

Diastereo- and Enantioselective Direct Vinylogous Michael Addition of γ -Substituted Butenolides to 2-Enoylpyridines Catalyzed by Chiral Bifunctional Amine-Squaramides

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Supporting Information

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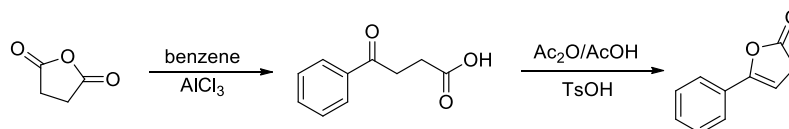
1. General experimental information

Reagents were purchased from commercial sources and were used as received unless mentioned otherwise. Reactions were monitored by TLC. ^1H NMR and ^{13}C NMR spectra were recorded in CDCl_3 and $\text{DMSO-}d_6$. ^1H NMR chemical shifts are reported in ppm relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard (CDCl_3 at 7.26 ppm, $\text{DMSO-}d_6$ at 2.50 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, br s = broad singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz) and integration. ^{13}C NMR chemical shifts are reported in ppm from tetramethylsilane (TMS) with the solvent resonance as the internal standard (CDCl_3 at 77.20 ppm, $\text{DMSO-}d_6$ at 39.51 ppm). Melting points were recorded on a melting point apparatus.

2. General procedure for the synthesis of bifunctional catalysts and starting materials.

Various chiral Bifunctional catalysts **A**,^{1a} **B**,^{1b} **C**,^{1b} **D**^{1c} and **E**^{1d} were prepared by the corresponding literature procedures. Various γ -Substituted butenolides **1a-1f** were prepared according to the literatures.^{2,3} **1g** was purchased from Urchem. 2-Enoylpyridines **2a-2q** were prepared according to the literature reported by Singh and co-workers.⁴ 2-Enoylpyridine **2r**⁵ and **2s**⁶ were prepared according to the literatures.

2.1 Typical procedure to prepare γ -phenyl butenolide (**1a**).



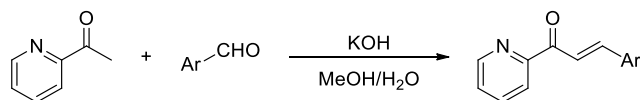
Step 1. Benzene (20 mL, 17.5 g, 225 mmol) and succinic anhydride (3.4 g, 34 mmol) were combined in a 100 mL flask equipped with a reflux condenser. The succinic anhydride was dissolved in the benzene, and then anhydrous aluminum chloride (10 g, 75 mmol) was added and the reaction started immediately and HCl was evolved. The resulting mixture was stirred for 30 min at room temperature and then warmed up for 1h at 80 °C. The solution was cooled in cold water. Then dilute HCl (20 mL, 10%) were added. Excess benzene was removed by steam distillation. The residue was cooled and filtered on a Buchner funnel and washed with dilute HCl (20 mL, 10%). The solid was dissolved in Na_2CO_3 (4 g in 25 mL H_2O) and then stirred for 15 min. The filtrate was cooled and acidified by conc. HCl and the precipitated acid was collected by filtration, dried at 50 °C and gave 4.2 g, 78% yield.

Step 2. Benzoylpropionic acid (4.2 g, 26 mmol) was slurried in Ac_2O (5 mL) and AcOH (3 mL) containing a catalytic amount of *p*-toluene sulphonic acid (30 mg). The slurry was allowed to stir for 2 h. The solid was dissolved and then the mixture was diluted with distilled water (7 mL), stirred for 30 min and the product was collected by filtration to give an off white crystalline solid which was washed with $\text{H}_2\text{O}/\text{AcOH}$ (V/V = 1:1) then H_2O . The crude product was crystallized with methanol and gave 2.2 g desired product, 60% yield.

2.2 The synthesis of enoylpyridines

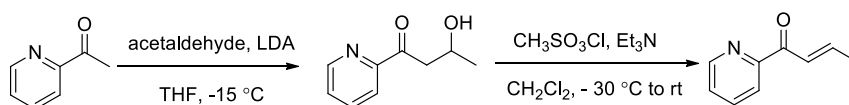
2.2.1 General procedure to prepare 2-Enoylpyridines **2a-2q**

2-Enoylpyridines **2a-2q** were prepared according to the literature reported by Singh and co-workers and slightly modified.



Potassium hydroxide solution (15 mL, 1 N) was added to a solution of 2-acetylpyridine (21 mmol) and aldehyde (20 mmol) in methanol (45 mL) at 0 °C. The reaction mixture was warmed to room temperature and stirred for 3 h. The precipitate was collected by filtration and then washed with water (25 mL). The filter cake was recrystallized with methanol.

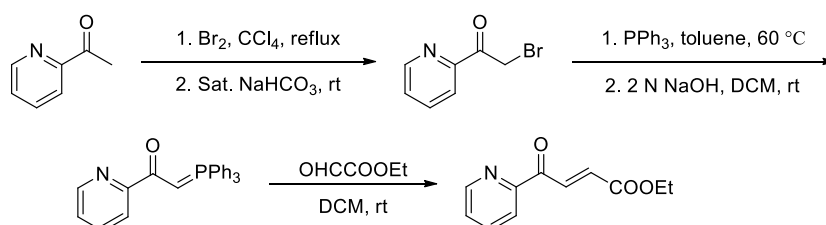
2.2.2 Typical procedure to prepare 2-Enoylpyridine **2r**



Step 1. 2-Acetylpyridine (2.4 g, 20 mmol) was added dropwise to a solution of LDA prepared from dry diisopropylamine (3.3 g, 4.6 mL, 30 mmol) and n-BuLi (2.5 N, 12 mL, 30 mmol) in dry THF (30 mL) cooled at -15 °C. The resulting solution was stirred at -15 °C for 2 h. Acetaldehyde (1.76 g, 2.2 mL, 40 mmol) was added dropwise and the reaction mixture was stirred for 0.5 h at -15 °C followed by the addition of a saturated solution of NH₄Cl (10 mL). The organic phase was collected, and the aqueous phase was extracted with Et₂O (50 mL). The organic phase was combined and dried over Na₂SO₄, and the solvent was evaporated. The crude product was purified on a column of silica gel and eluted with petroleum ether - EtOAc (3:2). 0.9 g of 3-hydroxy-1-(pyridin-2-yl)butan-1-one was obtained.

Step 2. 3-hydroxy-1-(pyridin-2-yl)butan-1-one (0.9 g, 5.4 mmol) was dissolved in CH₂Cl₂ (15 mL), and the solution was cooled to -30 °C. Et₃N (2.6 mL, 18.7 mmol) was added, and then methanesulfonyl chloride (0.6 mL, 7.8 mmol) was added dropwise. The solution was allowed to reach ambient temperature and stirred for 12 h. The dark solution was filtered with diatomite. Evaporation of solvent and purification on a column of silica gel eluting with petroleum ether - EtOAc (5:1) afforded 0.4 g of compound **2r** (yellow oil).

2.2.3 Typical procedure to prepare 2-Enoylpyridine **2s**



Step 1. 1-(pyridin-2-yl)ethanone (2.0 g, 16.6 mmol) was dissolved in CCl₄ (60 mL) and stirred at room temperature. Br₂ (2.7 g, 16.6 mmol) was added dropwise. And then the solution was refluxed at 70 °C for 1 h. The precipitate was collected by filtration and then washed with Et₂O. The precipitate was dissolved in sat. NaHCO₃ solution and stirred for 30 min at ambient temperature, Reaction mixture was extracted with DCM (3 × 25 mL). The combined organic

phase was washed with brine (1 × 30 mL), dried over anh. Na₂SO₄ and concentrated under reduced pressure. Obtained pale yellow oil and used without purification.

Step 2. Crude product was dissolved in toluene (60 mL) and was added PPh₃ (4.35 g, 16.6 mmol). The resulting mixture was warmed gradually to 60 °C and stirred at 60 °C for 12 h. The white precipitate was collected by filtration and then the solid was dissolved in DCM (60 mL). NaOH solution (2 N, 15 mL) was added dropwise and stirred for 6 h. The mixture diluted with H₂O (50 mL). Organic was separated and the aqueous layer was extracted with CH₂Cl₂ (2 × 25 mL). The combined organic phase was washed with brine (1 × 30 mL), dried over anh. Na₂SO₄ and concentrated under reduced pressure. Brown solid was obtained.

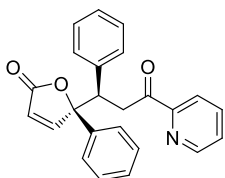
Step 3. Brown solid was dissolved in DCM (25 mL) and ethyl glyoxylate (50% w.t. in toluene, 3.5 g, 17.1 mmol) was added dropwise. The mixture was stirred at room temperature for 12 h. The resulting mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel using petroleum ether - EtOAc as eluent afforded **2s** (0.94 g, total yield 28%).

2.3. References

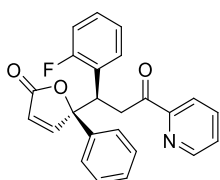
1. (a). T. Okino, Y. Hoashi and Y. Takemoto, *J. Am. Chem. Soc.* 2003, **125**, 12672; (b). M. Kaik and J. Gawroński. *Tetrahedron: Asymmetry* 2003, **14**, 1559; (c). J. Ye, D. J. Dixon and P. S. Hynes, *Chem. Commun*, 2005, 4481; (d). W. Yang and D. M. Du, *Org. Lett.*, 2010, **12**, 5450.
2. S. Žari, M. Kudrjashova, T. Pehk, M. Lopp and T. Kanger, *Org. Lett.*, 2014, **16**, 1740.
3. D. J. Jones, and V. C. Gibson, *Heterocycles*, 2006, **68**, 1128.
4. N. Molleti, N. K. Rana and V. K. Singh, *Org. Lett.*, 2012, **14**, 4322.
5. B Silvia, R Srinivas, YA Skorik and A. Catalina, *Inorganic Chemistry*, 2011, **50**, 11929.
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3. General procedure for the synthesis of compounds 3a-x.

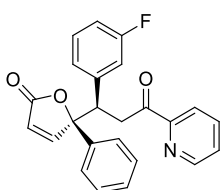
In an ordinary vial equipped with a magnetic stirring bar, the compounds **1** (0.10 mmol, 1.0 equiv), compounds **2** (0.15 mmol, 1.5 equiv) and catalyst **E** (5 mol %) were dissolved in DCE (2 mL), and then the mixture was stirred at 0 °C for the indicated time. After completion of the reaction as indicated by TLC, the products **3** were isolated by flash chromatography on silica gel (petroleum ether/ethyl acetate = 5/1-3/1).



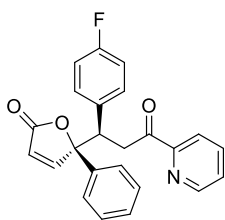
(S)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3a). White solid; 31.4 mg, 85% yield; 99:1 dr, 99% ee; $[\alpha]_D^{20} = +149.1$ (c 1.505, CHCl_3); m.p. 178.2-179.7 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 10.8$ min (minor), 13.8 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.20-3.31 (m, 1H), 4.22-4.33 (m, 2H), 5.66 (d, $J = 5.7$ Hz, 1H), 7.12-7.26 (m, 3H), 7.28-7.31 (m, 3H), 7.33-7.40 (m, 3H), 7.50-7.53 (m, 3H), 7.63-7.70 (m, 1H), 7.73-7.76 (m, 1H), 8.62 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 49.2, 92.9, 119.5, 121.6, 125.3, 127.1, 127.4, 128.2, 128.4, 128.8, 128.9, 136.6, 137.9, 138.2, 148.8, 152.8, 159.0, 172.1, 199.2; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{19}\text{NNaO}_3$ $[\text{M} + \text{Na}]^+$ 392.1257, found: 392.1245.



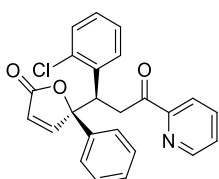
(S)-5-((R)-1-(2-fluorophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3b). White solid; 33.0 mg, 85% yield; >99:1 dr, >99% ee; $[\alpha]_D^{20} = +202.3$ (c 1.650, CHCl_3); m.p. 139.0-141.1 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 9.8$ min (minor), 10.7 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.20 (dd, $J = 3.3$ Hz, 18.6 Hz, 1H), 4.36 (dd, $J = 11.1$ Hz, 18.6 Hz, 1H), 4.74 (dd, $J = 3.3$ Hz, 11.1 Hz, 1H), 5.64 (d, $J = 5.7$ Hz, 1H), 6.96-7.02 (m, 2H), 7.12-7.19 (m, 1H), 7.27-7.41 (m, 5H), 7.56-7.63 (m, 3H), 7.66-7.71 (m, 1H), 7.75 (d, $J = 7.5$ Hz, 1H), 8.63 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 36.9, 39.9, 92.7, 114.9 (d, $J = 22.9$ Hz, 1C), 119.7, 121.6, 124.4 (d, $J = 3.4$ Hz, 1C), 124.8 (d, $J = 14.0$ Hz, 1C), 125.1, 127.2, 128.4, 128.6 (d, $J = 3.2$ Hz, 1C), 128.9, 129.0, 136.6, 137.7, 148.9, 152.7, 158.6, 160.7 (d, $J = 242.8$ Hz, 1C), 172.1, 199.0; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{FNNaO}_3$ $[\text{M} + \text{Na}]^+$ 410.1163, found: 410.1169.



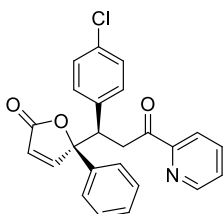
(S)-5-((R)-1-(3-fluorophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3c). White solid; 28.8 mg, 74% yield; 99:1 dr, >99% ee; $[\alpha]_D^{20} = +173.6$ (c 1.440, CHCl_3); m.p. 188.8-190.1 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 10.5$ min (major), 12.9 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 3.16-3.27 (m, 1H), 4.24-4.34 (m, 2H), 5.70 (d, $J = 5.7$ Hz, 1H), 6.83-6.89 (m, 1H), 7.02 (d, $J = 9.9$ Hz, 1H), 7.09 (d, $J = 7.8$ Hz, 1H), 7.15-7.22 (m, 1H), 7.27-7.42 (m, 4H), 7.49-7.54 (m, 3H), 7.66-7.72 (m, 1H), 7.77 (d, $J = 7.8$ Hz, 1H), 8.63 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 48.9, 92.6, 114.5 (d, $J = 20.7$ Hz, 1C), 116.0 (d, $J = 21.5$ Hz, 1C), 119.7, 121.6, 124.4 (d, $J = 2.8$ Hz, 1C), 125.2, 127.2, 128.4, 129.0, 129.9 (d, $J = 8.3$ Hz, 1C), 136.6, 137.8, 140.4 (d, $J = 7.1$ Hz, 1C), 148.9, 152.6, 158.8, 162.5 (d, $J = 244.8$ Hz, 1C), 171.9, 199.0; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{FNNaO}_3$ $[\text{M} + \text{Na}]^+$ 410.1163, found: 410.1172.



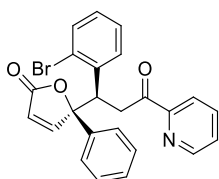
(S)-5-((R)-1-(4-fluorophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3d). White solid; 33.1 mg, 86% yield; 94:6 dr, 98% ee; $[\alpha]_D^{20} = +99.9$ (c 1.655, CHCl_3); m.p. 167.8-169.1 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 10.5$ min (minor), 16.0 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.13-3.24 (m, 1H), 4.21-4.33 (m, 2H), 5.70 (d, $J = 5.7$ Hz, 1H), 6.91 (t, $J = 8.7$ Hz, 2H), 7.24-7.32 (m, 3H), 7.34-7.42 (m, 3H), 7.51 (d, $J = 6.0$ Hz, 3H), 7.66-7.77 (m, 2H), 8.62 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.9, 48.4, 92.8, 115.3 (d, $J = 21.1$ Hz, 1C), 119.7, 121.6, 125.2, 127.2, 128.4, 129.0, 130.4 (d, $J = 8.0$ Hz, 1C), 133.6 (d, $J = 3.2$ Hz, 1C), 136.7, 137.9, 148.9, 152.7, 159.0, 162.0 (d, $J = 244.6$ Hz, 1C), 172.0, 199.2; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{FNNaO}_3$ $[\text{M} + \text{Na}]^+$ 410.1163, found: 410.1167.



(S)-5-((R)-1-(2-chlorophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3e). White solid; 30.8 mg, 76% yield; 99:1 dr, >99% ee; $[\alpha]_D^{20} = +198.7$ (c 1.540, CHCl_3); m.p. 97.5-99.3 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 8.1$ min (minor), 10.4 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.23 (dd, $J = 3.3$ Hz, 18.6 Hz, 1H), 4.40 (dd, $J = 11.1$ Hz, 18.6 Hz, 1H), 4.98 (dd, $J = 3.3$ Hz, 11.1 Hz, 1H), 5.59 (d, $J = 5.7$ Hz, 1H), 7.09-7.16 (m, 2H), 7.28-7.45 (m, 6H), 7.62 (d, $J = 7.8$ Hz, 2H), 7.65-7.76 (m, 3H), 8.62 (d, $J = 4.8$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.9, 44.1, 92.9, 119.4, 121.5, 125.0, 127.2, 127.3, 128.4, 128.5, 128.6, 129.1, 129.4, 134.7, 135.6, 136.6, 137.9, 148.8, 152.7, 158.4, 172.1, 199.1; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{ClNNaO}_3$ $[\text{M} + \text{Na}]^+$ 426.0867, found: 426.0886.

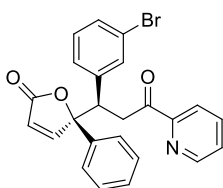


(S)-5-((R)-1-(4-chlorophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3f). White solid; 29.5 mg, 73% yield; 96:4 dr, 99% ee; $[\alpha]_D^{20} = +138.7$ (c 1.475, CHCl_3); m.p. 191.2-193.1 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 13.1$ min (minor), 17.6 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.13-3.24 (m, 1H), 4.23-4.34 (m, 2H), 5.71 (d, $J = 5.7$ Hz, 1H), 7.17-7.26 (m, 4H), 7.31 (d, $J = 7.2$ Hz, 1H), 7.35-7.42 (m, 3H), 7.51 (d, $J = 6.0$ Hz, 3H), 7.66-7.72 (m, 1H), 7.76 (d, $J = 7.8$ Hz, 1H), 8.62 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 48.6, 92.6, 119.8, 121.6, 125.2, 127.3, 128.4, 128.6, 129.0, 130.2, 133.3, 136.4, 136.7, 137.8, 148.9, 152.6, 158.9, 171.9, 199.1; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{ClNNaO}_3$ $[\text{M} + \text{Na}]^+$ 426.0867, found: 426.0875.

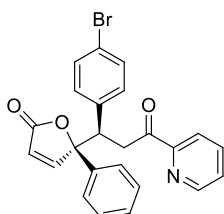


(S)-5-((R)-1-(2-bromophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3g). White solid; 33.1 mg, 74% yield; >99:1 dr, >99% ee; $[\alpha]_D^{20} = +179.2$ (c 1.655, CHCl_3); m.p. 92.5-93.9 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 8.6$ min (minor), 10.7 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.23 (dd, $J = 3.3$ Hz, 18.6 Hz, 1H), 4.39 (dd, $J = 11.1$ Hz, 18.6 Hz, 1H), 4.97 (dd, $J = 3.3$ Hz, 11.1 Hz, 1H), 5.59 (d, $J = 5.7$ Hz, 1H), 7.00-7.05 (m, 1H), 7.15-7.21 (m, 1H), 7.28-7.44 (m, 5H), 7.54 (d, $J = 7.8$ Hz, 1H), 7.62-7.70 (m, 3H), 7.73-7.77 (m, 2H), 8.62 (d, $J =$

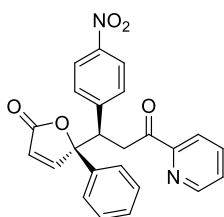
4.2 Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 38.2, 47.2, 92.9, 119.3, 121.5, 125.0, 126.2, 127.2, 127.9, 128.4, 128.6, 128.9, 129.1, 132.8, 136.6, 137.2, 137.9, 148.8, 152.6, 158.5, 172.1, 199.0; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{BrNNaO}_3$ $[\text{M} + \text{Na}]^+$ 470.0362, found: 470.0372.



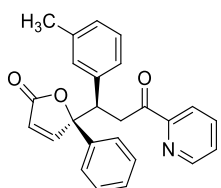
(S)-5-((R)-1-(3-bromophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3h). White solid; 39.0 mg, 87% yield; >99:1 dr, 98% ee; $[\alpha]_{\text{D}}^{20} = +81.4$ (c 1.950, CHCl_3); m.p. 208.9-210.3 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 11.1$ min (major), 14.3 min (minor); ^1H NMR (300 MHz, DMSO) δ 3.01 (dd, $J = 1.8$ Hz, 17.4 Hz, 1H), 4.16 (dd, $J = 11.1$ Hz, 17.7 Hz, 1H), 4.31 (dd, $J = 2.7$ Hz, 11.1 Hz, 1H), 5.88 (d, $J = 5.7$ Hz, 1H), 7.14-7.19 (m, 1H), 7.28-7.36 (m, 3H), 7.41-7.46 (m, 2H), 7.58-7.69 (m, 5H), 7.85-7.90 (m, 1H), 8.16 (d, $J = 5.7$ Hz, 1H), 8.69 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, DMSO) δ 36.9, 47.6, 92.2, 118.6, 121.2, 121.3, 125.2, 127.5, 128.0, 128.3, 129.0, 130.1, 132.3, 137.6, 138.2, 140.8, 149.2, 152.1, 161.3, 171.8, 198.7; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{BrNNaO}_3$ $[\text{M} + \text{Na}]^+$ 470.0362, found: 470.0357.



(S)-5-((R)-1-(4-bromophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3i). White solid; 33.5 mg, 75% yield; 98:2 dr, 99% ee; $[\alpha]_{\text{D}}^{20} = +131.7$ (c 1.675, CHCl_3); m.p. 177.9-178.8 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 16.8$ min (minor), 20.8 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.11-3.24 (m, 1H), 4.21-4.34 (m, 2H), 5.71 (d, $J = 5.7$ Hz, 1H), 7.18 (d, $J = 8.4$ Hz, 2H), 7.27-7.42 (m, 6H), 7.51 (d, $J = 6.0$ Hz, 3H), 7.66-7.77 (m, 2H), 8.62 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.7, 48.6, 92.6, 119.8, 121.5, 121.6, 125.2, 127.3, 128.4, 129.0, 130.5, 131.5, 136.7, 136.9, 137.8, 148.9, 152.6, 158.8, 171.9, 199.1; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{BrNNaO}_3$ $[\text{M} + \text{Na}]^+$ 470.0362, found: 470.0360.

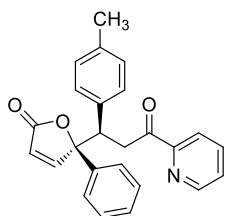


(S)-5-((R)-1-(4-nitrophenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3j). White solid; 36.3 mg, 88% yield; >99:1 dr, 99% ee; $[\alpha]_{\text{D}}^{20} = +154.5$ (c 1.815, CHCl_3); m.p. 153.5-154.4 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 17.0$ min (minor), 29.4 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.19-3.30 (m, 1H), 4.31-4.37 (m, 2H), 5.72 (d, $J = 5.4$ Hz, 1H), 7.32-7.40 (m, 4H), 7.49-7.56 (m, 5H), 7.68-7.76 (m, 2H), 8.09 (d, $J = 8.1$ Hz, 2H), 8.63 (d, $J = 3.3$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.9, 49.0, 92.1, 120.1, 121.6, 123.6, 125.1, 127.5, 128.7, 129.2, 129.9, 136.8, 137.3, 145.6, 147.2, 149.0, 152.4, 158.5, 171.5, 198.8; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{N}_2\text{NaO}_5$ $[\text{M} + \text{Na}]^+$ 437.1108, found: 437.1107.

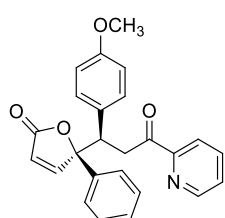


(S)-5-((R)-3-oxo-3-(pyridin-2-yl)-1-(m-tolyl)propyl)-5-phenylfuran-2(5H)-one (3k). White solid, 32.2 mg, 84% yield; >99:1 dr, >99% ee; $[\alpha]_{\text{D}}^{20} = +72.2$ (c 1.610, CHCl_3); m.p. 170.5-171.7 °C; HPLC (AD-H, EtOH/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 7.8$ min (minor), 9.8 min (major); ^1H NMR (300 MHz, CDCl_3) δ 2.26 (s, 3H), 3.19-3.30 (m, 1H), 4.21-4.32 (m, 2H), 5.66 (d, $J = 5.7$ Hz, 1H), 6.96-6.98 (m, 1H), 7.08-7.13 (m, 3H), 7.27-7.31 (m, 1H), 7.33-7.41 (m, 3H), 7.51 (d, $J = 6.3$ Hz, 3H), 7.65-7.71

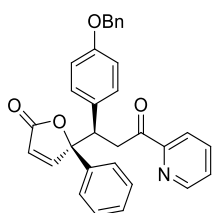
(m, 1H), 7.76 (d, $J = 7.8$ Hz, 1H), 8.63 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 21.4, 37.8, 49.1, 93.0, 119.4, 121.6, 125.3, 125.8, 127.1, 128.2, 128.8, 129.7, 136.6, 137.8, 137.9, 138.2, 148.8, 152.8, 159.1, 172.3, 199.3; HRMS (ESI-TOF) calcd. for $\text{C}_{25}\text{H}_{21}\text{NNaO}_3$ [$\text{M} + \text{Na}$] $^+$ 406.1414, found: 406.1410.



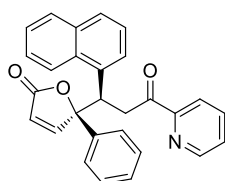
(S)-5-((R)-3-oxo-3-(pyridin-2-yl)-1-(p-tolyl)propyl)-5-phenylfuran-2(5H)-one (3l). White solid; 23.4 mg, 61% yield; >99:1 dr, 99% ee; $[\alpha]_{\text{D}}^{20} = +108.8$ (c 1.170, CHCl_3); m.p. 165.1-166.4 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 14.9$ min (minor), 16.5 min (major); ^1H NMR (300 MHz, CDCl_3) δ 2.24 (s, 3H), 3.22 (m, 1H), 4.22-4.33 (m, 2H), 5.67 (d, $J = 5.7$ Hz, 1H), 7.02 (d, $J = 7.8$ Hz, 2H), 7.17 (d, $J = 7.5$ Hz, 2H), 7.30 (d, $J = 6.9$ Hz, 1H), 7.34-7.39 (m, 3H), 7.51 (d, $J = 6.9$ Hz, 3H), 7.68 (t, $J = 7.5$ Hz, 1H), 7.76 (d, $J = 7.8$ Hz, 1H), 8.62 (d, $J = 3.9$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 21.0, 37.9, 48.7, 93.1, 119.5, 121.6, 125.3, 127.1, 128.2, 128.7, 128.9, 129.1, 134.7, 136.6, 137.0, 138.2, 148.8, 152.8, 159.2, 172.3, 199.4; HRMS (ESI-TOF) calcd. for $\text{C}_{25}\text{H}_{21}\text{NNaO}_3$ [$\text{M} + \text{Na}$] $^+$ 406.1414, found: 406.1407.



(S)-5-((R)-1-(4-methoxyphenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3m). White solid; 28.5 mg, 71% yield; 92:8 dr, 96% ee; $[\alpha]_{\text{D}}^{20} = +224.8$ (c 1.425, CHCl_3); m.p. 148.2-149.1 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 19.8$ min (minor), 27.3 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.13-3.24 (m, 1H), 3.70 (s, 3H), 4.20-4.31 (m, 2H), 5.68 (d, $J = 5.7$ Hz, 1H), 6.73 (d, $J = 8.4$ Hz, 2H), 7.20 (d, $J = 8.4$ Hz, 2H), 7.29 (d, $J = 7.2$ Hz, 1H), 7.32-7.38 (m, 3H), 7.49-7.52 (m, 3H), 7.64-7.69 (m, 1H), 7.75 (d, $J = 7.8$ Hz, 1H), 8.61 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.9, 48.3, 55.0, 93.1, 113.6, 119.4, 121.5, 125.2, 127.1, 128.2, 128.8, 129.7, 129.8, 136.5, 138.1, 148.8, 152.7, 158.6, 159.2, 172.2, 199.3; HRMS (ESI-TOF) calcd. for $\text{C}_{25}\text{H}_{21}\text{NNaO}_4$ [$\text{M} + \text{Na}$] $^+$ 422.1363, found: 422.1361.

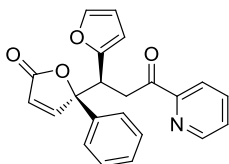


(S)-5-((R)-1-(4(benzyloxy)phenyl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3n). White solid; 34.5 mg, 72% yield; >99:1 dr, 99% ee; $[\alpha]_{\text{D}}^{20} = +74.7$ (c 1.725, CHCl_3); m.p. 166.1-168.2 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 17.1$ min (minor), 36.7 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.15-3.25 (m, 1H), 4.20-4.31 (m, 2H), 4.91-4.96 (m, 2H), 5.69 (d, $J = 5.7$ Hz, 1H), 6.83 (d, $J = 8.7$ Hz, 2H), 7.21 (d, $J = 8.7$ Hz, 2H), 7.28-7.41 (m, 9H), 7.51 (d, $J = 5.7$ Hz, 3H), 7.66-7.72 (m, 1H), 7.77 (d, $J = 7.8$ Hz, 1H), 8.63 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 38.0, 48.4, 69.8, 93.2, 114.6, 119.6, 121.6, 125.3, 127.1, 127.5, 127.9, 128.2, 128.5, 128.9, 129.9, 130.1, 136.6, 136.8, 138.2, 148.8, 152.8, 158.0, 159.2, 172.3, 199.4; HRMS (ESI-TOF) calcd. for $\text{C}_{31}\text{H}_{25}\text{NNaO}_4$ [$\text{M} + \text{Na}$] $^+$ 498.1676, found: 498.1681.

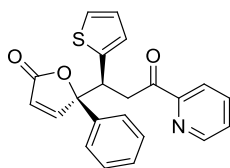


(S)-5-((R)-1-(naphthalen-1-yl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3o). White solid; 27.1 mg, 65% yield; 98:2 dr, 98% ee; $[\alpha]_{\text{D}}^{20} = +213.9$ (c 1.355, CHCl_3); m.p. 166.5-167.8 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 9.9$ min (minor), 14.6 min (major); ^1H NMR (300 MHz, CDCl_3)

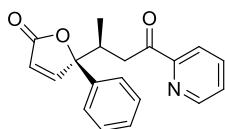
δ 3.40 (dd, $J = 3.3$ Hz, 18.3 Hz, 1H), 4.58 (dd, $J = 10.5$ Hz, 18.3 Hz, 1H), 5.31-5.38 (m, 2H), 7.29-7.45 (m, 6H), 7.48-7.53 (m, 1H), 7.61-7.70 (m, 7H), 7.84 (d, $J = 8.1$ Hz, 1H), 8.46 (d, $J = 8.4$ Hz, 1H), 8.65 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 38.6, 42.0, 93.0, 119.1, 121.6, 122.3, 125.2, 125.3, 125.5, 126.5, 127.1, 128.0, 128.3, 129.0, 129.3, 132.2, 133.7, 134.0, 136.6, 138.4, 148.8, 152.8, 158.2, 172.2, 199.4; HRMS (ESI-TOF) calcd. for $\text{C}_{28}\text{H}_{21}\text{NNaO}_3$ $[\text{M} + \text{Na}]^+$ 442.1414, found: 442.1416.



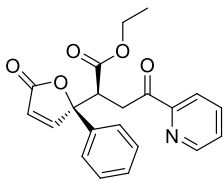
(S)-5-((R)-1-(furan-2-yl)-3-oxo-3-(pyridin-2-yl)propyl)-5-phenylfuran-2(5H)-one (3p). White solid; 27.4 mg, 76% yield; >99:1 dr, 99% ee; $[\alpha]_{\text{D}}^{20} = +96.1$ (c 1.370, CHCl_3); m.p. 131.7-132.9 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 11.8$ min (minor), 13.3 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.15 (dd, $J = 3.0$ Hz, 18.3 Hz, 1H), 4.17 (dd, $J = 11.1$ Hz, 18.3 Hz, 1H), 4.44 (dd, $J = 3.0$ Hz, 11.1 Hz, 1H), 5.83 (d, $J = 5.7$ Hz, 1H), 6.11 (d, $J = 3.0$ Hz, 1H), 6.17-6.19 (m, 1H), 7.24-7.26 (m, 1H), 7.29-7.48 (m, 6H), 7.69-7.73 (m, 2H), 7.85 (d, $J = 7.8$ Hz, 1H), 8.63 (d, $J = 4.8$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 36.7, 43.0, 92.2, 108.3, 110.5, 119.5, 121.7, 125.2, 127.2, 128.4, 128.9, 136.7, 137.5, 141.5, 148.9, 151.9, 152.7, 158.4, 172.0, 198.9; HRMS (ESI-TOF) calcd. for $\text{C}_{22}\text{H}_{17}\text{NNaO}_4$ $[\text{M} + \text{Na}]^+$ 382.1050, found: 382.1050.



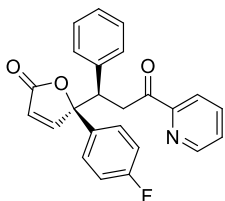
(S)-5-((S)-3-oxo-3-(pyridin-2-yl)-1-(thiophen-2-yl)propyl)-5-phenylfuran-2(5H)-one (3q). White solid; 31.9 mg, 85% yield; 96:4 dr, 97% ee; $[\alpha]_{\text{D}}^{20} = +127.1$ (c 1.595, CHCl_3); m.p. 170.1-172.2 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 11.7$ min (minor), 17.1 min (major); ^1H NMR (300 MHz, CDCl_3) δ 3.22 (dd, $J = 3.0$ Hz, 18.3 Hz, 1H), 4.24 (dd, $J = 10.8$ Hz, 18.3 Hz, 1H), 4.62 (dd, $J = 3.0$ Hz, 10.8 Hz, 1H), 5.77 (d, $J = 5.7$ Hz, 1H), 6.83-6.85 (m, 1H), 6.93 (d, $J = 3.0$ Hz, 1H), 7.08 (d, $J = 5.1$ Hz, 1H), 7.27-7.41 (m, 4H), 7.52 (d, $J = 7.2$ Hz, 2H), 7.57 (d, $J = 5.7$ Hz, 1H), 7.67-7.73 (m, 1H), 7.80 (d, $J = 7.8$ Hz, 1H), 8.61 (d, $J = 4.8$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 39.6, 44.0, 92.5, 119.7, 121.7, 124.5, 125.2, 126.4, 126.8, 127.2, 128.4, 129.0, 136.6, 137.7, 140.4, 148.9, 152.6, 158.6, 172.2, 198.7; HRMS (ESI-TOF) calcd. for $\text{C}_{22}\text{H}_{17}\text{NNaO}_3\text{S}$ $[\text{M} + \text{Na}]^+$ 398.0821, found: 398.0818.



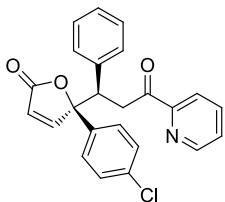
(R)-5-((S)-4-oxo-4-(pyridin-2-yl)butan-2-yl)-5-phenylfuran-2(5H)-one (3r). White solid; 32.2 mg, 84% yield; 97:3 dr, >99% ee; $[\alpha]_{\text{D}}^{20} = +249.3$ (c 1.295, CHCl_3); m.p. 151.1-151.9 °C; HPLC (OD-H, EtOH/hexane = 15/85, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 7.4$ min (major), 9.0 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 0.94 (d, $J = 6.6$ Hz, 3H), 3.01 (m, 1H), 3.11-3.18 (m, 1H), 3.43 (dd, $J = 9.9$ Hz, 18.0 Hz, 1H), 6.08 (d, $J = 5.7$ Hz, 1H), 7.23-7.29 (m, 1H), 7.31-7.36 (m, 2H), 7.39-7.44 (m, 3H), 7.67 (d, $J = 5.7$ Hz, 1H), 7.76 (t, $J = 7.5$ Hz, 1H), 7.90 (d, $J = 7.8$ Hz, 1H), 8.60 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 14.6, 36.7, 39.4, 93.9, 120.1, 121.6, 125.3, 127.1, 128.2, 128.8, 136.7, 138.4, 148.9, 153.0, 159.0, 172.4, 200.3; HRMS (ESI-TOF) calcd. for $\text{C}_{19}\text{H}_{17}\text{NNaO}_3$ $[\text{M} + \text{Na}]^+$ 330.1101, found: 330.1107.



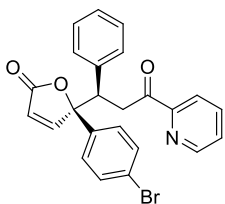
(S)-ethyl 4-oxo-2-((S)-5-oxo-2-phenyl-2,5-dihydrofuran-2-yl)-4-(pyridin-2-yl)butanoate (3s). White solid; 30.9 mg, 85% yield; >99:1 dr, 99% ee; $[\alpha]_D^{20} = +123.0$ (c 1.545, CHCl_3); m.p. 182.8-183.6 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 14.4$ min (major), 27.4 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 1.08 (t, $J = 7.2$ Hz, 3H), 3.19-3.25 (m, 1H), 3.81-3.85 (m, 1H), 3.90-4.11 (m, 3H), 6.10 (d, $J = 5.7$ Hz, 1H), 7.30-7.44 (m, 6H), 7.77 (t, $J = 7.5$ Hz, 1H), 7.91-7.96 (m, 2H), 8.63 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 13.9, 35.9, 50.2, 61.1, 90.2, 120.0, 121.6, 125.4, 127.4, 128.7, 129.0, 136.7, 137.3, 149.0, 152.4, 158.0, 170.6, 171.2, 199.2; HRMS (ESI-TOF) calcd. for $\text{C}_{21}\text{H}_{19}\text{NNaO}_5$ $[\text{M} + \text{Na}]^+$ 388.1155, found: 388.1157.



(S)-5-(4-fluorophenyl)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)furan-2(5H)-one (3t). White solid; 32.1 mg, 83% yield; 98:2 dr, 99% ee, $[\alpha]_D^{20} = +140.2$ (c 1.605, CHCl_3); m.p. 80.4-81.6 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 10.8$ min (major), 11.5 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 3.31 (dd, $J = 2.1$ Hz, 16.8 Hz, 1H), 4.14-4.28 (m, 2H), 5.70 (d, $J = 5.7$ Hz, 1H), 7.00-7.06 (m, 2H), 7.14-7.27 (m, 5H), 7.37-7.42 (m, 1H), 7.44-7.49 (m, 2H), 7.50-7.52 (m, 1H), 7.66-7.72 (m, 1H), 7.77 (d, $J = 7.8$ Hz, 1H), 8.63 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 49.3, 92.5, 115.8 (d, $J = 21.5$ Hz, 1C), 119.8, 121.6, 127.2, 127.4 (d, $J = 18.4$ Hz, 1C), 128.4, 128.9, 134.0 (d, $J = 3.1$ Hz, 1C), 136.6, 137.7, 148.8, 152.7, 158.6, 162.4 (d, $J = 246.4$ Hz, 1C), 171.9, 199.1; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{FNNaO}_3$ $[\text{M} + \text{Na}]^+$ 410.1163, found: 410.1170.

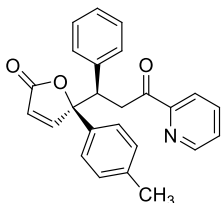


(S)-5-(4-chlorophenyl)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)furan-2(5H)-one (3u). White solid; 34.7 mg, 86% yield; 98:2 dr, 99% ee; $[\alpha]_D^{20} = +143.6$ (c 1.735, CHCl_3); m.p. 145.1-147.2 °C; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 15.0$ min (minor), 17.0 min (major). ^1H NMR (300 MHz, CDCl_3) δ 3.30 (dd, $J = 1.8$ Hz, 16.2 Hz, 1H), 4.14-4.28 (m, 2H), 5.70 (d, $J = 5.7$ Hz, 1H), 7.16-7.29 (m, 5H), 7.30-7.33 (m, 2H), 7.38-7.45 (m, 3H), 7.49 (d, $J = 5.7$ Hz, 1H), 7.67-7.78 (m, 2H), 8.63 (d, $J = 4.2$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 49.2, 92.4, 119.9, 121.7, 126.8, 127.2, 127.6, 128.5, 128.9, 129.0, 134.3, 136.6, 136.7, 137.6, 148.8, 152.7, 158.4, 171.7, 199.1; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{18}\text{ClNNaO}_3$ $[\text{M} + \text{Na}]^+$ 426.0867, found: 426.0872.

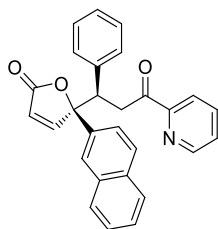


(S)-5-(4-bromophenyl)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)furan-2(5H)-one (3v). White solid; 34.5 mg, 77% yield; 97:3 dr, 98% ee; $[\alpha]_D^{20} = +135.8$ (c 1.725, CHCl_3); m.p. 155.4-157.1 °C; HPLC (Chiralpak AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 17.1$ min (minor), 24.0 min (major). ^1H NMR (300 MHz, CDCl_3) δ 3.30 (dd, $J = 1.8$ Hz, 16.2 Hz, 1H), 4.14-4.27 (m, 2H), 5.69 (d, $J = 5.7$ Hz, 1H), 7.14-7.29 (m, 5H), 7.35-7.43 (m, 3H), 7.46-7.49 (m, 3H), 7.67-7.78 (m, 2H), 8.62-8.64 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 37.8, 49.1, 92.5, 119.9, 121.7, 122.5, 127.1, 127.2, 127.6, 128.5, 128.9, 132.0, 136.6, 137.2, 137.6, 148.8, 152.7, 158.4,

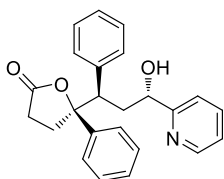
171.7, 199.1; HRMS (ESI-TOF) calcd. for $C_{24}H_{18}BrNNaO_3$ $[M + Na]^+$ 470.0362, found: 470.0369.



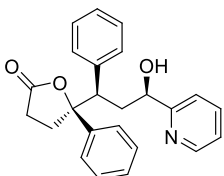
(S)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)-5-(p-tolyl)furan-2(5H)-one (3w). White solid; 30.9 mg, 81% yield; 98:2 dr, 99% ee; $[\alpha]_D^{20} = +147.5$ (c 1.545, $CHCl_3$); m.p. 159.1-160.8 °C; HPLC (Chiralpak AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 12.2$ min (minor), 23.9 min (major). 1H NMR (300 MHz, $CDCl_3$) δ 2.31 (s, 3H), 3.20-3.31 (m, 1H), 4.24-4.34 (m, 2H), 5.64 (d, $J = 5.7$ Hz, 1H), 7.13-7.24 (m, 5H), 7.28-7.31 (m, 2H), 7.36-7.41 (m, 3H), 7.49 (d, $J = 5.7$ Hz, 1H), 7.65-7.71 (m, 1H), 7.75 (d, $J = 7.8$ Hz, 1H), 8.62 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.9, 37.9, 49.1, 93.0, 119.3, 121.6, 125.2, 127.1, 127.4, 128.4, 128.9, 129.5, 135.1, 136.5, 138.0, 138.1, 148.8, 152.8, 159.3, 172.3, 199.3; HRMS (ESI-TOF) calcd. for $C_{25}H_{21}NNaO_3$ $[M + Na]^+$ 406.1414, found: 406.1415.



(S)-5-(naphthalen-2-yl)-5-((R)-3-oxo-1-phenyl-3-(pyridin-2-yl)propyl)furan-2(5H)-one (3x). White solid; 35.7 mg, 85% yield; 97:3 dr, 99% ee; $[\alpha]_D^{20} = +154.5$ (c 1.785, $CHCl_3$); m.p. 206.9-207.8 °C; HPLC (Chiralpak AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 14.9$ min (minor), 34.7 min (major); 1H NMR (300 MHz, $CDCl_3$) δ 3.37 (dd, $J = 3.6$ Hz, 18.0 Hz, 1H), 4.26 (dd, $J = 10.2$ Hz, 18.0 Hz, 1H), 4.43 (dd, $J = 3.6$ Hz, 10.2 Hz, 1H), 5.69 (d, $J = 5.7$ Hz, 1H), 7.16-7.28 (m, 3H), 7.30-7.38 (m, 3H), 7.46-7.51 (m, 2H), 7.56-7.66 (m, 4H), 7.79-7.82 (m, 2H), 7.87 (d, $J = 8.7$ Hz, 1H), 8.01 (d, $J = 1.5$ Hz, 1H), 8.58 (d, $J = 4.5$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 37.9, 49.1, 93.1, 119.6, 121.5, 122.8, 124.6, 126.5, 126.6, 127.0, 127.5, 128.2, 128.4, 128.8, 128.9, 132.8, 133.1, 135.4, 136.5, 137.9, 148.7, 152.7, 159.0, 172.2, 199.2; HRMS (ESI-TOF) calcd. for $C_{28}H_{21}NNaO_3$ $[M + Na]^+$ 442.1414, found: 442.1406.

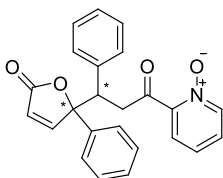


(S)-5-((1R,3S)-3-hydroxy-1-phenyl-3-(pyridin-2-yl)propyl)-5-phenyl dihydrofuran-2(3H)-one (4). White solid; 16.5 mg, 23% yield, >99% ee; $[\alpha]_D^{20} = +14.0$ (c, $CHCl_3$); m.p. 92.4-94.3 °C; HPLC (OD-H, *i*-propanol/*n*-hexane = 15/85, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R = 12.0$ min (minor), 15.2 min (major); 1H NMR (300 MHz, $CDCl_3$) δ 1.47-1.56 (m, 1H), 1.56-1.67 (m, 1H), 2.03-2.32 (m, 3H), 2.42-2.52 (m, 1H), 3.69 (dd, $J = 2.7$ Hz, 12.3 Hz, 1H), 4.10-4.18 (m, 2H), 6.98 (d, $J = 7.8$ Hz, 1H), 7.10 (dd, $J = 5.1$ Hz, 7.2 Hz, 1H), 7.24-7.44 (m, 8H), 7.48-7.51 (m, 2H), 7.54-7.60 (m, 1H), 8.38 (d, $J = 4.8$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 28.2, 34.3, 39.5, 52.4, 69.5, 91.1, 120.0, 122.2, 124.6, 127.4, 127.6, 128.6, 128.9, 130.2, 136.6, 138.5, 143.8, 147.8, 161.6, 177.0; HRMS (EI) calcd. for $C_{24}H_{19}NNaO_4$ $[M]^+$ 373.1678, found: 373.1670.



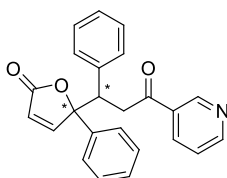
(S)-5-((1R,3R)-3-hydroxy-1-phenyl-3-(pyridin-2-yl)propyl)-5-phenyl dihydrofuran-2(3H)-one (4'). White solid; 32.3 mg, 44% yield, >99% ee; $[\alpha]_D^{20} = +3.8$ (c, $CHCl_3$); m.p. 129.6-131.1 °C; HPLC (OD-H, *i*-propanol/*n*-hexane = 15/85, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_R =$

8.3 min (major), 12.1 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 1.47-1.65 (m, 1H), 2.07-2.37 (m, 5H), 3.12 (dd, $J = 3.6$ Hz, 8.7 Hz, 1H), 3.60 (br s, 1H), 4.12 (t, $J = 6.3$ Hz, 1H), 6.76 (d, $J = 7.8$ Hz, 1H), 7.04-7.09 (m, 1H), 7.17-7.38 (m, 10H), 7.44-7.50 (m, 1H), 8.35 (d, $J = 4.8$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 28.3, 33.8, 39.2, 51.5, 71.5, 90.9, 120.9, 122.3, 124.9, 127.2, 127.6, 128.5, 130.0, 136.2, 139.3, 143.4, 148.3, 160.9, 176.7; HRMS (EI) calcd. for $\text{C}_{24}\text{H}_{19}\text{NNaO}_4$ $[\text{M}]^+$ 373.1678, found: 373.1685.



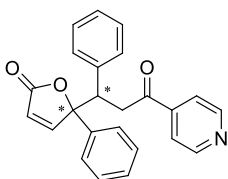
2-(3-(5-oxo-2-phenyl-2,5-dihydrofuran-2-yl)-3-phenylpropanoyl)pyridine 1-oxide (8).

White solid; 25.7 mg, 67% yield, 99:1 dr, 90% ee; $[\alpha]_{\text{D}}^{20} = +105.4$ (c 1.000, CHCl_3); m.p. 155.5-157.1 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 13.8$ min (major), 20.2 min (minor); ^1H NMR (300 MHz, CDCl_3) δ 3.43 (dd, $J = 4.2$ Hz, 17.7 Hz, 1H), 3.98 (dd, $J = 10.2$ Hz, 17.7 Hz, 1H), 4.22 (dd, $J = 4.2$ Hz, 10.2 Hz, 1H), 5.67 (d, $J = 5.7$ Hz, 1H), 7.00-7.11 (m, 2H), 7.12-7.29 (m, 6H), 7.30-7.41 (m, 3H), 7.45-7.50 (m, 3H), 8.09 (d, $J = 6.6$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 43.4, 49.4, 92.5, 119.8, 125.1, 125.4, 126.6, 127.6, 127.7, 128.4, 128.9, 137.5, 137.8, 140.2, 158.6, 171.8, 195.8; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{19}\text{NNaO}_4$ $[\text{M} + \text{Na}]^+$ 408.1206, found: 408.1211.



5-(3-oxo-1-phenyl-3-(pyridin-3-yl)propyl)-5-phenylfuran-2(5H)-one (10).

White solid; 16.4 mg, 44% yield, 96:4 dr, 92% ee; $[\alpha]_{\text{D}}^{20} = +111.7$ (c 0.820, CHCl_3); m.p. 184.2-185.7 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 25/75, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 15.1$ min (major), 31.7 min (minor); ^1H NMR (400 MHz, CDCl_3) δ 3.18 (dd, $J = 3.3$ Hz, 17.8 Hz, 1H), 3.82 (dd, $J = 10.1$ Hz, 17.8 Hz, 1H), 4.31 (dd, $J = 3.2$ Hz, 10.1 Hz, 1H), 5.65 (d, $J = 5.6$ Hz, 1H), 7.16-7.38 (m, 7H), 7.39-7.47 (m, 2H), 7.50 (d, $J = 5.6$ Hz, 1H), 7.52-7.62 (m, 2H), 7.96-8.08 (m, 1H), 8.71 (d, $J = 4.8$ Hz, 1H), 8.99 (s, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 29.7, 39.3, 48.9, 76.8, 92.7, 119.4, 123.5, 125.1, 127.8, 128.6, 128.6, 128.7, 129.2, 131.8, 135.2, 137.5, 137.9, 149.4, 153.5, 159.2, 172.1, 196.3; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{19}\text{NNaO}_3$ $[\text{M} + \text{Na}]^+$ 392.1257, found: 392.1253.



5-(3-oxo-1-phenyl-3-(pyridin-4-yl)propyl)-5-phenylfuran-2(5H)-one (12).

White solid; 22.5 mg, 61% yield, 99:1 dr, 93% ee; $[\alpha]_{\text{D}}^{20} = +134.2$ (c 1.125, CHCl_3); m.p. 186.8-188.1 $^{\circ}\text{C}$; HPLC (AD-H, *i*-propanol/*n*-hexane = 30/70, flow rate = 1.0 mL/min, $\lambda = 254$ nm) $t_{\text{R}} = 9.2$ min (minor), 9.9 min (major); ^1H NMR (400 MHz, CDCl_3) δ 3.17 (dd, $J = 3.2$ Hz, 17.9 Hz, 1H), 3.81 (dd, $J = 10.0$ Hz, 18.0 Hz, 1H), 4.28 (dd, $J = 3.3$ Hz, 10.1 Hz, 1H), 5.66 (d, $J = 5.6$ Hz, 1H), 7.19-7.25 (m, 1H), 7.27-7.37 (m, 5H), 7.39-7.45 (m, 2H), 7.49 (d, $J = 5.6$ Hz, 1H), 7.50-7.55 (m, 3H), 7.56 (d, $J = 1.7$ Hz, 1H), 8.72 (d, $J = 5.3$ Hz, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ 39.4, 48.9, 76.7, 92.7, 119.4, 120.8, 125.1, 127.9, 128.6, 128.6, 128.8, 129.2, 137.4, 137.8, 142.3, 150.8, 159.1, 172.0, 197.0; HRMS (ESI-TOF) calcd. for $\text{C}_{24}\text{H}_{19}\text{NNaO}_3$ $[\text{M} + \text{Na}]^+$ 392.1257, found: 392.1247.

4. X-ray crystallography of compound **3q**

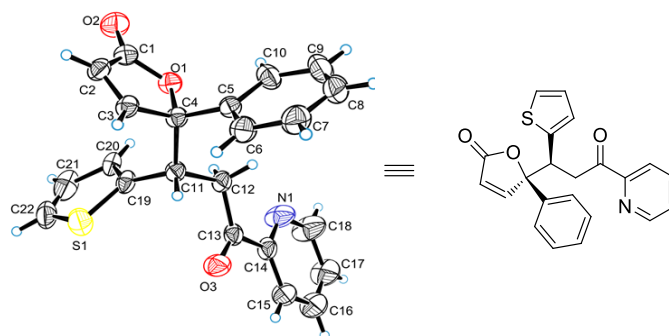


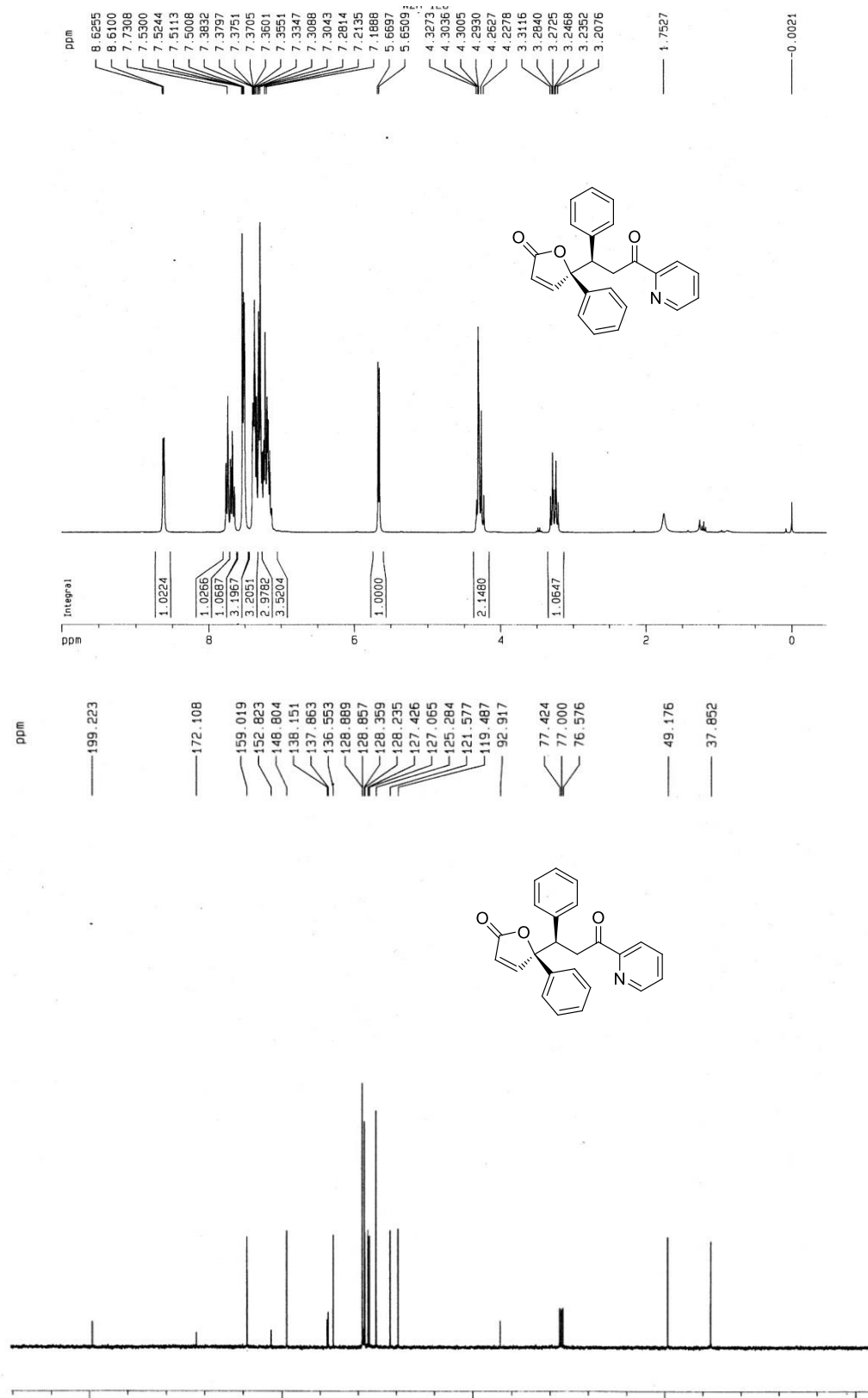
Table 1 Crystal data and structure refinement for **3q** (CCDC. 1057095).

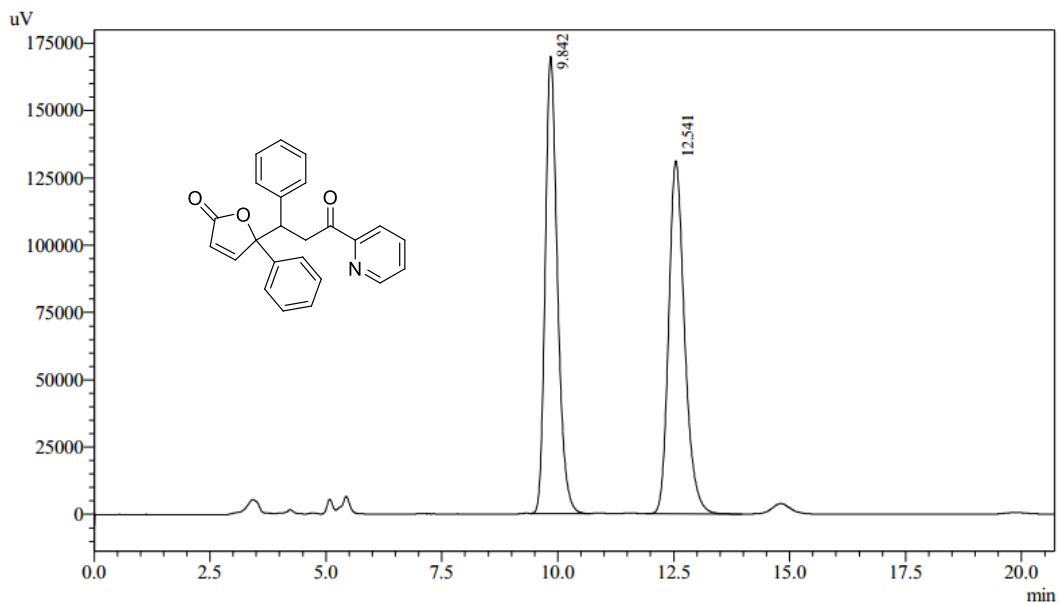
Identification code	3q
Empirical formula	C ₂₂ H ₁₇ NO ₃ S
Formula weight	375.30
Temperature/K	290(2)
Crystal system	monoclinic
Space group	C2
a/Å	20.9821(9)
b/Å	6.4380(3)
c/Å	15.2420(5)
α /°	90
β /°	111.466(3)
γ /°	90
Volume/Å ³	1916.11(14)
Z	4
$\rho_{\text{calc}}/\text{cm}^3$	1.301
μ/mm^{-1}	1.679
F(000)	784.0
Crystal size/mm ³	0.390 × 0.380 × 0.310
Radiation	CuK α (λ = 1.54184)
2 θ range for data collection/°	9.058 to 139.4
Index ranges	-25 ≤ h ≤ 25, -7 ≤ k ≤ 7, -18 ≤ l ≤ 18
Reflections collected	12444
Independent reflections	3429 [R _{int} = 0.0415, R _{sigma} = 0.0299]
Data/restraints/parameters	3429/7/244
Goodness-of-fit on F ²	1.089
Final R indexes [I ≥ 2 σ (I)]	R ₁ = 0.0788, wR ₂ = 0.2317
Final R indexes [all data]	R ₁ = 0.0802, wR ₂ = 0.2342

Largest diff. peak/hole / e Å ⁻³	0.99/-0.55
Flack parameter	0.066(58)

5. ^1H , ^{13}C NMR, and HPLC spectra for compounds 3a-x, and compounds 4, 4', 8, 10 and 12.

^1H NMR, ^{13}C NMR and HPLC of 3a

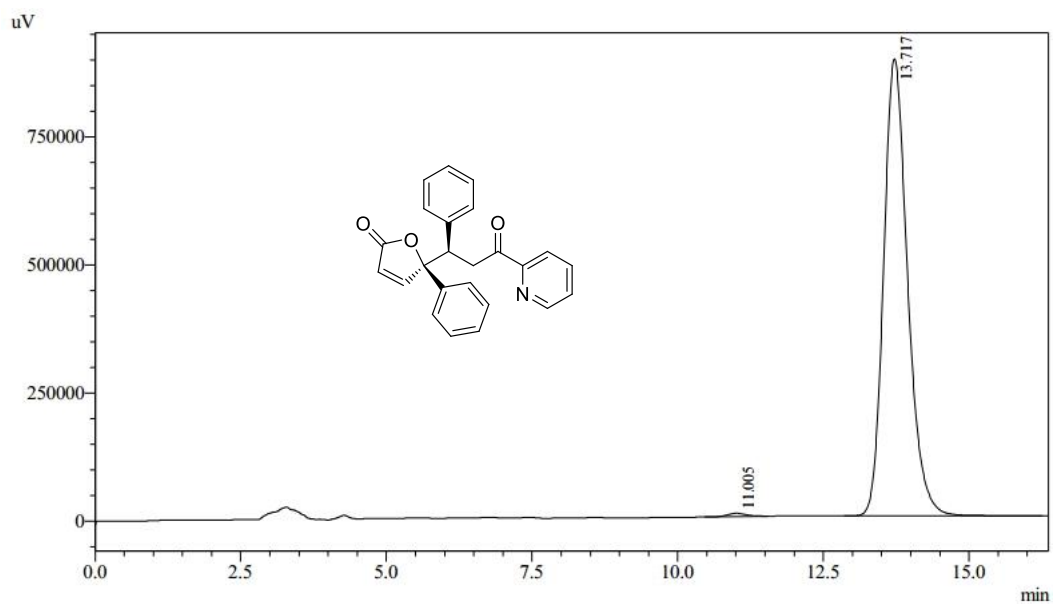




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.842	3109179	169872	49.789	56.428
2	12.541	3135473	131168	50.211	43.572
Total		6244652	301040	100.000	100.000

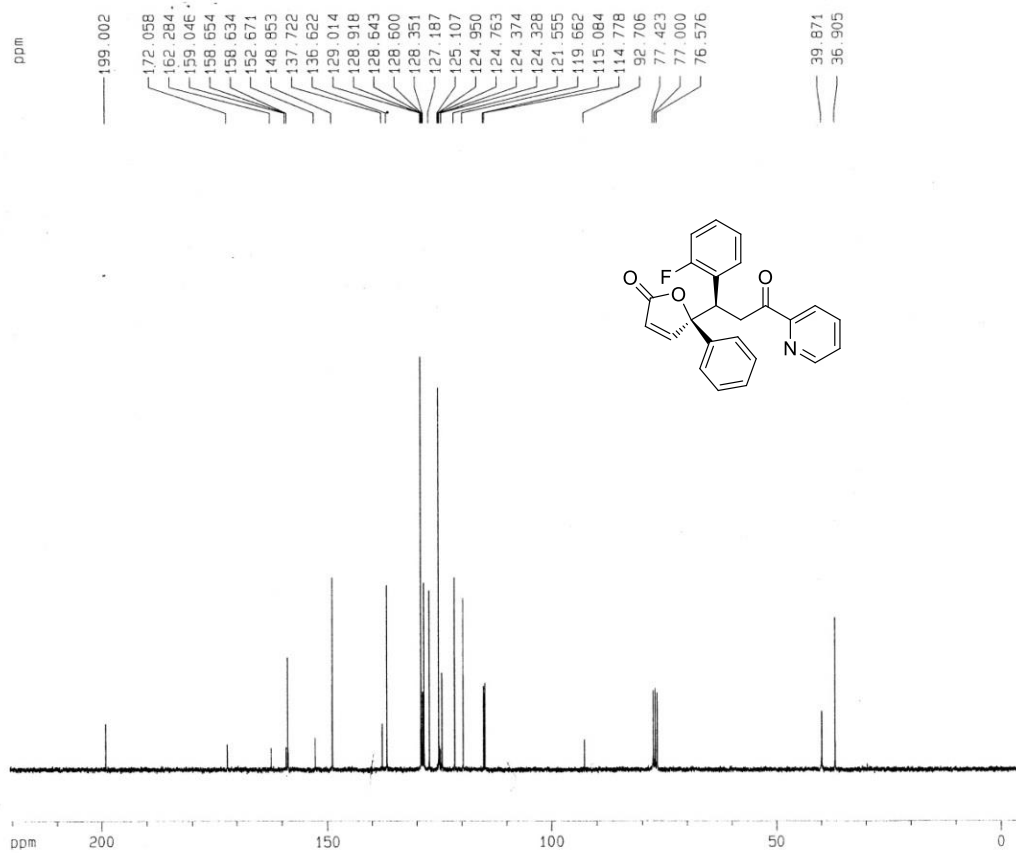
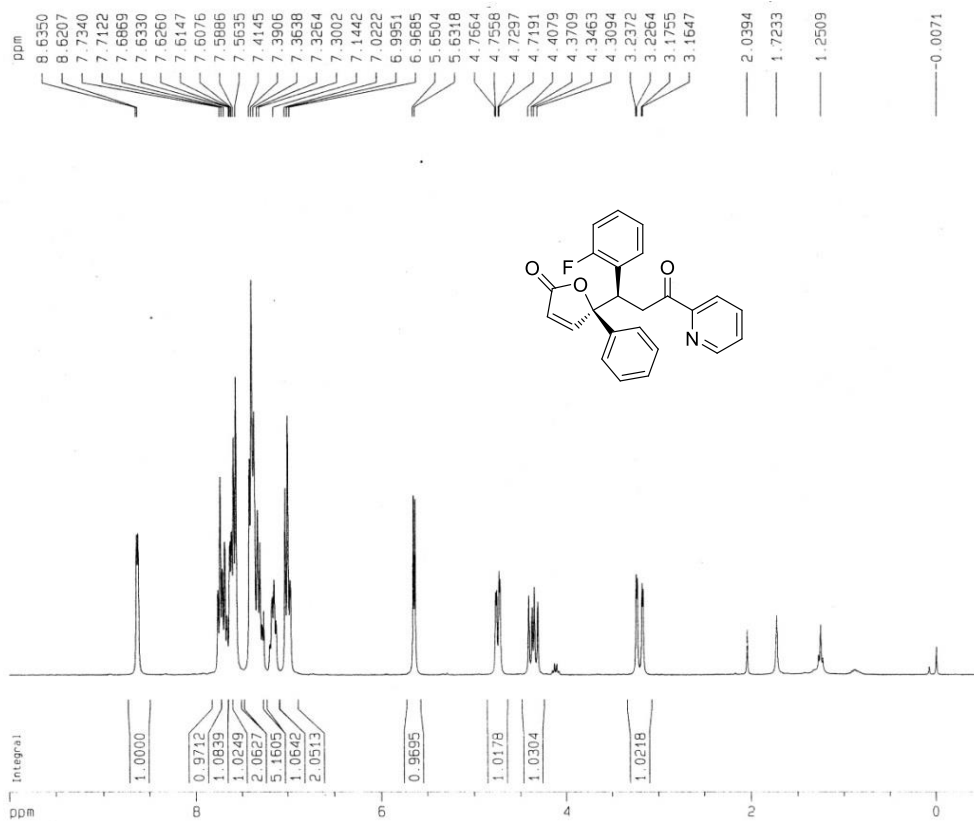


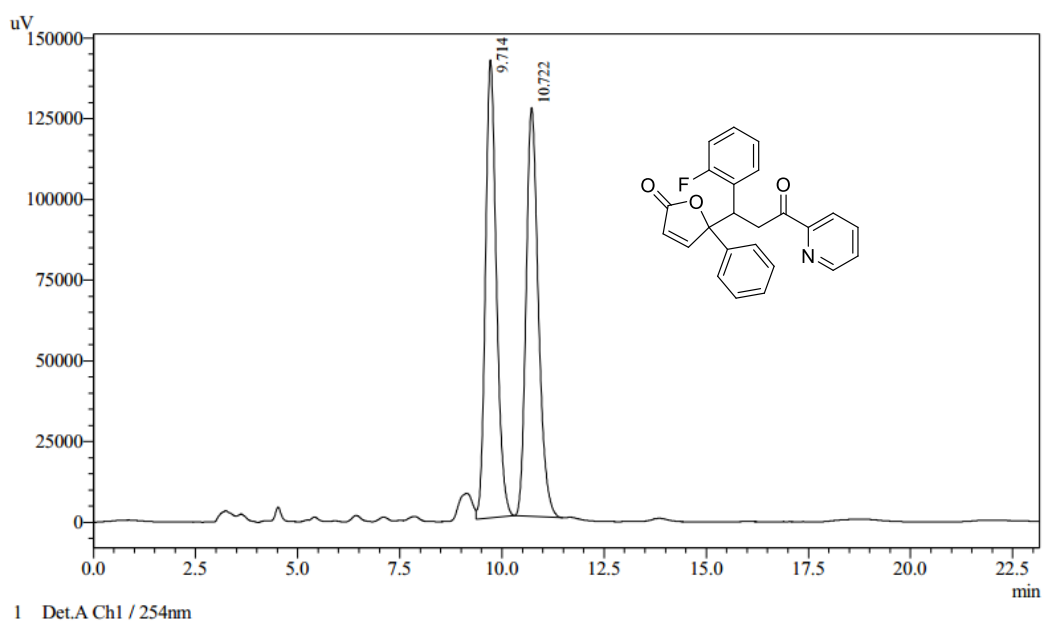
1 Det.A Ch1 / 220nm

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.005	140283	6387	0.548	0.712
2	13.717	25451536	891182	99.452	99.288
Total		25591819	897569	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3b

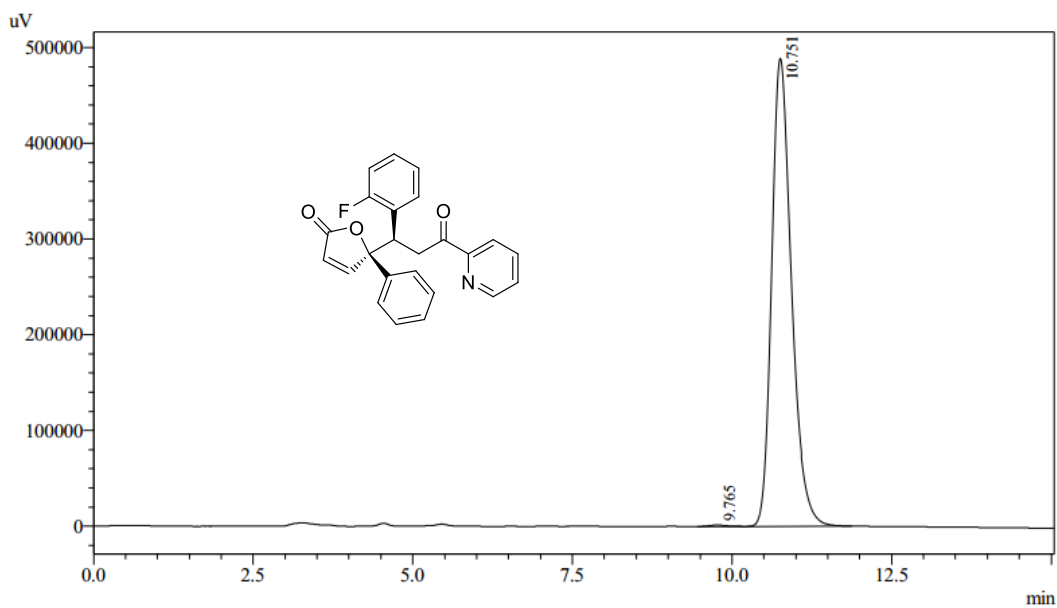




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.714	2640093	141874	49.909	52.829
2	10.722	2649699	126682	50.091	47.171
Total		5289792	268556	100.000	100.000

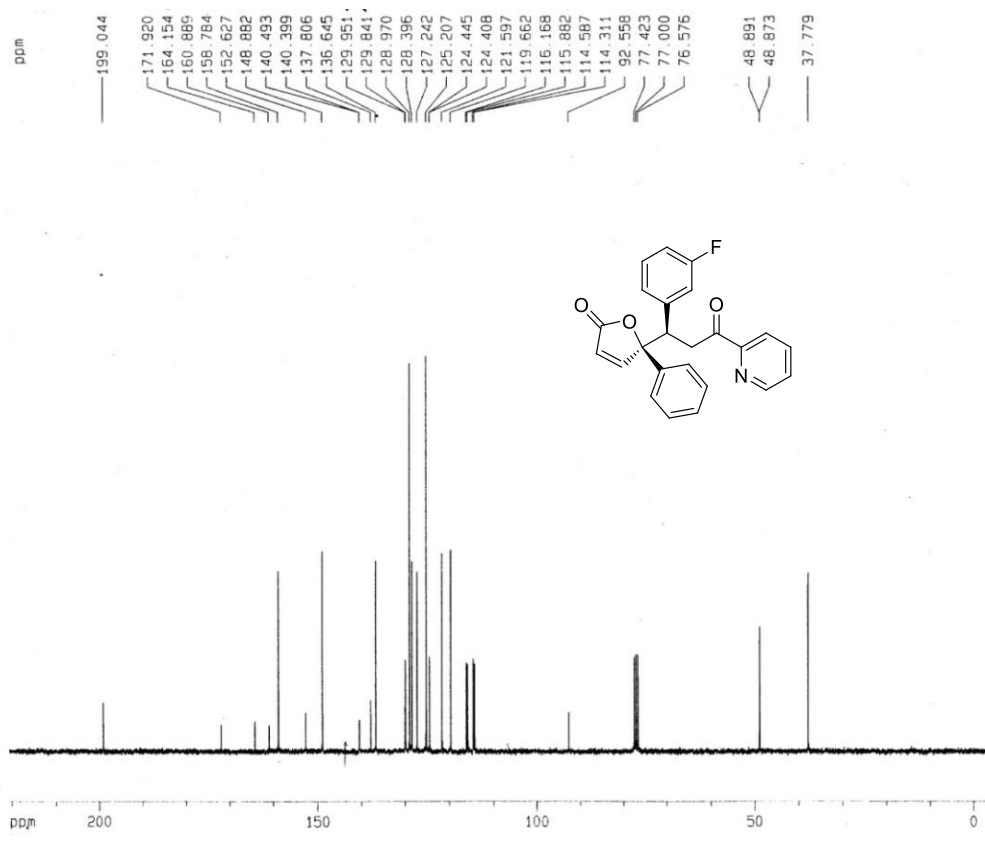
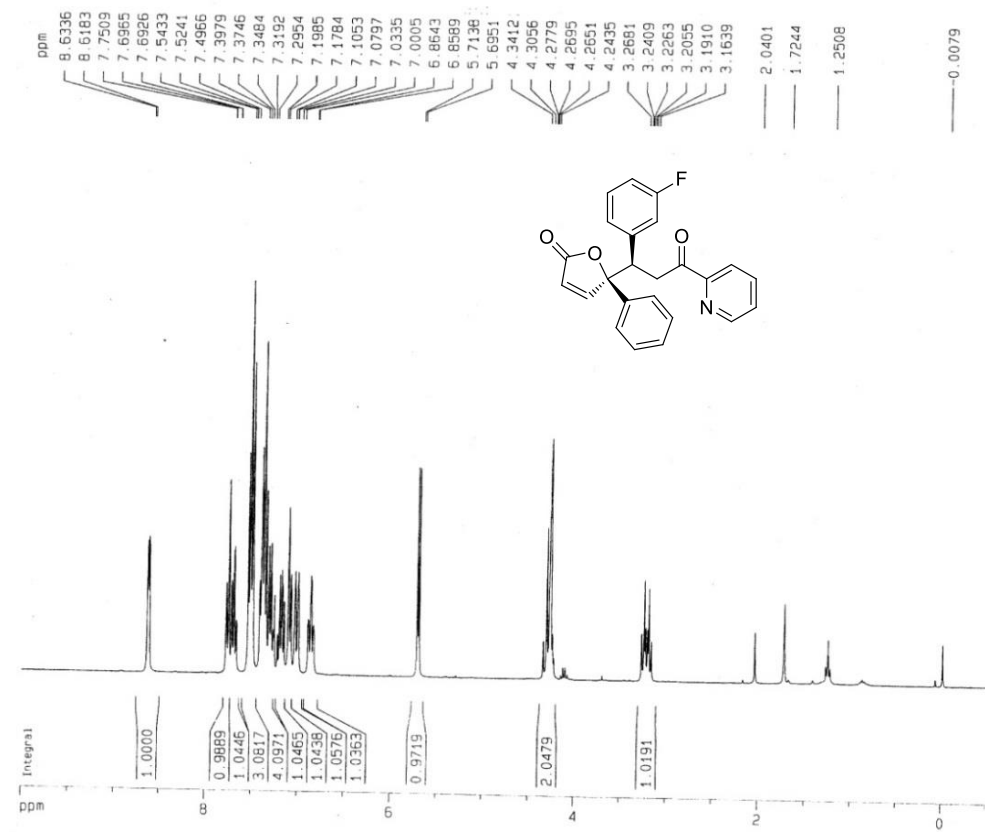


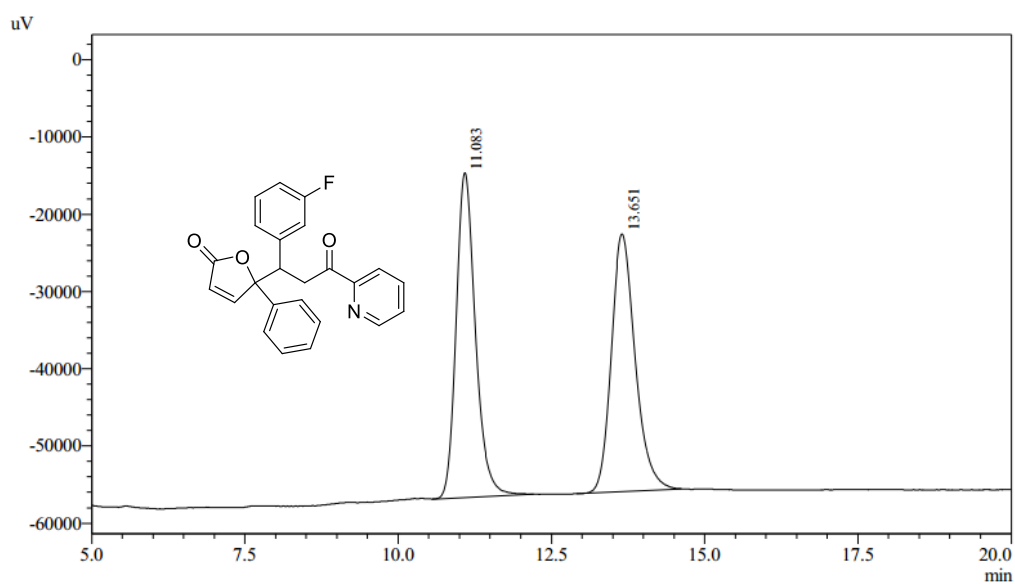
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.765	26124	1427	0.249	0.291
2	10.751	10468915	488744	99.751	99.709
Total		10495039	490171	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3c

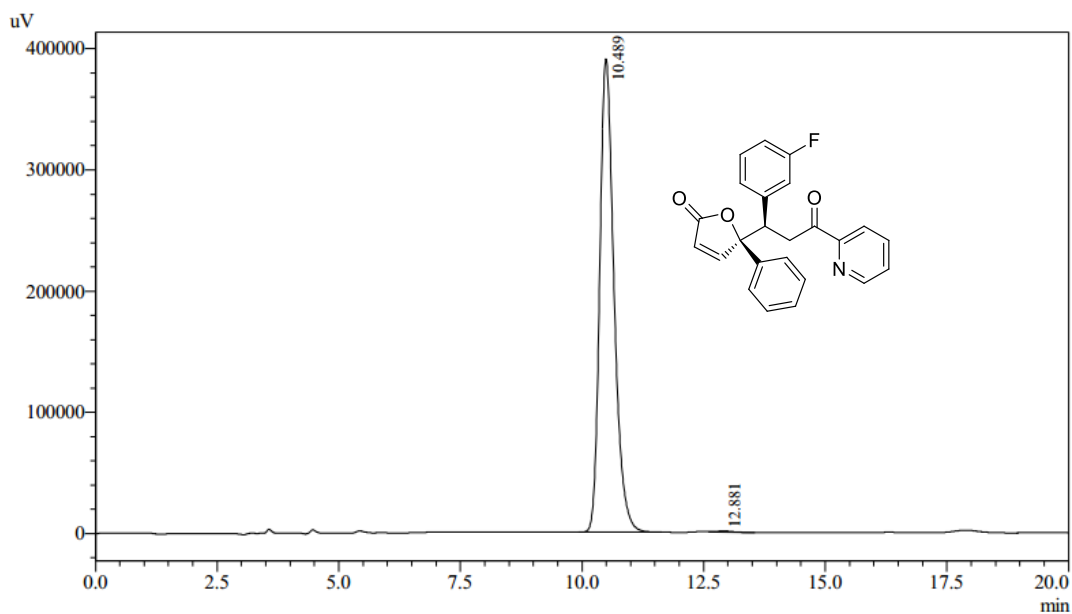




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.083	915573	42072	50.186	55.770
2	13.651	908777	33367	49.814	44.230
Total		1824350	75439	100.000	100.000

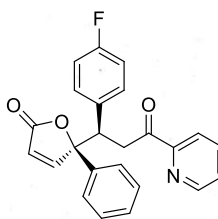
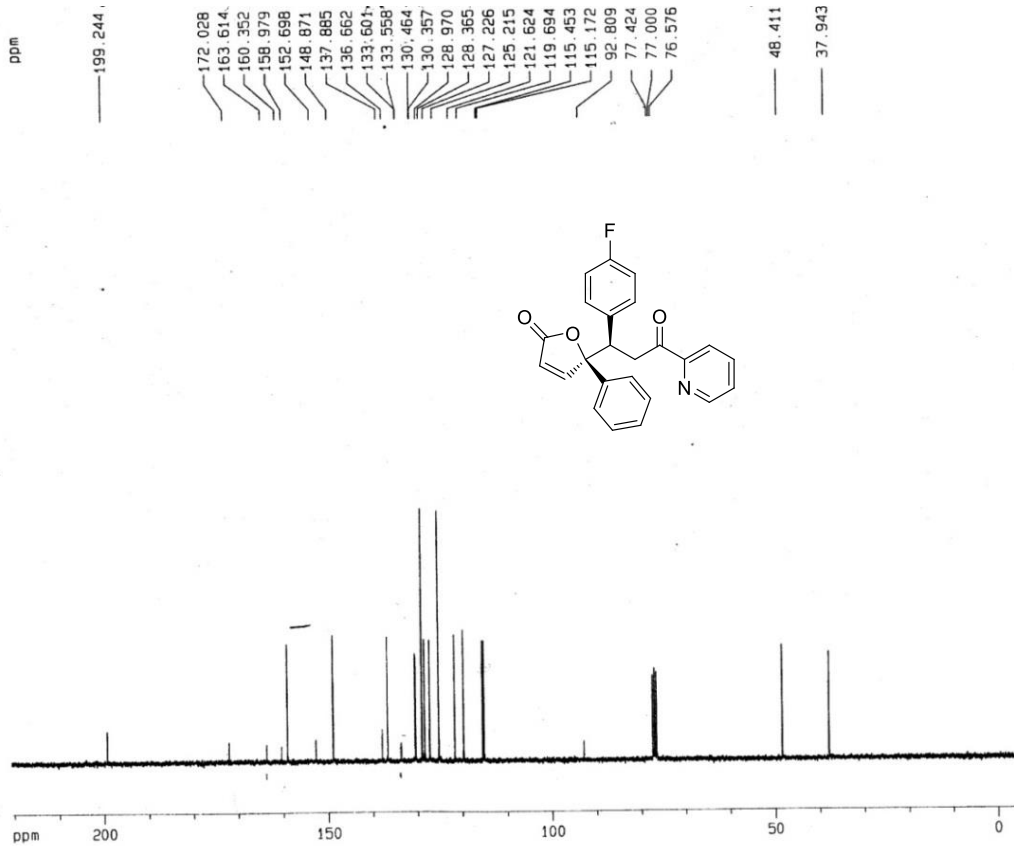
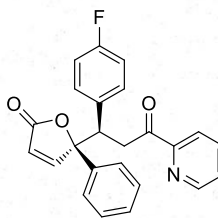
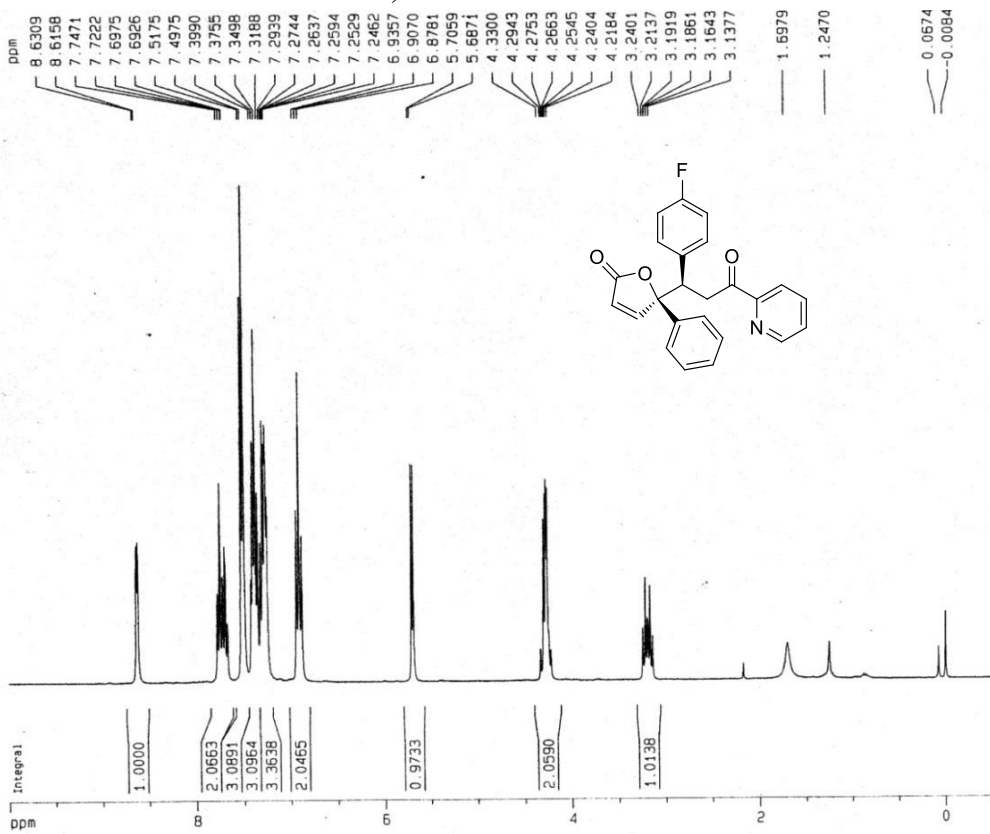


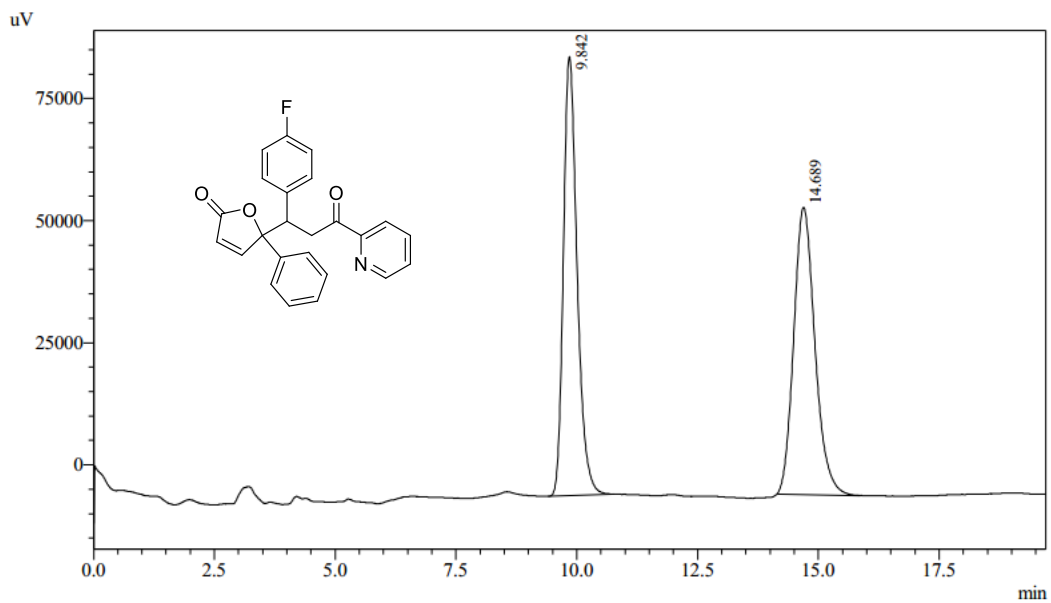
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.489	7968127	390640	99.654	99.723
2	12.881	27648	1084	0.346	0.277
Total		7995776	391724	100.000	100.000

¹H NMR, ¹³C NMR and HPLC 3d

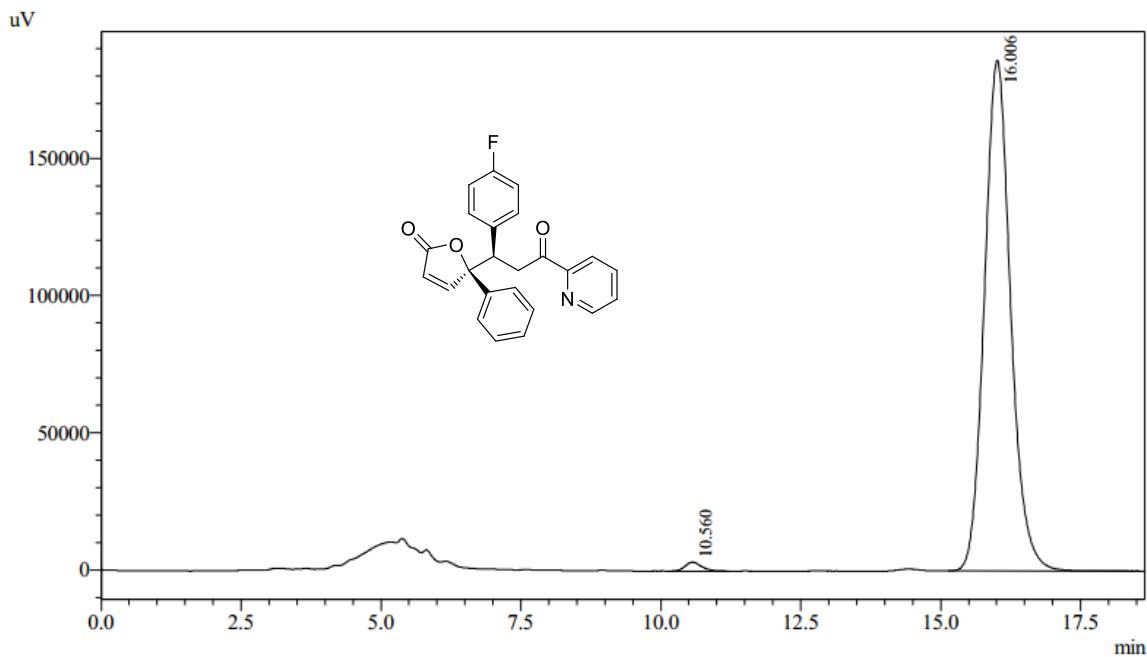




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.842	1771883	89911	49.688	60.458
2	14.689	1794124	58806	50.312	39.542
Total		3566007	148717	100.000	100.000

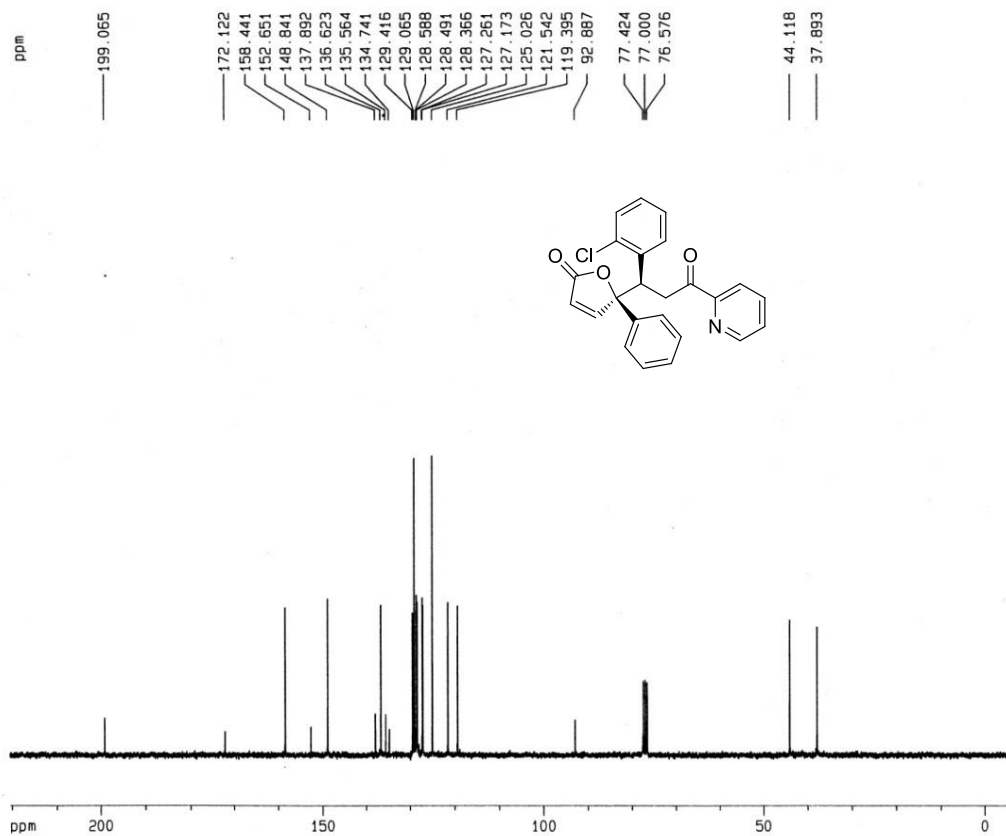
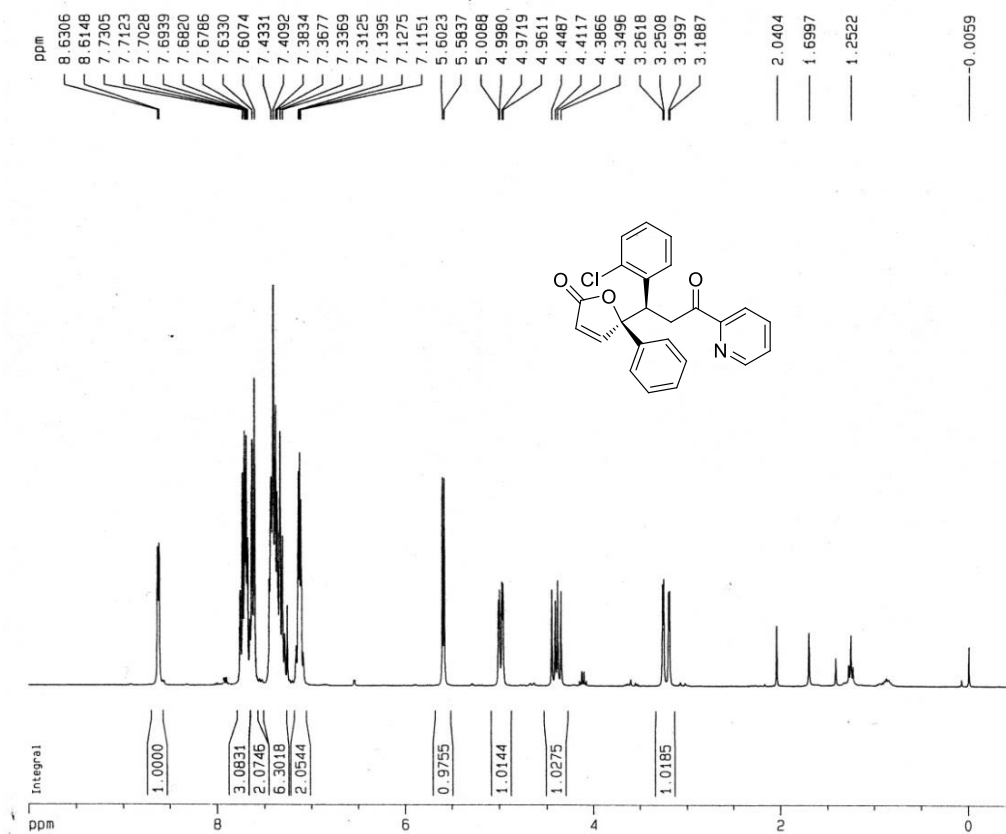


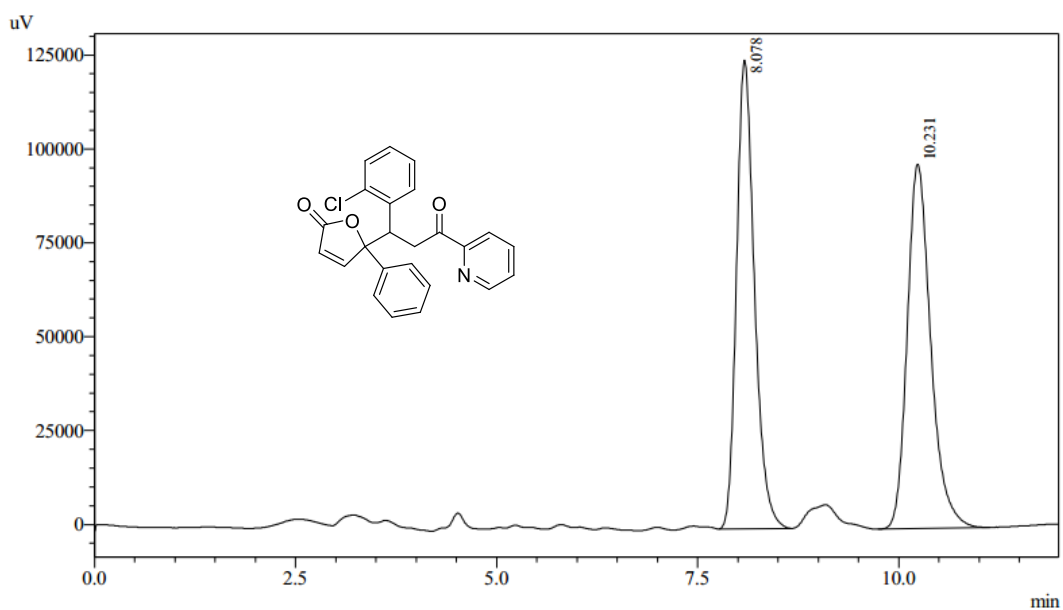
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.560	68191	3248	1.113	1.715
2	16.006	6060832	186127	98.887	98.285
Total		6129023	189375	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3e

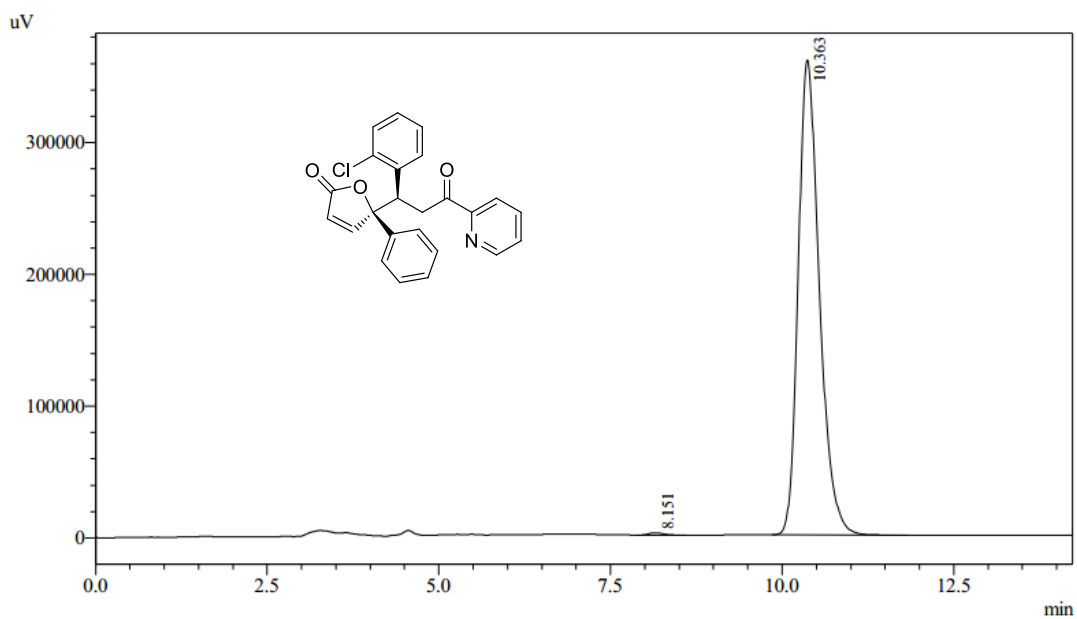




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.078	1936513	124787	49.513	56.260
2	10.231	1974612	97019	50.487	43.740
Total		3911125	221806	100.000	100.000

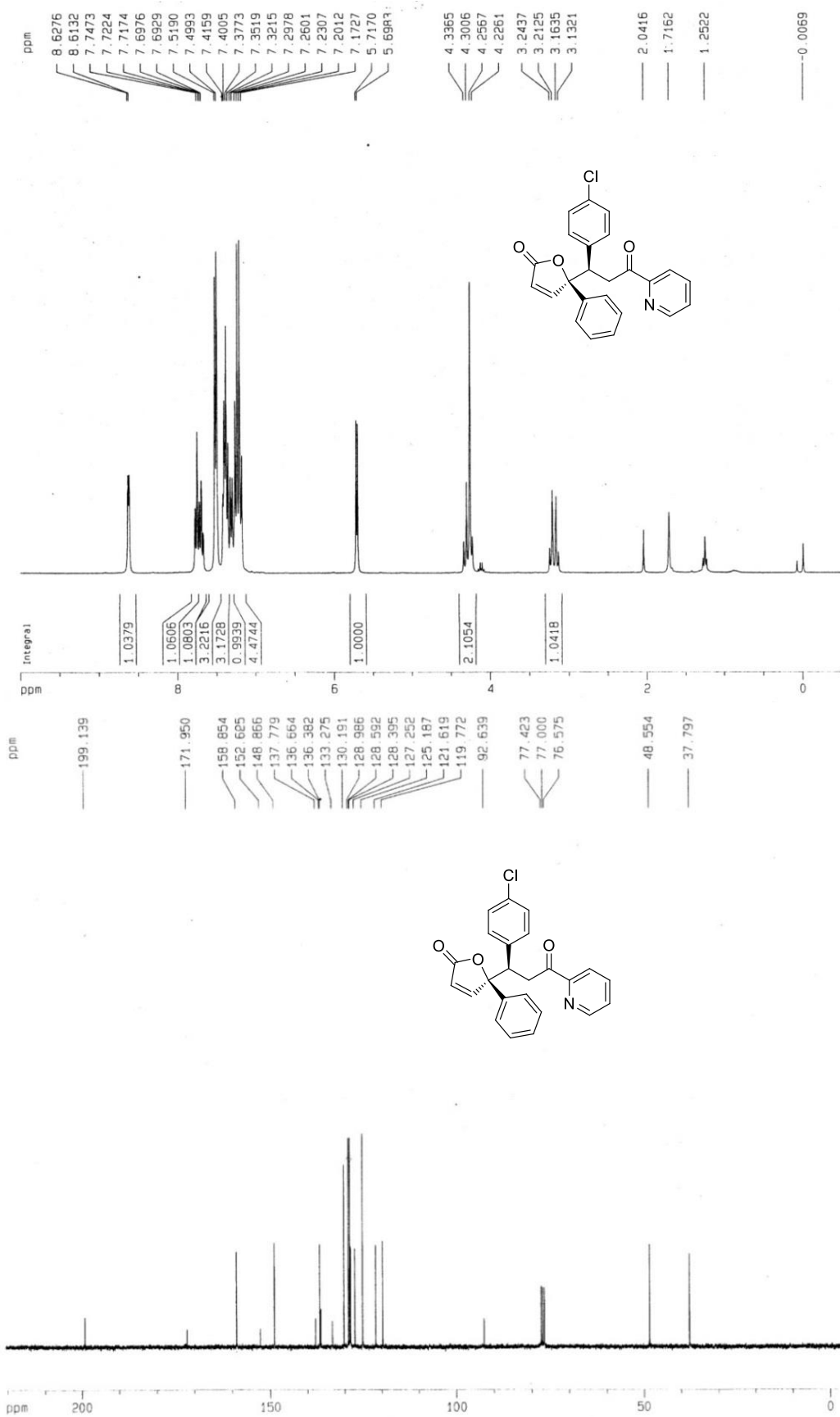


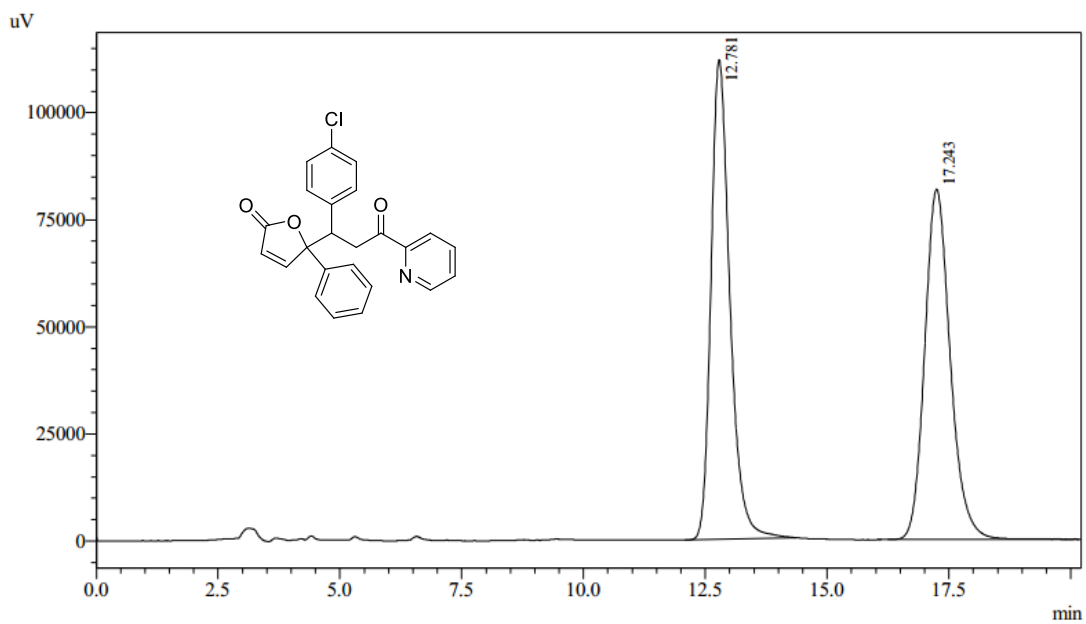
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.151	26790	1775	0.346	0.490
2	10.363	7715369	360327	99.654	99.510
Total		7742160	362103	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3f

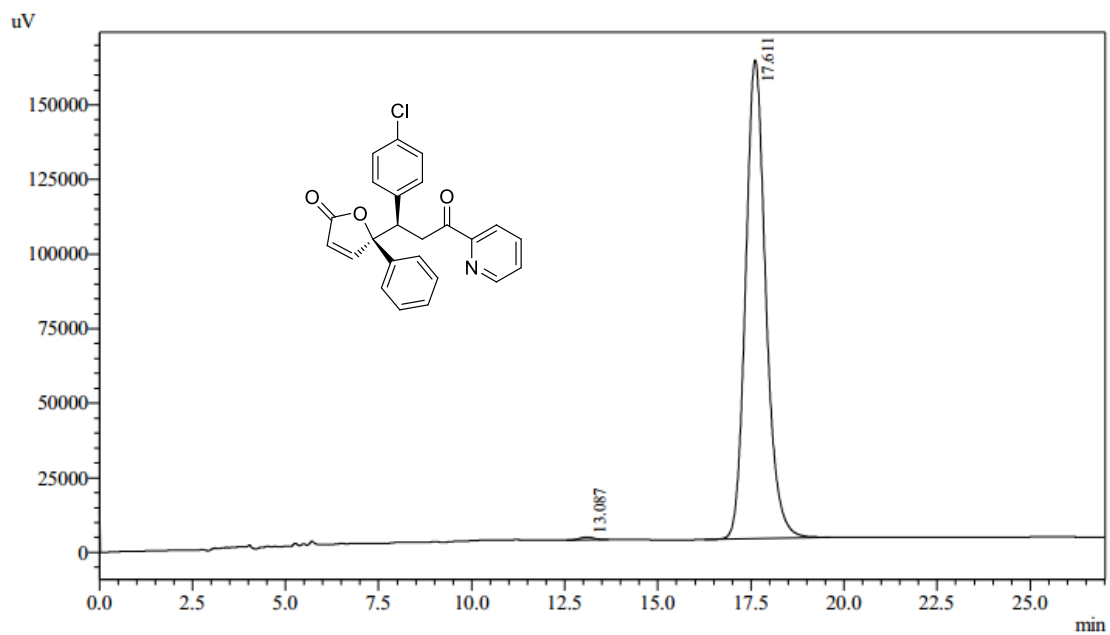




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.781	3021707	111974	50.313	57.790
2	17.243	2984058	81786	49.687	42.210
Total		6005765	193759	100.000	100.000

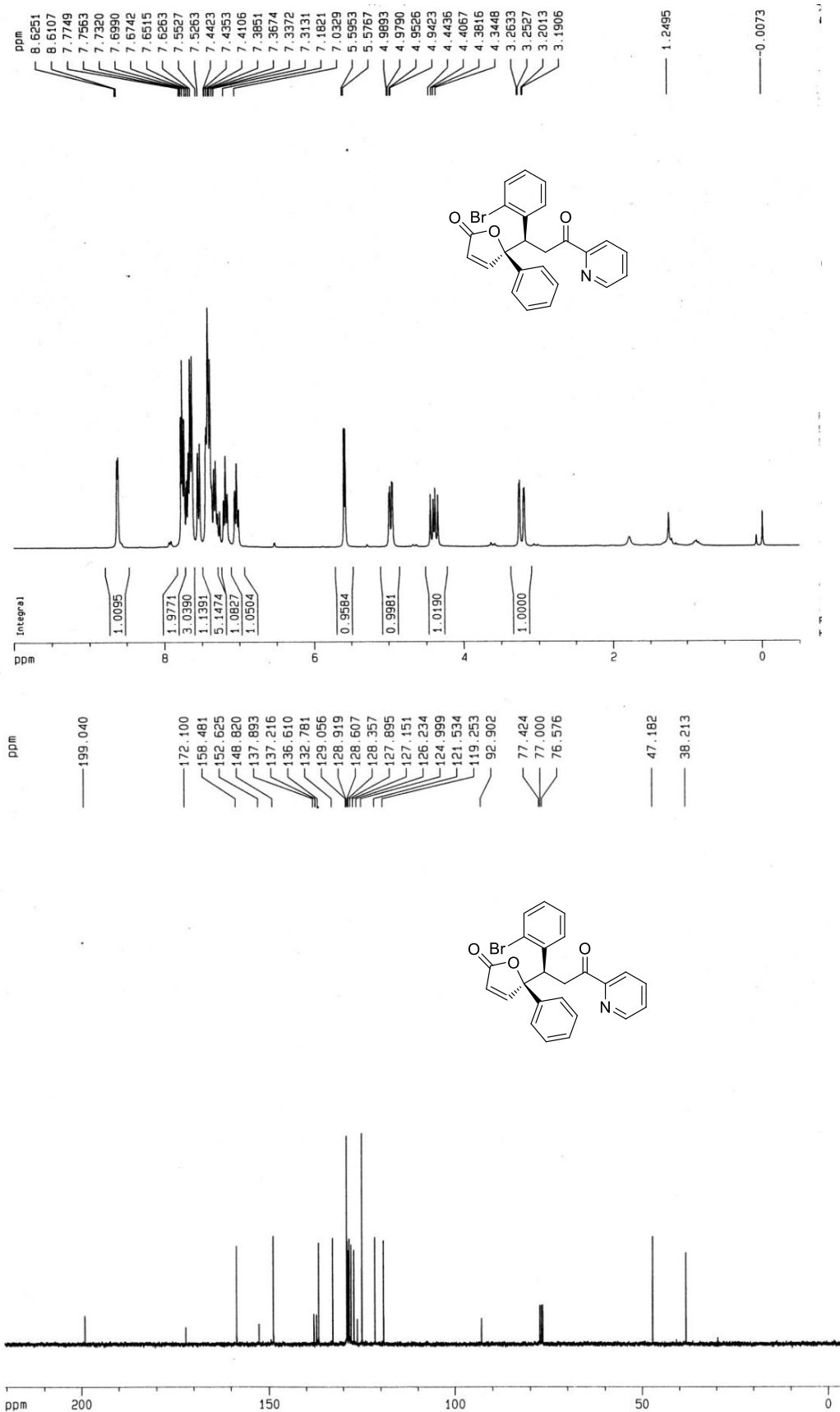


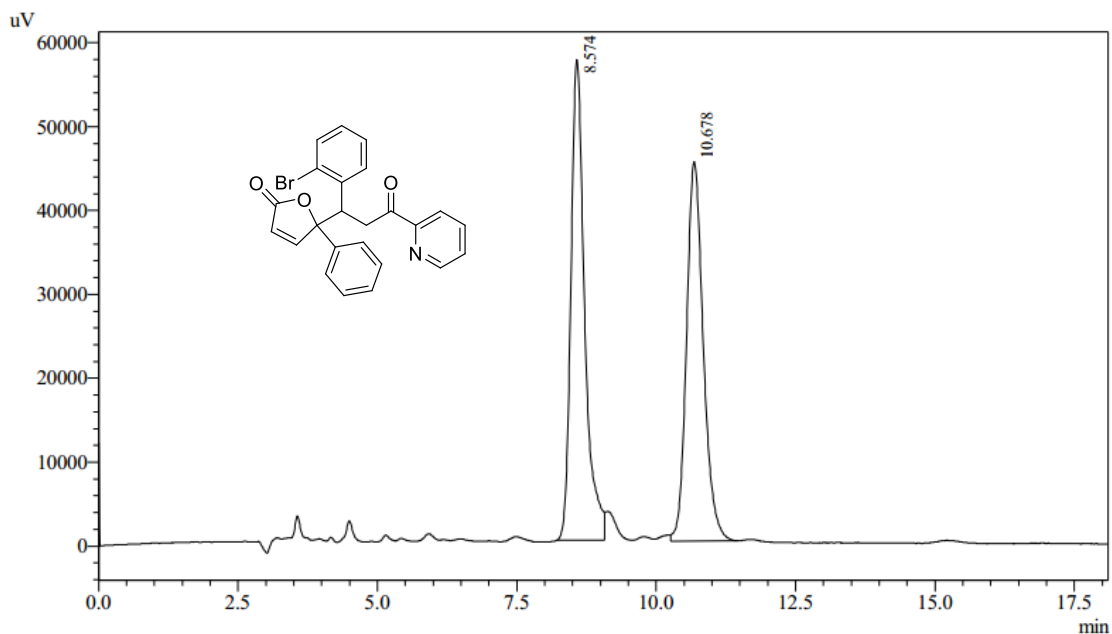
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.087	25242	989	0.415	0.612
2	17.611	6055641	160503	99.585	99.388
Total		6080882	161492	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3g

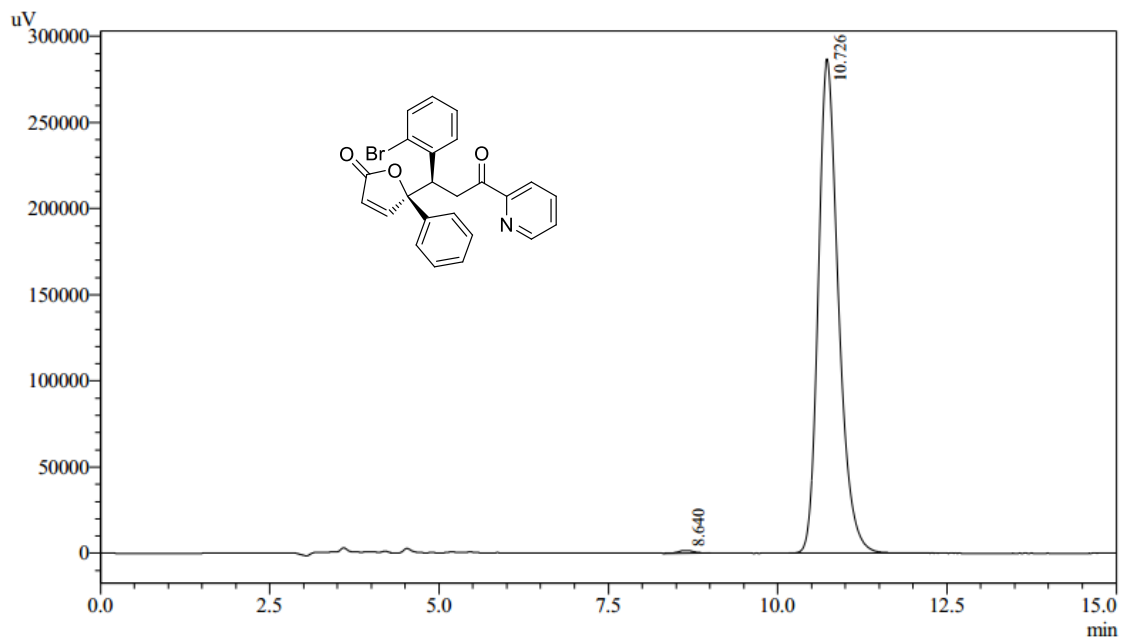




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.574	981012	57280	50.878	55.880
2	10.678	947154	45226	49.122	44.120
Total		1928166	102506	100.000	100.000

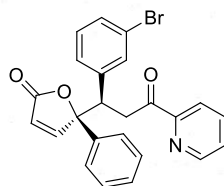
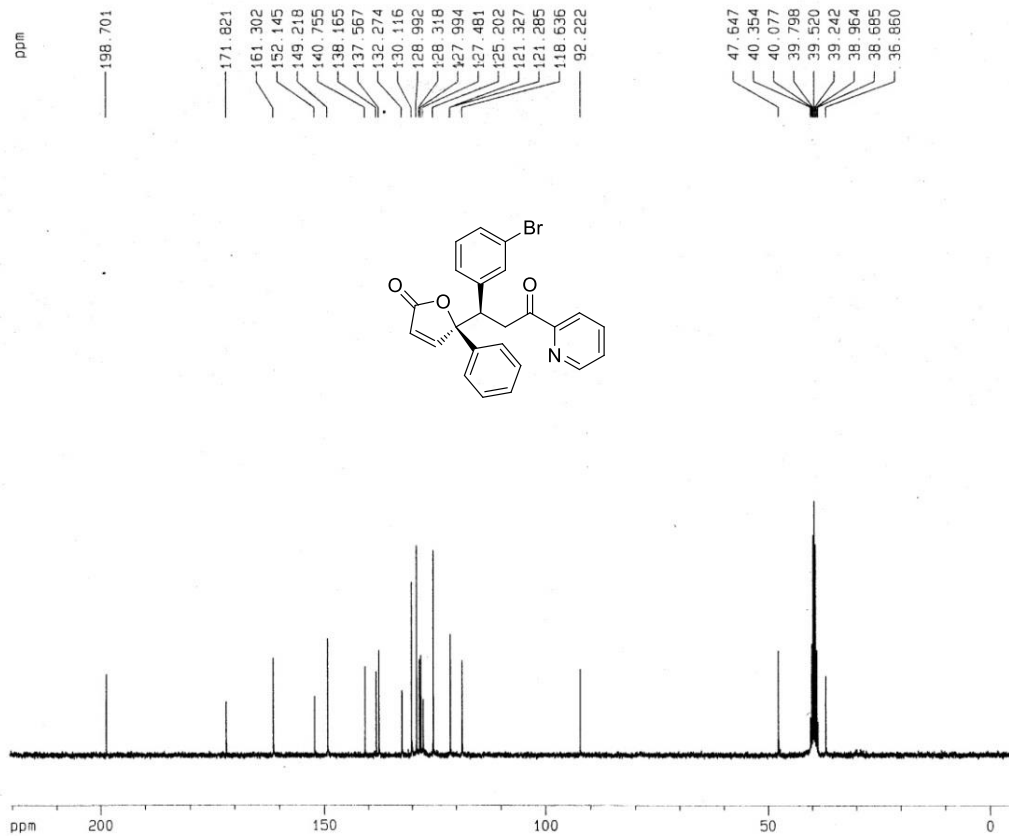
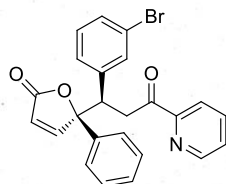
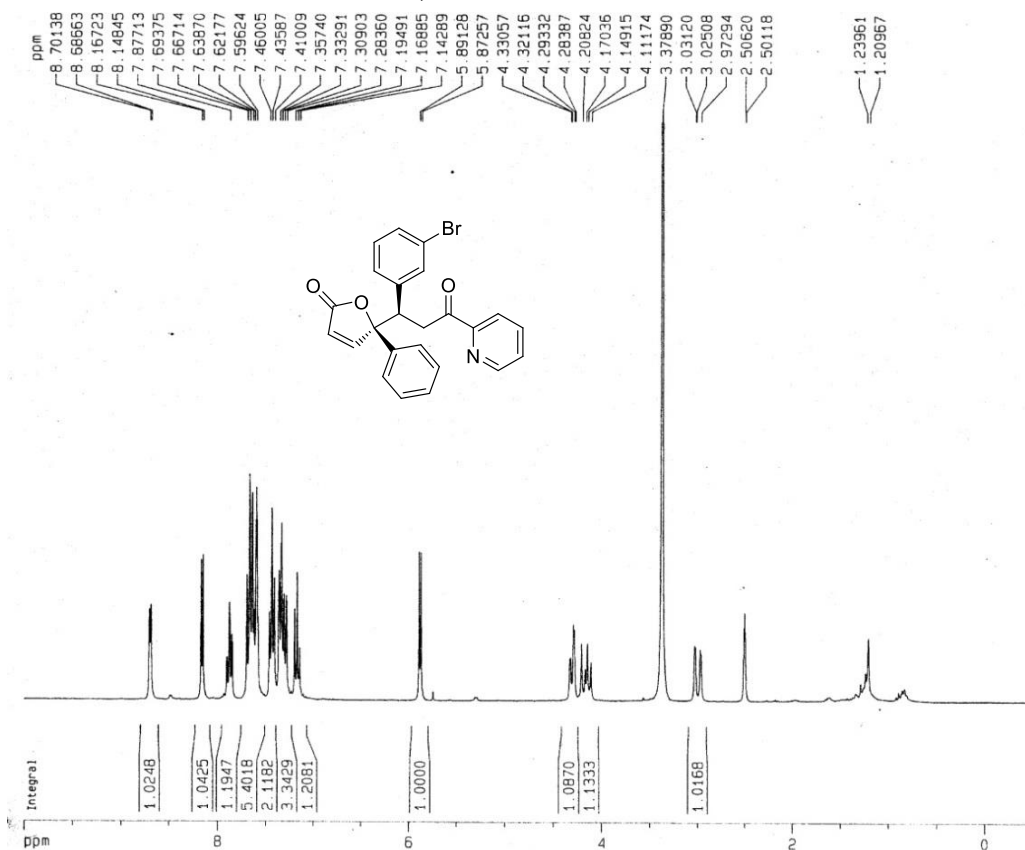


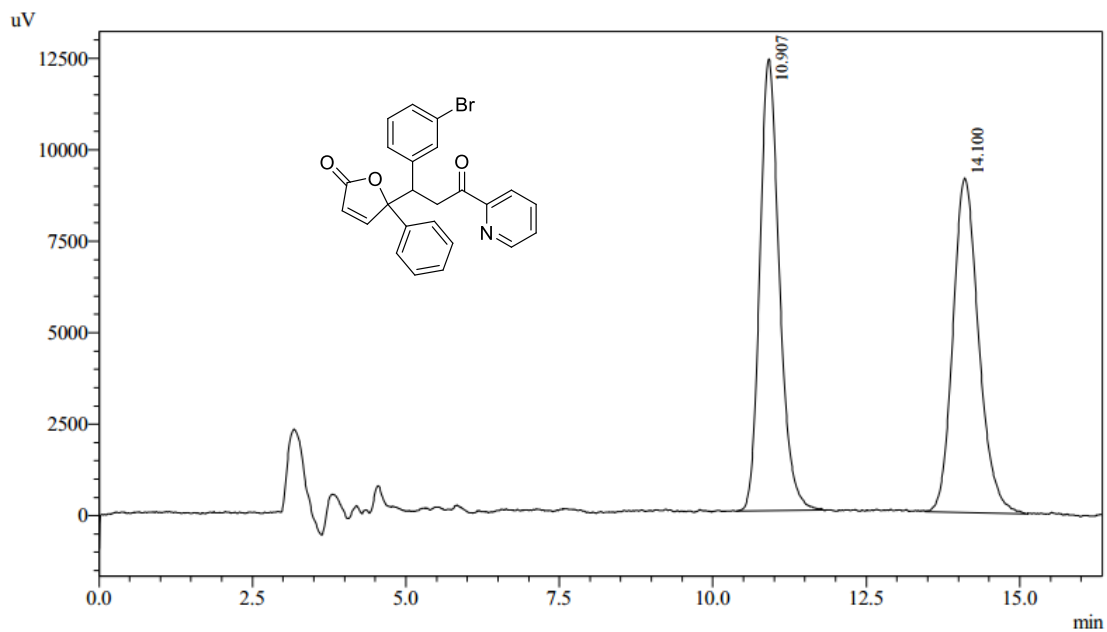
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.640	24601	1591	0.406	0.551
2	10.726	6032016	286885	99.594	99.449
Total		6056616	288475	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3h

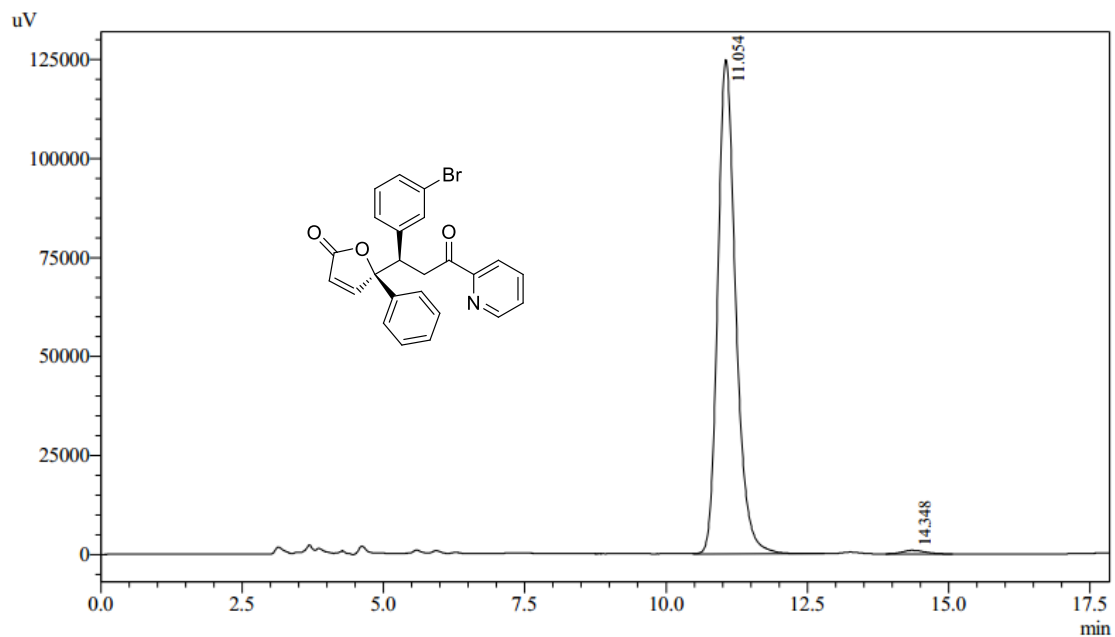




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.907	274190	12350	50.668	57.461
2	14.100	266963	9143	49.332	42.539
Total		541153	21493	100.000	100.000

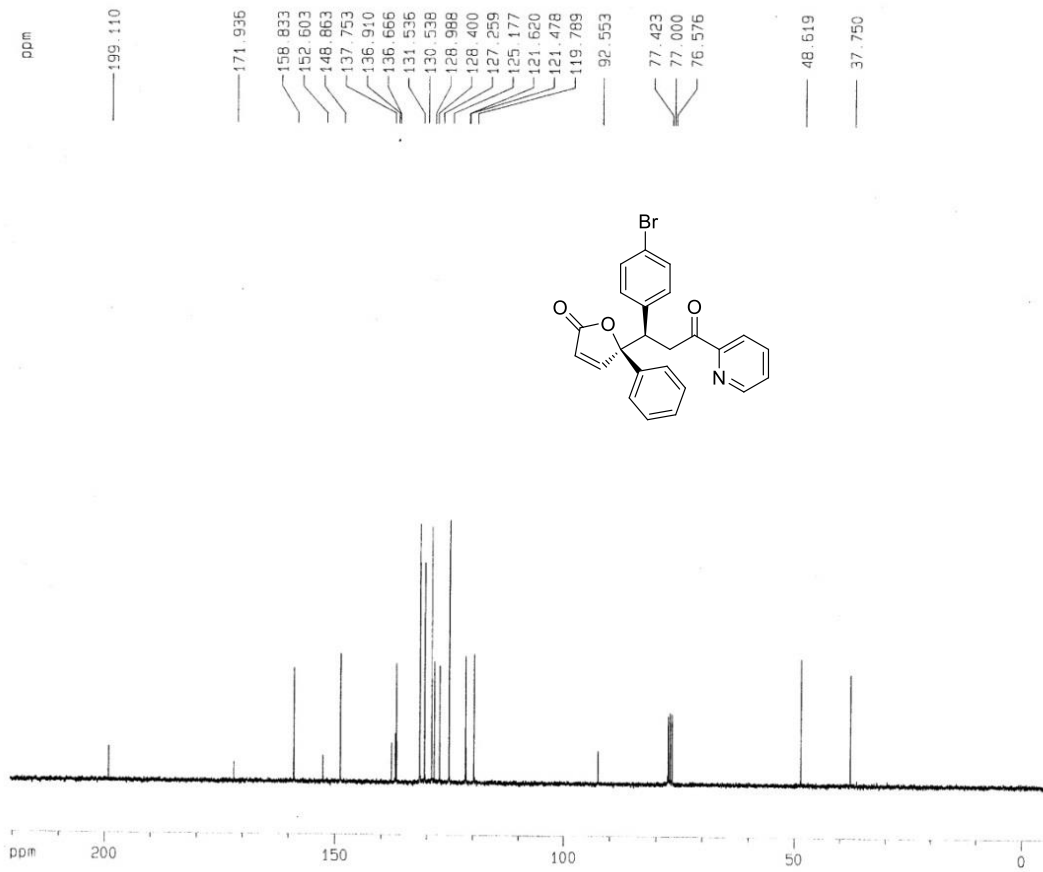
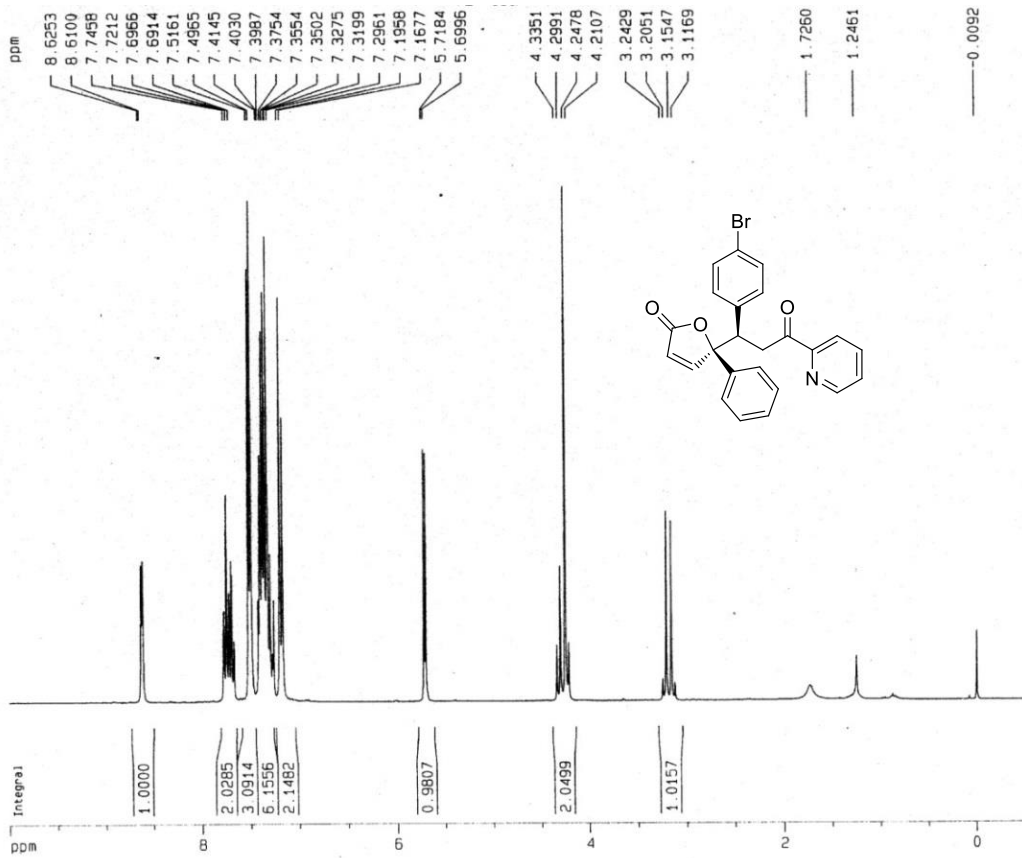


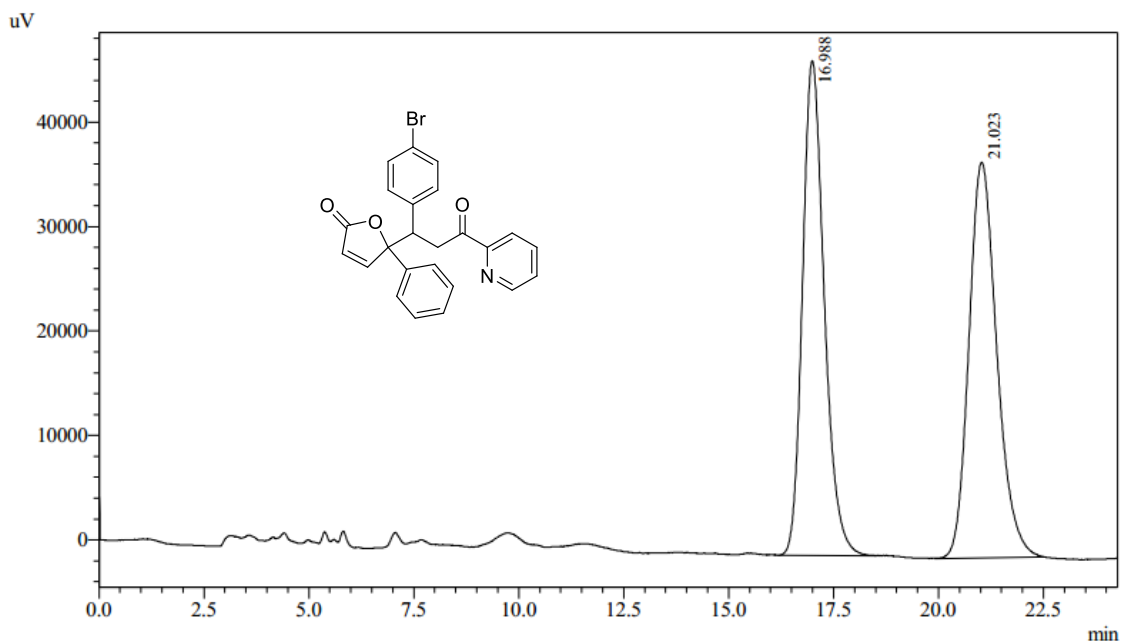
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.054	2763661	124858	99.022	99.238
2	14.348	27285	959	0.978	0.762
Total		2790946	125817	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3i

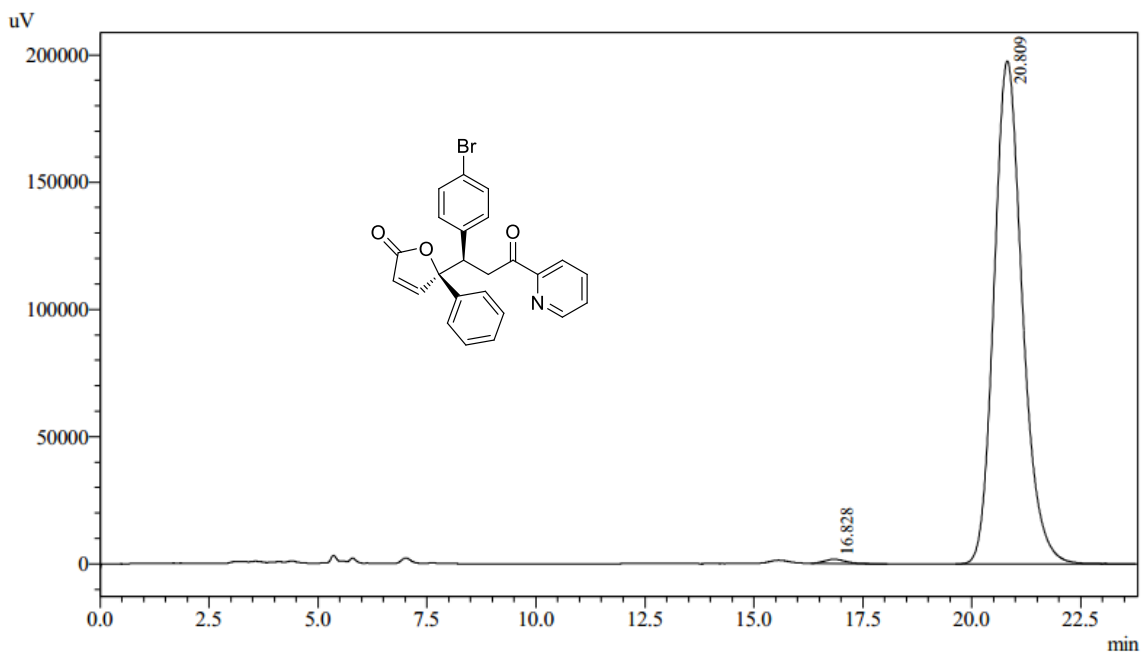




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.988	1708821	47383	49.384	55.583
2	21.023	1751458	37865	50.616	44.417
Total		3460279	85248	100.000	100.000

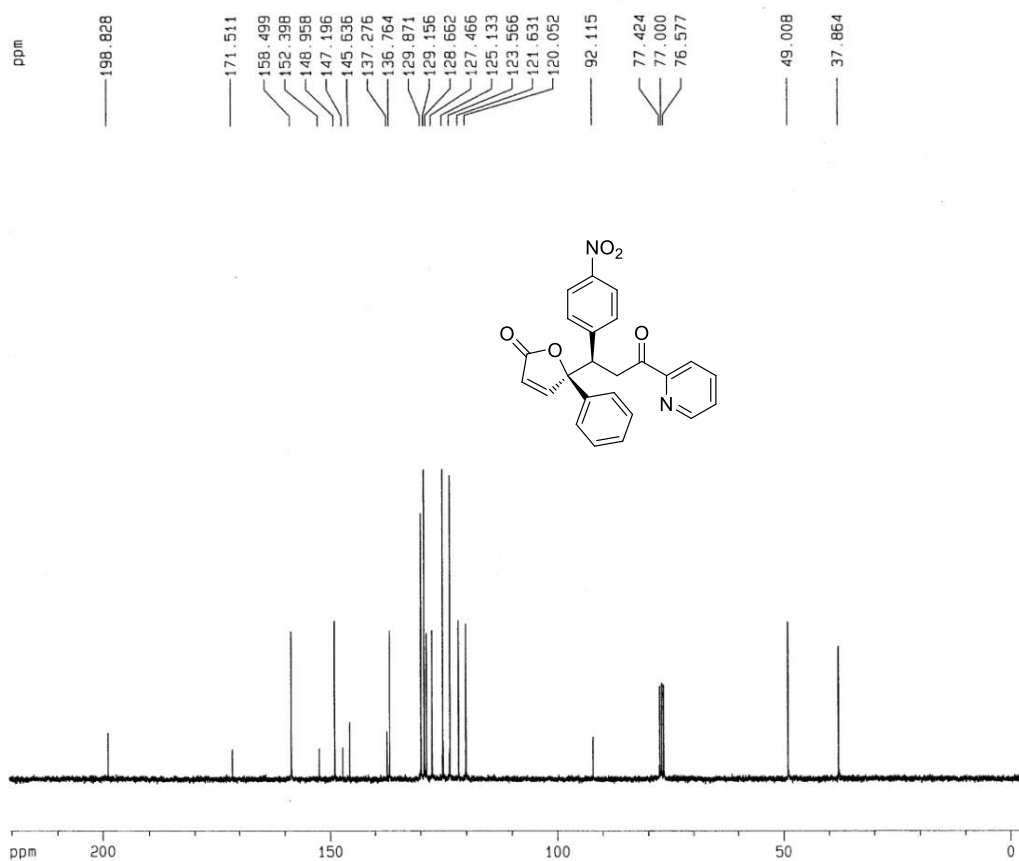
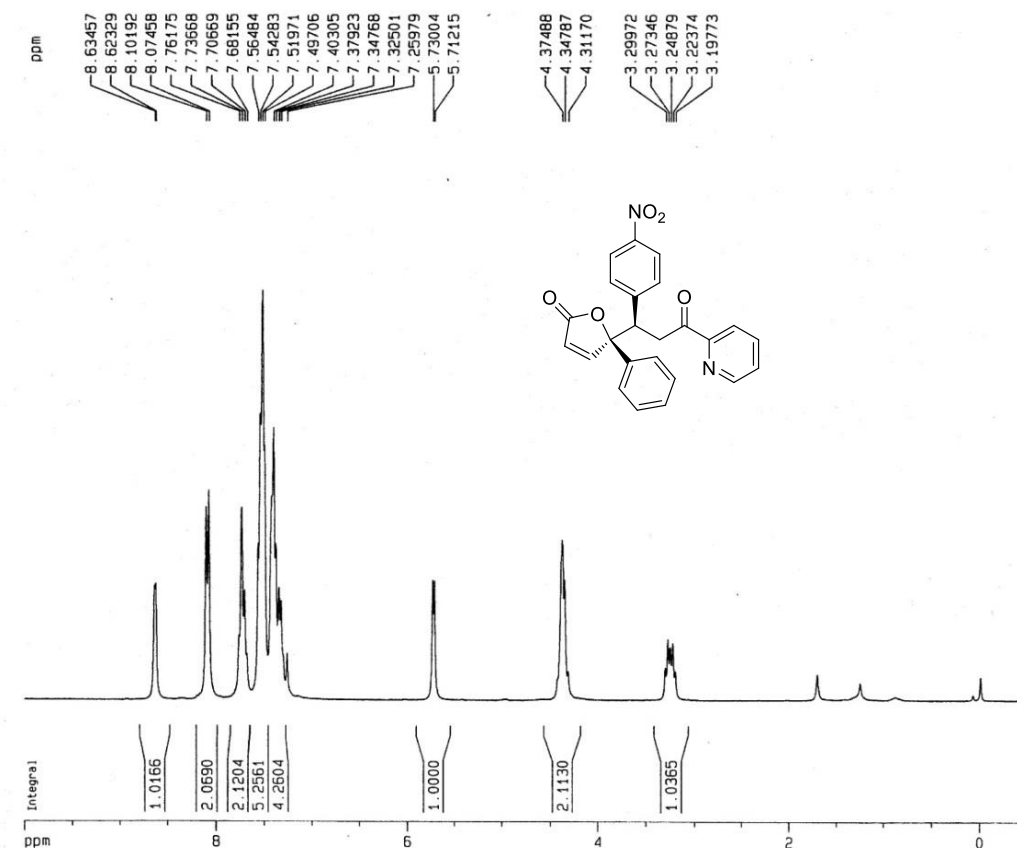


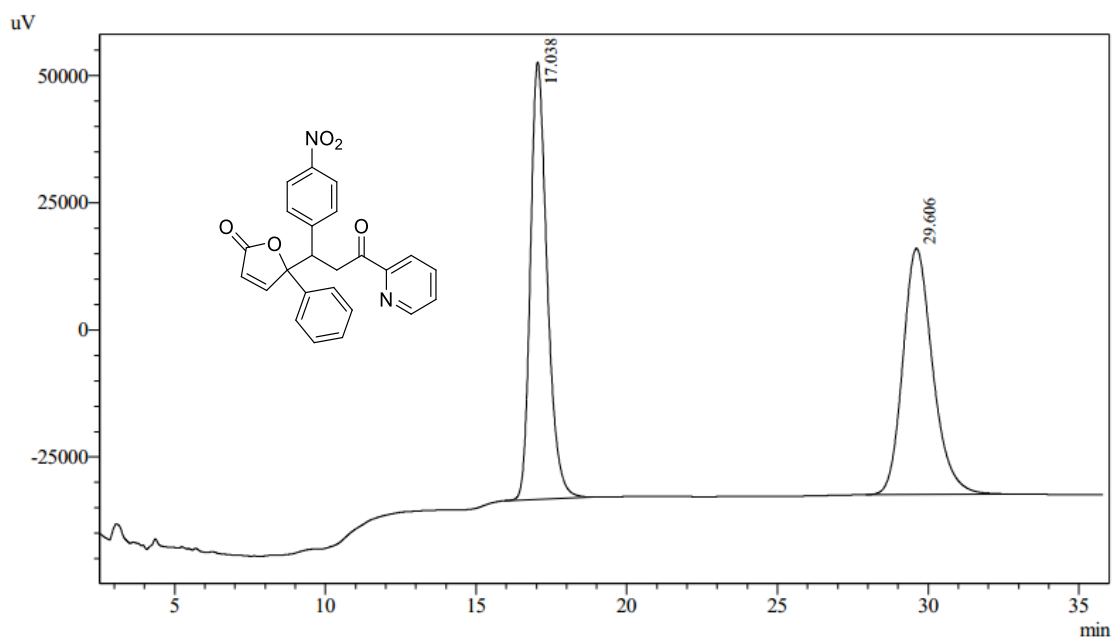
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.828	55155	1661	0.612	0.833
2	20.809	8951636	197726	99.388	99.167
Total		9006790	199388	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3j

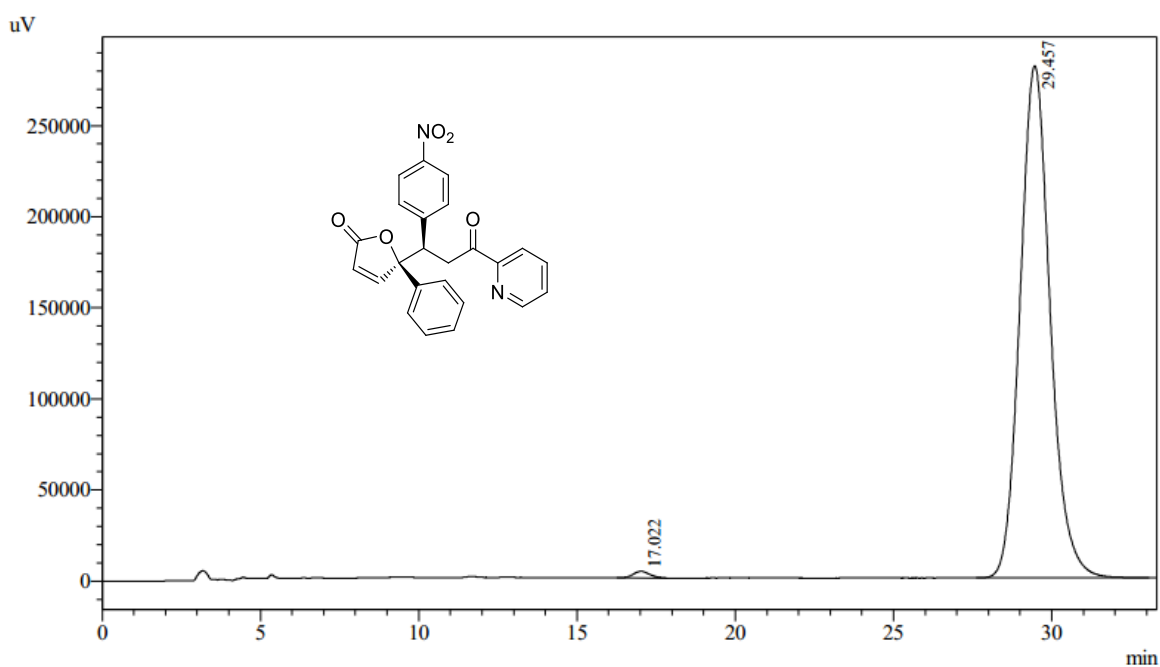




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.038	3324965	86037	49.940	63.994
2	29.606	3333018	48408	50.060	36.006
Total		6657983	134445	100.000	100.000

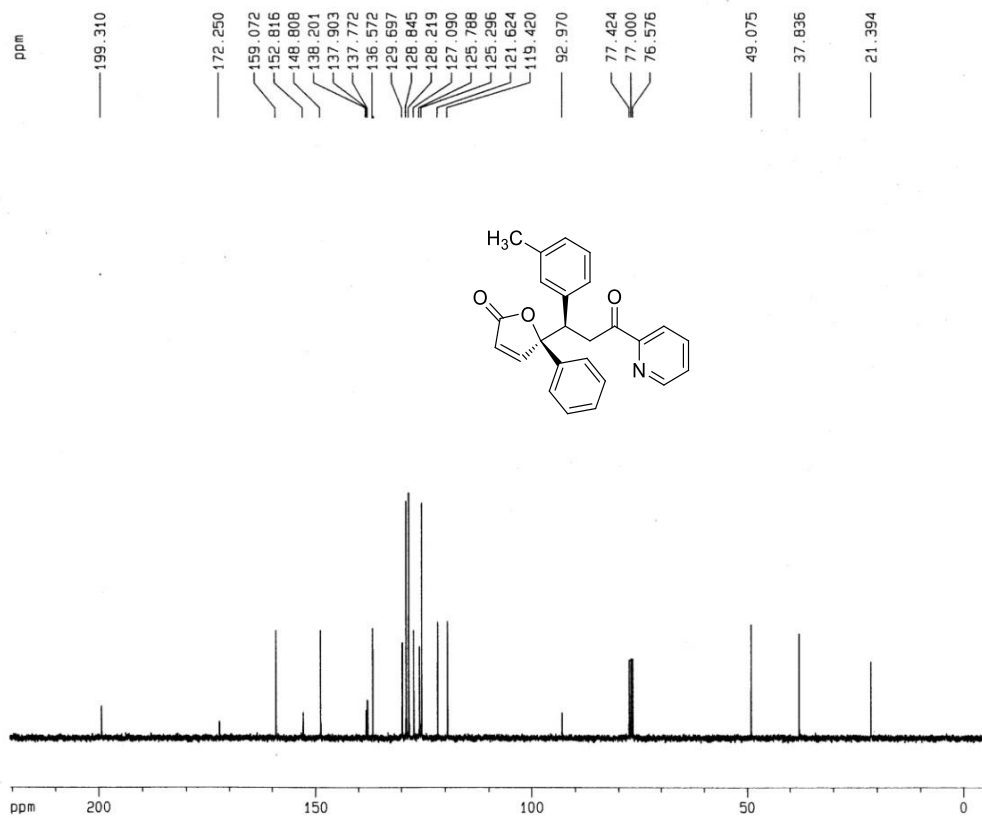
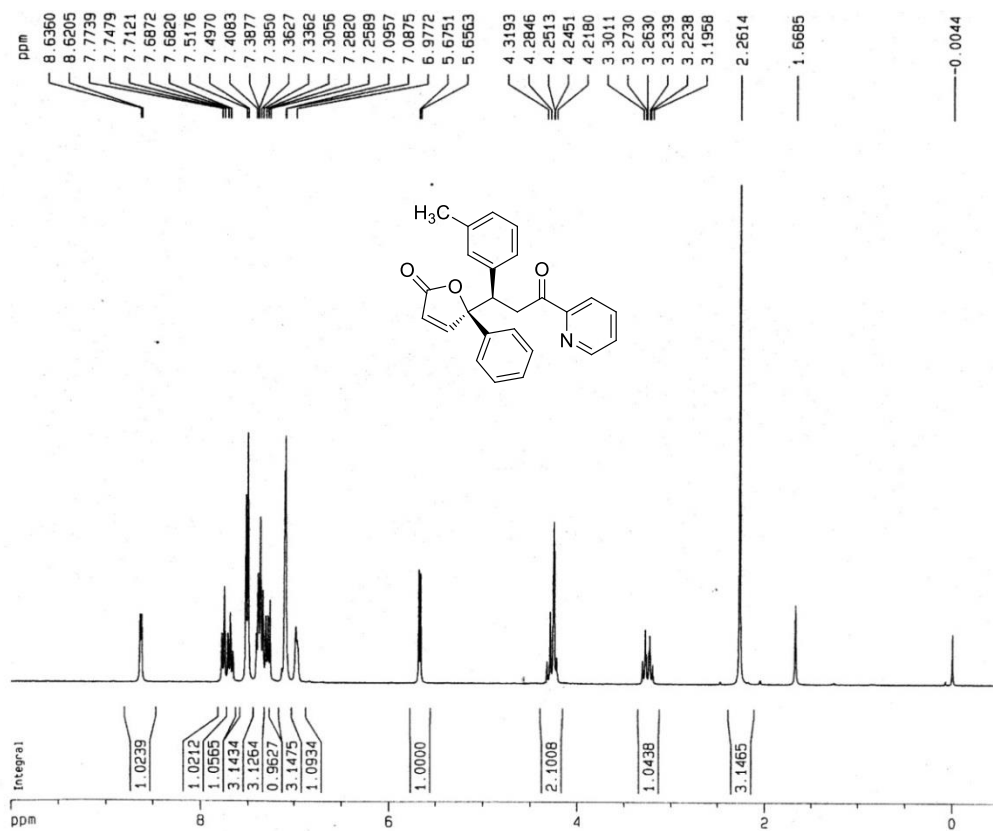


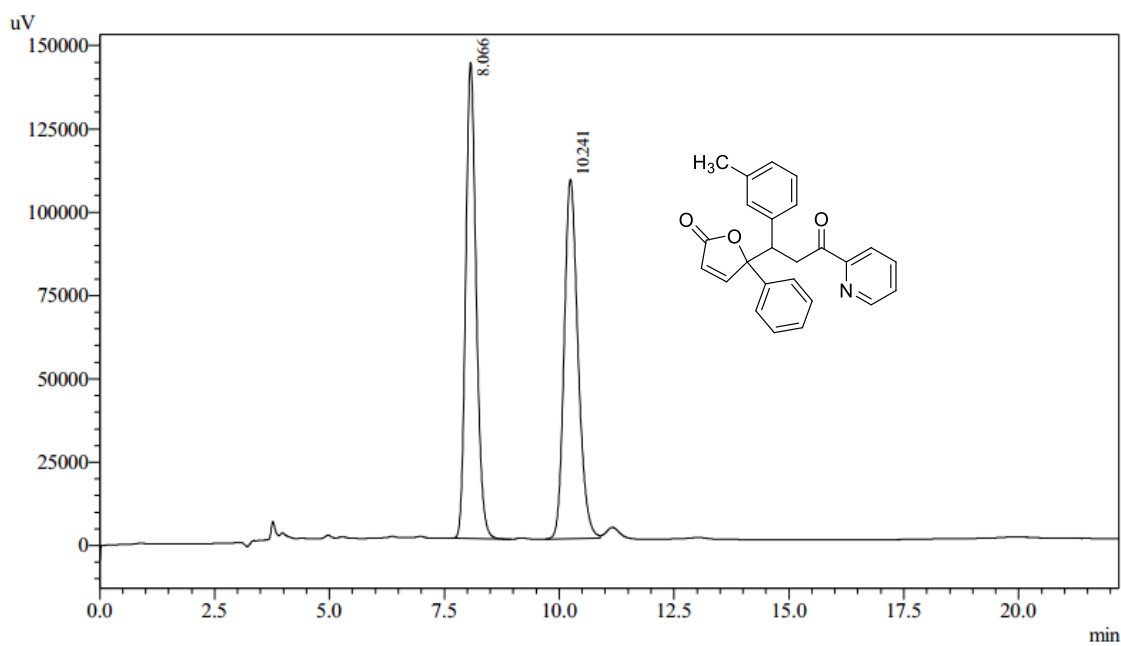
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.022	136444	3677	0.729	1.291
2	29.457	18578062	281043	99.271	98.709
Total		18714506	284719	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3k

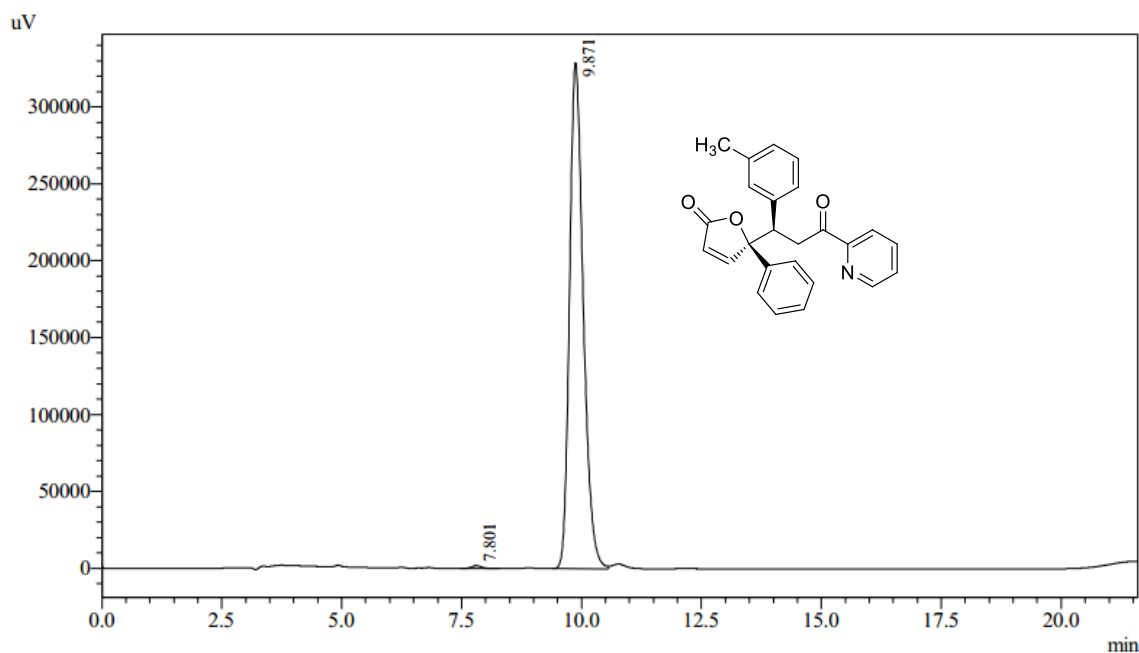




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.066	2256902	142853	49.893	56.974
2	10.241	2266552	107883	50.107	43.026
Total		4523453	250736	100.000	100.000

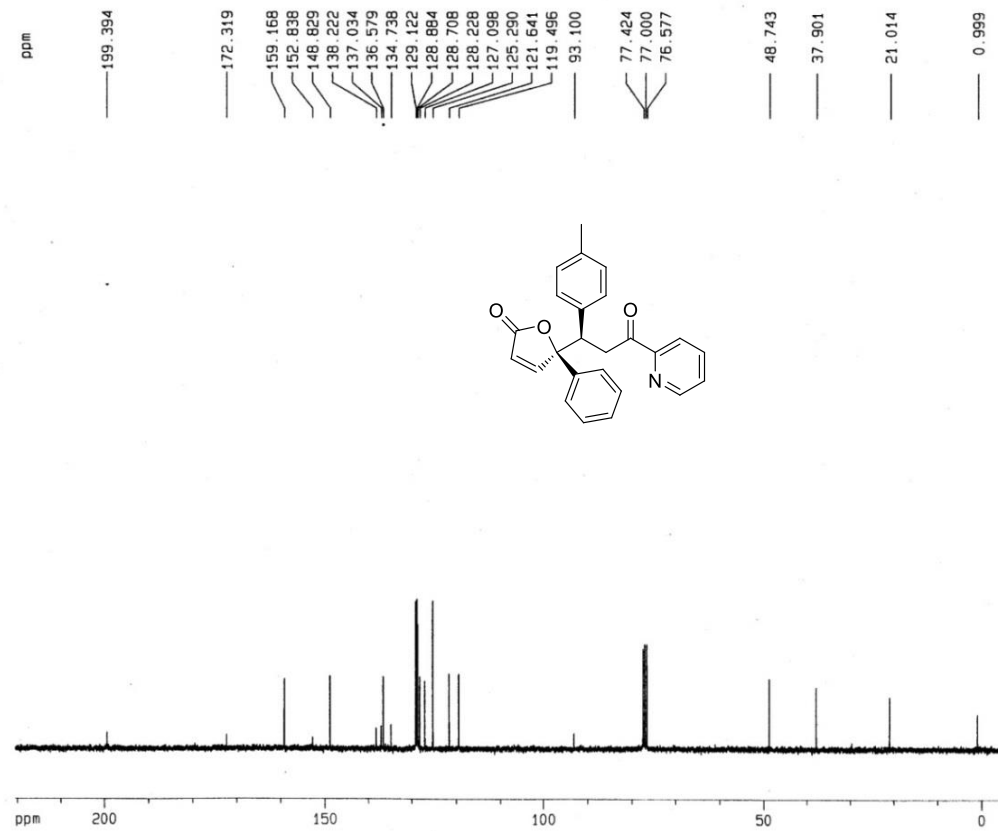
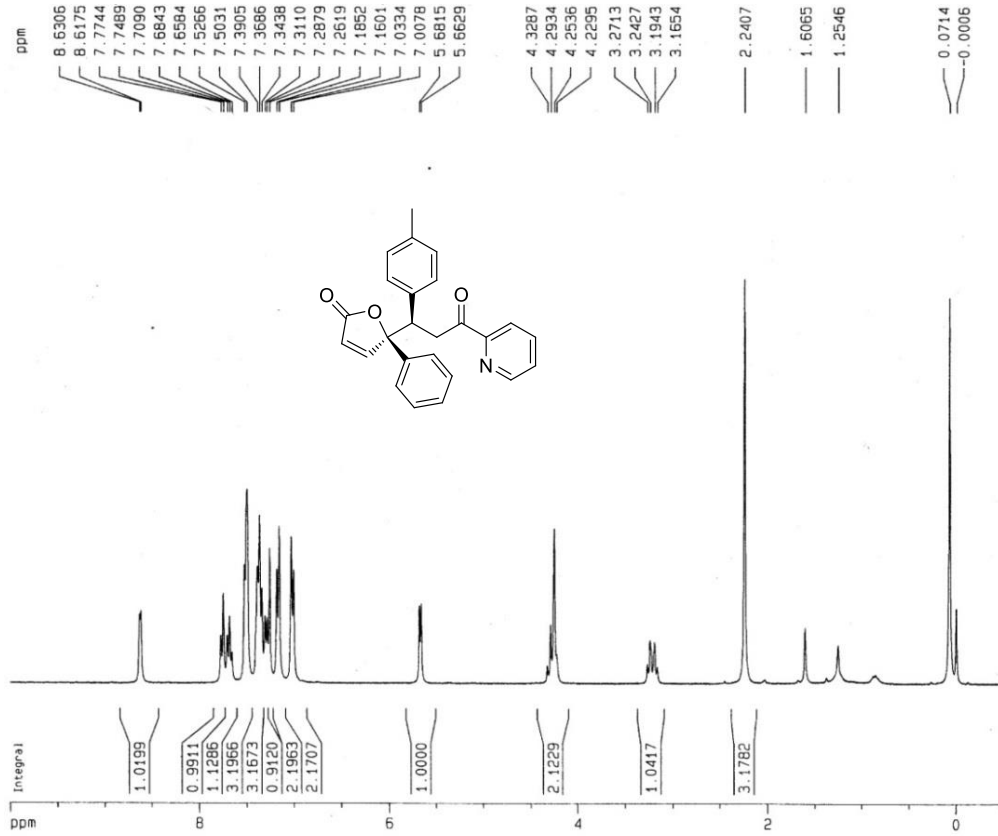


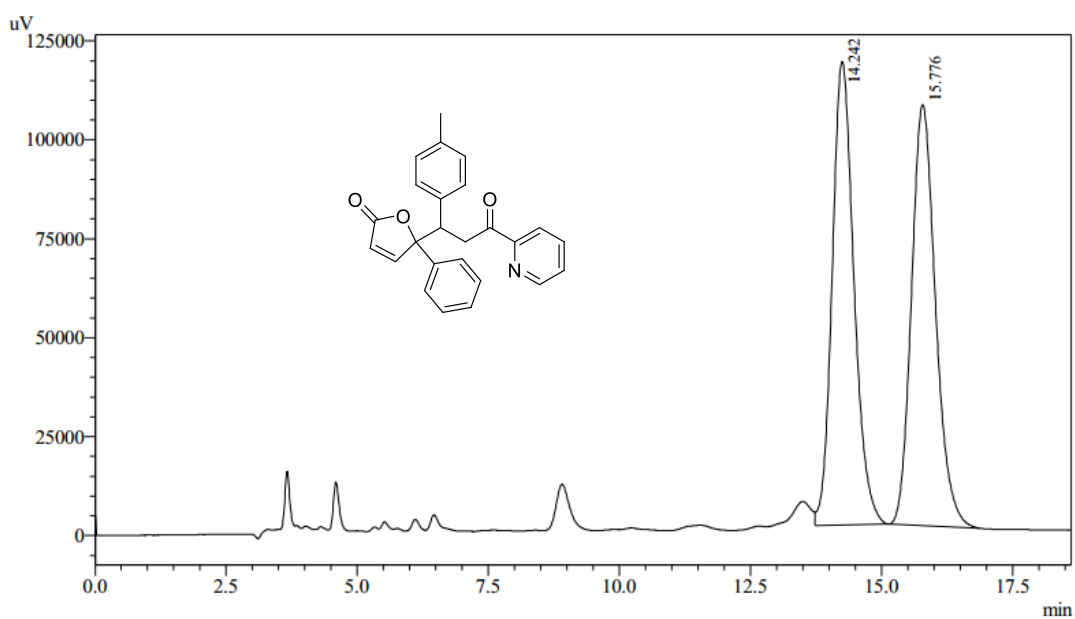
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.801	29298	1882	0.445	0.569
2	9.871	6551908	328941	99.555	99.431
Total		6581206	330822	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3l

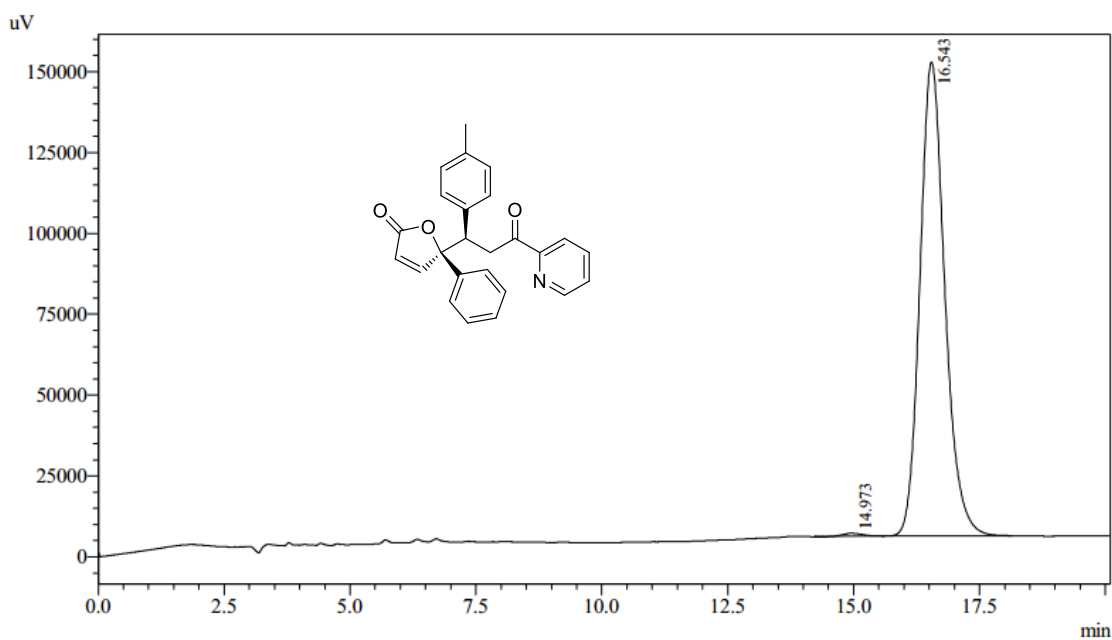




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.242	3375174	117076	49.894	52.384
2	15.776	3389491	106420	50.106	47.616
Total		6764665	223497	100.000	100.000

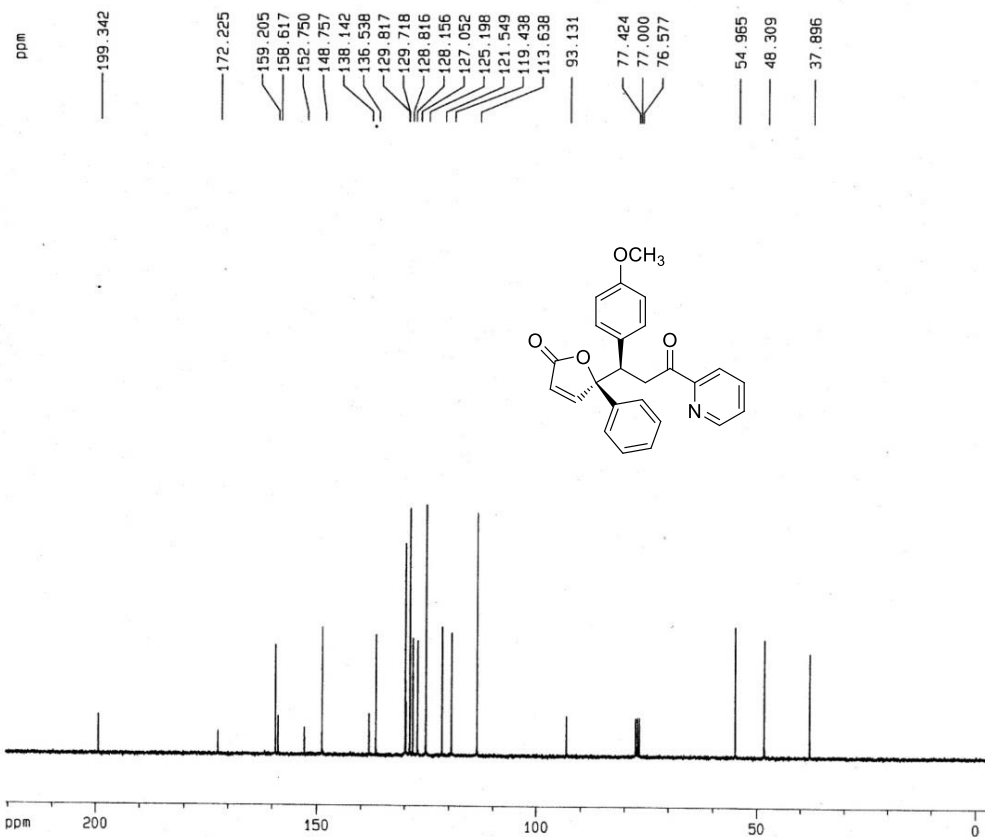
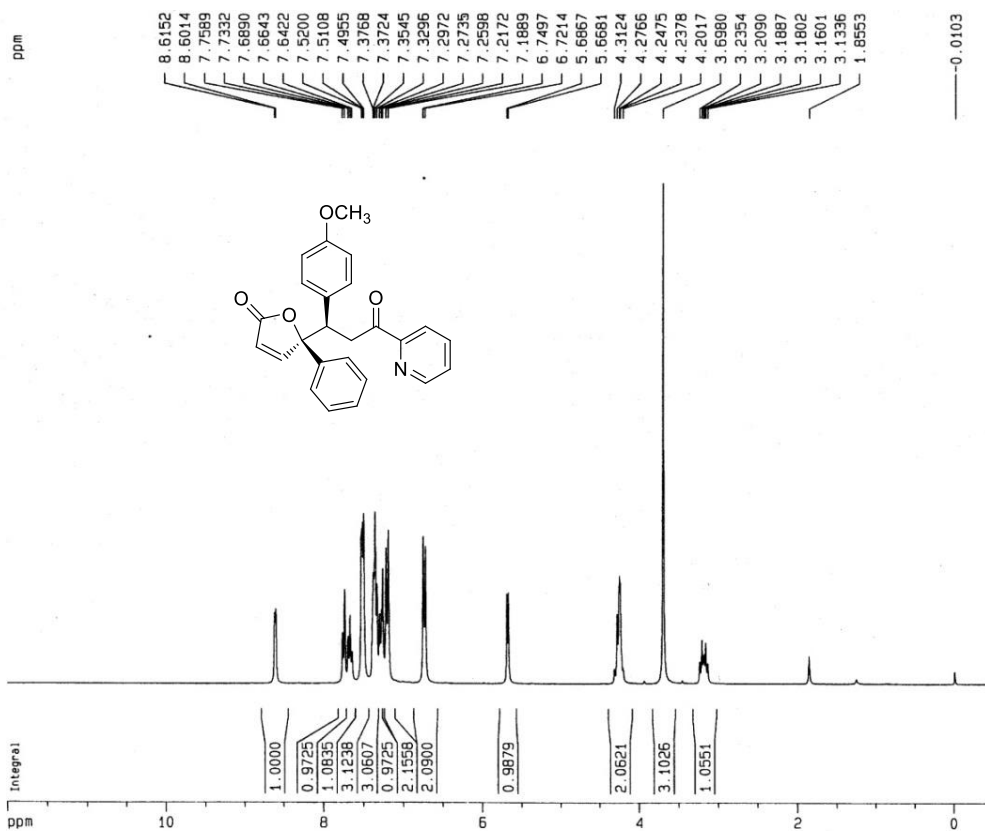


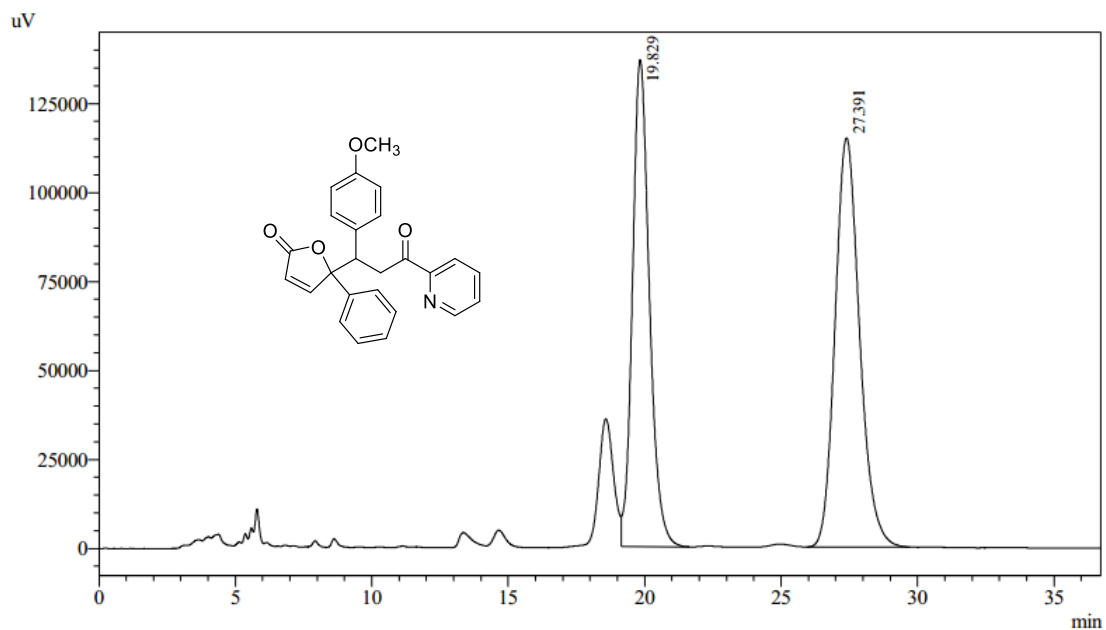
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.973	26380	957	0.521	0.649
2	16.543	5038189	146505	99.479	99.351
Total		5064569	147462	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3m

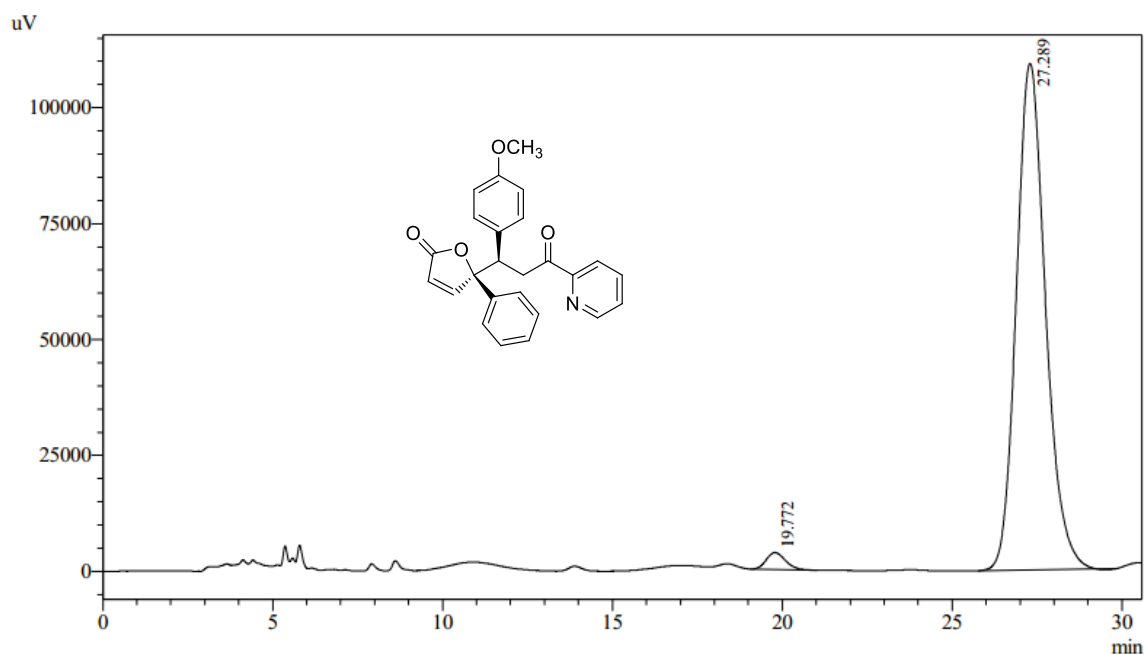




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	19.829	5897851	136868	45.096	54.344
2	27.391	7180514	114988	54.904	45.656
Total		13078365	251856	100.000	100.000

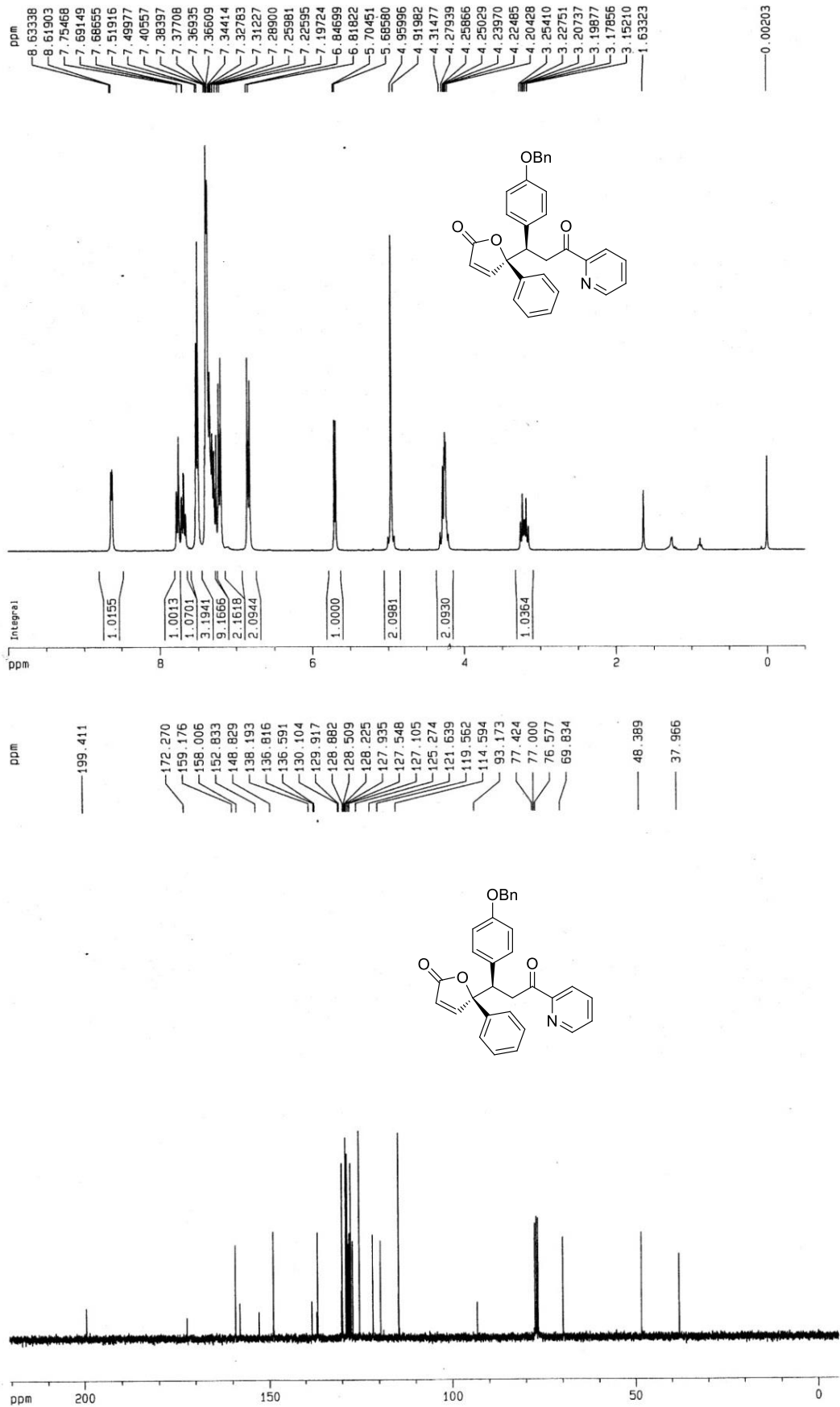


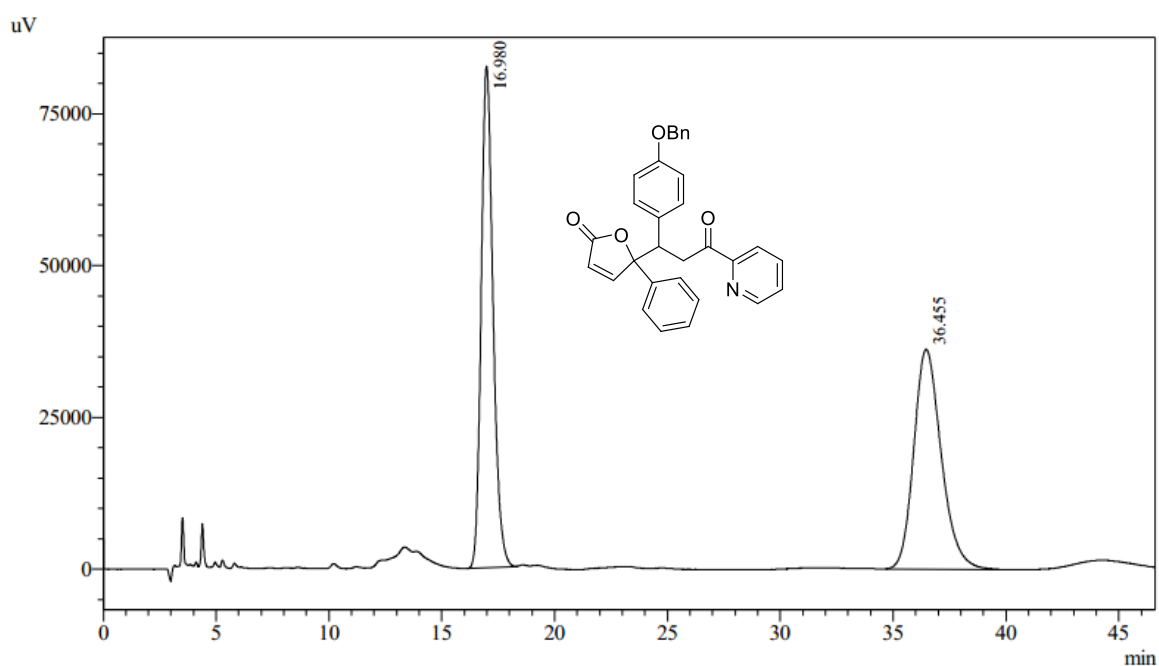
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	19.772	145247	3673	2.179	3.253
2	27.289	6520208	109256	97.821	96.747
Total		6665454	112929	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3n

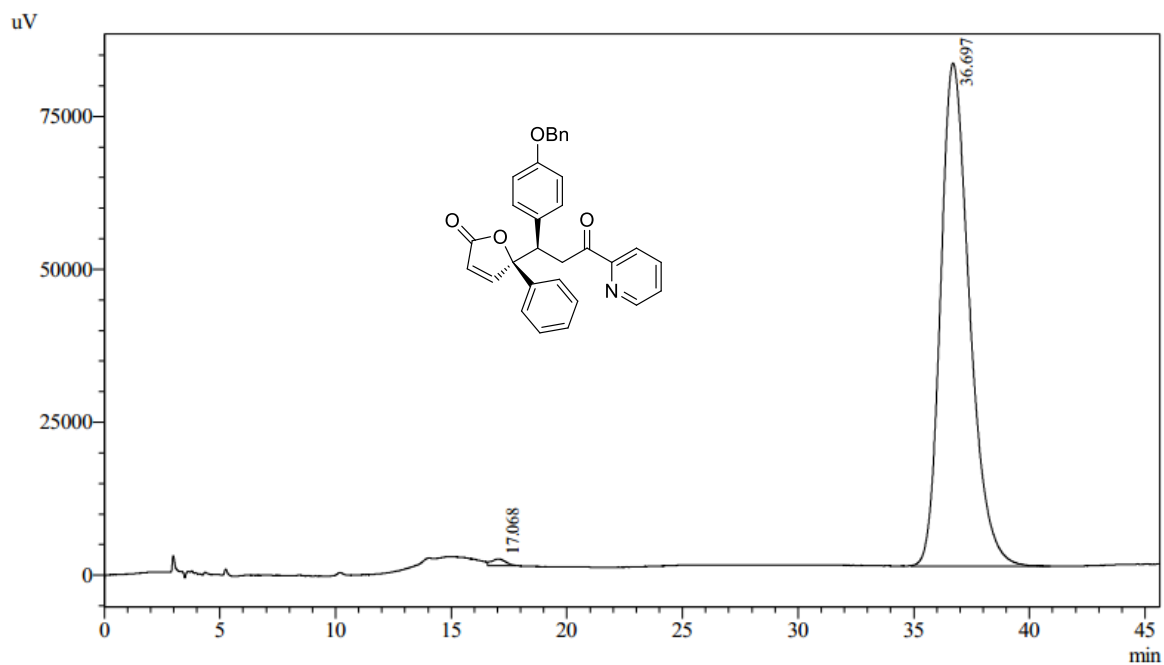




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.980	3011432	82560	49.555	69.506
2	36.455	3065538	36221	50.445	30.494
Total		6076970	118781	100.000	100.000

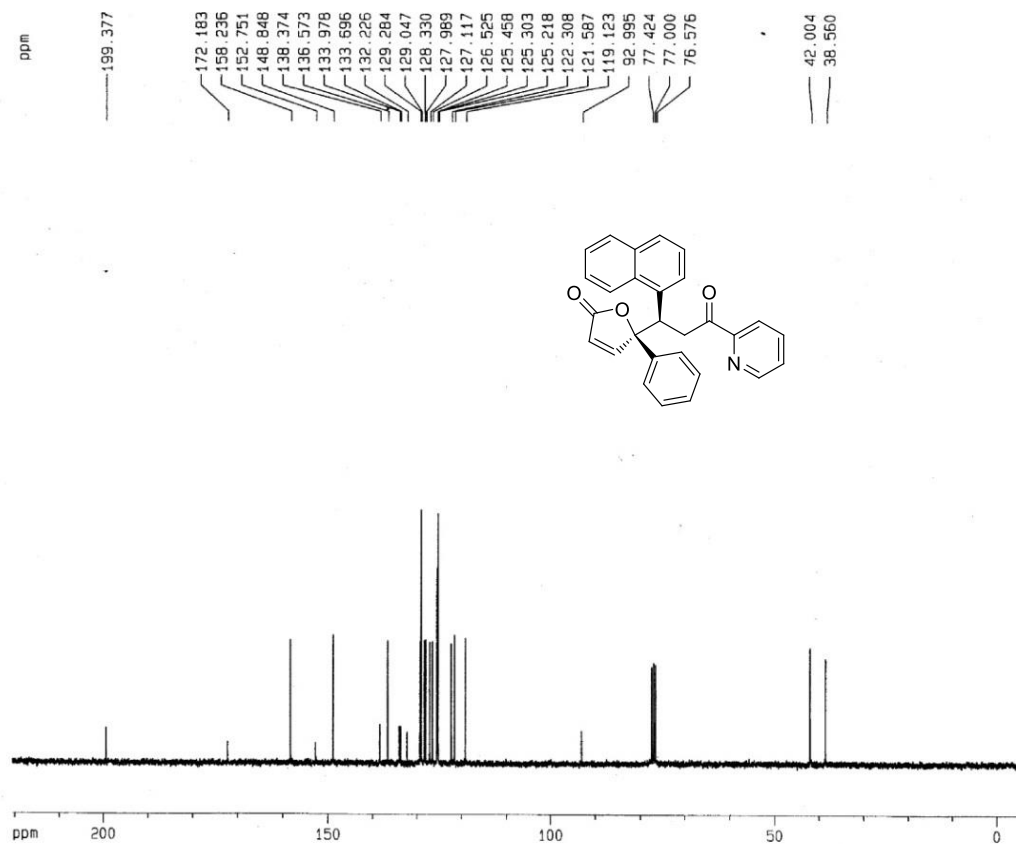
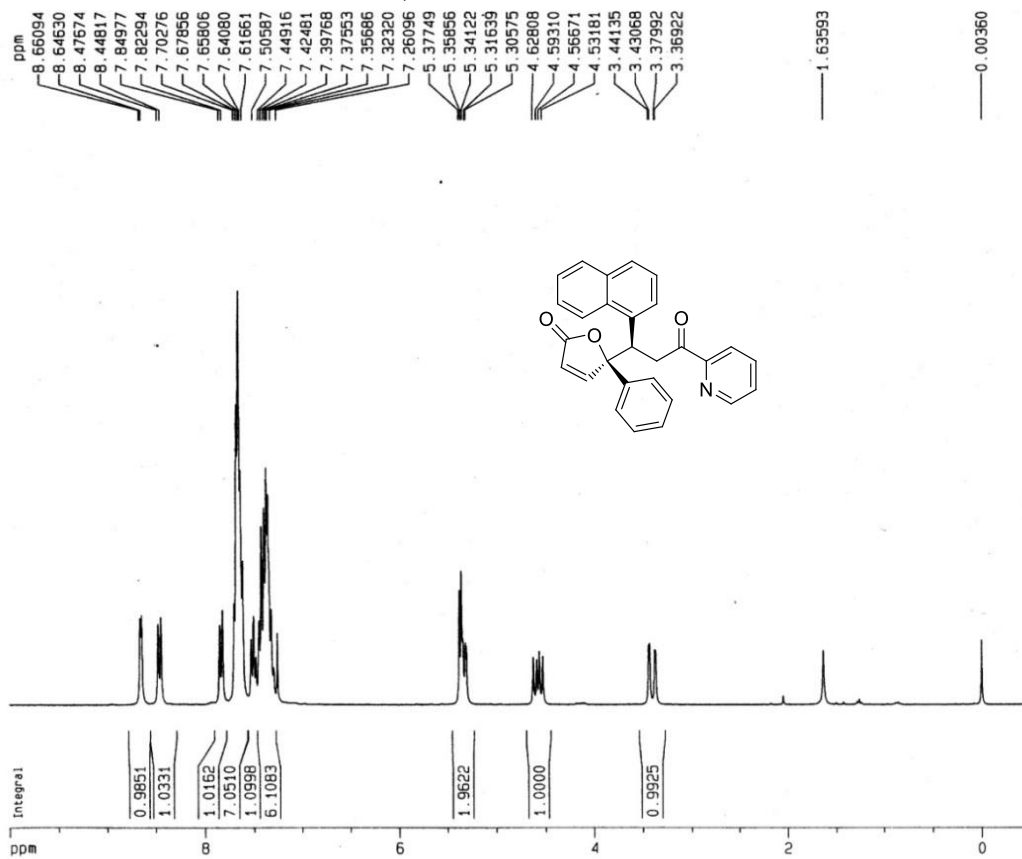


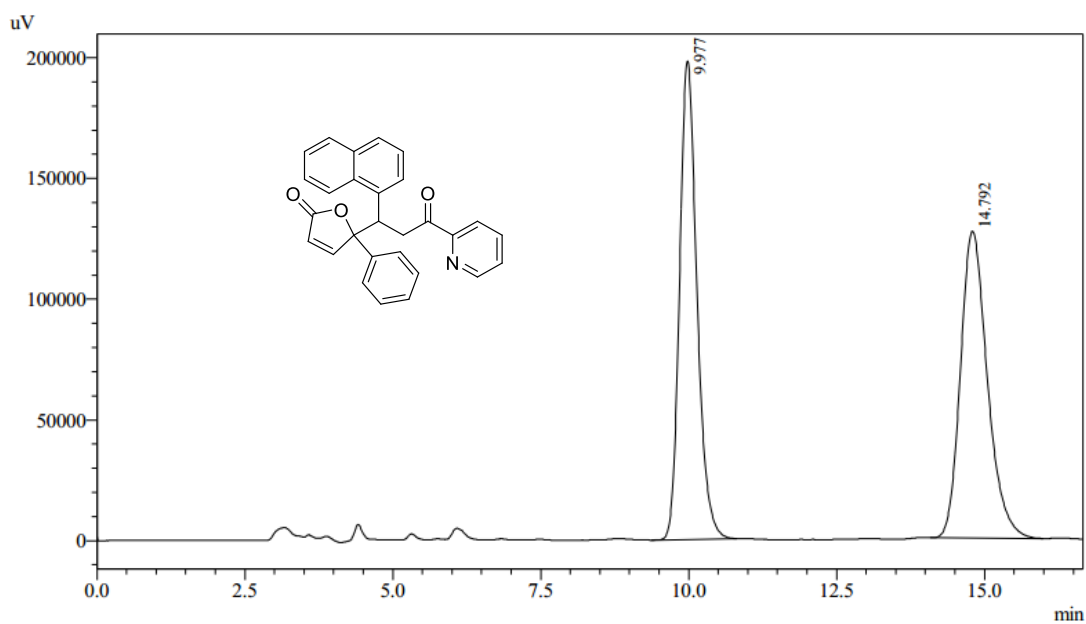
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.068	47328	1118	0.657	1.341
2	36.697	7159946	82283	99.343	98.659
Total		7207274	83402	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3o

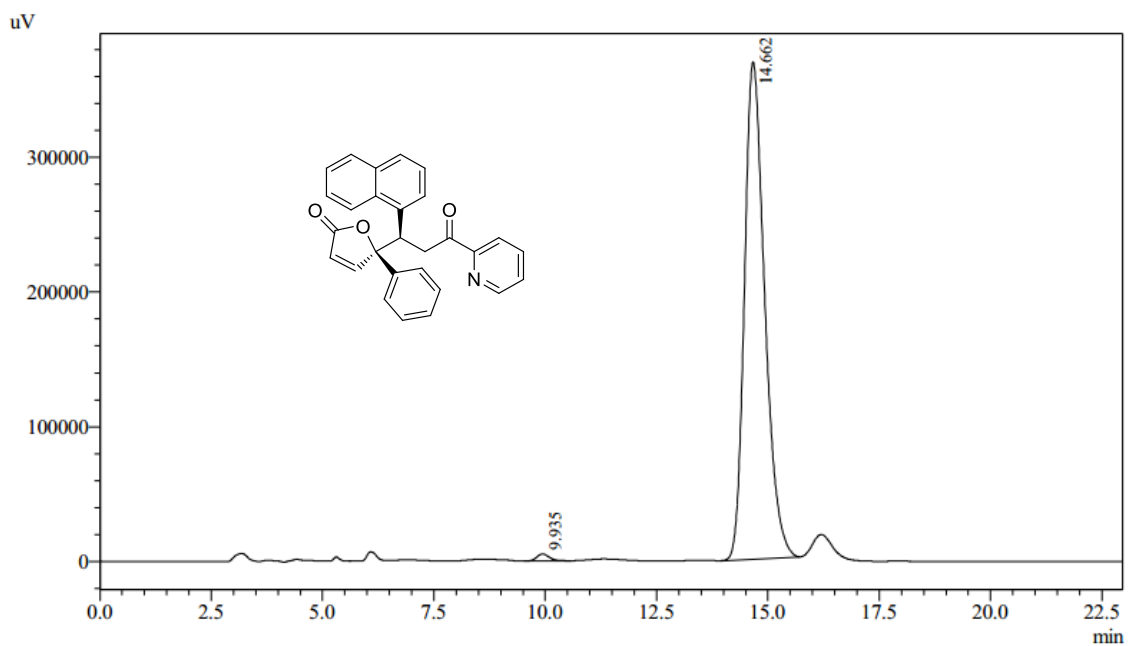




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.977	4036476	198168	50.083	60.915
2	14.792	4023056	127152	49.917	39.085
Total		8059532	325320	100.000	100.000

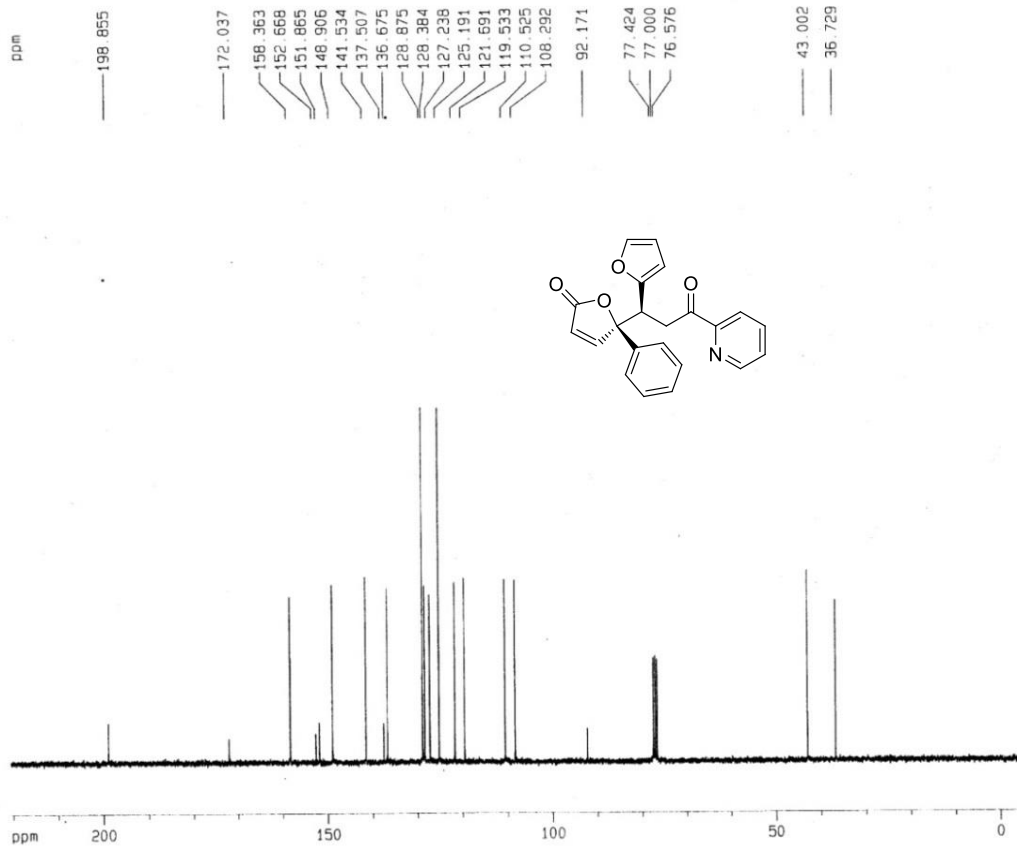
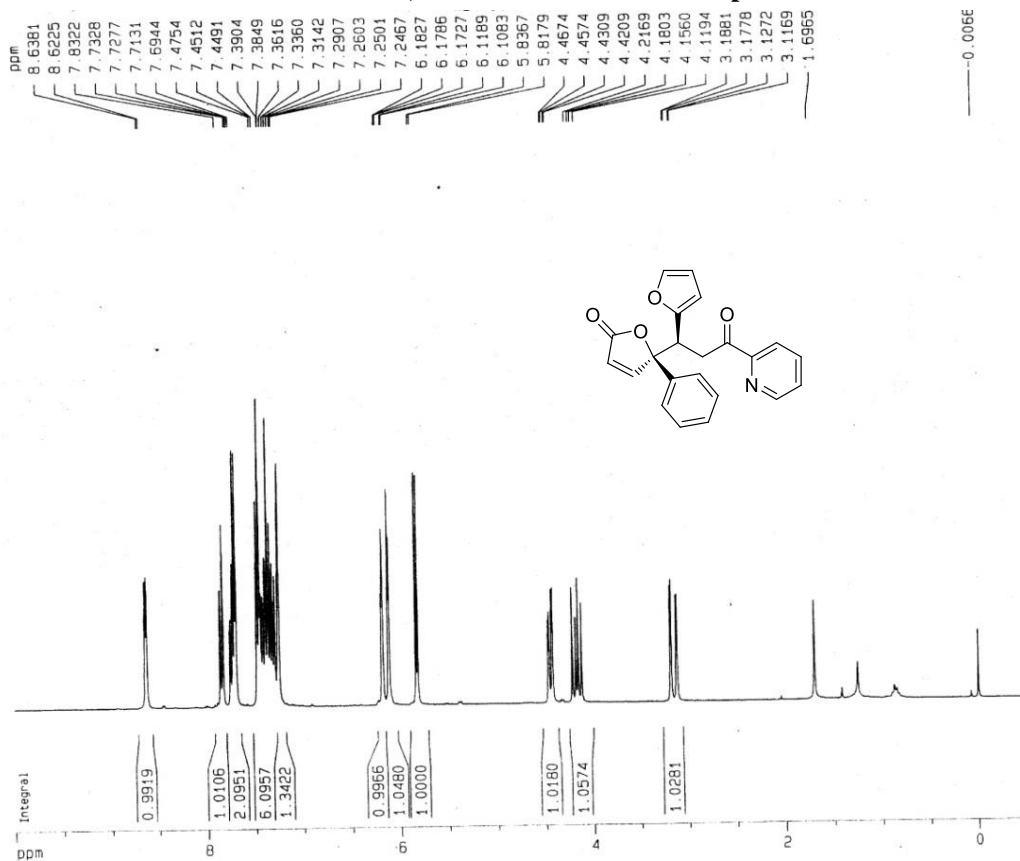


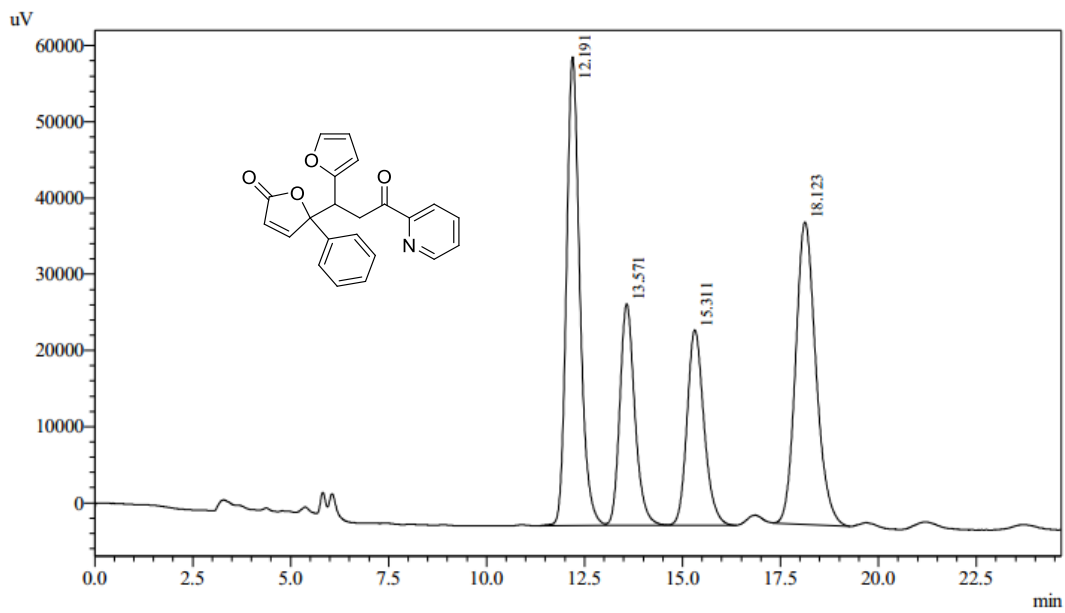
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.935	101587	5220	0.864	1.394
2	14.662	11650871	369252	99.136	98.606
Total		11752458	374472	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3p

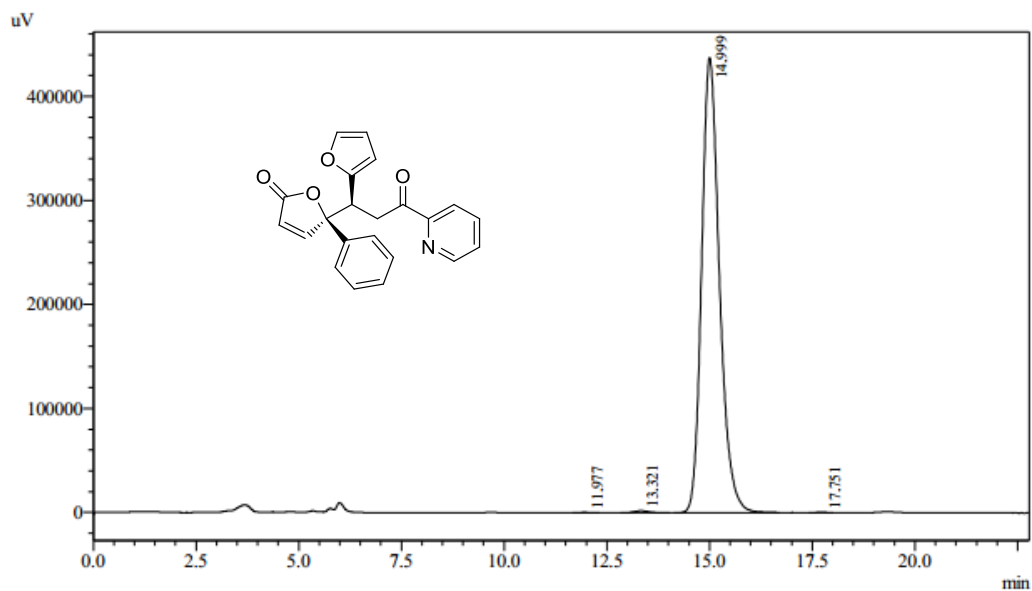




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.191	1462425	61517	32.923	39.447
2	13.571	776434	29113	17.480	18.668
3	15.311	775069	25657	17.449	16.452
4	18.123	1427998	39662	32.148	25.433
Total		4441926	155950	100.000	100.000

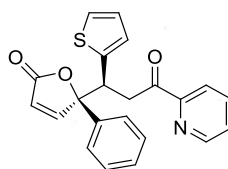
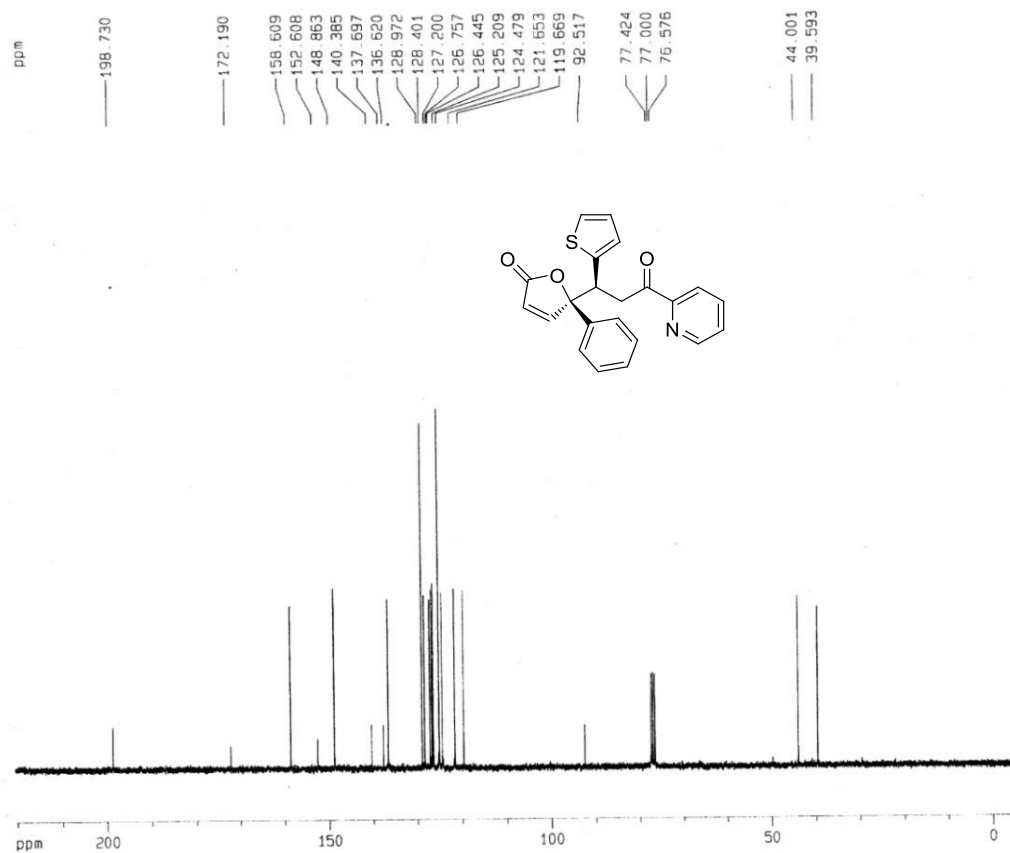
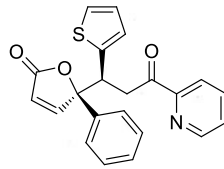
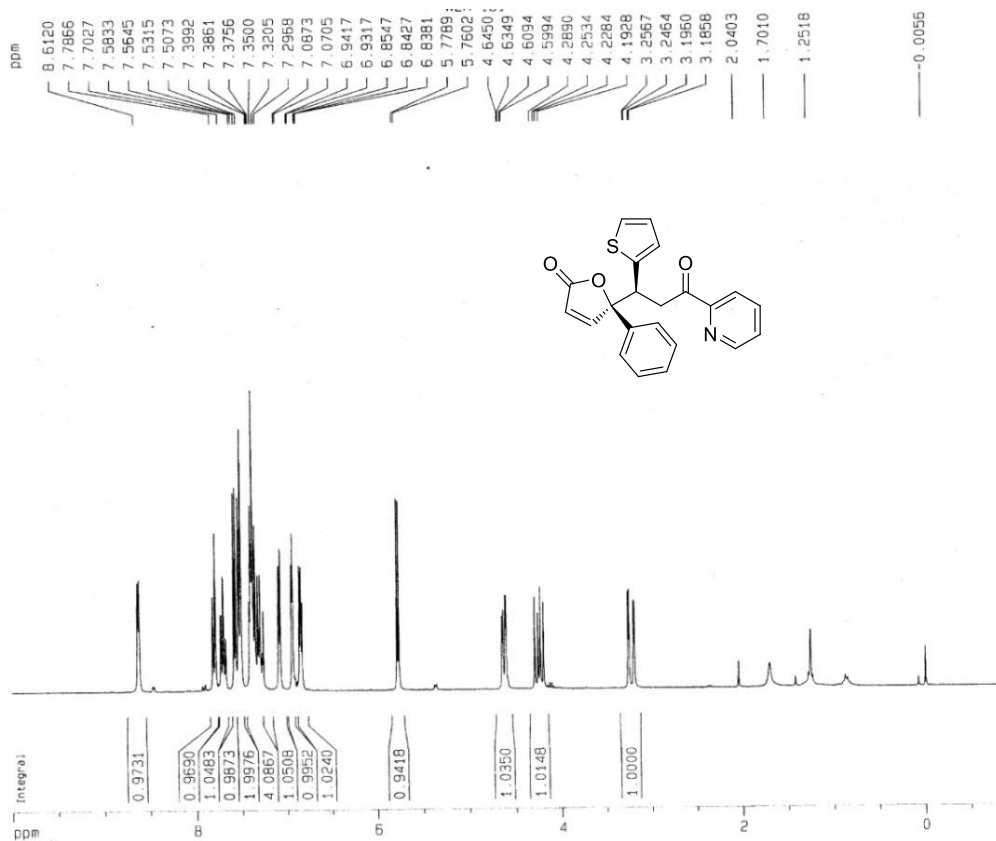


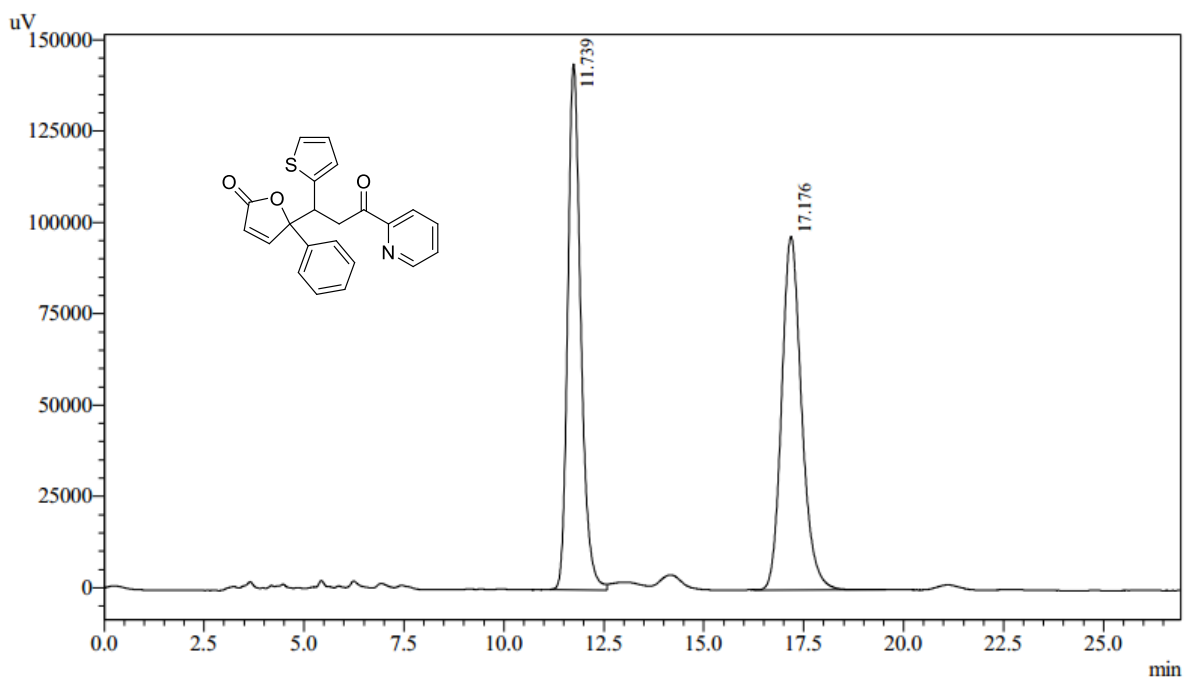
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.977	6783	381	0.051	0.087
2	13.321	51885	2062	0.391	0.469
3	14.999	13197467	437509	99.536	99.412
4	17.751	2834	145	0.021	0.033
Total		13258969	440097	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3q

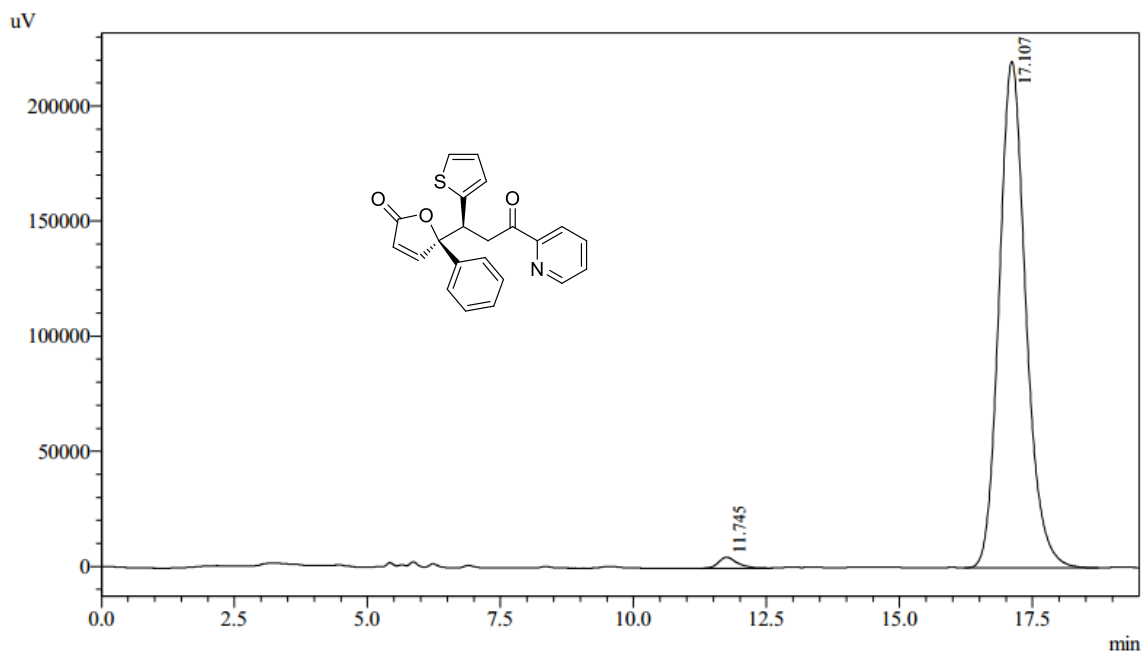




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.739	3276221	143930	49.381	59.816
2	17.176	3358341	96692	50.619	40.184
Total		6634562	240622	100.000	100.000

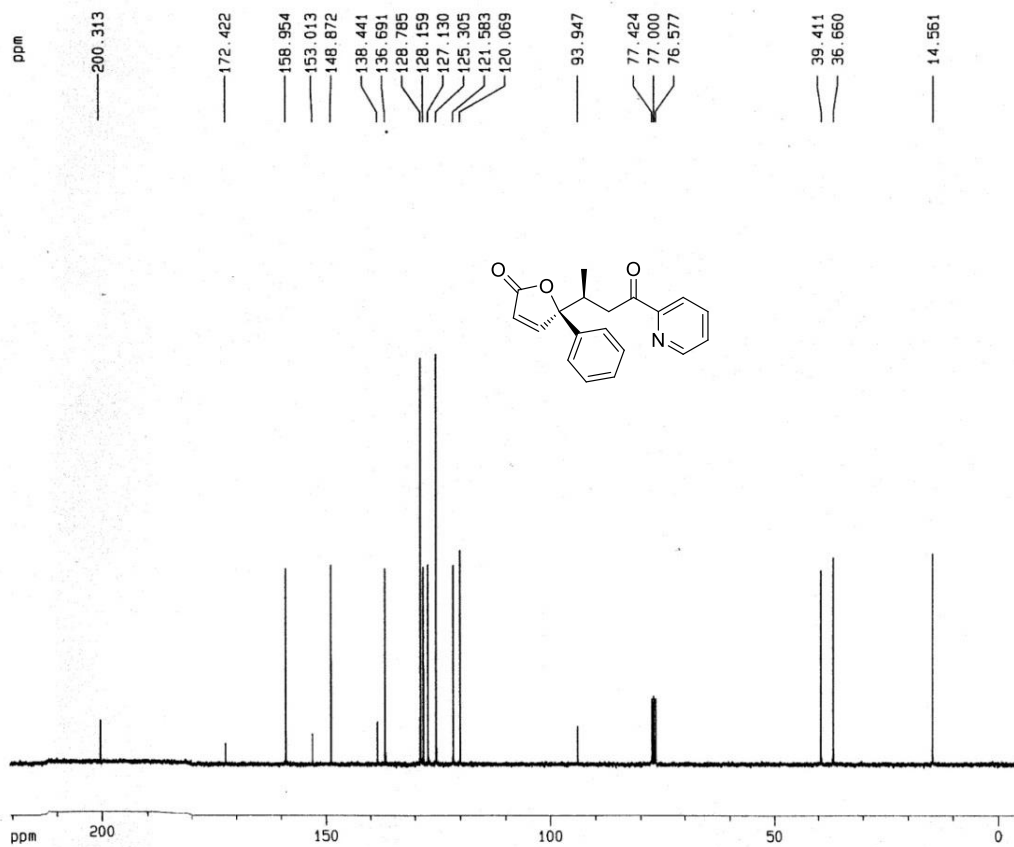
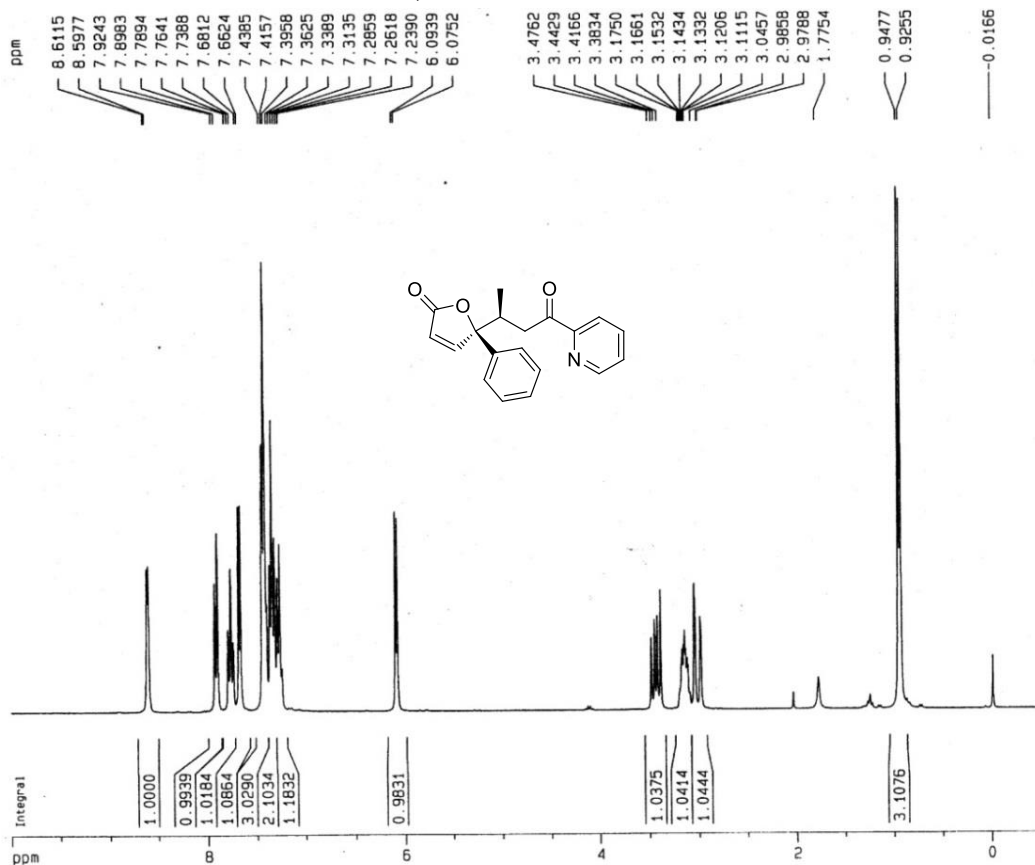


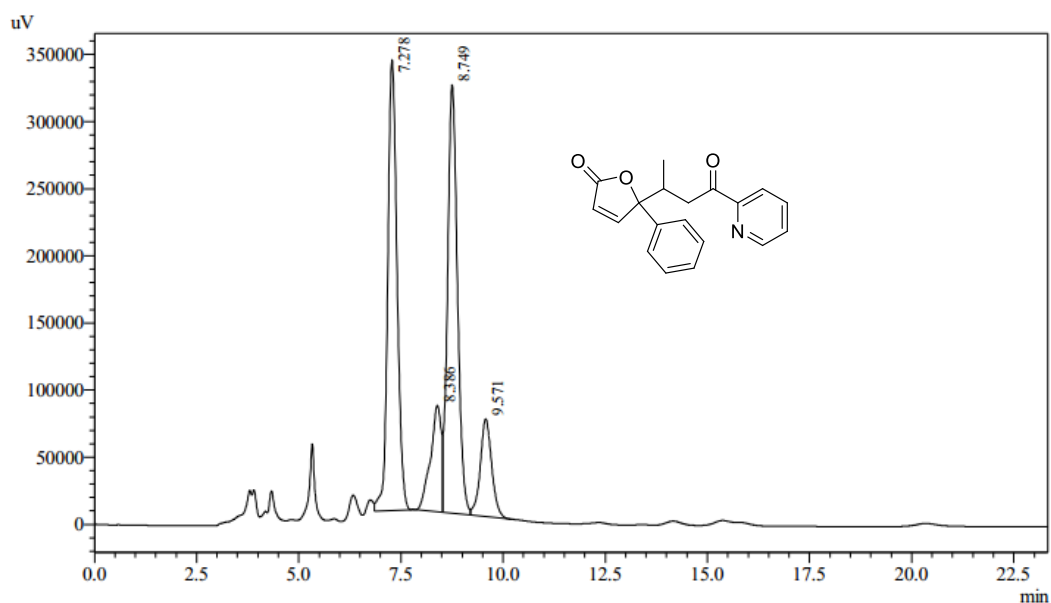
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.745	114960	4751	1.477	2.114
2	17.107	7670949	219948	98.523	97.886
Total		7785909	224699	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3r

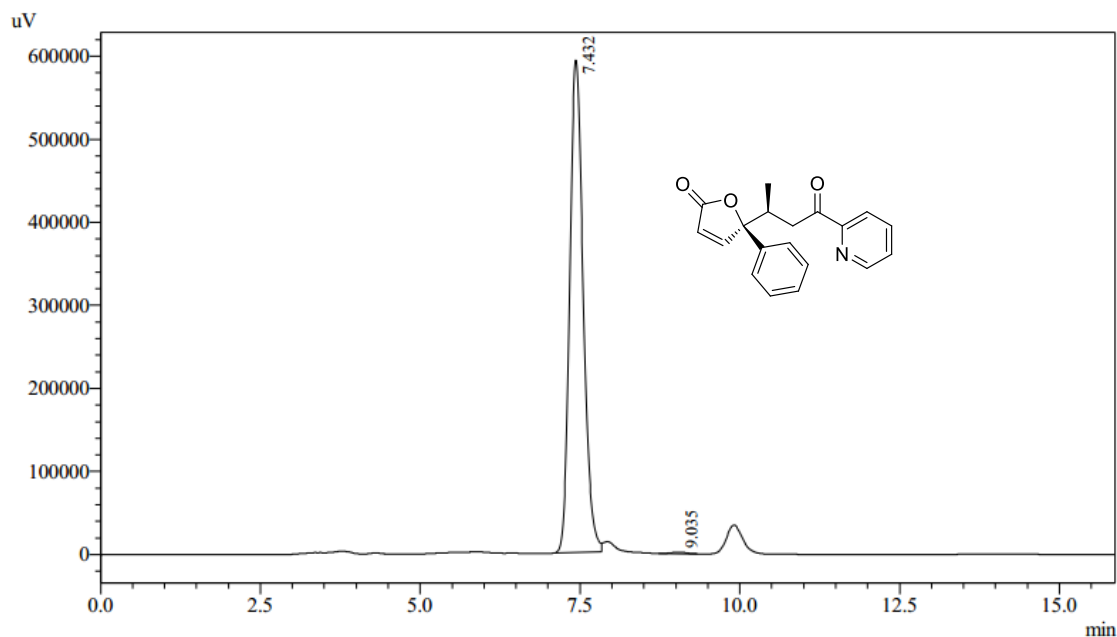




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.278	5313495	335743	39.095	41.613
2	8.386	1456908	79253	10.719	9.823
3	8.749	5398651	319052	39.722	39.544
4	9.571	1422191	72778	10.464	9.020
Total		13591245	806826	100.000	100.000

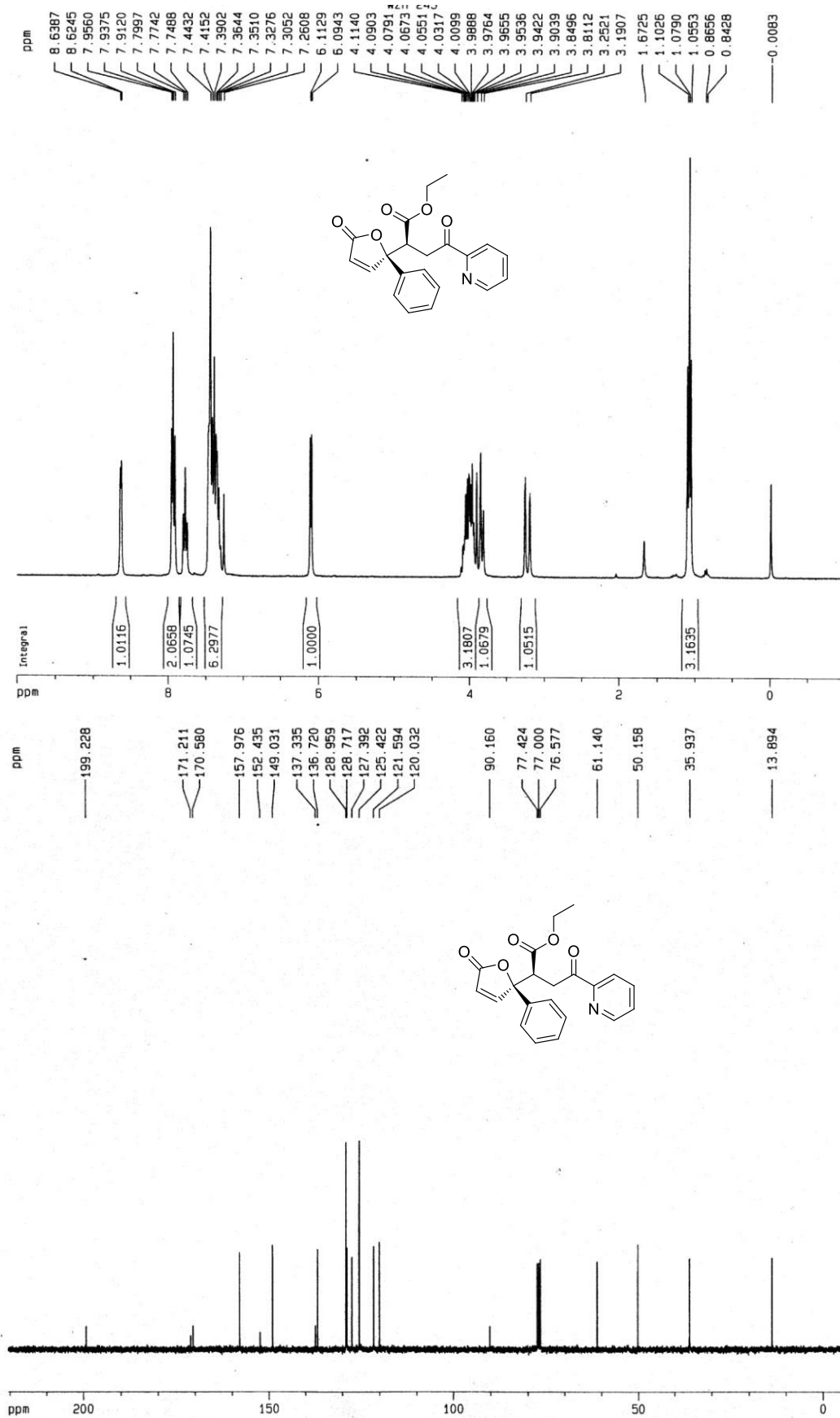


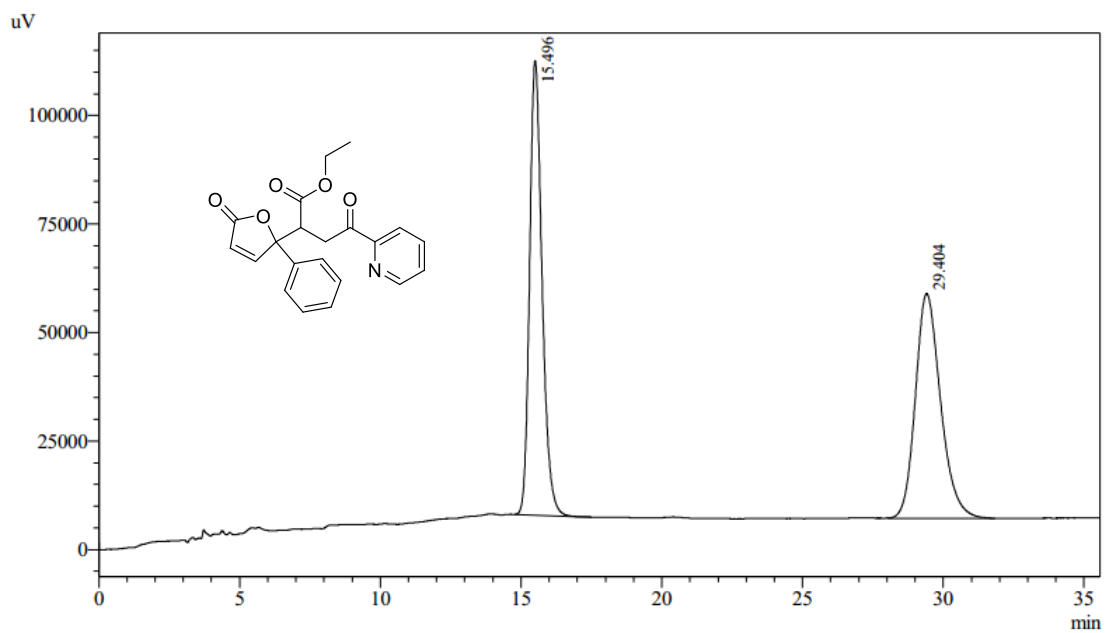
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.432	8705035	592624	99.692	99.704
2	9.035	26852	1759	0.308	0.296
Total		8731887	594384	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3s

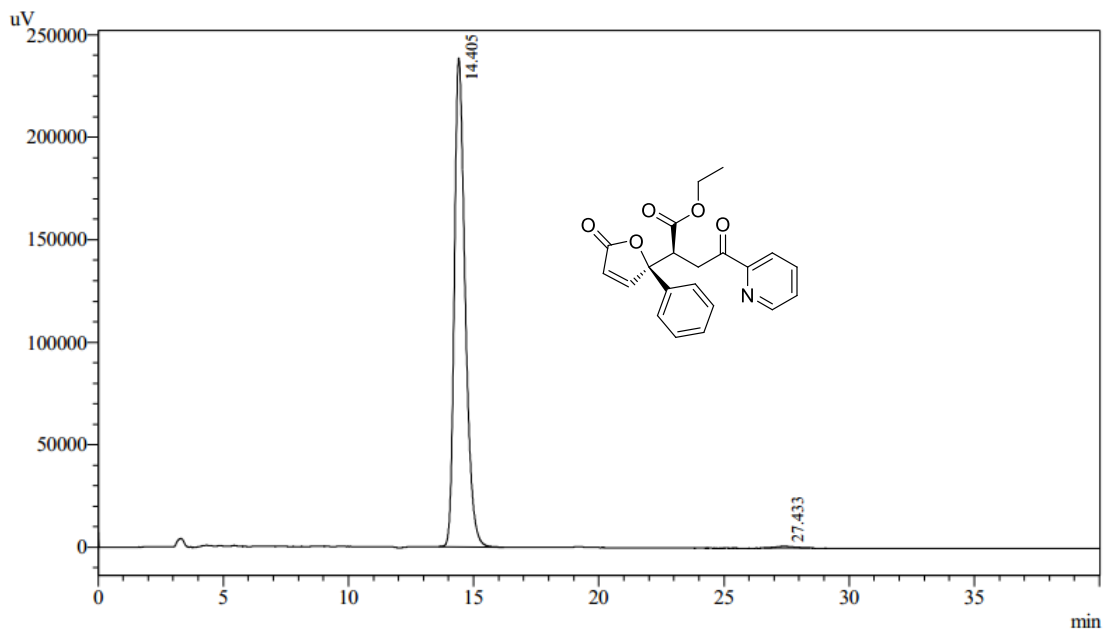




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.496	3219035	104720	49.968	66.923
2	29.404	3223190	51759	50.032	33.077
Total		6442224	156478	100.000	100.000

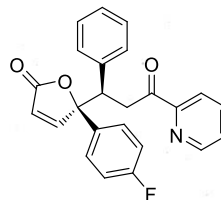
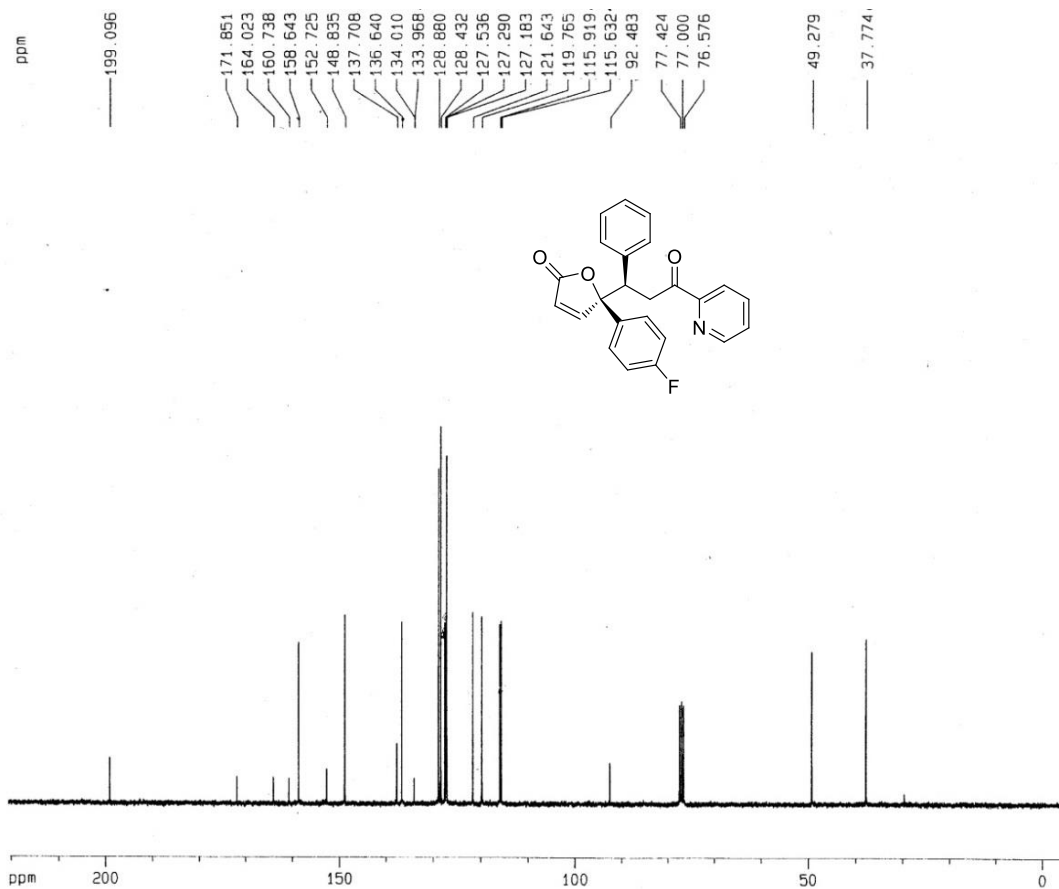
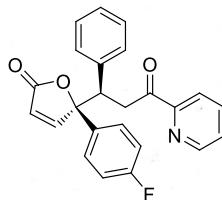
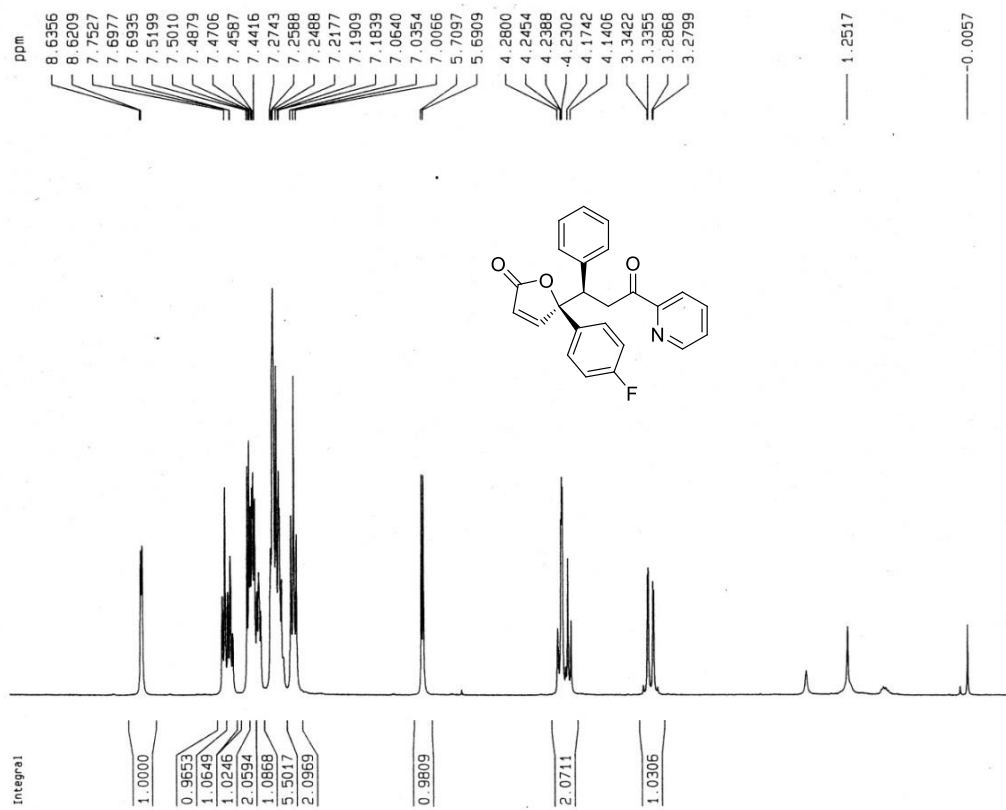


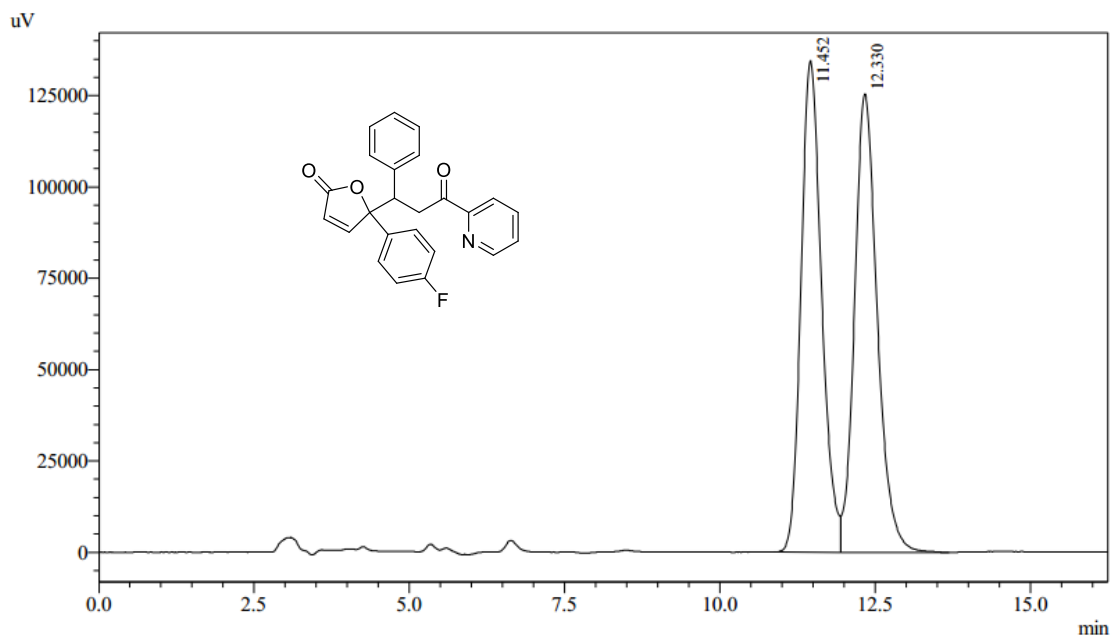
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.405	7198495	238431	99.362	99.643
2	27.433	46195	853	0.638	0.357
Total		7244691	239284	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3t

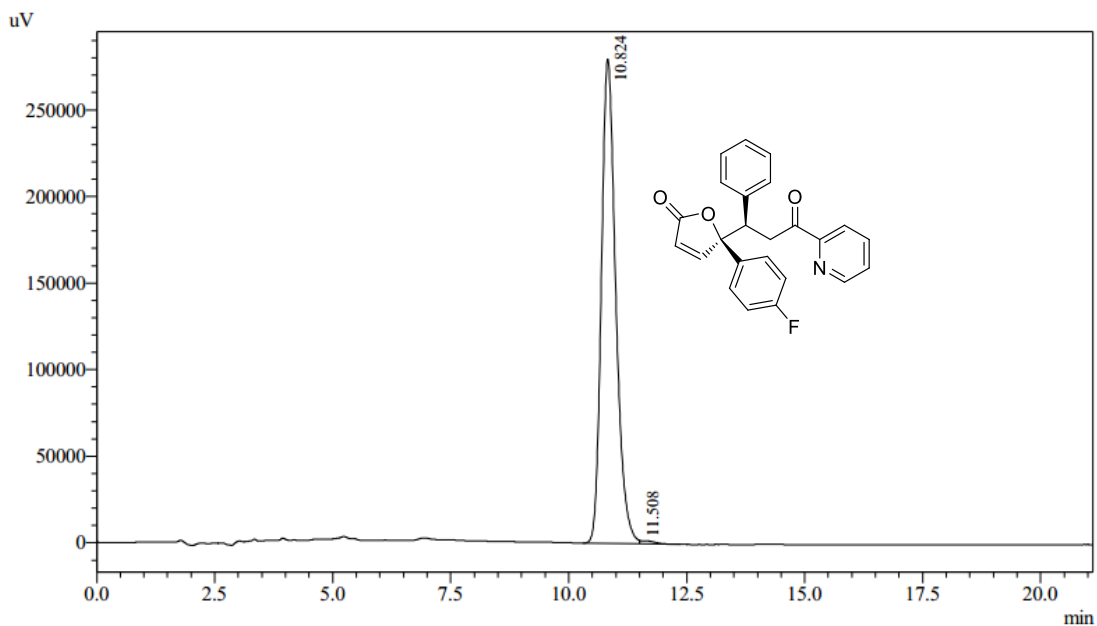




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.452	3109893	134580	49.352	51.762
2	12.330	3191567	125417	50.648	48.238
Total		6301460	259998	100.000	100.000

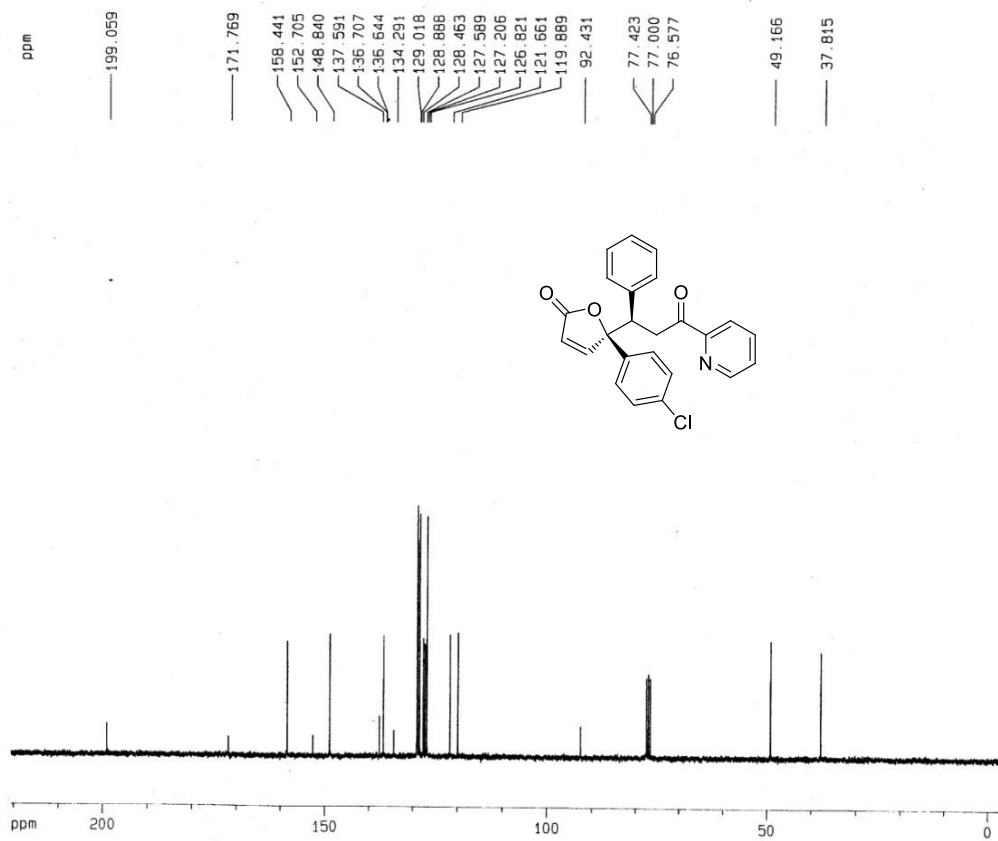
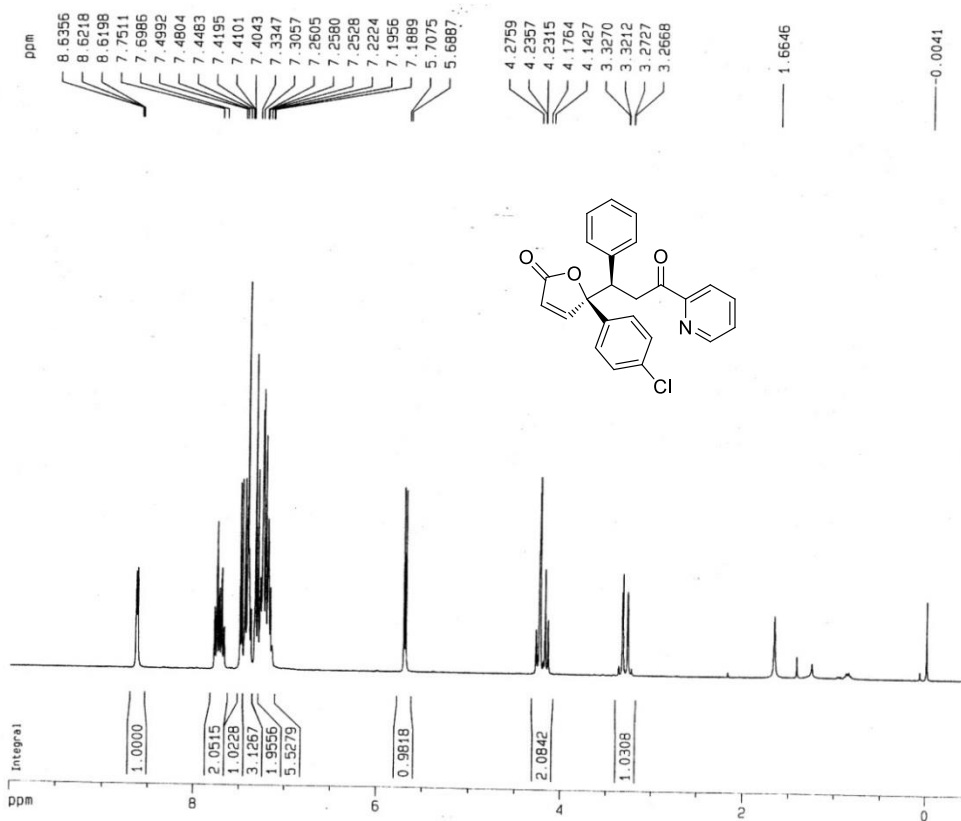


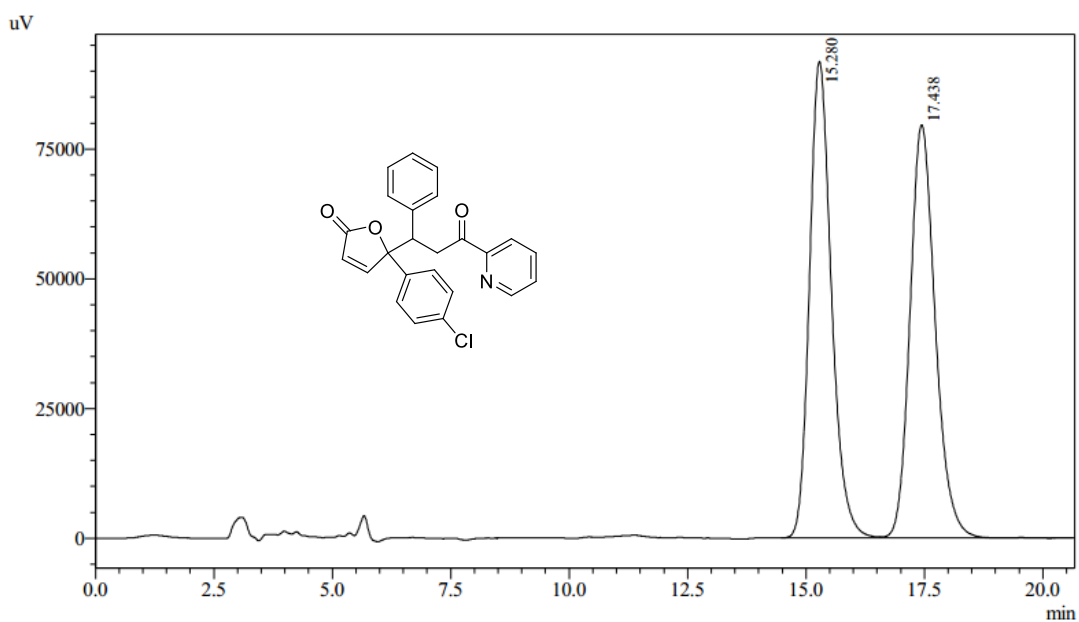
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.824	5918959	279764	99.321	99.289
2	11.508	40474	2002	0.679	0.711
Total		5959432	281766	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3u

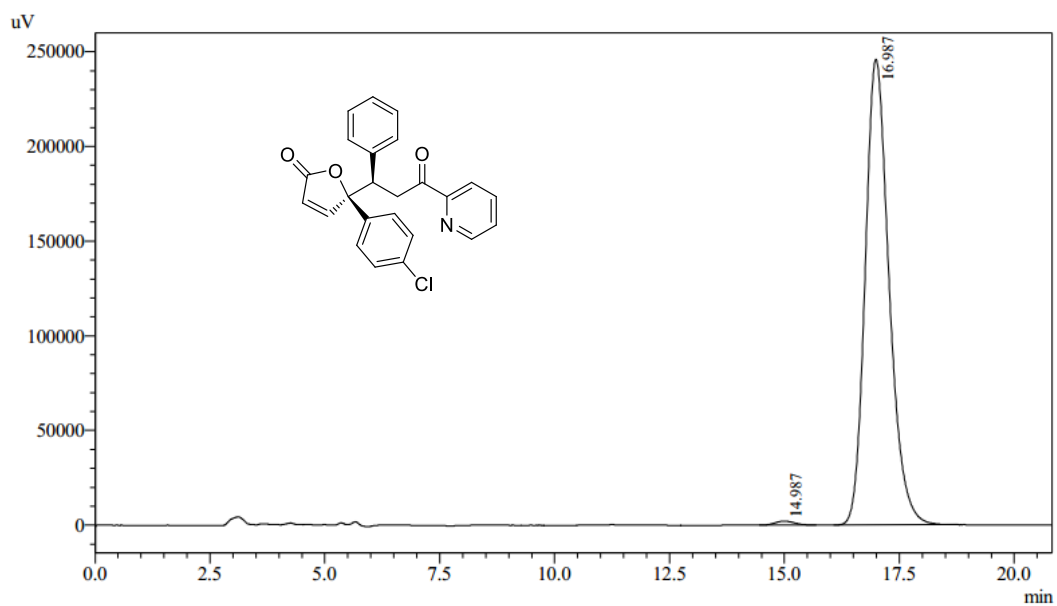




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.280	2958275	91873	50.018	53.569
2	17.438	2956115	79629	49.982	46.431
Total		5914390	171502	100.000	100.000

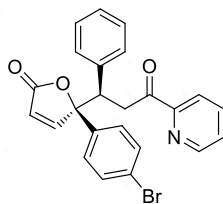
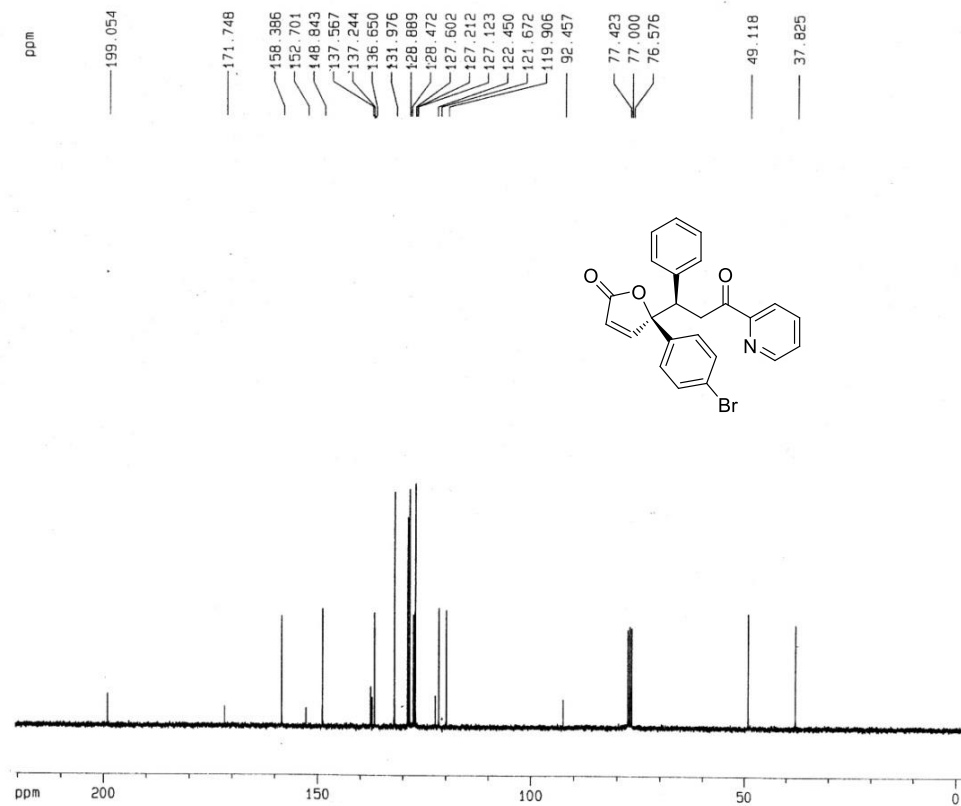
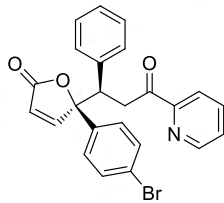
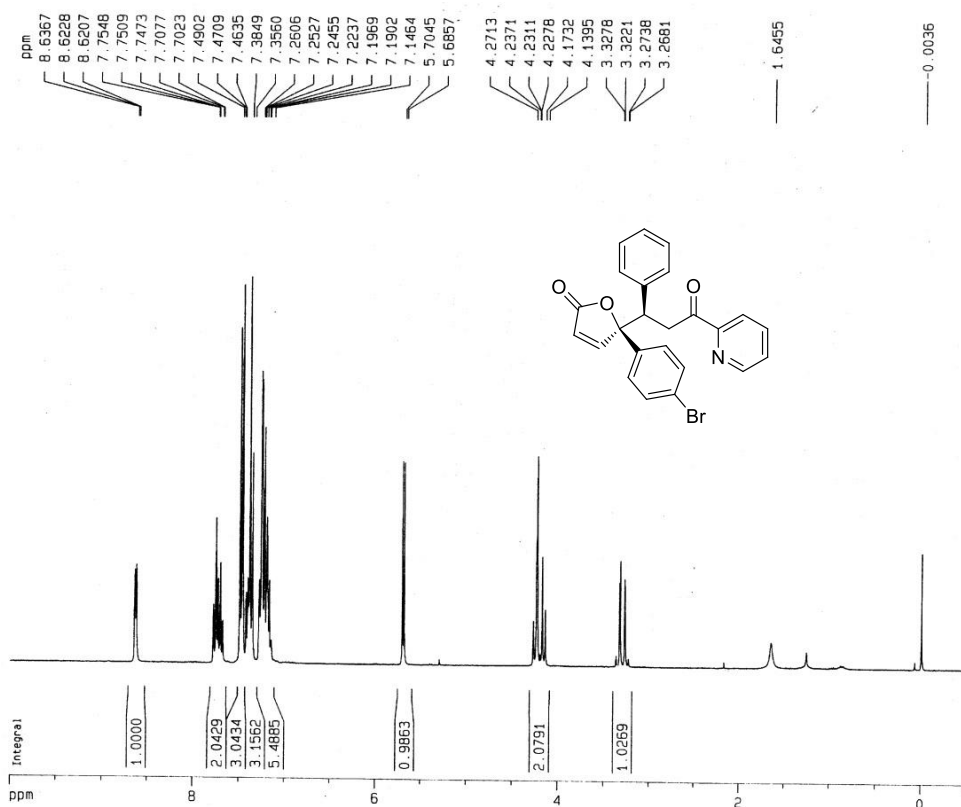


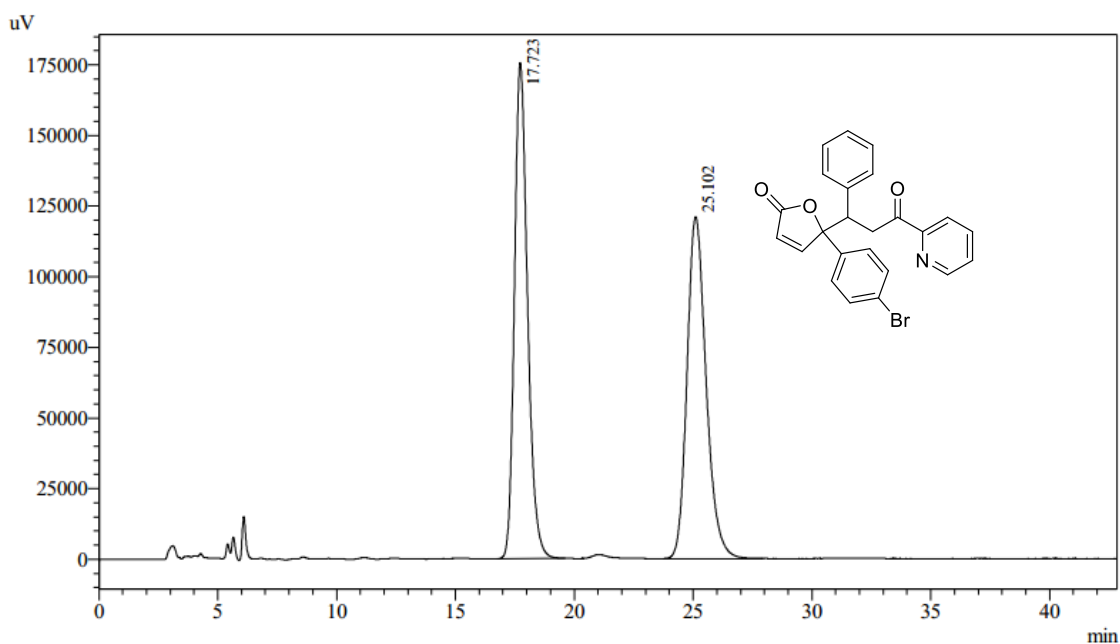
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.987	63748	2158	0.712	0.870
2	16.987	8893210	246017	99.288	99.130
Total		8956958	248175	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3v

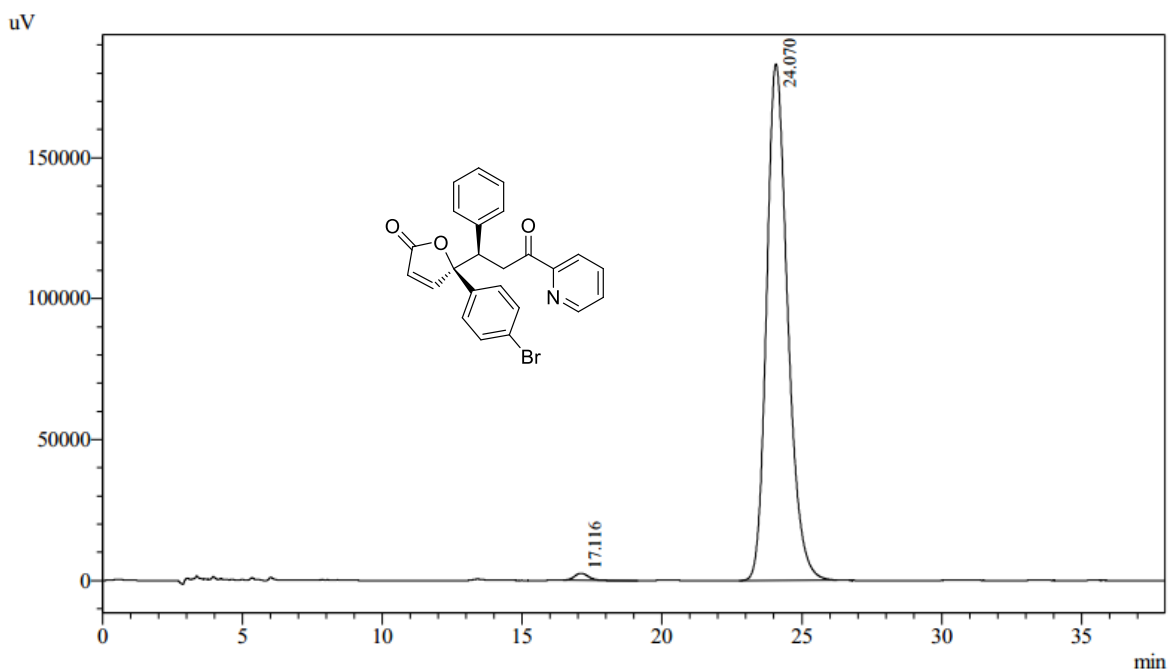




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.723	6728327	175579	49.892	59.191
2	25.102	6757497	121054	50.108	40.809
Total		13485824	296633	100.000	100.000

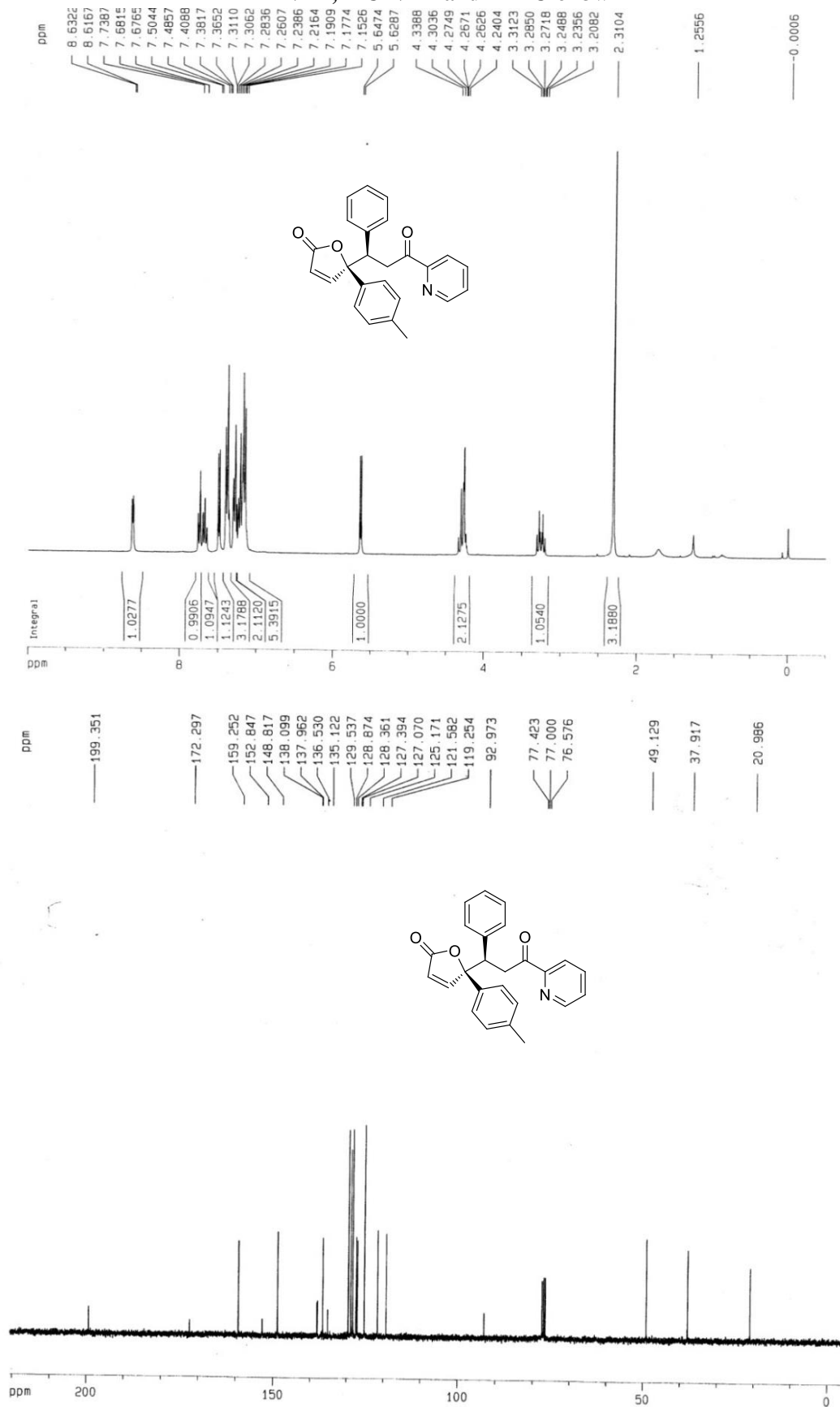


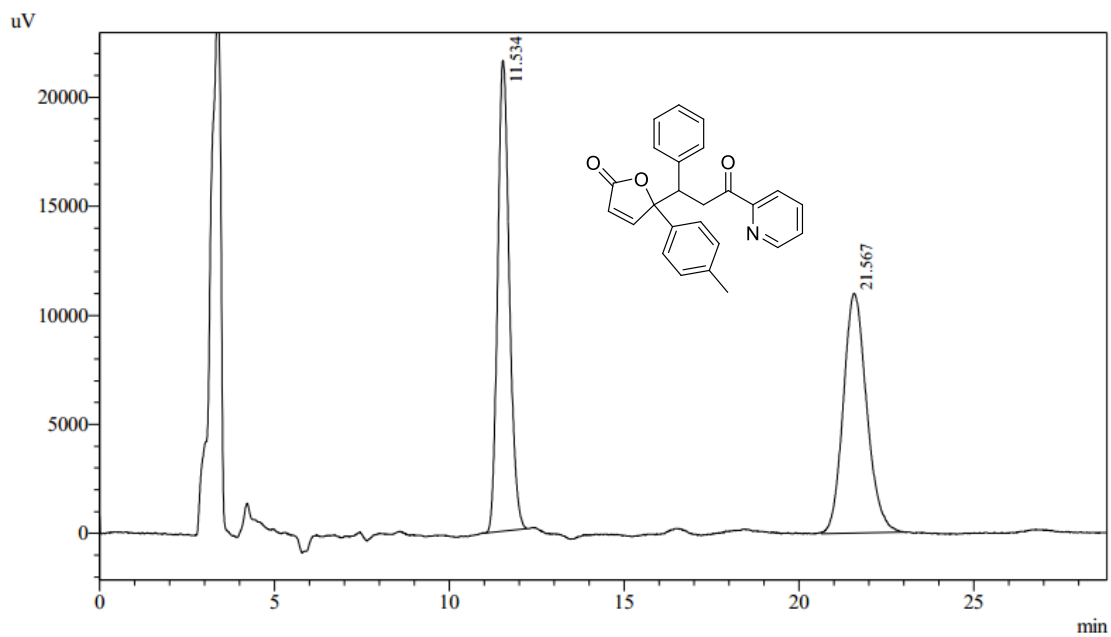
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.116	78543	2438	0.812	1.313
2	24.070	9598693	183269	99.188	98.687
Total		9677235	185706	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3w

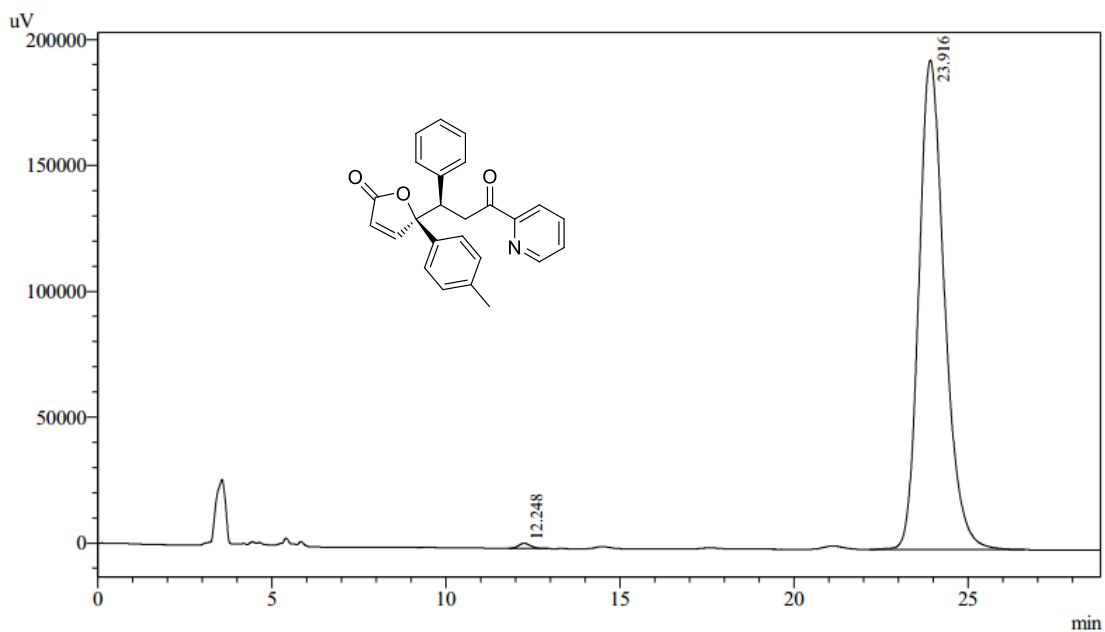




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.534	500282	21600	49.420	66.266
2	21.567	512022	10996	50.580	33.734
Total		1012304	32595	100.000	100.000

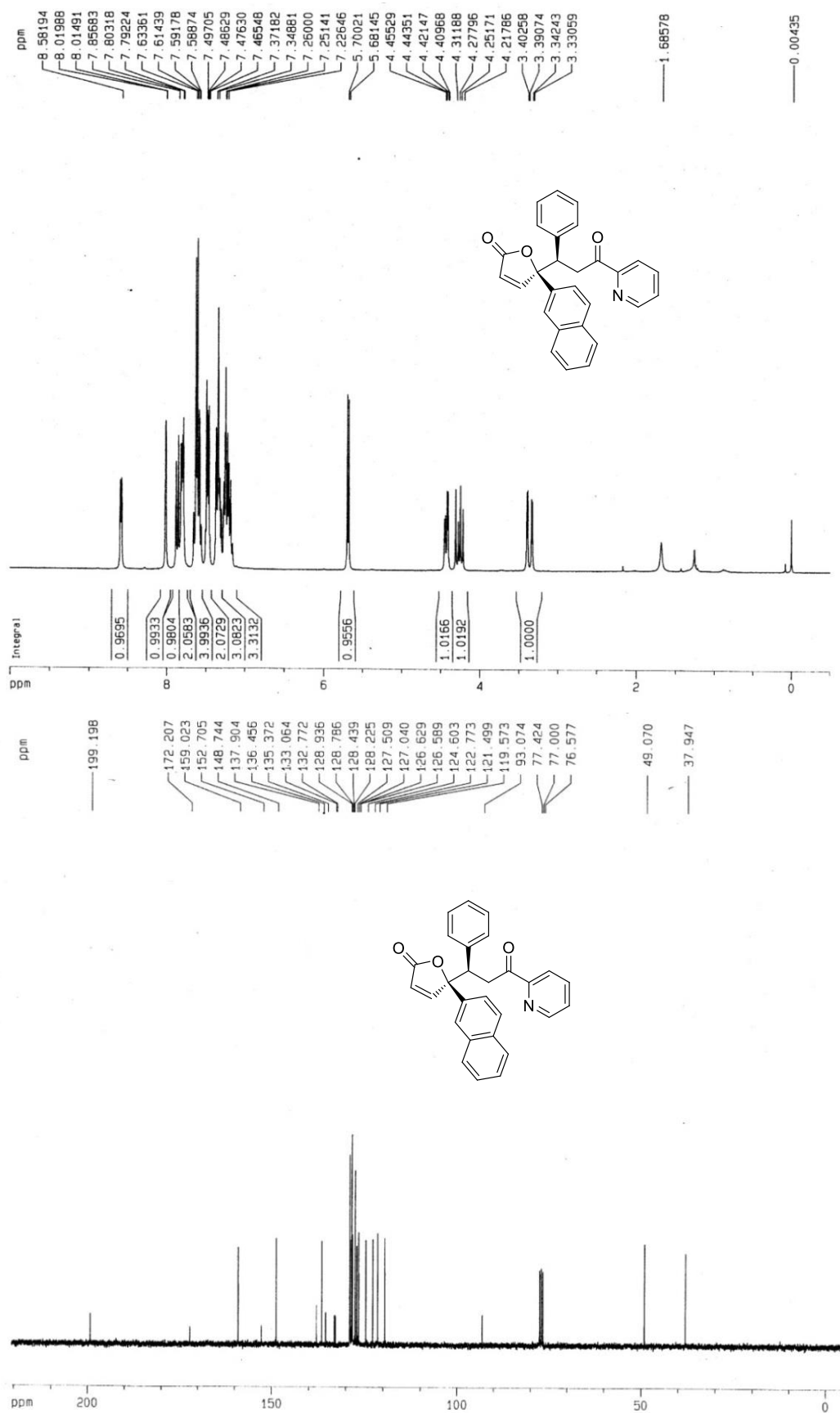


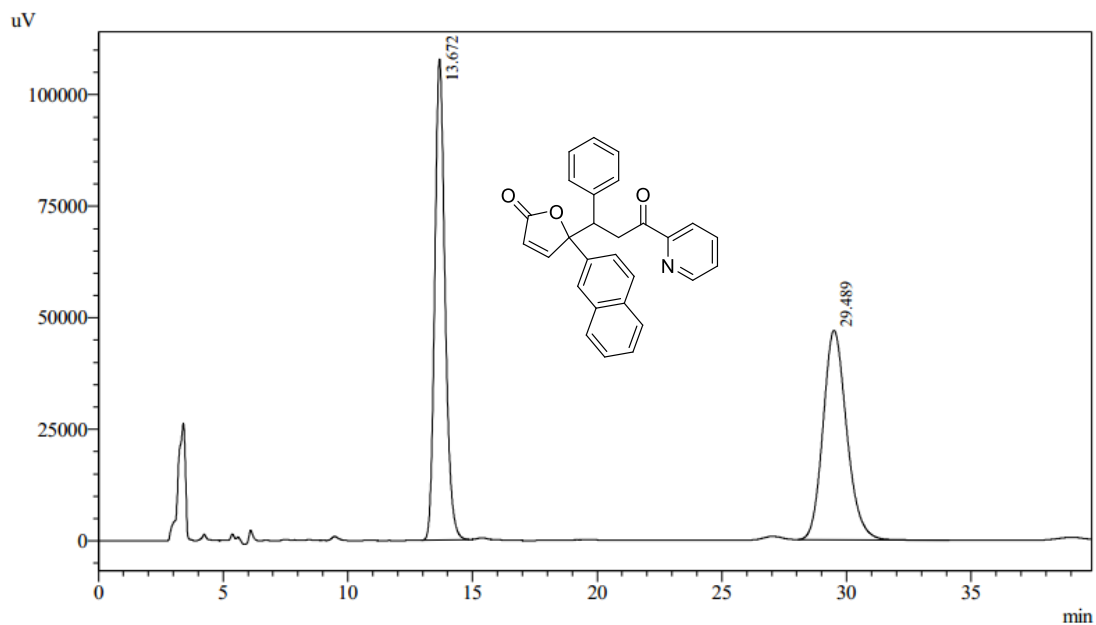
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.248	50469	2100	0.504	1.068
2	23.916	9960406	194478	99.496	98.932
Total		10010874	196578	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 3x

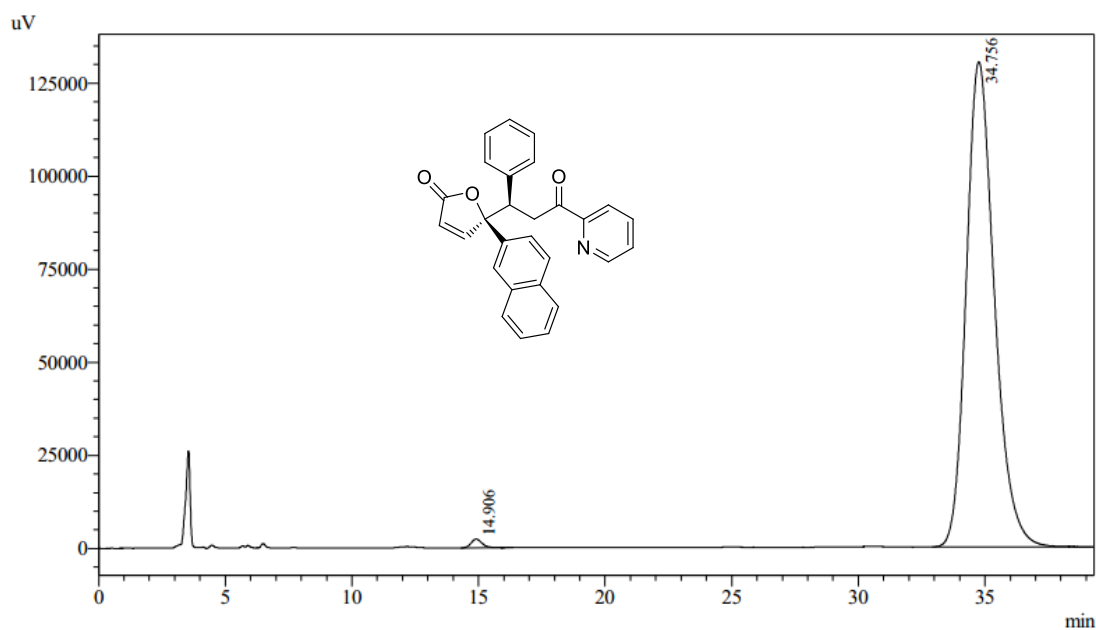




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.672	3092731	107835	49.974	69.667
2	29.489	3096009	46951	50.026	30.333
Total		6188740	154786	100.000	100.000

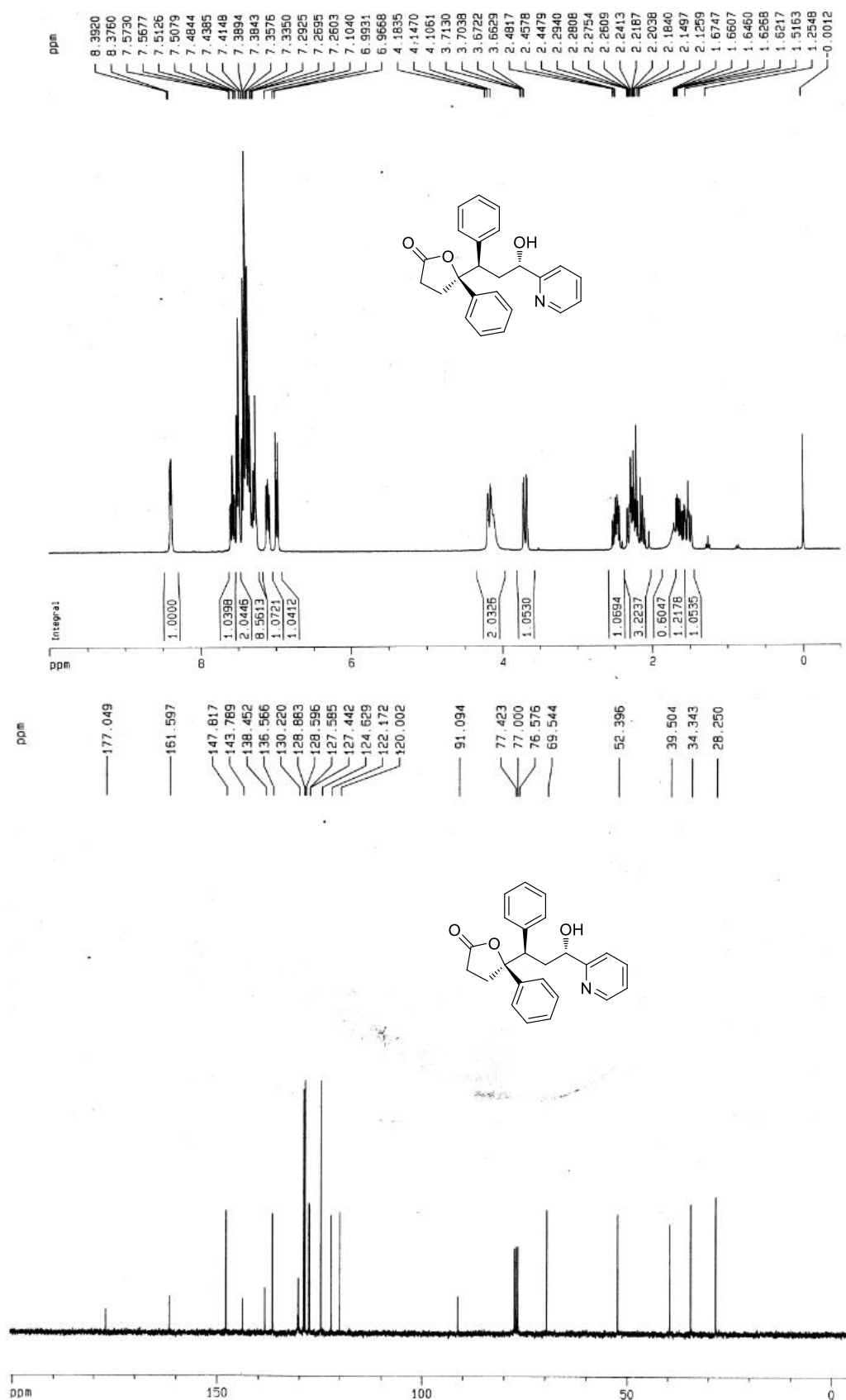


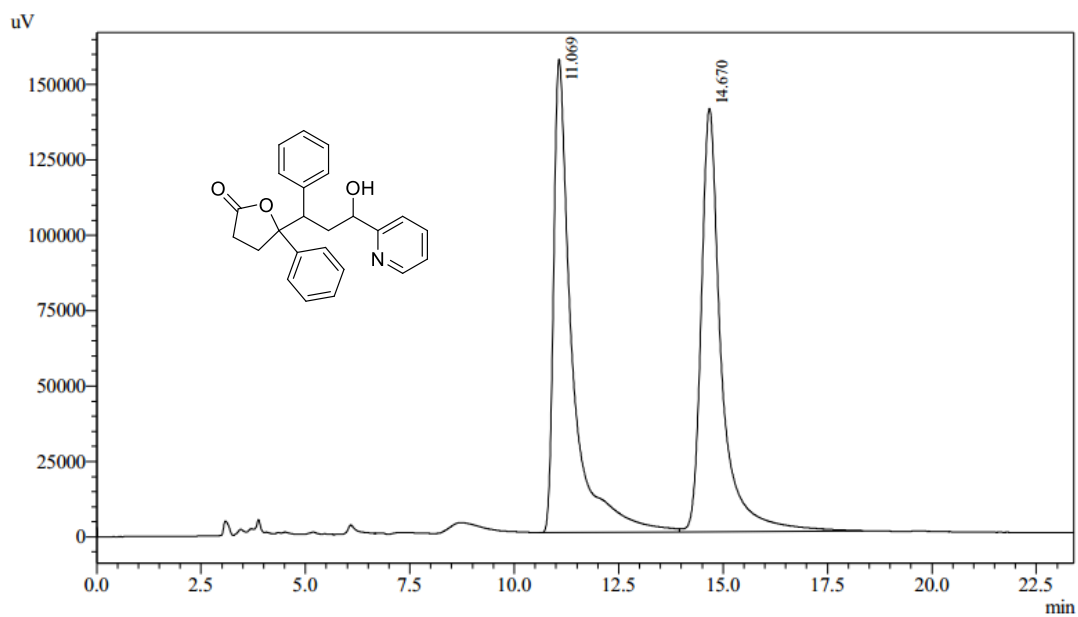
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.906	74390	2413	0.731	1.817
2	34.756	10096257	130375	99.269	98.183
Total		10170647	132788	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 4

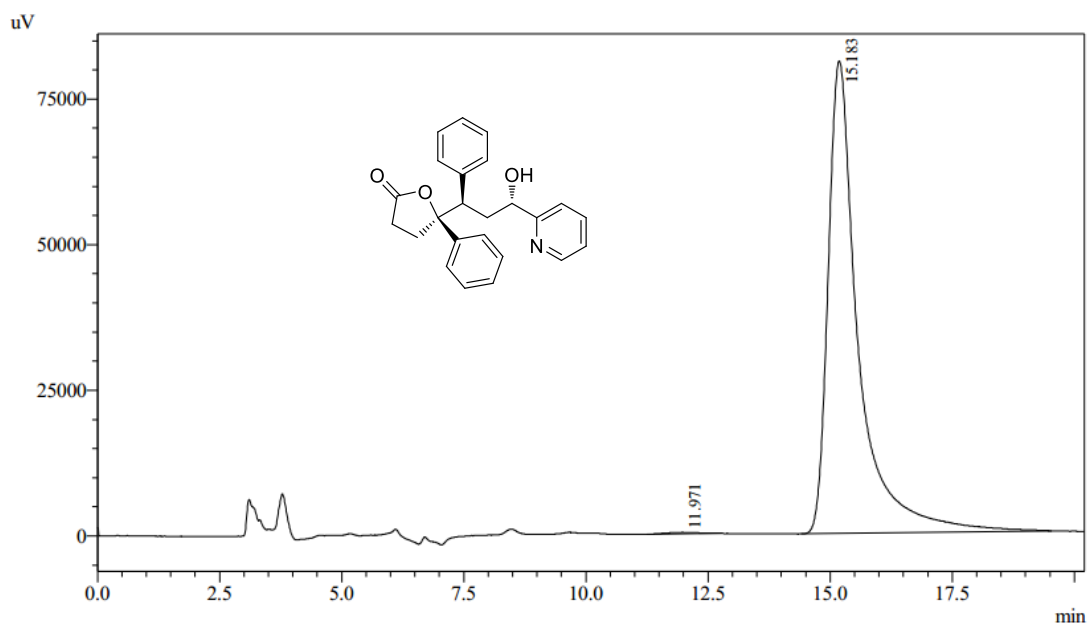




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.069	4826836	156999	50.664	52.787
2	14.670	4700347	140421	49.336	47.213
Total		9527183	297419	100.000	100.000

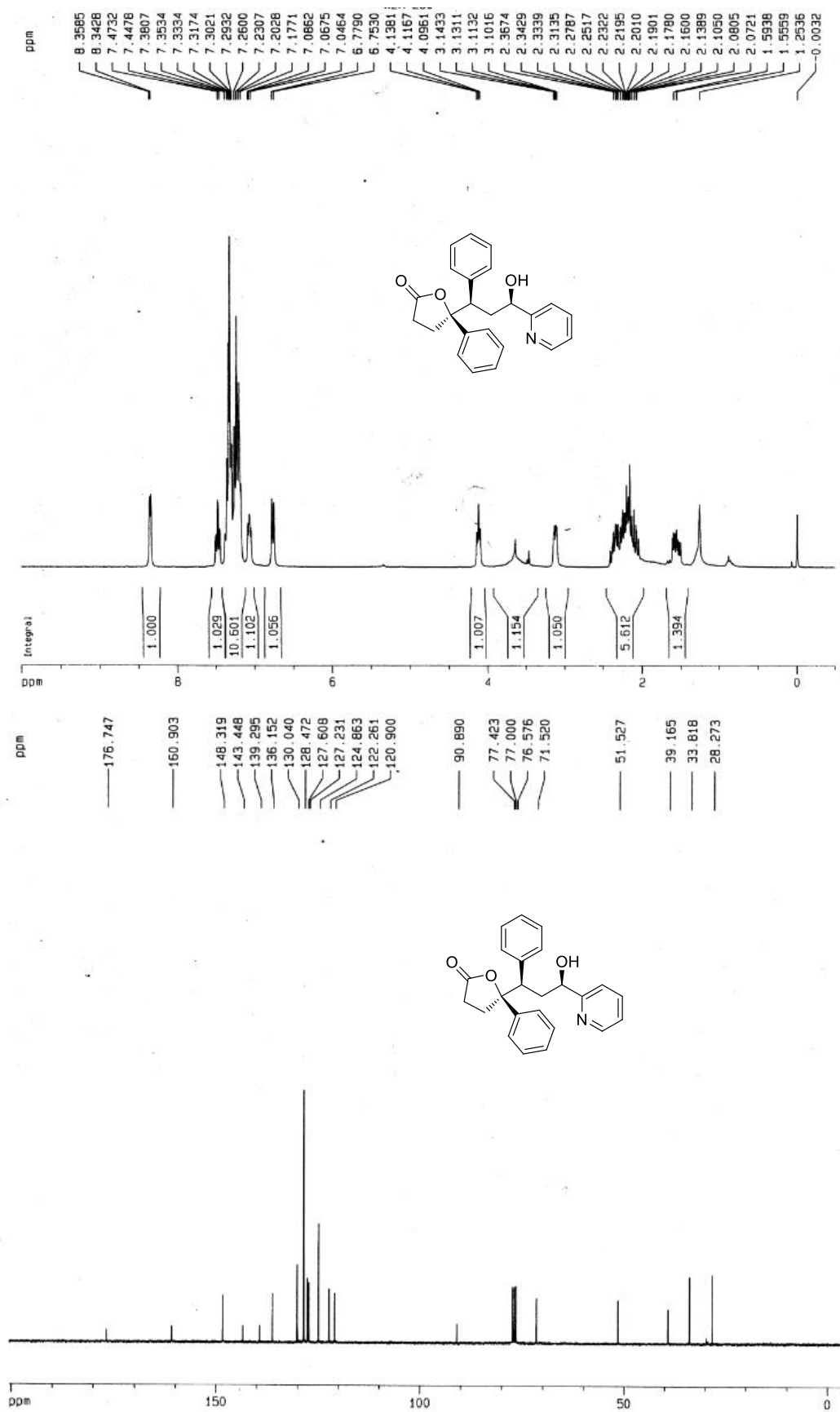


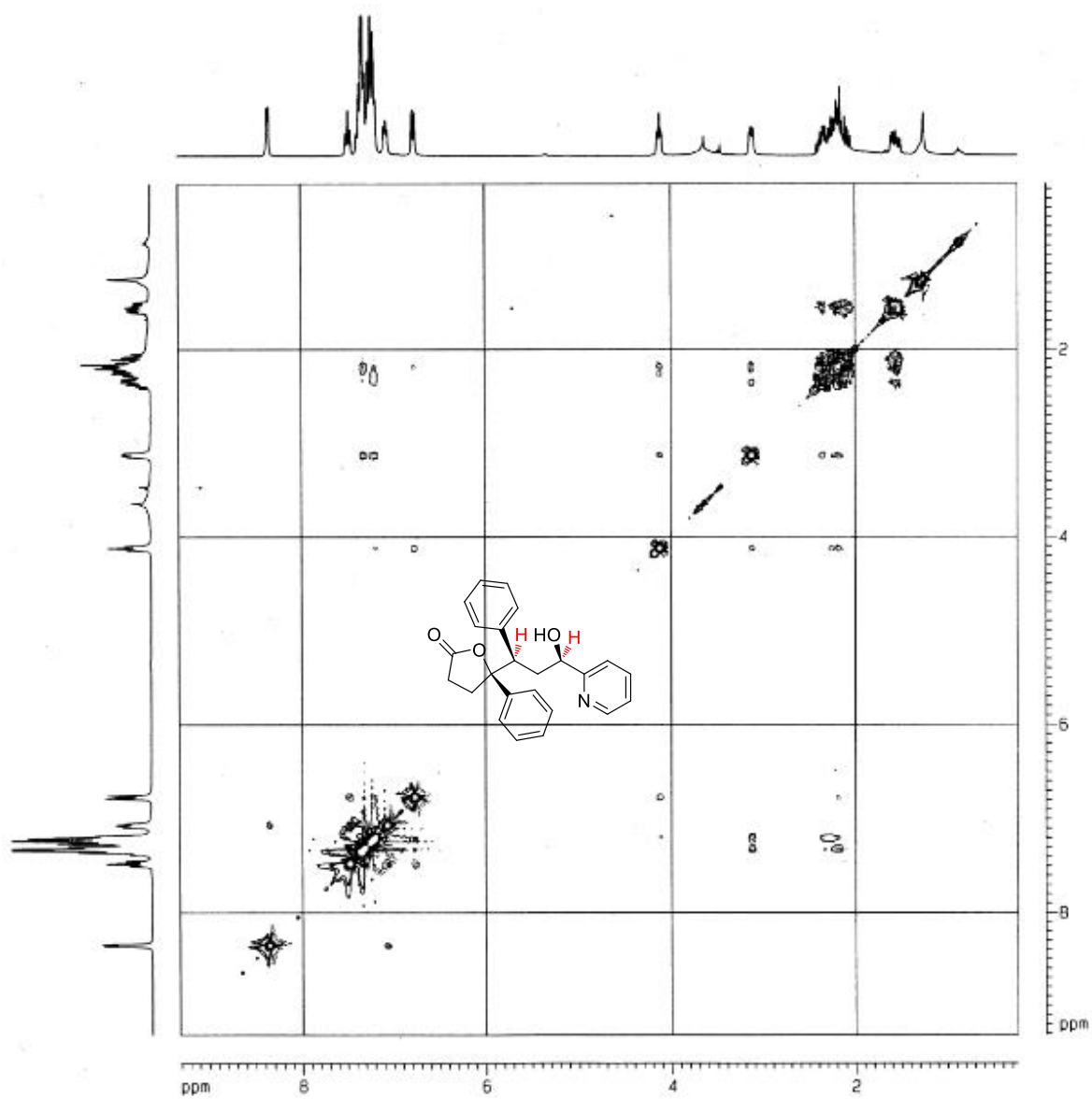
1 Det.A Ch1 / 254nm

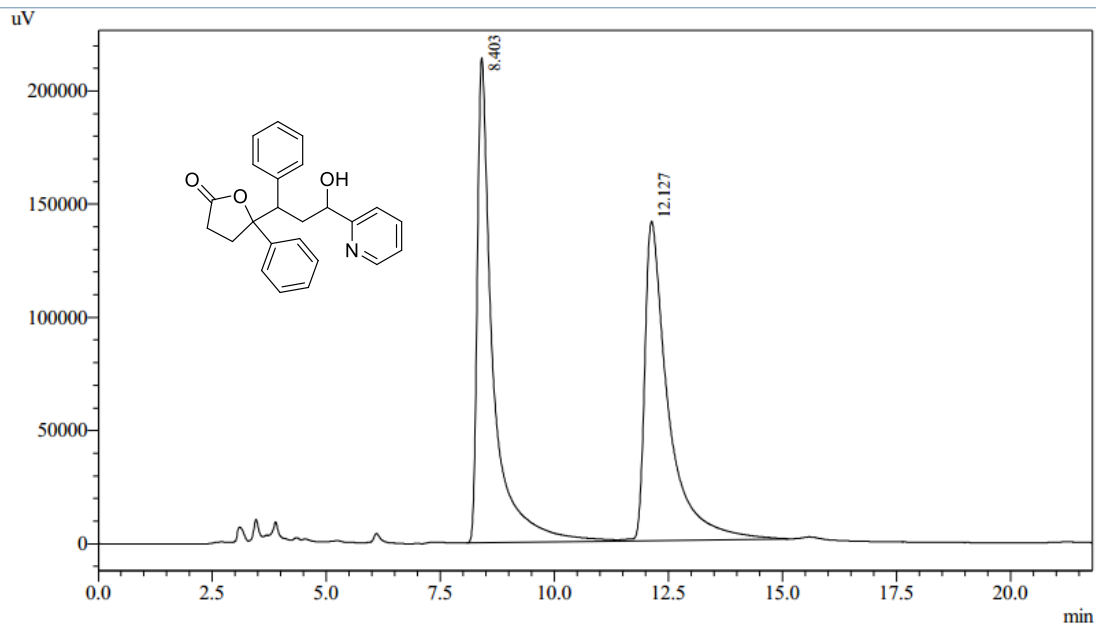
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.971	9960	242	0.283	0.298
2	15.183	3504420	81104	99.717	99.702
Total		3514380	81346	100.000	100.000

¹H NMR, ¹³C NMR and HPLC of 4'



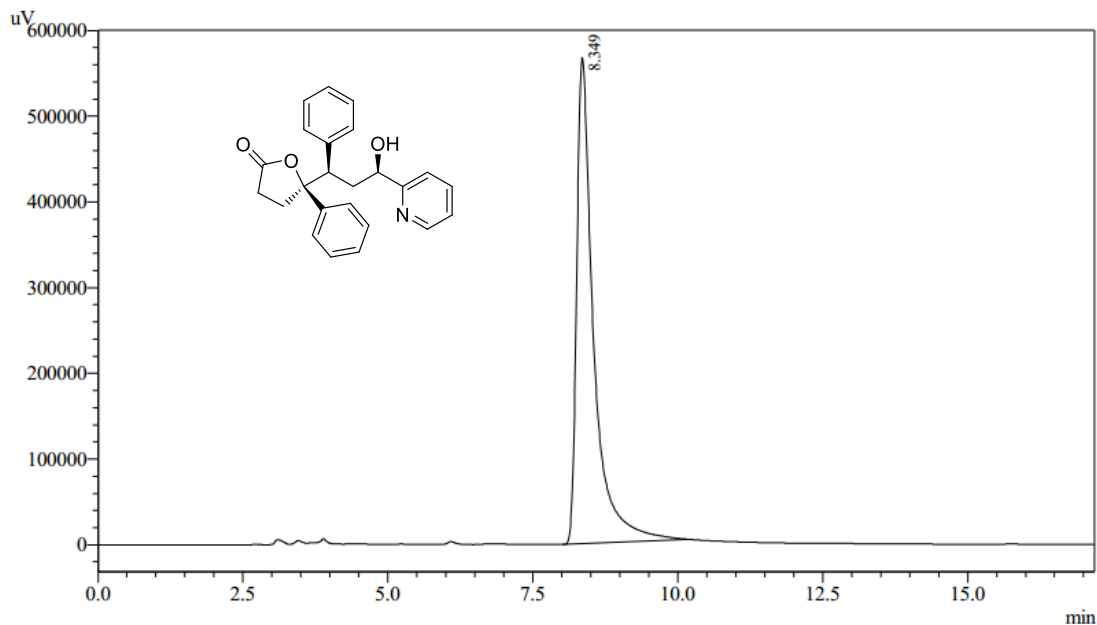




1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.403	5119714	214293	50.393	60.310
2	12.127	5039852	141027	49.607	39.690
Total		10159566	355320	100.000	100.000

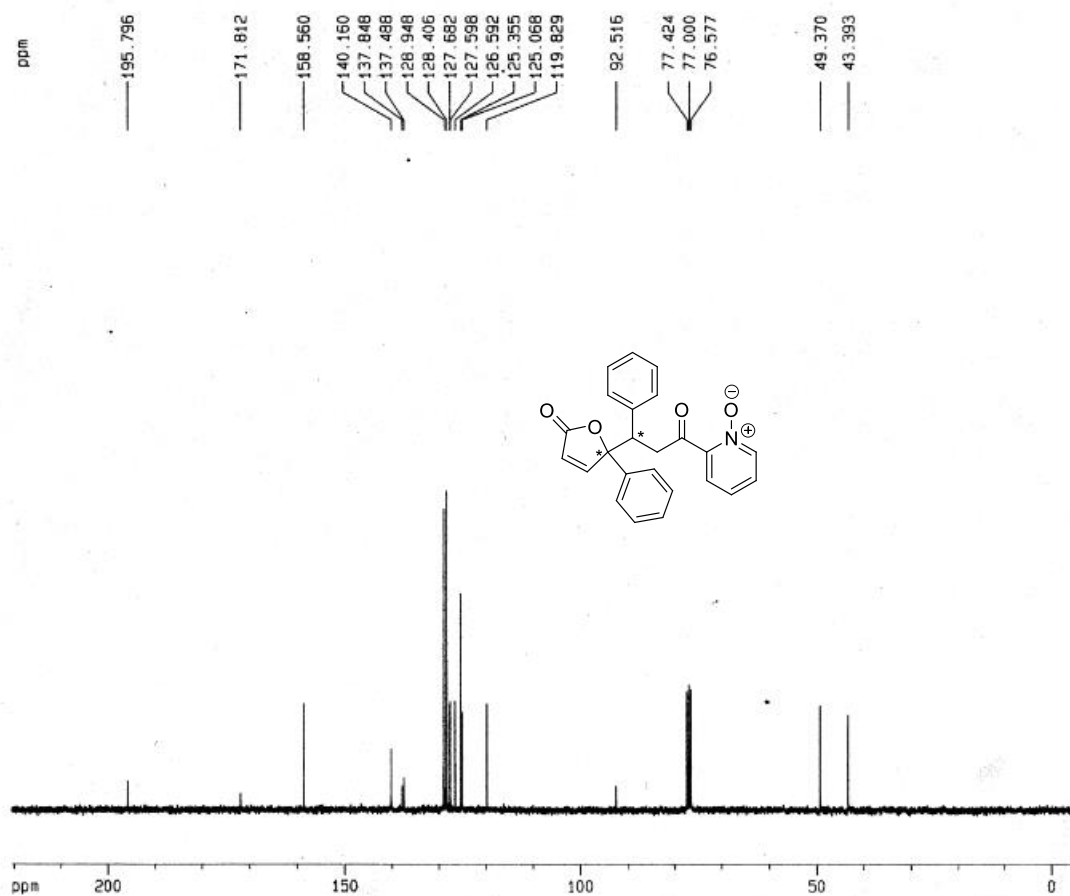
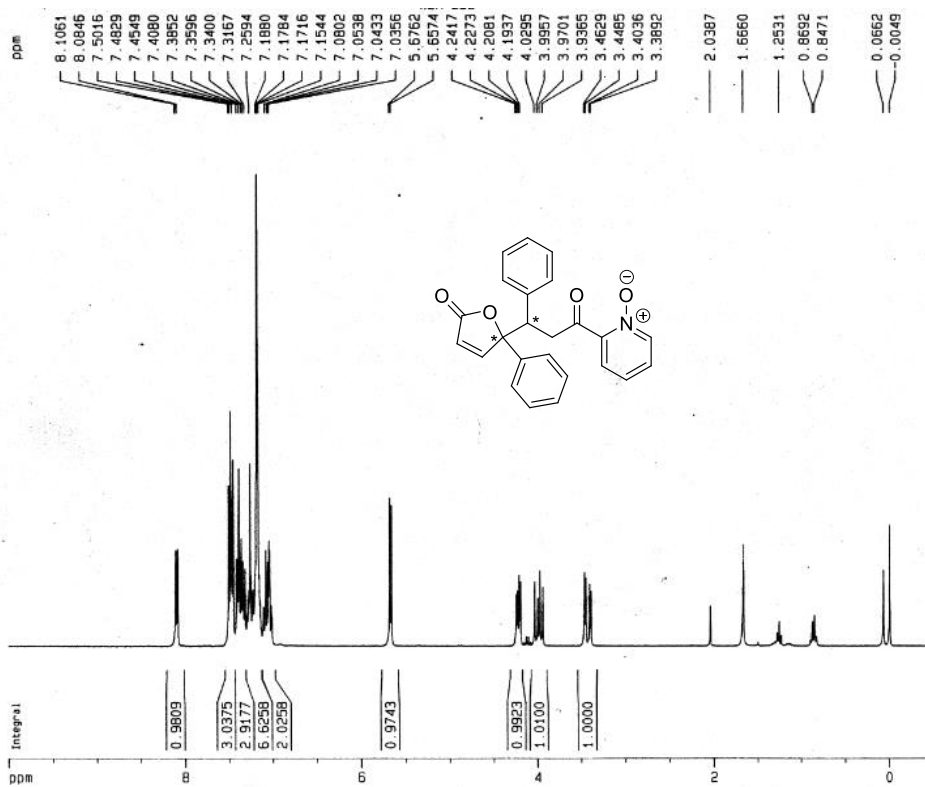


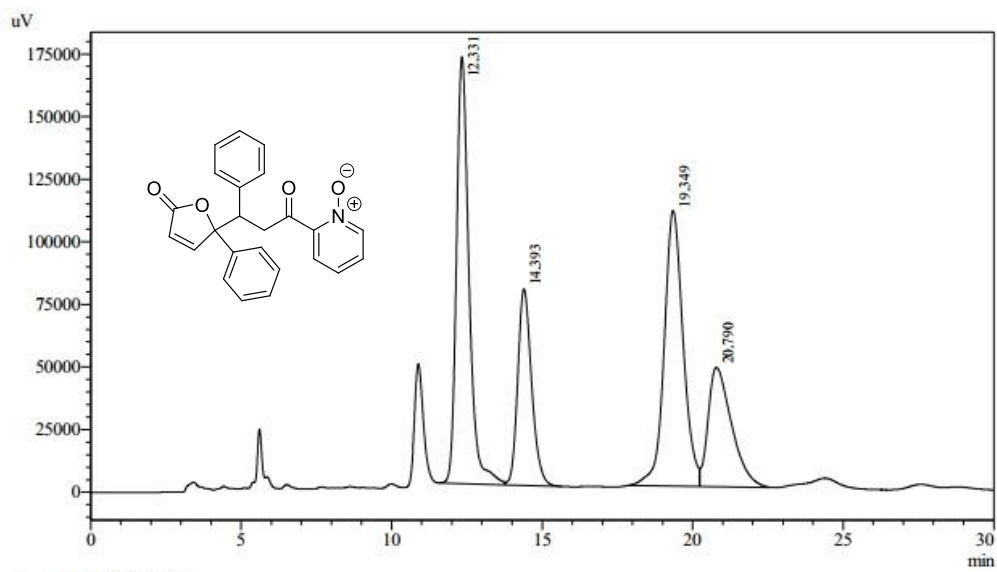
1 Det.A Ch1 / 254nm

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.349	11508260	567283	100.000	100.000
Total		11508260	567283	100.000	100.000

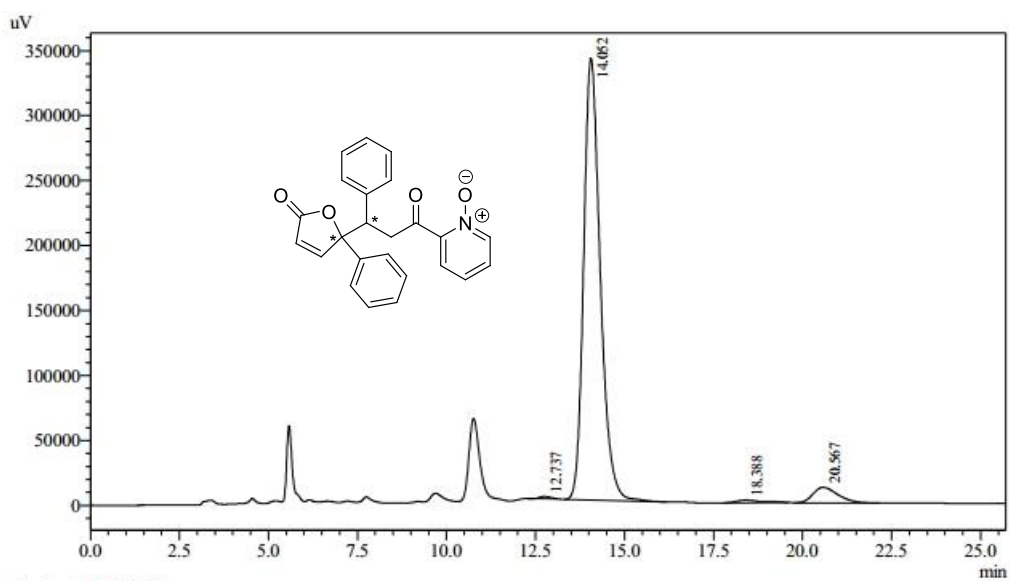
¹H NMR, ¹³C NMR and HPLC of 8





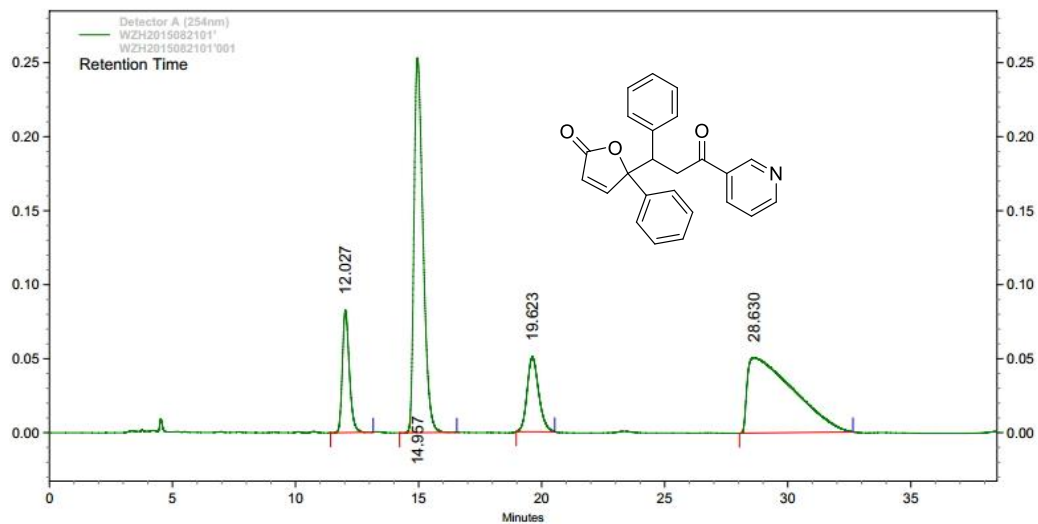
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.331	4894620	170414	33.054	41.925
2	14.393	2499092	78413	16.877	19.291
3	19.349	4836453	110017	32.661	27.066
4	20.790	2577858	47633	17.409	11.719
Total		14808023	406478	100.000	100.000



Detector A Ch1 254nm

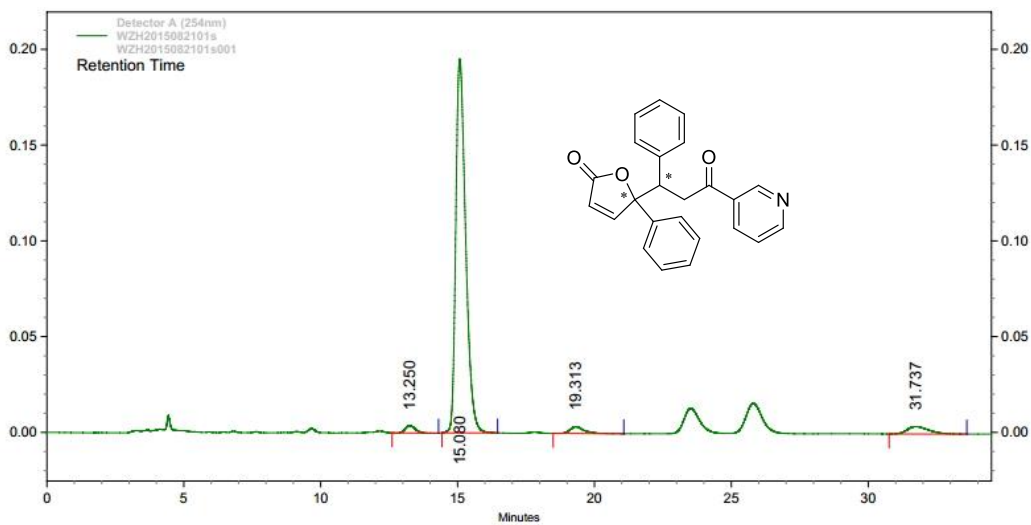
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.737	35378	1732	0.301	0.487
2	14.052	11029117	340209	93.828	95.578
3	18.388	105441	2075	0.897	0.583
4	20.567	584735	11933	4.974	3.352
Total		11754671	355950	100.000	100.000



Detector
A
(254nm)

Pk #	Retention Time	Height	Height Percent	Area	Area Percent
1	12.027	82600	18.90	1612195	9.89
2	14.957	253104	57.91	6456513	39.60
3	19.623	50479	11.55	1650610	10.12
4	28.630	50860	11.64	6584464	40.39

Totals		437043	100.00	16303782	100.00
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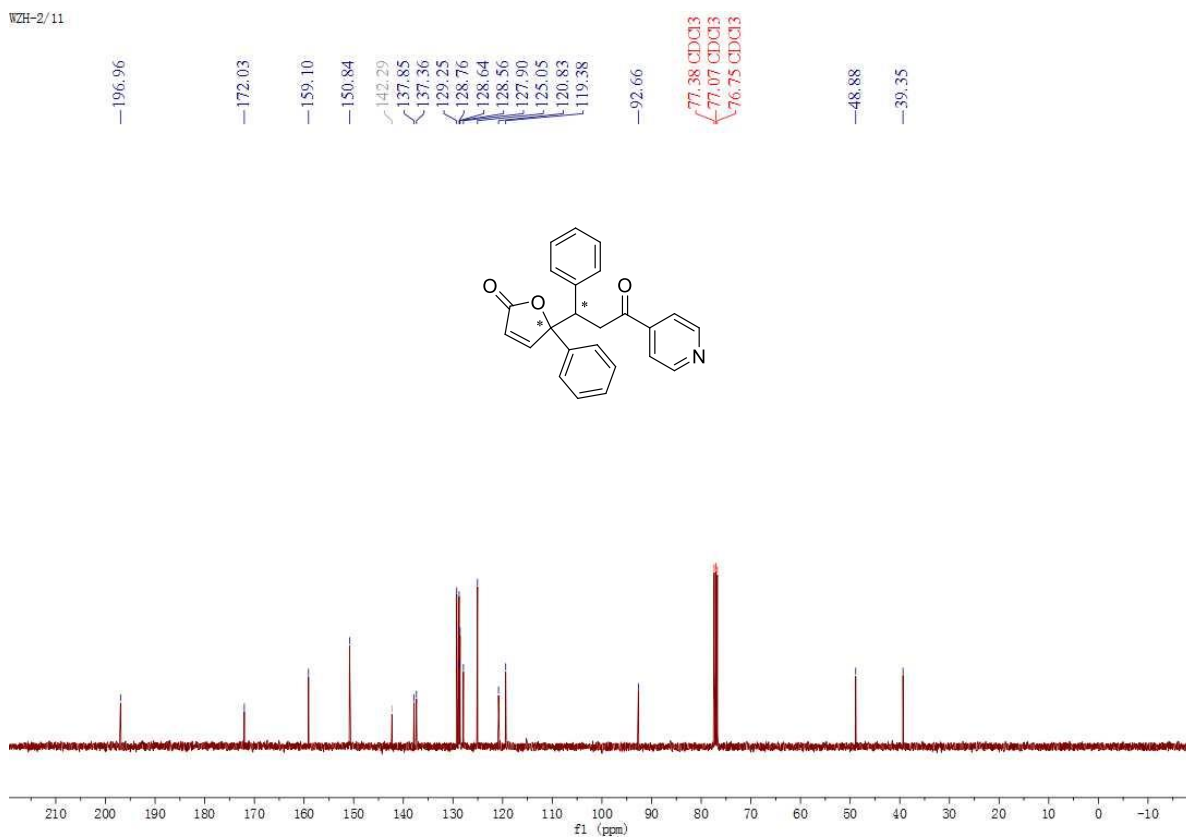
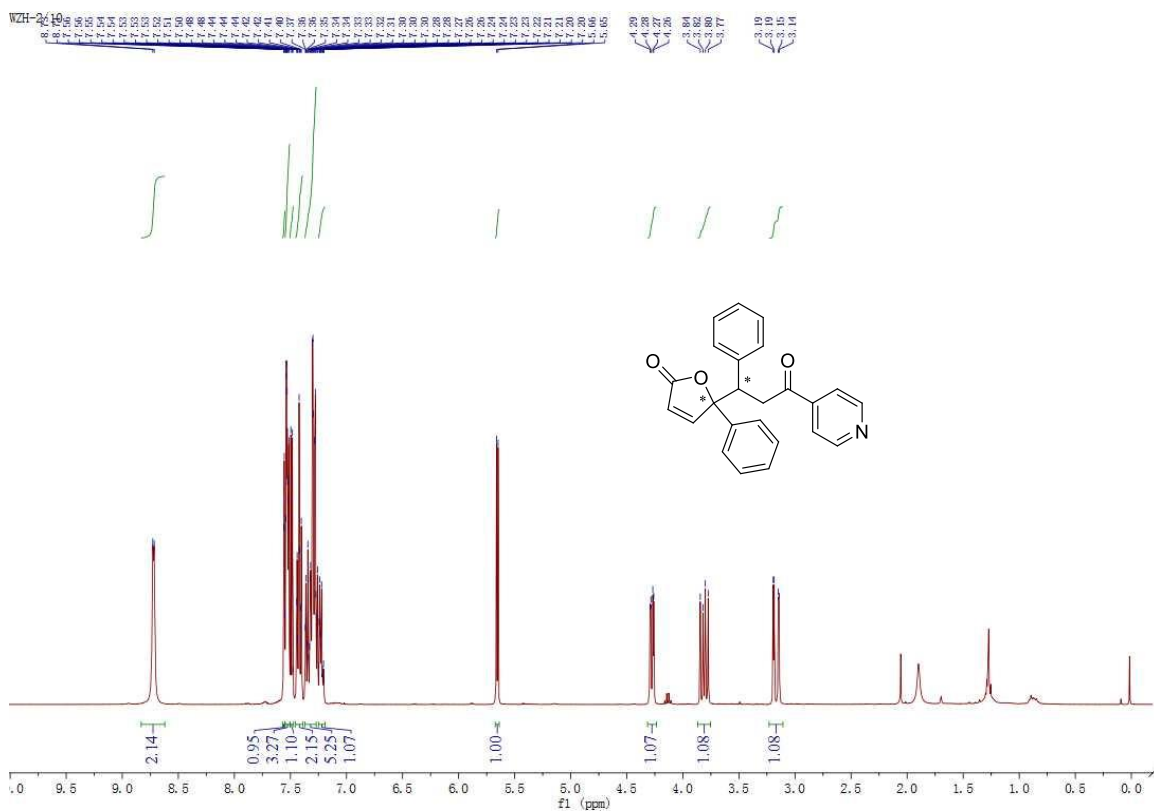


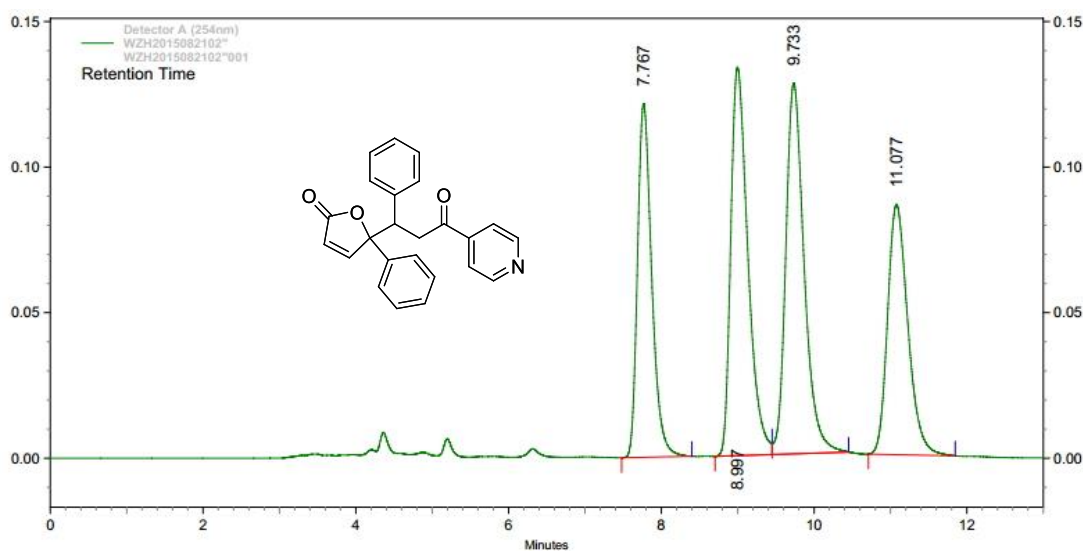
Detector
A
(254nm)

Pk #	Retention Time	Height	Height Percent	Area	Area Percent
1	13.250	3895	1.89	95530	1.80
2	15.080	195273	94.56	4877266	91.87
3	19.313	3510	1.70	125367	2.36
4	31.737	3835	1.86	210763	3.97

Totals		206513	100.00	5308926	100.00
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¹H NMR, ¹³C NMR and HPLC of 12

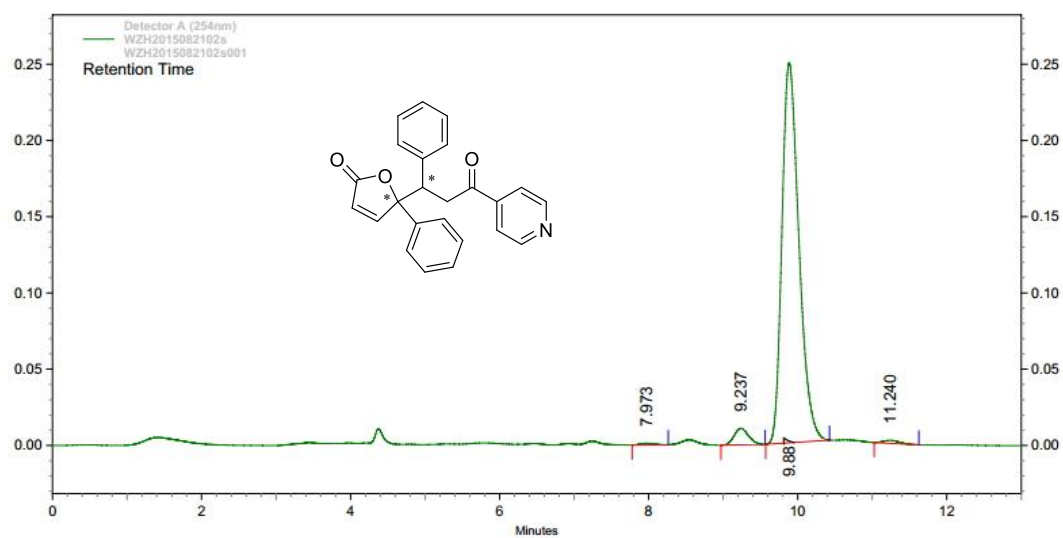




Detector
A
(254nm)

Pk #	Retention Time	Height	Height Percent	Area	Area Percent
1	7.767	121546	25.95	1569934	21.34
2	8.997	133419	28.49	2075534	28.21
3	9.733	127408	27.20	2127633	28.92
4	11.077	85983	18.36	1583946	21.53

Totals		468356	100.00	7357047	100.00
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Detector
A
(254nm)

Pk #	Retention Time	Height	Height Percent	Area	Area Percent
1	7.973	1086	0.41	13029	0.32
2	9.237	10794	4.10	144682	3.51
3	9.887	249213	94.74	3938670	95.49
4	11.240	1952	0.74	28342	0.69

Totals		263045	100.00	4124723	100.00
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