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Photocatalyzed Redox-Neutral Decarboxylative Dowd-Beckwith Radical-Polar Crossover Reaction: An Efficient Approach to Functionalized Medium-Sized Carbocyclic Compounds

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Table of Contents

1. General methods

1.1 Solvents, Reagents, Glassware and Reaction Setup

Unless otherwise specified, all reactions were conducted under an inert atmosphere of nitrogen or argon using hot air oven dried (120 ºC) glassware utilizing standard Schlenk-line technique. Air- and moisture-sensitive liquids and solutions were transferred via syringe into the reaction vessels through a rubber septum under inert atmosphere. Unless otherwise specified, all reagents were purchased at highest commercial quality and used as received. Non-anhydrous solvents were purchased at the highest commercial quality and used as received. Organic solvents used for carrying out reactions were dried using standard methods. All work up and purification were carried out with reagent grade solvents in air. Temperature described below −5 °C were achieved using immersion cooler by Julabo.

1.2 Analytical methods

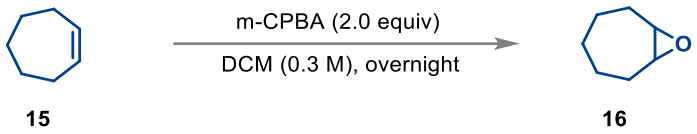
Chromatography: Column chromatography was carried out using Sigma-Aldrich silica gel (60 Å, 230-400 mesh, 40-63 μm). Reactions were monitored by thin-layer chromatography (TLC), using aluminium-backed Merck Kieselgel 60 F254 fluorescent treated silica gel plates, which were visualized under UV light or by staining with aqueous basic $KMnO_4$, or phosphomolybdic acid solution in ethanol. **IR:** Infrared (FT-IR) spectra were recorded of neat sample on Bruker alfa FT-IR, ν_{max} in cm^{-1} and the bands are characterized as strong (s), medium (m), and weak (w). **Melting Point**: Melting points were measured in open glass capillary on a Buchi M-560 melting point apparatus. **NMR:** NMR spectra were recorded on Bruker Ultrashield spectrometer at 400 MHz (for ^{1}H-NMR), 101 MHz (for ^{13}C-NMR), 376 MHz (for ^{19}F-NMR). Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as internal standard ($CDCl_3$: δ 7.26 ppm for ^{1}H-NMR and δ 77.00 ppm for ^{13}C-NMR). For ^{1}H-NMR, data are reported as follows: chemical shift, multiplicity (s = singlet, brs = broad singlet, d = doublet, dd = doublet of doublets, ddd = doublet of doublet of doublets, t = triplet, q = quartet, dt = doublet of triplets, m = multiplet etc.), coupling constants (Hz) and integration. **NMR yields:** Following work up or/and solvent evaporation, dibromomethane (relative to limiting starting material) was added to the crude residue. The resultant mixture was dissolved in $CDCl_3$, and a 0.5 mL sample of the resultant solution taken for ^{1}H NMR analysis. Yields were calculated based on the integrals of known

product resonances relative to dibromomethane (2H, at 4.94 ppm in $CDCl_3$). MS: High Resolution Mass Spectrometry (HRMS) was performed on Waters e2695 XEVO G2-XS Q-TOFinstrument.

2. Procedures for starting materials synthesis

2.1 Procedure for Epoxidation of cycloheptene

8-Oxabicyclo[5.1.0]octane (16)



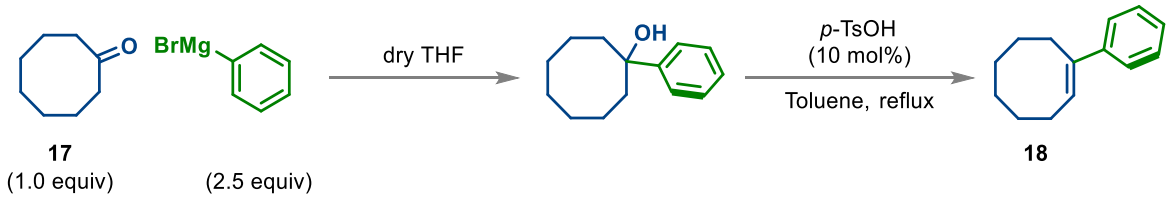
Following a slightly modified procedure,[1] a 100 mL round-bottom flask was charged with cycloheptene **15** (0.96 g, 1.17 mL, 10.0 mmol, 1.00 equiv) and 30 mL of DCM. After stirring for 5 minutes, 77% *m*-chloroperbenzoic acid (4.5 g, 20 mmol, 2.0 equiv) was added gradually over a period of 10 minutes. The reaction mixture was then stirred for overnight and then quenched by adding 25 mL of saturated $Na_2S_2O_3$ solution, followed by 15.0 mL of saturated $NaHCO_3$ aqueous solution. The aqueous layer was extracted using DCM (3×20 mL) and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum to obtain the crude product **16** as a colorless oil (1.54 g, 13.7 mmol, 69%). The crude product was used in the next step without further purification.

- **TLC (DCM:Hexane, 1:19 v/v):** R_f = 0.19, phosphomolybdic acid.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 3.13 – 3.03 (m, 2H), 2.04 – 1.80 (m, 4H), 1.69 – 1.35 (m, 6H).

  The characteristic data matched the reported data.[2]

2.2 Procedure for cyclooctene synthesis

(*E*)-1-Phenylcyclooct-1-ene (18)



Step 1: Following a slightly modified procedure,[3] a 150 mL round bottom flask was charged with cyclooctanone **17** (2.52 g, 20.0 mmol, 1.00 equiv) and 10 mL of THF under argon atmosphere. To this solution, 0.5 M PhMgBr in THF (100 mL, 50.0 mmol, 2.50 equiv) was added dropwise over 30 minutes using syringe pump at room temperature. After 6 h of stirring, the reaction mixture was quenched with 40 mL of saturated aqueous NH_4Cl solution. The mixture was extracted with EtOAc (3×20 mL), and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum to obtain the crude alcohol as colorless liquid, which was used in the next step without further purification.

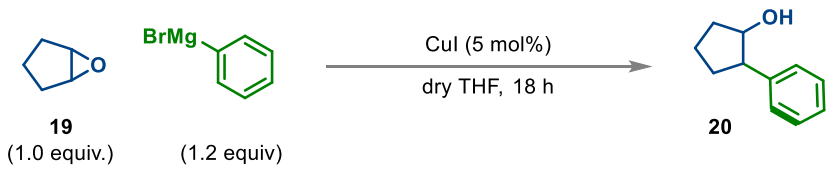
Step 2: Following a slightly modified procedure,[3] the crude alcohol (3.80 g, 18.6 mmol, 1.00 equiv) was taken into a 100 mL round bottom flask and dissolved in toluene (50 mL, 0.37 M). *p*-TsOH (320 mg, 1.86 mmol, 0.100 equiv) was added to the above solution and the solution was refluxed for 4 h. The reaction mixture was quenched with 20 mL saturated aqueous solution of Na_2CO_3. The mixture was extracted with hexane (3×20 mL), and organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash-column chromatography using pure hexane as eluent to obtain the pure product **18** as a colorless liquid (2.98 g, 16.0 mmol, 80%).

- **TLC (Hexane):** R_f = 0.7, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.43 (d, *J* = 7.6 Hz, 2H, Ar*H*), 7.32 (t, *J* = 7.5 Hz, 2H, Ar*H*), 7.24 (q, *J* = 7.4, 6.7 Hz, 1H, Ar*H*), 6.03 (t, *J* = 8.3 Hz, 1H, ArC=C*H*), 2.69 – 2.61 (m, 2H), 2.31 (dt, *J* = 11.8, 6.0 Hz, 2H), 1.74 – 1.49 (m, 8H).
- **^{13}C NMR (101 MHz, $CDCl_3$)**: δ 143.3, 140.3, 128.1, 128.0, 126.5, 125.8, 30.1, 29.5, 28.6, 27.3, 26.9, 26.3.

  The characterization data matched the reported values.[4]

2.3 Procedures for the synthesis of 2-aryl-cycloalkan-1-ols

2-Phenylcyclopentan-1-ol (20)

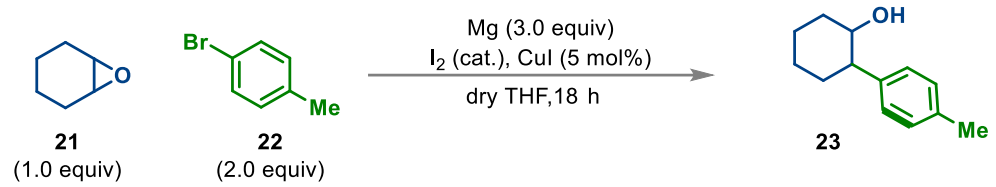


Following a slightly modified procedure,[5] a two-neck flask was charged with 1.0 M PhMgBr in THF (14.5 mL, 14.4 mmol, 1.20 equiv). To this, CuI (115 mg, 0.600 mmol, 0.050 equiv) was added under argon atmosphere. After 30 minutes, cyclopentene-oxide **19** (1.0 g, 0.92 mL, 12 mmol, 1.0 equiv) in dry THF (6.0 mL, 2.0 M) was added dropwise using syringe-pump over 20 minutes. The resulting mixture was stirred for 18 h at room temperature. Then the reaction mixture was quenched with 15 mL saturated NH_4Cl aqueous solution and extracted with Et_2O (3×15 mL) and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash-column chromatography using 1:9 EtOAc/Heaxne as eluent to obtain the pure product **20** as a white solid (1.90 g, 12.0 mmol, 99%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.34, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$)**: δ 7.31 – 7.22 (m, 2H, Ar*H*), 7.22 – 7.12 (m, 3H, Ar*H*), 4.10 (q, *J* = 7.2 Hz, 1H, C*H*OH), 2.81 (dt, *J* = 9.4, 7.8 Hz, 1H, C*H*Ar), 2.16 – 1.99 (m, 2H), 1.87 – 1.52 (m, 4H).

  The characterization data matched the reported values.[5]

2-(*p*-Tolyl)cyclohexan-1-ol (23)



21 (1.0 equiv) **22** (2.0 equiv) **23**

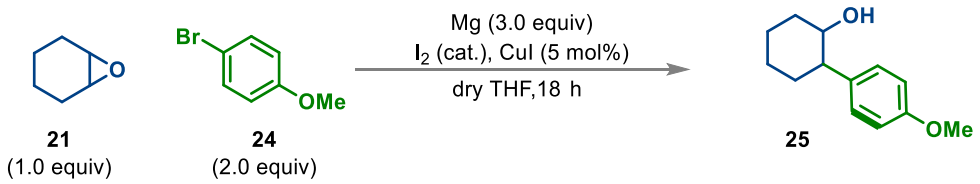
Following a slightly modified procedure,[6] a 50 mL two-neck flask was charged with magnesium (1.50 g, 60.0 mmol, 3.00 equiv) and molecular iodine (10.0 mg) in an argon atmosphere. To this, a solution of *p*-bromotoluene **22** (6.8 g, 4.9 mL, 40 mmol, 2.0 equiv) in dry THF (20 mL, 2.0 M) was added dropwise through a syringe-pump while stirring at room temperature over a period of 20 minutes. The mixture was stirred for an additional 30 minutes. Next, CuI (190 mg, 1.00 mmol, 0.05 equiv) was added and allowed to stir for 30 more minutes. The solution of cyclohexene-oxide **21** (1.9 g, 2.0 mL, 20 mmol, 1.0 equiv) in dry THF (20 mL, 1.0 M) was added dropwise via syringe-pump over a 20-minutes period. After 18 h, the reaction mixture was quenched with 20 mL of saturated aqueous NH_4Cl solution. The mixture was extracted with Et_2O (3×20 mL), and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and

concentrated under vacuum. The crude product was purified by flash column chromatography using a 1:9 eluent of EtOAc/Hexane to obtain the pure product **23** as a white solid (3.60 g, 19.2 mmol, 96%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.35, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.18 (d, *J* = 1.4 Hz, 4H, Ar*H*), 3.66 (td, *J* = 9.7, 3.9 Hz, 1H, C*H*OH), 2.42 (td, *J* = 10.9, 3.4 Hz, 1H, C*H*Ar), 2.36 (s, 3H, ArC*H*$_3$), 2.15 (dd, *J* = 8.6, 4.4 Hz, 1H), 1.95 – 1.83 (m, 2H), 1.58 – 1.33 (m, 3H).
- **^{13}C NMR (101 MHz, $CDCl_3$)**: δ 140.11, 136.4, 129.5, 127.7, 74.5, 52.8, 34.4, 33.4, 26.1, 25.1, 21.0.

  The characterization data matched the reported values.[6]

2-(4-methoxyphenyl)cyclohexan-1-ol (25)



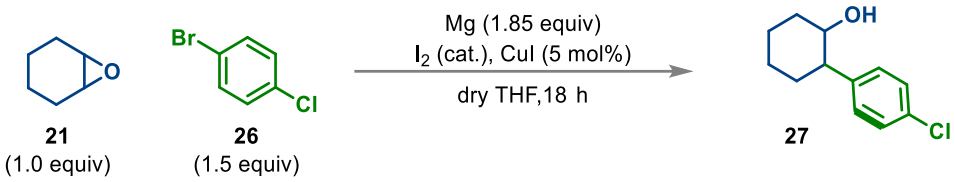
Following a slightly modified procedure,[6] a 50 mL two-neck flask was charged with magnesium (1.50 g, 60.0 mmol, 3.00 equiv) and molecular iodine (10.0 mg) in an argon atmosphere. Then, a solution of *p*-bromoanisole **24** (7.5 g, 5.0 mL, 40 mmol, 2.0 equiv) in dry THF (20 mL, 2.0 M) was added dropwise through a syringe-pump while stirring at room temperature over a period of 20 minutes. The mixture was stirred for an additional 30 minutes. Next, CuI (190 mg, 1.00 mmol, 0.05 equiv) was added and allowed to stir for 30 more minutes. The solution of cyclohexene-oxide **21** (1.9 g, 2.0 mL, 20 mmol, 1.0 equiv) in dry THF (20 mL, 1.0 M) was added dropwise via syringe-pump over a 20-minutes period. After 18 h, the reaction mixture was quenched with 20 mL saturated aqueous NH_4Cl solution. The mixture was extracted with Et_2O (3×20 mL), and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using a 1:9 eluent of EtOAc/Hexane to obtain the pure product **25** as a white solid (3.80 g, 18.4 mmol, 92%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.22, $KMnO_4$.

- **^{1}H NMR (400 MHz, $CDCl_3$)**: δ 7.18 (d, *J* = 7.5 Hz, 2H, Ar*H*), 6.88 (d, *J* = 8.4 Hz, 2H, Ar*H*), 3.80 (s, 3H, OCH_3), 3.60 (td, *J* = 10.1, 4.3 Hz, 1H, C*H*OH), 2.44 – 2.32 (m, 1H, C*H*Ar), 2.18 – 2.04 (m, 1H), 1.93 – 1.70 (m, 2H), 1.61 (s, 1H, O*H*), 1.56 – 1.23 (m, 3H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 158.4, 135.1, 128.8, 114.2, 74.6, 55.2, 52.3, 34.3, 33.4, 26.1, 25.0.

  The characterization data matched the reported values.[7]

2-(4-Chlorophenyl)cyclohexan-1-ol (27)



21 (1.0 equiv) **26** (1.5 equiv) **27**

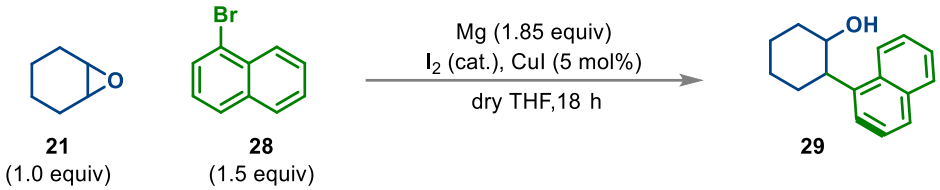
Following a slightly modified procedure,[8] a 50 mL two-neck flask was charged with magnesium (0.900 g, 37.0 mmol, 1.85 equiv) and molecular iodine (10.0 mg) in an argon atmosphere. Then, a solution of *p*-bromchlorobenzene **26** (5.70 g, 30.0 mmol, 1.50 equiv) in dry THF (15 mL, 2.0 M) was gradually added dropwise through a syringe-pump while stirring at room temperature over a period of 20 minutes. The mixture was stirred for an additional 30 minutes. Next, CuI (190 mg, 1.00 mmol, 0.05 equiv) was added and allowed to stir for 30 more minutes. The solution of cyclohexene-oxide **21** (1.9 g, 2.0 mL, 20 mmol, 1.0 equiv) in dry THF (20 mL, 1.0 M) was added dropwise via syringe-pump over a 20-minutes period. After 18 h, the reaction mixture was quenched with 20 mL of saturated aqueous NH_4Cl solution. The mixture was extracted with Et_2O (3×20 mL), and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using a 1:9 eluent of EtOAc/Hexane to obtain the pure product **27** as a white solid (3.60 g, 17.2 mmol, 86%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.31, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$)**: δ 7.30 (d, *J* = 8.5 Hz, 2H, Ar*H*), 7.19 (d, *J* = 8.4 Hz, 2H, Ar*H*), 3.61 (td, *J* = 10.1, 4.4 Hz, 1H, C*H*OH), 2.41 (ddd, *J* = 12.8, 9.9, 3.6 Hz, 1H, C*H*Ar), 2.19 – 2.04 (m, 1H), 1.85 (m, 3H), 1.76 (m, 1H), 1.54 – 1.22 (m, 4H).

- **^{13}C NMR (101 MHz, $CDCl_3$)**: δ 141.9, 132.4, 129.2, 128.8, 74.3, 52.5, 34.6, 33.3, 25.9, 25.0.

  The characterization data matched the reported values.[8]

2-(Naphthalen-1-yl)cyclohexan-1-ol (29)

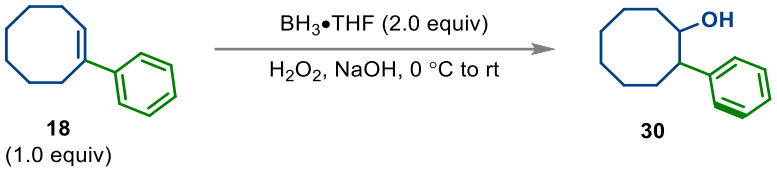


Following a slightly modified procedure,[8] a 50 mL two-neck flask was charged with magnesium (0.900 g, 37.0 mmol, 1.85 equiv) and molecular iodine (10.0 mg) in an argon atmosphere. Then, a solution of 1-bromonaphthalene **28** (6.2 g, 4.2 mL, 30 mmol, 1.5 equiv) in dry THF (15 mL, 2.0 M) was added dropwise through a syringe-pump while stirring at room temperature over a period of 20 minutes. The mixture was stirred for an additional 30 minutes. Next, CuI (190 mg, 1.00 mmol, 0.05 equiv) was added and allowed to stir for 30 more minutes. The solution of cyclohexene-oxide (1.9 g, 2.0 mL, 20 mmol, 1.0 equiv) in dry THF (20 mL, 1.0 M) was added dropwise via syringe-pump over a 20-minutes period. After 18 h, the reaction mixture was quenched with 20 mL of saturated aqueous NH_4Cl solution. The mixture was extracted with Et_2O (3×20 mL), and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using a 1:9 eluent of EtOAc/Hexane to obtain the pure product **29** as a white solid (2.90 g, 12.8 mmol, 64%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.29, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.21 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.87 (d, *J* = 8.0 Hz, 1H, Ar*H*), 7.76 (dd, *J* = 6.8, 2.8 Hz, 1H, Ar*H*), 7.57 – 7.46 (m, 4H, Ar*H*), 4.10 – 3.09 (m, 1H, C*H*OH), 3.50 – 3.31 (m, 1H, C*H*Ar), 2.35 – 2.17 (m, 1H), 2.11 – 1.89 (m, 1H), 1.89 – 1.75 (m, 1H), 1.68 – 1.40 (m, 5H).

  The characterization data matched the reported values.[8]

2-Phenylcyclooctan-1-ol (30)



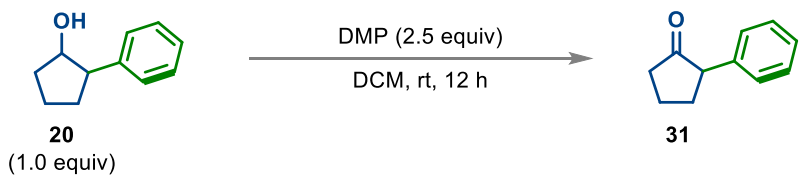
Following a slightly modified procedure,[9] To a solution of 1-phenylcycloheptene **18** (16 mmol, 1.0 equiv) in THF (40 mL, 0.4 M) at 0 °C, BH_3·THF (1.0 M in THF, 32 mL, 2.0 equiv) was added dropwise over 50 minutes, and the resulting solution was allowed to warm to room temperature and stirred for 2 h. NaOH (4.0 M aq, 10 mL, 2.5 equiv) and hydrogen peroxide (30% w/v aq, 50 mL) were added at 0 °C. The reaction mixture was then warmed to room temperature and stirred for 4 h. The resulting solution was washed with saturated $Na_2S_2O_3$ (20 mL) and saturated NaCl (20 mL), extracted with Et_2O (3×40 mL). The organic layers were combined and dried over $MgSO_4$, and concentrated in vacuum. The crude product was purified by flash column chromatography using 1:9 mixture of EtOAc and hexane as mobile phase to obtain the pure alcohol **30** as a white solid (900 mg, 4.40 mmol, 28%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.33, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.34 (t, *J* = 7.5 Hz, 2H, Ar*H*), 7.28 – 7.22 (m, 3H, Ar*H*), 3.94 (ddd, *J* = 9.7, 6.2, 2.6 Hz, 1H, C*H*OH), 2.77 (dt, *J* = 10.6, 5.6 Hz, 1H, C*H*Ar), 2.08 – 1.97 (m, 1H), 1.96 – 1.86 (m, 1H), 1.86 – 1.77 (m, 3H), 1.75 – 1.51 (m, 8H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 146.0, 128.8, 128.0, 126.6, 75.8, 51.4, 32.6, 32.1, 27.1, 27.0, 25.4, 23.1.

  The characterization data matched the reported values.[10]

2.4 Procedures for synthesis of 2-arylcycloalkan-1-one

2-Phenylcyclopentan-1-one (31)

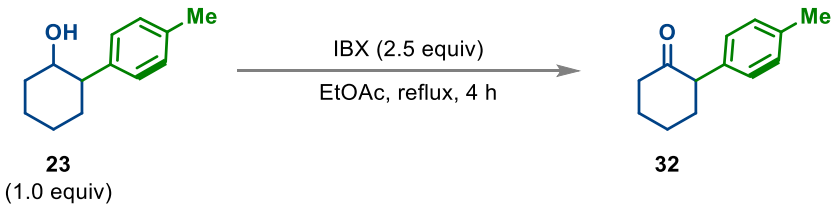


Following a slightly modified procedure,[11] a 100 mL round-bottomed flask was charged with 2-phenylcyclopetan-1-ol **20** (1.90 g, 12.0 mmol, 1.00 equiv), which was dissolved in 35 mL of dichloromethane (0.3 M). The resulting solution was stirred for 10 minutes. DMP (12.7 g, 30.0 mmol, 2.50 equiv) was then added gradually to the flask. The reaction mixture was then stirred for 12 h and quenched with 25 mL of saturated sodium sulfite ($Na_2S_2O_3$). The aqueous layer was then extracted with DCM (3×20 mL) and the organic layers were combined. The combined organic layers were dried using $MgSO_4$ and were concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 ratio of EtOAc to hexane as mobile phase to obtain the pure product **31** as a colorless oil (1.15 g, 7.20 mmol, 60%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.41, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.34 (t, *J* = 7.4 Hz, 2H), 7.25 (d, *J* = 4.2 Hz, 2H), 7.19 (d, *J* = 6.9 Hz, 1H), 3.42 – 3.23 (m, 1H, COC*H*Ar), 2.57 – 2.43 (m, 2H, COCH_2), 2.36 – 2.24 (m, 1H), 2.22 – 2.06 (m, 2H), 1.96 (m, 1H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 138.4, 128.6, 128.1, 126.9, 55.3, 38.4, 31.7, 20.8. ** One carbon was not resolved at 101 MHz.

  The characterization data matched the reported values.[12]

2-(*p*-Tolyl)cyclohexan-1-one (32)



23 (1.0 equiv) → **32**

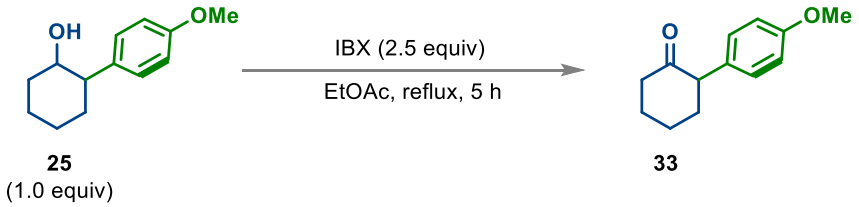
Following a slightly modified procedure,[13] a 100-mL round-bottom flask was charged with 2-(*p*-tolyl)cyclohexan-1-ol **23** (1.7 g, 8.9 mmol, 1.0 equiv) and IBX (6.2 g, 22 mmol, 2.5 equiv). To this reaction mixture, EtOAc (40.0 mL, 0.22 M) was added and refluxed. After 4 h, the reaction stopped and cooled down to room temperature. Next, the reaction mixture was filtered through a silica-crucible, the filtrate was concentrated under reduced pressure and purified by flash column

chromatography using a 1:19 EtOAc/Hexane mixture as mobile phase to obtain the pure product **32** as white solid (1.58 g, 8.40 mmol, 94%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.44, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.08 (d, *J* = 7.7 Hz, 2H, Ar*H*), 6.96 (d, *J* = 8.1 Hz, 2H, Ar*H*), 3.51 (dd, *J* = 12.0, 5.5 Hz, 1H, COC*H*Ar), 2.58 – 2.32 (m, 2H, COCH_2), 2.26 (s, 3H, ArCH_3), 2.24 – 2.13 (m, 1H), 2.08 (dddd, *J* = 12.1, 7.7, 5.0, 2.4 Hz, 1H), 2.03 – 1.88 (m, 2H), 1.84 – 1.67 (m, 2H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.5, 136.5, 135.7, 129.1, 128.3, 57.0, 42.2, 35.1, 27.8, 25.3, 21.1.

  The characterization data matched the reported values.[14]

2-(4-Methoxyphenyl)cyclohexan-1-one (33)

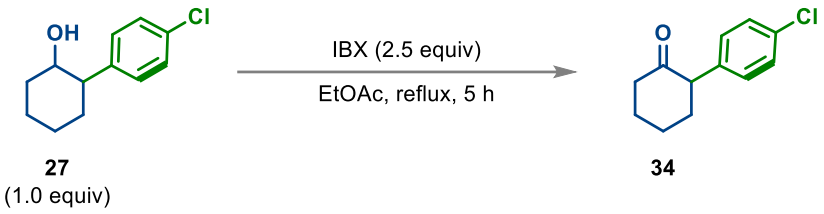


Following a slightly modified procedure,[13] a 100-mL round-bottom flask was charged with 2-(4-methoxyphenyl)cyclohexan-1-ol **25** (2.0 g, 10 mmol, 1.0 equiv) and IBX (7.0 g, 25 mmol, 2.5 equiv). To this reaction mixture, EtOAc (50 mL, 0.2 M) was added and refluxed. After 5 h, the reaction stopped and cooled down to room temperature. Next, the reaction mixture was filtered through a silica-crucible, the filtrate was concentrated under reduced pressure and purified by flash column chromatography using a 1:19 EtOAc/Hexane mixture as mobile phase to obtain the pure product **33** as a white solid (1.5 g, 7.4 mmol, 74%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.33, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.06 (d, *J* = 8.8 Hz, 2H, Ar*H*), 6.88 (d, *J* = 8.6 Hz, 2H, Ar*H*), 3.80 (s, 3H, OCH_3), 3.57 (dd, *J* = 12.4, 5.5 Hz, 1H, COC*H*Ar), 2.57 – 2.38 (m, 2H, COCH_2), 2.31 – 2.20 (m, 1H), 2.20 – 2.09 (m, 1H), 2.07 – 1.92 (m, 2H), 1.89 – 1.74 (m, 2H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.7, 158.4, 130.8, 129.4, 113.8, 56.6, 55.2, 42.1, 35.2, 27.8, 25.4.

The characterization data matched the reported values.[14]

2-(4-Chlorophenyl)cyclohexan-1-one (34)



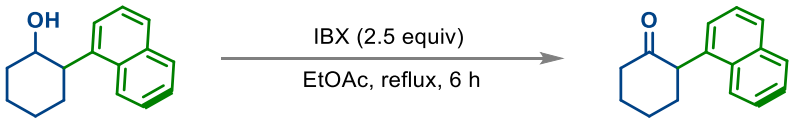
27 (1.0 equiv) **34**

Following a slightly modified procedure,[13] a 100-mL round-bottom flask was charged with 2-(4-chlorophenyl)cyclohexan-1-ol **27** (2.1 g, 10 mmol, 1.0 equiv) and IBX (7.0 g, 25 mmol, 2.5 equiv). To this reaction mixture EtOAc (50 mL, 0.2 M) was added and refluxed. After 5 h, the reaction stopped and cooled down to room temperature. Next, the reaction mixture was filtered through a silica-crucible, the filtrate was concentrated under reduced pressure and purified by flash column chromatography using a 1:19 EtOAc/Hexane mixture as mobile phase to obtain the pure product **34** as a white solid (1.73 g, 8.30 mmol, 83%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.40, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.30 (d, *J* = 8.5 Hz, 2H, Ar*H*), 7.07 (d, *J* = 8.4 Hz, 2H, Ar*H*), 3.59 (dd, *J* = 12.2, 5.4 Hz, 1H, COC*H*Ar), 2.61 – 2.39 (m, 2H, COCH_2), 2.39 – 2.21 (m, 1H), 2.20 – 2.10 (m, 1H), 2.08 – 1.90 (m, 2H), 1.90 – 1.66 (m, 2H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 209.8, 137.2, 132.7, 129.9, 128.4, 56.8, 42.2, 35.4, 27.9, 25.4.

  The characterization data matched the reported values.[14]

2-(Naphthalen-1-yl)cyclohexan-1-one (35)



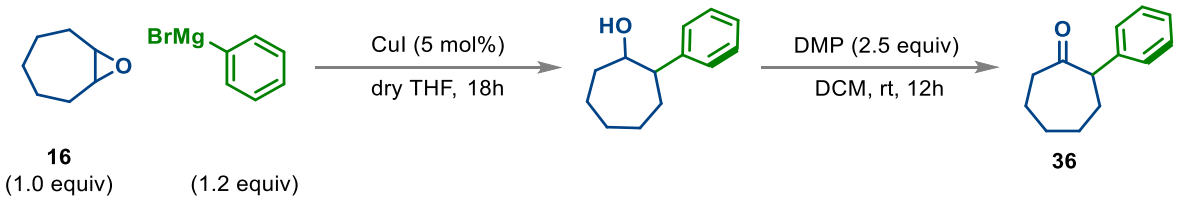
29 (1.0 equiv) **35**

Following a slightly modified procedure,[13] a 100-mL round-bottom flask was charged with 2-(naphthalen-1-yl)cyclohexan-1-ol **29** (2.0 g, 10 mmol, 1.0 equiv) and IBX (7.0 g, 25 mmol, 2.5 equiv). To this reaction mixture, EtOAc (50 mL, 0.2 M) was added and refluxed. After 5 h, the

reaction stopped and cooled down to room temperature. Next, the reaction mixture was filtered through a silica-crucible, the filtrate was concentrated under reduced pressure and purified by flash column chromatography using a 1:19 EtOAc/Hexane mixture as mobile phase to obtain the pure product **35** as a white-grey solid (1.7 g, 8.6 mmol, 86%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.39, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.90 – 7.83 (m, 1H, Ar*H*), 7.79 (d, *J* = 8.2 Hz, 1H, Ar*H*), 7.75 – 7.69 (m, 1H, Ar*H*), 7.58 – 7.41 (m, 3H, Ar*H*), 7.36 (d, *J* = 7.2 Hz, 1H, Ar*H*), 4.37 (dd, *J* = 12.6, 5.3 Hz, 1H, COC*H*Ar), 2.71 – 2.58 (m, 2H, COCH_2), 2.48 – 2.37 (m, 1H), 2.35 – 2.21 (m, 2H), 2.19 – 2.07 (m, 1H), 2.04 – 1.83 (m, 2H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.0, 135.2, 133.8, 131.8, 129.0, 127.6, 125.9, 125.4, 125.3, 125.3, 123.2, 53.3, 42.6, 34.3, 27.9, 25.9.
  The characterization data matched the reported values.[15]

2-Phenylcycloheptan-1-one (36)



Step 1: Following a modified procedure,[5] a two-neck flask was charged with 1.0 M PhMgBr in THF (17.0 mL, 16.8 mmol, 1.20 equiv). To this, CuI (135 mg, 0.70 mmol, 0.05 equiv) was added under argon atmosphere. After stirring for 30 minutes, cycloheptene-oxide **16** (1.54 g, 14.0 mmol, 1.00 equiv) in dry THF (7.0 mL, 2.0 M) was added dropwise using syringe-pump over 20 minutes. The resulting mixture was stirred for 18 h at room temperature. Next, the reaction mixture was quenched with 15 mL of saturated NH_4Cl and extracted with Et_2O (3×15 mL). The extracted organic layers were combined, dried over $MgSO_4$ and concentrated under reduced pressure to obtain the crude product. The crude product was used in the next step without further purification.

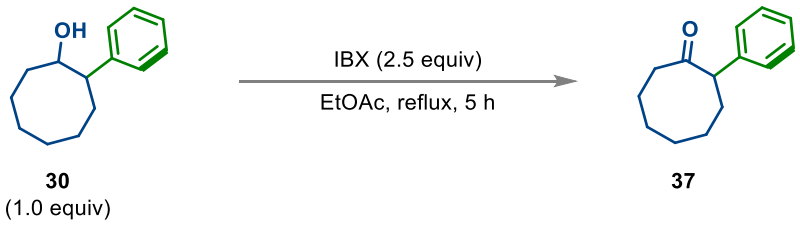
Step 2: Following a modified procedure,[11] a 100 mL round-bottomed flask was charged with the obtained crude 2-phenylcycloheptan-1-ol, which was dissolved in 40 mL of dichloromethane (0.3 M). The resulting solution was stirred for 10 minutes. DMP (14.8 g, 35.0 mmol, 2.50 equiv) was

then added gradually to the flask. The reaction mixture was stirred for 12 h and quenched with30 mL of saturated sodium sulfite ($Na_2S_2O_3$) solution. The aqueous layer was then extracted with DCM (3×20 mL). The organic layers were combined, dried using $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 ratio of EtOAc to hexane as eluent to obtain the pure product **36** as a white solid (1.44 g, 7.80 mmol, 56%, over 2 steps).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.43, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.25 (dd, *J* = 8.5, 6.5 Hz, 2H, Ar*H*), 7.21 – 7.12 (m, 3H, Ar*H*), 3.65 (dd, *J* = 11.4, 4.1 Hz, 1H, COC*H*Ar), 2.62 (td, *J* = 13.1, 3.2 Hz, 1H, COC*H*^{a}H^b), 2.52 – 2.38 (m, 1H), 2.07 (m, 1H), 2.02 – 1.83 (m, 3H), 1.70 – 1.51 (m, 2H), 1.46 – 1.30 (m, 2H).

  The characterization data matched the reported values.[9]

2-Phenylcyclooctan-1-one (37)



Following a modified procedure,[13] a 100-mL round-bottom flask was charged with 2-phenylcyclooctan-ol **30** (880 mg, 4.30 mmol, 1.00 equiv) and IBX (3.00 g, 10.7 mmol, 2.50 equiv). To this reaction mixture, EtOAc (20.0 mL, 0.22 M) was added and refluxed. After 5 h, the reaction stopped and cooled down to room temperature. Next, the reaction mixture was filtered through a silica-crucible, the filtrate was concentrated under reduced pressure and purified by flash column chromatography using a 1:19 EtOAc/Hexane mixture as mobile phase to obtain the pure product **37** as a colorless liquid (690 mg, 3.40 mmol, 79%).

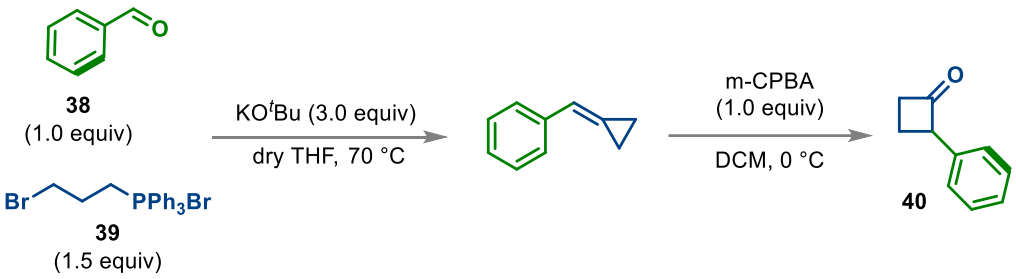
- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.46, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 – 7.30 (m, 4H, Ar*H*), 7.30 – 7.22 (m, 1H, Ar*H*), 3.81 (dd, *J* = 12.4, 2.9 Hz, 1H, COC*H*Ar), 2.64 (td, *J* = 12.3, 4.3 Hz, 1H), 2.38 (m, 1H), 2.32 – 2.23 (m, 1H), 1.97 (m, 3H), 1.78 (m, 2H), 1.61 (m, 2H), 1.55 – 1.37 (m, 2H).

- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 216.5, 139.3, 128.5, 127.8, 127.0, 57.4, 40.2, 31.5, 26.8, 26.7, 26.7, 24.6.

  The characterization data matched the reported values.[16]

2.5 Procedures for synthesis of 2-phenylcyclobutan-1-one

2-Phenylcyclobutan-1-one (40)



Step 1: Following a slightly modified a procedure,[17] a solution of KO^{t}Bu (6.74 g, 60.0 mmol, 3.00 equiv) in THF (46 mL, 1.3 M) was gradually added to a solution of (3-bromopropyl)triphenylphosphonium bromide **39** (13.9 g, 30.0 mmol, 1.50 equiv) in dry THF (60 mL, 0.5 M) and stirred at 70 °C for 1 h. Next, a solution of benzaldehyde **38** (2.04 mL, 20.0 mmol, 1.00 equiv) in THF (10 mL, 2.0 M) was added dropwise and the mixture was refluxed for 3 h. After cooling to the room temperature, the suspension was filtered, and the solvent was removed under vacuum to obtain the crude product. The crude product was used in the next step without further purification.

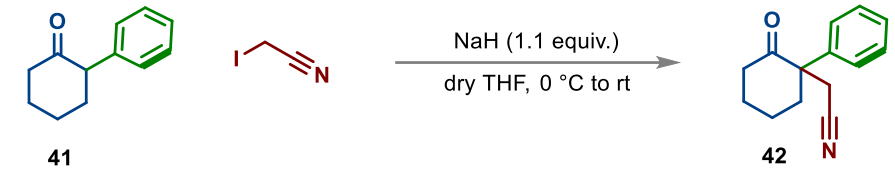
Step 2: Following a slightly modified procedure,[17] the crude alkene (1.4 g, 11 mmol, 1.0 equiv) was dissolved in DCM (70.0 mL, 0.15 M). To this, a solution of *m*-CPBA (2.5 g, 11 mmol, 1.0 equiv) in DCM (27 mL, 0.4 M) was added at 0°C and stirred for 1 h. The reaction mixture was then diluted with a saturated aqueous Na_2SO_3 solution (15 mL) and extracted with DCM (3×15 mL). The organic phases were combined and washed successively with a saturated aqueous $NaHCO_3$ solution (3×20 mL), and brine (20 mL). Thecombined organic layers were dried using $MgSO_4$ and concentrated under vacuum. The crude material was purified through flash column chromatography on silica gel using a petroleum ether and EtOAc (20:1) to obtain the pure product **40** as a colorless oil (1.00 g, 6.75 mmol, 34%, over 2 steps).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.33, $KMnO_4$.

- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.37 (t, *J* = 7.5 Hz, 2H, Ar*H*), 7.29 (m, 3H, Ar*H*), 4.63 – 4.52 (m, 1H), 3.33 – 3.18 (m, 1H), 3.13 – 2.99 (m, 1H), 2.57 (qd, *J* = 10.7, 4.9 Hz, 1H), 2.34 – 2.21 (m, 1H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 207.9, 136.4, 128.6, 126.9, 126.9, 64.4, 44.8, 17.6. The characterization data matched the reported values.[17]

2.6 Procedures for alkylation of 2-(aryl)-cycloalkan-1-one

2-(2-Oxo-1-phenylcyclohexyl)acetonitrile (42)

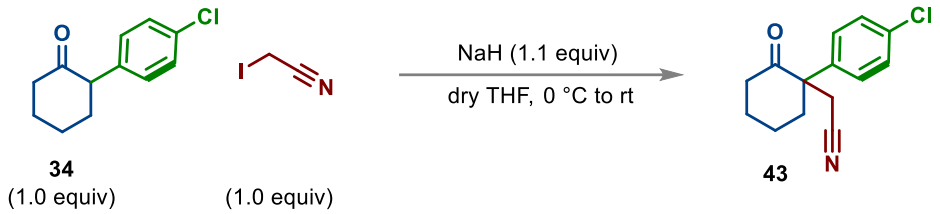


Following a slightly modified procedure,[18] a 100 mL two-neck flask was charged with NaH (440 mg, 11.0 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×10 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (30 mL, 0.3 M) and cooled down in an ice bath. A solution of commercially available 2-phenylcyclohexan-1-one **41** (1.74 g, 10.0 mmol, 1.00 equiv) in dry THF (5.0 mL, 2.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (1.67 g, 0.720 mL, 10.0 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 20 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as eluent to obtain the pure product **42** as a pale yellow liquid (1.4 g, 6.7 mmol, 67%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.22, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 (t, *J* = 7.6 Hz, 2H, Ar*H*), 7.34 (t, *J* = 7.3 Hz, 1H, Ar*H*), 7.22 (d, *J* = 7.8 Hz, 2H, Ar*H*), 3.06 – 2.93 (m, 1H), 2.75 (d, *J* = 16.9 Hz, 1H, C*H*^{a}H^{b}CN), 2.67 (d, *J* = 16.9 Hz, 1H, CH^{a}*H*^{b}CN), 2.46 – 2.32 (m, 2H), 2.06 – 1.95 (m, 1H), 1.93 – 1.69 (m, 4H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.2, 137.6, 129.5, 128.2, 126.5, 117.6, 55.2, 39.3, 35.0, 29.7, 28.1, 21.3. (*See Spectra*)

- **IR (Neat):** υ 2940 (m), 2866 (m), 2246 (w), 1709 (s), 1452 (m), 1417 (m), 1123 (m), 760 (m), 702 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{16}NO^+$ $[M+H]^+$ 214.1232; found: 214.1231.

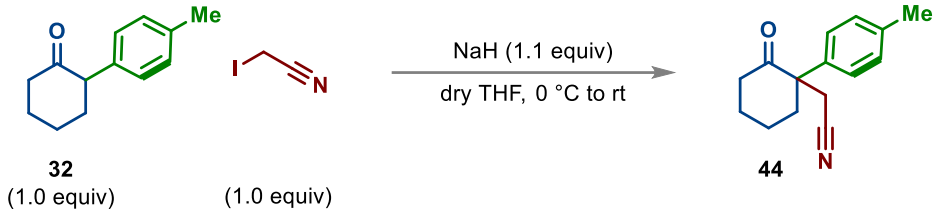
2-(1-(4-Chlorophenyl)-2-oxocyclohexyl)acetonitrile (43)



Following a slightly modified procedure,[18] a 50 mL two-neck flask was charged with NaH (203 mg, 5.06 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×5 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (15 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-(4-chlorophenyl)cyclohexan-1-one **34** (960 mg, 4.60 mmol, 1.00 equiv) in dry THF (5.0 mL, 1.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (768 mg, 0.330 mL, 4.60 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 10 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **43** as a pale yellow oil (640 mg, 2.60 mmol, 56%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.19, $KMnO_4$
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.40 (d, *J* = 8.6 Hz, 2H, Ar*H*), 7.16 (d, *J* = 8.6 Hz, 2H, Ar*H*), 2.93 (dd, *J* = 14.1, 2.9 Hz, 1H), 2.69 (dd, *J* = 20 Hz, 2.1 Hz, 2H, C*H*$_2$CN), 2.44 – 2.28 (m, 2H), 2.09 – 1.95 (m, 1H), 1.93 – 1.65 (m, 4H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 209.6, 136.0, 134.3, 129.7, 128.0, 117.3, 54.7, 39.3, 35.1, 29.6, 28.0, 21.2. (*See Spectra*)
- **IR (Neat):** υ 2934 (m), 2846 (m), 2247 (w), 1709 (s), 1493 (m), 1456 (m), 1095 (m), 1012 (m), 825 (m), 720 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{15}ClNO^+$ $[M+H]^+$ 248.0842; found: 248.0838.

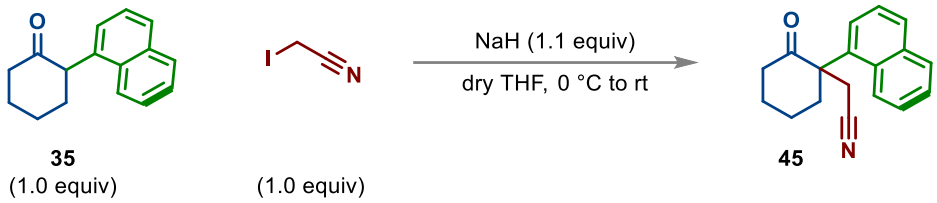
2-(2-Oxo-1-(*p*-tolyl)cyclohexyl)acetonitrile (44)



Following a slightly modified procedure,[18] a 100 mL two-neck flask was charged with NaH (390 mg, 9.70 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×10 mL) and dried in a Schlenk line. The dried NaHwas then dissolved in dry THF (28 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-((4-methylphenyl)cyclohexan-1-one **32** (1.66 g, 8.80 mmol, 1.00 equiv) in dry THF (5.0 mL, 2.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (1.50 g, 0.630 mL, 8.80 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 20 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **44** as a pale yellow oil (760 mg, 3.34 mmol, 38%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.24, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.21 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.14 – 7.06 (m, 2H, Ar*H*), 2.99 – 2.90 (m, 1H), 2.71 (d, *J* = 16.8 Hz, 1H, C*H*^{a}H^{b}CN), 2.64 (d, *J* = 16.9 Hz, 1H, CH^a*H*^{b}CN), 2.46 – 2.30 (m, 5H), 2.08 – 2.193 (m, 1H), 1.93 – 1.62 (m, 3H), 0.92 – 0.80 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.2, 138.0, 134.6, 130.2, 126.3, 117.6, 54.8, 39.2, 35.1, 29.7, 28.0, 21.3, 20.9. (*See Spectra*)
- **IR (Neat):** υ 2939 (m), 2866 (m), 2246 (w), 1707 (s), 1513 (m), 1452 (m), 1417 (m), 1124 (m), 815 (m), 723 (w), 690 (w).
- **HRMS (ESI):** calcd. for $C_{15}H_{18}NO^+$ $[M+H]^+$ 228.1388; found: 228.1389.

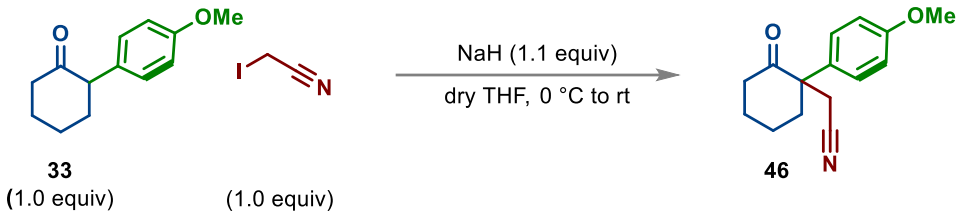
2-(1-(Naphthalen-1-yl)-2-oxocyclohexyl)acetonitrile (45)



Following a slightly modified procedure,[18] a 50 mL two-neck flask was charged with NaH (220 mg, 5.50 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×5 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (15 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-(naphthalen-1-yl)cyclohexan-1-one **35** (1.1 g, 5.0 mmol, 1.0 equiv) in dry THF (5.0 mL, 1.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (835 mg, 0.360 mL, 5.00 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 10 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **45** as a colorless oil (302 mg, 1.15 mmol, 23%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.21, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.97 – 7.84 (m, 2H, Ar*H*), 7.81 (d, *J* = 7.4 Hz, 1H, Ar*H*), 7.74 (dd, *J* = 8.9, 6.8 Hz, 1H, Ar*H*), 7.60 (t, *J* = 7.8 Hz, 1H, Ar*H*), 7.57 – 7.42 (m, 2H, Ar*H*), 3.36 – 3.25 (m, 1H), 3.19 (d, *J* = 17.1 Hz, 1H, C*H*^{a}H^{b}CN), 3.07 (d, *J* = 17.1 Hz, 1H, CH^a*H*^{b}CN), 2.34 – 2.11 (m, 2H), 2.01 (m, 2H), 1.90 – 1.73 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 215.0, 134.9, 132.3, 129.9, 129.7, 127.3, 126.6, 125.8, 125.3, 122.3, 117.5, 56.2, 40.2, 39.4, 30.2, 27.5, 21.1. (*See Spectra*)
- **IR (Neat):** υ 2930 (s), 2860 (m), 2244 (w), 1707 (s), 1510 (m), 1449 (m), 1255 (m), 1059 (m), 954 (w), 779 (s).
- **HRMS (ESI):** calcd. for $C_{18}H_{17}NONa^+$ $[M+Na]^+$ 286.1208; found: 286.1205.

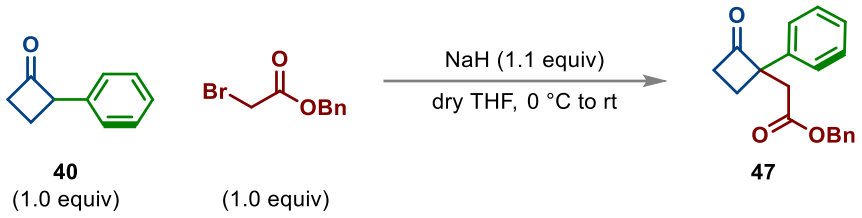
2-(2-Oxo-1-phenylcyclohexyl)acetonitrile (46)



Following a slightly modified procedure,[18] a 100 mL two-neck flask was charged with NaH (320 mg, 8.00 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×10 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (22 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-(4-methoxyphenyl)cyclohexan-1-one **33** (1.5 g, 7.3 mmol, 1.0 equiv) in dry THF (4.0 mL, 2.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (1.20 g, 0.53 mL, 7.30 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 20 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **46** as a colorless oil (600 mg, 2.50 mmol, 34%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.19, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.13 (d, *J* = 8.9 Hz, 2H, Ar*H*), 6.93 (d, *J* = 8.9 Hz, 2H, Ar*H*), 3.81 (s, 3H, OC*H*$_3$), 2.99 – 2.88 (m, 1H), 2.73 – 2.63 (dd, *J* =20 Hz, 3.3 Hz, 2H, C*H*$_2$CN), 2.48 – 2.29 (m, 2H), 2.07 – 1.94 (m, 1H), 1.92 – 1.64 (m, 4H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.3, 159.3, 129.4, 127.7, 117.7, 114.9, 55.30, 54.5, 39.2, 35.3, 29.8, 28.1, 21.3.
- **HRMS (ESI):** calcd. for $C_{15}H_{18}NO_2^+$ $[M+H]^+$ 244.1338; found: 244.1337.
  The characterization data matched the reported values.[18]

Benzyl 2-(2-oxo-1-phenylcyclobutyl)acetate (47)

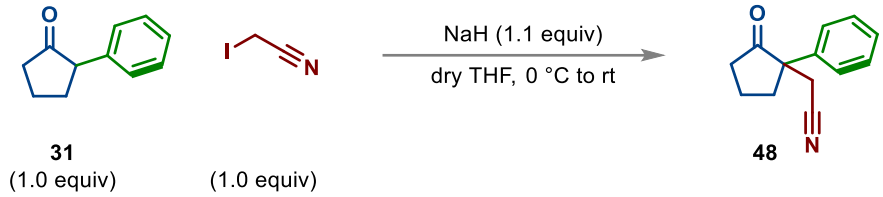


40 (1.0 equiv) (1.0 equiv) **47**

Following a slightly modified procedure,[18] a 25 mL two-neck flask was charged with NaH (27 mg, 1.1 mmol, 1.1 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×2 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (3.0 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-phenylcyclobutan-1-one **40** (146 mg, 1.00 mmol, 1.00 equiv) in dry THF (1.0 mL, 1.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2 h. Next, benzyl-2-bromoacetate (230 mg, 0.160 mL, 1.00 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 5 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **47** as a colorless oil (100 mg, 0.340 mmol, 34%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.19, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.47 – 7.32 (m, 6H, Ar*H*), 7.31 – 7.24 (m, 4H, Ar*H*), 5.08 (s, 2H, OCH_2Ph), 3.22 – 3.04 (m, 2H), 3.00 (d, *J* = 16.4 Hz, 1H, CH^a$H^b$$CO_2$Bn), 2.87 (d, *J* = 16.2 Hz, 1H, CH^aH^bCO_2Bn), 2.67 – 2.50 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 209.6, 170.1, 139.5, 135.4, 128.8, 128.5, 128.3, 127.3, 126.3, 68.5, 66.5, 43.5, 23.0. ** Two carbons were not resolved at 101 MHz (*See Spectra*)
- **IR (Neat):** υ 2927 (w), 1780 (s), 1734 (s), 1495 (w), 1452 (w), 1340 (w), 1164 (s), 1076 (m), 751 (m), 699 (m).
- **HRMS (ESI):** calcd. for $C_{19}H_{18}O_3Na^+$ $[M+Na]^+$ 317.1154; found: 317.1151.

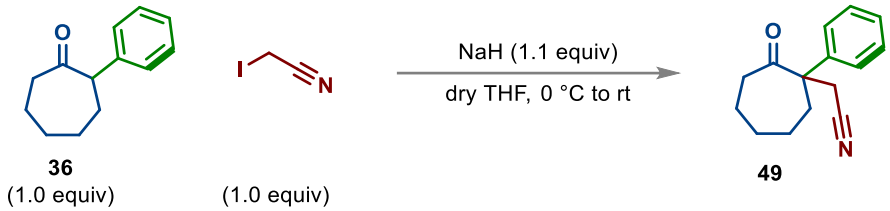
2-(2-Oxo-1-phenylcyclopentyl)acetonitrile (48)



Following a slightly modified procedure,[18] a 100 mL two-neck flask was charged with NaH (440 mg, 11.0 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×10 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (30 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-phenylcyclopentan-1-one **31** (1.6 g, 10 mmol, 1.0 equiv) in dry THF (5.0 mL, 2.0 M) was added dropwise to the NaH solution and allowed to stir at 0°C for 2.5 h. Next, iodoacetonitrile (1.67 g, 0.720 mL, 10.0 mmol, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 20 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **48** as a pale yellow oil (0.9 g, 4.5 mmol, 45%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.21, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 – 7.28 (m, 5H, Ar*H*), 2.86 (ddt, *J* = 13.4, 6.3, 2.0 Hz, 1H), 2.80 (d, *J* = 16.9 Hz, 1H, C*H*^{a}H^{b}CN), 2.73 (d, *J* = 17.0 Hz, 1H, CH^a*H*^{b}CN), 2.41 (ddt, *J* = 19.7, 9.5, 2.5 Hz, 1H), 2.36 – 2.24 (m, 1H), 2.18 (ddd, *J* = 13.4, 11.9, 6.9 Hz, 1H), 2.10 – 1.98 (m, 1H), 1.89 – 1.71 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 215.6, 136.2, 129.3, 128.3, 126.3, 117.2, 54.5, 36.2, 33.6, 27.3, 18.1. (*See Spectra*)
- **IR (Neat):** υ 2924 (m), 2856 (w), 2248 (w), 1737 (s), 1495 (w), 1454 (w), 1157 (m), 758 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{13}H_{13}NONa^+$ $[M+Na]^+$ 222.0895; found: 222.0896.

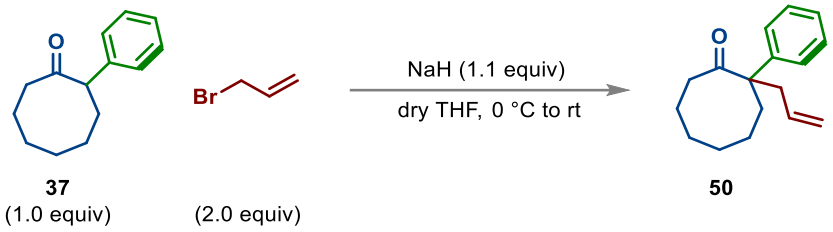
2-(2-Oxo-1-phenylcycloheptyl)acetonitrile (49)



Following a slightly modified procedure,[18] a 100 mL two-neck flask was charged with NaH (308 mg, 7.70 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×10 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (25 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-phenylcycloheptan-1-one **36** (1.3 g, 7.0 mmol, 1.0 equiv) in dry THF (3.5 mL, 2.0 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, iodoacetonitrile (1.20 g, 0.530 mL, 1.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 20 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **49** as a pale yellow oil (800 mg, 3.08 mmol, 44%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.22, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.46 – 7.36 (m, 2H, Ar*H*), 7.36 – 7.29 (m, 1H, Ar*H*), 7.25 – 7.20 (m, 2H, Ar*H*), 2.94 (dd, *J* = 17.0, 1.6 Hz, 1H, C*H*^{a}H^{b}CN), 2.68 (d, *J* = 17.0 Hz, 1H, CH^a*H*^{b}CN), 2.62 – 2.45 (m, 2H), 2.43 – 2.31 (m, 1H), 2.31 – 2.21 (m, 1H), 2.12 – 1.99 (m, 1H), 1.94 – 1.80 (m, 1H), 1.56 – 1.35 (m, 2H), 1.32 – 1.14 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.1, 139.3, 129.2, 128.2, 126.4, 118.2, 57.1, 40.3, 32.7, 30.3, 27.6, 26.9, 24.0. (*See Spectra*)
- **IR (Neat):** υ 2928 (s), 2857 (m), 2244 (w), 1705 (s), 1451 (m), 1157 (m), 164 (m), 702 (m).
- **HRMS (ESI):** calcd. for $C_{15}H_{17}NONa^+$ $[M+Na]^+$ 250.1208; found: 250.1206.

2-Allyl-2-phenylcyclooctan-1-one (50)

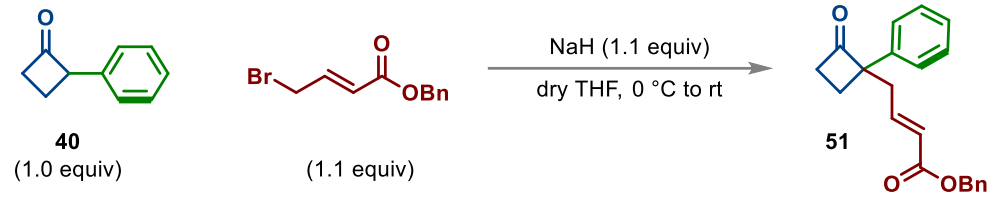


37 (1.0 equiv) (2.0 equiv) **50**

Following a slightly modified procedure,[18] a 50 mL two-neck flask was charged with NaH (145 mg, 3.63 mmol, 1.10 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×5 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (11 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-phenylcyclooctan-1-one **37** (667 mg, 3.30 mmol, 1.00 equiv) in dry THF (2.0 mL, 1.6 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2.5 h. Next, allylbromide (800 mg, 0.560 mL, 6.60 mmol, 2.00 equiv) was added to the reaction mixture. The mixture was stirred at room temperature for 18 h and then quenched with 10 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **50** as a colorless oil (620 mg, 2.50 mmol, 77%).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.58, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.38 – 7.30 (m, 2H, Ar*H*), 7.30 – 7.21 (m, 3H, Ar*H*), 5.31 – 5.16 (m, 1H, C*H*=CH_2), 5.04 – 4.81 (m, 2H, CH=CH_2), 2.90 (dd, *J* = 14.8, 5.2 Hz, 1H), 2.68 – 2.38 (m, 3H), 2.17 (dt, *J* = 14.6, 4.1 Hz, 1H), 1.90 (dt, *J* = 12.0, 4.3 Hz, 1H), 1.85 – 1.65 (m, 5 H) 1.64 – 1.50 (m, 1H), 1.38 – 1.23 (m, 1H), 1.19 – 1.03 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 216.9, 140.4, 134.5, 128.5, 127.0, 126.9, 117.2, 57.2, 37.9, 37.9, 29.7, 27.0, 25.6, 24.2, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2925 (s), 2857 (m), 1699 (s), 1458 (m), 1080 (m), 913 (m), 752 (m), 703 (s).
- **HRMS (ESI):** calcd. for $C_{17}H_{23}O^+$ $[M+H]^+$ 243.1749; found: 243.1751.

Benzyl (*E*)-4-(2-oxo-1-phenylcyclobutyl)but-2-enoate (51)



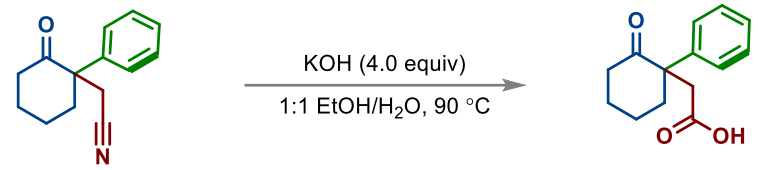
40 (1.0 equiv) (1.1 equiv) **51**

Following a slightly modified procedure,[18] a 25 mL two-neck flask was charged with NaH (90 mg, 3.7 mmol, 1.1 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×5 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (12 mL, 0.3 M) and cooled down in an ice bath. A solution of 2-phenylcyclobutan-1-one **40** (500 mg, 3.40 mmol, 1.00 equiv) in dry THF (4.0 mL, 0.8 M) was added dropwise to the NaH solution and allowed to stir at 0 °C for 2 h. Next, a solution of benzyl (E)-4-bromobut-2-enoate (955 mg, 3.74 mmol, 1.10 equiv) in THF (4 mL, 0.9 M) was added to the reaction mixture. The mixture was stirred at room temperature for 16 h and then quenched with 10 mL of saturated NH_4Cl solution. The aqueous layer was extracted using diethyl ether (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:19 EtOAc:Hexane as mobile phase to obtain the pure product **51** as a colorless oil (640 mg, 2.00 mmol, 58%).

- **TLC (EtOAc:Hexane, 1:19 v/v):** R_f = 0.29, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.32 – 7.17 (m, 10H, Ar*H*), 6.71 (dt, *J* = 15.3, 7.6 Hz, 1H, CH_2CH=CHCO), 5.75 (d, *J* = 15.5 Hz, 1H, CH_2CH=C*H*CO), 5.06 (s, 2H, OCH_2Ph), 3.08 – 2.90 (m, 2H), 2.62 (dt, *J* = 7.7, 1.8 Hz, 2H), 2.43 (ddd, *J* = 11.4, 9.7, 7.5 Hz, 1H), 2.16 (ddd, *J* = 11.5, 9.5, 7.4 Hz, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 209.9, 165.6, 143.3, 139.3, 135.9, 128.6, 128.5, 128.1, 128.0, 127.2, 126.2, 124.5, 70.9, 66.1, 42.8, 41.6, 22.4. (*See Spectra*)
- **HRMS (ESI):** calcd. for $C_{21}H_{20}O_3Na^+$ $[M+Na]^+$ 343.1310; found: 343.1307.

2.7 Procedures for synthesis of carboxylic acids

2-(2-Oxo-1-phenylcyclohexyl)acetic acid (52)



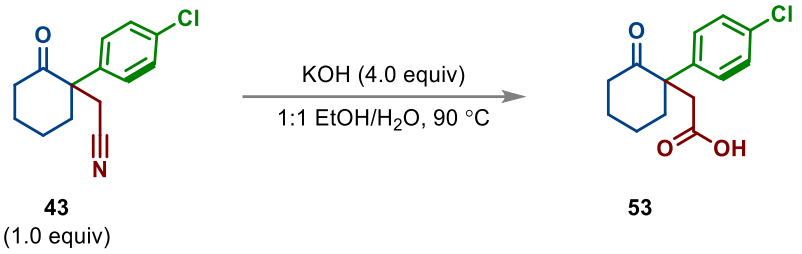
42
(1.0 equiv)

52

Following a slightly modified procedure,[19] the compound **42** (2.0 g, 9.4 mmol, 1.0 equiv) and KOH (2.10 g, 37.5 mmol, 4.00 equiv) were taken into a 100 mL round bottom flask and dissolved in 50 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×30 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **52** as a white solid (1.7 g, 7.3 mmol, 78%).

- **M.P.** 132 – 135 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.27, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.36 (t, *J* = 7.1 Hz, 2H, Ar*H*), 7.31 – 7.27 (m, 1H, Ar*H*), 7.20 (d, *J* = 7.7 Hz, 2H, Ar*H*), 2.94 – 2.74 (m, 2H), 2.66 (d, J = 15.1 Hz, 1H, C*H*^{a}H^bCO_2H), 2.44 – 2.29 (m, 2H), 2.26 – 2.07 (m, 1H), 2.02 – 1.87 (m, 1H), 1.83 – 1.67 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 212.6, 175.7, 139.2, 129.1, 127.4, 126.7, 55.9, 44.9, 39.7, 34.6, 27.7, 21.5. (*See Spectra*)
- **IR (Neat):** υ 3060 (m), 2935 (s), 2865 (m), 1706 (s), 1450 (m), 1410 (m), 1224 (m), 757 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{16}O_3Na^+$ $[M+Na]^+$ 255.0997; found: 255.0994.

2-(1-(4-Chlorophenyl)-2-oxocyclohexyl)acetic acid (53)



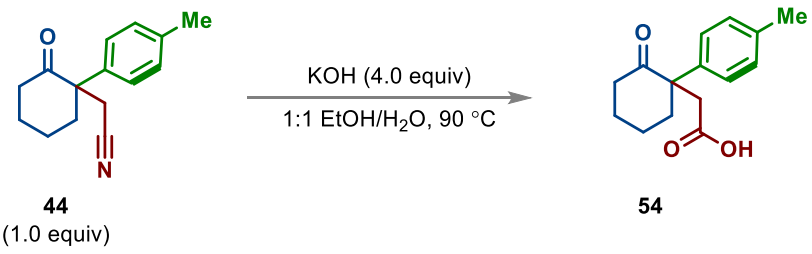
43
(1.0 equiv)

53

Following a slightly modified procedure,[19] the compound **43** (545 mg, 2.20 mmol, 1.00 equiv) and KOH (495 mg, 8.80 mmol, 4.00 equiv) were taken into a 50 mL round bottom flask and then dissolved in 15 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×10 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **53** as a white solid (490 mg, 1.80 mmol, 83%).

- **M.P.** 74 – 76 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.25, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.33 (d, *J* = 8.3 Hz, 2H, Ar*H*), 7.14 (d, *J* = 8.3 Hz, 2H, Ar*H*), 2.90 – 2.73 (m, 2H), 2.66 (d, *J* = 15.9 Hz, 1H, C*H*^{a}H^bCO_2H), 2.46 – 2.21 (m, 2H), 2.21 – 2.08 (m, 1H), 2.02 – 1.87 (m, 1H), 1.82 – 1.60 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.7, 175.9, 137.8, 133.4, 129.2, 128.3, 55.3, 44.6, 39.6, 34.5, 27.5, 21.4. (*See Spectra*)
- **IR (Neat):** υ 3097 (brs, m), 2932 (s), 2863 (m), 1707 (s), 1493 (m), 1453 (m), 1098 (m), 824 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{16}ClO_3^+$ $[M+H]^+$ 289.0607; found: 289.0605.

2-(2-Oxo-1-(p-tolyl)cyclohexyl)acetic acid (54)



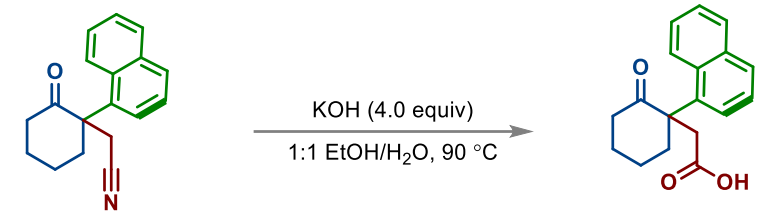
44
(1.0 equiv)

54

Following a slightly modified procedure,[19] the compound **44** (682 mg, 3.00 mmol, 1.00 equiv) and KOH (675 mg, 12.0 mmol, 4.00 equiv) were taken into a 50 mL round bottom flask and then dissolved in 25 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×10 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **54** as a white solid (618 mg, 2.52 mmol, 84%).

- **M.P.** 115 – 118 °C.
- **TLC (EtOAc:Hexane 2:8 v/v):** R_f = 0.28, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.16 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.08 (d, *J* = 8.0 Hz, 2H, Ar*H*), 2.92 – 2.72 (m, 2H), 2.63 (d, *J* = 15.5, 1H), 2.44 – 2.24 (m, 5H, ArC*H*$_3$, C*H*$_2$CO), 2.23 – 2.06 (m, 1H), 2.01 – 1.95 (m, 1H), 1.83 – 1.62 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 213.0, 175.5, 137.1, 136.2, 129.8, 126.5, 55.6, 45.1, 39.6, 34.7, 27.7, 21.5, 20.9. (*See Spectra*)
- **IR (Neat):** υ 2934 (m), 2864 (w), 1705 (s), 1449 (m), 1414 (m), 1121 (m), 921 (w), 664 (w).
- **HRMS (ESI):** calcd. for $C_{15}H_{18}O_3Na^+$ $[M+Na]^+$ 269.1154; found: 269.1150.

2-(1-(Naphthalen-1-yl)-2-oxocyclohexyl)acetic acid (55)



45
(1.0 equiv)

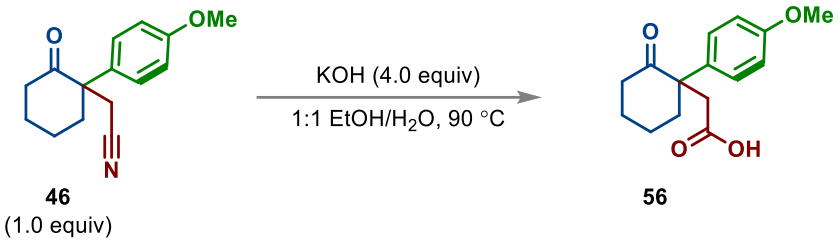
55

Following a slightly modified procedure,[19] the compound **45** (280 mg, 1.00 mmol, 1.00 equiv) and KOH (225 mg, 4.00 mmol, 4.00 equiv) were taken into a 25 mL round bottom flask and then dissolved in 5 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×10 mL) and the organic layers were

combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **55** as a white solid (115 mg, 0.390 mmol, 39%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.26, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.93 – 7.85 (m, 1H, Ar*H*), 7.84 – 7.77 (m, 2H, Ar*H*), 7.65 (d, *J* = 7.3 Hz, 1H, Ar*H*), 7.54 – 7.39 (m, 3H, Ar*H*), 3.44 – 3.31 (m, 1H), 3.07 (dd, *J* = 8.0, 4.0 Hz, 2H, C*H*$_2$CO$_2$H), 2.31 – 2.10 (m, 2H), 2.08 – 1.88 (m, 3H), 1.87 – 1.68 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 217.0, 176.1, 134.7, 133.9, 131.7, 129.6, 128.9, 126.9, 126.5, 125.5, 125.0, 123.0, 57.4, 42.4, 40.4, 39.2, 30.5, 21.2. (*See Spectra*)
- **IR (Neat):** υ 2929 (s), 2855 (m), 1704 (s), 1489 (m), 1326 (m), 1203 (m), 758 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{18}H_{18}O_3Na^+$ $[M+Na]^+$ 305.1154; found: 305.1151.

2-(1-(4-Methoxyphenyl)-2-oxocyclohexyl)acetic acid (56)



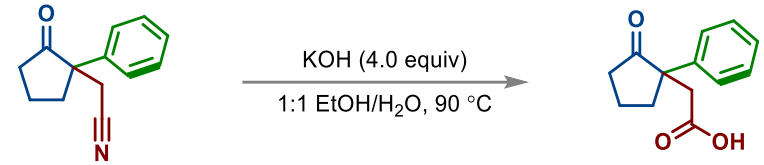
46 (1.0 equiv) **56**

Following a slightly modified procedure,[19] the compound **46** (780 mg, 3.20 mmol, 1.00 equiv) and KOH (720 mg, 12.8 mmol, 4.00 equiv) were taken into a 50 mL round bottom flask and then dissolved in 27 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×20 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 9:1 DCM/Heaxne as mobile phase to obtain the title compound **56** as a white solid (756 mg, 2.90 mmol, 90%).

- **M.P.** 84 – 87 °C.
- **TLC (EtOAc:Hexane 2:8 v/v):** R_f = 0.22, $KMnO_4$.

- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.11 (d, *J* = 8.4 Hz, 2H, Ar*H*), 6.96 – 6.82 (m, 2H, Ar*H*), 3.80 (s, 3H, OCH_3), 2.91 – 2.58 (m, 3H), 2.47 – 2.23 (m, 2H), 2.20 – 2.02 (m, 1H), 2.00 – 1.86 (m, 1H), 1.85 – 1.65 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 213.2, 175.0, 158.7, 131.0, 127.8, 114.5, 55.3, 55.2, 45.2, 39.5, 35.0, 27.7, 21.5. (*See Spectra*)
- **IR (Neat):** υ 2925 (s), 2857 (m), 1700 (s), 1609 (m), 1511 (s), 1455 (m), 1248 (s), 1184 (s), 1118 (m), 1031 (m), 920 (m), 827 (m), 554 (m).
- **HRMS (ESI):** calcd. for $C_{15}H_{18}O_4Na^+$ $[M+Na]^+$ 285.1103; found: 285.1102.

2-(2-Oxo-1-phenylcyclopentyl)acetic acid (57)



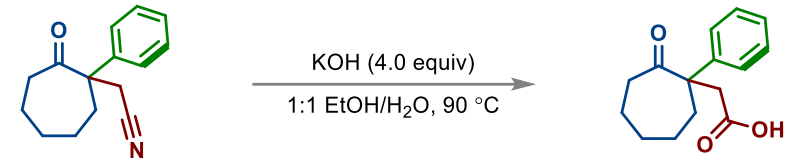
48 (1.0 equiv) **57**

Following a slightly modified procedure,[19] the compound **48** (800 mg, 4.00 mmol, 1.00 equiv) and KOH (900 mg, 16.0 mmol, 4.00 equiv) were taken into a 50 mL round bottom flask and then dissolved in 30 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×20 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **57** as a pale-yellow liquid (195 mg, 0.880 mmol, 22%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.25, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.40 – 7.30 (m, 4H, Ar*H*), 7.30 – 7.23 (m, 1H, Ar*H*), 2.97 (d, *J* = 16.9 Hz, 1H, C$H^aH^bCO_2H$), 2.88 (d, *J* = 16.9 Hz, 1H, C$H^aH^bCO_2H$), 2.72 (dd, *J* = 13.3, 6.3 Hz, 1H), 2.45 – 2.26 (m, 3H), 2.06 – 1.94 (m, 1H), 1.83 – 1.68 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 218.7, 176.5, 138.3, 128.8, 127.4, 126.6, 54.4, 42.9, 36.8, 33.5, 18.6. (*See Spectra*)

- IR (Neat): υ 2932 (s), 2851 (m), 1743 (s), 1467 (m), 1321 (m), 1214 (m), 754 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{13}H_{14}O_3Na^+$ $[M+Na]^+$ 241.0841; found: 241.0845.

2-(2-Oxo-1-phenylcycloheptyl)acetic acid (58)



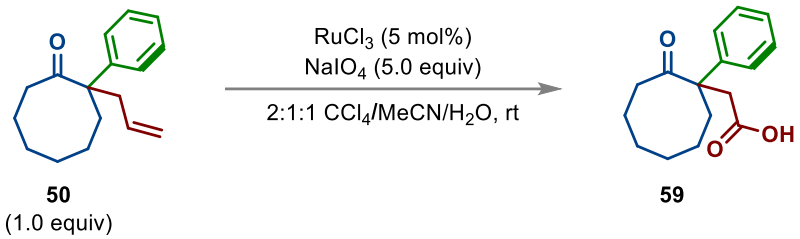
49
(1.0 equiv)

58

Following a slightly modified procedure,[19] the compound **49** (773 mg, 3.40 mmol, 1.00 equiv) and KOH (763 mg, 13.6 mmol, 4.00 equiv) were taken into a 50 mL round bottom flask and then dissolved in 27 mL of 1:1 mixture EtOH and water. The solution was boiled at 90 °C for 5 h. After cooling to room temperature, the solution was acidified with 5 M aqueous HCl and confirmed by pH paper. The resulting solution was extracted with DCM (3×20 mL) and the organic layers were combined. The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 7:3 DCM/Heaxne as mobile phase to obtain the title compound **58** as a white solid (200 mg, 0.82 mmol, 24%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.27, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 – 7.30 (m, 3H, Ar*H*), 7.31 – 7.27 (m, 1H, Ar*H*), 7.20 – 7.13 (m, 1H, Ar*H*), 3.02 (d, *J* = 14.7 Hz, 1H, C*H*^{a}H^bCO_2H), 2.80 – 2.48 (m, 3H), 2.44 – 2.34 (m, 1H), 2.28 – 2.11 (m, 1H), 2.06 – 1.71 (m, 3H), 1.68 – 1.35 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 214.9, 173.9, 140.7, 128.9, 127.4, 126.6, 58.1, 43.2, 40.9, 33.4, 30.3, 26.6, 24.0. (*See Spectra*)
- **IR (Neat):** υ 3212 (m), 2925 (s), 2856 (m), 1707 (s), 1453 (m), 1219 (m), 763 (m), 699 (s).
- **HRMS (ESI):** calcd. for $C_{15}H_{18}O_3Na^+$ $[M+Na]^+$ 269.1154; found: 269.1151.

2-(2-Oxo-1-phenylcyclooctyl)acetic acid (59)



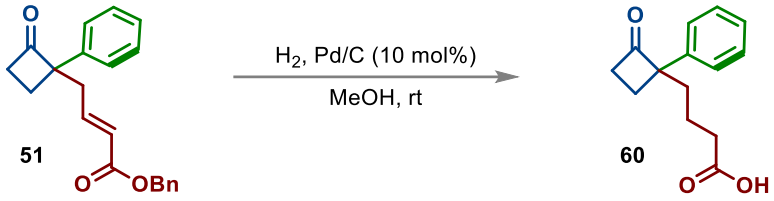
50
(1.0 equiv)

59

Following a slightly modified procedure,[19] the substrate **50** (600 mg, 2.50 mmol, 1.00 equiv), sodium periodate (2.65 g, 12.4 mmol, 5.00 equiv), and $RuCl_3$ (25 mg, 0.12 mmol, 0.05 equiv) were charged into a 50 mL round bottom flask. To this, a 20 mL mixture of carbon tetrachloride, acetonitrile, and water (2:1:1) was added to the flask, and the mixture was stirred for 12 h at room temperature. The reaction mixture was filtered through a celite pad, and the filtrate was concentrated under reduced pressure to obtain the crude product, which was purified by column chromatography using 2:8 mixture of EtOAc and hexane as mobile phase to afford carboxylic acid **59** as a pale-yellow solid (623 mg, 2.40 mmol, 96%).

- **M.P.** 133 – 136 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.24, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.34 – 7.28 (m, 2H, Ar*H*), 7.27 – 7.23 (m, 3H, Ar*H*), 3.21 (d, *J* = 15.4 Hz, 1H, C*H*^{a}H^bCO_2H), 2.76 (d, *J* = 15.4 Hz, 1H, CH^a*H*^{b}CO_2H), 2.70 – 2.57 (m, 1H), 2.58 – 2.41 (m, 2H), 1.91 (dt, *J* = 12.1, 4.2 Hz, 1H), 1.86 – 1.56 (m, 6H), 1.35 – 1.22 (m, 1H), 1.11 – 0.94 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 215.6, 177.0, 139.1, 128.7, 127.4, 126.8, 56.2, 38.2, 37.4, 29.5, 27.3, 25.4, 24.0. One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 3058 (w), 2926 (s), 2860 (m), 1700 (s), 1452 (m), 1203 (m), 753 (m), 702 (m).
- **HRMS (ESI):** calcd. for $C_{16}H_{20}O_3Na^+$ $[M+Na]^+$ 283.1310; found: 283.1312.

2-(2-Oxo-1-phenylcyclobutyl)acetic acid (60)

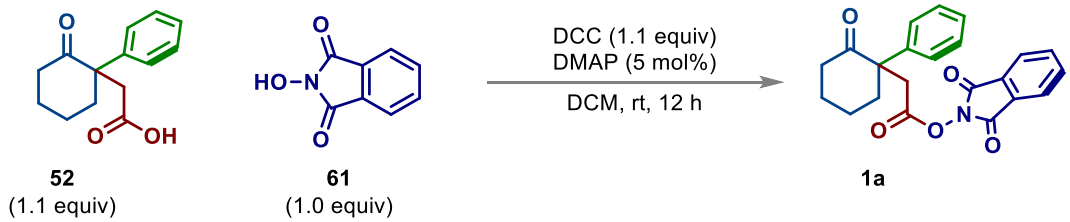


Following a slightly modified procedure,[20] a 25 mL round-bottom flask was charged with Pd/C (22 mg, 0.20 mmol, 0.10 equiv) and the substrate **51** (640 mg, 2.00 mmol, 1.00 equiv), were dissolved in methanol (5.0 mL, 0.4 M). A hydrogen gas balloon was connected to the flask. The solution was stirred overnight, and the consumption of the starting material was confirmed using TLC. Upon completion of the reaction, the catalyst was filtered using Celite-545® and the filterate was concentrated under reduced pressure. The crude product was then purified using flash chromatography on a silica column with a 7:3 mixture of DCM/hexane to give the pure product **60** as a colorless liquid (280 mg, 1.20 mmol, 60%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.27, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.40 – 7.30 (m, 3H, Ar*H*), 7.29 – 7.20 (m, 2H, Ar*H*), 3.20 – 2.91 (m, 2H), 2.61 – 2.44 (m, 1H), 2.37 – 2.19 (m, 3H), 1.98 – 1.84 (m, 2H), 1.62 – 1.45 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.6, 179.2, 140.0, 128.5, 126.9, 126.2, 71.9, 42.5, 38.4, 33.7, 23.2, 19.7. (*See Spectra*)
- **IR (Neat):** υ 3015 (m, brs), 2935 (s), 2855 (m), 1781 (s), 1474 (w), 1361 (m), 1091 (m), 703 (m) 697 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{16}O_3Na^+$ $[M+Na]^+$ 255.0997; found: 255.0997.

2.8 Procedures for synthesis of redox active esters

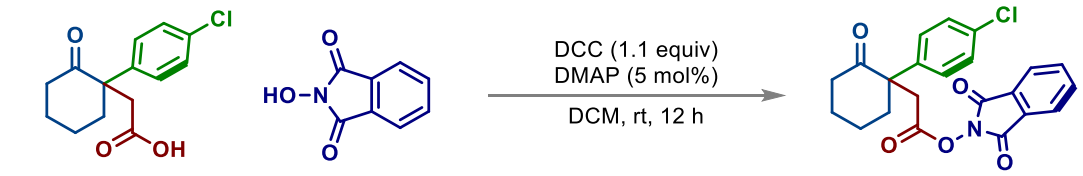
1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-phenylcyclohexyl)acetate (1a)



Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (718 mg, 4.40 mmol, 1.00 equiv), carboxylic acid **52** (1.12 g, 4.84 mmol, 1.11 equiv), DCC (1.00 g, 4.84 mmol, 1.1 equiv), and DMAP (26 mg, 0.20 mmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 10 ml of DCM (0.45 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was then purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1a** as a white solid (1.24 g, 3.30 mmol, 75%).

- **M.P.** 130 – 135 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.39, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.85 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.76 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.43 – 7.35 (m, 2H, Ar*H*), 7.34 – 7.27 (m, 3H, Ar*H*), 3.15 (d, *J* = 15.5 Hz, 1H, C*H*^{a}H^{b}CO$_2$N), 3.08 (dq, *J* = 14.7, 3.0 Hz, 1H), 2.99 (d, *J* = 15.4 Hz, 1H, CH^a*H*^{b}CO$_2$N), 2.43 – 2.31 (m, 2H), 2.20 – 2.07 (m, 1H), 2.03 – 1.98 (m, 1H), 1.87 – 1.70 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.4, 167.4, 161.8, 138.4, 134.6, 129.2, 128.9, 127.6, 126.9, 123.9, 55.9, 41.7, 39.4, 34.3, 27.9, 21.5. (*See Spectra*)
- **IR (Neat):** υ 2931 (s), 2853 (m), 1784 (m), 1745 (s), 1710 (m), 1463 (m), 1085 (m), 743 (m), 698 (m).
- **HRMS (ESI):** calcd. for $C_{22}H_{19}NO_5Na^+$ [M+Na]$^+$ 400.1161; found: 400.1163.

1,3-Dioxoisoindolin-2-yl 2-(1-(4-chlorophenyl)-2-oxocyclohexyl)acetate (1b)



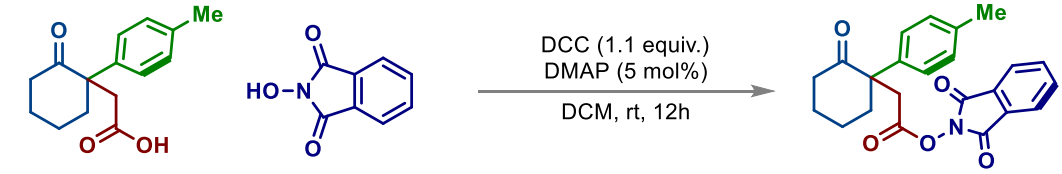
53 (1.1 equiv) **61** (1.0 equiv) **1b**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (163 mg, 1.00 mmol, 1.00 equiv), carboxylic acid **53** (293 mg, 1.10 mmol, 1.10 equiv), DCC (227 mg, 1.10 mmol, 1.10 equiv), and DMAP (6.0 mg, 5.0 µmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 2.0 ml of DCM (0.5 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was then

purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1b** as a white solid (323 mg, 0.780 mmol, 78%).

- **M.P.** 157 – 165 °C
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.33, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.78 (dt, *J* = 7.6, 3.9 Hz, 2H, Ar*H*), 7.70 (dd, *J* = 5.4, 3.1 Hz, 2H, Ar*H*), 7.29 (d, *J* = 8.6 Hz, 2H, Ar*H*), 7.17 (t, *J* = 8.6 Hz, 2H, Ar*H*), 3.15 – 2.94 (m, 3H), 2.46 – 2.24 (m, 2H), 2.20 – 2.05 (m, 1H), 2.04 – 1.92 (m, 1H), 1.88 – 1.65 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.0, 167.2, 161.8, 136.8, 134.7, 133.7, 129.4, 128.8, 128.5, 123.9, 55.4, 41.7, 39.4, 34.4, 27.8, 21.5. (*See Spectra*)
- **IR (Neat):** υ 2925 (s), 2857 (m), 1787 (m), 1744 (s), 1709 (m), 1460 (m), 1361 (m), 1082 (m), 698 (m).
- **HRMS (ESI):** calcd. for $C_{22}H_{18}ClNO_5Na^+$ $[M+Na]^+$ 434.0771; found: 434.0772.

1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-(*p*-tolyl)cyclohexyl)acetate (1c)



54 (1.1 equiv) **61** (1.0 equiv) **1c**

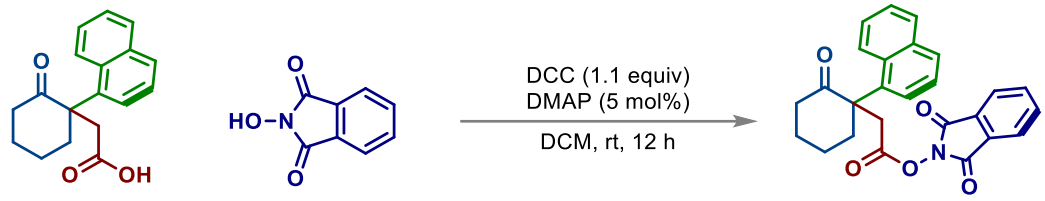
Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (163 mg, 1.00 mmol, 1.00 equiv), carboxylic acid **54** (270 mg, 1.10 mmol, 1.10 equiv), DCC (227 mg, 1.10 mmol, 1.10 equiv), and DMAP (6.0 mg, 5.0 μmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 2.0 ml of DCM (0.5 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1c** as a white solid (268 mg, 0.690 mmol, 69%).

- **M.P.** 148 – 155 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.45, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.84 (dt, *J* = 7.8, 3.9 Hz, 2H, Ar*H*), 7.76 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.22 – 7.13 (m, 4H, Ar*H*), 3.13 (d, *J* = 15.4 Hz, 1H, C*H*^{a}H^bCO_2N),

3.04 (dq, *J* = 14.7, 3.2 Hz, 1H), 2.94 (d, *J* = 15.4 Hz, 1H, CH^{a}*H*^{b}CO$_2$N), 2.45 – 2.34 (m, 2H), 2.32 (s, 3H), 2.19 – 2.07 (m, 1H), 2.00 – 1.90 (m, 1H), 1.89 – 1.61 (m, 3H). (*See Spectra*)

- **^{13}C NMR (101 MHz, CDCl$_3$):** δ 210.7, 167.5, 161.9, 137.4, 135.4, 134.7, 129.9, 128.9, 126.8, 123.9, 55.6, 41.7, 39.4, 34.3, 27.9, 21.6, 21.0. (*See Spectra*)
- **IR (Neat):** υ 2934 (m), 2864 (w), 1788 (m), 1744 (s), 1708 (m), 1517 (w), 1411 (m), 1226 (m), 819 (m), 670 (m).
- **HRMS (ESI):** calcd. for $C_{23}H_{21}NO_5Na^+$ [M+Na]$^+$ 414.1317; found: 414.1316.

1,3-Dioxoisoindolin-2-yl 2-(1-(naphthalen-1-yl)-2-oxocyclohexyl)acetate (1d)



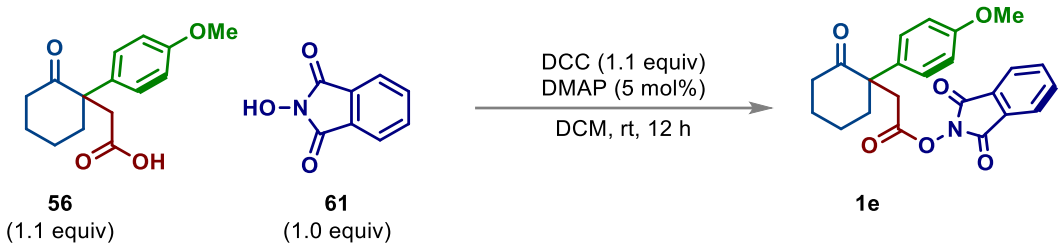
55 (1.1 equiv) **61** (1.0 equiv) **1d**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (49 mg, 0.30 mmol, 1.0 equiv), carboxylic acid **55** (93 mg, 0.33 mmol, 1.1 equiv), DCC (69 mg, 0.33 mmol, 1.1 equiv), and DMAP (2.0 mg, 1.6 µmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 1.0 ml of DCM (0.3 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1d** as a white solid (90 mg, 0.21 mmol, 70%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.39, $KMnO_4$.
- **^{1}H NMR (400 MHz, CDCl$_3$):** δ 7.93 – 7.78 (m, 6H, Ar*H*), 7.77 – 7.70 (m, 2H, Ar*H*), 7.56 (t, *J* = 7.8 Hz, 1H, Ar*H*), 7.47 (dd, *J* = 6.4, 3.3 Hz, 2H, Ar*H*), 3.55 – 3.45 (m, 2H), 3.39 (d, *J* = 14.5 Hz, 1H, C*H*^{a}H^{b}CO$_2$N), 2.32 – 2.24 (m, 1H), 2.24 – 2.15 (m, 1H) 2.15 – 1.95 (m, 3H), 1.90 – 1.73 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, CDCl$_3$):** δ 215.5, 167.4, 161.8, 134.8, 134.6, 132.8, 131.5, 129.8, 129.2, 128.8, 127.4, 127.1, 125.5, 125.2, 123.8, 122.8, 57.3, 40.2, 39.3, 38.8, 30.5, 21.3. (*See Spectra*)

- **IR (Neat):** υ 2925 (m), 2855 (w), 1813 (w), 1788 (m), 1743 (s), 1706 (m), 1466 (w), 1360 (w), 1134 (w), 974 (w) 778 (m), 697 (m).
- **HRMS (ESI):** calcd. for $C_{26}H_{21}NO_5Na^+$ $[M+Na]^+$ 450.1317; found: 450.1316.

1,3-Dioxoisoindolin-2-yl 2-(1-(4-methoxyphenyl)-2-oxocyclohexyl)acetate (1e)

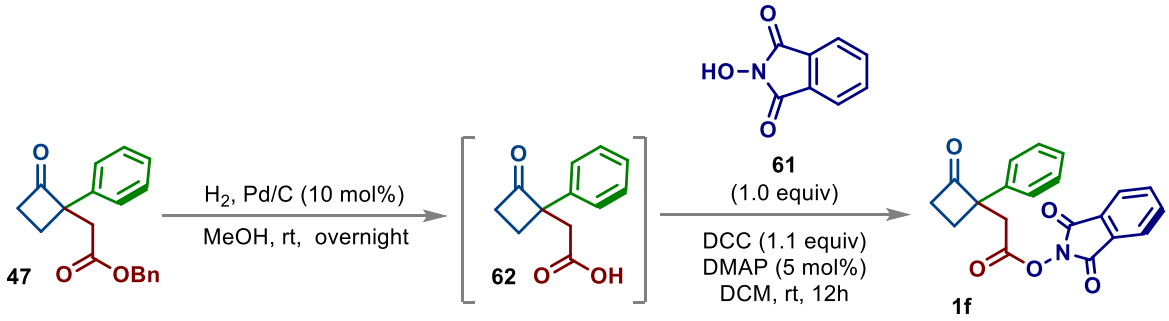


56 (1.1 equiv) **61** (1.0 equiv) **1e**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (163 mg, 1.00 mmol, 1.00 equiv), carboxylic acid **56** (290 mg, 1.10 mmol, 1.10 equiv), DCC (227 mg, 1.10 mmol, 1.10 equiv), and DMAP (6.0 mg, 5.0 μmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 1.0 ml of DCM (0.3 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1e** as a white solid (293 mg, 0.720 mmol, 72%).

- **M.P.** 146 – 150 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.33, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.83 (dt, *J* = 7.6, 4.0 Hz, 2H, Ar*H*), 7.75 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.19 (d, *J* = 8.8 Hz, 2H, Ar*H*), 6.90 (d, *J* = 8.8 Hz, 2H, Ar*H*), 3.78 (s, 3H, OC*H*$_3$), 3.11 (d, *J* = 15.3 Hz, 1H, C*H*^{a}H^{b}CO$_2$N), 3.02 (dq, *J* = 15.2, 3.4 Hz, 1H), 2.95 (d, *J* = 15.3 Hz, 1H, CH^a*H*^{b}CO$_2$N), 2.51 – 2.29 (m, 2H), 2.11 (m, 1H), 1.96 (m, 1H), 1.77 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.5, 167.4, 161.8, 158.8, 134.6, 130.2, 128.9, 128.1, 123.8, 114.5, 55.2, 41.7, 39.2, 34.4, 27.8, 21.5. (*See Spectra*)
- **IR (Neat):** υ 2939 (m), 2865 (w), 1787 (m), 1745 (s), 1707 (m), 1512 (m), 1361 (m), 1253 (m), 1185 (m), 969 (m), 699 (m).
- **HRMS (ESI):** calcd. for $C_{23}H_{21}NO_6Na^+$ $[M+Na]^+$ 430.1267; found: 430.1263.

1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-phenylcyclobutyl)acetate (1f)



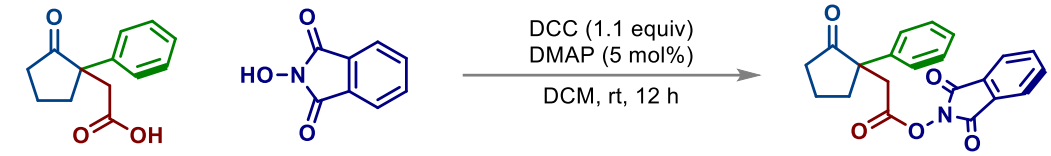
Step 1: Following a slightly modified procedure,[20] a 25 mL round-bottom flask was charged with Pd/C (4 mg, 0.1 equiv) and the substrate **47** (100 mg, 0.340 mmol, 1.00 equiv) were dissolved in 5 mL of methanol (0.07 M). A hydrogen balloon was connected to the flask. The solution was stirred overnight, and the consumption of the starting material was confirmed using TLC. Upon completion of the reaction, the catalyst was filtered using Celite-545® and the organic layer was concentrated under reduced pressure. The crude carboxylic acid **62** was used in the next step without further purification.

Step 2: Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (50 mg, 0.30 mmol, 1.0 equiv), crude carboxylic acid **62** (69 mg, 0.33 mmol, 1.1 equiv), DCC (63.5 mg, 0.330 mmol, 1.10 equiv), and DMAP (5.5 mg, 4.5 µmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 1.0 ml of DCM (0.3 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1f** as a white solid (60 mg, 0.17 mmol, 56%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.46, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.87 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.79 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.51 – 7.44 (m, 2H, Ar*H*), 7.42 – 7.35 (m, 2H, Ar*H*), 7.34 – 7.27 (m, 1H, Ar*H*), 3.28 (d, *J* = 16.1 Hz, 1H, C*H*^{a}H^{b}CO$_2$N), 3.25 – 3.13 (m, 2H), 3.10 (d, *J* = 16.1 Hz, 1H, CH^a*H*^{b}CO$_2$N), 2.73 (ddd, *J* = 12.1, 10.4, 6.2 Hz, 1H), 2.62 (ddd, *J* = 12.1, 9.9, 8.0 Hz, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 208.0, 166.5, 161.6, 138.5, 134.8, 129.0, 128.7, 127.7, 126.4, 124.0, 67.7, 43.9, 40.0, 22.6. (*See Spectra*)

- **IR (Neat):** υ 2925 (s), 2853 (m), 1775 (s), 1748 (s), 1442 (w), 1381 (m), 1365 (m), 1068 (m), 699 (m).
- **HRMS (ESI):** calcd. for $C_{20}H_{15}NO_5Na^+$ $[M+Na]^+$ 372.0848; found: 372.0845.

1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-phenylcyclopentyl)acetate (1g)

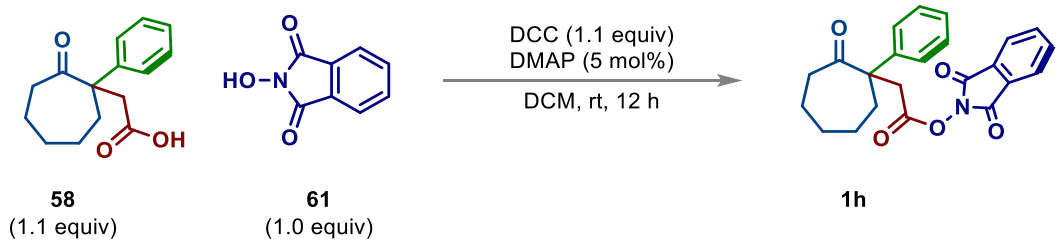


57 (1.1 equiv) **61** (1.0 equiv) **1g**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (135 mg, 0.820 mmol, 1.00 equiv), carboxylic acid **57** (200 mg, 0.910 mmol, 1.10 equiv), DCC (190 mg, 0.910 mmol, 1.10 equiv), and DMAP (5.0 mg, 4.0 μmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 2.0 ml of DCM (0.41 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to obtain the pure product **1g** as a white solid (173 mg, 0.470 mmol, 58%).

- **M.P.** 120 – 130 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.44, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.78 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.69 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.38 (d, *J* = 7.8 Hz, 2H, Ar*H*), 7.30 (t, *J* = 7.7 Hz, 2H, Ar*H*), 7.25 – 7.17 (m, 1H, Ar*H*), 3.11 (dd, *J* = 16 Hz, 1.9 Hz, 2H, C*H*^{a}*H*^{b}CO_2N), 2.85 (dd, *J* = 13.5, 6.1 Hz, 1H), 2.34 – 2.16 (m, 3H), 1.96 (dq, *J* = 11.5, 5.6, 5.1 Hz, 1H), 1.81 – 1.64 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 216.6, 167.1, 161.7, 136.9, 134.7, 129.0, 128.8, 127.7, 126.7, 123.9, 54.6, 40.1, 36.4, 32.9, 18.5. (*See Spectra*)
- **IR (Neat):** υ 2924 (s), 1816 (w), 1787 (m), 1744 (s), 1464 (w), 1359 (m), 1072 (m), 697 (m).
- **HRMS (ESI):** calcd. for $C_{21}H_{17}NO_5Na^+$ $[M+Na]^+$ 386.1004; found: 386.1003.

1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-phenylcycloheptyl)acetate (1h)

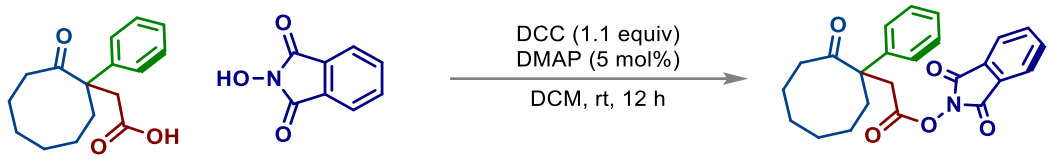


58 (1.1 equiv) **61** (1.0 equiv) **1h**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (120 mg, 0.730 mmol, 1.00 equiv), carboxylic acid **58** (200 mg, 0.800 mmol, 1.10 equiv), DCC (167 mg, 0.800 mmol, 1.10 equiv), and DMAP (5.0 mg, 3.5 µmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 2.0 ml of DCM (0.3 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1h** as a white solid (193 mg, 0.490 mmol, 67%).

- **M.P.** 122 – 125 °C.
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.43, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.82 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.74 (dd, *J* = 5.5, 3.1 Hz, 2H, Ar*H*), 7.40 – 7.32 (m, 2H, Ar*H*), 7.31 – 7.24 (m, 3H, Ar*H*), 3.34 (d, *J* = 15.1 Hz, 1H, C*H*^{a}H^{b}CO$_2$N), 3.00 (d, *J* = 15.1 Hz, 1H, CH^a*H*^{b}CO$_2$N), 2.78 (dd, *J* = 15.0, 9.3 Hz, 1H), 2.55 (td, *J* = 12.0, 2.7 Hz, 1H), 2.39 – 2.23 (m, 2H), 2.09 – 1.97 (m, 1H), 1.92 – 1.80 (m, 2H), 1.58 – 1.20 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.5, 167.6, 139.7, 134.6, 128.9, 128.8, 127.6, 127.0, 123.8, 57.9, 40.2, 39.0, 32.1, 30.3, 26.7, 23.9. ** One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 2934 (m), 2860 (w), 1787 (m), 1744 (s), 1704 (m), 1455 (w), 1361 (m), 1079 (m), 970 (m), 762 (w), 699 (m).
- **HRMS (ESI):** calcd. for $C_{23}H_{21}NO_5Na^+$ $[M+Na]^+$ 414.1317; found: 414.1316.

1,3-Dioxoisoindolin-2-yl 2-(2-oxo-1-phenylcyclooctyl)acetate (1i)

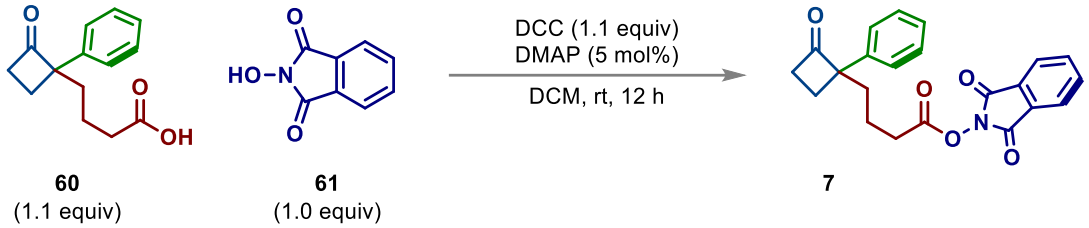


59 (1.1 equiv) **61** (1.0 equiv) **1i**

Following a slightly modified procedure,[21] *N*-hydroxyphathlimide **61** (163 mg, 1.00 mmol, 1.00 equiv), carboxylic acid **59** (287 mg, 1.10 mmol, 1.10 equiv), DCC (227 mg, 1.10 mmol, 1.10 equiv), and DMAP (6.0 mg, 5.0 μmol, 0.05 equiv) were taken into a Schlenk tube. The mixture was dissolved in 2.0 ml of DCM (0.5 M) and stirred for 12 h. The reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to afford the pure product **1i** as a white solid (200 mg, 0.500 mmol, 50%).

- **M.P.** 144 – 149 °C
- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.41, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.87 – 7.77 (m, 2H, Ar*H*), 7.76 – 7.69 (m, 2H, Ar*H*), 7.42 – 7.33 (m, 4H, Ar*H*), 7.33 – 7.24 (m, 1H, Ar*H*), 3.53 (d, *J* = 15.5 Hz, 1H, C*H*^{a}H^bCO_2N), 3.19 (d, *J* = 15.4 Hz, 1H, CH^a*H*^{b}CO_2N), 2.84 – 2.64 (m, 2H, CH_2CO), 2.52 (td, *J* = 12.4, 3.7 Hz, 1H), 2.03 – 1.89 (m, 2H), 1.88 – 1.63 (m, 5H), 1.41 – 1.28 (m, 1H), 1.17 – 1.03 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 214.3, 167.7, 138.4, 134.6, 128.8, 128.8, 127.7, 126.9, 123.8, 56.4, 37.3, 35.8, 29.5, 27.0, 25.5, 24.0, 23.9. ** One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 2927 (m), 2859 (w), 1787 (m), 1743 (s), 1700 (m), 1465 (m), 1362 (m), 1134 (m), 1076 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{24}H_{23}NO_5Na^+$ $[M+Na]^+$ 428.1474; found: 428.1475.

1,3-Dioxoisoindolin-2-yl 4-(2-oxo-1-phenylcyclobutyl)butanoate (7)



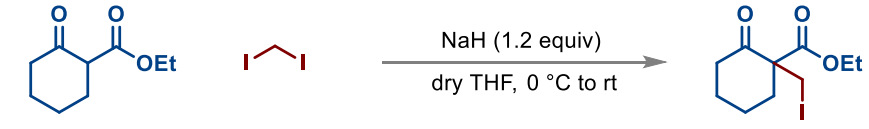
60 (1.1 equiv) **61** (1.0 equiv) **7**

Following a modified procedure,[21] *N*-hydroxyphathlimide **61** (195 mg, 1.20 mmol, 1.00 equiv), carboxylic acid **60** (280 mg, 1.20 mmol, 1.00 equiv), DCC (273 mg, 1.32 mmol, 1.10 equiv), and DMAP (7.5 mg, 6.0 µmol, 0.05 equiv.) were taken into a Schlenk tube. The mixture was dissolved in 2.5 ml of DCM (0.5 M) and stirred for 12 h. Next, the reaction mixture was filtered through Celite-545® and concentrated under reduced pressure. The crude product was purified by flash column chromatography using a 1:10 eluent of EtOAc:Hexane to obtain the pure product **7** as a white solid (326 mg, 0.860 mmol, 72%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.47, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.80 (dt, *J* = 7.5, 3.9 Hz, 2H, Ar*H*), 7.72 (dd, *J* = 5.6, 3.2 Hz, 2H, Ar*H*), 7.34 – 7.25 (m, 4H, Ar*H*), 7.21 – 7.15 (m, 1H, Ar*H*), 3.11 (ddd, *J* = 17.4, 10.2, 6.8 Hz, 1H), 2.95 (ddd, *J* = 17.8, 10.5, 6.5 Hz, 1H), 2.51 (t, *J* = 7.2 Hz, 2H), 2.43 (td, *J* = 11.0, 6.7 Hz, 1H), 2.20 (td, *J* = 10.7, 6.5 Hz, 1H), 1.92 (t, *J* = 8 Hz, 2H), 1.65 – 1.51 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.2, 169.1, 161.9, 139.9, 134.7, 128.9, 128.6, 126.9, 126.3, 123.9, 71.7, 42.5, 37.9, 30.8, 23.4, 19.9. (*See Spectra*)
- **IR (Neat):** υ, 2923 (s), 2855 (m), 1779 (s), 1742 (s), 1459 (w), 1366 (m), 1073 (m), 697 (m).
- **HRMS (ESI):** calcd. for $C_{22}H_{19}NO_5Na^+$ $[M+Na]^+$ 400.1161; found: 400.1164.

2.9 Procedures for synthesis of iodide radical precursor

Ethyl 1-(iodomethyl)-2-oxocyclohexane-1-carboxylate (3)



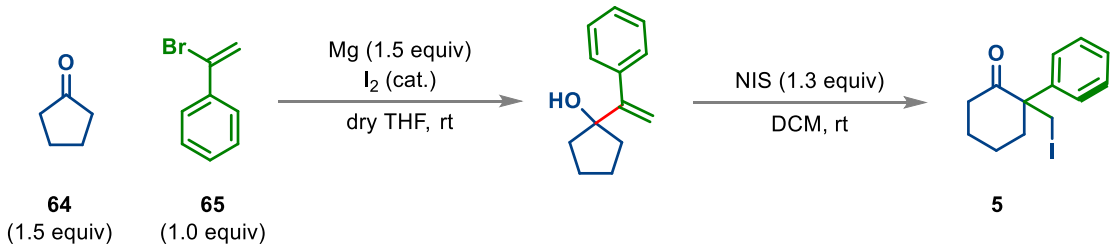
63 (1.0 equiv) (5.0 equiv) **3**

Following a slightly modified procedure,[22] a 100 mL two-neck flask was charged with NaH (240 mg, 6.00 mmol, 1.20 equiv, 60% dispersed in mineral oil) under an argon atmosphere. The mineral oil was removed by washing with dry hexane (3×5 mL) and dried in a Schlenk line. The dried NaH was then dissolved in dry THF (20 mL, 0.25 M) and cooled down in an ice bath. Next, commercially available ethyl 2-oxocyclohexane-1-carboxylate **63** (850 mg, 0.800 mL, 5.00 mmol, 1.00 equiv) was added dropwise to the NaH solution and allowed to stir at 0 °C for 0.5 h. Diiodomethane (6.69 g, 2.00 mL, 25.0 mmol, 5.00 equiv) was added to the reaction mixture. After 18 h, the mixture wasquenched with 15 mL of saturated NH_4Cl. The aqueous layer was extracted using diethyl ether (3×10 mL) The combined organic layers were dried over $MgSO_4$ and concentrated under vacuum. The crude product was purified by flash column chromatography using 1:3 EtOAc:Hexane to afford the pure compound **3** as a pale-yellow liquid (0.54 g, 1.7 mmol, 34%).

- **TLC (EtOAc:Hexane, 1:3 v/v):** R_f = 0.55, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 4.22 (m, 2H, OC*H*$_2$CH$_3$), 3.61 (dd, *J* = 10.3, 2.4 Hz, 1H, C*H*^{a}H^{b}I), 3.33 (dd, *J* = 10.3, 2.0 Hz, 1H, CH^a*H*^{b}I), 2.69 – 2.58 (m, 1H), 2.50 – 2.39 (m, 2H), 2.06 – 1.95 (m, 1H), 1.90 – 1.74 (m, 2H), 1.73 – 1.61 (m, 1H), 1.60 – 1.50 (m, 1H), 1.28 (t, *J* = 7.0, 3H, OCH$_2$C*H*$_3$).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 205.2, 168.9, 62.0, 60.7, 40.8, 37.2, 27.4, 22.3, 14.1, 8.5.

  The characterization data matched the reported values.[22]

2-(Iodomethyl)-2-phenylcyclohexan-1-one (5)



Step 1: Following a slightly modified literature procedure,[23] a 25 mL two-neck flask was charged with magnesium (128 mg, 5.20 mmol, 1.50 equiv) and molecular iodine (10.0 mg) under argon atmosphere. To this, a solution of (1-bromovinyl)benzene (640 mg, 3.50 mmol, 1.00 equiv) in dry THF (5 ml, 0.7 M) was added dropwise at room temperature. The resulting solution was refluxed

for 1 h and allowed to cool down to room temperature. Next, cyclopentanone (440 mg, 0.460 mL, 5.20 mmol, 1.50 equiv) was added dropwise to the Grignard solution and stirred. After 4 h, the reaction mixture was quenched with saturated aqueous solution of NH_4Cl (10 ml) and extracted with ethyl acetate (3×10 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure to afford the crude product. The crude alcohol was used in the next step without further purification.

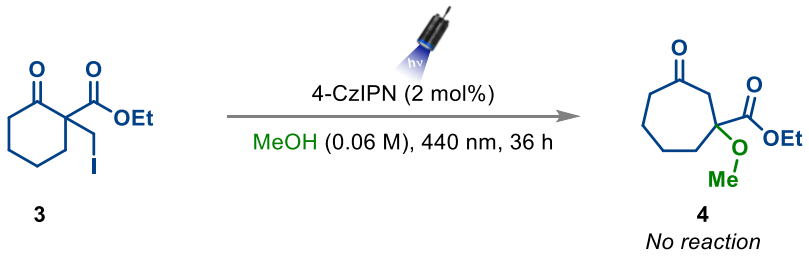
Step 2: The crude alcohol (180 mg, 1.00 mmol, 1.00 equiv) and NIS (280 mg, 1.30 mmol, 1.30 equiv) were added into a Schlenk tube and dissolved in DCM (3.0 ml, 0.33 M). The reaction mixture was stirred for 5 h at room temperature and quenched with 10 mL water. The organic layer was separated, and the aqueous layer was extracted with DCM (3×5 mL). The combined organic layers were dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:19 mixture of EtOAc/Hexane as mobile phase to obtain the pure product **5 as a** pale yellow liquid (205 mg, 0.670 mmol, 67%).

- **TLC (EtOAc:Hexane, 1:4 v/v):** R_f = 0.51, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.38 (t, *J* = 7.5 Hz, 2H, Ar*H*), 7.34 – 7.28 (m, 1H), 7.21 (d, *J* = 8.1 Hz, 2H, Ar*H*), 3.61 (d, *J* = 10.3 Hz, 1H, C*H*^{a}H^{b}I), 3.37 (d, *J* = 10.3 Hz, 1H, CH^a*H*^{b}I), 2.82 (dq, *J* = 14.1, 3.1 Hz, 1H), 2.37 – 2.24 (m, 2H), 2.00 – 1.84 (m, 2H), 1.84 – 1.63 (m, 3H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.2, 138.2, 129.1, 127.7, 126.8, 56.2, 40.1, 36.3, 27.8, 21.8, 19.4.

  The characterization data matched the reported values.[23]

3. Procedure for the photocatalytic Dowd-Beckwith reactions

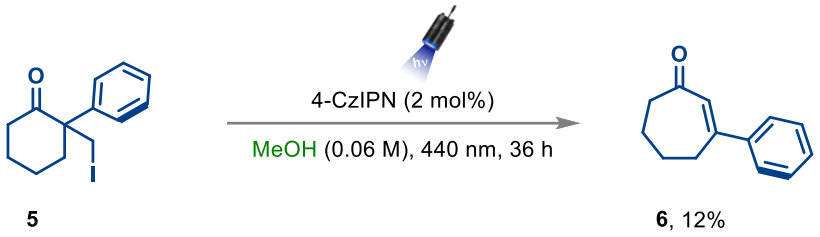
3.1 Initial Experiments



3 **4**

No reaction

An oven-dried 4 mL glass vial was charged with the *β*-ketoester **3** (32 mg, 0.10 mmol) and 4-CzIPN (1.6 mg, 2.0 μmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times). Methanol (1.65 mL, 0.06 M) was added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. ^{1}H NMR analysis of the crude reaction mixture confirmed the presence of starting material **3**.



An oven-dried 4 mL glass vial was charged with the ketone **5** (31 mg, 0.10 mmol) and 4-CzIPN (1.6 mg, 2.0 μmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times). Methanol (1.65 mL, 0.06 M) was added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. The crude product was purified by flash column chromatography using 10:1 Et_2O/Heaxne as eluent to obtain the alkene **6** as colorless liquid (2.2 mg, 12 μmol, 12%).

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.37, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.47 – 7.41 (m, 2H, Ar*H*), 7.41 – 7.34 (m, 3H, Ar*H*), 6.30 (s, 1H, COC*H*=CAr), 2.92 – 2.85 (m, 2H), 2.73 – 2.64 (m, 2H), 1.96 (m, 2H), 1.89 (m, 2H).
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 204.3, 157.6, 142.4, 130.4, 128.9, 128.5, 126.3, 41.9, 31.9, 25.2, 21.0.

  The characterization data matched the reported values.[24]

Cyclic Voltammetry experiments

Cyclic Voltammetry Test Conditions: A cyclic voltammograms in solvent (5 mL) by using (i) Working electrode: Glassy Carbon, (ii) Counter electrode: Platinum-wire, (iii)Reference electrode: Saturated calomel electrode (SCE), Electrolyte: 0.1 M $^{n}Bu_4PF_6$. Substrate concentration: 0.002 M, Solvent: Acetonitrile, Internal standard: Ferrocene.

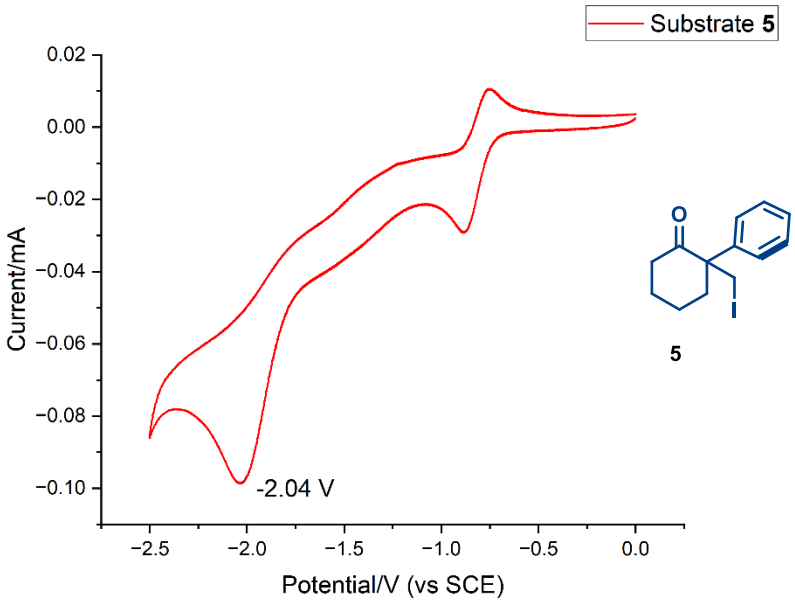


Figure 1: Cyclic voltammogram of substrate **5**.

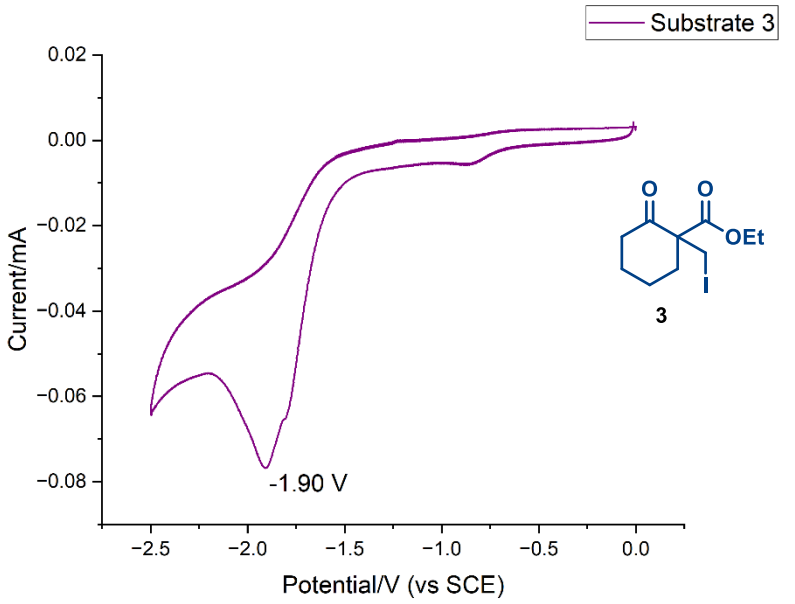


Figure 2: Cyclic voltammogram of substrate **3**.

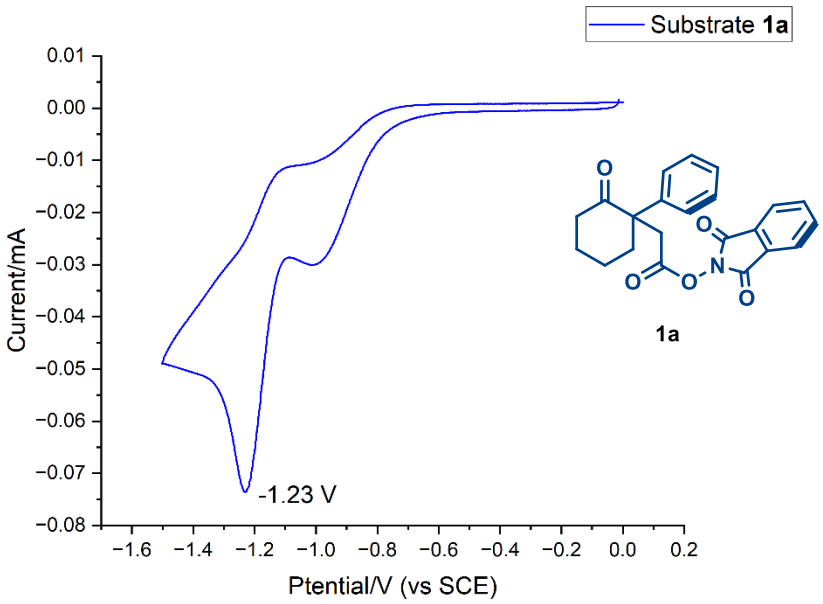
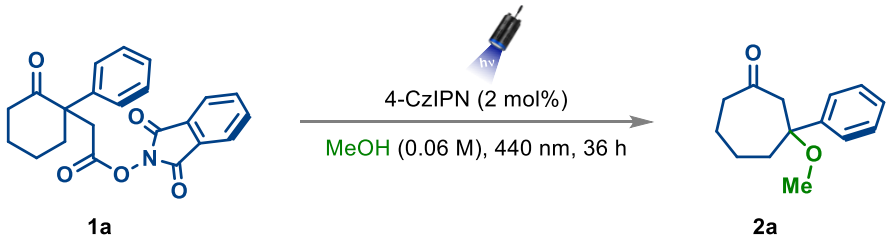


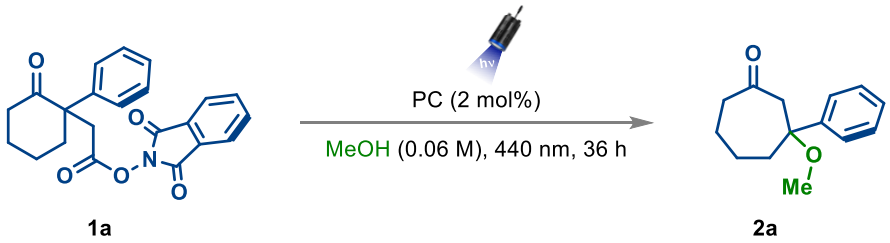
Figure 3: Cyclic voltammogram of substrate **1a**.



An oven-dried 4 mL glass vial was charged with the redox active ester **1a** (37.5 mg, 0.100 mmol) and 4-CzIPN (1.6 mg, 2.0 µmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times). Methanol (1.65 mL, 0.06 M) was added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. The ^{1}H NMR analysis of crude reaction mixture suggests presence of desired product **2a**. (*See characterization data*)

3.2 Optimization of reaction conditions

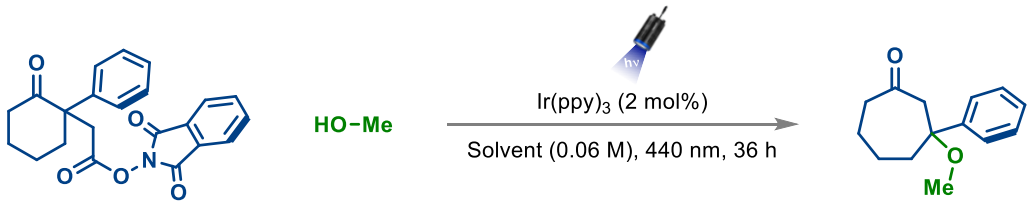
3.2.1 Screening of photocatalysts



An oven-dried 4 mL glass vial was charged with the redox active ester **1a** (37.5 mg, 0.100 mmol) and photocatalyst (2.0 μmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times). Methanol (1.65 mL, 0.06 M) was added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. The yield of the crude product was calculated by ^{1}H NMR using CH_2Br_2 as an internal standard.

Entry	PC	Yield
1	4-CzIPN	40
2	$Ru(bpy)_3Cl_2$	32
3	$[Ir(dF(CF_3)ppy)_2(dtbpy)]PF_6$	77
4	$[Ir(dFCF_3ppy)_2$-(5,5′-$dCF_3bpy)]PF_6$	80
5	$Ir(ppy)_3$	**83**

3.2.2 Screening of solvents

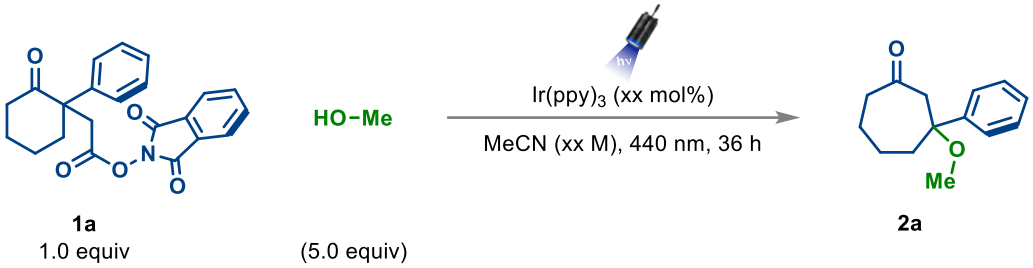


An oven-dried 4 mL glass vial was charged with the redox active ester **1a** (37.5 mg, 0.100 mmol) and $Ir(ppy)_3$ (0.60 mg, 2.0 μmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times).

Solvent (1.65 mL, 0.06 M) and methanol (20 µL, 0.50 mmol, 5.0 equiv) were added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. The yield of the crude product was calculated by ^{1}H NMR using CH_2Br_2 as an internal standard.

Entry	Solvent	Yield
1	CH_2Cl_2	66
2	Toluene	16
3	DMF	*ND*
4	CH_3CN	**81**

3.2.3 Screening of concentration and catalyst loading



1a
1.0 equiv

(5.0 equiv)

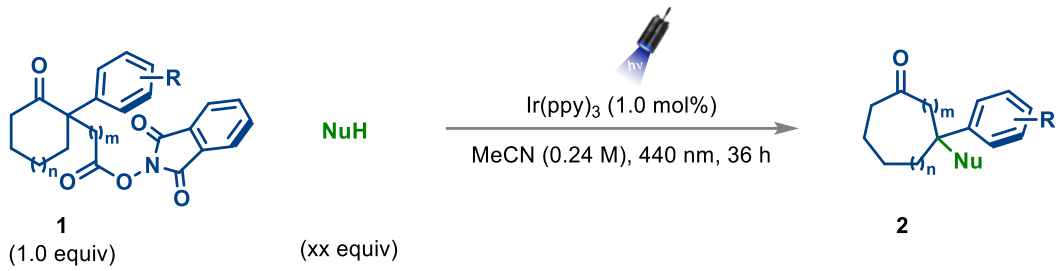
2a

An oven-dried 4 mL glass vial was charged with the redox active ester **1a** (37.5 mg, 0.100 mmol) and $Ir(ppy)_3$ (0.60 mg, 2.0 µmol, 0.02 equiv). Next, the vial was closed with a screw-cap septum. The vial was degassed and refilled with argon using the Schlenk-line technique (three times). Acetonitrile and methanol (20 µL, 0.50 mmol, 5.0 equiv) were added to the mixture and stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure. The yield of the crude product was calculated by ^{1}H NMR using CH_2Br_2 as an internal standard.

Entry	MeCN (xx M)	$Ir(ppy)_3$ (xx mol%)	Yield
1	0.06	2.0	81
2	0.24	2.0	86
3	0.24	1.0	84
4**	0.24	1.0	**88**

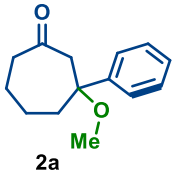
** Reaction was performed with 2.5 equiv. of MeOH.

3.2.4 Procedure A: Synthesis 3-alkoxy-3-phenylcycloheptan-1-one



An oven-dried 4 mL glass vial was charged with redox active ester **1** (0.3 mmol, 1.0 equiv) and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv). Next, the vial was closed with screw-cap septum. The vial was degassed and refill with argon using Schlenk-line technique (three times). Acetonitrile (1.25 mL, 0.24 M) and nucleophile (2.5 or 5.0 equiv) were added to the mixture and stirred for 36 h under the irradiation of 440 nm kessil lamp. The solvent was evaporated under reduced pressure. Finally, the crude product was purified by flash column chromatography.

3-Methoxy-3-phenylcycloheptan-1-one (2a)

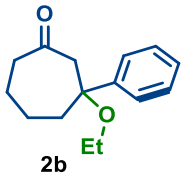


Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), methanol (60 μL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2a** as a colorless sticky liquid (52 mg, 0.24 mmol, 79%).

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.37, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.32 – 7.25 (m, 4H, Ar*H*), 7.24 – 7.16 (m, 1H, Ar*H*), 3.16 (d, *J* = 14.0 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.04 – 2.92 (m, 4H, COCH^a*H*^{b}CAr, OC*H*$_3$), 2.51 (dd, *J* = 7.9, 4.4 Hz, 2H, COC*H*$_2$CH$_2$), 2.29 – 2.19 (m, 1H), 1.96 – 1.60 (m, 5H). (*See Spectra*)

- **^{13}C NMR (101 MHz, $CDCl_3$)**: δ 211.7, 145.5, 128.4, 127.2, 125.8, 78.7, 53.8, 50.7, 44.0, 42.5, 24.5, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2926 (s), 2856 (m), 1698 (s), 1449 (m), 1216 (m), 1180 (m), 1068 (s), 756 (m), 702 (s).
- **HRMS (ESI):** calcd. for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$ 241.1204; found: 241.1205.

3-Ethoxy-3-phenylcycloheptan-1-one (2b)

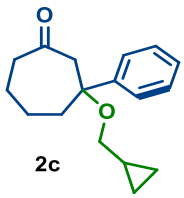


2b

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), ethanol (88 µL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2b** as a colorless sticky liquid (52 mg, 0.22 mmol, 75%).

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.39, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.33 – 7.23 (m, 4H, Ar*H*), 7.23 – 7.13 (m, 1H, Ar*H*), 3.21 – 3.05 (m, 3H, OC*H*$_2$CH$_3$, COC*H*^{a}H^{b}CAr), 3.02 (dd, *J* = 14.2, 2.2 Hz, 1H, COCH^a*H*^{b}CAr), 2.56 – 2.47 (m, 2H), 2.28 – 2.19 (m, 1H), 1.95 – 1.75 (m, 3H), 1.72 – 1.57 (m, 2H), 1.04 (m, *J* = 6.9 Hz, 3H, OCH$_2$*CH*$_3$). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 212.0, 146.3, 128.3, 127.0, 125.6, 78.1, 57.8, 54.1, 44.2, 43.1, 24.7, 23.7, 15.3. (*See Spectra*)
- **IR (Neat):** υ 2931 (s), 1699 (s), 1447 (m), 1212 (m), 1068 (s), 757 (m), 702 (m).
- **HRMS (ESI):** calcd. for $C_{15}H_{20}O_2Na^+$ $[M+Na]^+$ 255.1361; found: 255.1360;

3-(Cyclopropylmethoxy)-3-phenylcycloheptan-1-one (2c)

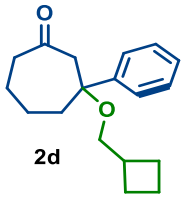


2c

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), cyclopropylmethanol (108 mg, 120 µL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to obtain the pure product **2c** as a colorless sticky liquid (51 mg, 0.20 mmol, 67%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.27, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.41 – 7.30 (m, 4H, Ar*H*), 7.29 – 7.21 (m, 1H, Ar*H*), 3.22 (d, J = 14.3 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.09 (dd, *J* = 14.3, 2.2 Hz, 1H, COCH^a*H*^{b}CAr), 3.06 – 2.91 (m, 2H, OC*H*$_2$CH), 2.69 – 2.53 (m, 2H), 2.37 – 2.25 (m, 1H), 2.02 – 1.82 (m, 4H), 1.78 – 1.63 (m, 1H), 1.04 – 0.89 (m, 1H), 0.52 – 0.39 (m, 2H), 0.09 (q, J = 4.9 Hz, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.9, 146.2, 128.3, 127.1, 125.7, 77.7, 67.0, 53.8, 44.3, 43.5, 24.8, 23.6, 10.7, 2.9, 2.8. (*See Spectra*)
- **IR (Neat):** υ 2931 (s), 2865 (m), 1698 (s), 1658 (m), 1447 (m), 1211 (m), 1055 (s), 758 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{17}H_{22}O_2Na^+$ $[M+Na]^+$ 281.1517; found: 281.1516.

3-(Cyclobutylmethoxy)-3-phenylcycloheptan-1-one (2d)



2d

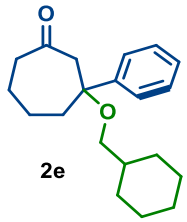
Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), cyclobutylmethanol (65 mg, 70 µL, 0.75 mmol, 2.5 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2d** as a colorless liquid (56 mg, 0.41 mmol, 69%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.29, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.40 – 7.31 (m, 4H, Ar*H*), 7.28 – 7.22 (m, 1H, Ar*H*), 3.19 (d, *J* = 14.4 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.15 – 3.03 (m, 3H, COCH^a*H*^{b}CAr,

OC*H*$_2$CH), 2.64 – 2.55 (m, 2H), 2.48 (hept, *J* = 7.2 Hz, 1H), 2.37 – 2.26 (m, 1H), 1.98 (m, 3H), 1.92 – 1.84 (m, 3H), 1.84 – 1.75 (m, 2H), 1.75 – 1.63 (m, 3H). (*See Spectra*)

- **^{13}C NMR (101 MHz, CDCl$_3$):** δ 211.9, 146.2, 128.3, 127.0, 125.8, 77.3, 66.3, 54.4, 44.2, 42.7, 35.3, 25.1, 25.1, 24.8, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2933 (s), 2863 (s), 1699 (s), 1447 (m), 1212 (m), 1062 (s), 758 (m), 702 (m).
- **HRMS (ESI)**: calcd. for $C_{18}H_{24}O_2Na^+$ $[M+Na]^+$ 295.1674; found: 295.1677.

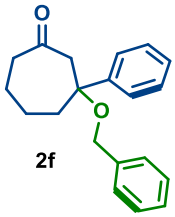
3-(Cyclohexylmethoxy)-3-phenylcycloheptan-1-one (2e)



Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), cyclohexylmethanol (170 mg, 1.50 mmol, 5.00 equiv), and Ir(ppy)$_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et$_2$O:Hexane 1:9 mixture as mobile phase to afford the pure product **2e** as a colorless sticky liquid (76 mg, 0.25 mmol, 84%).

- **TLC (Et$_2$O:Hexane, 3:7 v/v):** R$_f$ = 0.35, KMnO$_4$.
- **^{1}H NMR (400 MHz, CDCl$_3$):** δ 7.32 – 7.22 (m, 4H, Ar*H*), 7.18 (m, 1H, Ar*H*), 3.10 (d, *J* = 14.4 Hz, 1H, COC*H*^{a}H^{b}CAr), 2.99 (dd, *J* = 14.5, 2.2 Hz, 1H, COCH^a*H*^{b}CAr), 2.91 – 2.79 (m, 2H), 2.51 (dd, *J* = 8.0, 4.0 Hz, 2H), 2.31 – 2.22 (m, 1H), 1.94 – 1.74 (m, 3H), 1.71 – 1.50 (m, 6H), 1.49 – 1.35 (m, 1H), 1.28 – 0.94 (m, 3H), 0.93 – 0.72 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, CDCl$_3$):** δ 211.9, 146.2, 128.3, 127.0, 125.8, 77.3, 67.3, 54.8, 44.2, 42.3, 38.3, 30.1, 30.1, 26.6, 25.9, 25.9, 24.8, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2921 (s), 2853 (s), 1697 (s), 1447 (s), 1273 (m), 1212 (m), 1172 (m), 1060 (s), 757 (m), 701 (s).
- **HRMS (ESI):** calcd. for $C_{20}H_{28}O_2Na^+$ $[M+Na]^+$ 323.1987; found: 323.1985.

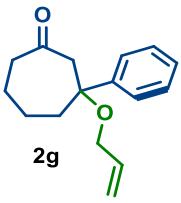
3-(Benzyloxy)-3-phenylcycloheptan-1-one (2f)



Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), benzylalcohol (160 mg, 156 µL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2f** as a colorless liquid (55 mg, 0.19 mmol, 62%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.45, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.39 – 7.33 (m, 2H, Ar*H*), 7.30 (d, *J* = 7.4 Hz, 2H, Ar*H*), 7.28 – 7.24 (m, 1H, Ar*H*), 7.24 – 7.15 (m, 5H, Ar*H*), 4.24 (d, *J* = 11.2 Hz, 1H, OC*H*^{a}H^{b}Ar), 4.11 (d, *J* = 11.2 Hz, 1H, OCH^a*H*^{b}Ar), 3.24 (d, *J* = 14.2 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.15 (dd, *J* = 14.2, 2.2 Hz, 1H, COCH^a*H*^{b}CAr), 2.56 – 2.51 (m, 2H), 2.41 – 2.31 (m, 1H), 2.03 – 1.77 (m, 4H), 1.77 – 1.61 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.5, 145.6, 138.6, 128.5, 128.2, 127.3, 127.1, 125.7, 78.5, 64.2, 54.2, 44.2, 43.0, 24.7, 23.7. ** One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 3030 (m), 2932 (s), 2836 (m), 1698 (s), 1494 (m), 1449 (s), 1212 (m), 1056 (s), 701 (s).
- **HRMS (ESI):** calcd. for $C_{20}H_{22}O_2Na^+$ $[M+Na]^+$ 317.1517; found: 317.1515.

3-(Allyloxy)-3-phenylcycloheptan-1-one (2g)

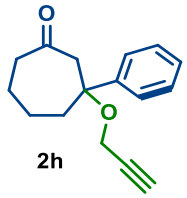


Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), allylalcohol (85.0 mg, 102 µL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv)

in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2g** as a colorless sticky liquid (41mg, 0.17 mmol, 56%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.65, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.36 – 7.24 (m, 4H, Ar*H*), 7.23 – 7.16 (m, 1H, Ar*H*), 5.85 – 5.71 (m, 1H, C*H*=CH^{a}H^b), 5.19 (dq, *J* = 17.1, 1.8 Hz, 1H, CH=C*H*^{a}H^b), 5.02 (dq, *J* = 10.5, 1.6 Hz, 1H, CH=CH^a*H*^{b}), 3.68 (ddt, *J* = 12.6, 4.9, 1.7 Hz, 1H, OC*H*^{a}H^{b}CH), 3.58 (ddt, *J* = 12.6, 5.2, 1.7 Hz, 1H, OCH^a*H*^{b}CH), 3.18 (d, *J* = 14.2 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.04 (dd, *J* = 14.2, 2.2 Hz, 1H, COCH^a*H*^{b}CAr), 2.52 (dd, *J* = 9.2, 4.2 Hz, 2H), 2.34 – 2.21 (m, 1H), 2.00 – 1.75 (m, 4H), 1.74 – 1.58 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.5, 145.8, 134.8, 128.4, 127.2, 125.6, 115.5, 78.4, 63.5, 54.0, 44.1, 43.0, 24.7, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2930 (s), 2861 (m), 1699 (s), 1448 (m), 1212 (m), 1056 (s), 923 (m), 759 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{16}H_{20}O_2Na^+$ $[M+Na]^+$ 267.1361; found: 267.1363.

3-Phenyl-3-(prop-2-yn-1-yloxy)cycloheptan-1-one (2h)



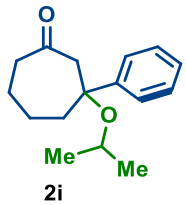
Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), propargylalcohol (84 mg, 87 µL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2h** as a colorless liquid (42 mg, 0.17 mmol, 58%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.52, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.34 – 7.26 (m, 4H, Ar*H*), 7.25 – 7.18 (m, 1H, Ar*H*), 3.90 (dd, *J* = 14.8, 2.5 Hz, 1H, OC*H*^{a}H^{b}C≡C), 3.70 (dd, *J* = 14.8, 2.5 Hz, 1H, ,

OCH^a*H*^{b}C≡C), 3.21 (d, *J* = 14.1 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.00 (dd, *J* = 14.2, 2.3 Hz, 1H, COCH^a*H*^{b}CAr), 2.64 – 2.46 (m, 2H), 2.30 (t, *J* = 2.5 Hz, 1H, C≡C*H*), 2.28 – 2.20 (m, 1H), 1.97 – 1.75 (m, 4H), 1.72 – 1.58 (m, 1H). (*See Spectra*)

- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.1, 144.7, 128.6, 127.6, 125.7, 80.3, 79.7, 73.5, 53.2, 51.5, 44.0, 43.4, 24.5, 23.5. (*See Spectra*)
- **IR (Neat):** υ 3286 9 (m), 2925 (s), 2859 (m), 1695 (s), 1448 (m), 1271 (m), 1211 (m), 1055 (s), 698 (m).
- **HRMS (ESI):** calcd. for $C_{16}H_{18}O_2Na^+$ [M+Na]$^+$ 265.1204; found: 265.1205.

3-Isopropoxy-3-phenylcycloheptan-1-one (2i)



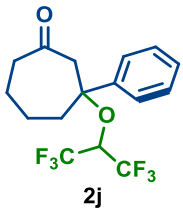
2i

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), *iso*-propanol (90.0 mg, 115 μL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2i** as a colorless liquid (54mg, 0.22 mmol, 73%).

- **TLC (Et_2O:Hexane, 1:9 v/v):** R_f = 0.38, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.45 – 7.39 (m, 2H, Ar*H*), 7.30 – 7.24 (m, 2H, Ar*H*), 7.24 – 7.16 (m, 1H, Ar*H*), 3.43 (hept, *J* = 6.1 Hz, 1H, OC*H*$(CH_3)_2$), 3.14 (d, *J* = 14.7 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.07 (dd, *J* = 14.7, 1.3 Hz, 1H, COCH^a*H*^{b}CAr), 2.49 (ddd, *J* = 17.3, 10.2, 3.5 Hz, 1H), 2.38 – 2.20 (m, 2H), 2.13 (ddd, *J* = 13.9, 9.8, 3.2 Hz, 1H), 1.96 – 1.73 (m, 2H), 1.71 – 1.55 (m, 2H), 0.86 (d, *J* = 6.1 Hz, 3H, OCH*(CH$_3$)*^{a}$(CH_3)^b$), 0.84 (d, *J* = 6.1 Hz, 3H, OCH$(CH_3)^a$*(CH$_3$)*^{b}). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.8, 144.5, 128.0, 127.5, 127.1, 78.4, 65.7, 54.9, 44.3, 42.1, 24.8, 24.5, 24.4, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2930 (s), 2863 (m), 1697 (s), 1450 (m), 1369 (m), 1208 (m), 1117 (m), 1032 (s), 760 (m), 703 (s).

- **HRMS (ESI):** calcd. for $C_{16}H_{22}O_2Na^+$ $[M+Na]^+$ 269.1517; found: 269.1521.

3-((1,1,1,3,3,3-Hexafluoropropan-2-yl)oxy)-3-phenylcycloheptan-1-one (2j)

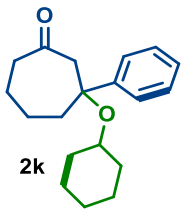


2j

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), hexafluoroisopropanol (90.0 mg, 115 µL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to obtain the pure product **2j** as pale a yellow sticky liquid (54 mg, 0.15 mmol, 51%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.58, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.29 – 7.20 (m, 2H, Ar*H*), 7.20 – 7.14 (m, 1H, Ar*H*), 7.14 – 7.09 (m, 2H, Ar*H*), 6.37 (hept, *J* = 6.6 Hz, 1H, OC*H*$(CF_3)_2$), 3.30 (d, *J* = 12.9 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.00 (dd, *J* = 12.9, 2.4 Hz, 1H, COCH^a*H*^{b}CAr), 2.54 – 2.43 (m, 1H), 2.29 – 2.13 (m, 2H), 1.95 – 1.80 (m, 3H), 1.79 – 1.62 (m, 2H). (*See Spectra*)
- **^{19}F NMR (376 MHz, $CDCl_3$):** δ -73.21. (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.3, 158.6, 148.1, 128.8, 126.9, 124.8, 65.6 (quintet, *J* = 34.5 Hz), 60.6, 55.2, 47.3, 43.2, 25.3, 23.6, 18.7. (*See Spectra*)
- **IR (Neat):** υ 2932 (m), 2860 (w), 1704 (s), 1386 (m), 1280 (m), 1226 (s), 1189 (s), 1103 (s), 896 (m), 734 (m), 694 (s).
- **GCMS:** calcd. for $C_{16}H_{16}F_6O_2^+$ $[M]^+$ 354; found 354.

3-(Cyclohexyloxy)-3-phenylcycloheptan-1-one (2k)



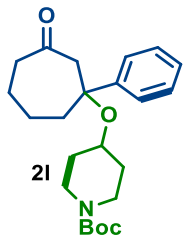
2k

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), cyclohexanol (150 mg, 156 µL, 1.50 mmol, 5.00 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01

equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2k** as a colorless sticky liquid (61 mg, 0.21 mmol, 71%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.45, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 – 7.40 (m, 2H, Ar*H*), 7.29 – 7.23 (m, 2H, Ar*H*), 7.23 – 7.17 (m, 1H, Ar*H*), 3.14 (d, *J* = 14.7 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.11 – 3.02 (m, 2H), 2.50 (ddd, *J* = 17.3, 10.4, 3.4 Hz, 1H), 2.37 – 2.21 (m, 2H), 2.13 (ddd, *J* = 14.1, 10.0, 3.3 Hz, 1H), 1.95 – 1.74 (m, 2H), 1.73 – 1.56 (m, 2H), 1.55 – 1.45 (m, 1H), 1.46 – 1.27 (m, 2H), 1.24 – 1.05 (m, 3H), 1.04 – 0.91 (m, 3H), 0.86 – 0.70 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.9, 144.7, 128.0, 127.4, 127.0, 78.3, 71.7, 55.1, 44.3, 42.1, 34.5, 25.5, 24.9, 24.5, 24.5, 23.7. ** One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 2929 (s), 2859 (m), 1704 (s), 1446 (m), 1057 (m), 758 (m), 701 (s).
- **HRMS (ESI):** calcd. for $C_{19}H_{26}O_2Na^+$ $[M+Na]^+$ 309.1830; found: 309.1832.

Tert-butyl 4-((3-oxo-1-phenylcycloheptyl)oxy)piperidine-1-carboxylate (2l)



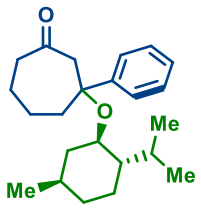
Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), *tert*-butyl 4-hydroxypiperidine-1-carboxylate (151 mg, 0.750 mmol, 2.50 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 2:8 mixture as mobile phase to afford the pure product **2l** as a white solid (60 mg, 0.15 mmol, 52%).

- **M.P.** 80 – 85 °C.
- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.32, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 – 7.38 (m, 2H, Ar*H*), 7.31 – 7.24 (m, 2H, Ar*H*), 7.22 (d, *J* = 7.0 Hz, 1H, Ar*H*), 3.70 – 3.53 (m, 2H), 3.28 (tt, *J* = 8.2, 4.1 Hz, 1H, C*H*OH),

3.15 (d, *J* = 14.4 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.09 (d, *J* = 13.4 Hz, 1H, COCH^{a}*H*^{b}CAr), 2.86 – 2.70 (m, 2H), 2.47 (ddd, *J* = 17.7, 10.4, 3.6 Hz, 1H), 2.41 – 2.24 (m, 2H), 2.12 (ddd, *J* = 14.1, 10.0, 3.3 Hz, 1H), 1.92 – 1.45 (m, 6H), 1.34 (s, 9H, OC(C*H*$_3$)$_3$), 1.33 – 1.23 (m, 2H). (*See Spectra*)

- **^{13}C NMR (101 MHz, CDCl$_3$):** δ 211.5, 154.7, 144.3, 128.2, 127.8, 126.9, 79.3, 78.7, 68.9, 54.8, 44.2, 42.0, 33.3, 33.2, 28.4, 24.8, 23.6. (*See Spectra*)
- **IR (Neat):** υ 2924 (s), 2856 (m), 1694 (s), 1453 (m), 1421 (m), 1237 (m), 1171 (m), 1056 (s), 702 (m).
- **HRMS (ESI):** calcd. for $C_{23}H_{33}NO_2Na^+$ [M+Na]$^+$ 410.2307; found: 410.2304.

3-(((1*R*,2*S*,5*R*)-2-Isopropyl-5-methylcyclohexyl)oxy)-3-phenylcycloheptan-1-one (2m)



2m

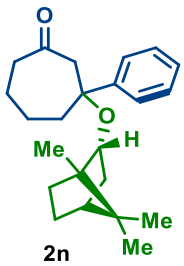
Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), (*L*)-menthol (117 mg, 0.750 mmol, 2.50 equiv), and Ir(ppy)$_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et$_2$O:Hexane 1:9 mixture as mobile phase to afford the pure product **2m** as a colorless sticky oil (43 mg, 0.13 mmol, 42%, 2:1 *dr*, inseparable diastereomers).

- **TLC (Et$_2$O:Hexane, 3:7 v/v):** R_f = 0.45, $KMnO_4$.
- **^{1}H NMR (400 MHz, CDCl$_3$):** δ 7.40 (m, 2H, Ar*H*), 7.26 (m, 2H, Ar*H*), 7.24 – 7.15 (m, 1H, Ar*H*), 3.29 (ddd, *J* = 14.5, 8.0, 1.6 Hz, 1H), 3.15 – 3.00 (m, 2H), 2.50 – 2.29 (m, 2H), 2.26 – 2.04 (m, 3H), 2.02 – 1.82 (m, 1H), 1.80 – 1.52 (m, 3H), 1.50 – 1.37 (m, 2H), 1.34 – 1.23 (m, 1H), 1.04 (m, 1H), 0.95 (ddddd, *J* = 14.3, 11.2, 8.1, 5.6, 2.4 Hz, 1H), 0.79 (dd, *J* = 7.1, 5.2 Hz, 5H), 0.61 (dd, *J* = 9.5, 6.5 Hz, 5H), 0.45 (d, *J* = 6.9 Hz, 1H), 0.39 (d, *J* = 6.9 Hz, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, CDCl$_3$): Major diastereomer:** δ 221.9, 142.9, 128.1, 127.5, 127.3, 77.7, 73.0, 55.2, 49.2, 44.0, 43.8, 43.3, 34.2, 31.5, 25.1, 24.8, 23.6, 23.0, 22.3, 21.6, 16.0; **Minor diastereomer:** δ 211.8, 142.6, 128.2, 127.6, 127.3, 77.6, 56.5, 49.2,

44.2, 42.1, 34.2, 31.5, 25.3, 23.8, 23.0, 22.3, 21.6. ** For carbons were not resolved at 101 MHz. (*See Spectra*)

- **IR (Neat):** υ 2927 (s) , 2861 (s), 1698 (s), 1659 (s0, 1451 (m), 1041 (m), 759 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{23}H_{34}O_2Na^+$ $[M+Na]^+$ 365.2456; found: 365.2456.

3-Phenyl-3-(((2*R*)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl)oxy)cycloheptan-1-one (2n)



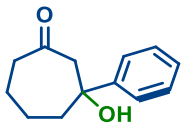
2n

Following general procedure A, using the redox active ester **1a** (113 mg, 0.300 mmol, 1.00 equiv), (-)-menthol (116 mg, 0.750 mmol, 2.50 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2n** as a colorless sticky liquid (50 mg, 0.15 mmol, 49%, 1:1 *dr*, inseparable diastereomers).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.58, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.50 – 7.42 (m, 2H, Ar*H*), 7.38 – 7.31 (m, 2H, Ar*H*), 7.31 – 7.24 (m, 1H, Ar*H*), 3.50 – 3.39 (m, 1H, C*H*OH), 3.29 (ddd, *J* = 15.4, 5.8, 1.6 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.11 (dd, *J* = 15.0, 13.7 Hz, 1H, COCH^a*H*^{b}CAr), 2.65 – 2.44 (m, 2H), 2.43 – 2.33 (m, 1H), 2.33 – 2.13 (m, 2H), 2.13 – 1.93 (m, 2H), 1.90 – 1.55 (m, 5H), 1.56 – 1.40 (m, 1H), 1.23 – 1.07 (m, 2H), 0.79 (dt, *J* = 13.2, 3.4 Hz, 1H), 0.75 (s, 3H), 0.61 (d, J = 4.7 Hz, 4H), 0.57 (s, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$): Diastereomer A:** δ 212.0, 142.8, 128.0, 127.7, 127.6, 77.9, 77.0, 55.0, 49.4, 46.7, 45.1, 44.5, 42.1, 38.3, 28.3, 26.6, 25.2, 23.7, 19.7, 18.7, 13.7; **Diastereomer B:** δ 211.8, 142.2, 128.0, 127.6, 127.5, 77.8, 54.5, 49.3, 46.6, 45.1, 44.2, 41.2, 37.7, 28.2, 24.8, 23.7, 19.7, 13.6. ** Three carbons were not resolved at 101 MHz. (*See Spectra*)

- **IR (Neat):** υ 2937 (s), 2872 (s), 1694 (s), 1654 (s), 1450 (s), 1261 (m), 1056 (s), 759 (s), 699 (s).
- **HRMS (ESI):** calcd. for $C_{23}H_{32}O_2Na^+$ $[M+Na]^+$ 363.2300; found: 363.2300.

3-Hydroxy-3-phenylcycloheptan-1-one (2o)

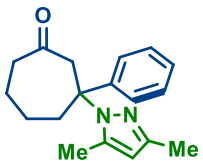


2o

Following general procedure A, using the redox active ester **1a** (38 mg, 0.10 mmol, 1.0 equiv), water (10 mg, 10 µL, 0.50 mmol, 5.0 equiv), and $Ir(ppy)_3$ (0.60 mg, 1.0 µmol, 0.01 equiv.) in dry acetonitrile (0.4 mL, 0.25 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 2:8 mixture as mobile phase to afford the pure product **2o** as a colorless liquid (17 mg, 0.08 mmol, 83%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.22, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.36 (d, *J* = 7.5 Hz, 2H, Ar*H*), 7.28 (t, *J* = 7.7 Hz, 2H, Ar*H*), 7.20 (d, *J* = 5.5 Hz, 1H, Ar*H*), 3.43 (d, *J* = 13.0 Hz, 1H, COC*H*^{a}H^{b}CAr), 2.65 (dd, *J* = 13.1, 1.8 Hz, 1H, COCH^a*H*^{b}CAr), 2.59 – 2.42 (m, 2H), 2.04 – 1.87 (m, 4H), 1.87 – 1.62 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.8, 149.5, 128.4, 127.0, 123.8, 73.7, 55.5, 45.2, 43.9, 24.2, 23.5. (*See Spectra*)
- **IR (Neat):** υ 3436 (m, brs), 2926 (s), 2857 (m), 1691 (s), 1449 (m), 1293 (m), 1027 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{13}H_{16}O_2Na^+$ $[M+Na]^+$ 227.1048; found: 227.1049.

3-(3,5-Dimethyl-1*H*-pyrazol-1-yl)-3-phenylcycloheptan-1-one (2p)



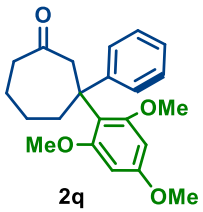
2p

Following general procedure A, using the redox active ester **1a** (38 mg, 0.10 mmol, 1.0 equiv), 3,5-dimethyl-1H-pyrazole (24 mg, 0.25 mmol, 2.5 equiv), and $Ir(ppy)_3$ (0.60 mg, 1.0 µmol, 0.01

equiv.) in dry acetonitrile (0.4 mL, 0.25 M). The crude reaction mixture was purified by flash column chromatography using EtOAc:Hexane 1:19 mixture as mobile phase to afford the pure product **2p** as a sticky liquid (15 mg, 0.05 mmol, 53%).

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.54, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.27 – 7.16 (m, 3H, Ar*H*), 6.90 (d, J = 7.3 Hz, 2H, Ar*H*), 5.87 (s, 1H), 3.65 (dd, *J* = 16.7, 2.7 Hz, 1H), 2.96 (dd, *J* = 16.6, 5.3 Hz, 2H), 2.55 – 2.49 (m, 2H), 2.40 (ddd, *J* = 14.9, 12.0, 3.1 Hz, 1H), 2.22 (s, 3H, C*H*$_3$), 2.06 – 1.94 (m, 1H), 1.82 (s, 3H, C*H*$_3$), 1.68 – 1.53 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 210.6, 147.7, 145.3, 139.6, 128.6, 127.2, 124.7, 108.3, 66.5, 57.8, 44.5, 41.3, 25.5, 24.0, 13.5, 13.0. (*See Spectra*)
- **IR (Neat):** υ 2926 (s), 2860 (m), 1694 (s), 1554 (m), 1449 (m), 1417 (m), 1355 (m), 1204 (m), 780 (w), 701 (m).
- **HRMS (ESI):** calcd. for $C_{18}H_{23}N_2O^+$ $[M+H]^+$ 283.1810; found: 283.1812.

3-Phenyl-3-(2,4,6-trimethoxyphenyl)cycloheptan-1-one (2q)



2q

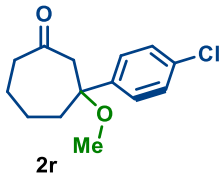
Following general procedure A, using the redox active ester **1a** (38 mg, 0.10 mmol, 1.0 equiv), 1,3,5-trimethoxybenzene (42 mg, 0.25 mmol, 2.5 equiv), and $Ir(ppy)_3$ (0.60 mg, 1.0 μmol, 0.01 equiv.) in dry acetonitrile (0.42 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using EtOAc:Hexane 1:19 mixture as mobile phase to afford the pure product **2q** as a white solid (9.0 mg, 0.03 mmol, 30%).

- **M.P.** 127 – 130 °C
- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.43, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** 7.21 – 7.12 (m, 4H, Ar*H*), 7.08 (td, *J* = 6.3, 2.4 Hz, 1H, Ar*H*), 6.14 (s, 2H, Ar*H*), 3.81 (s, 3H, OC*H*$_3$), 3.56 (dd, *J* = 18.1, 3.2 Hz, 1H, COC*H*^{a}H^{b}Ar), 3.51 (s, 6H, 2×OC*H*$_3$), 2.56 – 2.32 (m, 3H), 2.00 (ddd, *J* = 14.2, 12.4,

2.5 Hz, 1H), 1.95 – 1.84 (m, 1H), 1.81 – 1.65 (m, 2H), 1.57 – 1.31 (m, 2H). (*See Spectra*)

- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 212.3, 160.1, 159.8, 152.6, 127.7, 125.3, 125.0, 113.9, 92.1, 61.4, 55.1, 55.0, 47.8, 44.4, 41.7, 26.6, 24.5. (*See Spectra*)
- **IR (Neat):** υ 2925 (s), 2853 (m), 1687 (s), 1601 (s), 1458 (s), 1412 (m), 1330 (w), 1204 (m), 1130 (s), 815 (w), 698 (w).
- **HRMS (ESI):** calcd. for $C_{22}H_{26}O_4Na^+$ $[M+Na]^+$ 377.1729; found: 377.1729.

3-(4-Chlorophenyl)-3-methoxycycloheptan-1-one (2r)

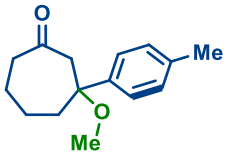


2r

Following general procedure A, using the redox active ester **1b** (123 mg, 0.300 mmol, 1.00 equiv), methanol (60 μL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2r** as a colorless sticky liquid (47 mg, 0.19 mmol, 62%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.41, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.32 – 7.17 (m, 4H, Ar*H*), 3.12 (d, *J* = 13.9 Hz, 1H, COC*H*^{a}H^{b}CAr), 2.96 (m, 4H, COCH^a*H*^{b}CAr, OC*H*$_3$), 2.50 (dd, *J* = 8.9, 4.1 Hz, 2H), 2.25 – 2.15 (m, 1H), 1.96 – 1.59 (m, 5H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.1, 144.1, 133.1, 128.6, 127.3, 78.3, 53.8, 50.6, 43.9, 42.3, 24.4, 23.6. (*See Spectra*)
- **IR (Neat):** υ 2932 (s), 2861 (m), 1700 (s), 1489 (m), 1400 (w), 1215 (w), 1093 (m), 1072 (s), 810 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{17}O_2ClNa^+$ $[M+Na]^+$ 275.0815; found: 275.0811.

3-Methoxy-3-(*p*-tolyl)cycloheptan-1-one (2s)

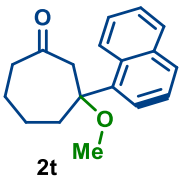


2s

Following general procedure A, using the redox active ester **1c** (118 mg, 0.300 mmol, 1.00 equiv), methanol (60 µL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 µmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2s** as a colorless liquid (55 mg, 0.24 mmol, 79%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.53, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.17 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.09 (d, *J* = 8.0 Hz, 2H, Ar*H*), 3.13 (d, *J* = 14.0 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.03 – 2.92 (s, 4H, COCH^a*H*^{b}CAr, OC*H*$_3$), 2.50 (dd, *J* = 7.8, 4.4 Hz, 2H), 2.33 – 2.17 (m, 4H, ArC*H*$_3$), 1.94 – 1.61 (m, 5H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.8, 142.4, 136.8, 129.1, 125.8, 78.5, 53.9, 50.5, 44.0, 42.4, 24.5, 23.7, 20.9. (*See Spectra*)
- **IR (Neat):** υ 2928 (s), 2861 (m), 1693 (s), 1656 (m), 1450 (m), 1266 (m), 1186 (m), 1070 (s), 807 (m).
- **HRMS (ESI):** calcd. for $C_{15}H_{20}O_2Na^+$ $[M+Na]^+$ 255.1361; found: 255.1358.

3-Methoxy-3-(naphthalen-1-yl)cycloheptan-1-one (2t)

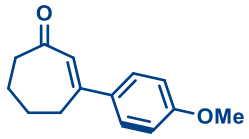


2t

Following general procedure A, using the redox active ester **1d** (82 mg, 0.20 mmol, 1.0 equiv), methanol (40 µL, 1.0 mmol, 5.0 equiv), and $Ir(ppy)_3$ (1.25 mg, 2.00 µmol, 0.010 equiv) in dry acetonitrile (0.8 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2t** as a colorless liquid (32 mg, 0.12 mmol, 62%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.53, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.89 (d, *J* = 8.7 Hz, 1H, Ar*H*), 7.86 (d, *J* = 8.1 Hz, 1H, Ar*H*), 7.79 (dd, *J* = 6.8, 2.5 Hz, 1H, Ar*H*), 7.58 – 7.44 (m, 2H, Ar*H*), 7.43 – 7.34 (m, 2H, Ar*H*), 3.52 (dd, *J* = 13.6, 2.4 Hz, 1H, COCH^aH^{b}CAr), 3.31 – 3.22 (m, 1H), 2.96 (s, 3H, OCH_3), 2.87 (d, *J* = 14.7 Hz, 1H), 2.64 (dd, *J* = 8.5, 3.4 Hz, 2H), 2.11 – 1.88 (m, 4H), 1.88 – 1.74 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.7, 140.1, 134.6, 131.1, 129.2, 129.0, 126.4, 126.3, 125.5, 124.8, 124.6, 80.2, 54.6, 50.6, 43.8, 24.3, 23.9. ** One carbon was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 2927 (s), 2858 (m), 1698 (s), 1454 (m), 1350 (m), 1275 (m), 1183 (m), 1071 (s), 780 (s).
- **HRMS (ESI):** calcd. for $C_{18}H_{20}O_2Na^+$ $[M+Na]^+$ 291.1361; found: 291.1360.

3-(4-Methoxyphenyl)cyclohept-2-en-1-one (2u)



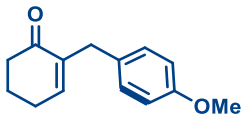
2u

Following general procedure A, using the redox active ester **1e** (110 mg, 0.270 mmol, 1.00 equiv), methanol (55.0 µL, 1.35 mmol, 5.00 equiv), and $Ir(ppy)_3$ (1.7 mg, 2.7 µmol, 0.01 equiv) in dry acetonitrile (1.20 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2u** as a colorless liquid (30 mg, 0.13 mmol, 51%). In addition, the product **2v** was obtained in 20% yield as a colorless liquid.

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.35, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.41 (d, *J* = 8.8 Hz, 2H, Ar*H*), 6.89 (d, *J* = 8.8 Hz, 2H, Ar*H*), 6.28 (s, 1H, C=C*H*CO), 3.82 (s, 3H, OCH_3), 2.86 (t, *J* = 6 Hz, 2H), 2.66 (t, *J* = 6 Hz, 2H), 1.99 – 1.81 (m, 4H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 204.3, 160.4, 157.2, 134.4, 128.9, 127.8, 113.9, 55.3, 41.8, 31.5, 25.1, 20.9. (*See Spectra*)

- **IR (Neat):** υ 2926 (s), 2856 (m), 1731 (m), 1649 (s), 1601 (s), 1511 (s), 1458 (m), 1249 (s), 1180 (s), 1031 (m), 833 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{16}O_2Na^+$ $[M+Na]^+$ 239.1048; found: 239.1046.

2-(4-Methoxybenzyl)cyclohex-2-en-1-one (2v)



2v

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.50, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.20 (d, *J* = 8.7 Hz, 2H, Ar*H*), 6.77 (d, *J* = 8.5 Hz, 2H, Ar*H*), 5.92 (t, *J* = 5.8 Hz, 1H, CH_2CH=C), 3.73 (s, 3H, OCH_3), 3.57 (s, 2H, HC=CCH_2Ar), 2.58 (t, *J* = 6.5 Hz, 2H, CH_2CO), 2.41 (q, *J* = 6.1 Hz, 2H, C=CHCH_2), 1.95 (p, *J* = 6.4 Hz, 2H, $CH_2CH_2CH_2$). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 208.7, 158.7, 135.8, 133.3, 127.8, 127.1, 113.7, 55.3, 46.6, 44.1, 28.5, 23.7. (*See Spectra*)
- **IR (Neat):** υ 2923 (s), 2854 (m), 1604 (m), 1510 (m), 1460 (m), 1251 (m), 1031 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{17}O_2^+$ $[M+H]^+$ 217.1229; found: 217.1229.

Mechanism for products 2u and 2v formation

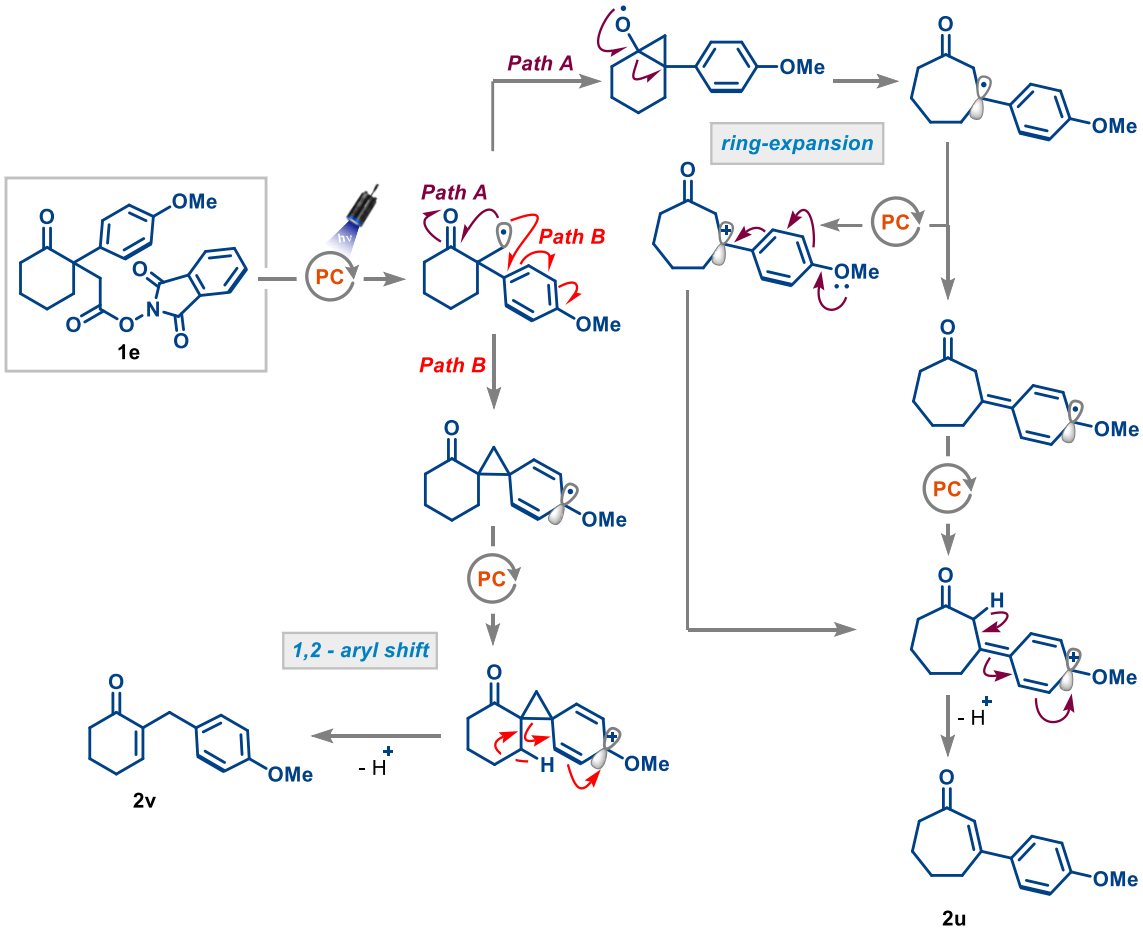
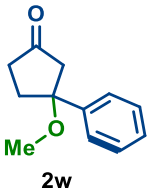


Figure 4: Mechanisms for the formation of products **2u** and **2v**.

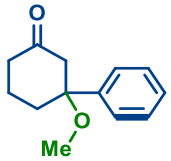
3-Methoxy-3-phenylcyclopentan-1-one (2w)



Following general procedure A, using the redox active ester **1f** (35 mg, 0.10 mmol, 1.0 equiv), methanol (20 μL, 0.50 mmol, 5.0 equiv), and $Ir(ppy)_3$ (0.70 mg, 1.0 μmol, 0.01 equiv) in dry acetonitrile (0.42 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2w** as a colorless liquid (4.0 mg, 0.025 mmol, 20%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.50, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.45 – 7.37 (m, 4H, Ar*H*), 7.36 – 7.29 (m, 1H, Ar*H*), 2.97 (s, 3H, OC*H*$_3$), 2.86 – 2.76 (m, 1H), 2.67 – 2.57 (m, 2H), 2.57 – 2.48 (m, 1H), 2.44 – 2.31 (m, 1H), 2.31 – 2.18 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 216.3, 140.8, 128.6, 128.0, 126.4, 84.3, 51.0, 49.2, 36.2, 32.9. (*See Spectra*)
- **IR (Neat):** υ 2924 (s), 2855 (m), 1745 (s), 1453 (w), 1156 (w), 1068 (m), 699 (w).
- **HRMS (ESI):** Not detected. ** Not detected also in GC-MS.

3-Methoxy-3-phenylcyclohexan-1-one (2x)

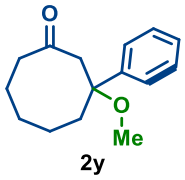


2x

Following general procedure A, using the redox active ester **1g** (109 mg, 0.300 mmol, 1.00 equiv), methanol (60 μL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2x** as a colorless sticky liquid (32.0 mg, 0.156 mmol, 52%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.55, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.45 – 7.34 (m, 4H, Ar*H*), 7.34 – 7.27 (m, 1H, Ar*H*), 2.96 (s, 3H, OC*H*$_3$), 2.81 (dt, *J* = 14.1, 2.2 Hz, 1H, COC*H*^{a}H^{b}CAr), 2.74 (d, *J* = 14.2 Hz, 1H, COCH^a*H*^{b}CAr), 2.53 – 2.41 (m, 1H), 2.40 – 2.21 (m, 2H), 2.16 – 1.99 (m, 2H), 1.98 – 1.84 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 209.7, 142.9, 128.6, 127.6, 125.9, 81.5, 51.6, 50.1, 40.5, 34.2, 20.8. (*See Spectra*)
- **IR (Neat):** υ 2926 (s), 2857 (m), 1716 (s), 1666 (m), 1450 (m), 1222 (w), 1068 (m), 759 (m), 699 (m).
- **HRMS (ESI):** calcd. for $C_{13}H_{16}O_2Na^+$ $[M+Na]^+$ 227.1048; found: 227.1046.

3-Methoxy-3-phenylcyclooctan-1-one (2y)

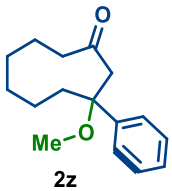


2y

Following general procedure A, using the redox active ester **1h** (118 mg, 0.300 mmol, 1.00 equiv), methanol (60 μL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2y** as a colorless liquid (47 mg, 0.20 mmol, 67%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.47, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.43 (d, *J* = 7.4 Hz, 2H, Ar*H*), 7.35 (t, *J* = 8.6 Hz, 2H, Ar*H*), 7.26 (t, *J* = 7.0, 1H, Ar*H*), 3.13 (d, *J* = 11.8 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.09 (s, 3H, OC*H*$_3$), 2.72 (dd, *J* = 11.9, 1.9 Hz, 1H, COCH^a*H*^{b}CAr), 2.50 – 2.31 (m, 2H), 2.23 – 2.05 (m, 2H), 1.98 – 1.83 (m, 2H), 1.69 – 1.50 (m, 4H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.5, 144.9, 128.4, 127.2, 125.9, 81.7, 50.8, 47.7, 45.0, 35.5, 28.5, 21.8, 18.8. (*See Spectra*)
- **IR (Neat):** υ 2929 (s), 2857 (m), 1699 (s), 1450 (m), 1201 (m), 1067 (m), 752 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{15}H_{20}O_2Na^+$ $[M+Na]^+$ 255.1361; found: 255.1360.

3-Methoxy-3-phenylcyclononan-1-one (2z)

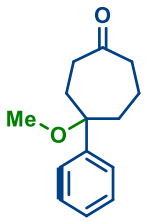


2z

Following general procedure A, using the redox active ester **1i** (122 mg, 0.300 mmol, 1.00 equiv), methanol (60 μL, 1.5 mmol, 5.0 equiv), and $Ir(ppy)_3$ (2.0 mg, 3.0 μmol, 0.01 equiv) in dry acetonitrile (1.25 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **2z** as a colorless liquid (46 mg, 0.19 mmol, 62%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.63, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.46 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.36 (t, *J* = 7.2 Hz, 2H, Ar*H*), 7.27 (d, *J* = 8.1 Hz, 1H, Ar*H*), 3.08 (s, 2H, COCH_2CAr), 2.99 (s, 3H, OCH_3), 2.64 – 2.51 (m, 1H), 2.50 – 2.39 (m, 1H), 2.10 (dt, *J* = 14.3, 6.8 Hz, 1H), 1.98 – 1.78 (m, 3H), 1.70 – 1.55 (m, 2H), 1.55 – 1.45 (m, 2H), 1.45 – 1.32 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 212.5, 144.1, 128.2, 127.2, 126.7, 81.3, 50.2, 48.3, 47.5, 32.6, 26.6, 24.3, 22.1, 19.1. (*See Spectra*)
- **IR (Neat):** υ 2927 (s), 2858 (m), 1702 (s), 1447 (m), 1337 (m), 1145 (m), 1077 (s), 762 (s), 701 (s).
- **HRMS (ESI):** calcd. for $C_{16}H_{22}O_2Na^+$ $[M+Na]^+$ 269.1517; found: 269.1518.

4-Methoxy-4-phenylcycloheptan-1-one (8a)



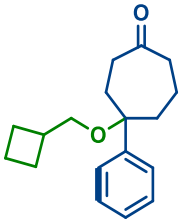
8a

Following general procedure A, using the redox active ester **7** (57 mg, 0.15 mmol, 1.0 equiv), methanol (30 μL, 0.75 mmol, 5.0 equiv), and $Ir(ppy)_3$ (1.0 mg, 1.5 μmol, 0.01 equiv) in dry acetonitrile (0.65 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **8a** as a colorless liquid (23 mg, 0.11 mmol, 70%).

- **TLC (Et_2O:Hexane, 3:7 v/v):** R_f = 0.42, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 – 7.31 (m, 4H, Ar*H*), 7.31 – 7.23 (m, 1H, Ar*H*), 3.17 – 3.06 (m, 1H), 3.03 (s, 3H, OCH_3), 2.60 (dt, *J* = 16.9, 4.3 Hz, 1H), 2.47 (ddd, *J* = 17.1, 12.3, 3.3 Hz, 1H), 2.40 – 2.26 (m, 2H), 2.27 – 2.09 (m, 2H), 2.09 – 1.97 (m, 1H), 1.86 – 1.70 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 214.7, 145.6, 128.4, 127.2, 125.8, 79.0, 50.2, 43.7, 39.8, 37.2, 34.0, 17.9. (*See Spectra*)
- **IR (Neat):** υ 2926 (s), 2856 (s), 1702 (s), 1452 (m), 1072 (m), 760 (m), 702 (m).

- **HRMS (ESI):** calcd. for $C_{14}H_{18}O_2Na^+$ $[M+Na]^+$ 241.1204; found: 241.1201.

4-(Cyclobutylmethoxy)-4-phenylcycloheptan-1-one (8b)

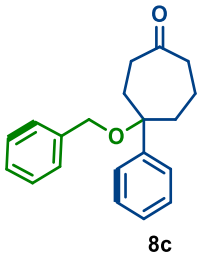


8b

Following general procedure A, using the redox active ester **7** (95 mg, 0.25 mmol, 1.0 equiv), cyclobutanmethanol (59 µL, 0.62 mmol, 2.5 equiv), and $Ir(ppy)_3$ (1.6 mg, 2.5 µmol, 0.01 equiv) in dry acetonitrile (1.10 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to obtain the pure product **8b** as a colorless sticky liquid (32 mg, 0.12 mmol, 47%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.57, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 – 7.30 (m, 4H, Ar*H*), 7.27 (m, 1H, Ar*H*), 3.16 (ddd, *J* = 14.5, 12.4, 2.1 Hz, 1H), 3.03 (ddd, *J* = 30.4, 8.8, 6.5 Hz, 2H), 2.65 – 2.40 (m, 3H), 2.39 – 2.28 (m, 2H), 2.28 – 2.12 (m, 2H), 2.11 – 1.98 (m, 3H), 1.98 – 1.88 (m, 1H), 1.88 – 1.65 (m, 5H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 215.0, 146.3, 128.3, 127.0, 125.8, 77.8, 66.1, 43.7, 39.9, 37.3, 35.4, 34.5, 25.2, 18.7, 17.8. (*See Spectra*)
- **IR (Neat):** υ 2930 (s), 2859 (m), 1701 (s), 1447 (m), 1195 (m), 1062 (s), 759 (s), 701 (s).
- **HRMS (ESI):** calcd. for $C_{18}H_{24}O_2^+$ $[M+Na]^+$ 295.1674; found: 295.1673.

4-(benzyloxy)-4-phenylcycloheptan-1-one (8c)

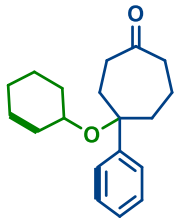


8c

Following general procedure A, using the redox active ester **7** (95 mg, 0.25 mmol, 1.0 equiv), benzylalcohol (65 µL, 0.62 mmol, 2.5 equiv), and $Ir(ppy)_3$ (1.6 mg, 2.5 µmol, 0.01 equiv) in dry acetonitrile (1.10 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to afford the pure product **8c** as colorless a sticky liquid (38 mg, 0.13 mmol, 52%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.45, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.50 – 7.43 (m, 2H, Ar*H*), 7.42 – 7.33 (m, 6H, Ar*H*), 7.33 – 7.27 (m, 2H, Ar*H*), 4.22 (d, *J* = 11.2 Hz, 1H, OC*H*^{a}H^{b}Ar), 4.14 (d, *J* = 11.2 Hz, 1H, OCH^a*H*^{b}Ar), 3.29 – 3.17 (m, 1H), 2.63 (dt, *J* = 17.5, 4.2 Hz, 1H), 2.57 – 2.42 (m, 2H), 2.42 – 2.31 (m, 2H), 2.31 – 2.20 (m, 1H), 2.16 – 2.04 (m, 1H), 1.96 – 1.85 (m, 1H), 1.85 – 1.73 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 214.7, 145.7, 138.6, 128.5, 128.4, 127.4, 127.3, 127.2, 125.8, 79.1, 64.1, 43.7, 39.9, 37.4, 34.7, 17.9. (*See Spectra*)
- **IR (Neat):** υ 3029 (w), 2927 (s), 2859 (m), 1701 (s), 1493 (w), 1450 (m), 1261 (m), 1088 (s), 1057 (s), 802 (m), 762 (m), 733 (m), 700 (s).
- **HRMS (ESI):** calcd. for $C_{20}H_{22}O_2Na^+$ $[M+Na]^+$ 317.1517; found: 317.1516.

4-(Cyclohexyloxy)-4-phenylcycloheptan-1-one (8d)



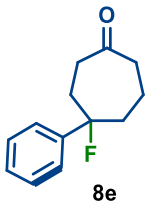
8d

Following general procedure A, using the redox active ester **7** (95 mg, 0.25 mmol, 1.0 equiv), cyclohexanol (65 µL, 0.62 mmol, 2.5 equiv), and $Ir(ppy)_3$ (1.6 mg, 2.5 µmol, 0.01 equiv) in dry acetonitrile (1.10 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to obtain the pure product **8d** as a colorless liquid (19 mg, 0.07 mmol, 28%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.50, $KMnO_4$.

- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.48 (d, *J* = 7.7 Hz, 2H, Ar*H*), 7.34 (t, *J* = 7.6 Hz, 2H, Ar*H*), 7.28 (d, *J* = 7.8 Hz, 1H, Ar*H*), 3.21 – 3.02 (m, 2H), 2.64 – 2.49 (m, 1H), 2.49 – 2.40 (m, 1H), 2.40 – 2.15 (m, 4H), 2.11 – 1.92 (m, 2H), 1.80 – 1.67 (m, 1H), 1.67 – 1.56 (m, 3H), 1.56 – 1.47 (m, 1H), 1.47 – 1.37 (m, 1H), 1.36 – 1.17 (m, 2H), 1.16 – 0.90 (m, 3H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 215.1, 145.5, 127.9, 127.3, 126.6, 79.0, 71.4, 43.5, 39.6, 37.8, 35.1, 34.7, 34.5, 25.5, 24.6, 24.5, 18.3. (*See Spectra*)
- **IR (Neat):** υ 2929 (s), 2855 (m), 1704 (s), 1450 (m), 1056 (m), 762 (m), 702 (m).
- **HRMS (ESI):** calcd. for $C_{19}H_{26}O_2Na^+$ $[M+Na]^+$ 309.1830; found: 309.1833.

4-Fluoro-4-phenylcycloheptan-1-one (8e)



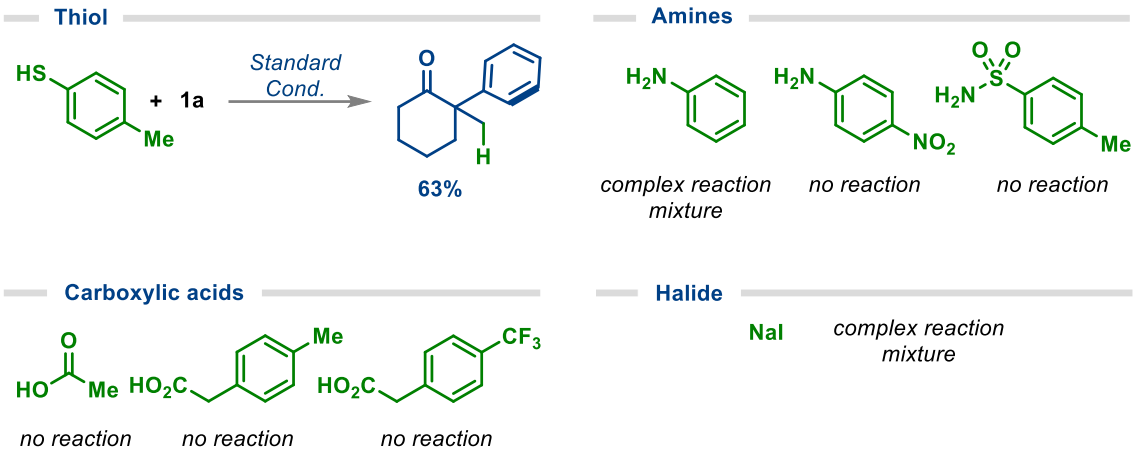
8e

Following general procedure A, using the redox active ester **7** (38 mg, 0.10 mmol, 1.0 equiv), $(HF)_3{\cdot}BF_3$ (51 μL, 0.30 mmol, 3.0 equiv), and $Ir(ppy)_3$ (0.60 mg, 1.0 μmol, 0.01 equiv) in dry dichloromethane (0.42 mL, 0.24 M). The crude reaction mixture was purified by flash column chromatography using EtOAc:Hexane 1:19 mixture as mobile phase to obtain the pure product **8e** as a colorless liquid (14 mg, 0.06 mmol, 67%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.49, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 – 7.33 (m, 4H, Ar*H*), 7.33 – 7.27 (m, 1H), 3.25 – 3.11 (m, 1H), 2.75 – 2.62 (m, 1H), 2.60 – 2.47 (m, 1H), 2.45 – 2.35 (m, 1H), 2.35 – 2.26 (m, 1H), 2.25 – 2.18 (m, 2H), 2.17 – 1.92 (m, 1H), 1.91 – 1.74 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 213.9, 145.7 (d, *J* = 21.2 Hz), 128.4 (d, *J* = 1.8 Hz), 127.5 (d, *J* = 1.0 Hz), 123.3 (d, *J* = 9.9 Hz), 96.9 (d, *J* = 177.9 Hz), 43.6, 41.6 (d, *J* = 24.4 Hz), 37.1 (d, *J* = 4.7 Hz), 35.7 (d, *J* = 24.6 Hz), 17.9 (d, *J* = 3.0 Hz). (*See Spectra*)
- **^{19}F NMR (376 MHz, $CDCl_3$):** δ 160.4. (*See Spectra*)

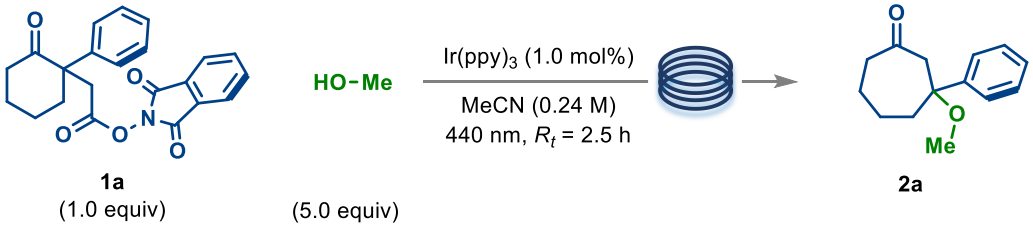
- **IR (Neat):** υ 2925 (m), 2855 (w), 1701 (s), 1446 (m), 1336 (w), 1236 (w), 1146 (w), 1020 (m), 908 (m), 873 (m), 757 (m), 699 (m).
- **GCMS:** calcd. for $C_{13}H_{15}FO^{+}$ $[M]^{+}$ 206; found 206.

Unsuccessful nucleophiles



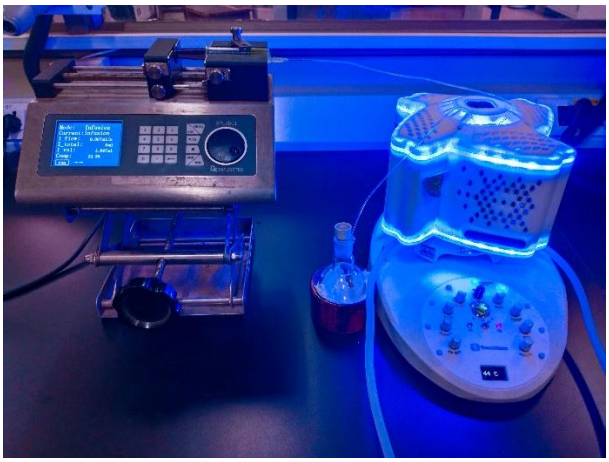
4. Procedures for scale-up the reaction in Flow and Product modifications

4.1 Reaction scale up in Flow



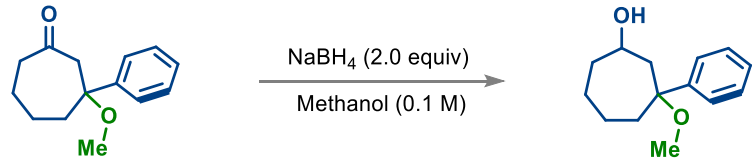
An oven-dried 10 mL glass vial was charged with the redox active ester **1a** (378 mg, 1.00 mmol, 1.00 equiv) and $Ir(ppy)_3$ (6.50 mg, 10.0 μmol, 0.01 equiv). Next, the vial was closed with screw-cap septum. The vial was degassed and refill with argon using schlenk line (three times). Acetonitrile (4.2 mL, 0.24 M) and methanol (160 mg, 205 μL, 5.00 equiv) were added to the mixture. The mixture was stirred for 30 minutes in the absence of light to make the reaction solution homogeneous. Next, the solution was transferred into a 10 mL syringe and put into continuous flow (8 mL/2.5 h) using a syringe pump while being irradiated (457 nm) in PhotoCube™ commercialized by ThalesNano. The solvent was evaporated under reduced pressure. The crude reaction mixture was purified by flash column chromatography using

Et_2O:Hexane 1:9 mixture as mobile phase to afford the product **2a** as a colorless sticky liquid (170 mg, 0.78 mmol, 78%).



4.2 Procedures for product modifications

3-Methoxy-3-phenylcycloheptan-1-ol (9)



2a
(1.0 equiv)

9

Following a slightly modified procedure, an oven-dried 4 mL glass vial was charged with the ketone **2a** (22 mg, 0.10 mmol, 1.0 equiv) and methanol (1.0 mL, 0.1 M). Sodium borohydride (7.5 mg, 0.20 mmol, 2.0 equiv) was added to the solution, and the mixture was stirred for 5 h at room temperature. The reaction was quenched with 5 mL saturated aqueous solution of NH_4Cl and extracted with diethyl ether (3×5 mL). The organic layers were combined, dried over $MgSO_4$, and evaporated under reduced pressure. The crude product was purified by flash column chromatography using a 1:9 mixture of Et_2O:Hexane as the mobile phase, yielding the products **9** as a colorless oil (18 mg, 0.95 mmol, 95%, 3:1 *dr*).

Major diastereomer

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.35, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 (d, *J* = 8.4 Hz, 2H, Ar*H*), 7.37 (t, *J* = 7.6 Hz, 2H, Ar*H*), 7.32 – 7.25 (m, 1H, Ar*H*), 4.03 (m, 1H, C*H*OH), 3.02 (s, 2H, OCH_3), 2.64 (s,

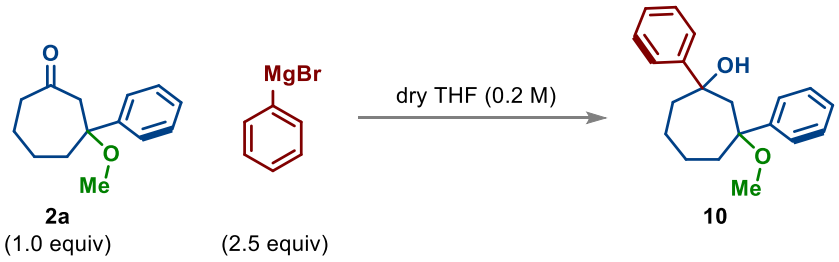
1H, CHO*H*), 2.36 – 2.20 (m, 3H), 2.09 – 1.64 (m, 6H), 1.57 – 1.40 (m, 1H). (*See Spectra*)

- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 145.9, 128.3, 127.0, 126.0, 81.5, 69.9, 50.2, 48.3, 38.5, 38.1, 25.3, 23.2. (*See Spectra*)
- **IR (Neat):** υ 3423 (m, brs), 2929 (s), 2858 (m), 1493 (w), 1449 (m), 1361 (w), 1073 (m), 1024 (m), 759 (m), 700 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{20}O_2Na^+$ $[M+Na]^+$ 243.1361; found: 243.1358.

Minor diastereomer:

- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.26, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.44 – 7.30 (m, 4H, Ar*H*), 7.31 – 7.20 (m, 1H, Ar*H*), 4.21 (m, 1H, C*H*OH), 3.02 (s, 3H, OCH_3), 2.32 (d, *J* = 14.3 Hz, 1H), 2.20 – 2.00 (m, 3H), 2.00 – 1.89 (m, 1H), 1.87 – 1.45 (m, 5H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 146.3, 128.3, 126.8, 125.9, 79.2, 67.7, 50.4, 49.8, 38.9, 38.0, 24.9, 21.9. (*See Spectra*)
- **IR (Neat):** υ 3434 (w, brs), 2926 (s), 2856 (s), 1727 (m), 1493 (w), 1454 (m), 1368 (w), 1075 (m), 1027 (w), 756 (m), 701 (m).
- **HRMS (ESI):** calcd. for $C_{14}H_{20}O_2Na^+$ $[M+Na]^+$ 243.1361; found: 243.1363.

3-Methoxy-1,3-diphenylcycloheptan-1-ol (10)

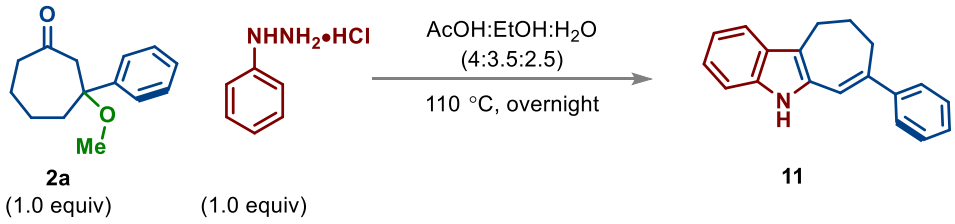


Following a modified procedure,[3] an oven-dried 5 mL glass vial was charged with ketone **2a** (22 mg, 0.10 mmol, 1.0 equiv) and dry THF (0.5 mL, 0.2 M). To this,0.5 M PhMgBr (0.50 mL, 0.25 mmol, 2.5 equiv) was added dropwise at 0 °C. After 10 h stirring at room temperature, the reaction mixture was quenched with 5 mL of saturated aqueous NH_4Cl solution and extracted with diethyl ether (3×5 mL). The organic layers were combined, dried over $MgSO_4$, and evaporated under reduced pressure. The crude product was purified by column chromatography using 1:9 mixture

of Et_2O and hexane to afford the pure product **10** as a colorless liquid (21 mg, 0.71 mmol, 71%, 15:1 *dr*, single diastereomer was isolated).

- **TLC (EtOAc:Hexane, 1:9 v/v):** R_f = 0.33, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.49 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.41 (d, *J* = 8.3 Hz, 2H, Ar*H*), 7.39 – 7.23 (m, 5H, Ar*H*), 7.23 – 7.15 (m, 1H, Ar*H*), 3.14 (s, 3H, OC*H*$_3$), 2.54 (ddd, *J* = 13.5, 9.9, 3.2 Hz, 1H), 2.43 (ddd, *J* = 14.7, 7.4, 2.8 Hz, 1H), 2.31 (d, *J* = 15.4 Hz, 1H), 2.23 (d, *J* = 15.4 Hz, 1H), 2.19 – 1.99 (m, 4H), 1.96 – 1.80 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 151.6, 146.0, 128.3, 127.9, 127.0, 126.0, 125.9, 123.9, 83.4, 76.2, 56.4, 50.4, 42.6, 34.7, 24.9, 23.8. (*See Spectra*)
- **IR (Neat):** υ 3485 (w), 2922 (s), 2854 (m), 1449 (m), 1393 (w), 1225 (w), 1062 (s), 967 (w), 755 (m), 700 (s).
- **HRMS (ESI):** calcd. for $C_{20}H_{24}O_2Na^+$ $[M+Na]^+$ 319.1674; found: 319.1670.

7-Phenyl-5,8,9,10-tetrahydrocyclohepta[b]indole (11)



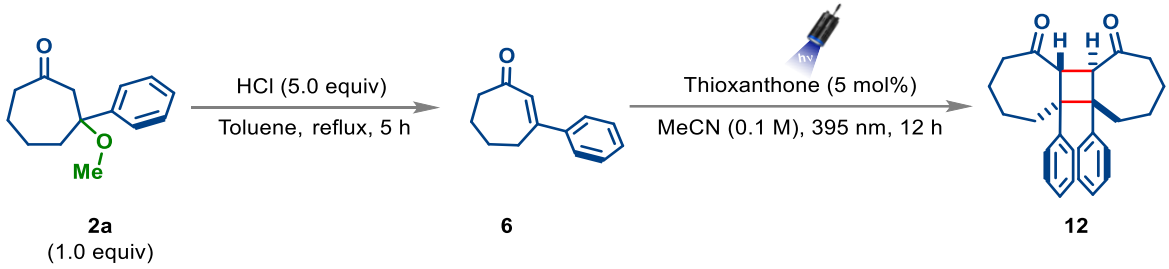
An oven-dried 5 mL glass vial was charged with ketone **2a** (22 mg, 0.10 mmol, 1.0 equiv) and phenylhydrazine hydrochloride (14.5 mg, 0.100 mmol, 1.00 equiv). Next, 2.0 mL of 4:3.5:2.5 mixture of acetic acid, ethanol and water was added. The solution was heated to 110 °C and stirred for overnight. The reaction mixture was quenched with saturated 5 mL of $NaHCO_3$ solution and extracted with ethyl acetate. The organic layers were combined, dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:19 mixture of EtOAc and hexane as mobile phase to obtain the pure product **11** as a yellow solid (8 mg, 0.03 mmol, 30%).

- **TLC (EtOAc:Hexane, 2:8 v/v):** R_f = 0.39, $KMnO_4$.
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.71 (s, brs, 1H, N*H*), 7.49 – 7.43 (m, 1H, Ar*H*), 7.43 – 7.36 (m, 2H, Ar*H*), 7.34 – 7.26 (m, 2H, Ar*H*), 7.25 – 7.19 (m, 2H, Ar*H*), 7.09 (td, *J*

= 8.1, 7.5, 1.2 Hz, 1H, Ar*H*), 7.03 (td, *J* = 7.5, 7.0, 1.1 Hz, 1H, Ar*H*), 6.49 (s, 1H, CC*H*=CAr), 3.03 (t, *J* = 6.0 Hz, 2H), 2.92 – 2.85 (m, 2H), 2.12 (m, 2H). (*See Spectra*)

- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 144.3, 143.1, 135.6, 132.4, 129.5, 128.4, 126.9, 125.9, 122.2, 119.4, 118.4, 118.3, 114.8, 110.4, 34.3, 26.3, 24.2. (*See Spectra*)
- **IR (Neat):** υ 3406 (w), 2923 (s), 2855 (m), 1455 (w), 1333 (w), 750 (w), 696 (w).
- **HRMS (ESI):** calcd. for $C_{19}H_{18}N^+$ $[M+H]^+$ 260.1439; found: 260.1436.

5a,5b-Diphenyldodecahydrocyclobuta[1,2:3,4]di[7]annulene-1,10-dione (12)



An oven-dried 4 mL glass vial was charged with ketone **2a** (44 mg, 0.20 mmol, 1.0 equiv) and hydrochloric acid (5.0 equiv) and toluene (2 mL). The solution was refluxed for 5 h, after which the crude reaction mixture was filtered using silica pad. The filterate was dried over $MgSO_4$ and concentrated. The crude product was used in the next step without further purification.

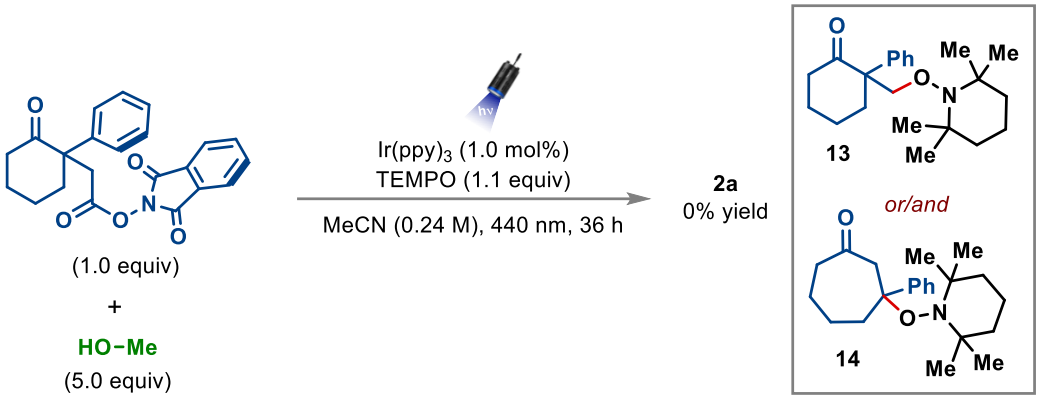
Following a slightly modified procedure,[25] an oven dried 4 mL glass vial was charged with the crude alkene and thioxanthone (1.0 mg, 1.0 μmol, 0.05 equiv) and closed the screw cap septum. The closed vial was degassed and filled with argon using schlenk line technique. Acetonitrile (1.0 mL, 0.2 M) was added and irradiated under 395 nm light source. After 12 h, the solvent was evaporated under vacuum. The crude product was purified by flash-column chromatography using 1:9 mixture of Et_2O and hexane as mobile phase to afford pure **12** as a white solid (16 mg, 0.070 mmol, 35%).

- **TLC (Et_2O:Hexane, 4:6 v/v):** R_f = 0.51, $KMnO_4$
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.43 (m, 2H, Ar*H*), 7.38 – 7.27 (m, 8H, Ar*H*), 3.86 (s, 2H, COC*H*), 2.57 (dd, *J* = 19.1, 4.6 Hz, 2H), 2.16 – 1.96 (m, 4H), 1.70 – 1.53 (m, 6H), 1.18 – 1.02 (m, 2H), 0.77 – 0.66 (m, 2H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 214.3, 141.1, 129.0, 128.7, 127.7, 126.7, 126.2, 57.0, 53.9, 43.7, 40.5, 26.6, 24.0. (*See Spectra*)

- **HRMS (ESI):** calcd. for $C_{26}H_{28}O_2Na^+$ $[M+Na]^+$ 395.1987; found: 395.1987. The characterized data is matched with the reported values.[25]

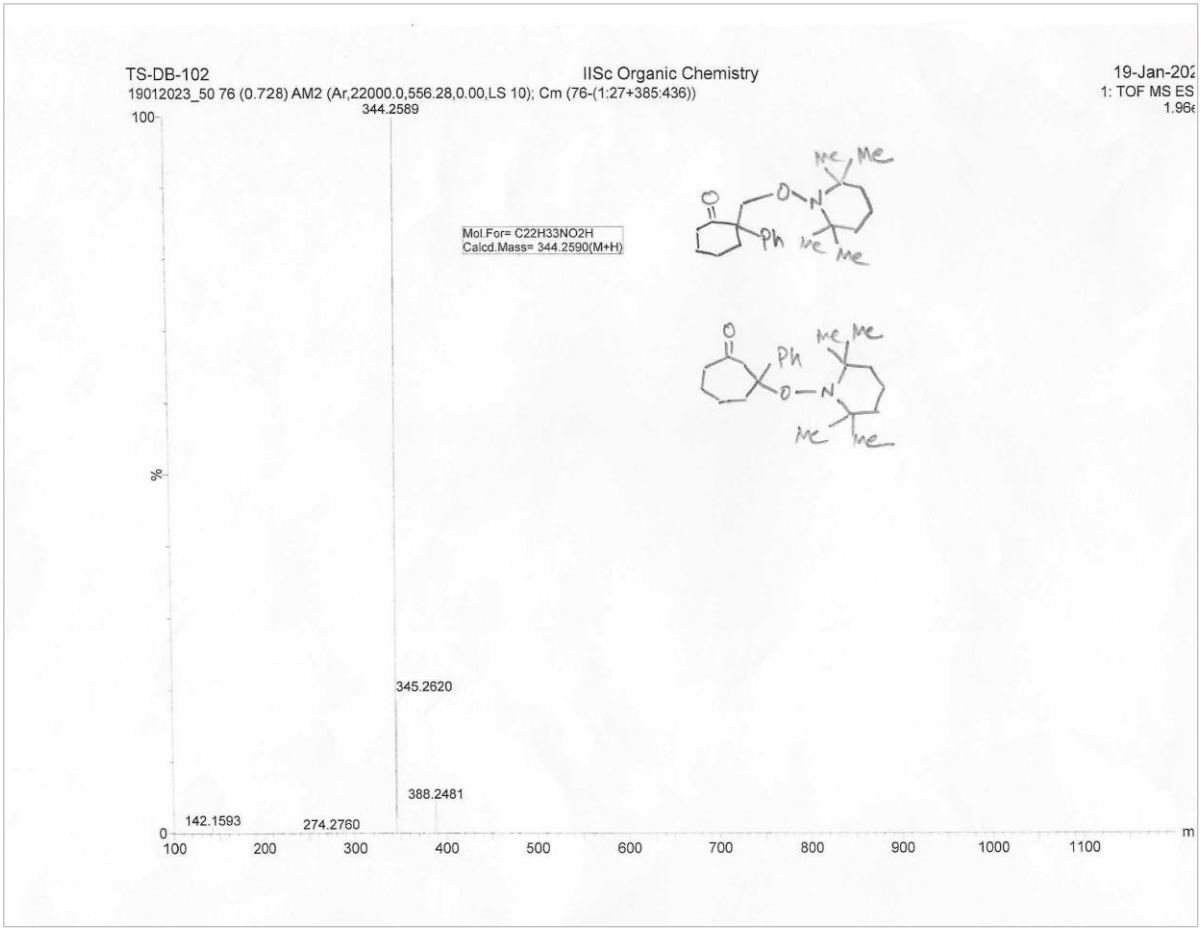
5. Procedures for controlled experiments

Radical trapping with TEMPO

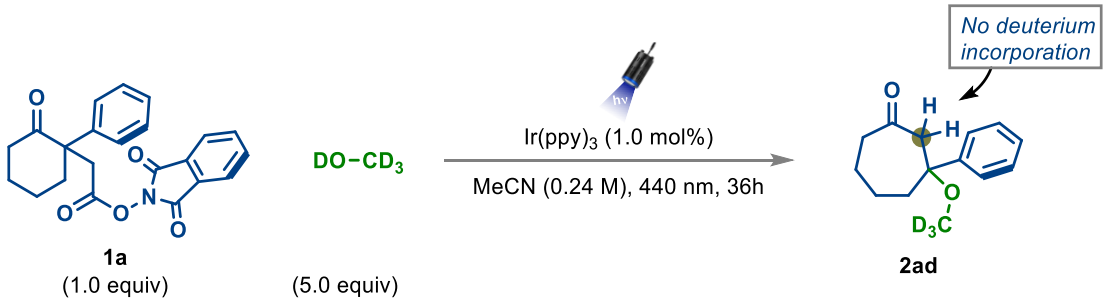


An oven-dried vial was charged with the redox active ester **1a** (38 mg, 0.10 mmol, 1.0 equiv), TEMPO (17.2 mg, 0.110 mmol, 1.10 equiv), and $Ir(ppy)_3$ (0.6 mg, 1 μmol, 0.01 equiv), then the vial was closed with screw-cap septum. The vial was degassed and refilled with argon using a Schlenk line (three times). Acetonitrile (0.42 mL, 0.24 M) and methanol (16.0 mg, 20.0 μL, 5.00 equiv) was added to the mixture. Then, the mixture was stirred for 36 h under the irradiation of a 440 nm Kessil lamp. The solvent was evaporated under reduced pressure to obtain the crude reaction mixture. The ^1H NMR of the crude reaction mixture confirmed the absence of desired product formation. However, the TEMPO adduct intermediates are detected in HRMS as the base peak.

- **HRMS (ESI):** calcd. for $C_{22}H_{34}NO_2^+$ $[M+H]^+$ 344.2590; found: 344.2589.



Deuterium labelling experiment

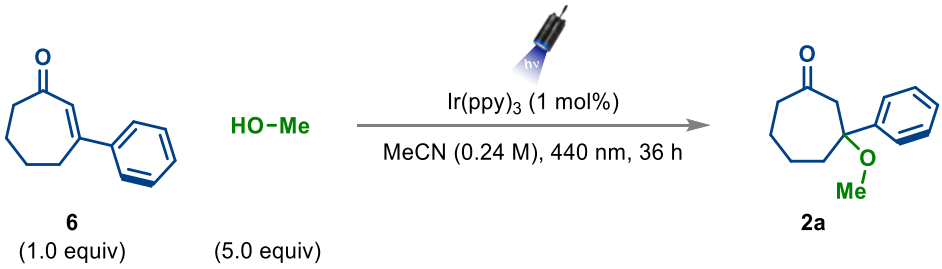


Following general procedure A, an oven-dried 4 mL glass vial was charged with the redox active ester **1a** (76 mg, 0.20 mmol, 1.0 equiv) and $Ir(ppy)_3$ (1.3 mg, 2.0 μmol, 0.01 equiv). Next, the vial was closed with screw-cap septum. The vial was degassed and refill with argon using schlenk line (three times). Acetonitrile (0.82 mL, 0.24 M) and methanol-d_4 (36 mg, 41 μL, 5.0 equiv) were added to the mixture and stirred for 36 h under the irradiation of 440 nm kessil lamp. The solvent was evaporated under reduced pressure. Finally, the crude product was purified by flash column

chromatography using Et_2O:Hexane 1:9 mixture as mobile phase to obtain the pure product **2ad** as a colorless oil (36.0 mg, 0.16 mmol, 81%).

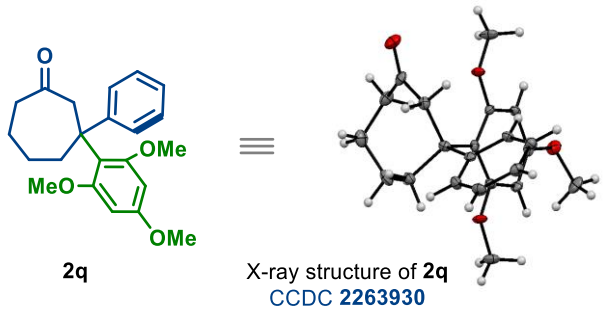
- **TLC (Et_2O:Hexane, 2:8 v/v):** R_f = 0.37, $KMnO_4$
- **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.35 (d, *J* = 4.3 Hz, 4H, Ar*H*), 7.32 – 7.21 (m, 1H, Ar*H*), 3.23 (d, *J* = 14.0 Hz, 1H, COC*H*^{a}H^{b}CAr), 3.06 (dd, *J* = 14.0, 2.3 Hz, 1H, COCH^a*H*^{b}CAr), 2.58 (dd, *J* = 8.4, 4.2 Hz, 2H), 2.34 – 2.24 (m, 1H), 2.02 – 1.85 (m, 3H), 1.85 – 1.75 (m, 1H), 1.75 – 1.63 (m, 1H). (*See Spectra*)
- **^{13}C NMR (101 MHz, $CDCl_3$):** δ 211.6, 145.5, 128.4, 127.2, 125.8, 78.6, 53.8, 44.0, 42.5, 24.5, 23.7. **The carbon attached with three deuterium was not resolved at 101 MHz. (*See Spectra*)
- **IR (Neat):** υ 2929 (s), 2859 (m), 1699 (s), 1658 (w), 1448 (m), 1212 (m), 1110 (m), 10678 (s), 756 (m), 701 (s).
- **HRMS (ESI):** calcd. for $C_{14}H_{15}D_3O_2Na^+$ [M+Na]$^+$ 244.1439; found: 244.1386.

Olefin trapping experiment



An oven-dried 4 mL glass vial was charged with the 3-phenylcyclohept-2-en-1-one **6** (14 mg, 0.10 mmol, 1.0 equiv) and $Ir(ppy)_3$ (0.60 mg, 1.0 µmol, 0.01 equiv). Next, the vial was closed with screw-cap septum. The vial was degassed and refilled with argon using schlenk line (three times). Acetonitrile (0.41 mL, 0.24 M) and methanol (16 mg, 20 µL, 5.0 equiv.) were added to the mixture and stirred for 36 h under the irradiation of 440 nm kessil lamp. The solvent was evaporated to afford the crude material. The ^{1}H NMR analysis of the crude material confirmed the absence of the desired product formation.

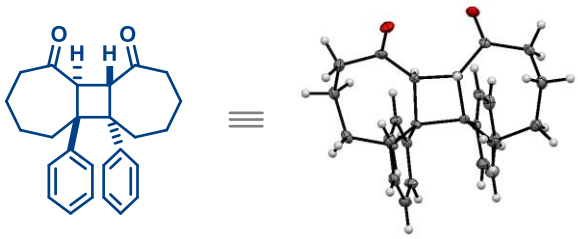
7. X-ray crystallography data



2q

X-ray structure of **2q**
CCDC **2263930**

Identification Code	SHELXL-2019/1
Empirical Formula	$C_{22}H_{26}O_4$
Molecular Weight	354.43
Temperature	120K
Wavelength	0.71073 Å
Crystal system	Orthorhombic
Space group	*P 21/n* (14)
Unit cell dimensions	a = 7.9842(4); b = 21.6573(12); c = 21.6791(11)
Angles	α = 90; β = 90; γ = 90
Volume	3748.7(3) $Å^3$
Z	8
Density (Calculated).	1.256 g/cm^3
Absorption coefficient	0.085 mm^{-1}
F (000)	1520
Theta range for data collection	2.659 to 25.037
Index ranges	-9<=h<=9, -25<=k<=25, -25<=l<=25
Completeness	99.9 %
Structure Refinement	SHELXL-2019/1 (Sheldrick, 2019)'
Data/ restraints/ parameters	3315 / 0/ 238
Goodness of fit on F^2	1.289
Final R indices [1>2 sigma (1)]	R_1 = 0.0688; wR_2 = 0.1459
Largest diff. peak and hole	0.242 and -0.338 e. Å



12

X-ray structure of **12**
CCDC **2264117**

Identification Code	SHELXL-2019/1
Empirical Formula	$C_{26}H_{28}O_2$
Molecular Weight	372.48
Temperature	120K
Wavelength	0.71073 Å
Crystal system	Monoclinic
Space group	*P 21/n* (14)
Unit cell dimensions	a = 8.0064(7); b = 24.8727(17); c = 10.4677(8)
Angles	α = 90; β = 110.575(3); γ = 90
Volume	1951.6(3) $Å^3$
Z	4
Density (Calculated)	1.268 g/cm^3
Absorption coefficient	0.078 mm^{-1}
F (000)	800
Theta range for data collection	2.65 to 28.15
Index ranges	-10<=h<=10, -33<=k<=33, -13<=l<=13
Completeness	99.9 %
Structure Refinement	SHELXL-2019/1 (Sheldrick, 2019)'
Data/ restraints/ parameters	4864 / 0/ 253
Goodness of fit on F^2	1.178
Final R indices [1>2 sigma (1)]	R_1 = 0.0678; wR_2 = 0.1542
Largest diff. peak and hole	0.398 and -0.284 e. Å

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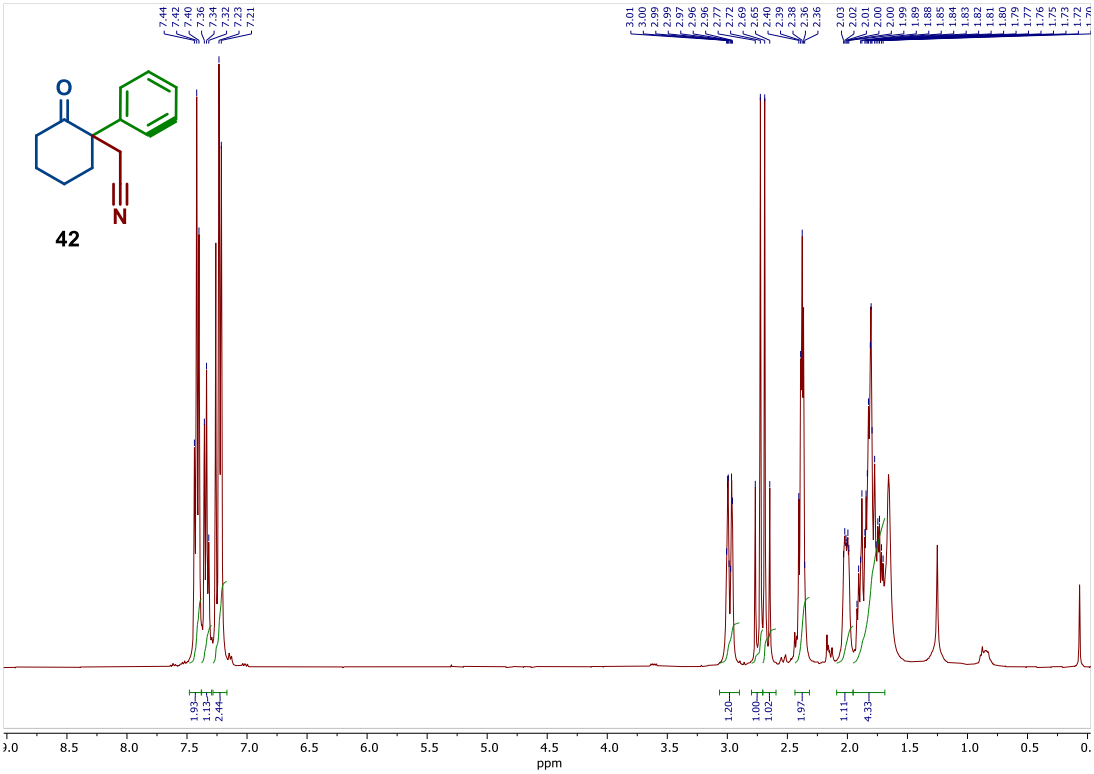
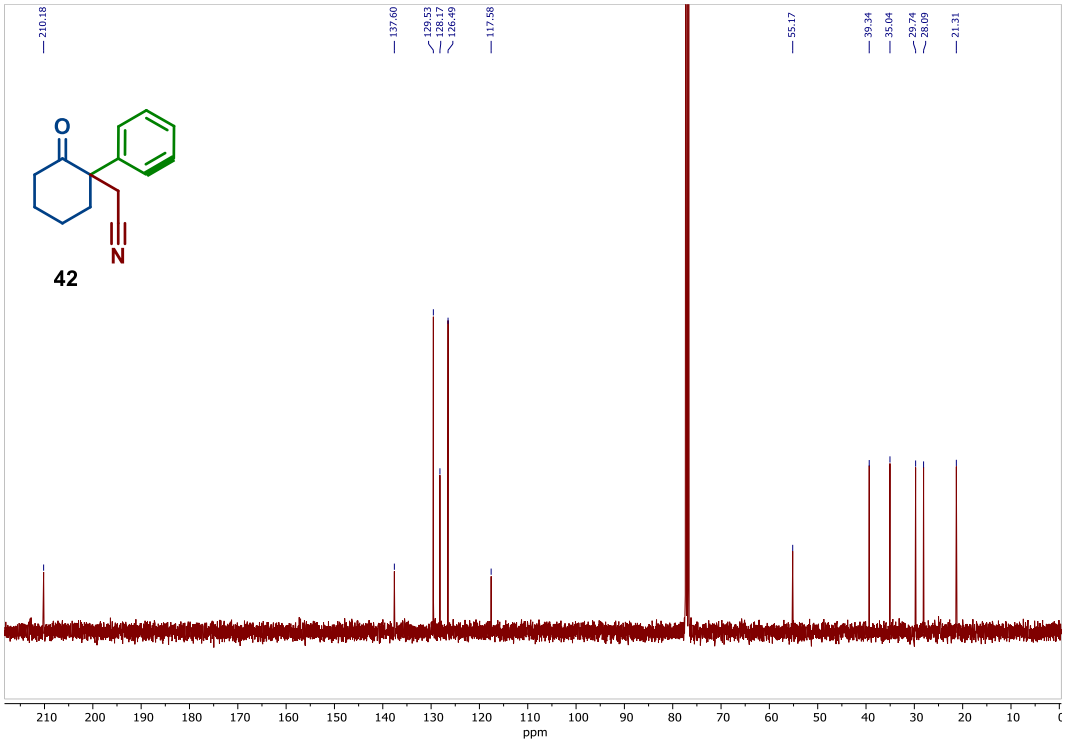
8. Spectra for new compounds

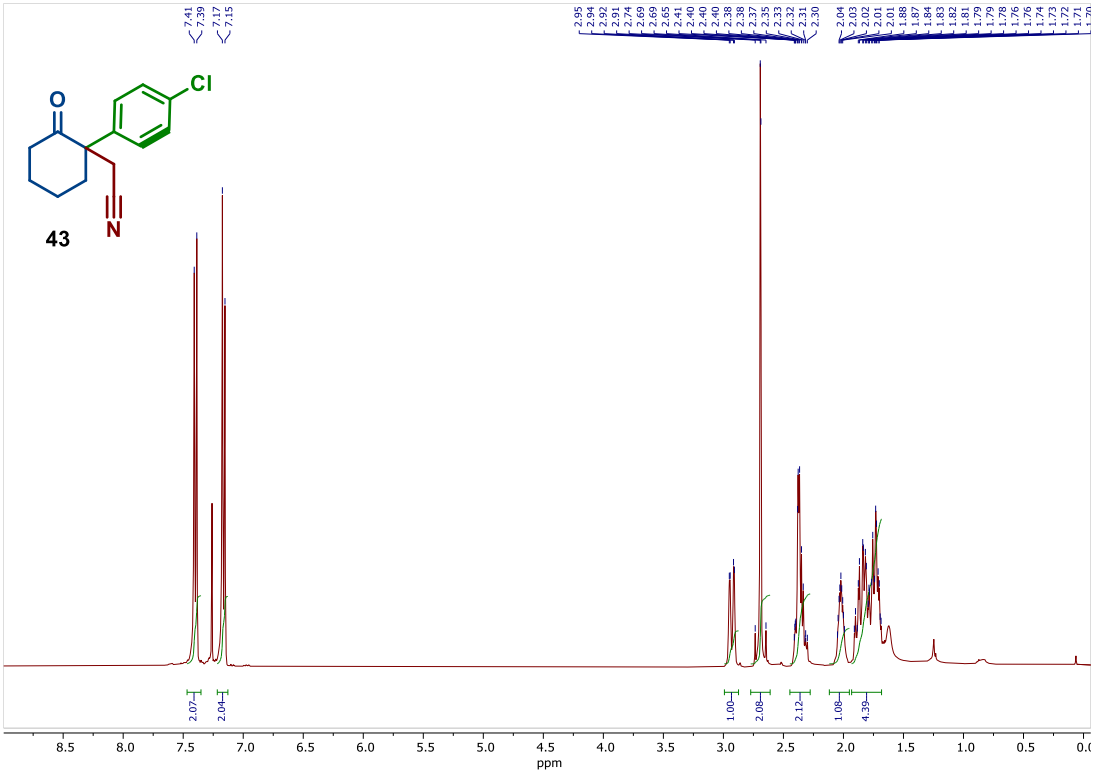
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **42** (*See Procedure*)



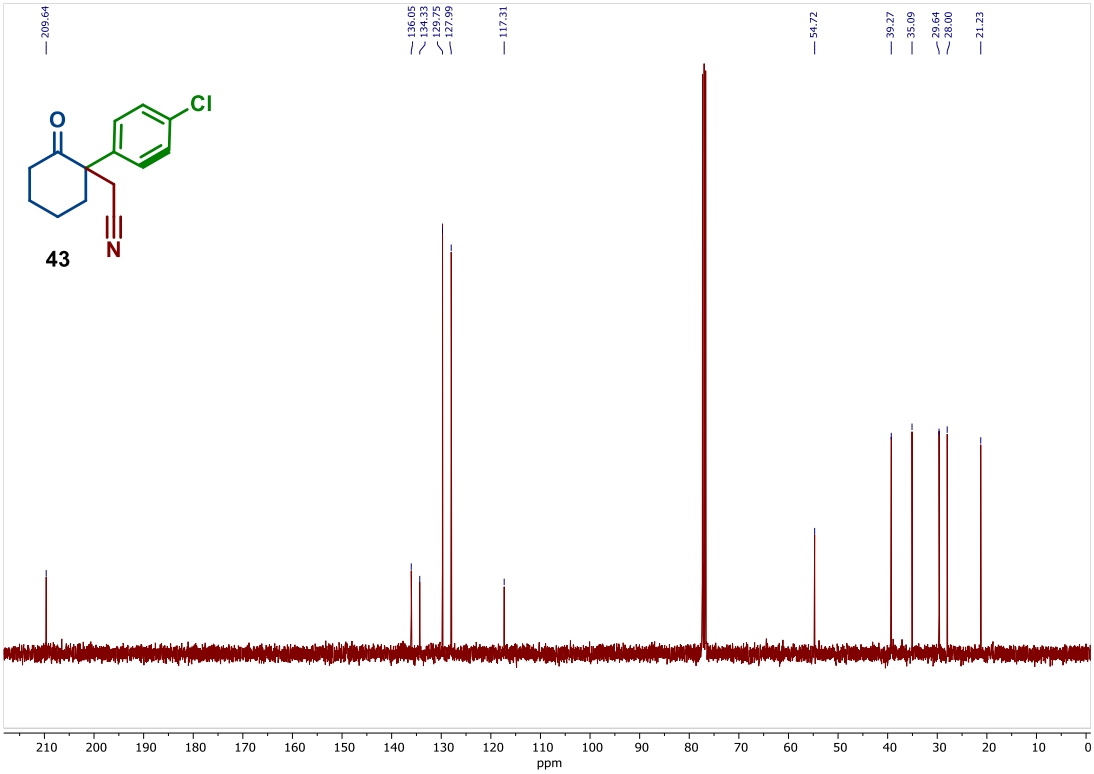
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **42**



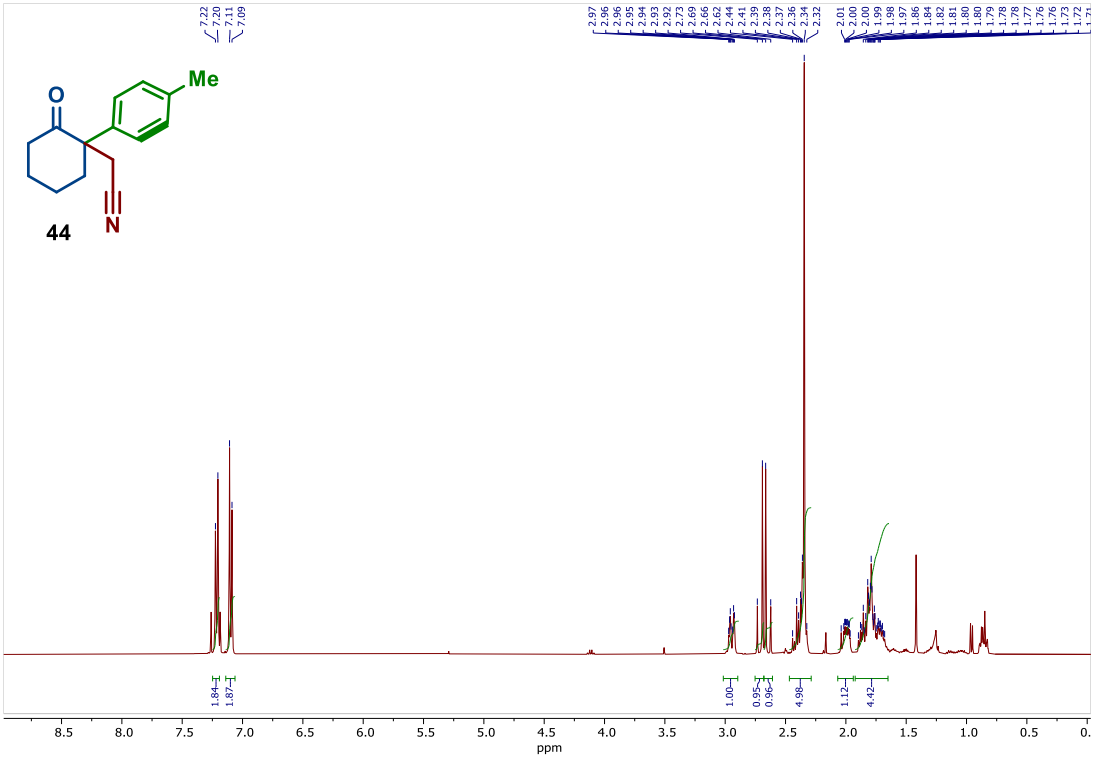
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **43** (*See Procedure*)



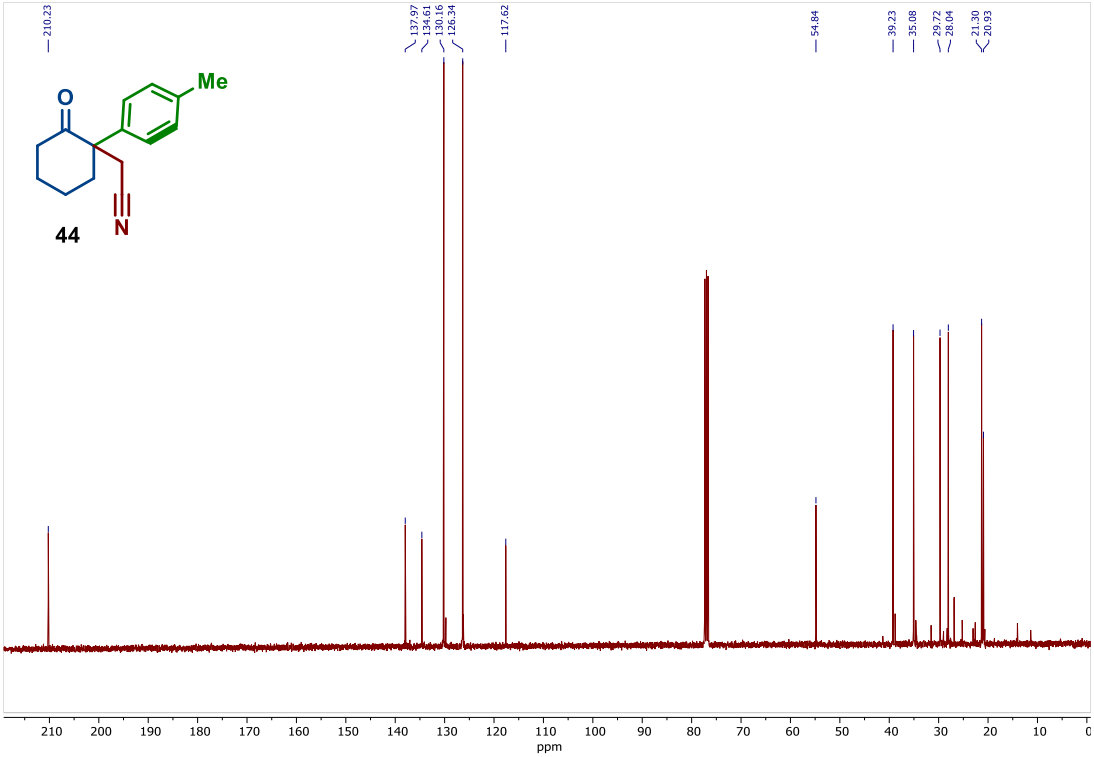
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **43**



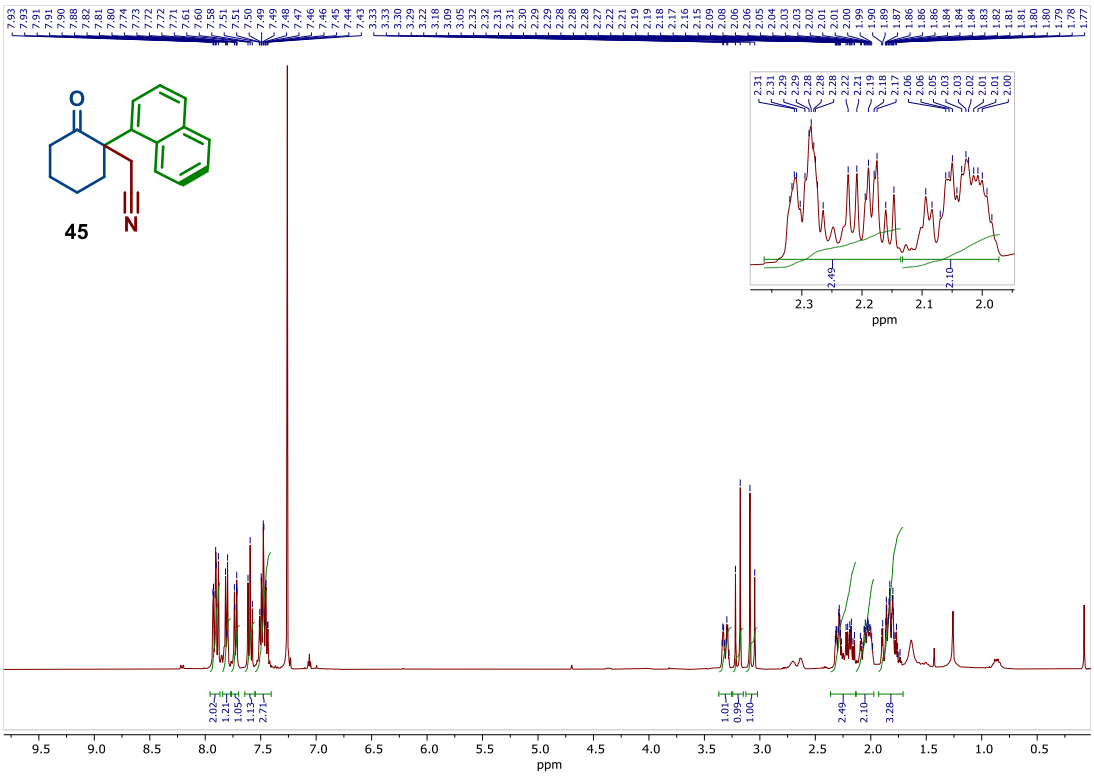
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **44** (*See Procedure*)



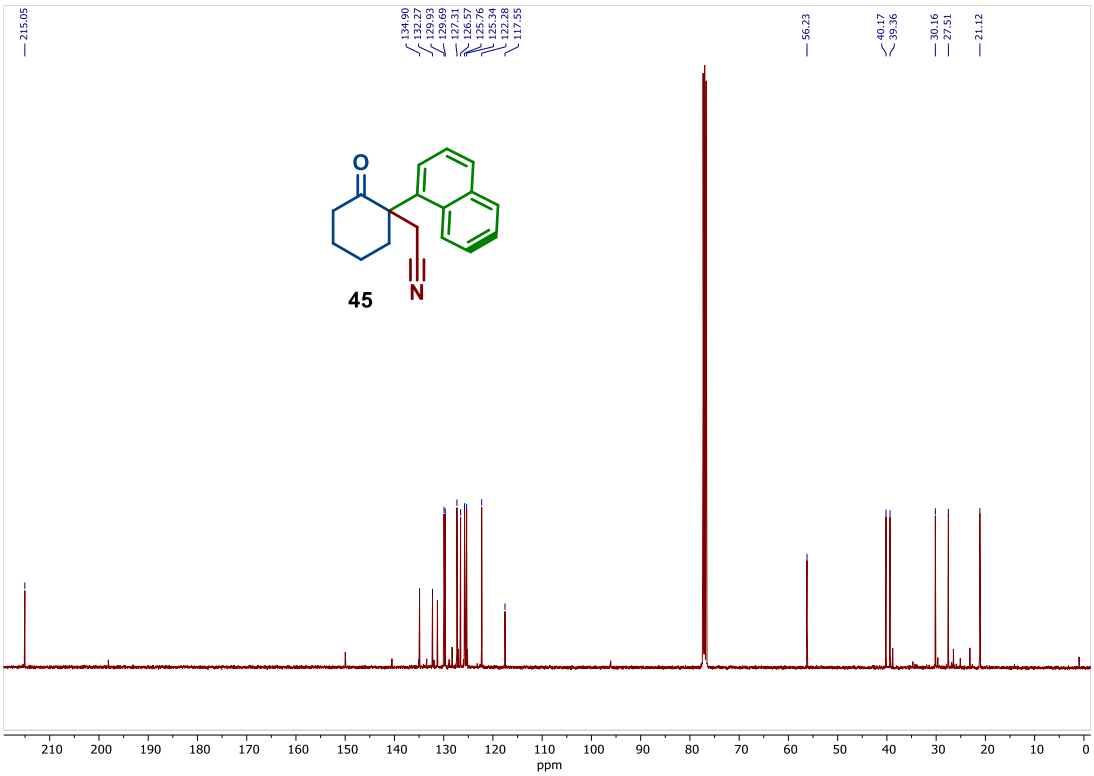
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **44**



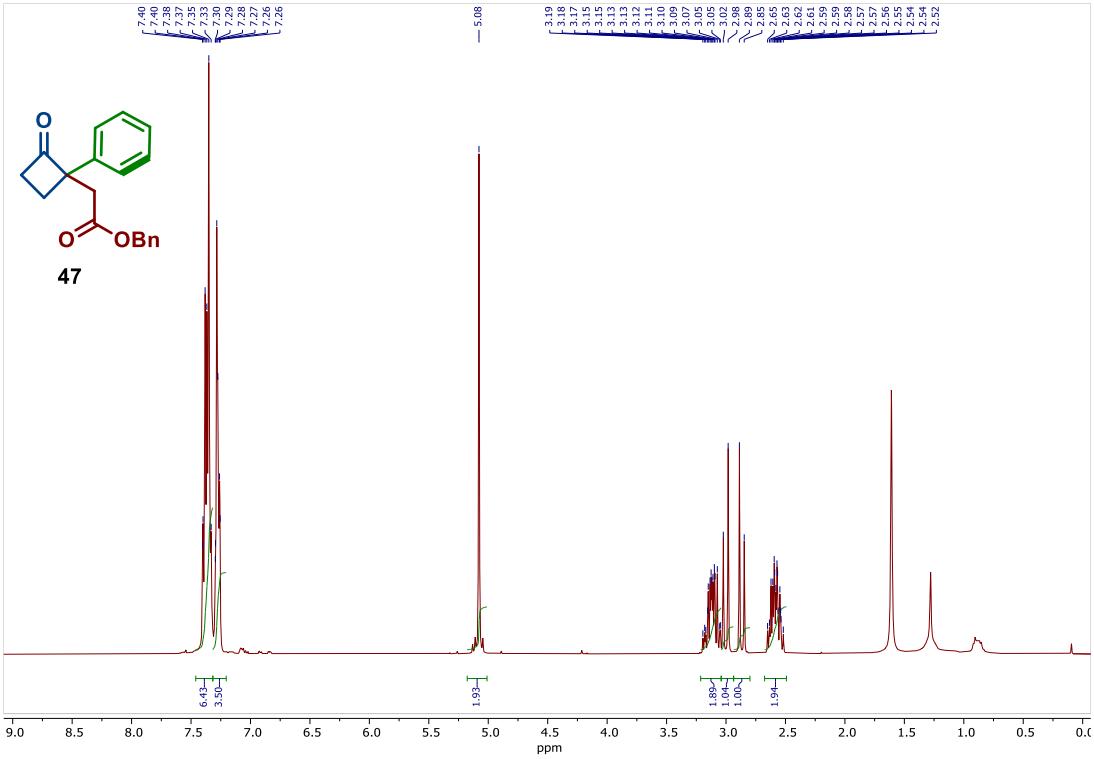
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **45** (*See Procedure*)



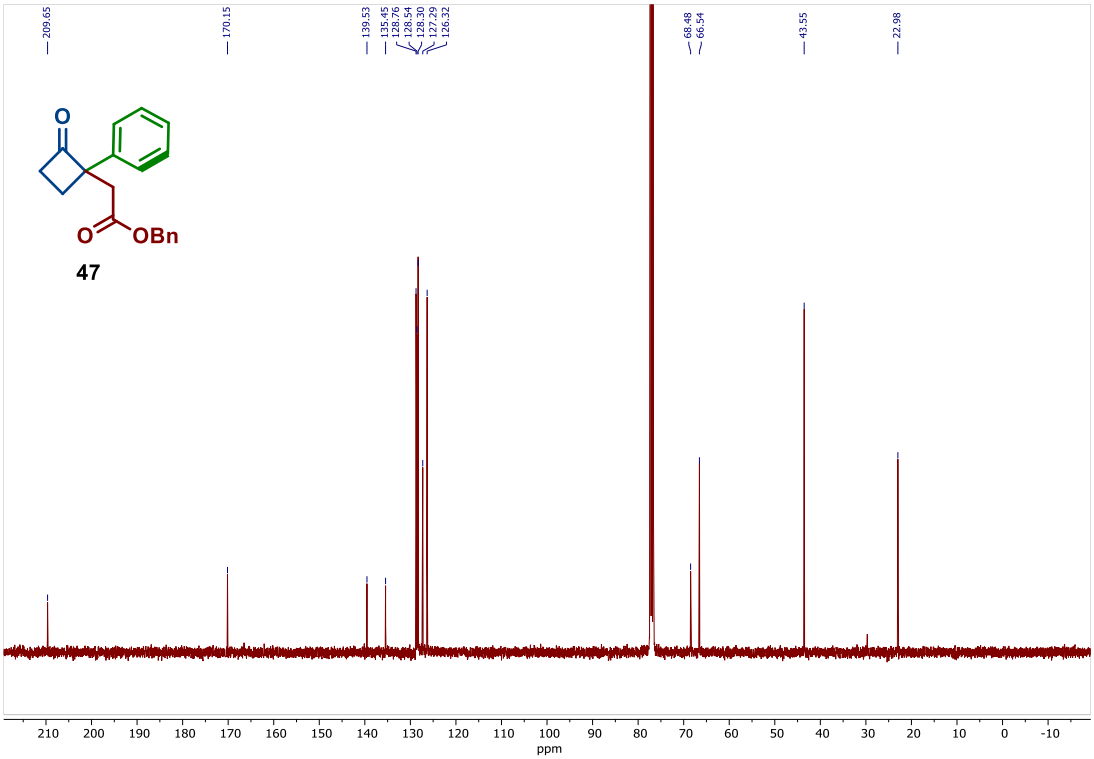
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **45**



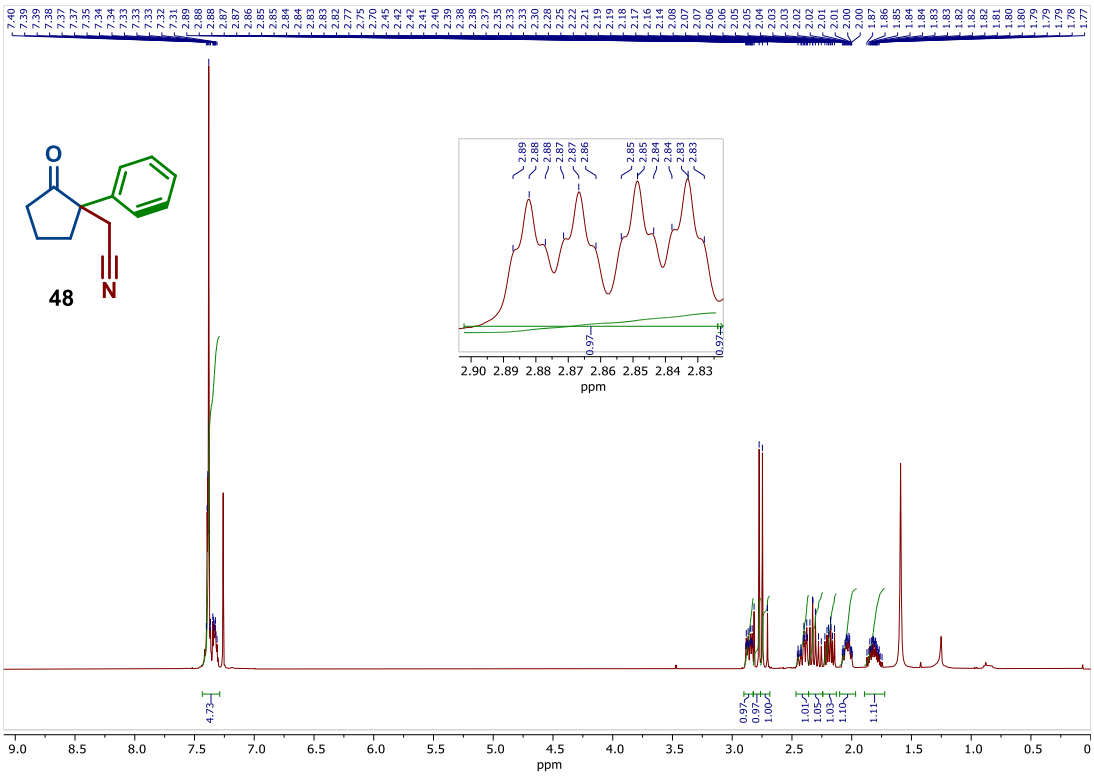
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **47** (*See Procedure*)



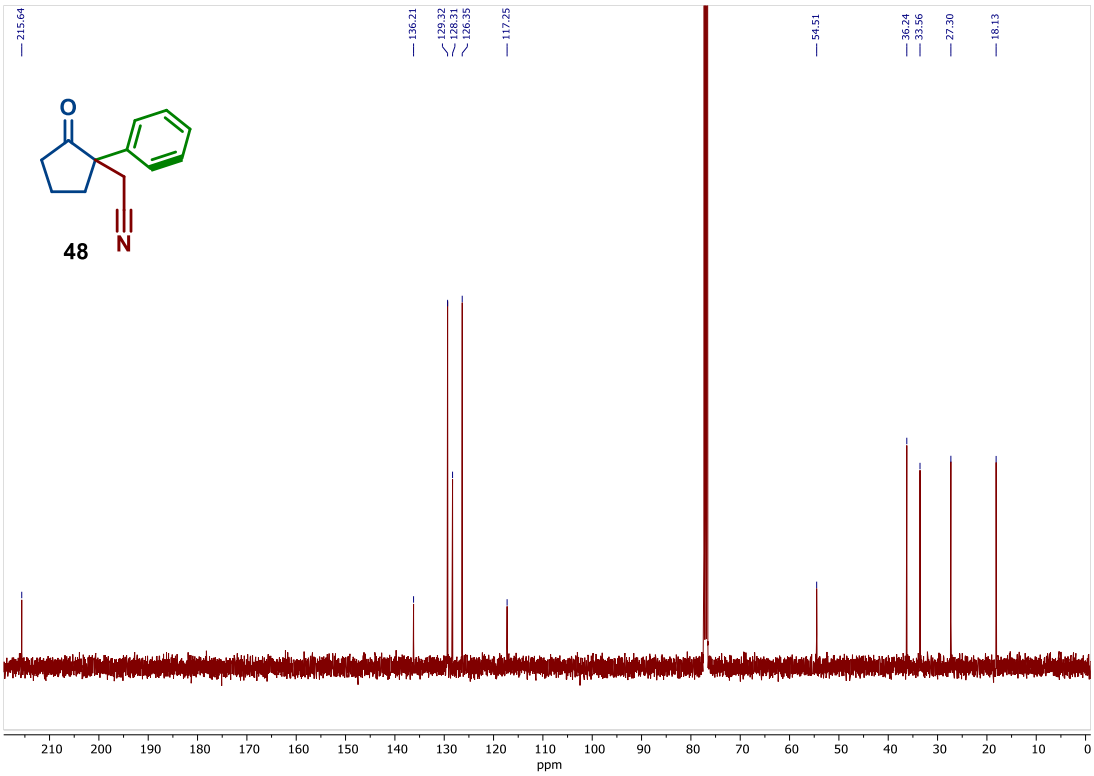
^{13}C NMR (400 MHz, $CDCl_3$) spectra of compound **47**



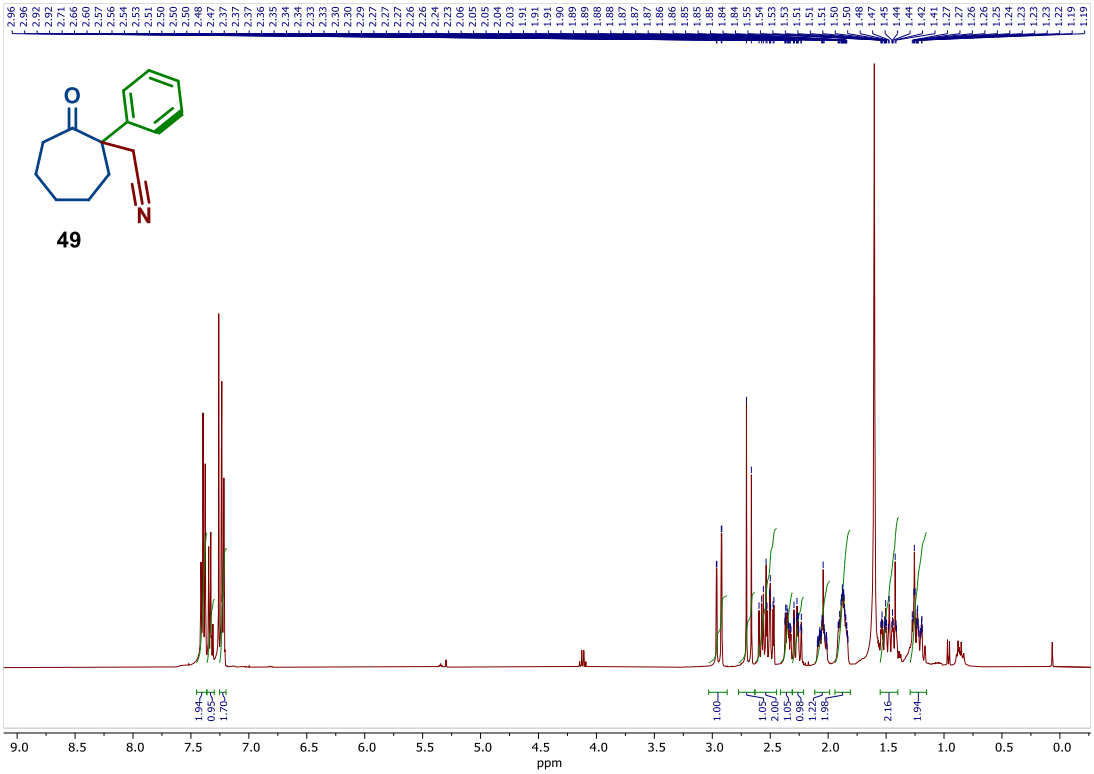
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **48** (*See Procedure*)



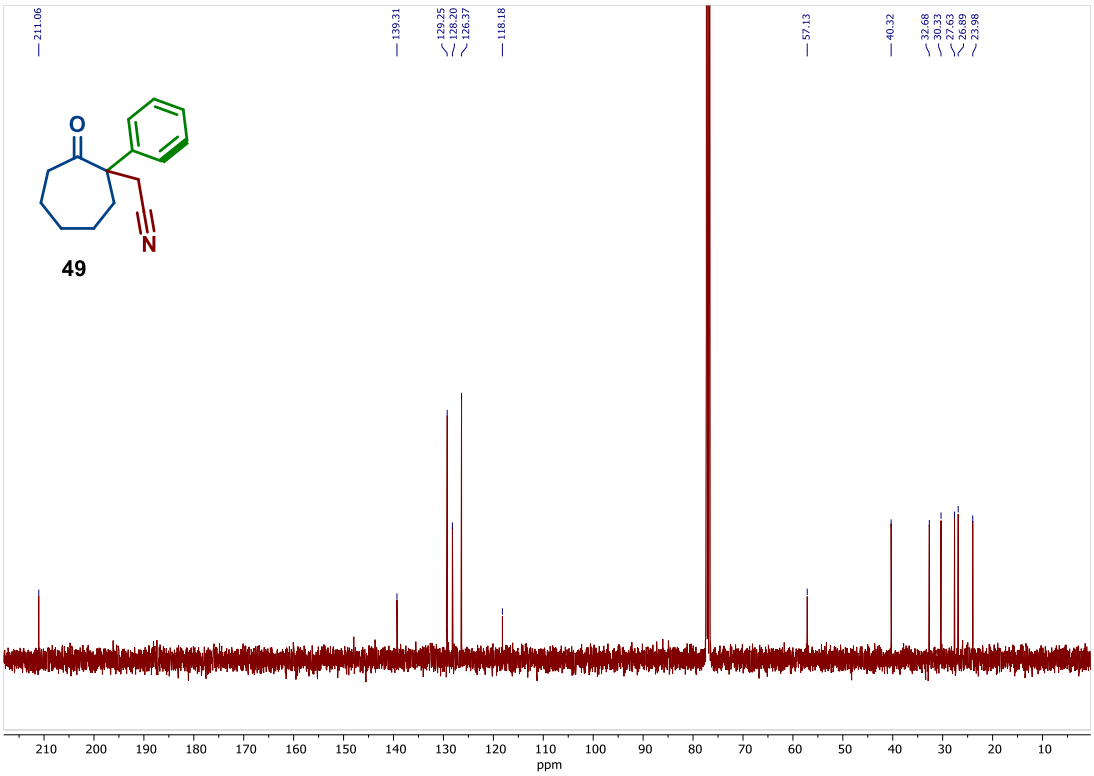
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **48**



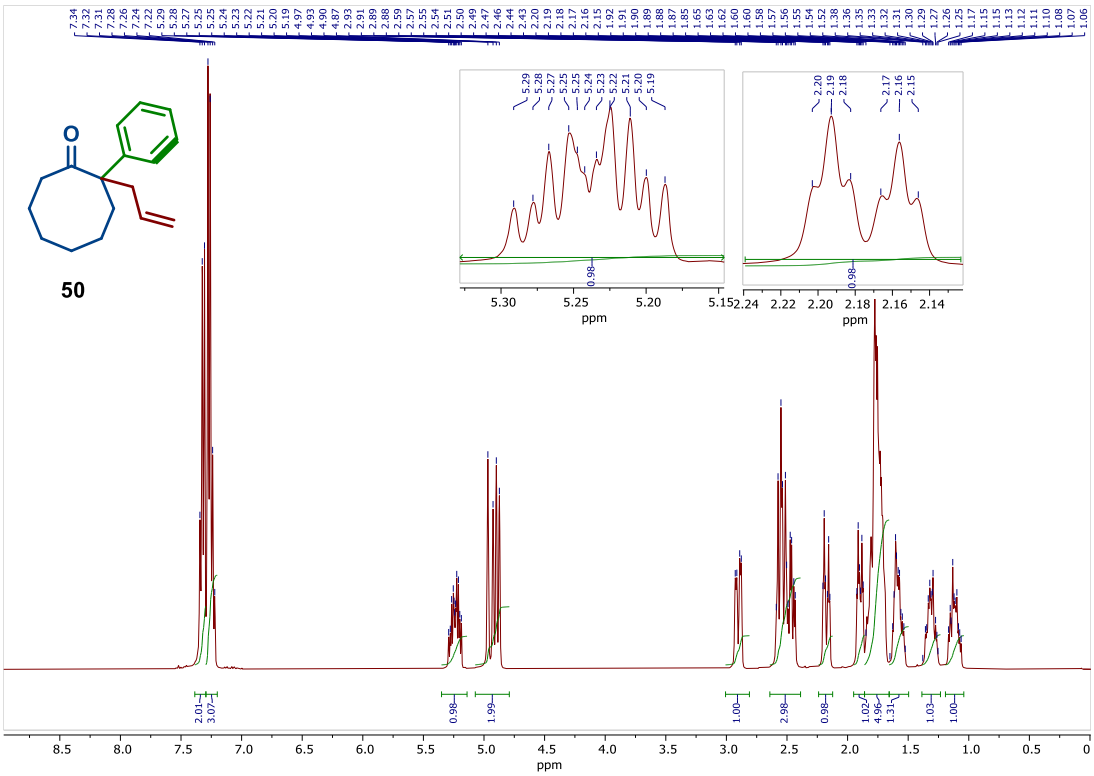
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **49** (*See Procedure*)



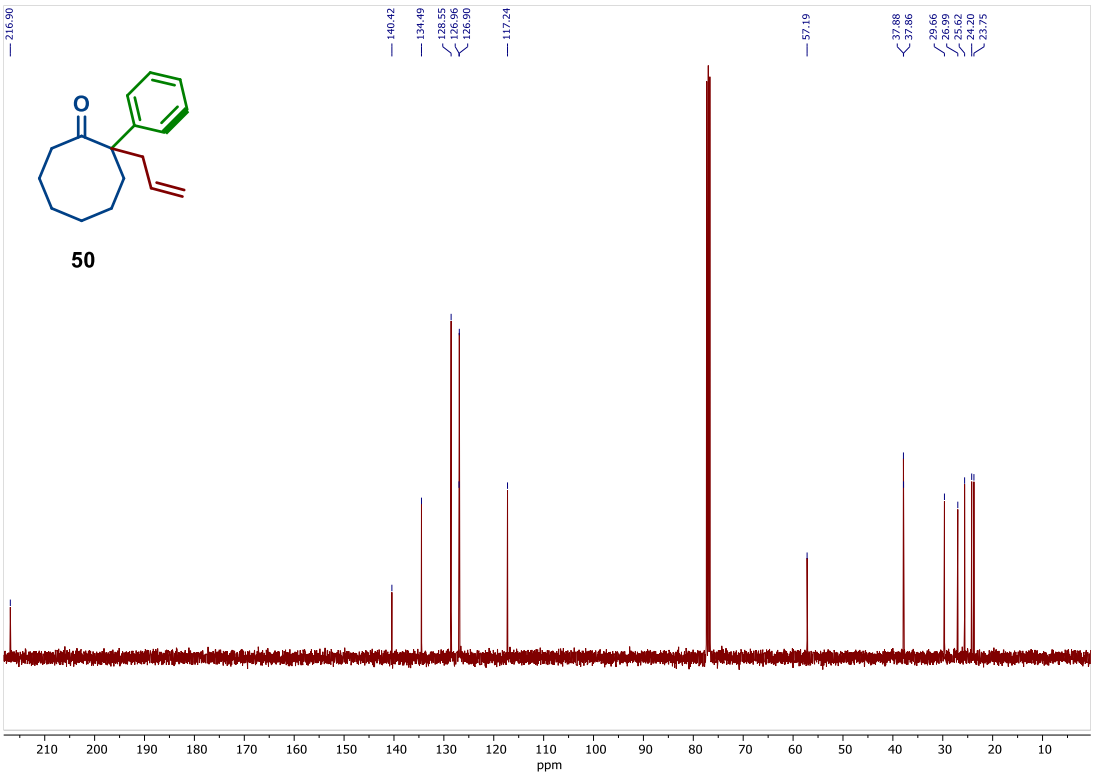
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **49**



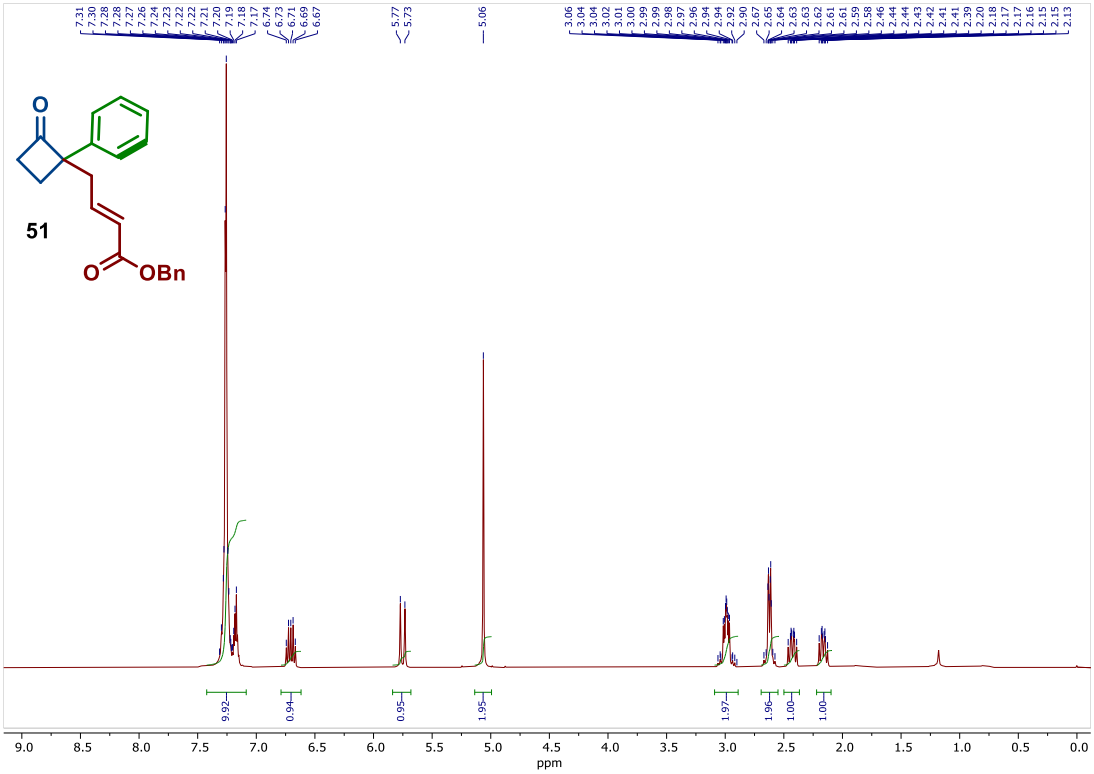
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **50** (*See Procedure*)



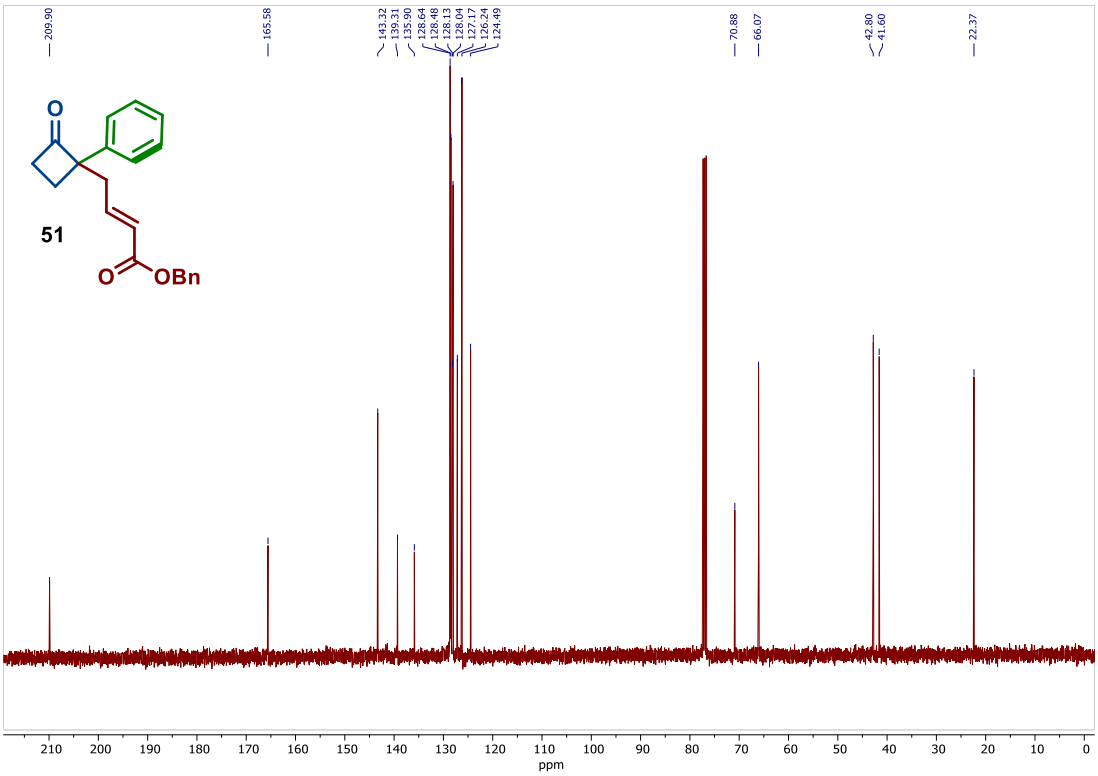
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **50**



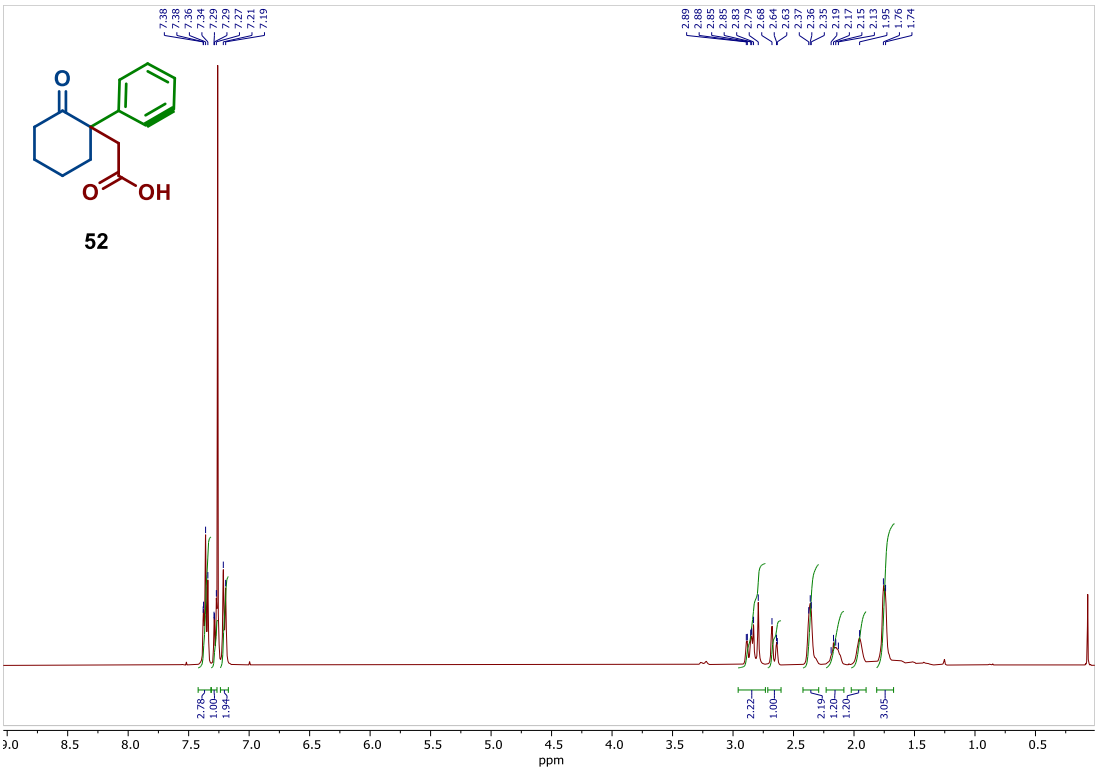
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **51** (*See Procedure*)



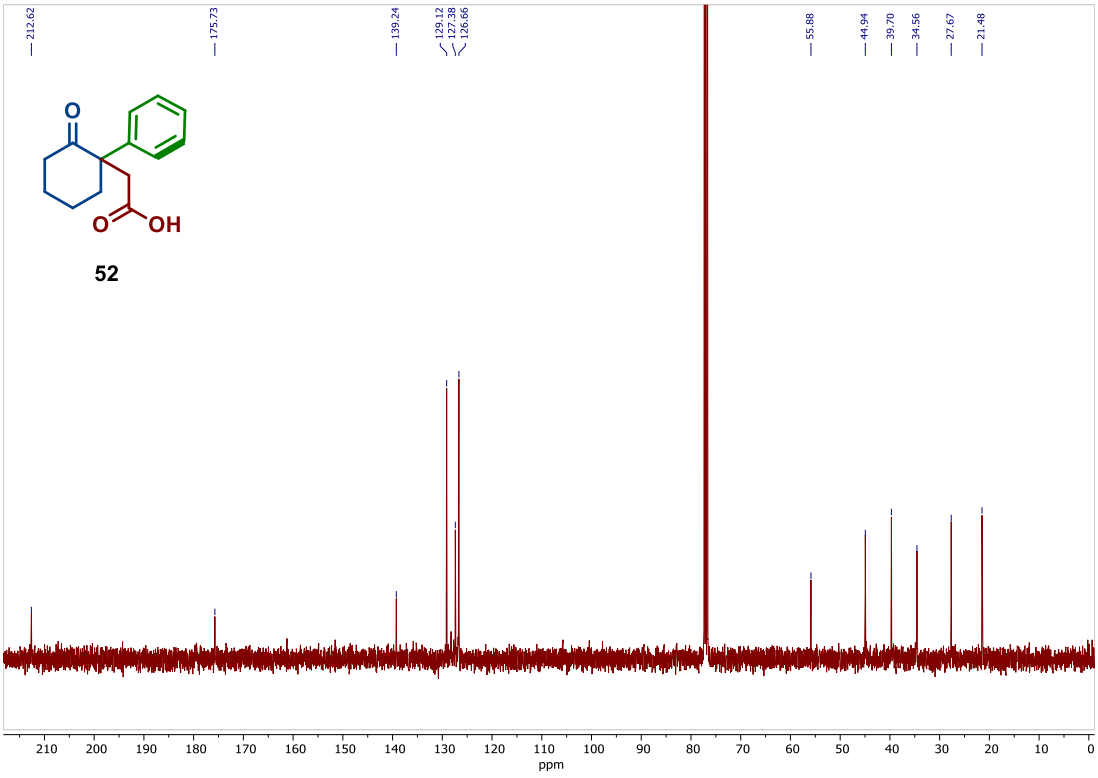
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **51**



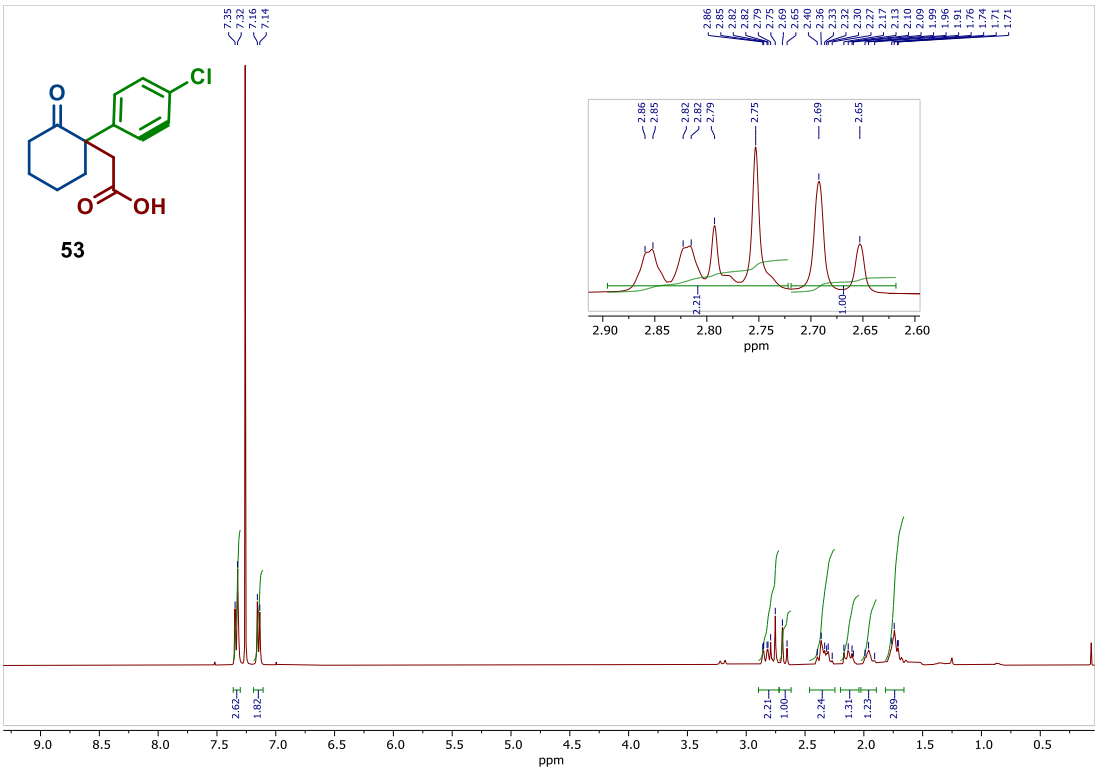
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **52** (*See Procedure*)



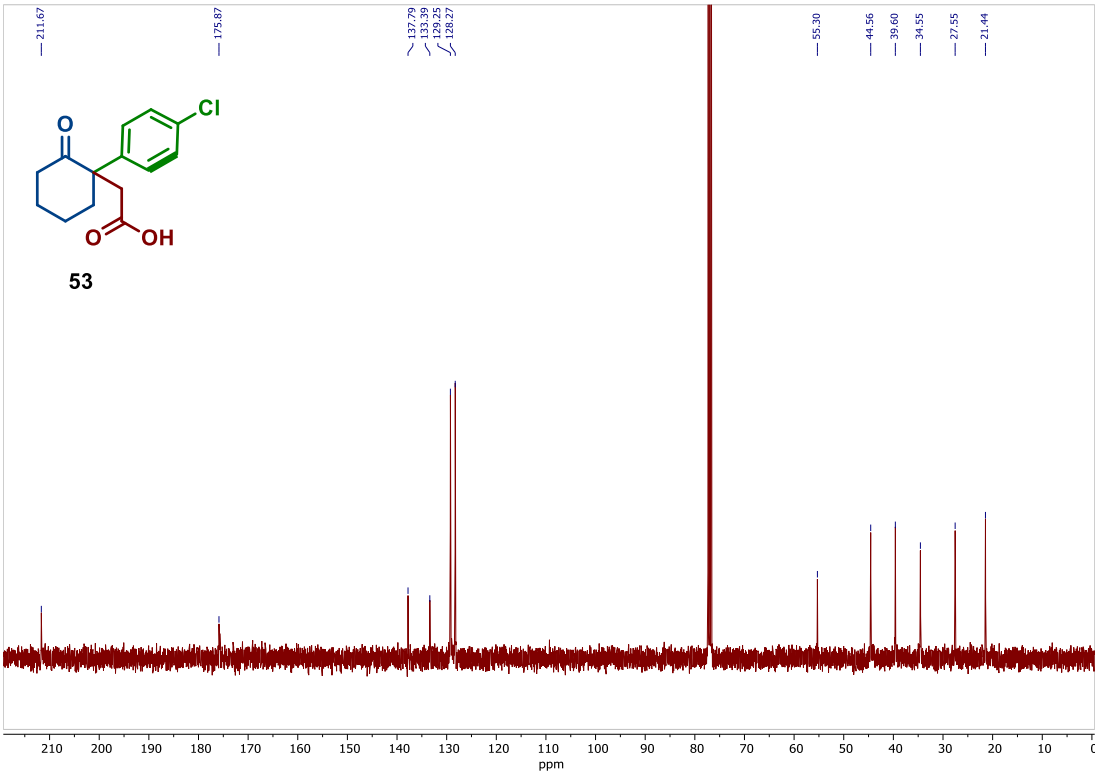
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **52**



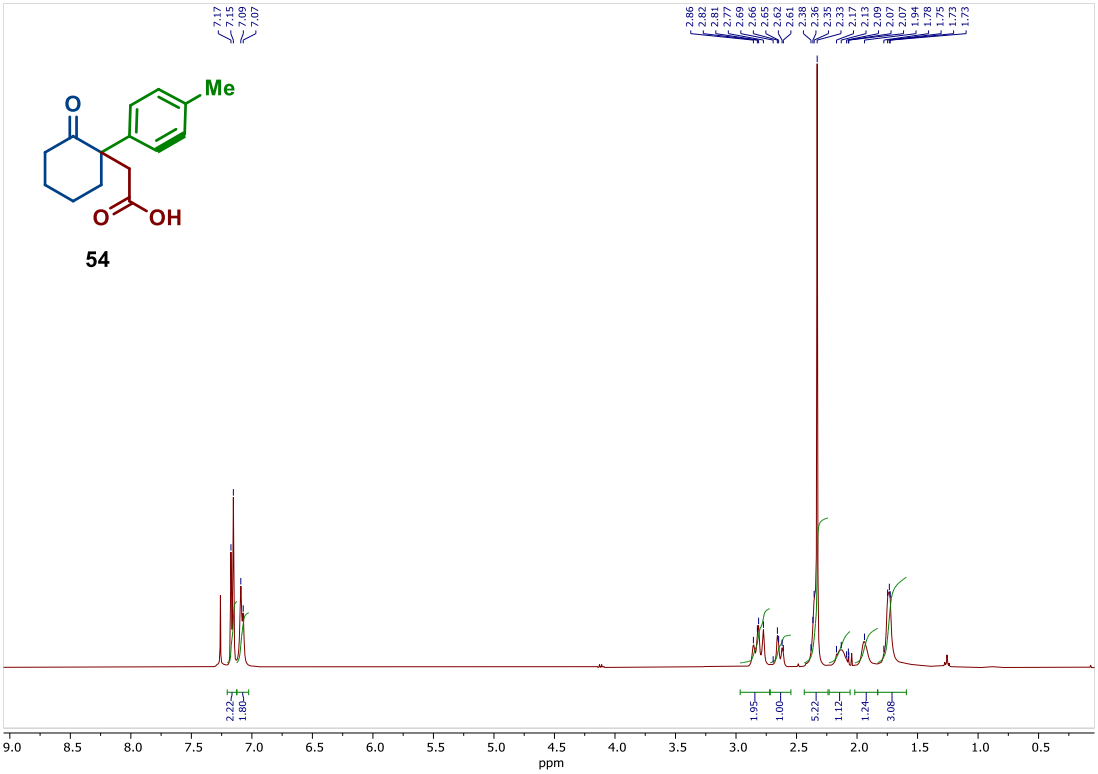
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **53** (*See Procedure*)



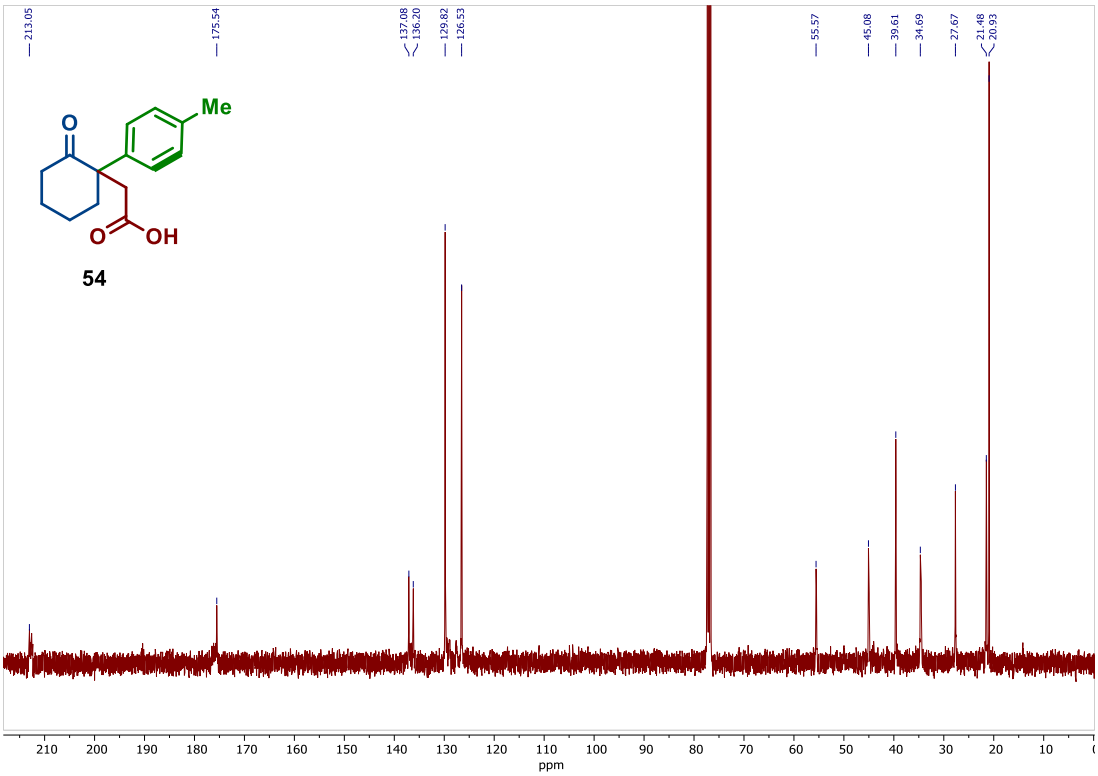
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **53**



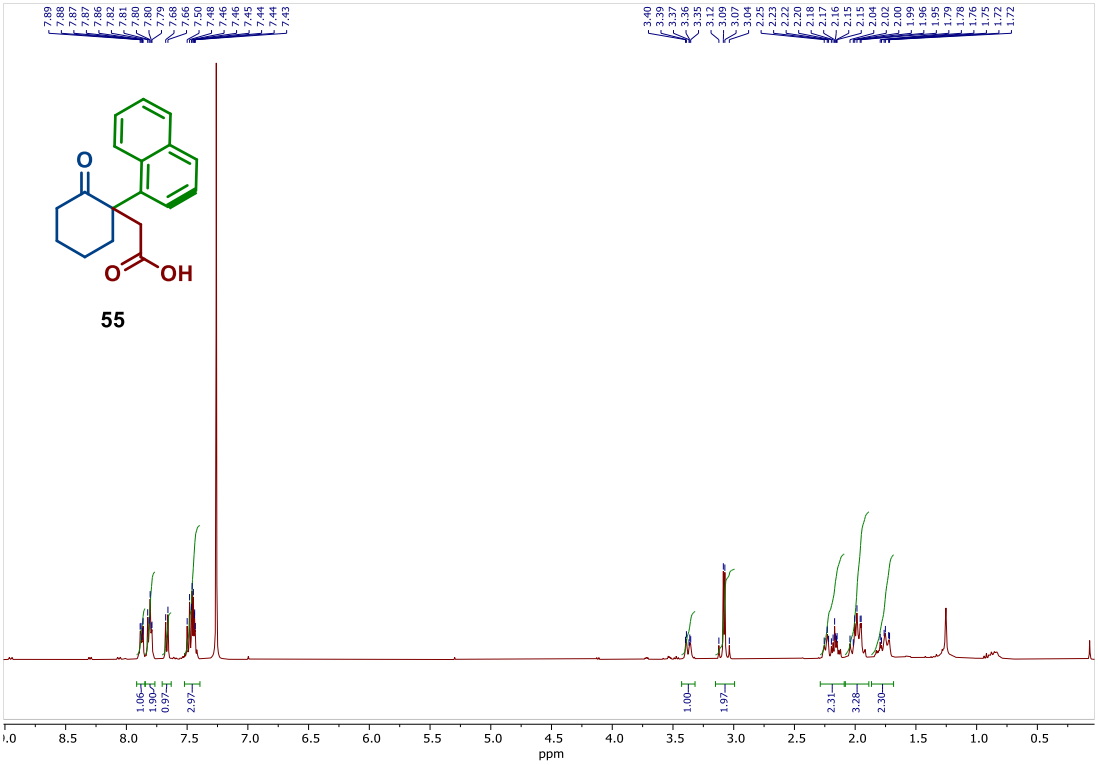
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **54** (*See Procedure*)



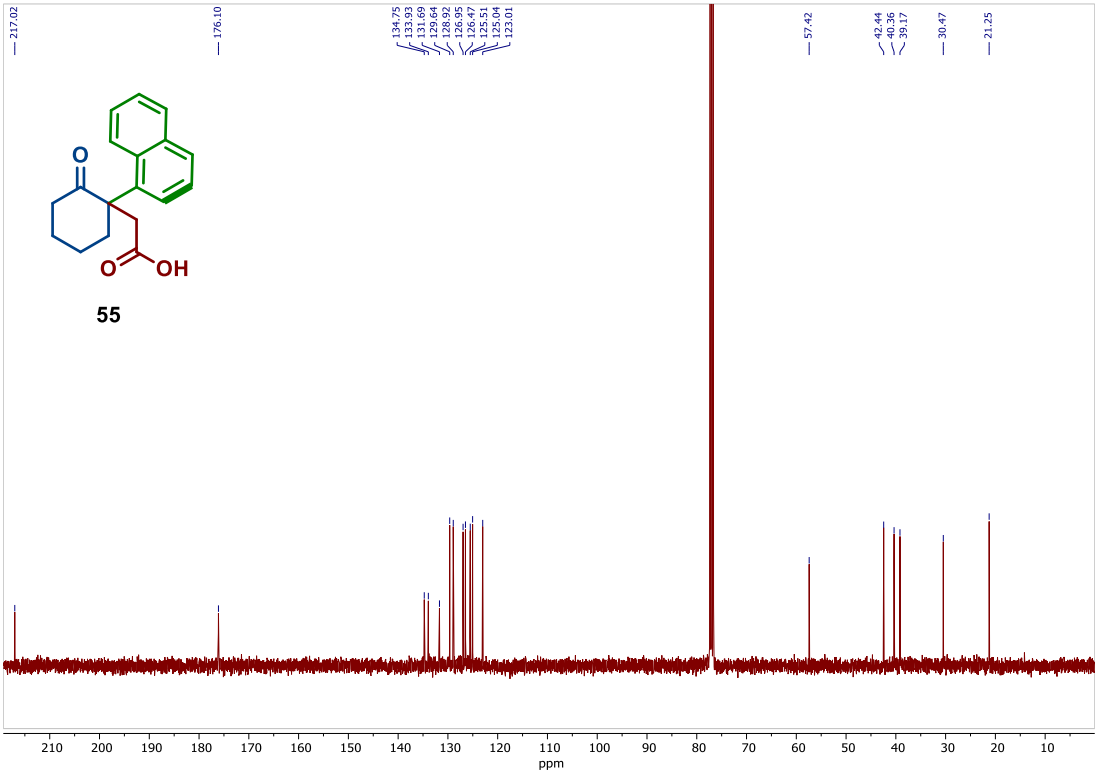
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **54**



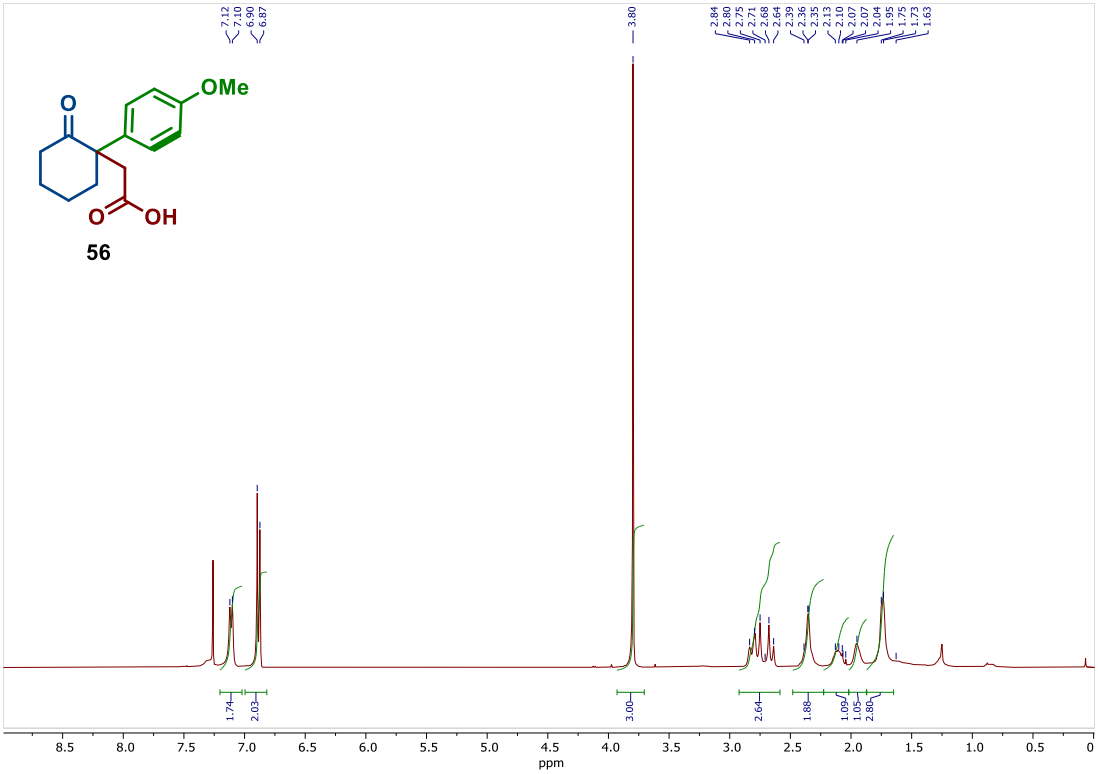
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **55** (*See Procedure*)



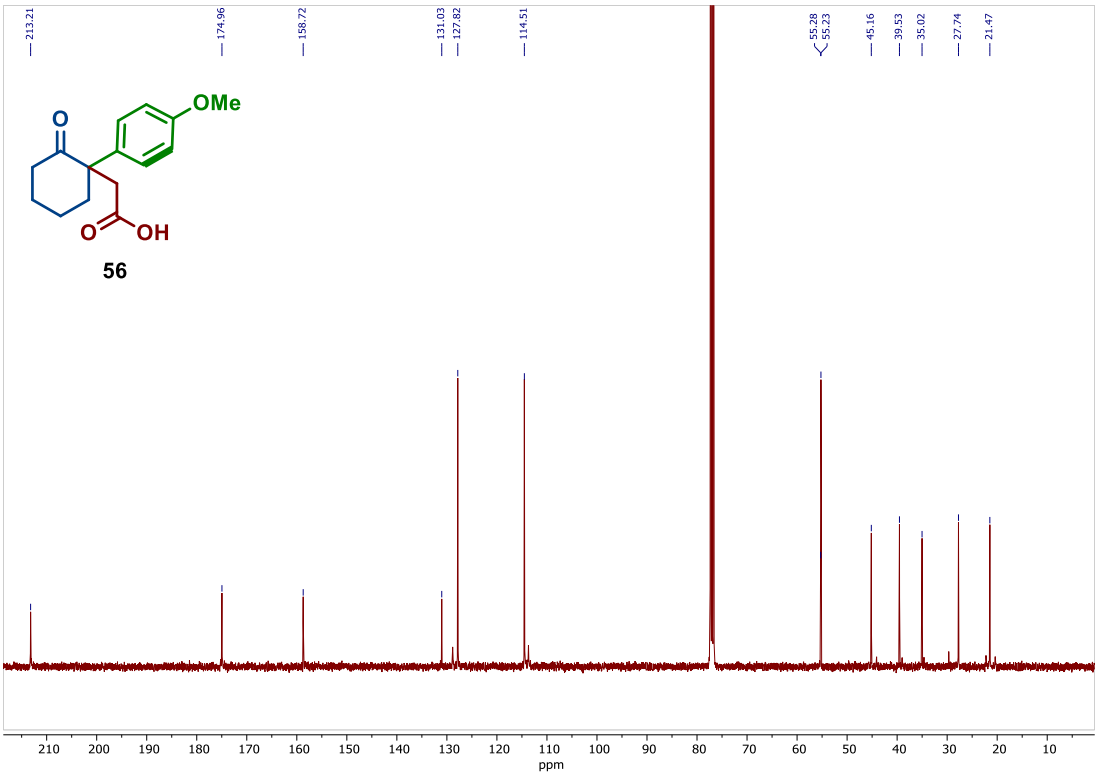
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **55**



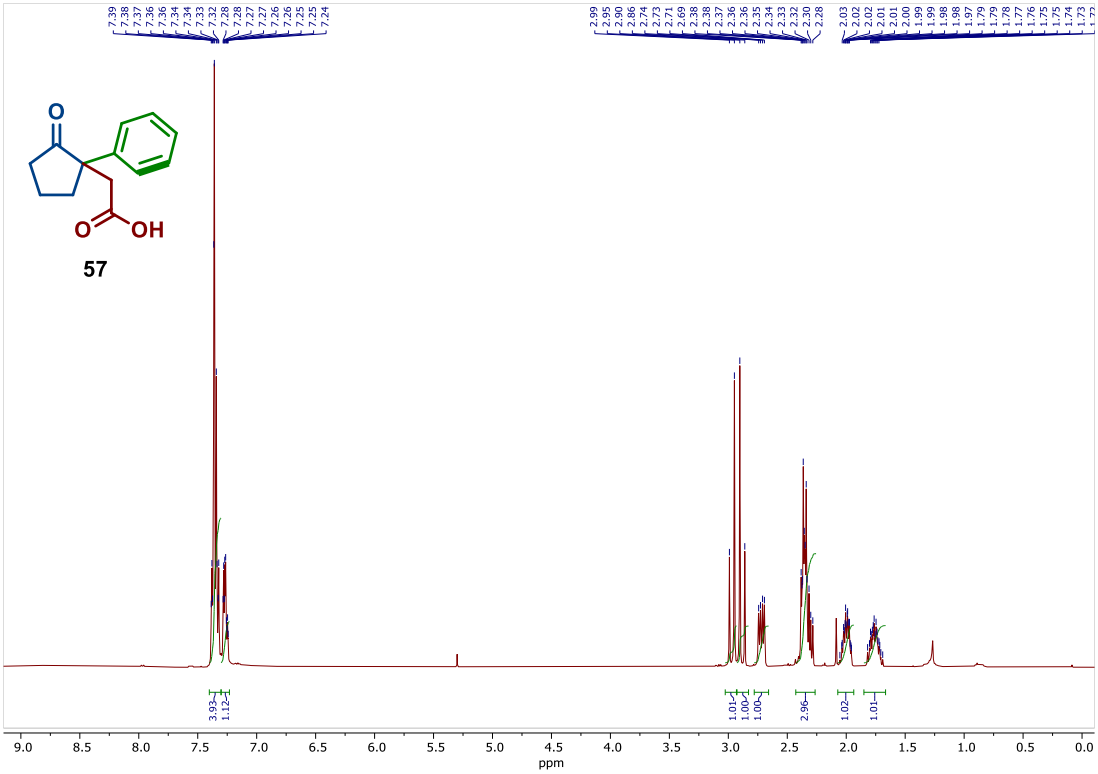
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **56** (*See Procedure*)



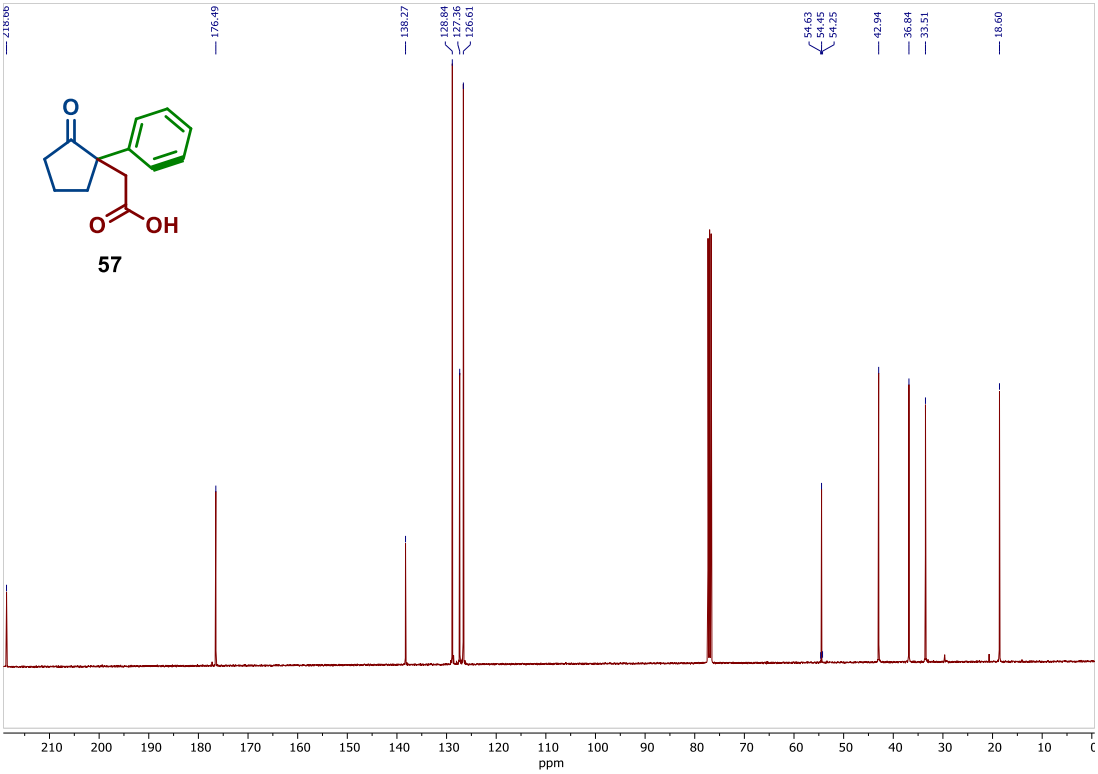
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **56**



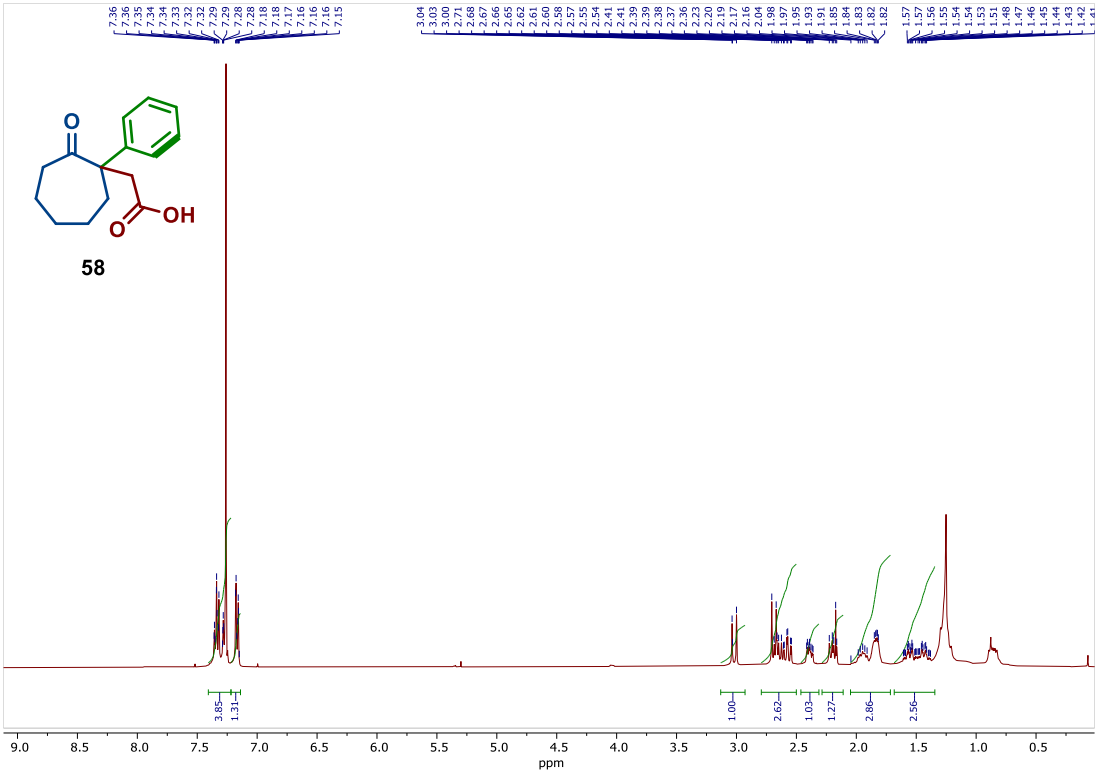
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **57** (*See Procedure*)



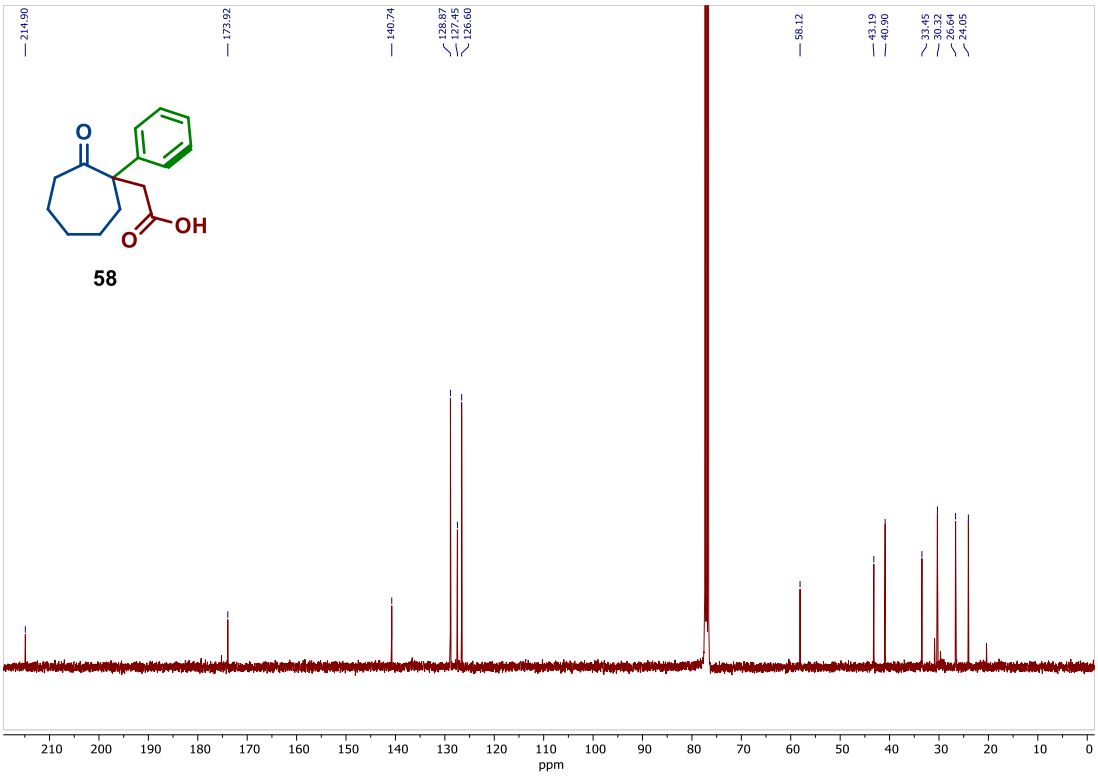
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **57**



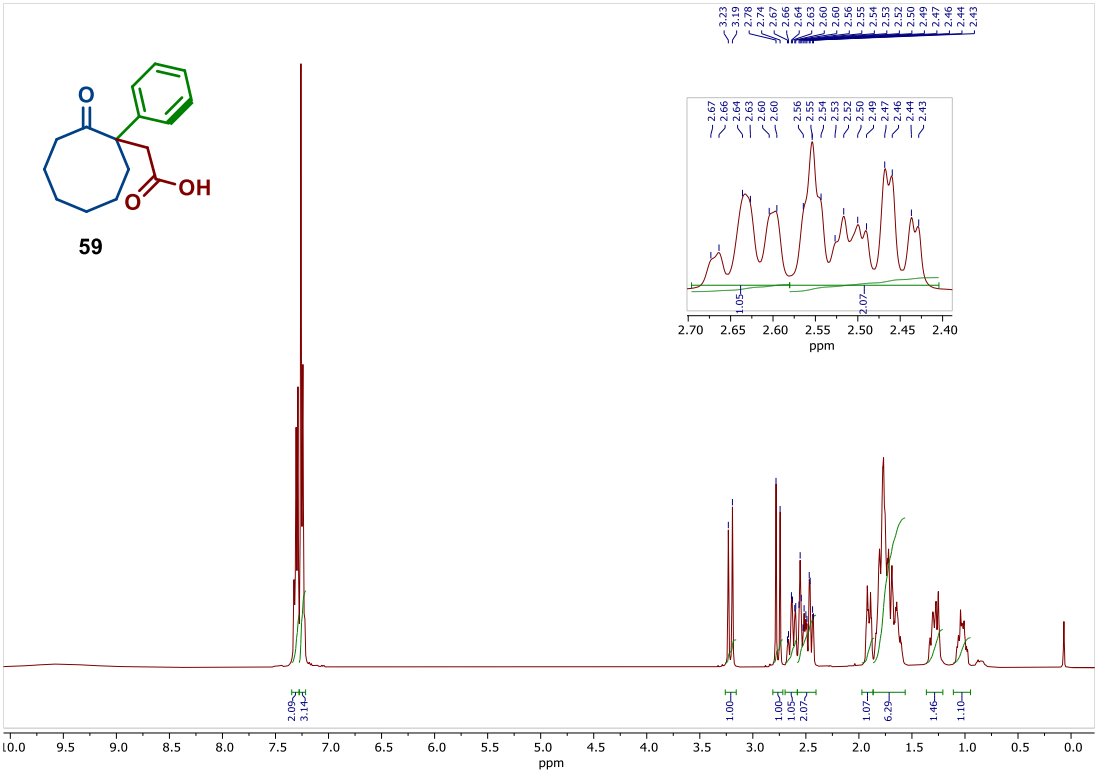
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **58** (*See Procedure*)



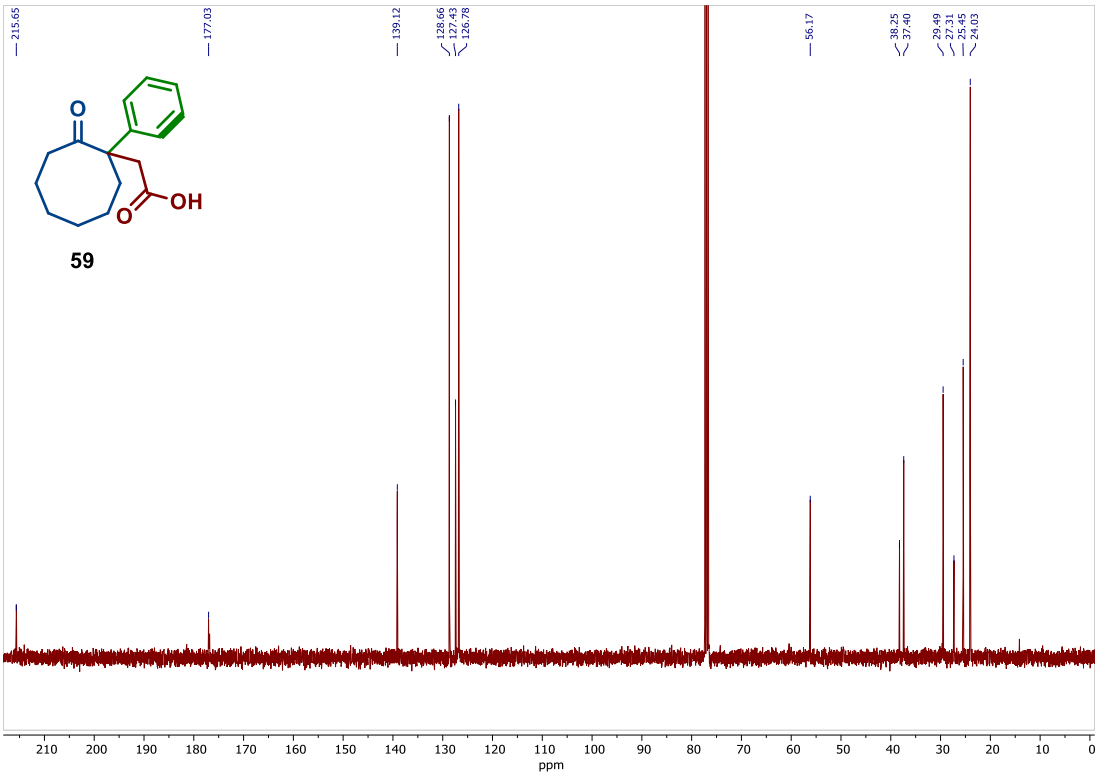
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **58**



^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **59** (*See Procedure*)



^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **59**



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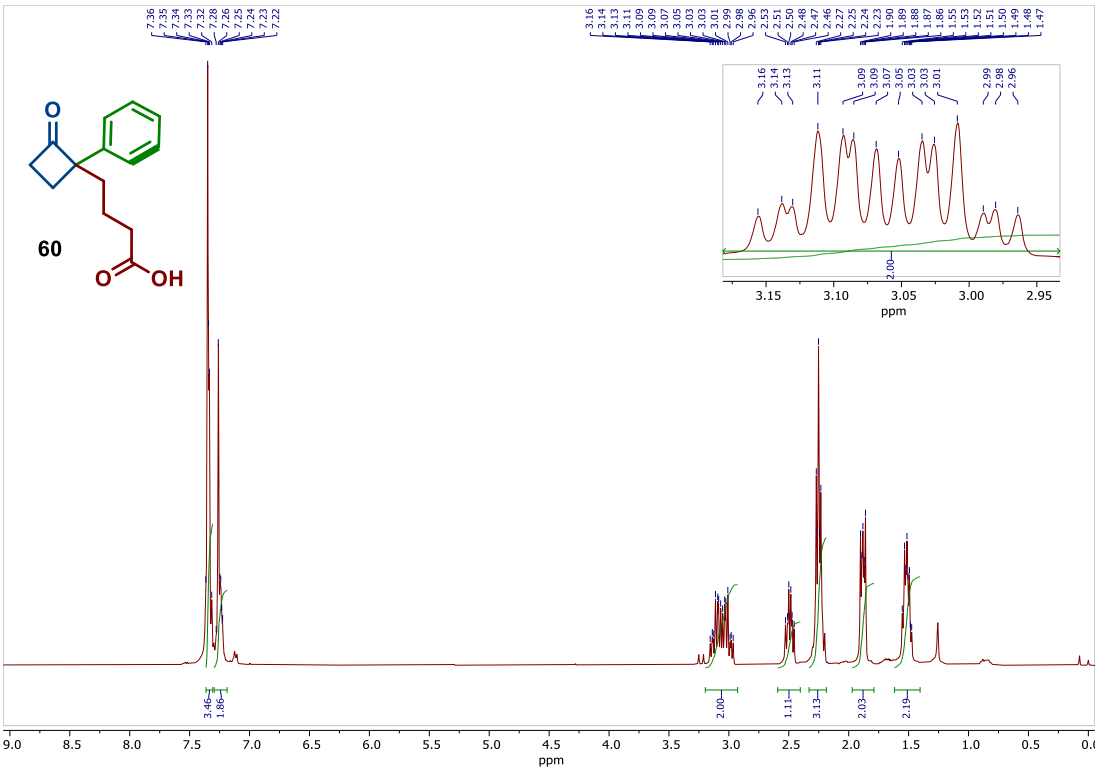
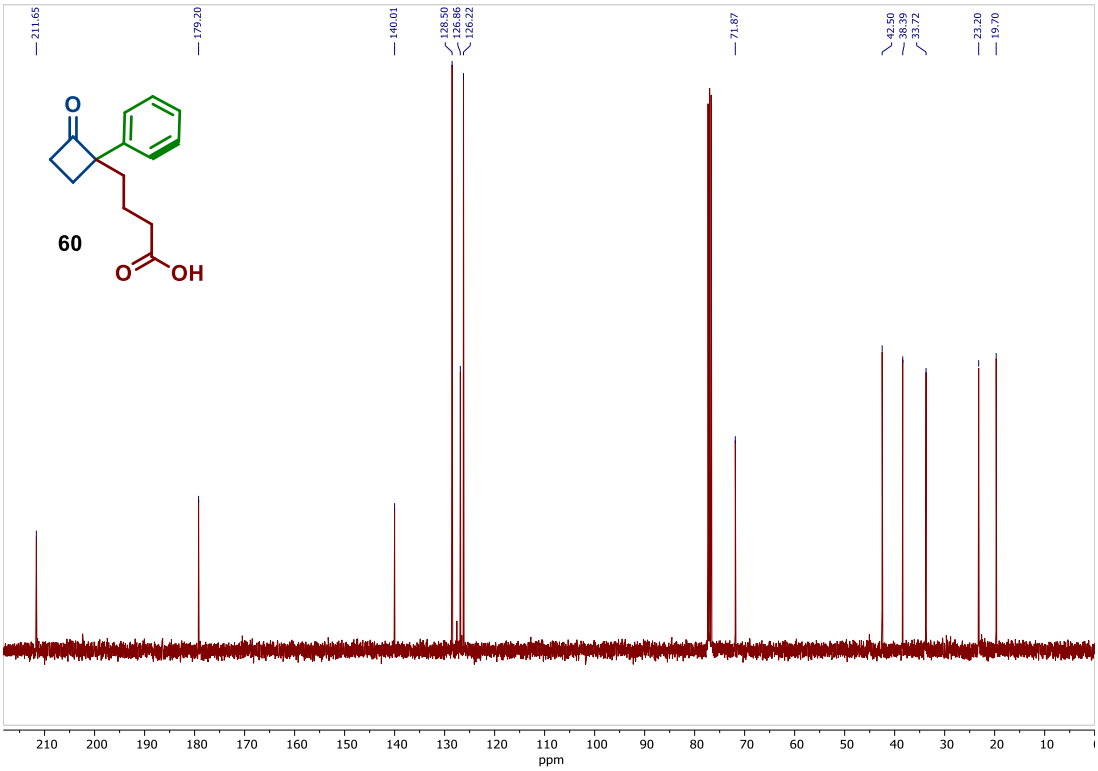
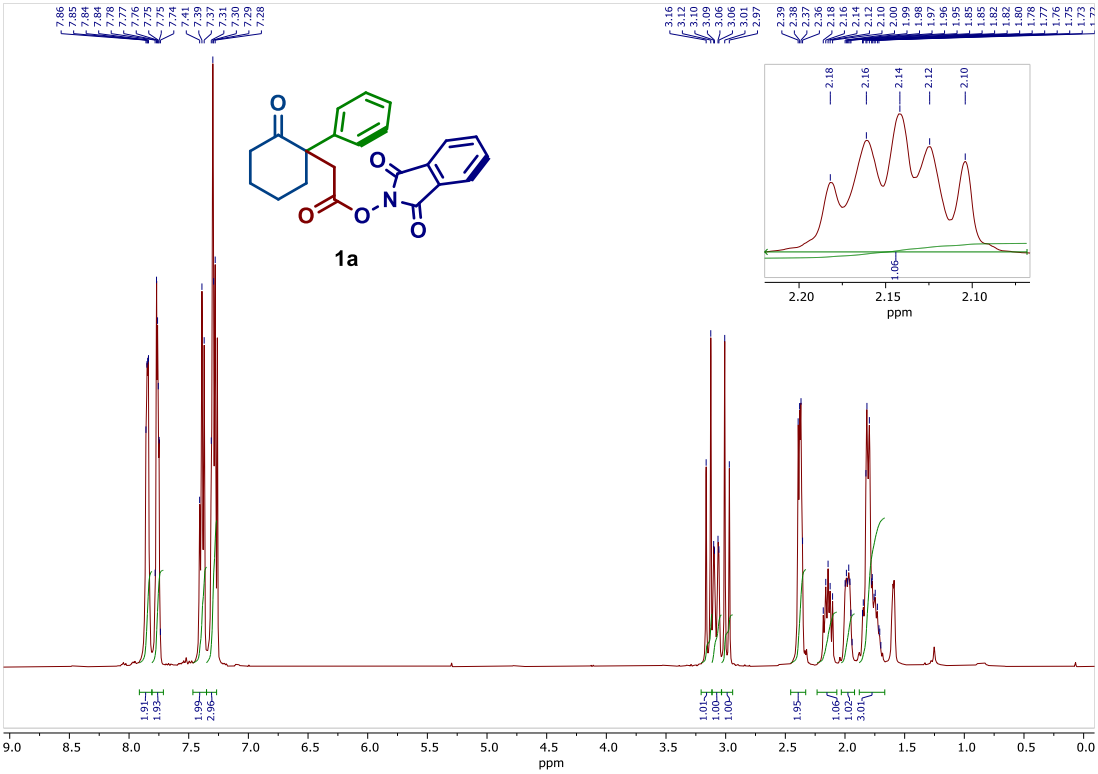


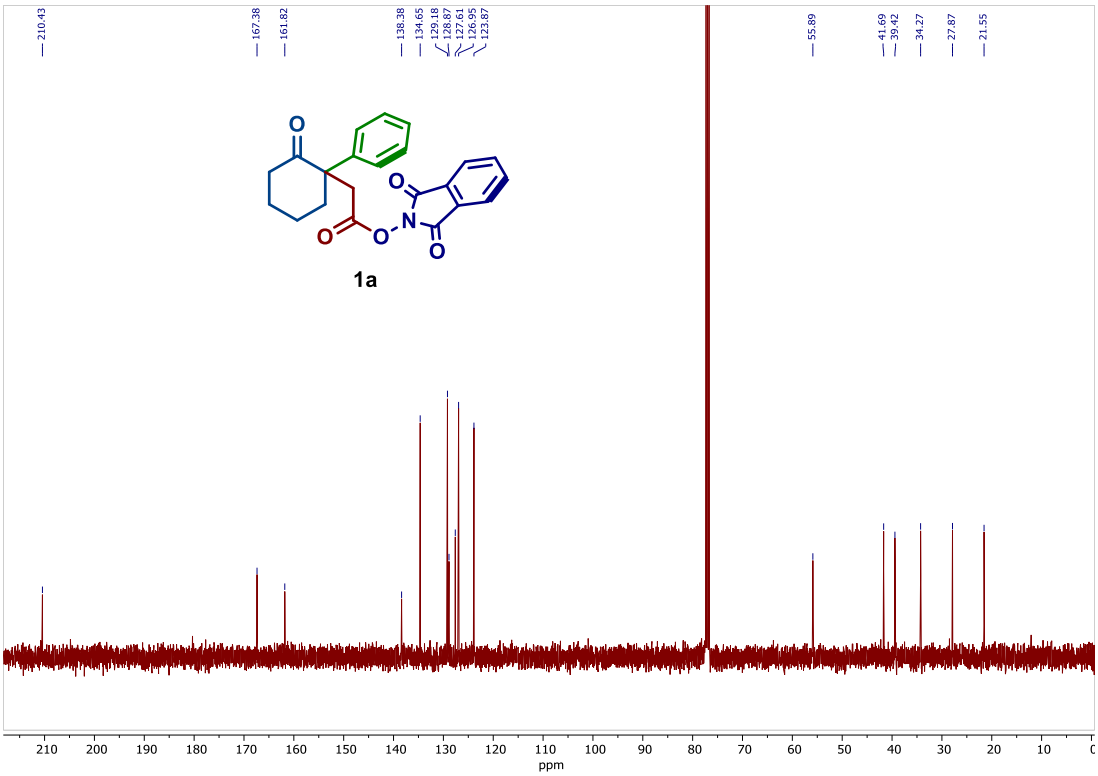
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **60**



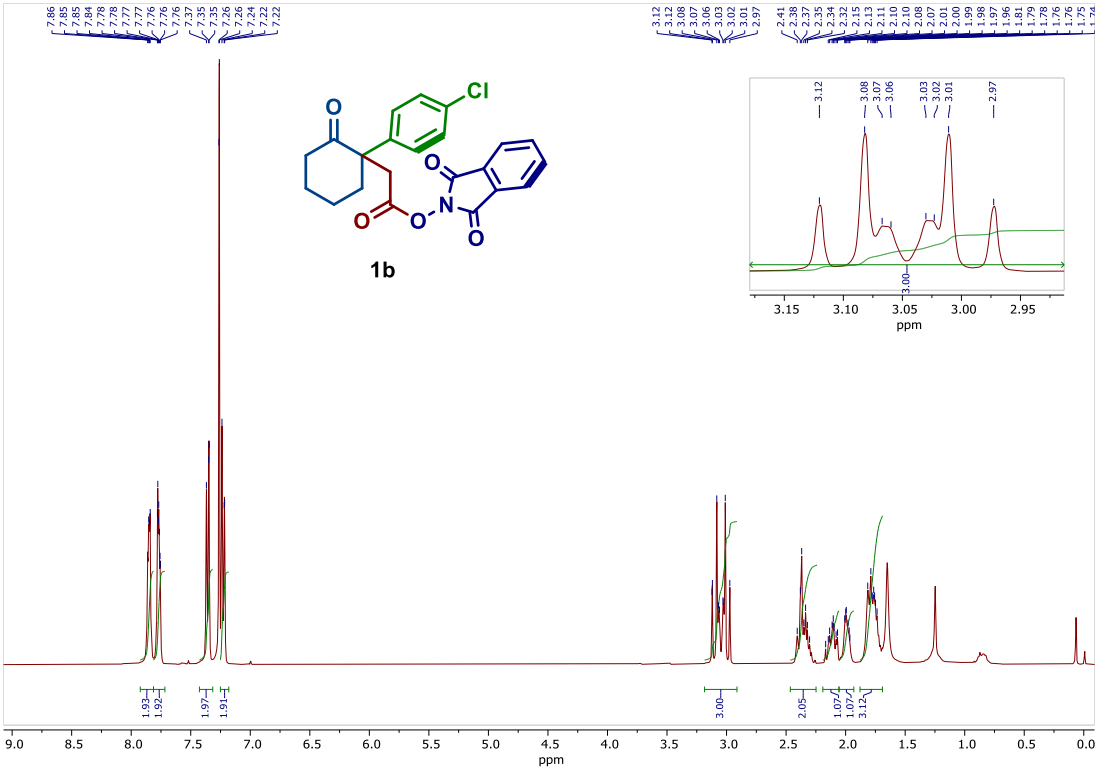
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1a** (*See Procedure*)



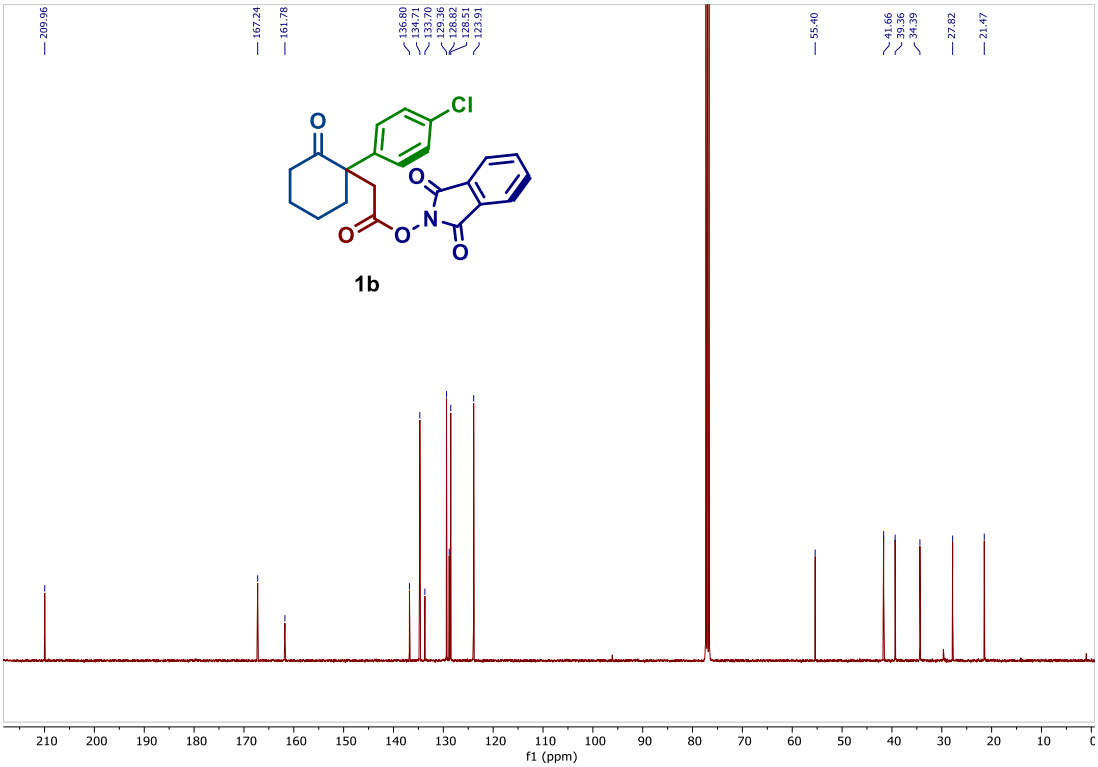
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1a**



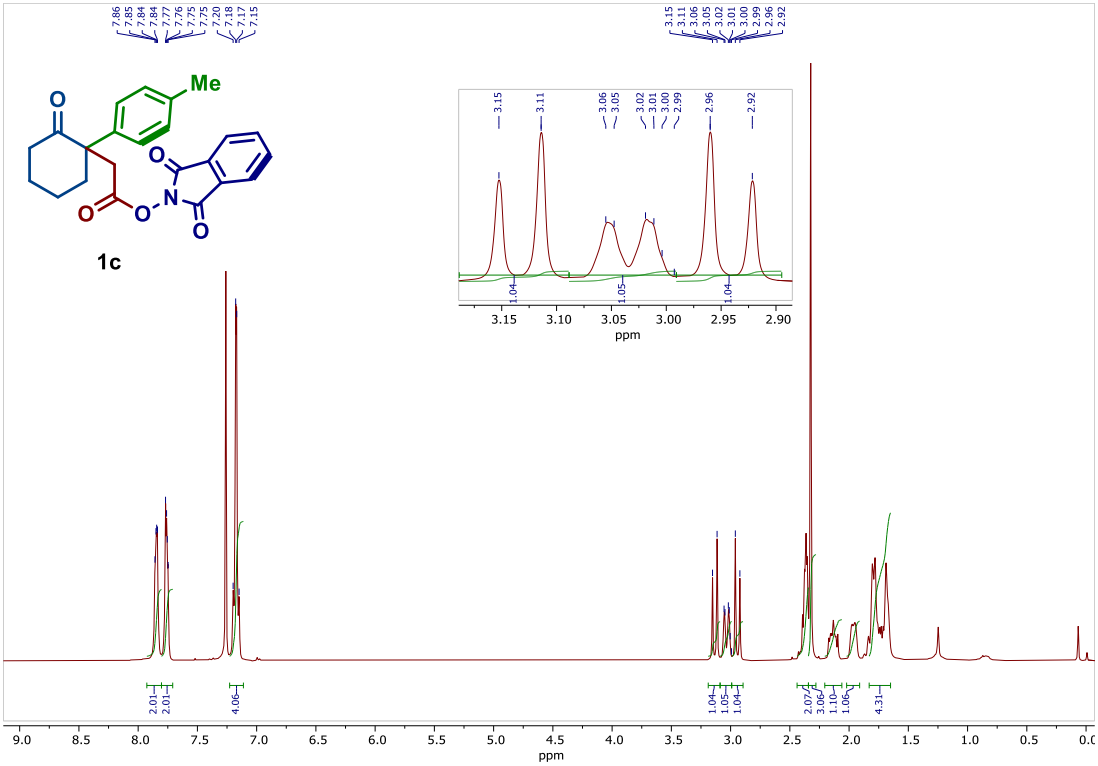
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1b** (*See Procedure*)



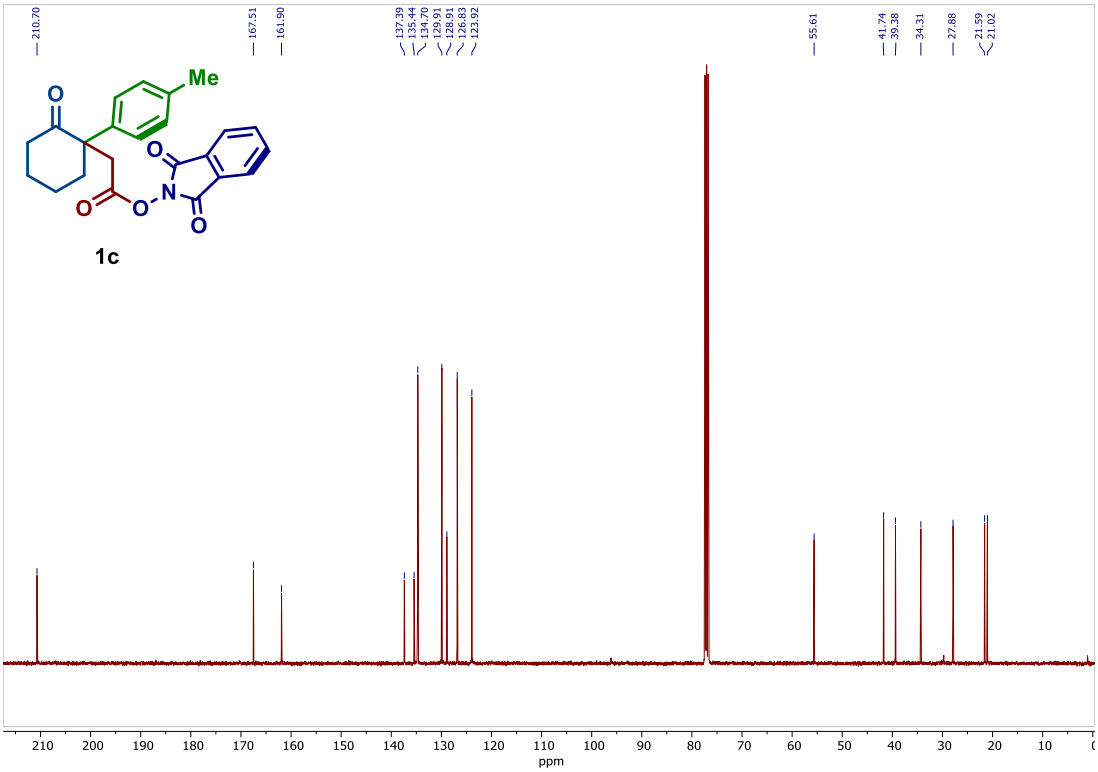
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1b**



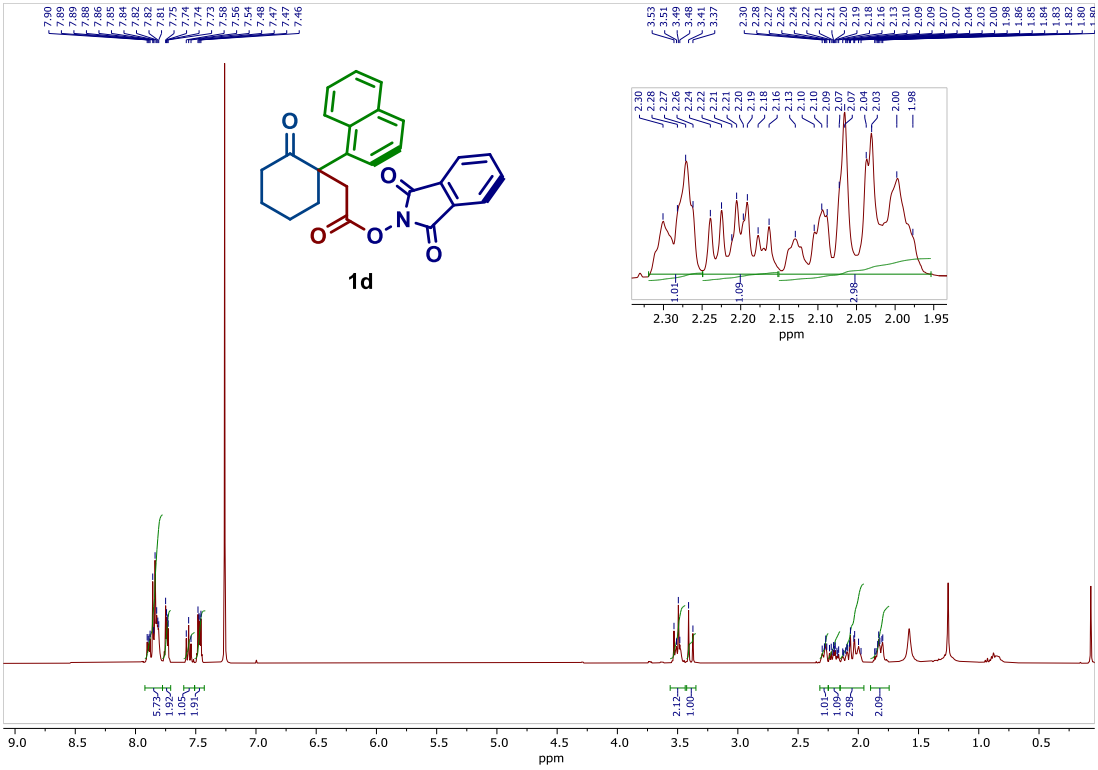
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1c** (*See Procedure*)



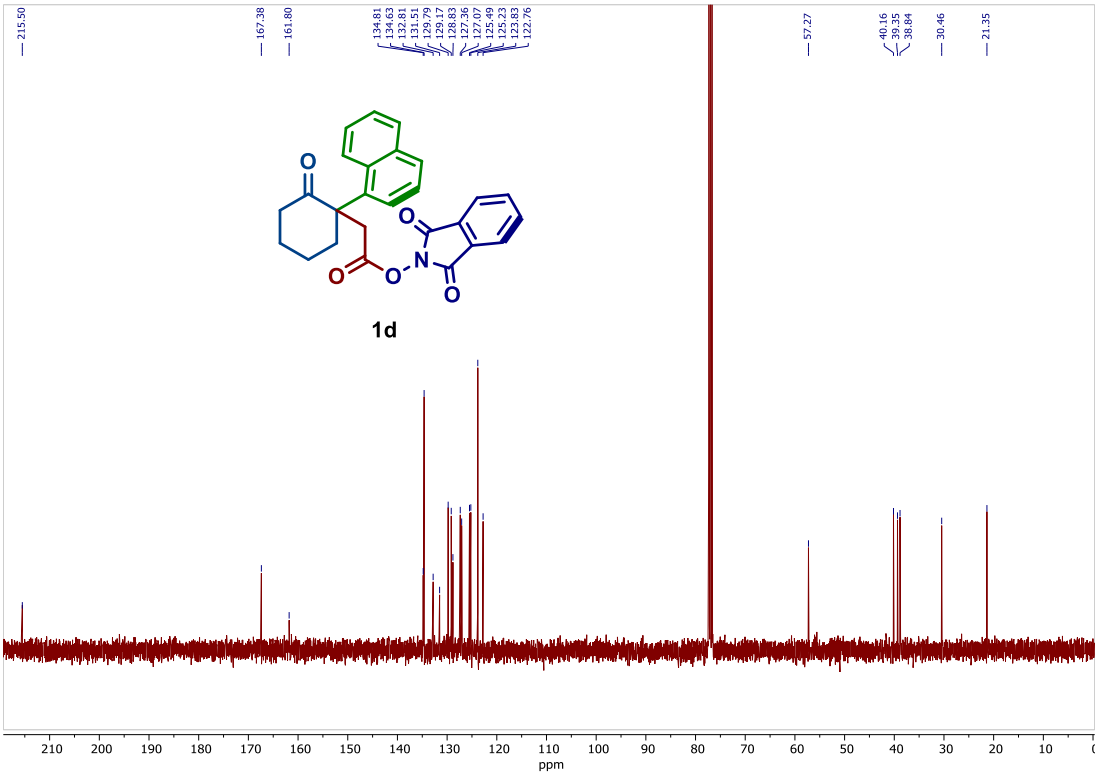
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1c**



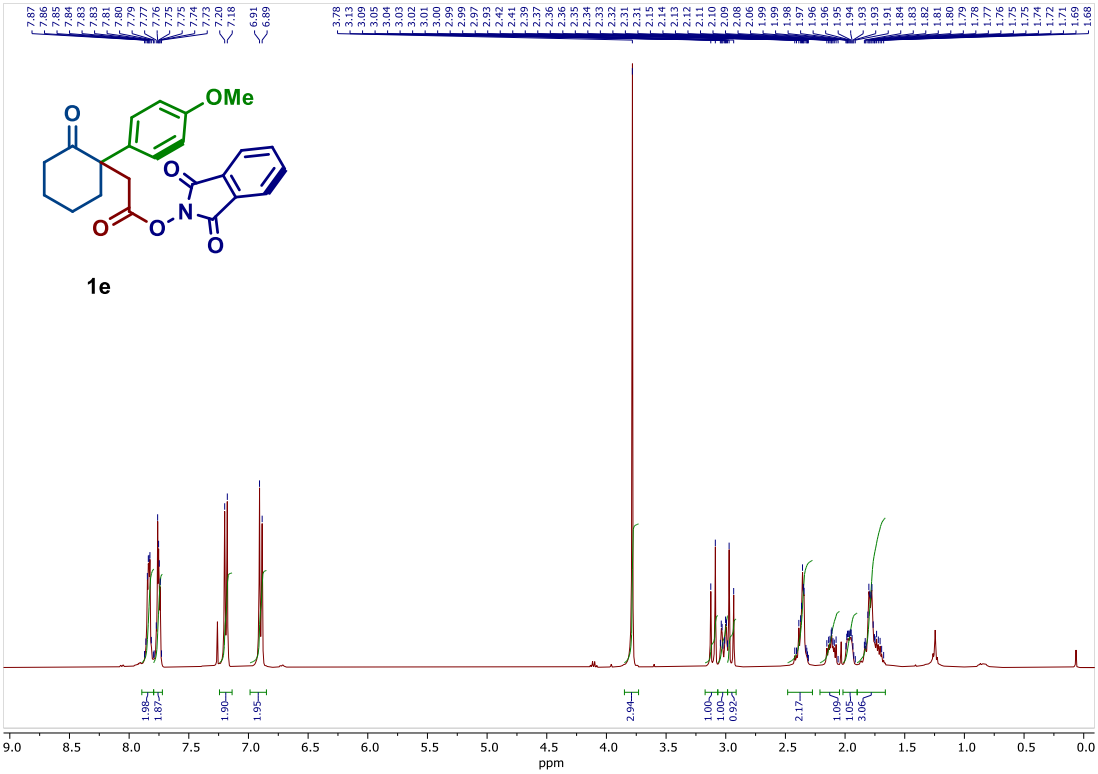
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1d** (*See Procedure*)



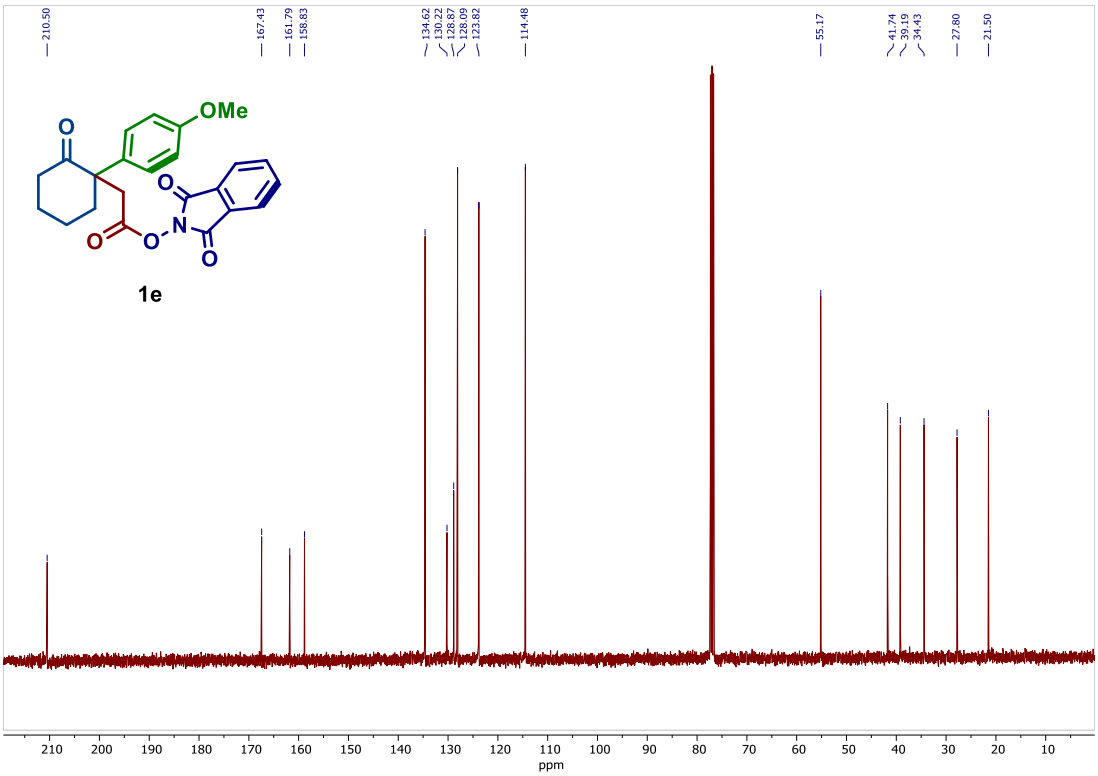
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1d**



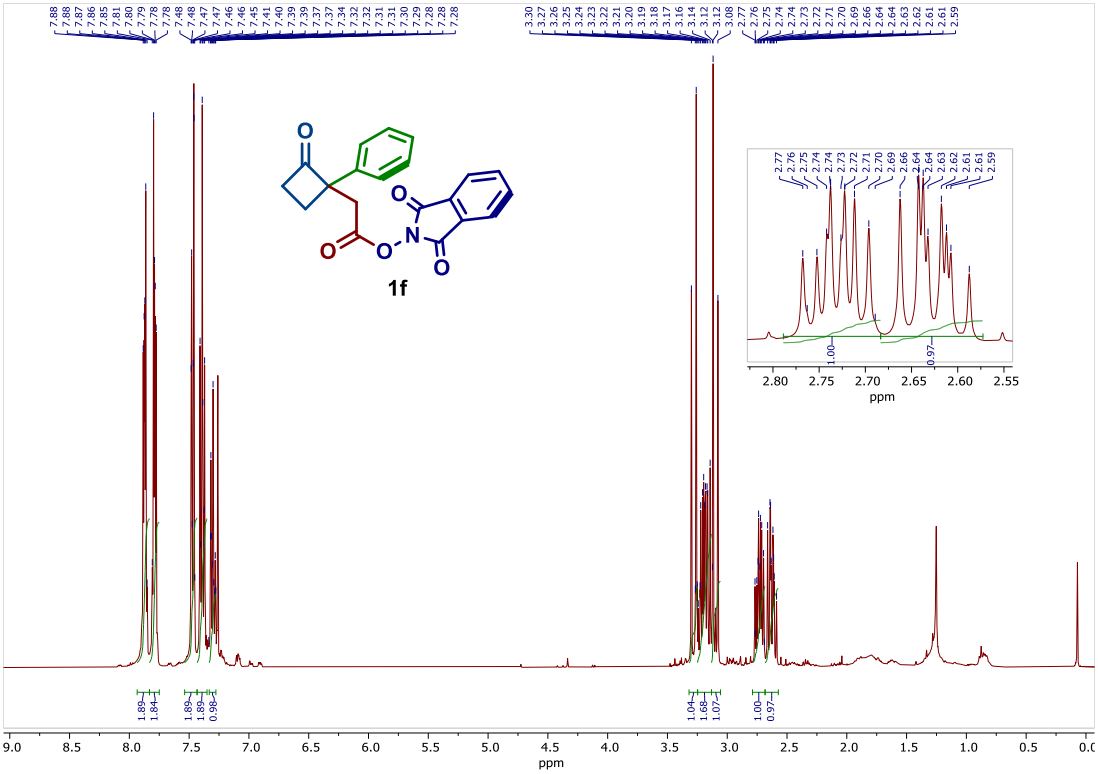
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1e** (*See Procedure*)



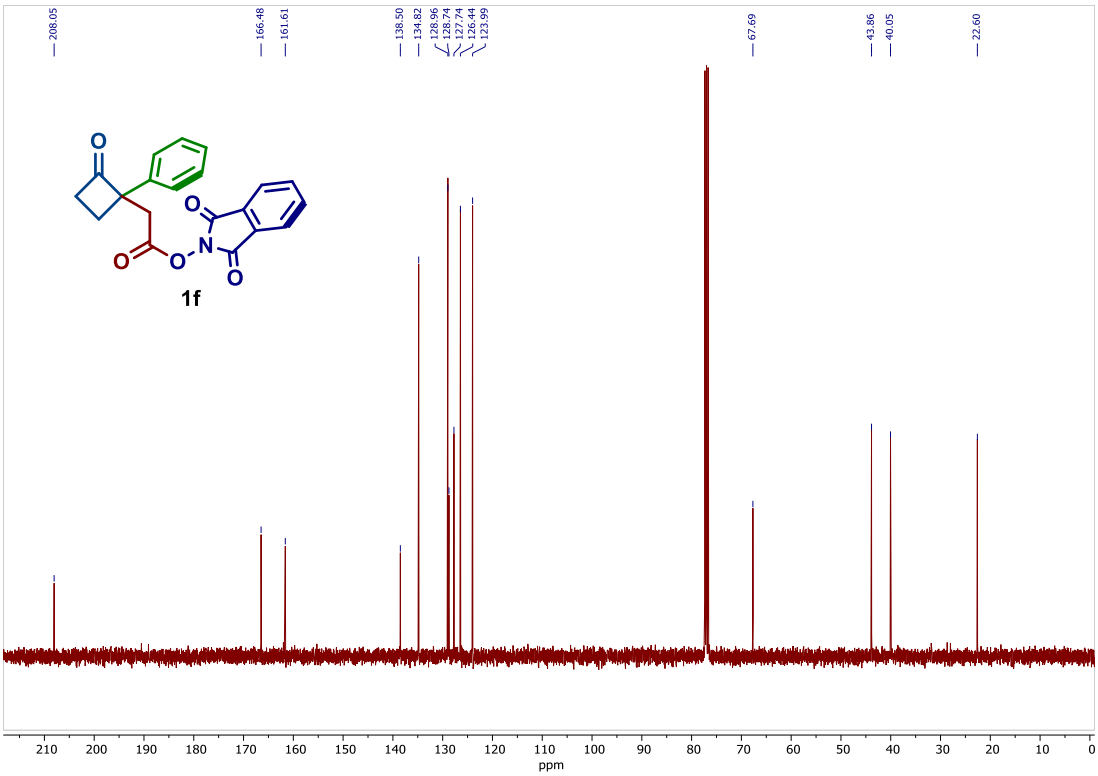
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1e**



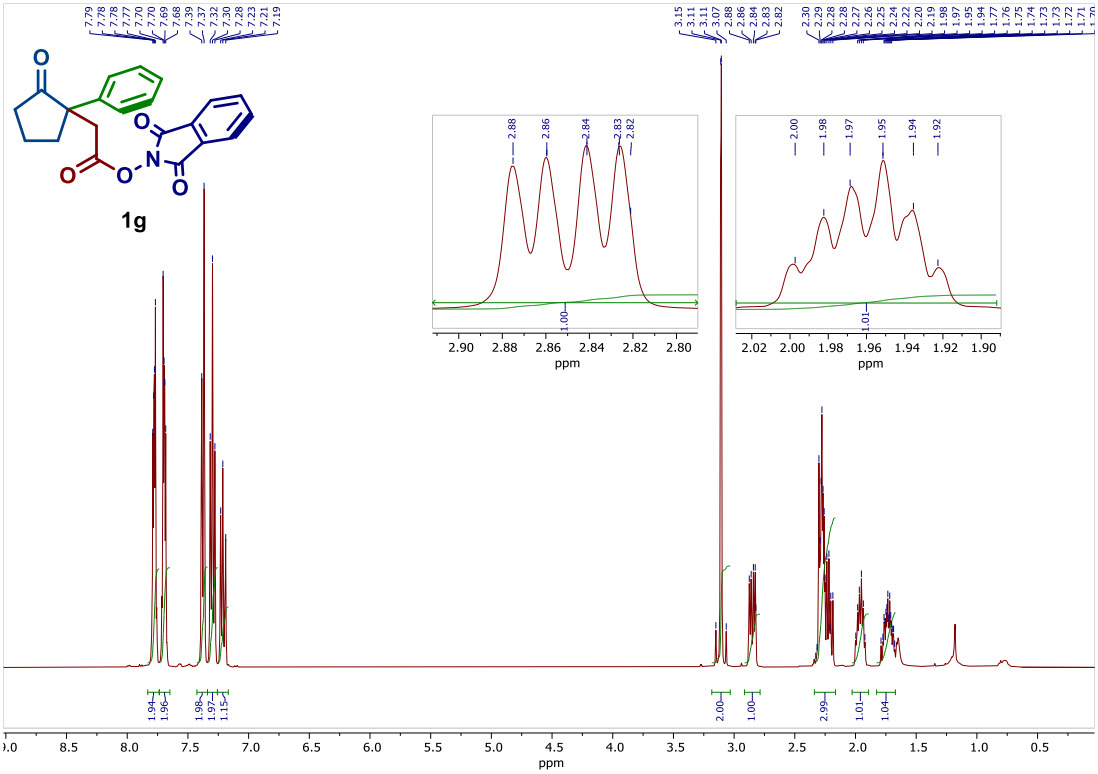
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1f** (*See Procedure*)



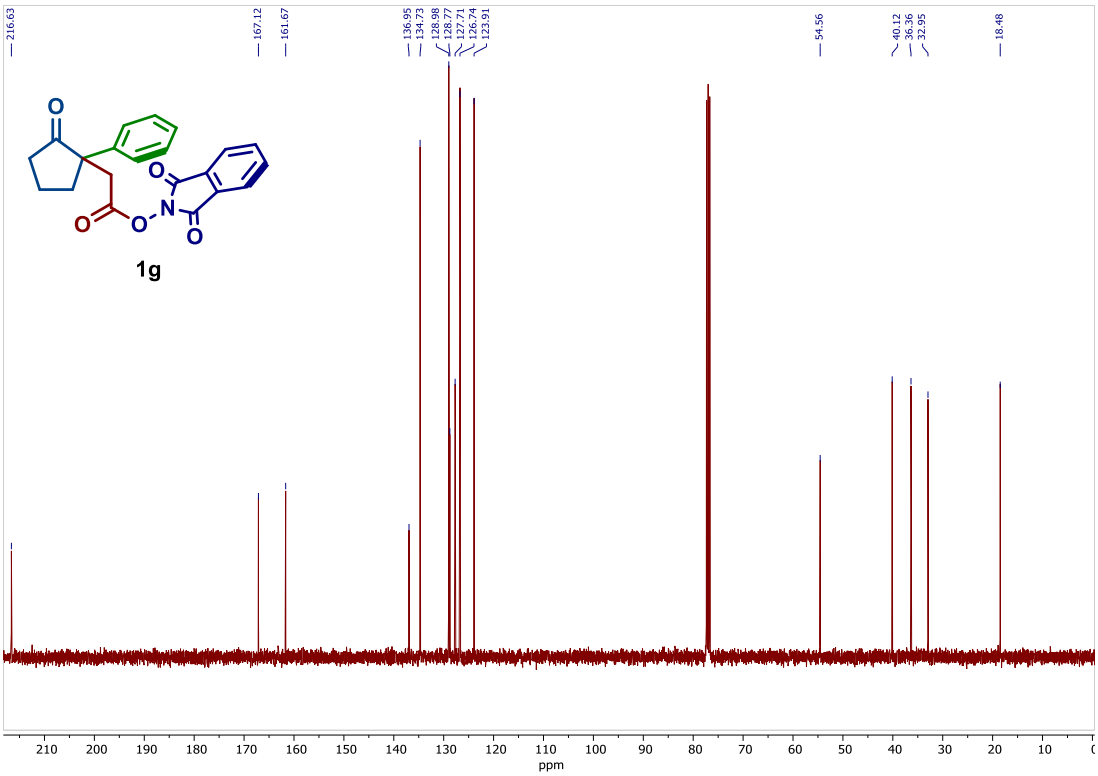
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1f**



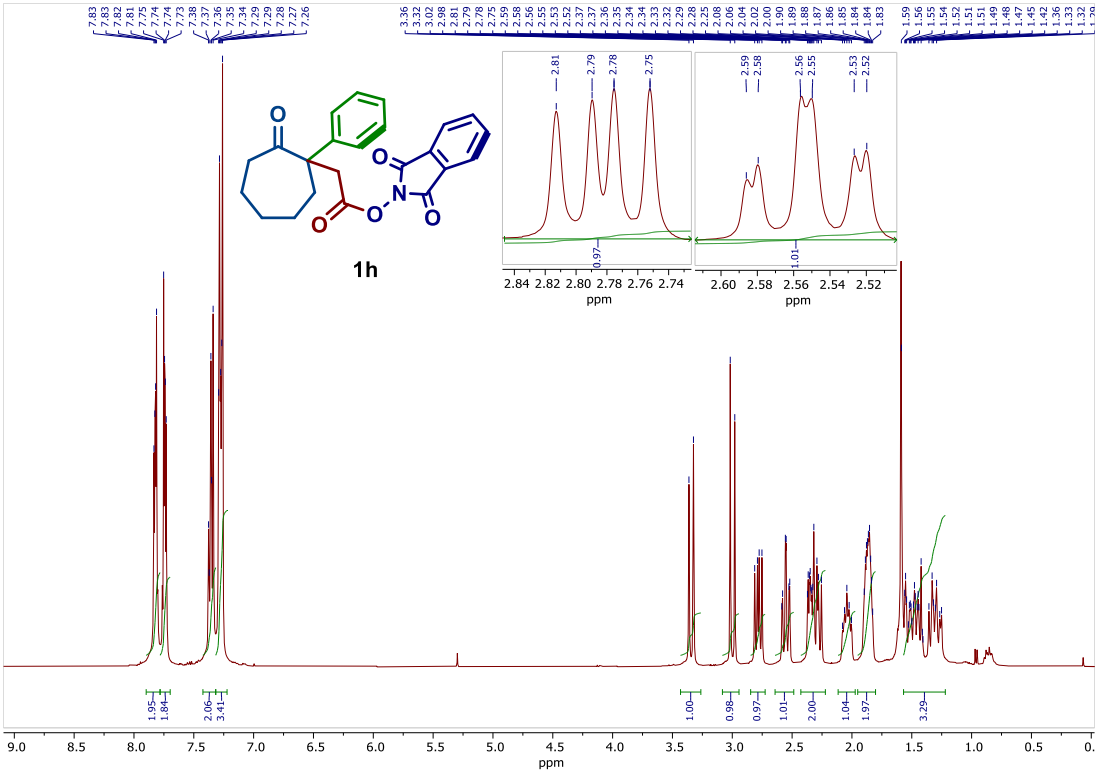
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1g** (*See Procedure*)



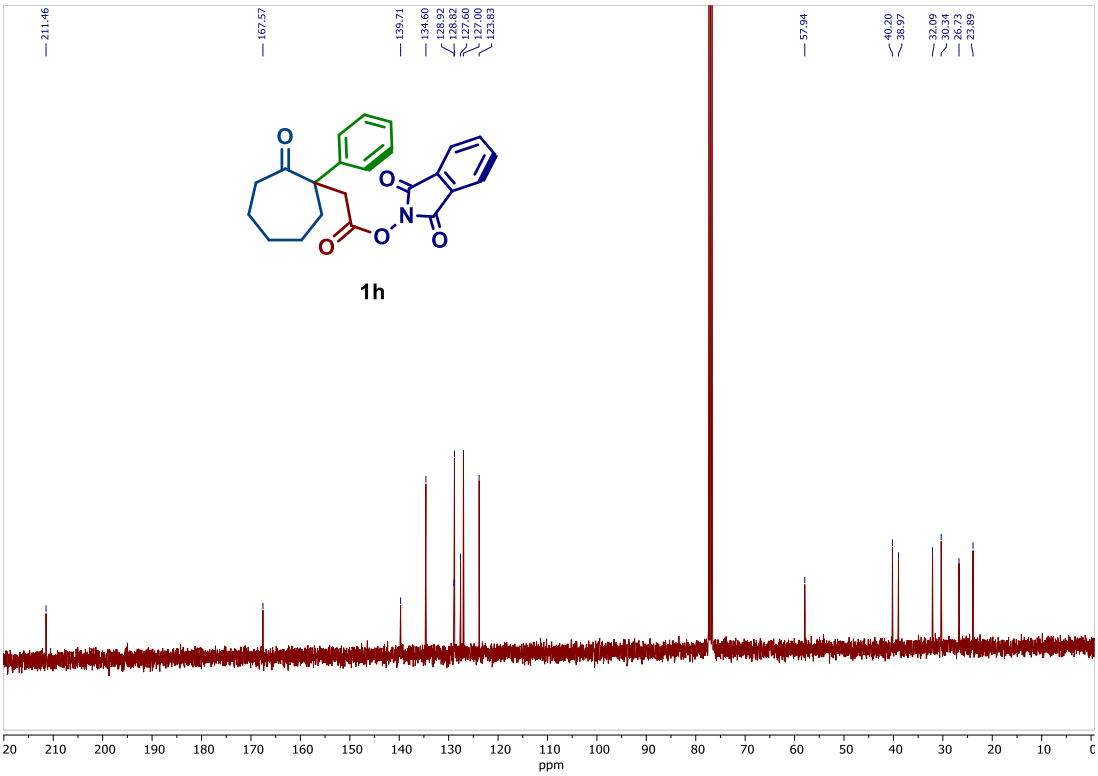
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1g**



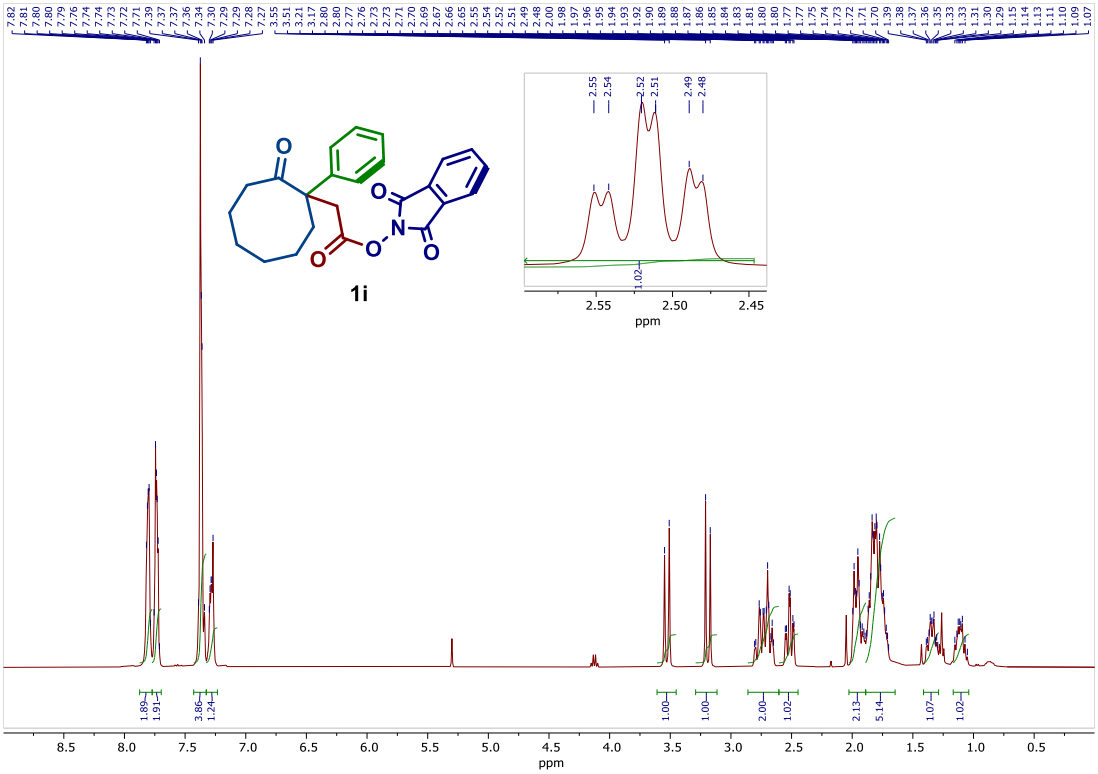
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1h** (*See Procedure*)



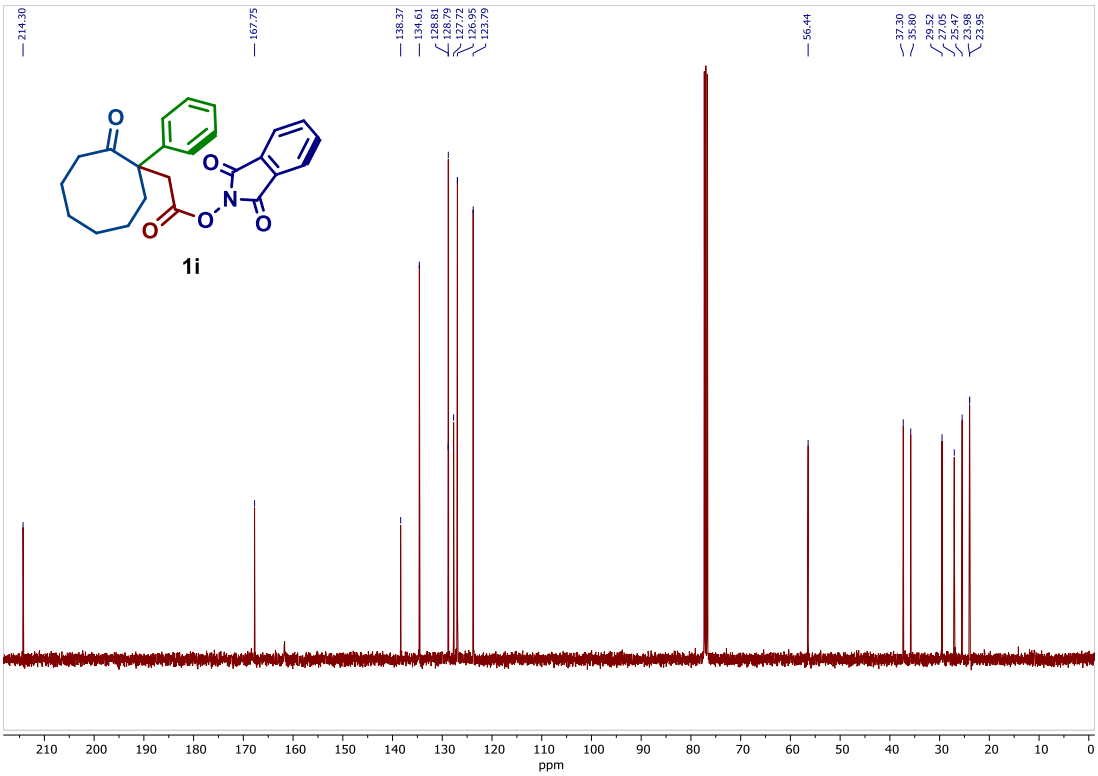
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1h**



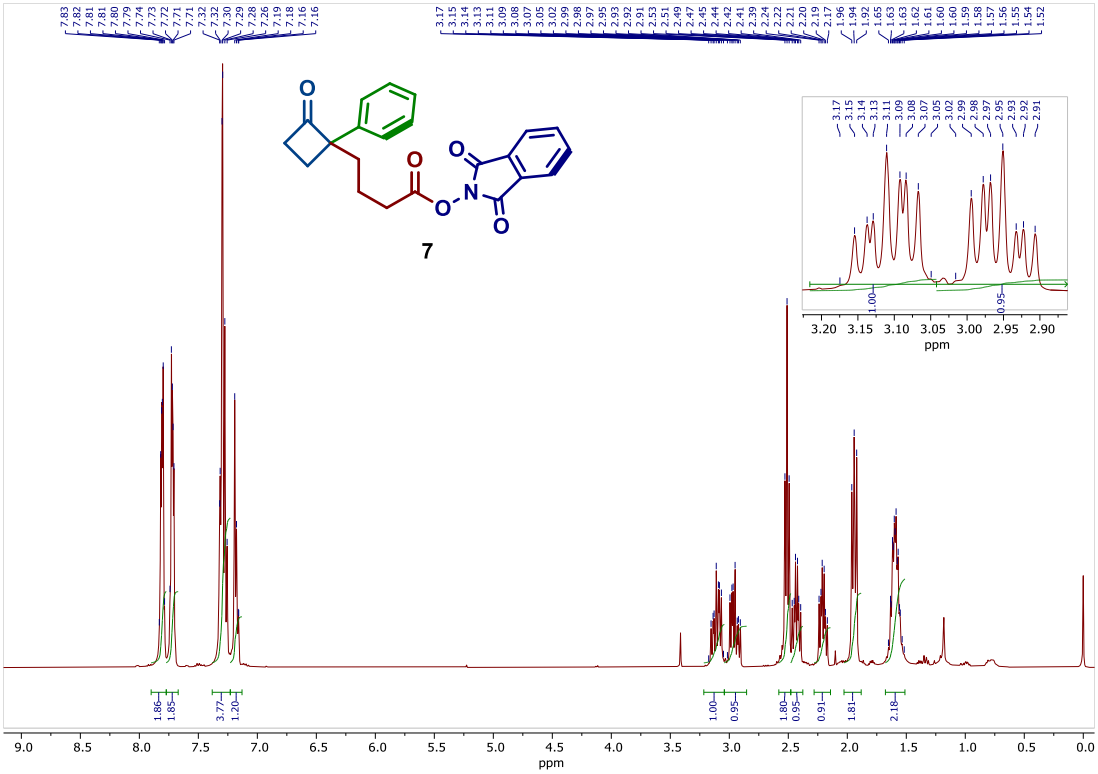
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **1i** (*See Procedure*)



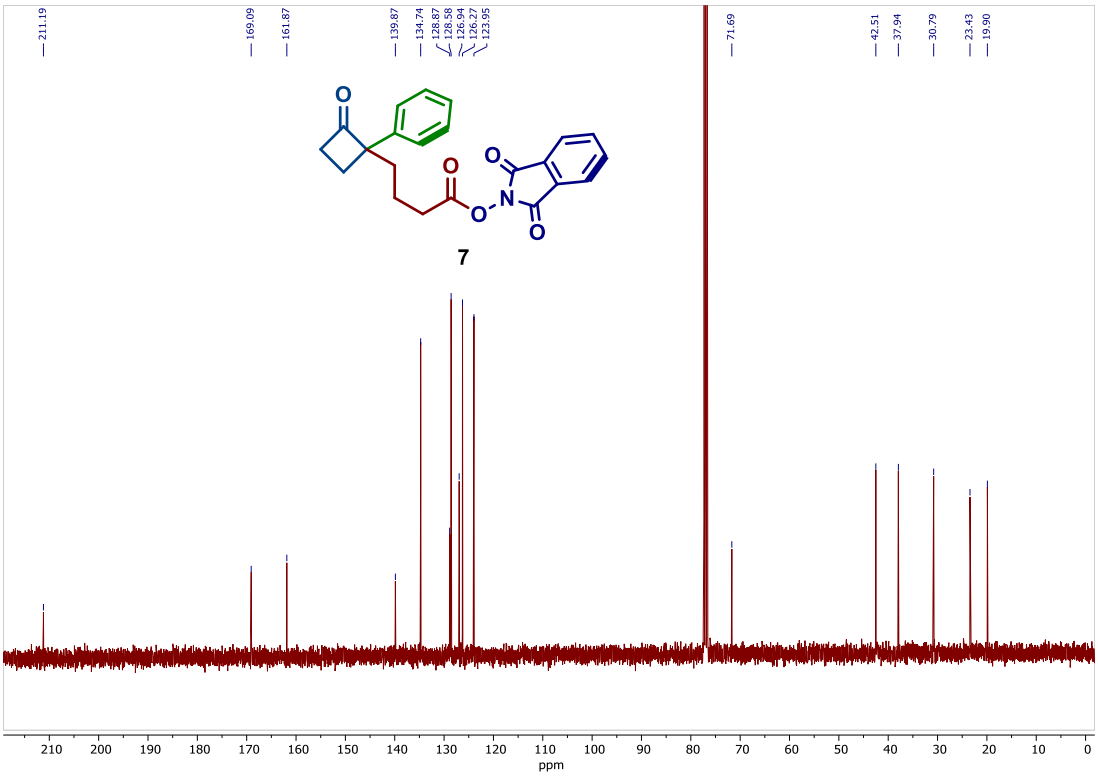
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **1i**



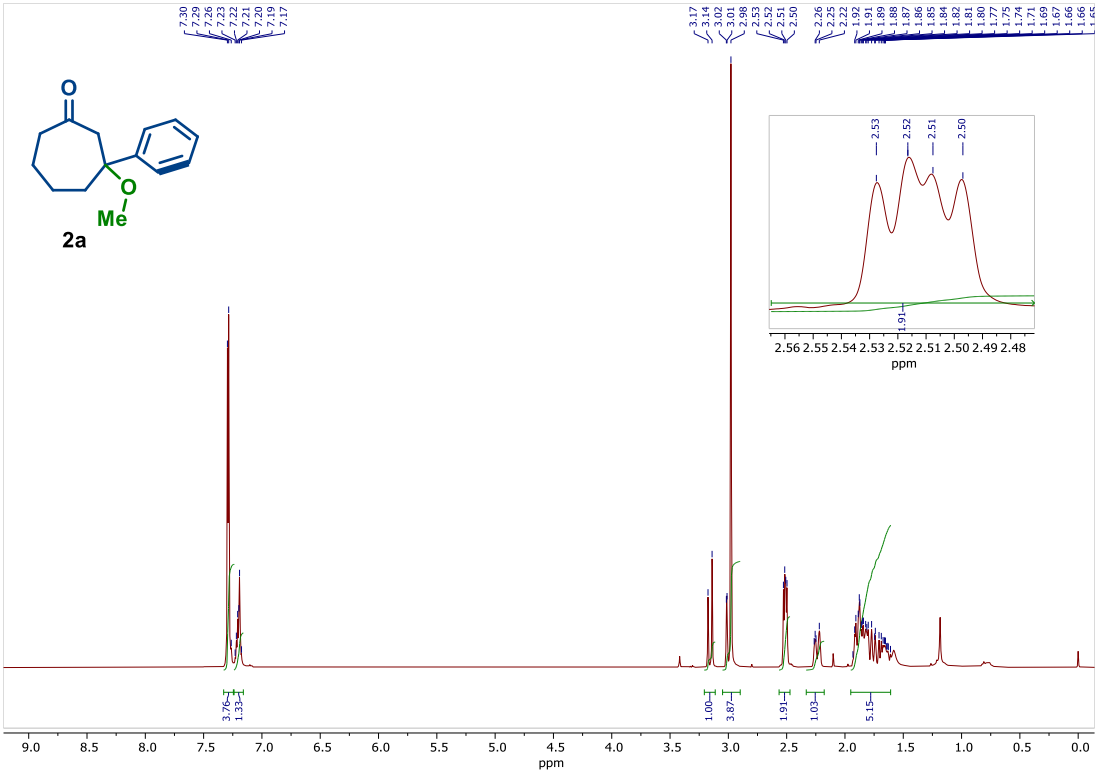
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **7** (*See Procedure*)



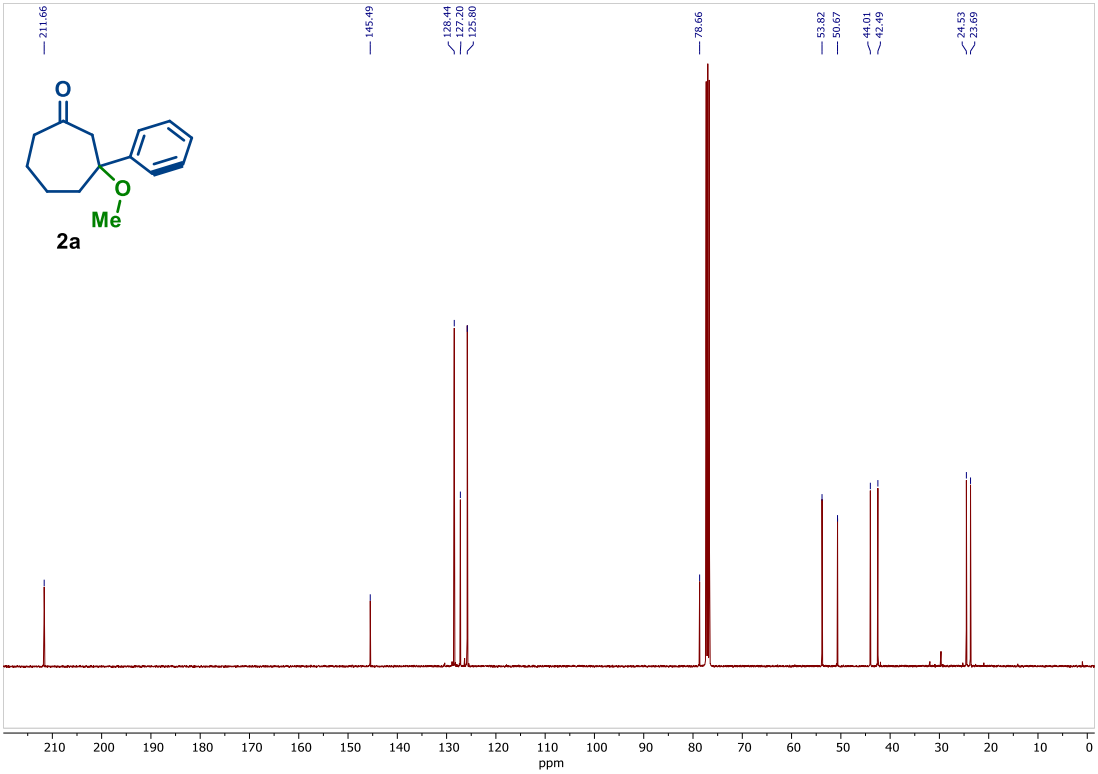
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **7**



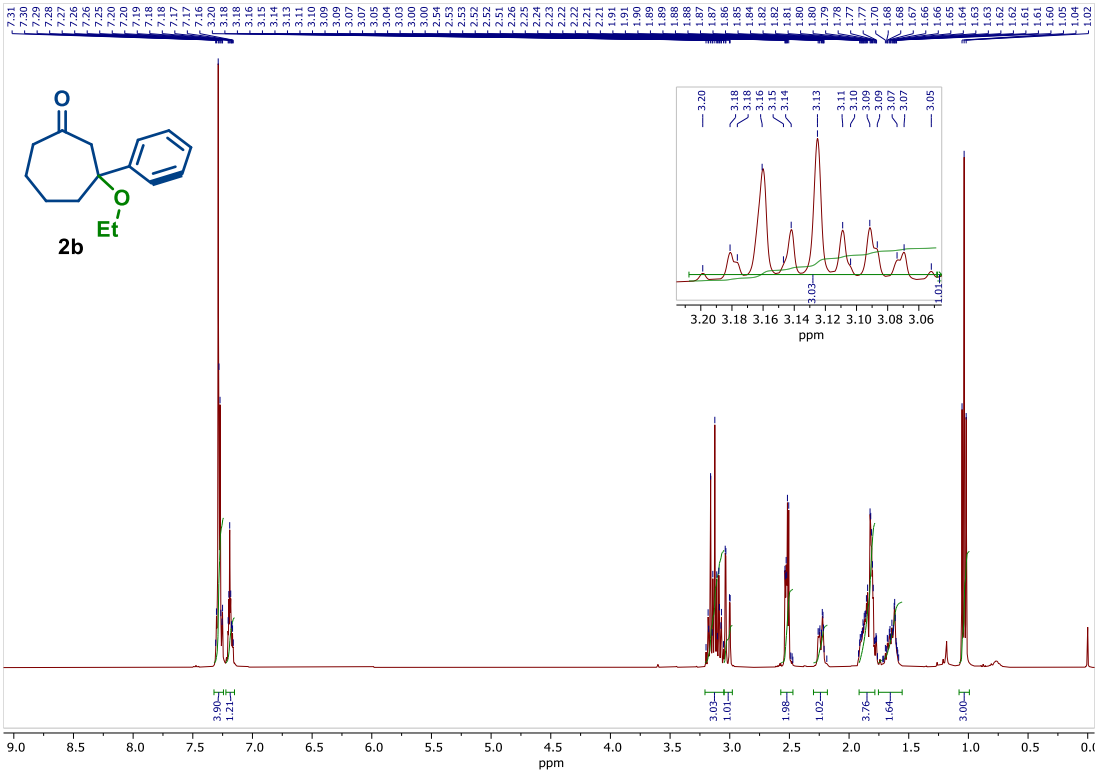
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2a** (*See Procedure*)



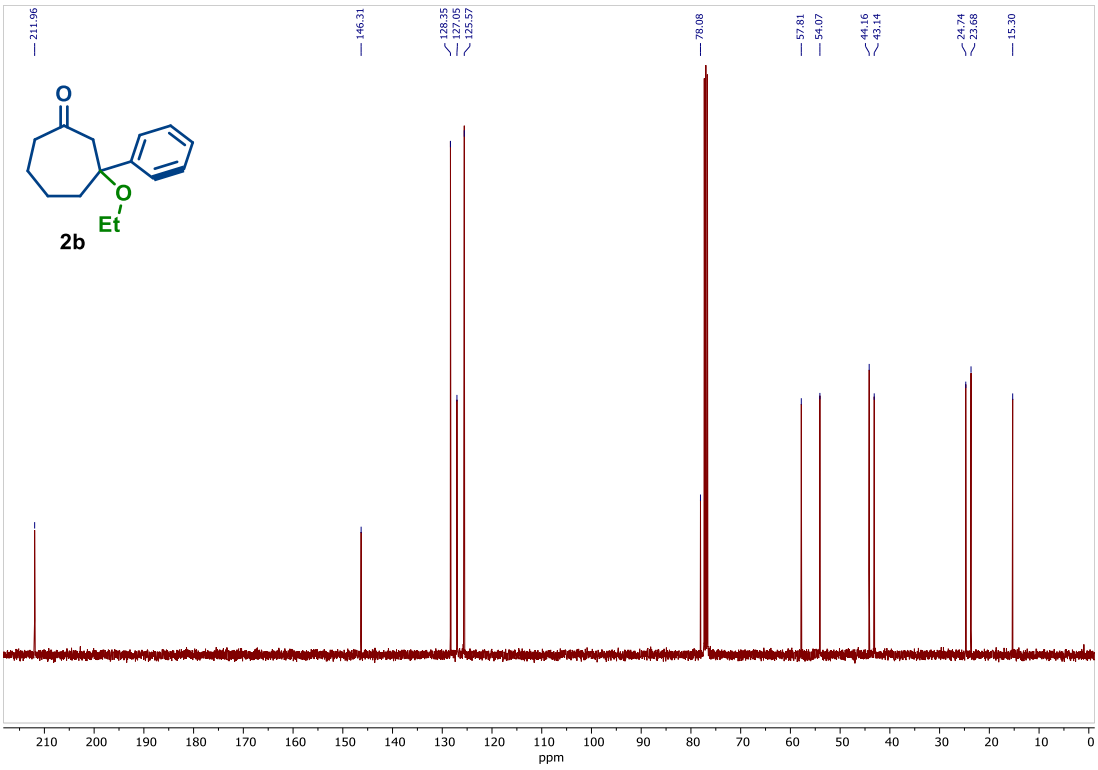
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2a**



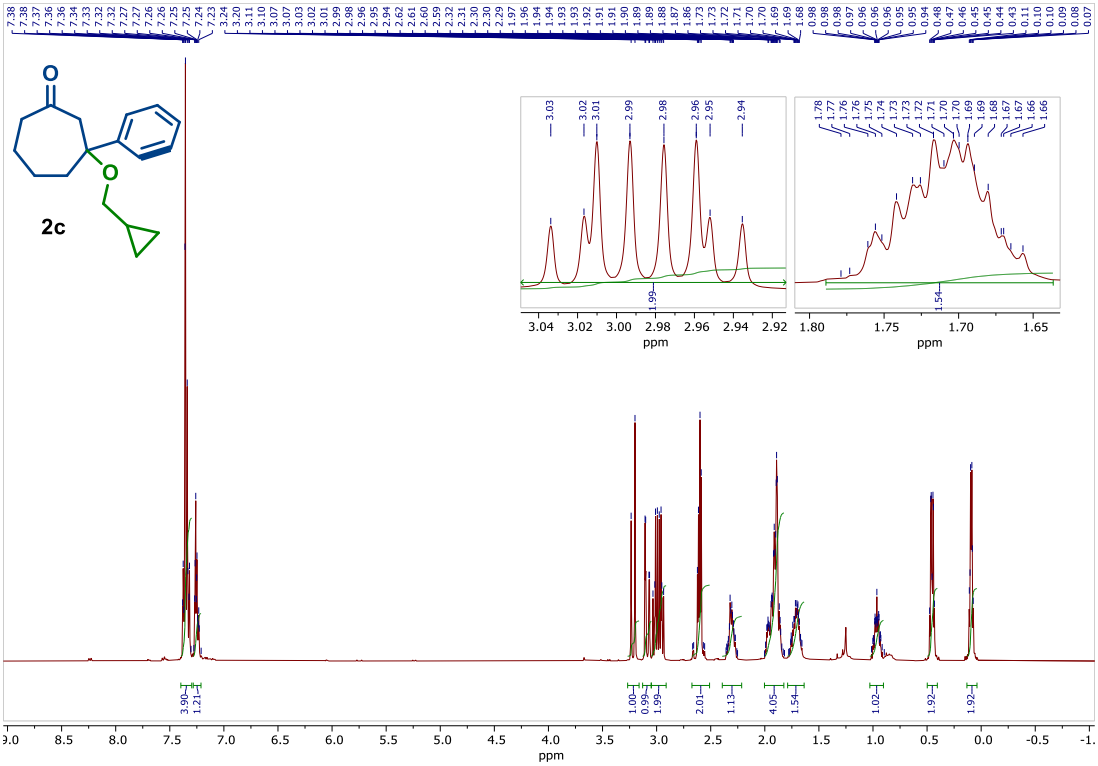
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2b** (*See Procedure*)



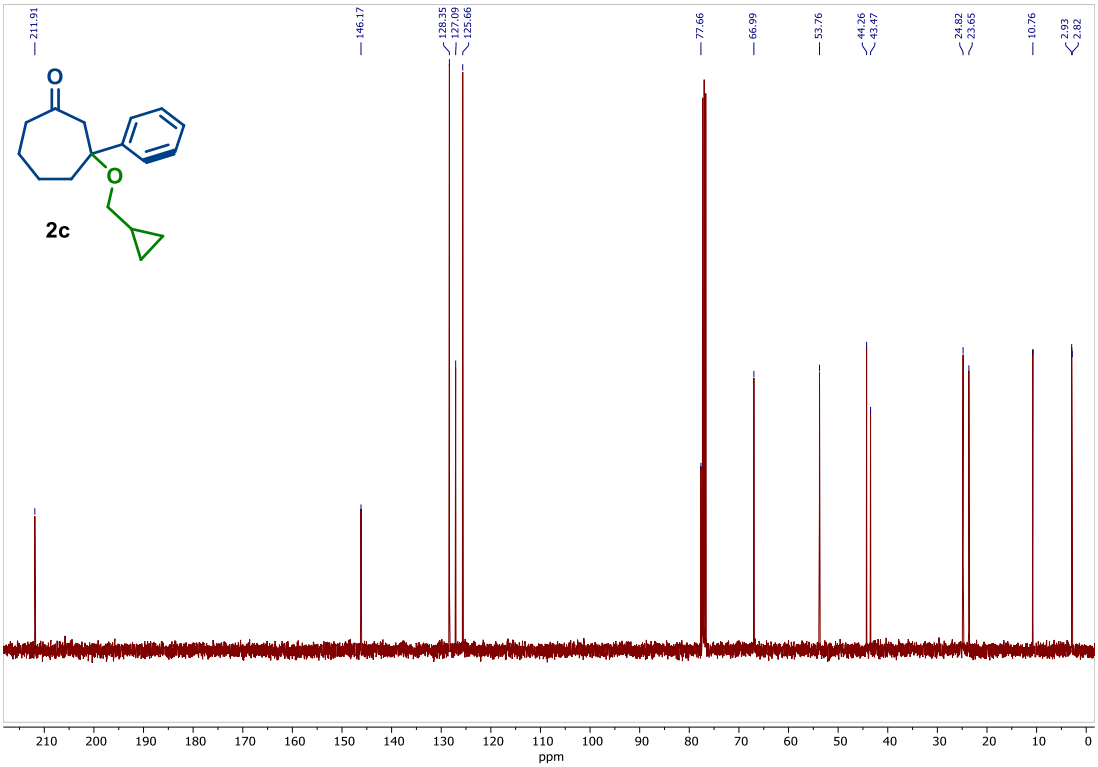
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2b**



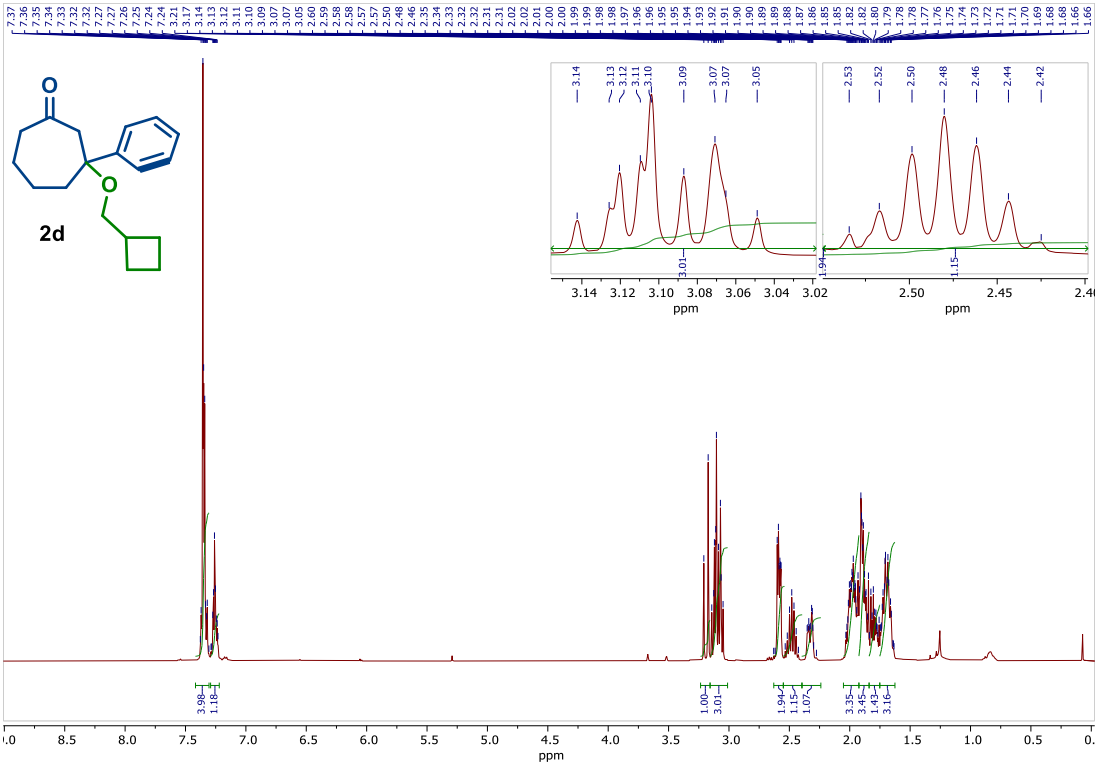
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2c** (*See Procedure*)



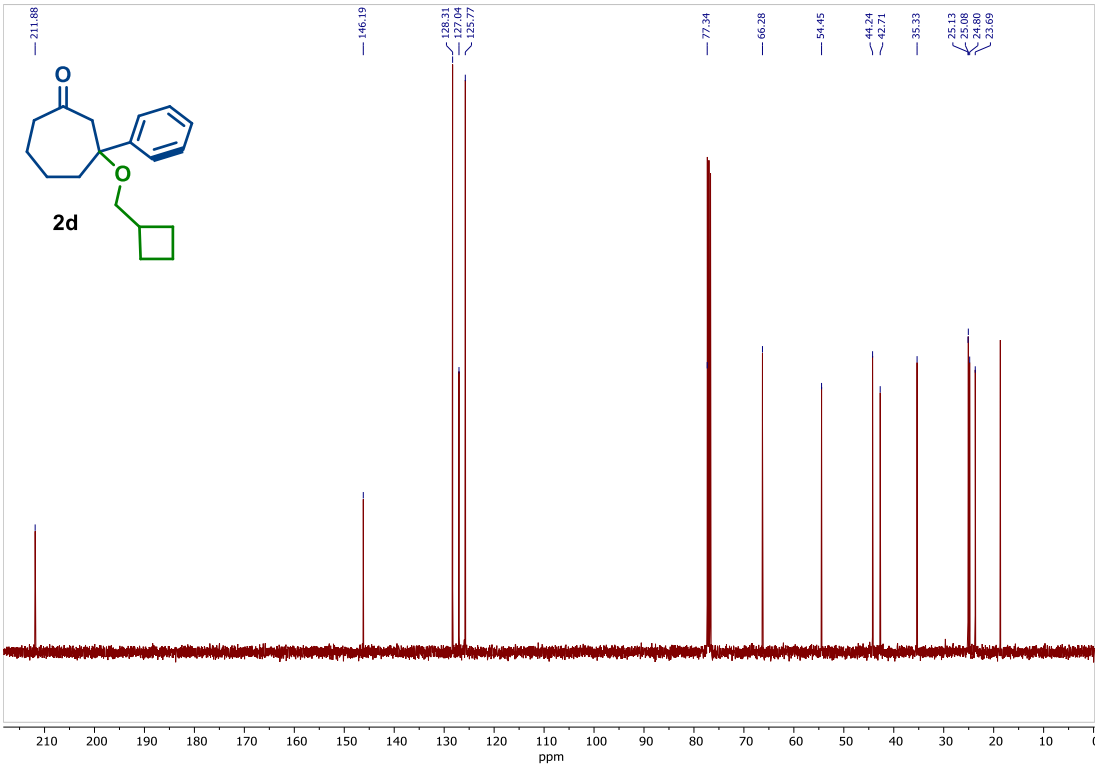
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2c**



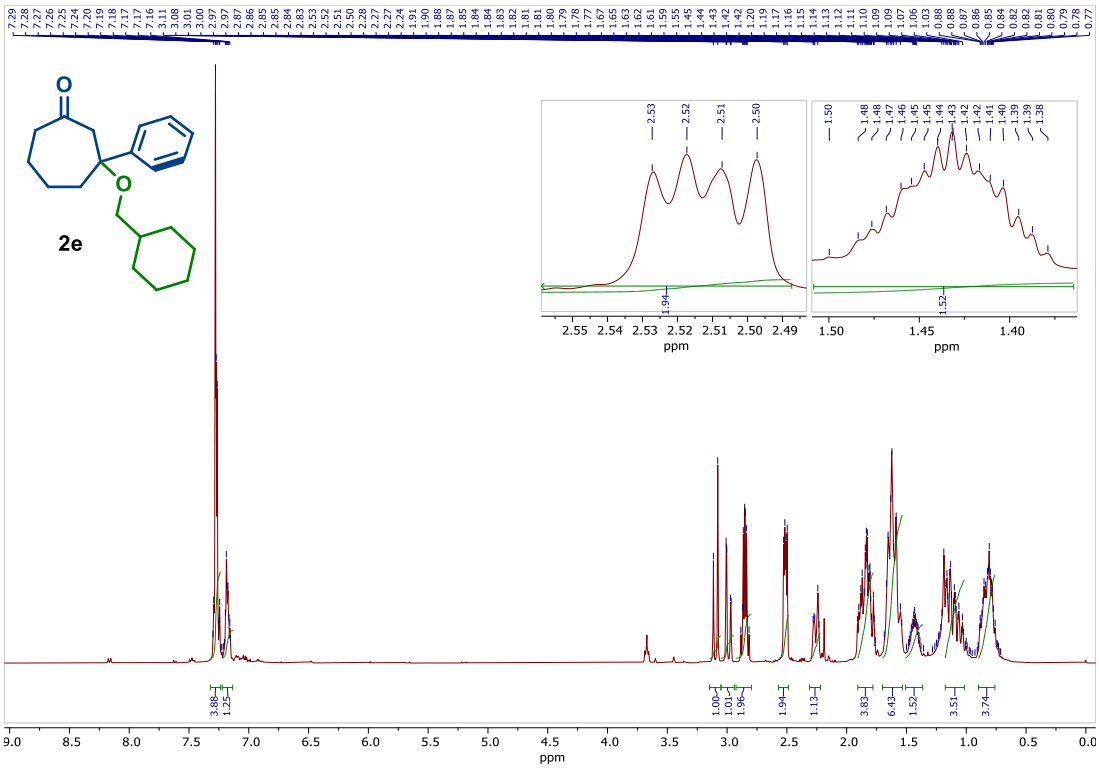
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2d** (*See Procedure*)



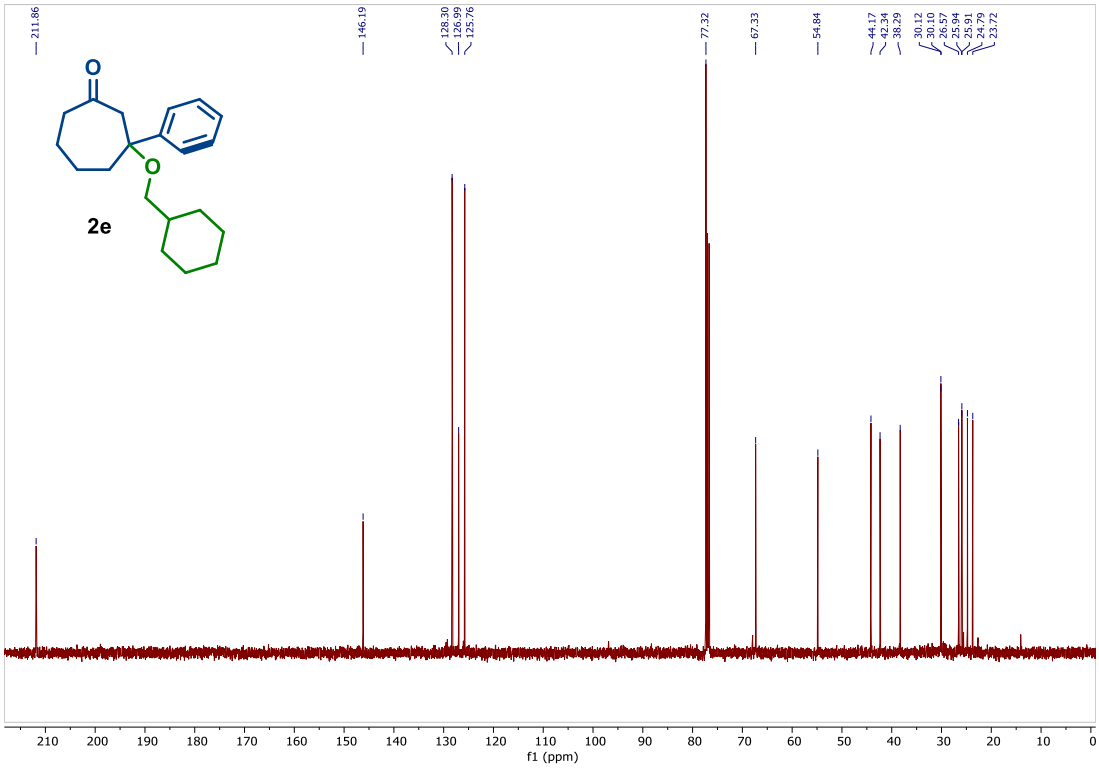
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2d**



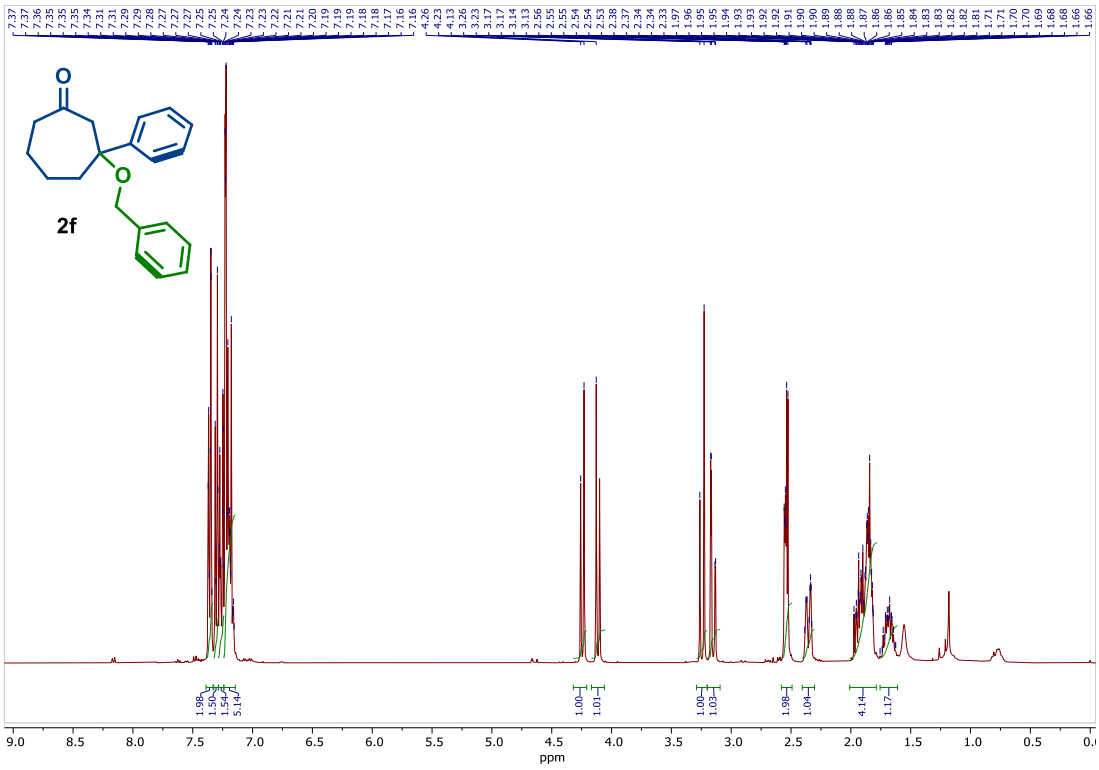
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2e** (*See Procedure*)



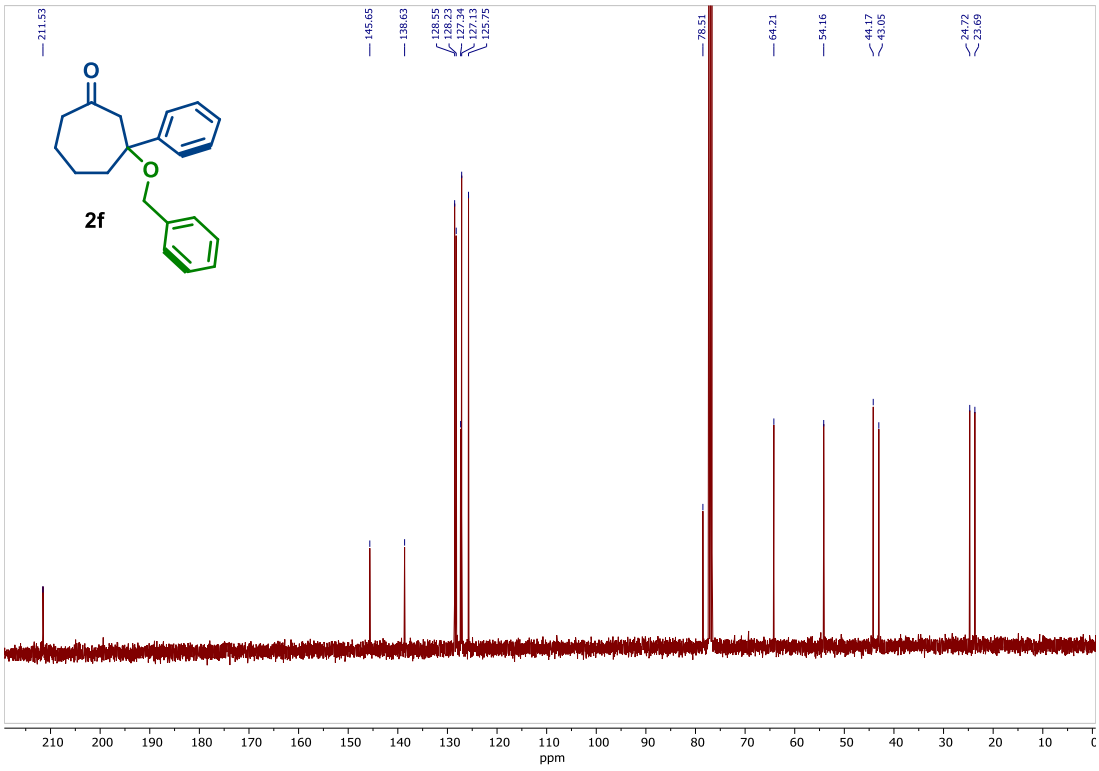
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2e**



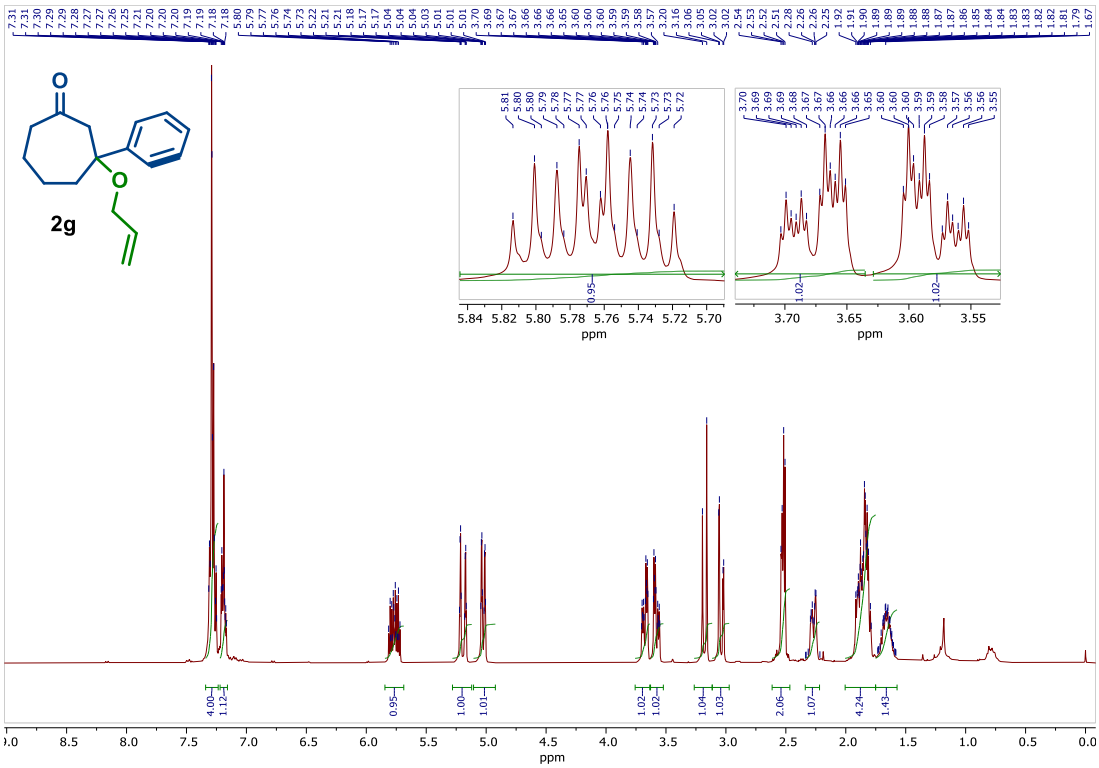
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2f** (*See Procedure*)



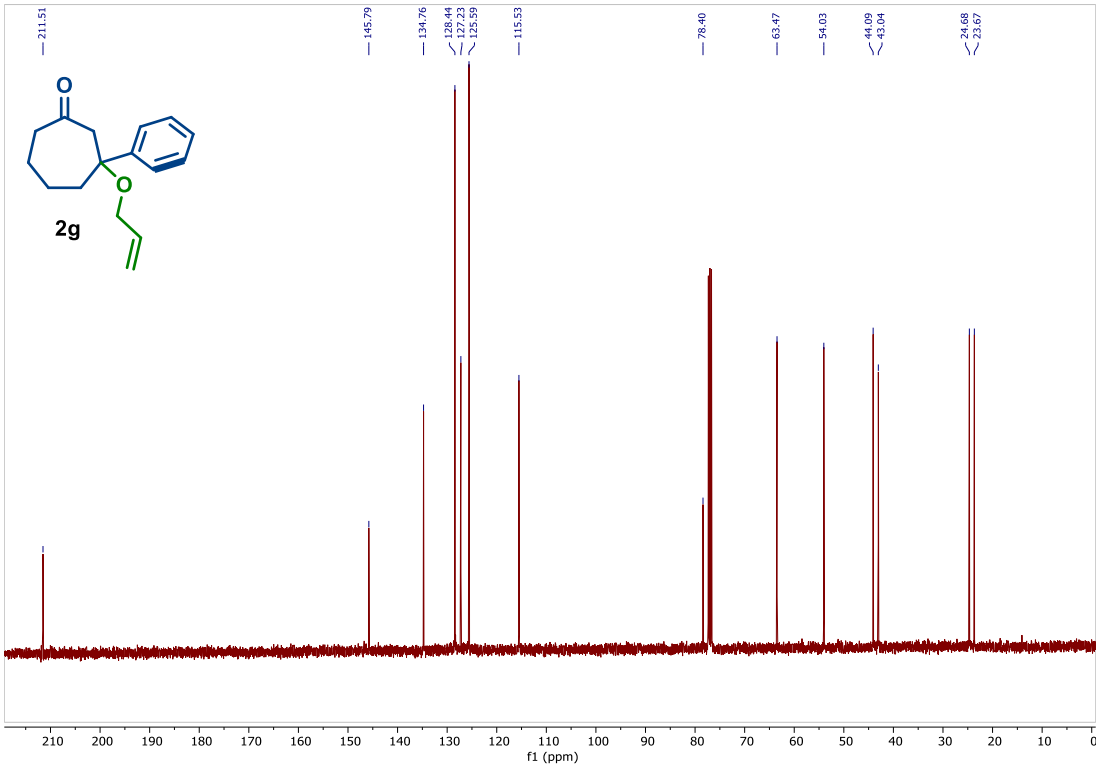
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2f**



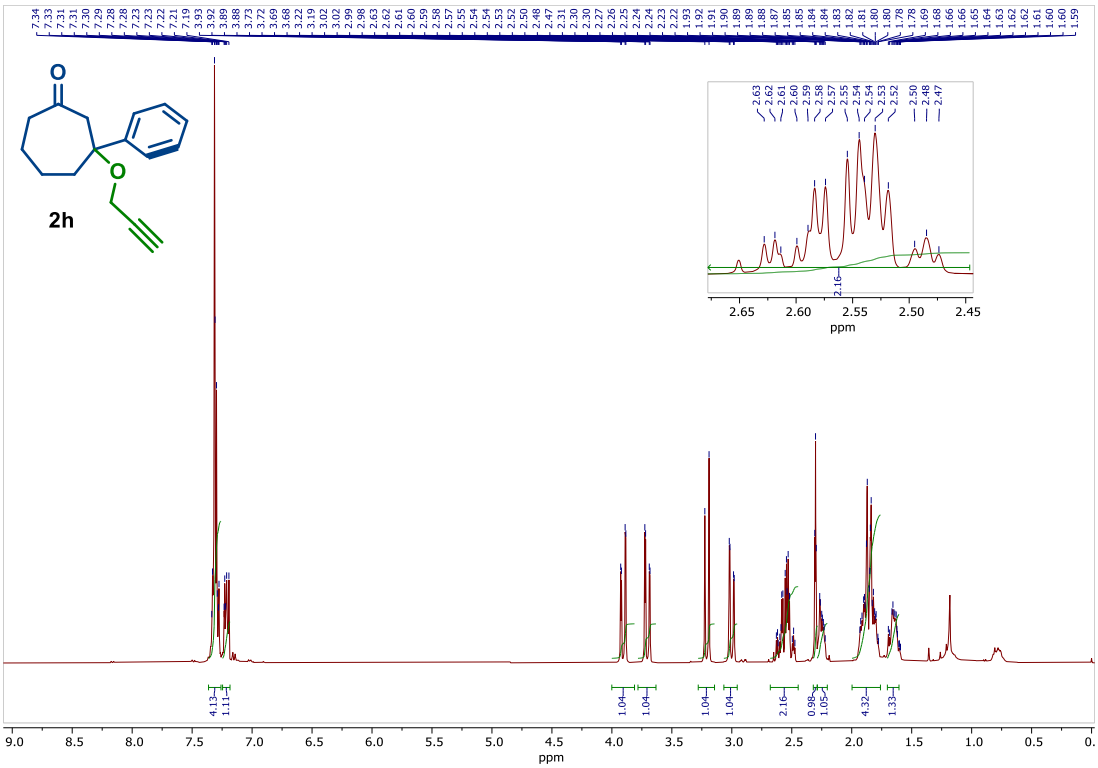
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2g** (*See Procedure*)



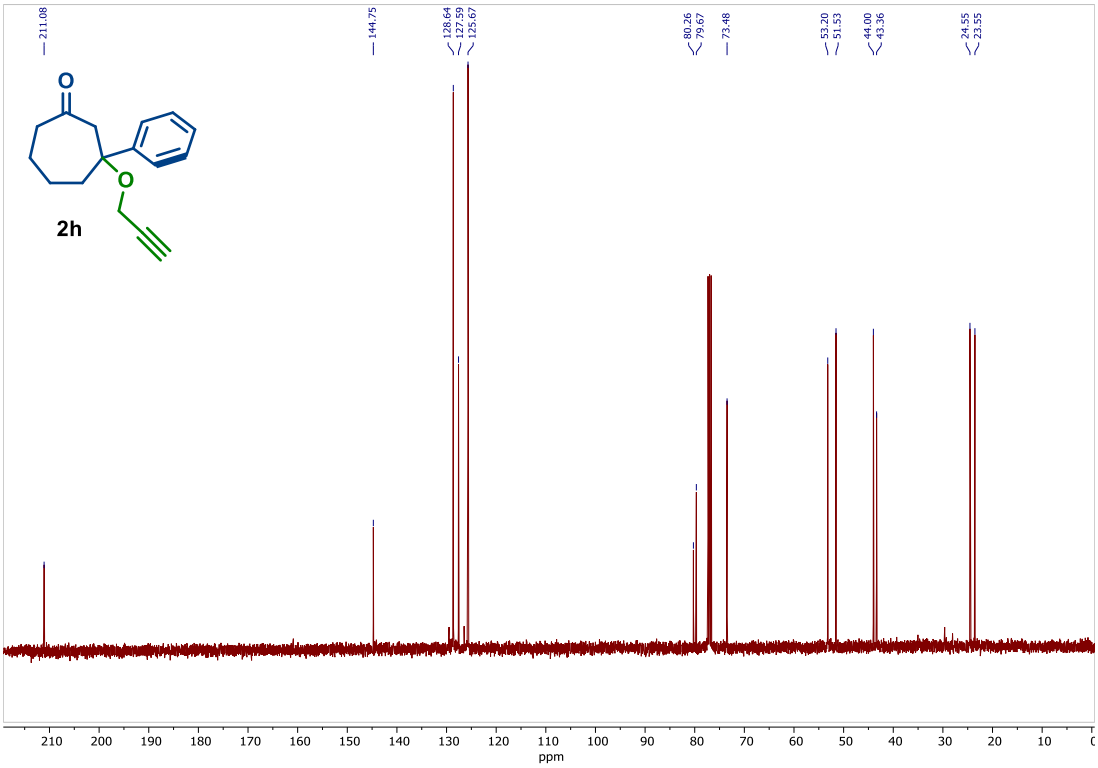
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2g**



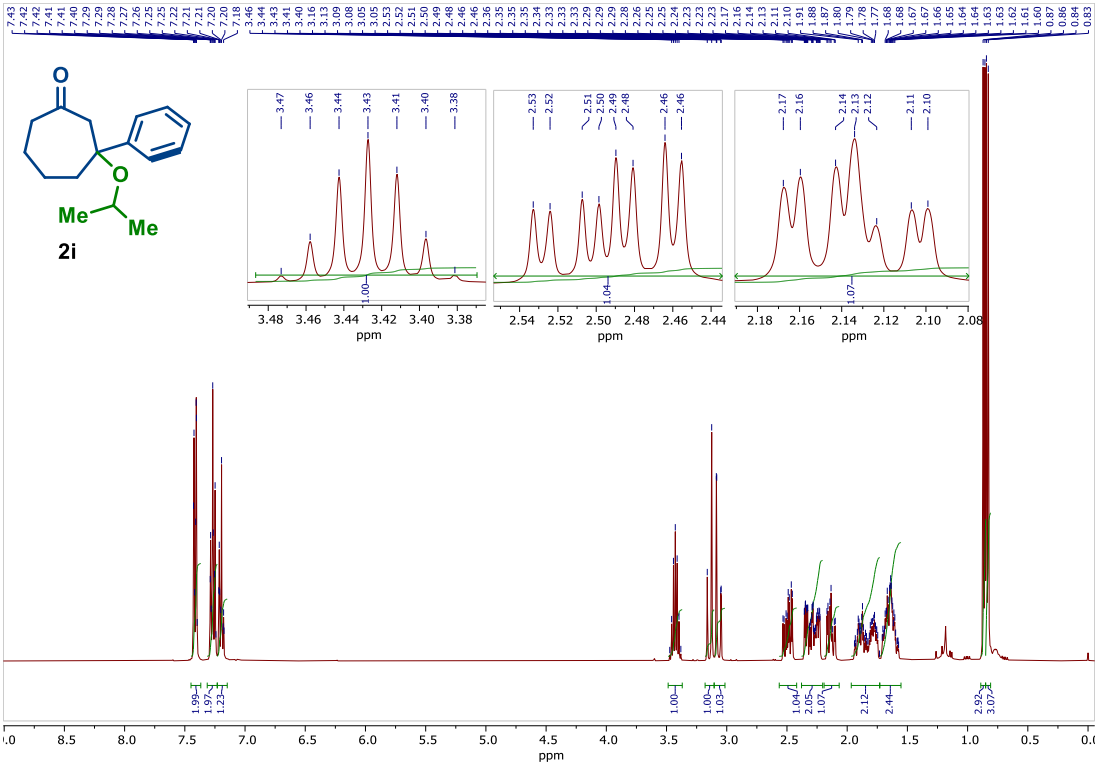
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2h** (*See Procedure*)



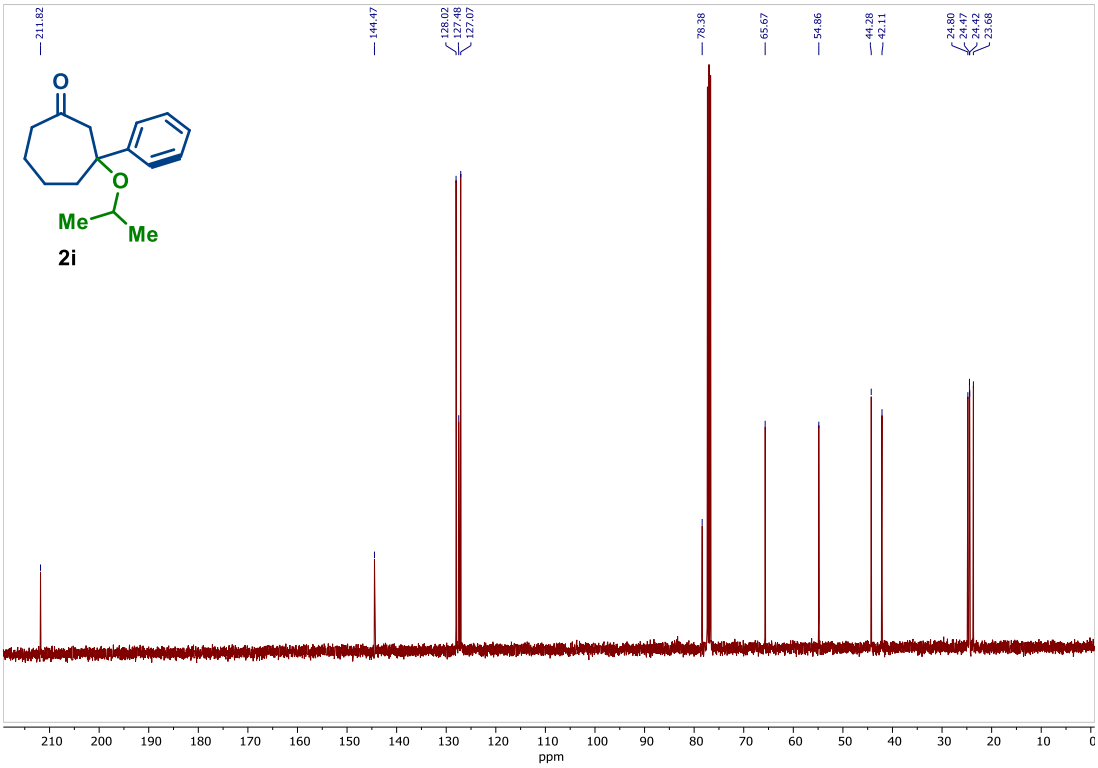
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2h**



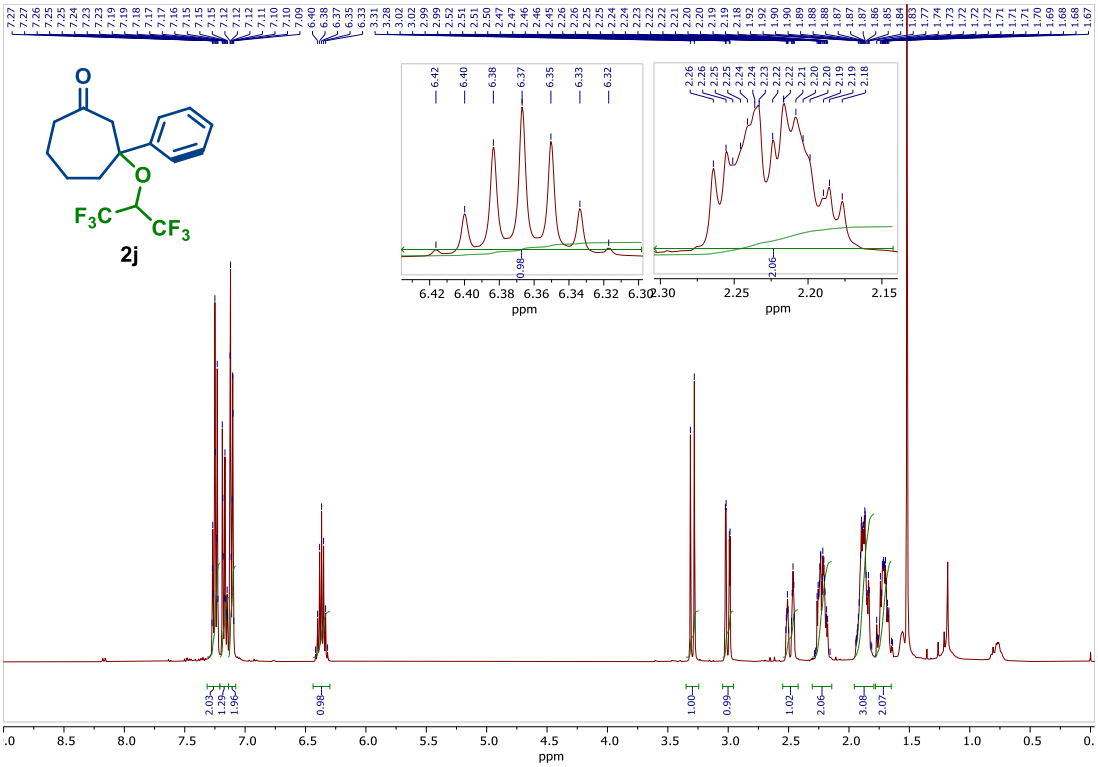
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2i** (*See Procedure*)



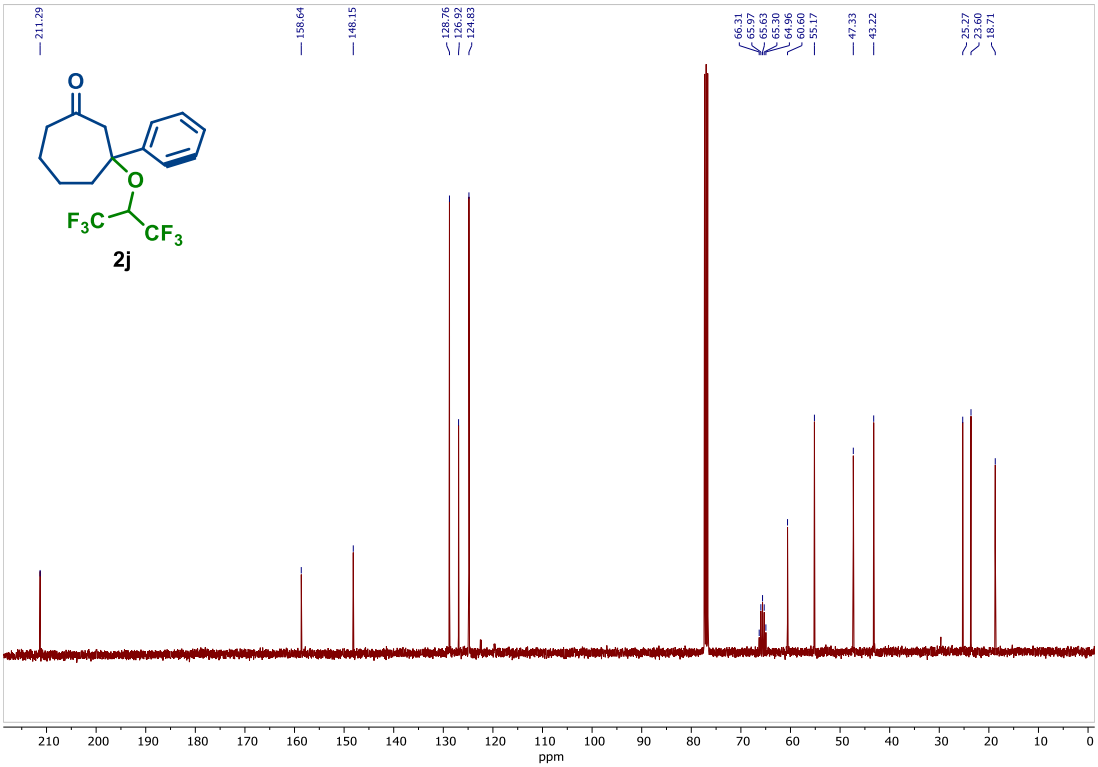
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2i**



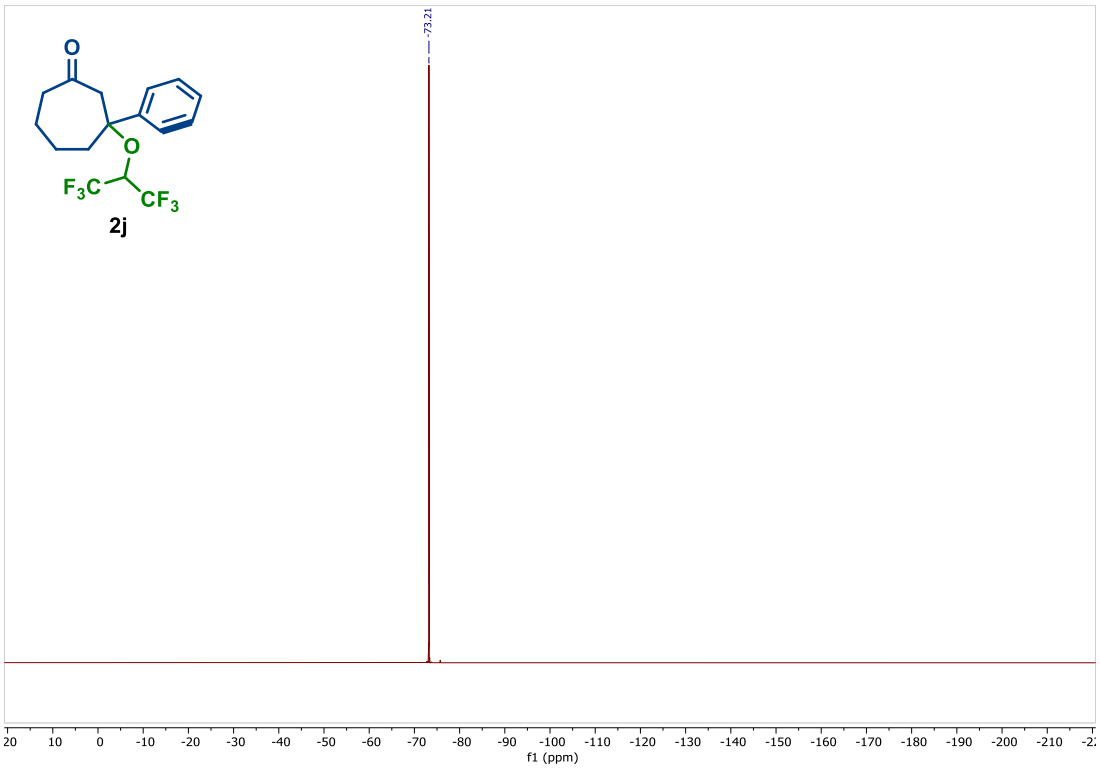
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2j** (*See Procedure*)



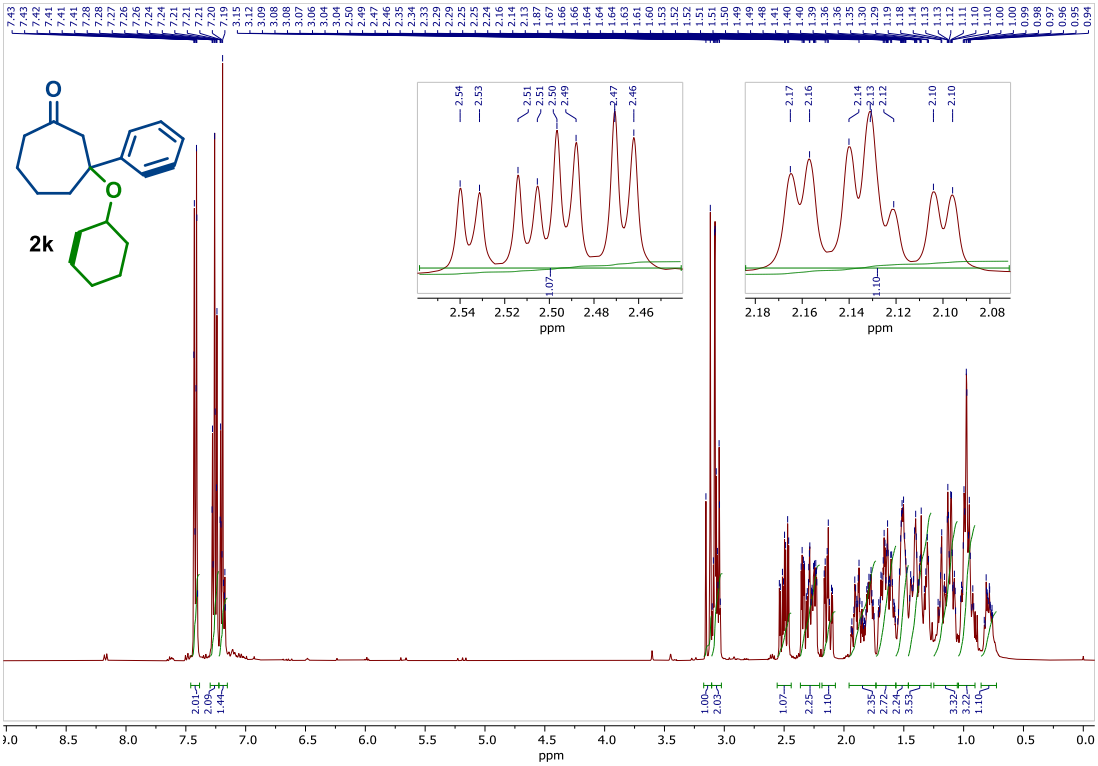
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2j**



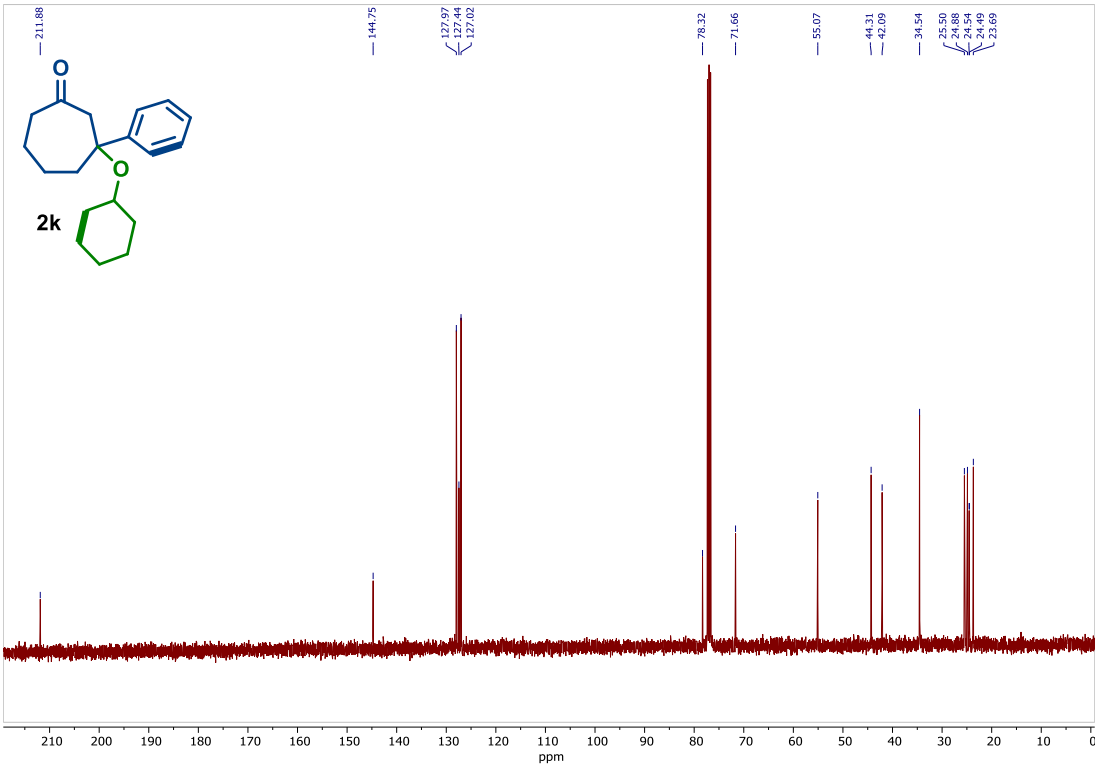
^{19}F NMR (376 MHz, $CDCl_3$) spectra of compound **2j**



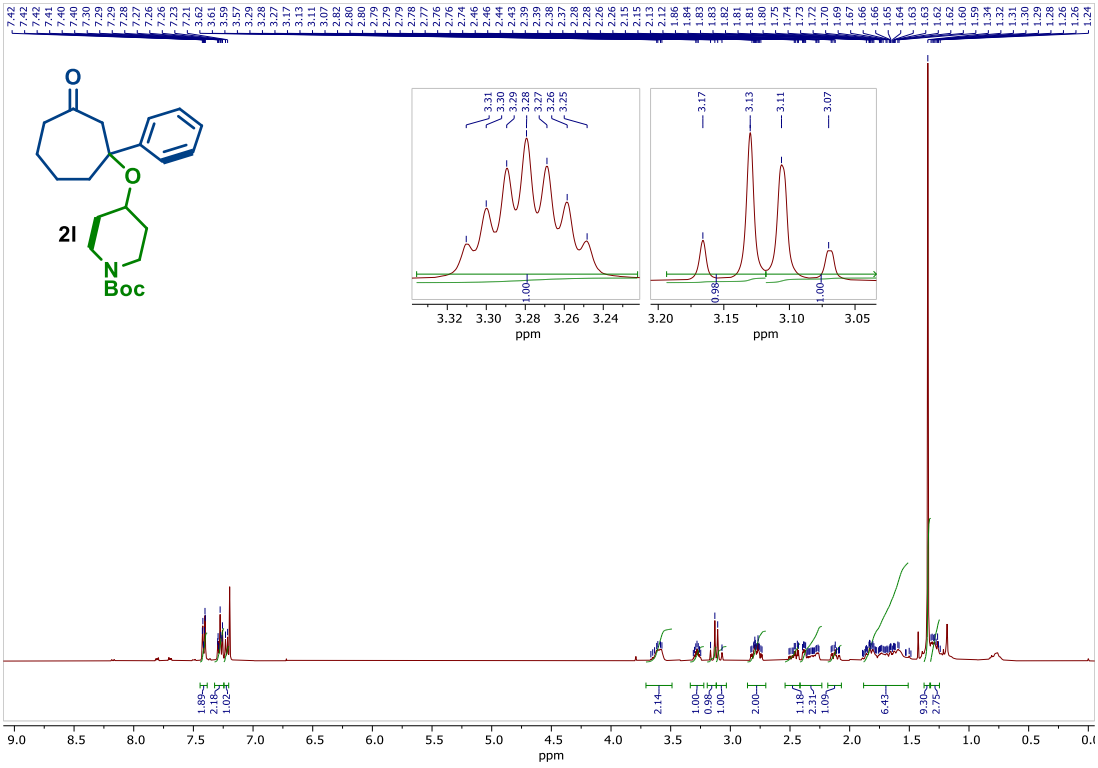
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2k** (*See Procedure*)



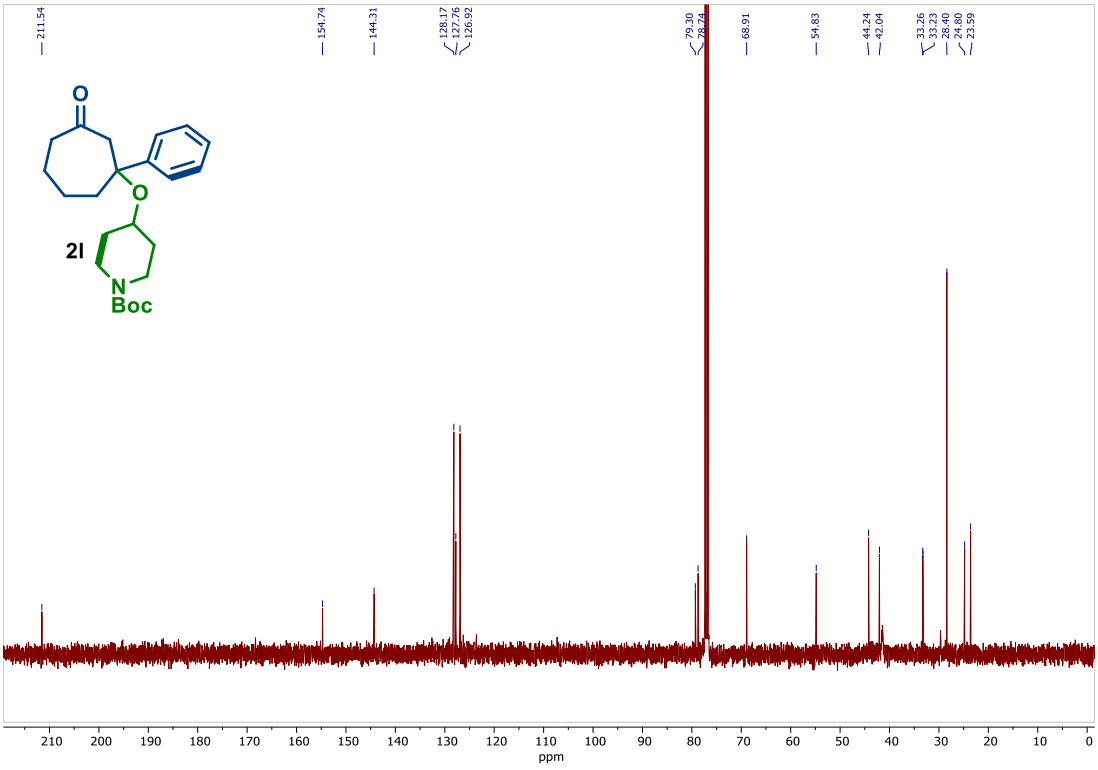
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2k**



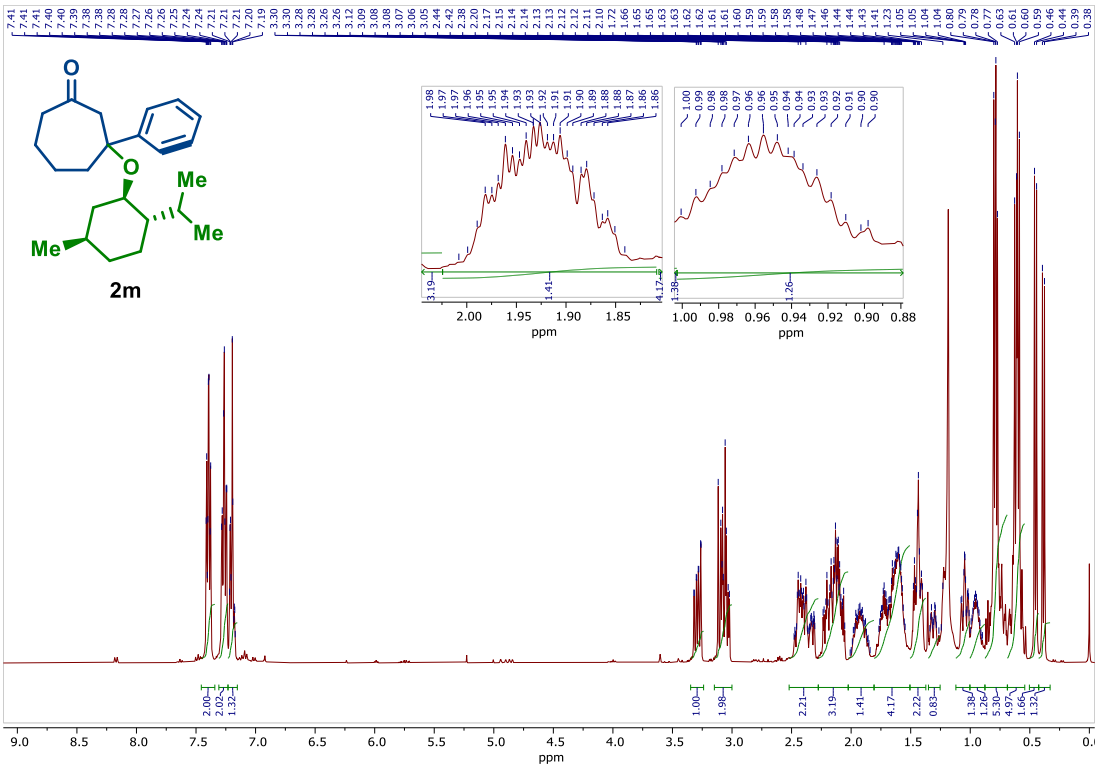
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2l** (*See Procedure*)



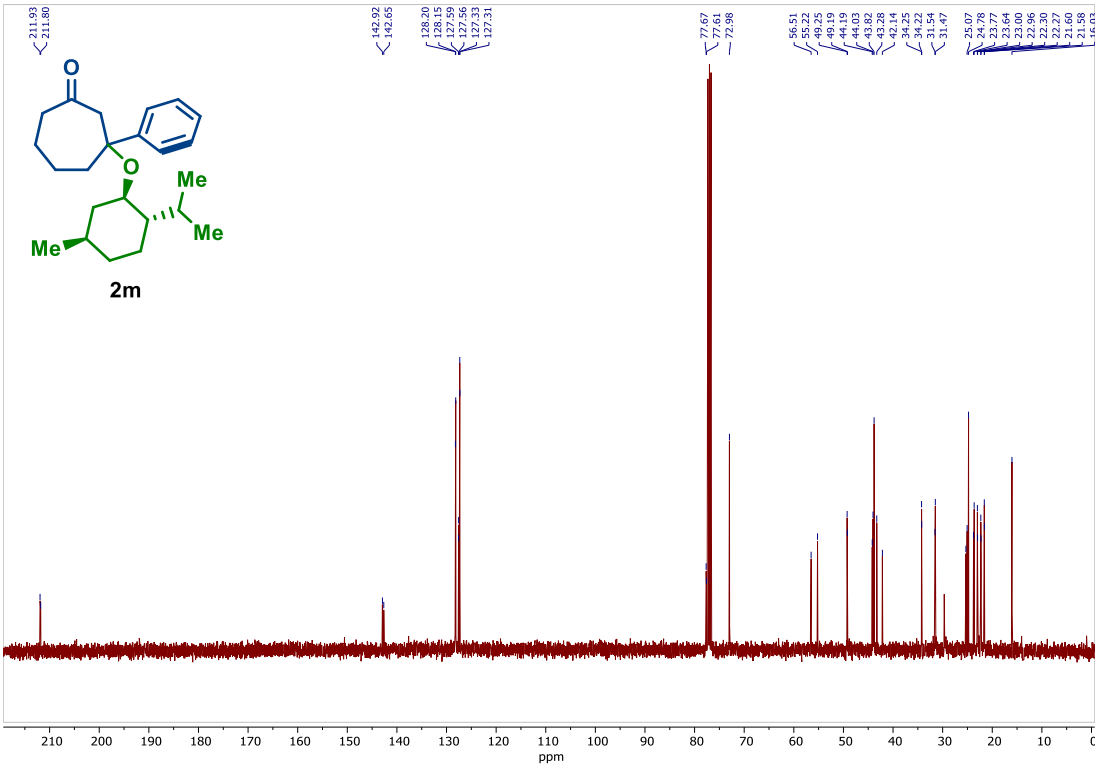
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2l**



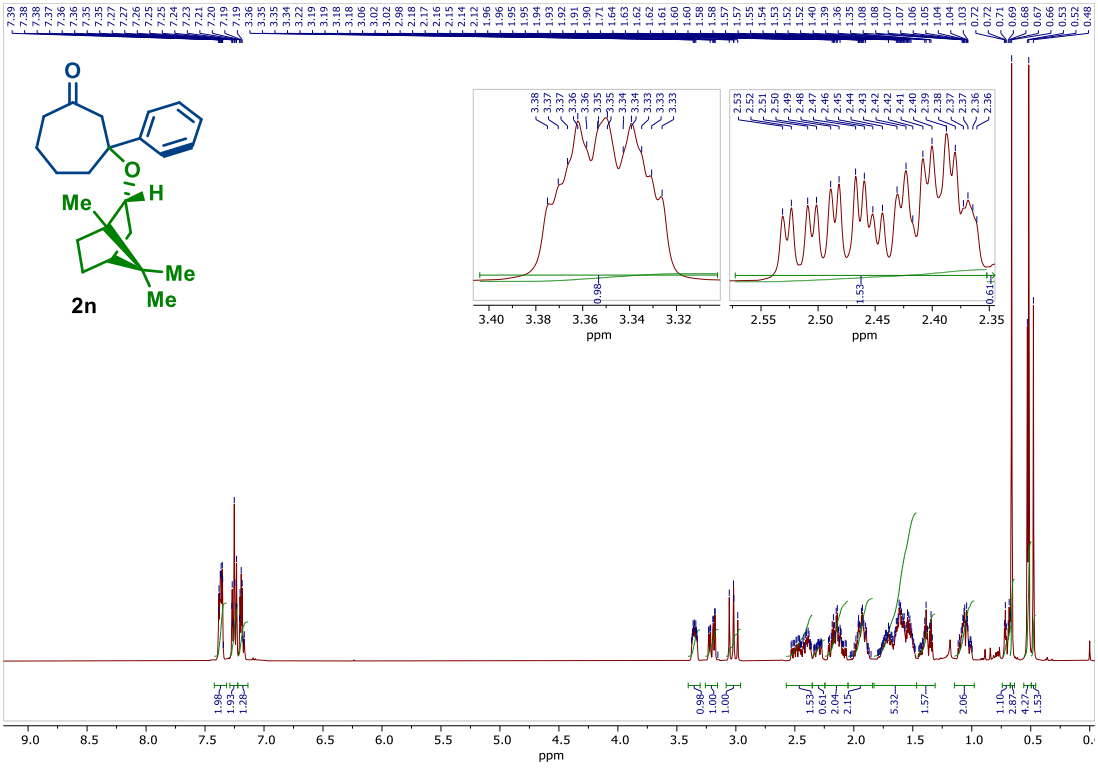
[1]H NMR (400 MHz, $CDCl_3$) spectra of compound **2m** (*See Procedure*)



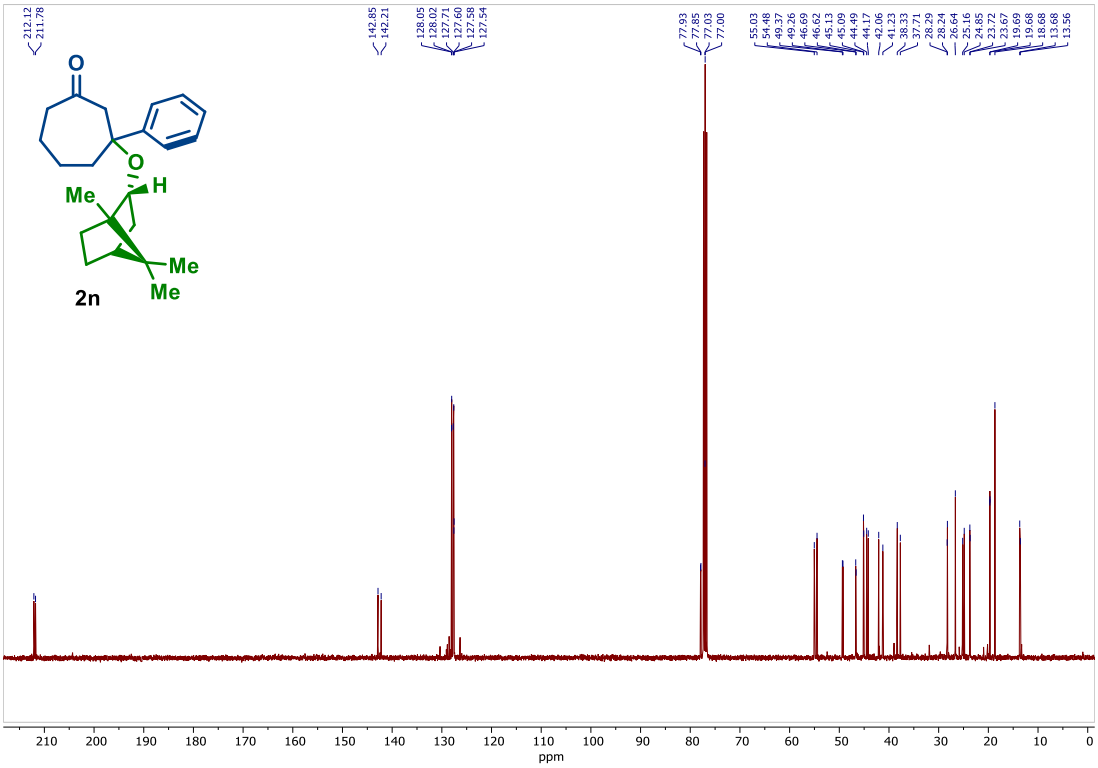
[13]C NMR (101 MHz, $CDCl_3$) spectra of compound **2m**



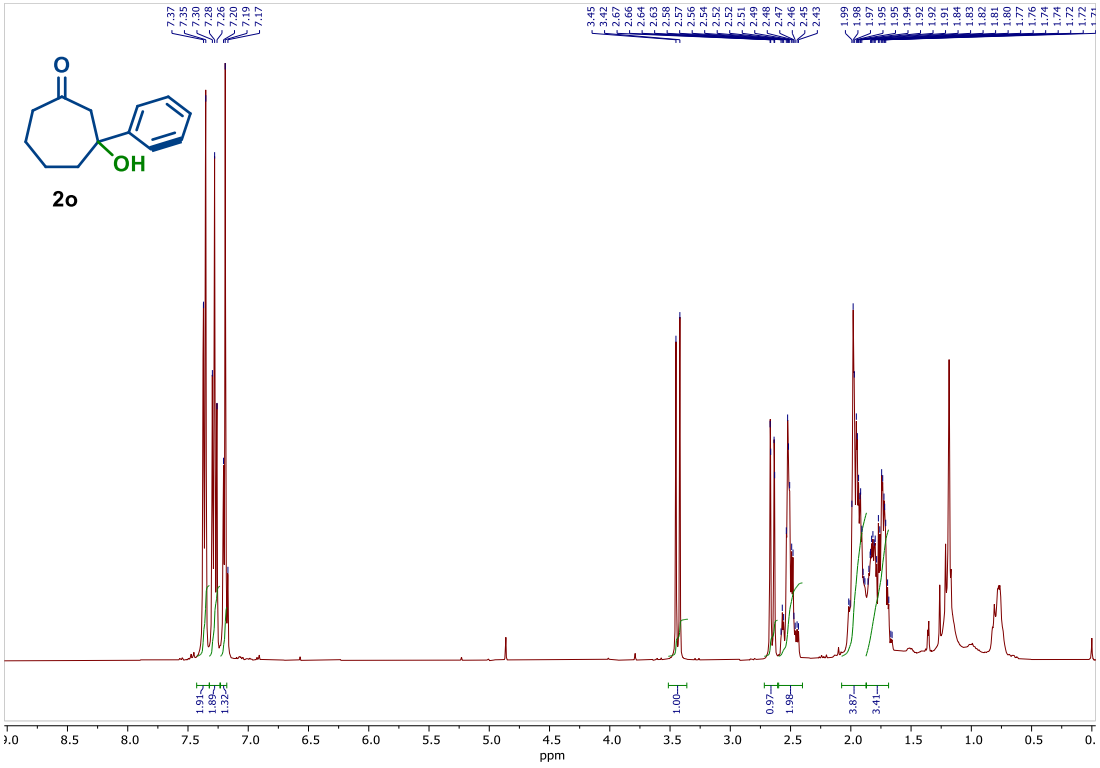
[1]H NMR (400 MHz, $CDCl_3$) spectra of compound **2n** (*See Procedure*)



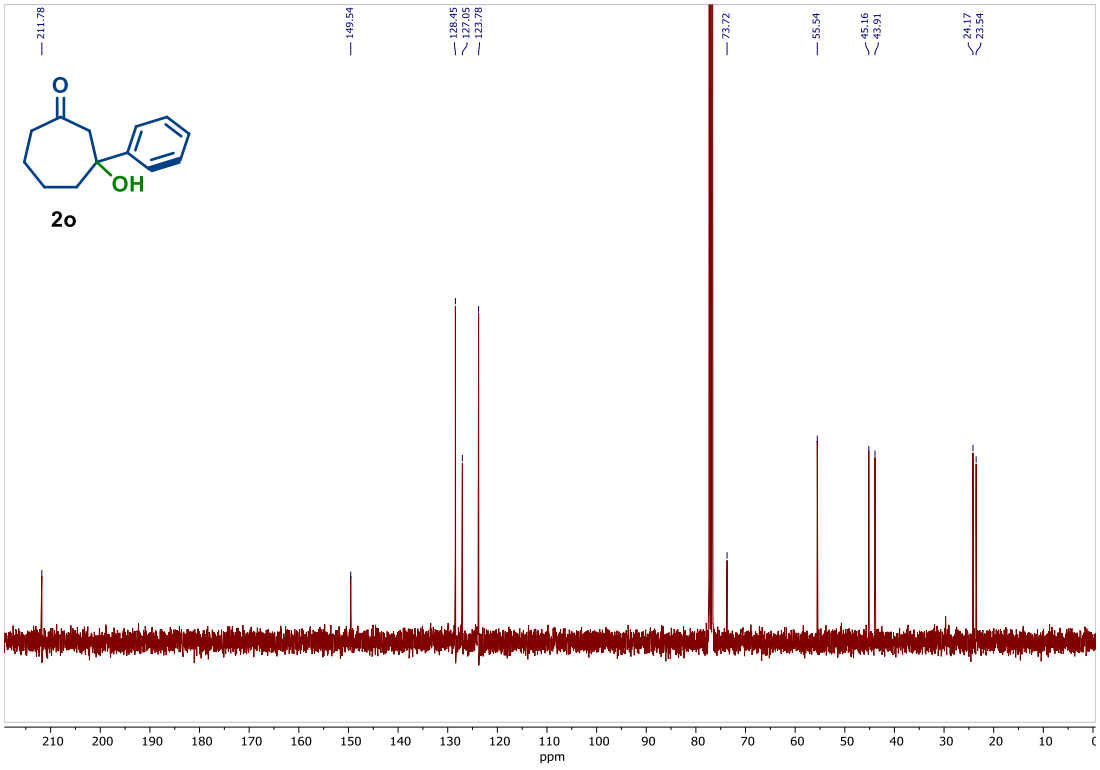
[13]C NMR (101 MHz, $CDCl_3$) spectra of compound **2n**



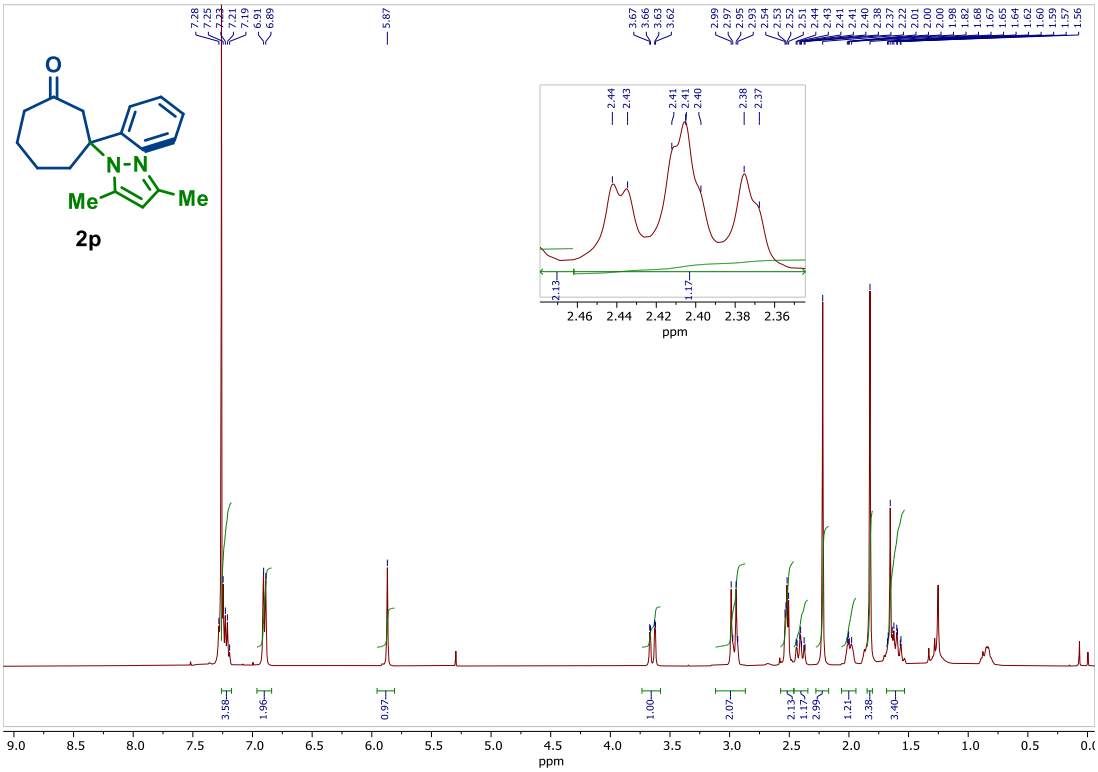
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2o** (*See Procedure*)



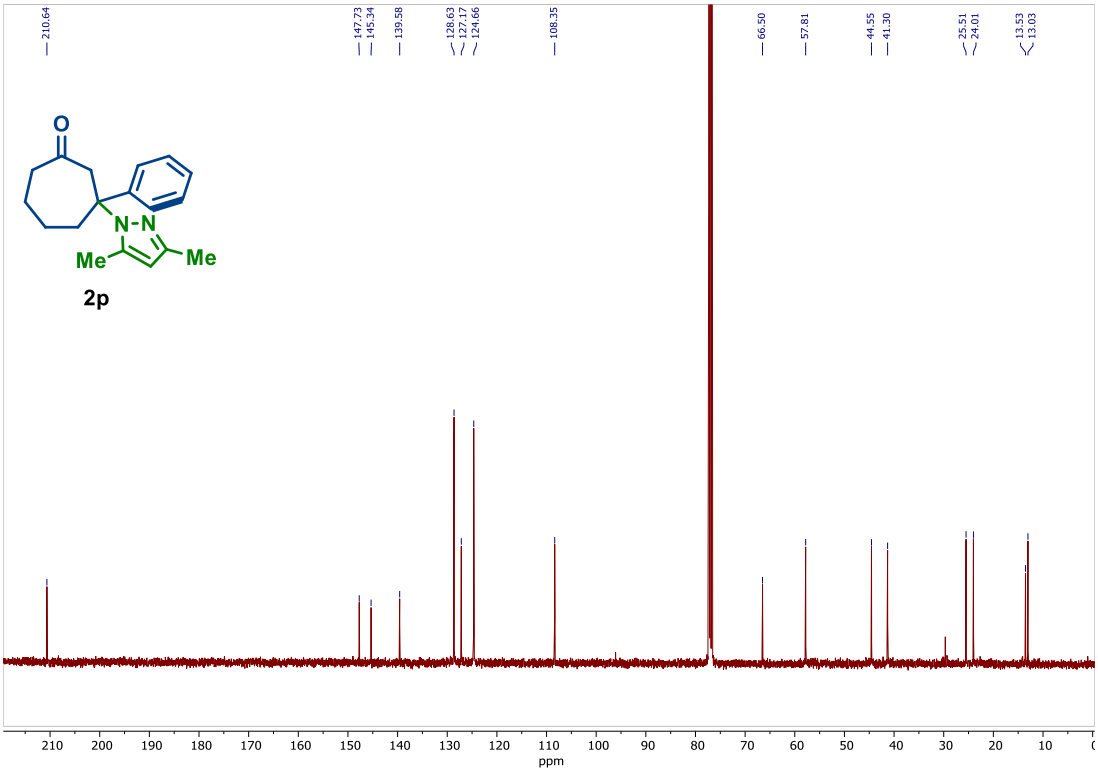
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2o**



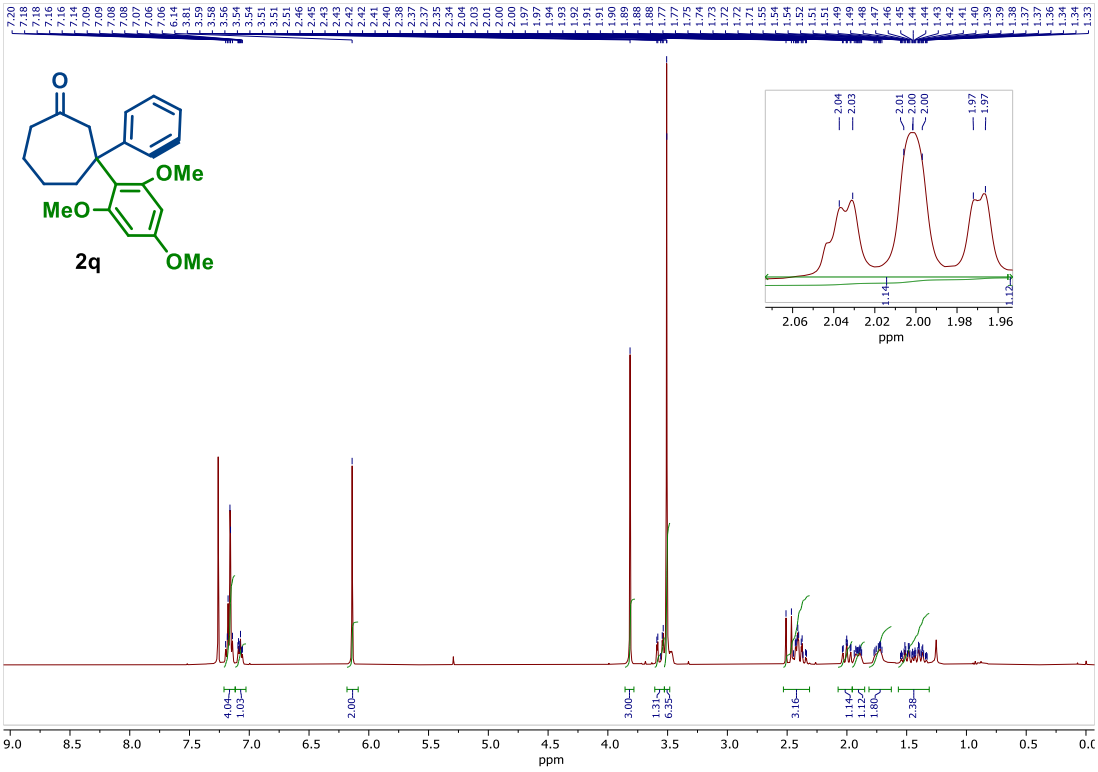
[1]H NMR (400 MHz, $CDCl_3$) spectra of compound **2p** (*See Procedure*)



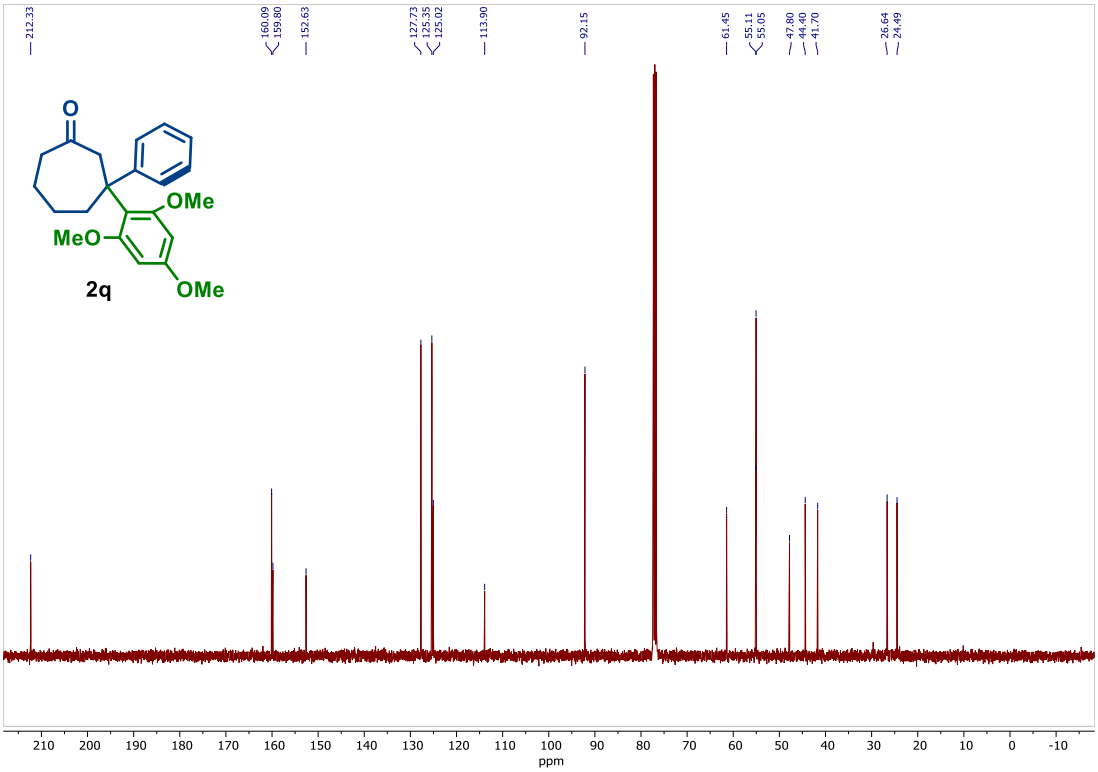
[13]C NMR (101 MHz, $CDCl_3$) spectra of compound **2p**



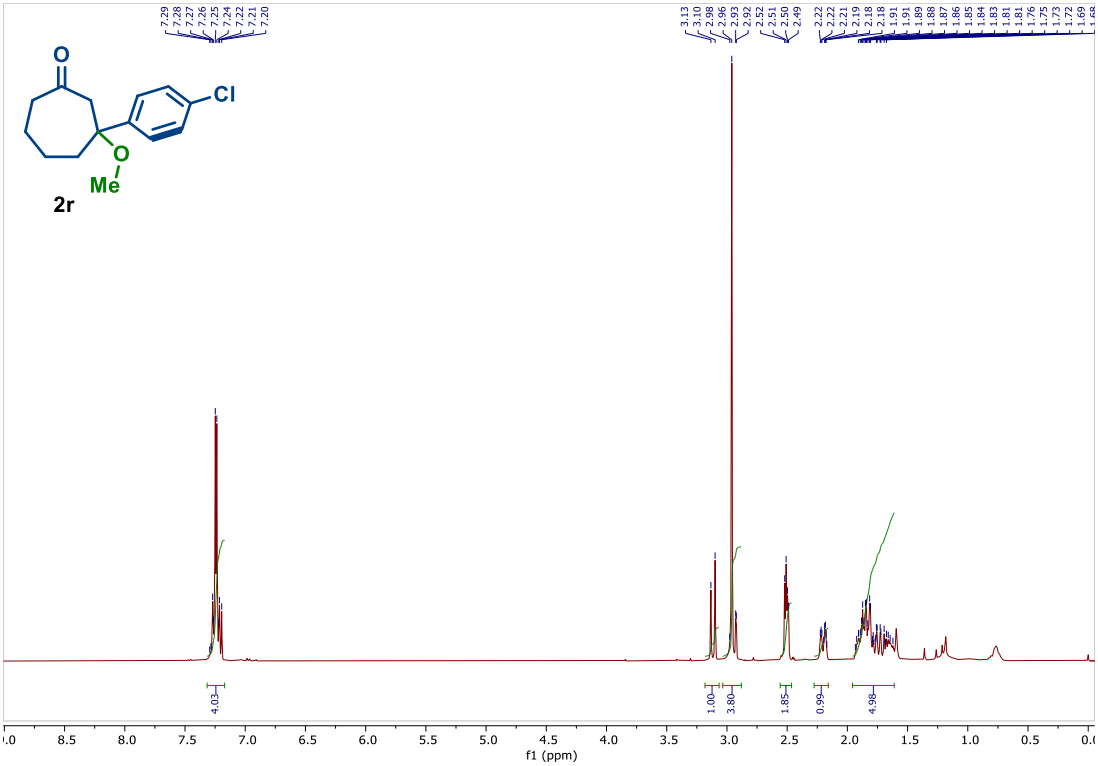
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2q** (*See Procedure*)



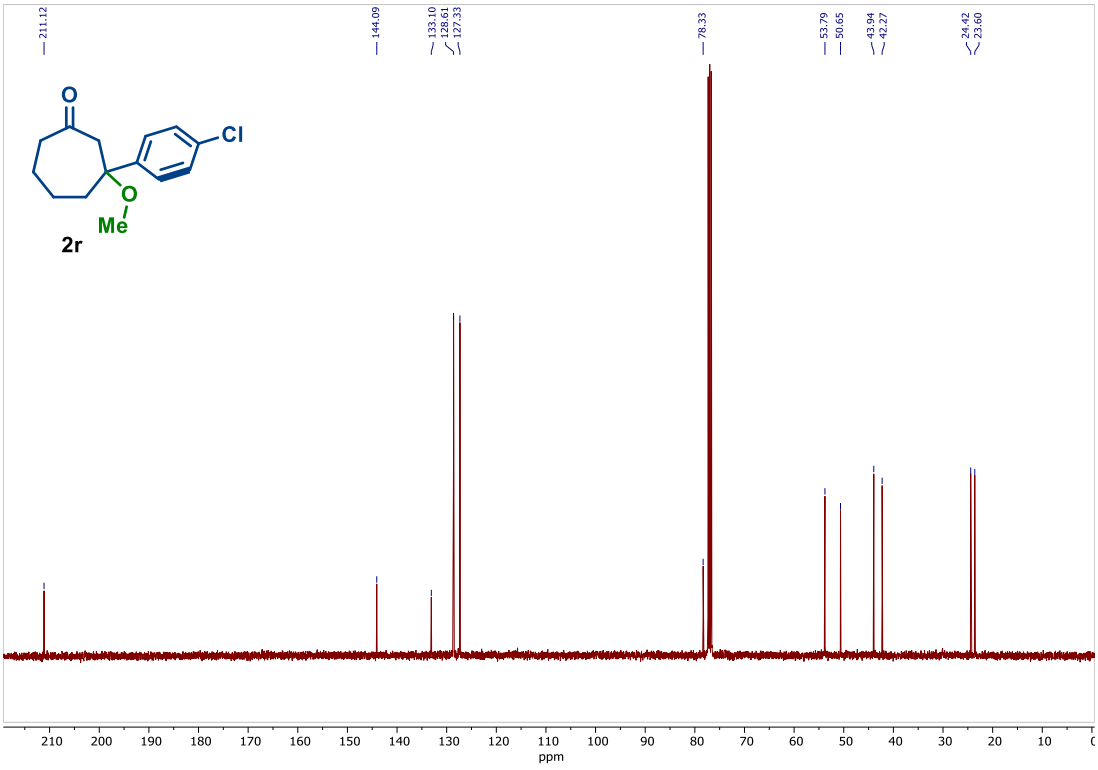
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2q**



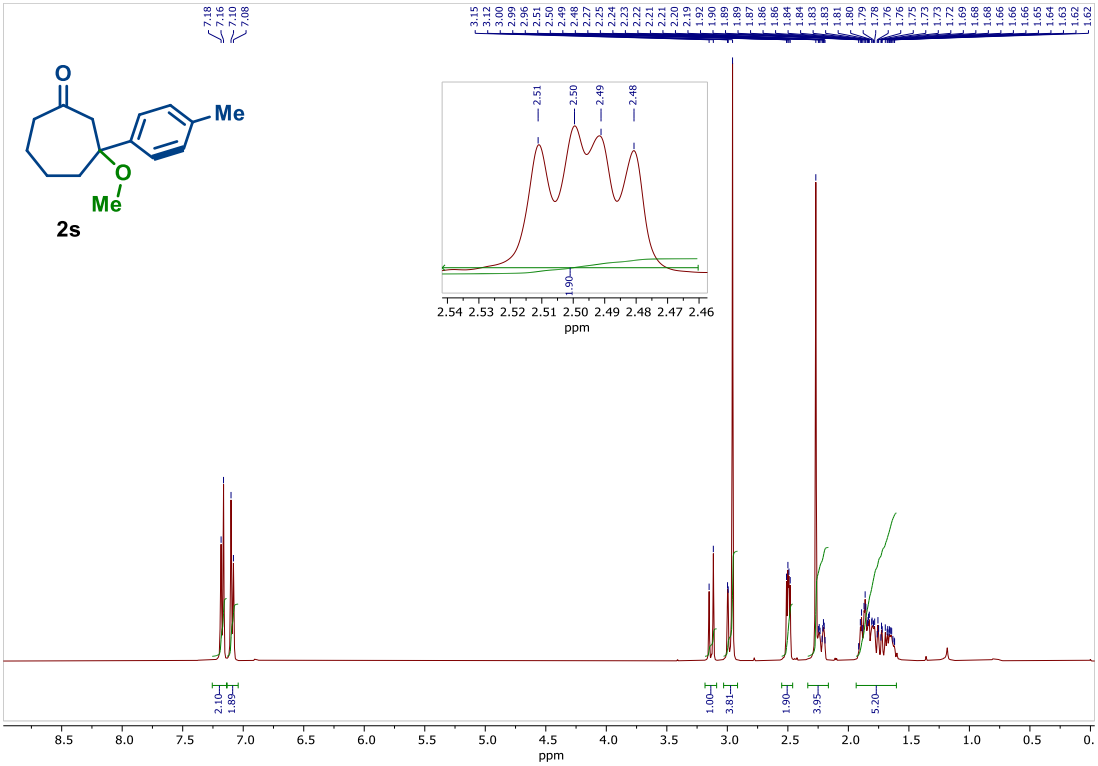
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2r** (*See Procedure*)



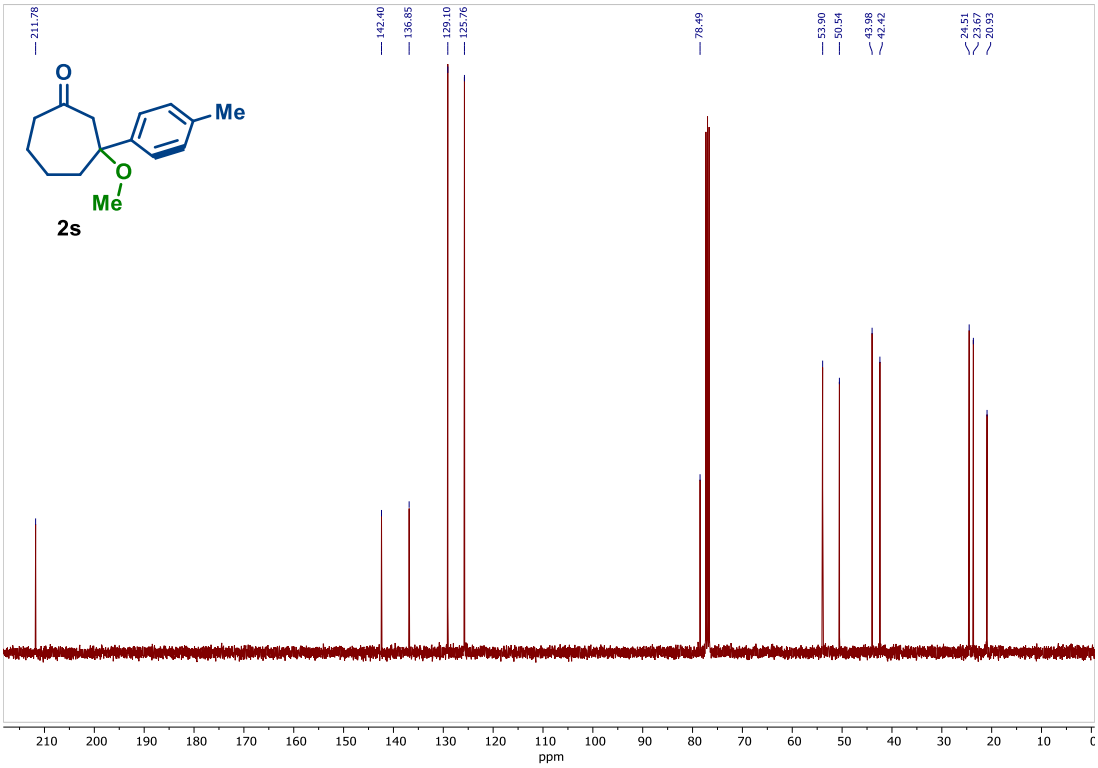
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2r**



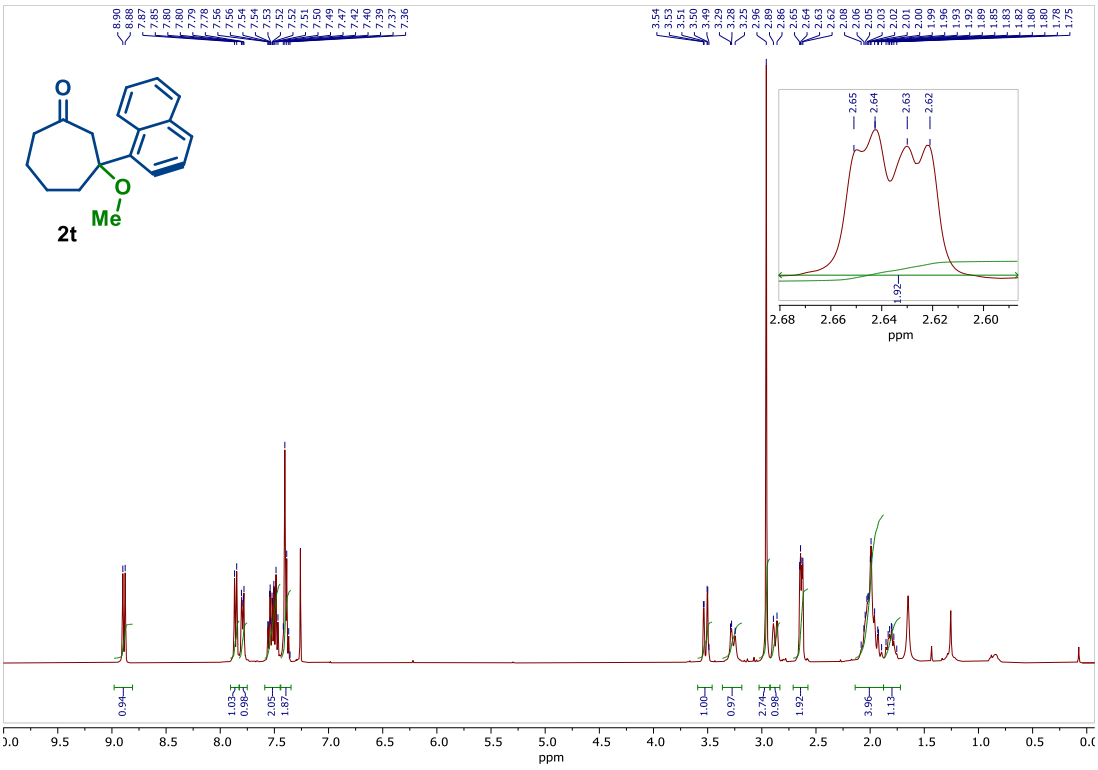
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2s** (*See Procedure*)



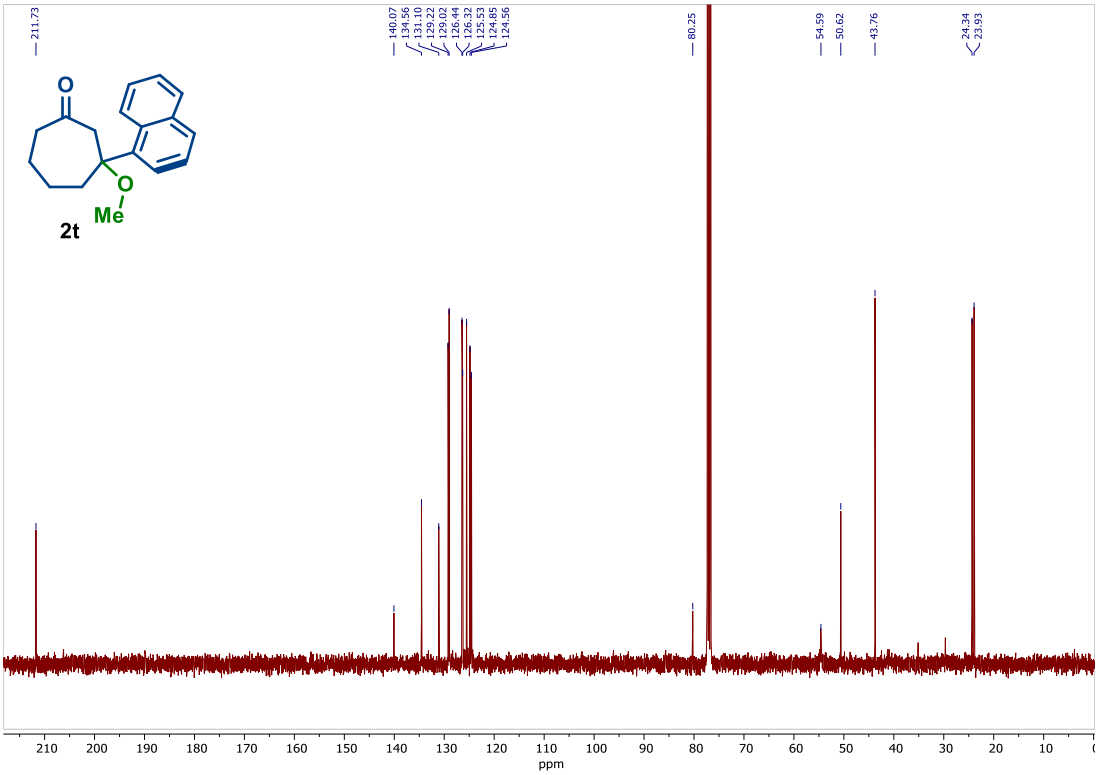
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2s**



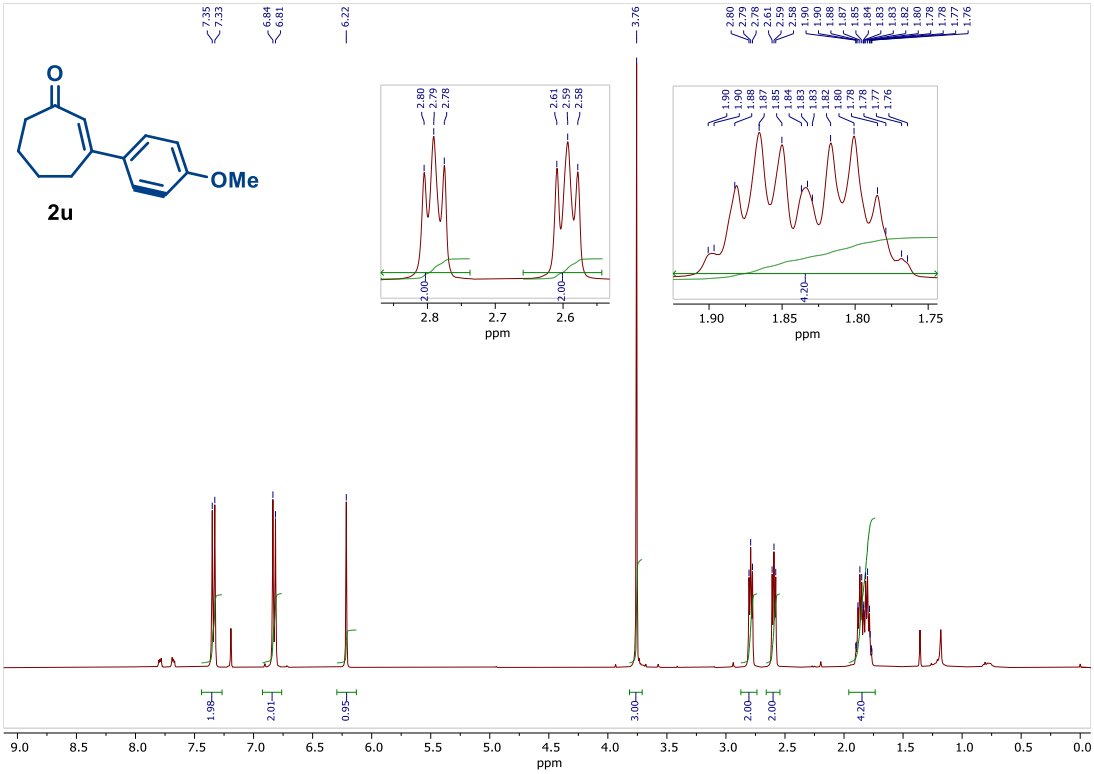
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2t** (*See Procedure*)



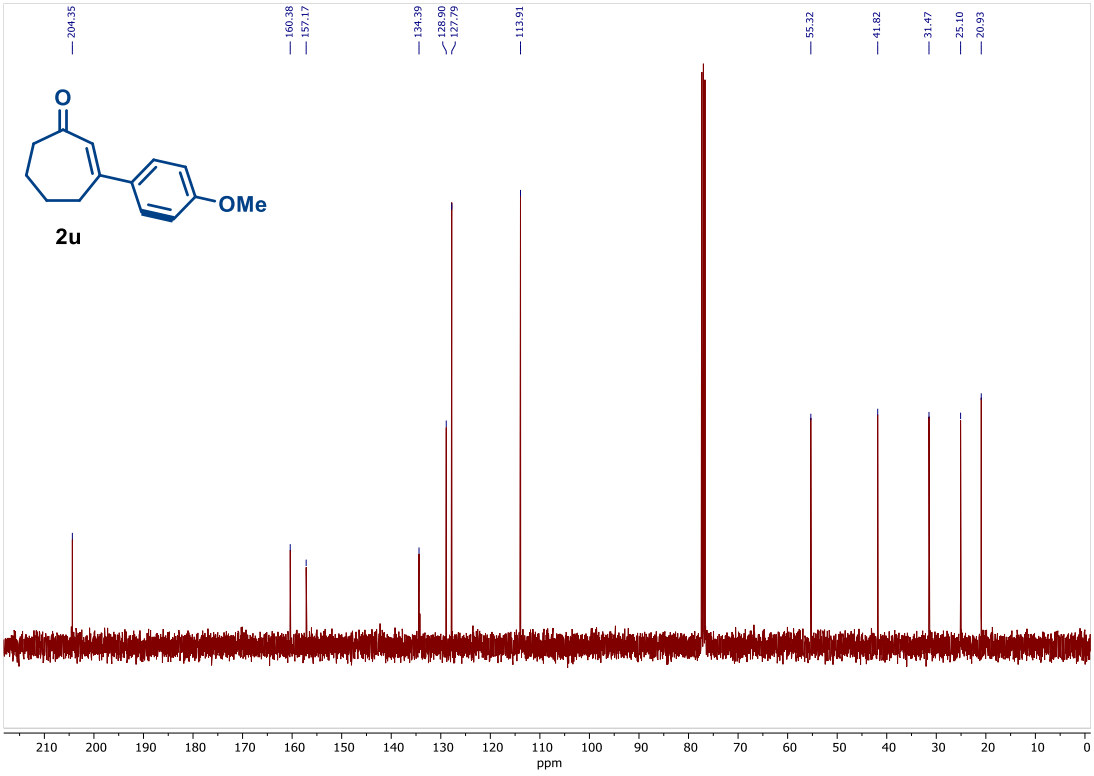
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2t**



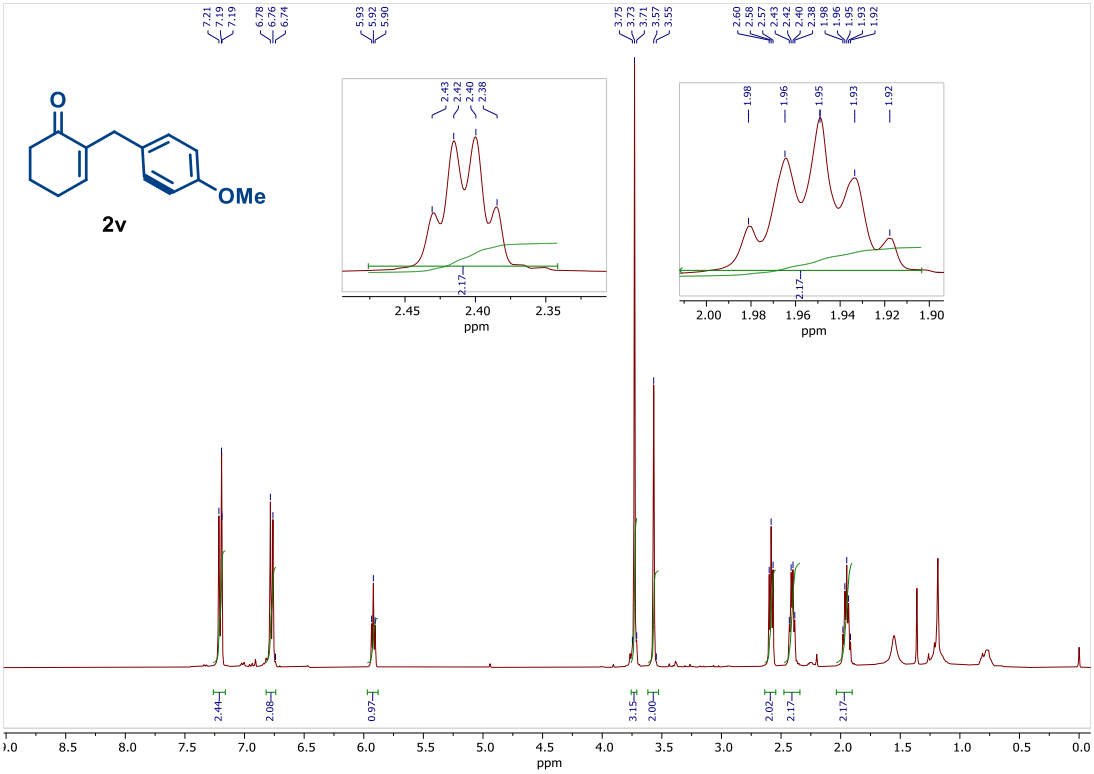
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2u** (*See Procedure*)



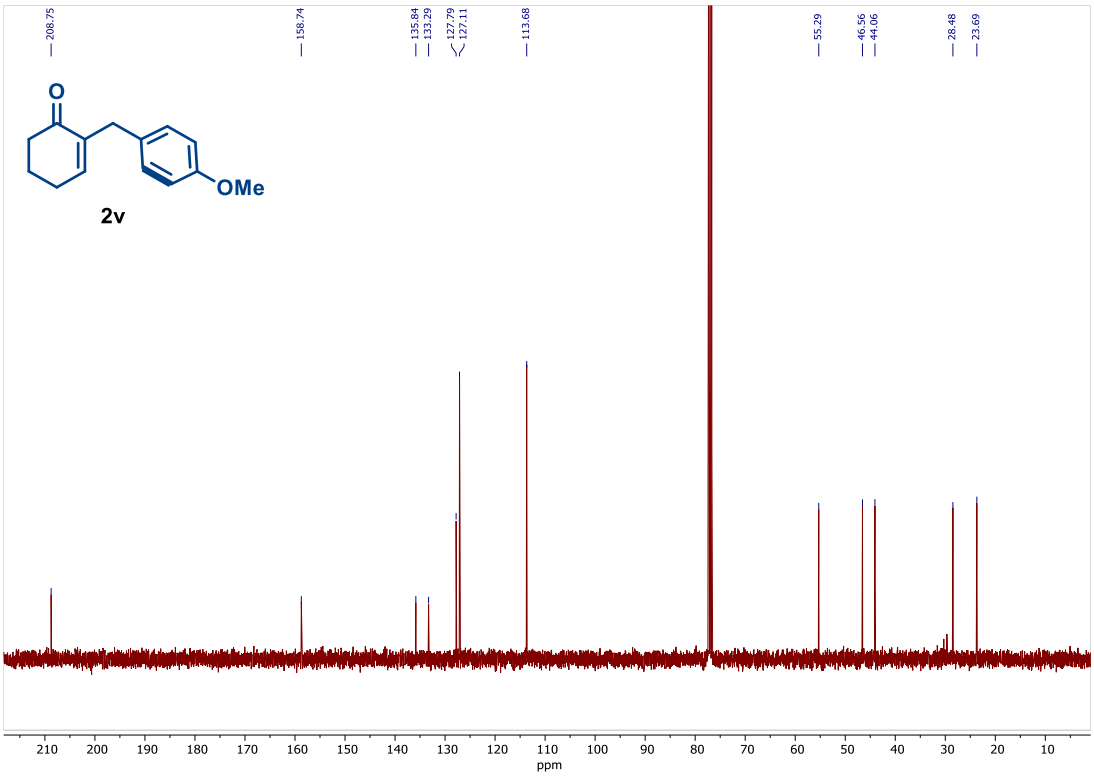
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2u**



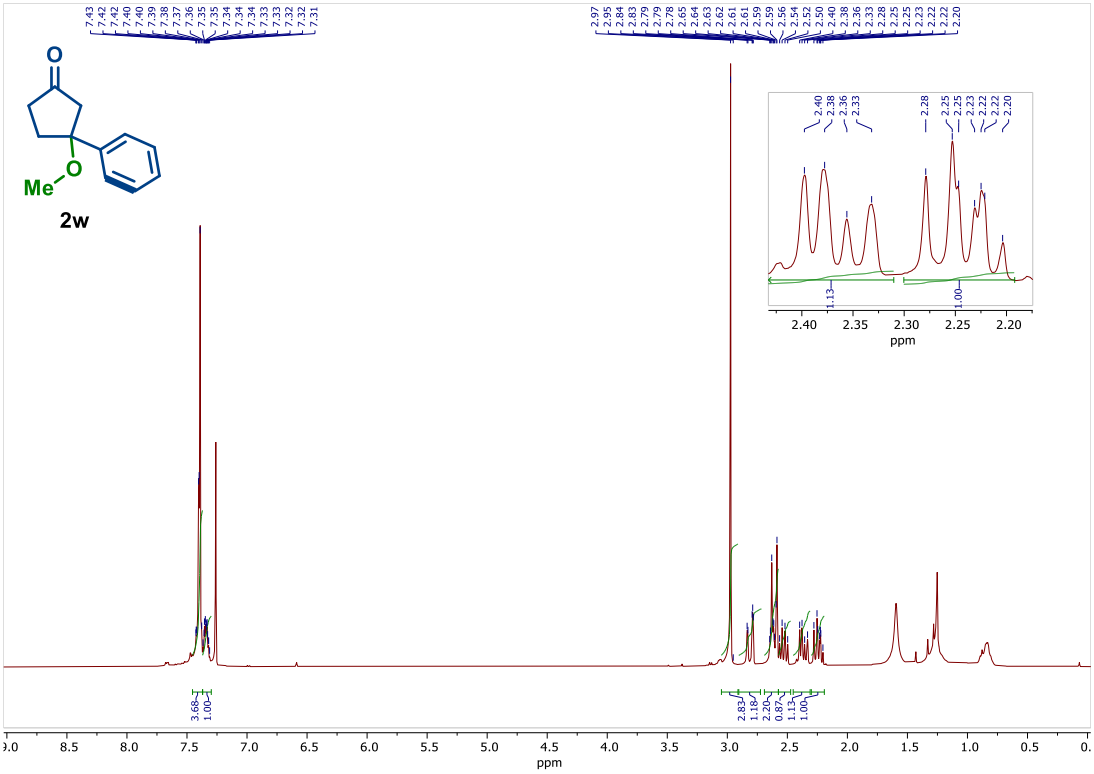
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2v** (*See Procedure*)



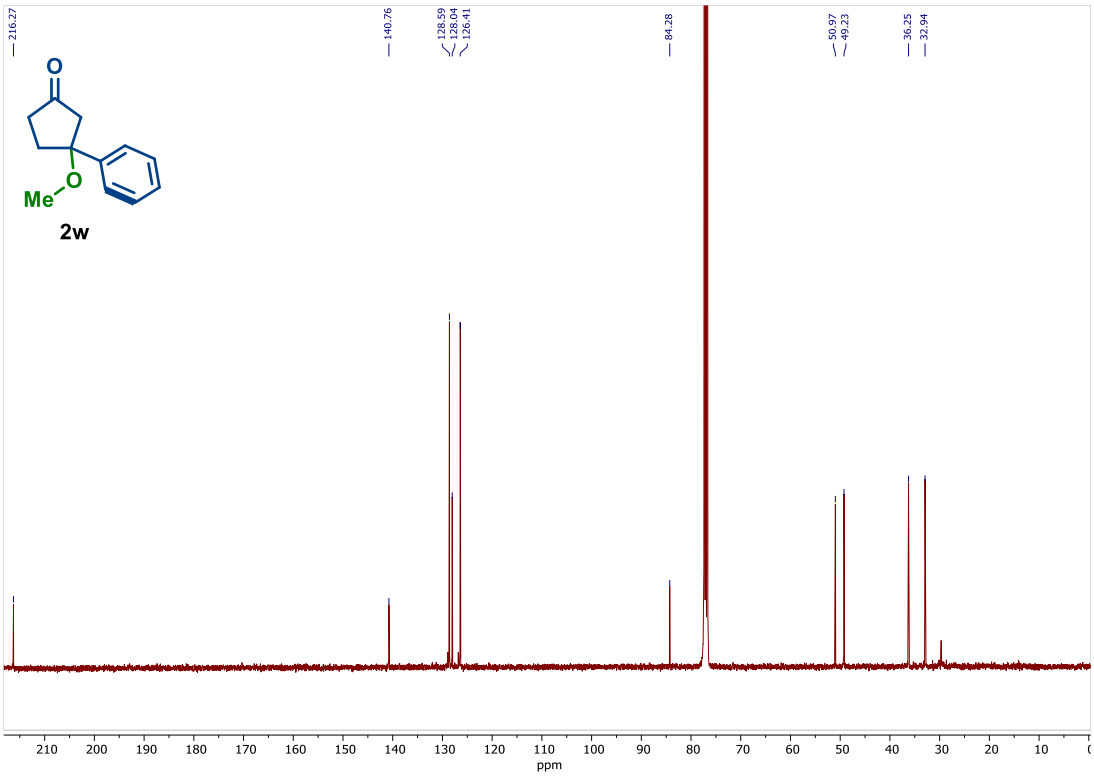
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2v**



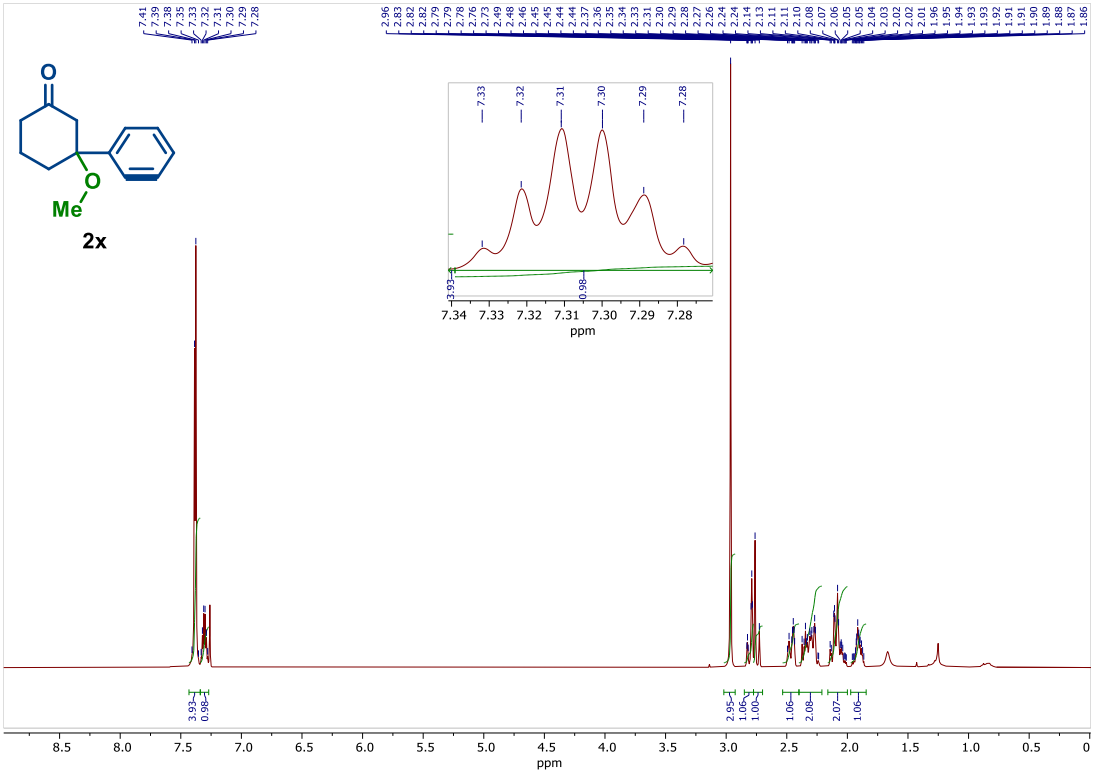
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2w** (*See Procedure*)



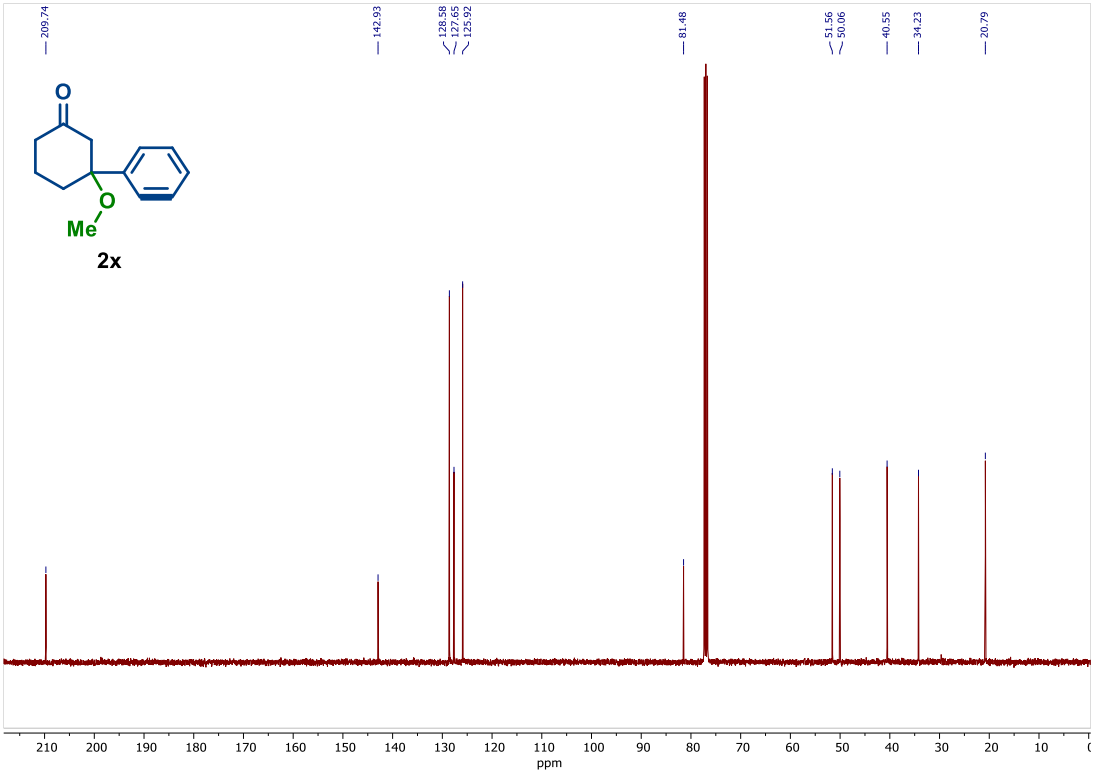
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2w**



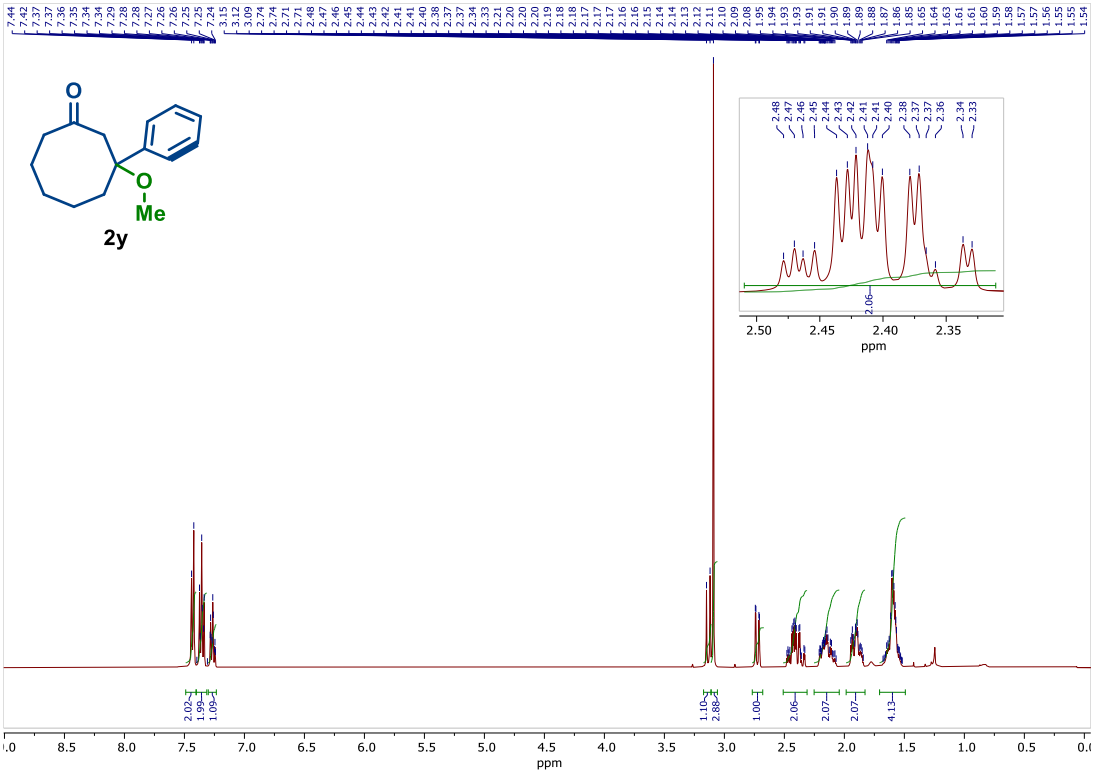
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2x** (*See Procedure*)



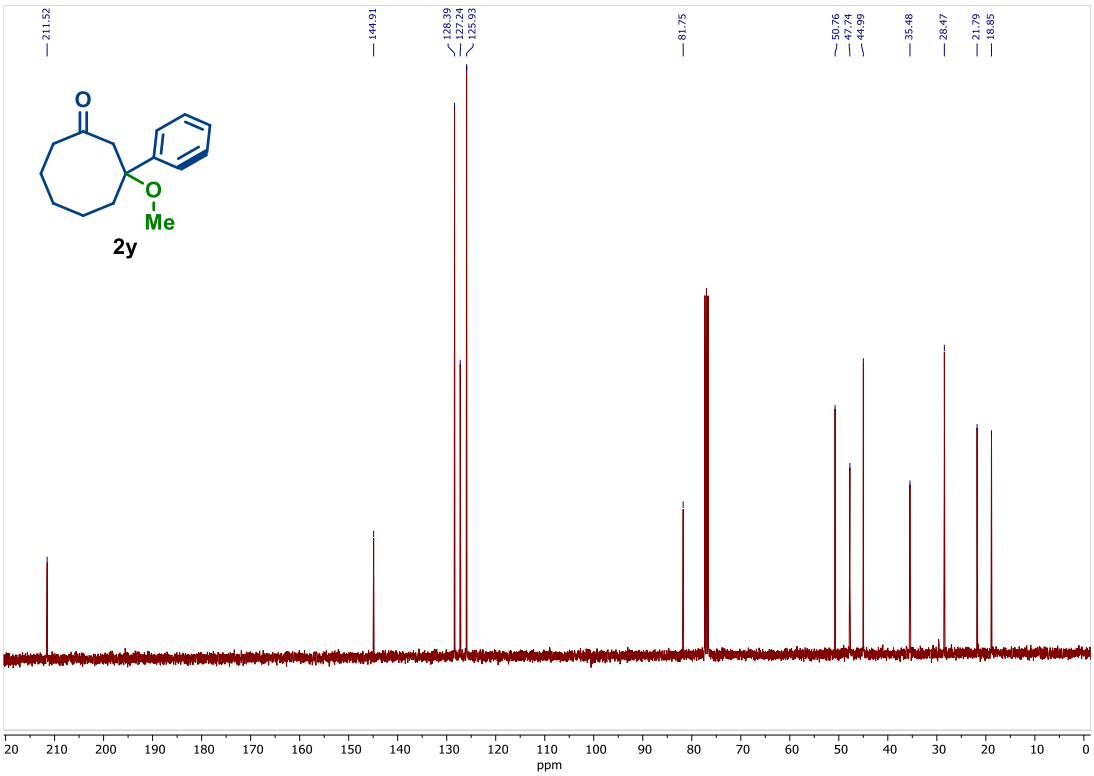
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2x**



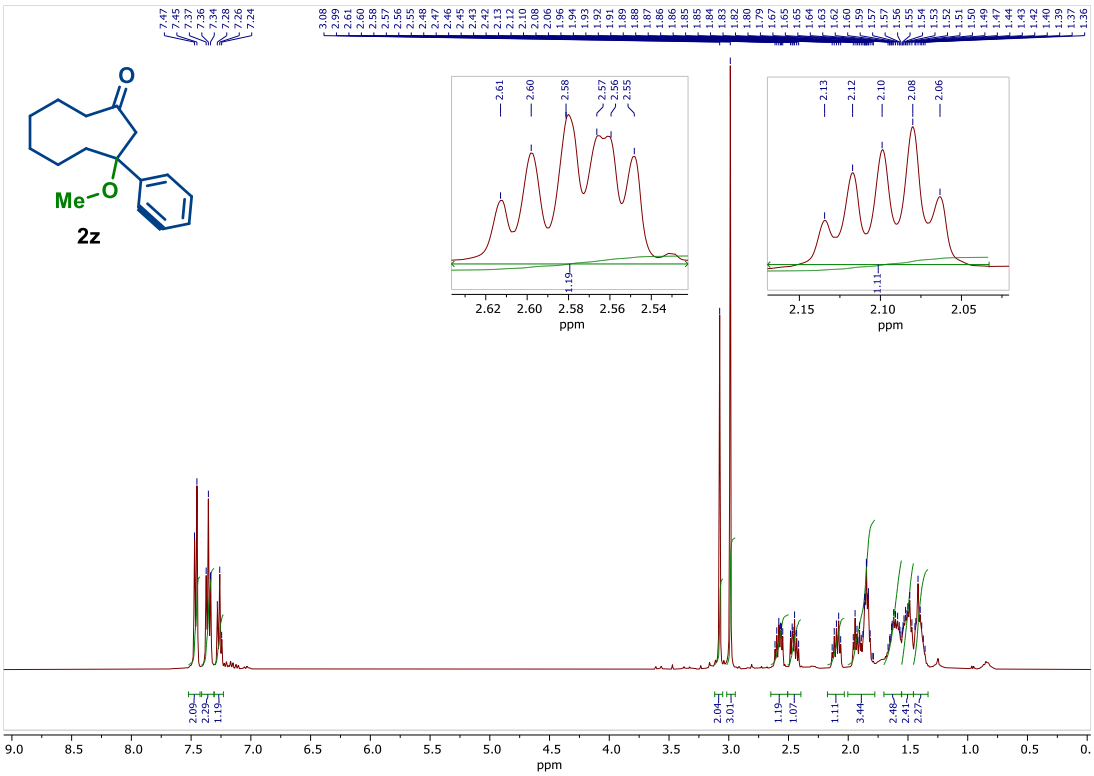
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2y** (*See Procedure*)



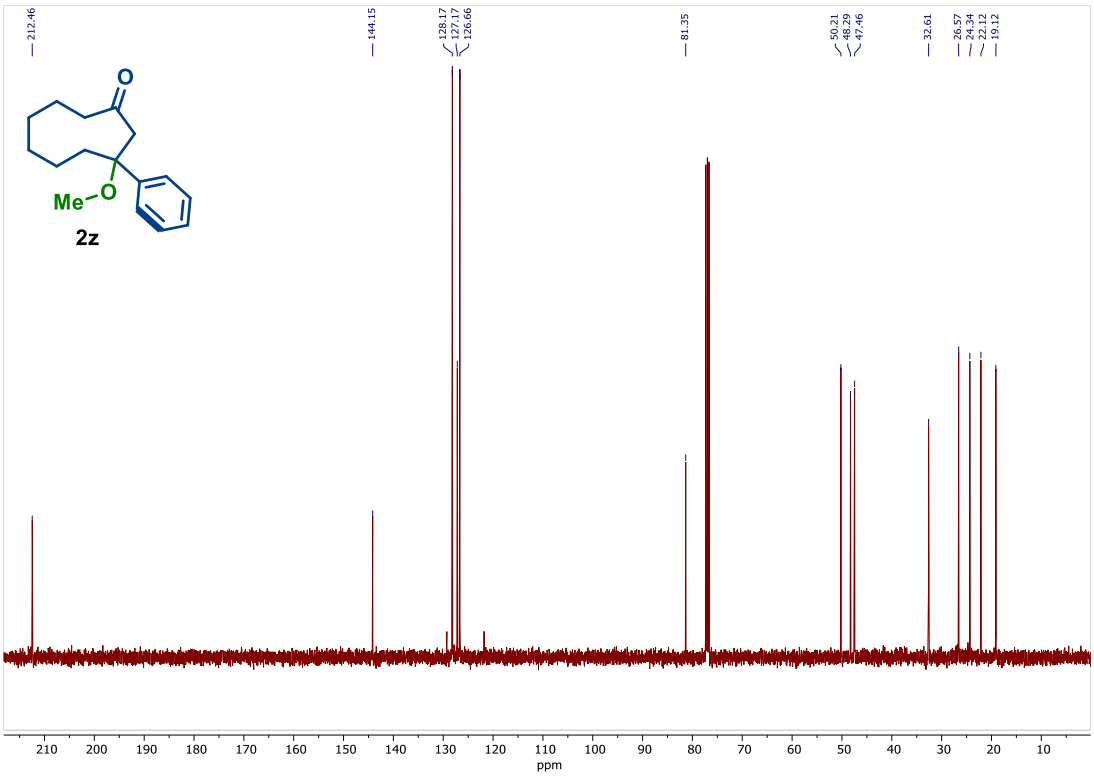
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2y**



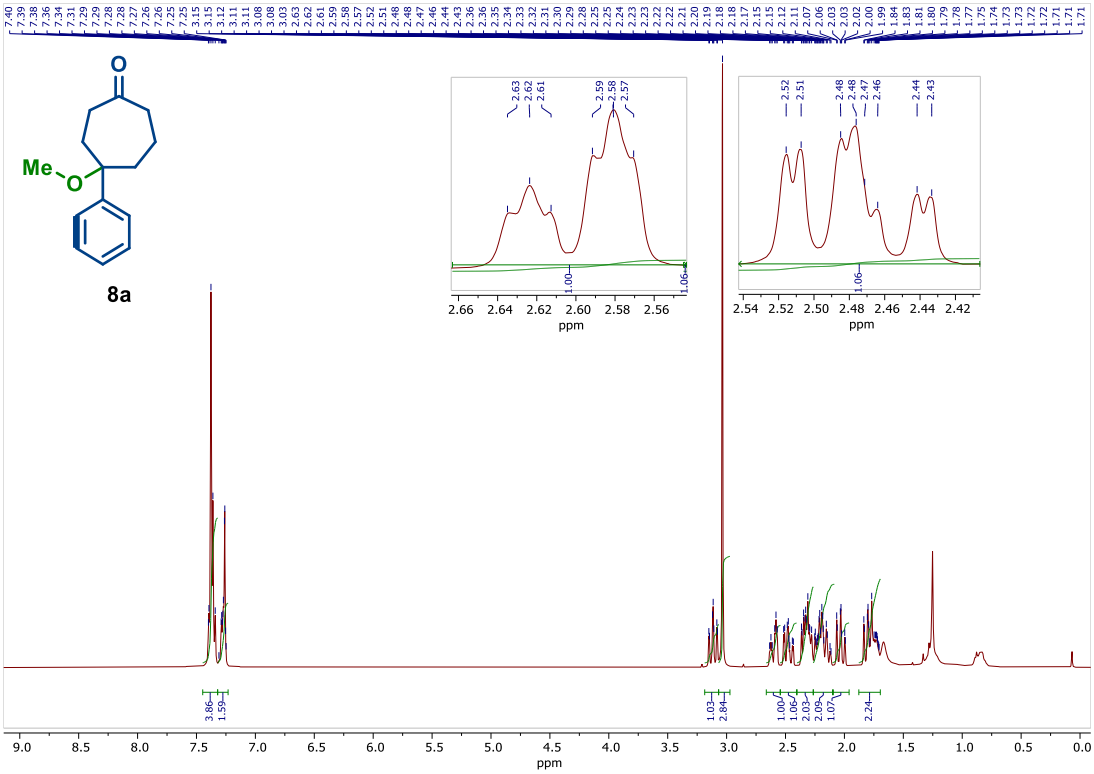
[1]H NMR (400 MHz, $CDCl_3$) spectra of compound **2z** (*See Procedure*)



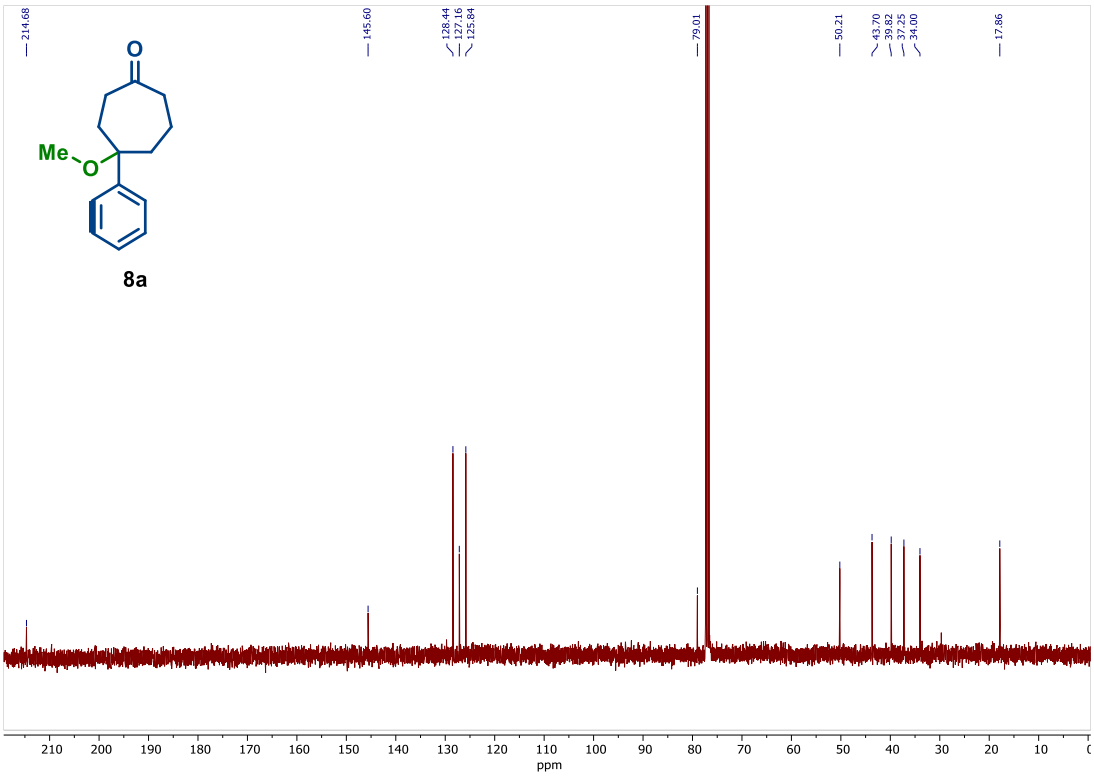
[13]C NMR (101 MHz, $CDCl_3$) spectra of compound **2z**



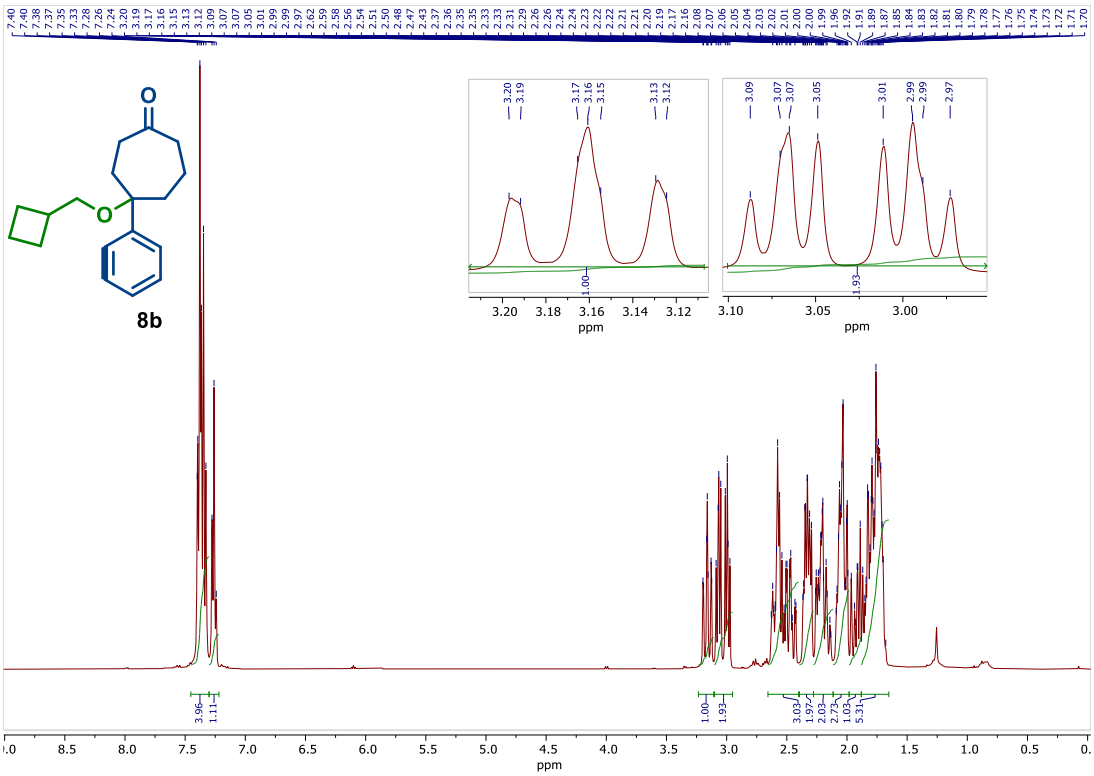
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **8a** (*See Procedure*)



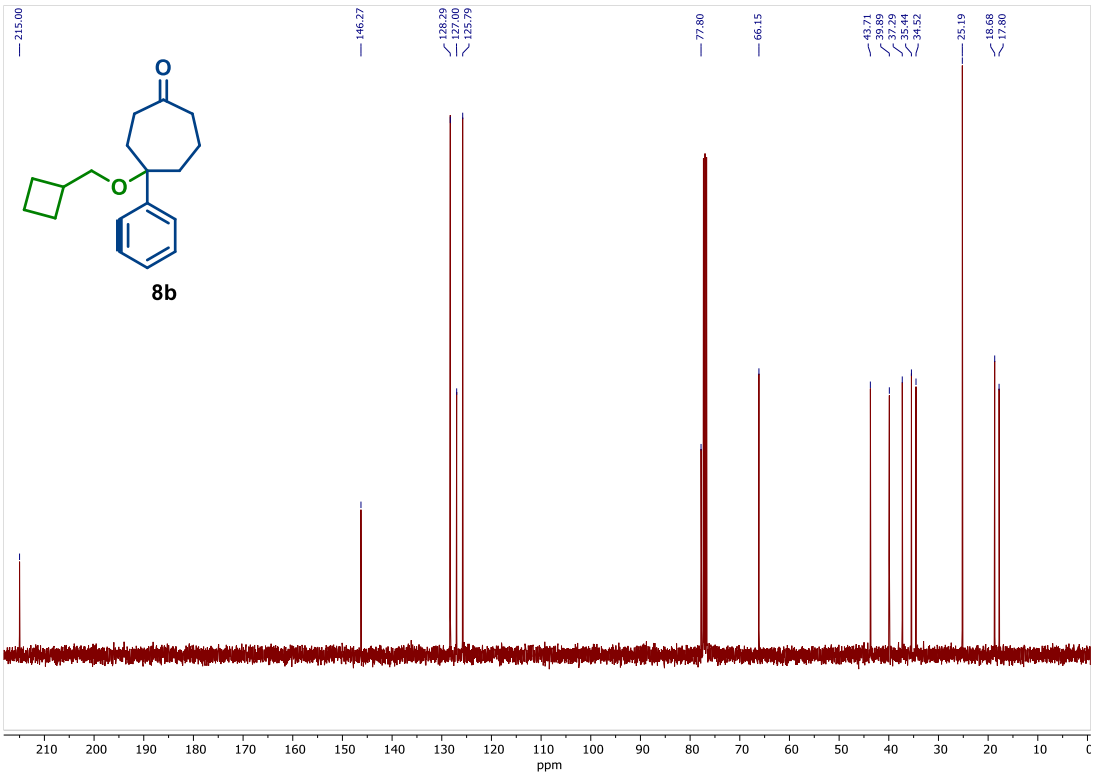
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **8a**



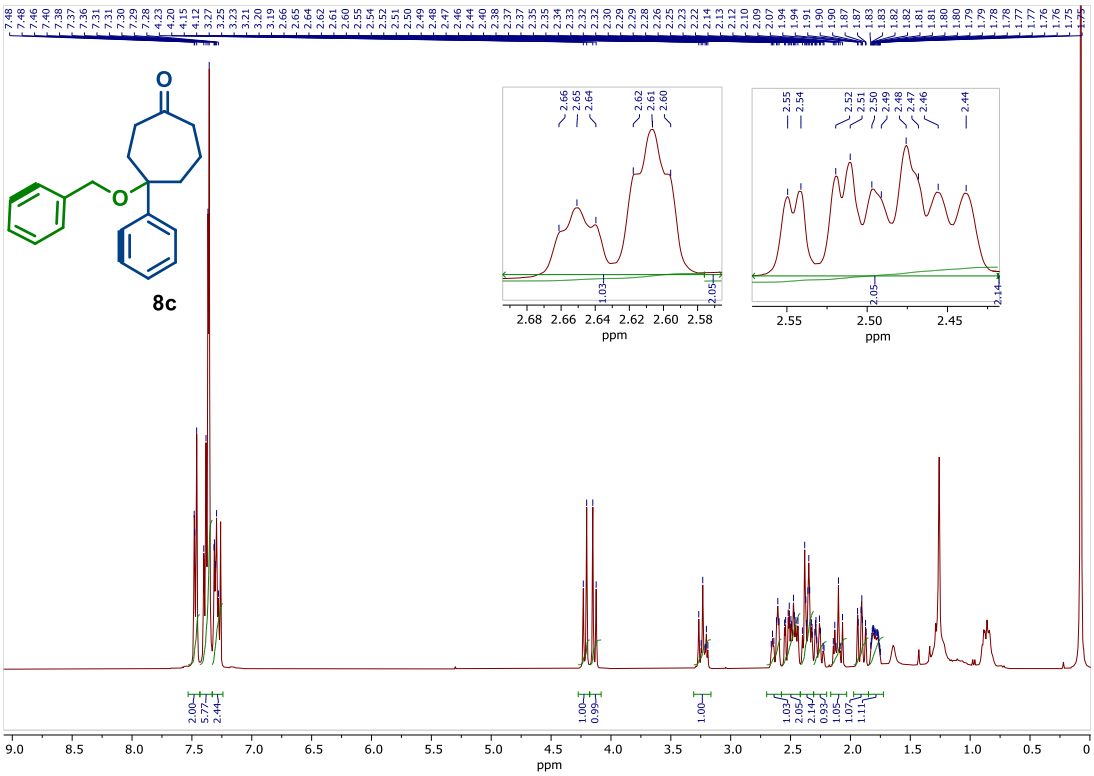
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **8b** (*See Procedure*)



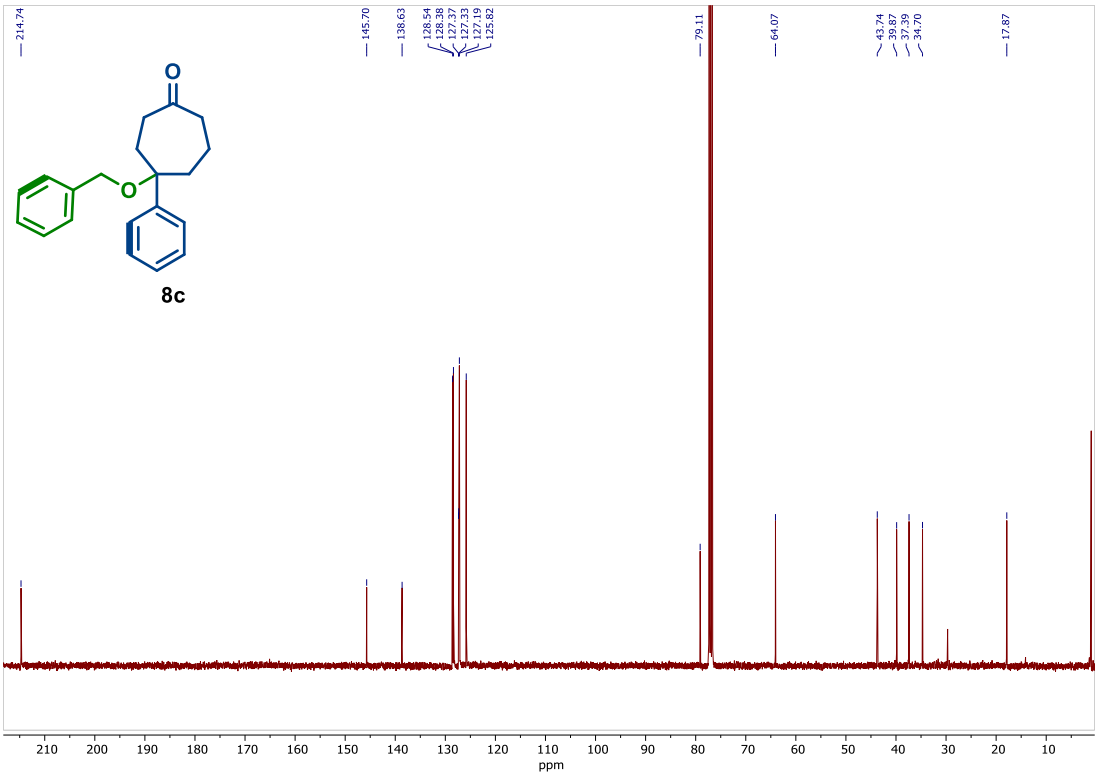
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **8b**



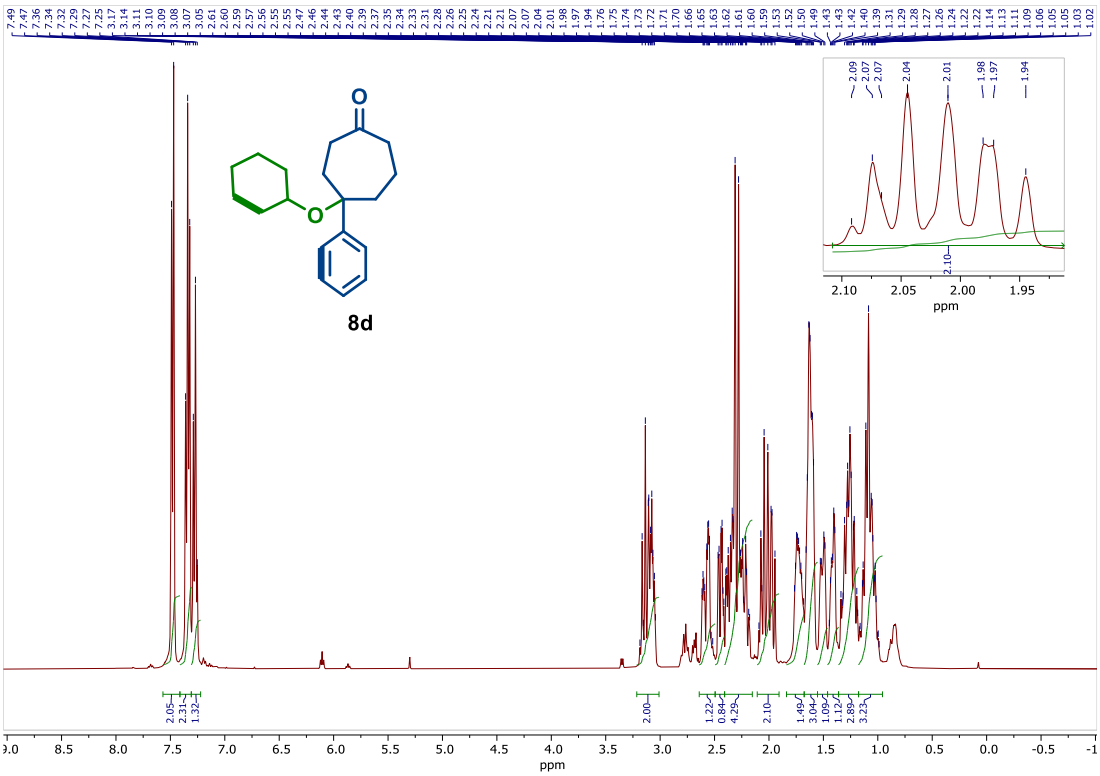
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **8c** (*See Procedure*)



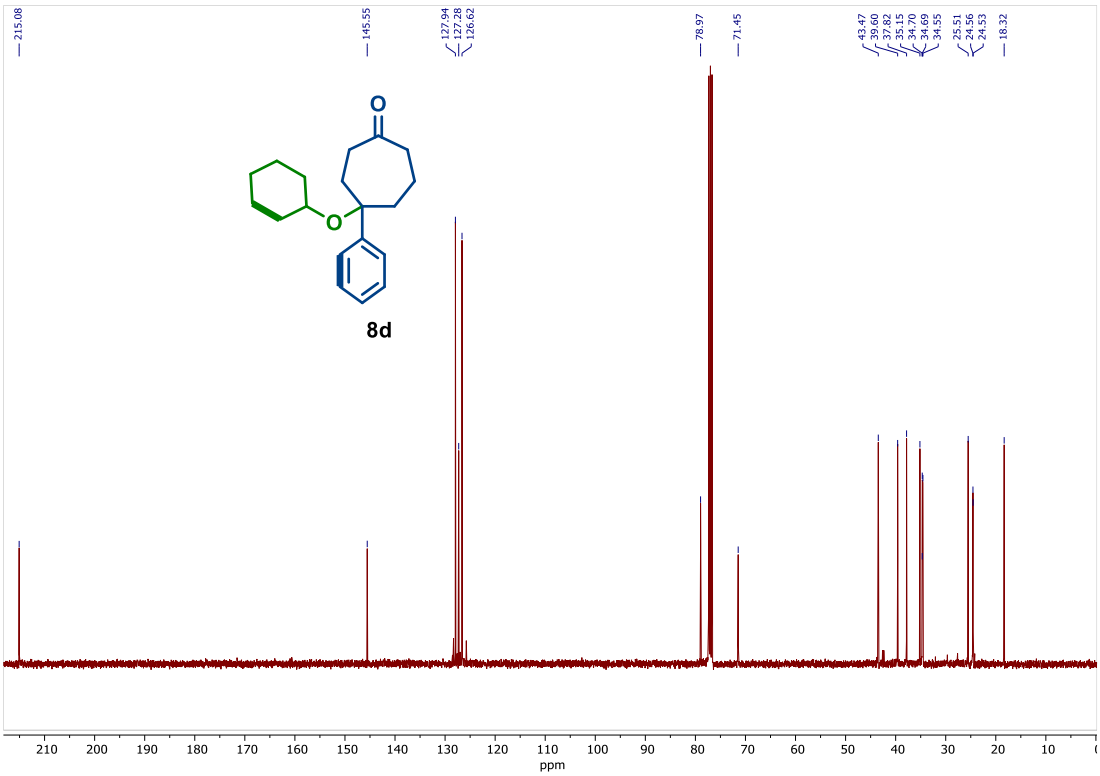
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **8c**



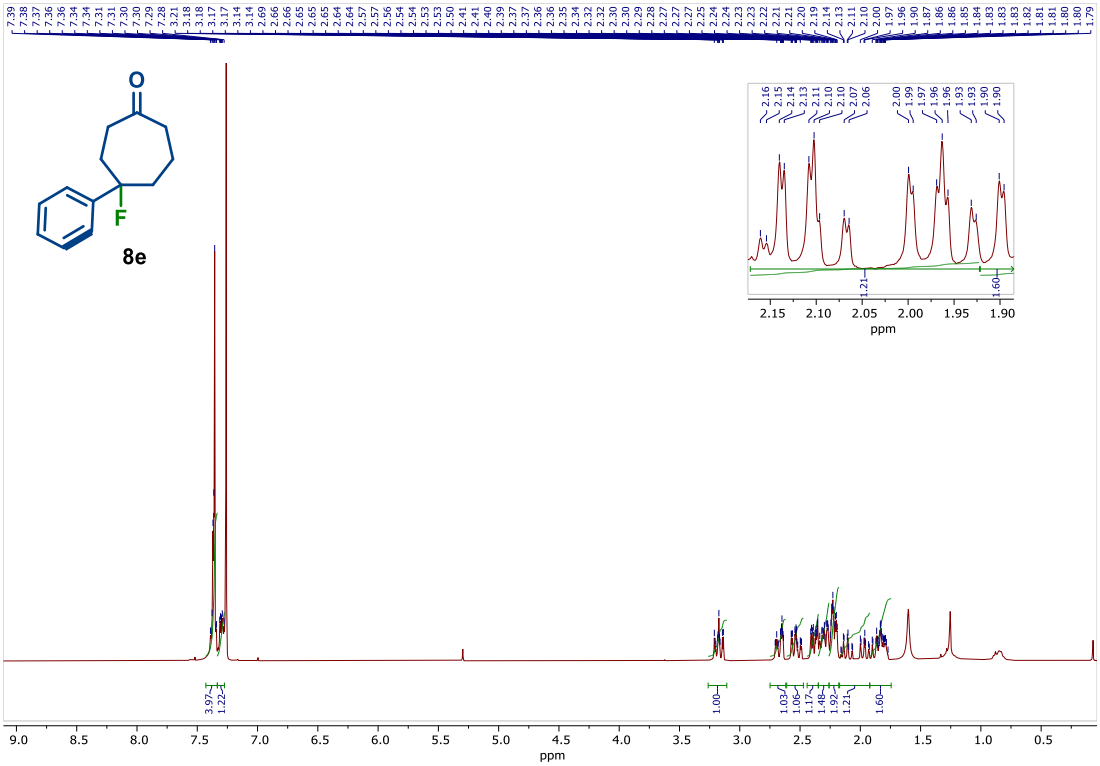
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **8d** (*See Procedure*)



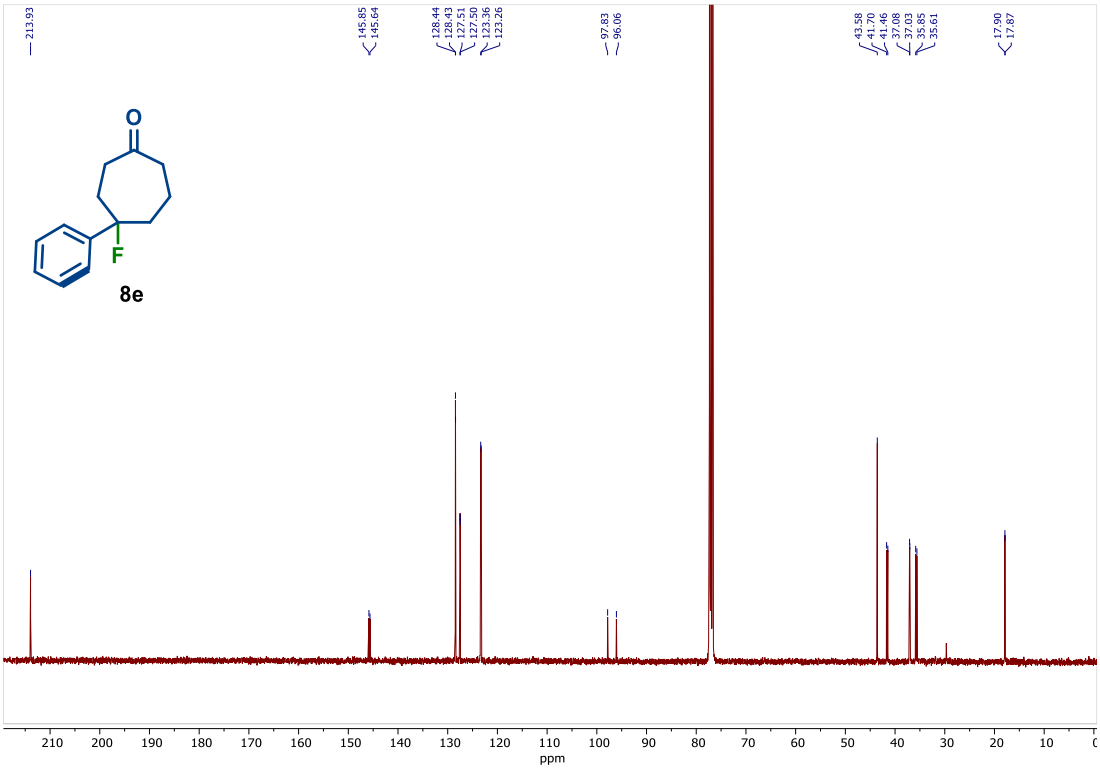
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **8d**



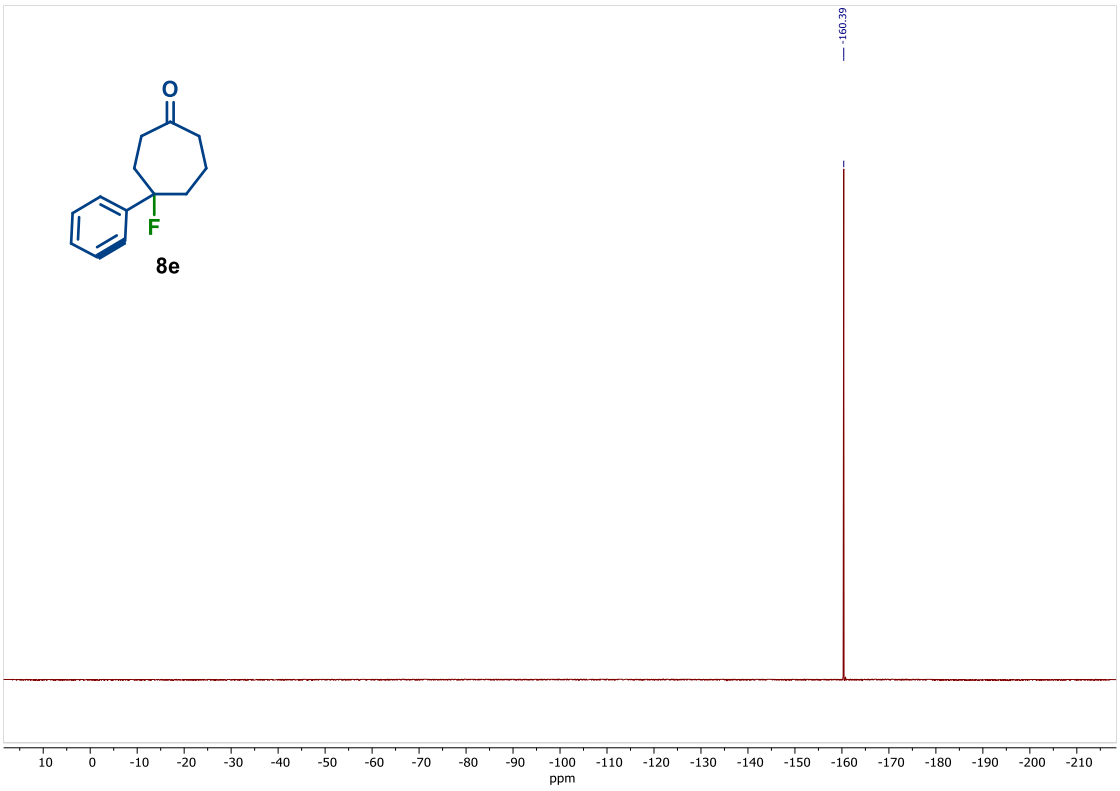
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **8e** (*See Procedure*)



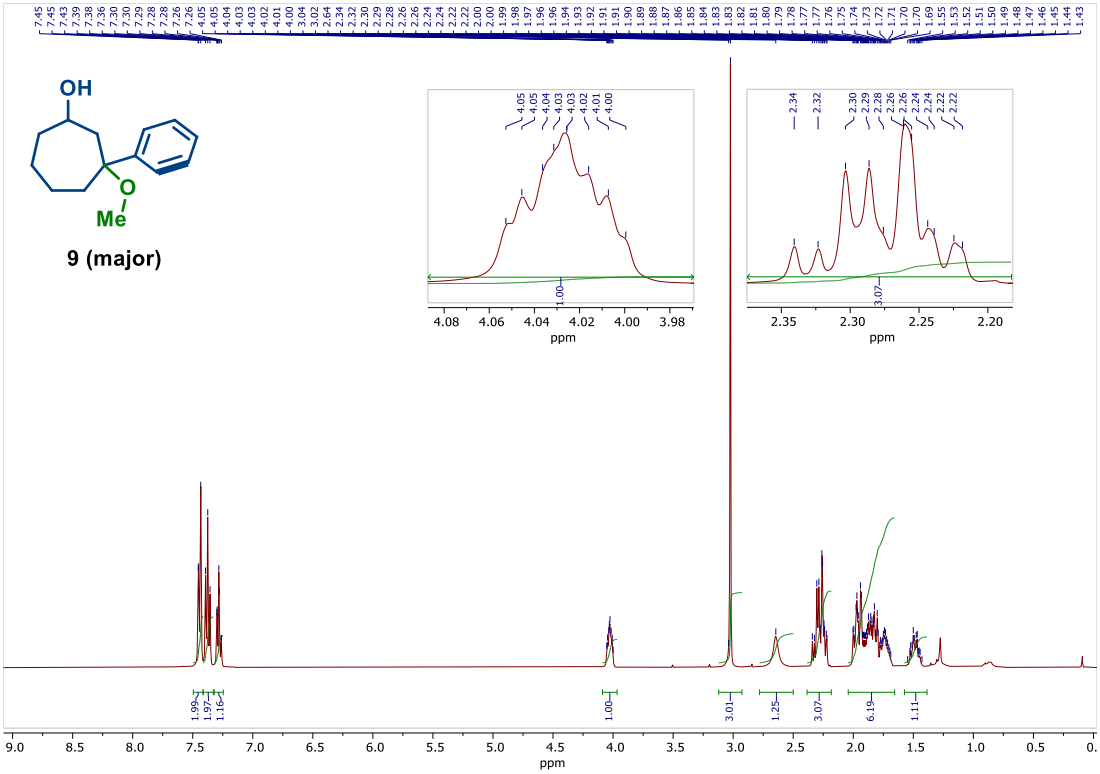
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **8e**



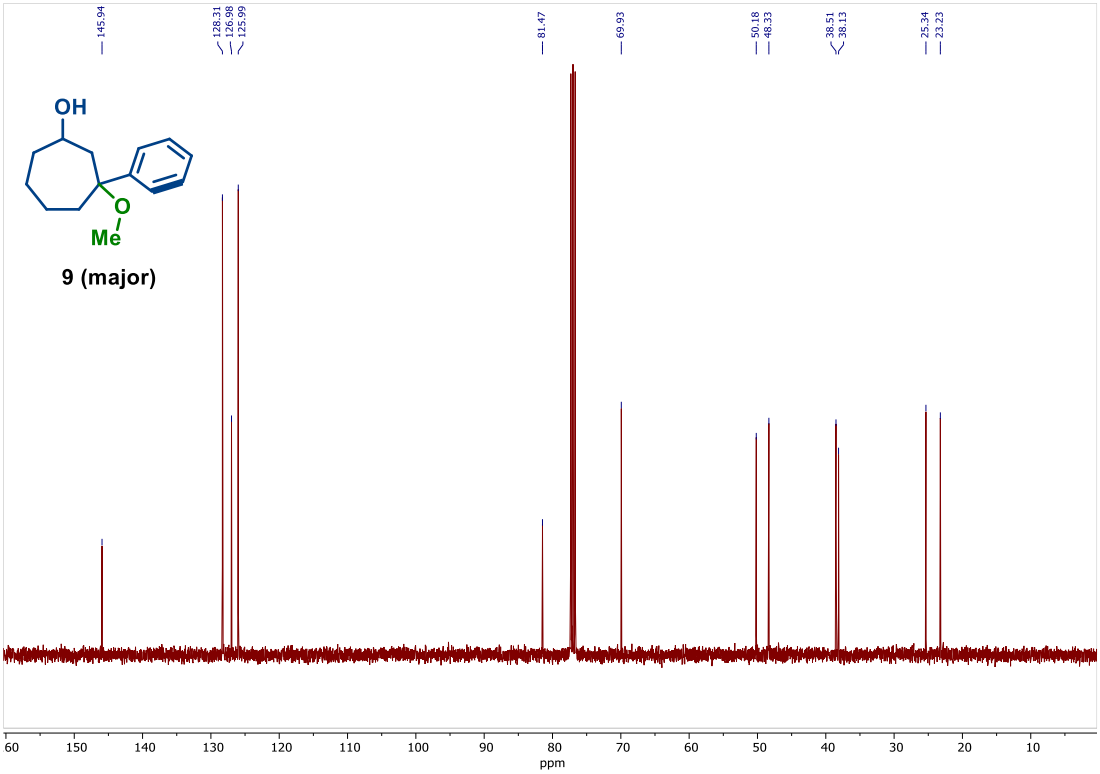
^{19}F NMR (376 MHz, $CDCl_3$) spectra of compound **8e**



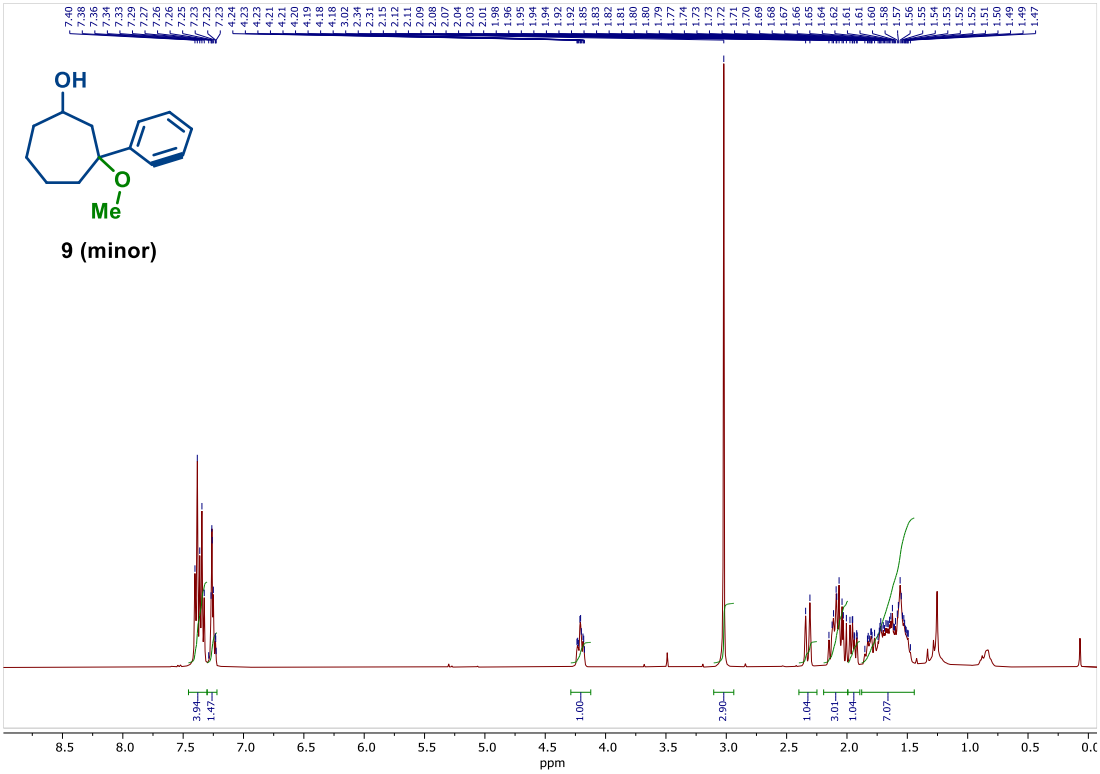
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **9 (major)** (*See Procedure*)



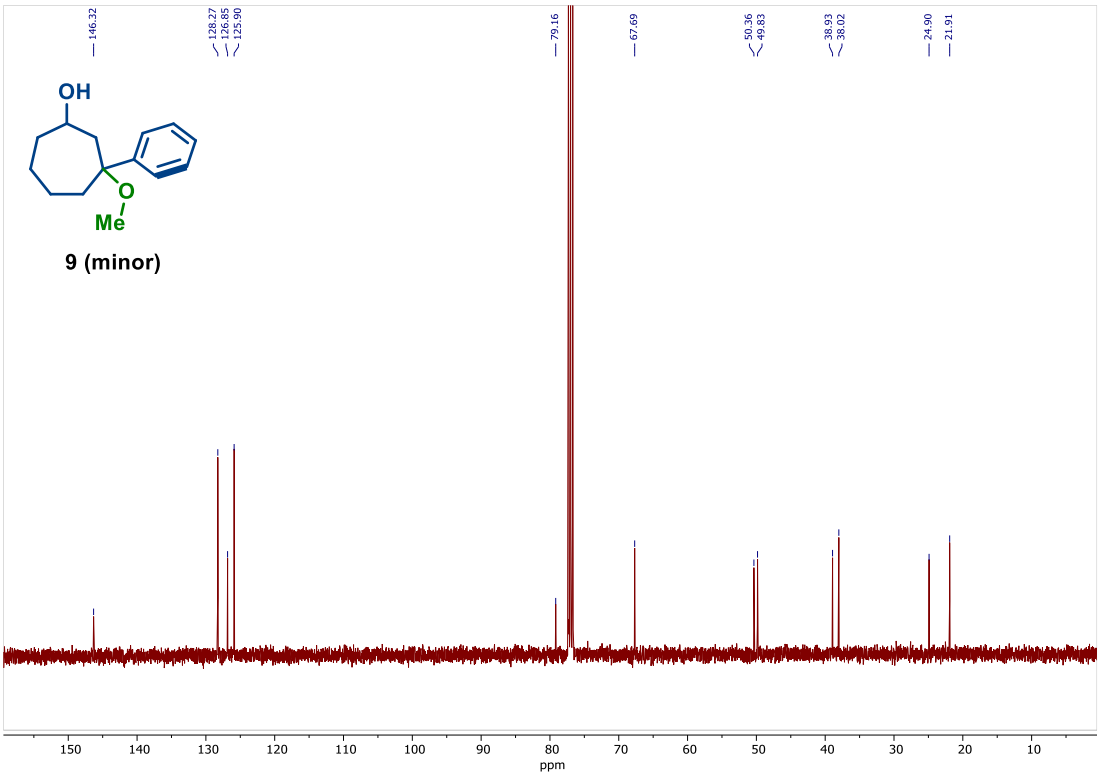
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **9 (major)**



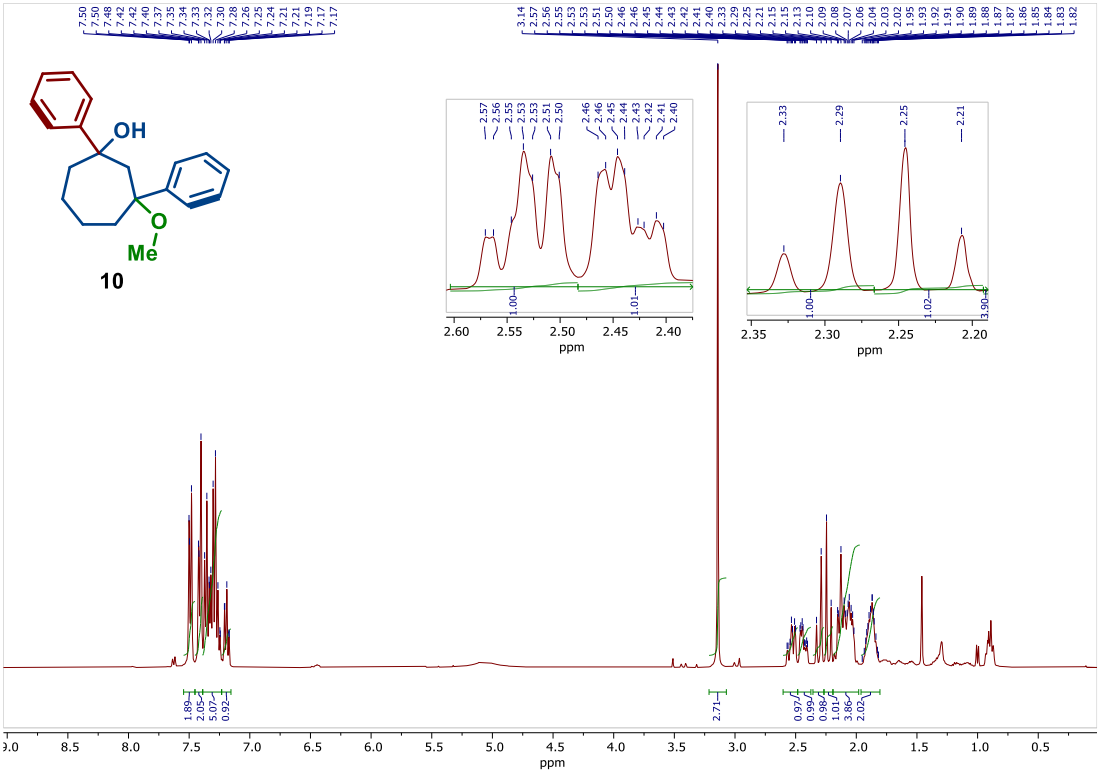
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **9 (minor)** (*See Procedure*)



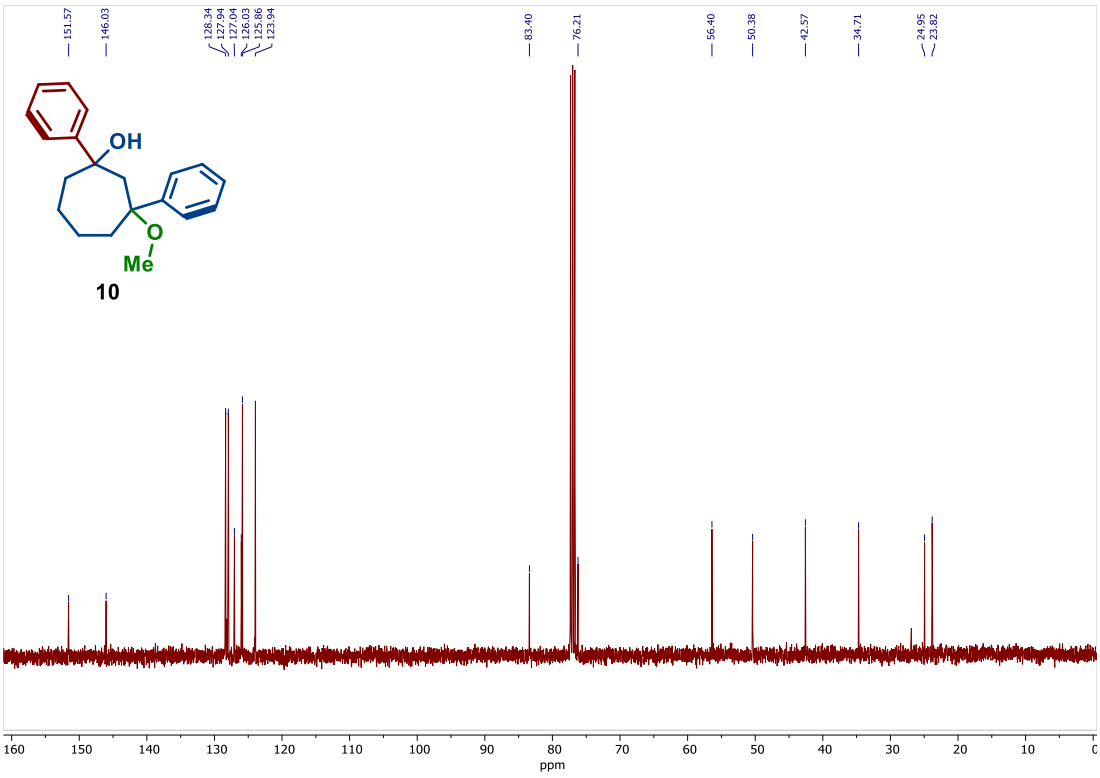
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **9 (minor)**



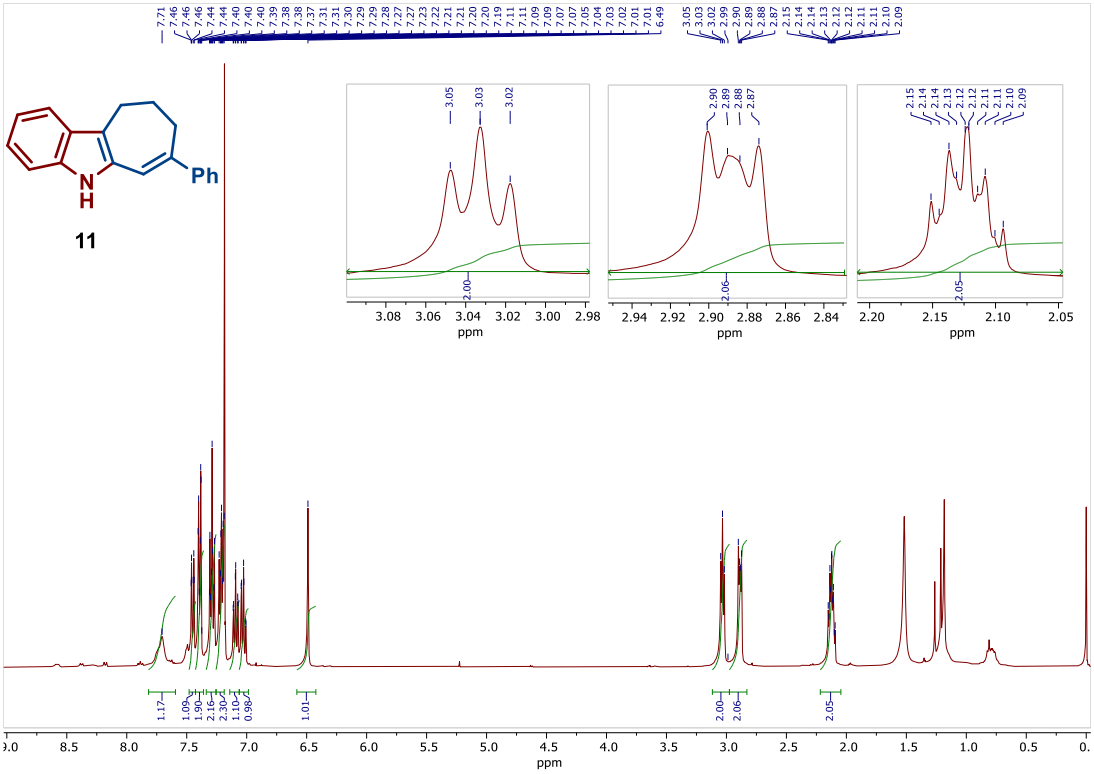
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **10** (*See Procedure*)



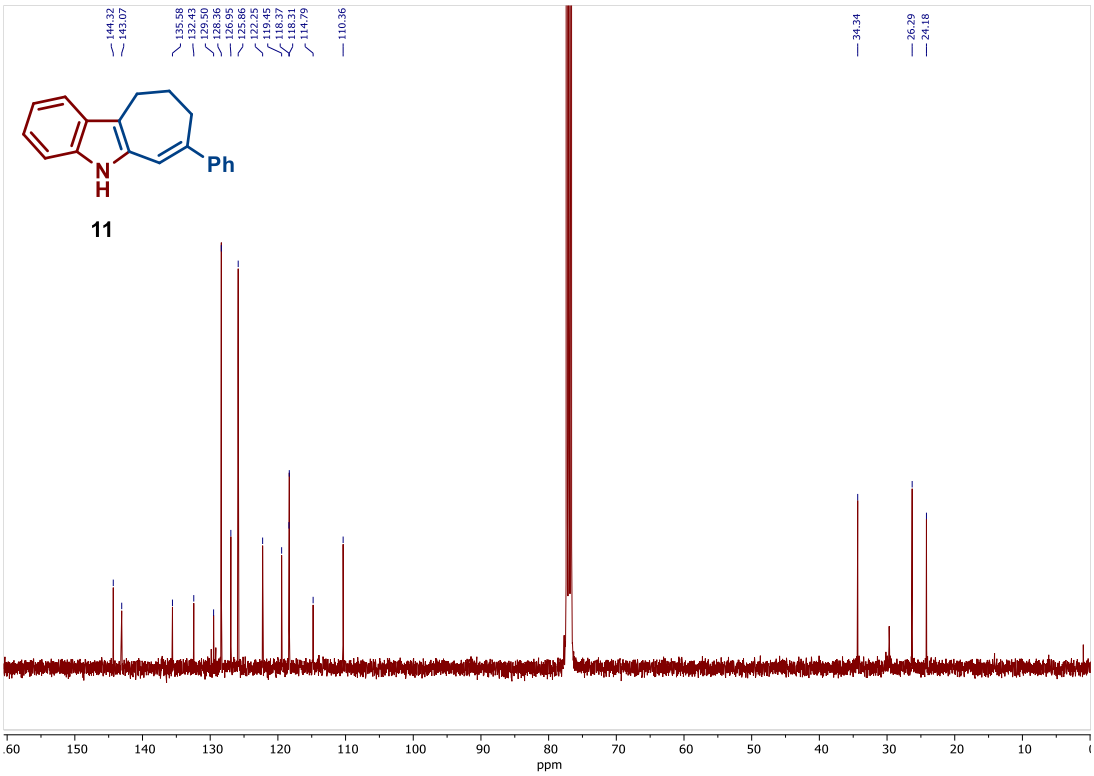
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **10**



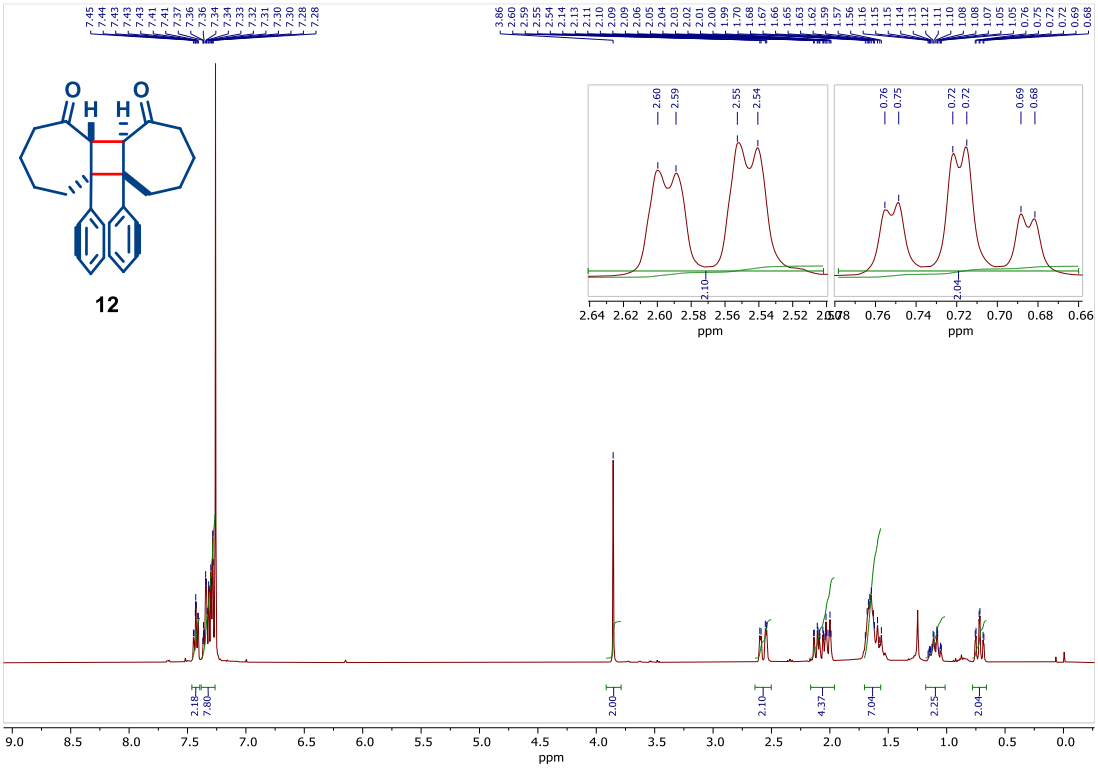
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **11** (*See Procedure*)



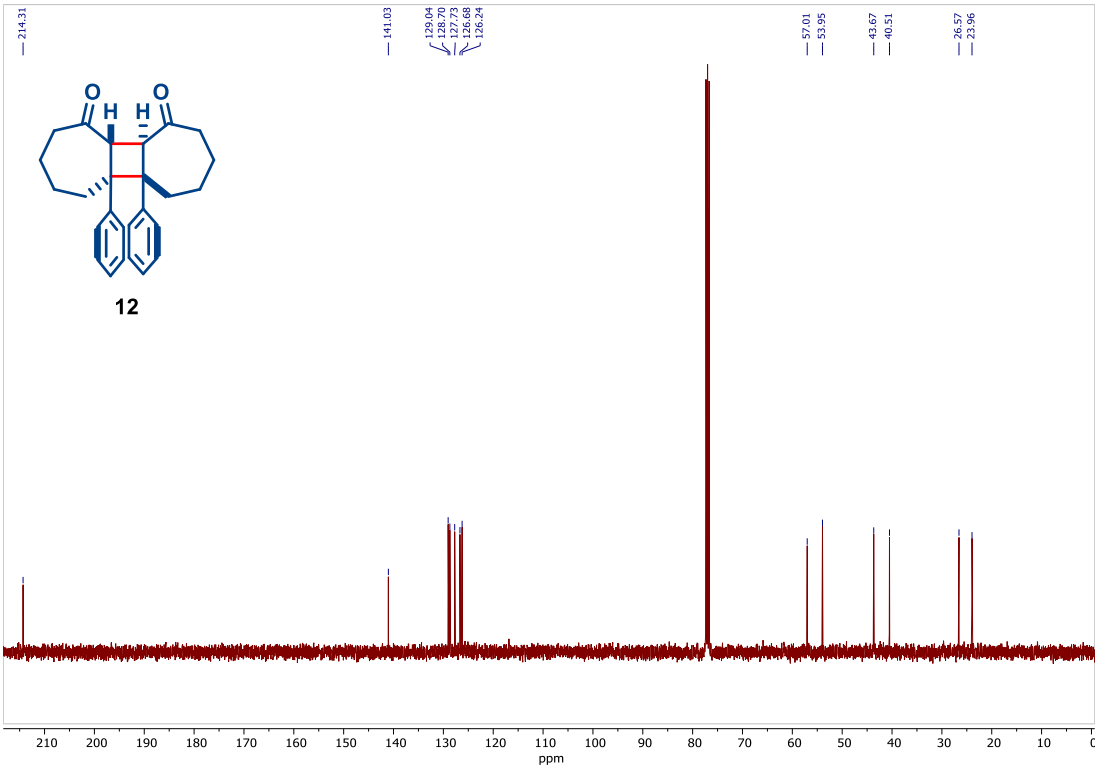
^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **11**



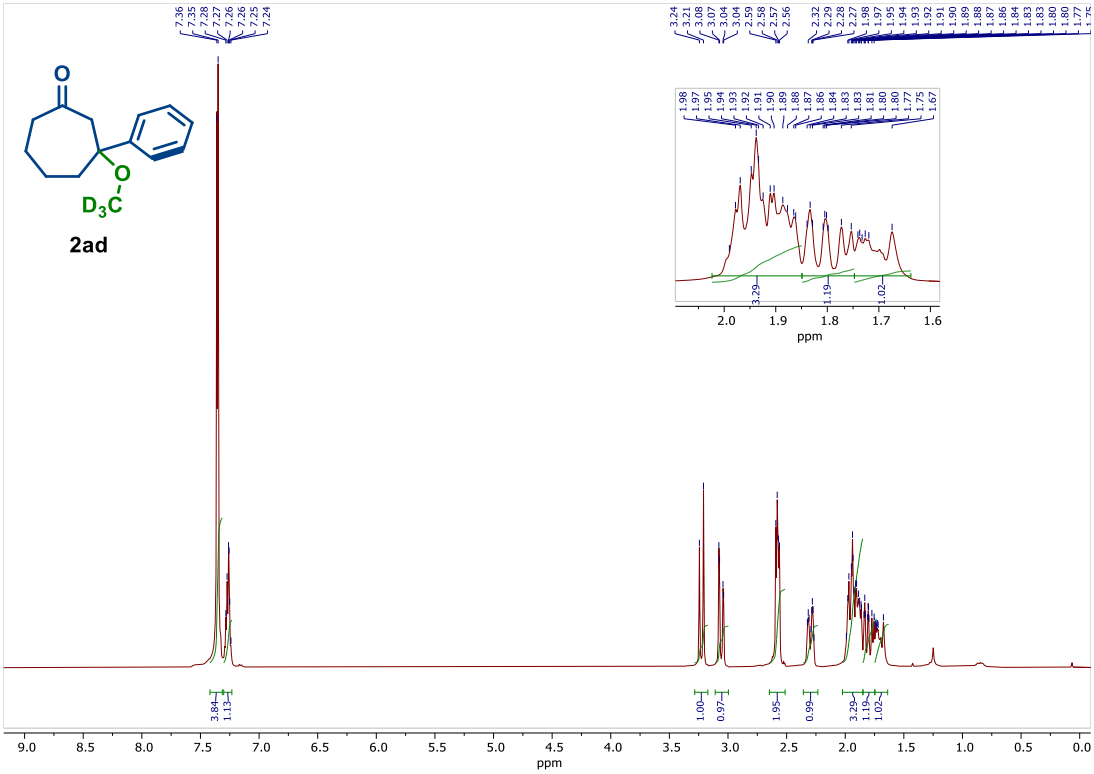
^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **12** (*See Procedure*)



^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **12**



^{1}H NMR (400 MHz, $CDCl_3$) spectra of compound **2ad** (*See Procedure*)



^{13}C NMR (101 MHz, $CDCl_3$) spectra of compound **2ad**