Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Asymmetric synthesis of bicyclic pyran scaffolds bearing two oxa-quaternary stereocenters via zinc-catalyzed [5 + 1] annulations

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General Information

All reactions were carried out under an atmosphere of argon using oven-dried glassware. Super dry solvents, metal catalysts, were purchased from chemical companies and used without further treatment. Flash column chromatography was performed using silica gel (300-400 mesh). ^{1}H NMR ,^{13}C NMR, ^{19}F NMR spectra were recorded in $CDCl_3$ or DMSO-d_6 on a 400 MHz spectrometer; chemical shifts are reported in ppm with the solvent signals as reference, and coupling constants (*J*) are given in Hertz. The peak information is described as: s = singlet, d = doublet, t = triplet, q = quartet, m= multiplet. High-resolution mass spectra (HRMS) were obtained using an Agilent LC-MSAD-Trap-XCT instrument using electrospray ionization time-of-flight (ESI-TOF). High performance liquid chromatography (HPLC) was performed on instrument consisted of JASCO model PU-1580 intelligent HPLC pump and JASCO model UV-1575 intelligent UV-vis detector (254 nm) using Daicel Chiralpak IC, IE, IF (4.6 mm × 250 mm) columns. Melting points were determined using YRT-3 melting point apparatus. Optical rotations were measured with Perkin Elmer, model 341 Polarimeter. The instrumentation used for the crystal measurement is Oxford Gemini E X-ray single-crystal diffractometer and Bruker D8 VENTURE Metaljet PHOTON II. Cyclohexadienone-tethered enones[1] and α-hydroxy aryl ketones[2] were synthesized according to the literature.

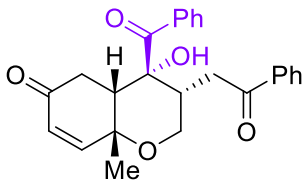
General Procedure for optimization of the reaction conditions.

Under the nitrogen atmosphere, a solution of diethylzinc (20 μL, 1.0 M in hexane, 0.02 mmol) was added dropwise to a solution of **L1** (0.01 mmol, 6.4 mg) and additives (50 mg) in solvent (2 mL). After the mixture was stirred for 30 min at 40 °C. 2-Hydroxy-1-phenylethan-1-one **1a** (0.1 mmol, 13.6 mg) and (E)-4-methyl-4-((4-oxo-4-phenylbut-2-en-1-yl) oxy) cyclohexa-2,5-dien-1-one **2a** (0.1 mmol, 26.8 mg) were added. The reaction mixture was stirred for corresponding time at the same temperature. The reaction was quenched with NH_4Cl solution (2 mL) and the aqueous layer was extracted with CH_2Cl_2 (3 × 5 mL). The combined organic layer was washed with brine and dried over Na_2SO_4. The solvent was removed under reduced pressure by using a rotary evaporator. The residue was purified by flash chromatography with petroleum ether/ethyl acetate (3:1) to afford the desired product **3a**.

Synthesis of enantioenriched 3

Under the nitrogen atmosphere, a solution of diethylzinc (40 μL, 1.0 M in hexane, 0.04 mmol) was added dropwise to a solution of **L1 or L2** (0.02 mmol) and 3Å MS (200 mg) in toluene (2 mL). After the mixture was stirred for 30 min at 40 °C. Then, **1a** (0.2 mmol, 53.6 mg) and **2a** (0.2 mmol, 27.2 mg) were added. The reaction mixture was stirred for 24 h at 40 ℃. The reaction was quenched with NH_4Cl solution (4 mL), and the aqueous layer was extracted with CH_2Cl_2 (3 × 5 mL). The combined organic layer was washed with brine and dried over Na_2SO_4. The solvent was removed under reduced pressure by using a rotary evaporator. The residue was purified by flash chromatography with petroleum ether/ethyl acetate (3:1) to afford the desired product **3**

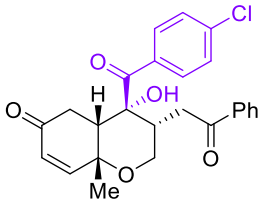
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3a)



3a

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3a** as a yellow solid (57.5 mg, 71% yield, >20:1 dr); $[\alpha]_D^{20}$ = -41.3 (c = 0.2, DCM, 95% ee); **m.p.** = 64.8-65.5 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 – 8.06 (m, 2H), 7.84 – 7.72 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.57 – 7.47 (m, 3H), 7.36 (t, *J* = 7.7 Hz, 2H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.70 (s, 1H), 4.13 – 3.80 (m, 1H), 3.68 (t, *J* = 11.0 Hz, 1H), 3.57 – 3.39 (m, 1H), 3.04 (d, *J* = 6.0 Hz, 1H), 2.87 – 2.71 (m, 1H), 2.65 – 2.55 (m, 1H), 2.50 – 2.36 (m, 1H), 1.98 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.5, 197.4, 196.2, 152.2, 136.4, 133.9, 133.4, 132.9, 131.3, 129.8, 128.9, 128.6, 127.9, 81.5, 79.8, 72.9, 63.7, 46.6, 4.1, 37.1, 34.7, 28.9. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{24}NaO_5]^+$: 427.1516, found: 427.1524; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 19.13 min and t_{minor} = 26.49 min.

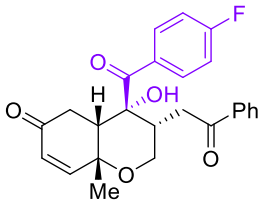
(3*R*,4*R*,4a*R*,8a*R*)-4-(4-chlorobenzoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3b)



3b

Followed the general procedure, using **1b** (0.2 mmol, 34.0 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3b** as a pale yellow solid (63.9 mg, 73% yield, >20:1 dr); $[\alpha]_D^{20}$ = -56.9 (c = 0.2, DCM, 90% ee); **m.p.** = 153.4-154.6 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.7 Hz, 2H), 7.79 – 7.72 (m, 2H), 7.56 – 7.45 (m, 3H), 7.38 (t, *J* = 7.7 Hz, 2H), 6.69 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.68 – 4.63 (m, 1H), 3.92 – 3.80 (m, 1H), 3.69 (t, *J* = 11.0 Hz, 1H), 3.46 – 3.32 (m, 1H), 2.96 (d, *J* = 6.0 Hz, 1H), 2.80 – 2.70 (m, 1H), 2.69 – 2.60 (m, 1H), 2.47 – 2.36 (m, 1H), 1.94 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.5, 197.4, 195.9, 152.1, 140.5, 136.3, 133.5, 131.3, 131.3, 129.2, 128.6, 127.9, 81.4, 73.0, 63.7, 46.7, 38.2, 37.1, 34.7, 28.9. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{23}FNaO_5]^+$: 461.1126, found: 461.1133; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 22.70 min and t_{minor} = 36.16 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-(4-fluorobenzoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3c)

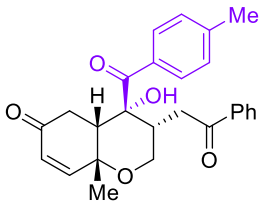


3c

Followed the general procedure, using **1c** (0.2 mmol, 30.8 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3c** as a white solid (55.7 mg, 66% yield, >20:1 dr); $[\alpha]_D^{20}$ = -63.3 (c = 0.4, DCM, 99% ee); **m.p.** = 113.9-115.3 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 – 8.05 (m, 2H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.55 – 7.46 (m, 1H), 7.36 (t, *J* = 7.6 Hz, 2H), 7.18 (t, *J* = 8.4 Hz, 2H), 6.68 (dd, *J* = 10.4, 1.3 Hz, 1H), 6.06 (d,

J = 10.4 Hz, 1H), 4.70 (s, 1H), 3.85 (m, *J* = 11.3, 4.4 Hz, 1H), 3.68 (t, *J* = 11.0 Hz, 1H), 3.48 – 3.32 (m, 1H), 2.98 (d, *J* = 6.0 Hz, 1H), 2.75 (m, *J* = 18.3, 7.9 Hz, 1H), 2.61 (m, *J* = 18.3, 3.9 Hz, 1H), 2.42 (m, *J* = 17.4, 6.1 Hz, 1H), 1.95 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 200.8, 197.4, 196.0, 165.9 (d, *J* = 258.56Hz), 152.1, 136.3, 133.4, 132.9, 132.8, 131.3, 128.6, 127.9, 116.2 (d, *J* = 22.22Hz), 81.3, 73.0, 63.7, 46.8, 38.3, 37.1, 34.7, 28.9. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -102.61. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{23}FNaO_5]^+$: 445.1422, found: 445.1426; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 21.21 min and t_{minor} = 29.70 min.

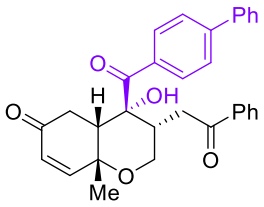
(3*R*,4*R*,4a*R*,8a*R*)-4-hydroxy-8a-methyl-4-(4-methylbenzoyl)-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3d)



3d

Followed the general procedure, using **1d** (0.2 mmol, 30.0 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3d** as a white solid (35.1 mg, 42% yield, >20:1 dr); $[\alpha]_D^{20}$ = -69.4 (c = 0.7, DCM, 98% ee); **m.p.** = 153.4-154.6 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.3 Hz, 2H), 7.84 – 7.69 (m, *J* = 8.3, 1.1 Hz, 2H), 7.56 – 7.44 (m, 1H), 7.39 – 7.28 (m, 4H), 6.69 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.77 (s, 1H), 3.95 – 3.85 (m, *J* = 11.3, 4.4 Hz, 1H), 3.68 (t, *J* = 11.0 Hz, 1H), 3.54 – 3.37 (m, 1H), 3.07 (d, *J* = 6.0 Hz, 1H), 2.87 – 2.68 (m, *J* = 18.2, 8.7 Hz, 1H), 2.64 – 2.53 (m, *J* = 18.1, 3.4 Hz, 1H), 2.48 – 2.32 (m, 4H), 1.97 (d, *J* = 17.4 Hz, 1H), 1.52 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.6, 197.4, 196.2, 152.2, 145.2, 136.4, 133.3, 131.3, 130.2, 129.9, 129.6, 128.6, 127.9, 81.2, 73.0, 63.7, 46.8, 38.3, 37.1, 34.7, 28.9, 21.7. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{26}H_{26}NaO_5]^+$: 441.1672, found: 441.1677; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 23.76 min and t_{minor} = 34.51 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-([1,1'-biphenyl]-4-carbonyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3e)

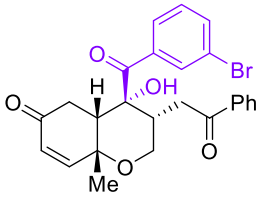


3e

Followed the general procedure, using **1e** (0.2 mmol, 42.4 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3e** as a yellow solid (77.8 mg, 81% yield, >20:1 dr); $[\alpha]_D^{20}$ = -80.5 (c = 0.9, DCM, 93% ee); **m.p.** = 72.3-74.1 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 8.5 Hz, 2H), 7.79 – 7.71 (m, 4H), 7.66 – 7.61 (m, 2H), 7.53 – 7.46 (m, *J* = 10.4, 4.2 Hz, 3H), 7.45 – 7.40 (m, 1H), 7.35 (t, *J* = 7.7 Hz, 2H), 6.71 (dd, *J* = 10.4, 1.4 Hz, 1H), 6.08 (d, 1H), 4.77 (s, 1H), 3.95 – 3.86 (m, *J* = 11.3, 4.4 Hz, 1H), 3.70 (t, *J* =

11.0 Hz, 1H), 3.59 – 3.42 (m, 1H), 3.11 (d, *J* = 6.0 Hz, 1H), 2.88 – 2.73 (m, *J* = 18.2, 8.5 Hz, 1H), 2.70 – 2.58 (m, *J* = 18.2, 3.5 Hz, 1H), 2.53 – 2.41 (m, *J* = 17.4, 6.1 Hz, 1H), 2.01 (d, *J* = 17.4 Hz, 1H), 1.54 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.7, 197.5, 196.3, 152.3, 146.6, 139.2, 136.4, 133.4, 131.3, 131.3, 130.7, 129.1, 128.7, 128.6, 128.0, 127.5, 127.3, 81.4, 73.1, 63.7, 46.8, 38.3, 37.2, 34.8, 29.0. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{31}H_{28}NaO_5]^+$: 503.1829, found: 503.1837; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 34.01 min and t_{minor} = 52.52 min.

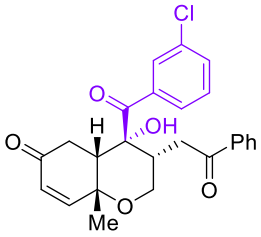
(3*R*,4*R*,4a*R*,8a*R*)-4-(3-bromobenzoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3f)



3f

Followed the general procedure, using **1f** (0.2 mmol, 42.8 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3f** as a light yellow solid (50.1 mg, 52% yield, >20:1 dr); $[\alpha]_D^{20}$ = -43.8 (c = 0.4, DCM, 99% ee); **m.p.** = 136,0-136.9 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 (t, *J* = 1.6 Hz, 1H), 8.07 (d, *J* = 7.9 Hz, 1H), 7.81 – 7.70 (m, 3H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.44 – 7.36 (m, *J* = 8.2 Hz, 3H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.60 (s, 1H), 3.92 – 3.80 (m, *J* = 11.4, 4.4 Hz, 1H), 3.69 (t, *J* = 11.0 Hz, 1H), 3.49 – 3.30 (m, *J* = 10.9, 7.0 Hz, 1H), 2.94 (d, *J* = 6.0 Hz, 1H), 2.79 – 2.63 (m, *J* = 18.3, 6.0 Hz, 2H), 2.51 – 2.40 (m, *J* = 17.4, 6.1 Hz, 1H), 1.95 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.8, 197.4, 195.9, 152.2, 136.6, 136.3, 135.0, 133.5, 132.8, 131.3, 130.3, 128.6, 127.9, 123.3, 81.7, 72.9, 63.6, 46.8, 38.0, 37.2, 34.7, 28.9. **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{23}BrNaO_5]^+$: 505.0621, found: 505.0623; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 17.18 min and t_{minor} = 24.40 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-(3-chlorobenzoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(*5H*)-one (3g)

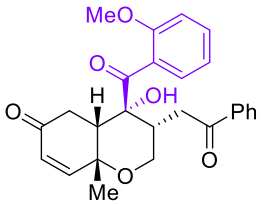


3g

Followed the general procedure, using **1g** (0.2 mmol, 34.0 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3g** as a bright yellow solid (50.8 mg, 58% yield, >20:1 dr); $[\alpha]_D^{20}$ = -11.3 (c = 0.2, DCM, 98% ee); **m.p.** = 66.5-67.8 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 – 7.95 (m, *J* = 3.7, 1.9 Hz, 2H), 7.78 (d, *J* = 7.3 Hz, 2H), 7.63 – 7.57 (m, *J* = 8.0, 0.7 Hz, 1H), 7.55 – 7.44 (m, *J* = 12.0, 11.5, 5.1 Hz, 2H), 7.38 (t, *J* = 7.7 Hz, 2H), 6.69 (dd, *J* = 10.4, 1.4 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.61 (s, 1H), 3.89 – 3.81 (m, *J* = 11.4, 4.4 Hz, 1H), 3.69 (t, *J* = 11.0 Hz, 1H), 3.46 – 3.33 (m, 1H), 2.95 (d, *J* = 5.9 Hz, 1H), 2.83 – 2.61 (m, *J* = 18.3, 6.0 Hz, 2H), 2.54 – 2.39 (m, *J* = 17.4, 6.1 Hz, 1H), 1.96 (d, *J* = 17.4 Hz, 1H), 1.52 (s,

3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.8, 197.4, 195.9, 152.2, 136.3, 135.3, 134.8, 133.7, 133.5, 131.3, 130.1, 129.9, 128.6, 127.9, 127.6, 81.7, 72.9, 63.6, 46.5, 38.0, 37.2, 34.7, 28.9. **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{25}H_{23}ClNaO_5]^+$: 461.1126, found: 461.1131; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 16.64 min and t_{minor} = 24.00 min.

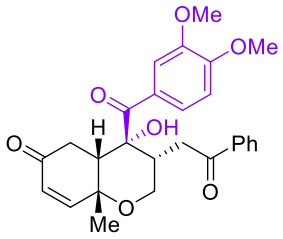
(3*R*,4*R*,4a*R*,8a*R*)-4-hydroxy-4-(2-methoxybenzoyl)-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3h)



3h

Followed the general procedure, using **1h** (0.2 mmol, 33.2 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3h** as a light yellow solid (31.2 mg, 36% yield, >20:1 dr); $[\alpha]_D^{20}$ = 12.1 (c = 0.2, DCM, 92% ee); **m.p.** = 84.9-85.7 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 7.3 Hz, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 3H), 7.16 – 7.10 (m, *J* = 7.6, 1.5 Hz, 1H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.95 (d, *J* = 8.4 Hz, 1H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.08 (d, *J* = 10.3 Hz, 1H), 4.47 (s, 1H), 3.87 – 3.76 (m, *J* = 11.2, 4.4 Hz, 1H), 3.66 (s, 3H), 3.50 (t, *J* = 11.0 Hz, 1H), 3.17 – 3.01 (m, *J* = 14.8, 8.2, 4.1 Hz, 1H), 2.85 – 2.73 (m, 3H), 2.63 – 2.52 (m, *J* = 17.5, 6.1 Hz, 1H), 2.38 (d, *J* = 17.5 Hz, 1H), 1.43 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 208.1, 197.6, 196.8, 156.1, 152.9, 136.7, 133.4, 132.2, 131.2, 128.7, 127.9, 127.7, 126.3, 120.9, 111.7, 83.5, 72.6, 63.3, 55.6, 44.2, 37.8, 35.5, 35.1, 28.7. **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{26}H_{26}NaO_6]^+$: 457.1622, found: 457.1629; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 44.50 min and t_{minor} = 25.51 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-(3,4-dimethoxybenzoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3i)

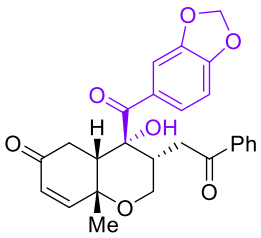


3i

Followed the general procedure, using **1i** (0.2 mmol, 39.2 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3i** as a yellow solid (58.5 mg, 63% yield, >20:1 dr); $[\alpha]_D^{20}$ = -83.6 (c = 0.6, DCM, 86% ee); **m.p.** = 135.6-136.8 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.96 – 7.91 (m, *J* = 8.6, 2.0 Hz, 1H), 7.79 – 7.74 (m, 2H), 7.64 (d, *J* = 2.0 Hz, 1H), 7.51 (t, *J* = 7.4 Hz, 1H), 7.36 (t, *J* = 7.7 Hz, 2H), 6.94 (d, *J* = 8.6 Hz, 1H), 6.70 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.08 (d, *J* = 10.4 Hz, 1H), 4.89 – 4.82 (m, 1H), 3.98 (s, 3H), 3.94 (s, 3H), 3.92 – 3.87 (m, *J* = 11.3, 4.4 Hz, 1H), 3.68 (t, *J* = 11.0 Hz, 1H), 3.52 – 3.41 (m, *J* = 11.9, 7.2 Hz, 1H), 3.12 (d, *J* = 5.8 Hz, 1H), 2.83 – 2.73 (m, *J* = 18.2, 8.9 Hz, 1H), 2.59 – 2.50 (m, *J* = 18.1, 2.7 Hz, 1H), 2.49 – 2.38 (m, *J* = 17.4, 6.1 Hz, 1H), 2.00 (d, *J* = 17.4 Hz, 1H), 1.53 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.9, 197.5, 196.3, 154.1, 152.2, 149.2, 136.4, 133.3, 131.3, 128.6, 128.0, 127.9, 124.9, 112.7,

110.1, 81.1, 73.1, 63.8, 56.2, 56.1, 47.4, 38.9, 37.2, 34.8, 29.1; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{27}H_{28}NaO_7]^+$: 487.1727, found: 487.1730; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 42.09 min and t_{minor} = 47.13 min.

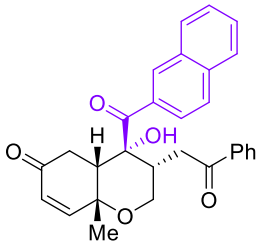
(3*R*,4*R*,4a*R*,8a*R*)-4-(benzo[d][1,3]dioxole-5-carbonyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3j)



3j

Followed the general procedure, using **1a** (0.2 mmol, 36.0 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3j** as a light yellow solid (41.2 mg, 46% yield, >20:1 dr); $[\alpha]_D^{20}$ = -95.6 (c = 0.2, DCM, 99% ee); **m.p.** = 100.0-100.8 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.84 (m, *J* = 8.3, 1.7 Hz, 1H), 7.80 – 7.73 (m, 2H), 7.61 (d, *J* = 1.7 Hz, 1H), 7.51 (t, *J* = 7.4 Hz, 1H), 7.37 (t, *J* = 7.7 Hz, 2H), 6.90 (d, *J* = 8.3 Hz, 1H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.07 (d, *J* = 9.5 Hz, 3H), 4.82 (s, 1H), 3.92 – 3.84 (m, *J* = 11.3, 4.4 Hz, 1H), 3.66 (t, *J* = 11.0 Hz, 1H), 3.49 – 3.30 (m, 1H), 3.06 (d, *J* = 6.0 Hz, 1H), 2.81 – 2.69 (m, *J* = 18.2, 8.6 Hz, 1H), 2.61 – 2.50 (m, *J* = 18.2, 3.3 Hz, 1H), 2.47 – 2.36 (m, *J* = 17.4, 6.1 Hz, 1H), 1.97 (d, *J* = 17.4 Hz, 1H), 1.53 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.7, 197.5, 196.2, 152.6, 152.2, 148.4, 136.4, 133.4, 131.3, 128.6, 127.9, 126.9, 110.0, 108.2, 102.3, 81.1, 73.1, 63.8, 47.1, 38.6, 37.2, 34.8, 29.0; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{26}H_{24}NaO_7]^+$: 471.1414, found: 471.1423; **HPLC**: Daicel Chiralpak IB, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 16.53 min and t_{minor} = 28.72 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-(2-naphthoyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3k)

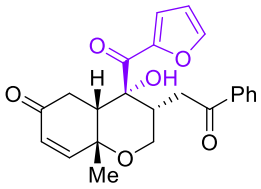


3k

Followed the general procedure, using **1k** (0.2 mmol, 37.2 mg), **2a** (0.2 mmol, 53,6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3k** as a white solid (63.6 mg, 70% yield, >20:1 dr); $[\alpha]_D^{20}$ = -113.4 (c = 0.6, DCM, 91% ee); **m.p.** = 88.9-91.1 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.22 – 8.09 (m, *J* = 8.7, 1.5 Hz, 1H), 8.01 (d, *J* = 8.1 Hz, 1H), 7.98 – 7.85 (m, *J* = 19.6, 8.4 Hz, 2H), 7.74 (d, *J* = 7.5 Hz, 2H), 7.69 – 7.55 (m, *J* = 23.8, 7.3 Hz, 2H), 7.46 (t, *J* = 7.4 Hz, 1H), 7.30 (t, *J* = 7.7 Hz, 2H), 6.71 (d, *J* = 10.4 Hz, 1H), 6.09 (d, *J* = 10.4 Hz, 1H), 4.81 (s, 1H), 3.93 (m, *J* = 11.2, 4.2 Hz, 1H), 3.74 (t, *J* = 10.9 Hz, 1H), 3.67 – 3.52 (m, 1H), 3.15 (d, *J* = 5.8 Hz, 1H), 2.87 – 2.75 (m, *J* = 18.1, 8.1 Hz, 1H), 2.74 – 2.63 (m, *J* = 18.1, 3.7 Hz, 1H), 2.48 – 2.32 (m, *J* = 17.4, 6.1 Hz, 1H), 2.03 (d, *J* = 17.4 Hz, 1H), 1.52 (s, 3H); **^{13}C NMR** (101 MHz,

$CDCl_3$) δ 202.4, 197.5, 196.3, 152.3, 136.4, 135.5, 133.4, 132.3, 131.9, 131.3, 130.3, 130.1, 129.4, 128.8, 128.6, 127.9, 127.7, 127.3, 125.1, 81.6, 73.1, 63.8, 46.8, 38.4, 37.2, 34.8, 29.0; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{29}H_{26}NaO_5]^+$: 477.1672, found: 477.1678; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 33.42 min and t_{minor} = 41.71 min.

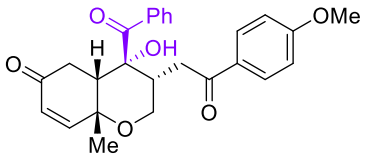
(3*R*,4*R*,4a*R*,8a*R*)-4-(furan-2-carbonyl)-4-hydroxy-8a-methyl-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3l)



3l

Followed the general procedure, using **1l** (0.2 mmol, 25.2 mg), **2a** (0.2 mmol, 53.6 mg) and **L1** (0.02 mmol, 12.8 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3l** as a yellow solid (64.6 mg, 82% yield, >20:1 dr); $[\alpha]_D^{20}$ = -81.0 (c = 0.4, DCM, 90% ee); **m.p.** = 67.9-69.5 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.77 – 7.70 (m, 3H), 7.55 – 7.47 (m, *J* = 9.4, 5.3 Hz, 2H), 7.37 (t, *J* = 7.7 Hz, 2H), 6.71 (dd, *J* = 10.4, 1.2 Hz, 1H), 6.65 (d, *J* = 2.0 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.48 (s, 1H), 3.99 – 3.78 (m, *J* = 11.3, 4.2 Hz, 1H), 3.65 (t, *J* = 11.1 Hz, 1H), 3.40 (s, 1H), 3.14 (d, *J* = 3.9 Hz, 1H), 2.81 – 2.62 (m, *J* = 17.8, 9.0 Hz, 1H), 2.57 – 2.44 (m, *J* = 17.5, 6.0 Hz, 2H), 2.03 (d, *J* = 17.4 Hz, 1H), 1.55 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 197.5, 196.4, 189.5, 152.5, 149.7, 147.7, 136.4, 133.3, 131.2, 128.6, 127.9, 122.5, 113.1, 80.5, 72.8, 63.4, 45.5, 37.2, 37.0, 34.7, 28.9. **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{23}H_{22}NaO_6]^+$: 417.1309, found: 417.1314; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 11.40 min and t_{minor} = 15.70 min.

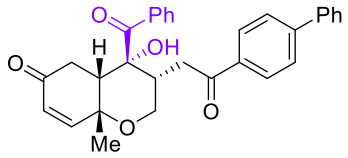
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-4-hydroxy-3-(2-(4-methoxyphenyl)-2-oxoethyl)-8a-methyl-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3m)



3m

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2b** (0.2 mmol, 59.6 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3m** as a yellow solid (46.0 mg, 46% yield, >20:1 dr); $[\alpha]_D^{20}$ = -63.8 (c = 0.4, DCM, 90% ee); **m.p.** = 59.1-63.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.17 – 8.05 (m, 2H), 7.80 – 7.73 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.52 (t, *J* = 7.7 Hz, 2H), 6.83 (d, *J* = 8.9 Hz, 2H), 6.69 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.70 (s, 1H), 3.92 – 3.80 (m, 4H), 3.67 (t, *J* = 11.0 Hz, 1H), 3.50 – 3.37 (m, 1H), 3.02 (d, *J* = 6.0 Hz, 1H), 2.79 – 2.65 (m, 1H), 2.59 – 2.50 (m, 1H), 2.47 – 2.37 (m, 1H), 1.98 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.7, 196.2, 195.9, 163.8, 152.3, 133.8, 133.1, 131.3, 130.3, 129.8, 129.5, 128.9, 113.7, 81.6, 72.9, 63.7, 55.8, 46.6, 38.2, 37.2, 34.3, 28.9; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{26}H_{26}NaO_6]^+$: 457.1622, found: 457.1630; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 30.08 min and t_{minor} = 53.48 min.

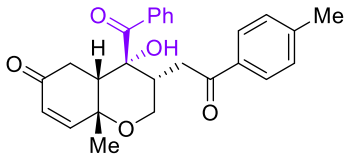
(3*R*,4*R*,4a*R*,8a*R*)-3-(2-([1,1'-biphenyl]-4-yl)-2-oxoethyl)-4-benzoyl-4-hydroxy-8a-methyl-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3n)



3n

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2c** (0.2 mmol, 68.8 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3n** as a yellow solid (38.4 mg, 40% yield, >20:1 dr); $[\alpha]_D^{20}$ = -93.0 (c = 0.4, DCM, 99% ee); **m.p.** = 189.0-190.1 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 – 8.09 (m, 2H), 7.83 (d, *J* = 8.4 Hz, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.60 – 7.49 (m, 6H), 7.45 (t, 2H), 7.38 (t, *J* = 7.3 Hz, 1H), 6.70 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.08 (d, *J* = 10.4 Hz, 1H), 4.73 (s, 1H), 3.98 – 3.82 (m, 1H), 3.70 (t, *J* = 11.0 Hz, 1H), 3.59 – 3.39 (m, 1H), 3.05 (d, *J* = 6.0 Hz, 1H), 2.86 – 2.72 (m, 1H), 2.68 – 2.57 (m, 1H), 2.50 – 2.37 (m, 1H), 1.99 (d, *J* = 17.4 Hz, 1H), 1.52 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.6, 197.0, 196.2, 152.3, 146.1, 139.7, 135.1, 133.9, 132.9, 131.3, 129.9, 128.9, 128.9, 128.6, 128.3, 127.2, 127.2, 81.5, 73.0, 63.7, 46.6, 38.2, 37.2, 34.8, 28.9; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{31}H_{28}NaO_5]^+$: 503.1829, found: 503.1837; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 33.35 min and t_{minor} = 60.89 min.

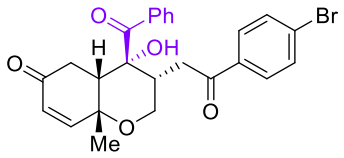
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-4-hydroxy-8a-methyl-3-(2-oxo-2-(p-tolyl)ethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3o)



3o

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2d** (0.2 mmol, 56.4 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3o** as an orange solid (58.5 mg, 70% yield, >20:1 dr); $[\alpha]_D^{20}$ = -99.6 (c = 0.2, DCM, 95% ee); **m.p.** = 68.4-70.1 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.7 Hz, 2H), 7.77 – 7.58 (m, 3H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.16 (d, *J* = 8.0 Hz, 2H), 6.69 (d, *J* = 10.4 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.70 (s, 1H), 3.96 – 3.80 (m, 1H), 3.67 (t, *J* = 11.0 Hz, 1H), 3.50 – 3.37 (m, 1H), 3.03 (d, *J* = 5.7 Hz, 1H), 2.82 – 2.70 (m, 1H), 2.61 – 2.53 (m, 1H), 2.47 – 2.38 (m, 1H), 2.36 (s, 3H), 1.98 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.6, 202.2, 197.1, 196.2, 152.3, 144.3, 133.9, 133.8, 133.0, 131.3, 129.8, 129.3, 128.9, 128.1, 81.5, 72.9, 63.7, 46.6, 38.2, 37.2, 34.6, 28.9, 21.6; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{26}H_{26}NaO_5]^+$: 441.1672, found: 441.1680; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 20.58 min and t_{minor} = 37.41 min.

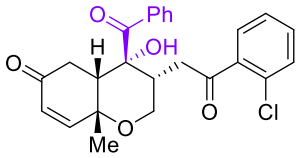
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-3-(2-(4-bromophenyl)-2-oxoethyl)-4-hydroxy-8a-methyl-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3p)



3p

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2e** (0.2 mmol, 69.2 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3p** as a yellow solid (65.6 mg, 68% yield, >20:1 dr); $[\alpha]_D^{20}$ = -78.6 (c = 0.6, DCM, 89% ee); **m.p.** = 57.1-58.0 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.5 Hz, 2H), 7.68 – 7.58 (m, 3H), 7.56 – 7.46 (m, 4H), 6.69 (dd, *J* = 10.4, 1.4 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.69 (s, 1H), 3.92 – 3.79 (m, 1H), 3.67 (t, *J* = 11.0 Hz, 1H), 3.53 – 3.36 (m, 1H), 3.04 (d, *J* = 6.0 Hz, 1H), 2.79 – 2.65 (m, 1H), 2.62 – 2.52 (m, 1H), 2.49 – 2.36 (m, 1H), 1.97 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.4, 196.4, 196.1, 152.1, 135.1, 133.9, 131.9, 131.3, 129.8, 129.5, 128.9, 128.6, 81.4, 73.0, 63.6, 46.6, 38.1, 37.1, 34.7, 28.9; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{23}BrNaO_5]^+$: 505.0621, found: 505.0630; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 26.06 min and t_{minor} = 36.18 min.

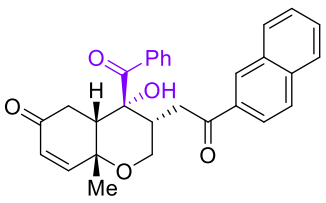
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-3-(2-(2-chlorophenyl)-2-oxoethyl)-4-hydroxy-8a-methyl-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3q)



3q

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2f** (0.2 mmol, 60.4 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3q** as a yellow solid (54.3 mg, 62% yield, >20:1 dr); $[\alpha]_D^{20}$ = -40.5 (c = 0.4, DCM, 95% ee); **m.p.** = 60.4-61.4 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.14 – 8.05 (m, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.34 – 7.28 (m, 2H), 7.25 – 7.16 (m, 2H), 6.68 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.06 (d, *J* = 10.4, 0.6 Hz, 1H), 4.63 (s, 1H), 4.00 – 3.89 (m, 1H), 3.78 – 3.63 (m, 1H), 3.50 – 3.31 (m, 1H), 3.03 (d, *J* = 6.1 Hz, 1H), 2.81 – 2.67 (m, 1H), 2.65 – 2.54 (m, 1H), 2.51 – 2.36 (m, 1H), 1.96 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.4, 200.9, 196.1, 152.1, 138.8, 133.9, 132.9, 131.9, 131.3, 130.6, 130.5, 129.8, 128.9, 128.6, 126.9, 81.3, 73.0, 63.6, 46.5, 39.3, 38.4, 37.1, 28.9; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{25}H_{23}ClNaO_5]^+$: 461.1126, found: 461.1137; **HPLC**: Daicel Chiralpak IC, *n*-hexane/*i*-PrOH = 70/30, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 26.60 min and t_{minor} = 19.12 min.

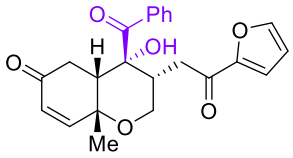
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-4-hydroxy-8a-methyl-3-(2-(naphthalen-2-yl)-2-oxoethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3r)



3r

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2g** (0.2 mmol, 63.6 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3r** as a light yellow solid (59.9 mg, 66% yield, >20:1 dr); $[\alpha]_D^{20}$ = -180.3 (c = 0.4, DCM, 93% ee); **m.p.** = 146.6-148.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.25 (s, 1H), 8.13 (d, *J* = 7.5 Hz, 2H), 7.86 – 7.76 (m, 4H), 7.65 – 7.46 (m, 5H), 6.70 (dd, *J* = 10.4, 1.4 Hz, 1H), 6.09 (d, *J* = 10.4 Hz, 1H), 4.77 (s, 1H), 3.99 – 3.85 (m, 1H), 3.73 (t, *J* = 11.0 Hz, 1H), 3.60 – 3.45 (m, 1H), 3.06 (d, *J* = 5.9 Hz, 1H), 2.97 – 2.83 (m, 1H), 2.81 – 2.69 (m, 1H), 2.52 – 2.37 (m, 1H), 2.00 (d, *J* = 17.4 Hz, 1H), 1.52 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.6, 197.4, 196.1, 152.2, 135.6, 133.9, 133.7, 133.0, 132.4, 131.3, 129.8, 129.8, 129.6, 128.9, 128.6, 128.5, 127.7, 126.8, 123.6, 81.6, 73.0, 63.7, 46.6, 38.3, 37.2, 34.8, 28.9; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{29}H_{26}NaO_5]^+$: 477.1672, found: 477.1682; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 22.41 min and t_{minor} = 32.28 min.

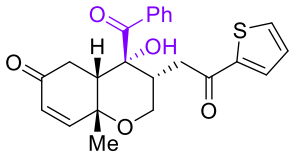
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-3-(2-(furan-2-yl)-2-oxoethyl)-4-hydroxy-8a-methyl-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3s)



3s

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2h** (0.2 mmol, 51.6 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3s** as a light yellow solid (35.5 mg, 45% yield, >20:1 dr); $[\alpha]_D^{20}$ = -51.3 (c = 0.2, DCM, 99% ee); **m.p.** = 74.8-76.1 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.15 – 8.06 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.44 (d, *J* = 1.0 Hz, 1H), 7.04 (d, *J* = 3.5 Hz, 1H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.45 (dd, *J* = 3.6, 1.6 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.68 (s, 1H), 3.91 – 3.80 (m, 1H), 3.69 (t, *J* = 11.0 Hz, 1H), 3.49 – 3.30 (m, 1H), 3.02 (d, *J* = 6.0 Hz, 1H), 2.69 – 2.56 (m, 1H), 2.52 – 2.38 (m, 2H), 1.98 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.4, 196.1, 186.6, 152.2, 146.5, 133.8, 132.9, 131.3, 129.8, 128.9, 117.4, 112.3, 100.0, 81.4, 72.9, 63.6, 46.6, 37.9, 37.16, 34.7, 28.9. **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{23}H_{22}NaO_6]^+$: 417.1309 , found: 417.1315 ; **HPLC**: Daicel Chiralpak IB, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 14.35 min and t_{minor} = 19.39 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-4-hydroxy-8a-methyl-3-(2-oxo-2-(thiophen-2-yl)ethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3t)

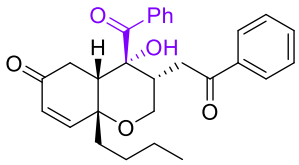


3t

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2i** (0.2 mmol, 54.8 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3t** as a yellow solid (43.5 mg, 53% yield, >20:1 dr); $[\alpha]_D^{20}$ = -46.4 (c = 0.1, DCM, 94% ee); **m.p.** = 76.1-78.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.5 Hz, 2H), 7.64 (t, *J* = 7.4 Hz, 1H),

7.60 – 7.56 (m, 1H), 7.56 – 7.47 (m, 3H), 7.06 – 7.00 (m, 1H), 6.69 (dd, *J* = 10.4, 1.5 Hz, 1H), 6.07 (d, *J* = 10.4 Hz, 1H), 4.70 (s, 1H), 3.94 – 3.84 (m, 1H), 3.69 (t, *J* = 11.0 Hz, 1H), 3.51 – 3.36 (m, 1H), 3.02 (d, *J* = 6.0 Hz, 1H), 2.78 – 2.66 (m, 1H), 2.59 – 2.48 (m, 1H), 2.48 – 2.38 (m, 1H), 1.98 (d, *J* = 17.4 Hz, 1H), 1.51 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.4, 196.2, 190.3, 152.2, 143.7, 134.1, 133.9, 132.9, 132.2, 131.3, 129.8, 129.0, 128.2, 81.4, 72.9, 63.6, 46.6, 38.3, 37.2, 35.4, 28.9; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{23}H_{22}NaO_5S]^+$: 433.1080, found: 433.1082; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 24.86 min and t_{minor} = 34.66 min.

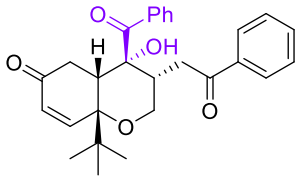
(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-8a-butyl-4-hydroxy-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3u)



3u

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2j** (0.2 mmol, 62.0 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3u** as a yellow solid (58.9 mg, 66% yield, >14:1 dr); $[\alpha]_D^{20}$ = -24.5 (c = 0.6, DCM, 97% ee); **m.p.** = 70.4-71.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 – 8.09 (m, 2H), 7.80 – 7.72 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.55 – 7.48 (m, 3H), 7.36 (t, *J* = 7.7 Hz, 2H), 6.74 (dd, *J* = 10.5, 1.5 Hz, 1H), 6.10 (d, *J* = 10.4 Hz, 1H), 4.70 (s, 1H), 3.93 – 3.83 (m, 1H), 3.67 (t, *J* = 11.0 Hz, 1H), 3.51 – 3.36 (m, 1H), 3.13 (d, *J* = 6.1 Hz, 1H), 2.83 – 2.73 (m, 1H), 2.64 – 2.54 (m, 1H), 2.44 – 2.33 (m, 1H), 1.94 (d, *J* = 17.5 Hz, 1H), 1.88 – 1.79 (m, 1H), 1.73 – 1.63 (m, 1H), 1.55 – 1.44 (m, 2H), 1.37 – 1.29 (m, 2H), 0.92 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.5, 197.5, 196.5, 152.4, 136.4, 133.9, 133.4, 132.8, 131.5, 129.9, 128.9, 128.6, 127.9, 81.6, 77.1, 76.8, 74.7, 63.5, 44.3, 41.6, 38.1, 36.9, 34.7, 25.3, 23.1, 14.1; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for $[C_{28}H_{30}NaO_5]^+$: 469.1985, found: 469.1991; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, major product: t_{major} = 14.63 min and t_{minor} = 21.85 min. minor product: t_{major} = 11.40 min and t_{minor} = 19.55 min.

(3*R*,4*R*,4a*R*,8a*R*)-4-benzoyl-8a-(tert-butyl)-4-hydroxy-3-(2-oxo-2-phenylethyl)-3,4,4a,8a-tetrahydro-2*H*-chromen-6(5*H*)-one (3v)

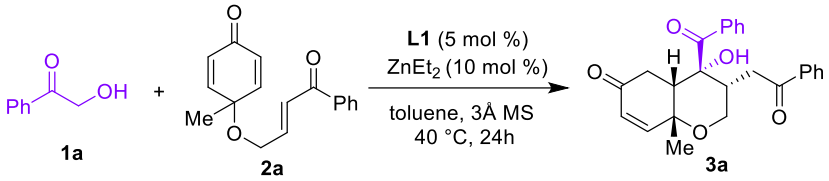


3v

Followed the general procedure, using **1a** (0.2 mmol, 29.6 mg), **2k** (0.2 mmol, 62.0 mg) and **L2** (0.02 mmol, 14.0 mg). Purified by flash column chromatography (petroleum ether/ethyl acetate 4:1) to afforded **3v** as a white solid (46.4 mg, 52% yield, >20:1 dr); $[\alpha]_D^{20}$ = -48.0 (c = 0.4, DCM, 98% ee); **m.p.** = 76.8-78.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.5 Hz, 2H), 7.77 (d, *J* = 7.4 Hz, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.56 – 7.47 (m, 3H), 7.36 (t, *J* = 7.7 Hz, 2H), 6.68 (dd, *J* = 10.7, 1.2 Hz, 1H), 6.27 (d, *J* = 10.7 Hz, 1H), 4.70 (s, 1H), 3.93 – 3.82 (m, 1H), 3.66 (t, *J* = 10.9 Hz, 1H), 3.42 – 3.29 (m, 2H), 2.85 – 2.70 (m, 1H), 2.62 – 2.41 (m, 2H), 1.86 (d, *J* = 18.3 Hz, 1H), 1.08 (s, 9H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.4, 197.6, 196.8, 150.2, 136.5, 134.1, 133.5, 133.4, 132.4, 130.1, 128.9, 128.6, 127.9, 82.3, 78.1,

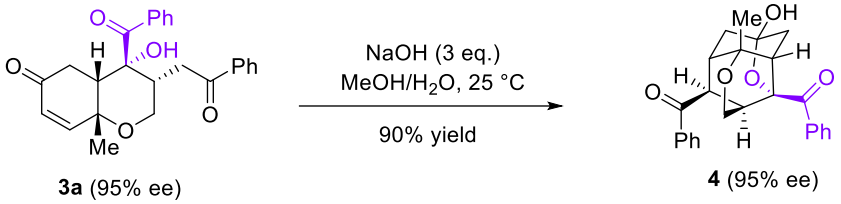
62.8, 41.3, 39.6, 38.5, 37.9, 34.7, 26.2; **HRMS** (ESI): m/z $[M + Na]^+$ calcd for $[C_{28}H_{30}NaO_5]^+$: 469.1985, found: 469.1991; **HPLC**: Daicel Chiralpak IA, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 13.76 min and t_{minor} = 21.30 min.

Scale-up reaction



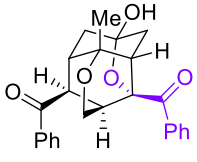
Under the nitrogen atmosphere, a solution of diethylzinc (100 μL, 1.0 M in hexane, 0.1 mmol) was added dropwise to a solution of **L1** (0.05 mmol, 35 mg) and 3A (400 mg) in toluene (6 mL). After the mixture was stirred for 60 min at 20 ℃. Then, **1a** (1 mmol, 136 mg) and **2a** (1 mmol, 268 mg) were added. The reaction mixture was stirred for 24 h at 40 ℃. First, the 3Å MS was filtered out with a sand core funnel and filtrate was quenched with NH_4Cl solution (10 mL), then the aqueous layer was extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layer was washed with brine and dried over Na_2SO_4. The solvent was removed under reduced pressure by using a rotary evaporator. The residue was purified by flash chromatography with petroleum ether/ethyl acetate (5:1) to afford the desired product **3a** (248 mg).

Derivatization



Synthesis of **4**[1]: Compound **3a** (80.8 mg, 0.2 mmol, 1 eq.) were dissolved in 3 mL of MeOH/H_2O (v:v = 1:2). Then NaOH (24 mg, 0.6 mmol, 3eq.) was added. Upon completion as shown by TLC, the reaction mixture was washed with NH_4Cl (2 mL) and extracted with CH_2Cl_2 (3 × 1 mL). The organic layer was dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by flash chromatography with petroleum ether/ethyl acetate (4:1) to give the product **4** as a white solid.

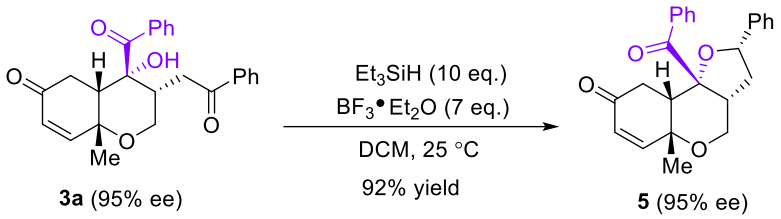
((3*R*,4*R*,4a*S*,6*S*,8*S*,8a*R*,9*S*)-6-hydroxy-8a-methyloctahydro-4*H*-4,6-epoxy-3,8-methanochromene-4,9-diyl)bis(phenylmethanone) (4)



4

White solid (72.7 mg) in 90% isolated yield; $[\alpha]_D^{20}$ = -75.6 (c = 0.6, DCM, 95% ee); **m.p.** = 195.0-196.0 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 7.6 Hz, 2H), 7.92 (d, *J* = 7.5 Hz, 2H), 7.57 – 7.49 (m, 2H), 7.45 (q, *J* = 17.2, 7.8 Hz, 4H), 4.32 (d, *J* = 4.2 Hz, 1H), 3.46 (d, *J* = 10.4 Hz, 1H), 3.42 – 3.35 (m, 1H), 3.33 – 3.24 (m, 2H), 2.93 (s, 1H), 2.86 (t, *J* = 3.7 Hz, 1H), 2.21 – 2.06 (m, 1H), 1.99 – 1.85 (m, 2H), 1.73 – 1.66 (m, 1H), 1.34 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 200.9, 196.2, 136.8, 133.4, 132.9, 130.4, 128.8, 128.4, 127.9, 108.2, 87.8, 72.5, 59.2, 46.7, 46.2, 41.7, 38.4, 38.4, 37.4, 23.3; **HRMS** (ESI):

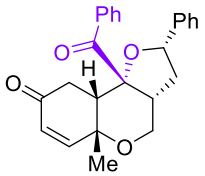
m/z [M + Na]$^+$ calcd for [$C_{25}H_{24}NaO_5$]$^+$: 427.1516, found: 427.1523; **HPLC**: Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 80/20, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 12.72 min and t_{minor} = 14.57 min.



3a (95% ee) **5** (95% ee)

Synthesis of **5**[2,3]: Compound **3a** (80.8 mg, 0.2 mmol, 1 eq.), Et_3SiH (232 mg, 2 mmol, 10 eq.) and BF_3•Et_2O (197.4 mg, 1.4 mmol, 7 eq) were add to the DCM (2 mL), and the mixture was stirred at room temperature for 3h. Upon completion as shown by TLC, the reaction mixture was washed with water (1 mL) and extracted with CH_2Cl_2 (3 × 1 mL). The organic layer was dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by flash chromatography with petroleum ether/ethyl acetate (4:1) to provide the product **5** as a light yellow solid.

(3a*R*,5a*R*,9a*S*,9b*R*)-9b-benzoyl-2-hydroxy-5a-methyl-2-phenyl-2,3,3a,9,9a,9b-hexahydro-4*H*-furo[3,2-c]chromen-8(5a*H*)-one (5a)



5

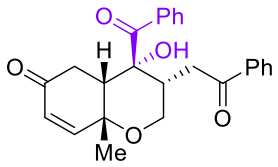
Light yellow solid (71.4 mg) in 92% isolated yield; $[\alpha]_D^{20}$ = -60.2 (c = 0.6, DCM, 95% ee); **m.p.** = 156.8-158.2 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.33 – 8.18 (m, 2H), 7.58 – 7.51 (m, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.32 – 7.26 (m, 2H), 7.24 – 7.19 (m, 1H), 7.16 (d, *J* = 7.5 Hz, 2H), 6.69 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.18 (d, *J* = 10.4 Hz, 1H), 4.78 – 4.70 (m, 1H), 3.77 – 3.61 (m, 1H), 3.32 – 3.17 (m, 1H), 3.00 – 2.88 (m, 1H), 2.85 – 2.77 (m, 2H), 2.76 – 2.69 (m, 1H), 2.31 – 2.22 (m, 1H), 1.59 – 1.49 (m, 4H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 205.7, 196.5, 153.6, 141.9, 136.6, 133.4, 130.9, 129.9, 128.9, 128.2, 127.1, 125.1, 93.9, 78.3, 77.4, 72.3, 63.1, 44.8, 41.6, 38.1, 34.2, 27.2; **HRMS** (ESI): m/z [M + Na]$^+$ calcd for [$C_{25}H_{24}NaO_4$]$^+$: 411.1567, found: 411.1569; **HPLC**: Daicel Chiralpak IF, *n*-hexane/*i*-PrOH = 70/30, flow rate = 1 mL/min, λ = 254 nm, t_{major} = 10.69 min and t_{minor} = 8.33 min.

References

1. H. Xu, Y.-X. Tan, P.-P. Xie, R. Ding, Q. Liao, J.-W. Zhang, Q.-H. Li, Y.-H. Wang, X. Hong, G.-Q. Lin and P. Tian, Rhodium(III)-Catalyzed Asymmetric Reductive Cyclization of Cyclohexadienone-Containing 1,6-Dienes via an Anti-Michael/Michael Cascade Process, *ACS Catal.*, **2021**, *11*, 8015−8022.
2. H. Yan, C. Zhang, J. J. Han, S. S. Du, Y. Z. Hua, M. C. Wang, G. J. Mei and S. K. Jia, Zinc-Catalyzed Asymmetric Cascade Michael/Acyl Transfer Reaction between α‐Hydroxy Aryl Ketones and Enynones, *Org. Lett*., **2023**, *25*, 1918−1923.
3. H.-G. Cheng, L.-Q. Lu, T. Wang, Q.-Q. Yang, X.-P. Liu, Y. Li, Q.-H. Deng, J.-R. Chen and W.-J. Xiao. Highly Enantioselective Friedel-Crafts Alkylation/N-hemi-acetalization Cascade Reactionwith Indoles. *Angew. Chem., Int. Ed.* **2013**, *52*, 3250−3254.

NMR Spectra of compounds

^{1}H NMR (400 MHz, $CDCl_3$)



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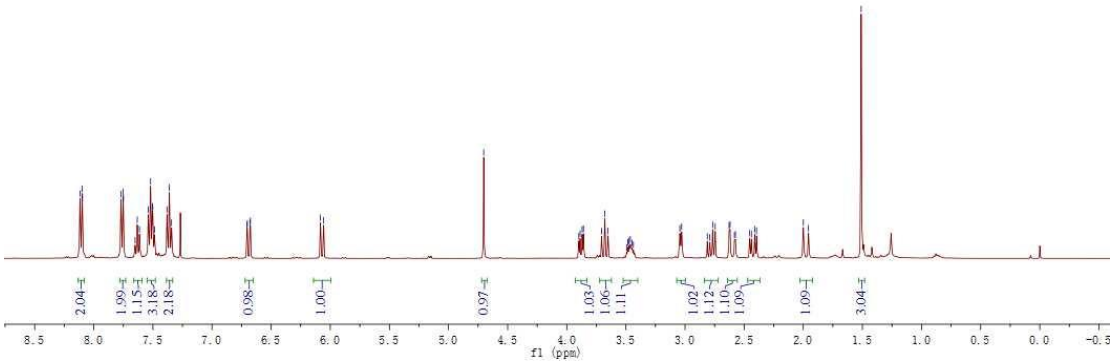
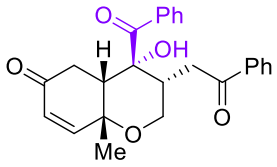


^{13}C NMR (101 MHz, $CDCl_3$)



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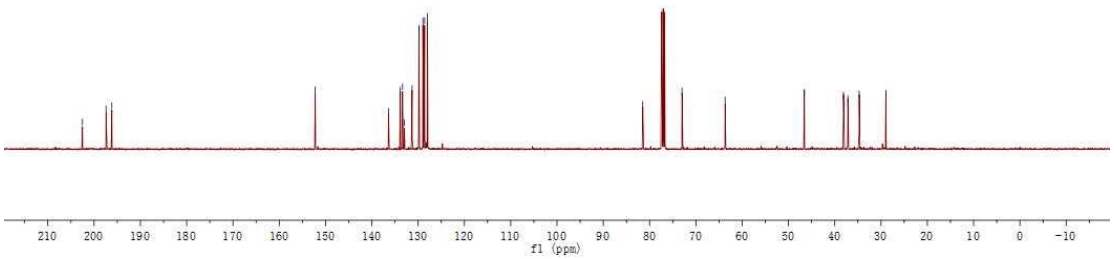
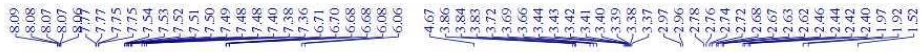
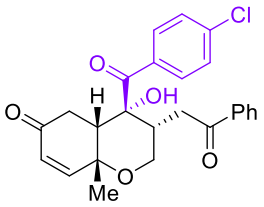


^{1}H NMR (400 MHz, $CDCl_3$)





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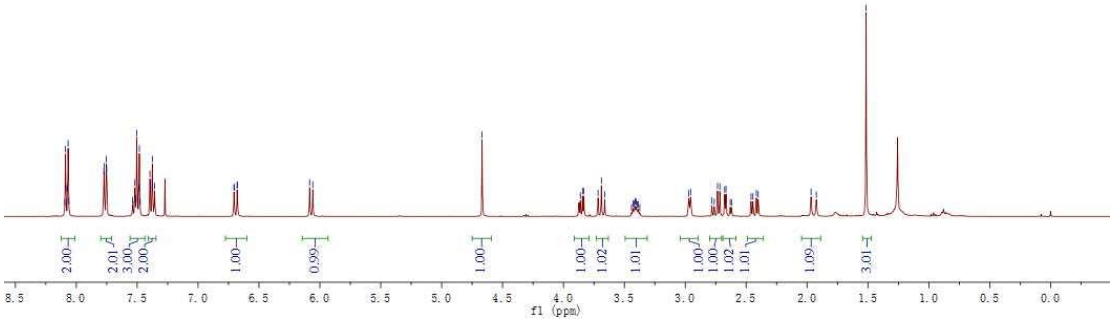
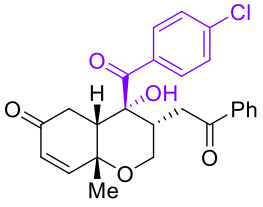


^{13}C NMR (101 MHz, $CDCl_3$)



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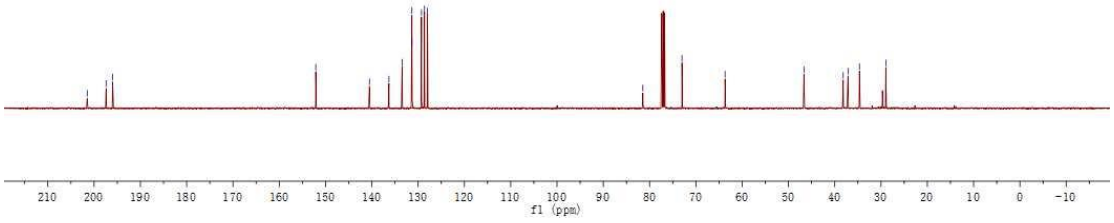

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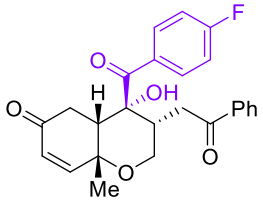

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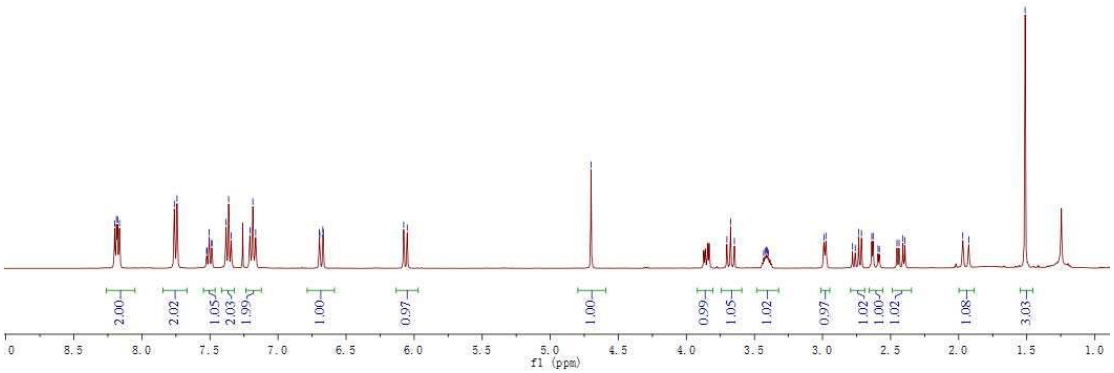

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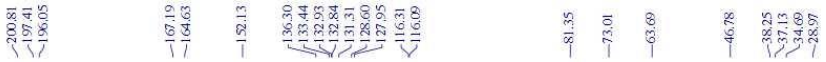

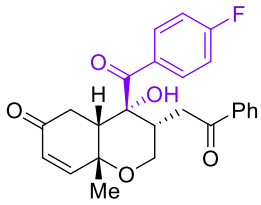

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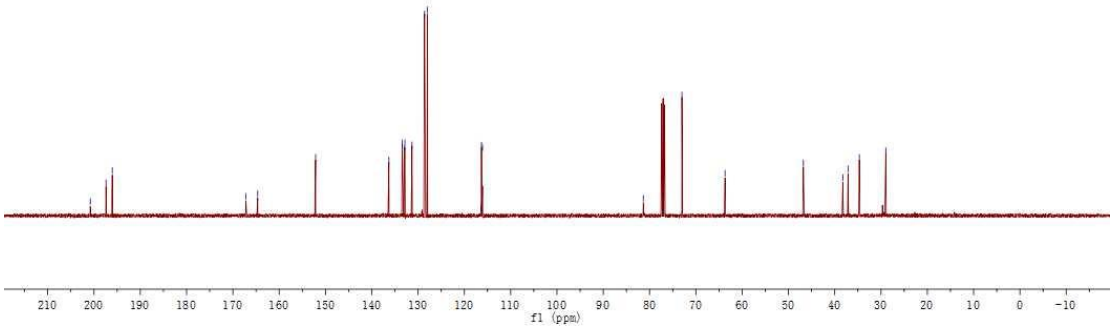
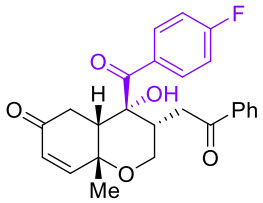


^{19}F NMR (376 MHz, $CDCl_3$)



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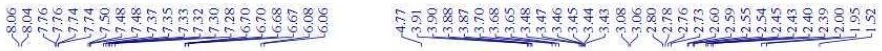

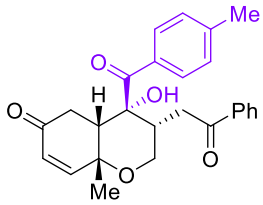

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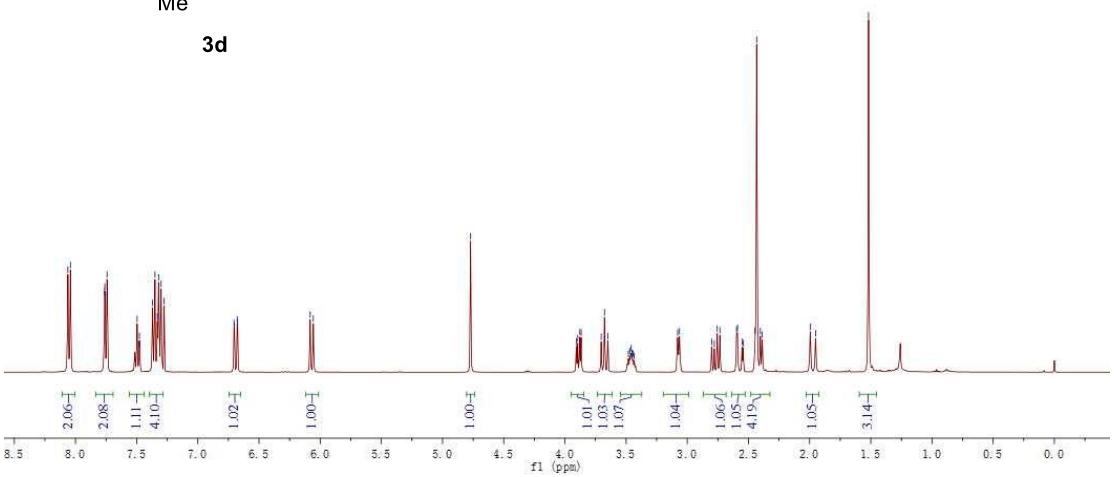
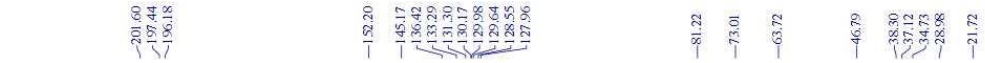
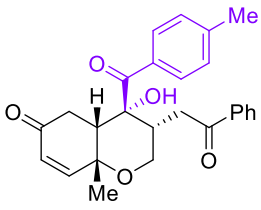


^{13}C NMR (101 MHz, $CDCl_3$)





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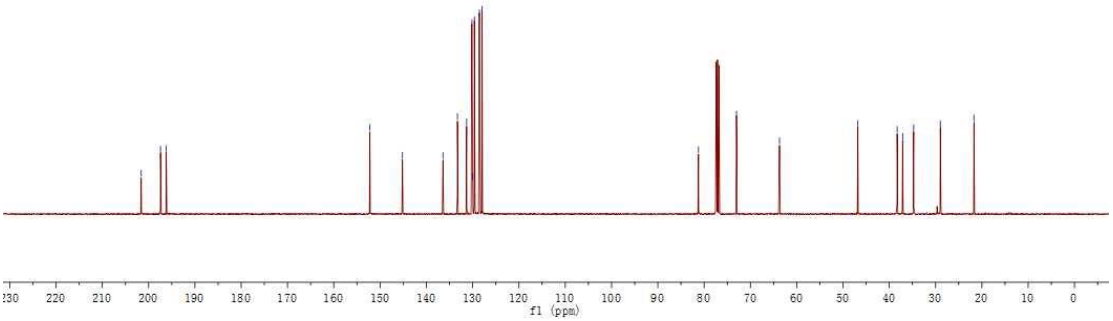
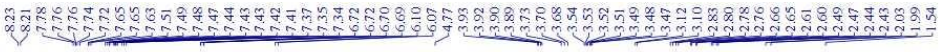
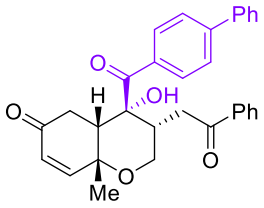


^{1}H NMR (400 MHz, $CDCl_3$)





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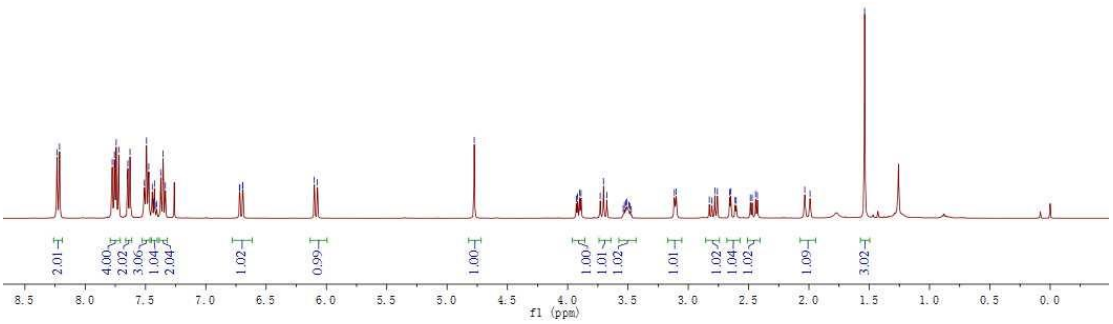

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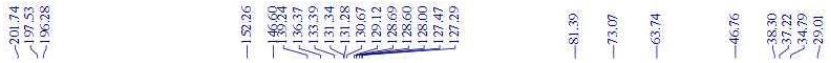

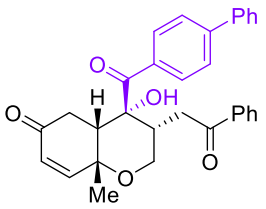

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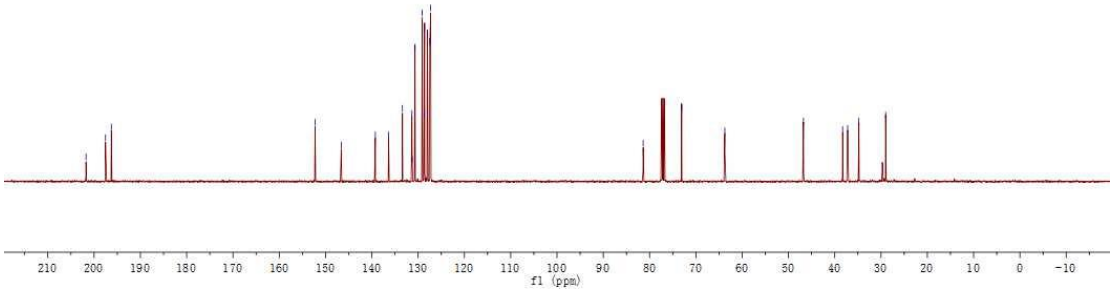

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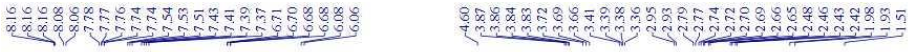

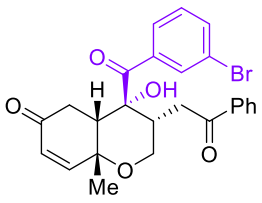

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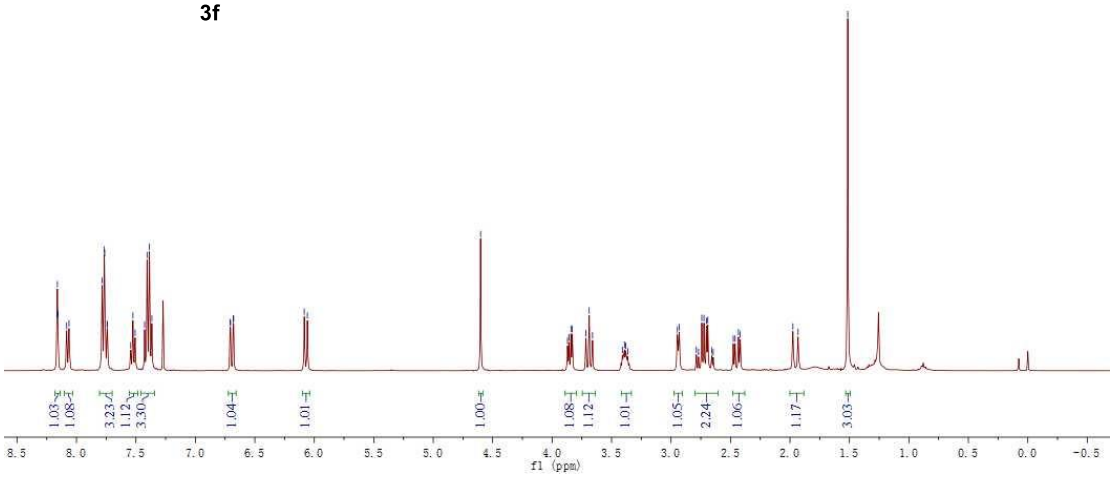

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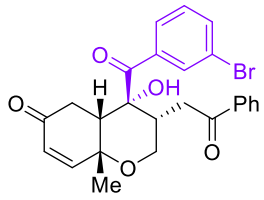

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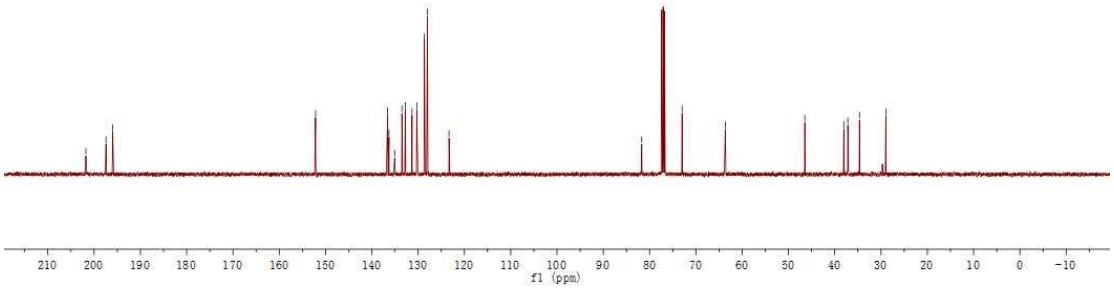

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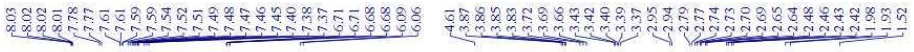

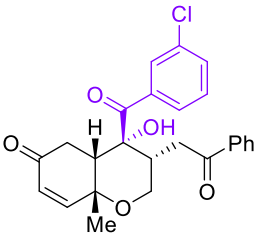

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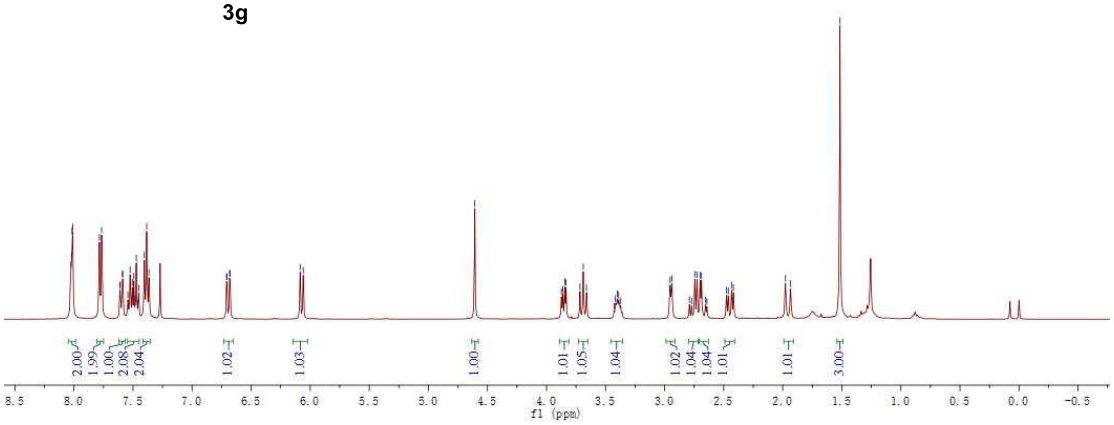

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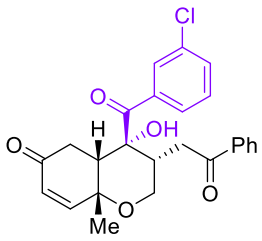

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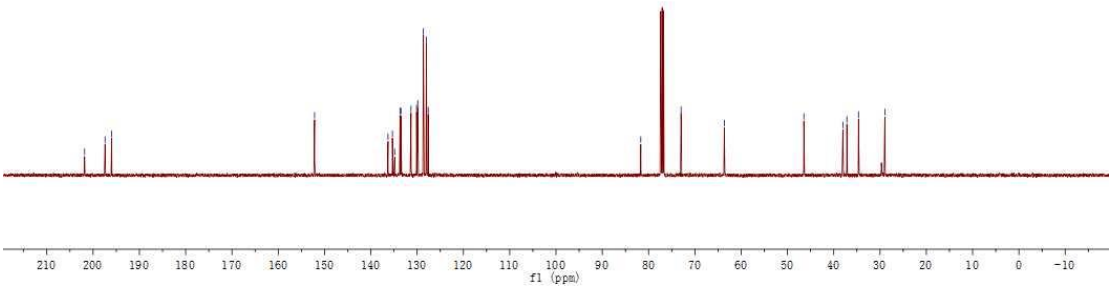

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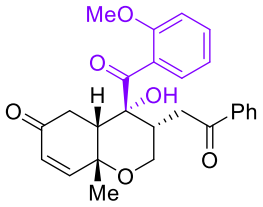

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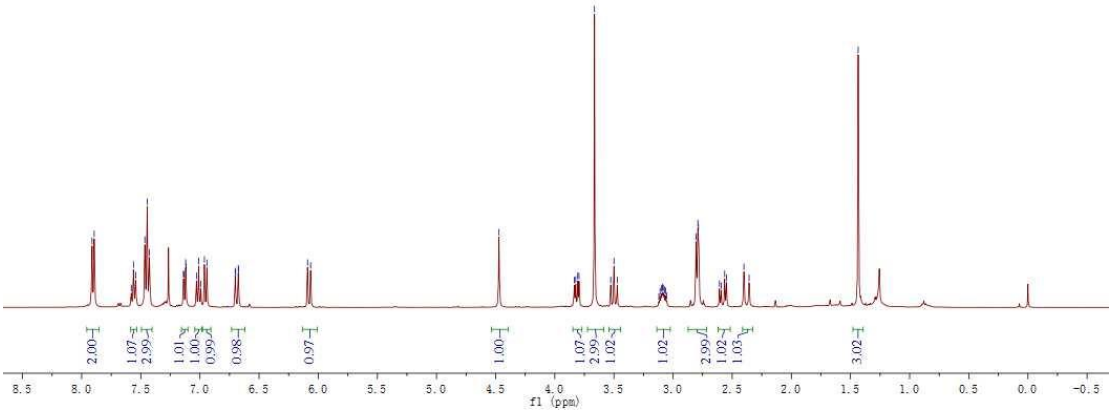

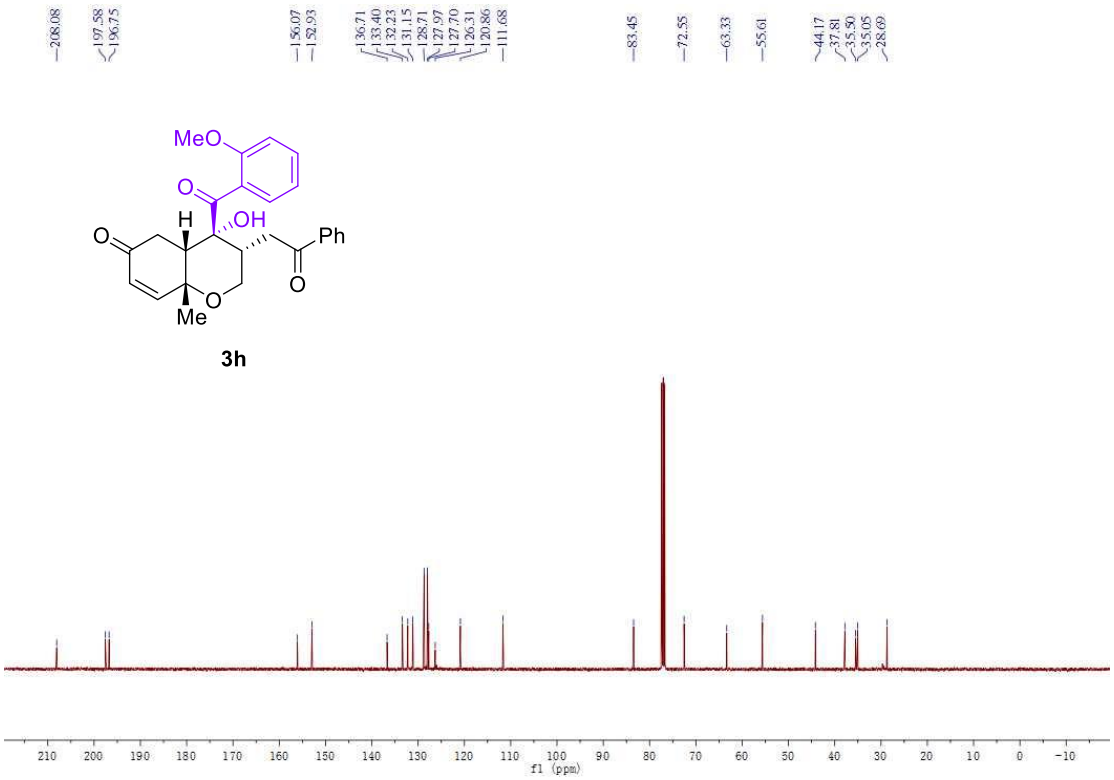

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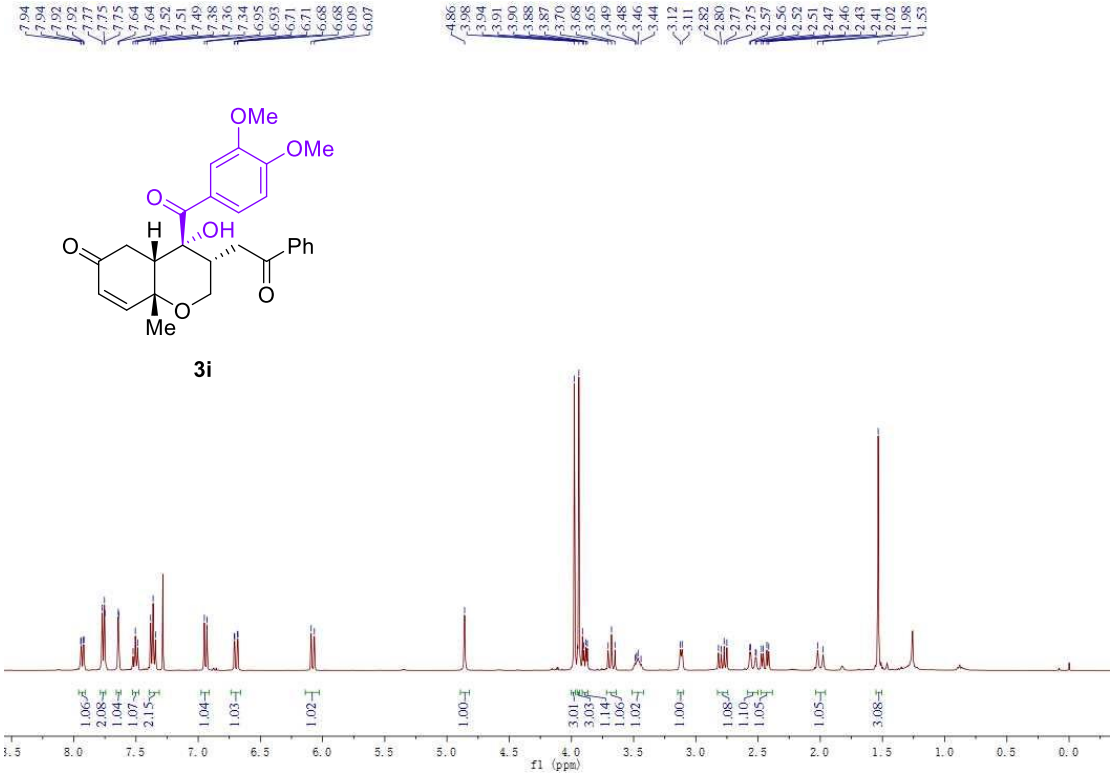

3i

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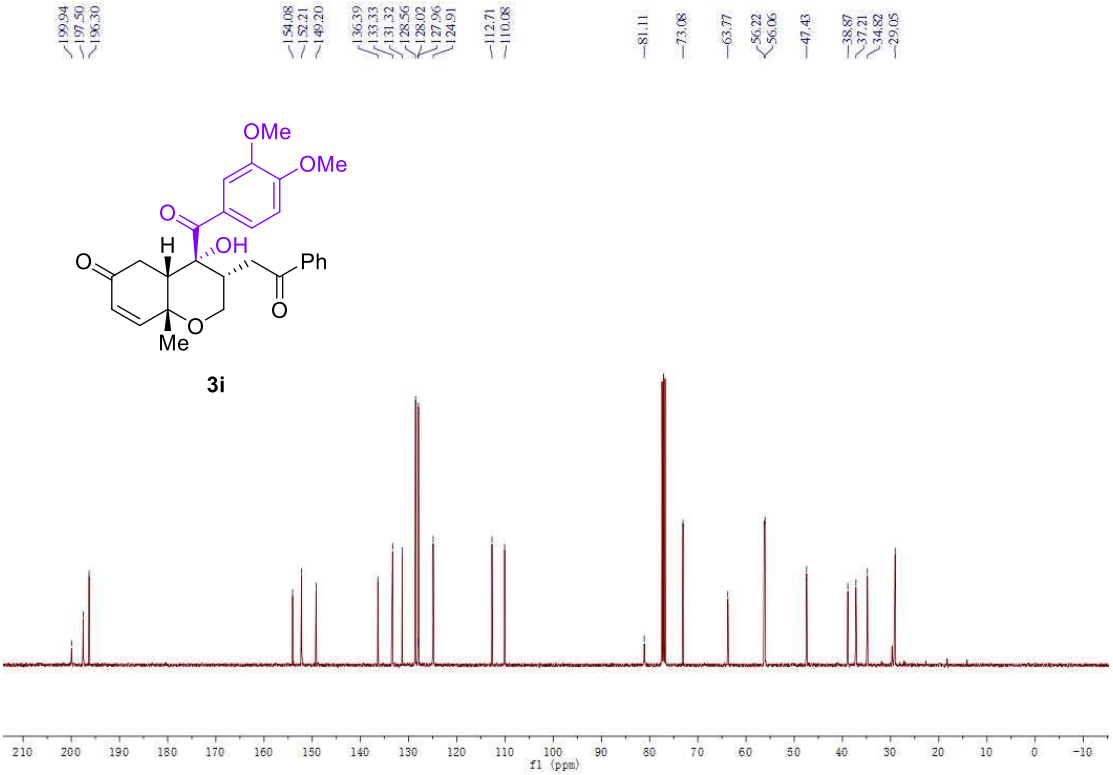
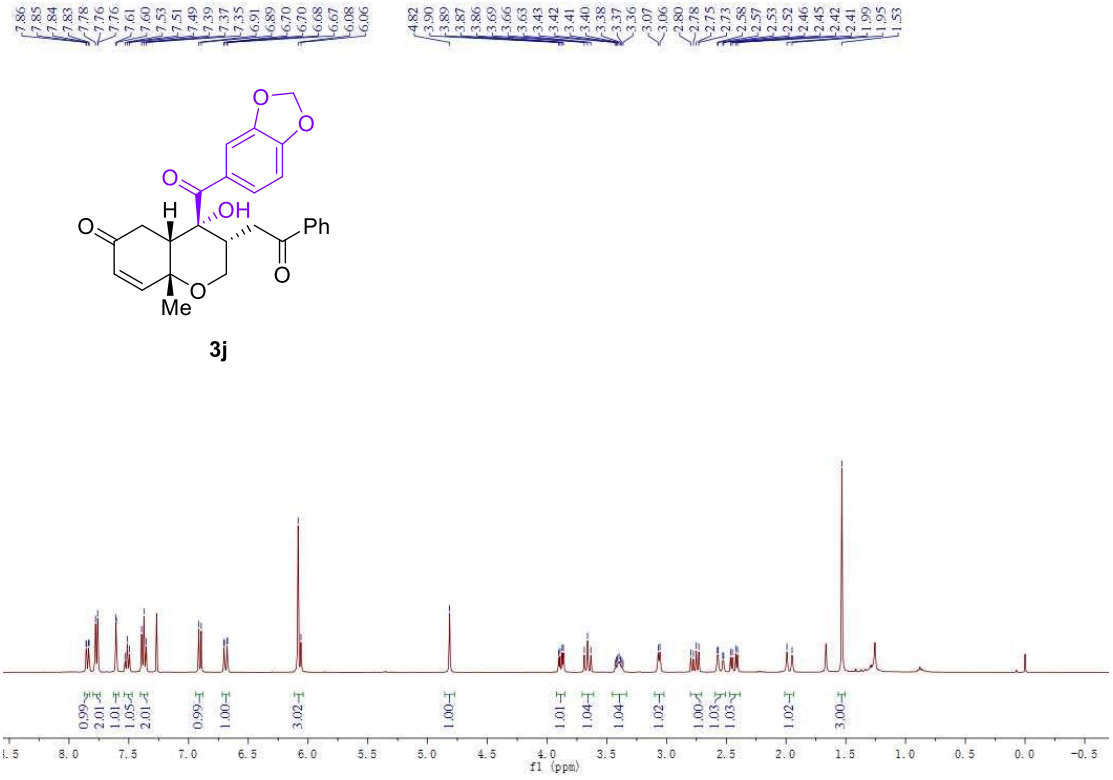


3i

^{1}H NMR (400 MHz, $CDCl_3$)



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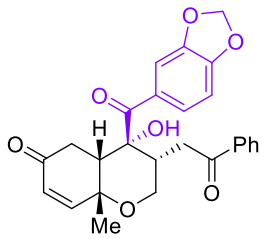

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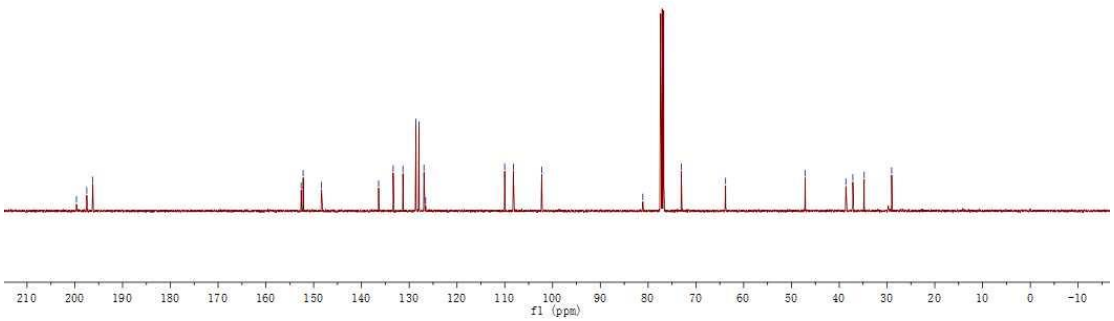

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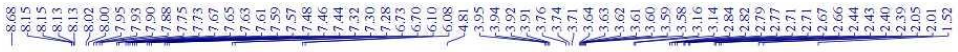

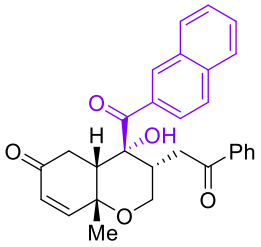

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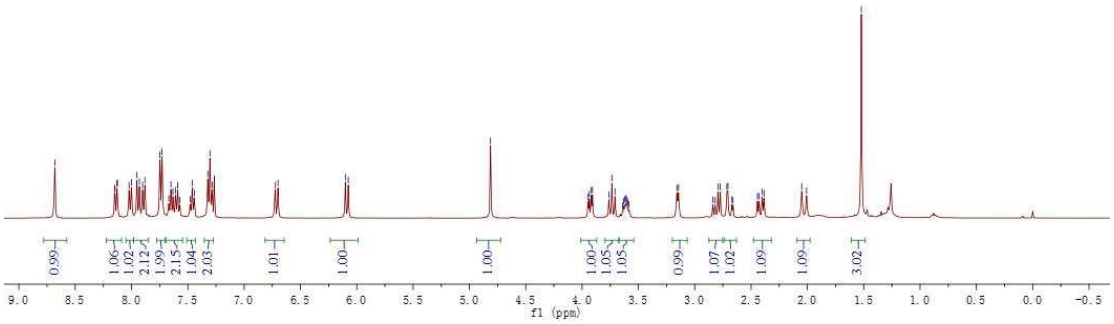

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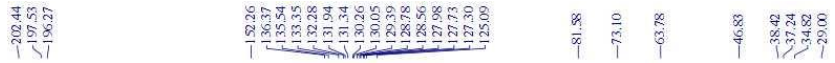

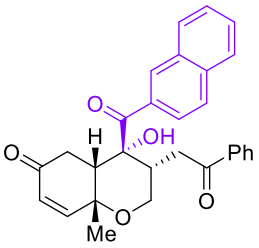

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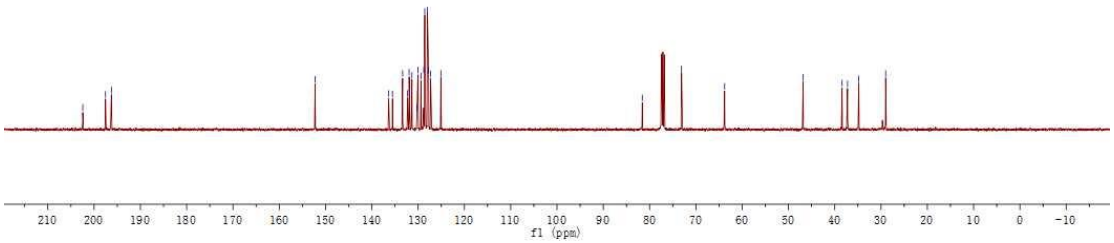
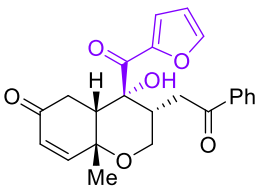


^{1}H NMR (400 MHz, $CDCl_3$)



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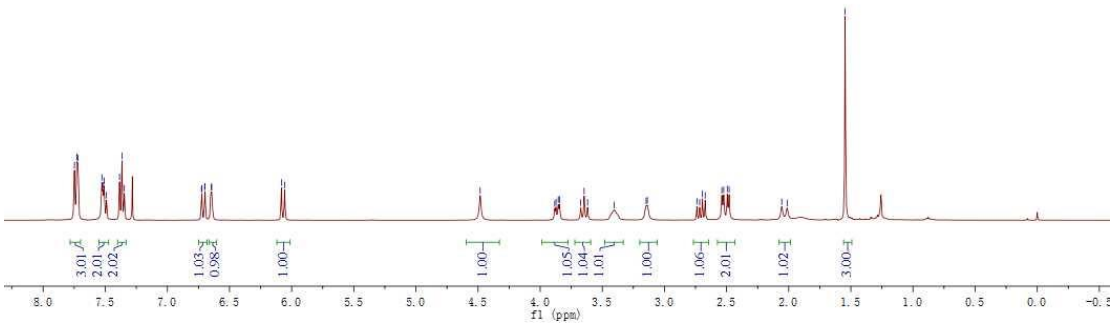
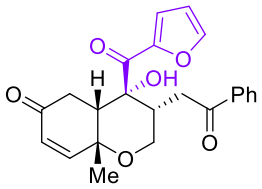


^{13}C NMR (101 MHz, $CDCl_3$)



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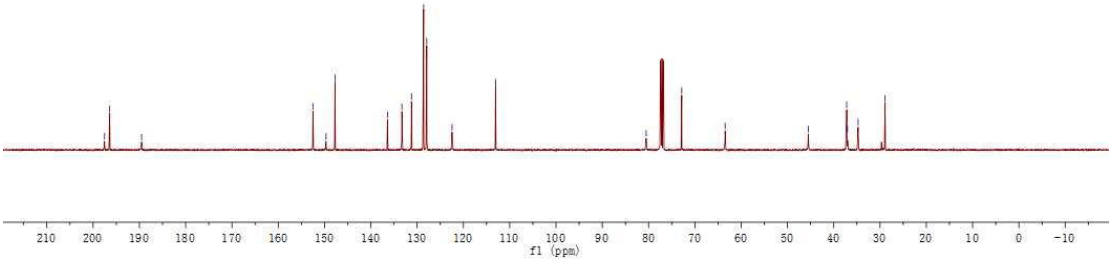
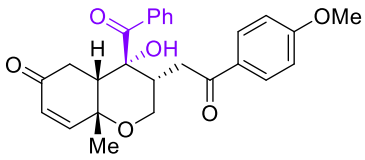


^{1}H NMR (400 MHz, $CDCl_3$)



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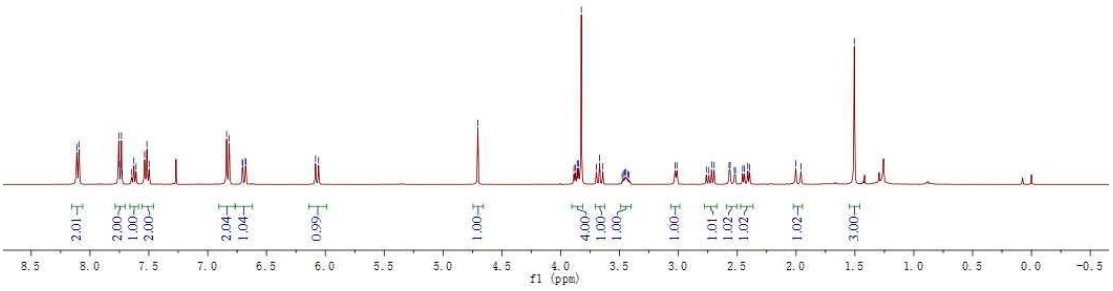
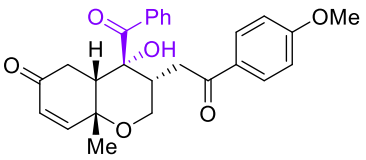


^{13}C NMR (101 MHz, $CDCl_3$)



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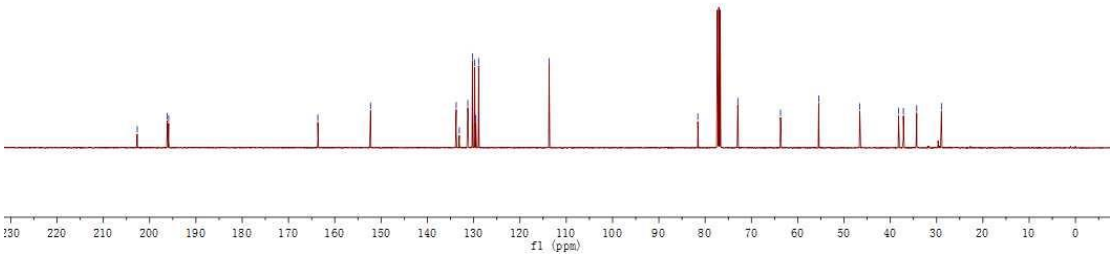
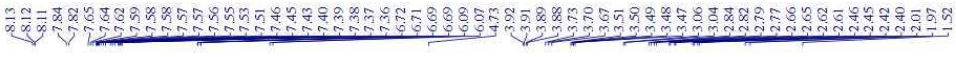
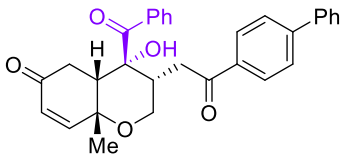


^{1}H NMR (400 MHz, $CDCl_3$)





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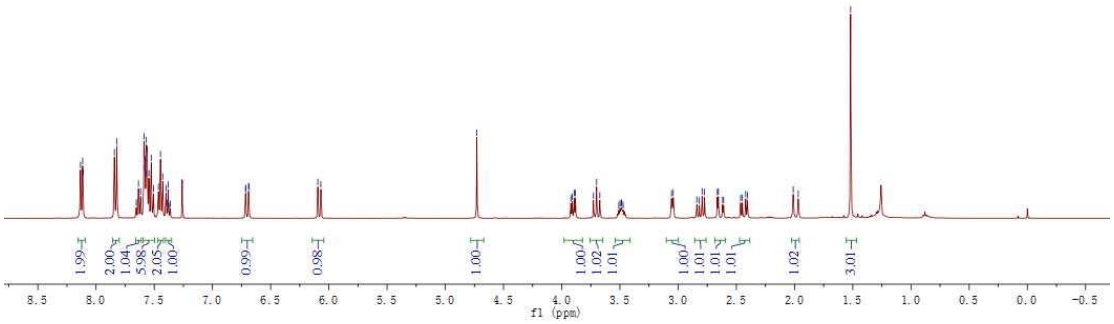
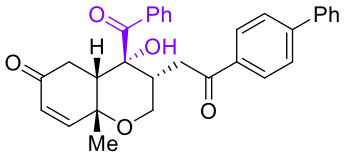


^{13}C NMR (101 MHz, $CDCl_3$)



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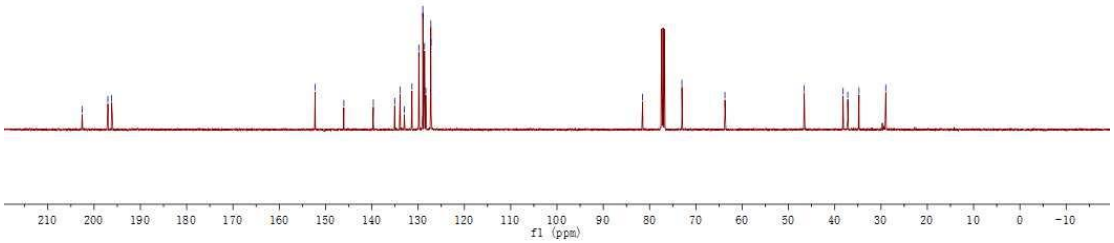
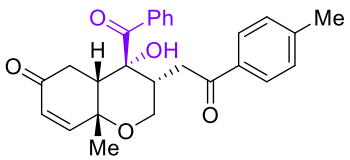


^{1}H NMR (400 MHz, $CDCl_3$)



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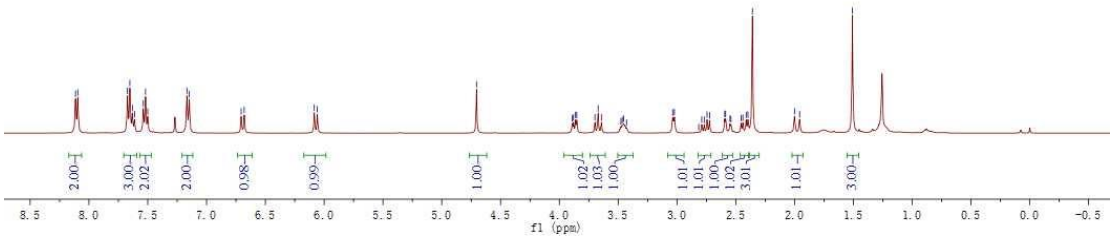
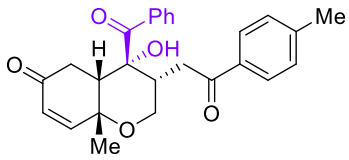


^{13}C NMR (101 MHz, $CDCl_3$)



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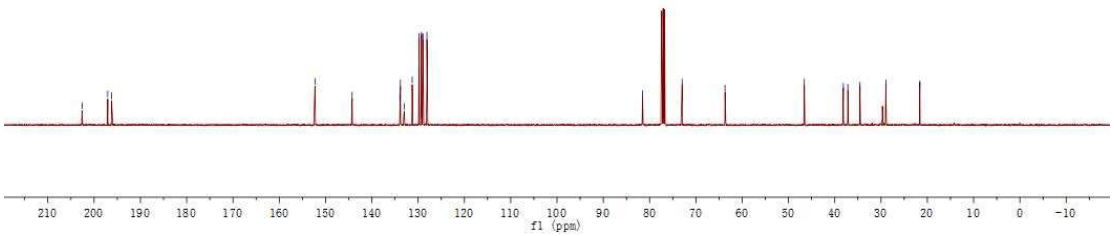
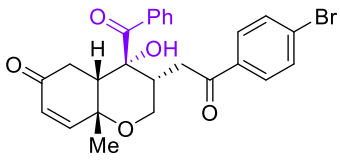


^{1}H NMR (400 MHz, $CDCl_3$)



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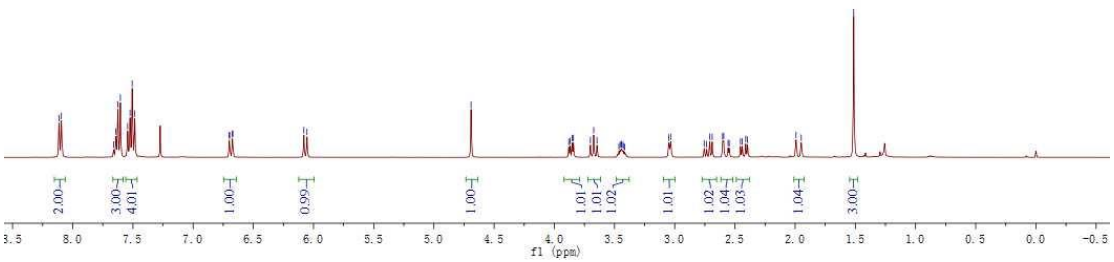
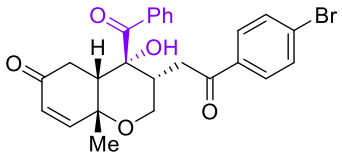


^{13}C NMR (101 MHz, $CDCl_3$)



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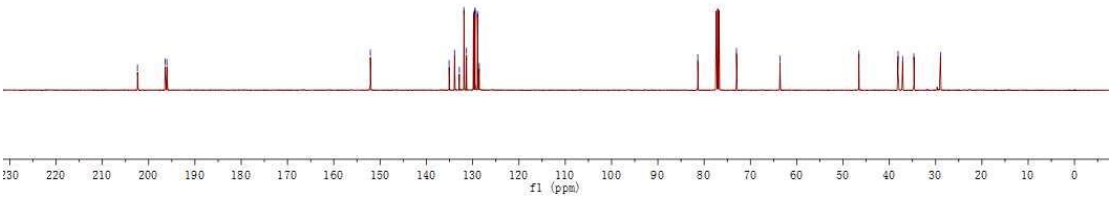
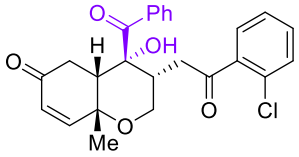


^{1}H NMR (400 MHz, $CDCl_3$)



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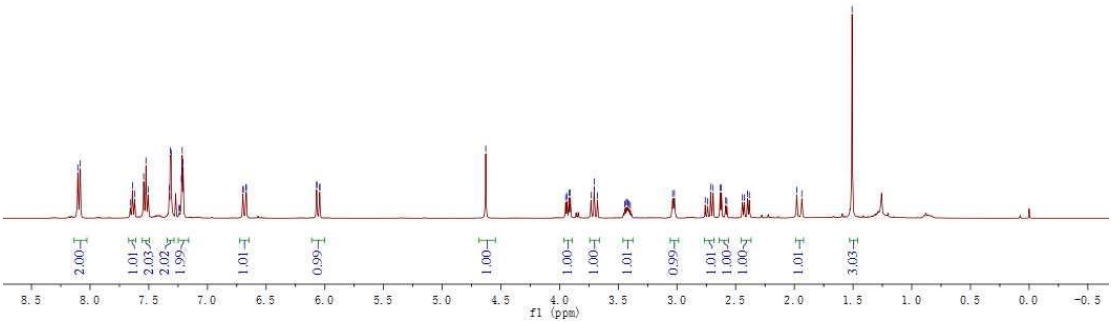
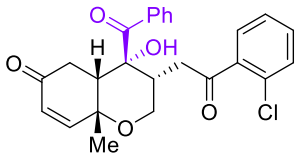


^{13}C NMR (101 MHz, $CDCl_3$)



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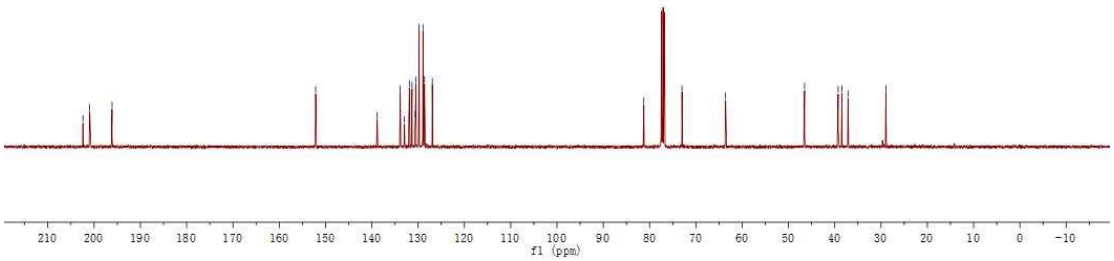

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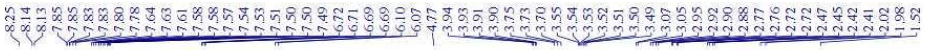

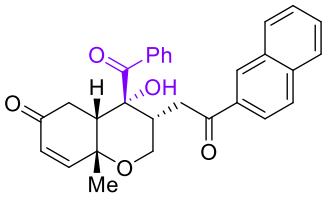

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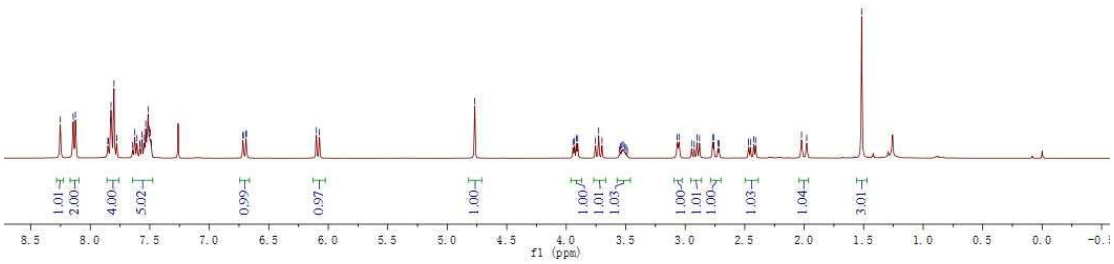
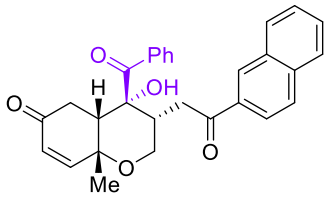


^{13}C NMR (101 MHz, $CDCl_3$)



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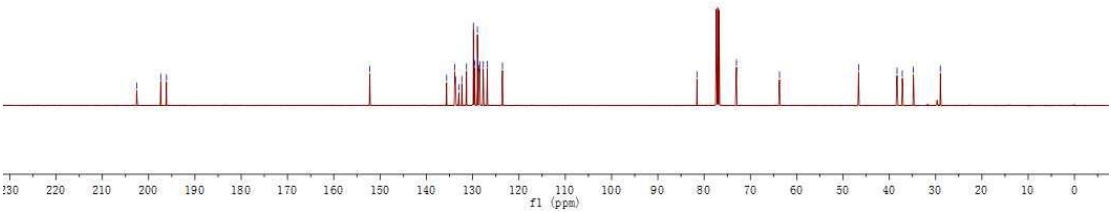

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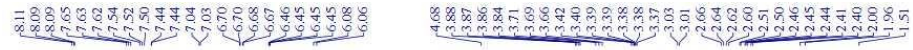

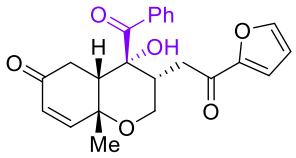

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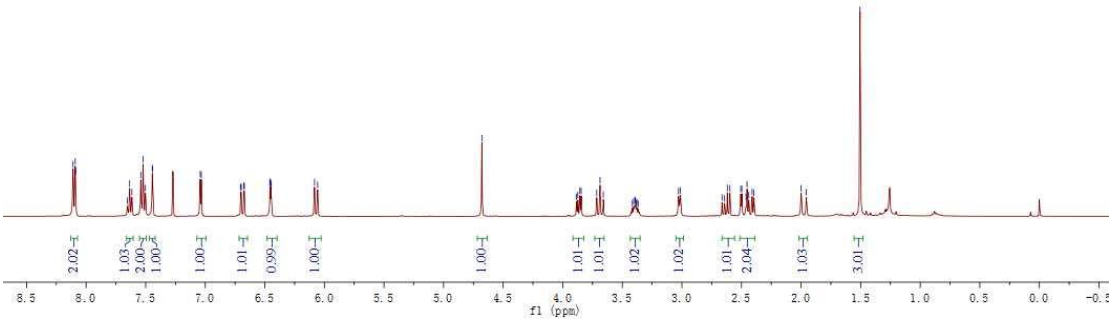
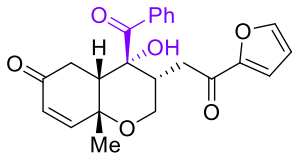


^{13}C NMR (101 MHz, $CDCl_3$)



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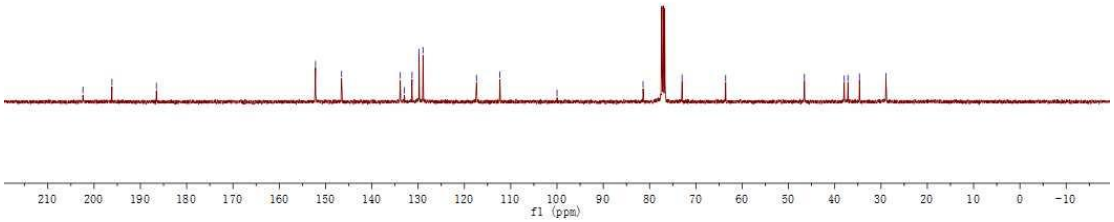

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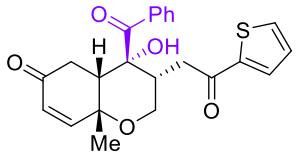

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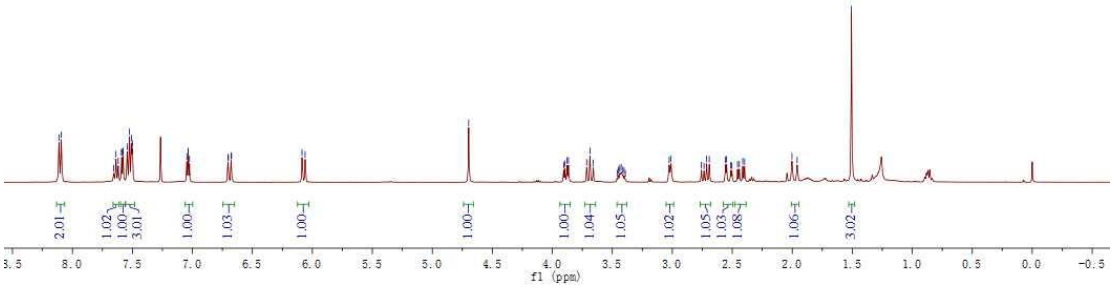
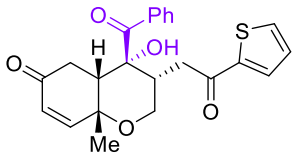


^{13}C NMR (101 MHz, $CDCl_3$)



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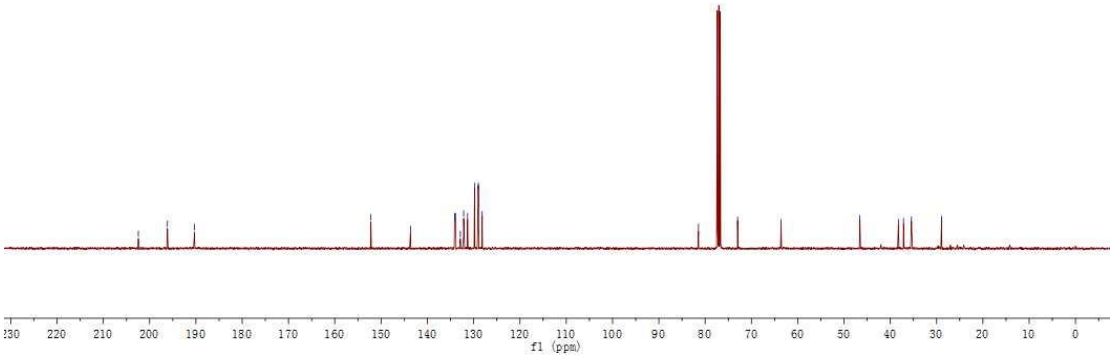
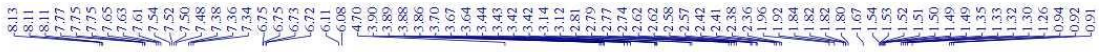
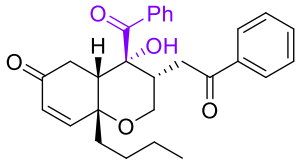


^{1}H NMR (400 MHz, $CDCl_3$)





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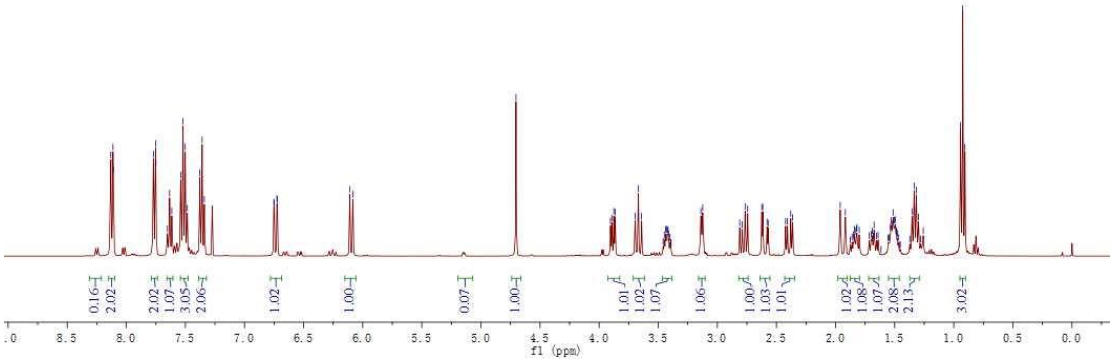
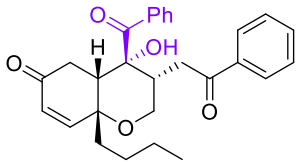


^{13}C NMR (101 MHz, $CDCl_3$)



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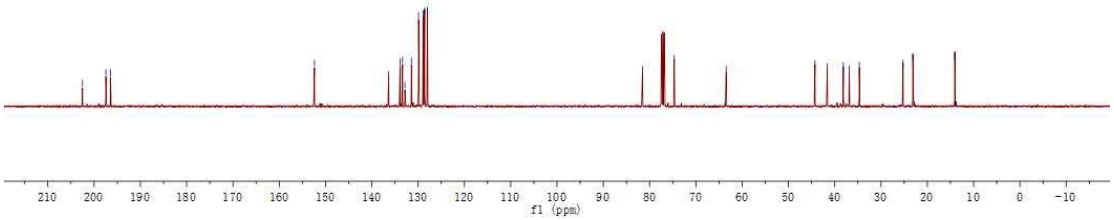
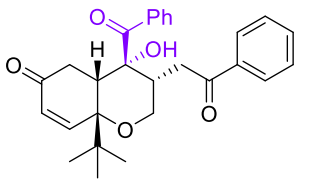


^{1}H NMR (400 MHz, $CDCl_3$)



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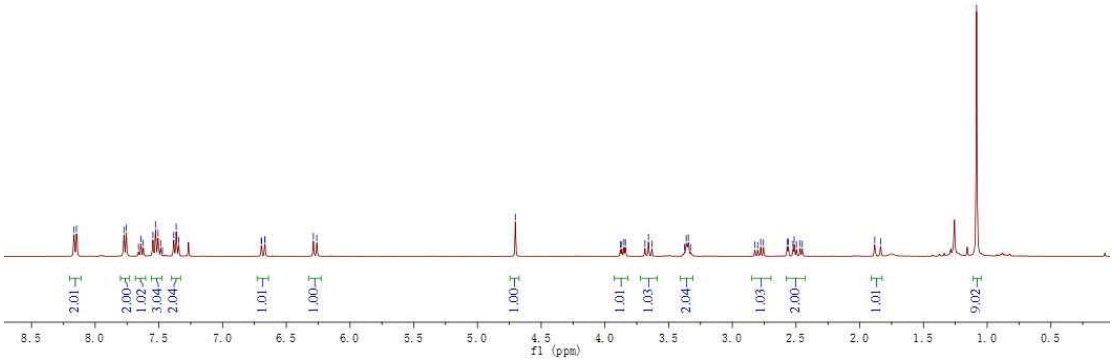
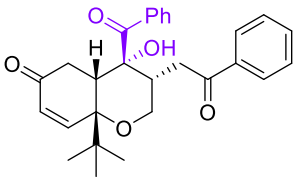


^{13}C NMR (101 MHz, $CDCl_3$)



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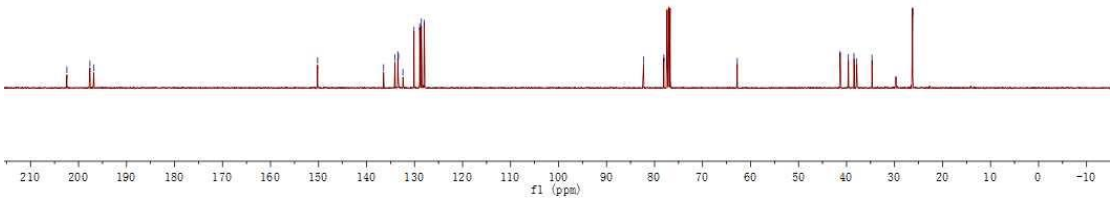
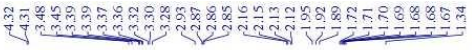
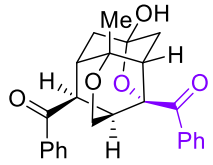


^{1}H NMR (400 MHz, $CDCl_3$)





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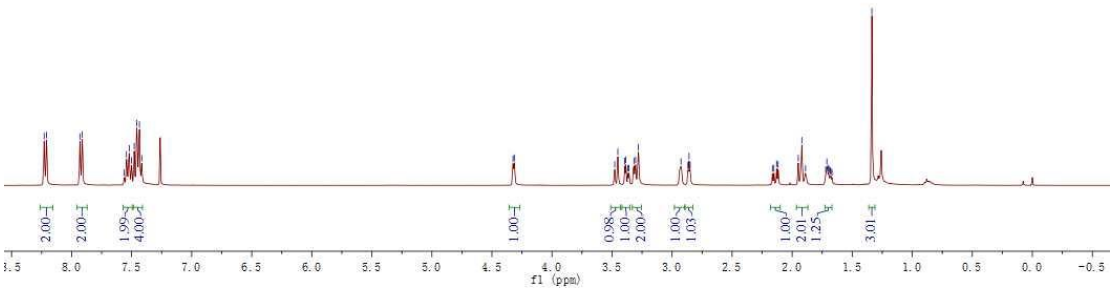
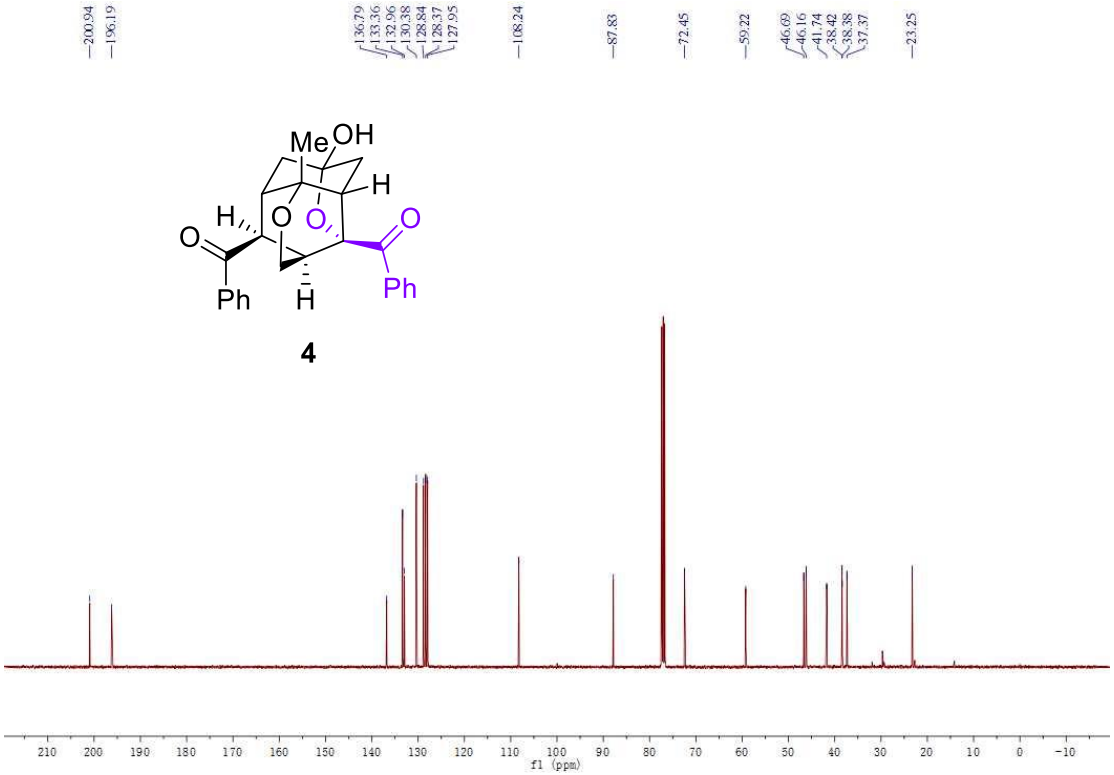


^{13}C NMR (101 MHz, $CDCl_3$)



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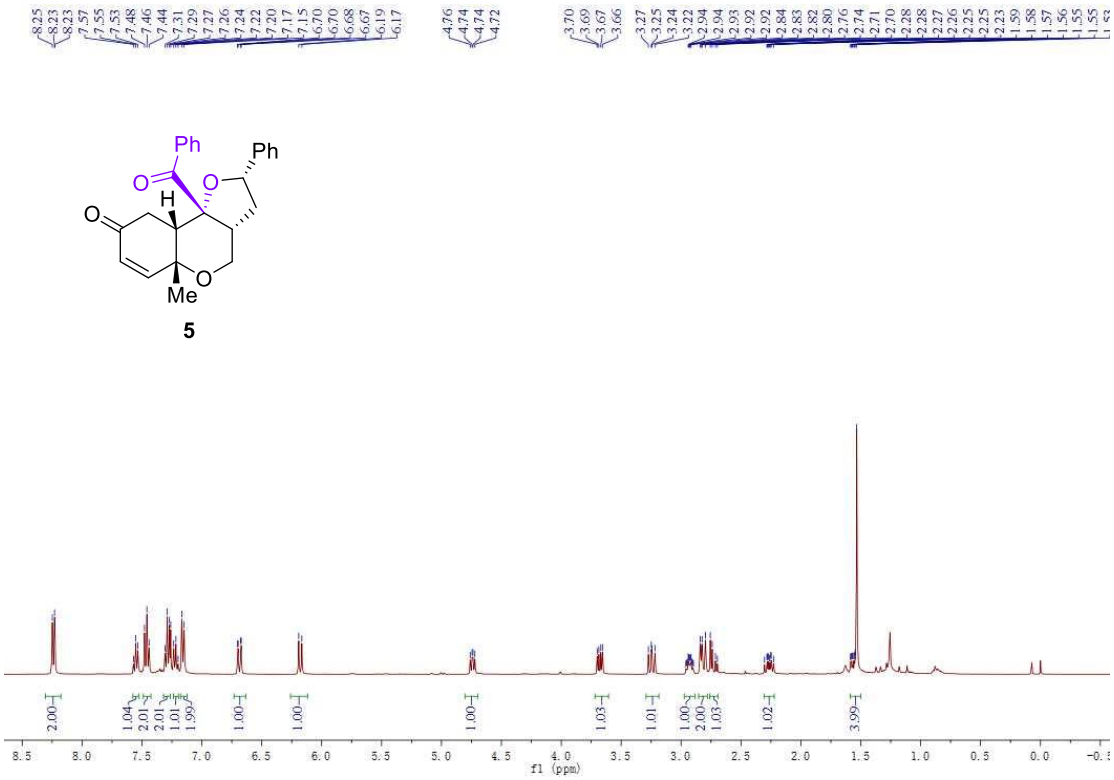

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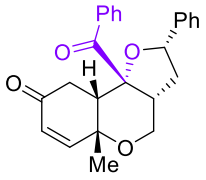

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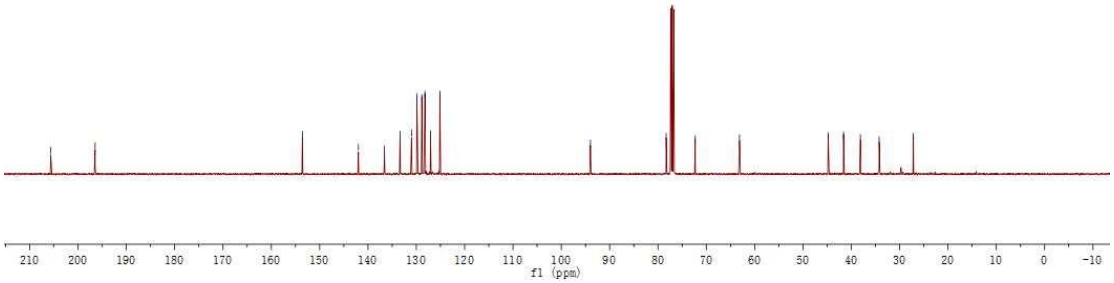
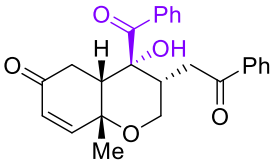


HPLC spectra of compound



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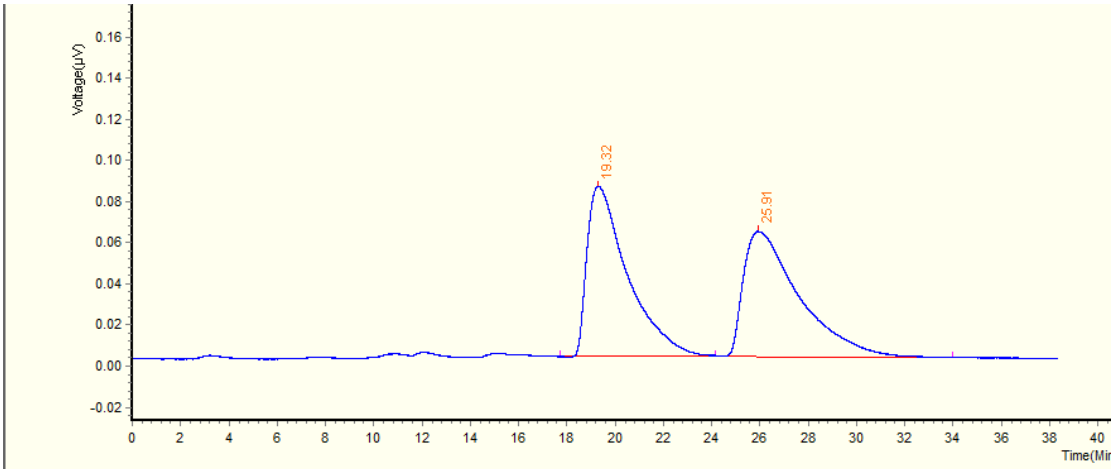
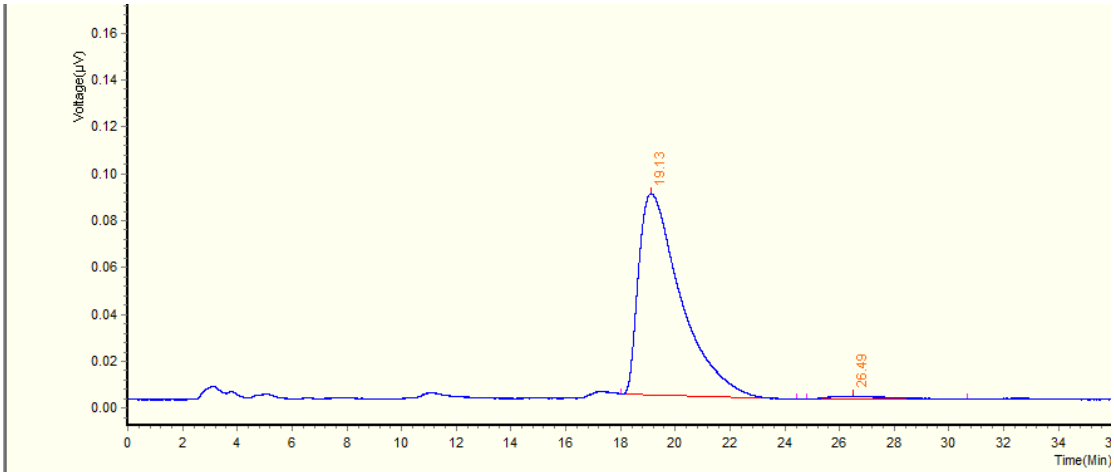


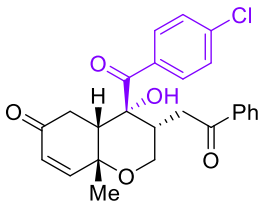
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	19.32	4852764	41402	49.63%	6.409	BV
2	25.91	4924984	30493	50.37%	9.848	VB
Total		9,777,748	71,895	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	19.13	4585943	42941	97.82%	6.43	BB
2	26.49	102216	729	2.18%	5.888	BB
Total		4,688,159	43,670	100.00%		



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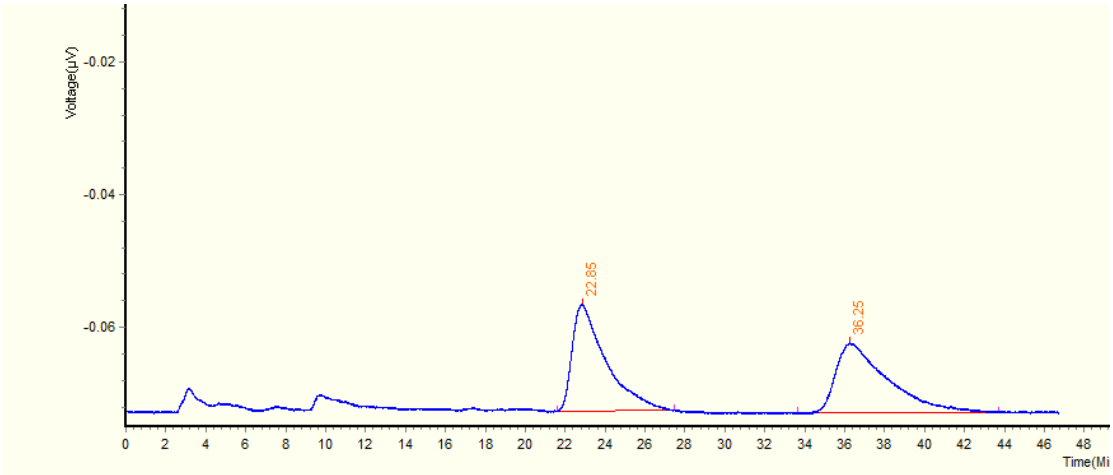
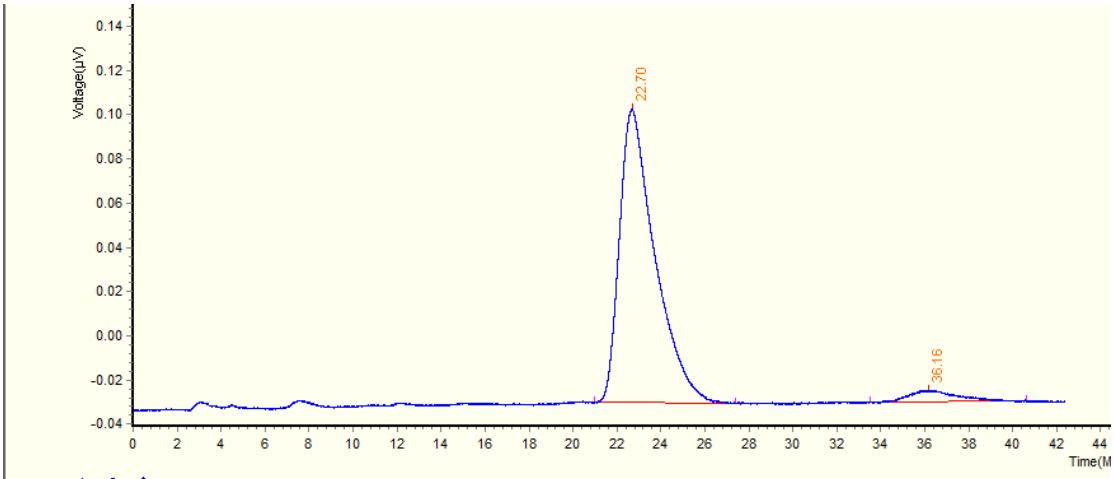


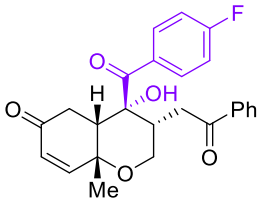
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	22.85	934888	7999	50.16%	5.862	BB
2	36.25	928950	5241	49.84%	10.068	BB
Total		1,863,838	13,240	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	22.70	7437430	66278	95.00%	6.414	BB
2	36.16	391587	2549	5.00%	7.107	BB
Total		7,829,017	68,827	100.00%		



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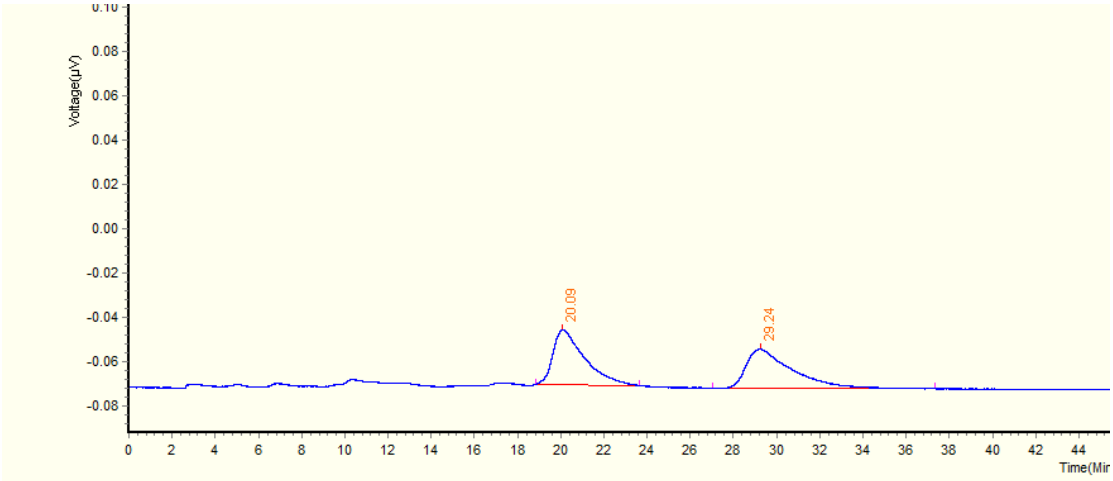
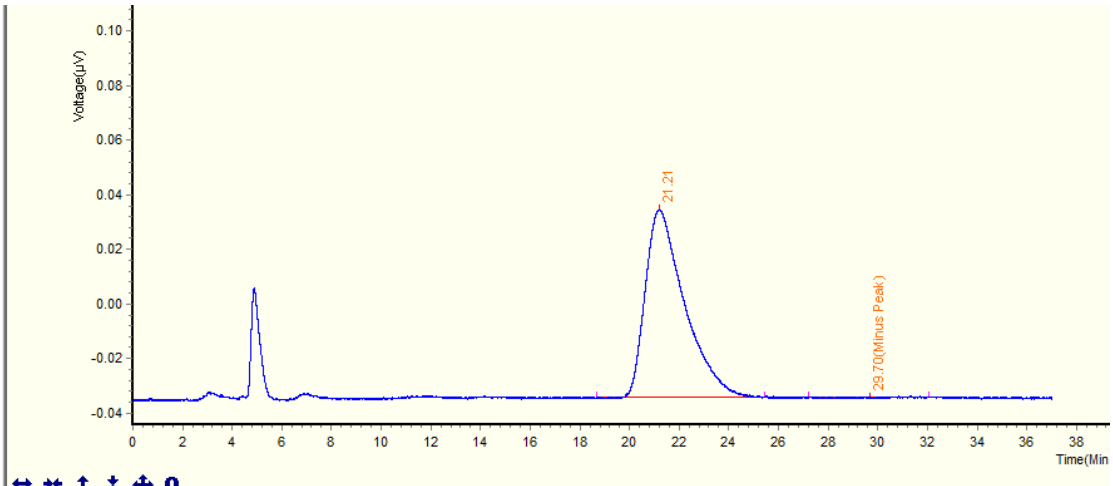


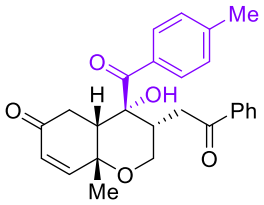
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	20.09	1275801	12554	49.74%	4.846	BB
2	29.24	1289352	8815	50.26%	10.3	BB
Total		2,565,153	21,369	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	21.21	3770250	34383	99.79%	6.785	BB
2	29.70	7891	230	0.21%	4.846	BB
Total		3,778,141	34,613	100.00%		



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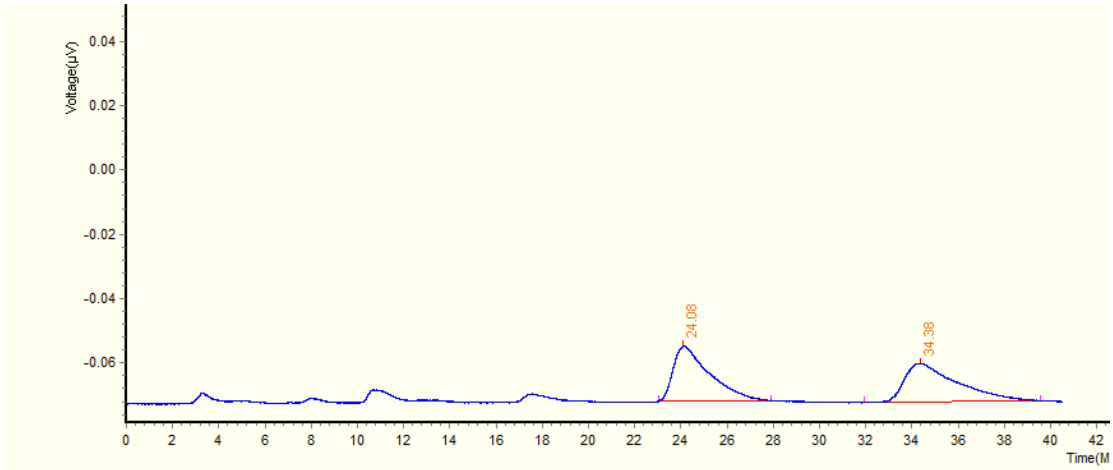
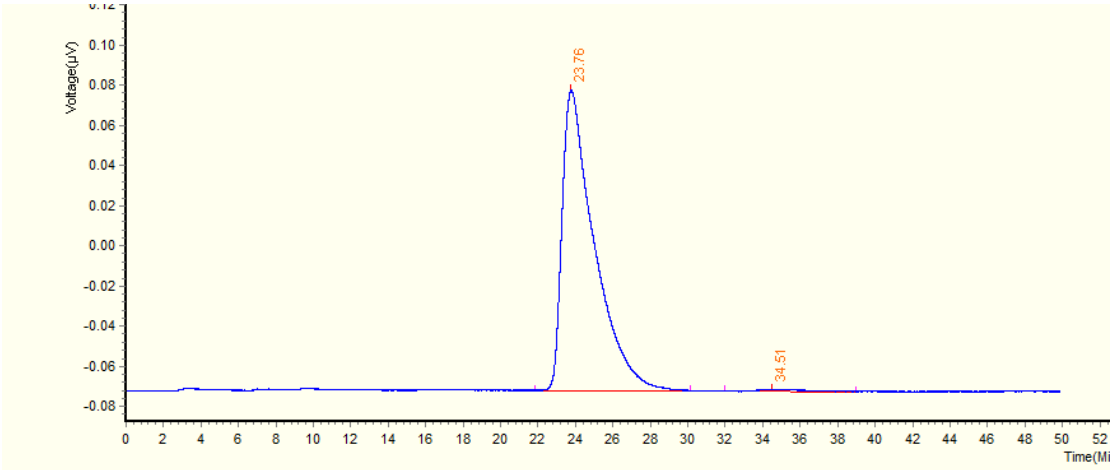


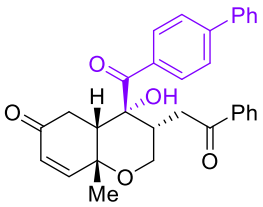
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	24.08	923110	8543	49.79%	4.862	BB
2	34.38	930961	5984	50.21%	7.623	BB
Total		1,854,071	14,527	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	23.76	8919551	74753	99.08%	8.298	BB
2	34.51	82960	557	0.92%	7.006	BB
Total		9,002,511	75,310	100.00%		



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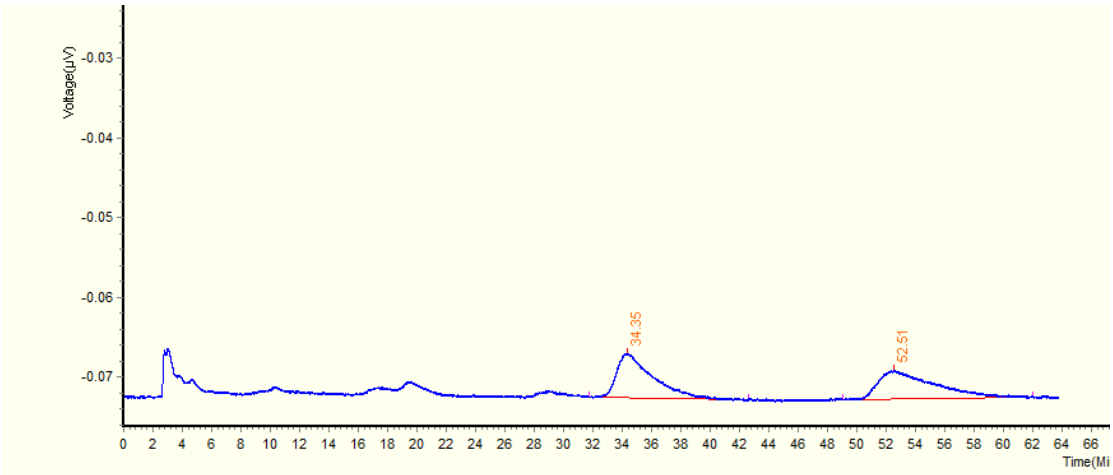
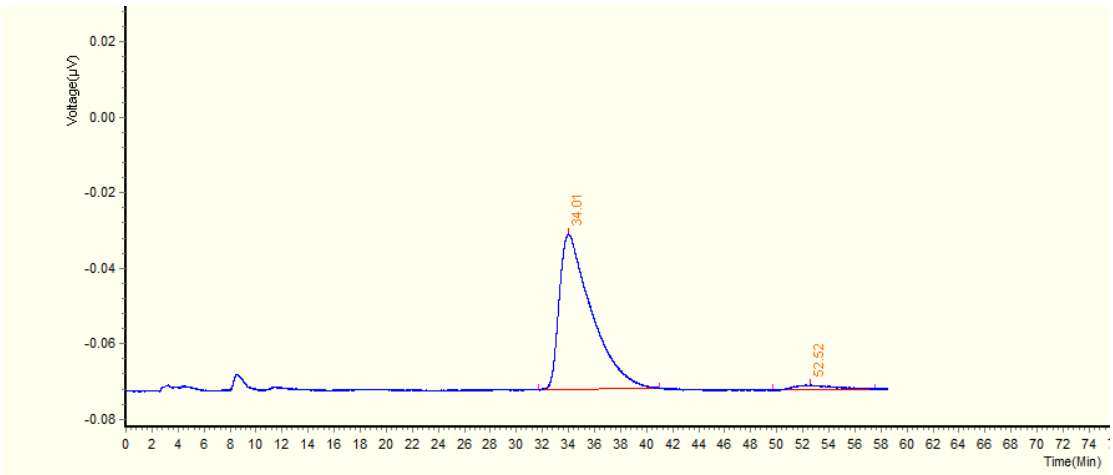


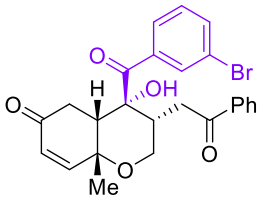
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	34.35	459611	2777	50.01%	10.872	BB
2	52.51	459387	1774	49.99%	12.959	BB
Total		918,998	4,551	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	34.01	3546867	20548	96.64%	9.287	BB
2	52.52	123508	614	3.36%	7.851	BB
Total		3,670,375	21,162	100.00%		



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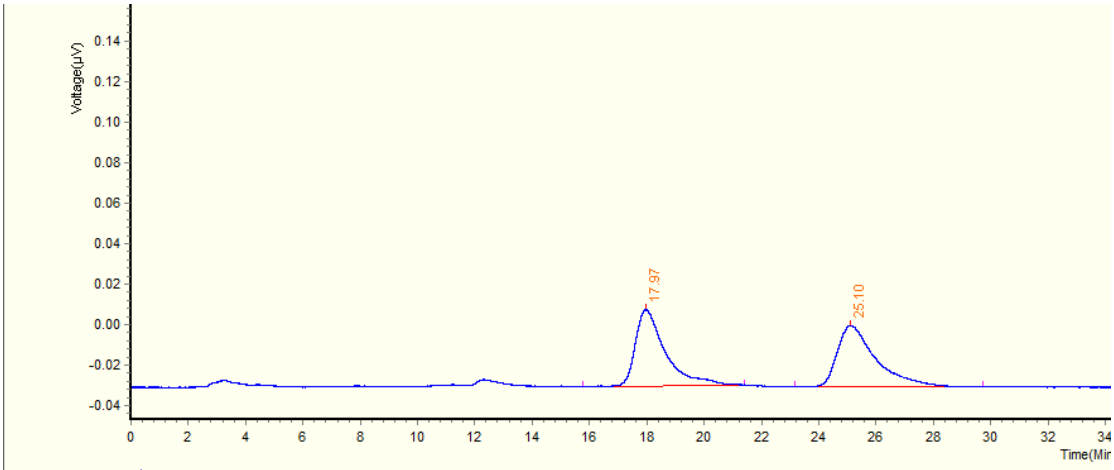
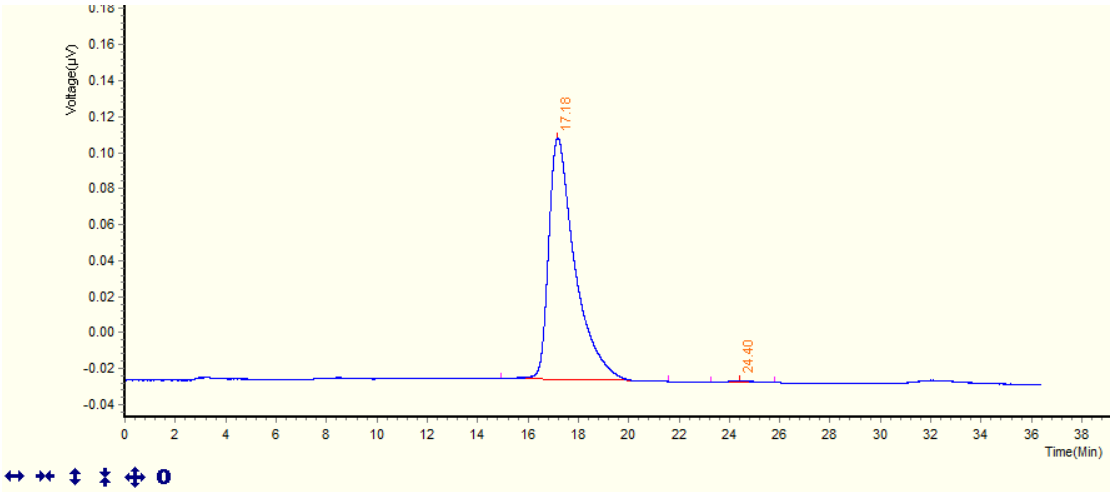


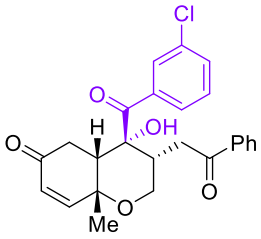
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	17.97	1355377	18720	49.41%	5.637	BB
2	25.10	1387917	15065	50.59%	6.562	BB
Total		2,743,294	33,785	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	17.18	4860296	67099	99.48%	6.659	BB
2	24.40	25417	472	0.52%	2.497	BB
Total		4,885,713	67,571	100.00%		



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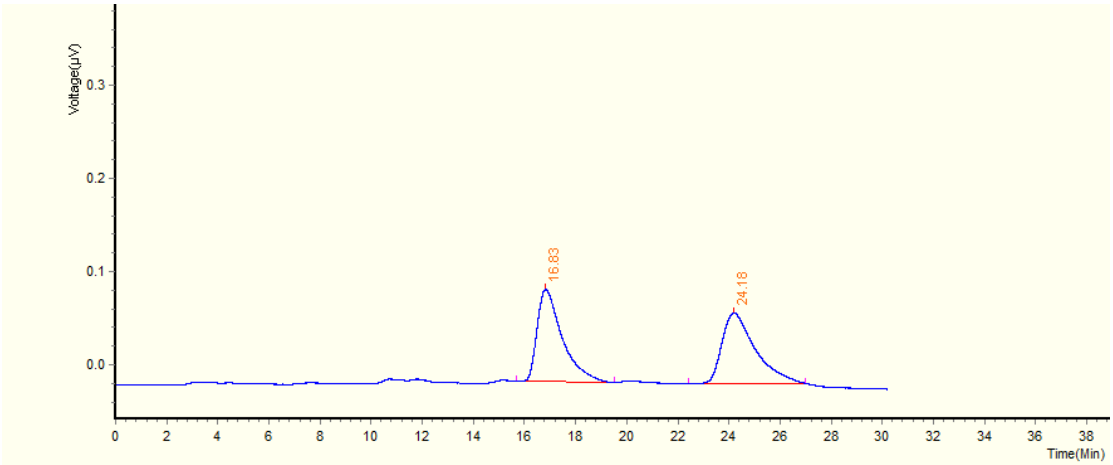
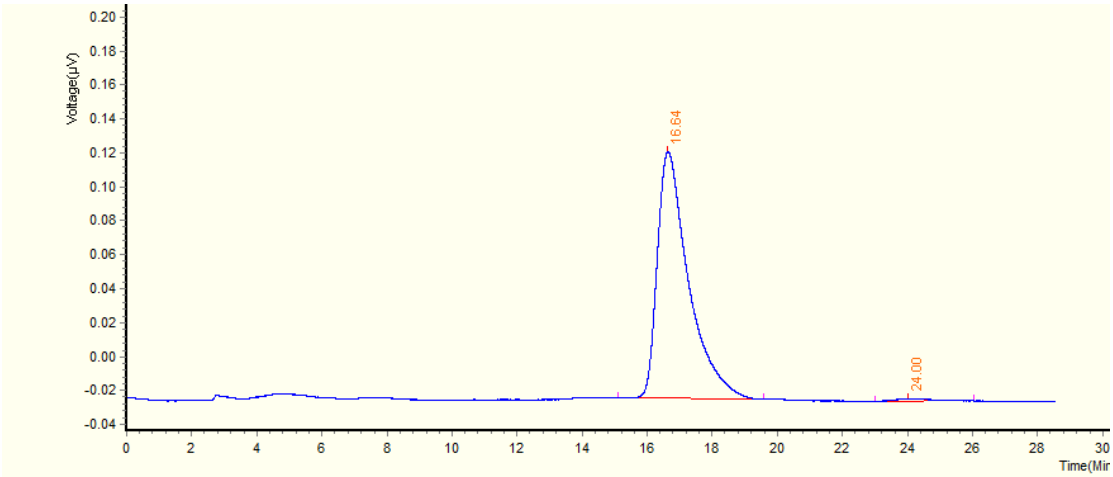


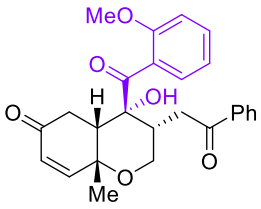
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	16.83	3387618	49515	50.02%	3.81	BB
2	24.18	3385007	37750	49.98%	4.553	BB
Total		6,772,625	87,265	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	16.64	4842584	72700	99.01%	4.483	BB
2	24.00	48539	693	0.99%	3.018	BB
Total		4,891,123	73,393	100.00%		



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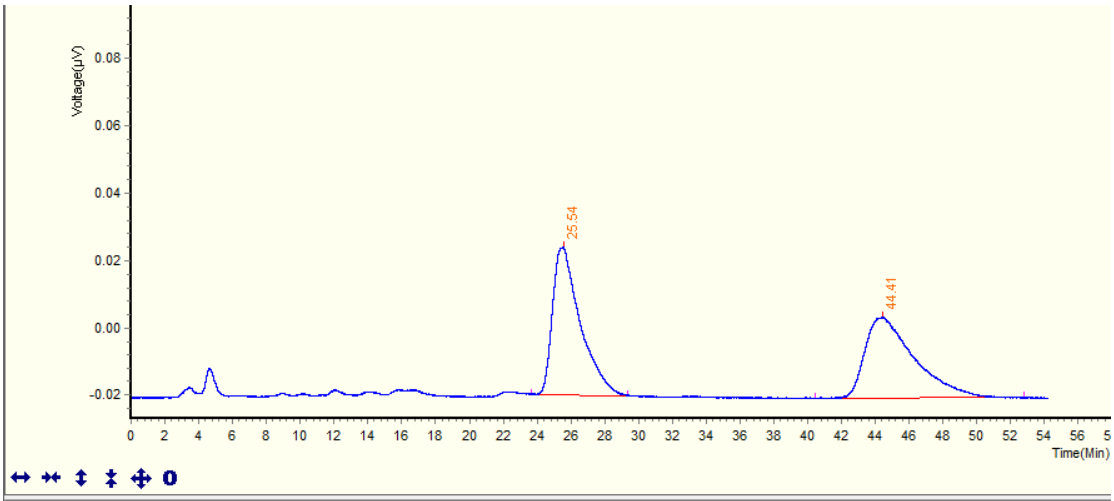
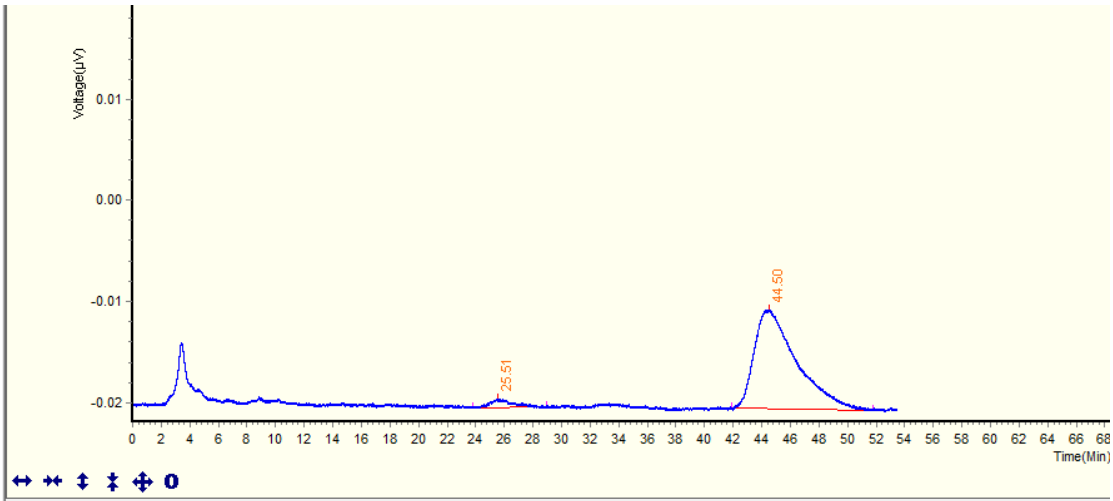


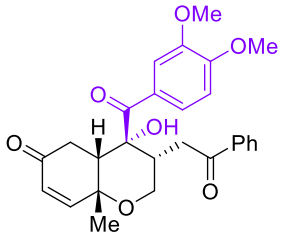
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	25.54	2474525	21938	50.52%	5.693	BB
2	44.41	2423446	11975	49.48%	12.28	BB
Total		4,897,971	33,913	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	25.51	41038	431	3.94%	5.188	BB
2	44.50	999988	4903	96.06%	9.912	BB
Total		1,041,026	5,334	100.00%		



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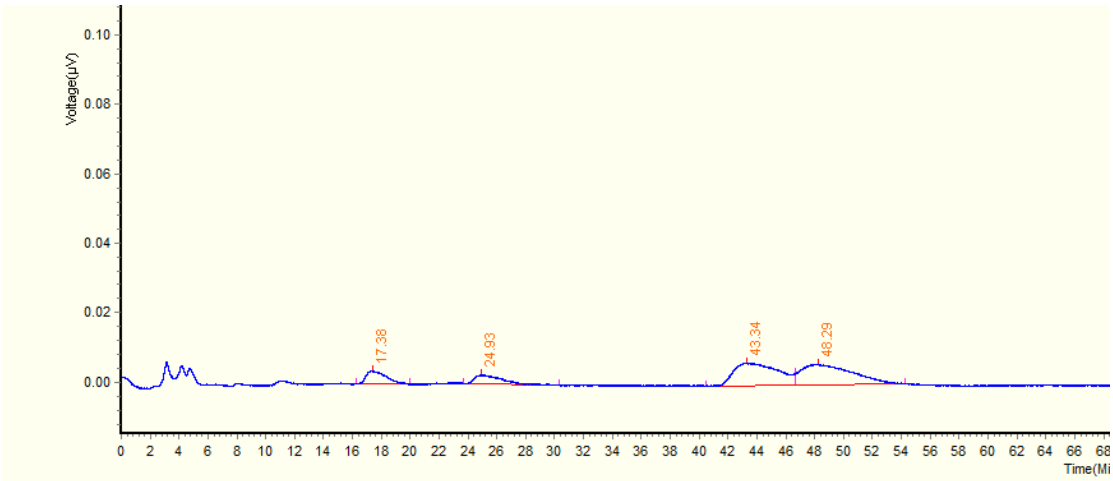
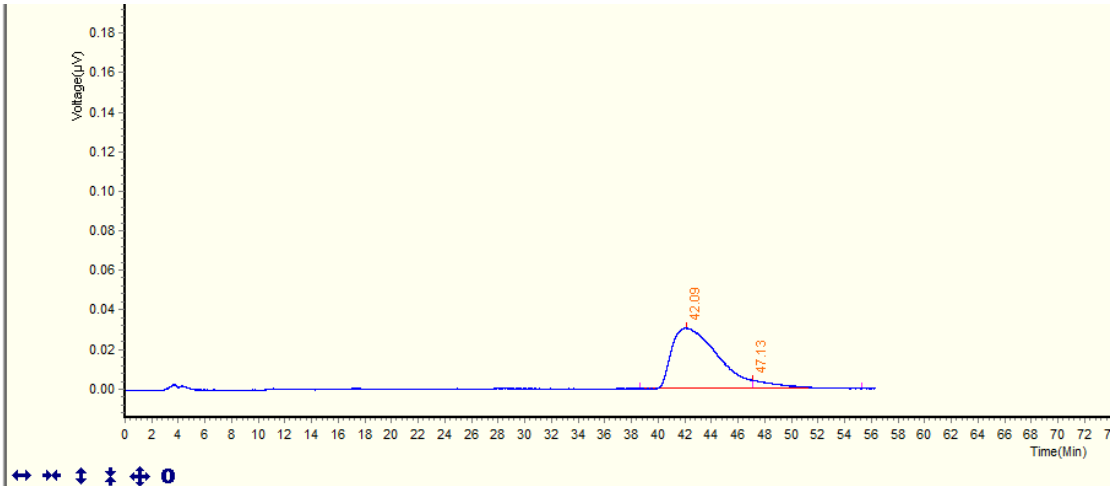


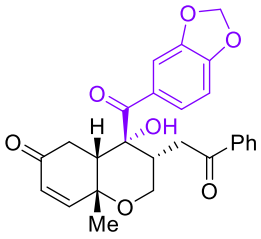
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	17.38	178562	1900	10.11%	3.712	BB
2	24.93	172102	1301	9.74%	6.609	BB
3	43.34	694717	3242	39.34%	6.239	BV
4	48.29	720703	2952	40.81%	7.597	VB
Total		1,766,084	9,395	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	42.09	3585041	15310	93.01%	8.452	BV
2	47.13	269536	2073	6.99%	8.211	VB
Total		3,854,577	17,383	100.00%		



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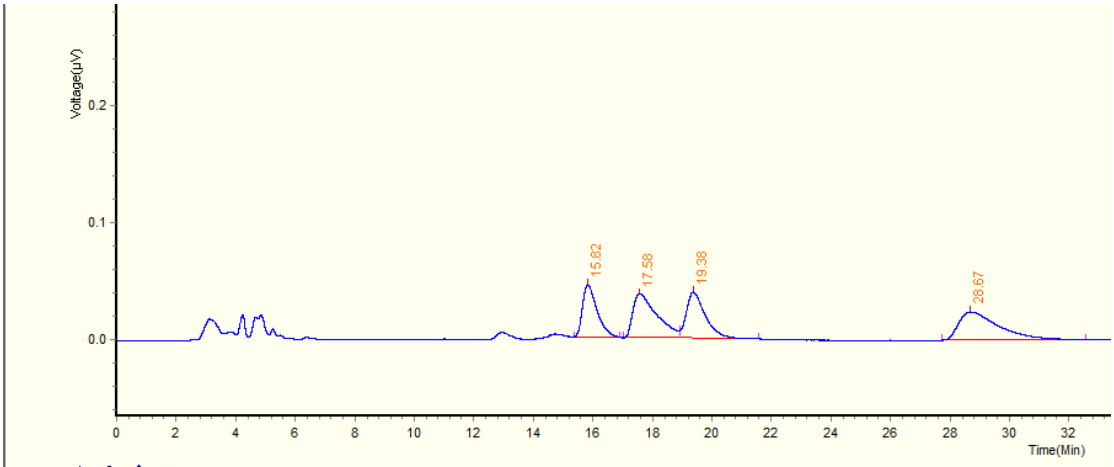
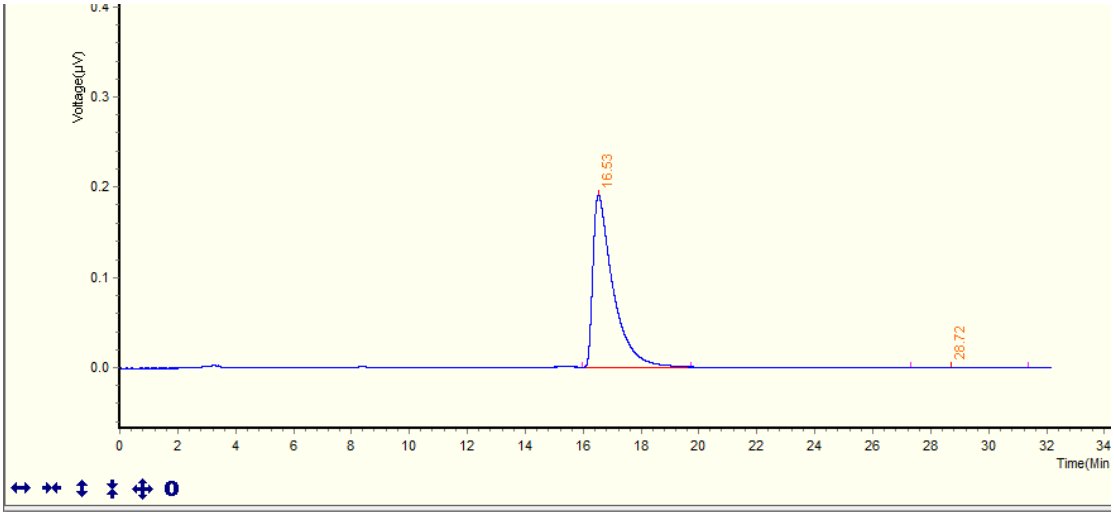


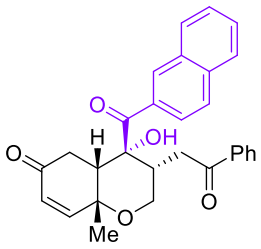
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	15.82	751120	22255	19.71%	1.538	BB
2	17.58	1064072	18903	27.92%	1.876	BV
3	19.38	878289	19752	23.05%	2.636	VB
4	28.67	1117370	12056	29.32%	4.839	BB
Total		3,810,851	72,966	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	16.53	4595493	95561	99.54%	3.752	BB
2	28.72	21249	269	0.46%	4.03	BB
Total		4,616,742	95,830	100.00%		



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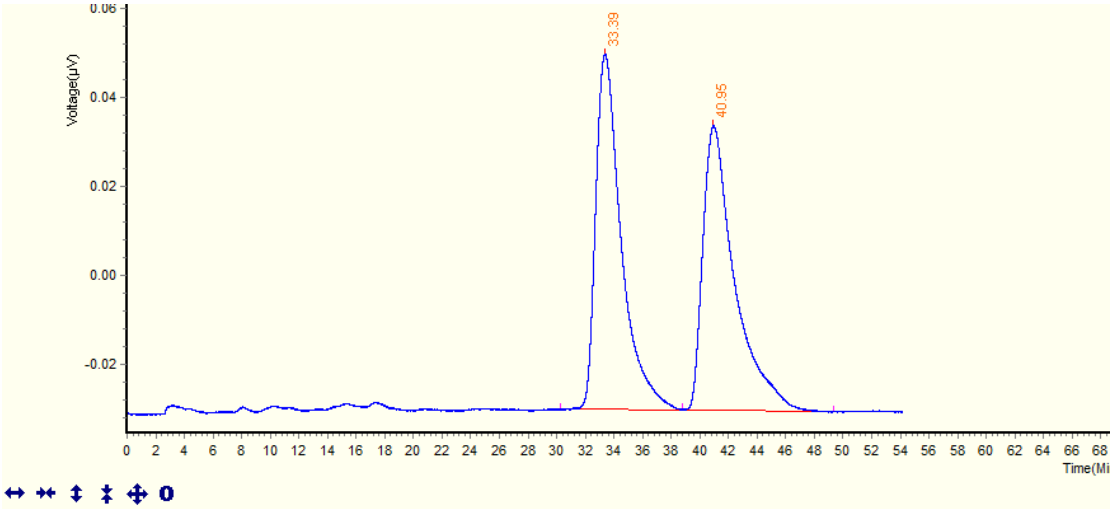
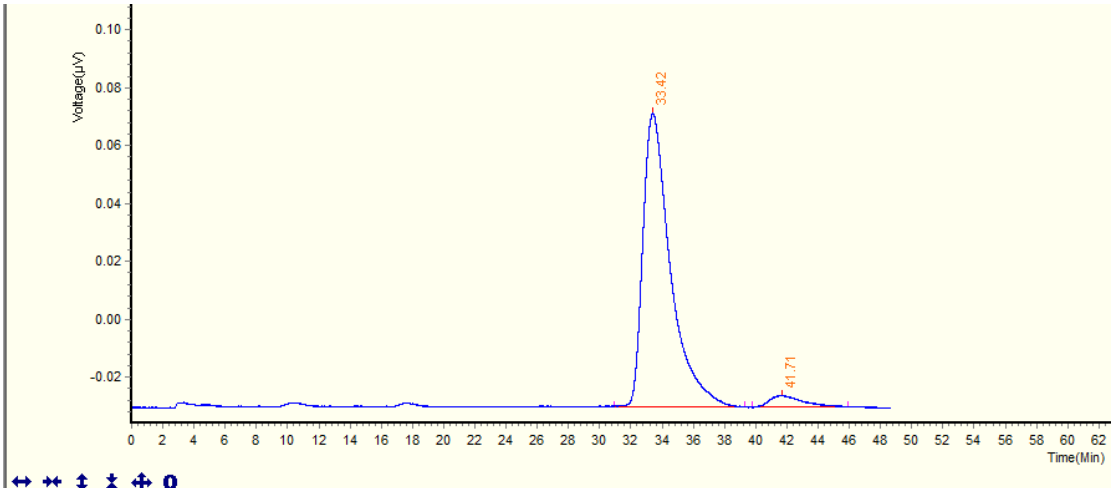


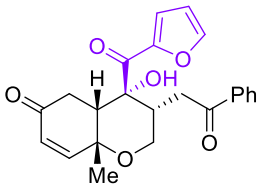
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	33.39	4967977	39974	50.04%	8.519	BV
2	40.95	4960137	31993	49.96%	10.559	VB
Total		9,928,114	71,967	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	33.42	6207675	50617	95.47%	8.419	BB
2	41.71	294881	2028	4.53%	6.151	BB
Total		6,502,556	52,645	100.00%		



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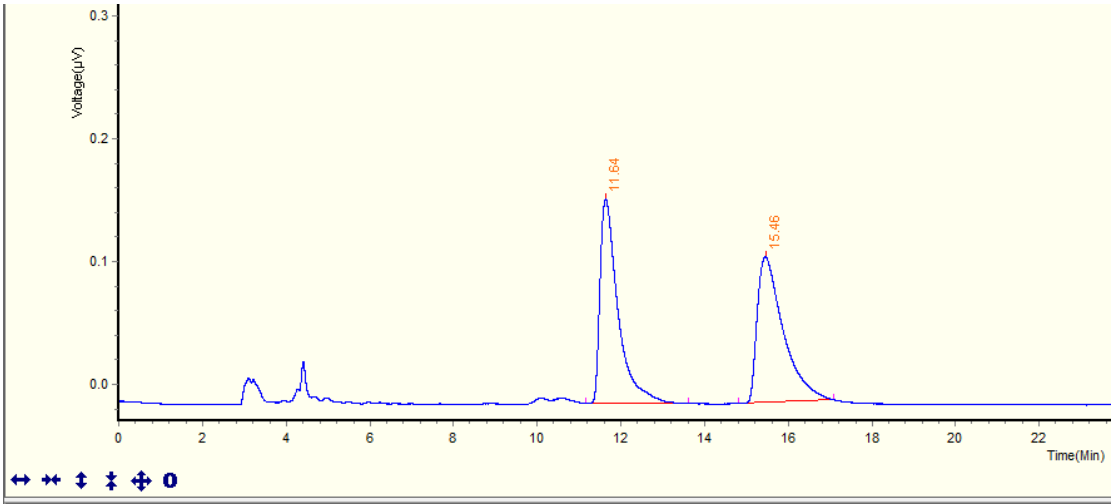
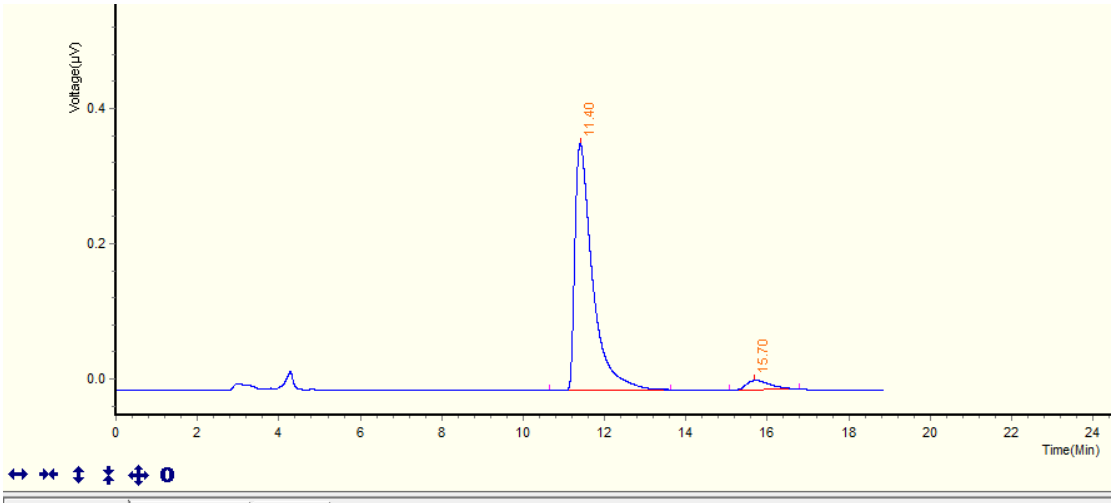


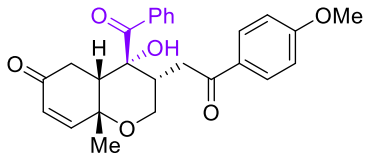
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	11.64	2498488	83238	49.33%	2.459	BB
2	15.46	2566162	59229	50.67%	2.277	BB
Total		5,064,650	142,467	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	11.40	5471569	182270	95.05%	2.982	BB
2	15.70	284659	7007	4.95%	1.717	BB
Total		5,756,228	189,277	100.00%		



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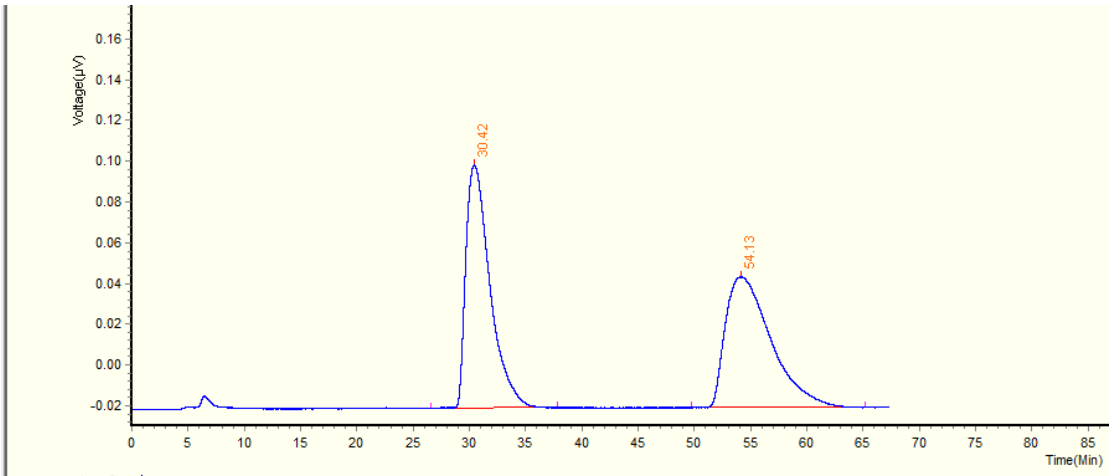
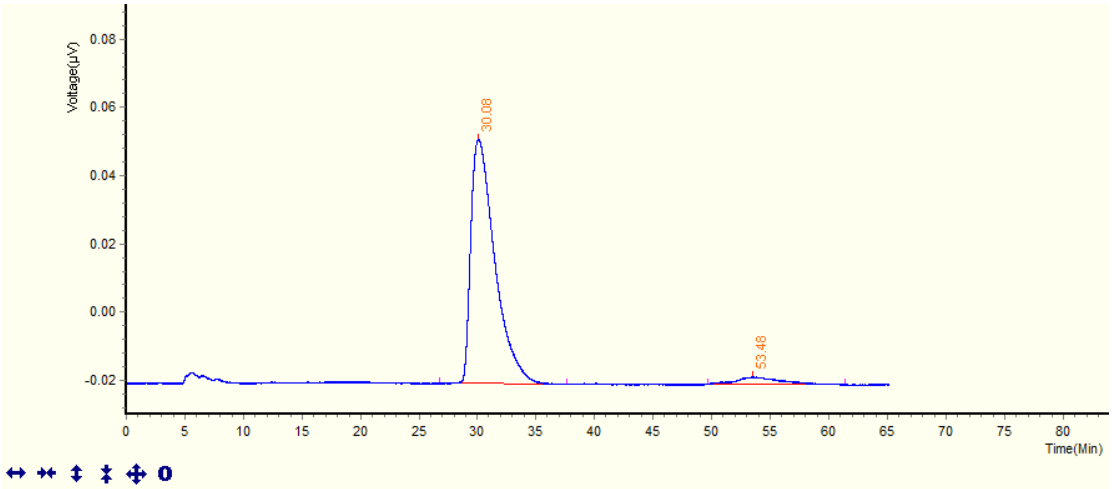


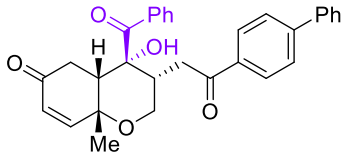
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	30.42	8916110	59677	49.65%	11.329	BB
2	54.13	9041585	32121	50.35%	15.371	BB
Total		17,957,695	91,798	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	30.08	5104903	35842	94.96%	10.897	BB
2	53.48	271136	1065	5.04%	11.724	BB
Total		5,376,039	36,907	100.00%		



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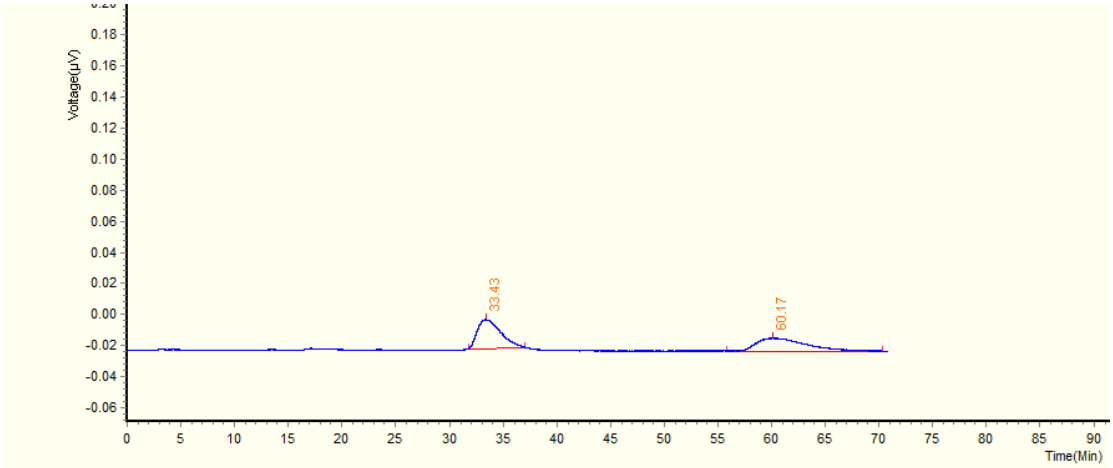
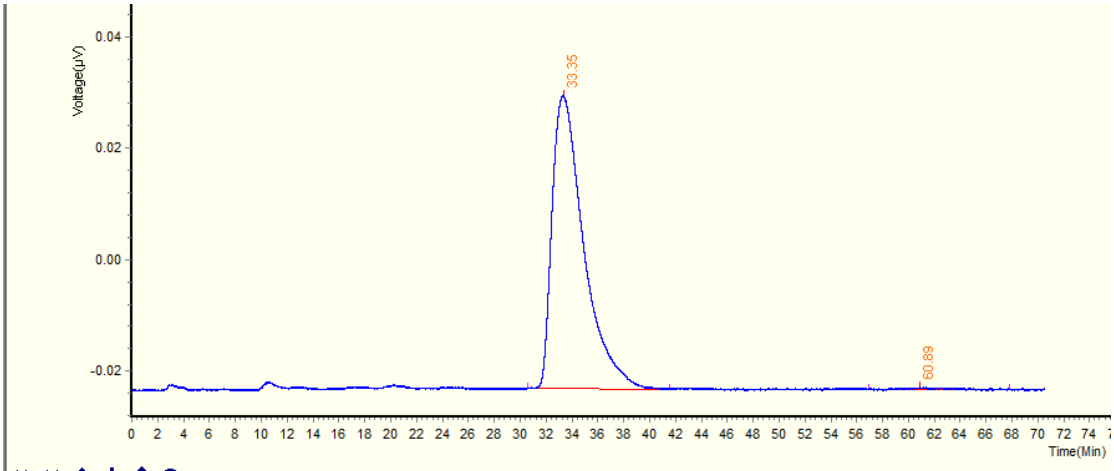


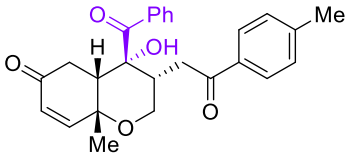
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	33.43	1379564	9178	51.43%	5.238	BB
2	60.17	1302907	4128	48.57%	14.482	BB
Total		2,682,471	13,306	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	33.35	4481812	26324	99.67%	11.019	BB
2	60.89	14743	168	0.33%	10.839	BB
Total		4,496,555	26,492	100.00%		



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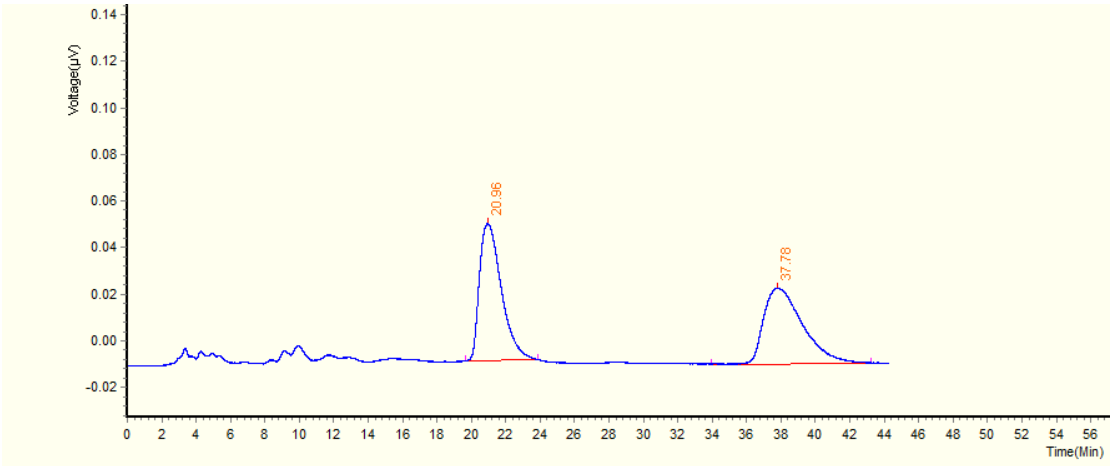
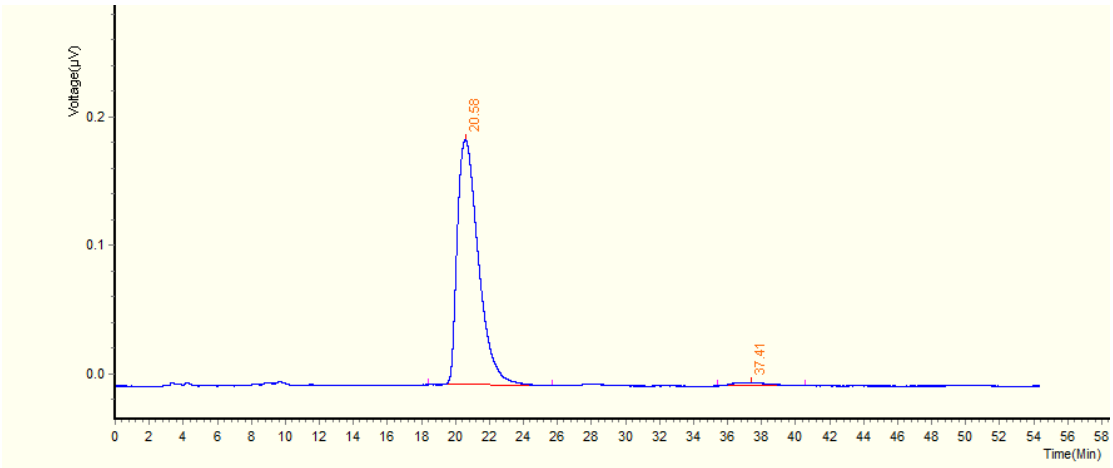


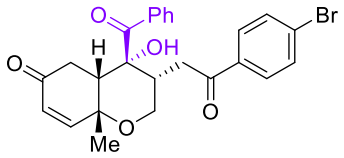
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	20.96	2607654	29411	50.85%	4.207	BB
2	37.78	2520378	16241	49.15%	9.283	BB
Total		5,128,032	45,652	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	20.58	8272723	95646	97.82%	7.228	BB
2	37.41	184538	1253	2.18%	5.133	BB
Total		8,457,261	96,899	100.00%		



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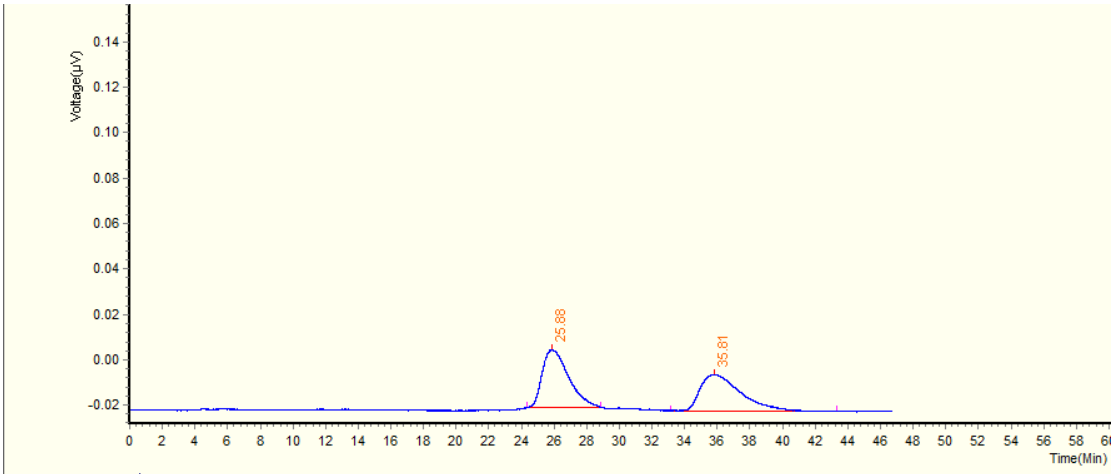
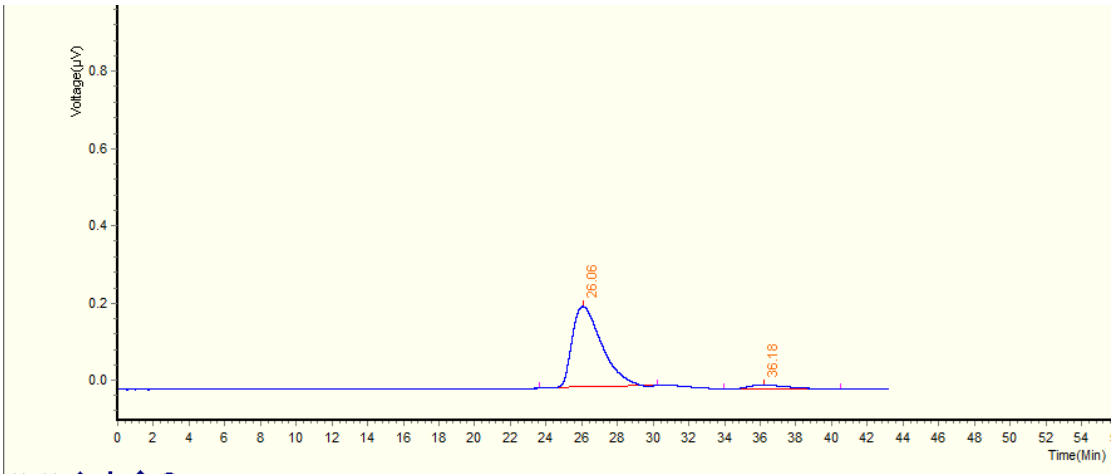


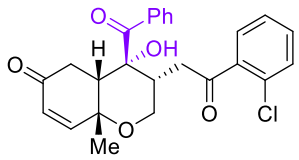
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	25.88	1418474	12652	50.81%	4.528	BB
2	35.81	1373029	8010	49.19%	10.15	BB
Total		2,791,503	20,662	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	26.06	11999120	104173	94.29%	6.609	BB
2	36.18	726037	4910	5.71%	6.486	BB
Total		12,725,157	109,083	100.00%		



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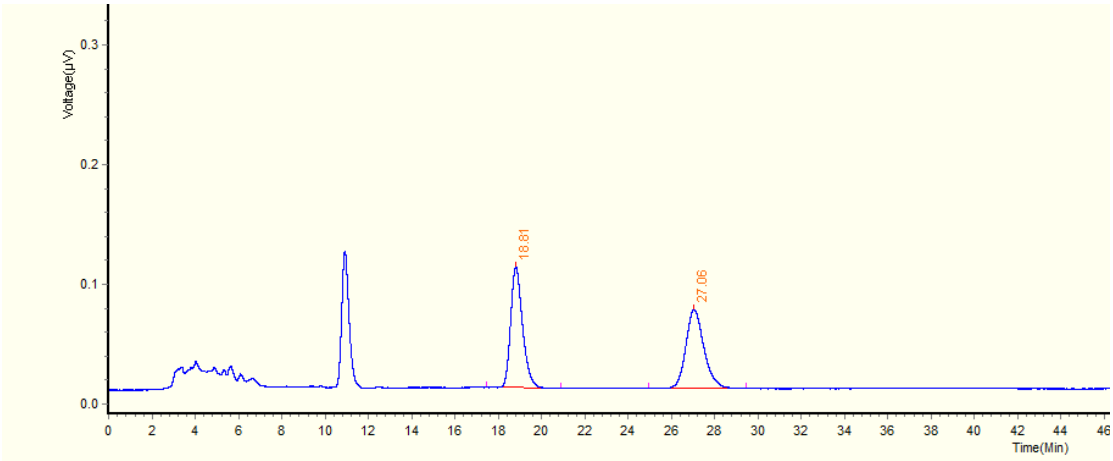
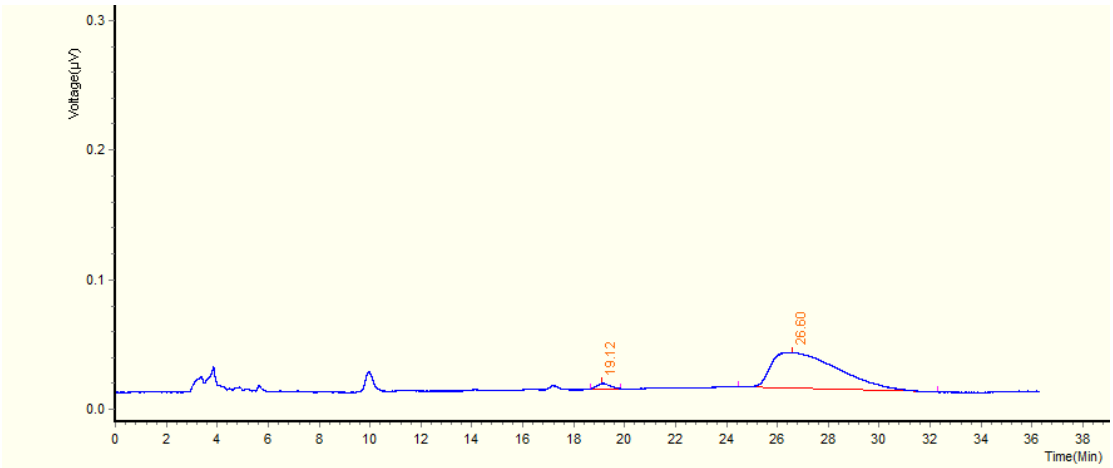


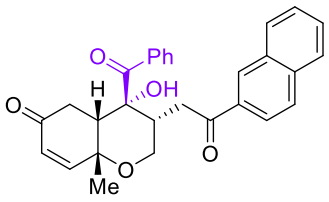
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	18.81	1930483	50475	50.25%	3.402	BB
2	27.06	1911402	32898	49.75%	4.49	BB
Total		3,841,885	83,373	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	19.12	67496	2018	2.58%	1.137	BB
2	26.60	2551169	13741	97.42%	7.825	BB
Total		2,618,665	15,759	100.00%		



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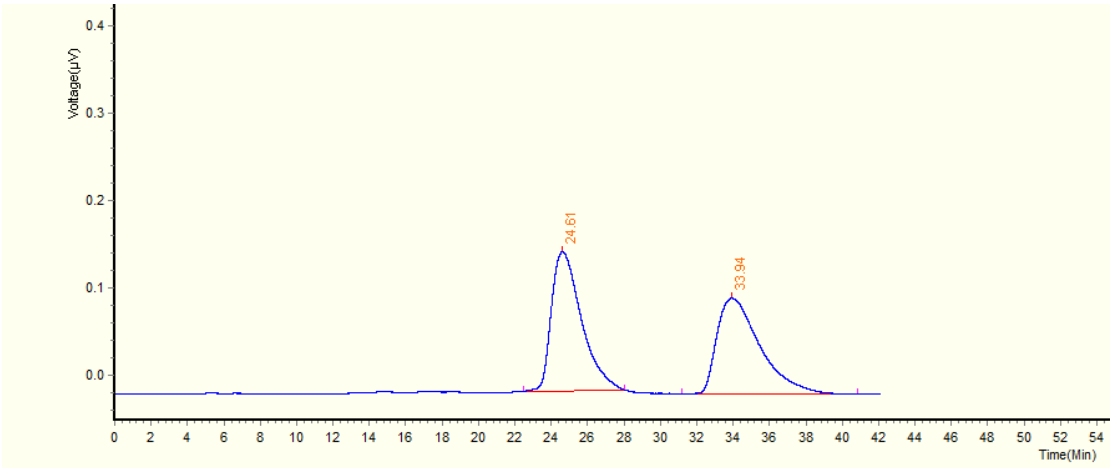
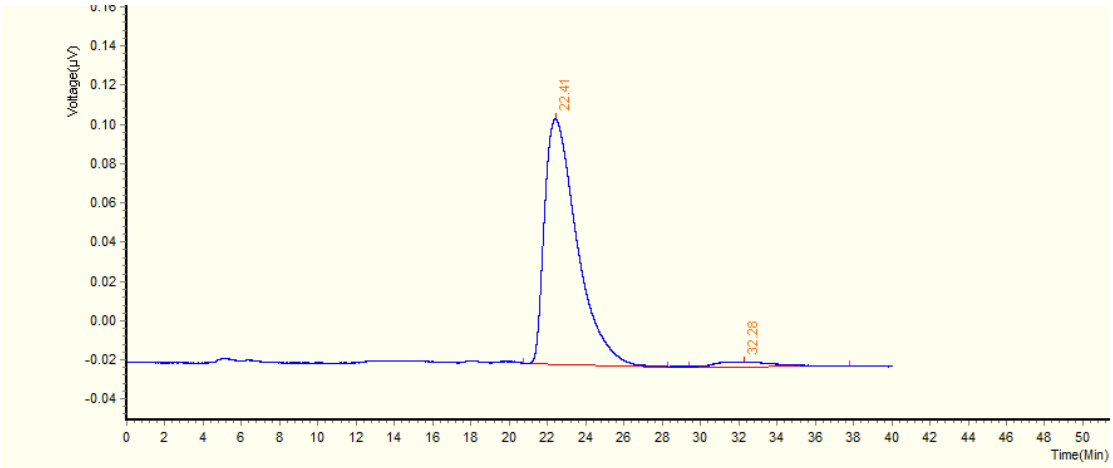


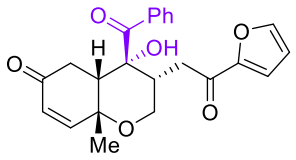
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	24.61	9102778	79458	50.35%	5.556	BB
2	33.94	8977584	54673	49.65%	9.68	BB
Total		18,080,362	134,131	100.00%		

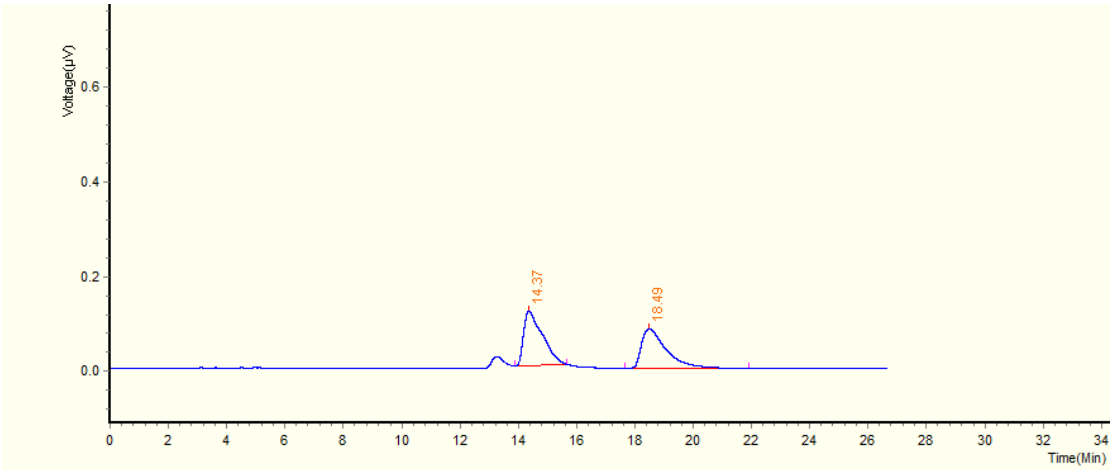


Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	22.41	7332759	62327	96.68%	7.5	BB
2	32.28	251991	1233	3.32%	8.418	BB
Total		7,584,750	63,560	100.00%		

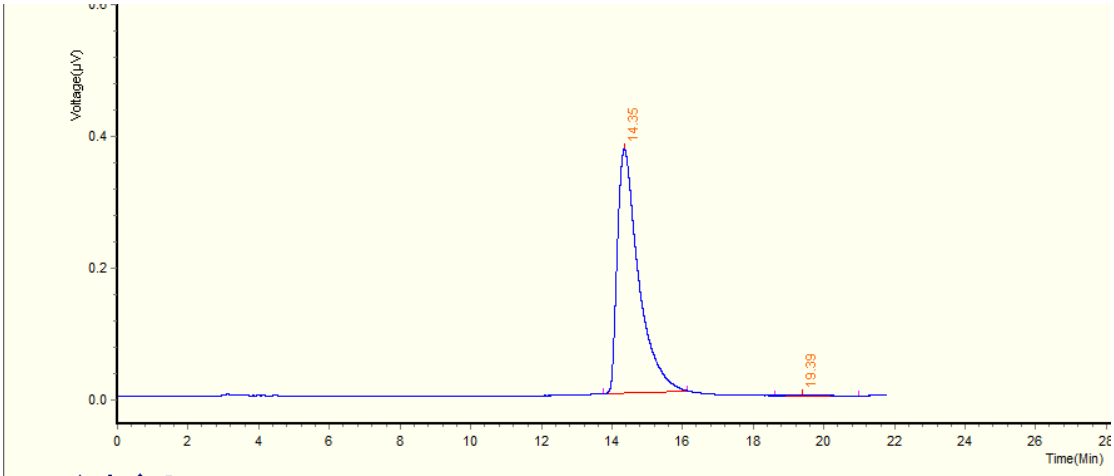


3s



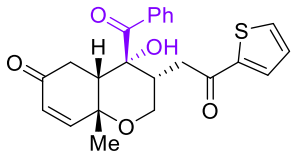
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	14.37	2577507	57911	51.26%	1.791	BB
2	18.49	2450924	41639	48.74%	4.279	BB
Total		5,028,431	99,550	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	14.35	7737642	185744	99.56%	2.392	BB
2	19.39	34514	694	0.44%	2.386	BB
Total		7,772,156	186,438	100.00%		



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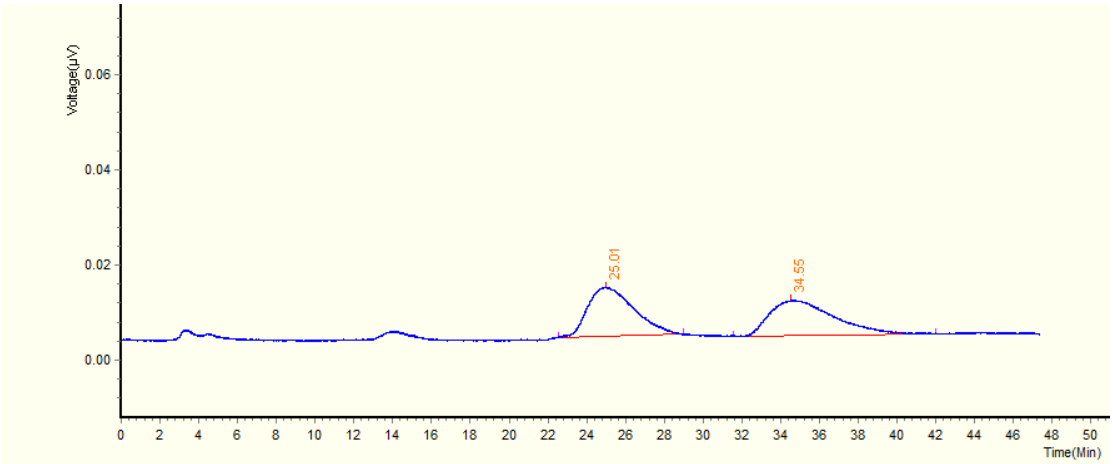
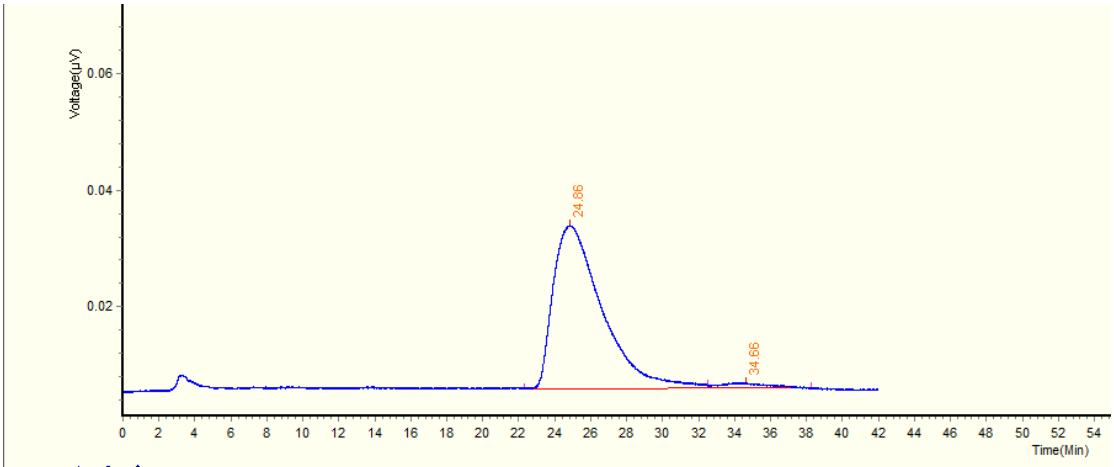


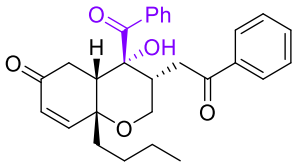
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	25.01	844409	5139	50.20%	6.437	BB
2	34.55	837834	3682	49.80%	10.478	BB
Total		1,682,243	8,821	100.00%		

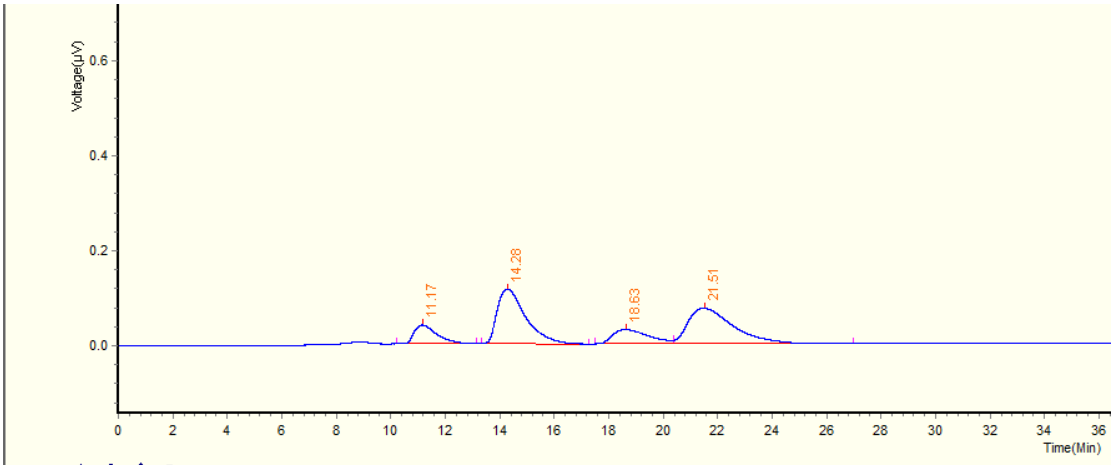


Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	24.86	2629718	13933	97.22%	10.193	BV
2	34.66	75301	425	2.78%	5.724	VB
Total		2,705,019	14,358	100.00%		

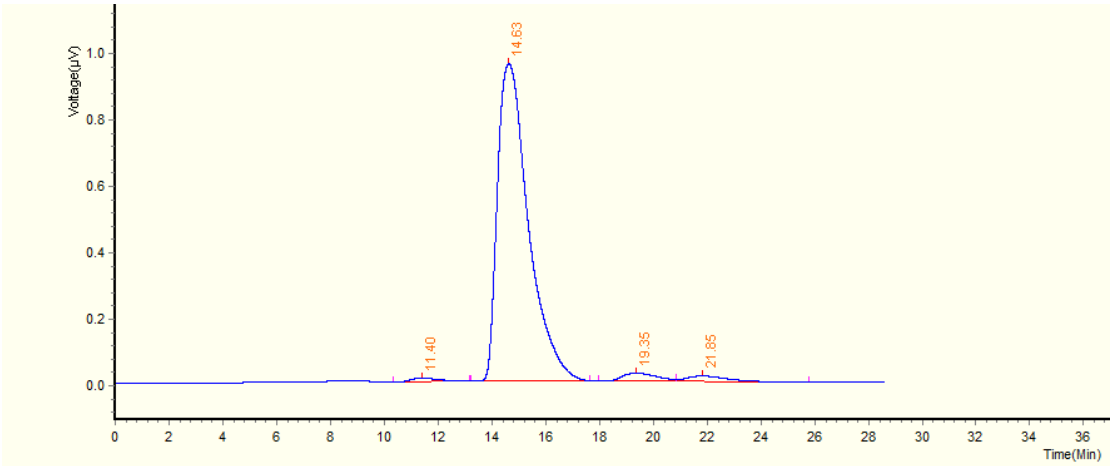


3u



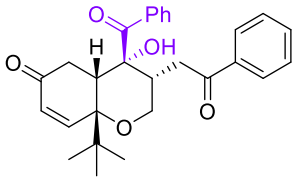
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	11.17	1142206	19669	10.43%	2.946	BB
2	14.28	4139630	57408	37.81%	3.906	BB
3	18.63	1381675	14889	12.62%	2.881	BV
4	21.51	4285366	37171	39.14%	6.564	VB
Total		10,948,877	129,137	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	11.40	337699	5063	0.83%	2.847	BB
2	14.63	38292082	478750	94.11%	4.433	BB
3	19.35	1115207	12364	2.74%	2.893	BV
4	21.85	943246	8580	2.32%	4.947	VB
Total		40,688,234	504,757	100.00%		



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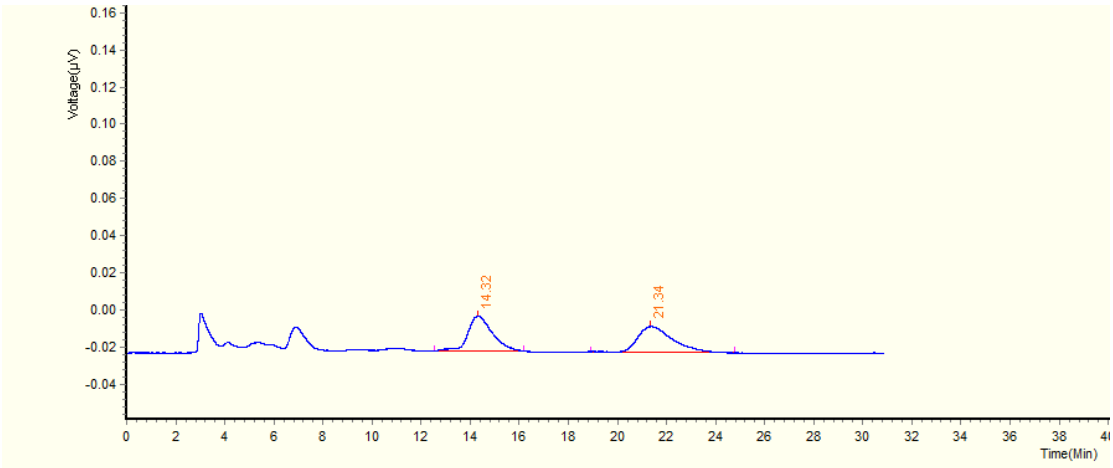
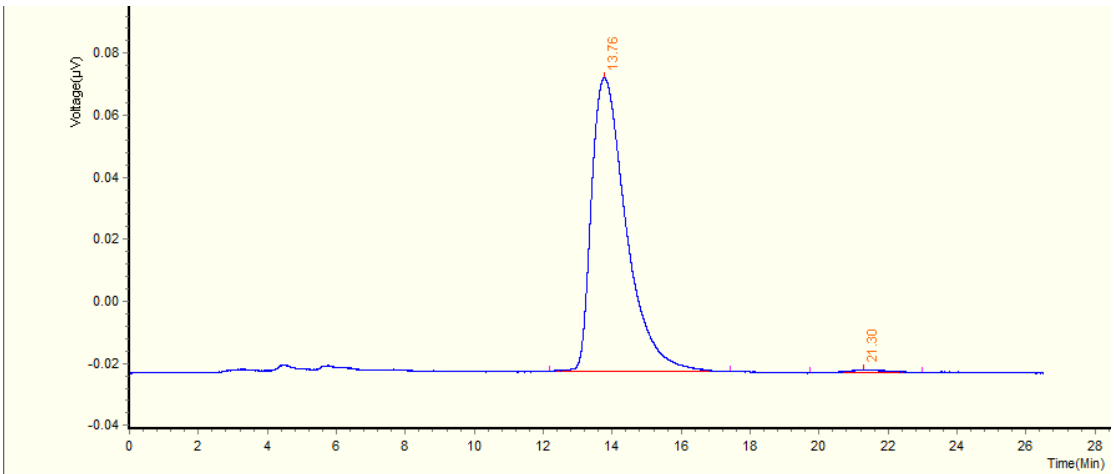


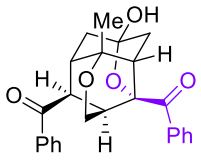
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	14.32	653699	9470	49.43%	3.641	BB
2	21.34	668888	6914	50.57%	5.866	BB
Total		1,322,587	16,384	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	13.76	3291295	47266	99.04%	5.251	BB
2	21.30	31803	450	0.96%	3.253	BB
Total		3,323,098	47,716	100.00%		



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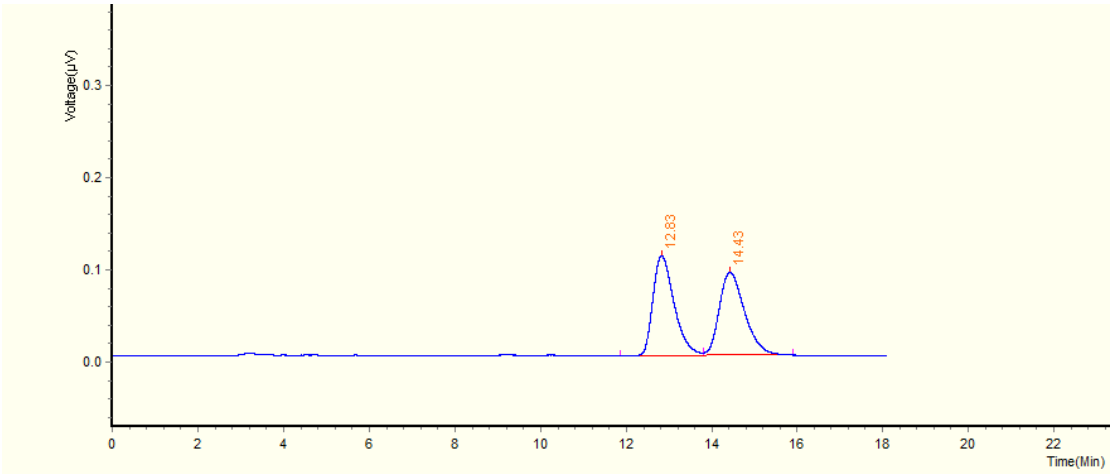
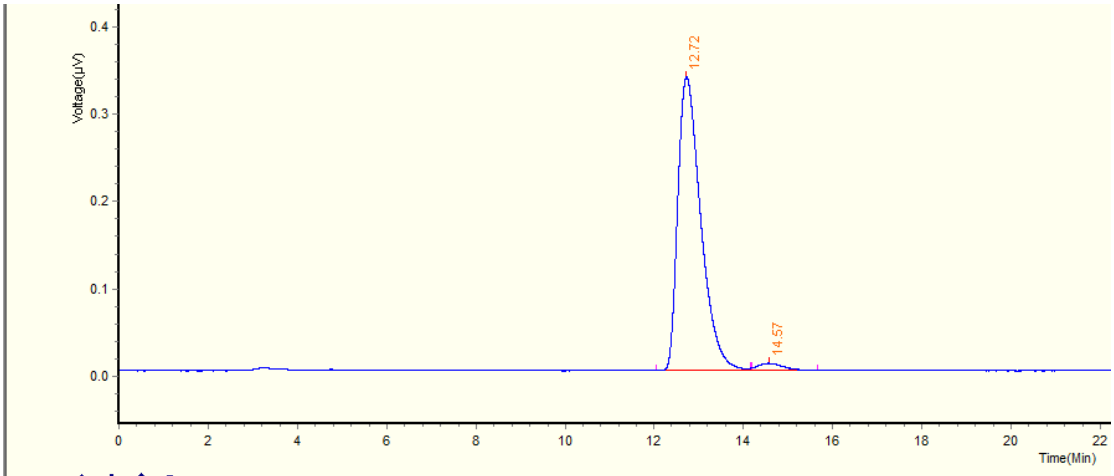


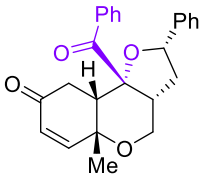
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	12.83	1858084	54132	50.07%	1.95	BV
2	14.43	1853213	45178	49.93%	2.08	VB
Total		3,711,297	99,310	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	12.72	6002971	168155	97.36%	2.141	BV
2	14.57	162961	4134	2.64%	1.489	VB
Total		6,165,932	172,289	100.00%		



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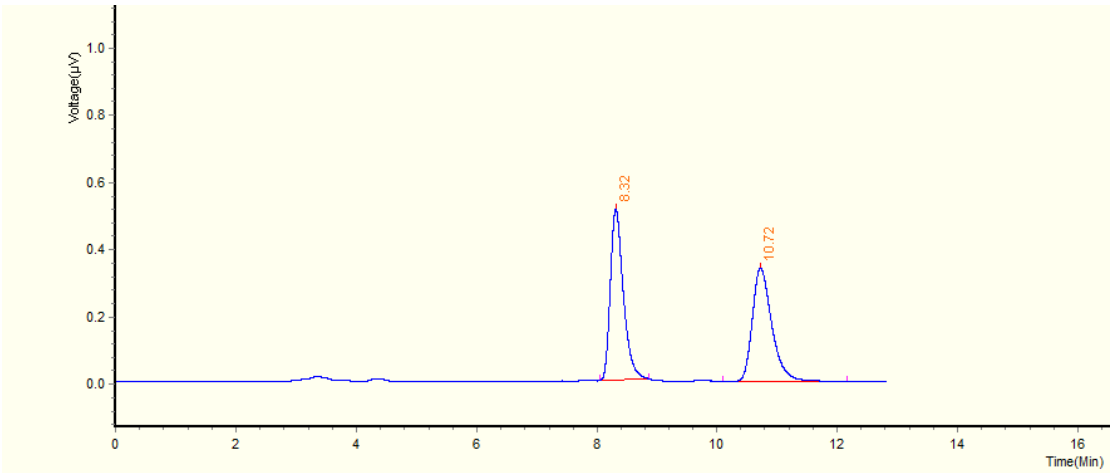
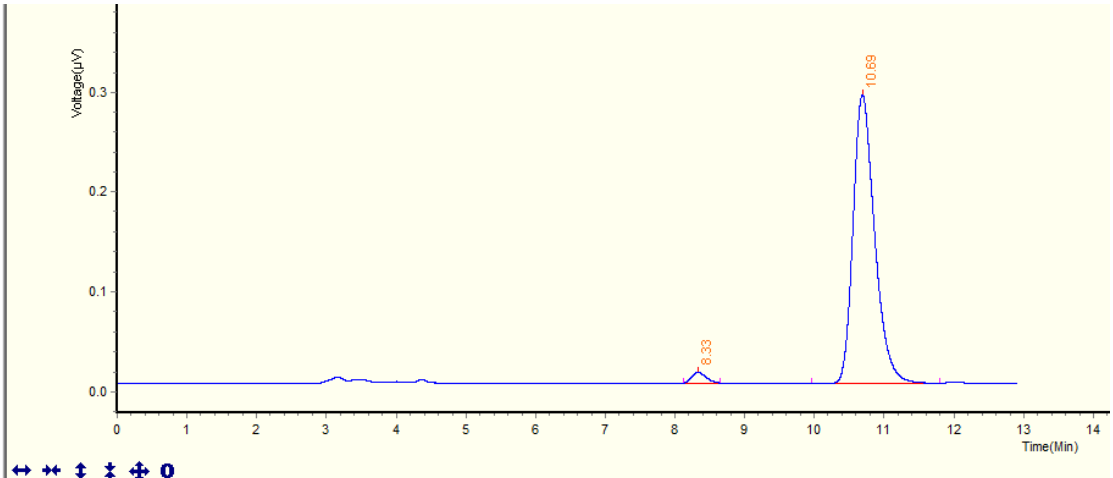


Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	8.32	3826591	254471	50.40%	0.817	BB
2	10.72	3766324	168538	49.60%	2.052	BB
Total		7,592,915	423,009	100.00%		



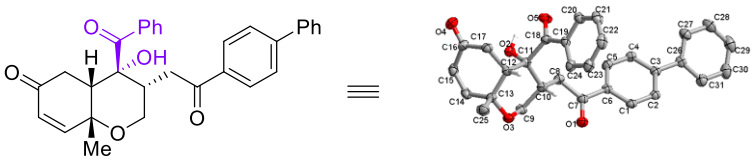
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	
1	8.33	77785	5586	2.46%	0.528	BB
2	10.69	3087864	144169	97.54%	1.839	BB
Total		3,165,649	149,755	100.00%		

Single-crystal X-ray diffraction of 3n (CCDC: 2234463)

X-ray analysis was carried out using the single crystal which was grown in Hexane/$CHCl_3$.

The instrumentation used for the crystal measurement is Oxford Gemini E X-ray single-crystal diffractometer (ellipsoid contour at 30% probability level).



3n

X-ray of **3n**
CCDC (2234463)

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) 230102lu_lgpz291191_0m

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: 230102lu_lgpz291191_0m

```
Bond precision:   C-C = 0.0031 A          Wavelength=1.34139

Cell:             a=9.1413(5)     b=12.3151(7)        c=11.0137(6)
                  alpha=90        beta=92.512(2)      gamma=90
Temperature:      193 K

                  Calculated                  Reported
Volume            1238.69(12)                 1238.69(12)
Space group       P 21                        P 1 21 1
Hall group        P 2yb                       P 2yb
Moiety formula    C31 H28 O5                  C31 H28 O5
Sum formula       C31 H28 O5                  C31 H28 O5
Mr                480.53                      480.53
Dx,g cm-3         1.288                       1.288
Z                 2                           2
Mu (mm-1)         0.445                       0.445
F000              508.0                       508.0
F000'             509.18
h,k,lmax          11,15,14                    11,15,14
Nref              5631[ 2947]                 5470
Tmin,Tmax         0.944,0.956                 0.677,0.752
Tmin'             0.944

Correction method= # Reported T Limits: Tmin=0.677 Tmax=0.752
AbsCorr = MULTI-SCAN

Data completeness= 1.86/0.97        Theta(max)= 60.365

R(reflections)= 0.0332( 4996)                wR2(reflections)=
                                             0.0825( 5470)
S = 1.058                  Npar= 327
```

```
The following ALERTS were generated. Each ALERT has the format
       test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.
```

Alert level C

```
PLAT911_ALERT_3_C Missing FCF Refl Between Thmin & STh/L=    0.600         19 Report
PLAT913_ALERT_3_C Missing # of Very Strong Reflections in FCF ....          6 Note
```

Alert level G

```
ABSMU01_ALERT_1_G  Calculation of _exptl_absorpt_correction_mu
                not performed for this radiation type.
PLAT007_ALERT_5_G Number of Unrefined Donor-H Atoms ..............          1 Report
PLAT791_ALERT_4_G Model has Chirality at C15         (Sohnke SpGr)         R Verify
PLAT791_ALERT_4_G Model has Chirality at C16         (Sohnke SpGr)         S Verify
PLAT791_ALERT_4_G Model has Chirality at C24         (Sohnke SpGr)         S Verify
PLAT791_ALERT_4_G Model has Chirality at C29         (Sohnke SpGr)         R Verify
PLAT850_ALERT_4_G Check Flack Parameter Exact Value 0.00 with s.u.      0.06 Check
PLAT912_ALERT_4_G Missing # of FCF Reflections Above STh/L=  0.600        36 Note
PLAT978_ALERT_2_G Number C-C Bonds with Positive Residual Density.         0 Info
PLAT992_ALERT_5_G Repd & Actual _reflns_number_gt Values Differ by         4 Check
```

```
   0 ALERT level A = Most likely a serious problem - resolve or explain
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   2 ALERT level C = Check. Ensure it is not caused by an omission or oversight
  10 ALERT level G = General information/check it is not something unexpected

   1 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
   1 ALERT type 2 Indicator that the structure model may be wrong or deficient
   2 ALERT type 3 Indicator that the structure quality may be low
   6 ALERT type 4 Improvement, methodology, query or suggestion
   2 ALERT type 5 Informative message, check
```

It is advisable to attempt to resolve as many as possible of the alerts in all categories. Often the minor alerts point to easily fixed oversights, errors and omissions in your CIF or refinement strategy, so attention to these fine details can be worthwhile. In order to resolve some of the more serious problems it may be necessary to carry out additional measurements or structure refinements. However, the purpose of your study may justify the reported deviations and the more serious of these should normally be commented upon in the discussion or experimental section of a paper or in the "special_details" fields of the CIF. checkCIF was carefully designed to identify outliers and unusual parameters, but every test has its limitations and alerts that are not important in a particular case may appear. Conversely, the absence of alerts does not guarantee there are no aspects of the results needing attention. It is up to the individual to critically assess their own results and, if necessary, seek expert advice.

Publication of your CIF in IUCr journals

A basic structural check has been run on your CIF. These basic checks will be run on all CIFs submitted for publication in IUCr journals (*Acta Crystallographica*, *Journal of Applied Crystallography*, *Journal of Synchrotron Radiation*); however, if you intend to submit to *Acta Crystallographica Section C* or *E* or *IUCrData*, you should make sure that full publication checks are run on the final version of your CIF prior to submission.

Publication of your CIF in other journals

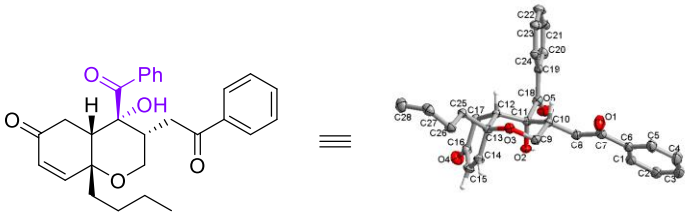
Please refer to the *Notes for Authors* of the relevant journal for any special instructions relating to CIF submission.

PLATON version of 28/11/2022; check.def file version of 28/11/2022

Single-crystal X-ray diffraction of 3u (CCDC: 2246355)

X-ray analysis was carried out using the single crystal which was grown in Hexane/$CHCl_3$.

The instrumentation used for the crystal measurement is Oxford Gemini E X-ray single-crystal diffractometer (ellipsoid contour at 30% probability level).



3u

X-ray of **3u**
CCDC (2246355)

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) 20230206

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: 20230206

```
Bond precision:   C-C = 0.0057 A          Wavelength=1.54184

Cell:             a=11.5324(2)      b=11.5324(2)      c=14.9982(3)
                  alpha=90          beta=90           gamma=120
Temperature:      293 K
```

	Calculated	Reported
Volume	1727.47(7)	1727.46(8)
Space group	P 31	P 31
Hall group	P 31	P 31
Moiety formula	C28 H30 O5	C28 H30 O5
Sum formula	C28 H30 O5	C28 H30 O5
Mr	446.52	446.52
Dx,g cm-3	1.288	1.288
Z	3	3
Mu (mm-1)	0.705	0.705
F000	714.0	714.0
F000'	716.18	
h,k,lmax	14,14,18	14,13,18
Nref	4454[2227]	4078
Tmin,Tmax	0.903,0.932	0.951,1.000
Tmin'	0.893	

```
Correction method= # Reported T Limits: Tmin=0.951 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.83/0.92        Theta(max)= 70.942

R(reflections)= 0.0465( 3850)                wR2(reflections)=
                                             0.1280( 4078)
S = 1.043                  Npar= 300
```

```
The following ALERTS were generated. Each ALERT has the format
       test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.
```

Alert level C

```
PLAT089_ALERT_3_C Poor Data / Parameter Ratio (Zmax < 18) ........       7.36 Note
PLAT340_ALERT_3_C Low Bond Precision on  C-C Bonds ...............     0.0057 Ang.
```

Alert level G

```
PLAT007_ALERT_5_G Number of Unrefined Donor-H Atoms ..............          1 Report
PLAT199_ALERT_1_G Reported _cell_measurement_temperature ..... (K)       293 Check
PLAT200_ALERT_1_G Reported   _diffrn_ambient_temperature ..... (K)       293 Check
PLAT791_ALERT_4_G Model has Chirality at C10         (Sohnke SpGr)         R Verify
PLAT791_ALERT_4_G Model has Chirality at C11         (Sohnke SpGr)         S Verify
PLAT791_ALERT_4_G Model has Chirality at C12         (Sohnke SpGr)         S Verify
PLAT791_ALERT_4_G Model has Chirality at C13         (Sohnke SpGr)         R Verify
PLAT912_ALERT_4_G Missing # of FCF Reflections Above STh/L=  0.600        19 Note
PLAT941_ALERT_3_G Average HKL Measurement Multiplicity ...........       4.3 Low
PLAT978_ALERT_2_G Number C-C Bonds with Positive Residual Density.         6 Info
PLAT992_ALERT_5_G Repd & Actual _reflns_number_gt Values Differ by         2 Check
```

```
   0 ALERT level A = Most likely a serious problem - resolve or explain
   0 ALERT level B = A potentially serious problem, consider carefully
   2 ALERT level C = Check. Ensure it is not caused by an omission or oversight
  11 ALERT level G = General information/check it is not something unexpected

   2 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
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   3 ALERT type 3 Indicator that the structure quality may be low
   5 ALERT type 4 Improvement, methodology, query or suggestion
   2 ALERT type 5 Informative message, check
```

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Publication of your CIF in IUCr journals

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Publication of your CIF in other journals

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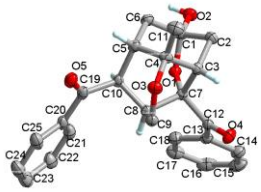
PLATON version of 28/11/2022; check.def file version of 28/11/2022

Single-crystal X-ray diffraction of rac-4 (CCDC: 2281199)

X-ray analysis was carried out using the single crystal which was grown in Hexane/$CHCl_3$.

The instrumentation used for the crystal measurement is Oxford Gemini E X-ray single-crystal diffractometer (ellipsoid contour at 30% probability level).



X-ray of *rac*-**4**
CCDC (2281199)

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) 202307177_auto

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: 202307177_auto

```
Bond precision:   C-C = 0.0033 A          Wavelength=1.54184

Cell:           a=8.0964(6)        b=11.2963(8)      c=12.0978(8)
                alpha=116.586(7)   beta=95.901(6)    gamma=91.924(6)
Temperature:    293 K

                 Calculated                Reported
Volume           980.27(14)                980.27(13)
Space group      P -1                      P -1
Hall group       -P 1                      -P 1
Moiety formula   C25 H24 O5                C25 H24 O5
Sum formula      C25 H24 O5                C25 H24 O5
Mr               404.44                    404.44
Dx,g cm-3        1.370                     1.370
Z                2                         2
Mu (mm-1)        0.772                     0.772
F000             428.0                     428.0
F000'            429.35
h,k,lmax         9,13,14                   9,13,14
Nref             3513                      3509
Tmin,Tmax        0.912,0.933               0.931,1.000
Tmin'            0.912

Correction method= # Reported T Limits: Tmin=0.931 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 0.999          Theta(max)= 67.022

R(reflections)= 0.0477( 2771)                wR2(reflections)=
                                             0.1287( 3509)
S = 1.037                 Npar= 273
```

The following ALERTS were generated. Each ALERT has the format
test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.

Alert level C

PLAT906_ALERT_3_C Large K Value in the Analysis of Variance ..... 2.538 Check
PLAT911_ALERT_3_C Missing FCF Refl Between Thmin & STh/L= 0.597 5 Report

Alert level G

PLAT007_ALERT_5_G Number of Unrefined Donor-H Atoms ..... 1 Report
PLAT199_ALERT_1_G Reported _cell_measurement_temperature ..... (K) 293 Check
PLAT200_ALERT_1_G Reported _diffrn_ambient_temperature ..... (K) 293 Check
PLAT398_ALERT_2_G Deviating C-O-C Angle From 120 for O1 . 107.7 Degree
PLAT909_ALERT_3_G Percentage of I>2sig(I) Data at Theta(Max) Still 69% Note
PLAT941_ALERT_3_G Average HKL Measurement Multiplicity ..... 2.0 Low
PLAT978_ALERT_2_G Number C-C Bonds with Positive Residual Density. 6 Info

0 **ALERT level A** = Most likely a serious problem - resolve or explain
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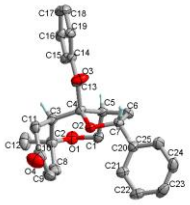
2 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
2 ALERT type 2 Indicator that the structure model may be wrong or deficient
4 ALERT type 3 Indicator that the structure quality may be low
0 ALERT type 4 Improvement, methodology, query or suggestion
1 ALERT type 5 Informative message, check

Single-crystal X-ray diffraction of rac-5 (CCDC: 2266697)

X-ray analysis was carried out using the single crystal which was grown in Hexane/$CHCl_3$.

The instrumentation used for the crystal measurement is Oxford Gemini E X-ray single-crystal diffractometer (ellipsoid contour at 30% probability level).



X-ray of *rac*-**5**
CCDC (2266697)

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) 20230356

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: 20230356

```
Bond precision:   C-C = 0.0046 A           Wavelength=1.54184

Cell:               a=8.5167(2)      b=14.0635(4)      c=17.0011(5)
                    alpha=90         beta=90           gamma=90
Temperature:        293 K

                  Calculated                  Reported
Volume            2036.30(10)                 2036.30(10)
Space group       P 21 21 21                  P 21 21 21
Hall group        P 2ac 2ab                   P 2ac 2ab
Moiety formula    C25 H24 O4                  C25 H24 O4
Sum formula       C25 H24 O4                  C25 H24 O4
Mr                388.44                      388.44
Dx,g cm-3         1.267                       1.267
Z                 4                           4
Mu (mm-1)         0.683                       0.683
F000              824.0                       824.0
F000'             826.50
h,k,lmax          10,17,20                    10,17,20
Nref              3891[ 2229]                 3872
Tmin,Tmax         0.914,0.940                 0.911,1.000
Tmin'             0.903

Correction method= # Reported T Limits: Tmin=0.911 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.74/1.00        Theta(max)= 70.457

R(reflections)= 0.0417( 3468)                wR2(reflections)=
                                             0.1152( 3872)
S = 1.047                  Npar= 263
```

The following ALERTS were generated. Each ALERT has the format
test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.

Alert level C

```
STRVA01_ALERT_4_C           Flack test results are ambiguous.
          From the CIF: _refine_ls_abs_structure_Flack    0.410
          From the CIF: _refine_ls_abs_structure_Flack_su    0.150
PLAT230_ALERT_2_C Hirshfeld Test Diff for    C10      --C11      .        5.5 s.u.
PLAT340_ALERT_3_C Low Bond Precision on  C-C Bonds ..............    0.00463 Ang.
```

Alert level G

```
PLAT199_ALERT_1_G Reported _cell_measurement_temperature ..... (K)         293 Check
PLAT200_ALERT_1_G Reported   _diffrn_ambient_temperature ..... (K)         293 Check
PLAT398_ALERT_2_G Deviating  C-O-C   Angle From 120 for O2       .       107.4 Degree
PLAT791_ALERT_4_G Model has Chirality at C2          (Sohnke SpGr)           S Verify
PLAT791_ALERT_4_G Model has Chirality at C3          (Sohnke SpGr)           R Verify
PLAT791_ALERT_4_G Model has Chirality at C4          (Sohnke SpGr)           R Verify
PLAT791_ALERT_4_G Model has Chirality at C5          (Sohnke SpGr)           S Verify
PLAT791_ALERT_4_G Model has Chirality at C7          (Sohnke SpGr)           R Verify
PLAT912_ALERT_4_G Missing # of FCF Reflections Above STh/L=  0.600           5 Note
PLAT978_ALERT_2_G Number C-C Bonds with Positive Residual Density.           2 Info
```

```
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   1 ALERT type 3 Indicator that the structure quality may be low
   7 ALERT type 4 Improvement, methodology, query or suggestion
   0 ALERT type 5 Informative message, check
```