Electronic Supplementary Material (ESI) for Green Chemistry.

$TMEDAO_2$ Facilitates Atom Economical/Open Atmosphere Ley–Griffith (TPAP) Tandem Oxidation-Wittig Reactions

Supplementary Information

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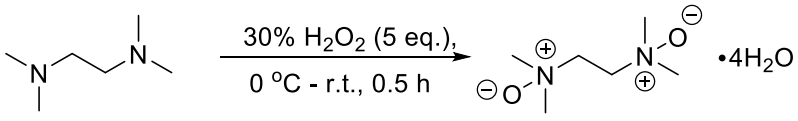
1. General Experimental

Reactions were monitored using silica-60 F_{254} TLC plates, visualised first under UV light then developed using a $KMnO_4$ dip. Column chromatography was undertaken using silica gel (flash silica gel, 230-400 mesh) using distilled solvents. All reagents and solvents were purified prior to use according to literature methods (D. D. Perin, W. L. F. Armarego, Purification of Laboratory Chemicals, 3rd ed., Pergamon Press, Oxford, England, 1988.) tetrapropylammonium perruthenate (97%) and fine chemicals were purchased from Sigma-Aldrich or Precious Metals Online. Dry DCM was freshly distilled from a CaH_2 still. NMR spectra were recorded using either a Bruker AV300 (300 MHz, 75 MHz), AV400 (400 MHz, 100 MHz) or AV500 (500 MHz, 125 MHz) instrument, with all data being processed using MestReNova software, version 9.1.0. Chemical shifts are given in parts per million (ppm) and referenced according to solvent; $CDCl_3$ (^{1}H δ: 7.26 ppm; ^{13}C δ: 77.0 ppm), D_2O (^{1}H δ: 4.79 ppm, internal reference: dioxane ^{13}C δ: 67.1 ppm), d_6-DMSO (^{1}H δ: 2.50 ppm; ^{13}C δ: 39.5 ppm). Coupling constants (*J*) are given in Hz. Gas Chromatography-Mass Spectrometry (GC-MS) was recorded using a GCMS-QP2010 Ultra machine with auto sampler and analysed using GCMSsolution, v4.20. Infra-red spectra were measured using a Perkin Elmer FT-IR spectrometer (Spectrum 2000). High resolution electrospray ionisation (HRESIMS) accurate mass measurements were recorded in positive mode on a Bruker MicroOTOF-Q (quadrupole-time of flight) instrument with a Bruker ESI source using sodium formate as a reference calibrant. Microanalyses were performed by the University of Queensland Microanalytical Service.

2. Synthesis of Reagents and Starting Material

2.1 $TMEDAO_2$•$4H_2O$ (6)

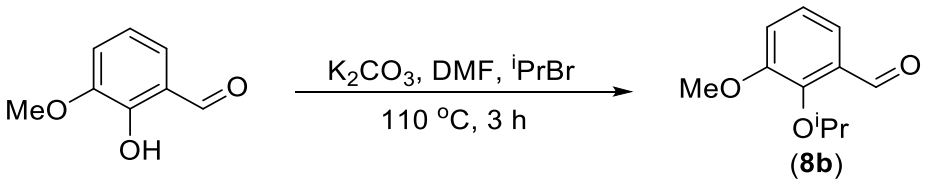


(**6**)

Hydrogen peroxide (9.0 mL, 90 mmol, 30%) was added to a wide necked round bottom flask and cooled to 0°C. TMEDA (2.7 mL, 18 mmol) was added drop-wise over 5 minutes and then stirred at 0°C for 30 minutes. The solution was allowed to warm to room temperature before being concentrated under reduced pressure (60 °C, 20 Torr, behind a blast shield). Water (3.0 mL) was added and the reaction mixture again concentrated under reduced pressure, followed by drying under high vacuum, providing $TMEDAO_2{\cdot}4H_2O$ (**6**, 3.805 g, 95%) as a white solid. $TMEDAO_2{\cdot}4H_2O$ (**6**) was stored in a desiccator. IR and ^{1}H NMR data matched that reported by Gelbard *et. al.*[1]

^{1}H NMR (300 MHz, D_2O): δ (ppm): 3.90(s, 4H), 3.30(s, 12H) ^{13}C NMR (100 MHz, D_2O, Dioxane reference): δ (ppm): 63.0(CH_2), 59.2(CH_3). IR (neat, cm^{-1}): 1697 (w), 1483 (m), 1467 (m), 1458 (m), 1439 (m), 1399 (m), 1289 (w), 1182 (w), 969 (s), 940 (s), 759 (s). HRMS *m*/*z* $C_6H_{16}N_2O_2H^+$ $[M+H]^+$, Calculated: 149.1285, Found: 149.1288.

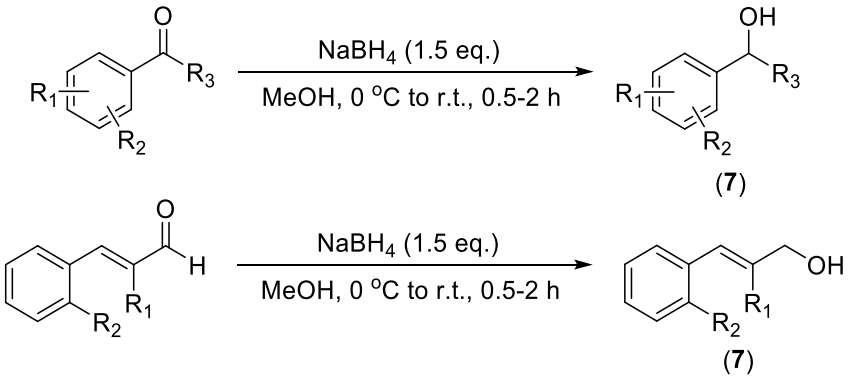
2.2. *O*-Vanillin Alkylation (8b)



(**8b**)

O-vanillin was alkylated with 2-bromopropane following the method of Couture, *et. al.*[2] A clear oil was obtained in 90% yield.

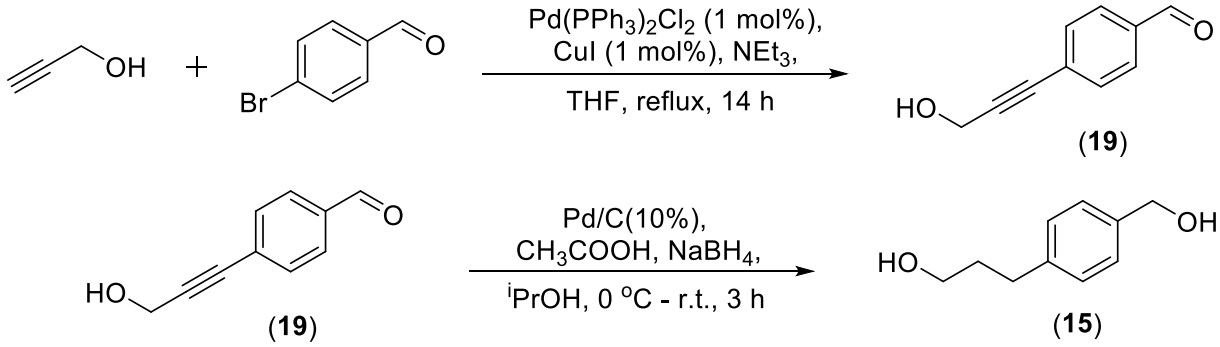
2.3 Sodium Borohydride Reduction Protocol



Aldehyde or ketone (1.0 eq.) was dissolved in methanol (0.6 M solution) and cooled to 0 ºC. $NaBH_4$ (1.5 eq.) was then added, and the reaction stirred for 5 minutes at 0 ºC followed by warming to room temperature until deemed complete by TLC (0.5 - 2 hrs). The reaction was quenched with water, stirred for 10 minutes, and then concentrated under reduced pressure to half volume. The remaining solution was extracted with Et_2O, the organic fractions were combined, washed with brine, dried over $MgSO_4$ or Na_2SO_4 and filtered. The crude alcohol was purified by flash chromatography (ethyl acetate / petroleum spirit) as required.

Alcohols synthesised by this method: (2-isopropoxy-3-methoxyphenyl)methanol, 4-bromobenzyl alcohol, (*E*)-2-methyl-3-phenylprop-2-en-1-ol, (*E*)-3-(2-methoxyphenyl)prop-2-en-1-ol, 1-phenylethan-1-ol, 4-isopropylbenzyl alcohol, 4-(hydroxymethyl)benzonitrile, and 2-(trifluoromethyl)benzyl alcohol.

2.4 Synthesis of Diol (15)

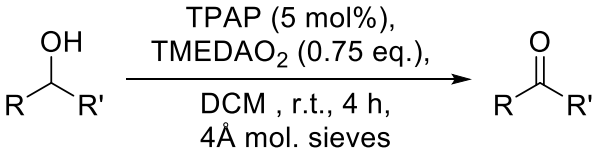


The method of Lipshutz *et. al.*[3] was followed. However, the extraction method for **15** was modified such that the residue was dissolved in DCM and extracted using water. The aqueous layers were combined and washed with fresh DCM, then concentrated to afford 3-(4-(hydroxymethyl)phenyl)propan-1-ol (**15**) (53% yield) as a clear oil. The data of **19** and **15** matched that reported by Lipshutz B. H., *et. al.*[3]

19: ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 10.00(s, 1H), 7.83(d, *J* = 8.5 Hz, 2H), 7.57(d, *J* = 8.2 Hz, 2H), 4.53(d, *J* = 5.9 Hz, 2H), 1.86(t, *J* = 6.0 Hz, 1H); GC-MS *m*/*z* (ion, % relative intensity): 160($[M]^+$, 41), 131($[M\text{-}CHO]^+$, 100), 129($[M\text{-}CH_3O]^+$, 5), 77($[M\text{-}C_4H_4O_2]^+$, 43).

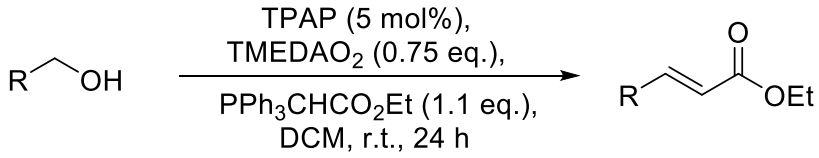
15: ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.29(d, *J* = 8.2 Hz, 2H), 8.17(d, *J* = 8.2 Hz, 2H), 4.65(s, 2H), 3.66(t, *J* = 6.4 Hz, 2H), 2.70(t, *J* = 6.4 Hz, 2H), 1.87(m, 3H), 1.46(s, br, 1H); GC-MS *m*/*z* (ion, % relative intensity): 166($[M]^+$, 38), 148($[M\text{-}O]^+$, 20), 147($[M\text{-}HO]^+$, 9), 133($[M\text{-}CH_3O]^+$, 28), 119($[M\text{-}C_2H_5O]^+$, 13), 105($[M\text{-}C_2H_7O]^+$, 37), 104($[M\text{-}C_2H_4O_2]^+$, 18), 77($[M\text{-}C_4H_8O_2]^+$, 44).

3. Alcohol Oxidation Protocol



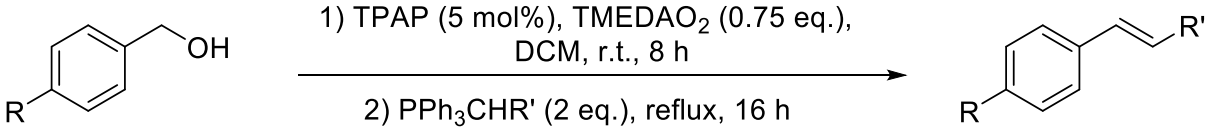
Alcohol (1.0 mmol) was added to a dry flask containing anhydrous DCM (2.0 mL) and powdered 4Å molecular sieves (500 mg / mmol) under an argon atmosphere. $TMEDAO_2$ (Treated as $TMEDAO_2 \bullet 4H_2O$, Mw = 220.27 g/mol, 165 mg, 0.75 mmol) was added and the reaction stirred for 5 minutes before addition of TPAP (17.6 mg, 5 mol%). The reaction was stirred for 4 hrs before the mixture was passed through a silica plug using Et_2O and concentrated under reduced pressure. The crude reaction products were purified by flash chromatography (solvent system ranging from 1:7 EtOAc:Pet. ether to 1:2 EtOAc:Pet. ether or 1:3 Et_2O:Pentane to 1:1 Et_2O:Pentane).

4. Tandem Protocol (Method A)



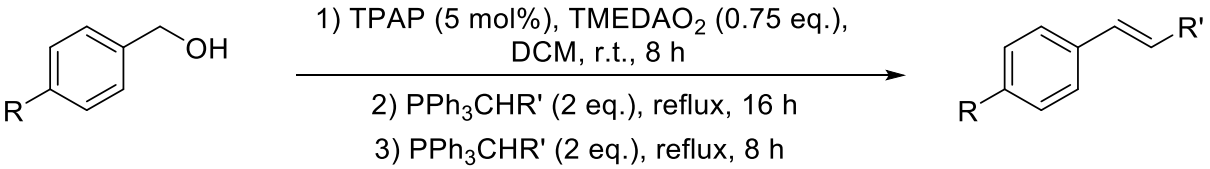
Alcohol (1.0 mmol) was dissolved in DCM (2.0 mL), $TMEDAO_2$ (165 mg, 0.75 mmol) and (carbethoxymethylene)triphenylphosphorane (366 mg, 1.05 mmol) were added and the reaction was stirred for 5 minutes. TPAP (17.6 mg, 5 mol%) was then added and the reaction mixture was left to stir for 24 hours. The reaction mixture was then passed through a silica plug using Et_2O (75 mL) and concentrated. Purification by flash chromatography (solvent system ranging from 1:14 EtOAc:Pet. ether to 1:3 EtOAc:Pet. ether) provided the desired product.

5. Tandem Protocol (Method B)



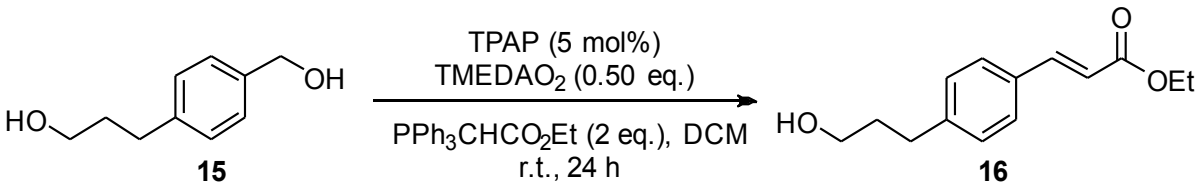
Alcohol (1.0 mmol) was dissolved in DCM (2.0 mL), $TMEDAO_2$ (165 mg, 0.75 mmol) was then added and the reaction was stirred for 5 minutes. TPAP (17.6 mg, 5 mol%) was added and the reaction mixture was left to stir for 8 hrs. Phosphorane (697 mg, 2.0 mmol) was added and the reaction was refluxed for 16 hrs. The reaction mixture was then passed through a silica plug using Et_2O (75 mL) and concentrated. Purification by flash chromatography (solvent system ranging from 1:7 EtOAc:Pet. ether to 1:2 EtOAc:Pet. ether) provided the desired product.

6. Tandem Protocol (Method C)



Alcohol (1.0 mmol) was dissolved in DCM (2.0 mL), $TMEDAO_2$ (165 mg, 0.75 mmol) was then added and the reaction was stirred for 5 minutes. TPAP (17.6 mg, 5 mol%) was added and the reaction mixture was left to stir for 8 hours. Phosphorane (697 mg, 2.0 mmol) was added and the reaction was heated to reflux for 16 hrs. A further addition of phosphorane (697 mg, 2.0 mmol) was made and the reaction continued at reflux for a further 8 hrs. The reaction mixture was then passed through a silica plug using Et_2O (75 mL) and concentrated. Purification by flash chromatography (solvent system ranging from 1:7 EtOAc:Pet. ether to 1:2 EtOAc:Pet. ether) provided the desired product.

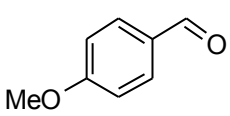
7. Tandem Protocol (Method D)



3-(4-(Hydroxymethyl)phenyl)propan-1-ol (**15**) (166.05 mg, 1.0 mmol), $TMEDAO_2$ (110.1 mg, 0.50 mmol), (carbethoxymethylene) triphenylphosphorane (697 mg, 2.0 mmol), and DCM (2.0 mL) were added to a round bottom flask and stirred for 5 minutes. TPAP (17.6 mg, 5 mol%) was added and the reaction mixture was left to stir for 24 hours. The reaction mixture was then passed through a silica plug using Et_2O (75 mL) and concentrated. Purification by column chromatography (40% EtOAc:Petroleum Ether) gave the final product **16** (113.6 mg, 49% [78% BRSM]), and by-products **17** (22 mg, 7% [11% BRSM]) and **18** (9.9 mg, 4% [7% BRSM]).

8. Analytical Data of Isolated Products

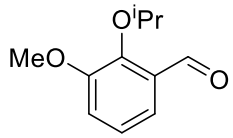
4-Methoxybenzaldehyde (8a)



Clear oil, 88% yield. Data matched that reported by Chen *et. al.*[4]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 9.89(s, 1H), 7.85(d, *J* = 9.0 Hz, 2H), 7.01(d, *J* = 9.0 Hz, 2H), 3.90 (s, 3H).

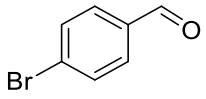
2-Isopropoxy-3-methoxybenzaldehyde (8b)



Clear oil, 90% data matched that reported by Couture *et. al.*[2]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 10.46(s, 1H), 7.42(dd, *J* = 6.8, 2.6 Hz, 1H), 7.14-7.08(m, 2H), 4.63(sep, *J* = 6.0, 3.0 Hz, 1H), 3.88(s, 3H), 1.33(d, *J* = 6.2 Hz, 6H).

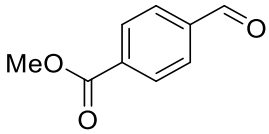
4-Bromobenzaldehyde (8c)



White solid, 46% yield. Data matched that reported by Couture *et. al.*[2]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 9.98(s, 1H), 7.75(d, *J* = 9.0 Hz, 2H), 7.69(d, *J* = 9.0 Hz, 2H).

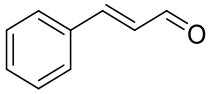
Methyl 4-formylbenzoate (8d)



White solid, 69% yield. Data matched that reported by Pelletier *et. al.*[5]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 10.11(s, 1H), 8.20(d, *J* = 8.0 Hz, 2H), 7.96(d, *J* = 8.0 Hz, 2H), 3.97(s, 3H).

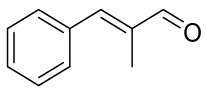
Cinnamaldehyde (8e)



Yellow oil, 78% yield. Data matched that reported by Chen *et. al.*[4]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 9.71(d, *J* = 7.9 Hz, 1H), 7.60-7.41(m, 6H), 6.75(dd, *J* = 15.8, 7.6 Hz, 1H).

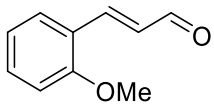
(*E*)-2-Methyl-3-phenylacrylaldehyde (8e)



Pale yellow oil, 85% yield. Data matched that reported by Dohi *et. al.* [6]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 9.60(s, 1H), 7.54(d, *J* = 8.0 Hz, 2H), 7.48-7.38(m, 3H), 7.28(s, 1H), 2.09(d, *J* = 1.3 Hz, 3H).

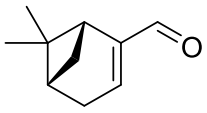
(*E*)-2-Methoxycinnamaldehyde (8g)



Yellow solid, 77% yield. Data matched that reported by Zhu *et. al.*[7]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 9.69(d, *J* = 8.0 Hz, 1H), 7.84(d, *J* = 16.0 Hz, 1H), 7.55(m, 1H), 7.41(m, 1H), 7.00(t, *J* = 8.0 Hz, 1H), 6.95(d, *J* = 8.0 Hz, 1H), 6.79(dd, *J* = 16.0, 8.0 Hz, 1H), 3.92(s, 3H).

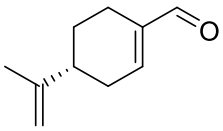
(1S,5R)-6,6-dimethylbicyclo[3.1.1]hept-2-ene-2-carbaldehyde (Myrtenal, 8h)



Clear oil, 67% yield. Data matched that reported by dos Santos *et. al.*[8]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 9.44(s, 1H), 6.71(m, 1H), 2.87(t, *J* = 6.0 Hz, 1H), 2.59-2.55(m, 2H), 2.49(m, 1H), 2.19(m, 1H), 1.34(s, 3H), 1.05(d, *J* = 9.0 Hz, 1H), 0.74(s, 3H).

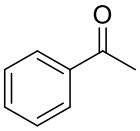
(*S*)-(−)-Perillaldehyde (8i)



Clear oil, 75% yield. Data matched that reported by Lu.[9]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 9.44(s, 1H), 6.83(m, 1H), 4.76(d, *J* = 14.5 Hz, 2H), 2.52-2.43(m, 2H), 2.31-2.22(m, 2H), 2.15(m, 1H), 1.93(m, 1H), 1.77(s, 3H), 1.46(m, 1H).

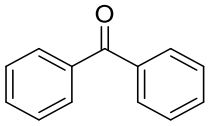
Acetophenone (8j)



Clear oil, 75% yield. Data matched that reported by Yuan *et.al*.[10]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.98-7.95(m, 2H), 7.57(m, 1H), 7.49-7.44(m, 2H), 2.61(s, 3H).

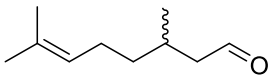
Benzophenone (8k)



White solid, 61% yield. Data matched that reported by Yuan, *et. al.*[10]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.83-7.80(m, 4H), 7.62-7.57(m, 2H), 7.52-7.47(m, 4H).

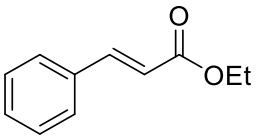
Citronellal (3,7-Dimethyloct-6-enal, 8l)



Clear oil, 47% yield. Data matched that reported by He *et. al.*[11]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 9.77(t, *J* = 4.0 Hz, 1H), 5.10(t, *J* = 8.0 Hz, 1H), 2.42(ddd, *J* = 16.0, 5.6, 1.9 Hz, 1H), 2.24(ddd, *J* = 15.9, 8.0, 2.5 Hz, 1H), 2.11-1.98(m, 3H), 1.70(s, 3H), 1.62(s, 3H), 1.42-1.26(m, 2H), 0.99(d, *J* = 8.0 Hz, 2H), 0.90 (m, 1H).

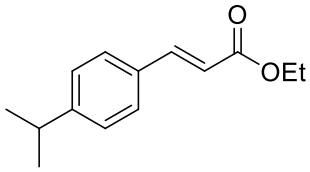
Ethyl cinnamate (10a)



Method A: Clear oil, 89% yield [*E*:*Z*, 16:1]. Data matched that reported by Lebel *et. al.*[12]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.69(d, *J* = 16.0 Hz, 1H), 7.54-7.52(m, 2H), 7.39-7.37(m, 3H), 6.44(d, *J* = 16.0 Hz, 1H), 4.27(q, *J* = 7.0 Hz, 2H), 1.33(t, *J* = 8.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 167.1, 144.7, 134.6, 130.4, 129.0, 128.1, 118.5, 60.7, 14.5; GC-MS *m*/*z* (ion, % relative intensity): 176($[M]^+$, 31), 131($[M-C_2H_5O]^+$, 100), 103(M^+-$C_3H_5O_2$, 45), 77(M^+-$C_5H_7O_2$, 24).

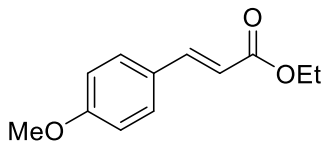
Ethyl (*E*)-3-(4-isopropylphenyl)acrylate (10b)



Method A: Clear oil, 83% yield [*E*:*Z* 40:1]. Data matched that reported by Ohkawa *et.al.*[13]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.68(d, *J* = 16.1 Hz, 1H), 7.47(d, *J* = 7.9 Hz, 2H), 7.26(d, *J* = 8.2 Hz, 2H), 6.41(d, *J* = 15.8 Hz, 1H), 4.27(q, *J* = 7.3 Hz, 2H), 2.94(sep, *J* = 6.8 Hz, 1H), 1.36(t, *J* = 7.0 Hz, 3H), 1.27(d, *J* = 7.0 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 167.2, 151.5, 144.6, 132.1, 128.1, 127.0, 117.2, 60.4, 34.1, 23.8, 14.3; GC-MS: m/z (ion, % relative intensity): 218($[M]^+$, 64), 203($[M-CH_3]^+$,100), 175($[M-C_3H_7]^+$, 13), 173($[M-C_2H_5O]^+$, 20).

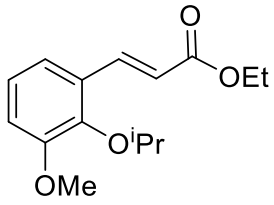
Ethyl (*E*)-(4-methoxyphenyl)acrylate (10c)



Method A: Clear oil, 83% yield [*E*:*Z*, 20:1]. Data matched that reported by Hyotanishi *et. al.*[14]

^{1}H NMR (300MHz, $CDCl_3$): δ (ppm): 7.64(d, *J* = 16.0 Hz, 1H), 7.47(d, *J* = 9.0 Hz, 2H), 6.89(d, *J* = 8.8 Hz, 2H), 6.30(d, *J* = 16.0 Hz, 1H), 4.25(q, *J* = 9.0 Hz, 2H), 3.83(s, 3H), 1.33(t, *J* = 9.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 167.5, 161.5, 144.4, 129.8, 127.4, 115.9, 114.5, 60.5, 55.5, 14.5; GC-MS *m*/*z* (ion, % relative intensity): 206($[M]^+$, 67), 161($[M-C_2H_5O]^+$, 100), 133($[M-C_3H_5O_2]^+$, 41).

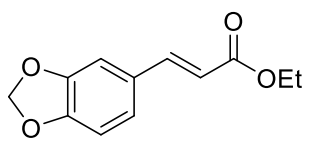
Ethyl (*E*)-(2-isopropoxy-3-methoxyphenyl)acrylate (10d)



Method A: Clear oil, 63% yield [*E*:*Z*, 4:1].

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 8.08(d, *J* = 16.2 Hz, 1H), 7.17(dd, *J* = 8.0, 1.2 Hz, 1H), 7.03(t, *J* = 8.0 Hz, 1H), 6.92(dd, *J* = 8.0, 1.2 Hz, 1H), 6.43(d, *J* = 16.2 Hz, 1H), 4.45(septet, *J* = 8.0 Hz, 1H), 4.26(q, *J* = 8.0 Hz, 2H), 3.85(s, 3H), 1.34(t, *J* = 8.0 Hz, 3H), 1.30(d, *J* = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 167.1, 153.4, 146.4, 140.3, 129.7, 123.6, 118.9, 118.8, 113.7, 76.1, 60.3, 55.8, 22.4, 14.3; GC-MS: m/z (ion, % relative intensity): 264($[M]^+$, 11), 222($[M-C_3H_7]^+$, 21), 176($[M-C_4H_6O_2]^+$, 100), 134($[M-C_6H_{10}O_3]^+$, 6), 77($[M-C_9H_{17}O_4]^+$, 7); IR (neat, cm^{-1}): 2976 (w), 1709 (m), 1632 (w), 1577 (w), 1262 (s), 1214 (m), 1105 (m), 776 (m), 737(m); Anal. Calcd. for $C_{15}H_{20}O_4$: C, 68.16; H, 7.63 O, 24.21. Found: C, 68.11; H, 7.71; O, 24.18; HRMS: *m*/*z* $C_{15}H_{20}O_4Na^+$ $[M+Na]^+$, Calculated: 287.1254, Found: 287.1262.

Ethyl (*E*)-3-(benzo[d][1,3]dioxol-5-yl)acrylate (10e)

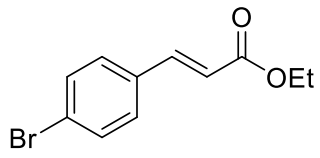


Method A: Clear oil, 90% yield [*E*:*Z* 11:1]. Data matched that reported by Leung *et.al.*[15]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.60(d, *J* = 15.8 Hz, 1H), 7.04(d, *J* = 1.8 Hz, 1H), 7.01(ddd, *J* = 7.9, 1.8, 0.5 Hz, 1H), 6.82(d, *J* = 7.9 Hz, 1H), 6.27(d, *J* = 16.1 Hz, 1H), 6.02(s, 2H), 4.26(q, *J* = 7.2 Hz, 2H), 1.34(t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 167.2, 149.5, 148.3, 144.3, 128.9, 124.4, 116.2, 108.5, 106.5,

101.5, 60.4, 14.3; GC-MS: m/z (ion, % relative intensity): 220([M]$^+$, 100), 175([M−HO]$^+$, 66), 147([M−C_2H_5O]$^+$, 13).

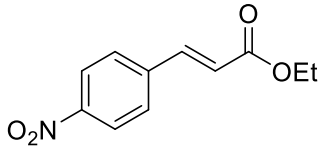
Ethyl (*E*)-(4-bromophenyl)acrylate (10f)



Method A: Clear oil, 95% yield [*E*:*Z*, 11:1]. Data matched that reported by Peñafiel *et. al.*[16]

^{1}H NMR (500 MHz, $CDCl_3$): δ (ppm): 7.61(d, *J* = 16.0 Hz, 1H), 7.52(d, *J* = 8.4 Hz, 2H), 7.39(d, *J* = 8.4 Hz, 2H), 6.42(d, *J* = 16.0 Hz, 1H), 4.27(q, *J* = 10.0, 5.0 Hz, 2H), 1.34(t, *J* = 10.0, 5.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.7, 143.2, 133.4, 132.1, 129.4, 124.5, 119.0, 60.6, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 256/254([M]$^+$, ^{79}Br/^{81}Br, 41/40), 211/209([M-C_2H_5O]$^+$, ^{79}Br/^{81}Br, 91/90), 183/181([M-$C_3H_5O_2$]$^+$, ^{79}Br/^{81}Br, 24/21), 102([M-$C_3H_5O_2Br$]$^+$,100).

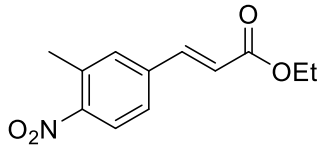
Ethyl (*E*)-(4-nitrophenyl)acrylate (10g)



Method A,: White solid, 80% yield [*E*:*Z*, 16:1]. Data matched that reported by Sharma *et. al.*[17]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 8.25(d, *J* = 9.0 Hz, 2H), 7.73(d, *J* = 16.0 Hz, 1H), 7.70(d, *J* = 8.5 Hz, 2H), 6.56(d, *J* = 16.0 Hz, 1H), 4.29(q, *J* = 8.0 Hz, 2H), 1.35(t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.0, 148.5, 141.6, 140.6, 128.6, 124.2, 122.6, 61.0, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 221([M]$^+$, 25), 192([M-C_2H_5]$^+$, 8), 176([M-C_2H_5O]$^+$, 100).

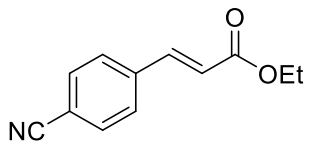
Ethyl (*E*)-3-(3-methyl-4-nitrophenyl)acrylate (10h)



Method A: Clear oil, 77% yield [*E*:*Z* 11:1].

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 8.00(d, *J* = 8.2 Hz, 1H), 7.65(d, *J* = 16.1 Hz, 1H), 7.50-7.46(m, 2H), 6.52(d, *J* = 15.8 Hz, 1H), 4.29(q, *J* = 7.1 Hz, 2H), 2.63(s, 3H), 1.35(t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.1, 149.5, 141.7, 138.9, 134.3, 132.3, 125.9, 125.4, 122.0, 60.9, 20.6, 14.2; GC-MS: m/z (ion, % relative intensity): 235([M]$^+$, 24), 219([M−O]$^+$, 13), 190([M−C_2H_5O]$^+$, 100), 144([M−$C_2H_5O_3N$]$^+$, 72); IR (neat, cm^{-1}): 3117(w), 3045(w), 2992(w), 1717(s), 16419(m), 1609(m), 1512(s), 1327(s), 1291(s), 1159(s), 1032(s), 981(s), 826(s), 760(s), 676(m); Anal. Calcd for $C_{12}H_{13}NO_4$: C, 61.27; H, 5.57; N, 5.95. Found: C, 61.07; H, 5.64; N, 6.00; HRMS: *m*/*z* $C_{12}H_{13}NO_4Na^+$ [M+Na]$^+$, Calcd. 258.0737, Found 258.0747.

Ethyl (*E*)-3-(4-cyanophenyl)acrylate (10i)

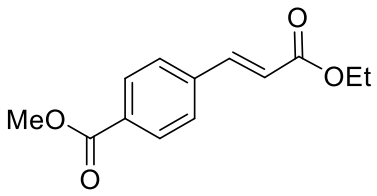


Method A: Clear oil, 80% yield [*E*:*Z* 10:1]. Data matched that reported by Leung *et.al.*[15]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.71-7.61(m, 5H), 6.52(d, *J* = 15.8 Hz, 1H), 4.29(q, *J* = 7.1 Hz, 2H), 1.36(t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.1, 142.1, 138.7, 132.6, 128.3, 121.8, 118.4, 113.3,

60.9, 14.2; GC-MS: m/z (ion, % relative intensity): 201([M]$^+$, 23), 156([M−C_2H_5O]$^+$, 100), 128([M−$C_3H_5O_2$]$^+$, 53).

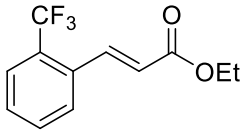
Ethyl (*E*)-(4-methylbenzanoate)acrylate (10j)



Method A: White solid, 87% yield [*E*:*Z*, 14:1]. Data matched that reported by Chintareddy *et. al*.[18]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 8.05(d, *J* = 8.0, 2H), 7.70 (d, *J* = 16.0 Hz, 1H) 7.58(d, *J* = 8.0, 2H), 6.52(d, *J* = 16.0 Hz, 1H), 4.28(q, *J* = 7.0 Hz, 2H), 3.93(s, 3H), 1.35(t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.6, 166.5, 143.2, 138.8, 131.4, 130.2, 128.0, 120.8, 60.9, 52.4, 14.4; GC-MS *m*/*z* (ion, % relative intensity): 234([M]$^+$, 86), 189([M-C_2H_5O]$^+$, 100), 175([M-$C_2H_3O_2$]$^+$, 60), 161([M-$C_3H_5O_2$]$^+$, 7).

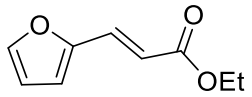
Ethyl (*E*)-3-(2-(trifluoromethyl)phenyl)acrylate (10k)



Method A: Clear oil, 77% yield [*E*:*Z,* 12:1]. Data matched that reported by Wang *et.al.*[19]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 8.07(dq, *J* = 15.6, 2.3 Hz, 1H), 7.73-7.70(m, 2H), 7.58(m, 1H), 7.49(t, *J* = 7.3 Hz, 1H), 6.42(d, *J* = 15.8 Hz, 1H), 4.30(q, *J* = 7.0 Hz, 2H), 1.36(t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.1, 140.0, 133.5, 132.1, 129.5, 127.9, 126.1 (q, *J* = 5.7 Hz), 125.3, 122.6, 60.8, 14.3; GC-MS: m/z (ion, % relative intensity): 244([M]$^+$, 18), 199([M−C_2H_5O]$^+$, 100), 175([M−CF_3]$^+$, 62), 171([M−$C_3H_5O_2$]$^+$, 26).

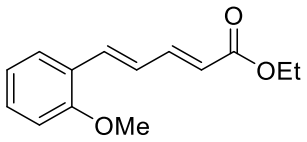
Ethyl (*E*)-(furan-2-yl)acrylate (10l)



Method A: Orange oil, 70% [*E*:*Z*, 7:1] yield. Data matched that reported by Chintareddy *et. al*.[18]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.48(m, 1H), 7.43(d, *J* = 18.0 Hz, 1H), 6.60(d, *J* = 3.0 Hz, 1H), 6.47(dd, *J* = 3.0, 1.9 Hz, 1H), 6.32(d, *J* = 18.0 Hz, 1H), 4.23(q, *J* = 6.0 Hz, 2H), 1.32(t, *J* = 6.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 167.1, 151.0, 144.7, 131.0, 116.0, 114.6, 112.2, 60.4, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 166([M]$^+$, 22), 121([M-C_2H_5O]$^+$, 100), 93([M-$C_2H_5O_2$]$^+$, 13).

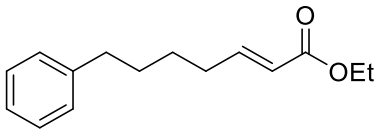
Ethyl (2*E*,4*E*)-5-(2-methoxyphenyl)penta-2,4-dienoate (10m)



Method A: Clear oil, 82% yield [*EE*:*EZ*, 6:1]. Data matched that reported by Magrioti *et. al.*[20]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.52-7.47(m, 2H), 7.31-7.23(m, 2H), 6.98-6.88(m, 3H), 5.96(d, *J* = 15.0 Hz, 1H), 4.32(q, *J* = 7.0 Hz, 2H), 3.88(s, 3H), 1.31(t, *J* = 7.0 Hz, 3H) ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 167.2, 157.4, 145.5, 135.5, 130.1, 127.3, 126.8, 125.1, 120.7, 120.6, 111.1, 60.2, 55.5, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 232([M]$^+$, 5), 159([M-$C_3H_5O_2$]$^+$, 24).

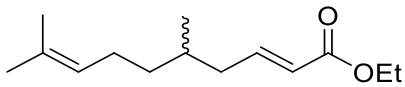
Ethyl (*E*)-7-phenylhept-2-enoate (10n)



Method A: Clear oil, 42% yield [*E*:*Z*, 9:1]. Data matched that reported by Ghogare *et. al.*[21]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.31-7.24(m, 2H), 7.21-7.16(m, 3H), 6.96(dt, *J* =15.6, 7.0 Hz, 1H), 5.81(dt, *J* = 15.6, 1.5 Hz, 1H), 4.19(q, *J* = 7.0 Hz, 2H), 2.63(t, *J* = 7.6 Hz, 2H), 2.23(qd, *J* = 7.3, 1.5 Hz, 2H), 1.70-1.62(m, 2H), 1.57-1.45(m, 2H), 1.29(t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 166.7, 149.0, 142.2, 128.4, 128.3, 125.7, 121.4, 60.1, 35.7, 32.0, 31.0, 27.6, 14.3. GC-MS: m/z (ion, % relative intensity): 232([M]$^+$, 8), 159([M−$C_3H_5O_2$]$^+$, 12), 158([M−$C_3H_6O_2$]$^+$, 29), 91([M−$C_8H_{13}O_2$]$^+$, 100).

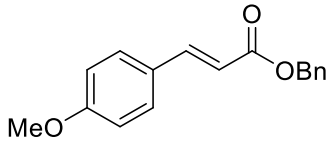
Ethyl (*E*)-5,9-dimethyldeca-2,8-dienoate (10o)



Method A: Clear oil, 48% yield [*E*:*Z*, 6:1]. Data matched that reported by Lebel *et. al.*[12]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 6.94(dt, *J* = 15.0, 7.5 Hz, 1H), 5.81(d, *J* = 15.0 Hz, 1H), 5.08(m, 1H), 4.19(q, *J* = 6.0 Hz, 2H), 2.20(m, 1H), 2.09-1.94(m, 3H), 1.68(s, 3H), 1.64(m, 1H), 1.60(s, 3H), 1.37(m, 1H), 1.29(t, *J* = 7.0 Hz, 3H), 1.17(m, 1H), 0.91(d, *J* = 7.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 166.7, 148.2, 131.5, 124.4, 122.4, 60.1, 39.6, 36.7, 32.0, 25.7, 25.5, 19.5, 17.7, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 224([M]$^+$, 2), 209([M-CH_3]$^+$, 3), 179([M-C_2H_5O]$^+$, 6), 155([M-C_5H_9]$^+$, 4), 151([M-$C_3H_5O_3$]$^+$, 5), 141([M-C_6H_{11}]$^+$, 14), 125([M-$C_5H_7O_2$]$^+$, 10), 83([M-$C_8H_{13}O_2$]$^+$, 8), 69([M-$C_9H_{15}O_2$]$^+$, 100), 55([M-$C_{10}H_{17}O_2$]$^+$, 40).

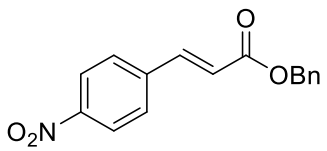
Benzyl (*E*)-(4-methoxyphenyl)acrylate (14a)



Method B: Clear oil, 84% yield [*E*:*Z*, 14:1]. Data matched that reported by El-Batta *et.al.*[22]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.73(d, *J* = 15.9 Hz, 1H), 7.47(d, *J* = 8.8 Hz, 2H), 7.44-7.33(m, 5H), 6.91(d, *J* = 8.8 Hz, 2H), 6.39(d, *J* = 15.9 Hz, 1H), 5.28(s, 2H), 3.81(s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 166.7, 161.1, 144.5, 135.9, 129.4, 128.2, 127.9, 127.8, 126.7, 115.0, 114.0, 65.8, 55.0 ;GC-MS *m*/*z* (ion, % relative intensity): 268([M]$^+$, 52), 177([M−$C_{11}H_{12}$]$^+$, 10), 161([M−C_7H_7O]$^+$, 60), 135([M−C_9H_9O]$^+$, 9), 133([M−$C_8H_7O_2$]$^+$, 24), 107([M−$C_{10}H_9O_2$]$^+$, 3), 77([M−$C_{11}H_{12}O_3$]$^+$, 16).

Benzyl (*E*)-(4-nitrophenyl)acrylate (14b)

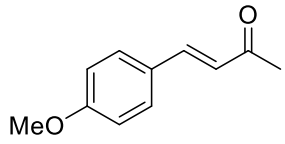


Method B,: White solid, 54% yield [*E*:*Z*, 10:1]. Data matched that reported by Echavarren *et.al.*[23]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 8.25(d, *J* = 8.7 Hz, 2H), 7.75(d, *J* = 16.0 Hz, 1H), 7.67(d, *J* = 8.6 Hz, 2H), 7.44-7.35(m, 5H), 6.60(d, *J* = 16.0 Hz ,1H), 5.28(s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm): 165.8, 148.5, 142.1, 140.4, 135.6, 128.7, 128.6, 128.5, 128.4, 124.2, 122.2, 66.8; GC-MS *m*/*z* (ion, % relative intensity): 283([M]$^+$, 2), 266([M−O]$^+$, 11), 238([M−O_2N]$^+$, 24),

192([M−C_7H_7]$^+$, 18), 176([M−C_7H_7O]$^+$, 35), 107([M−$C_9H_6O_3N$]$^+$, 6), 91([M−$C_9H_6O_4N$]$^+$, 100), 77([M−$C_{10}H_8O_4N$]$^+$, 10).

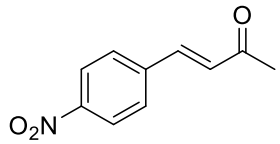
(*E*)-1-(4-Methoxyphenyl)but-1-en-3-one (14c)



Method B: White Solid, 75% yield [*E*:*Z*, >99%E]. Data matched that reported by Solin *et.al.*[24]

^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 7.53-7.45(m, 3H), 6.95-6.90(m, 2H), 6.61(d, *J* = 16.3 Hz, 1H), 3.85(s, 3H), 2.36(s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 198.5 , 161.7 , 143.4 , 130.1 , 127.2 , 125.2 , 114.6 , 55.6 , 27.6; GC-MS *m*/*z* (ion, % relative intensity): 176([M]$^+$, 49), 161([M−CH_3]$^+$, 100), 145([M−CH_3O]$^+$, 14), 133([M−C_2H_5O]$^+$, 45), 77([M−$C_5H_8O_2$]$^+$, 12).

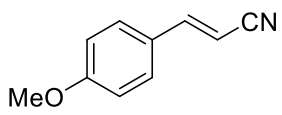
(*E*)-1-(4-Nitrophenyl)but-1-en-3-one (14d)



Method B: Pale Yellow Solid, 45% yield [*E*:*Z*, 11:1]. Data matched that reported by Leung *et.al.*[15]

^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 8.29-8.22(m, 2H), 7.72-7.66(m, 2H), 7.53(d, *J* = 16.3 Hz, 1H), 6.82(d, *J* = 16.3 Hz, 1H), 2.42(s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 197.6, 148.7, 140.8, 140.2, 130.5, 128.9, 124.4, 28.2; GC-MS *m*/*z* (ion, % relative intensity): 191([M]$^+$, 25), 176([M−CH_3]$^+$, 100), 146([M−NO_2]$^+$, 9), 77([M−$C_4H_5NO_3$]$^+$, 6).

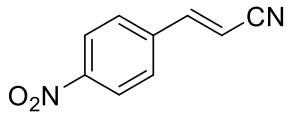
(*E*)-4-Methoxycinnamonitrile (14e)



Method C: Clear oil, 88% yield [*E*:*Z*, 3:1]. Data matched that reported by Qin *et.al.*[25]

^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm): 7.42-7.37(m, 2H), 7.33(d, *J* = 16.5 Hz, 1H), 6.98-6.88(m, 2H), 5.71(d, *J* = 16.6 Hz, 1H), 3.85(s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm): 162.0, 150.0, 129.0, 126.3, 118.7, 114.5, 93.4, 55.4; GC-MS *m*/*z* (ion, % relative intensity): 159([M]$^+$, 100), 144([M−CH_3]$^+$, 31), 129([M−CH_3O]$^+$, 11), 77([M−C_4H_5NO]$^+$, 4).

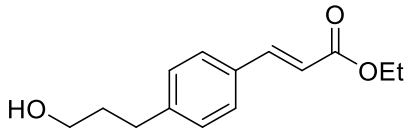
(*E*)-4-Nitrocinnamonitrile (14f)



Method B: Pale Yellow Solid, 21% yield [*E*:*Z*, 3:1]. Data matched that reported by Zhou *et.al.*[26]

^{1}H NMR (300 MHz, d_6-DMSO) δ (ppm): 8.32-8.24(m, 2H), 7.96-7.89(m, 2H), 7.82(d, *J* = 16.8 Hz, 1H), 6.73(d, *J* = 16.7 Hz, 1H). ^{13}C NMR (75 MHz, d_6-DMSO) δ (ppm): 148.2, 146.7, 139.8, 128.9, 124.1, 118.1, 101.4; GC-MS *m*/*z* (ion, % relative intensity): 174([M]$^+$, 100), 128([M−NO_2]$^+$, 69), 77([M−$C_3H_2N_2O_2$]$^+$, 51).

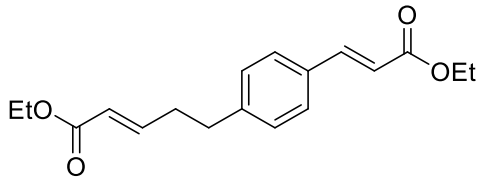
Ethyl (*E*)-3-(4-(3-hydroxypropyl)phenyl)acrylate (16)



Method D: Pale Yellow oil, 49% [77% BRSM] yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 7.67(d, *J* = 16.0 Hz, 1H), 7.45(d, *J* = 8.1 Hz, 2H), 7.22(d, *J* = 8.0 Hz, 2H), 6.40(d, *J* = 16.0 Hz, 1H), 4.26(q, *J* = 7.1 Hz, 2H), 3.73-3.64(m, 2H), 2.77-2.70(m, 2H), 1.94-1.85(m, 2H), 1.34(t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 167.1, 144.5, 144.4, 132.2, 129.0, 128.2, 117.4, 62.1, 60.4, 33.9, 31.9, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 234($[M]^+$, 100), 205($[M-C_2H_5]^+$, 8), 203($[M-CH_3O]^+$, 58), 189($[M-C_2H_5O]^+$, 50), 175($[M-C_3H_7O]^+$, 22), 161($[M-C_3H_5O_2]^+$, 36), 77($[M-C_{11}H_{11}O_2]^+$, 14); IR (neat, cm^{-1}): 3352 (br, w), 2936 (w), 1706 (s), 1634 (s), 1310 (m), 1173 (s), 1036 (m); Anal. Calcd. for $C_{14}H_{18}O_3$: C, 71.77; H, 7.74; O, 20.49. Found: C, 71.09; H, 7.82; O, 21.09; HRMS: m/z $C_{14}H_{18}O_3Na^+$ $[M+Na]^+$, Calculated: 257.1148, Found: 257.1150.

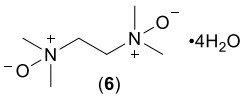
Ethyl (*E*)-5-(4-((*E*)-3-ethoxy-3-oxoprop-1-en-1-yl)phenyl)pent-2-enoate (17)



Method D: Clear oil, 7% [11% BRSM] yield. Data matched that reported by Panther *et.al.* [27]

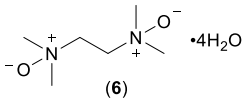
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm): 7.66(d, *J* = 16.1 Hz, 1H), 7.46(d, *J* = 7.6 Hz, 2H), 7.20(d, *J* = 7.7 Hz, 2H), 6.97(dt, *J* = 15.6, 6.8 Hz, 1H), 6.40(d, *J* = 16.0 Hz, 1H), 5.84(dt, *J* = 15.6, 1.6 Hz, 1H), 4.26(q, *J* = 7.1 Hz, 2H), 4.18(q, *J* = 7.0 Hz, 2H), 2.83-2.73(m, 2H), 2.57(m, 2H), 1.34(t, *J* = 7.1 Hz, 3H),1.28(t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm): 167.1, 166.4, 147.5, 144.3, 143.3, 133.6, 132.5, 128.9, 128.2, 122.1, 117.6, 60.4, 60.2, 34.2, 33.5, 14.3; GC-MS *m*/*z* (ion, % relative intensity): 302($[M]^+$, 7), 257($[M-C_2H_5O]^+$, 8), 211($[M-C_4H_{10}O_2]^+$, 4), 189($[M-C_6H_9O_2]^+$, 100).

9. NMR Spectra



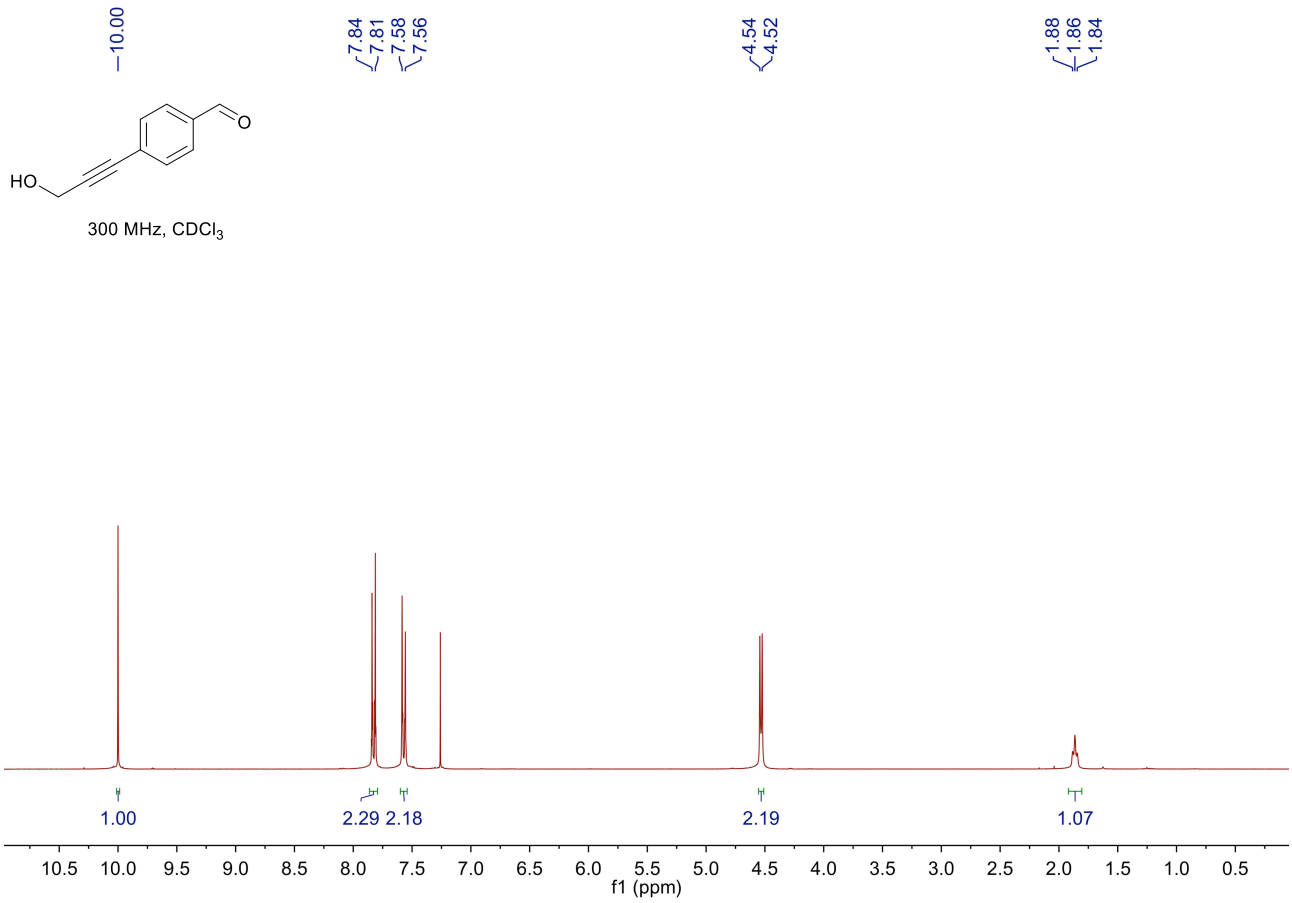
(**6**)

300 MHz, D_2O

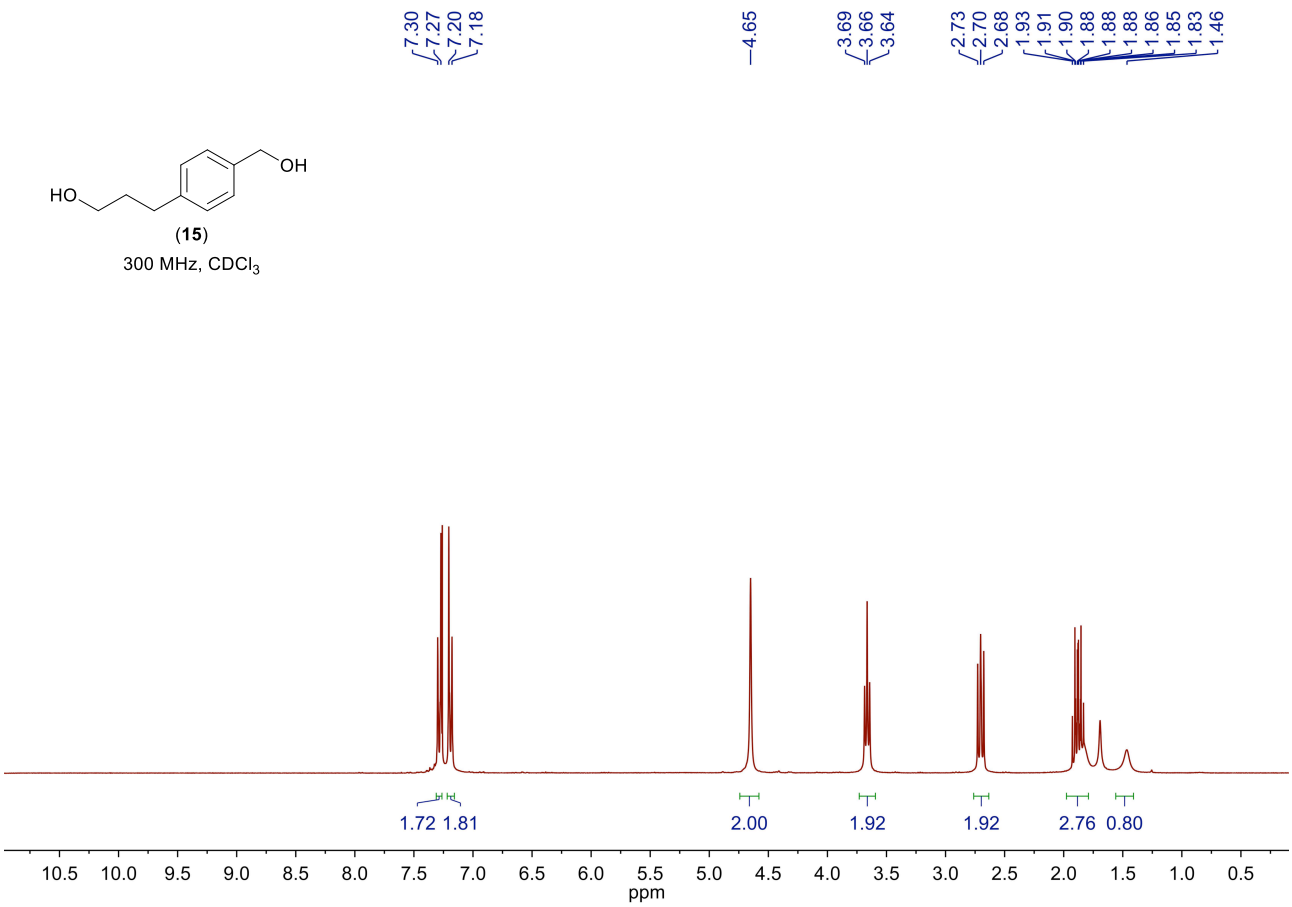


(**6**)

100 MHz, D_2O (Dioxane)

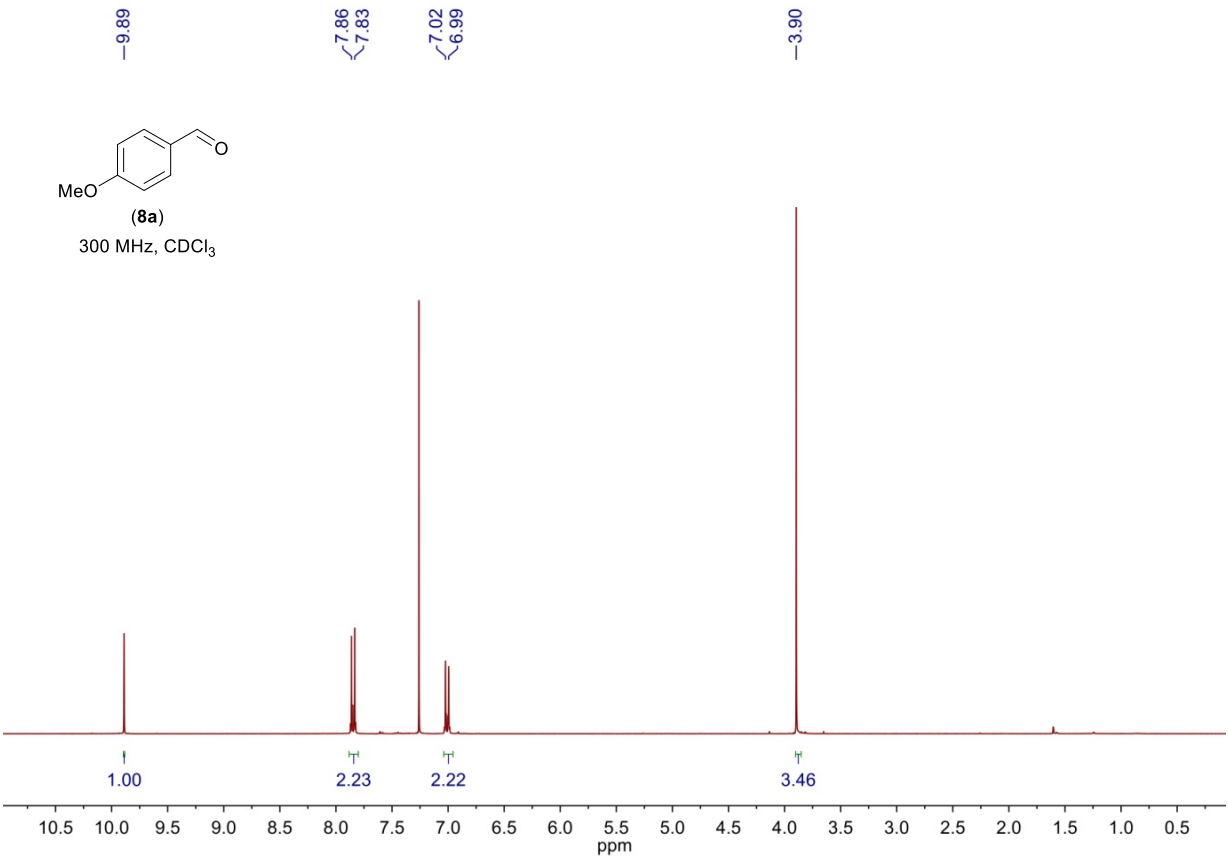


300 MHz, $CDCl_3$



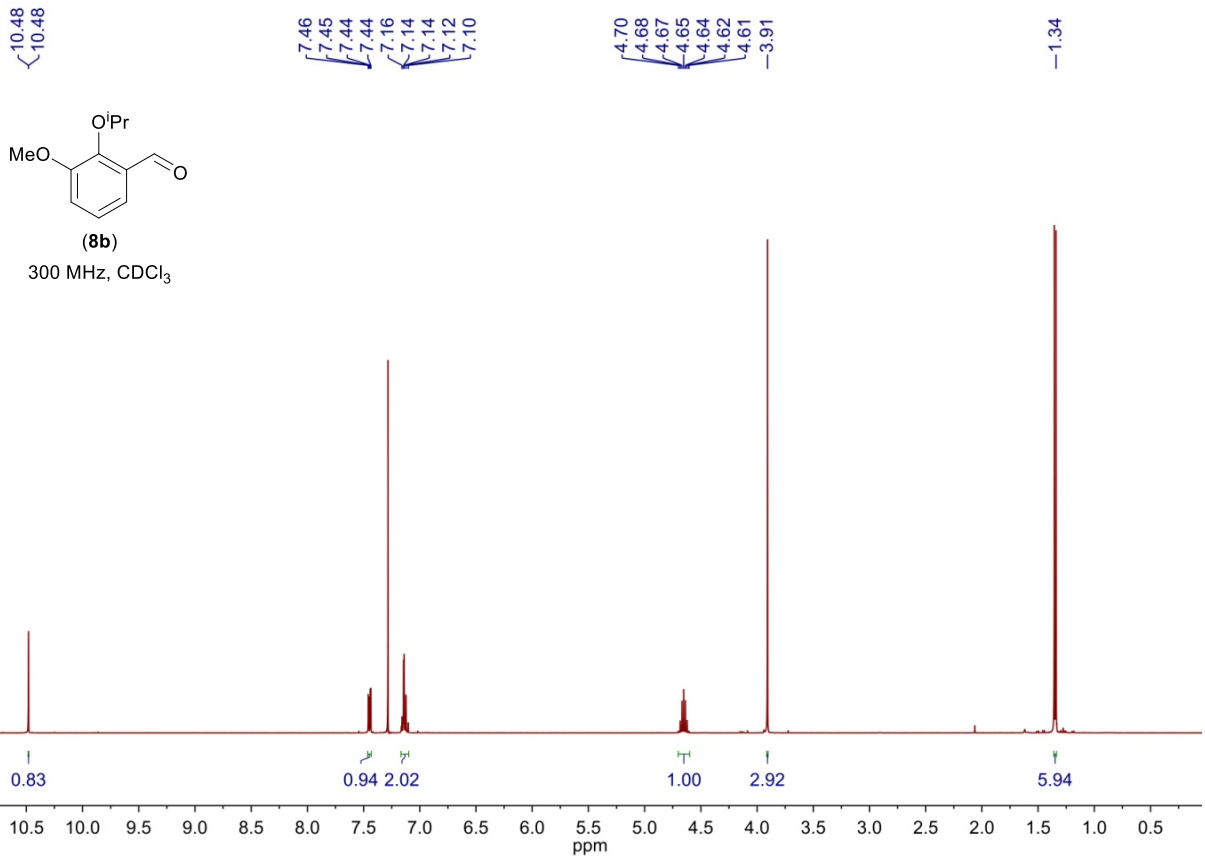
(**15**)

300 MHz, $CDCl_3$



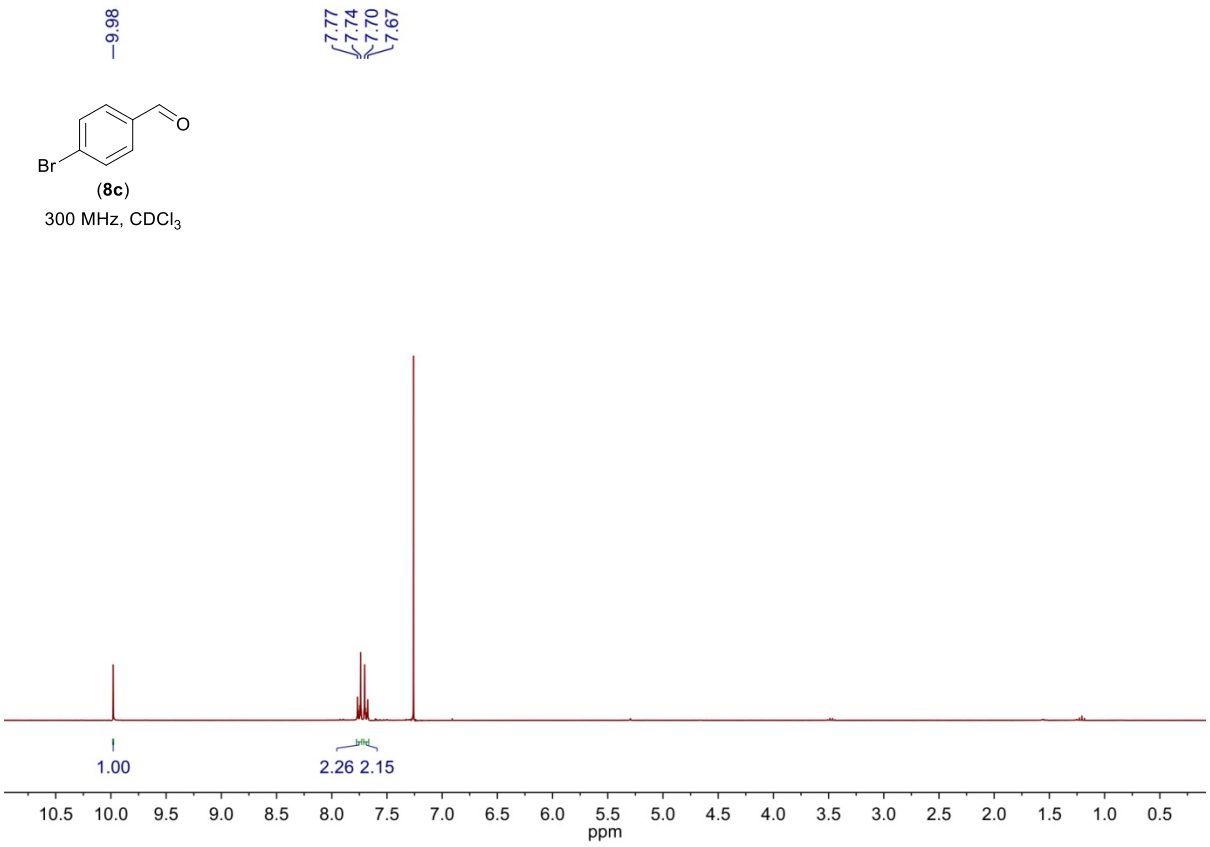
(**8a**)

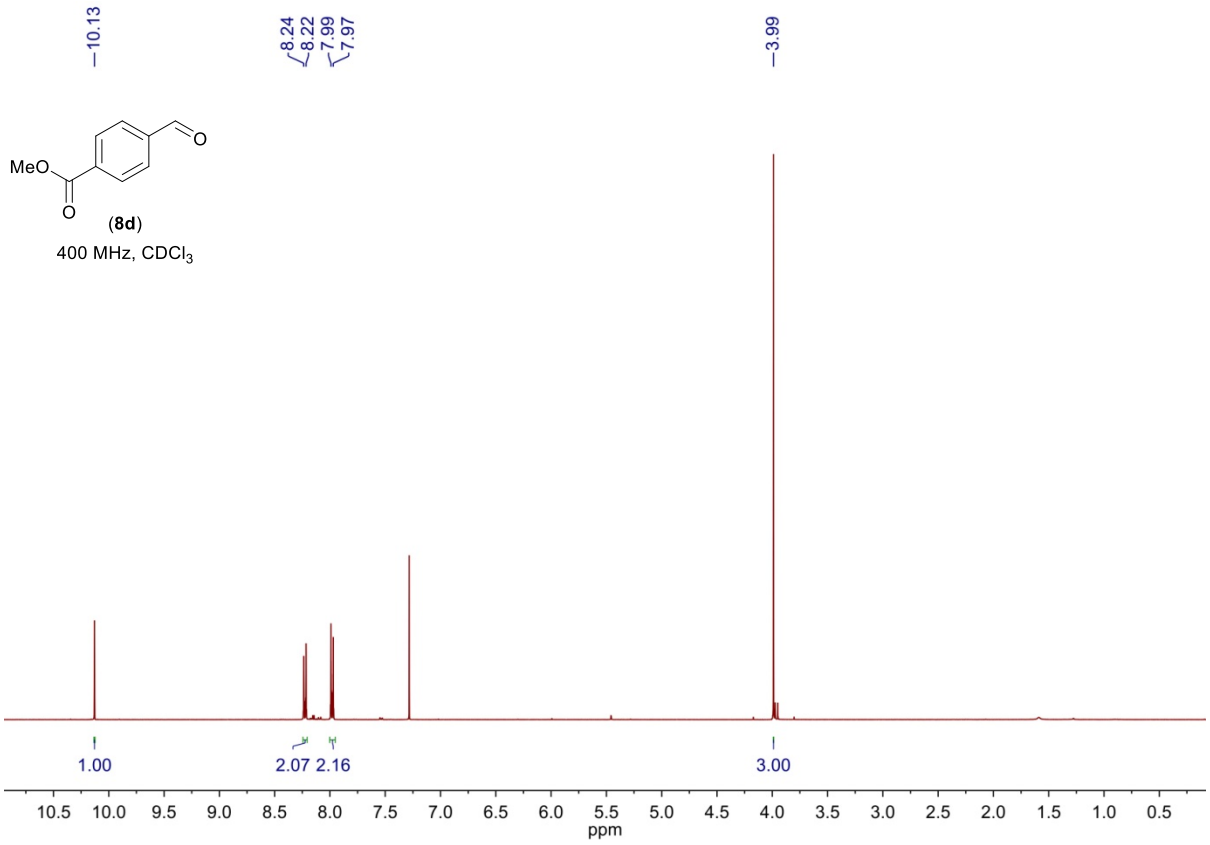
300 MHz, $CDCl_3$

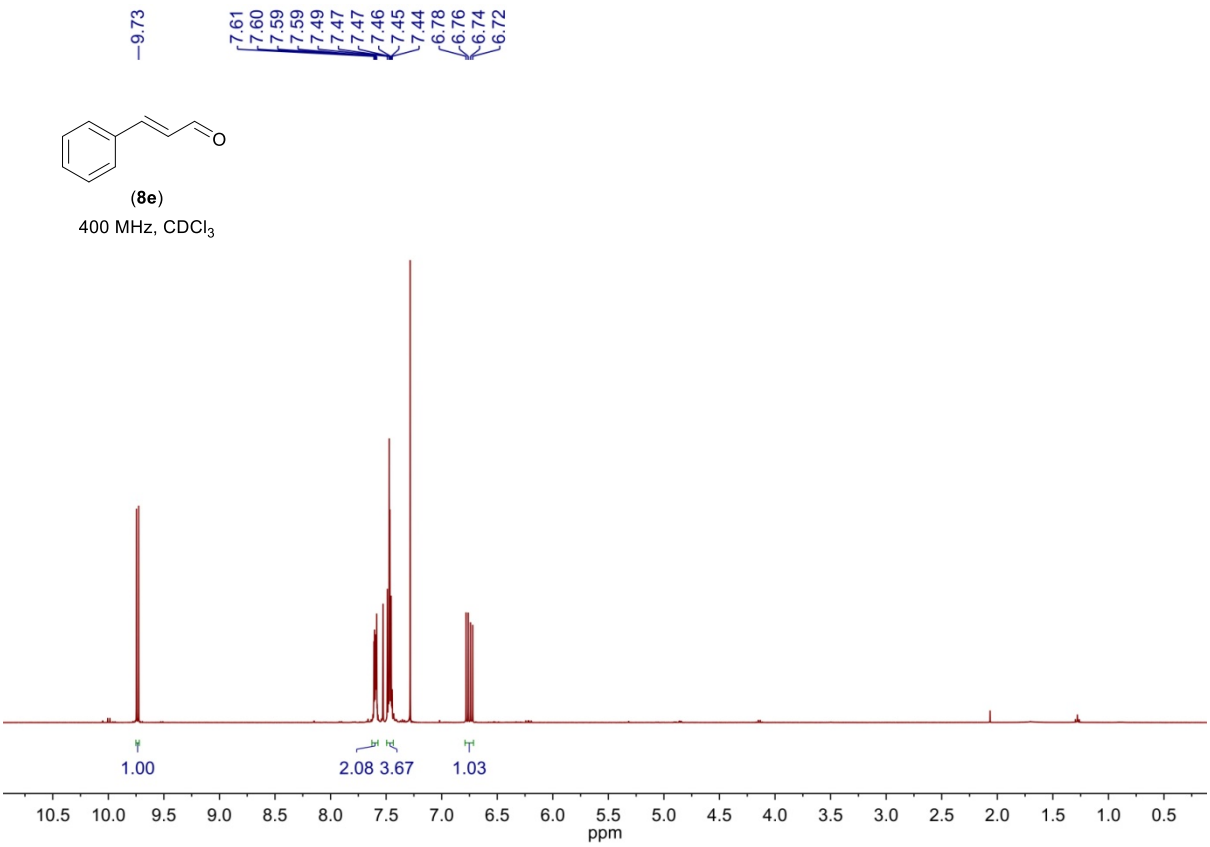


(**8b**)

300 MHz, $CDCl_3$

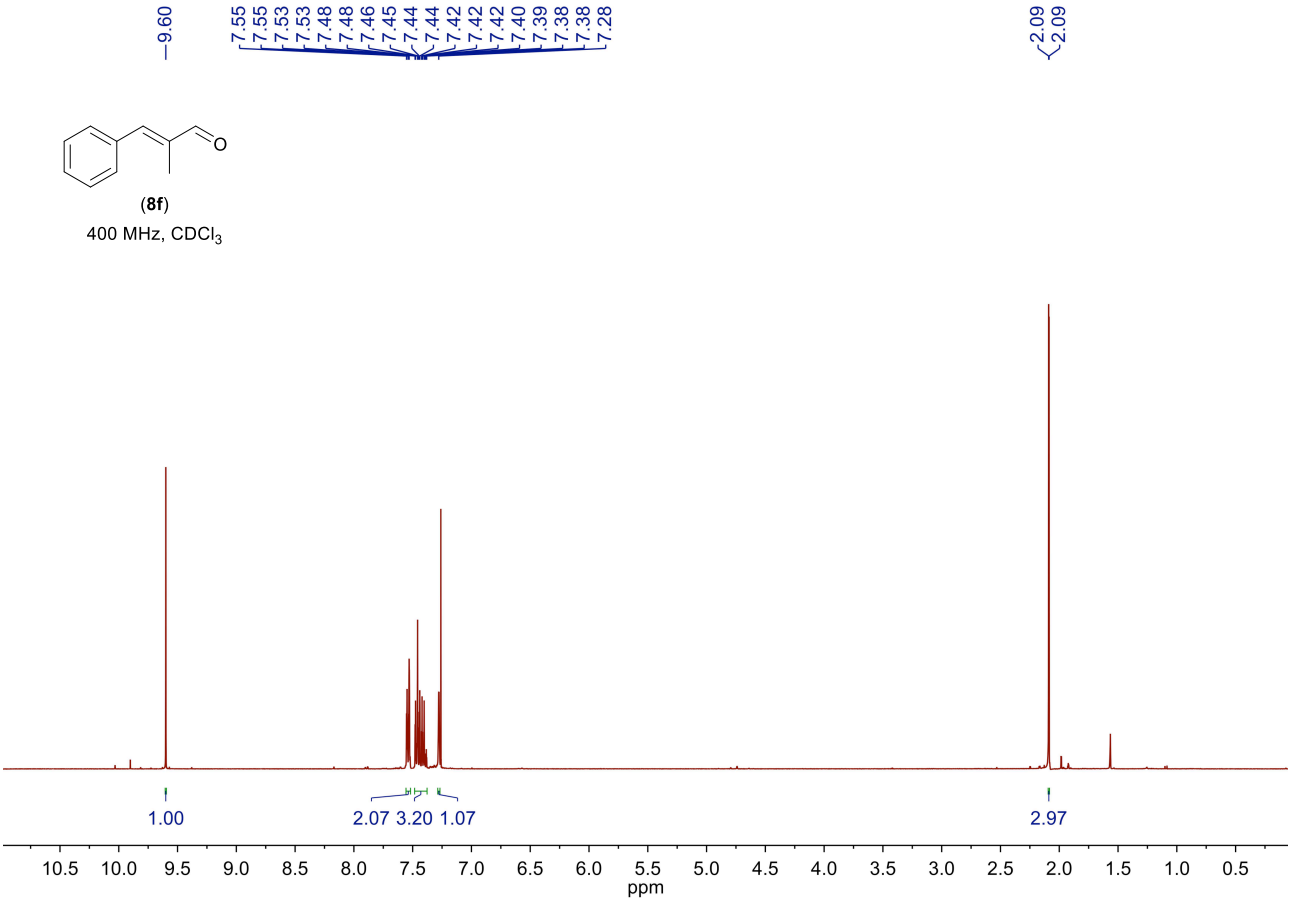

9.98
7.77
7.74
7.70
7.67
Br
O
(8c)
300 MHz, CDCl3
1.00
2.26 2.15
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm


10.13
8.24
8.22
7.99
7.97
3.99
MeO
O
O
(8d)
400 MHz, CDCl3
1.00
2.07 2.16
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm



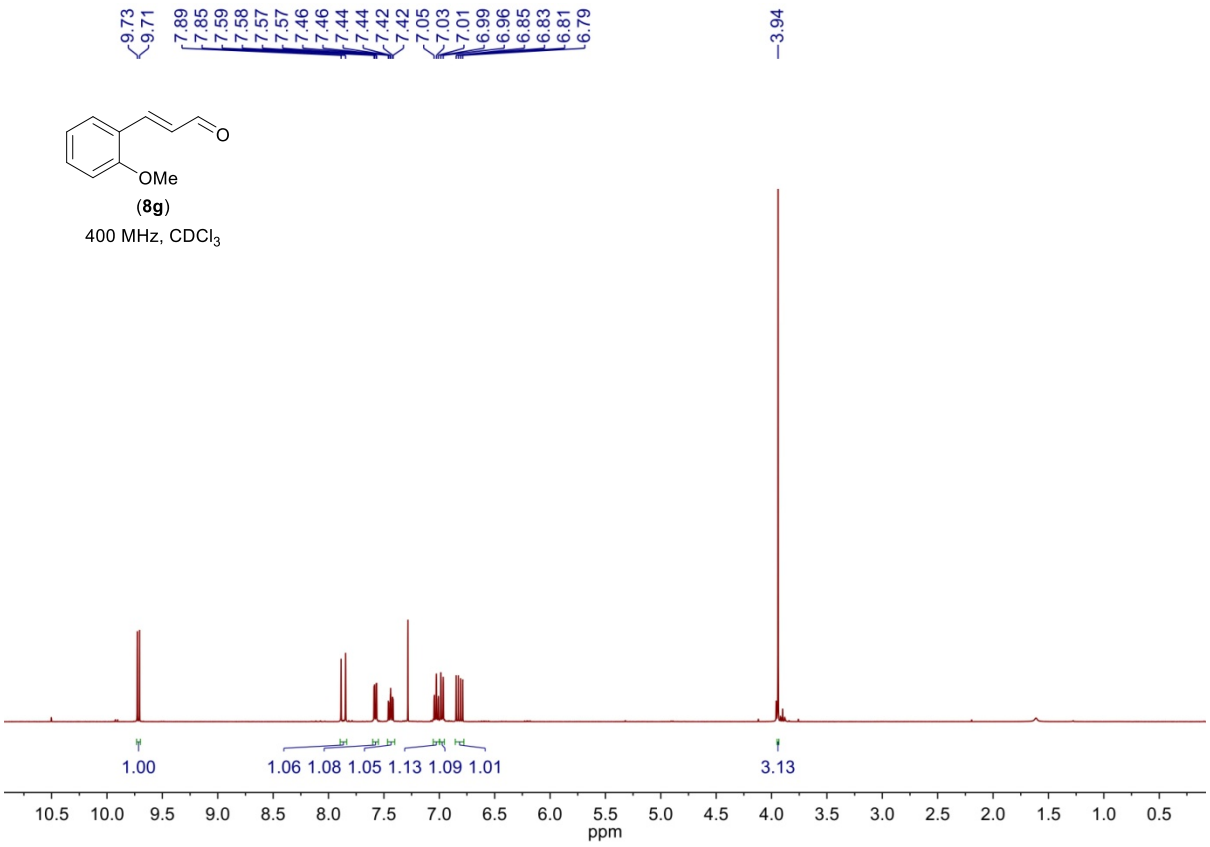
(**8e**)

400 MHz, $CDCl_3$



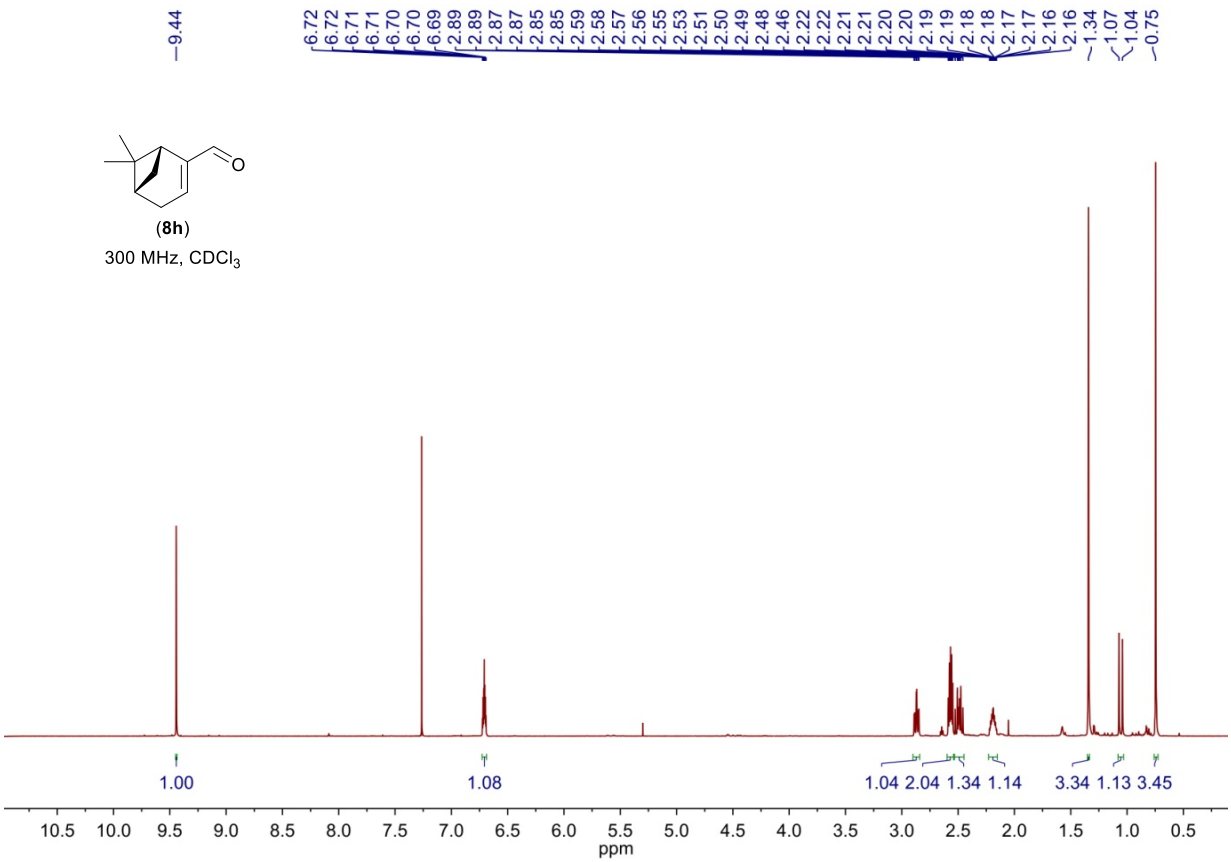
(**8f**)

400 MHz, $CDCl_3$



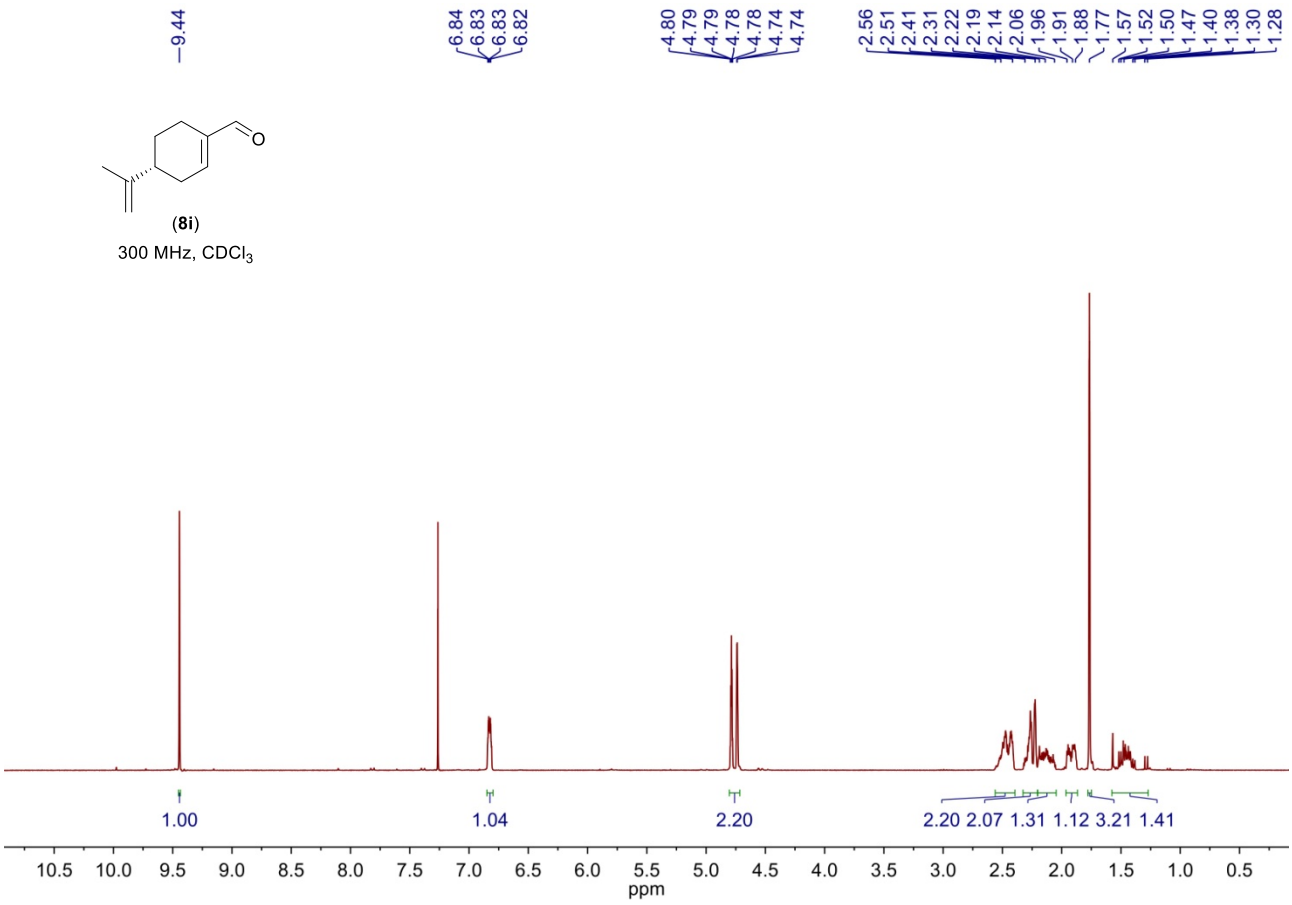
(**8g**)

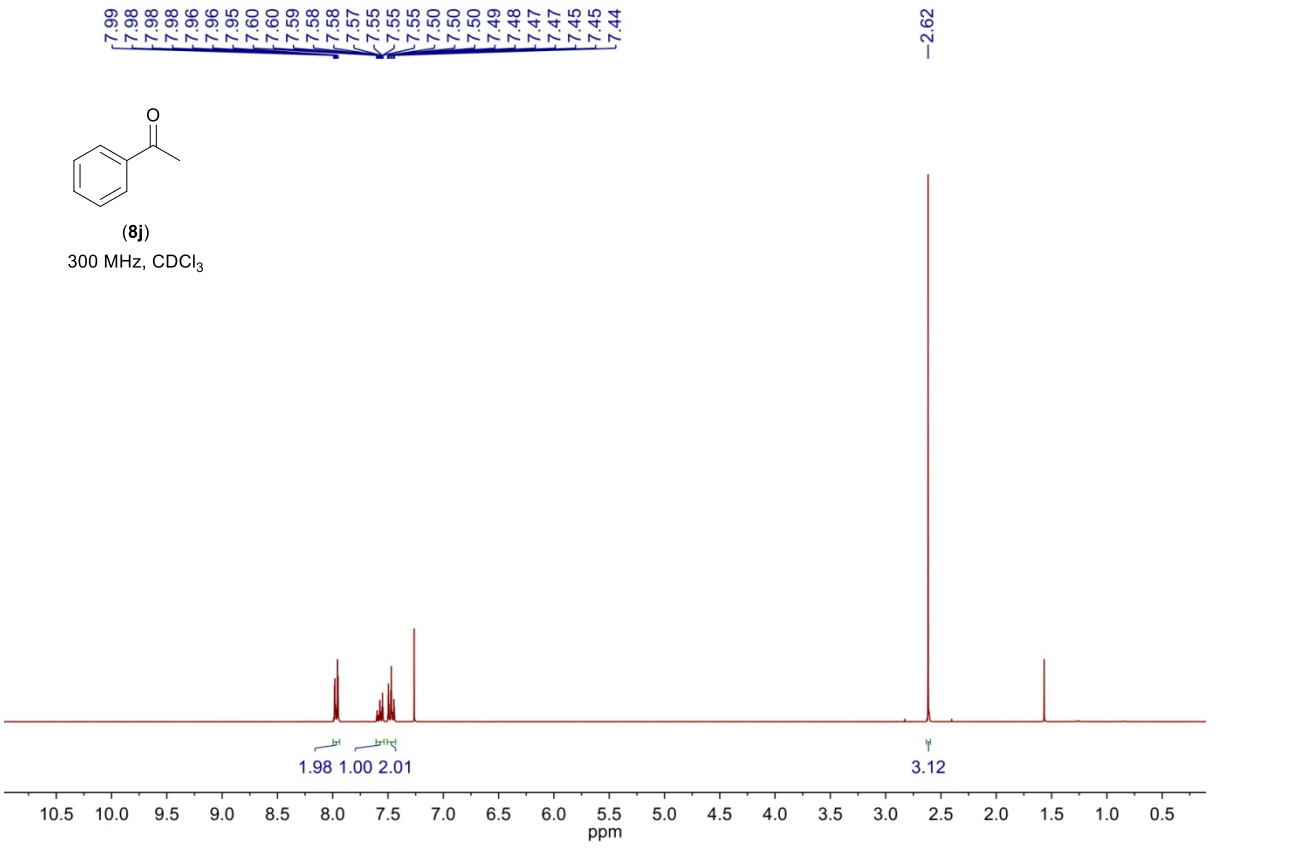
400 MHz, $CDCl_3$

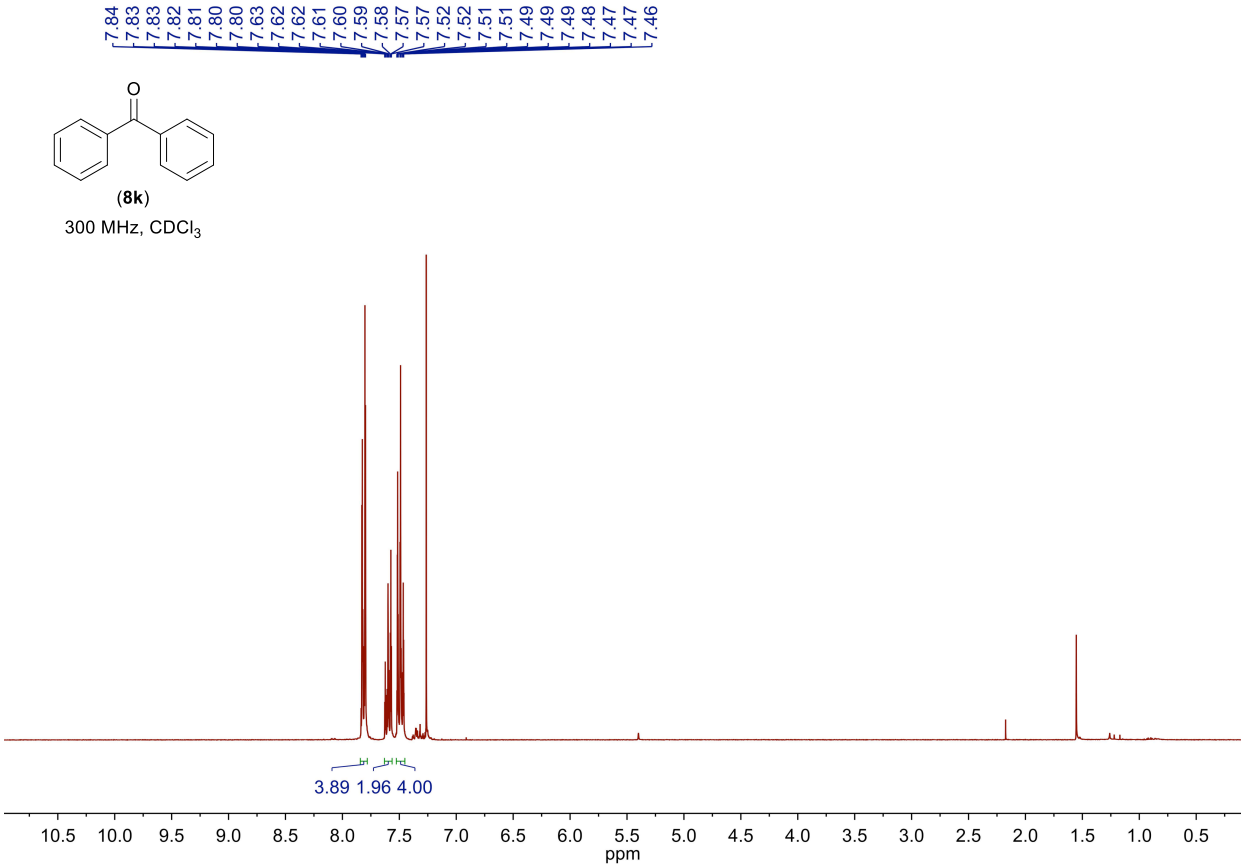


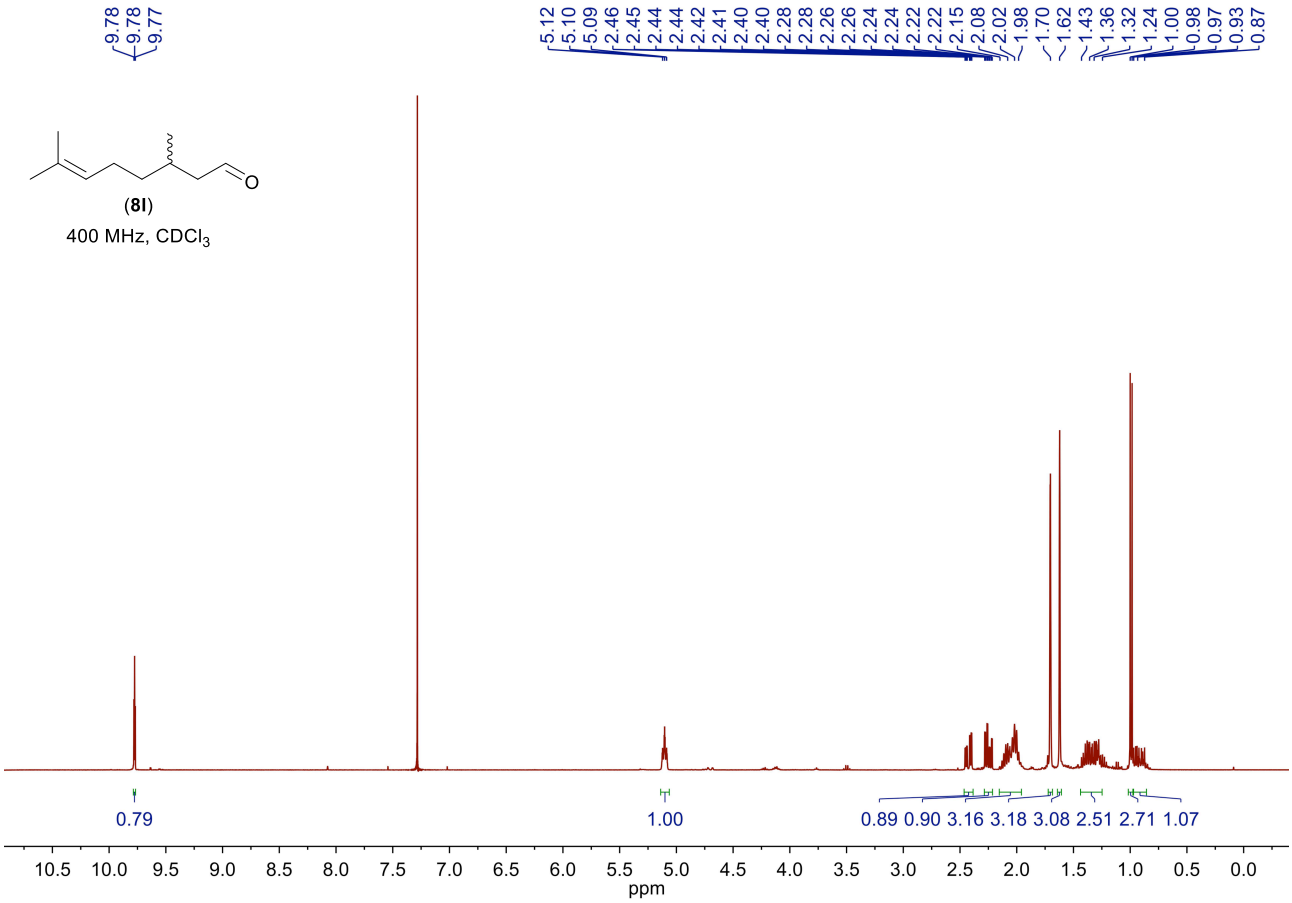
(**8h**)

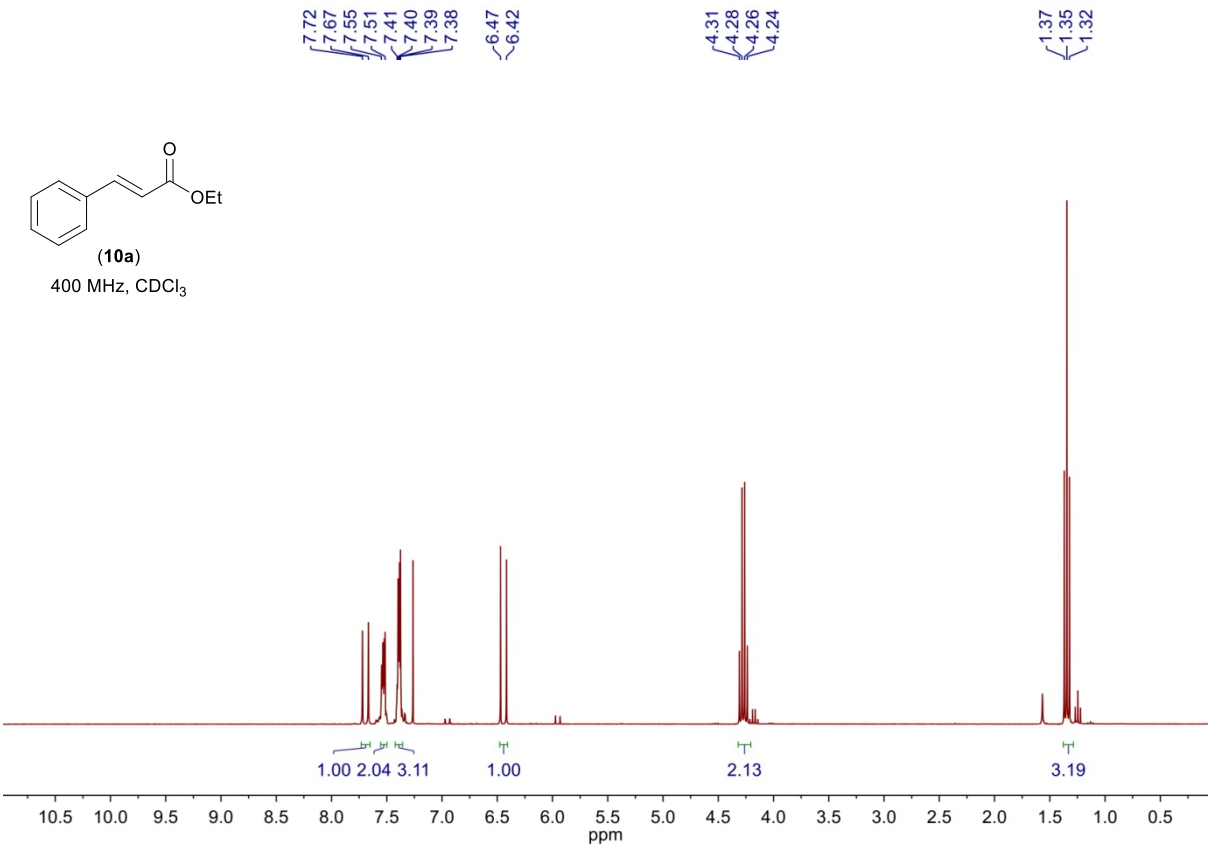
300 MHz, $CDCl_3$

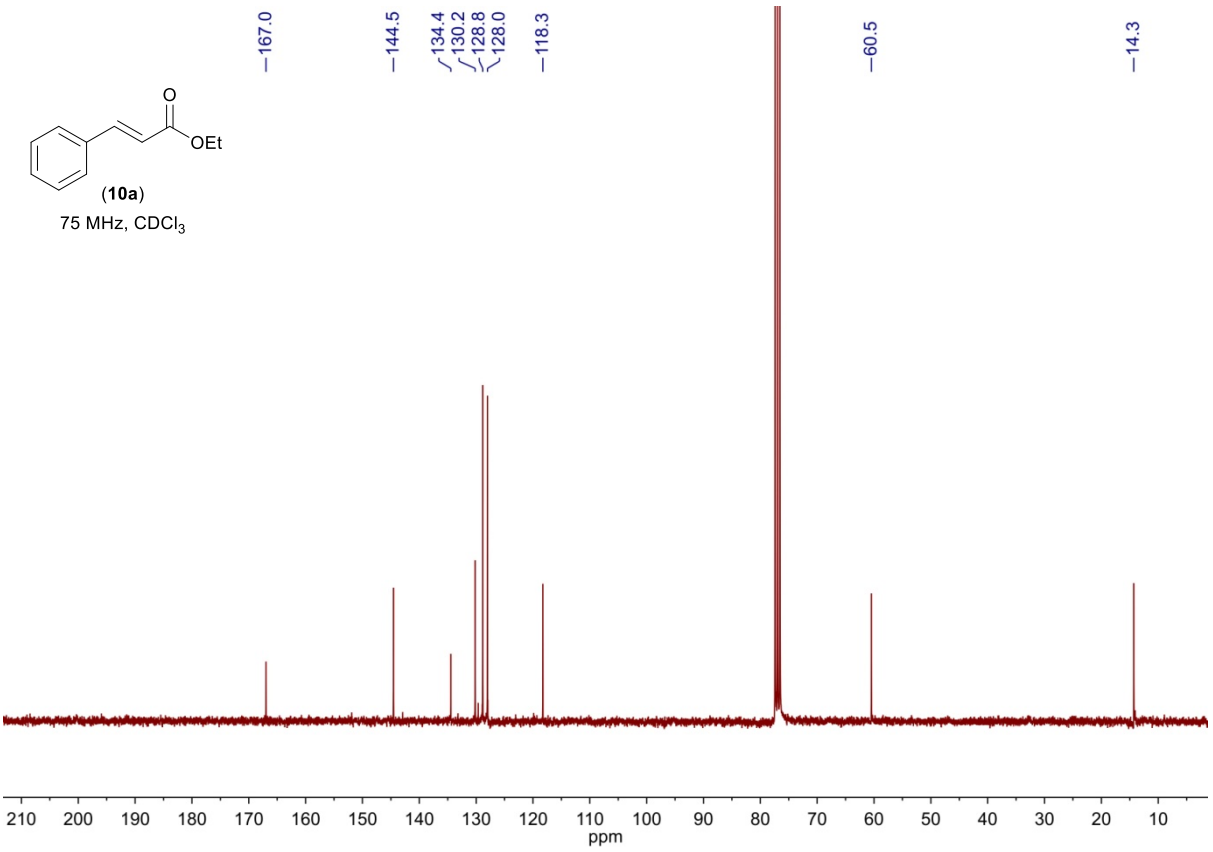

9.44
6.84
6.83
6.83
6.82
4.80
4.79
4.79
4.78
4.78
4.74
4.74
2.56
2.51
2.41
2.31
2.22
2.19
2.14
2.06
1.96
1.91
1.88
1.77
1.57
1.52
1.50
1.47
1.40
1.38
1.30
1.28
O
(8i)
300 MHz, CDCl3
1.00
1.04
2.20
2.20 2.07 1.31 1.12 3.21 1.41
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

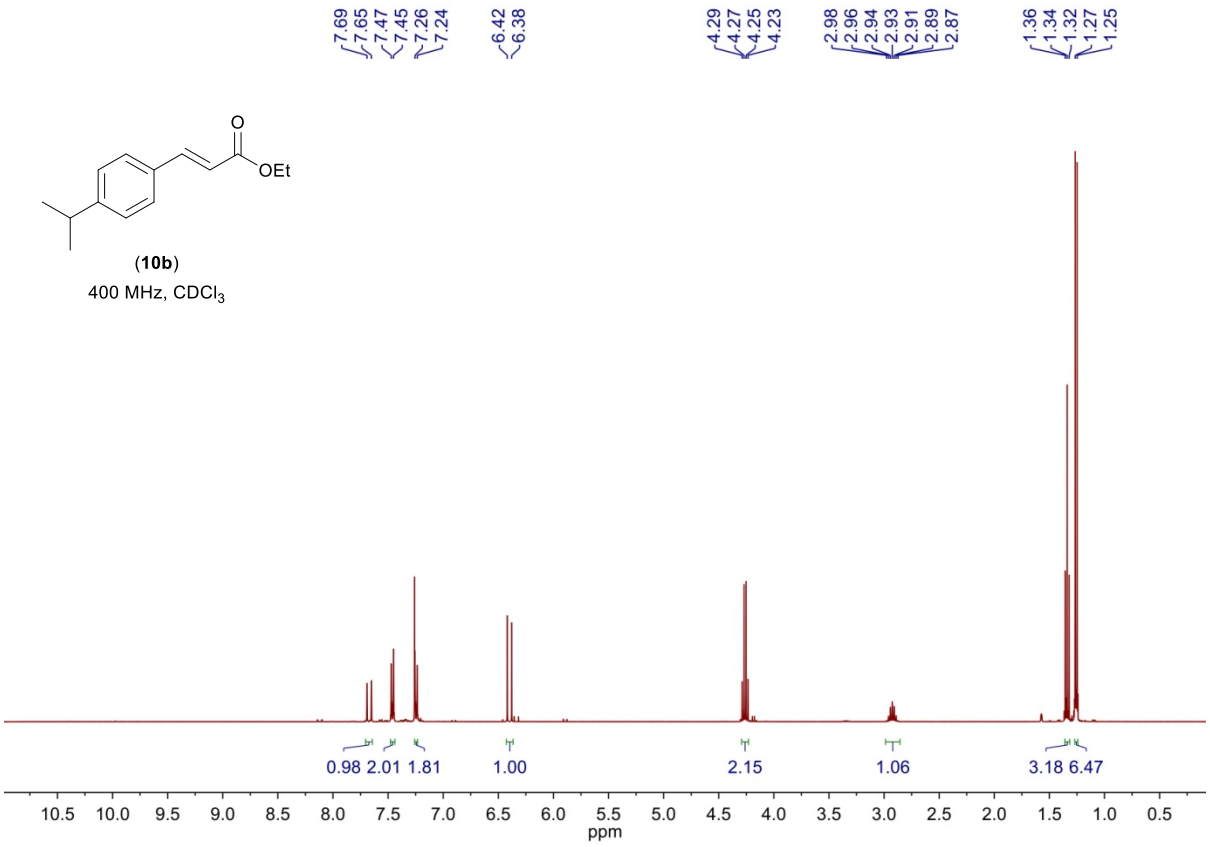

7.99
7.98
7.98
7.98
7.96
7.96
7.95
7.60
7.60
7.59
7.58
7.58
7.57
7.55
7.55
7.55
7.50
7.50
7.50
7.49
7.48
7.47
7.47
7.45
7.45
7.44
2.62
O
(8j)
300 MHz, CDCl3
1.98 1.00 2.01
3.12
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

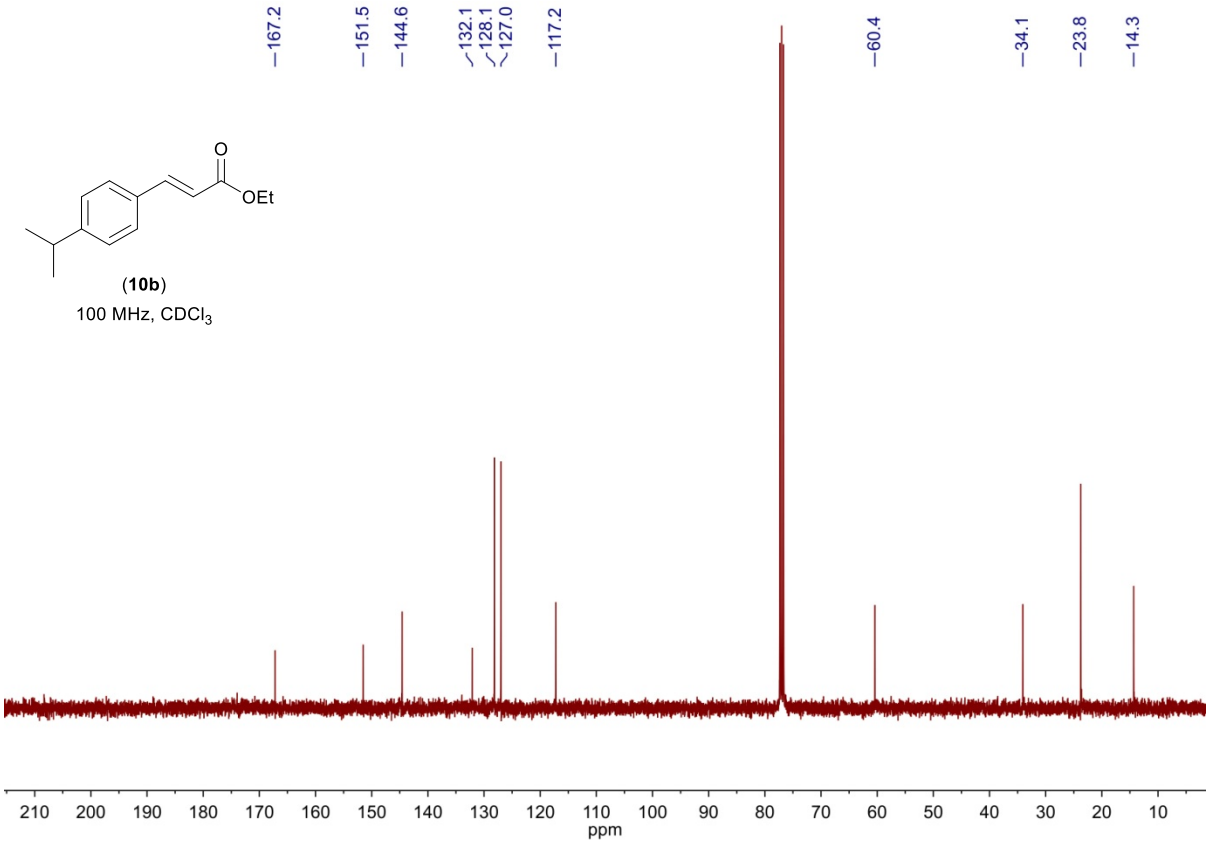

7.84 7.83 7.83 7.82 7.81 7.80 7.80 7.63 7.62 7.62 7.61 7.60 7.59 7.58 7.57 7.57 7.52 7.52 7.51 7.51 7.49 7.49 7.49 7.48 7.47 7.47 7.46
O
(8k)
300 MHz, CDCl3
3.89 1.96 4.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

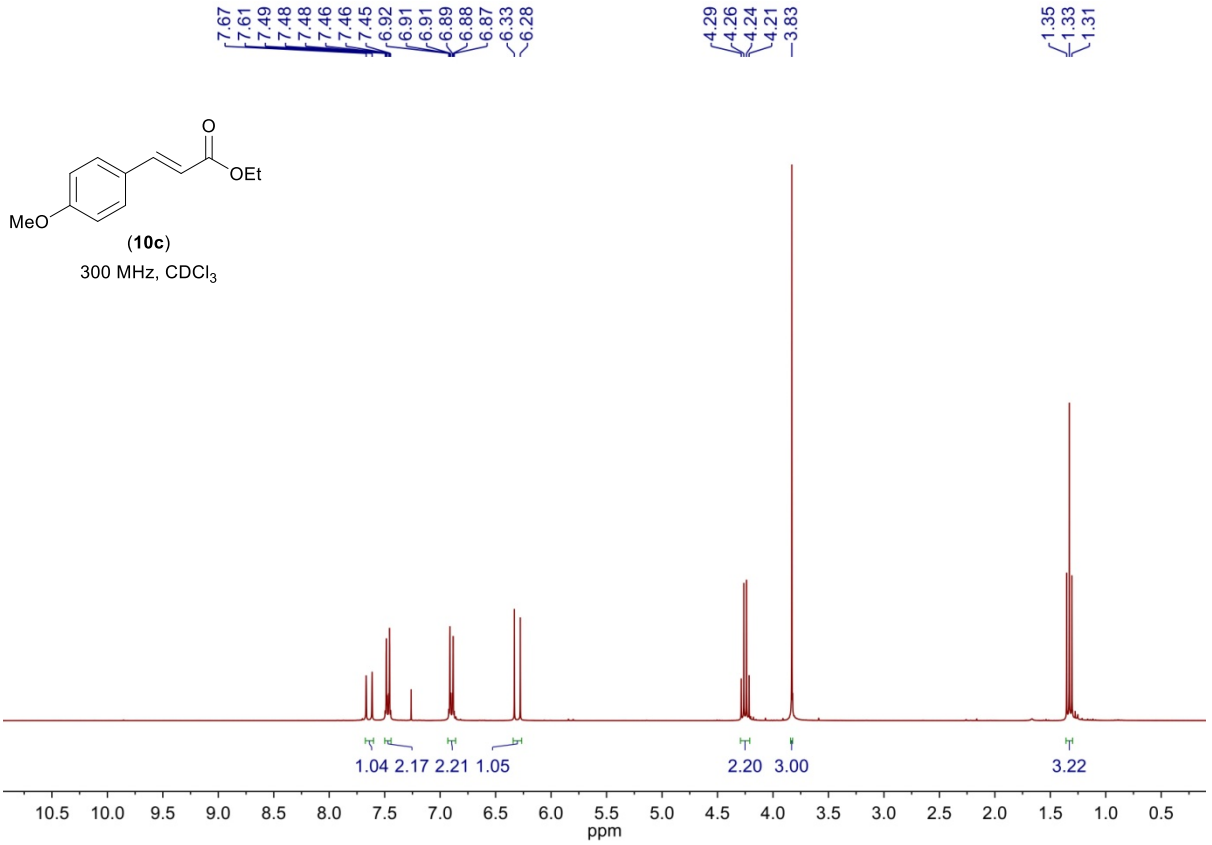

9.78 9.78 9.77
5.12 5.10 5.09 2.46 2.45 2.44 2.44 2.42 2.41 2.40 2.40 2.28 2.26 2.26 2.24 2.24 2.22 2.22 2.15 2.08 2.02 1.98 1.70 1.62 1.43 1.36 1.32 1.24 1.00 0.98 0.97 0.93 0.87
O
(8l)
400 MHz, CDCl3
0.79
1.00
0.89 0.90 3.16 3.18 3.08 2.51 2.71 1.07
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

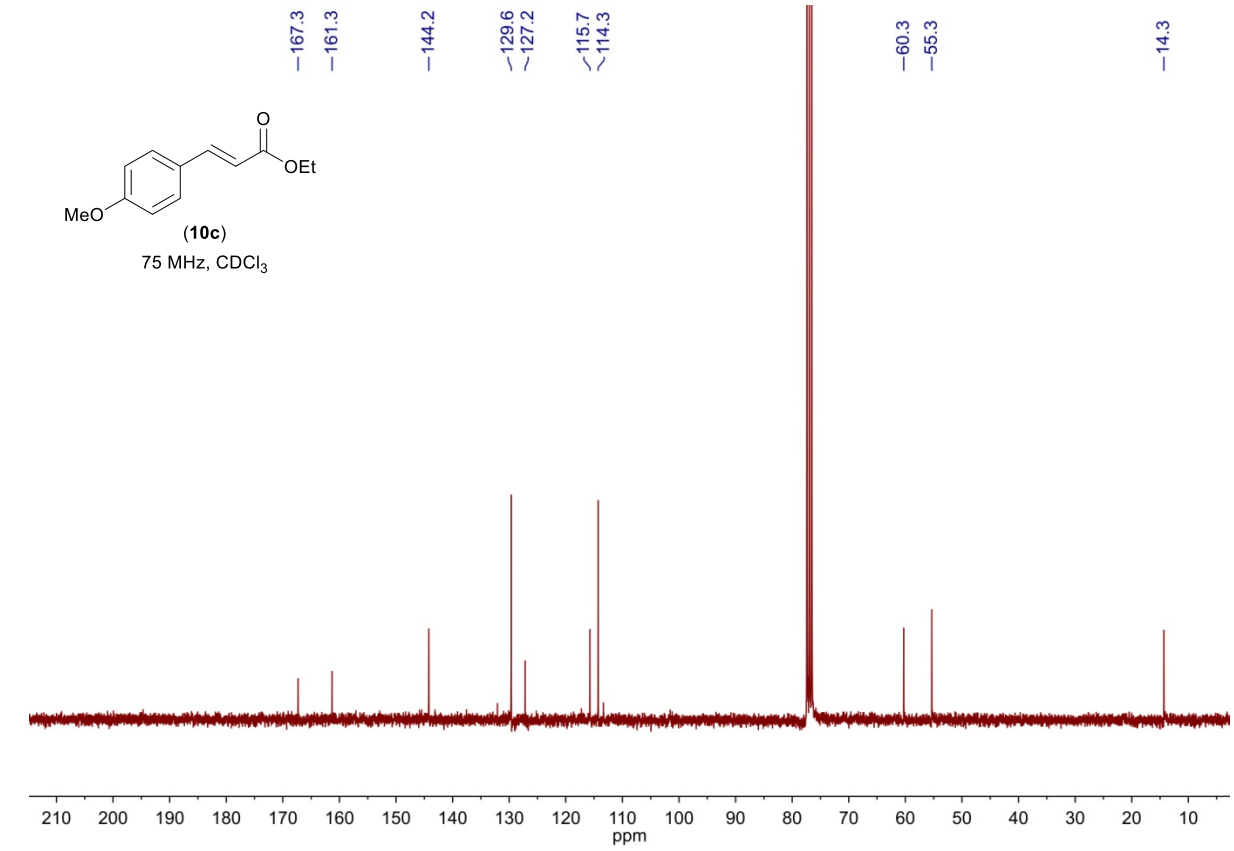

7.72
7.67
7.55
7.51
7.41
7.40
7.39
7.38
6.47
6.42
4.31
4.28
4.26
4.24
1.37
1.35
1.32
O
OEt
(10a)
400 MHz, CDCl3
1.00 2.04 3.11
1.00
2.13
3.19
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

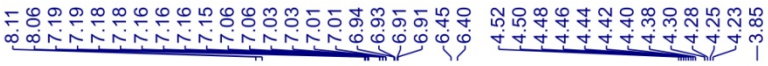

167.0
144.5
134.4
130.2
128.8
128.0
118.3
60.5
14.3
O
OEt
(10a)
75 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

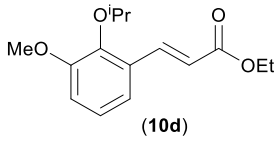

7.69
7.65
7.47
7.45
7.26
7.24
6.42
6.38
4.29
4.27
4.25
4.23
2.98
2.96
2.94
2.93
2.91
2.89
2.87
1.36
1.34
1.32
1.27
1.25
O
OEt
(10b)
400 MHz, CDCl3
0.98 2.01 1.81 1.00 2.15 1.06 3.18 6.47
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm


167.2
151.5
144.6
132.1
128.1
127.0
117.2
60.4
34.1
23.8
14.3
O
OEt
(10b)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm


7.67
7.61
7.49
7.48
7.48
7.46
7.46
7.45
6.92
6.91
6.91
6.89
6.88
6.87
6.33
6.28
4.29
4.26
4.24
4.21
3.83
1.35
1.33
1.31
O
OEt
MeO
(10c)
300 MHz, CDCl3
1.04 2.17 2.21 1.05
2.20 3.00
3.22
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

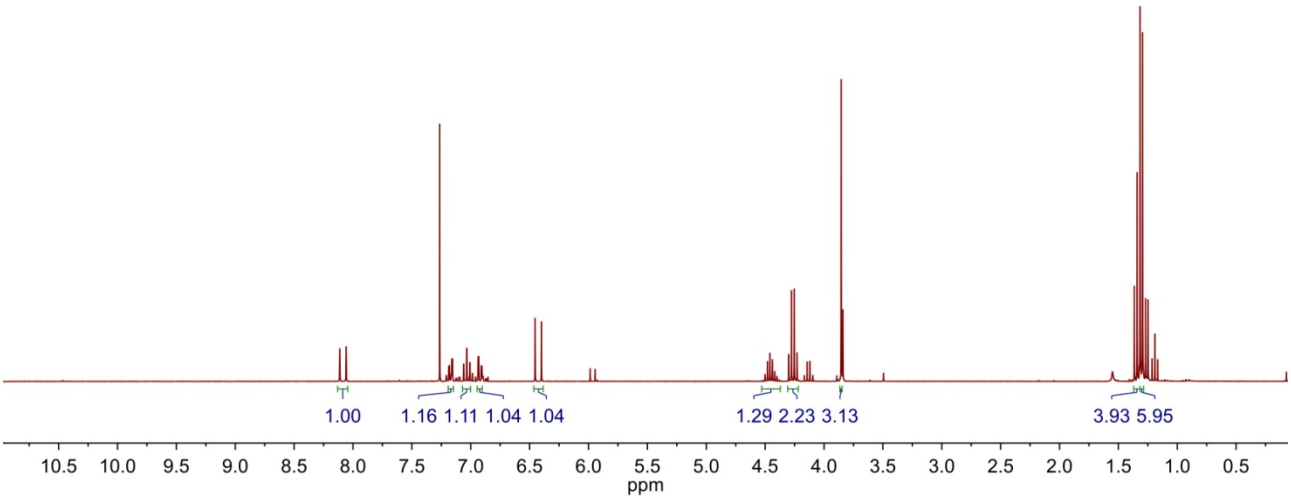

167.3
161.3
144.2
129.6
127.2
115.7
114.3
60.3
55.3
14.3
O
OEt
MeO
(10c)
75 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

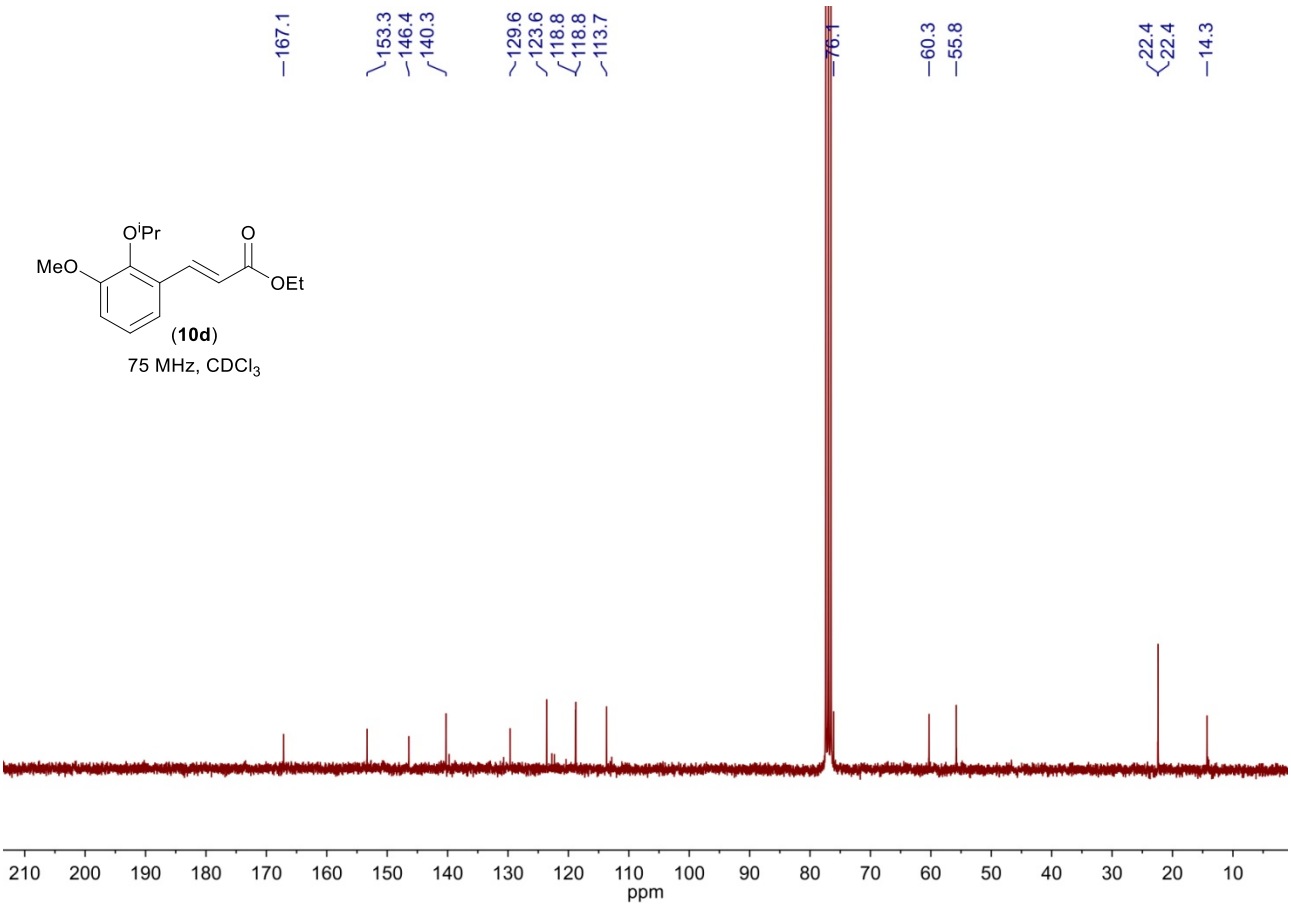




(**10d**)

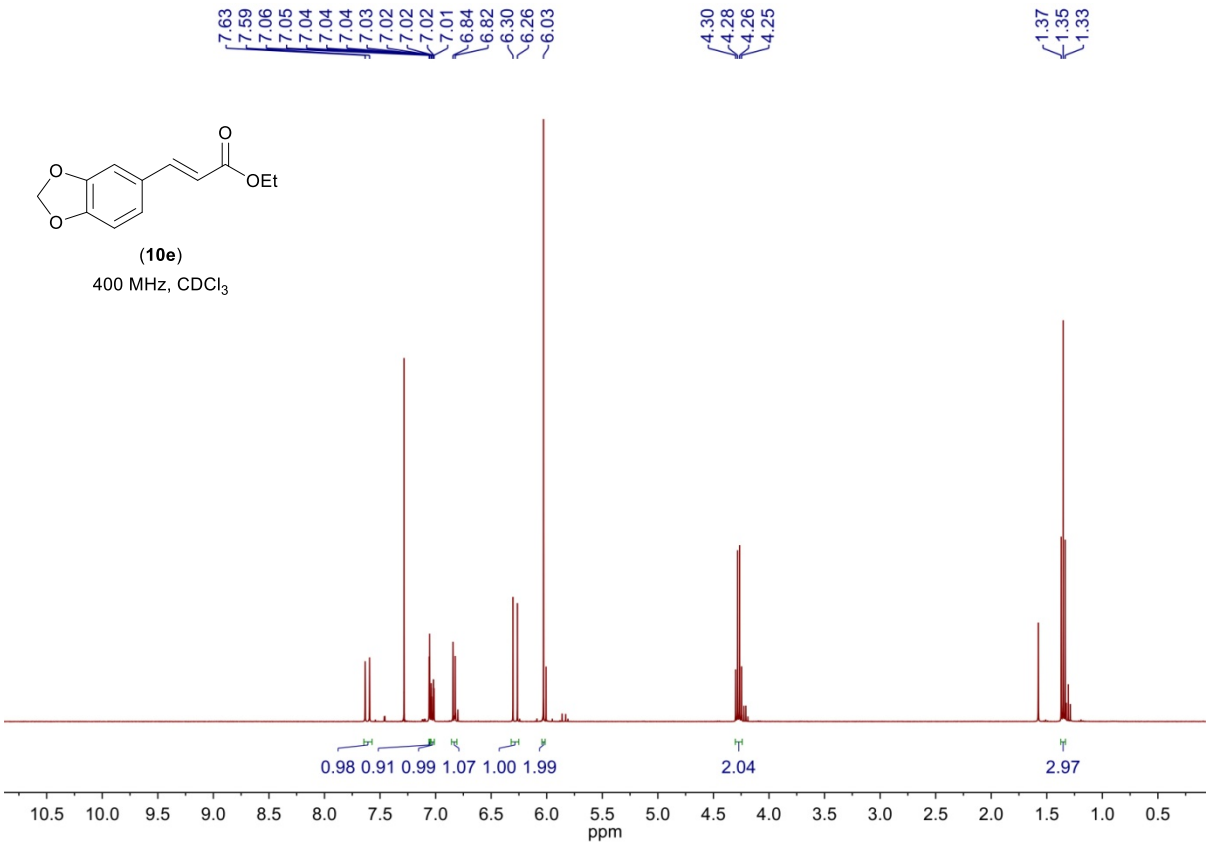
400 MHz, $CDCl_3$

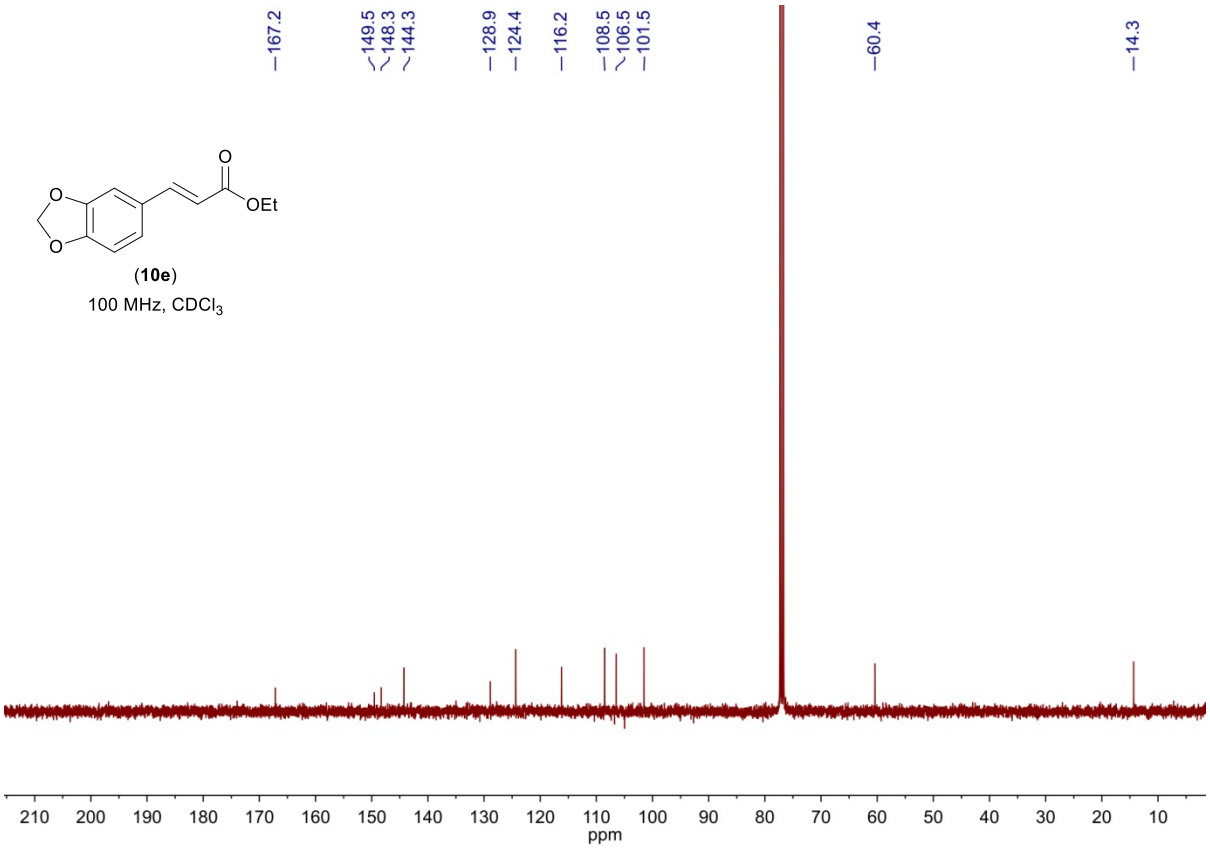


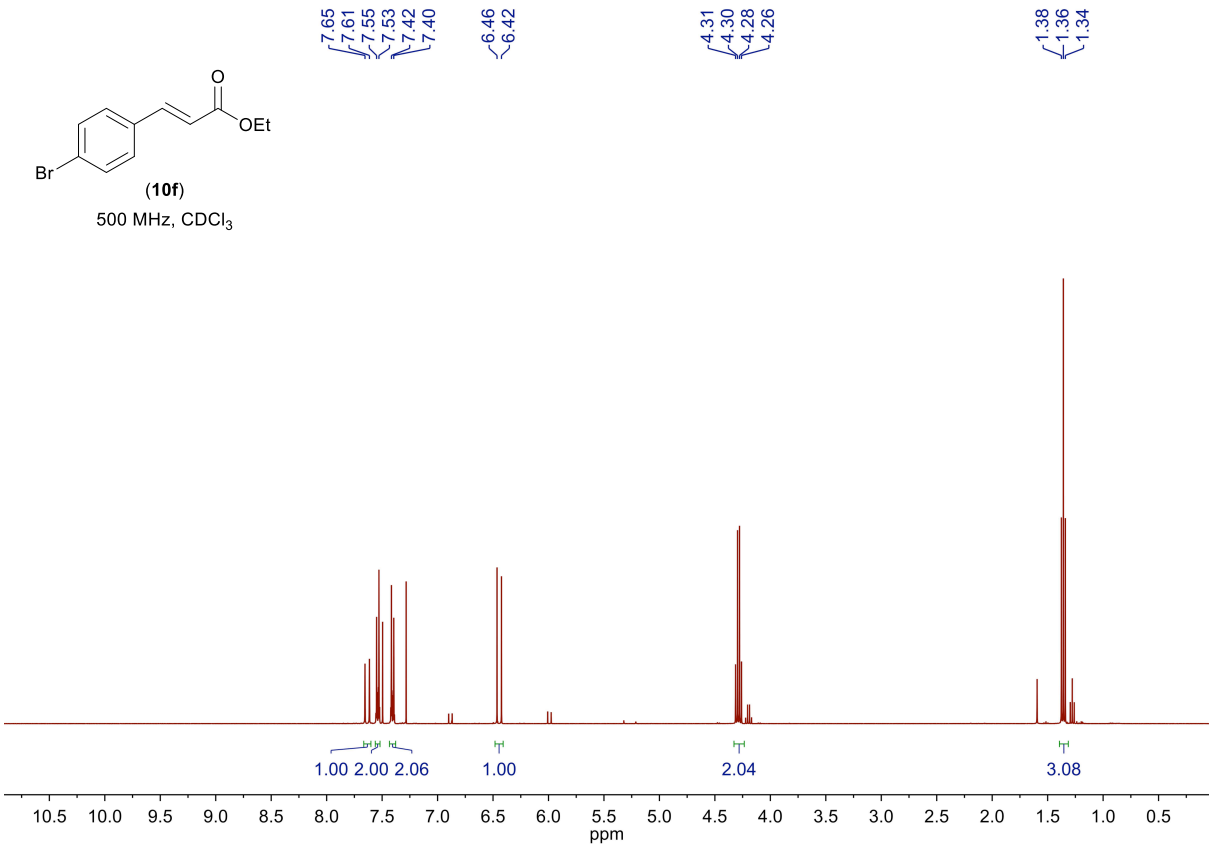


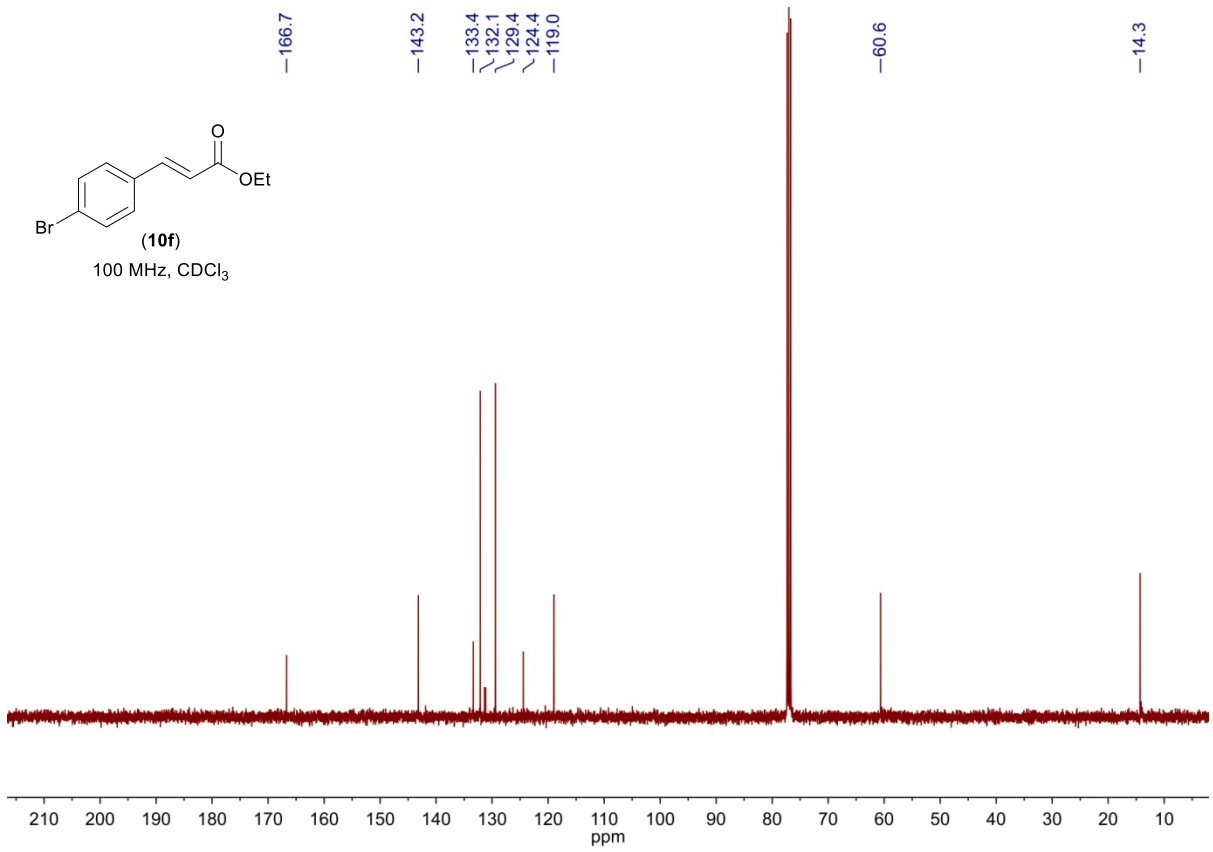
(**10d**)

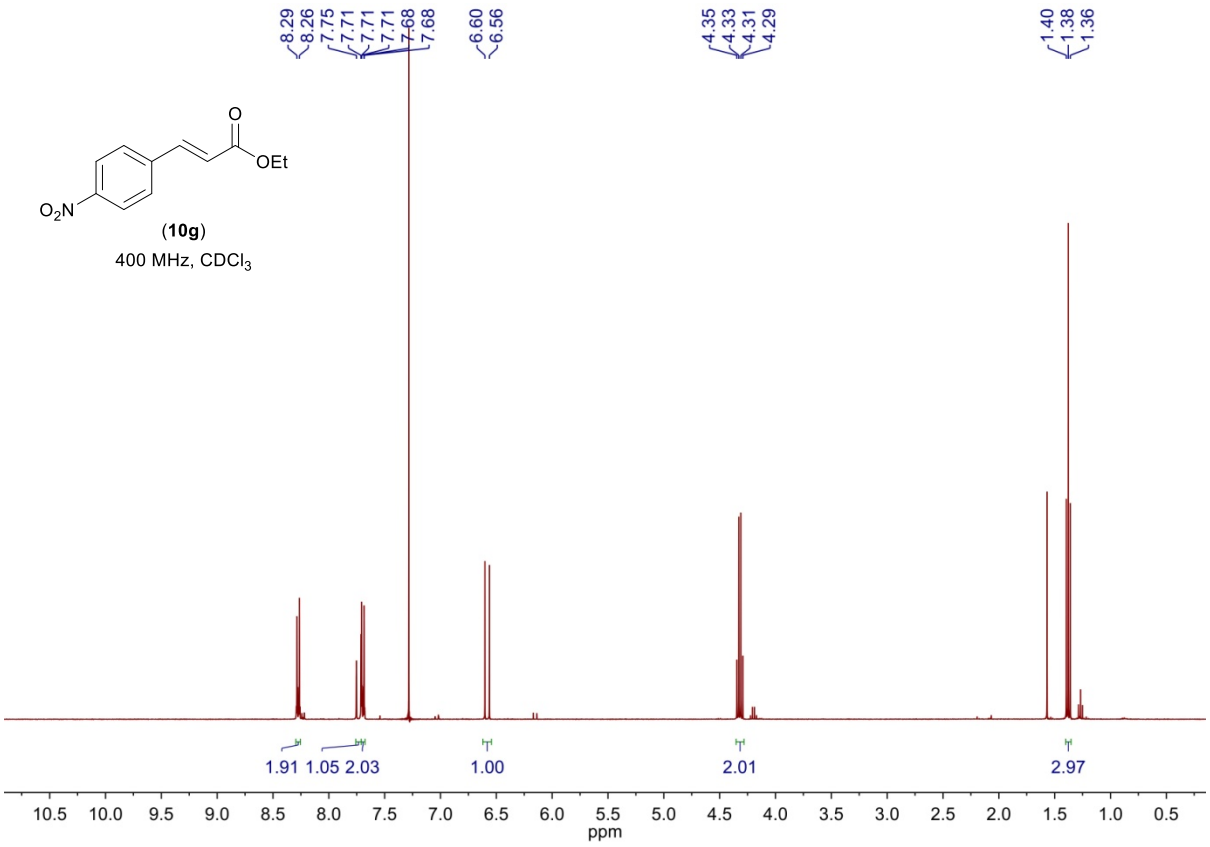
75 MHz, $CDCl_3$

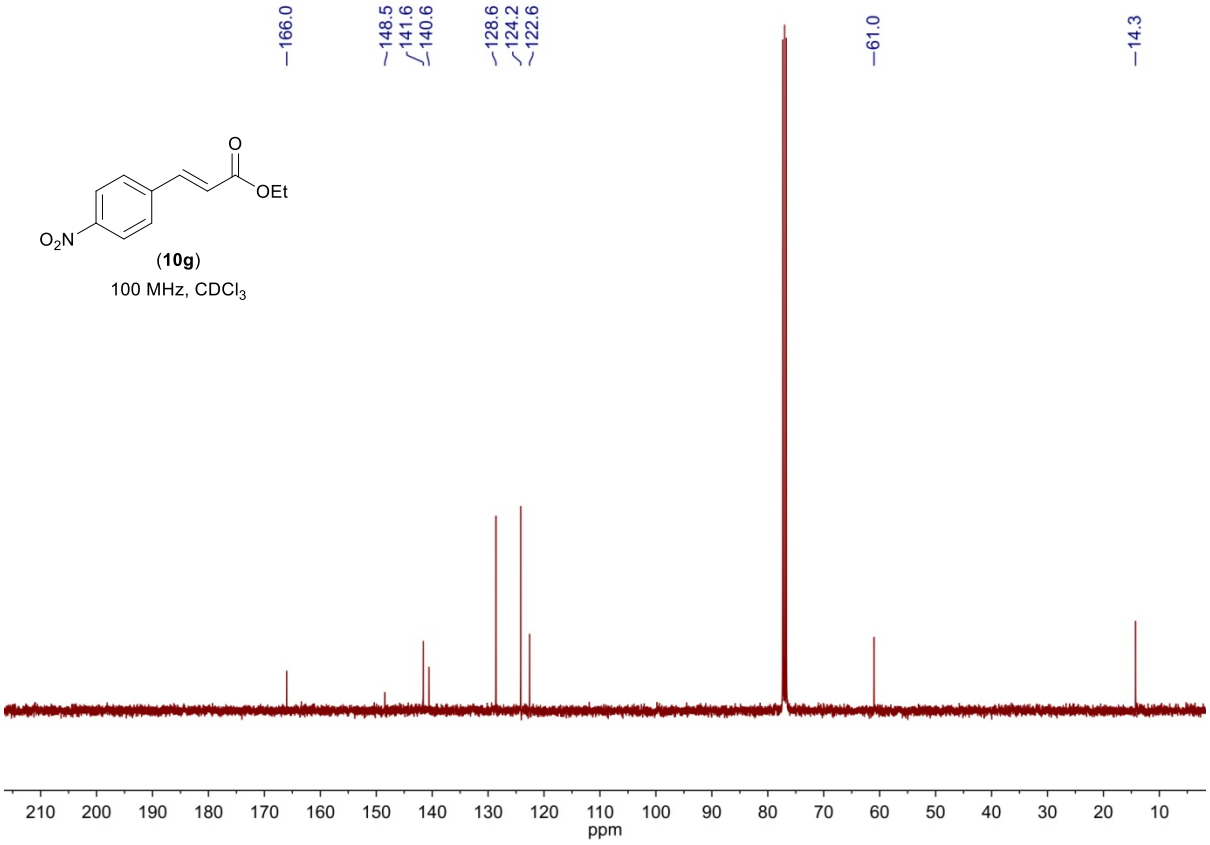

7.63
7.59
7.06
7.05
7.04
7.04
7.04
7.03
7.02
7.02
7.02
7.01
6.84
6.82
6.30
6.26
6.03
4.30
4.28
4.26
4.25
1.37
1.35
1.33
O
O
O
OEt
(10e)
400 MHz, CDCl3
0.98 0.91 0.99 1.07 1.00 1.99
2.04
2.97
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

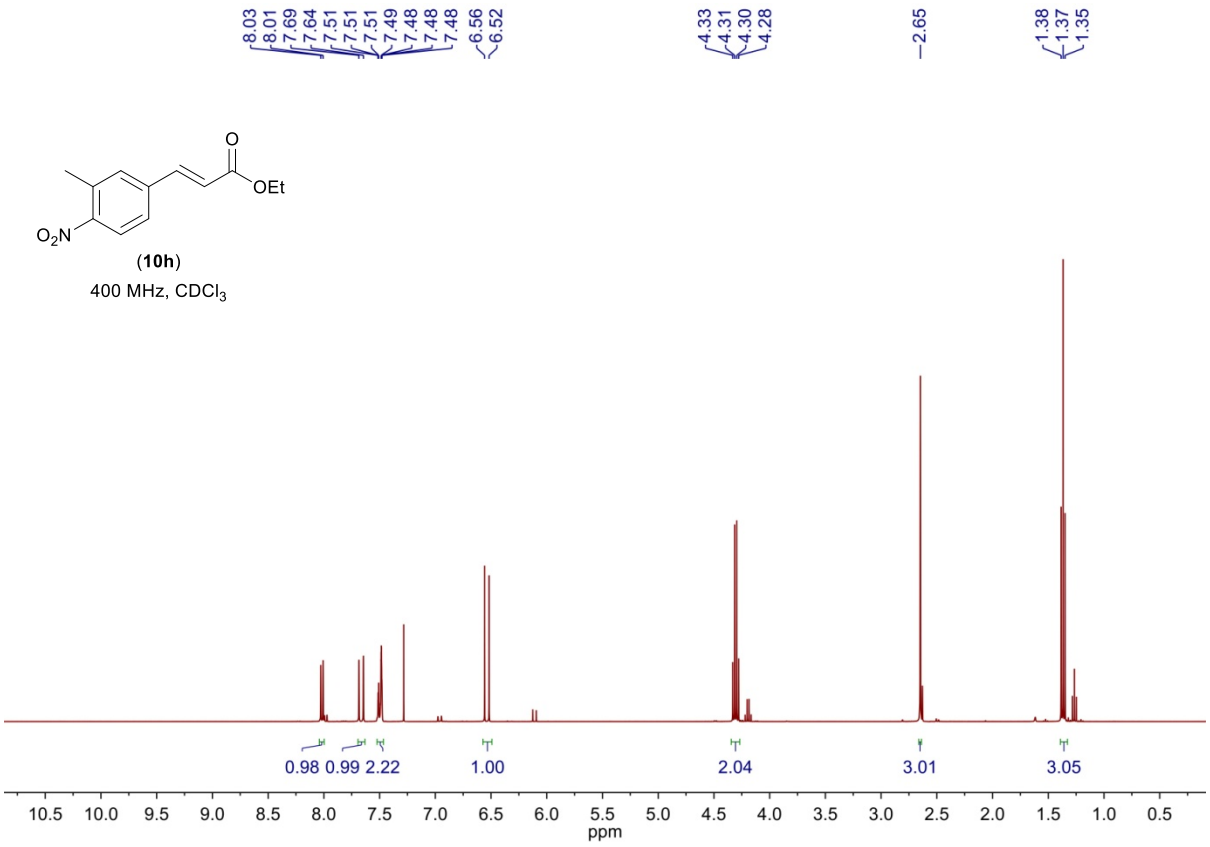

167.2
149.5
148.3
144.3
128.9
124.4
116.2
108.5
106.5
101.5
60.4
14.3
O
O
O
OEt
(10e)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

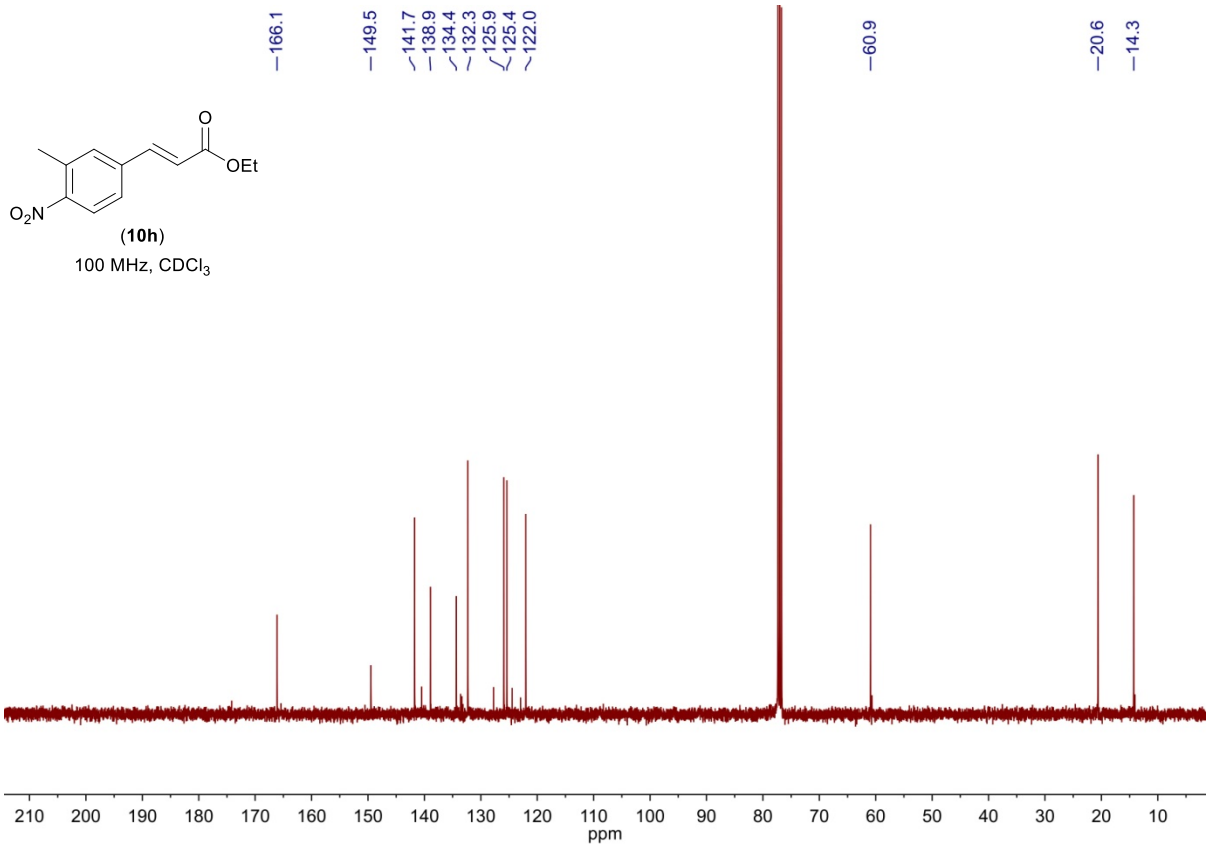

7.65
7.61
7.55
7.53
7.42
7.40
6.46
6.42
4.31
4.30
4.28
4.26
1.38
1.36
1.34
O
OEt
Br
(10f)
500 MHz, CDCl3
1.00 2.00 2.06
1.00
2.04
3.08
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

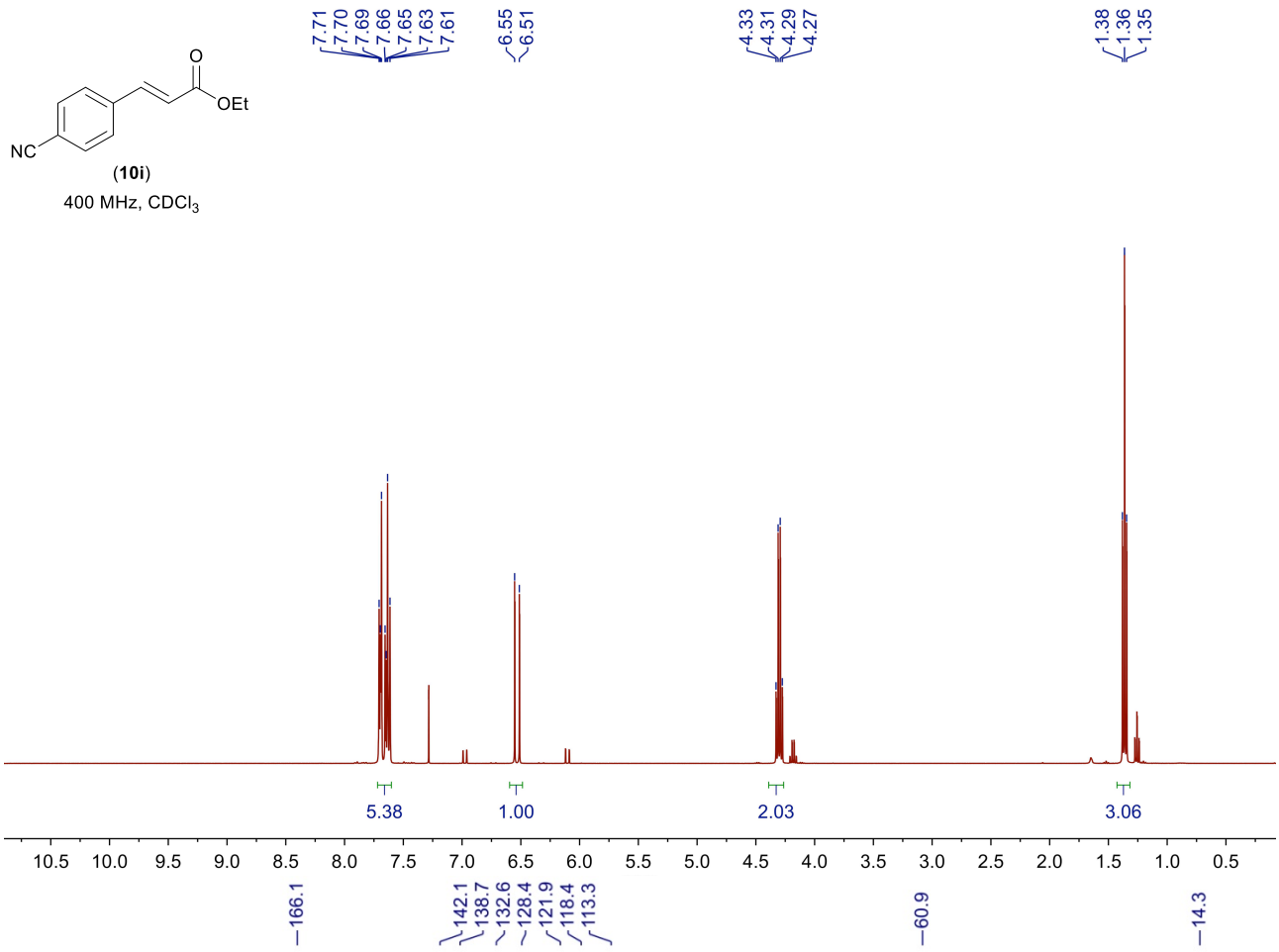

166.7
143.2
133.4
132.1
129.4
124.4
119.0
60.6
14.3
O
OEt
Br
(10f)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

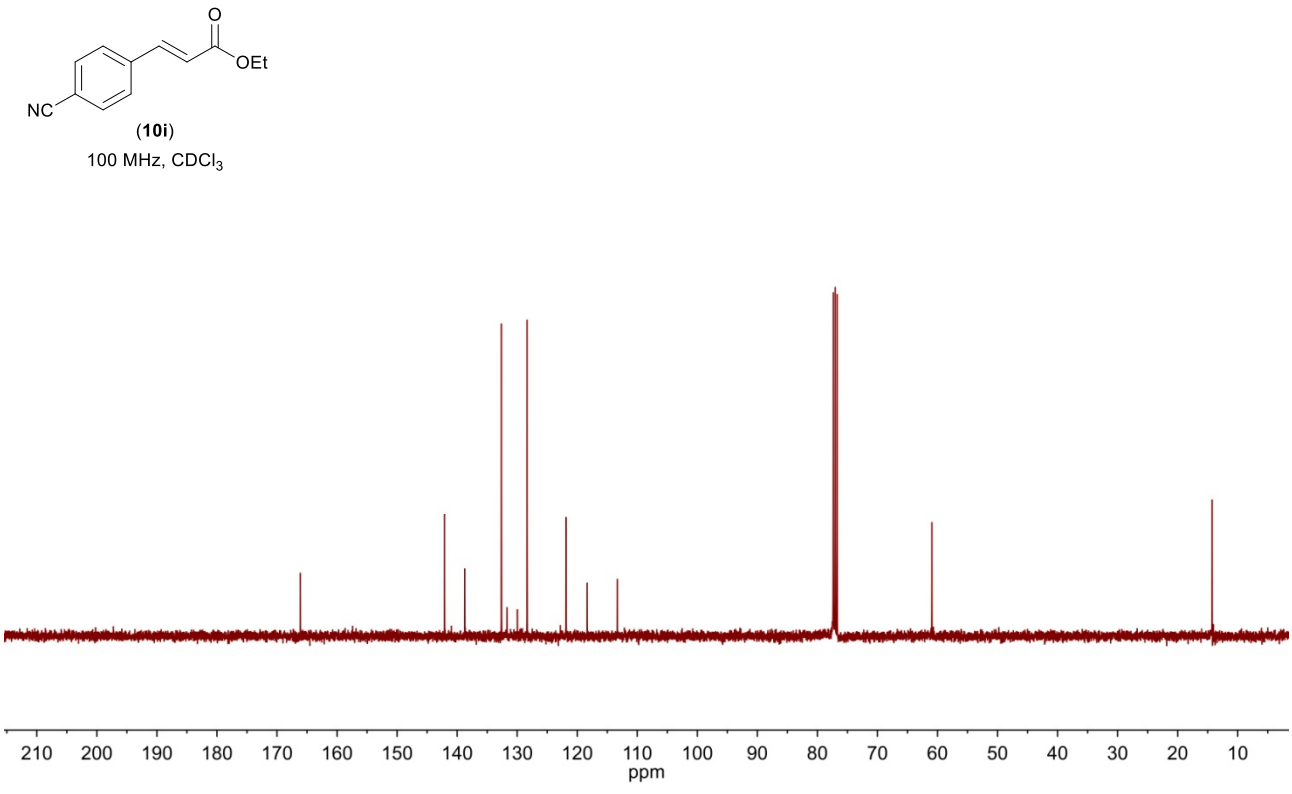

8.29
8.26
7.75
7.71
7.71
7.71
7.68
7.68
6.60
6.56
4.35
4.33
4.31
4.29
1.40
1.38
1.36
O
OEt
O2N
(10g)
400 MHz, CDCl3
1.91
1.05
2.03
1.00
2.01
2.97
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

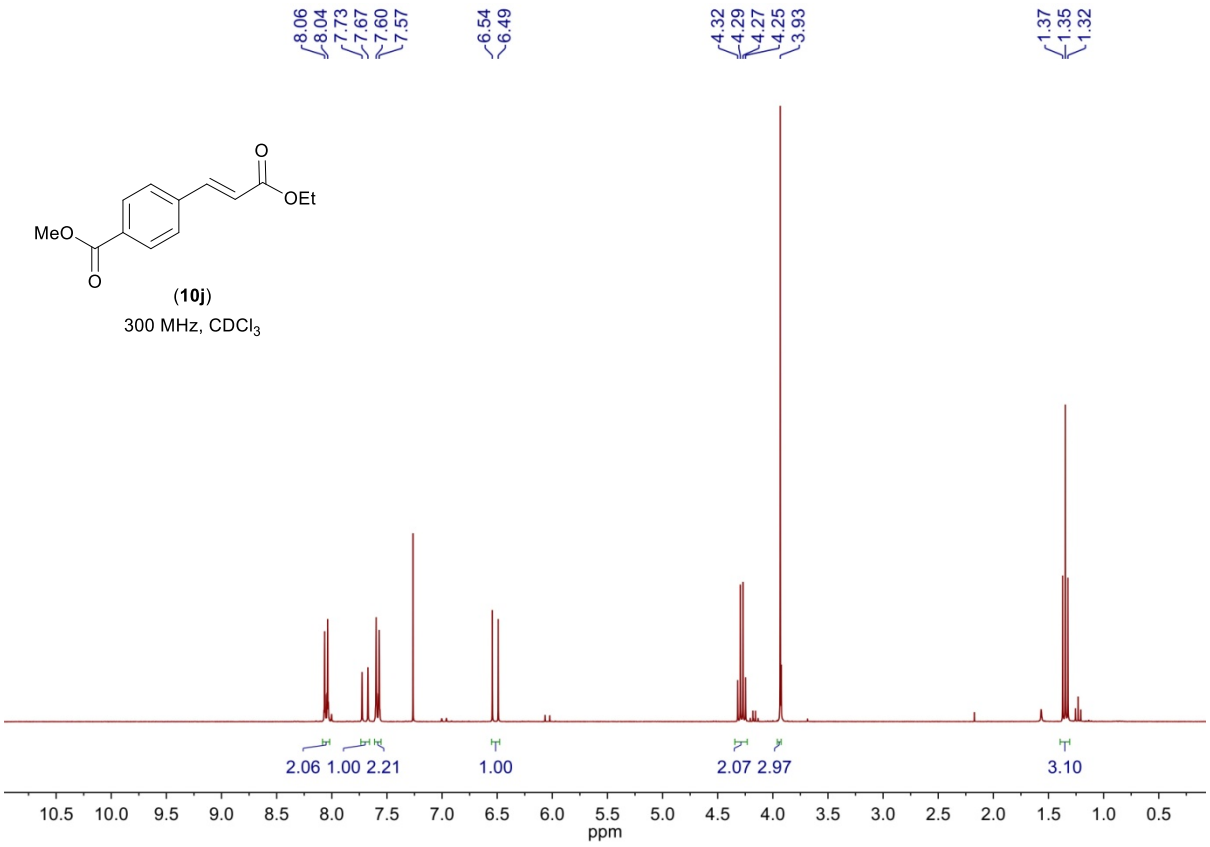

166.0
148.5
141.6
140.6
128.6
124.2
122.6
61.0
14.3
O
OEt
O2N
(10g)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

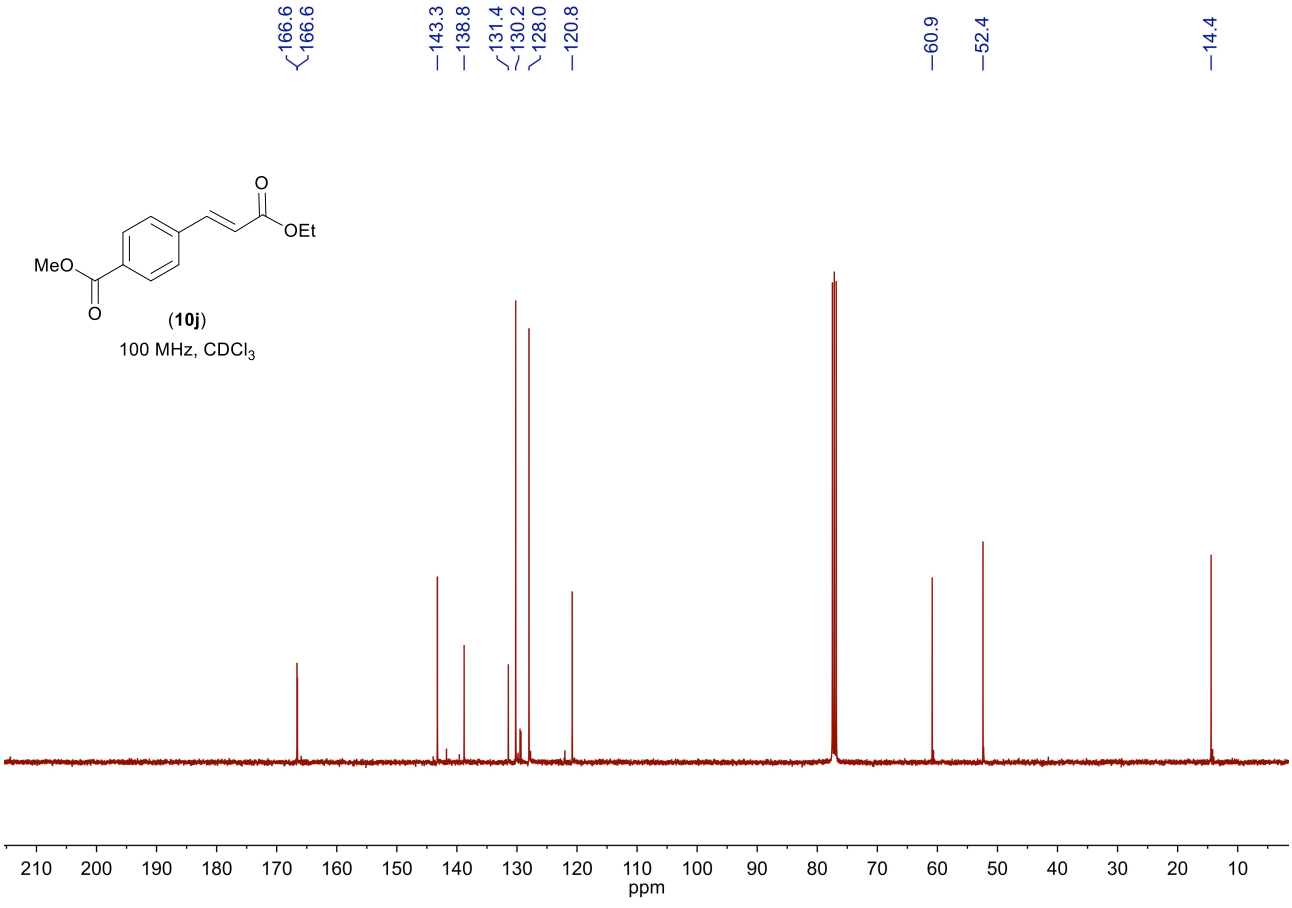

8.03
8.01
7.69
7.64
7.51
7.51
7.51
7.49
7.48
7.48
7.48
6.56
6.52
4.33
4.31
4.30
4.28
2.65
1.38
1.37
1.35
O
OEt
O2N
(10h)
400 MHz, CDCl3
0.98 0.99 2.22
1.00
2.04
3.01
3.05
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

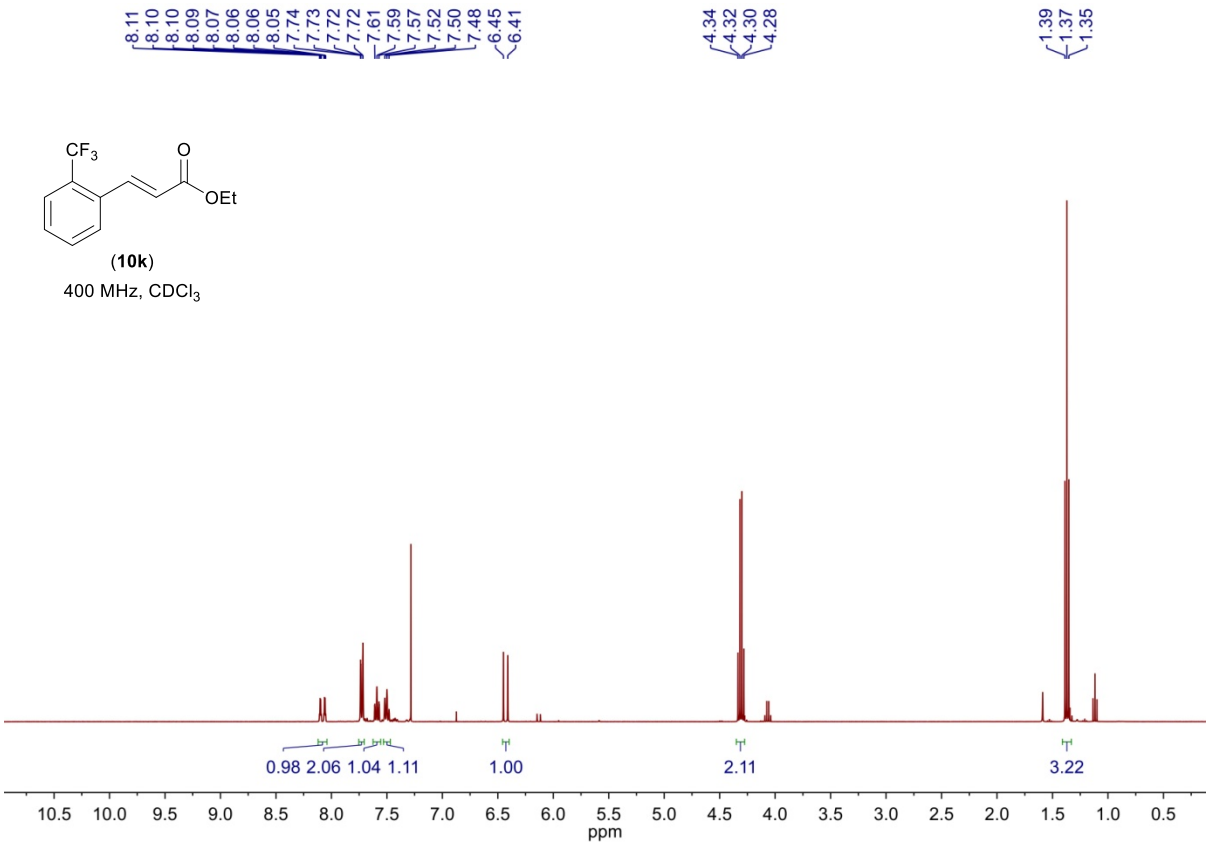

166.1
149.5
141.7
138.9
134.4
132.3
125.9
125.4
122.0
60.9
20.6
14.3
O
OEt
O2N
(10h)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

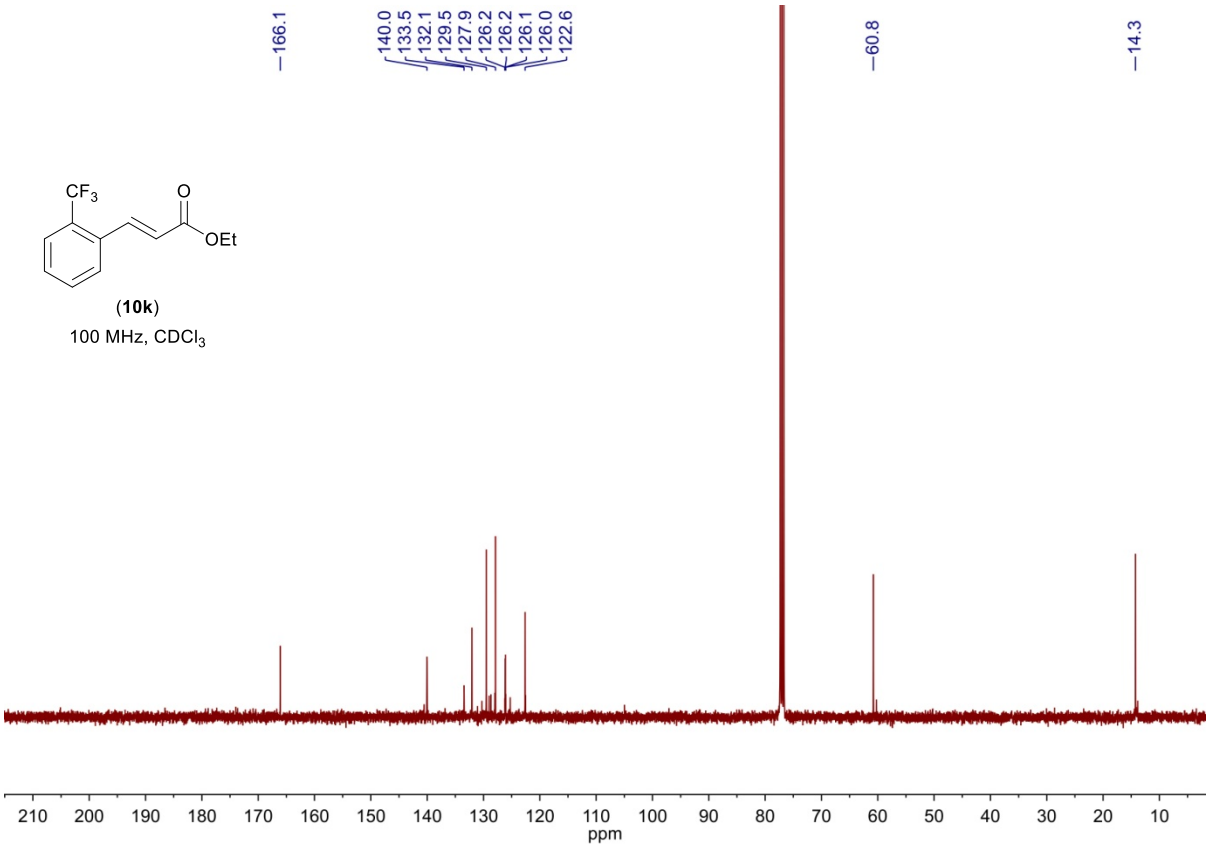

7.71
7.70
7.69
7.66
7.65
7.63
7.61
6.55
6.51
4.33
4.31
4.29
4.27
1.38
1.36
1.35
O
OEt
NC
(10i)
400 MHz, CDCl3
5.38
1.00
2.03
3.06
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
166.1
142.1
138.7
132.6
128.4
121.9
118.4
113.3
60.9
14.3

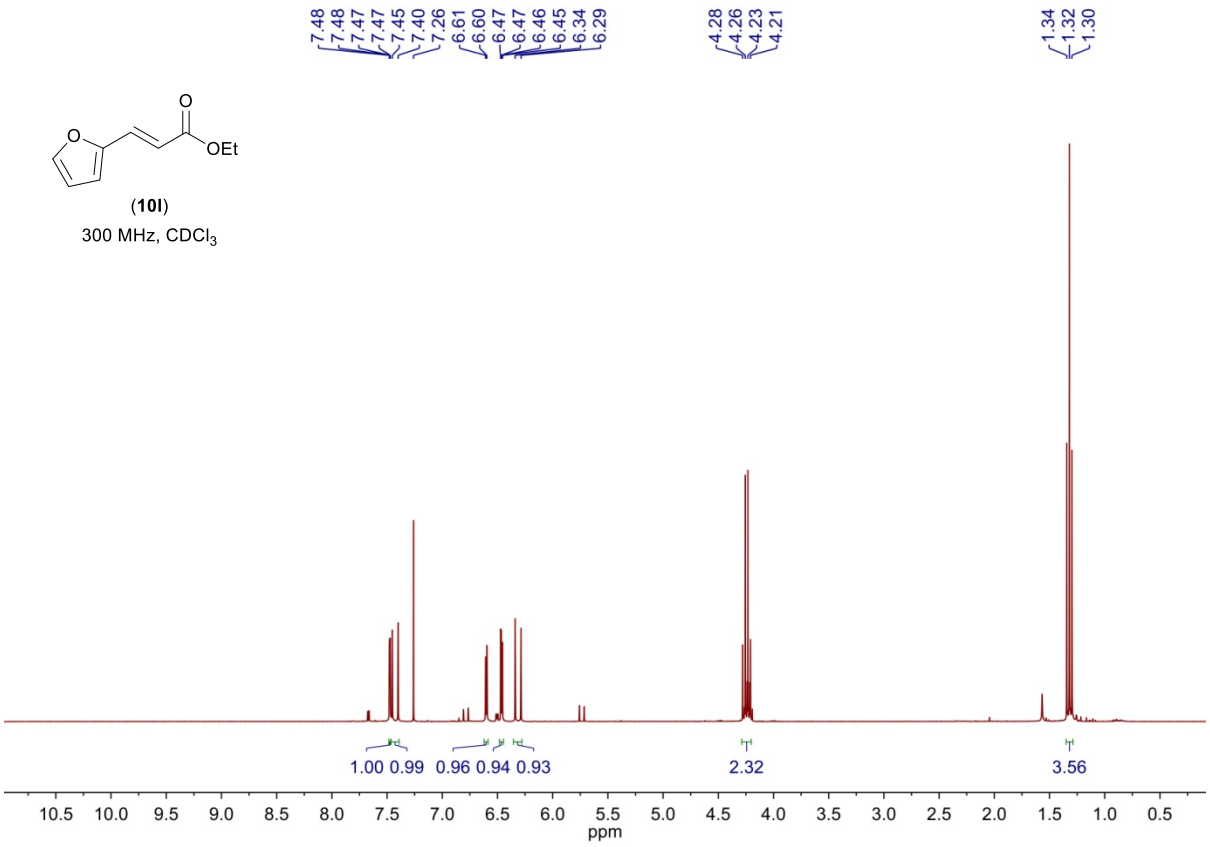

O
OEt
NC
(10i)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

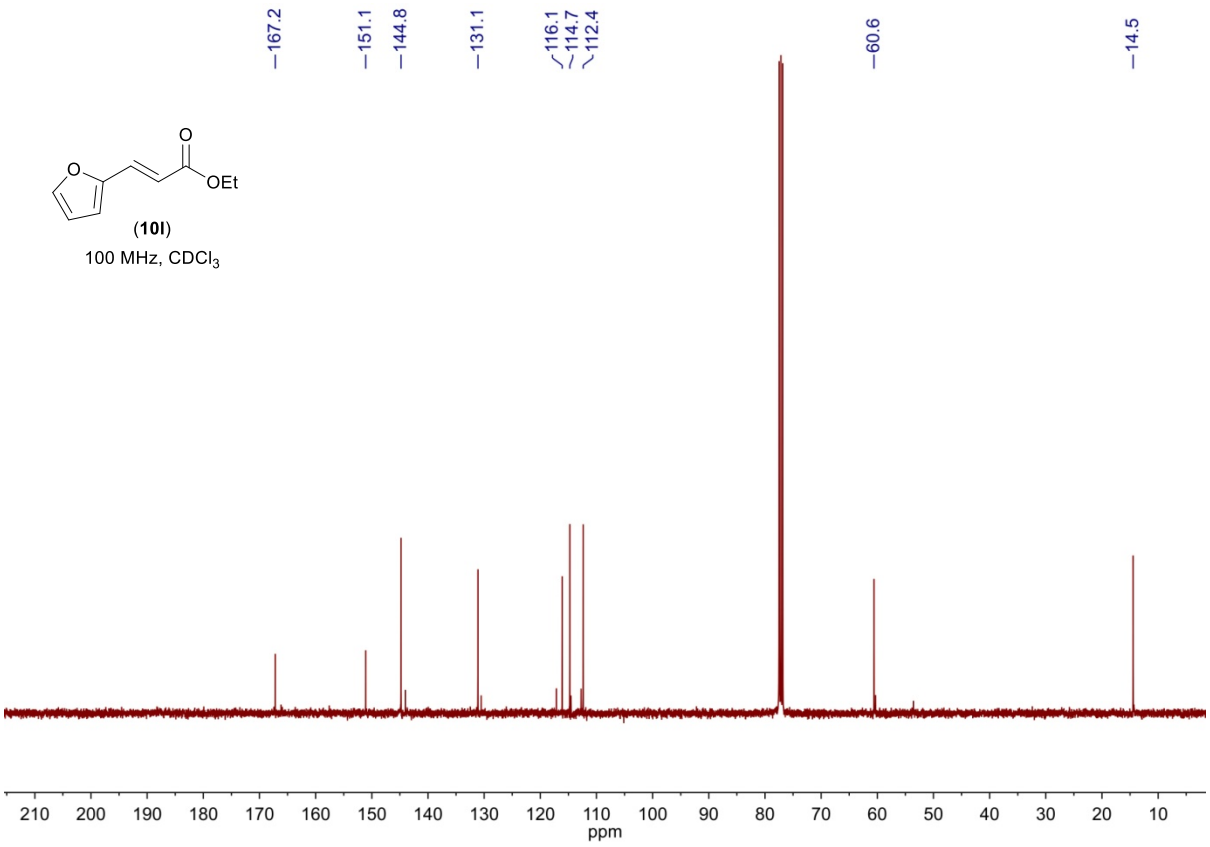

8.06
8.04
7.73
7.67
7.60
7.57
6.54
6.49
4.32
4.29
4.27
4.25
3.93
1.37
1.35
1.32
O
OEt
MeO
O
(10j)
300 MHz, CDCl3
2.06 1.00 2.21
1.00
2.07 2.97
3.10
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

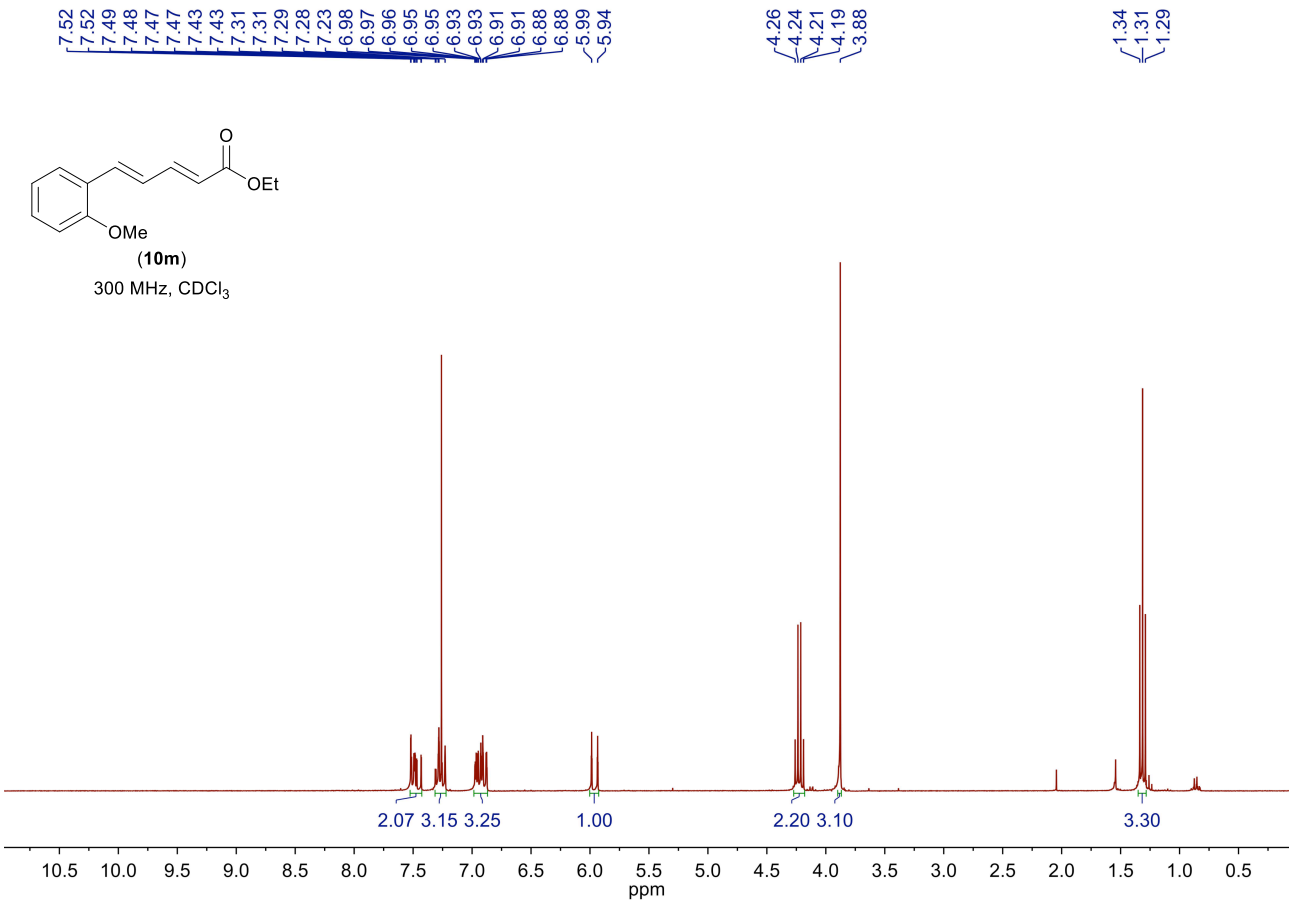

166.6
166.6
143.3
138.8
131.4
130.2
128.0
120.8
60.9
52.4
14.4
O
OEt
MeO
O
(10j)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

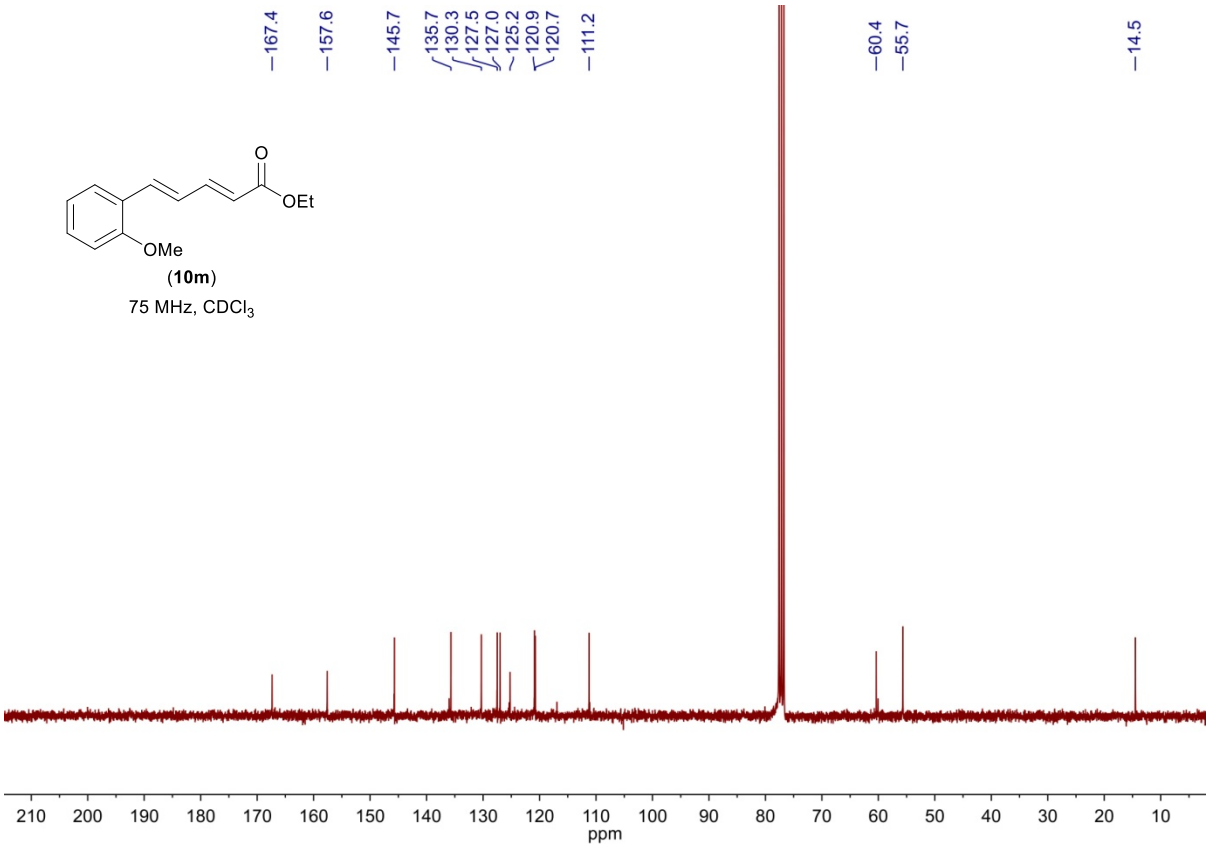

8.11
8.10
8.10
8.09
8.07
8.06
8.06
8.05
7.74
7.73
7.72
7.72
7.61
7.59
7.57
7.52
7.50
7.48
6.45
6.41
4.34
4.32
4.30
4.28
1.39
1.37
1.35
CF3
O
OEt
(10k)
400 MHz, CDCl3
0.98 2.06 1.04 1.11
1.00
2.11
3.22
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

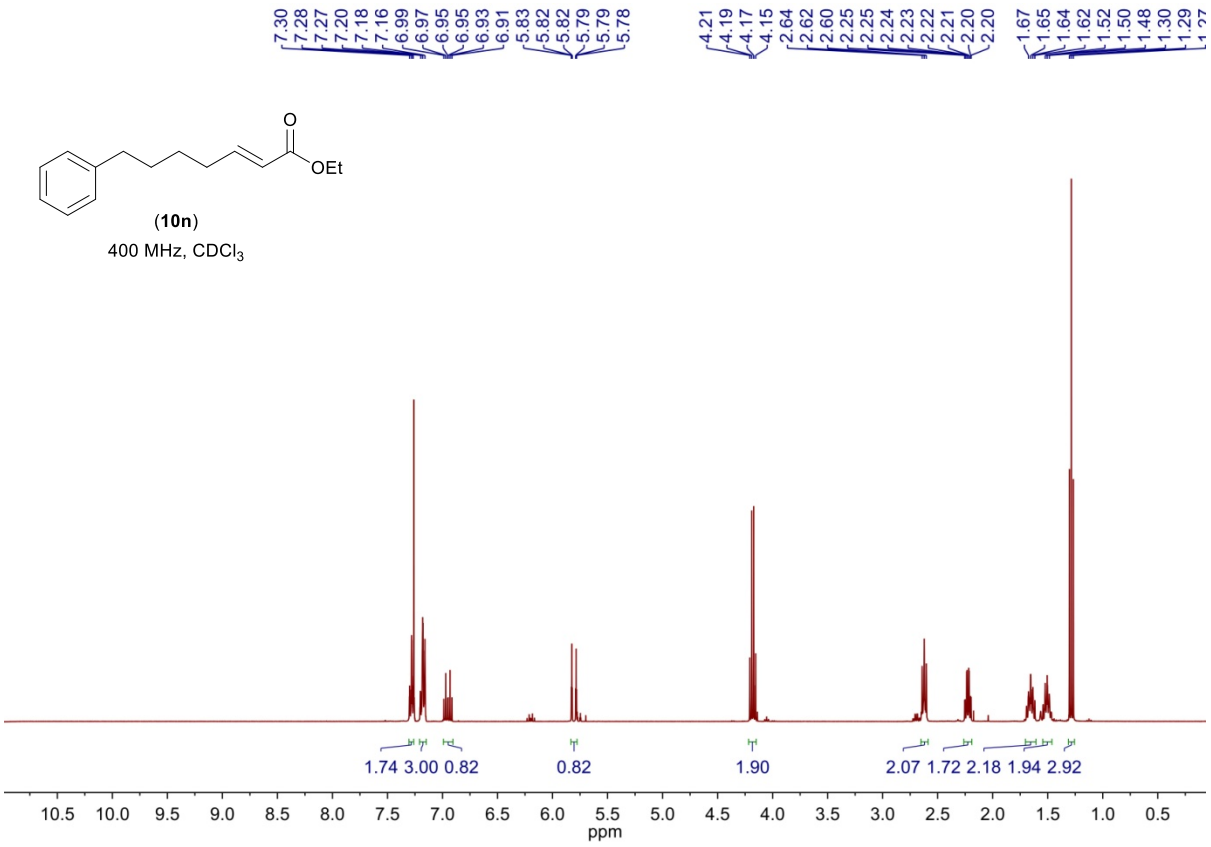

166.1
140.0
133.5
132.1
129.5
127.9
126.2
126.2
126.1
126.0
122.6
60.8
14.3
CF3
O
OEt
(10k)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

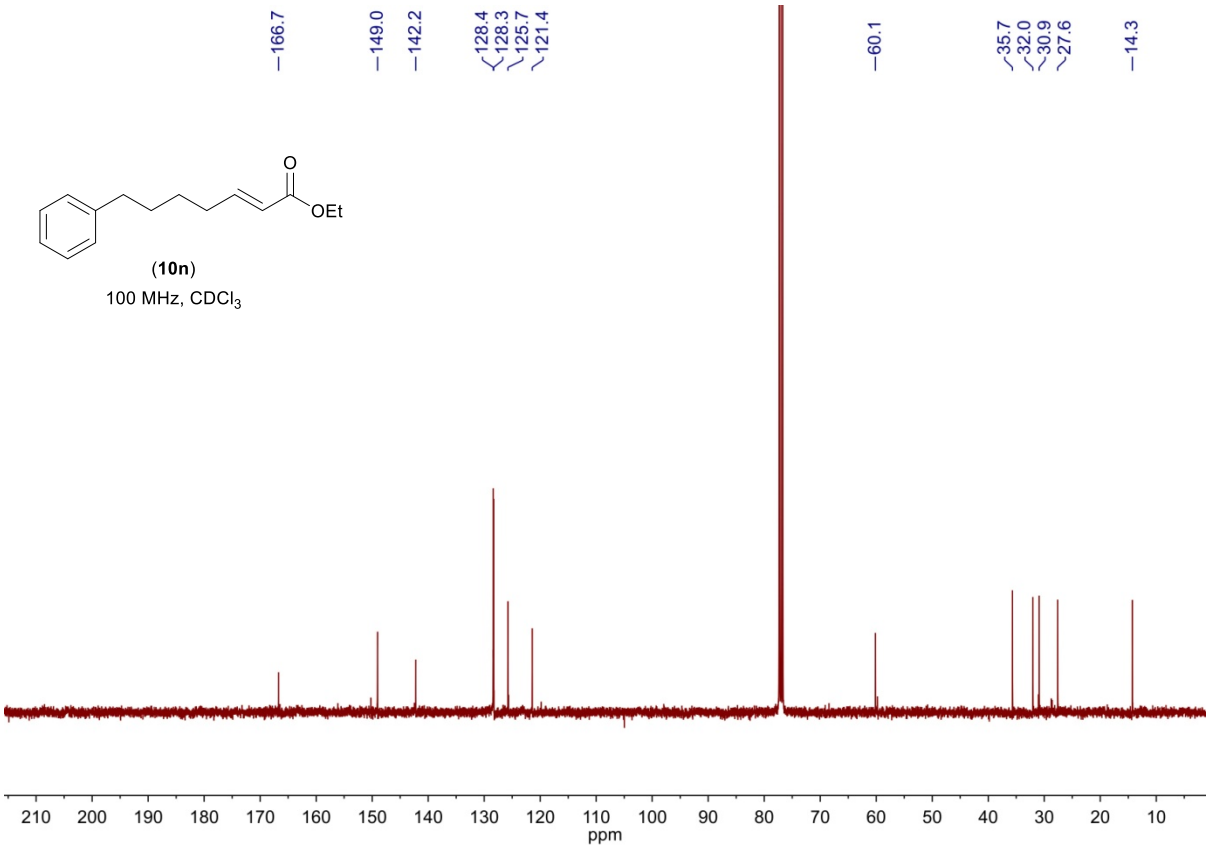

7.48
7.48
7.47
7.47
7.45
7.40
7.26
6.61
6.60
6.47
6.47
6.46
6.45
6.34
6.29
4.28
4.26
4.23
4.21
1.34
1.32
1.30
O
O
OEt
(10l)
300 MHz, CDCl3
1.00 0.99 0.96 0.94 0.93
2.32
3.56
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

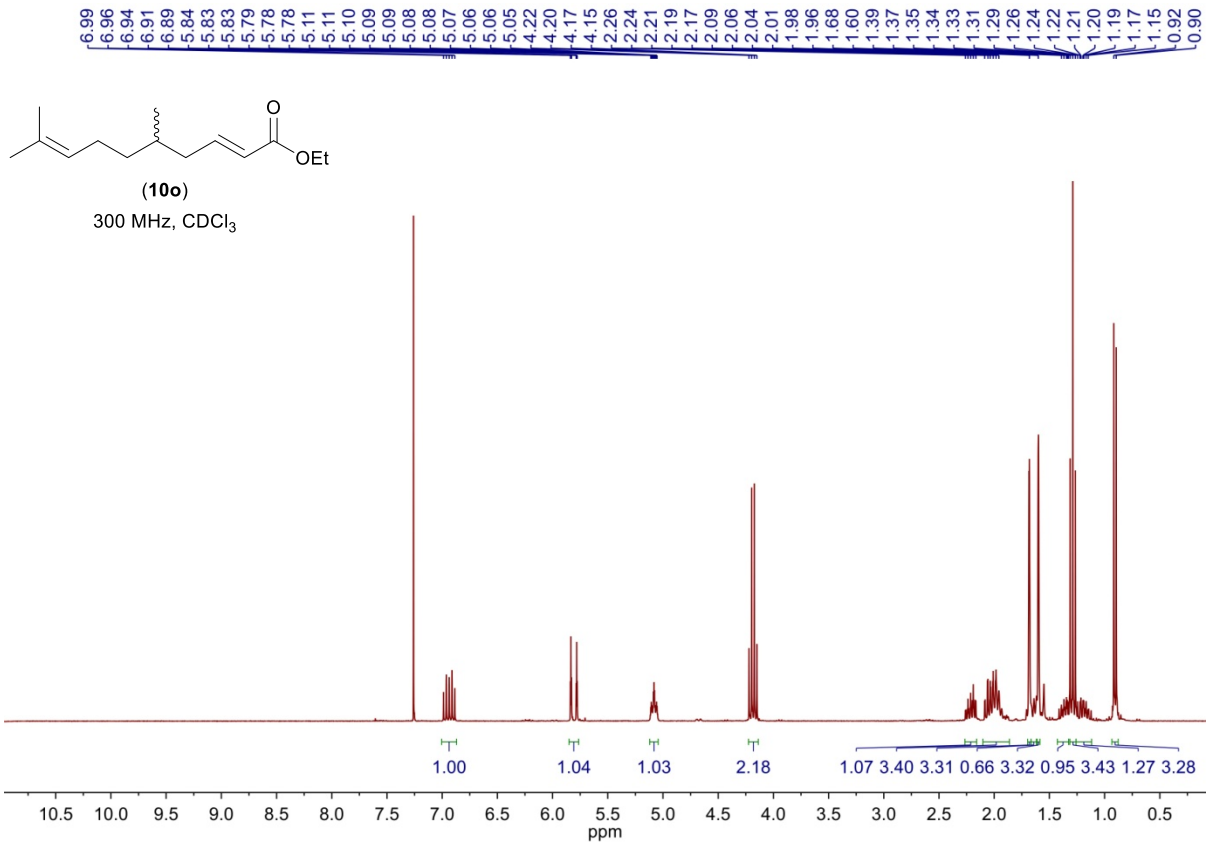

167.2
151.1
144.8
131.1
116.1
114.7
112.4
60.6
14.5
O
O
OEt
(10l)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

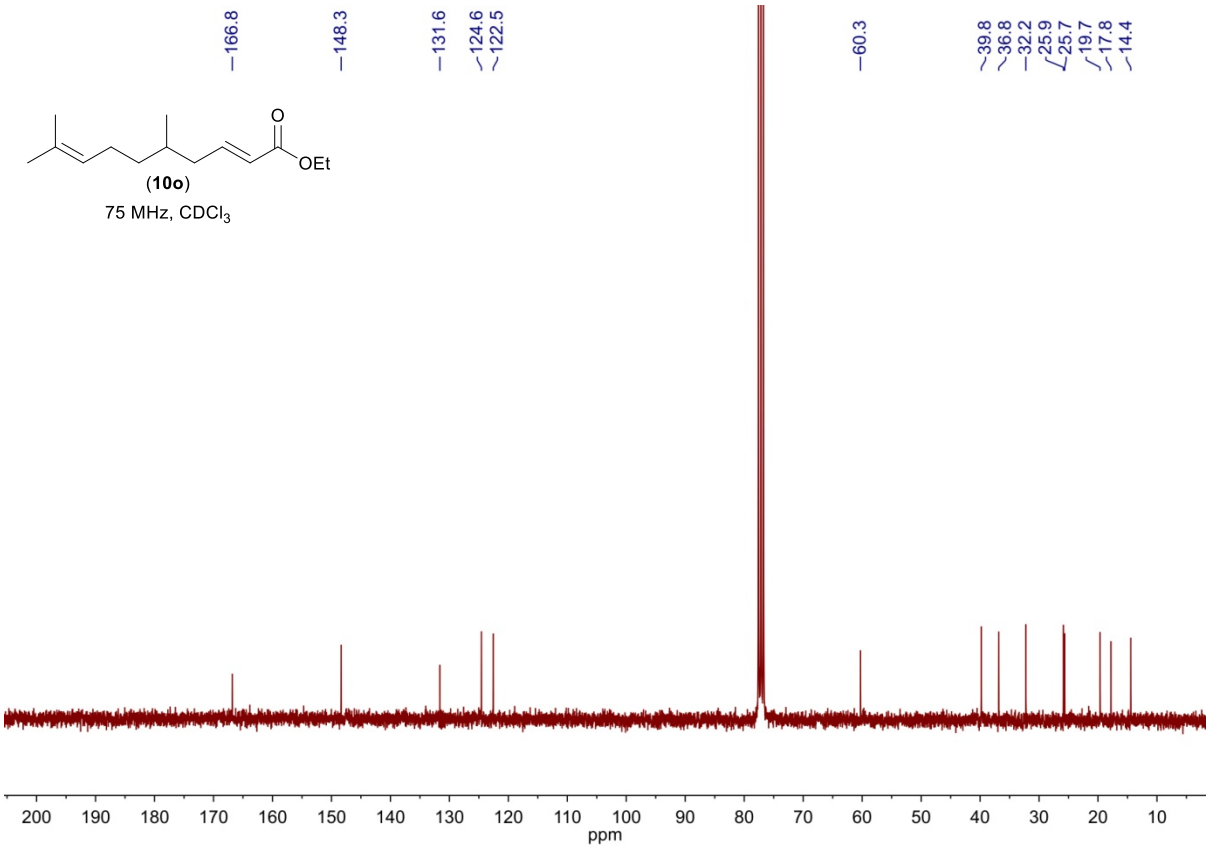

7.52
7.52
7.49
7.48
7.47
7.47
7.43
7.43
7.31
7.31
7.29
7.28
7.23
6.98
6.97
6.96
6.95
6.95
6.93
6.93
6.91
6.91
6.88
5.99
5.94
4.26
4.24
4.21
4.19
3.88
1.34
1.31
1.29
O
OEt
OMe
(10m)
300 MHz, CDCl3
2.07 3.15 3.25
1.00
2.20 3.10
3.30
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

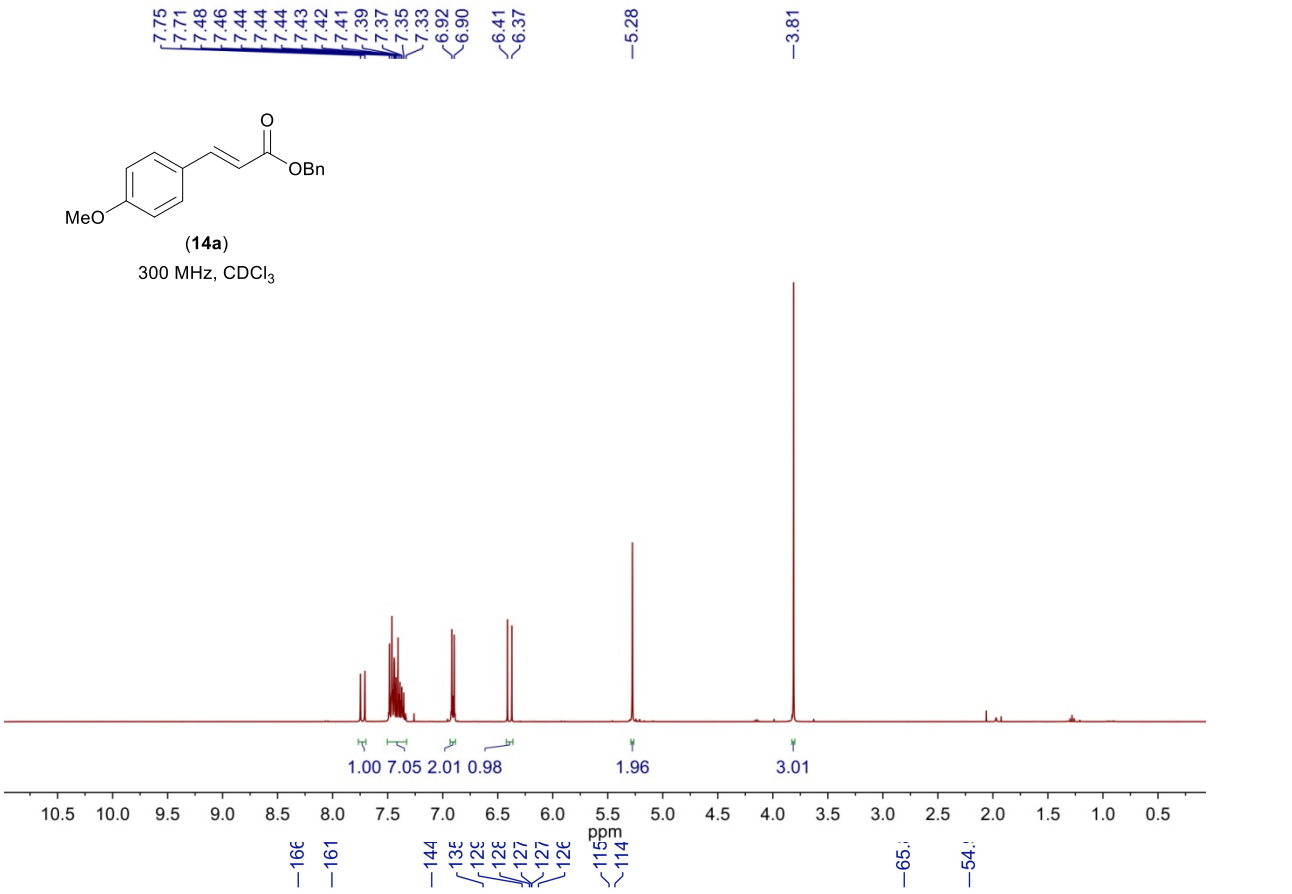

167.4
157.6
145.7
135.7
130.3
127.5
127.0
125.2
120.9
120.7
111.2
60.4
55.7
14.5
O
OEt
OMe
(10m)
75 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm


7.30
7.28
7.27
7.20
7.18
7.16
6.99
6.97
6.95
6.95
6.93
6.91
5.83
5.82
5.82
5.79
5.79
5.78
4.21
4.19
4.17
4.15
2.64
2.62
2.60
2.25
2.25
2.24
2.23
2.22
2.21
2.20
2.20
1.67
1.65
1.64
1.62
1.52
1.50
1.48
1.30
1.29
O
OEt
(10n)
400 MHz, CDCl3
1.74 3.00 0.82
0.82
1.90
2.07 1.72 2.18 1.94 2.92
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

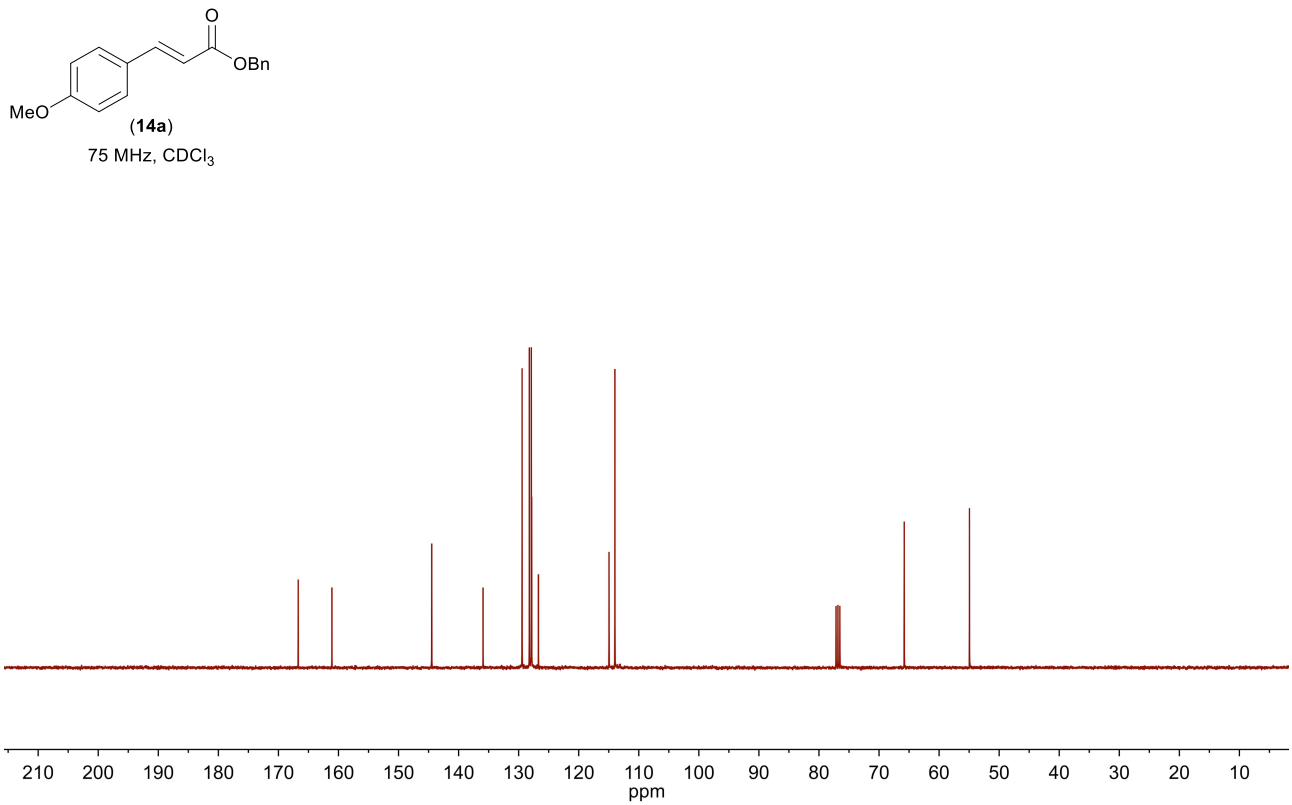

166.7
149.0
142.2
128.4
128.3
125.7
121.4
60.1
35.7
32.0
30.9
27.6
14.3
O
OEt
(10n)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm


6.99 6.96 6.94 6.91 6.89 5.84 5.83 5.83 5.79 5.78 5.78 5.11 5.11 5.10 5.09 5.09 5.08 5.08 5.07 5.06 5.06 5.05 4.22 4.20 4.17 4.15 2.26 2.24 2.21 2.19 2.17 2.09 2.06 2.04 2.01 1.98 1.96 1.68 1.60 1.39 1.37 1.35 1.34 1.33 1.31 1.29 1.26 1.24 1.22 1.21 1.20 1.19 1.17 1.15 0.92 0.90
O
OEt
(10o)
300 MHz, CDCl3
1.00 1.04 1.03 2.18 1.07 3.40 3.31 0.66 3.32 0.95 3.43 1.27 3.28
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

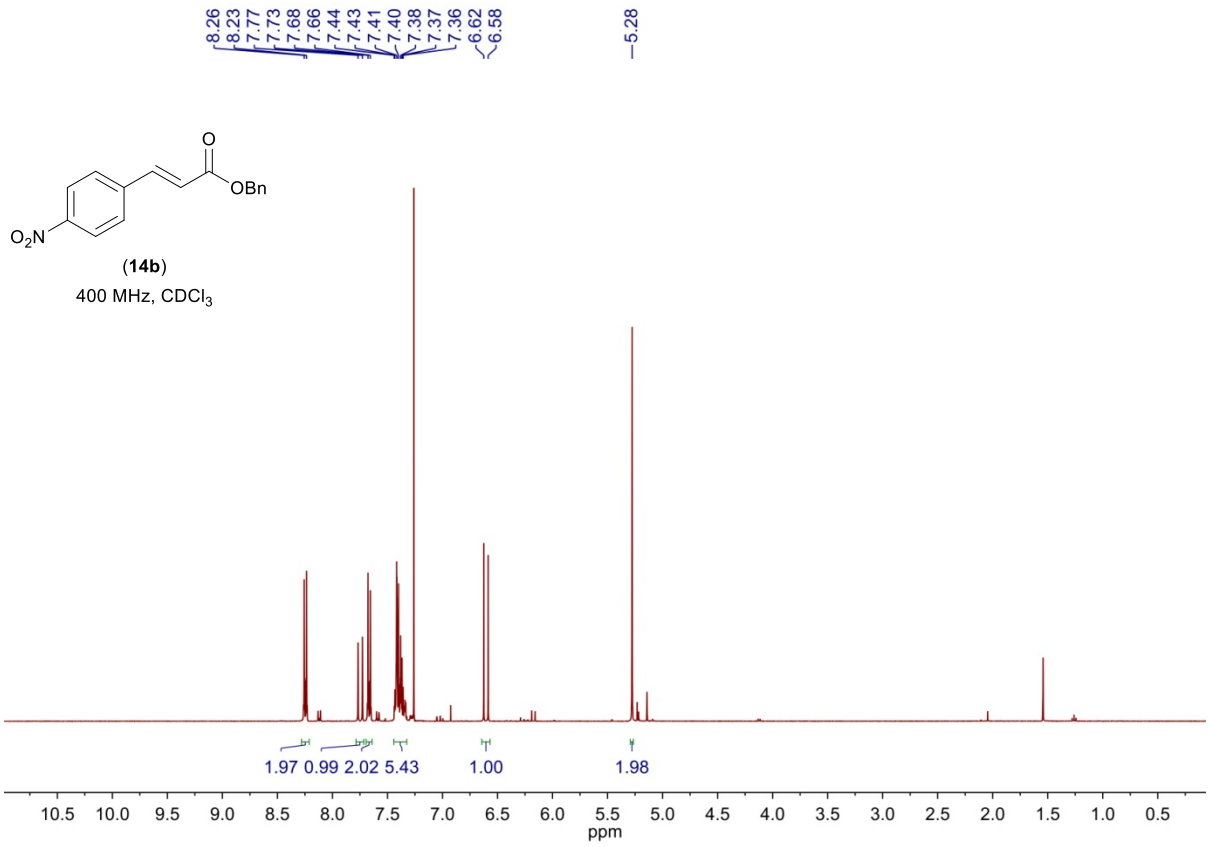

166.8 148.3 131.6 124.6 122.5 60.3 39.8 36.8 32.2 25.9 25.7 19.7 17.8 14.4
O
OEt
(10o)
75 MHz, CDCl3
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

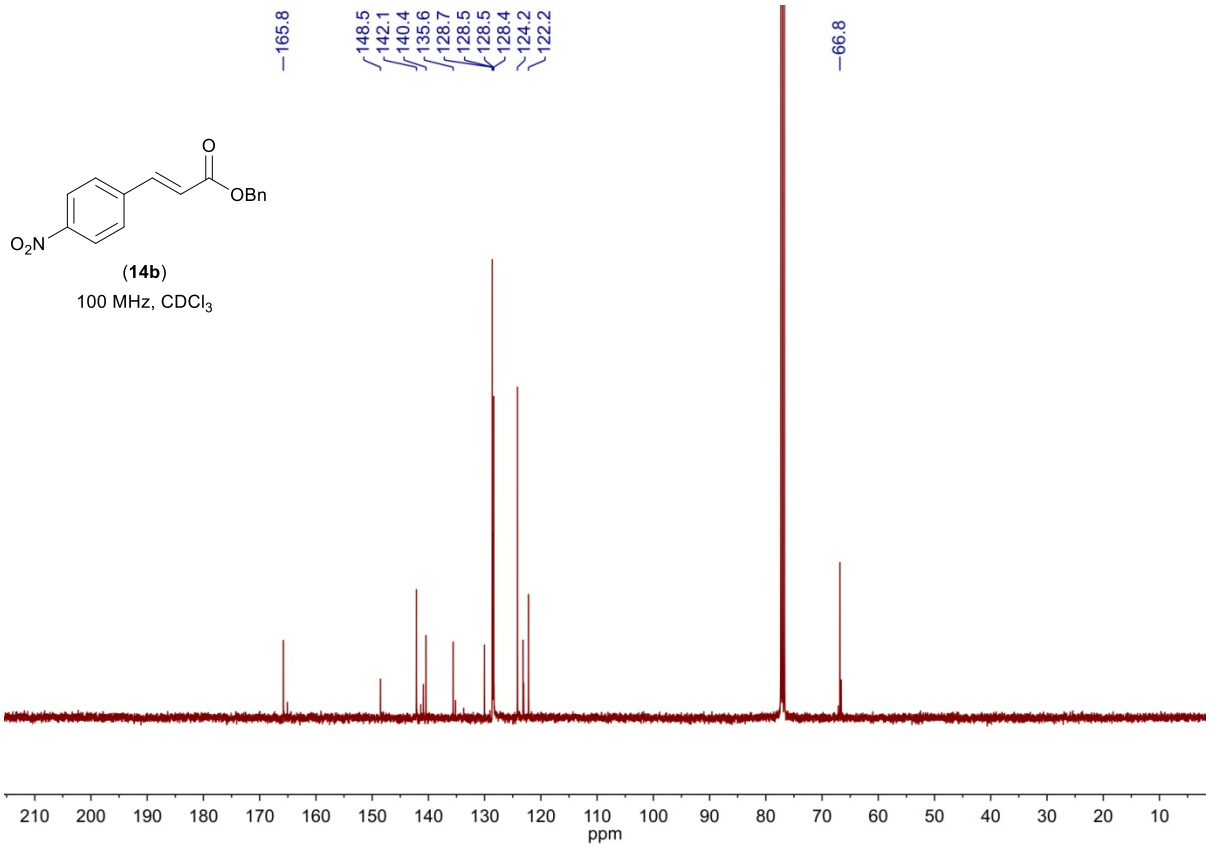


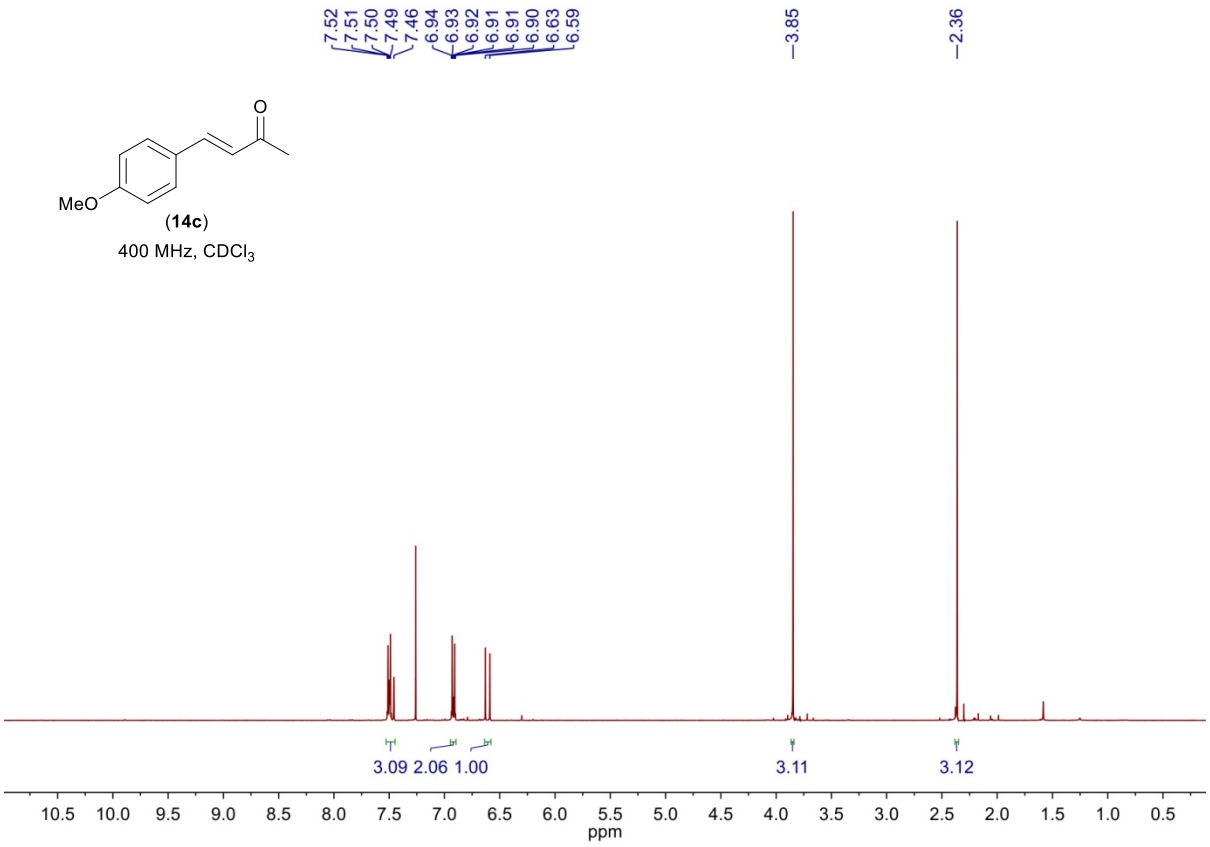
(**14a**)
300 MHz, $CDCl_3$

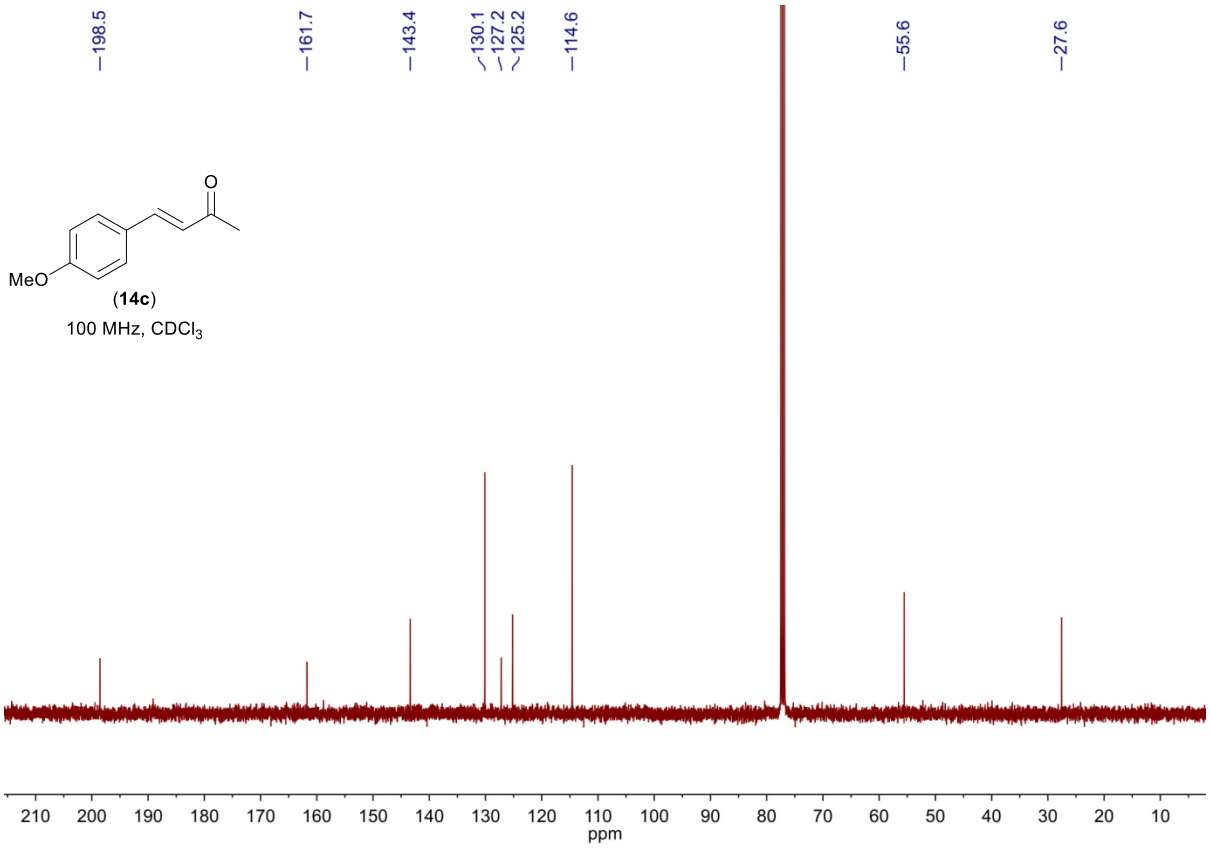


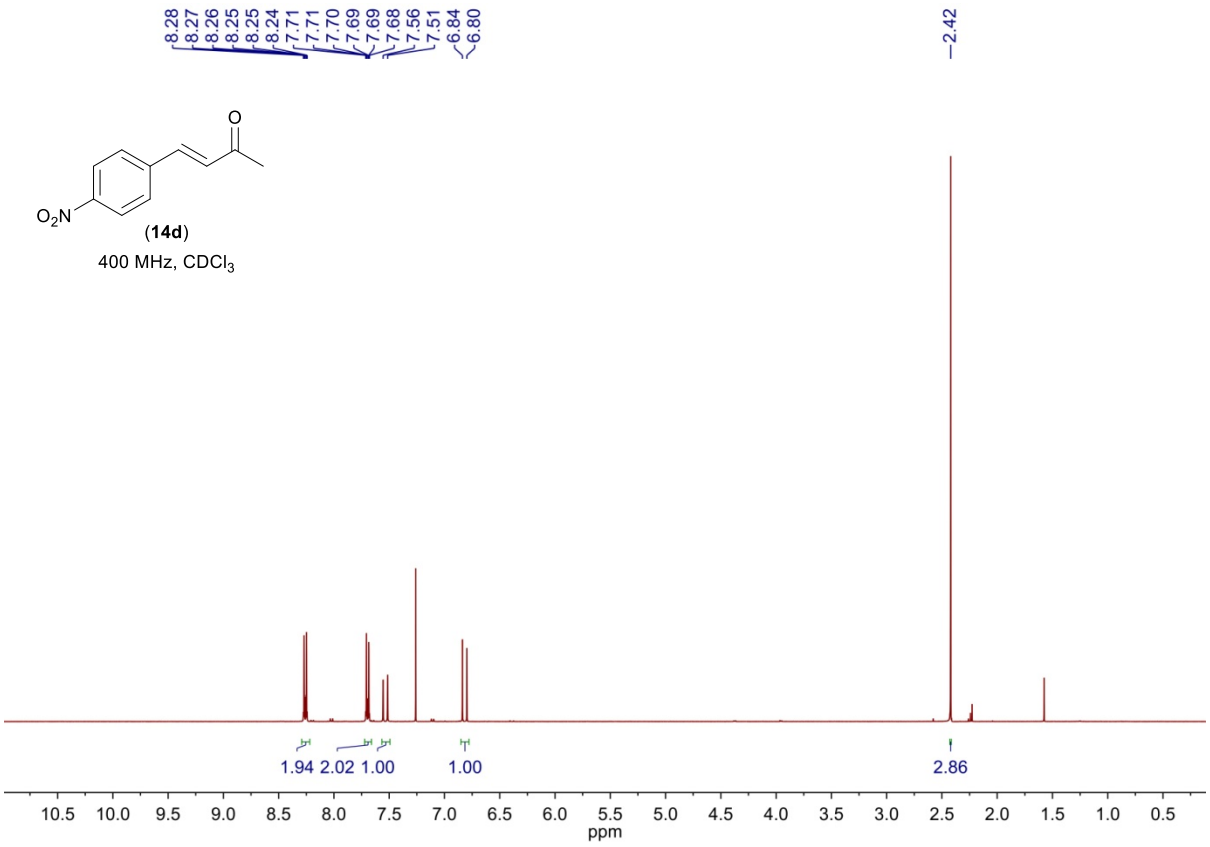
(**14a**)
75 MHz, $CDCl_3$

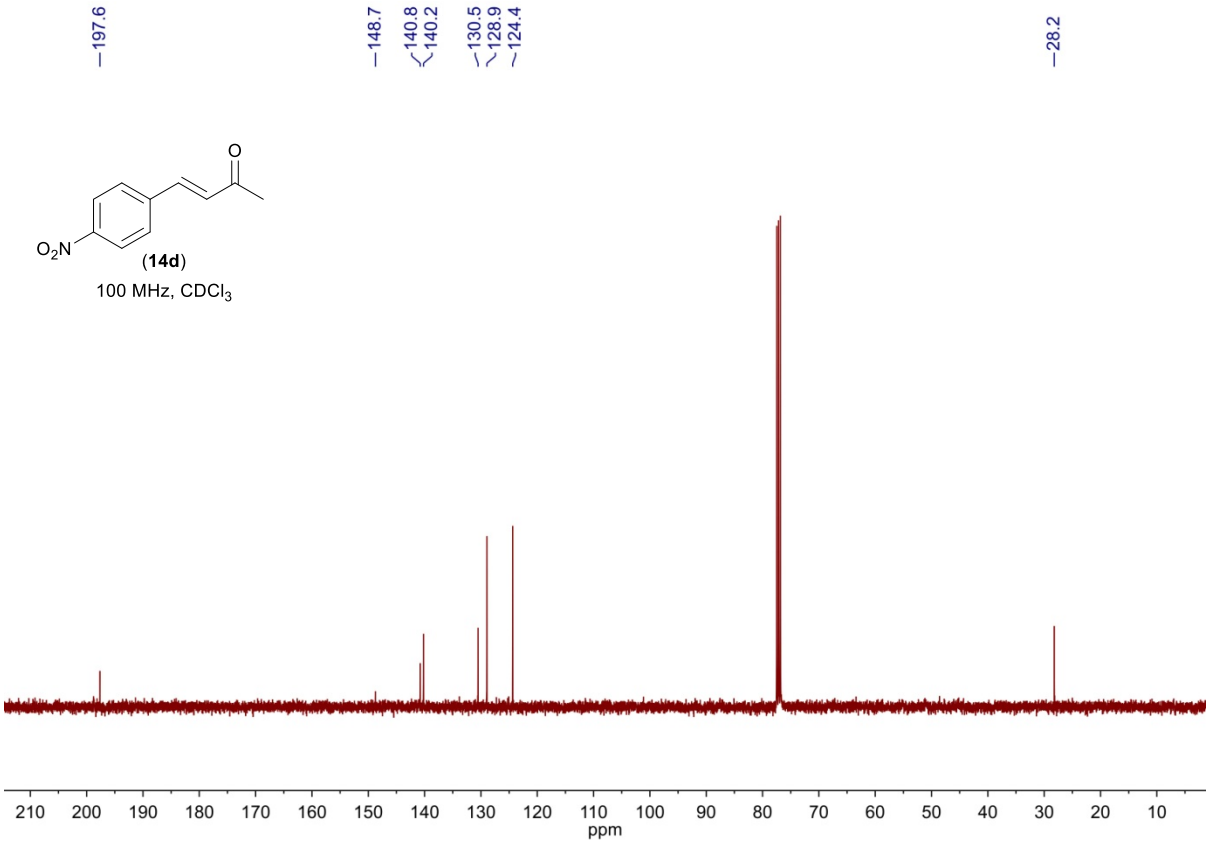

8.26
8.23
7.77
7.73
7.68
7.66
7.44
7.43
7.41
7.40
7.38
7.37
7.36
6.62
6.58
5.28
O
OBn
O2N
(14b)
400 MHz, CDCl3
1.97 0.99 2.02 5.43
1.00
1.98
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

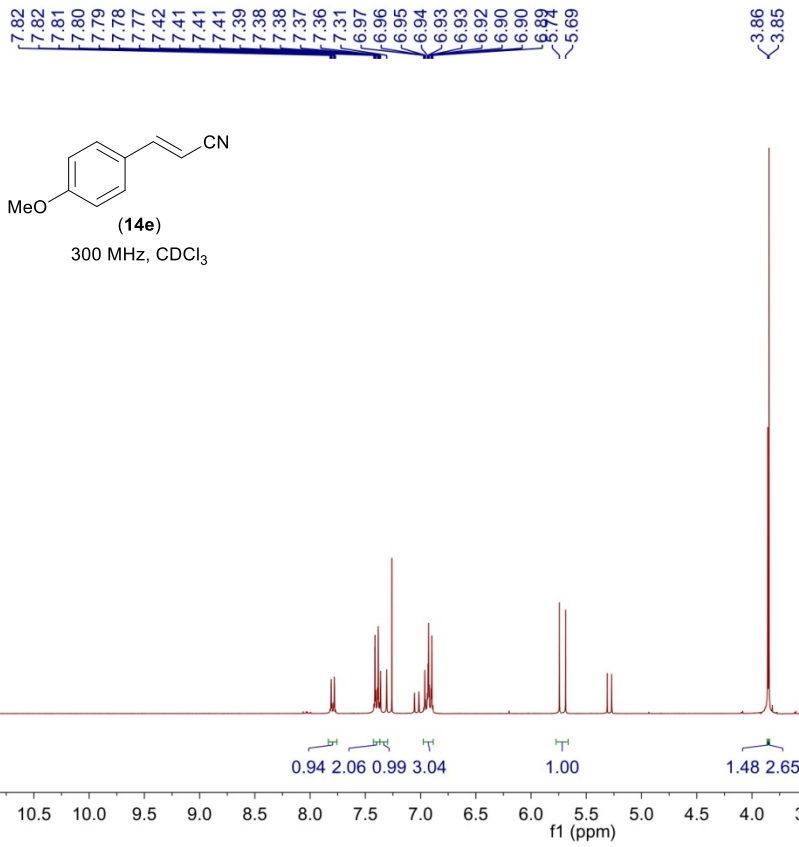

165.8
148.5
142.1
140.4
135.6
128.7
128.5
128.5
128.4
124.2
122.2
66.8
O
OBn
O2N
(14b)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

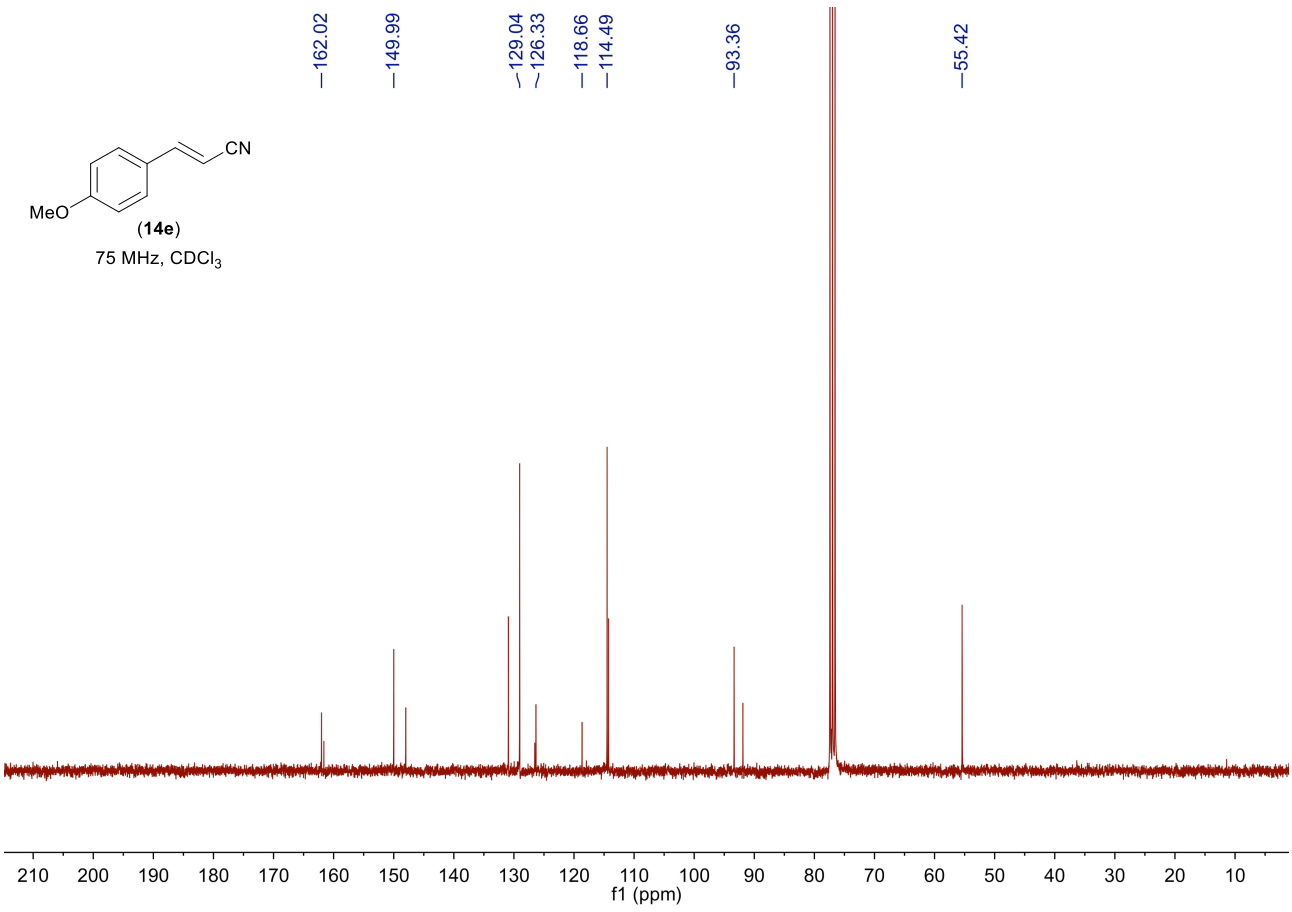

7.52
7.51
7.50
7.49
7.46
6.94
6.93
6.92
6.91
6.91
6.90
6.63
6.59
3.85
2.36
O
MeO
(14c)
400 MHz, CDCl3
3.09 2.06 1.00
3.11
3.12
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm

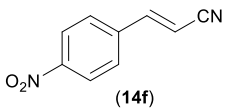

198.5
161.7
143.4
130.1
127.2
125.2
114.6
55.6
27.6
O
MeO
(14c)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm


8.28
8.27
8.26
8.25
8.25
8.24
7.71
7.71
7.70
7.69
7.69
7.68
7.56
7.51
6.84
6.80
2.42
O
O2N
(14d)
400 MHz, CDCl3
1.94 2.02 1.00
1.00
2.86
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm


197.6
148.7
140.8
140.2
130.5
128.9
124.4
28.2
O
O2N
(14d)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

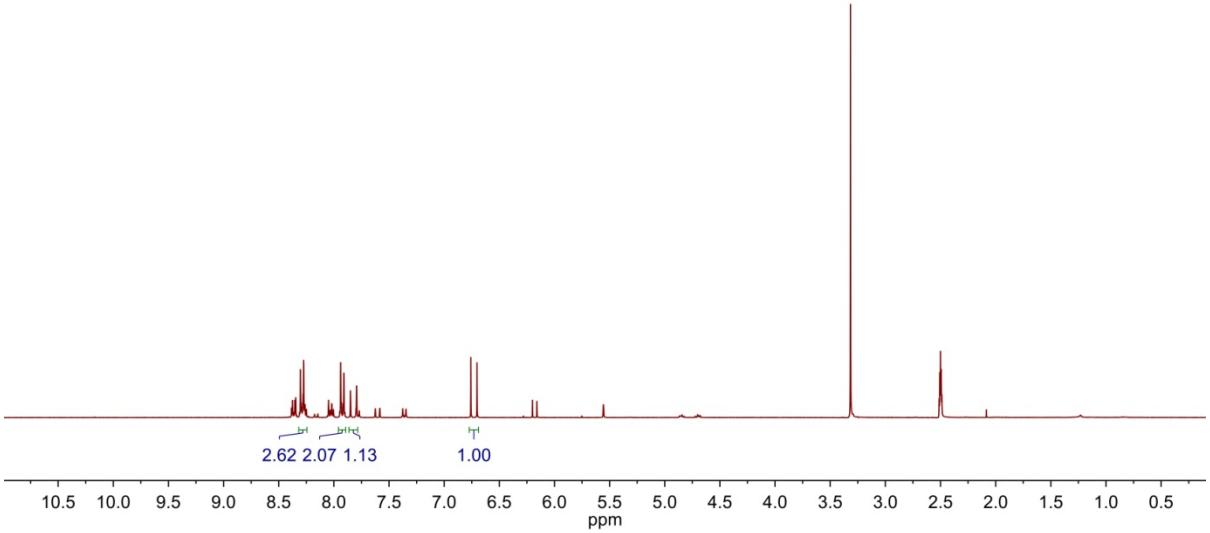

7.82
7.82
7.81
7.80
7.79
7.78
7.77
7.42
7.41
7.41
7.41
7.39
7.38
7.38
7.37
7.36
7.31
6.97
6.96
6.95
6.94
6.93
6.93
6.92
6.90
6.90
6.89
5.74
5.69
3.86
3.85
CN
MeO
(14e)
300 MHz, CDCl3
0.94 2.06 0.99 3.04
1.00
1.48 2.65
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

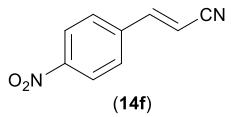

162.02
149.99
129.04
126.33
118.66
114.49
93.36
55.42
CN
MeO
(14e)
75 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)



(**14f**)

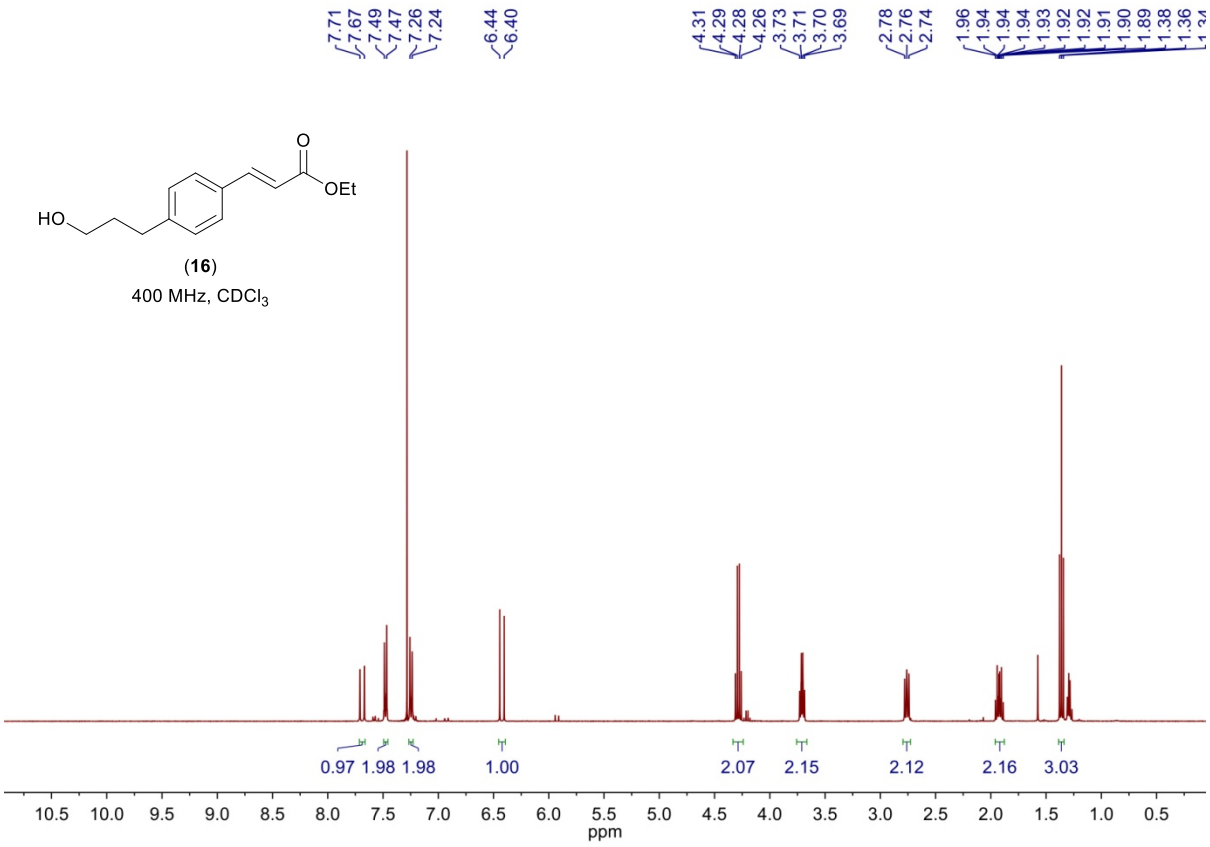
300 MHz, d_6-DMSO

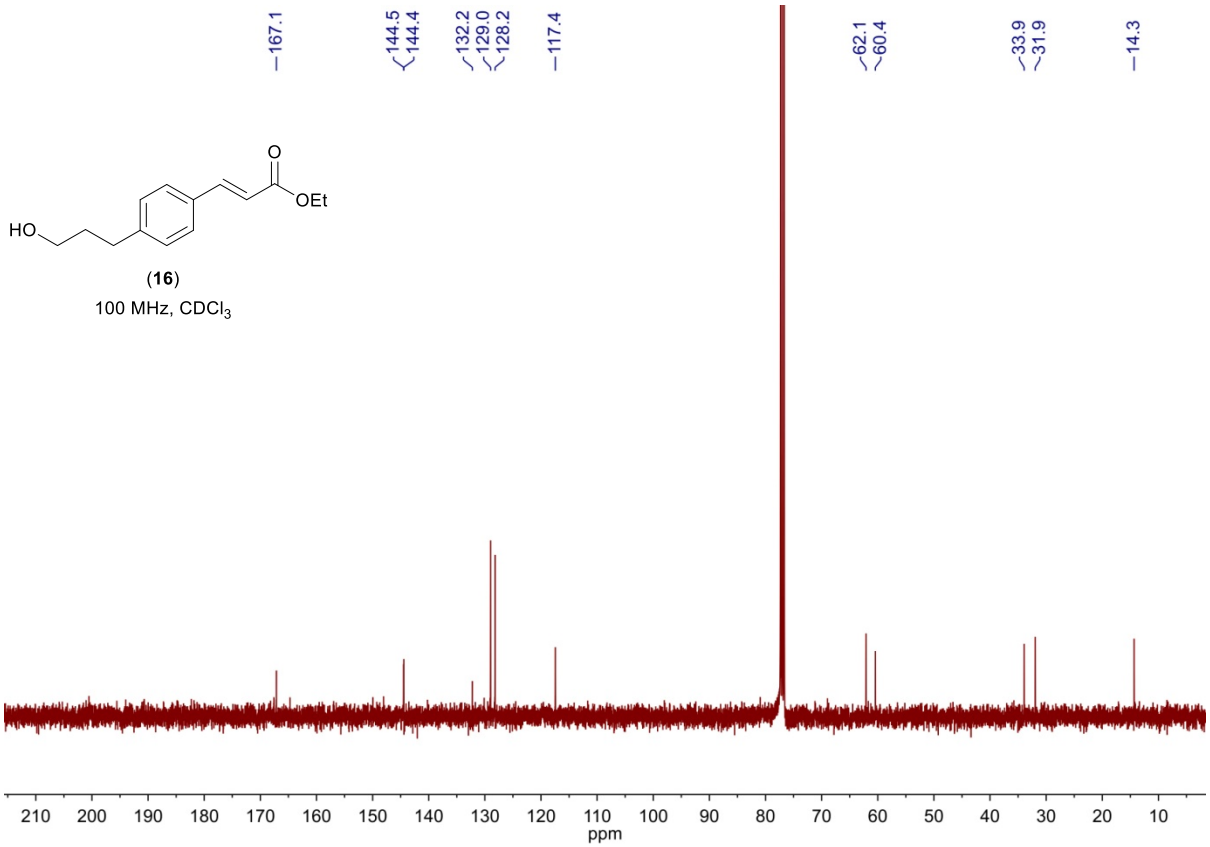


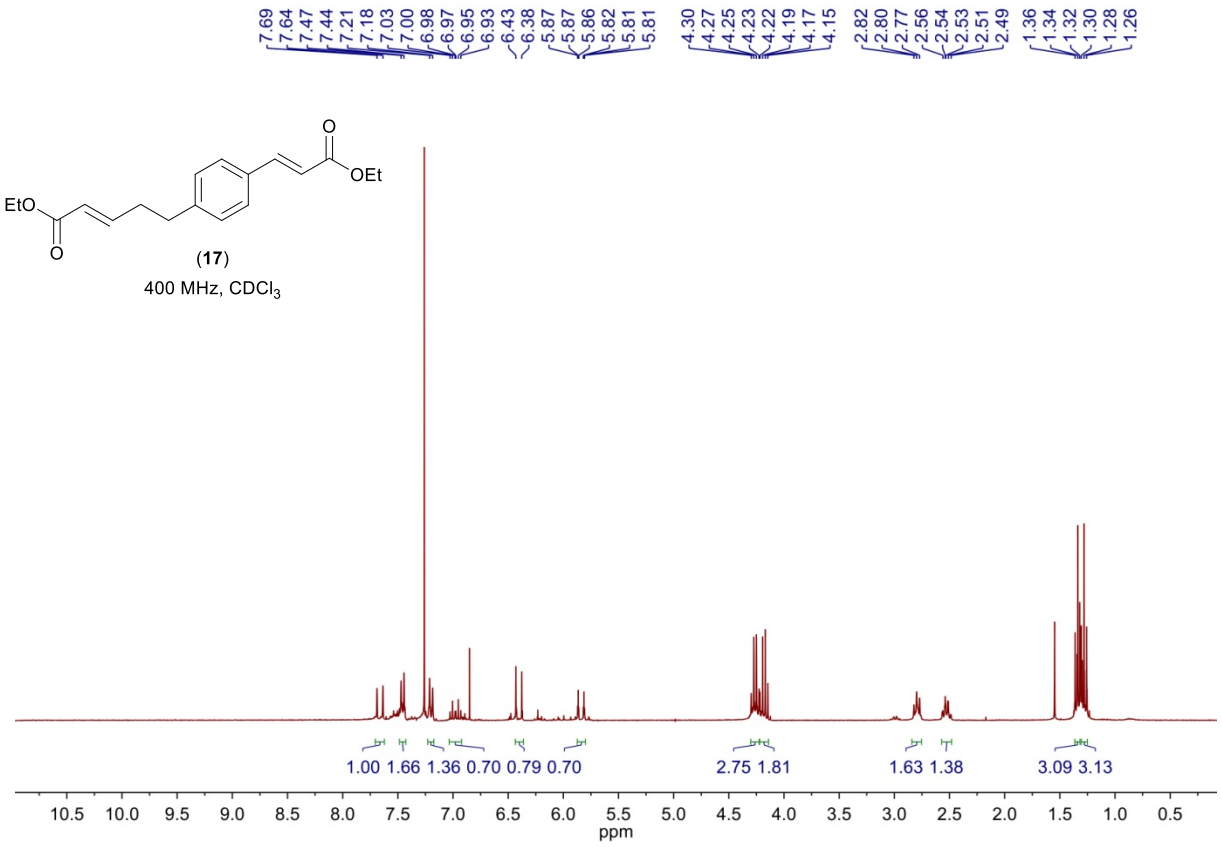


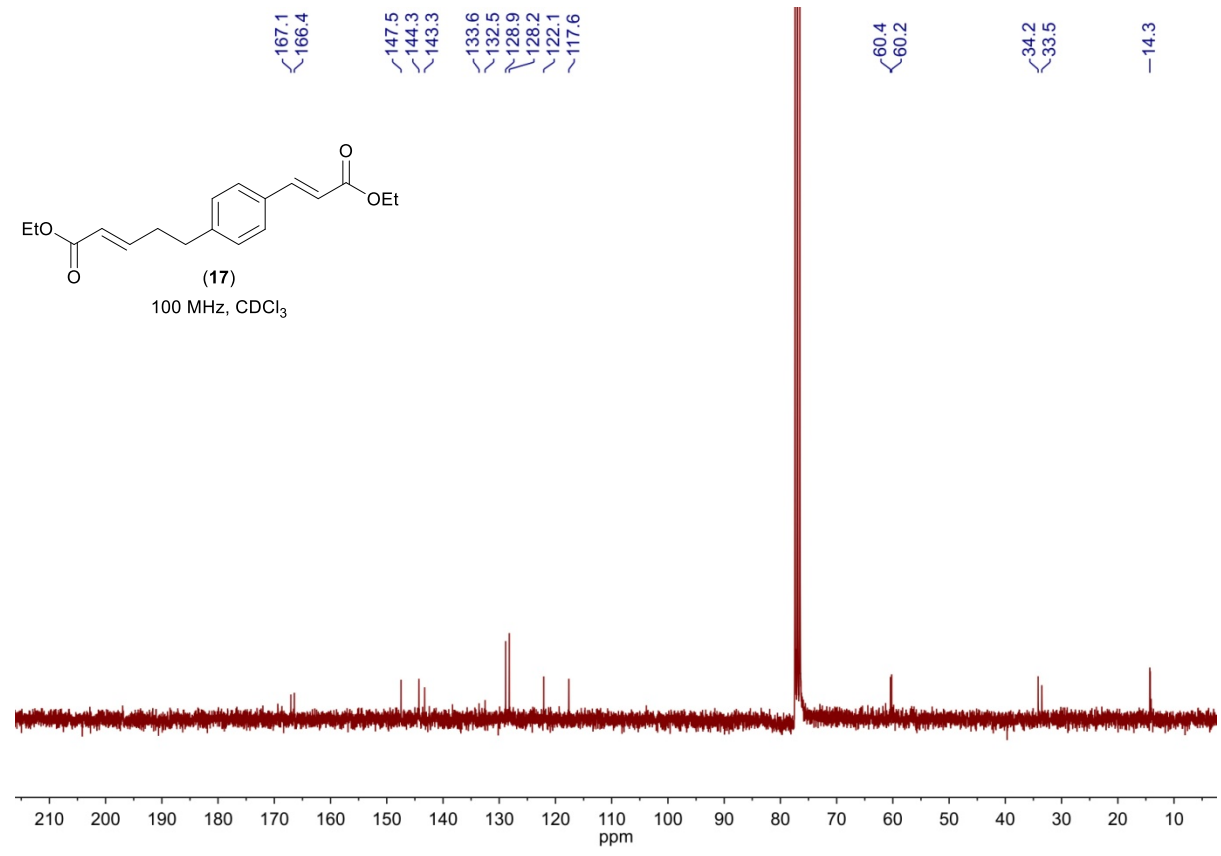
(**14f**)

75 MHz, d_6-DMSO

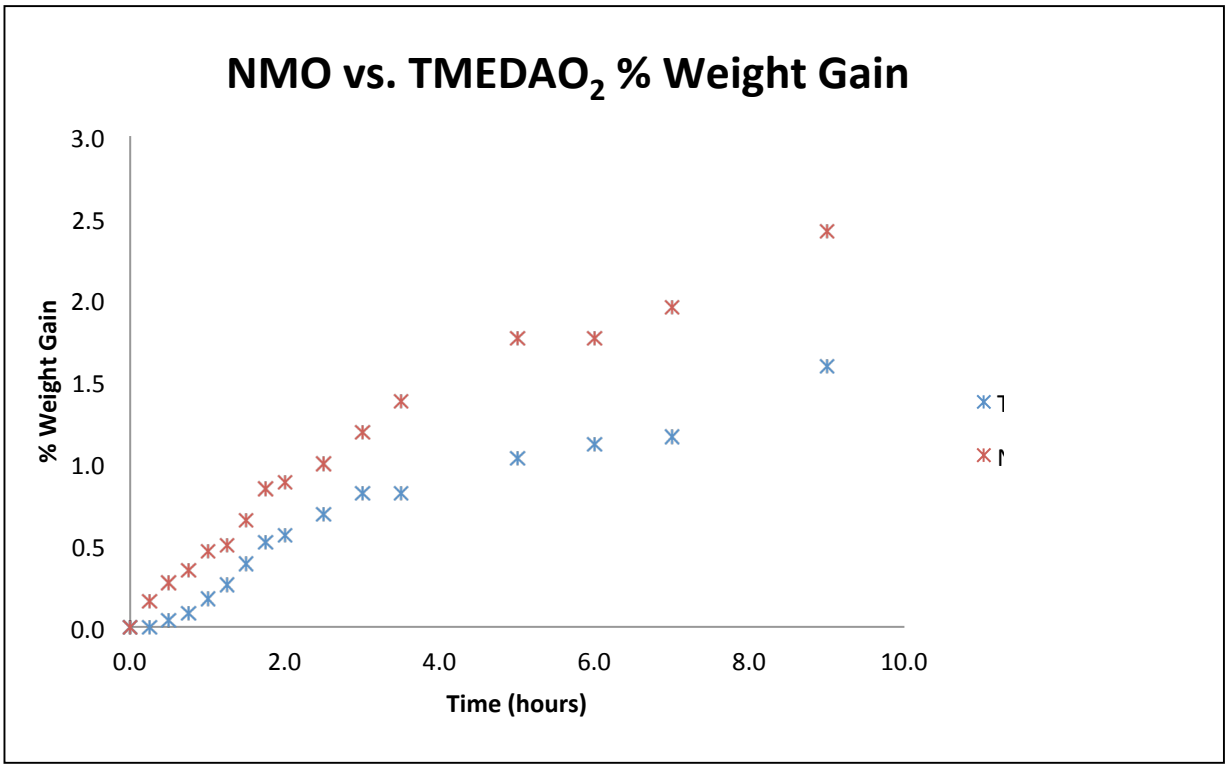

7.71
7.67
7.49
7.47
7.26
7.24
6.44
6.40
4.31
4.29
4.28
4.26
3.73
3.71
3.70
3.69
2.78
2.76
2.74
1.96
1.94
1.94
1.94
1.93
1.92
1.92
1.91
1.90
1.89
1.38
1.36
HO
O
OEt
(16)
400 MHz, CDCl3
0.97 1.98 1.98 1.00 2.07 2.15 2.12 2.16 3.03
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm


167.1
144.5
144.4
132.2
129.0
128.2
117.4
62.1
60.4
33.9
31.9
14.3
HO
O
OEt
(16)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm


7.69
7.64
7.47
7.44
7.21
7.18
7.03
7.00
6.98
6.97
6.95
6.93
6.43
6.38
5.87
5.86
5.82
5.81
5.81
4.30
4.27
4.25
4.23
4.22
4.19
4.17
4.15
2.82
2.80
2.77
2.56
2.54
2.53
2.51
2.49
1.36
1.34
1.32
1.30
1.28
1.26
EtO
O
O
OEt
(17)
400 MHz, CDCl3
1.00 1.66 1.36 0.70 0.79 0.70
2.75 1.81
1.63 1.38
3.09 3.13
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm


167.1
166.4
147.5
144.3
143.3
133.6
132.5
128.9
128.2
122.1
117.6
60.4
60.2
34.2
33.5
14.3
EtO
O
O
OEt
(17)
100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
ppm

v. NMO vs. $TMEDAO_2$ Water Absorption



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