

Supporting Information

**Merging Photoredox and Nickel Catalysis: The Direct Synthesis of Ketones by the Decarboxylative Arylation of  $\alpha$ -Oxo Acids\*\***

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## General Information

Commercial reagents were purchased from commercial suppliers and purified prior to use following the guidelines of Perrin and Armarego.<sup>1</sup> All solvents were purified by passage through columns of activated alumina. Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator using an acetone-dry ice bath for volatile compounds. Chromatographic purification of products was accomplished by flash chromatography on silica gel (Fluka, 230-400 mesh). Thin layer chromatography (TLC) was performed on Analtech Uniplat 250  $\mu\text{m}$  silica gel plates. Visualization of the developed chromatogram was performed by fluorescence quenching, p-anisaldehyde, potassium permanganate, or ceric ammonium molybdate stain.  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra were recorded on a Bruker 500 (500 or 501 and 125 or 126 MHz) instrument, and are internally referenced to residual protio solvent signals (note:  $\text{CDCl}_3$  referenced at 7.26 and 77.16 ppm respectively). Data for  $^1\text{H}$  NMR are reported as follows: chemical shift ( $\delta$  ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad), integration, and coupling constant (Hz). Data for  $^{13}\text{C}$  NMR are reported in terms of chemical shift and multiplicity where appropriate, with no special nomenclature used for equivalent carbons. All known compounds are referenced herein to previous reports in the literature. High resolution mass spectra were obtained at Princeton University mass spectrometry facilities. All keto acids were used from commercial suppliers or prepared by hydrolysis of the commercially available ester. All aryl and heteroaryl halides were used from commercial suppliers.

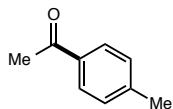
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<sup>1</sup> Perrin, D. D.; Armarego, W. L. F. In *Purification of Laboratory Chemicals*. 3rd ed., Pergamon Press: Oxford, 1988.

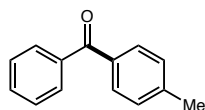
**General procedure A for the decarboxylation arylation of keto acids (acid scope):** An oven-dried 40 mL vial equipped with a Teflon septum cap and magnetic stir bar was charged with Ir[dF(CF<sub>3</sub>)ppy]<sub>2</sub>(dtbbpy)PF<sub>6</sub> (11.2 mg, 0.01 mmol, 0.02 equiv), NiCl<sub>2</sub>·glyme (11.2 mg, 0.05 mmol, 0.10 equiv), 4,4'-di-*tert*-butyl-2,2'-bipyridine (20.1 mg, 0.075 mmol, 0.15 equiv), the corresponding keto acid (1.00 mmol, 2.0 equiv), 4-iodotoluene (109 mg, 0.50 mmol, 1.0 equiv), and Li<sub>2</sub>CO<sub>3</sub> (73.9 mg, 1.00 mmol, 2.0 equiv) from a bottle stored in a dessicator. To this vial was added DMF (25 mL) and water (18 μL, 2.00 mmol, 2.0 equiv). The reaction mixture was degassed for 30 minutes by bubbling argon stream, then sealed with parafilm. The vial was irradiated with 34W Blue LED lamp (Kessil KSH150B LED Grow Light) for 72 hours, with cooling from a fan (vial temperature reached 37 °C). After 72 hours, the reaction was diluted with 25 mL H<sub>2</sub>O and extracted with 3x75 mL Et<sub>2</sub>O. The combined organic layers were washed with 3x25 mL H<sub>2</sub>O, then dried over MgSO<sub>4</sub>, filtered, and concentrated *in vacuo*. Purification of the crude product by flash chromatography on silica gel with a 25g column on a biotage instrument using the indicated solvent system provided the purified product.

**General procedure B for the decarboxylation arylation of keto acids (aryl halide scope):** An oven-dried 40 mL vial equipped with a Teflon septum cap and magnetic stir bar was charged with Ir[dF(CF<sub>3</sub>)ppy]<sub>2</sub>(dtbbpy)PF<sub>6</sub> (11.2 mg, 0.01 mmol, 0.02 equiv), NiCl<sub>2</sub>·glyme (11.2 mg, 0.05 mmol, 0.10 equiv), 4,4'-di-*tert*-butyl-2,2'-bipyridine (20.1 mg, 0.075 mmol, 0.15 equiv), phenylglyoxylic acid (150 mg, 1.00 mmol, 2.0 equiv), the corresponding aryl halide (0.50 mmol, 1.0 equiv), and Li<sub>2</sub>CO<sub>3</sub> (73.9 mg, 1.00 mmol, 2.0 equiv) from a bottle stored in a dessicator. To this vial was added DMF (25 mL) and water (18 μL, 2.00 mmol, 2.0 equiv). The reaction mixture was degassed for 30 minutes by bubbling argon stream, then sealed with parafilm. The vial was irradiated with 34W Blue LED lamp (Kessil KSH150B LED Grow Light) for 72 hours

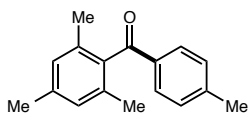
with cooling from a fan (vial temperature reached 37 °C). After 72 hours, the reaction was diluted with 25 mL H<sub>2</sub>O and extracted with 3x75 mL Et<sub>2</sub>O. The combined organic layers were washed with 3x25 mL H<sub>2</sub>O, then dried over MgSO<sub>4</sub>, filtered, and concentrated *in vacuo*. Purification of the crude product by flash chromatography on silica gel with a 25g column on a biotage instrument using the indicated solvent system provided the purified product.



1-(*p*-Tolyl)ethan-1-one (**10**)<sup>2</sup>: Prepared according to General Procedure A with 2-oxopropanoic acid (88.1 mg), purified with 5% EtOAc in hexanes as eluent, to yield **10** as a colorless viscous liquid, 38.2 mg, 57% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.86 (d, *J* = 8.2 Hz, 2H), 7.26 (d, *J* = 8.1 Hz, 2H), 2.58 (s, 3H), 2.41 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 198.0, 144.0, 134.83, 129.4, 128.6, 26.7, 21.8.



Phenyl(*p*-tolyl)methanone (**13**)<sup>3</sup>: Prepared according to General Procedure A with 2-oxo-2-phenylacetic acid (150 mg), purified with 5% EtOAc in hexanes as eluent, to yield **13** as an off-white solid, 86.4 mg, 88% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 7.82 – 7.76 (m, 2H), 7.73 (d, *J* = 8.1 Hz, 2H), 7.61 – 7.53 (m, 2H), 7.47 (t, *J* = 7.8 Hz, 1H), 7.28 (d, *J* = 7.8 Hz, 2H), 2.44 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 196.6, 143.4, 138.1, 135.0, 132.3, 130.4, 130.1, 129.1, 128.3, 21.8.

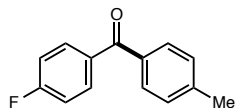


Mesityl(*p*-tolyl)methanone (**14**): Prepared according to General Procedure A with 2-mesityl-2-oxoacetic acid (192.2 mg), purified with 2% EtOAc in hexanes as eluent, to yield **14** as a pale yellow oil, 109.7 mg, 92% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 7.72 (d, *J* = 7.8 Hz, 2H), 7.24 (d, *J* = 7.8 Hz, 2H), 6.90 (s, 2H), 2.41 (s, 3H), 2.34 (s, 3H), 2.10 (s, 6H). <sup>13</sup>C NMR (126

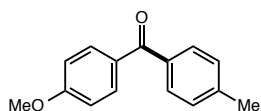
<sup>2</sup> Prebil, R.; Stavber, G.; Stavber, S. *Eur. J. Org. Chem.* **2014**, 2, 395.

<sup>3</sup> Wang, G.-Z.; Li, X.-L.; Dai, J.-J.; Xu, H.-J. *J. Org. Chem.* **2014**, 79, 7220.

MHz, CDCl<sub>3</sub>)  $\delta$  200.4, 144.5, 138.3, 137.1, 134.9, 134.1, 129.6, 129.5, 128.3, 21.8, 21.2, 19.4.  
 HRMS (EI) calcd for C<sub>17</sub>H<sub>19</sub>O [(M+H)<sup>+</sup>] 238.13577, found 238.13647. IR(film) 2977, 2920, 1665, 1604, 1573, 1440, 1270, 1169 cm<sup>-1</sup>.



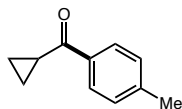
(4-Fluorophenyl)(*p*-tolyl)methanone (**15**)<sup>4</sup>: Prepared according to General Procedure A with 2-(4-fluorophenyl)-2-oxoacetic acid (168.1 mg), purified with 5% EtOAc in hexanes as eluent, to yield **15** as a pale white solid, 64.5 mg, 60% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*)  $\delta$  7.86 – 7.78 (m, 2H), 7.69 (d, *J* = 8.0 Hz, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.18 – 7.10 (m, 2H), 2.45 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>)  $\delta$  195.2, 165.4 (d, *J* = 253.5 Hz), 143.5, 134.9, 134.3, 132.7 (d, *J* = 9.1 Hz), 130.3, 129.2, 115.5 (d, *J* = 21.8 Hz), 21.8.



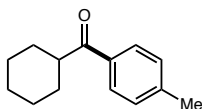
(4-Methoxyphenyl)(*p*-tolyl)methanone (**16**)<sup>5</sup>: Prepared according to General Procedure A with 2-(4-methoxyphenyl)-2-oxoacetic acid (180.2 mg), purified with 5% EtOAc in hexanes as eluent, to yield **16** as a yellow oil, 73.8 mg, 65% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*)  $\delta$  7.80 (d, *J* = 8.8 Hz, 2H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 2H), 6.94 (d, *J* = 8.8 Hz, 2H), 3.87 (s, 3H), 2.42 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>)  $\delta$  195.4, 163.1, 142.7, 135.6, 132.5, 130.6, 130.1, 129.0, 113.6, 55.6, 21.7.

<sup>4</sup> Fausett, B. W.; Liebeskind, L. S. *J. Org. Chem.* **2005**, *70*, 4851.

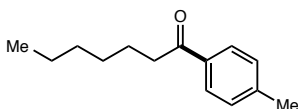
<sup>5</sup> Ushijima, S.; Dohi, S.; Moriyama, K.; Togo, H. *Tetrahedron* **2012**, *68*, 1436.



Cyclopropyl(*p*-tolyl)methanone (**17**)<sup>6</sup>: Prepared according to General Procedure A with 2-cyclopropyl-2-oxoacetic acid (114.1 mg), purified with 5% EtOAc in hexanes as eluent, to yield **17** as a pale yellow solid, 70.1, mg, 88% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 7.86 (d, *J* = 8.2 Hz, 2H), 7.20 (d, *J* = 8.2 Hz, 2H), 2.59 (tt, *J* = 7.8, 4.5 Hz, 1H), 2.35 (s, 3H), 1.16 (dd, *J* = 4.5, 3.1 Hz, 2H), 0.95 (dd, *J* = 7.8, 3.1 Hz, 2H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 200.3, 143.6, 135.6, 129.3, 128.2, 21.8, 17.1, 11.6.



Cyclohexyl(*p*-tolyl)methanone (**18**)<sup>4</sup>: Prepared according to General Procedure A with 2-cyclohexyl-2-oxoacetic acid (156.2 mg), purified with 5% EtOAc in hexanes as eluent, to yield **18** as a white solid, 80.3 mg, 80% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.82 (d, *J* = 8.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 3.22 (m, 1H), 2.38 (s, 3H), 1.90 – 1.76 (m, 4H), 1.73 – 1.68 (m, 1H), 1.52 – 1.26 (m, 5H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 203.6, 143.5, 133.9, 129.4, 128.5, 45.6, 29.6, 26.1, 26.0, 21.7.



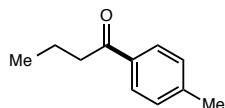
1-(*p*-Tolyl)heptan-1-one (**19**)<sup>7</sup>: Prepared according to General Procedure A with 2-oxooctanoic acid (158.2 mg), purified with 5% EtOAc in hexanes as eluent, to yield **19** as a yellow oil, 92.1 mg, 90% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.86 (d, *J* = 8.0 Hz, 2H), 7.25 (d, *J* = 8.0

<sup>6</sup> Salaun, J.; Hanack, M. *J. Org. Chem.* **1975**, *40*, 1994.

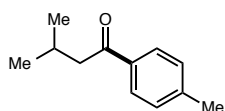
<sup>7</sup> Katritzky, A. R.; Kuzmierkiewicz, W. *J. Chem. Soc., Perkin Trans. 1*, **1987**, 819.



Hz, 2H), 2.93 (t,  $J = 7.2$  Hz, 2H), 2.41 (s, 3H), 1.72 (p,  $J = 7.2$  Hz, 2H), 1.42 – 1.16 (m, 6H), 0.89 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  200.5, 143.8, 134.8, 129.4, 128.4, 38.8, 31.9, 29.31, 24.7, 22.8, 21.8, 14.3.



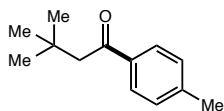
1-(*p*-Tolyl)butan-1-one (**20**)<sup>8</sup>: Prepared according to General Procedure A with 2-oxopentanoic acid (116.1 mg), purified with 5% EtOAc in hexanes as eluent, to yield **20** as a pale yellow oil, 73.4 mg, 91% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  7.86 (d,  $J = 8.8$  Hz, 2H), 7.25 (d,  $J = 8.0$  Hz, 2H), 2.92 (t,  $J = 7.4$  Hz, 2H), 2.40 (s, 3H), 1.76 (hex,  $J = 7.4$  Hz, 2H), 1.00 (t,  $J = 7.4$  Hz, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  200.3, 143.7, 134.8, 129.3, 128.3, 40.6, 21.8, 18.0, 14.1.



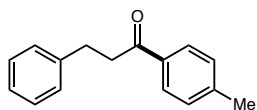
3-Methyl-1-(*p*-tolyl)butan-1-one (**21**)<sup>9</sup>: Prepared according to General Procedure A with 4-methyl-2-oxopentanoic acid (130.1 mg), purified with 5% EtOAc in hexanes as eluent, to yield **21** as a colorless oil, 73.0 mg, 83% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  7.85 (d,  $J = 8.0$  Hz, 2H), 7.25 (d,  $J = 8.0$  Hz, 2H), 2.80 (d,  $J = 6.8$  Hz, 2H), 2.40 (s, 3H), 2.29 (h,  $J = 6.8$  Hz, 1H), 0.99 (d,  $J = 6.8$  Hz, 6H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  200.1, 143.7, 135.0, 129.3, 128.4, 47.5, 25.4, 22.9, 21.7.

<sup>8</sup> Liu, Y.; Yao, B.; Deng, C.-L.; Tang, R.-Y.; Zhang, X.-G.; Li, J.-H. *Org. Lett.* **2011**, *13*, 2184-2187.

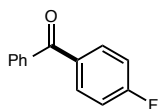
<sup>9</sup> Lee, S. W.; Lee, K.; Seomoon, D.; Kim, S.; Kim, H.; Kim, H.; Shim, E.; Lee, M.; Lee, S.; Kim, M.; Lee, P. H. *J. Org. Chem.* **2004**, *69*, 4852-4854.



3,3-Dimethyl-1-(*p*-tolyl)butan-1-one (**22**)<sup>10</sup>: Prepared according to General Procedure A with 4,4-dimethyl-2-oxopentanoic acid (144.2 mg), purified with 3% EtOAc in hexanes as eluent, to yield **22** as a colorless oil, 87.0 mg, 92% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.84 (d, *J* = 8.0 Hz, 2H), 7.24 (d, *J* = 8.0 Hz, 2H), 2.83 (s, 2H), 2.40 (s, 3H), 1.05 (s, 9H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 200.2, 143.5, 136.2, 129.3, 128.5, 50.1, 31.5, 30.2, 21.7.



3-Phenyl-1-(*p*-tolyl)propan-1-one (**23**)<sup>11</sup>: Prepared according to General Procedure A with 2-oxo-4-phenylbutanoic acid (178.2 mg), purified with 3% EtOAc in hexanes as eluent, to yield **23** as a yellow oil, 103.3 mg, 92% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 7.85 (d, *J* = 8.2 Hz, 2H), 7.29 (t, *J* = 7.5 Hz, 2H), 7.26 – 7.21 (m, 4H), 7.21 – 7.16 (m, 1H), 3.26 (dd, *J* = 8.6, 6.9 Hz, 2H), 3.05 (dd, *J* = 8.6, 6.9 Hz, 2H), 2.39 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 199.0, 144.0, 141.5, 134.5, 129.4, 128.6, 128.6, 128.3, 126.2, 40.5, 30.4, 21.8.

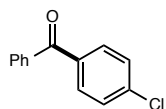


(4-Fluorophenyl)(phenyl)methanone (**24**)<sup>3</sup>: Prepared according to General Procedure B with 1-fluoro-4-iodobenzene (275.0 mg, 2.5 mmol, 5.0 equiv) and Li<sub>2</sub>CO<sub>3</sub> (184.8 mg, 2.5 mmol, 5.0 equiv), purified with 5% EtOAc in hexanes as eluent, to yield **24** as a pale yellow solid, 70.2 mg, 70% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.90 – 7.81 (m, 2H), 7.79 – 7.74 (m, 2H), 7.62

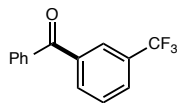
<sup>10</sup> Lu, W.; Liang, Z.; Zhang, Y.; Wu, F.; Wian, Q.; Gong, H. *Synthesis* **2013**, 45, 2234.

<sup>11</sup> Shimizu, K.; Sato, R.; Satsuma, A. *Angew. Chem. Int. Ed.* **2009**, 48, 3982-3986.

– 7.56 (m, 1H), 7.49 (dd,  $J = 8.5, 7.1$  Hz, 2H), 7.16 (t,  $J = 8.5$  Hz, 2H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  195.0, 165.3 (d,  $J = 264.3$  Hz), 137.6, 133.2 (d,  $J = 2.7$  Hz), 133.1 (d,  $J = 10.1$  Hz), 132.7, 129.5, 128.1, 115.6.

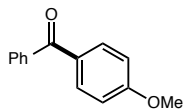


(4-Chlorophenyl)(phenyl)methanone (**25**)<sup>3</sup>: Prepared according to General Procedure B with 1-chloro-4-iodobenzene (119.2 mg), purified with 5% EtOAc in hexanes as eluent, to yield **25** as a yellow solid, 98.9 mg, 90% yield.  $^1\text{H}$  NMR (500 MHz, Chloroform-*d*)  $\delta$  7.79 – 7.74 (m, 4H), 7.63 – 7.58 (m, 1H), 7.52 – 7.44 (m, 4H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  195.6, 139.0, 137.4, 136.0, 132.8, 131.6, 130.1, 128.8, 128.5.

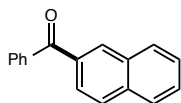


Phenyl(3-(trifluoromethyl)phenyl)methanone (**26**)<sup>12</sup>: Prepared according to General Procedure B with 1-iodo-3-(trifluoromethyl)benzene (136.0 mg), purified with 5% EtOAc in hexanes as eluent, to yield **26** as a colorless solid, 110.2 mg, 88% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  8.07 (s, 1H), 7.98 (d,  $J = 7.8$  Hz, 1H), 7.85 (d,  $J = 7.8$  Hz, 1H), 7.80 (dd,  $J = 7.8, 1.4$  Hz, 2H), 7.63 (t,  $J = 7.8$  Hz, 2H), 7.52 (t,  $J = 7.8$  Hz, 2H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  195.4, 138.4, 136.9, 133.3, 133.2, 131.1 (q,  $J = 32.9$  Hz), 129.1, 129.0 (q,  $J = 3.6$  Hz), 128.7, 126.8 (q,  $J = 3.8$  Hz), 123.8 (d,  $J = 272.6$  Hz).

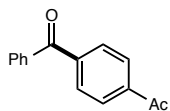
<sup>12</sup> Ahlburg, A.; Linghardt, A. T.; Taaning, R. H.; Modvig, A. E.; Skrydstrup, T. *J. Org. Chem.* **2013**, *78*, 10310.



(4-Methoxyphenyl)(phenyl)methanone (**27**)<sup>3</sup>: Prepared according to General Procedure B with 1-iodo-4-methoxybenzene (117.0 mg), reaction run to 84 hours, purified with 2% EtOAc in hexanes as eluent, to yield **27** as a white solid, 74.4 mg, 70% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 7.85 – 7.79 (m, 2H), 7.78 – 7.70 (m, 2H), 7.56 (tt, *J* = 7.6, 1.3 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 6.99 – 6.94 (m, 2H), 3.88 (s, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 195.7, 163.3, 138.4, 132.7, 132.0, 130.2, 129.8, 128.3, 113.7, 55.6.

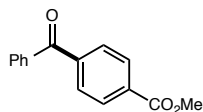


Naphthalen-2-yl(phenyl)methanone (**28**)<sup>3</sup>: Prepared according to General Procedure B with 2-iodonaphthalene (127.0 mg), reaction run to 90 hours, purified with 5% EtOAc in hexanes as eluent, to yield **28** as a white solid, 75.8 mg, 70% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 8.27 (s, 1H), 7.95 (d, *J* = 1.0 Hz, 2H), 7.94 – 7.90 (m, 2H), 7.88 – 7.85 (m, 2H), 7.65 – 7.60 (m, 2H), 7.58 – 7.50 (m, 3H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 196.9, 138.0, 135.4, 135.0, 132.5, 132.4, 132.0, 130.2, 129.6, 128.5, 128.5, 128.4, 128.0, 126.9, 125.9.

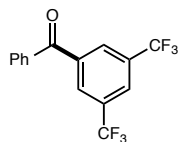


1-(4-Benzoylphenyl)ethan-1-one (**29**)<sup>3</sup>: Prepared according to General Procedure B with 1-(4-bromophenyl)ethan-1-one (99.5 mg), purified with 16% EtOAc in hexanes as eluent, to yield **29** as an off white solid, 82.3 mg, 73% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 8.04 (d, *J* = 8.3 Hz, 2H), 7.85 (d, *J* = 8.3 Hz, 2H), 7.79 (dd, *J* = 7.8, 1.2 Hz, 2H), 7.61 (tt, *J* = 7.8, 1.2, Hz, 1H),

7.49 (t,  $J = 7.8$  Hz, 2H), 2.66 (s, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  197.6, 196.1, 141.4, 139.7, 137.0, 133.1, 130.2, 130.2, 128.6, 128.3, 27.0.



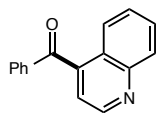
Methyl 4-benzoylbenzoate (**30**)<sup>13</sup>: Prepared according to General Procedure B with methyl 4-bromobenzoate (107.5 mg), purified with 5% EtOAc in hexanes as eluent, to yield **30** as a white solid, 97.2 mg, 81% yield.  $^1\text{H}$  NMR (500 MHz, Chloroform-*d*)  $\delta$  8.14 (d,  $J = 8.4$  Hz, 2H), 7.84 (d,  $J = 8.4$  Hz, 2H), 7.80 (dd,  $J = 7.5, 1.2$  Hz, 2H), 7.61 (tt,  $J = 7.5$  Hz,  $J = 1.2$  Hz, 1H), 7.49 (t,  $J = 7.5$  Hz, 2H), 3.96 (s, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  196.1, 166.4, 141.4, 137.0, 133.3, 133.1, 130.2, 129.9, 129.6, 128.6, 52.6.



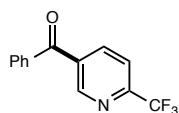
(3,5-Bis(trifluoromethyl)phenyl)(phenyl)methanone (**31**)<sup>14</sup>: Prepared according to General Procedure B with 1-bromo-3,5-bis(trifluoromethyl)benzene (146.5 mg), purified with 5% EtOAc in hexanes as eluent, to yield **31** as a colorless solid, 117.5 mg, 74% yield.  $^1\text{H}$  NMR (500 MHz, Chloroform-*d*)  $\delta$  8.24 (bs, 2H), 8.10 (bs, 1H), 7.82 – 7.77 (m, 2H), 7.71 – 7.66 (m, 1H), 7.56 (t,  $J = 7.7$  Hz, 2H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  193.7, 139.5, 136.0, 133.8, 132.2 (q,  $J = 33.9$  Hz), 130.2, 130.0 (d,  $J = 3.8$  Hz), 129.0, 125.8 (p,  $J = 3.7$  Hz), 123.0 (q,  $J = 273.1$  Hz).

<sup>13</sup> Zhou, W.; Wei, S.; Han, W. *J. Org. Chem.* **2014**, *79*, 1454.

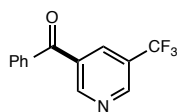
<sup>14</sup> Rohbogner, C. J.; Diène, C. R.; Korn, T. J.; Knochel, P. *Angew. Chem. Int. Ed.* **2010**, *49*, 1874.



Phenyl(quinolin-4-yl)methanone (**32**)<sup>15</sup>: Prepared according to General Procedure B with 4-bromoquinoline (104.0 mg), purified with 30% EtOAc in hexanes as eluent, to yield **32** as a yellow oil, 94.1 mg, 80% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 9.02 (d, *J* = 4.3 Hz, 1H), 8.20 (d, *J* = 8.4 Hz, 1H), 7.85 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 3H), 7.75 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.66 – 7.60 (m, 1H), 7.52 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.47 (t, *J* = 7.8 Hz, 2H), 7.39 (d, *J* = 4.3 Hz, 1H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 196.2, 149.6, 148.7, 144.5, 136.7, 134.3, 130.4, 130.1, 128.9, 127.8, 125.5, 125.0, 119.7.



Phenyl(6-(trifluoromethyl)pyridin-3-yl)methanone (**33**)<sup>16</sup>: Prepared according to General Procedure B with 5-bromo-2-(trifluoromethyl)pyridine (113.0 mg), purified with 12% EtOAc in hexanes as eluent, to yield **33** as a colorless solid, 100.1 mg, 80% yield. <sup>1</sup>H NMR (500 MHz, Chloroform-*d*) δ 9.07 (bs, 1H), 8.28 (d, *J* = 7.5 Hz, 1H), 7.90 – 7.77 (m, 3H), 7.68 (t, *J* = 7.5 Hz, 1H), 7.54 (t, *J* = 7.5 Hz, 2H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 193.7, 150.9, 150.7 (q, *J* = 35.2 Hz), 138.8, 136.1, 135.7, 134.0, 130.2, 129.0, 121.3 (q, *J* = 274.7 Hz), 120.4 (q, *J* = 2.7 Hz).

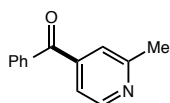


Phenyl(5-(trifluoromethyl)pyridin-3-yl)methanone (**34**): Prepared according to General Procedure B with 3-bromo-5-(trifluoromethyl)pyridine (113.0 mg), purified with 12% EtOAc in

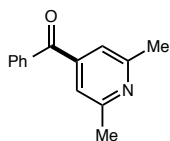
<sup>15</sup> Kuriyama, M.; Hamaguchi, N.; Sakata, K. Onomura, O. *Eur. J. Org. Chem.* **2013**, 3378.

<sup>16</sup> Loska, R.; Majcher, M.; Makosza, M. *J. Org. Chem.* **2007**, 72, 5574.

hexanes as eluent, to yield **34** as a yellow oil, 80.2 mg, 64% yield.  $^1\text{H}$  NMR (500 MHz, Chloroform-*d*)  $\delta$  9.17 (d,  $J = 2.2$  Hz, 1H), 9.08 (d,  $J = 2.2$  Hz, 1H), 8.36 (t,  $J = 2.2$  Hz, 1H), 7.82 (d,  $J = 7.6$  Hz, 2H), 7.69 (d,  $J = 7.6$  Hz, 1H), 7.56 (t,  $J = 7.6$  Hz, 2H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  193.4, 153.8, 149.5, 136.1, 134.4 (q,  $J = 3.6$  Hz), 133.9, 133.2, 130.2, 129.1, 126.9 (q,  $J = 33.6$  Hz), 123.2 (q,  $J = 273.4$  Hz). HRMS (EI) calcd for  $\text{C}_{13}\text{H}_9\text{F}_3\text{NO}$  [(M+H) $^+$ ] 251.05580, found 251.05572. IR(film) 2971, 1740, 1665, 1597, 1553, 1448, 1282  $\text{cm}^{-1}$ .



(2-Methylpyridin-4-yl)(phenyl)methanone (**35**): Prepared according to General Procedure B with 4-bromo-2-methylpyridine (86.0 mg), purified with 20% EtOAc in hexanes as eluent, to yield **35** as a yellow oil, 83.3 mg, 85% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  8.68 (d,  $J = 5.0$  Hz, 1H), 7.82 (d,  $J = 8.1$  Hz, 2H), 7.68 – 7.59 (m, 1H), 7.51 (t,  $J = 7.8$  Hz, 2H), 7.44 (bs, 1H), 7.36 (d,  $J = 5.0$  Hz, 1H), 2.65 (s, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  195.7, 159.5, 149.8, 145.0, 136.2, 133.6, 130.3, 128.8, 122.5, 120.2, 24.7. HRMS (EI) calcd for  $\text{C}_{13}\text{H}_{12}\text{NO}$  [(M+H) $^+$ ] 197.08406, found 197.08423. IR(film) 3035, 2971, 1739, 1666, 1598, 1579, 1446, 1338, 1265, 1134, 1084  $\text{cm}^{-1}$ .

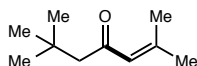


(2,6-Dimethylpyridin-4-yl)(phenyl)methanone (**36**)<sup>17</sup>: Prepared according to General Procedure B with 4-bromo-2,6-dimethylpyridine (93.0 mg), purified with 20% EtOAc in hexanes as eluent, to yield **36** as a colorless solid, 88.1 mg, 83% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  7.81

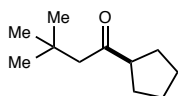
<sup>17</sup> Sakamoto, T.; Kondo, Y.; Murata, N.; Yamanaka, H. *Tetrahedron* **1993**, *49*, 9713.

(d,  $J = 7.0$  Hz, 2H), 7.68 – 7.58 (m, 1H), 7.51 (t,  $J = 7.7$  Hz, 2H), 7.22 (s, 2H), 2.61 (s, 6H).  $^{13}\text{C}$   
NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  196.1, 158.7, 145.5, 136.4, 133.5, 130.3, 128.7, 119.6, 24.8.





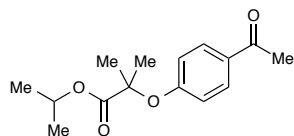
2,6,6-Trimethylhept-2-en-4-one (**37**)<sup>18</sup>: An oven-dried 40 mL vial equipped with a Teflon septum cap and magnetic stir bar was charged with Ir[dF(CF<sub>3</sub>)ppy]<sub>2</sub>(dtbbpy)PF<sub>6</sub> (11.2 mg, 0.01 mmol, 0.02 equiv), NiCl<sub>2</sub>·glyme (11.2 mg, 0.05 mmol, 0.10 equiv), 4,4'-di-*tert*-butyl-2,2'-bipyridine (20.1 mg, 0.075 mmol, 0.15 equiv), 4,4-dimethyl-2-oxopentanoic acid (144.2 mg, 1.00 mmol, 2.0 equiv), 1-bromo-2-methylprop-1-ene (68.9 mg, 0.50 mmol, 1.0 equiv), and Li<sub>2</sub>CO<sub>3</sub> (73.9 mg, 1.00 mmol, 2.0 equiv) from a bottle stored in a desiccator. To this vial was added DMF (25 mL) and water (18 μL, 2.00 mmol, 2.0 equiv). The reaction mixture was degassed for 30 minutes by bubbling argon stream, then sealed with parafilm. The vial was irradiated with 34W Blue LED lamp (Kessil KSH150B LED Grow Light) for 72 hours with cooling from a fan (vial temperature reached 37 °C). After 72 hours, the reaction was diluted with 25 mL H<sub>2</sub>O and extracted with 3x75 mL Et<sub>2</sub>O. The combined organic layers were washed with 3x25 mL H<sub>2</sub>O, then dried over MgSO<sub>4</sub>, filtered, and concentrated *in vacuo*. The crude product was purified by flash chromatography on silica gel with 2% Et<sub>2</sub>O in pentanes as eluent, to yield **37** as a yellow oil, 56.1 mg, 73% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 6.04 (s, 1H), 2.27 (s, 2H), 2.11 (d, *J* = 1.3 Hz, 3H), 1.85 (d, *J* = 1.3 Hz, 3H), 0.99 (s, 9 H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 201.3, 154.2, 125.9, 57.0, 31.6, 30.1, 27.8, 20.7.



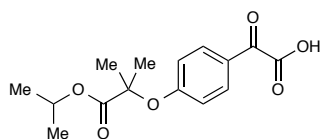
1-Cyclopentyl-3,3-dimethylbutan-1-one (**38**): An oven-dried 40 mL vial equipped with a Teflon septum cap and magnetic stir bar was charged with Ir[dF(CF<sub>3</sub>)ppy]<sub>2</sub>(dtbbpy)PF<sub>6</sub> (11.2 mg, 0.01 mmol, 0.02 equiv), NiCl<sub>2</sub>·glyme (11.2 mg, 0.05 mmol, 0.10 equiv), 4,4'-di-*tert*-butyl-2,2'-

<sup>18</sup> Jeffery, E. A.; Mesiters, A.; Mole, T. *J. Organometallic Chem.* **1974**, *74*, 365.

bipyridine (20.1 mg, 0.075 mmol, 0.15 equiv), 4,4-dimethyl-2-oxopentanoic acid (144.2 mg, 1.00 mmol, 2.0 equiv), bromocyclopentane (76.0 mg, 0.50 mmol, 1.0 equiv), and  $\text{Li}_2\text{CO}_3$  (73.9 mg, 1.00 mmol, 2.0 equiv) from a bottle stored in a desiccator. To this vial was added DMF (25 mL) and water (18  $\mu\text{L}$ , 2.00 mmol, 2.0 equiv). The reaction mixture was degassed for 30 minutes by bubbling argon stream, then sealed with parafilm. The vial was irradiated with 34W Blue LED lamp (Kessil KSH150B LED Grow Light) for 72 hours with cooling from a fan (vial temperature reached 37 °C). After 72 hours, the reaction was diluted with 25 mL  $\text{H}_2\text{O}$  and extracted with 3x75 mL  $\text{Et}_2\text{O}$ . The combined organic layers were washed with 3x25 mL  $\text{H}_2\text{O}$ , then dried over  $\text{MgSO}_4$ , filtered, and concentrated *in vacuo*. The crude product was purified by flash chromatography on silica gel with 1%  $\text{Et}_2\text{O}$  in pentanes as eluent, to yield **38** as a yellow oil, 74.3 mg, 88% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  2.83 (pent,  $J = 8.0$  Hz, 1H), 2.35 (s, 2H), 1.87-1.49 (m, 8H), 1.01 (s, 3H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  213.3, 54.3, 53.0, 31.1, 29.9, 28.9, 26.1. HRMS (EI) calcd for  $\text{C}_{11}\text{H}_{21}\text{O}$  [(M+H) $^+$ ] 168.15142, found 168.15261. IR(film) 2954, 2869, 1705, 1465, 1364, 905, 729  $\text{cm}^{-1}$ .



Isopropyl 2-(4-acetylphenoxy)-2-methylpropanoate (**S1**): Prepared according to literature methods.<sup>19</sup> In a 200 mL round bottom flask equipped with a magnetic stir bar, 1-(4-hydroxyphenyl)ethanone (2.72 g, 20.0 mmol, 1.0 equiv), isopropyl 2-bromo-2-methylpropanoate (4.74 g, 22.0 mmol, 1.1 equiv), and potassium carbonate (27.6 g, 200 mmol, 10 equiv) were taken up in anhydrous acetonitrile (67 mL, 0.3 M). The reaction mixture was heated to 90 °C for 12 hours with vigorous stirring. After 12 hours, the reaction was cooled to room temperature and filtered through a pad of celite and washed with excess EtOAc. This was then concentrated *in vacuo*. The crude mixture was purified by column chromatography with 20% EtOAc in hexanes as eluent, to yield **S1** as a colorless oil, 4.3 g, 81% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 8.9 Hz, 2H), 6.79 (d, *J* = 8.9 Hz, 2H), 5.03 (hept, *J* = 6.4 Hz, 1H), 2.49 (s, 3H), 1.60 (s, 6H), 1.14 (d, *J* = 6.4 Hz, 6H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 196.7, 173.1, 159.9, 130.7, 130.1, 117.2, 79.3, 69.3, 26.4, 25.4, 21.5. IR(film) 2985, 1940, 1729, 1678, 1598, 1245, 1145 cm<sup>-1</sup>.

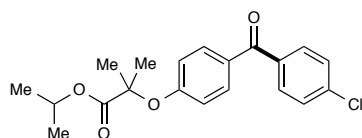


2-(4-((1-isopropoxy-2-methyl-1-oxopropan-2-yl)oxy)phenyl)-2-oxoacetic acid (**39**): Prepared according to literature methods.<sup>20</sup> In a 250 mL round bottom flask equipped with a magnetic stir bar, **S1** (4.0 g, 15.1 mmol, 1.0 equiv) was taken up in anhydrous pyridine (100 mL, 0.15 M). To the solution was added selenium dioxide (2.52 g, 22.7 mmol, 1.5 equiv). The reaction mixture

<sup>19</sup> Sashidhara, K. V.; Dodda, R. P.; Sonkar, R.; Palnati, G. R.; Bhatia, G. *Eur. J. Med. Chem.* **2014**, 8, 499.

<sup>20</sup> Wadhwa, K.; Yang, C.; West, P. R.; Deming, K. C.; Chemburkar, S. R.; Reddy, R. E. *Syn. Commun.* **2008**, 38, 4434.

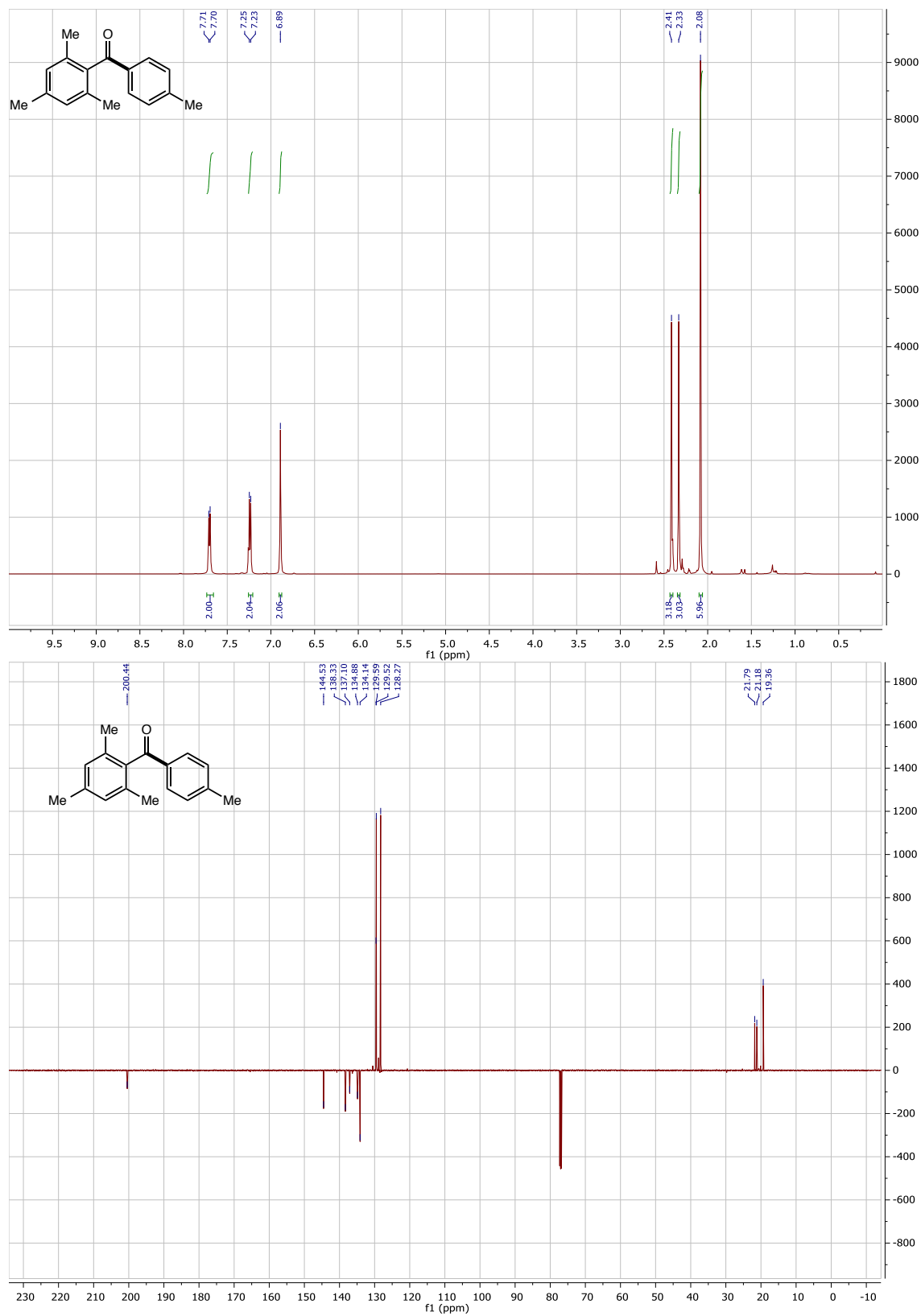
was heated to 110 °C for 14 hours. The mixture was then cooled to room temperature and filtered through a pad of celite and washed with 150 mL EtOAc. The filtered liquid was washed with 4x125 mL 1N HCl, the organic layer was dried with Na<sub>2</sub>SO<sub>4</sub>, filtered, and concentrated *in vacuo*. This provided **39** of sufficient purity (≥95%), as a viscous yellow-orange oil, 2.1 g, 47.2% yield. <sup>1</sup>H NMR (501 MHz, Chloroform-*d*) δ 8.39 (d, *J* = 8.9 Hz, 2H), 6.86 (d, *J* = 8.9 Hz, 2H), 5.08 (hept, *J* = 6.2 Hz, 1H), 1.67 (s, 6H), 1.18 (d, *J* = 8.9 Hz, 6H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 182.1, 172.8, 162.5, 160.9, 134.2, 125.0, 117.5, 80.0, 69.7, 25.5, 21.6. IR(film) 3921(br), 2986, 2940, 1729, 1678, 1595 cm<sup>-1</sup>.



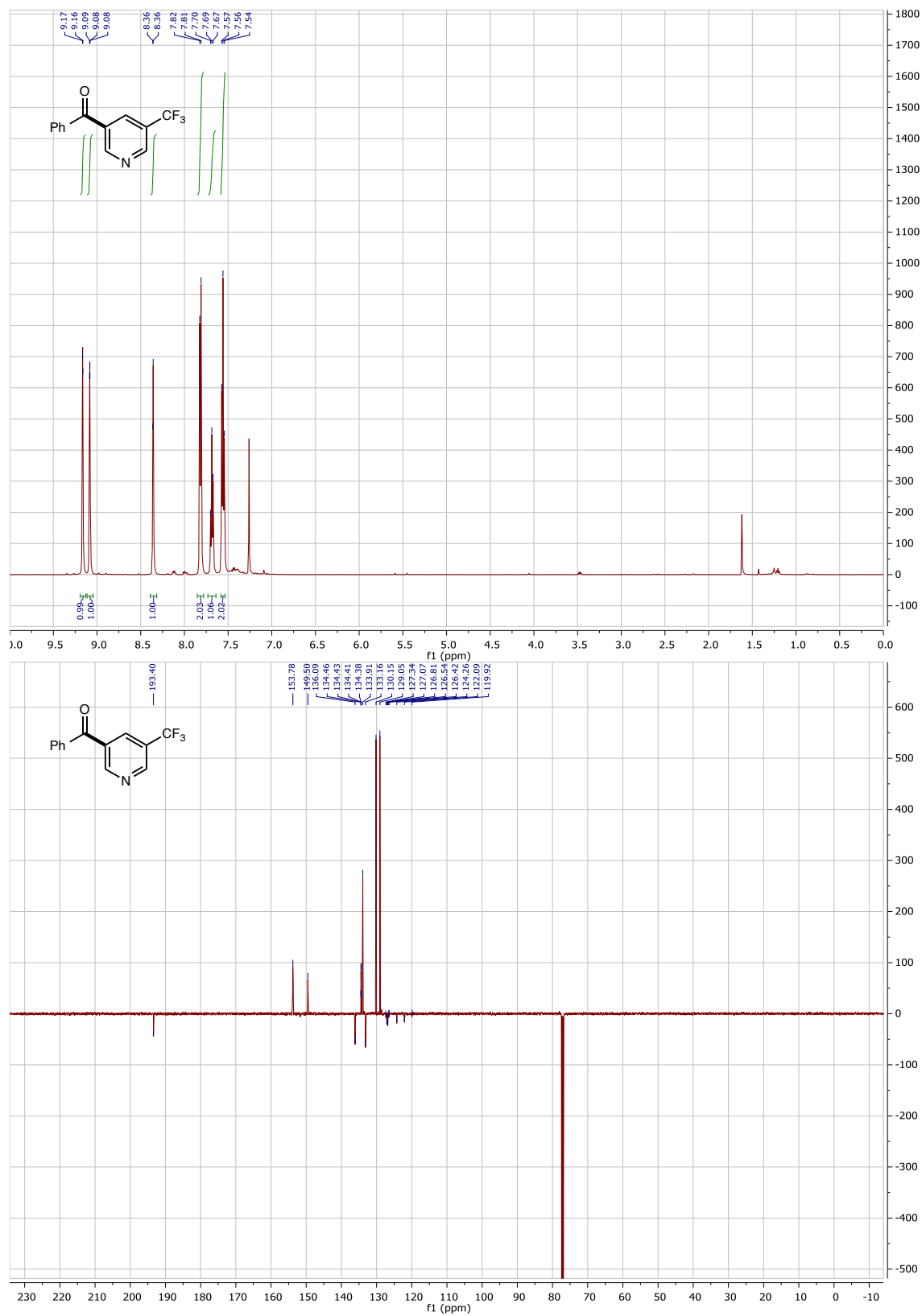
Fenofibrate (**40**)<sup>21</sup>: An oven-dried 40 mL vial equipped with a Teflon septum cap and magnetic stir bar was charged with Ir[dF(CF<sub>3</sub>)ppy]<sub>2</sub>(dtbbpy)PF<sub>6</sub> (11.2 mg, 0.01 mmol, 0.02 equiv), NiCl<sub>2</sub>·glyme (11.2 mg, 0.05 mmol, 0.10 equiv), 4,4'-di-*tert*-butyl-2,2'-bipyridine (20.1 mg, 0.075 mmol, 0.15 equiv), keto acid **39** (≥95%, 310 mg, 1.00 mmol, 2.0 equiv), 4-chloro-1-iodobenzene (120 mg, 0.50 mmol, 1.0 equiv), and Li<sub>2</sub>CO<sub>3</sub> (73.9 mg, 1.00 mmol, 2.0 equiv) from a bottle stored in a desiccator. To this vial was added DMF (25 mL) and water (18 μL, 2.00 mmol, 2.0 equiv). The reaction mixture was degassed for 30 minutes by bubbling argon stream, then sealed with parafilm. The vial was irradiated with 34W Blue LED lamp (Kessil KSH150B LED Grow Light) for 72 hours with cooling from a fan (vial temperature reached 37 °C). After 96 hours, the reaction was diluted with 25 mL H<sub>2</sub>O and extracted with 3x75 mL Et<sub>2</sub>O. The combined organic layers were washed with 3x25 mL H<sub>2</sub>O, then dried over MgSO<sub>4</sub>, filtered, and concentrated *in*

<sup>21</sup> Bjerglund, K.M.; Skrydstrup, T.; Molander, G.A. *Org. Lett.* **2014**, *16*, 1888.

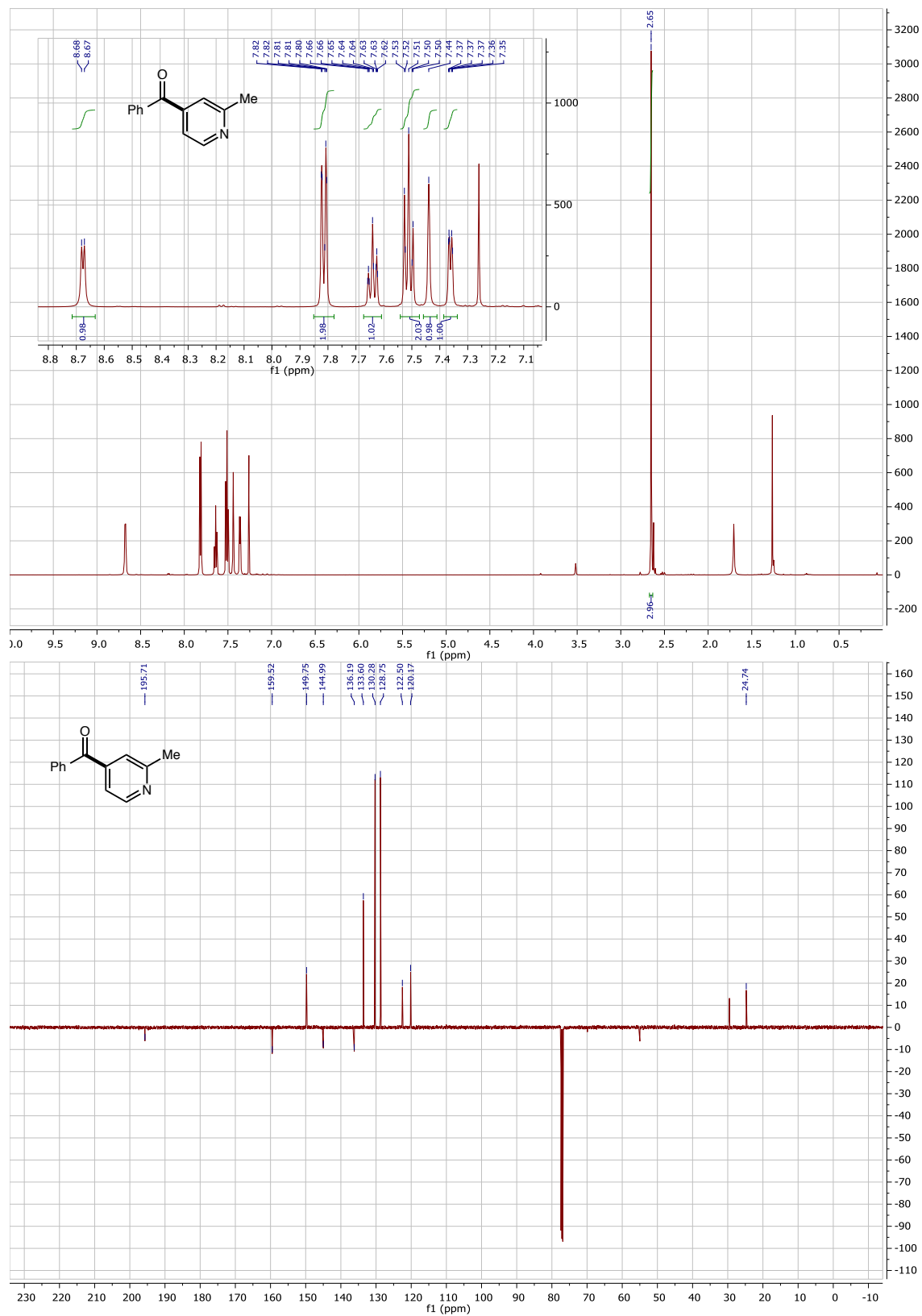
*vacuo*. The crude product was purified by flash chromatography on silica gel with a 25g column on a biotage instrument with 5% EtOAc in hexanes as eluent, to yield **40** as an off-white solid 127.9 mg, 71% yield.  $^1\text{H}$  NMR (501 MHz, Chloroform-*d*)  $\delta$  7.72 (d,  $J = 8.8$  Hz, 2H), 7.69 (d,  $J = 8.4$  Hz, 2H), 7.44 (d,  $J = 8.4$  Hz, 2H), 6.86 (d,  $J = 8.8$  Hz, 2H), 5.08 (hept,  $J = 6.3$  Hz, 1H), 1.65 (s, 6H), 1.20 (d,  $J = 6.3$  Hz, 6H).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  194.4, 173.2, 159.9, 138.5, 136.5, 132.1, 131.3, 130.3, 128.7, 117.4, 79.5, 69.5, 25.5, 21.7.

mesityl(*p*-tolyl)methanone (**14**)

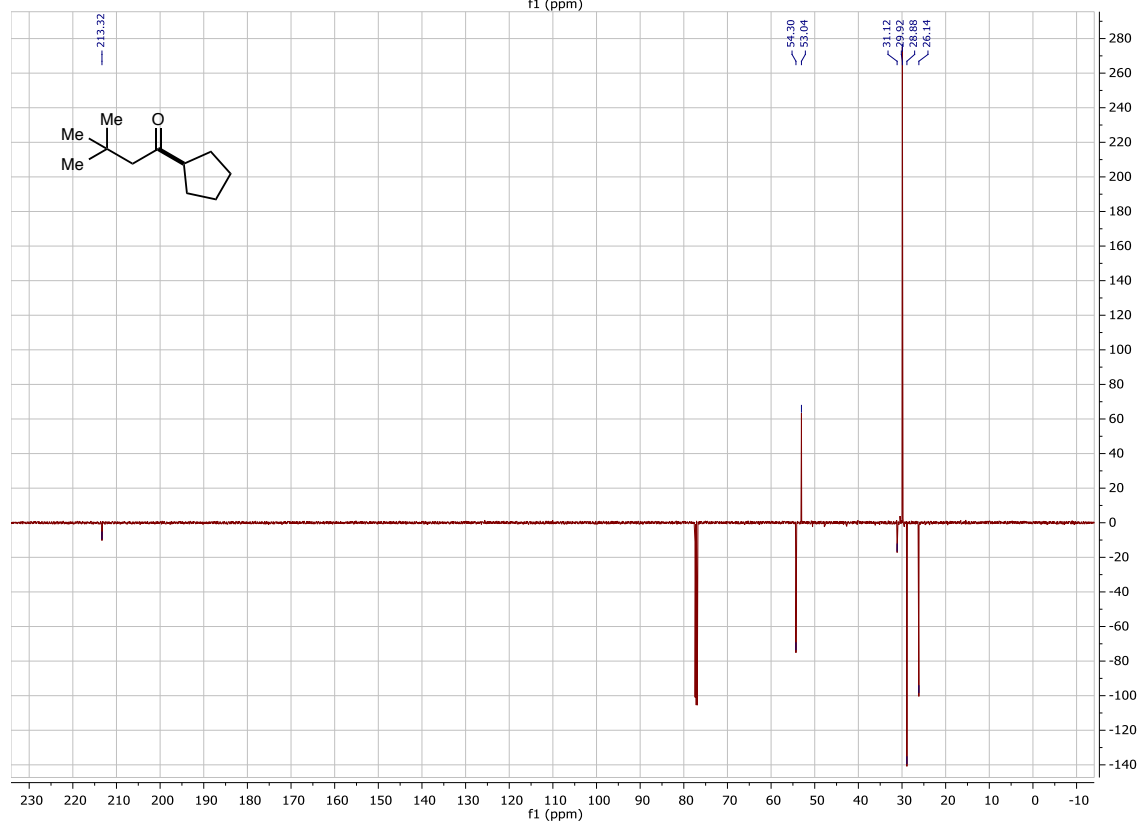
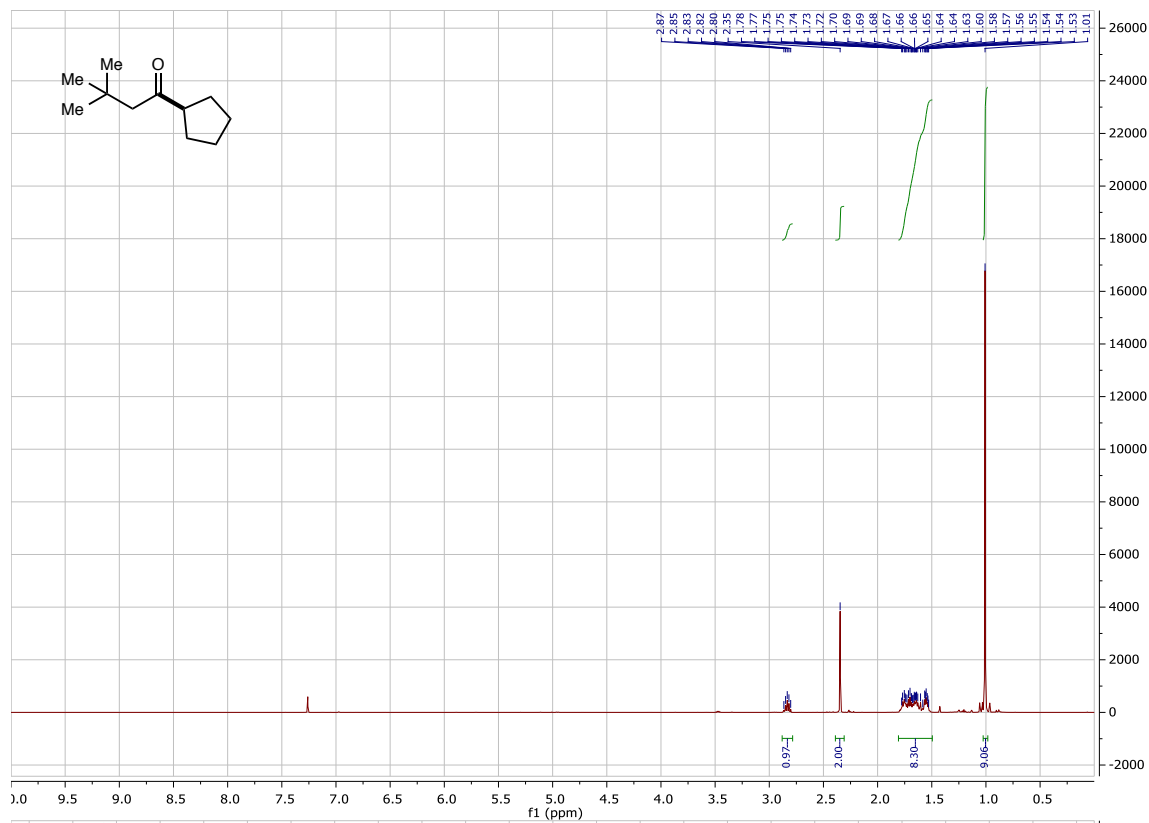
## phenyl(5-(trifluoromethyl)pyridin-3-yl)methanone (34)

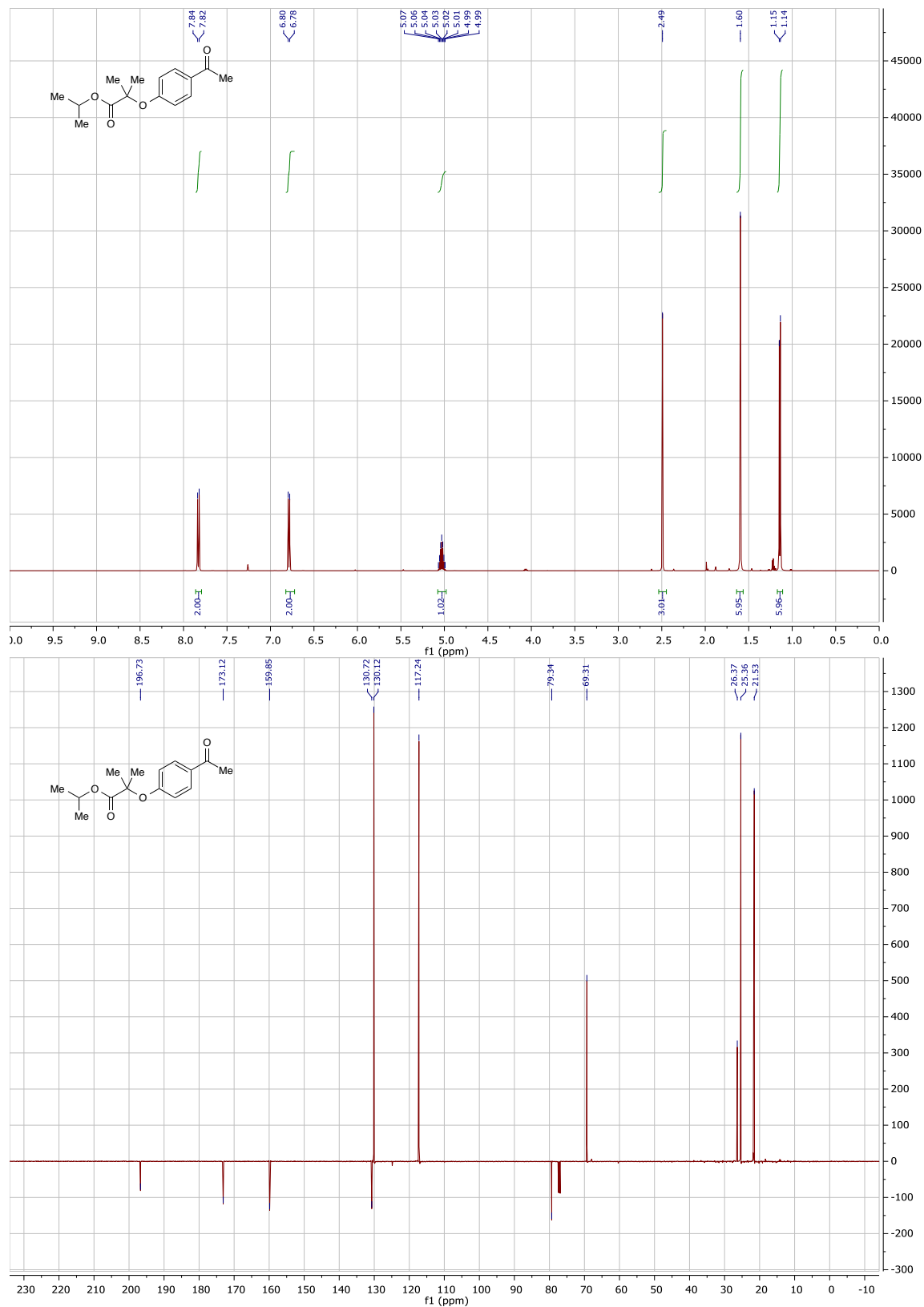


## (2-methylpyridin-4-yl)(phenyl)methanone (35)





1-cyclopentyl-3,3-dimethylbutan-1-one (**38**)

isopropyl 2-(4-acetylphenoxy)-2-methylpropanoate (**S1**):

2-(4-((1-isopropoxy-2-methyl-1-oxopropan-2-yl)oxy)phenyl)-2-oxoacetic acid (**39**)