Supporting Information

C-Acylation of Glycosides *via* Ni/Photoredox Dual Catalysis

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1. General considerations:

1.1 General

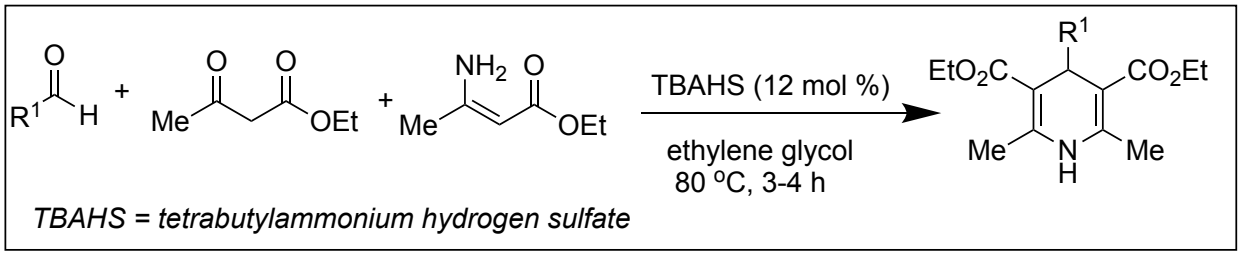
All chemical transformations were conducted under an inert atmosphere of argon utilizing Schlenk line techniques with a 4- or 5-port dual-bank manifold. NMR spectra (^{1}H, ^{13}C, ^{19}F) were obtained at 298 K using a 500 MHz or 300 MHz spectrometer. ^{1}H NMR spectra were referenced to residual, non-deuterated chloroform (δ 7.26) in $CDCl_3$. ^{13}C NMR spectra were referenced to chloroform (δ 77.30) in $CDCl_3$. Coupling constants, *J*, are reported in Hertz (Hz). In the case of diastereomeric mixtures, crude NMR was recorded to determine the ratio. HRMS was obtained by either ESI or CI with a TOF spectrometer in CH_3CN or CH_2Cl_2. IR spectra were obtained on neat samples. Reactions were monitored by HPLC, GC/MS, ^{1}H NMR, and/or by TLC on silica gel plates (60 Å porosity, 250 μm thickness). TLC analysis was performed using hexanes/EtOAc as the eluent and visualized using 2,4-dinitrophenylhydrazine stain, *p*-anisaldehyde stain, and/or UV light. Flash chromatography was accomplished using an automated system (visualizing at 254 nm and 280 nm) with silica cartridges (60 Å porosity, 20-40 μm). Solvents were purified by use of drying cartridges through a solvent delivery system. Melting points are uncorrected. Irradiation of reaction vessels was accomplished using blue LEDs (light-emitting diode, 470 nm) at a distance of ~3-5 cm. A fan was employed to ensure reactions remained at or near rt when using LEDs.

1.2 Chemicals

Deuterated NMR solvents were purchased and stored over 4Å molecular sieves. Na_2SO_4, $MgSO_4$, acetone, pentane, hexanes, and EtOAc were used as purchased. CH_2Cl_2 was purchased and dried *via* a solvent delivery system. Anhydrous acetone and anhydrous *i*-PrOAc were purchased and stored over 4Å molecular sieves. Ethylene glycol, carboxylic acids, aldehydes, dimethyl dicarbonate, 3-aminocrotonate, and ethyl acetoacetate were purchased from commercial suppliers and used without further purification. The quality of DMDC is crucial to this transformation and should be saved under molecular sieves. The organic photocatalyst 4CzIPN and the nickel complex $[Ni(dtbbpy)(H_2O)_4]Cl_2$ were prepared in-house by the procedures outlined in our previous reports.[1,2] New 1,4-dihydropyridines (1,4 DHPs) were prepared from their corresponding aldehydes according to the representative procedure outlined

below. Information (preparation protocols, characterization, etc.) for all other 1,4 DHP derivatives can be found in previous reports.[2,3]

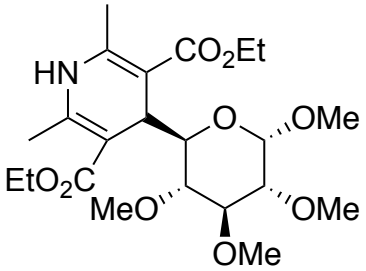
2. Synthesis of 1,4-Dihydropyridines:



Scheme S1. Synthesis of 1,4-DHP derivatives.

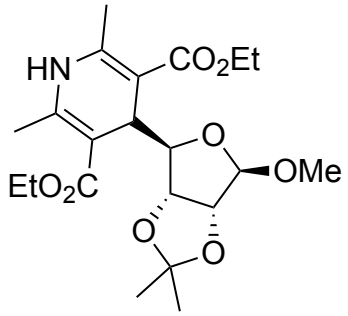
General Procedure I: Synthesis of 1,4-DHPs: 1,4-Dihydropyridines were prepared following a modified literature protocol.[3] A round-bottom flask was charged with ethyl 3-aminocrotonate (1.0 equiv) in ethylene glycol (2.5 M). To this mixture was added ethyl acetoacetate (1.0 equiv) and then the corresponding aldehyde (1.0 equiv). In some cases, the aldehyde was added as a stock solution in CH_2Cl_2. The reaction vessel was heated at 80 ºC for 3-4 h. After complete consumption of the aldehyde starting material, the reaction was cooled to rt and diluted with EtOAc. The reaction mixture was extracted three times with EtOAc using a separatory funnel containing brine. The organic layers were then combined, dried ($MgSO_4$), filtered, and taken to dryness. The crude reaction mixture was purified using an automated system (visualizing at 254 nm, monitoring at 280 nm) with silica cartridges (60 Å porosity, 20-40 μm) using hexanes/EtOAc (0 to 60%) as eluent.

2.1 Characterization Data



Diethyl 2,6-dimethyl-4-((2*R*,3*R*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)-1,4-dihydropyridine-3,5-dicarboxylate (1d): Following General Procedure 1 using the

corresponding aldehyde (1.0 g, 4.2 mmol, 1.0 equiv). The product was isolated (CombiFlash, silica gel, hexanes/EtOAc 0 to 70%) as a slightly yellow foam (630 mg, 28% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.40 (s, 1H), 4.63 (d, *J* = 3.1 Hz, 1H), 4.46 (d, *J* = 4.2 Hz, 1H), 4.28 – 4.08 (m, 4H), 3.57 (s, 3H), 3.49 (s, 3H), 3.47 (s, 3H), 3.31 (dd, *J* = 9.8, 4.3 Hz, 1H), 3.25 (s, 3H), 3.13 – 3.05 (m, 2H), 2.29 (s, 6H), 1.30 (t, *J* = 7.0 Hz, 6H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.7, 167.9, 145.1, 145.0, 99.7, 98.8, 96.3, 84.0, 81.8, 79.7, 72.8, 60.2, 59.6, 59.5, 58.7, 58.6, 54.1, 35.5, 19.3, 19.0, 14.3, 14.3 ppm. IR (neat, cm^{-1}): 3342, 2979, 2933, 1677, 1487, 1304, 1209, 1154, 1092, 1047. HRMS (EI+) *calcd for* $C_{22}H_{35}NO_9$ $[M]^+$ 458.2390, *found* 458.2379.



Diethyl 4-((3a*R*,4*R*,6*R*,6a*R*)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-*d*][1,3]dioxol-4-yl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (1z): Following General Procedure I using the corresponding aldehyde[5] (1.68 g, 8.3 mmol, 1.0 equiv). The product was isolated (CombiFlash, silica gel, hexanes/EtOAc 0 to 20%) as a yellow solid (1.46 g, 41% yield). Mp = 112-116 ºC. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.83 (s, 1H), 4.87 (s, 1H), 4.71 (dd, *J* = 6.0, 1.5 Hz, 1H), 4.45 (d, *J* = 6.0 Hz, 1H), 4.33 – 4.07 (m, 5H), 3.94 (dd, *J* = 7.8, 1.4 Hz, 1H), 3.31 (s, 3H), 2.36 (s, 3H), 2.32 (s, 3H), 1.42 (s, 3H), 1.33 – 1.28 (m, 6H), 1.27 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.2, 167.5, 147.0, 144.6, 112.1, 110.9, 101.4, 99.0, 89.5, 85.4, 81.6, 60.0, 60.0, 56.3, 37.3, 27.1, 25.5, 19.9, 19.5, 14.6, 14.5 ppm. IR (neat, cm^{-1}): 3335, 2978, 1687, 1661, 1483, 1210, 1093, 1050. HRMS (EI+) *calcd for* $C_{21}H_{31}NO_8$ $[M]^+$ 425.2050, *found* 425.2025.

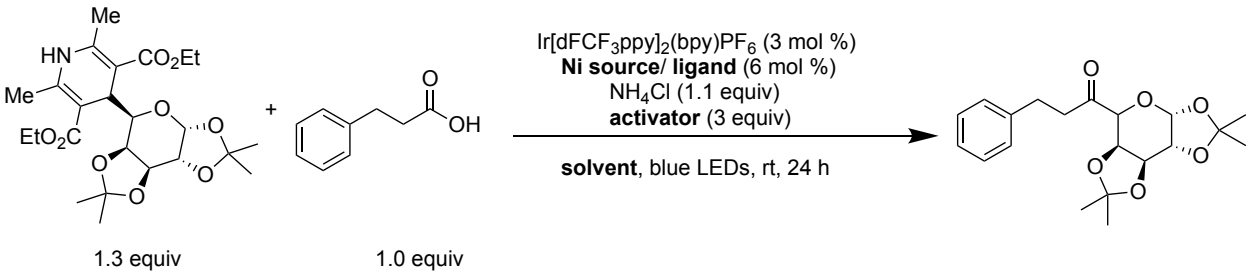
3. High-throughput experimentation design:

3.1 High-throughtput Experimentation (HTE) Information

High Throughput Experimentation (HTE) was performed at the Penn/Merck Center for High Throughput Experimentation at the University of Pennsylvania. The screens were conducted on a 0.01 mmol scale (relative to the carboxylic acid starting material) and analyzed by UPLC with addition of 4,4′-di-*tert*-butylbiphenyl as internal standard (IS). The ratios corresponding to the areas of the product to internal standard (P/IS) are outlined below. Each screen was carried out independently, and the ratios from one screen should not be quantitatively compared to those from a different screen.

General Procedure II for Screens: The reactions were carried out in a 96-well plate reactor block containing 1 mL glass vials equipped with a Teflon-coated magnetic stir bar. The plate was placed in a glovebox, and stock solutions of the appropriate reagents (1,4-DHP, carboxylic acid, ligands, nickel complexes, and photocatalysts) were added using micropipettes. A centrifugal evaporator was used to remove excess solvents. To these vials was then added 100 μL of an appropriate solvent. The vials were sealed and stirred over blue LED lights (470 nm) at rt (~24 ºC). After 24 hou, the reactions were exposed to air and diluted with 500 μL of a 0.002 μM solution of internal standard in MeCN. The vials were stirred for 5 min. Aliquots (25 μL) were transferred into a 96-well UPLC block, diluted with MeCN (700 μL) and then analyzed by UPLC.

Screen 1. Variation of activators, nickel sources, and solvents with NH_4Cl as additive



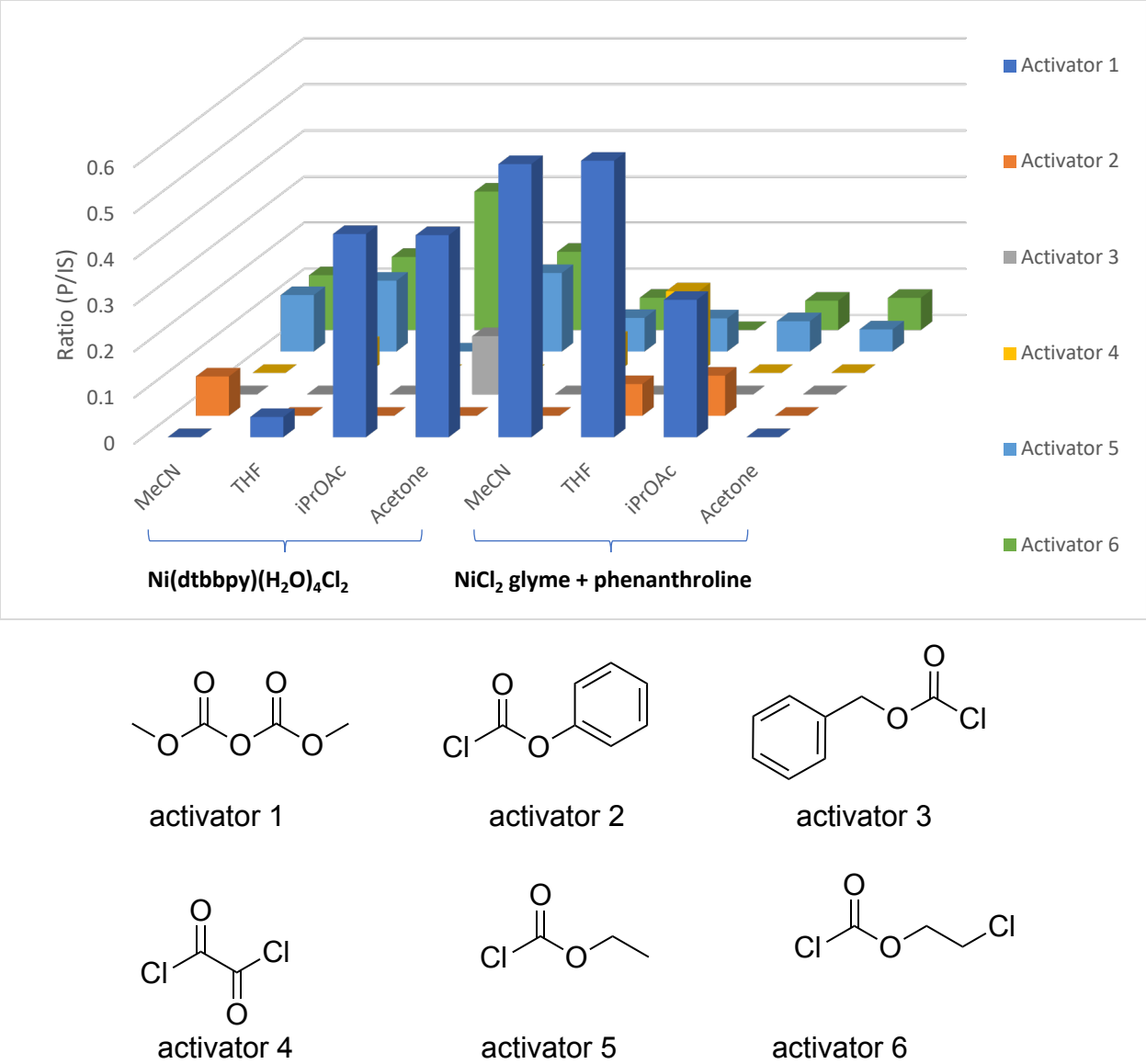
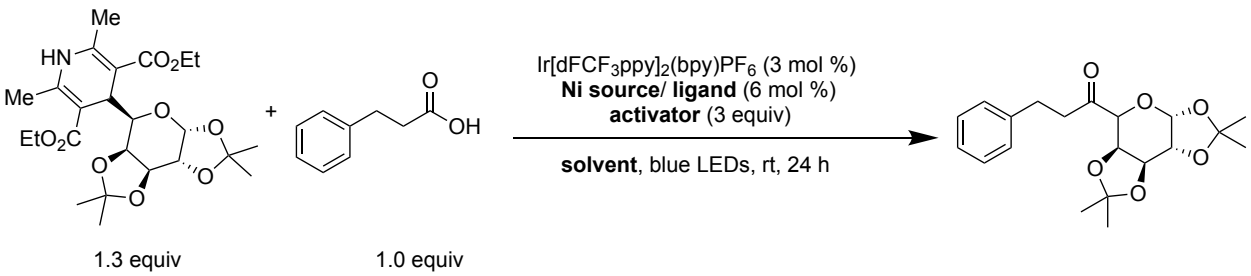


Figure S1. Optimization of activators, nickel sources, and solvents with NH_4Cl as additive

Screen 2. Variation of activators, nickel sources, and solvents without NH_4Cl as additive



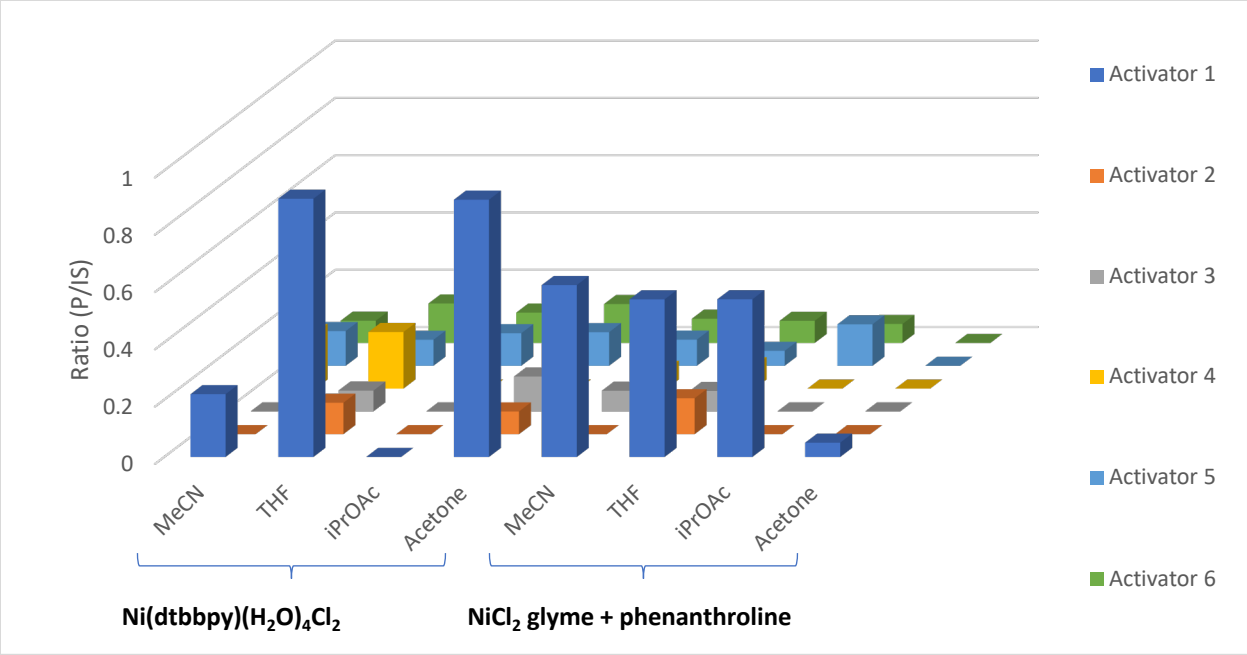
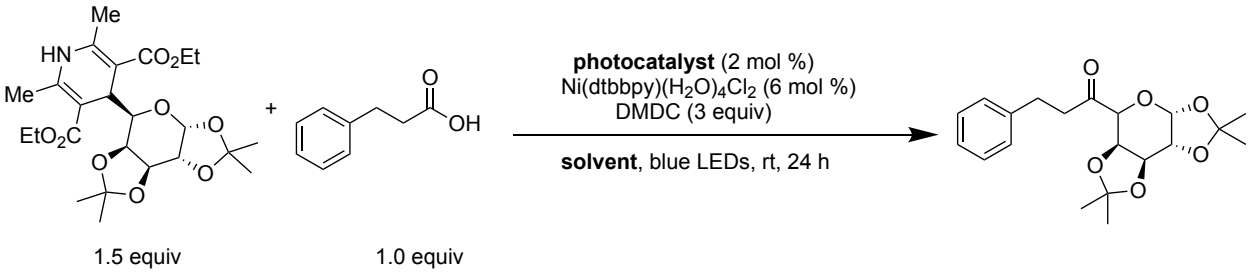
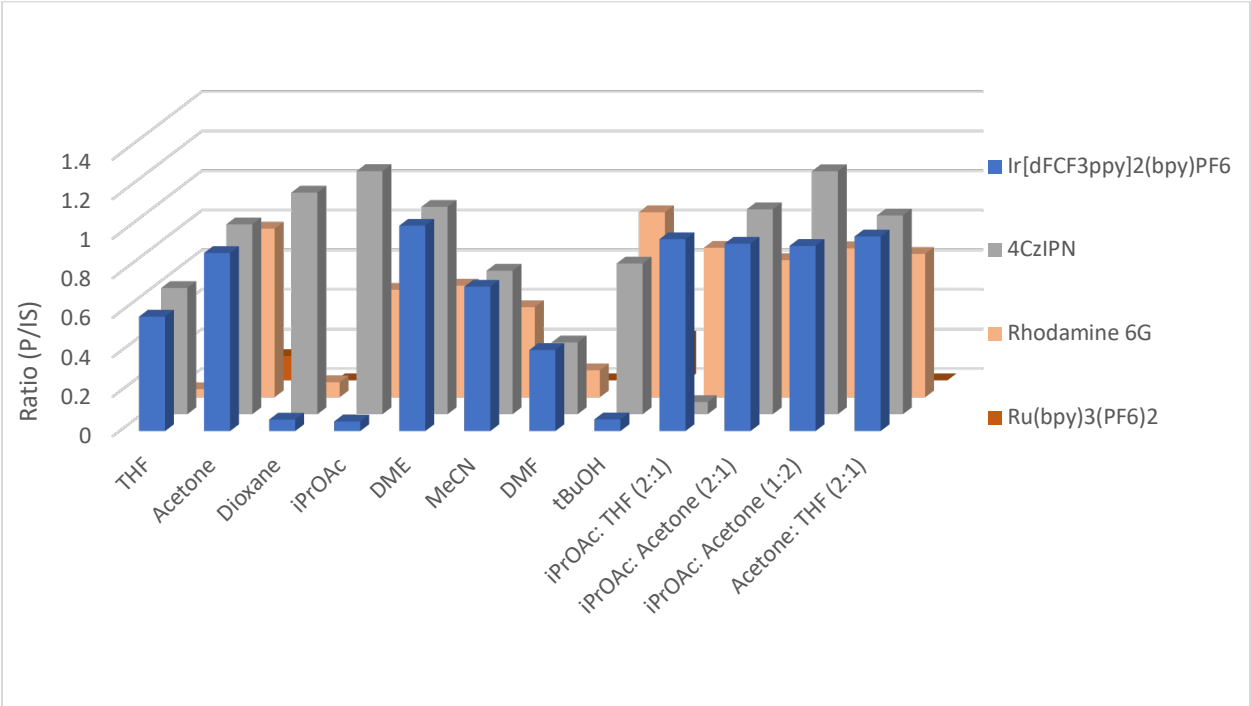
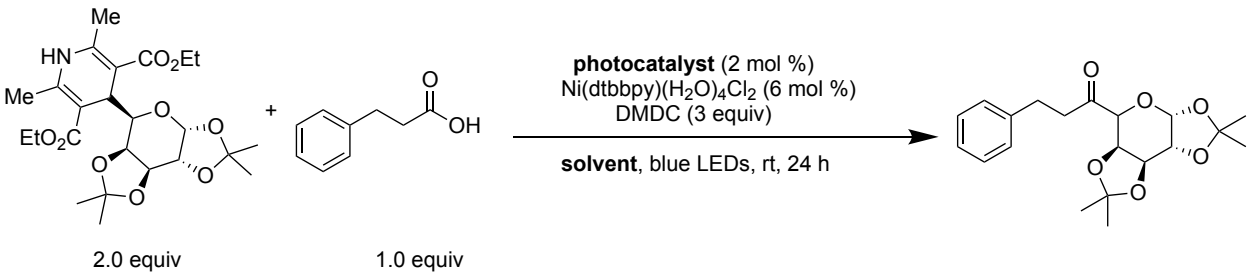


Figure S2. Optimization of activators, nickel sources, and solvents without NH_4Cl as additive

Screen 3. Variation of photocatalysts and solvents with different loadings of starting materials

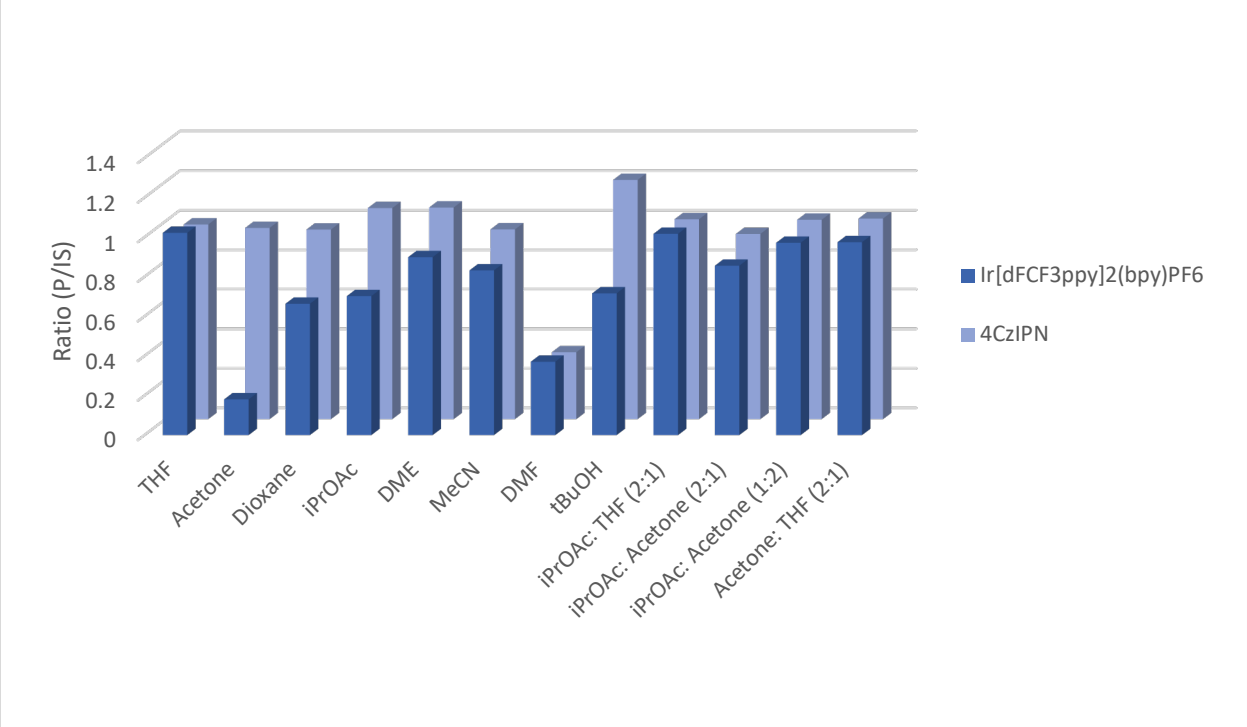






2.0 equiv 1.0 equiv

O



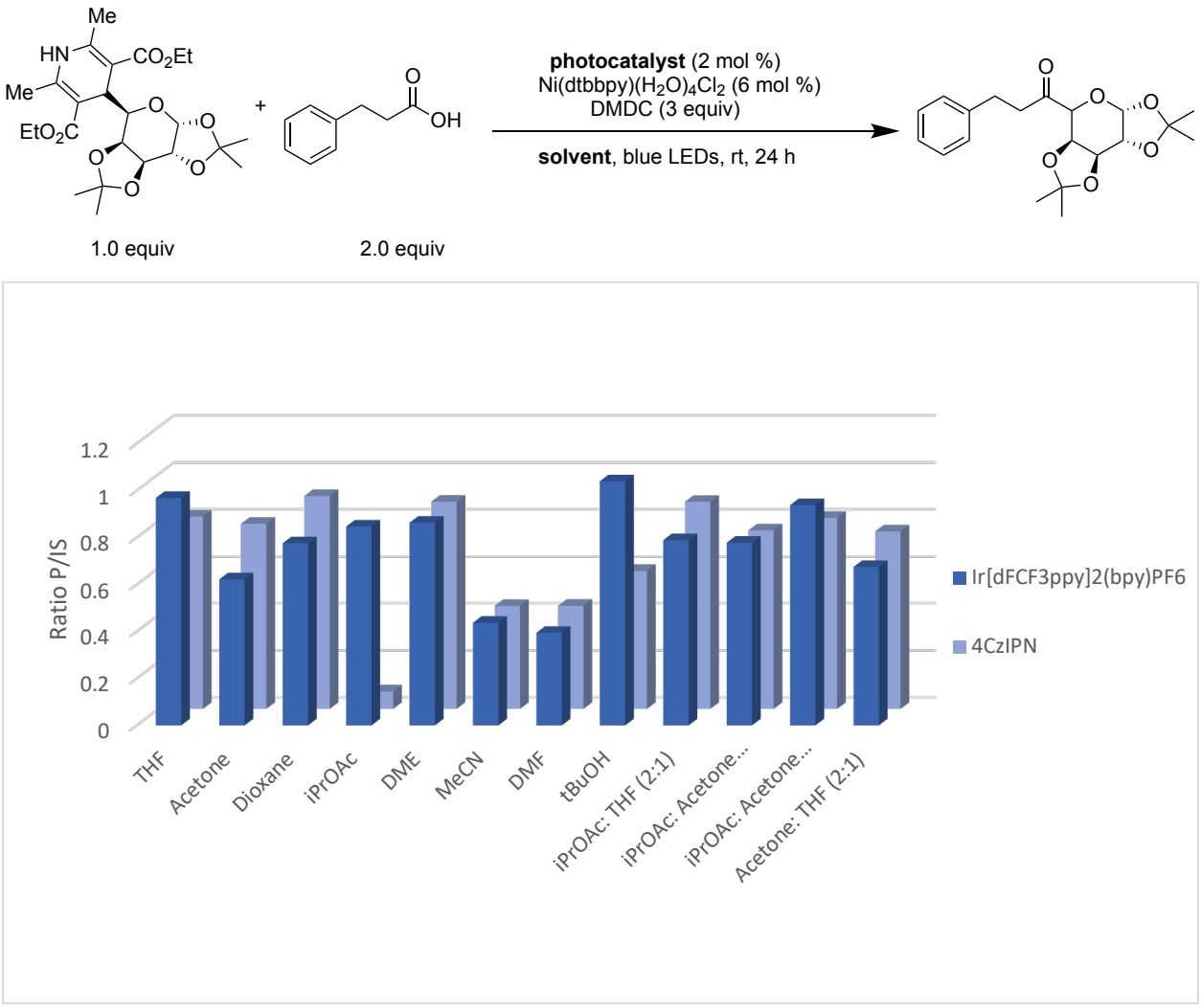
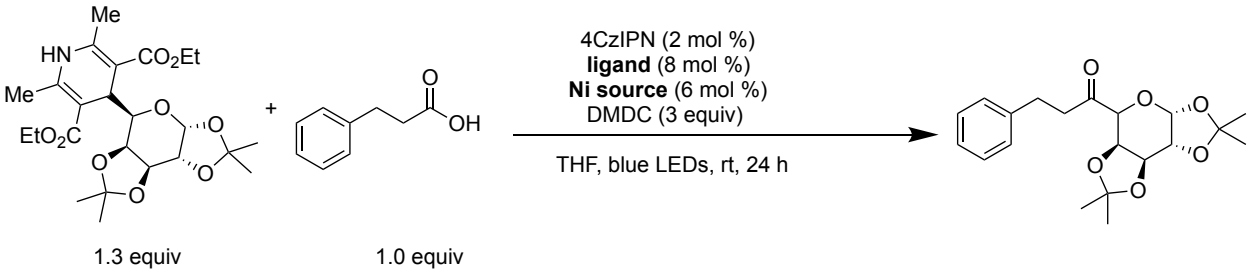
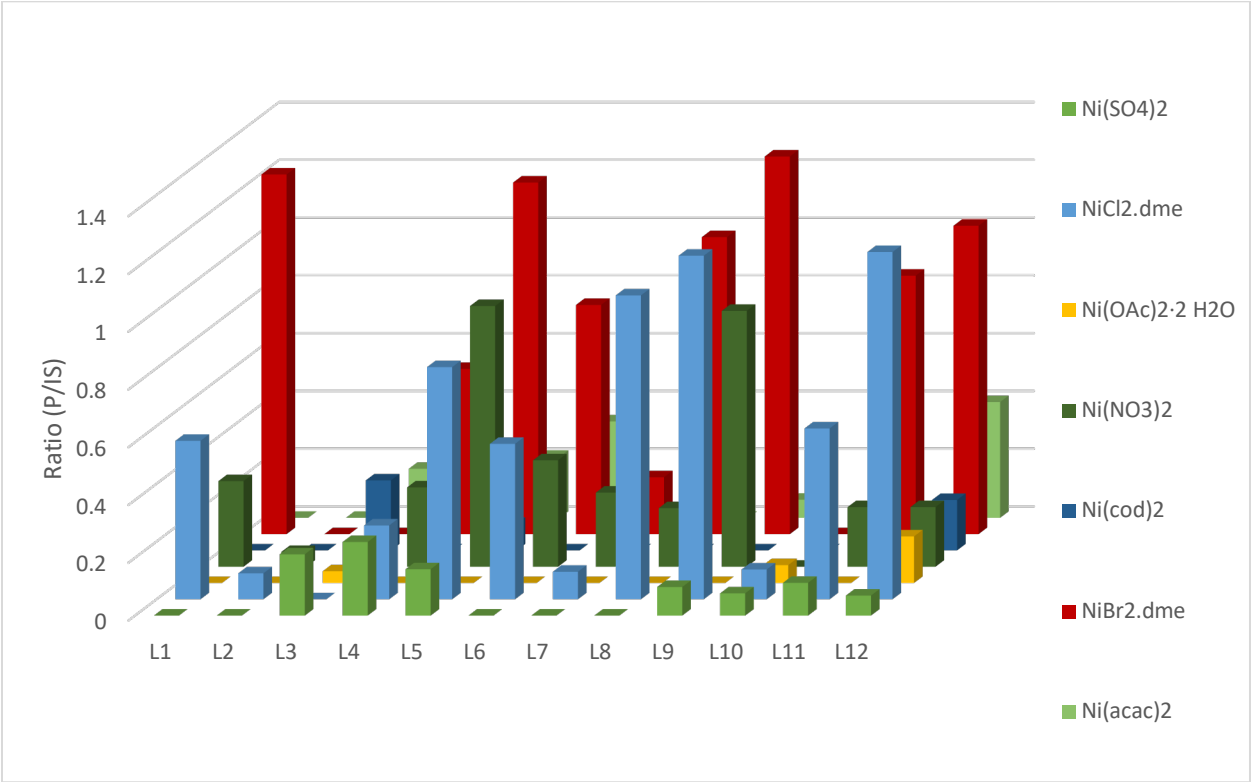


Figure S3. Ratios (P/IS) for different photocatalysts, solvents, and loading of starting materials

Screen 4. Variation of nickel sources and ligands.





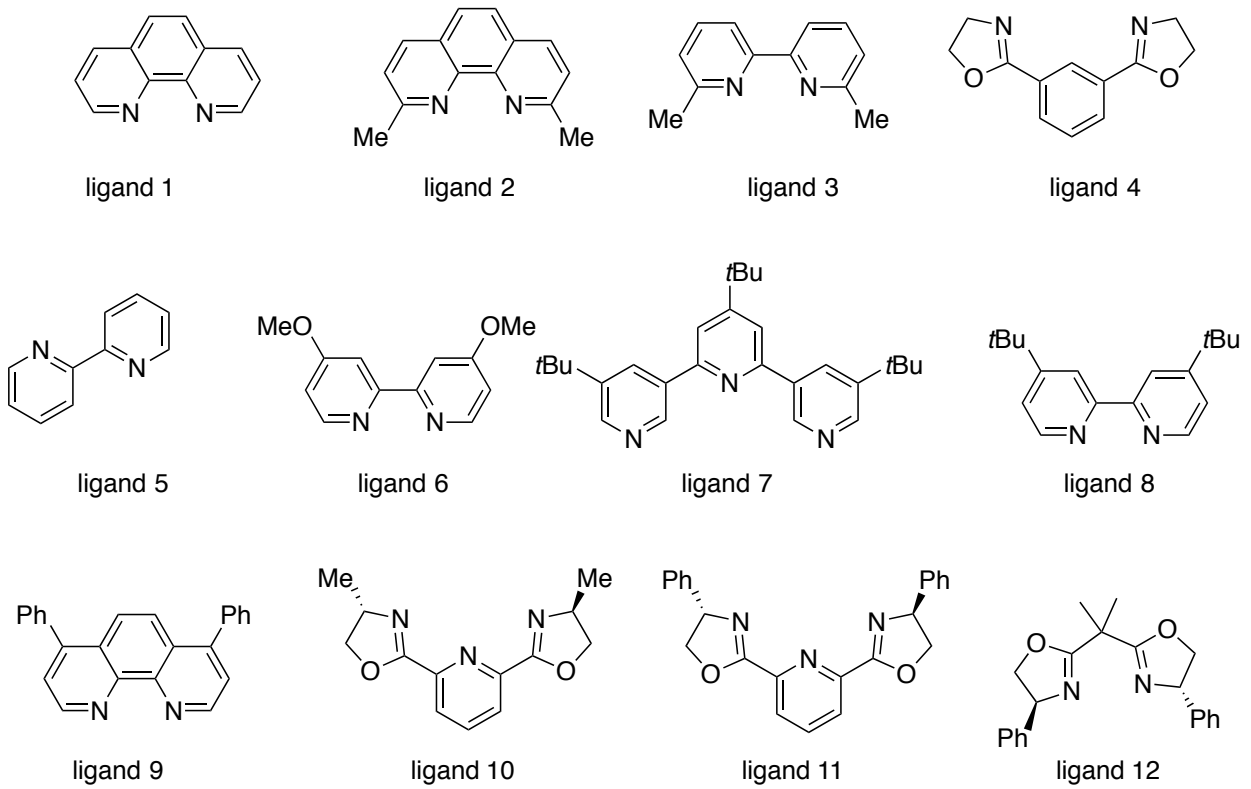


Figure S4. Ratios (P/IS) for the optimization of nickel sources and ligands

Table S1. Control Experiments.

Entry	Conditions[a]	Yield (%)[b]
1	no 4CzIPN	0
2	no Ni(dtbbpy)$(H_2O)_4Cl_2$	0
3	no light	0
4	no DMDC	0

[a] Reactions were carried out on 0.1 mmol scale. [b] NMR yields were calculated using 1,3,6-trimethoxybenzene as internal standard.

4. General Procedure for Cross-Coupling Reactions:

General Procedure III: Synthesis of aliphatic ketones: To an 8 mL reaction vial with a stir bar were added 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), 1,4-DHP **1** (0.45 mmol, 1.5 equiv), and carboxylic acid **2** (0.3 mmol, 1.0 equiv), if a solid. The vial

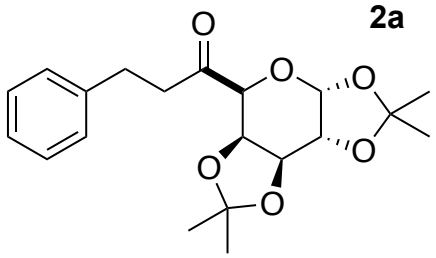
was sealed with a cap containing a TFE-lined silicone septa and placed under an argon atmosphere *via* an inlet needle. The vial was evacuated three times *via* an inlet needle then purged with argon. A dry and degassed mixture of acetone/*i*-PrOAc (2/1) was then added (3.0 mL, 0.1 M). If the carboxylic acid was an oil, it was added at this point directly *via* microsyringe. DMDC (64 µL, 0.6 mmol, 2 equiv) was then added to the reaction *via* a microsyringe. The reaction was placed under blue LED irradiation (470 nm) and stirred for 24 h. The reaction was maintained at approximately 24 °C *via* a fan. After completion, the reaction mixture was taken to dryness and then a crude NMR was obtained. The reaction mixture was then purified on an automated liquid chromatographic system to obtain the pure product.

Note:

A. In some cases, the product was isolated as a mixture with the pyridine by-product. To obtain a pure product, the mixture was dissolved in Et_2O and washed with HCl (1 M) several times.
B. The quality of DMDC is crucial to this transformation. It should be kept under molecular sieves.

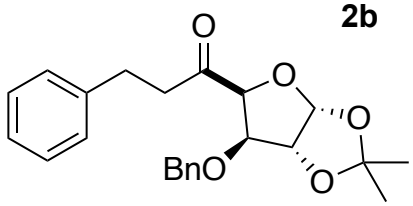
5. Compound Characterization Data:

5.1 Hantszch ester scope



3-Phenyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-yl)propan-1-one (2a): Following General Procedure III using **1a**-DHP (216.7 mg, 0.45 mmol, 1.5 equiv), hydrocinnamic acid (45.1 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (102.5 mg, 94%

yield). dr = 4.3:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.33 – 7.14 (m, 5H), 5.62 (d, *J* = 4.6 Hz, 1H), 4.63 (d, *J* = 7.4 Hz, 1H), 4.58 (d, *J* = 8.9 Hz, 1H), 4.38 – 4.31 (m, 1H), 4.21 (s, 1H), 2.97 – 2.84 (m, 4H), 1.50 (s, 3H), 1.42 (s, 3H), 1.33 (s, 3H), 1.31 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.33 – 7.14 (m, 5H), 5.30 (s, 1H), 4.63 (d, *J* = 7.4 Hz, 1H), 4.58 (d, *J* = 8.9 Hz, 1H), 4.24 (s, 1H), 3.71 (d, *J* = 8.7 Hz, 1H), 3.10 – 2.98 (m, 4H), 1.57 (s, 3H), 1.48 (s, 3H), 1.38 (s, 3H), 1.36 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 208.6, 141.4, 128.5 (4C), 126.0, 109.7, 109.0, 96.5, 73.8, 72.6, 70.7, 70.5, 41.7, 28.7, 26.1, 25.9, 24.9, 24.3 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 205.6, 141.1, 128.6 (4C), 126.2, 111.1, 109.5, 97.1, 77.5, 75.2, 74.2, 69.7, 41.1, 29.3, 27.9, 27.7, 25.8, 25.6 ppm. IR (neat, cm^{-1}): 2988, 2935, 1719, 1382, 1372, 1255, 1211, 1166, 1066. HRMS (ES+) *calcd for* $C_{20}H_{26}O_6Na$ $[M+Na]^+$ 385.1627, *found* 385.1646.

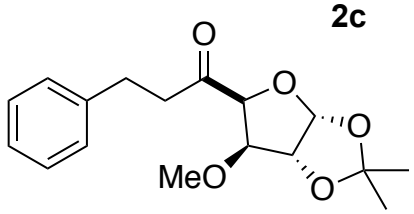


2b

1-((3a*R*,6*R*,6a*R*)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (2b): Following General Procedure III using **1b-DHP** (225.7 mg, 0.45 mmol, 1.5 equiv), hydrocinnamic acid (45.1 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (95.2 mg, 83% yield). dr = 3.8:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.37 – 7.15 (m, 10H), 5.99 (d, *J* = 3.9 Hz, 1H), 4.61 (d, *J* = 3.9 Hz, 1H), 4.59 – 4.56 (m, 2H), 4.46 (s, 1H), 4.45 (s, 1H), 4.03 (d, *J* = 1.8 Hz, 1H), 3.21 – 2.80 (m, 4H), 1.32 (s, 3H), 1.26 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.37 – 7.15 (m, 10H), 5.96 (d, *J* = 3.7 Hz, 1H), 4.61 (d, *J* = 3.9 Hz, 1H), 4.59 – 4.56 (m, 1H), 4.46 (s, 1H), 4.45 (s, 1H), 4.02 (d, *J* = 1.6 Hz, 1H), 3.21 – 2.80 (m, 4H), 1.61 (s, 3H), 1.47 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 208.3, 141.0, 137.1, 128.7 (2C), 128.6 (2C), 128.5 (2C), 128.2, 128.0 (2C), 126.2, 112.2, 106.5, 89.7, 83.8 (2C), 72.0, 40.7, 29.2, 26.0, 25.8 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 208.3, 141.3, 137.5, 128.6 (2C), 128.5 (2C), 128.0 (2C), 127.9, 127.8 (2C), 126.1, 111.7, 105.7, 83.1, 82.0,

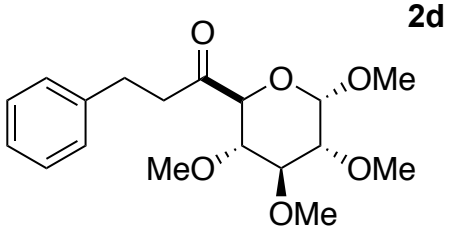
71.3, 70.5, 42.3, 28.8, 26.9, 26.8 ppm. IR (neat, cm^{-1}): 2986, 1715, 1454, 1374, 1260, 1211, 1163, 1070, 1011. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5Na$ $[M+Na]^+$ 405.1678, *found* 405.1664.

2c

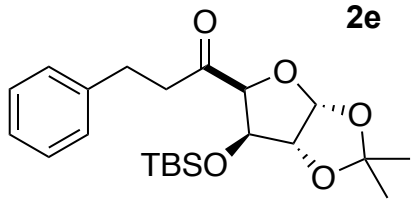


1-((3a*R*,6*R*,6a*R*)-6-Methoxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (2c): Following General Procedure III using **1c-DHP** (191.4 mg, 0.45 mmol, 1.5 equiv), hydrocinnamic acid (45.1 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (49.8 mg, 54% yield). dr = 2.7:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.33 – 7.11 (m, 5H), 5.96 (d, *J* = 3.9 Hz, 1H), 4.55 (t, *J* = 4.4 Hz, 1H), 4.37 (s, 1H), 4.23 (s, 1H), 3.40 (s, 3H), 3.23 – 2.84 (m, 4H), 1.33 (s, 3H), 1.27 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.33 – 7.11 (m, 5H), 6.02 (d, *J* = 3.5 Hz, 1H), 4.62 (d, *J* = 3.6 Hz, 1H), 4.56 (d, *J* = 4.7 Hz, 1H), 4.02 (d, *J* = 3.6 Hz, 1H), 3.26 (s, 3H), 3.23 – 2.84 (m, 4H), 1.47 (s, 3H), 1.33 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 208.4, 141.1, 128.6 (2C), 128.5 (2C), 126.2, 112.2, 106.4, 89.4, 85.7, 83.3, 57.5, 40.8, 29.3, 26.0, 25.8 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 207.5, 141.3, 128.6 (2C), 128.5 (2C), 126.1, 112.4, 106.0, 86.1, 85.5, 81.3, 58.3, 42.0, 28.7, 27.0, 26.4 ppm. IR (neat, cm^{-1}): 2988, 2936, 1715, 1375, 1212, 1049, 1079, 1016, 962. HRMS (ES+) *calcd for* $C_{17}H_{22}O_5Na$ $[M+Na]^+$ 329.1365, *found* 329.1365.

2d



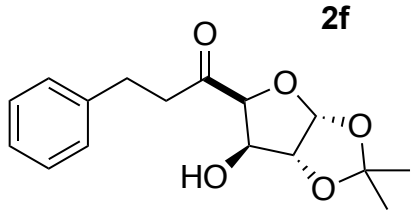
3-Phenyl-1-((3*S*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)propan-1-one (2d): Following General Procedure III using **1d-DHP** (171.6 mg, 0.375 mmol, 1.5 equiv), hydrocinnamic acid (37.6 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (7.0 mg, 0.015 mmol, 6 mol %), DMDC (53 μL, 0.5 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 2.5 mL, 1.0 M). The crude product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 20%) to afford a colorless oil (70.5 mg, 83% yield). dr = 1.9:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33 – 7.24 (m, 2H), 7.24 – 7.14 (m, 3H), 4.84 (d, *J* = 3.5 Hz, 1H), 4.01 (d, *J* = 9.9 Hz, 1H), 3.61 (s, 3H), 3.57 – 3.52 (m, 1H), 3.51 (s, 3H), 3.41 (s, 3H), 3.40 (s, 3H), 3.27 – 3.17 (m, 2H), 3.03 – 2.84 (m, 4H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 205.9, 141.0, 128.6 (2C), 128.5 (2C), 126.2, 98.1, 83.5, 81.4, 80.8, 73.6, 61.1, 60.5, 59.3, 55.7, 42.8, 29.2 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2931, 2834, 1727, 1453, 1361, 1187, 1094, 1064, 1046. HRMS (ES+) *calcd for* $C_{18}H_{26}O_6Na$ $[M+Na]^+$ 361.1627, *found* 361.1626.



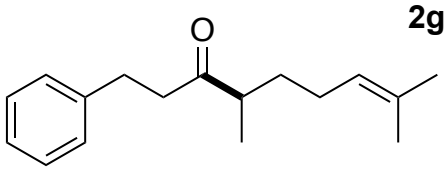
2e

1-((3a*R*,6*R*,6a*R*)-6-((*tert*-Butyldimethylsilyl)oxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (2e): Following General Procedure III using **1e-DHP** used as crude (197.1 mg, 0.375 mmol, 1.5 equiv), hydrocinnamic acid (37.6 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (7.0 mg, 0.015 mmol, 6 mol %), DMDC (53 μL, 0.5 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 2.5 mL, 1.0 M). The crude product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 3%) to afford a colorless oil (89.8 mg, 88% yield). dr = 3.8:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 – 7.24 (m, 2H), 7.21 – 7.15 (m, 3H), 6.00 (d, *J* = 3.7 Hz, 1H), 4.72 (s, 1H), 4.40 (d, *J* = 3.7 Hz, 1H), 4.23 (s, 1H), 3.29 – 3.10 (m, 1H), 2.99 – 2.78 (m, 3H), 1.31 (s, 3H), 1.26 (s, 3H), 0.89 (s, 9H), 0.13 (s, 3H), 0.11 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.5, 141.1, 128.6 (2C), 128.5 (2C), 126.2, 111.9, 106.5, 92.7, 86.3, 77.6, 40.8, 29.2, 25.9, 25.8 (3C), 25.7, 18.1, -4.8, -4.7 ppm. (*Only the*

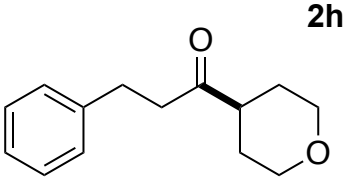
signals corresponding to the major stereoisomer are reported). IR (neat, cm^{-1}): 2980, 2976, 1703, 1403, 1402, 1187, 1163, 1076, 1003. HRMS (ES+) *calcd for* ($C_{22}H_{34}O_5SiNa$, $[M+Na]^+$) 429.2073, *found* 429.2086.



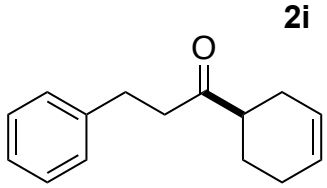
1-((3a*R*,6*R*,6a*R*)-6-Hydroxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (2f): Following General Procedure III using **1f-DHP** (197.1 mg, 0.375 mmol, 1.5 equiv), hydrocinnamic acid (37.6 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (7.0 mg, 0.015 mmol, 6 mol %), DMDC (53 µL, 0.5 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 2.5 mL, 1.0 M). After 24 h, a solution of TBAF (1.25 mL, 1.0 M in THF, 6.0 equiv) was added dropwise at 0 °C. The reaction was allowed to stir for 2 hours at rt, then quenched by addition of saturated aq soln of $NaHCO_3$. The aq layer was extracted with EtOAc, the combined organic layers were dried ($MgSO_4$) and concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 40%) to afford a crystalline solid (58.1 mg, 79% yield). mp = 124-126 °C. dr = 3.6:1 based on ^1H NMR of the crude reaction mixture. ^1H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.30 – 7.25 (m, 2H), 7.21 – 7.16 (m, 3H), 6.00 (d, J = 3.8 Hz, 1H), 4.72 (d, J = 3.2 Hz, 1H), 4.53 (d, J = 3.8 Hz, 1H), 4.33 (s, 1H), 3.24 – 3.14 (m, 1H), 3.03 – 2.81 (m, 4H), 1.33 (s, 3H), 1.27 (s, 3H) ppm. ^1H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.29 – 7.24 (m, 2H), 7.22 – 7.16 (m, 3H), 5.96 (d, J = 3.6 Hz, 1H), 4.51 (d, J = 3.6 Hz, 1H), 4.28 (s, 1H), 4.10 (dd, J = 10.2, 2.7 Hz, 1H), 3.88 (dd, J = 10.2, 0.9 Hz, 1H), 3.24 – 3.14 (m, 1H), 3.03 – 2.81 (m, 2H), 1.90 (s, 1H), 1.49 (s, 3H), 1.32 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 208.7, 140.9, 128.6 (2C), 128.5 (2C), 126.2, 112.3, 106.3, 91.7, 85.8, 76.7, 40.8, 29.2, 25.9, 25.7 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 208.5, 141.0, 128.6 (2C), 128.5 (2C), 126.3, 111.9, 105.3, 85.1, 75.5, 73.0, 40.8, 29.2, 25.9, 25.8 ppm. IR (neat, cm^{-1}): 3417, 2979, 1724, 1374, 1219, 1061, 1009, 974. HRMS (ES+) *calcd for* $C_{16}H_{20}O_5Na$ $[M+Na]^+$ 315.1208, *found* 315.1218.



4,8-Dimethyl-1-phenylnon-7-en-3-one (2g): Following General Procedure III using **1g-DHP** (163.5 mg, 0.375 mmol, 1.5 equiv), hydrocinnamic acid (37.6 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (7.0 mg, 0.015 mmol, 6 mol %), DMDC (53 μL, 0.5 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 2.5 mL, 1.0 M). The crude product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (51.3 mg, 70% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.26 (m, 2H), 7.23 – 7.13 (m, 3H), 5.04 (ddt, *J* = 8.6, 5.7, 1.5 Hz, 1H), 2.89 (t, *J* = 7.6 Hz, 2H), 2.78 – 2.71 (m, 2H), 2.50 (q, *J* = 6.9 Hz, 1H), 1.96 – 1.87 (m, 2H), 1.74 – 1.63 (m, 4H), 1.57 (d, *J* = 1.3 Hz, 3H), 1.33 (ddt, *J* = 13.5, 8.3, 6.8 Hz, 1H), 1.04 (d, *J* = 6.9 Hz, 3H) ppm.^{13}C NMR (126 MHz, $CDCl_3$) δ 213.9, 141.7, 132.5, 128.7, 128.6, 126.3, 124.0, 77.6, 77.3, 77.0, 46.2, 43.0, 33.2, 30.0, 26.0, 25.9, 18.0, 16.5. IR (neat, cm^{-1}): 2967, 2928, 1711, 1453, 1377, 905, 729, 700, 650. HRMS (EI) *calcd for* $C_{17}H_{24}O$ $[M]^+$ 244.1827, *found* 244.1843.

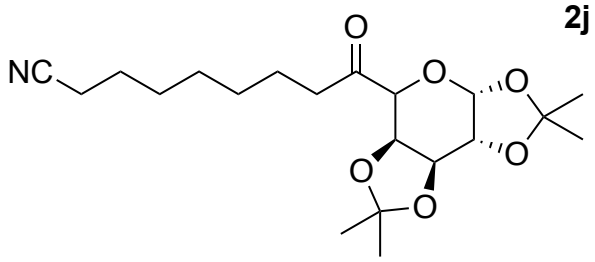


3-Phenyl-1-(tetrahydro-2*H*-pyran-4-yl)propan-1-one (2h): Following General Procedure III using **1h-DHP** (151.8 mg, 0.375 mmol, 1.5 equiv), hydrocinnamic acid (37.6 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (7.0 mg, 0.015 mmol, 6 mol %), DMDC (53 μL, 0.5 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 2.5 mL, 1.0 M). The crude was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (52.4 mg, 80% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.26 (m, 2H), 7.22 – 7.12 (m, 3H), 3.97 (ddd, *J* = 11.4, 4.1, 2.6 Hz, 2H), 3.39 (td, *J* = 11.3, 2.9 Hz, 2H), 2.90 (t, *J* = 7.5 Hz, 2H), 2.77 (dd, *J* = 8.0, 6.9 Hz, 2H), 2.50 (tt, *J* = 10.9, 4.4 Hz, 1H), 1.76 – 1.63 (m, 4H).^{13}C NMR (126 MHz, $CDCl_3$) δ 211.2, 141.4, 128.8, 128.6, 126.4, 77.6, 77.5, 77.3, 77.1, 67.5, 48.0, 42.2, 30.0, 28.3. IR (neat, cm^{-1}): 2931, 2834, 1727, 1453, 1361, 1187, 1094, 1064, 1046. HRMS (EI) *calcd for* $C_{14}H_{18}O_2$ $[M]^+$ 218.1307, *found* 218.1315.



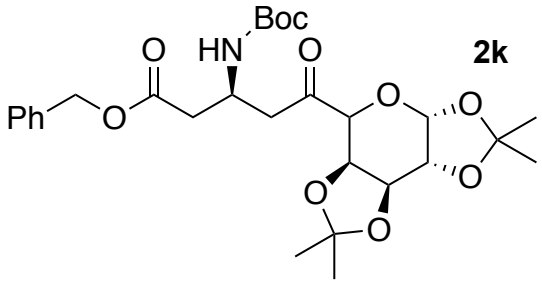
(R)-1-(Cyclohex-3-en-1-yl)-3-phenylpropan-1-one (2i): Following General Procedure III using **1i-DHP** (249.9 mg, 0.75 mmol, 1.5 equiv), hydrocinnamic acid (75.1.1 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 µL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 10%) to afford a colorless oil (98.5 mg, 92% yield). ^{1}H NMR (500 MHz, CDCl3) δ 7.30 – 7.26 (m, 2H), 7.19 (m, 3H), 5.68 (m, 2H), 2.91 (t, J = 7.5 Hz, 2H), 2.85 – 2.76 (m, 2H), 2.58 (dddd, J = 12.0, 9.3, 5.9, 2.9 Hz, 1H), 2.15 (dd, J = 14.4, 4.6 Hz, 2H), 2.08 (qt, J = 9.7, 3.7 Hz, 2H), 1.91 (dq, J = 12.6, 4.1 Hz, 1H), 1.59 – 1.52 (m, 1H). ^{13}C NMR (126 MHz, CDCl3) δ 212.7, 141.5, 128.6, 128.5, 126.8, 126.2, 125.5, 46.9, 42.5, 29.9, 26.9, 24.9, 24.7. IR (neat, cm^{-1}): 3026, 2924, 2839, 1707, 1604, 1496, 1453, 1374, 1104. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5Na$ $[M+Na]^+$ 405.1678, *found*.

5.2. Carboxylic acids scope



9-oxo-9-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonanenitrile (**2j**): Following General Procedure III using **1j-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), hydrocinnamic acid (55.0 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %),

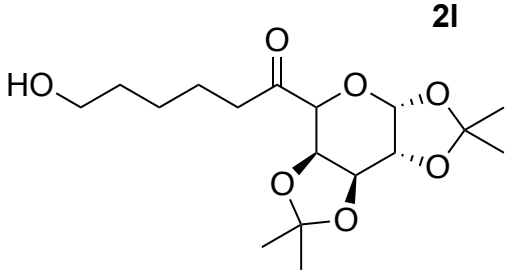
$Ni(dtbbpy)(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (109.0 mg, 92% yield). dr = 3.8:1 based on ^{1}H NMR of the crude reaction mixture. e. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.63 (d, *J* = 4.9 Hz, 1H), 4.68 – 4.59 (m, 1H), 4.55 (dd, *J* = 7.7, 1.9 Hz, 1H), 4.34 (dd, *J* = 4.8, 2.3 Hz, 1H), 4.16 (d, *J* = 1.7 Hz, 1H), 2.76 – 2.46 (m, 2H), 2.31 (t, *J* = 7.1 Hz, 2H), 1.69 – 1.20 (m, 22 H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.5, 119.9, 109.6, 109.0, 96.6, 73.8, 72.6, 70.7, 70.5, 39.9, 29.2, 29.0, 28.7, 28.7, 26.1, 26.0, 25.5, 24.9, 24.4, 22.5, 17.2 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2988, 2933, 2857, 1718, 1382, 1372, 1255, 1211, 1166, 1065. HRMS (ES+) *calcd for* $C_{20}H_{31}NO_6Na$ $[M+Na]^+$ 418.2206, *found*.



Benzyl (3*S*)-3-((*tert*-Butoxycarbonyl)amino)-5-oxo-5-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)pentanoate (2k): Following General Procedure III using **1k-DHP** (101.2 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (39.6 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), $Ni(dtbbpy)(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 20%) to afford a pale-yellow oil (123.6 mg, 75% yield). dr = 2:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.20 (m, 5H), 5.52 (d, *J* = 4.7 Hz, 1H), 5.22 (s, 1H), 5.02 (s, 2H), 4.53 (dd, *J* = 7.8, 2.6 Hz, 1H), 4.44 (dd, *J* = 7.8, 2.3 Hz, 1H), 4.35 – 4.26 (m, 1H), 4.25 (dd, *J* = 5.0, 2.5 Hz, 1H), 4.09 (d, *J* = 2.3 Hz, 1H), 2.93 (dd, *J* = 18.0, 5.9 Hz, 1H), 2.83 (dd, *J* = 18.1, 5.6 Hz, 1H), 2.70 (dd, *J* = 16.4, 5.7 Hz, 1H), 2.57 (dd, *J* = 16.4, 6.5 Hz, 1H), 1.42 (s, 3H), 1.33 (s, 12H), 1.25 (s, 3H), 1.20 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.0, 171.5, 155.3, 136.1, 128.8, 128.5, 128.4, 110.0, 109.3, 96.6, 73.9, 72.8, 70.9, 70.6, 66.6, 44.0, 43.8, 38.6, 28.6, 26.2, 26.0, 25.1, 24.4 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}):

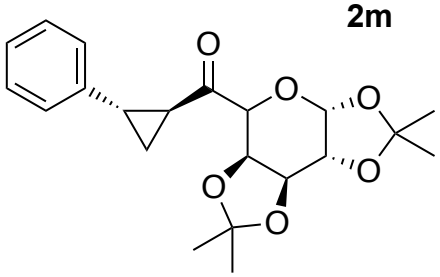
3425, 2981, 2936, 1715, 1498, 1456, 1383, 1369, 1306, 1254, 1211, 1165, 1108, 1067, 1006. HRMS (ES+) *calcd for* $C_{28}H_{40}NO_{10}$ $[M+H]^+$ 550.2652, *found* 550.2651.

2l



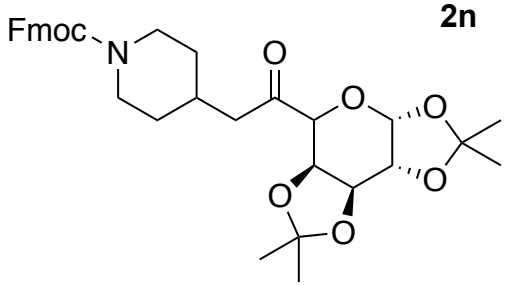
6-Hydroxy-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)hexan-1-one (xx): Following General Procedure III using **2l-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (39.6 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 20%) to afford a colorless oil (91.9 mg, 89% yield). dr = 2.9:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) ^{1}H NMR (500 MHz, Chloroform-*d*) δ 5.63 (d, *J* = 5.0 Hz, 1H), 4.62 (dd, *J* = 7.8, 2.4 Hz, 1H), 4.56 (dd, *J* = 7.8, 2.2 Hz, 1H), 4.34 (dd, *J* = 5.0, 2.4 Hz, 1H), 4.17 (d, *J* = 2.1 Hz, 1H), 3.64 (t, *J* = 6.6 Hz, 2H), 2.70 (ddd, *J* = 18.4, 8.1, 6.4 Hz, 1H), 2.56 (ddd, *J* = 18.4, 8.1, 6.4 Hz, 1H), 1.66 – 1.54 (m, 6H), 1.49 (s, 3H), 1.43 (s, 3H), 1.33 (s, 3H), 1.30 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.7, 109.8, 109.2, 96.7, 77.6, 77.3, 77.1, 74.0, 72.8, 70.9, 70.7, 63.0, 40.0, 32.8, 26.2, 26.1, 25.4, 25.1, 24.5, 22.4 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 3426, 2988, 2936, 1717, 1383, 1373, 1255, 1211, 1166, 1140, 1109, 1064, 1005. HRMS (ES+) *calcd for* $C_{17}H_{28}O_7Na$ $[M+Na]^+$ 367.1733, *found* 367.1737.

2m



((1*S*,2*S*)-2-Phenylcyclopropyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)methanone (2m): Following General Procedure III using **1m-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (48.7 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 μL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (78.6 mg, 70% yield). dr = 1:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.26 (m, 2H), 7.23 – 7.16 (m, 1H), 7.16 – 7.11 (m, 2H), 5.67 (d, *J* = 5.0 Hz, 1H), 4.65 (dd, *J* = 7.8, 2.6 Hz, 1H), 4.59 (dd, *J* = 7.8, 2.3 Hz, 1H), 4.38 (dd, *J* = 5.0, 2.6 Hz, 1H), 4.33 (d, *J* = 2.3 Hz, 1H), 2.73 (ddd, *J* = 8.3, 5.3, 4.1 Hz, 1H), 2.62 (ddd, *J* = 8.9, 6.7, 4.1 Hz, 1H), 1.73 (ddd, *J* = 9.2, 5.3, 4.0 Hz, 1H), 1.50 (s, 3H), 1.48 (s, 3H), 1.44 – 1.40 (m, 1H), 1.33 (d, *J* = 1.8 Hz, 6H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.6, 140.6, 128.6, 126.7, 126.7, 110.0, 109.2, 96.8, 77.6, 77.3, 77.1, 74.3, 72.5, 71.0, 70.6, 30.1, 29.2, 26.2, 26.2, 25.1, 24.7, 20.0 ppm.
(IR (neat, cm^{-1}): 2988, 2935, 1698, 1382, 1341, 1255, 1212, 1166, 1103, 1068, 1005. HRMS (EI) *calcd for* $C_{21}H_{26}O_6$ $[M]^+$ 374.1726, *found* 374.1733.

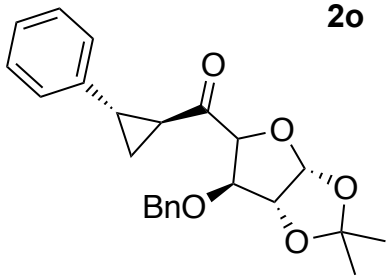
2n



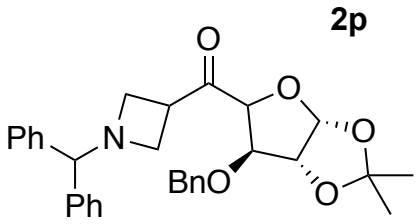
(9*H*-Fluoren-9-yl)methyl 4-(2-oxo-2-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethyl)piperidine-1-carboxylate (2n): Following General Procedure III using **1n-DHP** (101.2 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (109.5 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 μL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 20%) to afford a pale-yellow oil (138.5 mg, 80% yield). dr = 22:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (d, *J* = 7.5 Hz, 2H), 7.58 (d, *J* = 7.5 Hz, 2H), 7.40 (t, *J* = 7.4 Hz, 2H), 7.31 (t, *J* = 7.4 Hz, 2H), 5.65 (d, *J* = 5.0 Hz, 1H), 4.63 (dd, *J* = 7.9, 2.5 Hz, 1H), 4.57 (dd, *J* = 7.8, 2.2 Hz, 1H), 4.47 – 4.28 (m, 4H), 4.25 (d, *J* = 6.9 Hz, 1H), 4.16 (d, *J* = 2.2 Hz, 2H), 4.06 (d, *J* = 5.8 Hz, 1H), 2.83 (s, 2H), 2.57 (dd, *J* = 6.7, 3.6 Hz, 2H), 2.14 – 2.04 (m, 1H), 1.71 (t, *J* = 12.8 Hz,

2H), 1.51 (s, 3H), 1.44 (s, 3H), 1.34 (s, 3H), 1.31 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.6, 155.5, 144.4, 141.6, 127.9, 127.3, 125.3, 120.2, 109.8, 109.2, 96.6, 77.6, 77.3, 77.1, 74.0, 72.8, 70.8, 70.6, 67.4, 47.7, 46.4, 44.3, 30.7, 26.2, 26.1, 25.1, 24.5.

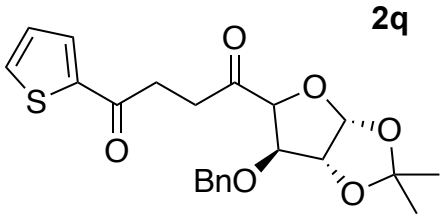
ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2988, 2934, 1698, 1450, 1382, 1254, 1237, 1211, 1066, 1006. HRMS (ES+) *calcd for* $C_{33}H_{39}NO_8$ $[M+H]^+$578.2754, *found* 578.2764.



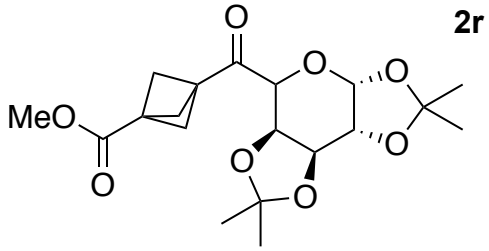
((3a*R*,6*R*,6a*R*)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)((1S,2S)-2-phenylcyclopropyl)methanone (2o): Following General Procedure III using **1o-DHP** (225.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (48.7 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (95.9 mg, 81% yield). dr = 2.5:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.44 – 7.05 (m, 10H), 6.03 (d, *J* = 3.6 Hz, 1H), 4.67 – 4.47 (m, 4H), 4.03 (d, *J* = 8.4 Hz, 1H), 2.86 – 2.79 (m, 1H), 2.67 (t, *J* = 9.7 Hz, 1H), 1.58 (dd, *J* = 9.2, 4.3 Hz, 1H), 1.41 (td, *J* = 8.2, 4.0 Hz, 1H), 1.22 (s, 3H), 1.14 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.44 – 7.05 (m, 10H), 5.97 (d, *J* = 3.5 Hz, 1H), 4.67 – 4.47 (m, 4H), 4.03 (d, *J* = 8.4 Hz, 1H), 2.86 – 2.79 (m, 1H), 2.67 (t, *J* = 9.7 Hz, 1H), 1.58 (dd, *J* = 9.2, 4.3 Hz, 1H), 1.47 (s, 3H), 1.41 (td, *J* = 8.2, 4.0 Hz, 1H), 1.31 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 207.0, 140.1, 137.1, 128.7 (2C), 128.5 (2C), 128.1 (2C), 127.8, 126.6, 126.4 (2C), 112.6, 106.6, 89.8, 84.0, 83.8, 72.0, 29.1, 28.1, 26.0, 25.9, 22.1 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 207.0, 140.0, 137.5, 128.7 (2C), 128.2 (2C), 128.1 (2C), 127.8, 126.6, 126.4 (2C), 111.7, 105.7, 83.1, 82.0, 71.4, 70.5, 29.8, 26.9, 26.4, 25.9, 22.1 ppm. IR (neat, cm^{-1}): 2927, 1694, 1398, 1374, 1212, 1075, 1013. HRMS (EI) *calcd for* ($C_{24}H_{26}O_5$, $[M]^+$) 394.1780, *found* 394.1767.



(1-Benzhydrylazetidin-3-yl)((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)methanone (2o): Following General Procedure III using **1o-DHP** (225.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (80.2 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 μL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a white foam (132.0 mg, 88% yield). dr = 3.9:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.45 – 7.10 (m, 15H), 5.94 (d, *J* = 3.8 Hz, 1H), 4.61 – 4.56 (m, 3H), 4.52 (s, 1H), 4.42 (s, 1H), 4.33 (s, 1H), 4.04 – 3.96 (m, 1H), 3.55 (t, *J* = 7.9 Hz, 1H), 3.37 (t, *J* = 7.5 Hz, 1H), 3.27 (t, *J* = 7.4 Hz, 1H), 3.03 (t, *J* = 7.4 Hz, 1H), 1.29 (s, 3H), 1.24 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.36 – 7.27 (m, 7H), 7.26 – 7.14 (m, 8H), 5.97 (d, *J* = 3.6 Hz, 1H), 4.69 (d, *J* = 3.7 Hz, 1H), 4.57 – 4.53 (m, 2H), 4.43 (d, *J* = 11.4 Hz, 1H), 4.27 (d, *J* = 3.7 Hz, 1H), 4.20 (s, 1H), 3.73 (t, *J* = 8.2 Hz, 1H), 3.39 (t, *J* = 7.9 Hz, 1H), 3.30 (t, *J* = 7.8 Hz, 1H), 3.22 (t, *J* = 7.8 Hz, 1H), 3.16 (t, *J* = 7.9 Hz, 1H), 1.44 (s, 3H), 1.30 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 207.9, 141.9, 141.8, 137.0, 128.7 (2C), 128.6 (2C), 128.2 (2C), 128.0 (2C), 127.8, 127.6 (2C), 127.5 (2C), 127.3 (2C), 112.2, 106.4, 88.4, 83.8, 83.7, 77.8, 72.0, 56.8, 54.1, 37.0, 26.0, 25.8 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 207.4, 142.0, 142.0, 136.9, 128.6 (2C), 128.5 (2C), 128.5 (2C), 128.3, 128.0 (2C), 127.7 (2C), 127.6 (2C), 127.2, 127.2, 112.5, 106.1, 85.6, 84.1, 81.9, 77.8, 72.9, 55.2, 54.8, 38.8, 27.1, 26.4 ppm. IR (neat, cm^{-1}): 2939, 2848, 1712, 1453, 1374, 1211, 1163, 1074, 1011. HRMS (ES+) *calcd for* ($C_{31}H_{34}NO_5$, $[M+H]^+$) 500.2437, *found* 500.2456.

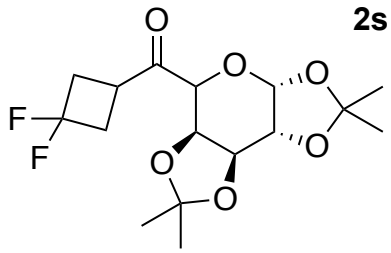


1-((3a*R*,6*R*,6a*R*)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-4-(thiophen-2-yl)butane-1,4-dione (2q): Following General Procedure III using **1q-DHP** (225.7 mg, 0.45 mmol, 1.5 equiv), the correspounding carboxylic acid (55.2 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 μL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 10%) to afford a colorless oil (108.5 mg, 86% yield). dr = 2.2:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$, major diastereomer) δ 7.76 (dd, *J* = 3.8, 1.1 Hz, 1H), 7.62 (dd, *J* = 4.9, 1.0 Hz, 1H), 7.37 – 7.25 (m, 5H), 7.13 (dd, *J* = 4.9, 3.8 Hz, 1H), 6.03 (d, *J* = 3.9 Hz, 1H), 4.65 – 4.63 (m, 2H), 4.62 (d, *J* = 3.2 Hz, 2H), 4.51 (d, *J* = 1.2 Hz, 1H), 3.36 – 3.28 (m, 1H), 3.19 – 3.00 (m, 3H), 1.41 (s, 3H), 1.29 (s, 3H) ppm. ^{1}H NMR (500 MHz, $CDCl_3$, minor diastereomer) δ 7.69 (dd, *J* = 3.8, 1.0 Hz, 1H), 7.61 (d, *J* = 1.0 Hz, 1H), 7.37 – 7.25 (m, 5H), 7.10 (dd, *J* = 5.0, 3.8 Hz, 1H), 6.09 (d, *J* = 3.6 Hz, 1H), 4.74 (d, *J* = 3.7 Hz, 1H), 4.63 – 4.57 (m, 3H), 4.30 (d, *J* = 3.7 Hz, 1H), 3.37 – 3.25 (m, 1H), 3.18 – 3.00 (m, 3H), 1.48 (s, 3H), 1.33 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$, major diastereomer) δ 207.7, 191.3, 143.8, 137.2, 133.6, 132.0, 128.7 (2C), 128.2, 128.1, 128.0 (2C), 112.3, 106.5, 89.6, 84.1, 83.8, 72.1, 33.3, 32.8, 26.1, 25.9 ppm. ^{13}C NMR (126 MHz, $CDCl_3$, minor diastereomer) δ 207.1, 191.4, 144.0, 137.1, 133.5, 132.0, 128.6, 128.2, 128.1, 127.9, 112.5, 106.1, 85.6, 83.8, 82.0, 72.6, 34.9, 32.5, 27.1, 26.5 ppm. IR (neat, cm^{-1}): 2987, 1717, 1662, 1415, 1374, 1236, 1212, 1075, 1012. HRMS (ES+) *calcd for* $C_{22}H_{24}O_{56}SNa$ $[M+Na]^+$ 439.1191, *found* 439.1193.



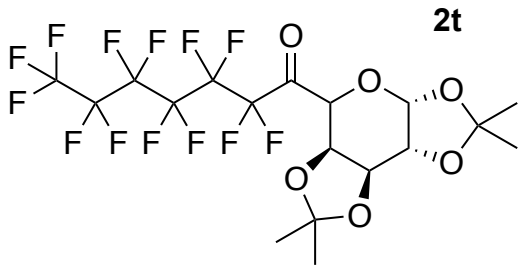
Methyl 3-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-Tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-carbonyl)bicyclo[1.1.1]pentane-1-carboxylate (2r): Following General Procedure III using **1r-DHP** (104.1 mg, 0.216 mmol, 1.5 equiv), carboxylic acid (24.5 mg, 0.144 mmol, 1.0

equiv), 4CzIPN (2.2 mg, 0.003 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (4.0 mg, 0.009 mmol, 6 mol %), DMDC (30 µL, 0.3 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 1.5 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 10%) to afford a crystalline white solid (42.5 mg, 76% yield). dr = 4.6:1 based on ^{1}H NMR of the crude reaction mixture. mp = 58-60 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.61 (d, *J* = 5.0 Hz, 1H), 4.60 (dd, *J* = 7.8, 1.9 Hz, 1H), 4.51 (dd, *J* = 7.8, 1.5 Hz, 1H), 4.32 (s, 2H), 3.66 (s, 3H), 2.37 (s, 6H), 1.48 (s, 3H), 1.42 (s, 3H), 1.32 (s, 3H), 1.28 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 204.3, 170.3, 109.7, 108.9, 96.4, 74.6, 72.3, 70.6, 70.3, 53.7 (2C), 53.5, 51.9, 43.6, 38.3, 26.1, 25.9, 24.9, 24.1 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2989, 2928, 1732, 1704, 1256, 1205, 1165, 1109, 1064, 999. HRMS (ES+) *calcd for* ($C_{19}H_{26}O_6Na$, $[M+Na]^+$) 405.1549, *found* 405.1535.

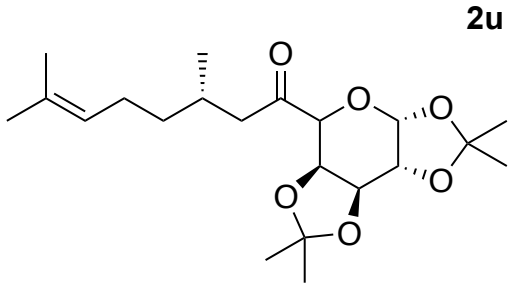


(3,3-Difluorocyclobutyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-yl)methanone (2s): Following General Procedure III using **1s-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), hydrocinnamic acid (40.8 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (88.7 mg, 85% yield). dr = 7.5:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.60 (d, *J* = 4.9 Hz, 1H), 4.62 (dd, *J* = 7.8, 2.1 Hz, 1H), 4.57 (dd, *J* = 7.8, 1.7 Hz, 1H), 4.33 (dd, *J* = 4.8, 2.2 Hz, 1H), 4.27 (d, *J* = 1.5 Hz, 1H), 3.68 – 3.52 (m, 1H), 2.91 – 2.77 (m, 2H), 2.72 – 2.59 (m, 2H), 1.48 (s, 3H), 1.41 (s, 3H), 1.33 (s, 3H), 1.30 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 207.6, 119.1 (dd, $^1J_{C\text{-}F}$ = 285.1, 269.6 Hz), 109.7, 109.1, 96.6, 73.6, 72.2, 70.6, 70.5, 37.74 (t, $^2J_{C\text{-}F}$ = 24.3 Hz), 36.91 (t, $^2J_{C\text{-}F}$ = 24.3 Hz), 30.76 (dd, $^3J_{C\text{-}F}$ = 14.2, 5.0 Hz), 26.1, 25.9, 24.9, 24.1 ppm. ^{19}F NMR (471 MHz, $CDCl_3$) δ -82.9 (d, $^1J_{F\text{-}F}$ = 191.9 Hz), -97.0 (d, $^1J_{F\text{-}F}$ = 192.0 Hz) ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2987, 2939, 1718, 1294,

1210, 1162, 1063, 1006, 897. HRMS (ES+) *calcd for* $C_{16}H_{22}F_2O_6Na$ $[M+Na]^+$) 371.1282, *found* 371.1284.

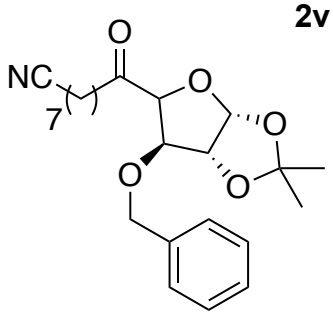


4,4,5,5,6,6,7,7,8,8,9,9,9-Tridecafluoro-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonan-1-one (2t): Following General Procedure III using **1t-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (117.6 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), $Ni(dtbbpy)(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (114.3 mg, 63% yield). dr = 1.8:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.65 (d, *J* = 4.9 Hz, 1H), 4.64 (dd, *J* = 7.8, 2.5 Hz, 1H), 4.53 (dd, *J* = 7.8, 2.2 Hz, 1H), 4.37 (dd, *J* = 5.0, 2.5 Hz, 1H), 4.24 (d, *J* = 2.2 Hz, 1H), 3.01 (ddd, *J* = 19.2, 9.9, 5.7 Hz, 1H), 2.90 (ddd, *J* = 19.3, 10.1, 5.5 Hz, 1H), 2.54 – 2.24 (m, 2H), 1.50 (s, 3H), 1.44 (s, 3H), 1.34 (s, 3H), 1.30 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$ δ 206.9, 110.0, 109.4, 96.6, 77.6, 77.3, 77.1, 74.0, 72.8, 70.9, 70.6, 26.2, 26.0, 25.1, 24.4 ppm. ^{19}F NMR (471 MHz, $CDCl_3$) δ -80.79 (t, *J* = 10.0 Hz), -114.09 – -114.31 (m), -121.87 (t, *J* = 14.0 Hz), -122.72 – -122.95 (m), -123.45 (t, *J* = 15.1 Hz), -126.10 (td, *J* = 14.9, 6.4 Hz). (*Only the signals corresponding to the minor stereoisomer are reported*). IR (neat, cm^{-1}): 2986, 2935, 1724, 1381, 1372, 1250, 1210, 1166, 1145, 1114, 1077, 1052. HRMS (ES+) *calcd for* $C_{20}H_{22}F_{13}O_6$ $[M+H]^+$ 605.1209, *found* 605.1219.



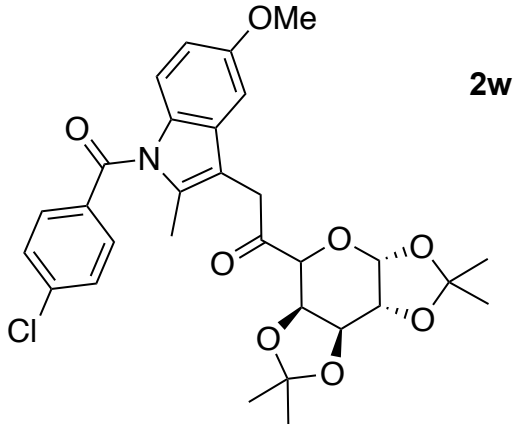
(3*S*)-3,7-Dimethyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)oct-6-en-1-one (2u): Following General Procedure III using **1u-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (51.0 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 μL, 0.6 mmol, 2.0 equiv) in acetone/*i*PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (81.5 mg, 71% yield). dr = 3.8:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.64 (d, *J* = 5.0 Hz, 1H), 5.09 (tdt, *J* = 5.7, 2.8, 1.4 Hz, 1H), 4.62 (dd, *J* = 7.8, 2.4 Hz, 1H), 4.58 (dd, *J* = 7.8, 2.1 Hz, 1H), 4.34 (dd, *J* = 5.0, 2.4 Hz, 1H), 4.14 (d, *J* = 2.1 Hz, 1H), 2.64 (dd, *J* = 17.8, 5.1 Hz, 1H), 2.41 (dd, *J* = 17.7, 8.2 Hz, 1H), 2.11 – 2.04 (m, 1H), 1.97 (m, *J* = 6.7 Hz, 2H), 1.67 (d, *J* = 1.4 Hz, 3H), 1.59 (d, *J* = 1.3 Hz, 3H), 1.56 (s, 3H), 1.50 (s, 4H), 1.43 (s, 3H), 1.34 (s, 3H), 1.30 (s, 3H), 1.19 (dddd, *J* = 13.6, 9.2, 7.7, 6.3 Hz, 2H), 0.89 (d, *J* = 6.6 Hz, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.3, 131.5, 124.9, 109.8, 109.1, 96.8, 74.0, 72.8, 70.9, 70.7, 47.3, 37.4, 27.9, 26.2, 26.2, 26.0, 25.8, 25.1, 24.6, 20.1, 17.9 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2982, 2928, 1719, 1382, 1255, 1212, 1067, 1006. HRMS (EI) *calcd for* $C_{21}H_{34}O_6$ $[M]^+$ 382.2355, *found* 382.2360.

2v



10-((3aR,5S,6R,6aR)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-10-oxodecanenitrile (2v): Following General Procedure III using **1v-DHP** (188.0 mg, 0.375 mmol, 1.5 equiv), 9-cyanopelargonic acid (45.8 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (6.8 mg, 0.015 mmol, 6 mol %), DMDC (80 μL, 0.3 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 2.5 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 5%) to afford a colorless oil (83.2 mg, 83% yield). dr > 20:1 based on ^{1}H NMR of the crude

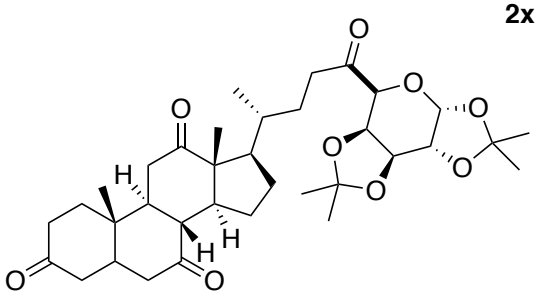
reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 (q, J = 7.8, 7.2 Hz, 5H), 6.02 (dd, J = 13.2, 4.0 Hz, 1H), 4.65 – 4.60 (m, 3H), 4.47 (s, 2H), 2.83 – 2.72 (m, 1H), 2.70 – 2.60 (m, 1H), 2.33 (t, J = 7.3 Hz, 2H), 1.64 (q, J = 7.6 Hz, 2H), 1.58 – 1.42 (m, 4H), 1.37 (s, 3H), 1.29 (dq, J = 13.1, 7.0, 4.4 Hz, 7H). 13C NMR (126 MHz, CDCl3) δ 209.4, 137.1, 128.7, 128.2, 128.0, 127.8, 119.9, 112.2, 106.5, 89.7, 86.9, 83.8, 72.0, 39.1, 29.2, 29.1, 28.7, 28.7, 26.0, 25.8, 25.5, 23.1, 17.2.. IR (neat, cm^{-1}): 2933, 2858, 1715, 1456, 1375, 1213, 1164. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5Na$ $[M+Na]^+$ 405.1678, *found* .



2w

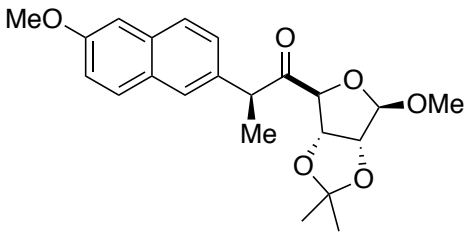
2-(1-(4-Chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethan-1-one (2w):
Following General Procedure III using **1w-DHP** (101.2 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (107.3 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), $Ni(dtbbpy)(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 20%) to afford a yellow oil (82.6 mg, 51% yield). dr = 1.49:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$δ 7.65 (d, *J* = 8.5 Hz, 2H), 7.46 (d, *J* = 8.5 Hz, 2H), 6.94 (d, *J* = 2.5 Hz, 1H), 6.90 (d, *J* = 9.0 Hz, 1H), 6.67 (dd, *J* = 9.0, 2.5 Hz, 1H), 5.30 (d, *J* = 3.0 Hz, 1H), 4.58 (dd, *J* = 5.8, 1.3 Hz, 1H), 4.47 (dd, *J* = 8.2, 5.7 Hz, 1H), 4.25 (dd, *J* = 3.0, 1.3 Hz, 1H), 4.11 (d, *J* = 16.3 Hz, 1H), 3.83 (s, 2H), 2.34 (s, 3H), 1.51 (s, 3H), 1.39 (s, 3H), 1.35 (d, *J* = 4.4 Hz, 6H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 203.2, 168.5, 156.4, 139.6, 136.6, 134.2, 131.5, 131.1, 130.9, 129.4, 115.3, 112.4, 112.3, 111.2, 109.6, 101.3, 97.4, 76.1, 75.1, 74.0, 69.5, 55.9, 35.9, 27.9, 27.6, 25.9, 25.7, 13.8 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2989, 2936, 1728, 1682, 1479, 1371, 1322, 1257, 1214, 1088, 1067, 1006. HRMS (ES+) *calcd for* $C_{30}H_{32}ClNO_8$ $[M+H]^+$ 570.1895, *found* 570.1870.

2x



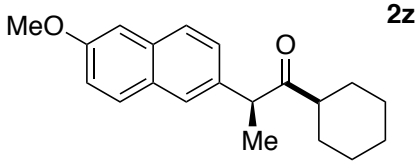
(8*R*,9*S*,10*S*,13*R*,14*S*,17*R*)-10,13-Dimethyl-17-((2*R*)-5-oxo-5-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)pentan-2-yl)dodecahydro-3*H*-cyclopenta[*a*]phenanthrene-3,7,12(2*H*,4*H*)-trione (2x): Following General Procedure III using **1x-DHP** (216.7 mg, 0.45 mmol, 1.5 equiv), carboxylic acid (120.7 mg, 0.3 mmol, 1.0 equiv), 4CzIPN (4.7 mg, 0.006 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (8.4 mg, 0.018 mmol, 6 mol %), DMDC (64 µL, 0.6 mmol, 2.0 equiv) in acetone/*i*-PrOAc (2/1, 3.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 50%) to afford a white solid (138.2 mg, 65% yield). Mp = 178-207 ºC. dr = 4.1:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) ^{1}H NMR (500 MHz, Chloroform-*d*) δ 5.71 – 5.29 (m, 1H), 4.69 – 4.56 (m, 2H), 4.41 – 4.24 (m, 1H), 4.22 – 4.10 (m, 1H), 2.99 – 2.82 (m, 3H), 2.80 – 2.68 (m, 1H), 2.58 (ddd, *J* = 18.1, 8.5, 6.3 Hz, 1H), 2.31 (dddd, *J* = 42.2, 20.7, 14.2, 5.1 Hz, 6H), 2.21 – 2.11 (m, 2H), 2.11 – 1.95 (m, 4H), 1.94 – 1.80 (m, 2H), 1.64 (td, *J* = 13.7, 13.2, 4.2 Hz, 1H), 1.54 (d, *J* = 3.1 Hz, 4H), 1.49 – 1.21 (m, 16H), 1.14 – 1.06 (m, 3H), 0.86 (d, *J* = 6.0 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 212.3, 210.0, 209.4, 209.0, 109.7, 109.1, 96.6, 77.6, 77.3, 77.1, 73.9, 72.7, 70.8, 70.6, 57.1, 52.0, 49.2, 47.1, 45.9, 45.8, 45.2, 43.0, 38.9, 37.1, 36.7, 36.3, 35.5, 35.4, 28.2, 27.8, 26.2, 26.1, 25.4, 25.1, 24.5, 22.2, 19.1, 12.1 ppm. (*Only the signals corresponding to the major stereoisomer are reported*). IR (neat, cm^{-1}): 2980, 1714, 1383, 1252, 1212, 1067, 1006. HRMS (ES+) *calcd for* $C_{35}H_{50}O_9Na$ $[M+Na]^+$ 637.3353, *found* 637.3343.

2y



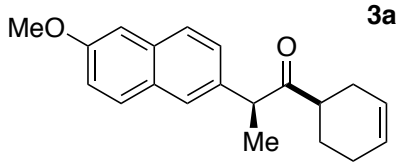
(2S)-1-((4S,6R)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-d][1,3]dioxol-4-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one (2y): Following General Procedure III using **1y-DHP** (157.4 mg, 0.375 mmol, 1.5 equiv), naproxen (57.5 mg, 0.25 mmol, 1.0 equiv), 4CzIPN (3.9 mg, 0.005 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (6.8 mg, 0.015 mmol, 6 mol %), DMDC (80 μL, 0.3 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 2.5 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 40%) to afford a colorless oil (77.2 mg, 80% yield). dr > 20:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.74 – 7.66 (m, 2H), 7.64 (s, 1H), 7.35 (d, J = 8.4 Hz, 1H), 7.18 – 7.05 (m, 2H), 5.10 (d, J = 5.8 Hz, 1H), 5.02 (s, 1H), 4.74 (s, 1H), 4.50 (d, J = 5.9 Hz, 1H), 4.35 (d, J = 7.1 Hz, 1H), 3.91 (s, 3H), 3.34 (s, 3H), 1.56 (d, J = 7.1 Hz, 3H), 1.47 (s, 3H), 1.33 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.1, 157.8, 135.0, 133.9, 129.4, 129.2, 127.4, 126.9, 126.7, 119.1, 113.1, 109.8, 105.7, 89.4, 84.8, 81.1, 56.1, 55.5, 47.9, 26.8, 25.3, 18.6. IR (neat, cm^{-1}): 2987, 2937, 1720, 1633, 1606, 1506, 1485, 1267, 1094. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5$ $[M]^+$ 386.1729, *found* 386.1738.

2z

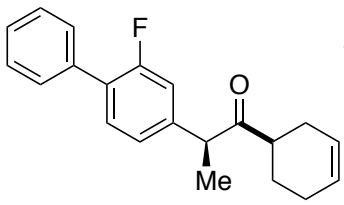


(S)-1-Cyclohexyl-2-(6-methoxynaphthalen-2-yl)propan-1-one (2z): Following General Procedure III using **1z-DHP** (251.4 mg, 0.75 mmol, 1.5 equiv), naproxen (115.1 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 μL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 40%) to afford a colorless oil (83.4 mg, 56% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (d, J = 3.9 Hz, 1H), 7.69 (d, J = 3.5 Hz, 1H), 7.60 (s, 1H), 7.29 (d, J = 8.4 Hz, 1H), 7.15 (dd, J = 9.0, 2.6 Hz, 1H), 7.12 (d, J = 2.5 Hz, 1H),

4.04 (q, J = 6.9 Hz, 1H), 3.92 (s, 3H), 2.45 (tt, J = 11.3, 3.6 Hz, 1H), 1.87 (d, J = 12.1 Hz, 1H), 1.77 – 1.71 (m, 1H), 1.64 – 1.57 (m, 2H), 1.43 (d, J = 6.8 Hz, 3H), 1.40 – 1.00 (m, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 214.2, 157.8, 136.0, 133.7, 129.3, 127.5, 126.7, 119.2, 105.7, 55.5, 51.2, 49.6, 29.7, 28.4, 26.1, 25.9, 25.4, 18.4. IR (neat, cm^{-1}): 2930, 2854, 1707, 1633, 1606, 1505, 1484, 1266, 853. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5$ $[M]^+$ 314.1518, *found* 314.1531.

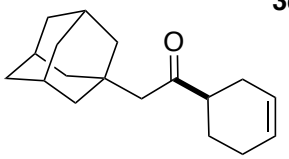


(S)-1-((R)-Cyclohex-3-en-1-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one (3a): Following General Procedure III using DHP (249.9 mg, 0.75 mmol, 1.5 equiv), naproxen (115.1 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 μL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 30%) to afford a colorless oil (113.3 mg, 77% yield). dr = 1.9:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, J = 8.6 Hz, 2H), 7.61 (d, J = 8.6 Hz, 1H), 7.30 (t, J = 9.5 Hz, 1H), 7.16 (dd, J = 8.9, 2.5 Hz, 1H), 7.12 (s, 1H), 5.71 – 5.51 (m, 2H), 4.13 – 4.00 (m, 1H), 3.92 (s, 3H), 2.77 – 2.66 (m, 1H), 2.25 – 2.16 (m, 1H), 2.15 – 1.78 (m, 3H), 1.74 – 1.54 (m, 2H), 1.46 (d, J = 6.9 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 213.4, 213.7, 157.8, 157.7, 135.8, 135.7, 133.8, 129.3, 129.3, 129.2, 129.1, 127.6, 127.5, 127.1, 126.7, 126.6, 126.1, 125.9, 125.3, 119.3, 119.2, 105.7, 55.5, 51.5, 51.4, 45.4, 45.3, 28.2, 27.2, 25.8, 25.0, 24.7, 24.6, 18.29, 18.6 (mixture of diastereomers, 5 overlapping peaks). IR (neat, cm^{-1}): 1705, 1632, 1605, 1505, 1484, 1452, 1437, 1391, 1372, 1266, 1228, 1216. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5$ $[M]^+$ 294.1620, *found* 294.1600.



3b

(S)-1-((R)-Cyclohex-3-en-1-yl)-2-(2-fluoro-[1,1'-biphenyl]-4-yl)propan-1-one (3b): Folllowing General Procedure III using DHP (249.9 mg, 0.75 mmol, 1.5 equiv), flurbiprofen (244.26 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 µL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 30%) to afford a colorless oil (113.3 mg, 77% yield). dr = 1:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 – 7.51 (m, 2H), 7.51 – 7.33 (m, 4H), 7.15 – 6.99 (m, 2H), 5.67 (d, J = 18.1 Hz, 2H), 4.00 (dq, J = 13.8, 6.9 Hz, 1H), 2.73 (ddt, J = 14.0, 8.0, 2.8 Hz, 1H), 2.31 – 2.19 (m, 1H), 2.18 – 2.03 (m, 2H), 1.96 (dt, J = 13.6, 4.4 Hz, 1H), 1.88 – 1.56 (m, 2H), 1.44 (dd, J = 7.0, 1.9 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ *cryoprobe for J coupling!* IR (neat, cm^{-1}): 3027, 2929, 1709, 1484, 1451, 1436, 1417, 1374, 1268, 1132, 1030. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5Na$ $[M+Na]^+$ 405.1678, *found*.

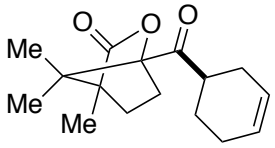


3c

2-((3R,5R,7R)-Adamantan-1-yl)-1-((R)-cyclohex-3-en-1-yl)ethan-1-one (3c): Following General Procedure III using DHP (249.9 mg, 0.75 mmol, 1.5 equiv), 2-((3r,5r,7r)-adamantan-1-yl)acetic acid (97.1 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 µL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 30%) to afford a colorless oil (103.4, 80% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.71 – 5.66 (m, 2H), 2.63 – 2.50 (m, 1H), 2.27 – 2.19 (m, 2H), 2.15 – 2.06 (m, 4H), 1.95 (s, 4H), 1.69 (d, J = 12.3 Hz, 4H),

1.64 (d, J = 7.3 Hz, 6H), 1.53 – 1.44 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 213.8, 126.7, 125.7, 54.3, 48.7, 42.7, 37.0, 33.8, 28.8, 26.7, 25.1, 24.6. IR (neat, cm^{-1}): 1705, 1632, 1605, 1505, 1484, 1452, 1437, 1391, 1372, 1266, 1228, 1216. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5$ $[M]^+$ 258.1984, *found* 258.1992.

3d



(4R)-1-((R)-Cyclohex-3-ene-1-carbonyl)-4,7,7-trimethyl-2-oxabicyclo[2.2.1]heptan-3-one (3d): Following General Procedure III using DHP (249.9 mg, 0.75 mmol, 1.5 equiv), (1S)-(–)-camphanic acid (99.1 mg, 0.5 mmol, 1.0 equiv), 4CzIPN (7.8 mg, 0.01 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (14.1 mg, 0.03 mmol, 6 mol %), DMDC (160 μL, 0.6 mmol, 1.50 equiv) in acetone/*i*PrOAc (2:1, 5.0 mL, 1.0 M). The product was purified by flash chromatography on silica gel (hexanes/EtOAc 0 to 30%) to afford a colorless oil (80.7 mg, 61% yield). dr = 1.1:1 based on ^{1}H NMR of the crude reaction mixture. ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.70 (m, 2H), 3.23 – 3.10 (m, 1H), 2.45 – 2.28 (m, 2H), 2.20 – 1.97 (m, 4H), 1.97 – 1.87 (m, 2H), 1.74 – 1.64 (m, 1H), 1.53 – 1.21 (m, 1H), 1.11 (s, 3H), 1.05 (s, 3H; 1:1 mixture of diastereomers), 0.92 (s, 3H; 1:1 mixture of diastereomers). ^{13}C NMR (126 MHz, $CDCl_3$) δ 211.2, 210.6, 179.1, 179.0, 126.8, 126.5, 125.3, 125.0, 96.7, 96.7, 60.5, 55.4, 55.3, 55.1, 43.7, 43.5, 31.8, 31.8, 29.4, 29.4, 27.5, 25.2, 25.1, 24.9, 24.5, 23.0, 16.9, 16.8, 16.8, 14.3, 9.7, 9.6. IR (neat, cm^{-1}): 3025, 1787, 1704, 1449, 1438, 1395, 1376, 1162. HRMS (ES+) *calcd for* $C_{23}H_{26}O_5$ $[M]^+$ 262.1569, *found* 262.1563.

6. General Procedure for Cross-Coupling Reaction (1 gram scale):

To an oven dried, 50 mL round bottom flask equipped with a stir bar were added 4CzIPN (39.1 mg, 0.049 mmol, 2 mol %), Ni(dtbbpy)$(H_2O)_4Cl_2$ (67.5 mg, 0.15 mmol, 6 mol %), 1,4-DHP **1y** (1.80 g, 3.75 mmol, 1.5 equiv), and dehydrocholic acid (1.00 g, 2.5 mmol, 1.0 equiv). The flask was sealed with a rubber septum, evacuated, and purged with argon three times *via* an inlet needle. The flask was then charged with a mixture (25 mL, 0.1 M) of dry and degassed acetone/*i*-PrOAc (2/1). At this point, DMDC (0.53 mL, 5 mmol) was added *via* a syringe. The reaction flask was then stirred vigorously and subjected to light irradiation by blue LEDs (~ 470 nm) as shown here. The reaction was maintained at approximately 24 °C *via* a fan. Once complete (~24 h), the reaction was taken to dryness and then purified on an automated liquid chromatographic system to obtain the pure product as a white solid in 71% yield. The obtained product presented slightly higher yield in comparison to the reaction on 0.3 mmol scale.

7. References:

(1) N. R. Patel; C. B. Kelly; A. P. Siegenfeld; G. A. Molander, *ACS Catal.* **2017**, *7*, 1766.

(2) Á. Gutiérrez-Bonet.; J. C. Tellis; J. K. Matsui; B. A. Vara; G. A. Molander, *ACS Catal.* **2016**, *6*, 8004.

(3) N. Tewari; N. Dwivedi; R. Tripathi, *Tetrahedron Lett*. **2004**, *45*, 9011.

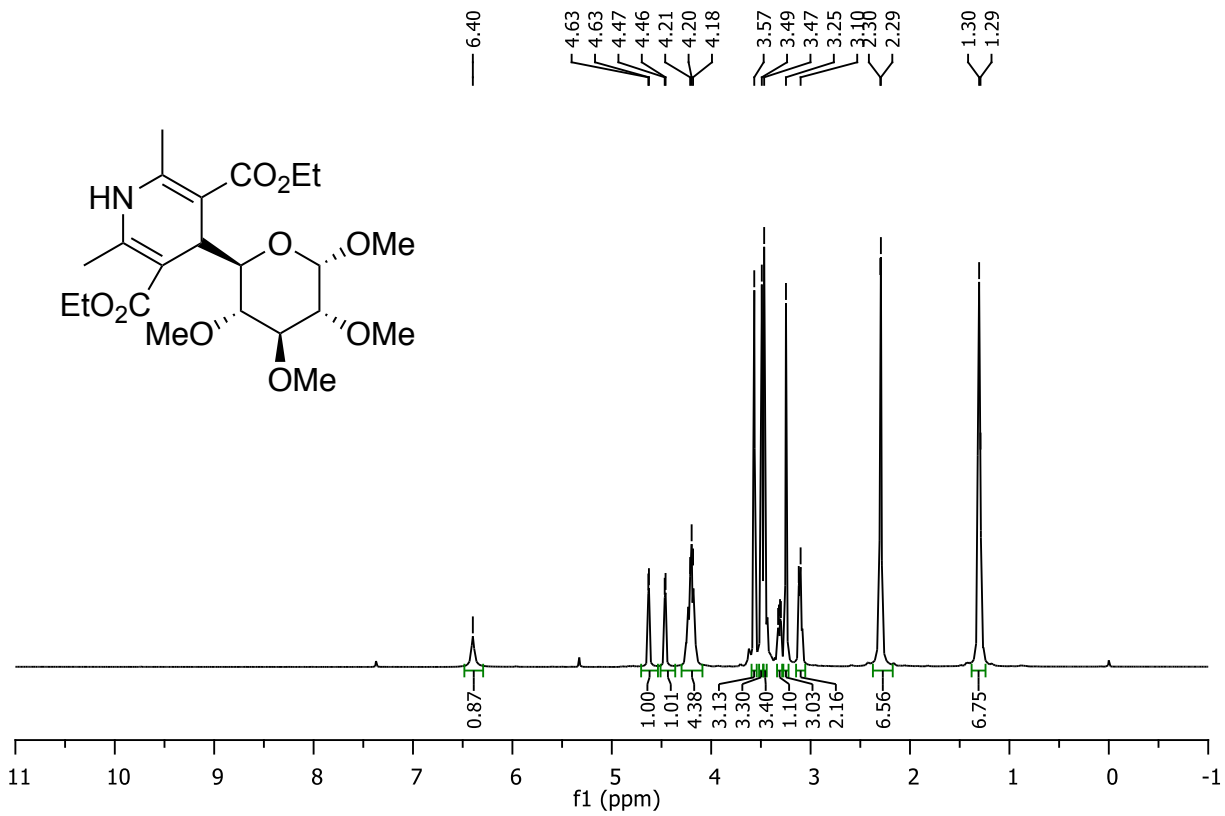
(4) Z. Liu; S. F. Jenkinson; T. Vermaas; I. Adachi; M. R. Wormald; Y. Hata; Y. Kurashima; A. Kaji; C.-Y. Yu; A. Kato; G. W. J. Fleet, *J. Org. Chem.* **2015**, *80*, 4244.

(5) K. L. Stoltz; A.-N. R. Alba; F. E. McDonald; M. B. Wieliczko; J. Bacsa, *Heterocycles* **2014**, *8*, 1519.

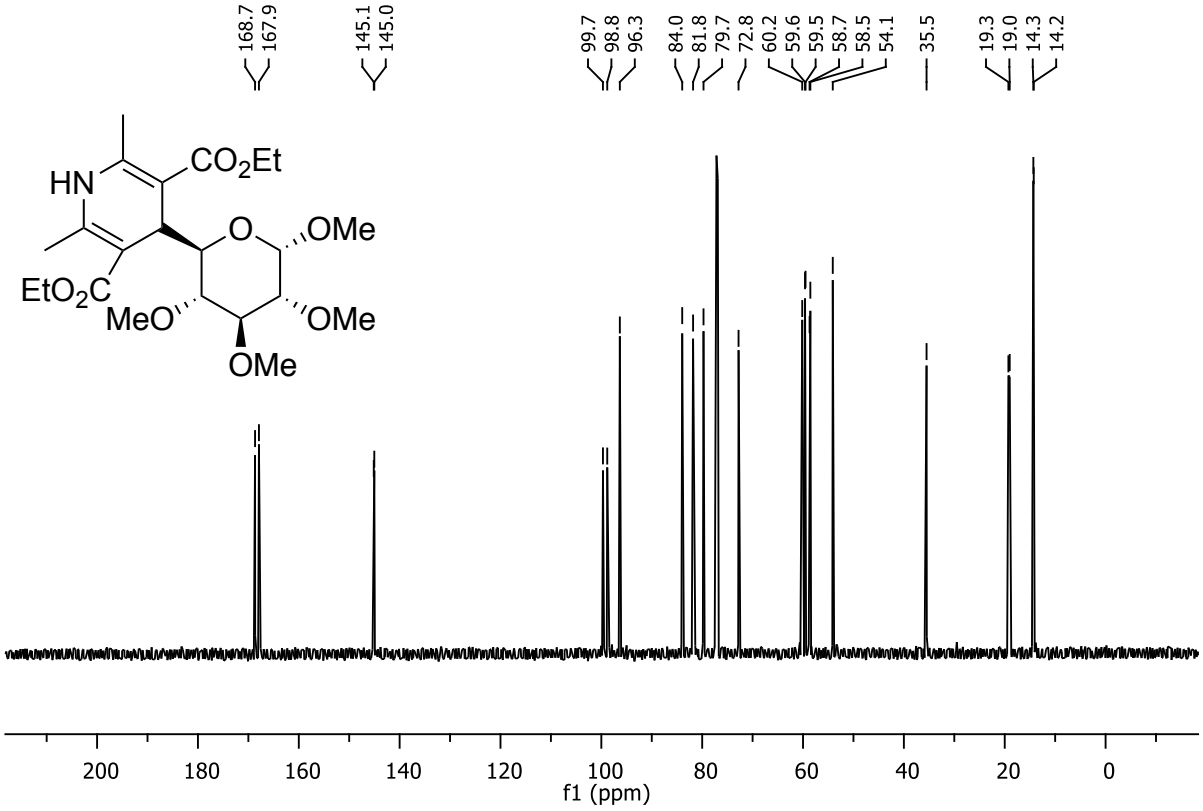
8. ^{1}H and ^{13}C NMR Spectra:

8.1 Spectra for new 1,4-dihydropyridine derivatives:

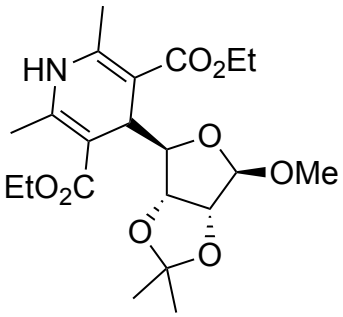
^{1}H NMR ($CDCl_3$, 500 MHz) of diethyl 2,6-dimethyl-4-((2*R*,3*R*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)-1,4-dihydropyridine-3,5-dicarboxylate (**1d**)

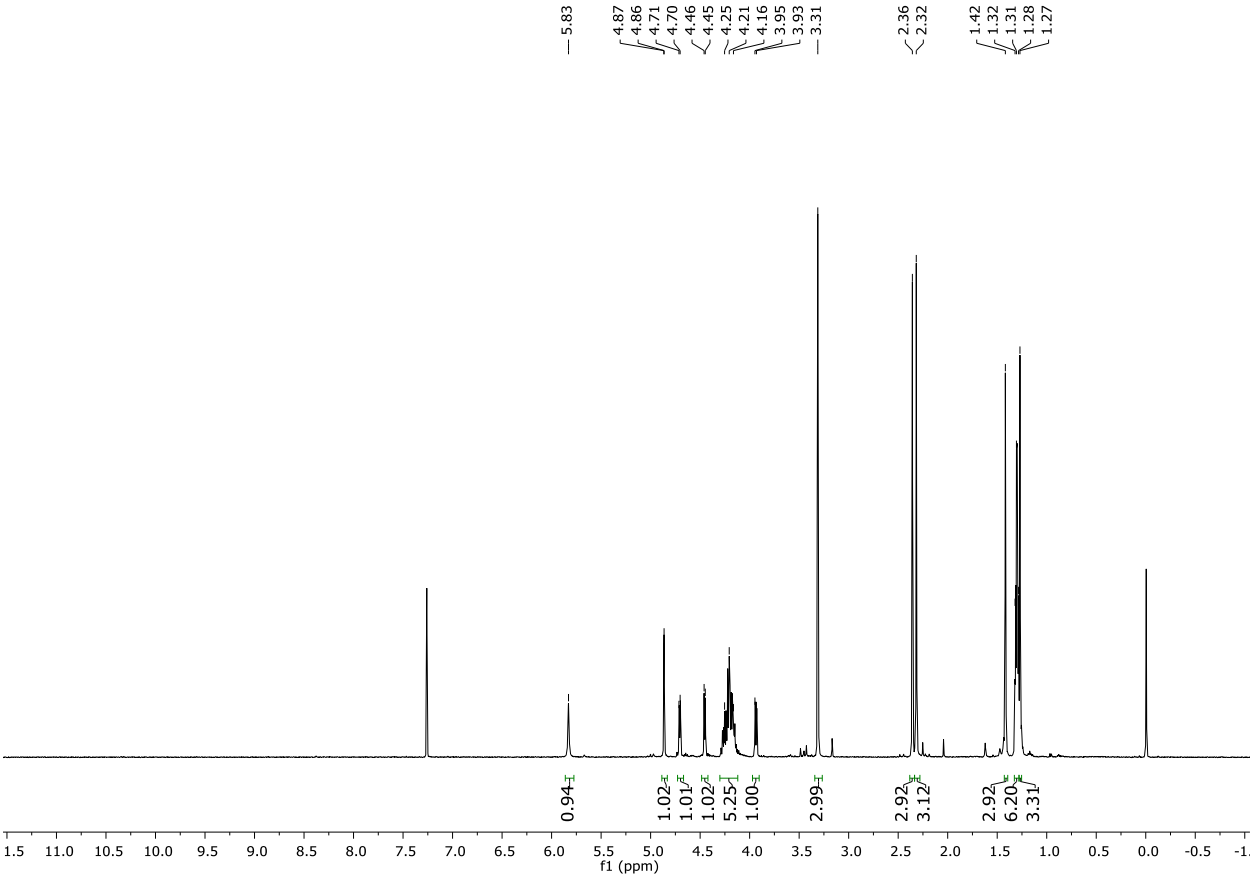


^{13}C NMR ($CDCl_3$, 126 MHz) of diethyl 2,6-dimethyl-4-((2*R*,3*R*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)-1,4-dihydropyridine-3,5-dicarboxylate (**1d**)

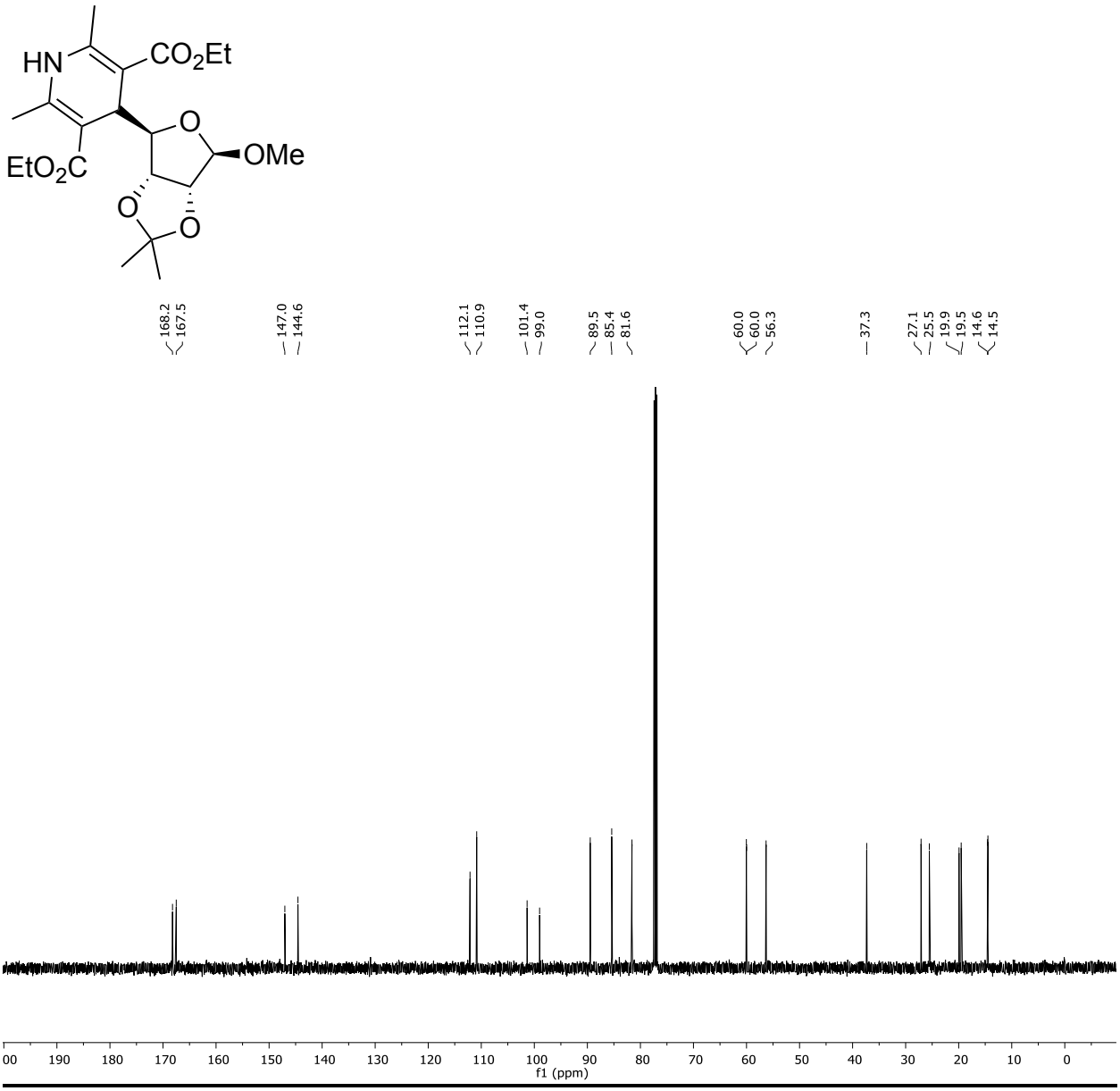


^{1}H NMR ($CDCl_3$, 500 MHz) of diethyl 4-((3a*R*,4*R*,6*R*,6a*R*)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-*d*][1,3]dioxol-4-yl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (**1z**)



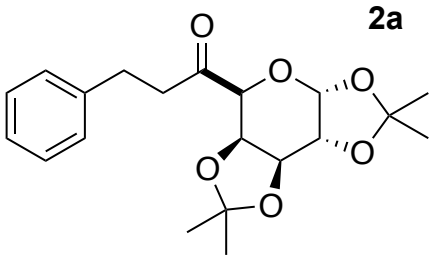


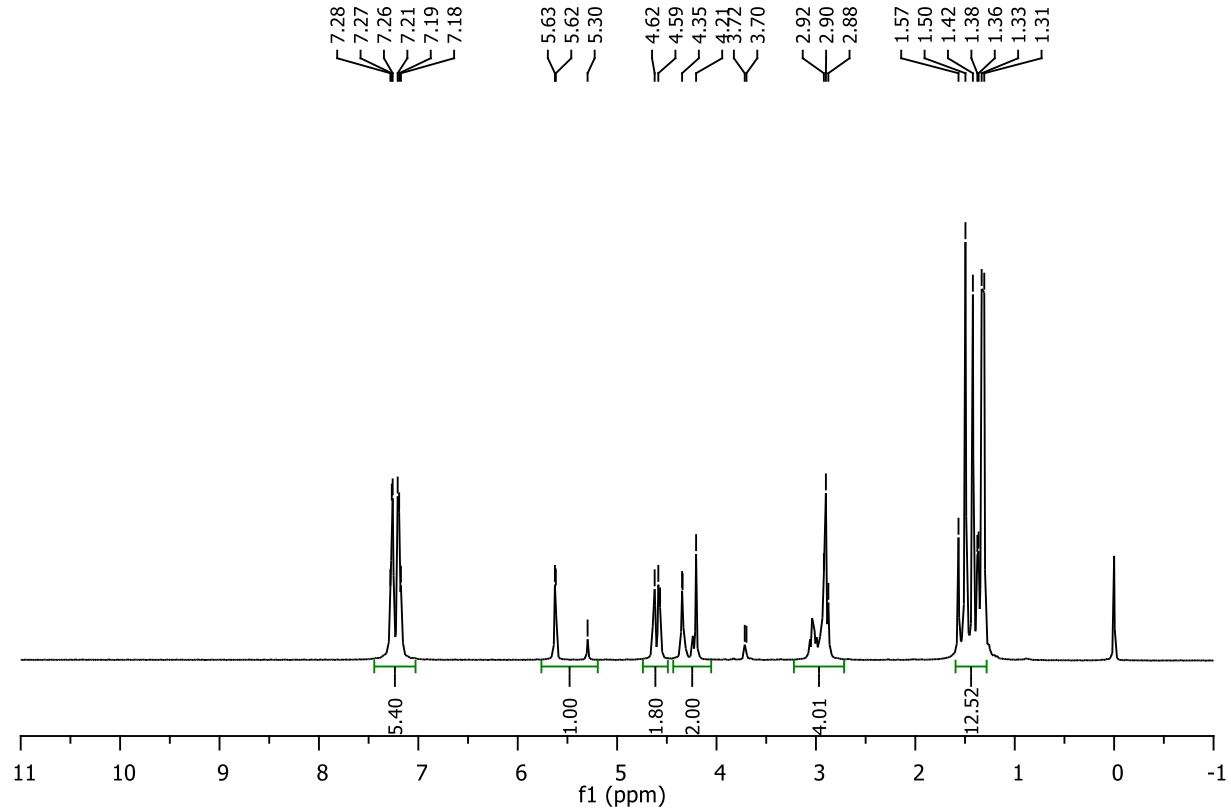
^{13}C NMR ($CDCl_3$, 126 MHz) of diethyl 4-((3a*R*,4*R*,6*R*,6a*R*)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-*d*][1,3]dioxol-4-yl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (**1z**)



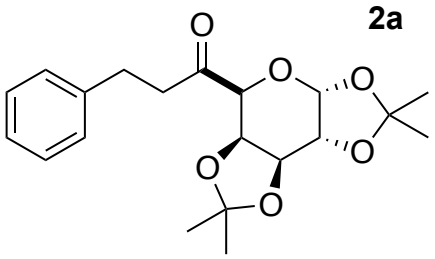
8.2 Spectra for hantszch esters scope:

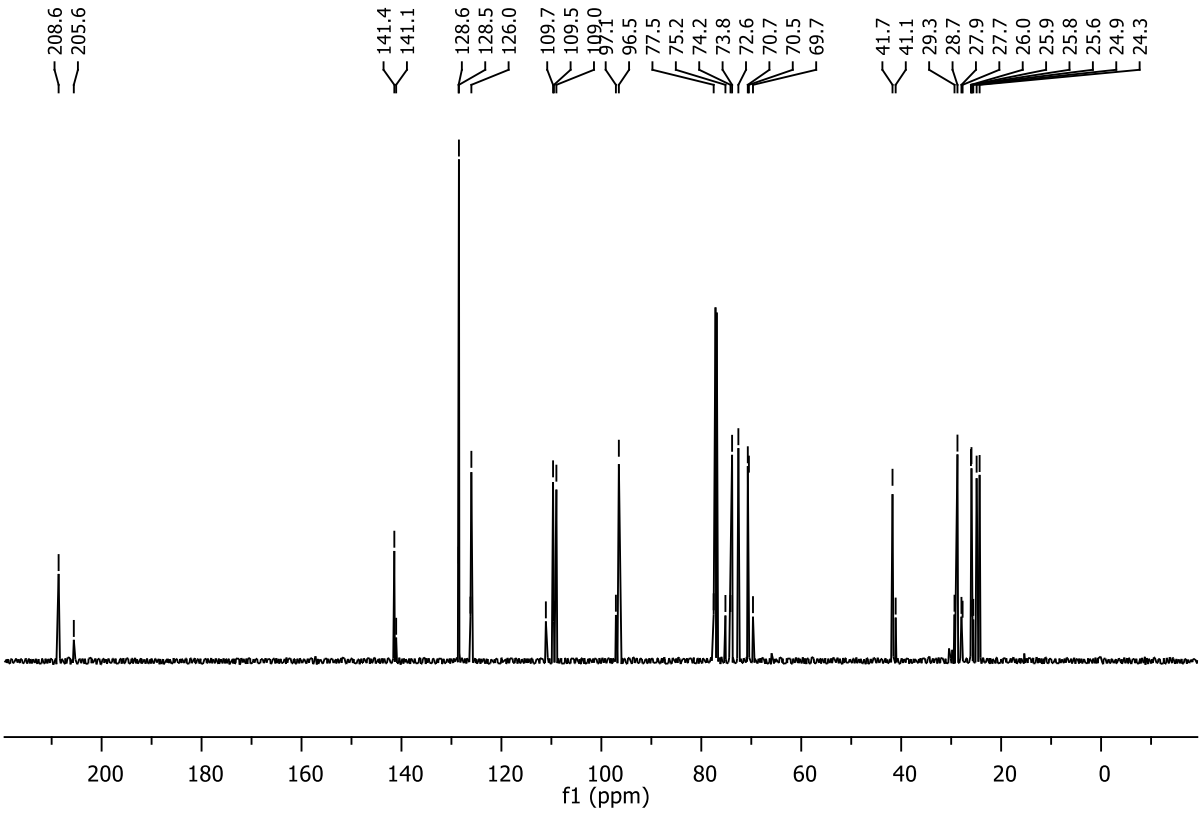
^{1}H NMR ($CDCl_3$, 500 MHz) of 3-phenyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-yl)propan-1-one (**2a**)



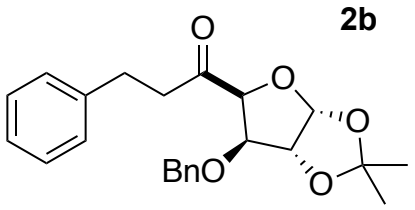


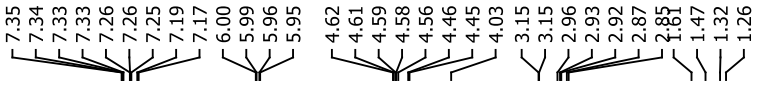
^{13}C NMR (126 MHz, $CDCl_3$) of 3-phenyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-yl)propan-1-one (**2a**)

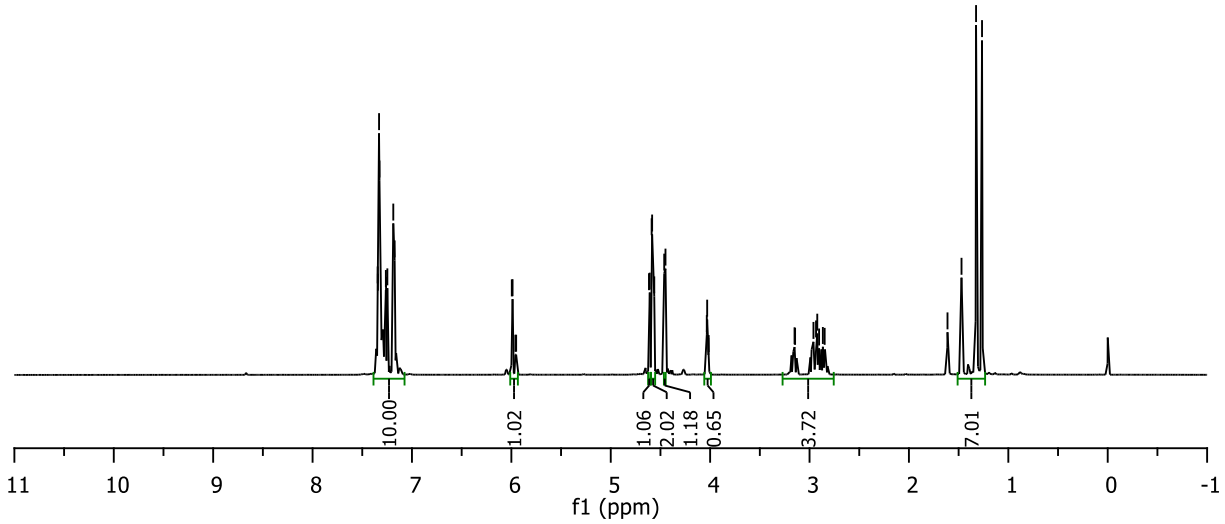




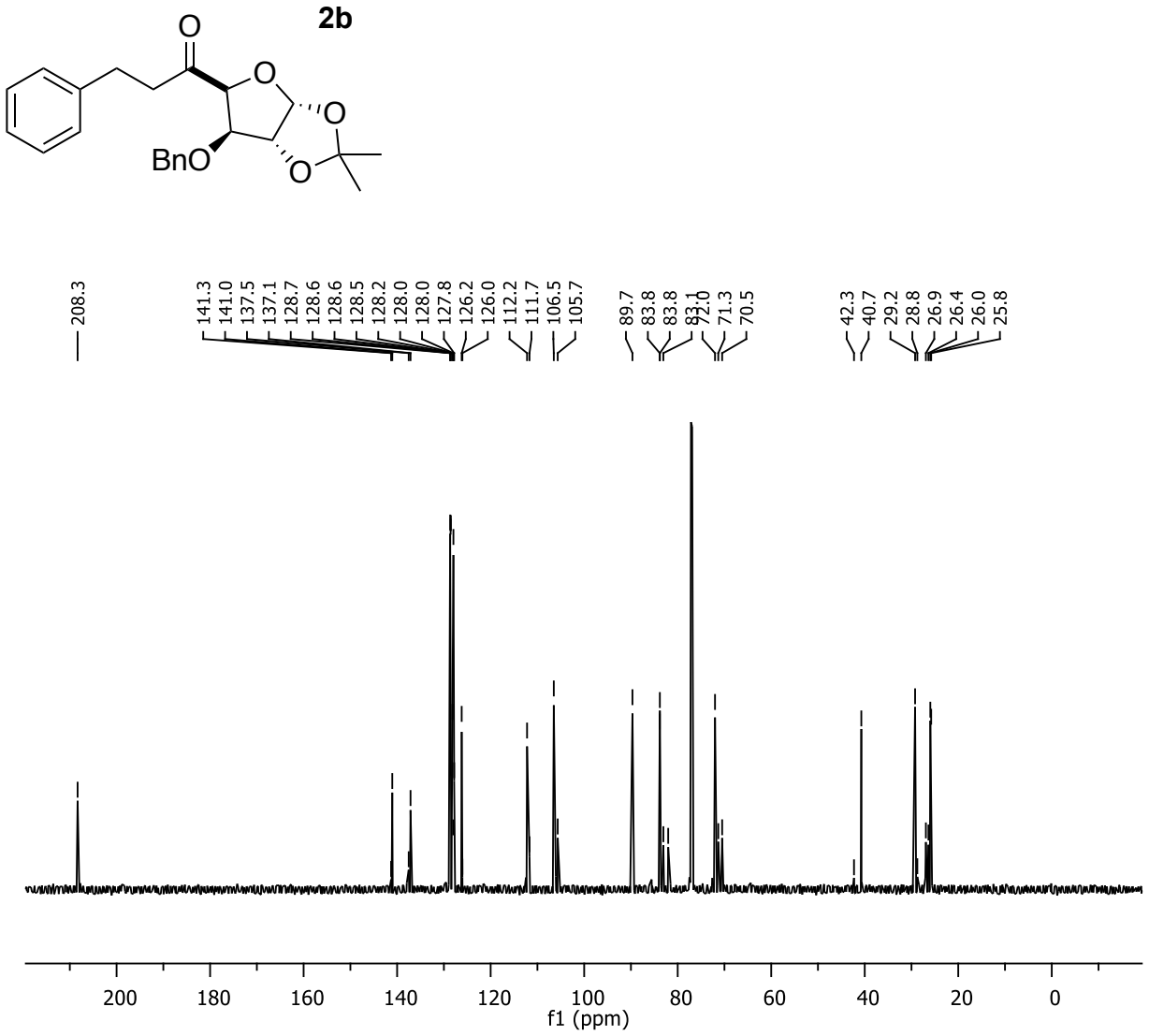
^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2b**)



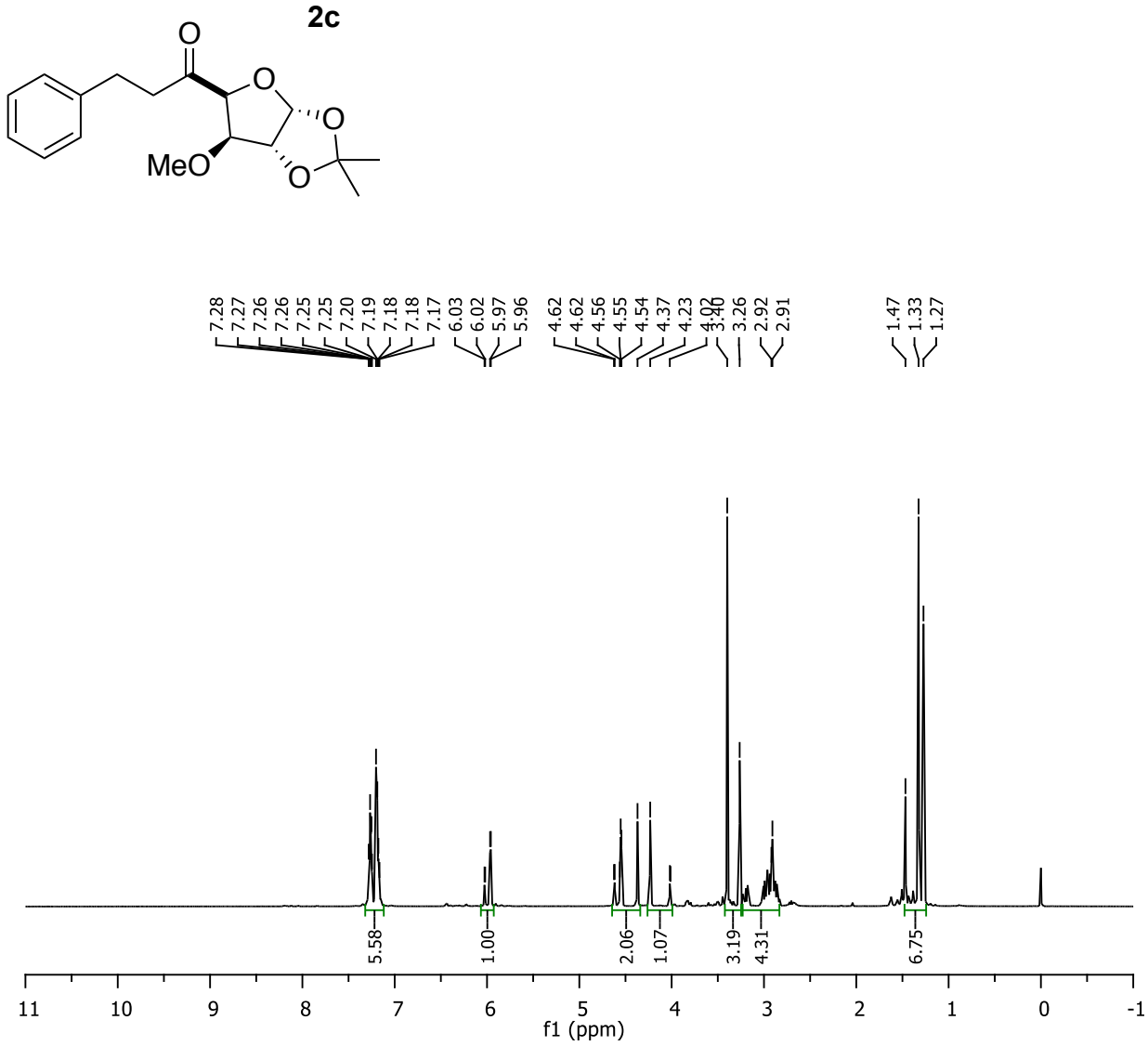




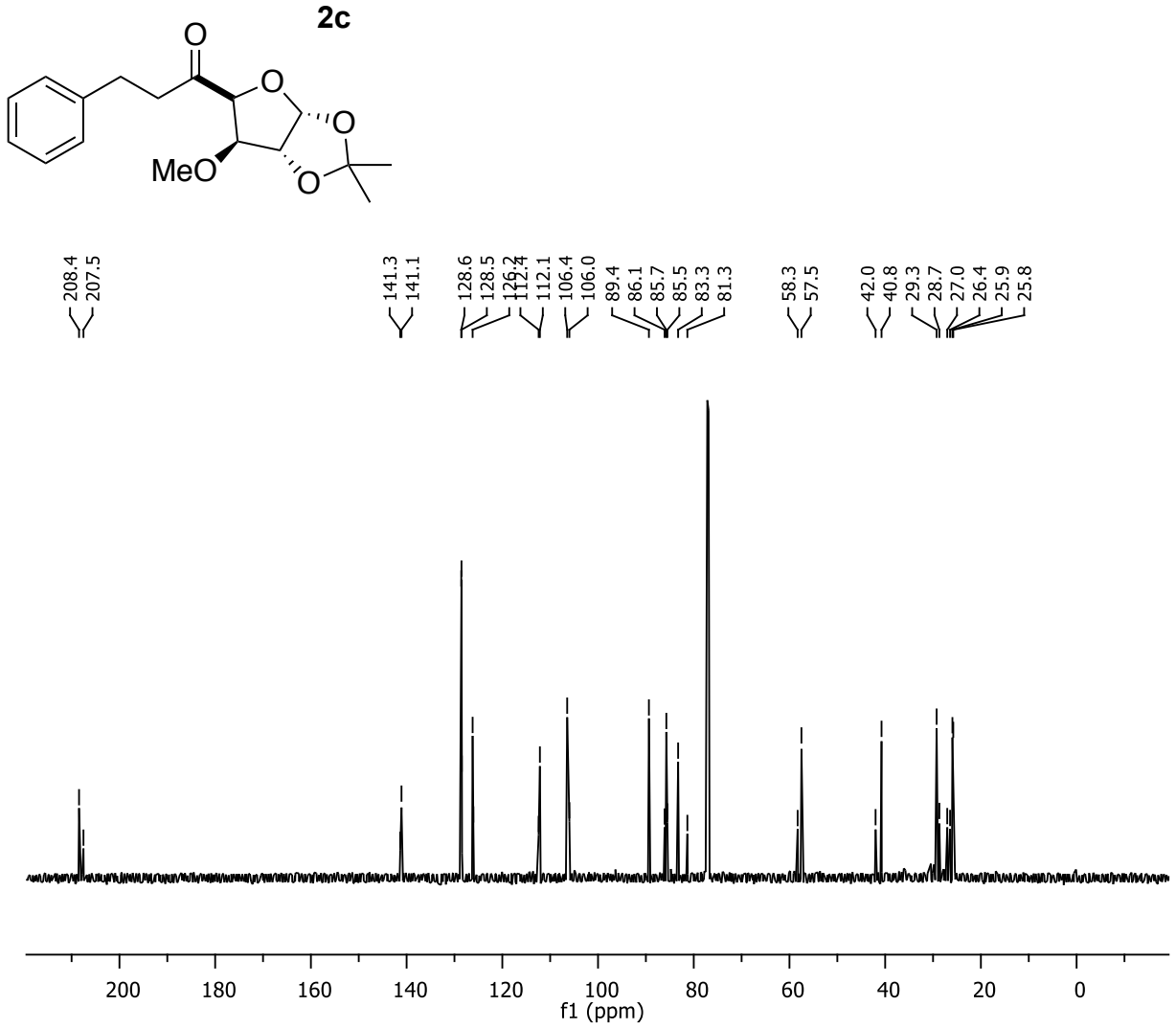
^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2b**)



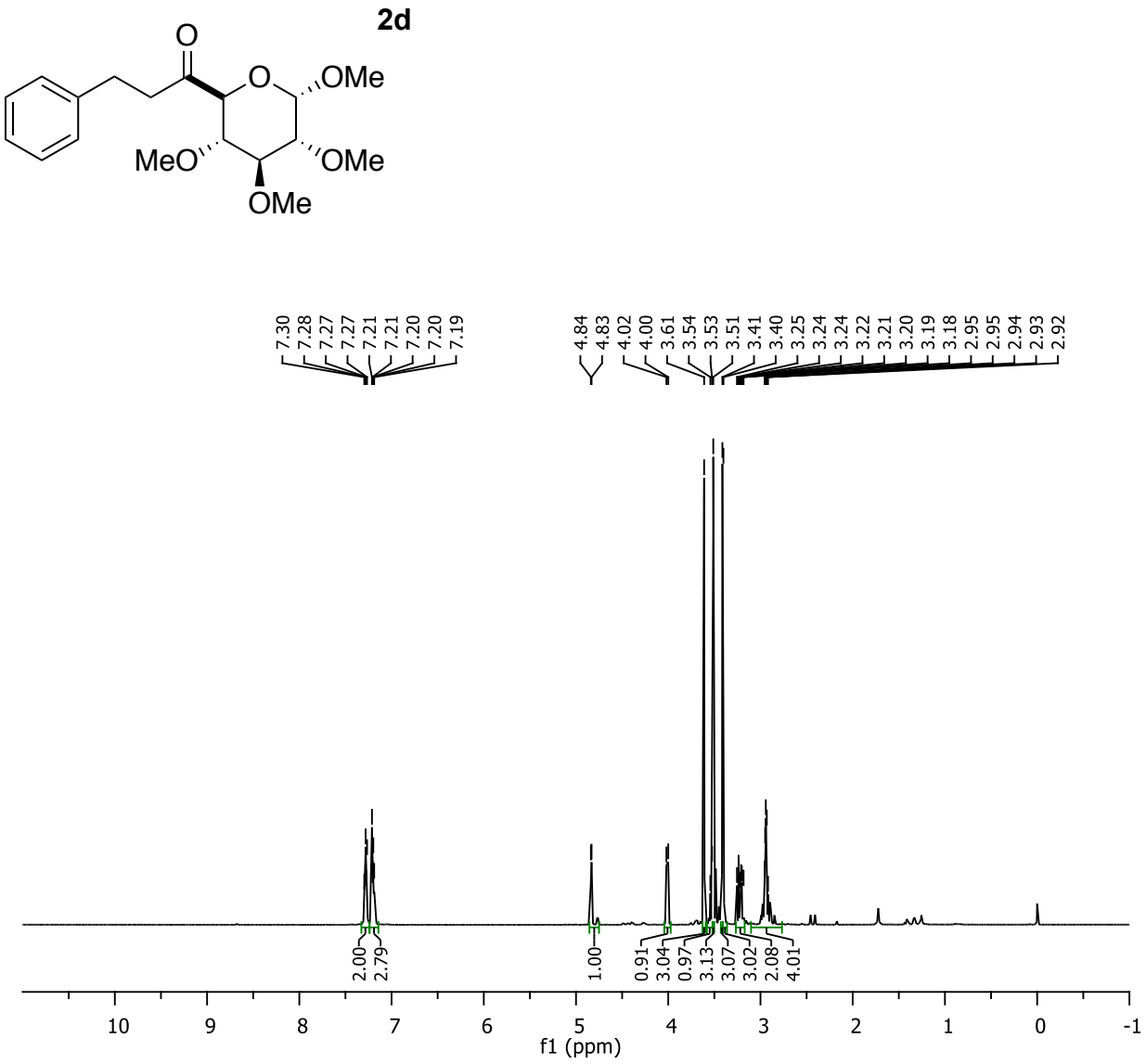
^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-methoxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2c**)



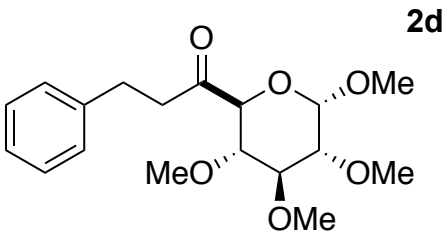
^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-methoxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2c**)

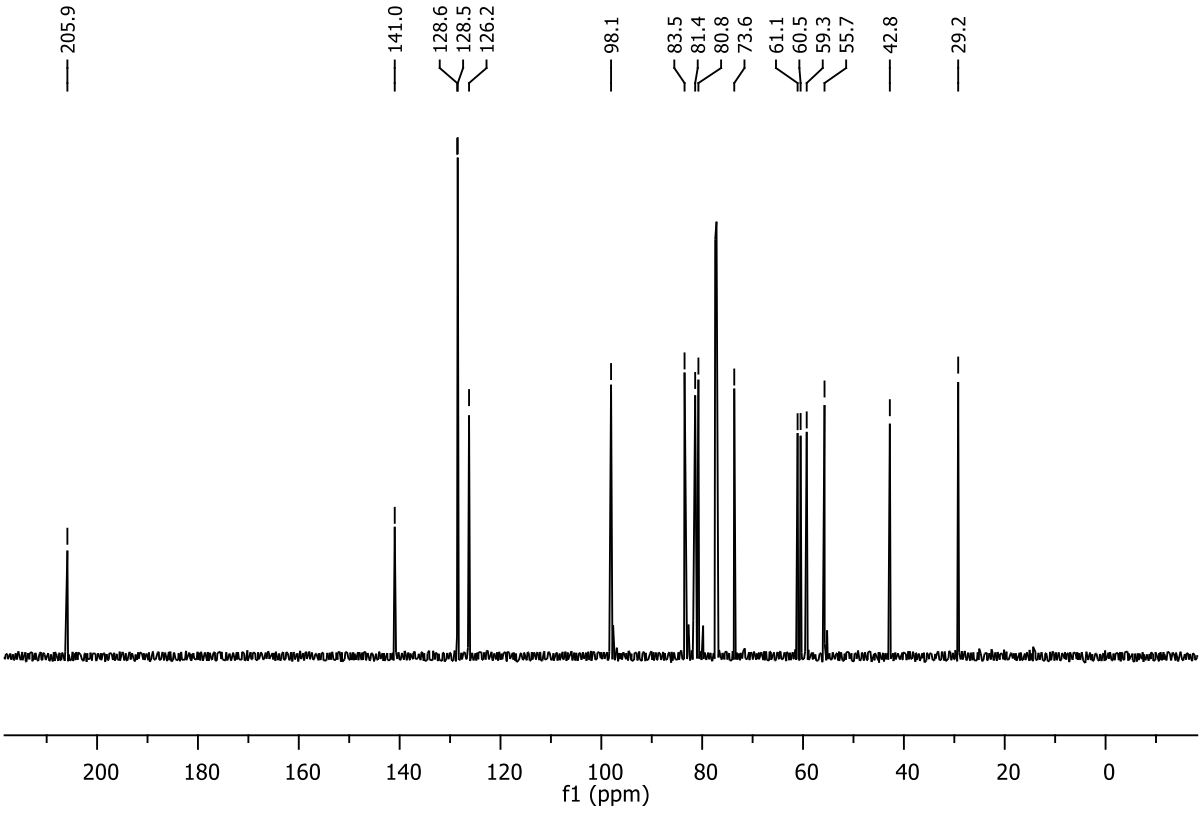


^{1}H NMR ($CDCl_3$, 500 MHz) of 3-phenyl-1-((3*S*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)propan-1-one (**2d**)

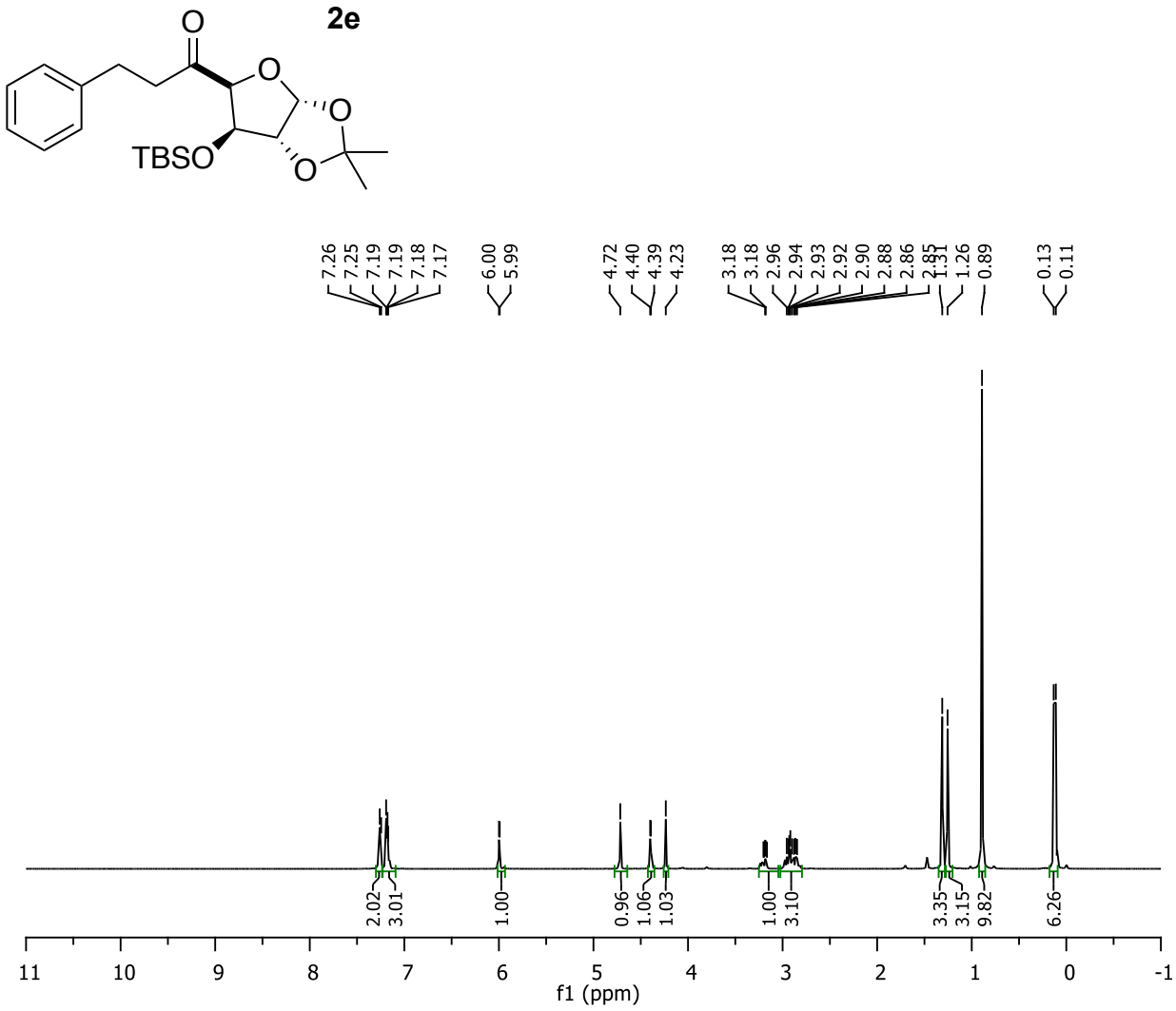


^{13}C NMR ($CDCl_3$, 126 MHz) of 3-phenyl-1-((3*S*,4*S*,5*R*,6*S*)-3,4,5,6-tetramethoxytetrahydro-2H-pyran-2-yl)propan-1-one (**2d**)

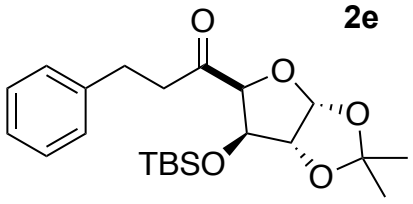


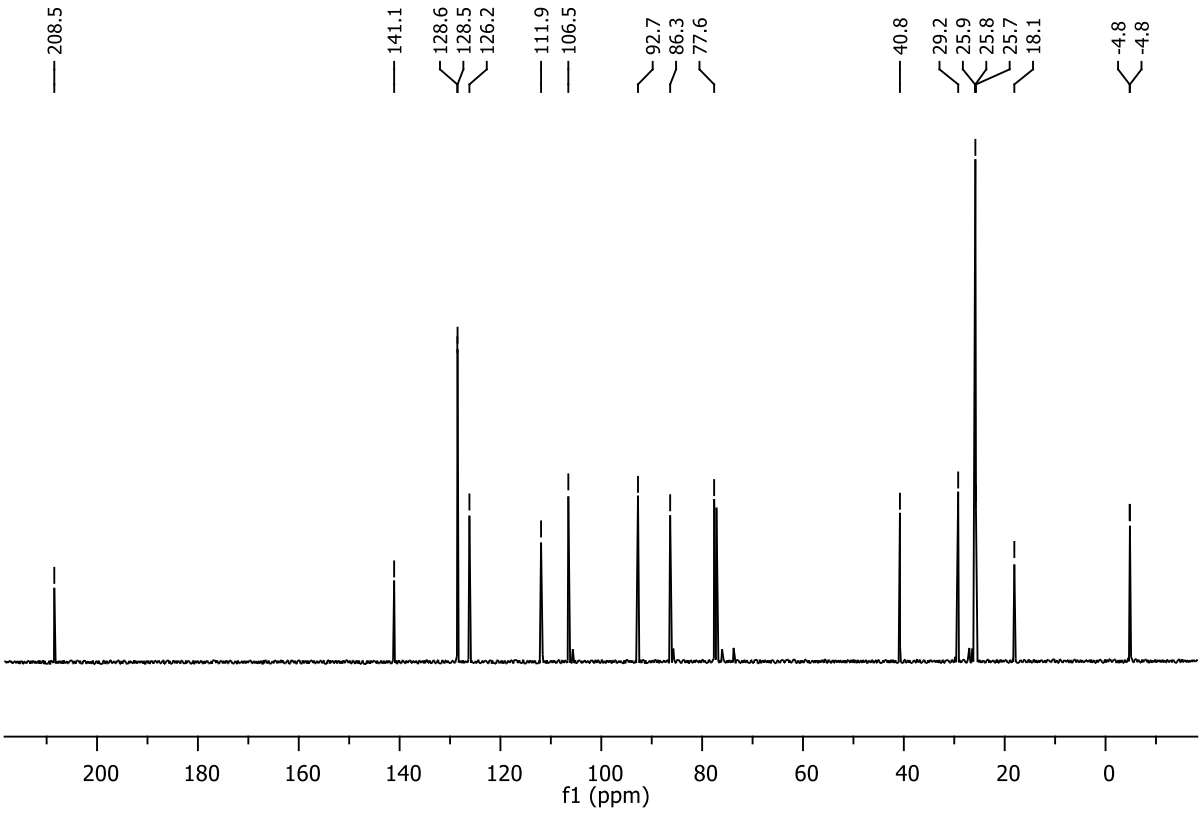


^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-((*tert*-butyldimethylsilyl)oxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2e**)

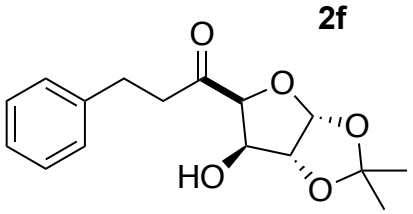


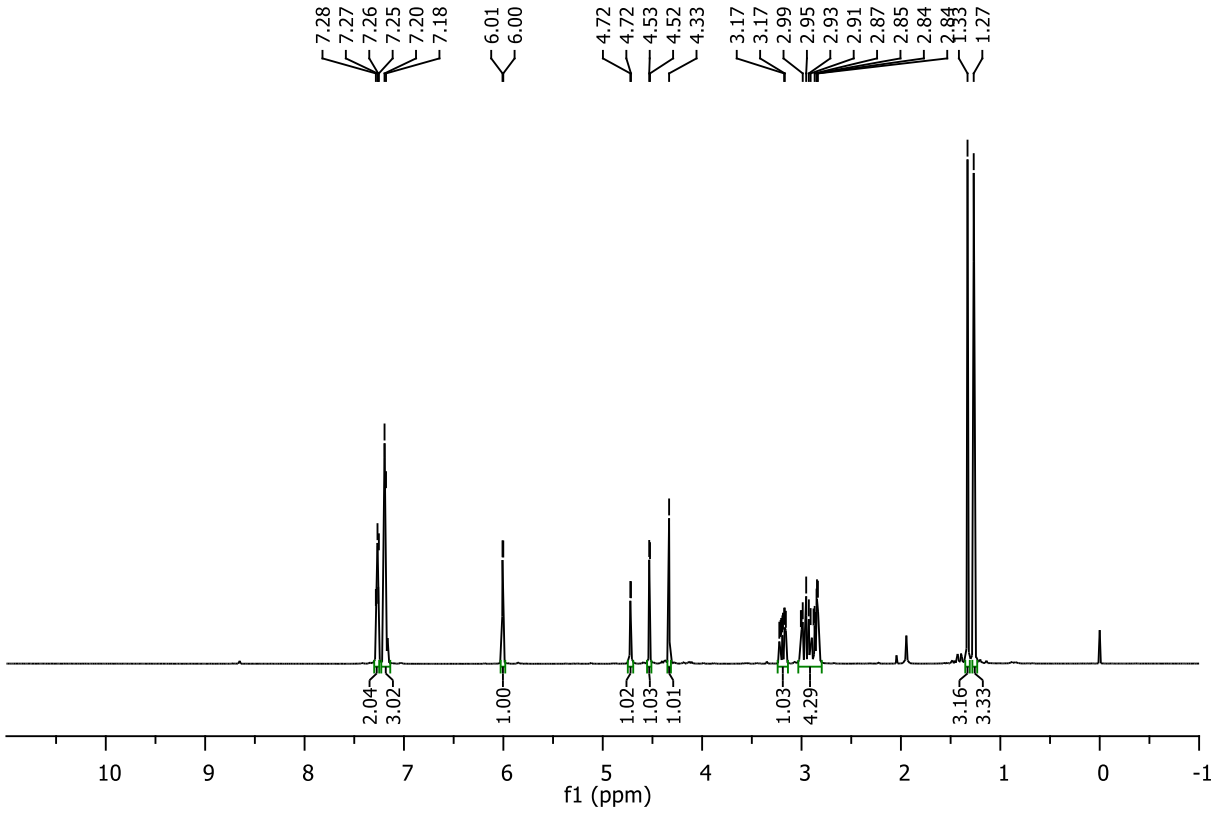
^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-((*tert*-butyldimethylsilyl)oxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2e**)



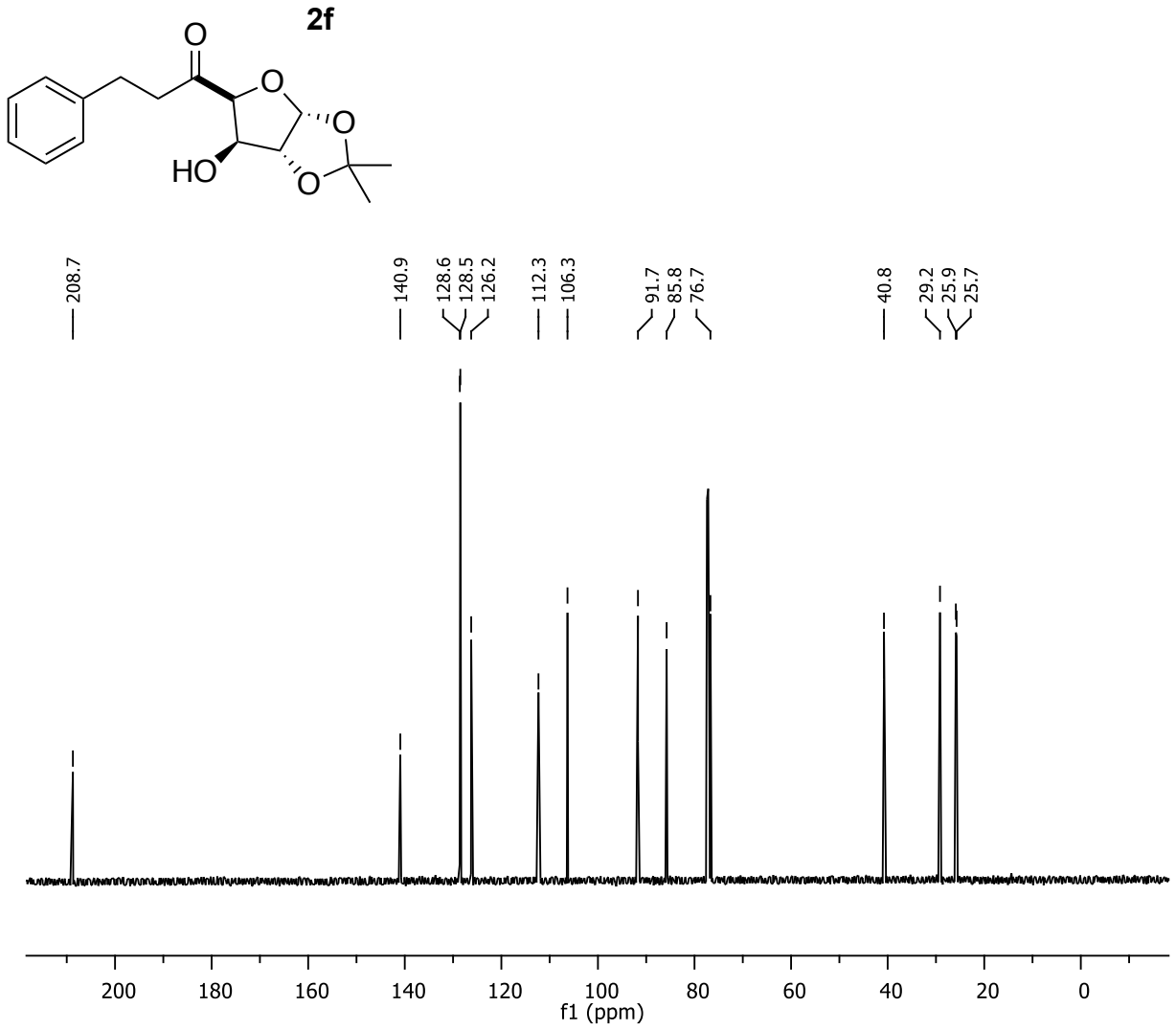


^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-hydroxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2f**) (major diastereomer)

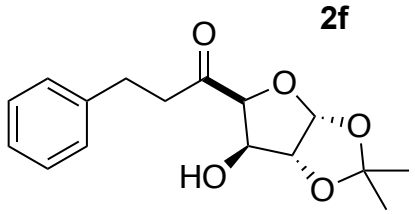


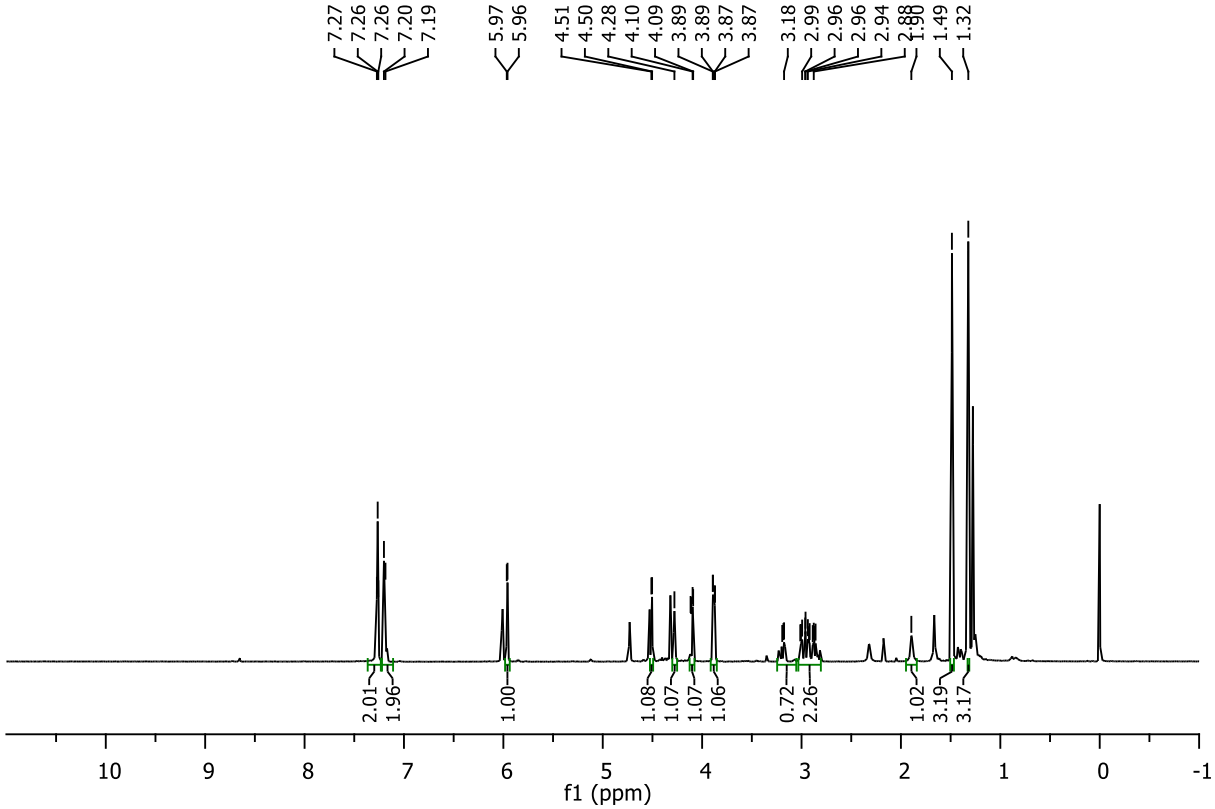


^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-hydroxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2f**) (major diastereomer)

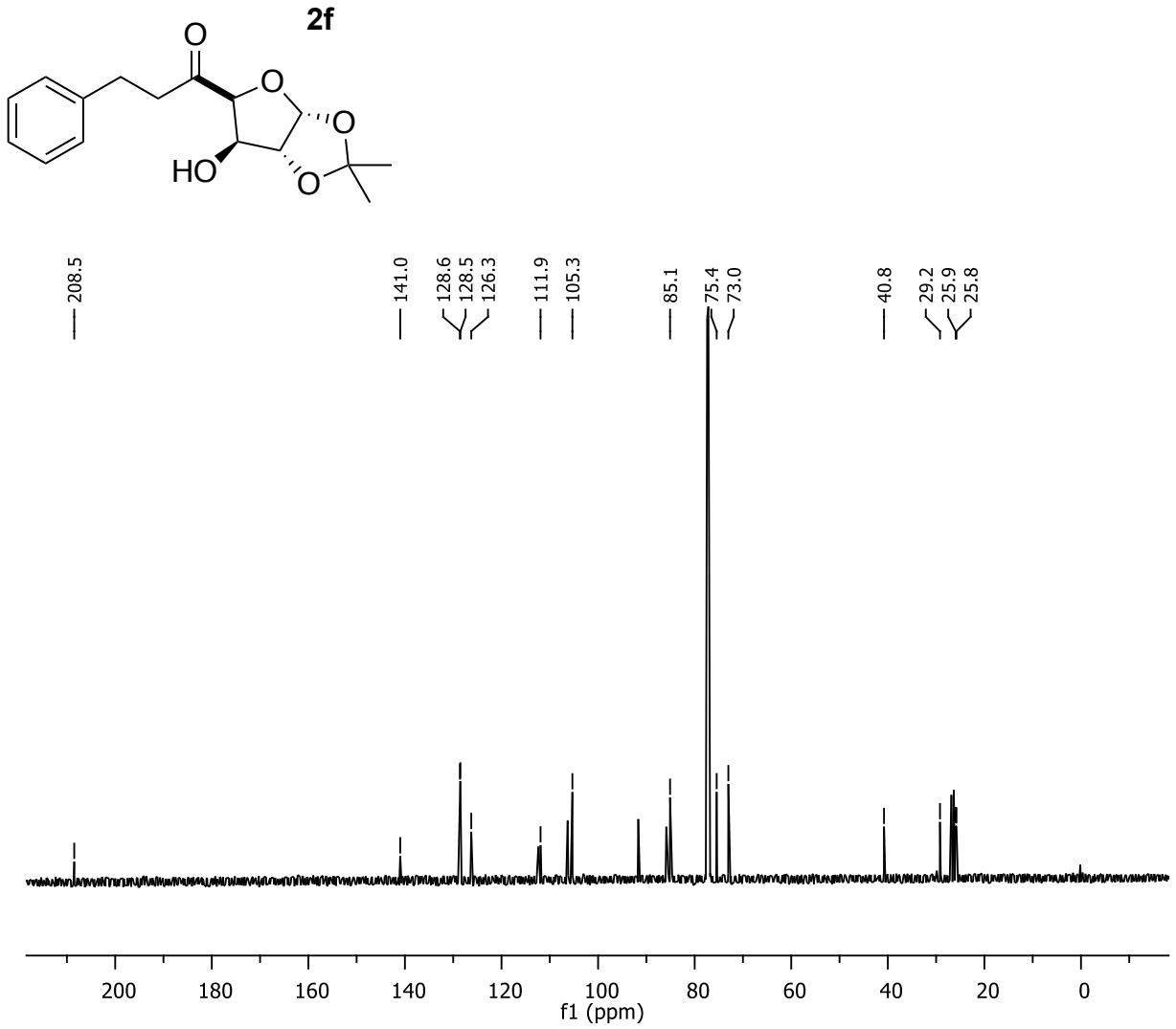


^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-hydroxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2f**) (minor diastereomer)

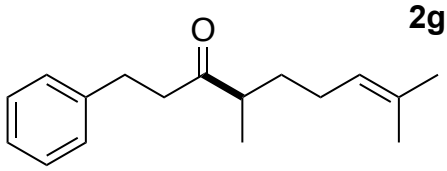


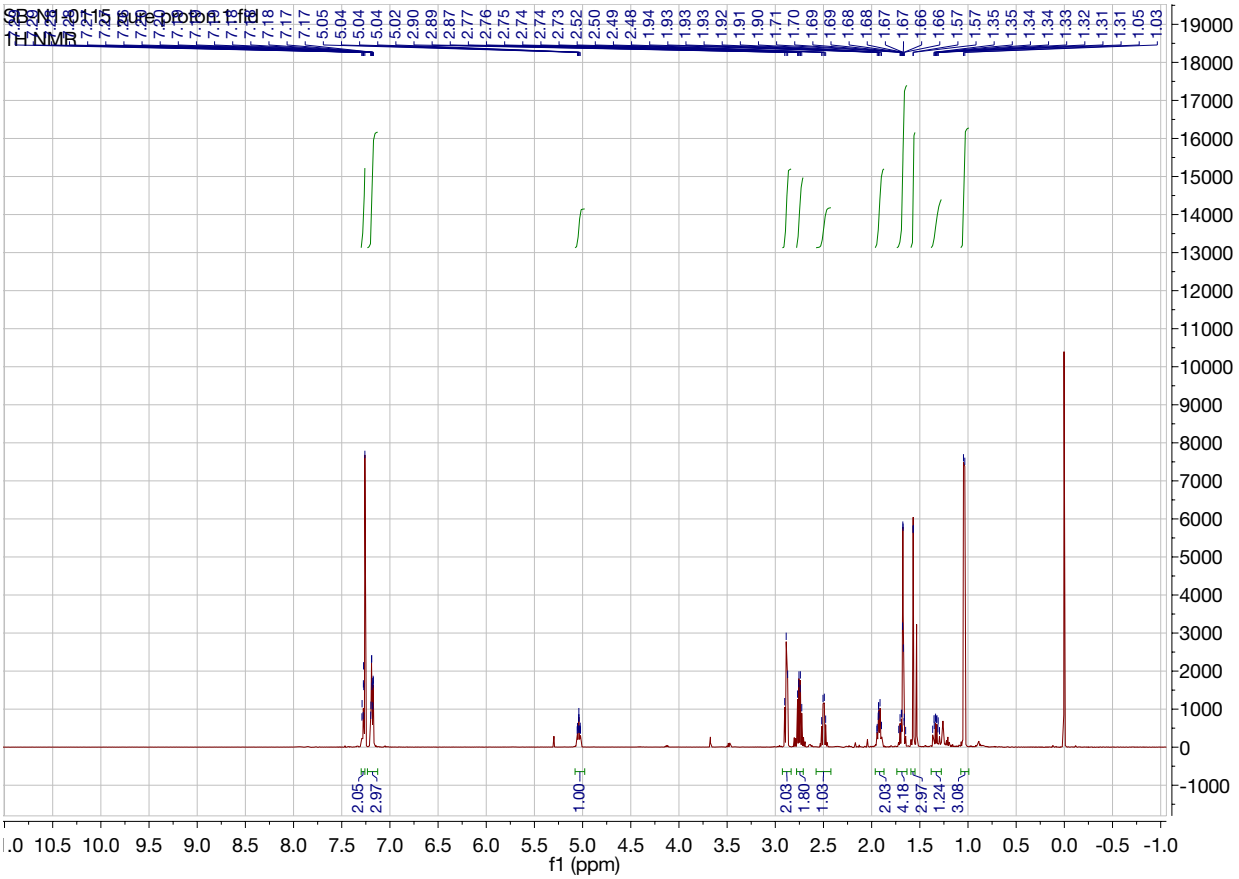


^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-hydroxy-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-3-phenylpropan-1-one (**2f**)

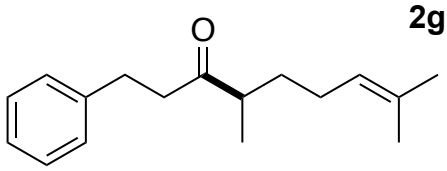


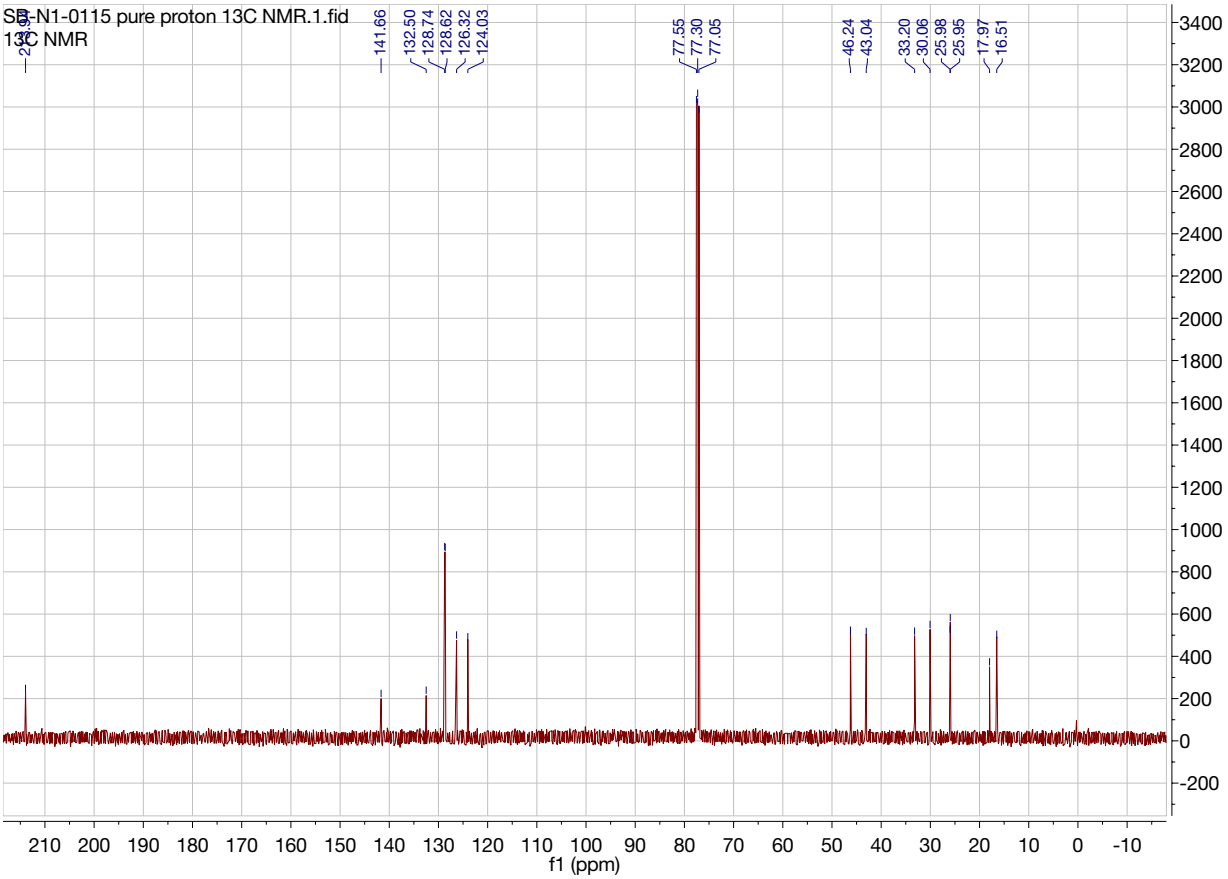
^{1}H NMR ($CDCl_3$, 500 MHz) of 4,8-dimethyl-1-phenylnon-7-en-3-one **(2g)**





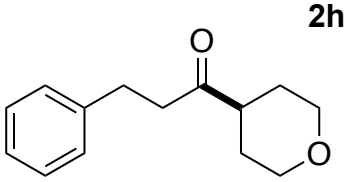
^{13}C NMR ($CDCl_3$, 126 MHz) of 4,8-dimethyl-1-phenylnon-7-en-3-one **(2g)**

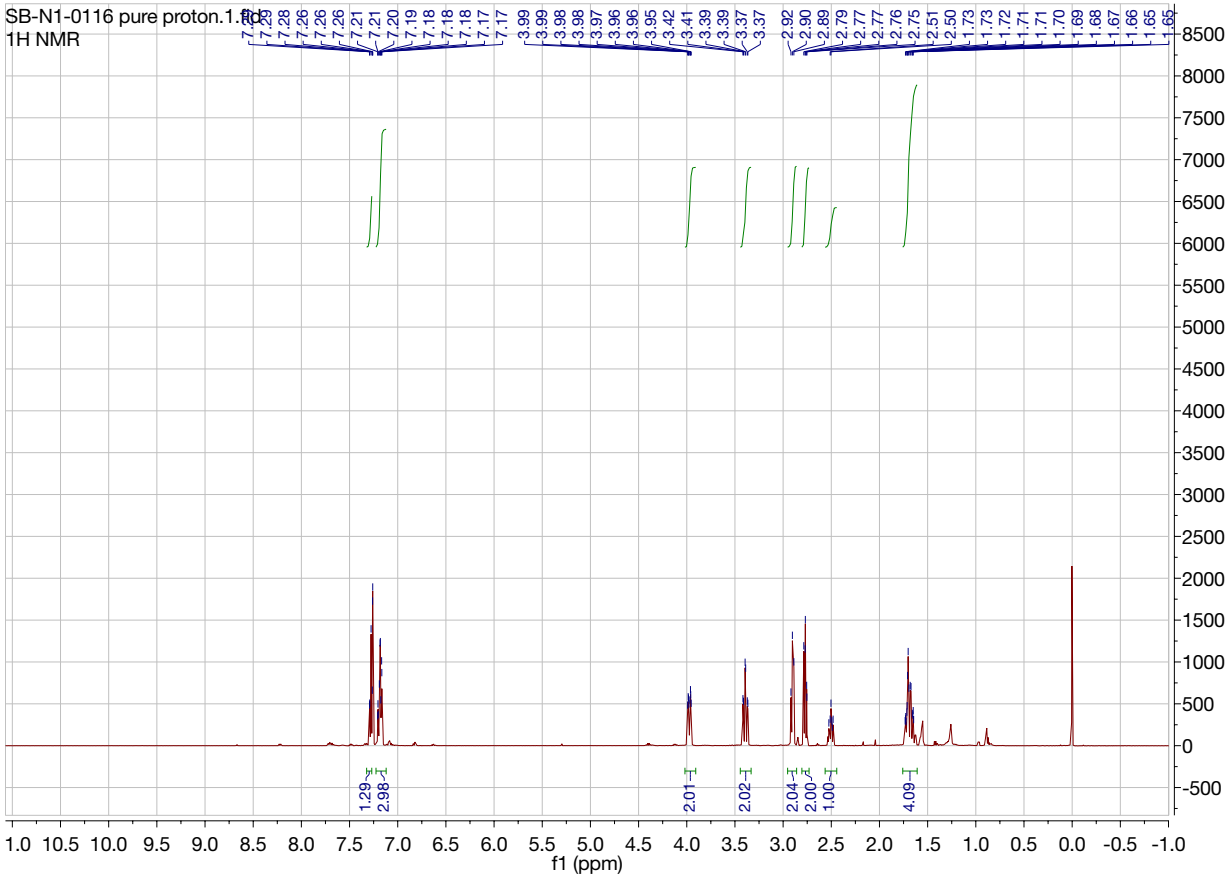




^{1}H NMR ($CDCl_3$, 500 MHz) of 3-phenyl-1-(tetrahydro-2*H*-pyran-4-yl)propan-1-one **(2h)**

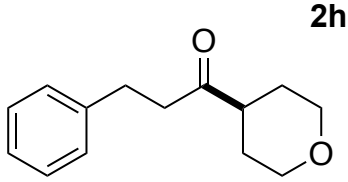
2h

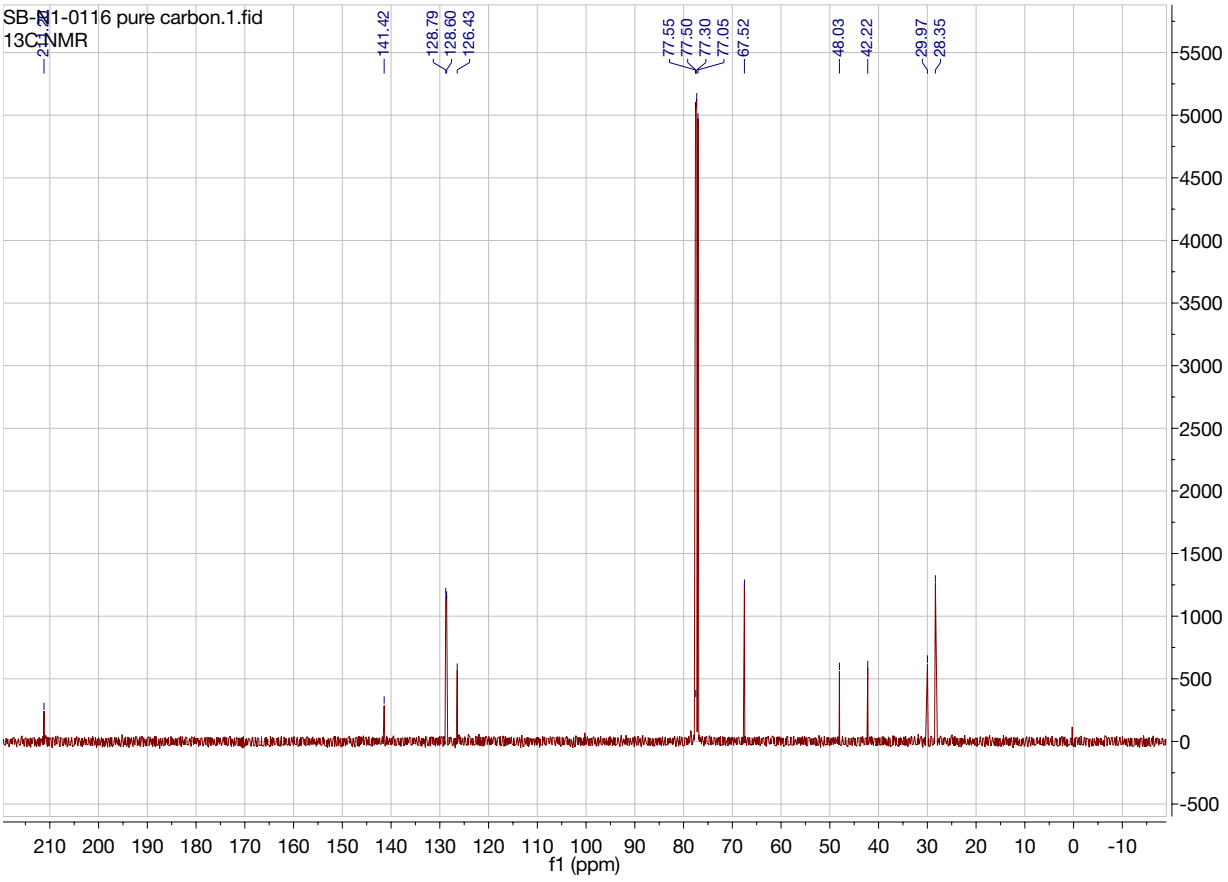




^{13}C NMR ($CDCl_3$, 126 MHz) of 3-phenyl-1-(tetrahydro-2*H*-pyran-4-yl)propan-1-one **(2h)**

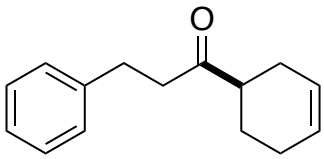
2h

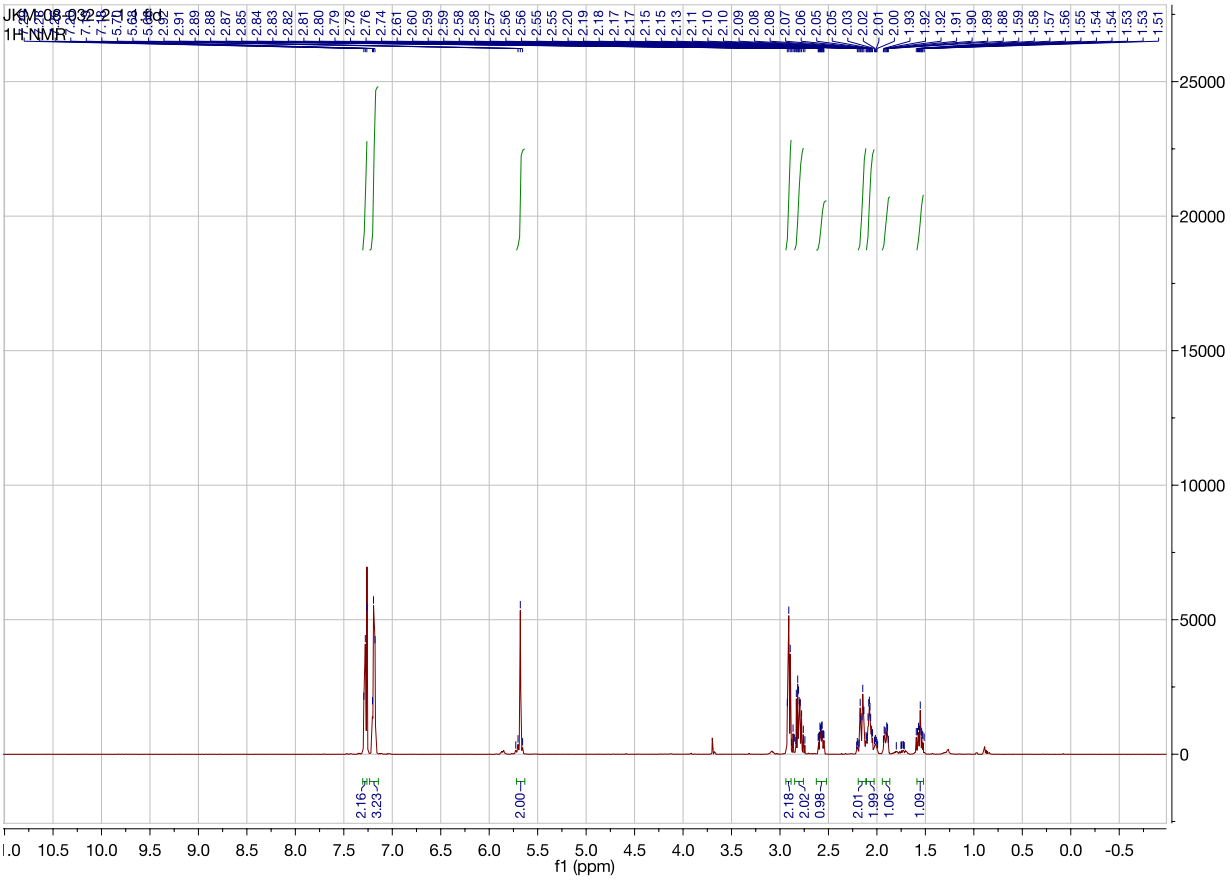




^{1}H NMR ($CDCl_3$, 500 MHz) of (R)-1-(Cyclohex-3-en-1-yl)-3-phenylpropan-1-one **(2i)**

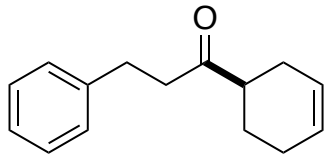
2i

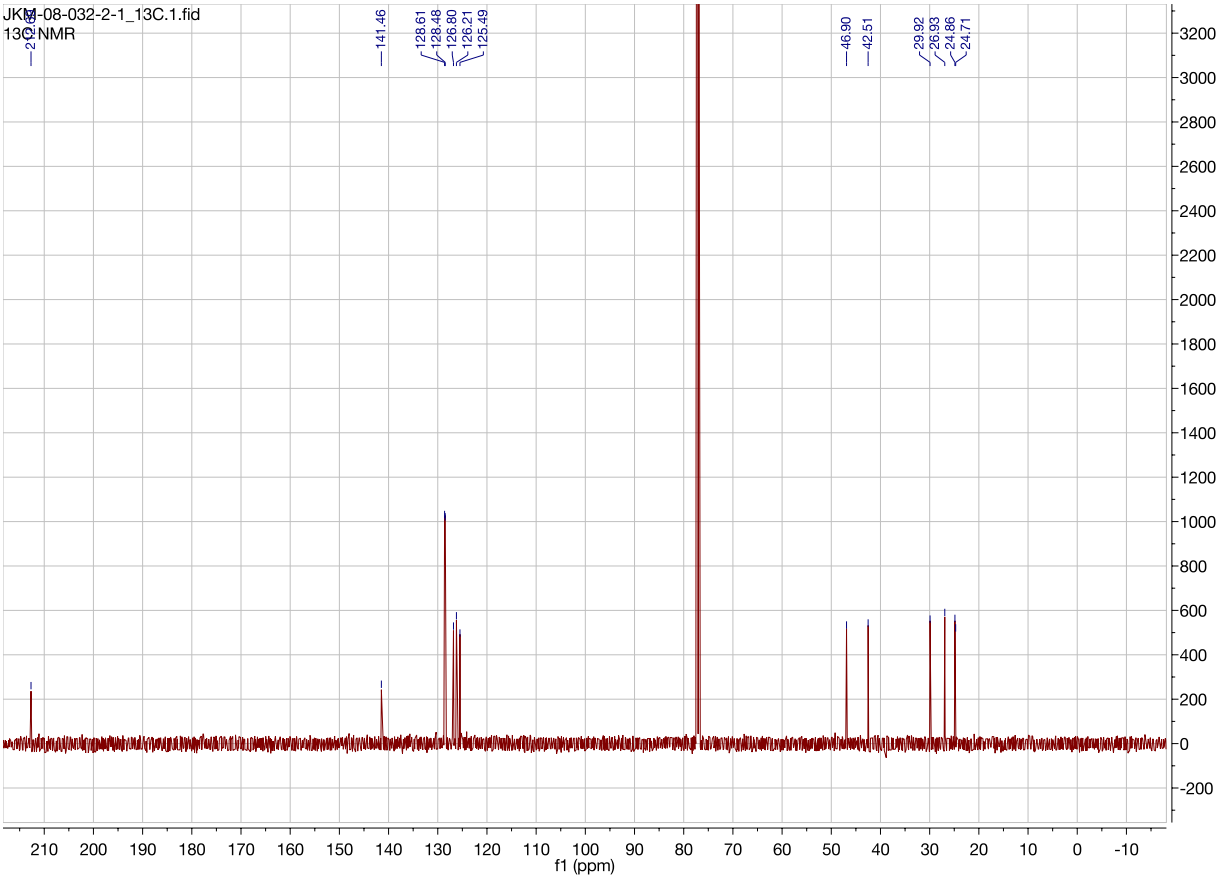




^{13}C NMR ($CDCl_3$, 126 MHz) of (R)-1-(Cyclohex-3-en-1-yl)-3-phenylpropan-1-one **(2i)**

2i

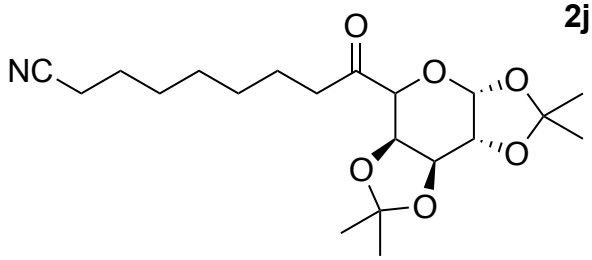


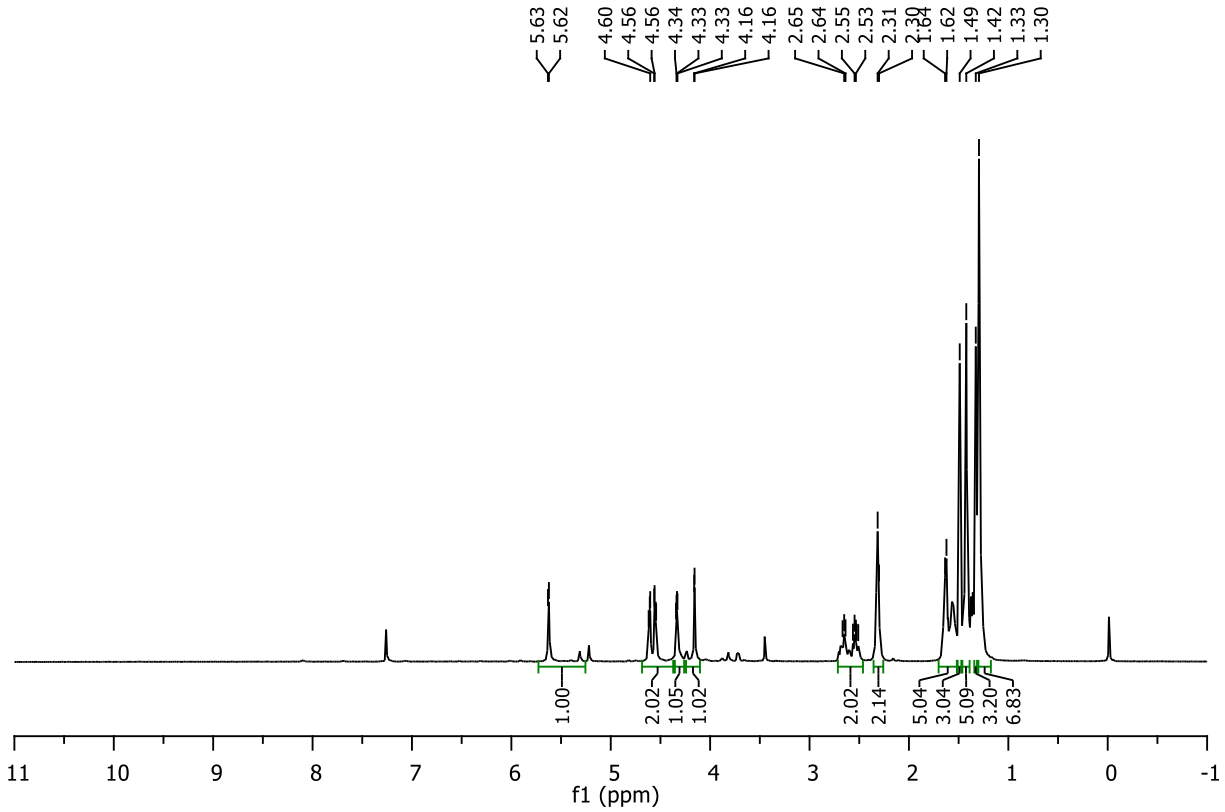


8.3 Spectra for carboxylic acids scope:

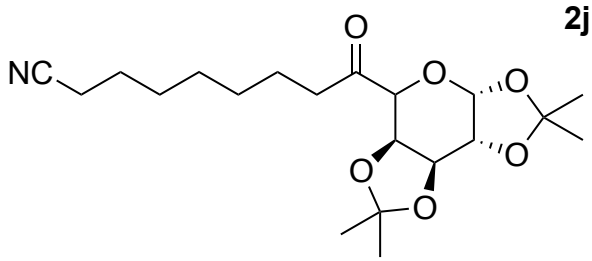
^{1}H NMR ($CDCl_3$, 500 MHz) of 9-oxo-9-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonanenitrile (**2j**)

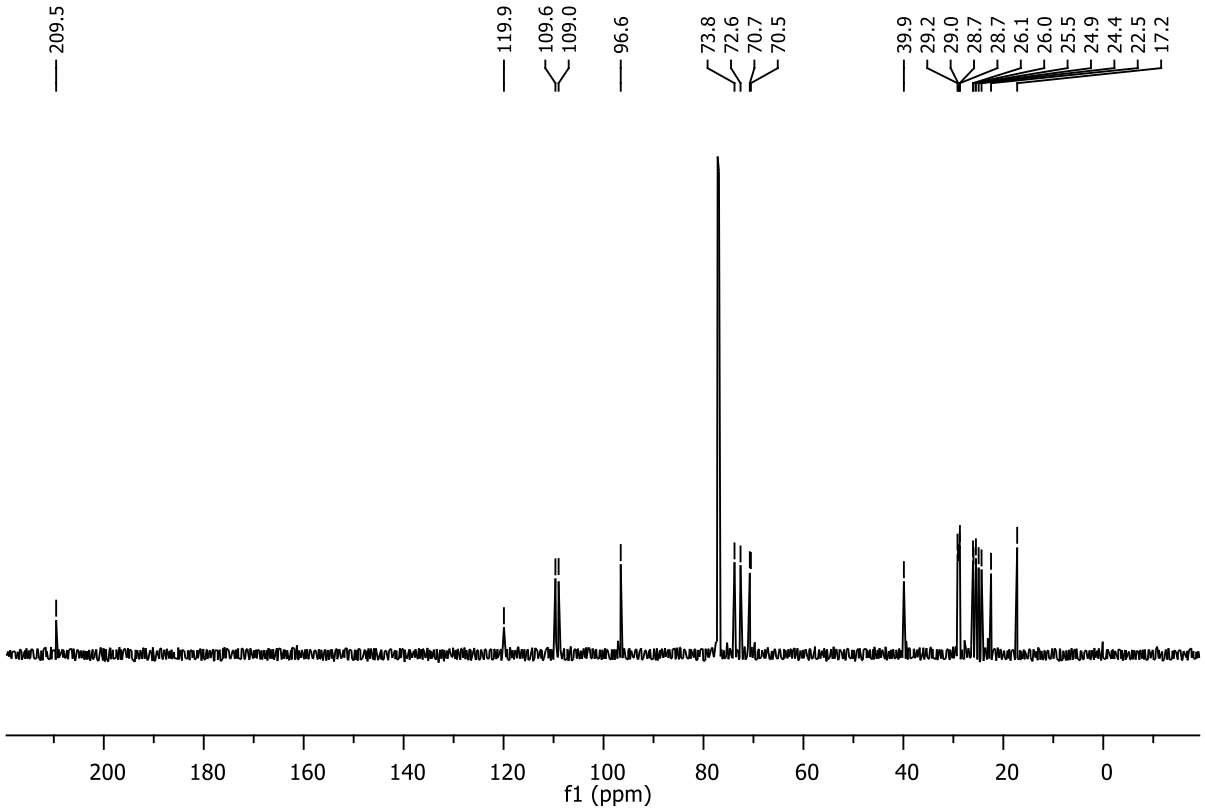
2j



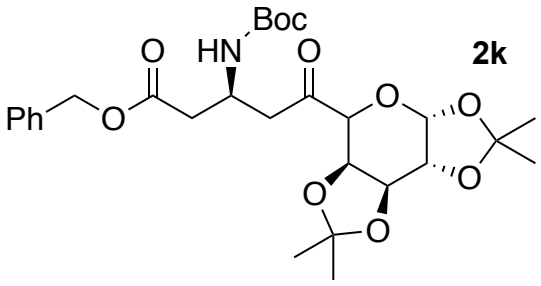


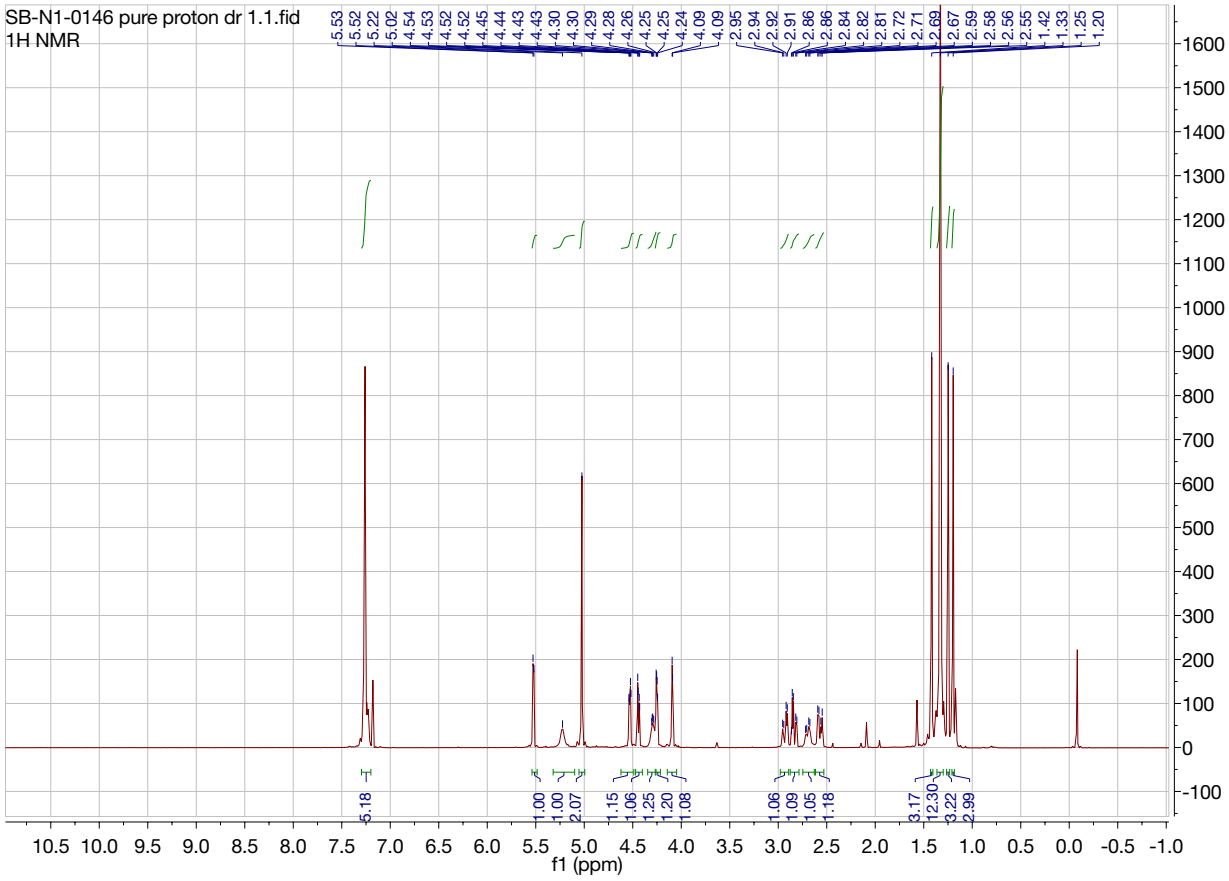
^{13}C NMR ($CDCl_3$, 126 MHz) of 9-oxo-9-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonanenitrile (**2j**)



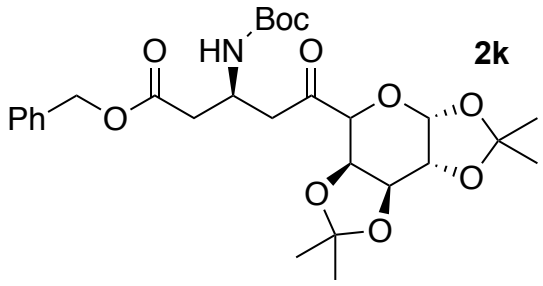


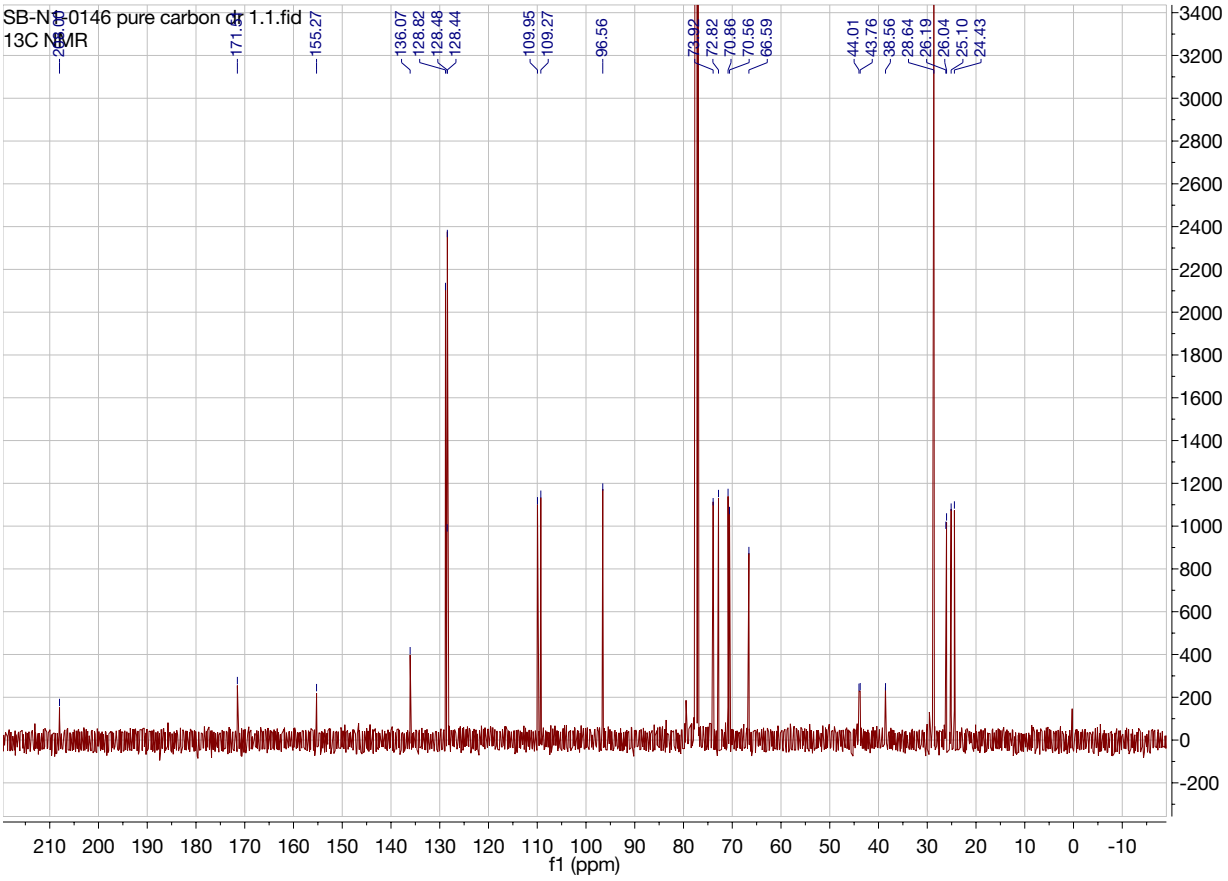
^{1}H NMR ($CDCl_3$, 500 MHz) of benzyl (3*S*)-3-((*tert*-butoxycarbonyl)amino)-5-oxo-5-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)pentanoate **(2k)**





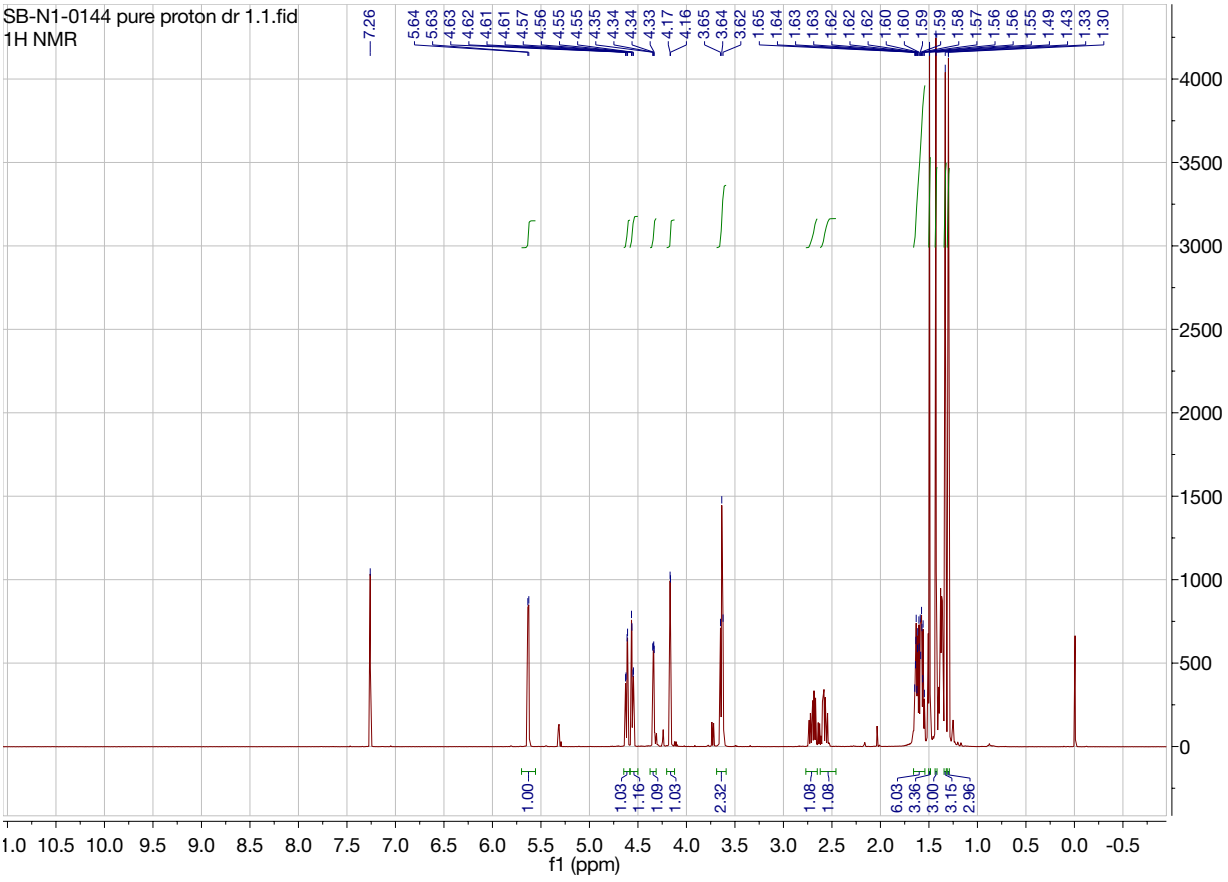
^{13}C NMR ($CDCl_3$, 126 MHz) of benzyl (3*S*)-3-((*tert*-butoxycarbonyl)amino)-5-oxo-5-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)pentanoate **(2k)**





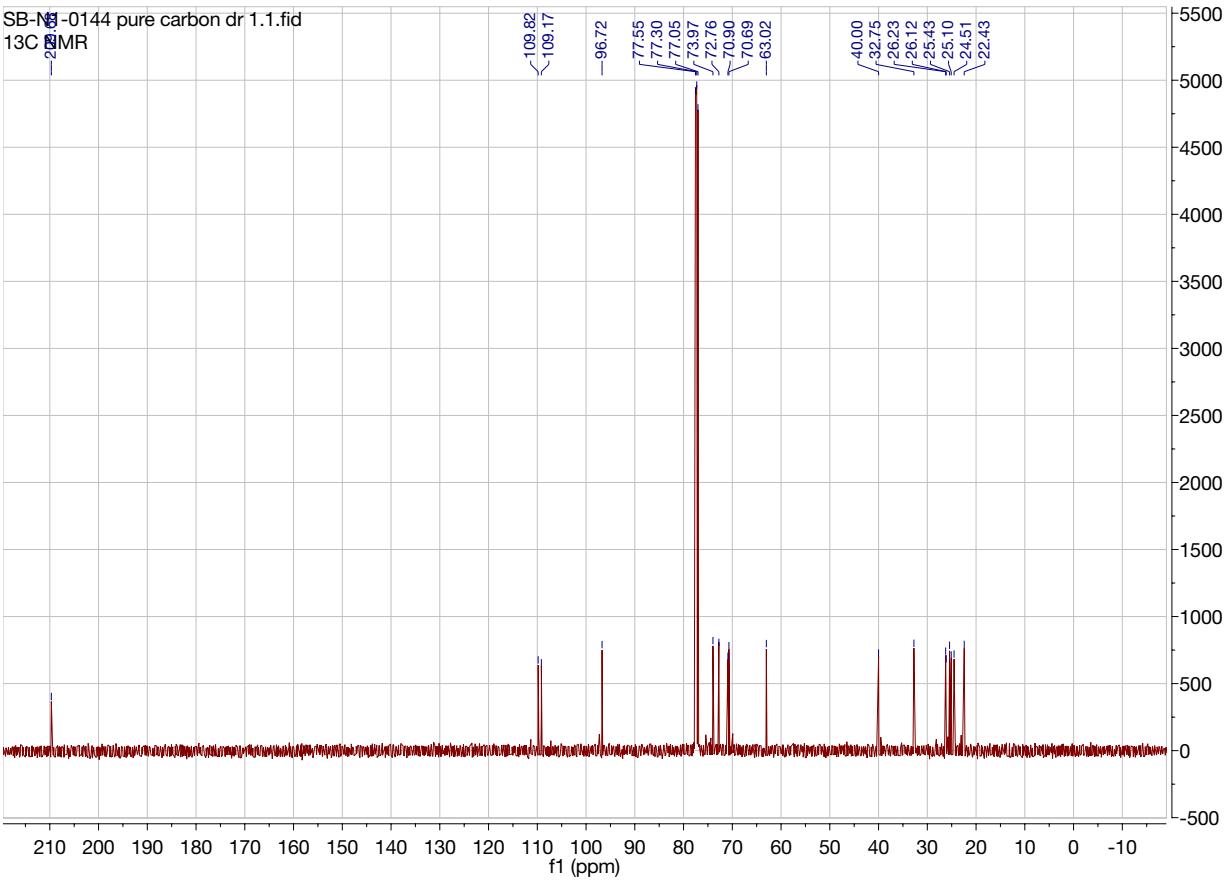
^{1}H NMR ($CDCl_3$, 500 MHz) of 6-hydroxy-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)hexan-1-one **(2l)**

2l

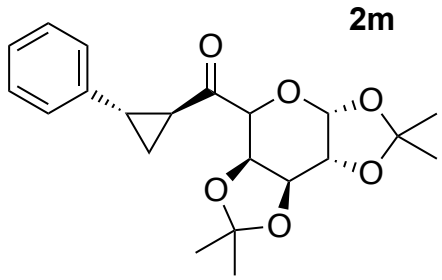


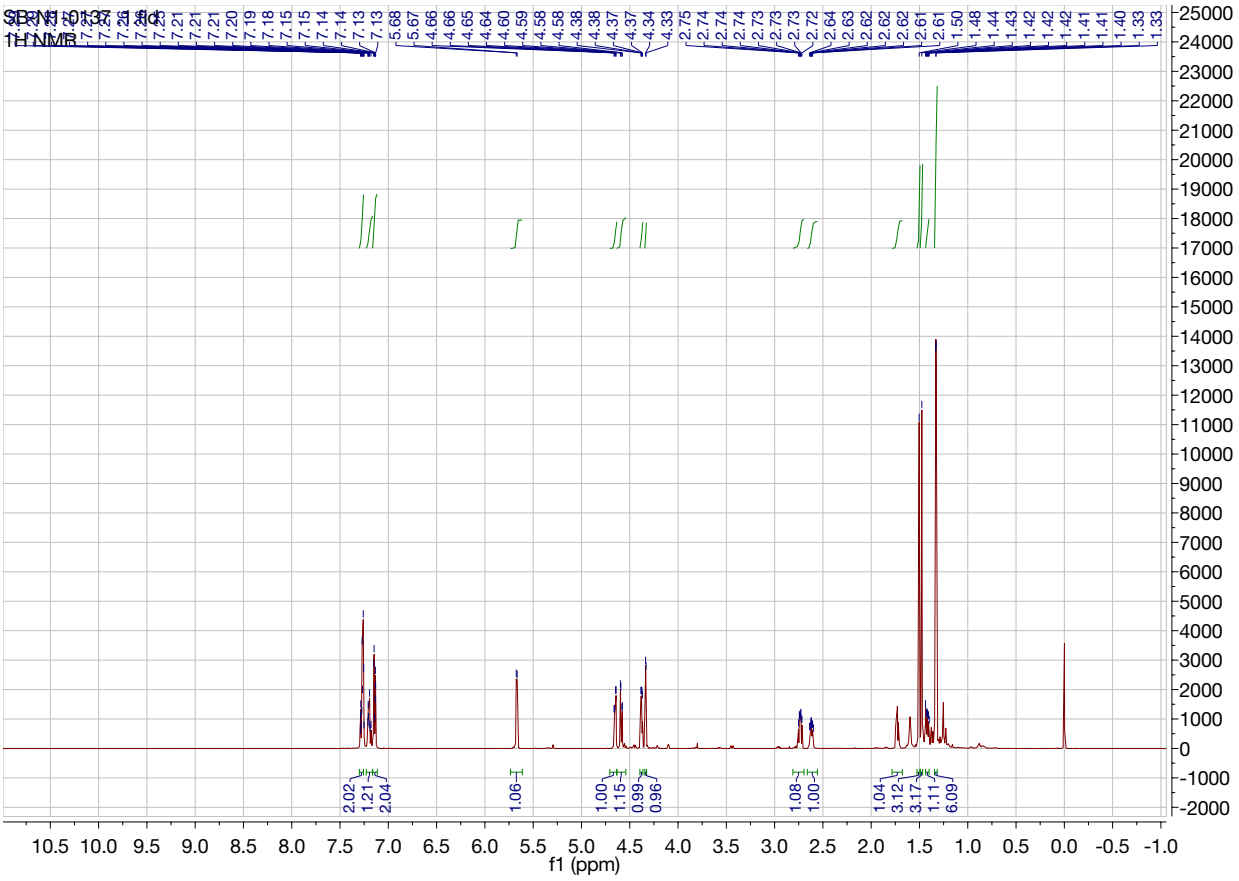
^{13}C NMR ($CDCl_3$, 126 MHz) of 6-hydroxy-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)hexan-1-one **(2l)**

2l

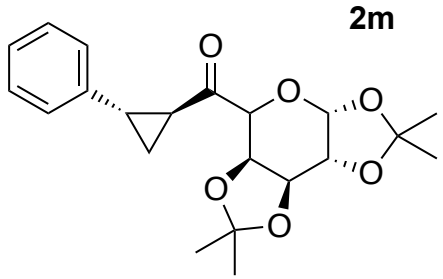


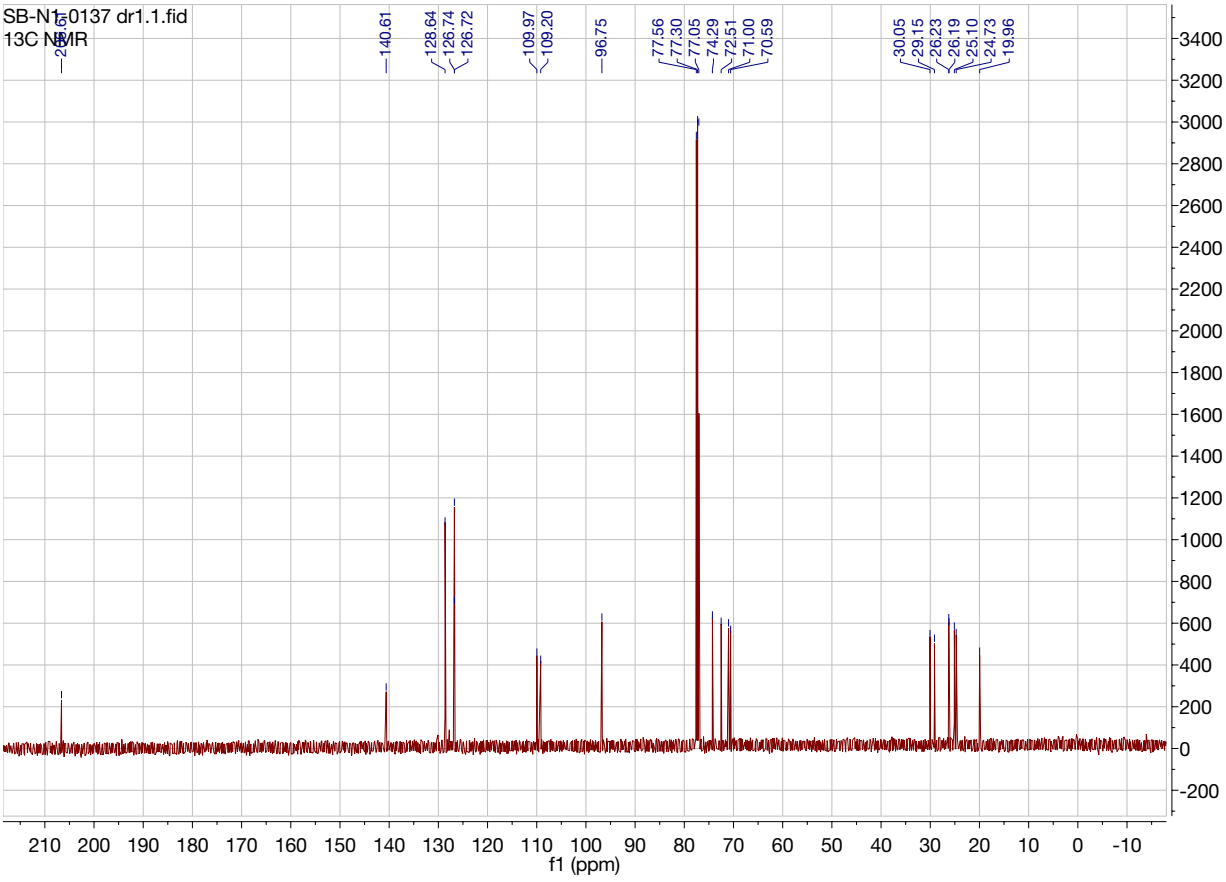
^{1}H NMR ($CDCl_3$, 500 MHz) of ((1*S*,2*S*)-2-phenylcyclopropyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)methanone **(2m)**



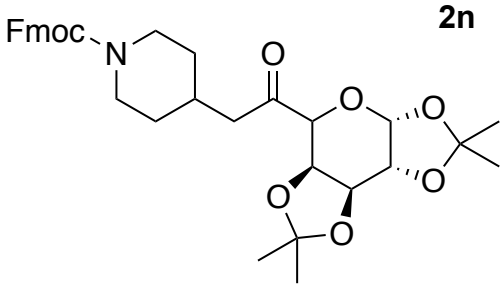


^{13}C NMR ($CDCl_3$, 126 MHz) of ((1*S*,2*S*)-2-phenylcyclopropyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)methanone **(2m)**

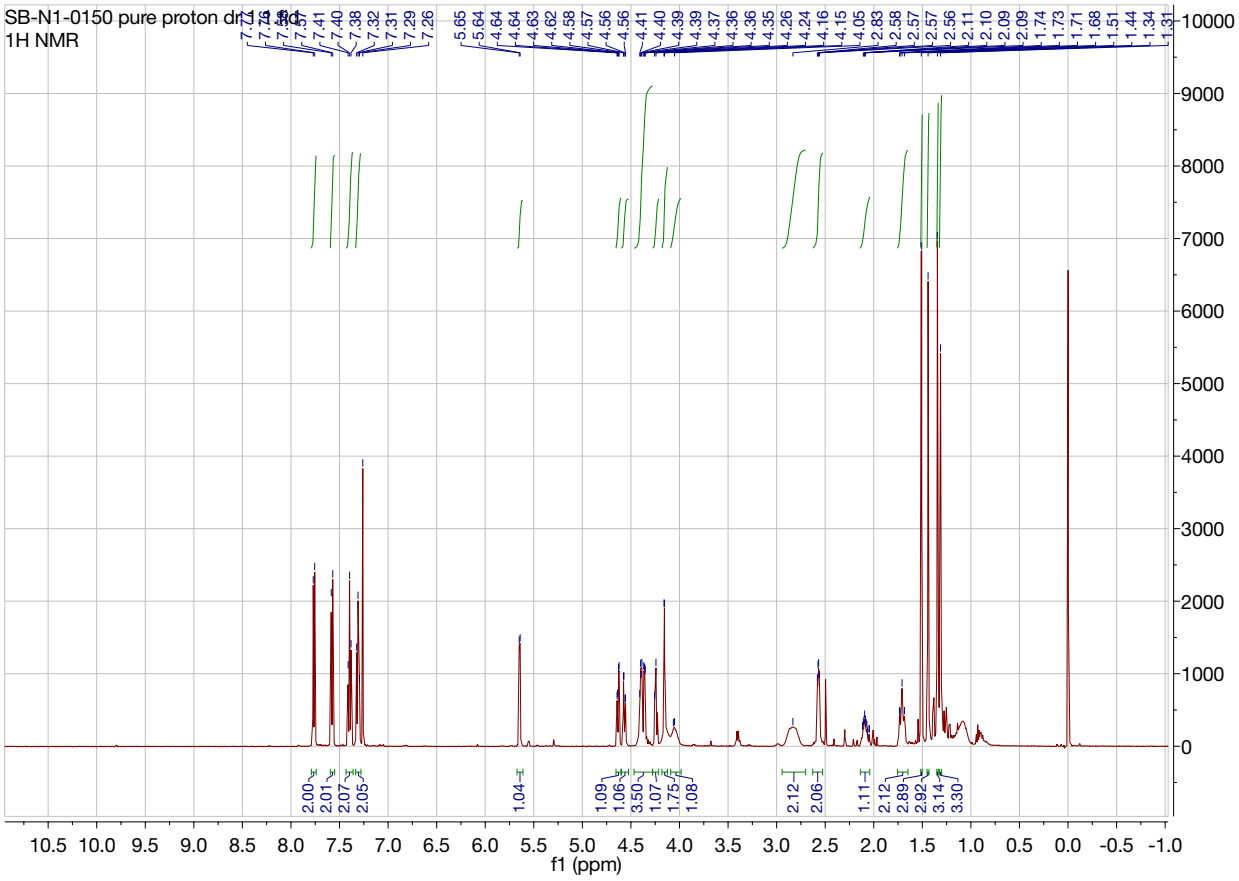




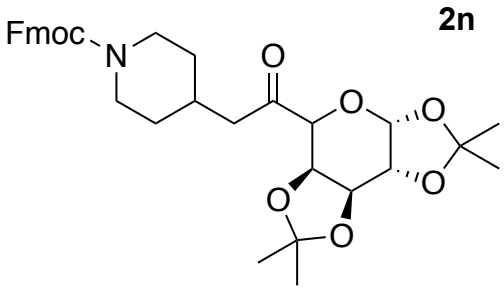
^{1}H NMR ($CDCl_3$, 500 MHz) of **(**9*H*-fluoren-9-yl)methyl 4-(2-oxo-2-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethyl)piperidine-1-carboxylate **(2n)**

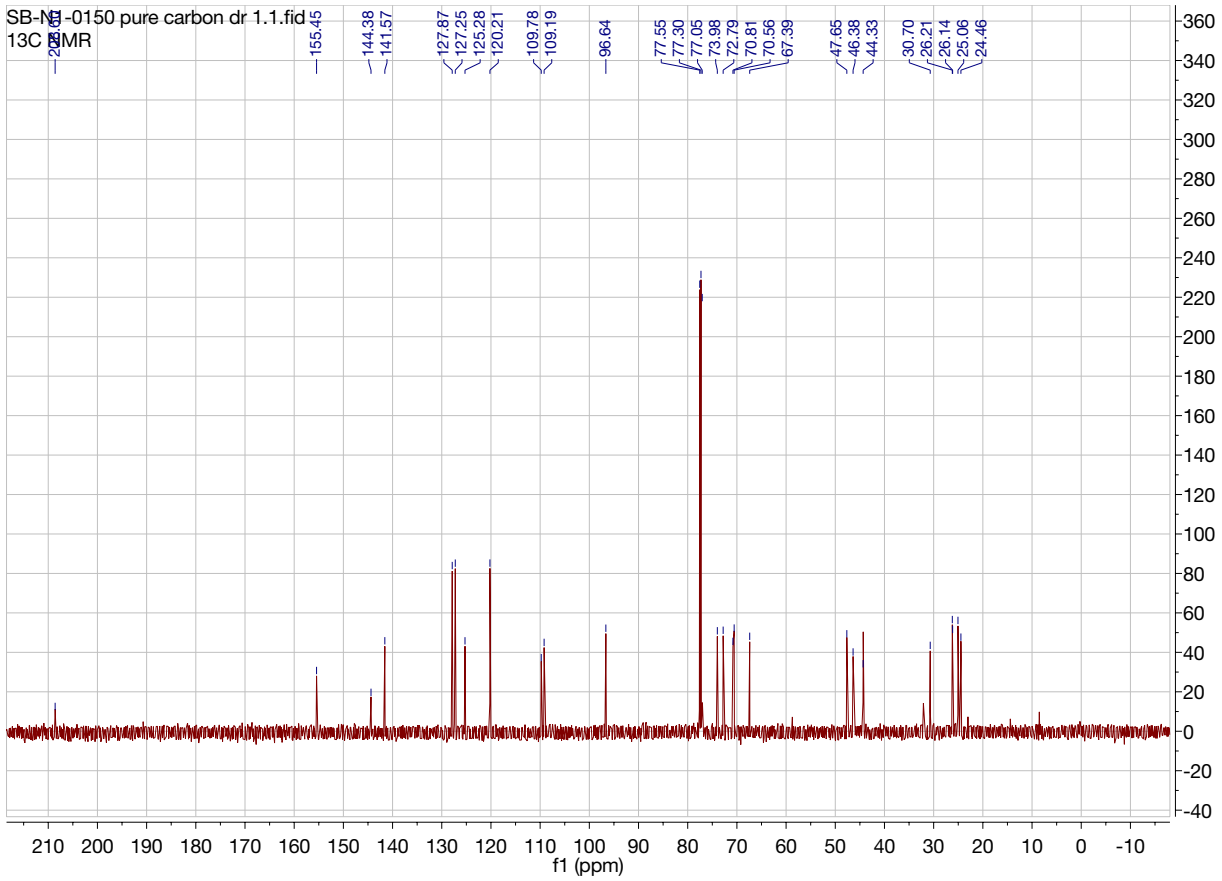


2n

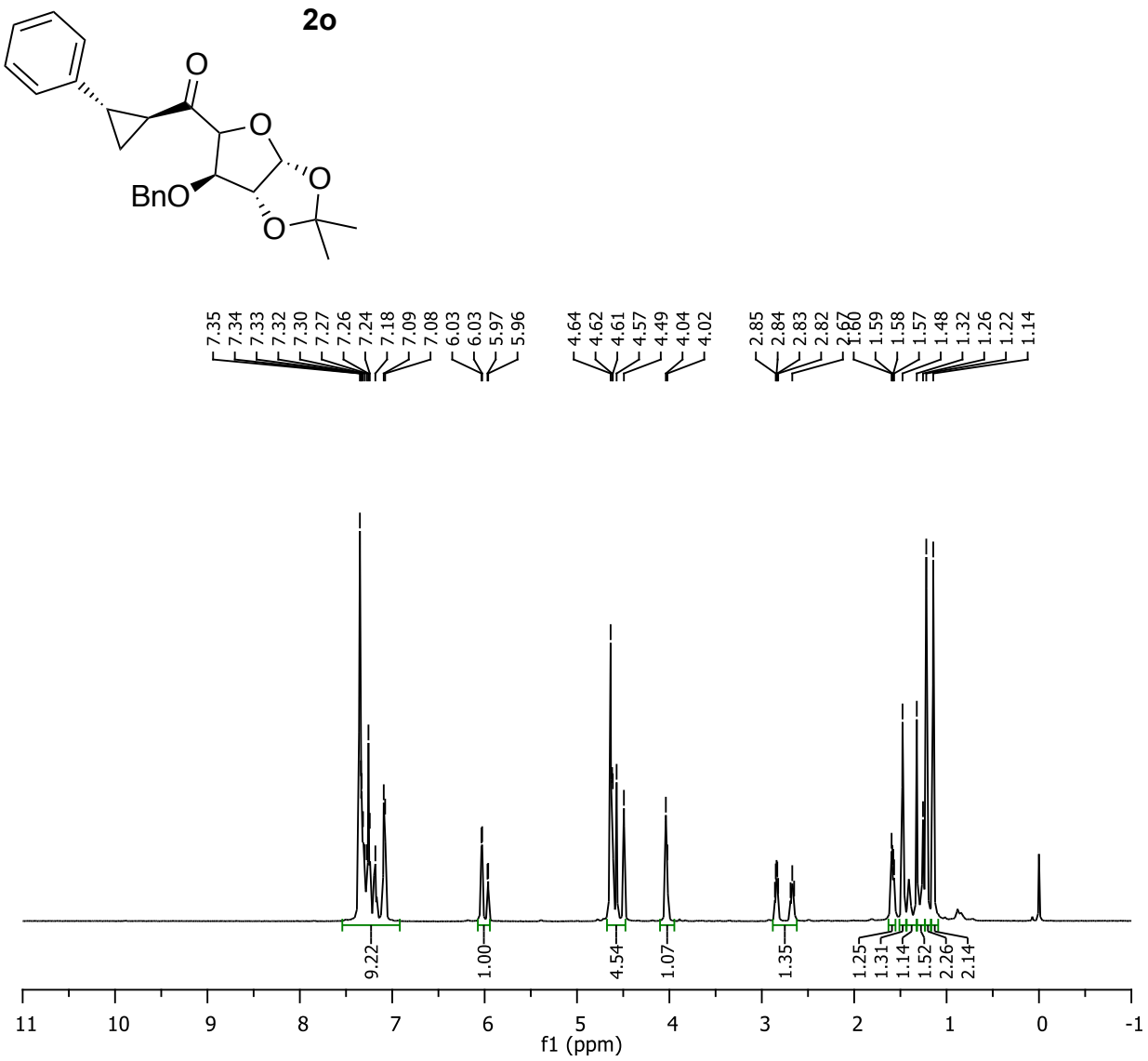


^{13}C NMR ($CDCl_3$, 126 MHz) of **(**9*H*-fluoren-9-yl)methyl 4-(2-oxo-2-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethyl)piperidine-1-carboxylate **(2n)**

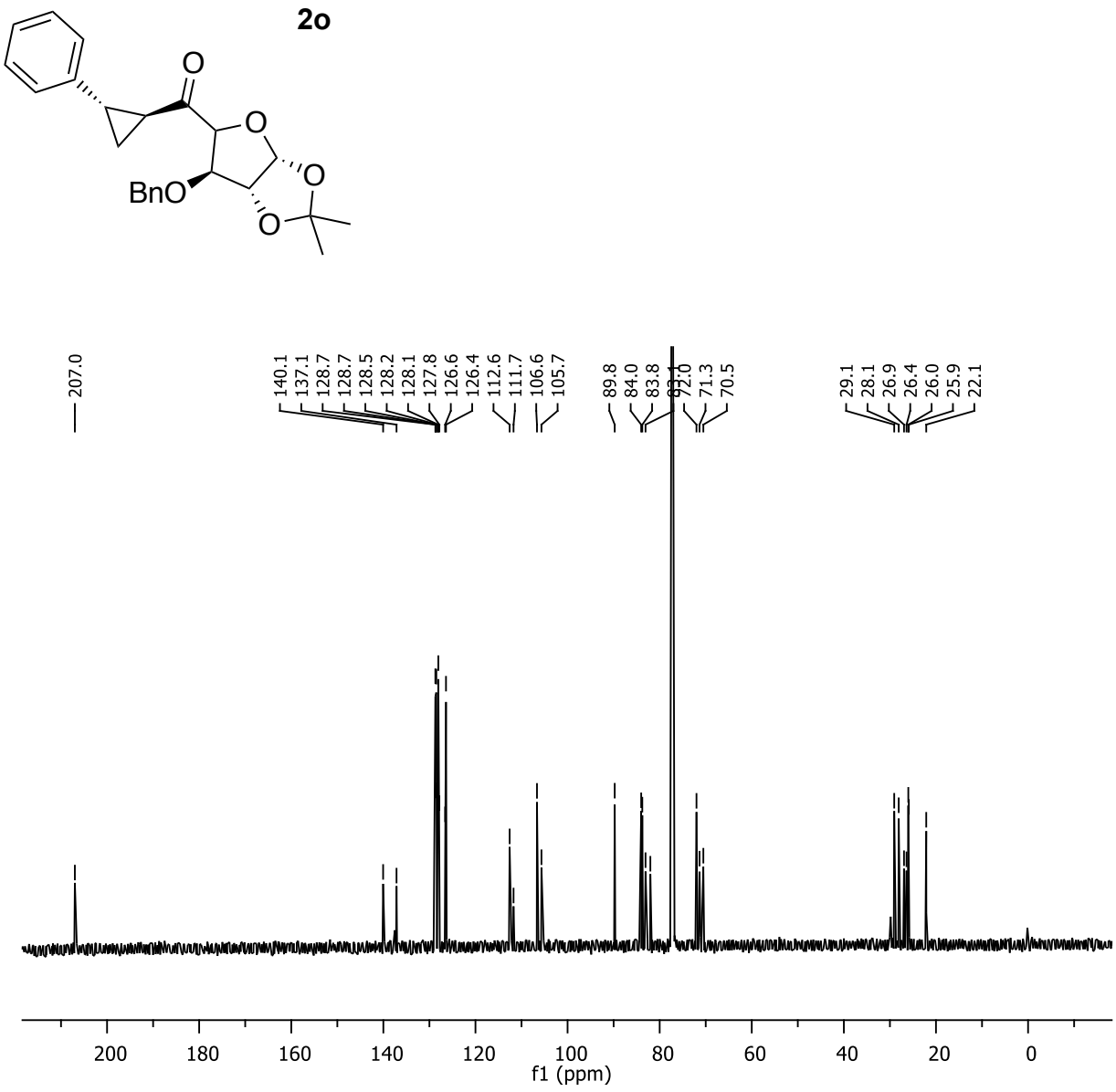




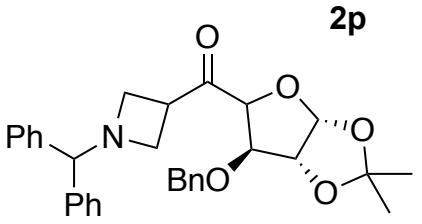
^{1}H NMR ($CDCl_3$, 500 MHz) of ((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)((1S,2S)-2-phenylcyclopropyl)methanone (**2o)**

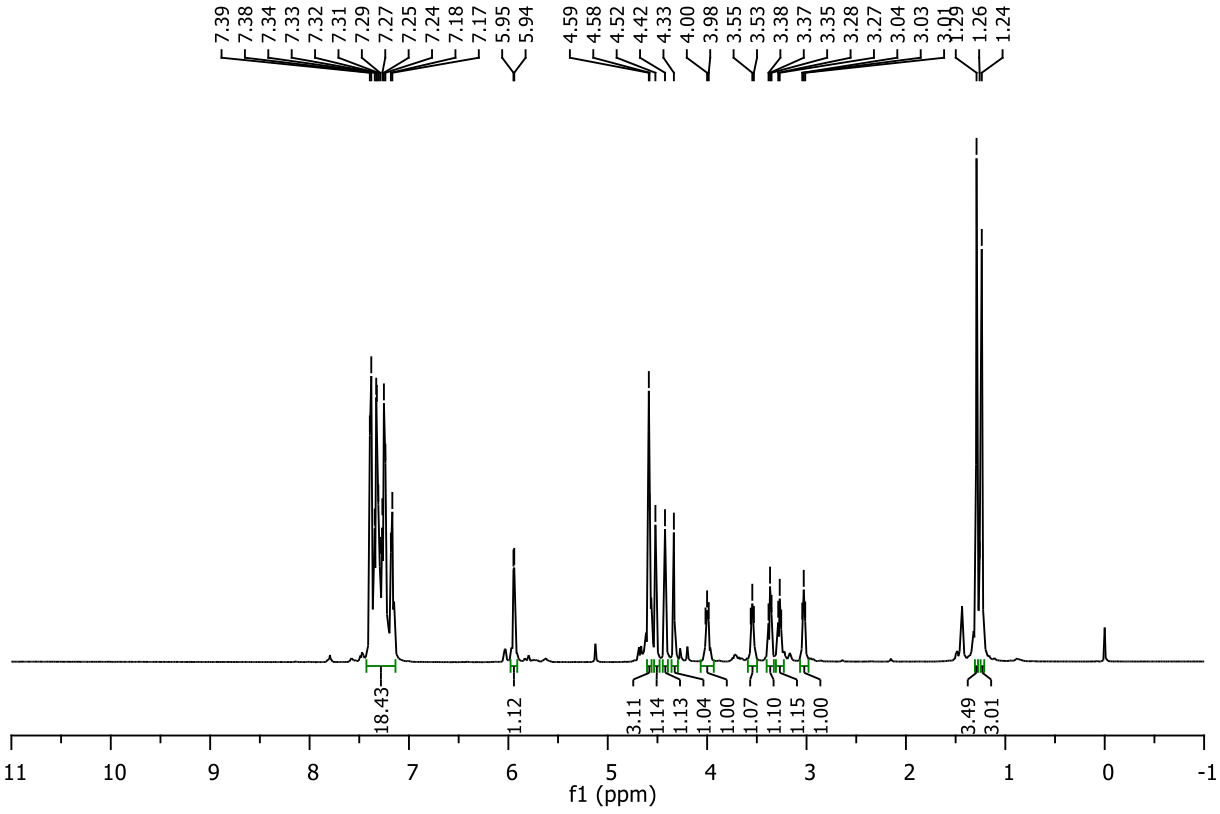


^{13}C NMR ($CDCl_3$, 126 MHz) of ((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)((1S,2S)-2-phenylcyclopropyl)methanone (**2o**)

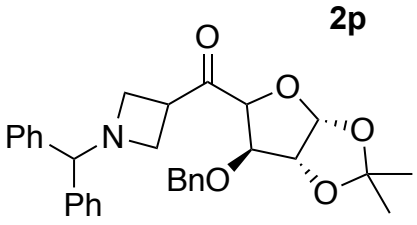


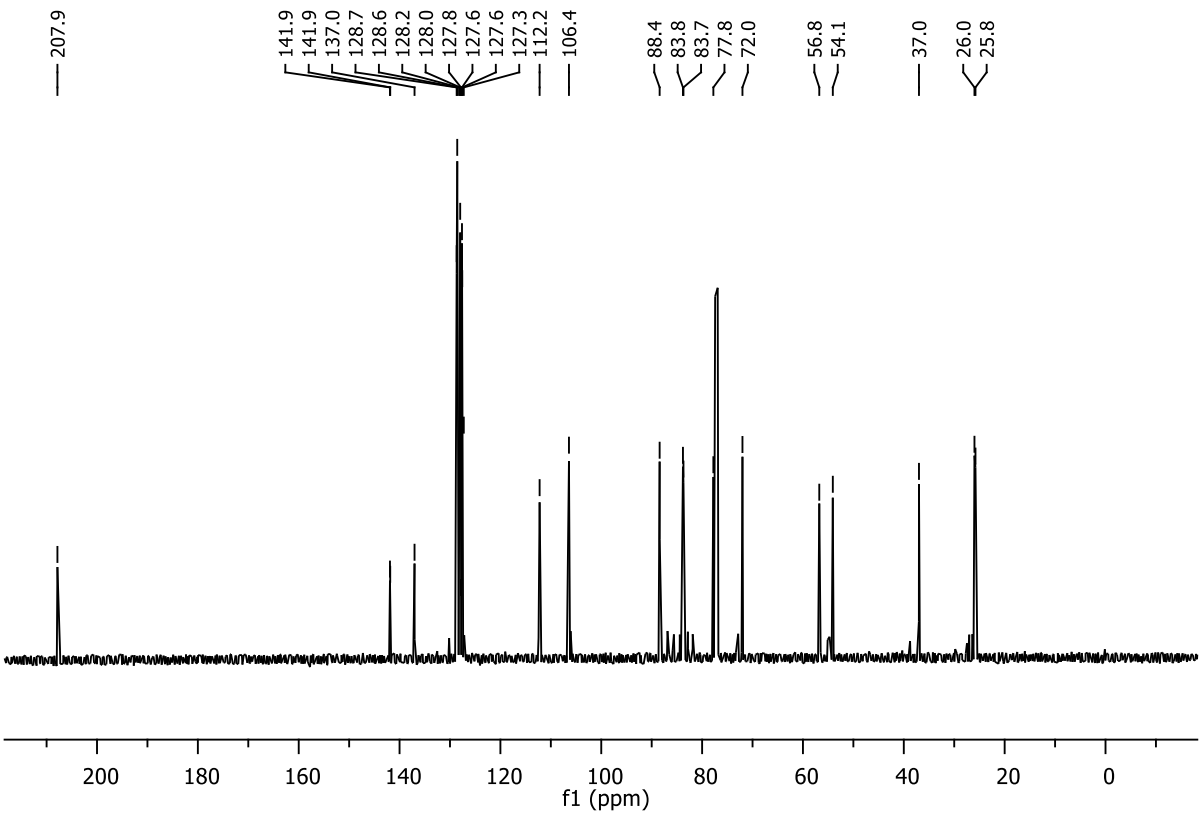
^{1}H NMR ($CDCl_3$, 500 MHz) of (1-benzhydrylazetidin-3-yl)((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d] [1,3]dioxol-5-yl)methanone (**2p**) (major diastereomer)



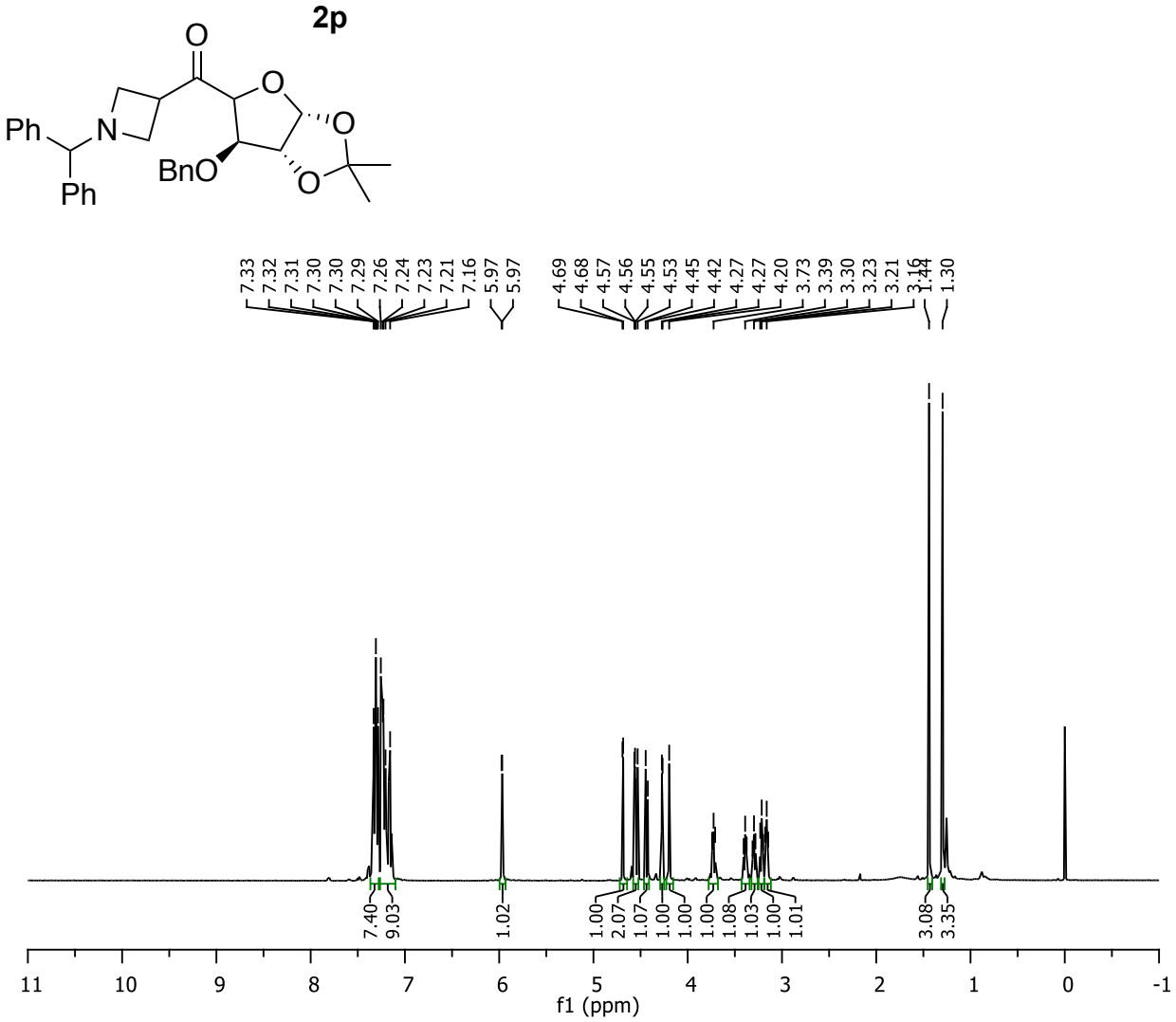


^{13}C NMR ($CDCl_3$, 126 MHz) of (1-benzhydrylazetidin-3-yl)((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d] [1,3]dioxol-5-yl)methanone (**2p**) (major diastereomer)

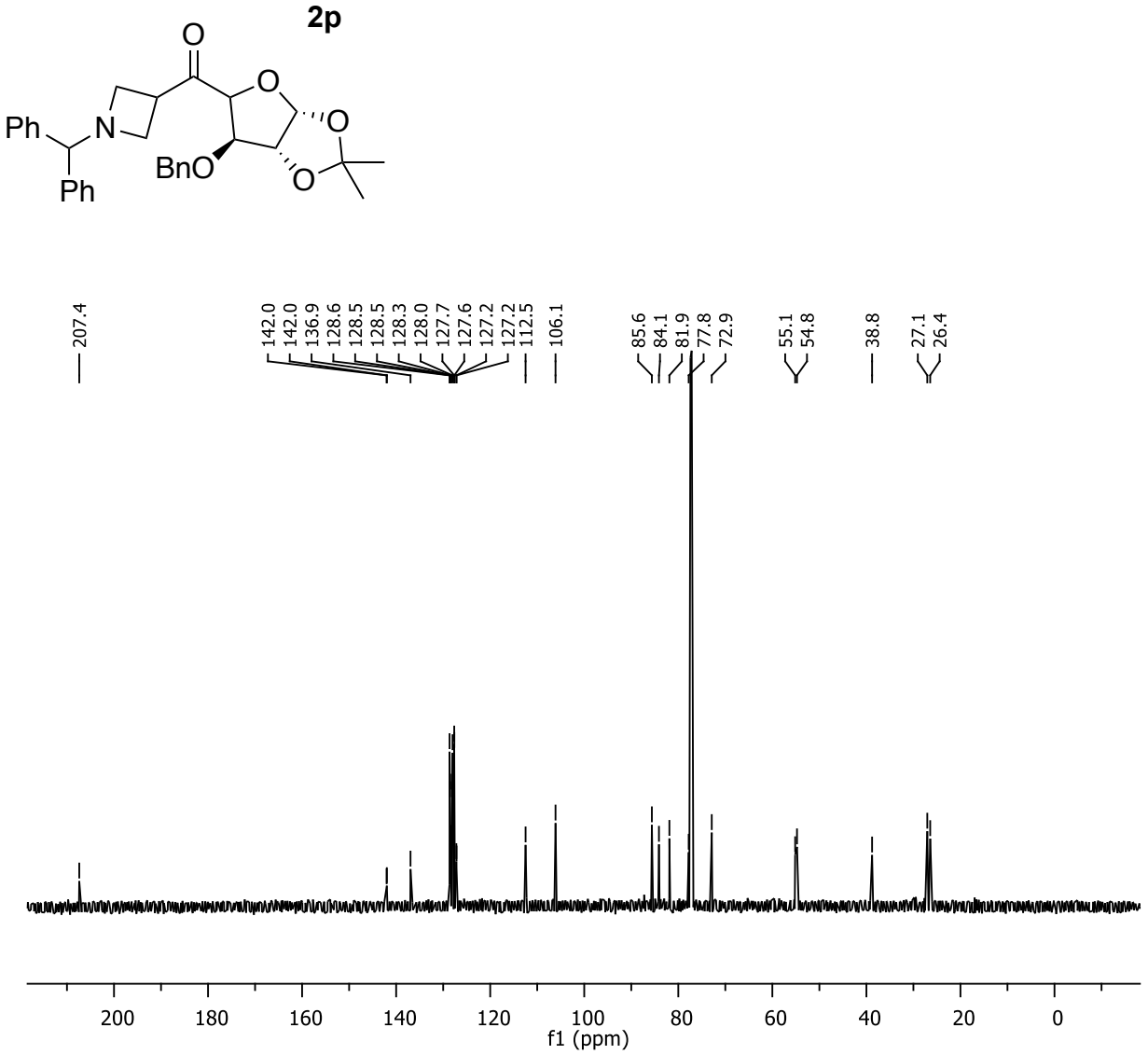




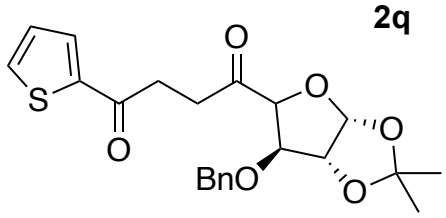
^{1}H NMR ($CDCl_3$, 500 MHz) of (1-benzhydrylazetidin-3-yl)((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d] [1,3]dioxol-5-yl)methanone (**2p**) (minor diastereomer)

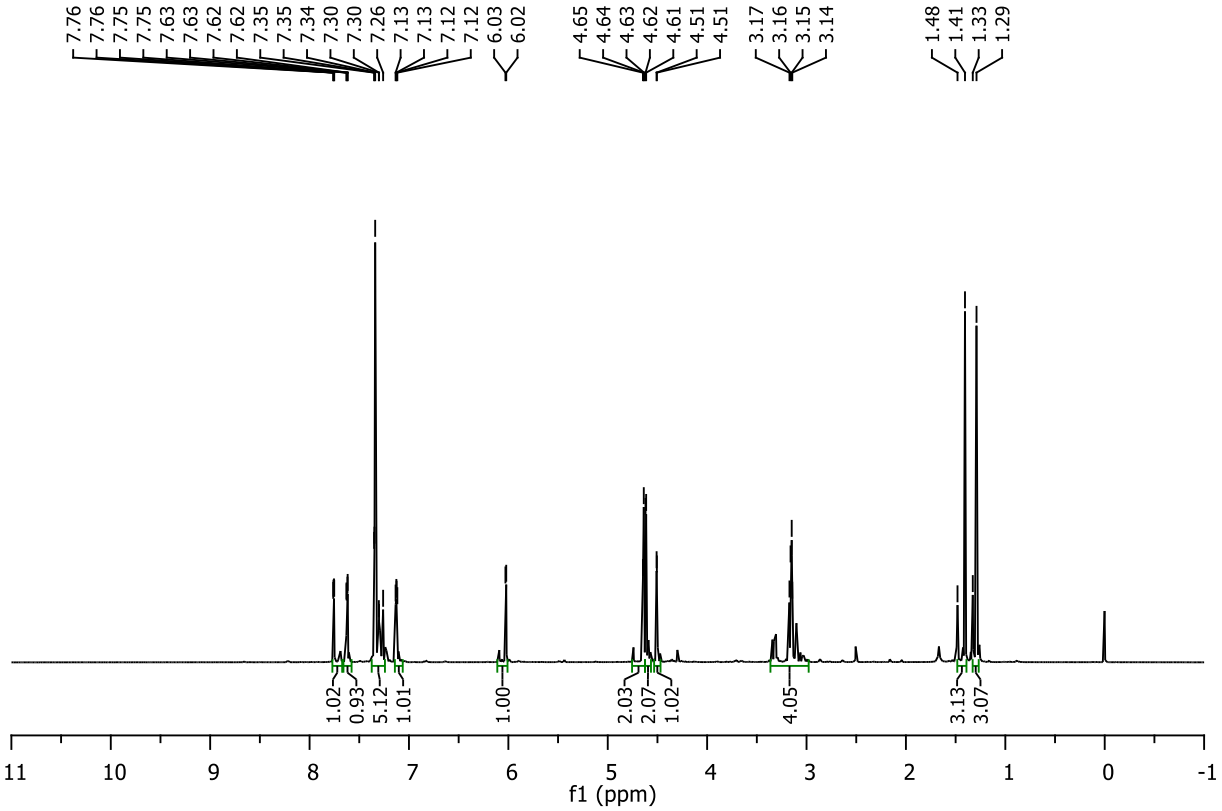


^{13}C NMR ($CDCl_3$, 126 MHz) of (1-benzhydrylazetidin-3-yl)((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d] [1,3]dioxol-5-yl)methanone (**2p**) (minor diastereomer)

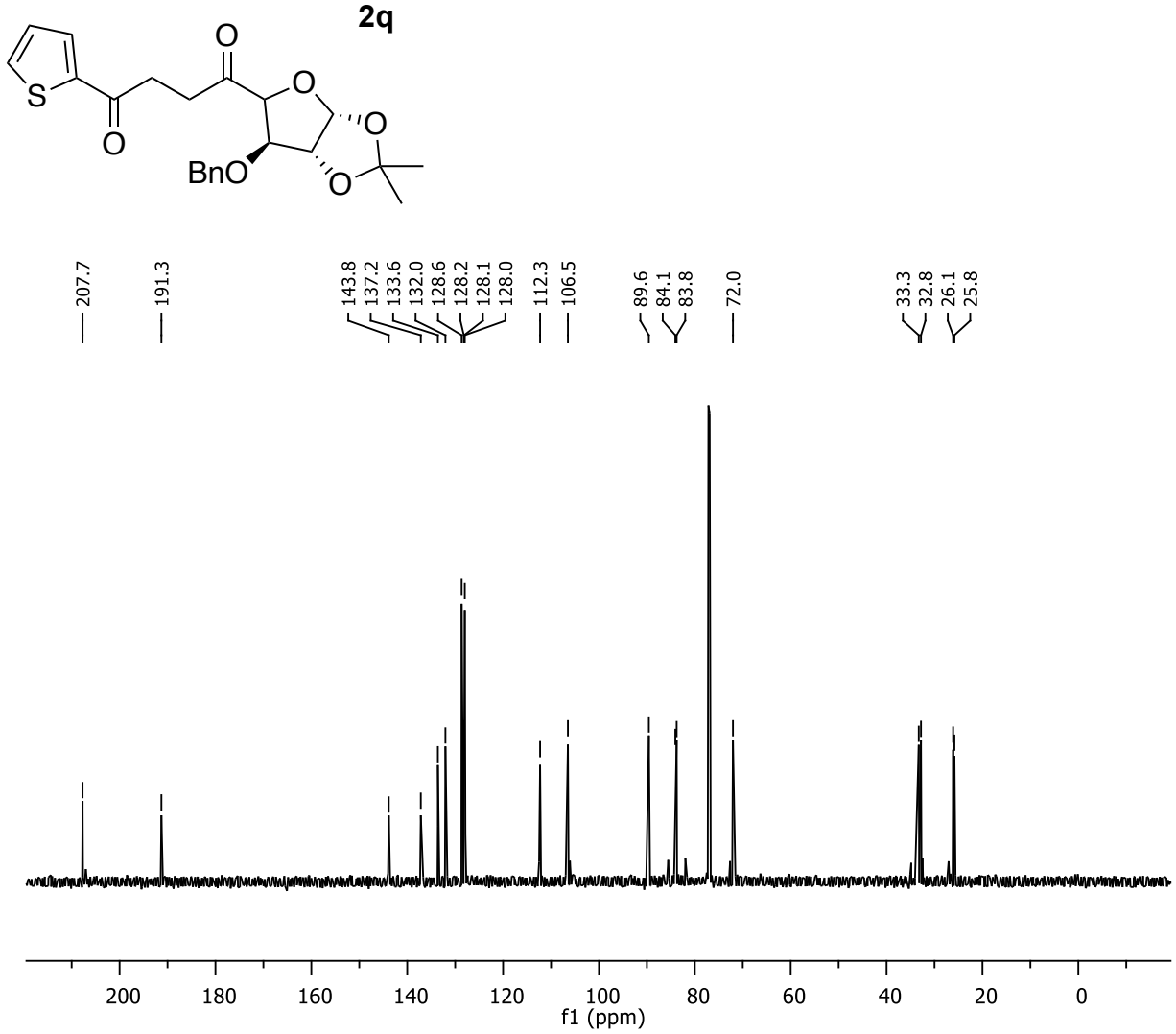


^{1}H NMR ($CDCl_3$, 500 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-4-(thiophen-2-yl)butane-1,4-dione (**2q**)

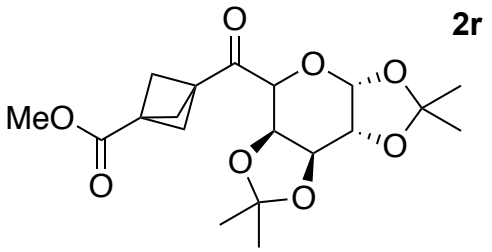


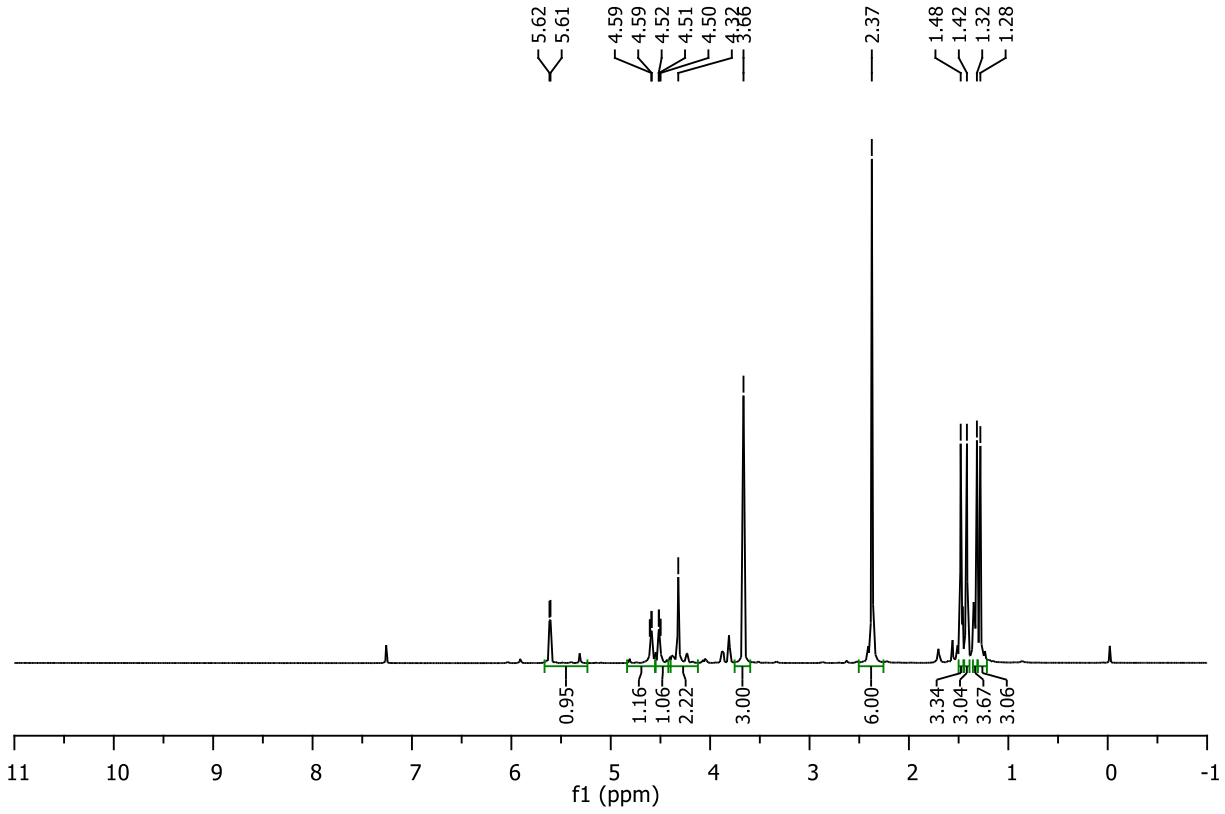


^{13}C NMR ($CDCl_3$, 126 MHz) of 1-((3a*R*,6*R*,6a*R*)-6-(benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-4-(thiophen-2-yl)butane-1,4-dione (**2q**)

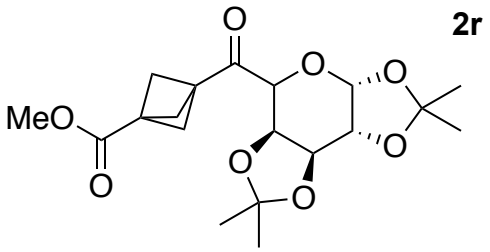


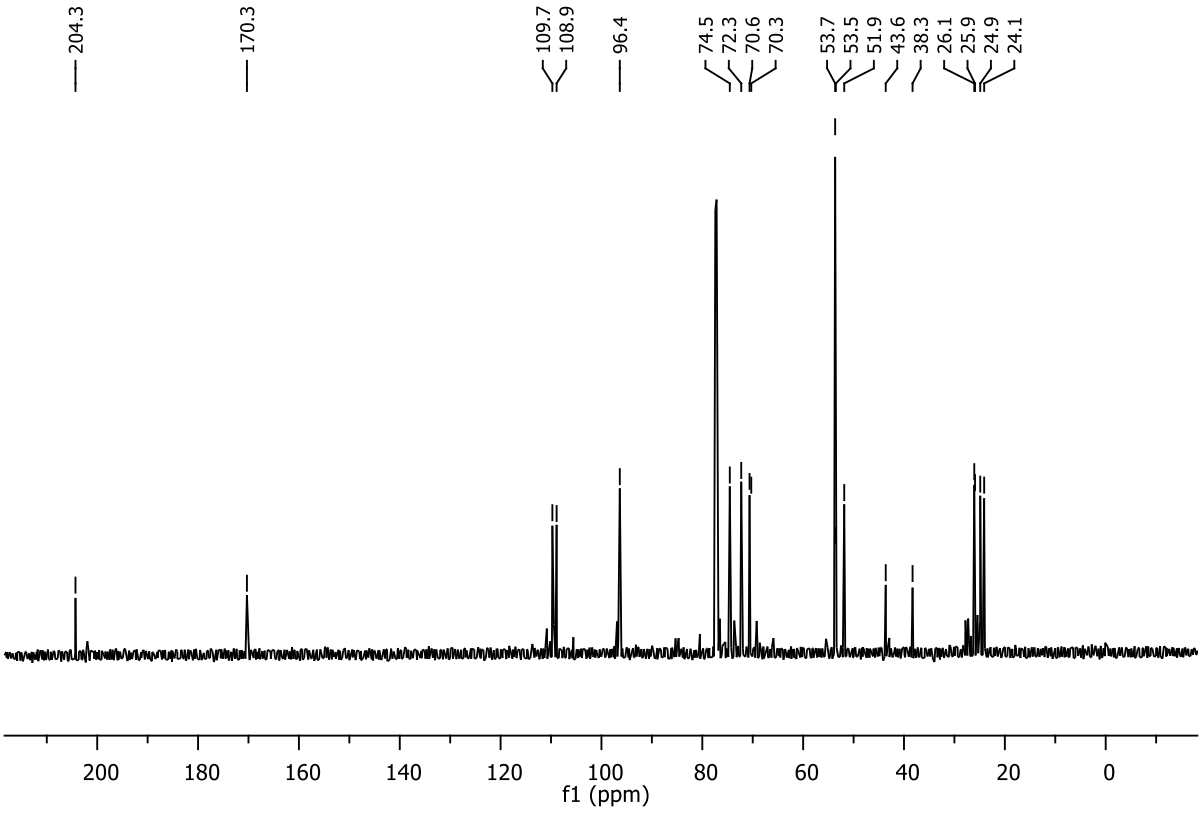
^{1}H NMR ($CDCl_3$, 500 MHz) of methyl 3-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-carbonyl)bicyclo[1.1.1]pentane-1-carboxylate (**2r**)



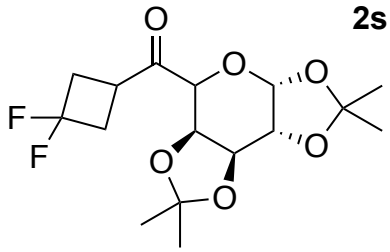


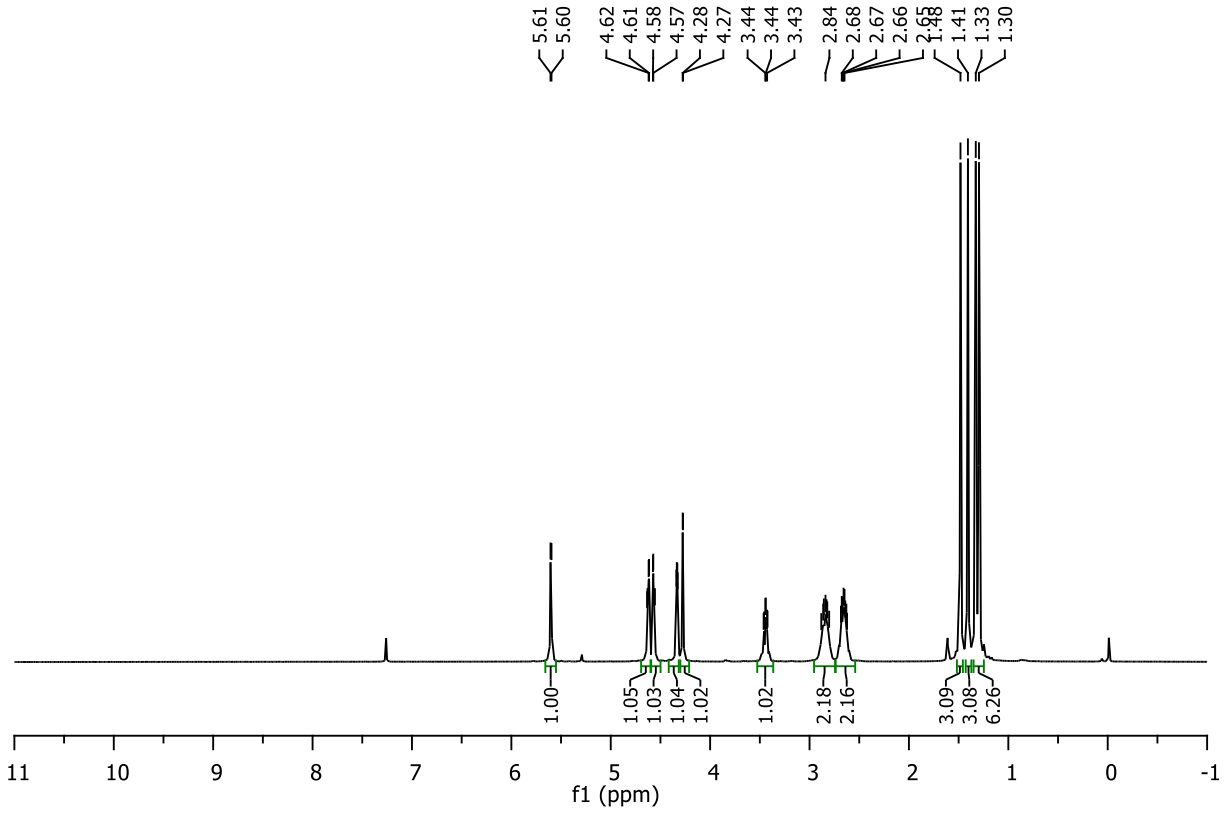
^{13}C NMR ($CDCl_3$, 126 MHz) of methyl 3-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-carbonyl)bicyclo[1.1.1]pentane-1-carboxylate (**2r**)



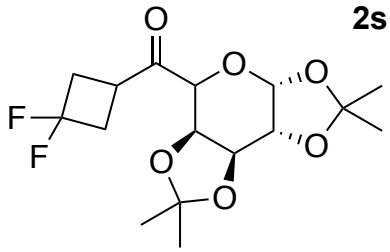


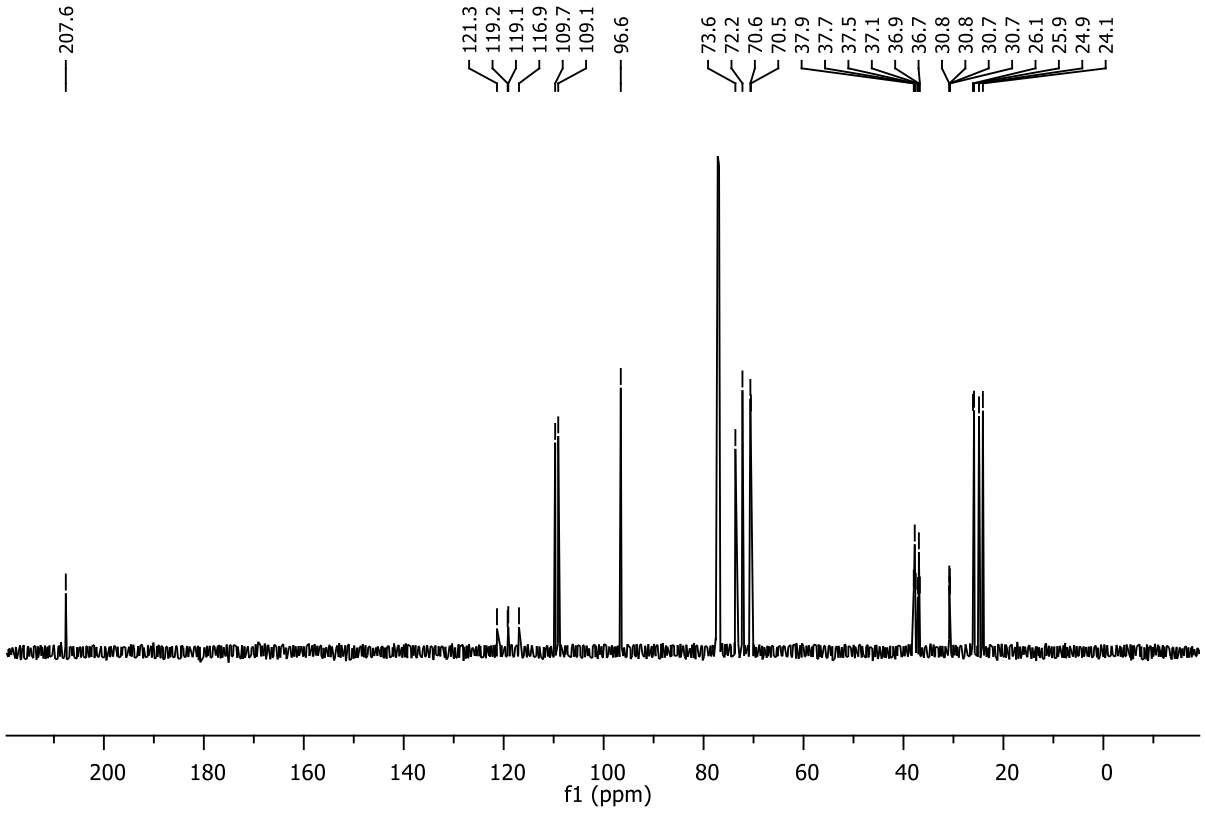
^{1}H NMR ($CDCl_3$, 500 MHz) of (3,3-difluorocyclobutyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo) [4,5-b:4',5'-d]pyran-5-yl)methanone (**2s**)



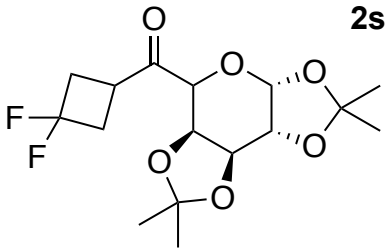


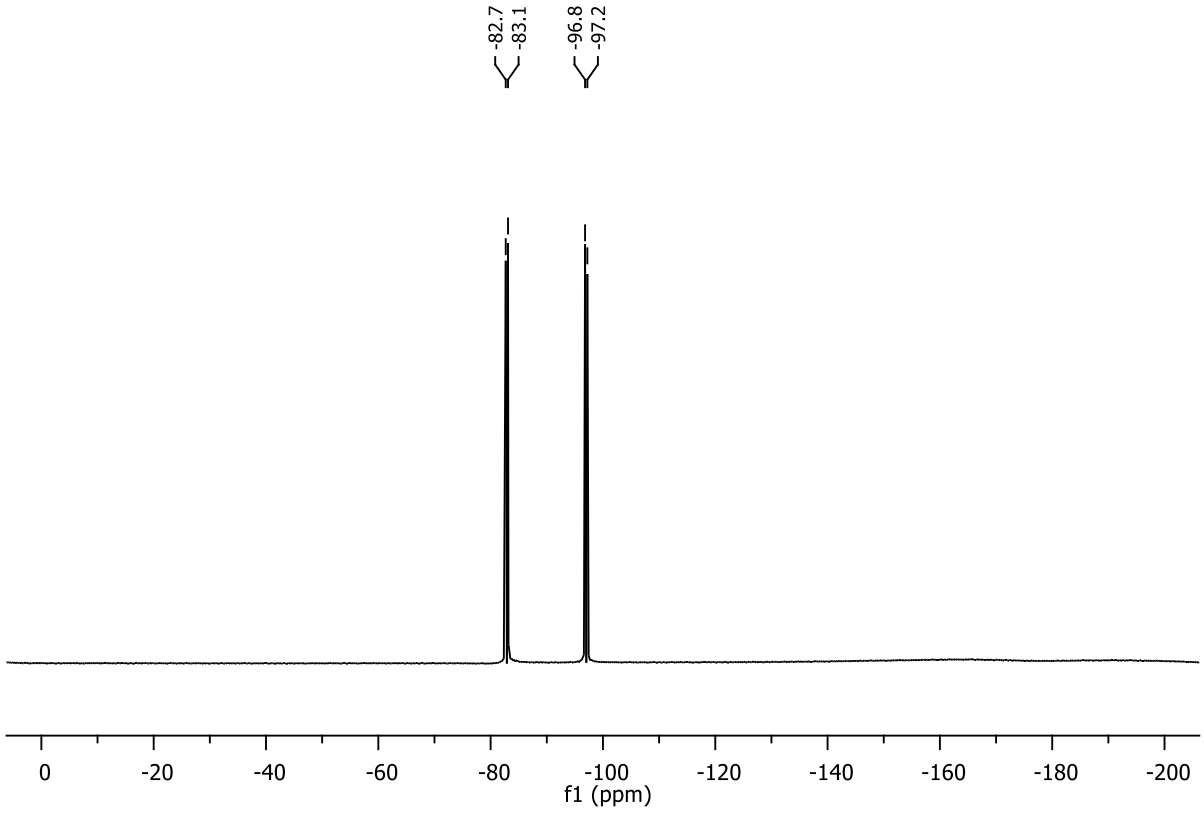
^{13}C NMR ($CDCl_3$, 126 MHz) of (3,3-difluorocyclobutyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo) [4,5-b:4',5'-d]pyran-5-yl)methanone (**2s**)



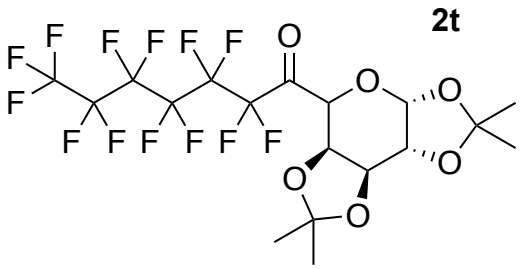


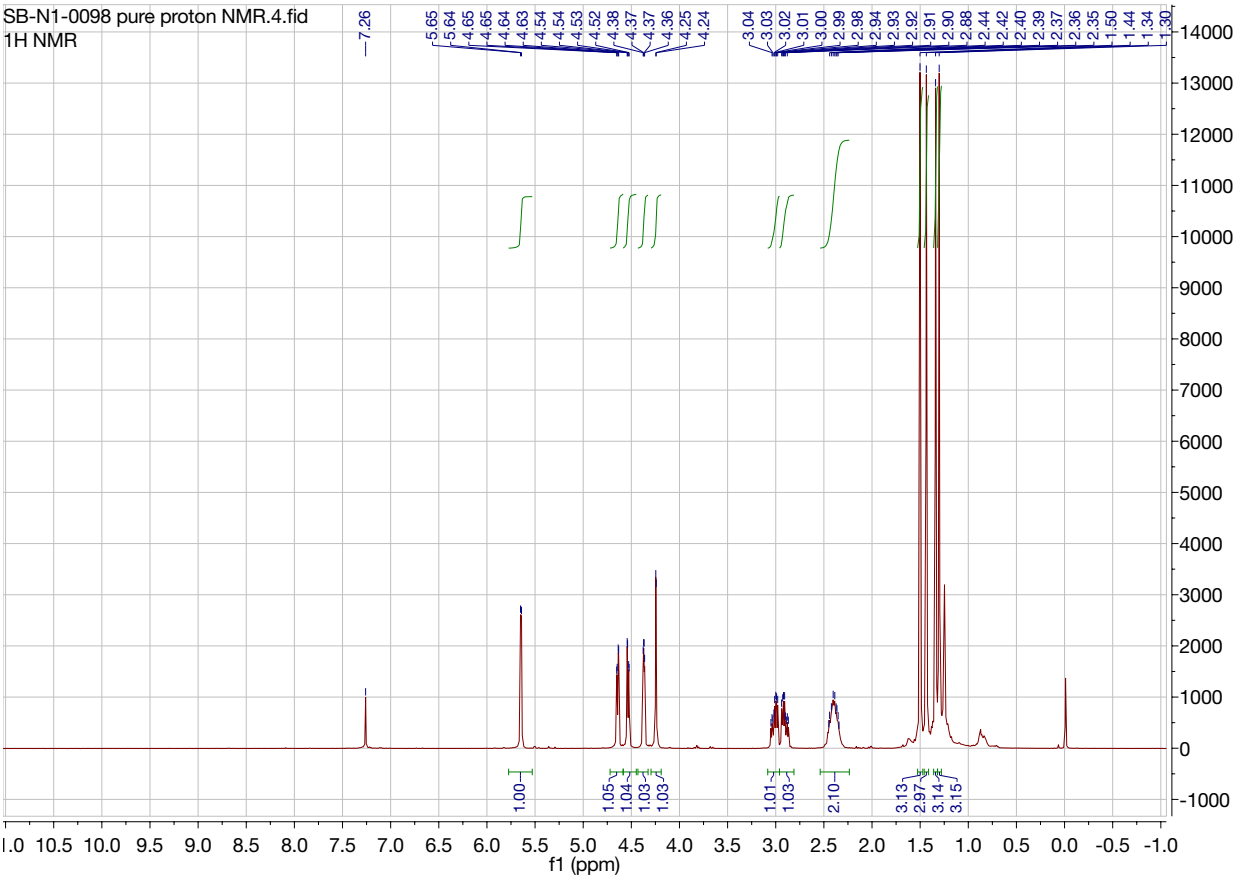
^{19}F NMR ($CDCl_3$, 471 MHz) of (3,3-difluorocyclobutyl)((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo) [4,5-b:4',5'-d]pyran-5-yl)methanone (**2s**)



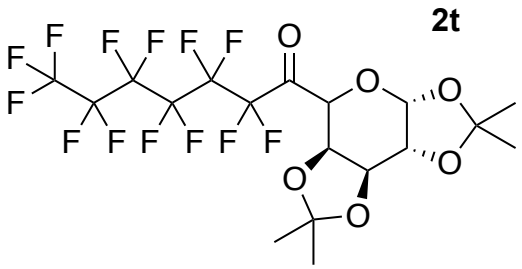


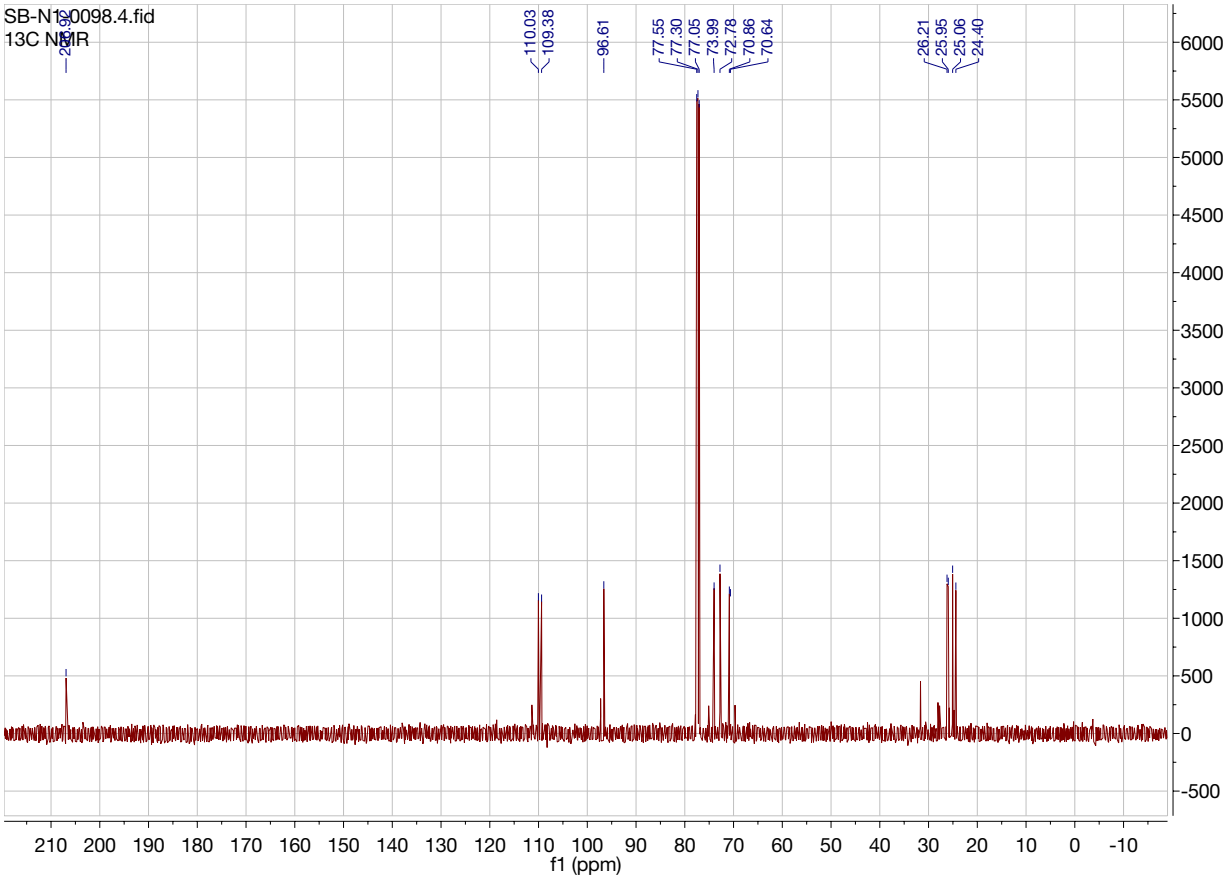
^{1}H NMR ($CDCl_3$, 500 MHz) of 4,4,5,5,6,6,7,7,8,8,9,9,9-tridecafluoro-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonan-1-one **(2t)**



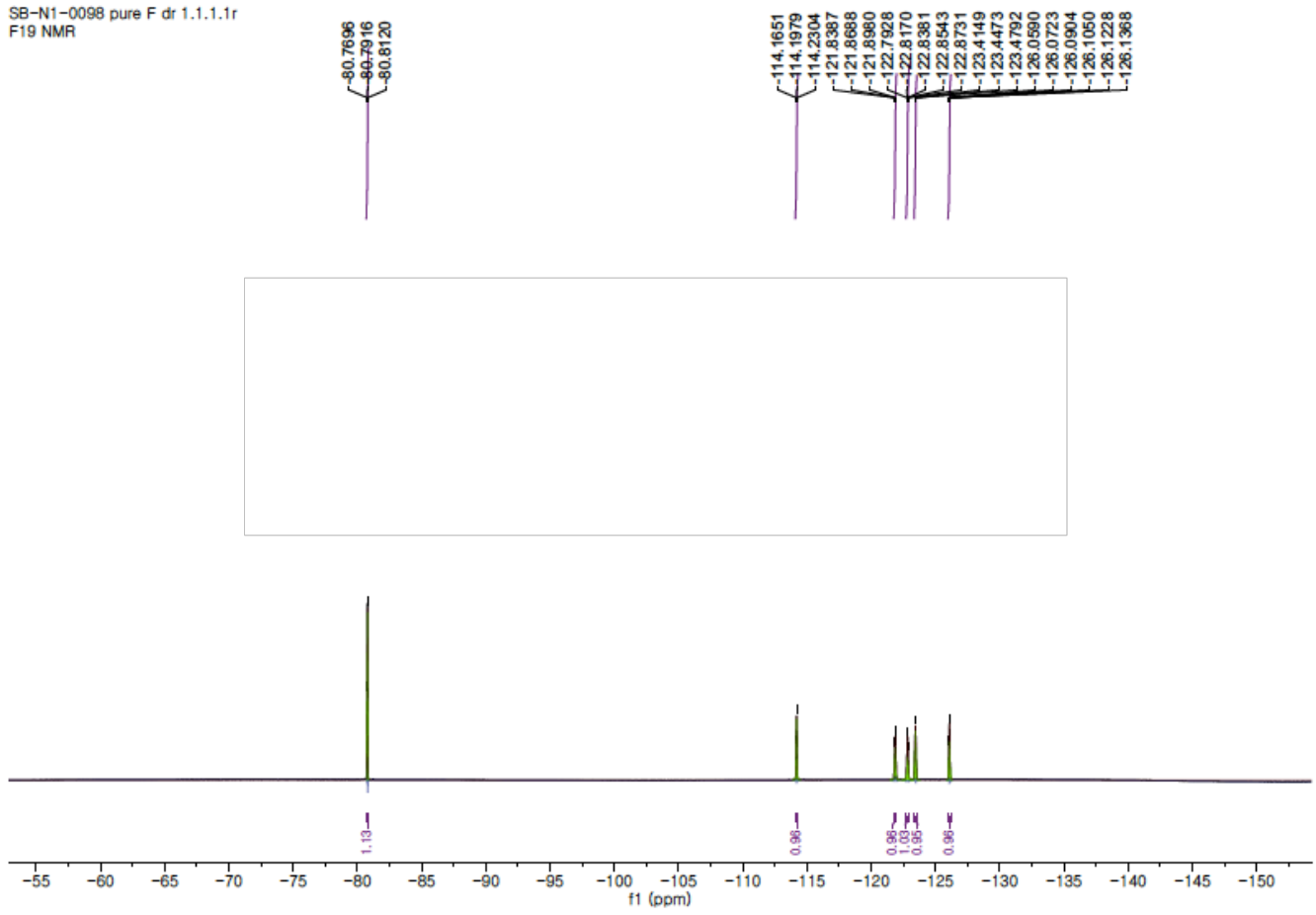


^{13}C NMR ($CDCl_3$, 126 MHz) 4,4,5,5,6,6,7,7,8,8,9,9,9-tridecafluoro-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonan-1-one **(2t)**



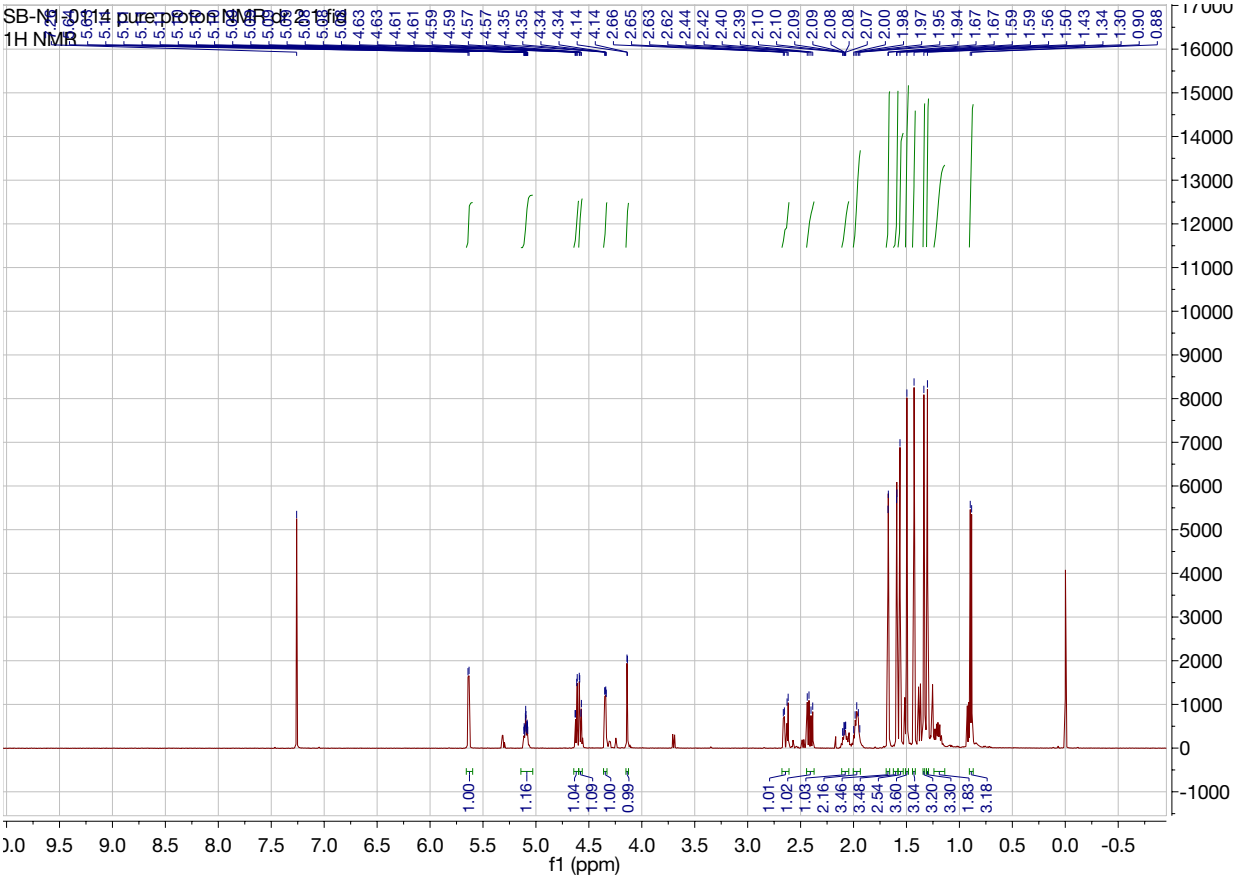


^{19}F NMR ($CDCl_3$, 471 MHz) of 4,4,5,5,6,6,7,7,8,8,9,9,9-tridecafluoro-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)nonan-1-one **(2t)**



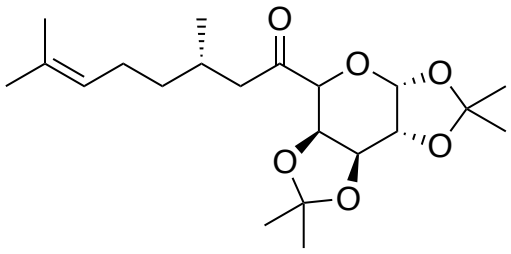
^{1}H NMR ($CDCl_3$, 500 MHz) of (3*S*)-3,7-dimethyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)oct-6-en-1-one **(2u)**

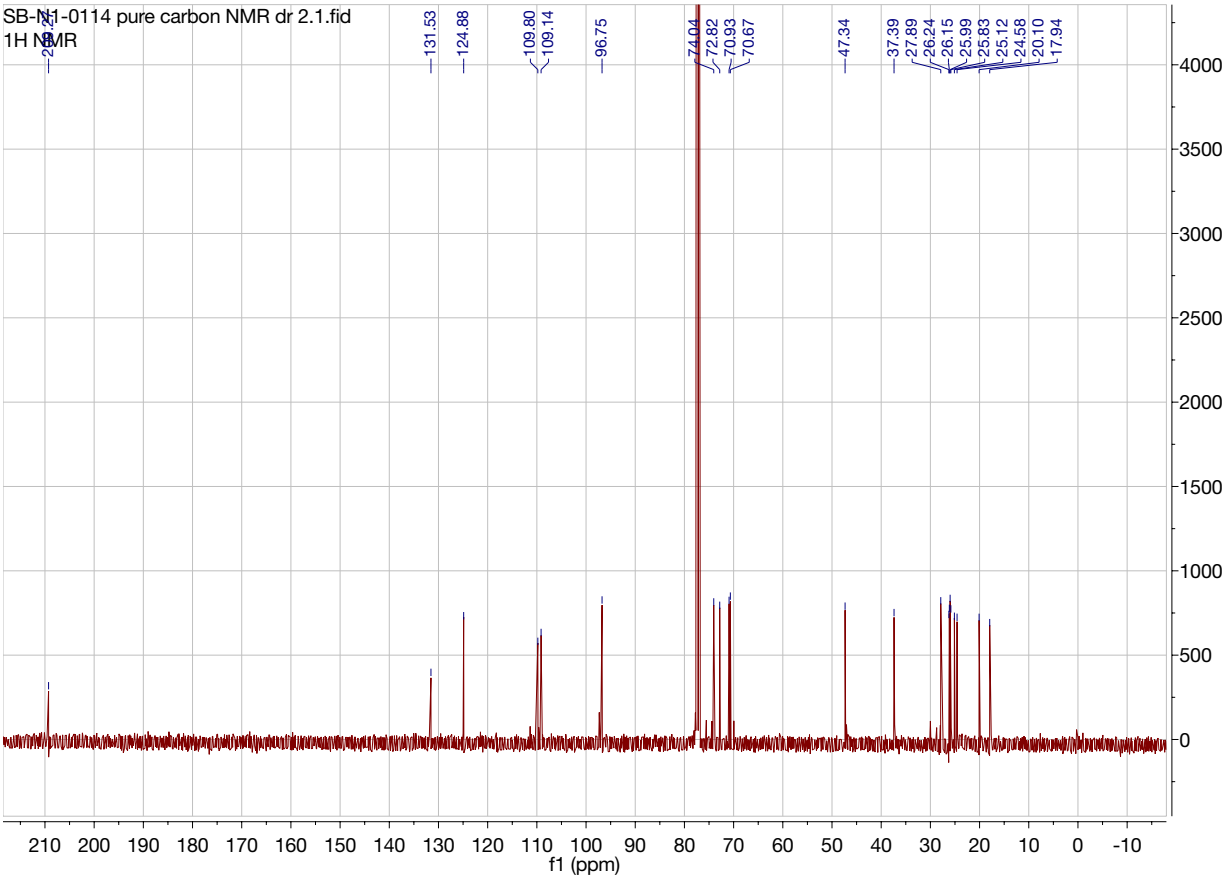
2u



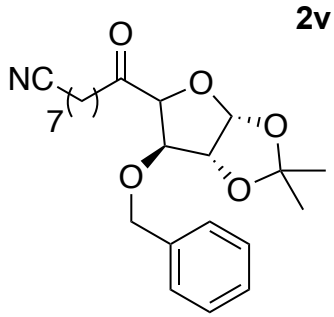
^{13}C NMR ($CDCl_3$, 126 MHz) of (3*S*)-3,7-dimethyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)oct-6-en-1-one **(2u)**

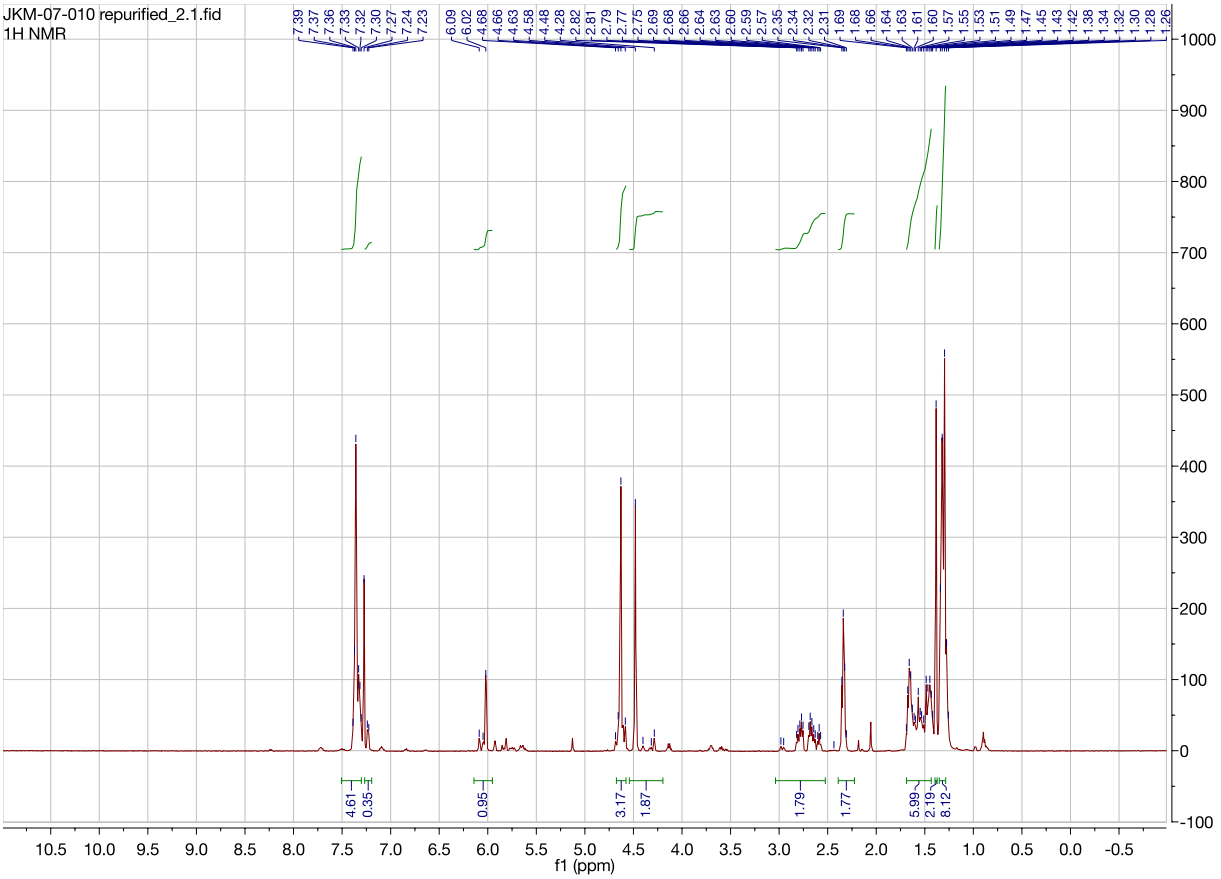
2u





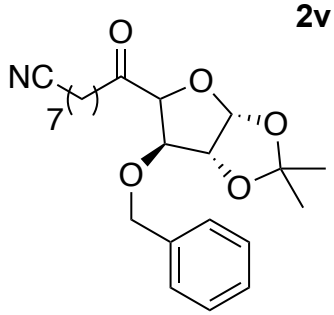
^{1}H NMR ($CDCl_3$, 500 MHz) of 10-((3aR,5S,6R,6aR)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-10-oxodecanenitrile **(2v)**

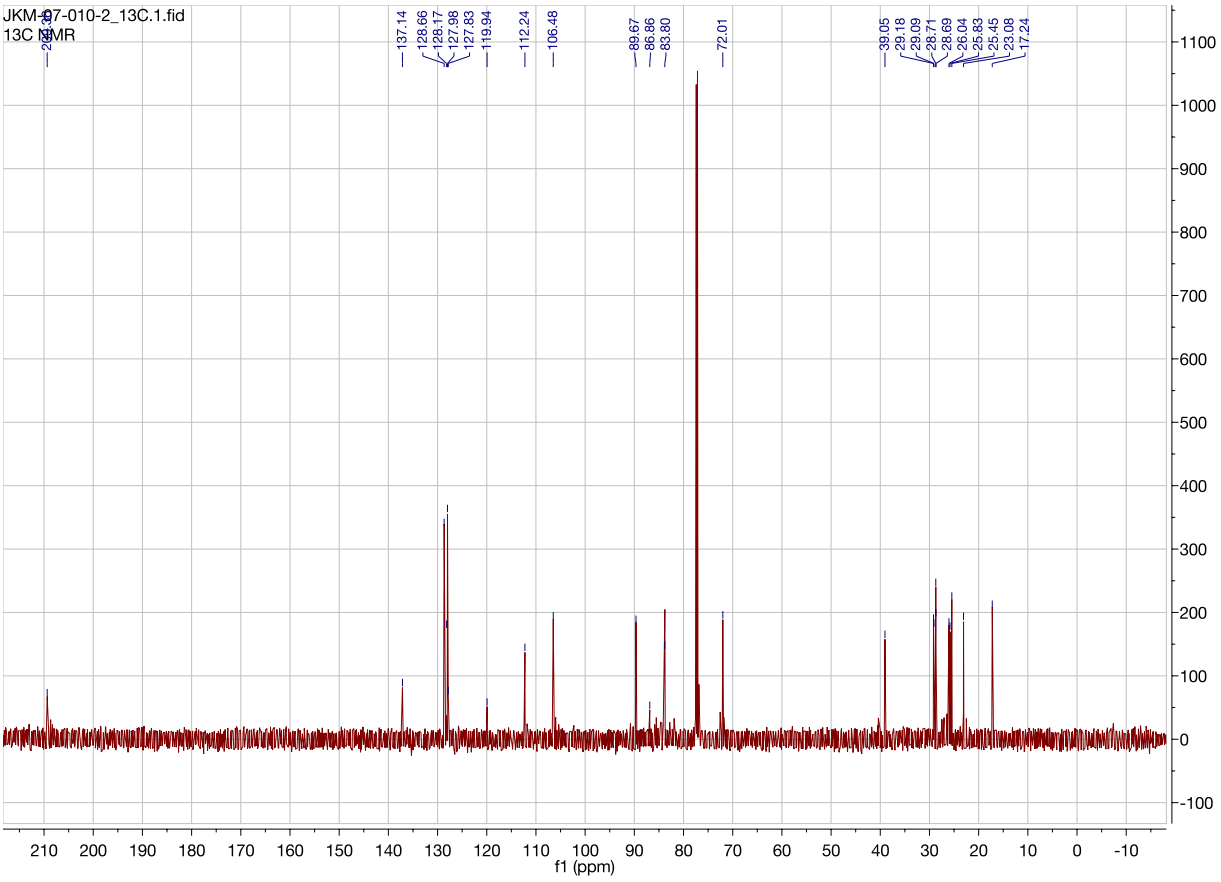




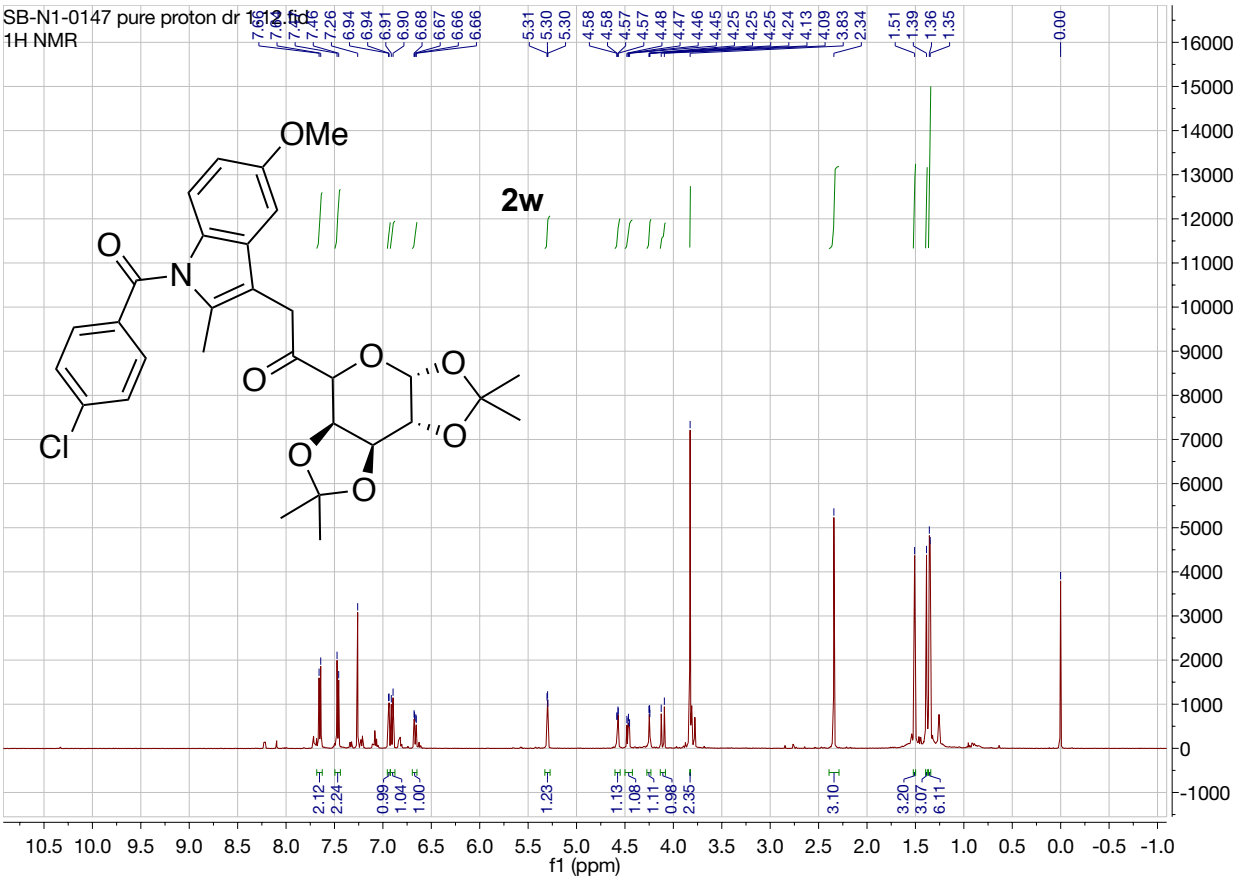
^{13}C NMR ($CDCl_3$, 126 MHz) of of 10-((3aR,5S,6R,6aR)-6-(Benzyloxy)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-5-yl)-10-oxodecanenitrile **(2v)**

2v

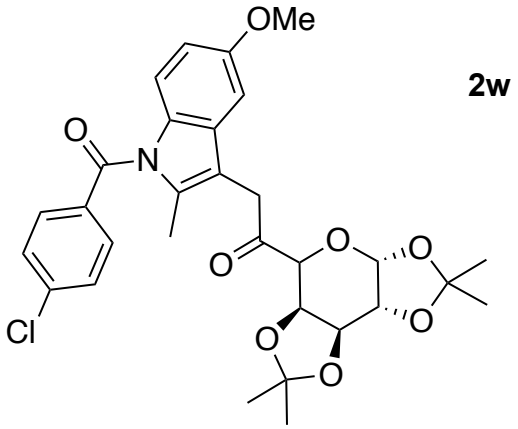




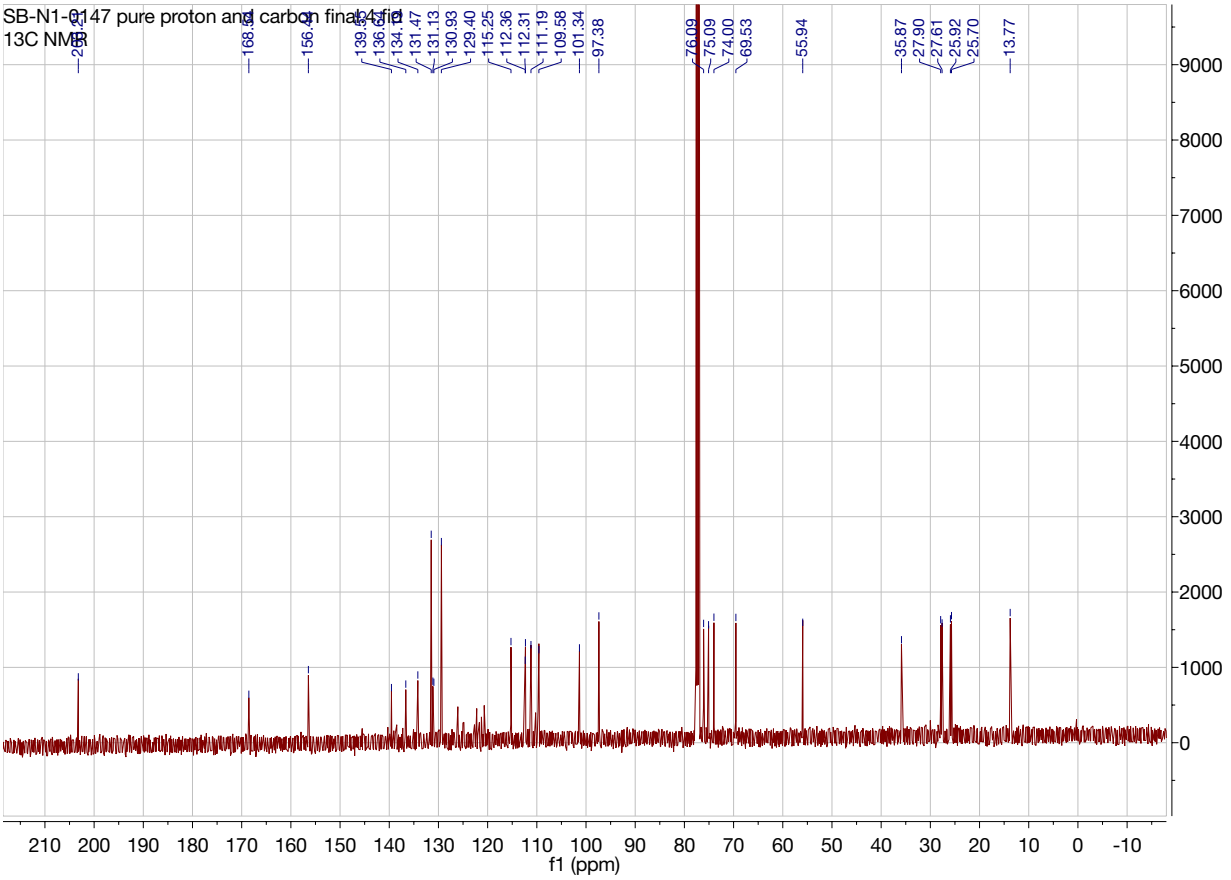
^{1}H NMR ($CDCl_3$, 500 MHz) of 2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethan-1-one **(2w)**



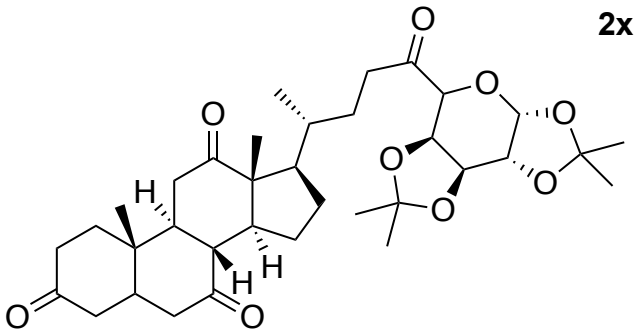
^{13}C NMR ($CDCl_3$, 126 MHz) of 2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)ethan-1-one **(2w)**

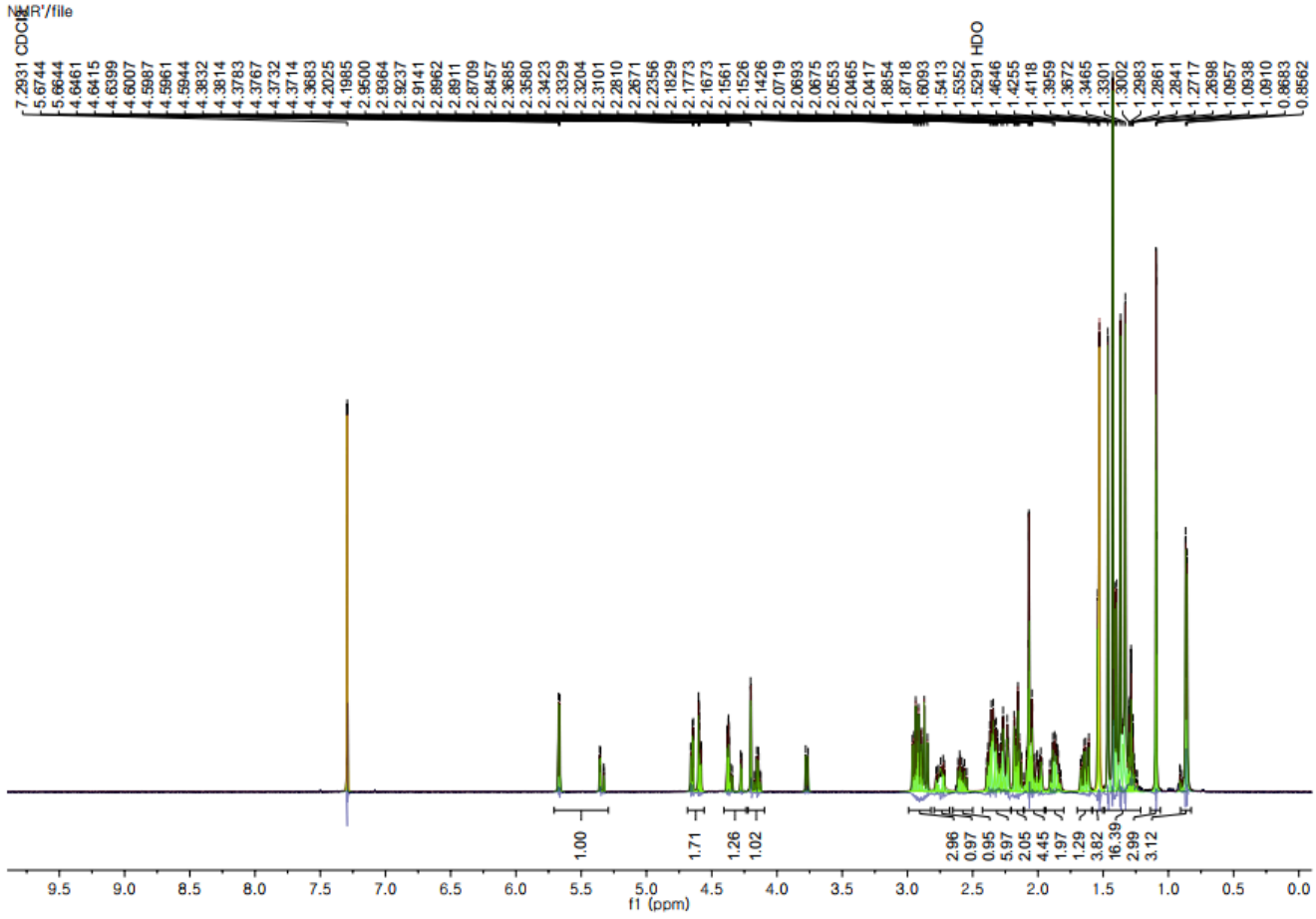


2w

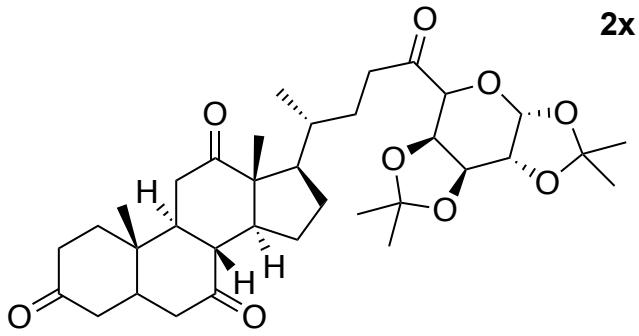


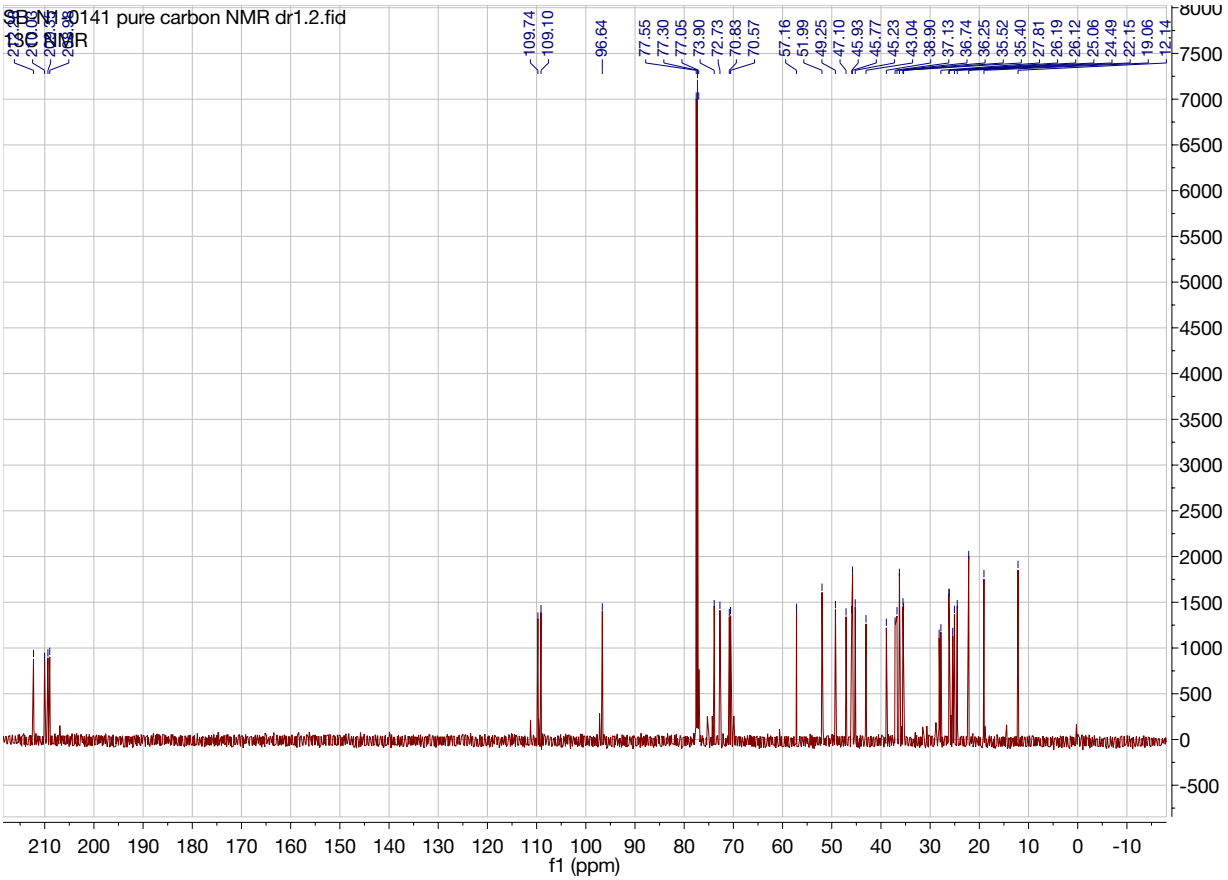
^{1}H NMR ($CDCl_3$, 500 MHz) of (3*S*)-3,7-dimethyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7 tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)oct-6-en-1-one **(2x)**



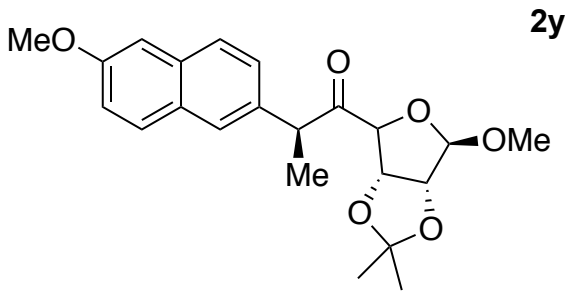


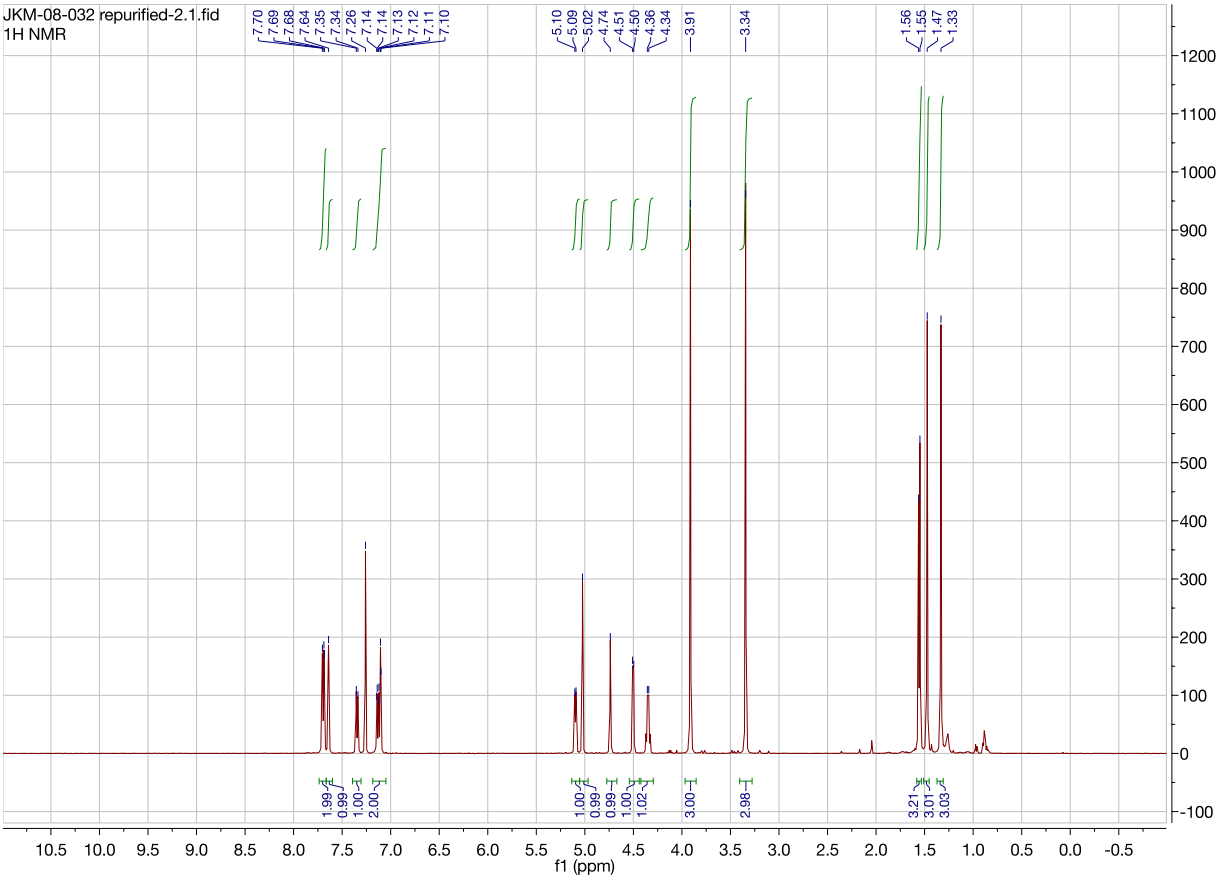
^{13}C NMR ($CDCl_3$, 126 MHz) of (3*S*)-3,7-dimethyl-1-((3a*R*,5a*R*,8a*S*,8b*R*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)oct-6-en-1-one **(2x)**



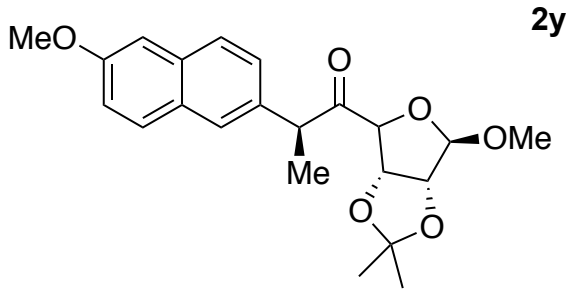


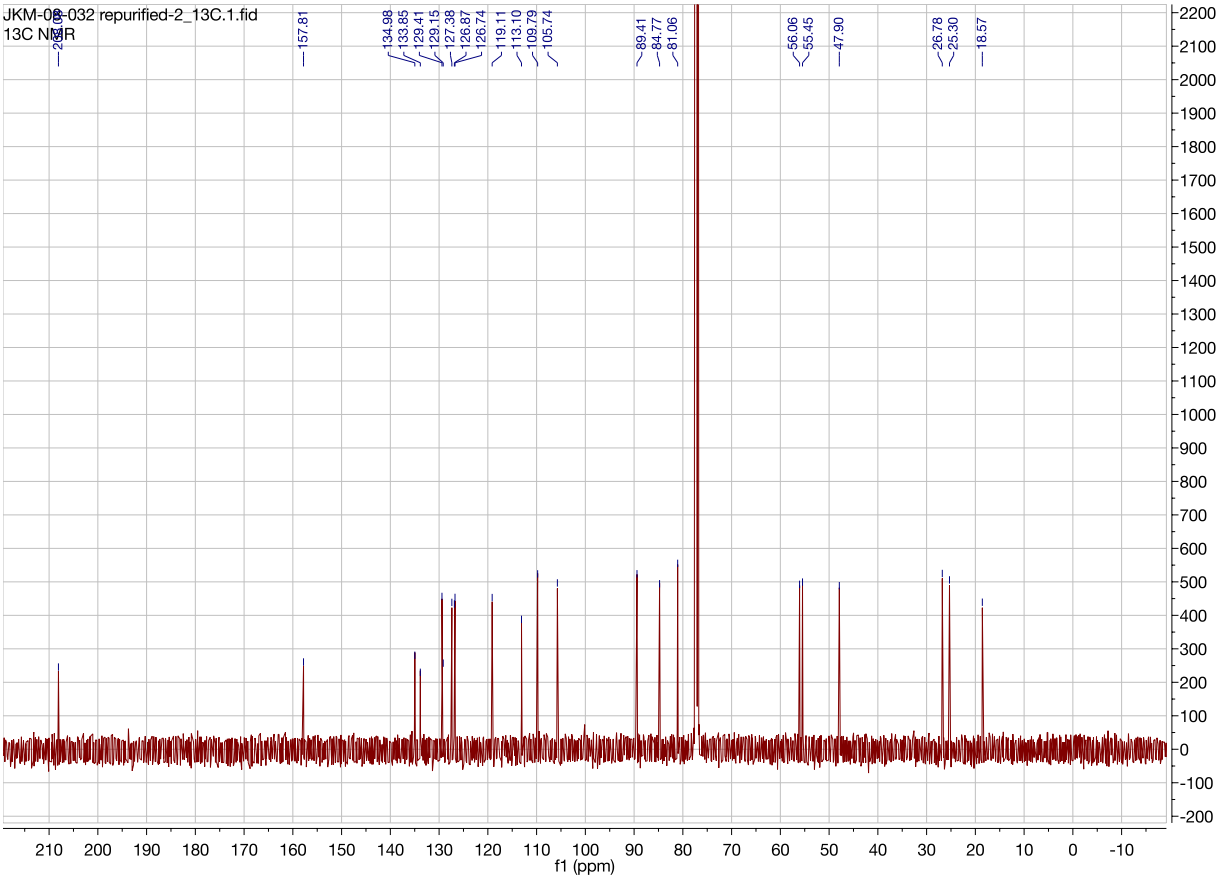
^{1}H NMR ($CDCl_3$, 500 MHz) of (2S)-1-((4S,6R)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-d][1,3]dioxol-4-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one **(2y)**



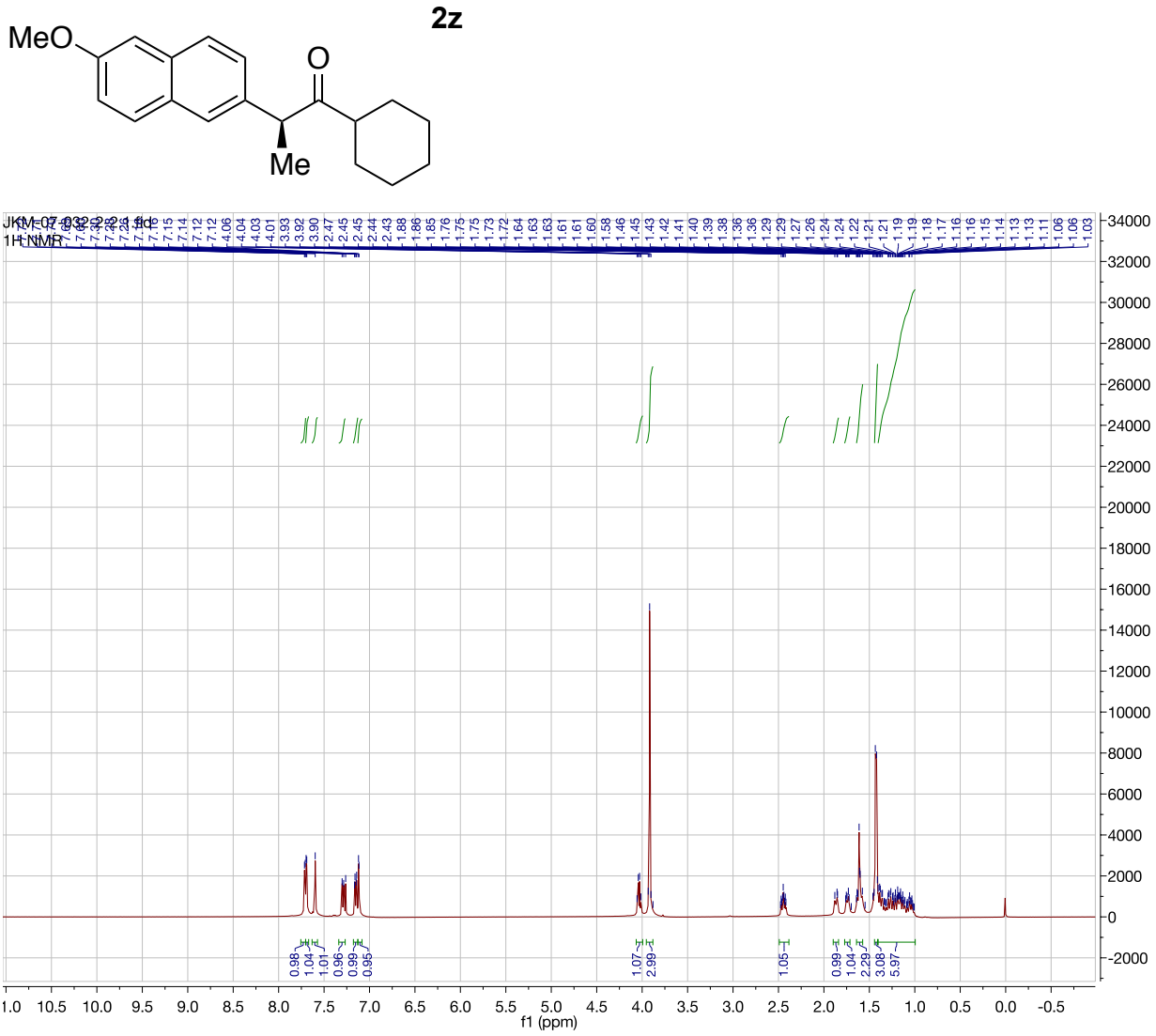


^{13}C NMR ($CDCl_3$, 126 MHz) of (2S)-1-((4S,6R)-6-Methoxy-2,2-dimethyltetrahydrofuro[3,4-d][1,3]dioxol-4-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one **(2y)**



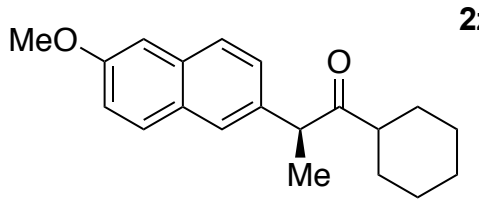


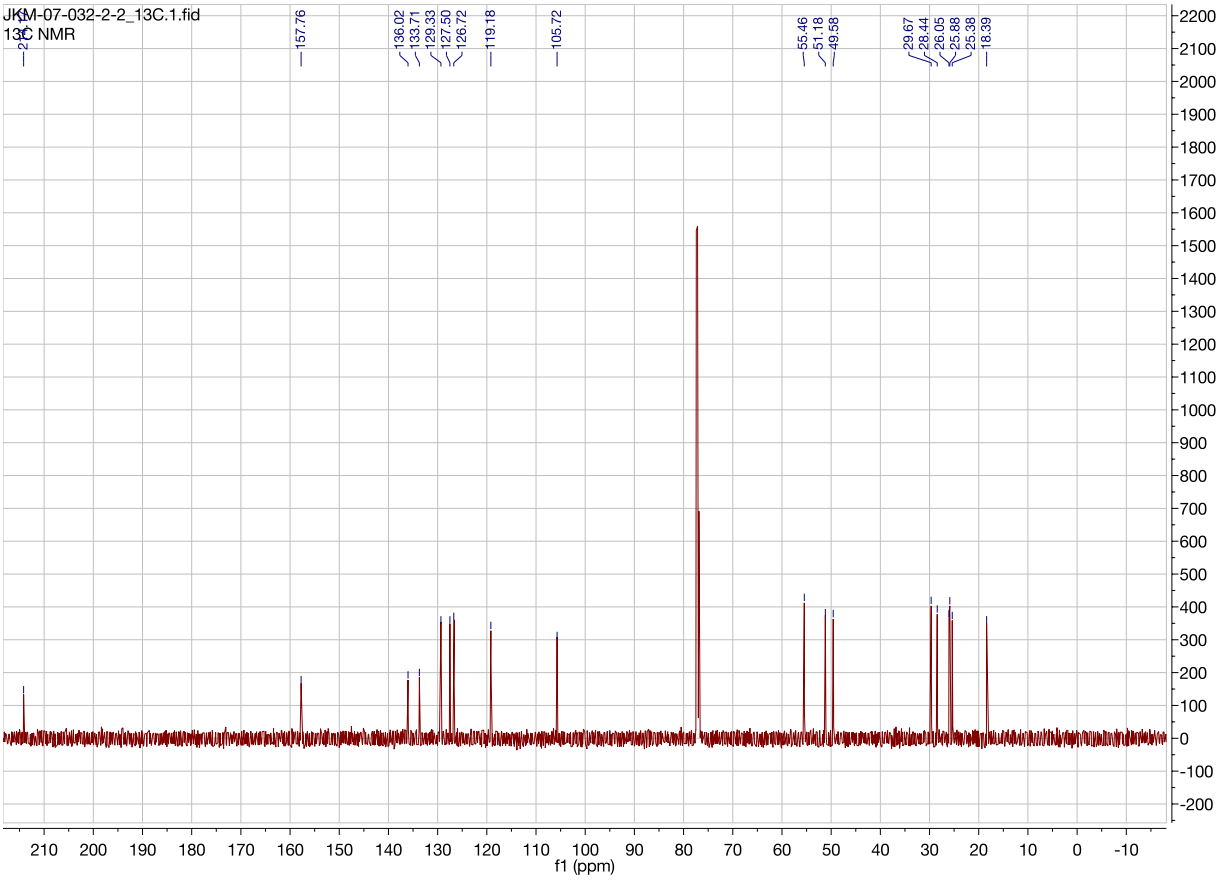
^{1}H NMR ($CDCl_3$, 500 MHz) of (S)-1-Cyclohexyl-2-(6-methoxynaphthalen-2-yl)propan-1-one **(2z)**



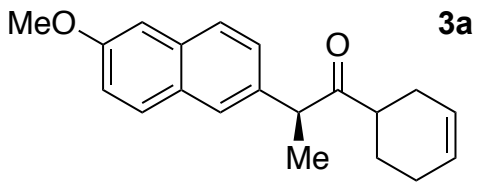
^{13}C NMR ($CDCl_3$, 126 MHz) of (S)-1-Cyclohexyl-2-(6-methoxynaphthalen-2-yl)propan-1-one **(2z)**

2z

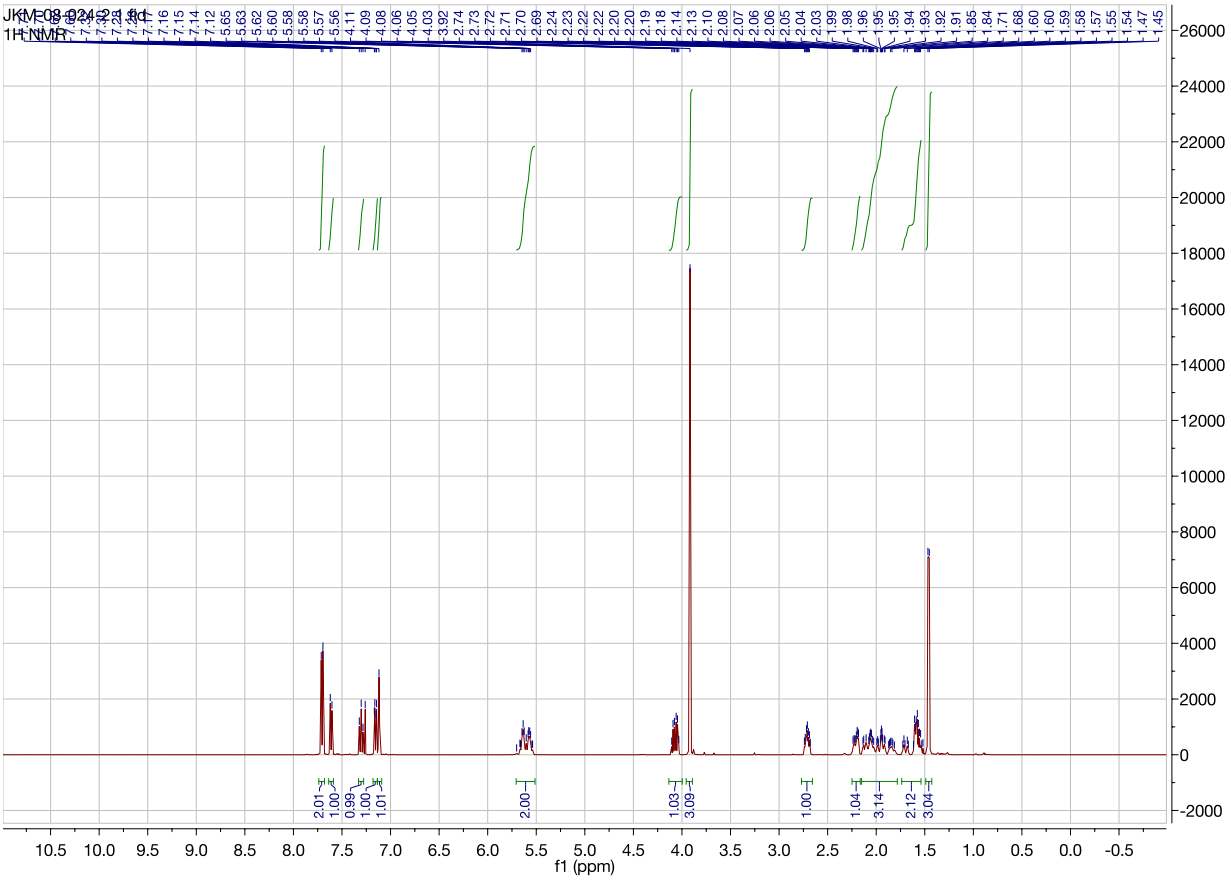




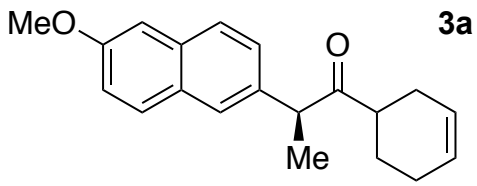
^{1}H NMR ($CDCl_3$, 500 MHz) of (S)-1-((R)-Cyclohex-3-en-1-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one **(3a)**



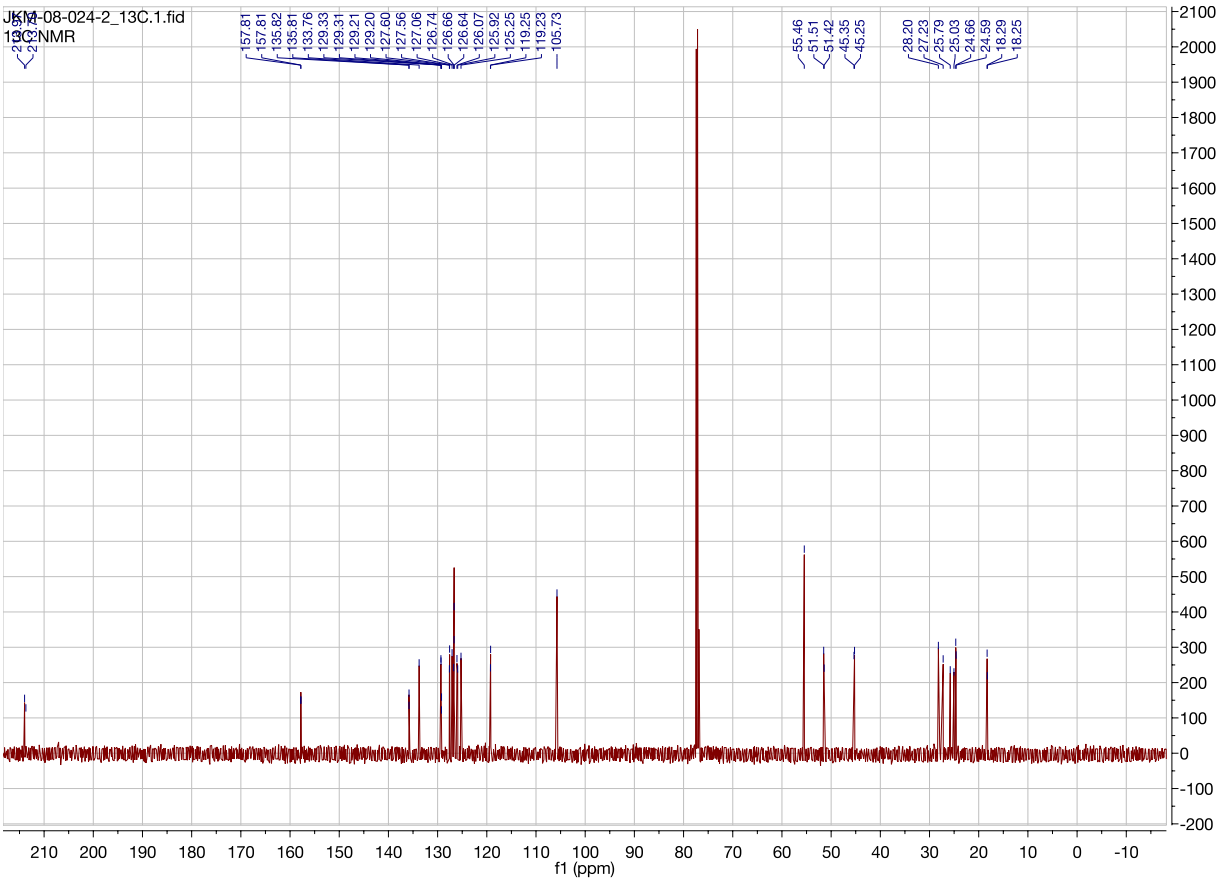
3a



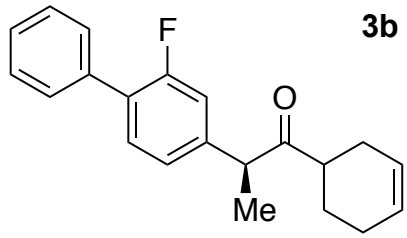
^{13}C NMR ($CDCl_3$, 126 MHz) of (S)-1-((R)-Cyclohex-3-en-1-yl)-2-(6-methoxynaphthalen-2-yl)propan-1-one **(3a)**



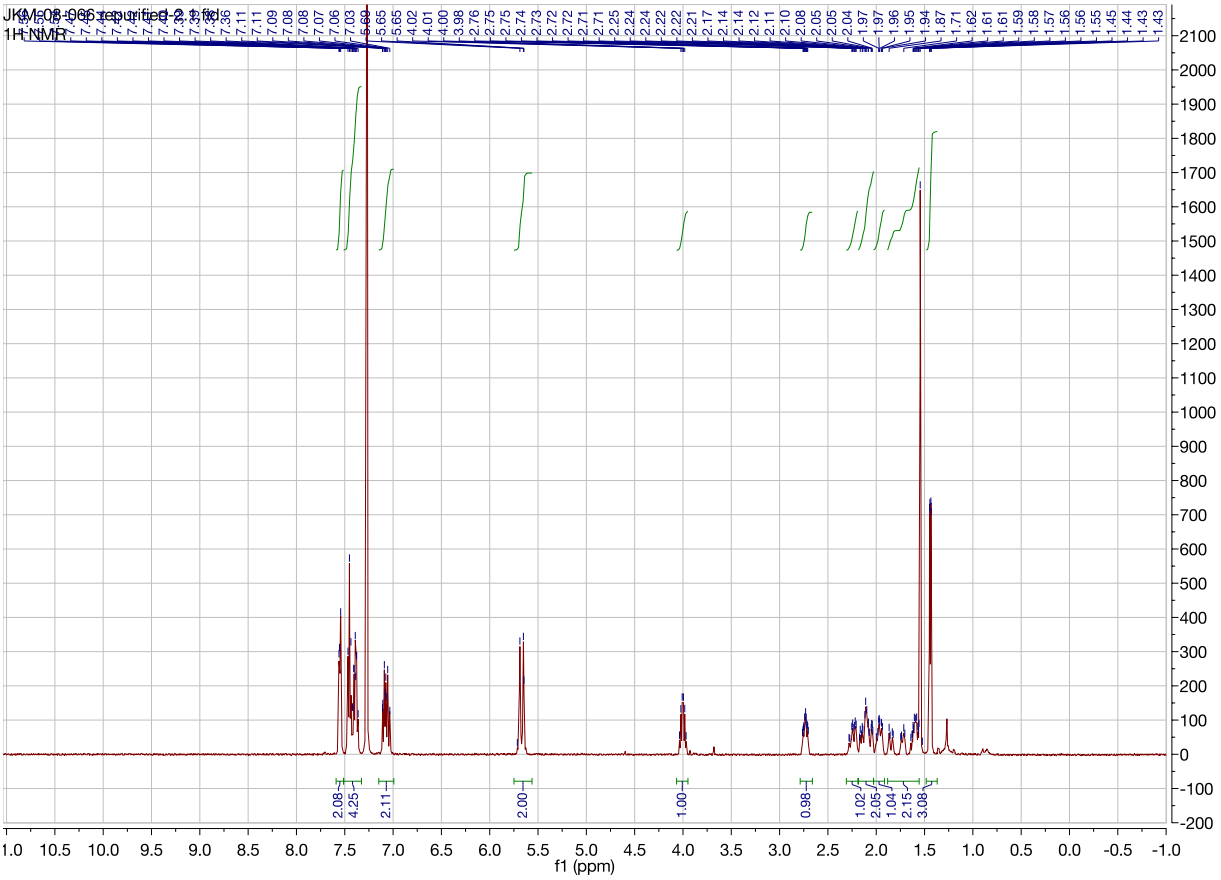
3a



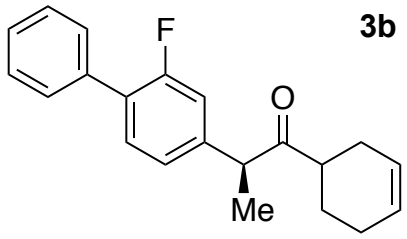
^{1}H NMR ($CDCl_3$, 500 MHz) of (S)-1-((R)-Cyclohex-3-en-1-yl)-2-(2-fluoro-[1,1'-biphenyl]-4-yl)propan-1-one **(3b)**



3b



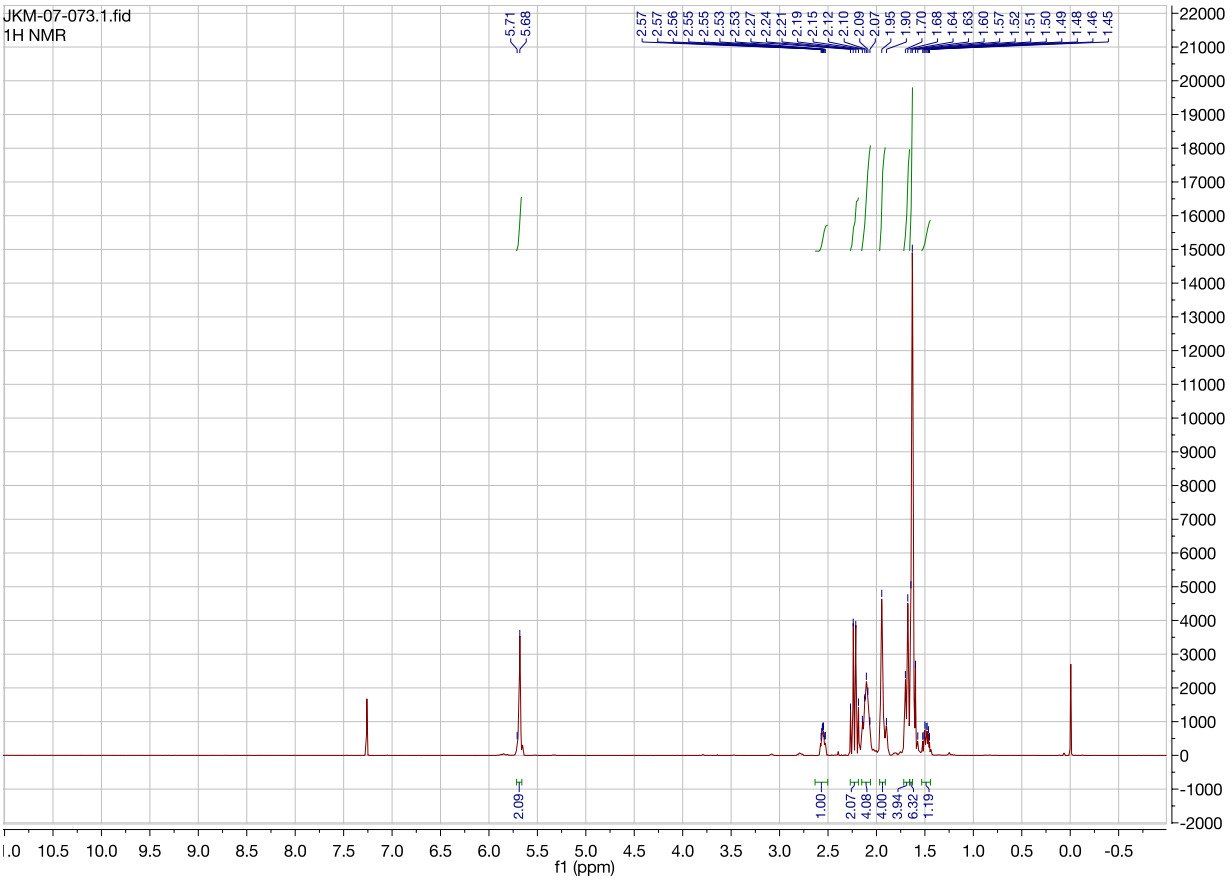
^{13}C NMR ($CDCl_3$, 126 MHz) of (S)-1-((R)-Cyclohex-3-en-1-yl)-2-(2-fluoro-[1,1'-biphenyl]-4-yl)propan-1-one **(3b)**



3b

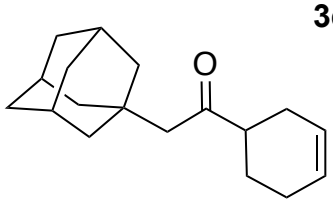
^{1}H NMR ($CDCl_3$, 500 MHz) of 2-((3R,5R,7R)-Adamantan-1-yl)-1-((R)-cyclohex-3-en-1-yl)ethan-1-one **(3c)**

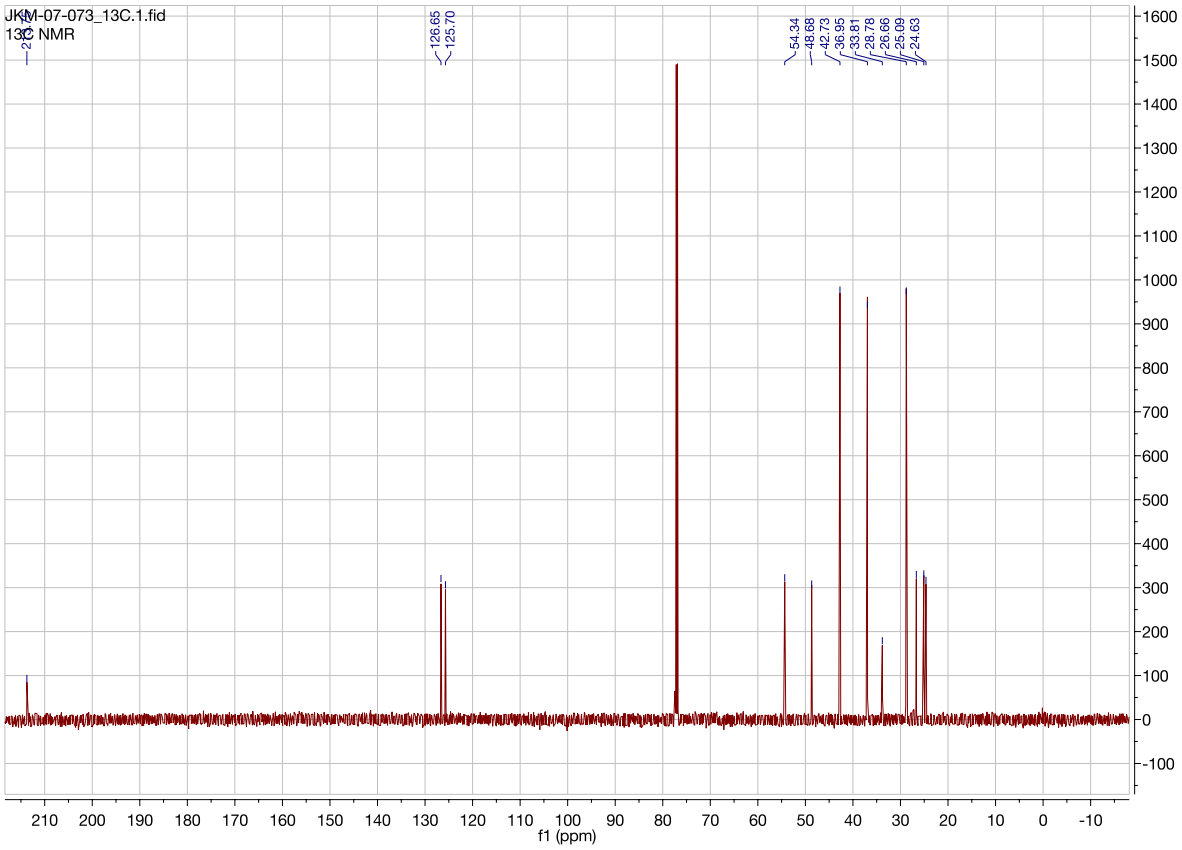
3c



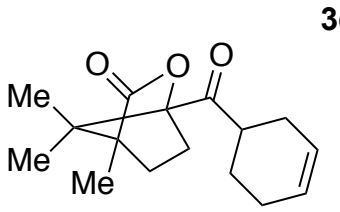
^{13}C NMR ($CDCl_3$, 126 MHz) of 2-((3R,5R,7R)-Adamantan-1-yl)-1-((R)-cyclohex-3-en-1-yl)ethan-1-one **(3c)**

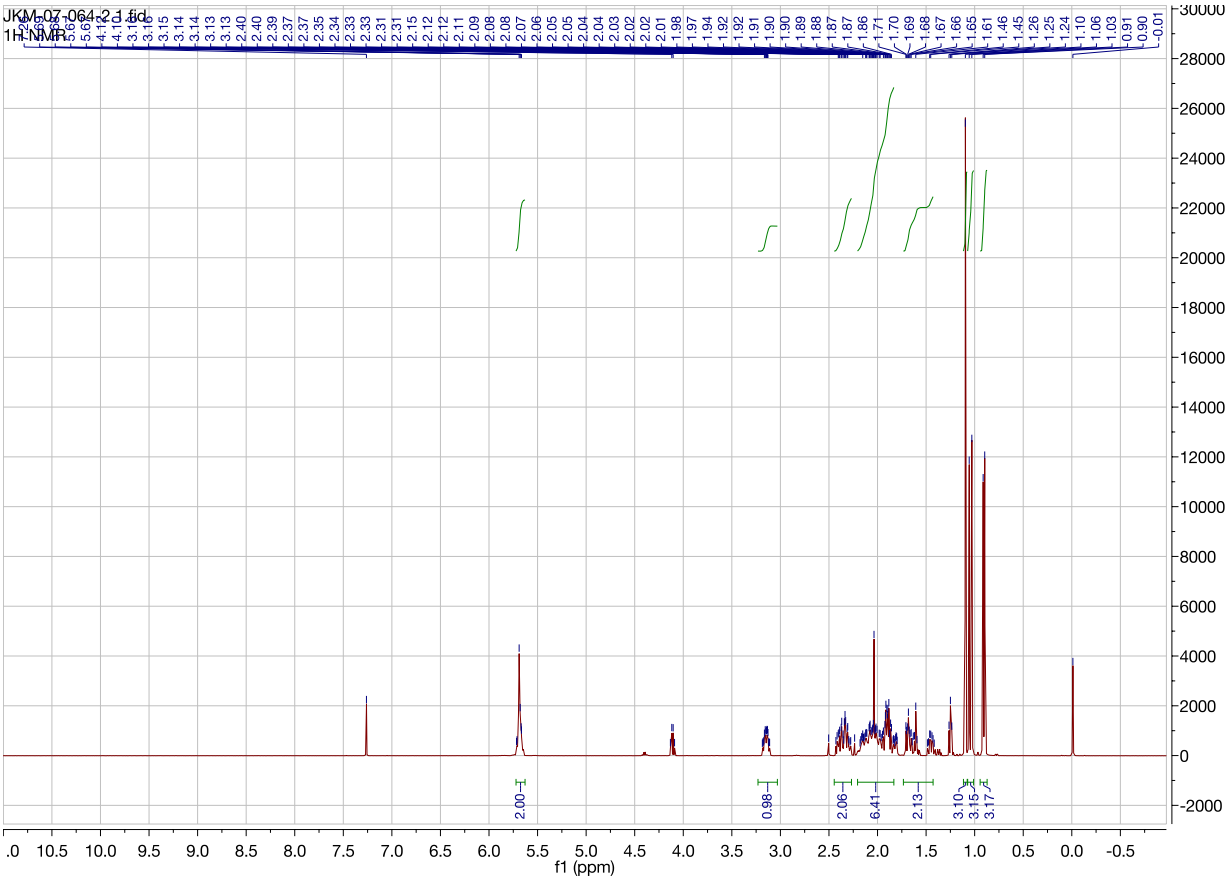
3c





^{1}H NMR ($CDCl_3$, 500 MHz) of (4R)-1-((R)-Cyclohex-3-ene-1-carbonyl)-4,7,7-trimethyl-2-oxabicyclo[2.2.1]heptan-3-one **(3d)**





^{13}C NMR ($CDCl_3$, 126 MHz) of (4R)-1-((R)-Cyclohex-3-ene-1-carbonyl)-4,7,7-trimethyl-2-oxabicyclo[2.2.1]heptan-3-one **(3d)**

3d