

Iridium-Catalyzed Arylation of Sulfoxonium Ylides and Arylboronic Acid: A Straightforward Preparation of α -Aryl Ketones.

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Supporting Information

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1. General information

Unless otherwise noted, all reactions were carried out at room temperature under an atmosphere of nitrogen with flame-dried glassware. If reaction was not conducted at room temperature, reaction temperatures are reported as the temperature of the bath surrounding the vessel unless otherwise stated. The dry solvents used were purified by distillation over the drying agents indicated in parentheses and were transferred under nitrogen: THF (Na, benzophenone), Toluene (Na, benzophenone), Et₂O (Na, benzophenone), dichloromethane (CaH₂). Anhydrous DMF was purchased from Acros Organics and stored under nitrogen atmosphere. Commercially available chemicals were obtained from commercial suppliers and used without further purification unless otherwise stated.

Proton NMR (¹H) were recorded at 400 MHz, and Carbon NMR (¹³C) at 101 MHz NMR spectrometer unless otherwise stated. The following abbreviations are used for the multiplicities: s: singlet, d: doublet, t: triplet, q: quartet, m: multiplet, br s: broad singlet for proton spectra. Coupling constants (*J*) are reported in Hertz (Hz).

Analytical thin layer chromatography was performed on Polygram SIL G/UV254 plates. Visualization was accomplished with short wave UV light, or KMnO₄ staining solutions followed by heating. Flash column chromatography was performed using silica gel (200-300 mesh) with solvents distilled prior to use.

No attempts were made to optimize yields for substrate synthesis.

2. Synthesis of substrates **1**

The substrates of sulfoxonium ylides **1** were prepared according to the procedure reported by Burtoloso and Aïssa.^[1] All the characteristic data are consistent with the data reported before.^[2]

3. General procedure and characterization of products

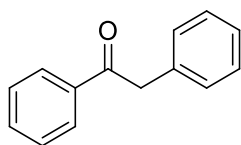
General procedure A

In an oven-dried Schlenk tube under air, a mixture of the substrates **1** (0.2 mmol, 1.0 equiv), boronic acid **2** (0.3 mmol, 2.5 equiv), (Cp*IrCl₂)₂ (2.5 mol%), AgSbF₆ (10.0 mol%), DIPA (1.5 equiv) in PhMe (1.0 mL) at 60 °C. For synthesis of **3ca**, **3ja**, and **3ua**, the reaction mixture was stirred at 80 °C. For synthesis of **3fa**, 1.5 equiv of K₂HPO₄ was used and the reaction mixture was stirred at 80 °C. For synthesis of **3ta**, 1.5 equiv of K₂HPO₄ was used at 60 °C. The obtained solution was stirred for 12 h.

The reaction mixture was then diluted with EA (10.0 mL) and washed with H₂O. The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na₂SO₄. The pure product was purified by flash column chromatography on silica with an appropriate eluent to afford the pure product.

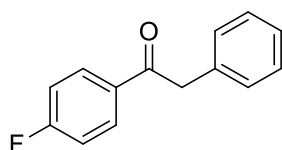
Characterization of products

1,2-diphenylethanone (**3aa**)^[3]



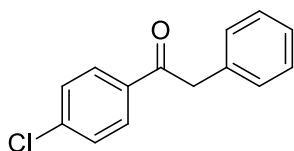
Following the general procedure A, the product **3aa** was obtained in 75% yield (29.8 mg, 0.15 mmol) as a colourless liquid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.21. ¹H NMR (400 MHz, CDCl₃) δ 7.97 – 7.89 (m, 2H), 7.51 – 7.42 (m, 1H), 7.41 – 7.34 (m, 2H), 7.27 – 7.21 (m, 2H), 7.21 – 7.16 (m, 3H), 4.21 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 197.6, 136.6, 134.6, 133.1, 129.5, 128.7, 128.6, 128.6, 126.9, 45.5.

1-(4-fluorophenyl)-2-phenylethanone (**3ba**)^[4]



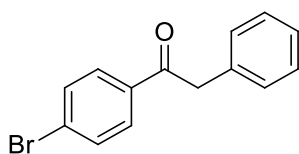
Following the general procedure A, the product **3ba** was obtained in 58% yield (24.7 mg, 0.116 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.20. ^1H NMR (500 MHz, CDCl_3) δ 8.06 – 7.85 (m, 2H), 7.25 (t, $J = 7.4$ Hz, 2H), 7.18 - 7.17 (m, 3H), 7.04 (t, $J = 8.4$ Hz, 2H), 4.17 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.1, 165.8 (d, $J = 255.0$ Hz), 134.3, 133.0 (d, $J = 2.9$ Hz), 131.3 (d, $J = 9.3$ Hz), 129.4, 128.77, 127.0, 115.8 (d, $J = 21.9$ Hz), 45.5. ^{19}F NMR (471 MHz, CDCl_3) δ -105.0.

1-(4-chlorophenyl)-2-phenylethanone (**3ca**) ^[5]



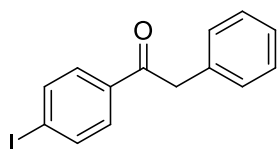
Following the general procedure A, the product **3ca** was obtained in 81% yield (37.5 mg, 0.162 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.21. ^1H NMR (500 MHz, CDCl_3) δ 7.86 (d, $J = 7.4$ Hz, 2H), 7.34 (d, $J = 7.4$ Hz, 2H), 7.25 (t, $J = 7.2$ Hz, 2H), 7.19 - 7.16 (m, 3H), 4.17 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.5, 139.6, 134.9, 134.2, 130.1, 129.4, 123.0, 128.8, 127.1, 45.6.

1-(4-bromophenyl)-2-phenylethanone (**3da**) ^[4]



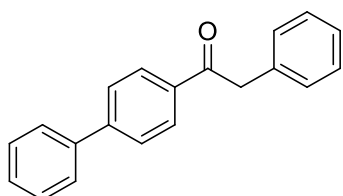
Following the general procedure A, the product **3da** was obtained in 62% yield (34.0 mg, 0.124 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.23. ^1H NMR (500 MHz, CDCl_3) δ 7.78 (d, $J = 7.9$ Hz, 2H), 7.50 (d, $J = 7.9$ Hz, 2H), 7.24 (t, $J = 7.3$ Hz, 2H), 7.19 - 7.16 (m, 3H), 4.16 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.7, 135.3, 134.2, 132.0, 130.2, 129.4, 128.8, 128.4, 127.1, 45.6.

1-(4-iodophenyl)-2-phenylethanone (**3ea**) ^[6]



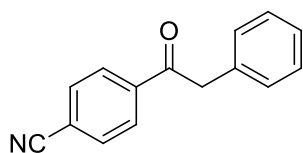
Following the general procedure A, the product **3ea** was obtained in 87% yield (56.2 mg, 0.174 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.18. ^1H NMR (500 MHz, CDCl_3) δ 7.74 (d, J = 7.7 Hz, 2H), 7.63 (d, J = 7.6 Hz, 2H), 7.25 (t, J = 7.2 Hz, 2H), 7.20 - 7.16 (m, 3H), 4.16 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 195.9, 136.9, 134.7, 133.1, 129.0, 128.3, 127.7, 126.0, 100.2, 44.4.

1-([1,1'-biphenyl]-4-yl)-2-phenylethanone (**3fa**)^[7]



Following the general procedure A, the product **3fa** was obtained in 76% yield (41.5 mg, 0.152 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.25. ^1H NMR (500 MHz, CDCl_3) δ 8.00 (d, J = 7.3 Hz, 2H), 7.58 (d, J = 7.3 Hz, 2H), 7.53 (d, J = 7.5 Hz, 2H), 7.38 (t, J = 7.3 Hz, 2H), 7.31 (t, J = 7.3 Hz, 1H), 7.25 (t, J = 7.2 Hz, 2H), 7.23 - 7.14 (m, 3H), 4.22 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.2, 144.8, 138.8, 134.2, 133.6, 128.4, 128.2, 127.9, 127.7, 127.2, 126.2, 126.2, 125.9, 44.5.

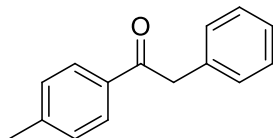
4-(2-phenylacetyl)benzonitrile (**3ga**)^[6]



Following the general procedure A, the product **3ga** was obtained in 37% yield (16.6 mg, 0.074 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.20. ^1H NMR (500 MHz, CDCl_3) δ 8.01 (d, J = 7.3 Hz, 2H), 7.68 (d, J = 7.3 Hz, 2H), 7.27 (t, J = 7.2 Hz, 2H), 7.21 (d, J = 7.0 Hz, 1H), 7.18 (t, J = 6.5 Hz, 2H), 4.22 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.3, 139.5, 133.5, 132.6, 129.4, 129.0,

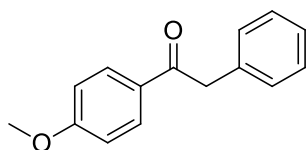
128.9, 127.3, 117.9, 116.4, 45.9.

2-phenyl-1-(p-tolyl)ethanone (3ha) ^[7]



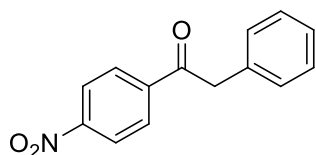
Following the general procedure A, the product **3ha** was obtained in 98% yield (41.3 mg, 0.196 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.22. ¹H NMR (400 MHz, CDCl₃) δ 7.94 (d, *J* = 8.2 Hz, 2H), 7.38-7.32 (m, 2H), 7.30-7.25 (m, 5H), 4.28 (s, 2H), 2.43 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 197.3, 144.0, 134.8, 134.2, 129.4, 129.3, 128.8, 128.6, 126.8, 45.4, 21.7.

1-(4-methoxyphenyl)-2-phenylethanone (3ia) ^[7]



Following the general procedure A, the product **3ia** was obtained in 80% yield (36.3 mg, 0.16 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.26. ¹H NMR (500 MHz, CDCl₃) δ 7.92 (d, *J* = 7.7 Hz, 2H), 7.24 (t, *J* = 7.2 Hz, 2H), 7.20 - 7.15 (m, 3H), 6.85 (d, *J* = 7.7 Hz, 2H), 4.16 (s, 2H), 3.78 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 196.3, 163.5, 134.0, 131.0, 129.6, 129.4, 128.7, 126.8, 113.8, 55.5, 45.3.

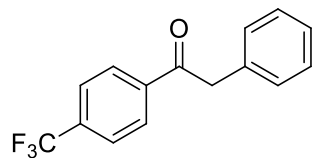
1-(4-nitrophenyl)-2-phenylethanone (3ja) ^[8]



Following the general procedure A, the product **3ja** was obtained in 63% yield (30.3 mg, 0.126 mmol) as a yellow solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.22. ¹H NMR (500 MHz, CDCl₃) δ 8.22 (d, *J* = 7.7 Hz, 2H), 8.07 (d, *J* = 7.7 Hz, 2H), 7.28 (t, *J* = 7.2 Hz, 2H), 7.22 (d, *J* = 7.0 Hz, 1H), 7.18 (d, *J* =

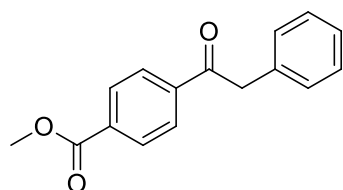
7.4 Hz, 2H), 4.26 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.1, 150.3, 141.0, 133.4, 129.7, 129.4, 129.0, 127.4, 123.9, 46.1.

2-phenyl-1-(4-(trifluoromethyl)phenyl)ethanone (3ka) ^[7]



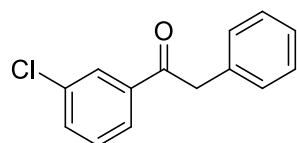
Following the general procedure A, the product **3ka** was obtained in 78% yield (41.4 mg, 0.156 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.21. ^1H NMR (500 MHz, CDCl_3) δ 8.03 (d, $J = 7.9$ Hz, 2H), 7.65 (d, $J = 7.8$ Hz, 2H), 7.27 (t, $J = 7.1$ Hz, 2H), 7.22 - 7.18 (m, 3H), 4.24 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.6, 139.2, 134.5 ($J = 32.7$ Hz), 133.8, 129.4, 128.9, 128.9, 127.2, 125.7 ($J = 3.7$ Hz), 123.6 (d, $J = 272.8$ Hz), 45.9. ^{19}F NMR (471 MHz, CDCl_3) δ -63.2.

methyl 4-(2-phenylacetyl)benzoate (3la) ^[9]



Following the general procedure A, the product **3la** was obtained in 83% yield (42.4 mg, 0.166 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 16:1 v/v). RF (Petroleum ether/EtOAc 16:1): 0.23. ^1H NMR (400 MHz, CDCl_3) δ 8.13 (d, $J = 8.5$ Hz, 2H), 8.07 (d, $J = 8.4$ Hz, 2H), 7.39 - 7.32 (m, 2H), 7.32 - 7.26 (m, 3H), 4.33 (s, 2H), 3.96 (s, 3H). ^{13}C NMR (126 MHz, CDCl_3) δ 197.2, 166.2, 139.8, 134.0, 133.9, 129.9, 129.5, 128.8, 128.5, 127.1, 52.5, 45.9.

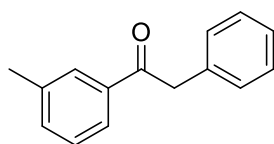
1-(3-chlorophenyl)-2-phenylethanone (3ma) ^[10]



Following the general procedure A, the product **3ma** was obtained in 61% yield (28.1 mg,

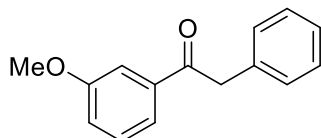
0.124 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.21. ^1H NMR (400 MHz, CDCl_3) δ 8.00 (t, $J = 1.8$ Hz, 1H), 7.90 (d, $J = 7.8$ Hz, 1H), 7.56 – 7.54 (m, 1H), 7.42 (t, $J = 7.9$ Hz, 1H), 7.39 – 7.33 (m, 2H), 7.32 – 7.26 (m, 3H), 4.28 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.4, 138.2, 135.0, 134.0, 133.1, 130.0, 129.5, 128.8, 128.7, 127.1, 126.7, 45.6.

2-phenyl-1-(m-tolyl)ethan-1-one (3na) ^[6]



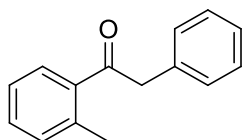
Following the general procedure A, the product **3na** was obtained in 73% yield (30.5 mg, 0.146 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.24. ^1H NMR (400 MHz, CDCl_3) δ 7.86 – 7.83 (m, 2H), 7.42 – 7.33 (m, 4H), 7.32 – 7.27 (m, 3H), 4.30 (s, 2H), 2.44 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.9, 138.5, 136.7, 134.7, 133.9, 129.5, 129.1, 128.7, 128.5, 126.9, 125.9, 45.5, 21.4.

1-(3-methoxyphenyl)-2-phenylethan-1-one (3oa) ^[6]



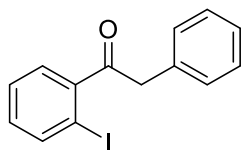
Following the general procedure A, the product **3oa** was obtained in 77% yield (35.1 mg, 0.154 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.20. ^1H NMR (400 MHz, CDCl_3) δ 7.63 (d, $J = 7.7$ Hz, 1H), 7.57 – 7.54 (m, 1H), 7.43 – 7.32 (m, 3H), 7.32 – 7.25 (m, 4H), 7.15 – 7.10 (m, 1H), 4.30 (s, 2H), 3.86 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.5, 159.9, 138.0, 134.6, 129.6, 129.4, 128.7, 126.9, 121.3, 119.7, 112.9, 55.4, 45.6.

2-phenyl-1-(o-tolyl)ethanone (3pa) ^[11]



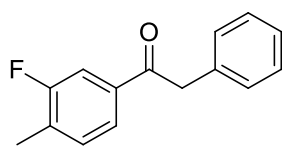
Following the general procedure A, the product **3pa** was obtained in 70% yield (29.6 mg, 0.146 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.20. ¹H NMR (400 MHz, CDCl₃) δ 7.71 (d, *J* = 7.8 Hz, 1H), 7.39 – 7.29 (m, 3H), 7.28 - 7.27 (m, 1H), 7.24 - 7.22 (m, 4H), 4.21 (s, 2H), 2.44 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 201.5, 138.6, 137.6, 134.5, 132.0, 131.4, 129.6, 128.6, 128.6, 126.9, 125.6, 48.5, 21.3.

1-(2-iodophenyl)-2-phenylethan-1-one (**3qa**)^[7]



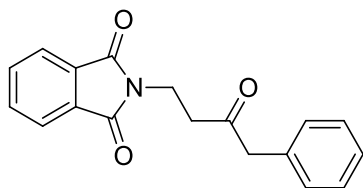
Following the general procedure A, the product **3qa** was obtained in 41% yield (26.6 mg, 0.082 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.21. ¹H NMR (500 MHz, CDCl₃) δ 7.81 (d, *J* = 7.9 Hz, 1H), 7.31 – 7.21 (m, 4H), 7.21 – 7.14 (m, 3H), 7.02 (t, *J* = 7.6 Hz, 1H), 4.13 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 202.1, 144.4, 140.4, 133.3, 131.5, 129.7, 128.6, 127.9, 127.9, 127.1, 91.2, 48.8.

1-(3-fluoro-4-methylphenyl)-2-phenylethanone (**3ra**)



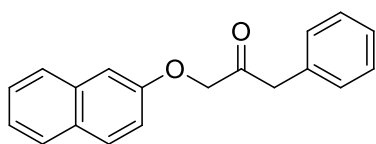
Following the general procedure A, the product **3ra** was obtained in 46% yield (30.1 mg, 0.092 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.19. Mp 83-84 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.62 (d, *J* = 7.8 Hz, 1H), 7.56 (d, *J* = 10.3 Hz, 1H), 7.25 (t, *J* = 7.3 Hz, 2H), 7.20 - 7.17 (m, 4H), 4.16 (s, 2H), 2.25 (s, 3H). ¹⁹F NMR (471 MHz, CDCl₃) δ -116.1. ¹³C NMR (126 MHz, CDCl₃) δ 196.3, 161.3 (d, *J* = 246.5 Hz), 136.3 (d, *J* = 6.3 Hz), 134.3, 131.6 (d, *J* = 4.8 Hz), 131.0 (d, *J* = 17.7 Hz), 129.4, 128.7, 127.0, 124.3 (d, *J* = 3.2 Hz), 115.0 (d, *J* = 23.2 Hz), 45.5, 14.9 (d, *J* = 3.5 Hz). ESI-MS: calculated C₁₅H₁₄FO [M+H]⁺ 229.1023; Found 229.1001.

2-(3-oxo-4-phenylbutyl)isoindoline-1,3-dione (3sa)



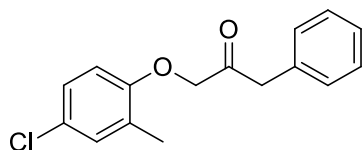
Following the general procedure A, the product **3sa** was obtained in 66% yield (39.0 mg, 0.132 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 16:1 v/v). RF (Petroleum ether/EtOAc 16:1): 0.23. Mp 115-116 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.82-7.79 (m, 2H), 7.75 – 7.67 (m, 2H), 7.30 (t, *J* = 7.2 Hz, 2H), 7.23 (t, *J* = 4.9 Hz, 1H), 7.21 – 7.16 (m, 2H), 3.94 (t, *J* = 7.3 Hz, 2H), 3.73 (s, 2H), 2.88 (t, *J* = 7.3 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 205.5, 168.0, 133.9, 133.6, 132.0, 129.4, 128.8, 127.1, 123.2, 50.2, 39.8, 33.1. ESI-MS: calculated C₁₈H₁₆NO₃ [M+H]⁺ 294.1125; Found 294.1134.

1-(naphthalen-2-yloxy)-3-phenylpropan-2-one (3ta)



Following the general procedure A, the product **3ta** was obtained in 61% yield (33.7 mg, 0.122 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 16:1 v/v). RF (Petroleum ether/EtOAc 16:1): 0.22. Mp 101-102 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.70 (d, *J* = 8.5 Hz, 2H), 7.57 (d, *J* = 8.2 Hz, 1H), 7.36 (t, *J* = 7.5 Hz, 1H), 7.30 - 7.25 (m, 3H), 7.23 – 7.12 (m, 4H), 6.86 (s, 1H), 4.64 (s, 2H), 3.85 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 204.9, 155.6, 134.3, 133.1, 129.9, 129.6, 129.4, 128.9, 127.7, 127.4, 126.9, 126.7, 124.2, 118.5, 106.9, 72.1, 46.4. ESI-MS: calculated C₁₉H₁₆O₂Na [M+Na]⁺ 299.1043; Found 299.1007.

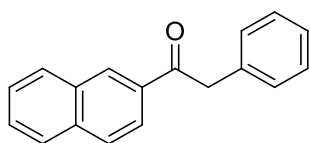
1-(4-chloro-2-methylphenoxy)-3-phenylpropan-2-one (3ua)



Following the general procedure A, the product **3ua** was obtained in 76% yield (41.5 mg,

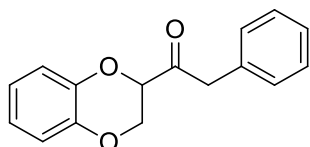
0.152 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 16:1 v/v). RF (Petroleum ether/EtOAc 16:1): 0.21. Mp 101-102 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.26 (t, *J* = 7.2 Hz, 2H), 7.22 - 7.18 (m, 1H), 7.15 (d, *J* = 7.5 Hz, 2H), 7.07 (s, 1H), 6.98 (d, *J* = 8.6 Hz, 1H), 6.42 (d, *J* = 8.6 Hz, 1H), 4.51 (s, 2H), 3.83 (s, 2H), 2.21 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 204.7, 154.4, 132.9, 130.9, 129.5, 128.9, 127.4, 126.5, 126.2, 111.9, 72.4, 46.2, 16.3. ESI-MS: calculated C₁₆H₁₅ClO₂Na [M+Na]⁺ 297.0653; Found 297.0645.

1-(naphthalen-2-yl)-2-phenylethanone (3va) ^[7]



Following the general procedure A, the product **3va** was obtained in 75% yield (37.1 mg, 0.15 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.21. ¹H NMR (500 MHz, CDCl₃) δ 8.45 (s, 1H), 7.97 (d, *J* = 8.6 Hz, 1H), 7.87 (d, *J* = 8.1 Hz, 1H), 7.78 (t, *J* = 9.0 Hz, 2H), 7.50 (t, *J* = 7.5 Hz, 1H), 7.45 (t, *J* = 7.4 Hz, 1H), 7.28 – 7.21 (m, 4H), 7.20 – 7.13 (m, 1H), 4.32 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.7, 135.6, 134.7, 134.0, 132.5, 130.5, 129.7, 129.5, 128.8, 128.6, 128.6, 127.8, 126.9, 126.8, 124.3, 45.6.

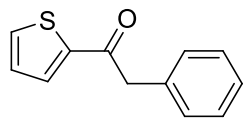
1-(2,3-dihydrobenzo[b][1,4]dioxin-2-yl)-2-phenylethanone (3wa)



Following the general procedure A, the product **3wa** was obtained in 30% yield (15.4 mg, 0.06 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.24. Mp 86-87 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.24 (t, *J* = 7.3 Hz, 2H), 7.18 (t, *J* = 7.0 Hz, 1H), 7.12 (d, *J* = 7.5 Hz, 2H), 6.96 (d, *J* = 7.7 Hz, 1H), 6.87 – 6.79 (m, 3H), 4.68 – 4.57 (m, 1H), 4.25 (d, *J* = 11.4 Hz, 1H), 4.14 (dd, *J* = 11.4, 5.9 Hz, 1H), 3.96 (d, *J* = 15.9 Hz, 1H), 3.80 (d, *J* = 15.9 Hz, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 205.2, 143.3, 142.2, 132.7, 129.7, 128.7, 127.3, 122.2, 122.2, 117.6, 117.4, 64.6, 45.8. ESI-MS:

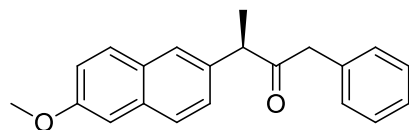
calculated C₁₆H₁₄O₃Na [M+Na]⁺ 277.0835; Found 277.0845.

2-phenyl-1-(thiophen-2-yl)ethanone (3xa) ^[12]



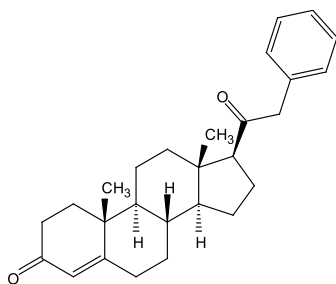
Following the general procedure A, the product **3xa** was obtained in 64% yield (25.8 mg, 0.128 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.19. ¹H NMR (400 MHz, CDCl₃) δ 7.79 (dd, *J* = 3.8, 1.1 Hz, 1H), 7.66 (dd, *J* = 5.0, 1.1 Hz, 1H), 7.36 (dd, *J* = 5.1, 3.2 Hz, 1H), 7.35 – 7.32 (m, 3H), 7.30 (d, *J* = 2.0 Hz, 1H), 7.14 (dd, *J* = 4.9, 3.8 Hz, 1H), 4.22 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 190.5, 143.9, 134.3, 134.1, 132.7, 129.4, 128.7, 128.2, 127.1, 46.4.

(R)-3-(6-methoxynaphthalen-2-yl)-1-phenylbutan-2-one (3ya)



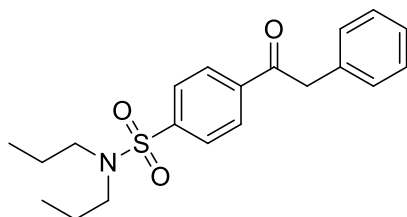
Following the general procedure A, the product **3ya** was obtained in 32% yield (19.7 mg, 0.064 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 16:1 v/v). RF (Petroleum ether/EtOAc 16:1): 0.20. Mp 78-79 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.63 (t, *J* = 9.2 Hz, 2H), 7.50 (s, 1H), 7.22 – 7.11 (m, 4H), 7.09 (d, *J* = 8.9 Hz, 1H), 7.05 (s, 1H), 6.96 (d, *J* = 7.4 Hz, 2H), 3.90 (q, *J* = 6.8 Hz, 1H), 3.84 (s, 3H), 3.57 (s, 2H), 1.36 (d, *J* = 6.9 Hz, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 208.3, 157.8, 135.5, 134.4, 133.8, 129.5, 129.2, 129.2, 128.6, 127.7, 126.9, 126.8, 126.5, 119.2, 105.6, 55.4, 52.0, 48.1, 17.7. ESI-MS: calculated C₂₁H₂₁O₂ [M+H]⁺ 305.1536; Found 305.1519.

(8S,9S,10R,13S,14S,17S)-10,13-dimethyl-17-(2-phenylacetyl)-6,7,8,9,10,11,12,13,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3(2H)-one (3za)



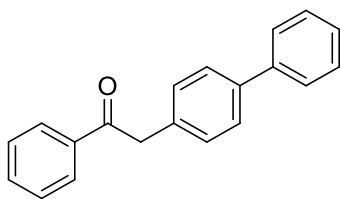
Following the general procedure A, the product **3za** was obtained in 66% yield (51.8 mg, 0.132 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.17. Mp 133-134 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.23 (d, *J* = 7.2 Hz, 2H), 7.19 – 7.15 (m, 1H), 7.10 (d, *J* = 7.4 Hz, 2H), 5.99 (s, 1H), 3.66 - 3.57 (m, 2H), 2.60 - 2.57 (m, 1H), 2.47 - 2.41 (m, 1H), 2.28 - 2.23 (m, 1H), 2.15 - 2.11 (m, 2H), 2.04 - 1.99 (m, 1H), 1.80 - 1.77 (m, 1H), 1.63 – 1.53 (m, 6H), 1.45 – 1.35 (m, 2H), 1.29 – 1.16 (m, 3H), 1.14 - 1.09 (m, 1H), 1.00 - 0.96 (m, 1H), 0.89 (s, 3H), 0.63 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 208.6, 140.5, 134.4, 130.4, 129.6, 128.6, 127.0, 126.9, 123.9, 61.9, 57.0, 51.2, 47.8, 44.6, 39.0, 34.8, 34.5, 31.7, 31.6, 30.7, 24.5, 23.5, 21.2, 18.9, 13.7. ESI-MS: calculated C₂₇H₃₅O₂ [M+H]⁺ 391.2553; Found 391.2549.

4-(2-phenylacetyl)-N,N-dipropylbenzenesulfonamide (**3aaa**)



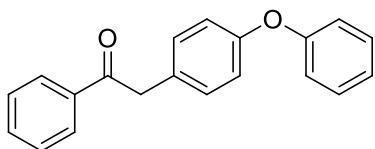
Following the general procedure A, the product **3aaa** was obtained in 55% yield (39.5 mg, 0.11 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.26. Mp 63-64 °C. ¹H NMR (500 MHz, CDCl₃) δ 8.02 (d, *J* = 7.8 Hz, 2H), 7.81 (d, *J* = 7.9 Hz, 2H), 7.27 (t, *J* = 7.2 Hz, 2H), 7.21 - 7.17 (m, 3H), 4.23 (s, 2H), 3.04 – 2.98 (m, 4H), 1.52 – 1.42 (m, 4H), 0.79 (t, *J* = 7.2 Hz, 6H). ¹³C NMR (126 MHz, CDCl₃) δ 196.6, 144.2, 139.2, 133.7, 129.4, 129.2, 128.9, 127.3, 127.2, 50.0, 45.9, 22.0, 11.2. ESI-MS: calculated C₂₀H₂₆NO₃S [M+H]⁺ 360.1628; Found 360.1630.

2-([1,1'-biphenyl]-4-yl)-1-phenylethanone (**3ab**)^[13]



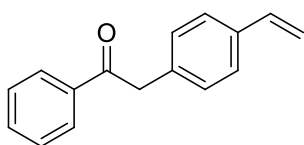
Following the general procedure A, the product **3ab** was obtained in 76% yield (41.4 mg, 0.152 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.21. ^1H NMR (400 MHz, CDCl_3) δ 7.98 – 7.91 (m, 2H), 7.52 – 7.42 (m, 5H), 7.40 – 7.29 (m, 4H), 7.28 – 7.20 (m, 3H), 4.23 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.6, 140.9, 139.9, 136.7, 133.6, 133.3, 130.0, 128.8, 128.7, 128.7, 127.5, 127.3, 127.1, 45.1.

2-(4-phenoxyphenyl)-1-phenylethanone (**3ac**)^[14]



Following the general procedure A, the product **3ac** was obtained in 90% yield (52.1 mg, 0.18 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.27. ^1H NMR (400 MHz, CDCl_3) δ 8.07 – 8.05 (m, 2H), 7.64 – 7.56 (m, 1H), 7.52 – 7.49 (m, 2H), 7.40 – 7.32 (m, 2H), 7.30 – 7.23 (m, 2H), 7.17 – 7.09 (m, 1H), 7.08 – 6.96 (m, 4H), 4.30 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.6, 157.2, 156.3, 136.6, 133.2, 130.8, 129.7, 129.3, 128.7, 128.6, 123.3, 119.0, 118.9, 44.7.

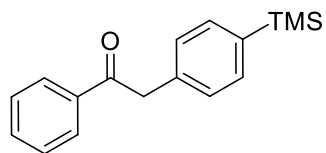
1-phenyl-2-(4-vinylphenyl)ethanone (**3ad**)^[15]



Following the general procedure A, the product **3ad** was obtained in 98% yield (43.5 mg, 0.196 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.22. ^1H NMR (400 MHz, CDCl_3) δ 8.05 – 8.03 (m, 2H), 7.58 (t, $J = 7.3$ Hz, 1H), 7.48 (t, $J = 7.7$ Hz, 2H), 7.40 (d, $J = 8.1$ Hz, 2H), 7.29 – 7.22 (m, 2H), 6.72 (dd, $J = 17.6, 10.9$ Hz, 1H), 5.75 (d, $J = 17.6$ Hz, 1H), 5.25 (d, $J = 10.9$ Hz, 1H), 4.30 (s,

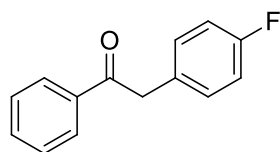
2H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.5, 136.6, 136.5, 136.3, 134.1, 133.2, 129.6, 128.7, 128.6, 126.5, 113.7, 45.3.

1-phenyl-2-(4-(trimethylsilyl)phenyl)ethan-1-one (**3ae**)^[16]



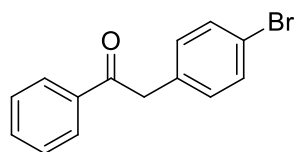
Following the general procedure A, the product **3ae** was obtained in 77% yield (41.4 mg, 0.154 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.19. ^1H NMR (500 MHz, CDCl_3) δ 8.02 (d, J = 7.2 Hz, 2H), 7.54 (d, J = 7.1 Hz, 1H), 7.49 - 7.44 (m, 4H), 7.26 (d, J = 8.7 Hz, 2H), 4.28 (s, 2H), 0.25 (s, 9H). ^{13}C NMR (126 MHz, CDCl_3) δ 197.7, 138.9, 136.7, 135.2, 133.7, 133.3, 129.0, 128.8, 128.8, 45.6, -1.0.

2-(4-fluorophenyl)-1-phenylethanone (**3af**)^[13]



Following the general procedure A, the product **3af** was obtained in 86% yield (37.0 mg, 0.176 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.21. ^1H NMR (500 MHz, CDCl_3) δ 8.01 (d, J = 7.8 Hz, 2H), 7.58 (t, J = 7.3 Hz, 1H), 7.48 (t, J = 7.5 Hz, 2H), 7.24 - 7.22 (m, 2H), 7.03 (t, J = 8.3 Hz, 2H), 4.27 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 197.4, 161.9 (d, J = 245.2 Hz), 136.5, 133.33, 131.1 (d, J = 8.0 Hz), 130.2 (d, J = 3.3 Hz), 128.7, 128.53, 115.5 (d, J = 21.4 Hz), 44.5. ^{19}F NMR (471 MHz, CDCl_3) δ -116.0.

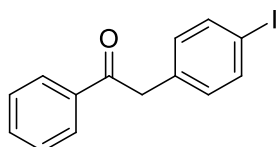
2-(4-bromophenyl)-1-phenylethanone (**3ag**)^[13]



Following the general procedure A, the product **3ag** was obtained in 65% yield (35.7 mg,

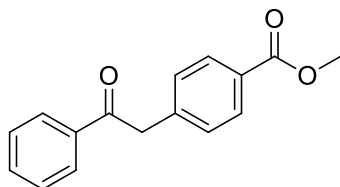
0.13 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.23. ¹H NMR (400 MHz, CDCl₃) δ 8.06 – 7.97 (m, 2H), 7.64 – 7.55 (m, 1H), 7.53 – 7.42 (m, 4H), 7.16 (d, *J* = 8.4 Hz, 2H), 4.27 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 197.0, 136.4, 133.4 (d, *J* = 10.5 Hz), 131.8, 131.3, 128.7, 128.5, 121.0, 44.8.

2-(4-iodophenyl)-1-phenylethanone (3ah) ^[17]



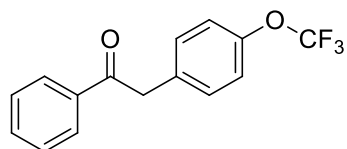
Following the general procedure A, the product **3ah** was obtained in 57% yield (36.8 mg, 0.114 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.21. ¹H NMR (400 MHz, CDCl₃) δ 8.05 – 7.95 (m, 2H), 7.68 (d, *J* = 8.3 Hz, 2H), 7.64 – 7.56 (m, 1H), 7.51 - 7.47 (m, 2H), 7.04 (d, *J* = 8.3 Hz, 2H), 4.25 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 196.9, 137.7, 136.4, 134.1, 133.4, 131.6, 128.7, 128.5, 92.4, 44.9.

methyl 4-(2-oxo-2-phenylethyl)benzoate (3ai) ^[17]



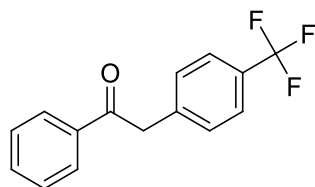
Following the general procedure A, the product **3ai** was obtained in 49% yield (25.1 mg, 0.10 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.22. ¹H NMR (400 MHz, CDCl₃) δ 8.04 - 8.01 (m, 4H), 7.63 – 7.56 (m, 1H), 7.51 - 7.47 (m, 2H), 7.36 (d, *J* = 8.3 Hz, 2H), 4.37 (s, 2H), 3.92 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 196.8, 166.9, 139.8, 136.4, 133.4, 129.9, 129.6, 128.8, 128.7, 128.5, 77.3, 77.3, 77.1, 76.8, 52.1, 45.4.

1-phenyl-2-(4-(trifluoromethoxy)phenyl)ethanone (3aj) ^[18]



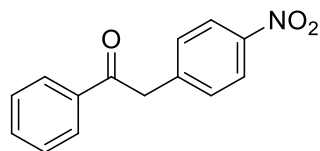
Following the general procedure A, the product **3aj** was obtained in 66% yield (37.0 mg, 0.132 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.22. ^1H NMR (400 MHz, CDCl_3) δ 7.94 – 7.92 (m, 2H), 7.53 - 7.49 (m, 1H), 7.42 - 7.38 (m, 2H), 7.21 (d, $J = 8.6$ Hz, 2H), 7.10 (d, $J = 8.0$ Hz, 2H), 4.22 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 197.0, 148.2, 136.5, 133.4, 133.2, 131.0, 128.6 (d, $J = 26.1$ Hz), 120.5 (d, $J = 256.9$ Hz), 44.5. ^{19}F NMR (471 MHz, CDCl_3) δ -57.9.

1-phenyl-2-(4-(trifluoromethyl)phenyl)ethanone (**3ak**) ^[18]



Following the general procedure A, the product **3ak** was obtained in 47% yield (24.7 mg, 0.092 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.23. ^1H NMR (500 MHz, CDCl_3) δ 8.02 (d, $J = 7.8$ Hz, 2H), 7.63 – 7.56 (m, 3H), 7.49 (t, $J = 7.4$ Hz, 2H), 7.39 (d, $J = 7.8$ Hz, 2H), 4.36 (s, 1H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.7, 138.6, 136.3, 133.5, 130.0, 129.3 (q, $J = 32.4$ Hz), 128.8, 128.5, 125.6 (q, $J = 3.8$ Hz), 124.2 (q, $J = 272.0$ Hz), 45.1. ^{19}F NMR (471 MHz, CDCl_3) δ -62.5.

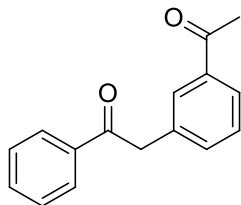
2-(4-nitrophenyl)-1-phenylethanone (**3al**) ^[6]



Following the general procedure A, the product **3al** was obtained in 52% yield (25.2 mg, 0.102 mmol) as a light yellow solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.21. ^1H NMR (400 MHz, CDCl_3) δ 8.22 (d, $J = 8.7$ Hz, 2H), 8.08 – 7.99 (m, 2H), 7.64 (t, $J = 7.4$ Hz, 1H), 7.53 (t, $J = 7.7$ Hz, 2H), 7.46 (d, $J = 8.6$ Hz, 2H), 4.44 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 196.0, 147.1, 142.0, 136.2,

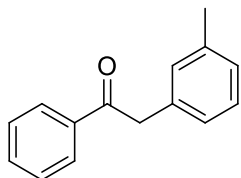
133.8, 130.7, 128.9, 128.5, 123.8, 45.0.

2-(3-acetylphenyl)-1-phenylethanone (3am) ^[16]



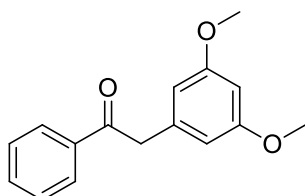
Following the general procedure A, the product **3am** was obtained in 50% yield (23.8 mg, 0.10 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.19. ¹H NMR (400 MHz, CDCl₃) δ 8.09 – 8.01 (m, 2H), 7.88 (d, *J* = 6.6 Hz, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.55 – 7.42 (m, 4H), 4.38 (s, 2H), 2.62 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 198.0, 197.0, 137.5, 136.4, 135.1, 134.4, 133.4, 129.4, 128.9, 128.8, 128.5, 127.1, 45.1, 26.7.

1-phenyl-2-(m-tolyl)ethanone (3an) ^[16]



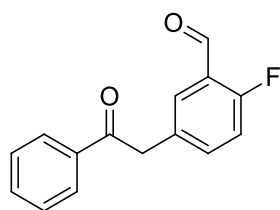
Following the general procedure A, the product **3an** was obtained in 53% yield (22.4 mg, 0.10 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 100:1 v/v). RF (Petroleum ether/EtOAc 100:1): 0.20. ¹H NMR (500 MHz, CDCl₃) δ 8.03 (d, *J* = 7.7 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.23 (t, *J* = 7.5 Hz, 1H), 7.13 – 7.05 (m, 3H), 4.26 (s, 2H), 2.34 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 197.8, 138.3, 136.7, 134.5, 133.2, 130.2, 128.7, 128.6, 127.7, 126.5, 45.5, 21.4.

2-(3,5-dimethoxyphenyl)-1-phenylethanone (3ao) ^[19]



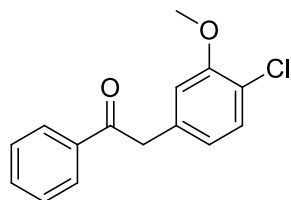
Following the general procedure A, the product **3ao** was obtained in 61% yield (31.2 mg, 0.122 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.18. ¹H NMR (400 MHz, CDCl₃) δ 8.06 – 7.98 (m, 2H), 7.62 – 7.52 (m, 1H), 7.52 – 7.43 (m, 2H), 6.45 (d, *J* = 2.2 Hz, 2H), 6.38 (t, *J* = 2.2 Hz, 1H), 4.23 (s, 2H), 3.78 (s, 6H). ¹³C NMR (101 MHz, CDCl₃) δ 197.4, 161.0, 136.7, 136.6, 133.2, 128.7, 128.6, 107.5, 99.0, 55.3, 45.8.

2-fluoro-5-(2-oxo-2-phenylethyl)benzaldehyde (**3ap**)



Following the general procedure A, the product **3ap** was obtained in 43% yield (21.0 mg, 0.088 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.22. Mp 107-108 °C. ¹H NMR (500 MHz, CDCl₃) δ 10.35 (s, 1H), 8.01 (d, *J* = 7.8 Hz, 2H), 7.75 (d, *J* = 6.4 Hz, 1H), 7.60 (t, *J* = 7.2 Hz, 1H), 7.55 – 7.46 (m, 3H), 7.16 (t, *J* = 9.3 Hz, 1H), 4.33 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 196.6, 187.1 (d, *J* = 6.4 Hz), 163.9 (d, *J* = 258.4 Hz), 137.7 (d, *J* = 9.1 Hz), 136.2, 133.6, 131.2 (d, *J* = 3.7 Hz), 129.6 (d, *J* = 1.9 Hz), 128.9, 128.4, 124.0 (d, *J* = 8.4 Hz), 116.8 (d, *J* = 20.9 Hz), 44.1. ESI-MS: calculated C₁₅H₁₂FO₂ [M+H]⁺ 243.0816; Found 243.0787. ¹⁹F NMR (471 MHz, CDCl₃) δ -124.6.

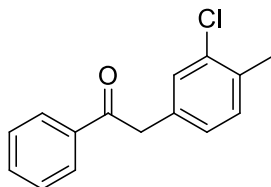
2-(4-chloro-3-methoxyphenyl)-1-phenylethanone (**3aq**)



Following the general procedure A, the product **3aq** was obtained in 70% yield (36.6 mg, 0.14 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.21. Mp 93-94 °C. ¹H NMR (500 MHz, CDCl₃) δ 7.92 (d, *J* = 7.5 Hz, 2H), 7.49 (t, *J* = 7.2 Hz, 1H), 7.39 (t, *J* = 7.4 Hz, 2H), 7.22 (d, *J* = 7.9 Hz, 1H),

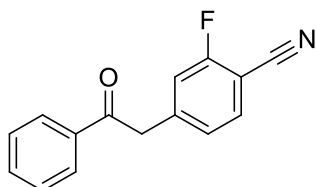
6.76 (s, 1H), 6.72 (d, $J = 7.9$ Hz, 1H), 4.18 (s, 2H), 3.79 (s, 3H). ^{13}C NMR (126 MHz, CDCl_3) δ 197.2, 155.0, 136.4, 134.5, 133.4, 130.2, 128.8, 128.6, 122.4, 121.2, 113.3, 56.1, 45.2. ESI-MS: calculated $\text{C}_{15}\text{H}_{14}\text{ClO}_2$ $[\text{M}+\text{H}]^+$ 261.0677; Found 261.0666.

2-(3-chloro-4-methylphenyl)-1-phenylethanone (3ar)



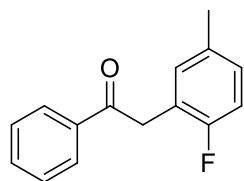
Following the general procedure A, the product **3ar** was obtained in 78% yield (38.3 mg, 0.15 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.23. Mp 61-62 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.04 – 8.01 (m, 2H), 7.59 (t, $J = 7.4$ Hz, 1H), 7.49 (t, $J = 7.6$ Hz, 2H), 7.28 (s, 1H), 7.20 (d, $J = 7.7$ Hz, 1H), 7.08 (dd, $J = 7.7, 1.3$ Hz, 1H), 4.25 (s, 2H), 2.37 (s, 3H). ^{13}C NMR (126 MHz, CDCl_3) δ 197.1, 136.4, 134.6, 134.5, 133.6, 133.4, 131.1, 130.0, 128.7, 128.6, 127.8, 44.6, 19.7. ESI-MS: calculated $\text{C}_{15}\text{H}_{14}\text{ClO}$ $[\text{M}+\text{H}]^+$ 245.0728; Found 245.0726.

2-fluoro-4-(2-oxo-2-phenylethyl)benzonitrile (3as)



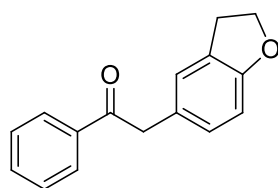
Following the general procedure A, the product **3as** was obtained in 32% yield (15.2 mg, 0.06 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.24. Mp 91-92 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.02 – 8.00 (m, 2H), 7.66 - 7.59 (m, 2H), 7.53 (t, $J = 7.7$ Hz, 2H), 7.19 - 7.16 (m, 2H), 4.39 (s, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 195.5, 163.1 (d, $J = 259.2$ Hz), 143.0 (d, $J = 8.1$ Hz), 136.0, 133.9, 133.4, 129.0, 128.4, 126.4 (d, $J = 3.4$ Hz), 117.9 (d, $J = 19.9$ Hz), 113.9, 100.1 (d, $J = 15.5$ Hz), 45.0 (d, $J = 1.5$ Hz). ESI-MS: calculated $\text{C}_{15}\text{H}_{11}\text{FNO}$ $[\text{M}+\text{H}]^+$ 240.0819; Found 240.0839. ^{19}F NMR (471 MHz, CDCl_3) δ -106.4.

2-(2-fluoro-5-methylphenyl)-1-phenylethanone (**3at**) ^[16]



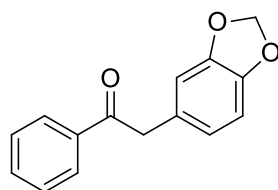
Following the general procedure A, the product **3at** was obtained in 21% yield (9.5 mg, 0.042 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.22. ¹H NMR (500 MHz, CDCl₃) δ 8.04 (d, *J* = 7.6 Hz, 2H), 7.57 (t, *J* = 7.1 Hz, 1H), 7.48 (t, *J* = 7.3 Hz, 2H), 7.03 (d, *J* = 6.4 Hz, 2H), 6.96 (t, *J* = 8.8 Hz, 1H), 4.28 (s, 2H), 2.29 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 196.6, 159.1 (d, *J* = 242.7 Hz), 136.4, 133.6 (d, *J* = 3.5 Hz), 133.3, 132.0 (d, *J* = 4.1 Hz), 129.3 (d, *J* = 8.0 Hz), 128.7, 128.5, 121.3 (d, *J* = 16.2 Hz), 115.0 (d, *J* = 22.0 Hz), 38.6, 20.7.

2-(2,3-dihydrobenzofuran-5-yl)-1-phenylethanone (**3au**) ^[20]



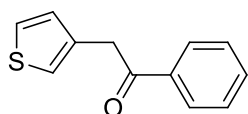
Following the general procedure A, the product **3au** was obtained in 62% yield (29.6 mg, 0.124 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.28. ¹H NMR (500 MHz, CDCl₃) δ 8.01 (d, *J* = 7.4 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.45 (t, *J* = 7.4 Hz, 2H), 7.09 (s, 1H), 6.98 (d, *J* = 8.0 Hz, 1H), 6.73 (d, *J* = 8.0 Hz, 1H), 4.53 (t, *J* = 8.6 Hz, 2H), 4.20 (s, 2H), 3.17 (t, *J* = 8.6 Hz, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 198.2, 159.1, 136.7, 133.1, 129.1, 128.6, 128.6, 127.6, 126.3, 126.0, 109.3, 71.3, 44.9, 29.7.

2-(benzo[d][1,3]dioxol-5-yl)-1-phenylethanone (**3av**) ^[20]



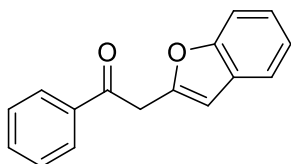
Following the general procedure A, the product **3av** was obtained in 62% yield (40.4 mg, 0.124 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.23. ¹H NMR (500 MHz, CDCl₃) δ 8.04 – 7.97 (m, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 6.76 (d, *J* = 7.9 Hz, 2H), 6.71 (dd, *J* = 7.9, 1.5 Hz, 1H), 5.93 (s, 2H), 4.20 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.7, 147.9, 146.6, 136.5, 133.2, 128.7, 128.6, 128.1, 122.6, 109.9, 108.5, 101.0, 45.1.

1-phenyl-2-(thiophen-3-yl)ethanone (**3aw**) ^[20]



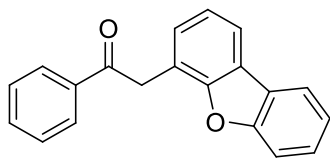
Following the general procedure A, the product **3aw** was obtained in 48% yield (19.5 mg, 0.098 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.25. ¹H NMR (400 MHz, CDCl₃) δ 8.03 (d, *J* = 7.3 Hz, 2H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 2H), 7.32 (dd, *J* = 4.9, 3.0 Hz, 1H), 7.18 – 7.13 (m, 1H), 7.05 (d, *J* = 4.8 Hz, 1H), 4.33 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.1, 136.5, 134.2, 133.3, 128.7, 128.7, 128.6, 125.8, 122.9, 40.1.

2-(benzofuran-2-yl)-1-phenylethanone (**3ax**)



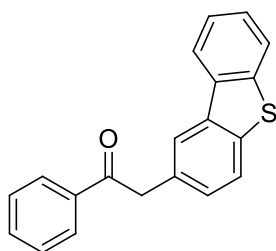
Following the general procedure A, the product **3ax** was obtained in 71% yield (33.7 mg, 0.14 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 64:1 v/v). RF (Petroleum ether/EtOAc 64:1): 0.22. Mp 86-87 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.07 (dd, *J* = 5.2, 3.3 Hz, 2H), 7.67 – 7.58 (m, 1H), 7.54 - 7.50 (m, 3H), 7.49 – 7.44 (m, 1H), 7.28 – 7.18 (m, 2H), 6.67 (s, 1H), 4.48 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 194.5, 155.0, 151.4, 136.1, 133.6, 128.8, 128.7, 123.8, 122.7, 120.7, 111.0, 105.4, 38.9. ESI-MS: calculated C₁₆H₁₃O₂ [M+H]⁺ 237.0910; Found 237.0903.

2-(dibenzo[b,d]furan-4-yl)-1-phenylethanone (3ay)



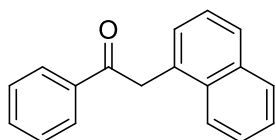
Following the general procedure A, the product **3ay** was obtained in 45% yield (26.1 mg, 0.094 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.19. Mp 95-96 °C. ¹H NMR (500 MHz, CDCl₃) δ 8.02 (d, *J* = 7.4 Hz, 2H), 7.85 (d, *J* = 7.4 Hz, 1H), 7.77 (d, *J* = 7.2 Hz, 1H), 7.47 (d, *J* = 7.6 Hz, 2H), 7.39 - 7.34 (m, 3H), 7.26 - 7.20 (m, 3H), 4.56 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 196.6, 156.1, 154.7, 136.6, 133.3, 128.7, 128.6, 128.4, 127.1, 124.6, 124.2, 123.0, 122.8, 120.8, 119.6, 118.8, 111.7, 39.4. ESI-MS: calculated C₂₀H₁₅O₂ [M+H]⁺ 287.1067; Found 287.1059.

2-(dibenzo[b,d]thiophen-2-yl)-1-phenylethanone (3az)



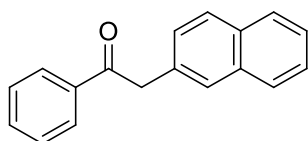
Following the general procedure A, the product **3az** was obtained in 75% yield (45.4 mg, 0.15 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.21. Mp 96-97 °C. ¹H NMR (500 MHz, CDCl₃) δ 8.05 - 7.99 (m, 1H), 7.96 - 7.94 (m, 3H), 7.79 - 7.64 (m, 2H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.40 - 7.29 (m, 4H), 7.25 (d, *J* = 8.1 Hz, 1H), 4.34 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.7, 139.8, 138.1, 136.6, 136.0, 135.3, 133.3, 130.9, 128.7, 128.7, 128.3, 126.8, 124.4, 123.0, 122.9, 122.5, 121.7, 45.5. ESI-MS: calculated C₂₀H₁₅OS [M+H]⁺ 303.0838; Found 303.0839.

2-(naphthalen-1-yl)-1-phenylethanone (4aa)^[7]



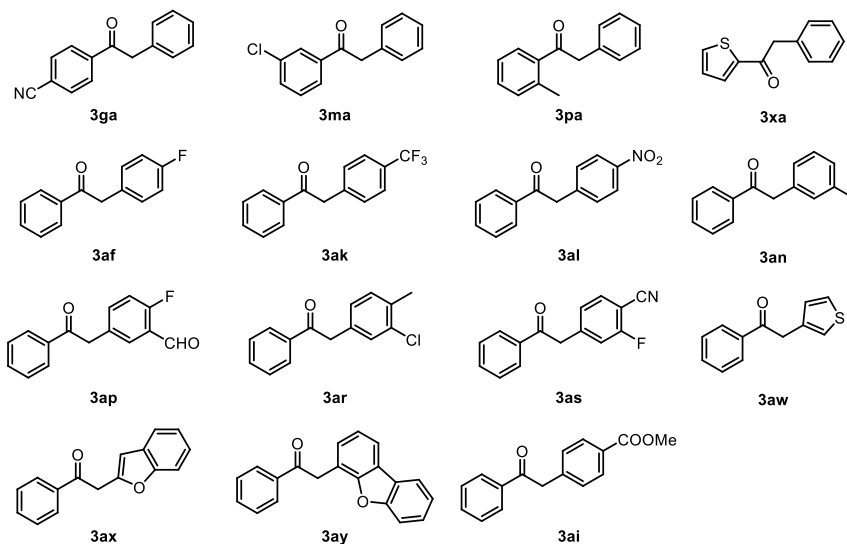
Following the general procedure A, the product **4aa** was obtained in 40% yield (19.9 mg, 0.080 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.21. ¹H NMR (400 MHz, CDCl₃) δ 8.14 – 8.08 (m, 2H), 7.93 – 7.87 (m, 2H), 7.82 (d, *J* = 8.2 Hz, 1H), 7.63 – 7.59 (m, 1H), 7.56 – 7.48 (m, 4H), 7.48 – 7.42 (m, 1H), 7.39 (d, *J* = 6.7 Hz, 1H), 4.77 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.7, 136.7, 133.9, 133.3, 132.3, 131.4, 128.8, 128.7, 128.5, 128.0, 127.9, 126.3, 125.8, 125.5, 123.9, 43.1.

2-(naphthalen-2-yl)-1-phenylethanone (4ab) ^[16]



Following the general procedure A, the product **4ab** was obtained in 67% yield (33.2 mg, 0.134 mmol) as a white solid after chromatography on silica gel (eluent = petroleum ether/EtOAc 32:1 v/v). RF (Petroleum ether/EtOAc 32:1): 0.20. ¹H NMR (400 MHz, CDCl₃) δ 8.12 – 8.05 (m, 2H), 7.84 (d, *J* = 8.8 Hz, 1H), 7.82 (d, *J* = 6.9 Hz, 1H), 7.76 (s, 1H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.53 – 7.46 (m, 4H), 7.44 (dd, *J* = 8.4, 1.6 Hz, 1H), 4.48 (s, 2H). ¹³C NMR (126 MHz, CDCl₃) δ 197.7, 136.6, 133.6, 133.3, 132.4, 132.2, 128.7, 128.7, 128.4, 128.1, 127.7, 127.7, 127.6, 126.2, 125.8, 45.7.

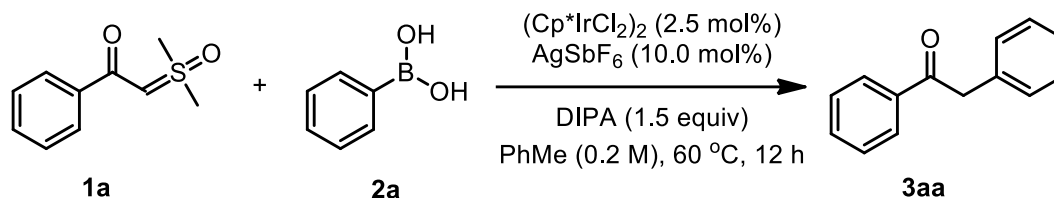
Note: In order to verify the reliability and repeatability of the product yield in the article, we selectively repeated experiments on some substrates. The specific reaction results are shown in the following table:



Number	Yield (original)	Yield (repeat)	Yield (average)
3ga	37%	38%	37%
3ma	62%	60%	61%
3pa	73%	68%	70%
3xa	66%	63%	64%
3af	88%	85%	86%
3ak	46%	49%	47%
3al	51%	54%	52%
3an	50%	57%	53%
3ap	44%	43%	43%
3ar	75%	81%	78%
3as	30%	34%	32%
3aw	49%	47%	48%
3ax	70%	73%	71%
3ay	47%	44%	45%
3ai	50%	49%	49%

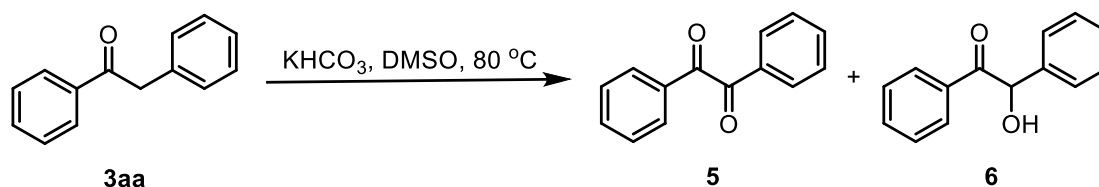
4. Synthetic application of the product **3aa**

4.1 Gram Scale Synthesis



In an oven-dried Schlenk tube under air, a mixture of the substrates **1a** (3 mmol, 1.0 equiv), boronic acid **2a** (4.5 mmol, 1.5 equiv), $(\text{Cp}^*\text{IrCl}_2)_2$ (2.5 mol%), AgSbF_6 (10.0 mol%), DIPA (1.5 equiv) and PhMe (0.2 M) was stirred at 60 °C for 12 h. Then the reaction mixture was then diluted with EA (30.0 mL) and washed with H_2O . The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na_2SO_4 . The pure product was purified by flash column chromatography on silica with an appropriate solvent to afford the pure product (petroleum ether : ethyl acetate = 100:1) to give **3aa** (0.4 g, 68%).

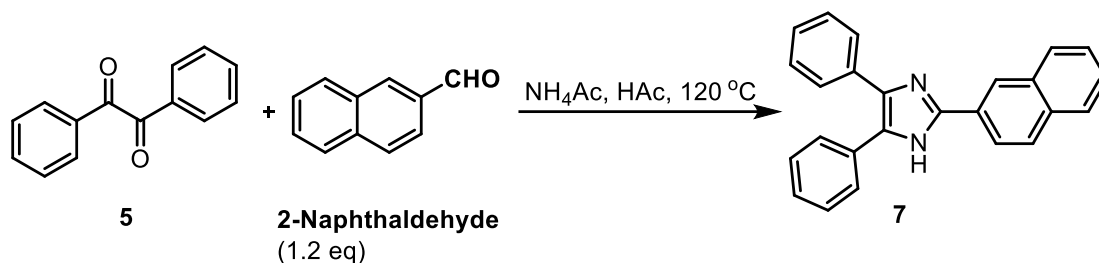
4.2 Synthesis of benzil (**5**) and benzoin (**6**)



In an oven-dried Schlenk tube under air, a mixture of the substrates **3aa** (0.5 mmol, 1.0 equiv), KHCO_3 (25.0 mol%), DMSO (0.05M) was stirred at 80 °C overnight. Then the reaction mixture was then diluted with EA (10.0 mL) and washed with H_2O . The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na_2SO_4 . The pure product was purified by flash column chromatography on silica with an appropriate solvent to afford the pure product (petroleum ether : ethyl acetate = 32:1-8:1) to give **5** (78.7 mg, 75%) and **6** (19.0 mg, 18%). Compound **5**, light yellow solid. ^1H NMR (400 MHz, CDCl_3) δ 7.95 – 7.86 (m, 2H), 7.59 (t, J = 7.4 Hz, 1H), 7.44 (t, J = 7.8 Hz, 2H). ^{13}C NMR (126 MHz, CDCl_3) δ 194.61, 134.92, 132.99, 129.91, 129.04. Compound **6**, white solid. ^1H NMR (400 MHz, CDCl_3) δ 7.91 (d, J = 7.4 Hz, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.38 (t, J = 7.7 Hz, 2H), 7.36 –

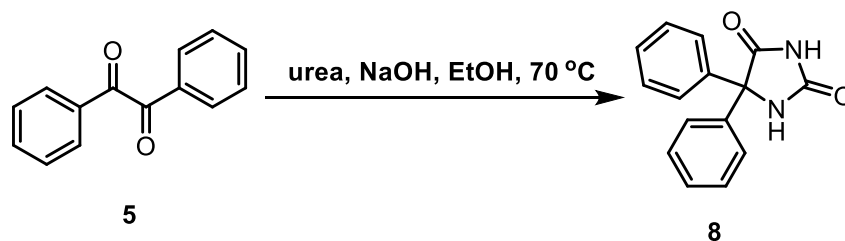
7.25 (m, 5H), 5.95 (s, 1H). ^{13}C NMR (126 MHz, CDCl_3) δ 199.0, 139.1, 134.0, 133.6, 129.2, 129.3, 128.8, 128.7, 127.9, 76.3.

4.3 Synthesis of 2-(naphthalen-2-yl)-4,5-diphenyl-1H-imidazole (7)



In an oven-dried Schlenk tube, a mixture of the substrates **5** (0.2 mmol, 1.0 equiv), 2-Naphthaldehyde (1.2 eq), NH_4Ac (3.0 eq), HAc (0.04M) was stirred at $120\text{ }^\circ\text{C}$ overnight. Then the reaction mixture was then diluted with EA (10.0 mL) and washed with saturated sodium hydrogencarbonate to adjust pH to 7-8. The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na_2SO_4 . The pure product was purified by flash column chromatography on silica with an appropriate solvent to afford the pure product (petroleum ether : ethyl acetate = 4:1-1:1) to give **7** (52.0 mg, 75%) as a white solid. ^1H NMR (400 MHz, DMSO) δ 12.87 (s, 1H), 8.63 (s, 1H), 8.27 (dd, $J = 8.6, 1.7$ Hz, 1H), 8.02 (d, $J = 8.8$ Hz, 1H), 8.00 – 7.93 (m, 2H), 7.60 (d, $J = 7.2$ Hz, 2H), 7.58 – 7.51 (m, 4H), 7.47 (t, $J = 7.4$ Hz, 2H), 7.40 (t, $J = 7.2$ Hz, 1H), 7.33 (t, $J = 7.5$ Hz, 2H), 7.25 (t, $J = 7.2$ Hz, 1H). ^{13}C NMR (101 MHz, DMSO) δ 146.0, 137.9, 135.6, 133.5, 133.2, 131.5, 129.2, 129.0, 129.0, 128.9, 128.7, 128.7, 128.6, 128.3, 128.2, 127.6, 127.2, 127.1, 126.8, 124.4, 124.0.

4.4 Synthesis of 5,5-diphenylimidazolidine-2,4-dione (phenytoin, 8)

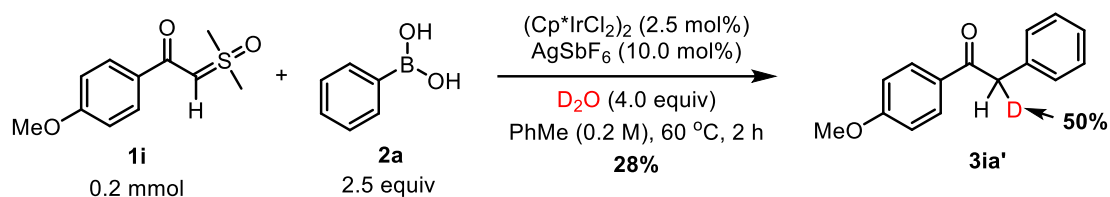


In an oven-dried Schlenk tube, a mixture of the substrates **5** (0.2 mmol, 1.0 equiv), urea (2.0 eq), 20% NaOH (0.2 mL), EtOH (0.02 M) was stirred at $70\text{ }^\circ\text{C}$ for 2 h. Then the reaction mixture

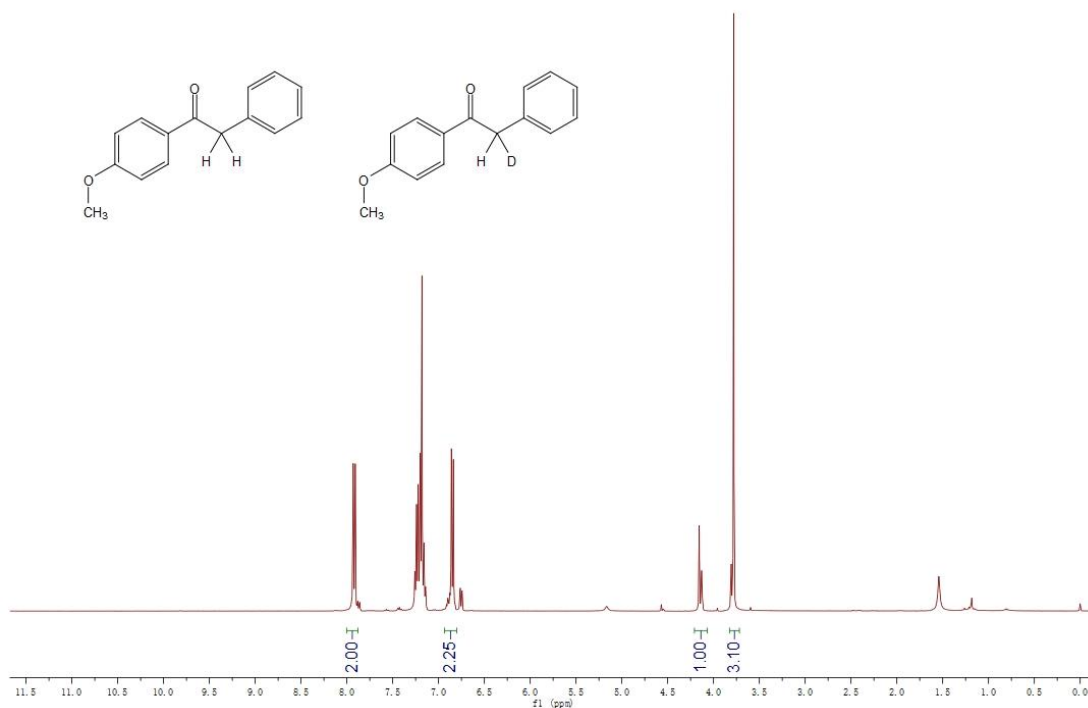
was then diluted with EA (10.0 mL) and washed with 10% hydrochloric acid to adjust pH to 5-6. The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na₂SO₄. The pure product was purified by flash column chromatography on silica with an appropriate solvent to afford the pure product (petroleum ether : ethyl acetate = 2:1-1:2) to give **8** (44.3 mg, 88%) as a white solid. ¹H NMR (500 MHz, DMSO) δ 11.08 (s, 1H), 9.31 (s, 1H), 7.40 - 7.39 (m, 4H), 7.36 - 7.35 (m, 6H). ¹³C NMR (126 MHz, DMSO) δ 175.3, 156.4, 140.4, 129.0, 128.5, 127.0, 70.7.

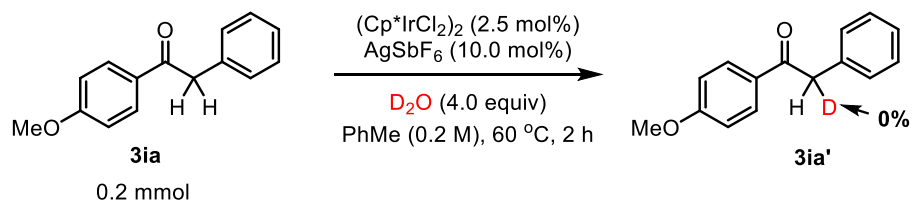
5. Mechanistic Studies

5.1 Deuterated experiment

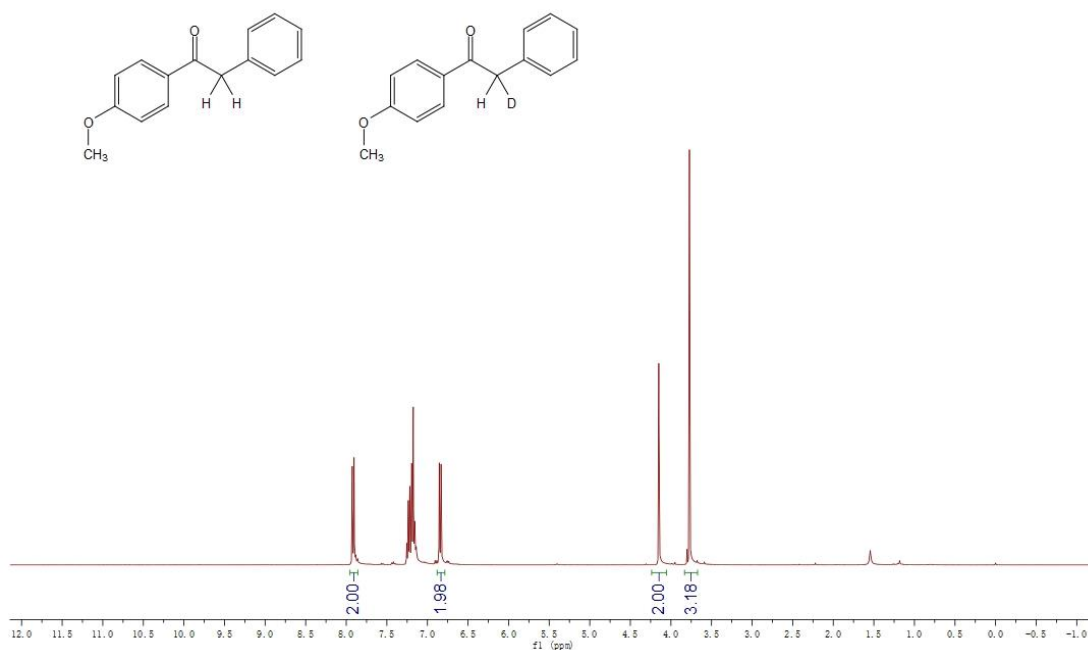


In an oven-dried Schlenk tube under air, a mixture of the substrates **1i** (0.2 mmol), boronic acid **2a** (0.5 mmol, 2.5 equiv), $(\text{Cp}^*\text{IrCl}_2)_2$ (2.5 mol%), AgSbF_6 (10.0 mol%), D_2O (0.8 mmol, 4.0 equiv) and PhMe (0.2 M) was stirred at 60 °C for 2 h. Then the reaction mixture was then diluted with EA (30.0 mL) and washed with H_2O . The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na_2SO_4 . The pure product was purified by flash column chromatography on silica with an appropriate solvent (petroleum ether : ethyl acetate = 16:1) to afford the mixture product **3ia** and **3ia'** (12.7 mg, 28%). The spectra of the products are shown in the following figure.

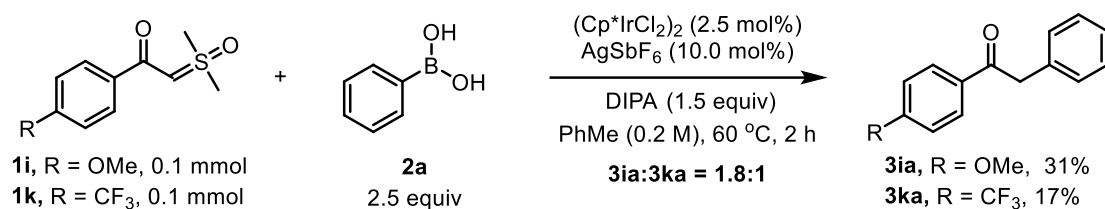




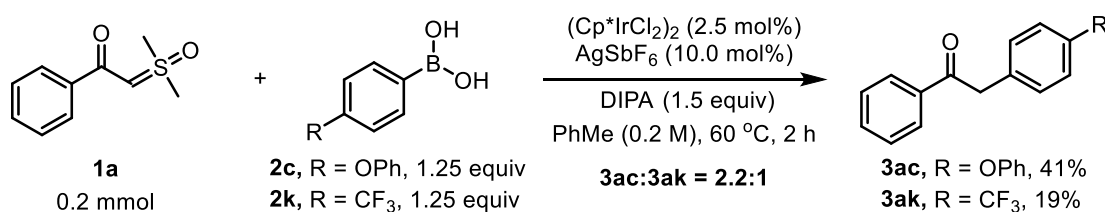
In an oven-dried Schlenk tube under air, a mixture of the product **3ia** (0.2 mmol), $(\text{Cp}^*\text{IrCl}_2)_2$ (2.5 mol%), AgSbF_6 (10.0 mol%), D_2O (0.8 mmol, 4.0 equiv) and PhMe (0.2 M) was stirred at 60 °C for 2 h. Then the reaction mixture was then diluted with EA (30.0 mL) and washed with H_2O . The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na_2SO_4 . The pure product was purified by flash column chromatography on silica with an appropriate solvent (petroleum ether : ethyl acetate = 16:1) to afford the product **3ia** (40.1 mg, 88%). The spectra of the products are shown in the following figure.



5.2 Competitive experiment

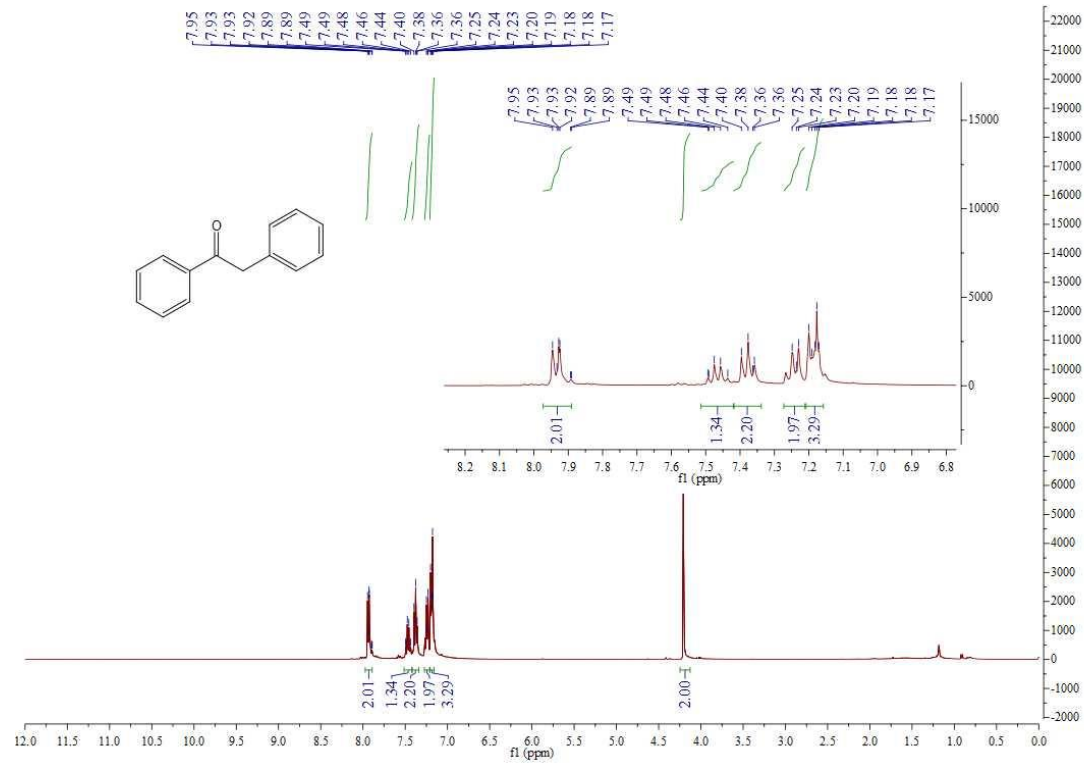


In an oven-dried Schlenk tube under air, a mixture of the substrates **1i** (0.1 mmol), **1k** (0.1 mmol), boronic acid **2a** (0.5 mmol, 2.5 equiv), (Cp*IrCl₂)₂ (2.5 mol%), AgSbF₆ (10.0 mol%), DIAP (0.3 mmol, 1.5 equiv) and PhMe (0.2 M) was stirred at 60 °C for 2 h. Then the reaction mixture was then diluted with EA (30.0 mL) and washed with H₂O. The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na₂SO₄. The pure product was purified by flash column chromatography on silica with an appropriate solvent (petroleum ether : ethyl acetate = 16:1) to afford the product **3ia** (14.2 mg, 31%) and **3ka** (9.2 mg, 17%).

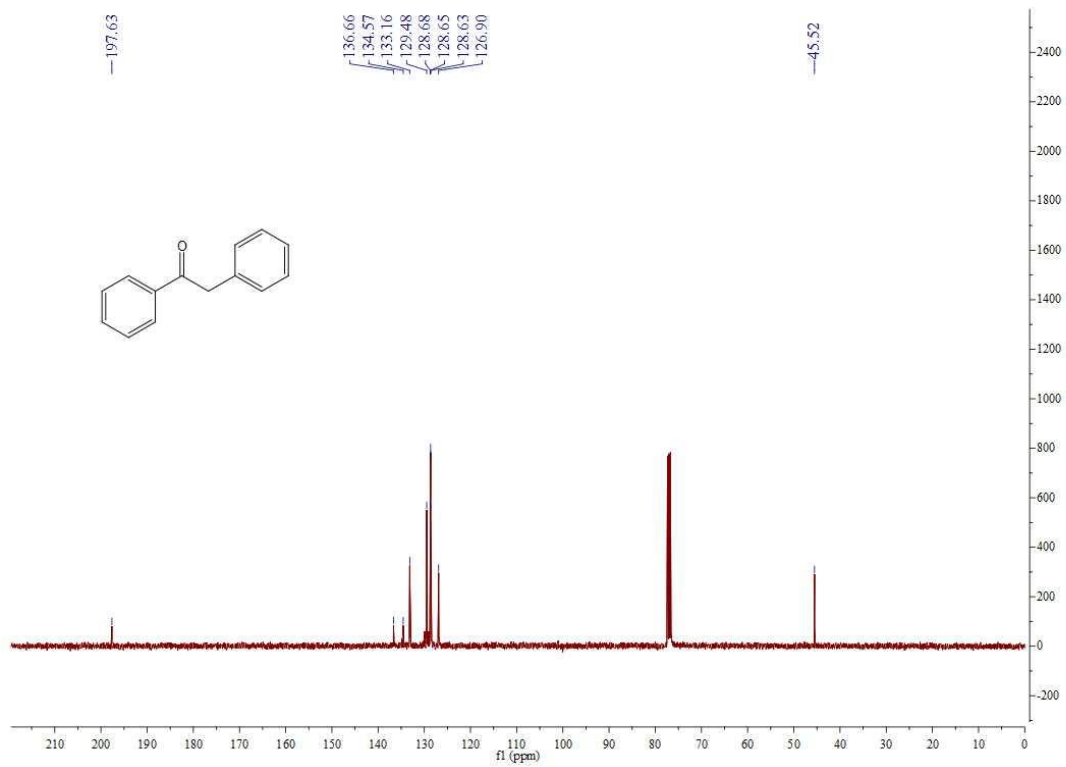


In an oven-dried Schlenk tube under air, a mixture of the substrates **1a** (0.2 mmol), boronic acid **2c** (0.25 mmol, 1.25 equiv), boronic acid **2k** (0.25 mmol, 1.25 equiv), (Cp*IrCl₂)₂ (2.5 mol%), AgSbF₆ (10.0 mol%), DIAP (0.3 mmol, 1.5 equiv) and PhMe (0.2 M) was stirred at 60 °C for 2 h. Then the reaction mixture was then diluted with EA (30.0 mL) and washed with H₂O. The aqueous phase was extracted with EA again. The organic layers were combined, washed with brine and dried over Na₂SO₄. The pure product was purified by flash column chromatography on silica with an appropriate solvent (petroleum ether : ethyl acetate = 16:1) to afford the product **3ac** (23.9 mg, 41%) and **3ak** (10.1 mg, 19%).

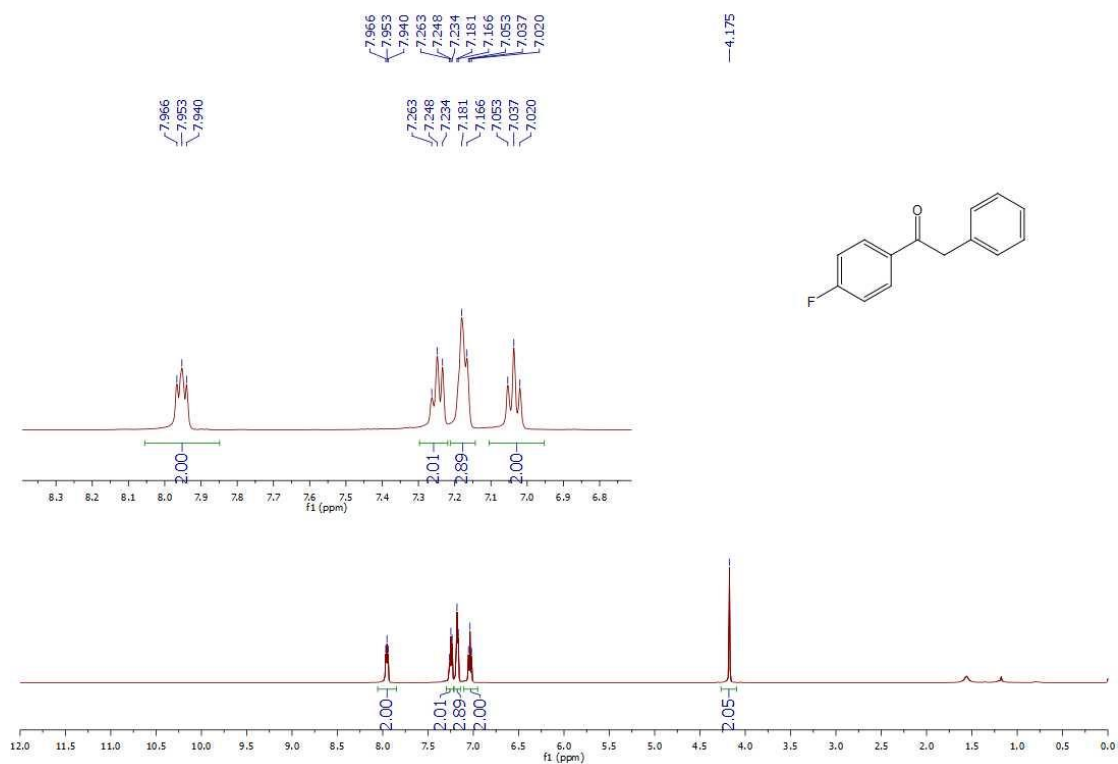
6. ^1H NMR and ^{13}C NMR spectra



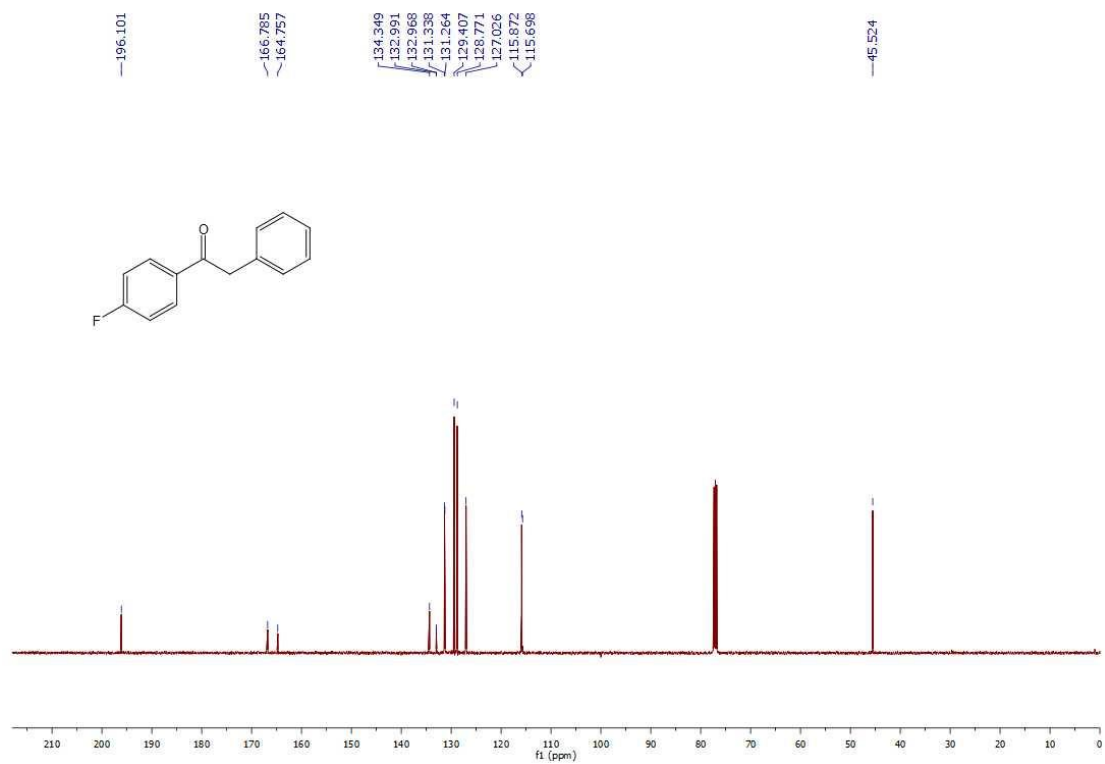
^1H NMR spectrum of **3aa**



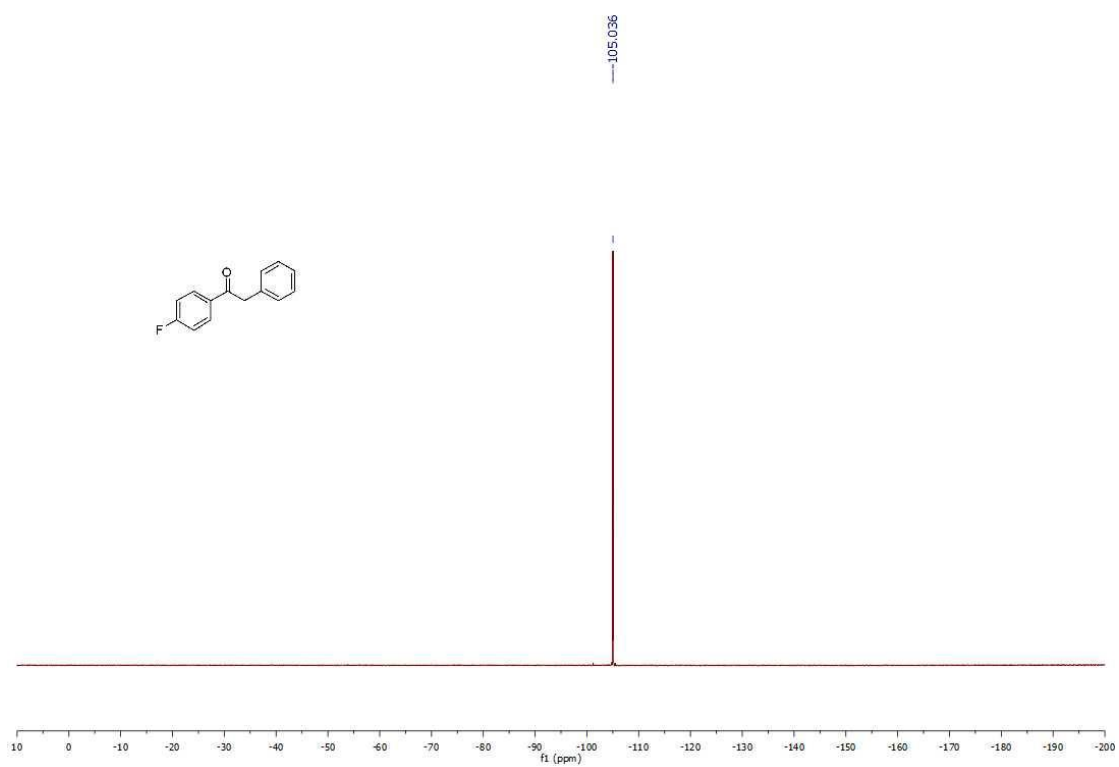
^{13}C NMR spectrum of **3aa**



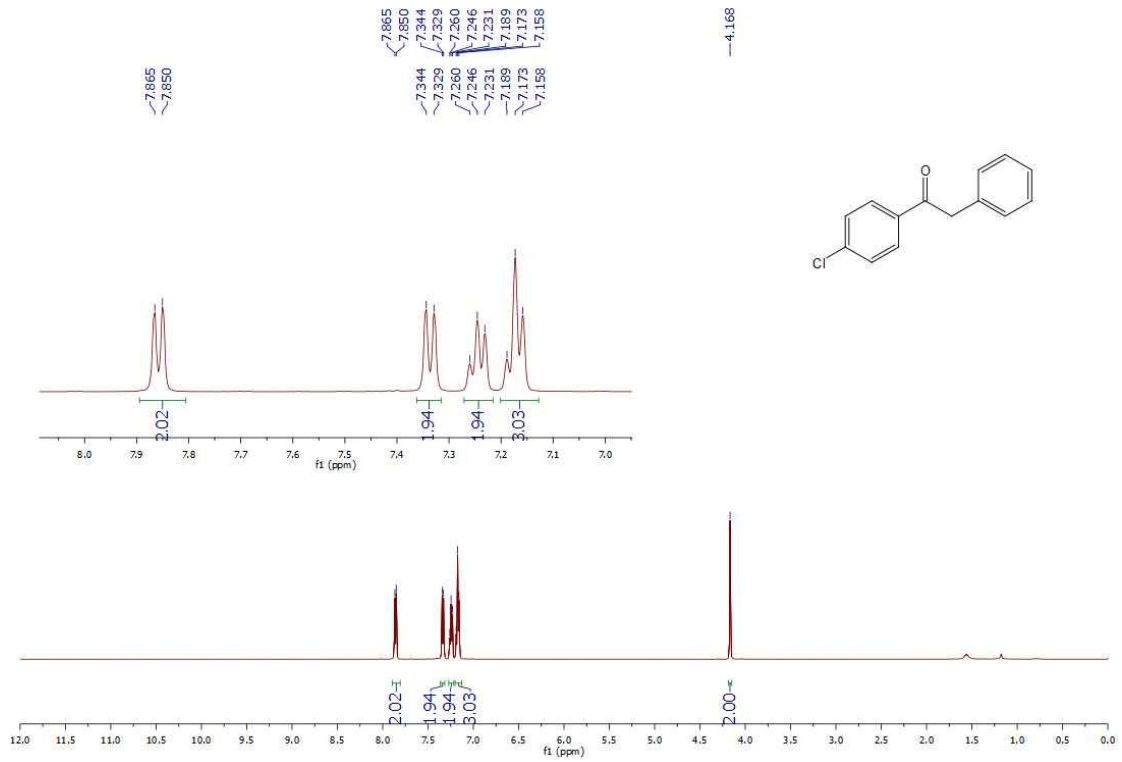
¹H NMR spectrum of **3ba**



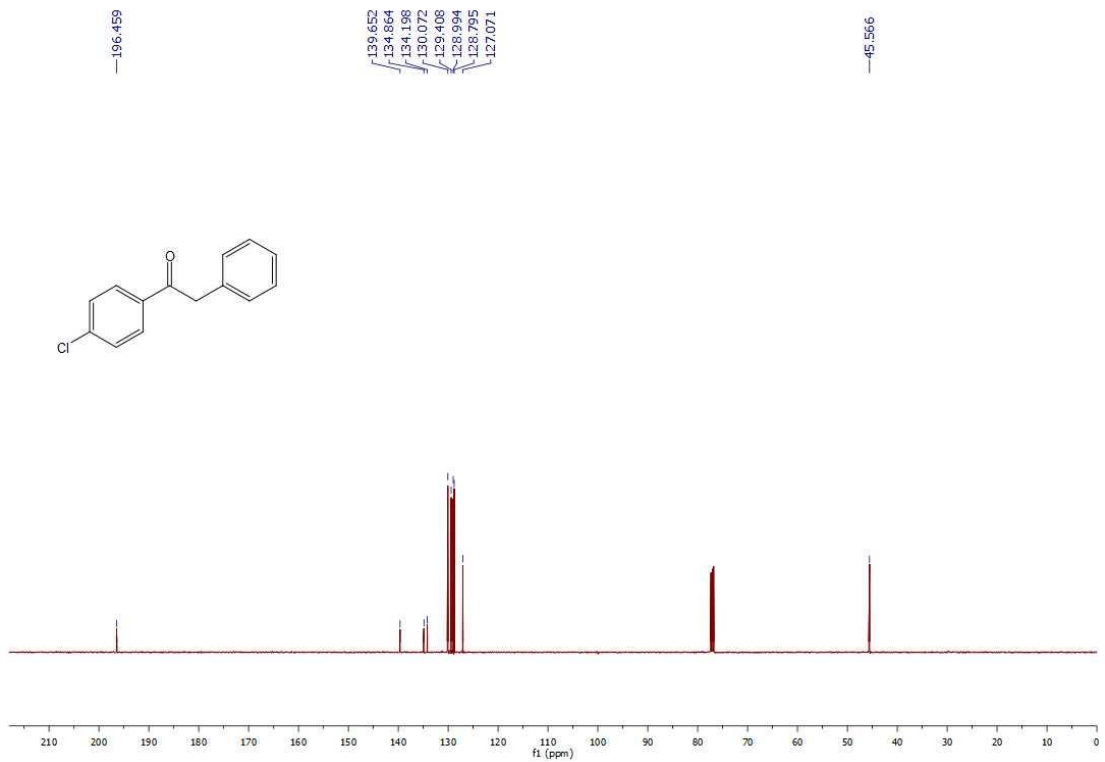
¹³C NMR spectrum of **3ba**



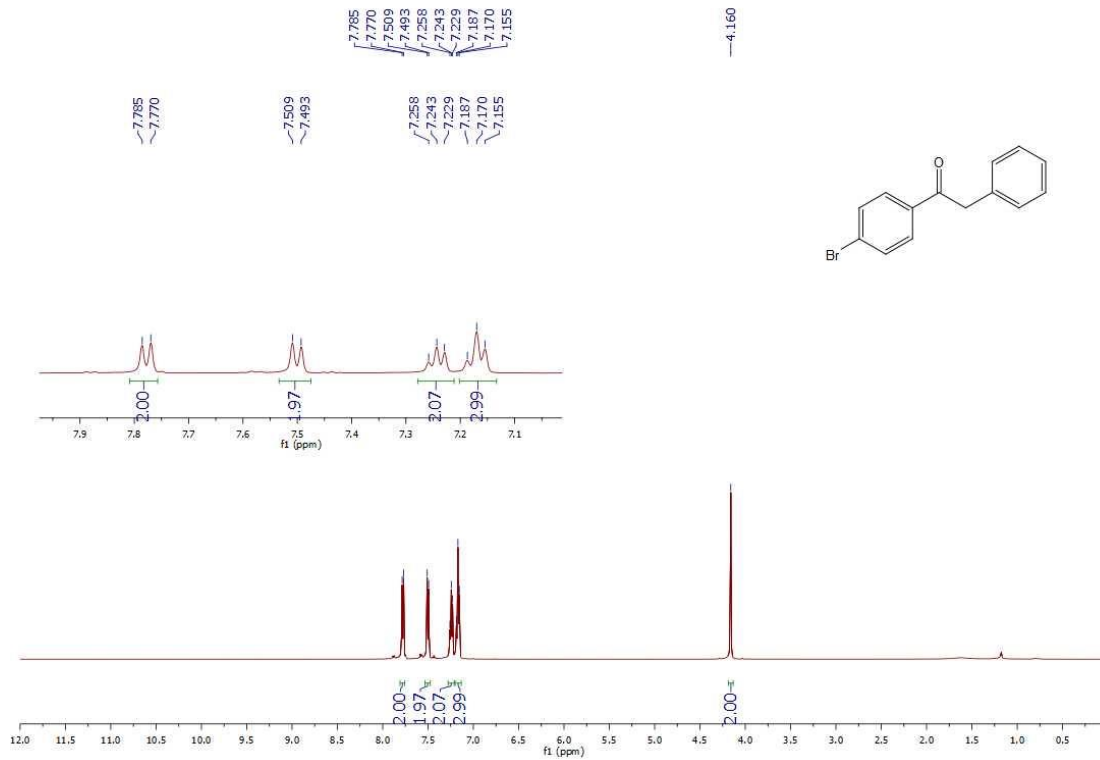
^{19}F NMR spectrum of **3ba**



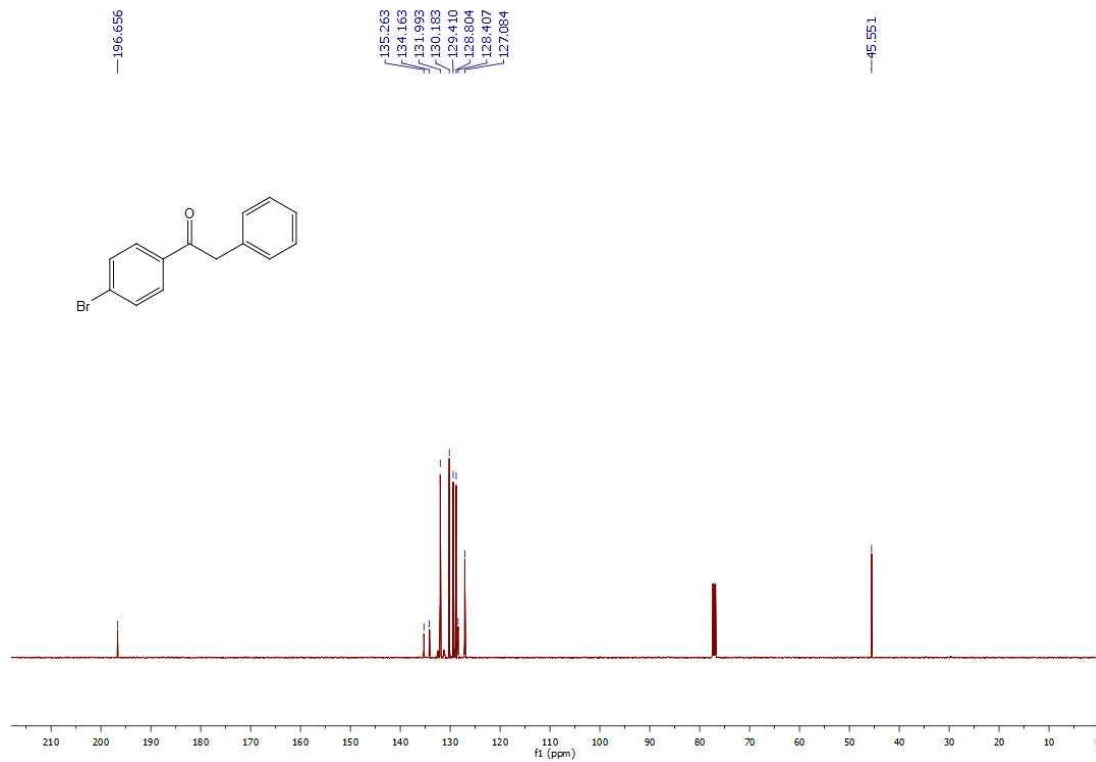
¹H NMR spectrum of 3ca



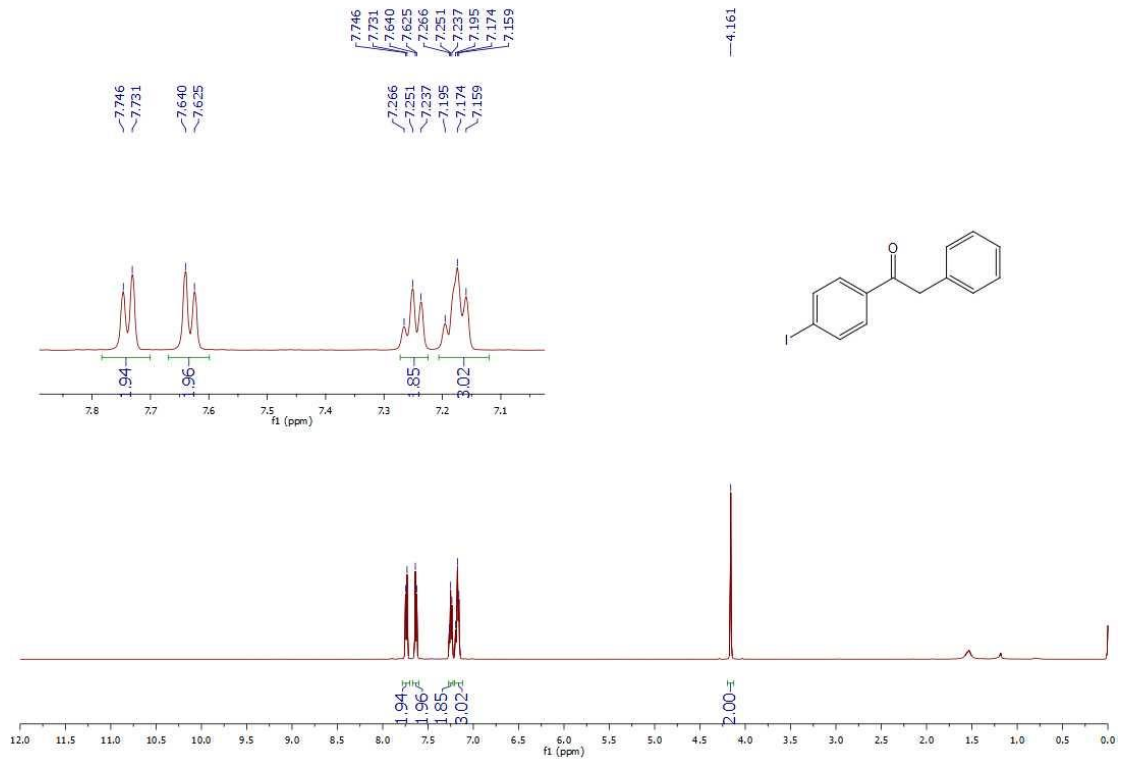
¹³C NMR spectrum of 3ca



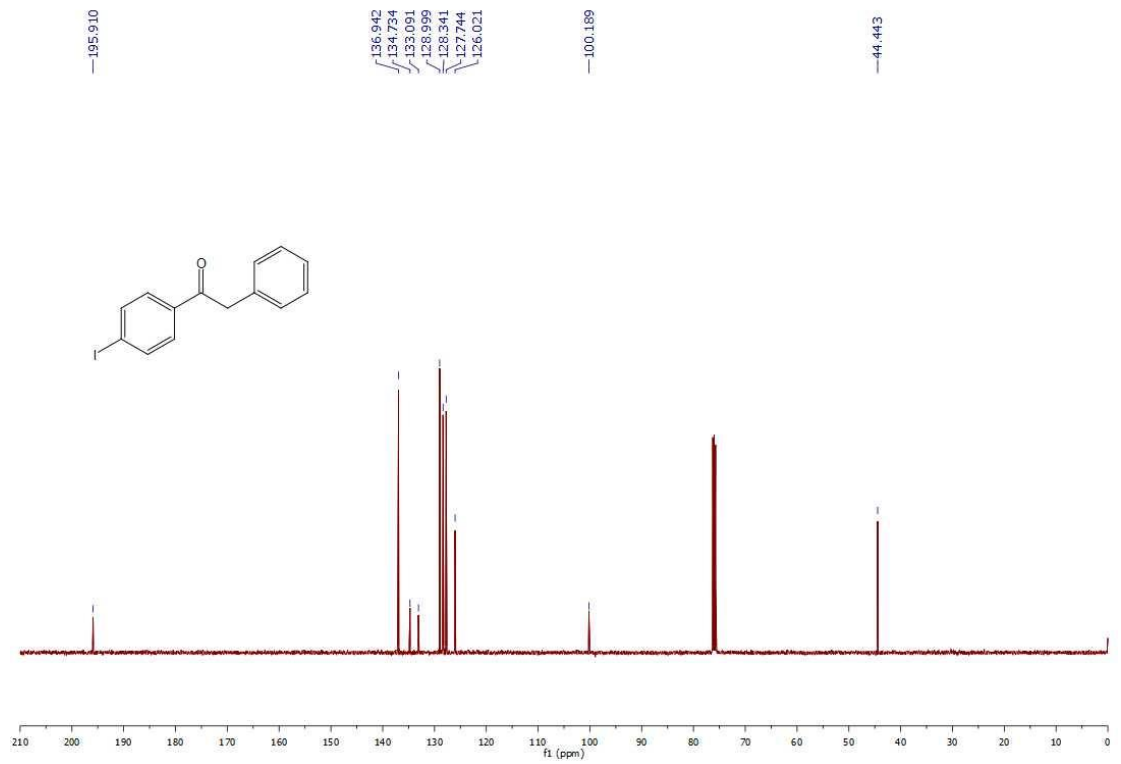
¹H NMR spectrum of 3da



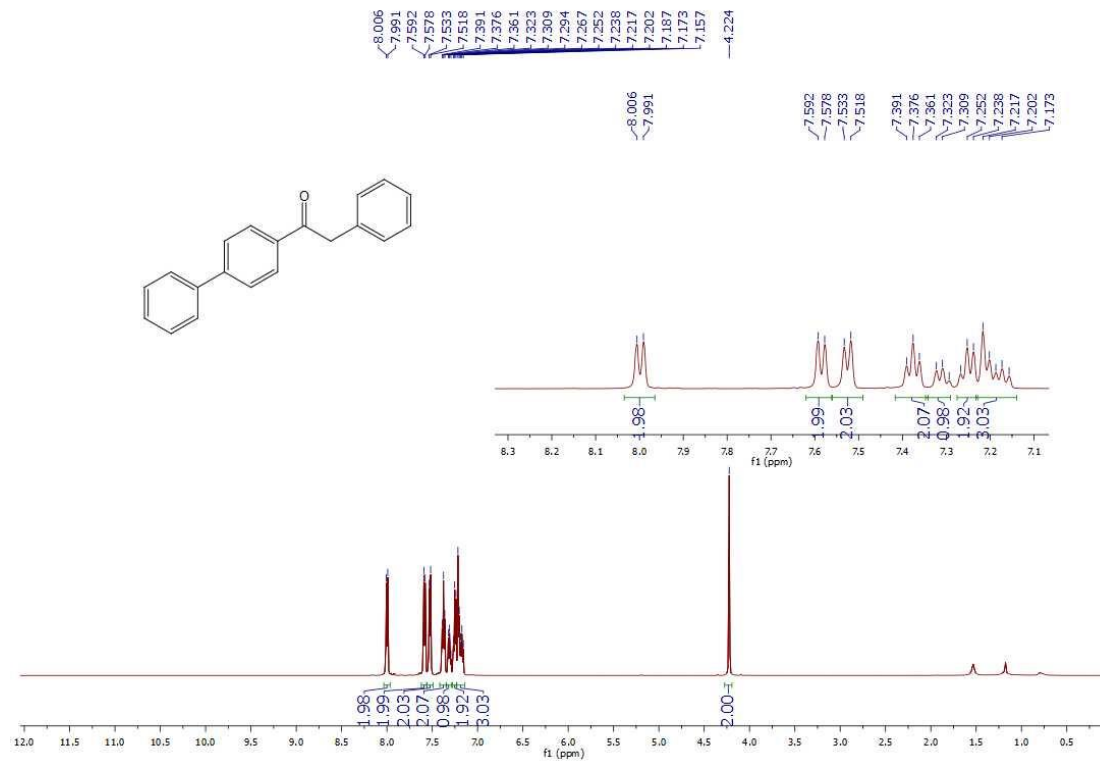
¹³C NMR spectrum of 3da



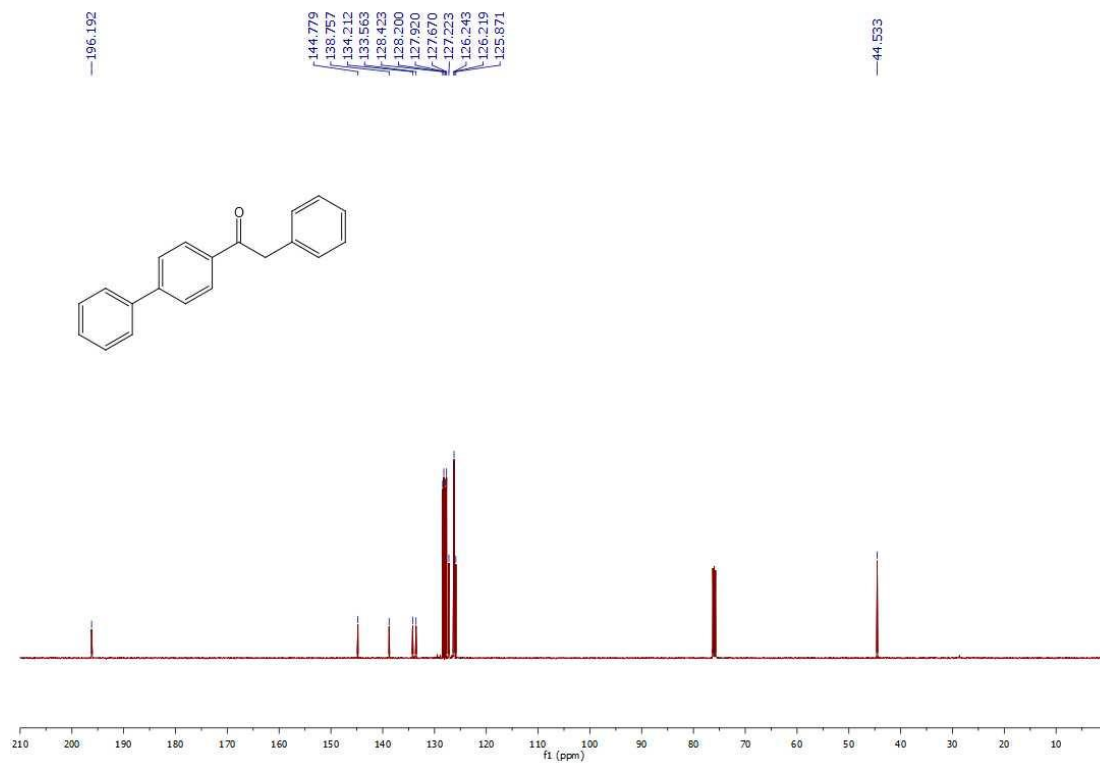
¹H NMR spectrum of 3ea



¹³C NMR spectrum of 3ea



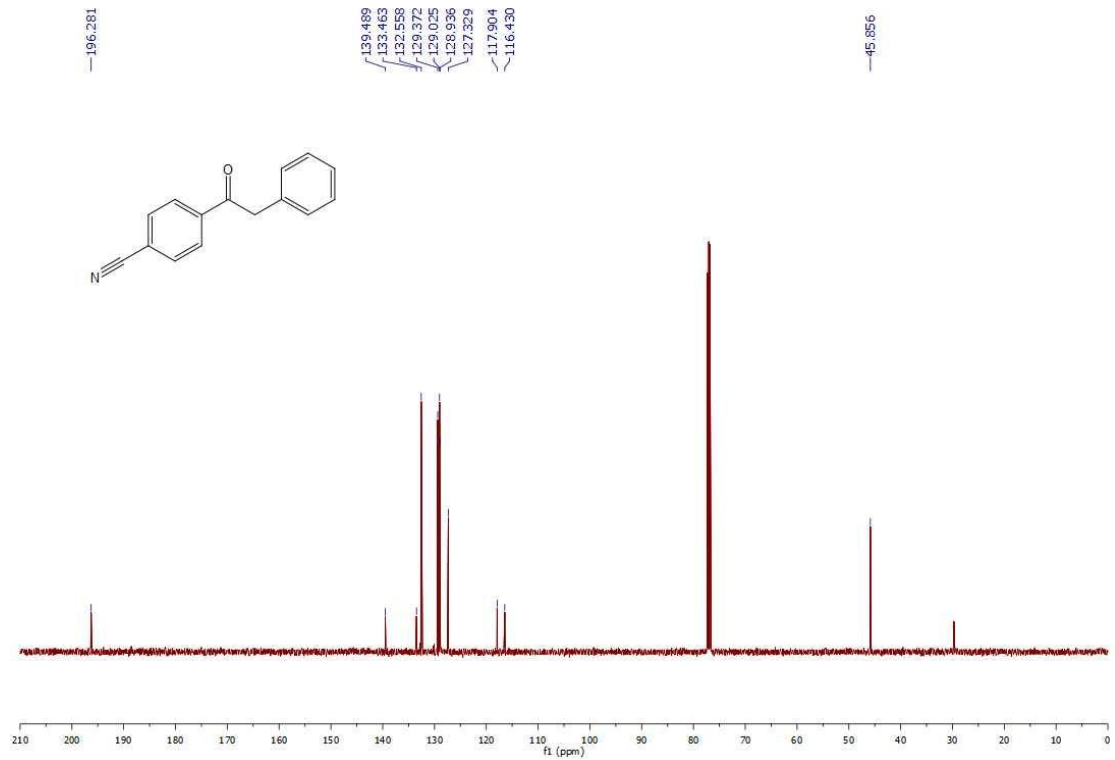
¹H NMR spectrum of 3fa



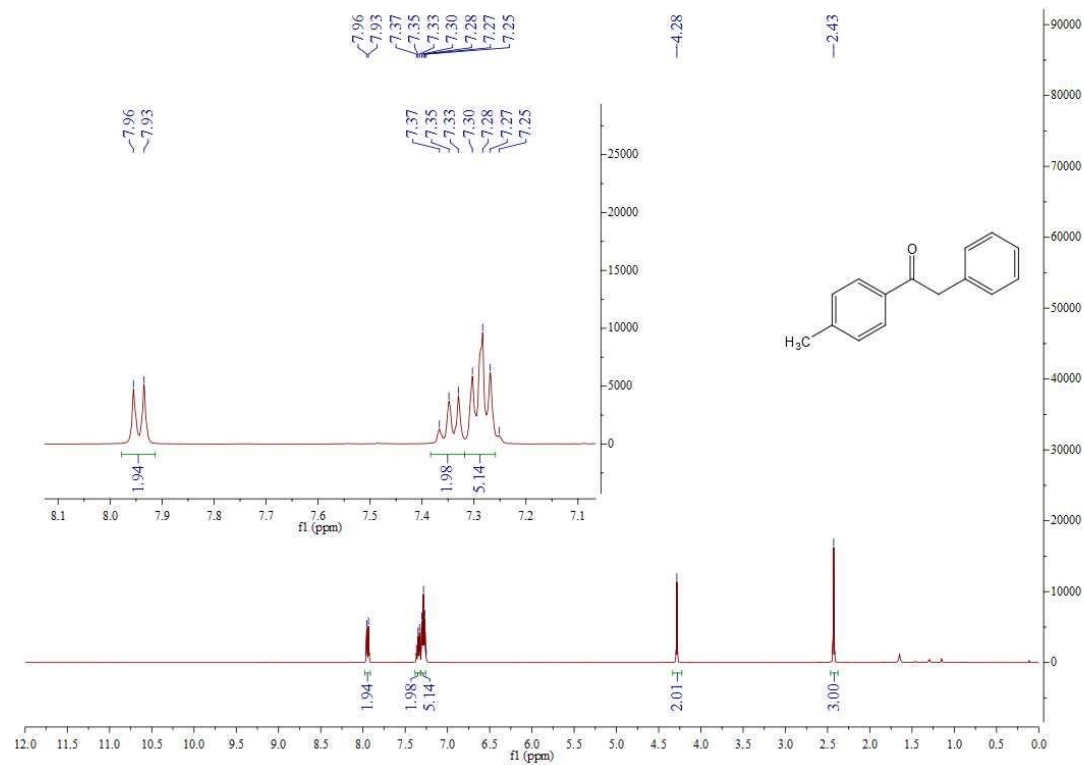
¹³C NMR spectrum of 3fa



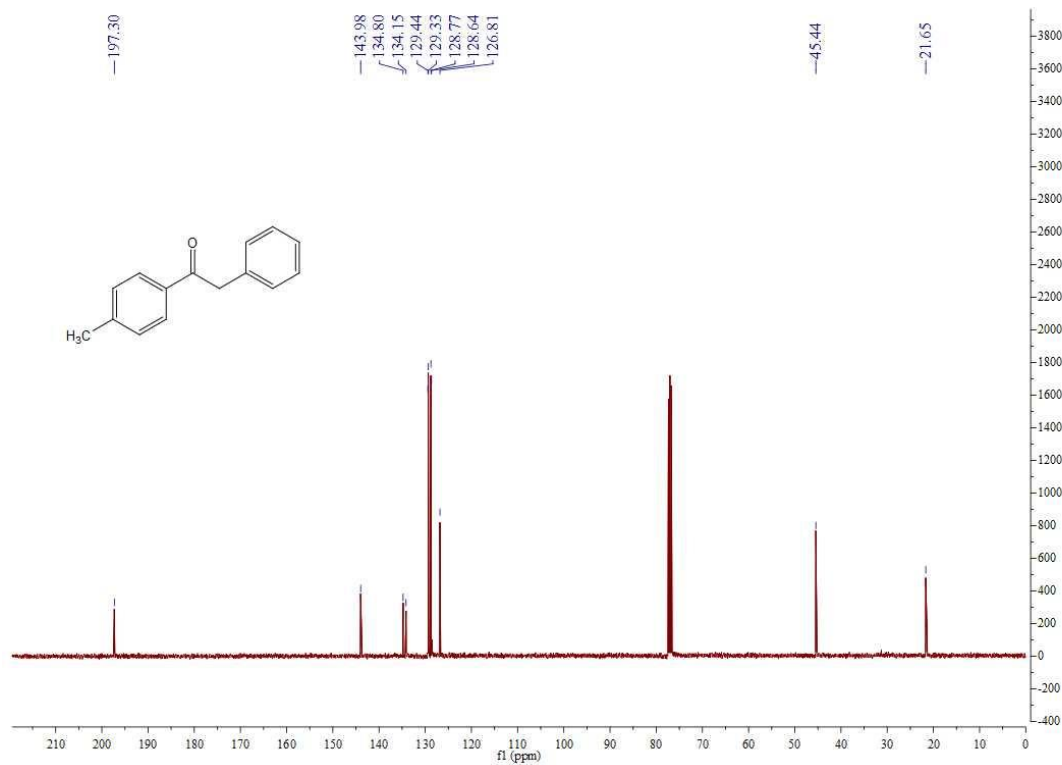
¹H NMR spectrum of 3ga



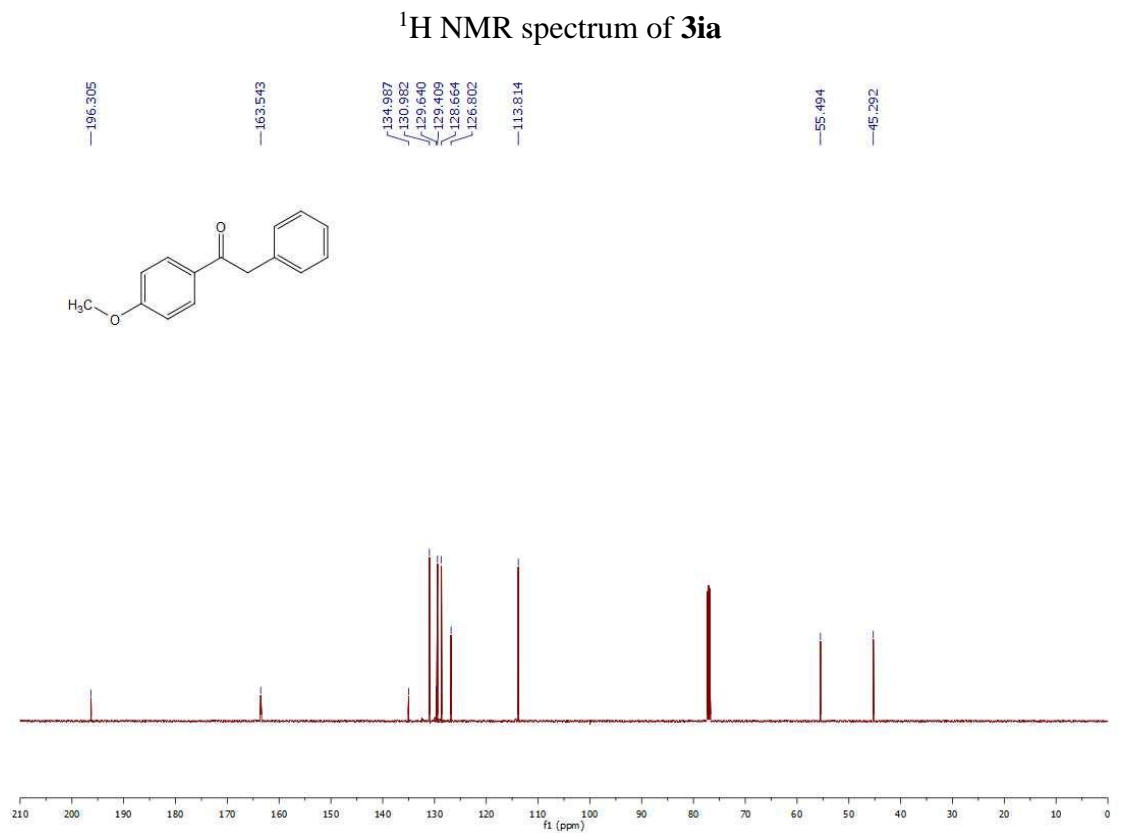
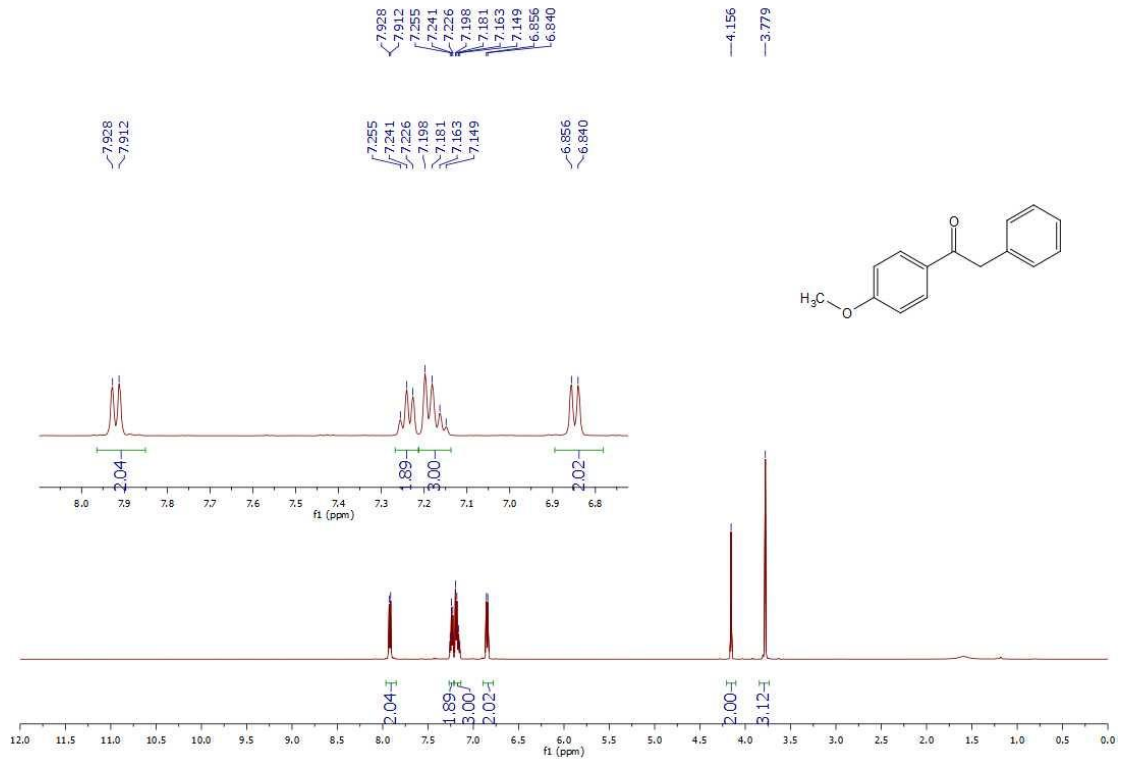
¹³C NMR spectrum of 3ga

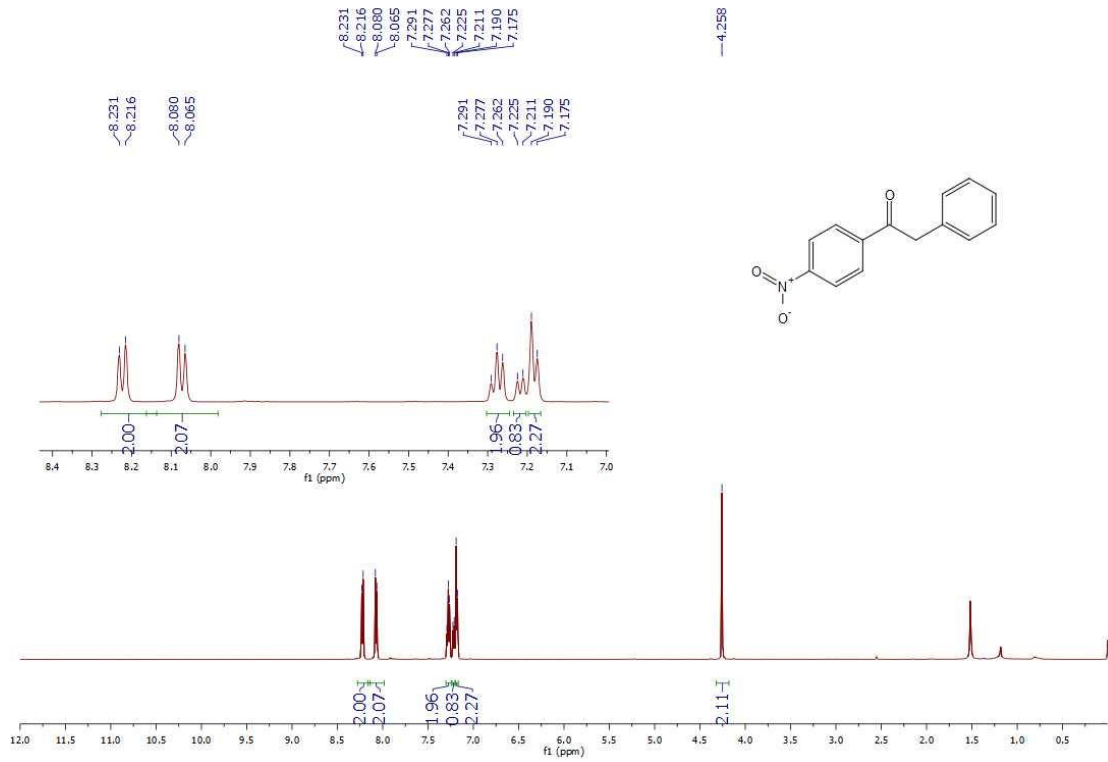


^1H NMR spectrum of **3ha**

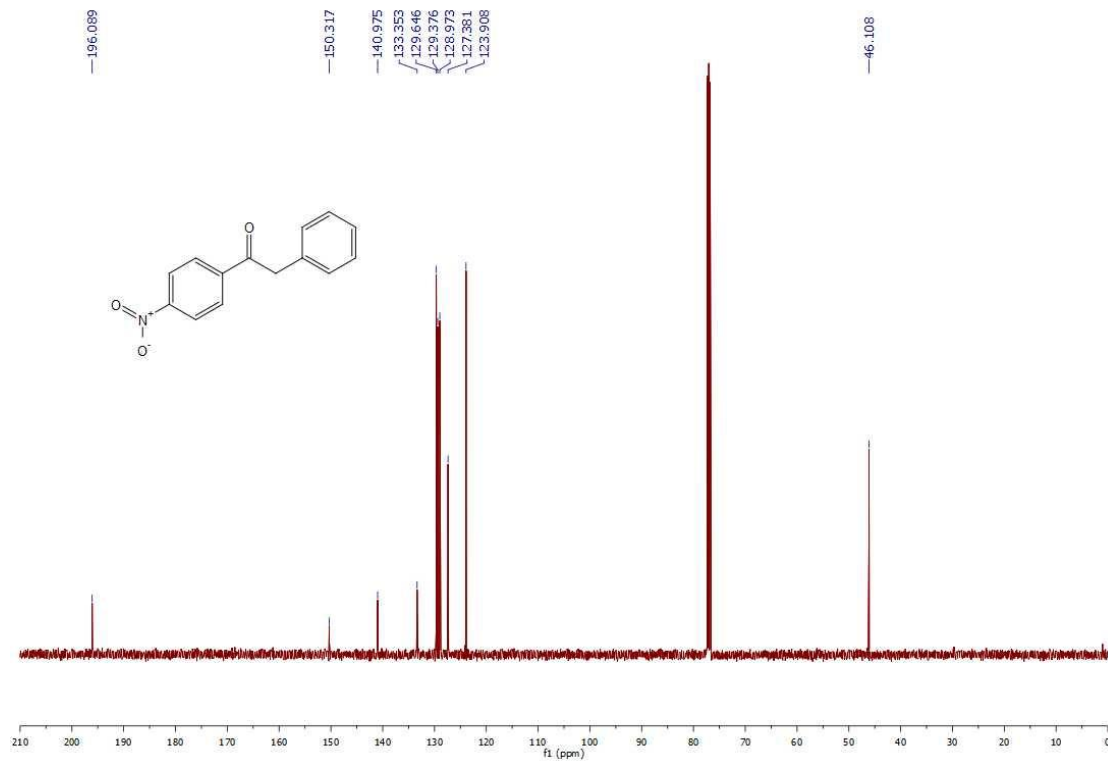


^{13}C NMR spectrum of **3ha**

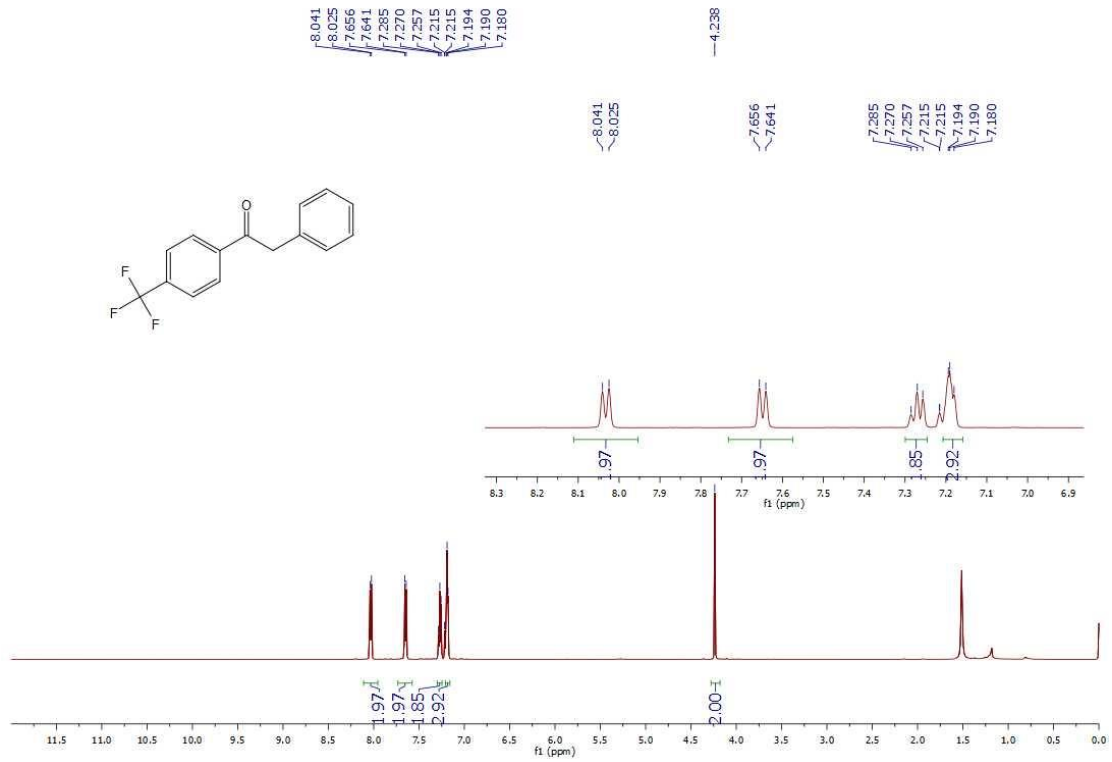




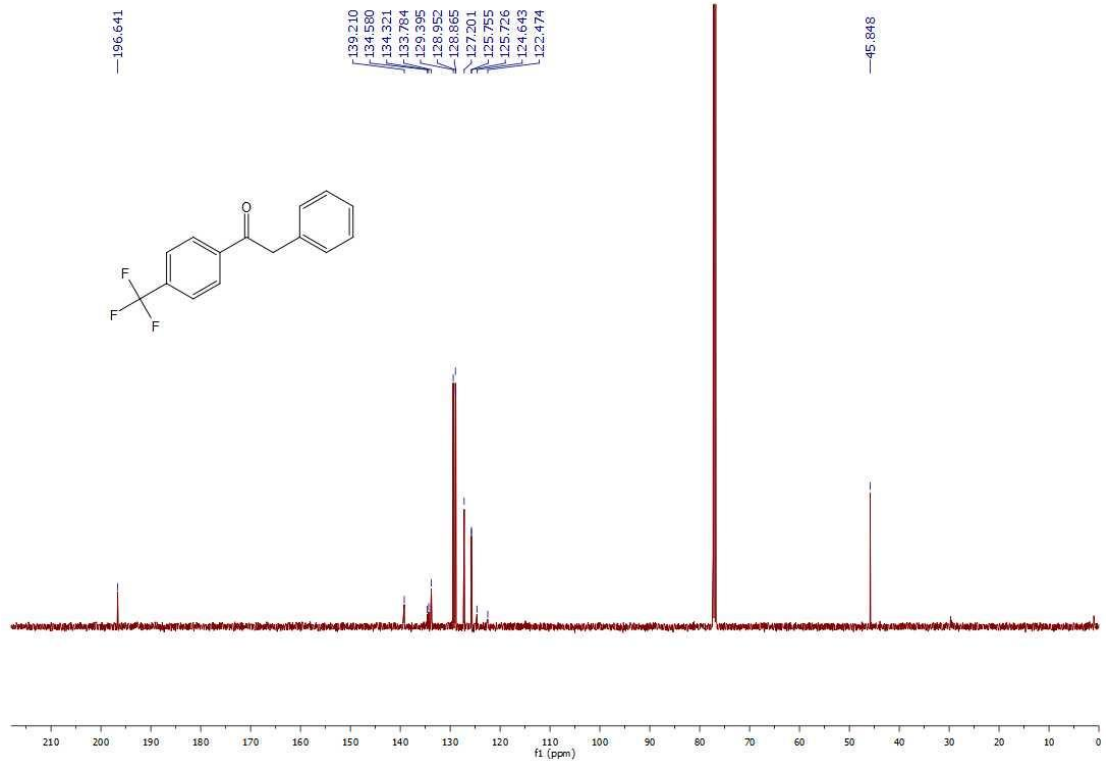
¹H NMR spectrum of 3ja



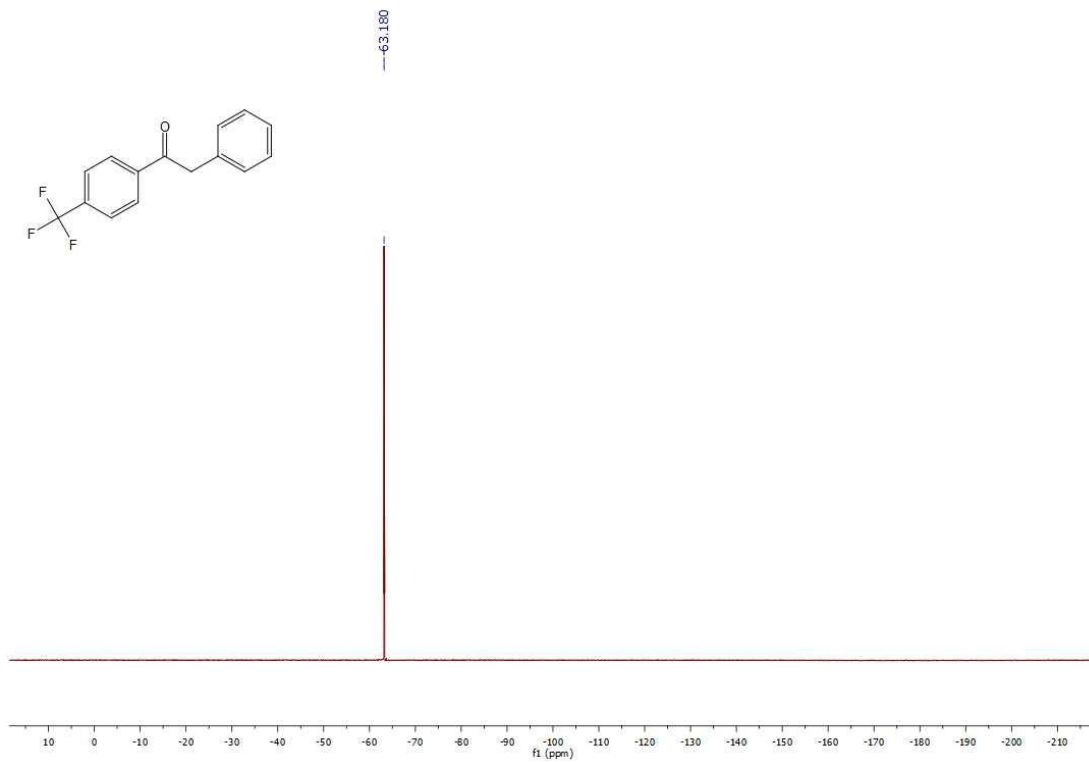
¹³C NMR spectrum of 3ja



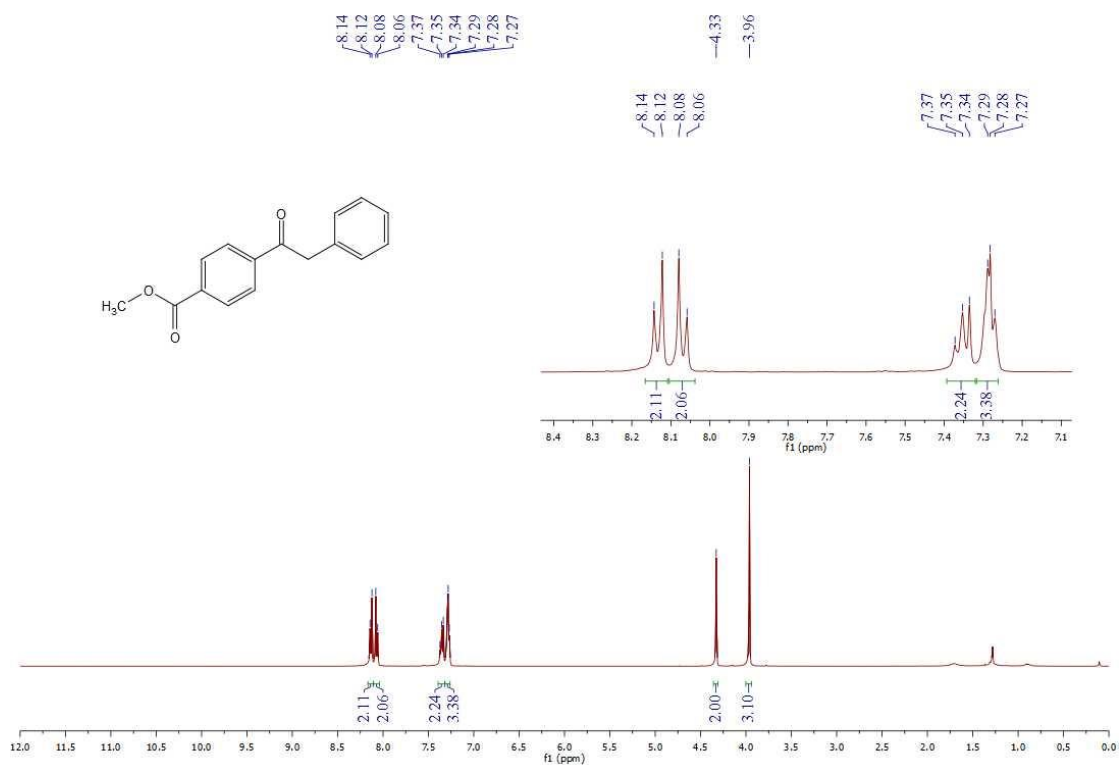
¹H NMR spectrum of **3ka**



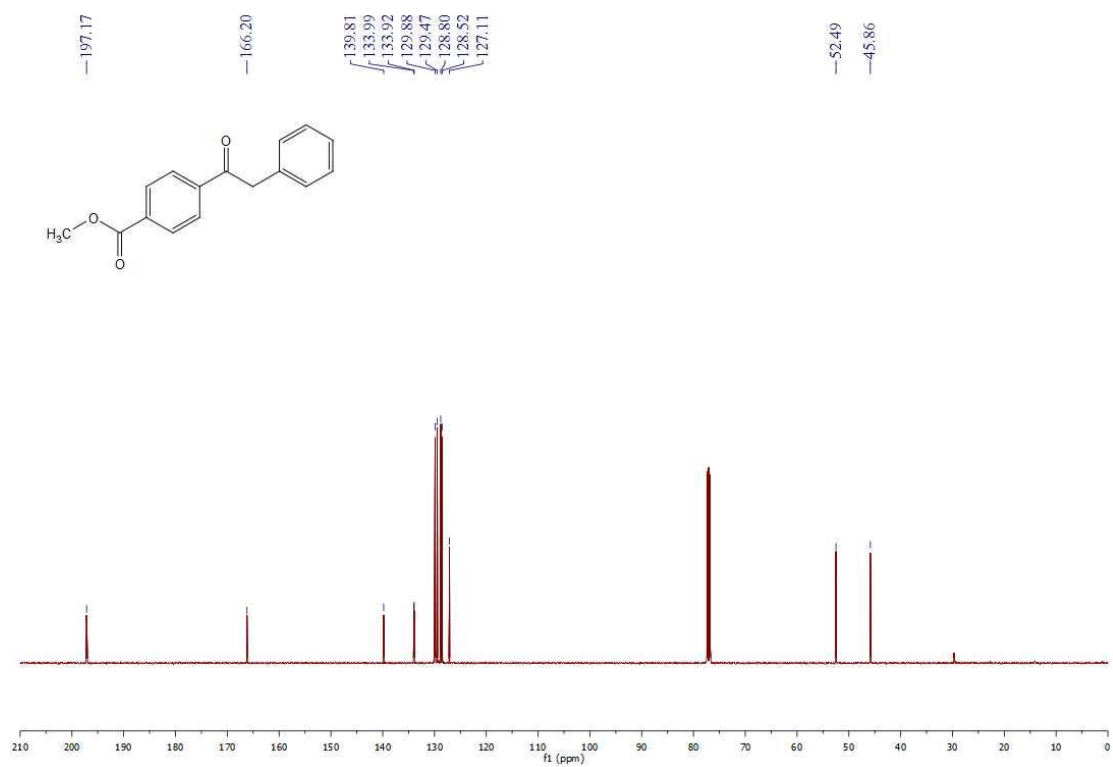
¹³C NMR spectrum of **3ka**



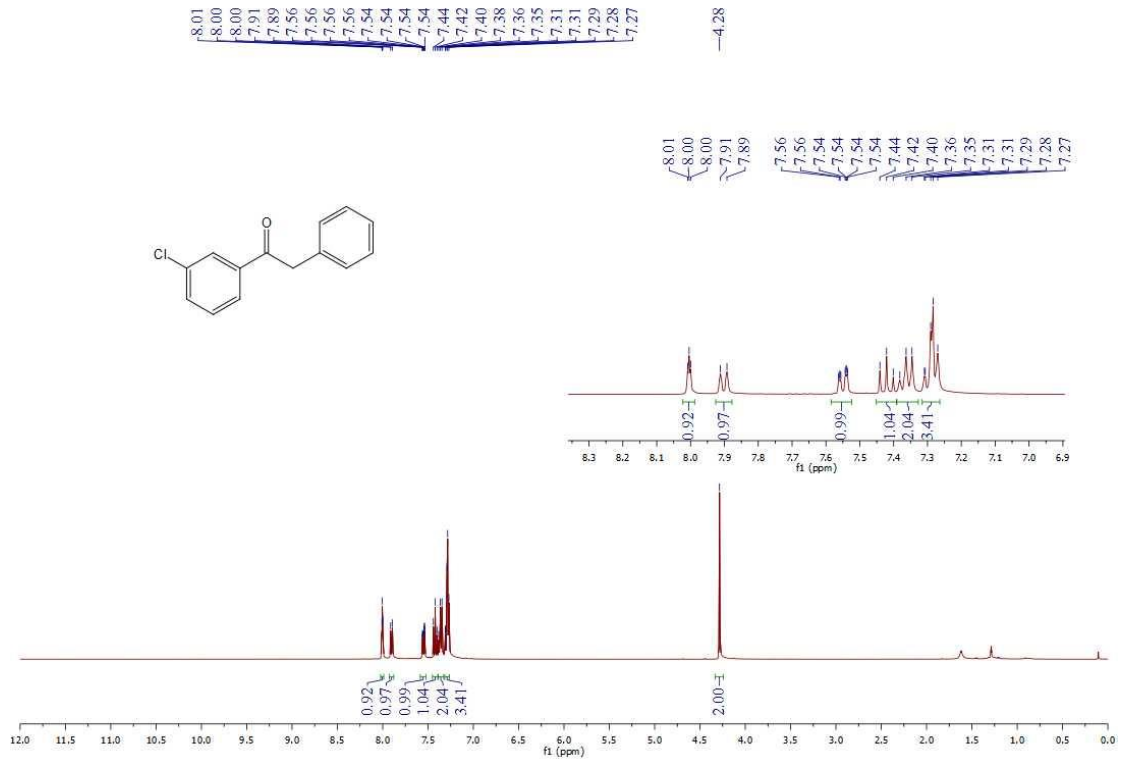
^{19}F NMR spectrum of **3ka**



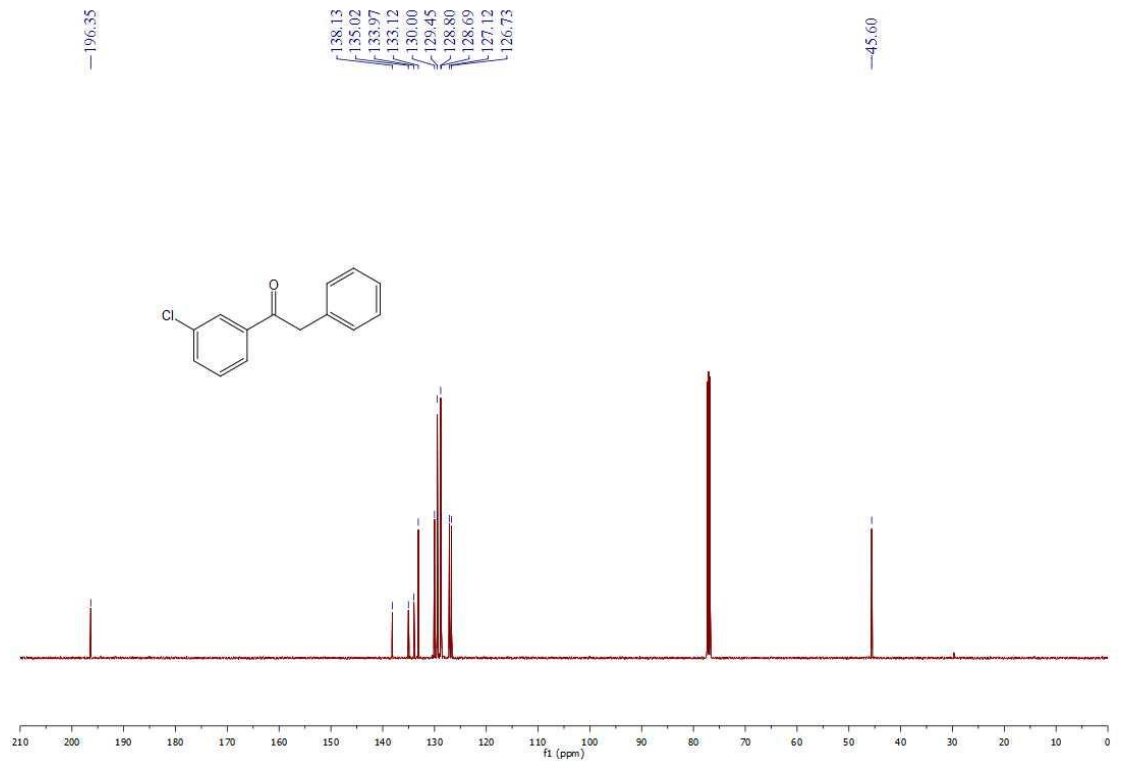
¹H NMR spectrum of 3la



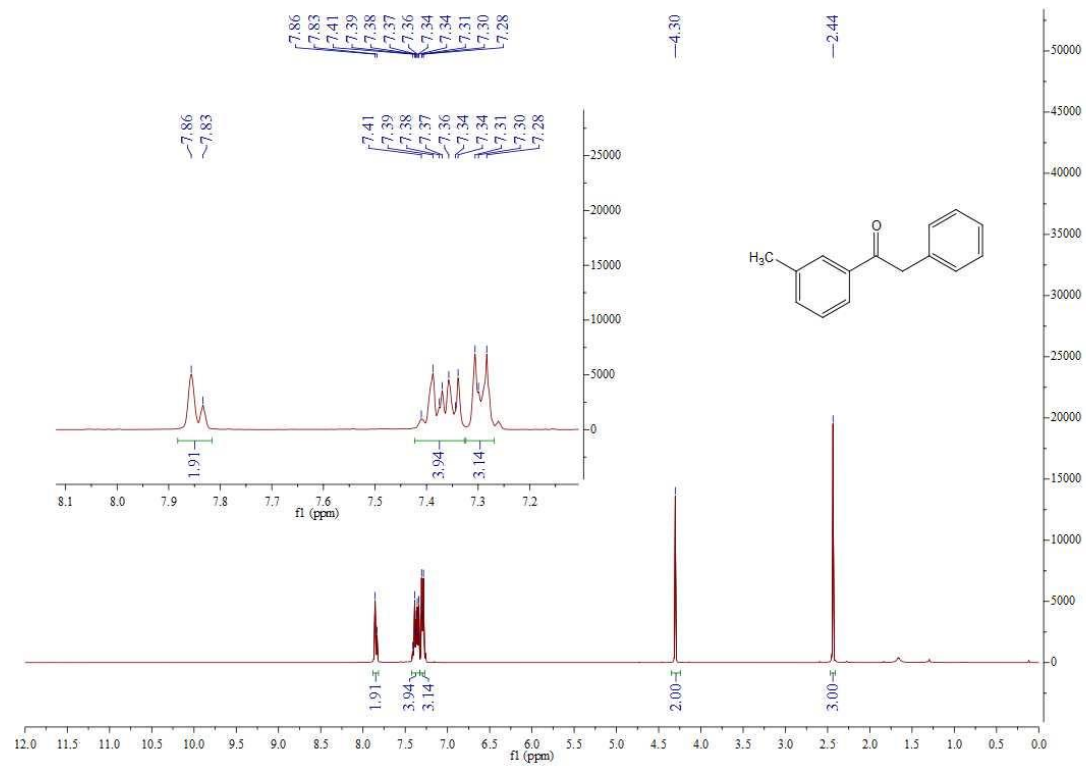
¹³C NMR spectrum of 3la



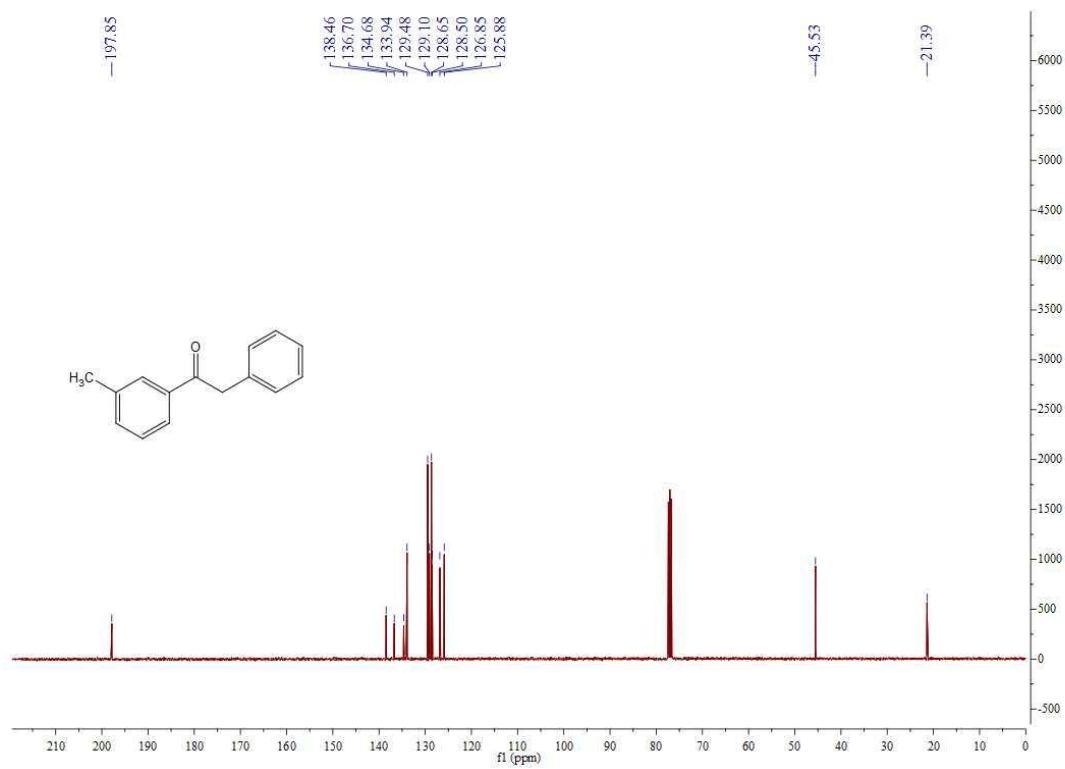
¹H NMR spectrum of **3ma**



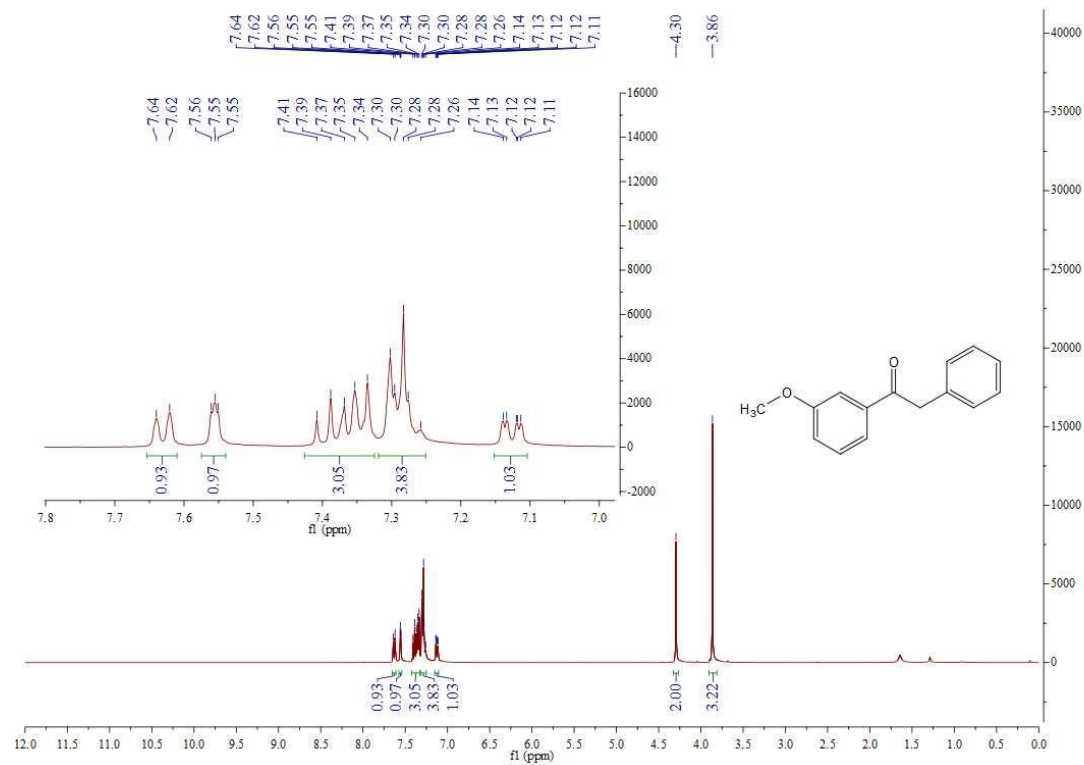
¹³C NMR spectrum of **3ma**



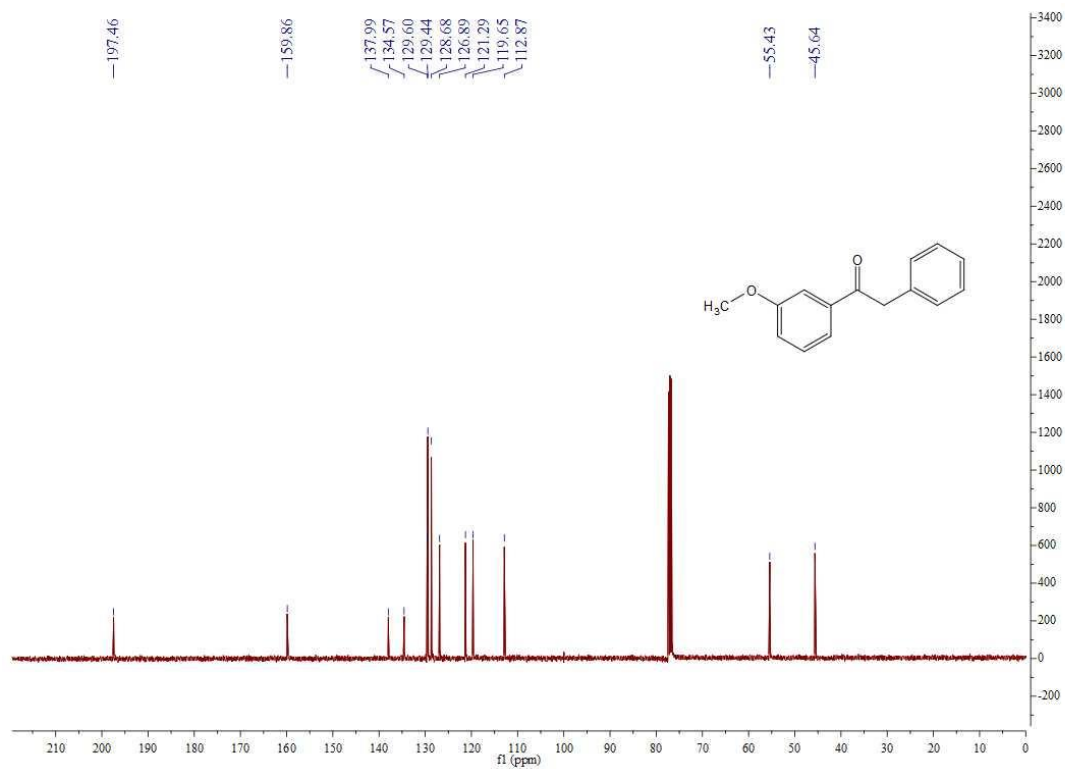
¹H NMR spectrum of 3na



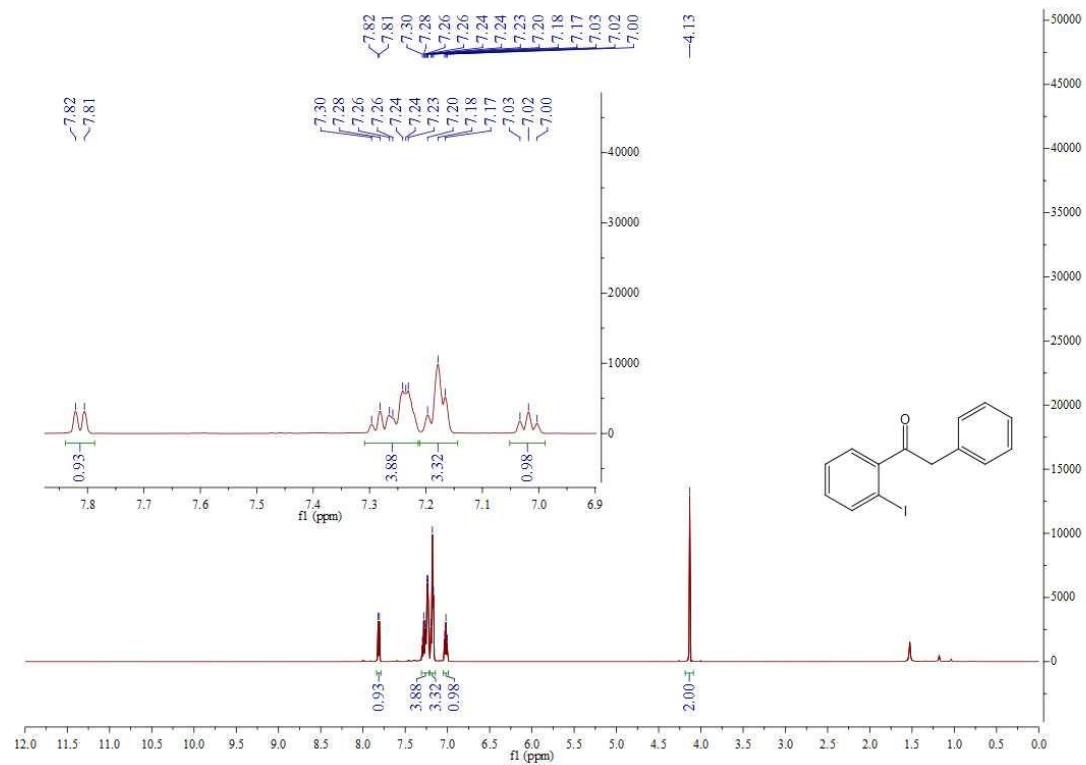
¹³C NMR spectrum of 3na



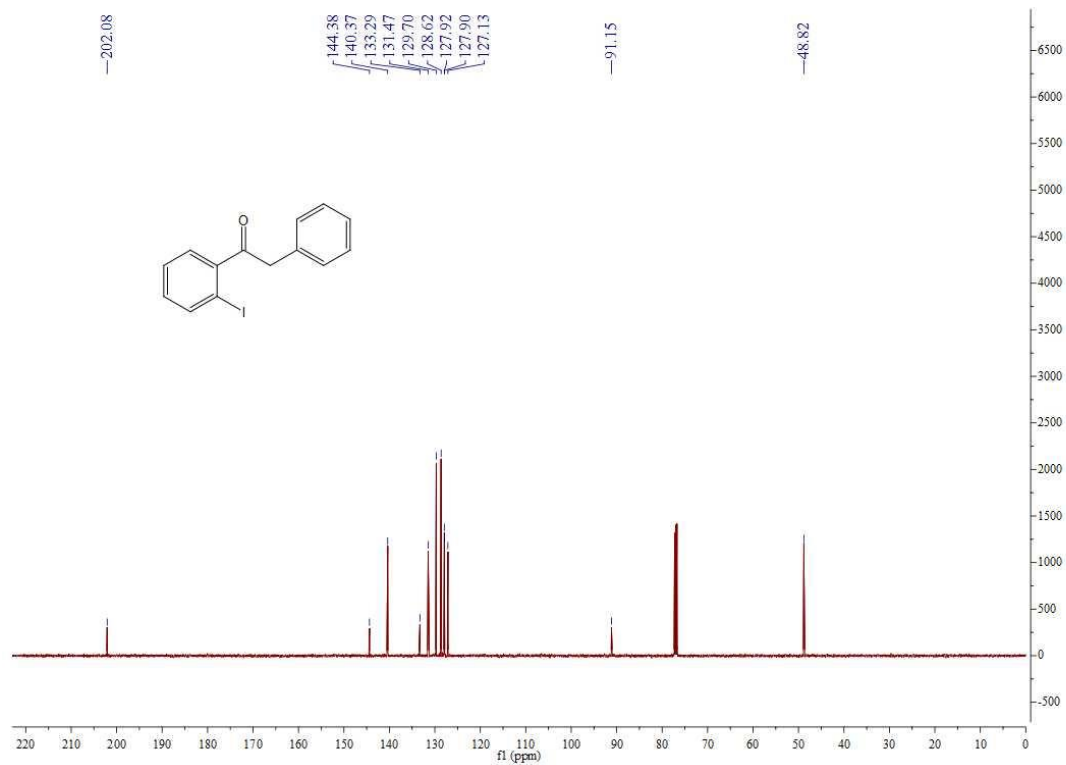
^1H NMR spectrum of 30a



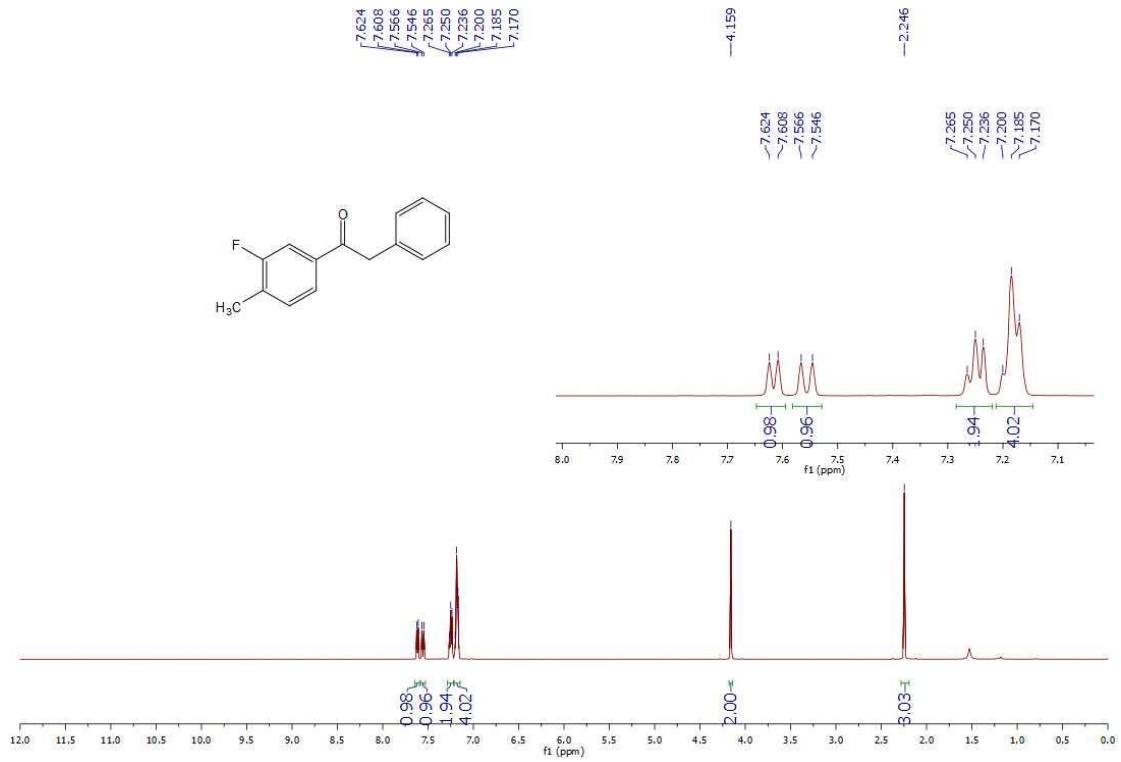
^{13}C NMR spectrum of 30a



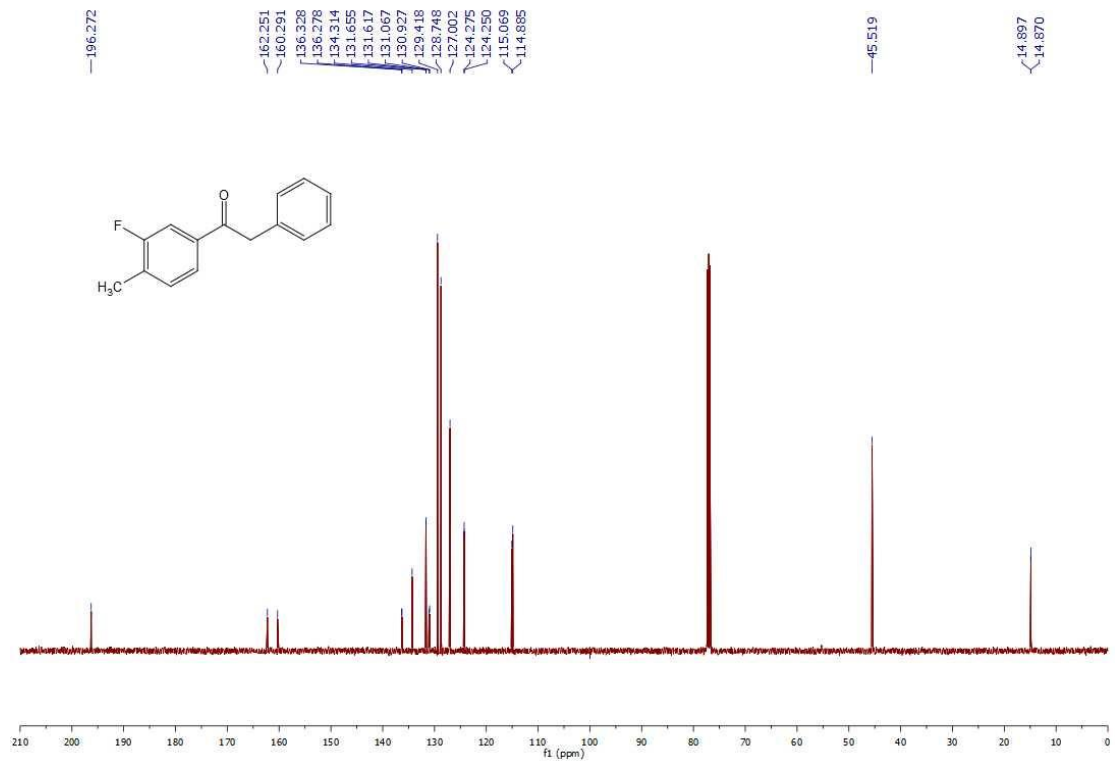
¹H NMR spectrum of 3qa



¹³C NMR spectrum of 3qa



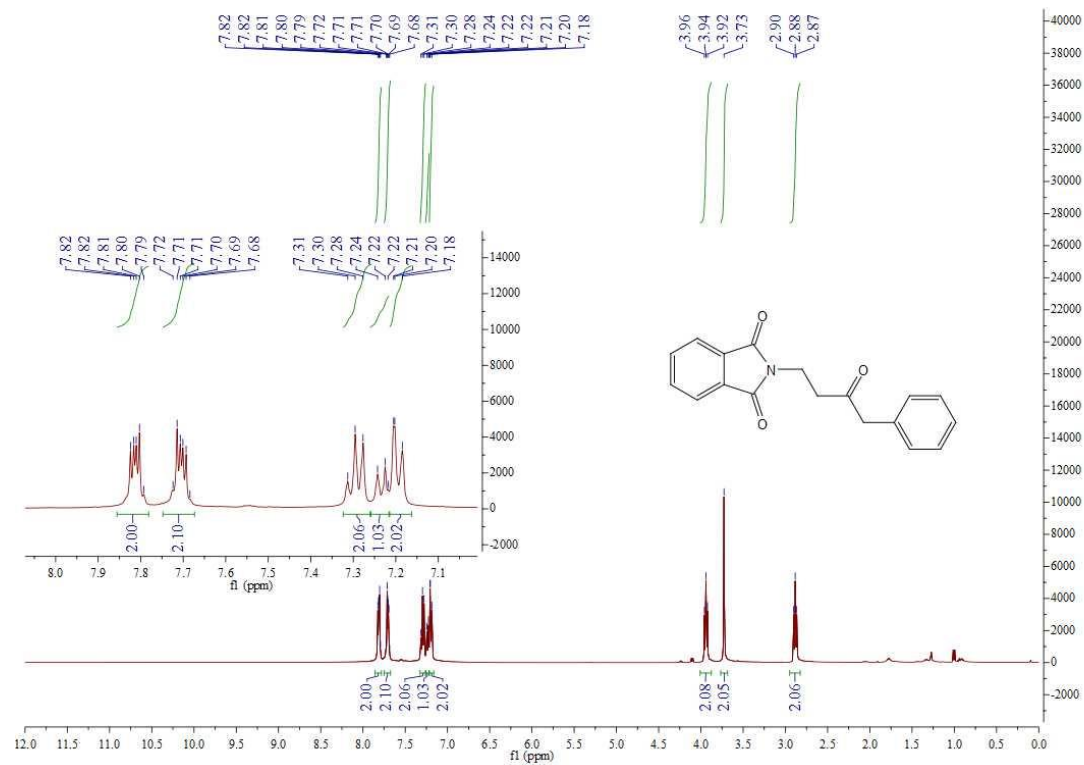
¹H NMR spectrum of 3ra



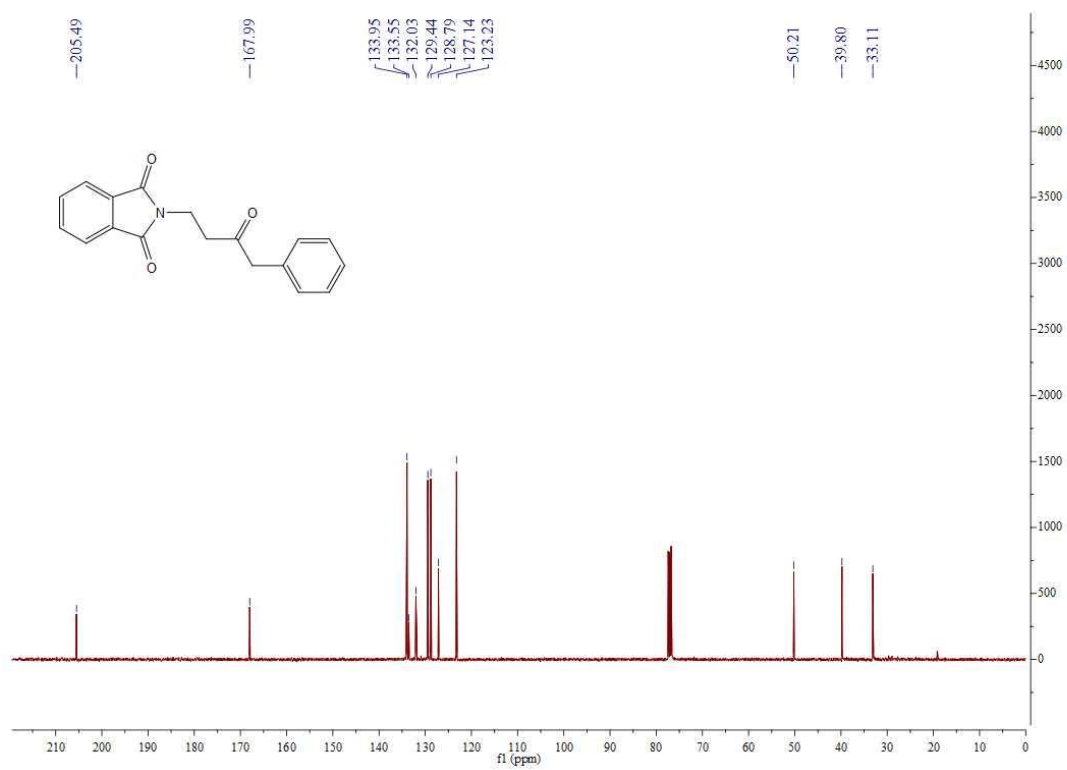
¹³C NMR spectrum of 3ra



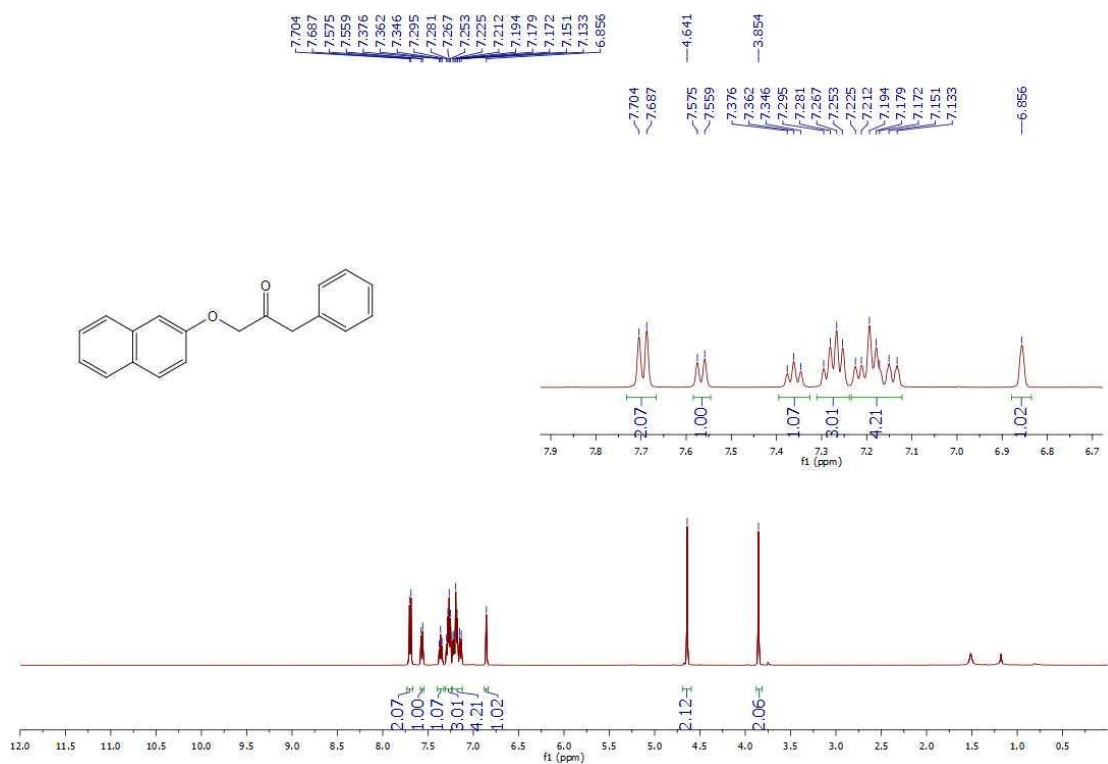
^{19}F NMR spectrum of **3ra**



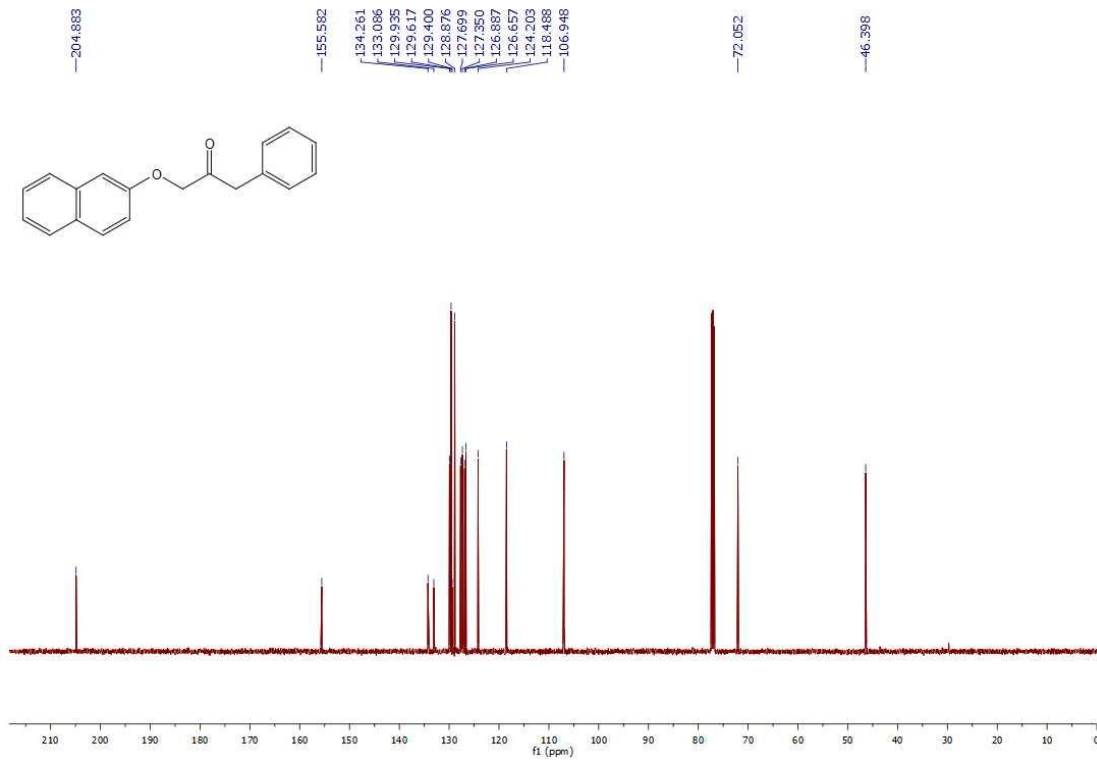
¹H NMR spectrum of 3sa



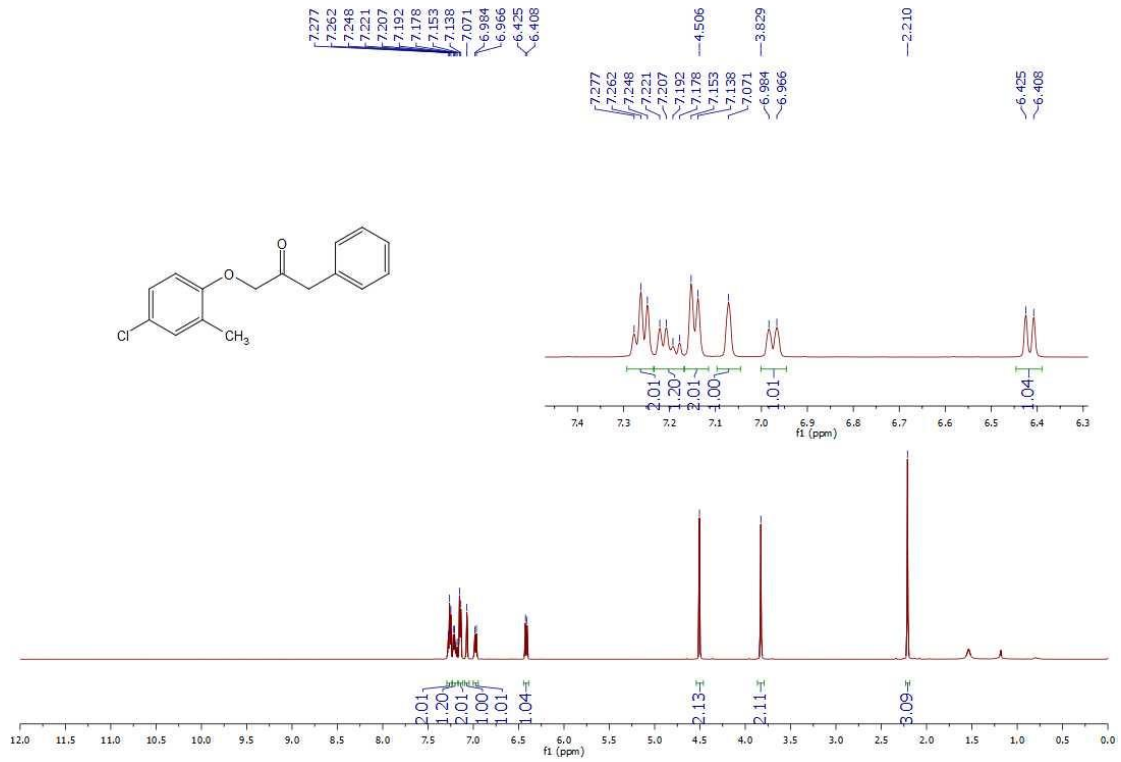
¹³C NMR spectrum of 3sa



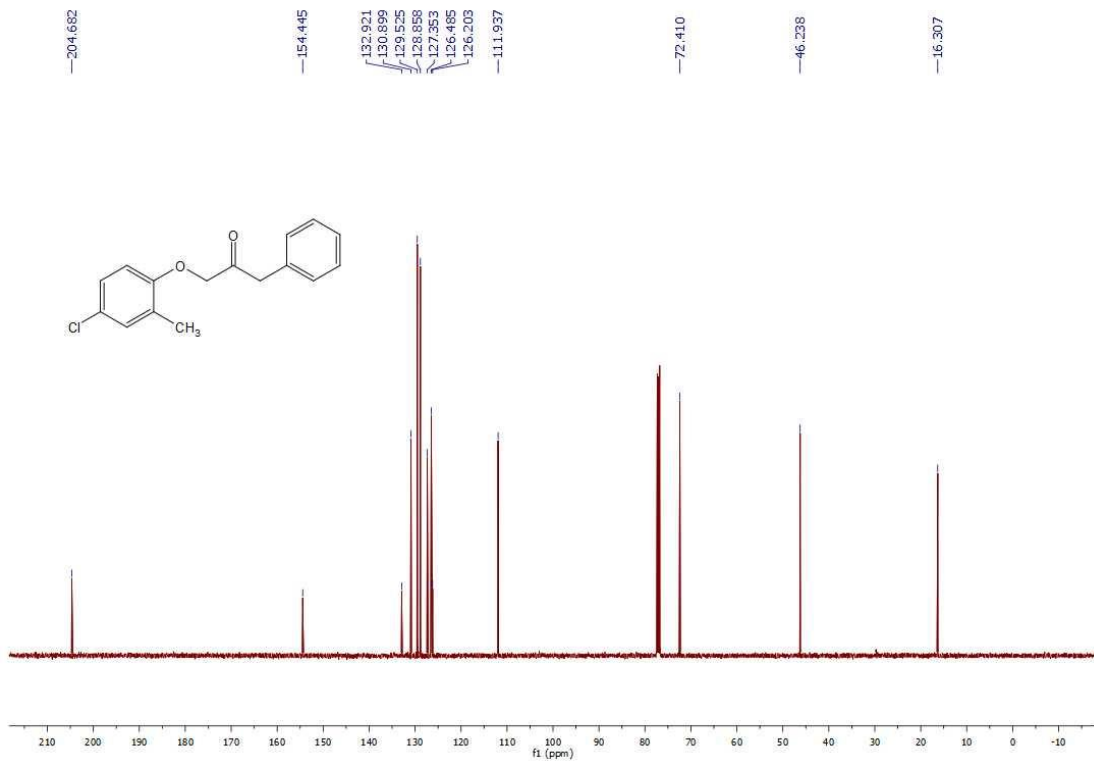
¹H NMR spectrum of 3ta



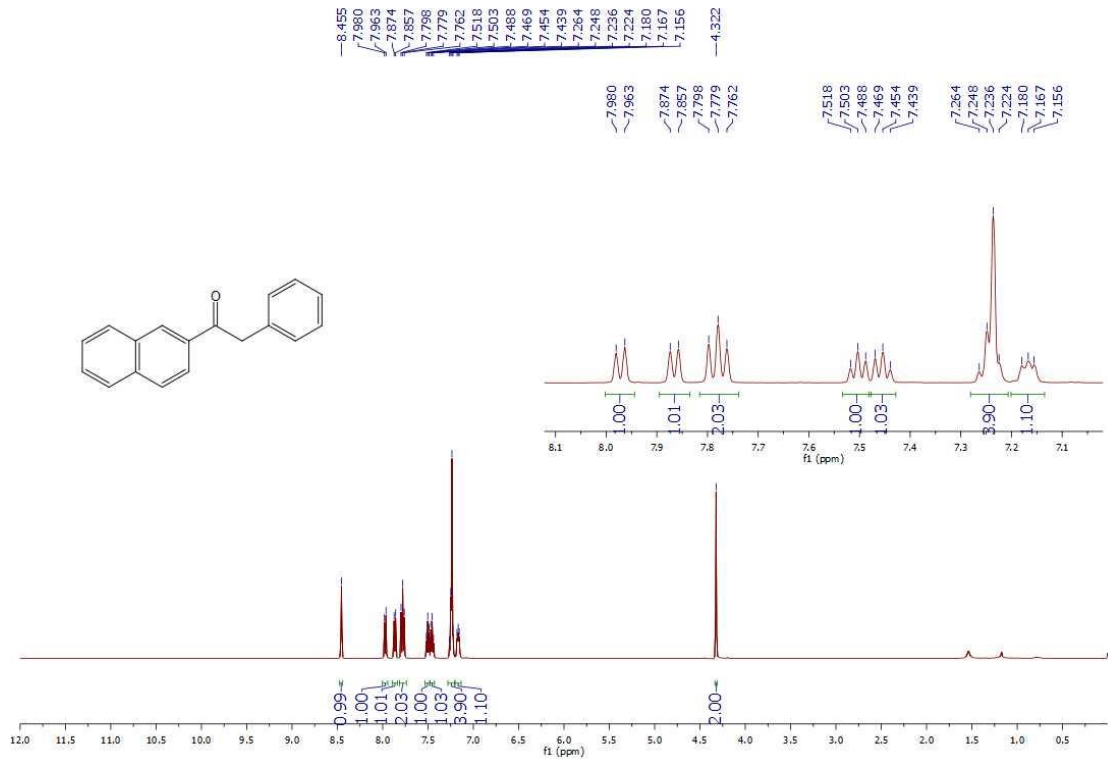
¹³C NMR spectrum of 3ta



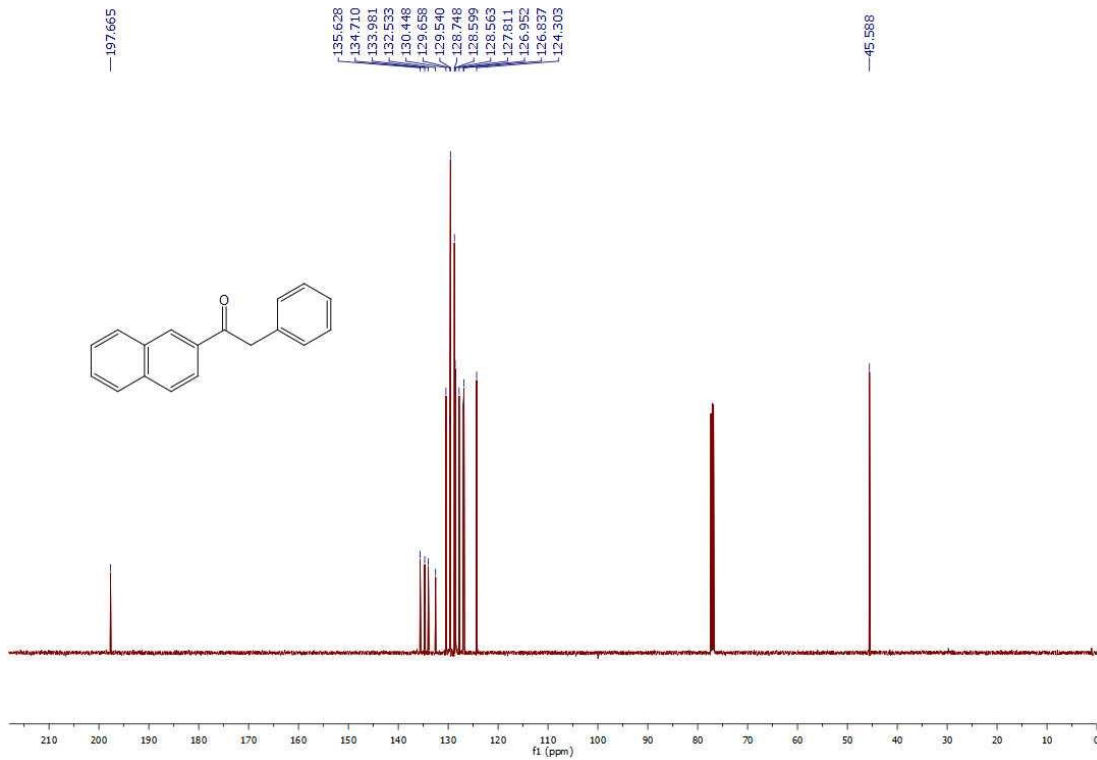
¹H NMR spectrum of 3ua



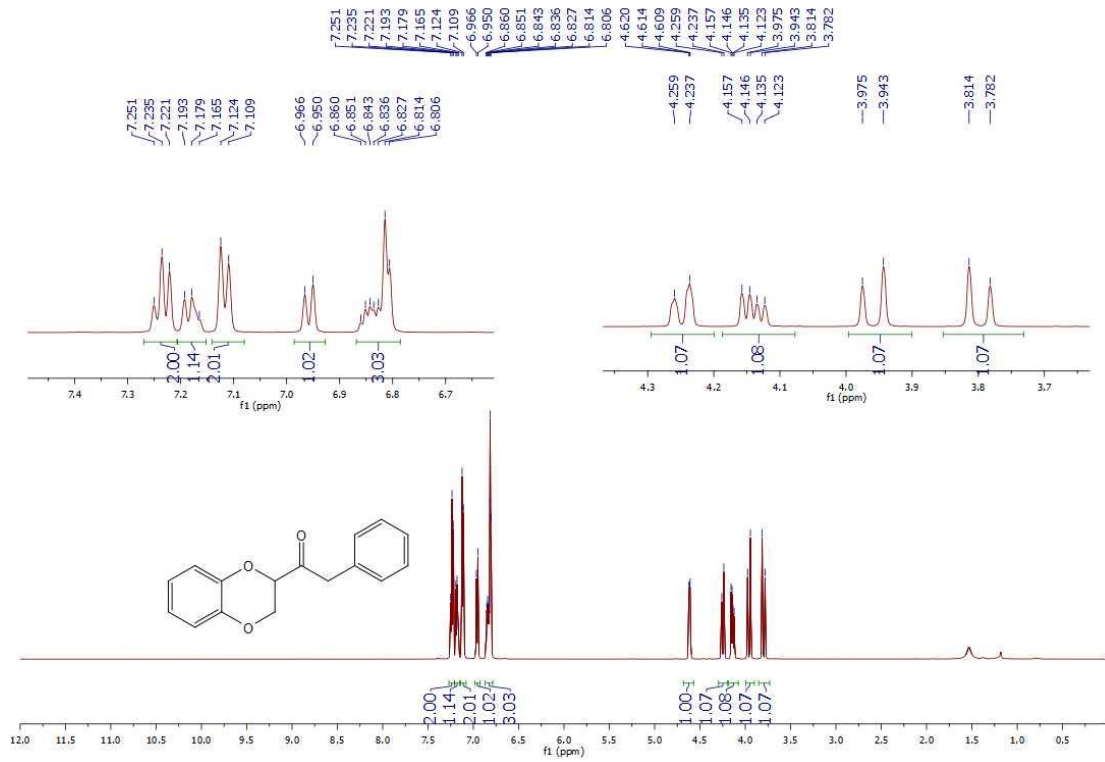
¹³C NMR spectrum of 3ua



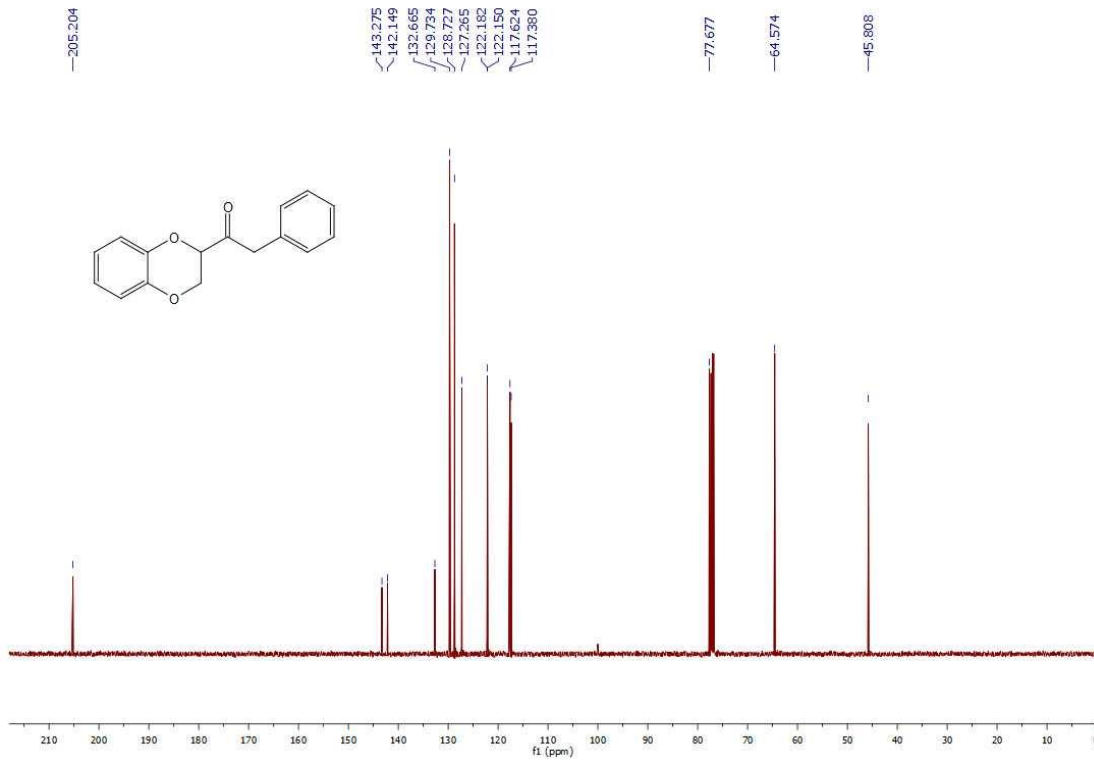
¹H NMR spectrum of 3va



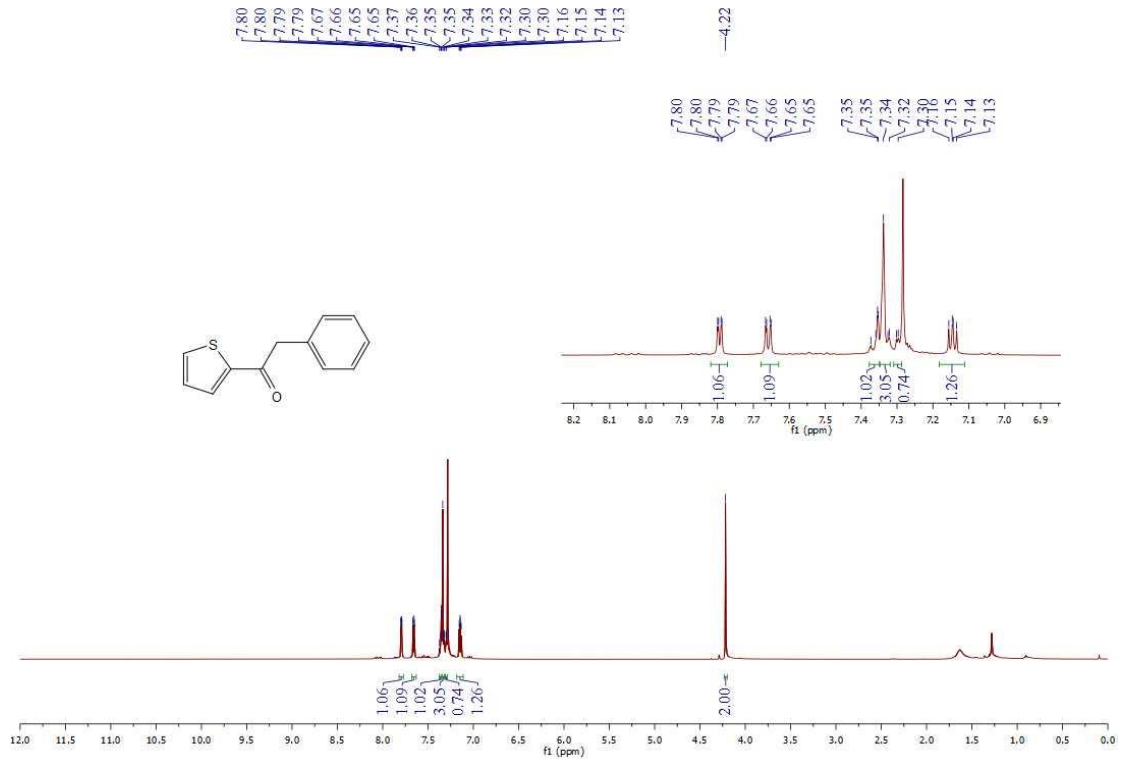
¹³C NMR spectrum of 3va



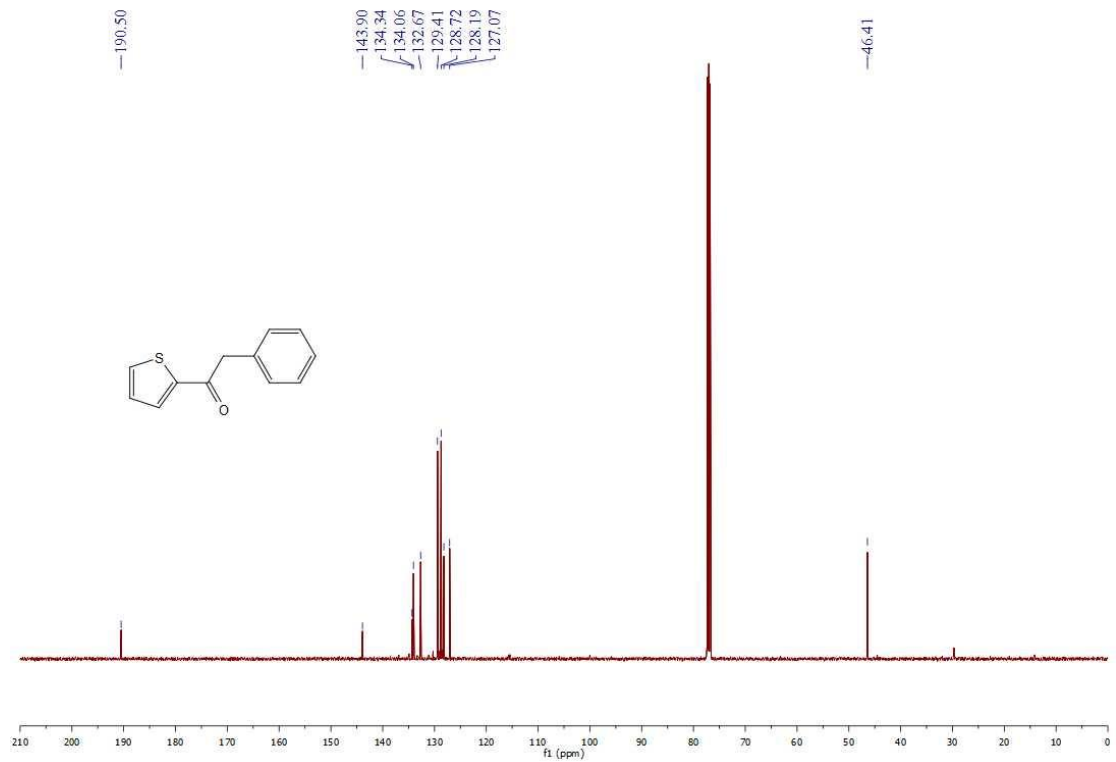
¹H NMR spectrum of 3wa



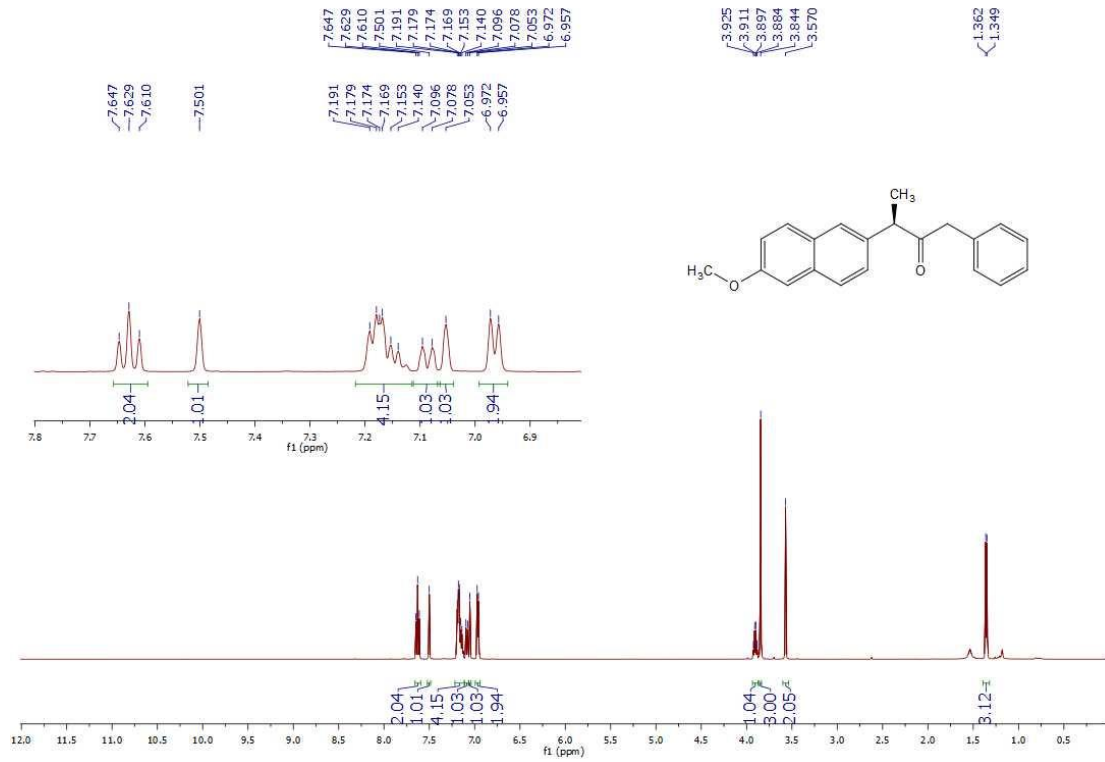
¹³C NMR spectrum of 3wa



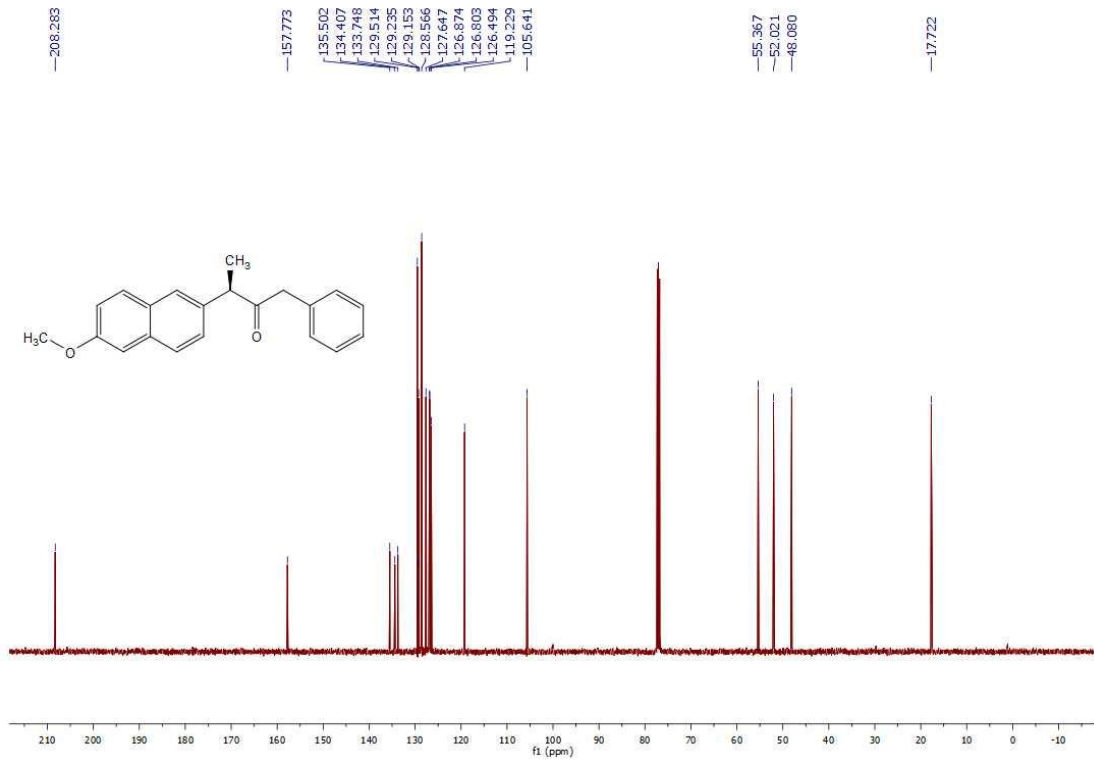
¹H NMR spectrum of **3xa**



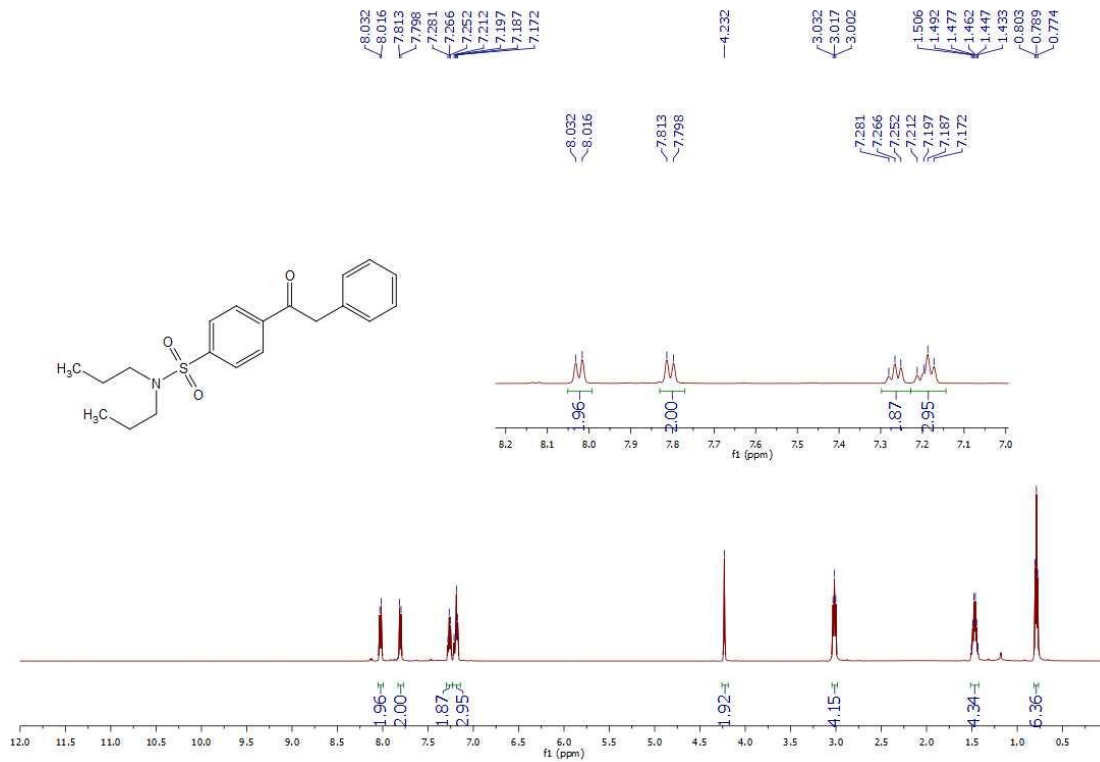
¹³C NMR spectrum of **3xa**



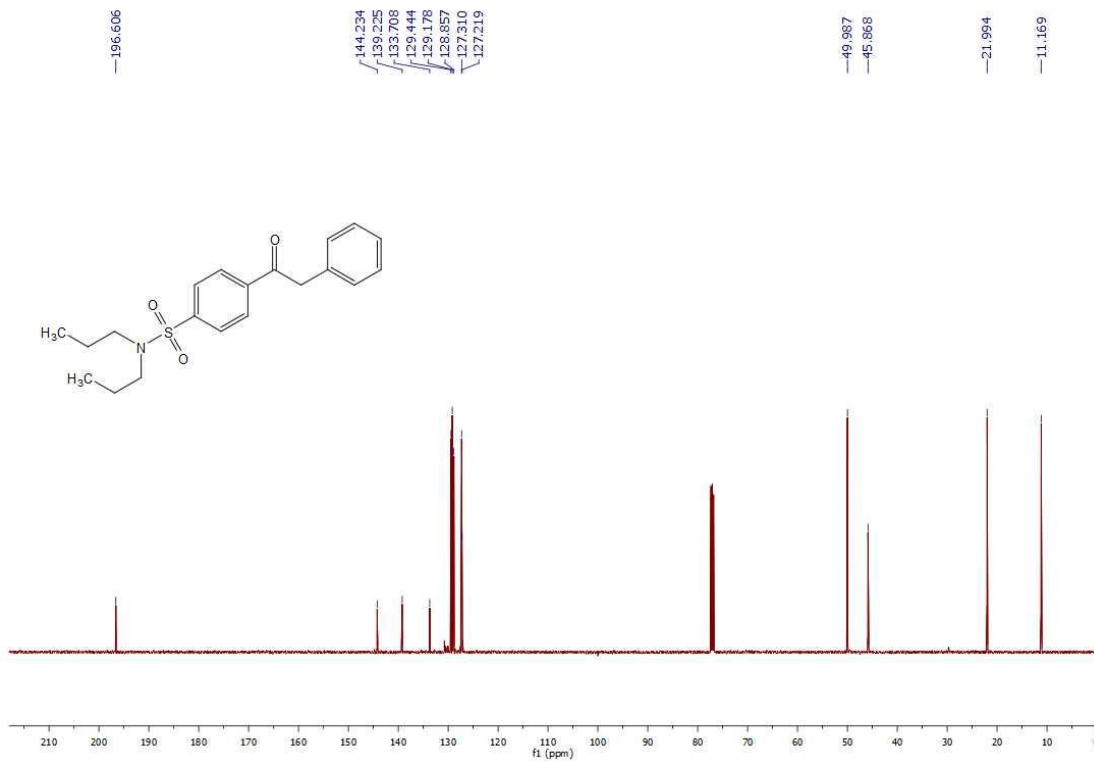
¹H NMR spectrum of 3ya



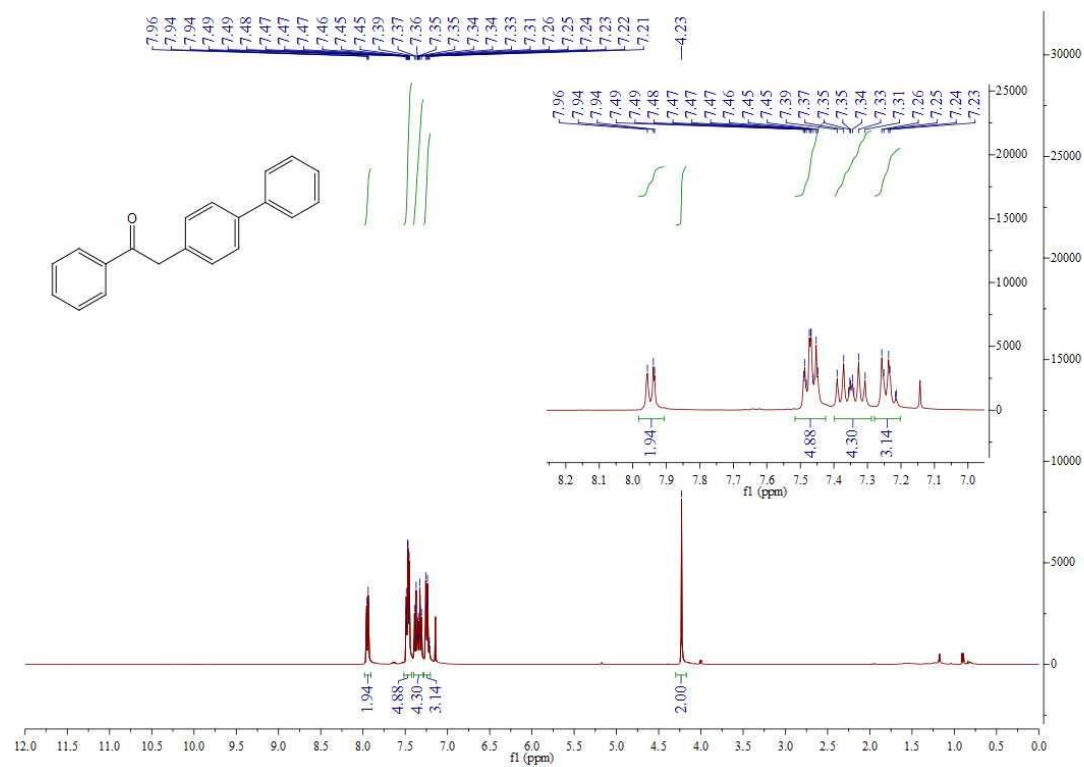
¹³C NMR spectrum of 3ya



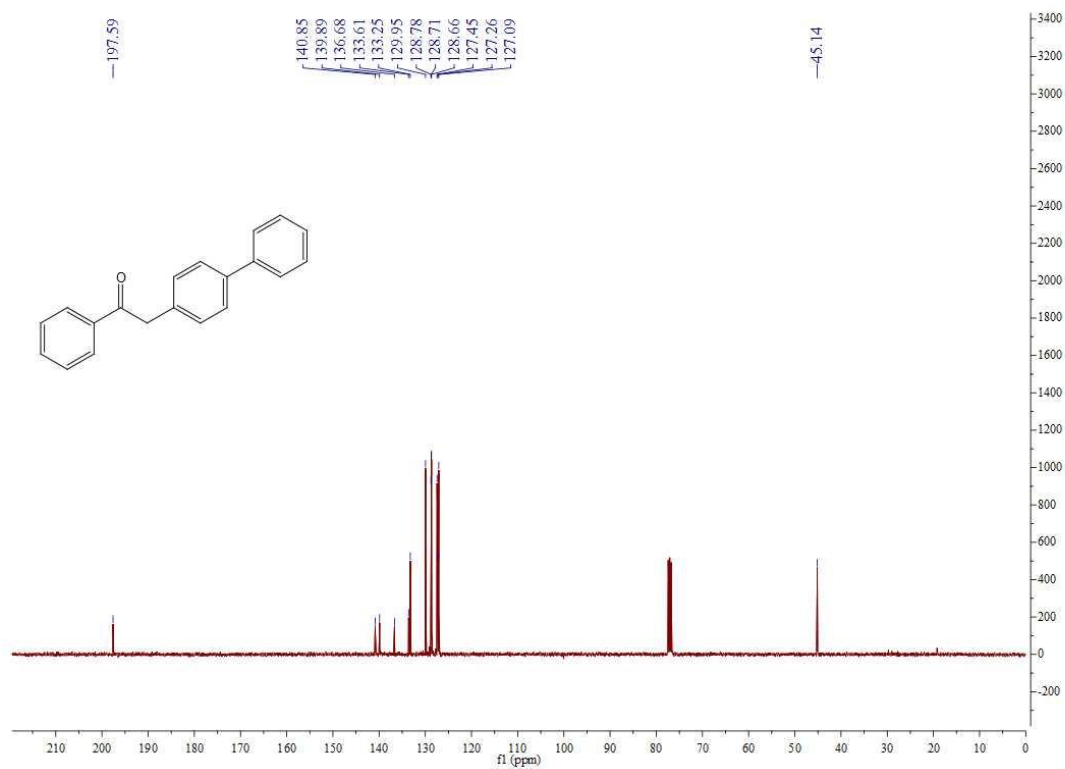
¹H NMR spectrum of 3aaa



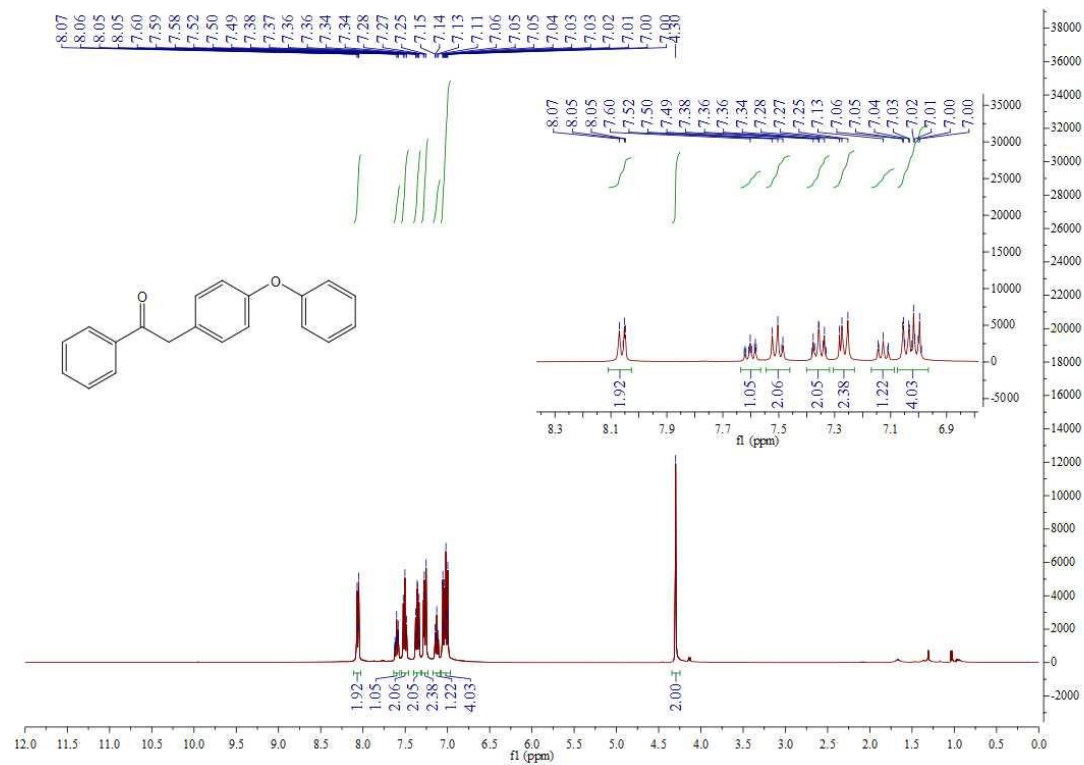
¹³C NMR spectrum of 3aaa



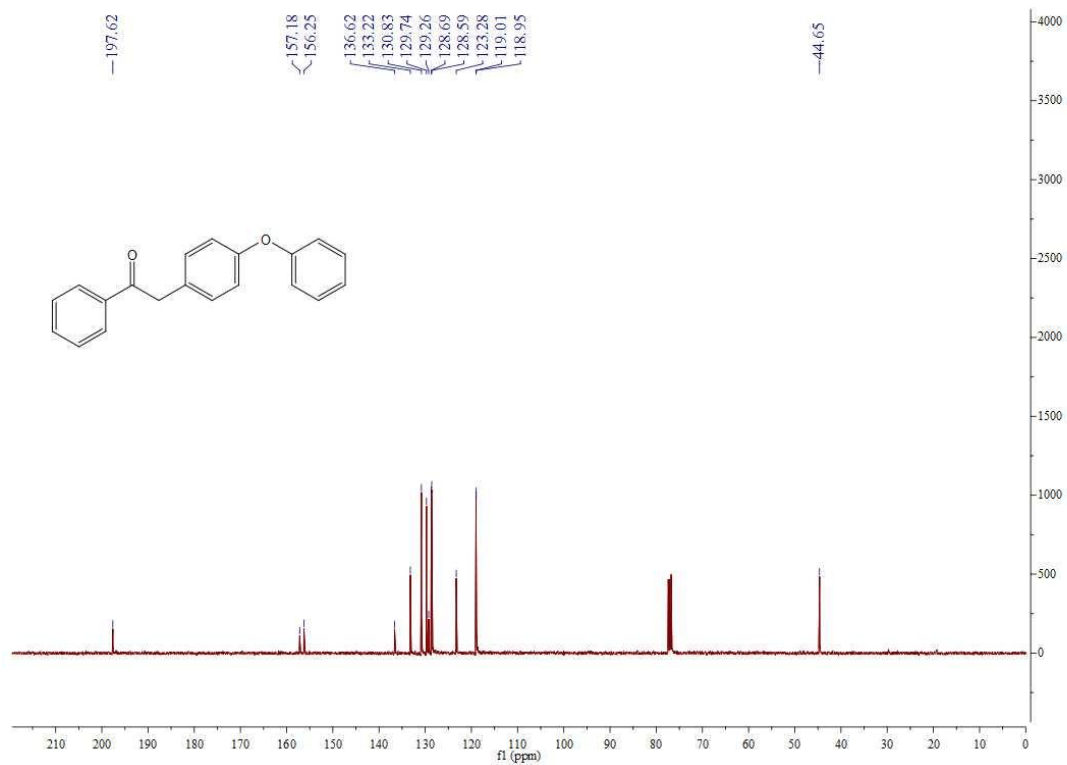
¹H NMR spectrum of **3ab**



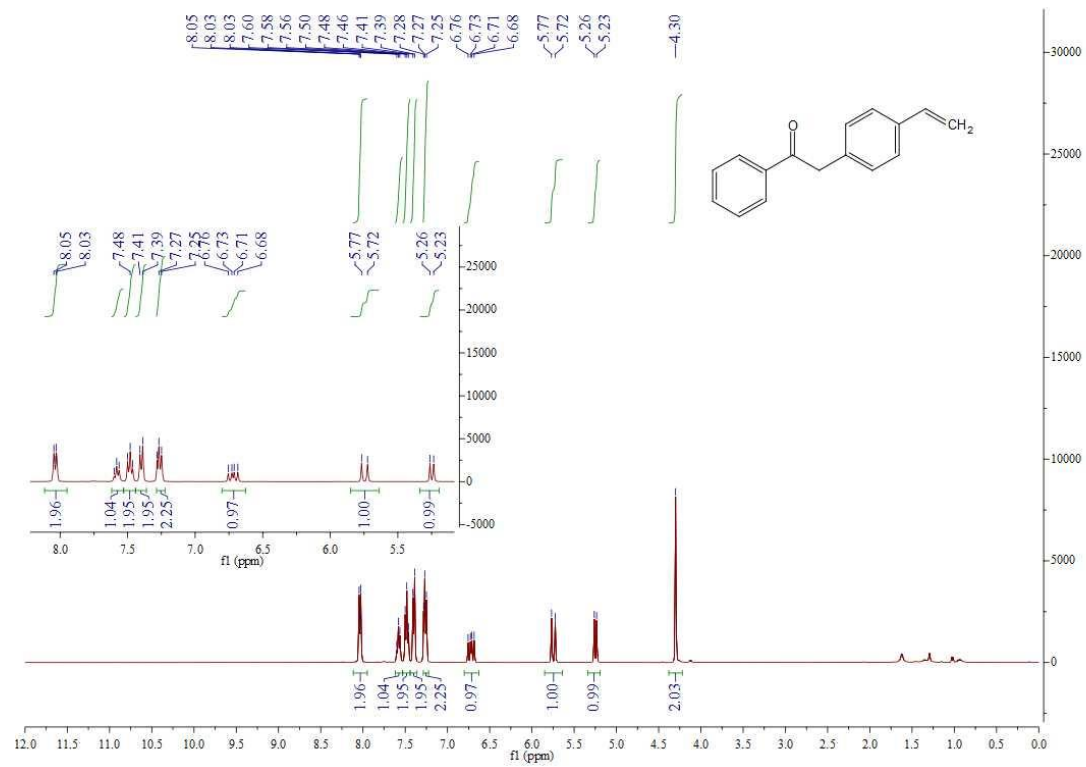
¹³C NMR spectrum of **3ab**



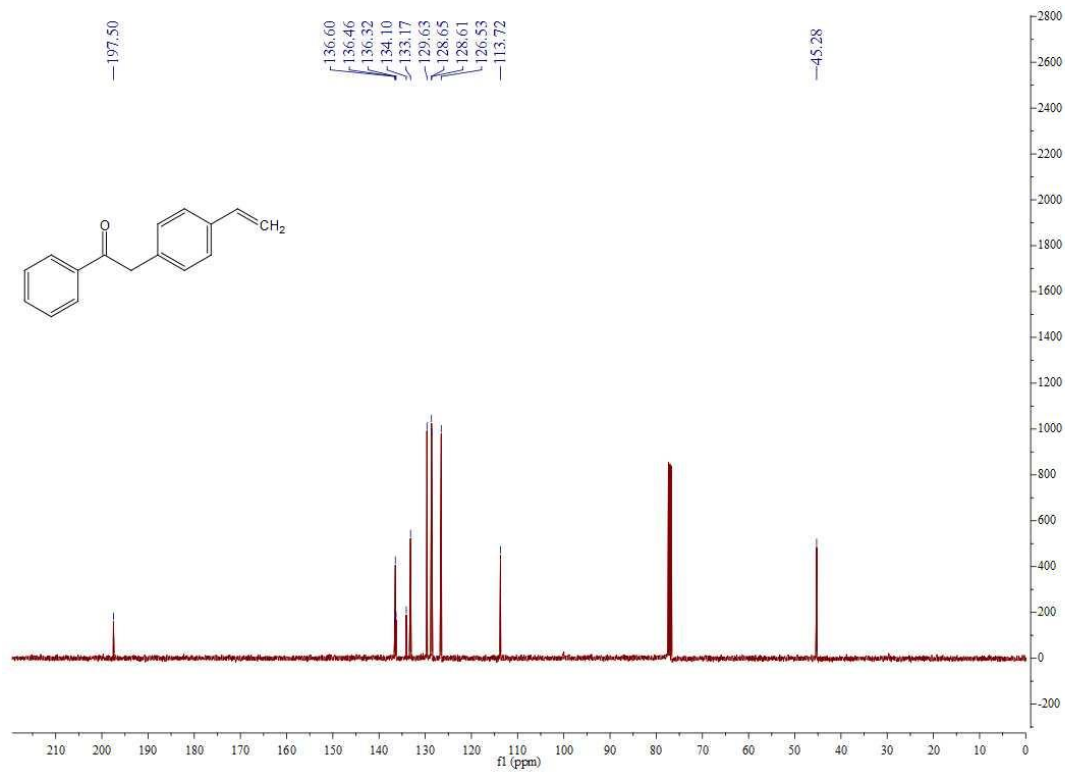
¹H NMR spectrum of 3ac



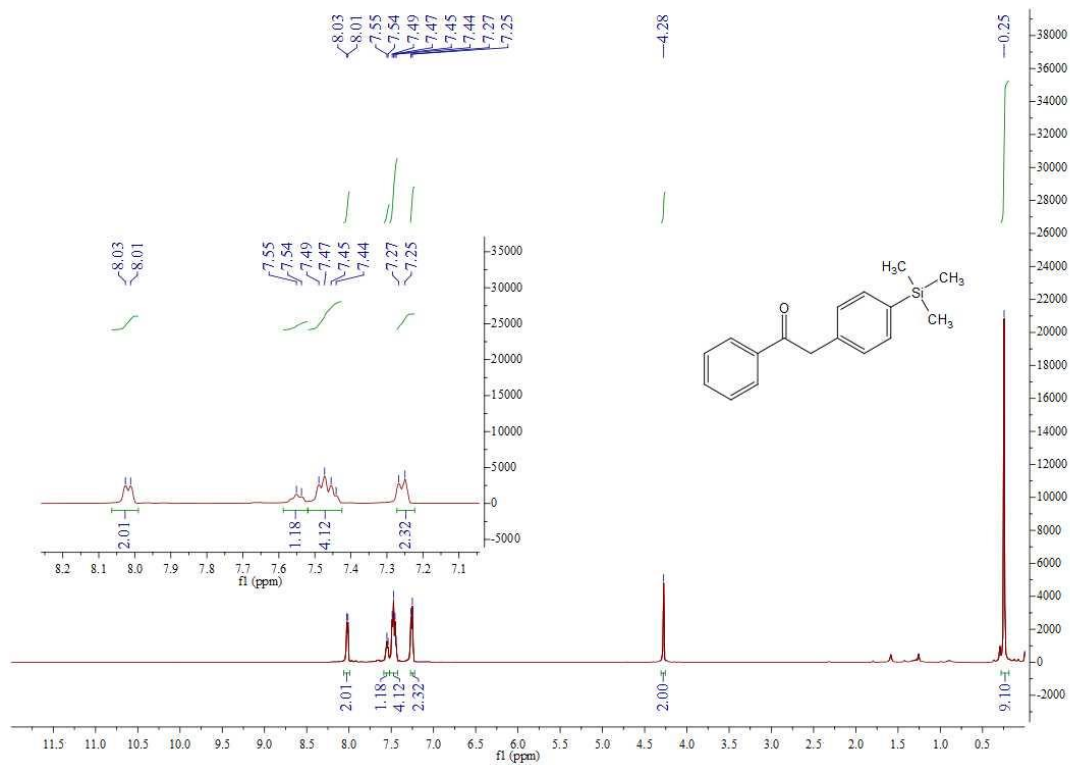
¹³C NMR spectrum of 3ac



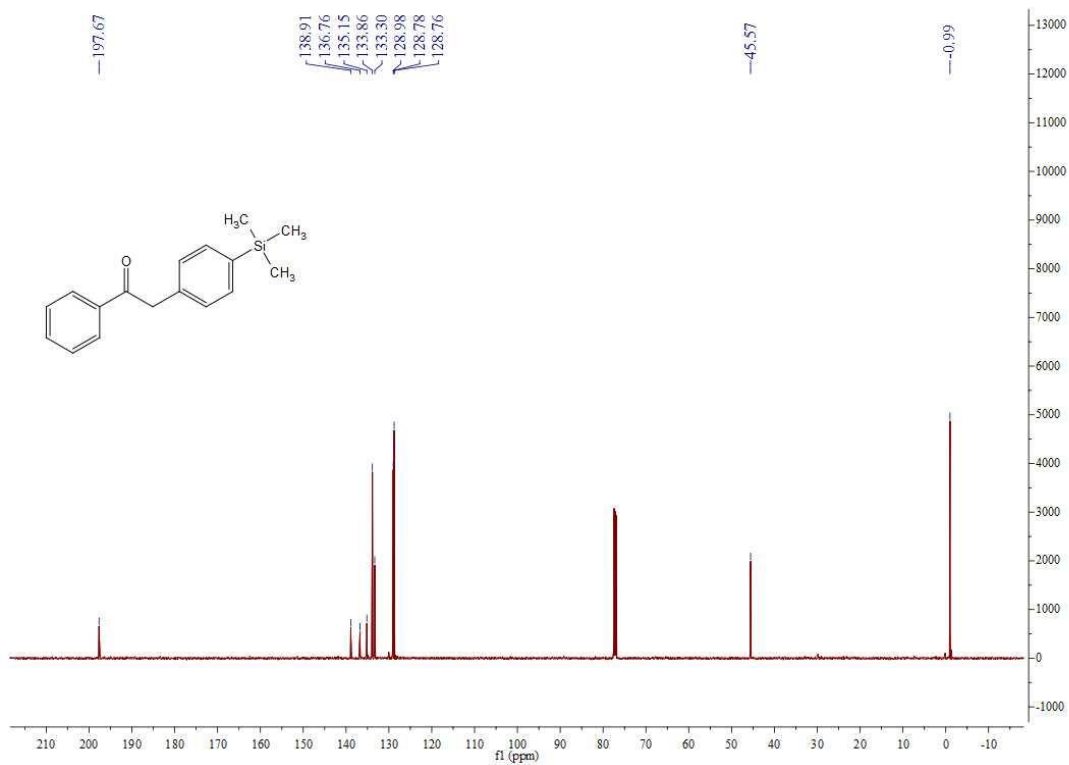
¹H NMR spectrum of 3ad



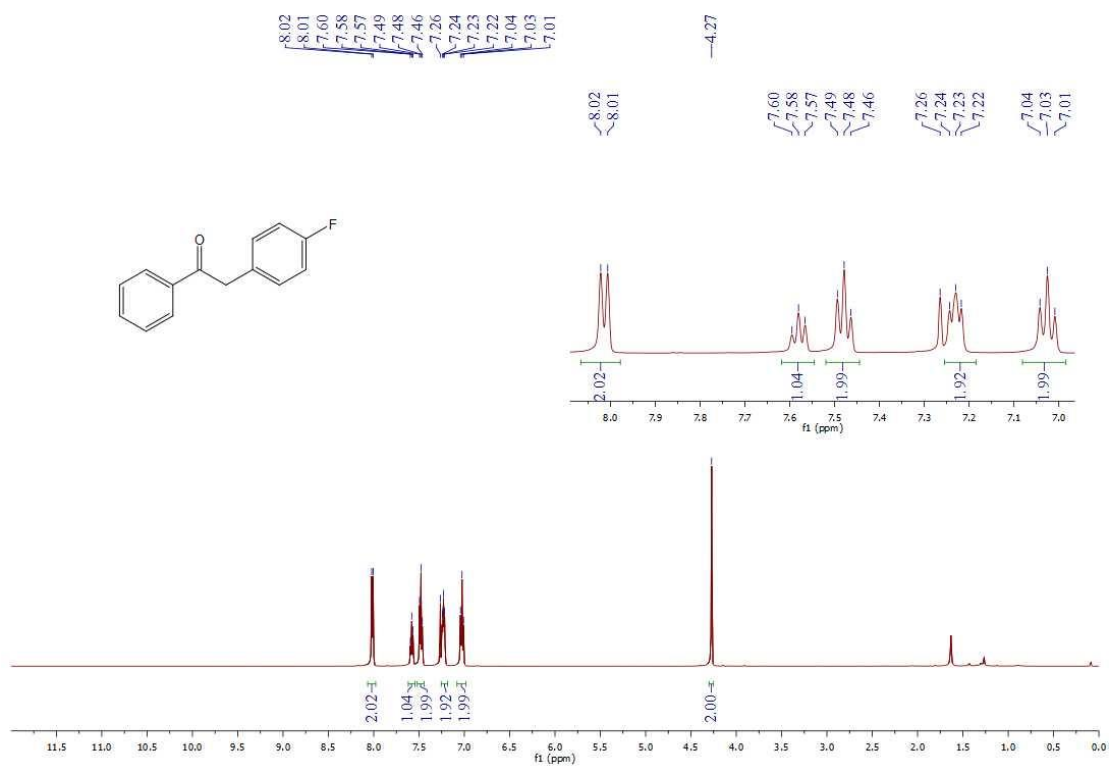
¹³C NMR spectrum of 3ad



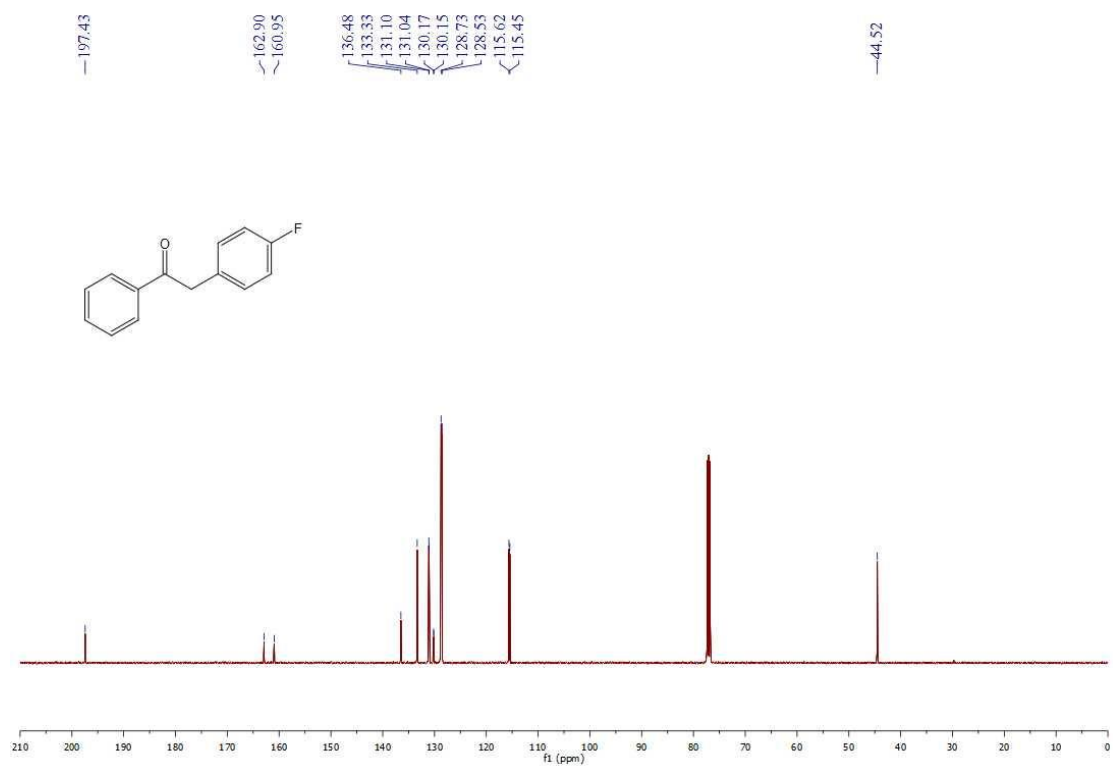
¹H NMR spectrum of 3ae



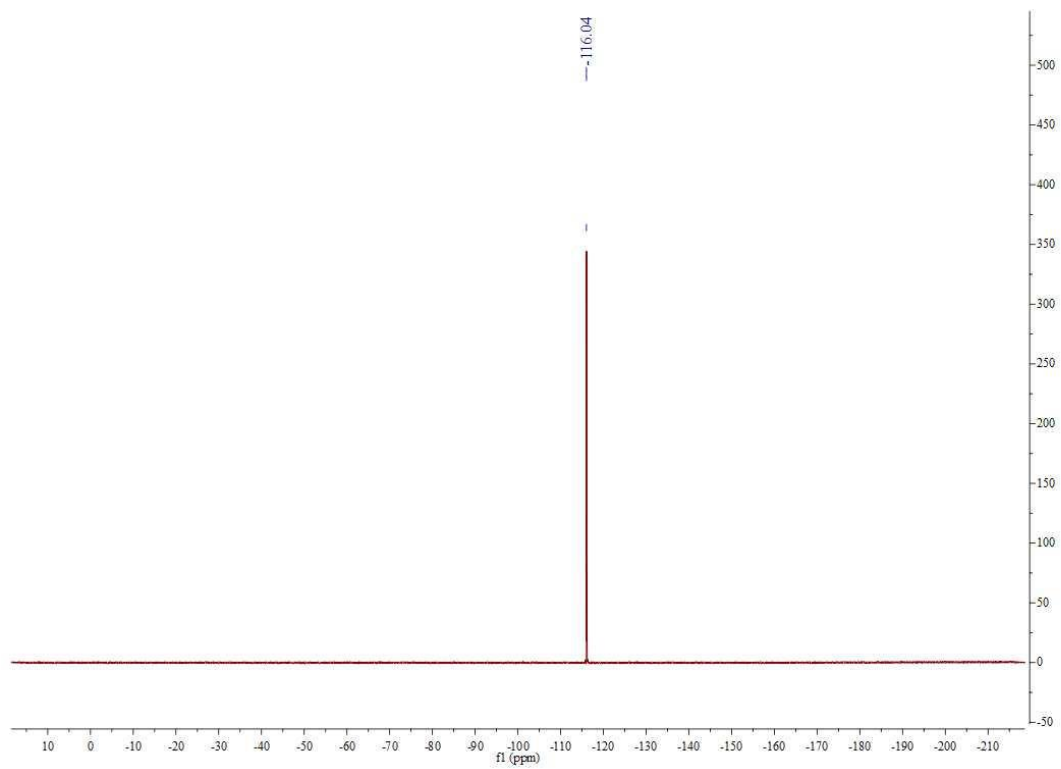
¹³C NMR spectrum of 3ae



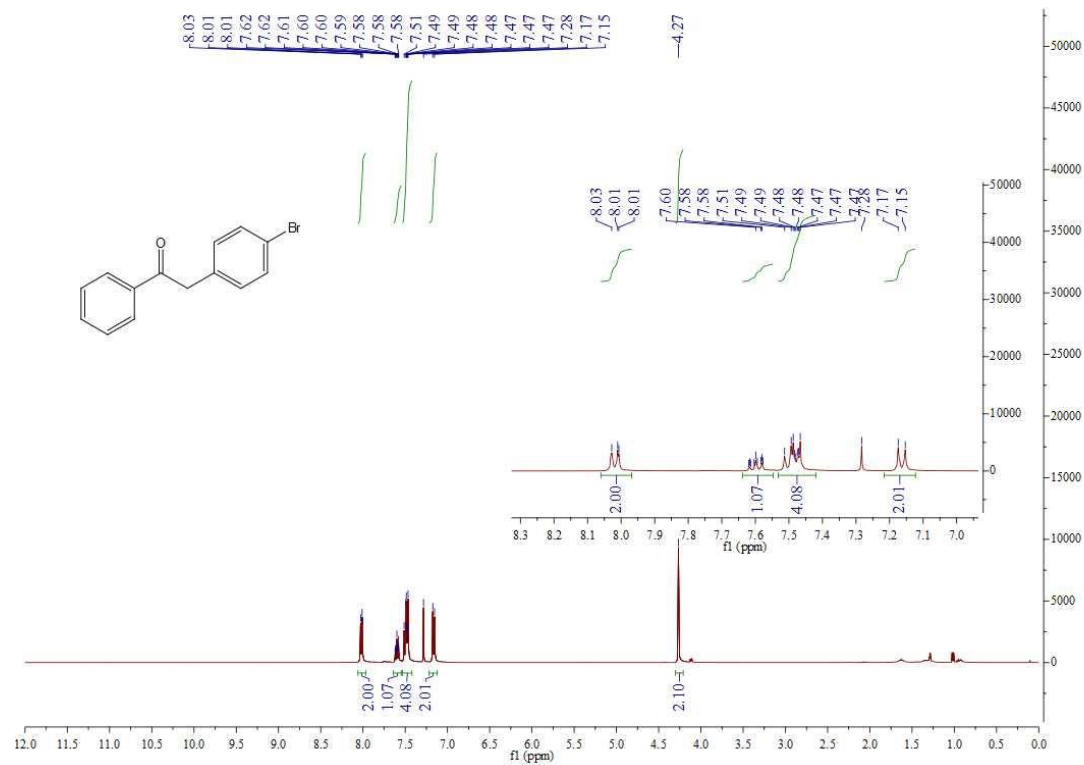
¹H NMR spectrum of 3af



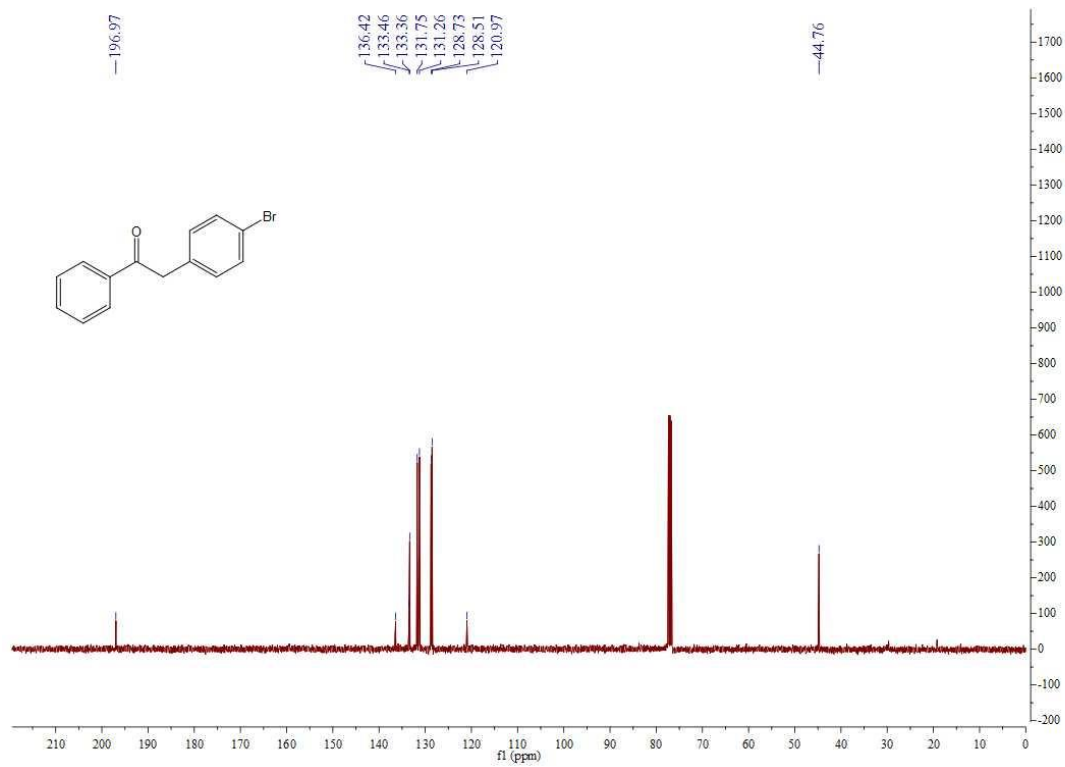
¹³C NMR spectrum of 3af



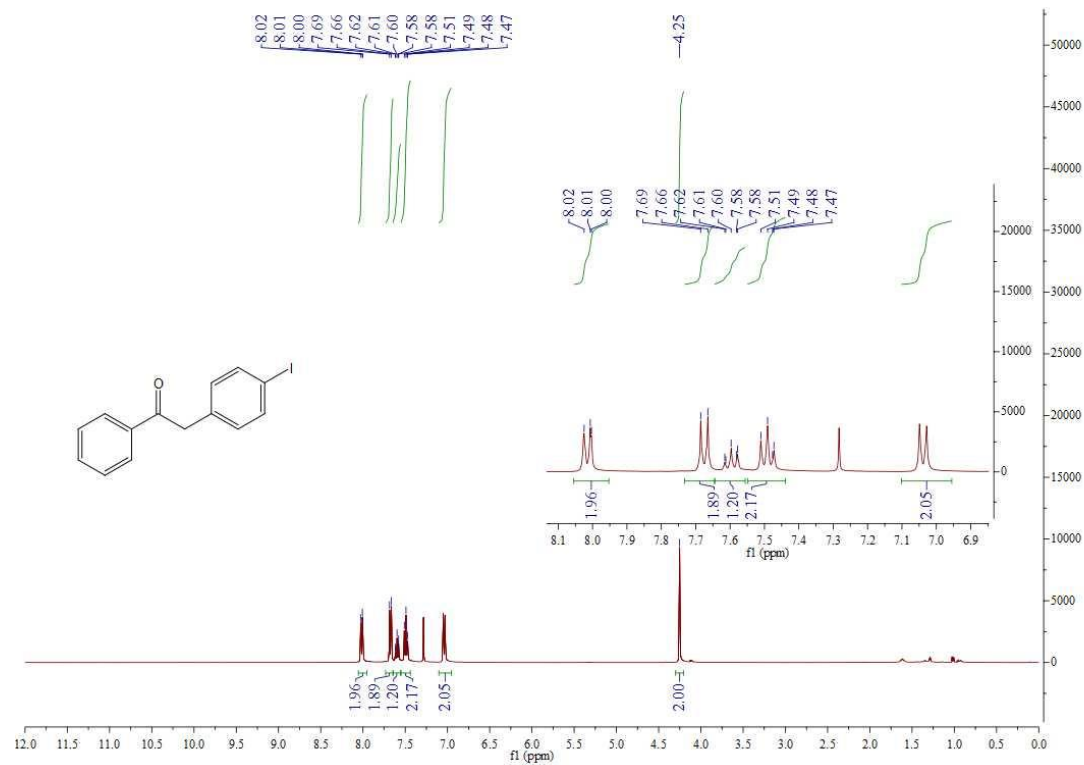
^{19}F NMR spectrum of **3af**



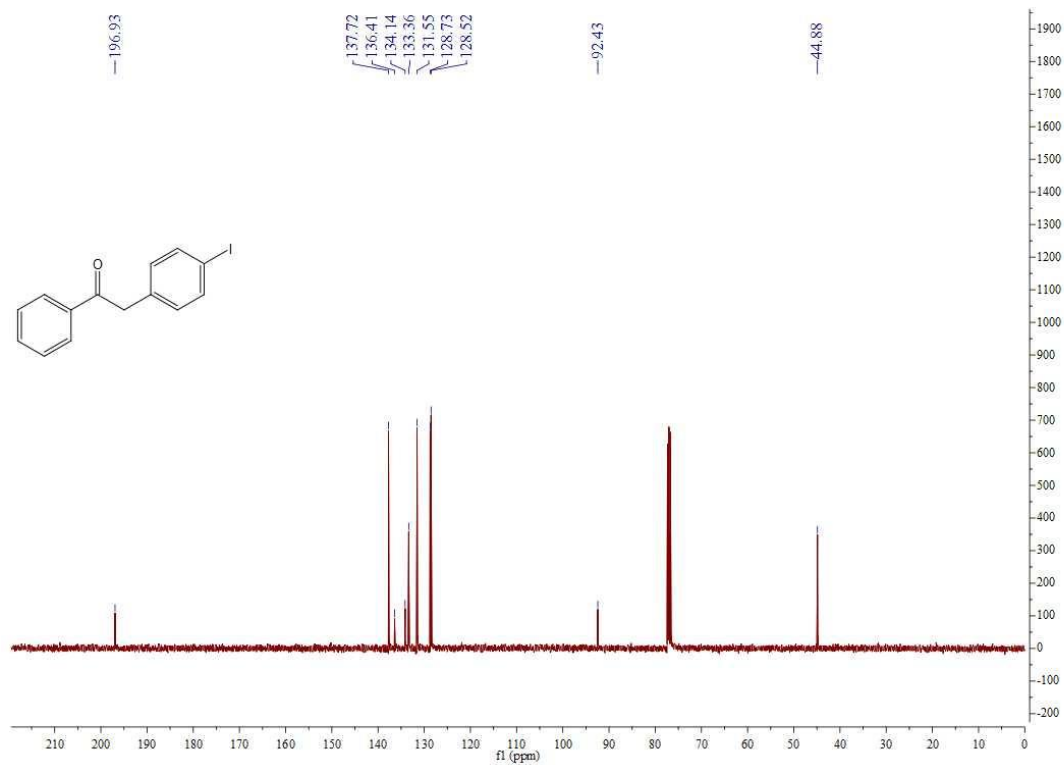
¹H NMR spectrum of 3ag



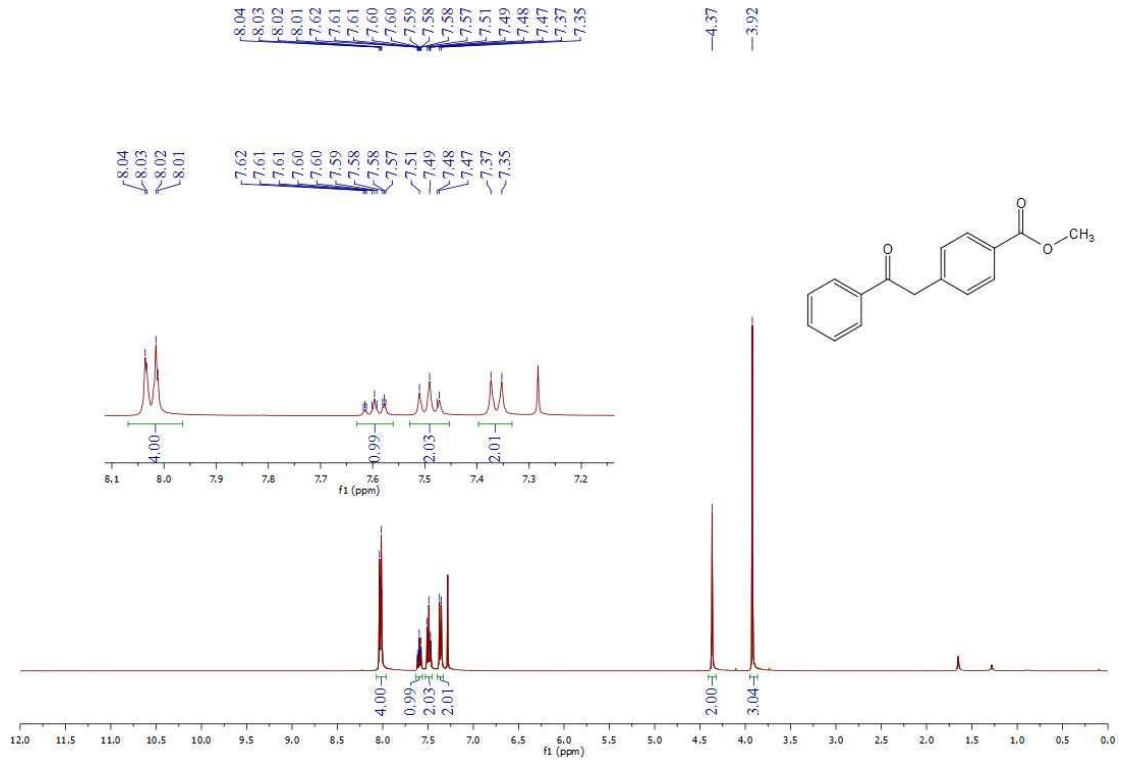
¹³C NMR spectrum of 3ag



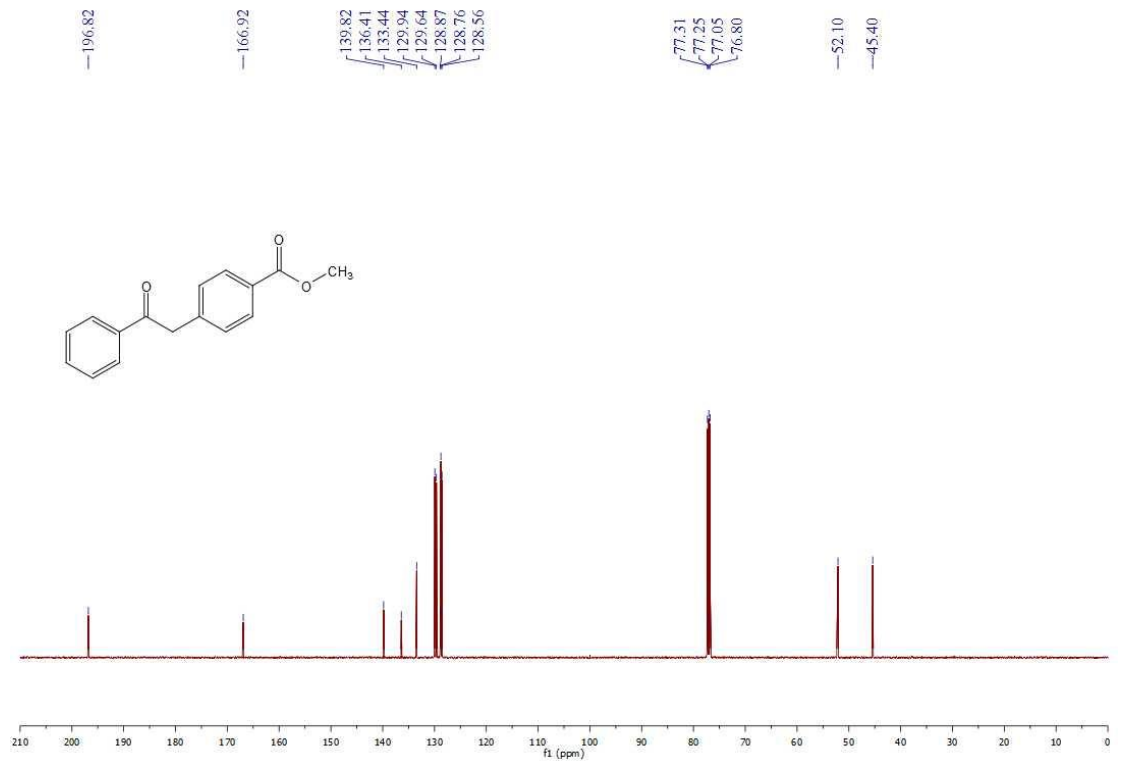
¹H NMR spectrum of 3ah



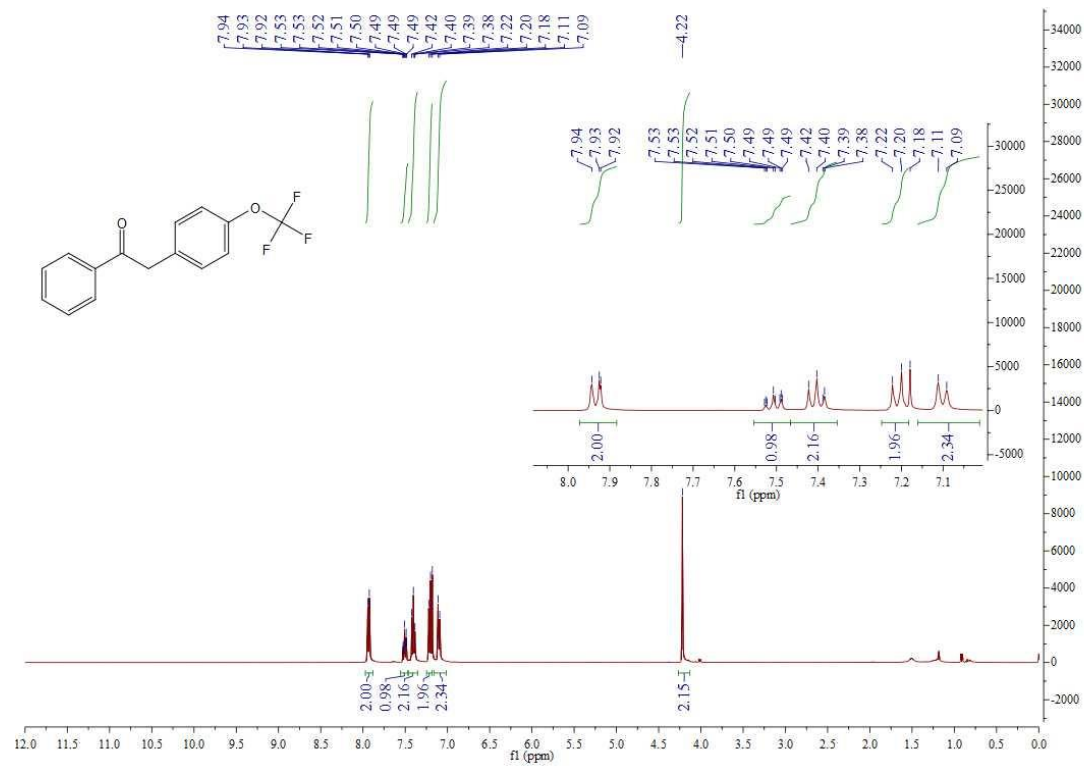
¹³C NMR spectrum of 3ah



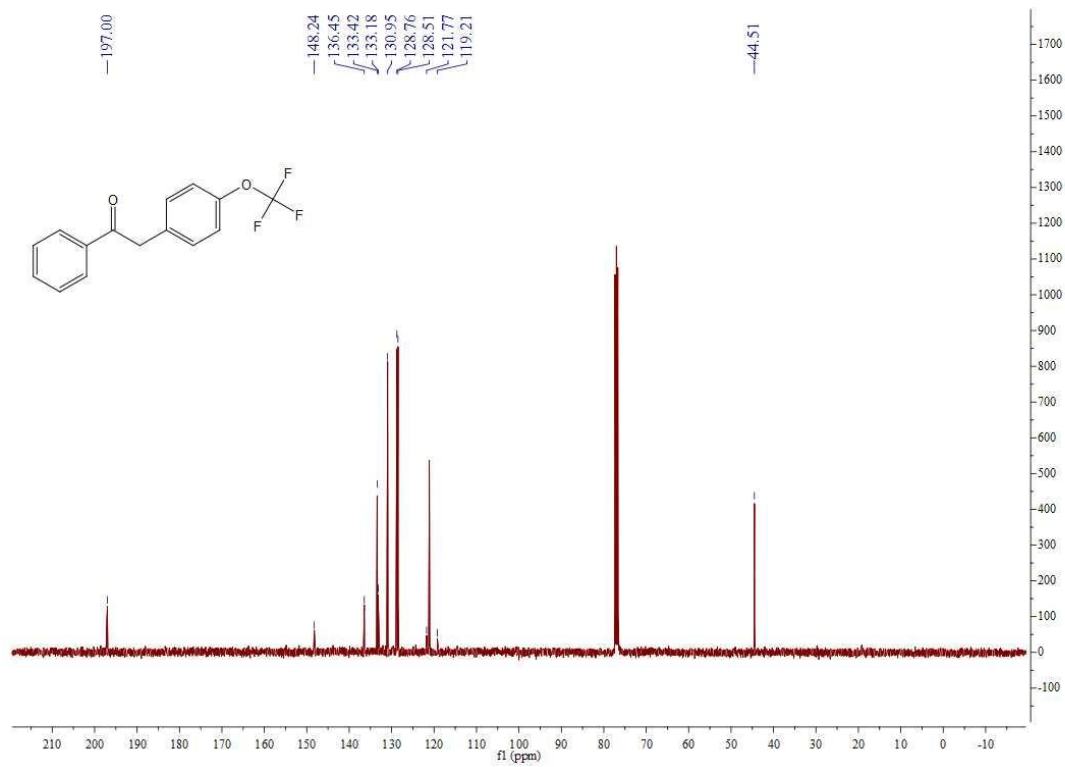
¹H NMR spectrum of 3ai



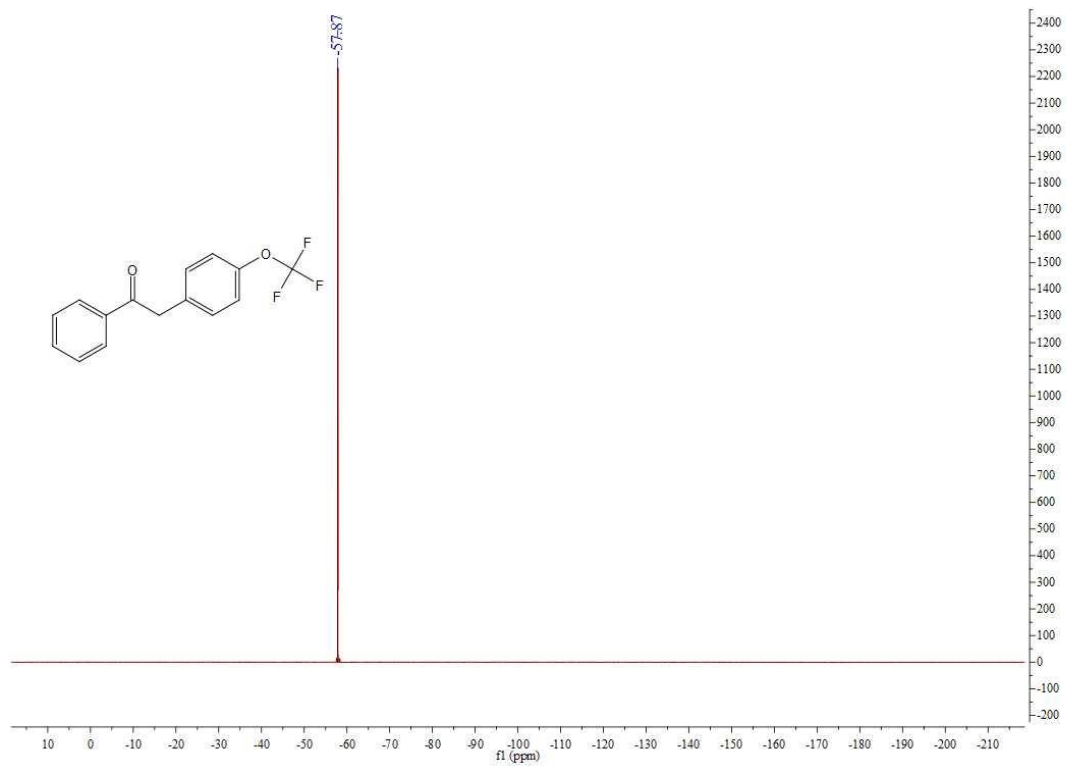
¹³C NMR spectrum of 3ai



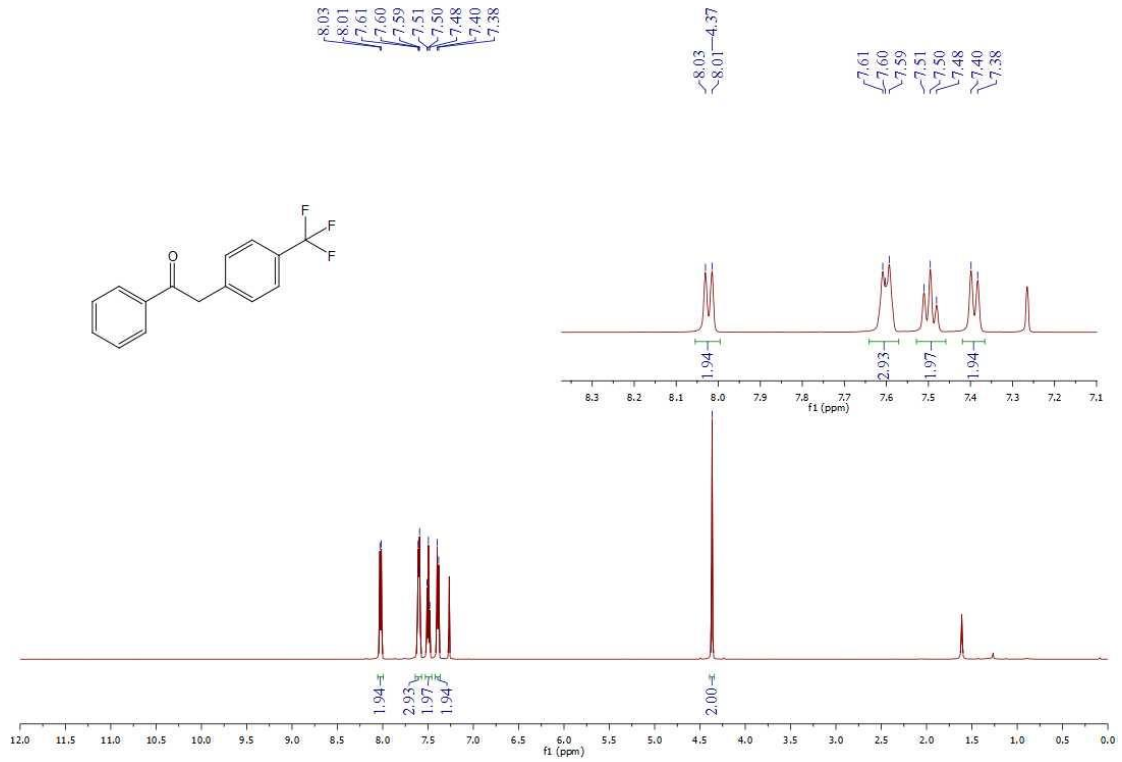
¹H NMR spectrum of 3aj



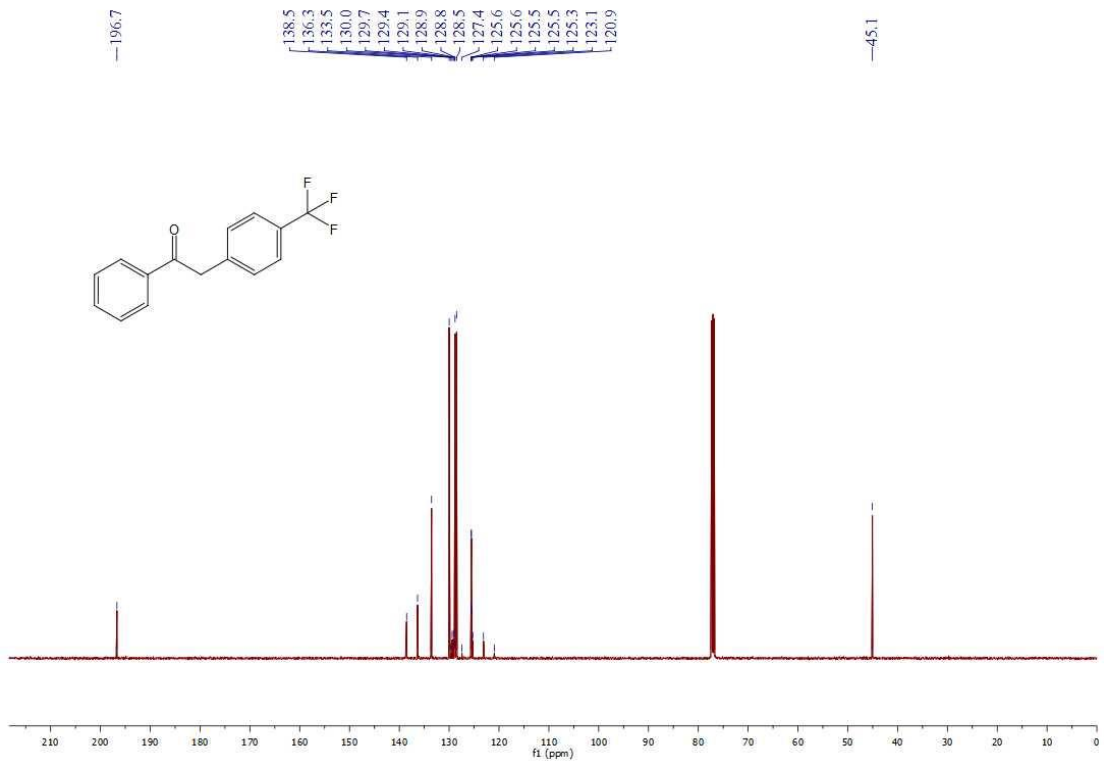
¹³C NMR spectrum of 3aj



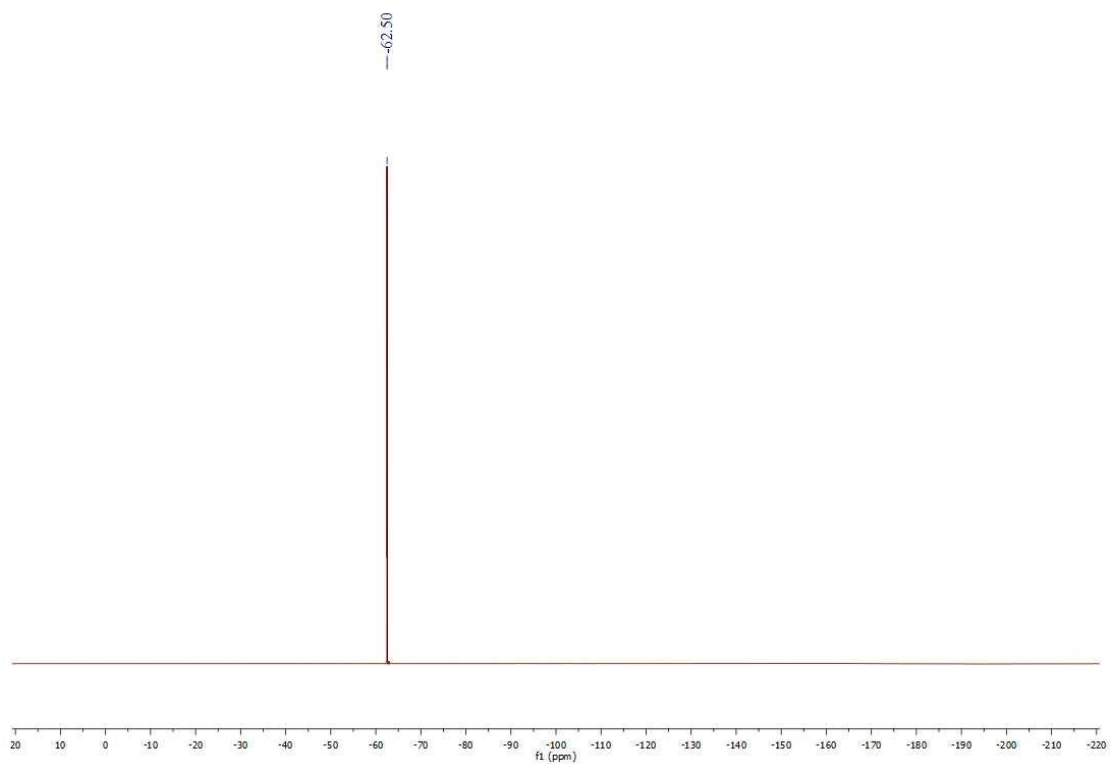
^{19}F NMR spectrum of **3aj**



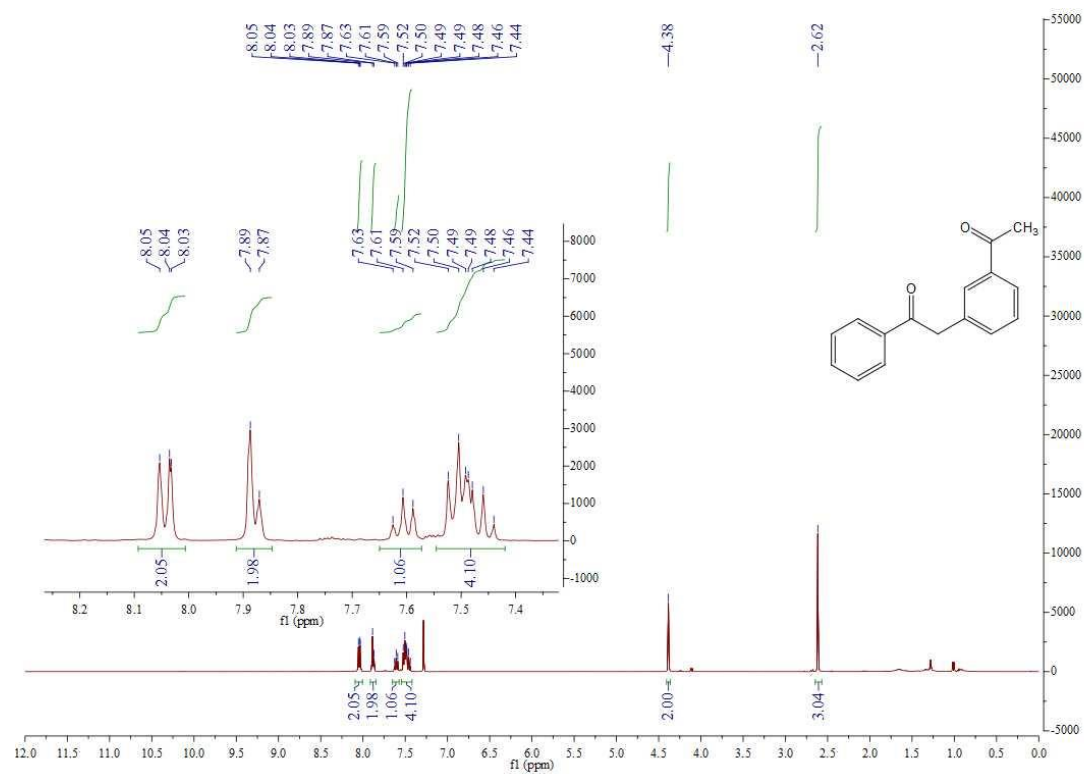
¹H NMR spectrum of **3ak**



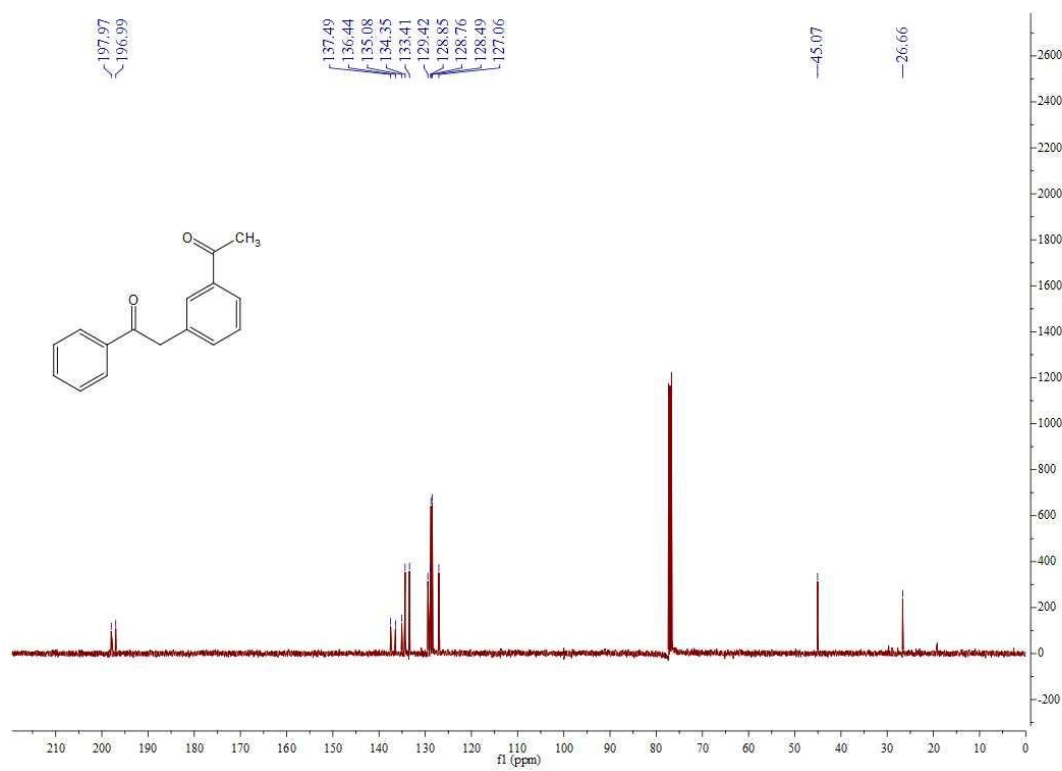
¹³C NMR spectrum of **3ak**



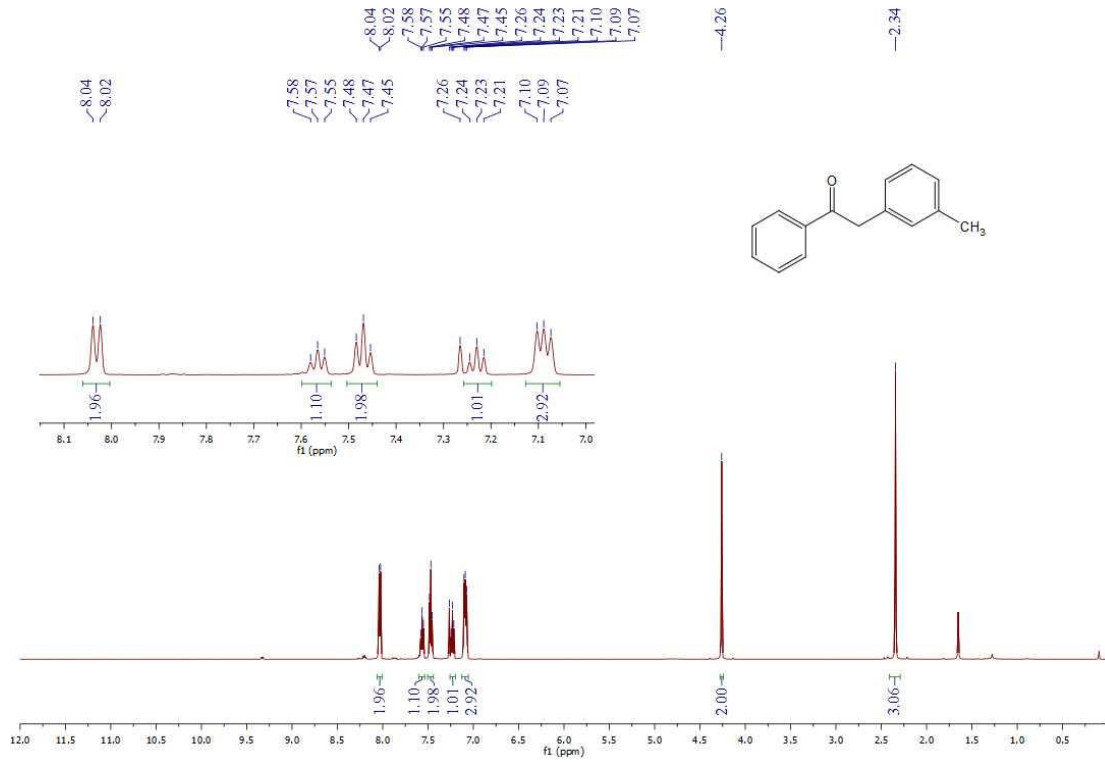
^{19}F NMR spectrum of **3ak**



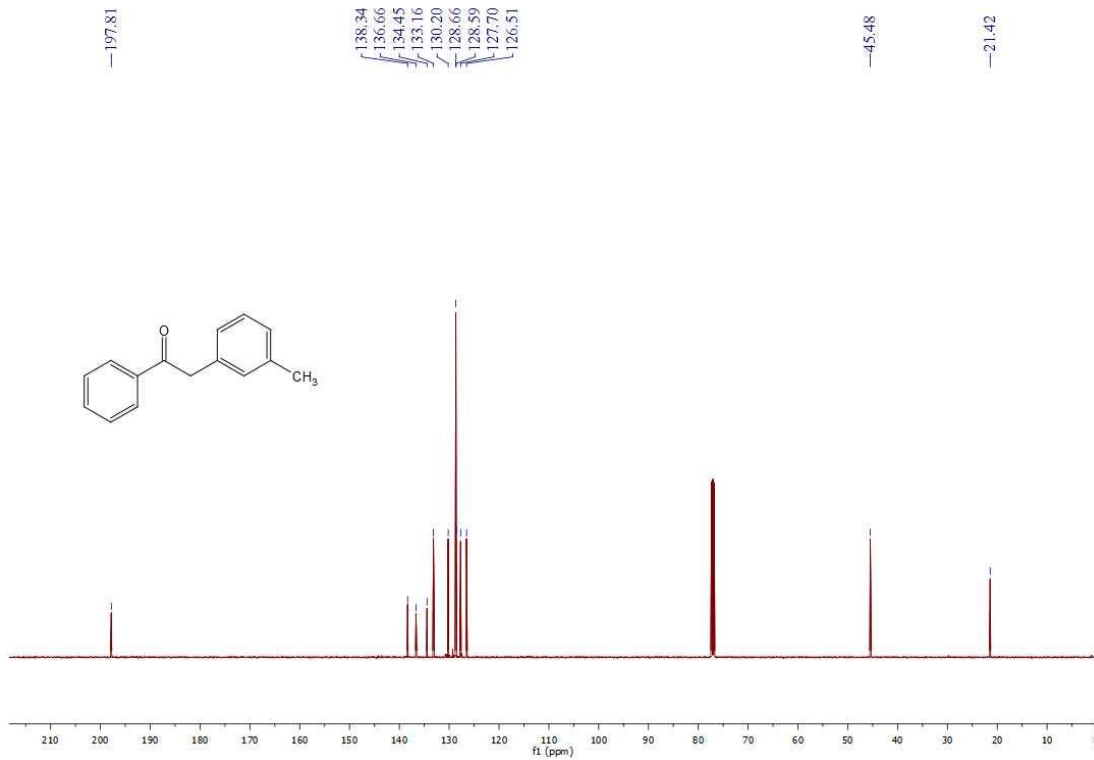
¹H NMR spectrum of 3am



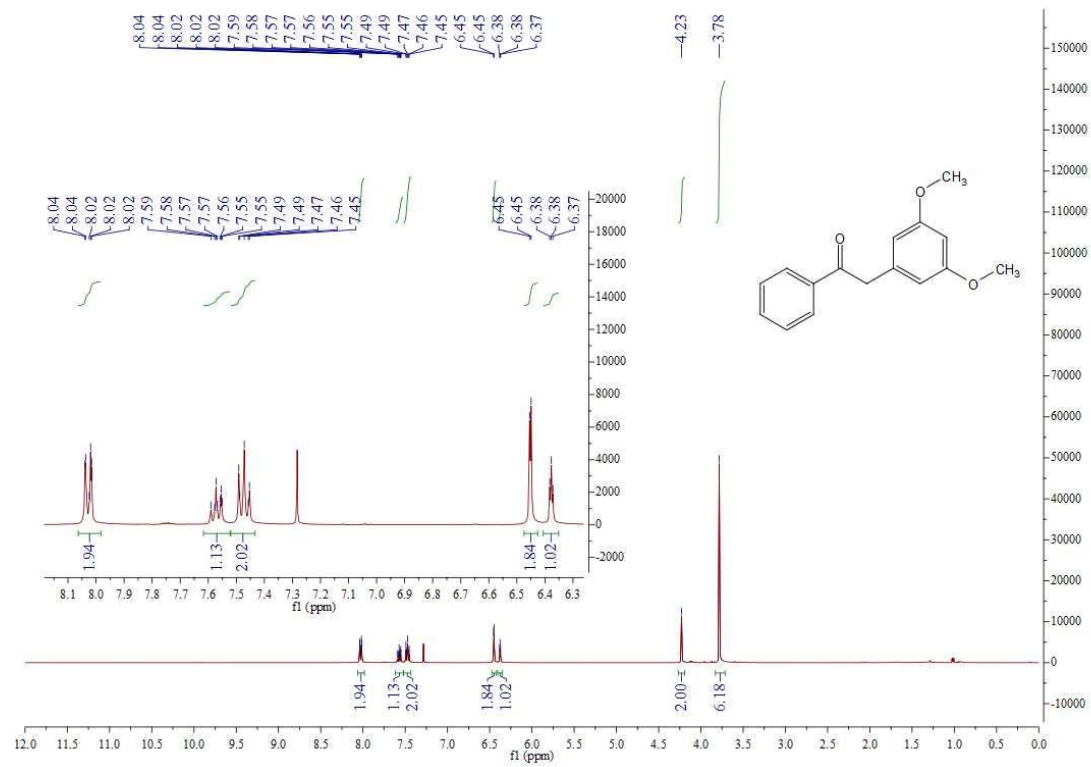
¹³C NMR spectrum of 3am



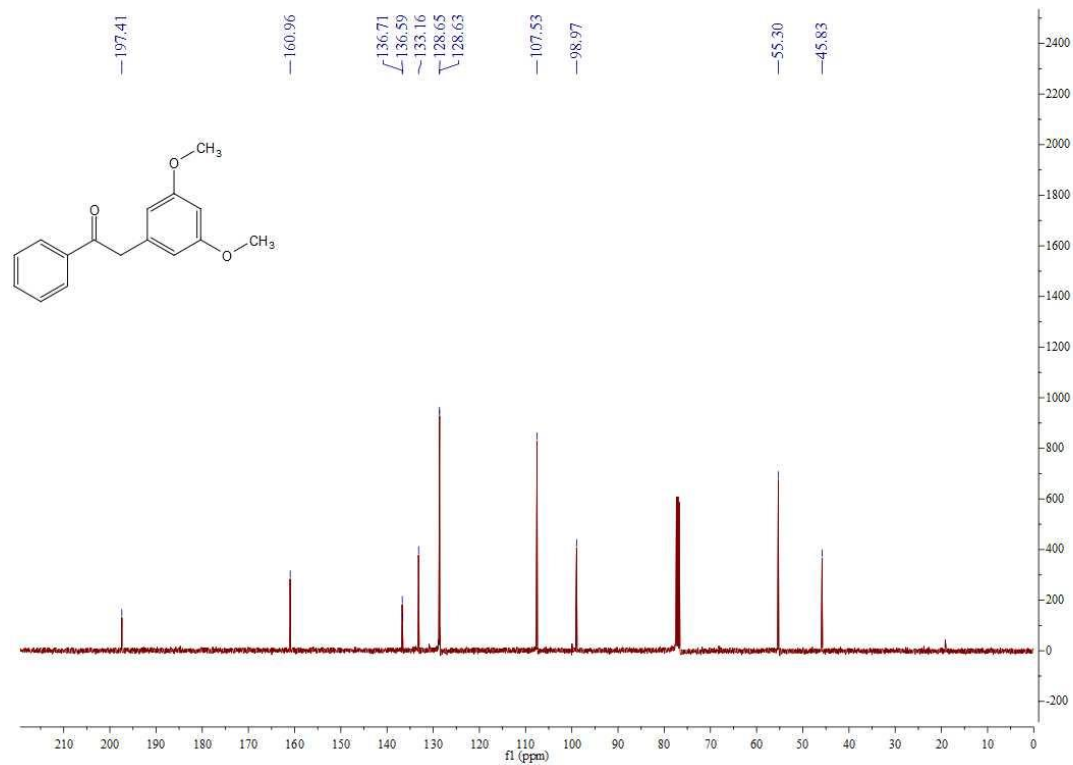
¹H NMR spectrum of **3an**



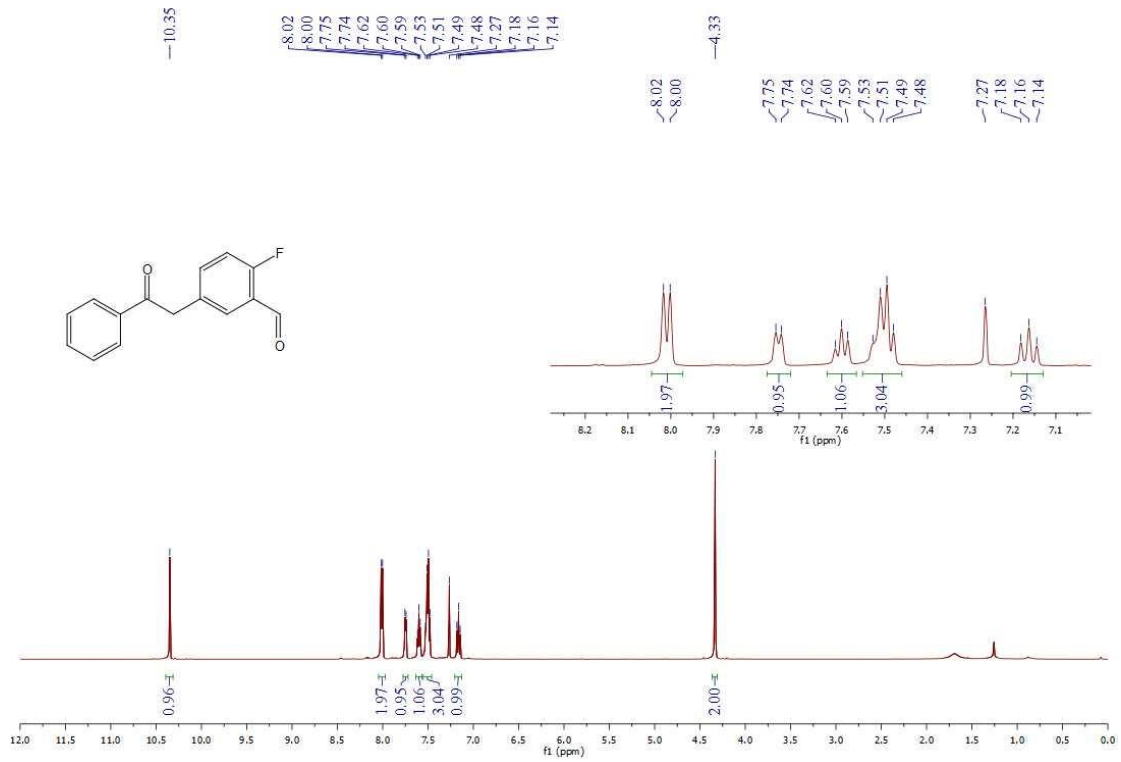
¹³C NMR spectrum of **3an**



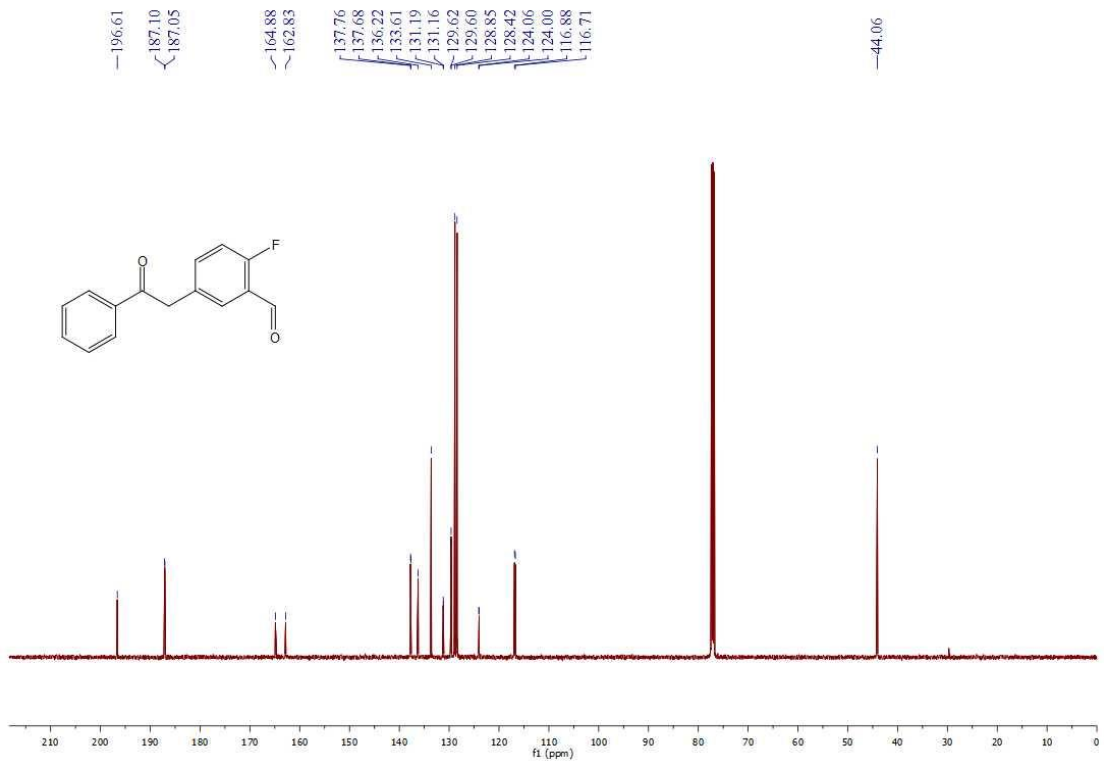
¹H NMR spectrum of 3ao



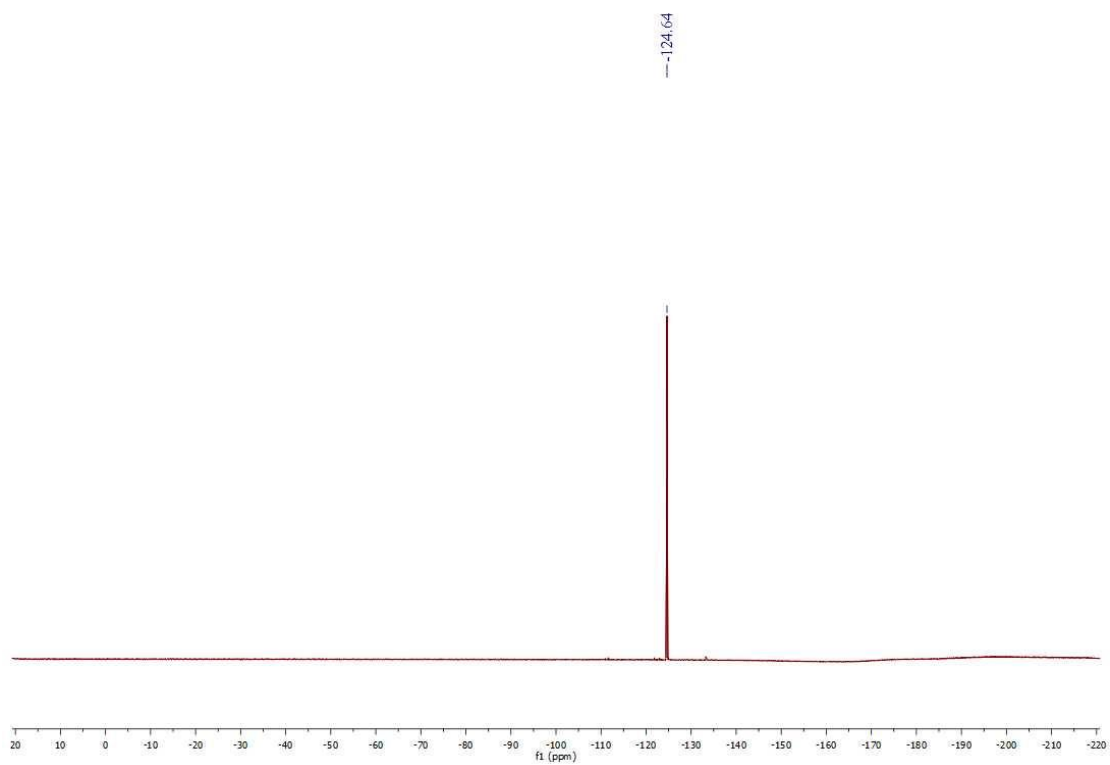
¹³C NMR spectrum of 3ao



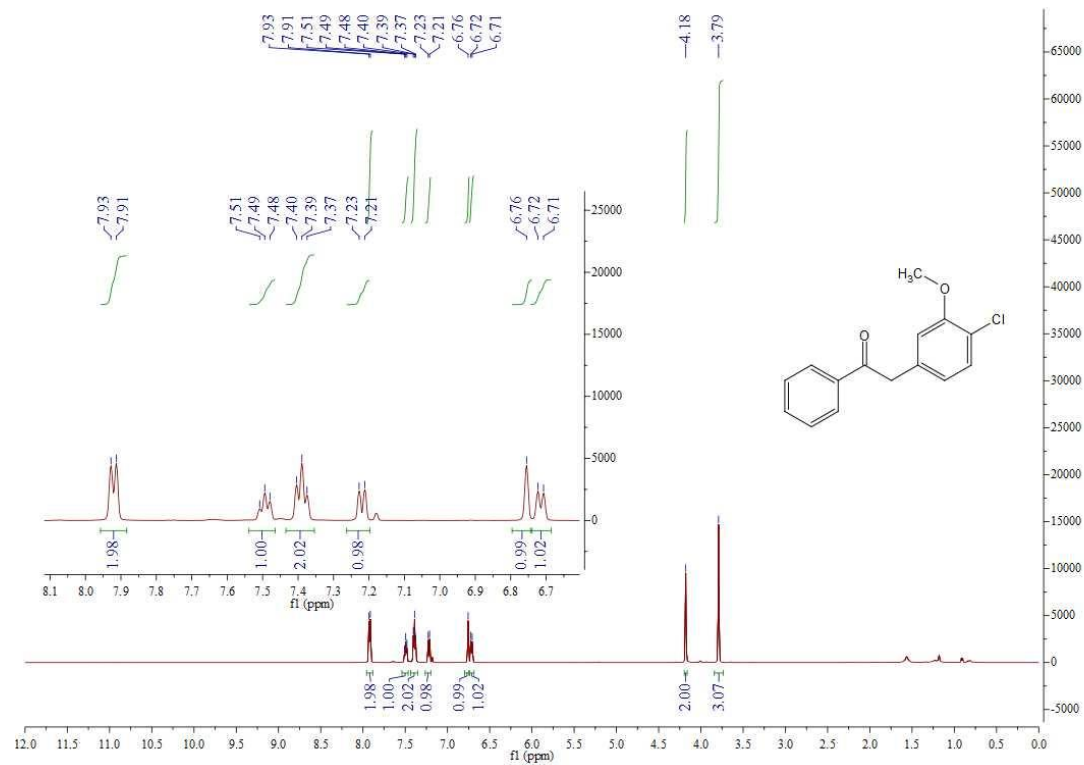
¹H NMR spectrum of 3ap



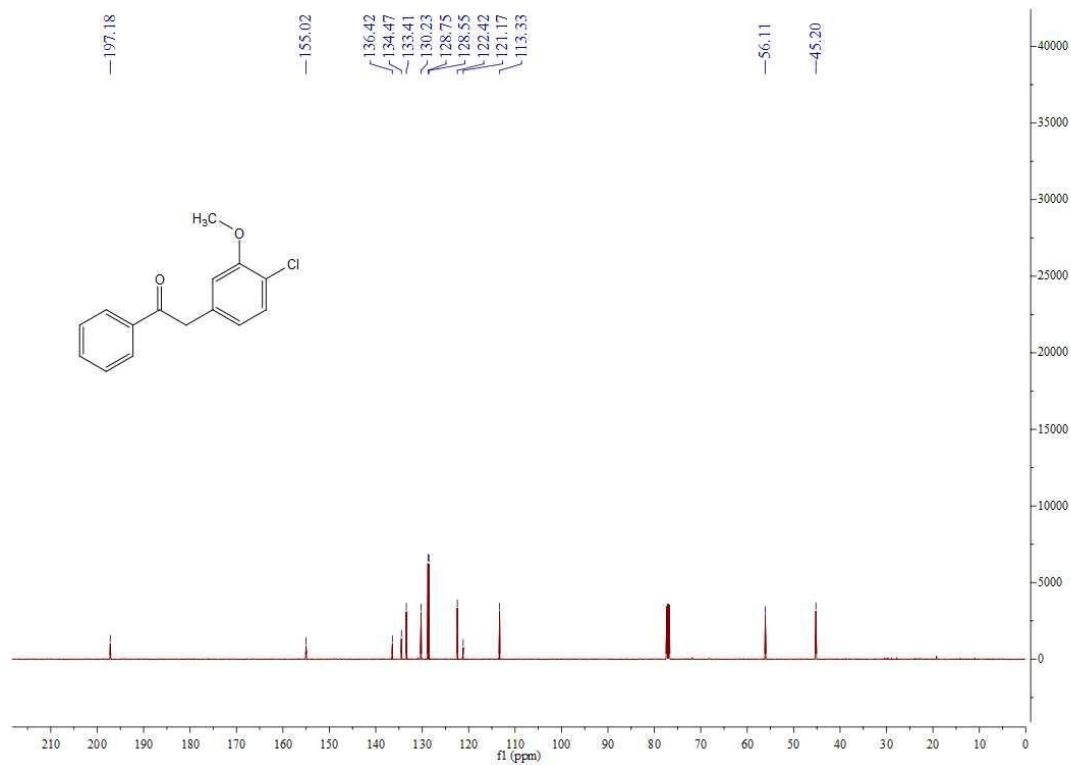
¹³C NMR spectrum of 3ap



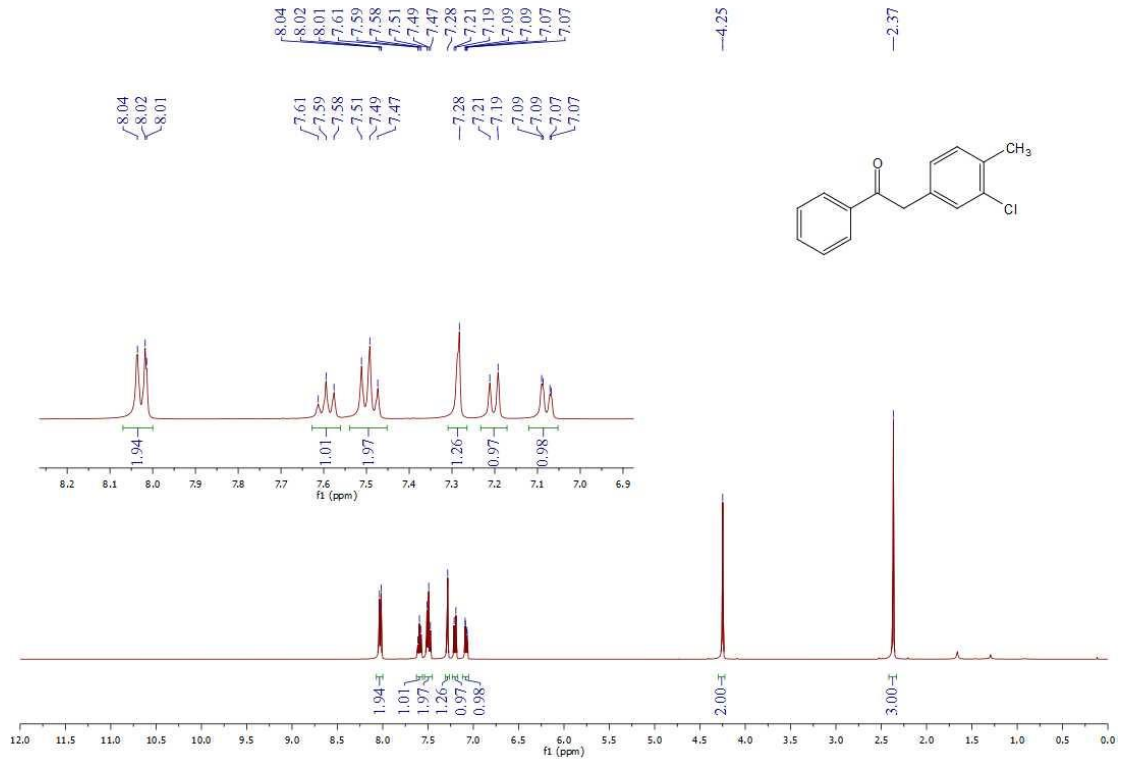
^{19}F NMR spectrum of **3ap**



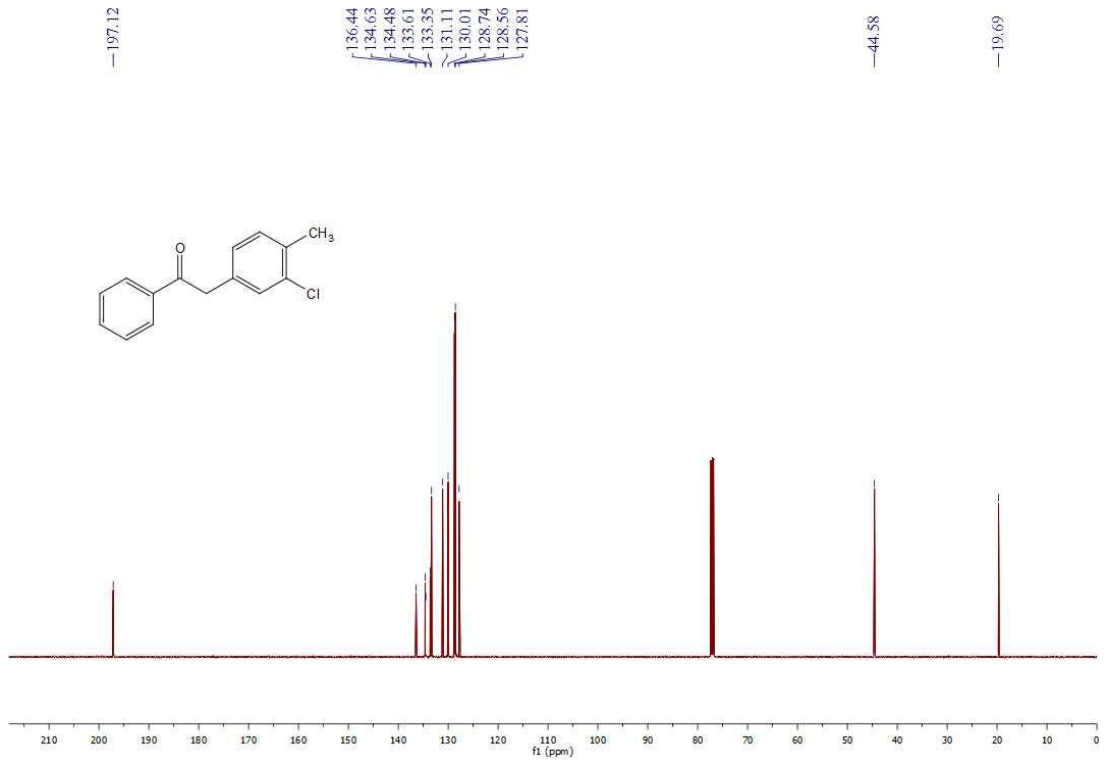
¹H NMR spectrum of 3aq



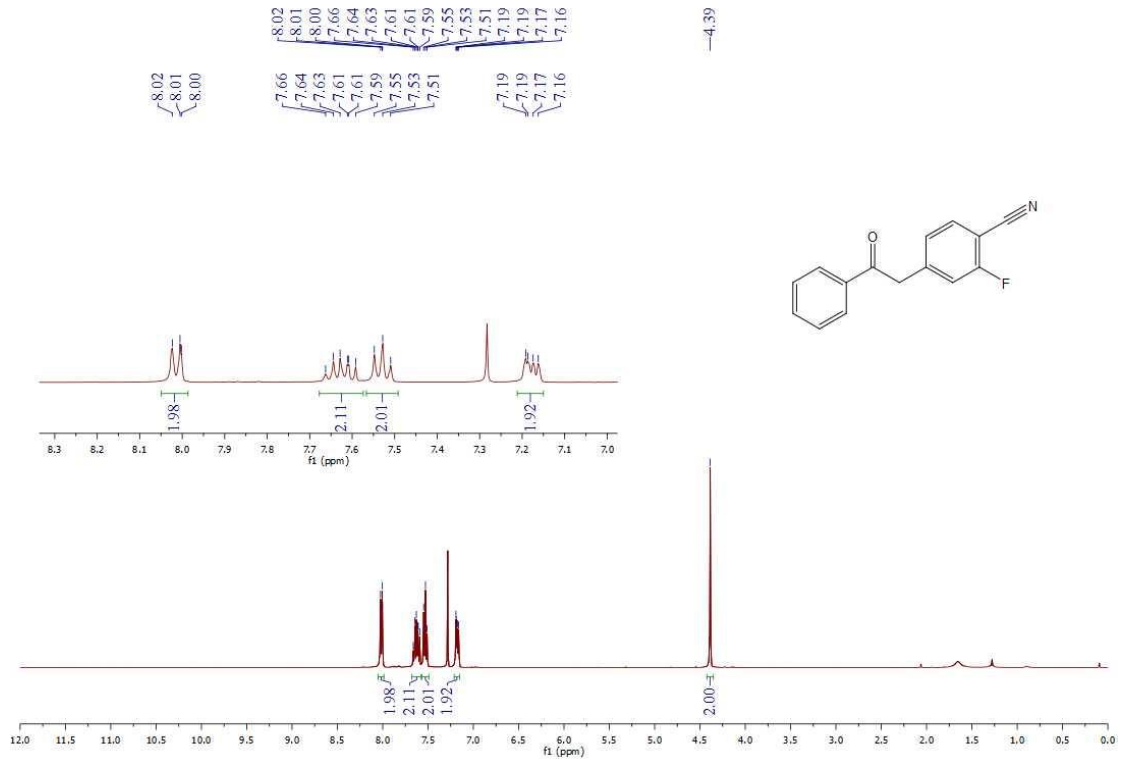
¹³C NMR spectrum of 3aq



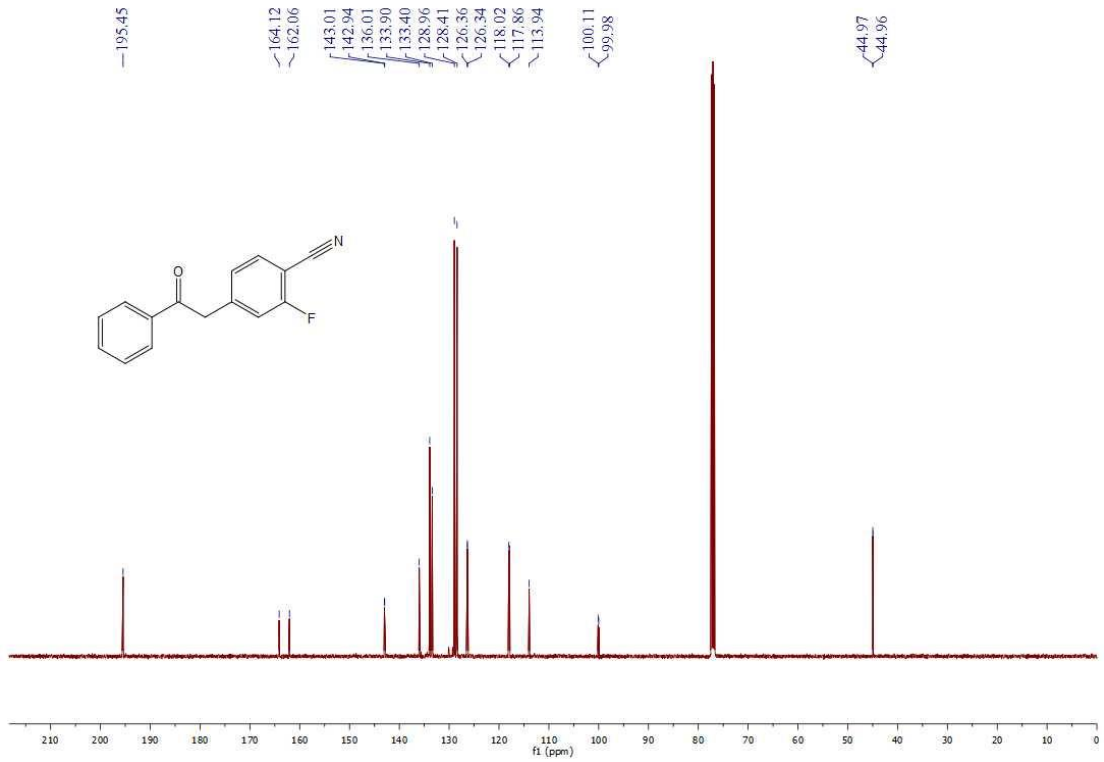
¹H NMR spectrum of **3ar**



¹³C NMR spectrum of **3ar**



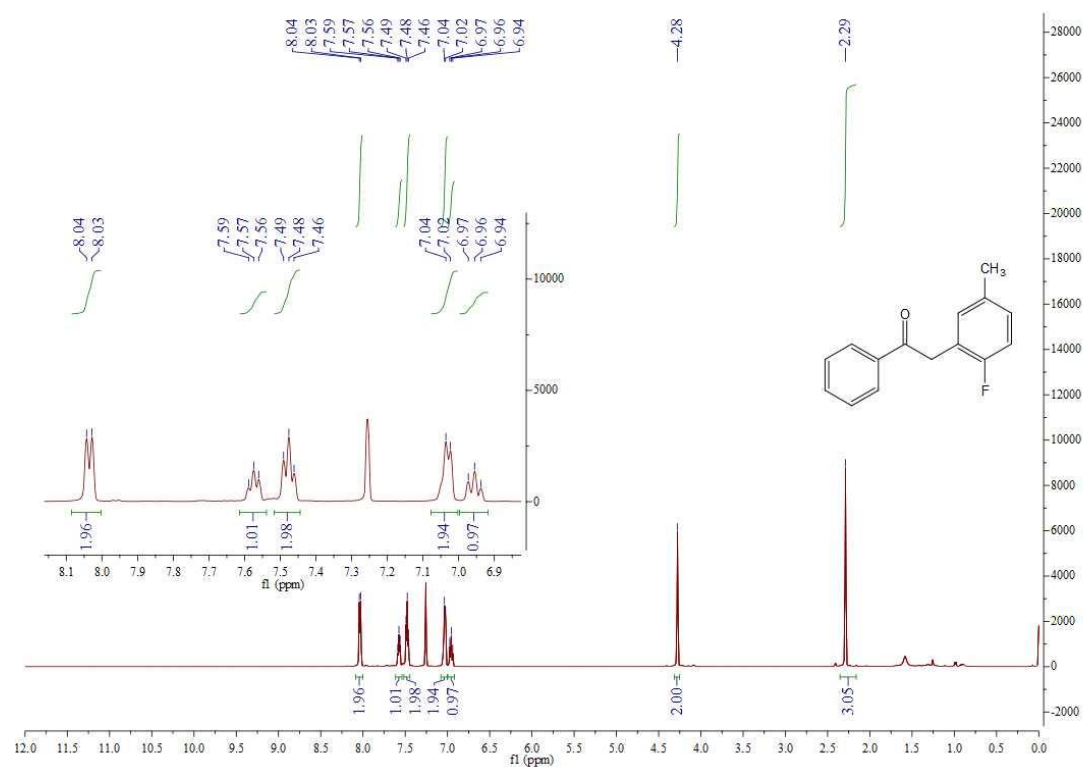
¹H NMR spectrum of 3as



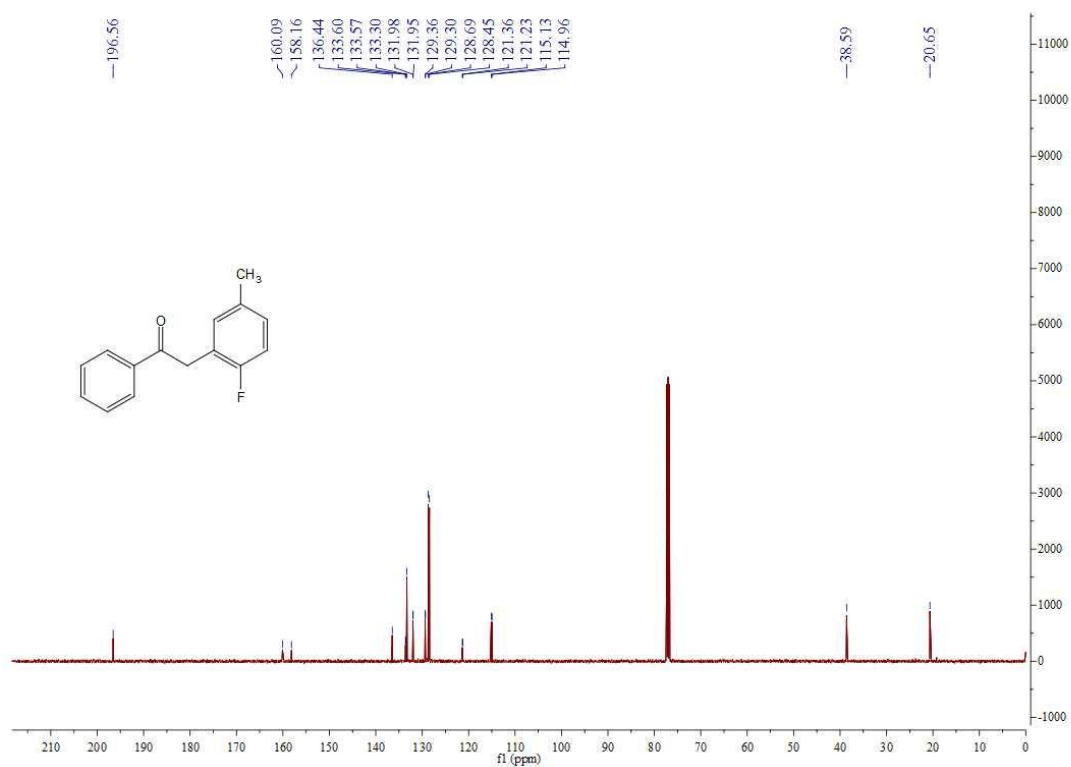
¹³C NMR spectrum of 3as



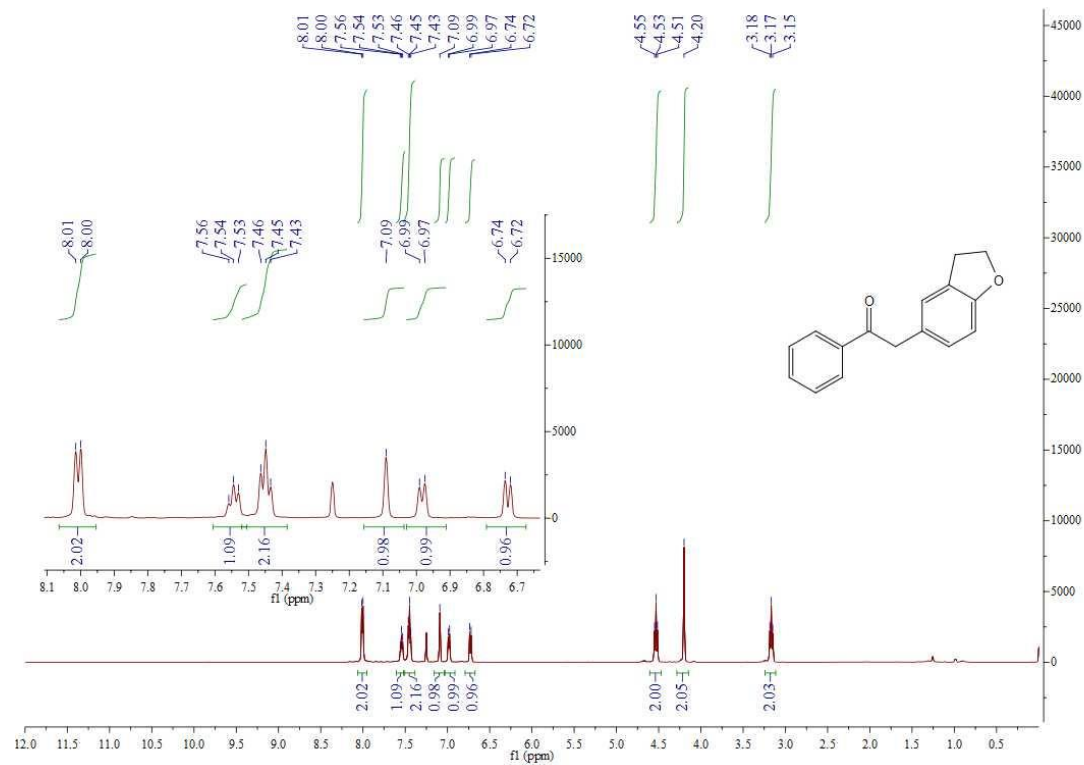
^{19}F NMR spectrum of **3as**



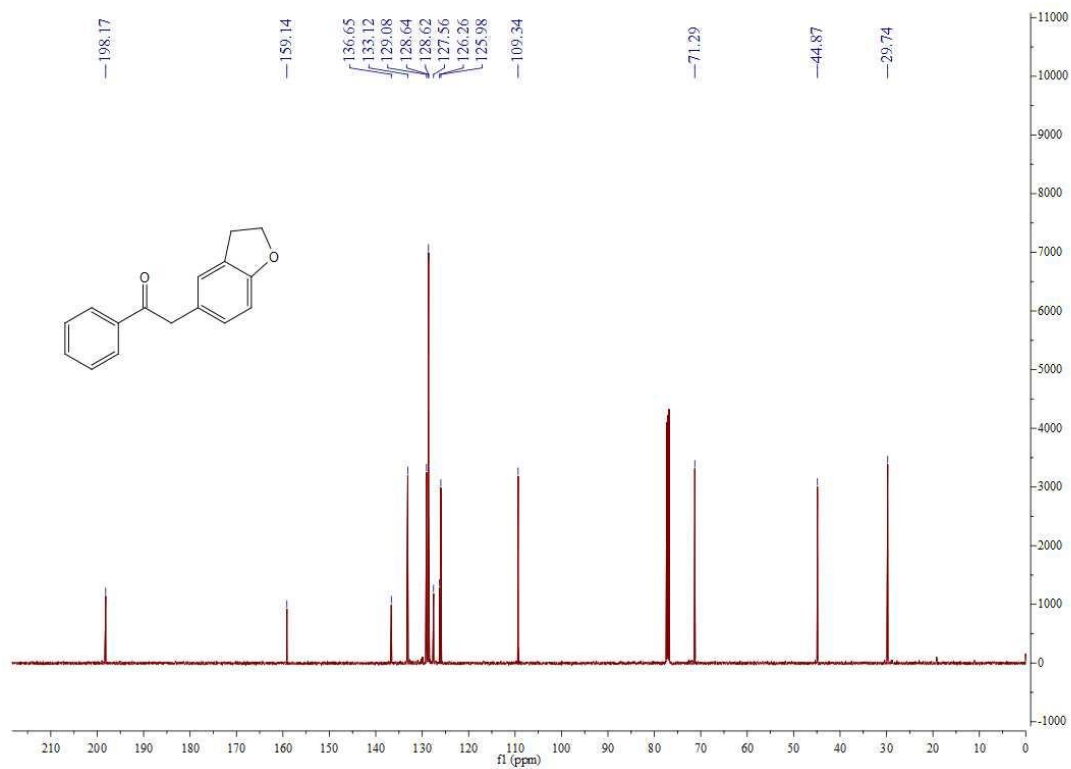
¹H NMR spectrum of 3at



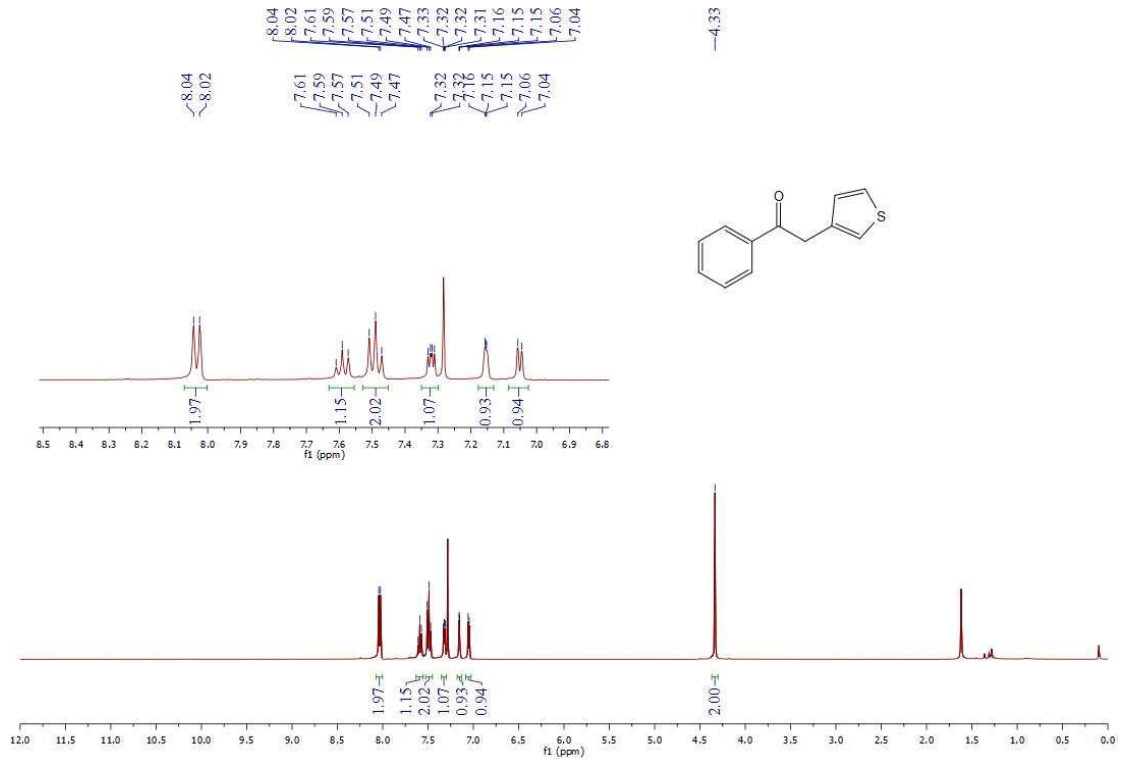
¹³C NMR spectrum of 3at



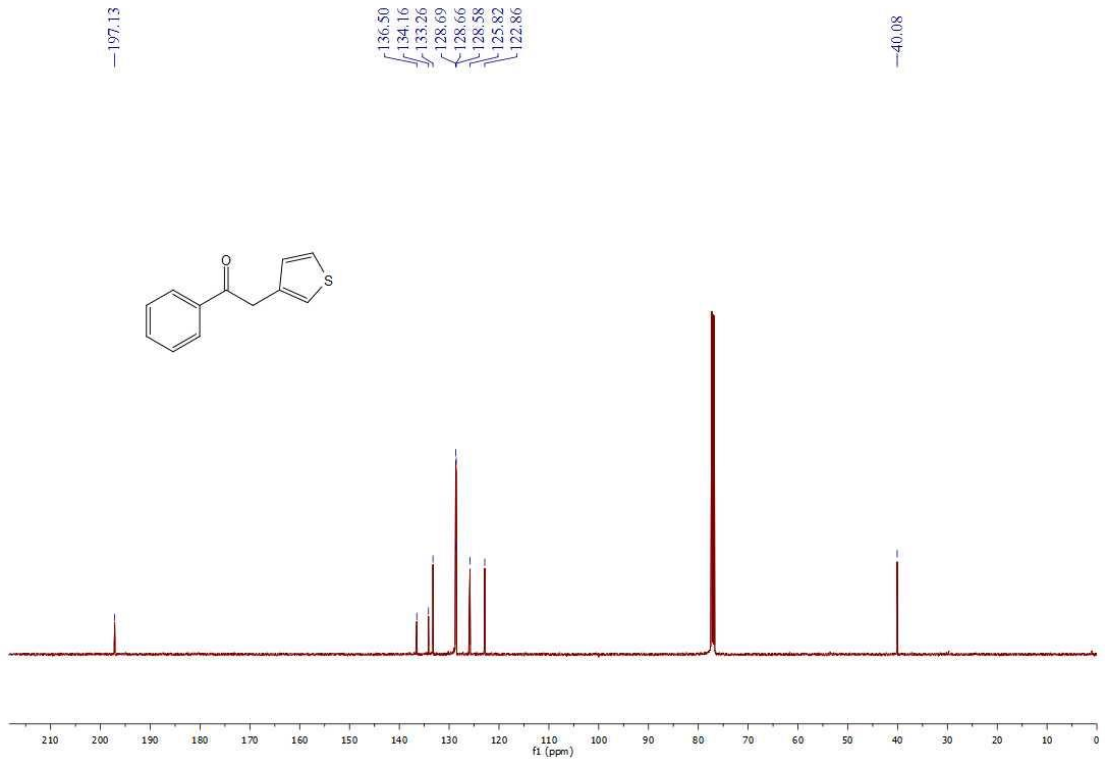
^1H NMR spectrum of **3au**



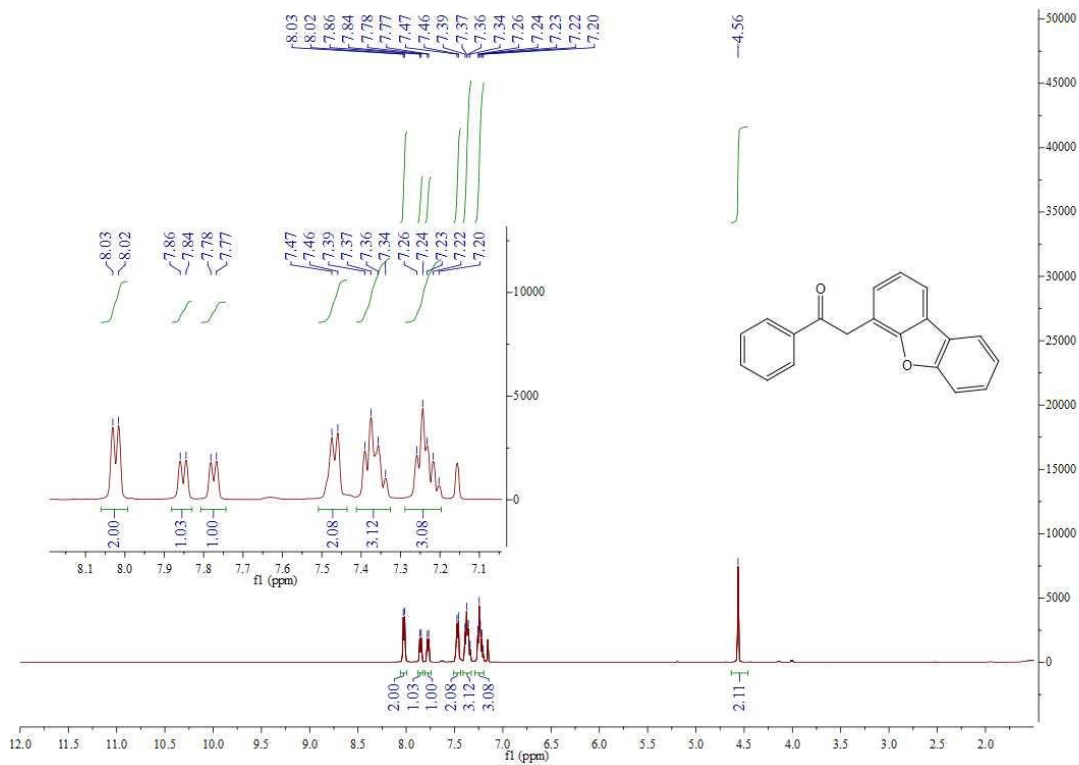
^{13}C NMR spectrum of **3au**



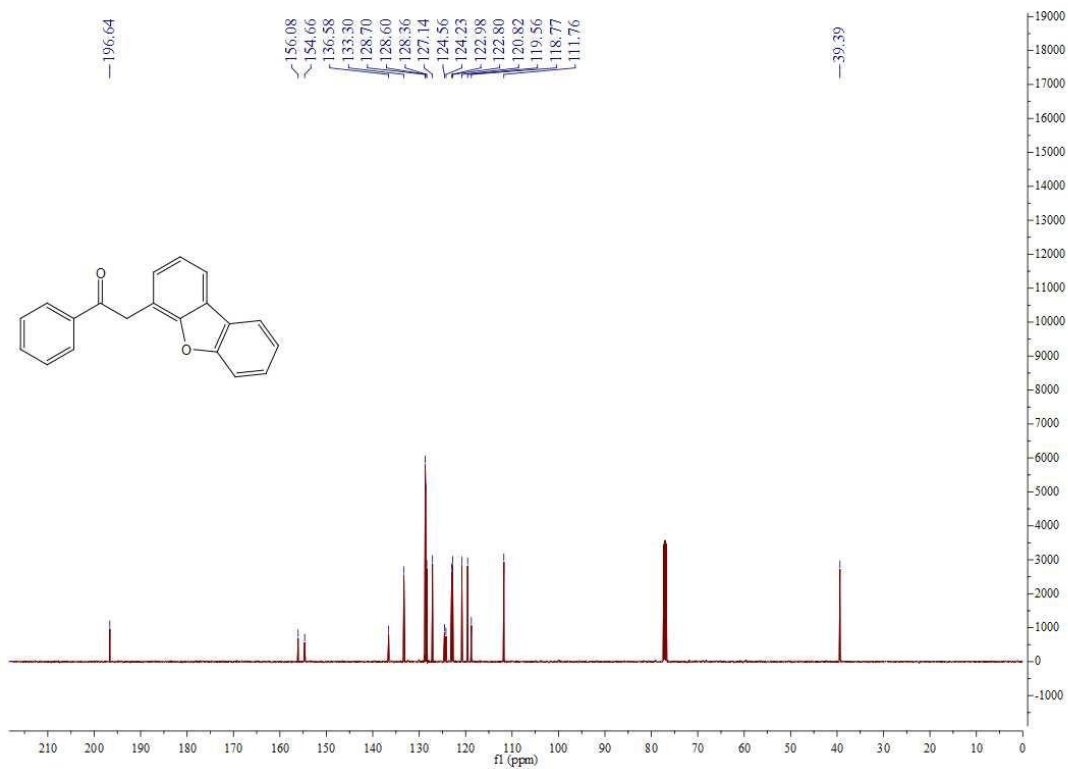
¹H NMR spectrum of 3aw



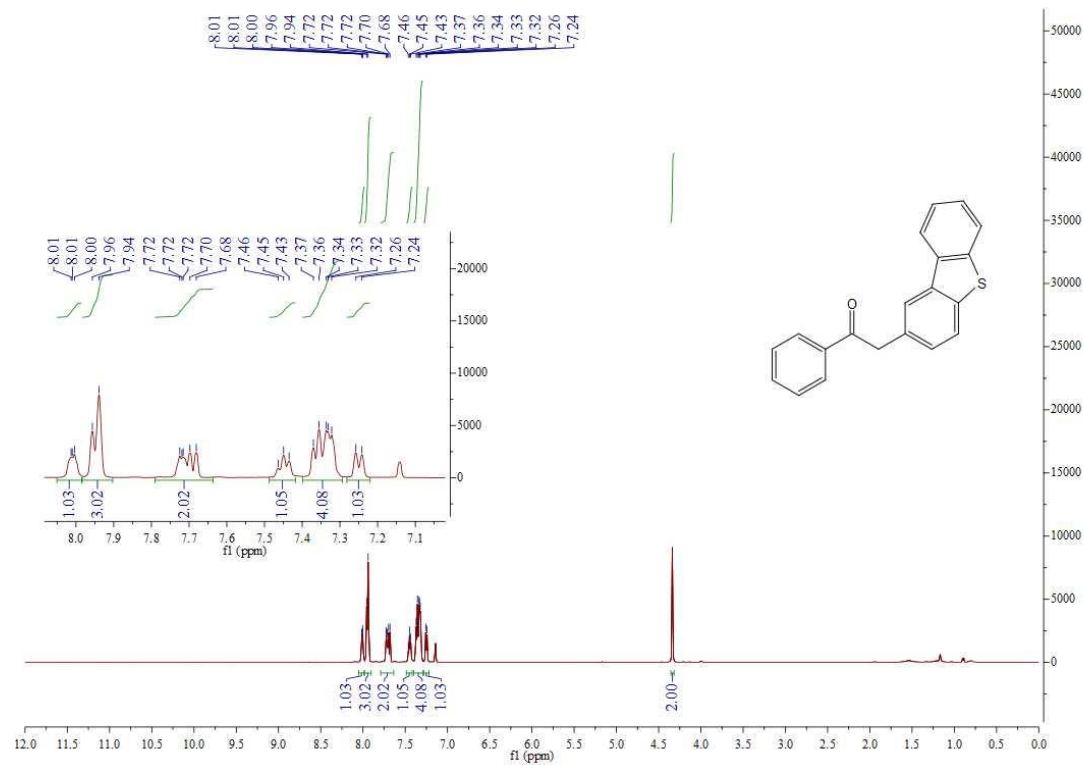
¹³C NMR spectrum of 3aw



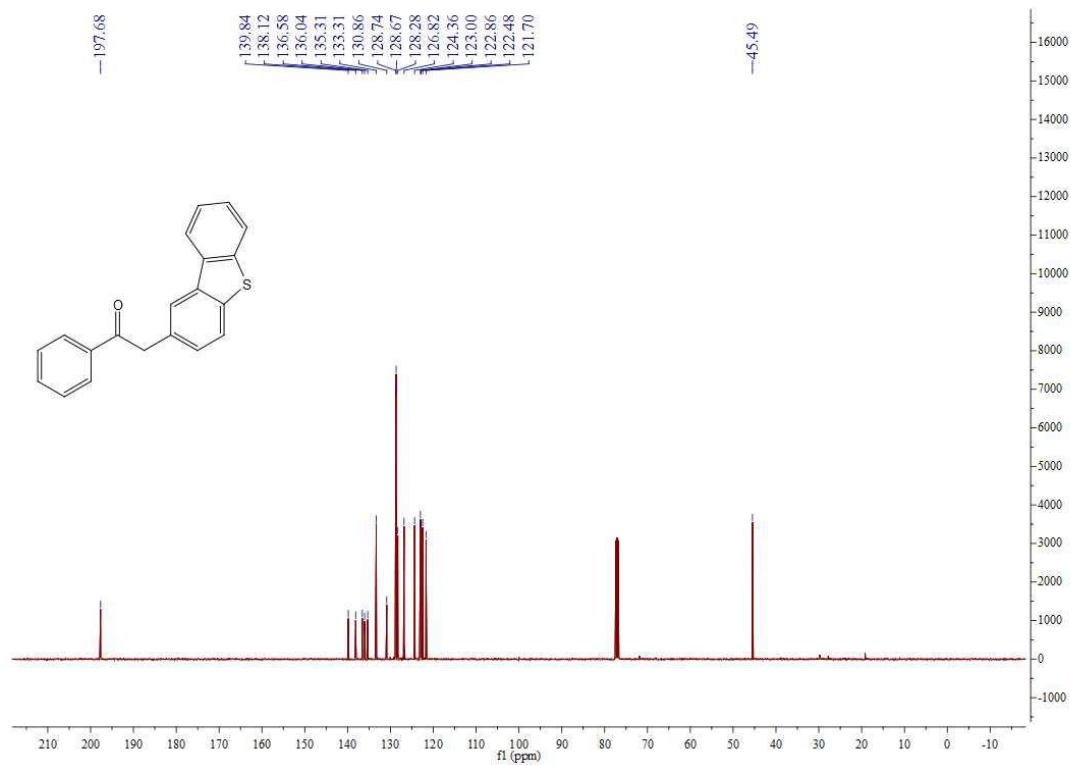
¹H NMR spectrum of 3ay



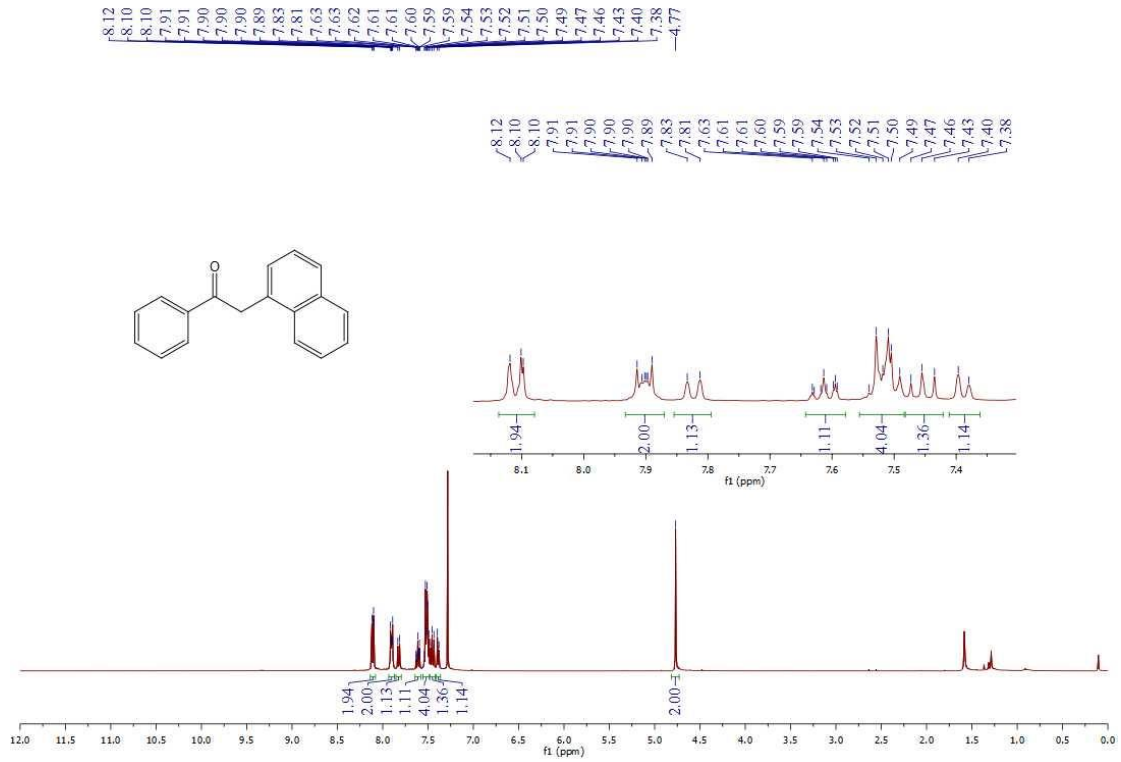
¹³C NMR spectrum of 3ay



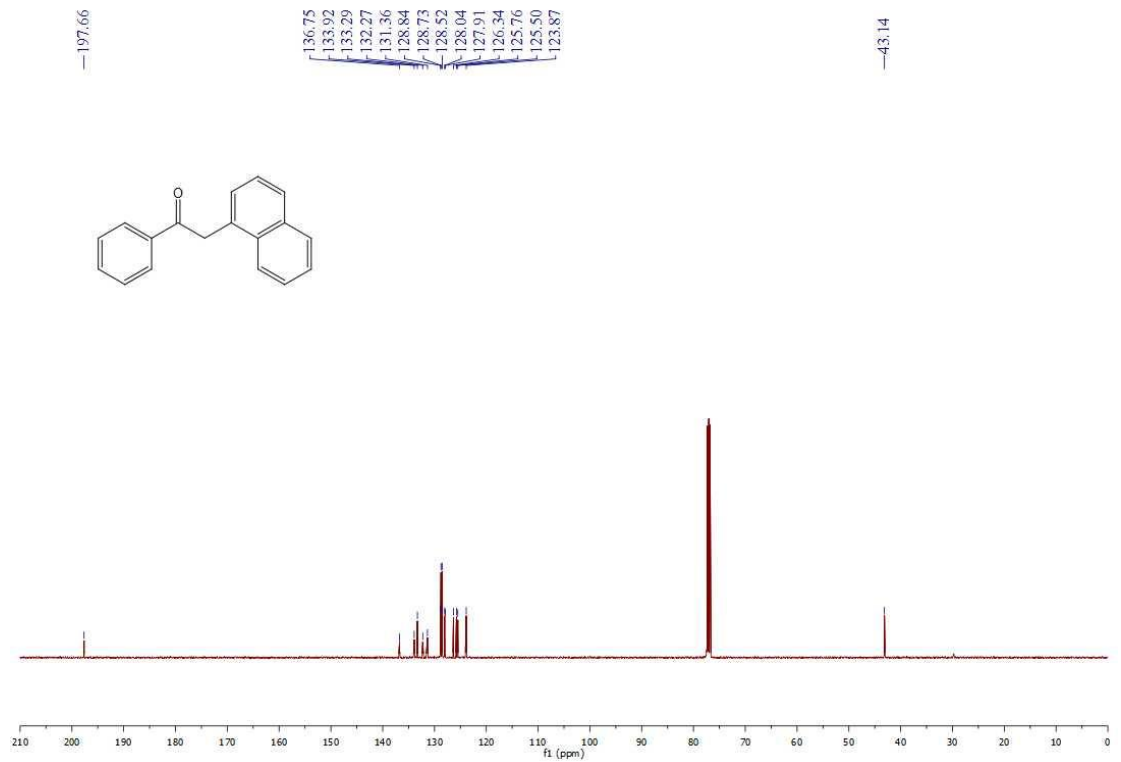
¹H NMR spectrum of **3az**



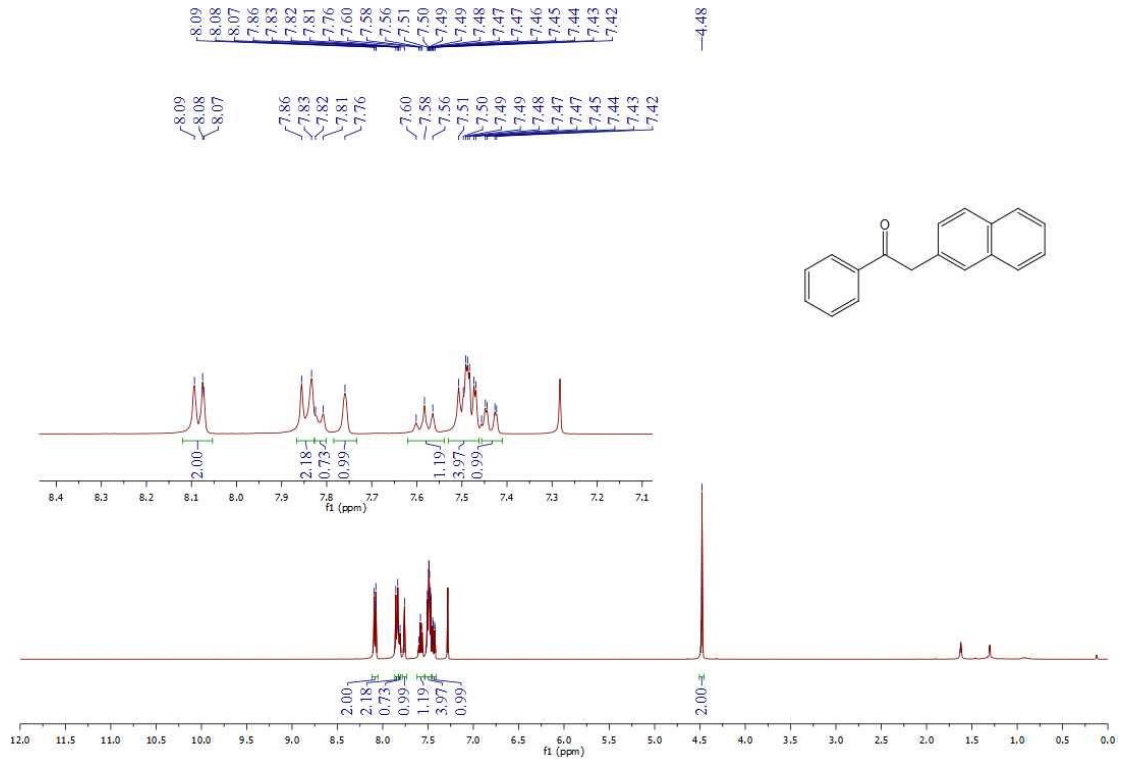
¹³C NMR spectrum of **3az**



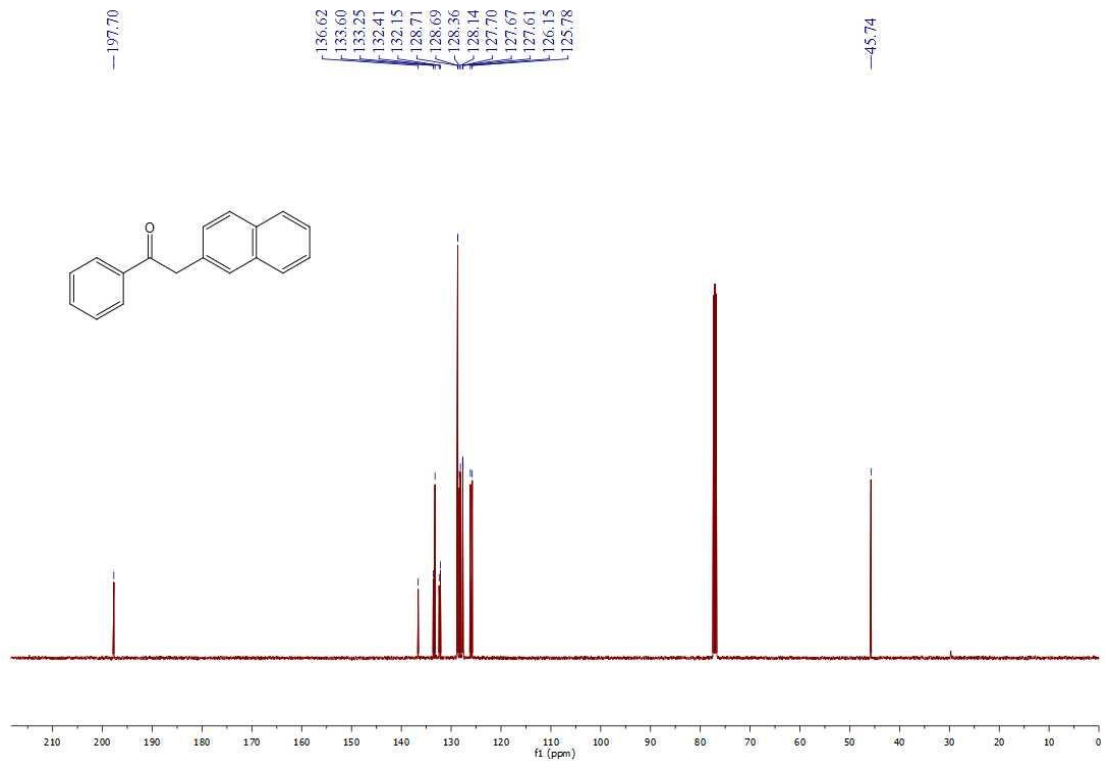
¹H NMR spectrum of 4aa



¹³C NMR spectrum of 4aa



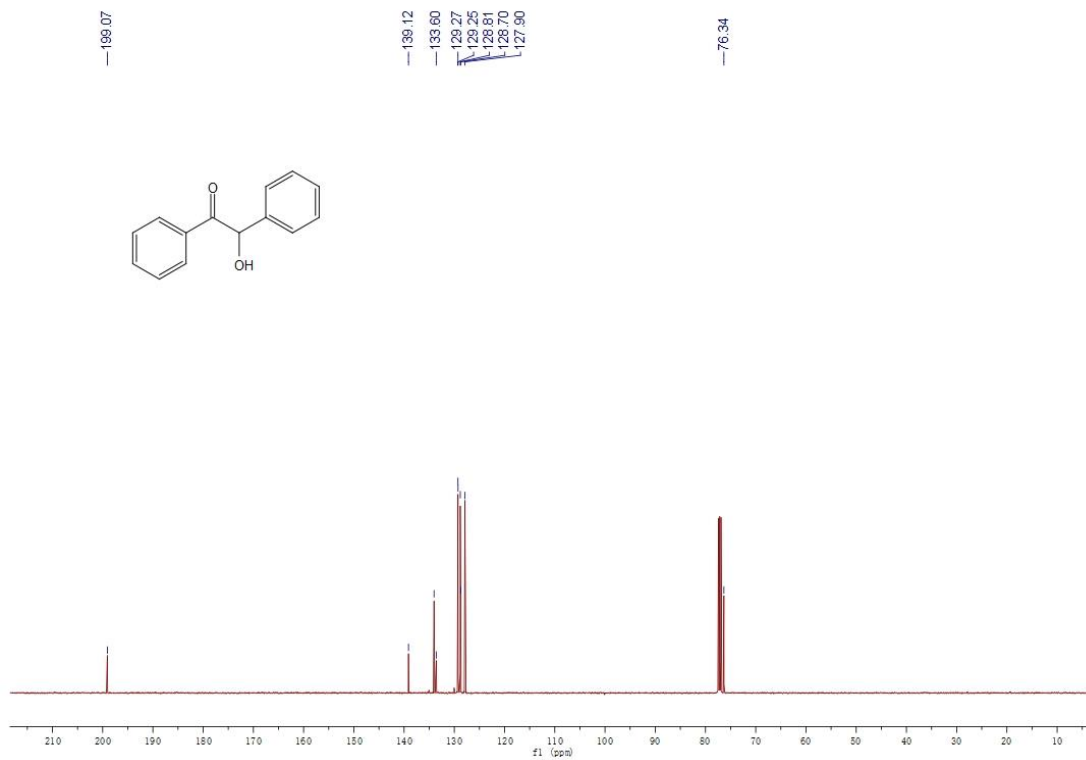
¹H NMR spectrum of 4ab



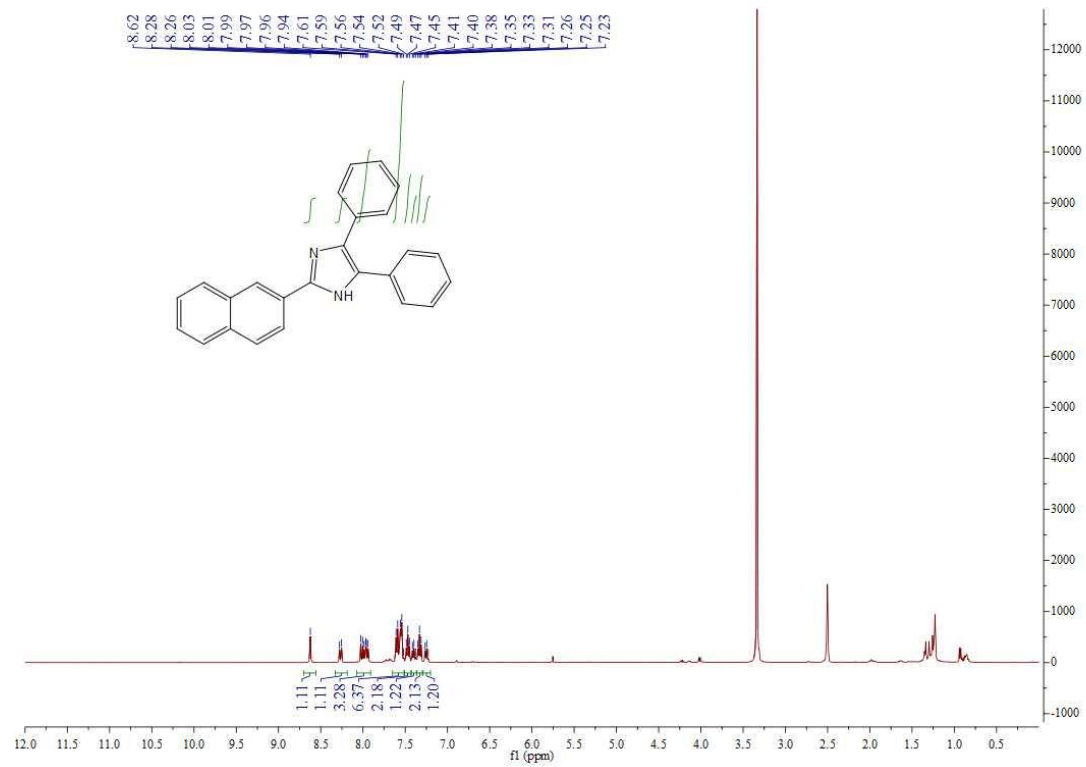
¹³C NMR spectrum of 4ab



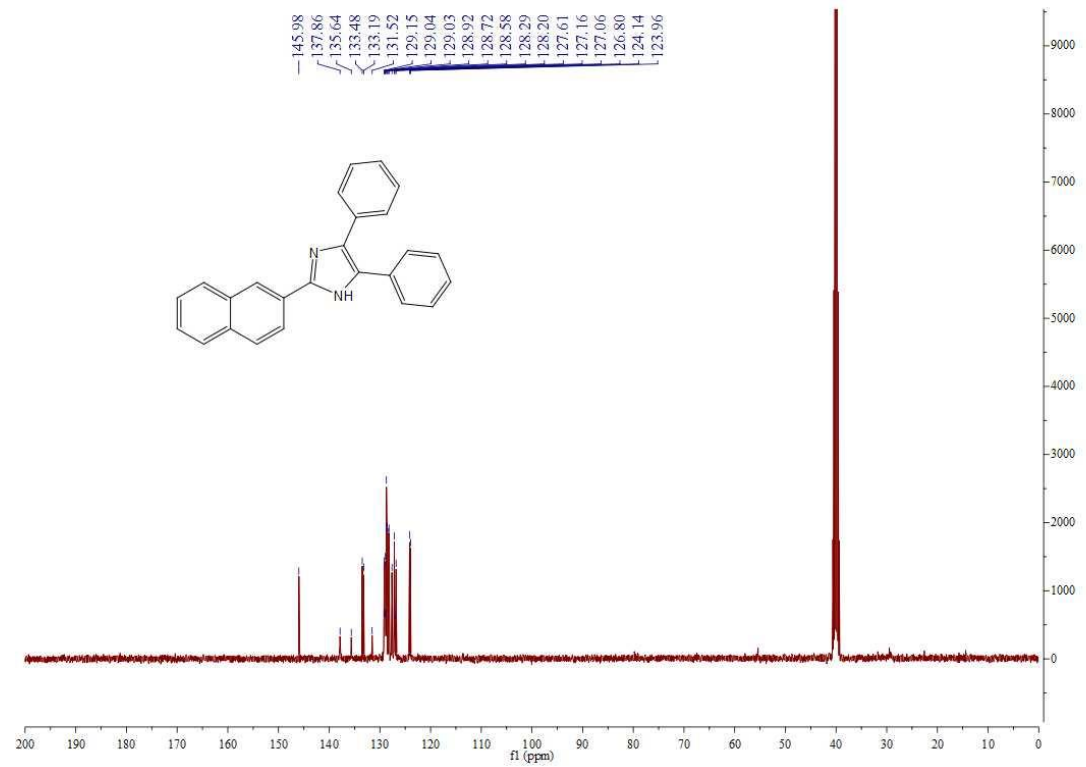
¹H NMR spectrum of 5



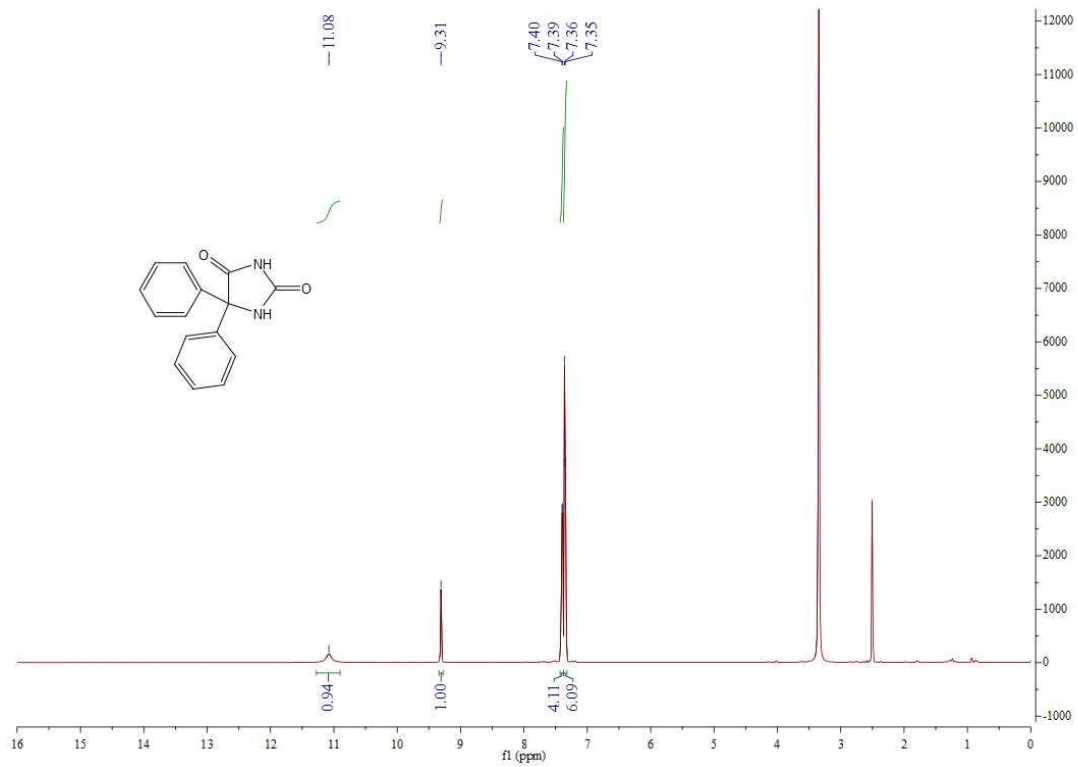
¹³C NMR spectrum of 5



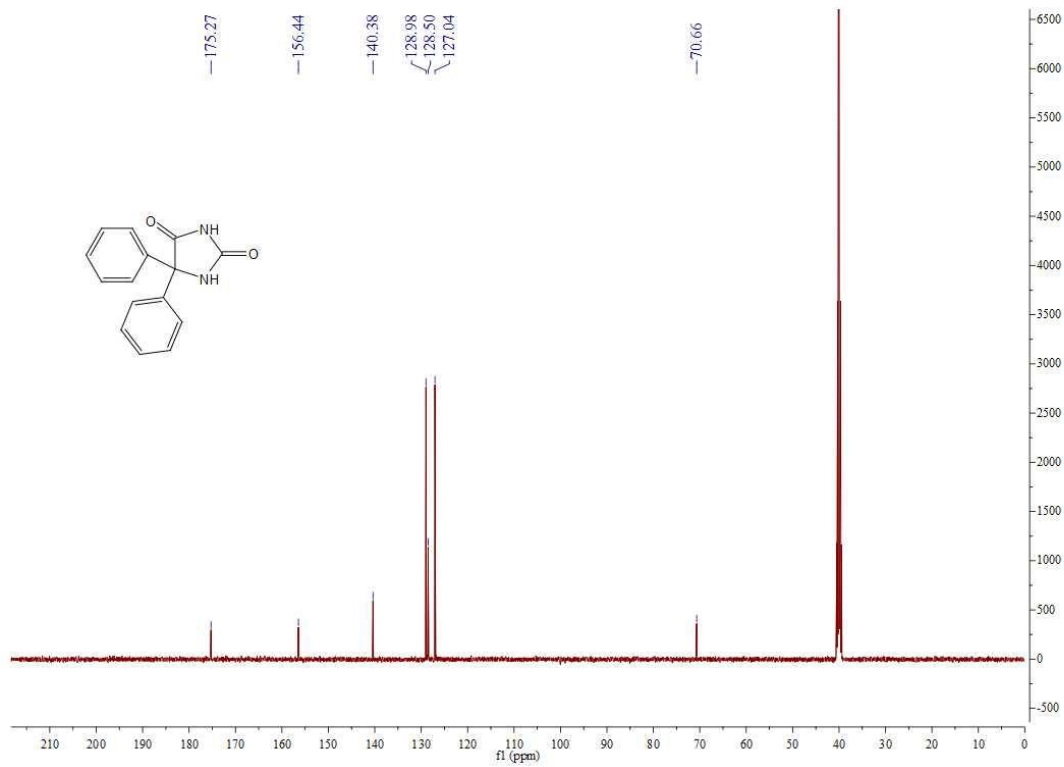
¹H NMR spectrum of 6



¹³C NMR spectrum of 6



^1H NMR spectrum of 7



^{13}C NMR spectrum of 7

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