Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

A C_1-Symmetric N-Heterocyclic Carbene Catalysed Oxidative Spiroannulation of Isatin-Derived Enals: Highly Enantioselective Synthesis of Spirooxindole δ-Lactones

Jun-Bing Lin, [a],+ Xi-Na Cheng, [a],+ Xiao-Dong Tian, [a] Guo-Qiang Xu, [a] Yong-Chun Luo, [a] and Peng-Fei Xu*[a]

State Key Laboratory of Applied Organic Chemistry and College of Chemistry and Chemical Engeneering, Lanzhou University, Lanzhou 730000, China.

xupf@lzu.edu.cn

Contents

A. General Information

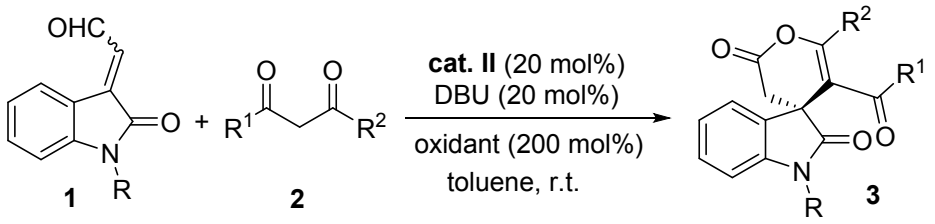
Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. ^{1}H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ with chemical shifts and were reported in ppm relative to either the residual solvent peak or internal standard (TMS). IR spectra were recorded on FT-IR instrument and are reported in wavenumbers (cm^{-1}). HRMS were performed on FTMS mass instrument (ESI). HPLC analysis was conducted on a IC column delta eluting with DCM and *n*-hexane. Optical rotation was measured on a polarimeter with $[\alpha]_D$ values reported in degrees with the concentration (c) in g/100 mL. Chiral N-heterocyclic carbene catalysts (NHC) [1], α,β-unsaturated aldehyde [2] **and** 1,3-dicarbonyl compounds [3] were prepared according to the literature procedures.

[1] Lu, H.; Liu, J. Y.; Li, C. G.; Lin, J. B.; Liang, Y. M.; Xu, P. F. *Chem. Commun.* **2015**, *51*, 4473.

[2] Mukaiyama, T.; Ogata, K.; Sato, I.; Hayashi, Y. *Chem. Eur. J.* **2014**, *20*, 13583.

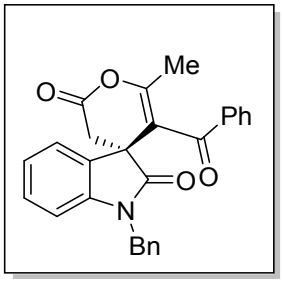
[3] a) Ji, C. Y.; Huang, C. Z.; Wang, N.; Jiang, Y. Z.; Peng, Y. G. *Synlett* **2005**, *6*, 986; b) Bartlett, S. L.; Beaudry, C. M. *J. Org. Chem.* **2011**, *76*, 9852.

B. General Procedure for the Synthesis of Spirooxindole 3



DBU (0.02mmol) was added to the mixture of 2-(1-benzyl-2-oxoindolin-3-ylidene) acetaldehyde **1a** (0.1 mmol), 1-phenylbutane-1,3-dione **2a** (0.1 mmol), chiral catalyst **II** (12.2 mg, 0.02mmol), and oxidant (0.2 mmol) in toluene (1.0 mL) at room temperature under N_2 atmosphere. The reaction was stirred at room temperature until **2a** was consumed as monitored by TLC. The reaction mixture was concentrated in vacuo and purified by flash column chromatography or preparative TLC to afford the corresponding product **3**.

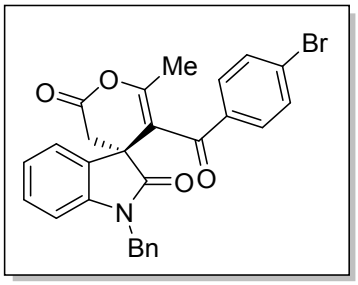
(S)-5'-benzoyl-1-benzyl-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3a):



White solid; m.p. 174–176℃; [α]25 D = -8.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 70:30), 1.0 mL/min; major enantiomer t_R = 11.9min, minor enantiomer t_R = 27.8 min; ^{1}HNMR (400 MHz, $CDCl_3$) δ7.53 (d, *J* = 6.4Hz, 2H),7.51 (t, *J* = 1.2Hz, 1H), 7.39 (t, *J* = 8.0Hz, 2H), 7.29 (m, 5H),7.13 (q, *J* = 5.2Hz, 2H), 6.97 (m, 1H), 6.63 (d, *J* = 7.6Hz,1H), 4.90 (d, *J* = 16.0Hz,

1H), 4.75 (d, J = 16.0Hz, 1H), 3.16 (d, J = 15.6Hz, 1H), 2.89 (d, J = 15.6Hz, 1H), 1.94 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.5, 176.2, 164.5, 157.8, 142.2, 138.4, 135.2, 133.1, 129.6, 129.3, 128.8, 128.7, 127.7, 127.2, 123.3, 122.6, 115.9, 110.0, 50.0, 44.2, 38.0, 19.6; IR (KBr): 3060, 2924, 1785, 1715, 1649, 1612, 1489, 1467, 1364, 1325, 1181, 1137, 931, 736, 704 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{21}NO_4$ 446.1363, found 446.1372.

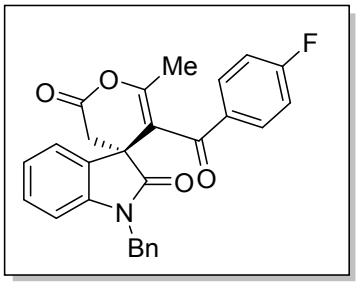
(S)-1-benzyl-5'-(4-bromobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3b):



White solid; m.p. 225–228℃; [α]26 D= 9.0 (c=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: n-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 13.6min, minor enantiomer t_R = 28.9min; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (q, J = 8.8Hz, 4H), 7.31 (q, J = 7.2Hz, 5H), 7.15 (q, J = 7.6Hz, 2H), 6.99 (t, J = 7.2Hz, 1H), 6.66 (d, J = 7.6Hz, 1H), 4.88 (d, J = 15.6Hz, 1H), 4.78 (d, J = 16.0Hz, 1H), 3.15 (d, J = 15.6Hz, 1H), 2.88 (d, J = 15.6Hz, 1H), 1.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$)δ 193.5, 176.1, 164.3, 157.8, 142.2, 137.0, 135.1, 132.1, 130.3, 129.4, 128.8, 128.4, 127.8, 127.2, 123.4, 122.6, 115.6, 110.0, 50.0, 44.2, 38.0, 19.6. IR (KBr): 3061, 2926, 1786, 1715, 1650, 1488, 1365, 1265, 1180, 1136, 1069, 1009, 930, 738, 700, 491, 458

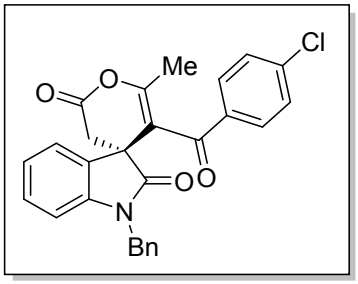
cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}BrNO_4$ 524.0468, found 524.0469.

(S)-1-benzyl-5'-(4-fluorobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3c):



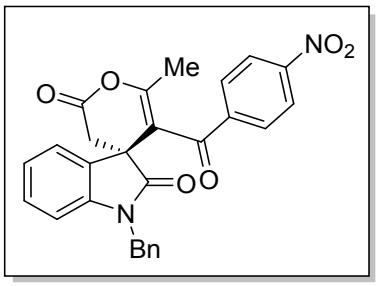
White solid; m.p. 79–81℃; [α]25 D= –4.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 13.1min, minor enantiomer t_R = 27.7min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (q, *J*= 6.4Hz, 2H), 7.30 (m, 5H), 7.15 (q, *J* = 7.2Hz, 2H), 7.05 (t, *J* = 8.0Hz, 2H), 6.99 (t, *J* = 7.6Hz, 1H), 6.65 (d, *J* = 7.6Hz, 1H), 4.88 (d, *J* = 15.6Hz, 1H), 4.78 (d, *J* = 16.0Hz, 1H), 3.15 (d, *J* = 15.6Hz, 1H), 2.88 (d, *J* = 16.0Hz, 1H), 1.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.0, 176.1, 164.4, 157.4, 142.2, 135.1, 134.7, 134.6, 131.6, 131.5, 129.5, 129.4, 128.8, 127.8, 127.2, 123.4, 122.6, 116.1, 115.8, 115.6, 110.0, 50.0, 44.3, 38.0, 19.5. IR (KBr): 3062, 2925, 1786, 1714, 1650, 1597, 1489, 1467, 1365, 1323, 1136, 1005, 931, 736, 699, 600 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}FNO_4$ 464.1269, found 464.1271.

(S)-1-benzyl-5'-(4-chlorobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3d):



White solid; m.p. 206–208℃; [α]26 D= 2.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 13.3min, minor enantiomer t_R = 27.6min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.4Hz, 2H), 7.35 (d, *J* = 8.4Hz, 2H), 7.29 (m, 5H), 7.15 (q, *J* = 7.2Hz, 2H), 6.99 (t, *J* = 7.6Hz, 1H), 6.66 (d, *J* = 7.6Hz, 1H), 4.88 (d, *J* = 15.6Hz, 1H), 4.78 (d, *J* = 15.6Hz, 1H), 3.15 (d, *J* = 16.0Hz, 1H), 2.88 (d, *J* = 16.0Hz, 1H), 1.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 176.0, 164.3, 157.7, 142.1, 139.8, 136.6, 135.0, 130.2, 129.4, 129.1, 128.8, 127.7, 127.2, 123.3, 122.6, 115.6, 110.0, 50.0, 44.3, 38.0, 19.6. IR (KBr): 3060, 2925, 1787, 1716, 1651, 1488, 1365, 1323, 1265, 1181, 1134, 1012, 931, 738, 701 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}ClNO_4$ 480.0973, found 480.0972.

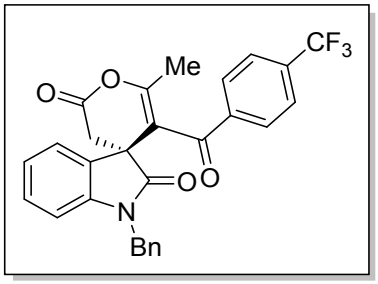
(S)-1-benzyl-6'-methyl-5'-(4-nitrobenzoyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3e):



White solid; m.p. 68–70℃; [α]26 D= –3.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min;

major enantiomer t_R = 17.2min, minor enantiomer t_R = 28.6min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.8Hz, 2H), 7.79 (d, *J* = 8.8Hz, 2H), 7.30 (m, 5H), 7.16 (m, 2H), 7.01 (t, *J* = 7.6Hz, 1H), 6.67 (d, *J* = 7.6Hz, 1H), 4.87 (d, *J* = 15.6Hz, 1H), 4.76 (d, *J* = 15.6Hz, 1H), 3.19 (d, *J* = 15.6Hz, 1H), 2.88 (d, *J* = 16.0Hz, 1H), 1.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.1, 176.0, 163.9, 159.5, 150.1, 143.2, 142.0, 134.9, 129.6, 129.5, 128.9, 127.9, 127.3, 123.9, 123.5, 115.7, 110.1, 49.9, 44.3, 38.1, 19.8. IR (KBr): 3062, 2925, 2854, 2374, 1788, 1715, 1610, 1527, 1467, 1350, 1180, 851, 754, 737, 699cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}N_2O_6$ 491.1214, found 491.1210.

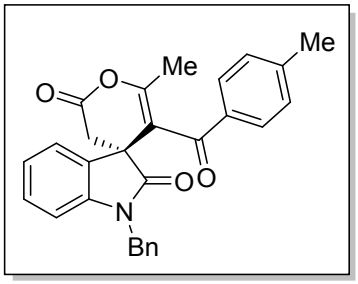
(S)-1-benzyl-6'-methyl-5'-(4-(trifluoromethyl)benzoyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3f):



White solid; m.p. 58–60℃; [α]26 D= –12.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 50:50), 1.0 mL/min; major enantiomer t_R = 17.6min, minor enantiomer t_R = 34.9min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.0Hz, 2H), 7.63 (d, *J* = 8.0Hz, 2H), 7.28 (m, 5H), 7.16 (t, *J* = 8.0Hz, 2H), 7.00 (t, *J* = 7.6Hz, 1H), 6.64 (d, *J* = 8.0Hz, 1H), 4.89 (d, *J* = 16.0Hz, 1H), 4.72 (d, *J* = 15.6Hz, 1H), 3.18 (d, *J* = 16.0Hz, 1H), 2.89 (d, *J* = 15.6Hz, 1H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.6, 176.1, 164.1, 158.9, 142.1, 141.3, 135.0, 129.5, 129.0, 128.8,

127.8, 127.2, 123.4, 122.5, 115.7, 110.0, 50.0, 44.2, 38.0, 19.7. IR (KBr): 3062, 2926, 1716, 1612, 1468, 1358, 1327, 1175, 1133, 1068, 855, 738, 699 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{28}H_{20}F_3NO_4$ 514.1237, found 514.1241.

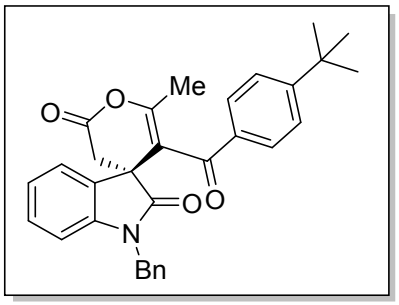
(S)-1-benzyl-6'-methyl-5'-(4-methylbenzoyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3g):



White solid; m.p. 201–204℃; [α]26 D =–2.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column(CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 16.0min, minor enantiomer t_R = 39.2min. ^1H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.0Hz, 2H), 7.29 (t, *J* = 6.8Hz, 5H), 7.19 (d, *J* = 8.0Hz, 2H), 7.14 (m, 2H), 6.96 (t, *J* = 7.6Hz, 1H), 6.64 (d, *J* = 8.0Hz, 1H), 4.89 (d, *J* = 16.0Hz, 1H), 4.70 (d, *J* = 16.0Hz, 1H), 3.15 (d, *J* = 15.6Hz, 1H), 2.89 (d, *J* = 15.6Hz, 1H), 2.39 (s, 3H), 1.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.0, 176.2, 164.7, 157.0, 144.3, 142.2, 135.7, 135.2, 129.7, 129.4, 129.2, 129.1, 128.8, 127.6, 127.2, 123.2, 122.5, 115.8, 109.9, 50.1, 44.2, 38.0, 21.7, 19.6. IR (KBr): 3059, 2925, 1785, 1715, 1646, 1607, 1489, 1467, 1325, 1264, 1181, 1136, 931, 736 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{28}H_{23}NO_4$ 460.1519, found 460.1516.

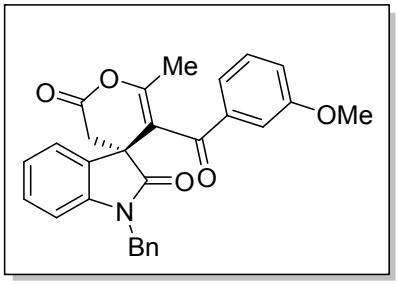
(S)-1-benzyl-5'-(4-(tert-butyl)benzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-

dione (3h):



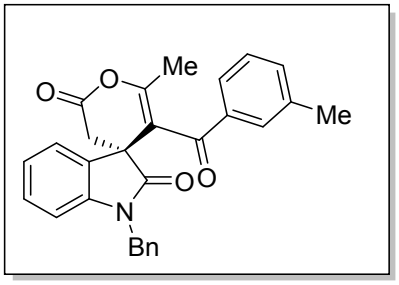
White solid; m.p. 75–76℃, [α]26 D= –7.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 13.0min, minor enantiomer t_R = 30.9min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.4Hz, 2H), 7.29 (d, *J* = 8.4Hz, 2H), 7.27(m, 5H), 7.14 (t, *J* = 8.0Hz, 2H), 6.97 (t, *J* = 7.6Hz, 1H), 6.62 (d, *J* = 8.0Hz, 1H), 4.92 (d, *J* = 15.6Hz, 1H), 4.73 (d, *J* = 16.0Hz, 1H), 3.16 (d, *J* = 15.6Hz, 1H), 2.88 (d, *J* = 15.6Hz, 1H), 2.96 (s, 3H), 1.33 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.1, 176.2, 164.7, 157.3, 157.1, 142.2, 135.7, 135.2, 129.8, 129.2, 128.9, 128.8, 127.7, 127.2, 125.7, 123.3, 122.6, 115.9, 109.9, 50.1, 44.2, 38.0, 35.2, 31.1, 19.6. IR (KBr): 2925, 1786, 1718, 1608, 1467, 1363, 1181, 1109, 1016, 933, 853, 737, 698, 551 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{31}H_{29}NO_4$ 502.1989, found 502.1992.

(S)-1-benzyl-5'-(3-methoxybenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3i):



White solid; m.p. 78–80℃; [α]26 D =–3.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 16.2min, minor enantiomer t_R = 37.6min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (t, *J* = 34.4Hz, 7H), 7.14 (t, *J* = 6.8Hz, 3H), 7.06 (d, *J* = 3.6Hz, 1H), 6.98 (t, *J* = 7.6Hz, 1H), 6.62 (d, *J* = 8.0Hz, 1H), 4.92 (d, *J* = 15.6Hz, 1H), 4.73 (d, *J* = 15.6Hz, 1H), 3.78 (s, 3H), 3.12 (d, *J* = 16.0Hz, 1H), 2.89 (d, *J* = 15.6Hz, 1H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.4, 176.2, 164.5, 159.8, 157.9, 142.3, 139.7, 135.2, 129.7, 129.5, 129.3, 128.8, 128.7, 127.7, 127.2, 123.3, 122.6, 121.6, 119.8, 115.9, 112.6, 110.0, 55.4, 50.0, 44.2, 38.0, 19.5. IR (KBr): 2923, 1786, 1718, 1612, 1466, 1431, 1364, 1317, 1264, 1177, 1129, 1040, 739, 700 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{28}H_{23}NO_5$ 476.1468, found 476.1479.

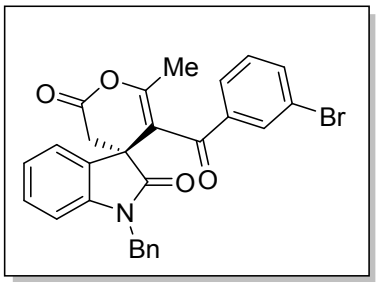
(S)-1-benzyl-6'-methyl-5'-(3-methylbenzoyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3j):



White solid; m.p. 182–184℃; [α]26 D= –10.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess

was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 14.8min, minor enantiomer t_R = 35.6min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (t, *J* = 9.2Hz, 2H), 7.29 (m, 7H), 7.14 (t, *J* = 7.6Hz, 2H), 6.97 (t, *J* = 7.6Hz, 1H), 6.62 (d, *J* = 7.6Hz, 1H), 4.91 (d, *J* = 15.6Hz, 1H), 4.73 (d, *J* = 15.6Hz, 1H), 3.15 (d, *J* = 16.0Hz, 1H), 2.88 (d, *J* = 16.0Hz, 1H), 2.35 (s, 3H), 1.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.7, 176.2, 164.6, 157.7, 142.2, 138.6, 138.5, 135.2, 133.9, 129.7, 129.2, 129.1, 128.8, 128.5, 127.6, 127.1, 126.1, 123.2, 122.5, 116.1, 109.9, 50.0, 44.2, 38.1, 21.2, 19.6. IR (KBr): 3060, 2924, 1787, 1716, 1648, 1612, 1489, 1467, 1364, 1319, 1179, 1132, 1008, 946, 736, 700 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{28}H_{23}NO_4$ 460.1519, found 460.1519.

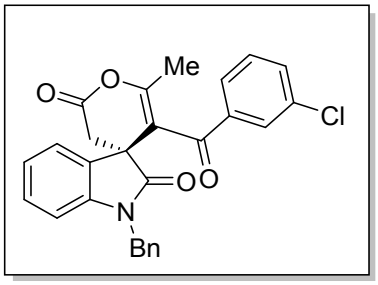
(S)-1-benzyl-5'-(3-bromobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3k):



White solid; m.p. 196–198℃; [α]26 D= –6.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 12.0min, minor enantiomer t_R = 24.5min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (s, 1H), 7.61 (q, *J* = 8.0Hz, 2H), 7.29 (m, 6H), 7.15 (m, 2H), 6.99 (t, *J* = 7.6Hz, 1H), 6.64 (d, *J* = 8.0Hz, 1H), 4.92 (d, *J* = 15.6Hz, 1H), 4.73 (d, *J* = 15.6Hz, 1H),

3.15 (d, J = 16.0Hz, 1H), 2.89 (d, J = 15.6Hz, 1H), 1.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.1, 176.0, 164.2, 158.5, 142.1, 140.1, 135.9, 135.0, 131.5, 130.2, 129.4, 129.3, 128.8, 127.7, 127.3, 127.1, 123.3, 122.8, 122.4, 115.6, 110.0, 49.9, 44.2, 37.9, 19.7. IR (KBr): 2925, 1786, 1715, 1656, 1612, 1489, 1467, 1364, 1317, 1180, 1138, 937, 739, 699 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}BrNO_4$ 524.0468, found 524.0470.

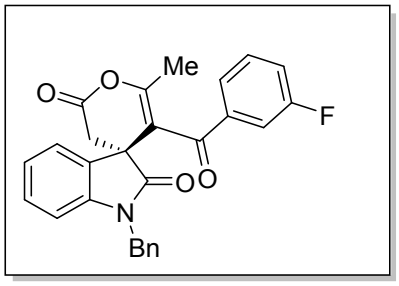
(S)-1-benzyl-5'-(3-chlorobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3l):



White solid; m.p. 199–203℃, [α]26 D= –8.0 (c=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: n-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 11.7min, minor enantiomer t_R = 23.9min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (s, 1H), 7.56 (d, J = 7.6Hz, 1H), 7.49 (d, J = 8.8Hz, 1H), 7.30 (m, 6H), 7.15 (q, J = 7.2Hz, 2H), 7.00 (t, J = 7.6Hz, 1H), 6.64 (d, J = 8.0Hz, 1H), 4.92 (d, J = 15.6Hz, 1H), 4.74 (d, J = 16.0Hz, 1H), 3.16 (d, J = 15.6Hz, 1H), 2.88 (d, J = 15.6Hz, 1H), 1.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.2, 176.1, 164.3, 158.5, 142.2, 140.0, 135.1, 135.0, 133.0, 130.0, 129.5, 129.4, 128.9, 128.6, 127.8, 127.2, 126.9, 123.4, 122.5, 115.7, 110.1, 50.0, 44.3, 38.0, 19.7. IR (KBr): 2925, 1787, 1715, 1648, 1612, 1488, 1467, 1364, 1316, 1262, 1181, 1137, 940, 738, 698 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}ClNO_4$

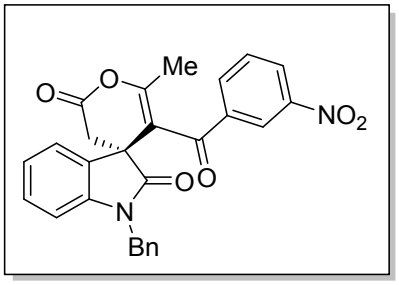
480.0973, found 480.0974.

(S)-1-benzyl-5'-(3-fluorobenzoyl)-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3m):



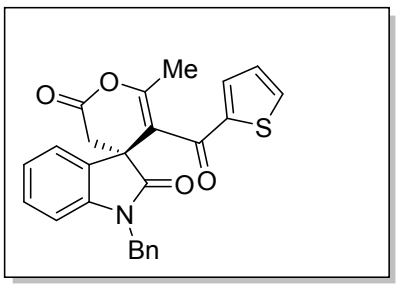
White solid; m.p. 214–215℃, [α]26 D= –6.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 12.5min, minor enantiomer t_R = 25.3min. ^{1}H NMR (400 MHz, $CDCl_3$) δ7.50 (d, *J* = 7.6Hz, 1H), 7.37 (m,2H), 7.29 (m, 5H), 7.21 (q, *J* = 1.6Hz, 1H), 7.15 (q, *J* = 7.2Hz, 2H), 6.99 (t, *J* = 7.2Hz, 1H), 6.65 (d, *J* = 8.0Hz, 1H), 4.91 (d, *J* = 16.0Hz, 1H), 4.77 (d, *J* = 15.6Hz, 1H), 3.17 (d, *J* = 16.0Hz, 1H), 2.88 (d, *J* = 15.6Hz, 1H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.2, 176.1, 164.3, 158.3, 142.2, 140.5, 140.4, 135.1, 130.5, 130.4, 129.5, 129.4, 128.8, 127.7, 127.2, 124.7, 124.6, 123.4, 122.5, 120.3, 120.1, 115.7, 115.5, 115.2, 110.0, 50.0, 44.2, 38.0, 19.6. IR (KBr): 3420, 3064, 2924, 1789, 1714, 1651, 1364, 1316, 1266, 1177, 1129, 1005, 735, 700 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{27}H_{20}FNO_4$ 464.1269, found 464.1272.

(S)-1-benzyl-6'-methyl-5'-(3-nitrobenzoyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3n):



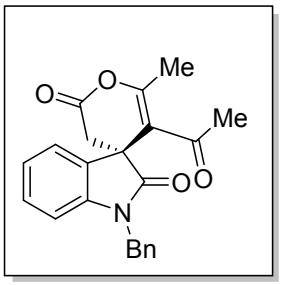
Yellow solid; m.p. 76–78℃, [α]26 D= –16.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 65:35), 1.0 mL/min; major enantiomer t_R = 22.0min, minor enantiomer t_R = 42.3min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.43 (s, 1H), 8.36 (d, *J* = 8.4Hz, 1H), 8.00 (d, *J* = 8.0Hz, 1H),7.58 (t, *J* = 8.0Hz, 1H), 7.30 (m, 5H), 7.17 (t, *J* = 8.8Hz, 2H), 7.01 (t, *J* = 7.6Hz, 1H), 6.66 (t, *J* = 8.0Hz, 1H), 4.87 (d, *J* = 15.6Hz, 1H), 4.73 (d, *J* = 15.6Hz, 1H), 3.22 (d, *J* = 15.6Hz, 1H), 2.88 (d, *J* = 16.0Hz, 1H), 2.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ192.3, 175.9, 163.9, 159.2, 148.3, 142.0, 139.7, 134.9, 134.2, 133.9, 130.0, 129.6, 129.3, 128.9, 127.8, 127.6, 127.3.127.2, 123.5, 122.5, 115.4, 110.1, 50.0, 44.2, 38.0, 19.8. IR (KBr): 2924, 1788, 1714, 1612, 1532, 1467, 1352, 1181, 1143, 721, 698, 633, 554 cm^{-1}; HRMS (ESI) m/z: $[M+H]^+$ calcd for $C_{27}H_{20}N_2O_6$ 469.1394, found 469.1402.

(S)-1-benzyl-6'-methyl-5'-(thiophene-2-carbonyl)spiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3o):



Yellow solid; m.p. 86–88℃, [α]26 D= 20.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 90:10), 1.0 mL/min; major enantiomer t_R = 8.1min, minor enantiomer t_R = 20.6min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 7.6Hz,2H),7.21 (m, 5H), 7.07 (t, *J* = 8.0Hz, 2H), 6.97 (t, *J* = 4.4Hz, 1H), 6.89 (t, *J* = 7.6Hz, 1H), 6.57 (d, *J* = 8.0Hz,1H), 4.81 (d, *J* = 15.6Hz, 1H), 4.75 (d, *J* = 16.0Hz, 1H), 3.00 (d, *J* = 15.6Hz, 1H), 2.86 (d, *J* = 16.0Hz, 1H), 2.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.4, 175.8, 164.5, 155.9, 144.1, 142.3, 135.3, 135.1, 134.2, 129.4, 128.9, 128.8, 128.2, 127.7, 127.2, 123.3, 123.0, 115.5, 109.9, 49.9, 44.2, 37.8, 19.5. IR (KBr): 3366, 2924, 2372, 1784, 1710, 1607, 1464, 1410, 1356, 1262, 1178, 1126, 737, 663 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{25}H_{19}NO_4S$ 452.0927, found 452.0937.

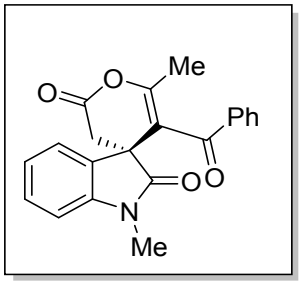
(S)-5'-acetyl-1-benzyl-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3p):



White solid; m.p. 144–146℃, [α]26 D= –111.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 90:10), 1.0 mL/min; major enantiomer t_R = 6.8min, minor enantiomer t_R = 14.1min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (m, 4H), 7.29 (d, *J* = 7.2Hz, 1H), 7.19 (t, *J* = 7.6Hz, 1H), 7.05 (d, *J* = 7.2Hz, 1H), 6.99 (t, *J* = 7.6Hz, 1H), 6.76 (d, *J* = 7.6Hz, 1H), 4.97 (s, 2H), 3.12 (d, *J* = 15.6Hz, 1H), 2.63 (d, *J* = 15.6Hz, 1H), 2.43 (s, 3H), 2.15 (s, 3H); ^{13}C NMR (100 MHz,

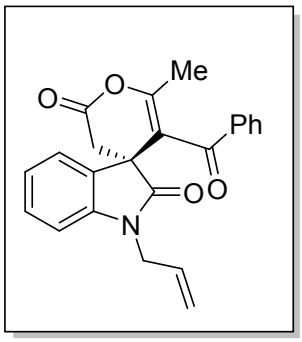
$CDCl_3$) δ 196.1, 176.7, 164.3, 160.4, 141.8, 135.3, 129.9, 129.3, 128.8, 127.8, 127.3, 123.2, 122.3, 119.3, 110.1, 49.5, 44.3, 38.4, 30.9, 19.7. IR (KBr): 3300, 2925, 1786, 1715, 1610, 1489, 1466, 1359, 1311, 1178, 736, 700, 584, 495 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{22}H_{19}NO_4$ 384.1206, found 384.1210.

(S)-5'-benzoyl-1,6'-dimethylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3q):



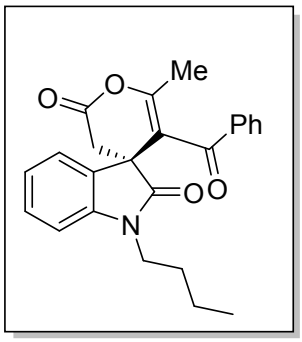
White solid; m.p. 176–178℃, [α]26 D= –40.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 80:20), 1.0 mL/min; major enantiomer t_R = 17.9min, minor enantiomer t_R = 27.5min. ^1H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.2Hz, 2H),7.48 (t, *J* = 7.6Hz, 1H), 7.35 (t, *J* = 7.6Hz, 2H), 7.26 (t, *J* = 8.0Hz, 1H), 7.15 (d, *J* = 7.6Hz, 1H), 7.02 (t, J = 7.6Hz, 1H), 6.72 (d, *J* = 7.6Hz, 1H), 3.08 (d, *J* = 16.8Hz, 4H), 2.84 (d, *J* = 16.0Hz, 1H), 1.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 176.0, 164.6, 157.9, 143.1, 138.4, 132.9, 129.4, 128.5, 128.4, 123.3, 122.6, 116.2, 108.7, 49.7, 37.5, 26.5, 19.4. IR (KBr): 3297, 2925, 1786, 1714, 1612, 1469, 1374, 1325, 1141, 1089, 932, 753, 705, 585, 542 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{21}H_{17}NO_4$ 370.1050, found 370.1047.

(S)-1-allyl-5'-benzoyl-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3r):



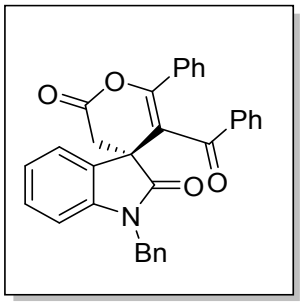
White solid; m.p. 169–172℃, [α]26 D= –12.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 70:30), 1.0 mL/min; major enantiomer t_R = 15.2min, minor enantiomer t_R = 42.3min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 7.6Hz, 2H),7.51 (t, *J* = 7.6Hz, 1H), 7.38 (t, *J* = 7.6Hz, 2H), 7.22 (d, *J* = 8.0Hz, 1H), 7.15 (d, *J* = 7.2Hz, 1H), 7.01 (t, *J* = 7.6Hz, 1H), 6.77 (d, *J* = 7.6Hz, 1H), 5.75 (m, 1H), 5.24 (q, *J* = 12.8Hz, 2H), 4.25 (d, *J* = 5.2Hz, 2H), 3.11 (d, *J* = 16.0Hz, 1H), 2.85 (d, *J* = 15.6Hz, 1H), 1.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.6, 175.8, 164.6, 157.8, 142.3, 138.5, 133.1, 130.8, 129.6, 129.3, 128.7, 128.6, 123.2, 122.5, 117.9, 116.0, 109.8, 49.8, 42.7, 37.8, 19.5. IR (KBr): 3059, 2925, 1785, 1711, 1646, 1466, 1363, 1264, 1184, 1133, 1001, 930, 739, 704 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{23}H_{19}NO_4$ 396.1206, found 396.1209.

(S)-5'-benzoyl-1-butyl-6'-methylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3s):



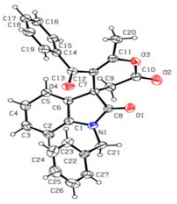
White solid; m.p. 207–210℃, [α]26 D= –7.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 70:30), 1.0 mL/min; major enantiomer t_R = 10.8min, minor enantiomer t_R = 33.2min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (t, *J* = 7.2Hz, 2H), 7.50 (t, *J* = 7.6Hz, 1H), 7.37 (t, *J* = 7.6Hz, 2H), 7.26 (m, 2H)(including $CDCl_3$), 7.15 (d, *J* = 6.8Hz, 1H), 7.01 (t, *J* = 7.6Hz, 1H), 6.78 (d, *J* = 7.6Hz, 1H), 3.59 (m, 2H), 3.09 (d, *J* = 15.6Hz, 1H), 2.82 (d, *J* = 16.0Hz, 1H), 1.93 (s, 3H), 1.57 (m, 2H), 1.34 (m, 2H), 0.93 (t, *J* = 7.6Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.6, 175.9, 164.7, 157.6, 142.6, 138.4, 133.0, 129.8, 129.3, 128.7, 128.6, 123.0, 122.7, 116.1, 109.1, 49.8, 40.2, 37.9, 29.2, 20.1, 19.4, 13.7. IR (KBr): 3408, 2929, 1786, 1711, 1649, 1611, 1466, 1364, 1324, 1189, 1134, 929, 737, 640 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{24}H_{23}NO_4$ 412.1519, found 412.1526.

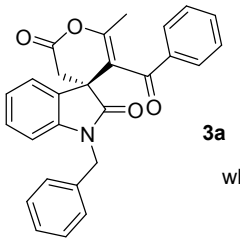
(S)-5'-benzoyl-1-benzyl-6'-phenylspiro[indoline-3,4'-pyran]-2,2'(3'H)-dione (3t):



White solid; m.p. 88–90℃, [α]26 D= –16.0 (*c*=1.0 in CH_2Cl_2); The enantiomeric excess was determined by HPLC with an IC column (CH_2Cl_2: *n*-hexane = 90:10), 1.0 mL/min; major enantiomer t_R = 6.5min, minor enantiomer t_R = 7.8min. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.2Hz, 2H), 7.33 (m, 6H), 7.26 (m,3H), 7.15 (t, *J* = 10.4Hz, 2H), 7.10 (d, *J* = 8.4Hz, 4H), 6.99 (t, *J* = 7.6Hz, 1H), 6.70 (d, *J* = 8.0Hz, 1H), 4.91 (t, *J* = 16.4Hz, 2H), 3.41 (d, *J* = 16.4Hz, 1H), 3.00 (d, *J* = 16.4Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.6, 175.9, 164.7, 157.9, 142.2, 137.4, 135.2, 132.6, 131.8, 130.8, 129.7, 129.4, 129.2, 129.1, 128.8, 128.1, 128.0, 127.7, 127.2, 123.4, 122.7, 115.8, 110.1, 50.9, 44.3, 38.2. IR (KBr): 3060, 2926, 1786, 1716, 1649, 1612, 1467, 1365, 1180, 1105, 1060, 911, 737, 696 cm^{-1}; HRMS (ESI) m/z: $[M+Na]^+$ calcd for $C_{32}H_{23}NO_4$ 508.1519, found 508.1519.

C. X-ray Crystallographic Data of Product 3a (CCDC 1010784)





3a

A Cu target was used
when performing XRD experiment

Bond precision: C-C = 0.0036 A Wavelength=1.54180

Cell:	a=11.1093(2)	b=12.6235(3)	c=15.3660(3)
	alpha=90	beta=90	gamma=90

Temperature: 293 K

	Calculated	Reported
Volume	2154.90(8)	2154.91(8)
Space group	P 21 21 21	P 21 21 21
Hall group	P 2ac 2ab	P 2ac 2ab
Moiety formula	C_{27} H_{21} N O_4	C_{27} H_{21} N O_4

Sum formula	$C_{27}H_{21}NO_4$	$C_{27}H_{21}NO_4$
Mr	423.45	423.45
Dx,g cm-3	1.305	1.305
Z	4	4
Mu (mm-1)	0.711	0.711
F000	888.0	888.0
F000'	890.75	
h,k,lmax	13,15,18	13,15,18
Nref	4143[2357]	4052
Tmin,Tmax	0.815,0.861	0.629,1.000
Tmin'	0.802	

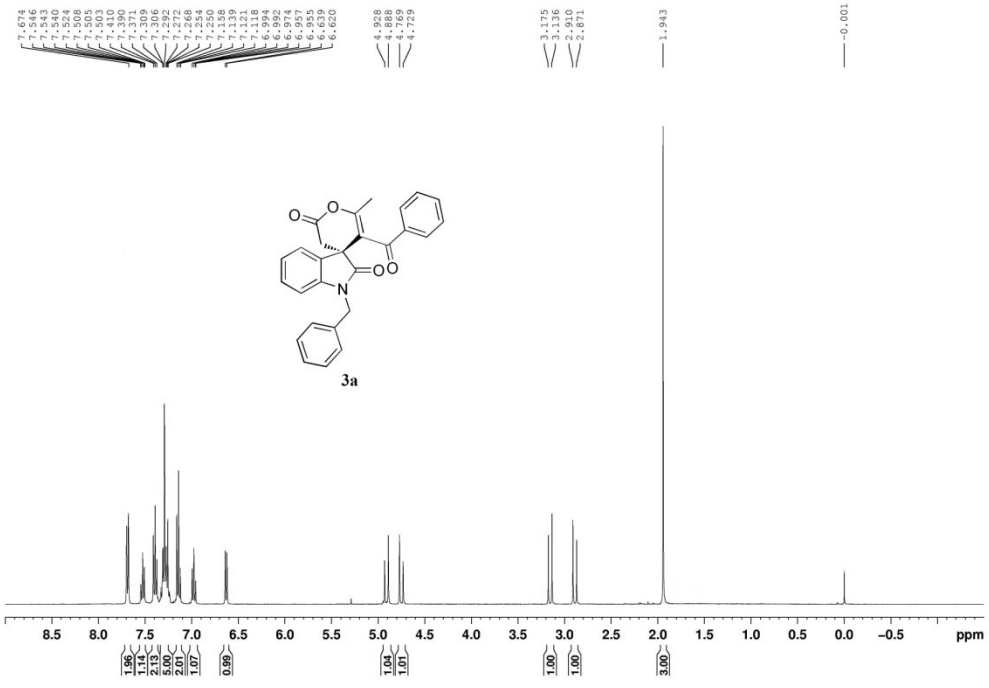
Correction method= MULTI-SCAN

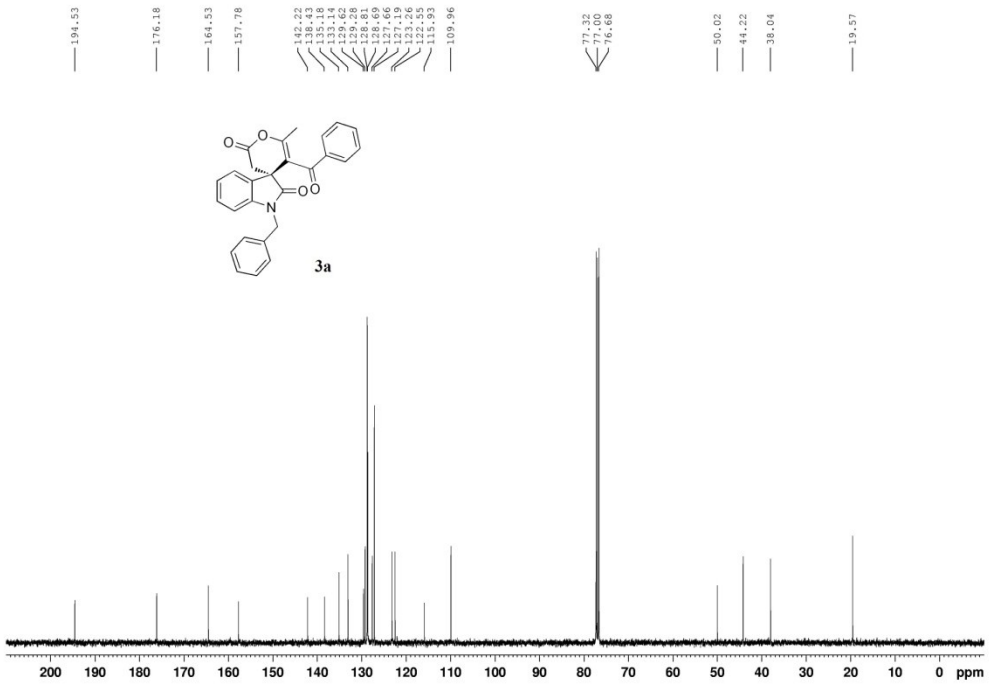
Data completeness= 1.72/0.98 Theta(max)= 70.683

R(reflections)= 0.0418(3898) wR2(reflections)= 0.1119(4052)

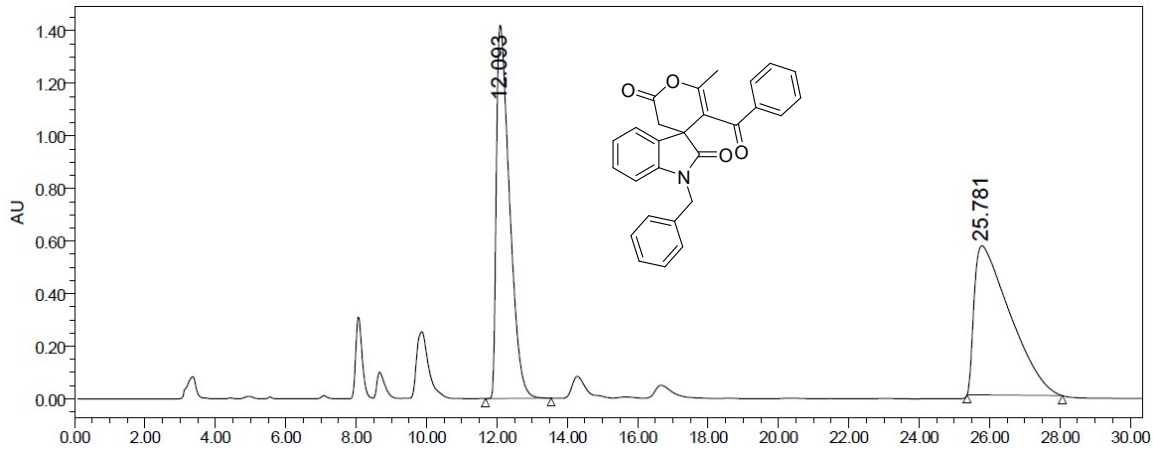
S = 1.040 Npar= 290

D. NMR Spectra and HPLC Chromatograms

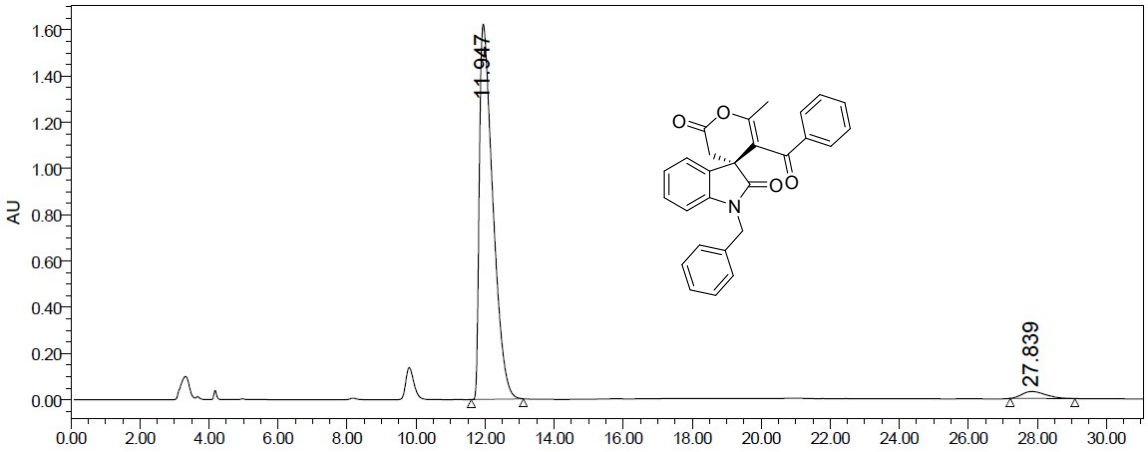




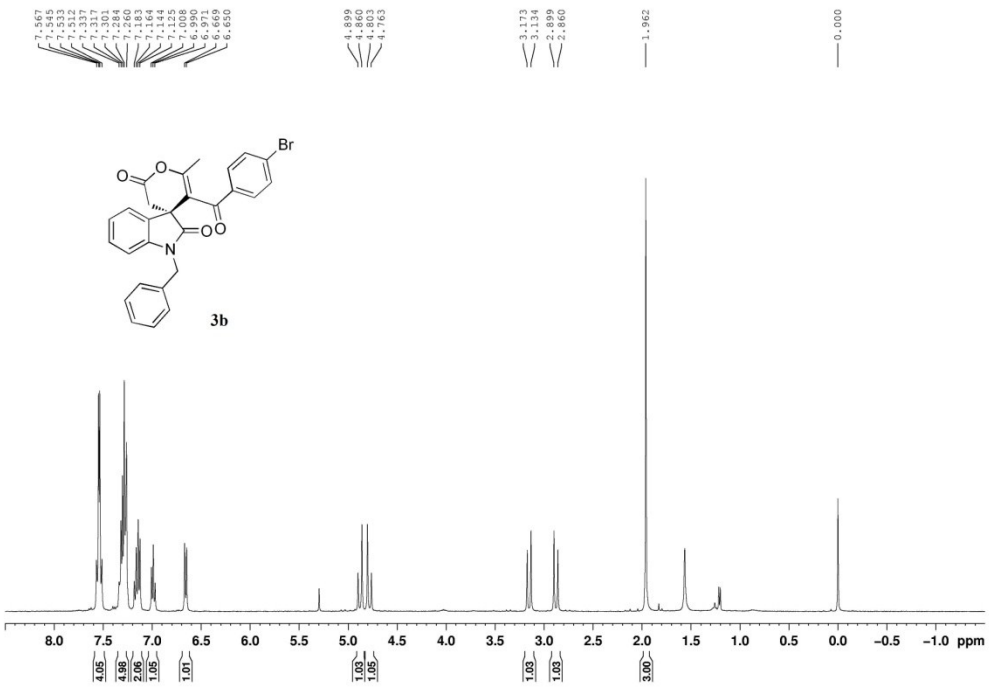
HPLC analysis of **3a** using chiral IC Column (CH_2Cl_2: *n*-hexane = 70:30, 1.0 mL/min)

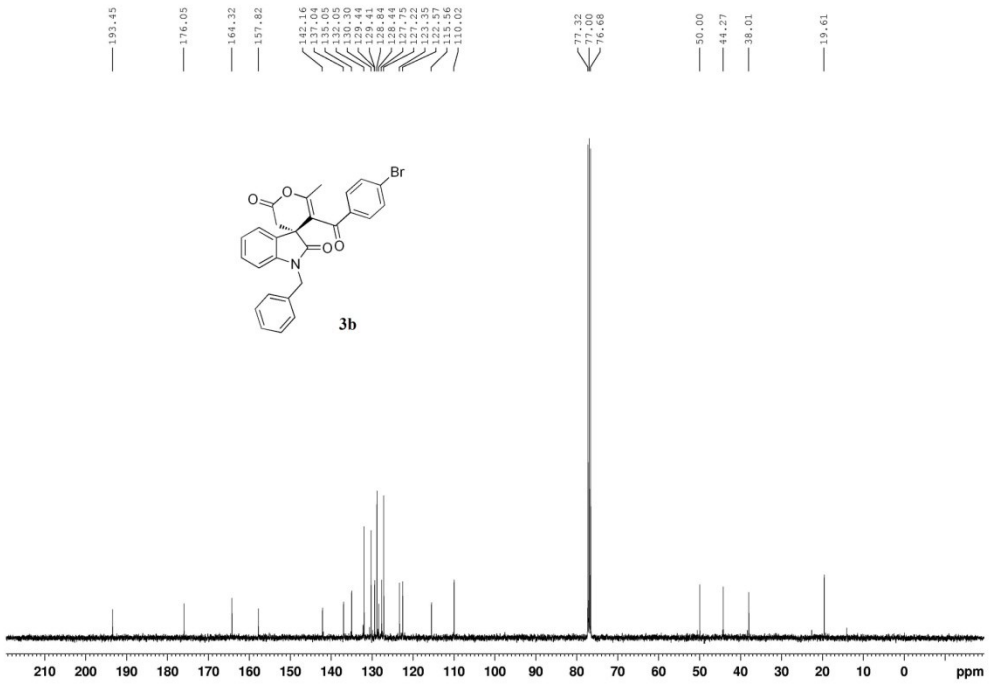


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.093	36945996	1419882	47.88
2	25.781	40225708	567292	52.12

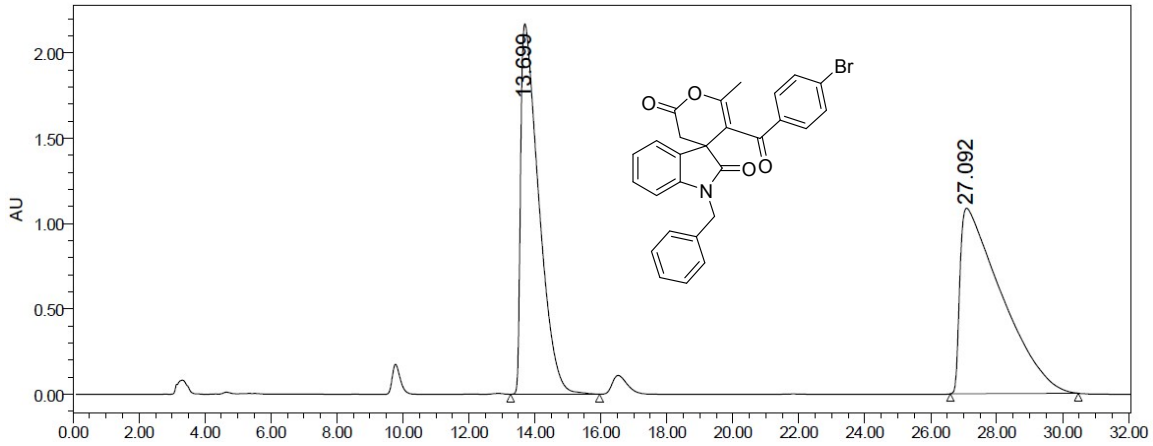


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	11.947	43919780	1622670	96.84
2	27.839	1431456	30235	3.16

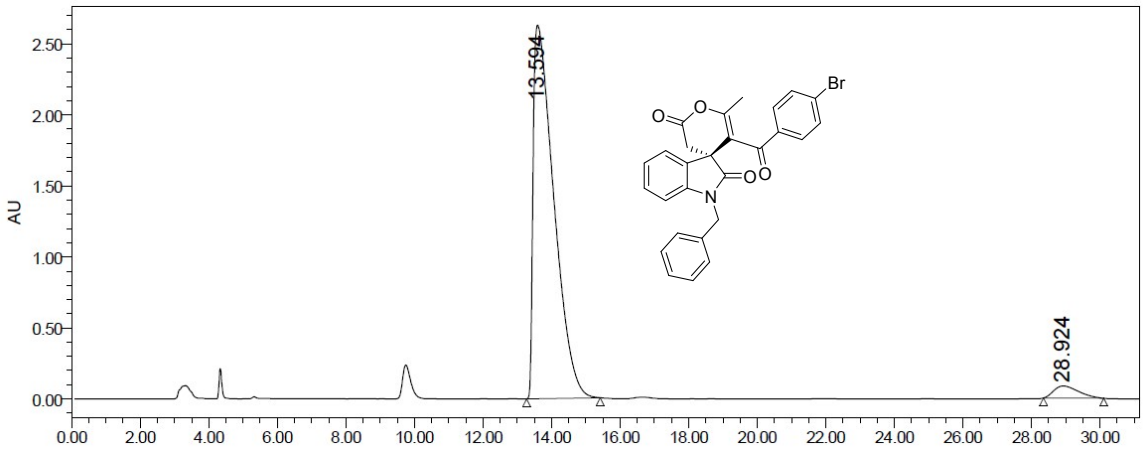




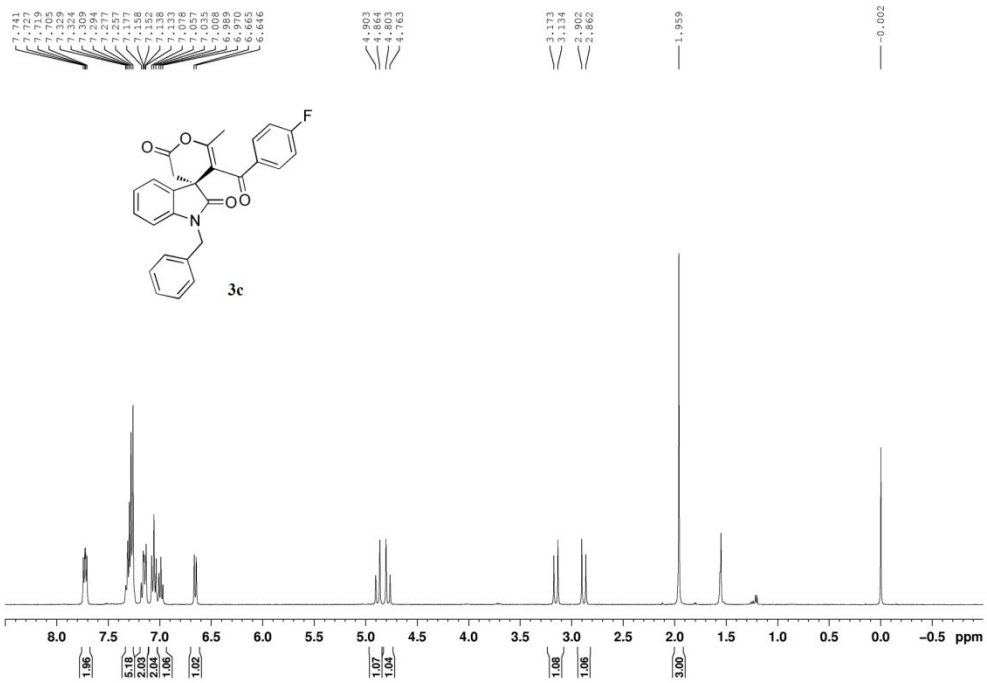
HPLC analysis of **3b** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

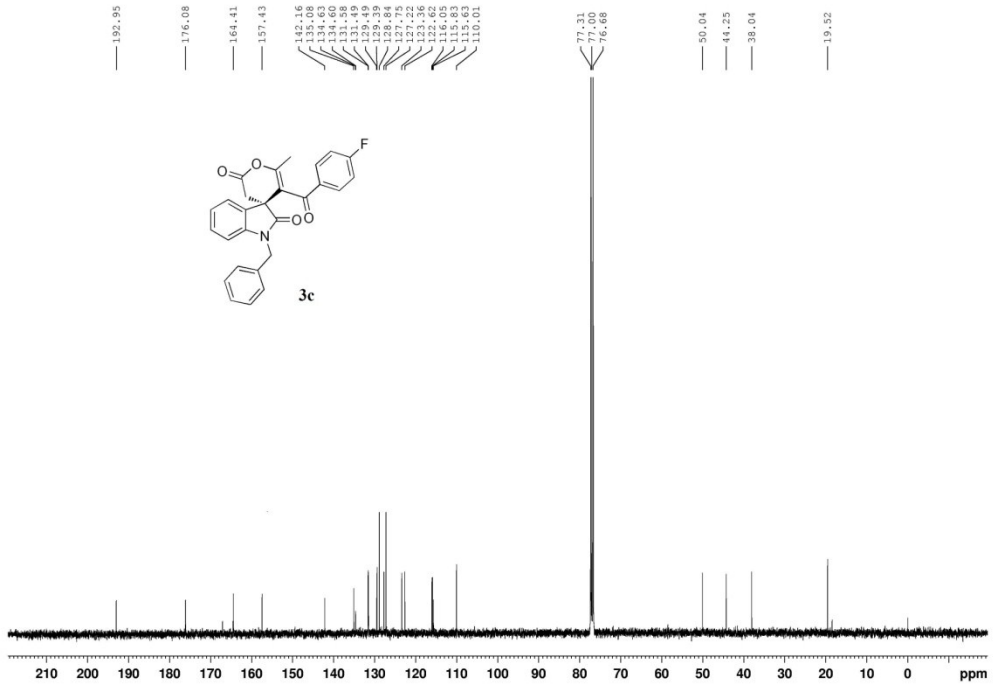


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.699	82851942	2170508	46.40
2	27.092	95693021	1086846	53.60

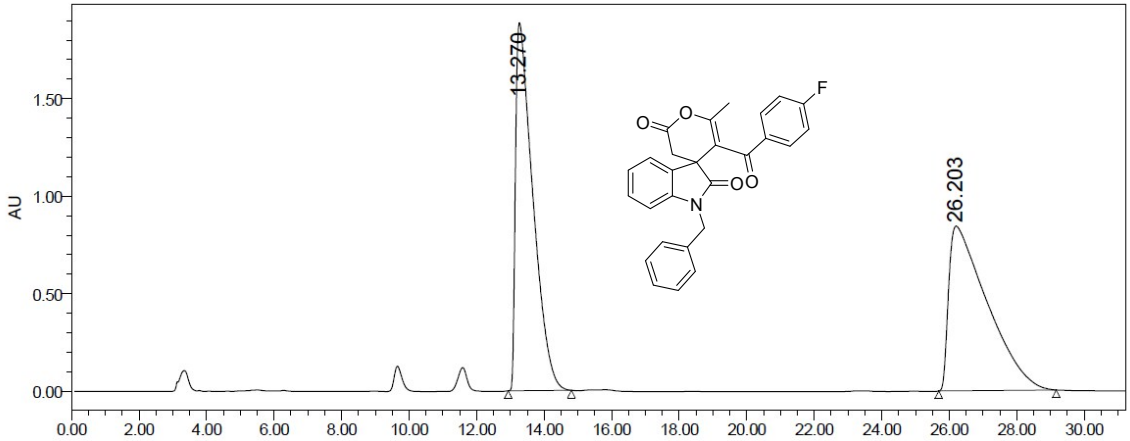


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.594	109889625	2629747	96.28
2	28.924	4249272	85.169	3.72

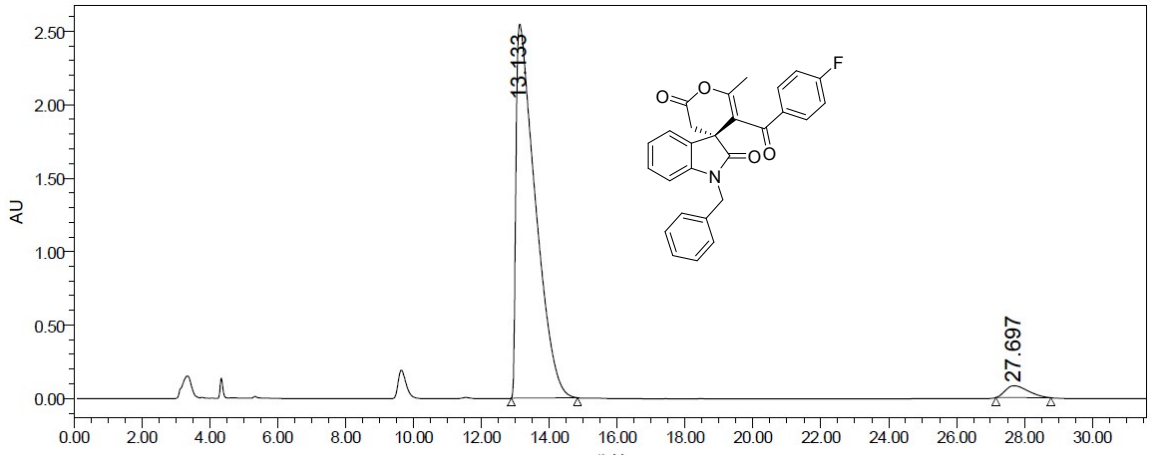




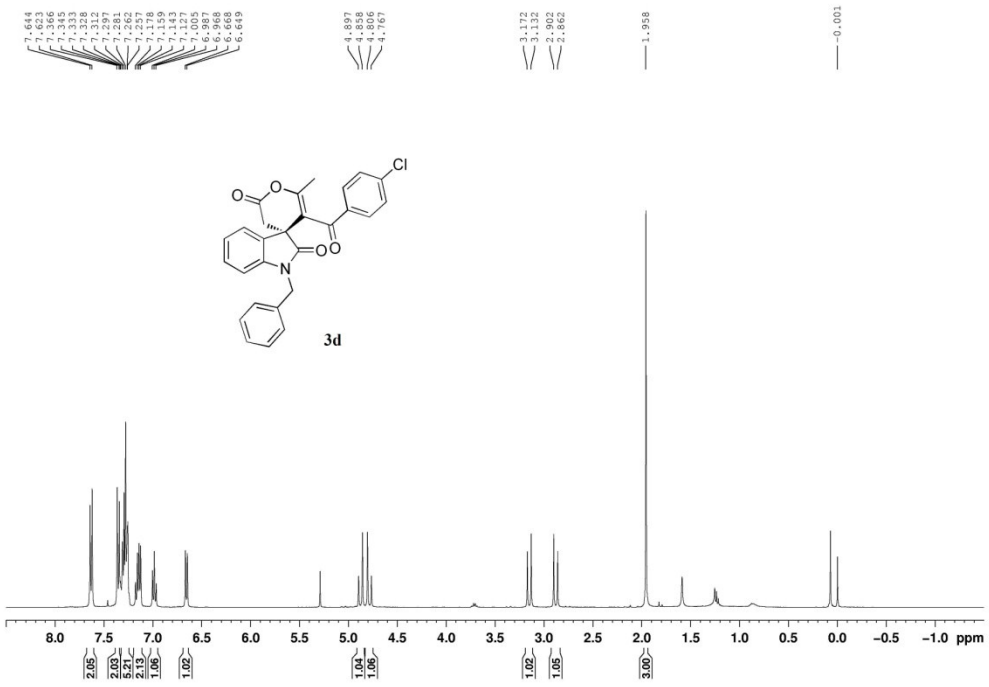
HPLC analysis of **3c** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

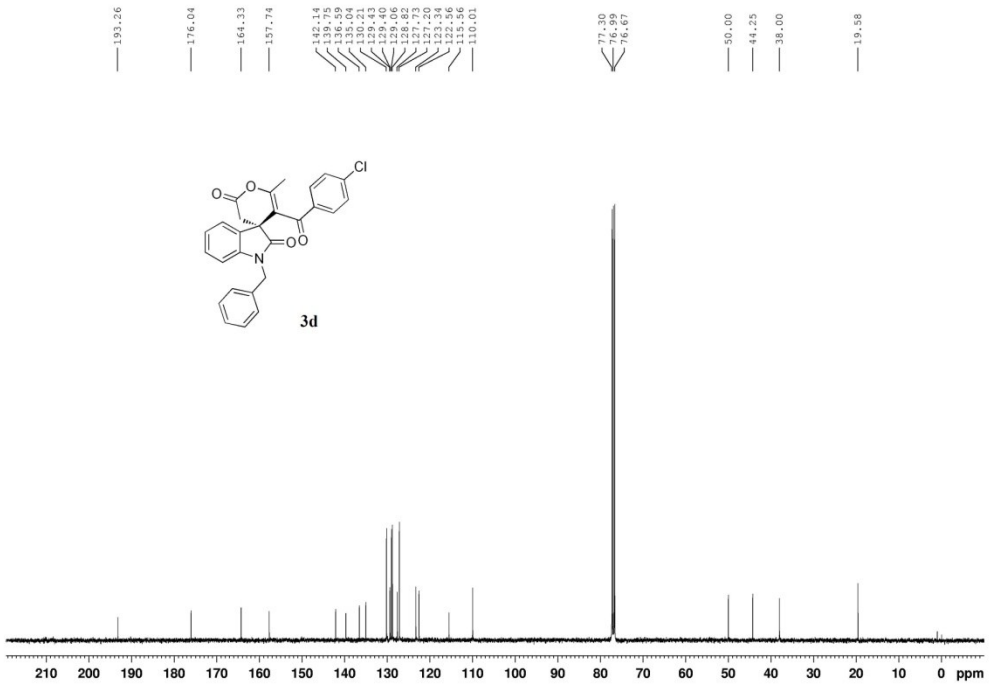


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.270	67303113	1885941	50.12
2	26.203	66976137	844006	49.88

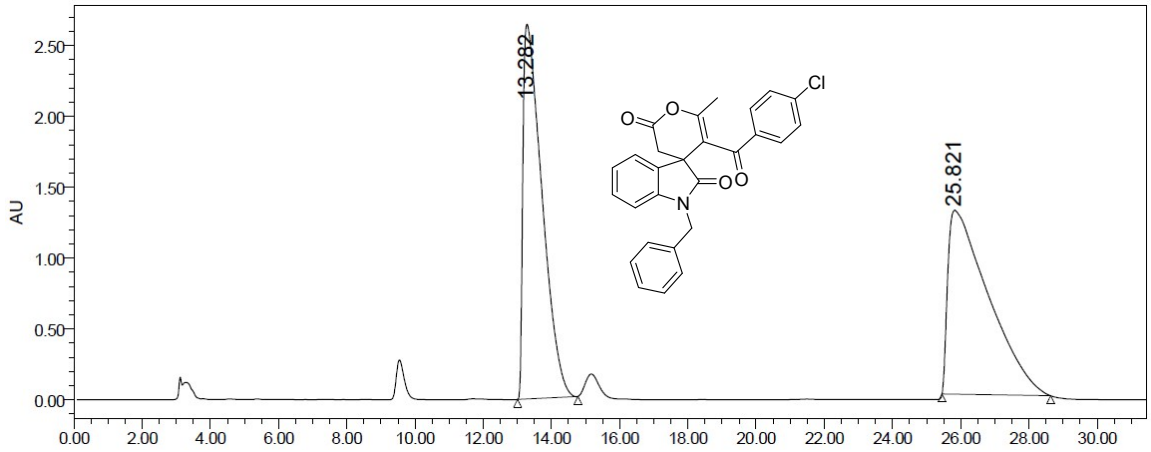


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.133	100589268	2546817	96.39
2	27.697	3769388	81053	3.61

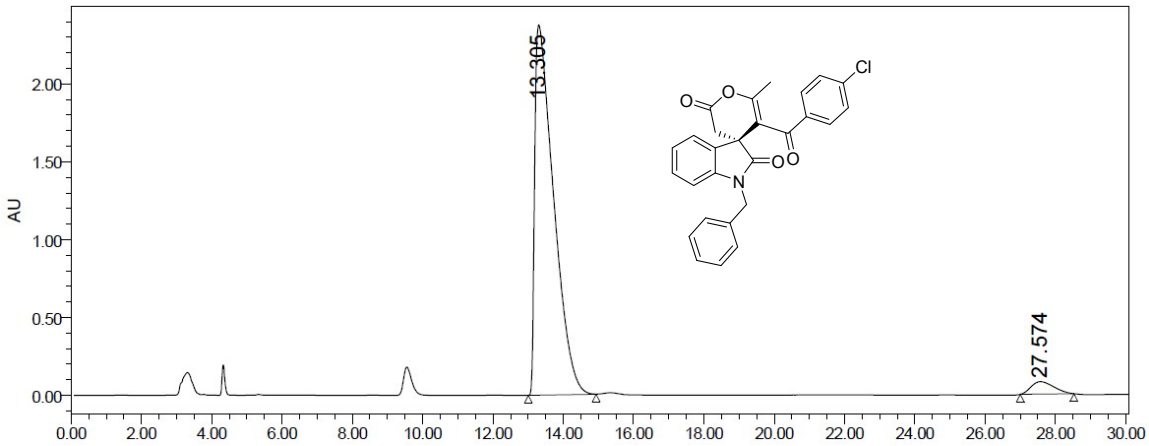




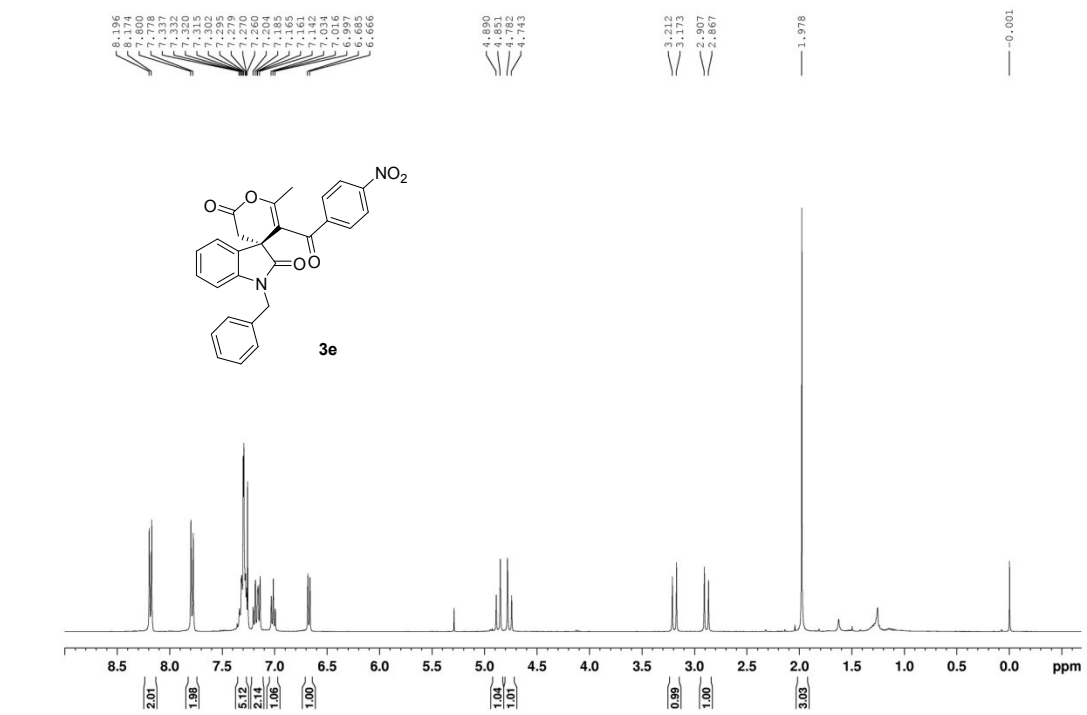
HPLC analysis of **3d** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

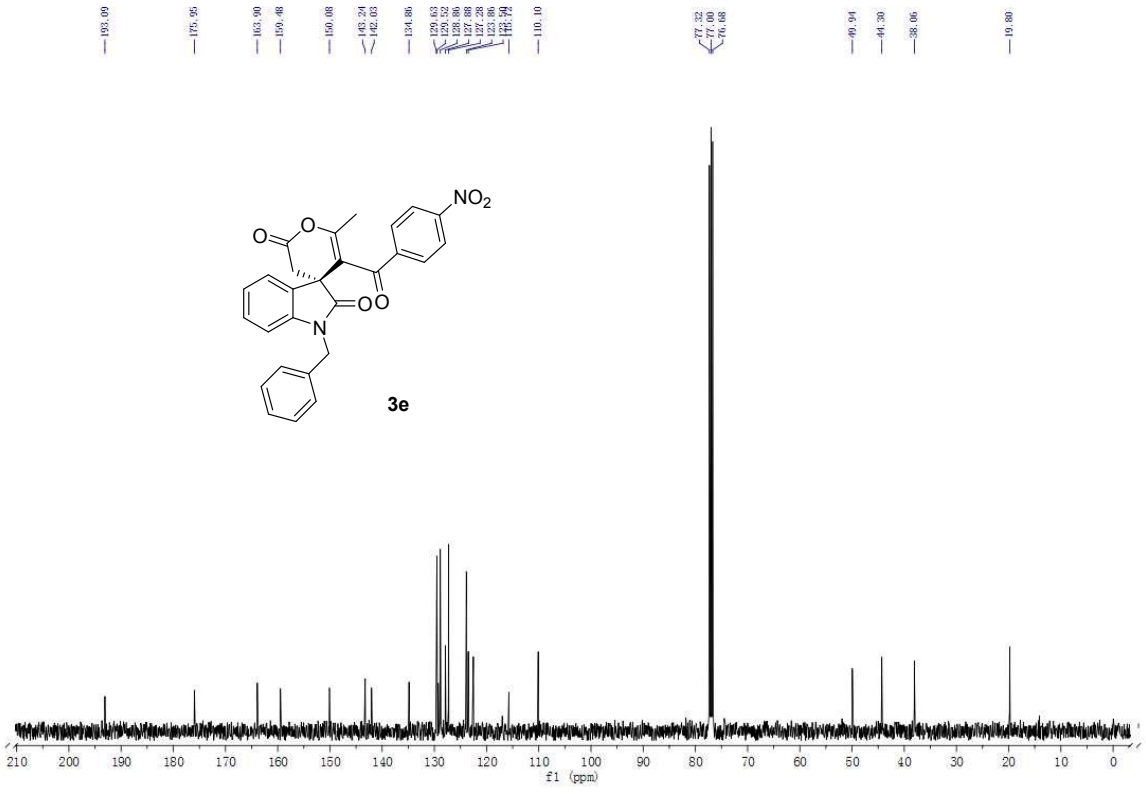


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.282	102688555	2645408	48.79
2	25.821	107789206	1297725	51.21

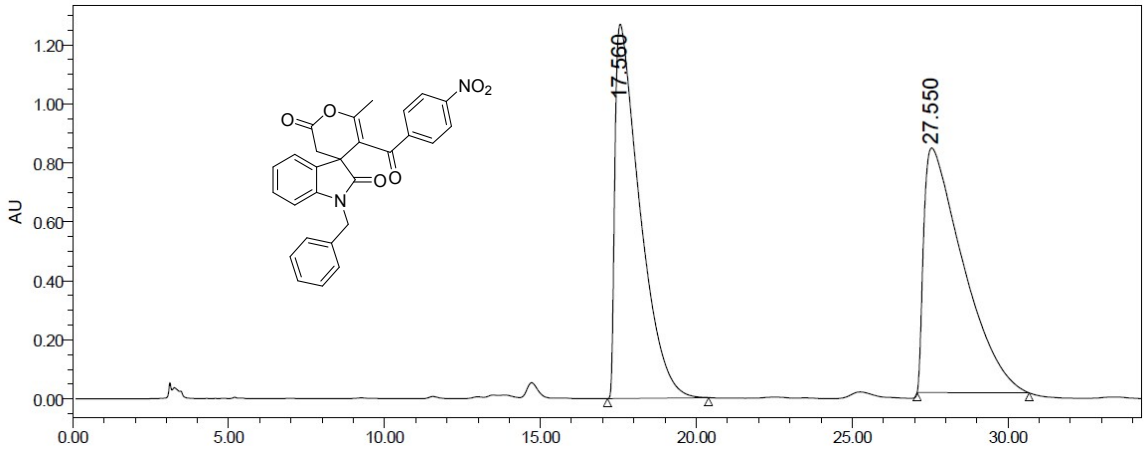


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.305	88675355	2377858	96.12
2	27.574	3580874	79642	3.88

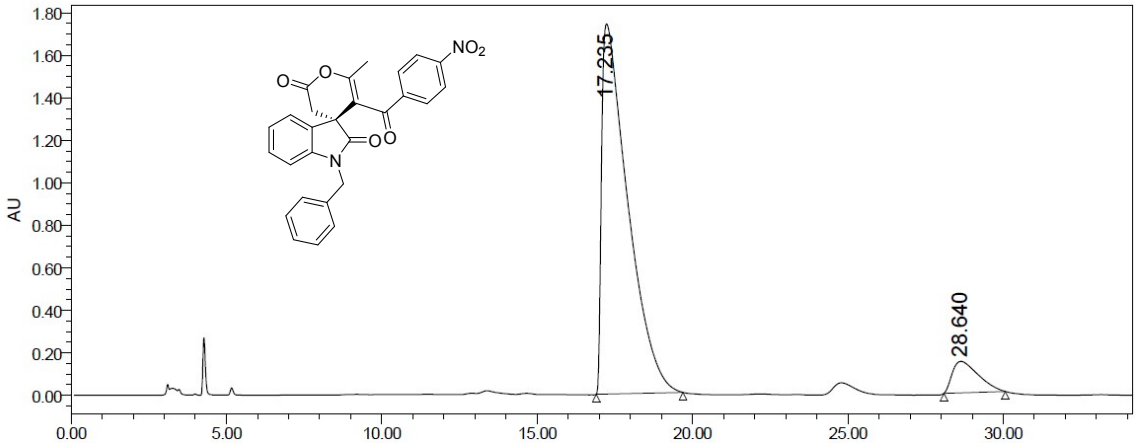

8.196
8.174
7.800
7.778
7.337
7.332
7.320
7.315
7.302
7.295
7.278
7.270
7.260
7.204
7.185
7.165
7.161
7.142
7.034
7.016
6.997
6.685
6.666
4.890
4.851
4.782
4.743
3.212
3.173
2.907
2.867
1.978
-0.001
NO2
O
O
O
O
N
3e
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.01
1.98
5.12
2.14
1.06
1.00
1.04
1.01
0.99
1.00
3.03


193.09
175.95
163.90
159.48
150.08
145.24
142.63
134.86
129.63
129.32
128.86
127.88
127.28
123.86
122.94
110.10
77.32
77.00
76.68
69.94
64.30
38.06
19.80
NO2
O
O
O
O
N
3e
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

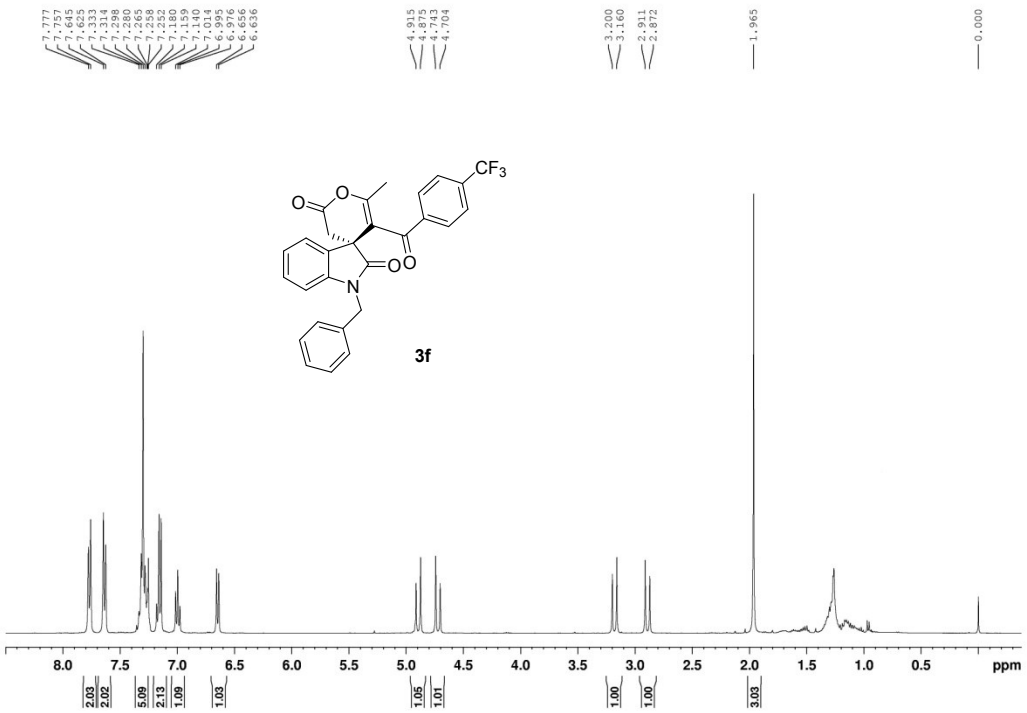
HPLC analysis of **3e** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

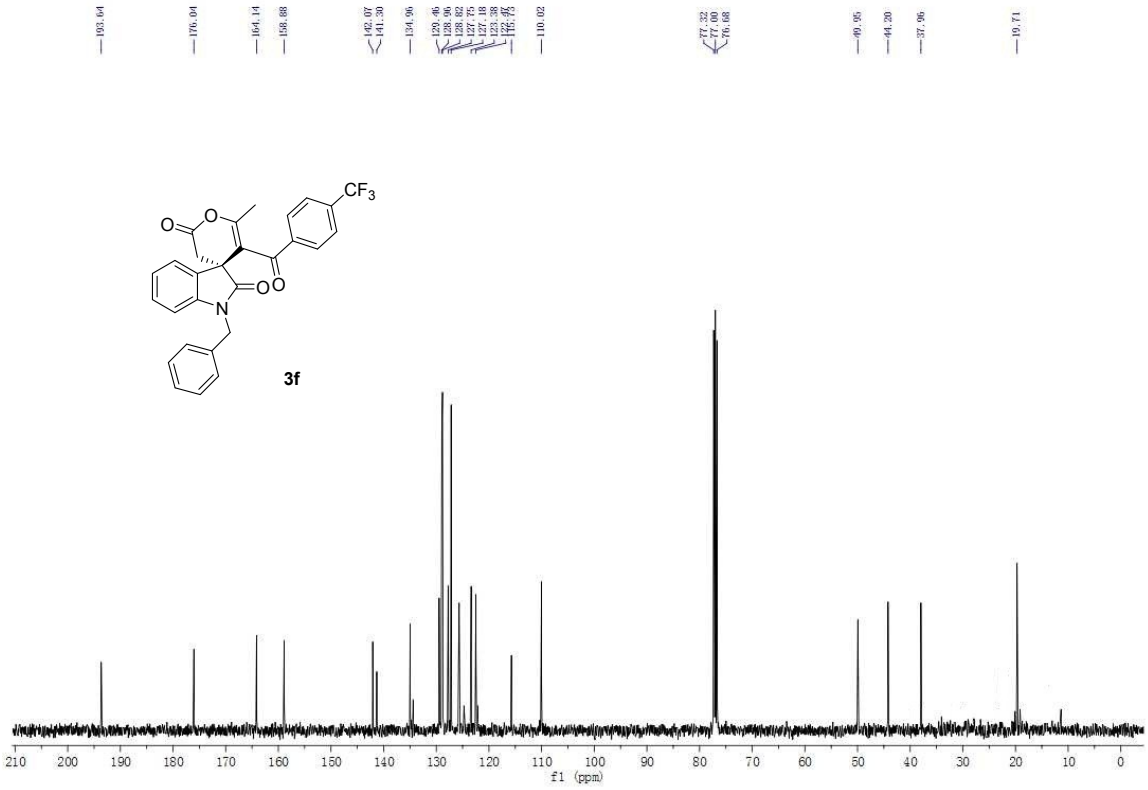


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	17.560	70146338	1268200	49.05
2	27.550	72856798	828507	50.95

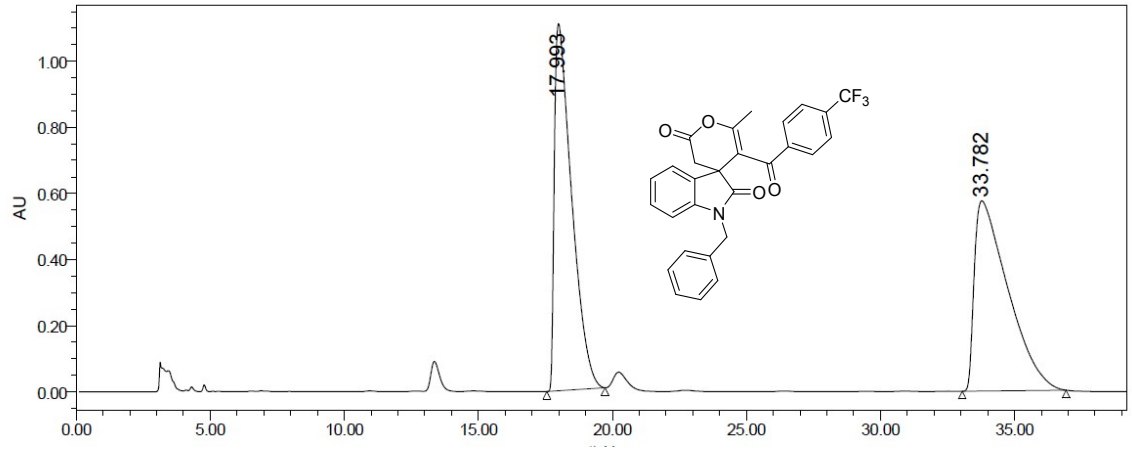


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	17.235	101834725	1742672	92.22
2	28.640	8595320	147780	7.78

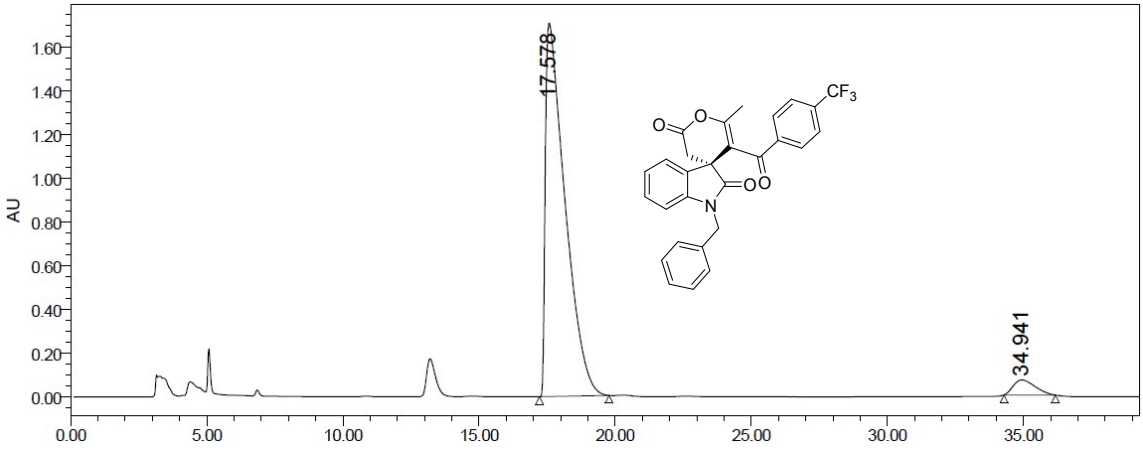

7.777
7.757
7.645
7.625
7.333
7.314
7.288
7.280
7.265
7.258
7.252
7.180
7.159
7.140
7.014
6.995
6.976
6.656
6.636
4.915
4.875
4.743
4.704
3.200
3.160
2.911
2.872
1.965
0.000
CF3
O
O
O
O
N
3f
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
2.03
2.02
5.09
2.13
1.09
1.03
1.05
1.01
1.00
1.00
3.03


193.64
176.04
164.14
158.88
142.07
141.30
134.96
129.46
128.96
128.82
127.75
127.18
123.38
122.47
110.02
77.32
77.00
76.68
49.95
44.20
37.96
19.74
CF3
O
O
O
O
N
3f
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

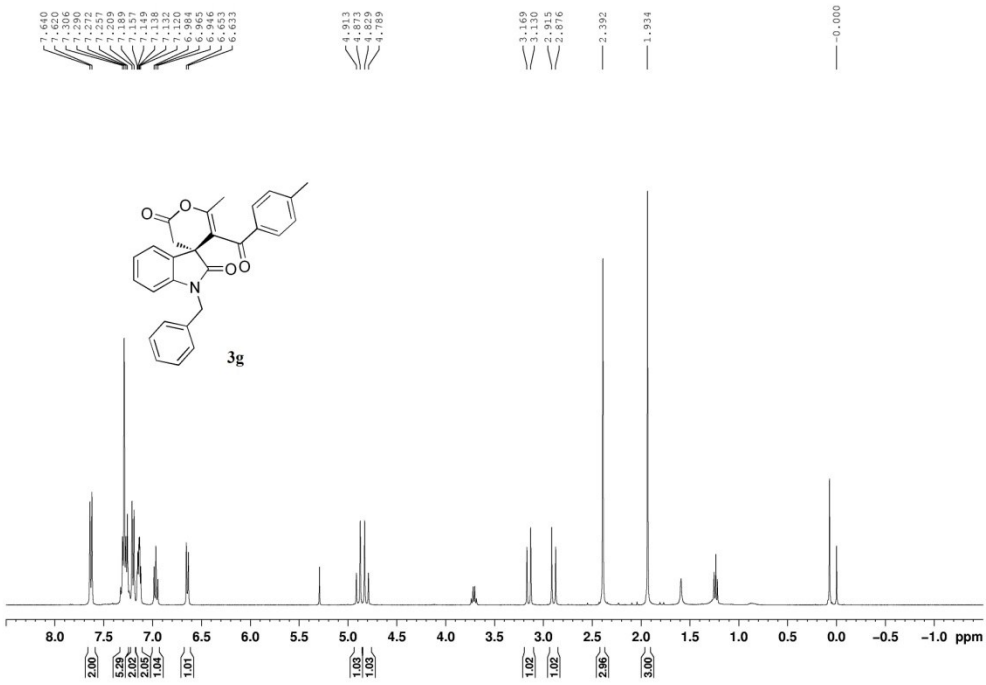
HPLC analysis of **3f** using chiral IC Column (CH_2Cl_2: *n*-hexane = 50:50, 1.0 mL/min)

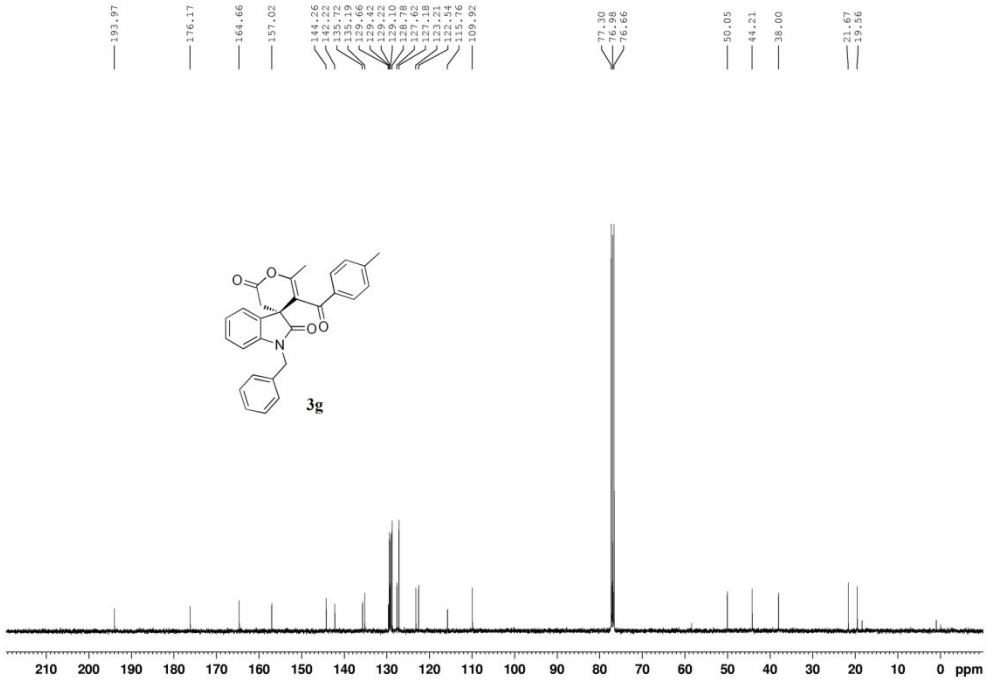


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	17.993	49814355	1110137	49.75
2	33.782	50313409	575412	50.25

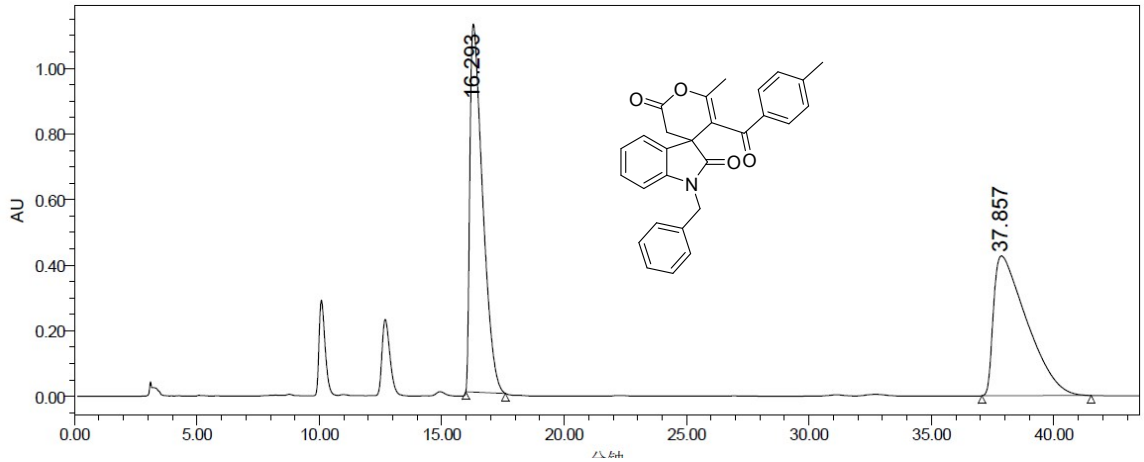


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	17.578	85584496	1709406	95.70
2	34.941	3846181	69093	4.30

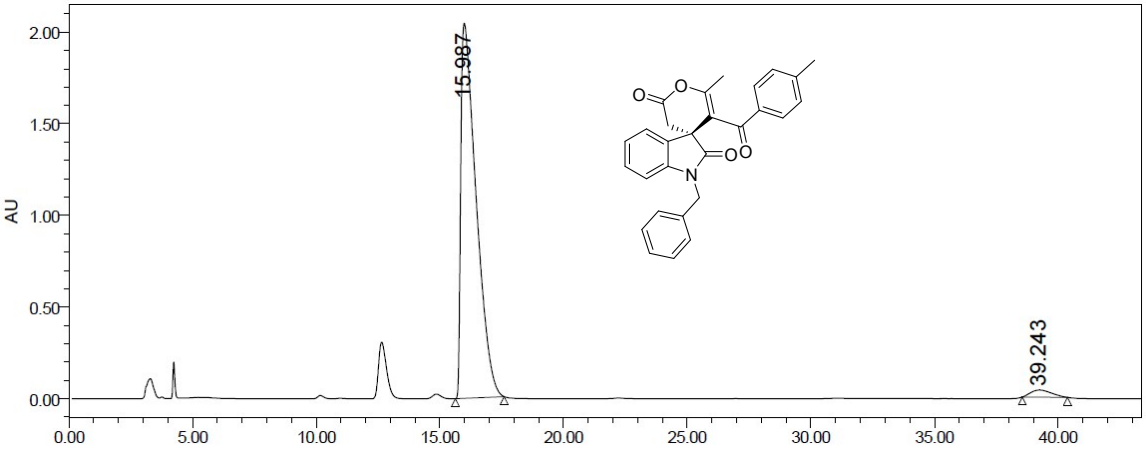

7.640
7.630
7.306
7.290
7.272
7.257
7.189
7.169
7.157
7.149
7.138
7.122
7.120
6.984
6.965
6.946
6.653
6.633
4.913
4.873
4.829
4.789
3.169
3.130
2.915
2.876
2.392
1.934
-0.000
3g
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 ppm
2.00 5.29 2.02 2.05 1.04 1.01 1.03 1.03 1.02 1.02 2.96 3.00


193.97
176.17
164.66
157.02
144.26
142.22
135.72
134.19
129.66
129.42
129.22
129.10
128.78
127.62
127.18
123.21
122.54
115.76
109.92
77.30
76.98
76.66
50.05
44.21
38.00
21.67
19.56
3g
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

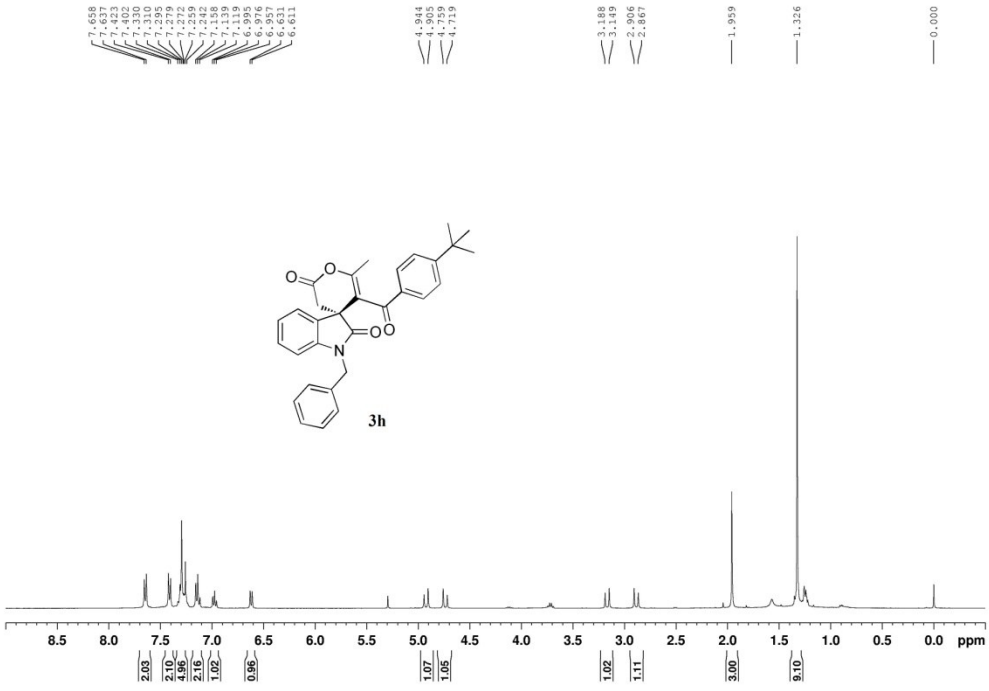
HPLC analysis of **3g** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

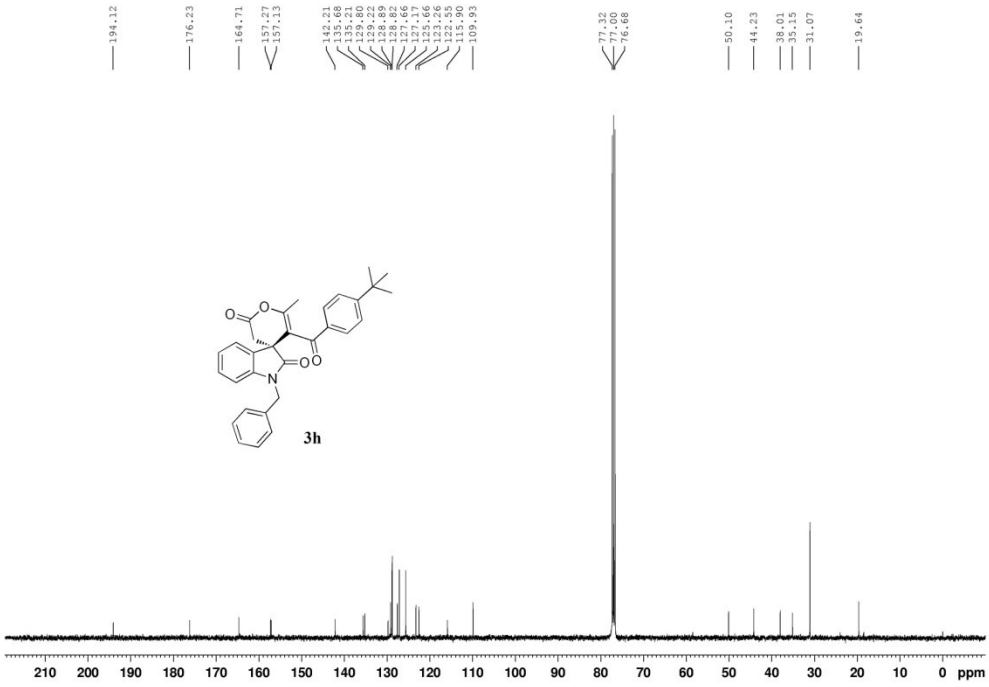


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	16.293	40651194	1122180	50.26
2	37.857	40237228	425988	49.74

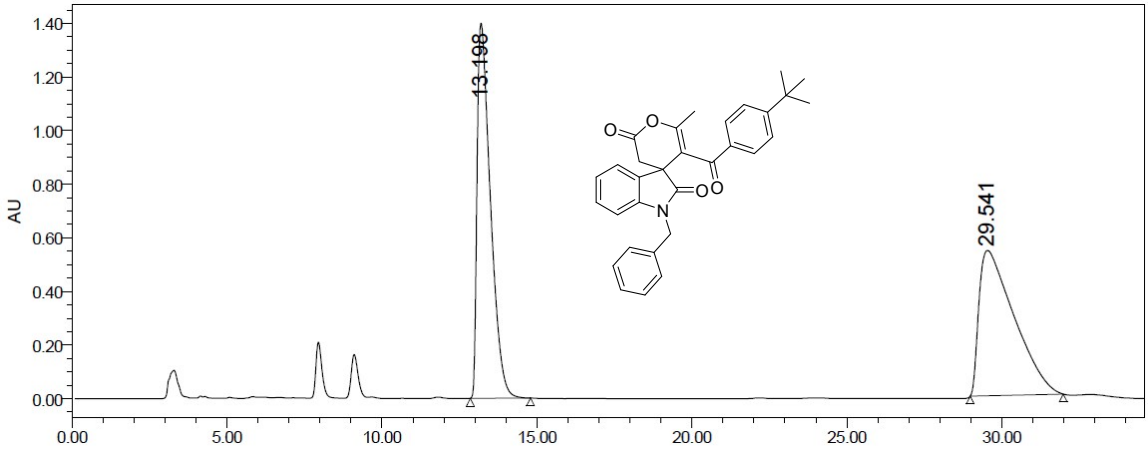


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	15.987	879.03777	2046651	97.48
2	39.243	2275791	38691	2.52

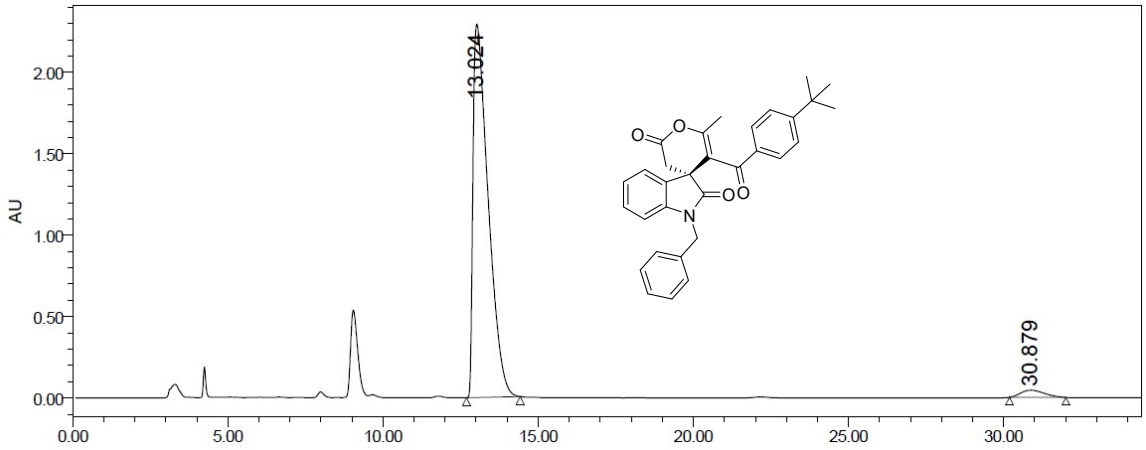

7.658
7.637
7.423
7.402
7.330
7.310
7.295
7.279
7.273
7.259
7.242
7.158
7.139
7.119
6.995
6.976
6.957
6.631
6.611
4.944
4.905
4.759
4.719
3.188
3.149
2.906
2.867
1.959
1.326
0.000
3h
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
2.03 2.10 4.06 2.16 1.02 0.96 1.07 1.05 1.02 1.11 3.00 9.10


194.12
176.23
164.71
157.27
157.13
142.21
135.68
135.21
129.80
129.22
128.89
128.82
127.66
127.17
125.66
123.26
122.55
115.80
109.93
77.32
77.00
76.68
50.10
44.23
38.01
35.15
31.07
19.64
3h
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

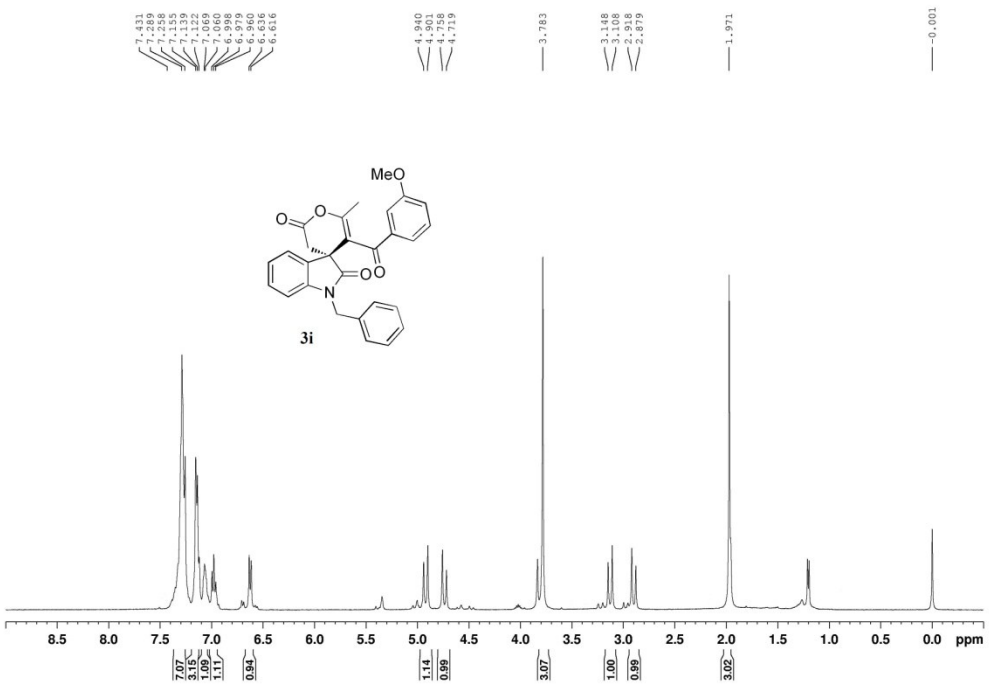
HPLC analysis of **3h** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

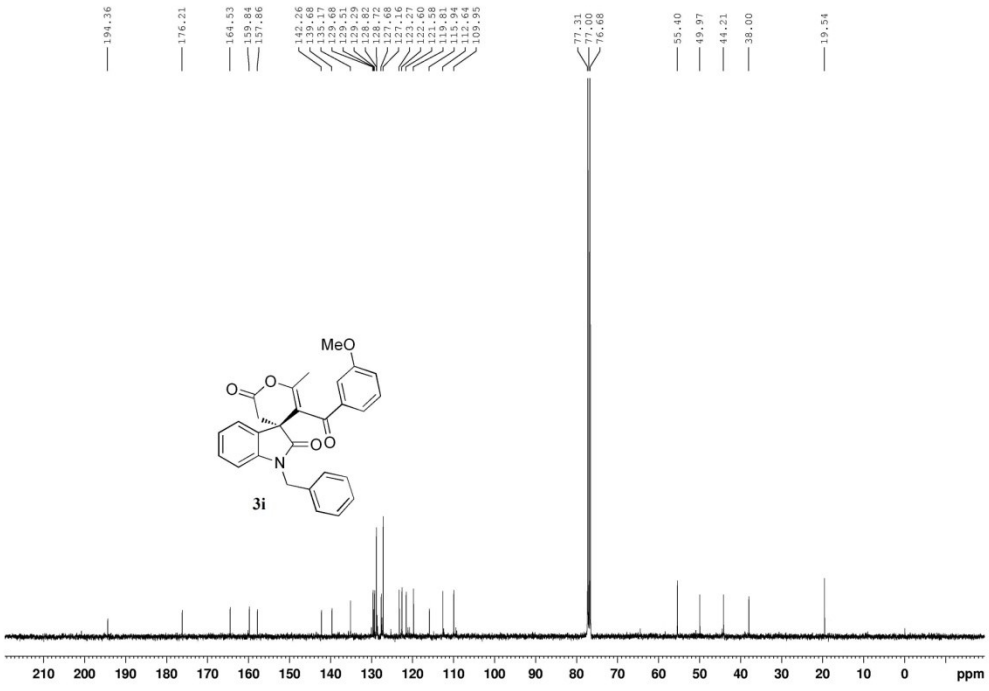


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.198	41814370	1398545	49.50
2	29.541	42663595	542188	50.50

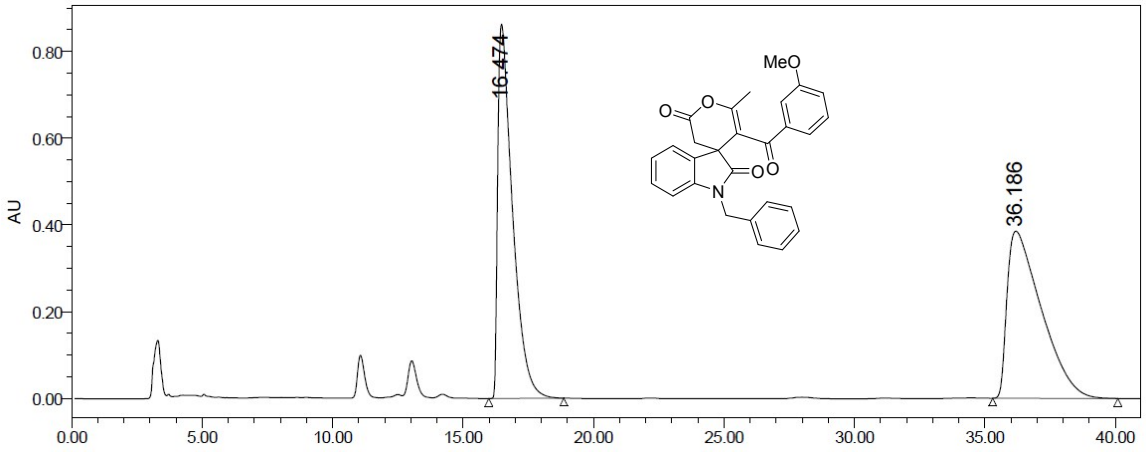


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	13.024	77741525	2294357	97.14
2	30.879	2290120	43476	2.86

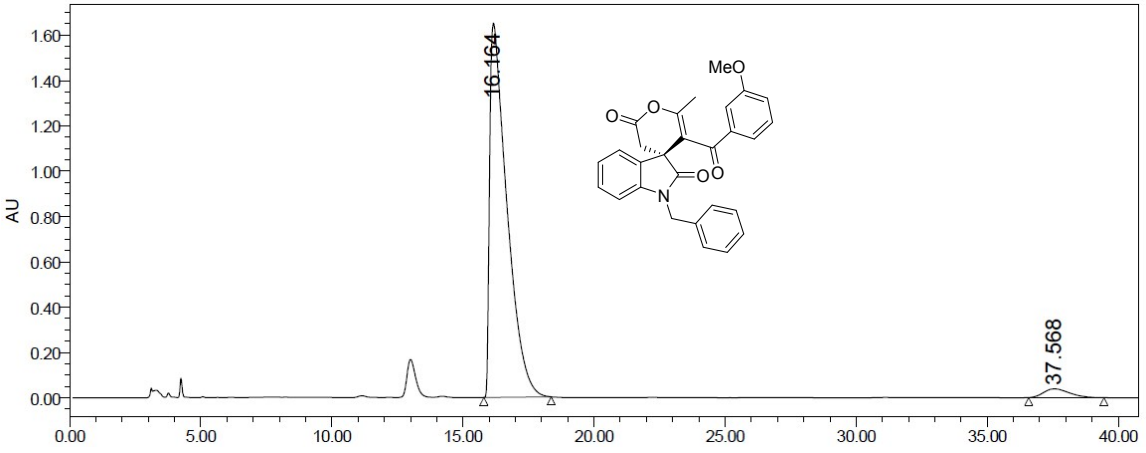

7.431
7.289
7.258
7.155
7.139
7.122
7.069
7.060
6.998
6.979
6.960
6.636
6.616
4.940
4.901
4.758
4.719
3.783
3.148
3.108
2.918
2.879
1.971
-0.001
MeO
O
O
O
O
N
3i
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
7.07
3.15
1.09
1.11
0.94
1.14
0.99
3.07
1.00
0.99
3.02


194.36
176.21
164.53
159.84
157.86
142.26
139.68
135.17
129.68
129.51
129.29
128.82
128.72
127.68
127.16
123.27
122.60
121.58
119.81
115.94
112.64
109.95
77.31
77.00
76.68
55.40
49.97
44.21
38.00
19.54
MeO
O
O
O
O
N
3i
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

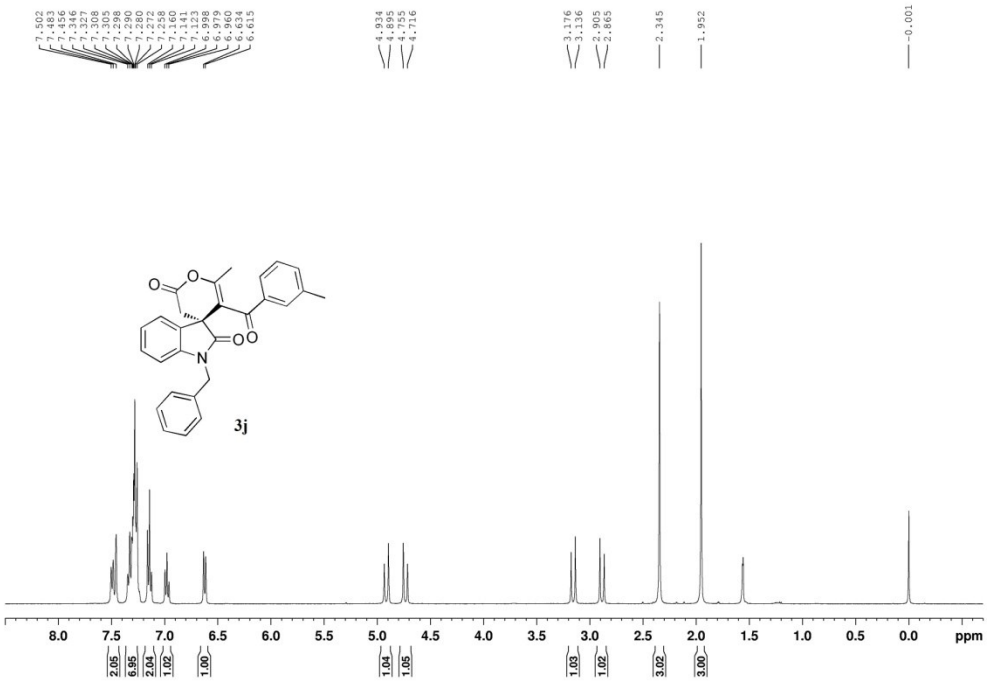
HPLC analysis of **3i** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

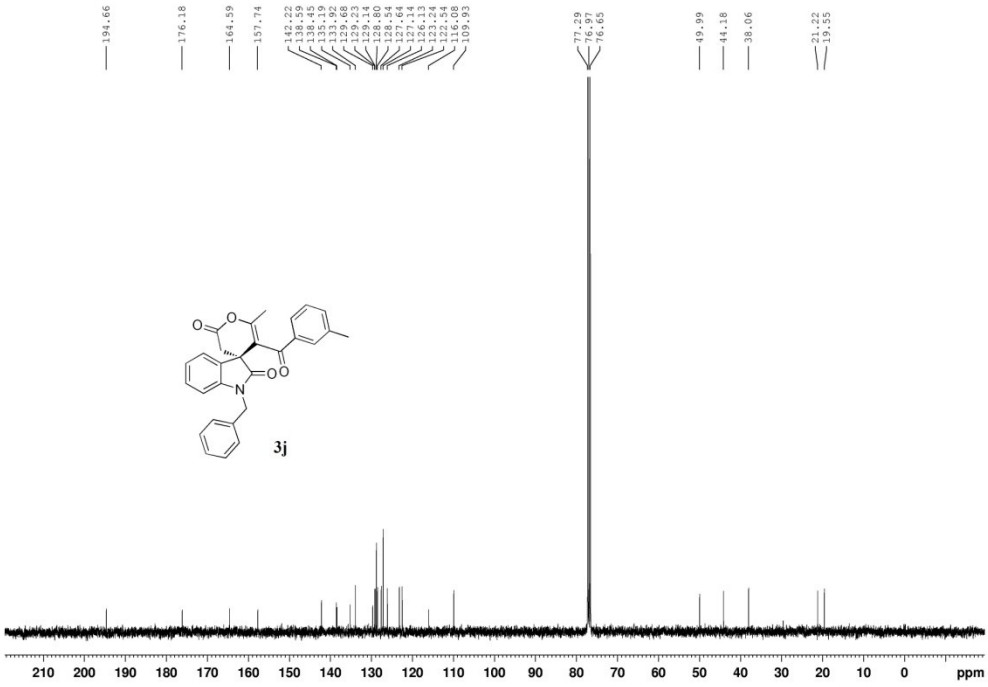


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	16.474	33931349	862241	49.16
2	36.186	35086088	385051	50.84

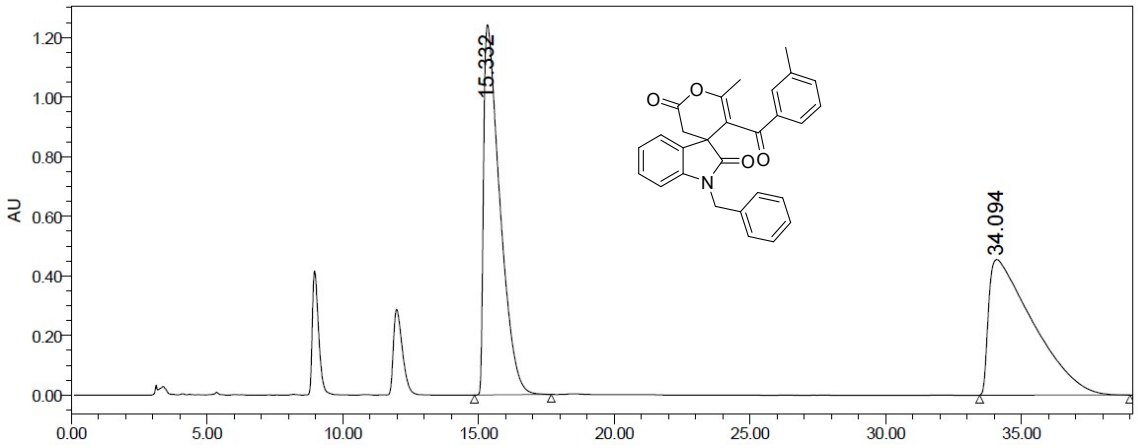


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	16.164	75517645	1650711	96.65
2	37.568	2617482	38581	3.35

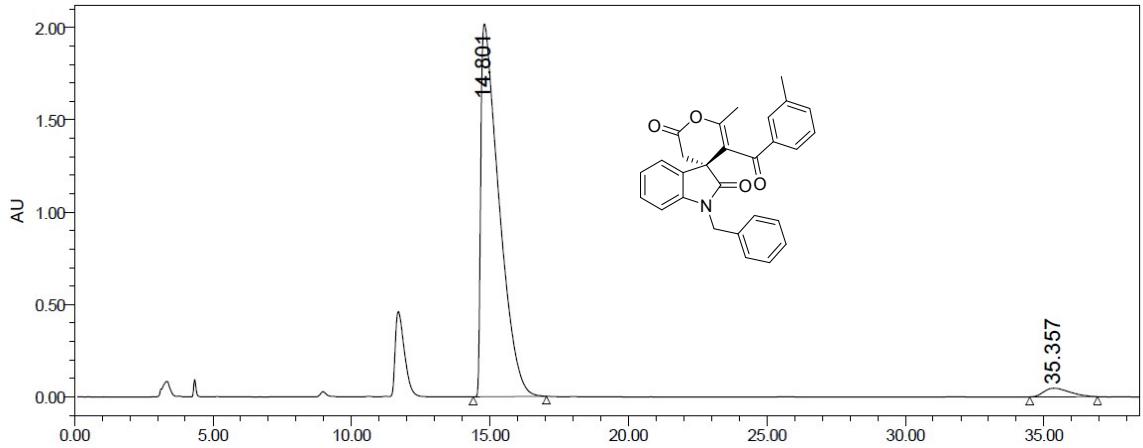

7.502
7.483
7.456
7.346
7.337
7.308
7.305
7.298
7.290
7.280
7.272
7.258
7.160
7.141
7.123
6.998
6.979
6.960
6.634
6.615
4.934
4.895
4.755
4.716
3.176
3.136
2.905
2.865
2.345
1.952
-0.001
3j
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
2.05 6.95 2.04 1.02 1.00 1.04 1.05 1.03 1.02 3.02 3.00


194.66
176.18
164.59
157.74
142.22
138.59
138.45
135.09
133.92
129.68
129.23
129.14
128.80
128.54
127.64
127.14
126.13
123.24
122.54
116.08
109.93
77.29
76.97
76.65
49.99
44.18
38.06
21.22
19.55
3j
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

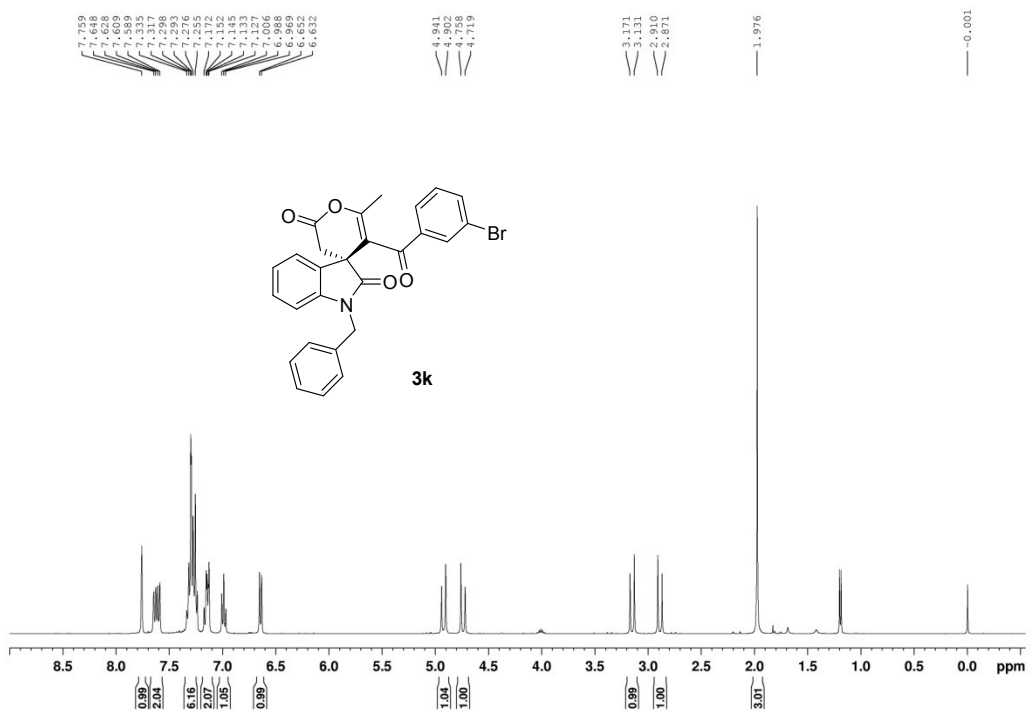
HPLC analysis of **3j** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

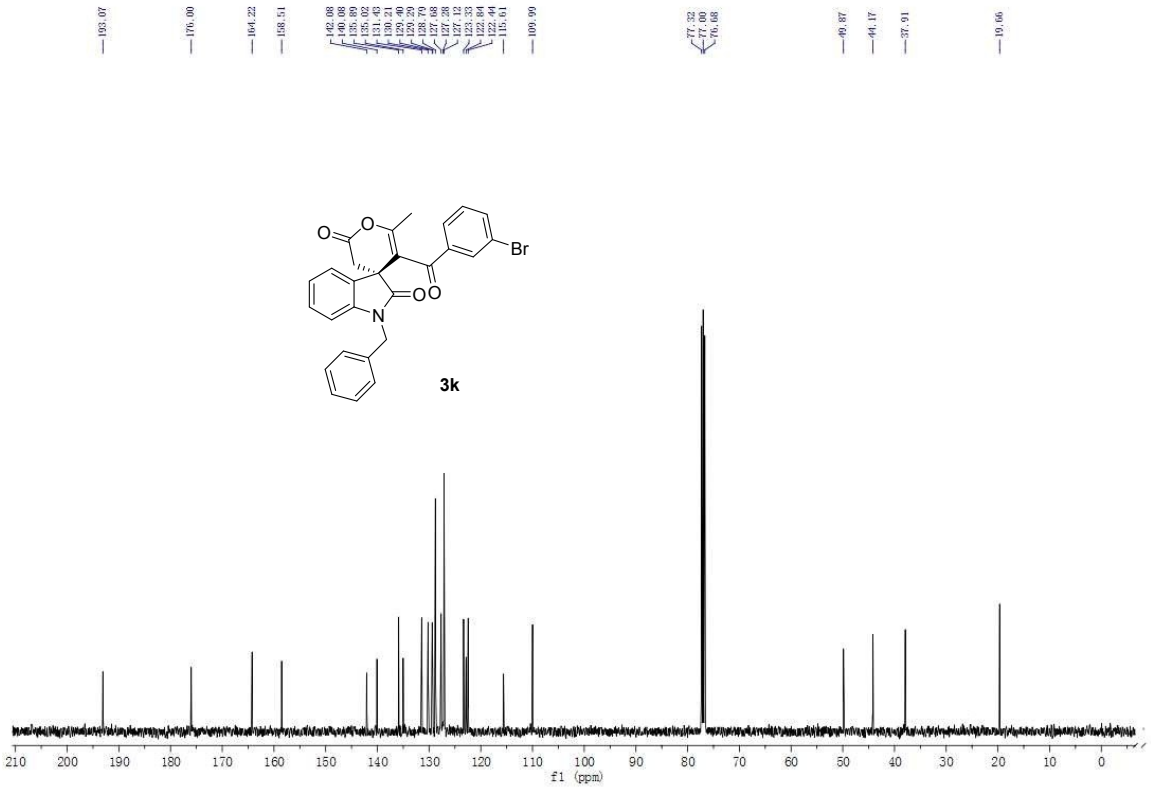


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	15.332	51573759	1241674	49.90
2	34.094	51774328	454486	50.10

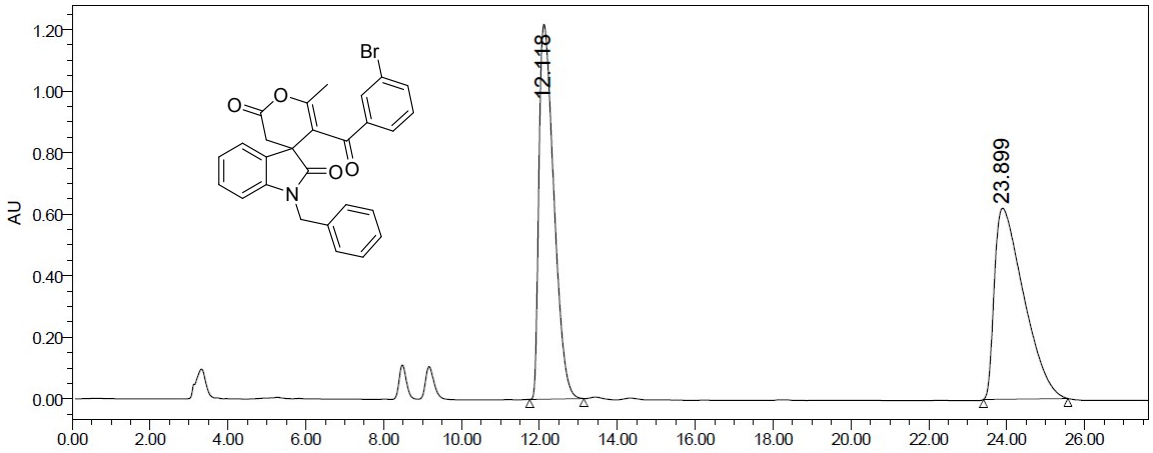


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	14.801	92296298	2018600	96.84
2	35.357	3013713	46469	3.16

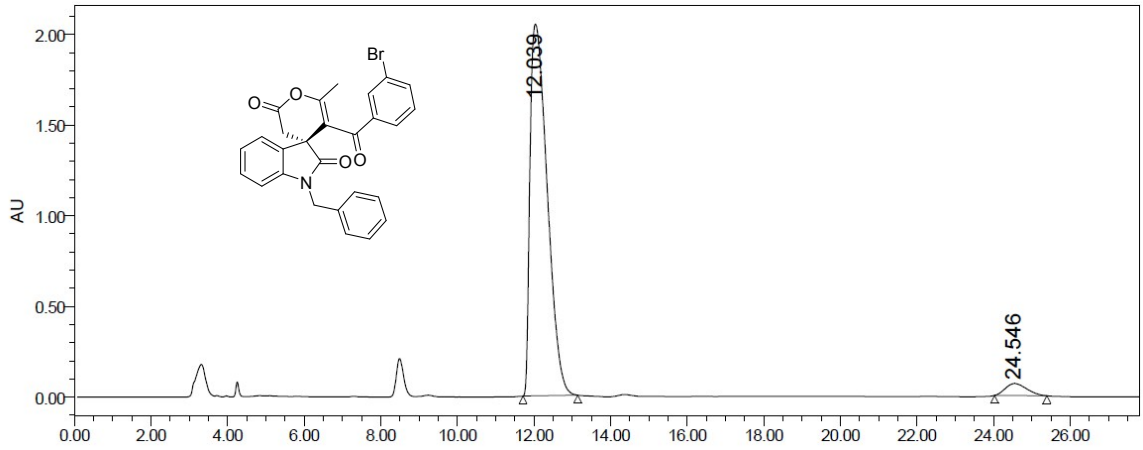

7.759
7.648
7.628
7.609
7.589
7.335
7.317
7.298
7.293
7.276
7.255
7.172
7.152
7.145
7.133
7.127
7.006
6.988
6.669
6.652
6.632
4.941
4.902
4.758
4.719
3.171
3.131
2.910
2.871
1.976
-0.001
Br
O
N
3k
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.99
2.04
5.16
2.07
1.05
0.99
1.04
1.00
0.99
1.00
3.01


193.07
176.00
164.22
158.51
142.08
140.08
135.89
135.02
131.45
130.21
129.40
129.29
128.79
127.68
127.28
127.12
123.33
122.84
122.44
115.61
109.99
77.32
77.00
76.68
69.87
44.17
37.91
19.66
Br
O
N
3k
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

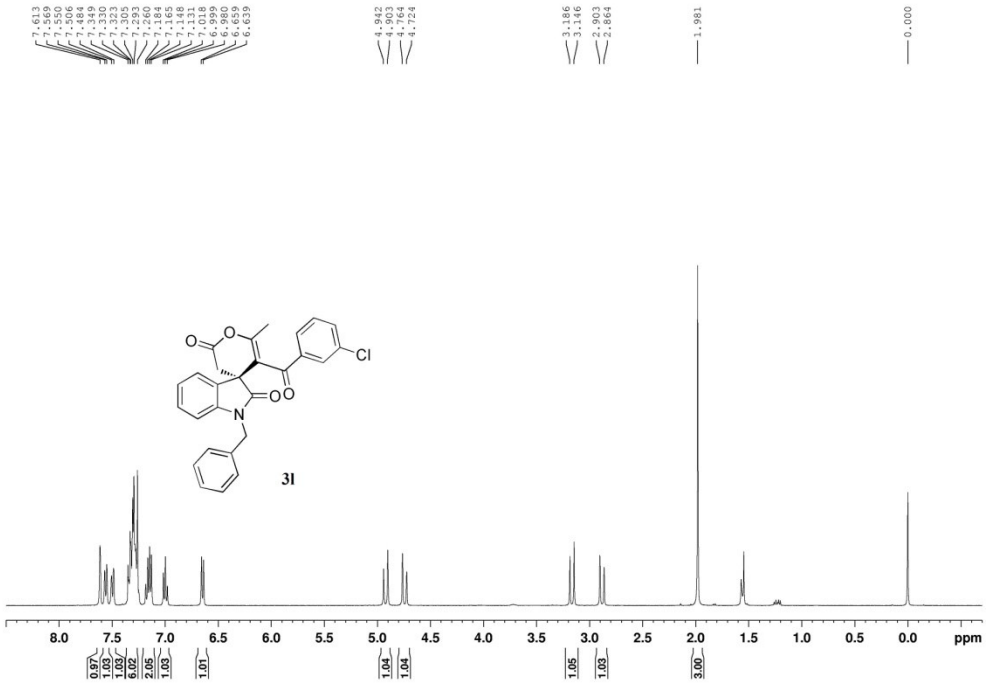
HPLC analysis of **3k** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

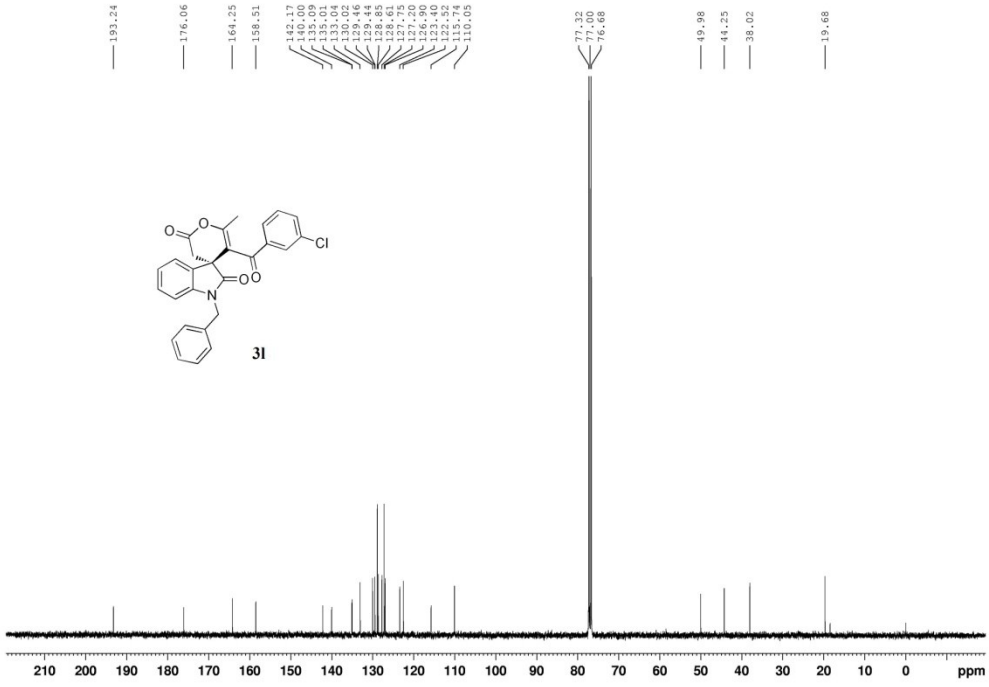


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.118	3.243e7	1.218e6	49.99
2	23.899	3.245e7	6.201e5	50.01

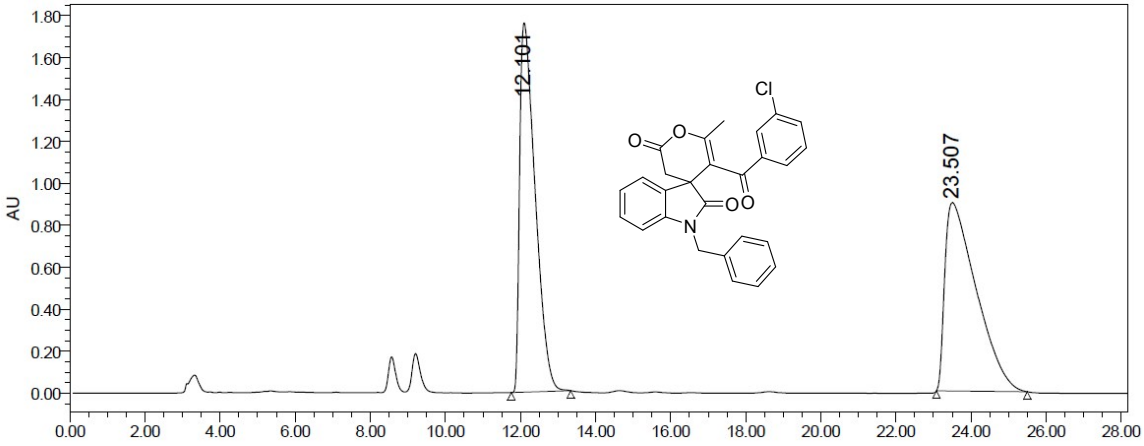


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.039	6.373e7	2.050e6	96.12
2	24.546	2.575e6	6.604e4	3.88

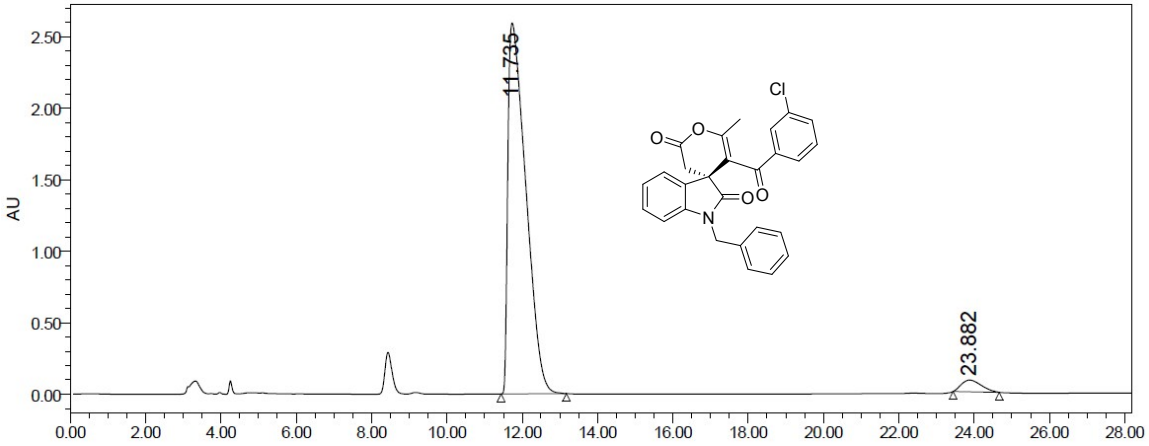

7.613
7.569
7.550
7.506
7.484
7.349
7.330
7.323
7.305
7.293
7.260
7.184
7.165
7.148
7.131
7.018
6.999
6.980
6.659
6.639
4.842
4.803
4.764
4.724
3.186
3.146
2.903
2.864
1.981
0.000
Cl
O
O
O
O
N
3l
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.87
1.03
1.03
6.02
2.05
1.03
1.01
1.04
1.04
1.05
1.03
3.00


193.24
176.06
164.25
158.51
142.17
140.00
135.09
135.01
133.04
130.02
129.44
128.85
128.61
127.75
127.20
126.90
123.40
122.52
115.74
110.05
77.32
77.00
76.68
49.98
44.25
38.02
19.68
Cl
O
O
O
O
N
3l
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

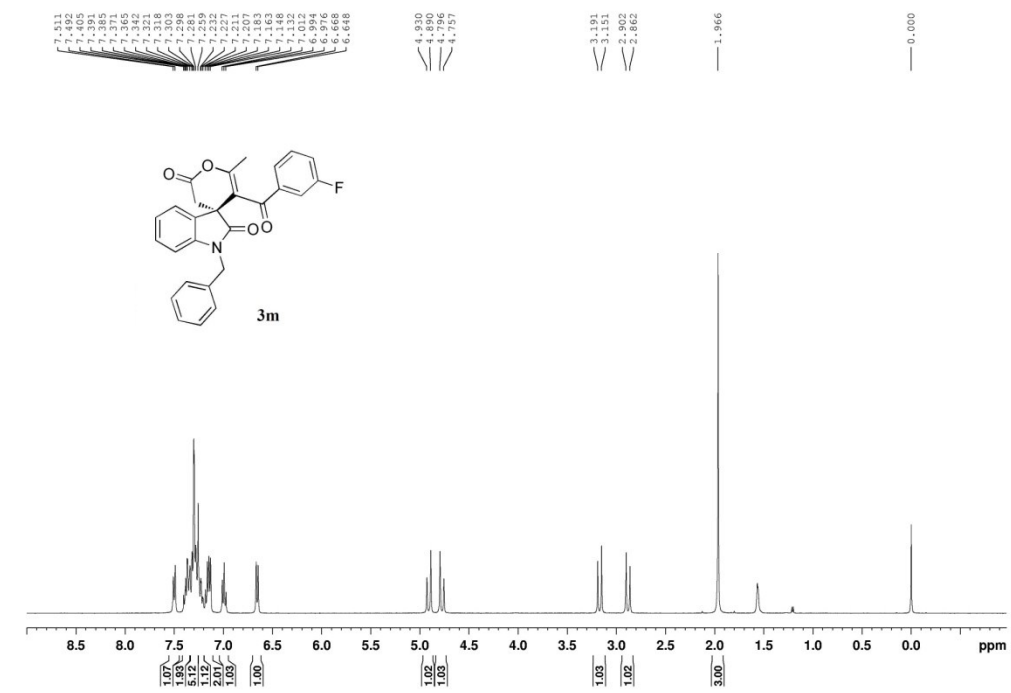
HPLC analysis of **3l** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

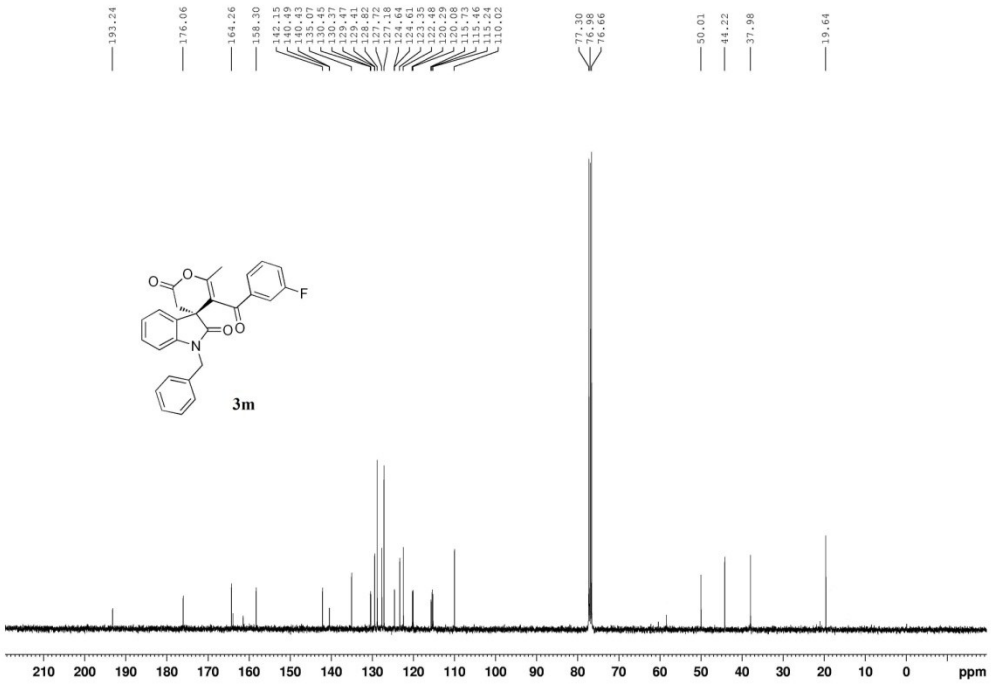


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.101	50666678	1759850	49.90
2	23.507	52263185	897960	50.78

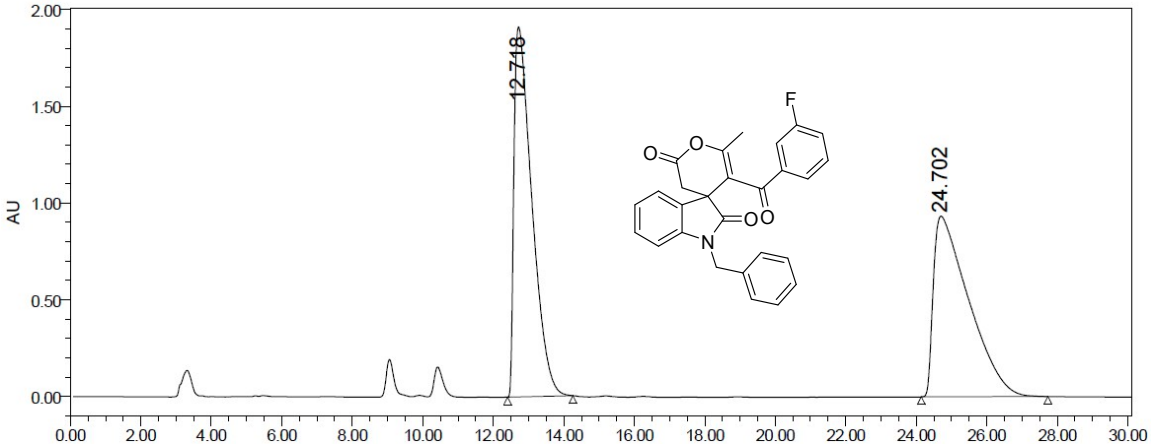


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	11.735	85833961	2595404	96.61
2	23.882	3007733	81918	3.39

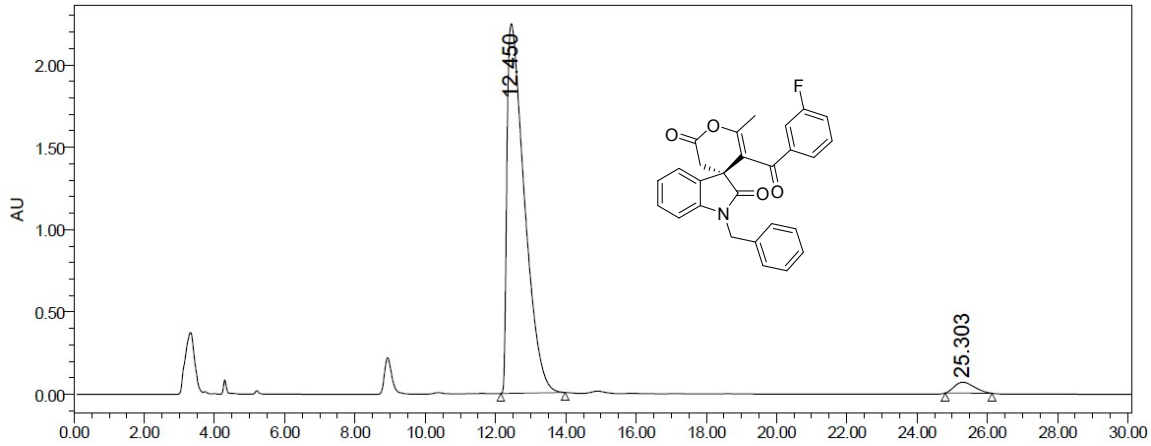

7.511
7.492
7.405
7.391
7.385
7.371
7.365
7.342
7.321
7.318
7.303
7.298
7.281
7.259
7.232
7.227
7.211
7.207
7.183
7.163
7.148
7.132
7.012
6.994
6.976
6.668
6.648
4.930
4.890
4.866
4.757
3.191
3.151
2.902
2.862
1.966
0.000
F
O
N
3m
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.07
1.93
5.12
1.12
2.01
1.05
1.00
1.02
1.03
1.03
1.02
3.00


193.24
176.06
164.26
158.30
142.15
140.49
140.45
135.07
130.45
130.37
129.47
129.41
128.82
127.72
127.18
124.64
124.61
123.35
122.48
120.29
120.08
115.73
115.46
115.24
110.02
77.30
76.98
76.66
50.01
44.22
37.98
19.64
F
O
N
3m
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

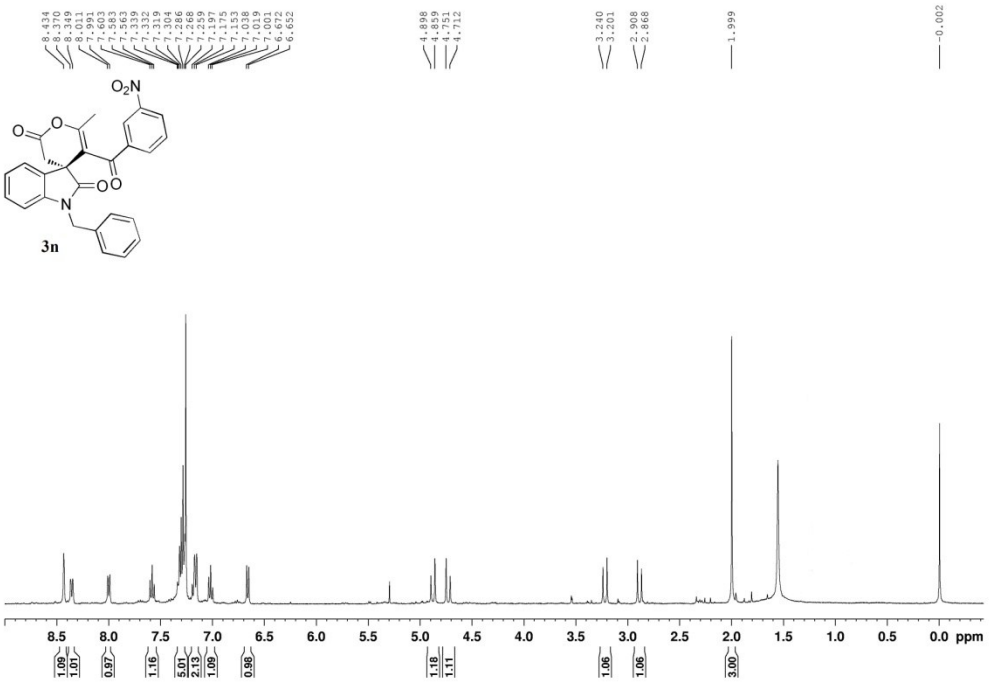
HPLC analysis of **3m** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

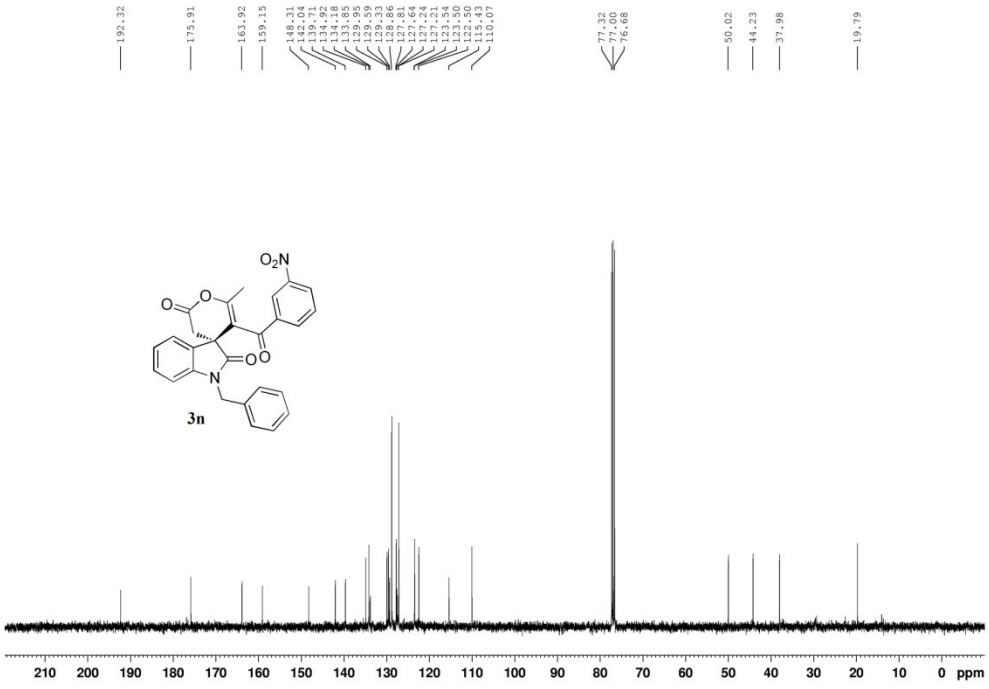


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.718	67484827	1912216	50.91
2	24.702	65075520	933310	49.09

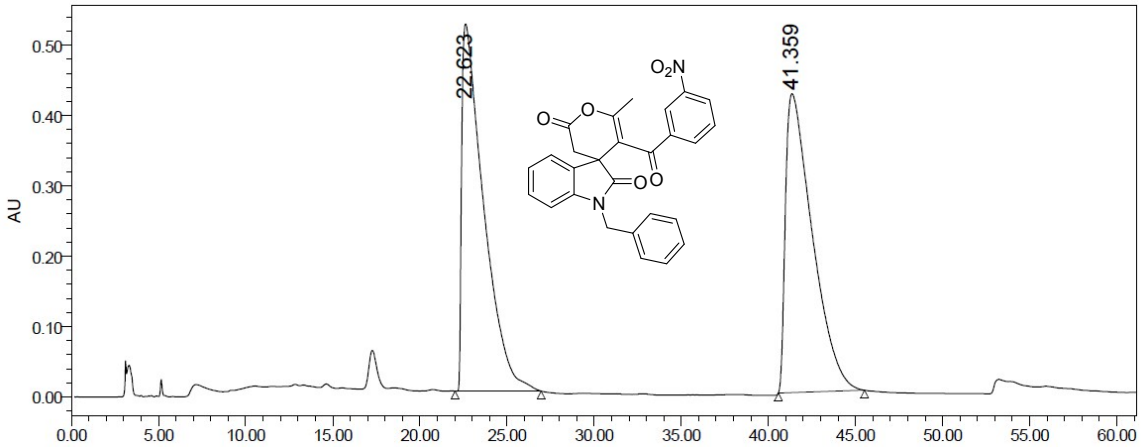


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	12.450	77241562	2242993	96.75
2	25.303	2595578	65729	3.25

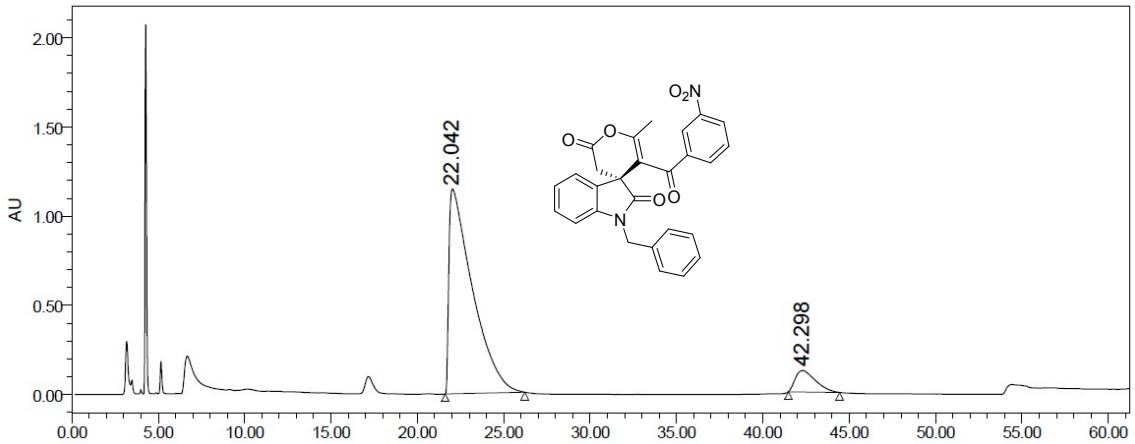

3n
8.434
8.370
8.349
8.011
7.991
7.603
7.563
7.545
7.339
7.332
7.319
7.304
7.286
7.268
7.259
7.197
7.175
7.153
7.038
7.019
7.001
6.672
6.652
4.898
4.859
4.731
4.712
3.240
3.201
2.908
2.868
1.999
-0.002
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0 ppm
1.09
1.01
0.97
1.16
5.01
2.13
1.09
0.98
1.18
1.11
1.06
1.06
3.00


3n
192.32
175.91
163.92
159.15
148.31
142.04
139.71
134.92
134.18
133.85
129.95
129.59
129.33
128.86
127.81
127.64
127.24
127.21
123.54
123.50
122.50
115.43
110.07
77.32
77.00
76.68
50.02
44.23
37.98
19.79
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

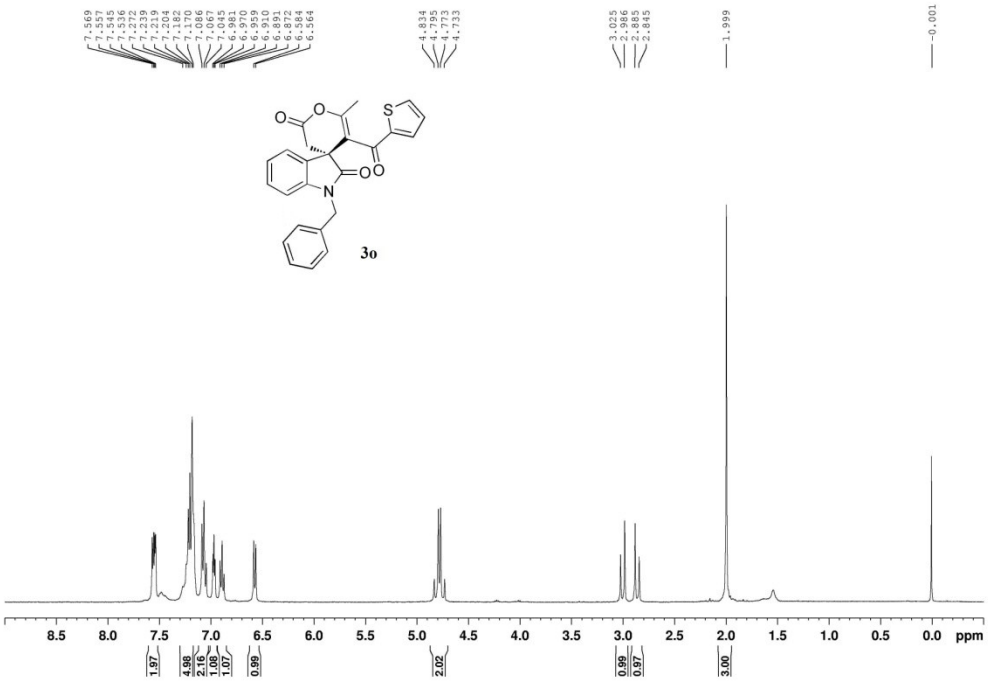
HPLC analysis of **3n** using chiral IC Column (CH_2Cl_2: *n*-hexane = 65:35, 1.0 mL/min)

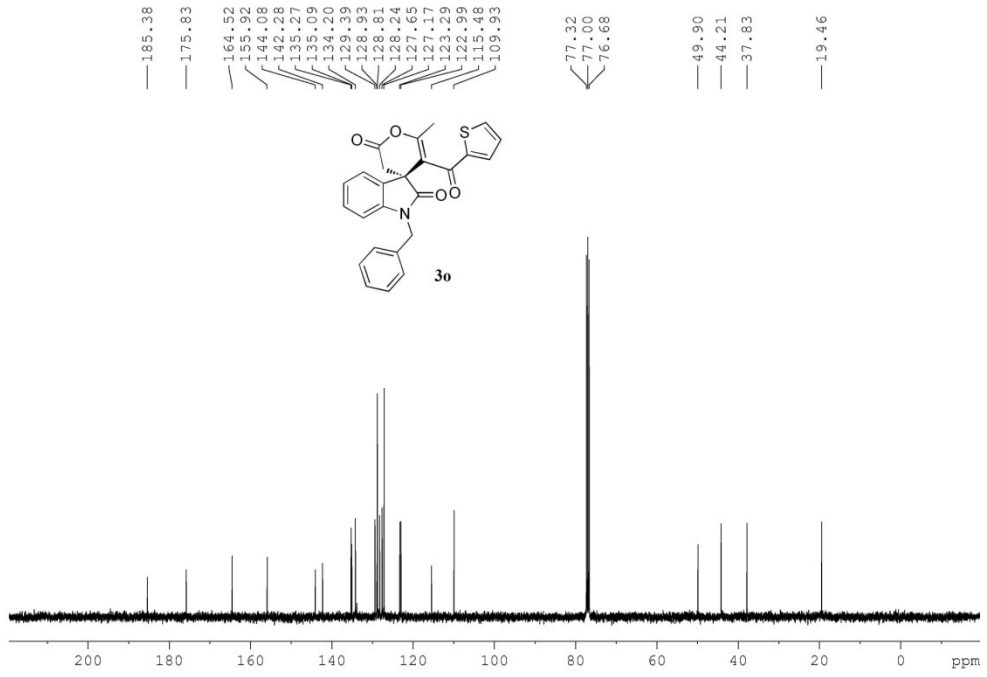


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	22.623	45565661	521863	50.00
2	41.359	45556734	425066	50.00

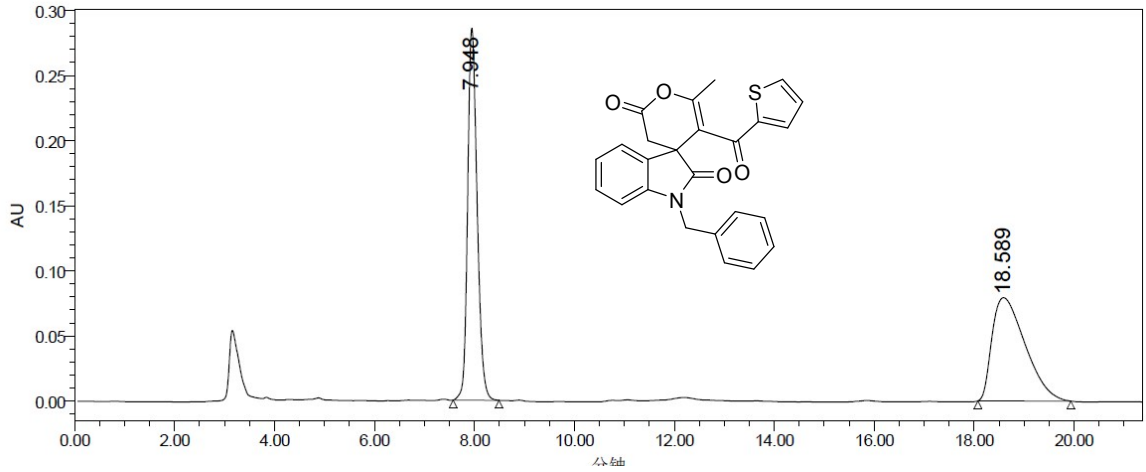


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	22.042	108776004	1148345	91.78
2	42.298	9744592	120534	8.22

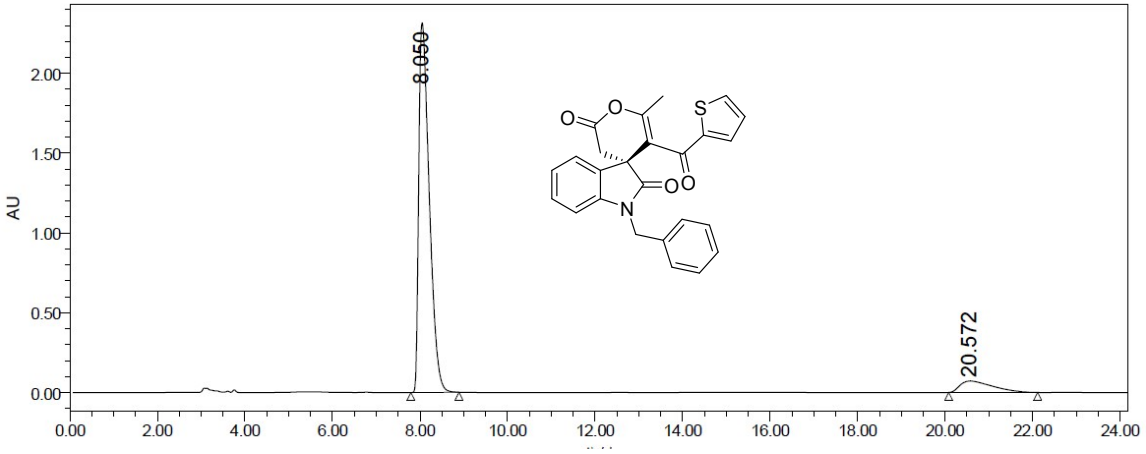

7.569
7.557
7.555
7.536
7.272
7.239
7.219
7.204
7.182
7.170
7.086
7.067
7.045
6.981
6.970
6.959
6.910
6.891
6.872
6.584
6.564
4.834
4.795
4.773
4.733
3.025
2.986
2.885
2.845
1.999
-0.001
3o
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
1.97 4.98 2.16 1.08 1.07 0.99 2.02 0.99 0.97 3.00


185.38
175.83
164.52
155.92
144.08
142.28
135.27
135.09
134.20
129.39
128.93
128.81
128.24
127.65
127.17
123.29
122.99
115.48
109.93
77.32
77.00
76.68
49.90
44.21
37.83
19.46
3o
200 180 160 140 120 100 80 60 40 20 0 ppm

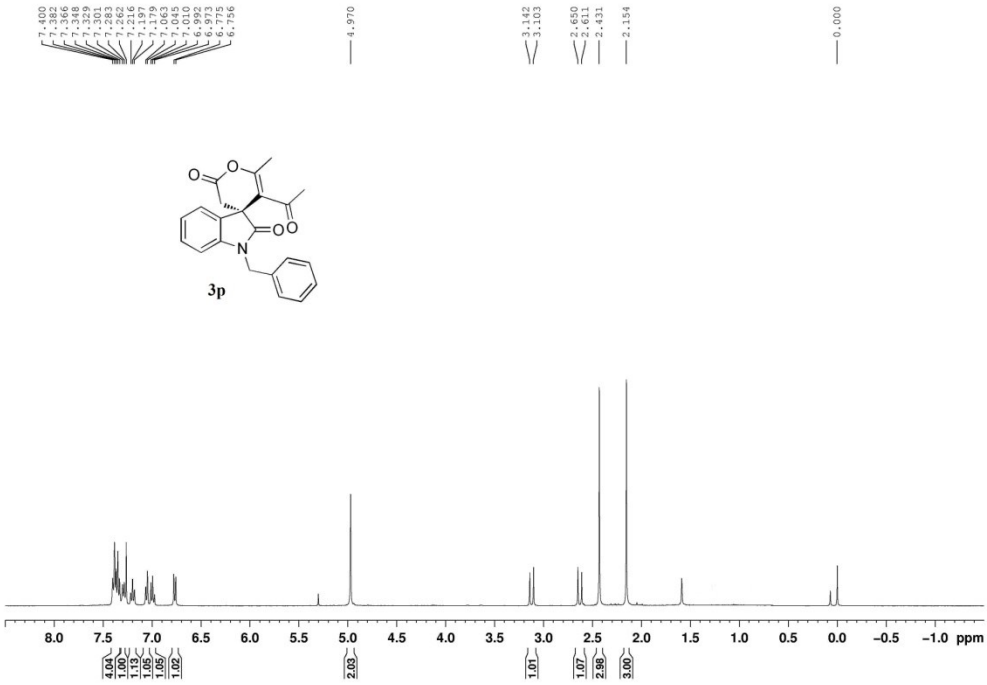
HPLC analysis of **3o** using chiral IC Column (CH_2Cl_2: *n*-hexane = 90:10, 1.0 mL/min)

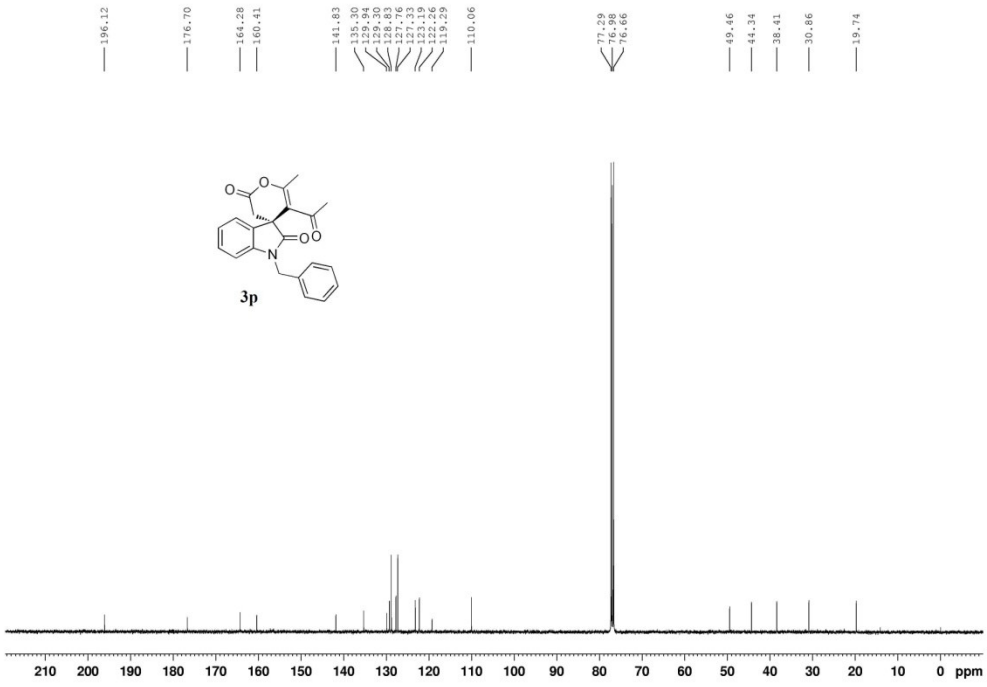


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	7.948	3752145	285635	50.72
2	18.589	3645622	79237	49.28

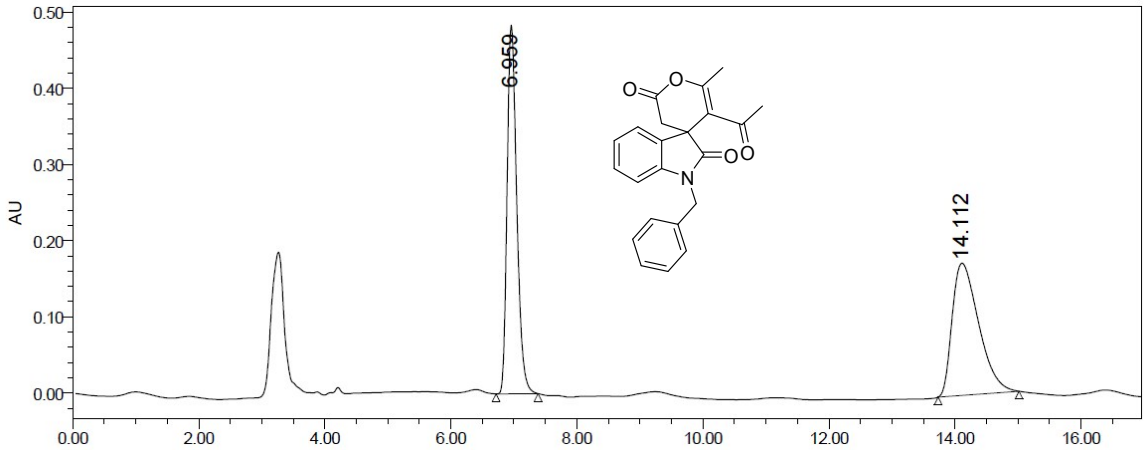


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	8.050	38659121	2316413	91.25
2	20.572	3705882	71414	8.75

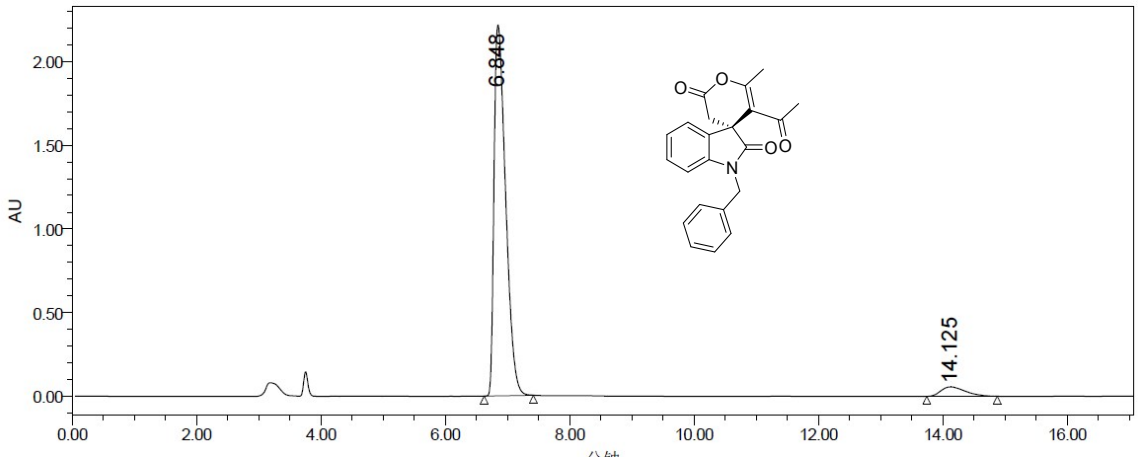

7.400
7.382
7.366
7.348
7.329
7.301
7.283
7.262
7.216
7.197
7.179
7.063
7.045
7.010
6.992
6.973
6.775
6.756
4.970
3.142
3.103
2.650
2.611
2.431
2.154
0.000
3p
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0 ppm
4.00
1.00
1.13
1.05
1.05
1.02
2.03
1.01
1.07
2.98
3.00


196.12
176.70
164.28
160.41
141.83
135.30
129.94
129.30
128.83
127.76
127.33
123.19
122.66
119.29
110.06
77.29
76.98
76.66
49.46
44.34
38.41
30.86
19.74
3p
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

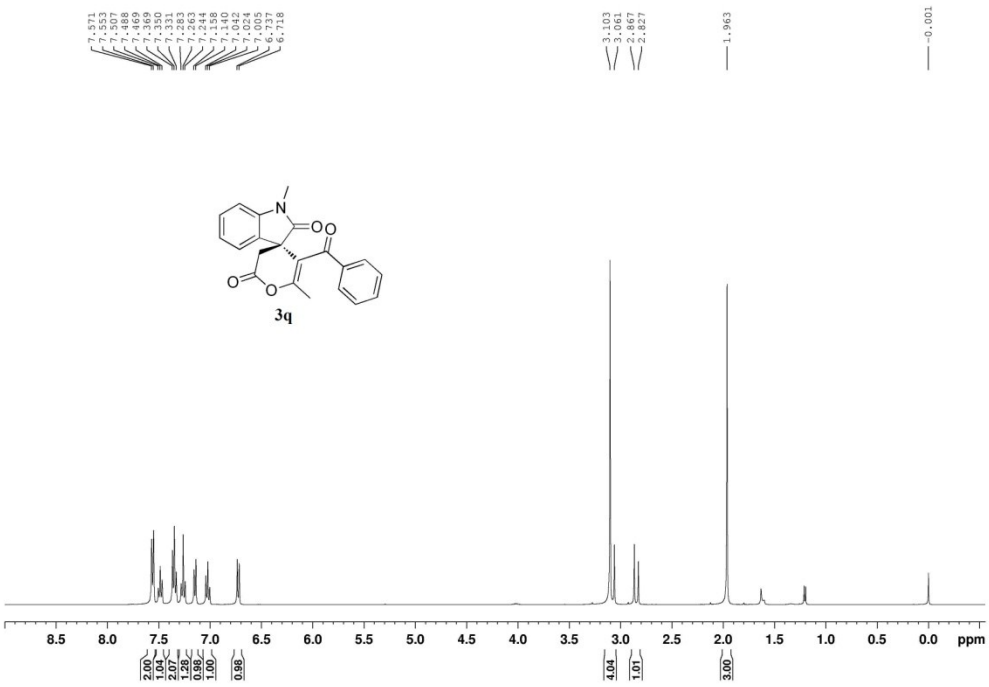
HPLC analysis of **3p** using chiral IC Column (CH_2Cl_2: *n*-hexane = 90:10, 1.0 mL/min)

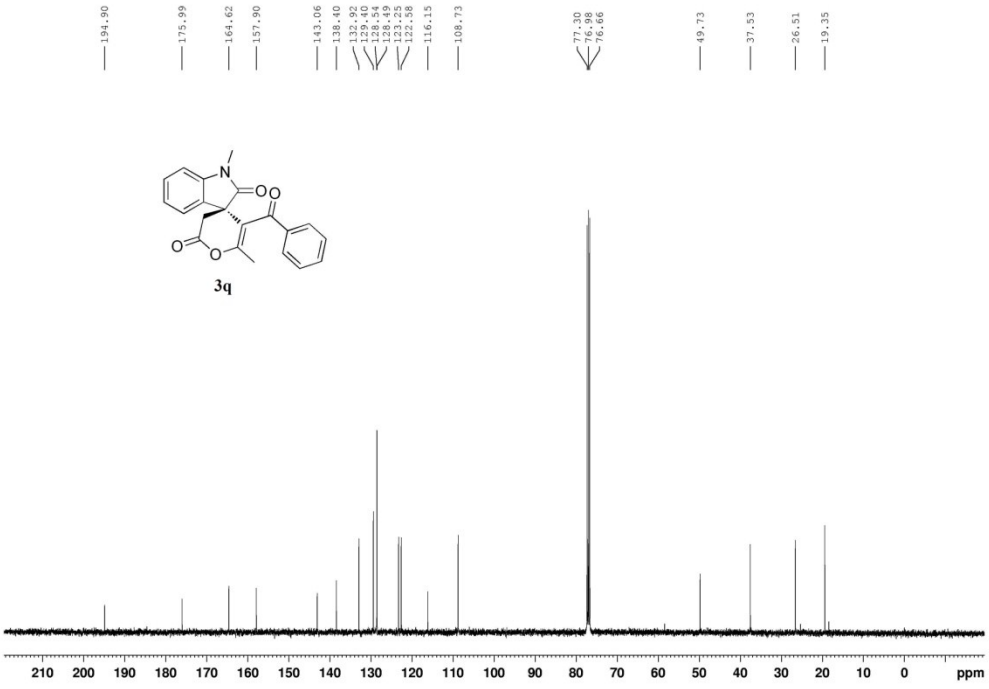


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	6.959	5134957	483882	50.31
2	14.112	5072403	173597	49.69

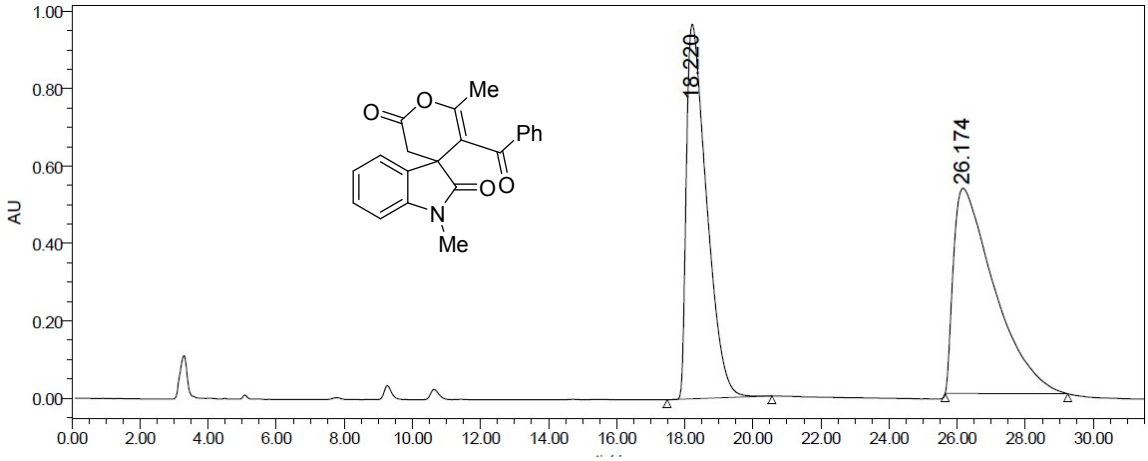


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	6.848	28578656	2216712	94.91
2	14.125	1532598	56012	5.09

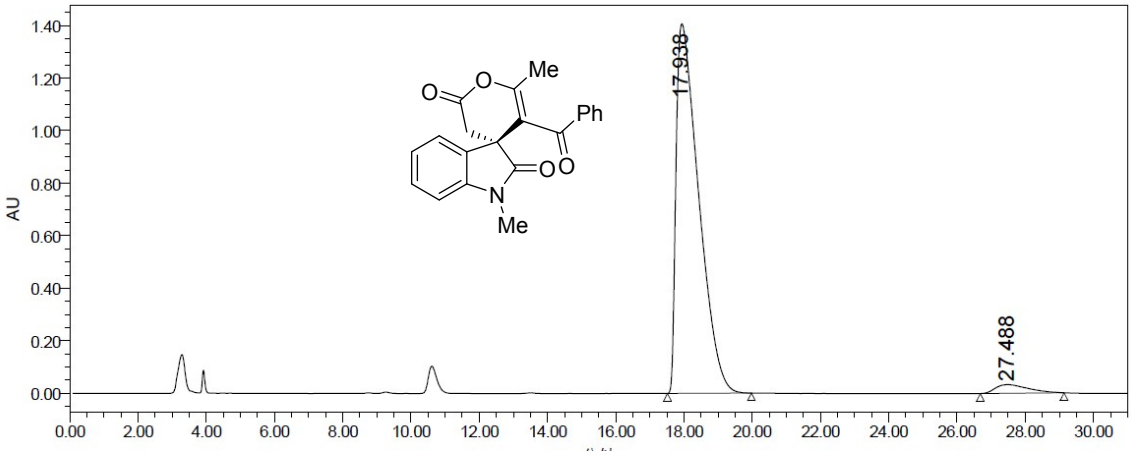

7.571
7.553
7.507
7.488
7.469
7.369
7.350
7.331
7.283
7.263
7.244
7.158
7.140
7.082
7.062
7.024
7.005
6.737
6.718
3.103
3.061
2.867
2.827
1.963
-0.001
3q
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
2.00
1.04
2.07
1.28
0.98
1.00
0.98
4.04
1.01
3.00


194.90
175.99
164.62
157.90
143.06
138.40
132.92
129.40
129.34
128.49
123.25
122.58
116.15
108.73
77.30
76.98
76.66
49.73
37.53
26.51
19.35
3q
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

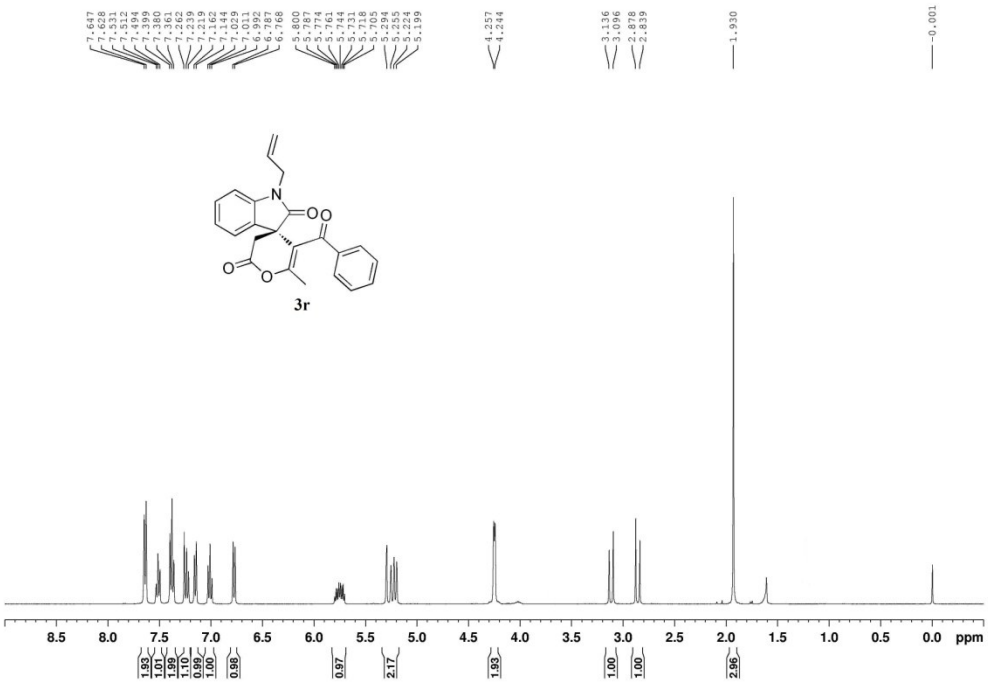
HPLC analysis of **3q** using chiral IC Column (CH_2Cl_2: *n*-hexane = 80:20, 1.0 mL/min)

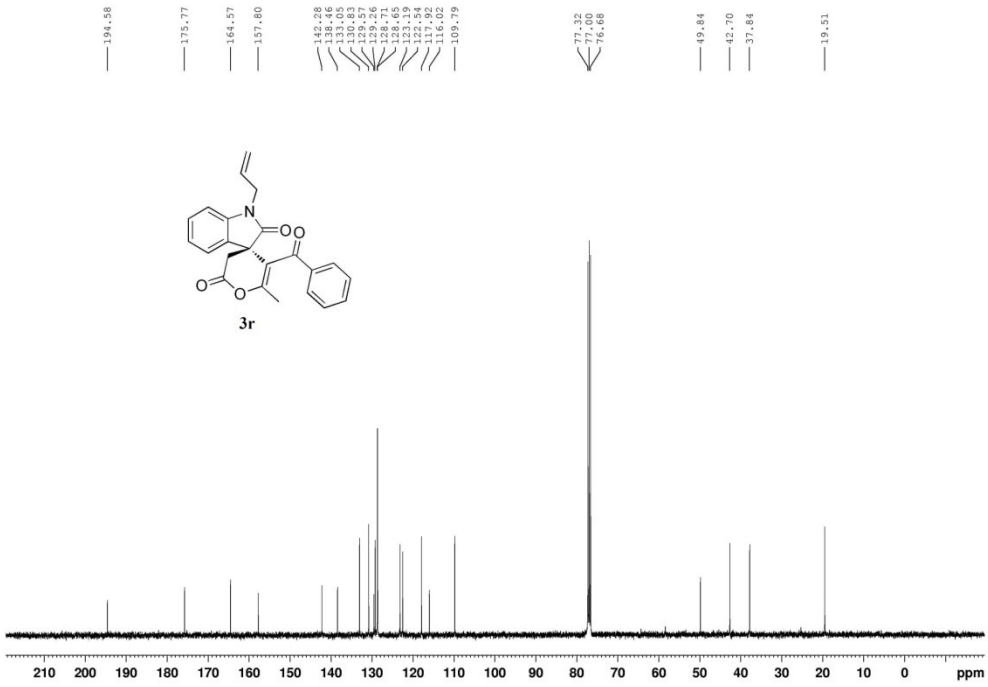


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	18.220	39863499	968068	47.34
2	26.174	44347396	529984	52.66

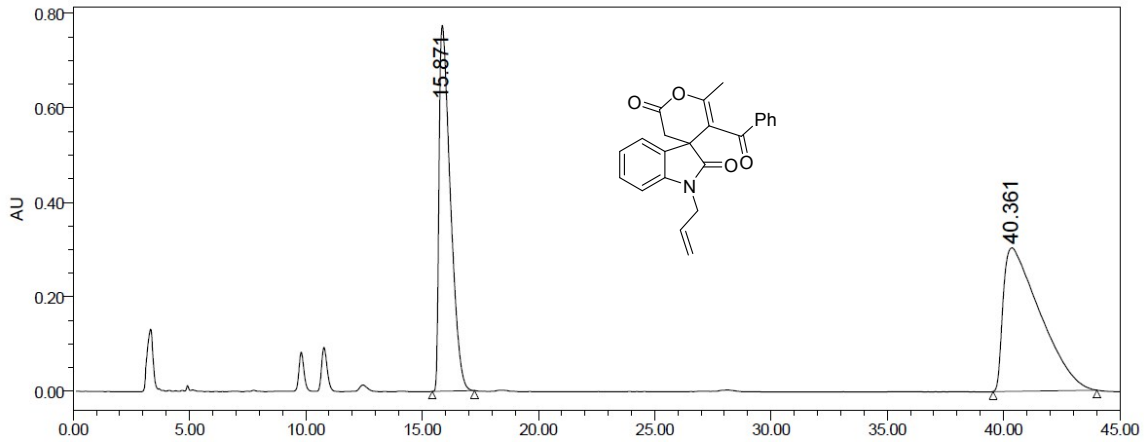


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	17.938	64653654	1407681	96.75
2	27.488	2175149	32950	3.25

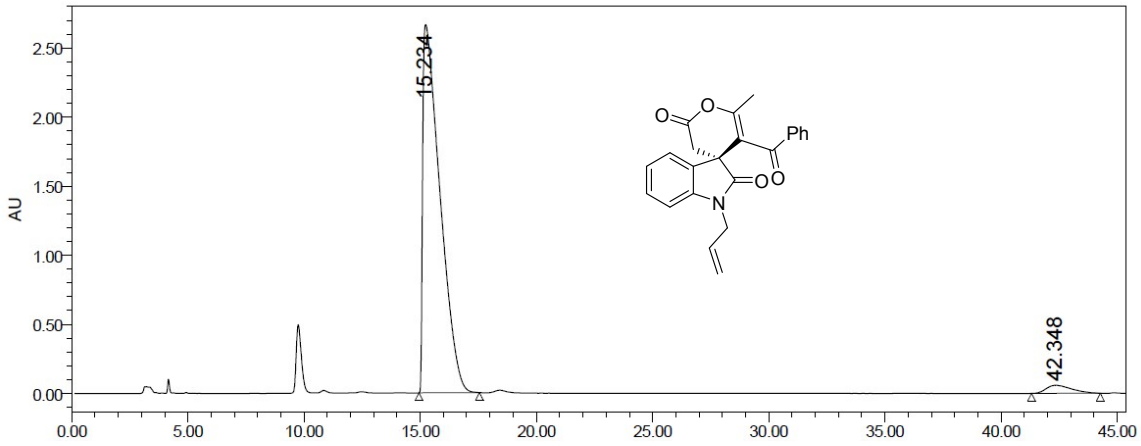

7.647
7.628
7.531
7.512
7.494
7.399
7.380
7.361
7.262
7.239
7.219
7.162
7.144
7.029
7.011
6.992
6.787
6.768
5.800
5.777
5.774
5.761
5.744
5.731
5.718
5.705
5.294
5.255
5.234
5.199
4.257
4.244
3.136
3.096
2.878
2.839
1.930
-0.001
3r
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
1.93
1.01
1.99
1.10
0.99
1.00
0.98
0.97
2.17
1.93
1.00
1.00
2.96


194.58
175.77
164.57
157.80
142.28
138.46
133.05
130.83
130.57
129.26
128.71
128.65
123.19
122.54
117.92
116.02
109.79
77.32
77.00
76.68
49.84
42.70
37.84
19.51
3r
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

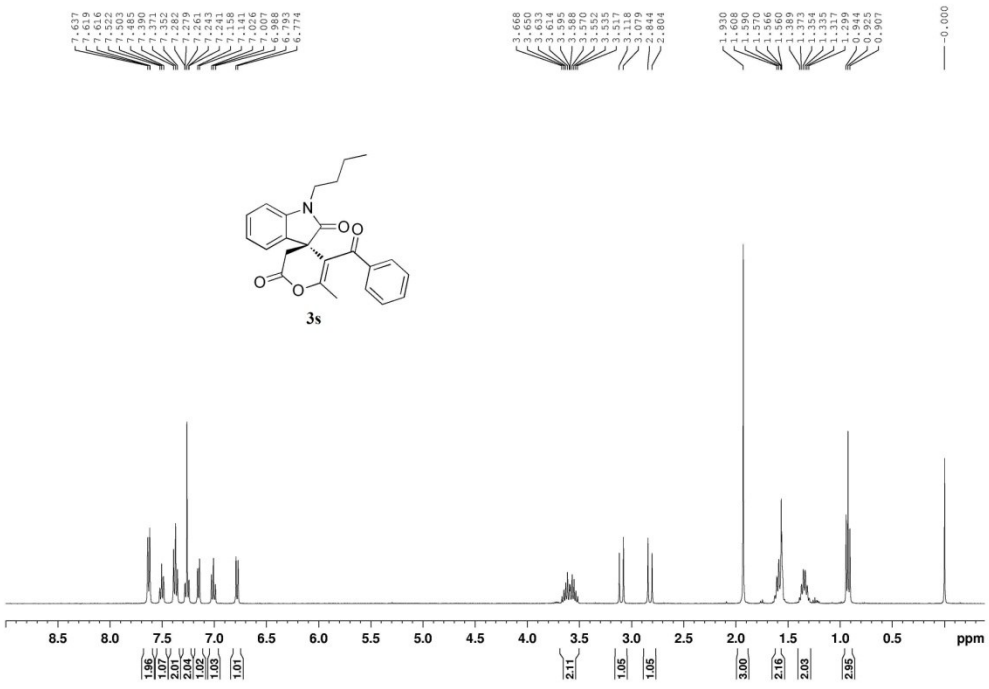
HPLC analysis of **3r** using chiral IC Column (CH_2Cl_2: *n*-hexane = 70:30, 1.0 mL/min)

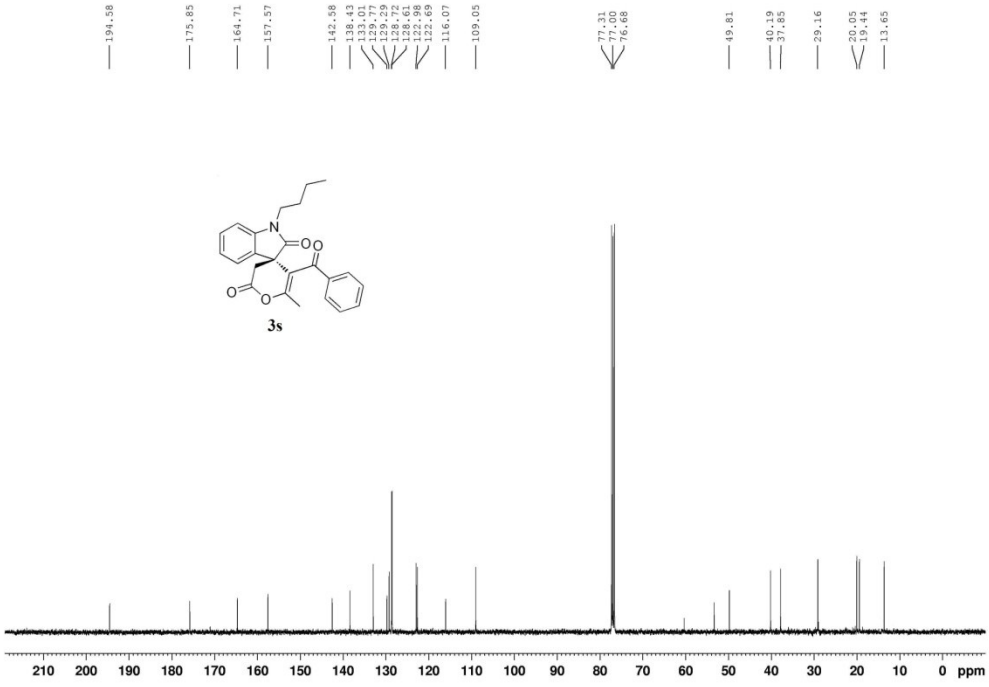


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	15.871	26192315	774314	43.91
2	40.361	33450996	303465	56.09

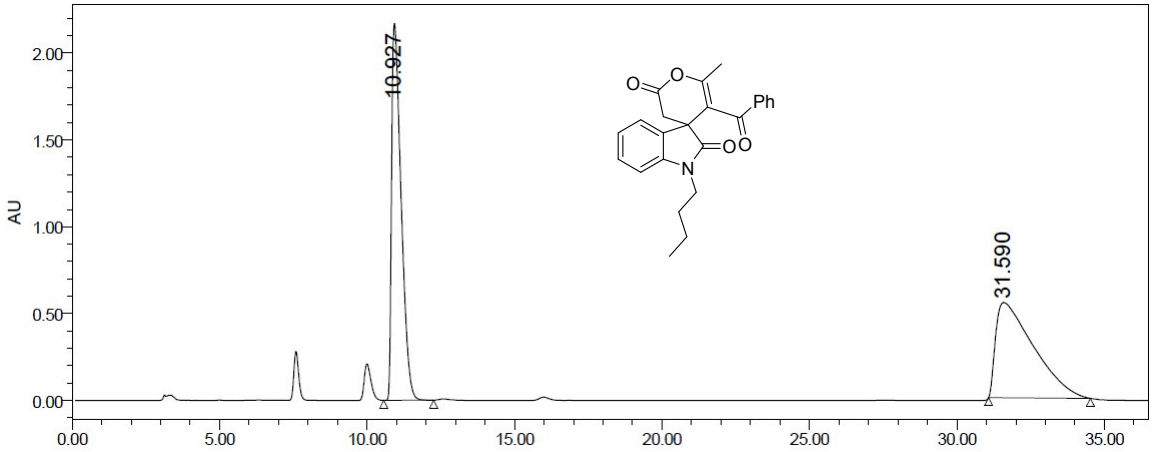


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	15.234	137389530	2664460	96.93
2	42.348	4358172	57947	3.07

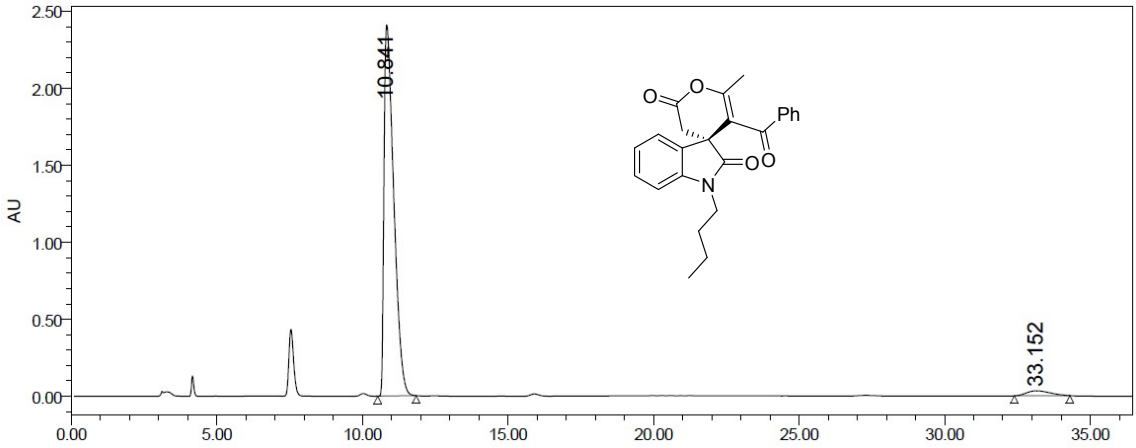

7.637
7.619
7.616
7.606
7.503
7.485
7.390
7.371
7.352
7.282
7.279
7.261
7.243
7.241
7.158
7.141
7.006
7.007
6.988
6.793
6.774
3.668
3.650
3.633
3.614
3.595
3.588
3.570
3.552
3.535
3.517
3.118
3.079
2.844
2.804
1.930
1.608
1.590
1.570
1.566
1.560
1.389
1.373
1.334
1.335
1.317
1.299
0.944
0.935
0.907
-0.000
3s
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.96 1.07 2.01 2.04 1.02 1.03 1.01
2.11 1.05 1.05 3.00 2.16 2.03 2.95


194.58
175.85
164.71
157.57
142.58
138.43
133.01
129.77
129.29
128.72
128.61
128.08
122.69
116.07
109.05
77.31
77.00
76.68
49.81
40.19
37.85
29.16
20.05
19.44
13.65
3s
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

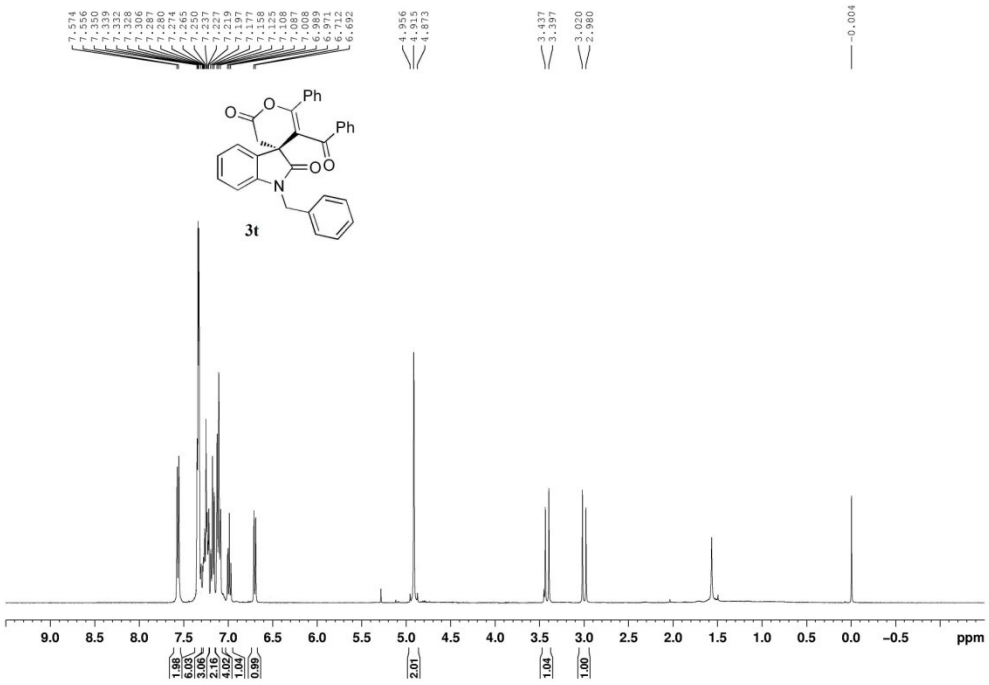
HPLC analysis of **3s** using chiral IC Column (CH_2Cl_2: *n*-hexane = 70:30, 1.0 mL/min)

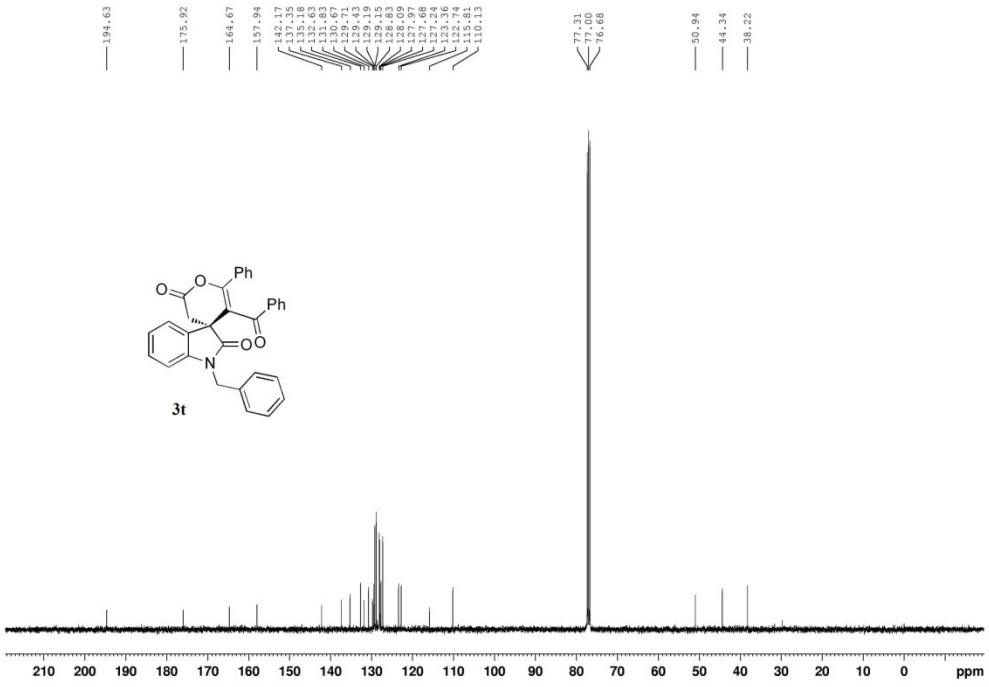


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	10.927	48593211	2169751	49.79
2	31.590	49010703	547279	50.21

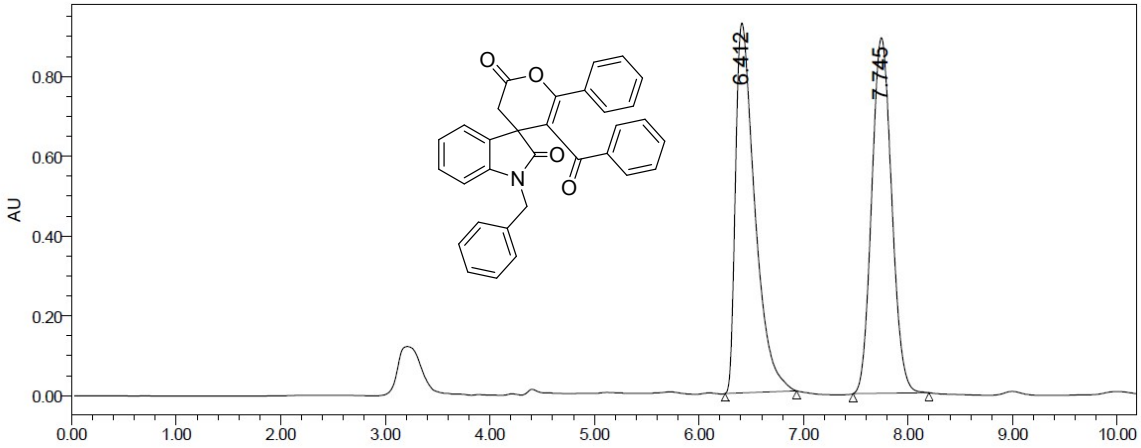


Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	10.841	56031752	2409049	96.88
2	33.152	1803060	32520	3.12

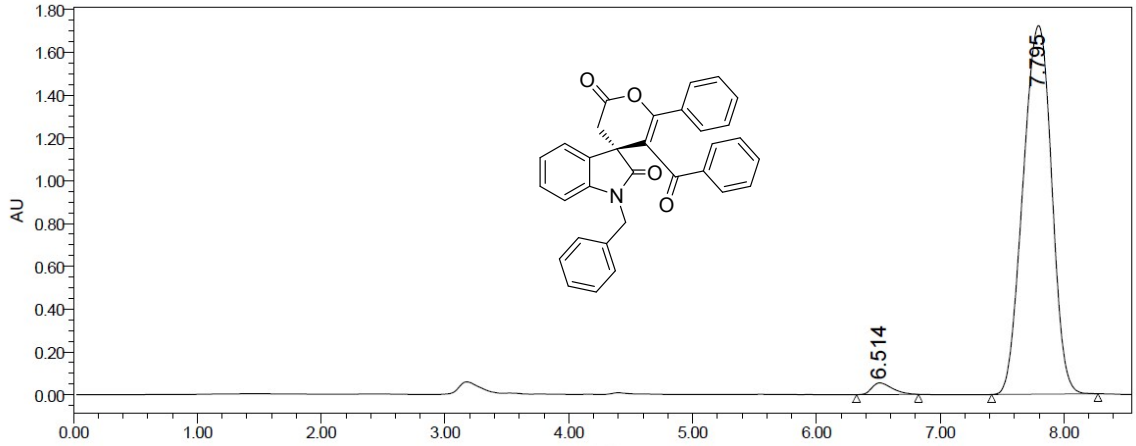

7.574
7.566
7.350
7.339
7.332
7.328
7.296
7.287
7.280
7.274
7.265
7.260
7.237
7.227
7.219
7.197
7.177
7.158
7.125
7.108
7.087
7.068
6.989
6.971
6.712
6.692
4.956
4.915
4.873
3.437
3.397
3.020
2.980
-0.004
Ph
Ph
O
O
O
O
N
3t
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 ppm
1.98
6.03
3.06
2.16
4.02
1.04
0.99
2.01
1.04
1.00


194.63
175.92
164.67
157.94
142.17
137.35
135.18
132.63
131.83
130.67
129.71
129.43
129.19
129.15
128.83
128.09
127.97
127.68
123.34
123.16
122.74
115.81
110.13
77.31
77.00
76.68
50.94
44.34
38.22
Ph
Ph
O
O
O
O
N
3t
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

HPLC analysis of **3t** using chiral IC Column (CH_2Cl_2: *n*-hexane = 90:10, 1.0 mL/min)



Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	6.412	11892079	927533	50.20
2	7.745	11795620	891159	49.80



Peak	Retention time (min)	Peak area (mAU*s)	Peak height (mAU)	Peak area (%)
1	6.514	614896	53948	2.17
2	7.795	27699988	1721837	97.83