Electronic Supplementary Material (ESI) for Green Chemistry.


# Electronic Supplementary Information

## Visible-light-mediated β-acylative divergent alkene difunctionalization with Katritzky salt/$CO_2$

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**Electronic Supplementary Information**

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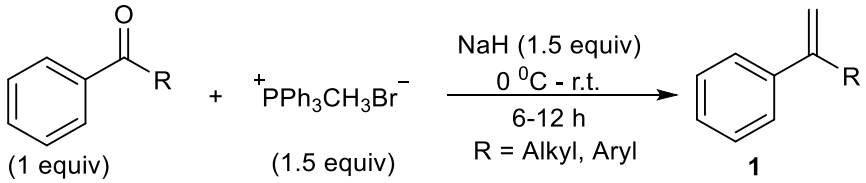
## 1. General information

Melting points were determined in open end-capillary tubes and are uncorrected. TLC was performed on silica gel plates (Merck silica gel 60, f254), and the spots were visualized with UV light (254 and 365 nm) and $KMnO_4$ stain. X-ray of crystals was recorded in Bruker D8 Venture with a Photon-III detector instrument. $^1H$ NMR was recorded at 400 MHz (JEOL-JNM-ECZ400S/L1) frequency and 600 MHz (Bruker-Avance) frequency; $^{13}C$ NMR spectra were recorded at 100 MHz (JEOL-JNM-ECZ400S/L1) frequency and 150 MHz (Bruker-Avance) frequency in $CDCl_3$, DMSO-$D_6$ and (DMSO-$D_6$ + 1 drop $CDCl_3$) solvent using TMS as the internal standard. Chemical shifts were measured in parts per million (ppm) referenced to 0.0 ppm for tetramethylsilane. The following abbreviations were used to explain multiplicities: s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet. Coupling constants, *J* were reported in Hertz unit (Hz). HRMS (m/z) were measured using ESI (Q-TOF, positive ion) technique. Unless otherwise stated, all commercial reagents were used without additional purification.

## 2. Preparation of starting materials

### 2.1. General procedure for preparation of substituted olefins (1)

Slightly modifying a literature protocol[1], these were prepared by Wittig reaction as follows.




An oven-dried round-bottom flask was charged with $CH_3PPh_3Br$ (1.5 equiv.) and THF (carbonyl substrate concentration = 0.2 M). NaH (1.5 equiv.) was added in portion to the suspension at 0 °C. The resulting mixture was allowed to warm up to room temperature and stirred for 1 h. The yellow suspension was cooled to 0 °C again followed by addition of the carbonyl substrate (1 equiv.). Subsequently, the mixture was further stirred at room temperature for 1-12 hours. After the completion of the reaction, the solvent was removed by evaporation, the resulting reaction mixture was extracted with ethyl acetate (40 mL), water (20 mL × 2), washed with brine (20 mL), and the combined organic layer was dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified via column chromatography (eluting with petroleum ether/ethyl acetate) to afford the substituted olefin substrates **1**.

### 2.2. Synthesis of α-oxocarboxylic acid

The α-oxocarboxylic acids were prepared from oxidation of corresponding methyl ketones by $SeO_2$ according to the reported procedure.[2]

### 2.3. Synthesis of Katritzky salts

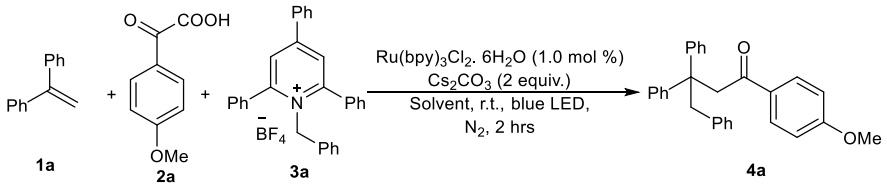
The α-oxocarboxylic acids were prepared from according to the reported procedure.[3]

## 3. Optimization details

### 3.1. Procedure for optimization of the carbobenzylation reaction

1-benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate **3a** (0.4 mmol, 2.0 equiv., 194 mg), 2-(4-methoxyphenyl)-2-oxoacetic acid **2a** (0.4 mmol, 2.0 equiv., 72 mg), photocatalyst and base were taken in a 7 mL screw-capped vial. Solvent was added to the mixture. The whole mixture was de-gassed and re-filled with inert gas by two consecutive freeze-pump-thaw cycles followed by the addition of 1,1-diphenylethylene **1a** (0.2 mmol, 1.0 equiv., 35 μL). The reaction mixture was then stirred under 5W blue LED irradiation for 2 hours. After that, the solvent was evaporated under reduced pressure and the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethyl acetate) to afford the desired product.

**Table S1. Screening of solvents for carbobenzylation**

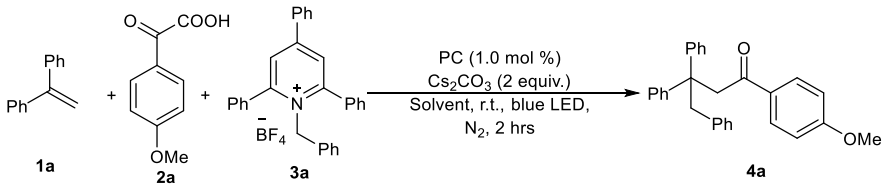



| Entry | Solvent[a] | Yield of **4a** (%) |
|---|---|---|
| **1** | **MeCN** | **82** |
| 2 | THF | 46 |
| 3 | DMF | trace |
| 5 | DCE | 66 |

| | | |
|---|---|---|
| 6 | DMSO | 23 |
| 7 | $PhCH_3$ | 9 |

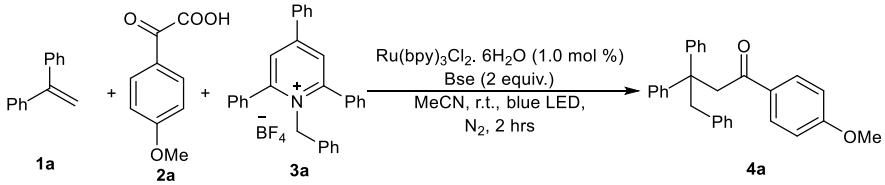
[a]All solvents are anhydrous.

**Table S2. Screening of photocatalysts for carbobenzylation**




| Entry | Photocatalyst | Yield of **4a** (%) |
|---|---|---|
| **1** | **$Ru(bpy)_3Cl_2.6H_2O$** | **82** |
| 2 | *fac*-$Ir(ppy)_3$ | 12 |
| 5 | Eosin Y | trace |
| 6 | $Ir(ppy)_2(dtbpy)PF_6$ | 66 |
| 7 | $Ir[dF(CF_3)(ppy)]_2(dtbpy)PF_6$ | 74 |
| 8 | 4-CzIPN | 43 |
| 9 | $Ru(bpy)_3(PF_6)_2$ | 76 |

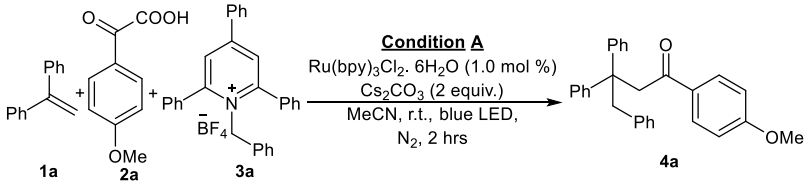
**Table S3. Screening of bases for carbobenzylation**




| Entry | Base | Yield of **4a** (%) |
|---|---|---|
| **1** | **$Cs_2CO_3$** | **82** |
| 2 | CsF | 71 |
| 3 | CsOAc | 77 |
| 4 | NaOAC | 41 |

| | | |
|---|---|---|
| 5 | $K_2CO_3$ | 31 |
| 6 | LiOH | 18 |

**Table S4. Control experiments for carbobenzylation**



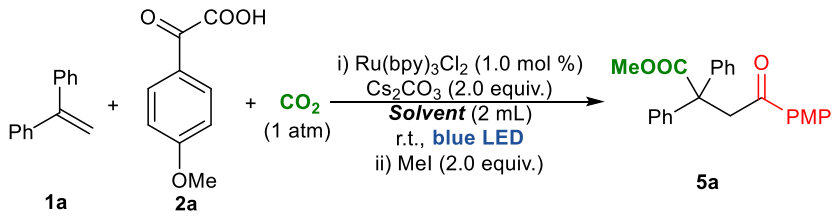

| Entry | Variation from "Condition A" | Yield of **4a** (%) |
|---|---|---|
| **1** | **no variation** | **82** |
| 2 | no PC | 0 |
| 3 | no light | 0 |
| 4 | $Ir(ppy)_2(dtbpy)PF_6$ instead of $Ru(bpy)_3Cl_2 \cdot 6H_2O$ | 66 |
| 5 | 4CzIPN instead of $Ru(bpy)_3Cl_2 \cdot 6H_2O$ | 43 |
| 6 | $Ir(ppy)_3$ instead of $Ru(bpy)_3Cl_2 \cdot 6H_2O$ | 12 |
| 7 | without $Cs_2CO_3$ | 0 |
| 8 | $K_2CO_3$ instead of $Cs_2CO_3$ | 31 |
| 9 | CsF instead of $Cs_2CO_3$ | 71 |
| 10 | Addition of 20 mol % $Cu(OTf)_2$ | 9 |
| 11 | Addition of 10 mol % $In(OTf)_2$ | 66 |

### 3.2. Procedure for optimization of the carbocarboxylation reaction

The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with **2a** (43.2 mg, 0.24 mmol, 1.2 equiv), photocatalyst and transferred to glovebox to add base. The tube was then evacuated and back-filled with $CO_2$ for 3 times. Therefore, under continuous $CO_2$ flow, solvent and **1a** (35 μL, 1.0 equiv., 0.2 mmol) were added with syringe and subsequently

the tube was sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12 hours. After 12 hours, the light was switched off, the Schlenk tube was opened and to the mixture, methyl iodide (24.9 μL, 0.4 mmol, 2.0 equiv.) was added. The mixture was stirred for additional 4 hours at room temperature. After that, the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethyl acetate 93:7) to afford the desired product **5a**.

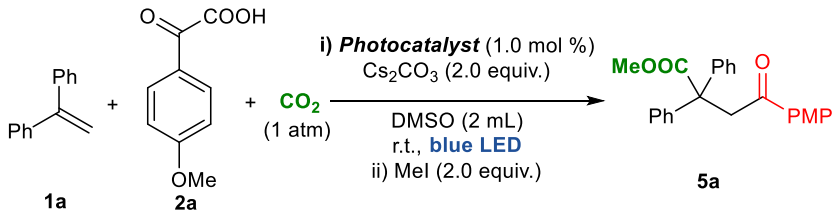
**Table S5. Screening of solvents for carbocarboxylation**




| Entry | Solvent[a] | Yield of **5a** (%) |
|---|---|---|
| 1 | MeCN | 16 |
| 2 | THF | 25 |
| 3 | DMF | 31 |
| 4 | DMA | 28 |
| 5 | DCE | trace |
| **6** | **DMSO** | **37** |
| 7 | $PhCH_3$ | trace |
| 8 | HFIP | 10 |
| 9 | NMP | trace |

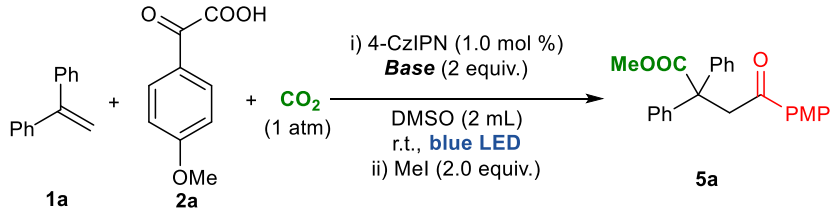
[a]All solvents are anhydrous.

**Table S6. Screening of photocatalysts for carbocarboxylation**




| Entry | Photocatalyst | Yield of **5a** (%) |
|---|---|---|
| 1 | $Ru(bpy)_3Cl_2.6H_2O$ | 37 |
| 2 | *fac*-$Ir(ppy)_3$ | 43 |
| 3 | *p*-terphenyl | ND |
| 4 | Xanthone | ND |
| 5 | Rose bengal | trace |
| 6 | $Ir(ppy)_2(dtbpy)PF_6$ | 70 |
| 7 | $Ir[dF(CF_3)(ppy)]_2(dtbpy)PF_6$ | 67 |
| **8** | **4-CzIPN** | **81** |
| 9 | $Ru(bpy)_3(PF_6)_2$ | 32 |
| 10 | 4-DPAIPN | 44 |

**Table S7. Screening of bases for carbocarboxylation**

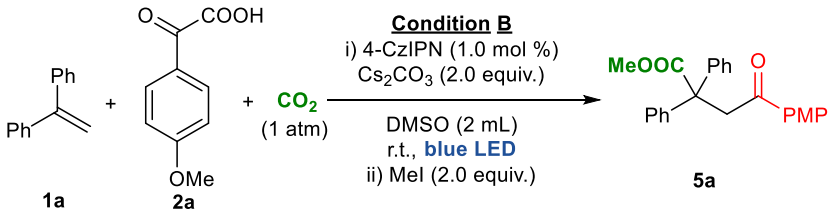



| Entry | Base | Yield of **5a** (%) |
|---|---|---|
| **1** | **$Cs_2CO_3$** | **81** |
| 2 | CsF | 51 |
| 3 | $K_2CO_3$ | 67 |
| 4 | $KO^tBu$ | 41 |

| | | |
|---|---|---|
| 5 | $Na_2CO_3$ | 33 |
| 6 | $Li_2CO_3$ | 30 |
| 7 | LiCl | 74 |
| 8 | $Et_3N$ | trace |
| 9 | $^{i}Pr_2NEt$ | trace |
| 10 | CsOAc | 35 |
| 11[a] | $Cs_2CO_3$ | 78 |

[a]3 equiv. of $Cs_2CO_3$.

**Table S8. Control experiments for carbocarboxylation**




| Entry | Variation from "Condition B" | Yield of **5a** (%) |
|---|---|---|
| **1** | **None** | **81** |
| 2 | Without $Cs_2CO_3$ | trace |
| 3 | Without 4-CzIPN | nd |
| 4 | Without blue LEDs | nd |
| 5 | Without 4-CzIPN, without blue LEDs | nd |
| 6 | Ar instead of $CO_2$ | 30 |
| 7 | $O_2$ instead of $CO_2$ | nd |
| 8 | Ar instead of $CO_2$ and 6 equiv. of **2a** | 58 |
| 9 | 3 equiv. of **2a** | 75 |

## 4. General experimental procedures

### 4.1. General procedure for carbobenzylation (Table 2).

The Katritzky salt **3** (0.4 mmol, 2.0 equiv.), α-oxocarboxylic acid **2** (0.4 mmol, 2.0 equiv.), tris(2,2′-bipyridyl)dichlororuthenium(II) hexahydrate (0.002 mmol, 1 mol %, 2.9 mg) and caesium carbonate (0.4 mmol, 2.0 equiv., 130 mg) were taken in a 7 mL screw-capped vial. 2 mL distilled acetonitrile solvent was added to the mixture. The whole mixture was de-gassed and re-filled with inert gas by two consecutive freeze-pump-thaw cycles followed by the addition of alkene **1** (0.2 mmol, 1.0 equiv.). The reaction mixture was then stirred under 5W blue LED irradiation for 2-6 hours. After completion, the solvent was evaporated under reduced pressure and the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate) to afford the desired product.

### 4.2. General procedure for carbocarboxylation under blue LED irradiation (Table 3).

The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with **1** (0.2 mmol, 1.0 equiv, if solid), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %), **2** (0.24 mmol, 1.2 equiv) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with $CO_2$ for 3 times. Therefore, under continuous $CO_2$ flow, anhydrous DMSO (3.0 mL) and **1** (if liquid) were added with syringe and subsequently the tube was sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12 hours. After 12 hours, the light was switched off, the shlenk tube was opened and to the mixture, methyl iodide (24.9 μL, 0.4 mmol, 2.0 equiv.) was added. The mixture was stirred for additional 4 hours at room temperature. After that, the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate) to afford the desired product.

### 4.3. General procedure for carbocarboxylation under sunlight irradiation (Table 3).

The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with **1** (0.2 mmol, 1.0 equiv, if solid), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %), **2** (0.24 mmol, 1.2 equiv) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with $CO_2$ for 3 times. Therefore, under continuous $CO_2$ flow,

anhydrous DMSO (3.0 mL) and **1** (if liquid) were added with syringe and subsequently the tube was sealed. The reaction was stirred under direct sunlight (at Kolkata, $22.57^0$ N, $88.36^0$ E from 1100 hrs in December) for 5 hours. After 5 hours, the reaction was replaced from sunlight to indoor environment, the shlenk tube was opened and to the mixture, methyl iodide (24.9 μL, 0.4 mmol, 2.0 equiv.) was added. The mixture was stirred for additional 4 hours at room temperature. After that, the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate) to afford the desired product.

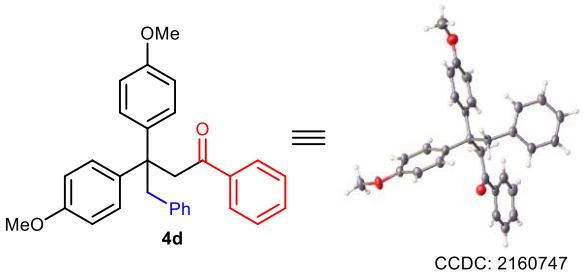
### 4.4. General procedure for carbobenzylation scale-up reaction under sunlight (Scheme 2).

4,4'-(ethene-1,1-diyl)bis(methoxybenzene) (3.16 mmol, 1 equiv), 1-benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate **2a** (6.32 mmol, 2.0 equiv., 3.06 g), 2-phenyl-2-oxoacetic acid **3a** (6.32 mmol, 2.0 equiv., 948 mg), tris(2,2′-bipyridyl)dichlororuthenium(II) hexahydrate (0.0316 mmol, 1 mol %, 23.6 mg) and cesium carbonate (6.32 mmol, 2.0 equiv., 2.05 g) were taken in a 50 mL round-bottomed flask connected to a nitrogen balloon *via* an adapter. 20 mL distilled acetonitrile solvent was added to the mixture. The whole mixture was de-gassed and re-filled with the inert gas by two consecutive freeze-pump-thaw cycles. Then the adapter was closed and balloon was removed. The reaction mixture was then stirred under direct sunlight for 2 hours. After that, the solvent was evaporated under reduced pressure and the reaction mixture was extracted with ethyl acetate (40 mL), water (15 mL × 2), washed with brine (15 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate) to afford the desired product.

## 5. Crystal data

### 5.1. Crystal data of 4d.

The crystal of compound **4d** were grown in acetone-hexane solvent system by slow evaporation procedure. The crystal data was collected in X-ray spectroscopy (Bruker D8 Venture with a Photon-III detector instrument), and the data was analyzed using OLEX2 software. The structure is given below. The corresponding cif file is uploaded separately as supporting information.




Thermal ellipsoid of **4d**. Ellipsoids are represented with 50% probability.

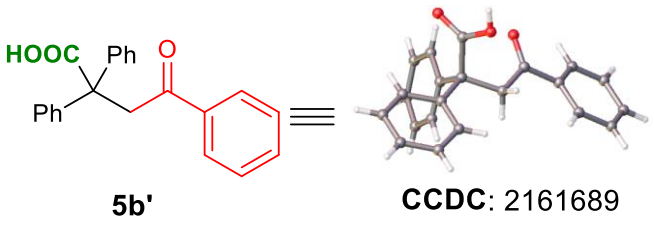
**Table S9. Crystal data and structure refinement for 4d.**

| | |
|---|---|
| Identification code | **4d** |
| Empirical formula | $C_{30}H_{28}O_3$ |
| Formula weight | 436.52 |
| Temperature/K | 100.0 |
| Crystal system | triclinic |
| Space group | P-1 |
| a/Å | 9.7371(9) |
| b/Å | 10.1536(10) |
| c/Å | 12.7652(12) |
| α/° | 102.012(3) |
| β/° | 94.177(2) |
| γ/° | 110.290(2) |
| Volume/Å$^3$ | 1143.27(19) |
| Z | 2 |
| $\rho_{calc}$g/cm$^3$ | 1.268 |
| μ/mm$^{-1}$ | 0.635 |
| F(000) | 464.0 |
| Crystal size/mm$^3$ | 0.45 × 0.34 × 0.15 |

| | |
|---|---|
| Radiation | CuKα (λ = 1.54178) |
| 2Θ range for data collection/° | 7.17 to 129.932 |
| Index ranges | -11 ≤ h ≤ 11, -11 ≤ k ≤ 11, -14 ≤ l ≤ 14 |
| Reflections collected | 28980 |
| Independent reflections | 3779 [$R_{int}$= 0.0657, $R_{sigma}$= 0.0442] |
| Data/restraints/parameters | 3779/0/300 |
| Goodness-of-fit on $F^2$ | 1.045 |
| Final R indexes [I>=2σ (I)] | $R_1$= 0.0676, $wR_2$= 0.1901 |
| Final R indexes [all data] | $R_1$ = 0.0689, $wR_2$ = 0.1918 |
| Largest diff. peak/hole / e $Å^{-3}$ | 0.61/-0.29 |

### 5.2. Crystal data of 5b'.

The crystal of compound **5b'** were grown in chloroform-hexane solvent system by slow evaporation procedure. The crystal data was collected in X-ray spectroscopy (Bruker D8 Venture with a Photon-III detector instrument), and the data was analyzed using OLEX2 software. The structure is given below. The corresponding cif file is uploaded separately as supporting information.




Thermal ellipsoid of **5b'**. Ellipsoids are represented with 50% probability.

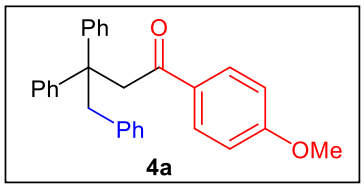
**Table S10. Crystal data and structure refinement for 5b'.**

| | |
|---|---|
| Identification code | **5b'** |
| Empirical formula | $C_{44}H_{36}O_6$ |
| Formula weight | 660.73 |
| Temperature/K | 298.0 |
| Crystal system | triclinic |

| | |
|---|---|
| Space group | P-1 |
| a/Å | 8.9980(2) |
| b/Å | 11.5521(2) |
| c/Å | 18.5351(4) |
| α/° | 79.7640(10) |
| β/° | 84.2930(10) |
| γ/° | 67.4670(10) |
| Volume/$Å^3$ | 1750.20(6) |
| Z | 2 |
| $\rho_{calc}g/cm^3$ | 1.254 |
| $\mu/mm^{-1}$ | 0.663 |
| F(000) | 696.0 |
| Crystal size/$mm^3$ | 0.2 × 0.2 × 0.2 |
| Radiation | CuKα (λ = 1.54178) |
| 2Θ range for data collection/° | 4.848 to 136.656 |
| Index ranges | $-10 \leq h \leq 10$, $-13 \leq k \leq 13$, $-22 \leq l \leq 22$ |
| Reflections collected | 59503 |
| Independent reflections | 6396 [$R_{int}$ = 0.0782, $R_{sigma}$ = 0.0395] |
| Data/restraints/parameters | 6396/0/453 |
| Goodness-of-fit on $F^2$ | 1.098 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0684, $wR_2$ = 0.1755 |
| Final R indexes [all data] | $R_1$ = 0.0788, $wR_2$ = 0.1871 |
| Largest diff. peak/hole / e $Å^{-3}$ | 0.27/-0.38 |

## 6. Spectral data

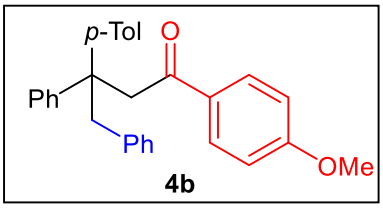
### 1-(4-methoxyphenyl)-3,3,4-triphenylbutan-1-one (4a)



4a

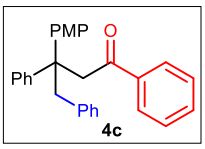
Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (71.4 mg, 82%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 9.2 Hz, 2H), 7.22-7.06 (m, 11H), 7.01 (t, *J* = 8.0 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 6.61-6.59 (m, 2H), 3.86 (s, 2H), 3.81 (s, 3H), 3.62 (s, 2H); δ $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.4, 163.2, 148.0, 138.1, 131.4, 130.9, 130.2, 128.2, 127.8, 127.5, 126.1, 126.0, 113.4, 55.5, 49.7, 43.8, 42; HRMS (ESI, m/z) calcd. For $C_{29}H_{26}O_2Na$ $[M+Na]^+$: 429.1830; found: 429.1830.

**1-(4-methoxyphenyl)-3,4-diphenyl-3-(p-tolyl)butan-1-one (4b)**



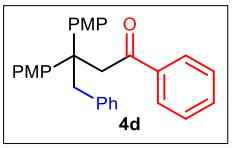

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (48.7 mg, 58%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 8.8 Hz, 2H), 7.22-6.99 (m, 12H), 6.80 (d, *J* = 8.8 Hz, 2H), 6.60 (d, *J* = 7.2 Hz, 2H), 3.88-3.84 (m, 2H), 3.81 (s, 3H), 3.61 (s, 2H), 2.28 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.4, 163.1, 148.3, 145.1, 138.3, 135.3, 131.5, 130.9, 130.2, 128.6, 128.1, 128.0, 127.8, 127.5, 126.1, 125.9, 113.4, 55.5, 49.4, 43.8, 42.9, 21.0; HRMS (ESI, m/z) calcd. For $C_{30}H_{28}O_2Na$ $[M+Na]^+$: 443.1987; found: 443.2007.

**3-(4-methoxyphenyl)-1,3,4-triphenylbutan-1-one (4c)**



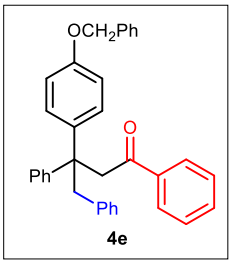

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (58.4 mg, 72%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 7.6 Hz, 2H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.33 (t, *J* = 8.0 Hz, 2H), 7.23-7.07 (m, 8H), 7.03 (t, *J* = 7.6 Hz, 2H), 6.75 (d, *J* = 8.8Hz, 2H), 6.61 (d, *J* = 7.2 Hz, 2H), 3.83 (s, 2H), 3.76 (s, 3H), 3.64 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.1, 157.7, 148.1, 140.0, 138.5, 138.1, 132.6, 130.9, 129.2, 128.3, 128.1, 127.9, 127.8, 127.5, 126.1, 126.0, 113.2, 55.3, 49.1, 43.9, 43.6 HRMS (ESI, m/z) calcd. For $C_{29}H_{26}O_2Na$ $[M+Na]^+$: 429.1830; found: 429.1837.

**3,3-bis(4-methoxyphenyl)-1,4-diphenylbutan-1-one (4d)**



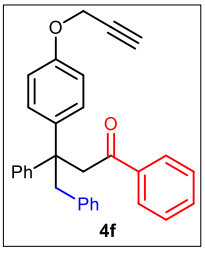

Column chromatography ($SiO_2$, eluting with 95:5 hexane/ethyl acetate) afforded the desired product as a white solid (61.0 mg, 70%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 7.2 Hz, 2H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.33 (t, *J* = 9.2 Hz, 2H), 7.10-7.02 (m, 7H), 6.75 (d, *J* = 8.8 Hz, 4H), 6.63 (d, *J* = 7.2 Hz, 2H), 3.79 (s, 2H), 3.76 (s, 3H), 3.60 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.3, 157.6, 140.2, 138.5, 138.3, 132.6, 131.0, 129.1, 128.3, 127.8, 127.5, 126.1, 113.2, 55.2, 48.6, 44.1, 43.7 HRMS (ESI, m/z) calcd. For $C_{30}H_{28}O_3Na$ $[M+Na]^+$: 459.1936; found: 459.1952.

**3-(4-(benzyloxy)phenyl)-1,3,4-triphenylbutan-1-one (4e)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (75.2 mg, 78%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 8.4 Hz, 2H), 7.48-7.32 (m, 8H), 7.22-7.08 (m, 8H), 7.05-7.02 (m, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 6.62 (d, *J* = 7.2 Hz, 2H), 5.02 (s, 2H), 3.84 (s, 2H), 3.65 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.1, 157.0, 148.1, 140.3, 138.5, 138.1, 137.2, 132.6, 130.9, 129.2, 128.6, 128.4, 128.1, 128.0, 127.9, 127.8, 127.6, 127.5, 126.2, 126.1, 114.2, 70.1, 49.2, 43.9, 43.5.

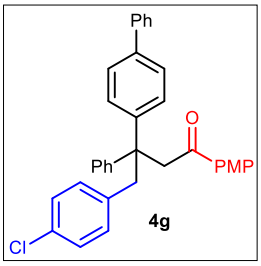
**1,3,4-triphenyl-3-(4-(prop-2-yn-1-yloxy)phenyl)butan-1-one (4f)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (56.7 mg, 66%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.8 Hz, 2H), 7.23-7.08 (m, 8H), 7.04-7.00 (m, 2H), 6.82 (dd, $J_1$ = 8.8 Hz, $J_2$ = 6 Hz, 4H), 6.62 (d, *J* =

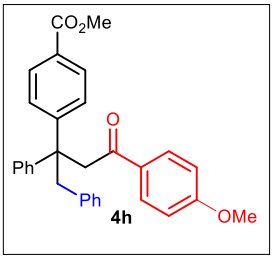
7.2 Hz, 2H), 4.63 (d, *J* = 2.4 Hz, 2H), 3.82 (d, *J* = 1.6 Hz, 2H), 3.81 (s, 3H), 3.59 (s, 2H), 2.50 (t, *J* = 2.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.5, 163.2, 155.7, 148.1, 141.1, 138.2, 131.5, 131.0, 130.2, 129.2, 128.1, 127.8, 127.5, 126.1, 126.0, 114.2, 113.5, 78.8, 75.5, 55.9, 55.5, 49.3, 43.9, 42.9; HRMS (ESI, m/z) calcd. For $C_{32}H_{28}O_3Na$ $[M+Na]^+$: 483.1936; found: 483.1948.

**3-([1,1'-biphenyl]-4-yl)-4-(4-chlorophenyl)-1-(4-methoxyphenyl)-3-phenylbutan-1-one (4g)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (72.2 mg, 70%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.8 Hz, 2H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.46-7.39 (m, 4H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.26-7.15 (m, 7H), 7.00 (d, *J* = 8.8 Hz, 2H), 6.79 (d, *J* = 8.8 Hz, 2H), 6.59 (d, *J* = 8.8 Hz, 2H), 3.91-3.80 (m, 2H), 3.79 (s, 3H), 3.66-3.56 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.6, 163.3, 147.5, 146.8, 140.7, 138.8, 136.6, 132.3, 132.1, 131.4, 130.2, 128.8, 128.6, 128.2, 128.0, 127.7, 127.3, 127.0, 126.6, 126.3, 113.5, 55.5, 49.7, 43.1, 42.7; HRMS (ESI, m/z) calcd. For $C_{35}H_{30}O_2Cl$ $[M+H]^+$: 517.1934; found: 517.1945.

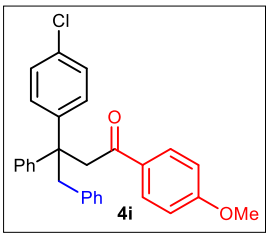
**methyl 4-(4-oxo-1,2,4-triphenylbutan-2-yl)benzoate (4h)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (31.2 mg, 36%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, *J* = 8.8 Hz, 2H), 7.74 (d, *J* = 9.2 Hz, 2H), 7.26 (d, *J* = 8.8 Hz, 2H), 7.23-7.06 (m, 6H), 7.00 (t, *J* = 7.2 Hz, 2H), 6.81 (d, *J* = 9.2 Hz, 2H), 6.55 (d, *J* = 8.4 Hz, 2H), 3.91-3.86 (m, 5H), 3.81 (s, 3H), 3.65 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.8, 167.1, 163.3, 153.7, 147.3, 137.6, 131.2, 130.8,

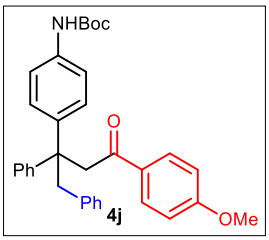
130.1, 129.2, 128.2, 128.1, 128.0, 127.8, 127.6, 126.3, 126.3, 113.6, 55.5, 52.1, 49.9, 43.7, 42.8; HRMS (ESI, m/z) calcd. For $C_{31}H_{29}O_4$ $[M+H]^+$: 465.2066; found: 465.2067.

**3-(4-chlorophenyl)-1-(4-methoxyphenyl)-3,4-diphenylbutan-1-one (4i)**



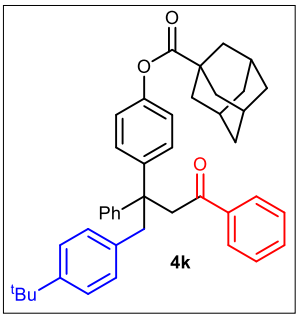

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (54.5 mg, 62%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 9.2 Hz, 2H), 7.24-7.08 (m, 10H), 7.03 (t, *J* = 7.2 Hz, 2H), 6.82 (d, *J* = 9.2 Hz, 2H), 6.59 (d, *J* = 7.2 Hz, 2H), 3.88-3.78 (m, 5H), 3.60 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.0, 163.3, 147.5, 146.7, 137.7, 131.8, 131.3, 130.9, 130.2, 129.6, 128.1, 128.0, 127.6, 126.3, 113.6, 55.5, 49.4, 43.8, 42.8; HRMS (ESI, m/z) calcd. For $C_{29}H_{26}O_2Cl$ $[M+H]^+$: 441.1621; found: 441.1626.

**tert-butyl (4-(4-(4-methoxyphenyl)-4-oxo-1,2-diphenylbutan-2-yl)phenyl)carbamate (4j)**



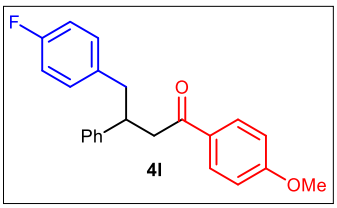

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (50.0 mg, 48%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.8 Hz, 2H), 7.21-6.99 (m, 3H), 6.80 (d, *J* = 9.2 Hz, 2H), 6.61 (d, *J* = 6.8 Hz, 2H), 6.47 (br. S, 1H), 3.83-3.81 (m, 5H), 3.58 (s, 2H), 1.49 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.4, 163.2, 152.8, 148.0, 142.7, 138.1, 136.3, 131.4, 131.0, 130.1, 128.7, 128.1, 127.8, 127.5, 126.1, 126.0, 117.9, 113.5, 55.4, 49.3, 43.8, 42.9, 29.7, 28.4; HRMS (ESI, m/z) calcd. For $C_{34}H_{35}O_4NaN$ $[M+Na]^+$: 544.2464; found: 544.2470.

**4-(1-(4-(tert-butyl)phenyl)-4-oxo-2,4-diphenylbutan-2-yl)phenyl (1s,3s)-adamantane-1-carboxylate (4k)**



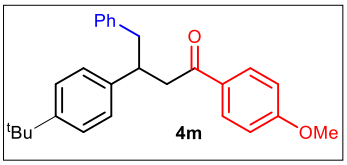

Column chromatography ($SiO_2$, eluting with 95:5 hexane/ethyl acetate) afforded the desired product as a white solid (81.7 mg, 67%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 8.4 Hz, 2H), 7.46 (d, *J* = 7.2 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.21-7.16 (m, 7H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 8.8 Hz, 2H), 6.52 (d, *J* = 8.4 Hz, 2H), 3.89-3.78 (m, 2H), 3.73-3.63 (m, 4H), 2.08-2.04 (m, 9H), 1.77 (s, 6H), 1.24 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 198.7, 176.2, 149.2, 148.9, 147.8, 145.3, 138.4, 134.6, 132.6, 130.5, 129.1, 128.4, 128.2, 127.9, 127.8, 126.1, 124.5, 120.8, 49.4, 43.7, 43.5, 41.1, 38.8, 36.6, 34.4, 31.4, 28.0.

**4-(4-fluorophenyl)-1-(4-methoxyphenyl)-3-phenylbutan-1-one (4l)**




Column chromatography ($SiO_2$, eluting with 95:5 hexane/ethyl acetate) afforded the desired product as a white solid (36.2 mg, 52%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, *J* = 9.2 Hz, 2H), 7.24-7.21 (m, 2H), 7.16-7.12 (m, 3H), 6.98-6.95 (m, 2H), 6.89-6.83 (m, 4H), 3.84 (s, 3H), 3.64-3.56 (m, 1H), 3.31-3.19 (m, 2H), 3.03-2.97 (m, 1H), 2.89-2.84 (m, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.4, 163.5, 161.4 (d, *J* = 241.8 Hz), 143.9, 135.6 (d, *J* = 3.3 Hz), 130.6 (d, *J* = 7.8 Hz), 130.3, 130.3, 128.4, 127.7, 126.5, 114.9 (d, *J* = 21.0 Hz), 113.7, 55.5, 43.9, 43.3, 42.1; HRMS (ESI, m/z) calcd. For $C_{23}H_{22}O_2F$ $[M+H]^+$: 349.1604; found: 349.1602.

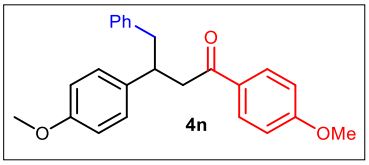
**3-(4-(tert-butyl)phenyl)-1-(4-methoxyphenyl)-4-phenylbutan-1-one (4m)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (44.0 mg, 57%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.81 (d, *J* = 8.8 Hz,

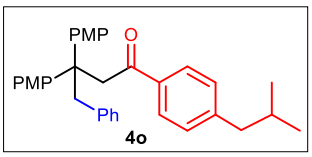
2H), 7.26-7.08 (m, 9H), 6.86 (d, *J* = 9.2 Hz, 2H), 3.83 (s, 3H), 3.63-3.59 (m, 1H), 3.28-3.15 (s, 2H), 2.96 (d, *J* = 7.2 Hz, 2H), 1.27 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.7, 163.4, 149.1, 141.3, 140.2, 130.4, 130.3, 129.4, 128.2, 127.3, 126.1, 125.3, 113.7, 55.5, 43.8, 43.0, 42.6, 34.4, 31.5; HRMS (ESI, m/z) calcd. For $C_{27}H_{31}O_2$ $[M+H]^+$: 387.2324; found: 387.2328.

**1,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4n)**



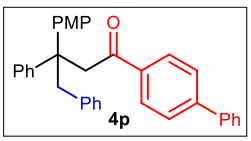

Column chromatography ($SiO_2$, eluting with 95:5 hexane/ethyl acetate) afforded the desired product as a white solid (38.1 mg, 53%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, *J* = 9.2 Hz, 2H), 7.22-7.17 (m, 2H), 7.15-7.11 (m, 1H), 7.09-7.05 (m, 4H), 6.87 (d, *J* = 9.2 Hz, 2H), 6.76 (d, *J* = 8.8 Hz, 2H), 3.83 (s, 3H), 3.74 (s, 3H), 3.63-3.56 (s, 1H), 3.26-3.15 (m, 2H), 3.00-2.87 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.7, 163.4, 158.1, 140.1, 136.3, 130.4, 129.4, 128.6, 128.2, 126.1, 113.8, 113.7, 55.5, 55.2, 44.1, 43.2, 42.5; HRMS (ESI, m/z) calcd. For $C_{24}H_{25}O_3$ $[M+H]^+$: 361.1804; found: 361.1818.

**1-(4-isobutylphenyl)-3,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4o)**



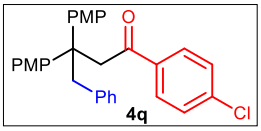

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (71.8 mg, 73%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.0 Hz, 2H), 7.11-7.02 (m, 9H), 6.75 (d, *J* = 8.8 Hz, 4H), 6.65 (d, *J* = 6.8 Hz, 2H), 3.80 (s, 2H), 3.76 (s, 6H), 3.59 (s, 2H), 2.48 (d, *J* = 7.2 Hz, 2H), 1.86 (m, 1H), 0.89 (s, 3H), 0.88 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 198.9, 157.6, 146.9, 140.3, 138.3, 136.3, 131.1, 129.1, 129.0, 127.9, 127.5, 126.1, 113.1, 55.2, 48.6, 45.4, 44.1, 43.5, 30.2, 22.4; HRMS (ESI, m/z) calcd. For $C_{34}H_{36}O_3Na$ $[M+Na]^+$: 515.2562; found: 515.2566

**1-([1,1'-biphenyl]-4-yl)-3-(4-methoxyphenyl)-3,4-diphenylbutan-1-one (4p)**



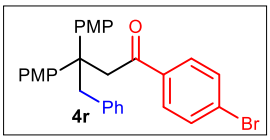
Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (65.5 mg, 68%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.84 (d, *J* = 8.4 Hz, 2H), 7.60-7.56 (m, 4H), 7.47-7.44 (m, 2H), 7.39 (t, *J* = 7.2 Hz, 1H), 7.26-7.11 (s, 3H), 7.06 (d, *J* = 8.0 Hz, 2H), 6.77 (d, *J* = 8.8 Hz, 2H), 6.66 (d, *J* = 7.2Hz, 2H), 3.91-3.83 (m, 2H), 3.76 (s, 3H), 3.69 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 198.7, 157.7, 148.2, 145.3, 140.1, 140.0, 138.2, 137.1, 131.0, 129.2, 129.0, 128.5, 128.3, 128.2, 127.9, 127.6, 127.3, 127.0, 126.2, 126.1, 113.3, 55.3, 49.2, 44.0, 43.6; HRMS (ESI, m/z) calcd. For $C_{35}H_{30}O_2Na$ $[M+Na]^+$: 505.2143; found: 505.2153

**1-(4-chlorophenyl)-3,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4q)**



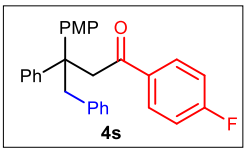

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (58.3 mg, 62%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.64 (d, *J* = 8.8 Hz, 2H), 7.28 (d, *J* = 8.8 Hz, 2H), 7.11-7.02 (m, 7H), 6.73 (d, *J* = 8.8 Hz, 4H), 6.62 (d, *J* = 6.8 Hz, 2H), 3.74-3.74 (m, 8H), 3.53 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 198.3, 157.7, 139.9, 138.9, 138.1, 136.8, 131.0, 129.3, 129.1, 128.6, 127.5, 126.2, 113.2, 55.3, 48.8, 44.0, 43.7; HRMS (ESI, m/z) calcd. For $C_{30}H_{27}O_3NaCl$ $[M+Na]^+$: 493.1546; found: 493.1543.

**1-(4-bromophenyl)-3,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4r)**



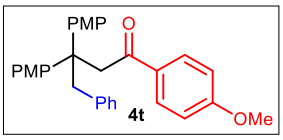

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (47.3 mg, 46%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.56 (d, *J* = 8.4 Hz, 2H), 7.44 (d, *J* = 8.8 Hz, 2H), 7.09 (t, *J* = 7.2 Hz, 1H), 7.05-7.02 (m, 6H), 6.73 (d, *J* = 8.8 Hz, 4H), 6.62-6.61 (m, 2H), 3.75 (s, 6H), 3.74 (s, 2H), 3.52 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 198.5, 157.7, 139.9, 138.1, 137.2, 131.5, 131.0, 129.4, 129.1, 127.6, 127.5, 126.2, 113.2, 55.3, 48.7, 43.9, 43.7.

**1-(4-fluorophenyl)-3-(4-methoxyphenyl)-3,4-diphenylbutan-1-one (4s)**



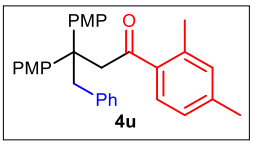

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (56.8 mg, 67%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.77-7.74 (m, 2H), 7.23-6.96 (m, 12H), 6.75 (d, *J* = 9.2 Hz, 2H), 6.63 (d, *J* = 7.2 Hz, 2H), 3.81 (s, 2H), 3.76 (s, 3H), 3.59 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.7, 165.4 (d, *J* = 252.9 Hz), 157.8, 147.9, 139.8, 138.0, 134.8 (d, *J* = 2.7 Hz), 131.0, 130.5 (d, *J* = 9.0 Hz), 129.2, 128.1, 127.9, 127.5, 126.2, 126.1, 115.3 (d, *J* = 21.5 Hz), 113.2, 55.3, 49.3, 43.9, 43.4; HRMS (ESI, m/z) calcd. For $C_{29}H_{25}O_2NaF$ $[M+Na]^+$: 447.1736; found: 447.1732.

**1,3,3-tris(4-methoxyphenyl)-4-phenylbutan-1-one (4t)**




Column chromatography ($SiO_2$, eluting with 95:5 hexane/ethyl acetate) afforded the desired product as a white solid (69.9 mg, 75%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.8 Hz, 2H), 7.10-7.00 (m, 7H), 6.79 (d, *J* = 8.8 Hz, 2H), 6.73 (d, *J* = 8.8 Hz, 2H), 6.62 (d, *J* = 8.0 Hz, 2H), 3.81 (s, 3H), 3.78 (s, 2H), 3.75 (s, 6H), 3.53 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.6, 163.1, 157.6, 140.4, 138.4, 131.5, 131.0, 130.2, 129.1, 127.5, 126.0, 113.4, 113.1, 55.5, 55.3, 48.6, 44.1, 43.1; HRMS (ESI, m/z) calcd. For $C_{31}H_{30}O_4Na$ $[M+Na]^+$: 489.2042; found: 489.2040.

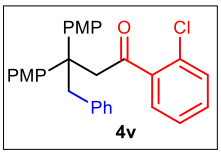
**1-(2,4-dimethylphenyl)-3,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4u)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (64.9 mg, 70%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.20 (d, *J* = 8.4 Hz, 2H), 7.13-7.03 (m, 8H), 6.93-6.91 (m, 2H), 6.75 (d, *J* = 9.2 Hz, 2H), 6.68 (d, *J* = 6.8 Hz, 2H), 3.83 (s, 2H), 3.77 (s, 6H), 3.50 (s, 2H), 2.28 (s, 3H), 2.15 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 203.7, 157.7, 140.8, 140.3, 138.4, 137.8, 137.2, 132.3, 131.1, 129.1, 127.5, 126.1, 125.9,

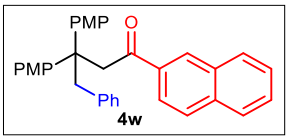
113.2, 55.3, 48.8, 46.7, 44.1, 21.3, 20.6; HRMS (ESI, m/z) calcd. For $C_{32}H_{32}O_3Na$ $[M+Na]^+$: 487.2249; found: 487.2251.

**1-(2-chlorophenyl)-3,3-bis(4-methoxyphenyl)-4-phenylbutan-1-one (4v)**



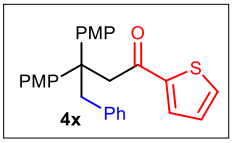

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (62.0 mg, 66%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.48 (dd, $J_1$ = 4.8 Hz, $J_2$ = 1.2 Hz, 1H), 7.42 (dd, $J_1$ = 4.0 Hz, $J_2$ = 1.2 Hz, 1H), 7.10-6.94 (m, 8H), 6.95 (dd, $J_1$ = 4.8 Hz, $J_2$ = 3.6 Hz, 1H), 6.74 (d, $J$ = 8.8 Hz, 4H), 6.70 (d, $J$ = 8.0 Hz, 2H), 3.76-3.75 (m, 8H), 3.49 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 203.3, 157.8, 141.4, 139.8, 138.0, 131.2, 130.9, 129.9, 129.9, 129.1, 128.2, 127.5, 126.6, 126.2, 113.2, 55.3, 49.3, 48.6, 43.9; HRMS (ESI, m/z) calcd. For $C_{30}H_{27}O_3NaCl$ $[M+Na]^+$: 493.1546; found: 493.1548.

**3,3-bis(4-methoxyphenyl)-1-(naphthalen-2-yl)-4-phenylbutan-1-one (4w)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (65.1 mg, 67%). $^1$H NMR (400 MHz, $CDCl_3$): δ 8.21 (s, 1H), 7.87-7.76 (m, 4H), 7.57-7.48 (m, 2H), 7.13-7.03 (m, 7H), 6.75 (d, $J$ = 8.8 Hz, 4H), 6.69 (d, $J$ = 7.2 Hz, 2H), 3.84 (s, 2H), 3.74 (s, 2H), 3.72 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.3, 157.7, 140.2, 138.3, 135.8, 135.3, 132.4, 131.1, 129.6, 129.4, 129.2, 128.3, 128.1, 127.7, 127.5, 126.7, 126.1, 123.8, 113.2, 55.2, 48.8, 44.1, 43.8; HRMS (ESI, m/z) calcd. For $C_{34}H_{30}O_3Na$ $[M+Na]^+$: 509.2093; found: 509.2111.

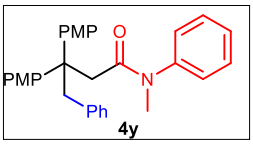
**3,3-bis(4-methoxyphenyl)-4-phenyl-1-(thiophen-2-yl)butan-1-one (4x)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (57.4 mg, 65%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.27-7.19 (m, 1H), 7.15-7.04 (m, 4H), 7.00 (d, $J$ = 8.8 Hz, 4H), 6.73-6.68 (m, 7H), 3.76 (s, 6H), 3.74 (s, 2H), 3.58

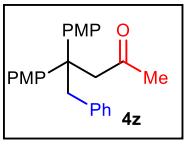
(s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 192.2, 157.7, 145.8, 139.8, 138.1, 133.4, 131.8, 131.2, 129.2, 127.8, 127.5, 126.1, 113.2, 55.3, 49.1, 44.7, 44.1; HRMS (ESI, m/z) calcd. For $C_{28}H_{26}O_3NaS$ $[M+Na]^+$: 465.1500; found: 465.1510.

**3,3-bis(4-methoxyphenyl)-N-methyl-N,4-diphenylbutanamide (4y)**



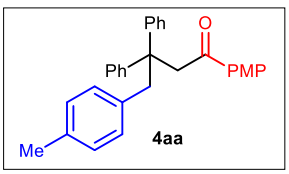

Column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) afforded the desired product as a white solid (55.8 mg, 60%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.30 (t, *J* = 5.2 Hz, 2H), 7.25 (t, *J* = 4.8 Hz, 1H), 7.13-7.07 (m, 3H), 6.85-6.81 (m, 6H), 6.76-6.73 (m, 6H), 3.82-3.80 (m, 8H), 3.06 (s, 3H), 2.72 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 170.6, 157.0, 143.5, 139.7, 138.0, 130.8, 128.9, 128.7, 127.0, 126.9, 126.8, 125.3, 112.4, 54.7, 48.7, 43.5, 38.5, 36.7; HRMS (ESI, m/z) calcd. For $C_{31}H_{32}O_3N$ $[M+H]^+$: 466.2382; found: 466.2384.

**4,4-bis(4-methoxyphenyl)-5-phenylpentan-2-one (4z)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (41.8 mg, 56%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.11-7.02 (m, 3H), 6.99 (d, *J* = 8.8 Hz, 4H), 6.77 (d, *J* = 8.8 Hz, 4H), 6.66 (dd, $J_1$ = 8.0 Hz, $J_2$ = 1.2 Hz, 2H), 3.78 (s, 6H), 3.58 (s, 2H), 2.99 (s, 2H), 1.7 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 208.8, 157.8, 139.8, 138.0, 131.2, 129.1, 127.4, 126.0, 113.2, 55.3, 48.9, 48.7, 43.5, 32.8.

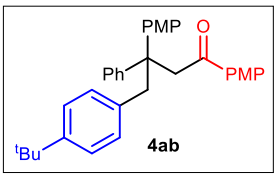
**1-(4-methoxyphenyl)-3,3-diphenyl-4-(p-tolyl)butan-1-one (4aa)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (52.1 mg, 62%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 9.2 Hz, 2H), 7.23-7.06 (m, 10H), 6.84-6.79 (m, 4H), 6.48 (d, *J* = 9.2 Hz, 2H), 3.83-3.81 (m, 5H), 3.63

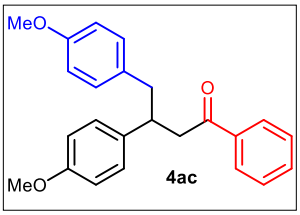
(s, 2H), 2.23 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.3, 163.1, 148.2, 135.5, 134.9, 131.5, 130.8, 130.2, 128.2, 128.2, 127.8, 125.9, 113.5, 55.5, 49.7, 43.4, 42.9, 21.1.

**4-(4-(tert-butyl)phenyl)-1,3-bis(4-methoxyphenyl)-3-phenylbutan-1-one (4ab)**



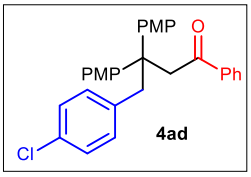

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (52 mg, 53%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.45 (d, *J* = 8.8 Hz, 2H), 7.23-7.13 (m, 5H), 7.09 (d, *J* = 9.2 Hz, 2H), 7.03 (d, *J* = 8.4 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 6.75 (d, *J* = 9.2 Hz, 2H), 6.53 (d, *J* = 8.4 Hz, 2H), 3.81-3.79 (m, 5H), 3.76 (s, 3H), 3.60 (s, 2H), 1.23 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.5, 163.1, 157.6, 148.8, 148.4, 140.4, 135.0, 131.6, 130.6, 130.2, 129.2, 128.2, 127.8, 125.9, 124.4, 113.4, 113.1, 55.4, 55.2, 49.1, 43.5, 43.1, 34.3, 31.4; HRMS (ESI, m/z) calcd. For $C_{34}H_{36}O_3Na$ $[M+Na]^+$: 515.2562; found: 515.2561.

**3,4-bis(4-methoxyphenyl)-1-phenylbutan-1-one (4ac)**



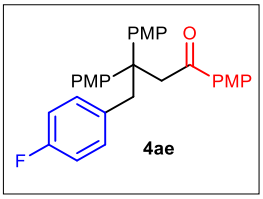

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (41.0 mg, 57%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, *J* = 7.2 Hz, 2H), 7.50 (t, *J* = 7.2 Hz, 1H), 7.40 (d, *J* = 7.2 Hz, 2H), 7.06 (d, *J* = 8.4 Hz, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 6.77-6.72 (m, 4H), 3.74 (s, 6H), 3.59-3.52 (m, 1H), 3.29-3.18 (m, 2H), 2.92-2.82 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.2, 158.1, 157.9, 137.3, 136.3, 132.9, 132.1, 130.3, 128.6, 128.5, 128.1, 113.8, 55.3, 44.4, 42.5, 42.3.

**4-(4-chlorophenyl)-3,3-bis(4-methoxyphenyl)-1-phenylbutan-1-one (4ad)**



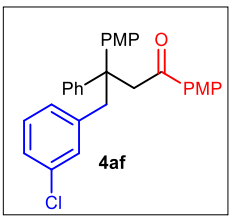
Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (52.6 mg, 56%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.71 (dd, $J_1$ = 8.4 Hz, $J_2$ = 1.2 Hz, 2H), 7.44 (t, $J$ = 7.2 Hz, 1H), 7.32 (t, $J$ = 7.2 Hz, 1H), 7.04 (d, $J$ = 8.8 Hz, 2H), 7.00 (d, $J$ = 8.4 Hz, 2H), 6.73 (t, $J$ = 8.8 Hz, 4H), 6.55 (d, $J$ = 8.4 Hz, 2H), 3.75 (s, 8H), 3.54 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.4, 157.7, 139.8, 138.3, 136.7, 132.7, 132.3, 132.0, 129.1, 128.4, 127.8, 127.6, 113.2, 55.3, 48.6, 43.4, 43.3.

**4-(4-fluorophenyl)-1,3,3-tris(4-methoxyphenyl)butan-1-one (4ae)**



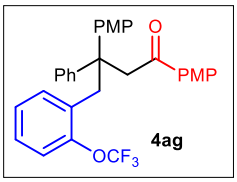

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (77.4 mg, 80%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, $J$ = 9.2 Hz, 2H), 7.04 (d, $J$ = 9.2 Hz, 4H), 6.79 (d, $J$ = 8.8 Hz, 2H), 6.74-6.69 (m, 6H), 6.61-6.57 (m, 2H), 3.80 (s, 3H), 3.75 (s, 8H), 3.49 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.8, 163.2, 161.6 (d, $J$ = 242.5 Hz), 157.7, 140.1, 133.9 (d, $J$ = 2.8 Hz), 132.3 (d, $J$ = 7.6 Hz), 131.5, 130.2, 129.1, 114.2 (d, $J$ = 20.6 Hz), 113.4, 113.2, 55.5, 55.2, 48.7, 43.2, 42.9; HRMS (ESI, m/z) calcd. For $C_{31}H_{29}O_4NaF$ $[M+Na]^+$: 507.1948; found: 507.1953.

**4-(3-chlorophenyl)-1,3-bis(4-methoxyphenyl)-3-phenylbutan-1-one (4af)**



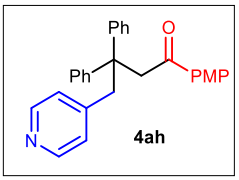

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (45.1 mg, 48%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.69 (dd, $J_1$ = 8.4 Hz, $J_2$ = 1.2 Hz, 2H), 7.43 (td, $J_1$ = 7.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.31 (t, $J$ = 8.0 Hz, 2H), 7.08-7.03 (m, 5H), 6.96 (t, $J$ = 7.8 Hz, 1H), 6.74 (d, $J$ = 8.8 Hz, 2H), 6.57-6.53 (m, 2H), 3.75 (s, 6H), 3.73 (s, 2H), 3.54 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 199.6, 157.8, 140.4, 139.6, 138.5, 133.2, 132.6, 131.0, 129.1, 129.0, 128.6, 128.3, 127.8, 126.3, 113.3, 55.3, 48.7, 43.7, 43.4.

**1,3-bis(4-methoxyphenyl)-3-phenyl-4-(2-(trifluoromethoxy)phenyl)butan-1-one (4ag)**



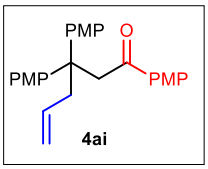

Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (42.6 mg, 41%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.79 (dd, $J_1$ = 8.0 Hz, $J_2$ = 1.2 Hz, 2H), 7.46 (td, $J_1$ = 7.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.35 (d, $J$ = 8.0 Hz, 2H), 7.14-7.01 (m, 6H), 6.93-6.88 (m, 1H), 6.73 (d, $J$ = 9.2 Hz, 2H), 6.54 (dd, $J_1$ = 8.0 Hz, $J_2$ = 1.6 Hz, 1H), 3.84 (s, 2H), 3.75 (s, 6H), 3.67 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.6, 157.7, 148.6, 139.7, 138.2, 133.5, 132.5, 130.6, 129.1, 128.3, 127.8, 127.6, 125.6, 121.6, 120.3 (q, $J$ = 256.0 Hz), 119.6, 119.0, 113.1, 55.2, 48.4, 44.1, 38.4; HRMS (ESI, m/z) calcd. For $C_{31}H_{27}O_4NaF_3$ $[M+Na]^+$: 543.1759; found: 543.1761.

**1-(4-methoxyphenyl)-3,3-diphenyl-4-(pyridin-4-yl)butan-1-one (4ah)**




Column chromatography ($SiO_2$, eluting with 80:20 hexane/ethyl acetate) afforded the desired product as a white solid (25.2 mg, 31%). $^1$H NMR (400 MHz, $CDCl_3$): δ 8.26 (d, $J$ = 3.2 Hz, 2H), 7.68 (d, $J$ = 8.8 Hz, 2H), 7.23-7.18 (m, 4H), 7.16-7.11 (m, 6H), 6.77 (d, $J$ = 8.8 Hz, 2H), 6.65 (d, $J$ = 6.0 Hz, 2H), 3.87 (s, 2H), 3.80 (s, 3H), 3.51 (s, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.6, 163.4, 148.2, 146.9, 131.1, 130.3, 128.2, 127.9, 126.9, 126.6, 113.5, 55.5, 49.8, 43.2, 42.5; HRMS (ESI, m/z) calcd. For $C_{28}H_{26}O_2N$ $[M+H]^+$: 408.1964; found: 408.1965.

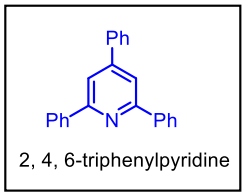
**1-(4-methoxyphenyl)-3,3-diphenylhex-5-en-1-one (4ai)**




Column chromatography ($SiO_2$, eluting with 96:4 hexane/ethyl acetate) afforded the desired product as a white solid (28.3 mg, 34%). $^1$H NMR (600 MHz, $CDCl_3$): δ 7.73 (d, $J$ = 8.4 Hz, 2H), 7.13 (d, $J$ = 9.0Hz, 4H), 6.80 (d, $J$ = 9.0 Hz, 2H), 6.77 (d, $J$ = 9.0 Hz, 4H), 5.47-5.41 (m, 1H), 5.07-5.04 (m, 1H), 4.98 (dd, $J_1$ = 10.2 Hz, $J_2$ = 1.8 Hz, 1H), 3.82 (s, 3H), 3.76 (s, 6H), 3.69 (s, 2H), 3.20 (d, $J$ = 7.2 Hz, 2H); $^{13}$C NMR (150 MHz, $CDCl_3$): δ 196.7, 162.4, 157.0,

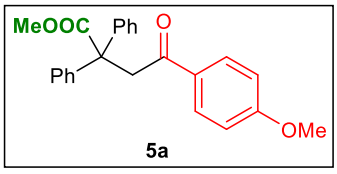
139.5, 134.5, 130.9, 129.6, 128.2, 117.9, 112.8, 112.6, 54.9, 54.7, 47.1, 43.8, 42.4; HRMS (ESI, m/z) calcd. For $C_{27}H_{28}O_4Na$ $[M+Na]^+$: 439.1885; found: 439.1888.

**2,4,6-triphenylpyridine** (byproduct formed from carbobenzylation reaction)



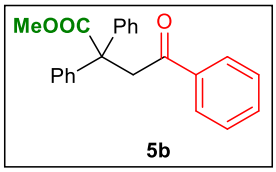

This was recovered in quantitative amount from each of the carbobenzylation reaction and purified in column chromatography ($SiO_2$, eluting with hexane) affording as white solid (61.5 mg, quant.). $^1H$ NMR (400 MHz, $CDCl_3$): δ 8.23-8.20 (m, 4H), 7.90 (s, 2H), 7.77-7.74 (m, 2H), 7.56-7.43 (m, 9H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 195.02, 173.90, 163.66, 143.36, 130.37, 130.00, 128.81, 128.00, 126.87, 113.80, 57.14, 55.58, 52.51, 48.04; HRMS (ESI, m/z) calcd. For $C_{23}H_{17}N$ $[M]^+$: 307.1361; found: 307.1359.

**4-(4-methoxyphenyl)-4-oxo-2,2-diphenylbutanoic acid (5a)**




This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (61.3 mg, 82%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.92 (d, *J* = 7 Hz, 2H), 7.32-7.19 (m, 10H), 6.89 (d, *J* = 8.8 Hz, 2H), 4.15 (s, 2H), 3.84 (s, 3H), 3.74 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 195.02, 173.90, 163.66, 143.36, 130.37, 130.00, 128.81, 128.00, 126.87, 113.80, 57.14, 55.58, 52.51, 48.04; HRMS (ESI, m/z) calcd. For $C_{24}H_{22}O_4$ $[M]^+$: 374.1518; found: 374.1515.

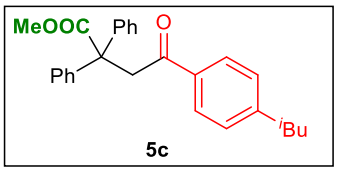
**methyl 4-oxo-2,2,4-triphenylbutanoate (5b)**




This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (51.6 mg, 72%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.95-7.92 (m, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 8 Hz, 2H),

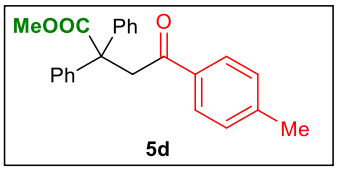
7.32-7.29 (m, 4H), 7.27-7.18 (m, 6H), 4.20 (s, 2H), 3.74 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.5, 173.7, 143.2, 136.9, 133.3, 128.8, 128.6, 128.0, 128.0, 126.9, 51.1, 52.5, 48.3; HRMS (ESI, m/z) calcd. For $C_{23}H_{21}O_3$ $[M+H]^+$: 345.1491; found: 345.1494.

**methyl 4-(4-isobutylphenyl)-4-oxo-2,2-diphenylbutanoate (5c)**



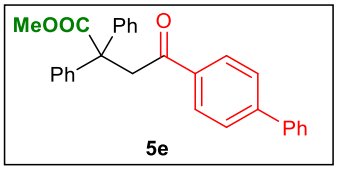

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellowish white solid (64.0 mg, 80%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, J = 8 Hz, 2H), 7.32-7.25 (m, 7H), 7.23-7.18 (m, 5H), 4.18 (s, 1H), 3.73 (s, 3H), 2.51 (d, *J* = 7.6 Hz, 2H), 1.87 (sept., *J* = 6.8 Hz, 1H), 0.90 (s, 3H), 0.88 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.14, 173.85, 147.85, 143.30, 134.68, 129.38, 128.81, 128.06, 128.00, 126.88, 57.07, 52.51, 48.30, 45.46, 30.20, 22.39; HRMS (ESI, m/z) calcd. For $C_{27}H_{29}O_4$ $[M+H]^+$: 401.2117; found: 401.2112.

**methyl 4-oxo-2,2-diphenyl-4-(p-tolyl)butanoate (5d)**



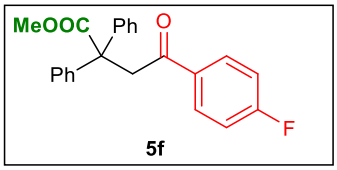

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (55.8 mg, 78%). $^1$H NMR (400 MHz, $CDCl_3$): δ $^1$H NMR (400 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 8 Hz, 2H), 7.31 – 7.25 (m, 7H), 7.23 – 7.17 (m, 5H), 4.17 (s, 2H), 3.74 (s, 3H), 2.39 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.10, 173.84, 144.13, 143.29, 134.45, 129.33, 128.80, 128.20, 128.00, 126.89, 57.11, 52.52, 48.26, 21.72; HRMS (ESI, m/z) calcd. For $C_{24}H_{23}O_3$ $[M+H]^+$: 359.1647; found: 359.1648.

**methyl 4-([1,1'-biphenyl]-4-yl)-4-oxo-2,2-diphenylbutanoate (5e)**



This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (51.2 mg, 61%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 8.02-8.00 (m, 2H), 7.66-7.64 (m, 2H), 7.61-7.59 (m, 2H), 7.48-7.44 (m, 2H), 7.41-7.39 (m, 1H), 7.34-7.26 (m, 8H), 7.23-7.19 (m, 2H), 4.23 (s, 2H), 3.75 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 196.08, 173.80, 146.02, 143.22, 139.90, 135.60, 129.05, 128.81, 128.68, 128.36, 128.04, 127.35, 127.32, 126.95, 57.16, 52.56, 48.39; HRMS (ESI, m/z) calcd. For $C_{29}H_{25}O_3$ $[M+H]^+$: 421.1804; found: 421.1799.

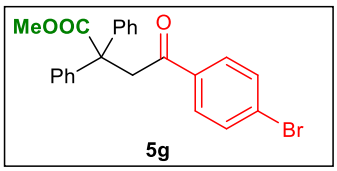
**methyl 4-(4-fluorophenyl)-4-oxo-2,2-diphenylbutanoate (5f)**



**5f**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as brown solid (49.2 mg, 68%). $^1H$ NMR (400 MHz, $CDCl_3$): δ $^1H$ NMR (400 MHz, Chloroform-*d*) δ 7.97-7.93 (m, 2H), 7.30-7.25 (m, 7H), 7.24-7.18 (m, 3H), 7.09 (t, *J* = 8.4 Hz, 2H), 4.15 (s, 2H), 3.74 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 194.98, 173.70, 165.88 (d, *J* = 254 Hz), 143.07, 133.36 (d, *J* = 3 Hz), 130.72 (d, *J* = 9 Hz), 128.76, 128.05, 126.99, 115.76 (d, *J* = 22 Hz), 57.19, 52.58, 48.21; HRMS (ESI, m/z) calcd. For $C_{24}H_{23}O_3$ $[M+H]^+$: 359.1647; found: 359.1647.

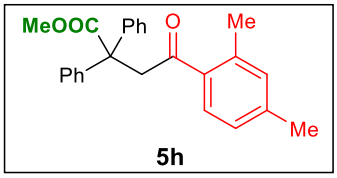
**methyl 4-(4-bromophenyl)-4-oxo-2,2-diphenylbutanoate (5g)**



**5g**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow solid (41.4 mg, 49%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.57 (d, *J* = 4.8 Hz, 2H), 7.36-7.34 (m, 3H), 7.28-7.22 (m, 3H), 7.16-7.12 (m, 3H), 7.02 (s, 1H), 6.65 (d, *J* = 8 Hz, 2H), 3.70 (s, 2H), 3.67 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 192.72, 173.79, 154.19, 142.85, 142.44, 141.50, 139.17, 136.33, 131.05, 129.85, 129.25, 128.63, 128.49, 128.40, 128.07, 128.02, 127.85, 127.12, 124.28, 62.04, 52.39, 44.52; HRMS (ESI, m/z) calcd. For $C_{23}H_{20}BrO_3$ $[M+H]^+$: 423.0596; found: 423.0602.

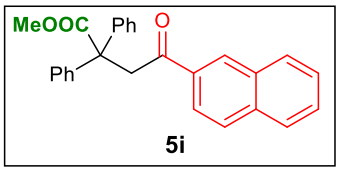
**methyl 4-(2,4-dimethylphenyl)-4-oxo-2,2-diphenylbutanoate (5h)**




**5h**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (54.3 mg, 73%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.49 (d, J = 8 Hz, 2H), 7.32-7.26 (m, 6H), 7.25-7.18 (m, 4H), 7.03-7.02 (m, 2H), 4.11 (s, 2H), 3.76 (s, 3H), 2.34 (s, 3H), 2.32 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 200.08, 173.88, 143.29, 141.99, 138.52, 135.22, 132.87, 128.81, 128.51, 128.01, 126.89, 126.30, 57.26, 52.48, 51.06, 21.43, 21.16; HRMS (ESI, m/z) calcd. For $C_{25}H_{25}O_3$ $[M+H]^+$: 373.1804; found: 373.1800.

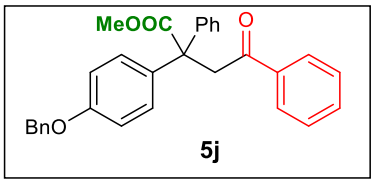
**methyl 4-(naphthalen-2-yl)-4-oxo-2,2-diphenylbutanoate (5i)**




**5i**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellowish white solid (51.2 mg, 65%). $^1$H NMR (400 MHz, $CDCl_3$): δ 8.46 (s, 1H), 7.99 (dd, $J_1$ = 8.4 Hz, $J_2$ = 1.6 Hz, 1H), 7.94 (d, $J$ = 7.2 Hz, 1H), 7.87-7.84 (m, 2H), 7.61-7.52 (m, 2H), 7.36-7.34 (m, 4H), 7.30-7.26 (m, 4H), 7.23-7.19 (m, 2H), 4.34 (s, 2H), 3.76 (m, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.48, 173.83, 143.24, 135.70, 134.24, 132.52, 129.68, 129.63, 128.84, 128.63, 128.55, 128.06, 127.86, 126.96, 126.93, 123.86, 57.28, 52.59, 48.44; HRMS (ESI, m/z) calcd. For $C_{27}H_{23}O_3$ $[M+H]^+$: 395.1647; found: 395.1645.

**methyl 2-(4-(benzyloxy)phenyl)-4-oxo-2,4-diphenylbutanoate (5j)**

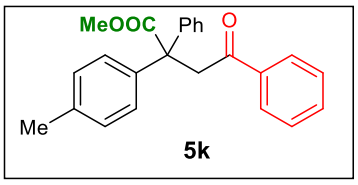



**5j**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (70.2 mg, 78%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.95-7.93 (m, 2H), 7.55 (t, $J$ = 8 Hz, 1H), 7.46-7.26 (m, 12H), 7.23-7.21 (m, 2H), 6.89-6.86 (m, 2H), 5.02 (s, 2H), 4.19 (s, 2H), 3.74 (s, 3H); $^{13}$C NMR (100

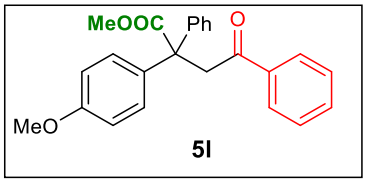
MHz, $CDCl_3$): δ 196.59, 174.00, 157.63, 143.49, 137.07, 136.97, 135.52, 133.29, 130.04, 128.67, 128.07, 127.61, 126.93, 114.22, 70.08, 56.49, 52.54, 48.50; HRMS (ESI, m/z) calcd. For $C_{30}H_{27}O_4$ $[M+H]^+$: 451.1909; found: 451.1911.

**methyl 4-oxo-2,4-diphenyl-2-(p-tolyl)butanoate (5k)**



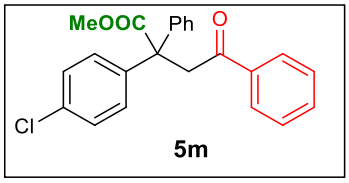

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (58.0 mg, 81%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.95-7.93 (m, 2H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.43 (m, 2H), 7.33-7.30 (m, 2H), 7.27-7.25 (m, 1H) , 7.24-7.17 (m, 4H), 4.19 (s, 2H), 3.73 (s, 3H), 2.29 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 196.55, 173.92, 143.36, 140.24, 136.97, 136.60, 133.25, 128.80, 128.76, 128.66, 128.60, 128.08, 127.98, 126.86, 56.78, 52.51, 48.41, 21.01; HRMS (ESI, m/z) calcd. For $C_{24}H_{23}O_3$ $[M+H]^+$: 359.1647; found: 359.1634.

**methyl 2-(4-methoxyphenyl)-4-oxo-2,4-diphenylbutanoate (5l)**



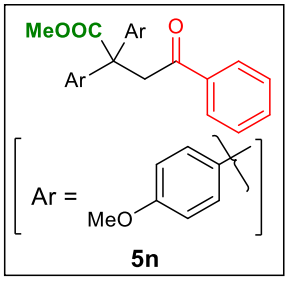

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow gel (57.6 mg, 77%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.95-7.92 (m, 2H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.45-7.41 (m, 2H), 7.34-7.31 (m, 2H), 7.28-7.26 (m, 2H), 7.24-7.18 (m, 3H), 6.81-6.77 (m, 2H), 4.18 (s, 2H), 3.76 (s, 3H), 3.73 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 196.58, 174.01, 158.32, 143.51, 136.97, 135.23, 133.27, 129.99, 128.68, 128.07, 128.04, 126.90, 113.33, 56.46, 55.27, 52.51, 48.49; HRMS (ESI, m/z) calcd. For $C_{24}H_{23}O_4$ $[M+H]^+$: 375.1596; found: 375.1588.

**methyl 2-(4-chlorophenyl)-4-oxo-2,4-diphenylbutanoate (5m)**



This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (55.2 mg, 73%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.94-7.91 (m, 2H), 7.55 (t, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.30-7.25 (m, 5H), 7.24-7.19 (m, 4H), 4.17 ($AB_q$, *J* = 49.6 Hz, 2H), 3.73 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 196.27, 173.45, 142.89, 141.61, 136.74, 133.45, 132.81, 130.62, 128.73, 128.38, 128.33, 128.07, 127.99, 127.28, 56.64, 52.66, 48.25; HRMS (ESI, m/z) calcd. For $C_{23}H_{20}ClO_3$ $[M+H]^+$: 379.1101; found: 379.1094.

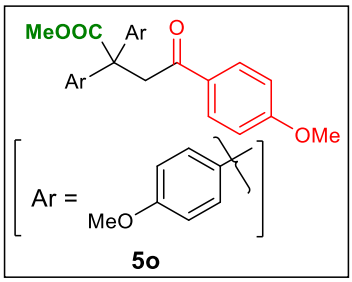
**methyl 2,2-bis(4-methoxyphenyl)-4-oxo-4-phenylbutanoate (5n)**



**5n**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (50.1 mg, 62%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.94-7.91 (m, 2H), 7.53 (t, *J* = 7.8 Hz, 1H), 7.44-7.40 (m, 2H), 7.25-7.22 (m, 4H), 6.80-6.76 (m, 4H), 4.14 (s, 2H), 3.76 (s, 6H), 3.72 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 196.62, 174.19, 158.29, 137.02, 135.51, 133.22, 129.86, 128.65, 128.06, 113.32, 55.78, 55.28, 52.47, 48.59; HRMS (ESI, m/z) calcd. For $C_{25}H_{25}O_5$ $[M+H]^+$: 405.1624; found: 405.1623.

**methyl 2,2,4-tris(4-methoxyphenyl)-4-oxobutanoate (5o)**

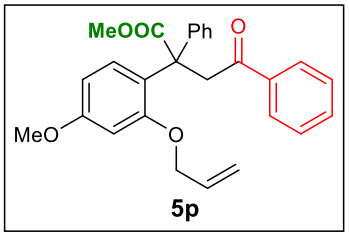


**5o**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (65.1 mg, 75%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.91 (d, *J* = 8.8 Hz, 2H), 7.22 (d, *J* = 8.8 Hz, 4H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.78 (d, *J* = 8.8 Hz, 4H), 4.08 (s, 2H), 3.84 (s, 3H), 3.76 (s, 6H), 3.72 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 195.15, 174.32, 163.61, 158.23, 135.66, 130.34, 130.10, 129.87,

113.77, 113.29, 55.81, 55.57, 55.27, 52.44, 48.26; HRMS (ESI, m/z) calcd. For $C_{26}H_{27}O_6$ $[M+H]^+$: 435.1808; found: 435.1820.

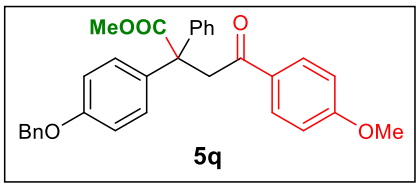
**methyl 2-(2-(allyloxy)-4-methoxyphenyl)-4-oxo-2,4-diphenylbutanoate (5p)**



**5p**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellowish white solid (58.5 mg, 68%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.93-7.90 (m, 2H), 7.53-7.49 (m, 1H), 7.42-7.38 (m, 4H), 7.29-7.26 (m, 2H), 7.24-7.20 (m, 2H), 6.42 (dd, $J_1$ = 8.8 Hz, $J_2$ = 2.4 Hz, 1H), 6.35 (d, $J$ = 2.4 Hz, 1H), 5.85-5.75 (m, 1H), 5.28-5.17 (m, 2H), 4.38-4.31 (m, 4H), 3.74 (s, 3H), 3.64 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.28, 174.76, 159.79, 156.72, 140.26, 137.68, 132.97, 132.84, 132.00, 128.83, 128.48, 128.04, 127.81, 126.89, 124.00, 117.46, 103.80, 100.14, 69.29, 56.02, 55.31, 52.46, 42.90; HRMS (ESI, m/z) calcd. For $C_{26}H_{25}O_4$ $[M+H]^+$: 401.1753; found: 401.1760.

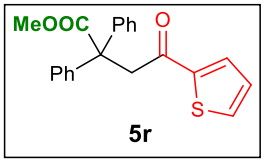
**methyl 2-(4-(benzyloxy)phenyl)-4-(4-methoxyphenyl)-4-oxo-2-phenylbutanoate (5q)**



**5q**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow gum (82.6 mg, 86%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.94-7.91 (m, 2H), 7.42-7.19 (m, 12H), 6.92-6.85 (m, 4H), 5.01 (s, 2H), 4.14-4.13 (m, 2H), 3.85 (s, 3H), 3.74 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 195.11, 174.12, 163.66, 157.59, 143.66, 137.10, 135.68, 130.38, 130.06, 130.05, 128.71, 128.67, 128.04, 127.61, 126.87, 114.18, 113.81, 70.07, 56.52, 55.59, 52.50, 48.17; HRMS (ESI, m/z) calcd. For $C_{31}H_{29}O_5$ $[M+H]^+$: 481.2015; found: 481.2022.

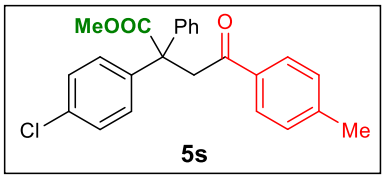
**methyl 4-oxo-2,2-diphenyl-4-(thiophen-2-yl)butanoate (5r)**



**5r**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow solid (58.1 mg, 83%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.68 (dd, $J_1$ = 3.6 Hz, $J_2$ = 1.2 Hz, 1H, 7.58 (dd, $J_1$ = 5.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.33-7.26 (m, 7H), 7.25-7.19 (m, 3H), 7.08-7.06 (m, 1H), 4.13 (s, 2H), 3.74 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 189.46, 173.60, 144.08, 142.97, 133.72, 131.85, 128.80, 128.12, 128.06, 127.02, 57.26, 52.63, 48.63; HRMS (ESI, m/z) calcd. For $C_{21}H_{19}O_3S$ $[M+H]^+$: 351.1055; found: 351.1055.

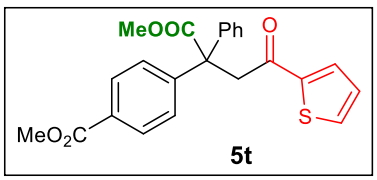
**methyl 2-(4-chlorophenyl)-4-oxo-2-phenyl-4-(p-tolyl)butanoate (5s)**



**5s**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as colourless gum (51.7 mg, 66%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.86-7.83 (m, 2H), 7.53 (dd, $J_1$ = 5.6 Hz, $J_2$ = 2.0 Hz, 1H), 7.39-7.35 (m, 2H), 7.31-7.25 (m, 4H), 7.23-7.16 (m, 4H), 4.48 ($AB_q$, $J$ = 18.8 Hz, 2H), 3.70 (s, 3H), 2.39 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.09, 173.67, 144.03, 139.70, 134.69, 133.85, 133.12, 130.91, 129.31, 128.82, 128.51, 128.18, 128.10, 127.28, 125.92, 58.33, 52.86, 43.16, 21.70; HRMS (ESI, m/z) calcd. For $C_{24}H_{21}ClO_3$ $[M+H]^+$: 393.1257; found: 393.1249.

**methyl 4-(1-methoxy-1,4-dioxo-2-phenyl-4-(thiophen-2-yl)butan-2-yl)benzoate (5t)**

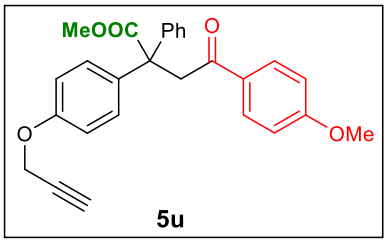


**5t**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (58.8 mg, 72%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.57 (dd, $J_1$ = 4 Hz, $J_2$ = 1.2 Hz, 1H, 7.52 (dd, $J_1$ = 5.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.39 (dd, $J_1$ = 4.8 Hz, $J_2$ = 0.8 Hz, 1H), 7.33-7.31 (m, 3H), 7.11 (dd, $J_1$ = 4 Hz, $J_2$ = 1.2 Hz, 1H), 7.01 (dd, $J_1$ = 5.2 Hz, $J_2$ = 4 Hz, 1H), 6.83-6.80 (m, 4H), 4.14 (s, 2H), 3.76

(s, 6H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 192.71, 189.65, 158.60, 144.88, 143.24, 133.61, 133.48, 132.56, 131.68, 130.83, 129.87, 127.99, 127.32, 113.61, 61.95, 55.28, 50.25; HRMS (ESI, m/z) calcd. For $C_{23}H_{21}O_5S$ $[M+H]^+$: 411.1266; found: 411.1269.

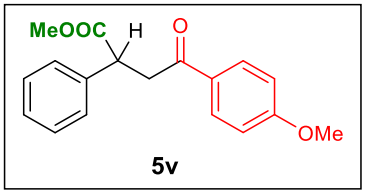
**methyl 4-(4-methoxyphenyl)-4-oxo-2-phenyl-2-(4-(prop-2-yn-1-yloxy)phenyl)butanoate (5u)**



**5u**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as colourless gum (58.3 mg, 68%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.92-7.90 (m, 2H), 7.31-7.27 (m, 3H), 7.24-7.19 (m, 4H), 6.91-6.83 (m, 4H), 4.62 (d, *J* = 7.2 Hz, 2H), 4.11 (s, 2H), 3.85 (s, 3H), 3.73 (s, 3H), 2.49 (t, *J* = 2.4 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 195.03, 174.02, 163.65, 156.33, 143.54, 136.29, 130.35, 130.09, 130.01, 128.63, 128.04, 126.89, 114.16, 113.79, 78.67, 75.57, 56.51, 55.86, 55.57, 52.50, 48.13; HRMS (ESI, m/z) calcd. For $C_{27}H_{25}O_5$ $[M+H]^+$: 429.1702; found: 429.1689.

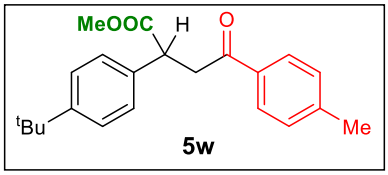
**methyl 4-oxo-2,4-diphenylbutanoate (5v)**



**5v**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as brown solid (44.7 mg, 75%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.96-7.92 (m, 2H), 7.34-7.26 (m, 5H), 6.92-6.89 (m, 2H), 4.27 (dd, $J_1$ = 10.4 Hz, $J_2$ = 4 Hz, 1H), 3.95-3.88 (m, 1H), 3.85 (s, 3H), 3.21 (dd, $J_1$ = 17.6 Hz, $J_2$ = 4 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.19, 174.05, 163.73, 138.59, 132.75, 130.45, 129.61, 128.98, 127.92, 127.59, 113.82, 55.56, 52.39, 46.51, 42.56; HRMS (ESI, m/z) calcd. For $C_{18}H_{19}O_4$ $[M+H]^+$: 299.1283; found: 299.1287.

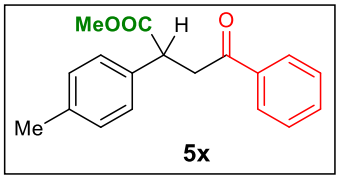
**methyl 2-(4-(tert-butyl)phenyl)-4-oxo-4-(p-tolyl)butanoate (5w)**



5w

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as colourless gum (49.3 mg, 73%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.87-7.85 (m, 2H), 7.36-7.34 (m, 2H), 7.29-7.26 (m, 2H), 7.23 (d, $J$ = 8 Hz, 2H), 4.26 (dd, $J_1$ = 10.4 Hz, $J_2$ = 4 Hz, 1H), 3.91 (dd, $J_1$ = 18 Hz, $J_2$ = 10.4 Hz, 1H), 3.69 (s, 3H), 3.23 (dd, $J_1$ = 18 Hz, $J_2$ = 4 Hz, 1H), 2.39 (s, 3H), 1.31 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.48, 174.18, 150.48, 144.17, 135.42, 134.07, 129.35, 128.30, 127.52, 125.91, 52.35, 45.97, 42.90, 34.57, 31.40, 21.74; HRMS (ESI, m/z) calcd. For $C_{22}H_{27}O_3$ $[M+H]^+$: 339.1960; found: 339.1969.

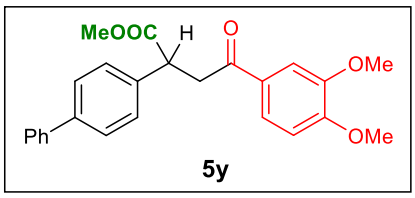
**methyl 4-oxo-4-phenyl-2-(p-tolyl)butanoate (5x)**



5x

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white crystalline solid (38.9 mg, 69%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.97-7.95 (m, 2H), 7.55 (tt, $J_1$ = 7.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.44 (t, $J$ = 8 Hz, 2H), 7.23 (d, $J$ = 8 Hz, 2H), 7.15 (d, $J$ = 8 Hz, 2H), 4.26 (dd, $J_1$ = 10 Hz, $J_2$ = 4 Hz, 1H), 3.92 (dd, $J_1$ = 17.2 Hz, $J_2$ = 9.6 Hz, 1H), 3.68 (s, 3H), 3.24 (dd, $J_1$ = 18 Hz, $J_2$ = 4 Hz, 1H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.81, 174.11, 137.37, 136.52, 135.43, 133.37, 129.69, 128.68, 128.17, 127.77, 52.40, 46.02, 42.93, 21.14; HRMS (ESI, m/z) calcd. For $C_{18}H_{19}O_3$ $[M+H]^+$: 283.1334; found: 283.1326.

**methyl 2-([1,1'-biphenyl]-4-yl)-4-(3,4-dimethoxyphenyl)-4-oxobutanoate (5y)**

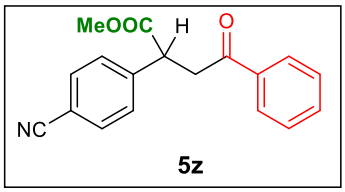


5y

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (52.5 mg, 65%). $^1$H

NMR (400 MHz, $CDCl_3$): δ 7.61 (dd, $J_1$ = 8 Hz, $J_2$ = 2 Hz, 1H), 7.57 (m, 4H), 7.52 (d, $J$ = 2 Hz, 1H), 7.44-7.41 (m, 4H), 7.34 (tt, $J_1$ = 7.2 Hz, $J_2$ = 2 Hz, 1H), 6.86 (d, $J$ = 8.4 Hz, 1H), 4.33 (dd, $J_1$ = 10.0 Hz, $J_2$ = 4 Hz, 1H), 3.95-3.88 (m, 7H), 3.72 (s, 3H), 3.29 (dd, $J_1$ = 18 Hz, $J_2$ = 4.4 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.26, 174.06, 153.59, 149.12, 140.65, 137.54, 129.73, 128.88, 128.36, 127.71, 127.48, 127.13, 122.92, 110.21, 110.12, 56.16, 56.06, 52.48, 46.27, 42.44; HRMS (ESI, m/z) calcd. For $C_{25}H_{25}O_5$ $[M+H]^+$: 405.1702; found: 405.1702.

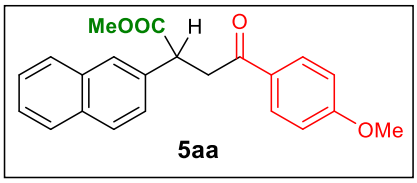
**methyl 2-(4-cyanophenyl)-4-oxo-4-phenylbutanoate (5z)**



**5z**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (36.9 mg, 63%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.96-7.92 (m, 2H), 7.64-7.61 (m, 2H), 7.56 (tt, $J_1$ = 8 Hz, $J_2$ = 1.2 Hz, 1H), 7.48-7.43 (m, 4H), 4.36 (q, $J$= 4.4 Hz, 1H), 3.90 (q, $J$=9.2 Hz, 1H), 3.69 (s, 3H), 3.30 (dd, $J_1$= 18 Hz, $J_2$ = 4.8 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.4, 163.2, 148.0, 138.1, 131.4, 130.9, 130.2, 128.2, 127.8, 127.5, 126.1, 126.0, 113.4, 55.5, 49.7, 43.8, 42; HRMS (ESI, m/z) calcd. For $C_{18}H_{16}O_3$ $[M+H]^+$: 294.1130; found: 294.1133.

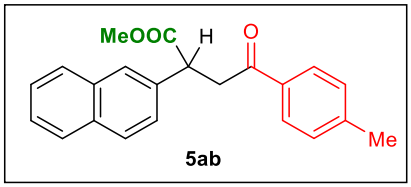
**methyl 4-(4-methoxyphenyl)-2-(naphthalen-2-yl)-4-oxobutanoate (5aa)**



**5aa**

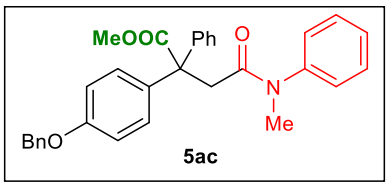
This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as reddish white solid (45.9 mg, 66%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.97-7.94 (m, 2H), 7.83-7.80 (m, 4H), 7.48-7.45 (m, 3H), 6.92-6.90 (m, 2H), 4.45 (dd, $J_1$= 6 Hz, $J_2$ = 4 Hz, 1H), 3.98 (dd, $J_1$ = 18 Hz, $J_2$ = 10.4 Hz, 1H), 3.85 ( s, 3H), 3.69 (s, 3H), 3.30 (dd, $J_1$ = 18 Hz, $J_2$ = 4Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.13, 174.06, 163.76, 135.99, 133.57, 132.78, 130.47, 129.62, 128.73, 127.89, 127.74, 126.76, 126.42, 126.10, 125.91, 113.84, 55.56, 52.45, 46.62, 42.54; HRMS (ESI, m/z) calcd. For $C_{22}H_{21}O_4$ $[M+H]^+$: 349.1440; found: 349.1444.

**methyl 2-(naphthalen-2-yl)-4-oxo-4-(p-tolyl)butanoate (5ab)**



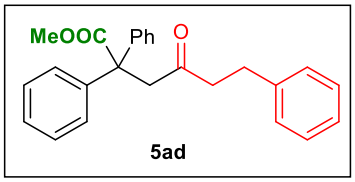

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white solid (47.2 mg, 71%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.89-7.87 (m, 2H), 7.83-7.80 (m, 4H), 7.49-7.44 (m, 3H), 7.24-7.23 (m, 2H), 4.46 (dd, $J_1$ = 10.0 Hz, $J_2$ = 4.0 Hz, 1H), 4.02 (dd, $J_1$ = 18.0 Hz, $J_2$ = 10.0 Hz, 1H), 3.70 (s, 3H), 3.33 (dd, $J_1$ = 18.0 Hz, $J_2$ = 4.0 Hz, 1H), 2.39 (s, 3H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 197.28, 174.01, 144.26, 135.93, 134.03, 133.57, 132.79, 129.38, 128.75, 128.31, 127.90, 127.74, 126.77, 126.43, 126.12, 125.90, 52.47, 46.57, 42.76, 21.74; HRMS (ESI, m/z) calcd. For $C_{22}H_{20}O_3$ $[M+H]^+$: 332.1412; found: 332.1413.

**methyl 2-(4-(benzyloxy)phenyl)-4-(methyl(phenyl)amino)-4-oxo-2-phenylbutanoate (5ac)**




This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow solid (71.9 mg, 83%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.43-7.27 (m, 8H), 7.26-7.18 (m, 4H), 6.90-6.86 (m, 2H), 5.03 (s, 2H), 3.73 (s, 3H), 3.55 (s, 3H), 3.46 (s, 2H); $^{13}C$ NMR (100 MHz, $CDCl_3$): δ 173.65, 171.22, 157.80, 142.67, 137.01, 134.74, 129.86, 128.67, 128.54, 128.08, 127.62, 127.14, 114.26, 57.03, 52.65, 51.75, 43.88; HRMS (ESI, m/z) calcd. For $C_{31}H_{30}NO_5$ $[M+H]^+$: 480.2175; found: 480.2169.

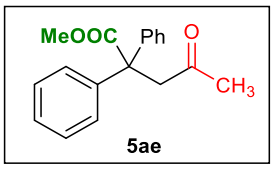
**methyl 4-oxo-2,2,6-triphenylhexanoate (5ad)**




This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as white gum (40.9 mg, 55%). $^1H$ NMR (400 MHz, $CDCl_3$): δ 7.26-7.16 (m, 13H), 7.08-7.06 (m, 2H), 3.68 (s, 3H), 3.58 (s, 2H),

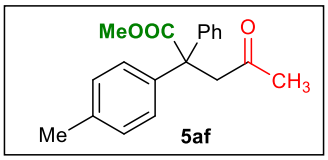
2.79 (t, $J$ = 7.6 Hz, 1H), 2.62 (t, $J$ = 7.6 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 206.42, 173.61, 142.92, 140.91, 128.69, 128.52, 128.37, 128.04, 126.99, 126.15, 57.12, 52.51, 52.10, 44.88, 29.54; HRMS (ESI, m/z) calcd. For $C_{25}H_{24}O_3$ $[M+H]^+$: 373.1804; found: 373.1801.

**methyl 4-oxo-2,2-diphenylpentanoate (5ae)**



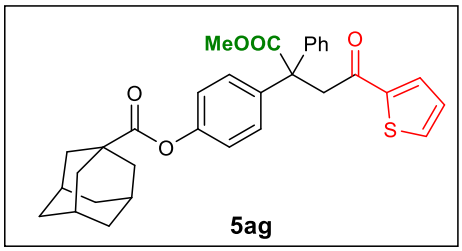

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as colourless gummy liquid (29.9 mg, 53%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.28-7.20 (m, 10 H), 3.71 (s, 3H), 3.64 (s, 2H), 2.07 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 205.02, 173.64, 142.99, 128.69, 128.04, 127.00, 57.05, 52.54, 30.72; HRMS (ESI, m/z) calcd. For $C_{18}H_{18}O_3$ $[M+H]^+$: 283.1334; found: 283.1334.

**methyl 4-oxo-2-phenyl-2-(p-tolyl)pentanoate (5af)**



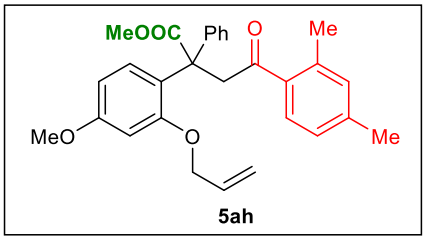

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as colourless gummy liquid (29.6 mg, 50%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.26-7.19 (m, 5H), 7.13-7.11 (m, 2H), 7.07-7.05 (m, 2H), 3.70 (s, 3H), 3.61 (d, $J$ = 2.4 Hz, 2H), 2.30 (s, 3H), 2.07 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 205.10, 173.77, 143.14, 139.99, 136.66, 128.76, 128.69, 128.51, 127.98, 126.92, 56.73, 52.71, 52.50, 30.74, 21.02; HRMS (ESI, m/z) calcd. For $C_{19}H_{20}O_3$ $[M+H]^+$: 297.1491; found: 297.1499.

**4-(1-methoxy-1,4-dioxo-2-phenyl-4-(thiophen-2-yl)butan-2-yl)phenyl (3r,5r,7r)-adamantane-1-carboxylate (5ag)**



This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as ash coloured solid (88.7 mg, 84%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.67 (dd, $J_1$ = 4.0 Hz, $J_2$ = 1.2 Hz, 1H), 7.59 (dd, $J_1$ = 4.8 Hz, $J_2$ = 0.8 Hz, 1H), 7.32-7.26 (m, 6H), 7.24-7.21 (m, 1H), 7.09-7.07 (m, 1H), 6.96-6.93 (m, 2H), 4.15-4.05 (m, 2H), 3.73 (s, 3H), 2.06-2.01 (m, 9H), 1.78-1.71 (m, 6H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 189.27, 176.10, 173.44, 149.91, 143.99, 142.78, 140.10, 133.76, 131.86, 129.99, 128.70, 128.14, 127.14, 120.93, 56.80, 52.66, 48.70, 41.11, 38.81, 36.53, 27.98; HRMS (ESI, m/z) calcd. For $C_{32}H_{32}O_5S$ $[M+H]^+$: 529.2049; found: 529.2061.

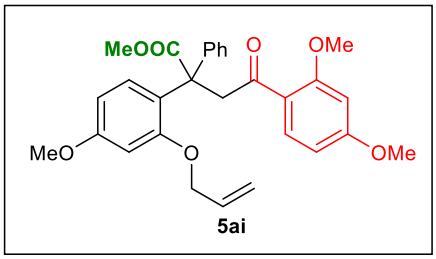
**methyl 2-(2-(allyloxy)-4-methoxyphenyl)-4-(2,4-dimethylphenyl)-4-oxo-2-phenylbutanoate (5ah)**



**5ah**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow gel (53.1 mg, 58%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.50 (d, $J$ = 8.0 Hz, 1H), 7.44-7.42 (m, 2H), 7.33-7.27 (m, 2H), 7.23-7.17 (m, 2H), 7.00-6.96 (m, 2H), 6.40 (dd, $J_1$ = 8.8 Hz, $J_2$ = 2.8 Hz, 1H), 6.34 (d, $J$ = 2.4 Hz, 1H), 5.79-5.69 (m, 1H), 5.22-5.13 (m, 2H), 4.37-4.16 (m, 4H), 3.74 (s, 3H), 3.64 (s, 3H), 2.31 (s, 3H), 2.25 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 201.22, 174.69, 159.80, 156.77, 141.35, 140.68, 138.09, 136.22, 132.96, 132.59, 131.71, 128.95, 128.82, 128.52, 127.74, 126.77, 126.50, 126.11, 124.17, 117.37, 103.82, 100.28, 69.28, 56.20, 55.34, 52.40, 45.88, 21.37, 21.10; HRMS (ESI, m/z) calcd. For $C_{29}H_{30}O_5$ $[M+H]^+$: 459.2171; found: 459.2172.

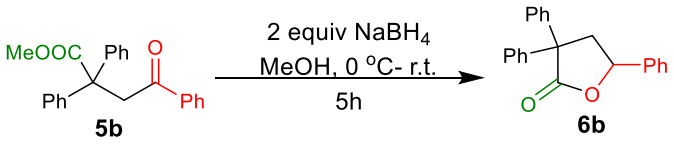
**methyl 2-(2-(allyloxy)-4-methoxyphenyl)-4-(2,4-dimethoxyphenyl)-4-oxo-2-phenylbutanoate (5ai)**



**5ai**

This was prepared following the general procedure and purified in column chromatography ($SiO_2$, eluting with 90:10 hexane/ethyl acetate) affording as yellow gel (66.6 mg, 68%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.63 (dd, $J_1$ = 8.4 Hz, $J_2$ = 2.0 Hz, 1H), 7.44-7.40 (m, 3H), 7.29-7.21 (m, 4H), 6.84 (d, $J$ = 8.4 Hz, 1H), 6.43 (dd, $J_1$ = 8.4 Hz, $J_2$ = 2.4 Hz, 1H), 6.37 (d, $J$ = 2.8 Hz, 1H), 5.86-5.76 (m, 1H), 5.21 (qq, $J_1$ = 15.6 Hz, $J_2$ = 2.0 Hz, 2H), 4.39-4.30 (m, 4H), 3.92 (s, 3H), 3.85 (s, 3H), 3.75 (s, 3H), 3.64 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 195.86, 174.85, 159.76, 156.75, 153.12, 148.96, 140.37, 133.02, 132.01, 130.95, 128.85, 127.79, 126.85, 124.10, 122.52, 117.33, 110.29, 109.91, 103.80, 100.13, 69.27, 56.14, 55.99, 55.30, 52.45, 42.37; HRMS (ESI, m/z) calcd. For $C_{29}H_{30}O_7$ $[M+H]^+$: 491.2070; found: 491.2077.

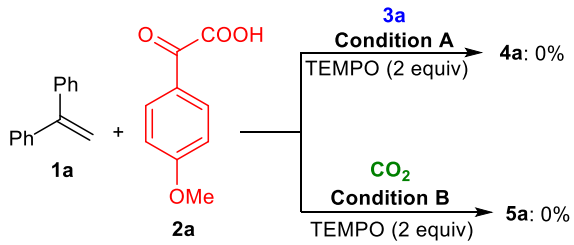
## 7. Product derivatization




In a clean 25 mL round bottom flask, methyl 4-oxo-2,2,4-triphenylbutanoate (**5b**) (68.8 mg, 0.2 mmol, 1 equiv.) was taken and to it 2 mL methanol was added. Then the solution was set up for stirring at. At 0 $^0$C, sodium borohydride ($NaBH_4$) (15.1 mg, 0.4 mmol, 2 equiv.) was added to the mixture and the flask was closed. Then, the reaction mixture was allowed to stir at room temperature for 5 hours. After that, 5 mL 2(N) HCl was added dropwise to the reaction mixture to quench the excess $NaBH_4$. Therefore, reaction mixture was extracted with ethyl acetate (40 mL), water (15 mL × 2), washed with brine (15 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate 98:2) to afford **6b** as white solid (39 mg, 61%). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.47-7.26 (m, 15H), 5.32 (q, $J$ = 5.2 Hz, 1H), 3.30 (dd, $J_1$ = 12.8 Hz, $J_2$ = 4.8 Hz, 1H), 2.94 (dd, $J_1$ = 12.8 Hz, $J_2$ = 10.8 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 176.96, 141.73, 139.62, 138.41, 129.18, 128.87, 128.77, 128.49, 127.97, 127.81, 127.49, 127.41, 125.76, 78.07, 58.79, 46.35; HRMS (ESI, m/z) calcd. For $C_{32}H_{32}O_5S$ $[M+H]^+$: 315.1385; found: 315.1297.

## 8. Control experiments

### 8.1. Radical inhibition experiment



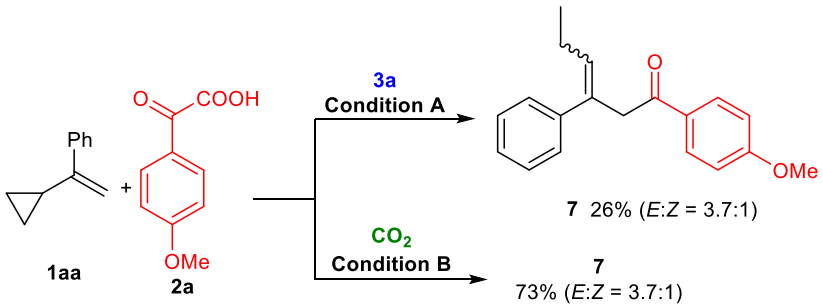

### 8.1.1. Radical inhibition experiment for carbobenzylation (Condition A)

1-benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate **3a** (0.4 mmol, 2.0 equiv., 194 mg), 2-(4-methoxyphenyl)-2-oxoacetic acid **2a** (0.4 mmol, 2.0 equiv., 72 mg), tris(2,2′-bipyridyl)dichlororuthenium(II) hexahydrate (0.002 mmol, 1 mol %, 2.9 mg), caesium carbonate (0.4 mmol, 2.0 equiv., 130 mg) and TEMPO (62.5 mg, 0.4 mmol, 2.0 equiv.) were taken in a 7 mL screw-capped vial. MeCN was added to the mixture. The whole mixture was de-gassed and re-filled with inert gas by two consecutive freeze-pump-thaw cycles followed by the addition of 1,1-diphenylethylene **1a** (0.2 mmol, 1.0 equiv., 35 µL). The reaction mixture was then stirred under 5W blue LED irradiation for 2 hours. After 2 hours, TLC was checked and no formation of the expected product **4a** was observed.

### 8.1.2. Radical inhibition experiment for carbocarboxylation (Condition B)

The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with **2a** (43.2 mg, 0.24 mmol, 1.2 equiv), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %), **2** (0.24 mmol, 1.2 equiv), TEMPO (62.5 mg, 0.4 mmol, 2.0 equiv.) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with $CO_2$ for 3 times. Therefore, under continuous $CO_2$ flow, anhydrous DMSO (3 mL) and **1a** (35 µL, 1.0 equiv., 0.2 mmol) was added with syringe and subsequently the tube is sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12 hours. After 12 hours, the light is switched off, the shlenk tube is opened and to the mixture, methyl iodide (24.9 µL, 0.4 mmol, 2.0 equiv.) is added. The mixture is stirred for additional 4 hours at room temperature. After that, TLC was checked which showed no formation of expected product **5a**.

## 8.2. Radical-clock experiment




### 8.2.1. Radical-clock experiment for carbobenzylation (Condition A)

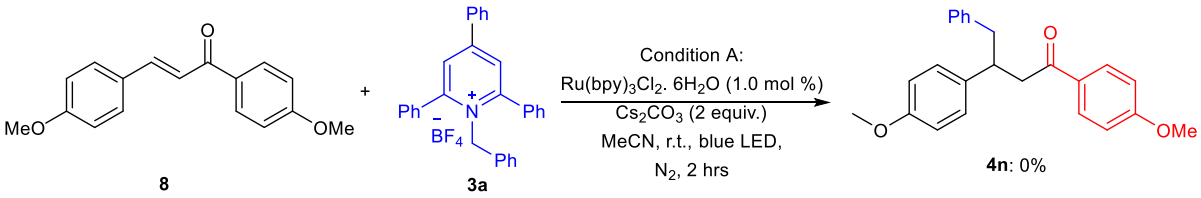
1-benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate **2a** (0.4 mmol, 2.0 equiv., 194 mg), 2-(4-methoxyphenyl)-2-oxoacetic acid **3a** (0.4 mmol, 2.0 equiv., 72 mg), tris(2,2′-bipyridyl)dichlororuthenium(II) hexahydrate (0.002 mmol, 1 mol %, 2.9 mg), caesium carbonate (0.4 mmol, 2.0 equiv., 130 mg) were taken in a 7 mL screw-capped vial. MeCN was added to the mixture. The whole mixture was de-gassed and re-filled with inert gas by two consecutive freeze-pump-thaw cycles followed by the addition of radical-clock substrate **1aa** (0.2 mmol, 1.0 equiv., 28.8 mg). The reaction mixture was then stirred under 5W blue LED irradiation for 2 hours. After 2 hours, TLC was checked and no formation of the expected product **4a** was observed, instead ring opening product **7** was achieved with column chromatography (eluting with petroleum ether/ethyl acetate 97:3) as colourless liquid (9 mg, 26%).

### 8.2.2. Radical-clock experiment for carbocarboxylation (Condition B)

The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with **2a** (43.2 mg, 0.24 mmol, 1.2 equiv), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with $CO_2$ for 3 times. Therefore, under continuous $CO_2$ flow, anhydrous DMSO (3.0 mL) and radical-clock substrate **1aa** (0.2 mmol, 1.0 equiv., 28.8 mg) were added with syringe and subsequently the tube is sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12 hours. After 12 hours, the light is switched off, the shlenk tube is opened and to the mixture, methyl iodide (24.9 µL, 0.4 mmol, 2.0 equiv.) is added. The mixture is stirred for additional 4 hours at room temperature. After that, TLC was checked which showed no formation of expected product **5a**, instead ring opening product **7** was achieved with column chromatography (eluting with petroleum ether/ethyl acetate 97:3) as colourless liquid (25.3 mg, 73%).

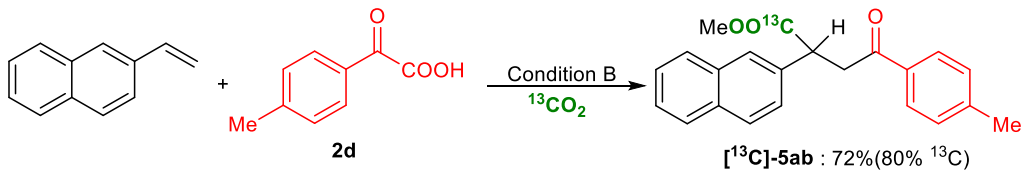
Characterization of **7** (*E* isomer): $^{1}$H NMR (400 MHz, $CDCl_3$): δ 7.98-7.94 (m, 2H), 7.31-7.23 (m, 5H), 6.93-6.91 (m, 2H), 5.99 (t, *J* = 7.2 Hz, 1H), 4.13 (s, 2H), 3.85 (s, 3H), 2.18 (pent., *J* = 7.6 Hz, 2H), 1.07 (t, *J* = 7.6 Hz, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 196.86, 195.78, 163.56, 163.43, 143.02, 140.65, 134.39, 133.95, 132.81, 130.81, 130.58, 130.07, 128.51, 128.35, 128.17, 126.83, 126.75, 126.11, 126.10, 113.79, 113.69, 55.56, 55.51, 48.48, 40.45, 22.65, 22.62, 14.45, 14.03; HRMS (ESI, m/z) calcd. For $C_{32}H_{32}O_5S$ $[M+H]^+$: 281.1542; found: 281.1544.

### 8.3. Checking the possibility of Michael addition in carbobenzylation (Condition A)




1-benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate **3a** (0.4 mmol, 2.0 equiv., 194 mg), (*E*)-1,3-bis(4-methoxyphenyl)prop-2-en-1-one **8** (0.2 mmol, 1.0 equiv.), tris(2,2′-bipyridyl)dichlororuthenium(II) hexahydrate (0.002 mmol, 1 mol %, 2.9 mg), caesium carbonate (0.4 mmol, 2.0 equiv., 130 mg) were taken in a 7 mL screw-capped vial. MeCN was added to the mixture. The whole mixture was de-gassed and re-filled with inert gas by two consecutive freeze-pump-thaw cycles. The reaction mixture was then stirred under 5W blue LED irradiation for 12 hours. After 12 hours, TLC was checked and no formation of the expected product **4n** was observed.

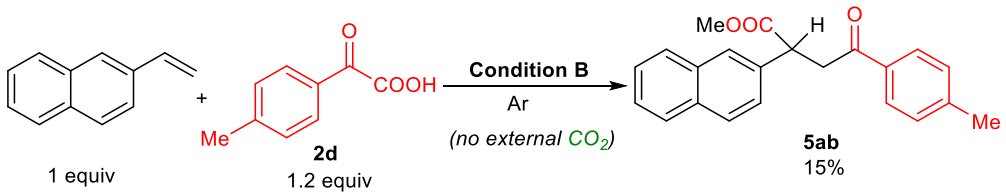
### 8.4. $^{13}$C-labelling experiment for carbocarboxylation (Condition B)




The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with 2-vinylnaphthalene (30.8 mg, 0.20 mmol, 1.0 equiv.), **2d** (39.4 mg, 0.24 mmol, 1.2 equiv), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with $^{13}CO_2$ for 3 times. Therefore, under continuous $^{13}CO_2$ flow, anhydrous DMSO (3.0 mL) was added with syringe and subsequently the tube is sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12

hours. After 12 hours, the light is switched off, the shlenk tube is opened and to the mixture, methyl iodide (24.9 μL, 0.4 mmol, 2.0 equiv.) is added. The mixture was stirred for additional 4 hours at room temperature. After that, the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate 97:3) to afford the desired product **[$^{13}$C]-5ab** as white solid (47.9 mg, 72% with 80% $^{13}$C incorporation). $^1$H NMR (400 MHz, $CDCl_3$): δ 7.89-7.87 (m, 2H), 7.83-7.80 (m, 4H), 7.49-7.44 (m, 3H), 7.23-7.22 (m, 2H), 4.48-4.43 (m, 1H), 4.01 (qd, $J_1$ = 10.0 Hz, $J_2$ = 2.8 Hz, 1H), 3.69 (d, $J$ = 4 Hz, 3H), 3.33 (dq, $J_1$ = 18.0 Hz, $J_2$ = 4.0 Hz, 1H), 2.39 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ 197.28, 174.01, 144.26, 135.93, 134.03, 133.57, 132.79, 129.38, 128.75, 128.31, 127.90, 127.74, 126.78, 126.43, 126.12, 125.89, 52.47, 46.55 (d, $J$ = 57 Hz, 46.27, 42.76, 21.75; HRMS (ESI, m/z) calcd. For $C_{22}H_{20}O_3$ $[M+H]^+$: 333.1491; found: 333.1389.

### 8.5. Carbocarboxylation reaction under Argon (Ar) atmosphere

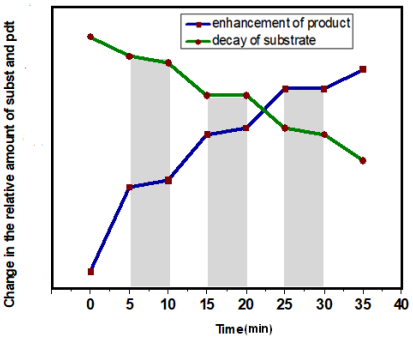



The oven-dried Schlenk tube (10 mL) containing a stirring bar was charged with 2-vinylnaphthalene (30.8 mg, 0.20 mmol, 1.0 equiv.), **2d** (39.4 mg, 0.24 mmol, 1.2 equiv), 4-CzIPN (1.5 mg, 0.002 mmol, 1.0 mol %) and transferred to glovebox to add $Cs_2CO_3$ (130.3 mg, 0.4 mmol, 2.0 equiv). The tube was then evacuated and back-filled with argon (Ar) for 3 times. Therefore, under continuous Ar flow, anhydrous DMSO (3.0 mL) was added with syringe and subsequently the tube is sealed. The reaction was stirred with irradiating with a 30 W blue LED lamp (3 cm away, with cooling fan to keep the reaction temperature at 25~30 °C) for 12 hours. After 12 hours, the light is switched off, the shlenk tube is opened and to the mixture, methyl iodide (24.9 μL, 0.4 mmol, 2.0 equiv.) is added. The mixture was stirred for additional 4 hours at room temperature. After that, the reaction mixture was extracted with ethyl acetate (30 mL), water (10 mL × 2), washed with brine (10 mL), dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography ($SiO_2$, eluting with hexane/ethylacetate 97:3) to afford the desired carboxylated product **5ab** as white solid (10.0 mg, 15%).

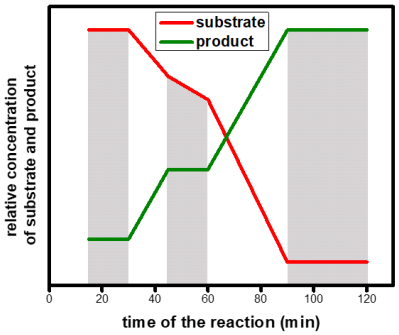
### 8.6. Light on-off experiment for both carbobenzylation (Condition A) and carbocarboxylation (Condition B)

In both the conditions, for carbobenzylation and carbocarboxylation, the standard reactions were set-up and stirred sequentially under light and in dark with a certain interval.

a)




b)



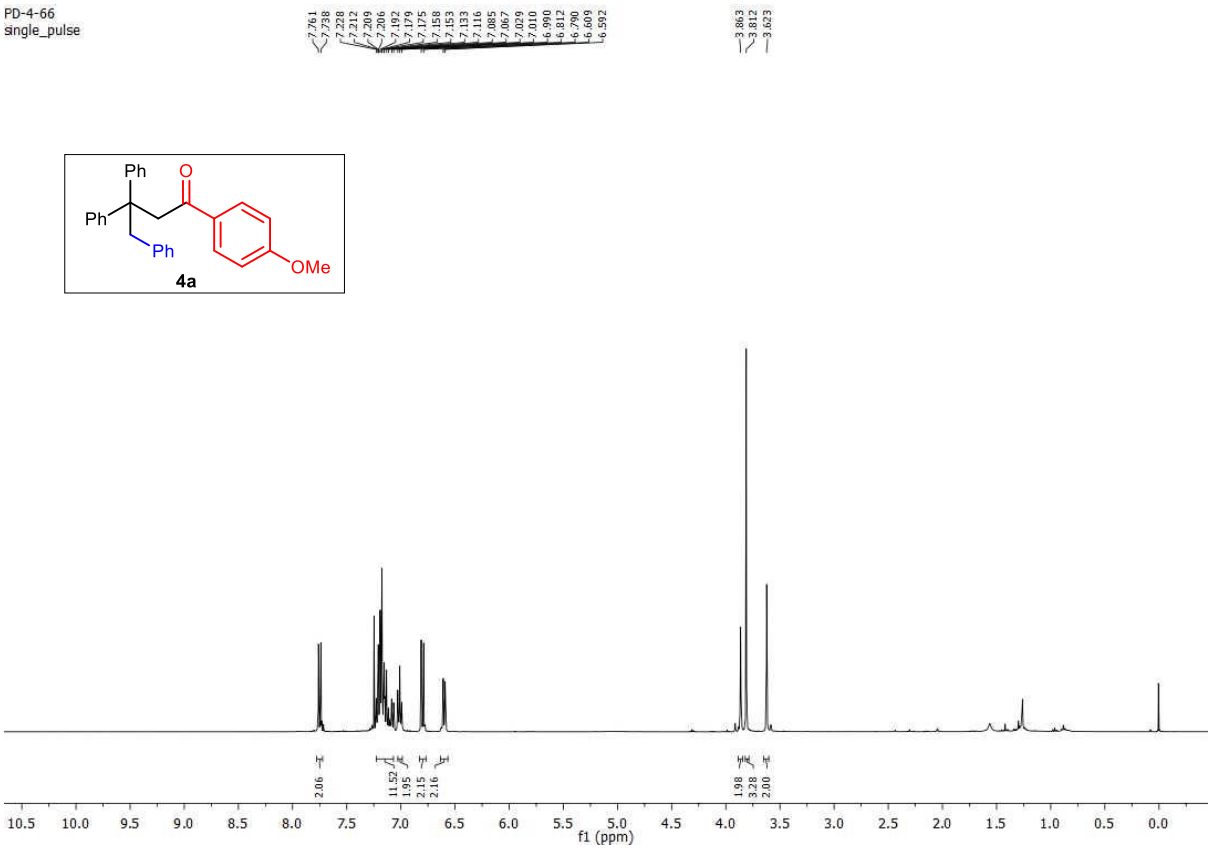

Light on-off experiment for a) carbobenzylation (**Condition A**) and b) carbocarboxylation (**Condition B**)

The corresponding increase of product and decrease of starting material concentration was monitored using 1,2,3,4,5-pentafluoro-6-methylbenzene as internal standard. The relative concentration of the substrates and the corresponding product were calculated and presented graphically.

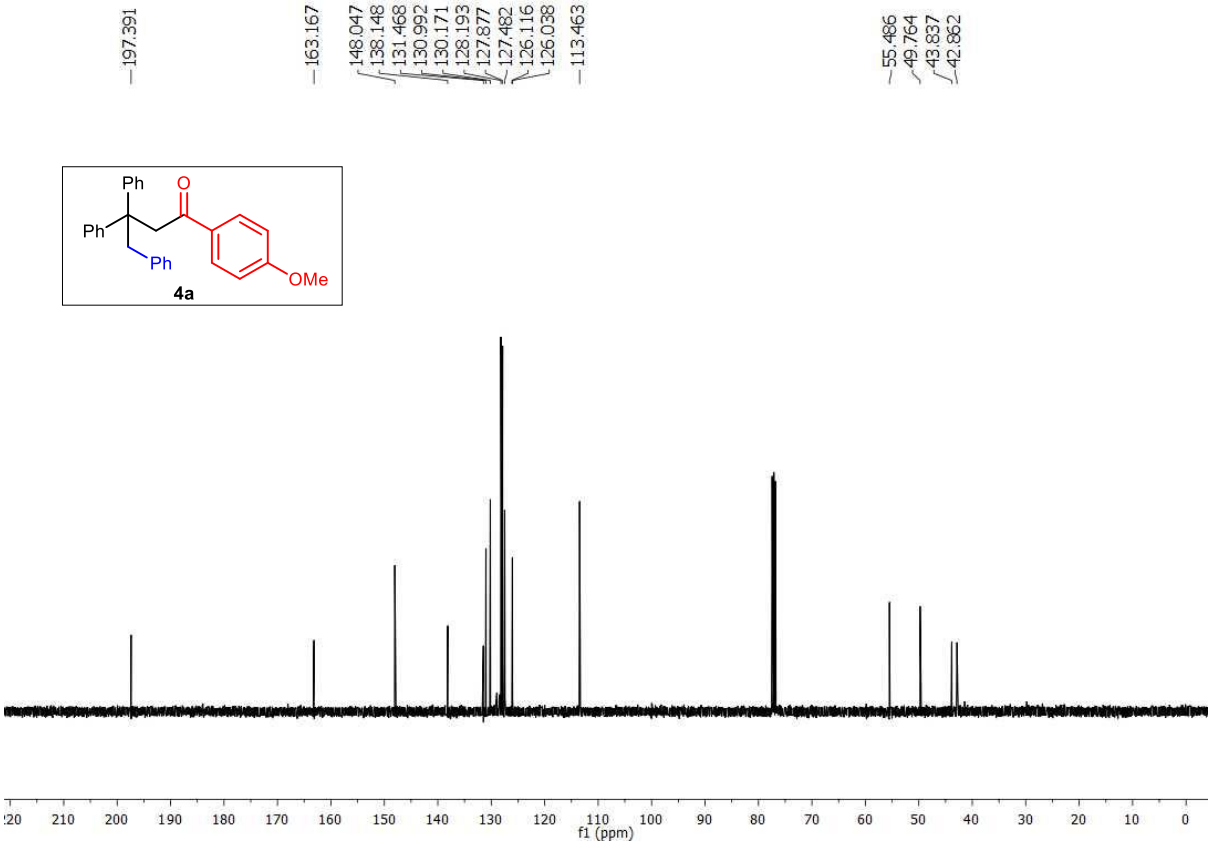
## 9. References


1. C. Wan, R.-J. Song and J.-H. Li, *Org. Lett.*, 2019, **21**, 2800-2803.
2. A. Hossian, K. Manna, P. Das and R. Jana, *ChemistrySelect*, 2018, **3**, 4315-4318.
3. F. J. R. Klauck, H. Yoon, M. J. James, M. Lautens and F. Glorius, *ACS Catal.*, 2019, **9**, 236-241.

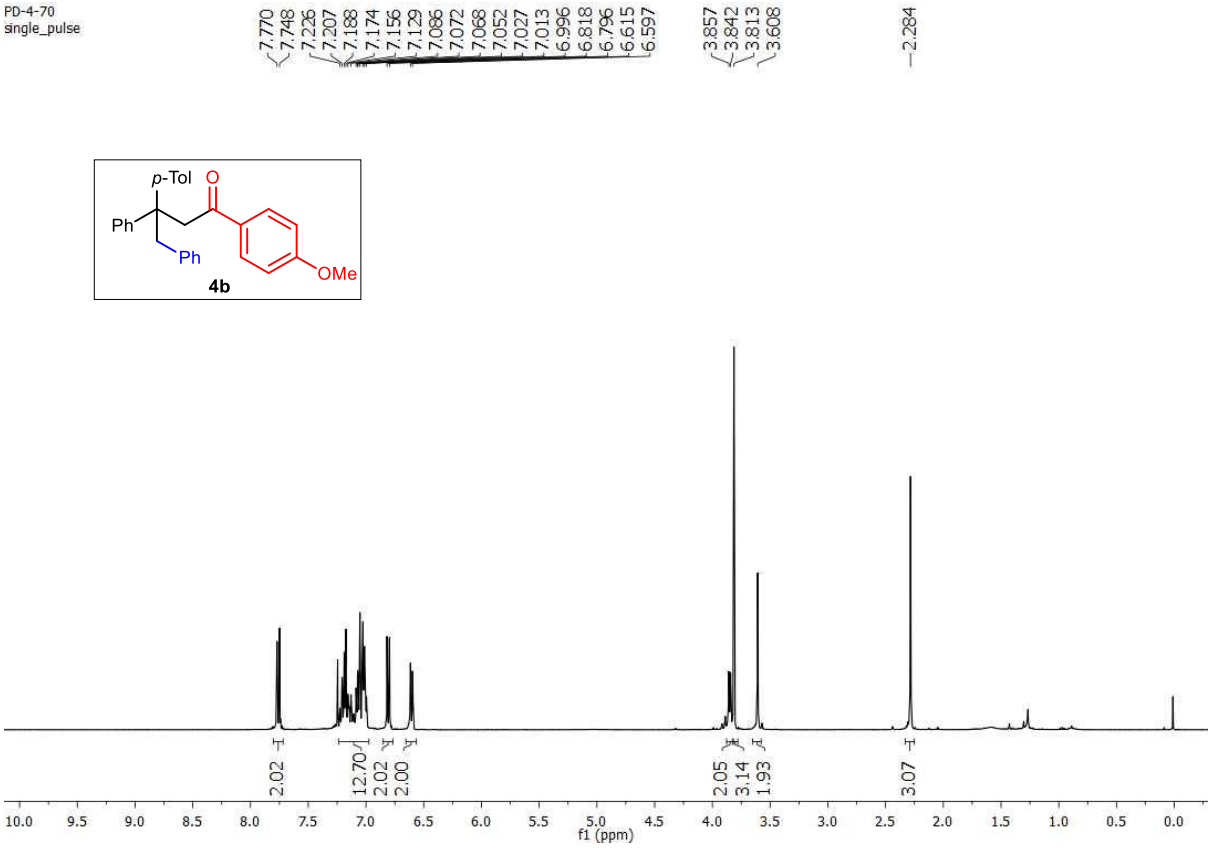

## 10. Copies of $^{1}H$ and $^{13}C$ Spectra



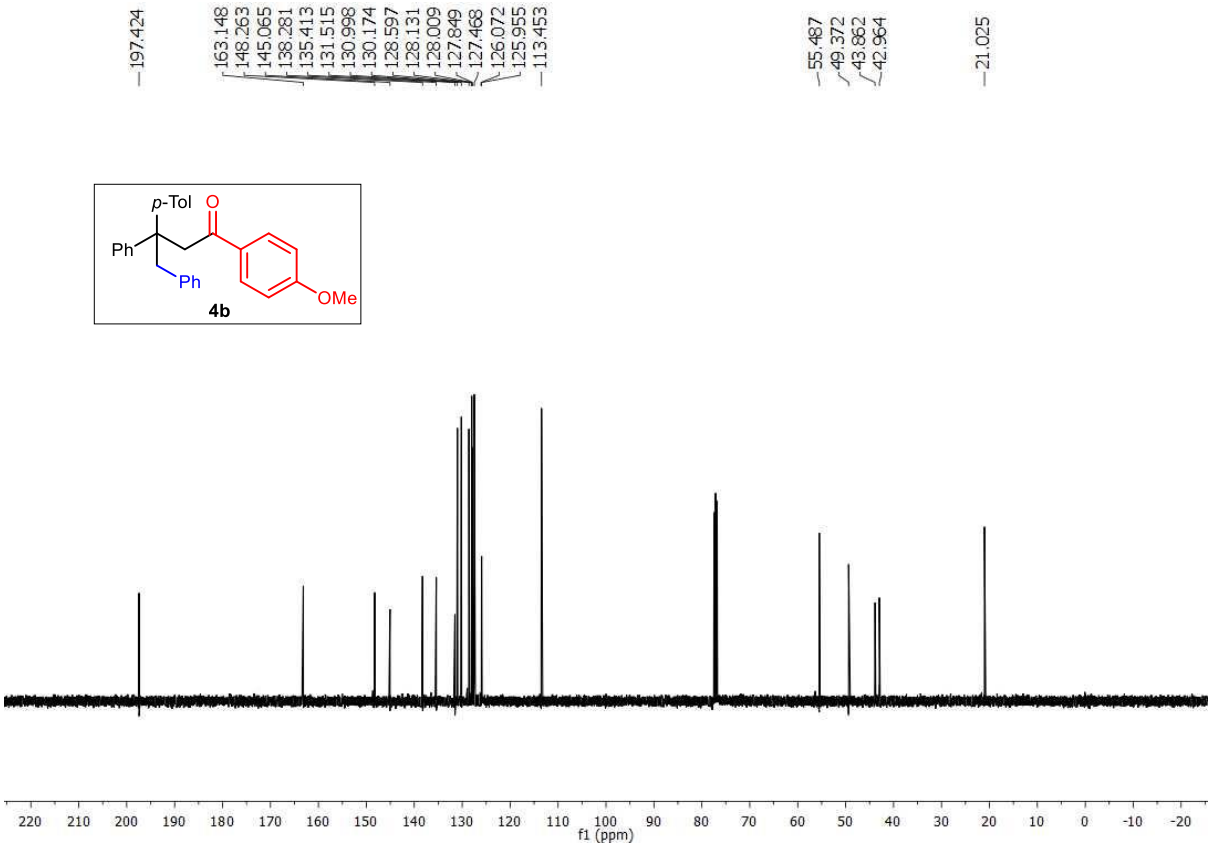

$^{1}$H spectra of **4a**



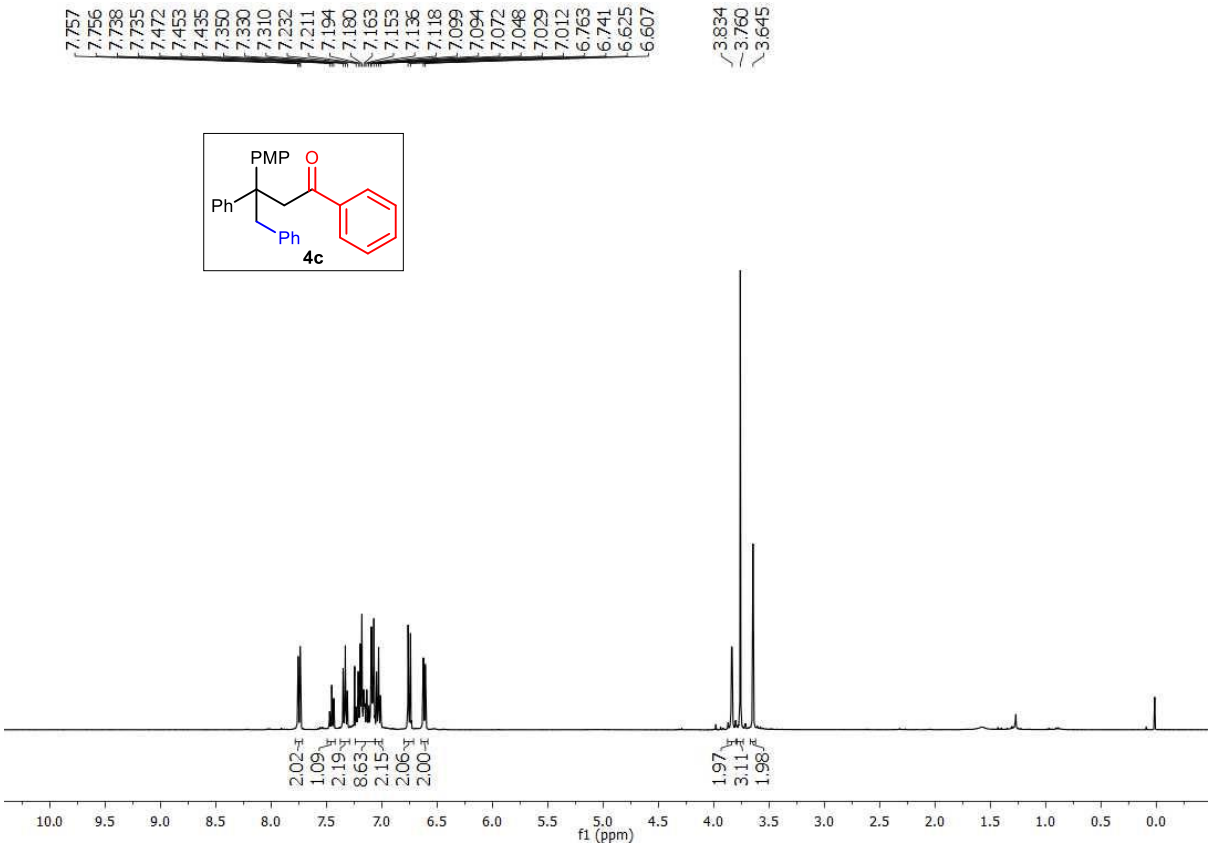

$^{13}$C spectra of **4a**



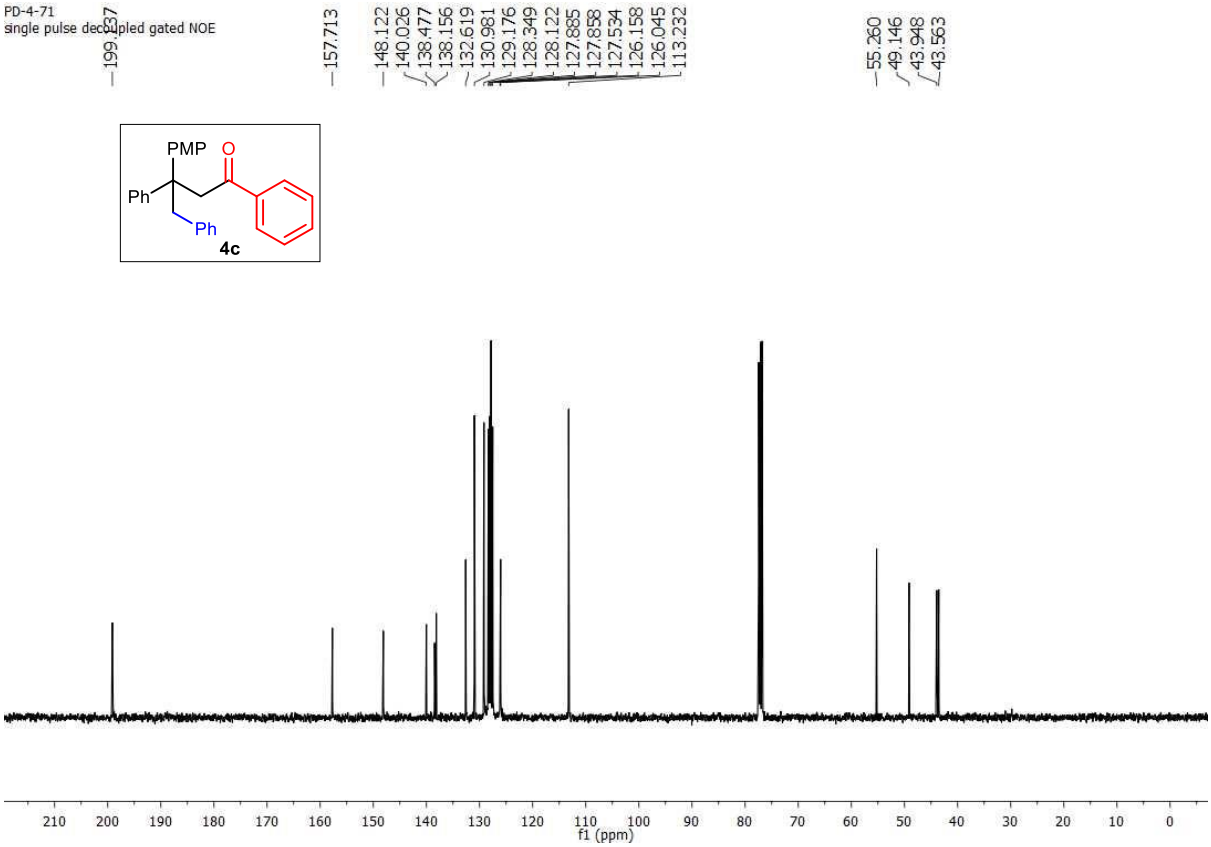

$^{1}$H spectra of **4b**



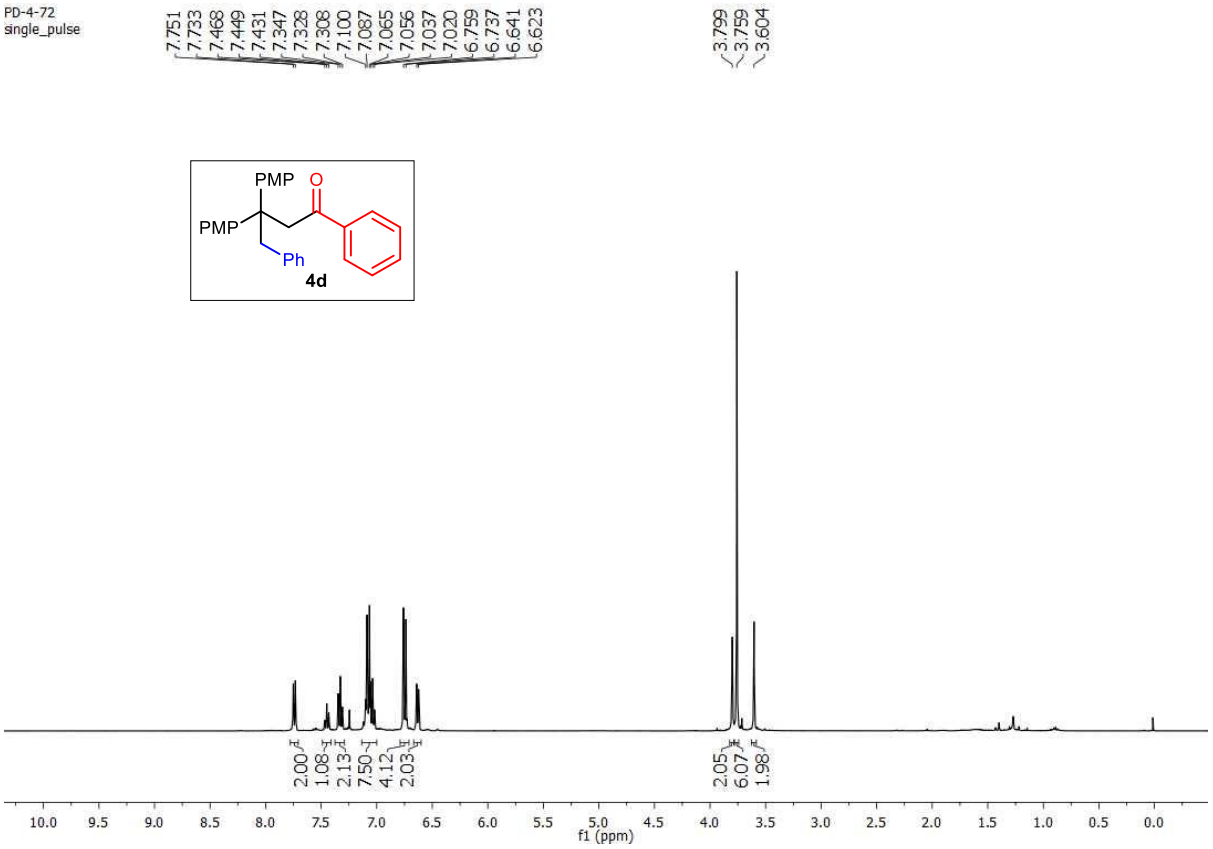

$^{13}$C spectra of **4b**



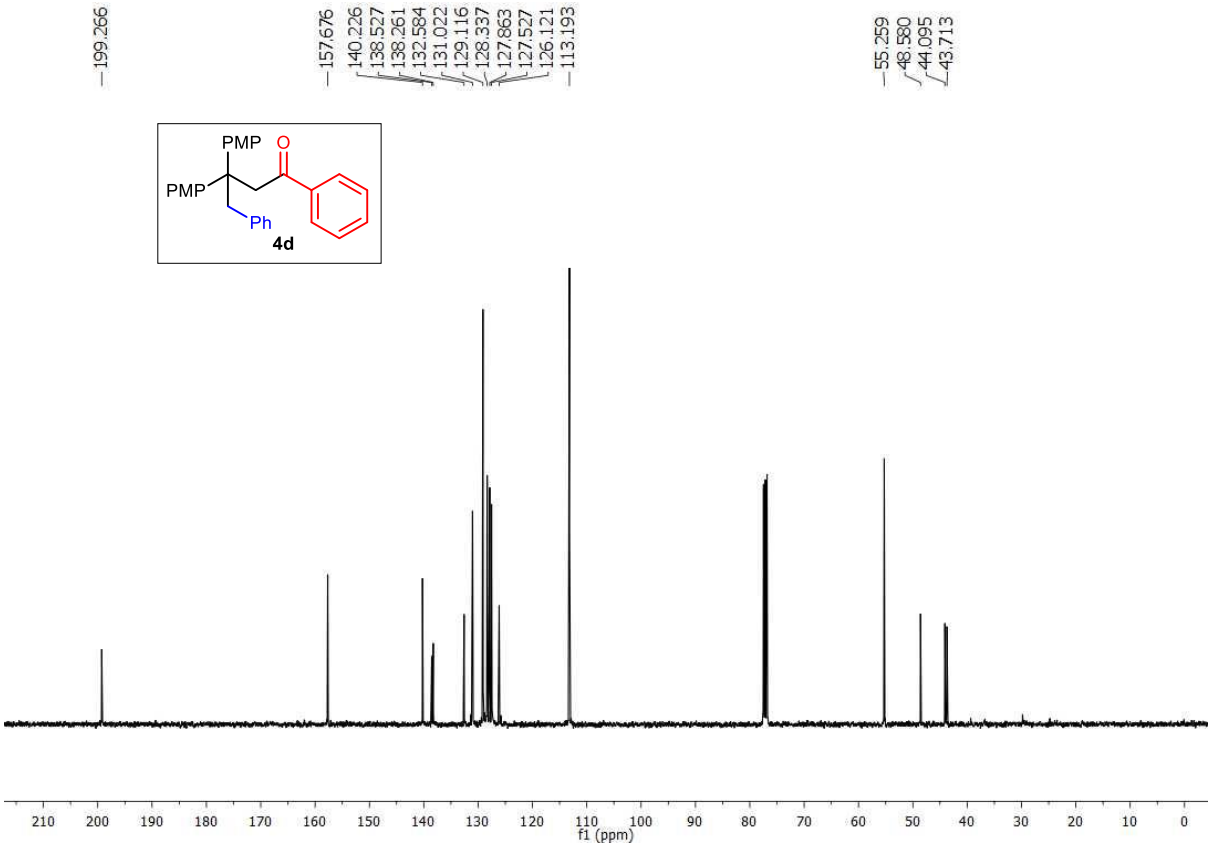

$^{1}$H spectra of **4c**



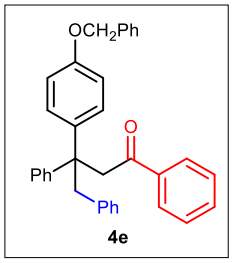

$^{13}$C spectra of **4c**

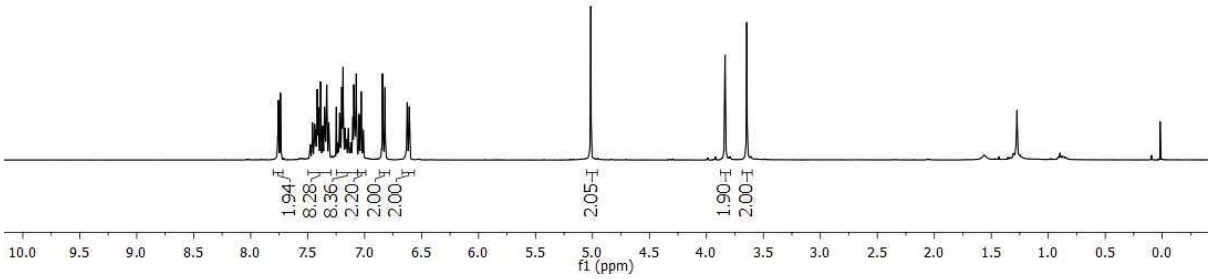



$^{1}$H spectra of **4d**

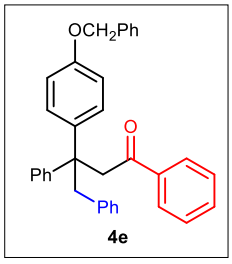


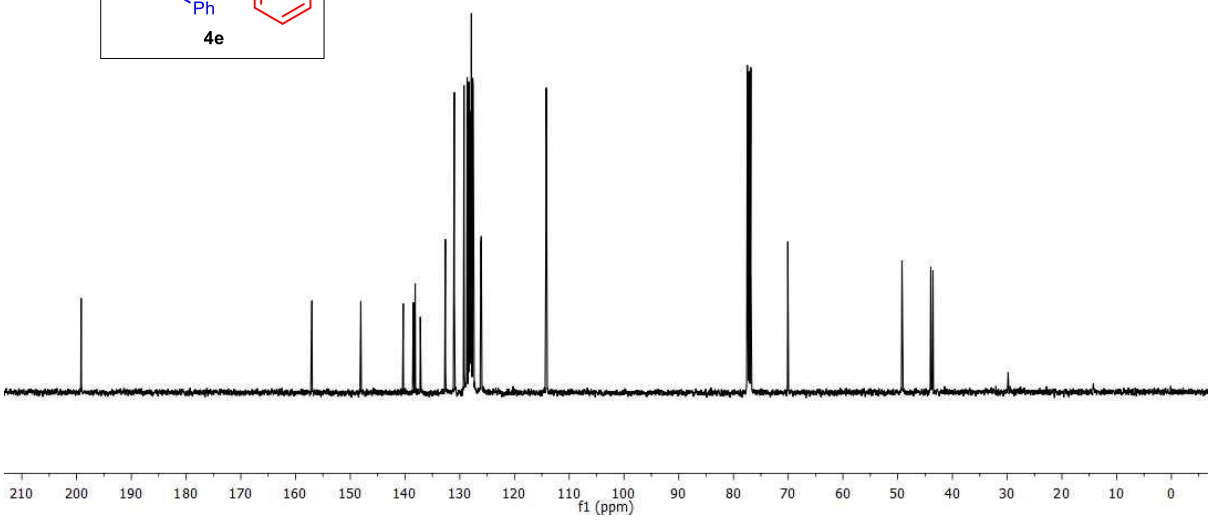

$^{13}$C spectra of **4d**

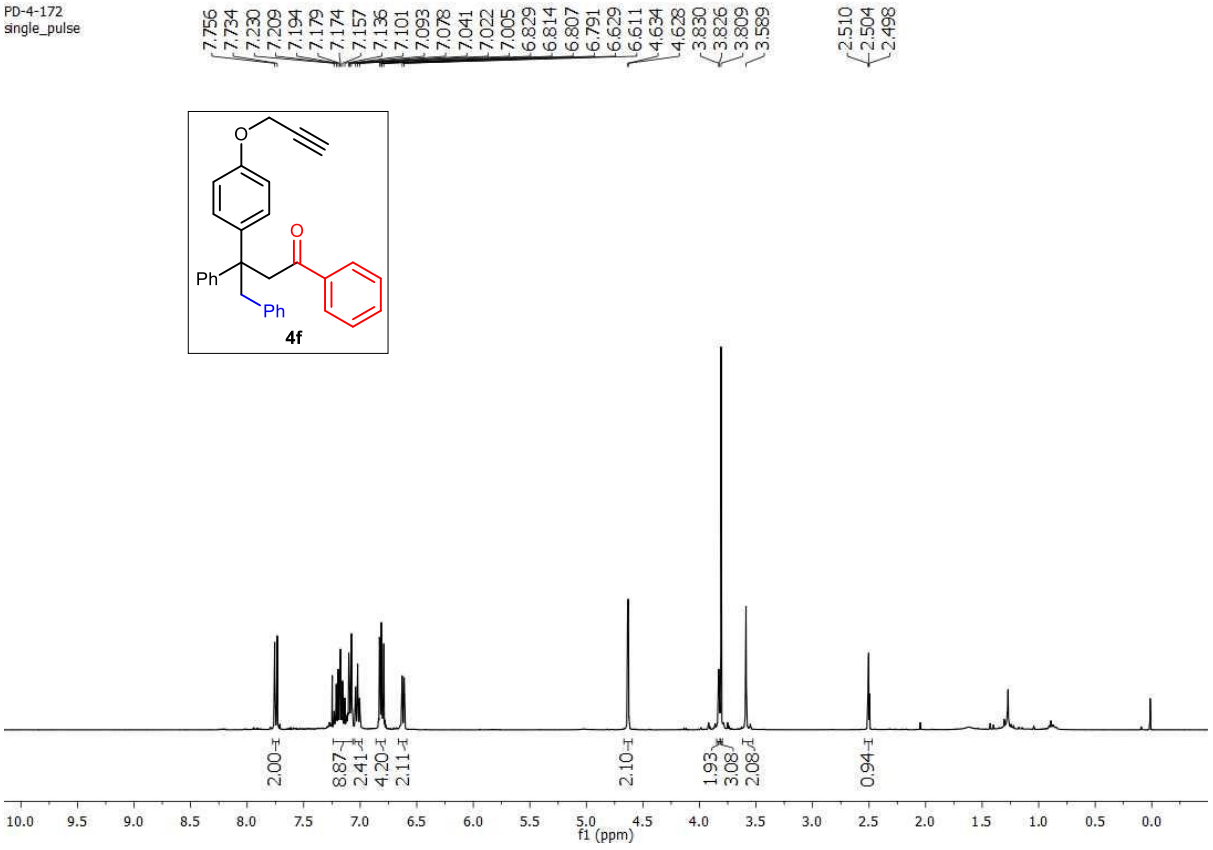




$^{1}$H spectra of **4e**

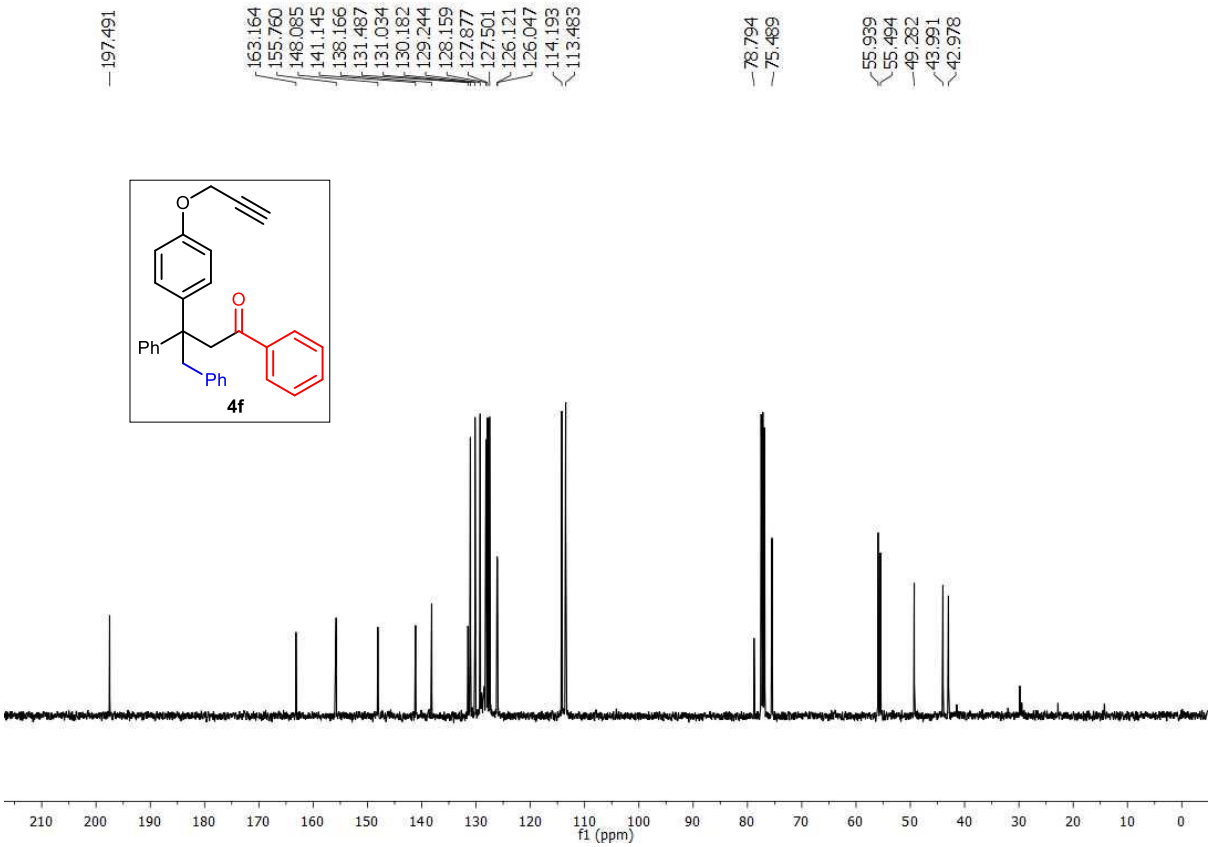



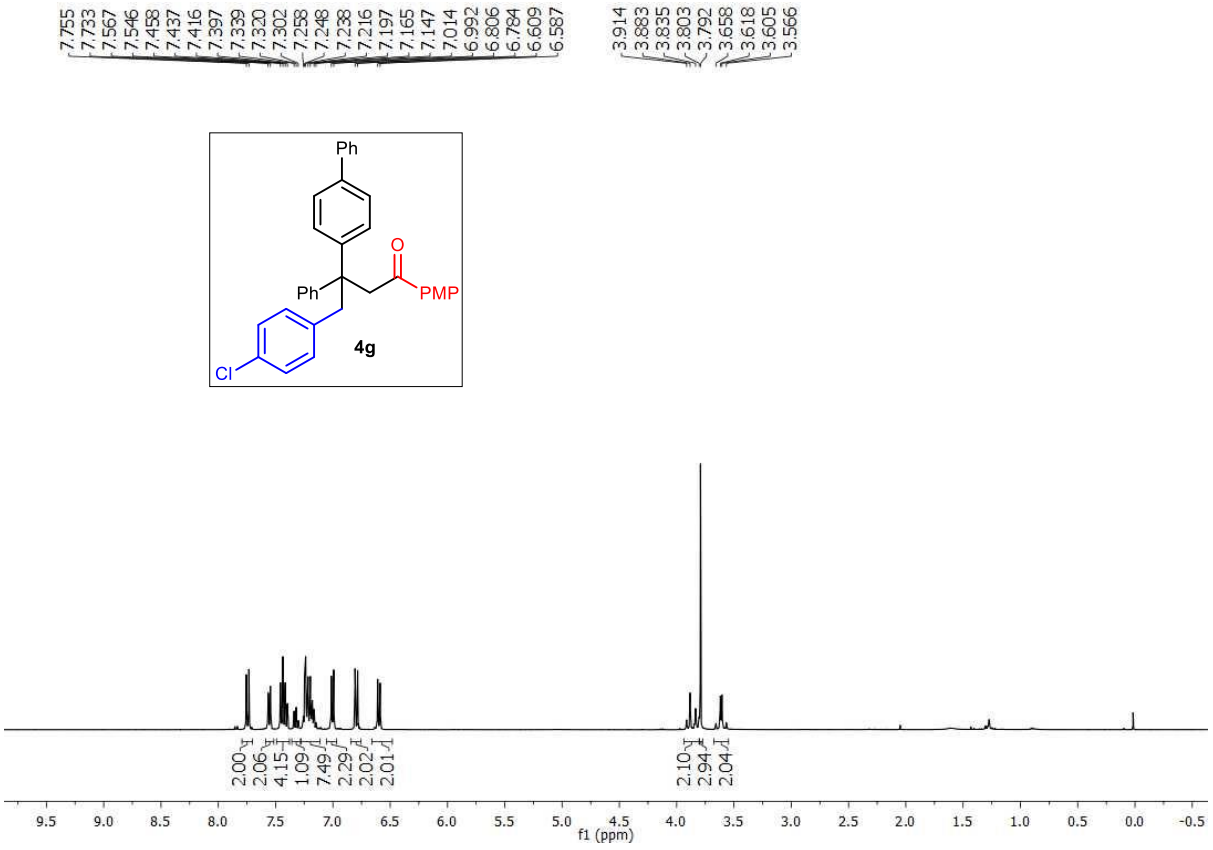

$^{13}$C spectra of **4e**



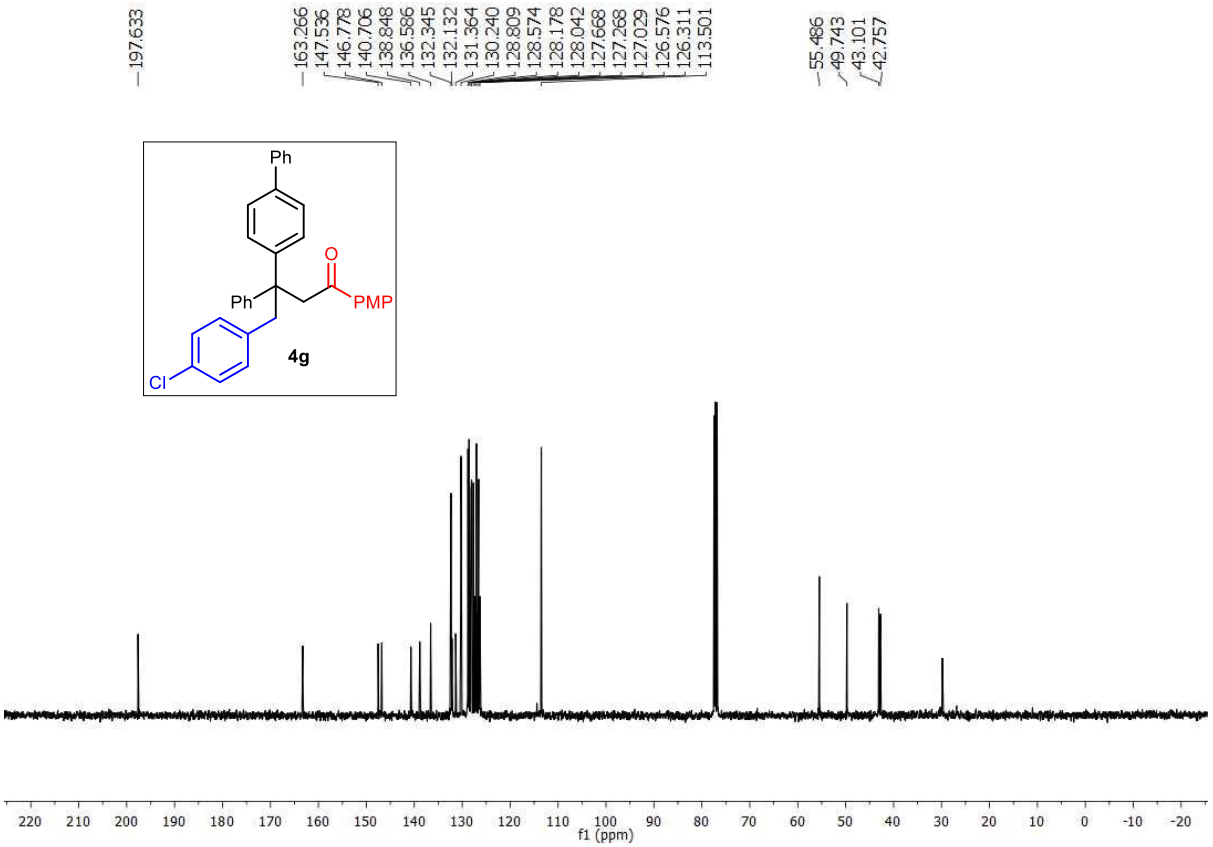

$^{1}$H spectra of **4f**



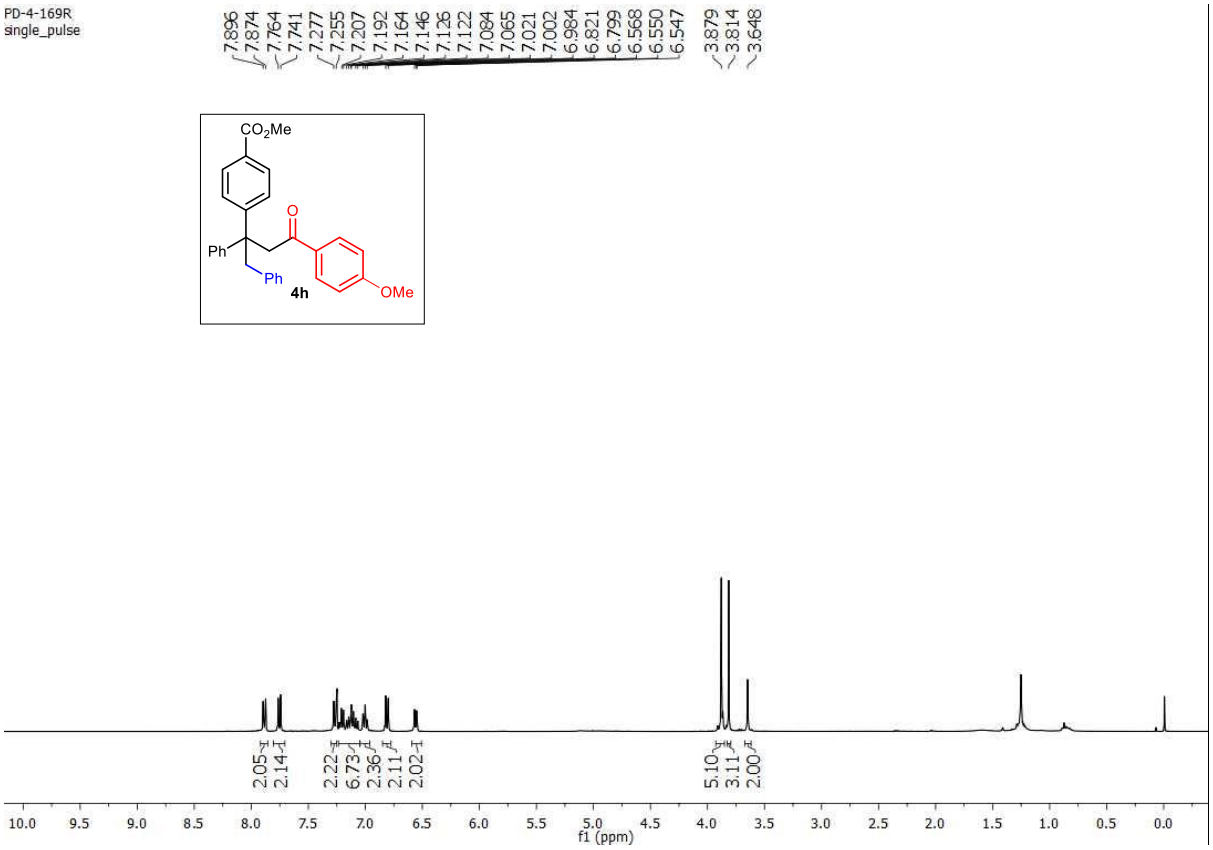

$^{13}$C spectra of **4f**



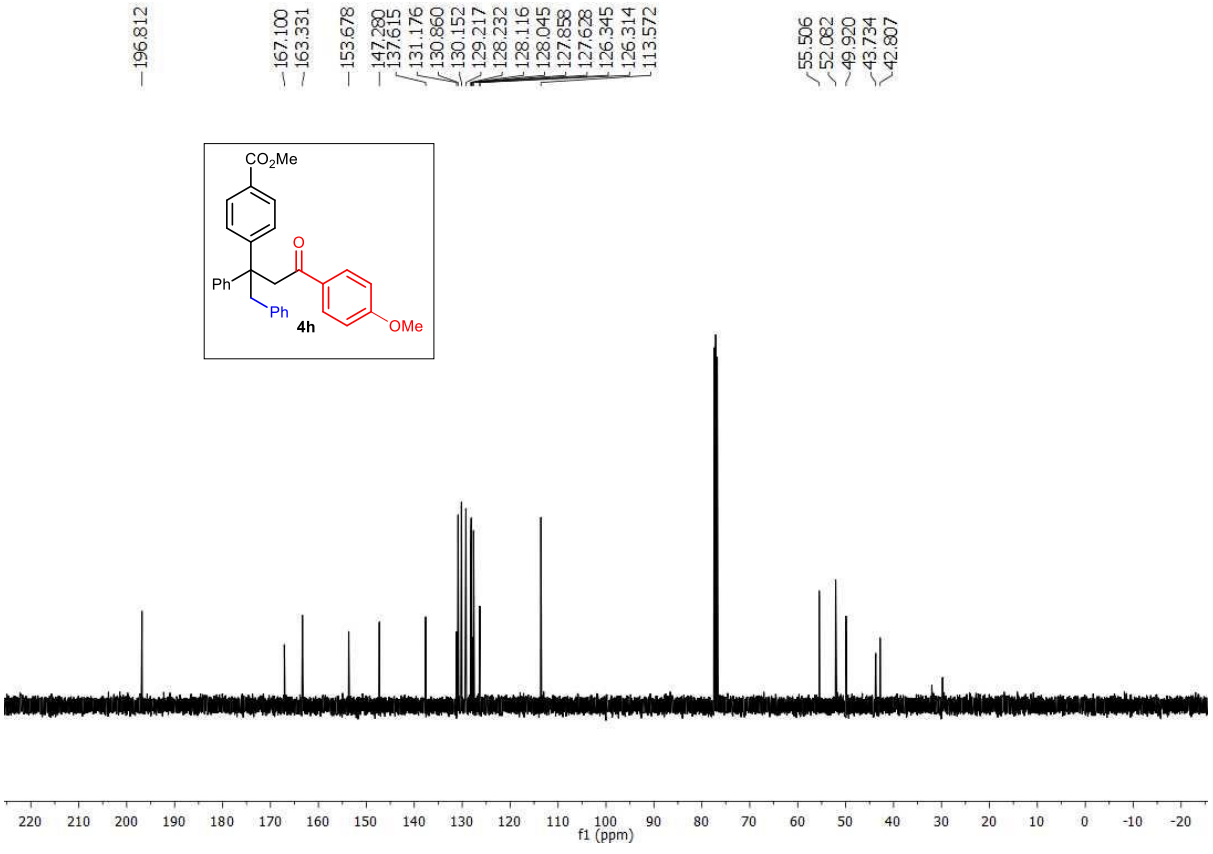

$^{1}$H spectra of **4g**



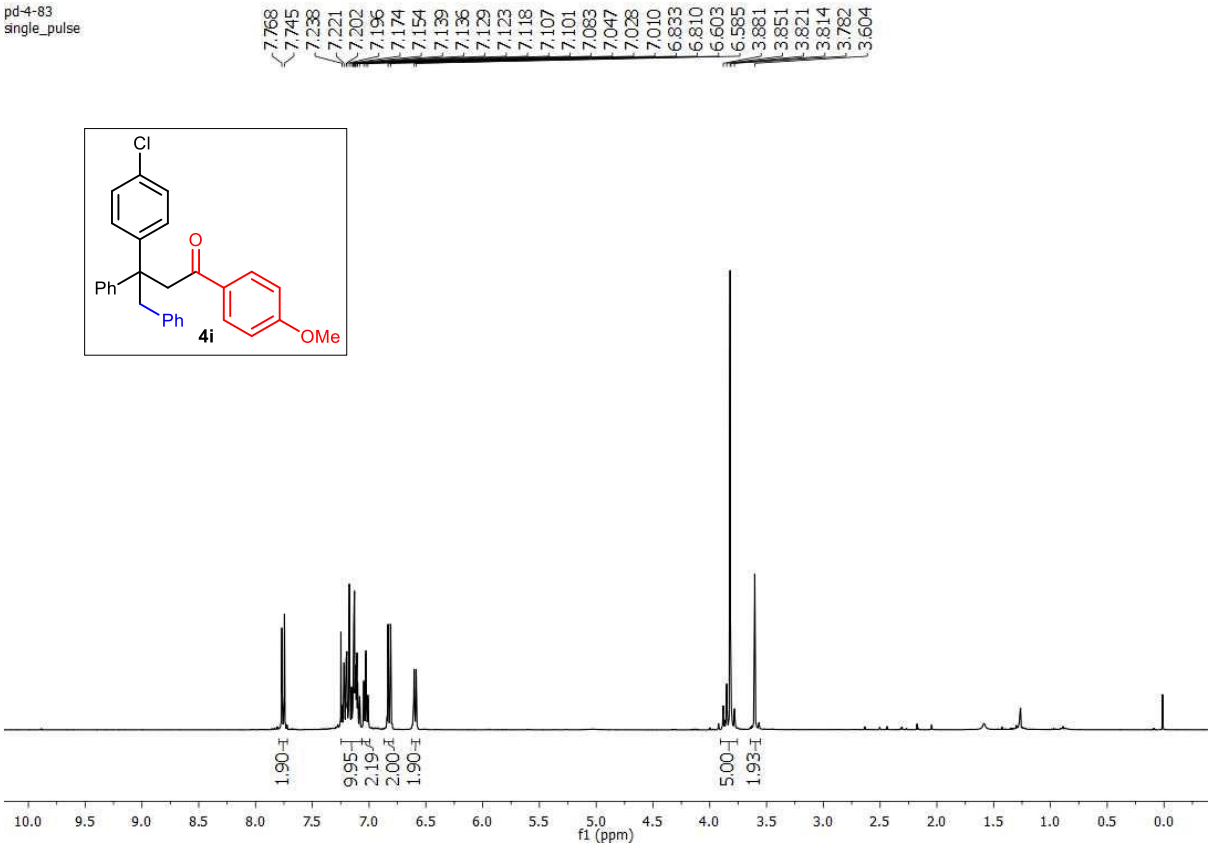

$^{13}$C spectra of **4g**



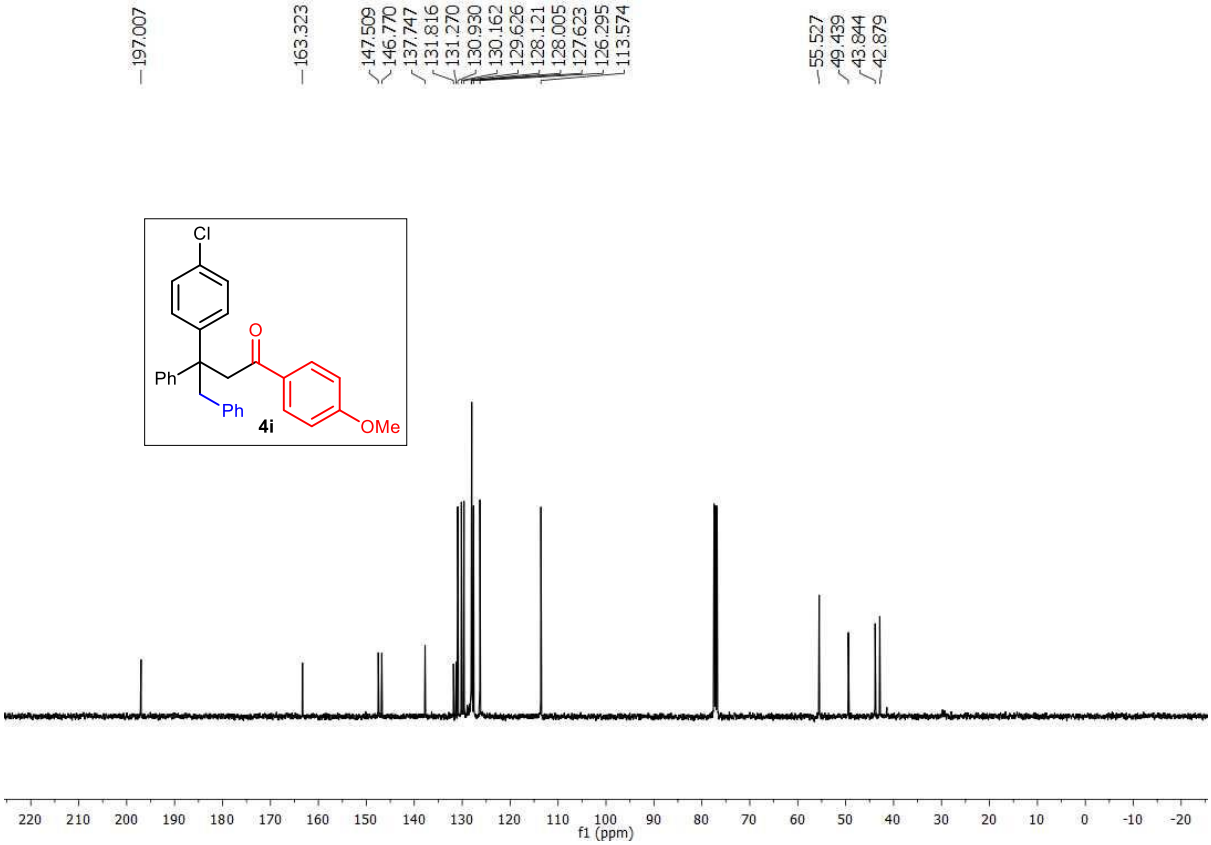

$^{1}$H spectra of **4h**




$^{13}$C spectra of **4h**




$^{1}$H spectra of **4i**

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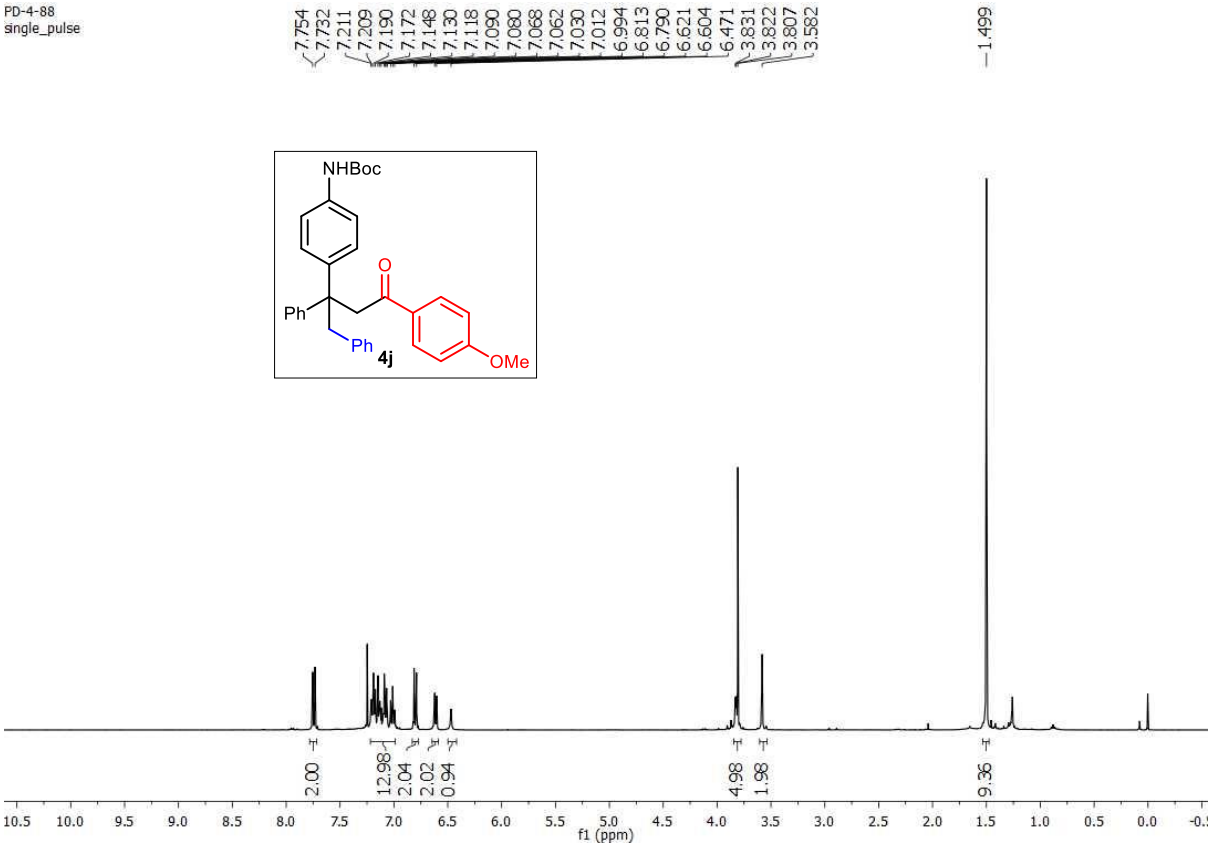
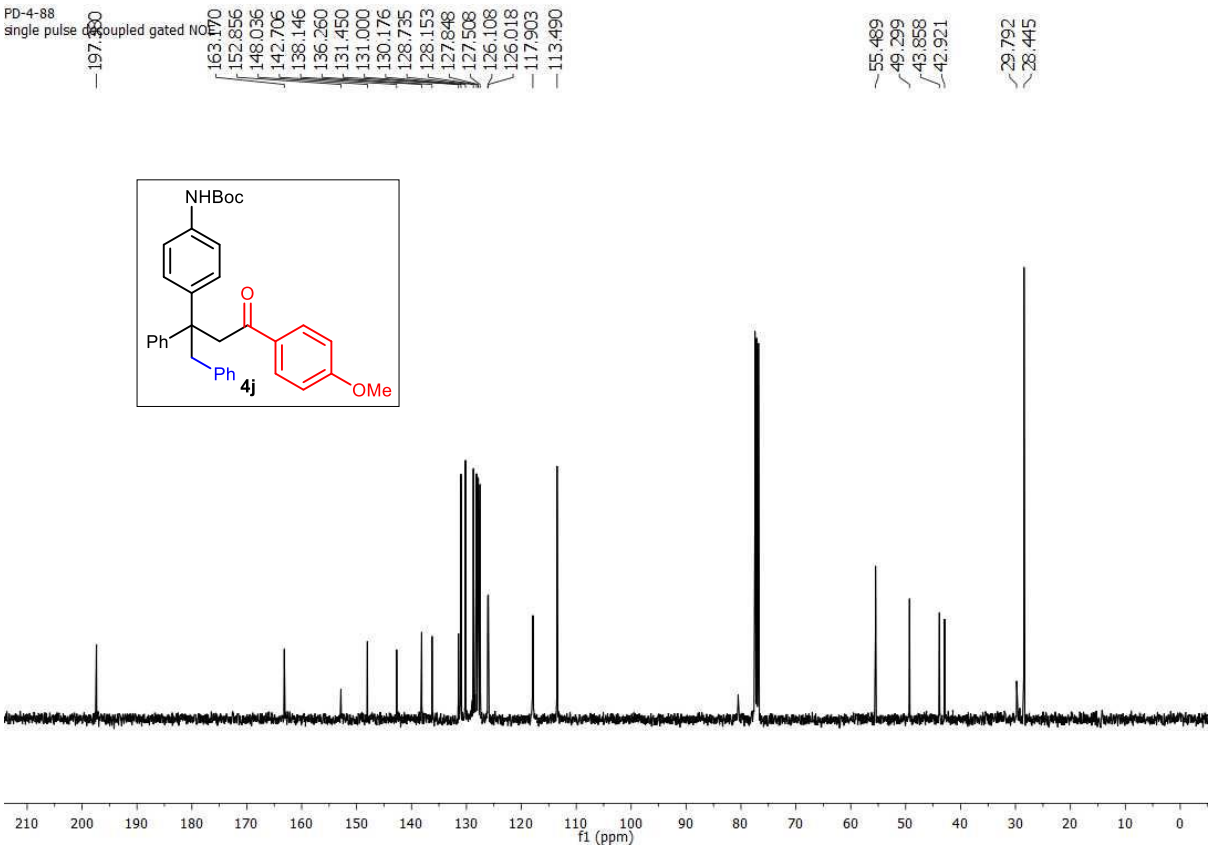



$^{1}$H spectra of **4j**

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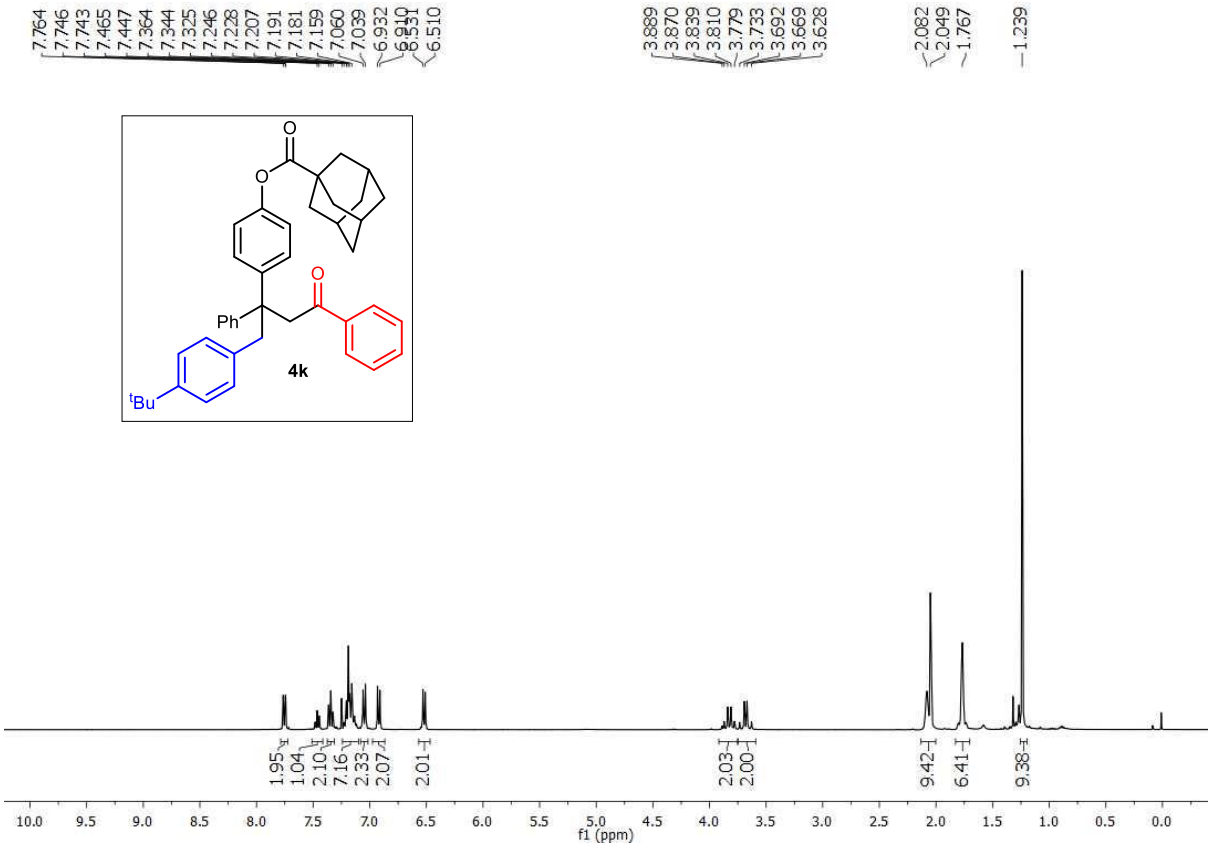
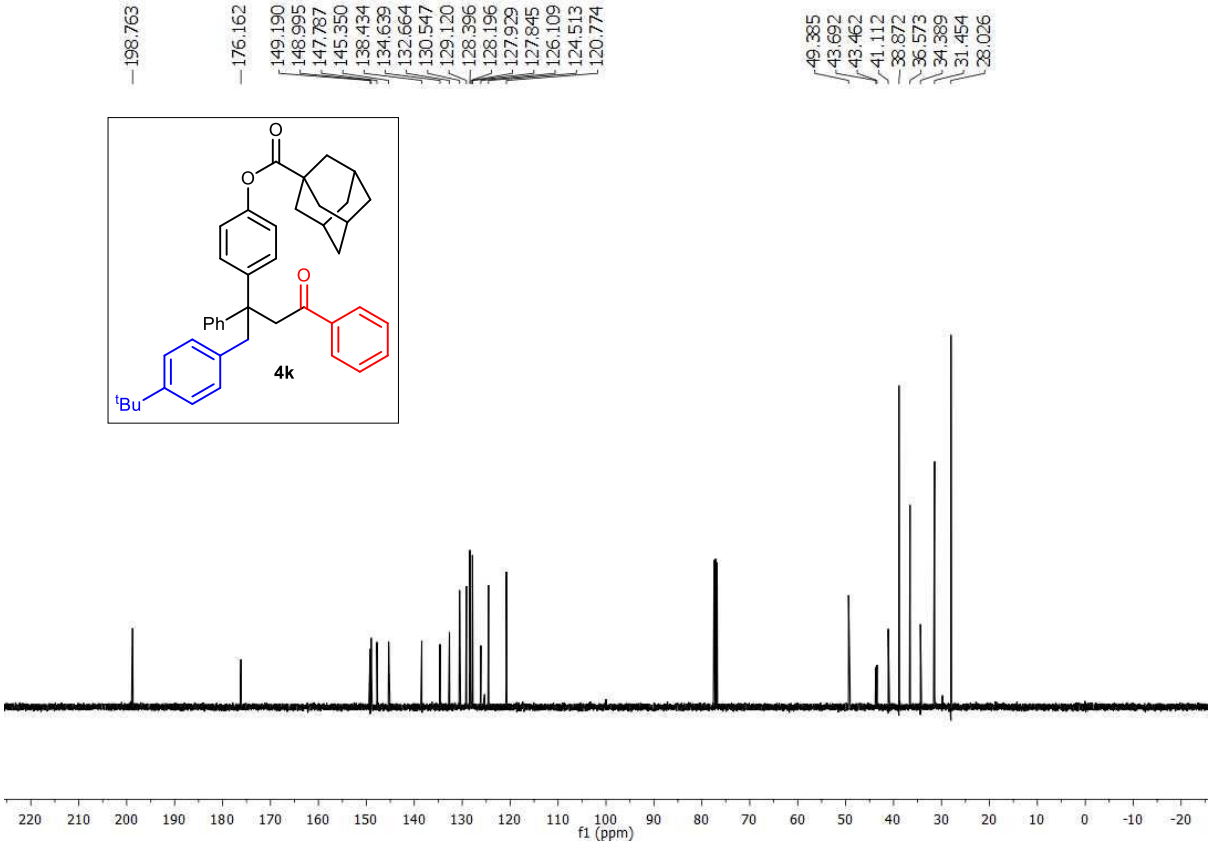
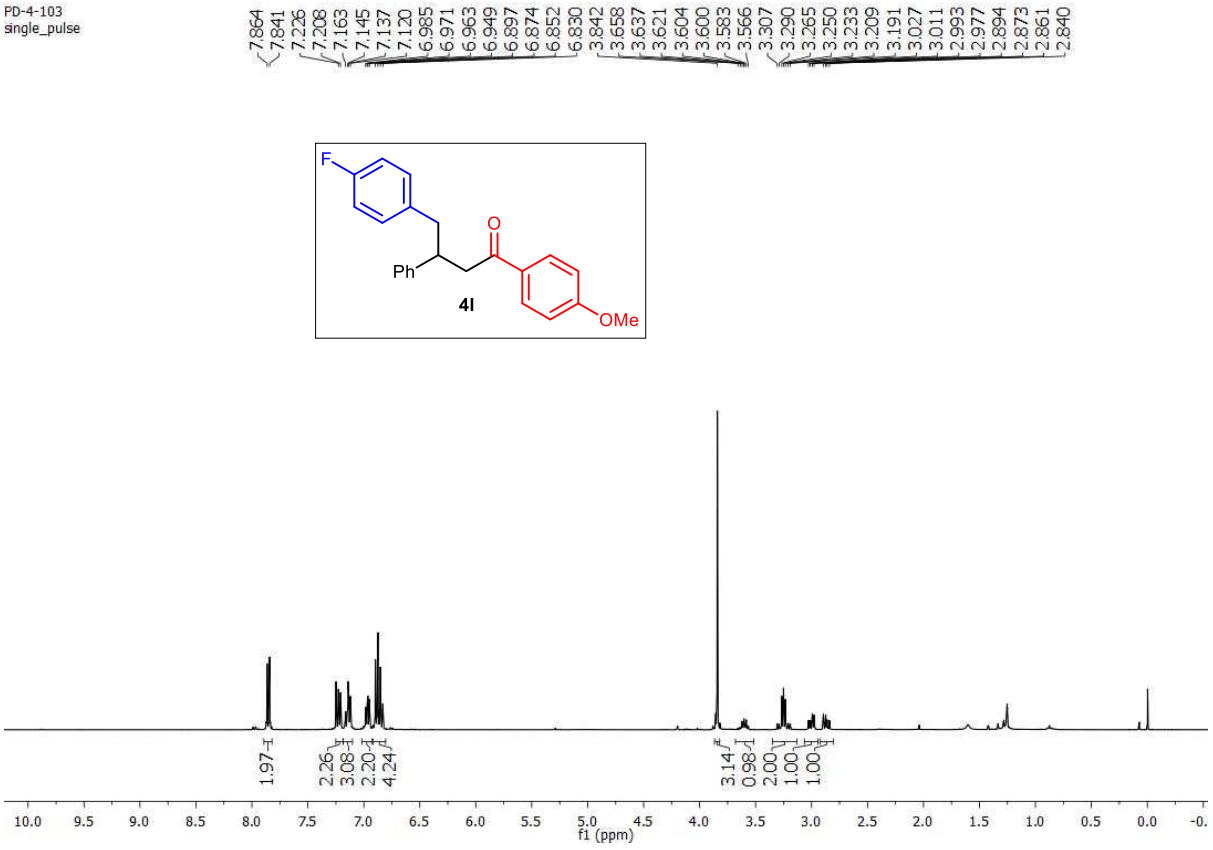


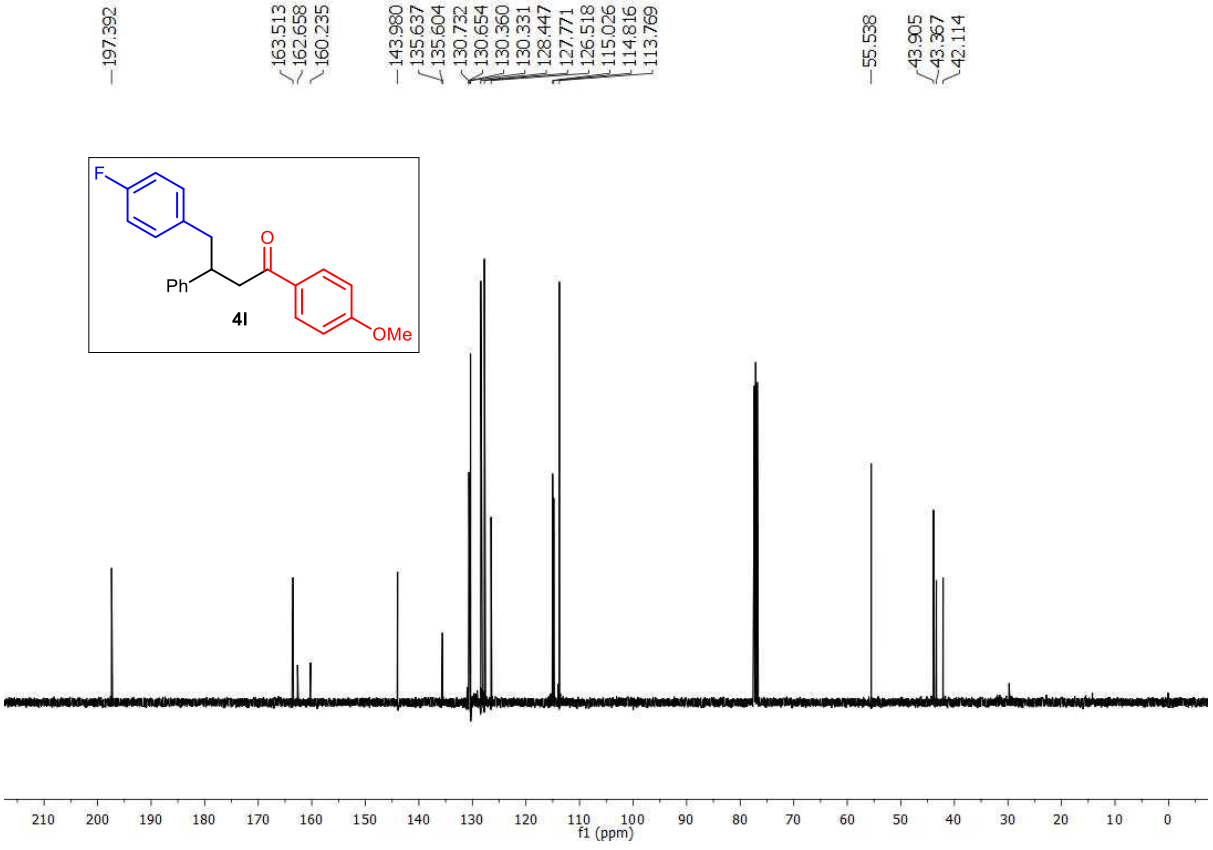

$^{1}$H spectra of **4k**



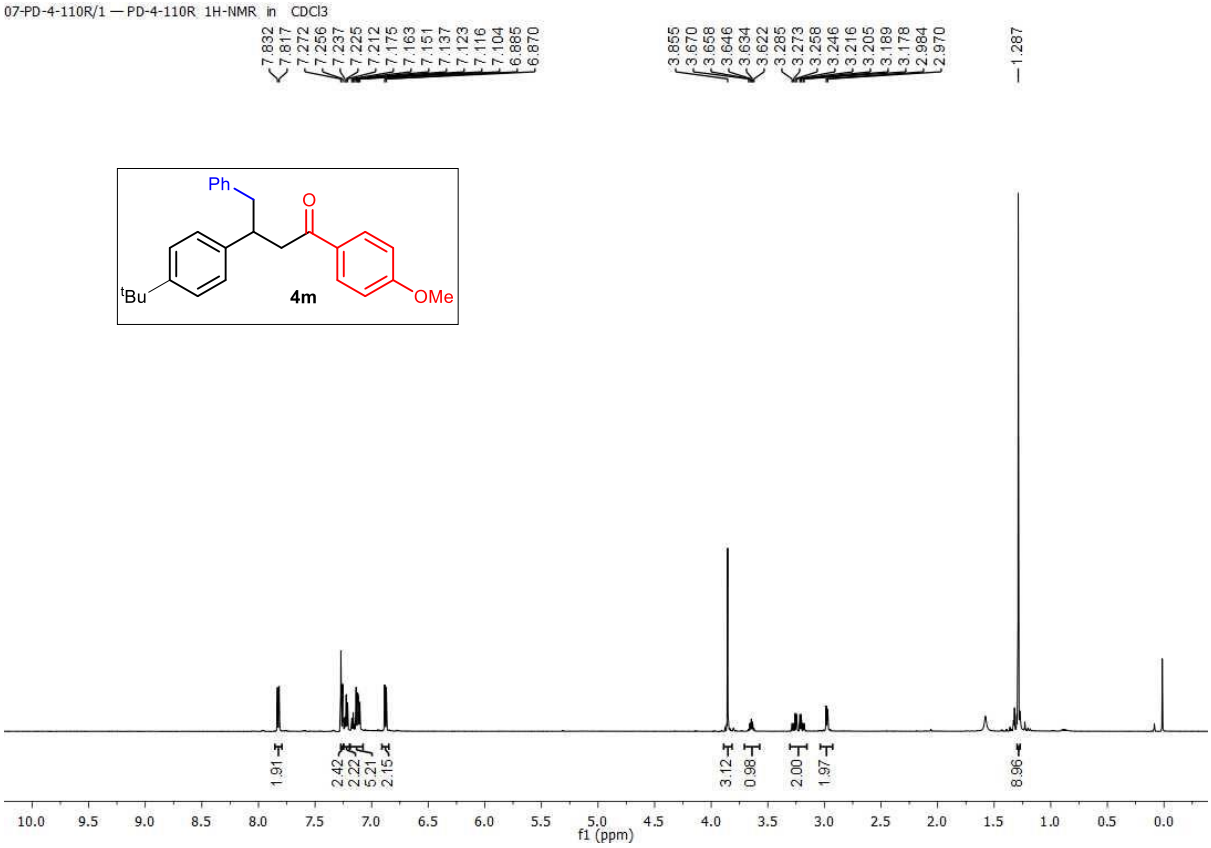

$^{13}$C spectra of **4k**



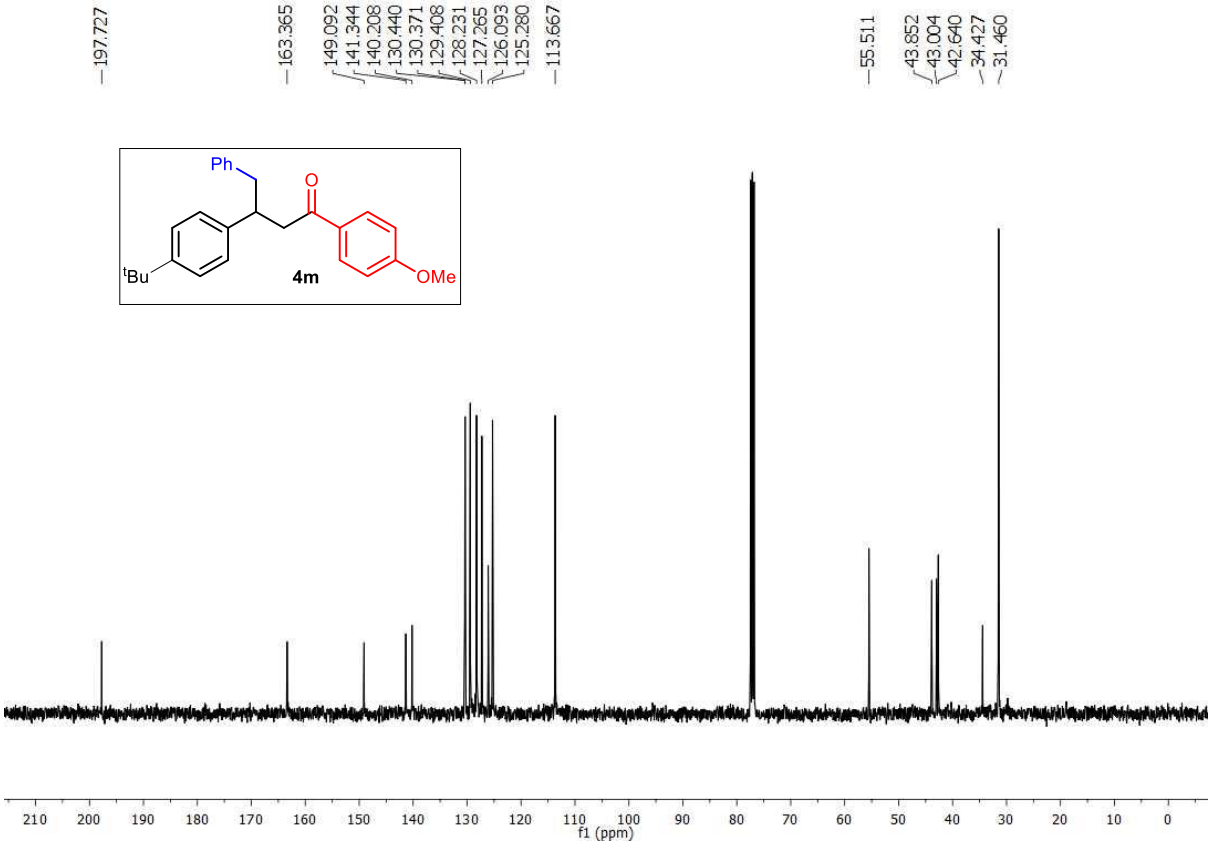

$^{1}$H spectra of **4l**



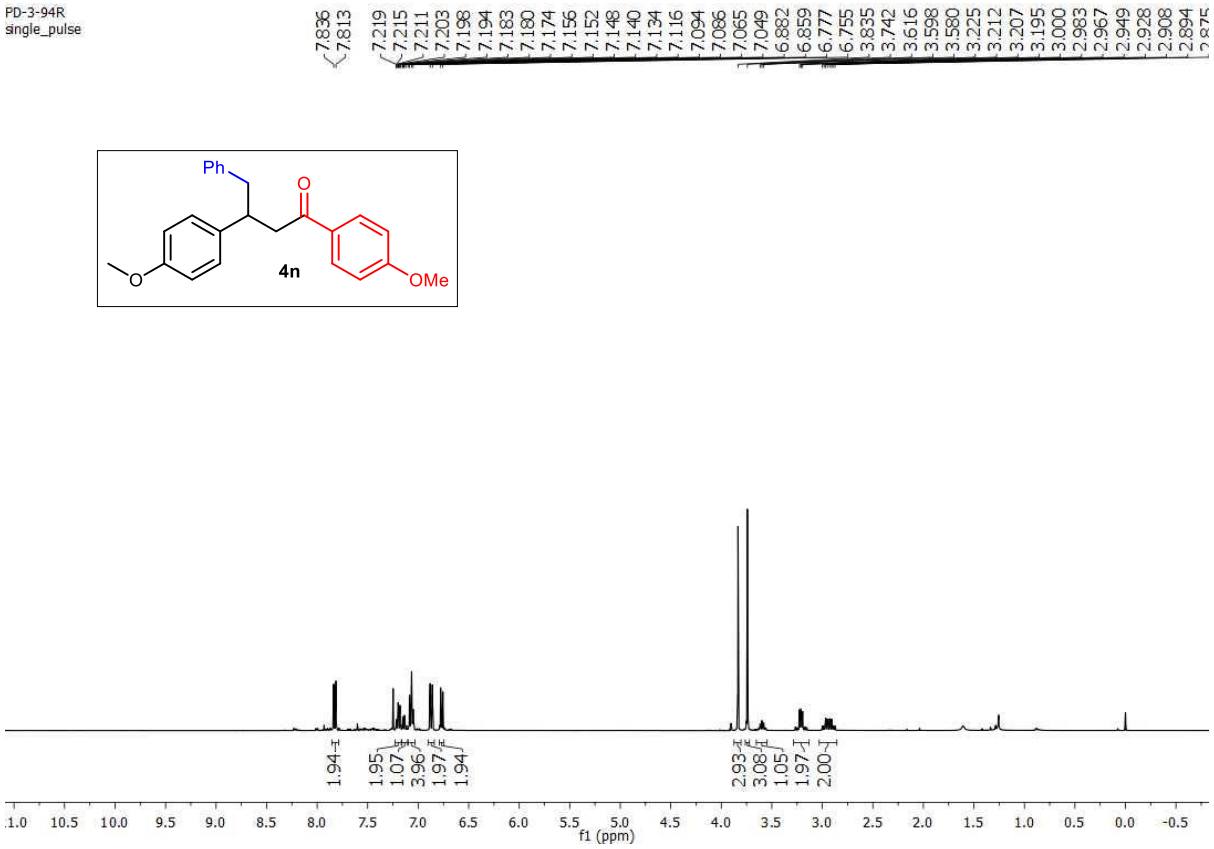

$^{13}$C spectra of **4l**



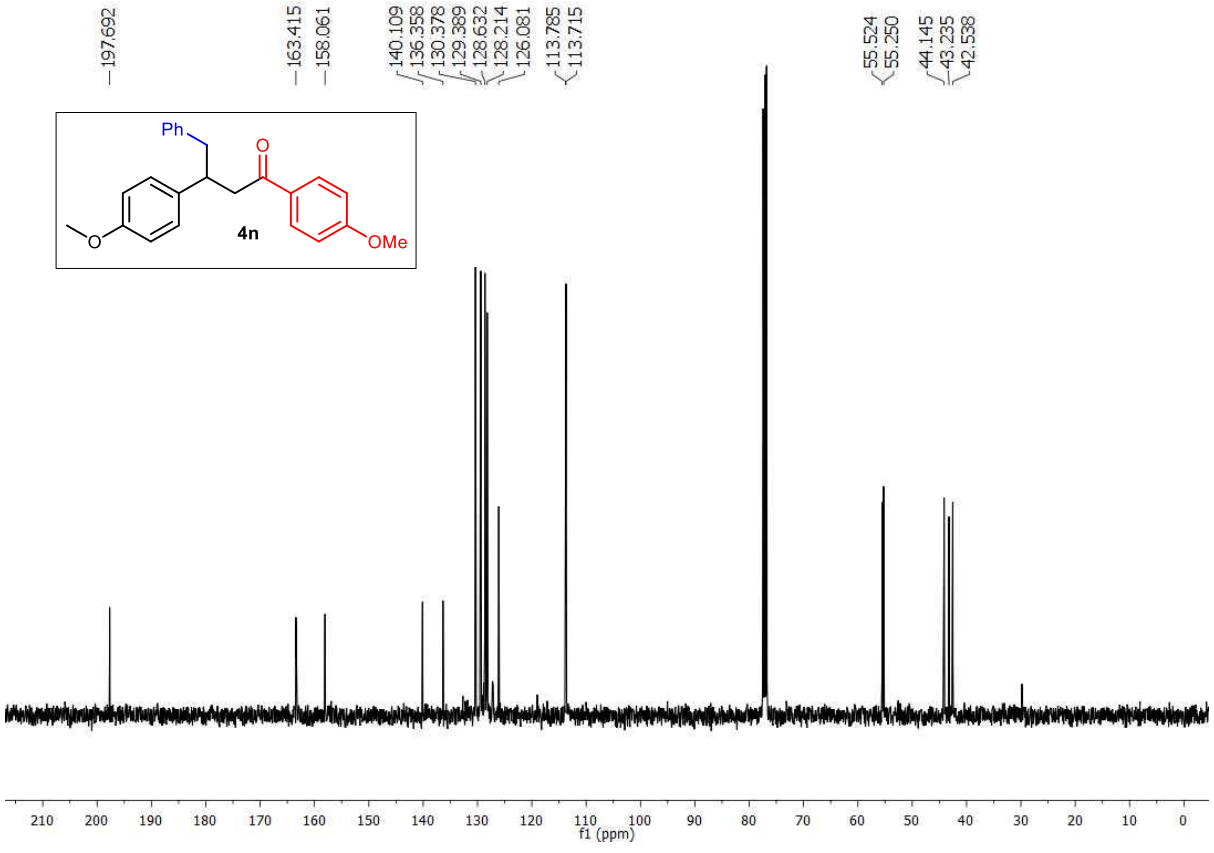

$^{1}$H spectra of **4m**



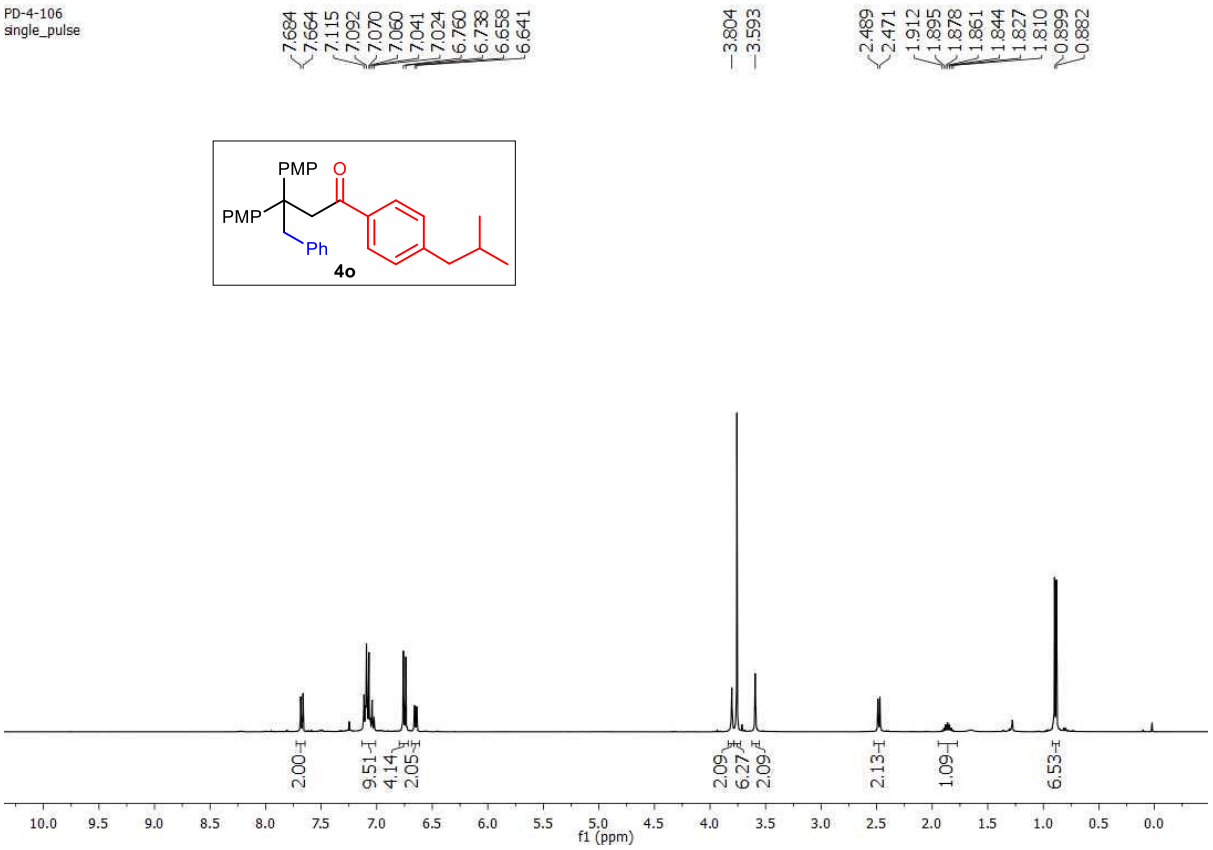

$^{13}$C spectra of **4m**



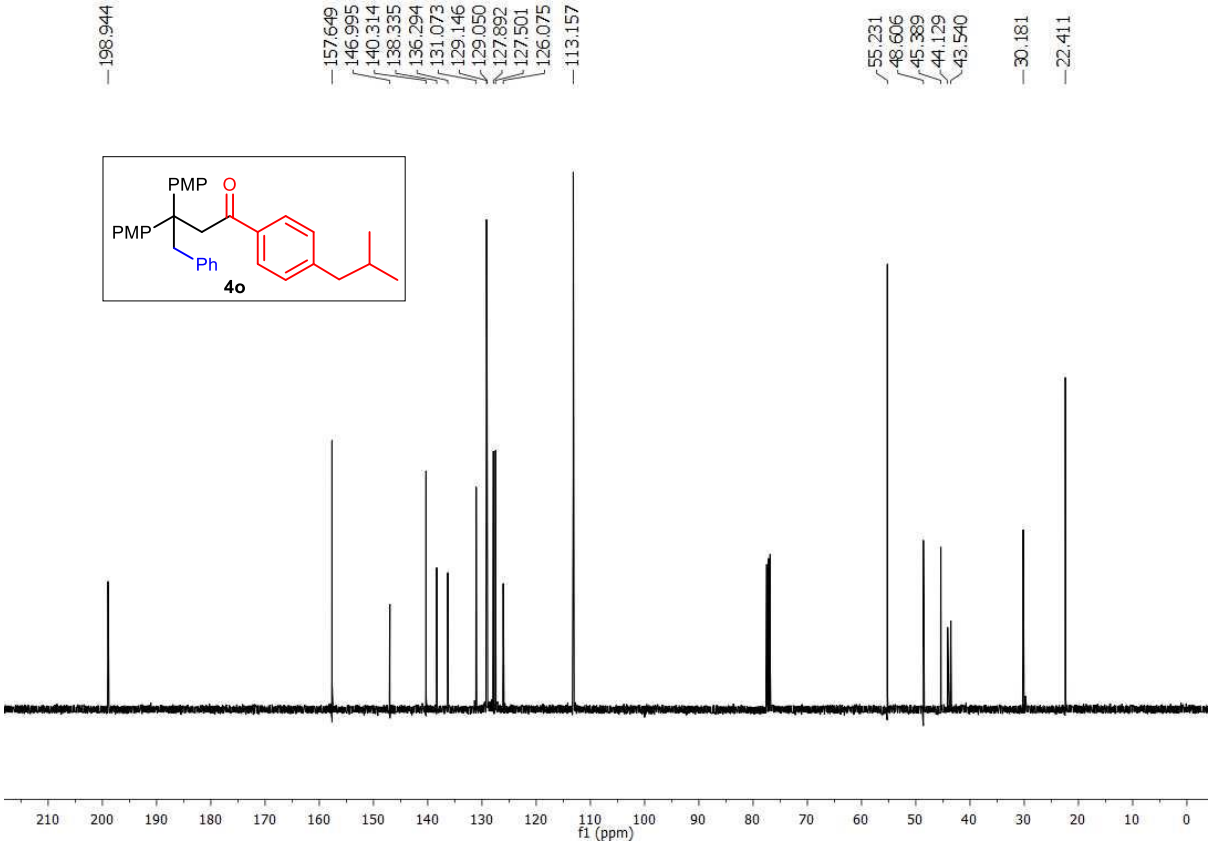

$^{1}$H spectra of **4n**



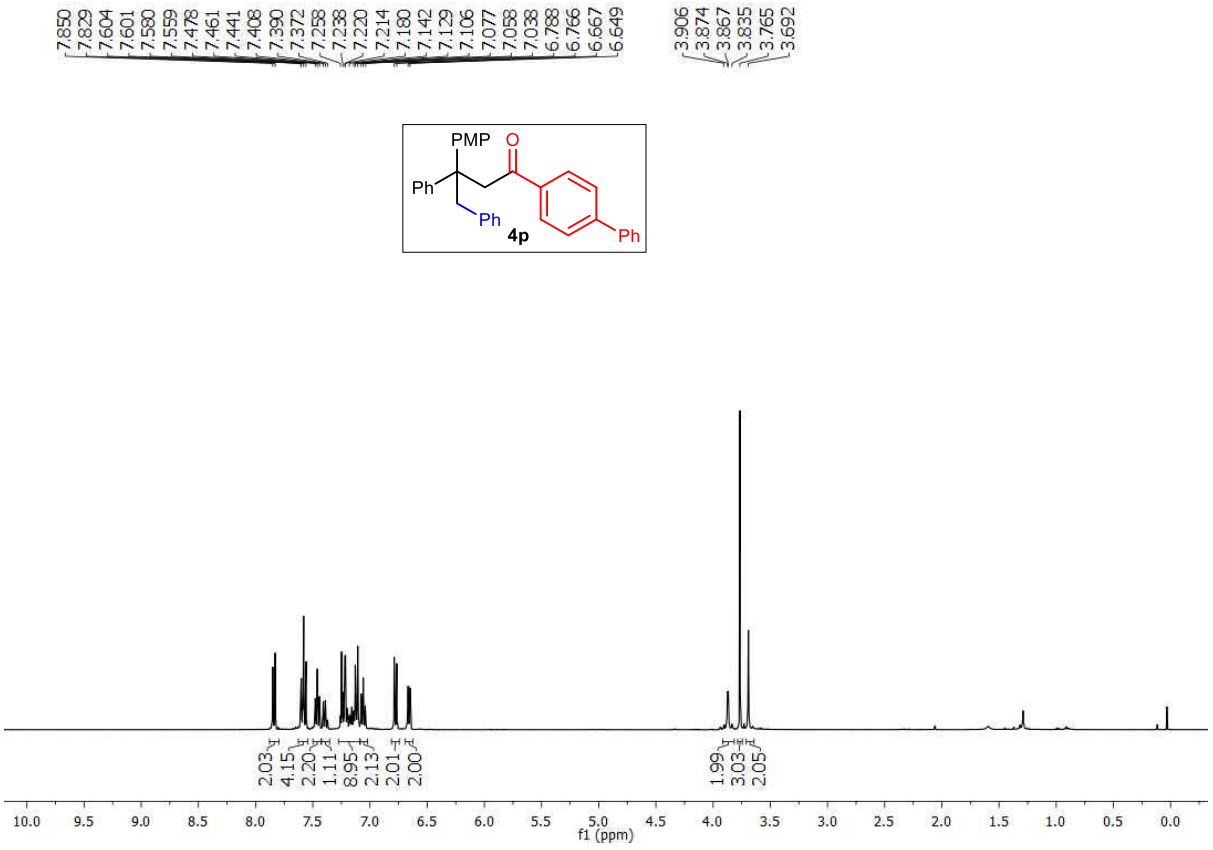

$^{13}$C spectra of **4n**



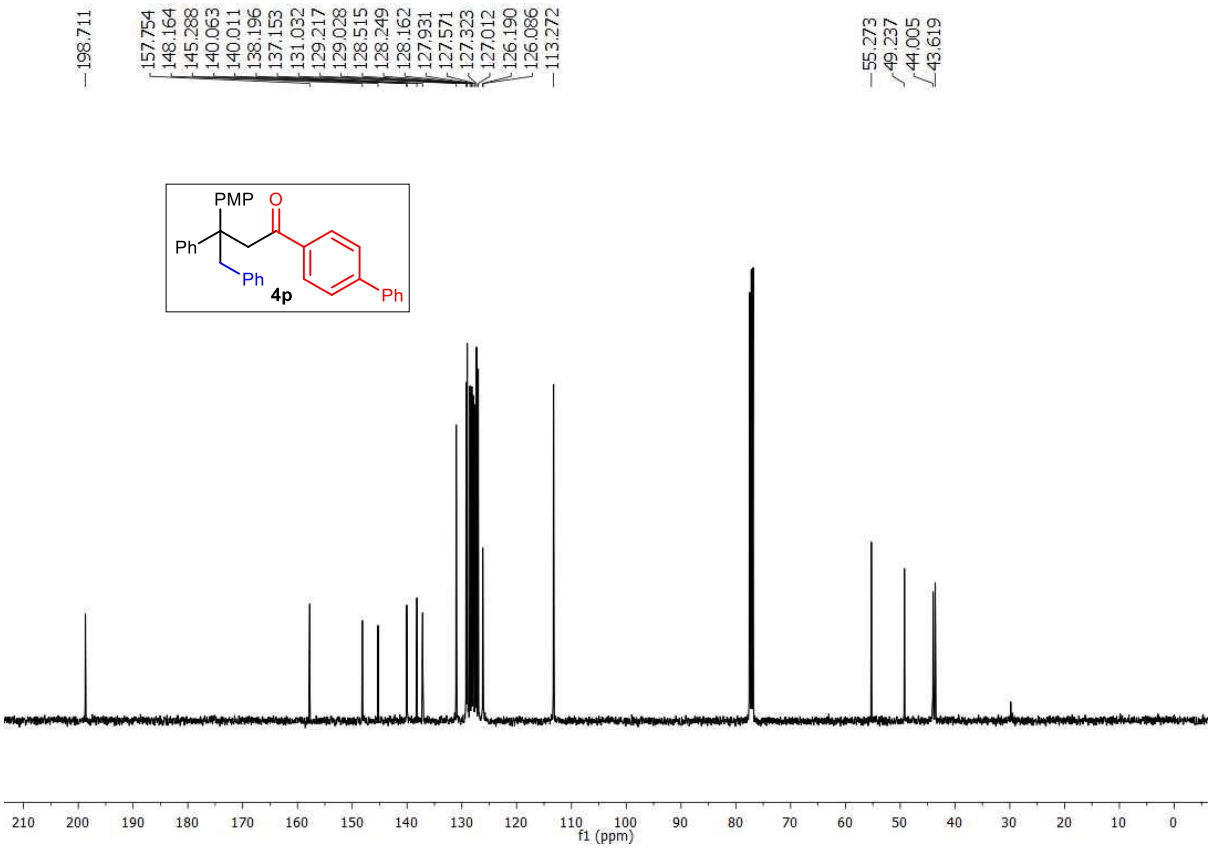

$^{1}$H spectra of **4o**



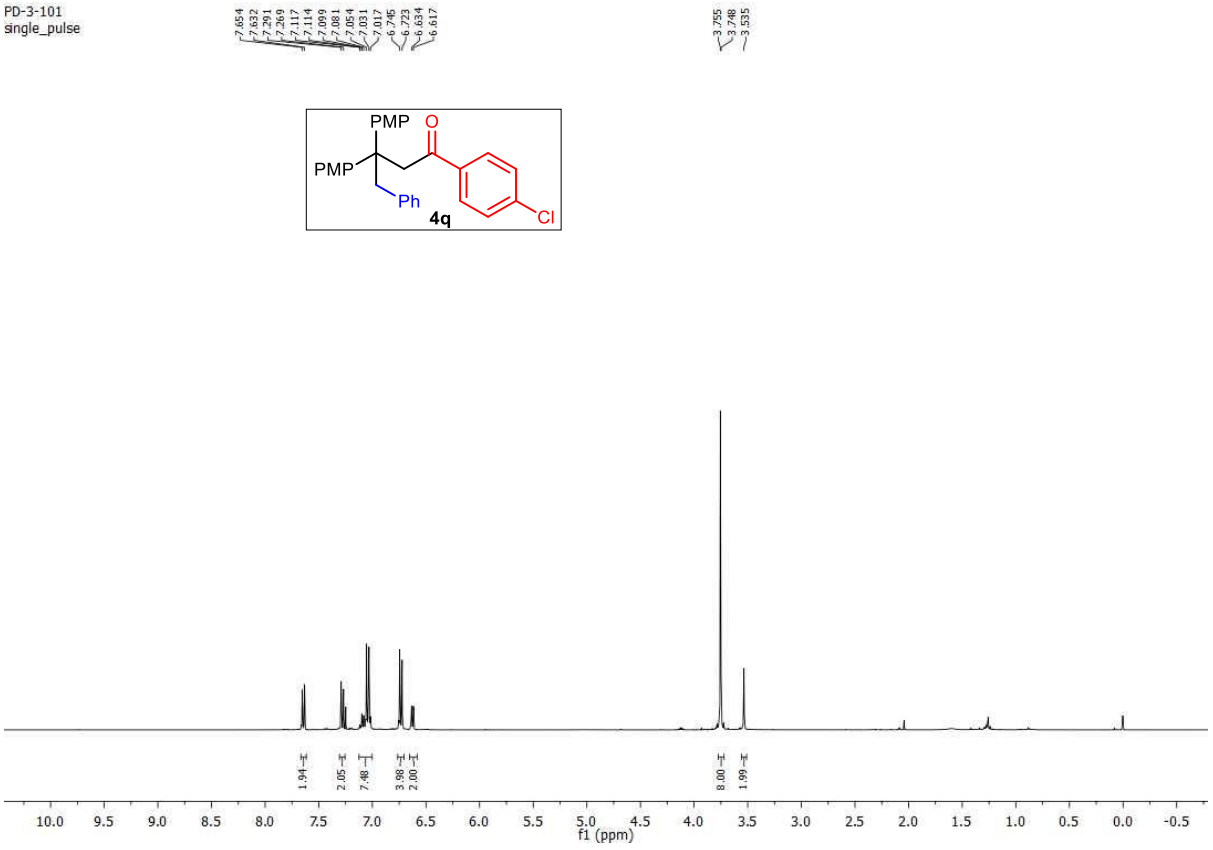

$^{13}$C spectra of **4o**



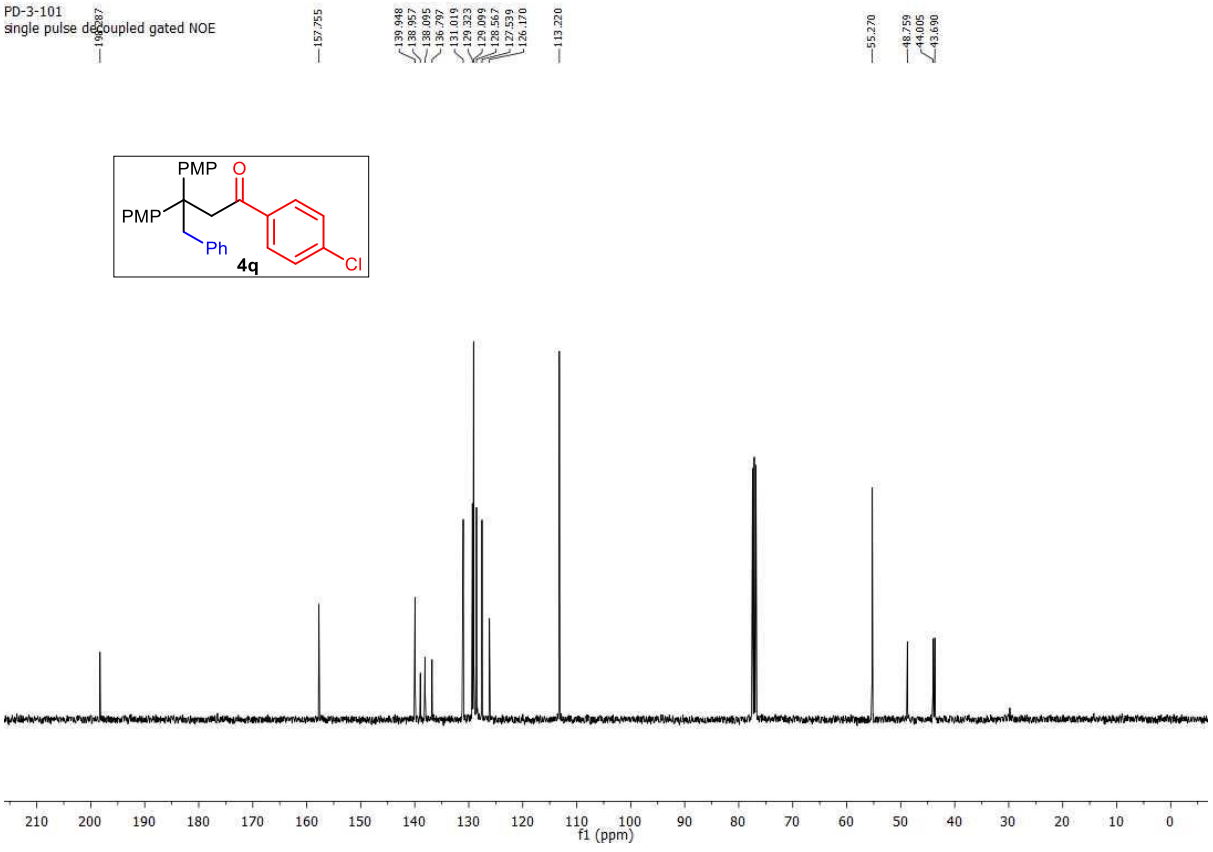

$^{1}$H spectra of **4p**



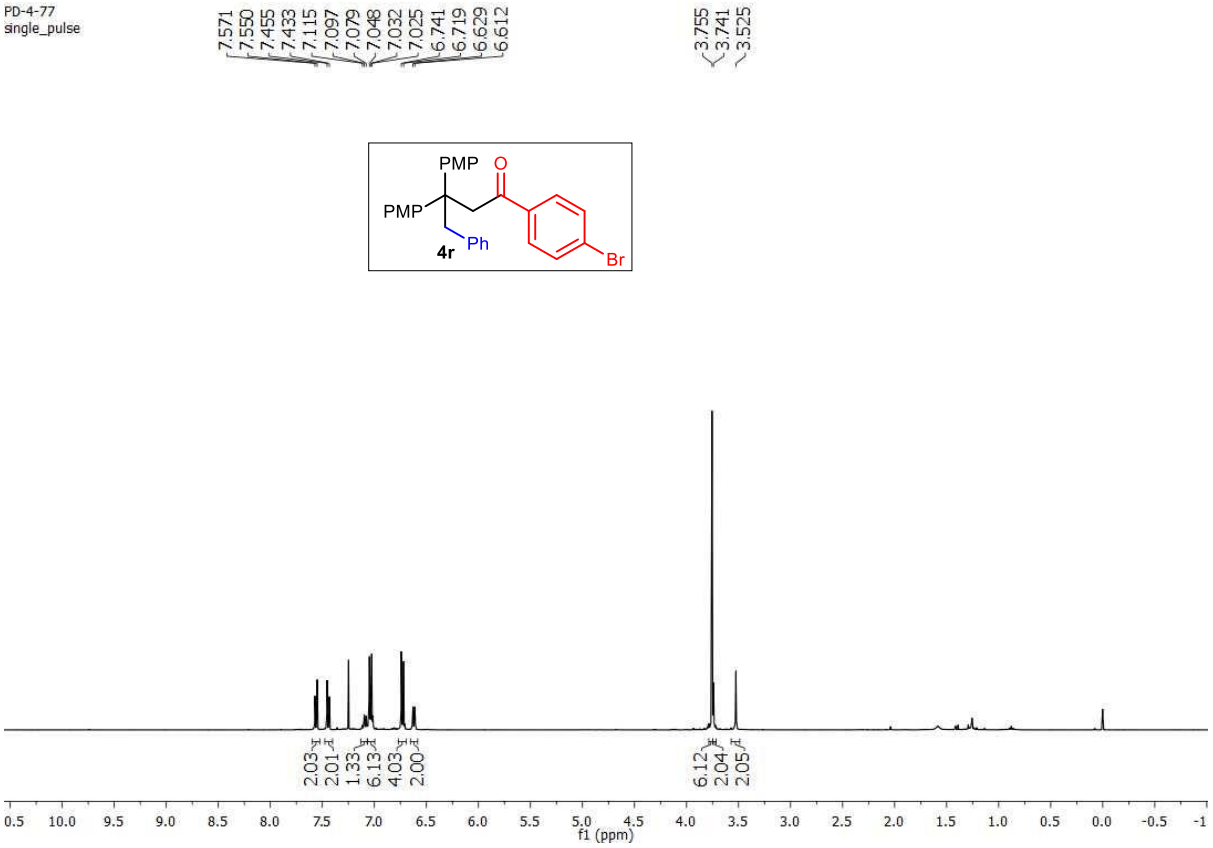

$^{13}$C spectra of **4p**



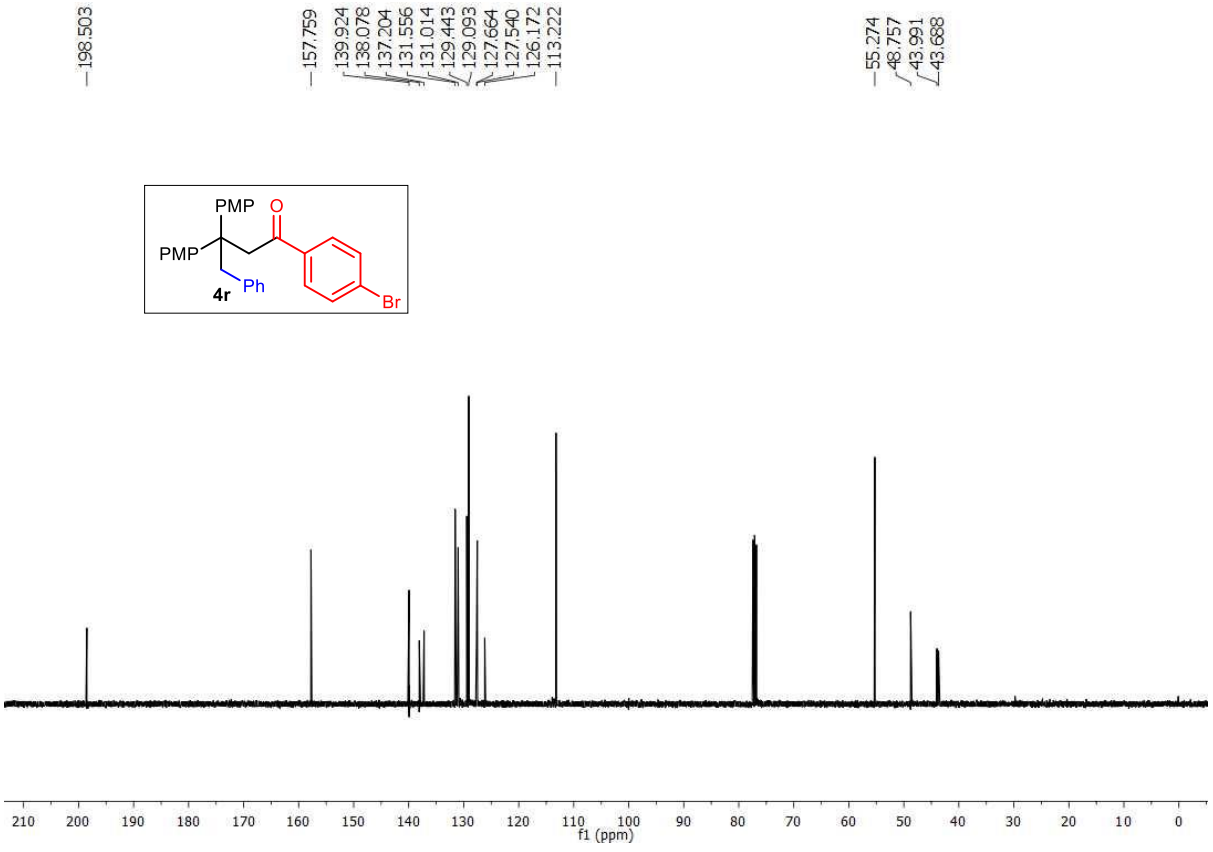

$^{1}$H spectra of **4q**




$^{13}$C spectra of **4q**




$^{1}$H spectra of **4r**

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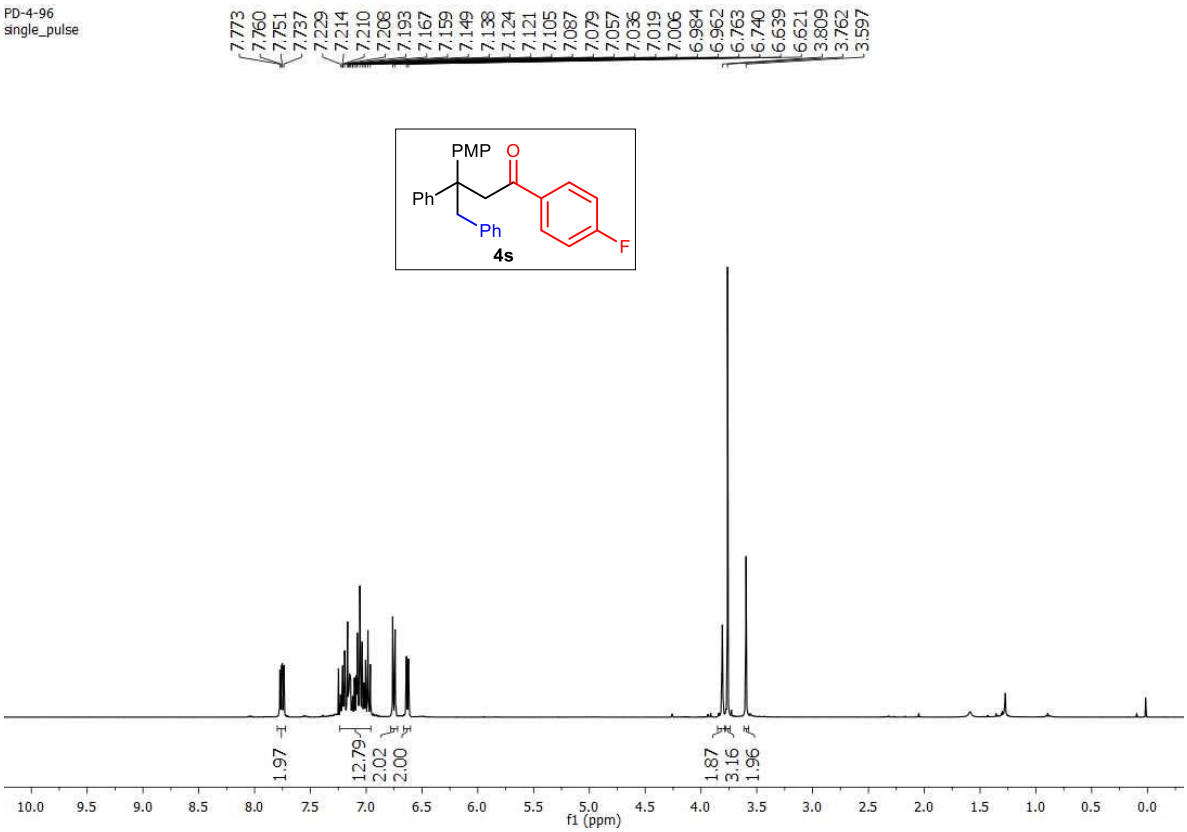
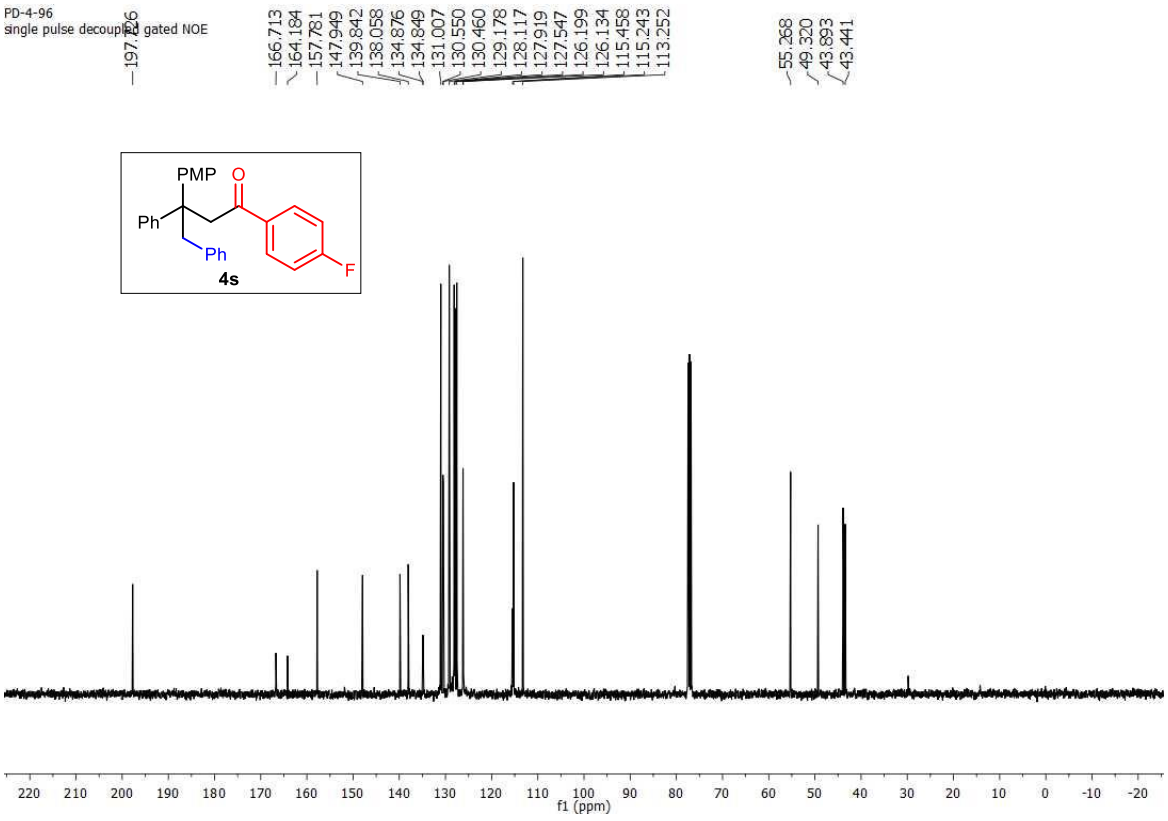
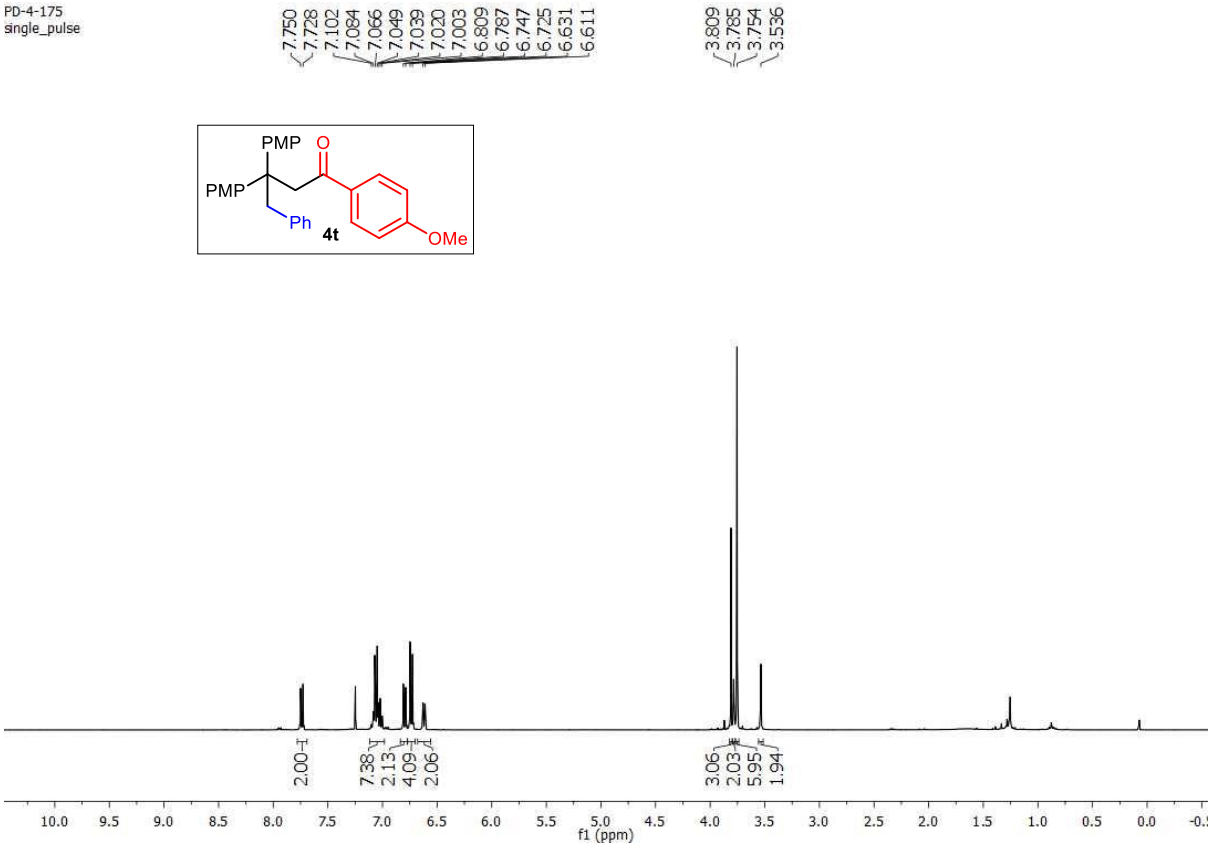


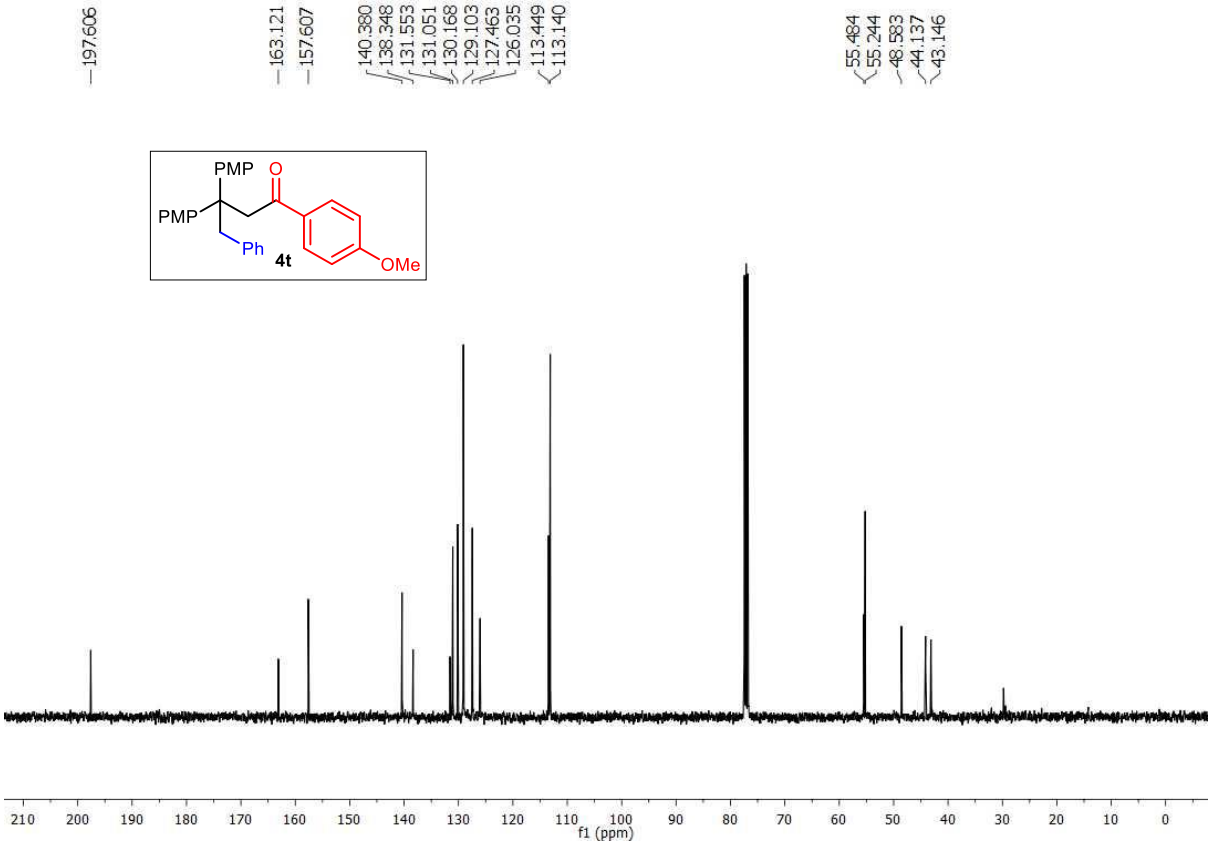

$^{1}$H spectra of **4s**



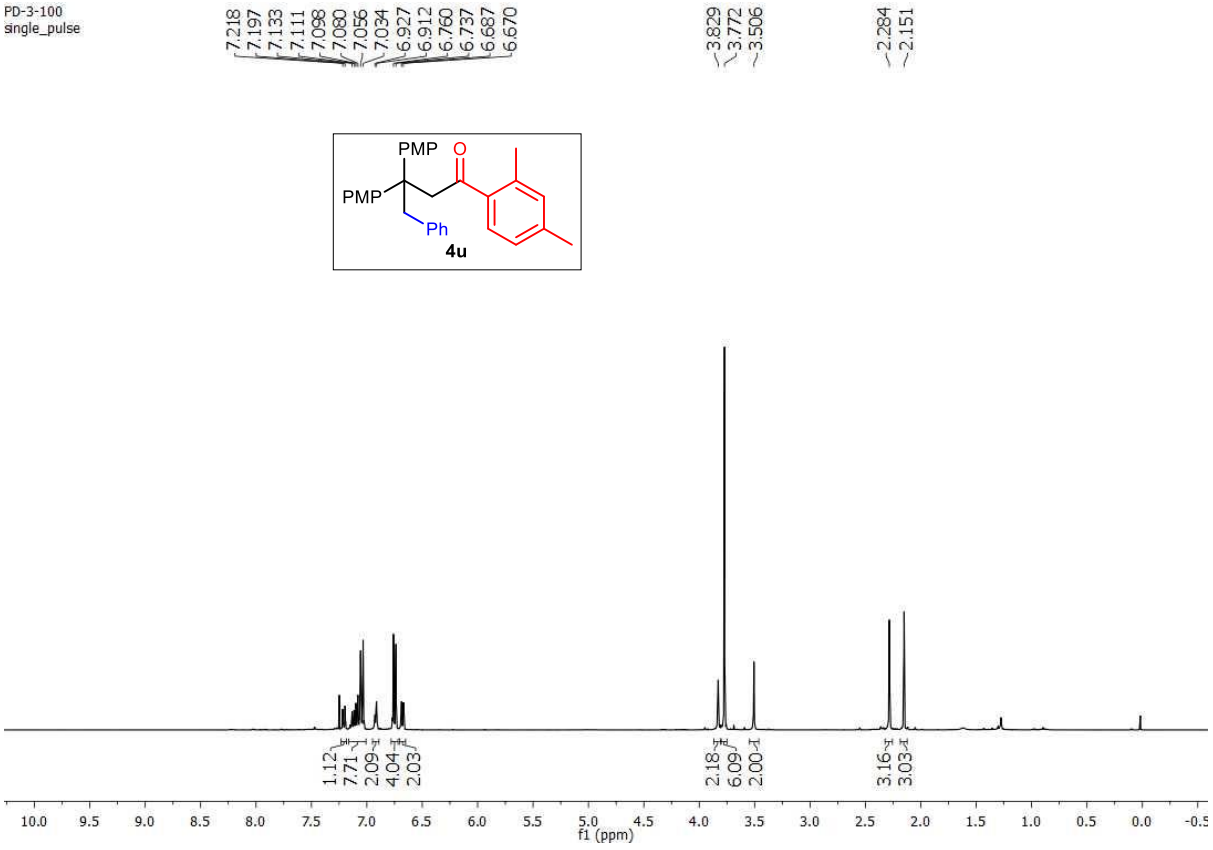

$^{13}$C spectra of **4s**



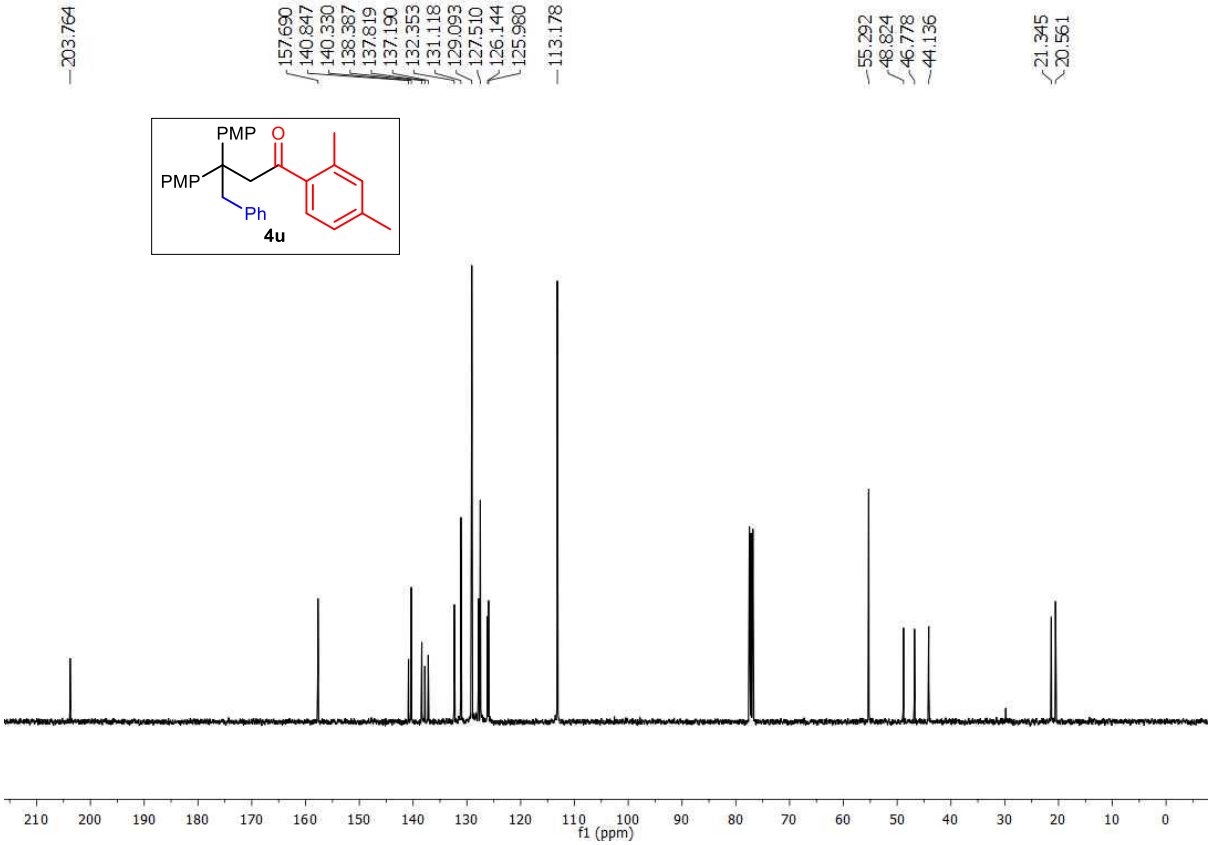

$^{1}$H spectra of **4t**



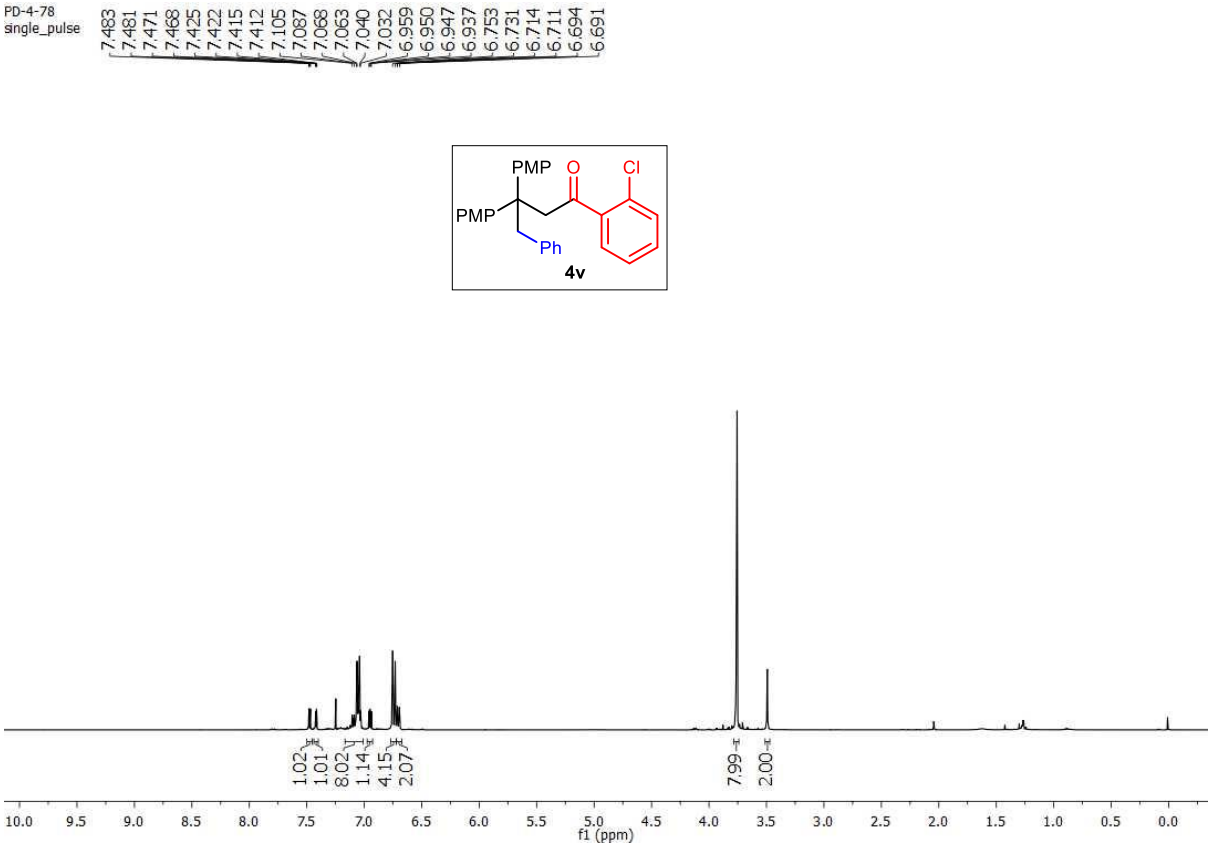

$^{13}$C spectra of **4t**



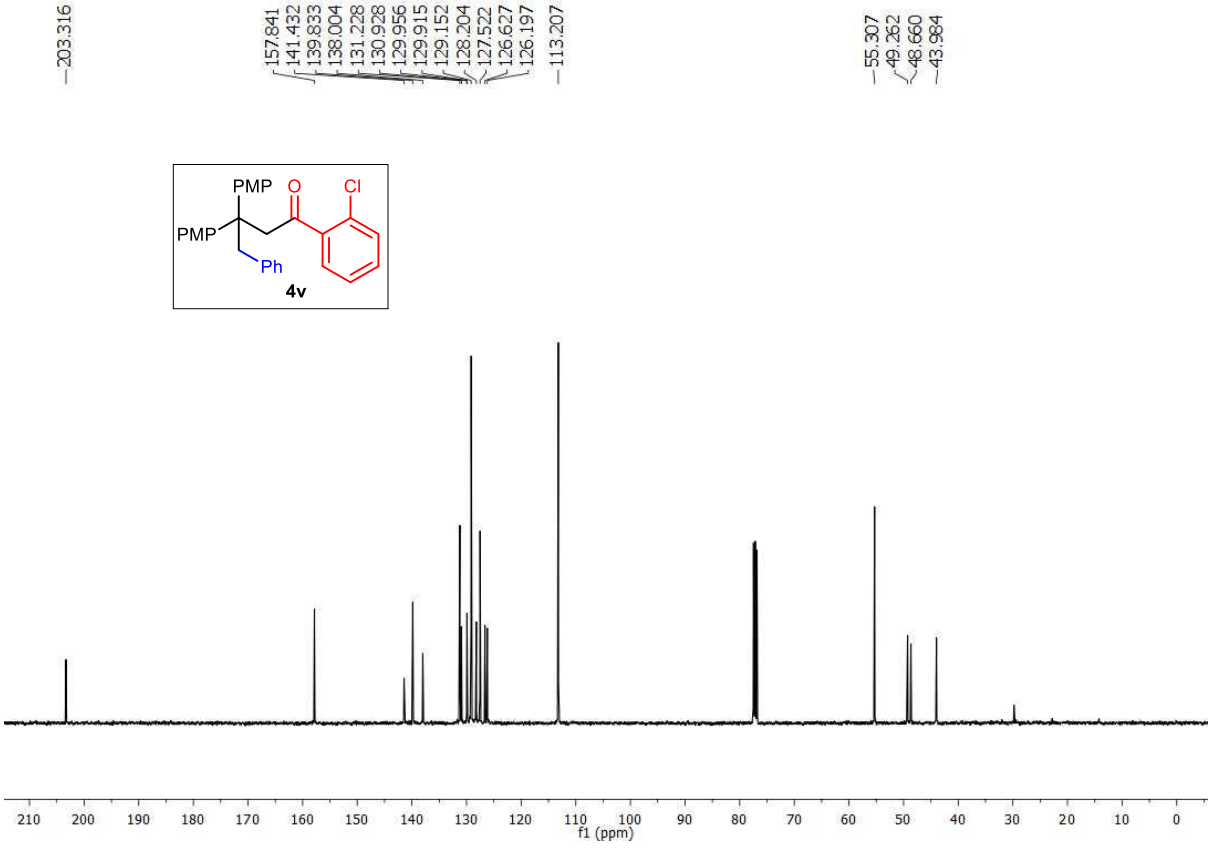

$^{1}$H spectra of **4u**



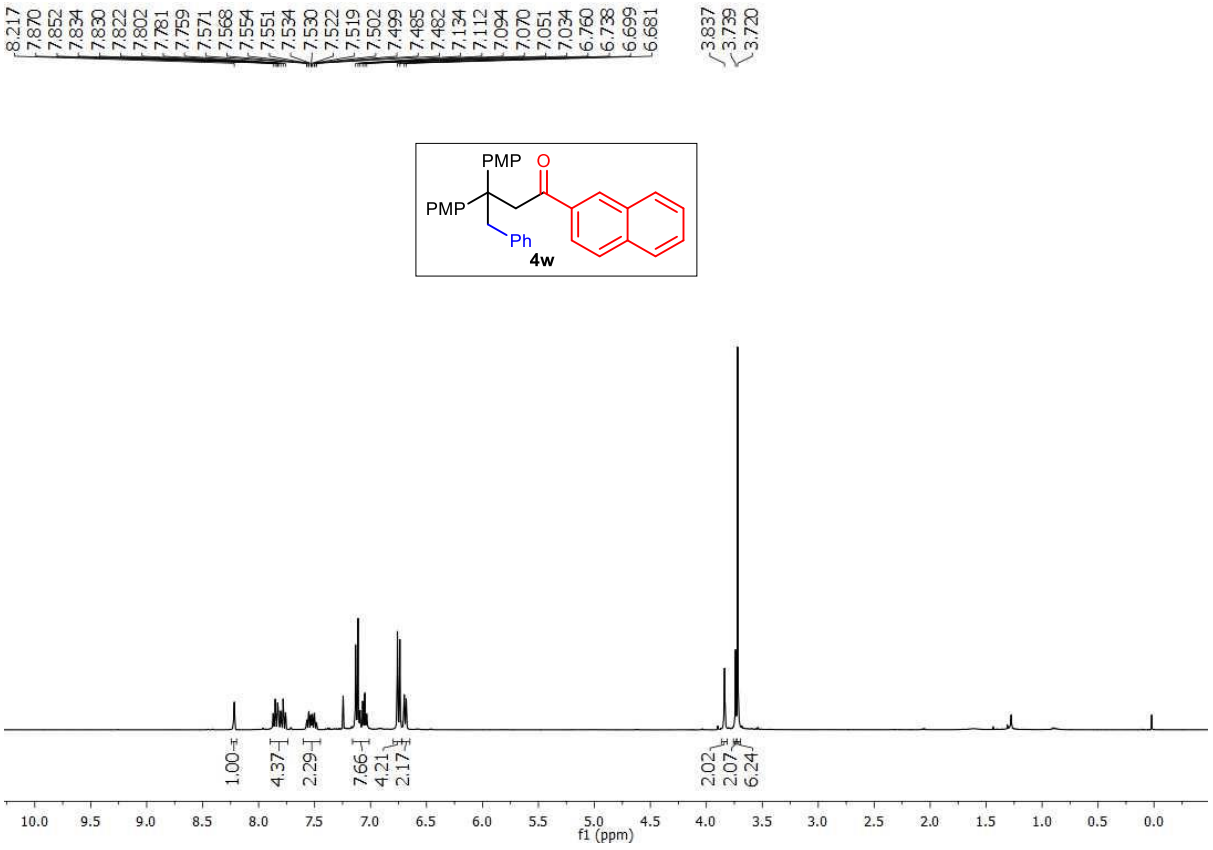

$^{13}$C spectra of **4u**



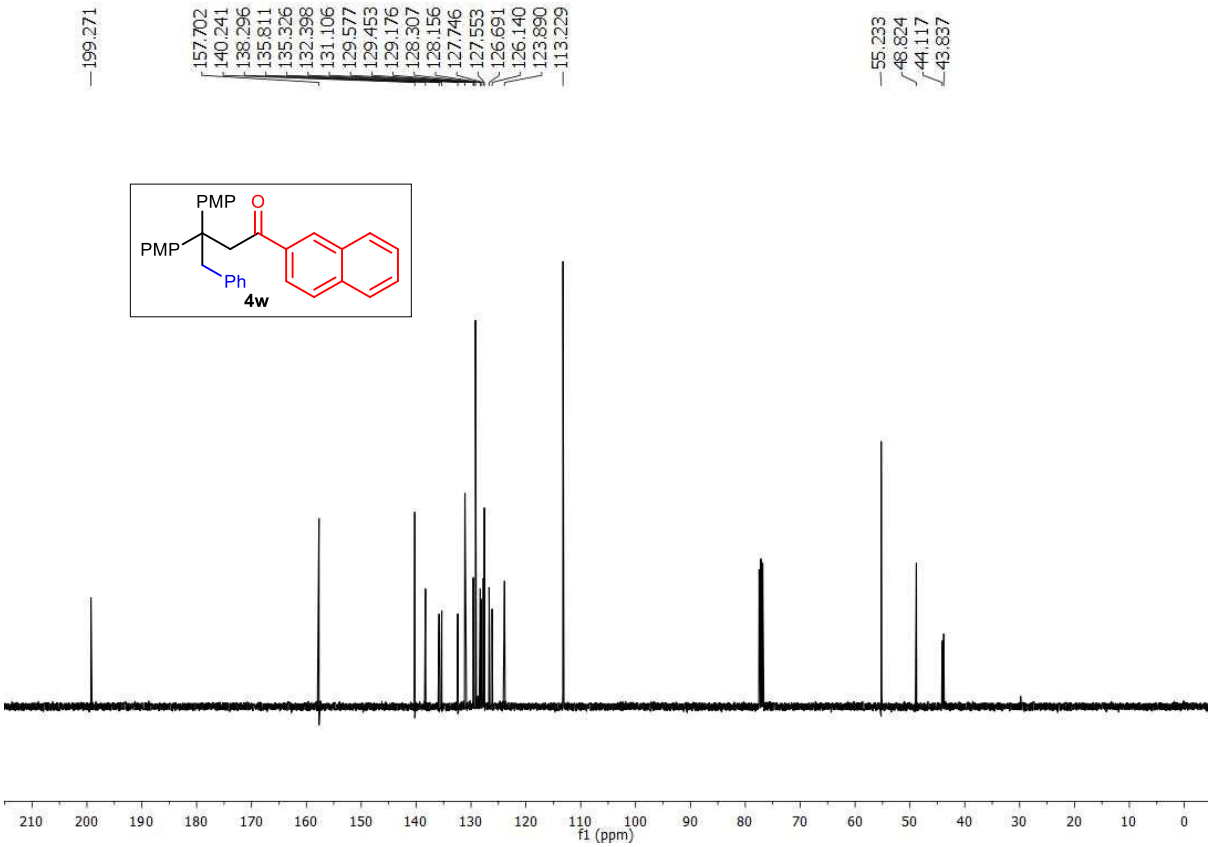

$^{1}$H spectra of **4v**



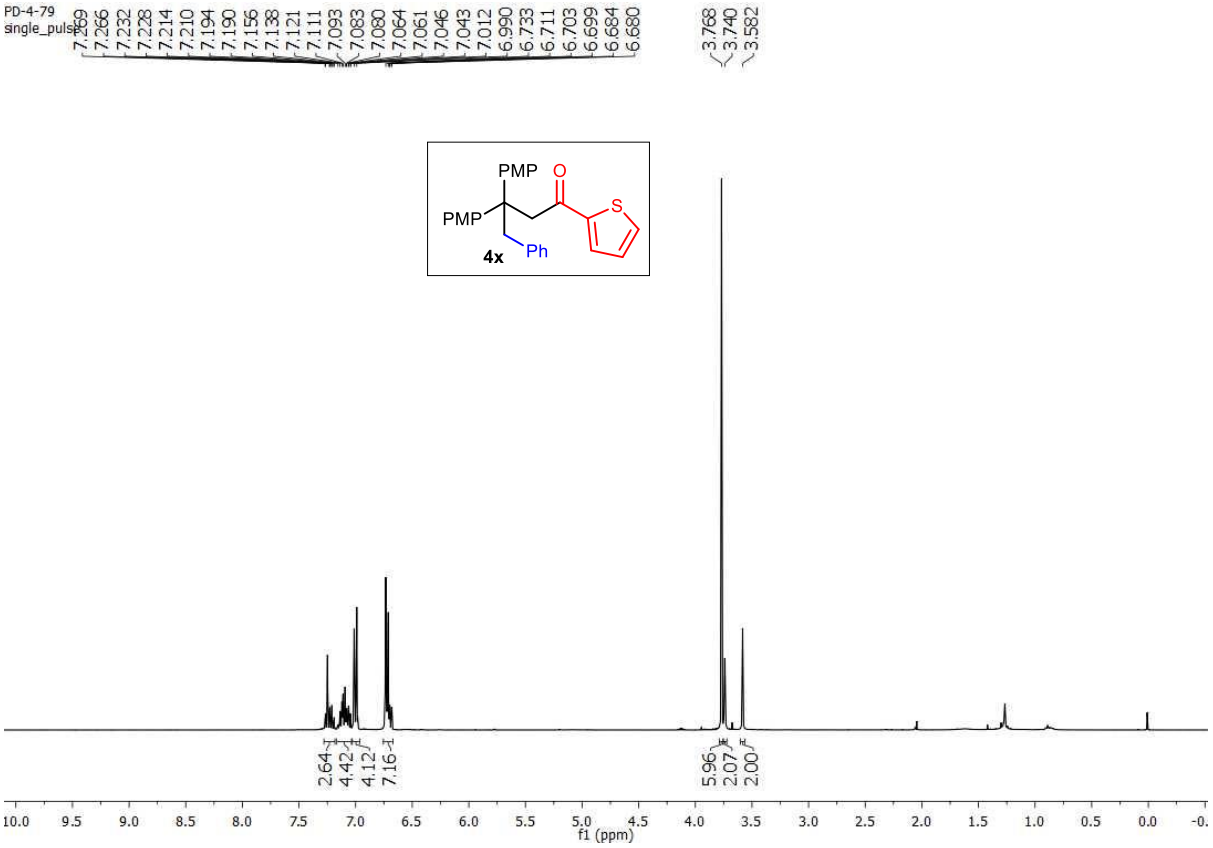

$^{13}$C spectra of **4v**



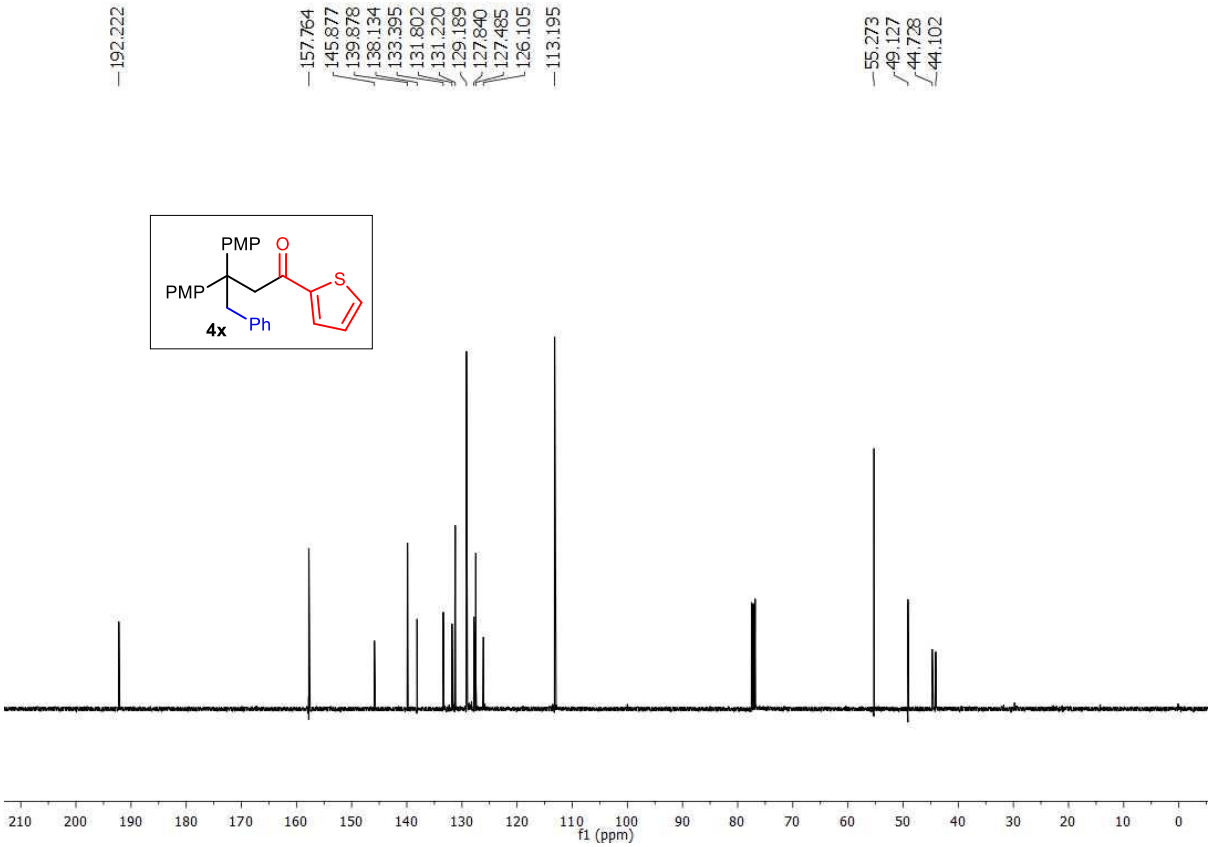

$^{1}$H spectra of **4w**



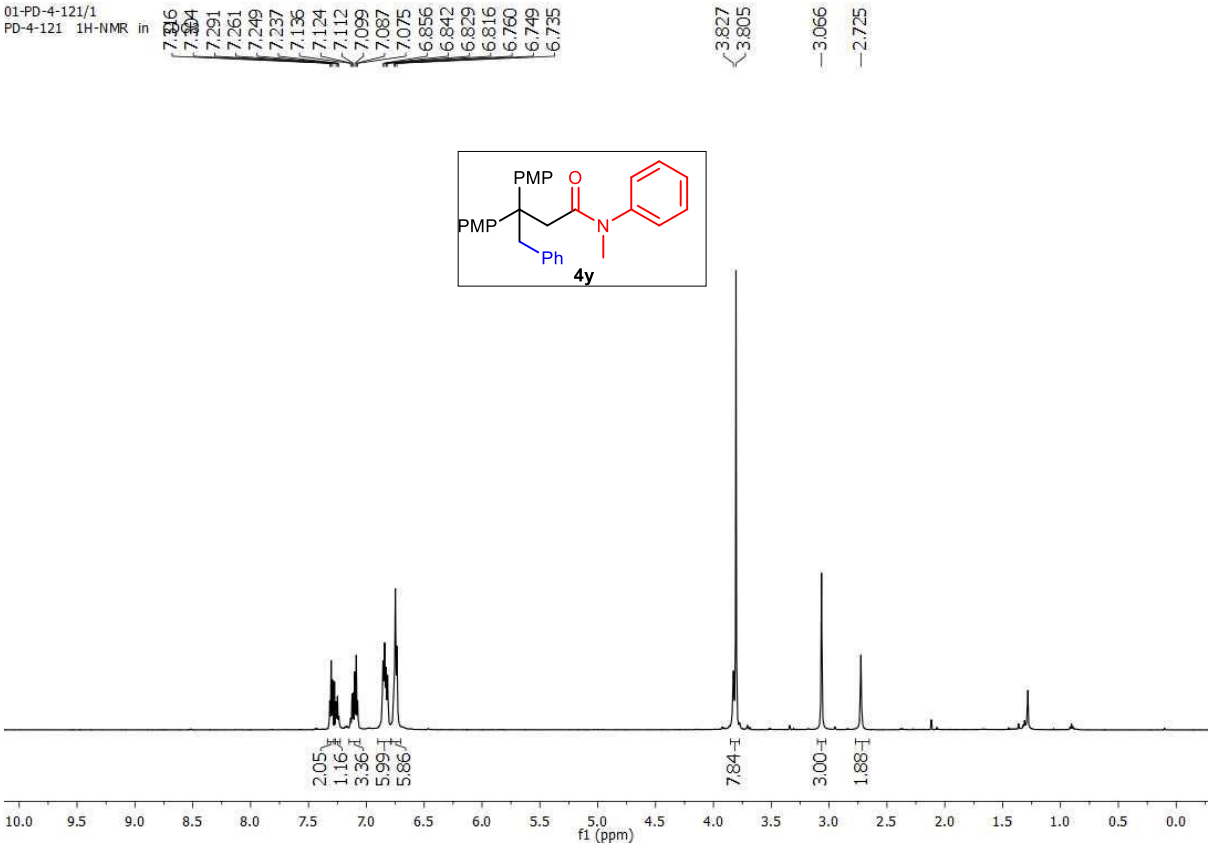

$^{13}$C spectra of **4w**



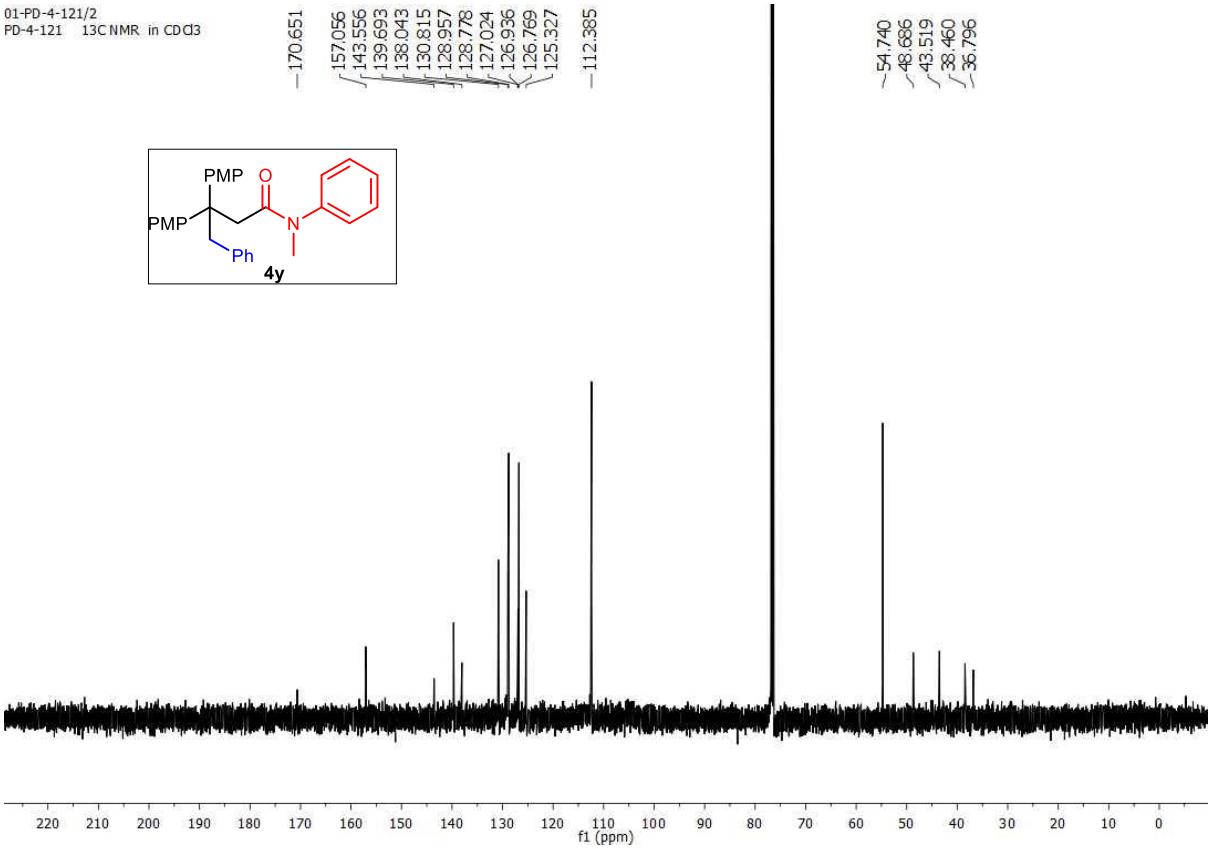

$^{1}$H spectra of **4x**



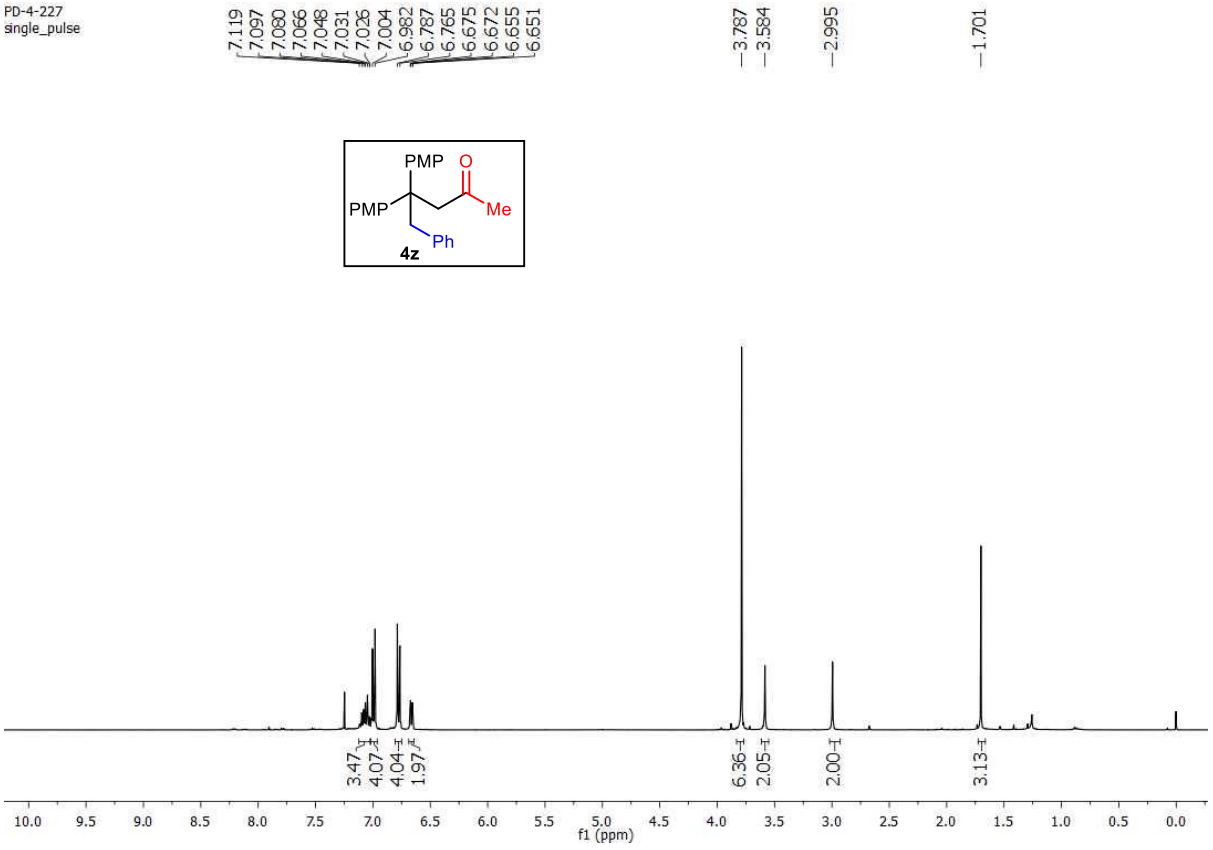

$^{13}$C spectra of **4x**



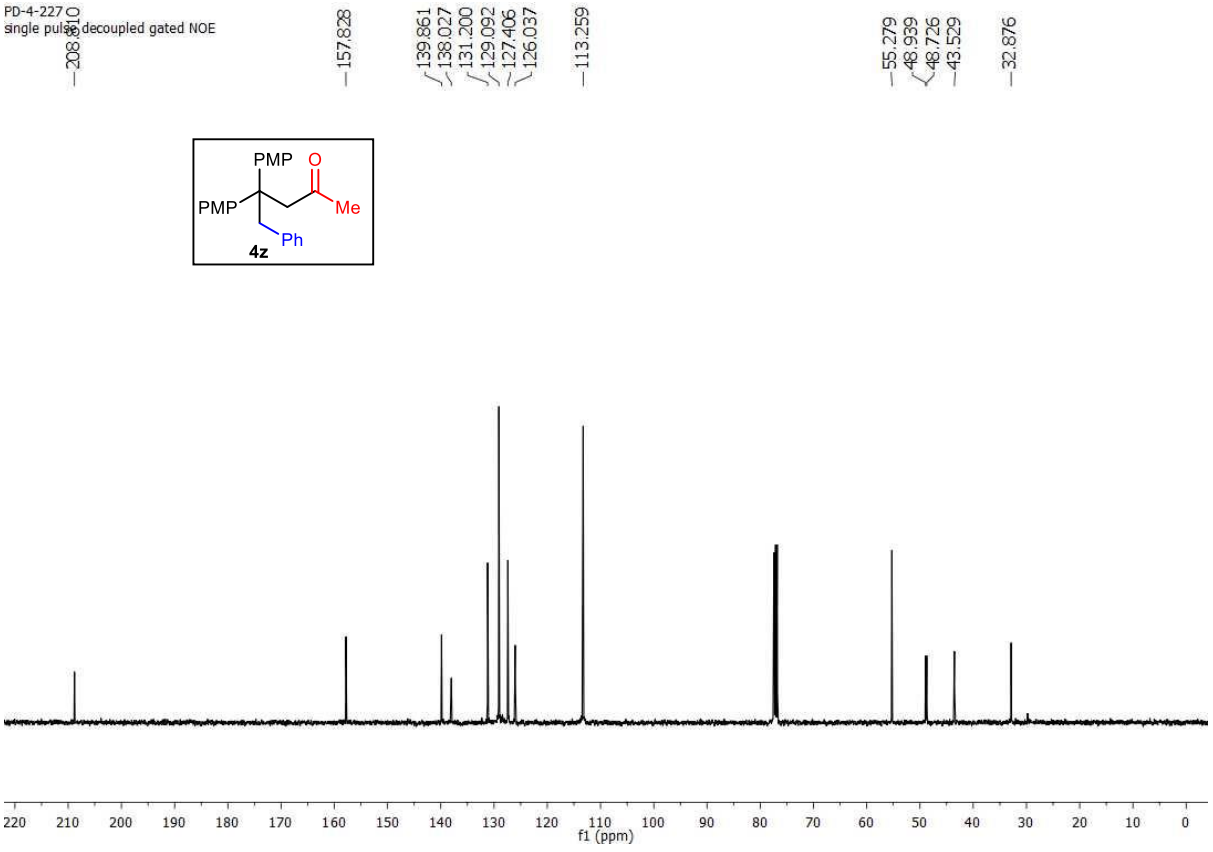

$^{1}$H spectra of **4y**



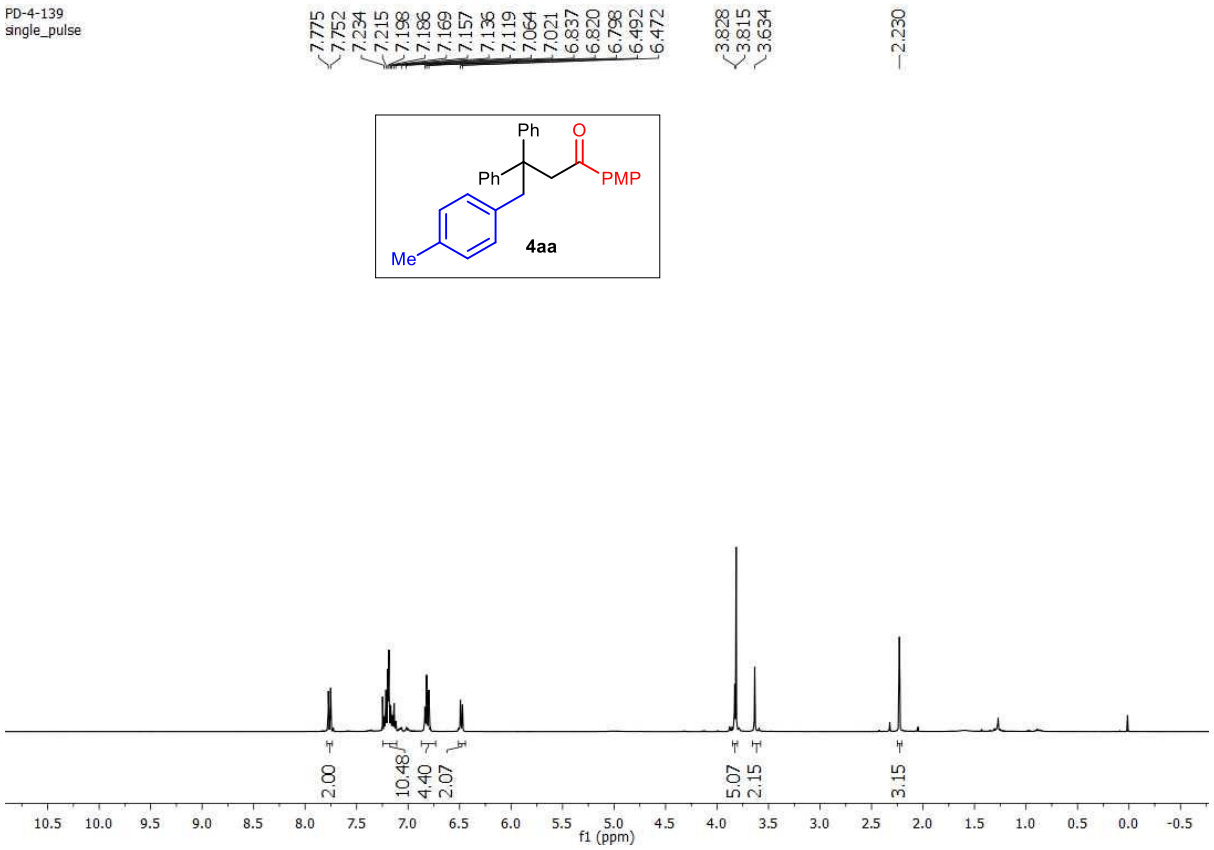

$^{13}$C spectra of **4y**



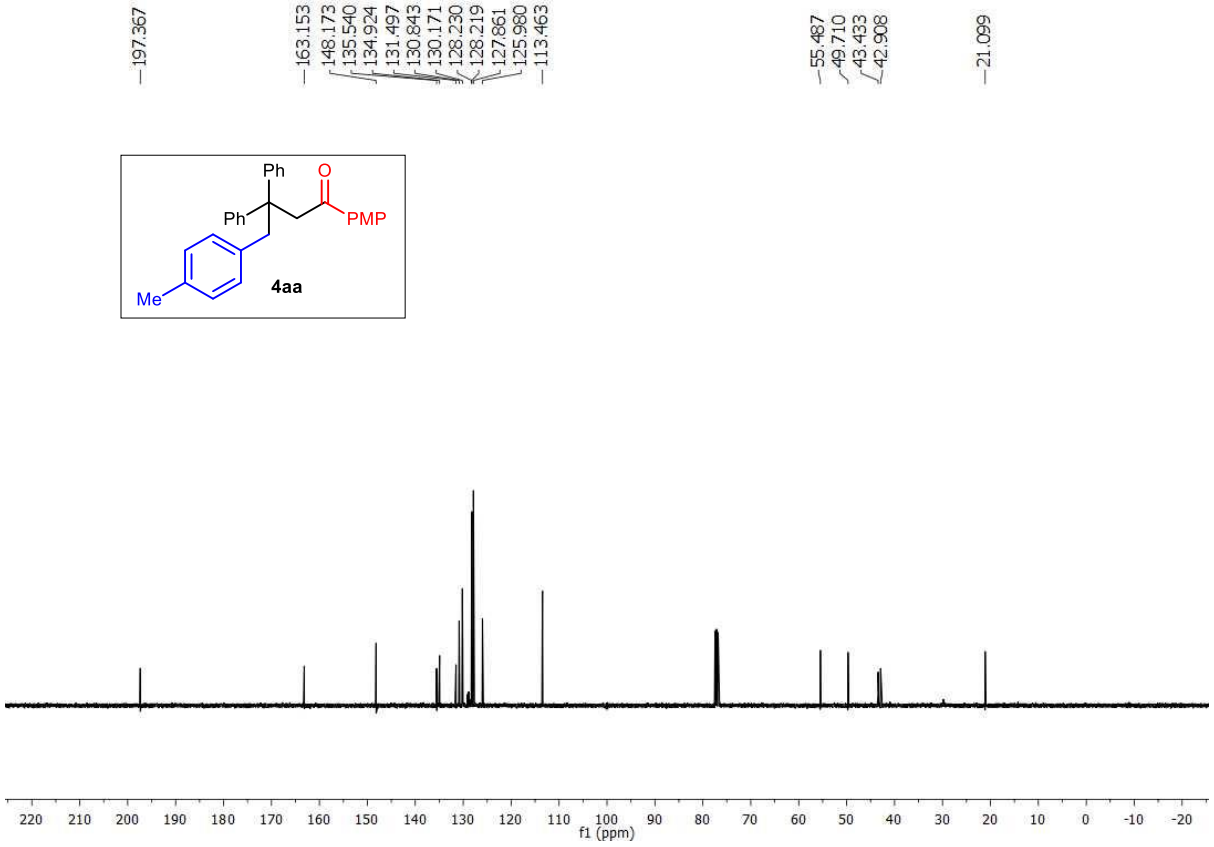

$^{1}$H spectra of **4z**



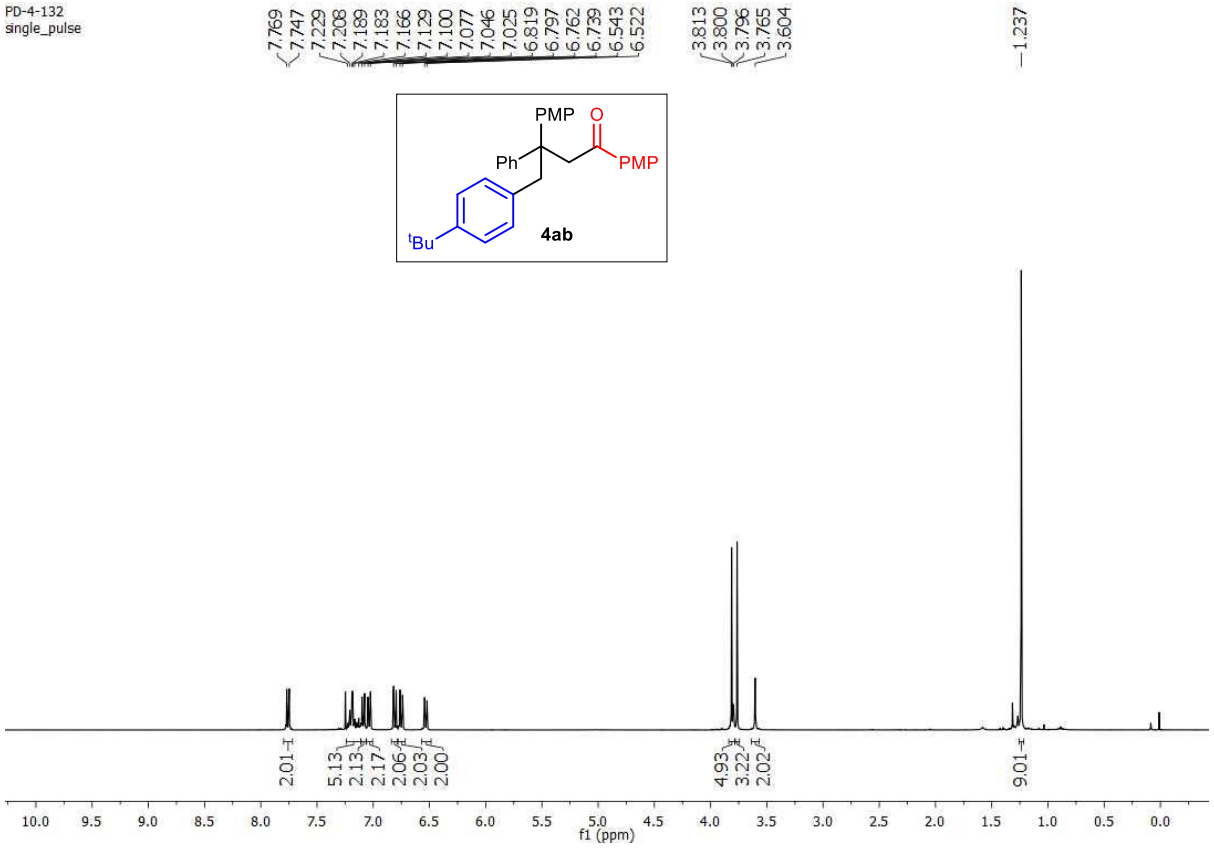

$^{13}$C spectra of **4z**



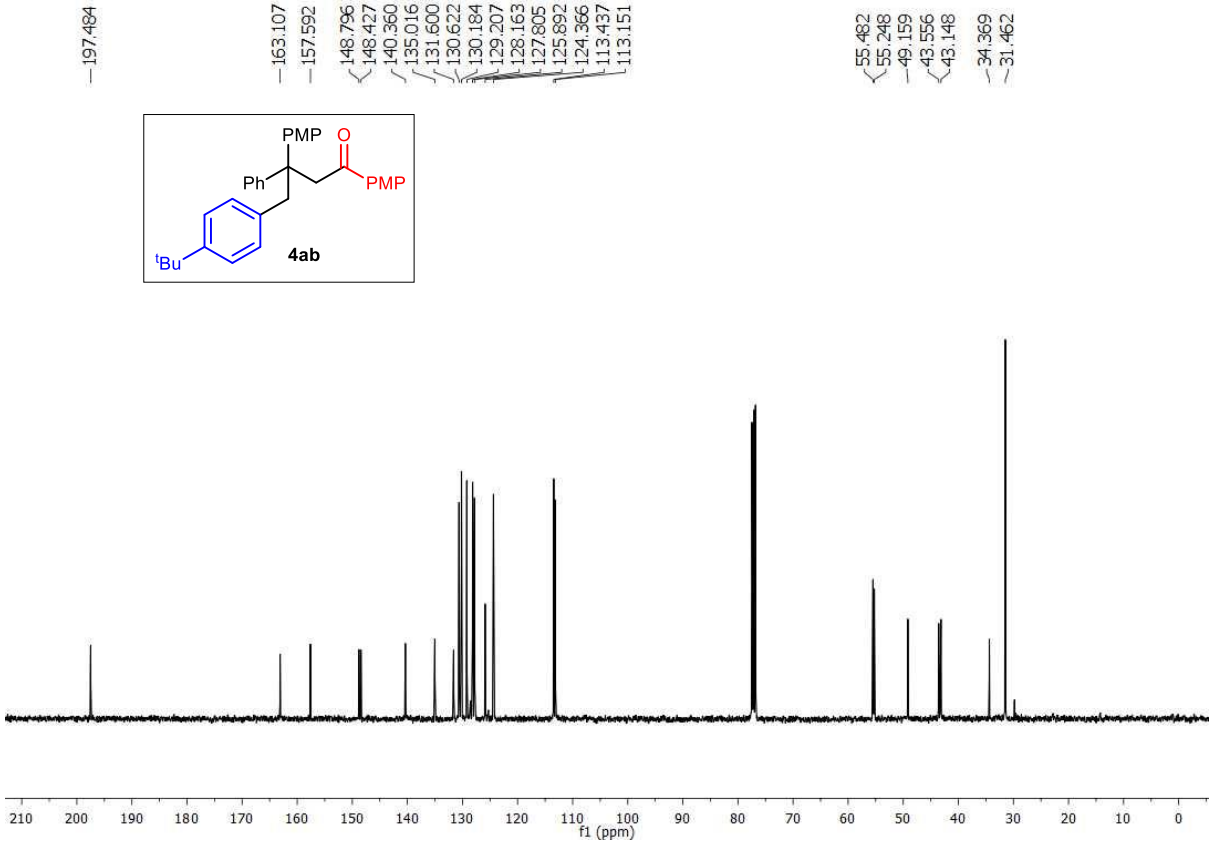

$^{1}$H spectra of **4aa**



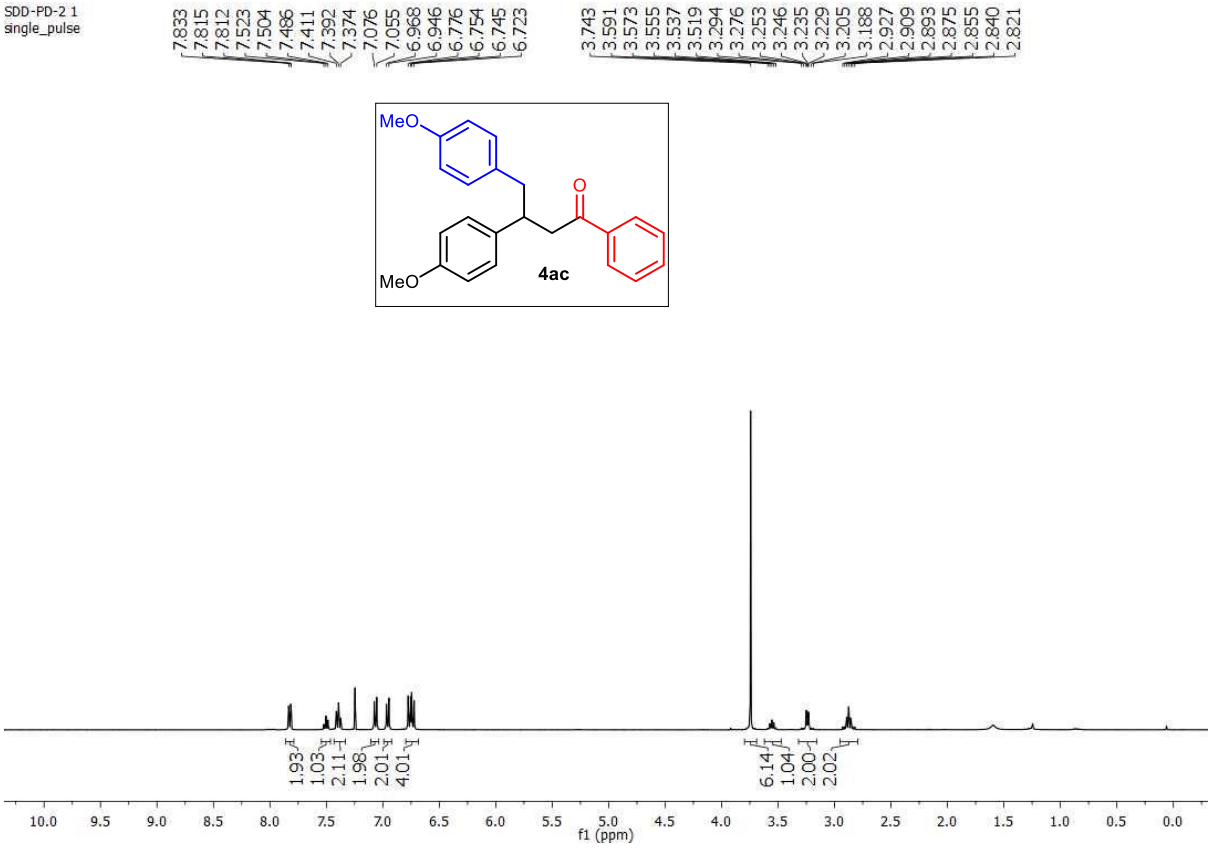

$^{13}$C spectra of **4aa**



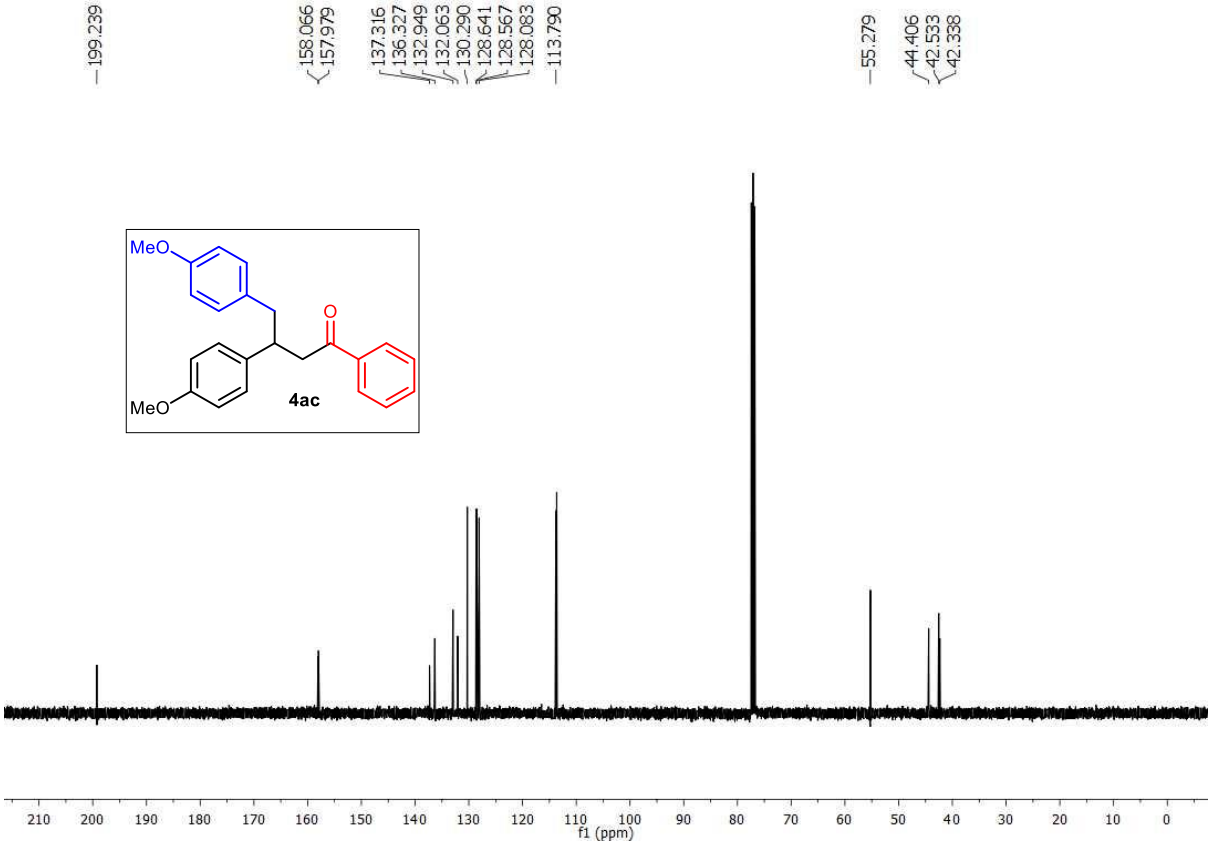

$^{1}$H spectra of **4ab**



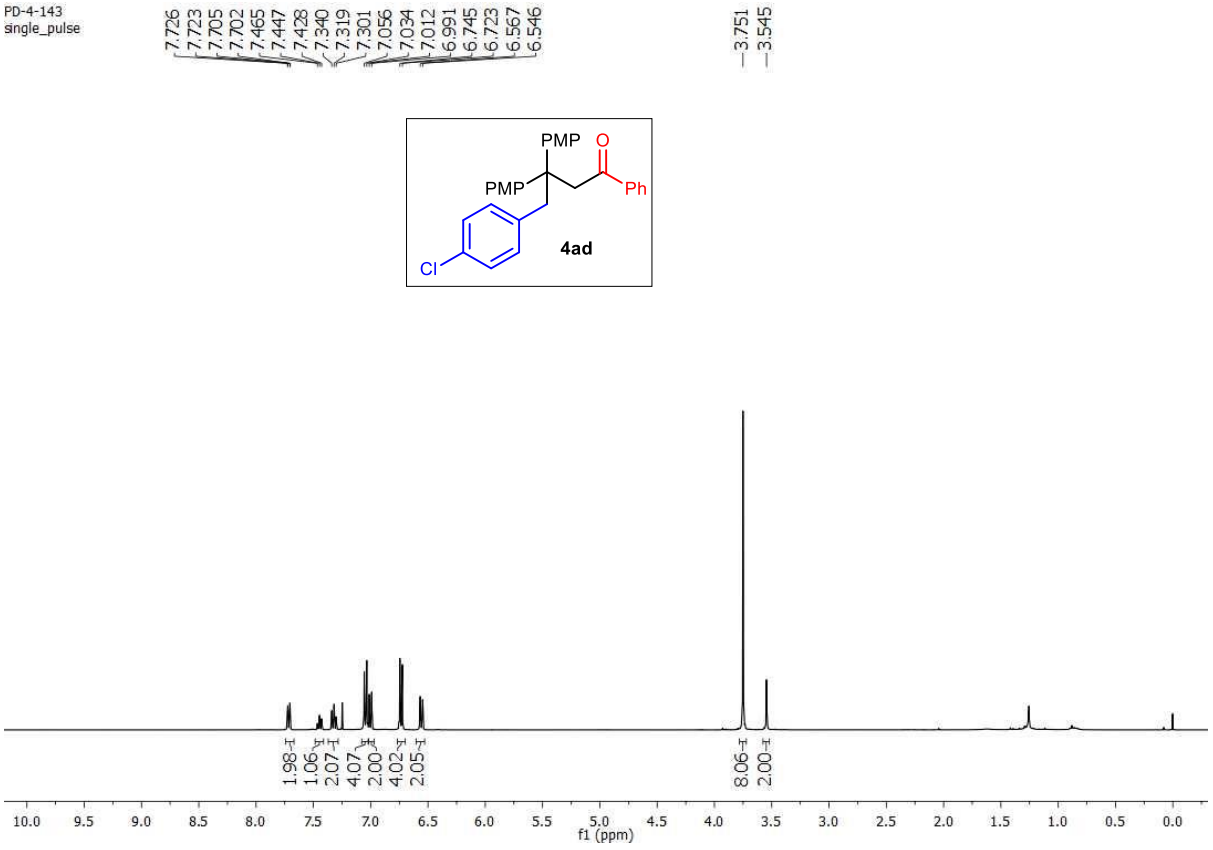

$^{13}$C spectra of **4ab**



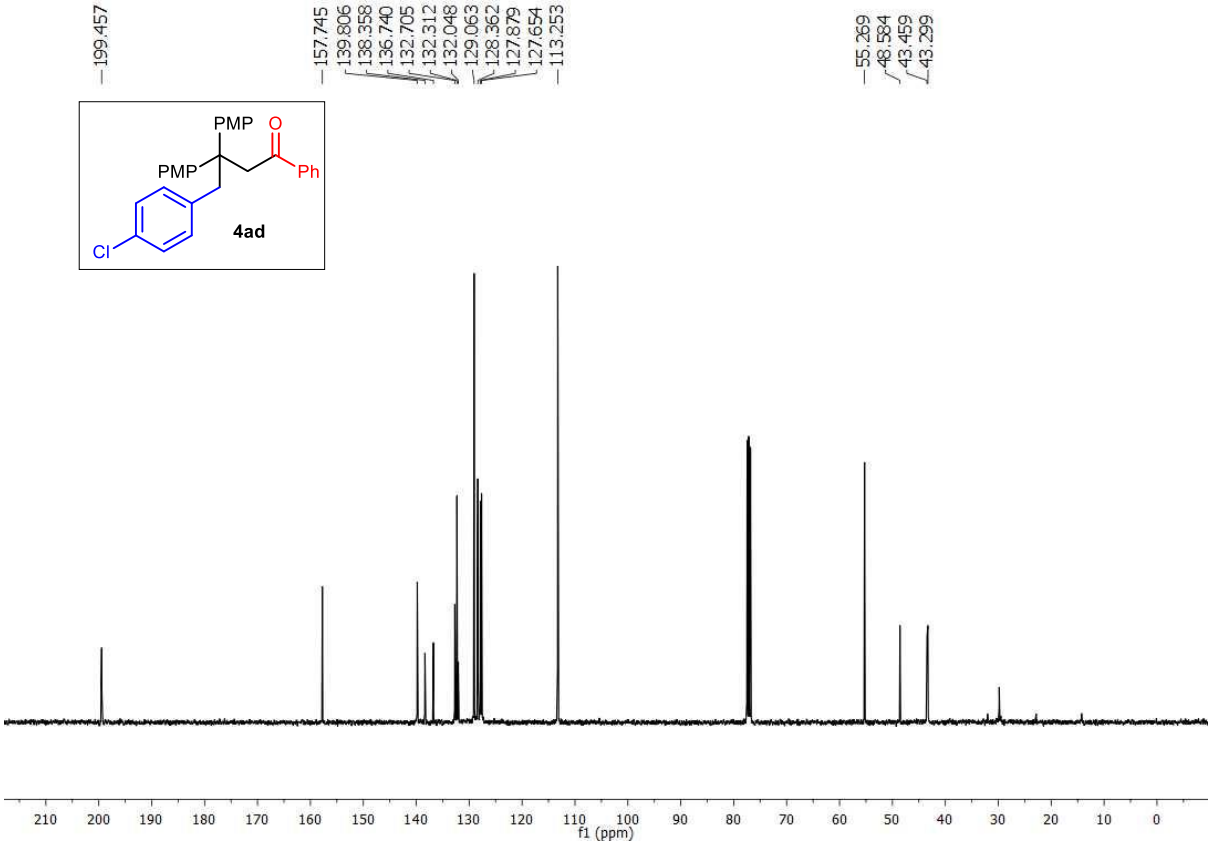

$^{1}$H spectra of **4ac**



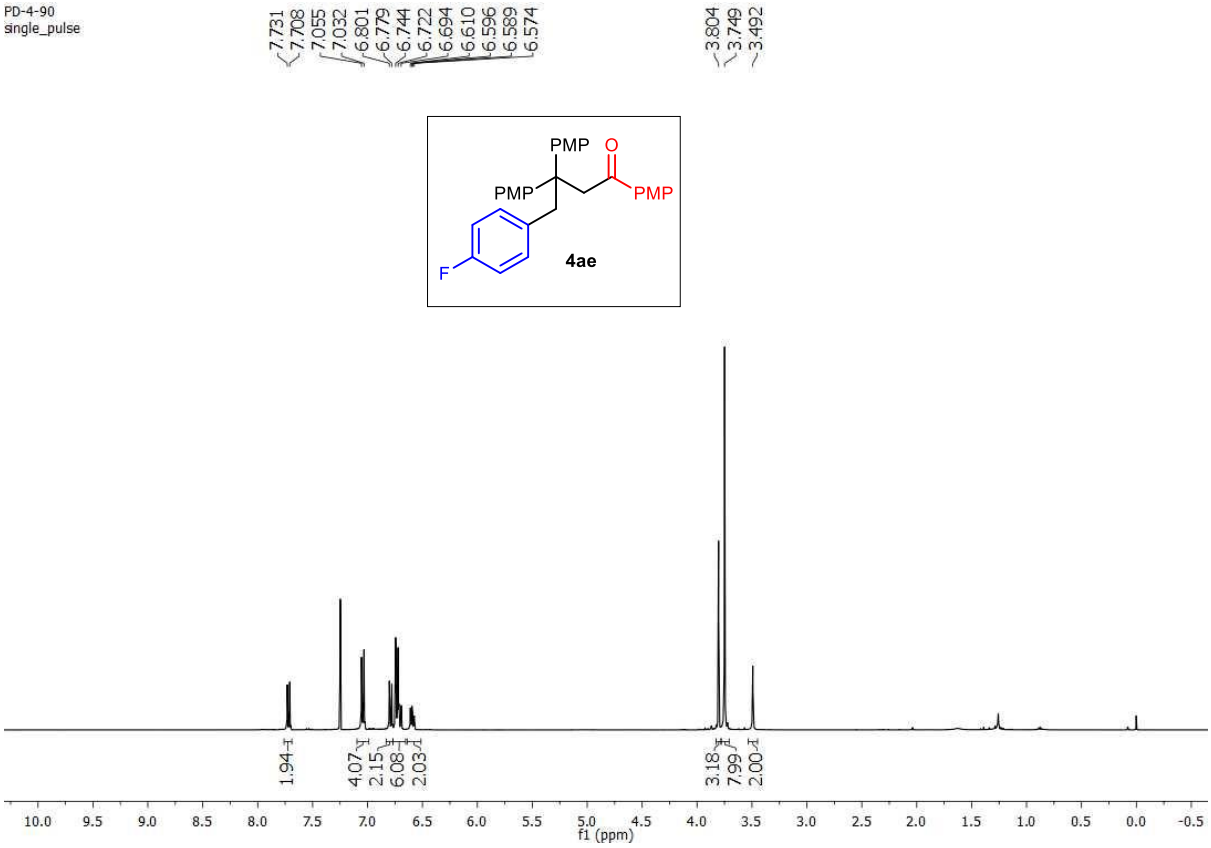

$^{13}$C spectra of **4ac**



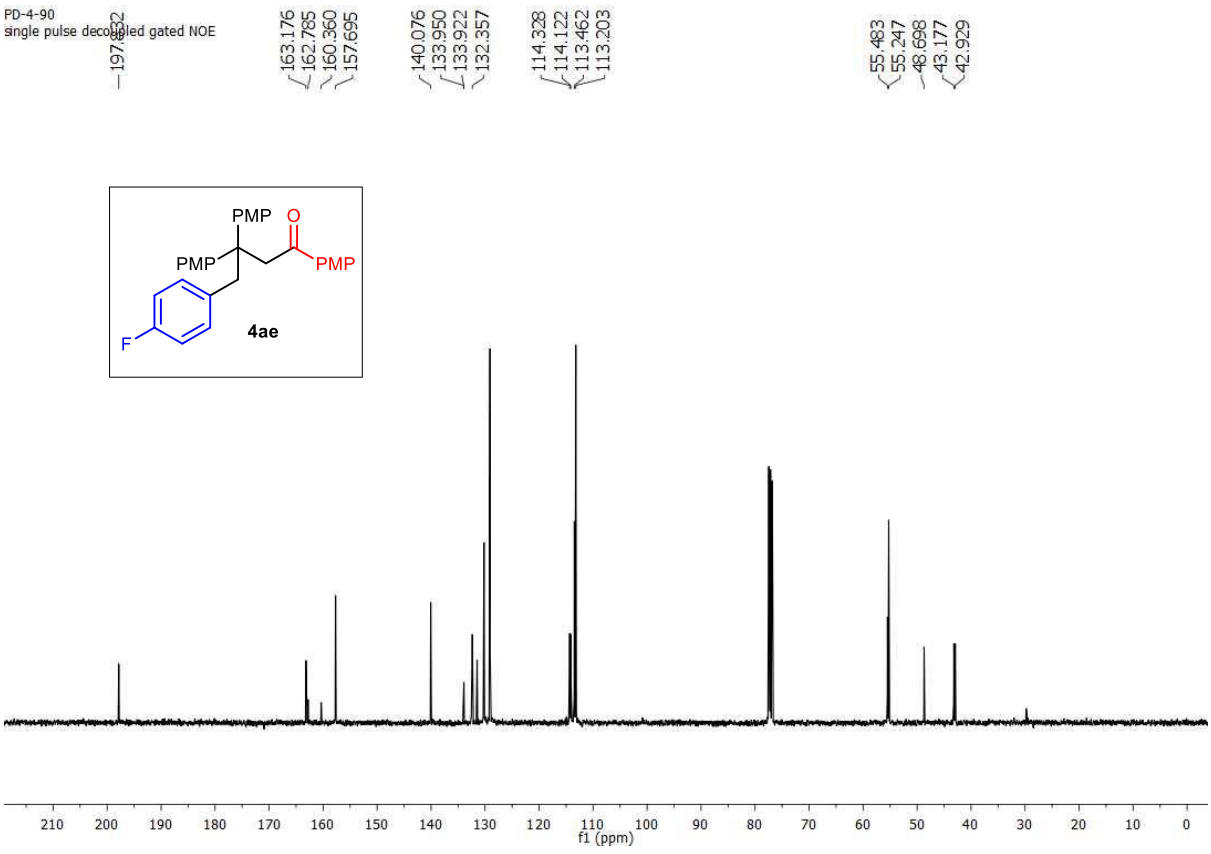

$^{1}$H spectra of **4ad**



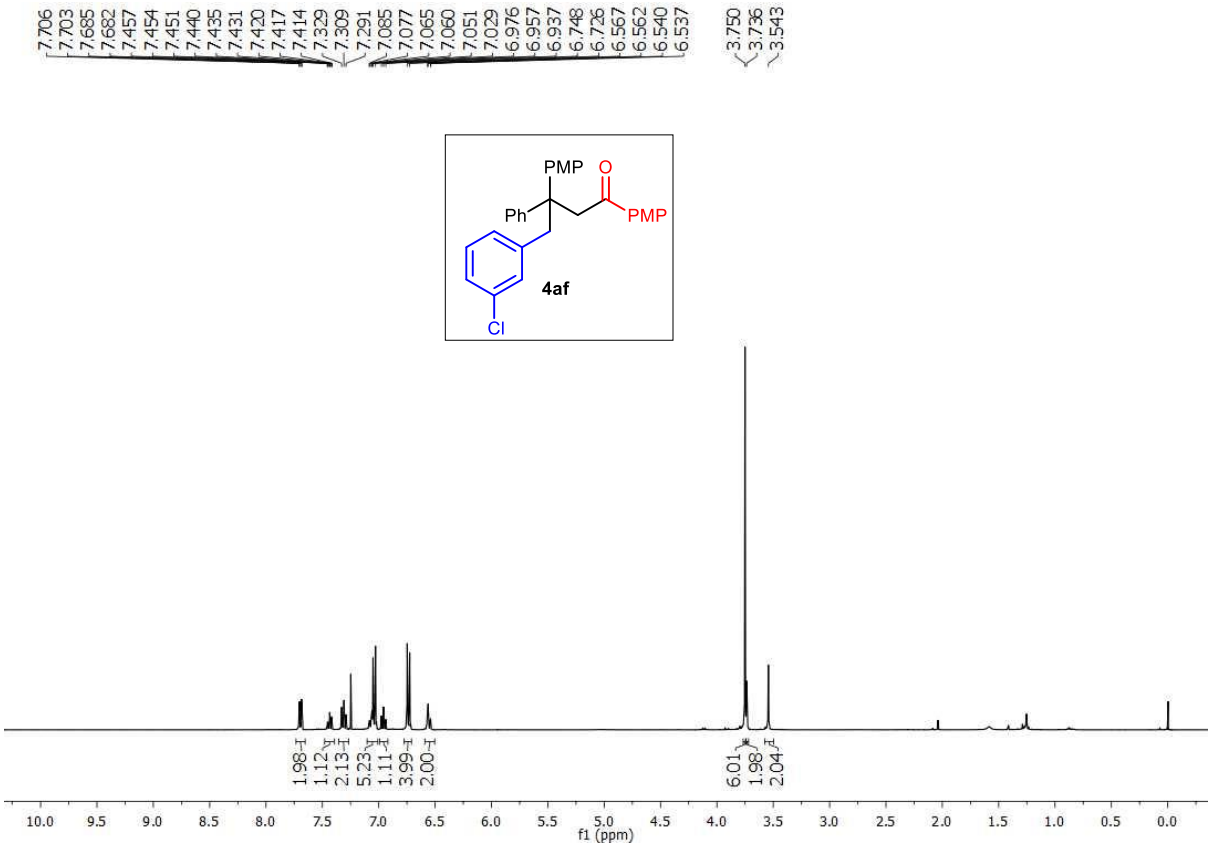

$^{13}$C spectra of **4ad**



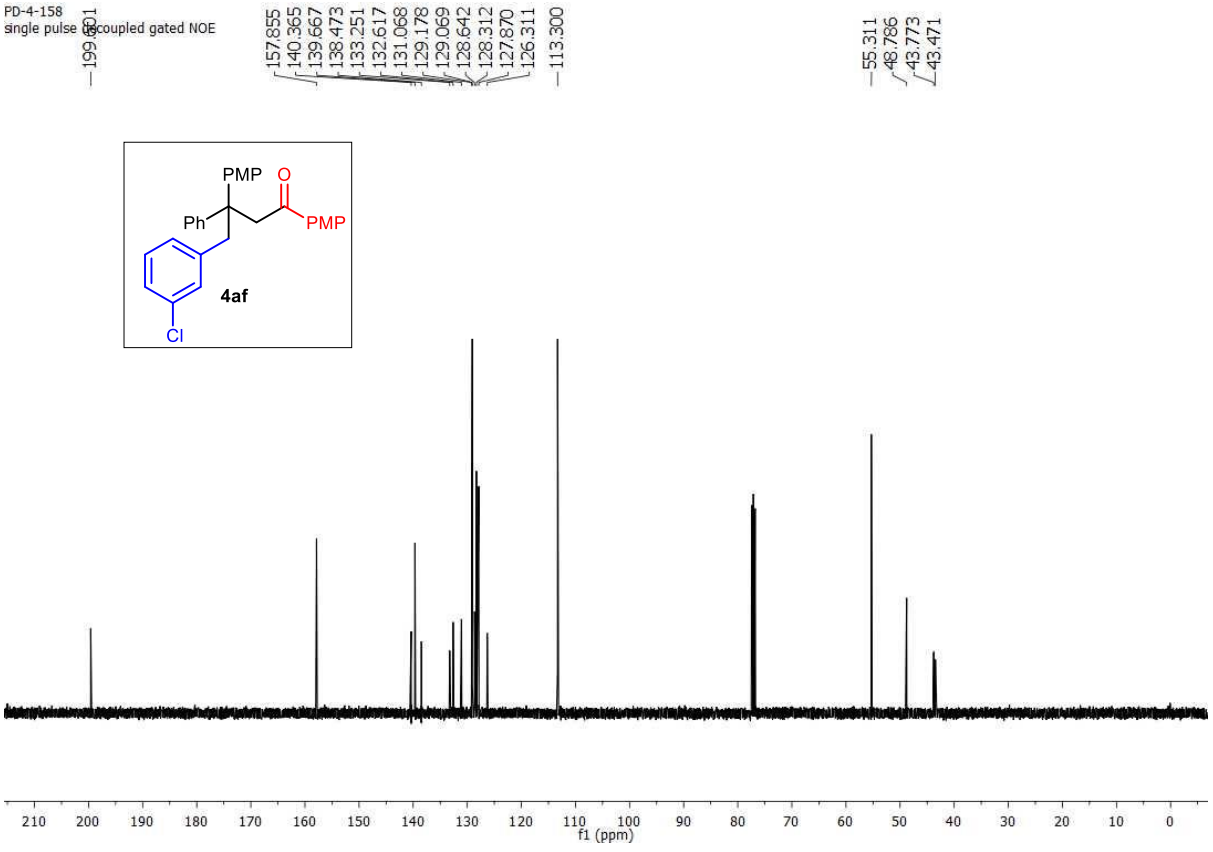

$^{1}$H spectra of **4ae**



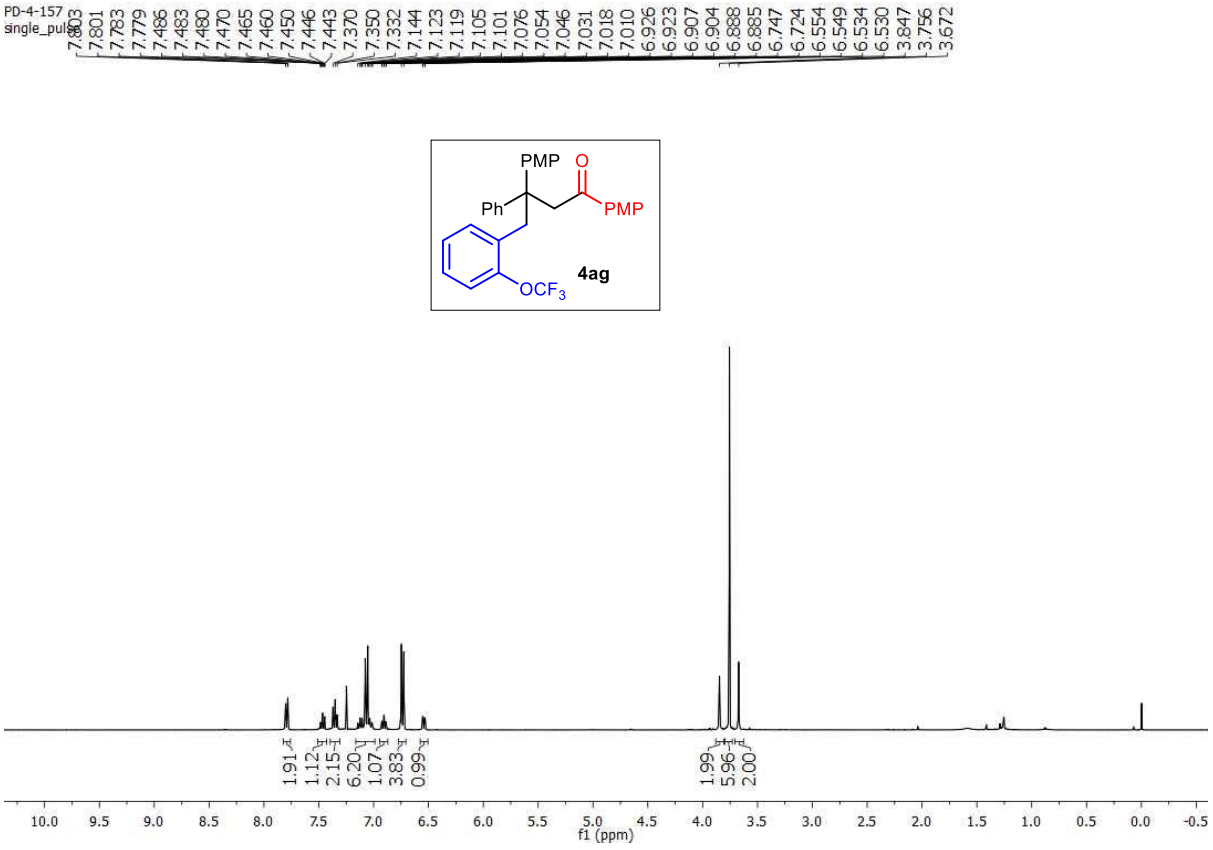

$^{13}$C spectra of **4ae**



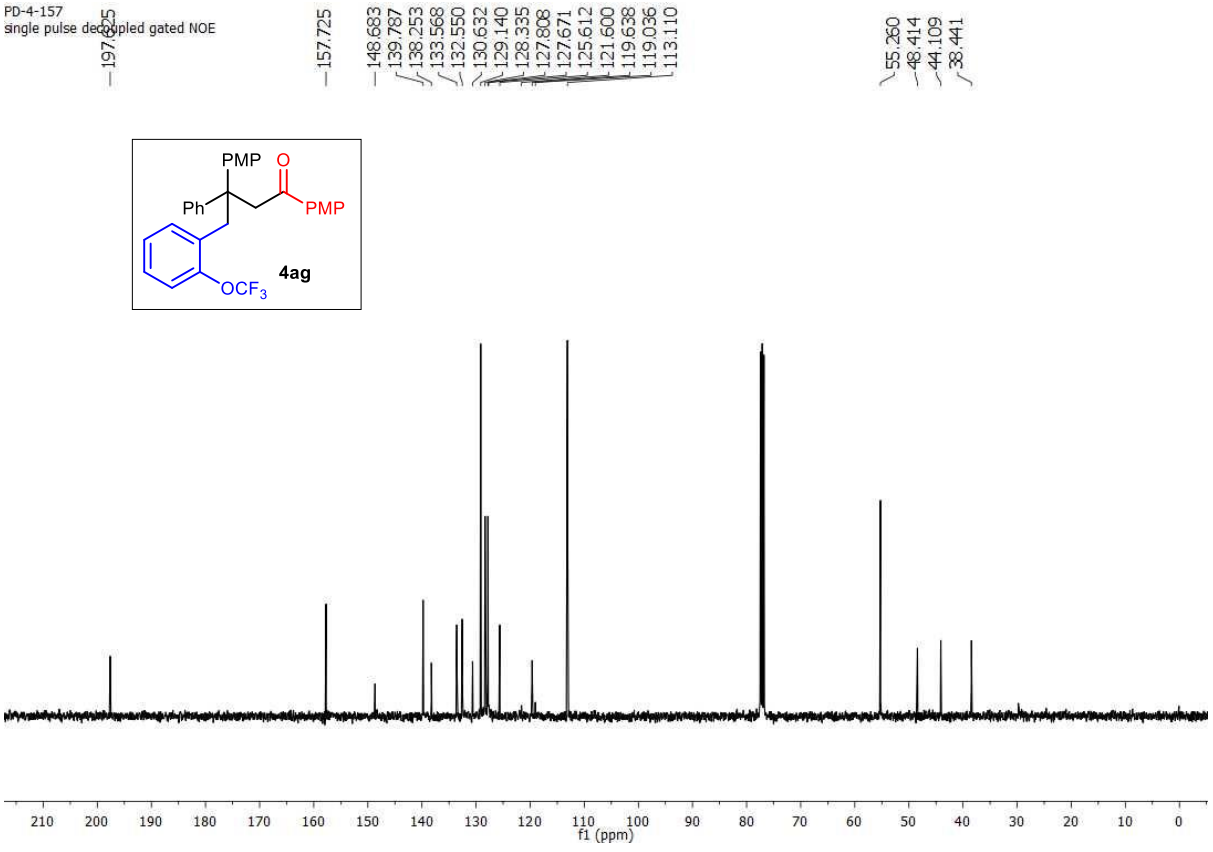

$^{1}$H spectra of **4af**



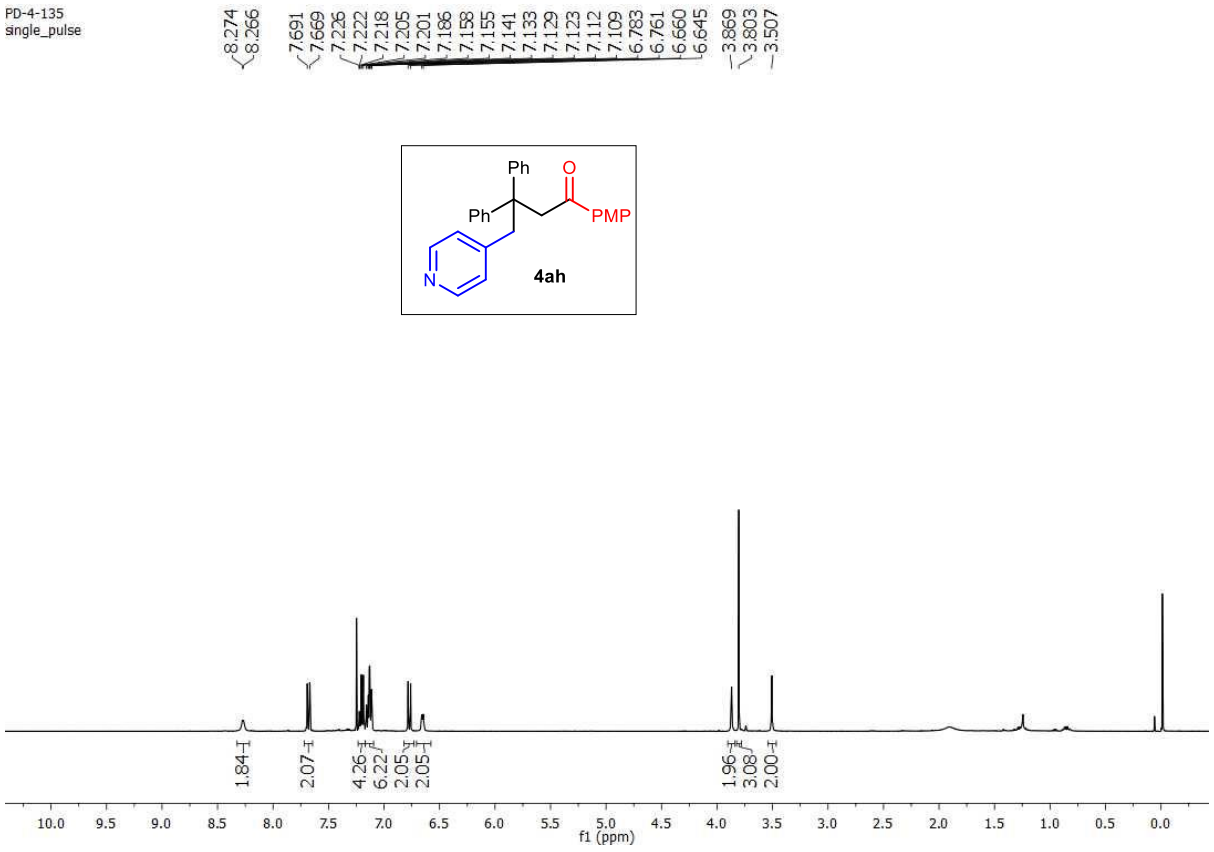

$^{13}$C spectra of **4af**



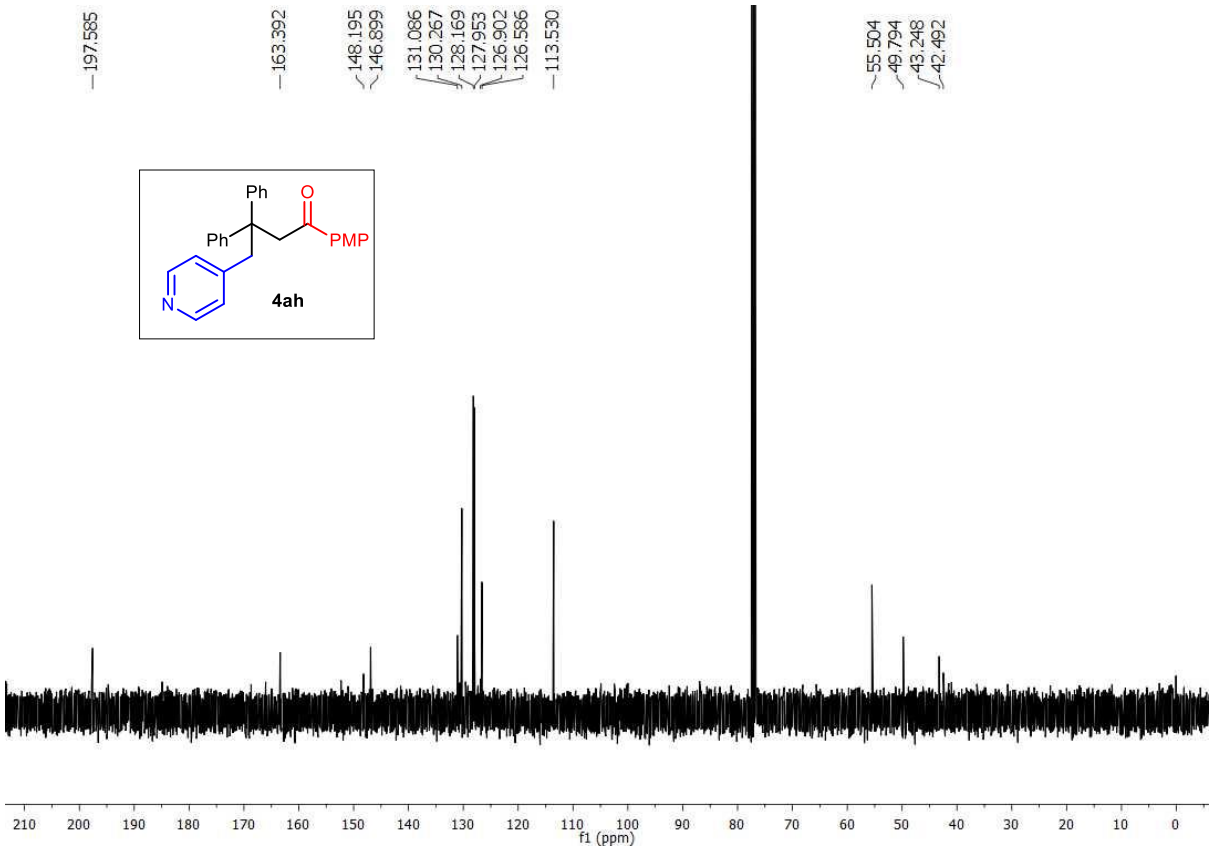

$^{1}$H spectra of **4ag**



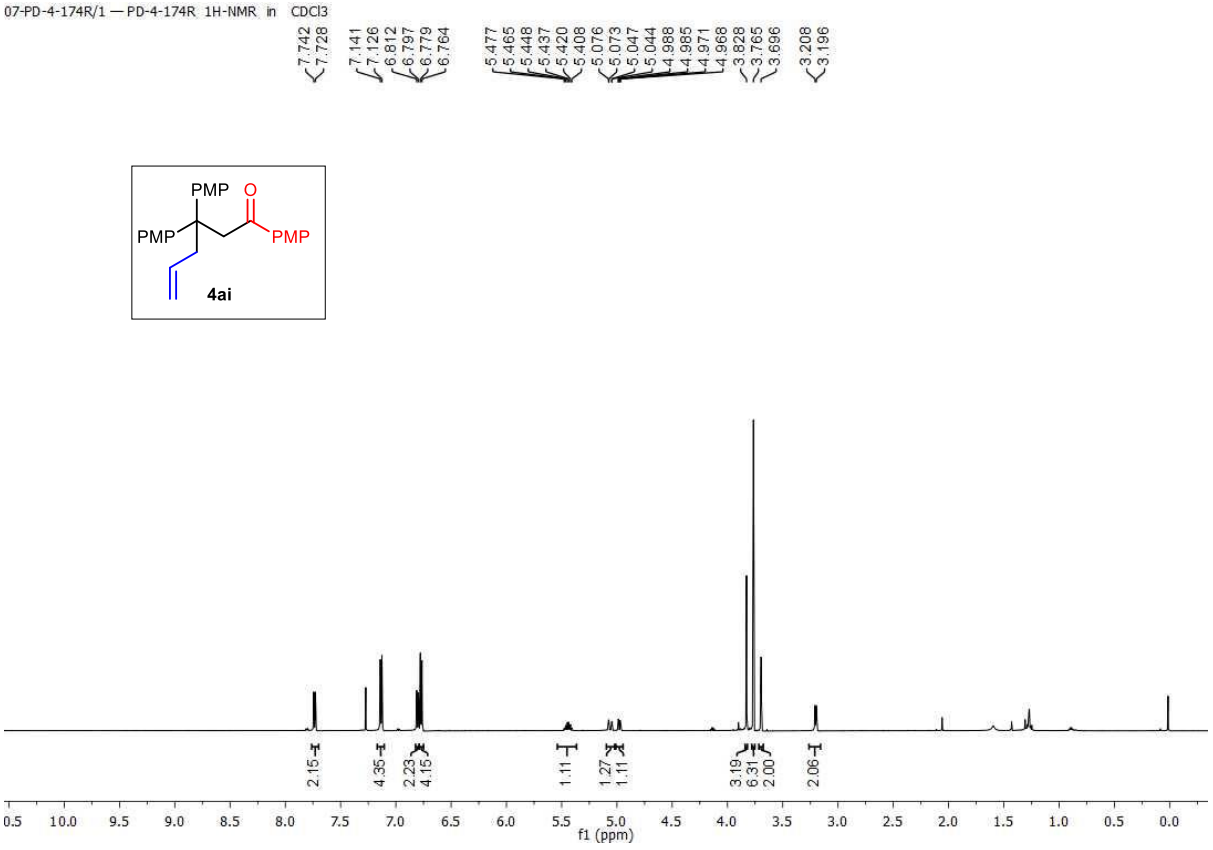

$^{13}$C spectra of **4ag**



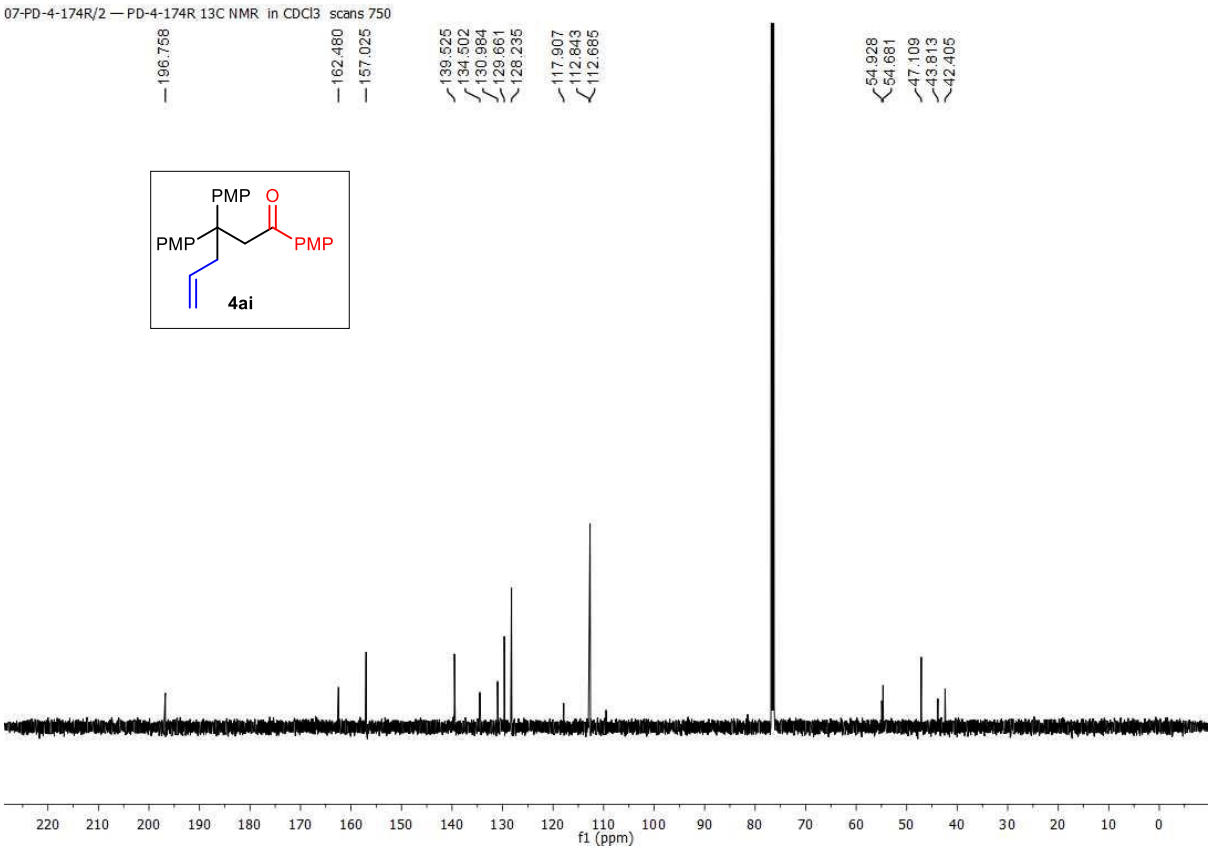

$^{1}$H spectra of **4ah**



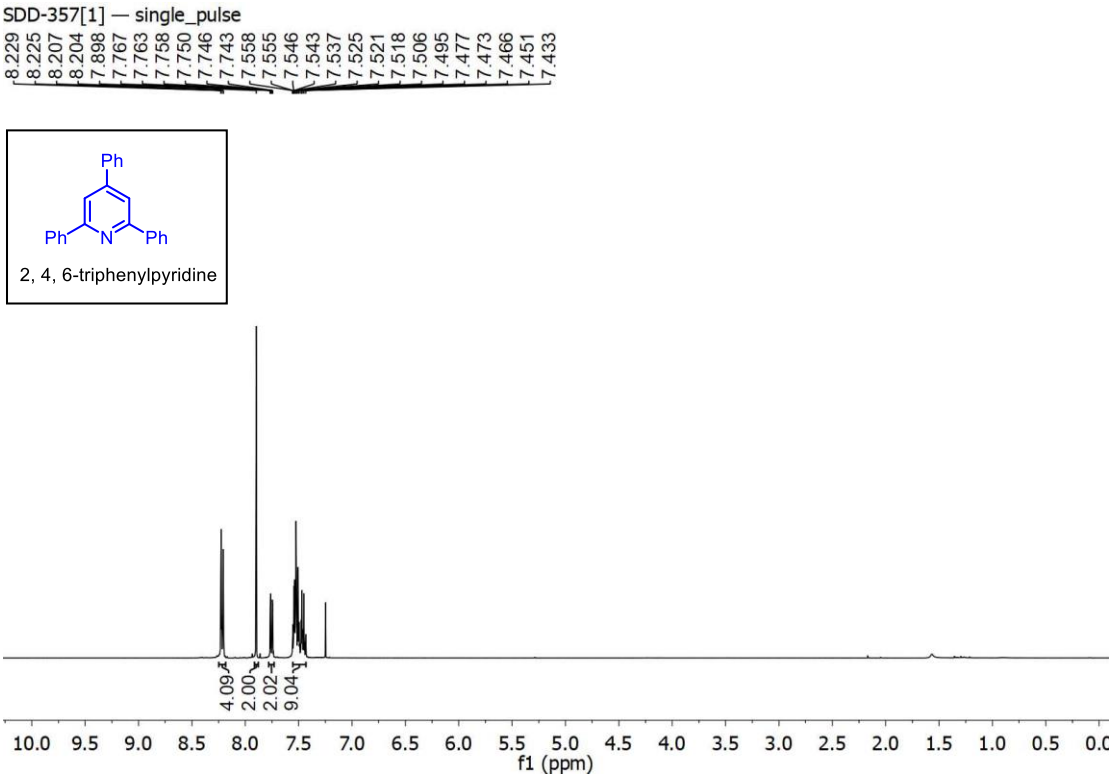

$^{13}$C spectra of **4ah**



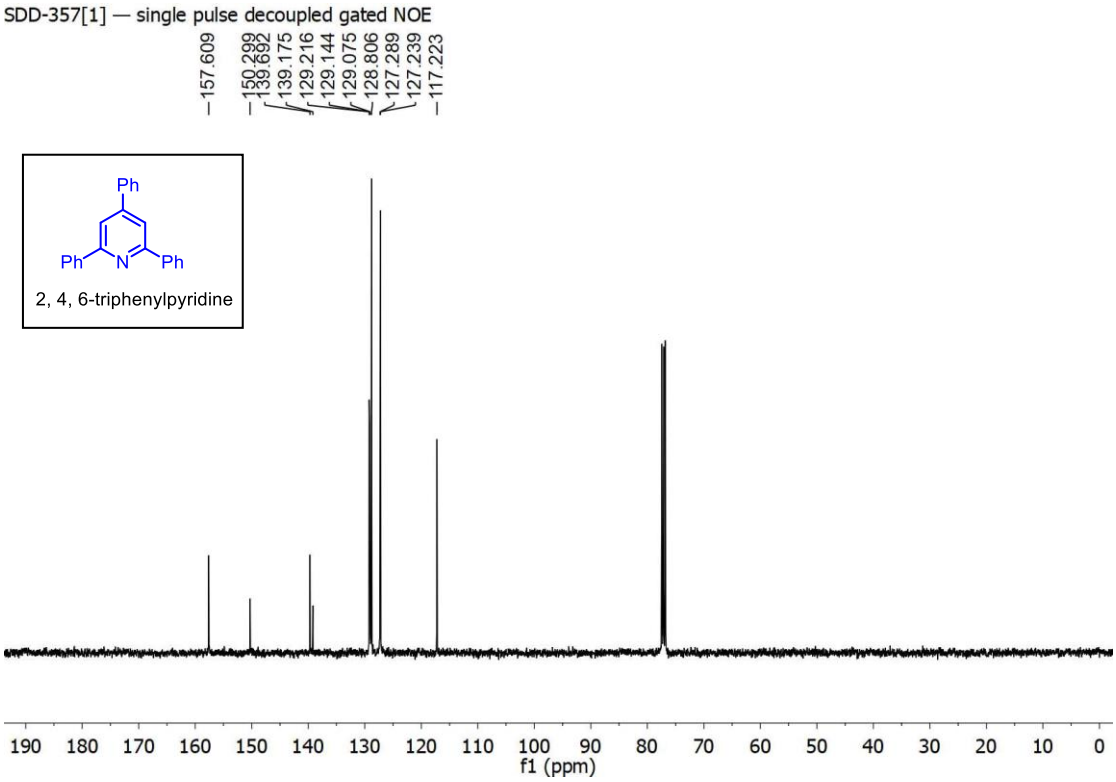

$^{1}$H spectra of **4ai**



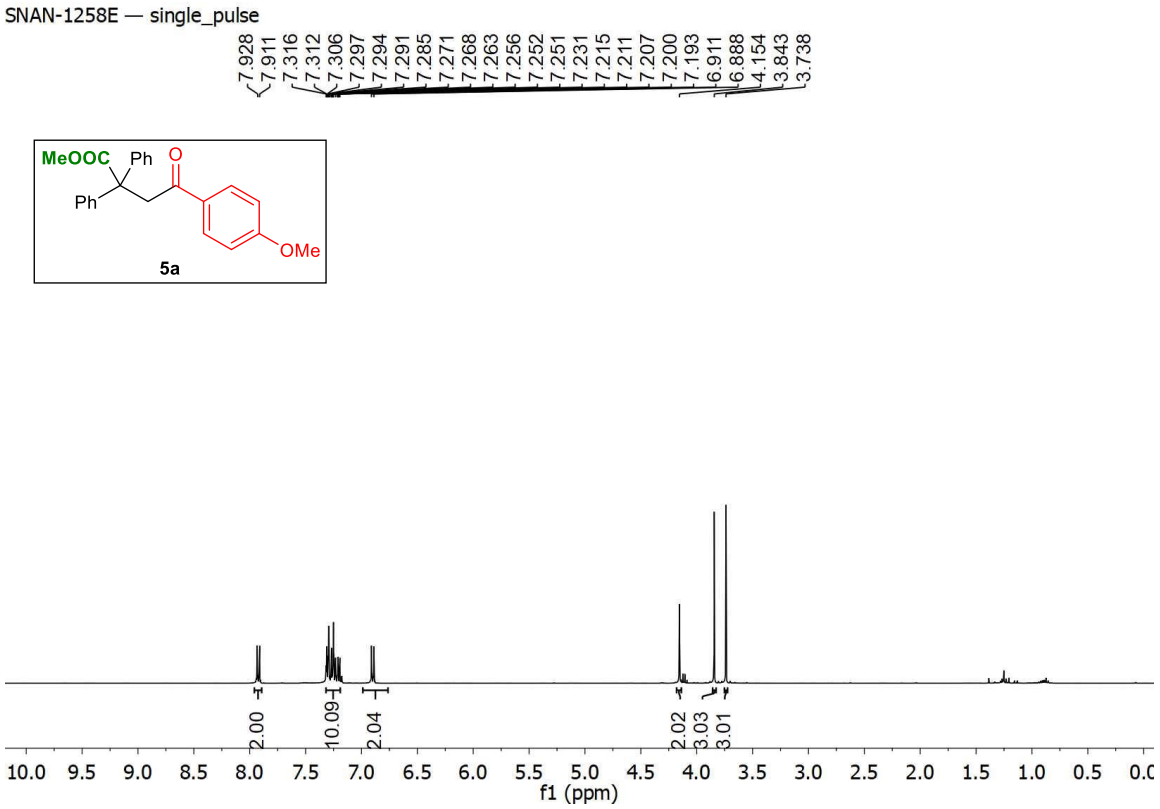

$^{13}$C spectra of **4ai**



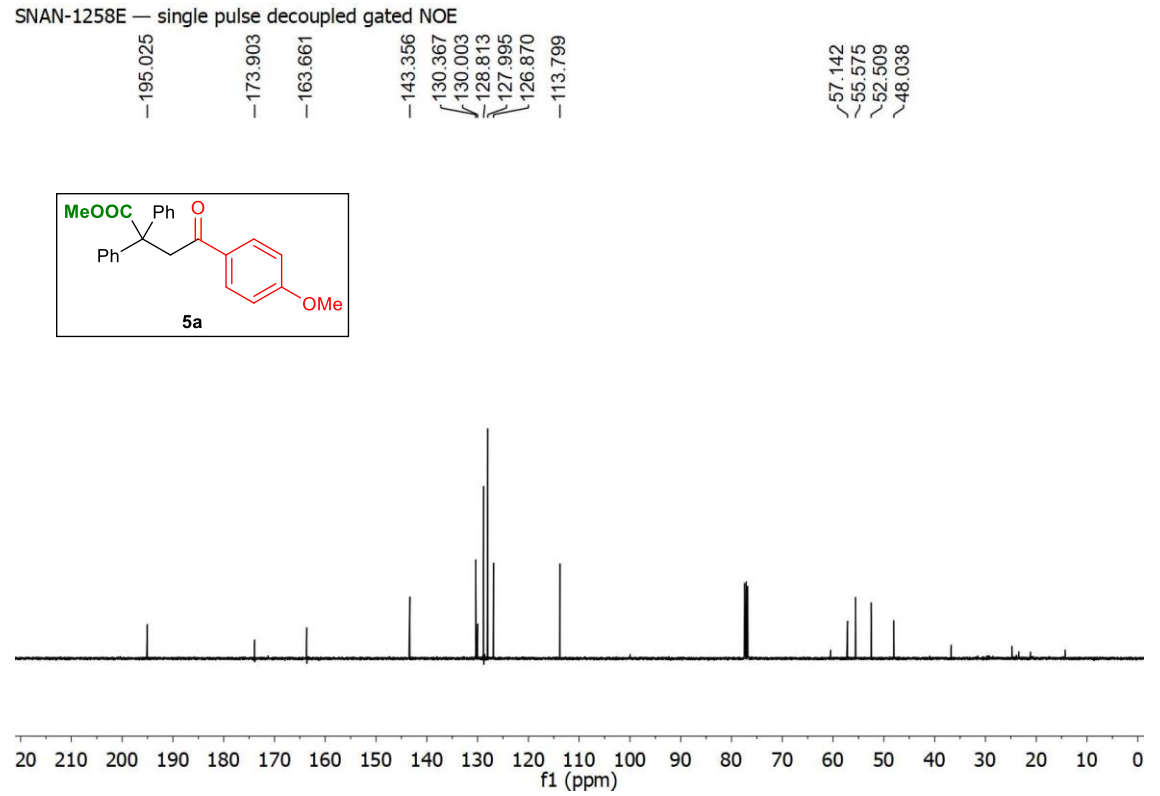

$^{1}$H spectra of **2,4,6-triphenylpyridine**



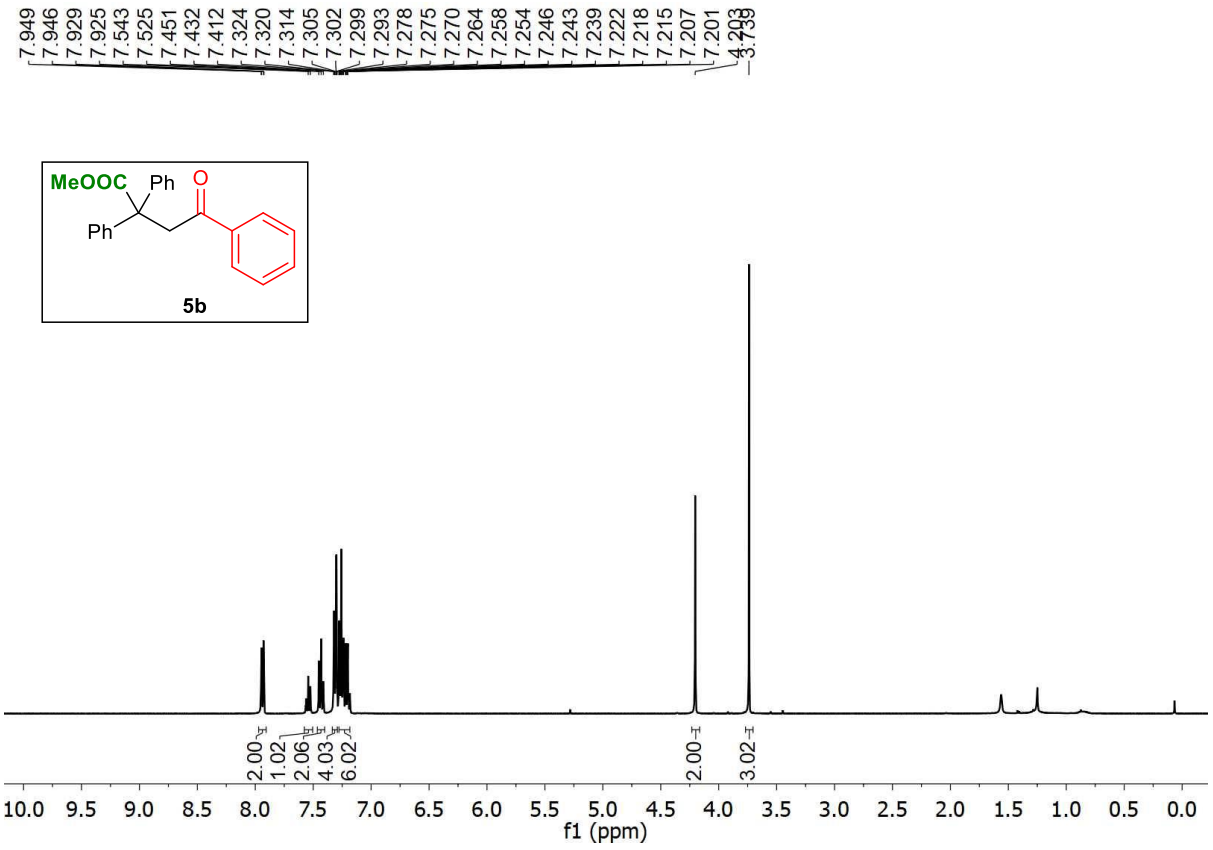

$^{13}$C spectra of **2,4,6-triphenylpyridine**



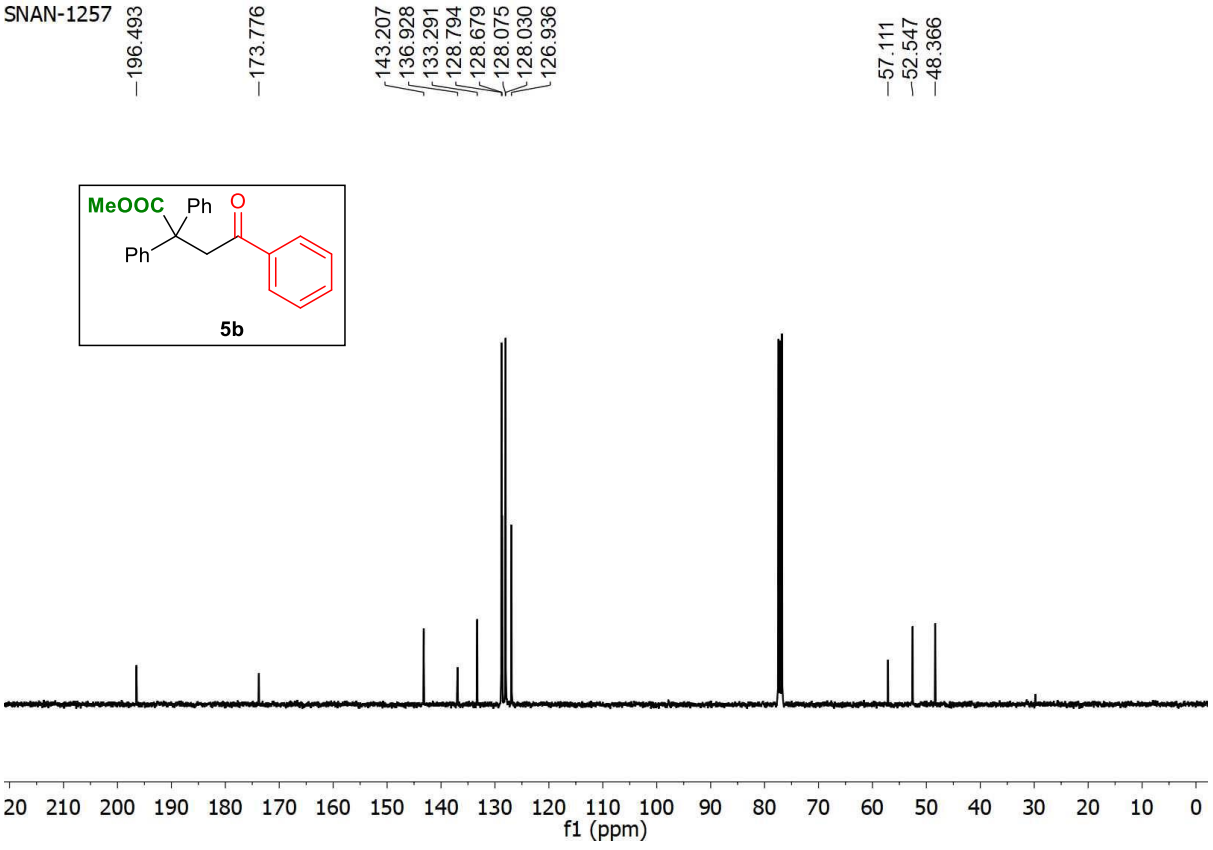

$^{1}$H spectra of **5a**



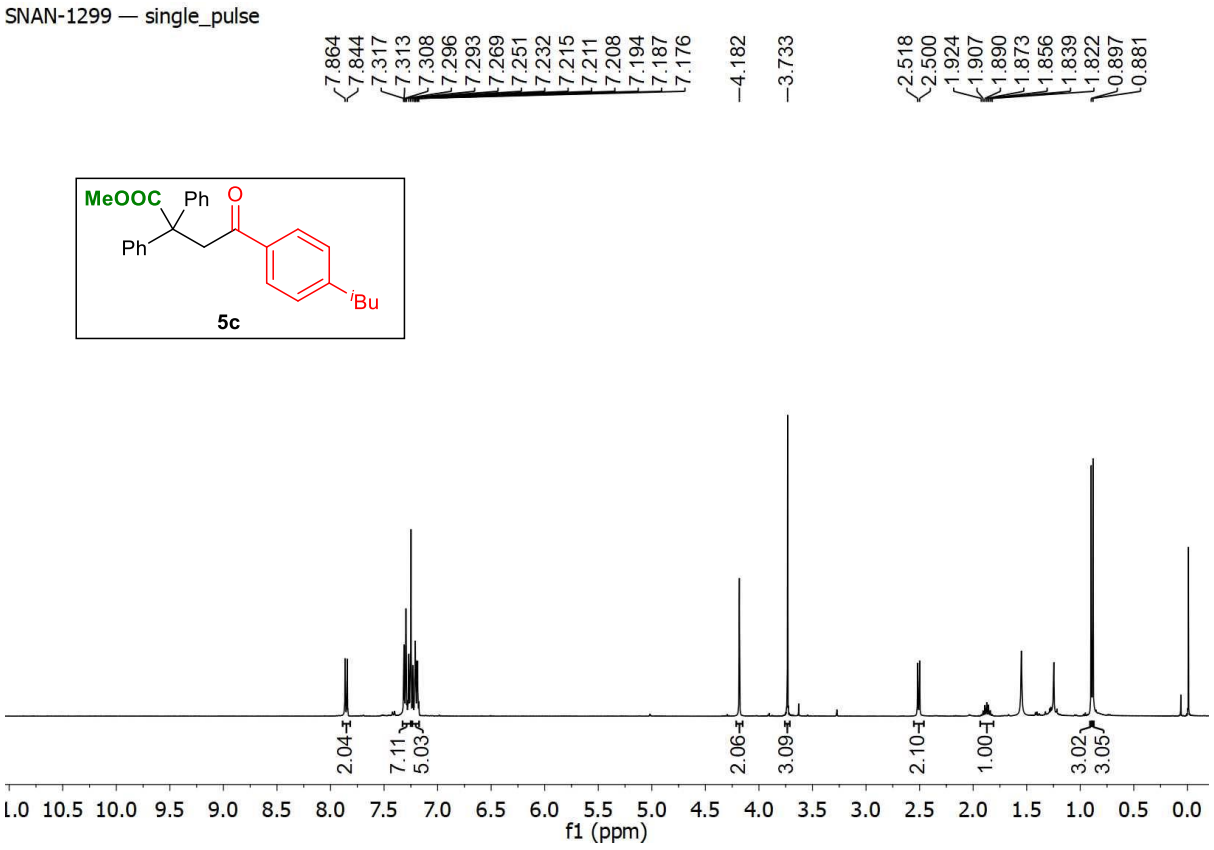

$^{13}$C spectra of **5a**



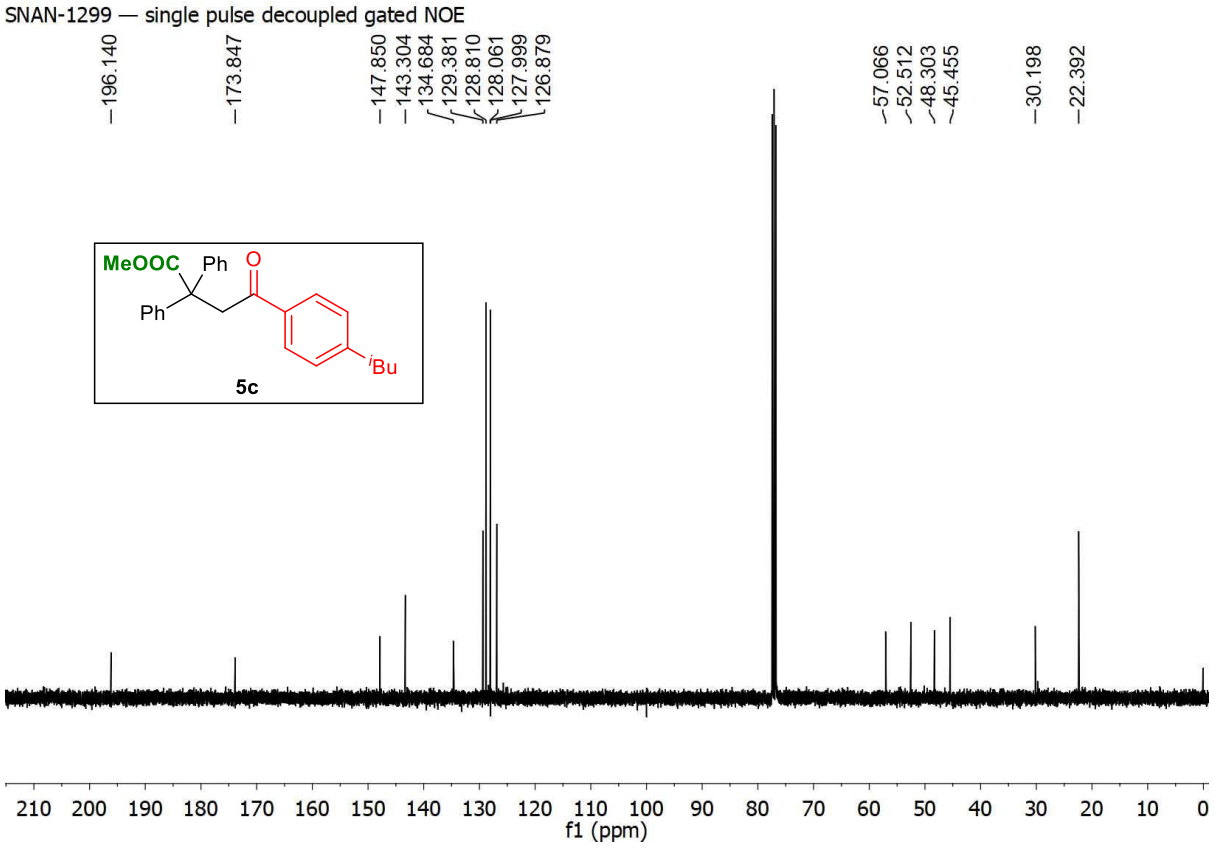

$^{1}$H spectra of **5b**



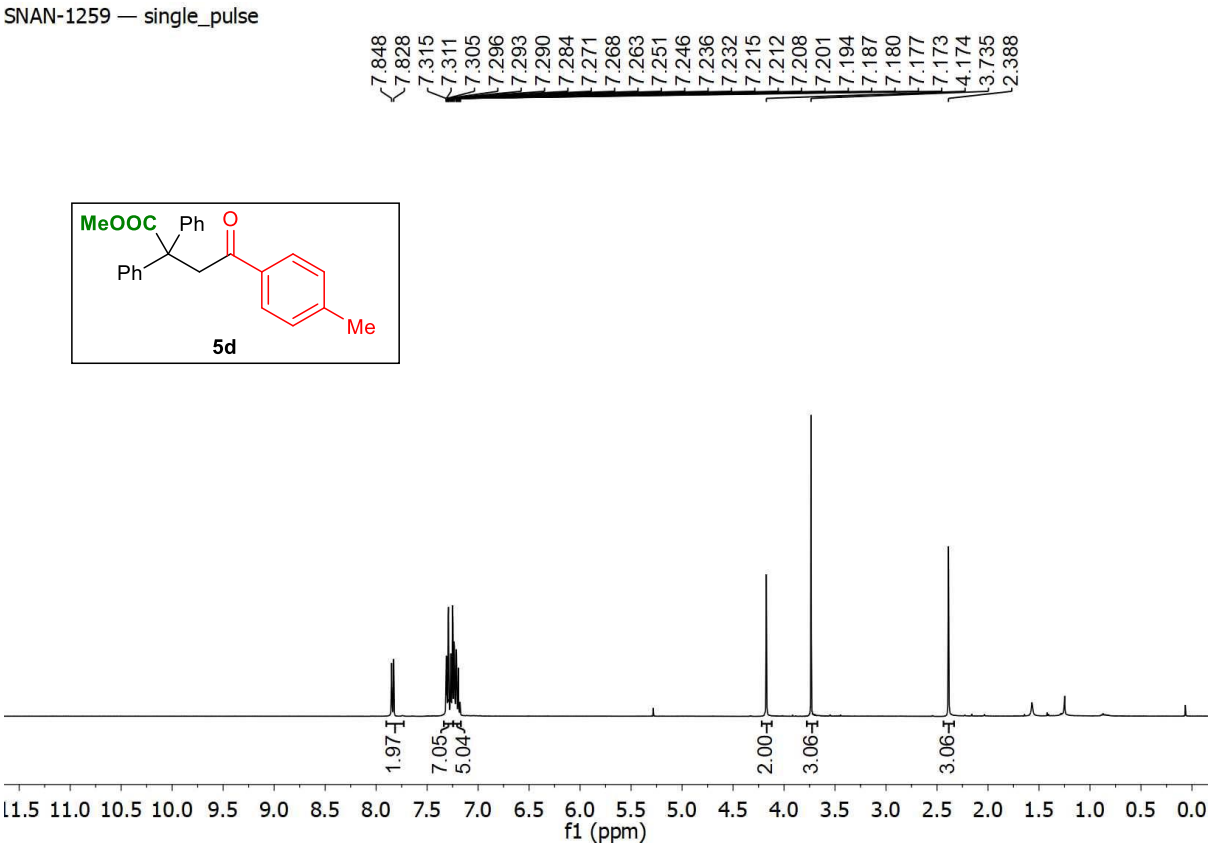

$^{13}$C spectra of **5b**



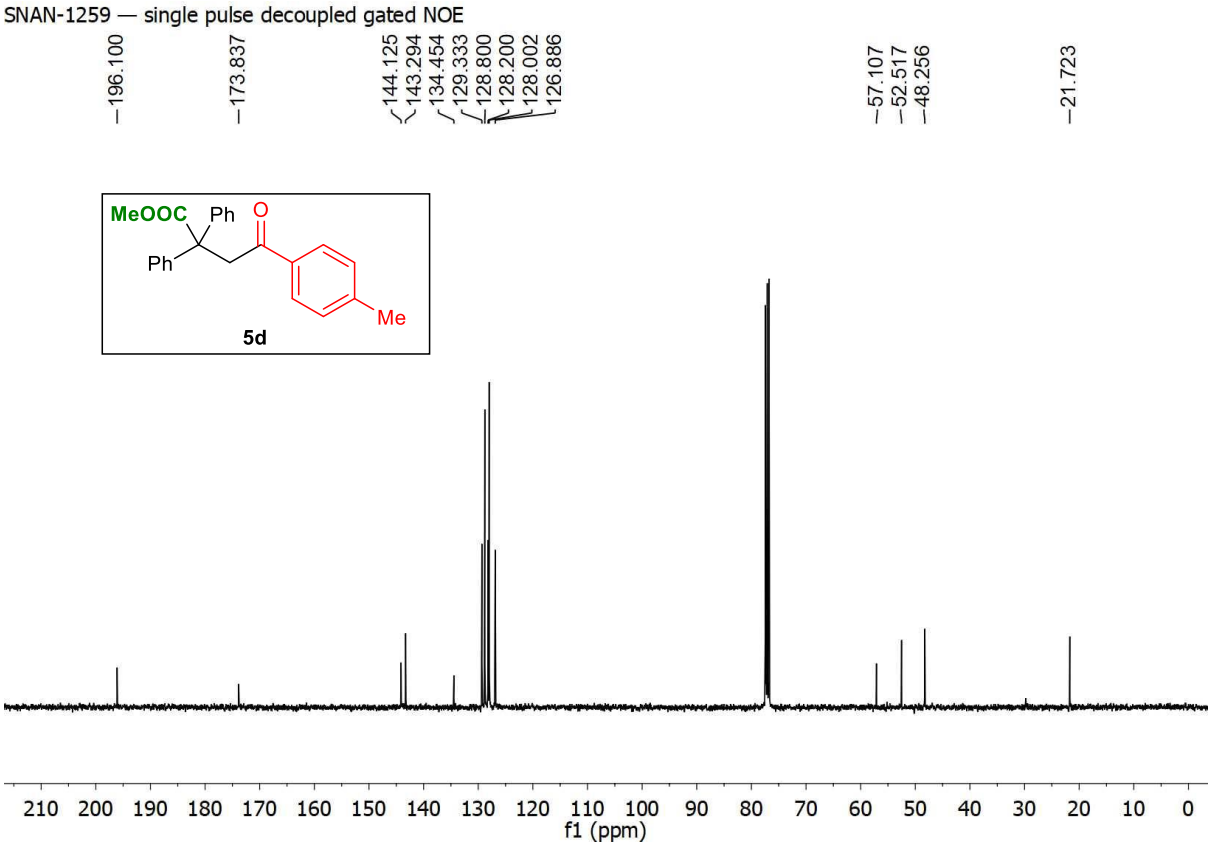

$^{1}$H spectra of **5c**



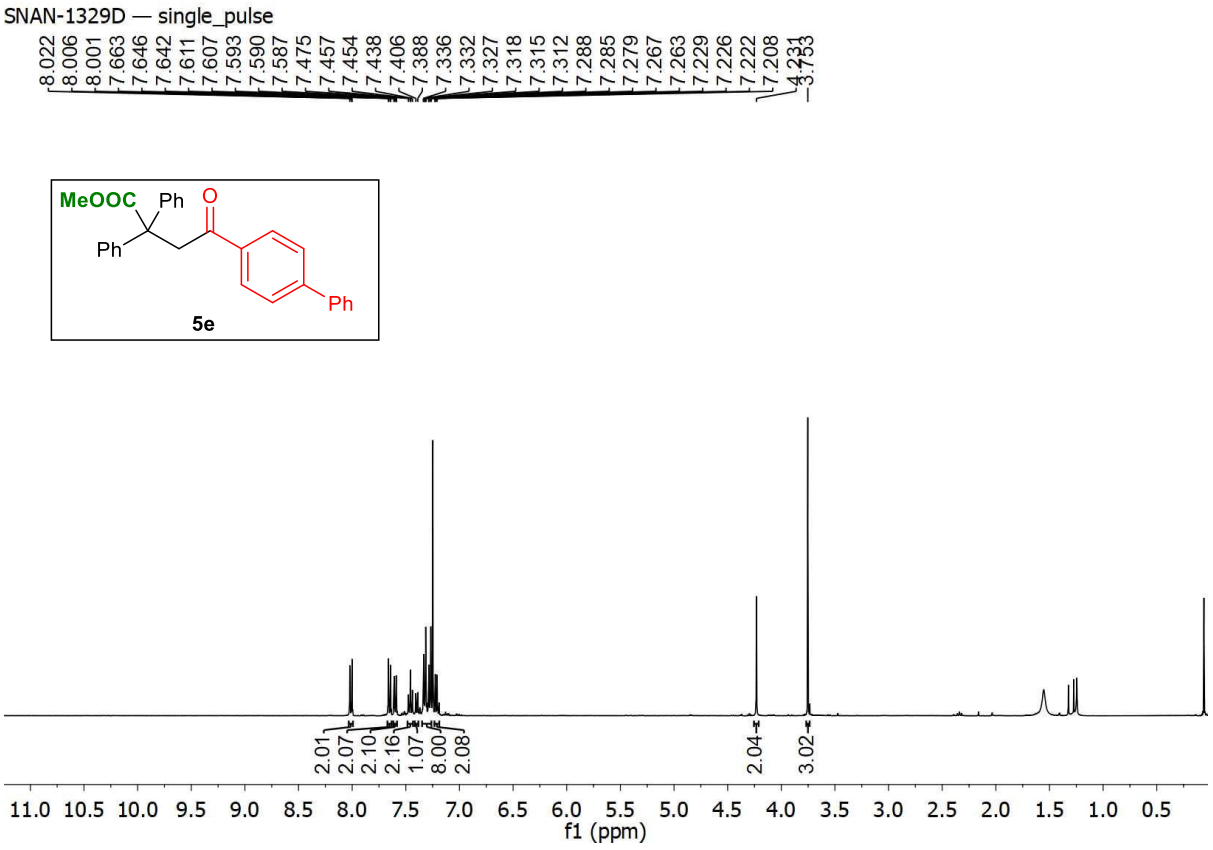

$^{13}$C spectra of **5c**



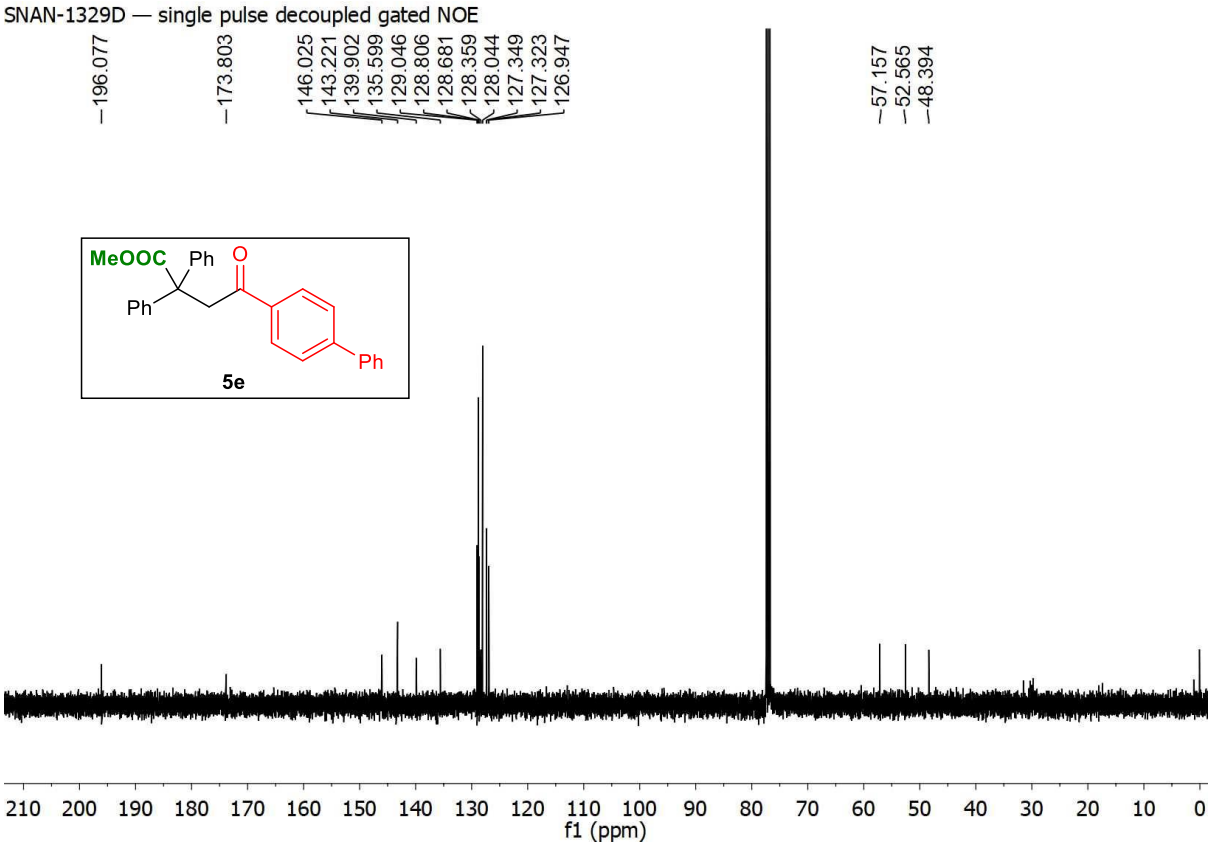

$^{1}$H spectra of **5d**



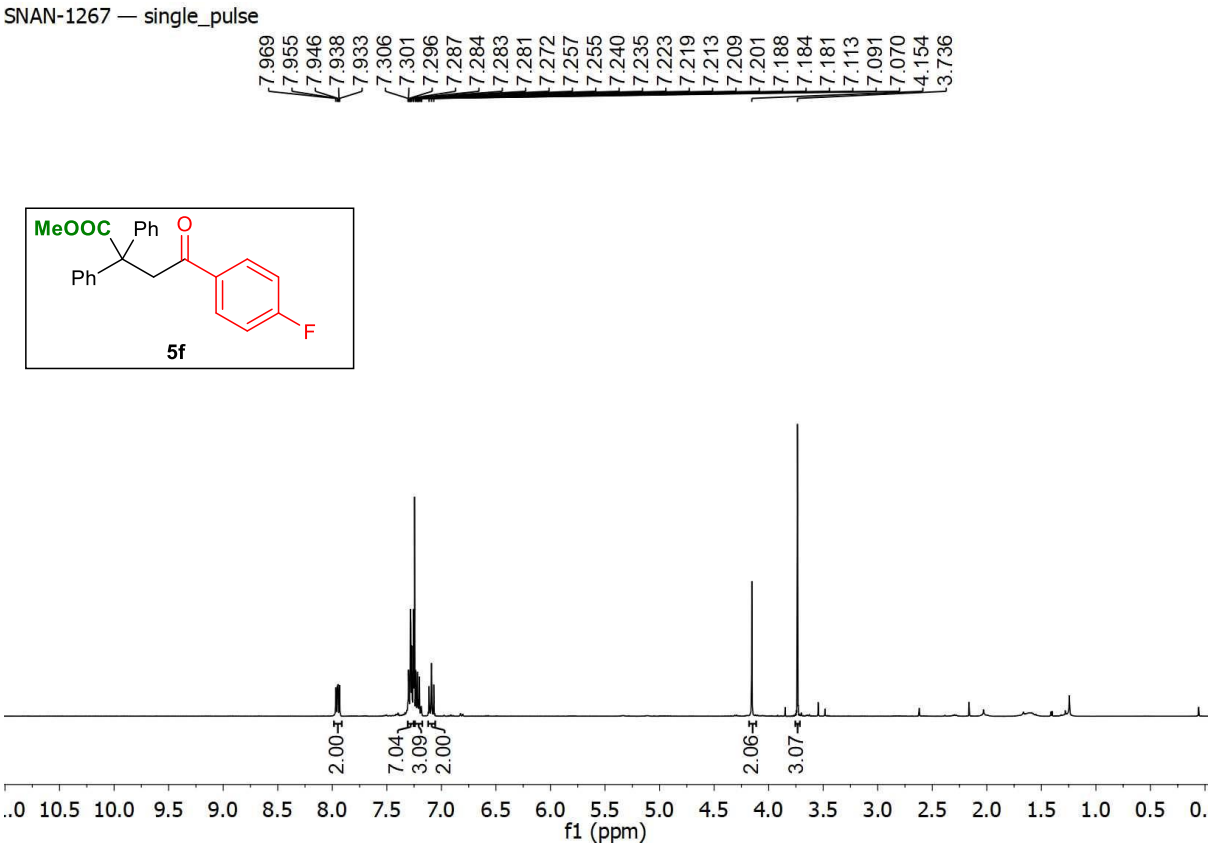

$^{13}$C spectra of **5d**



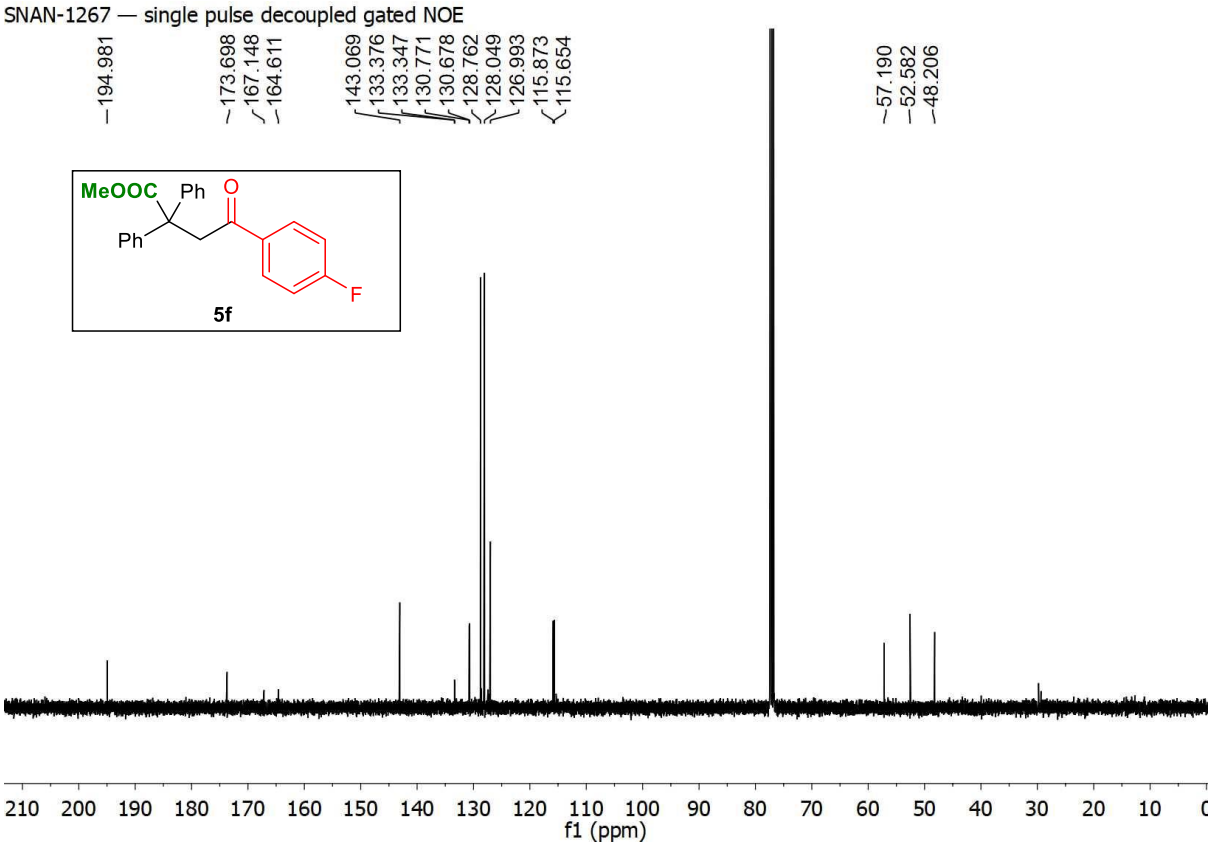

$^{1}$H spectra of **5e**



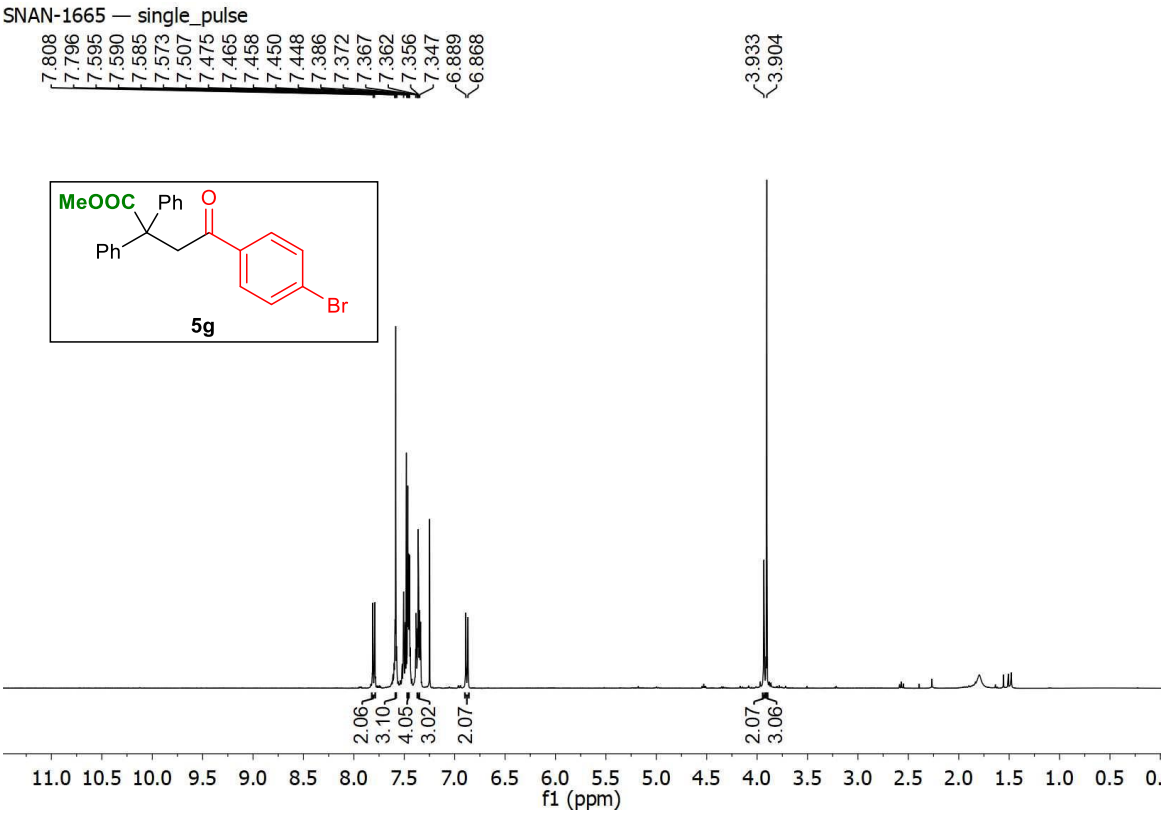

$^{13}$C spectra of **5e**



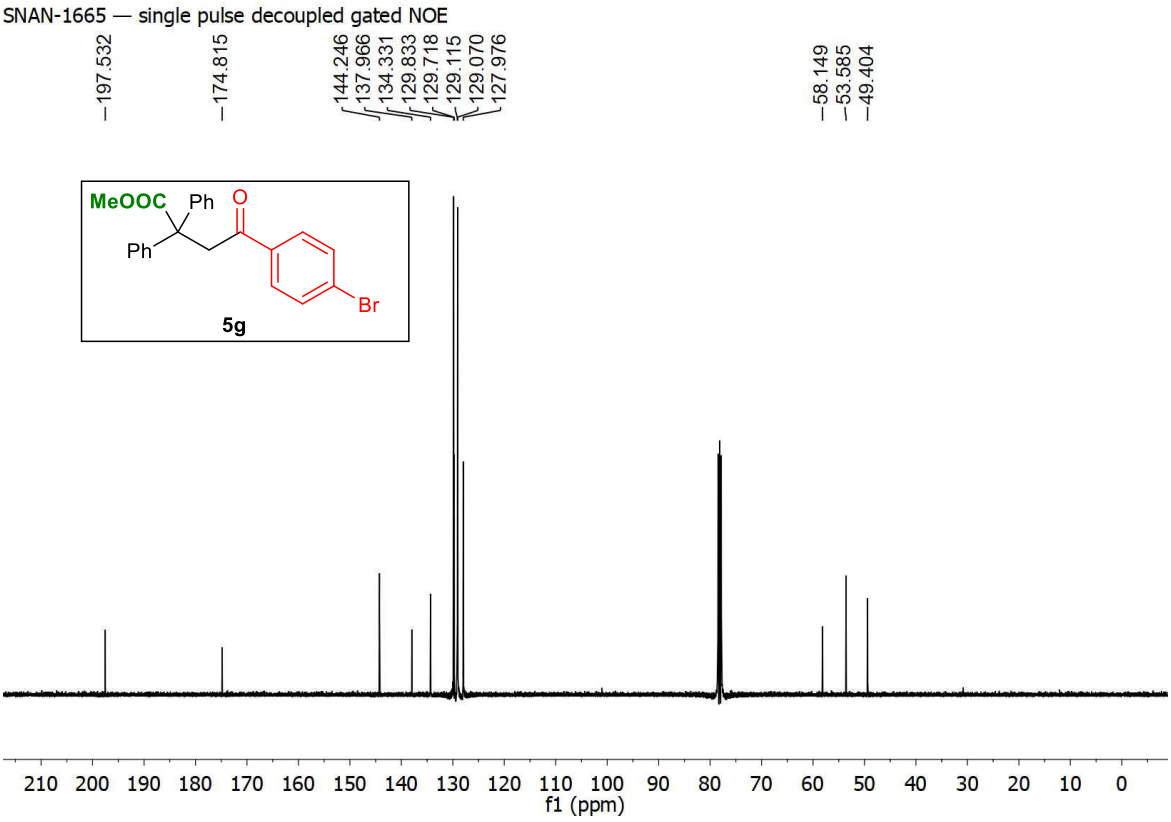

$^{1}$H spectra of **5f**



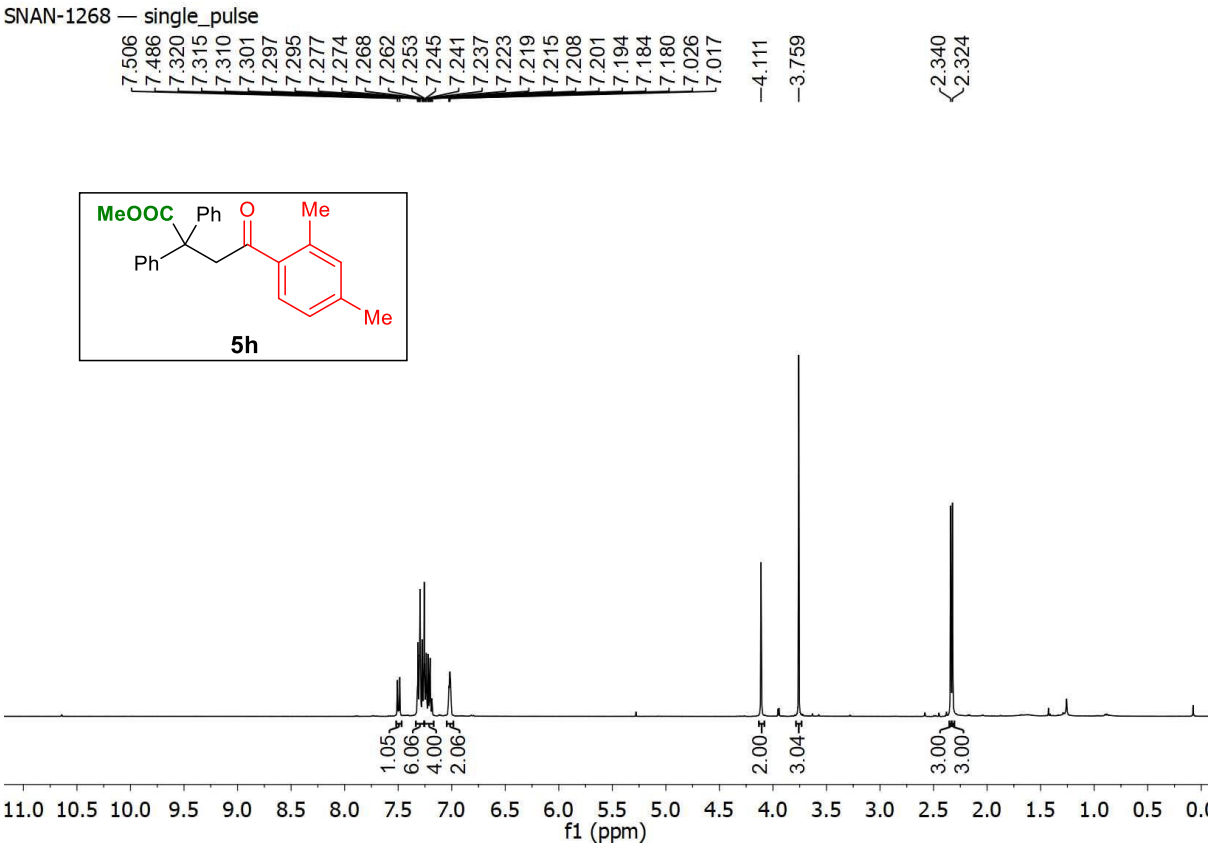

$^{13}$C spectra of **5f**



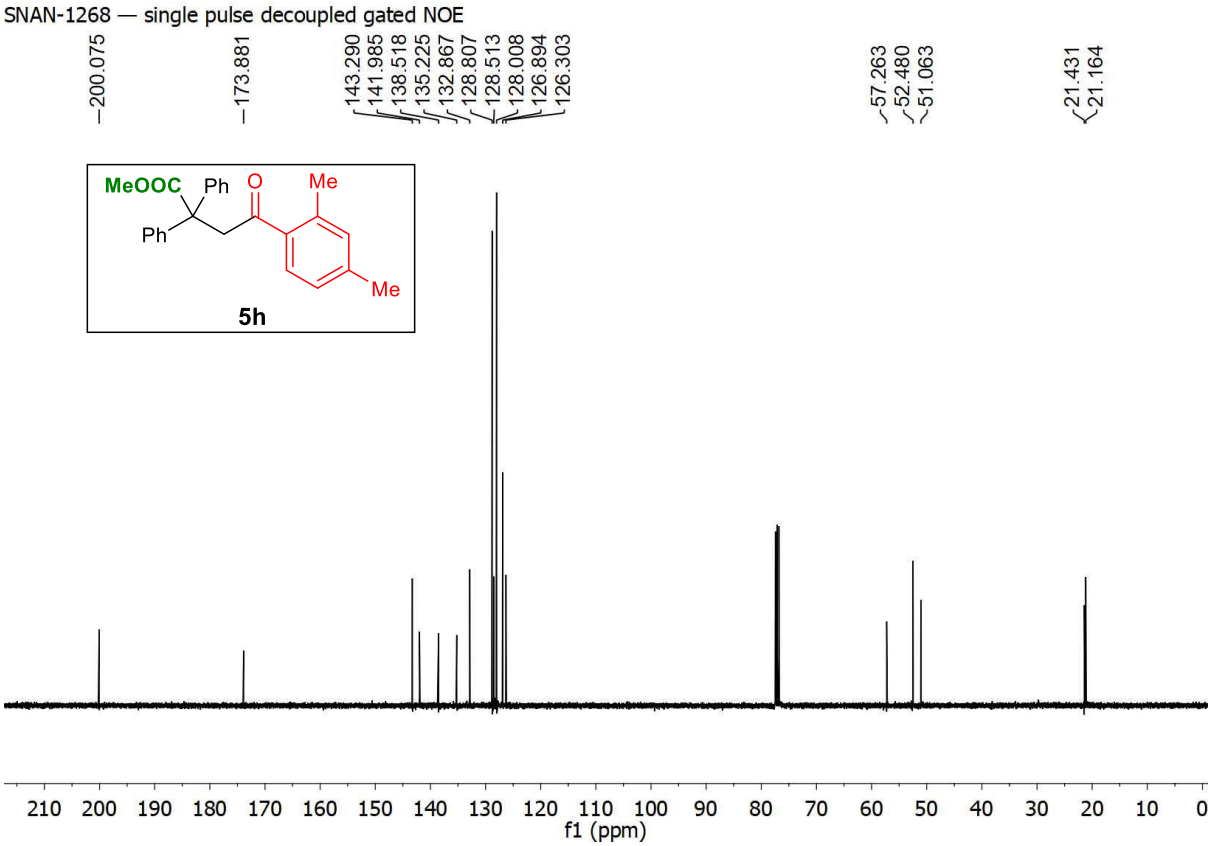

$^{1}$H spectra of **5g**



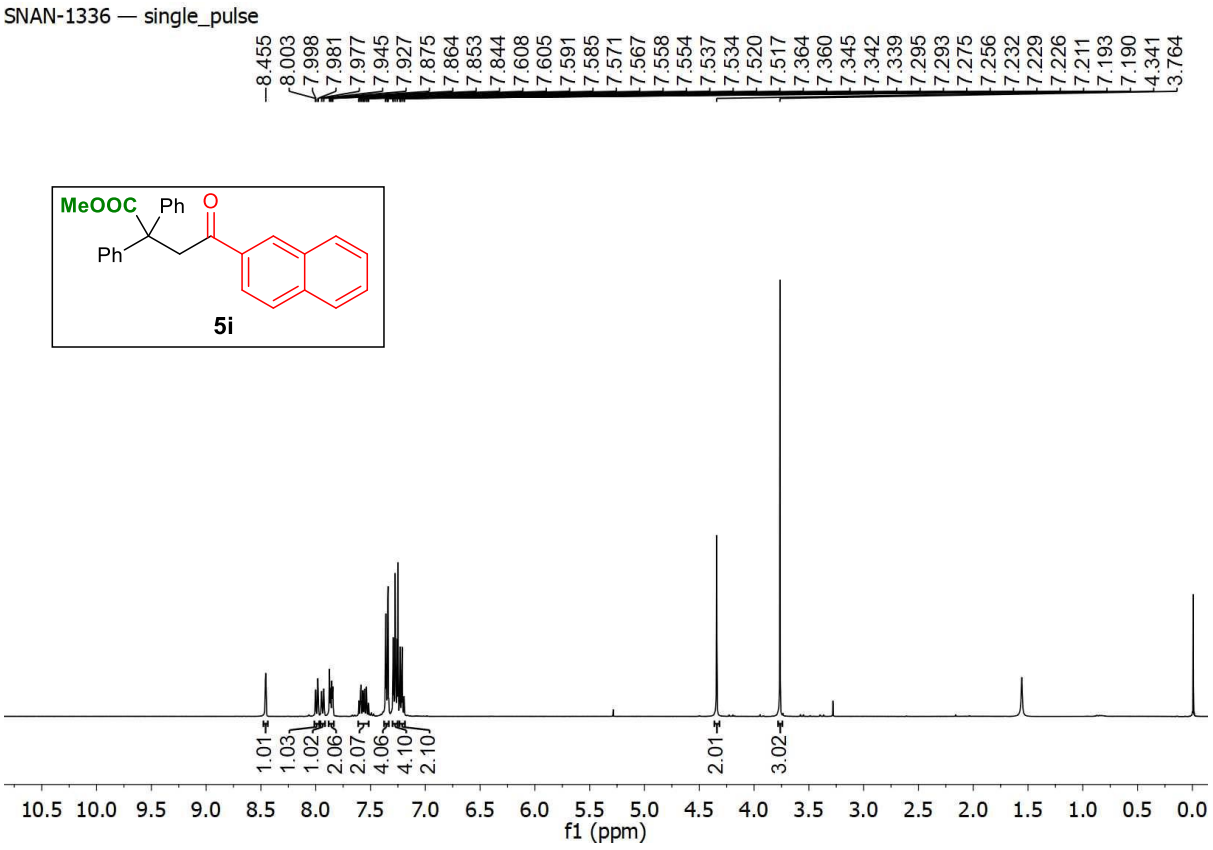

$^{13}$C spectra of **5g**



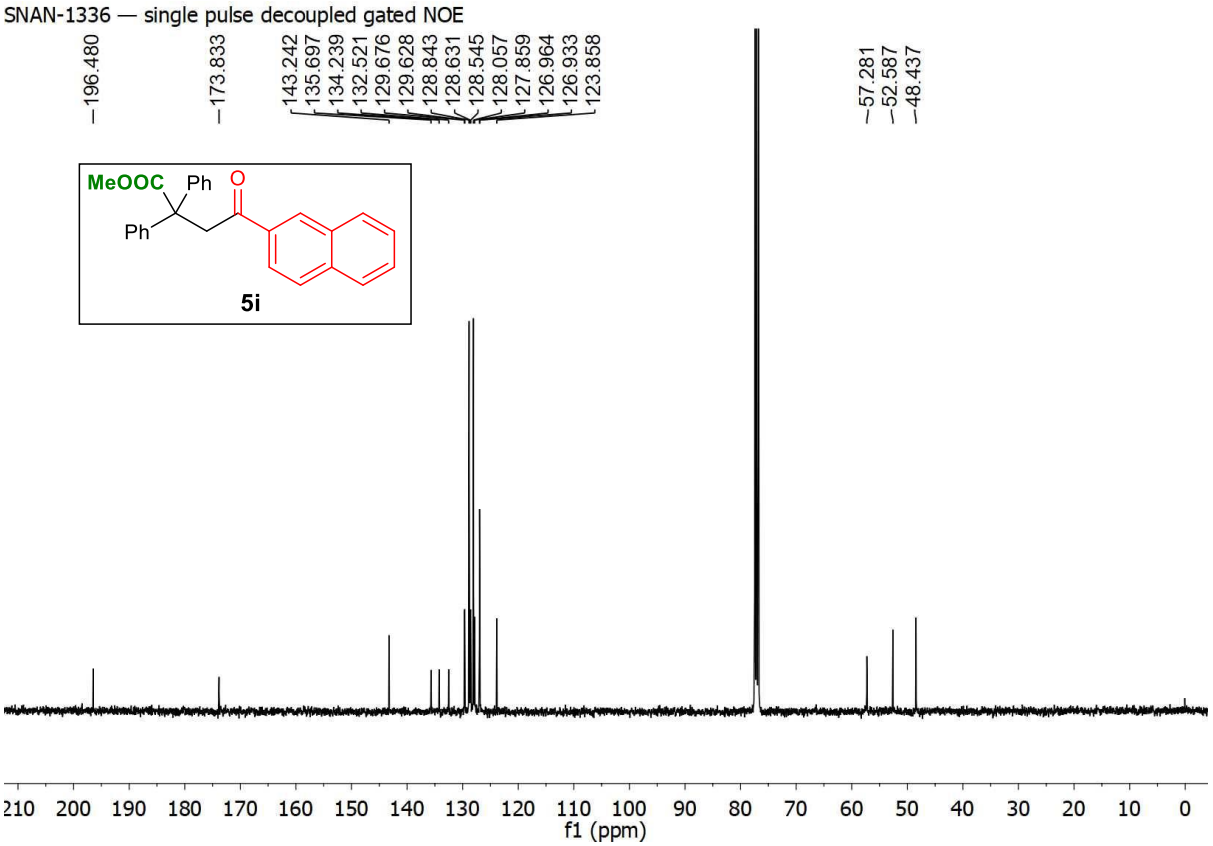

$^{1}$H spectra of **5h**



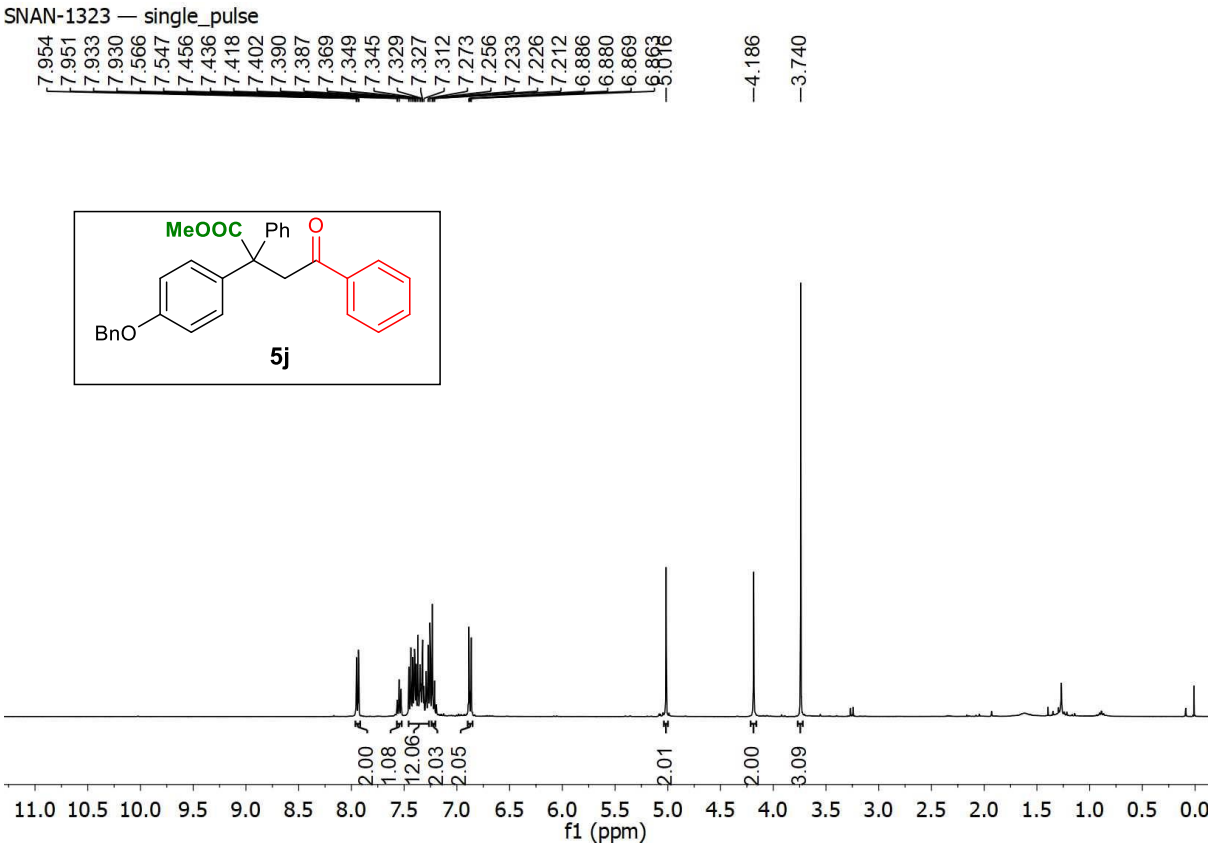

$^{13}$C spectra of **5h**



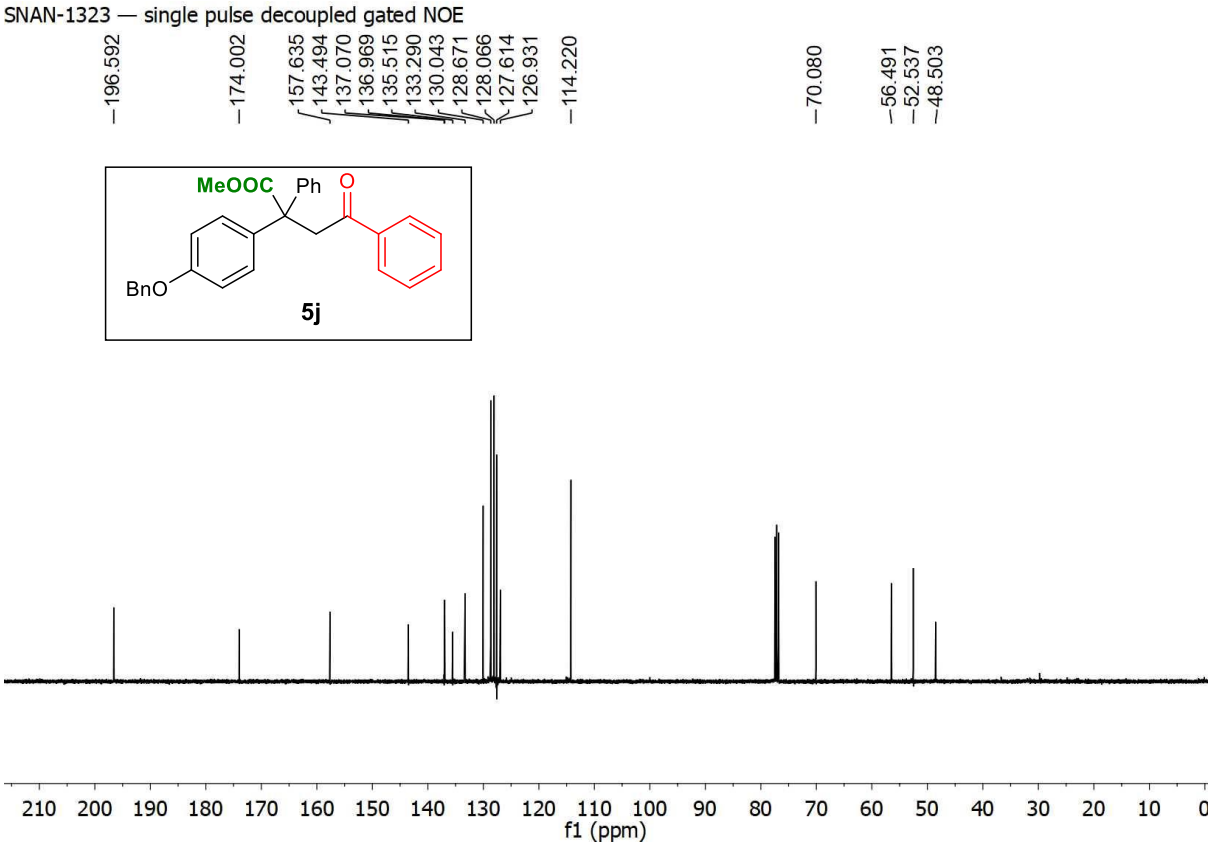

$^{1}$H spectra of **5i**



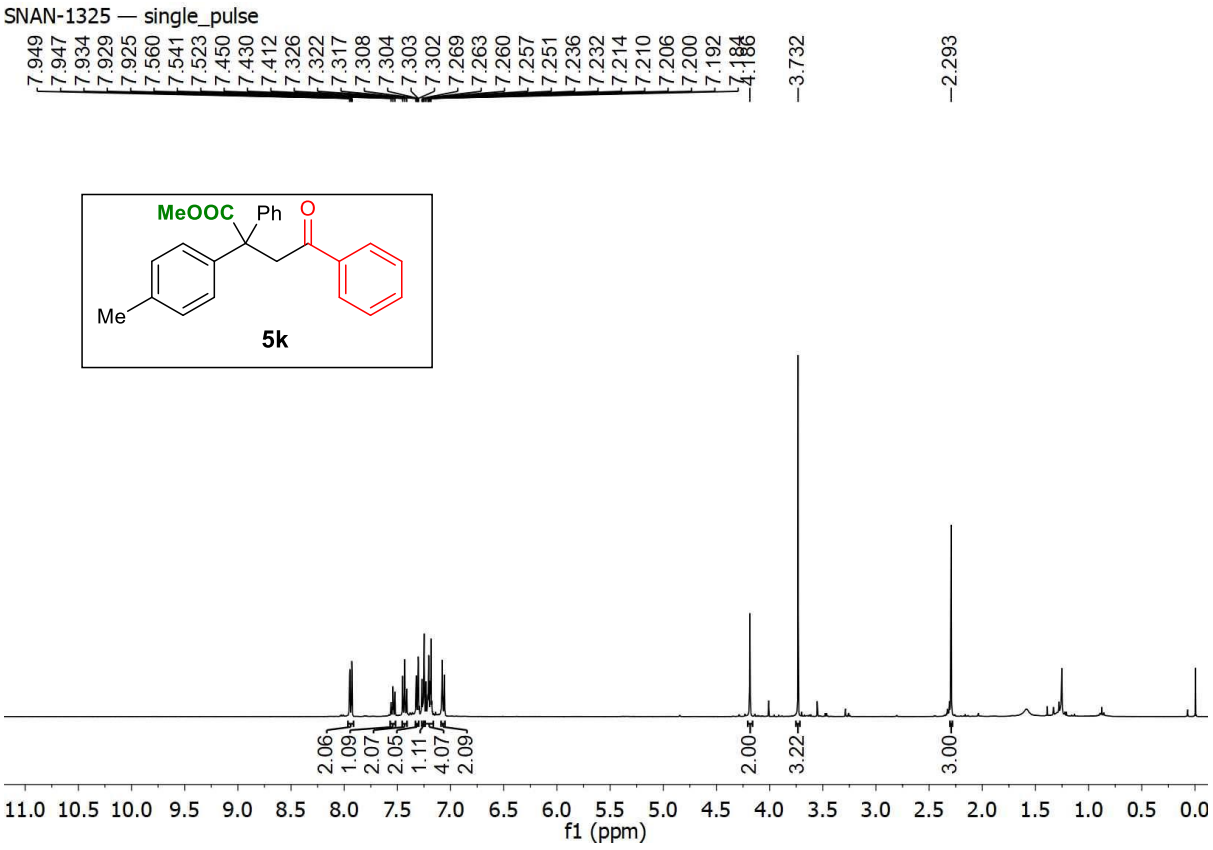

$^{13}$C spectra of **5i**



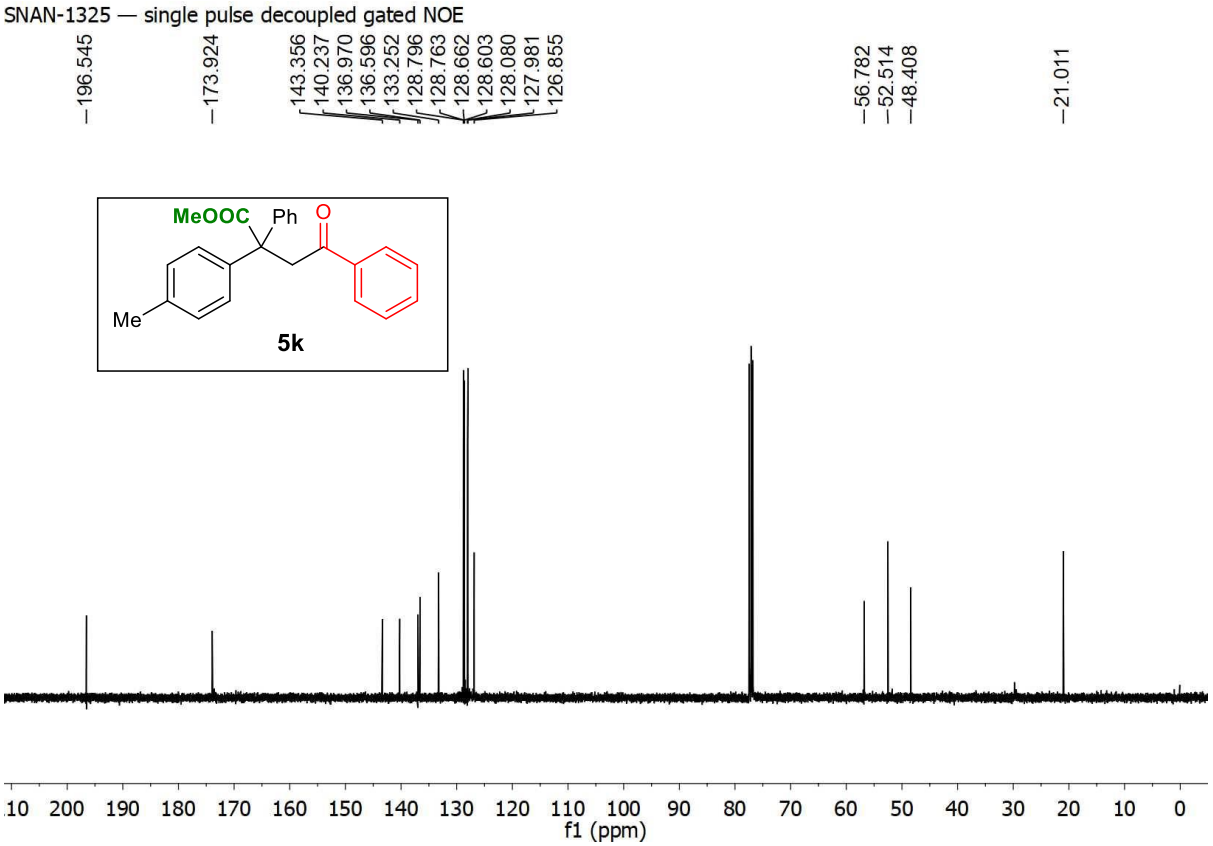

$^{1}$H spectra of **5j**



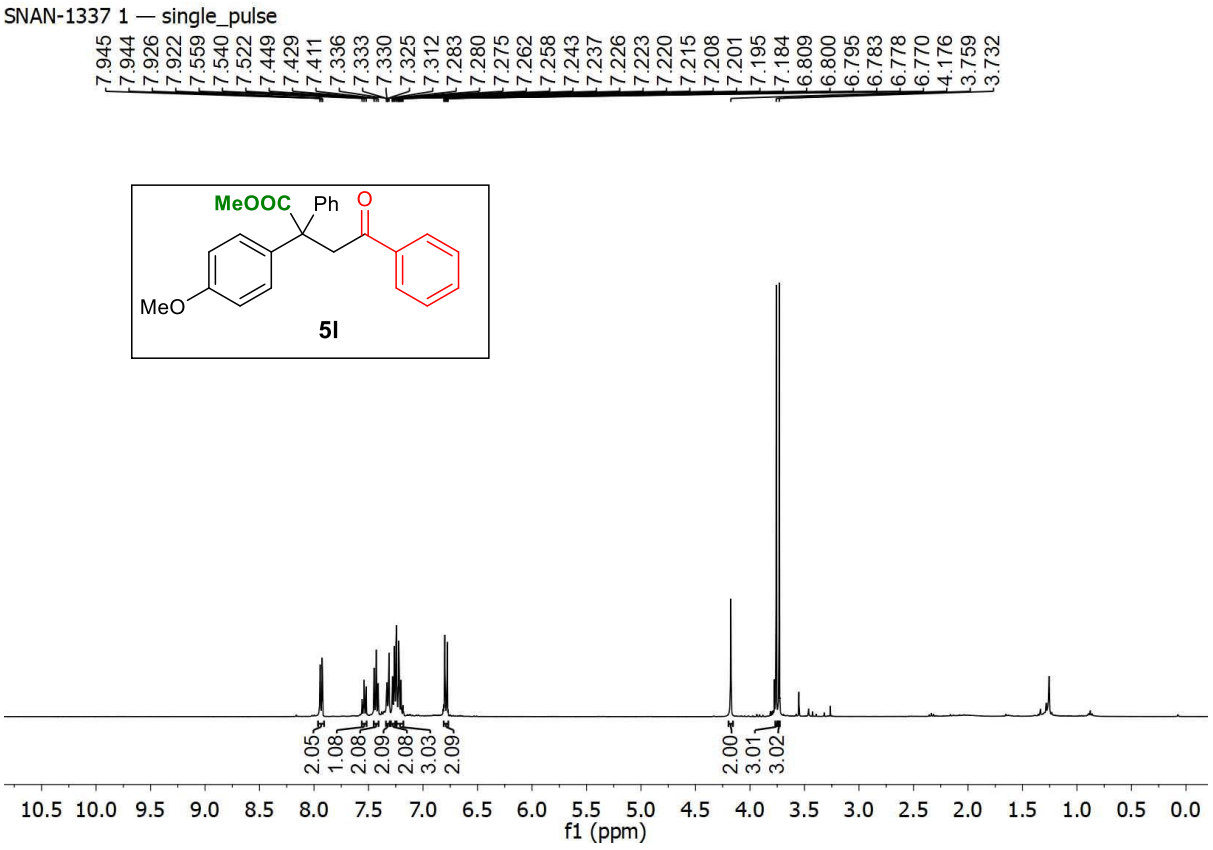

$^{13}$C spectra of **5j**



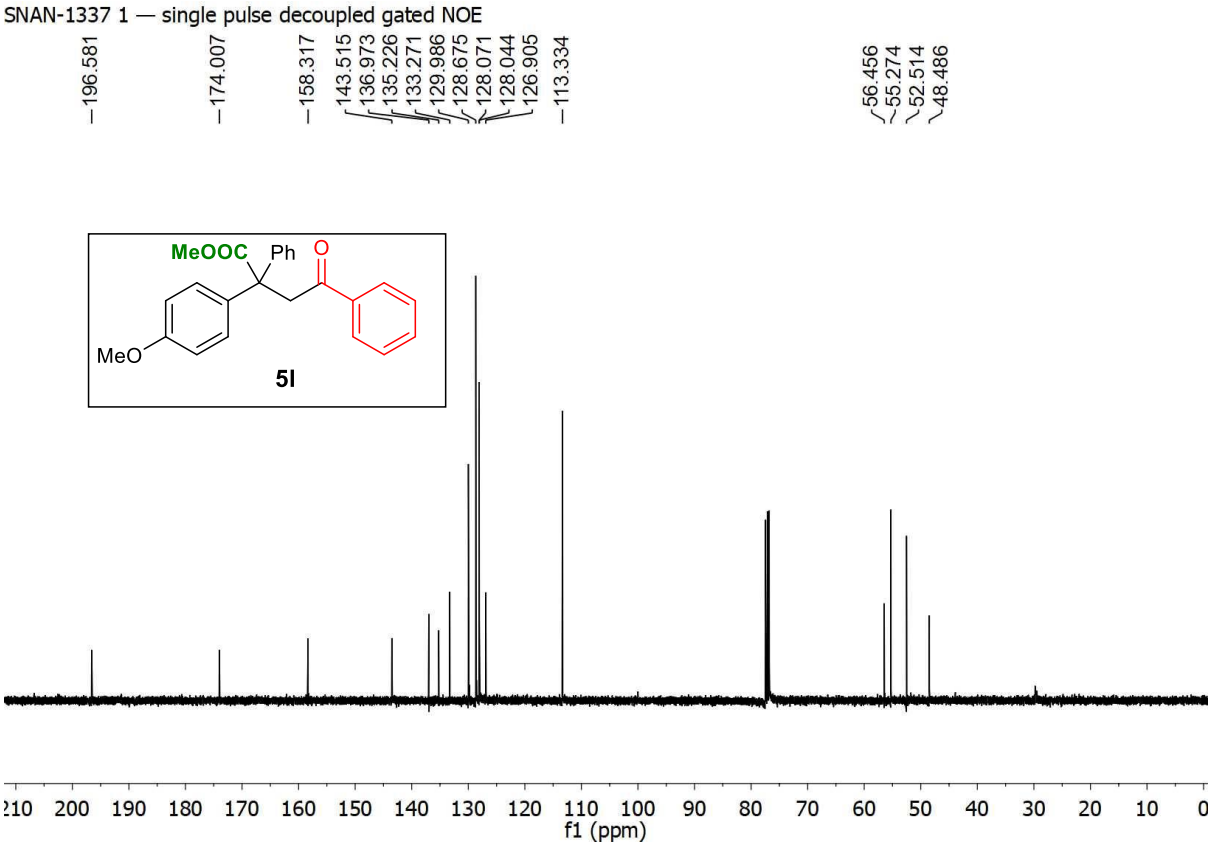

$^{1}$H spectra of **5k**



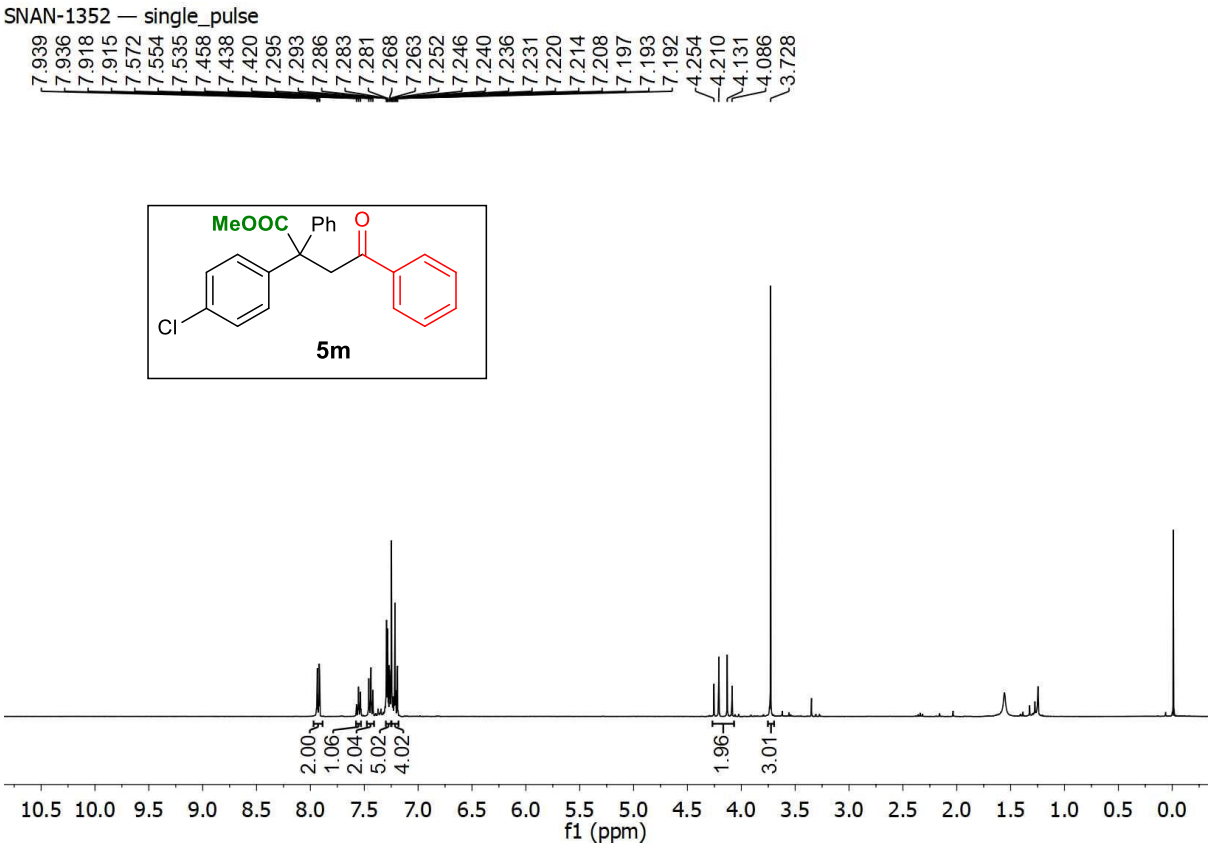

$^{13}$C spectra of **5k**



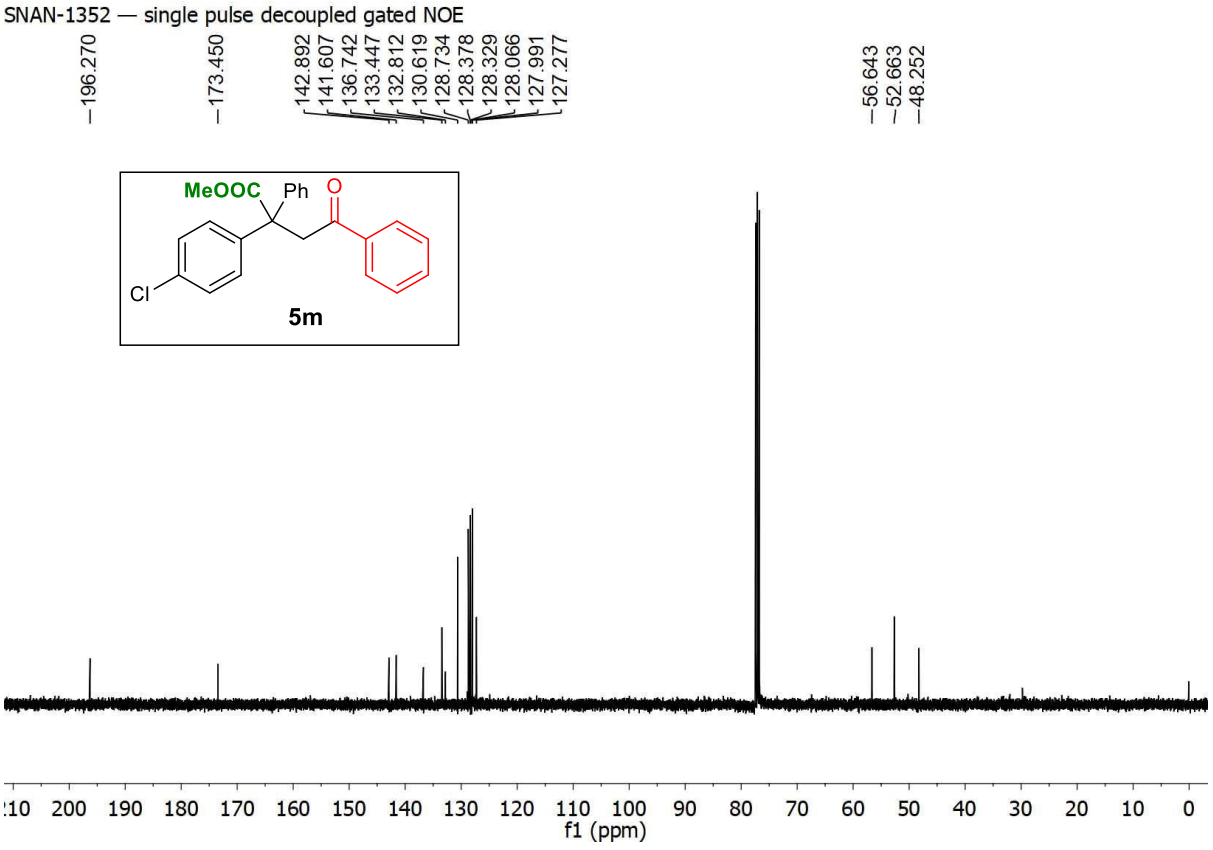

$^{1}$H spectra of **5l**



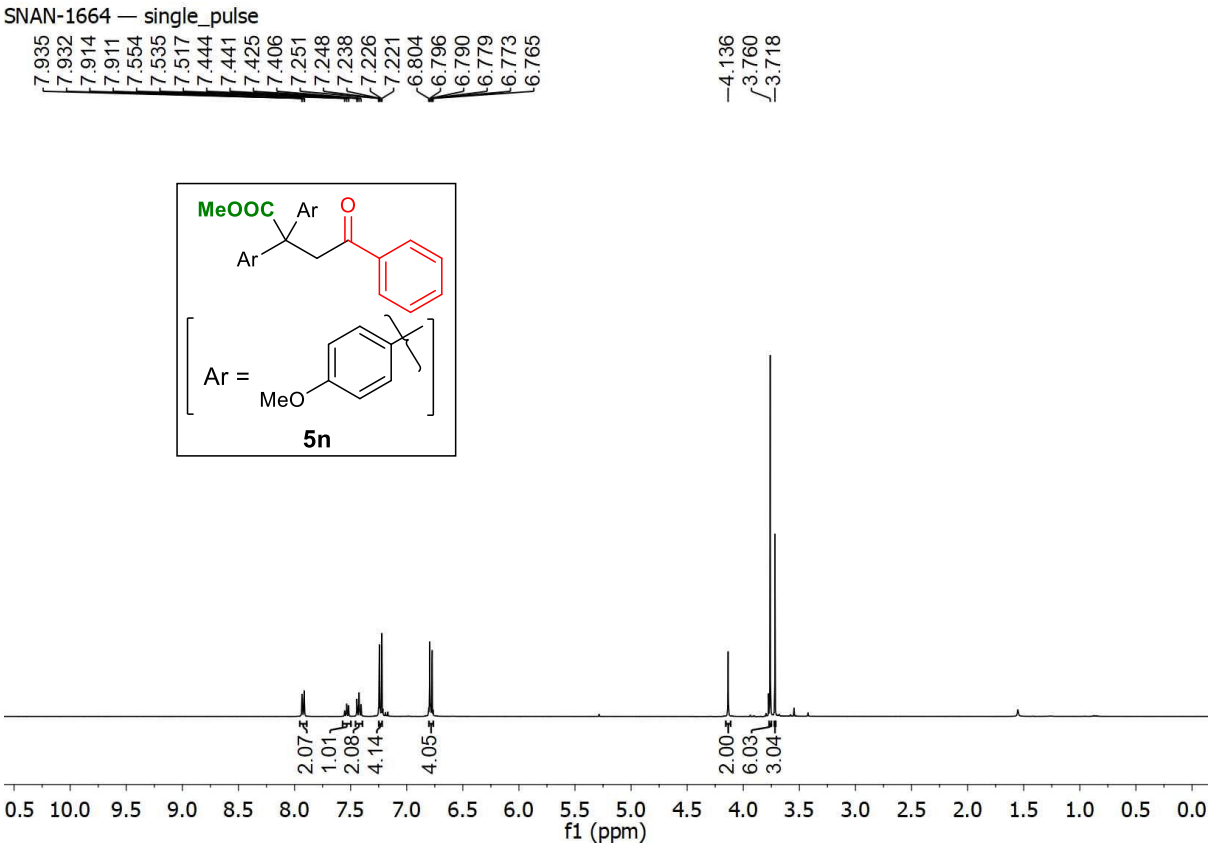

$^{13}$C spectra of **5l**



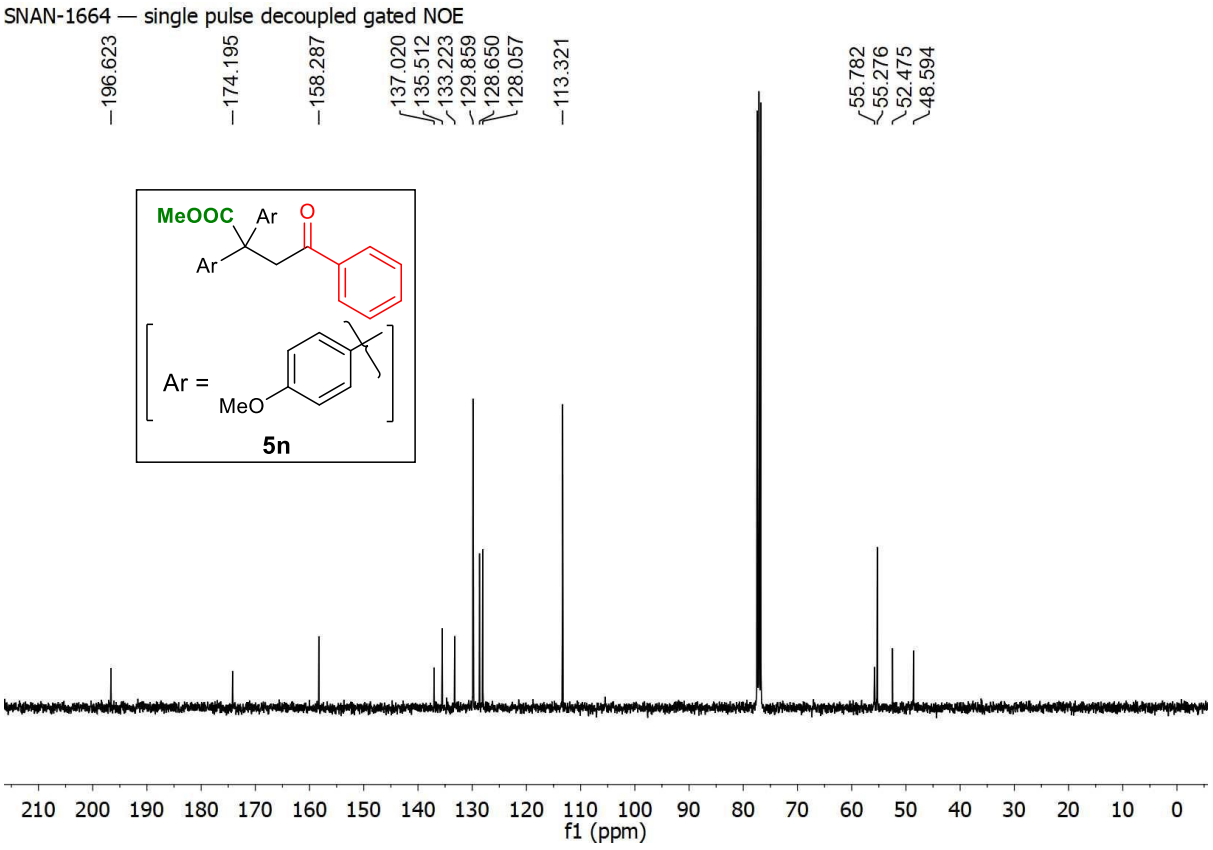

$^{1}$H spectra of **5m**



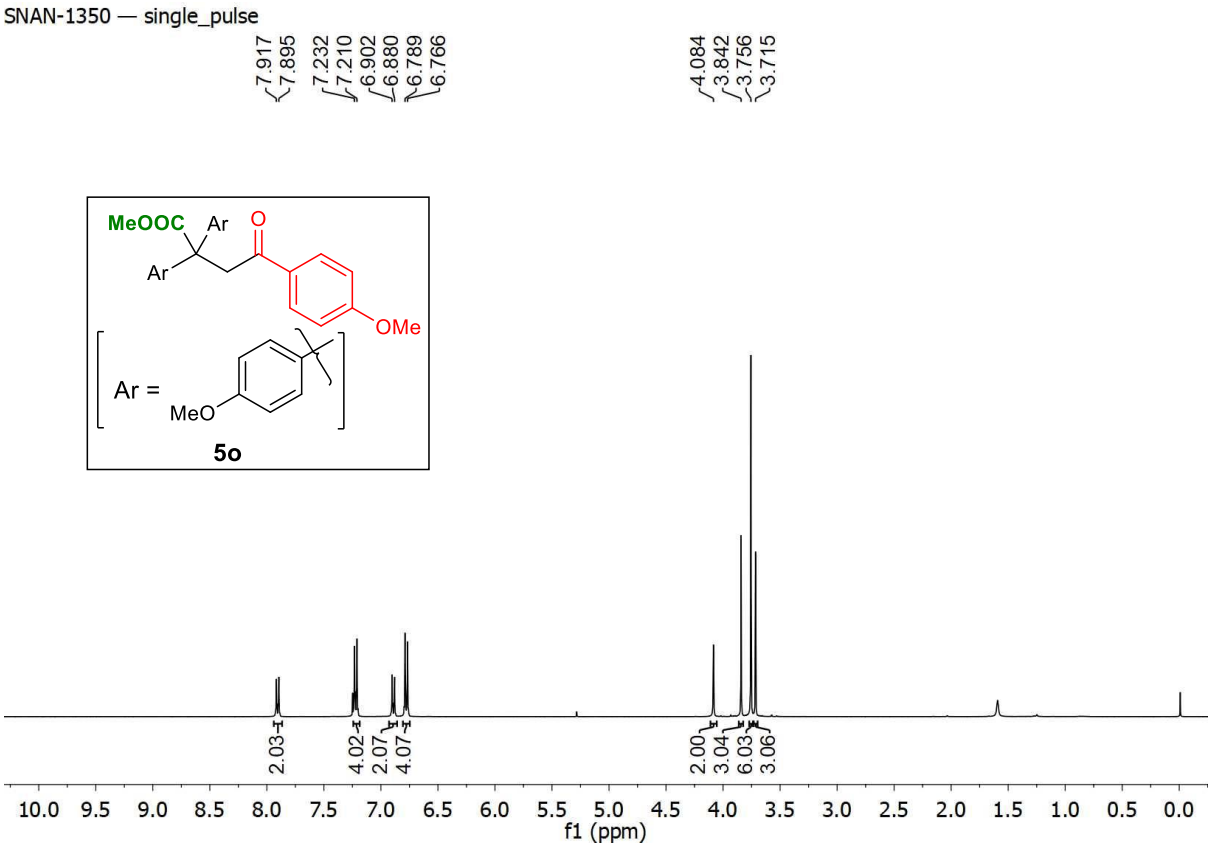

$^{13}$C spectra of **5m**



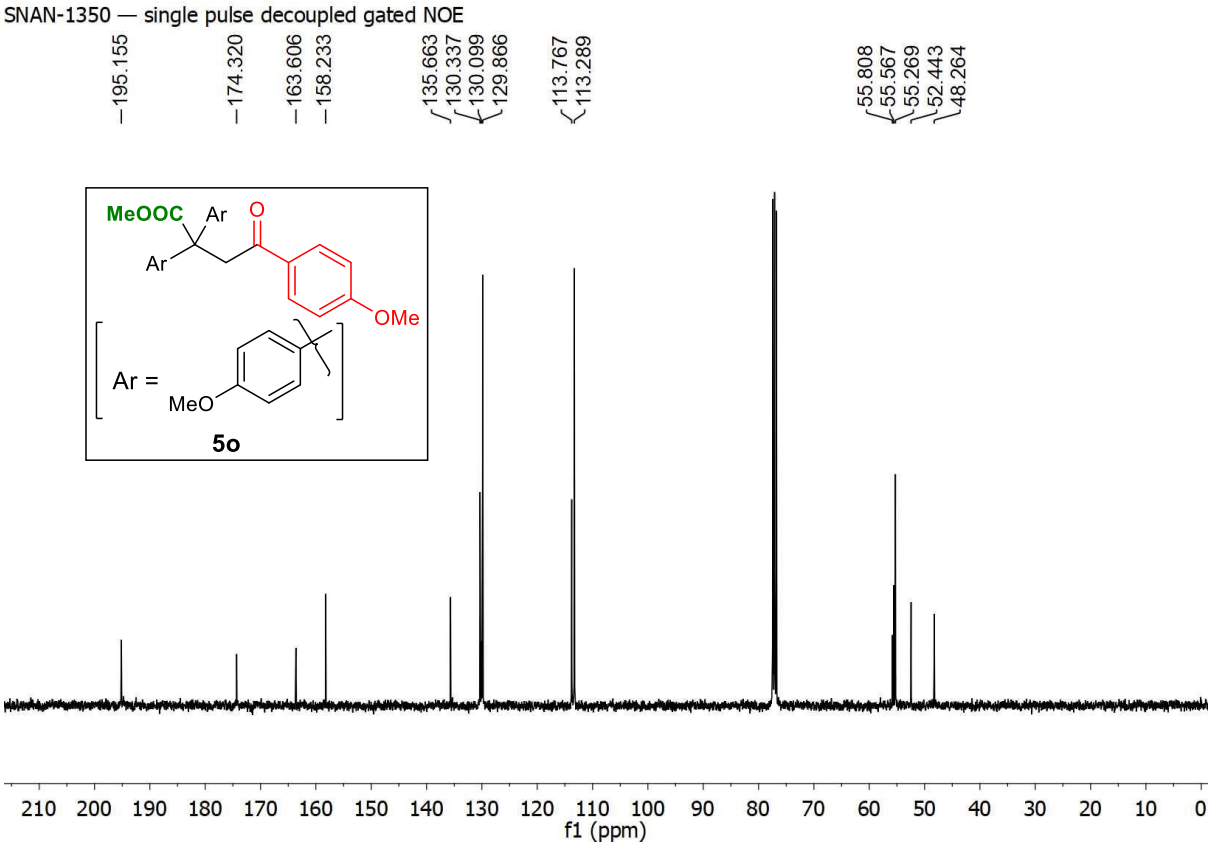

$^{1}$H spectra of **5n**



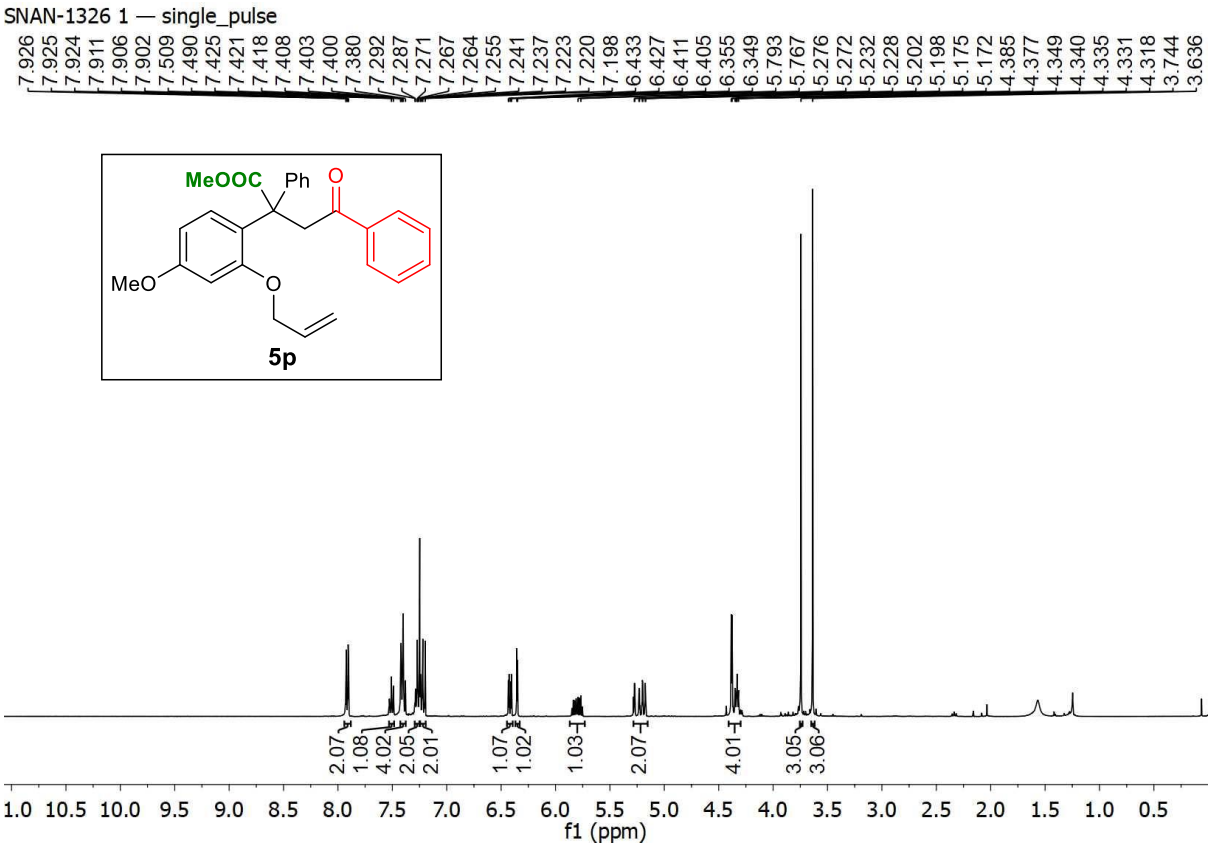

$^{13}$C spectra of **5n**



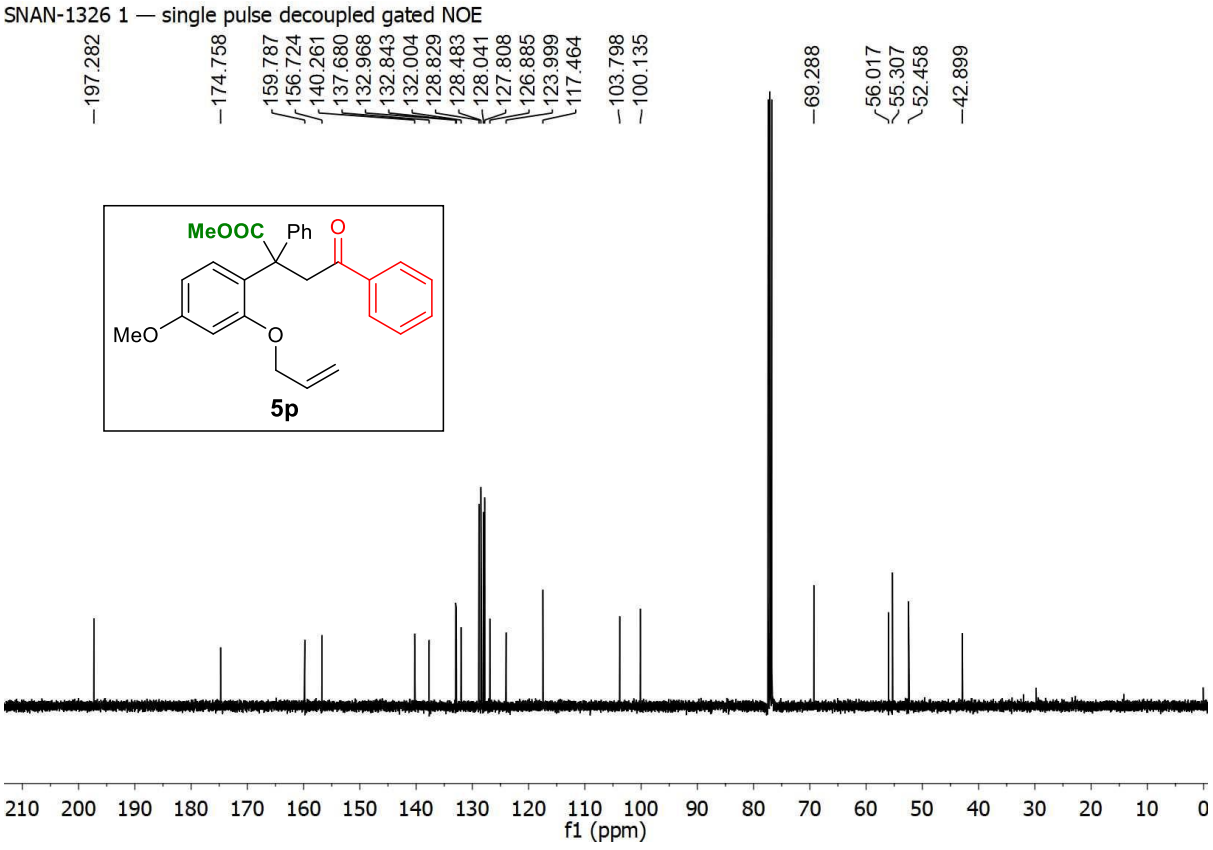

$^{1}$H spectra of **5o**



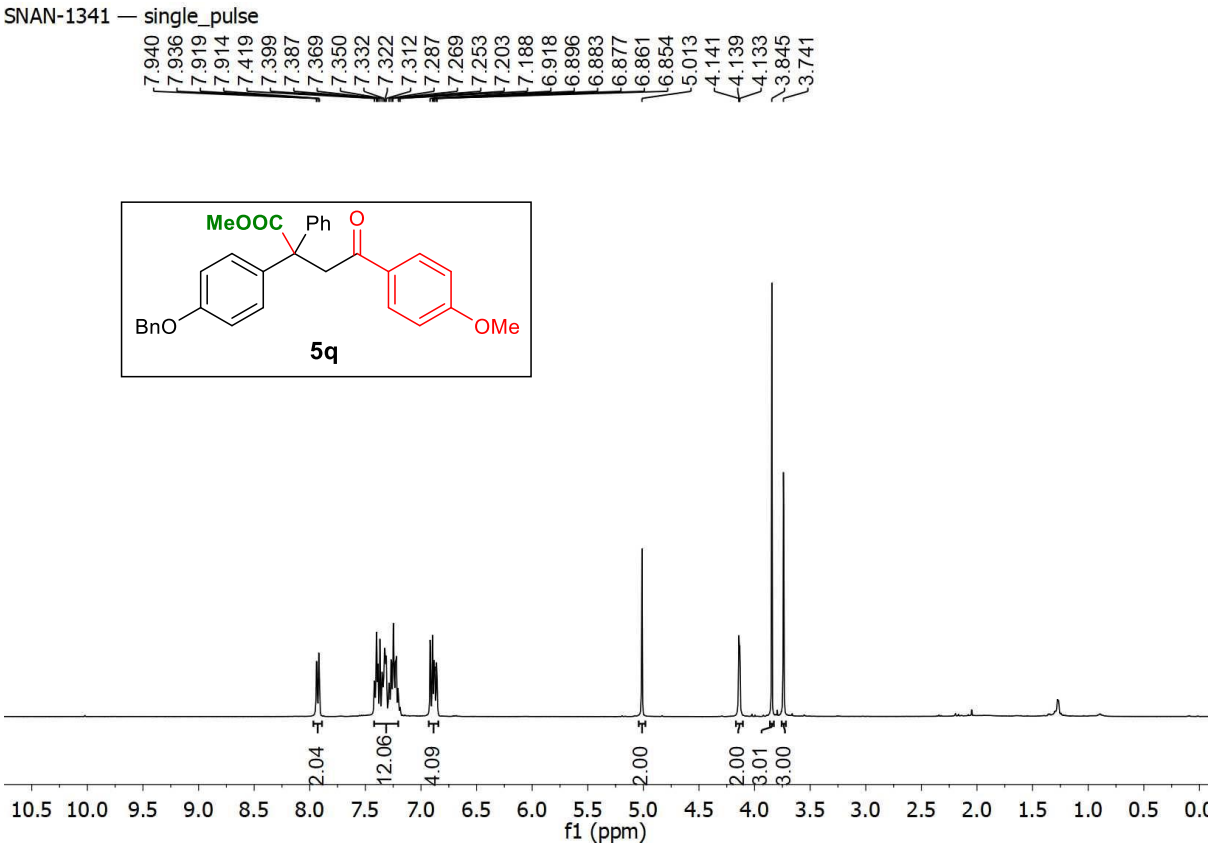

$^{13}$C spectra of **5o**



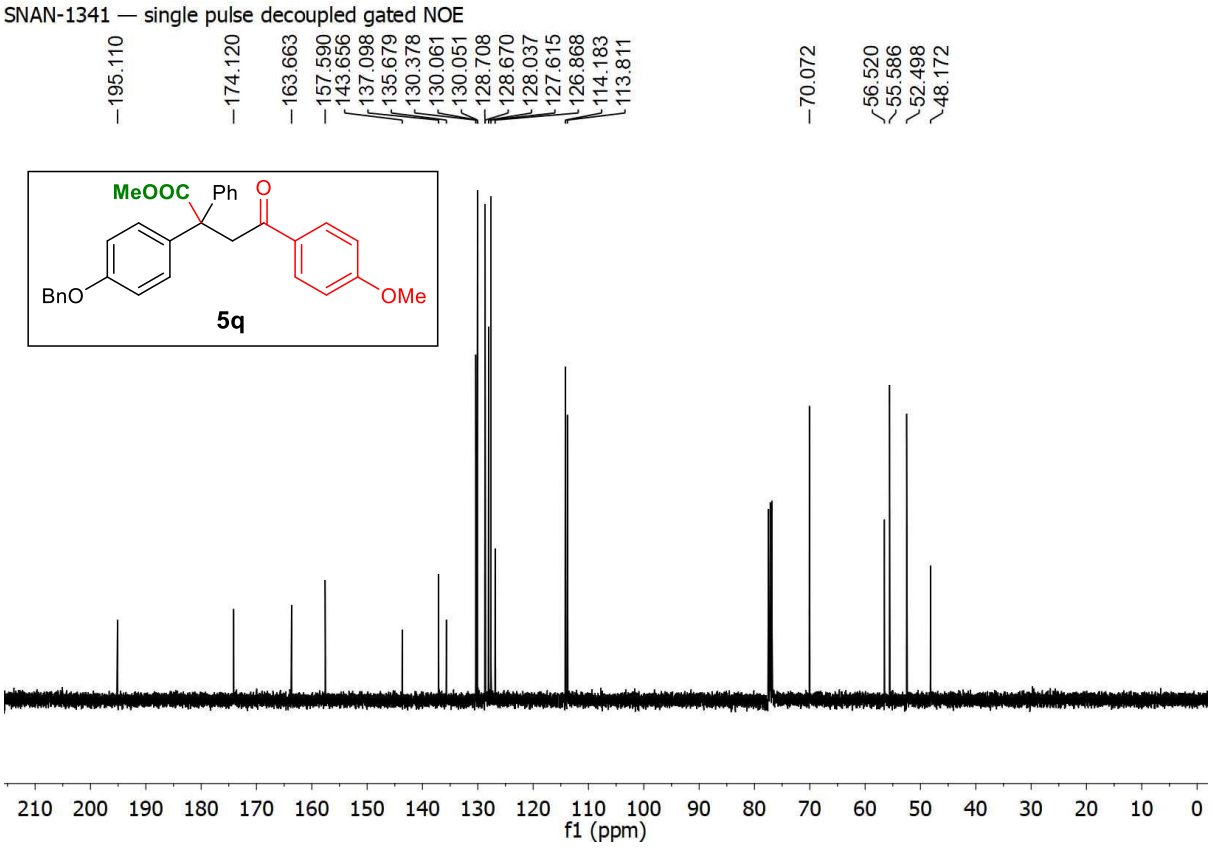

$^{1}$H spectra of **5p**



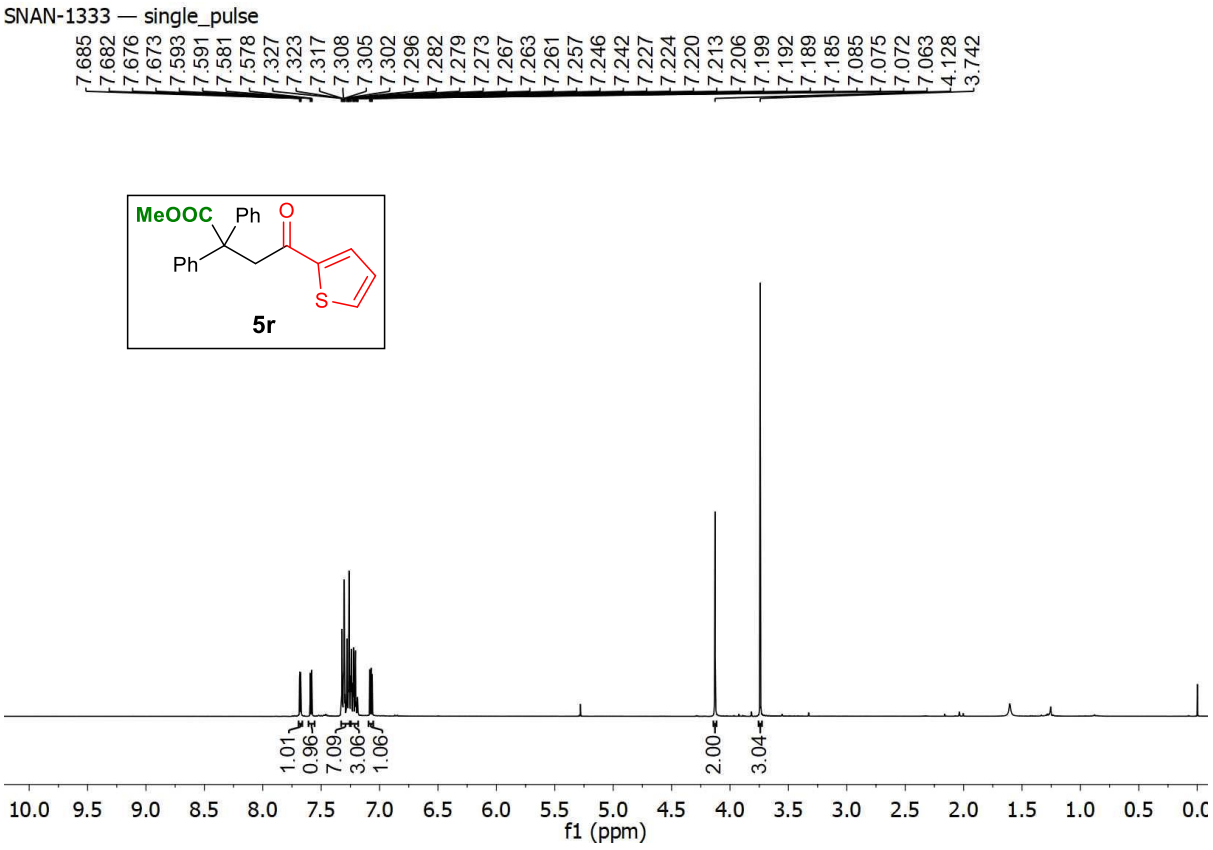

$^{13}$C spectra of **5p**



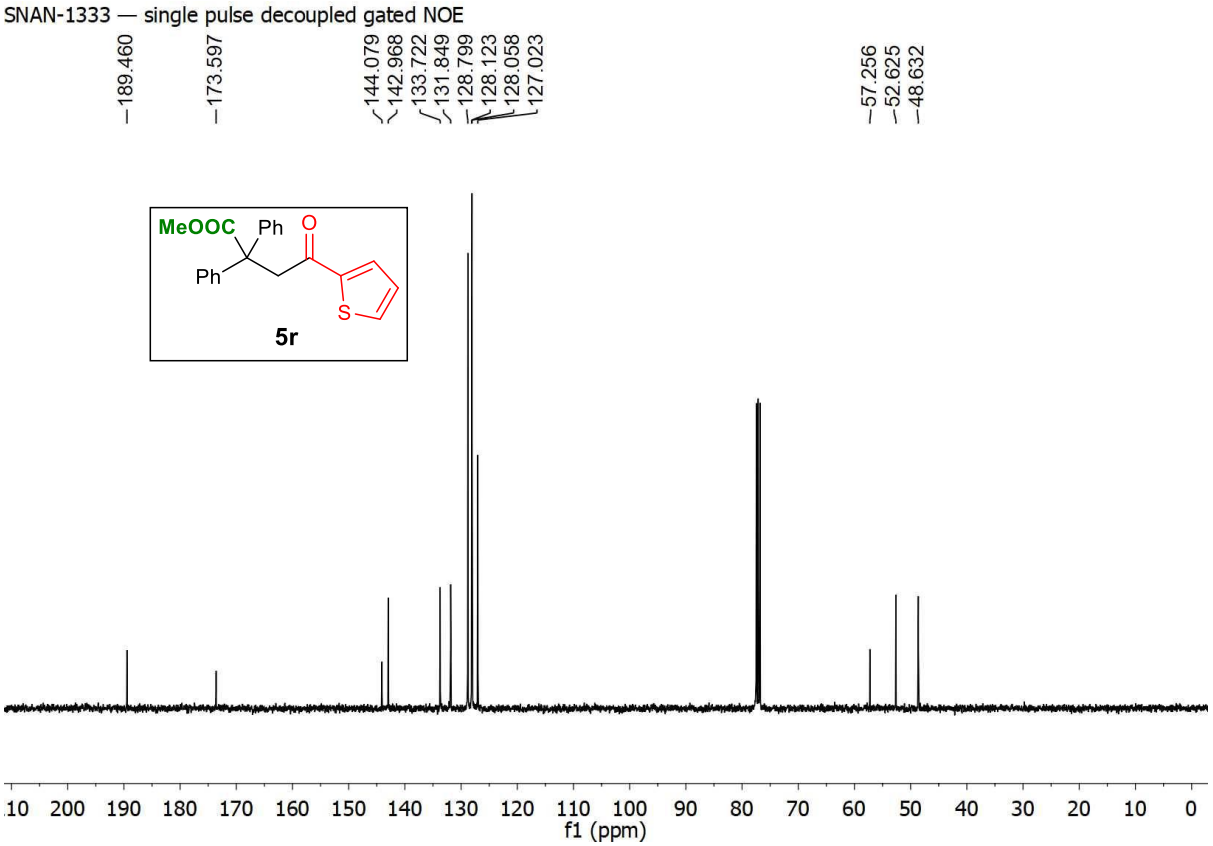

$^{1}$H spectra of **5q**



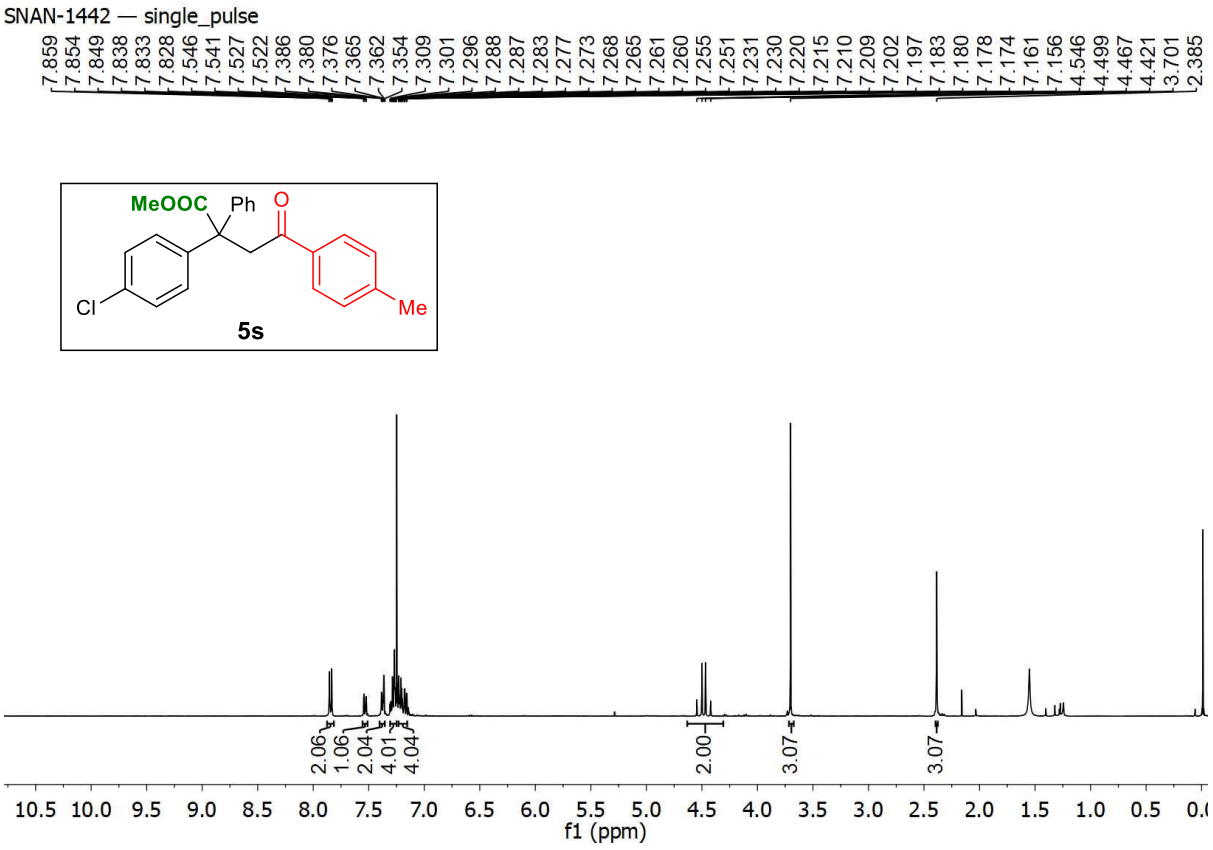

$^{13}$C spectra of **5q**



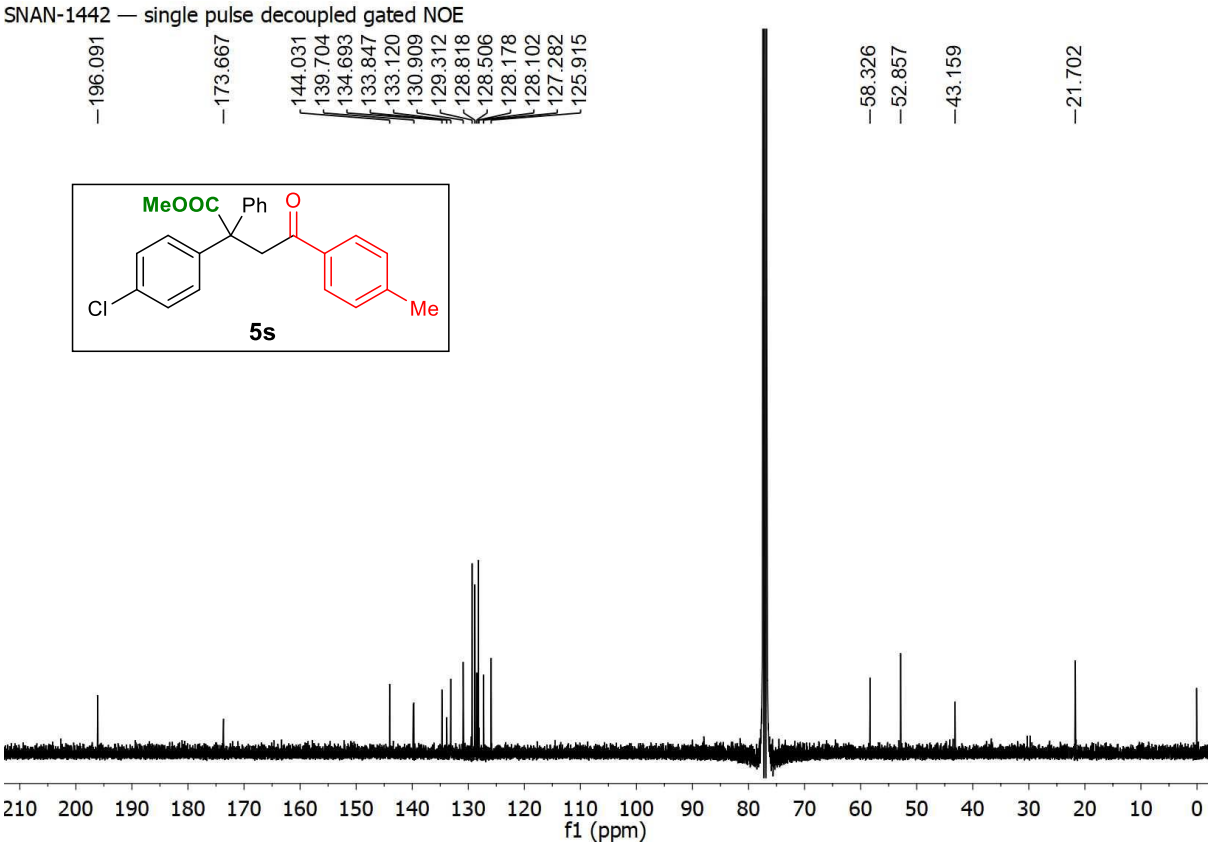

$^{1}$H spectra of **5r**



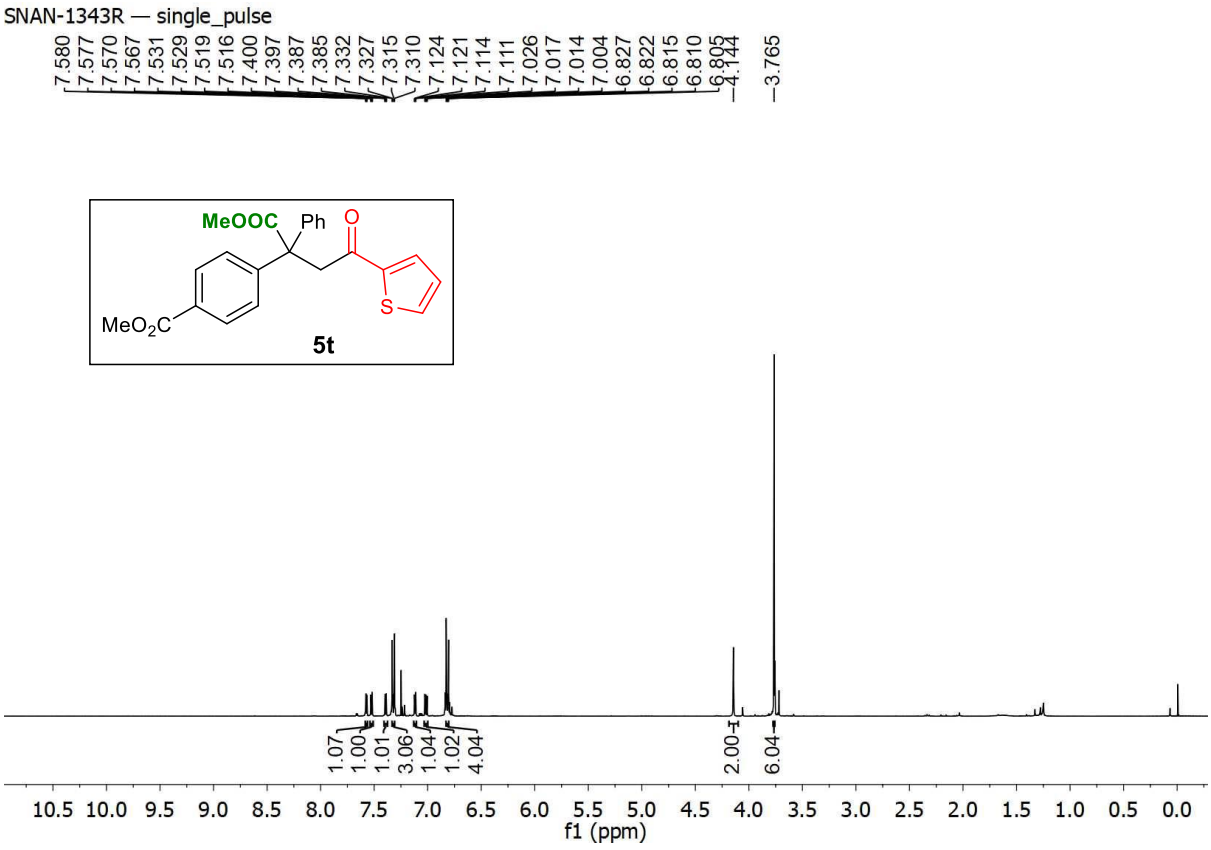

$^{13}$C spectra of **5r**



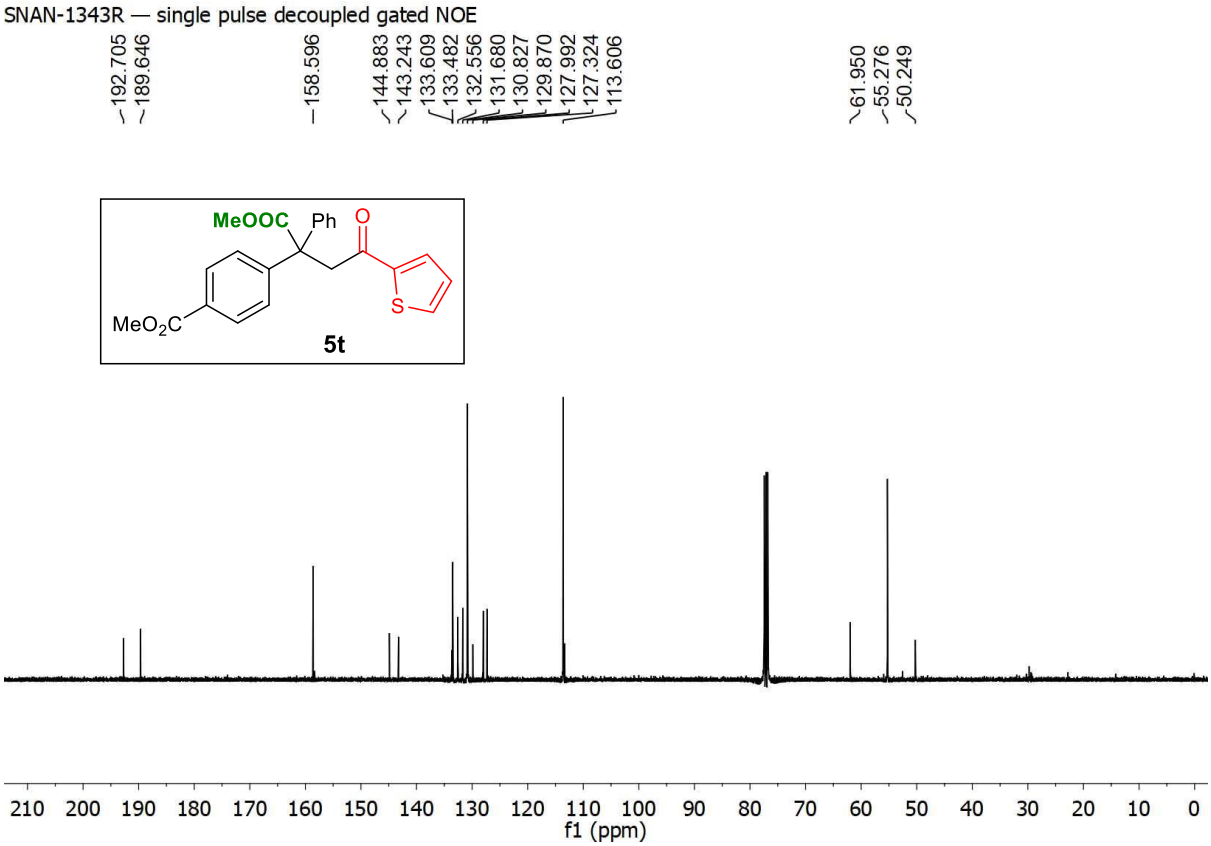

$^{1}$H spectra of **5s**



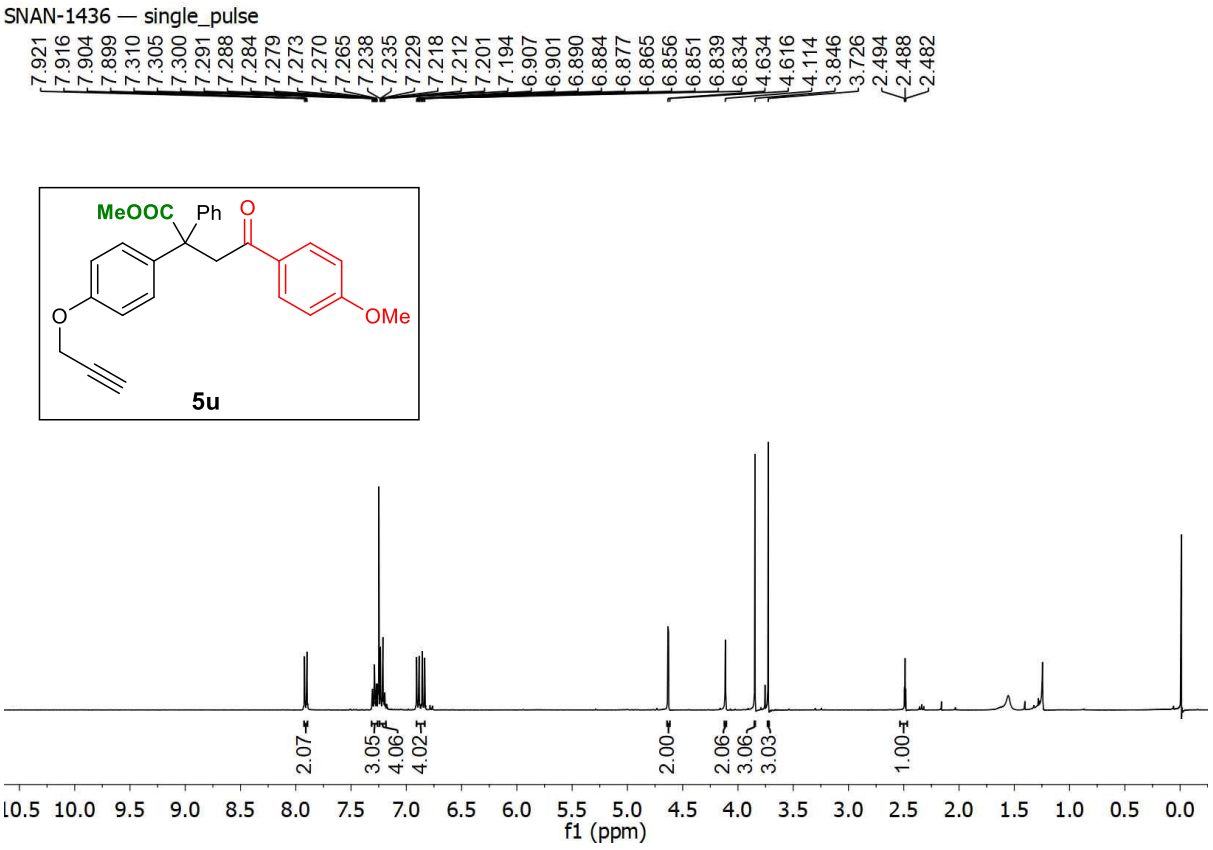

$^{13}$C spectra of **5s**



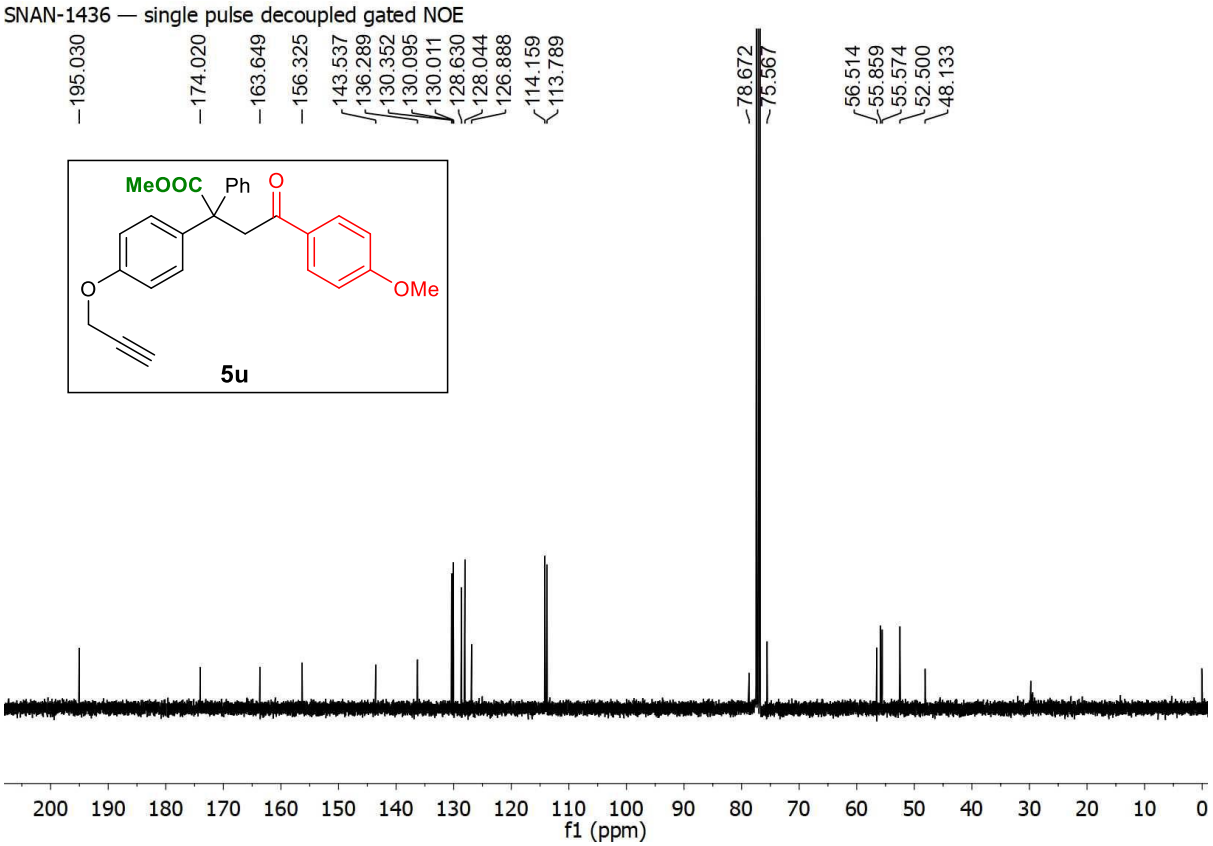

$^{1}$H spectra of **5t**



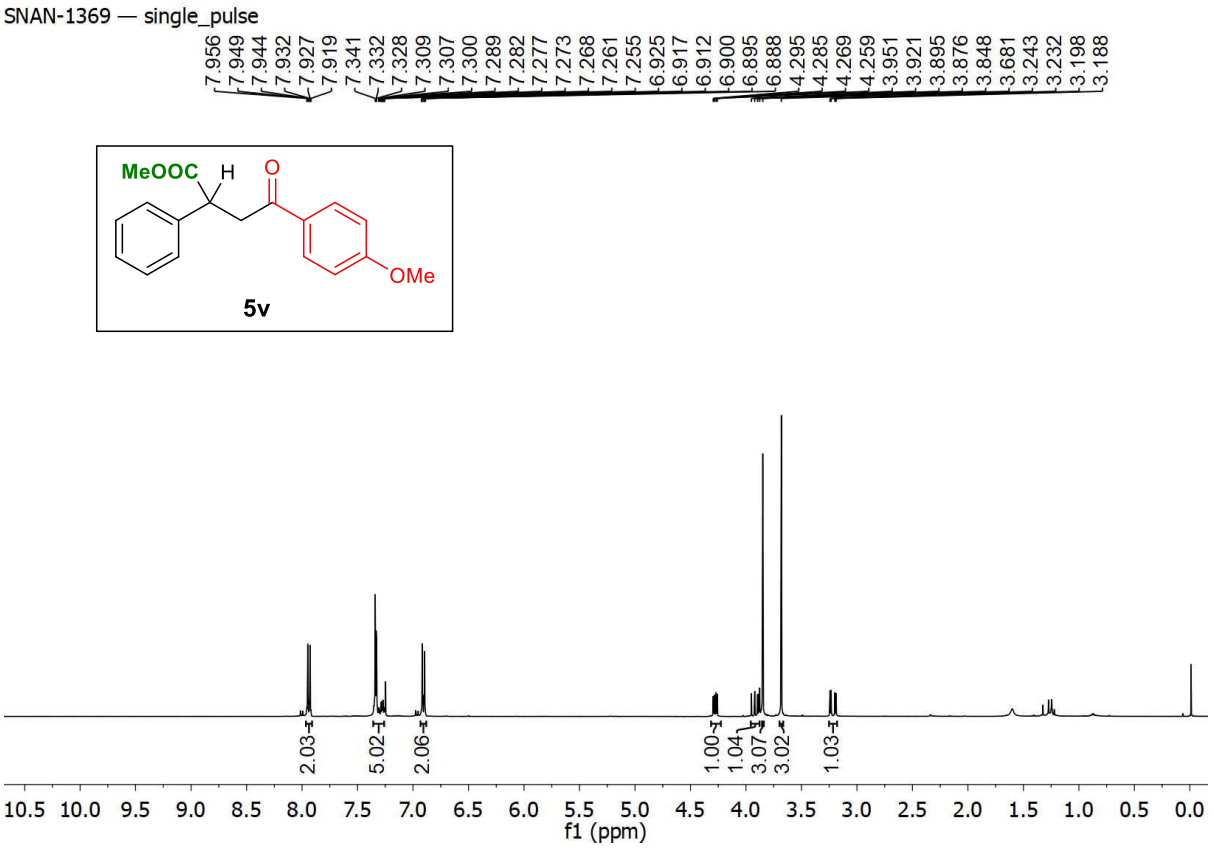

$^{13}$C spectra of **5t**



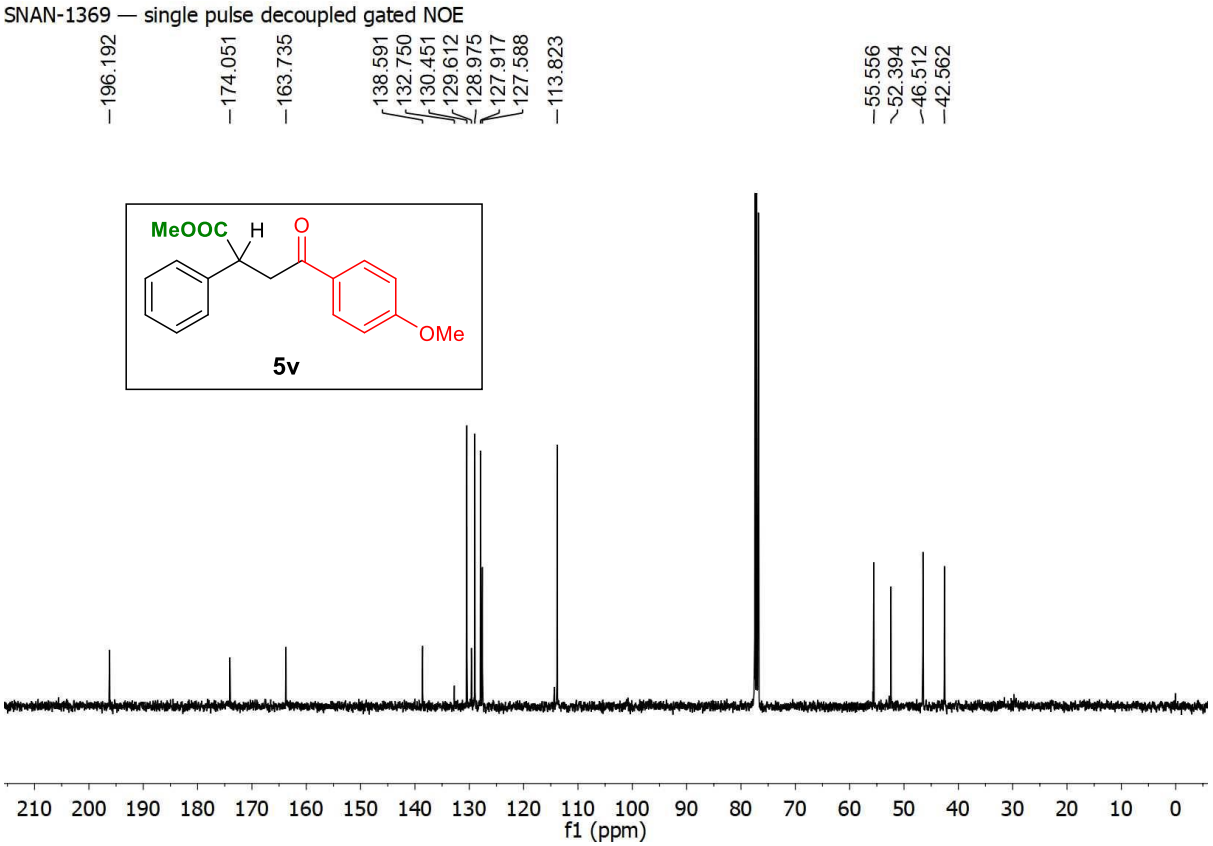

$^{1}$H spectra of **5u**



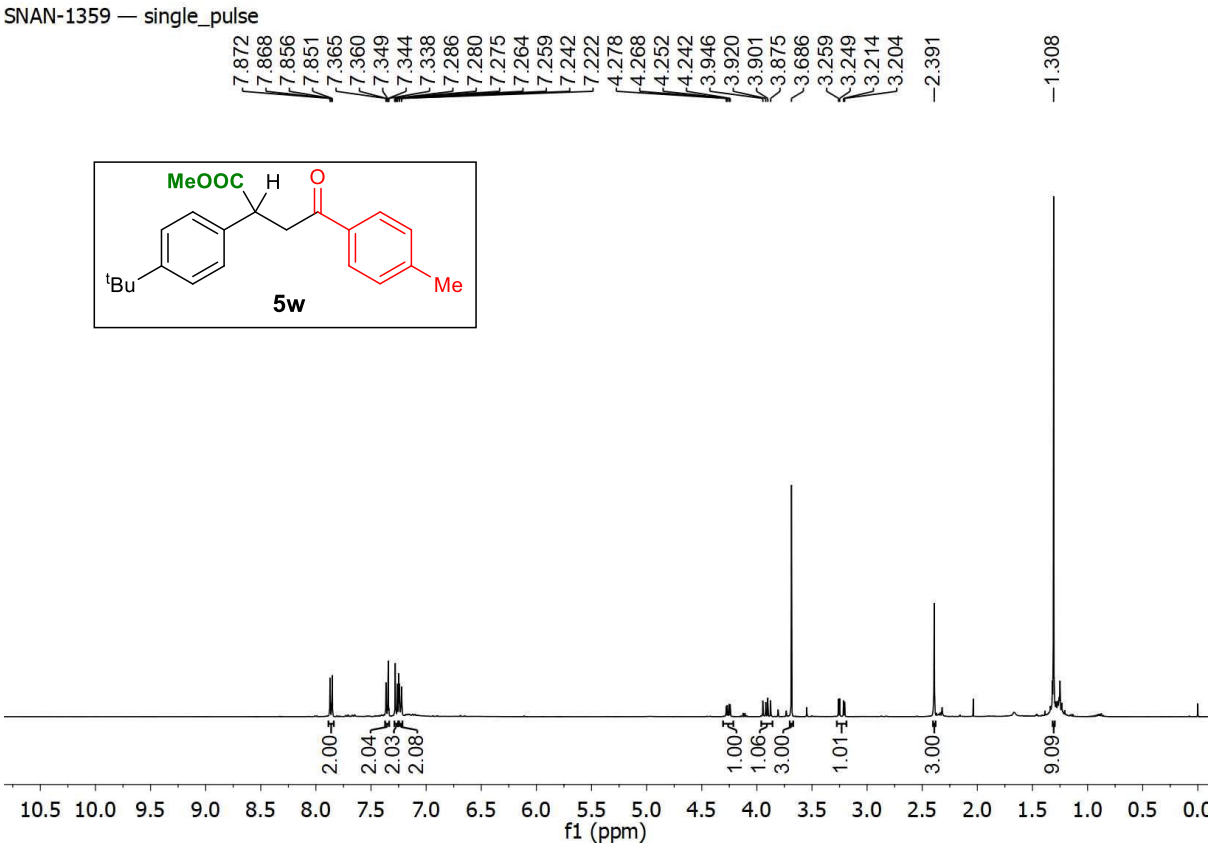

$^{13}$C spectra of **5u**



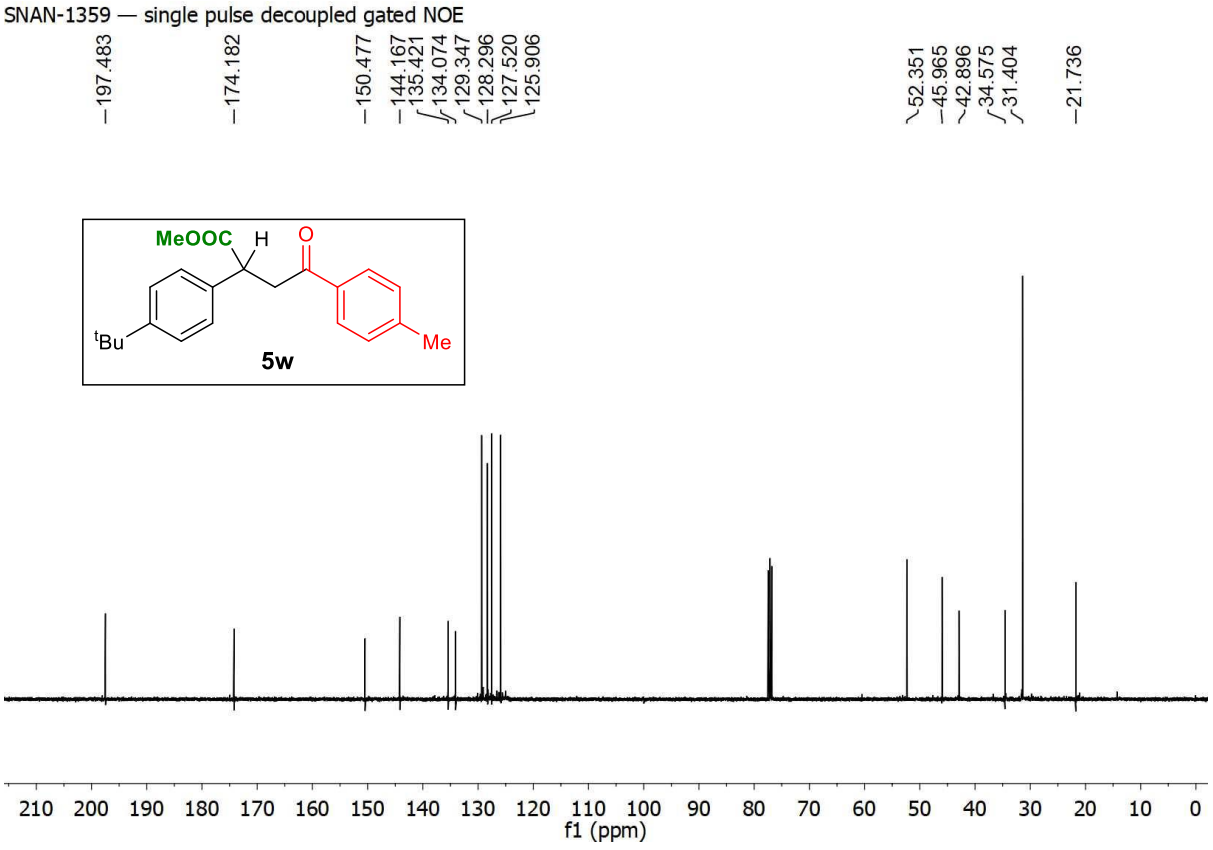

$^{1}$H spectra of **5v**



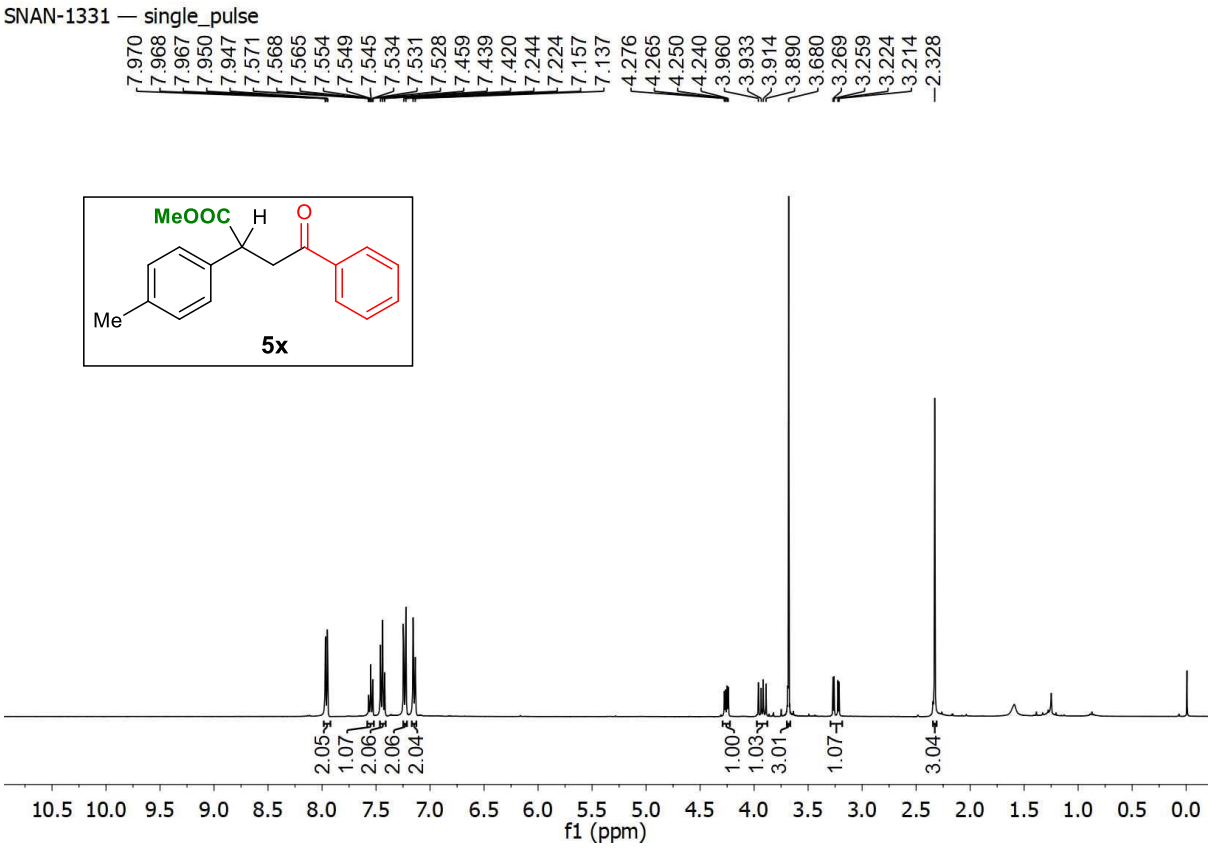

$^{13}$C spectra of **5v**



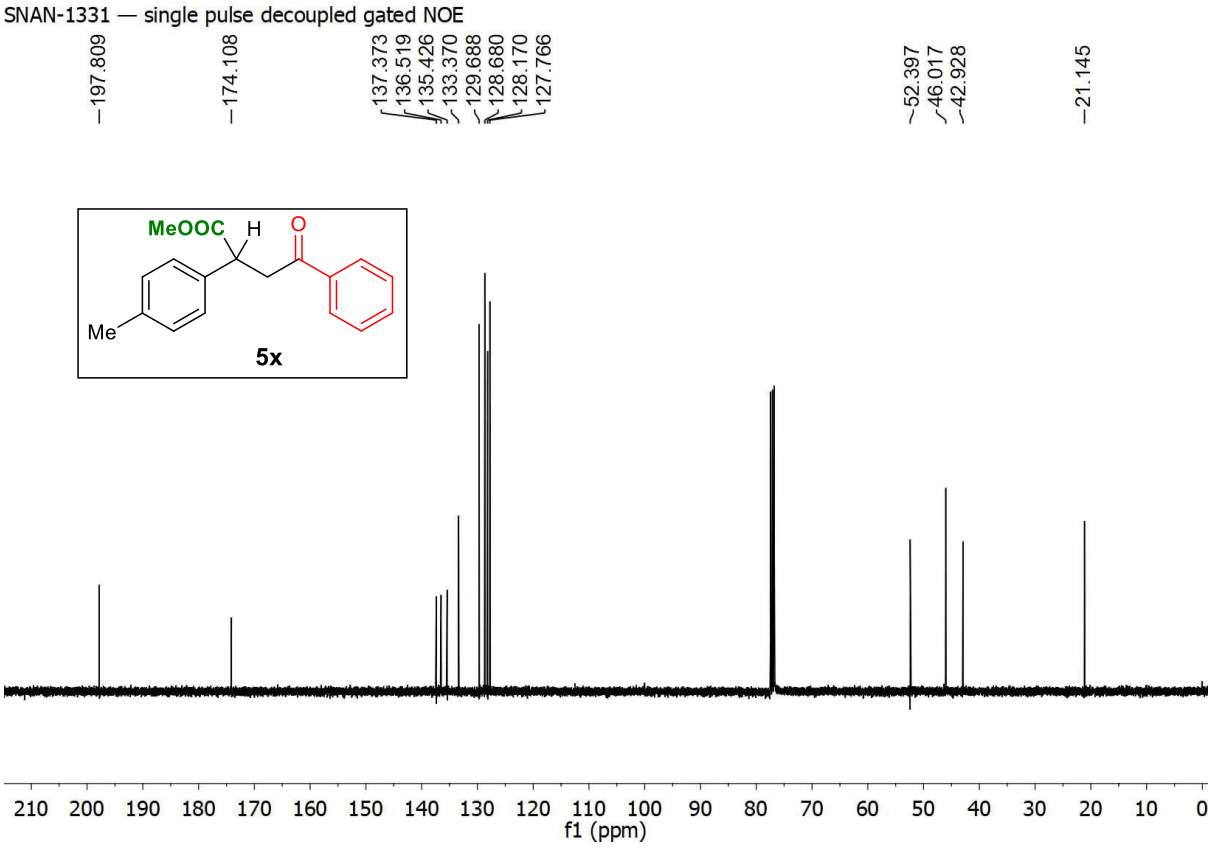

$^{1}$H spectra of **5w**



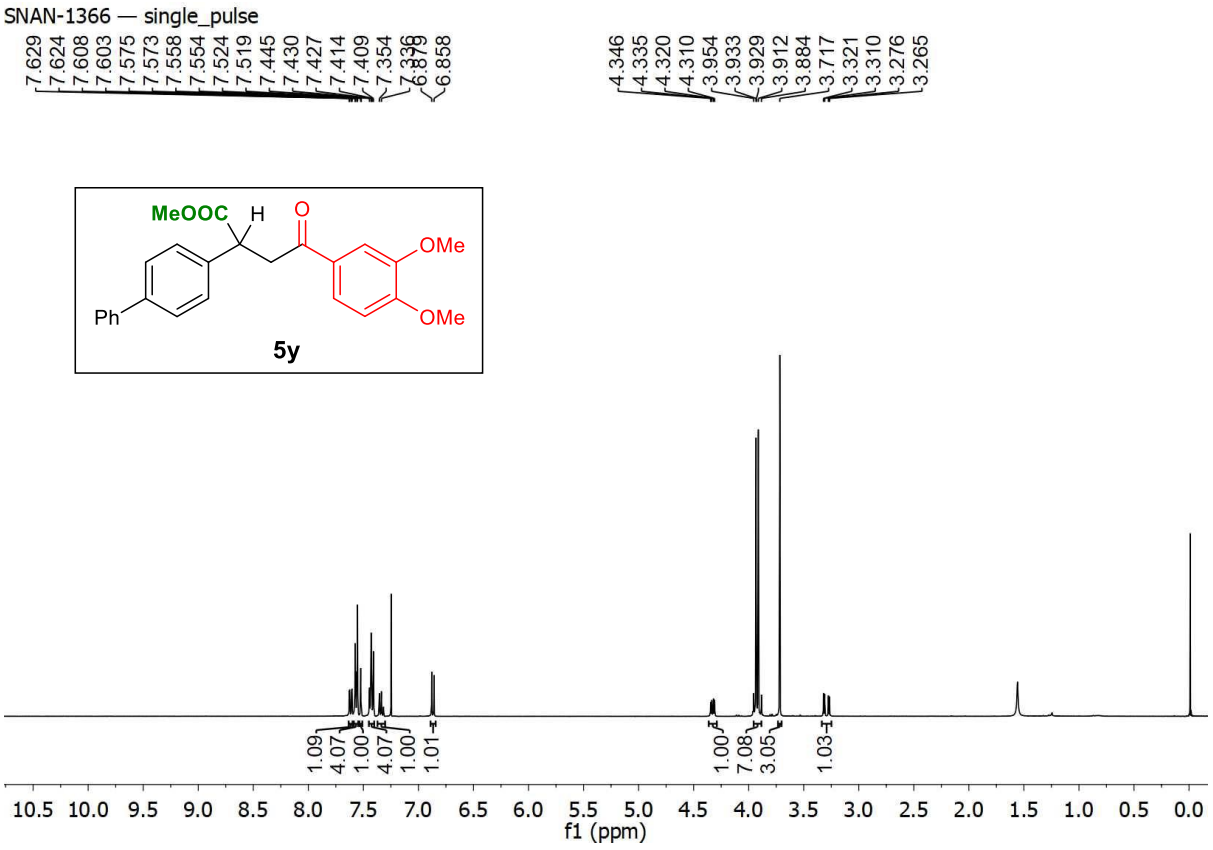

$^{13}$C spectra of **5w**



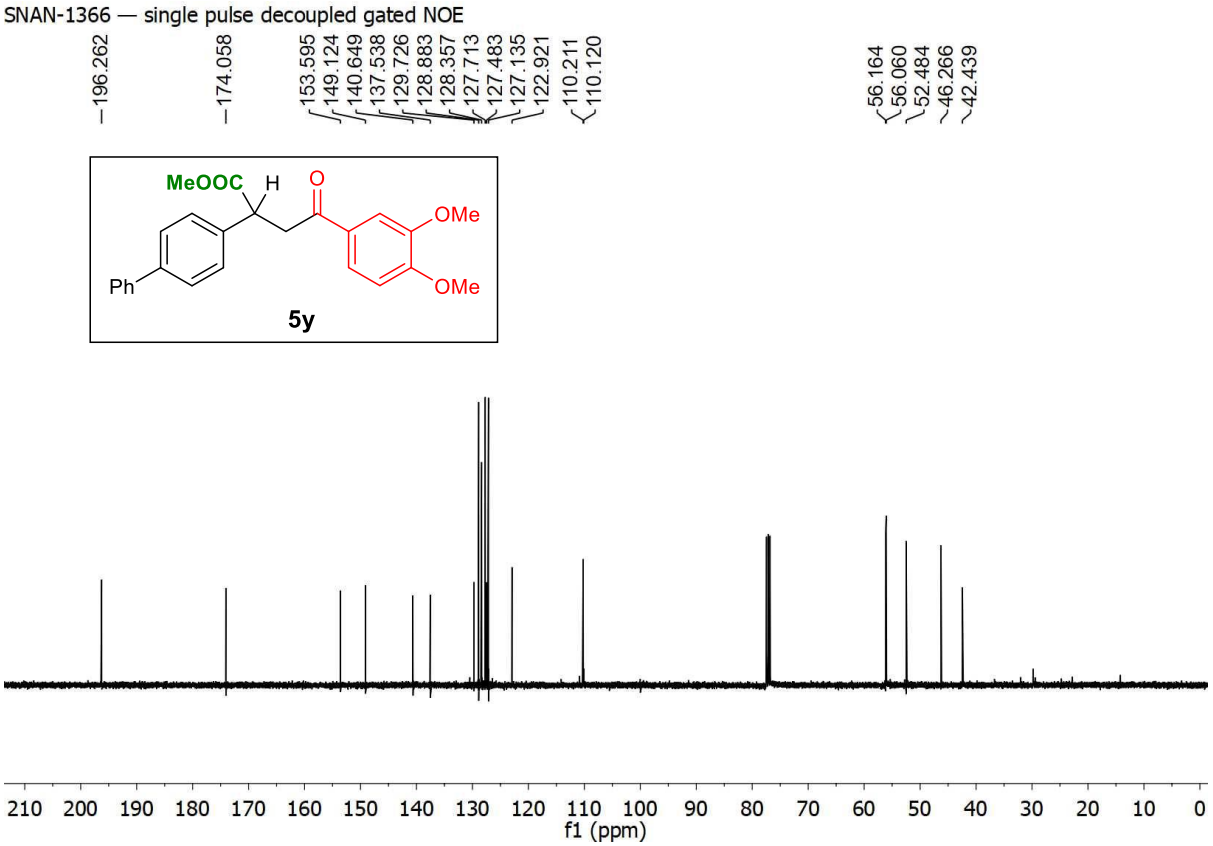

$^{1}$H spectra of **5x**



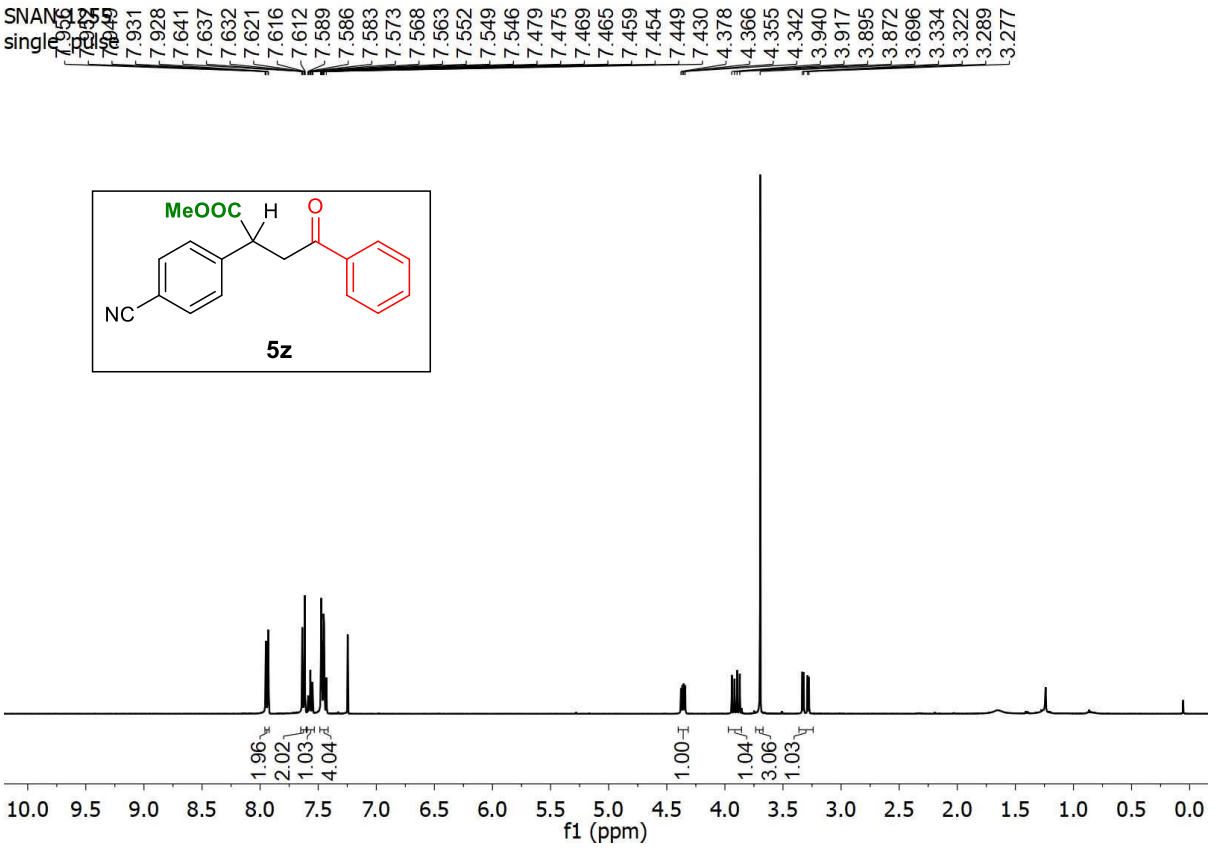

$^{13}$C spectra of **5x**



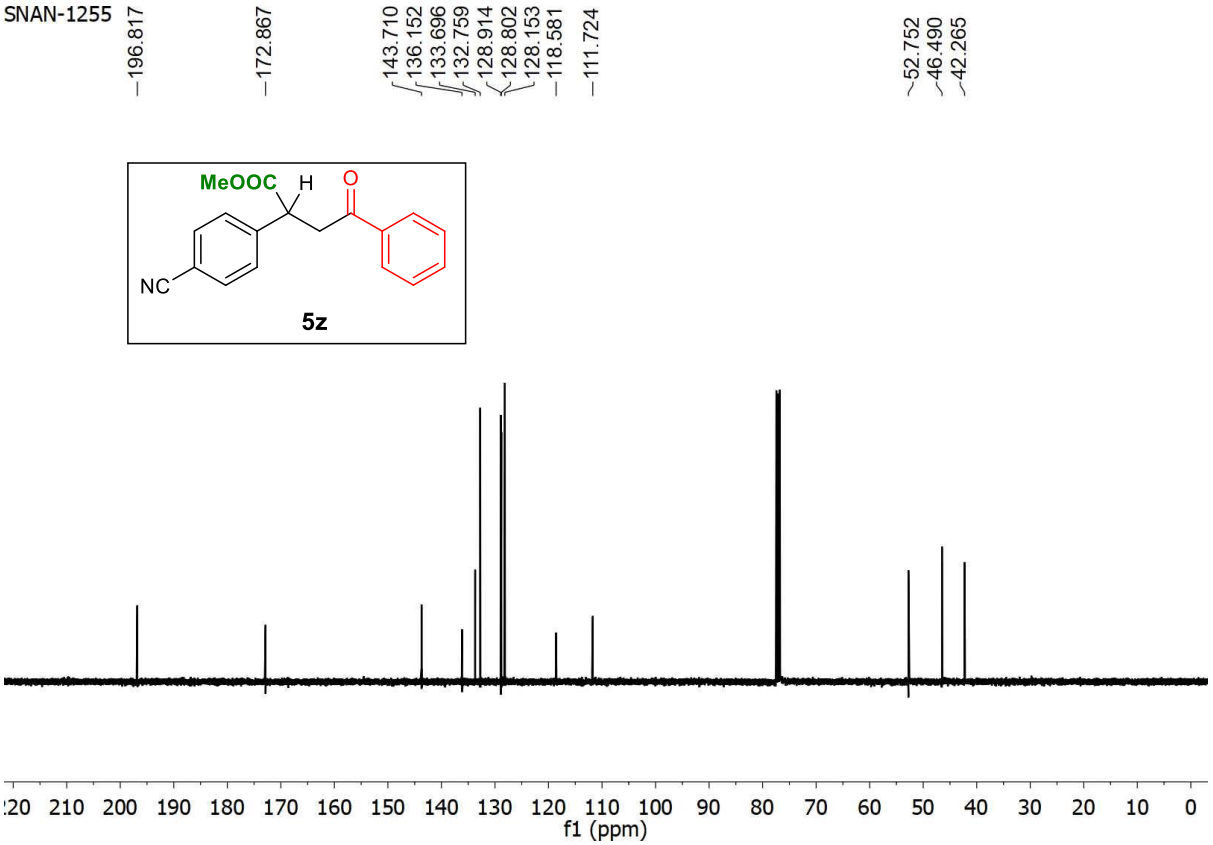

$^{1}$H spectra of **5y**



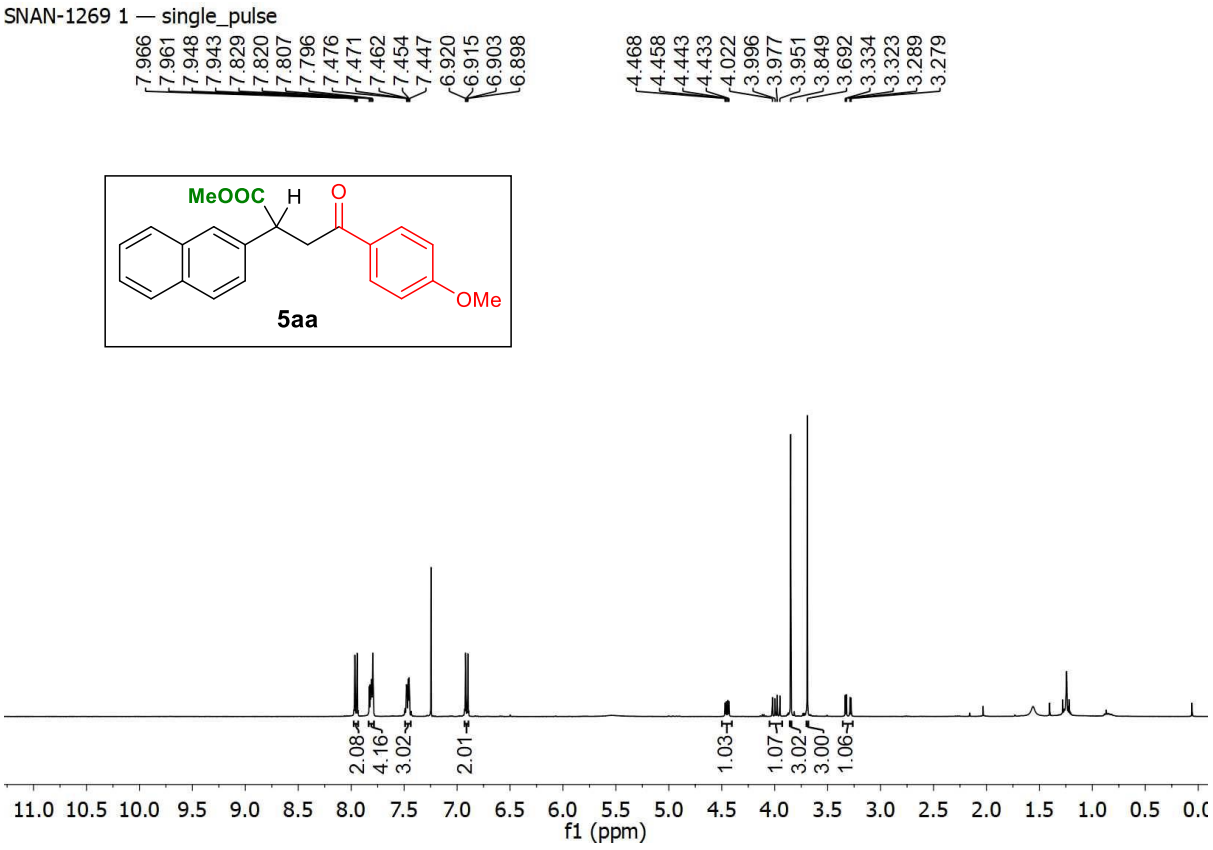

$^{13}$C spectra of **5y**



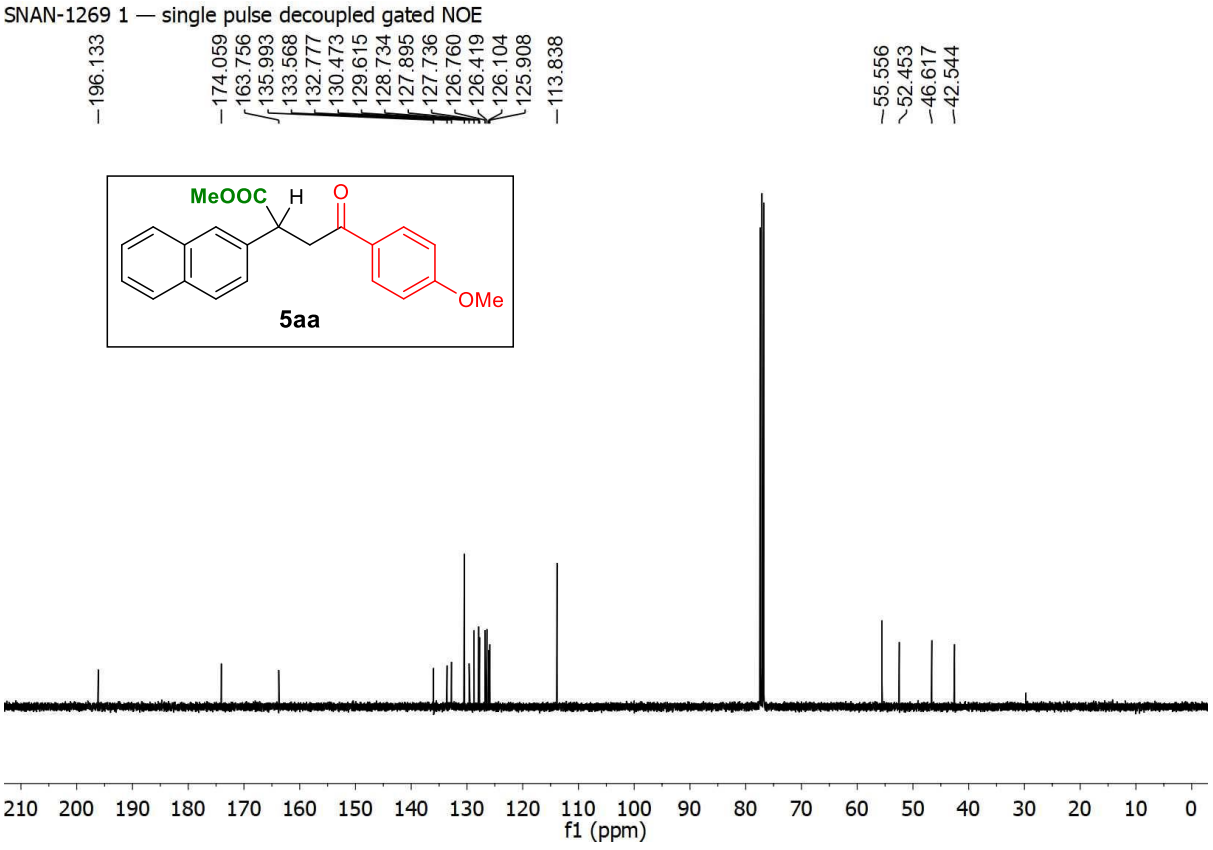

$^{1}$H spectra of **5z**



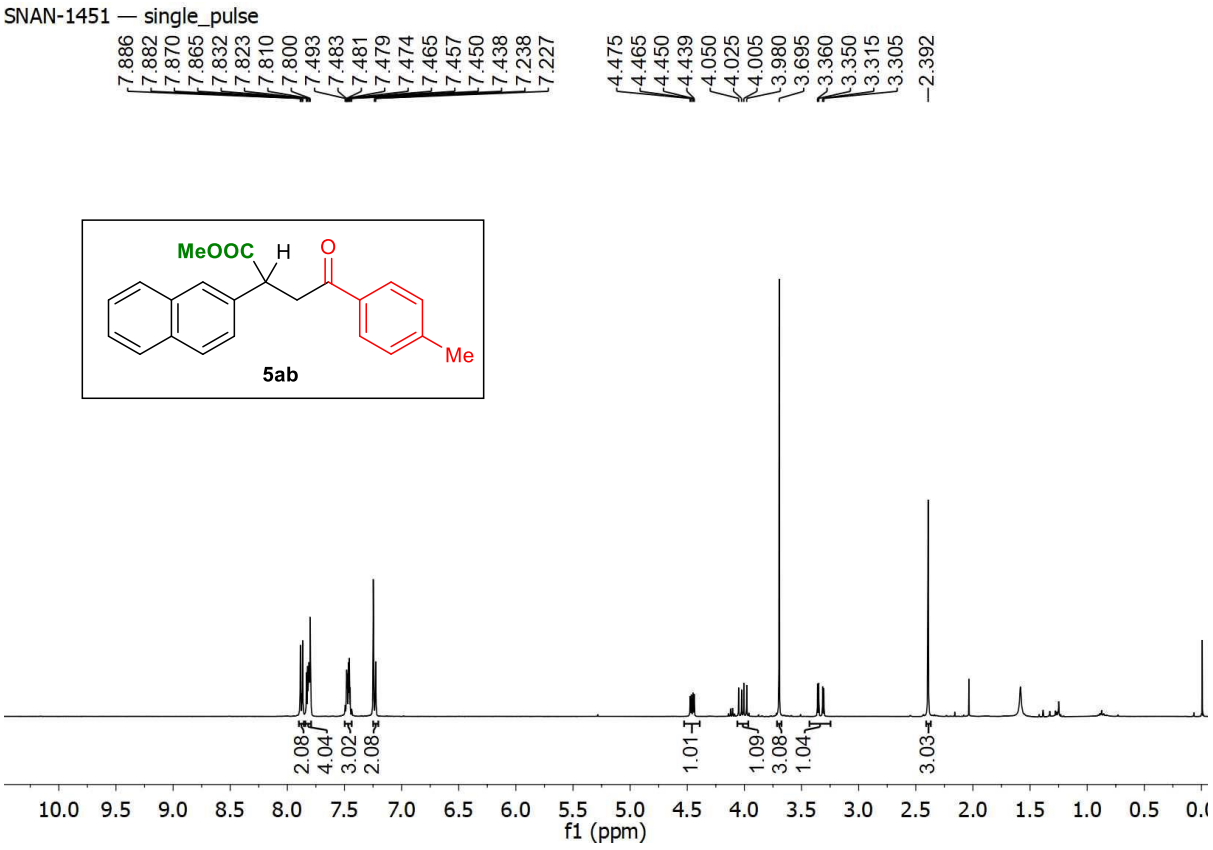

$^{13}$C spectra of **5z**



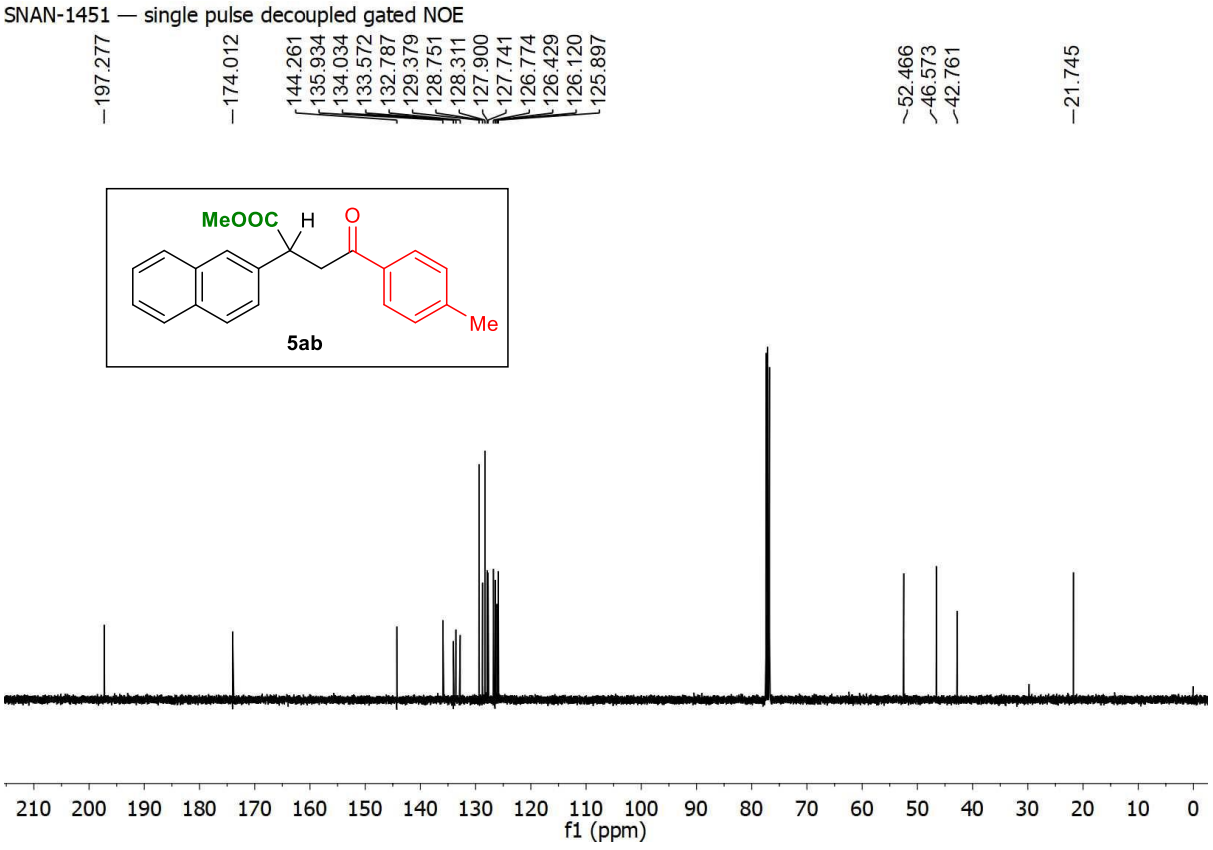

$^{1}$H spectra of **5aa**



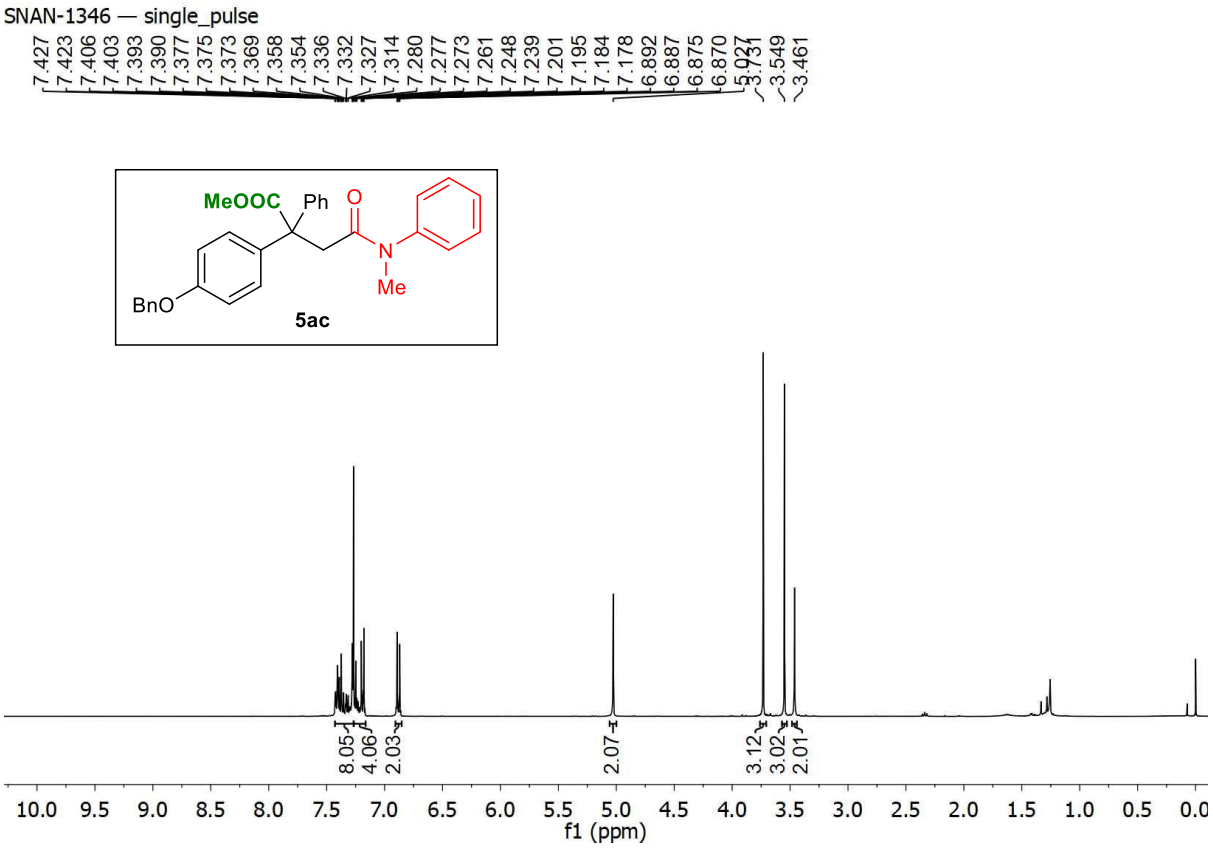

$^{13}$C spectra of **5aa**



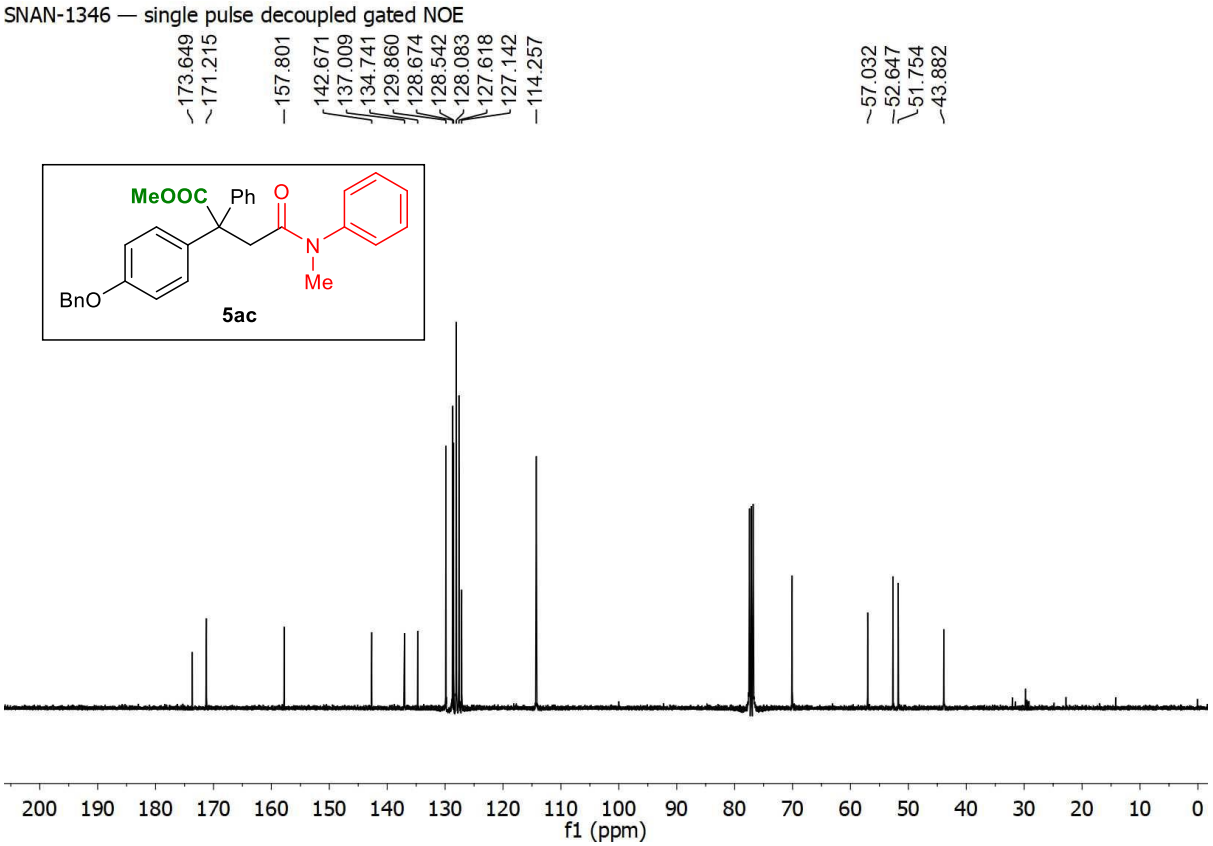

$^{1}$H spectra of **5ab**



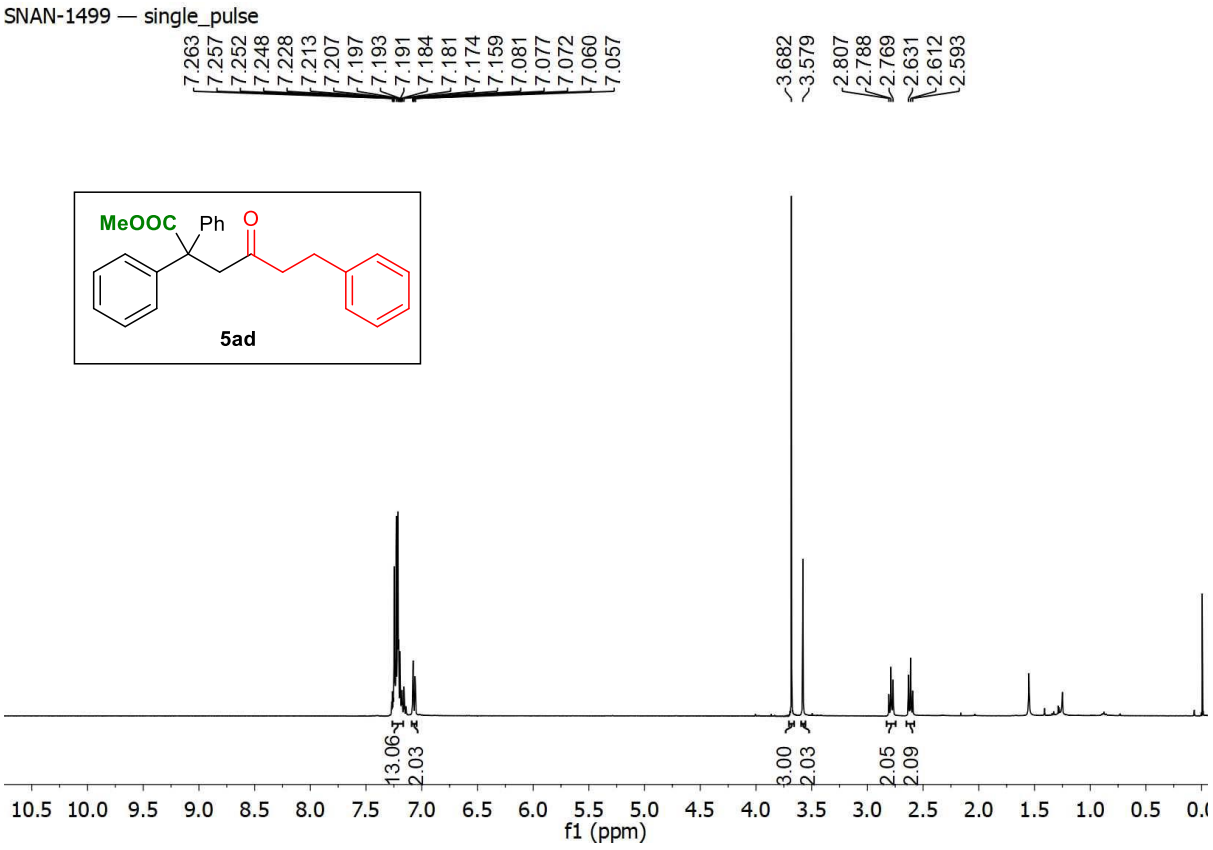

$^{13}$C spectra of **5ab**



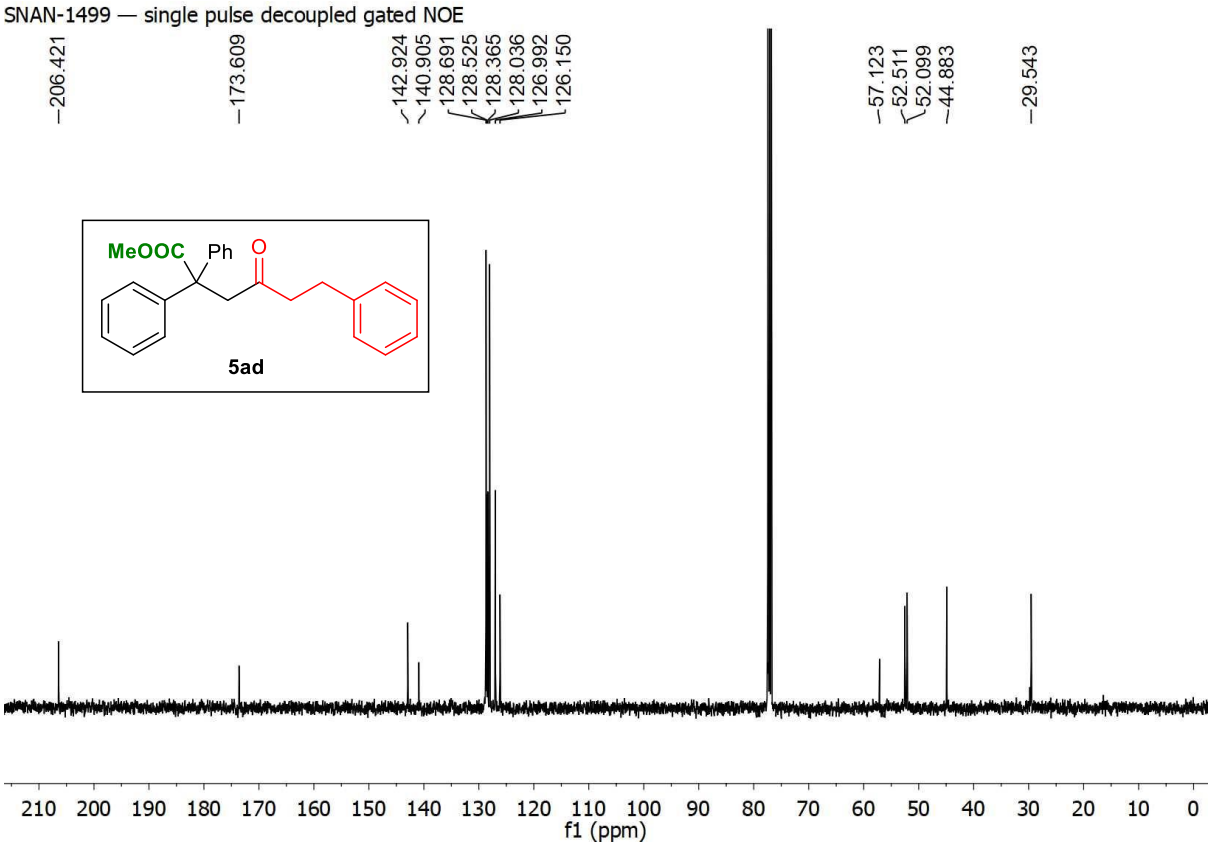

$^{1}$H spectra of **5ac**



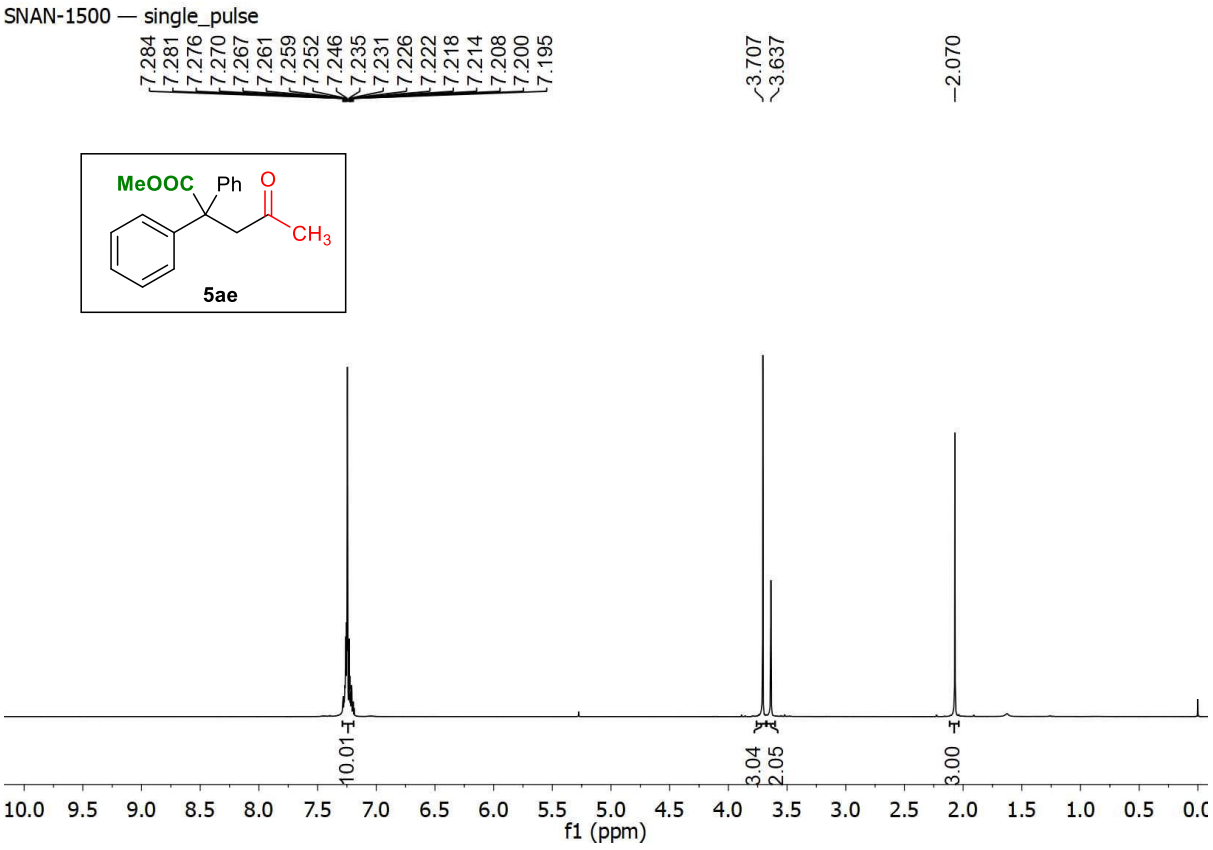

$^{13}$C spectra of **5ac**



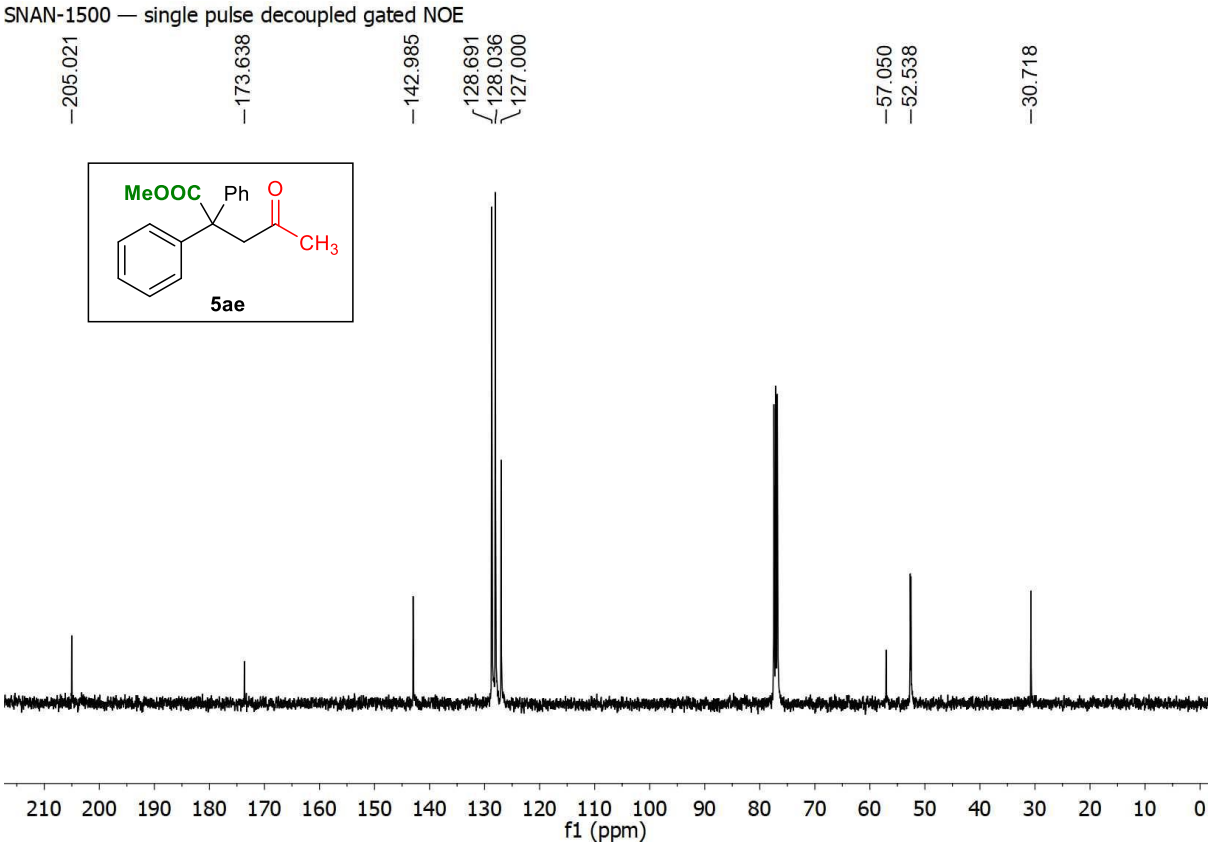

$^{1}$H spectra of **5ad**



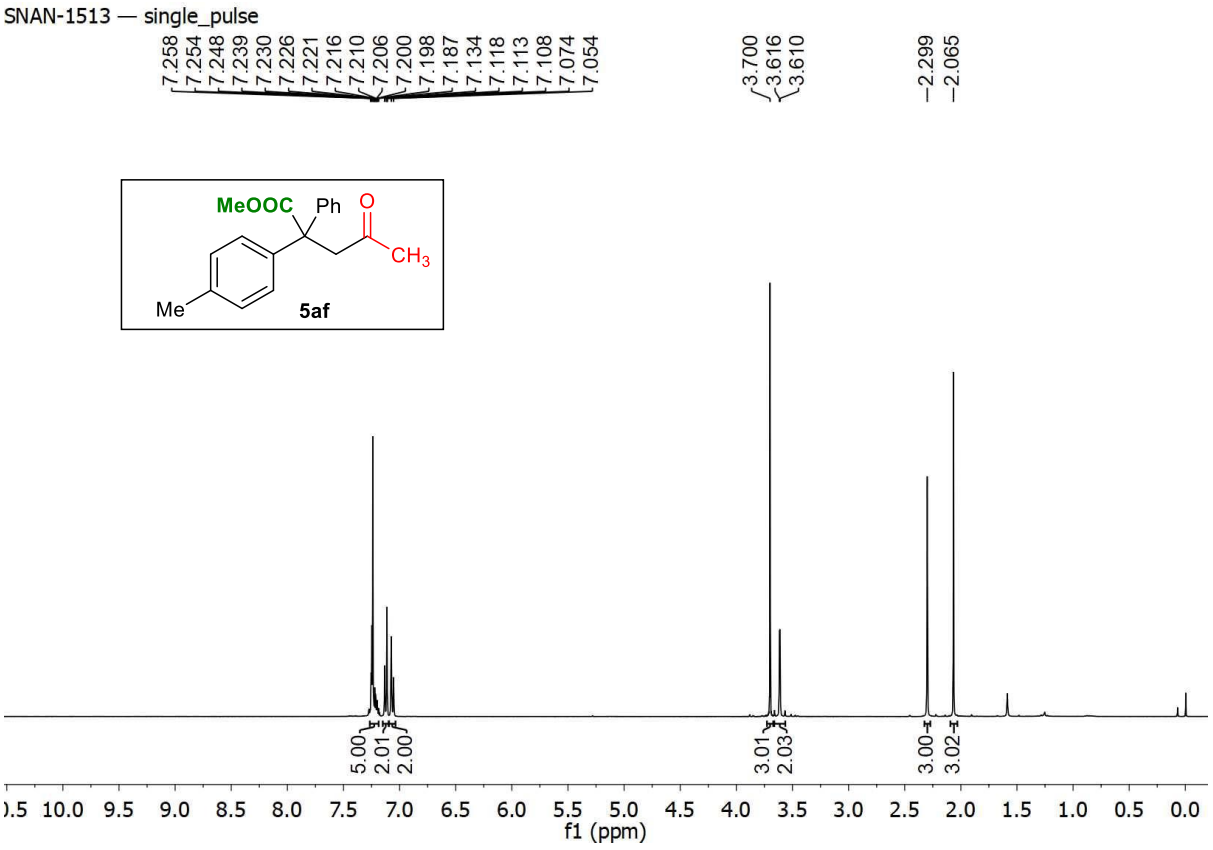

$^{13}$C spectra of **5ad**



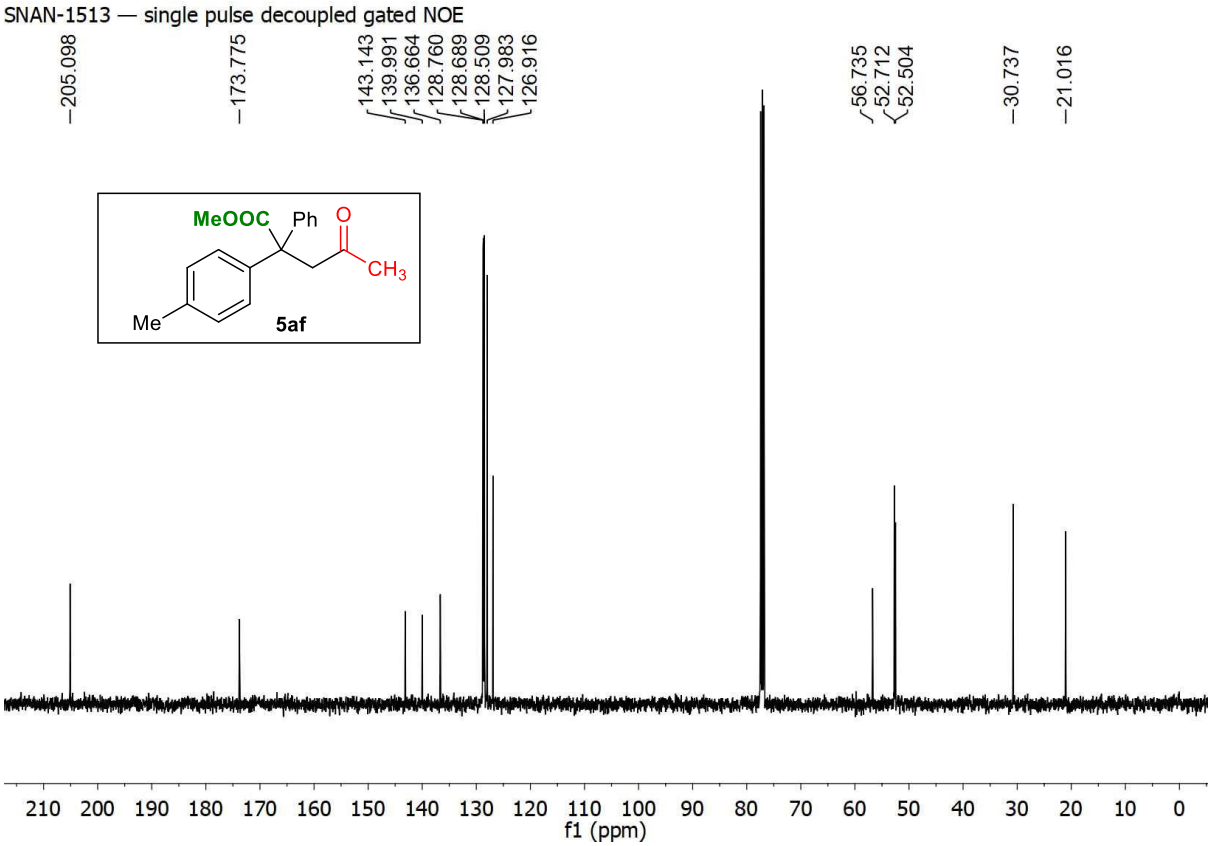

$^{1}$H spectra of **5ae**



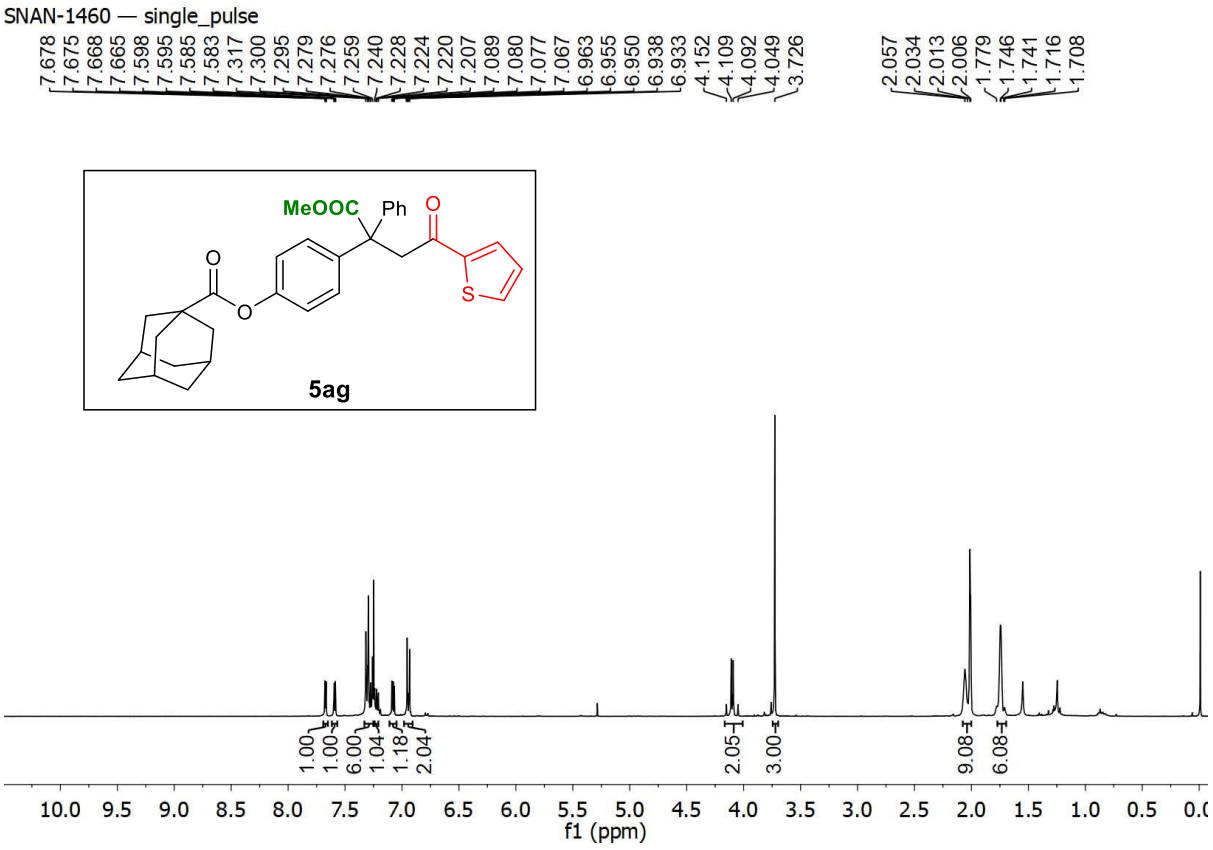

$^{13}$C spectra of **5ae**



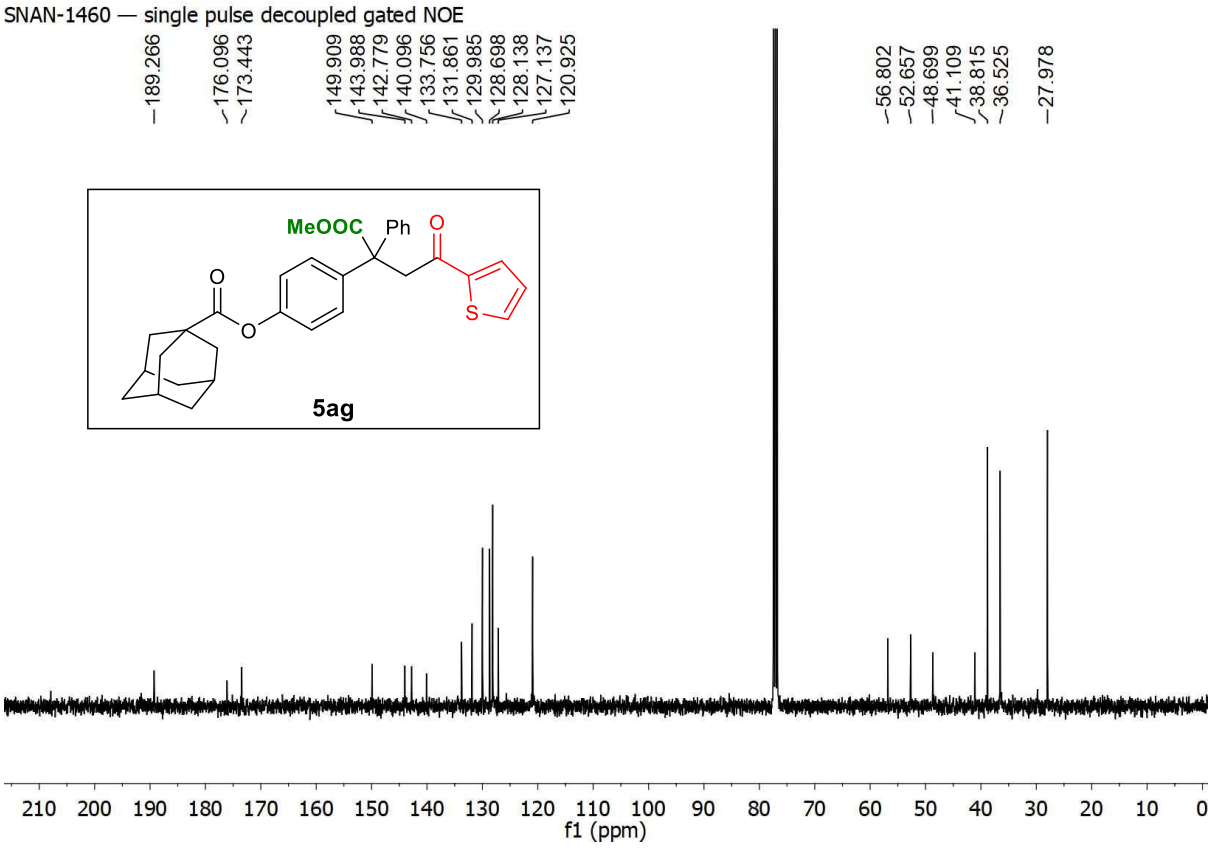

$^{1}$H spectra of **5af**



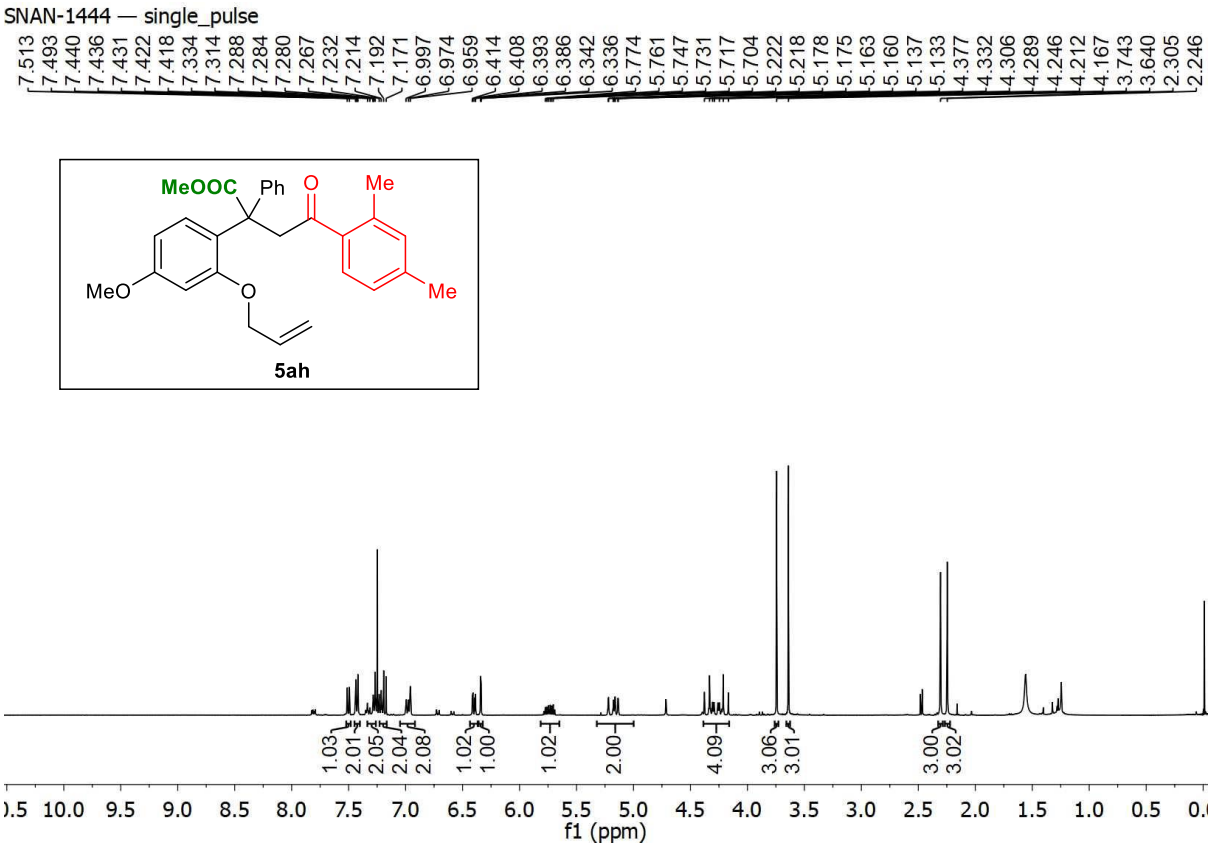

$^{13}$C spectra of **5af**



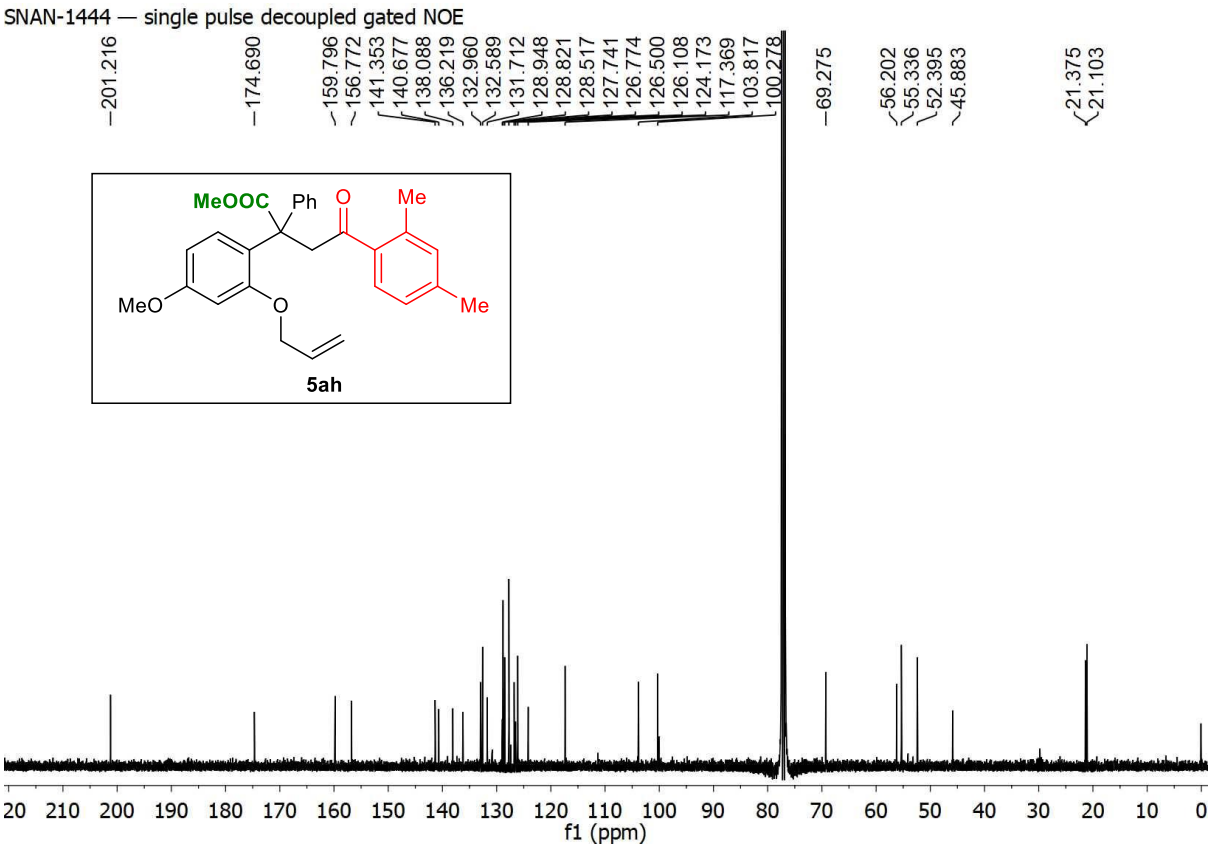

$^{1}$H spectra of **5ag**



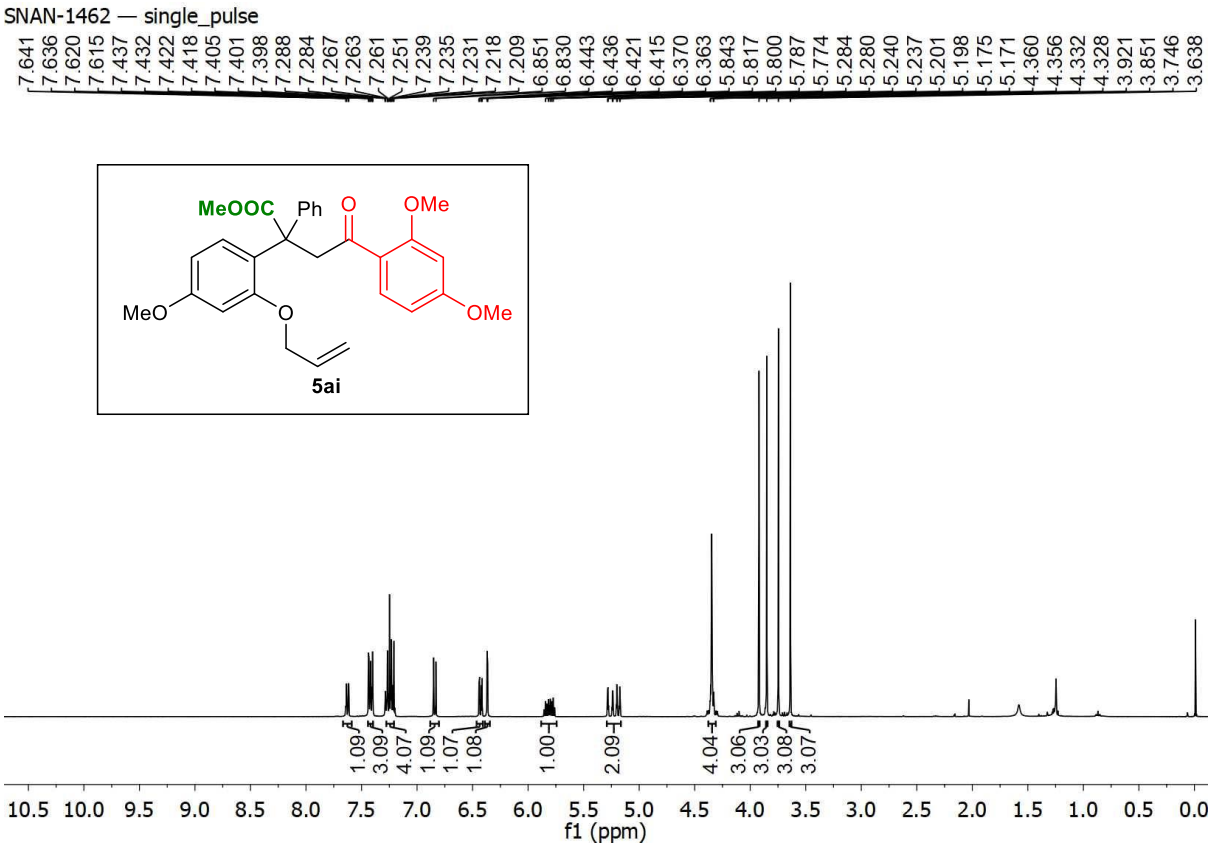

$^{13}$C spectra of **5ag**



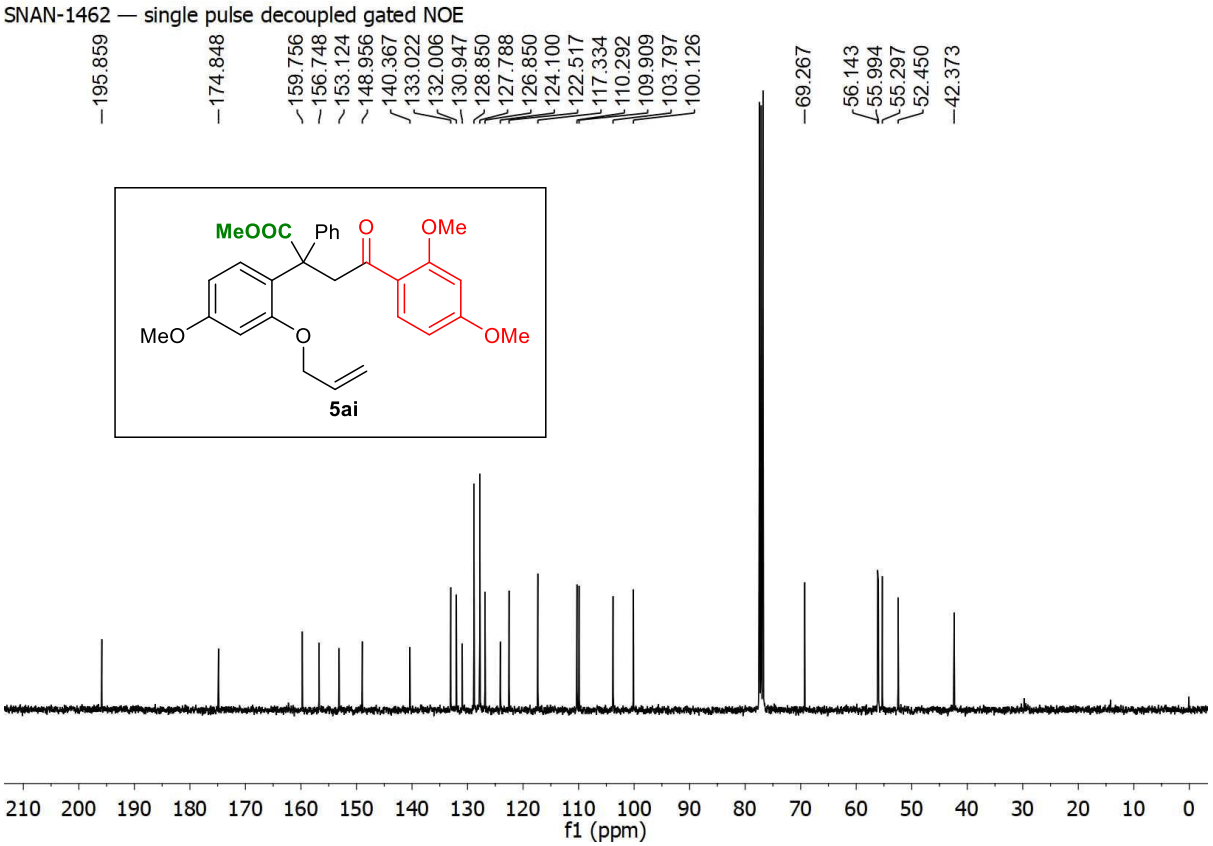

$^{1}$H spectra of **5ah**



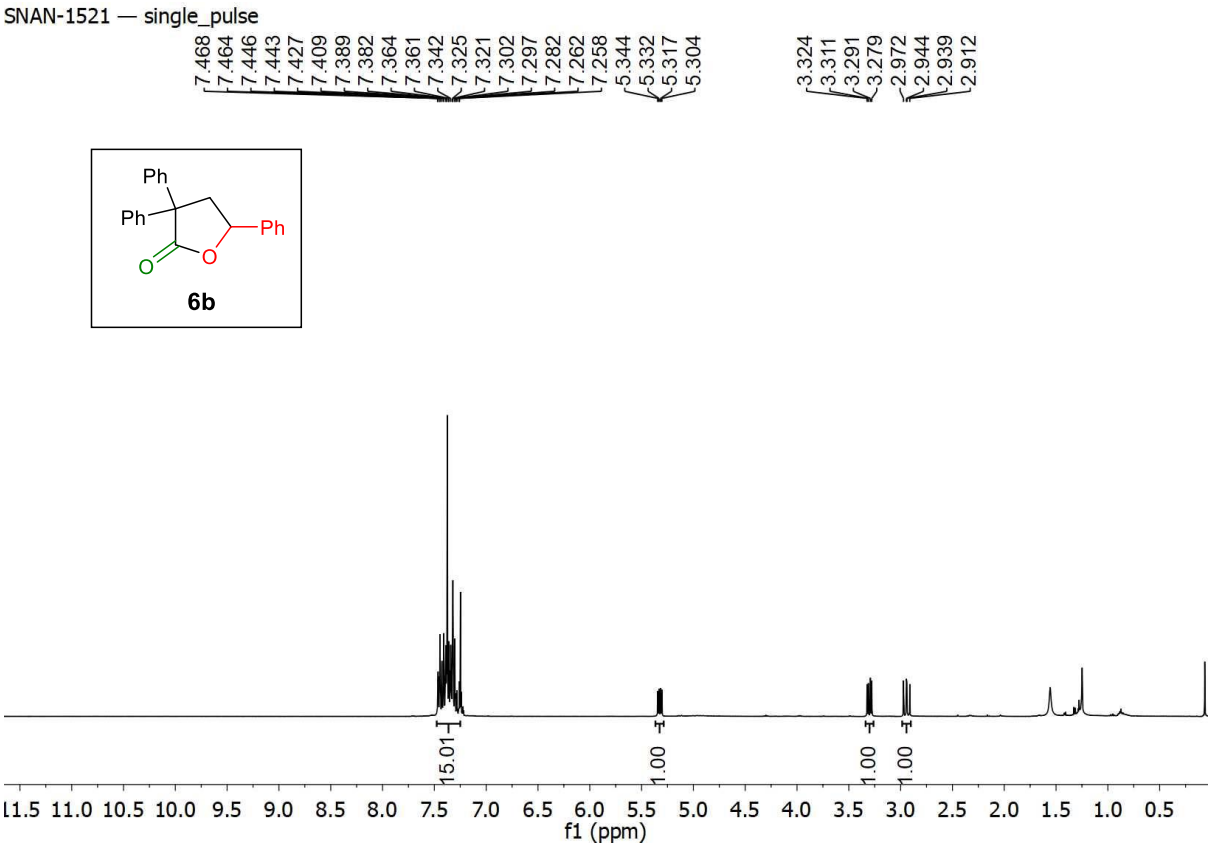

$^{13}$C spectra of **5ah**



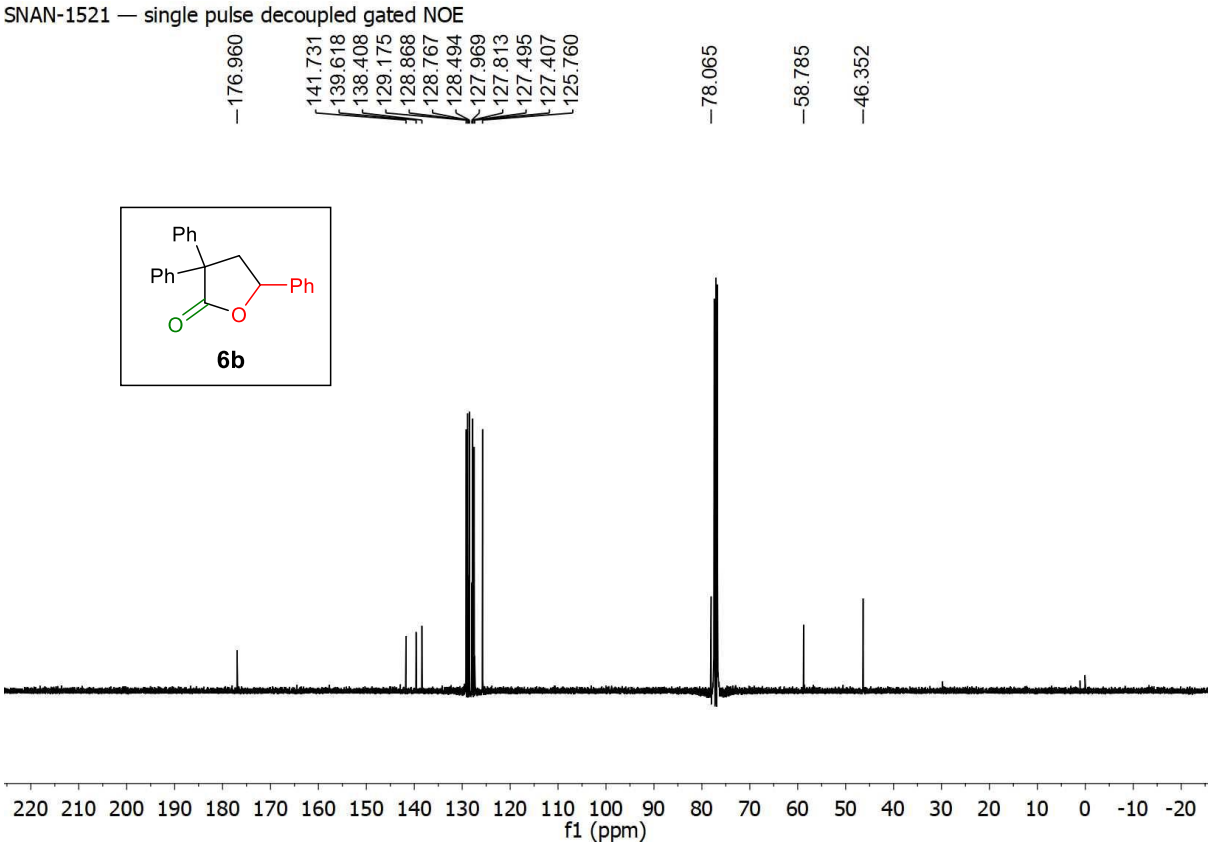

$^{1}$H spectra of **5ai**



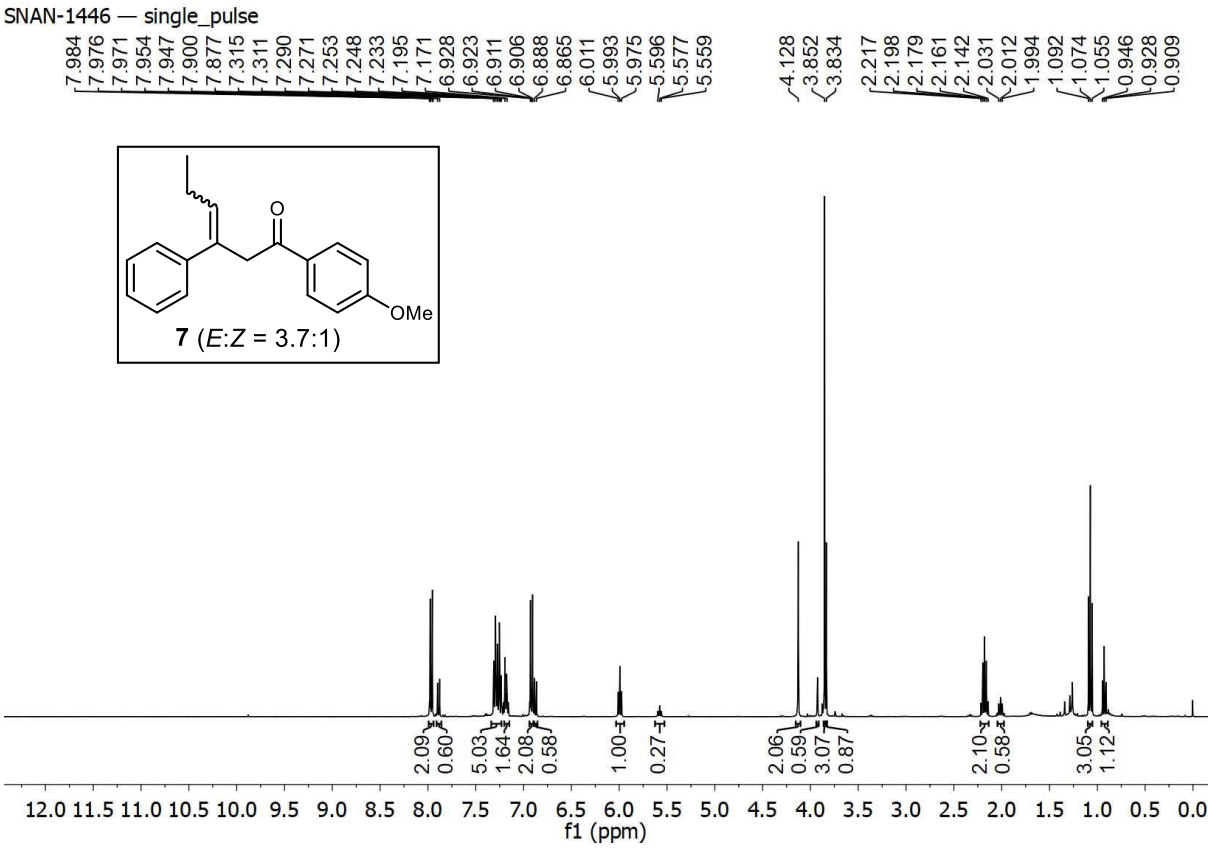

$^{13}$C spectra of **5ai**



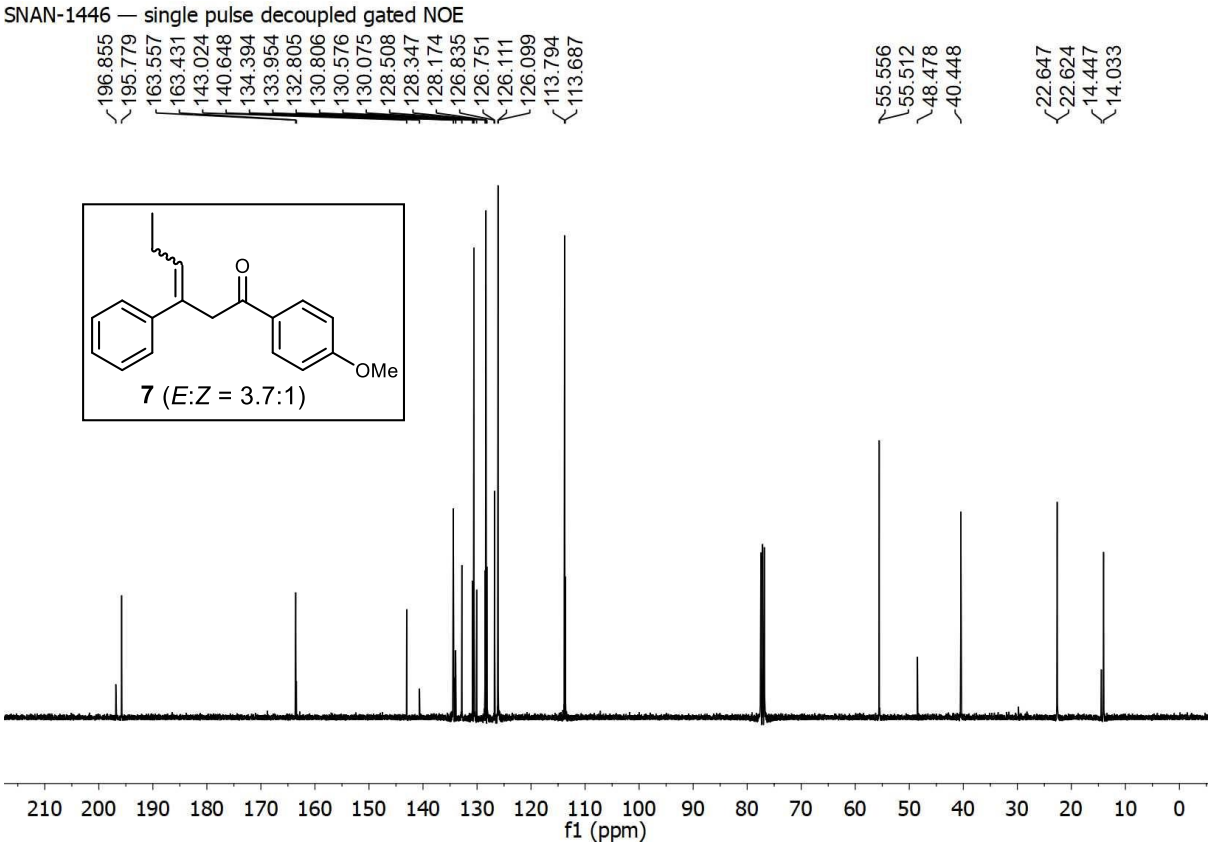

$^{1}$H spectra of **6b**




$^{13}$C spectra of **6b**




$^{1}$H spectra of **7**




$^{13}$C spectra of **7**