

Supplementary Materials

Enantioselective synthesis of 6-(indole-2-yl)-3,4-dihydropyran-2-one skeletons by carbene organocatalytic asymmetric [3 + 3] cycloaddition of α -bromocinnamaldehyde

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1. General information	2
2. Synthetic procedures and characterization data of substrates 1.....	3
3. Synthetic procedures and characterization data of compounds 3	10
4. NMR spectra of substrates 1 as new compounds.....	26
1a: ¹H NMR (500 MHz, CDCl₃).....	26
5. NMR and HPLC spectra of products 3	40
6. X-ray single crystal data	81
7. References.....	83

1. General information

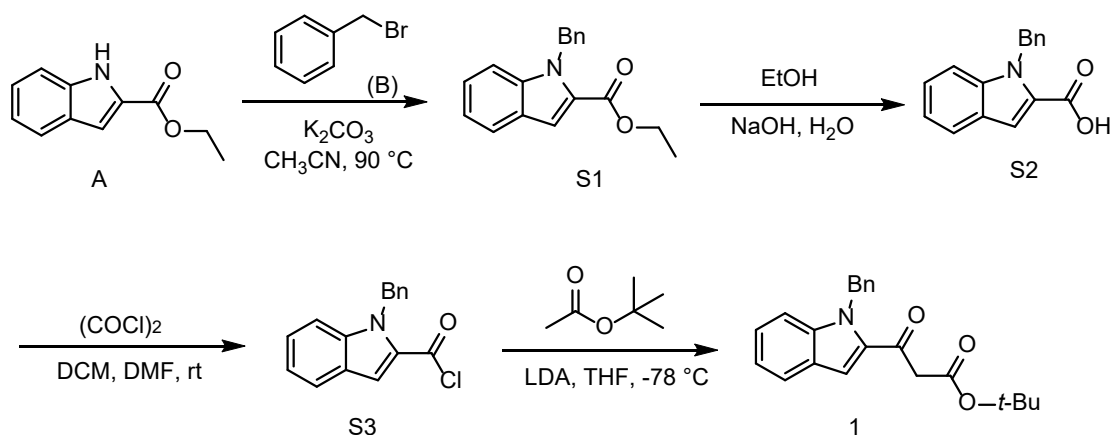
Analytical thin layer chromatography (TLC) was performed using Merck 60 F254 precoated silica gel plates (0.2 mm thickness). After elution, plates were visualized using UV radiation (254 nm) on Spectroline Model ENF- 24061/F 254 nm. Further visualization was possible by staining with a basic solution of potassium permanganate or an acidic solution of ceric molybdate.

Proton nuclear magnetic resonance spectra (^1H NMR) were recorded on Bruker AMX 500 spectrophotometer (CDCl_3 as the solvent). Chemical shifts for ^1H NMR spectra are reported as δ in units of parts per million (ppm) downfield from SiMe_4 (δ 0.0) and relative to the signal of chloroform-d (δ 7.26, singlet). Multiplicities were given as s (singlet), d (doublet), t (triplet), dd (doublets of doublet), or m (multiplets). The number of protons (n) for a given resonance is indicated by nH. Coupling constants are reported as a J value in Hz. Carbon nuclear magnetic resonance spectra (^{13}C NMR) are reported as δ in units of parts per million (ppm) downfield from SiMe_4 (δ 0.0) and relative to the signal of chloroform-d (δ 77.0, triplet).

Enantiomeric excesses were determined by high-performance liquid chromatography (HPLC) analysis on a chiral stationary phase, CHIRALCEL AD-H (5μ 25cm \times 4.6mm), CHIRALCEL IA (5μ 25cm \times 4.6mm), and CHIRALPAK OD-H (5μ 25cm \times 4.6mm). Optical rotations were measured in CHCl_3 on a Schmidt⁺ Haensdchpolarimeter (Polartronic MH8) with a 10 cm cell (c given in 0.5 g/100 mL).

The absolute configuration of the products was determined by X-ray crystallography. High-resolution mass spectrometry (HRMS) was recorded on a QTOF premier for ESI⁺.

2. Synthetic procedures and characterization data of substrates 1



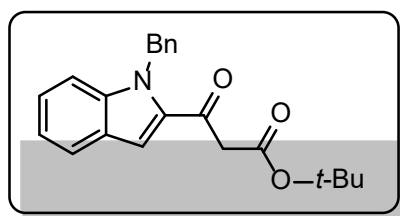
Step 1: To a solution of the 1H-indole-2-carboxylate **A** (3.9 g, 16.4 mmol) in anhydrous acetonitrile (40 mL), added anhydrous potassium carbonate (5.7 g, 41 mmol), followed by the addition of benzyl bromide **B** (3.7 g, 21.4 mmol). After reflux for 16 hours, the reaction mixture was concentrated in vacuo, dissolved in dichloromethane (50 mL), and washed with distilled water (3×20 mL). The combined organic layers were then washed with brine solution (30 mL), dried with anhydrous Na₂SO₄, and concentrated under vacuum to provide **S1** (yellow solid, 4.5 g, 79% yield).^[1]

Step 2: To the dried flask, added **S1** (6.0 mmol), 10% NaOH (12.0 mL), and ethanol (24.0 mL). Warmed the reaction mixture to 70 °C and stirred for 2 h. The reaction mixture was then cooled to room temperature, and then the reaction mixture was concentrated in vacuo to remove ethanol. The reaction mixture is acidified with 4 M HCl (4 mol/L) to pH = 2.0. The filtered solids were washed with water to obtain carboxylic acid substrate **S2** with a yield of 78%.^[2]

Step 3: Diluted compound **S2** (5 mmol) with CH₂Cl₂ (10 mL) and DMF (40 μL, 0.5 mmol). (COCl)₂ (508 μL, 6 mmol) was added to the mixture at 0 °C. After stirring for 0.5 h, raised the solution to room temperature. Continued stirring for 2 hours; excess (COCl)₂ was removed under reduced pressure to give acyl chloride **S3** with a yield of 81%.^[3]

Step 4: Under the condition of -78 °C, diisopropylamino lithium (LDA) (1.0m THF solution, 10 mmol) was dripped into THF (25 mL) solution of tert-butyl acetate (5 mmol) and stirred for 1 h. The prepared THF (5 mL) solution of acyl chloride S3 was added to the solution at the same temperature and stirred. After the reaction is complete, the reaction mixture was allowed to rest and then quenched with NH₄Cl aqueous solution. The layers were extracted and separated, and the water layer was extracted three times with Et₂O. The combined organic layer was dried, filtered, and concentrated under reduced pressure by Na₂SO₄. The resulting residue was purified by rapid column chromatography, and 3-(1-benzyl-1H-indole-2-yl)-3-oxopropionate **1** was obtained in 51% yield.

Tert-butyl 3-(1-benzyl-1H-indol-2-yl)-3-oxopropanoate (1a):



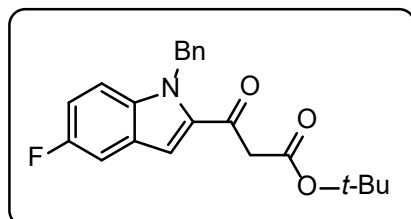
The title compound was prepared according to the typical procedure, as described above, in 51% yield; white solid; m.p. = 66 – 68 °C.

¹H NMR (500 MHz, CDCl₃) δ 7.72 (d, *J* = 8.1 Hz, 1H), 7.39 (s, 1H), 7.38 – 7.32 (m, 2H), 7.24 – 7.15 (m, 4H), 7.06 (d, *J* = 7.1 Hz, 2H), 5.86 (s, 2H), 3.87 (s, 2H), 1.40 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 184.6, 165.7, 139.3, 137.1, 132.6, 127.5, 126.1, 125.7, 125.5, 125.0, 122.2, 120.2, 112.6, 110.0, 80.9, 47.8, 47.2, 26.9.

HRMS (ESI) calcd for C₂₂H₂₃NO₃ [M+Na]⁺ *m/z* 372.157, found 372.1575.

Tert-butyl 3-(1-benzyl-5-fluoro-1H-indol-2-yl)-3-oxopropanoate (1b):



The title compound was prepared according to the typical procedure, as described above,

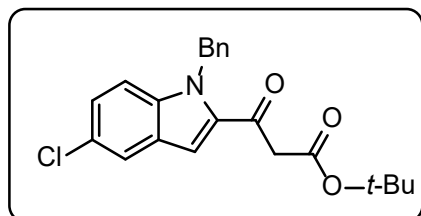
in 61% yield; white solid; m.p. = 92 – 94 °C.

¹H NMR (500 MHz, CDCl₃) δ 7.36 – 7.33 (m, 2H), 7.30 – 7.27 (m, 1H), 7.25 – 7.19 (m, 3H), 7.12 – 7.08 (m, 1H), 7.03 (d, *J* = 7.5 Hz, 2H), 5.84 (s, 2H), 3.86 (s, 2H), 1.41 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 184.6, 165.6, 158.2, 156.3, 136.8, 135.9, 133.8, 127.6, 126.3, 125.4, 125.0, 125.0, 115.0, 114.8, 112.0, 111.9, 111.2, 111.1, 106.2, 106.0, 81.1, 47.8, 47.4, 26.9.

HRMS (ESI) calcd for C₂₂H₂₂FNO₃ [M+Na]⁺ m/z 390.1476, found 390.1475.

Tert-butyl 3-(1-benzyl-5-chloro-1H-indol-2-yl)-3-oxopropanoate (1c):



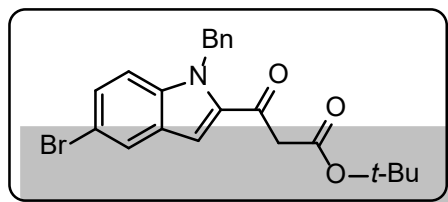
The title compound was prepared according to the typical procedure, as described above, in 58% yield; white solid; m.p. = 81 – 83 °C.

¹H NMR (500 MHz, CDCl₃) δ 7.68 (s, 1H), 7.30 (s, 1H), 7.27 – 7.26 (m, 2H), 7.25 – 7.17 (m, 3H), 7.02 (d, *J* = 7.4 Hz, 2H), 5.82 (s, 2H), 3.85 (s, 2H), 1.40 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 184.6, 165.5, 137.4, 136.6, 133.5, 127.5, 126.3, 126.0, 125.8, 125.7, 125.4, 121.2, 111.5, 111.2, 81.1, 47.8, 47.3, 26.9.

HRMS (ESI) calcd for C₂₂H₂₂ClNO₃ [M+K]⁺ m/z 422.092, found 422.093.

Tert-butyl 3-(1-benzyl-5-bromo-1H-indol-2-yl)-3-oxopropanoate (1d):



The title compound was prepared according to the typical procedure, as described above, in 71% yield; white solid; m.p. = 110 – 111 °C.

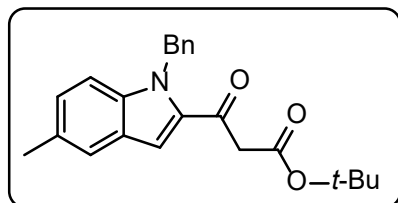
¹H NMR (500 MHz, CDCl₃) δ 7.85 (d, *J* = 1.7 Hz, 1H), 7.40 – 7.38 (m, 1H), 7.30 (s,

1H), 7.25 – 7.18 (m, 4H), 7.02 (d, $J = 7.0$ Hz, 2H), 5.82 (s, 2H), 3.85 (s, 2H), 1.40 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.6, 165.5, 137.7, 136.6, 133.3, 128.5, 127.6, 126.4, 126.3, 125.4, 124.4, 113.3, 111.6, 111.4, 81.1, 47.8, 47.3, 26.9.

HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{22}\text{BrNO}_3$ $[\text{M}+\text{K}]^+$ m/z 466.0415, found 466.0424.

Tert-butyl 3-(1-benzyl-5-methyl-1H-indol-2-yl)-3-oxopropanoate (1e):



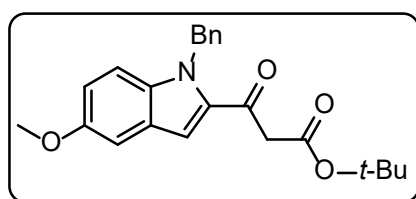
The title compound was prepared according to the typical procedure, as described above, in 71% yield; white solid; m.p. = 84 – 86 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.48 (s, 1H), 7.30 (s, 1H), 7.25 – 7.16 (m, 5H), 7.04 (d, $J = 7.4$ Hz, 2H), 5.83 (s, 2H), 3.85 (s, 2H), 2.43 (s, 3H), 1.40 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.5, 165.8, 137.8, 137.2, 132.6, 129.5, 127.7, 127.4, 126.0, 125.5, 125.2, 121.3, 112.0, 109.7, 80.9, 47.7, 47.2, 26.9, 20.3.

HRMS (ESI) calcd for $\text{C}_{23}\text{H}_{25}\text{NO}_3$ $[\text{M}+\text{K}]^+$ m/z 402.1466, found 402.1475.

Tert-butyl 3-(1-benzyl-5-methoxy-1H-indol-2-yl)-3-oxopropanoate (1f):



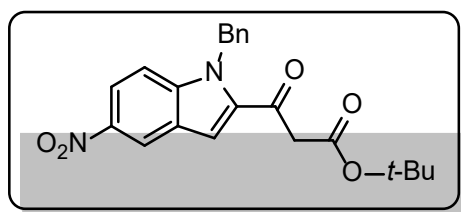
The title compound was prepared according to the typical procedure, as described above, in 72% yield; white solid; m.p. = 81 – 83 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.29 (s, 1H), 7.25 – 7.20 (m, 3H), 7.19 – 7.15 (m, 1H), 7.08 (d, $J = 2.5$ Hz, 1H), 7.04 – 7.00 (m, 3H), 5.82 (s, 2H), 3.84 (s, 2H), 3.83 (s, 3H), 1.40 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.3, 165.8, 153.9, 137.2, 134.9, 132.8, 127.5, 126.1, 125.4, 125.3, 117.6, 111.9, 111.0, 101.6, 80.9, 54.6, 47.7, 47.2, 26.9.

HRMS (ESI) calcd for $C_{23}H_{25}NO_4$ $[M+K]^+$ m/z 418.1415, found 418.1421.

Tert-butyl 3-(1-benzyl-5-nitro-1H-indol-2-yl)-3-oxopropanoate (1g):



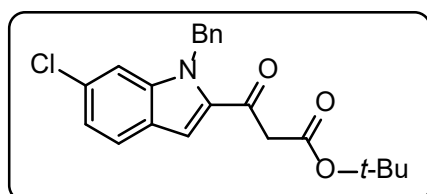
The title compound was prepared according to the typical procedure, as described above, in 81% yield; white solid; m.p. = 88 – 89 °C.

1H NMR (500 MHz, $CDCl_3$) δ 8.71 (d, J = 2.1 Hz, 1H), 8.21 (dd, J = 9.3, 2.2 Hz, 1H), 7.56 (s, 1H), 7.43 (d, J = 9.3 Hz, 1H), 7.28 – 7.22 (m, 3H), 7.05 – 7.04 (m, 2H), 5.90 (s, 2H), 3.90 (s, 2H), 1.41 (s, 9H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 184.7, 165.2, 141.8, 141.2, 135.8, 135.3, 127.8, 126.6, 125.4, 124.0, 120.4, 119.5, 114.0, 110.4, 81.4, 47.8, 47.8, 26.9.

HRMS (ESI) calcd for $C_{22}H_{22}N_2O_5$ $[M+K]^+$ m/z 433.116, found 433.117.

Tert-butyl 3-(1-benzyl-6-chloro-1H-indol-2-yl)-3-oxopropanoate (1h):



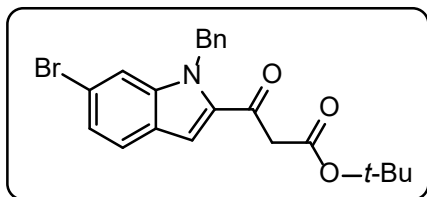
The title compound was prepared according to the typical procedure, as described above, in 67% yield; white solid; m.p. = 83 – 85 °C.

1H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, J = 8.6 Hz, 1H), 7.36 – 7.35 (m, 2H), 7.26 – 7.19 (m, 3H), 7.14 – 7.12 (m, 1H), 7.04 – 7.03 (m, 2H), 5.80 (s, 2H), 3.85 (s, 2H), 1.40 (s, 9H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 184.4, 165.6, 139.5, 136.5, 133.2, 131.7, 127.6, 126.3, 125.4, 123.4, 123.2, 121.3, 112.5, 109.8, 81.1, 47.7, 47.3, 26.9.

HRMS (ESI) calcd for $C_{22}H_{22}ClNO_3$ $[M+K]^+$ m/z 422.092, found 422.0922.

Tert-butyl 3-(1-benzyl-6-bromo-1H-indol-2-yl)-3-oxopropanoate (1i):



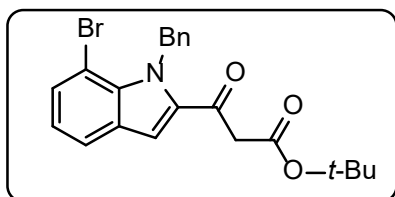
The title compound was prepared according to the typical procedure, as described above, in 67% yield; white solid; m.p. = 111 – 113 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.58 (d, J = 8.5 Hz, 1H), 7.53 (s, 1H), 7.35 (s, 1H), 7.28 – 7.20 (m, 4H), 7.04 – 7.03 (m, 2H), 5.80 (s, 2H), 3.84 (s, 2H), 1.39 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.4, 165.5, 139.8, 136.5, 133.0, 127.6, 126.3, 125.4, 123.9, 123.7, 123.4, 119.6, 112.9, 112.5, 81.1, 47.8, 47.3, 26.9.

HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{22}\text{BrNO}_3$ $[\text{M}+\text{K}]^+$ m/z 466.0415, found 466.0417.

Tert-butyl 3-(1-benzyl-7-bromo-1H-indol-2-yl)-3-oxopropanoate (1j):



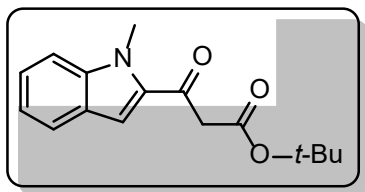
The title compound was prepared according to the typical procedure, as described above, in 74% yield; white solid; m.p. = 105 – 107 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.68 (d, J = 7.6 Hz, 1H), 7.55 – 7.53 (m, 1H), 7.41 (s, 1H), 7.25 – 7.16 (m, 3H), 7.01 (t, J = 7.8 Hz, 1H), 6.91 – 6.89 (m, 2H), 6.40 (s, 2H), 3.82 (s, 2H), 1.37 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.3, 165.5, 138.5, 135.3, 134.1, 131.4, 128.2, 127.3, 125.7, 124.8, 121.7, 121.1, 113.6, 103.4, 81.1, 48.2, 47.5, 26.8.

HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{22}\text{BrNO}_3$ $[\text{M}+\text{Na}]^+$ m/z 450.0675, found 450.0678.

Tert-butyl 3-(1-methyl-1H-indol-2-yl)-3-oxopropanoate (1k):



The title compound was prepared according to the typical procedure, as described above,

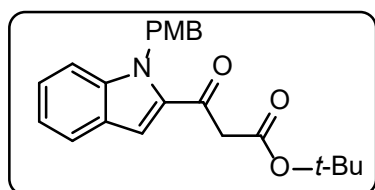
in 65% yield; white solid; m.p. = 89 – 91 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.68 (d, J = 8.1 Hz, 1H), 7.40 – 7.36 (m, 2H), 7.28 (s, 1H), 7.17 – 7.14 (m, 1H), 4.06 (s, 3H), 3.88 (s, 2H), 1.46 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 185.0, 165.8, 139.3, 133.1, 125.3, 124.7, 122.1, 119.8, 111.5, 109.4, 80.9, 47.4, 31.1, 27.0, 26.8.

HRMS (ESI) calcd for $\text{C}_{16}\text{H}_{19}\text{NO}_3$ $[\text{M}+\text{Na}]^+$ m/z 296.1257, found 296.1251.

Tert-butyl 3-(1-(4-methoxybenzyl)-1H-indol-2-yl)-3-oxopropanoate (11):



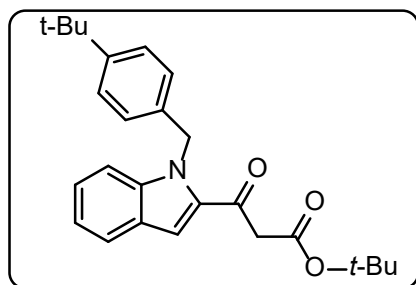
The title compound was prepared according to the typical procedure, as described above, in 65% yield; white solid; m.p. = 80 – 81 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.71 (d, J = 8.1 Hz, 1H), 7.40 – 7.33 (m, 3H), 7.17 – 7.14 (m, 1H), 7.05 – 7.03 (m, 2H), 6.77 – 7.75 (m, 2H), 5.79 (s, 2H), 3.86 (s, 2H), 3.72 (s, 3H), 1.41 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.6, 165.8, 157.7, 139.2, 132.5, 129.2, 126.9, 125.6, 125.0, 122.2, 120.1, 112.9, 112.6, 110.1, 80.9, 54.2, 47.8, 46.6, 26.9.

HRMS (ESI) calcd for $\text{C}_{23}\text{H}_{25}\text{NO}_4$ $[\text{M}+\text{K}]^+$ m/z 418.1415, found 418.1408.

Tert-butyl 3-(1-(4-(tert-butyl)benzyl)-1H-indol-2-yl)-3-oxopropanoate (m):



The title compound was prepared according to the typical procedure, as described above, in 45% yield; white solid; m.p. = 92 – 94 °C.

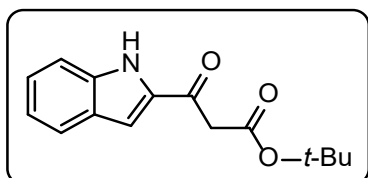
^1H NMR (500 MHz, CDCl_3) δ 7.71 (d, J = 8.0 Hz, 1H), 7.41 – 7.37 (m, 2H), 7.34 (t, J = 7.6 Hz, 1H), 7.25 – 7.23 (m, 2H), 7.15 (t, J = 7.4 Hz, 1H), 7.01 – 7.00 (m, 2H), 5.82

(s, 2H), 3.86 (s, 2H), 1.39 (s, 9H), 1.24 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 184.5, 165.7, 148.8, 139.2, 134.0, 132.5, 125.5, 125.2, 125.0, 124.3, 122.1, 120.1, 112.5, 110.1, 80.8, 47.8, 46.7, 33.3, 30.3, 26.9.

HRMS (ESI) calcd for $\text{C}_{26}\text{H}_{31}\text{NO}_3$ $[\text{M}+\text{Na}]^+$ m/z 428.2196, found 428.2186.

Tert-butyl 3-(1H-indol-2-yl)-3-oxopropanoate (1n):



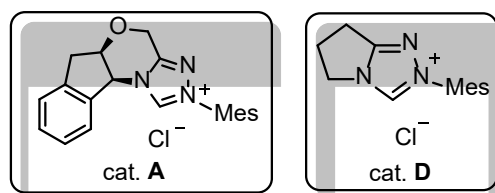
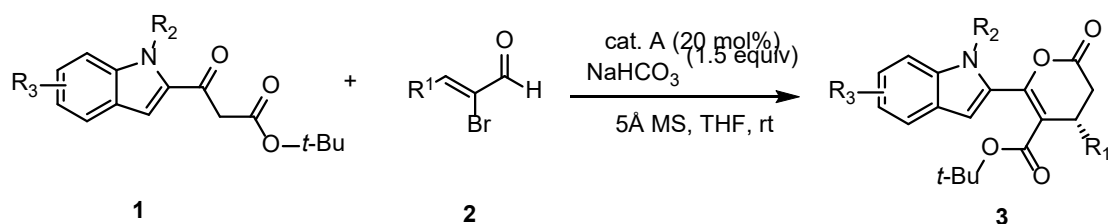
The title compound was prepared according to the typical procedure, as described above, in 78% yield; white solid; m.p. = 209 – 210 °C.

^1H NMR (500 MHz, CDCl_3) δ 9.16 (s, 1H), 7.71 (d, J = 8.1 Hz, 1H), 7.43 (d, J = 8.4 Hz, 1H), 7.36 (t, J = 7.6 Hz, 1H), 7.24 (d, J = 2.0 Hz, 1H), 7.16 (t, J = 7.6 Hz, 1H), 3.87 (s, 2H), 1.46 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 183.9, 165.4, 136.6, 133.5, 126.5, 125.8, 122.2, 120.1, 111.2, 109.6, 81.2, 45.9, 26.9.

HRMS (ESI) calcd for $\text{C}_{15}\text{H}_{17}\text{NO}_3$ $[\text{M}+\text{Na}]^+$ m/z 282.11, found 282.1107.

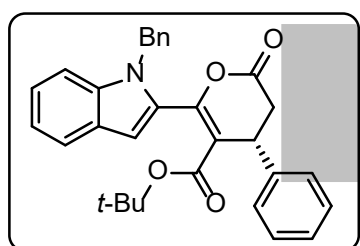
3. Synthetic procedures and characterization data of compounds 3



To the oven-dried 10 mL vial, added dihydropyrazolinone **1** (0.1 mmol, 1.0 equiv.), β -bromo- α,β -unsaturated aldehyde **2** (0.1 mmol, 1.2 equiv.), cat. **A** (7.4 mg, 0.02 mmol,

0.2 equiv.), NaHCO₃ (12.6 mg, 0.15 mmol, 1.5 equiv.) followed by 1.5 mL of THF. Stirring overnight at room temperature, TLC monitors the starting substance until it completely disappears. The desired product **3** was purified by silica gel column chromatography with EA/PE (1:10) as an eluent. The corresponding racemic product is made of racemic catalyst cat. **D** synthesis.

tert-butyl (R)-6-(1-benzyl-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3a



The title compound was prepared according to the typical procedure, as described above, in 78% yield (37.3 mg); white solid; 97% *ee*; [α]_D²⁵ = -92.20 (*c* = 0.5, CHCl₃); m.p. = 110 – 112 °C.

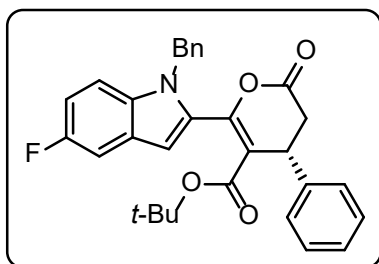
¹H NMR (500 MHz, CDCl₃) δ 7.65 (d, *J* = 7.9 Hz, 1H), 7.34 (d, *J* = 8.3 Hz, 1H), 7.28 – 7.22 (m, 7H), 7.16 – 7.13 (m, 3H), 7.05 – 7.04 (m, 2H), 6.80 (s, 1H), 5.45 (s, 2H), 4.25 (dd, *J* = 7.3, 3.8 Hz, 1H), 2.80 (dd, *J* = 16.0, 7.3 Hz, 1H), 2.73 (dd, *J* = 16.0, 3.9 Hz, 1H), 1.06 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 164.6, 163.9, 148.0, 138.6, 136.9, 136.4, 129.5, 128.1, 127.6, 126.6, 126.5, 125.9, 125.8, 125.7, 122.4, 120.4, 119.2, 116.2, 108.9, 106.0, 80.8, 47.1, 38.0, 34.9, 26.5.

HRMS (ESI) calcd for C₃₁H₂₉NO₄ [M+H]⁺ *m/z* 480.2169, found 480.2167.

HPLC: Chiralcel AD (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, λ = 254 nm), *t*_R (minor) = 11.829 min, *t*_R (major) = 15.198 min; 97% *ee*.

tert-butyl (R)-6-(1-benzyl-5-fluoro-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3b



The title compound was prepared according to the typical procedure, as described above, in 62% yield (30.8 mg); white solid; 97% *ee*; $[\alpha]_D^{25} = -40.38$ ($c = 0.5$, CHCl_3); m.p. = 155 – 157 °C.

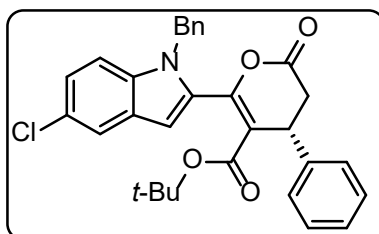
^1H NMR (500 MHz, CDCl_3) δ 7.31 – 7.27 (m, 4H), 7.26 – 7.22 (m, 4H), 7.15 – 7.13 (m, 2H), 7.06 – 7.04 (m, 2H), 7.01 – 6.97 (m, 1H), 6.74 (s, 1H), 5.41 (s, 2H), 4.26 (dd, $J = 7.3, 3.8$ Hz, 1H), 2.82 (dd, $J = 16.0, 7.4$ Hz, 1H), 2.75 (dd, $J = 16.0, 3.8$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.5, 163.7, 147.7, 138.5, 136.1, 133.4, 131.2, 128.1, 127.7, 126.7, 126.7, 125.8, 125.7, 116.7, 111.2, 111.0, 109.8, 109.7, 105.5, 105.5, 105.0, 104.8, 80.9, 47.4, 38.0, 34.8, 26.5.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{FNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 520.1895, found 520.1903.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (minor) = 12.680 min, t_R (major) = 15.446 min; 97% *ee*.

tert-butyl (R)-6-(1-benzyl-5-chloro-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3c



The title compound was prepared according to the typical procedure, as described above, in 75% yield (38.4 mg); white solid; 96% *ee*; $[\alpha]_D^{25} = -84.82$ ($c = 0.5$, CHCl_3); m.p. = 104 – 107 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.62 (d, $J = 1.9$ Hz, 1H), 7.28 – 7.27 (m, 3H), 7.26 –

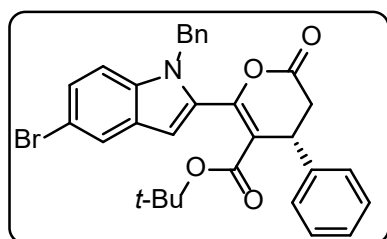
7.23 (m, 4H), 7.20 – 7.18 (m, 1H), 7.13 – 7.11 (m, 2H), 7.05 – 7.04 (m, 2H), 6.72 (s, 1H), 5.41 (s, 2H), 4.26 (dd, $J = 7.3, 3.8$ Hz, 1H), 2.82 (dd, $J = 16.0, 7.3$ Hz, 1H), 2.75 (dd, $J = 16.0, 3.8$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 165.5, 164.7, 148.5, 139.5, 136.9, 136.2, 132.0, 129.2, 128.7, 127.9, 127.8, 127.7, 126.8, 126.7, 126.0, 123.9, 120.7, 117.8, 111.1, 106.2, 82.0, 48.4, 39.0, 35.8, 27.6.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{ClNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 536.1599, found 536.1591.

HPLC: Chiralcel AD (n-hexane/i-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (minor) = 14.190 min, t_R (major) = 24.914 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-5-bromo-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3d



The title compound was prepared according to the typical procedure, as described above, in 61% yield (33.9 mg); white solid; 92% *ee*; $[\alpha]_D^{25} = -93.34$ ($c = 0.5$, CHCl_3); m.p. = 157 – 159 °C.

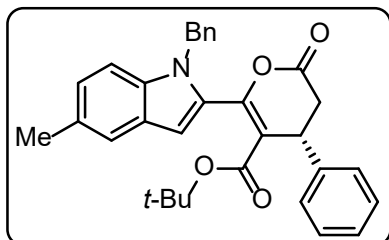
^1H NMR (500 MHz, CDCl_3) δ 7.78 (d, $J = 1.7$ Hz, 1H), 7.33 – 7.31 (m, 1H), 7.28 – 7.24 (m, 6H), 7.21 – 7.19 (m, 1H), 7.14 – 7.10 (m, 2H), 7.05 – 7.03 (m, 2H), 6.74 – 6.70 (m, 1H), 5.41 (s, 2H), 4.26 (dd, $J = 7.3, 3.8$ Hz, 1H), 2.82 (dd, $J = 16.0, 7.3$ Hz, 1H), 2.75 (dd, $J = 16.0, 3.8$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.4, 163.6, 147.4, 138.5, 135.8, 135.4, 130.8, 128.1, 127.7, 127.5, 126.7, 126.7, 125.8, 125.7, 125.3, 122.8, 116.8, 112.5, 110.5, 105.0, 81.0, 47.4, 37.9, 34.8, 26.5.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{NO}_4$ $[\text{M}+\text{Na}]^+$ m/z 580.1094, found 580.1088.

HPLC: Chiralcel IA (n-hexane/i-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (minor) = 11.780 min, t_R (major) = 13.673 min; 92% *ee*.

tert-butyl (R)-6-(1-benzyl-5-methyl-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3e



The title compound was prepared according to the typical procedure, as described above, in 61% yield (30.1 mg); white solid; 96% *ee*; $[\alpha]_D^{25} = -79.20$ ($c = 0.5$, CHCl_3); m.p. = 80 – 82 °C.

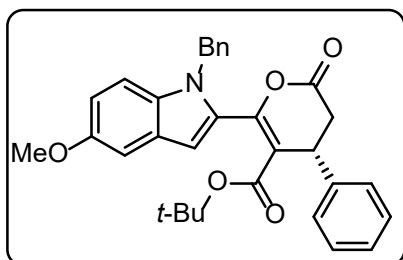
^1H NMR (500 MHz, CDCl_3) δ 7.42 (s, 1H), 7.28 – 7.21 (m, 7H), 7.14 – 7.04 (m, 5H), 6.71 (s, 1H), 5.42 (s, 2H), 4.25 – 4.23 (m, 1H), 2.82 – 2.77 (m, 1H), 2.74 – 2.71 (m, 1H), 2.44 (s, 3H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.7, 164.0, 148.0, 138.6, 136.6, 135.4, 129.4, 128.5, 128.0, 127.6, 126.6, 126.5, 126.2, 125.8, 125.7, 124.2, 119.9, 116.0, 108.6, 105.6, 80.7, 47.1, 38.0, 34.9, 26.5, 20.4.

HRMS (ESI) calcd for $\text{C}_{32}\text{H}_{31}\text{NO}_4$ $[\text{M}+\text{Na}]^+$ m/z 516.2145, found 516.2143.

HPLC: Chiralcel AD (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (minor) = 18.771 min, t_R (major) = 24.345 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-5-methoxy-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3f



The title compound was prepared according to the typical procedure, as described above, in 69% yield (35.1 mg); white solid; 96% *ee*; $[\alpha]_D^{25} = -79.58$ ($c = 0.5$, CHCl_3);

m.p. = 125 – 126 °C.

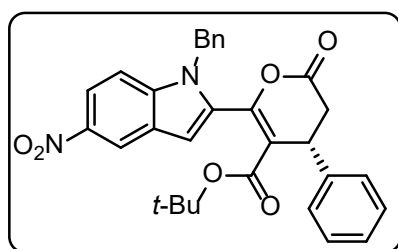
¹H NMR (500 MHz, CDCl₃) δ 7.27 – 7.21 (m, 7H), 7.14 – 7.13 (m, 2H), 7.08 – 7.03 (m, 3H), 6.91 (dd, *J* = 9.0, 2.5 Hz, 1H), 6.71 (s, 1H), 5.40 (s, 2H), 4.25 (dd, *J* = 7.3, 3.7 Hz, 1H), 3.85 (s, 3H), 2.80 (dd, *J* = 16.0, 7.4 Hz, 1H), 2.73 (dd, *J* = 16.0, 3.8 Hz, 1H), 1.08 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 164.7, 164.0, 153.4, 148.0, 138.6, 136.5, 132.3, 129.9, 128.1, 127.6, 126.6, 126.5, 126.3, 125.8, 125.7, 116.1, 113.1, 109.8, 105.5, 101.4, 80.8, 54.8, 47.3, 38.0, 34.9, 26.5.

HRMS (ESI) calcd for C₃₂H₃₁NO₅ [M+Na]⁺ *m/z* 532.2094, found 532.2093.

HPLC: Chiralcel AD (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, λ = 254 nm), *t_R* (minor) = 15.774 min, *t_R* (major) = 24.019 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-5-nitro-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3g



The title compound was prepared according to the typical procedure, as described above, in 63% yield (30.0 mg); white solid; 98% *ee*; [α]_D²⁵ = -75.34 (c = 0.5, CHCl₃); m.p. = 168 – 170 °C.

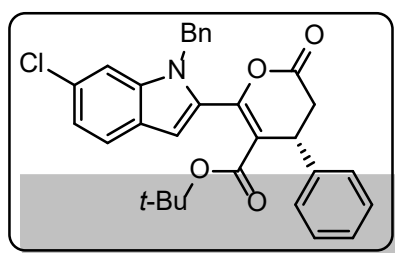
¹H NMR (500 MHz, CDCl₃) δ 8.63 (d, *J* = 2.2 Hz, 1H), 8.15 (dd, *J* = 9.2, 2.2 Hz, 1H), 7.38 (d, *J* = 9.2 Hz, 1H), 7.31 – 7.30 (m, 3H), 7.27 – 7.26 (m, 3H), 7.14 – 7.13 (m, 2H), 7.06 – 7.04 (m, 2H), 6.96 (s, 1H), 5.48 (s, 2H), 4.28 (dd, *J* = 7.3, 3.9 Hz, 1H), 2.85 (dd, *J* = 16.1, 7.4 Hz, 1H), 2.77 (dd, *J* = 16.1, 3.9 Hz, 1H), 1.07 (s, 9H).

¹³C NMR (126 MHz, CDCl₃) δ 164.1, 163.1, 146.7, 141.2, 139.2, 138.3, 135.0, 133.2, 128.2, 127.9, 127.1, 126.8, 125.8, 125.6, 125.1, 117.9, 117.7, 117.6, 109.1, 107.5, 81.3, 47.8, 37.9, 34.6, 26.5.

HRMS (ESI) calcd for C₃₁H₂₈N₂O₆ [M+Na]⁺ *m/z* 547.184, found 547.1837.

HPLC: Chiralcel IB (n-hexane/i-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (minor) = 24.081 min, t_R (major) = 38.296 min; 98% *ee*.

tert-butyl (R)-6-(1-benzyl-6-chloro-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3h



The title compound was prepared according to the typical procedure, as described above, in 80% yield (41.0 mg); white solid; 96% *ee*; $[\alpha]_D^{25} = -46.14$ ($c = 0.5$, CHCl_3); m.p. = 76 - 78 °C.

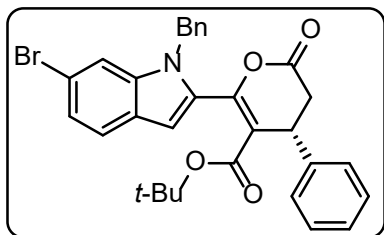
^1H NMR (500 MHz, CDCl_3) δ 7.55 (d, $J = 8.5$ Hz, 1H), 7.34 (s, 1H), 7.29 – 7.28 (m, 3H), 7.26 – 7.24 (m, 3H), 7.14 – 7.10 (m, 3H), 7.04 – 7.02 (m, 2H), 6.76 (s, 1H), 5.39 (s, 2H), 4.24 (dd, $J = 7.2, 3.9$ Hz, 1H), 2.80 (dd, $J = 16.0, 7.3$ Hz, 1H), 2.73 (dd, $J = 16.0, 3.9$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.5, 163.7, 147.5, 138.5, 137.2, 135.8, 130.4, 128.4, 128.1, 127.7, 126.7, 126.7, 125.8, 125.7, 124.4, 121.3, 120.2, 116.6, 108.9, 105.9, 80.9, 47.3, 37.9, 34.8, 26.5.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{ClNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 536.1599, found 536.16.

HPLC: Chiralcel IA (n-hexane/i-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (major) = 8.718 min, t_R (minor) = 12.193 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-6-bromo-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3i



The title compound was prepared according to the typical procedure, as described above, in 64% yield (35.6 mg); white solid; 96% *ee*; $[\alpha]_{\text{D}}^{25} = -107.60$ ($c = 0.5$, CHCl_3); m.p. = 179 – 181 °C.

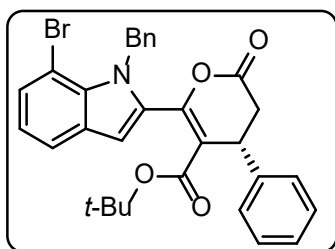
^1H NMR (500 MHz, CDCl_3) δ 7.52 – 7.50 (m, 2H), 7.29 – 7.24 (m, 7H), 7.13 – 7.12 (m, 2H), 7.04 – 7.02 (m, 2H), 6.76 (s, 1H), 5.39 (s, 2H), 4.24 (dd, $J = 7.1, 3.9$ Hz, 1H), 2.79 (dd, $J = 15.8, 7.1$ Hz, 1H), 2.73 (dd, $J = 15.9, 3.6$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.5, 163.7, 147.5, 138.5, 137.6, 135.8, 130.2, 128.1, 127.7, 126.7, 126.6, 125.7, 125.7, 124.7, 122.8, 121.6, 116.6, 116.2, 111.9, 106.0, 80.9, 47.2, 37.9, 34.8, 26.5.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{BrNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 580.1094, found 580.1101.

HPLC: Chiralcel IA (*n*-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 8.820 min, t_{R} (minor) = 13.125 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-7-bromo-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3j



The title compound was prepared according to the typical procedure, as described above, in 75% yield (41.7 mg); white solid; 96% *ee*; $[\alpha]_{\text{D}}^{25} = -152.10$ ($c = 0.5$, CHCl_3); m.p. = 163 – 165 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.60 (dd, $J = 7.9, 0.9$ Hz, 1H), 7.43 (dd, $J = 7.6, 0.9$ Hz, 1H), 7.27 – 7.23 (m, 6H), 7.06 – 6.99 (m, 5H), 6.80 (s, 1H), 6.13 (d, $J = 17.3$ Hz, 1H),

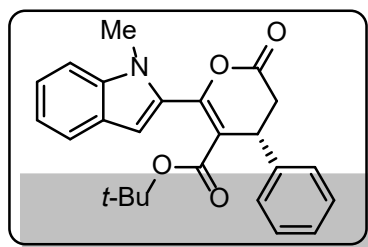
5.83 (d, $J = 17.3$ Hz, 1H), 4.26 (dd, $J = 7.2, 3.8$ Hz, 1H), 2.80 (dd, $J = 16.1, 7.2$ Hz, 1H), 2.74 (dd, $J = 16.1, 3.8$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.3, 163.3, 147.9, 138.6, 137.6, 132.8, 132.2, 129.2, 128.1, 128.1, 127.5, 126.7, 126.2, 125.7, 125.1, 120.4, 120.0, 117.2, 106.3, 102.8, 81.0, 47.5, 37.8, 34.7, 26.5.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{BrNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 580.1094, found 580.1103.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 6.077 min, t_{R} (minor) = 8.119 min; 96% *ee*.

tert-butyl (R)-6-(1-methyl-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3k



The title compound was prepared according to the typical procedure, as described above, in 78% yield (31.4 mg); white solid; 98% *ee*; $[\alpha]_{\text{D}}^{25} = -85.24$ ($c = 0.5$, CHCl_3); m.p. = 140 – 142 °C.

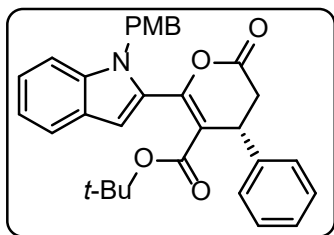
^1H NMR (500 MHz, CDCl_3) δ 7.62 (d, $J = 7.9$ Hz, 1H), 7.37 – 7.33 (m, 3H), 7.30 – 7.24 (m, 4H), 7.14 – 7.11 (m, 1H), 6.68 (s, 1H), 4.40 (dd, $J = 7.7, 2.8$ Hz, 1H), 3.77 (s, 3H), 3.14 (dd, $J = 16.0, 7.8$ Hz, 1H), 2.98 (dd, $J = 16.0, 2.9$ Hz, 1H), 0.99 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.8, 163.8, 148.4, 138.8, 136.7, 130.5, 128.2, 126.8, 125.9, 125.7, 122.1, 120.3, 119.0, 117.4, 108.5, 103.9, 80.7, 37.8, 35.1, 29.8, 26.4.

HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{24}\text{N}_2\text{O}_5$ $[\text{M}+\text{Na}]^+$ m/z 426.1676, found 426.1671.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 95/5, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 11.231 min, t_{R} (minor) = 12.153 min; 98% *ee*.

tert-butyl (R)-6-(1-(4-methoxybenzyl)-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3l



The title compound was prepared according to the typical procedure, as described above, in 67% yield (34.1 mg); white solid; 98% *ee*; $[\alpha]_{\text{D}}^{25} = -79.62$ ($c = 0.5$, CHCl_3); m.p. = 120 – 122 °C.

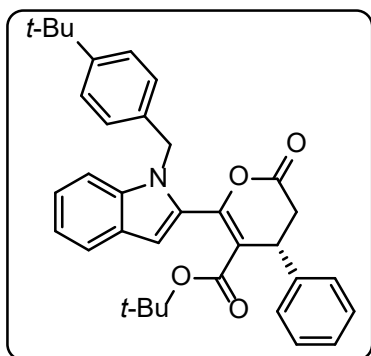
^1H NMR (500 MHz, CDCl_3) δ 7.64 (d, $J = 7.8$ Hz, 1H), 7.35 (d, $J = 8.3$ Hz, 1H), 7.27 – 7.23 (m, 4H), 7.15 – 7.06 (m, 5H), 6.80 – 6.77 (m, 3H), 5.38 (d, $J = 3.9$ Hz, 2H), 4.27 (dd, $J = 7.4, 3.7$ Hz, 1H), 3.76 (s, 3H), 2.86 (dd, $J = 15.9, 7.5$ Hz, 1H), 2.77 (dd, $J = 16.0, 3.4$ Hz, 1H), 1.05 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.7, 164.0, 158.0, 148.0, 138.7, 136.8, 129.5, 128.4, 128.0, 127.2, 126.6, 125.9, 125.8, 122.4, 120.4, 119.2, 116.2, 113.0, 109.0, 105.9, 80.7, 54.2, 46.6, 38.0, 34.9, 26.5.

HRMS (ESI) calcd for $\text{C}_{32}\text{H}_{31}\text{NO}_5$ $[\text{M}+\text{Na}]^+$ m/z 532.2094, found 532.2098.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 15.100 min, t_{R} (minor) = 23.055 min; 98% *ee*.

tert-butyl (R)-6-(1-(4-(tert-butyl)benzyl)-1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3m



The title compound was prepared according to the typical procedure, as described above, in 60% yield (32.1 mg); white solid; 98% *ee*; $[\alpha]_{\text{D}}^{25} = -68.94$ ($c = 0.5$, CHCl_3); m.p. = 129 – 131 °C.

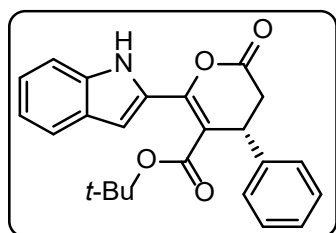
^1H NMR (500 MHz, CDCl_3) δ 7.64 (d, $J = 7.9$ Hz, 1H), 7.36 (d, $J = 8.3$ Hz, 1H), 7.29 – 7.23 (m, 6H), 7.15 – 7.08 (m, 5H), 6.78 (s, 1H), 5.45 – 5.35 (m, 2H), 4.24 (dd, $J = 7.1, 4.3$ Hz, 1H), 2.75 (dd, $J = 16.0, 7.2$ Hz, 1H), 2.69 (dd, $J = 16.0, 4.3$ Hz, 1H), 1.28 (s, 9H), 1.03 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.8, 163.9, 149.5, 148.1, 138.7, 136.8, 133.4, 129.6, 128.0, 126.6, 126.0, 125.8, 125.7, 124.5, 122.3, 120.4, 119.2, 116.4, 109.0, 105.8, 80.7, 46.8, 37.9, 34.8, 33.5, 30.3, 26.5.

HRMS (ESI) calcd for $\text{C}_{35}\text{H}_{37}\text{NO}_4$ $[\text{M}+\text{Na}]^+$ m/z 558.2615, found 558.2625.

HPLC: Chiralcel IB (n-hexane/*i*-PrOH, 97/3, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (minor) = 8.420 min, t_{R} (major) = 9.163 min; 98% *ee*.

tert-butyl (R)-6-(1H-indol-2-yl)-2-oxo-4-phenyl-3,4-dihydro-2H-pyran-5-carboxylate 3n



The title compound was prepared according to the typical procedure, as described above, in 71% yield (27.6 mg); white solid; 87% *ee*; $[\alpha]_{\text{D}}^{25} = -64.38$ ($c = 0.5$, CHCl_3); m.p. = 162 – 164 °C.

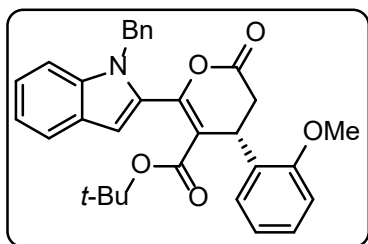
^1H NMR (500 MHz, CDCl_3) δ 11.72 (s, 1H), 7.68 (d, $J = 8.0$ Hz, 1H), 7.47 (d, $J = 8.3$ Hz, 1H), 7.33 – 7.26 (m, 5H), 7.22 – 7.20 (m, 2H), 7.13 (t, $J = 7.5$ Hz, 1H), 4.41 (dd, $J = 7.0, 3.6$ Hz, 1H), 3.05 (dd, $J = 15.8, 7.1$ Hz, 1H), 2.90 (dd, $J = 15.8, 3.6$ Hz, 1H), 1.35 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 165.8, 164.5, 151.0, 139.7, 136.2, 128.0, 127.9, 126.5, 126.0, 125.7, 123.6, 120.8, 119.4, 111.0, 108.8, 107.5, 81.9, 39.4, 35.5, 26.8.

HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{23}\text{NO}_4$ $[\text{M}+\text{Na}]^+$ m/z 412.1519, found 412.1528.

HPLC: Chiralcel AD (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 7.407 min, t_{R} (minor) = 11.927 min; 87% *ee*.

tert-butyl (R)-6-(1-benzyl-1H-indol-2-yl)-4-(2-methoxyphenyl)-2-oxo-3,4-dihydro-2H-pyran-5-carboxylate 3o



The title compound was prepared according to the typical procedure, as described above, in 65% yield (33.1 mg); white solid; 96% *ee*; $[\alpha]_{\text{D}}^{25} = -102.30$ ($c = 0.5$, CHCl_3); m.p. = 146 – 148 °C.

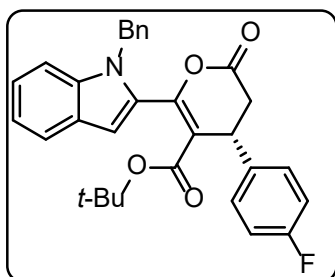
^1H NMR (500 MHz, CDCl_3) δ 7.63 (d, $J = 7.9$ Hz, 1H), 7.33 (dd, $J = 8.7, 2.5$ Hz, 1H), 7.27 – 7.20 (m, 9H), 7.13 – 7.10 (m, 1H), 6.77 – 6.73 (m, 1H), 6.69 (d, $J = 8.7$ Hz, 1H), 5.40 (s, 2H), 4.39 (dd, $J = 8.6, 3.0$ Hz, 1H), 3.59 (s, 3H), 2.82 (dd, $J = 16.6, 8.6$ Hz, 1H), 2.74 (dd, $J = 16.5, 3.0$ Hz, 1H), 1.05 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.4, 163.9, 155.2, 147.7, 136.5, 136.4, 130.8, 130.6, 130.3, 128.8, 127.6, 126.5, 126.1, 125.8, 122.2, 120.3, 119.2, 114.3, 111.8, 111.4, 109.2, 105.0, 80.9, 53.8, 47.3, 34.6, 32.4, 26.5.

HRMS (ESI) calcd for $\text{C}_{32}\text{H}_{31}\text{NO}_5$ $[\text{M}+\text{Na}]^+$ m/z 532.2094, found 532.2102.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 95/5, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (minor) = 13.570 min, t_{R} (major) = 15.689 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-1H-indol-2-yl)-4-(4-fluorophenyl)-2-oxo-3,4-dihydro-2H-pyran-5-carboxylate 3p



The title compound was prepared according to the typical procedure, as described above, in 50% yield (24.8 mg); white solid; 97% *ee*; $[\alpha]_{\text{D}}^{25} = -78.80$ ($c = 0.5$, CHCl_3); m.p. = 118 – 120 °C.

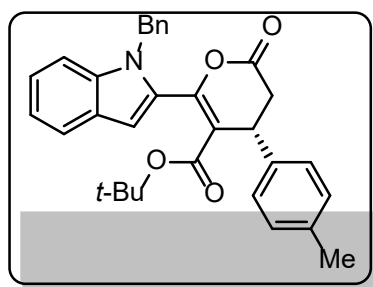
^1H NMR (500 MHz, CDCl_3) δ 7.65 (d, $J = 7.9$ Hz, 1H), 7.35 (d, $J = 8.1$ Hz, 1H), 7.28 – 7.24 (m, 4H), 7.17 – 7.13 (m, 3H), 6.99 – 6.90 (m, 4H), 6.80 (s, 1H), 5.46 (s, 2H), 4.23 (dd, $J = 7.4, 3.4$ Hz, 1H), 2.79 (dd, $J = 16.0, 7.5$ Hz, 1H), 2.69 (dd, $J = 16.0, 3.5$ Hz, 1H), 1.08 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 165.5, 164.9, 163.1, 161.1, 149.2, 138.0, 137.4, 135.4, 135.4, 130.3, 128.7, 128.4, 128.4, 127.6, 126.9, 126.8, 123.6, 121.5, 120.4, 116.9, 116.1, 115.9, 109.9, 107.3, 82.0, 48.1, 38.3, 36.0, 27.6.

HRMS (ESI) calcd for $\text{C}_{31}\text{H}_{28}\text{FNO}_4$ $[\text{M}+\text{Na}]^+$ m/z 520.1895, found 520.1904.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 10.780 min, t_{R} (minor) = 15.026 min; 97% *ee*.

tert-butyl (R)-6-(1-benzyl-1H-indol-2-yl)-2-oxo-4-(p-tolyl)-3,4-dihydro-2H-pyran-5-carboxylate 3q



The title compound was prepared according to the typical procedure, as described above, in 62% yield (30.5 mg); white solid; 96% *ee*; $[\alpha]_{\text{D}}^{25} = -87.22$ ($c = 0.5$, CHCl_3); m.p. = 120 – 122 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.64 (d, $J = 7.8$ Hz, 1H), 7.33 (d, $J = 8.3$ Hz, 1H), 7.28 – 7.23 (m, 4H), 7.16 – 7.12 (m, 3H), 7.05 (d, $J = 7.9$ Hz, 2H), 6.94 (d, $J = 8.0$ Hz, 2H), 6.78 (s, 1H), 5.44 (s, 2H), 4.21 (dd, $J = 7.1, 3.7$ Hz, 1H), 2.77 (dd, $J = 16.0, 7.2$ Hz, 1H), 2.71 (dd, $J = 15.9, 3.7$ Hz, 1H), 2.30 (s, 3H), 1.06 (s, 9H).

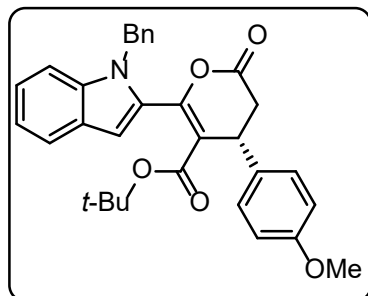
^{13}C NMR (126 MHz, CDCl_3) δ 164.8, 164.0, 147.9, 136.8, 136.4, 136.2, 135.6, 129.6, 128.7, 127.6, 126.5, 126.0, 125.9, 125.6, 122.4, 120.4, 119.2, 116.5, 108.9, 105.9, 80.7, 47.1, 37.5, 35.0, 26.5, 20.0.

HRMS (ESI) calcd for $\text{C}_{32}\text{H}_{31}\text{NO}_4$ $[\text{M}+\text{Na}]^+$ m/z 516.2145, found 516.2145.

HPLC: Chiralcel AD (n-hexane/*i*-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R}

(minor) = 11.541 min, t_R (major) = 13.394 min; 96% *ee*.

tert-butyl (R)-6-(1-benzyl-1H-indol-2-yl)-4-(4-methoxyphenyl)-2-oxo-3,4-dihydro-2H-pyran-5-carboxylate 3r



The title compound was prepared according to the typical procedure, as described above, in 64% yield (32.6 mg); white solid; 93% *ee*; $[\alpha]_D^{25} = -172.94$ ($c = 0.5$, CHCl_3); m.p. = 167 – 169 °C.

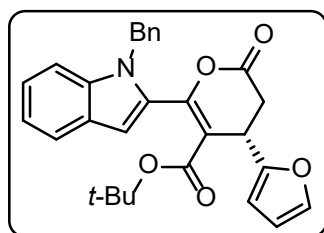
^1H NMR (500 MHz, CDCl_3) δ 7.64 (d, $J = 7.9$ Hz, 1H), 7.33 – 7.32 (m, 1H), 7.28 – 7.24 (m, 4H), 7.16 – 7.14 (m, 3H), 6.96 (d, $J = 8.6$ Hz, 2H), 6.78 – 6.76 (m, 3H), 5.44 (s, 2H), 4.20 (dd, $J = 7.2, 3.6$ Hz, 1H), 3.77 (s, 3H), 2.76 (d, $J = 7.3$ Hz, 1H), 2.72 (d, $J = 3.7$ Hz, 1H), 1.07 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.8, 164.0, 157.9, 147.8, 136.9, 136.4, 130.6, 129.6, 127.6, 126.8, 126.5, 126.0, 125.8, 122.4, 120.4, 119.3, 116.6, 113.4, 108.9, 105.9, 80.8, 54.2, 47.1, 37.2, 35.1, 26.5.

HRMS (ESI) calcd for $\text{C}_{32}\text{H}_{31}\text{NO}_5$ $[\text{M}+\text{Na}]^+$ m/z 532.2094, found 532.21.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 95/5, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_R (major) = 23.497 min, t_R (minor) = 25.358 min; 93% *ee*.

tert-butyl (S)-6-(1-benzyl-1H-indol-2-yl)-4-(furan-2-yl)-2-oxo-3,4-dihydro-2H-pyran-5-carboxylate 3s



The title compound was prepared according to the typical procedure, as described above,

in 68% yield (31.9 mg); yellow solid; 83% *ee*; $[\alpha]_{\text{D}}^{25} = -53.32$ ($c = 0.5$, CHCl_3); m.p. = 102 – 104 °C.

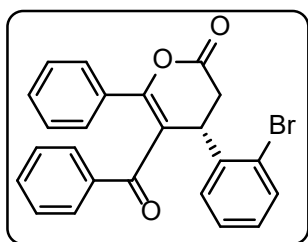
^1H NMR (500 MHz, CDCl_3) δ 7.63 (d, $J = 7.9$ Hz, 1H), 7.34 – 7.29 (m, 2H), 7.25 – 7.22 (m, 4H), 7.14 – 7.11 (m, 3H), 6.73 (s, 1H), 6.25 (dd, $J = 3.1, 1.9$ Hz, 1H), 5.99 (d, $J = 3.2$ Hz, 1H), 5.37 (s, 2H), 4.37 (dd, $J = 7.2, 1.8$ Hz, 1H), 2.98 (dd, $J = 16.0, 2.1$ Hz, 1H), 2.70 (dd, $J = 16.0, 7.3$ Hz, 1H), 1.10 (s, 9H).

^{13}C NMR (126 MHz, CDCl_3) δ 164.4, 163.6, 151.0, 149.1, 141.5, 136.7, 136.3, 129.6, 127.5, 126.5, 126.0, 126.0, 122.4, 120.4, 119.2, 114.1, 109.4, 109.0, 105.7, 105.4, 80.9, 47.1, 31.8, 31.6, 26.5.

HRMS (ESI) calcd for $\text{C}_{29}\text{H}_{27}\text{NO}_5$ $[\text{M}+\text{Na}]^+$ m/z 492.1781, found 492.1775.

HPLC: Chiralcel IA (n-hexane/*i*-PrOH, 95/5, flow rate 1.0 mL/min, $\lambda = 254$ nm), t_{R} (major) = 12.628 min, t_{R} (minor) = 13.463 min; 83% *ee*.

(4S)-5-benzoyl-4-(2-bromophenyl)-6-phenyl-3,4-dihydro-2H-pyran-2-one 3t



The title compound was prepared according to the typical procedure, as described above, in 85% yield (36.7 mg); White solid; 87% *ee*; $[\alpha]_{\text{D}}^{25} = -6.40$ ($c = 0.05$, CHCl_3); m.p. = 155 – 159 °C.

^1H NMR (500 MHz, CDCl_3) δ 7.61 (dd, $J = 8.3, 1.1$ Hz, 2H), 7.56 (dd, $J = 8.0, 1.1$ Hz, 1H), 7.45 – 7.38 (m, 3H), 7.33 – 7.26 (m, 2H), 7.23 – 7.18 (m, 1H), 7.19 – 7.06 (m, 5H), 5.04 (dd, $J = 7.9, 2.5$ Hz, 1H), 3.19 (dd, $J = 16.0, 7.9$ Hz, 1H), 3.06 (dd, $J = 16.0, 2.5$ Hz, 1H).

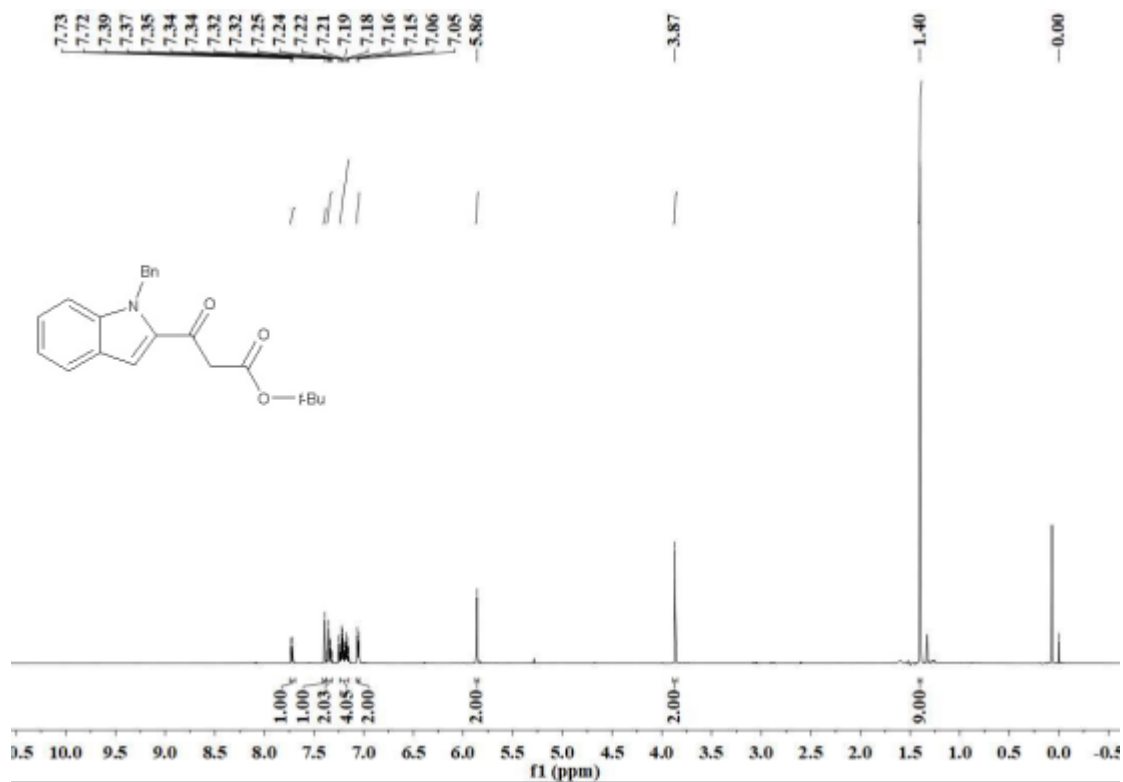
^{13}C NMR (126 MHz, CDCl_3) δ 195.01, 166.02, 156.52, 138.09, 136.68, 133.83, 132.78, 131.85, 130.54, 129.48, 129.31, 129.03, 128.27, 128.20, 128.16, 127.83, 123.94, 117.04, 39.64, 35.24.

HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{17}\text{BrO}_3$ $[\text{M}+\text{Na}]^+$ m/z 455.0253, found 455.0257.

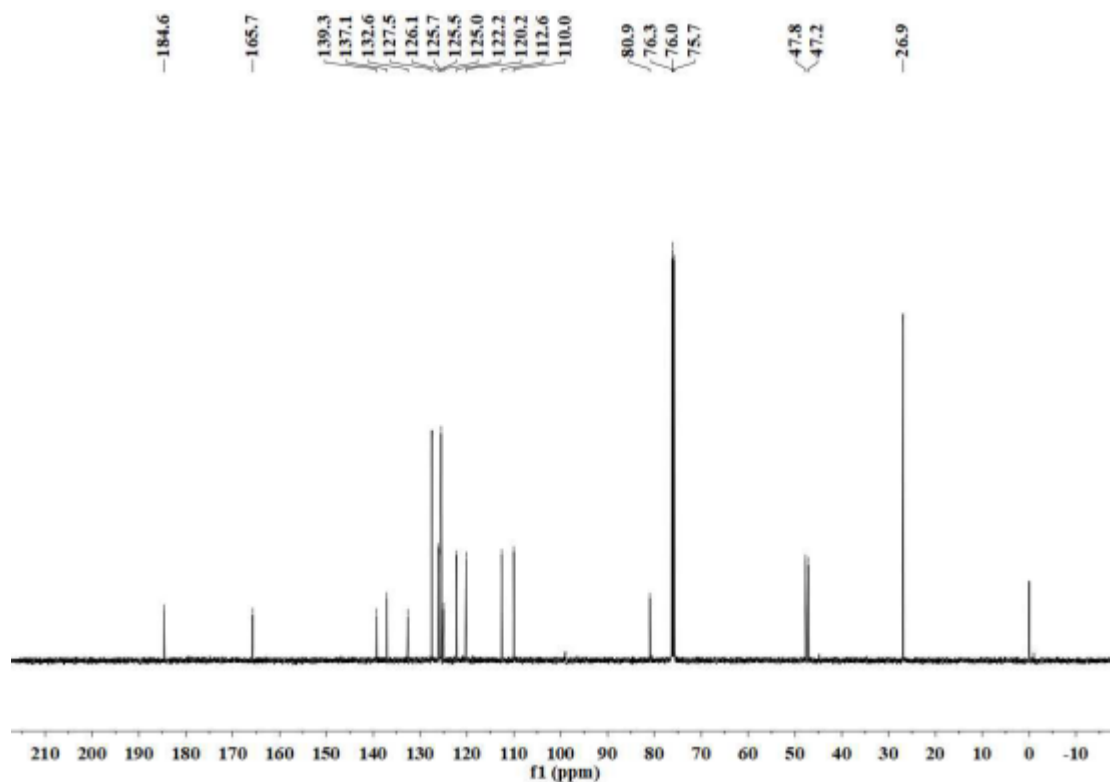
HPLC: Chiralcel AD-H (n-hexane/i-PrOH, 90/10, flow rate 1.0 mL/min, $\lambda = 254$ nm),
 t_R (major) = 19.164 min, t_R (minor) = 16.162 min; 87% *ee*.

4. NMR spectra of substrates 1 as new compounds

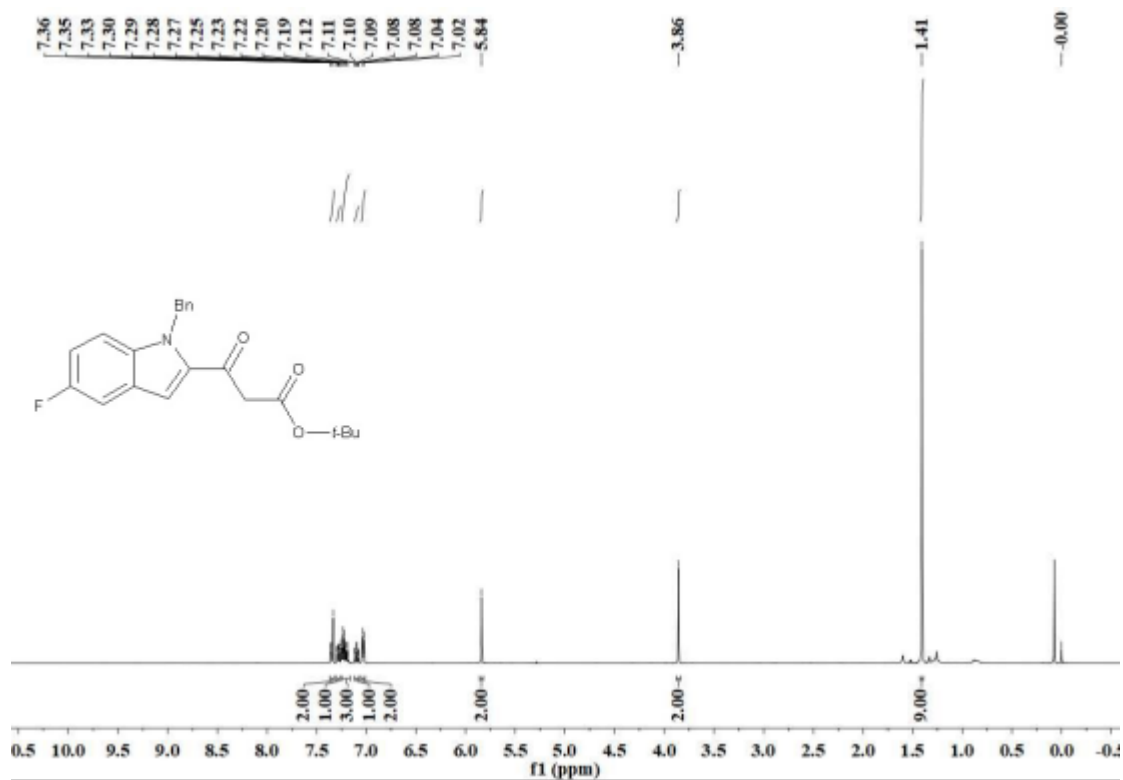
1a: ^1H NMR (500 MHz, CDCl_3)



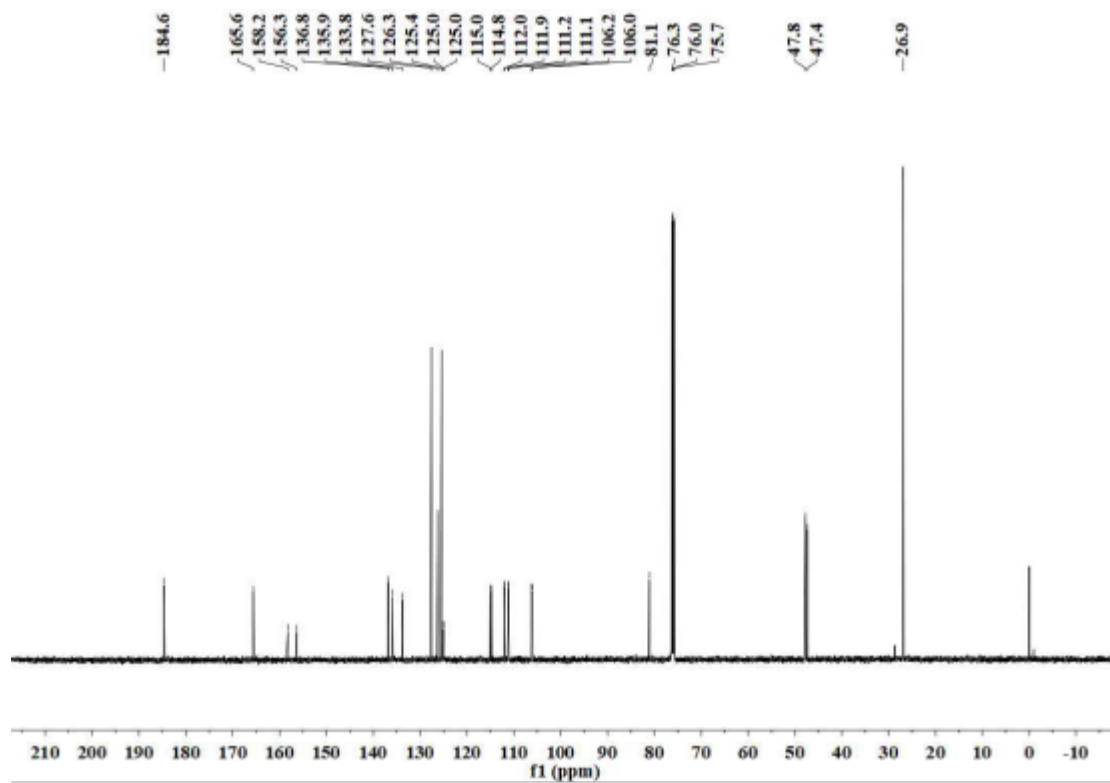
1a: ^{13}C NMR (126 MHz, CDCl_3)



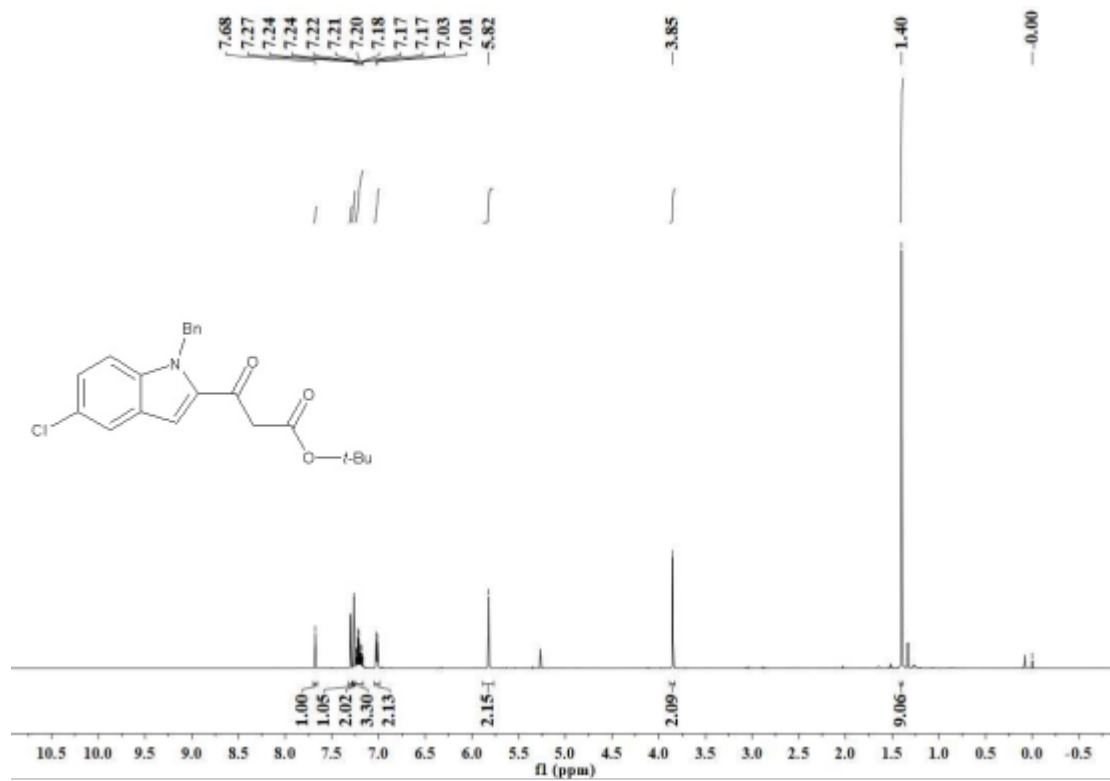
1b: ^1H NMR (500 MHz, CDCl_3)



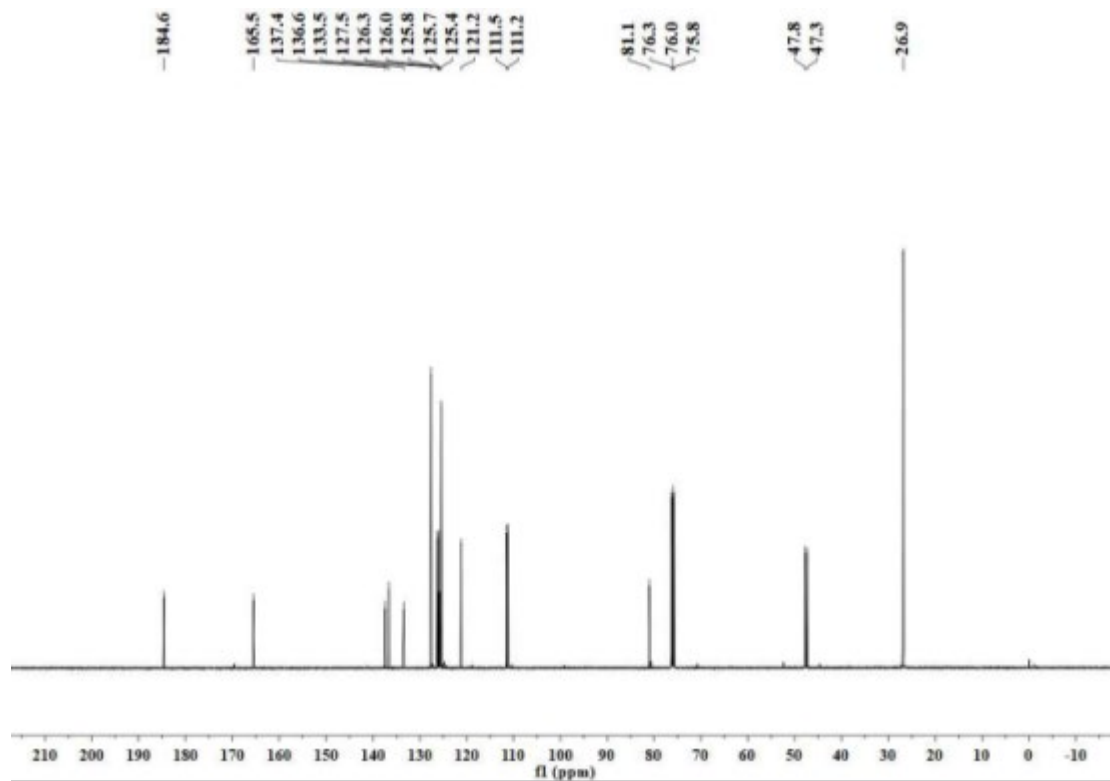
1b: ^{13}C NMR (126 MHz, CDCl_3)



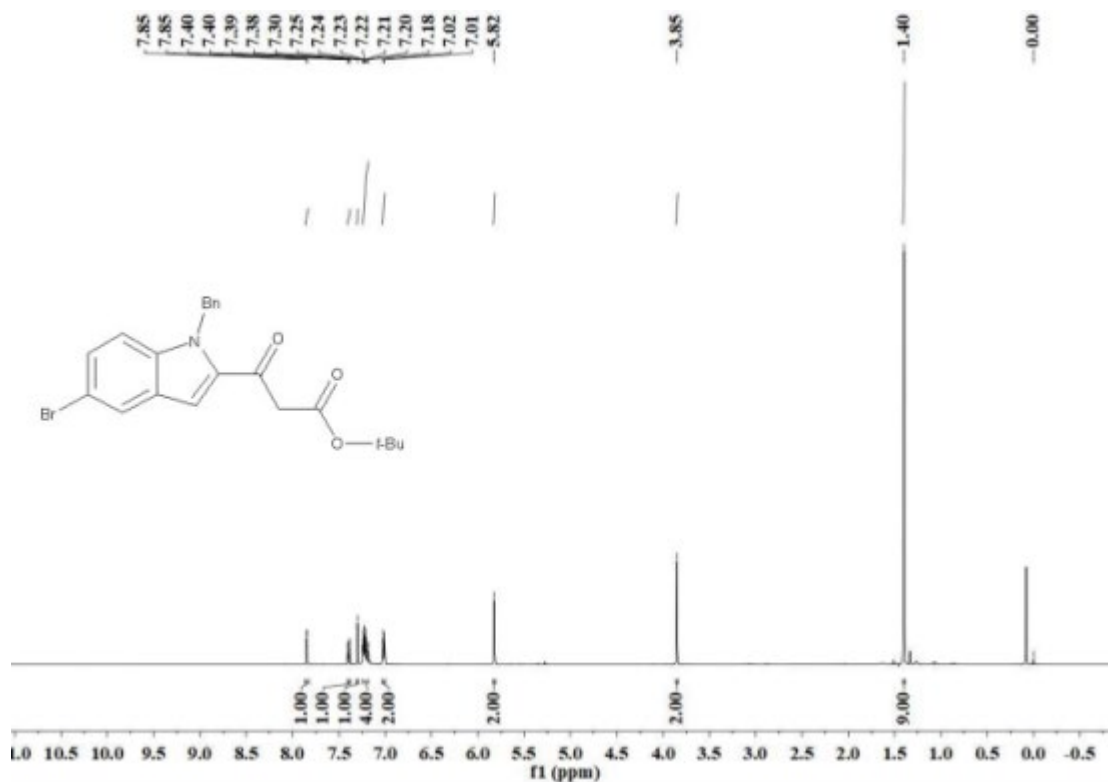
1c: ^1H NMR (500 MHz, CDCl_3)



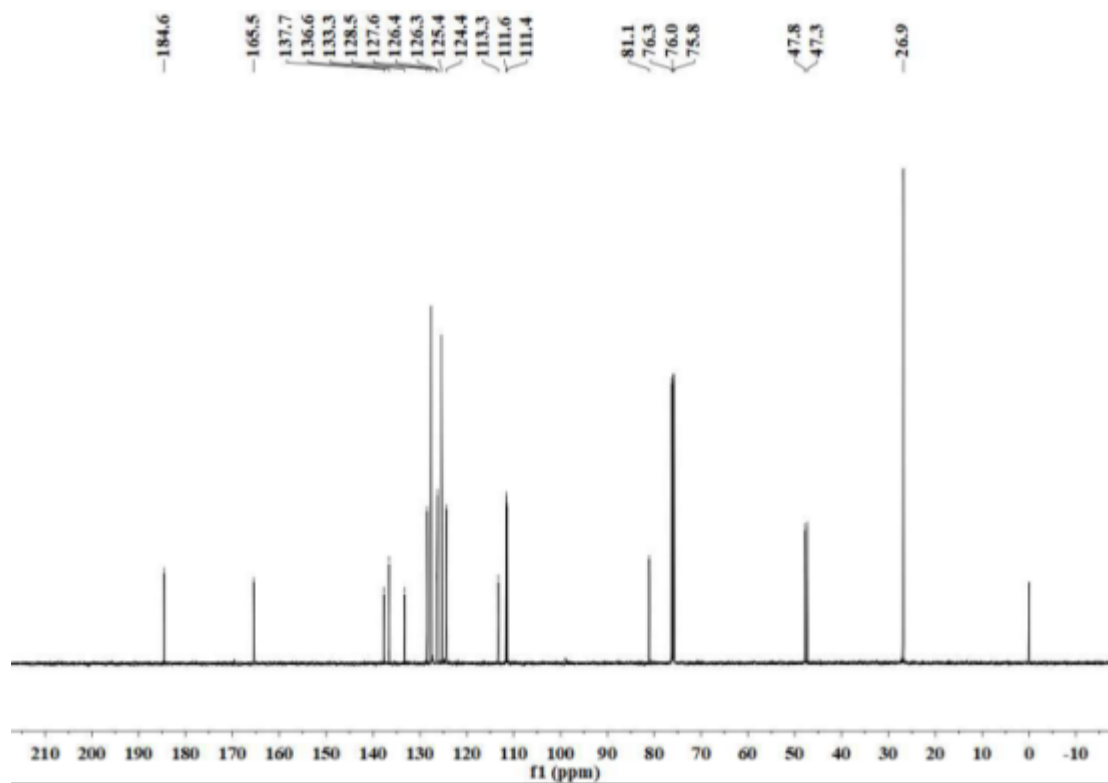
1c: ^{13}C NMR (126 MHz, CDCl_3)



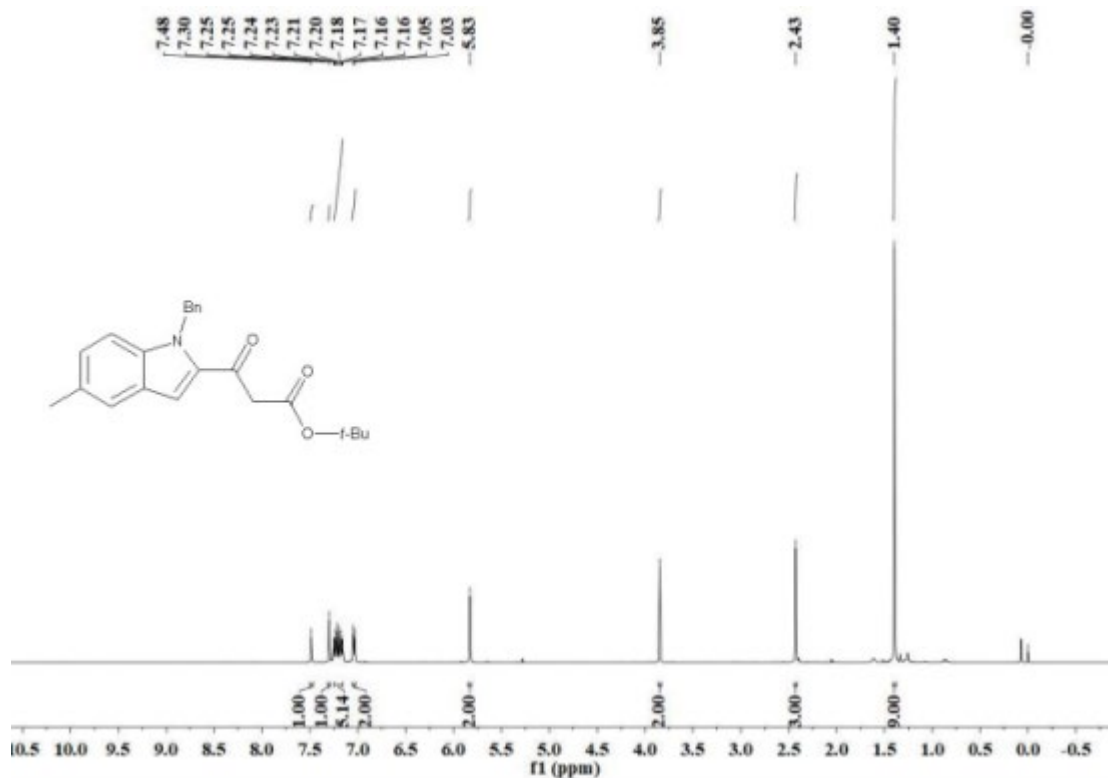
1d: ^1H NMR (500 MHz, CDCl_3)



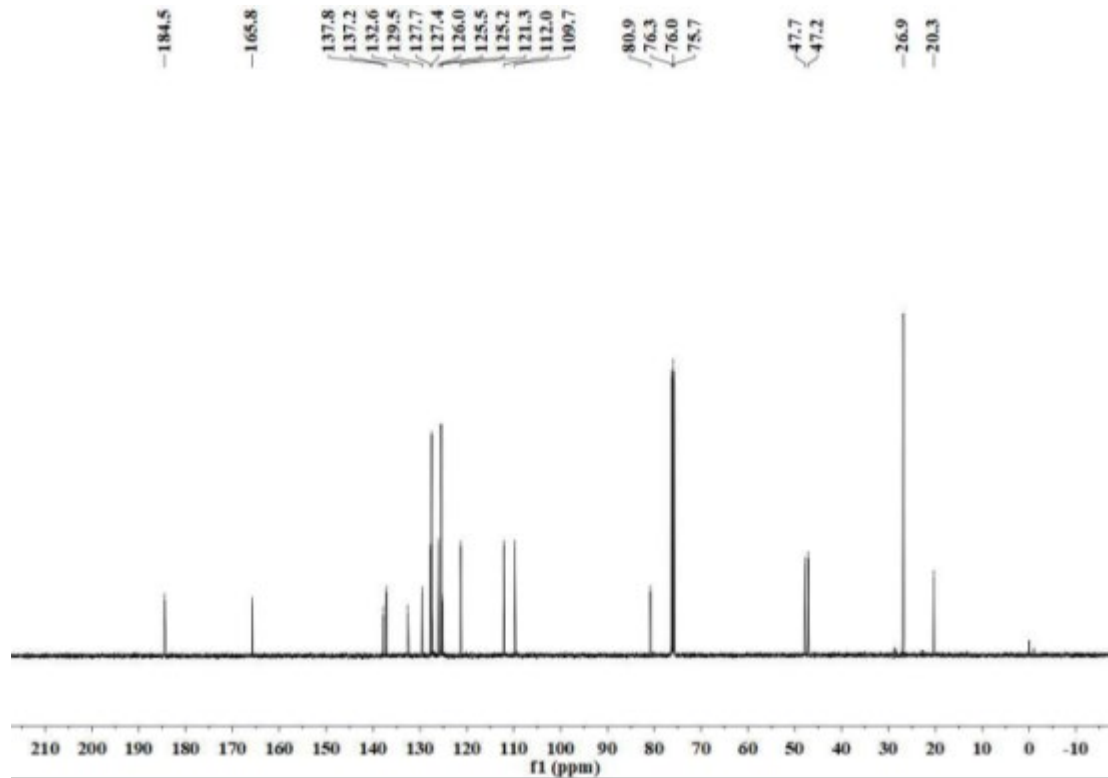
1d: ^{13}C NMR (126 MHz, CDCl_3)



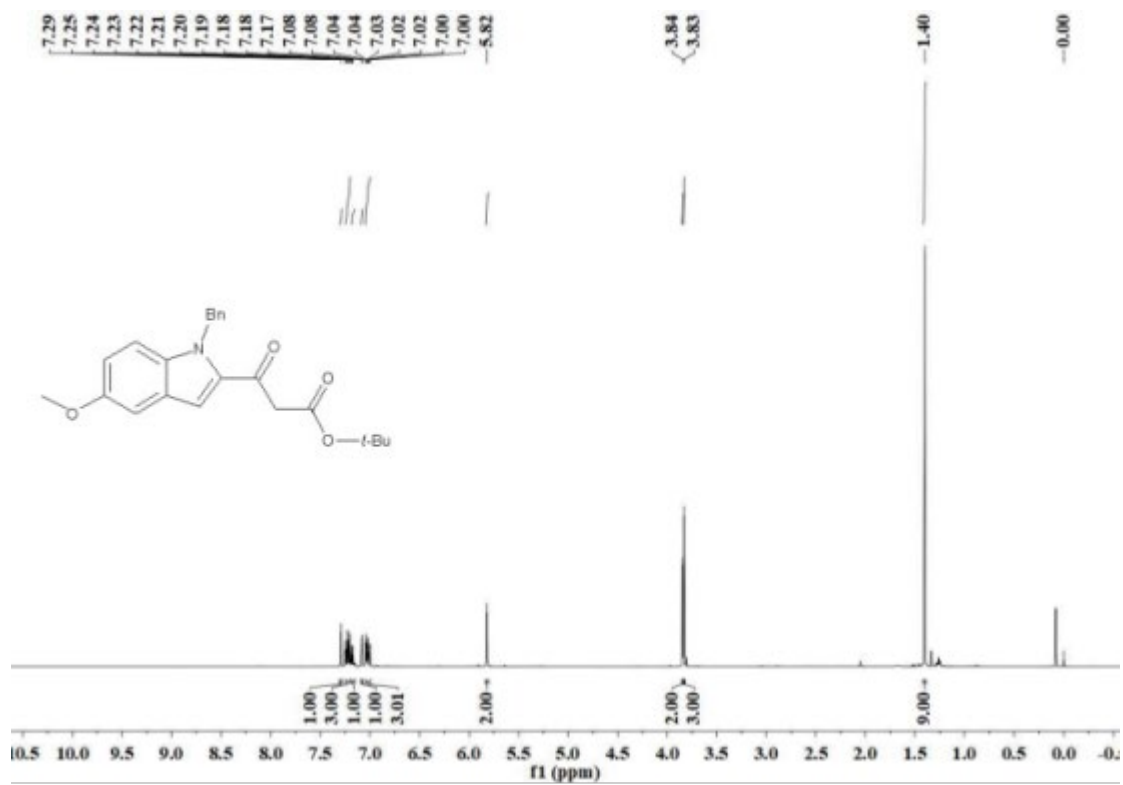
1e: ^1H NMR (500 MHz, CDCl_3)



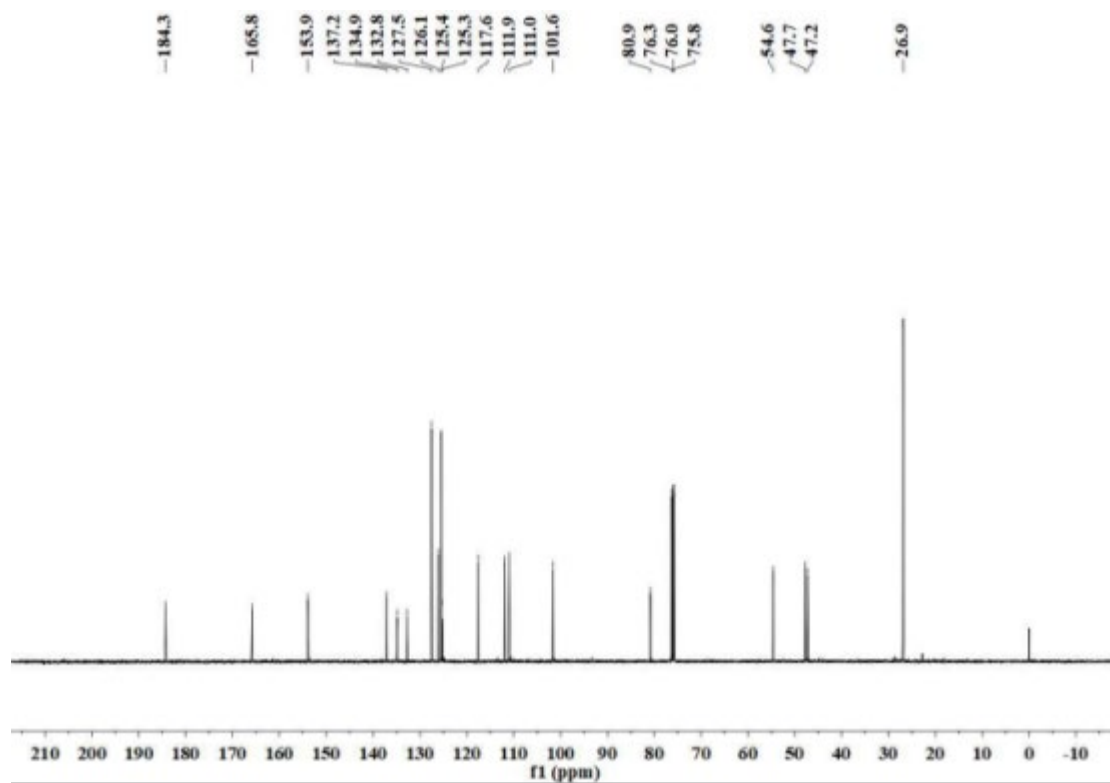
1e: ^{13}C NMR (126 MHz, CDCl_3)



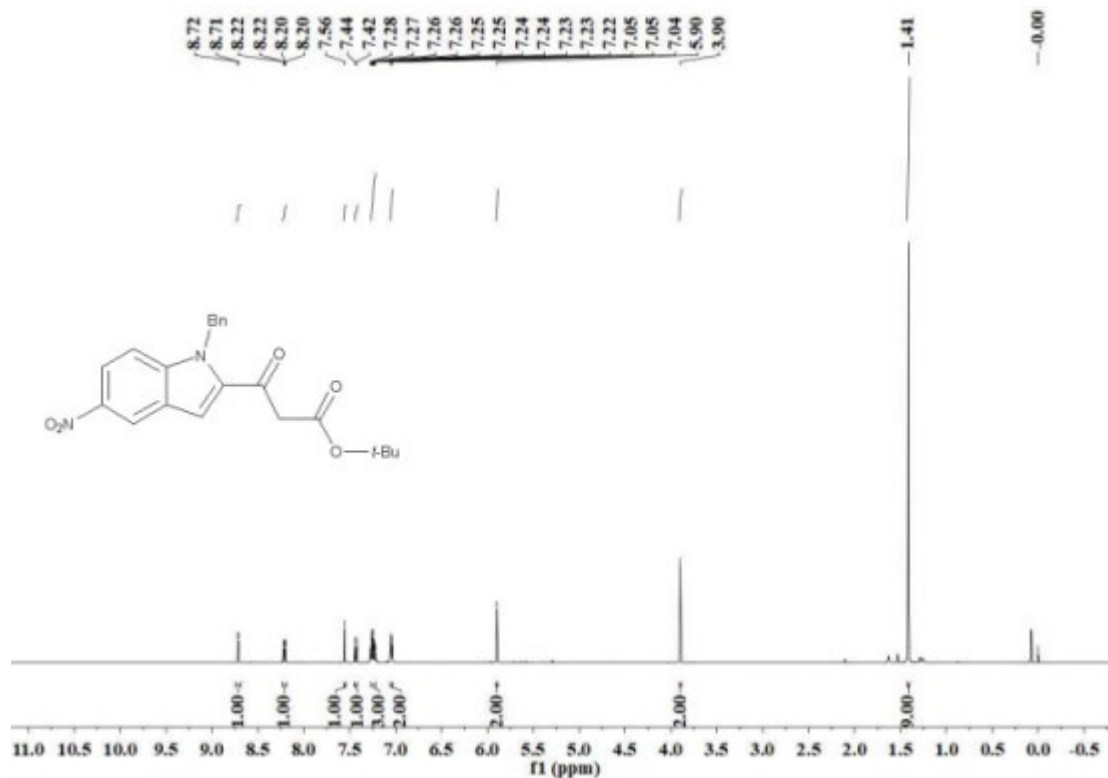
1f: ^1H NMR (500 MHz, CDCl_3)



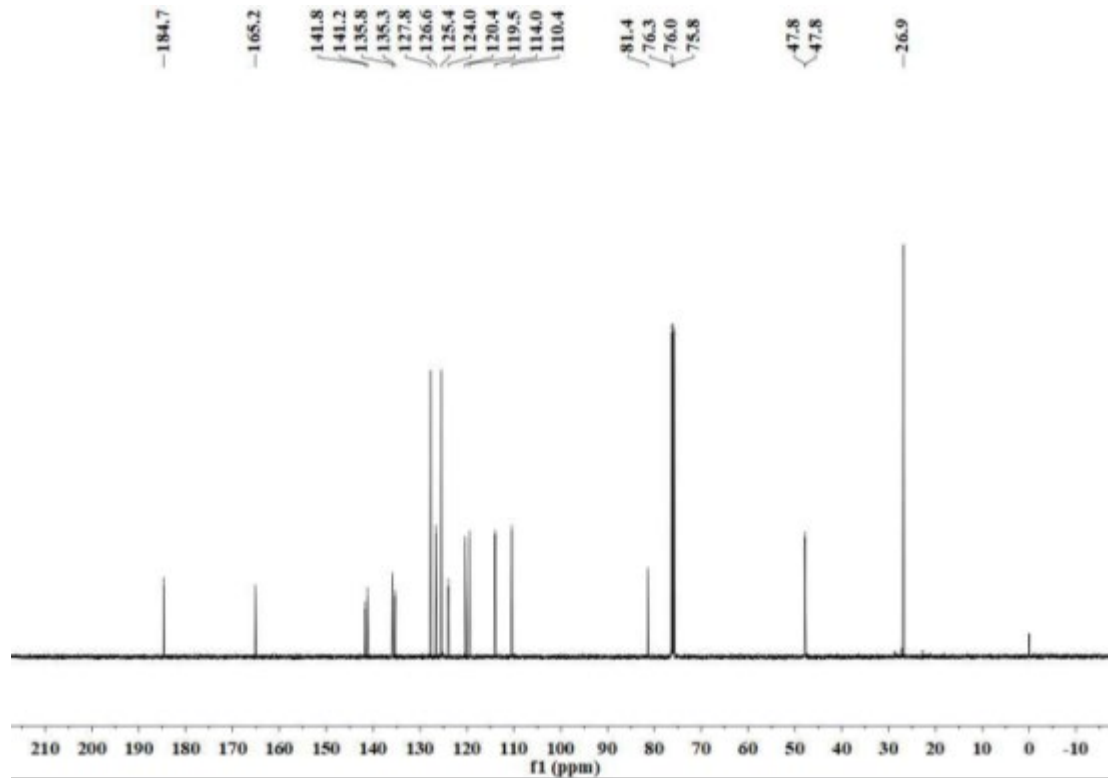
1f: ^{13}C NMR (126 MHz, CDCl_3)



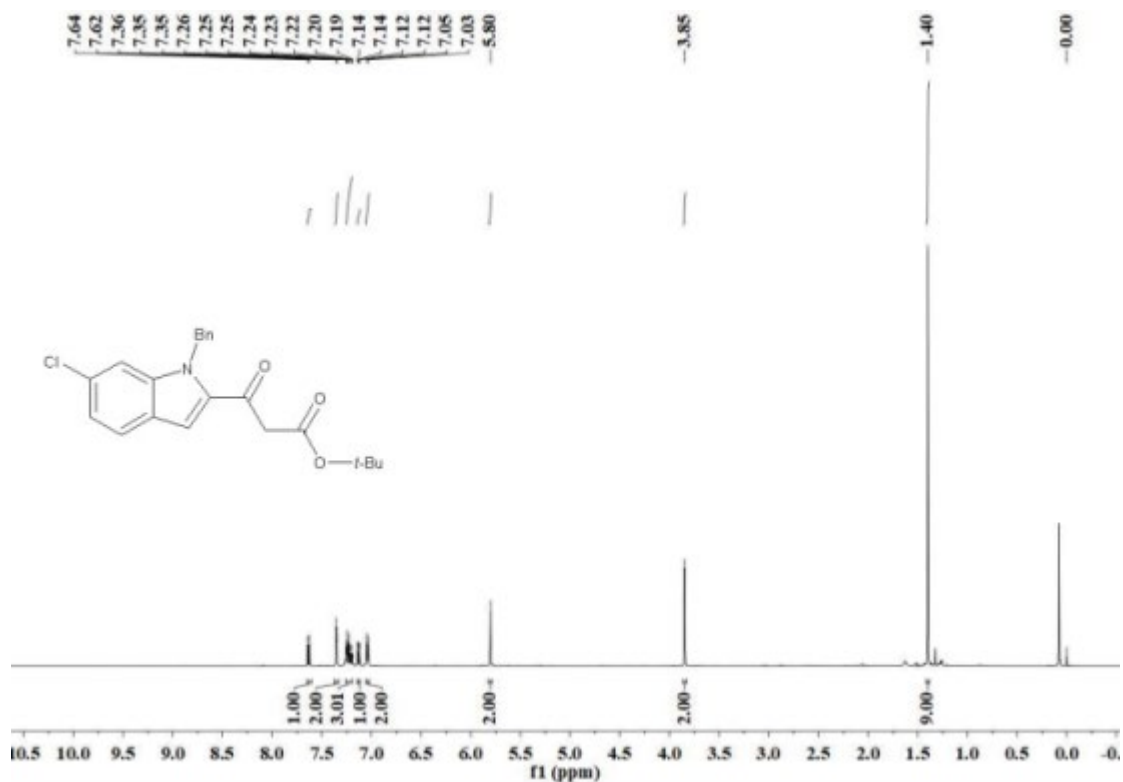
1g: ^1H NMR (500 MHz, CDCl_3)



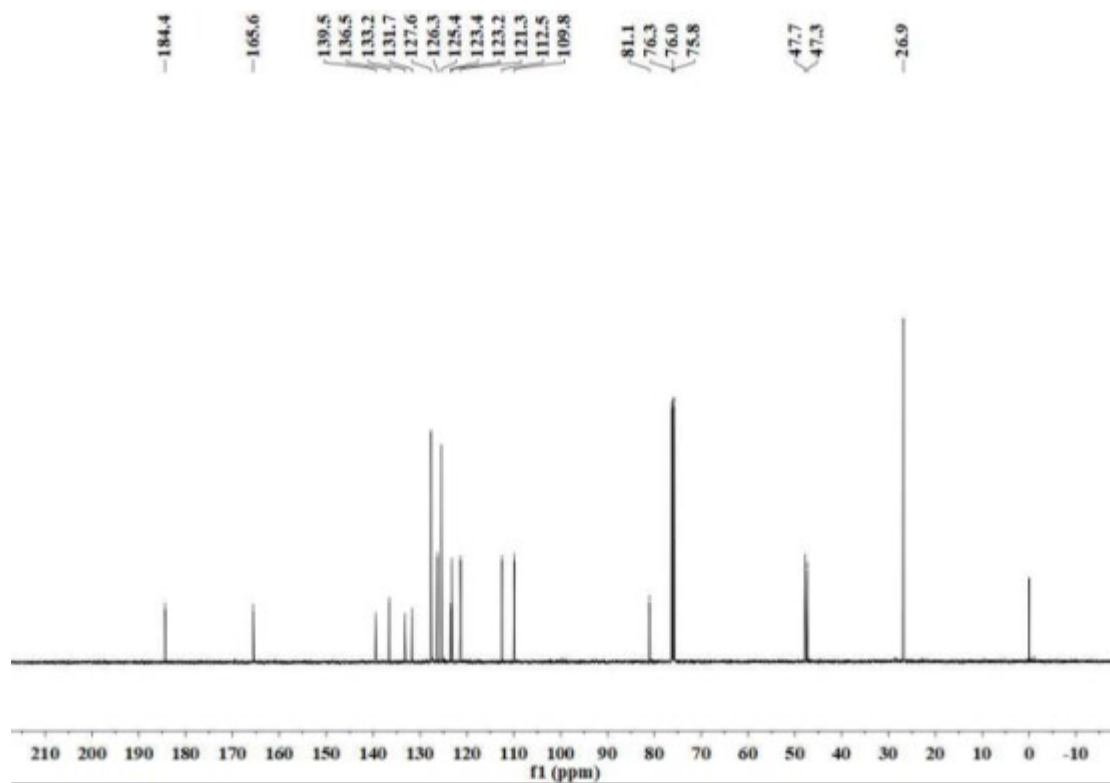
1g: ^{13}C NMR (126 MHz, CDCl_3)



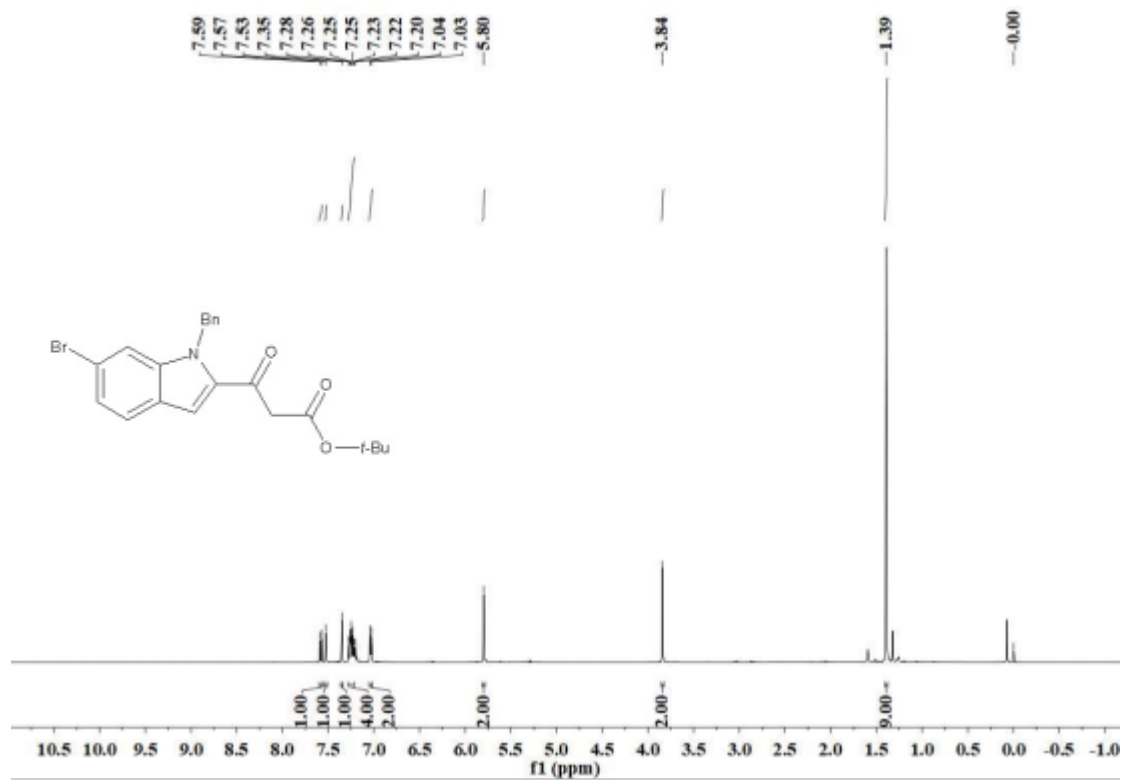
1h: ^1H NMR (500 MHz, CDCl_3)



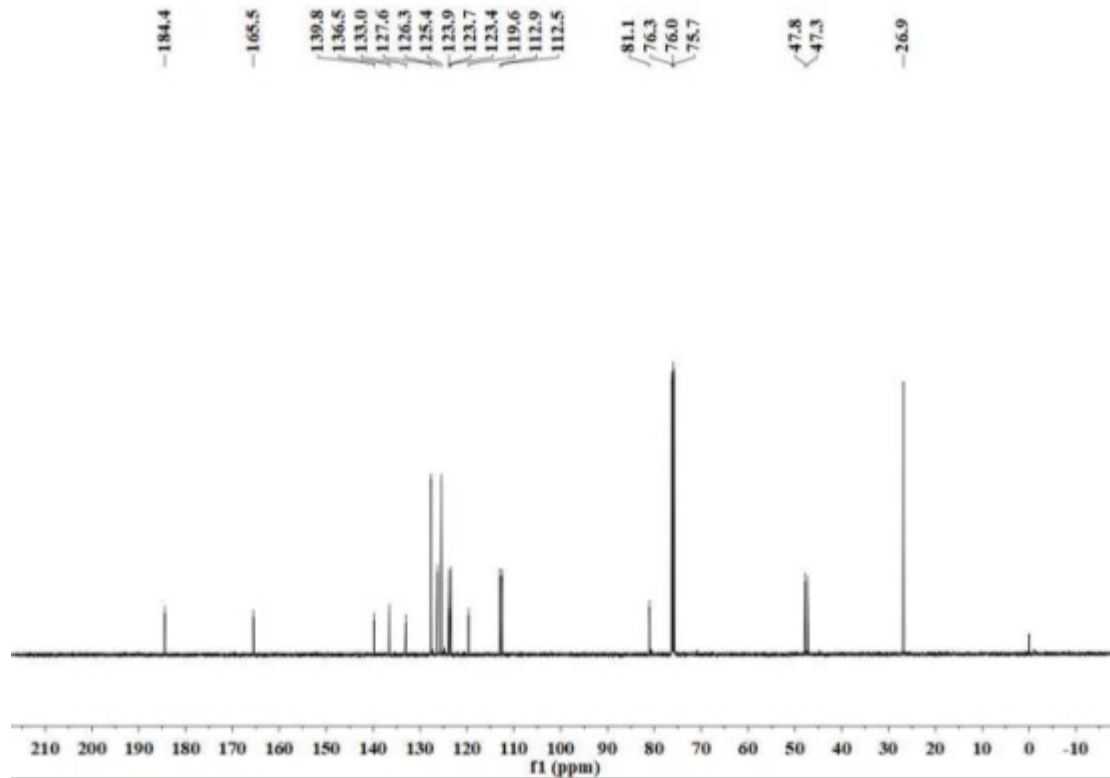
1h: ^{13}C NMR (126 MHz, CDCl_3)



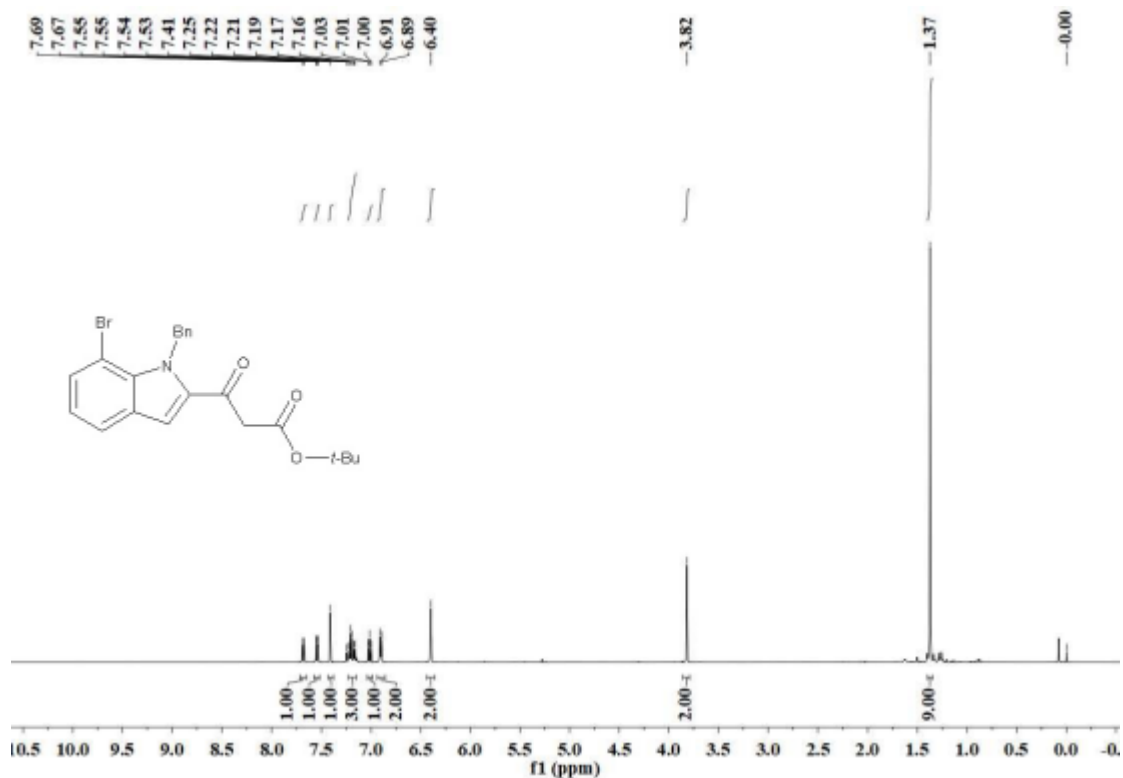
1i: ^1H NMR (500 MHz, CDCl_3)



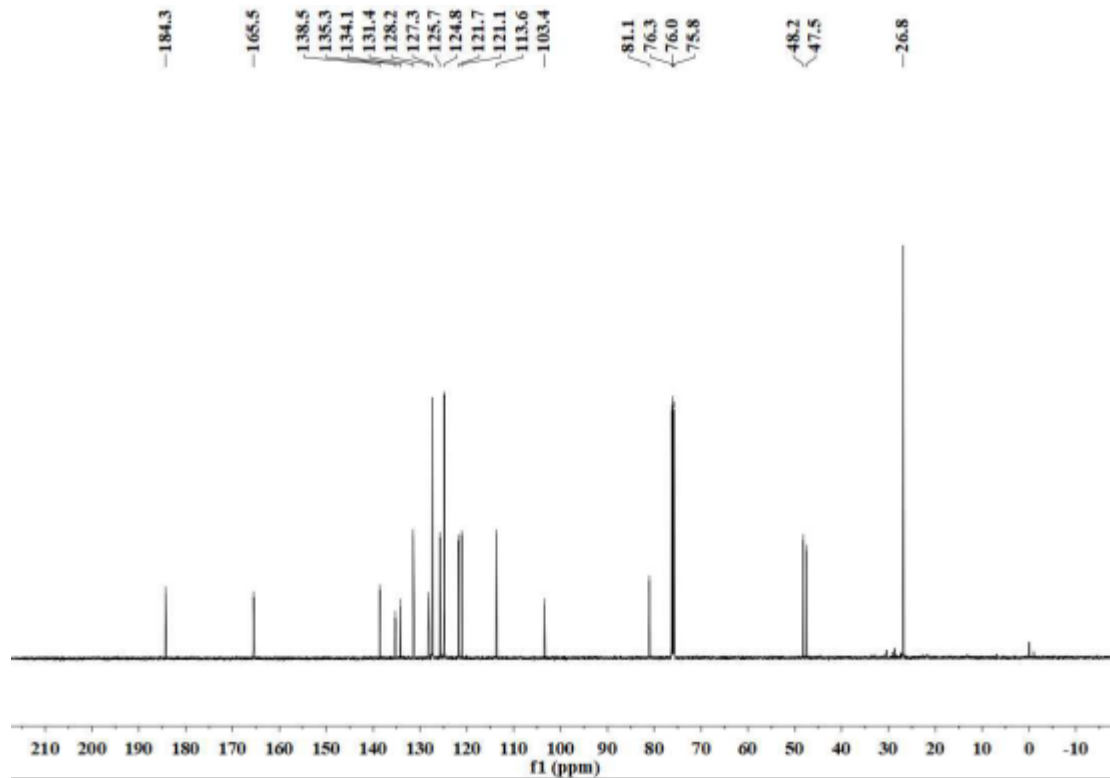
1i: ^{13}C NMR (126 MHz, CDCl_3)



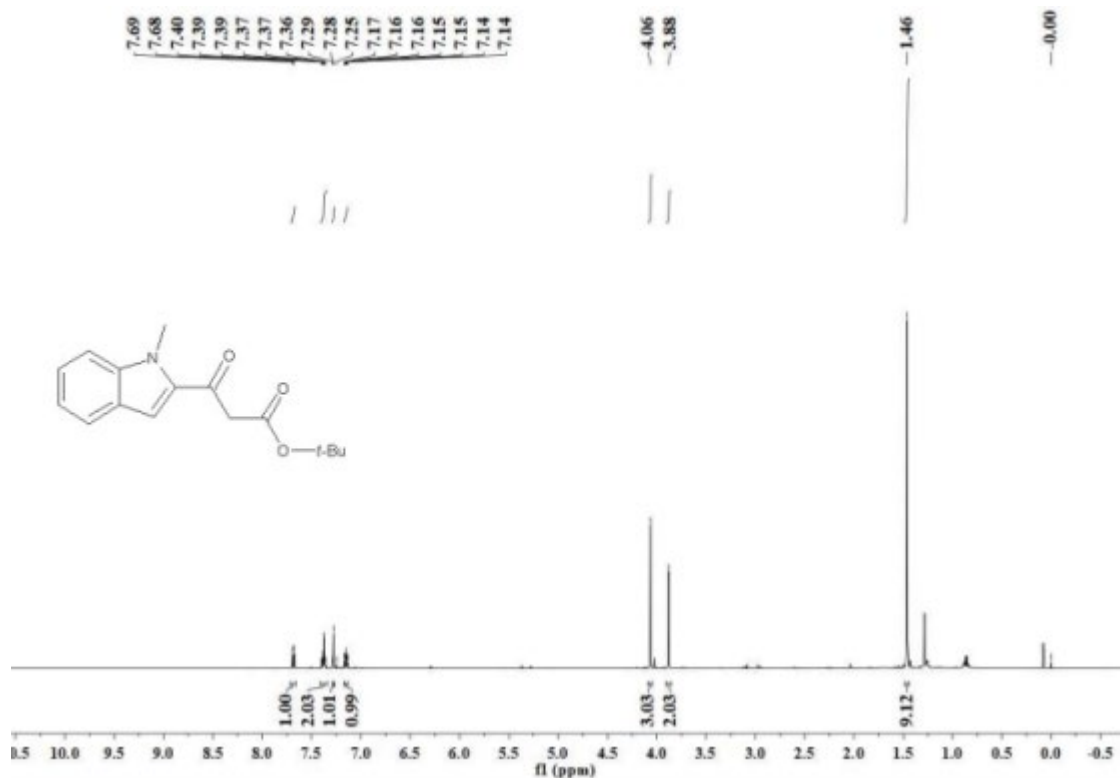
1j: ^1H NMR (500 MHz, CDCl_3)



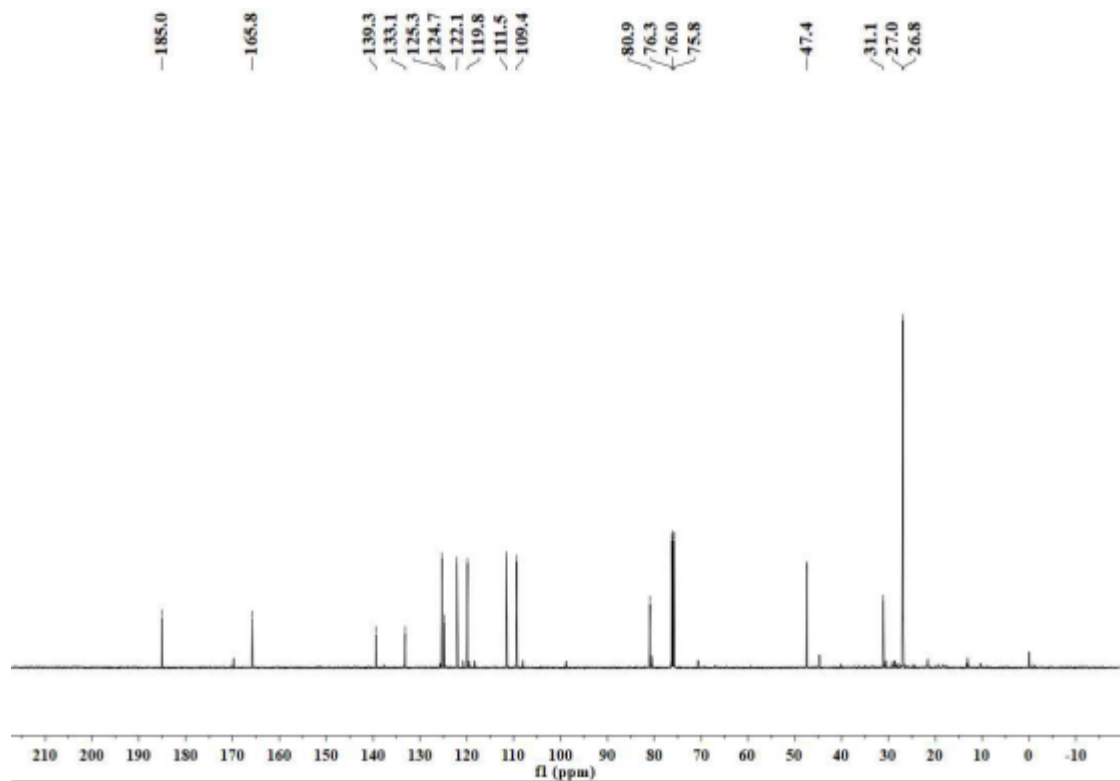
1j: ^{13}C NMR (126 MHz, CDCl_3)



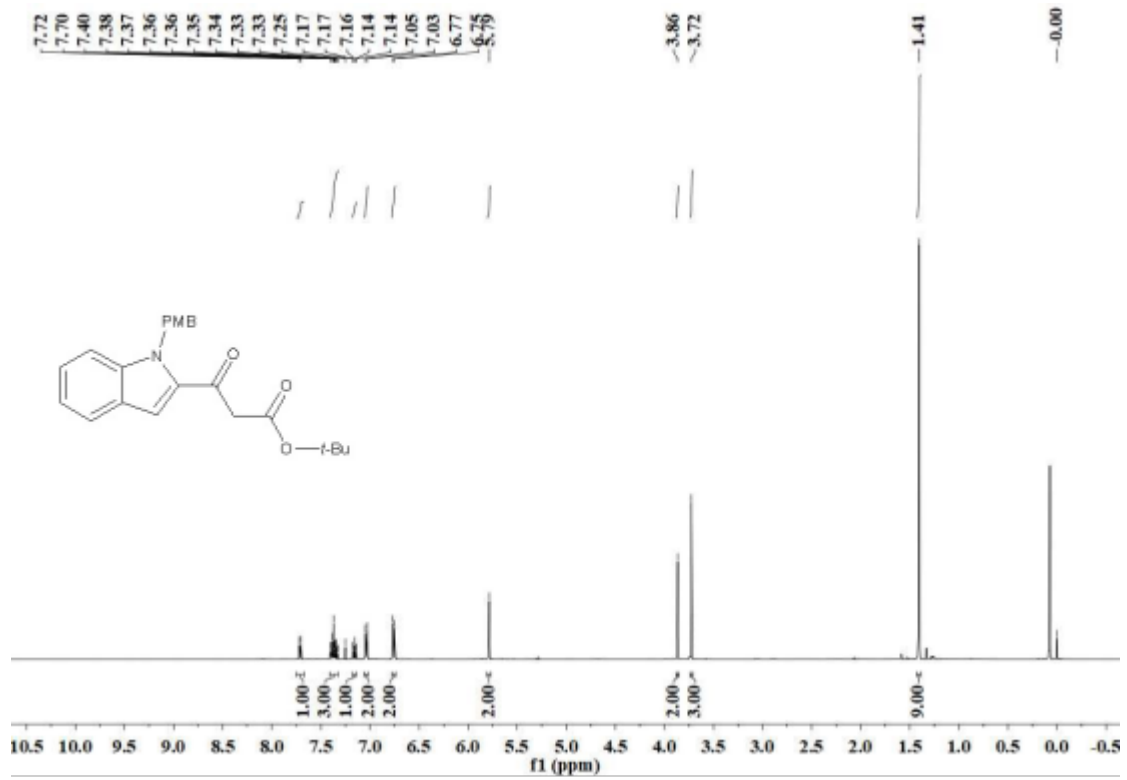
1k: ^1H NMR (500 MHz, CDCl_3)



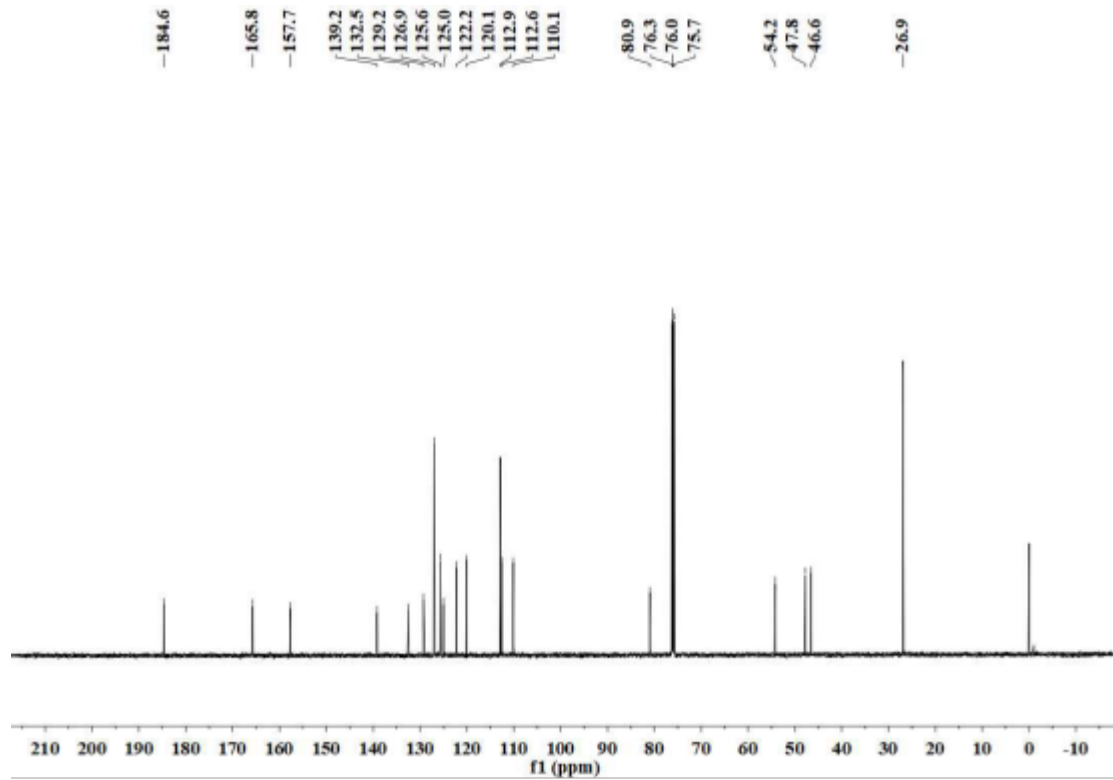
1k: ^{13}C NMR (126 MHz, CDCl_3)



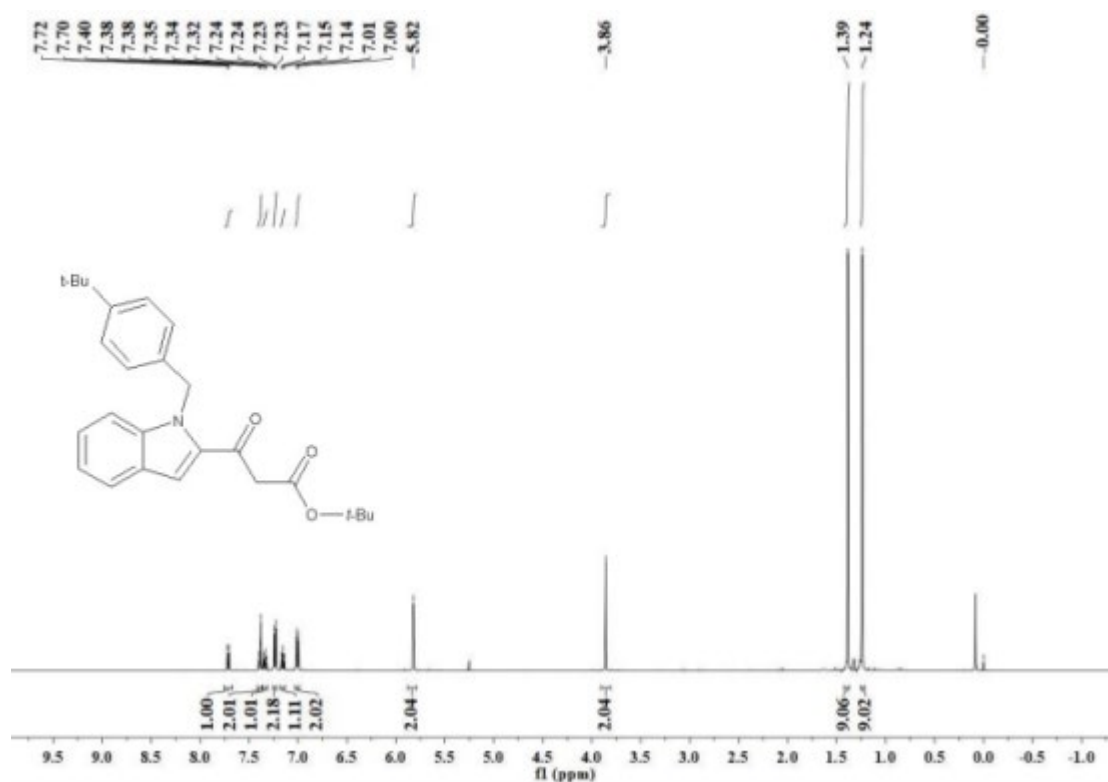
11: ^1H NMR (500 MHz, CDCl_3)



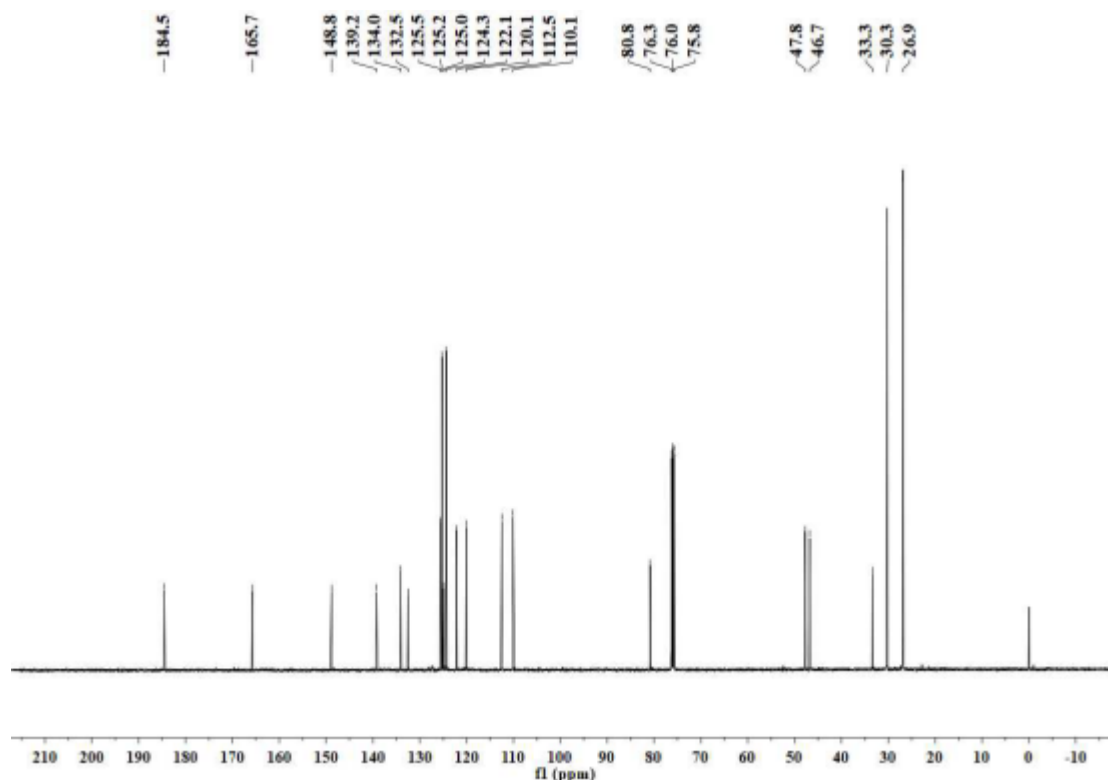
11: ^{13}C NMR (126 MHz, CDCl_3)



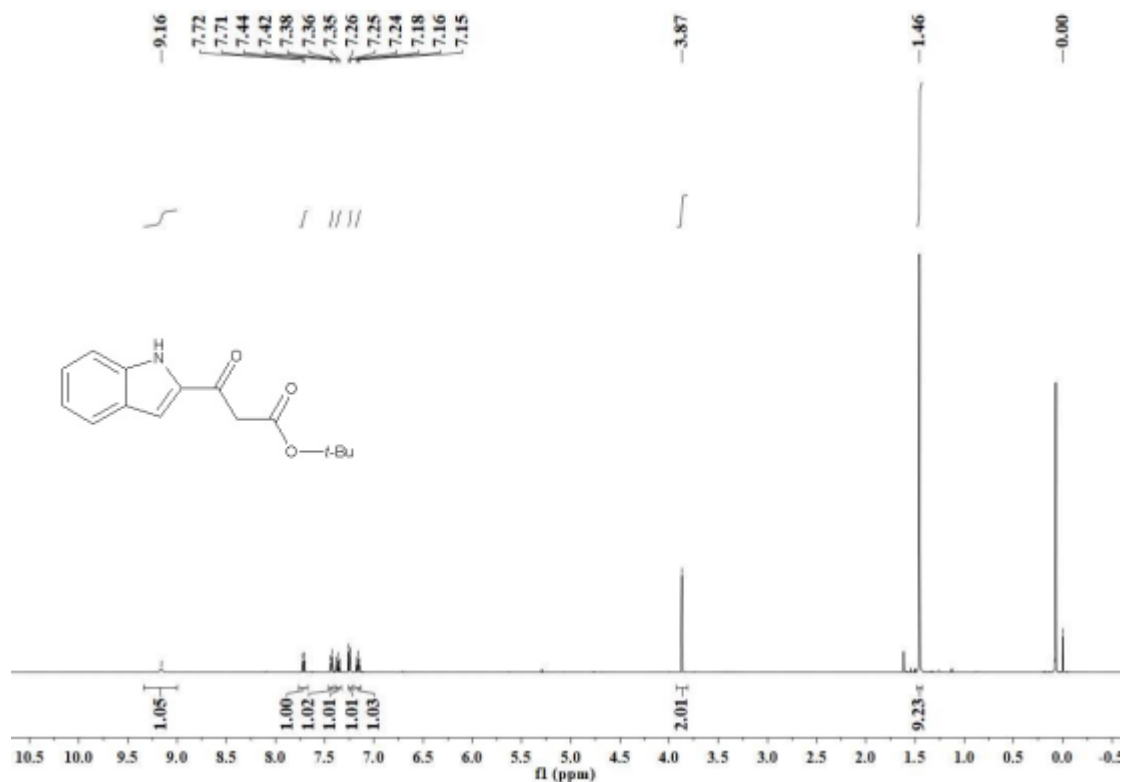
1m: ^1H NMR (500 MHz, CDCl_3)



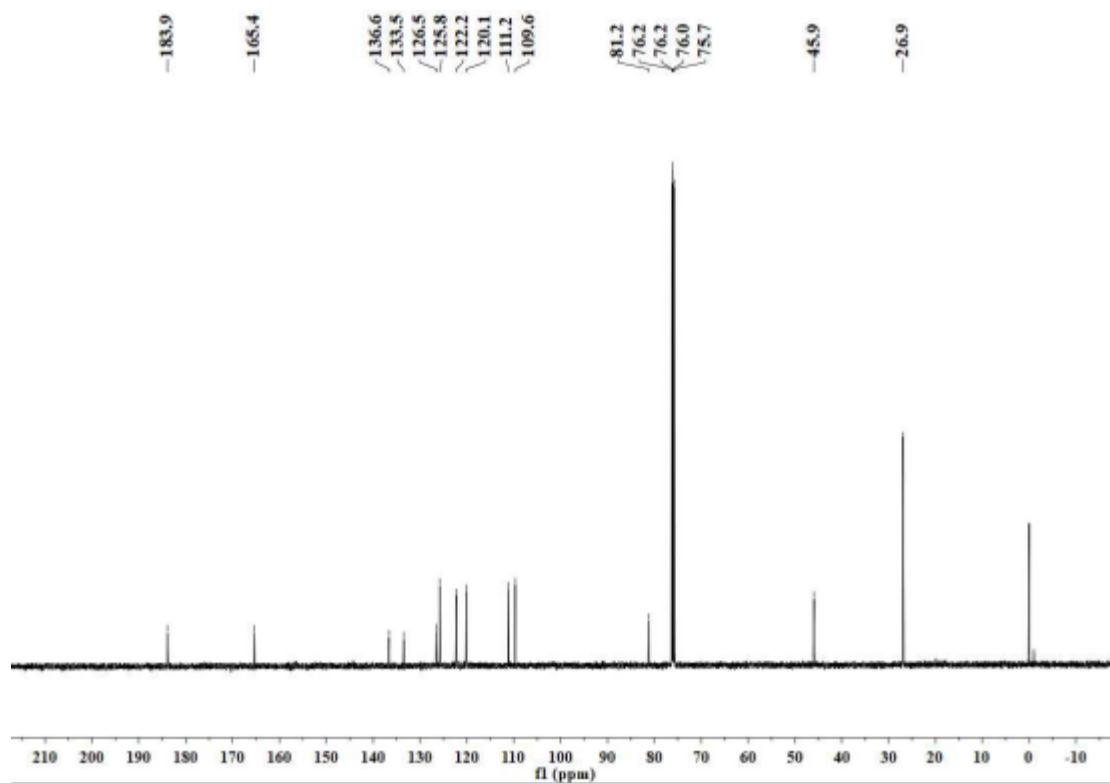
1m: ^{13}C NMR (126 MHz, CDCl_3)



1n: ^1H NMR (500 MHz, CDCl_3)

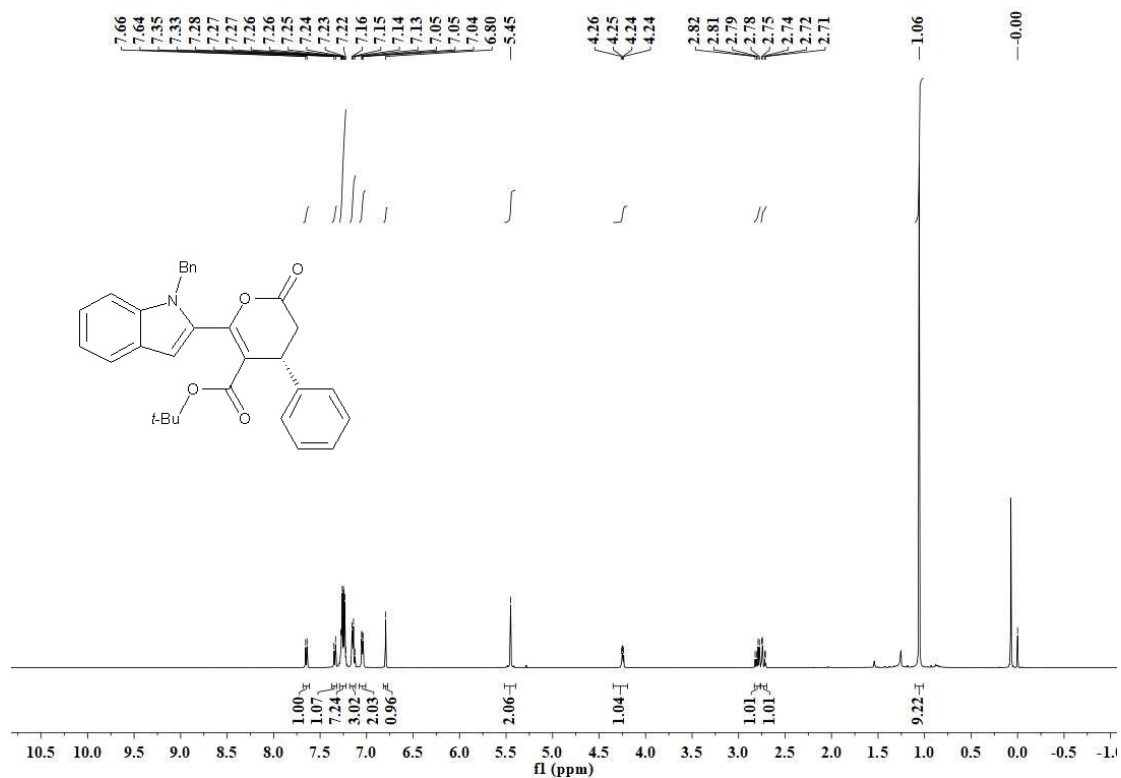


1n: ^{13}C NMR (126 MHz, CDCl_3)

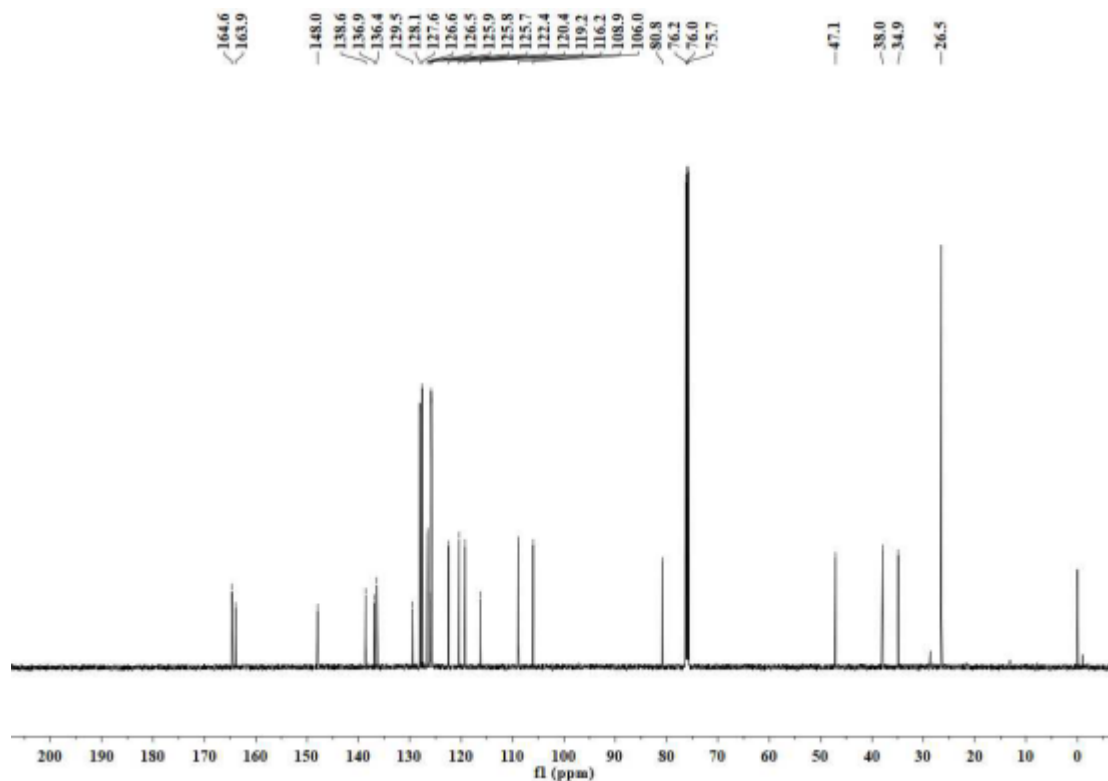


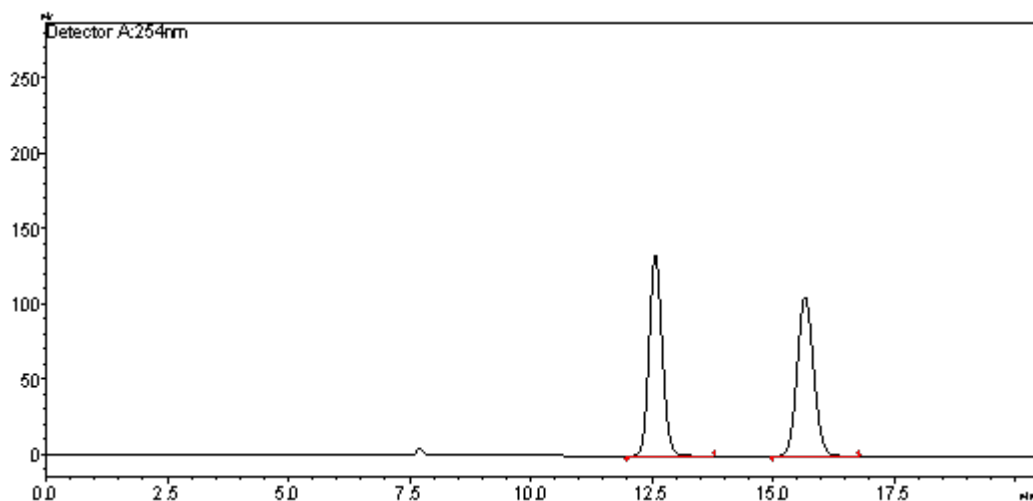
5. NMR and HPLC spectra of products 3

3a: ^1H NMR (500 MHz, CDCl_3)

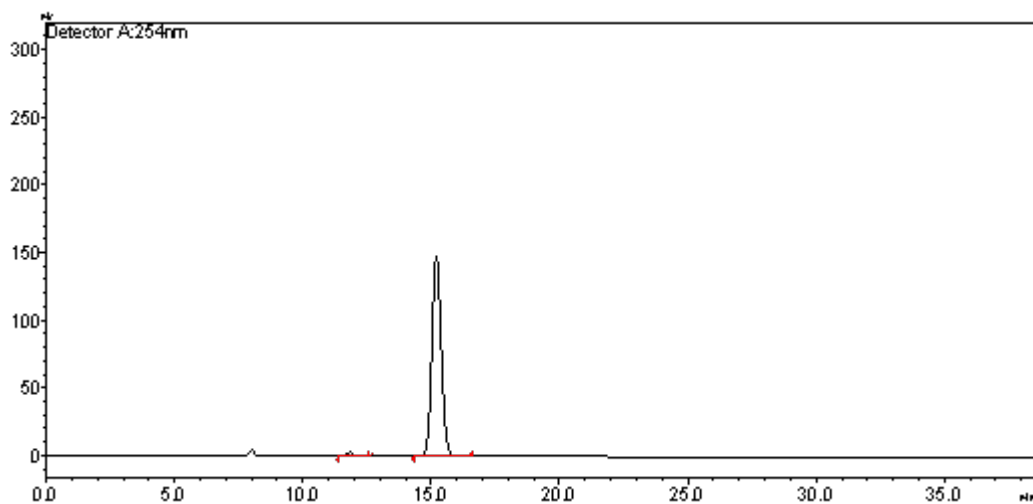


3a: ^{13}C NMR (126 MHz, CDCl_3)



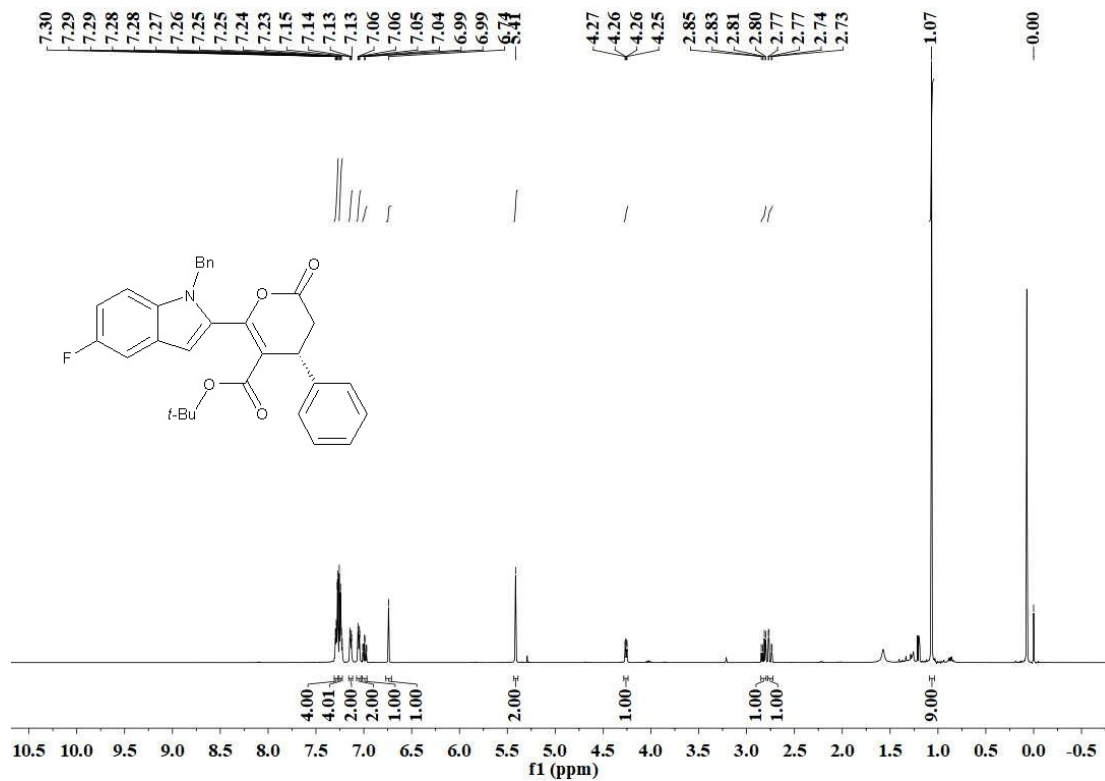


Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.571	2504751	133135	49.929	55.786
2	15.662	2511896	105519	50.071	44.214
Total		5016647	238654	100.000	100.000

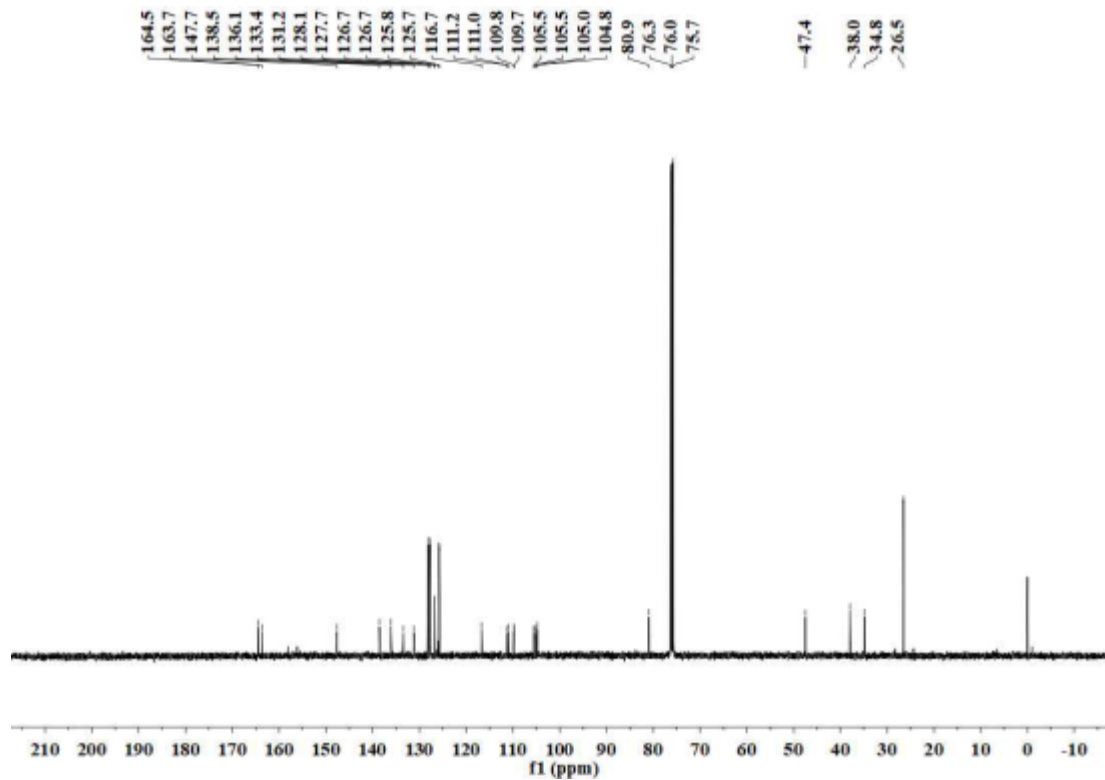


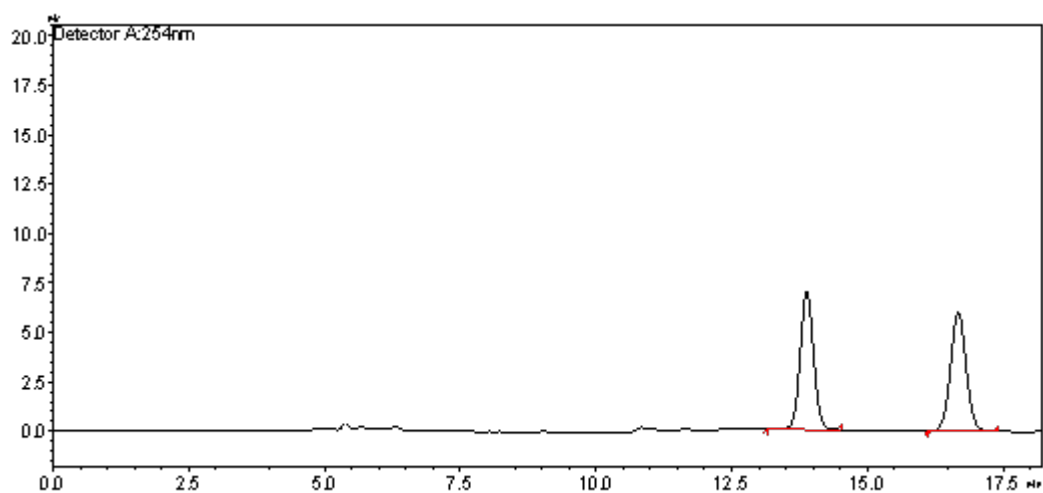
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.829	56262	2958	1.473	1.958
2	15.198	3763086	148103	98.527	98.042
Total		3819348	151062	100.000	100.000

3b: ^1H NMR (500 MHz, CDCl_3)

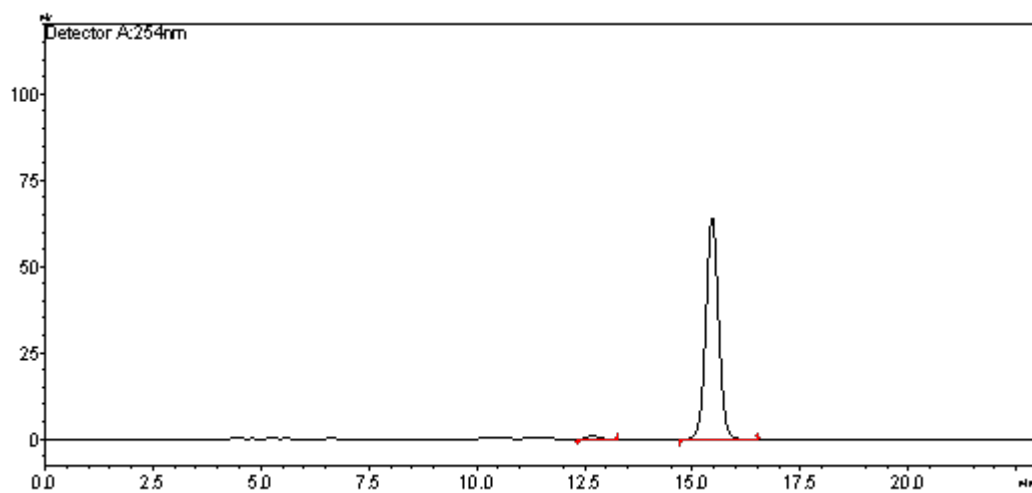


3b: ^{13}C NMR (126 MHz, CDCl_3)



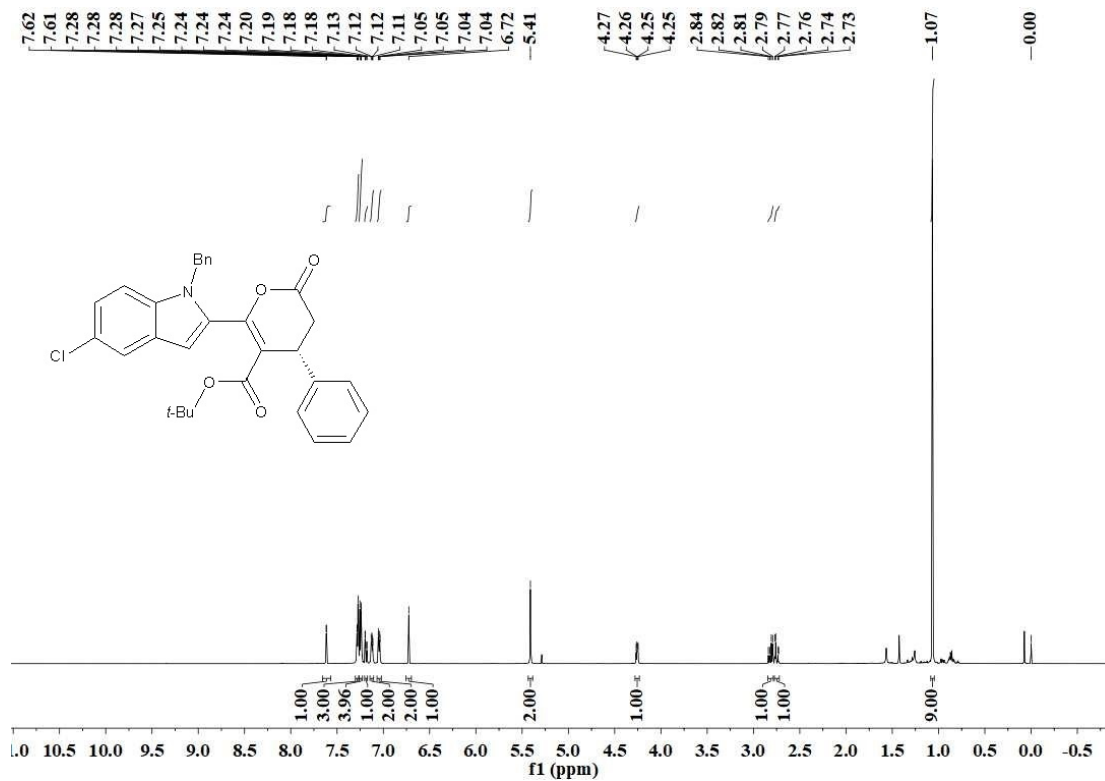


Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.881	121621	7000	50.161	53.813
2	16.670	120841	6008	49.839	46.187
Total		242462	13008	100.000	100.000

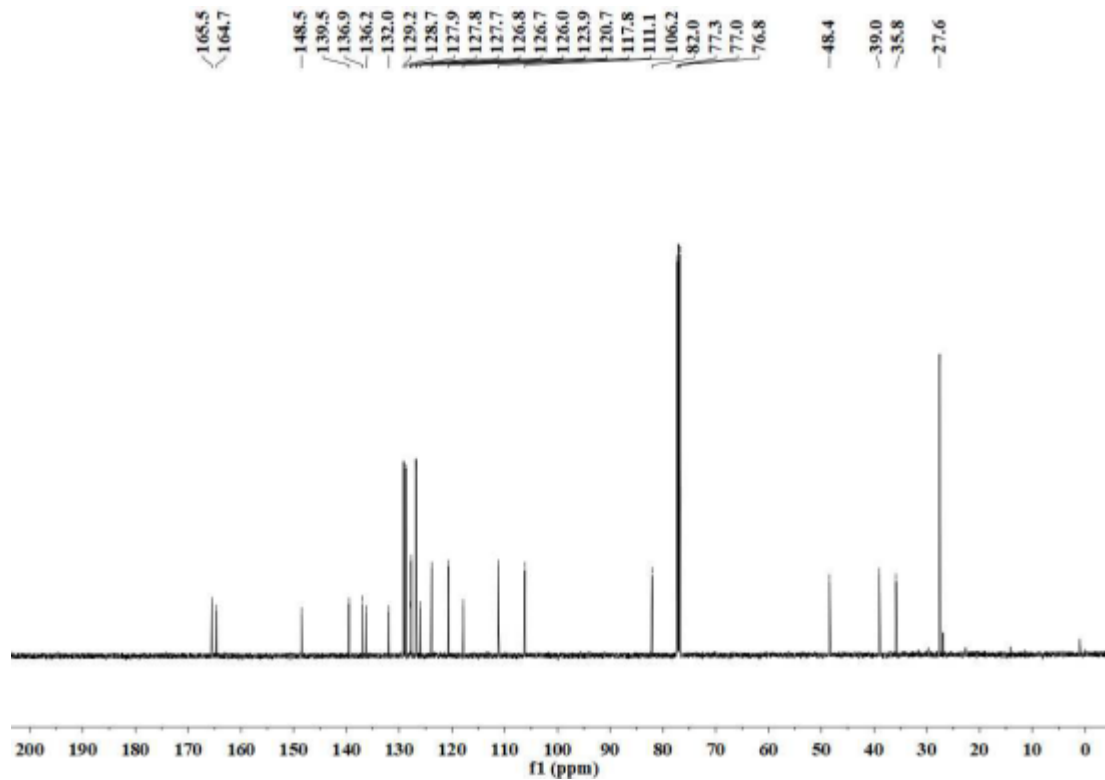


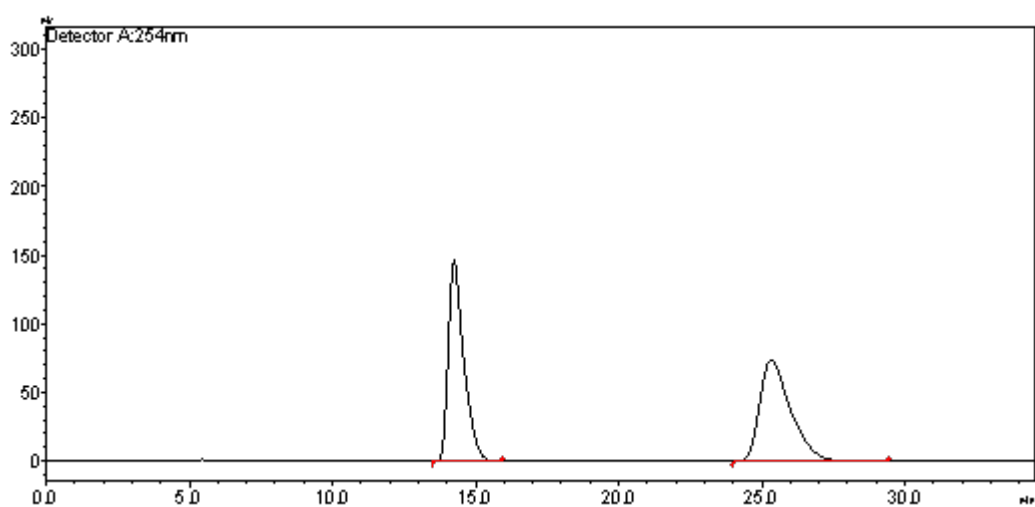
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.680	18340	1098	1.369	1.679
2	15.446	1320984	64304	98.631	98.321
Total		1339324	65402	100.000	100.000

3c: ¹H NMR (500 MHz, CDCl₃)

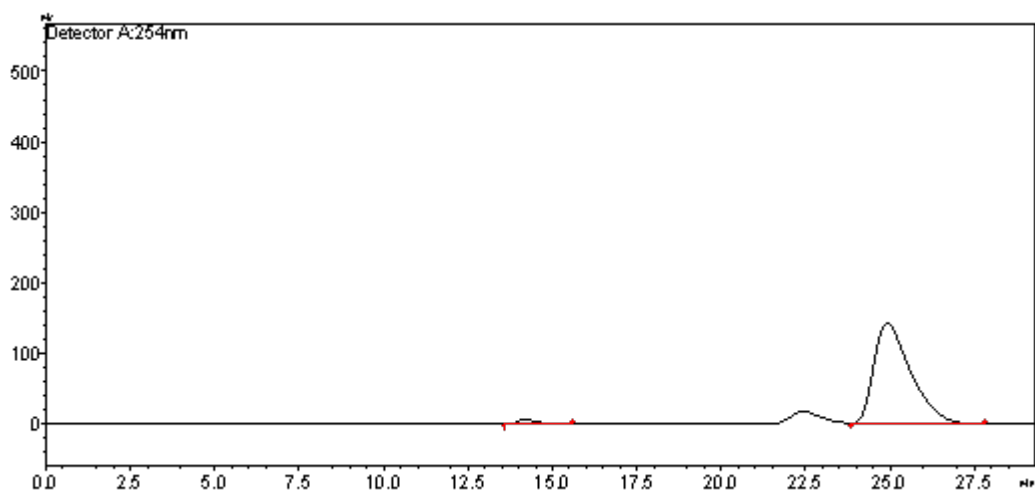


3c: ¹³C NMR (126 MHz, CDCl₃)



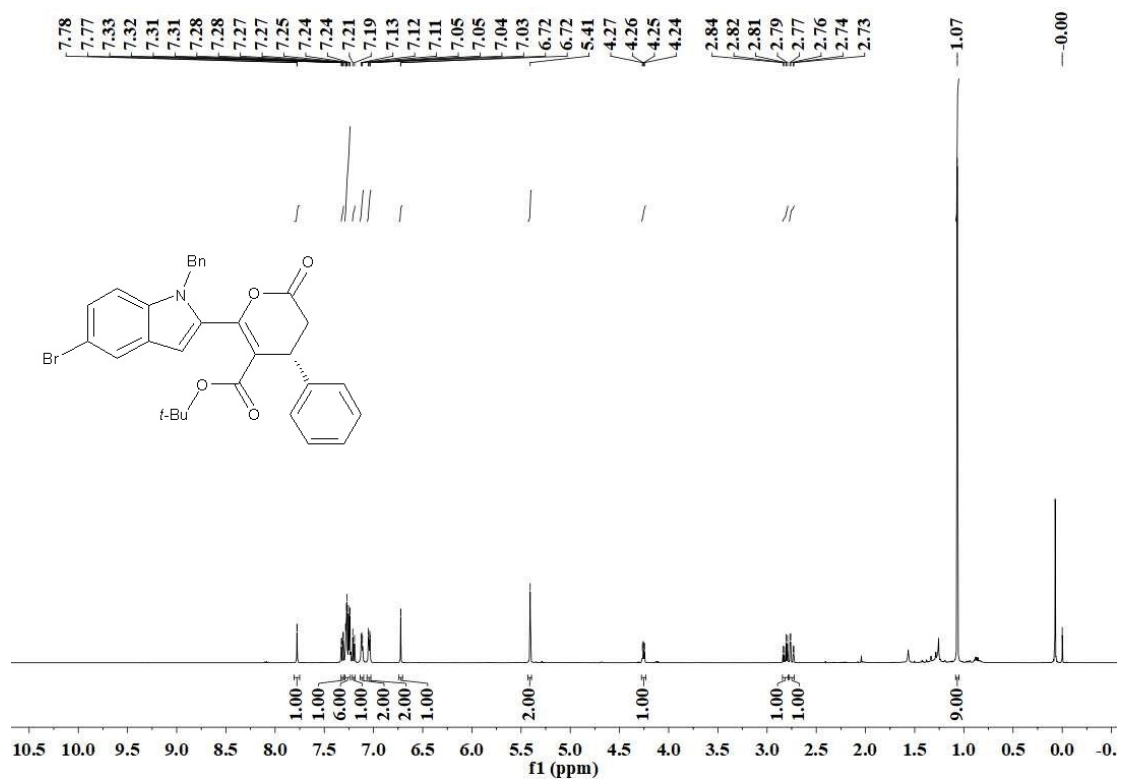


Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.246	5484862	145953	49.796	66.310
2	25.327	5529835	74155	50.204	33.690
Total		11014697	220108	100.000	100.000

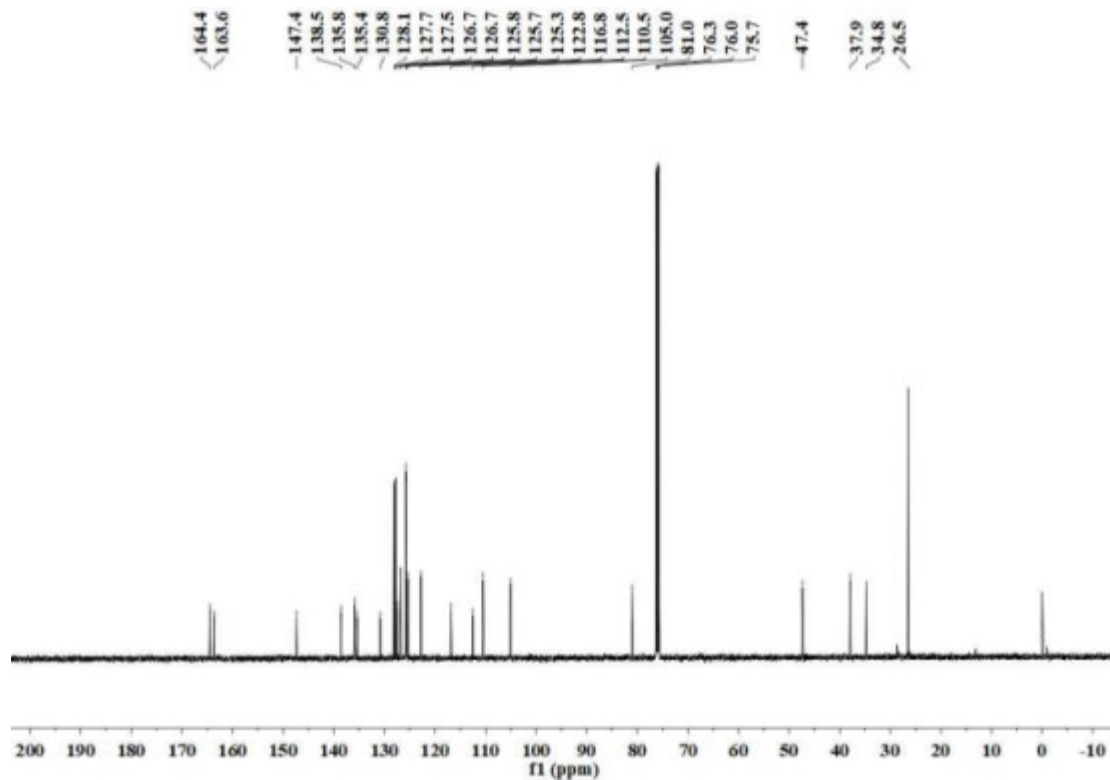


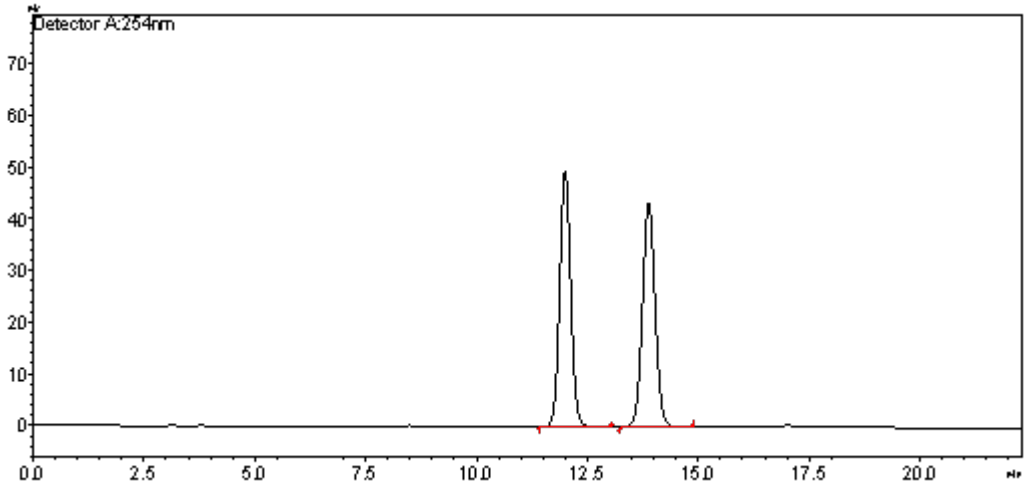
Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.190	234901	6302	2.142	4.262
2	24.914	10731625	141555	97.858	95.738
Total		10966526	147857	100.000	100.000

3d: ^1H NMR (500 MHz, CDCl_3)

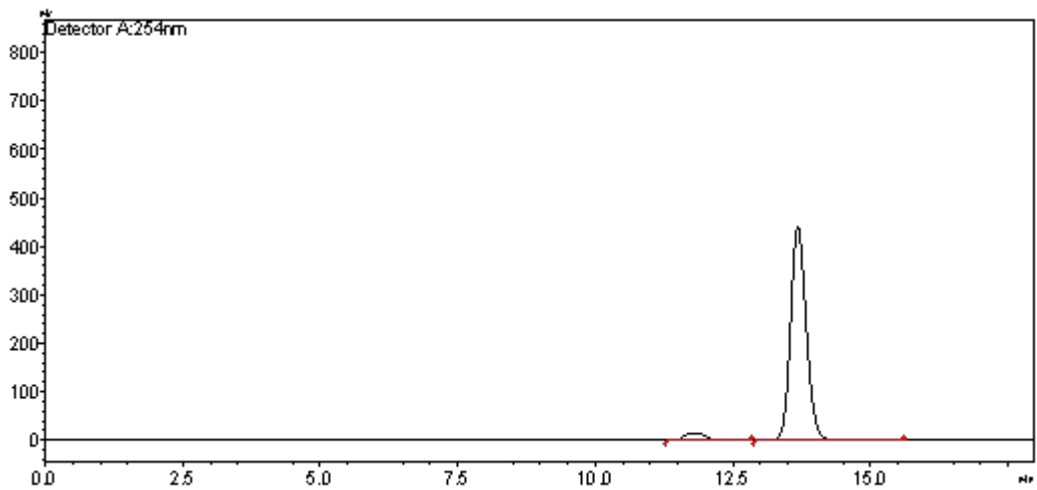


3d: ¹³C NMR (126 MHz, CDCl₃)



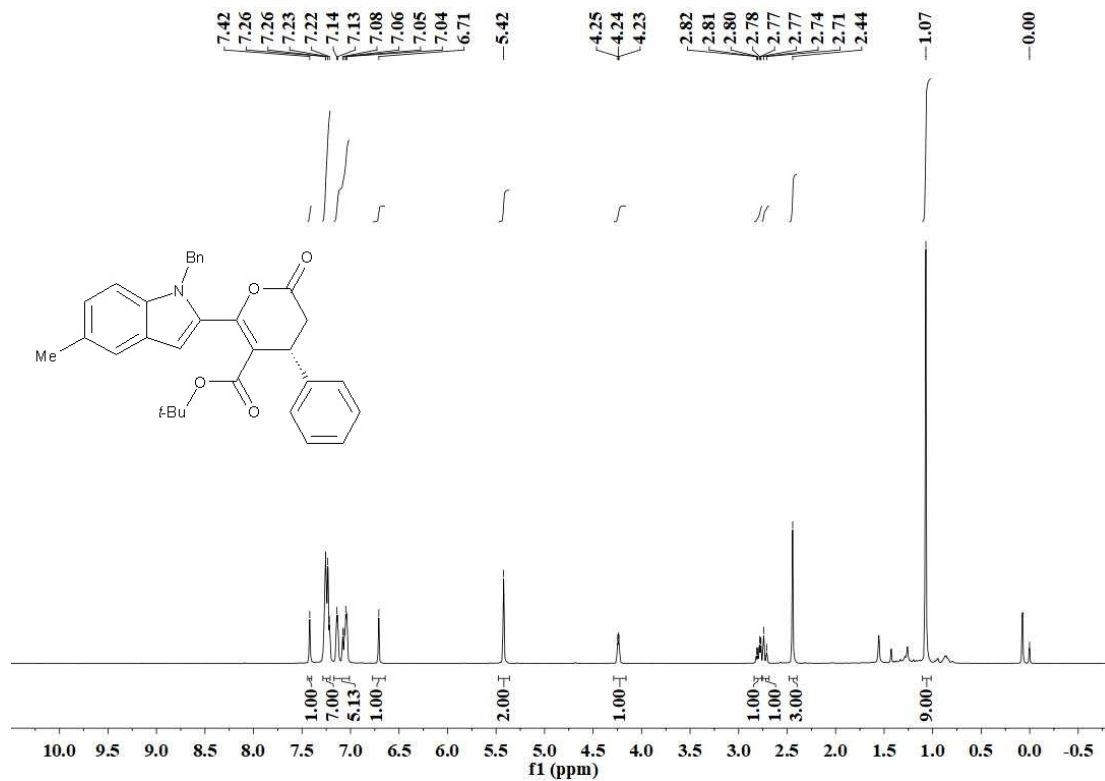


Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.992	861122	49646	49.957	53.427
2	13.877	862589	43277	50.043	46.573
Total		1723711	92922	100.000	100.000

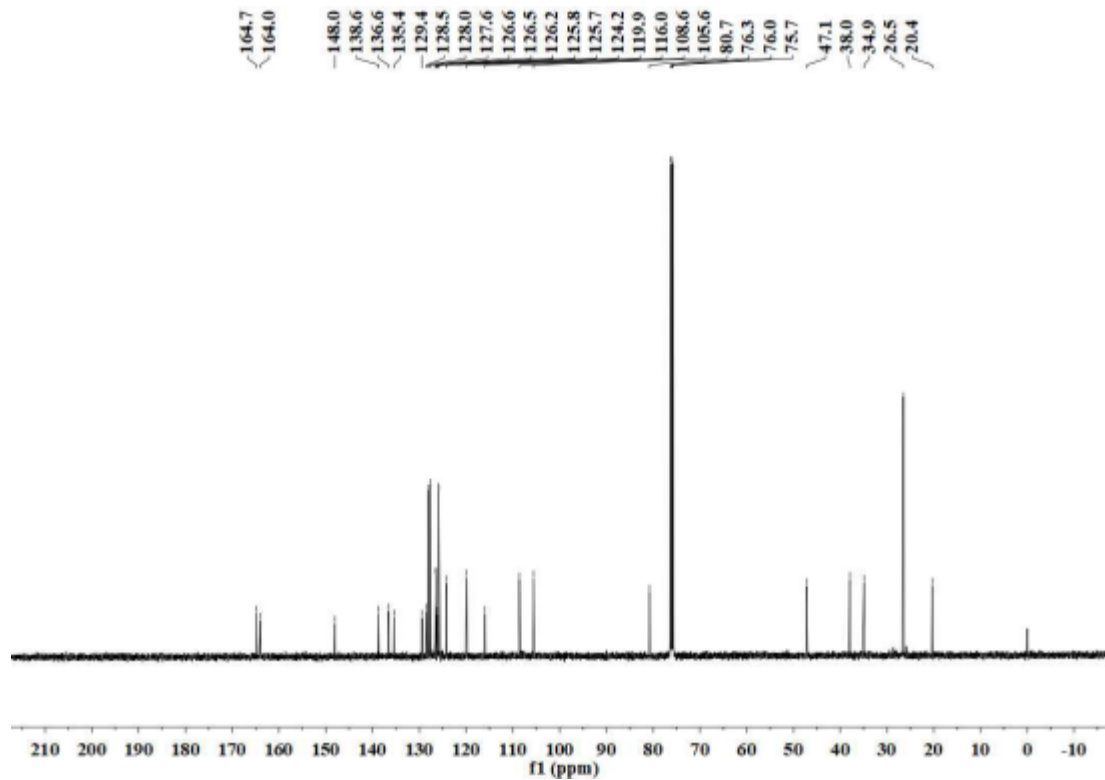


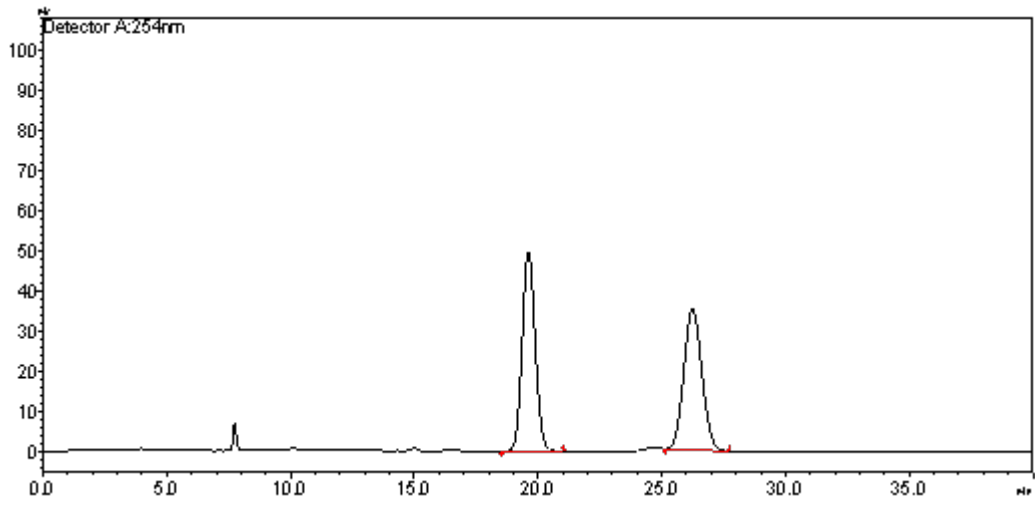
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.780	379500	15134	4.169	3.321
2	13.673	8723238	440650	95.831	96.679
Total		9102738	455784	100.000	100.000

3e: ^1H NMR (500 MHz, CDCl_3)

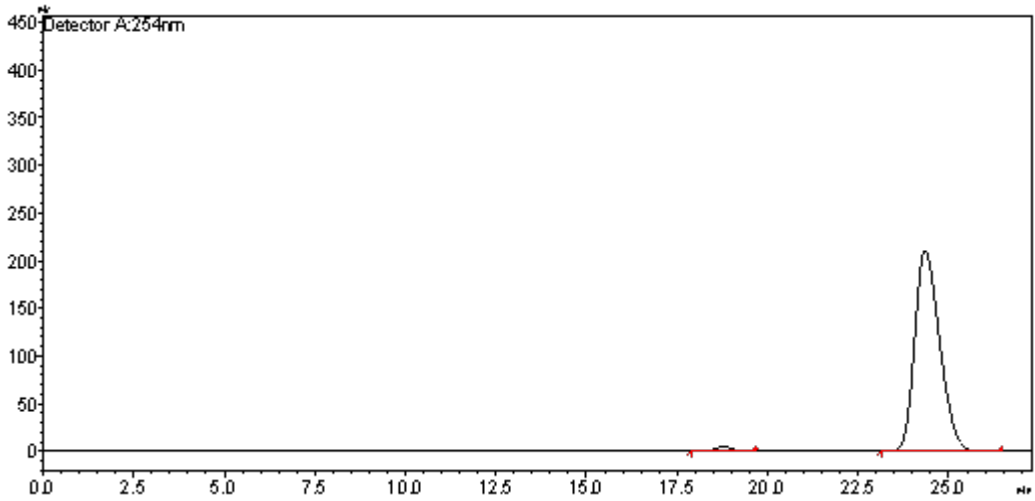


3e: ^{13}C NMR (126 MHz, CDCl_3)



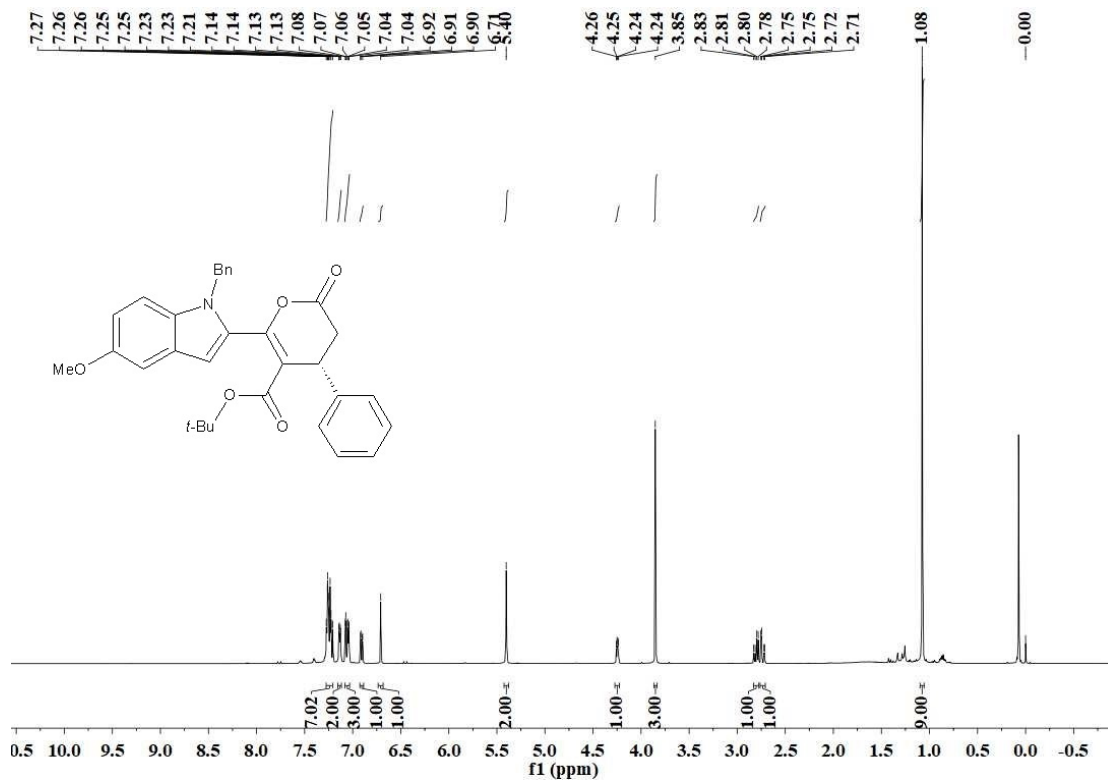


Peak#	Ret. Time	Area	Height	Area %	Height %
1	19.605	1825279	49877	50.460	58.593
2	26.233	1791982	35247	49.540	41.407
Total		3617261	85124	100.000	100.000

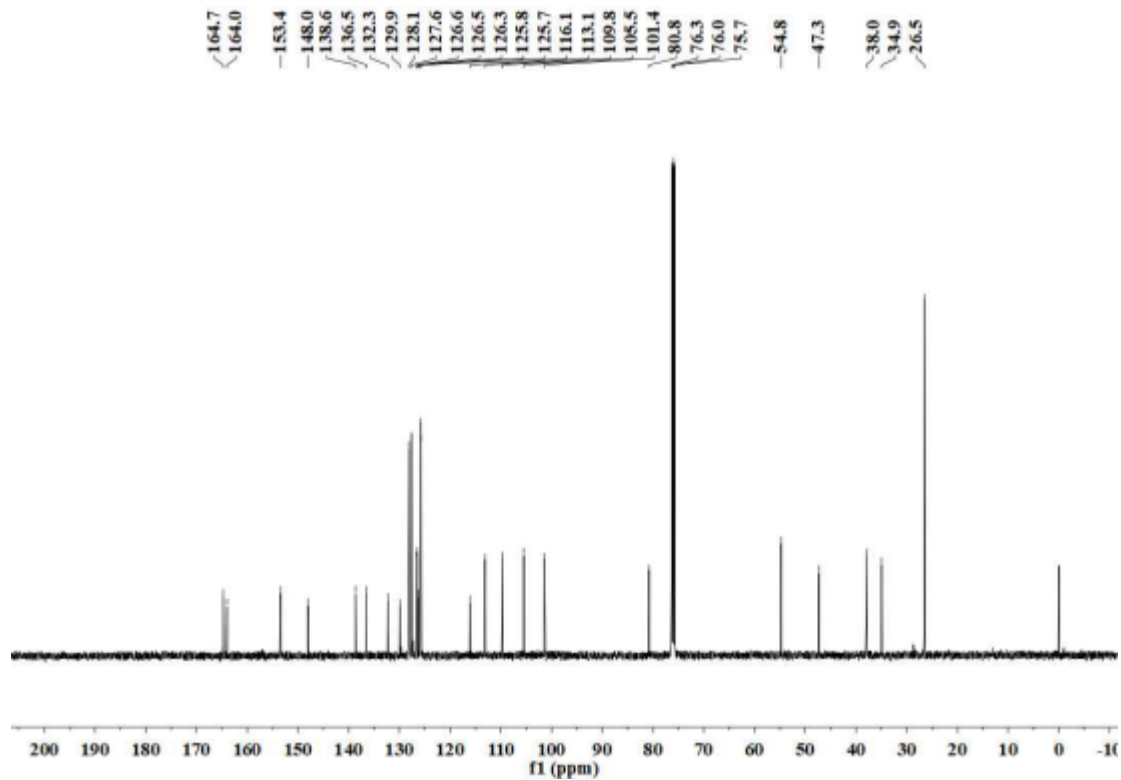


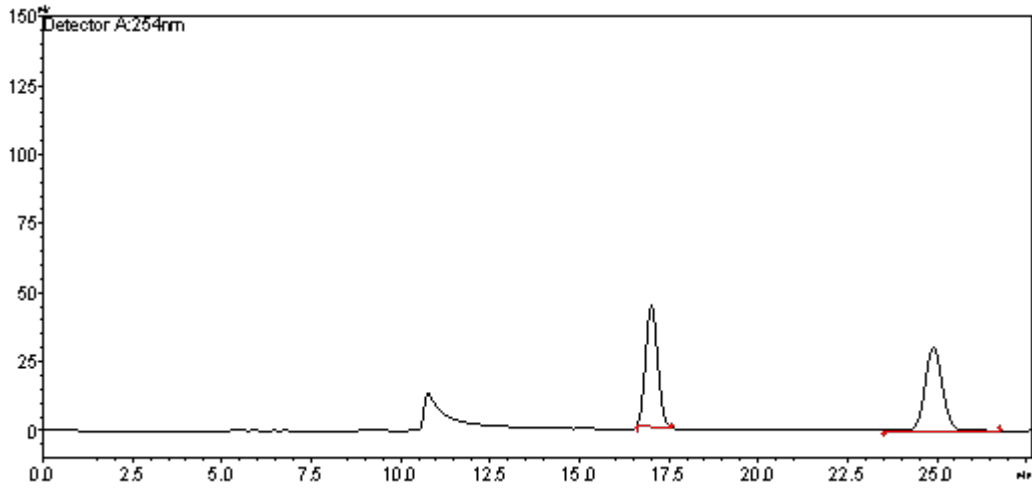
Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.771	181084	5207	1.752	2.409
2	24.345	10152229	210911	98.248	97.591
Total		10333313	216118	100.000	100.000

3f: ^1H NMR (500 MHz, CDCl_3)

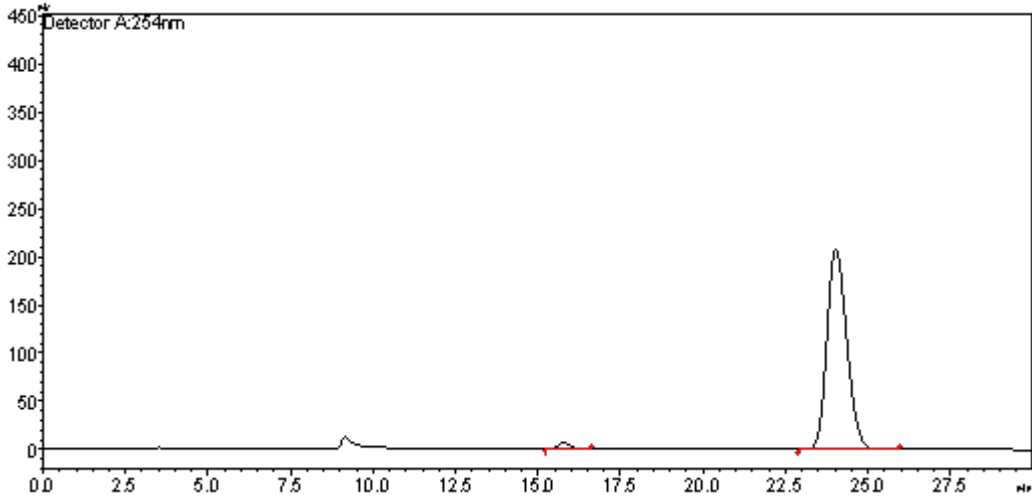


3f: ^{13}C NMR (126 MHz, CDCl_3)



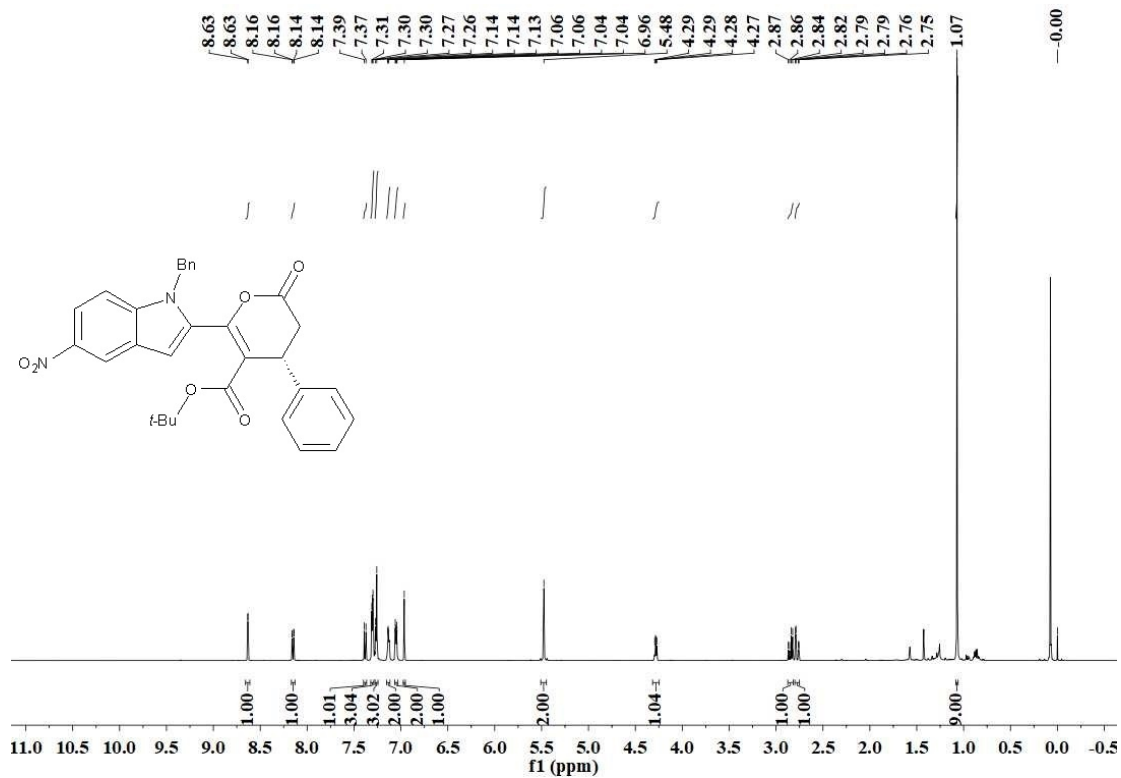


Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.010	1033748	43746	50.698	59.130
2	24.895	1005283	30236	49.302	40.870
Total		2039032	73982	100.000	100.000

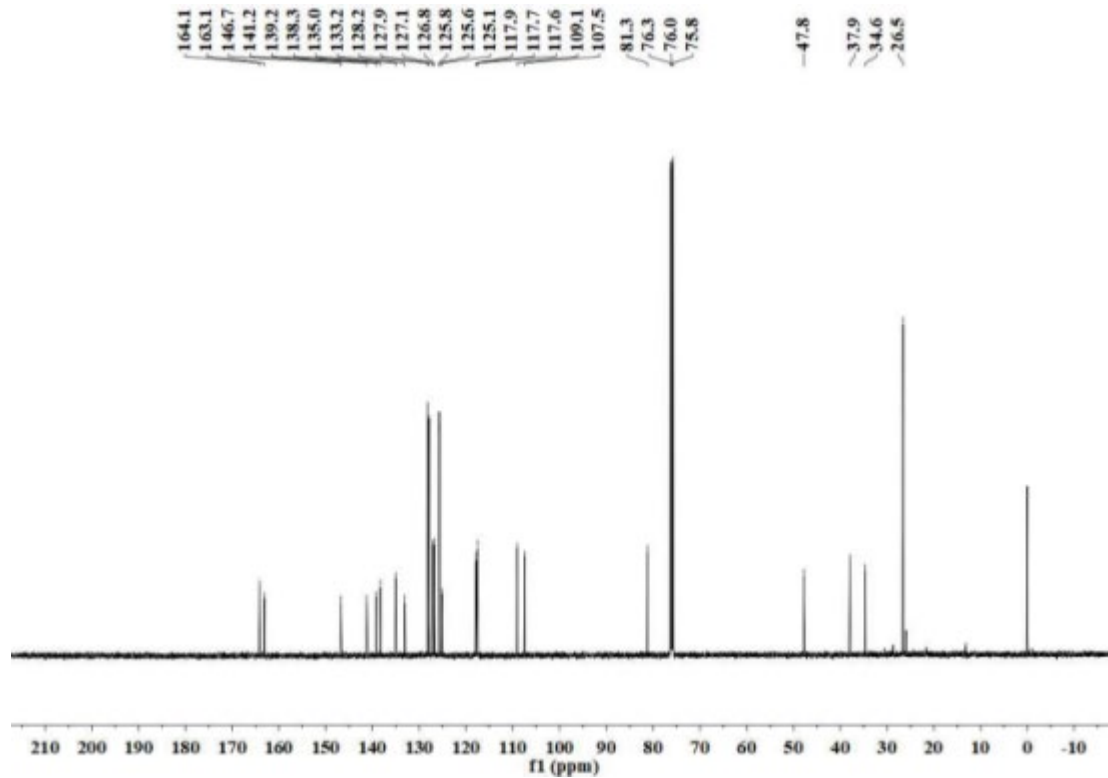


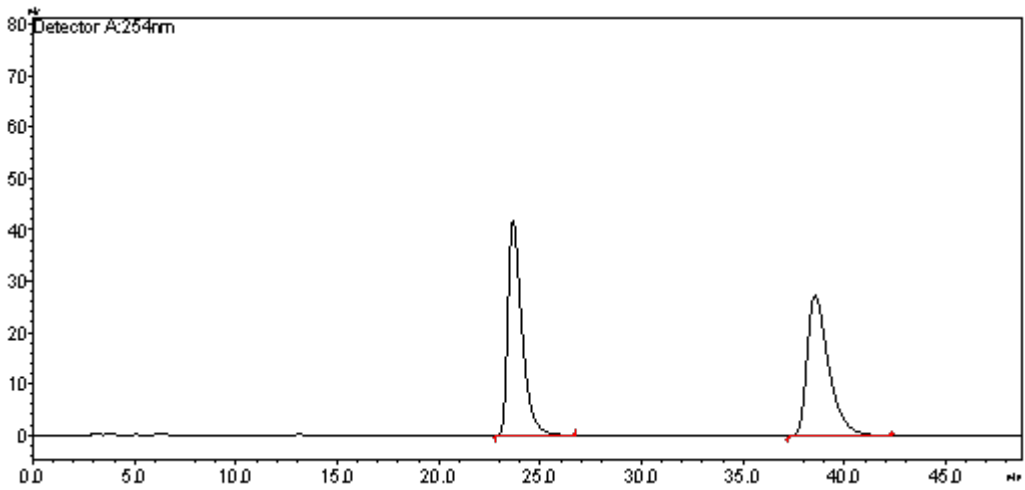
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.774	169387	6790	1.908	3.157
2	24.019	8706624	208292	98.092	96.843
Total		8876011	215083	100.000	100.000

3g: ^1H NMR (500 MHz, CDCl_3)

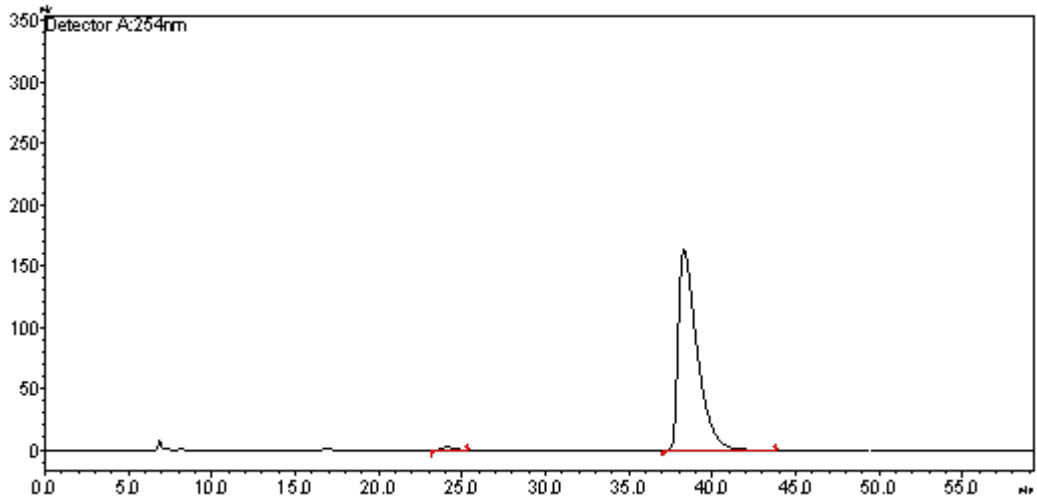


3g: ^{13}C NMR (126 MHz, CDCl_3)



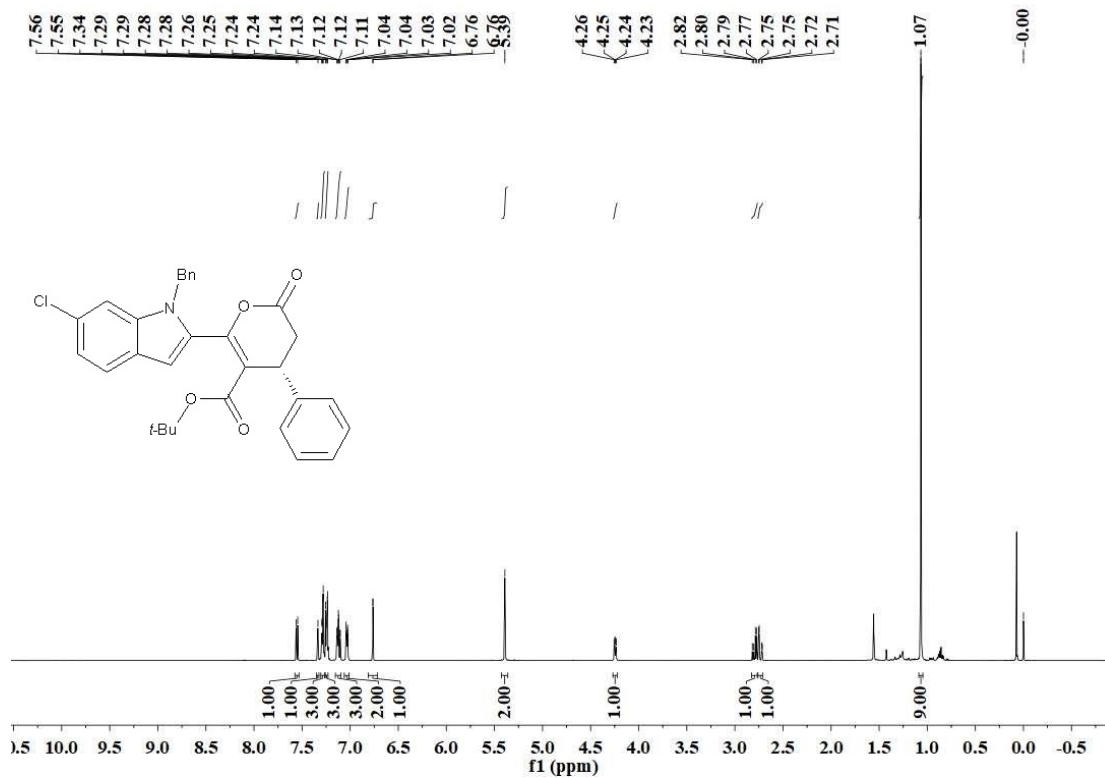


Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.657	2047595	42086	50.034	60.472
2	38.542	2044809	27510	49.966	39.528
Total		4092404	69597	100.000	100.000

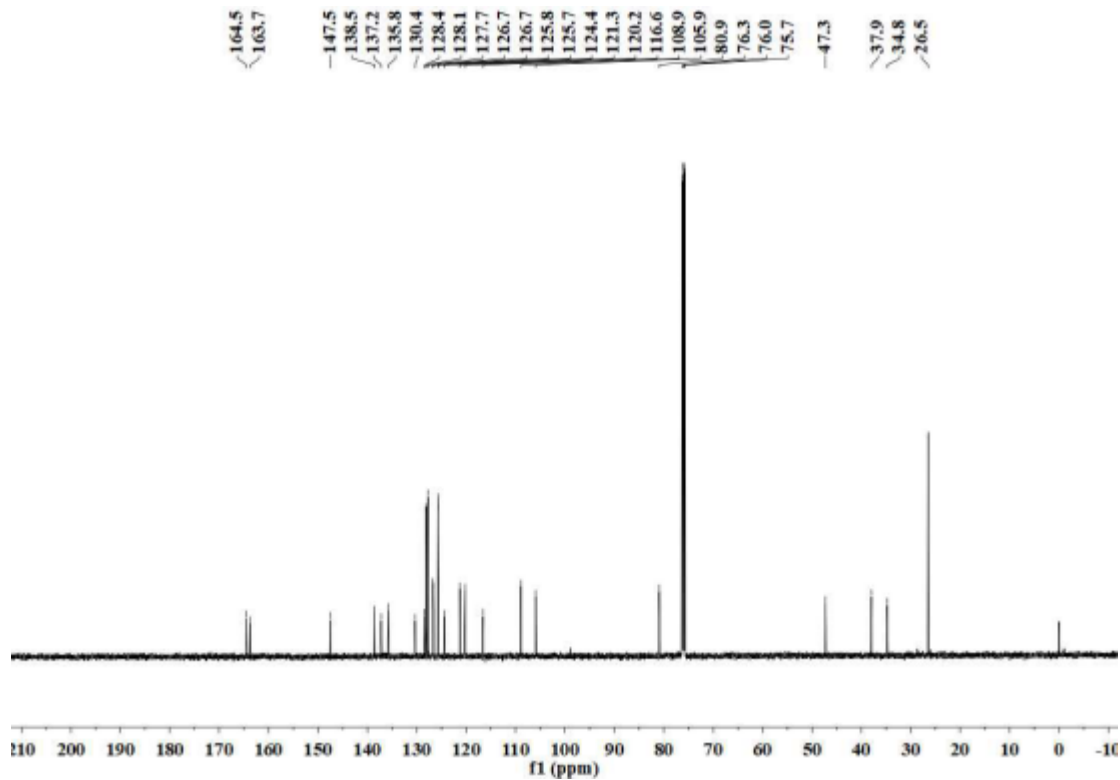


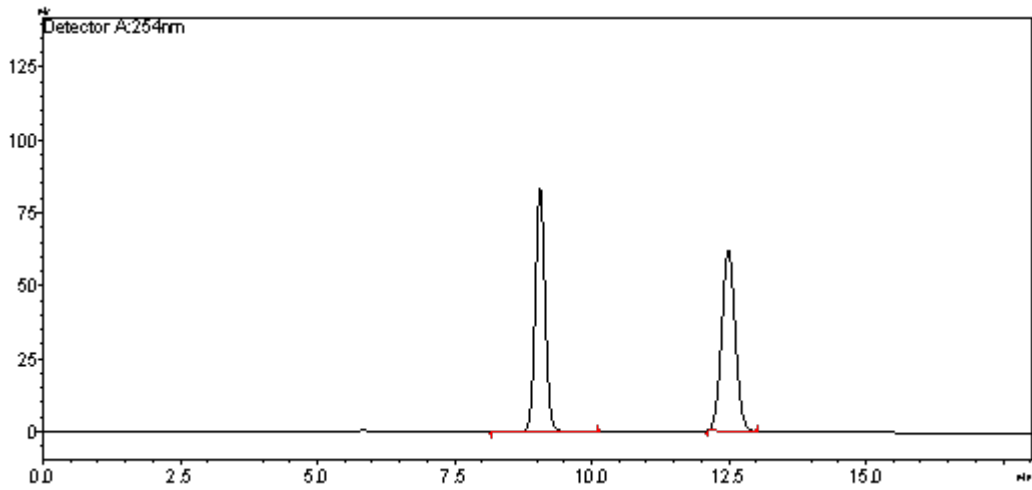
Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.081	118690	2335	0.910	1.405
2	38.296	12927526	163800	99.090	98.595
Total		13046217	166135	100.000	100.000

3h: ^1H NMR (500 MHz, CDCl_3)

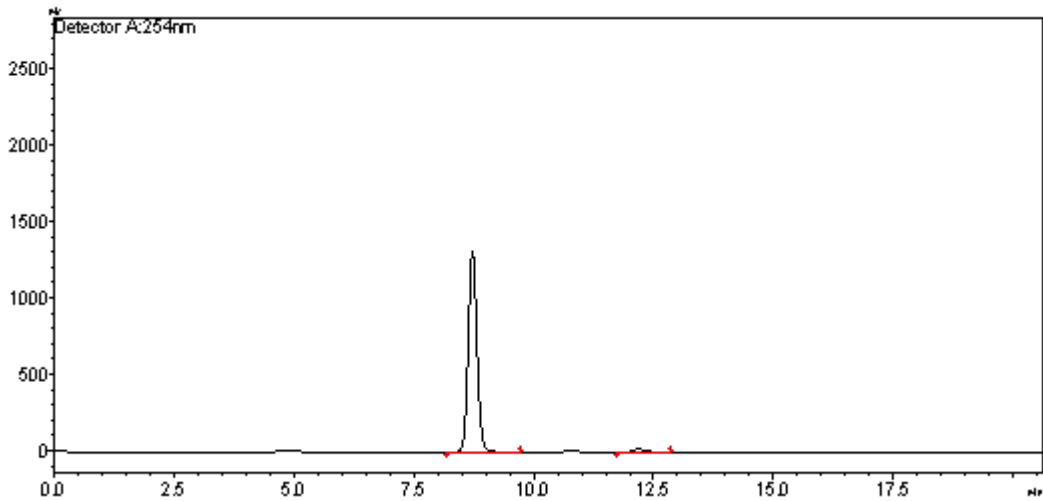


3h: ^{13}C NMR (126 MHz, CDCl_3)



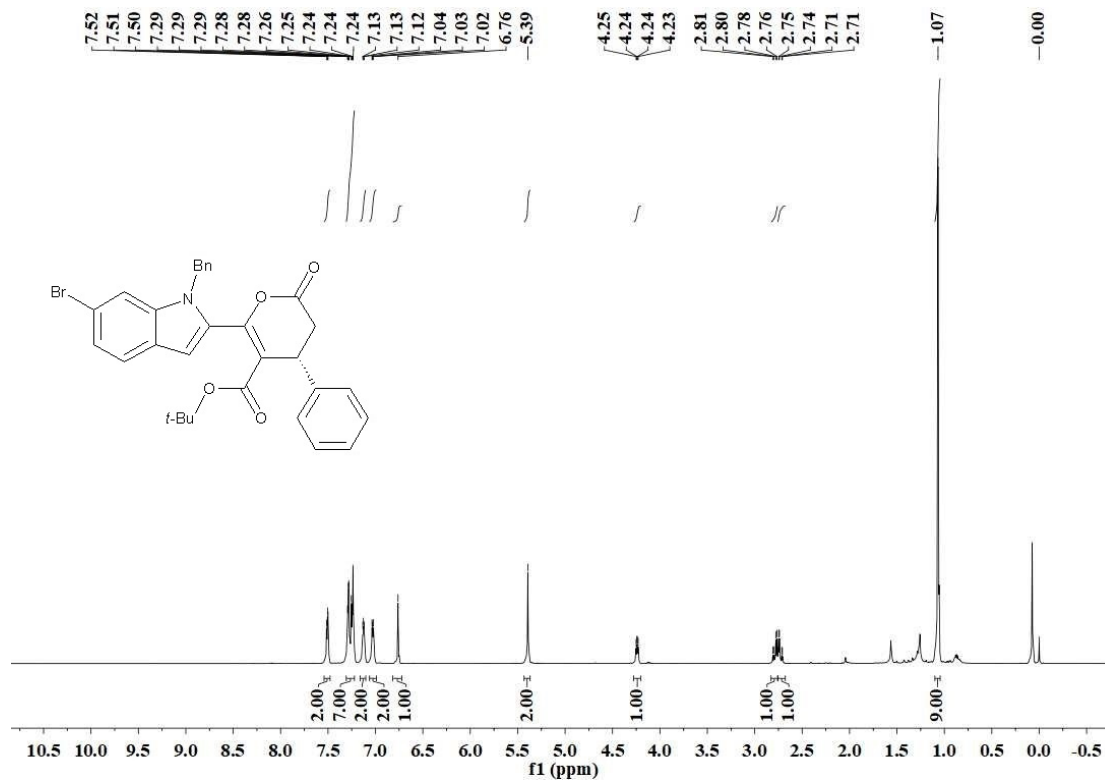


Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.057	1042359	83286	49.388	57.275
2	12.489	1068196	62127	50.612	42.725
Total		2110555	145413	100.000	100.000

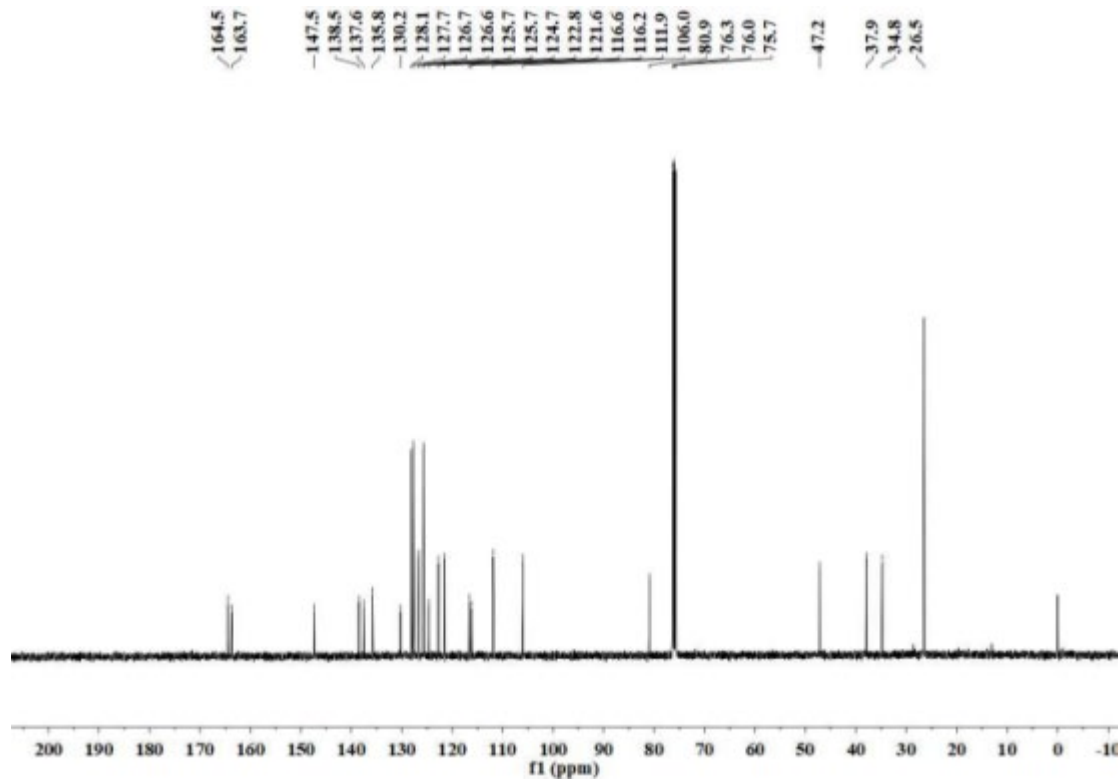


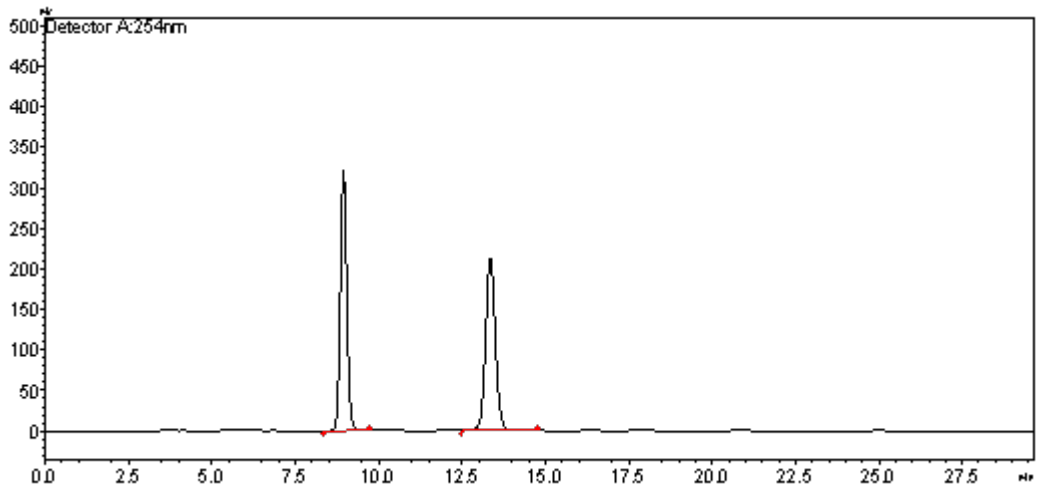
Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.718	16811526	1317090	97.833	98.510
2	12.193	372334	19921	2.167	1.490
Total		17183860	1337011	100.000	100.000

3i: ^1H NMR (500 MHz, CDCl_3)

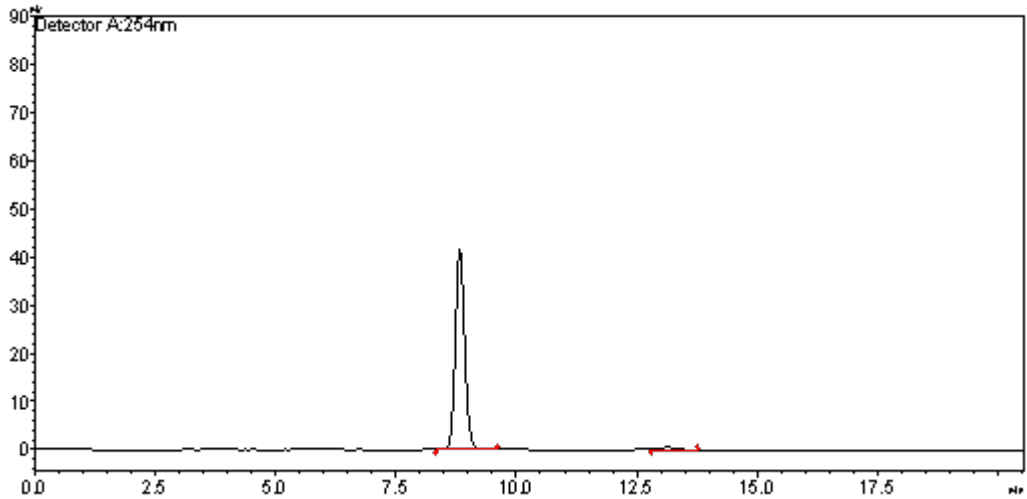


3i: ^{13}C NMR (126 MHz, CDCl_3)



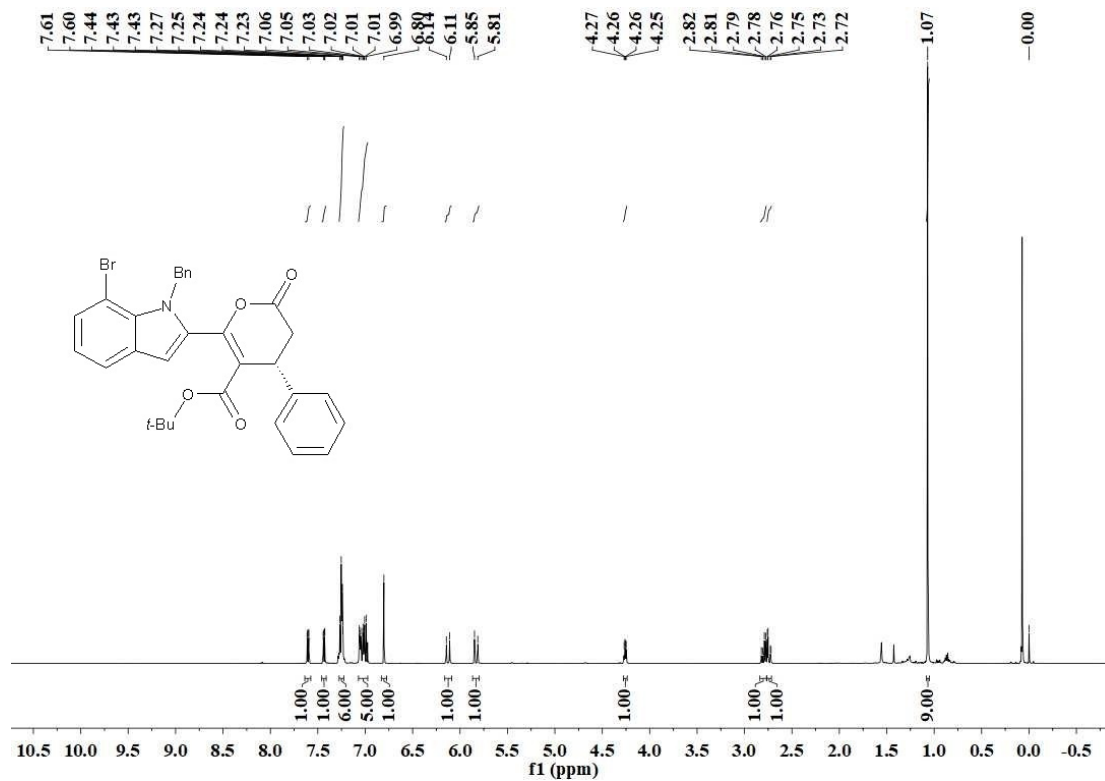


Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.940	4358570	320805	50.070	60.104
2	13.344	4346392	212947	49.930	39.896
Total		8704962	533752	100.000	100.000

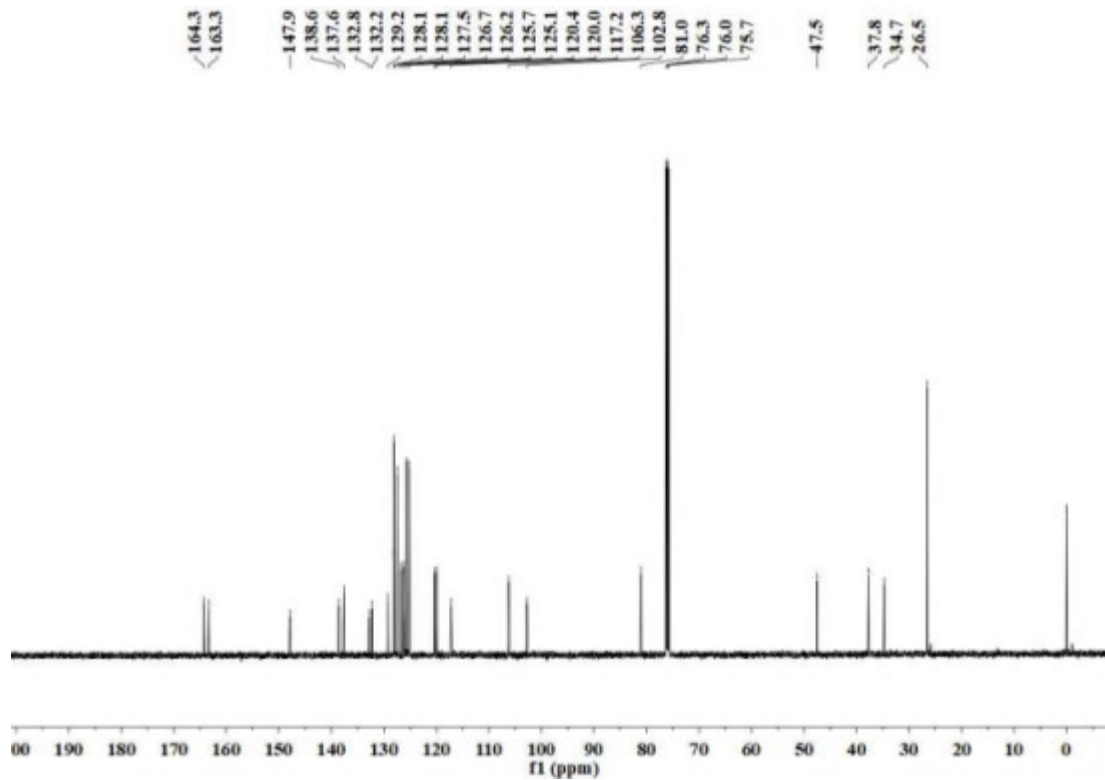


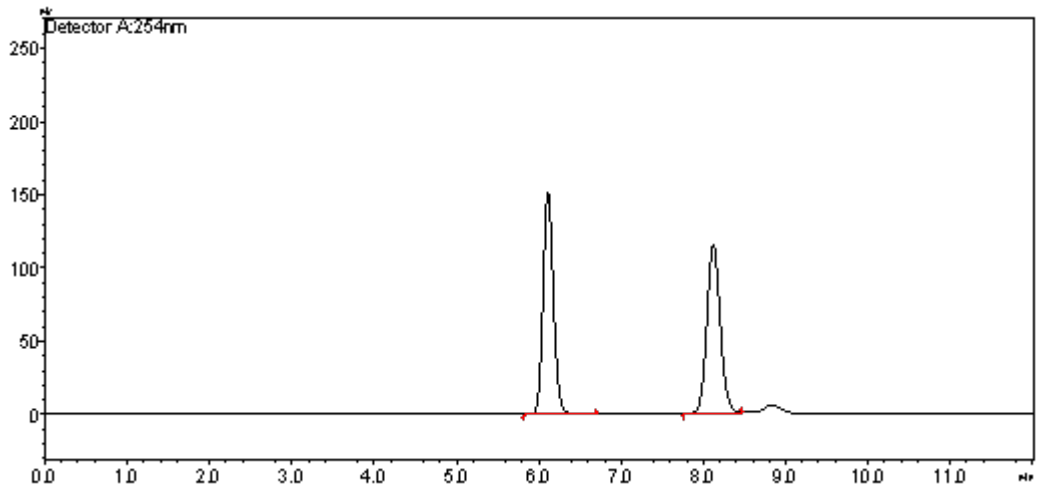
Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.820	562850	41602	98.315	98.829
2	13.125	9644	493	1.685	1.171
Total		572494	42094	100.000	100.000

3j: ^1H NMR (500 MHz, CDCl_3)

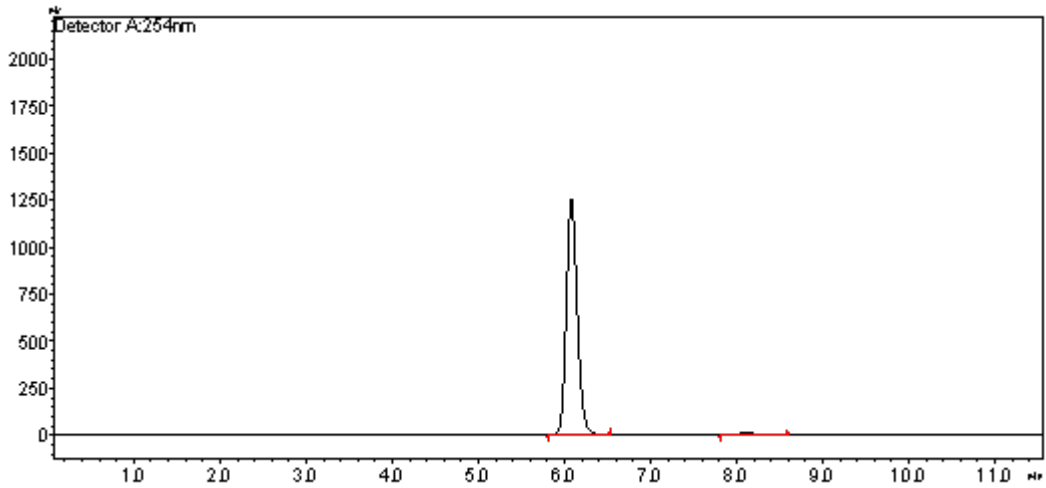


3j: ^{13}C NMR (126 MHz, CDCl_3)



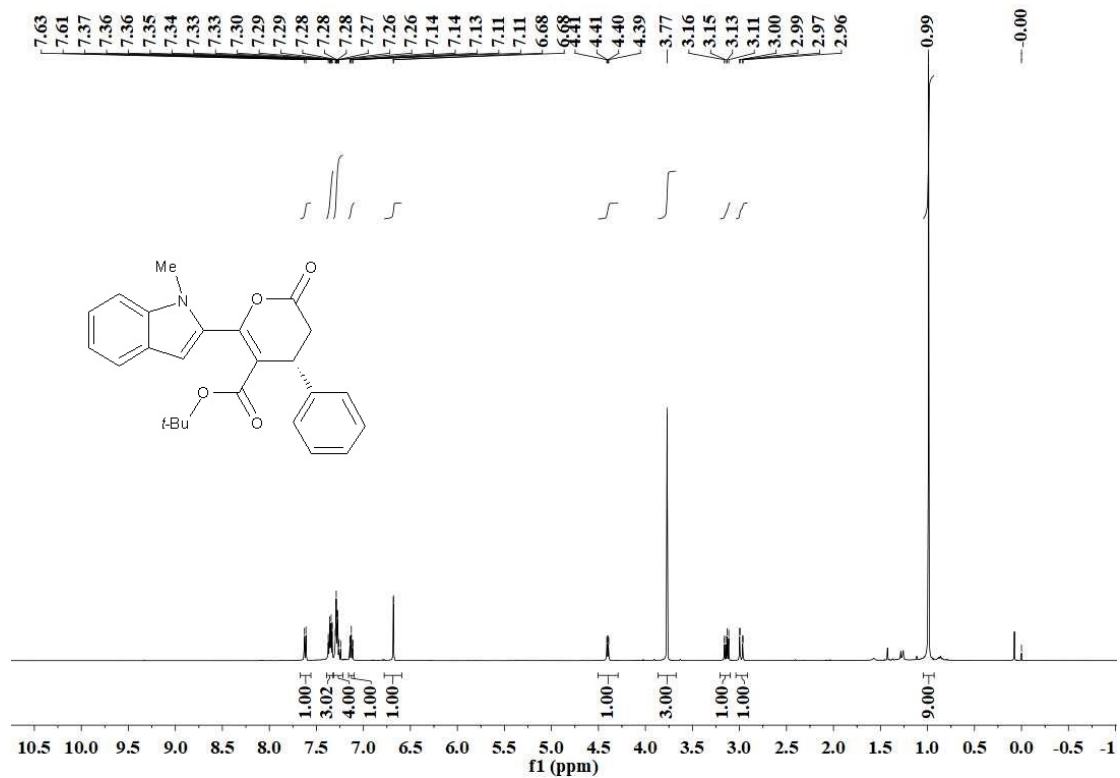


Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.106	1327126	151109	50.349	56.700
2	8.115	1308750	115396	49.651	43.300
Total		2635876	266505	100.000	100.000

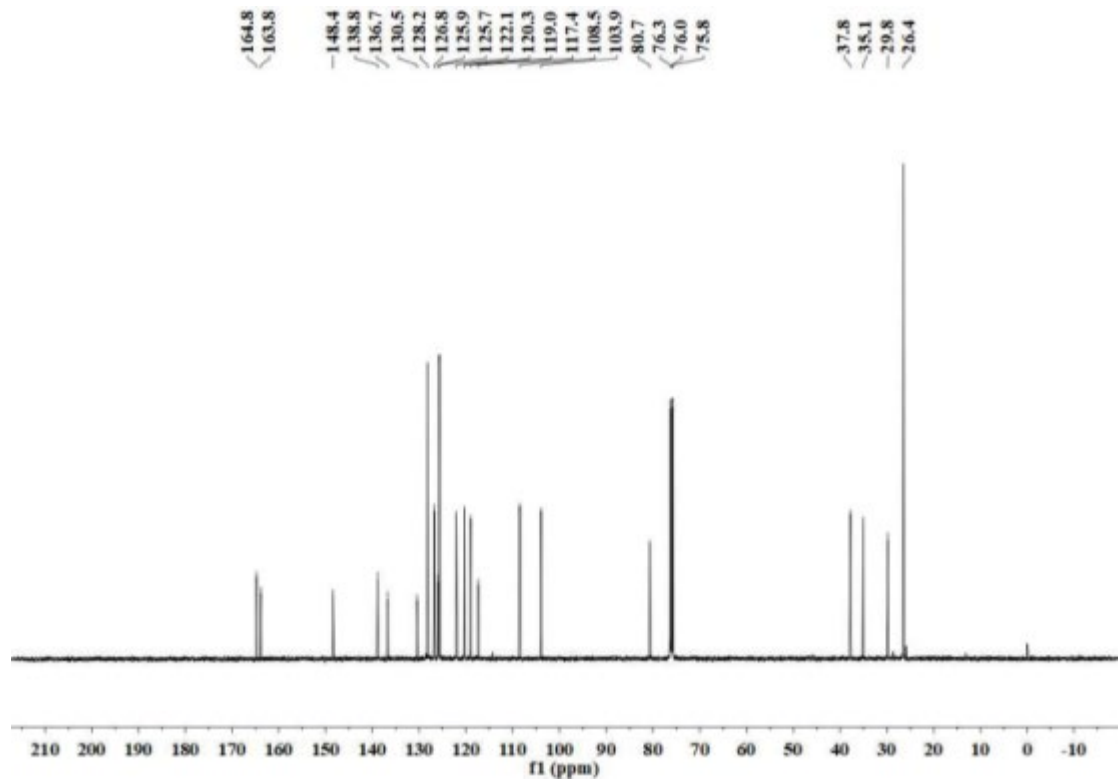


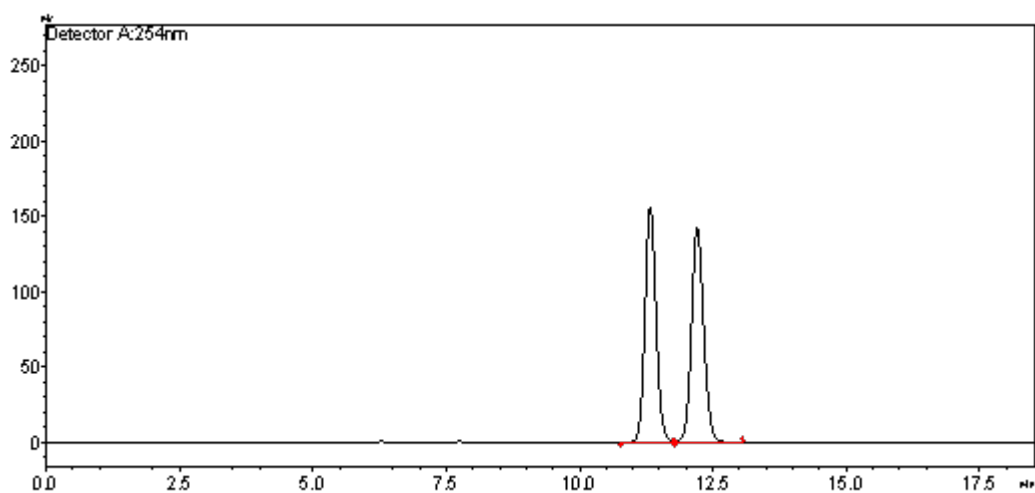
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.077	11071078	1255842	98.399	98.822
2	8.119	180171	14973	1.601	1.178
Total		11251250	1270815	100.000	100.000

3k: ^1H NMR (500 MHz, CDCl_3)

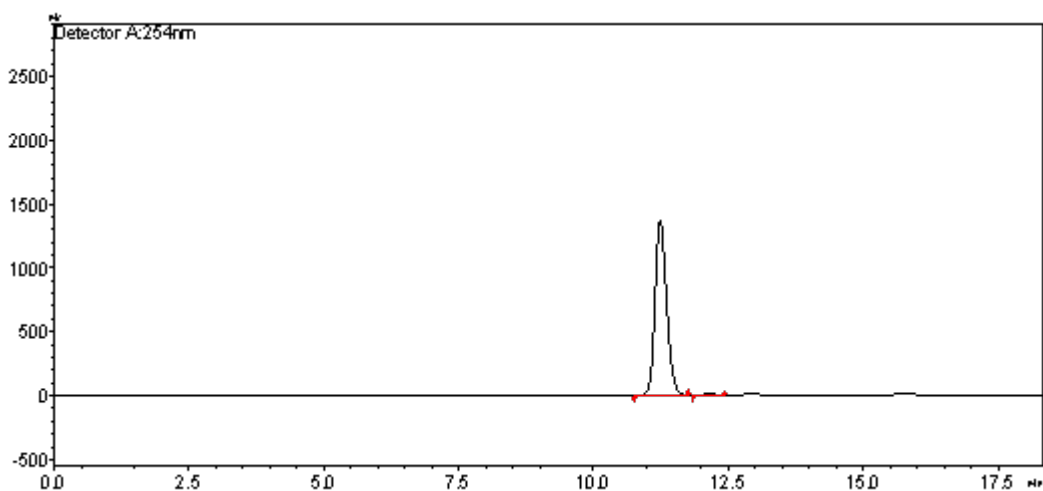


3k: ^{13}C NMR (126 MHz, CDCl_3)



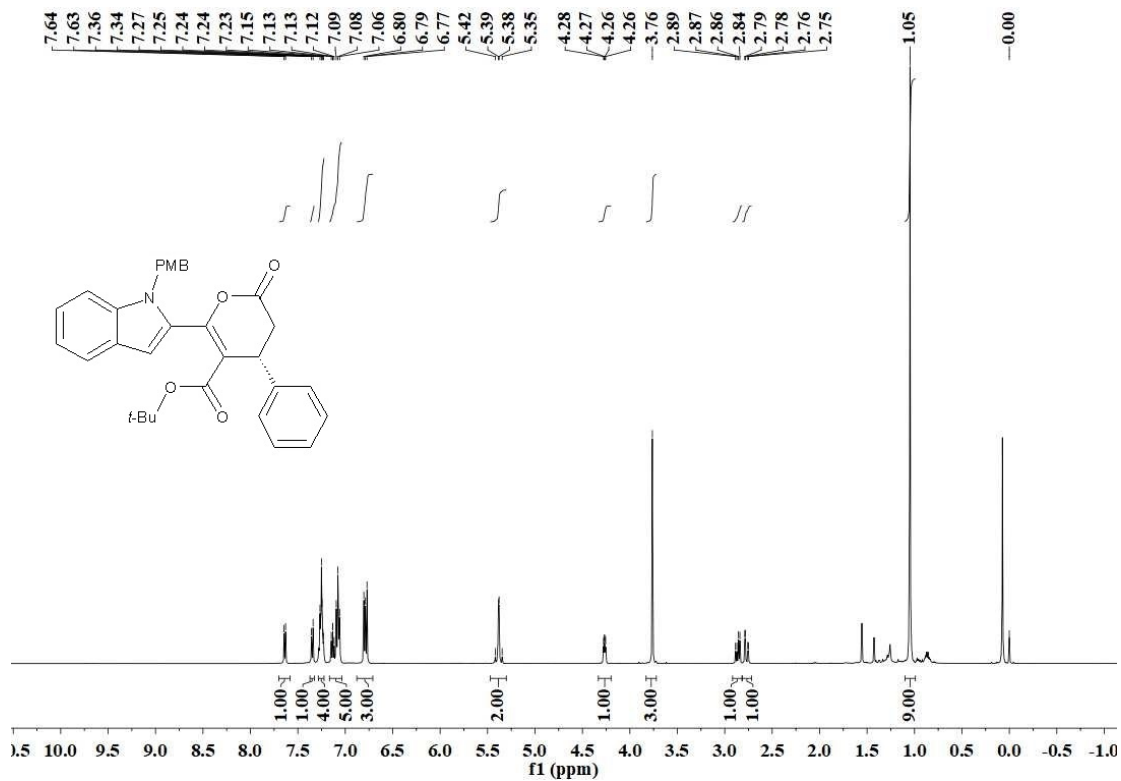


Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.321	2274072	156048	49.790	52.238
2	12.200	2293267	142680	50.210	47.762
Total		4567339	298727	100.000	100.000

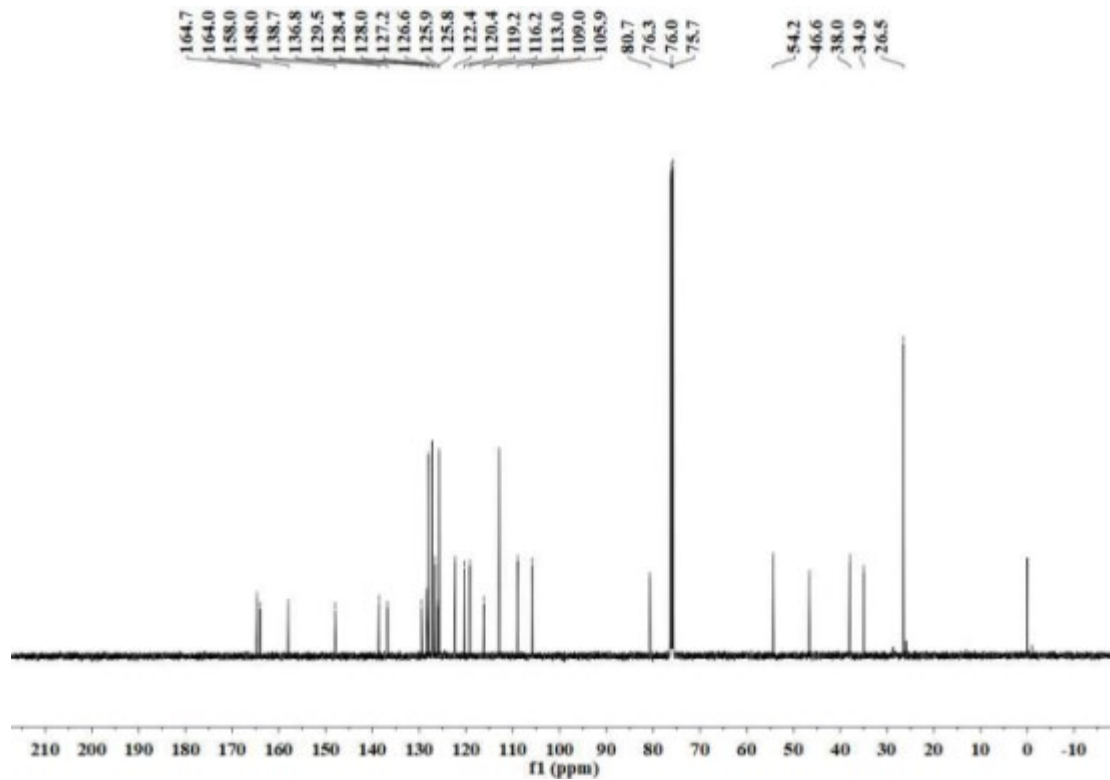


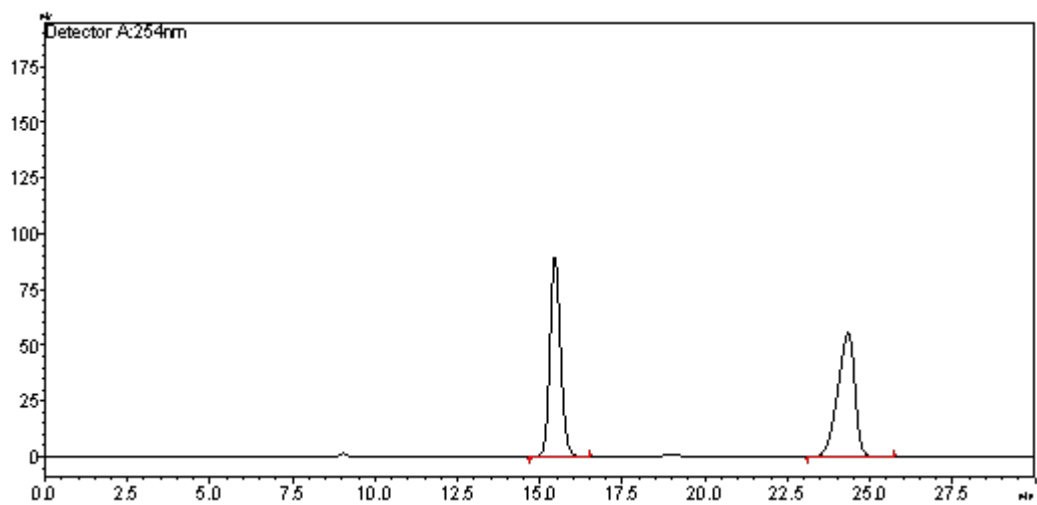
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.231	20411358	1368964	99.143	99.107
2	12.153	176344	12340	0.857	0.893
Total		20587702	1381304	100.000	100.000

3l: ^1H NMR (500 MHz, CDCl_3)

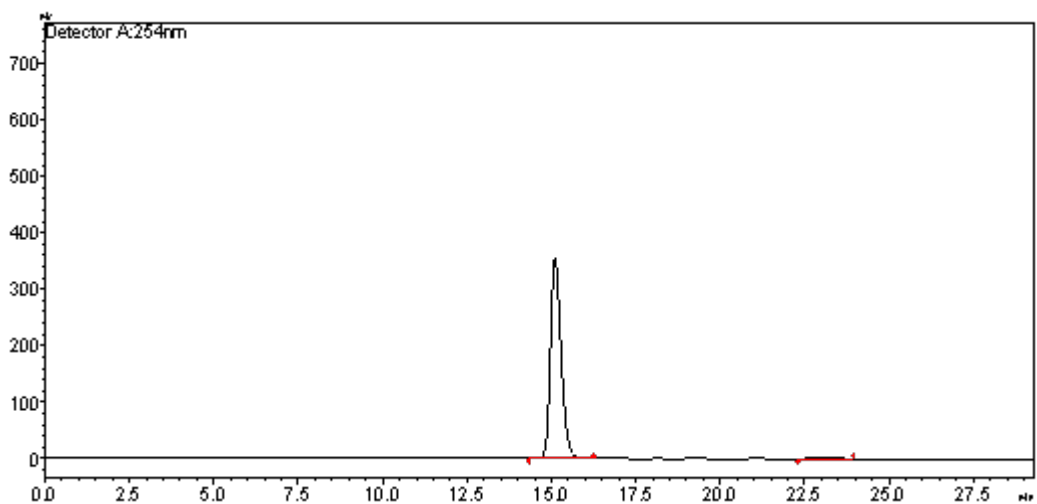


3l: ^{13}C NMR (126 MHz, CDCl_3)



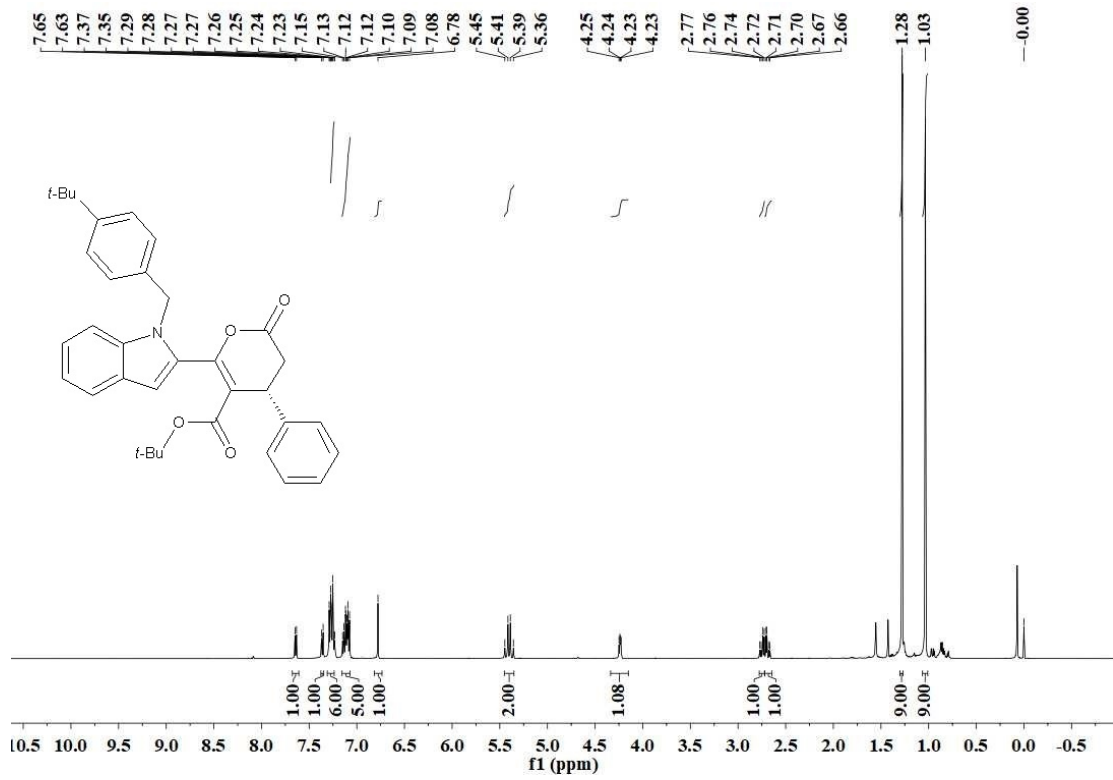


Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.444	2022499	89773	49.997	61.733
2	24.337	2022709	55649	50.003	38.267
Total		4045208	145422	100.000	100.000

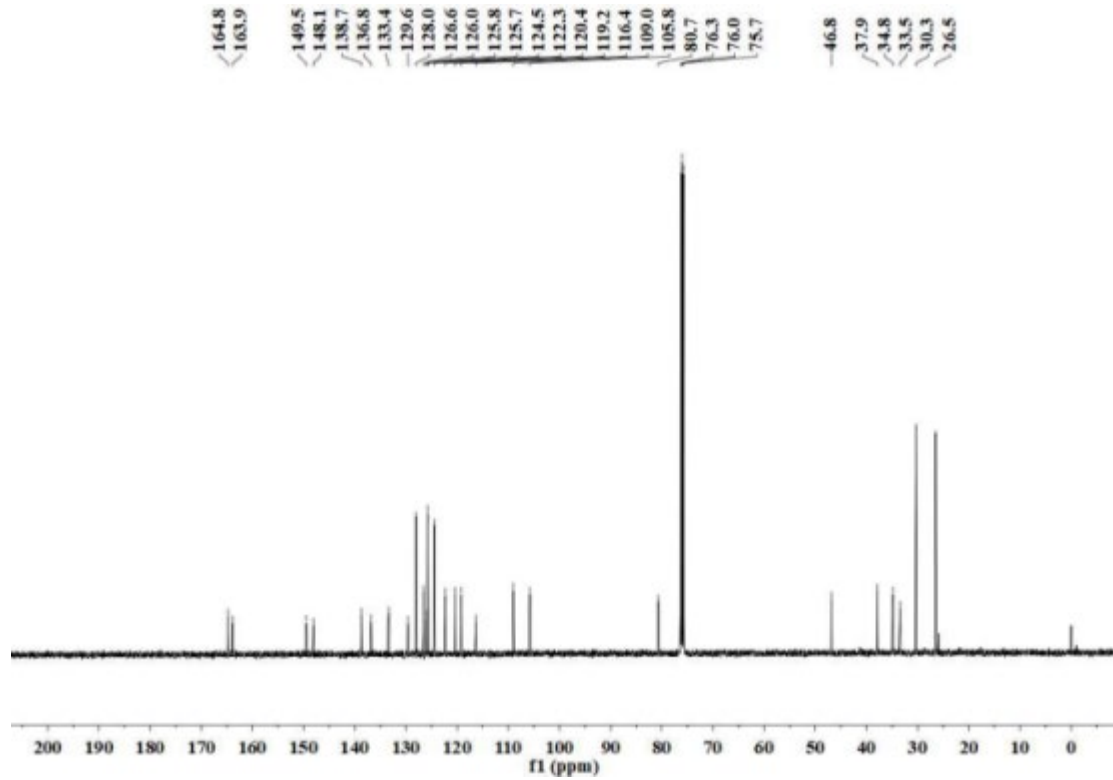


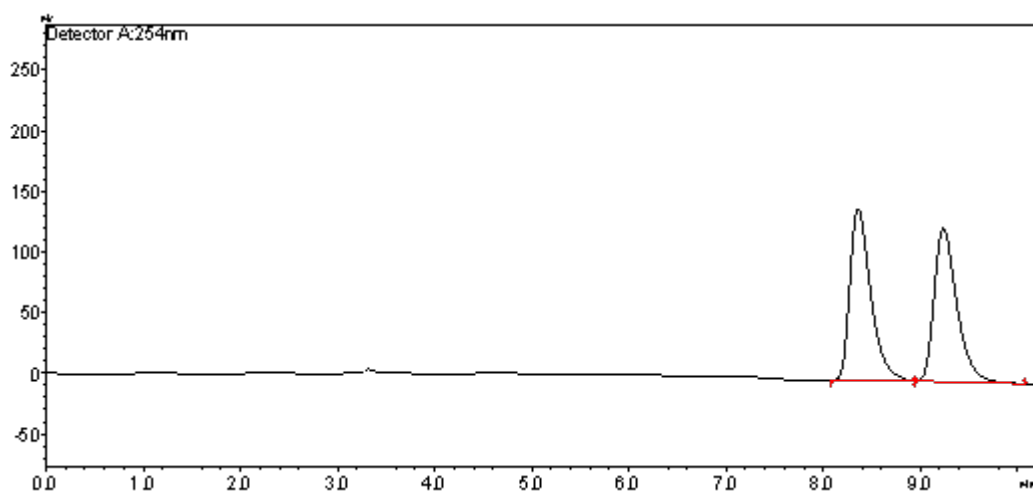
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.100	7801052	355809	98.946	99.278
2	23.055	83062	2587	1.054	0.722
Total		7884113	358397	100.000	100.000

3m: ^1H NMR (500 MHz, CDCl_3)

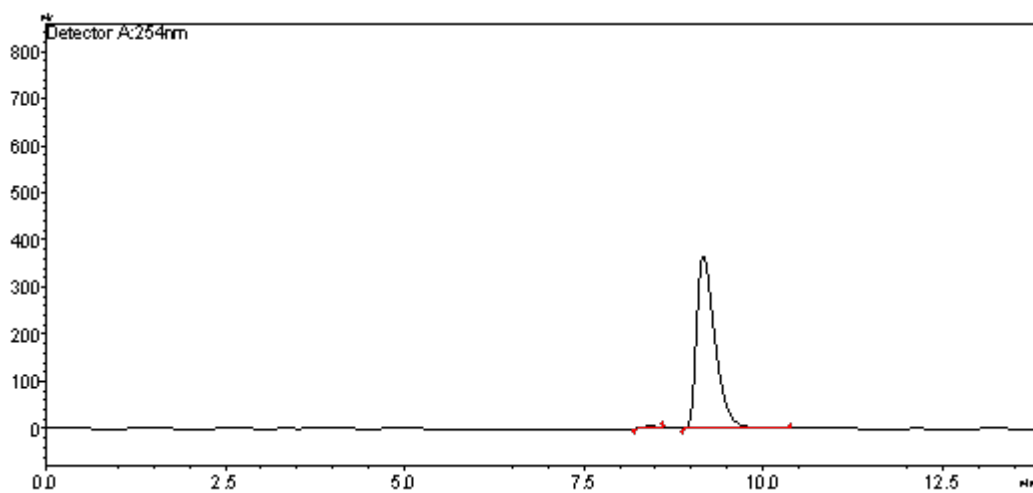


3m: ^{13}C NMR (126 MHz, CDCl_3)



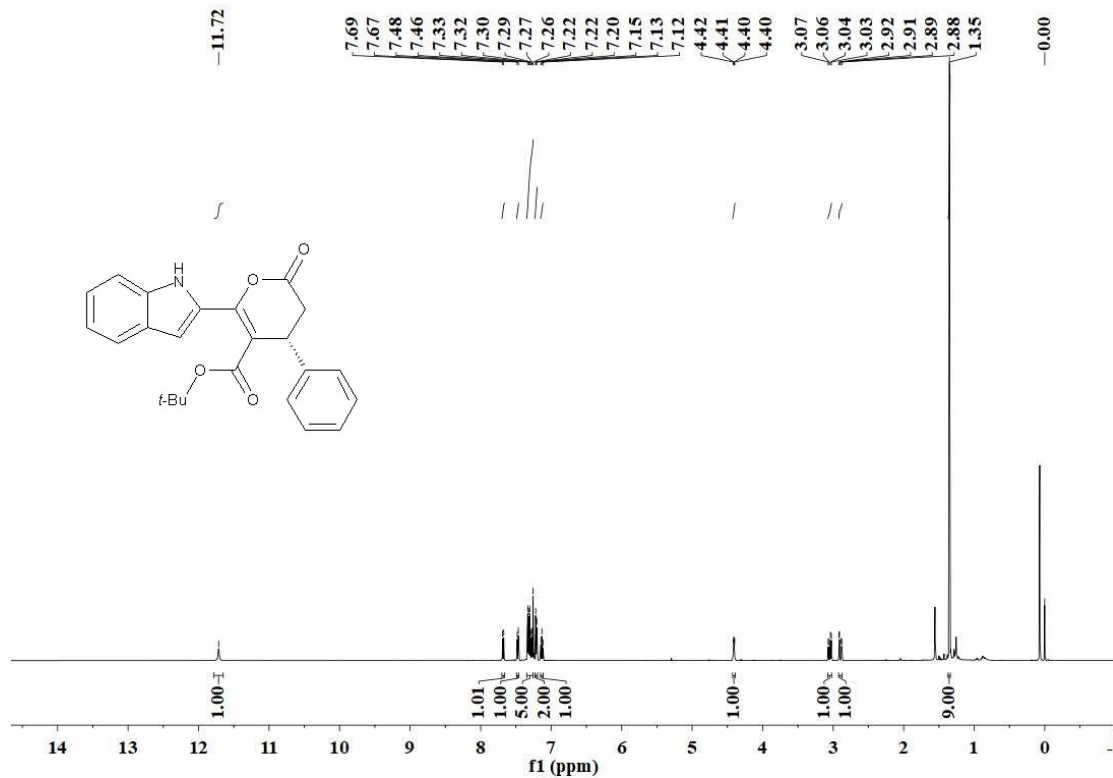


Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.354	2116649	141554	50.645	52.793
2	9.232	2062699	126575	49.355	47.207
Total		4179348	268129	100.000	100.000

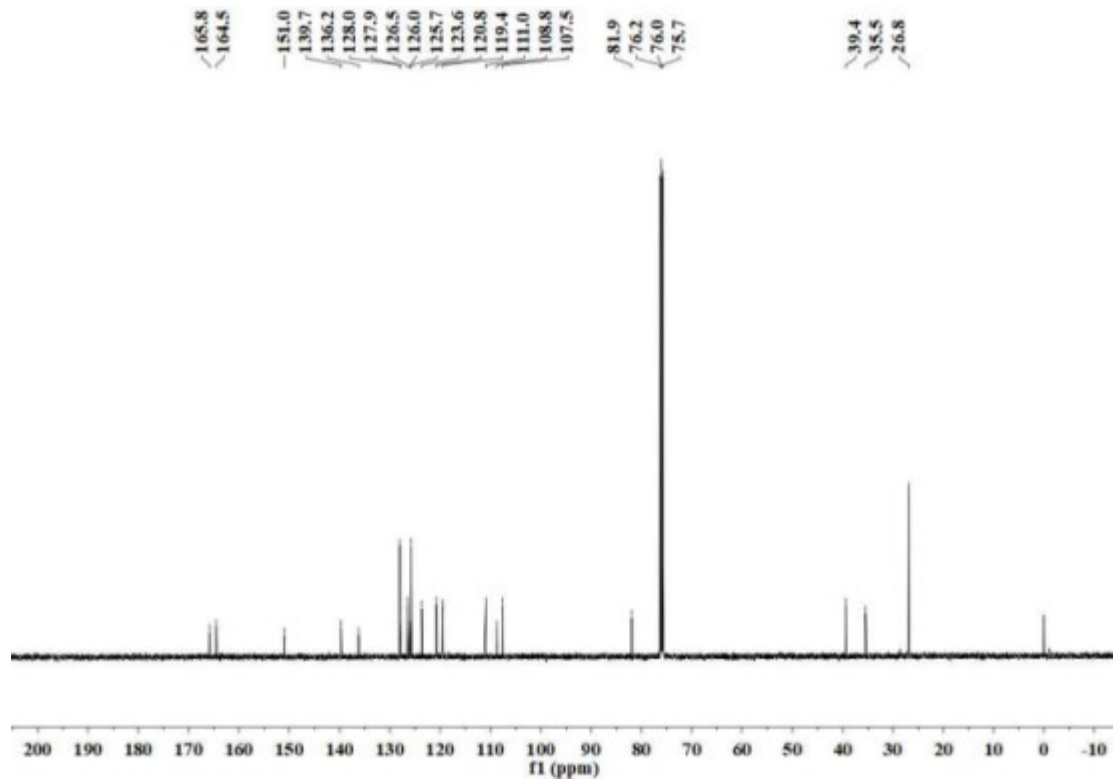


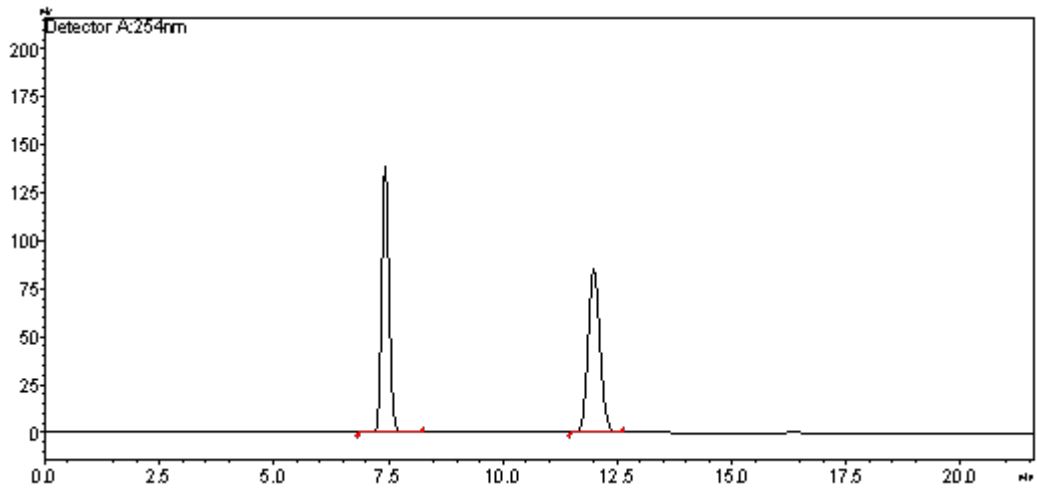
Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.420	56548	4942	0.862	1.333
2	9.163	6502401	365720	99.138	98.667
Total		6558950	370662	100.000	100.000

3n: ^1H NMR (500 MHz, CDCl_3)

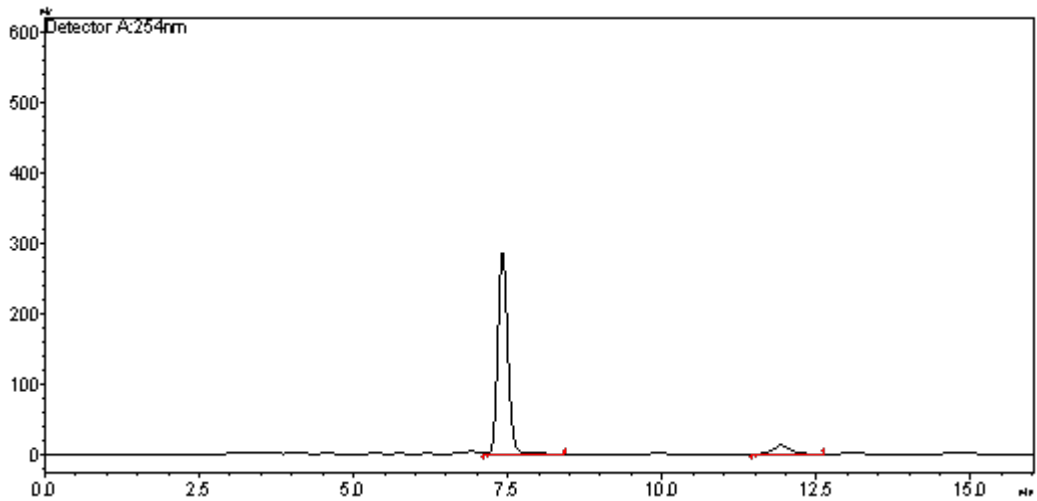


3n: ^{13}C NMR (126 MHz, CDCl_3)



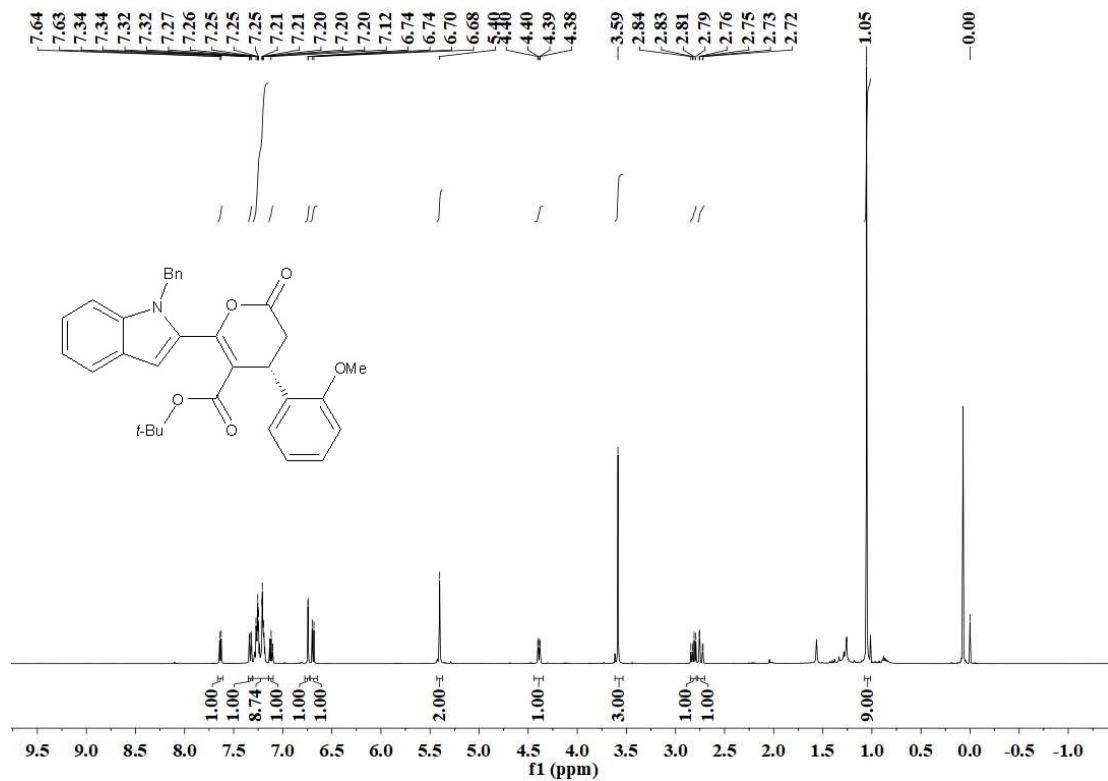


Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.423	1546847	138719	50.069	61.994
2	11.978	1542592	85043	49.931	38.006
Total		3089439	223762	100.000	100.000

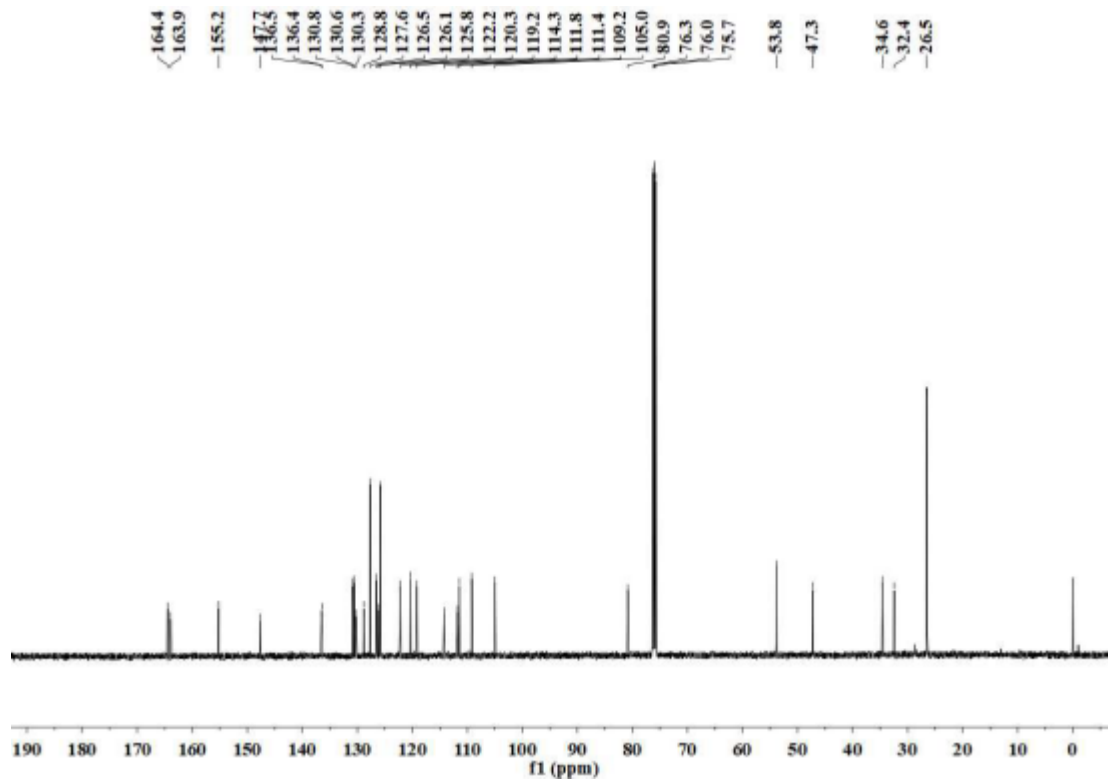


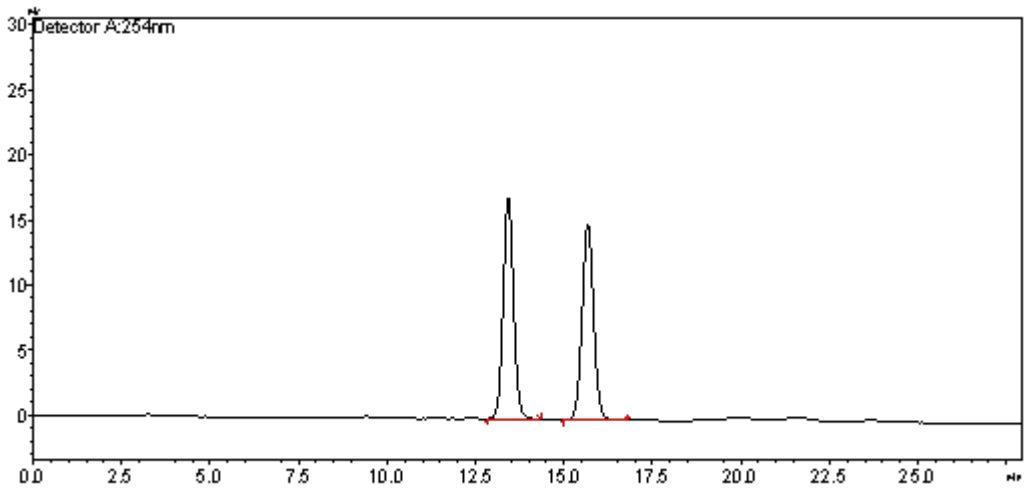
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.407	3179055	285663	93.536	95.921
2	11.927	219678	12148	6.464	4.079
Total		3398733	297811	100.000	100.000

3o: ¹H NMR (500 MHz, CDCl₃)

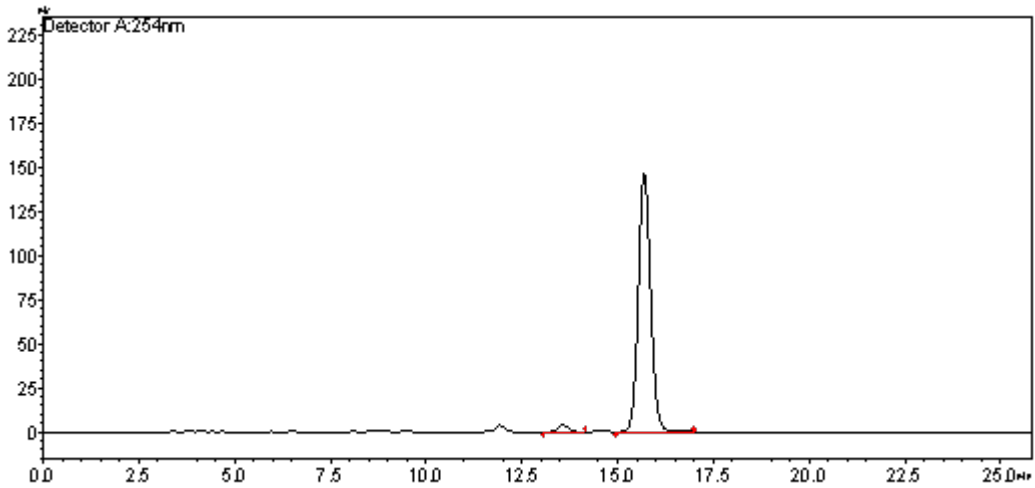


3o: ¹³C NMR (126 MHz, CDCl₃)



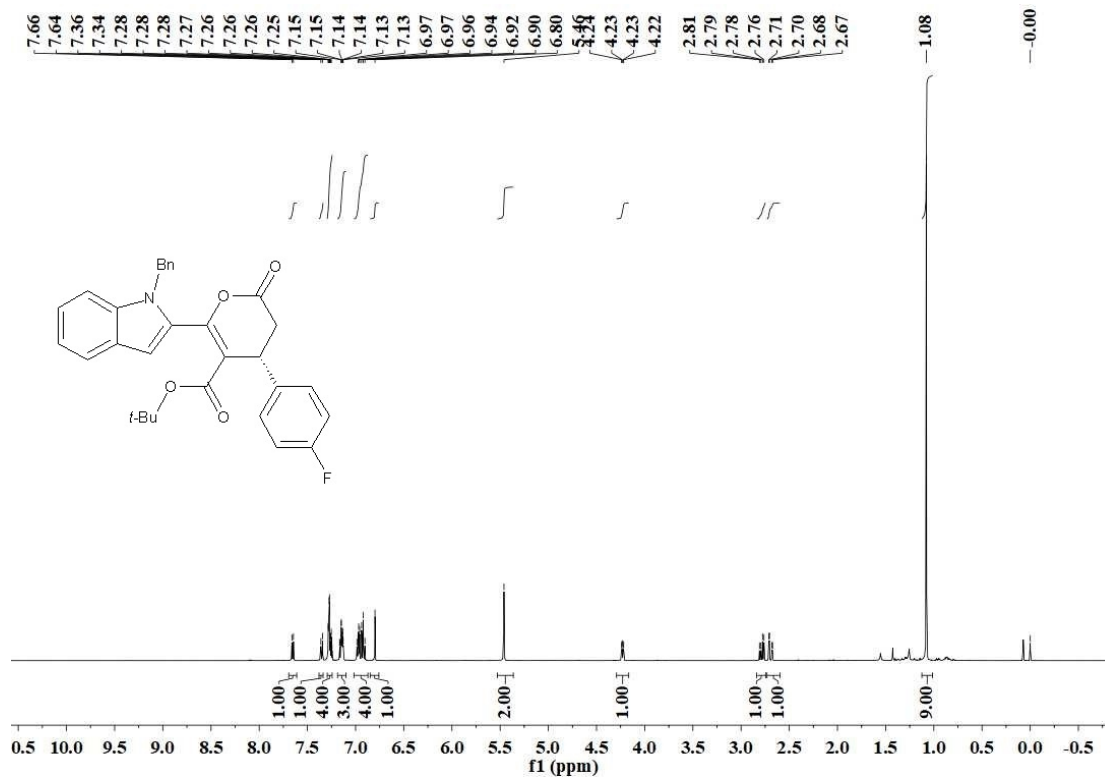


Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.422	345215	16942	50.287	52.943
2	15.668	341277	15059	49.713	47.057
Total		686493	32001	100.000	100.000

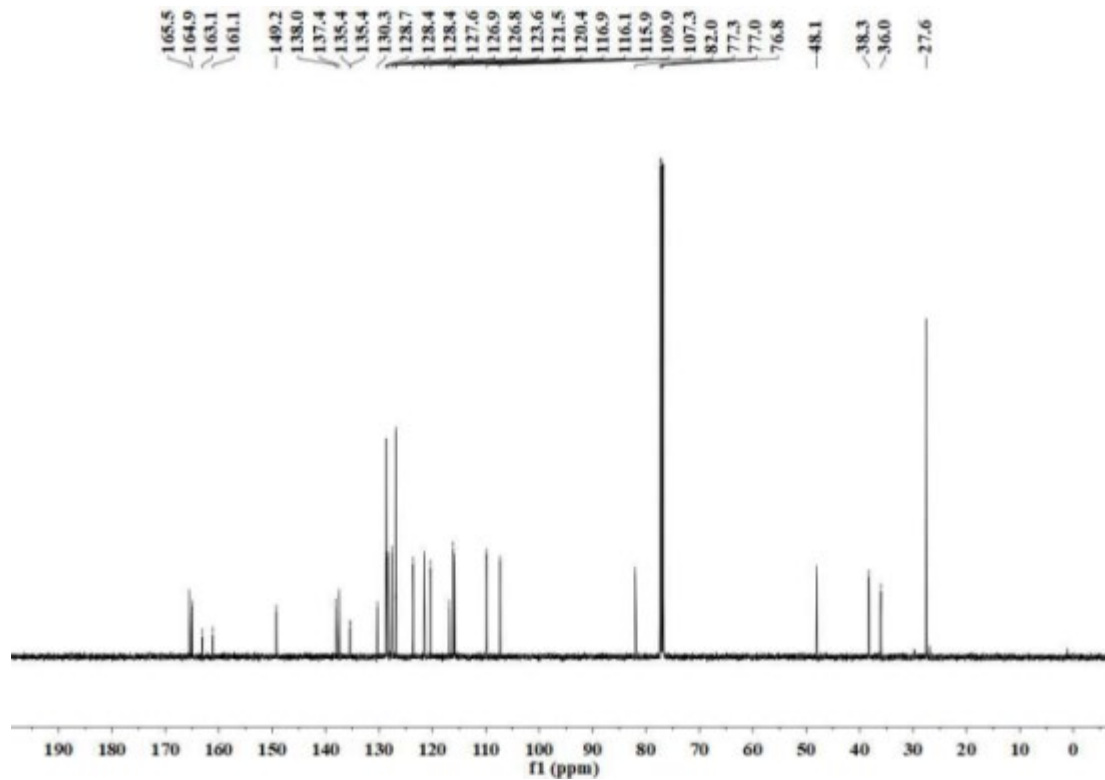


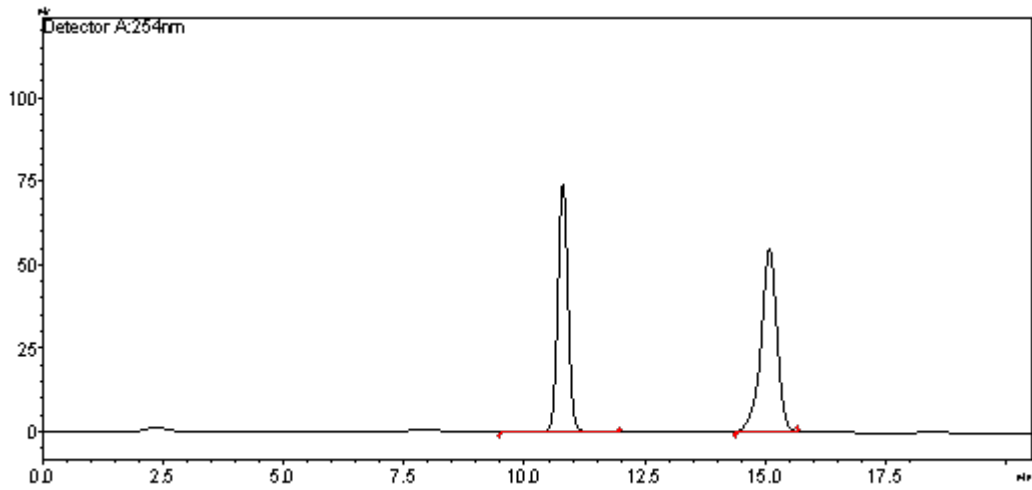
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.570	75366	3863	2.253	2.570
2	15.689	3270472	146440	97.747	97.430
Total		3345838	150303	100.000	100.000

3p: ^1H NMR (500 MHz, CDCl_3)

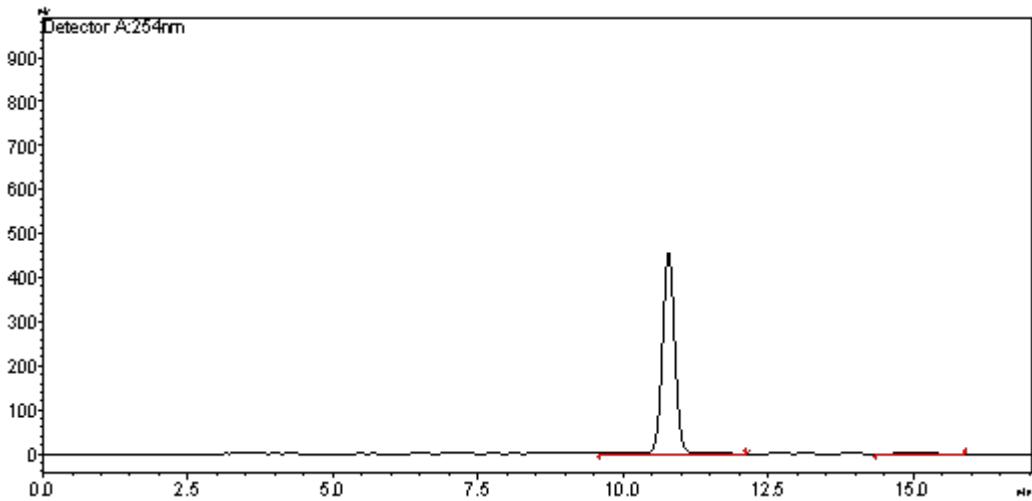


3p: ^{13}C NMR (126 MHz, CDCl_3)



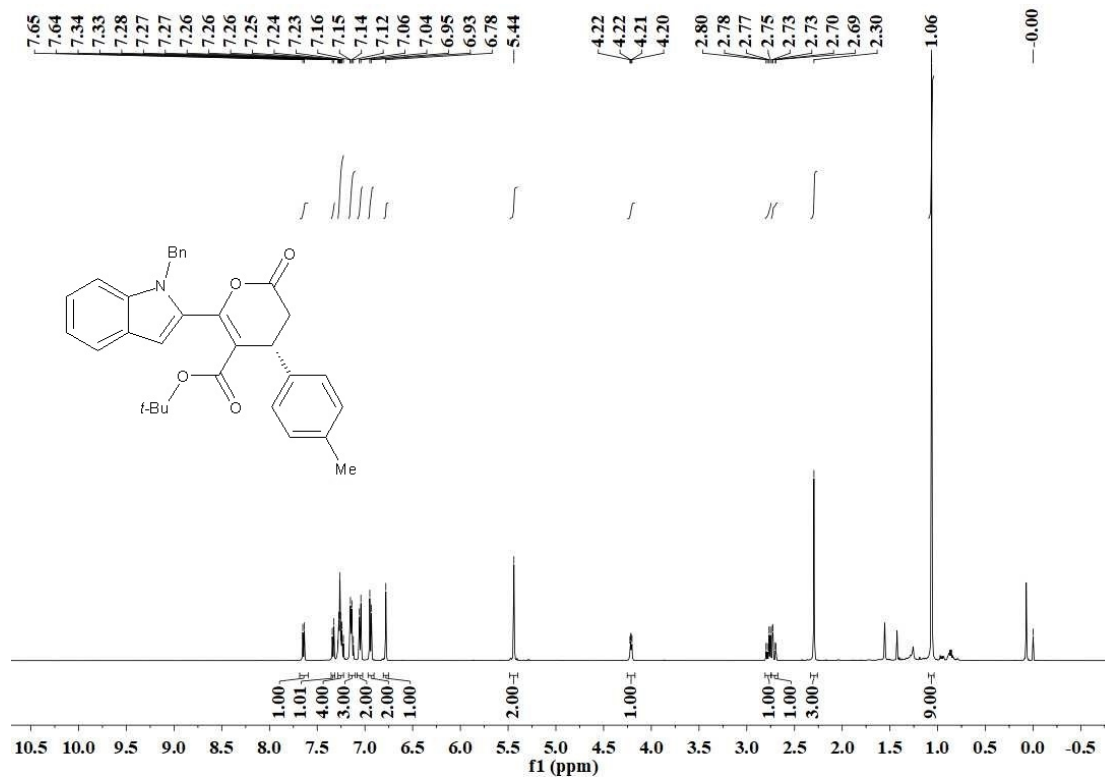


Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.794	1101395	74308	49.166	58.474
2	15.086	1138757	52771	50.834	41.526
Total		2240152	127079	100.000	100.000

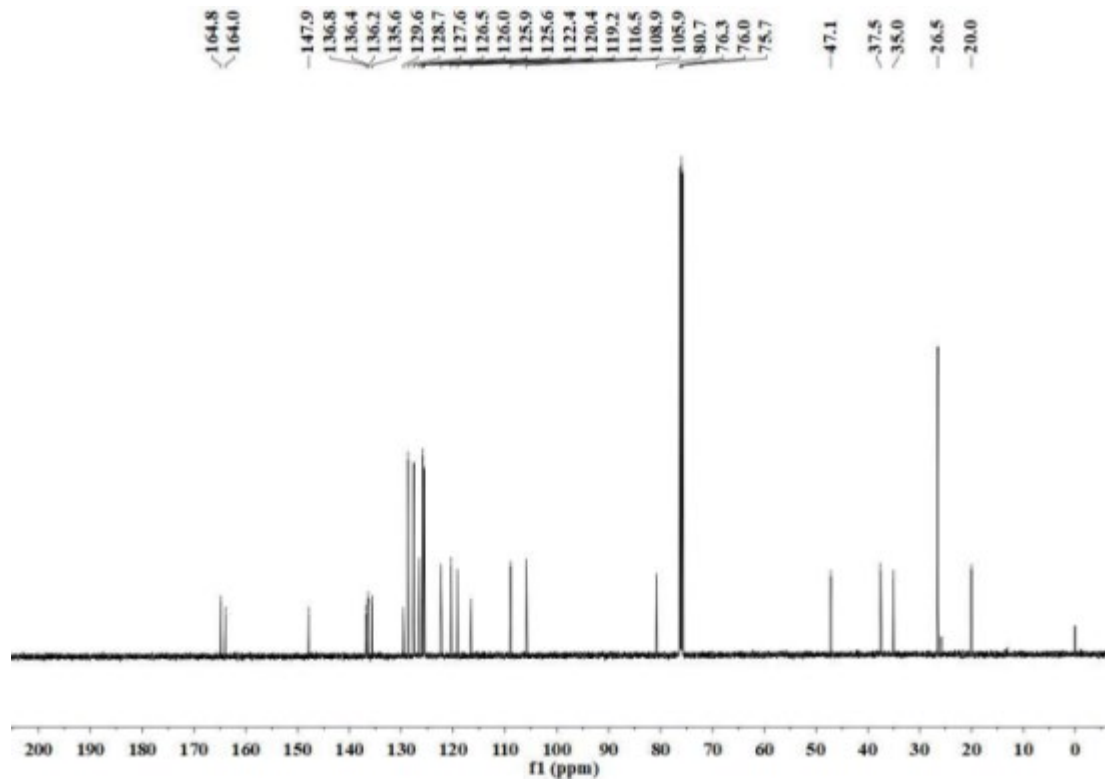


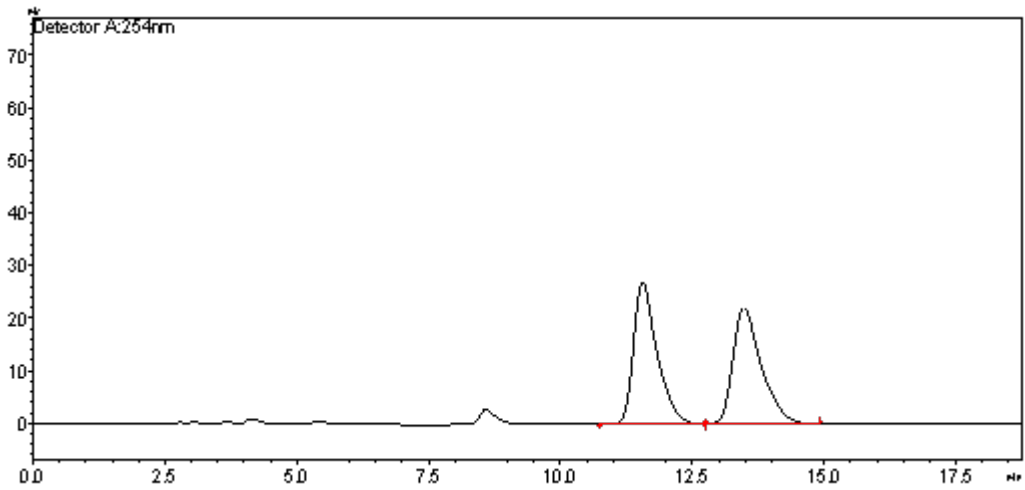
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.780	6762964	456653	98.627	99.046
2	15.026	94179	4398	1.373	0.954
Total		6857143	461051	100.000	100.000

3q: ^1H NMR (500 MHz, CDCl_3)

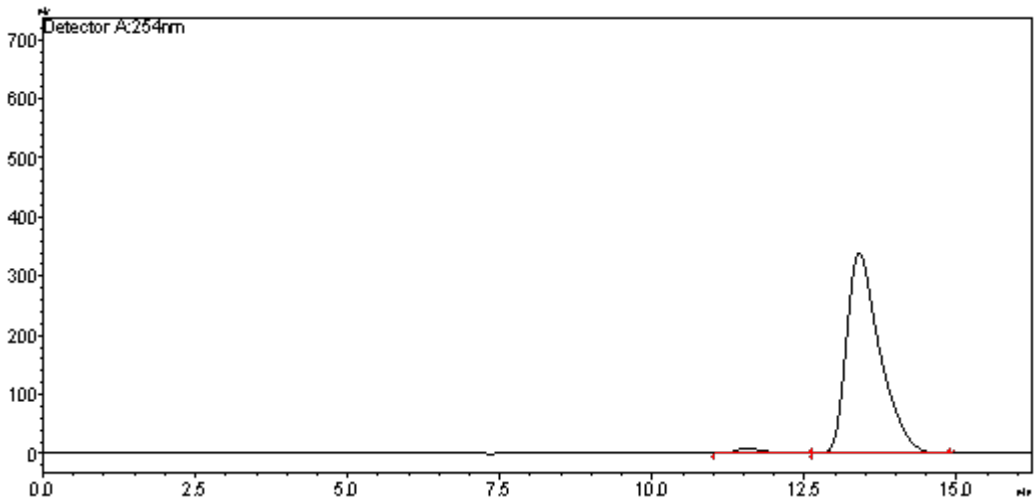


3q: ^{13}C NMR (126 MHz, CDCl_3)



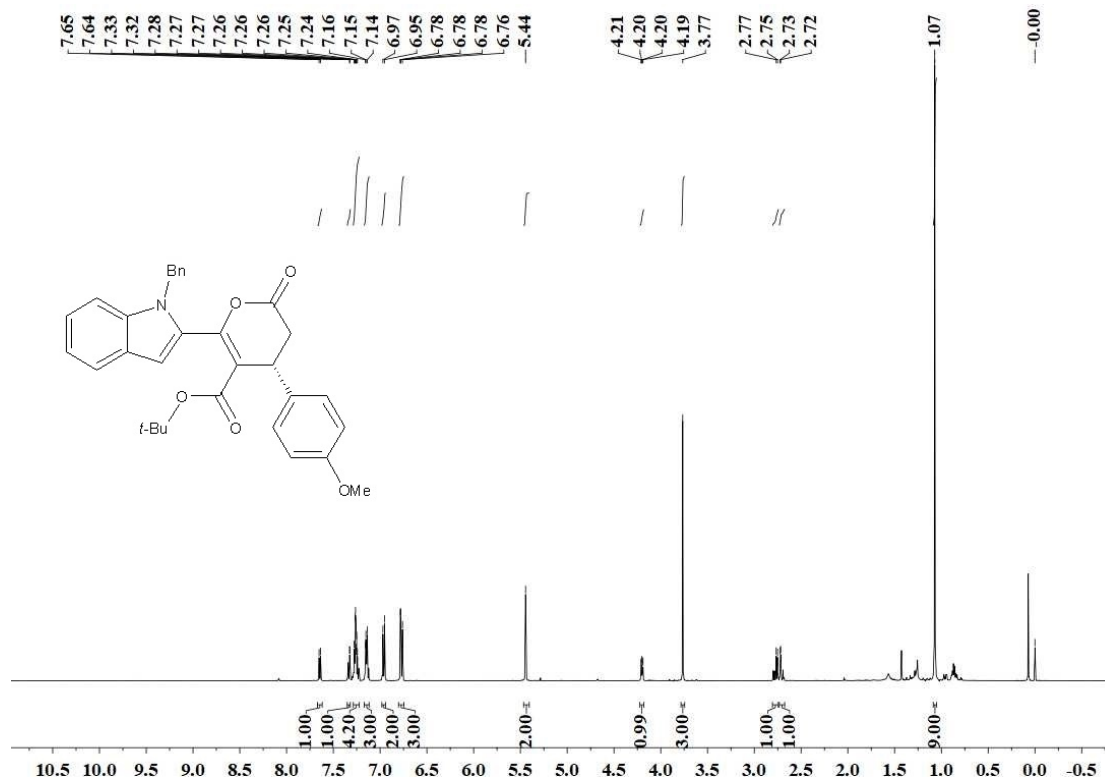


Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.554	828468	26934	50.159	54.828
2	13.476	823230	22190	49.841	45.172
Total		1651698	49124	100.000	100.000

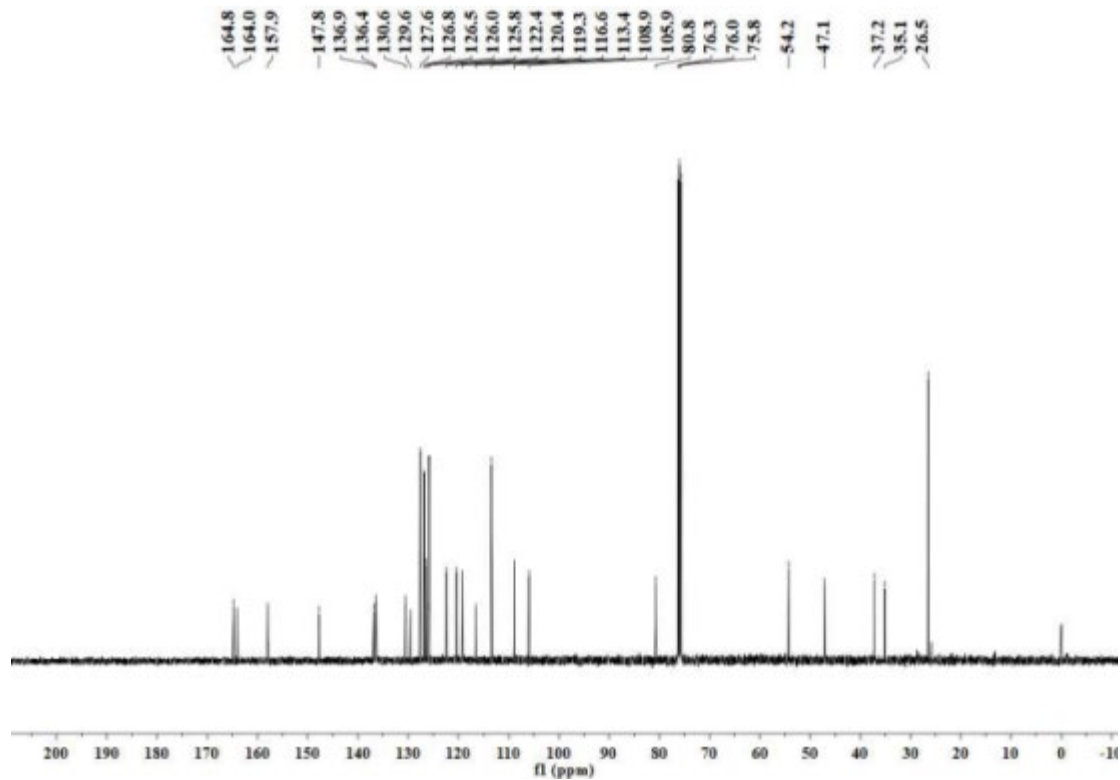


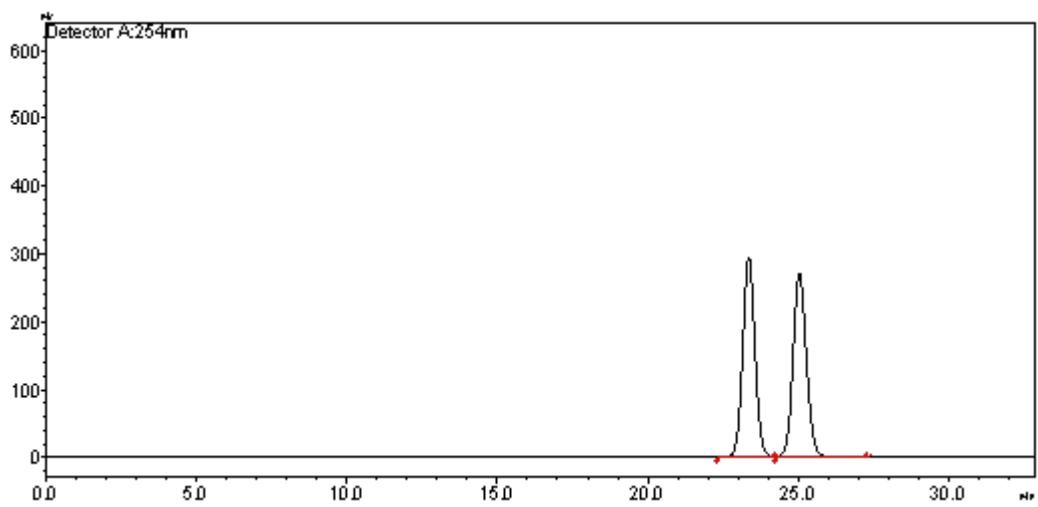
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.541	290521	9446	2.198	2.705
2	13.394	12925891	339785	97.802	97.295
Total		13216412	349231	100.000	100.000

3r: ^1H NMR (500 MHz, CDCl_3)

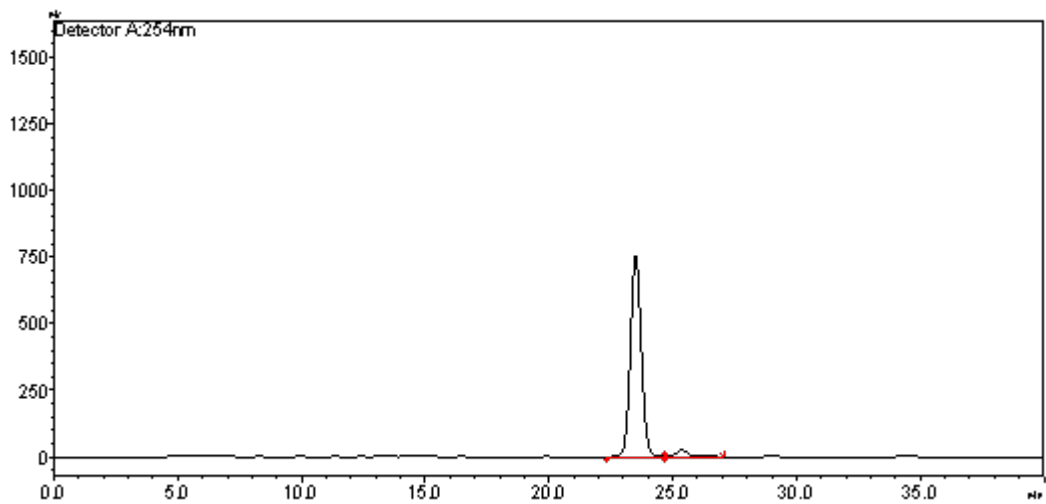


3r: ^{13}C NMR (126 MHz, CDCl_3)



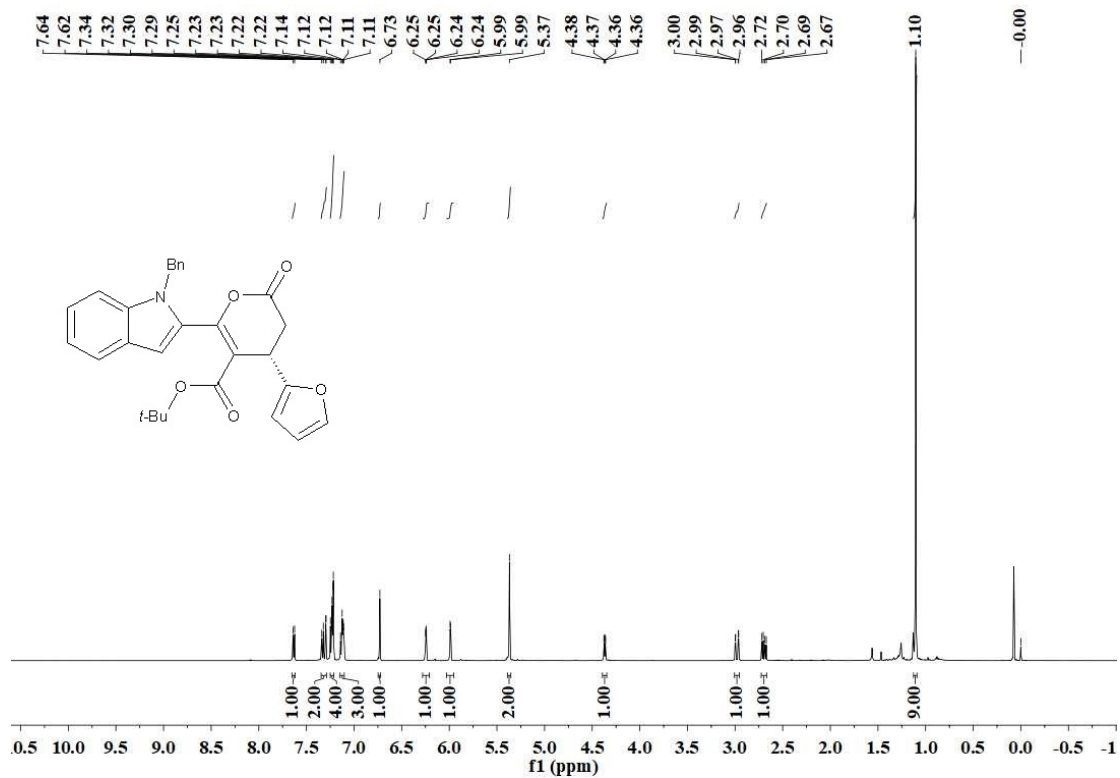


Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.353	8401246	295612	49.822	52.149
2	25.033	8461324	271246	50.178	47.851
Total		16862570	566858	100.000	100.000

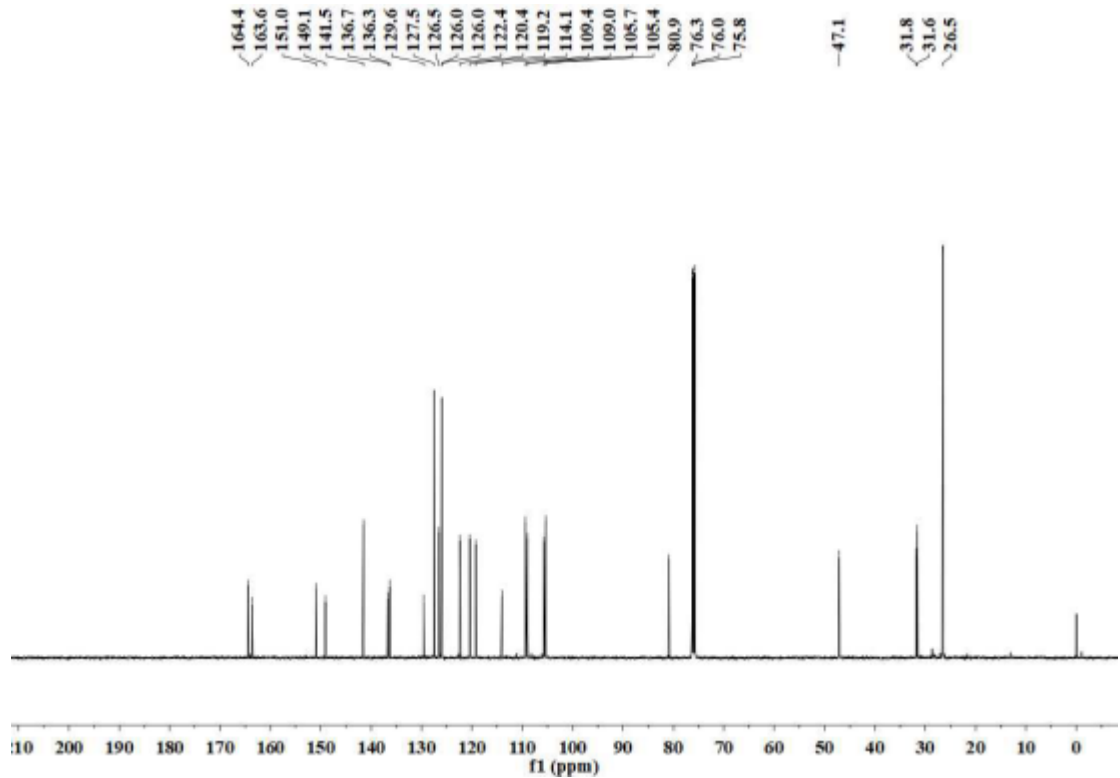


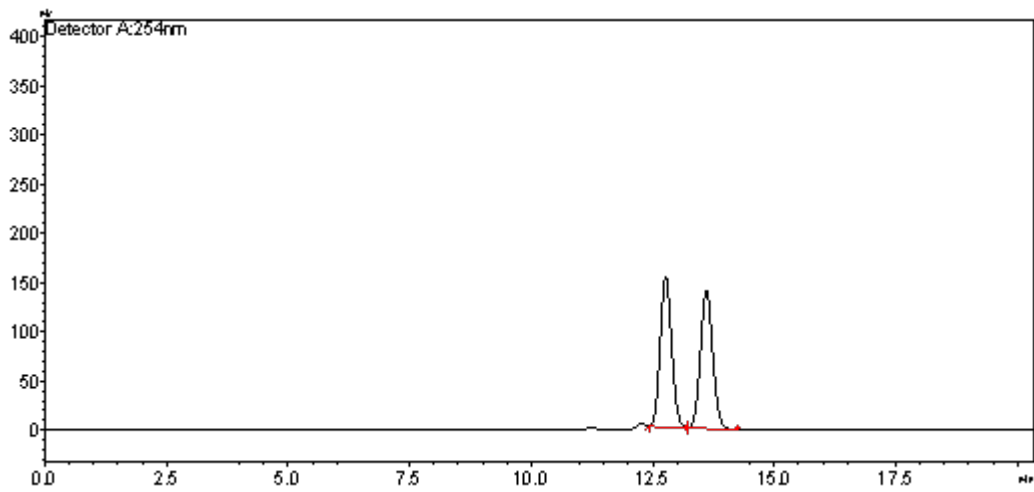
Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.497	23102657	754638	96.630	96.965
2	25.358	805602	23617	3.370	3.035
Total		23908259	778254	100.000	100.000

3s: ^1H NMR (500 MHz, CDCl_3)

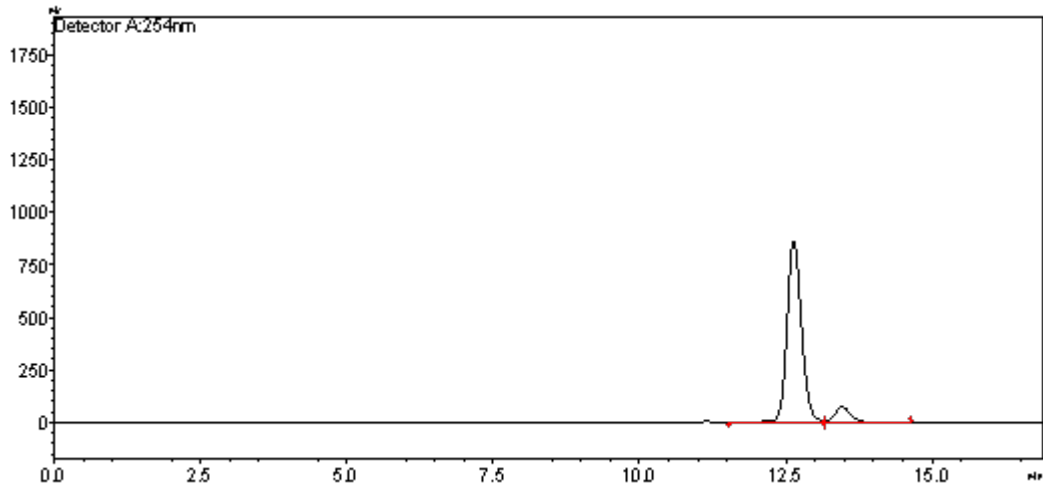


3s: ^{13}C NMR (126 MHz, CDCl_3)



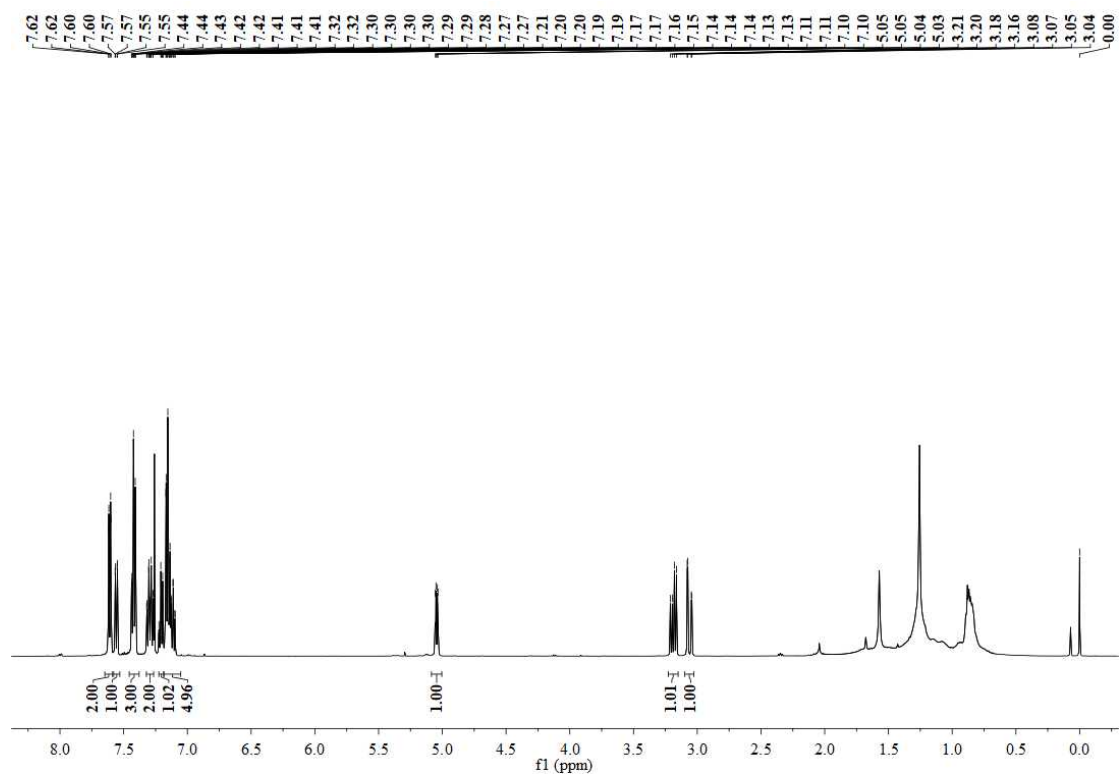


Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.760	2503066	153008	50.271	52.095
2	13.597	2476080	140700	49.729	47.905
Total		4979146	293708	100.000	100.000

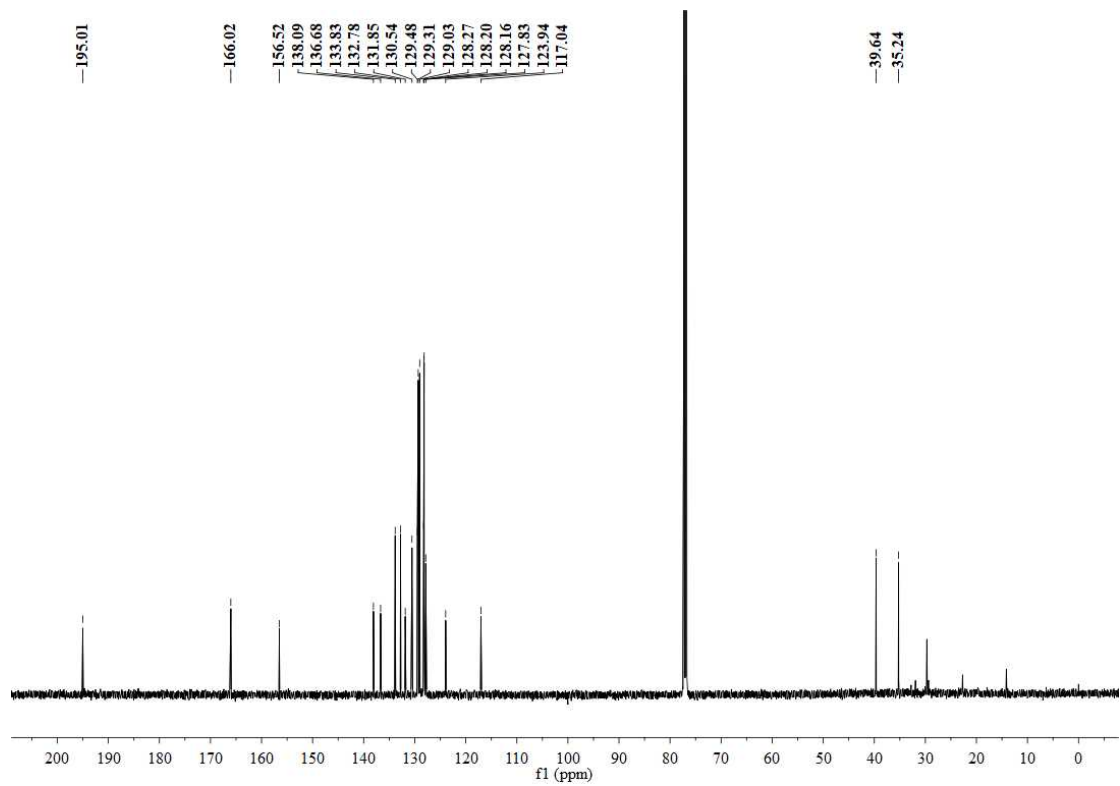


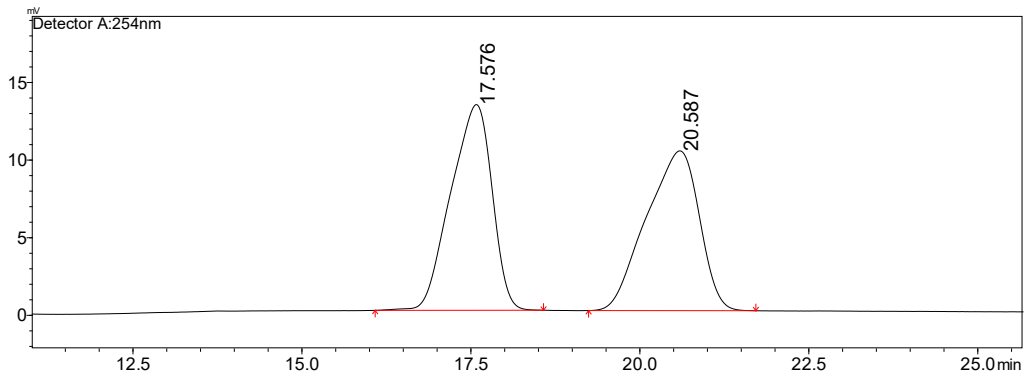
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.628	14888900	867094	91.473	92.144
2	13.463	1387966	73930	8.527	7.856
Total		16276866	941025	100.000	100.000

3t: ^1H NMR (500 MHz, CDCl_3)

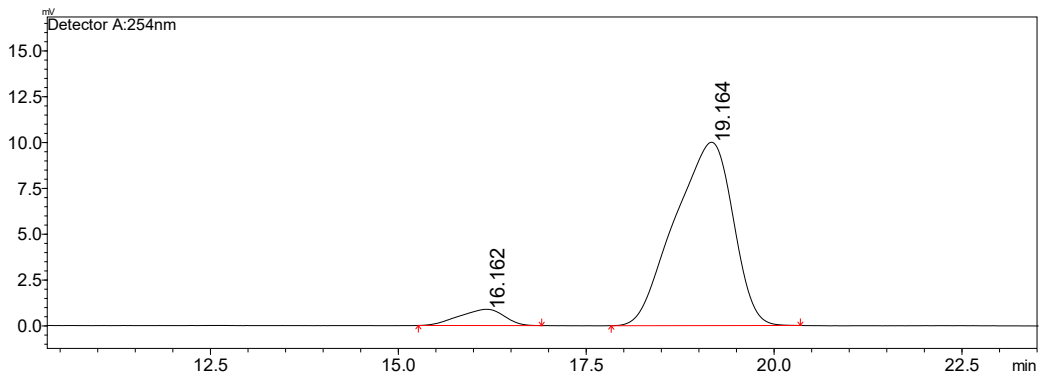


3t: ^{13}C NMR (126 MHz, CDCl_3)



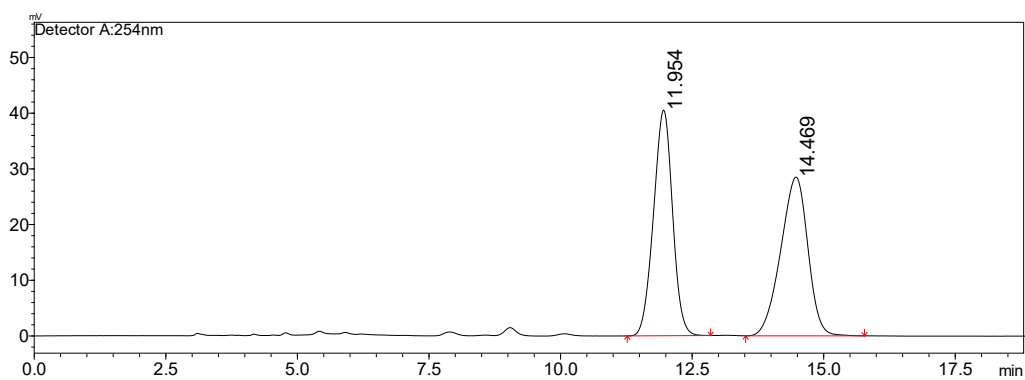


Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.576	564020	13249	50.094	56.282
2	20.587	561900	10292	49.906	43.718
Total		1125919	23541	100.000	100.000

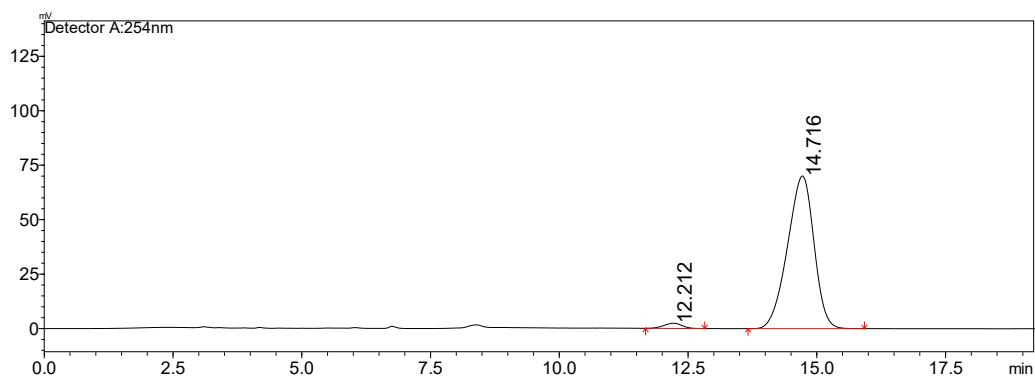


Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.162	36695	885	6.371	8.132
2	19.164	539299	9999	93.629	91.868
Total		575994	10884	100.000	100.000

Practical reaction



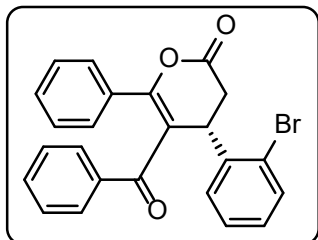
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.954	1019939	40510	49.896	58.698
2	14.469	1024188	28504	50.104	41.302
Total		2044126	69013	100.000	100.000



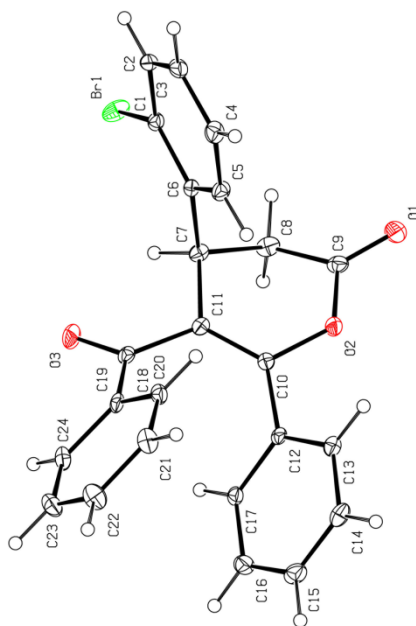
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.212	54497	2304	2.127	3.182
2	14.716	2508207	70095	97.873	96.818
Total		2562705	72399	100.000	100.000

6. X-ray single crystal data

X-ray single crystal data for compound **3t**^[4].



Experimental: The sample (30mg) was dissolved in appropriate amount of THF (1 mL), followed by the addition of ether (4mL) to furnish a saturated solution. Afterward, the mixture was allowed to stand at room temperature to form the crystals. The crystal structure was determined on a Bruker APEX-II CCD diffractometer.



Empirical formula	C ₂₄ H ₁₇ BrO ₃
Formula weight	433.28
Temperature/K	170.0
Crystal system	orthorhombic
Space group	P2 ₁ 2 ₁ 2 ₁
a/Å	7.6062(4)
b/Å	11.6121(5)
c/Å	21.4232(10)

$\alpha/^\circ$	90
$\beta/^\circ$	90
$\gamma/^\circ$	90
Volume/ \AA^3	1892.18(16)
Z	4
$\rho_{\text{calc}}/\text{g}/\text{cm}^3$	1.521
μ/mm^{-1}	3.146
F(000)	880.0
Crystal size/ mm^3	$0.42 \times 0.35 \times 0.26$
Radiation	CuK α ($\lambda = 1.54178$)
2Θ range for data collection/ $^\circ$	8.254 to 136.612
Index ranges	$-9 \leq h \leq 9, -13 \leq k \leq 13, -23 \leq l \leq 25$
Reflections collected	17296
Independent reflections	3435 [$R_{\text{int}} = 0.0464, R_{\text{sigma}} = 0.0352$]
Data/restraints/parameters	3435/0/253
Goodness-of-fit on F^2	1.136
Final R indexes [$I \geq 2\sigma(I)$]	$R_1 = 0.0256, wR_2 = 0.0643$
Final R indexes [all data]	$R_1 = 0.0257, wR_2 = 0.0643$
Largest diff. peak/hole / $e \text{\AA}^{-3}$	0.37/-0.64
Flack parameter	0.062(6)

7. References

1. González Cabrera D, Douelle F, Feng T-S, et al. Novel Orally Active Antimalarial Thiazoles. *J Med Chem* 2011; 54:7713-7719. <https://doi.org/10.1021/jm201108k>.
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3. Parker AN, Martin MC, Shenje R, France S. Calcium-Catalyzed Formal [5 + 2] Cycloadditions of Alkylidene β -Ketoesters with Olefins: Chemodivergent Synthesis of Highly Functionalized Cyclohepta[b]indole Derivatives. *Org Lett* 2019; 21:7268-7273. <https://doi.org/10.1021/acs.orglett.9b02498>.
4. Rong Z-Q, Jia M-Q, You S-L. Enantioselective N-Heterocyclic Carbene-Catalyzed Michael Addition to α,β -Unsaturated Aldehydes by Redox Oxidation. *Org Lett* 2011; 13:4080-4083. <https://doi.org/10.1021/ol201595f>.