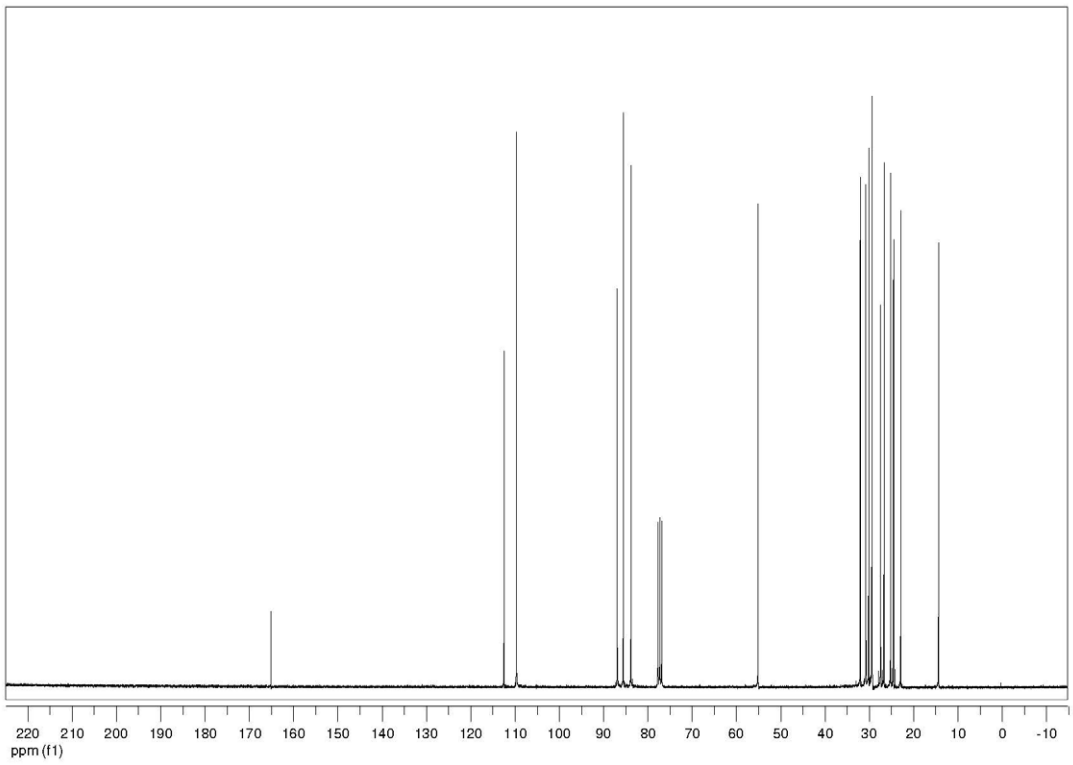

Figure S6. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **6a**.

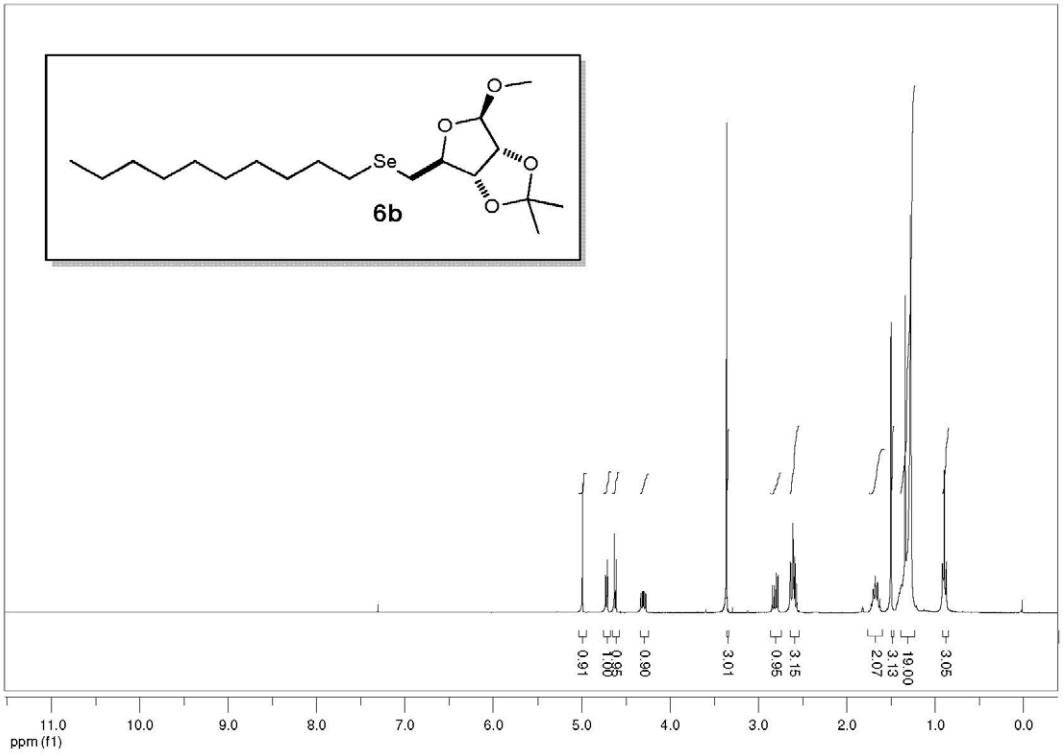

Figure S7. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **6b**.

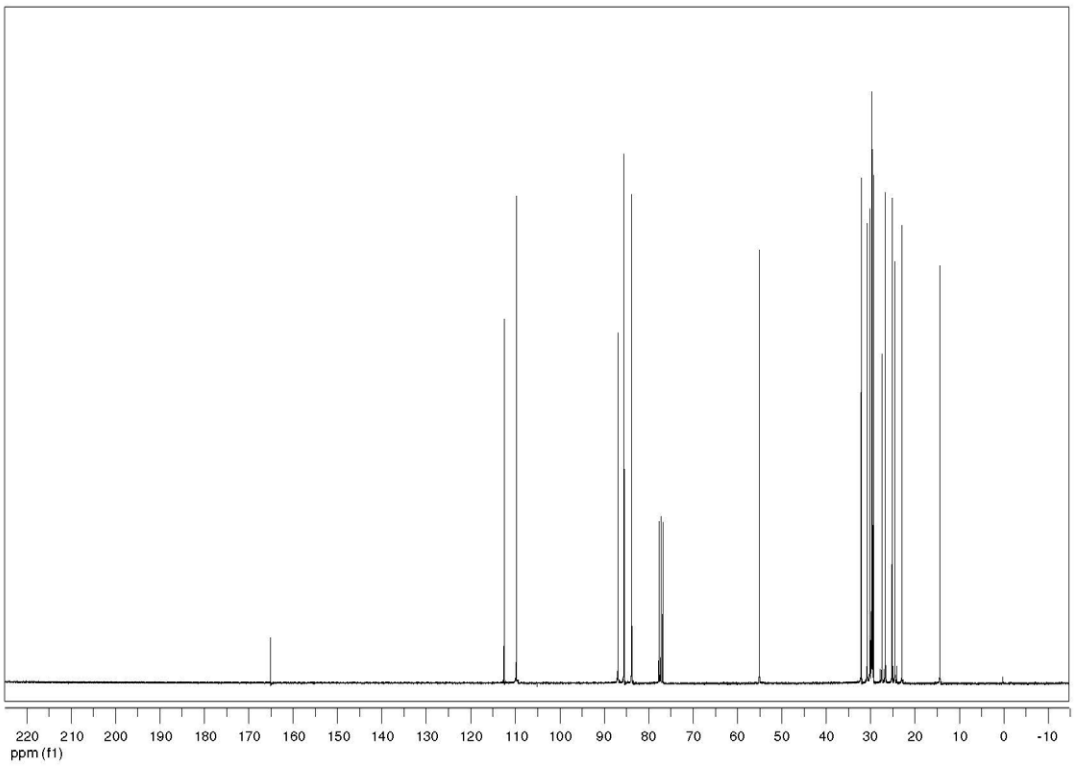

Figure S8. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **6b**.

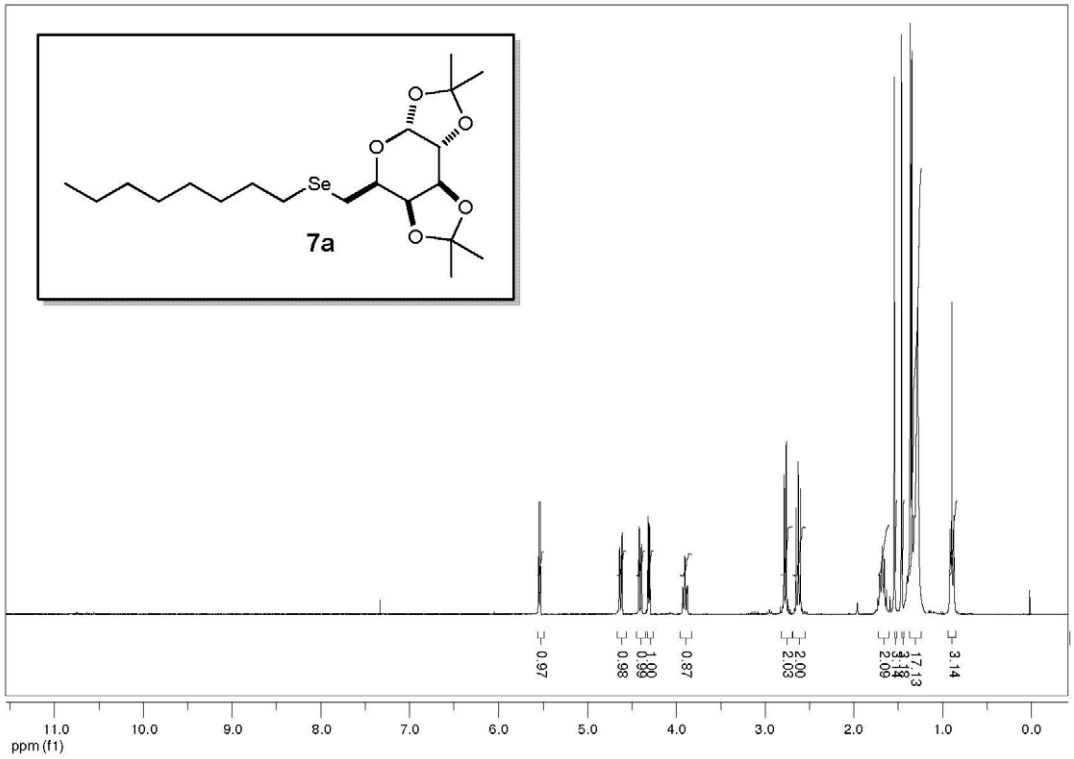

Figure S9. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **7a**.

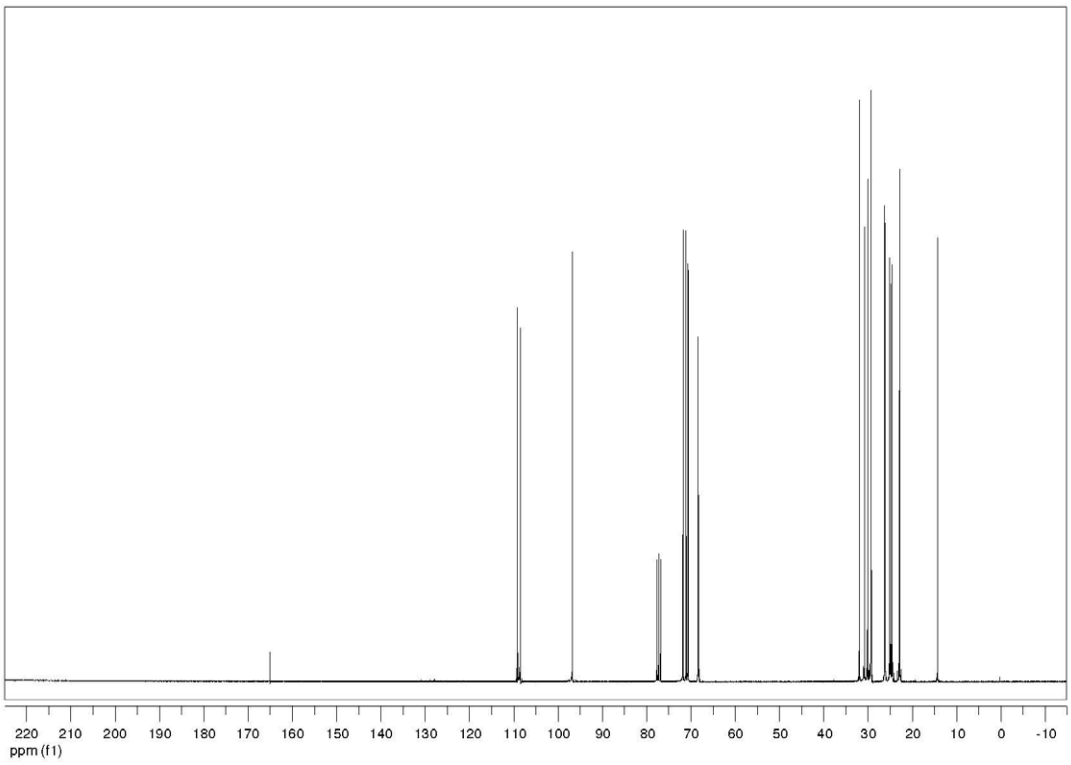

Figure S10. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **7a**.

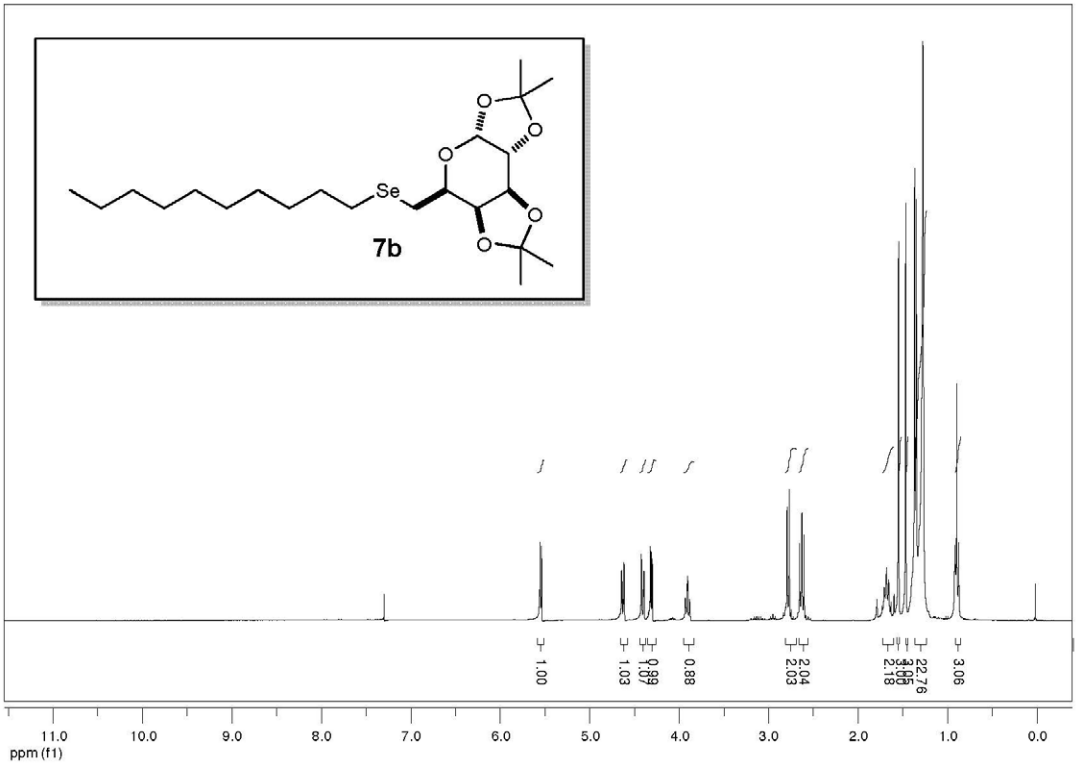

Figure S11. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **7b**.

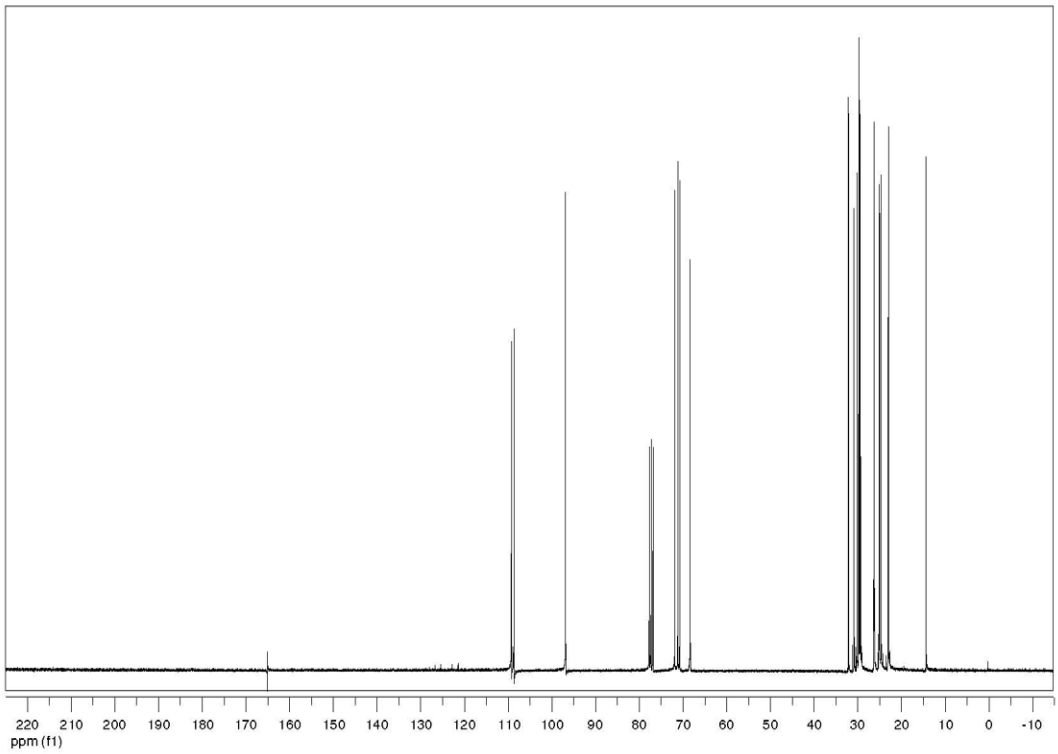

Figure S12. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **7b**.

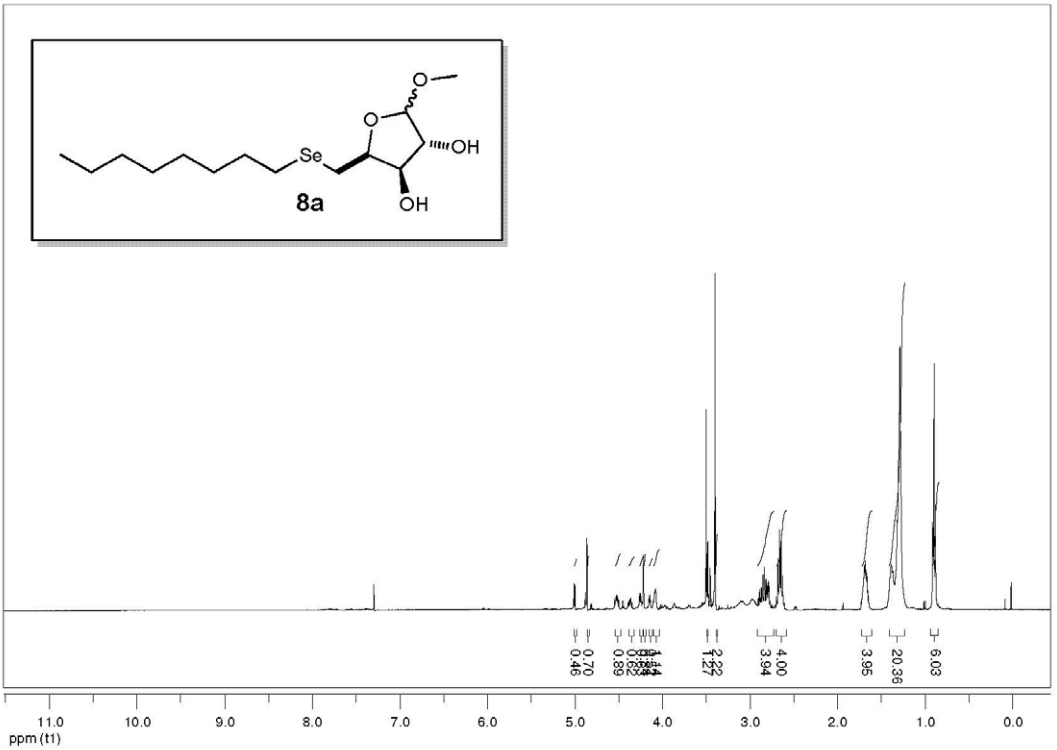

Figure S13. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **8a**.

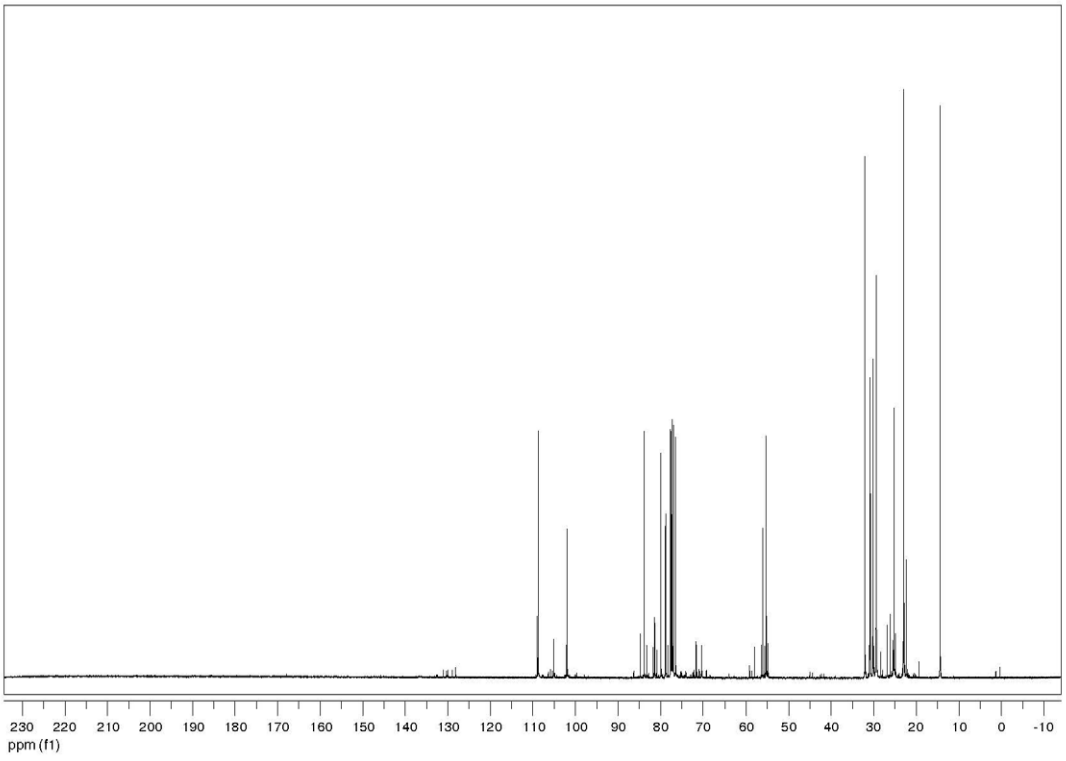

Figure S14. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **8a**.

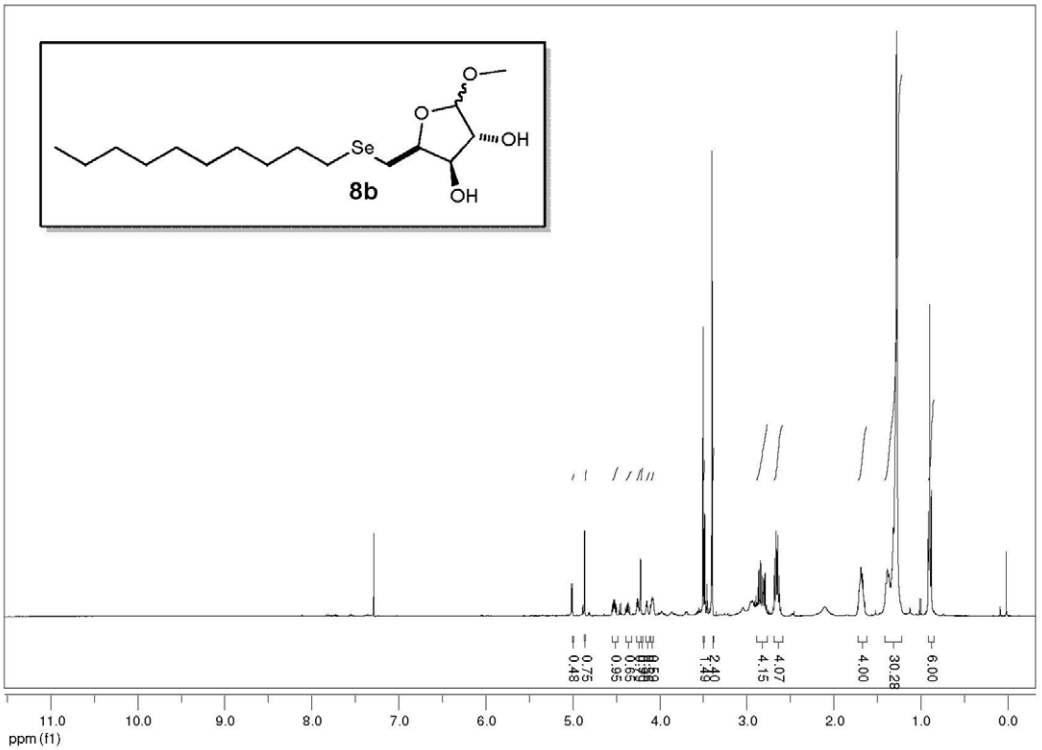

Figure S15. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **8b**.

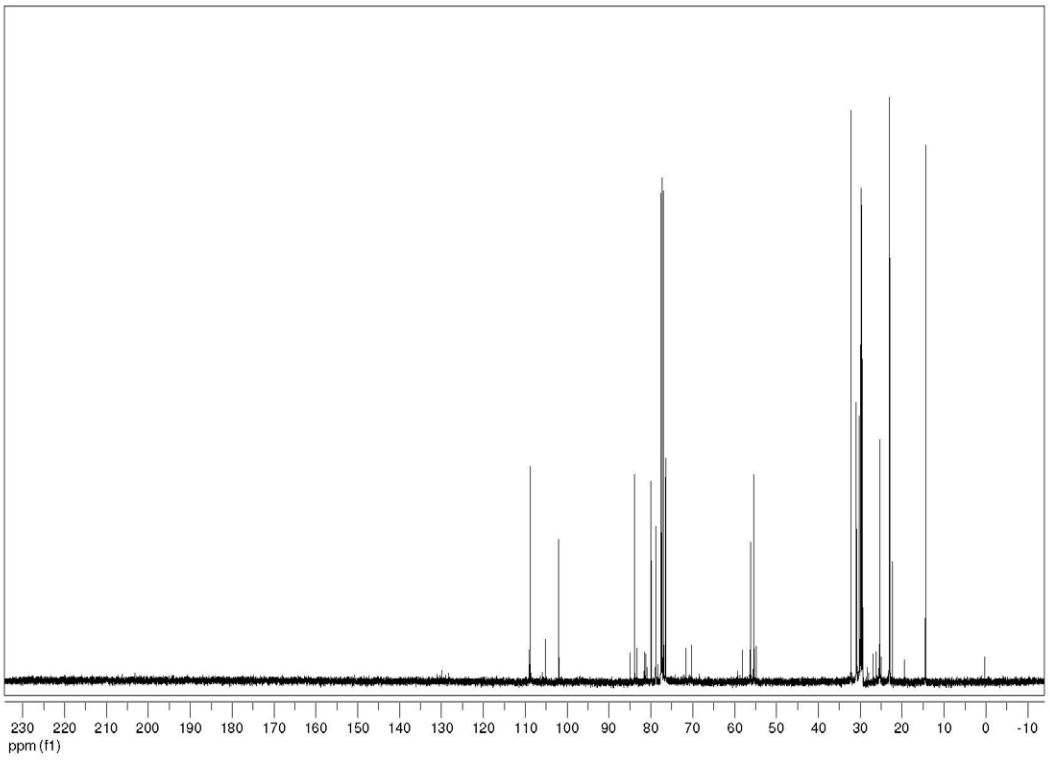

Figure S16. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **8b**.

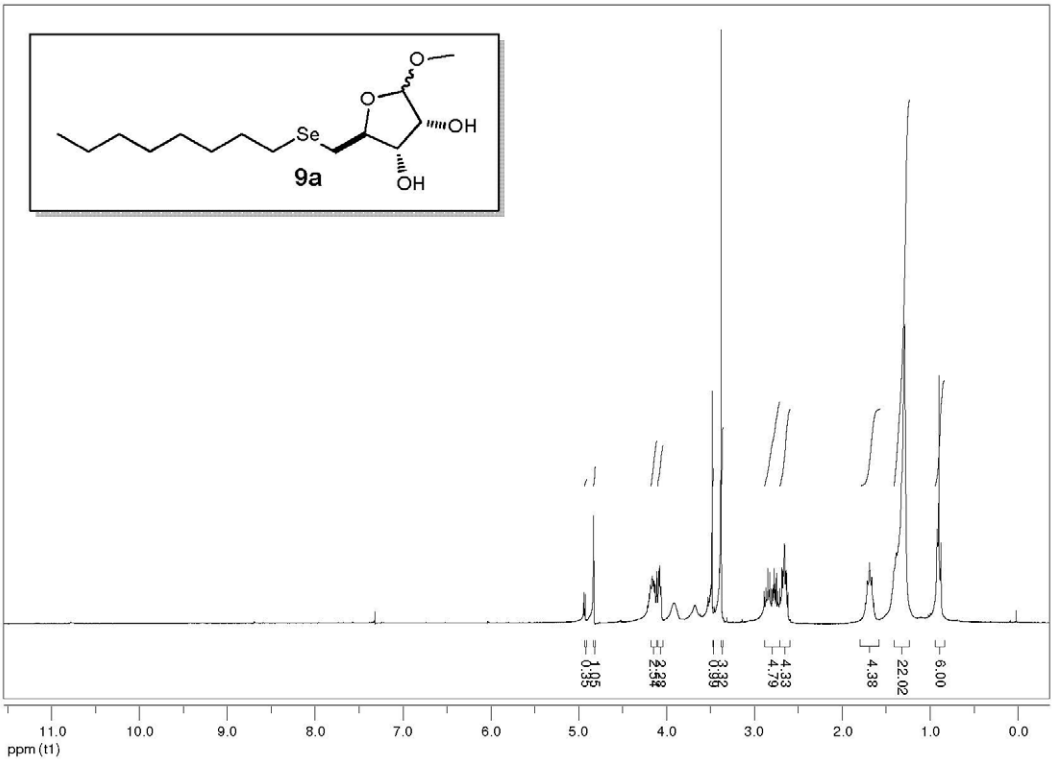

Figure S17. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **9a**.

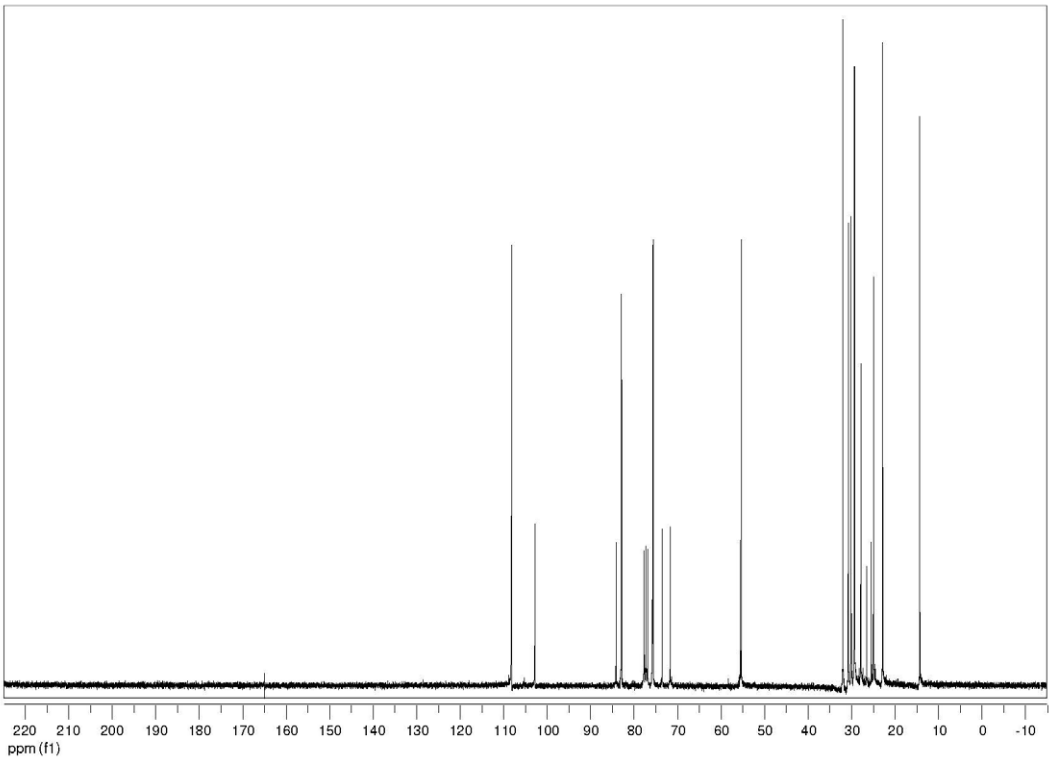

Figure S18. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **9a**.

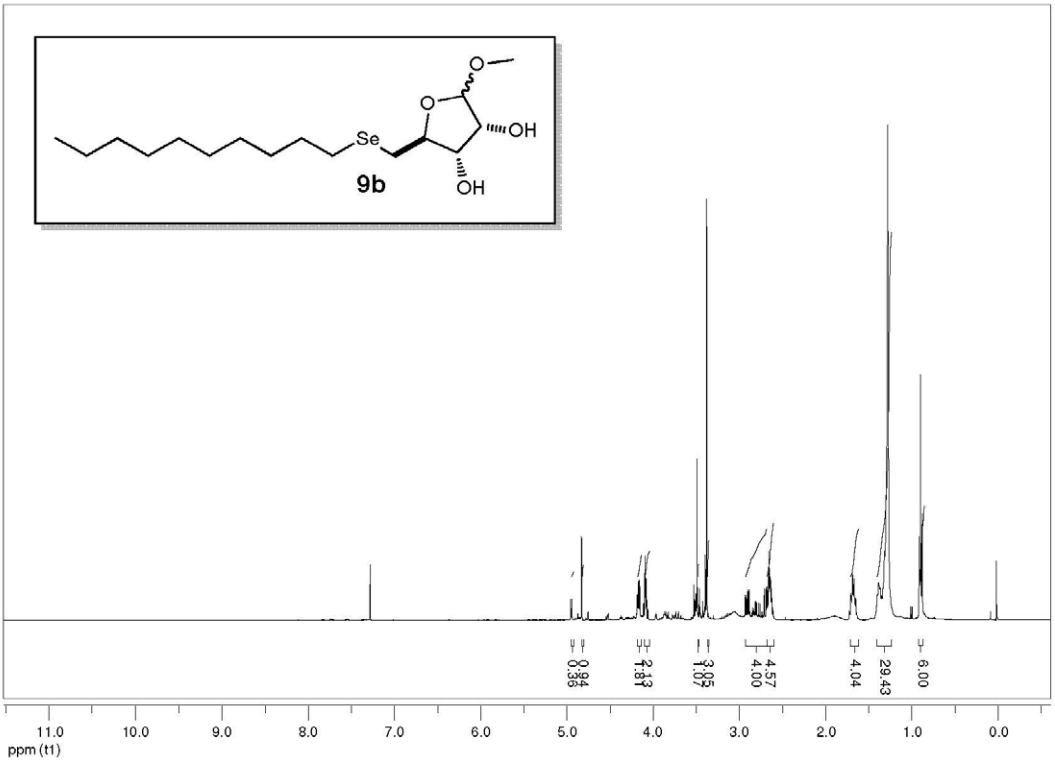

Figure S19. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **9b**.

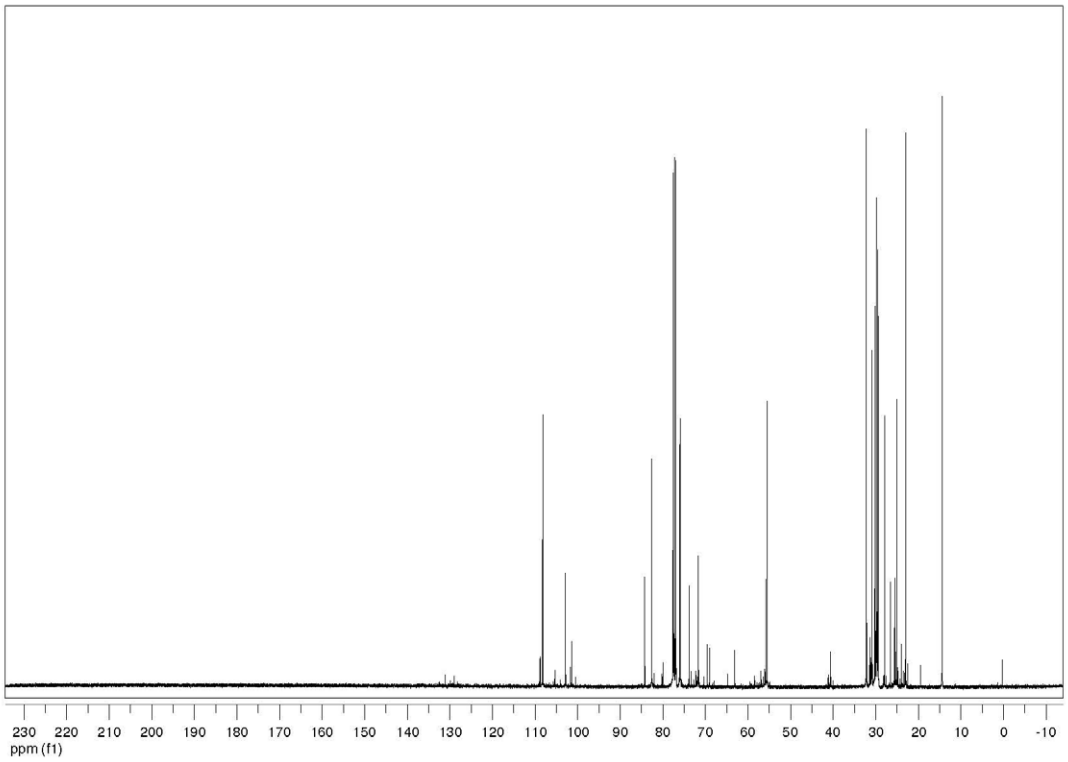

Figure S20. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **9b**.

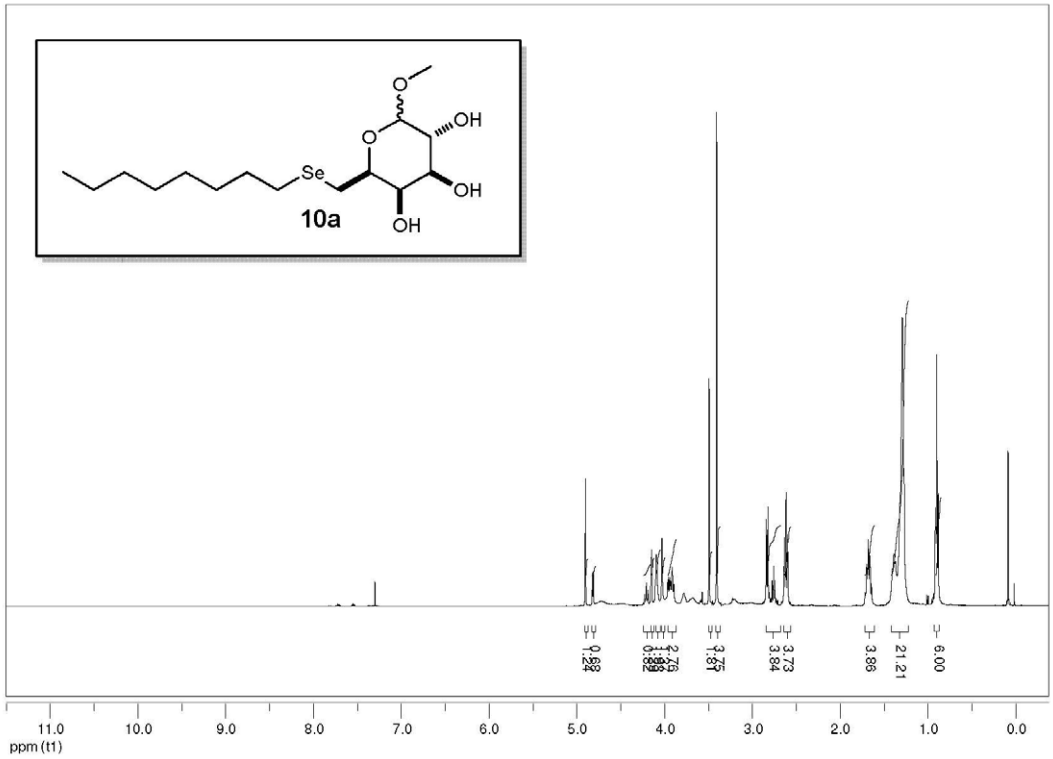

Figure S21. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **10a**.

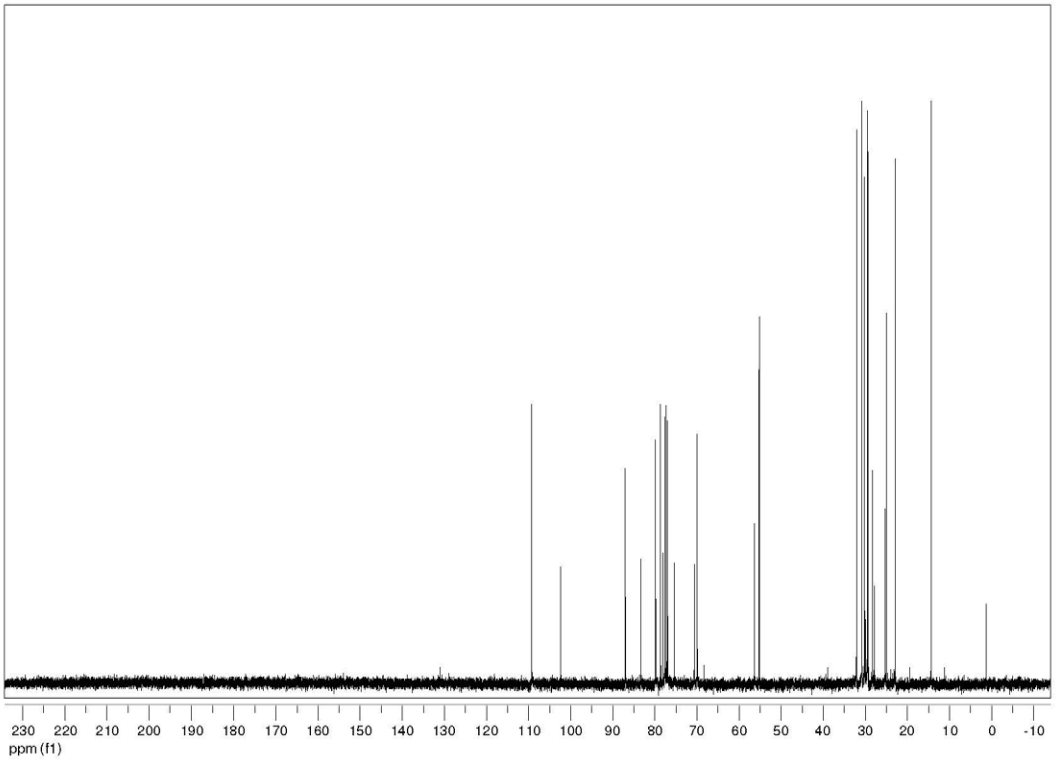

Figure S22. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **10a**.

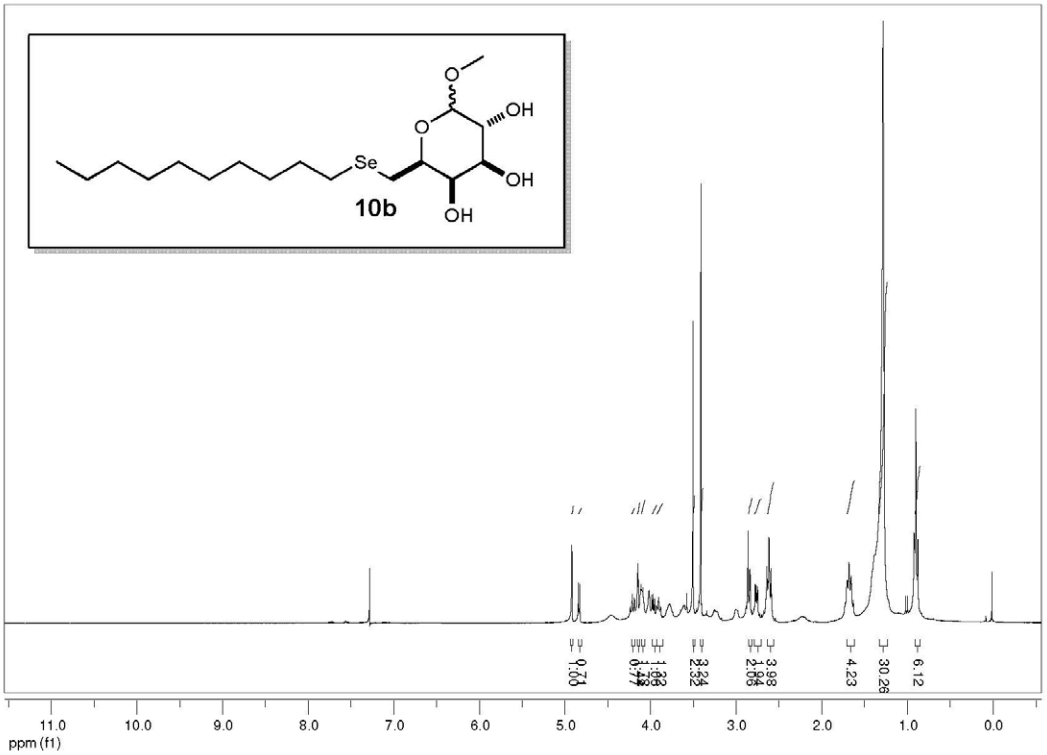

Figure S23. ^{1}H NMR (300 MHz, $CDCl_3$) spectrum for **10b**.

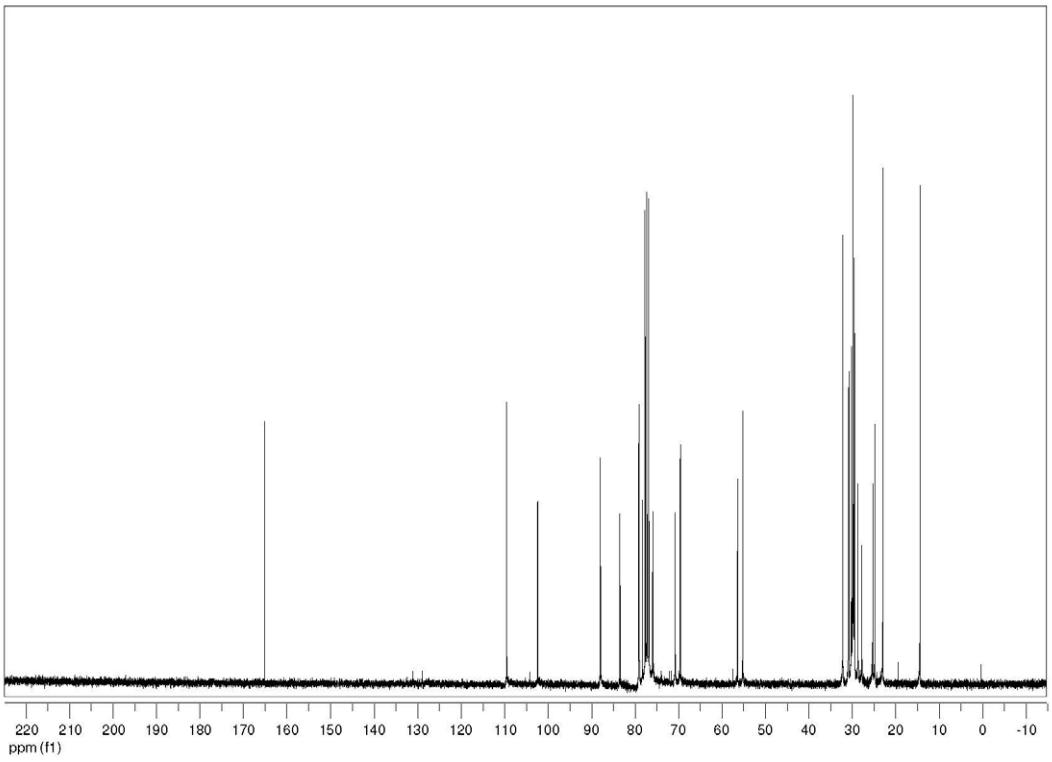

Figure S24. ^{13}C NMR (75 MHz, $CDCl_3$) spectrum for **10b**.

References

1. Choi, E. M.; Hwang, J. K.; Lee, J. H.; *Fitoterapia* **2005**, *76*, 684.
2. Re, R.; Pellegrini, N.; Proteggente, A.; Pannala, A.; Yang, M.; Rice-Evans, C.; *Free Radical Biol. Med.* **1999**, *26*, 1231.
3. Smirnoff, N.; Cumbes, Q. J.; *Phytochemistry* **1989**, *28*, 1057.
4. Marcocci, L.; Maguire, J. J.; Packer, L.; *Biochem. Mol. Biol. Int.* **1994**, *34*, 531.
5. Marklund, S.; Marklund, G.; *Eur. J. Biochem.* **1974**, *47*, 469.
6. Stratil, P.; Klejdus, B.; Kubán, V.; *Talanta* **2006**, *71*, 1741.