

Supporting information

Organocatalytic Knoevenagel Condensation by Chiral C₂-Symmetric Tertiary Diamines

Xiaoyu Gu^a, Yan Tang^a, Xiang Zhang^a, Zhibin Luo^b and Hongfei Lu^{a*}

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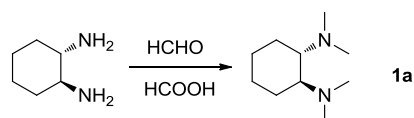
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General Information:

Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. All solvents used in the reactions were distilled from appropriate drying agents prior to use. Reactions were monitored by thin layer chromatography on silica gel. Column chromatography was performed with silica gel 200-300 mesh. All ^1H NMR and ^{13}C NMR spectra were recorded in CDCl_3 and CD_3OD solution and reported in ppm (δ). ^1H NMR spectra were referenced internally to the residual proton resonance in CDCl_3 ($\delta=7.26$ ppm), or with tetramethylsilane (TMS, $\delta=0.00$ ppm) as the internal standard. HPLC chromatograms of Knoevenagel condensates were obtained using a Shimadzu apparatus, LC-20AT Pump, SPD-10A UV/Vis Detector, SCL-10A System Controller, using a Chiralcel IA (4.6 mm \times 250 mmL, particle size 5 μm) or a Chiralcel OD-H (4.6 mm \times 250 mmL, particle size 5 μm).

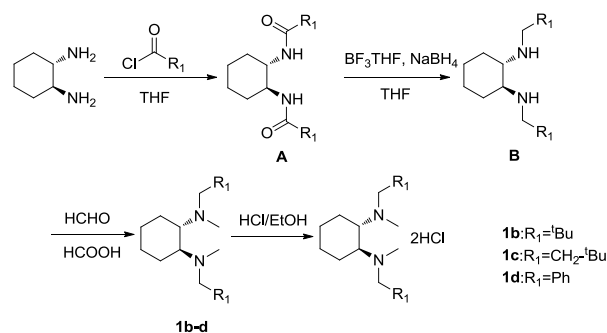
1. Synthesis of the organocatalysts [1]:

1.1 General synthetic procedure for catalyst 1a:



(S, S)-1, 2-Diaminocyclohexane (11.4g, 0.1mol) was dissolved in formic acid 85% (40mL) and paraformaldehyde 95% (50mL) was added slowly at room temperature. The mixture was heated at reflux 6h. After cooling, the reaction mixture was made basic until PH=14 and extracted with ether. The combined organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated under reduced pressure. The product **1a** was distilled to give a colorless liquid (12.8g 75%).

1.2 General synthetic procedure for other catalysts:



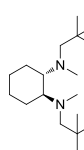
To take 1c as example for synthetic procedure. Drop-wise tert-butylacetyl chloride (14.8g, 0.11mol) was added to a cooled (0°C) solution of 1, 2-Diaminocyclohexane (5.7g, 0.05mol) in dry THF. The suspension was stirred in an ice bath for 30 min, then heated to 50°C . After stirring 12h at this temperature, the mixture was quenched with 1M aqueous sodium hydroxide until $\text{pH}>12$. The layers were separated and the organic phase was washed with brine, driven over Na_2SO_4 filtered and concentrated in vacuum. The residue was dried adequately under reduced pressure to give A as a white solid. This material was pure enough to be used in the next step without further purification. To a cooled suspension of A (9.3g, 0.03mol) and NaBH_4 (4.5 g, 0.12mol) in dry THF (60mL) at 0°C was added drop-wise a solution of $\text{BF}_3\cdot\text{THF}$ (37.8g, 0.135mol) in 20mL of dry THF over 30 min. The reaction mixture was heated to reflux slowly and reacted for 72h. The suspension was cooled to room

temperature, poured into crushed ice and extracted with ether. The combined organic layer was dried over Na_2CO_3 , filtered and concentrated to give the crude diamine B as a solid, which was methylated without purification. The diamine B (6.8g, 0.24mol) was dissolved in formic acid 85% (35mL), paraformaldehyde 95% (3.0g) was added and the mixture was refluxed 8h. After basification and extraction with ether, the organic layer was dried over Na_2SO_4 , filtered and concentrated. The crude product was purified by recrystallization with EtOH-HCl to give the desired products.

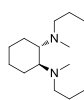
1.3 Spectral details of organocatalysts^[1]:



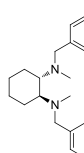
1a: ^1H NMR (500 MHz, CDCl_3) δ 2.37 (dd, $J = 8.8, 5.7$ Hz, 2H), 2.26 (s, 12H), 1.84–1.79 (m, 2H), 1.74–1.69 (m, 2H), 1.10 (dd, $J = 16.3, 8.6$ Hz, 4H). $[\alpha]_{\text{D}}^{20} = -62.9$ (c 1.05, CHCl_3).



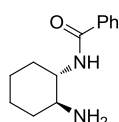
1b: ^1H NMR (500 MHz, CDCl_3) δ 2.35–2.32 (m, 2H), 2.30 (d, $J = 4.5$ Hz, 4H), 2.28 (s, 6H), 1.75 (d, $J = 13.1$ Hz, 2H), 1.68–1.61 (m, 2H), 1.22 (ddd, $J = 21.0, 9.7, 3.3$ Hz, 2H), 1.09–0.99 (m, 2H), 0.88 (s, 18H). $[\alpha]_{\text{D}}^{20} = +6.3$ (c 1.03, CHCl_3).



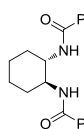
1c: ^1H NMR (500 MHz, CDCl_3) δ 2.46–2.54 (m, 6H), 2.26 (s, 6H), 1.78–1.81 (m, 2H), 1.72–1.73 (m, 2H), 1.40 (m, 4H), 1.11–1.20 (m, 4H), 0.91 (s, 18H). $[\alpha]_{\text{D}}^{20} = -31.1$ (c 1.02, CHCl_3).



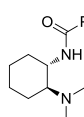
1d: ^1H NMR (500 MHz, CDCl_3) δ 7.38 (d, $J = 7.3$ Hz, 4H), 7.27 (t, $J = 7.4$ Hz, 4H), 7.21 (t, $J = 7.2$ Hz, 2H), 3.74 (d, $J = 13.3$ Hz, 2H), 3.65 (d, $J = 13.3$ Hz, 2H), 2.62 (dd, $J = 5.7, 3.3$ Hz, 2H), 2.21 (s, 6H), 1.92 (d, $J = 12.8$ Hz, 2H), 1.73 (dd, $J = 6.4, 2.5$ Hz, 2H), 1.25 (dd, $J = 8.4, 5.9$ Hz, 2H), 1.12 (t, $J = 9.5$ Hz, 2H). $[\alpha]_{\text{D}}^{20} = +7.22$ (c 1.02, CHCl_3).



1e: ^1H NMR (400MHz, CDCl_3) δ 7.90-7.74 (m, 2H), 7.59-7.37 (m, 3H), 6.97 (s, 1H), 4.15-4.01 (m, 1H), 3.13 (dd, $J=8.5, 3.9$ Hz, 1H), 1.71-1.42 (m, 8H).

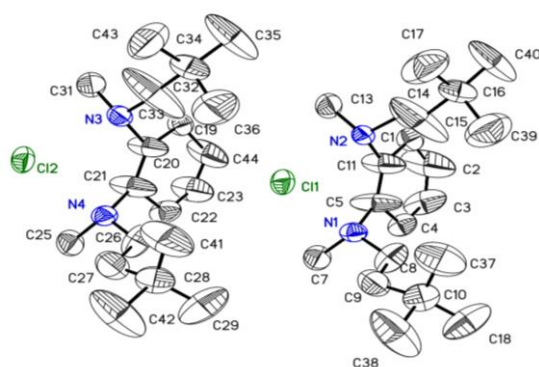


1f: ^1H NMR (300MHz, CDCl_3) δ 7.74-7.67 (m, 4H), 7.48-7.42 (m, 2H), 7.42-7.36 (m, 4H), 3.93 (s, 2H), 2.52-2.49 (m, 2H), 1.91 (d, $J=12.9$ Hz, 2H), 1.74 (d, $J=7.9$ Hz, 2H), 1.51 (d, $J=9.1$ Hz, 2H), 1.29 (t, $J=9.8$ Hz, 2H).



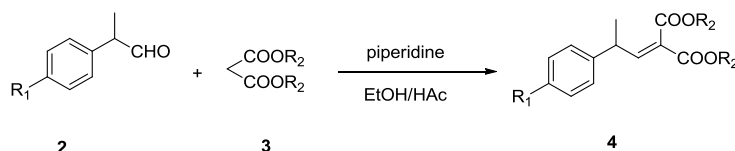
1g: ^1H NMR (400MHz, CDCl_3) δ 7.81 (d, $J=7.1$ Hz, 2H), 7.46 (dt, $J=14.5, 7.0$ Hz, 3H), 6.67 (s, 1H), 4.33 (s, 1H), 2.56-2.46 (m, 1H), 2.26 (s, 6H), 2.05 (d, $J=2.9$ Hz, 2H), 1.81 (dd, $J=6.0, 2.9$ Hz, 1H), 1.48 (d, $J=3.1$ Hz, 1H), 1.42-1.22 (m, 4H).

1.4 The crystal structure of compound 1c:



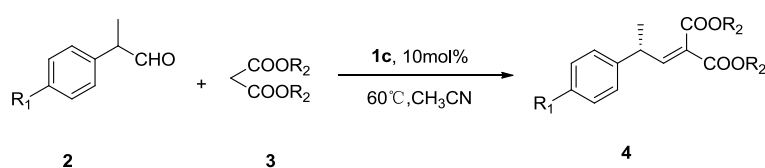
2. General procedure for the catalytic enantioselective Knoevenagel condensation reaction:

2.1 General procedure for racemates preparation:

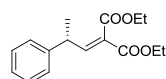


The aldehyde **2** (1 mmol), malonate **3** (1.1 mmol) and piperidine catalyst (0.1mmol) were dissolved in EtOH (3mL) / HAc (0.1mL). After refluxing for 8h, the reaction mixture was poured to water and organic layer was extracted with ethyl acetate. The organic fractions were dried over anhydrous MgSO₄ and concentrated under reduced pressure. Purification by silica gel column chromatography afforded the racemic compound **4**.

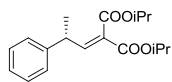
2.2 General procedure, Spectral details for the asymmetric Knoevenagel condensation reaction:



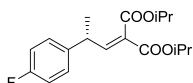
The catalyst **1c** (0.01mmol) and aldehyde **2** (0.1mmol) were dissolved in CH₃CN (2.0mL). The reaction mixture was stirred for 10min and malonate **3** (1.0mmol) was added at the same temperature. After heating to 60°C and vigorous stirring for 168h, the reaction mixture was poured to water (3mL) and extracted with ethyl acetate (3 × 15mL). The organic fractions were dried over anhydrous MgSO₄ and concentrated under reduced pressure. Purification by flash column chromatography afforded **4a-l** as desired products.



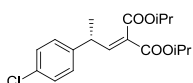
4a^[2]: colorless oil, yield: 75%, ¹H NMR (300MHz, CDCl₃) δ 7.37 (ddd, *J*=7.1, 4.3, 1.7Hz, 2H), 7.31 (s, 2H), 7.29-7.23 (m, 1H), 7.02 (d, *J*=10.8Hz, 1H), 4.37 (q, *J*=7.1Hz, 2H), 4.25 (q, *J*=7.1Hz, 2H), 3.92 (dq, *J*=10.8, 6.9Hz, 1H), 1.49 (d, *J*=6.9Hz, 3H), 1.38 (t, *J*=7.1Hz, 3H), 1.31 (t, *J*=7.1Hz, 3H). HPLC: Daicel CHIRALCEL IA acetonitrile /methyl alcohol (99/1), flow rate: 0.4mL/min, λ=210nm, (τ_{major}=19.567min, τ_{minor}=17.089min).



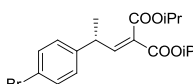
4b: colorless oil, yield: 73%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.35-7.30 (m, 2H), 7.28-7.25 (m, 3H), 6.93 (d, $J=10.8\text{Hz}$, 1H), 5.22 (p, $J=6.3\text{Hz}$, 1H), 5.07 (p, $J=6.3\text{Hz}$, 1H), 3.87 (dq, $J=10.7$, 6.9Hz, 1H), 1.45 (d, $J=6.9\text{Hz}$, 3H), 1.33 (dd, $J=6.3$, 4.4Hz, 6H), 1.29-1.26 (m, 6H). $^{13}\text{C NMR}$ (126MHz, CDCl_3) δ 150.81, 142.59, 128.72, 127.58, 127.12, 126.86, 68.94, 60.38, 39.46, 21.71, 20.23. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=6.085\text{min}$, $\tau_{\text{minor}}=5.368\text{min}$).



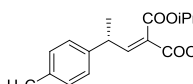
4c: colorless oil, yield: 74%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.25-7.19 (m, 2H), 7.03-6.98 (m, 2H), 6.86 (d, $J=10.8\text{Hz}$, 1H), 5.21 (m, 1H), 5.09-5.04 (m, 1H), 3.86 (dq, $J=10.7$, 6.9Hz, 1H), 1.43 (d, $J=7.0\text{Hz}$, 3H), 1.32 (t, $J=6.0\text{Hz}$, 6H), 1.26 (dd, $J=6.2$, 2.7Hz, 6H). $^{13}\text{C NMR}$ (101MHz, CDCl_3) δ 164.02, 162.46, 148.99, 140.59, 130.78, 130.31, 127.88, 127.00, 119.73, 68.07, 37.84, 20.69, 19.11. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=4.726\text{min}$, $\tau_{\text{minor}}=4.501\text{min}$).



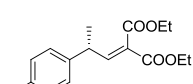
4d: colorless oil, yield: 72%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.28 (dd, $J=8.4$, 6.3Hz, 2H), 7.19 (d, $J=8.5\text{Hz}$, 2H), 6.85 (d, $J=10.7\text{Hz}$, 1H), 5.21 (p, $J=6.3\text{Hz}$, 1H), 5.07 (p, $J=6.3\text{Hz}$, 1H), 3.86 (dq, $J=10.7$, 6.9Hz, 1H), 1.43 (d, $J=7.0\text{Hz}$, 3H), 1.32 (d, $J=6.5\text{Hz}$, 6H), 1.26 (d, $J=6.7\text{Hz}$, 6H). $^{13}\text{C NMR}$ (101MHz, CDCl_3) δ 165.07, 163.50, 150.13, 141.06, 132.69, 128.84, 128.52, 127.96, 69.10, 38.81, 21.73, 20.18. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=5.209\text{min}$, $\tau_{\text{minor}}=4.876\text{min}$).



4e: colorless oil, yield: 74%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.46-7.42 (m, 2H), 7.16-7.12 (m, 2H), 6.85 (d, $J=10.7\text{Hz}$, 1H), 5.22 (dq, $J=12.6$, 6.3Hz, 1H), 5.10-5.04 (m, 1H), 3.84 (dq, $J=10.8$, 6.9Hz, 1H), 1.43 (d, $J=7.0\text{Hz}$, 3H), 1.33 (d, $J=6.5\text{Hz}$, 6H), 1.27-1.25 (m, 6H). $^{13}\text{C NMR}$ (101MHz, CDCl_3) δ 165.12, 163.54, 150.48, 138.27, 138.24, 128.66, 128.58, 127.72, 115.61, 115.40, 69.04, 38.67, 21.71, 20.29. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=5.476\text{min}$, $\tau_{\text{minor}}=5.009\text{min}$).

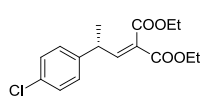


4f: colorless oil, yield: 72%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.19-7.10 (m, 4H), 6.91 (d, $J=10.8\text{Hz}$, 1H), 5.22 (p, $J=6.3\text{Hz}$, 1H), 5.06 (p, $J=6.3\text{Hz}$, 1H), 4.12 (q, $J=7.1\text{Hz}$, 1H), 2.32 (s, 3H), 1.43 (d, $J=6.9\text{Hz}$, 3H), 1.33 (dd, $J=6.3$, 3.0Hz, 6H), 1.26-1.24 (m, 6H). $^{13}\text{C NMR}$ (101MHz, CDCl_3) δ 165.23, 163.63, 151.07, 139.57, 129.40, 127.36, 127.00, 68.90, 39.10, 29.72, 21.73, 20.99, 20.23. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=5.334\text{min}$, $\tau_{\text{minor}}=4.917\text{min}$).

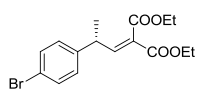


4g^[2]: colorless oil, yield: 72%, $^1\text{H NMR}$ (400MHz, CDCl_3) δ 7.25-7.20 (m, 2H), 7.01 (t, $J=8.7\text{Hz}$, 2H), 6.92 (d, $J=10.8\text{Hz}$, 1H), 4.33 (m, $J=7.1\text{Hz}$, 2H), 4.23 (m, $J=7.1\text{Hz}$, 2H), 3.87 (m, $J=10.9\text{Hz}$, 1H), 1.44 (d, $J=7.0\text{Hz}$, 3H), 1.35 (t, $J=7.1\text{Hz}$, 3H), 1.28 (t,

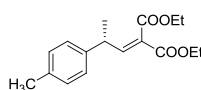
$J=7.1\text{Hz}$, 3H). HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=7.244\text{min}$, $\tau_{\text{minor}}=6.635\text{min}$).



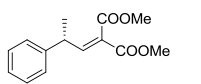
4h^[2]: colorless oil, yield: 72%, ¹H NMR (400MHz, CDCl₃) δ 7.31-7.26 (m, 2H), 7.21-7.18 (m, 2H), 6.91 (d, $J=10.7\text{Hz}$, 1H), 4.33 (q, $J=7.1\text{Hz}$, 2H), 4.23 (q, $J=7.2\text{ Hz}$, 2H), 3.87 (dq, $J=10.7, 6.9\text{Hz}$, 1H), 1.43 (d, $J=6.9\text{Hz}$, 3H), 1.34 (t, $J=7.1\text{Hz}$, 3H), 1.29 (d, $J=7.3\text{Hz}$, 3H). HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=6.802\text{min}$, $\tau_{\text{minor}}=6.385\text{min}$).



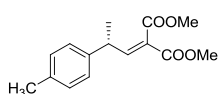
4i: colorless oil, yield: 73%, ¹H NMR (400MHz, CDCl₃) δ 7.44 (d, $J=8.5\text{Hz}$, 2H), 7.14 (d, $J=8.5\text{Hz}$, 2H), 6.91 (d, $J=10.8\text{Hz}$, 1H), 4.32 (q, $J=7.1\text{Hz}$, 2H), 4.23 (dd, $J=7.2, 2.1\text{Hz}$, 2H), 3.86 (dd, $J=10.7, 6.9\text{Hz}$, 1H), 1.43 (d, $J=6.9\text{Hz}$, 3H), 1.36-1.33 (m, 3H), 1.32-1.29 (m, 3H). ¹³C NMR (101MHz, CDCl₃) δ 168.01, 150.92, 141.33, 131.33, 128.88, 127.66, 119.60, 61.77, 20.10, 16.46. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=7.977\text{min}$, $\tau_{\text{minor}}=7.410\text{min}$).



4j^[2]: colorless oil, yield: 70%, ¹H NMR (400MHz, CDCl₃) δ 7.20-7.09 (m, 4H), 6.97 (d, $J=10.8\text{Hz}$, 1H), 4.33 (q, $J=7.1\text{Hz}$, 2H), 4.23 (d, $J=7.1\text{Hz}$, 2H), 3.90-3.80 (m, 1H), 2.32 (s, 3H), 1.43 (d, $J=6.9\text{Hz}$, 3H), 1.34 (d, $J=7.1\text{Hz}$, 3H), 1.27 (d, $J=1.6\text{Hz}$, 3H). HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=7.660\text{min}$, $\tau_{\text{minor}}=6.718\text{min}$).

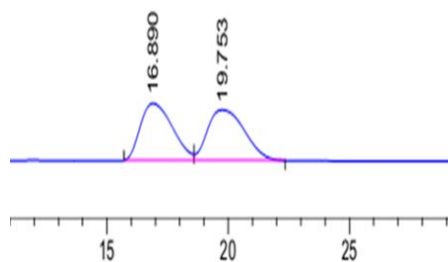
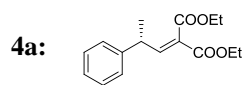


4k^[2]: colorless oil, yield: 71%, ¹H NMR (400MHz, CDCl₃) δ 7.36-7.29 (m, 2H), 7.28-7.20 (m, 3H), 7.04 (d, $J=10.8\text{Hz}$, 1H), 3.92-3.86 (m, 1H), 3.85 (s, 3H), 3.76 (d, $J=3.8\text{Hz}$, 3H), 1.45 (d, $J=6.9\text{Hz}$, 3H). HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (98/2), flow rate: 0.4mL/min, $\lambda=230\text{nm}$, ($\tau_{\text{major}}=13.397\text{min}$, $\tau_{\text{minor}}=11.096\text{min}$).



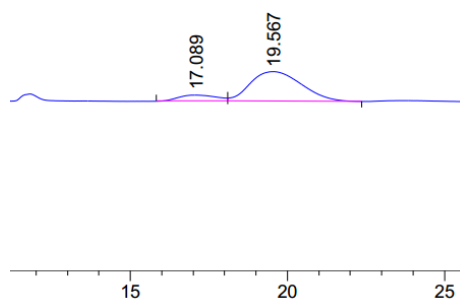
4l: colorless oil, yield: 68%, ¹H NMR (400MHz, CDCl₃) δ 7.14 (s, 4H), 7.02 (d, $J=10.9\text{Hz}$, 1H), 4.12 (d, $J=7.1\text{Hz}$, 1H), 3.86 (s, 3H), 3.76 (s, 3H), 2.32 (s, 3H), 1.43 (d, $J=6.9\text{Hz}$, 3H). ¹³C NMR (101MHz, CDCl₃) δ 165.90, 153.10, 139.27, 136.63, 129.46, 126.96, 52.38, 39.27, 21.00, 20.24. HPLC: Daicel CHIRALCEL OD-H hexane/2-propanol (99/1), flow rate: 1mL/min, $\lambda=220\text{nm}$, ($\tau_{\text{major}}=10.320\text{min}$, $\tau_{\text{minor}}=9.270\text{min}$).

2.3 Chromatograms of racemic mixtures and condensates obtained by organocatalysts:



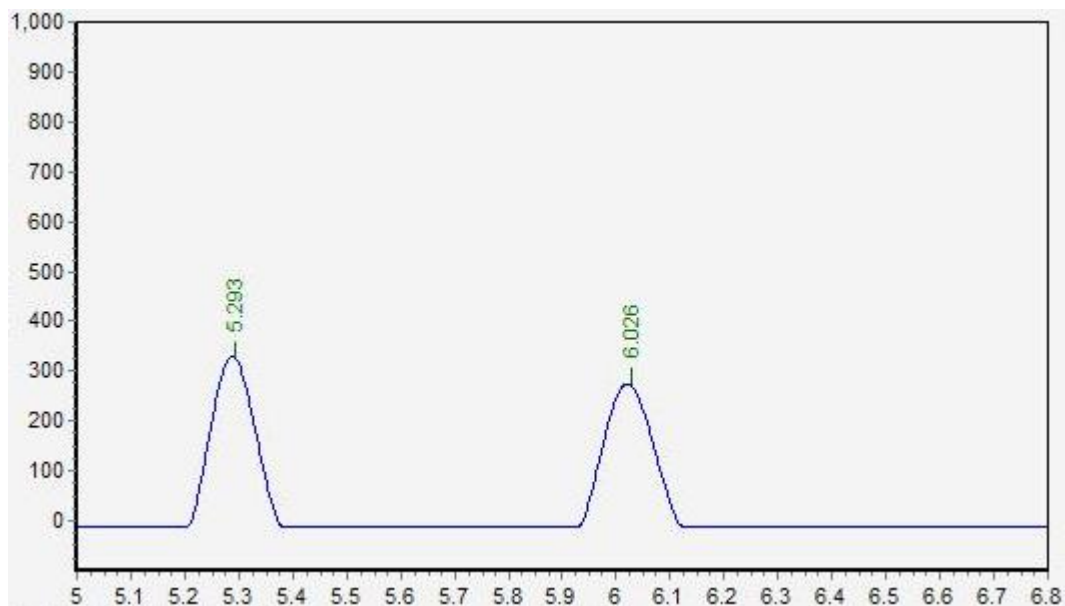
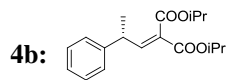
Peak #	RetTime/ min	Area	Area%
1	16.890	1843.70581	49.273
2	19.753	1898.12061	50.727
Total			100

Chromatogram of racemic mixture of **4a**



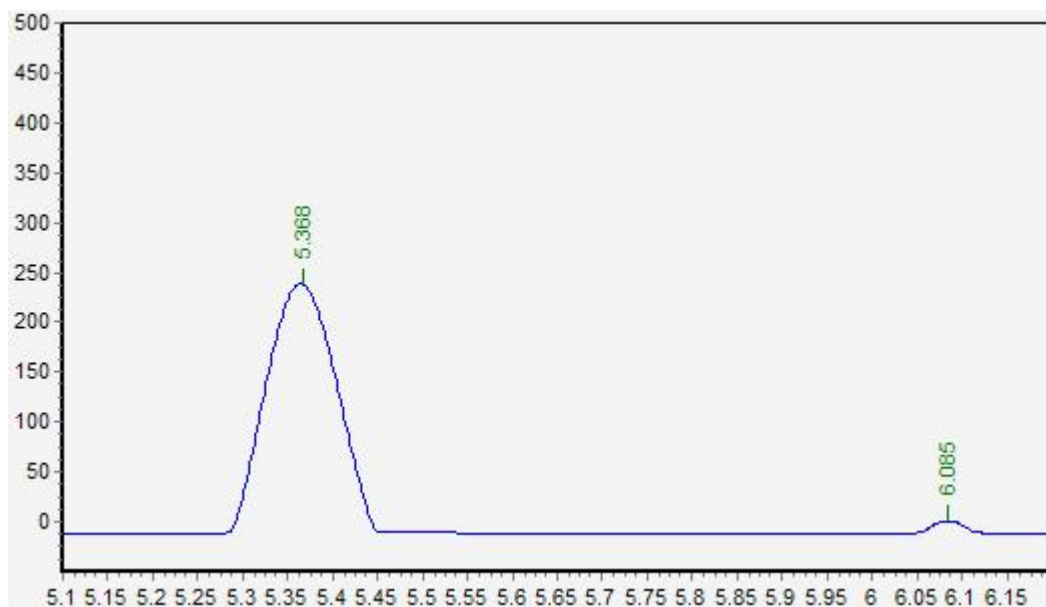
Peak #	RetTime/ min	Area	Area%
1	17.089	62.37217	13.477
2	19.567	400.42651	86.523
Total			100

Chromatogram of **4a**



Peak #	RetTime/ min	Height	Area	Area%
1	5.293	339525.844	1867389.875	51.562
2	6.026	284525.156	1754240.000	48.438
Total				100

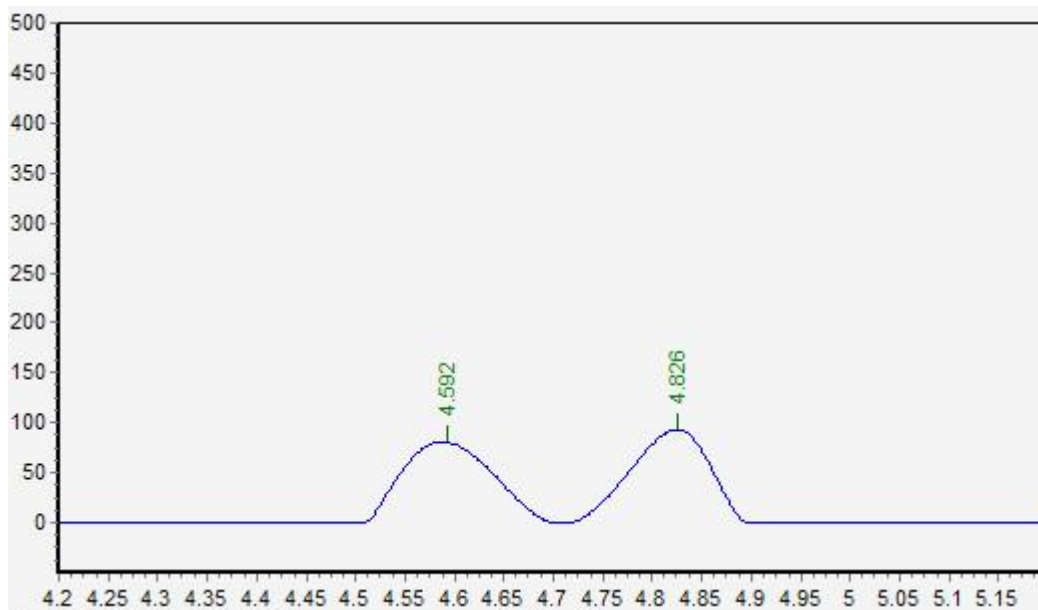
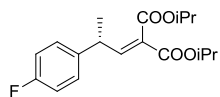
Chromatogram of racemic mixture of **4b**



Peak #	RetTime/ min	Height	Area	Area%
1	5.368	248775.563	1338241.750	98.060
2	6.085	11587.044	26466.051	1.940
Total				100

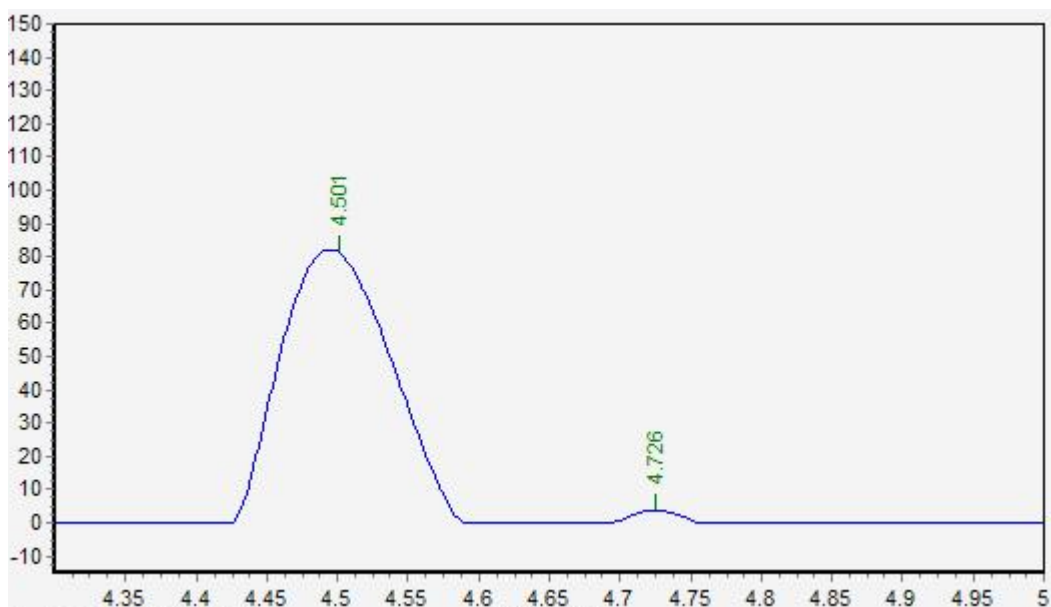
Chromatogram of **4b**

4c:



Peak #	RetTime/ min	Height	Area	Area%
1	4.592	80818.070	514359.063	49.921
2	4.826	93171.453	515983.344	50.079
Total				100

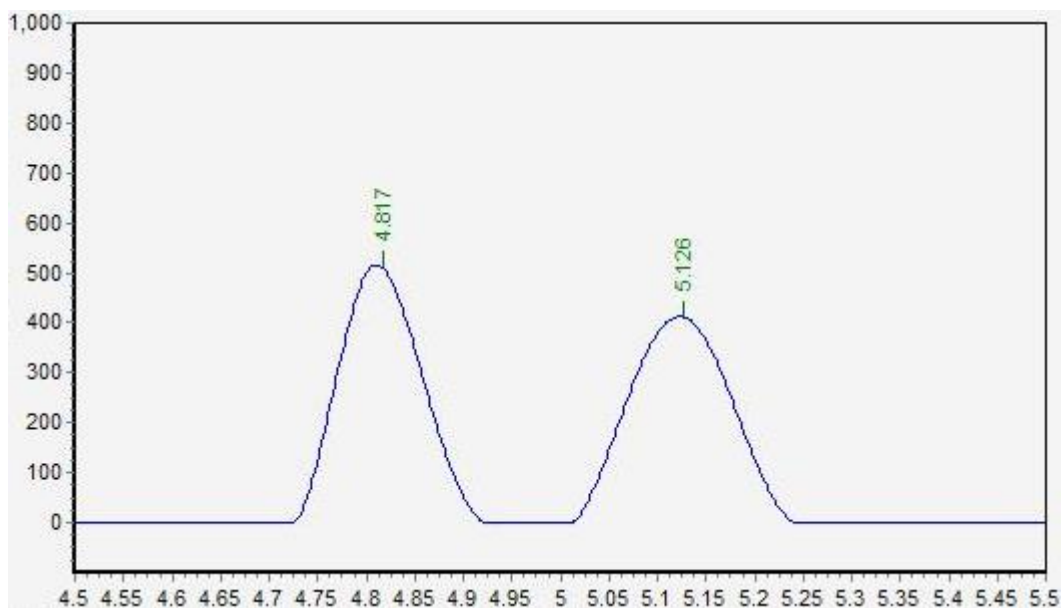
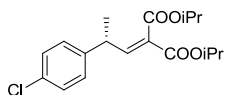
Chromatogram of racemic mixture of **4c**



Peak #	RetTime/ min	Height	Area	Area%
1	4.501	81888.250	441521.125	98.120
2	4.726	3687.813	8468.079	1.880
Total				100

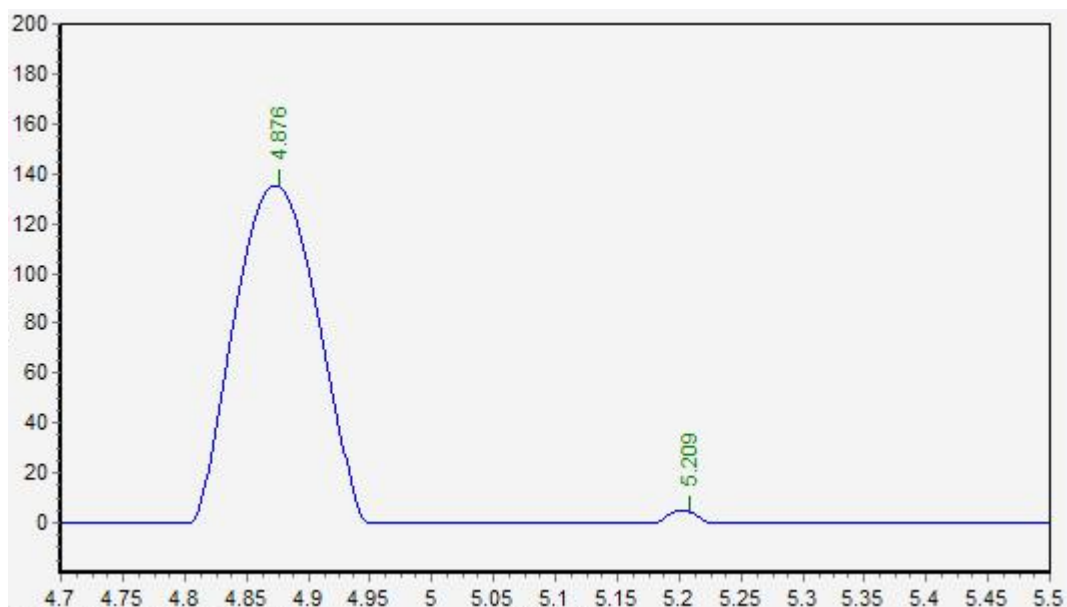
Chromatogram of **4c**

4d:



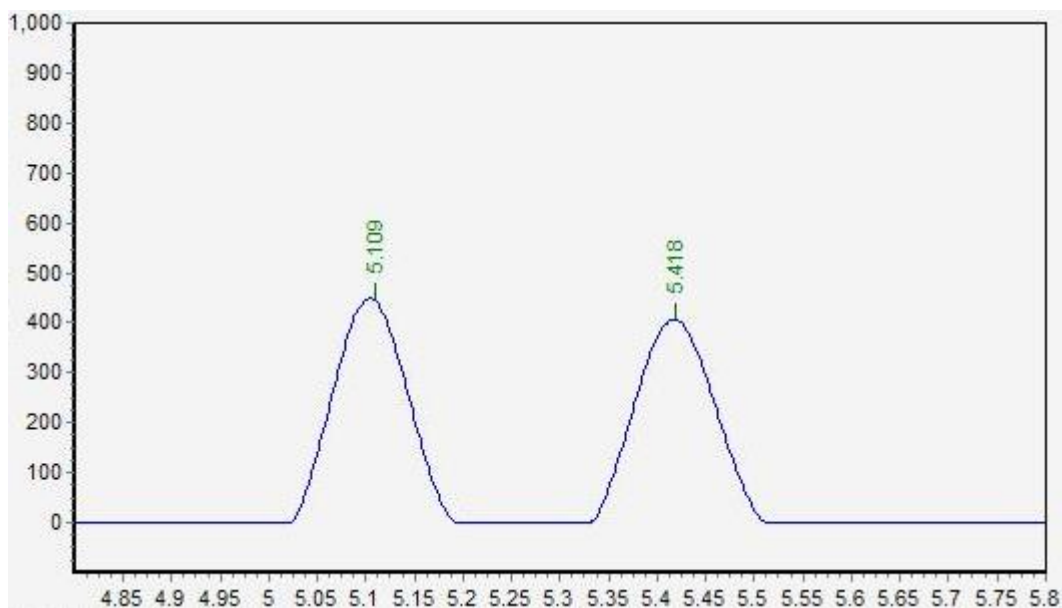
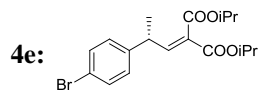
Peak #	RetTime/ min	Height	Area	Area%
1	4.817	513490.938	3051591.250	50.164
2	5.126	412100.156	3031594.250	49.836
Total				100

Chromatogram of racemic mixture of **4d**



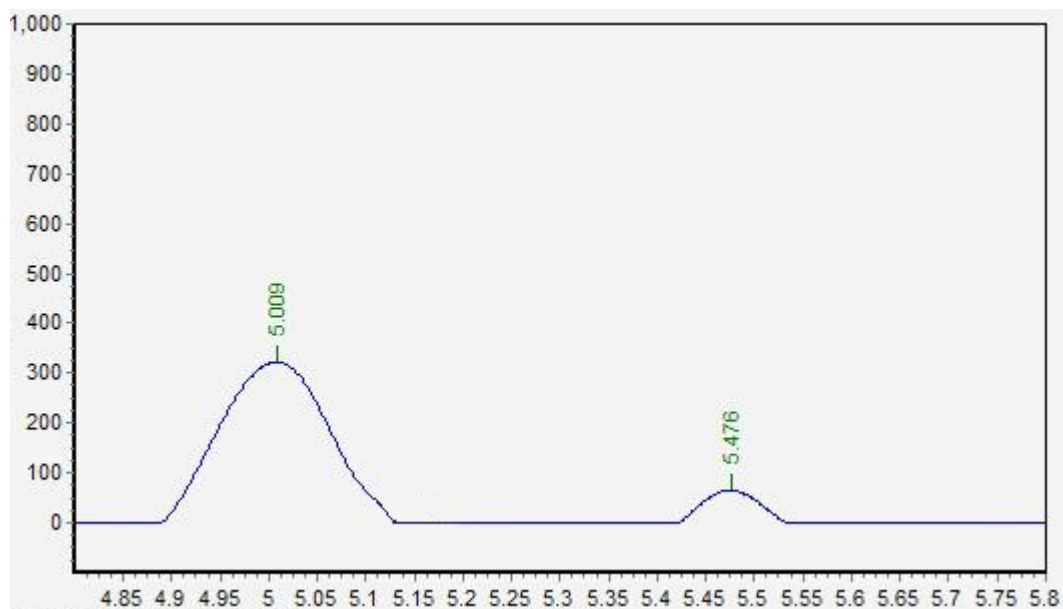
Peak #	RetTime/ min	Height	Area	Area%
1	4.876	134740.000	628086.375	98.783
2	5.209	4804.000	7732.900	1.217
Total				100

Chromatogram of **4d**



Peak #	RetTime/ min	Height	Area	Area%
1	5.109	447233.813	2350263.000	50.664
2	5.418	405149.156	2288643.000	49.336
Total				100

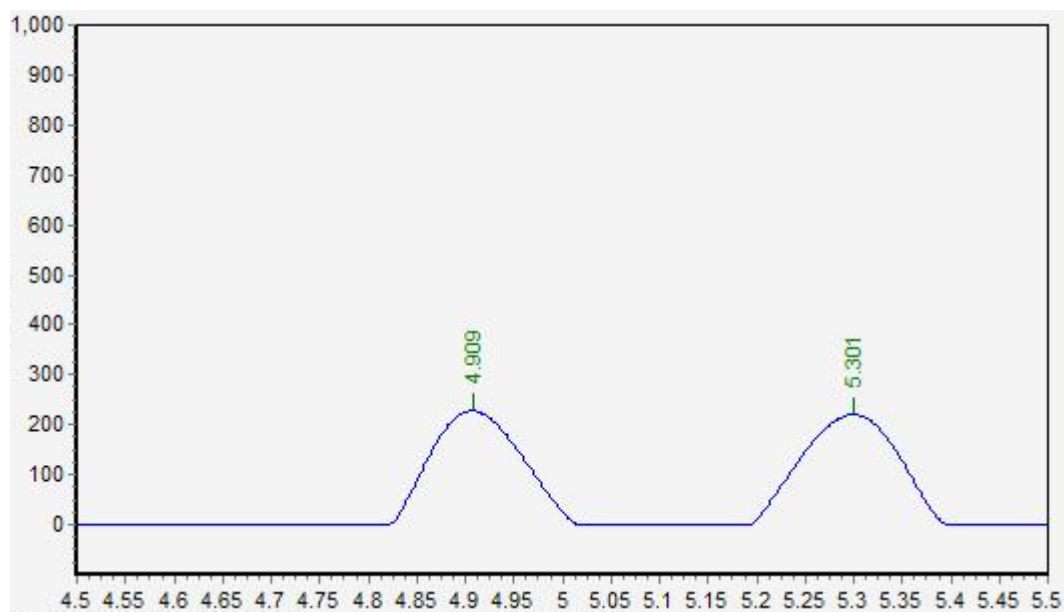
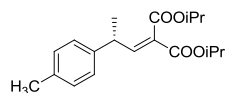
Chromatogram of racemic mixture of **4e**



Peak #	RetTime/ min	Height	Area	Area%
1	5.009	322118.844	2623093.250	91.012
2	5.476	64789.281	259028.500	8.988
Total				100

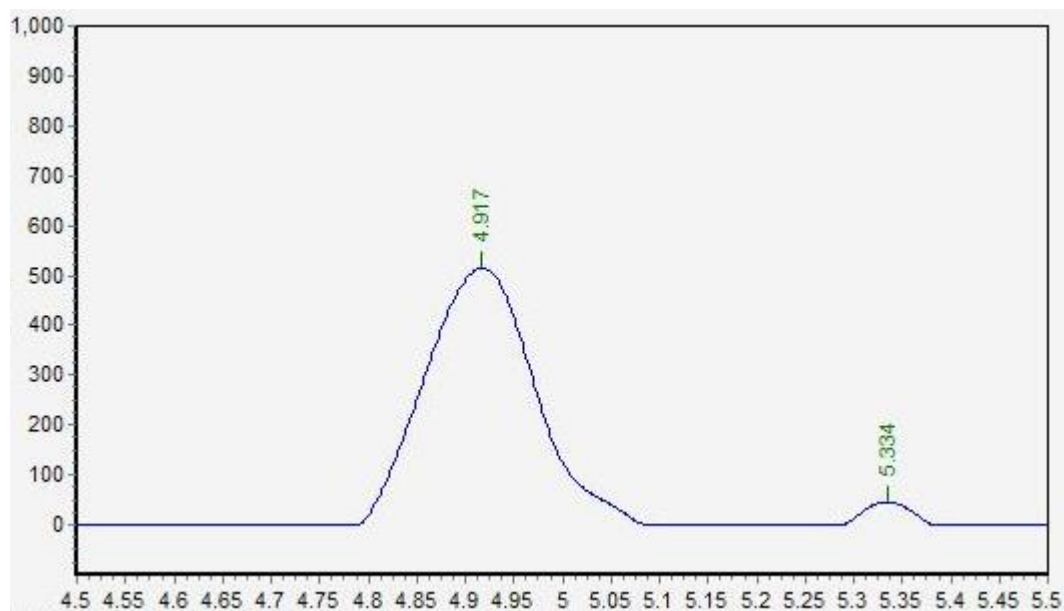
Chromatogram of **4e**

4f:



Peak #	RetTime/ min	Height	Area	Area%
1	4.909	227756.781	1482091.875	49.200
2	5.301	220025.875	1530298.375	50.800
Total				100

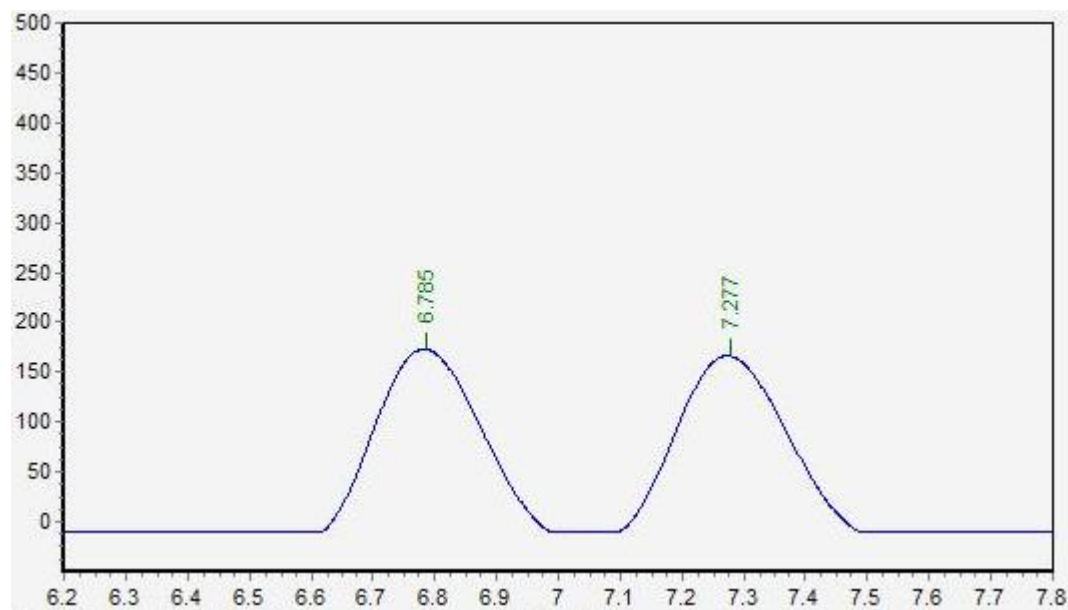
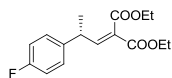
Chromatogram of racemic mixture of **4f**



Peak #	RetTime/ min	Height	Area	Area%
1	4.917	513338.500	4037205.750	96.418
2	5.334	45135.137	149984.797	3.582
Total				100

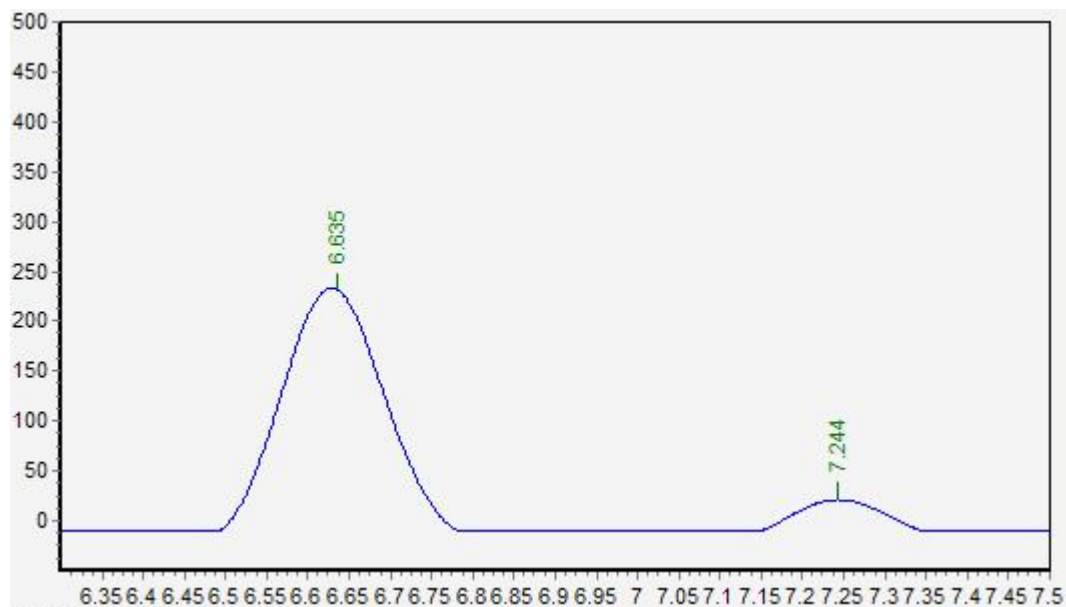
Chromatogram of **4f**

4g:



Peak #	RetTime/ min	Height	Area	Area%
1	6.785	183160.313	2107645.250	49.896
2	7.277	176311.175	2116408.000	50.104
Total				100

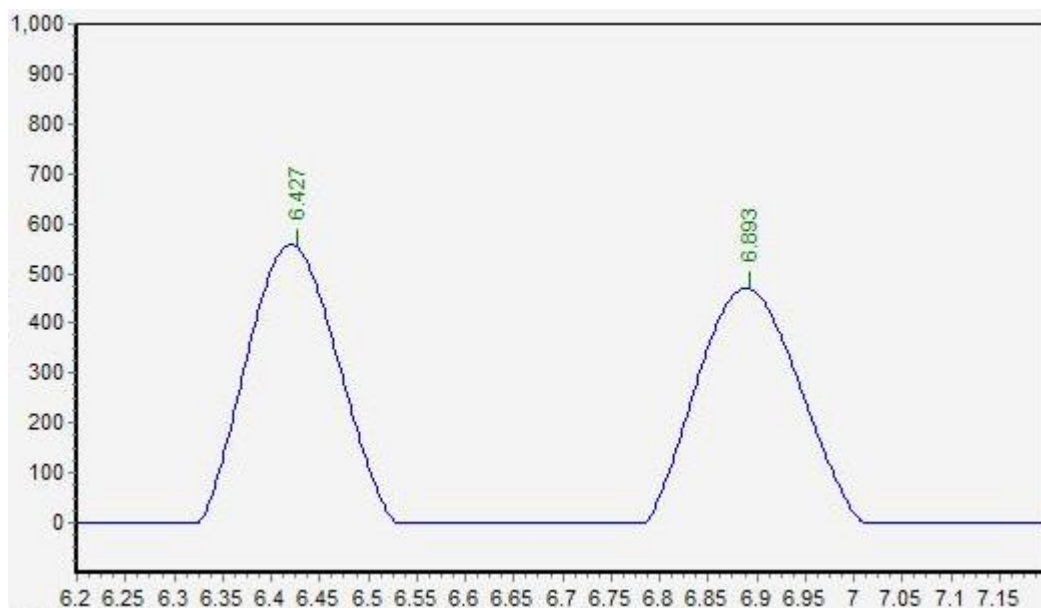
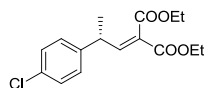
Chromatogram of racemic mixture of **4g**



Peak #	RetTime/ min	Height	Area	Area%
1	6.635	242946.813	2051427.500	90.535
2	7.244	31242.648	214449.953	9.465
Total				100

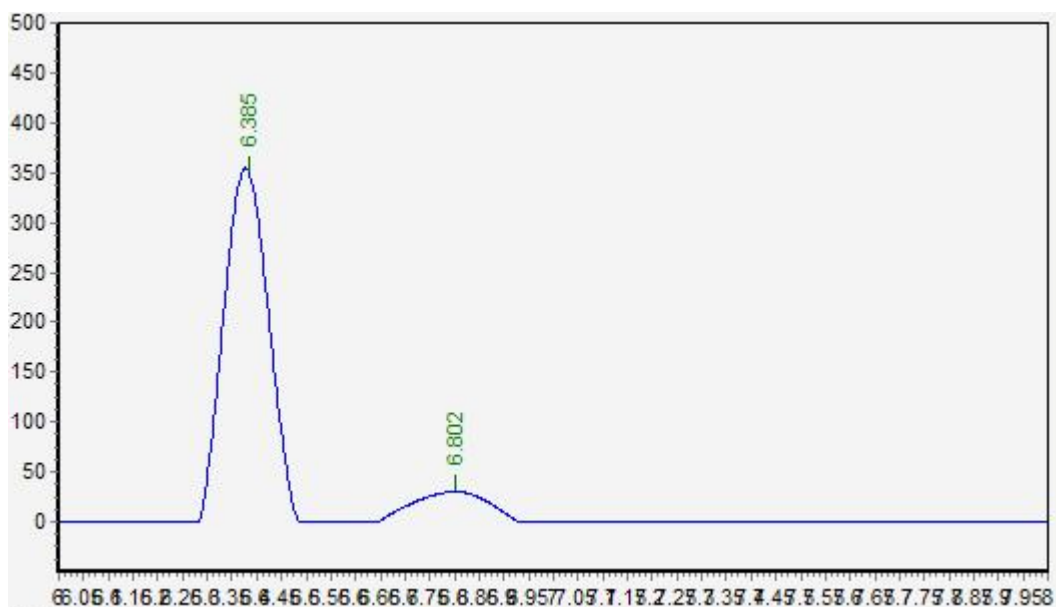
Chromatogram of **4g**

4h:



Peak #	RetTime/ min	Height	Area	Area%
1	6.427	556001.250	3577783.500	51.237
2	6.893	469305.219	3405034.250	48.763
Total				100

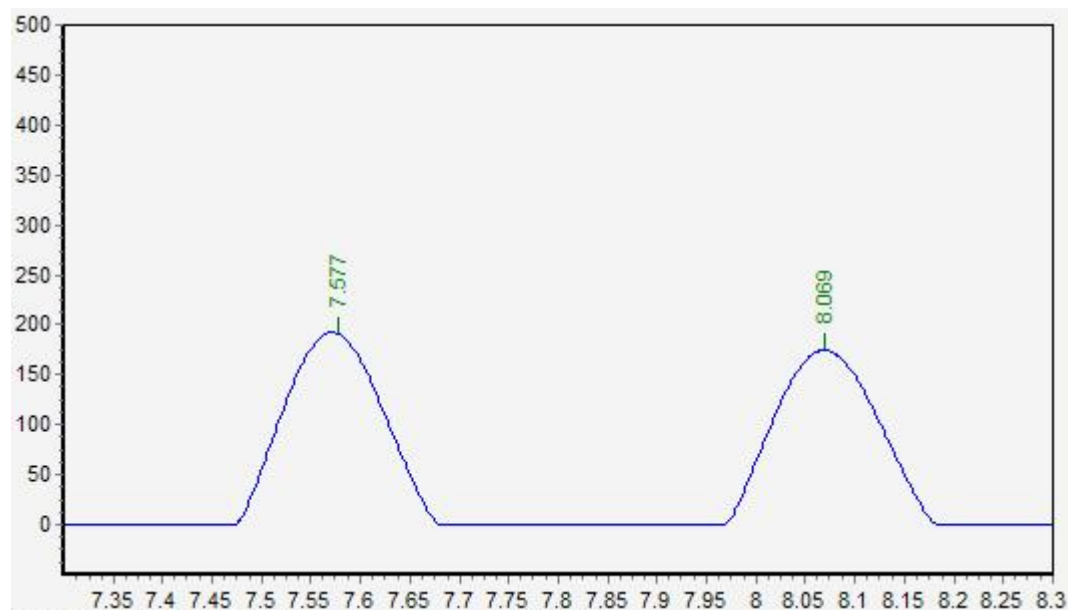
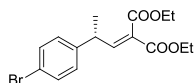
Chromatogram of racemic mixture of **4h**



Peak #	RetTime/ min	Height	Area	Area%
1	6.385	352630.125	2208220.000	87.323
2	6.802	30105.619	320612.500	12.677
Total				100

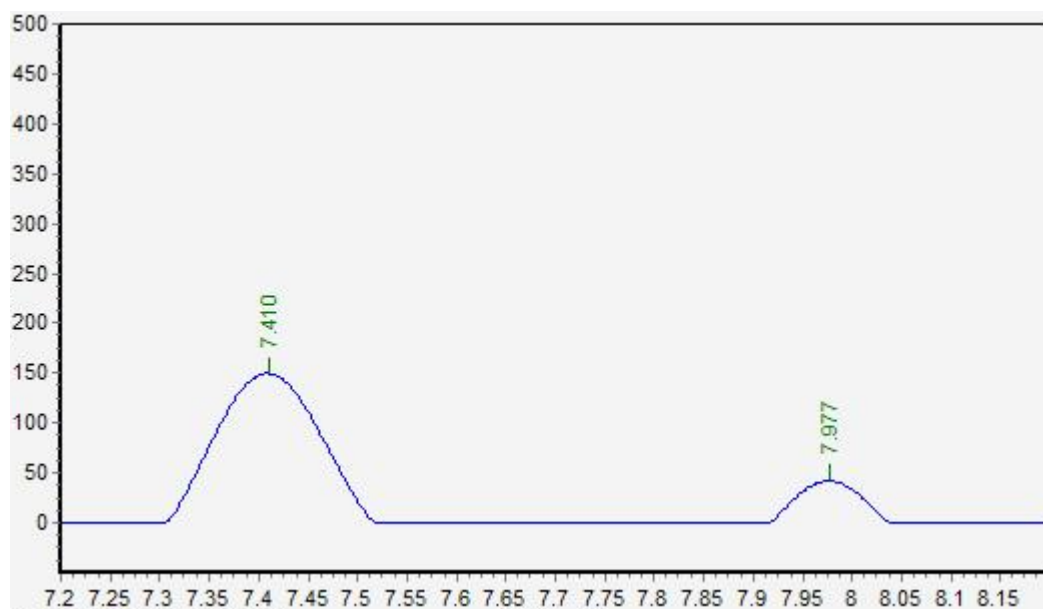
Chromatogram of **4h**

4i:



Peak #	RetTime/ min	Height	Area	Area%
1	7.577	192087.594	1322351.625	51.196
2	8.069	172415.672	1260554.000	48.804
Total				100

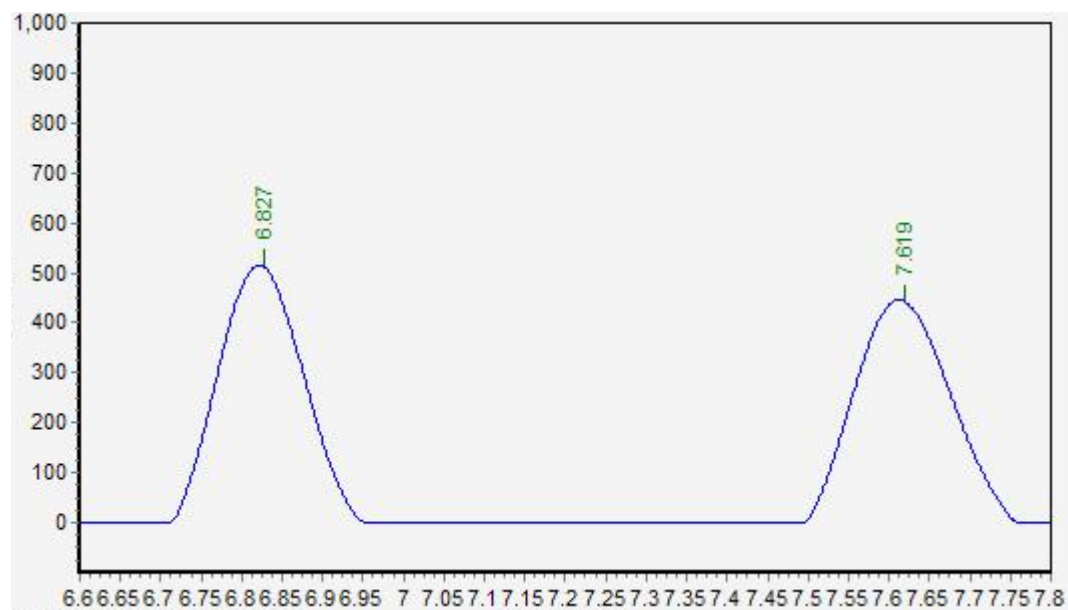
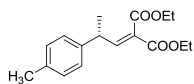
Chromatogram of racemic mixture of **4i**



Peak #	RetTime/ min	Height	Area	Area%
1	7.410	149584.938	1072228.000	85.174
2	7.977	41746.000	186640.797	14.826
Total				100

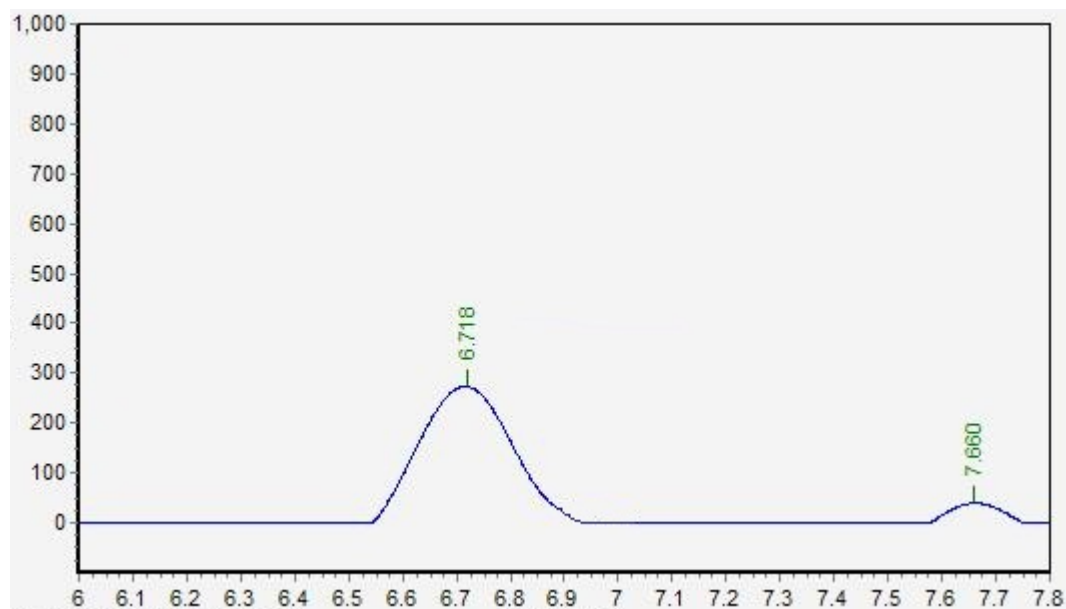
Chromatogram of **4i**

4j:



Peak #	RetTime/ min	Height	Area	Area%
1	6.827	514620.844	3727768.000	50.573
2	7.619	444577.500	3643328.500	49.427
Total				100

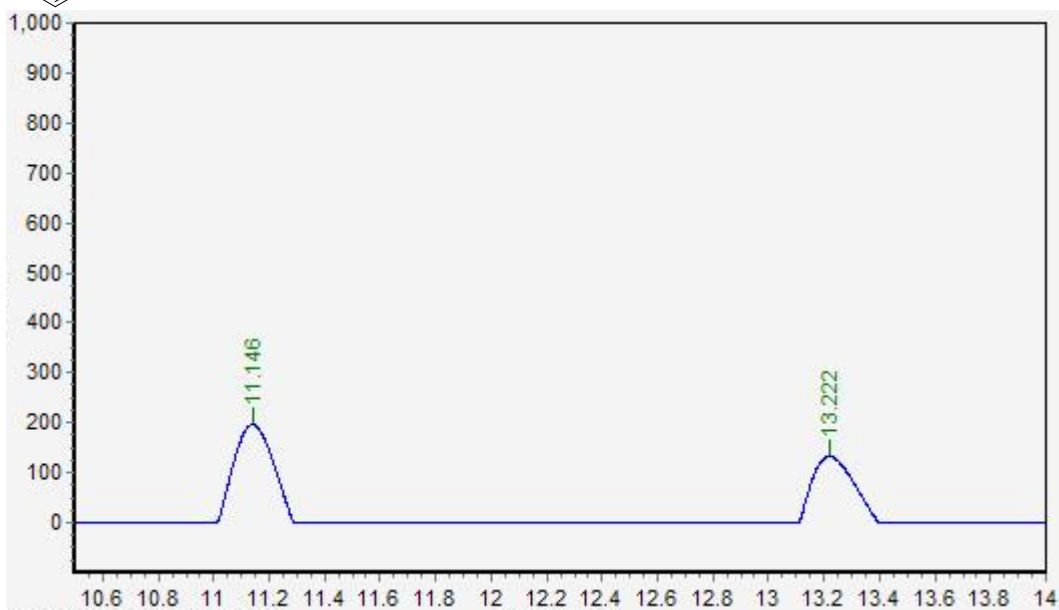
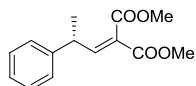
Chromatogram of racemic mixture of **4j**



Peak #	RetTime/ min	Height	Area	Area%
1	6.718	273170.281	3334752.750	92.920
2	7.660	39300.637	254106.156	7.080
Total				100

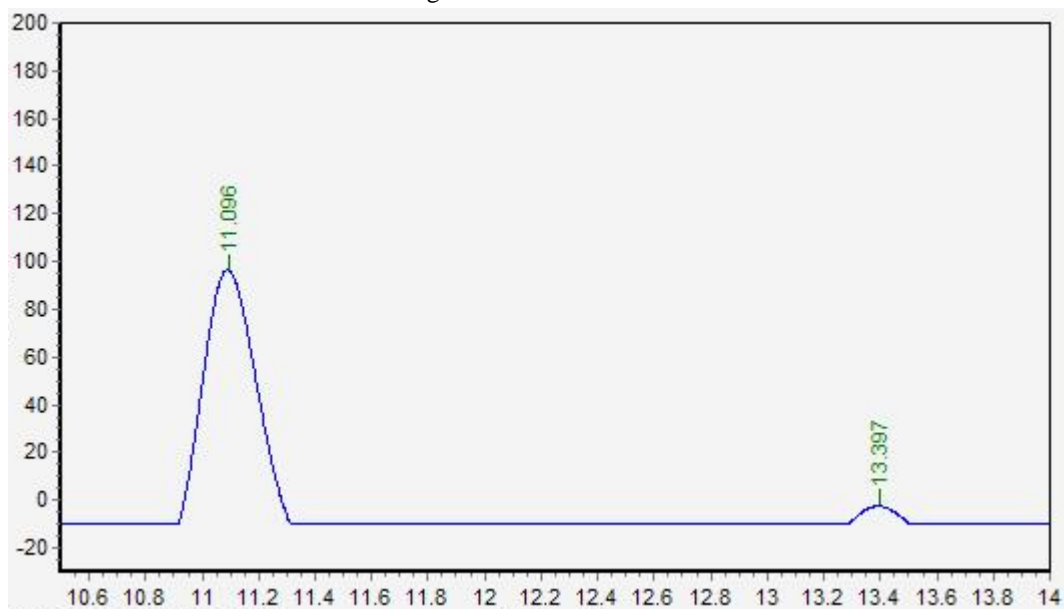
Chromatogram of **4j**

4k:



Peak #	RetTime/ min	Height	Area	Area%
1	11.146	186389.328	1717009.500	50.797
2	13.222	142371.953	1663098.875	49.203
Total				100

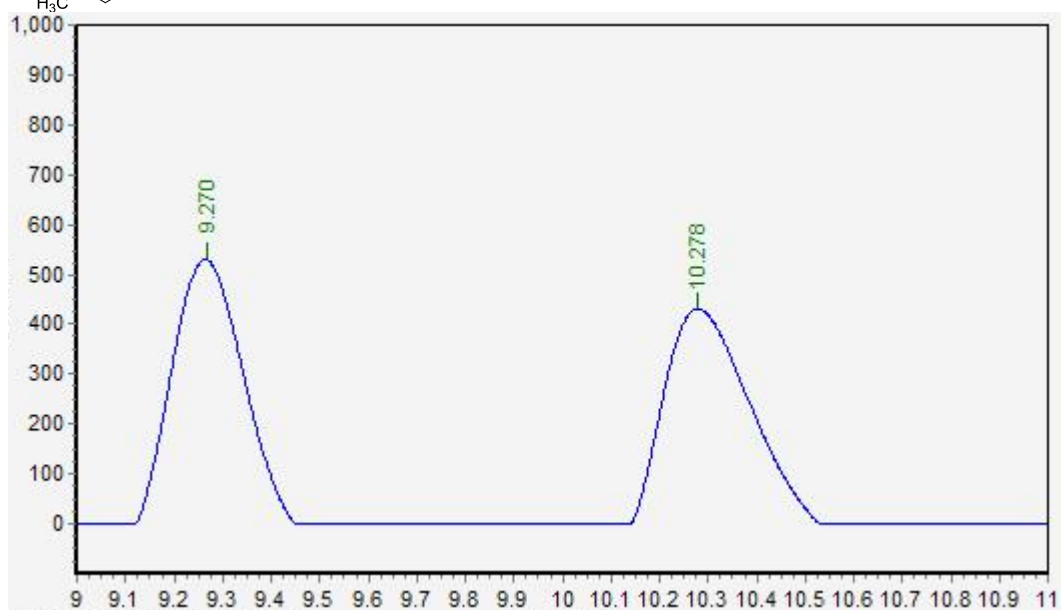
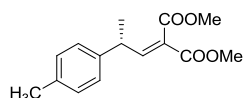
Chromatogram of racemic mixture of **4k**



Peak #	RetTime/ min	Height	Area	Area%
1	11.096	106453.305	1337974.250	95.580
2	13.397	7577.231	61883.199	4.420
Total				100

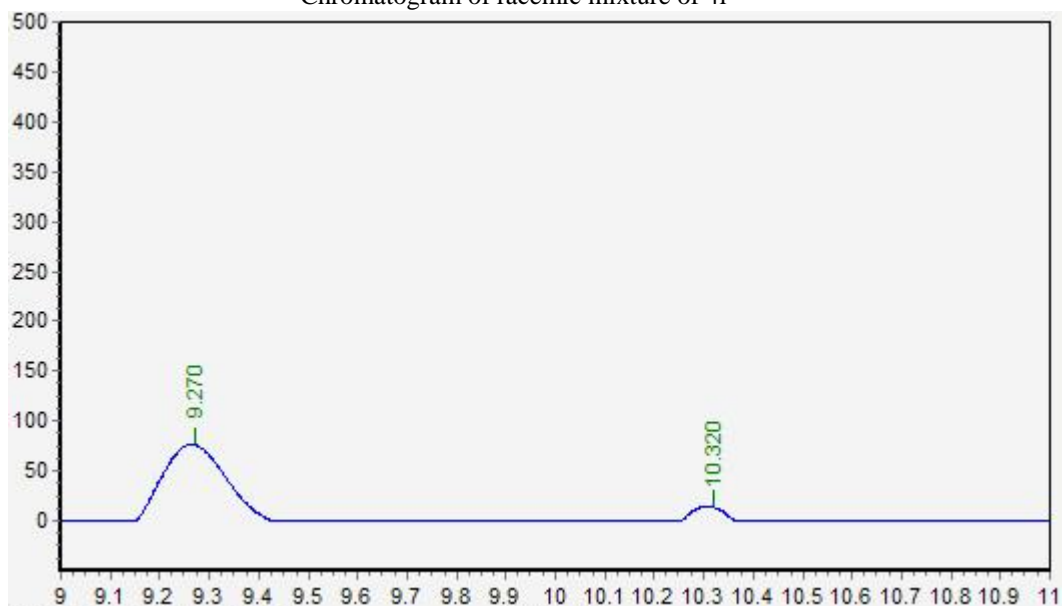
Chromatogram of **4k**

4l:



Peak #	RetTime/ min	Height	Area	Area%
1	9.270	529697.250	5315405.000	50.587
2	10.278	430680.594	5192008.500	49.413
Total				100

Chromatogram of racemic mixture of 4l



Peak #	RetTime/ min	Height	Area	Area%
1	9.270	76335.484	664035.188	91.500
2	10.320	14310.923	61698.898	8.500
Total				100

Chromatogram of 4l

Reference:

[1] J. Kizirian, N. Cabello, L. Pinchard, J. Caille, A. Alexakis, *Tetrahedron*. **2005**, *61*, 8939-8946.

[2] A. Lee, A. Michrowska, S. Sulzer-Mosse, B. List, *Angew. Chem., Int. Ed.* **2011**, *50*, 1707.

3. Copy of original ^1H NMR spectra of all products and ^{13}C NMR spectra of 4b-f, 4i and 4l

