

Supporting Information

Squaramide-Catalyzed Enantioselective Michael Addition of Nitromethane to 2-Enoylazaarenes: Synthesis of Chiral Azaarene-Containing γ -Nitroketones

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1. Experimental section

1.1. General experimental details

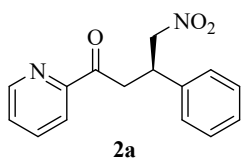
All reagents were purchased from commercial suppliers and used without further purification. All solvents were purified by standard operating method. The crude products were subjected to column chromatography using silica gel (200-300 mesh). The specific rotation was measured by Yimai IP-digi300/8 automatic digital polarimeter (Shanghai, China): The length of the polariscope tube was 0.5 dm, the wavelength was 589.44 nm, and the temperature was 20 °C. NMR spectra were obtained on a Bruker Avance III (400 MHz or 500 MHz, Switzerland) spectrometer. Chemical shifts were published as parts per million (ppm) in δ units with tetramethylsilane (TMS, $\delta = 0.00$ ppm) as the referenced standard. The enantiomeric excesses (*e.e.*) of chiral products were determined by chiral HPLC analysis employing a Shimadzu LC-20AT instrument (Japan) with Daicel Chiralcel AD-H, OD-H, IC or IA column (0.46 cm diameter \times 25 cm length) in comparison with racemic samples and n-hexane/*i*-PrOH as the eluent. Bifunctional catalysts **R1-R3**,¹ **Q4-CN7**,^{2, 3} and substrates⁴⁻¹⁰ from (*E*)-**1a** to (*E*)-**1w** were prepared according to the literature procedures. The absolute configuration of the products was assigned by comparing HPLC and optical rotation with the literature data or by analogy to other compounds.

1.2. Experimental methods

General procedure: 2-Enoylazaarenes **1a-1w** (0.10 mmol), nitromethane (1 mL) and catalyst **Q4** (10 mol%, 0.01 mmol) were added to an 8 mL glassware bottle and the mixture was stirred in an oil bath at 25°C. After the reaction finished (monitored by TLC), the solvent was removed under vacuum on rotary evaporator, and the crude mixture was subjected to flash chromatography on silica gel (petroleum ether/EtOAc = 8:1) to obtain the corresponding products **2a-2w**.

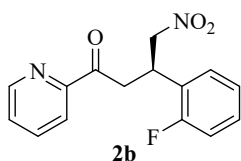
Physical and spectral data of the products **2a-2w** are listed as following:

(*R*)-(+)-4-Nitro-3-phenyl-1-(pyridin-2-yl)butan-1-one (**2a**)¹¹⁻¹³



98% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 95/5, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 22.9$ min, $t_{\text{major}} = 24.9$ min. $[\alpha]_{\text{D}}^{20} = +44.8$ (c 0.50, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.67 (ddd, $J = 4.7, 1.8, 0.9$ Hz, 1H), 7.99 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.83 (td, $J = 7.7, 1.7$ Hz, 1H), 7.48 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.34-7.21 (m, 5H), 4.79 (dd, $J = 12.4, 6.8$ Hz, 1H), 4.68 (dd, $J = 12.4, 8.2$ Hz, 1H), 4.30-4.21 (m, 1H), 3.84 (dd, $J = 18.2, 7.1$ Hz, 1H), 3.63 (dd, $J = 18.2, 7.2$ Hz, 1H).

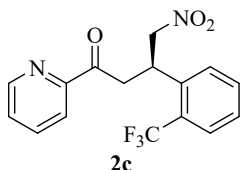
(*R*)-(+)-3-(2-Fluorophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (**2b**)¹²



97% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 90/10, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 13.6$ min, $t_{\text{major}} = 14.5$ min. $[\alpha]_{\text{D}}^{20} = +32.9$ (c 0.51, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.66

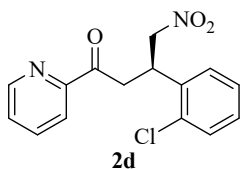
(ddd, $J = 4.7, 1.7, 0.9$ Hz, 1H), 7.99 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.82 (td, $J = 7.7, 1.7$ Hz, 1H), 7.48 (ddd, $J = 7.5, 4.7, 1.2$ Hz, 1H), 7.31 (td, $J = 7.6, 1.8$ Hz, 1H), 7.26-7.21 (m, 1H), 7.13-6.98 (m, 2H), 4.82 (qd, $J = 12.7, 7.3$ Hz, 2H), 4.43 (p, $J = 7.1$ Hz, 1H), 3.86 (dd, $J = 18.5, 6.9$ Hz, 1H), 3.81-3.63 (m, 1H). ^{13}C NMR (126 MHz, CDCl_3): δ 198.56, 161.99, 160.03, 152.68, 149.05, 137.04, 130.06, 130.02, 129.52, 129.45, 127.60, 126.07, 125.97, 124.55, 124.53, 121.89, 116.15, 115.98, 78.15, 78.13, 39.57, 39.56, 34.72.

(*R*)-(+)-4-Nitro-1-(pyridin-2-yl)-3-(2-(trifluoromethyl)phenyl)butan-1-one (2c)¹²



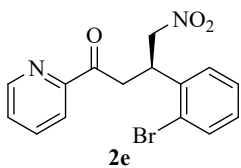
95% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 98/2, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 25.3$ min, $t_{\text{major}} = 27.7$ min. $[\alpha]_{\text{D}}^{20} = +29.6$ (c 0.52, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 8.65 (ddd, $J = 4.8, 1.7, 0.9$ Hz, 1H), 8.01 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.83 (td, $J = 7.8, 1.7$ Hz, 1H), 7.70 (dd, $J = 8.0, 1.3$ Hz, 1H), 7.60-7.43 (m, 3H), 7.43-7.33 (m, 1H), 4.81 (qd, $J = 12.5, 6.9$ Hz, 2H), 4.71-4.63 (m, 1H), 3.86-3.72 (m, 2H). ^{13}C NMR (126 MHz, CDCl_3): δ 198.16, 152.60, 149.01, 138.15, 137.08, 132.40, 128.87, 128.64, 127.74, 127.66, 126.85, 126.80, 126.75, 126.71, 125.29, 123.11, 121.95, 78.71, 40.95, 34.58, 34.57.

(*R*)-(+)-3-(2-Chlorophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2d)¹¹



98% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel OD-H, n-hexane/*i*-PrOH = 85/15, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 13.9$ min, $t_{\text{major}} = 17.0$ min. $[\alpha]_{\text{D}}^{20} = +46.2$ (c 0.52, CH_2Cl_2). ^1H NMR (400 MHz, CDCl_3): δ 8.67 (ddd, $J = 4.7, 1.7, 0.9$ Hz, 1H), 8.00 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.83 (td, $J = 7.7, 1.7$ Hz, 1H), 7.49 (ddd, $J = 7.6, 4.7, 1.2$ Hz, 1H), 7.39 (dd, $J = 7.5, 1.8$ Hz, 1H), 7.34 (dd, $J = 7.5, 2.0$ Hz, 1H), 7.25-7.17 (m, 2H), 4.88-4.81 (m, 2H), 4.78-4.68 (m, 1H), 3.88 (dd, $J = 18.6, 6.5$ Hz, 1H), 3.77 (dd, $J = 18.6, 7.5$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 198.54, 152.69, 149.05, 137.06, 136.47, 133.97, 130.34, 128.89, 128.43, 127.63, 127.34, 121.92, 77.89, 39.44, 35.92.

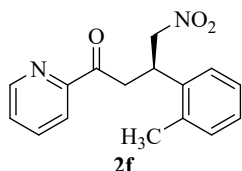
(*R*)-(+)-3-(2-Bromophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2e)¹²



96% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 95/5, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 20.5$ min, $t_{\text{major}} = 22.1$ min. $[\alpha]_{\text{D}}^{20} = +50.8$ (c 0.52, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 8.67

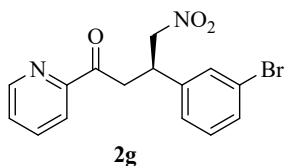
(ddd, $J = 4.8, 1.7, 0.9$ Hz, 1H), 8.00 (dt, $J = 7.8, 1.1$ Hz, 1H), 7.83 (td, $J = 7.7, 1.7$ Hz, 1H), 7.59 (dd, $J = 7.9, 1.3$ Hz, 1H), 7.49 (ddd, $J = 7.6, 4.7, 1.2$ Hz, 1H), 7.33-7.27 (m, 2H), 7.12 (ddd, $J = 8.9, 7.3, 1.7$ Hz, 1H), 4.85-4.78 (m, 2H), 4.76-4.69 (m, 1H), 3.87 (dd, $J = 18.5, 6.4$ Hz, 1H), 3.77 (dd, $J = 18.5, 7.5$ Hz, 1H). ^{13}C NMR (126 MHz, CDCl_3): δ 198.49, 152.69, 149.04, 138.10, 137.06, 133.69, 129.15, 128.16, 127.97, 127.62, 124.67, 121.93, 77.98, 39.62, 38.13.

(R)-(+)-4-Nitro-1-(pyridin-2-yl)-3-(*o*-tolyl)butan-1-one (2f)¹²



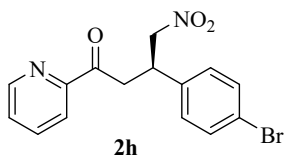
97% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 95/5, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 15.2$ min, $t_{\text{major}} = 16.3$ min. $[\alpha]_{\text{D}}^{20} = +53.8$ (c 0.52, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 8.66 (ddd, $J = 4.8, 1.8, 0.9$ Hz, 1H), 7.97 (dt, $J = 7.8, 1.1$ Hz, 1H), 7.81 (td, $J = 7.7, 1.7$ Hz, 1H), 7.47 (ddd, $J = 7.6, 4.7, 1.2$ Hz, 1H), 7.25-7.21 (m, 1H), 7.19-7.09 (m, 3H), 4.78-4.62 (m, 2H), 4.55 (p, $J = 7.2$ Hz, 1H), 3.85 (dd, $J = 18.1, 7.1$ Hz, 1H), 3.57 (dd, $J = 18.0, 7.0$ Hz, 1H), 2.49 (s, 3H). ^{13}C NMR (126 MHz, CDCl_3): δ 198.77, 152.75, 148.99, 137.54, 137.03, 136.57, 131.05, 127.55, 127.39, 126.55, 125.62, 121.90, 79.34, 40.98, 34.44, 19.59.

(R)-(+)-3-(3-Bromophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2g)^{11, 12}



96% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel IC, n-hexane/*i*-PrOH = 97/3, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{major}} = 33.0$ min, $t_{\text{minor}} = 36.4$ min. $[\alpha]_{\text{D}}^{20} = +39.2$ (c 0.50, CH_2Cl_2). ^1H NMR (400 MHz, CDCl_3): δ 8.67 (dt, $J = 4.8, 1.4$ Hz, 1H), 7.99 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.83 (td, $J = 7.8, 1.7$ Hz, 1H), 7.54-7.44 (m, 2H), 7.38 (dt, $J = 7.8, 1.4$ Hz, 1H), 7.26 (dt, $J = 7.9, 1.3$ Hz, 1H), 7.19 (t, $J = 7.8$ Hz, 1H), 4.86-4.59 (m, 2H), 4.22 (m, 1H), 3.81 (dd, $J = 18.3, 7.0$ Hz, 1H), 3.61 (dd, $J = 18.3, 7.2$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 198.24, 152.58, 149.05, 141.63, 137.10, 130.98, 130.71, 130.51, 127.71, 126.43, 122.97, 121.97, 79.45, 40.62, 38.92.

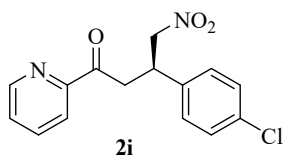
(R)-(+)-3-(4-Bromophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2h)^{11, 12}



98% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 90/10, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 18.9$ min, $t_{\text{major}} = 21.7$ min. $[\alpha]_{\text{D}}^{20} = +35.6$ (c 0.50, CH_2Cl_2). ^1H NMR (400 MHz, CDCl_3): δ 8.66 (dt, $J = 4.7, 1.2$ Hz, 1H), 7.99 (d, $J = 7.8$ Hz, 1H), 7.83 (td, $J = 7.7, 1.7$ Hz, 1H), 7.49 (ddd, $J = 7.6, 4.7, 1.3$ Hz, 1H), 7.47-7.41 (m, 2H), 7.25-7.14 (m, 2H), 4.82-4.60 (m, 2H), 4.28-4.16 (m, 1H), 3.81 (dd, $J = 18.2, 7.3$ Hz, 1H), 3.59 (dd, $J = 18.2, 6.9$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 198.30,

152.61, 149.04, 138.29, 137.10, 132.09, 129.37, 127.68, 121.95, 121.71, 79.56, 40.57, 38.82.

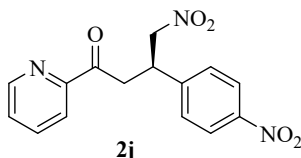
(R)-(+)-3-(4-Chlorophenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2i)^{11, 12}



97% yield, white solid, 98% ee determined by HPLC (Daicel Chiralcel IA, n-hexane/i-PrOH = 95/5, 30°C, flow rate 1.0 mL/min, UV detection at 254

nm): $t_{\text{minor}} = 27.5$ min, $t_{\text{major}} = 29.8$ min. $[\alpha]_D^{20} = +52.0$ (c 0.50, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.66 (ddd, $J = 4.8, 1.8, 0.9$ Hz, 1H), 7.98 (dt, $J = 8.0, 1.1$ Hz, 1H), 7.82 (td, $J = 7.7, 1.8$ Hz, 1H), 7.48 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.30-7.24 (m, 4H), 4.82-4.61 (m, 2H), 4.28-4.19 (m, 1H), 3.80 (dd, $J = 18.2, 7.3$ Hz, 1H), 3.59 (dd, $J = 18.2, 7.0$ Hz, 1H). ¹³C NMR (126 MHz, CDCl₃): δ 198.34, 152.61, 149.04, 137.74, 137.10, 133.60, 129.14, 129.02, 127.69, 121.95, 79.65, 40.62, 38.75.

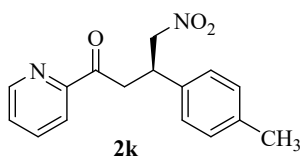
(R)-(+)-4-Nitro-3-(4-nitrophenyl)-1-(pyridin-2-yl)butan-1-one (2j)¹¹



96% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/i-PrOH = 75/25, 30°C, flow rate 1.0 mL/min, UV

detection at 254 nm): $t_{\text{minor}} = 17.8$ min, $t_{\text{major}} = 23.7$ min. $[\alpha]_D^{20} = +47.2$ (c 0.50, CH₂Cl₂). ¹H NMR (400 MHz, CDCl₃): δ 8.67 (dt, $J = 4.7, 1.2$ Hz, 1H), 8.29-8.07 (m, 2H), 8.06-7.96 (m, 1H), 7.92-7.78 (m, 1H), 7.67-7.40 (m, 3H), 4.92-4.67 (m, 2H), 4.46-4.34 (m, 1H), 3.87 (dd, $J = 18.4, 7.5$ Hz, 1H), 3.66 (dd, $J = 18.4, 6.7$ Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 197.88, 152.37, 149.11, 147.46, 146.76, 137.20, 128.77, 127.90, 124.16, 121.99, 79.06, 40.42, 39.06.

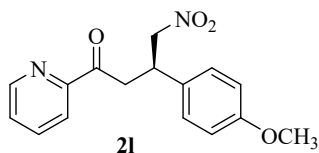
(R)-(+)-4-Nitro-1-(pyridin-2-yl)-3-(p-tolyl)butan-1-one (2k)¹²



97% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/i-PrOH = 95/5, 30°C, flow rate 1.0 mL/min, UV detection

at 254 nm): $t_{\text{minor}} = 19.5$ min, $t_{\text{major}} = 22.3$ min. $[\alpha]_D^{20} = +52.9$ (c 0.51, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.66 (ddd, $J = 4.9, 1.8, 0.9$ Hz, 1H), 7.98 (dt, $J = 7.8, 1.1$ Hz, 1H), 7.81 (td, $J = 7.7, 1.7$ Hz, 1H), 7.48 (ddd, $J = 7.6, 4.7, 1.2$ Hz, 1H), 7.23-7.16 (m, 2H), 7.12 (d, $J = 7.9$ Hz, 2H), 4.76 (dd, $J = 12.4, 6.8$ Hz, 1H), 4.65 (dd, $J = 12.4, 8.3$ Hz, 1H), 4.30-4.11 (m, 1H), 3.81 (dd, $J = 18.2, 7.2$ Hz, 1H), 3.61 (dd, $J = 18.2, 7.1$ Hz, 1H), 2.29 (s, 3H). ¹³C NMR (126 MHz, CDCl₃): δ 198.70, 152.80, 149.00, 137.40, 137.01, 136.20, 129.63, 127.53, 127.44, 121.92, 80.06, 40.82, 38.97, 21.05.

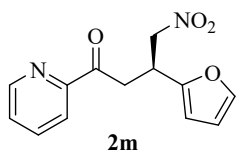
(R)-(+)-3-(4-Methoxyphenyl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2l)^{11, 12}



90% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel S6

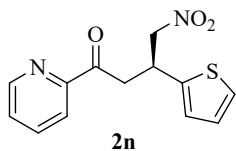
AD-H, n-hexane/i-PrOH = 90/10, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 21.5$ min, $t_{\text{major}} = 23.6$ min. $[\alpha]_{\text{D}}^{20} = +44.6$ (c 0.52, CH₂Cl₂). ¹H NMR (400 MHz, CDCl₃): δ 8.66 (ddd, $J = 4.8, 1.7, 1.0$ Hz, 1H), 7.98 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.81 (td, $J = 7.7, 1.7$ Hz, 1H), 7.47 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.25-7.18 (m, 2H), 6.88-6.77 (m, 2H), 4.80-4.59 (m, 2H), 4.25-4.15 (m, 1H), 3.80 (dd, $J = 18.1, 7.3$ Hz, 1H), 3.76 (s, 3H), 3.58 (dd, $J = 18.1, 7.1$ Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 198.72, 159.00, 152.79, 149.00, 137.03, 131.17, 128.64, 127.54, 121.92, 114.32, 80.17, 55.23, 40.86, 38.64.

(S)-(+)-3-(Furan-2-yl)-4-nitro-1-(pyridin-2-yl)butan-1-one (2m)^{11, 12}



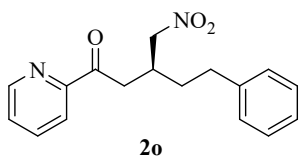
80% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel OD-H, n-hexane/i-PrOH = 85/15, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 10.8$ min, $t_{\text{major}} = 12.0$ min $[\alpha]_{\text{D}}^{20} = +26.7$ (c 0.54, CH₂Cl₂). ¹H NMR (400 MHz, CDCl₃): δ 8.68 (ddd, $J = 4.8, 1.7, 0.9$ Hz, 1H), 8.03 (dt, $J = 8.0, 1.1$ Hz, 1H), 7.85 (td, $J = 7.7, 1.7$ Hz, 1H), 7.50 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.33 (dd, $J = 1.8, 0.8$ Hz, 1H), 6.35-6.15 (m, 2H), 4.77 (d, $J = 6.9$ Hz, 2H), 4.41-4.31 (m, 1H), 3.84 (dd, $J = 18.4, 6.7$ Hz, 1H), 3.64 (dd, $J = 18.4, 7.2$ Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 198.34, 152.65, 152.16, 149.08, 142.26, 137.06, 127.64, 121.94, 110.42, 107.12, 77.47, 38.47, 33.16.

(S)-(+)-4-Nitro-1-(pyridin-2-yl)-3-(thiophen-2-yl)butan-1-one (2n)^{11, 12}



87% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel OD-H, n-hexane/i-PrOH = 85/15, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 15.5$ min, $t_{\text{major}} = 18.7$ min $[\alpha]_{\text{D}}^{20} = +55.6$ (c 0.50, CH₂Cl₂). ¹H NMR (400 MHz, CDCl₃): δ 8.68 (ddd, $J = 4.8, 1.7, 0.9$ Hz, 1H), 8.03 (dt, $J = 8.0, 1.1$ Hz, 1H), 7.85 (td, $J = 7.7, 1.7$ Hz, 1H), 7.50 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.33 (dd, $J = 1.8, 0.8$ Hz, 1H), 6.28 (dd, $J = 3.3, 1.9$ Hz, 1H), 6.20 (dt, $J = 3.2, 0.8$ Hz, 1H), 4.77 (d, $J = 6.9$ Hz, 2H), 4.41-4.31 (m, 1H), 3.84 (dd, $J = 18.4, 6.7$ Hz, 1H), 3.64 (dd, $J = 18.4, 7.2$ Hz, 1H). ¹³C NMR (126 MHz, CDCl₃): δ 198.22, 152.64, 149.07, 142.10, 137.06, 127.66, 127.07, 125.55, 124.65, 121.97, 80.17, 77.25, 41.67, 34.74.

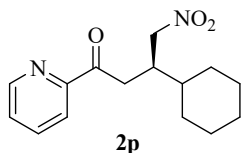
(S)-(+)-3-(Nitromethyl)-5-phenyl-1-(pyridin-2-yl)pentan-1-one (2o)



97% yield, colourless oil, 97% ee determined by HPLC (Daicel Chiralcel IA, n-hexane/i-PrOH = 98/2, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 24.4$ min, $t_{\text{major}} = 25.8$ min. $[\alpha]_{\text{D}}^{20} = +8.6$ (c 0.35, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.68 (dt, $J = 4.8, 1.4$ Hz, 1H), 8.05 (dt, $J = 7.8, 1.2$ Hz, 1H), 7.86 (td, $J = 7.7, 1.7$ Hz, 1H), 7.50 (ddd, $J = 7.6, 4.8, 1.3$ Hz, 1H), 7.32-7.25 (m, 2H), 7.18 (ddd, $J = 8.5, 7.1, 1.6$ Hz, 3H), 4.68-4.49 (m, 2H), 3.45

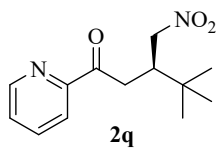
(d, $J = 6.5$ Hz, 2H), 2.97-2.89 (m, 1H), 2.74 (ddd, $J = 10.7, 6.3, 2.8$ Hz, 2H), 1.90-1.77 (m, 2H). ^{13}C NMR (126 MHz, CDCl_3): δ 199.76, 152.94, 149.03, 141.00, 137.07, 128.54, 128.32, 127.55, 126.17, 121.86, 78.69, 38.88, 33.53, 33.08, 32.88.

(R)-(+)-3-Cyclohexyl-4-nitro-1-(pyridin-2-yl)butan-1-one (2p)¹⁴



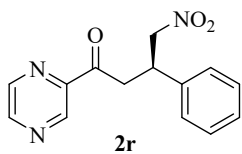
90% yield, colourless oil, 95% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 85/15, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 6.8$ min, $t_{\text{major}} = 7.6$ min. $[\alpha]_{\text{D}}^{20} = +9.6$ (c 0.31, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 8.68 (d, $J = 4.7$ Hz, 1H), 8.04 (d, $J = 7.8$ Hz, 1H), 7.86 (td, $J = 7.7, 1.7$ Hz, 1H), 7.50 (dd, $J = 7.5, 4.8$ Hz, 1H), 4.52 (d, $J = 6.7$ Hz, 2H), 3.48 (dd, $J = 18.4, 5.0$ Hz, 1H), 3.27 (dd, $J = 18.4, 7.9$ Hz, 1H), 2.97-2.72 (m, 1H), 1.80-1.73 (m, 4H), 1.70-1.64 (m, 1H), 1.51 (m, 1H), 1.30-1.02 (m, 5H).

(R)-(+)-4,4-Dimethyl-3-(nitromethyl)-1-(pyridin-2-yl)pentan-1-one (2q)¹¹



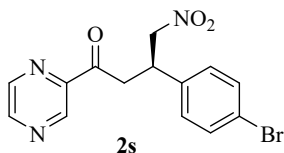
30% yield, colourless oil, 91% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 98/2, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 13.5$ min, $t_{\text{major}} = 14.3$ min. $[\alpha]_{\text{D}}^{20} = +8.8$ (c 0.14, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 8.68 (ddd, $J = 4.7, 1.8, 0.9$ Hz, 1H), 8.04 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.84 (td, $J = 7.7, 1.8$ Hz, 1H), 7.49 (ddd, $J = 7.6, 4.8, 1.2$ Hz, 1H), 4.60 (dd, $J = 12.6, 4.6$ Hz, 1H), 4.35 (dd, $J = 12.6, 8.0$ Hz, 1H), 3.59 (dd, $J = 18.3, 4.4$ Hz, 1H), 3.24 (dd, $J = 18.3, 7.5$ Hz, 1H), 3.07-2.91 (m, 1H), 1.00 (s, 9H).

(R)-(+)-4-Nitro-3-phenyl-1-(pyrazin-2-yl)butan-1-one (2r)¹⁴



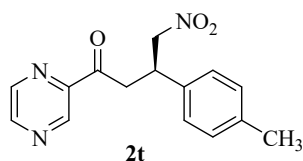
97% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 85/15, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 15.9$ min, $t_{\text{major}} = 17.2$ min. $[\alpha]_{\text{D}}^{20} = +27.9$ (c 0.51, CH_2Cl_2). ^1H NMR (500 MHz, CDCl_3): δ 9.17 (d, $J = 1.5$ Hz, 1H), 8.77 (d, $J = 2.5$ Hz, 1H), 8.63 (dd, $J = 2.5, 1.5$ Hz, 1H), 7.42-7.15 (m, 5H), 4.86-4.61 (m, 2H), 4.25 (m, 1H), 3.82 (dd, $J = 18.3, 7.4$ Hz, 1H), 3.60 (dd, $J = 18.3, 6.8$ Hz, 1H). ^{13}C NMR (126 MHz, CDCl_3): δ 198.25, 152.54, 149.06, 141.66, 137.13, 130.96, 130.72, 130.53, 127.75, 126.44, 122.94, 121.97, 79.45, 40.62, 38.90.

(R)-(+)-3-(4-Bromophenyl)-4-nitro-1-(pyrazin-2-yl)butan-1-one (2s)



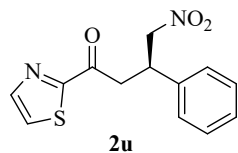
97% yield, white solid, 97% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/i-PrOH = 70/30, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 11.7$ min, $t_{\text{major}} = 13.9$ min. $[\alpha]_{\text{D}}^{20} = +12.4$ (c 0.58, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 9.18 (d, $J = 1.5$ Hz, 1H), 8.78 (d, $J = 2.4$ Hz, 1H), 8.63 (t, $J = 2.0$ Hz, 1H), 7.54-7.40 (m, 2H), 7.26-7.14 (m, 2H), 4.89-4.57 (m, 2H), 4.22 (t, $J = 7.3$ Hz, 1H), 3.79 (dd, $J = 18.4, 7.5$ Hz, 1H), 3.57 (dd, $J = 18.4, 6.6$ Hz, 1H). ¹³C NMR (126 MHz, CDCl₃): δ 197.80, 148.42, 146.75, 143.72, 143.60, 137.80, 132.23, 129.31, 121.94, 79.39, 40.58, 38.51.

(R)-(+)-4-Nitro-1-(pyrazin-2-yl)-3-(p-tolyl)butan-1-one(2t)



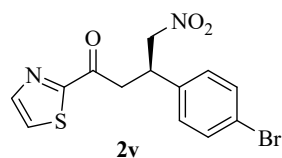
96% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/i-PrOH = 70/30, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 10.2$ min, $t_{\text{major}} = 11.6$ min. $[\alpha]_{\text{D}}^{20} = +54.8$ (c 0.46, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 9.18 (s, 1H), 8.77 (s, 1H), 8.64 (s, 1H), 7.22-7.08 (m, 4H), 4.83-4.62 (m, 2H), 4.25-4.17 (m, 1H), 3.80 (dd, $J = 18.2, 7.5$ Hz, 1H), 3.57 (dd, $J = 18.2, 6.7$ Hz, 1H), 2.30 (s, 3H). ¹³C NMR (126 MHz, CDCl₃): δ 198.21, 148.22, 146.97, 143.69, 143.61, 137.67, 135.70, 129.74, 127.39, 79.90, 40.82, 38.73, 21.08.

(R)-(+)-4-Nitro-3-phenyl-1-(thiazol-2-yl)butan-1-one (2u)¹⁴



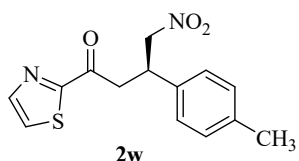
98% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel OD-H, n-hexane/i-PrOH = 80/20, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{major}} = 19.3$ min, $t_{\text{minor}} = 21.7$ min. $[\alpha]_{\text{D}}^{20} = +9.8$ (c 0.51, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.00 (d, $J = 3.0$ Hz, 1H), 7.69 (d, $J = 3.0$ Hz, 1H), 7.37-7.24 (m, 5H), 4.83-4.66 (m, 2H), 4.31-4.22 (m, 1H), 3.77 (dd, $J = 17.8, 7.3$ Hz, 1H), 3.58 (dd, $J = 17.8, 7.0$ Hz, 1H). ¹³C NMR (126 MHz, CDCl₃): 190.62, 166.22, 144.87, 138.58, 129.08, 127.98, 127.55, 126.90, 79.61, 41.49, 39.18.

(R)-(+)-3-(4-Bromophenyl)-4-nitro-1-(thiazol-2-yl)butan-1-one (2v)¹⁴



98% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/i-PrOH = 95/05, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{minor}} = 40.0$ min, $t_{\text{major}} = 43.5$ min. $[\alpha]_{\text{D}}^{20} = +2.4$ (c 0.58, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.00 (d, $J = 3.0$ Hz, 1H), 7.71 (d, $J = 3.0$ Hz, 1H), 7.52-7.39 (m, 2H), 7.24-7.13 (m, 2H), 4.86-4.59 (m, 2H), 4.22 (p, $J = 7.1$ Hz, 1H), 3.74 (dd, $J = 17.8, 7.6$ Hz, 1H), 3.54 (dd, $J = 17.8, 6.9$ Hz, 1H). ¹³C NMR (126 MHz, CDCl₃): δ 190.32, 165.99, 144.93, 137.61, 132.21, 129.33, 127.11, 121.95, 79.28, 41.25, 38.67.

(R)-(+)-4-Nitro-1-(thiazol-2-yl)-3-(*p*-tolyl)butan-1-one (2w)

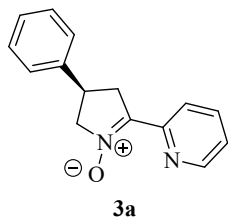


97% yield, white solid, 96% ee determined by HPLC (Daicel Chiralcel OD-H, n-hexane/*i*-PrOH = 90/10, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{major}} = 24.9$ min, $t_{\text{minor}} = 31.7$ min. $[\alpha]_{\text{D}}^{20} = +5.6$ (c 0.58, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 8.00 (d, $J = 3.0$ Hz, 1H), 7.69 (d, $J = 3.0$ Hz, 1H), 7.21-7.10 (m, 4H), 4.89-4.58 (m, 2H), 4.27-4.18 (m, 1H), 3.75 (dd, $J = 17.7, 7.4$ Hz, 1H), 3.56 (dd, $J = 17.7, 7.0$ Hz, 1H), 2.30 (s, 3H). ¹³C NMR (126 MHz, CDCl₃): δ 190.70, 166.28, 144.85, 137.69, 135.49, 129.75, 127.38, 126.85, 79.79, 41.52, 38.84, 21.09.

Synthesis of 3a¹⁵⁻¹⁸

A solution of **2a** (1.11 g, 4.1 mmol) and Zn dust (533 mg, 8.2 mmol) in THF/saturated NH₄Cl (v/v 1:1, 12 mL) was stirred at room temperature for 2.5 h. The resulting mixture was extracted with ethyl acetate and dried over MgSO₄. Purification by silica gel column chromatography (PE/EA = 1/1) furnished the product **3a** as an oil (350 mg, 1.47 mmol).

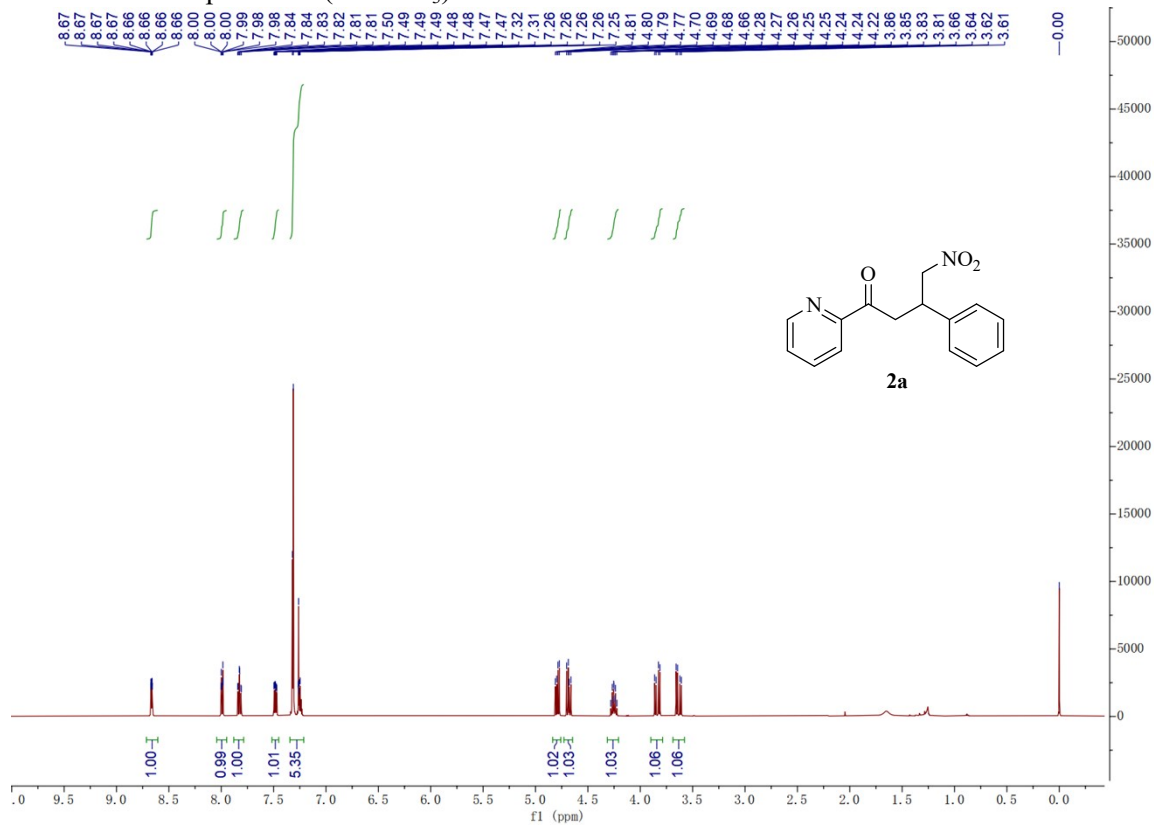
(R)-(-)-2-(3-Phenyl-3,4-dihydro-2H-pyrrol-5-yl)pyridine *N*-oxide (3a)



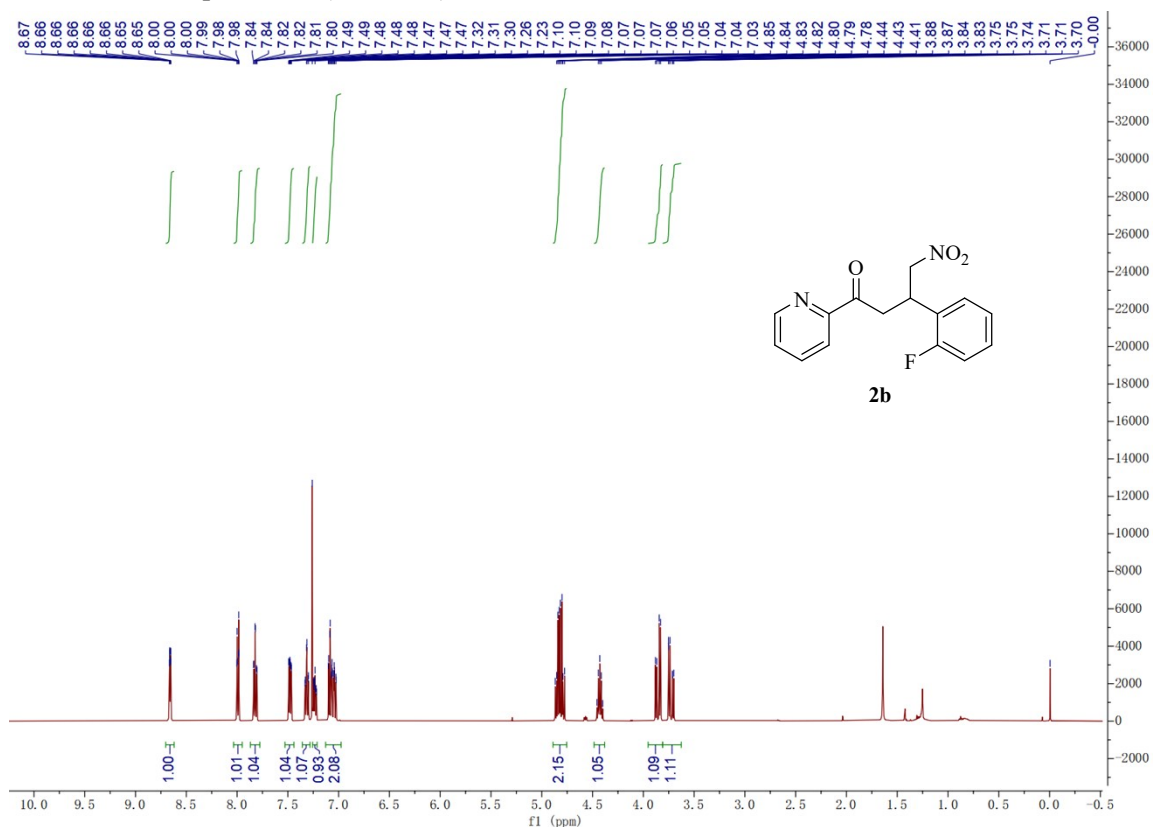
36% yield, colourless oil, 98% ee determined by HPLC (Daicel Chiralcel AD-H, n-hexane/*i*-PrOH = 90/10, 30°C, flow rate 1.0 mL/min, UV detection at 254 nm): $t_{\text{major}} = 22.1$ min, $t_{\text{minor}} = 24.8$ min. $[\alpha]_{\text{D}}^{20} = -63.0$ (c 0.34, CH₂Cl₂). ¹H NMR (500 MHz, CDCl₃): δ 9.32 (dd, $J = 8.1, 1.2$ Hz, 1H), 8.66 (ddd, $J = 4.8, 1.8, 1.0$ Hz, 1H), 7.84 (td, $J = 7.9, 1.8$ Hz, 1H), 7.41-7.27 (m, 6H), 4.69-4.61 (m, 1H), 4.42 (ddt, $J = 14.1, 7.6, 2.2$ Hz, 1H), 3.93-3.76 (m, 2H), 3.49-3.41 (m, 1H). ¹³C NMR (126 MHz, CDCl₃): δ 149.37, 147.93, 142.33, 141.74, 136.70, 129.08, 127.33, 126.73, 124.53, 123.46, 72.02, 39.02, 36.00. MS (ESI): m/z [M+H]⁺ 239.1; [M+Na]⁺ 261.1.

2. NMR spectra of products 2a-2w and 3a

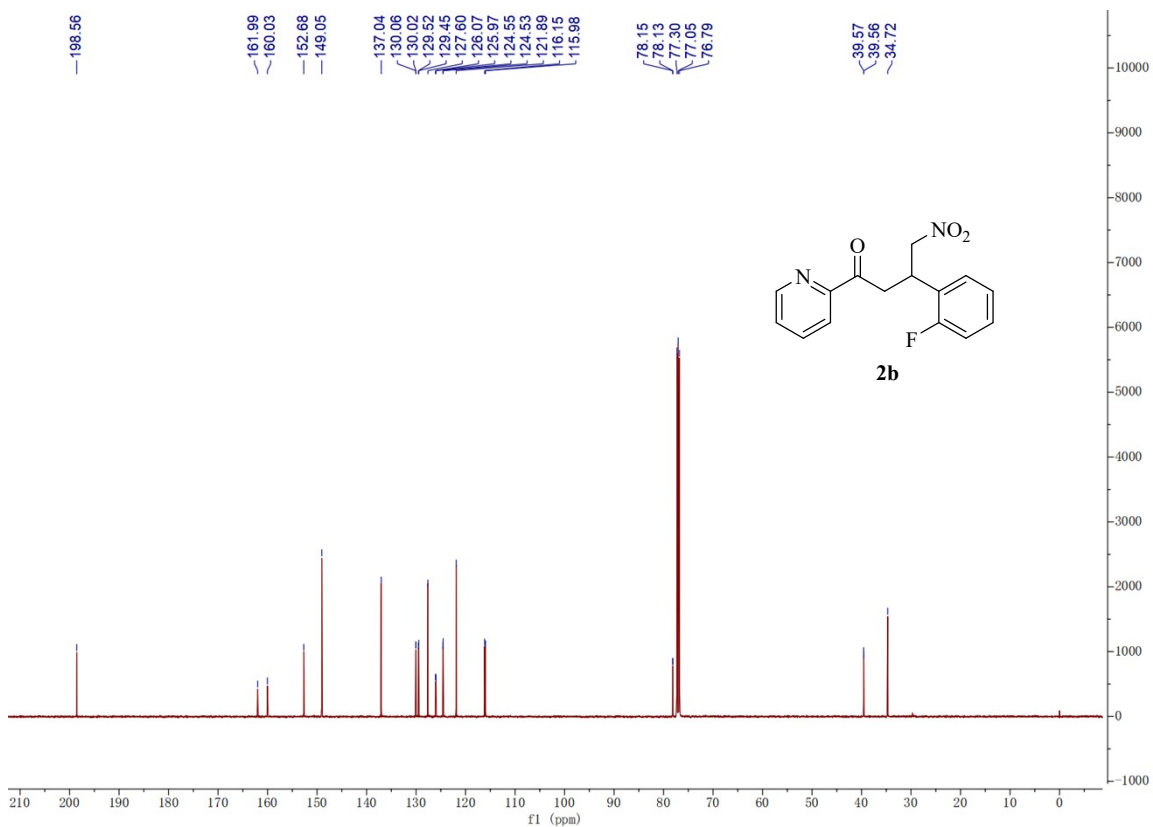
^1H NMR of compound **2a** (in CDCl_3):



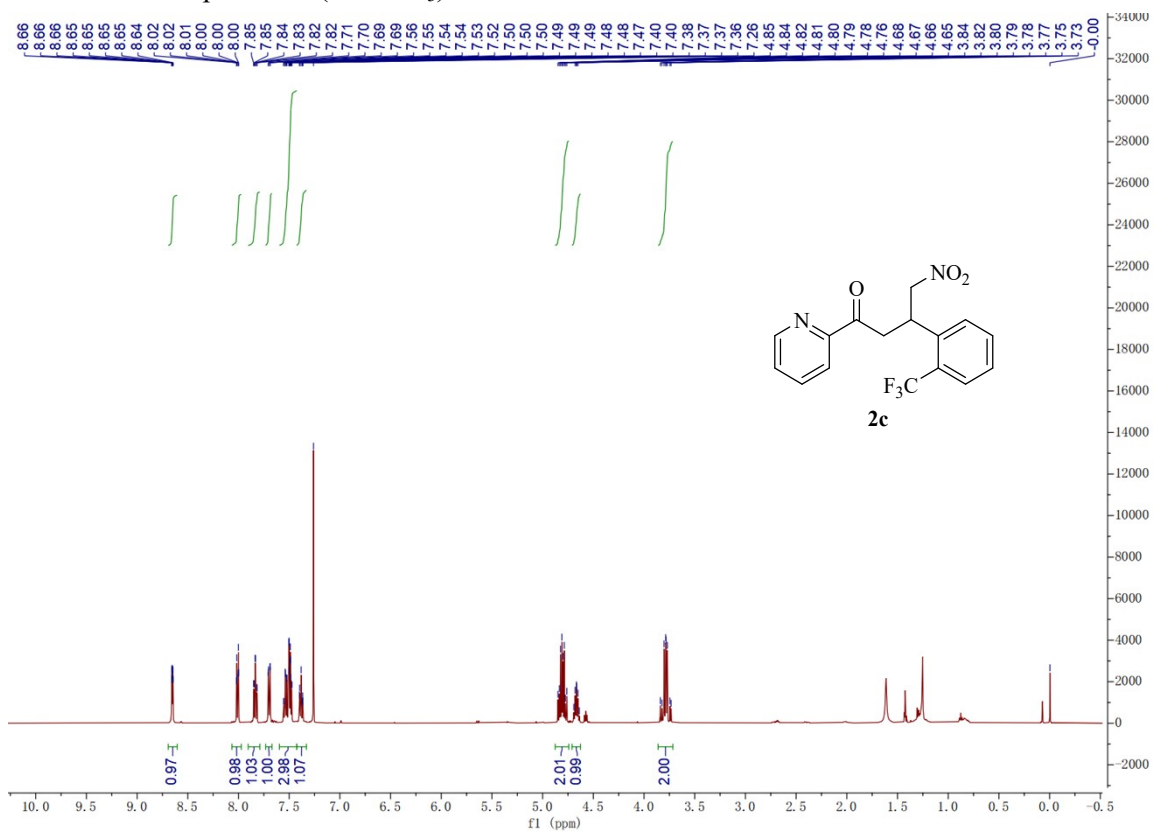
¹H NMR of compound **2b** (in CDCl₃):



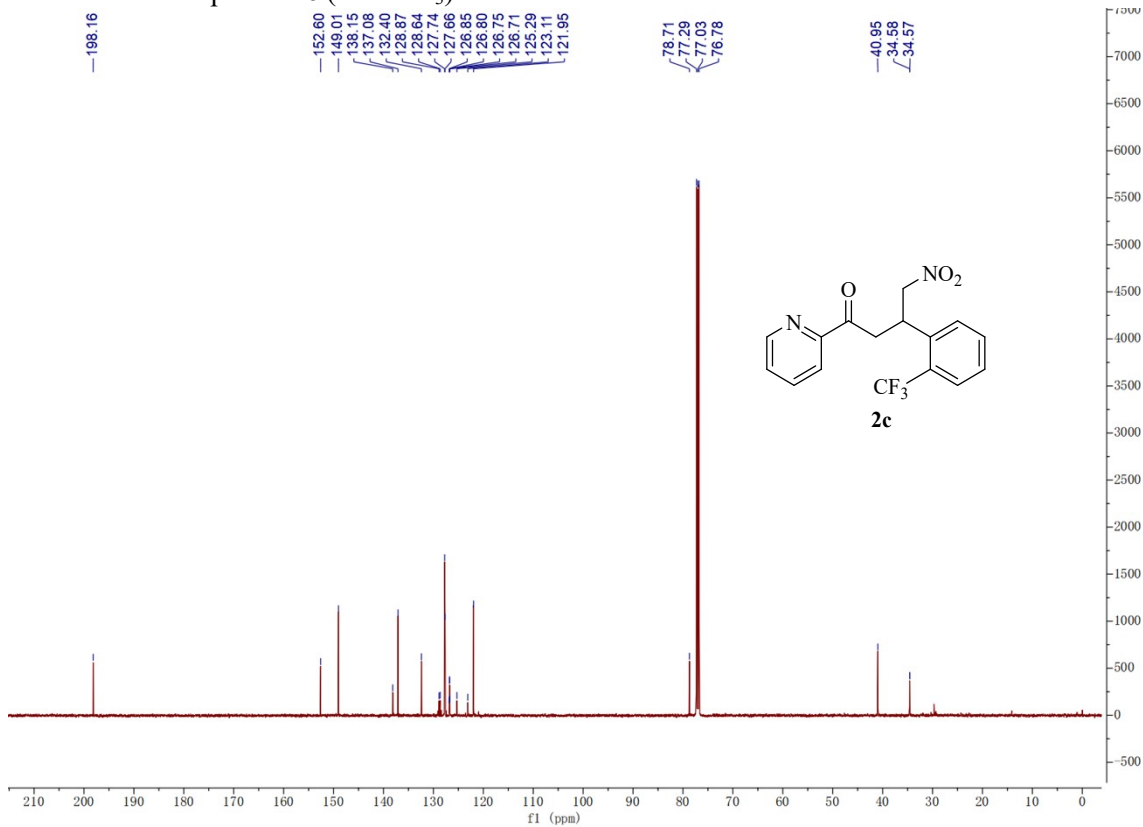
¹³C NMR of compound **2b** (in CDCl₃):



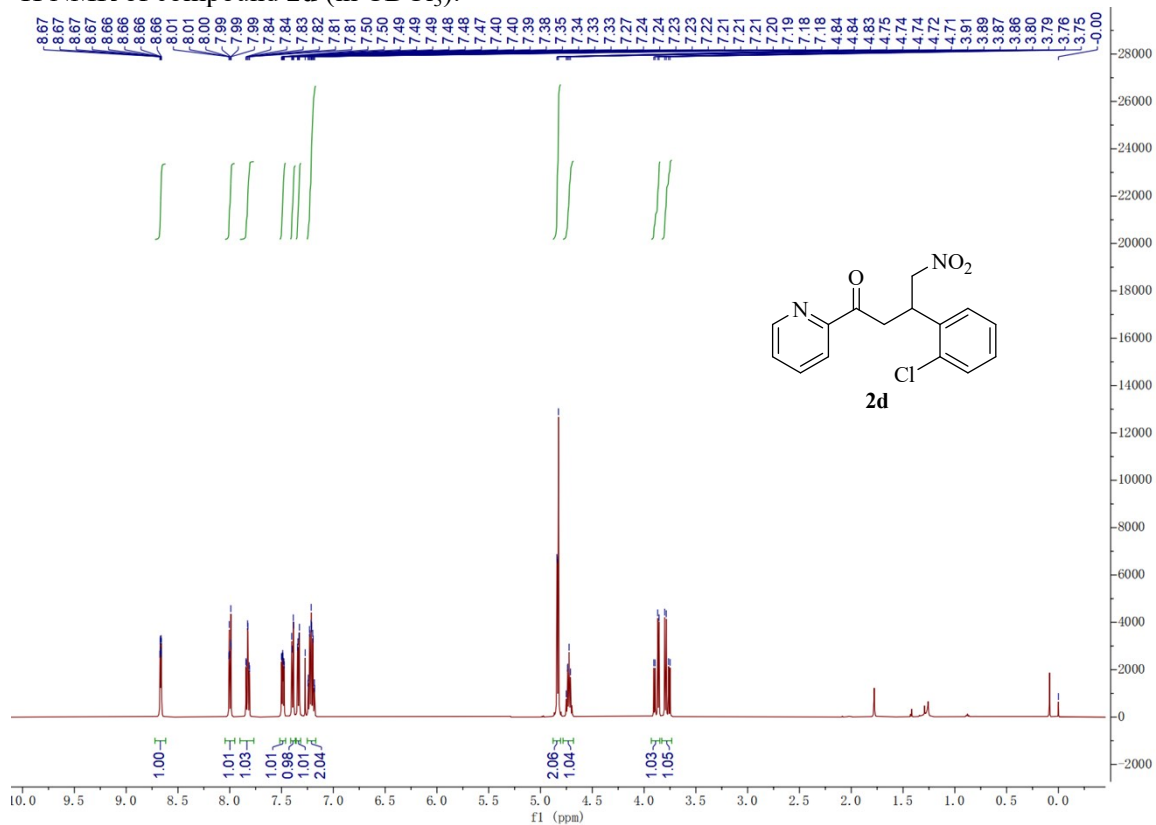
¹H NMR of compound **2c** (in CDCl₃):



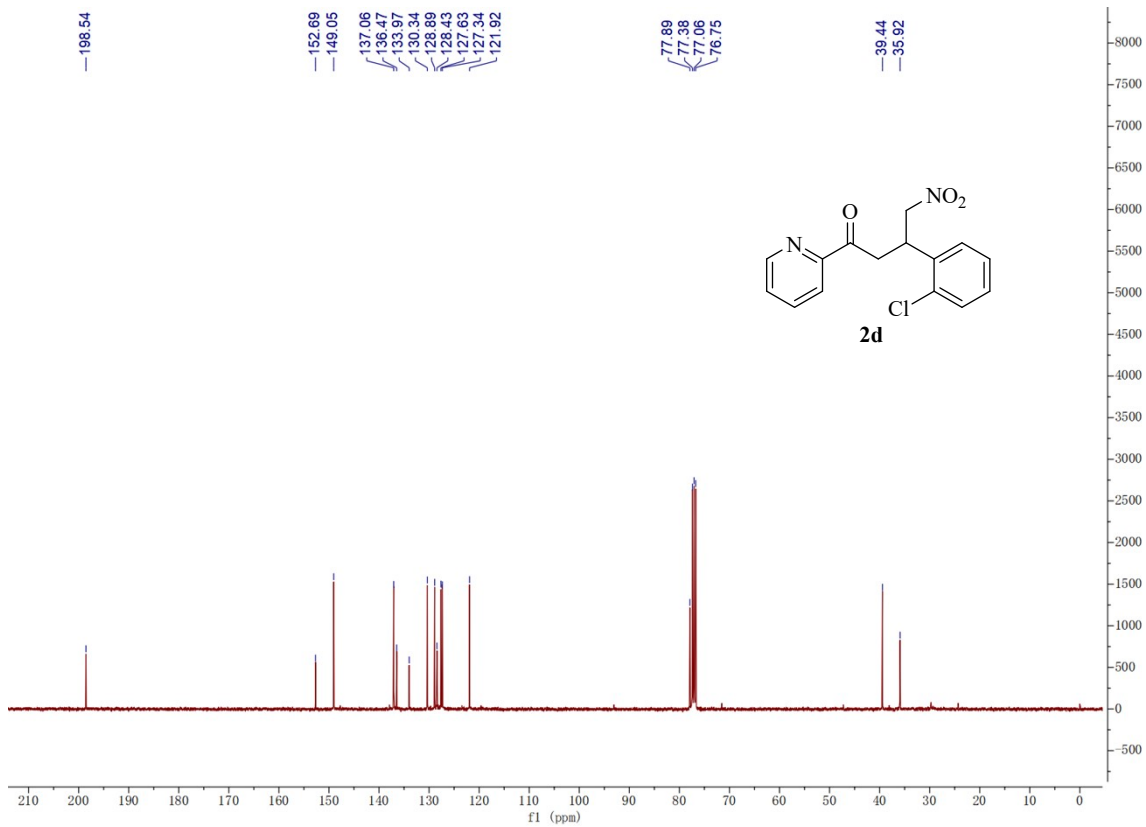
¹³C NMR of compound **2c** (in CDCl₃):



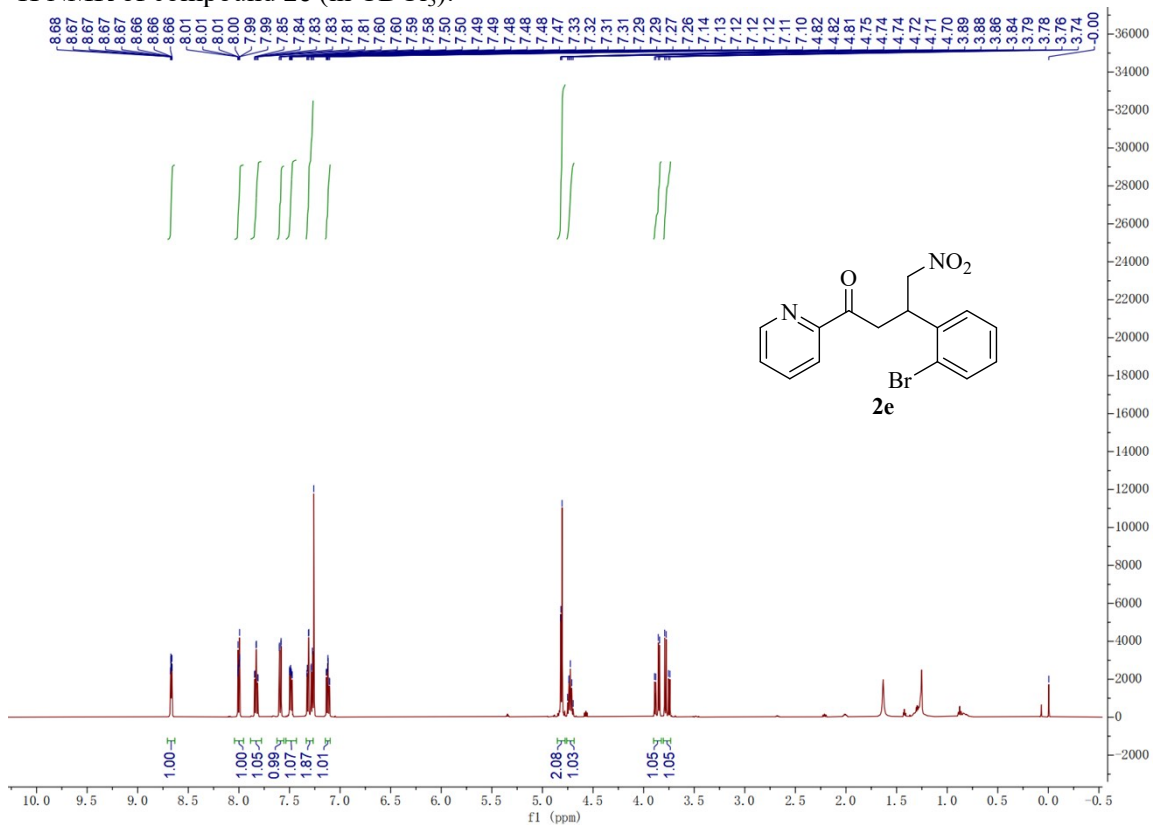
¹H NMR of compound **2d** (in CDCl₃):



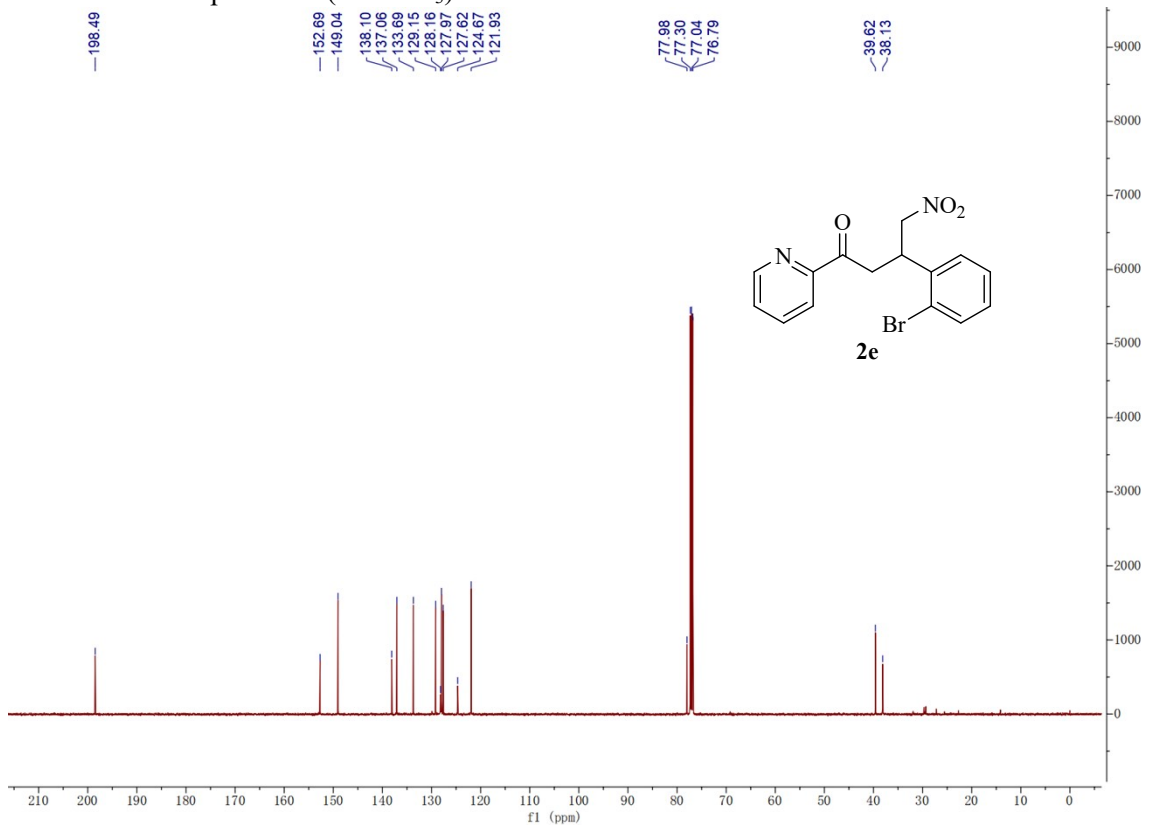
¹³C NMR of compound **2d** (in CDCl₃):



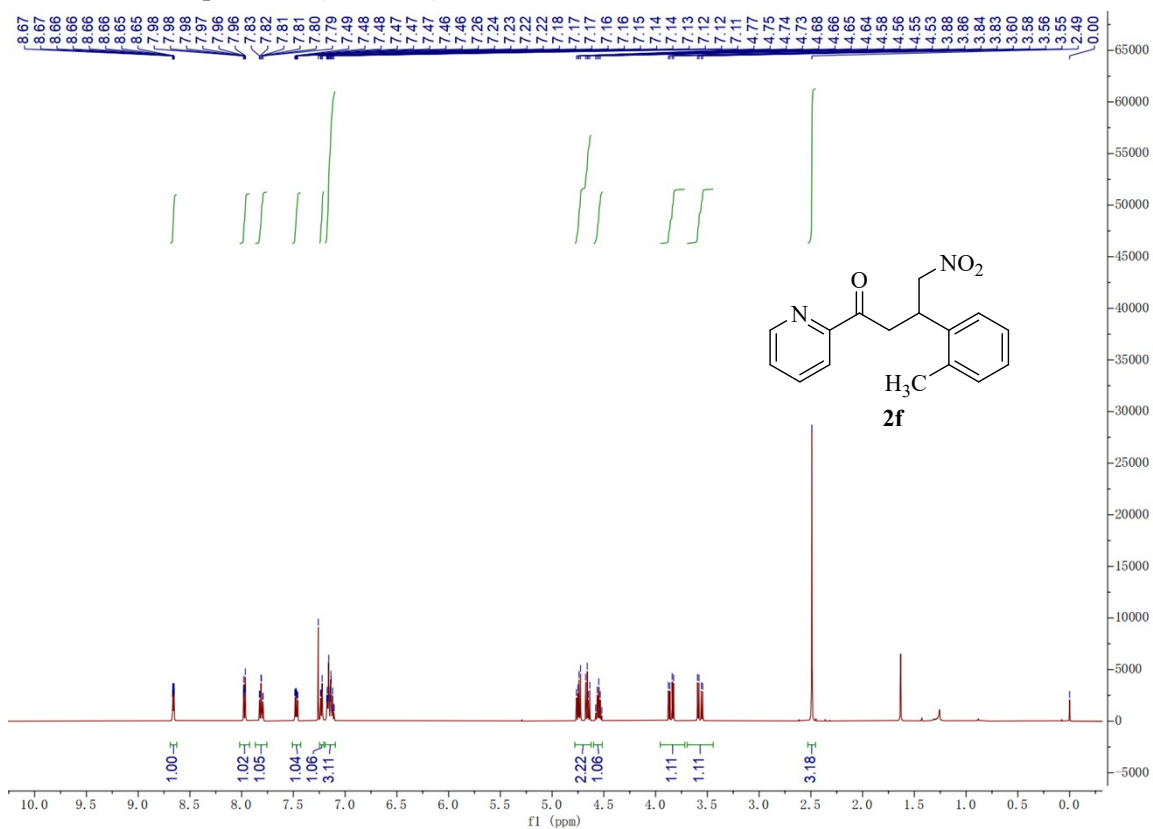
^1H NMR of compound **2e** (in CDCl_3):



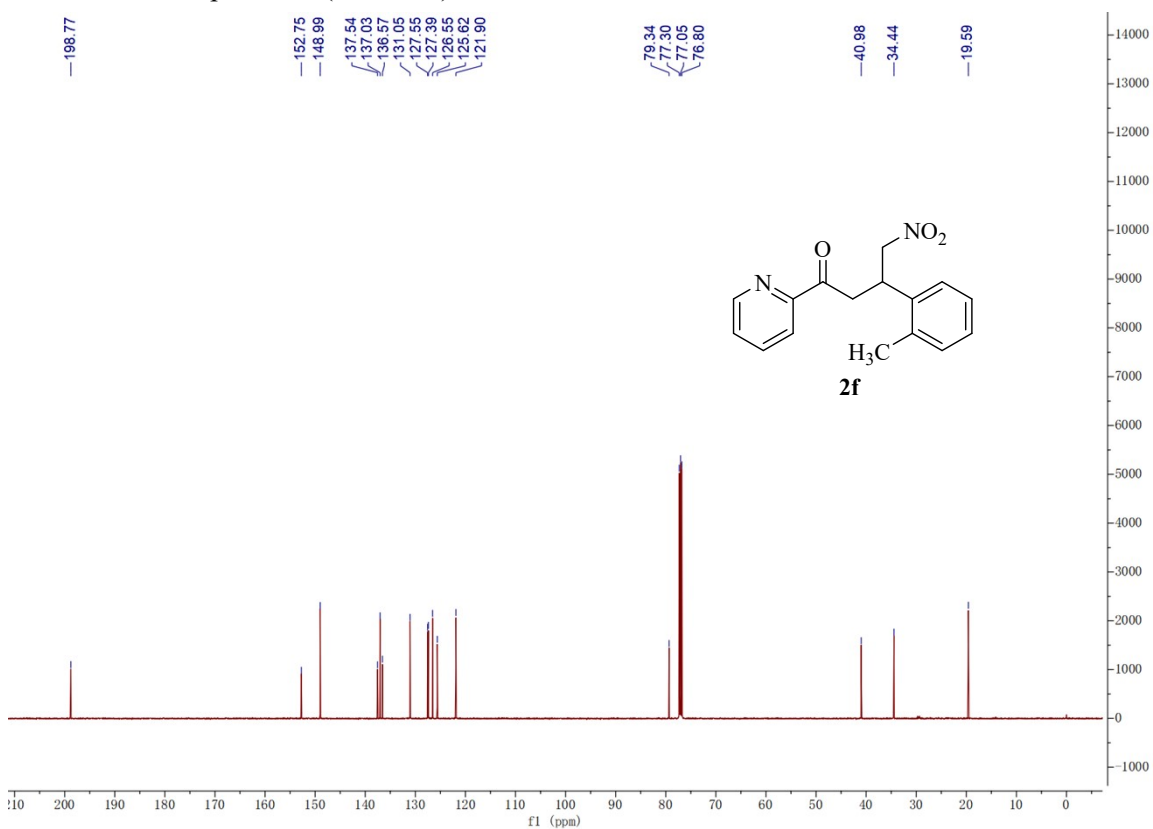
^{13}C NMR of compound **2e** (in CDCl_3):



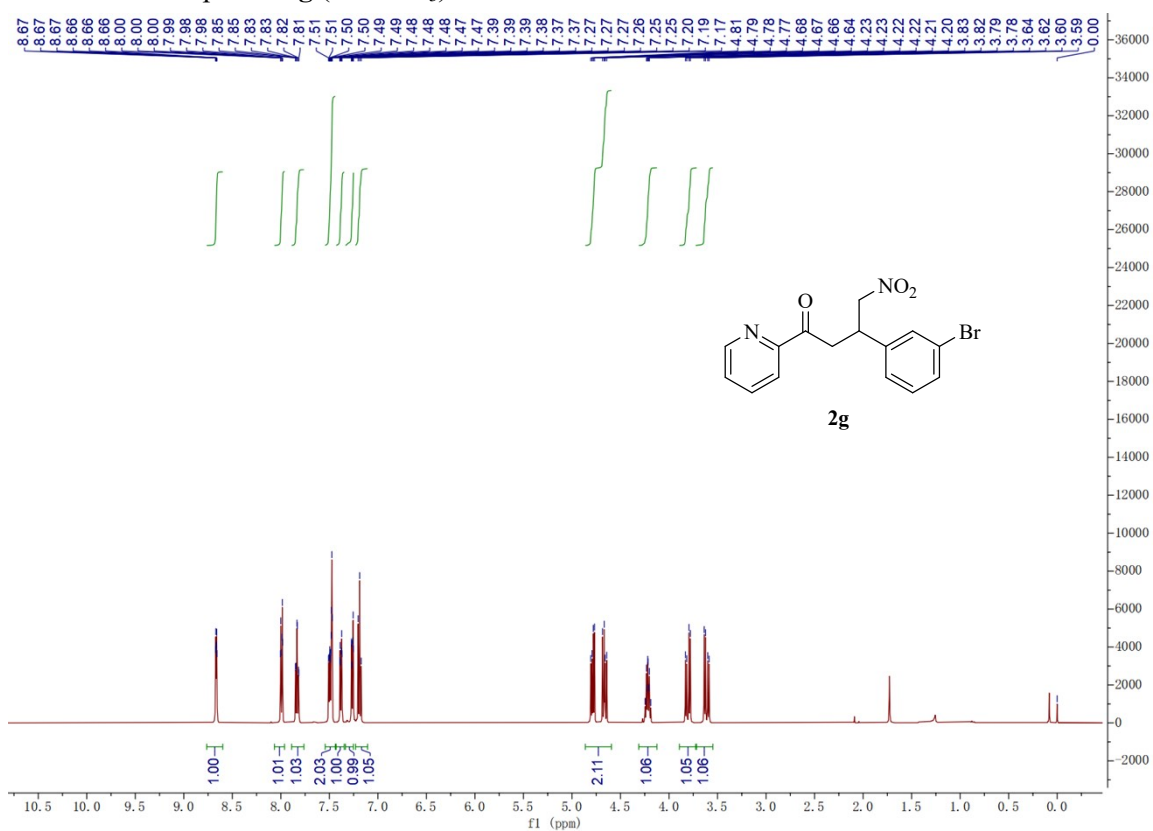
¹H NMR of compound **2f** (in CDCl₃):



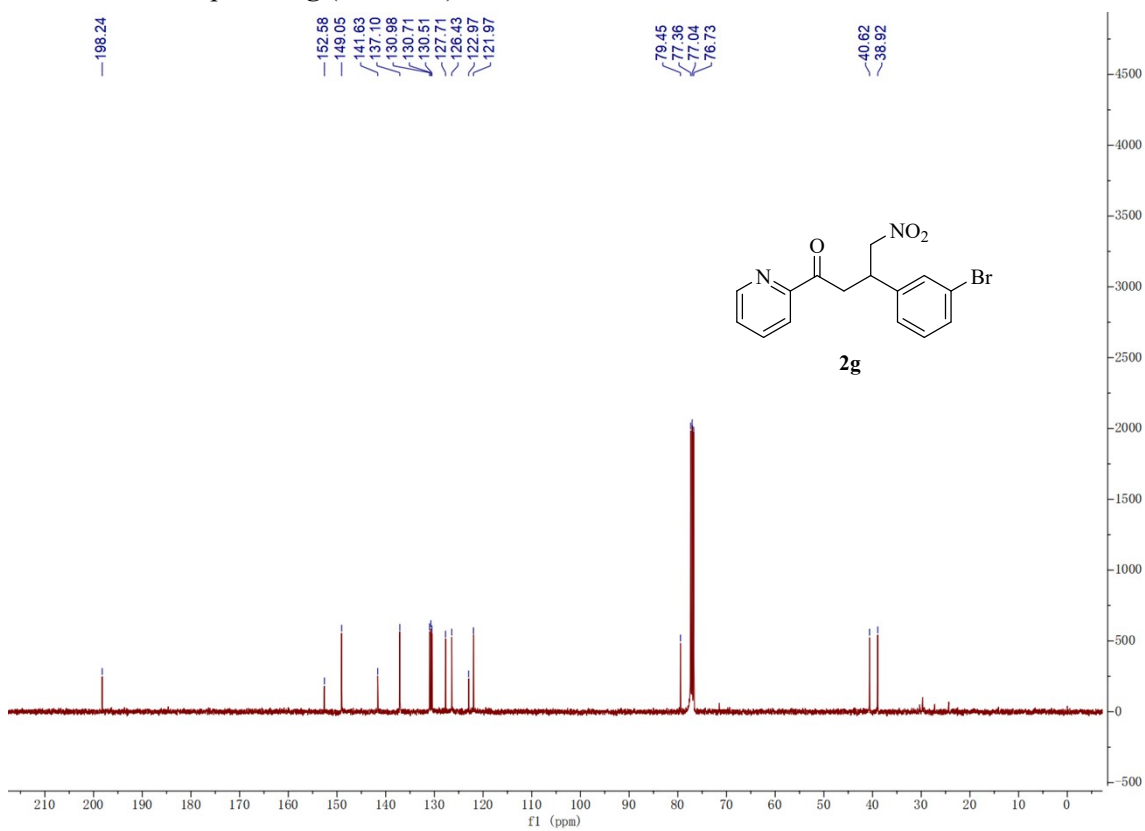
¹³C NMR of compound **2f** (in CDCl₃):



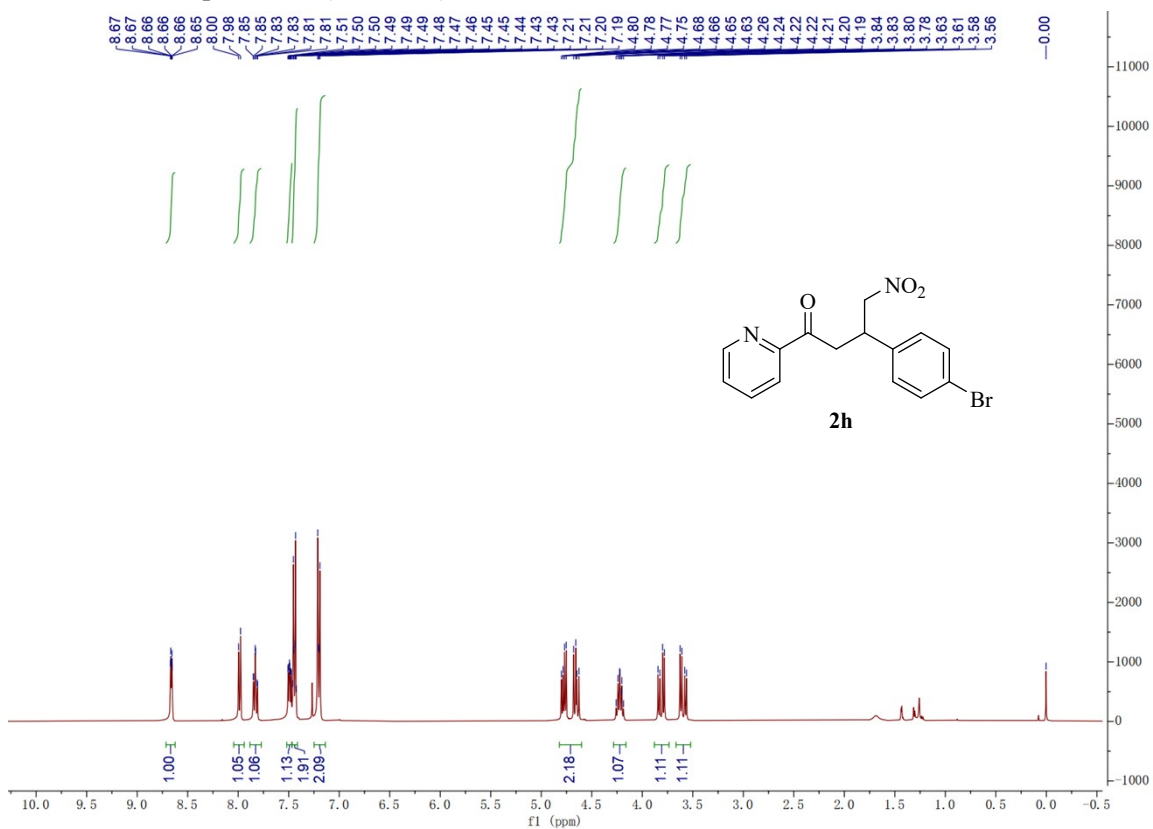
^1H NMR of compound **2g** (in CDCl_3):



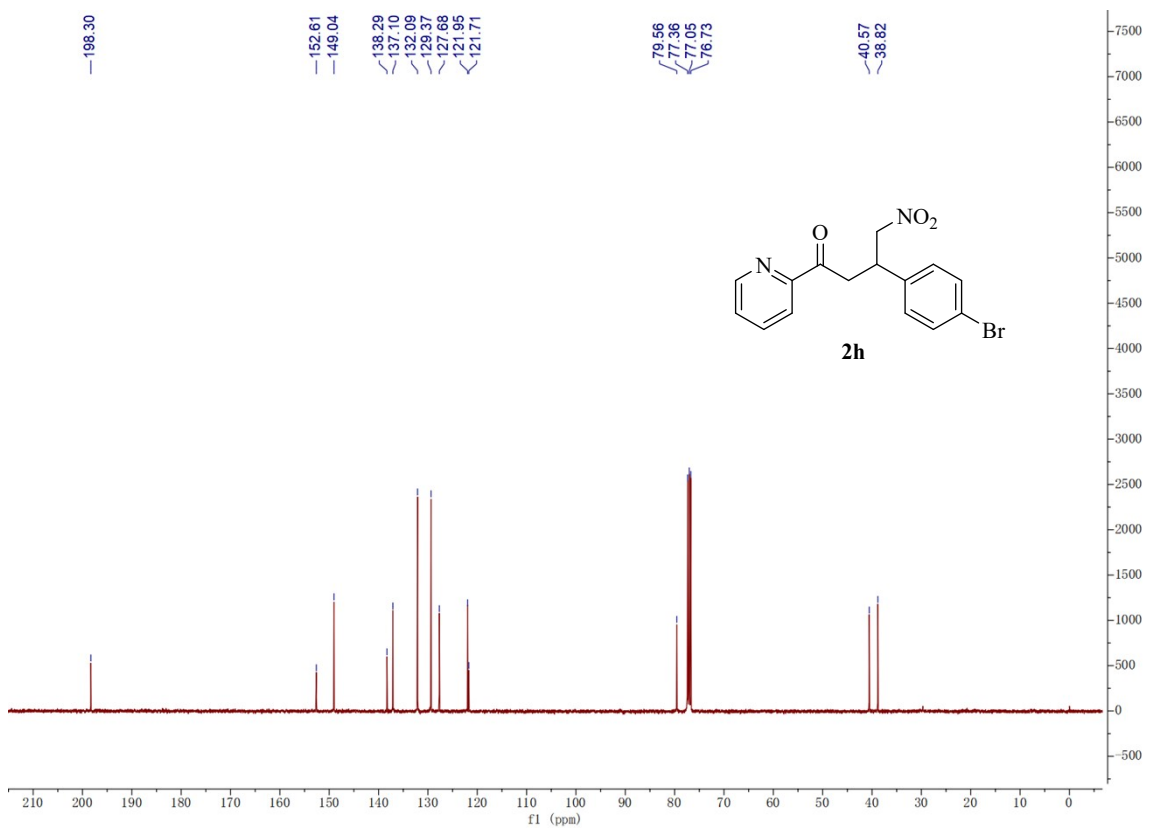
^{13}C NMR of compound **2g** (in CDCl_3):



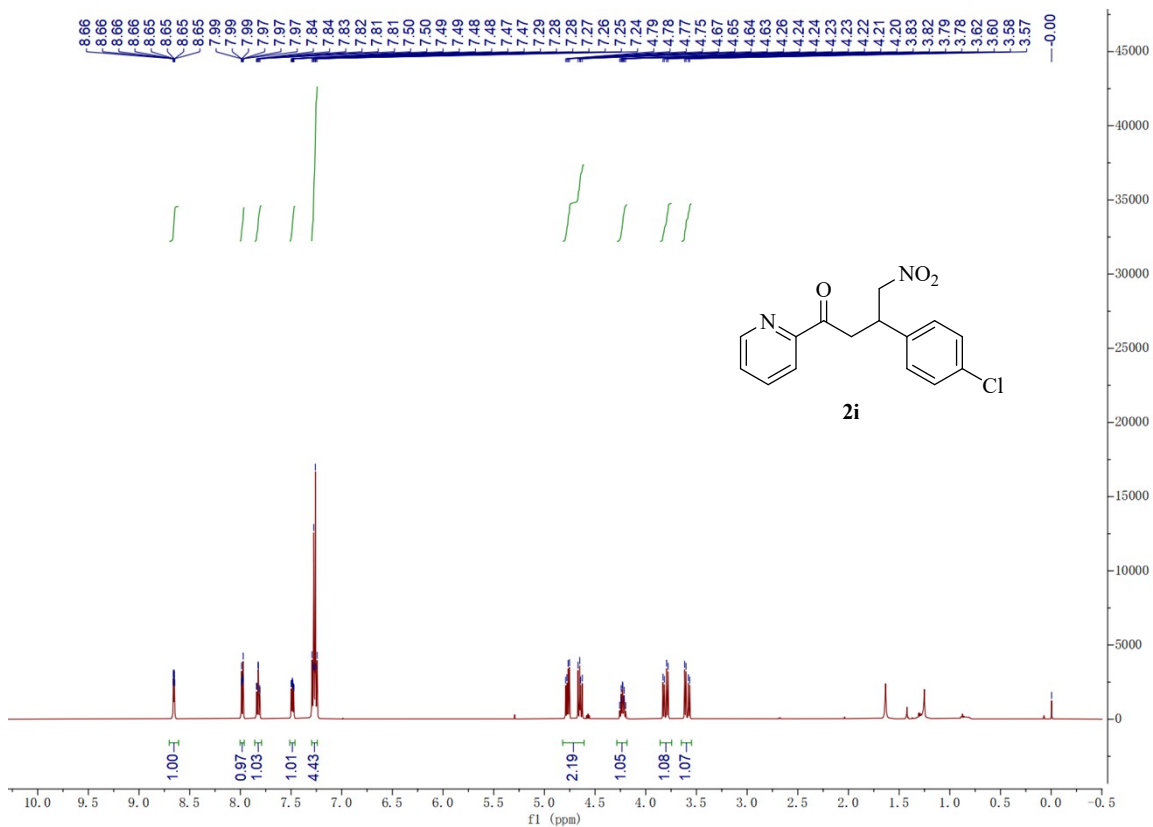
^1H NMR of compound **2h** (in CDCl_3):



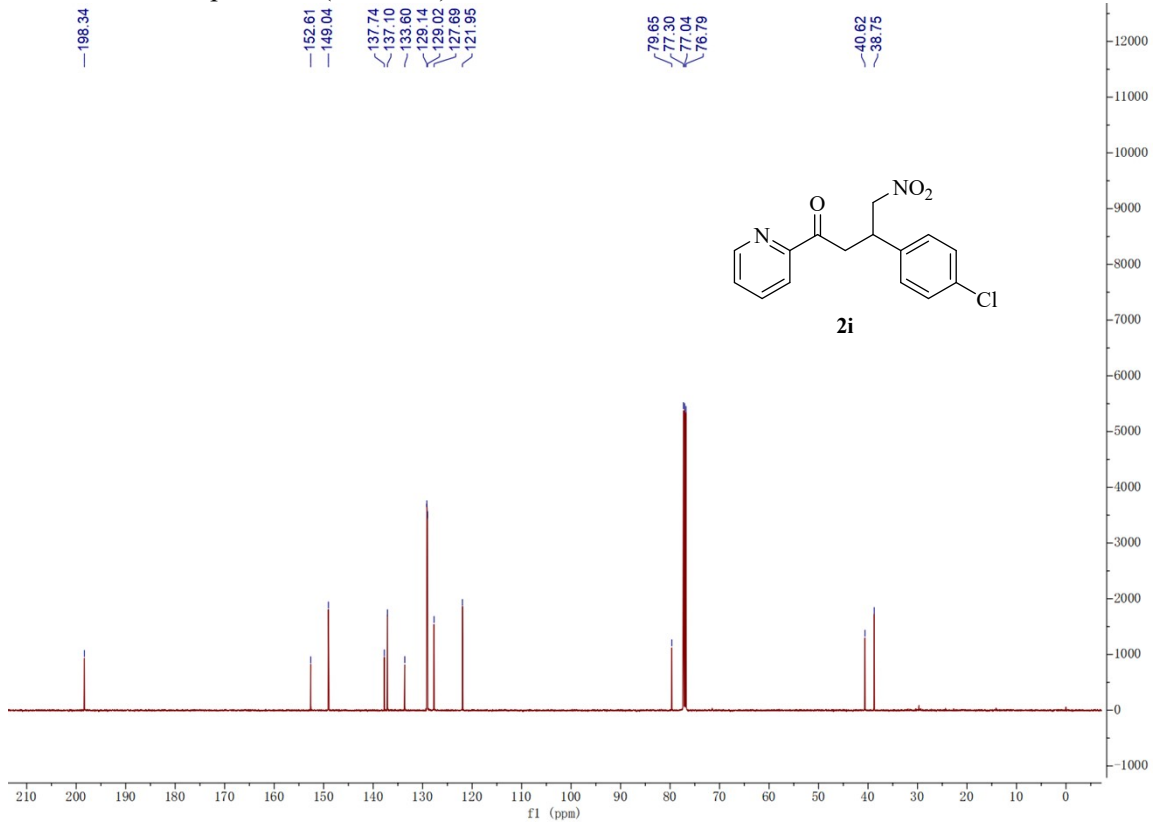
^{13}C NMR of compound **2h** (in CDCl_3):



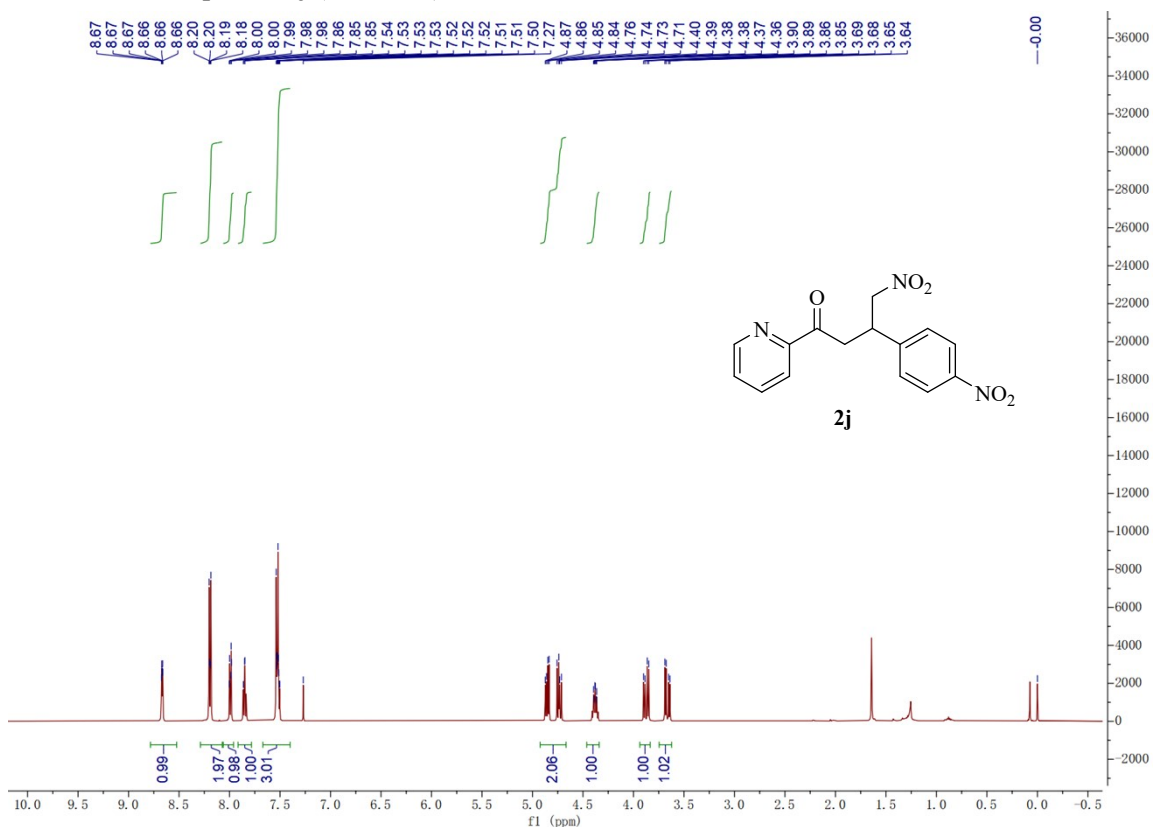
^1H NMR of compound **2i** (in CDCl_3):



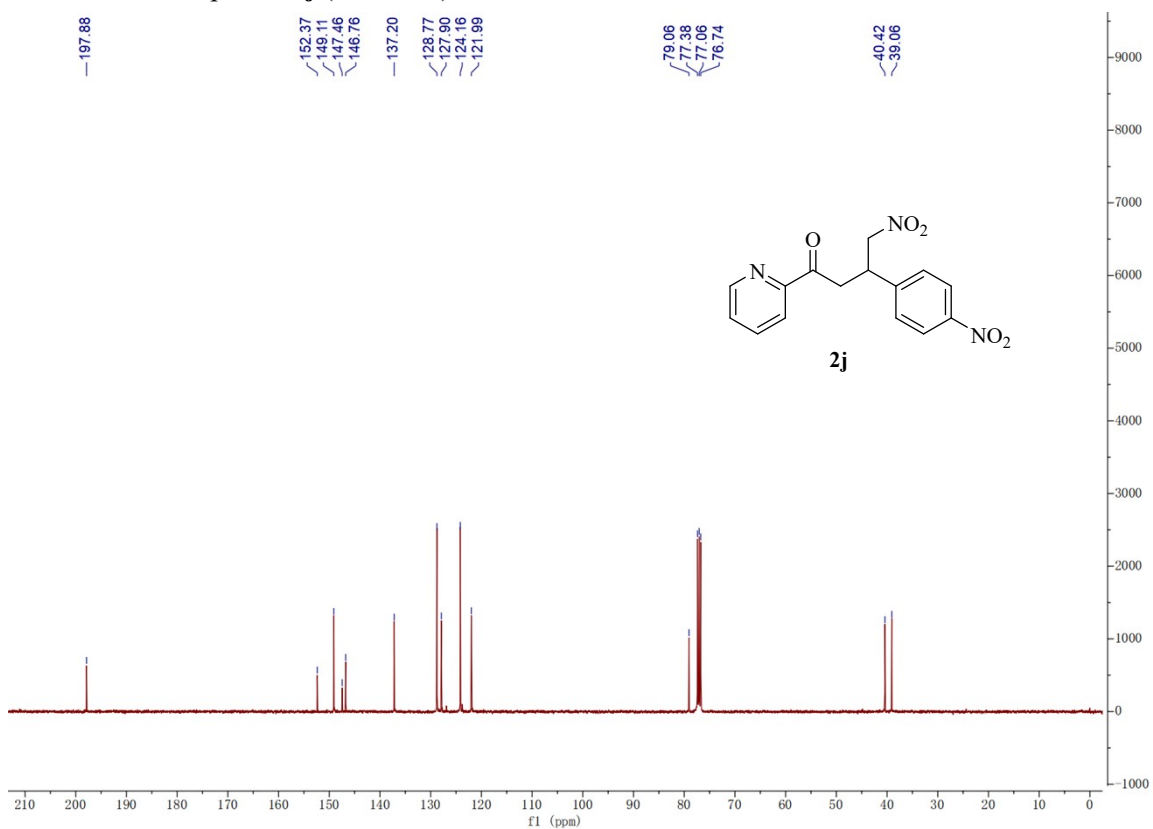
^{13}C NMR of compound **2i** (in CDCl_3):



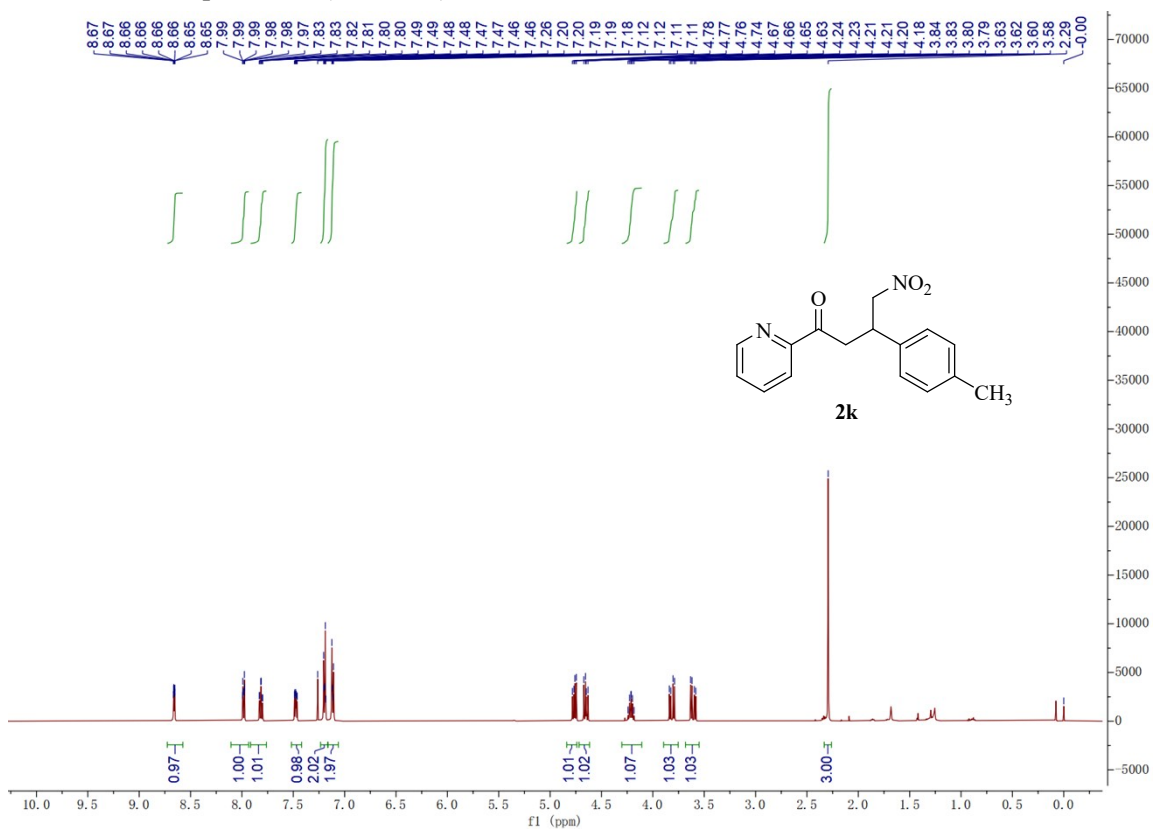
^1H NMR of compound **2j** (in CDCl_3):



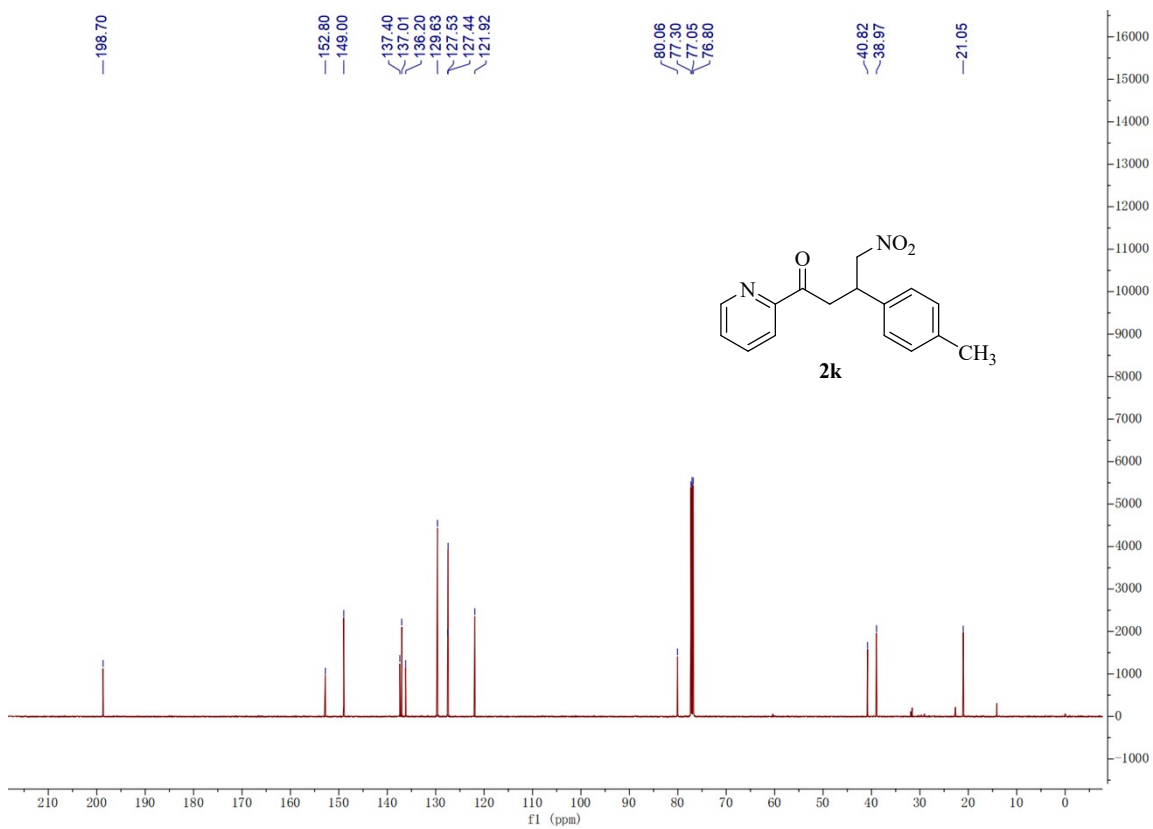
^{13}C NMR of compound **2j** (in CDCl_3):



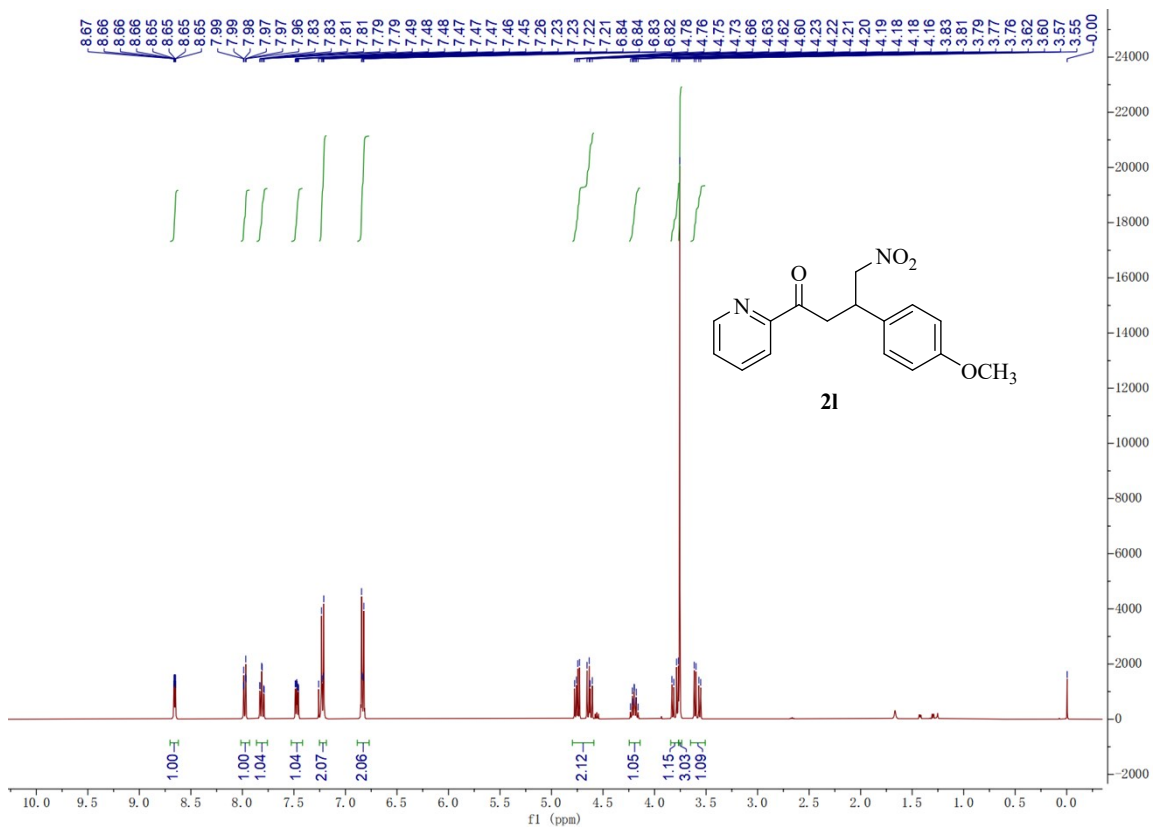
^1H NMR of compound **2k** (in CDCl_3):



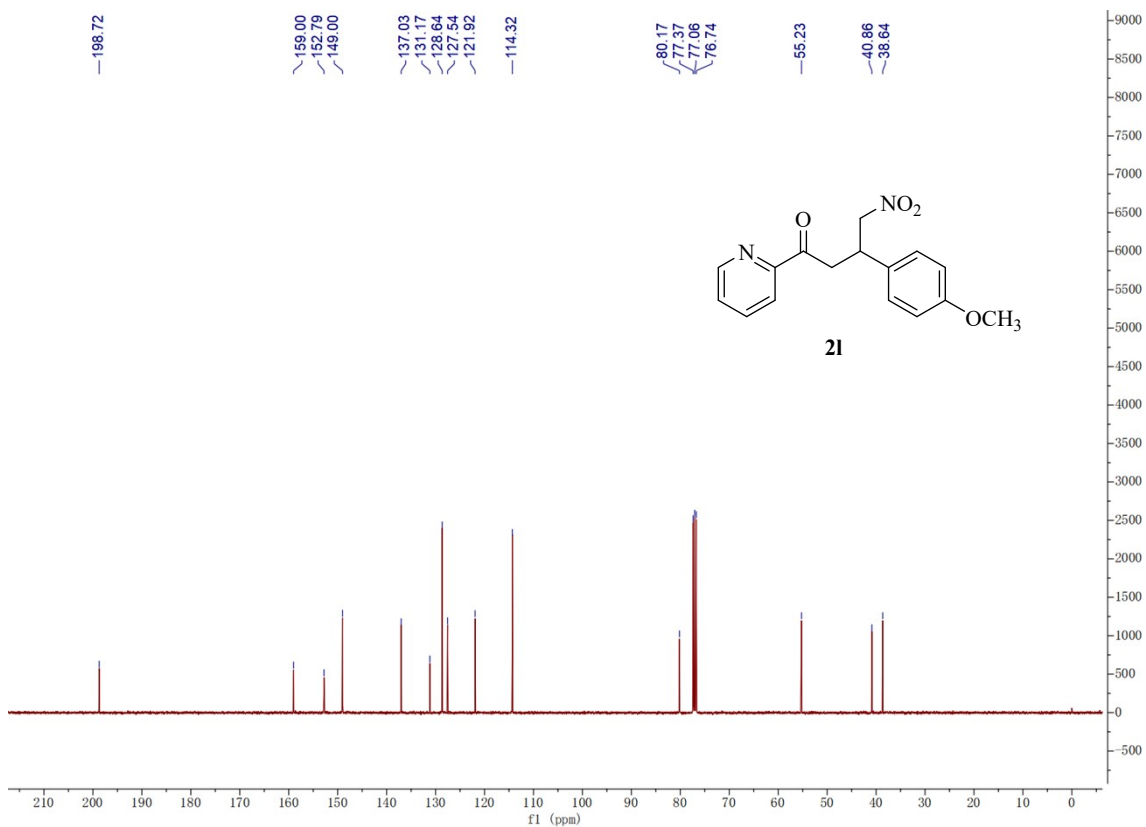
^{13}C NMR of compound **2k** (in CDCl_3):



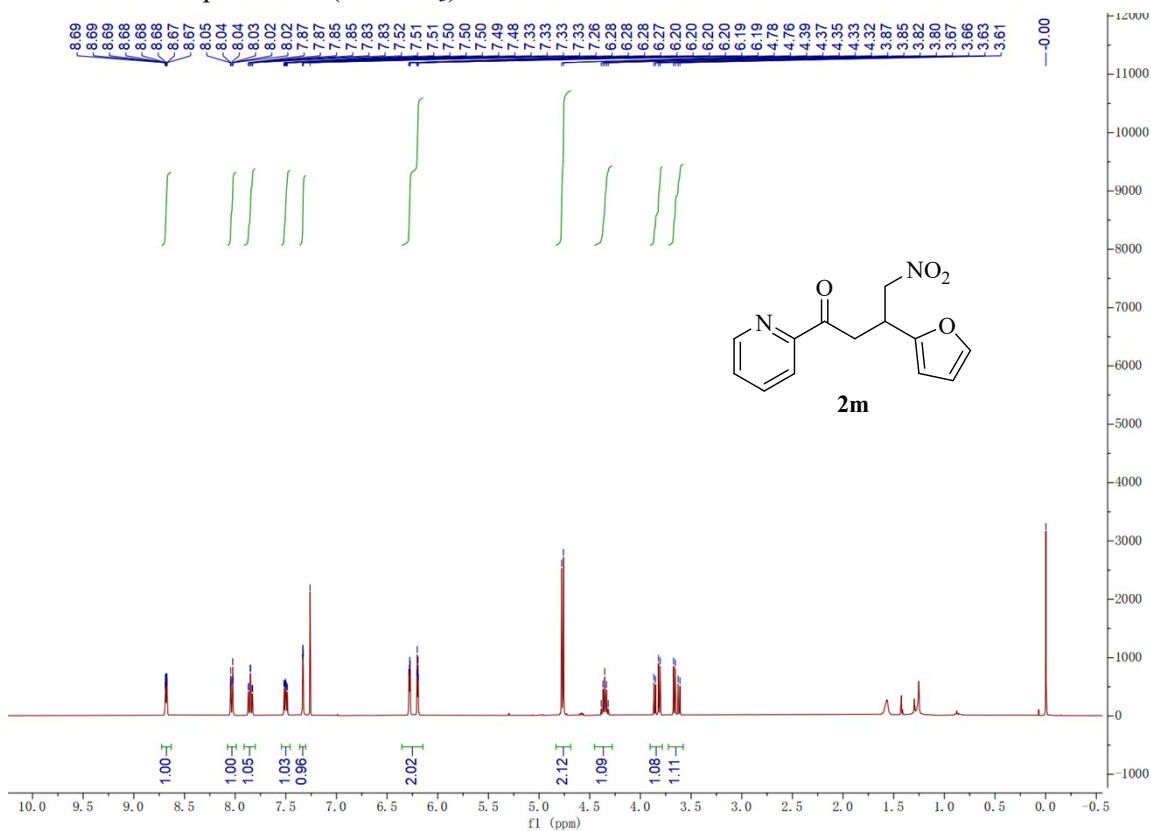
¹H NMR of compound **21** (in CDCl₃):



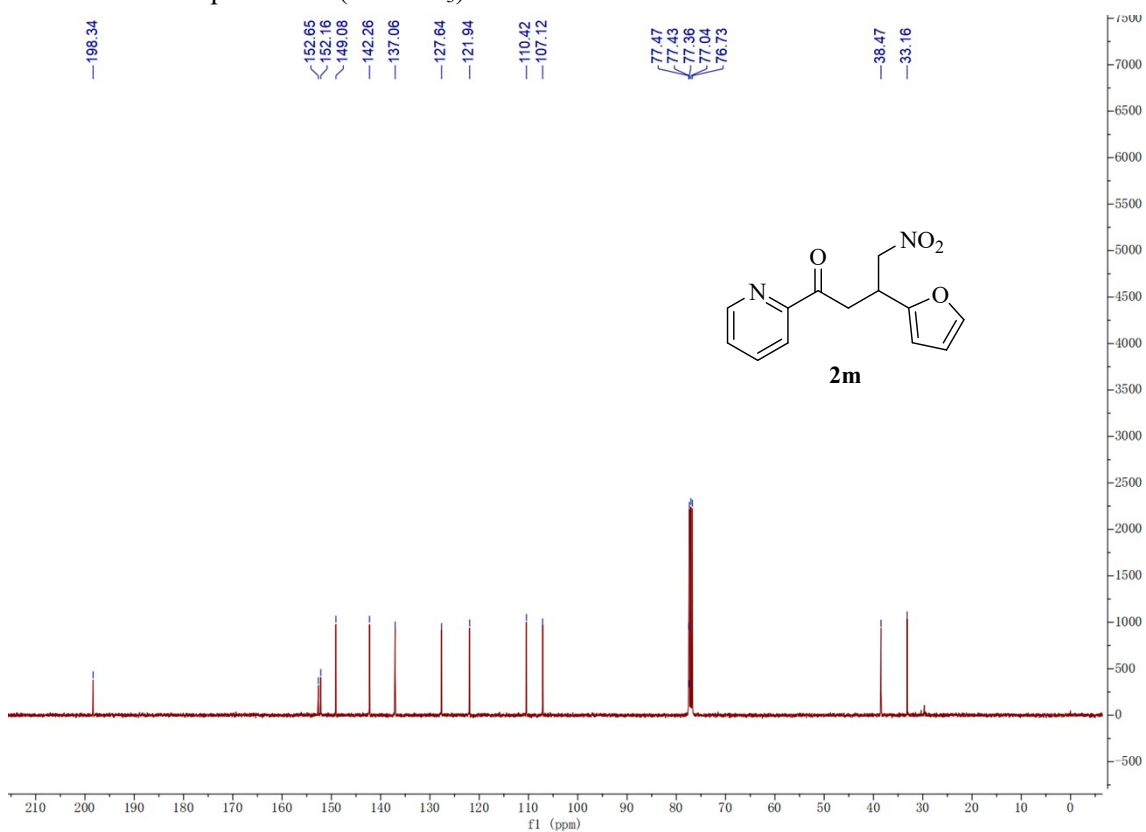
¹³C NMR of compound **21** (in CDCl₃):



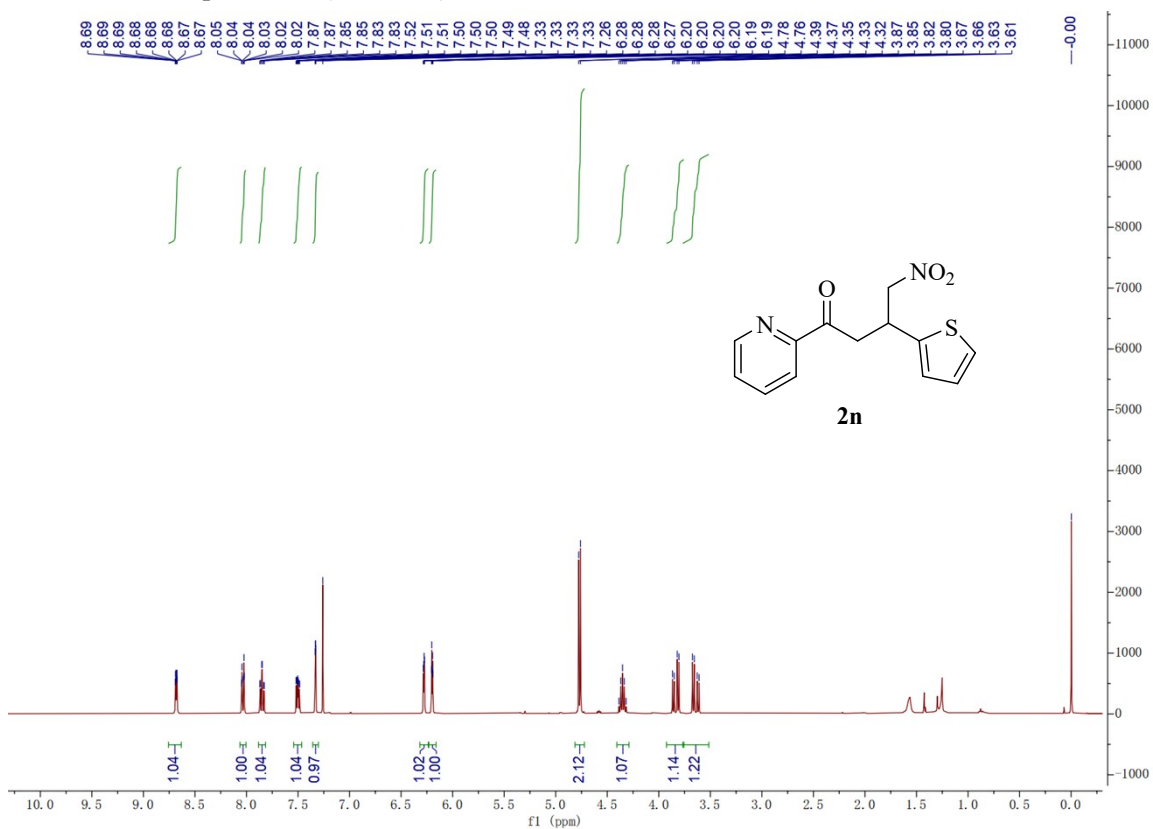
^1H NMR of compound **2m** (in CDCl_3):



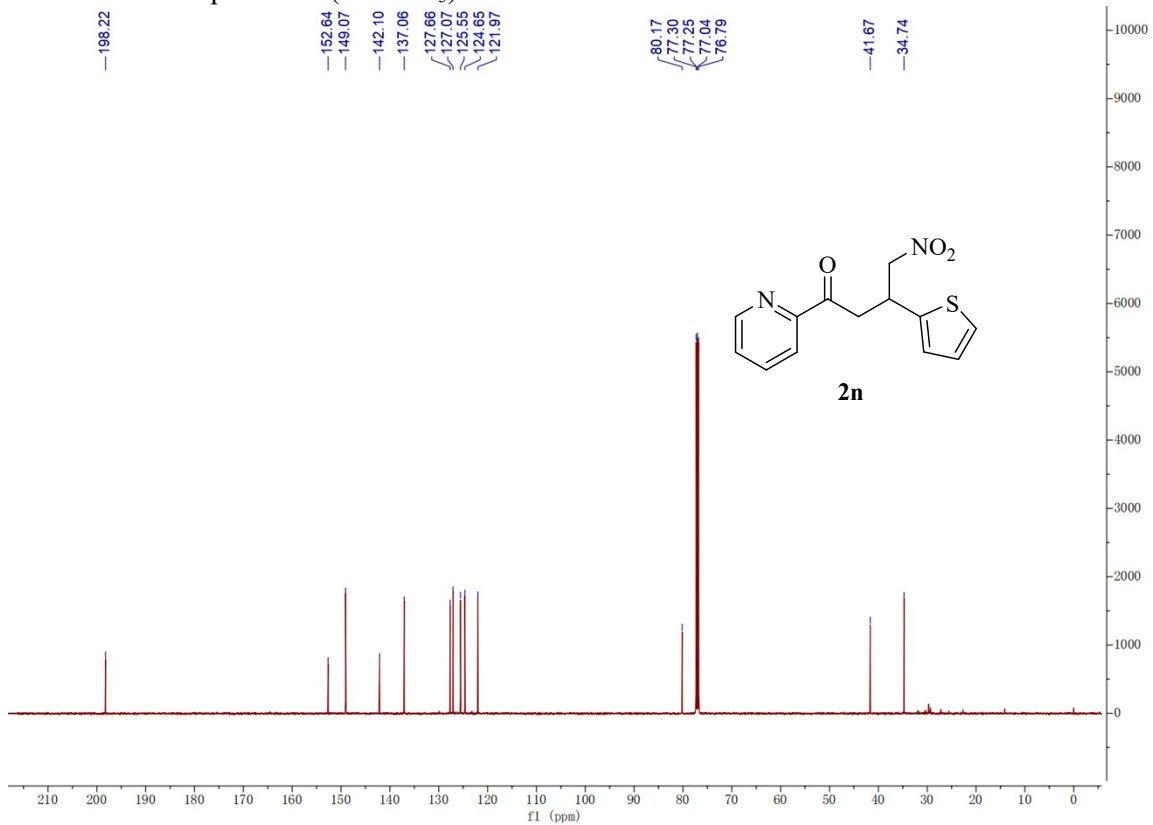
^{13}C NMR of compound **2m** (in CDCl_3):



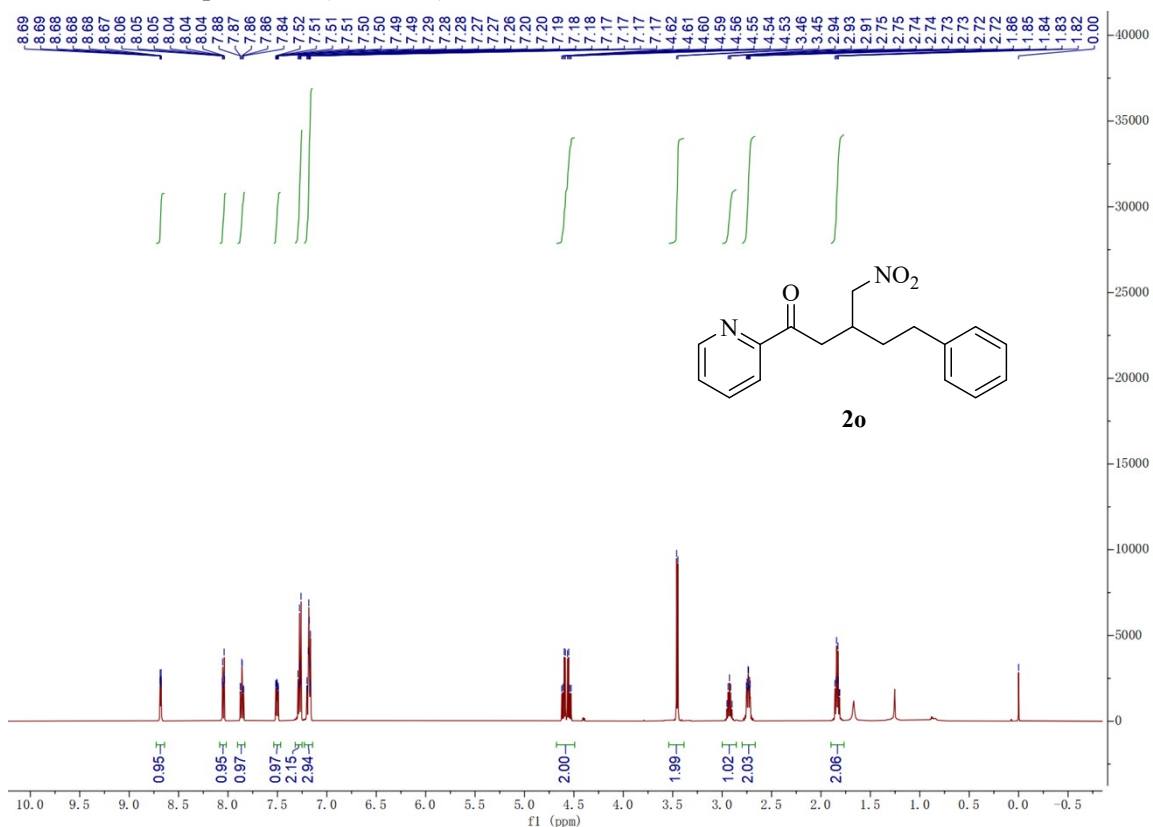
^1H NMR of compound **2n** (in CDCl_3):



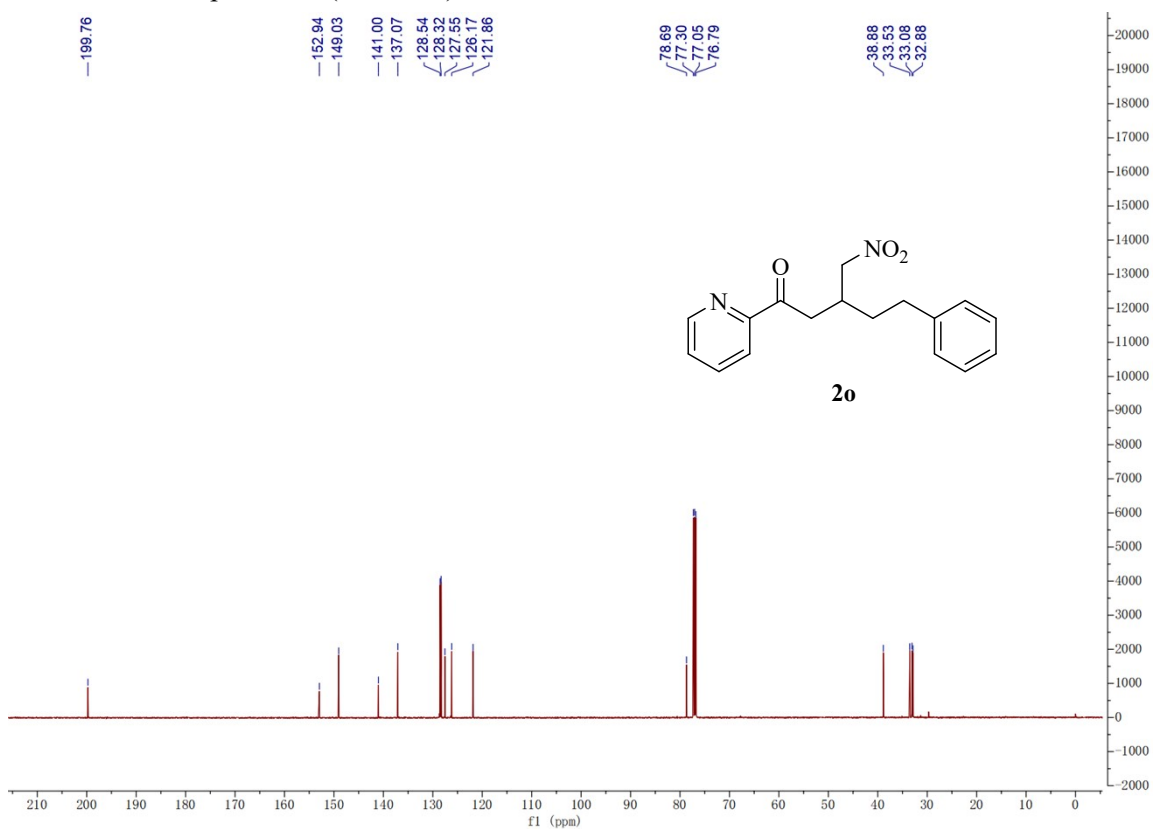
^{13}C NMR of compound **2n** (in CDCl_3):



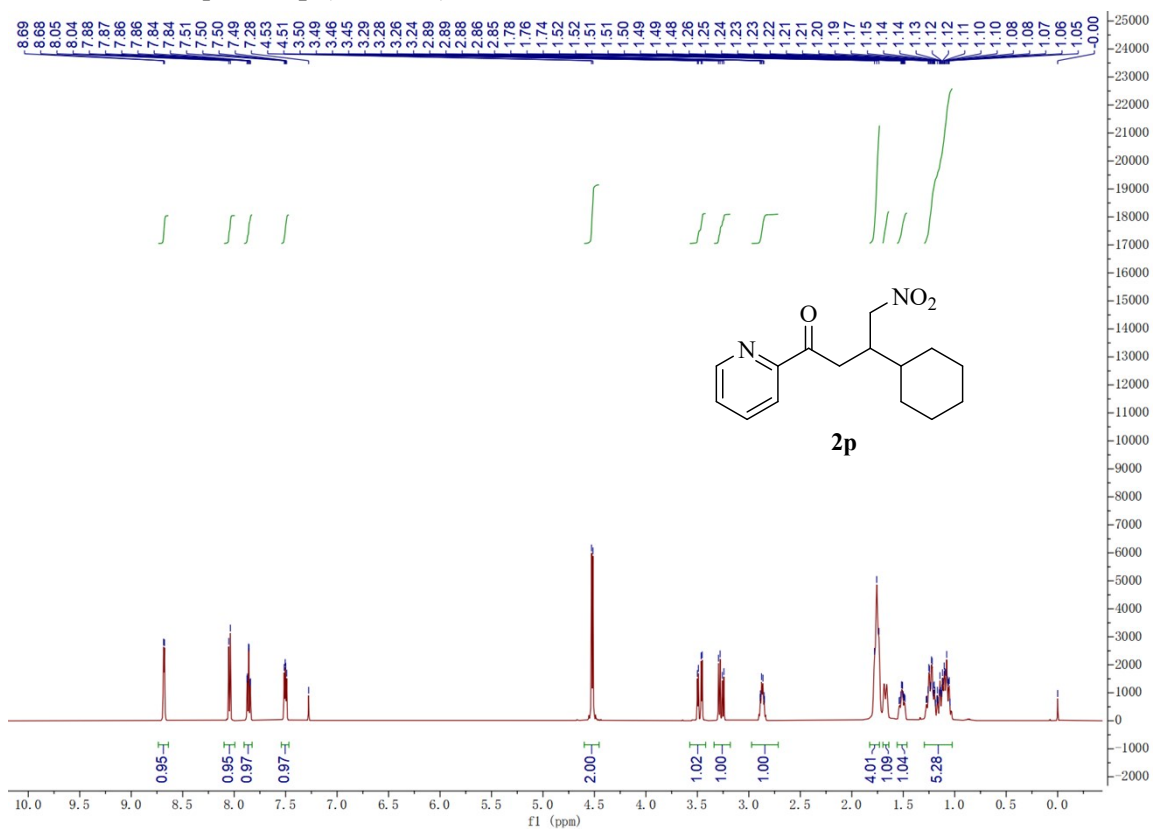
^1H NMR of compound **2o** (in CDCl_3):



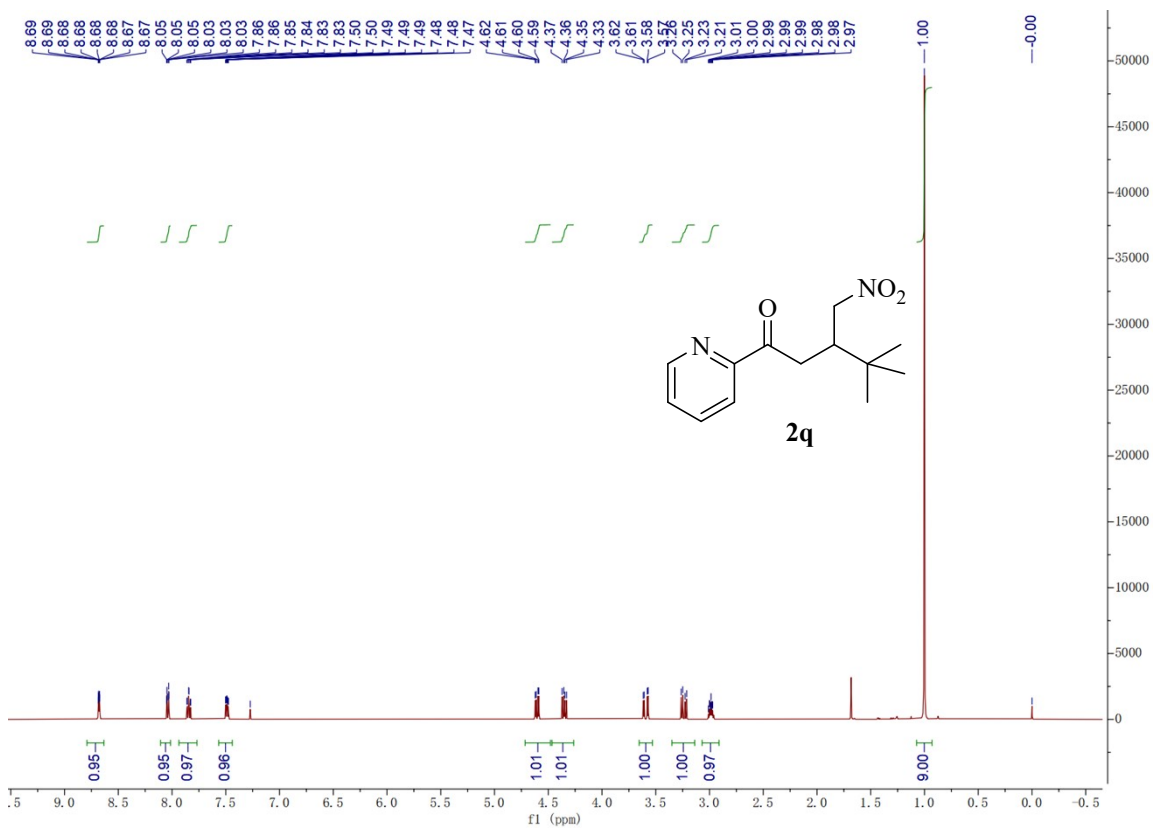
^{13}C NMR of compound **2o** (in CDCl_3):



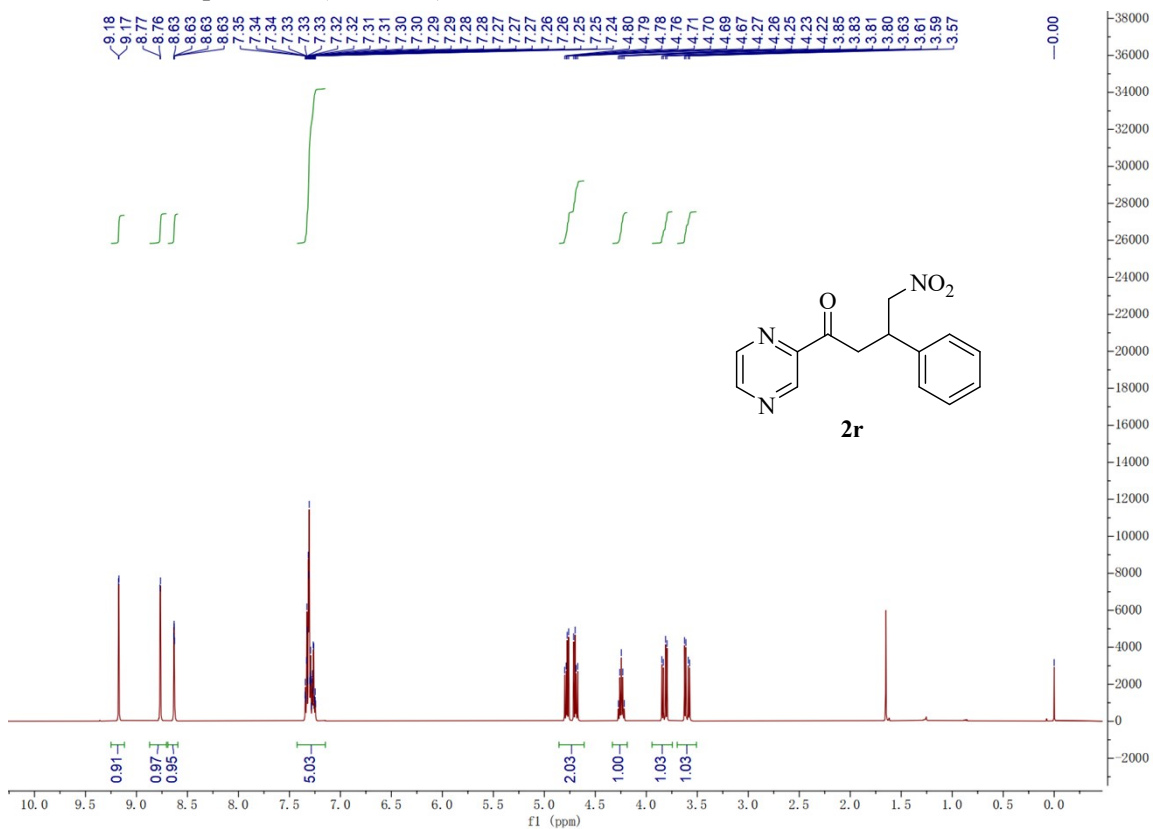
¹H NMR of compound **2p** (in CDCl₃):



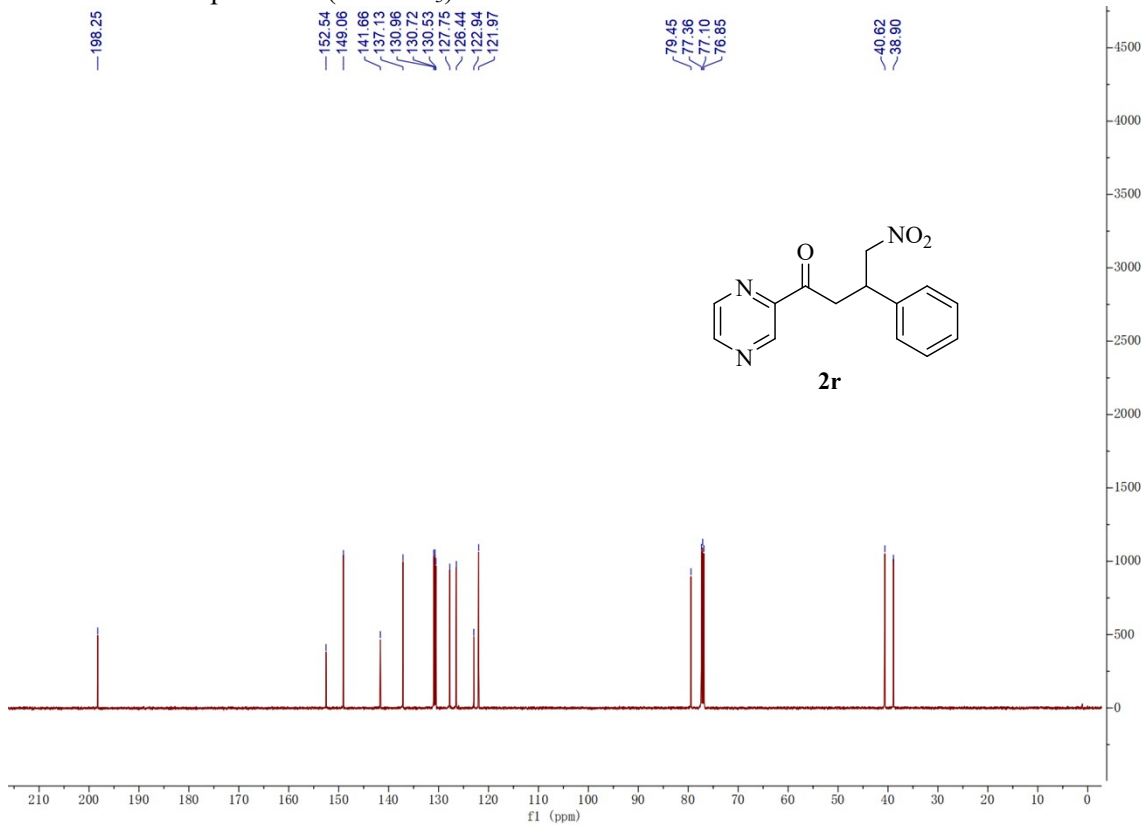
¹H NMR of compound **2q** (in CDCl₃):



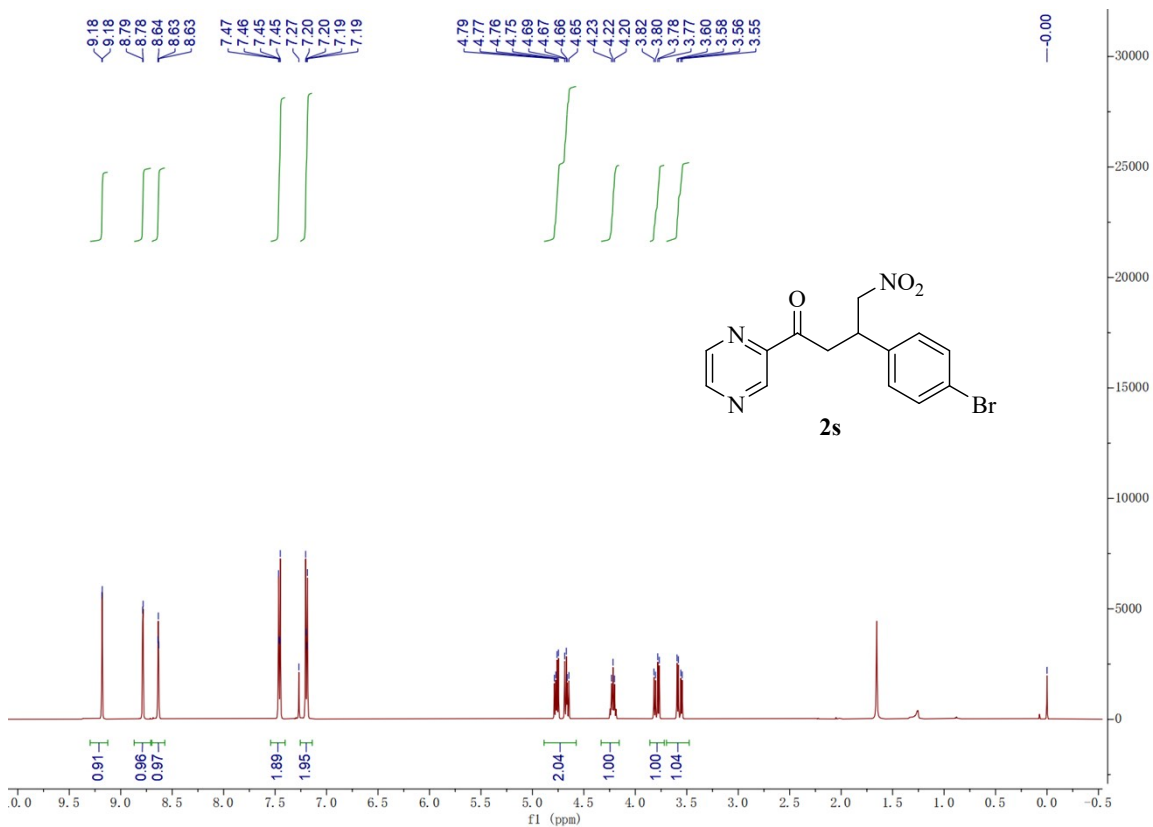
¹H NMR of compound **2r** (in CDCl₃):



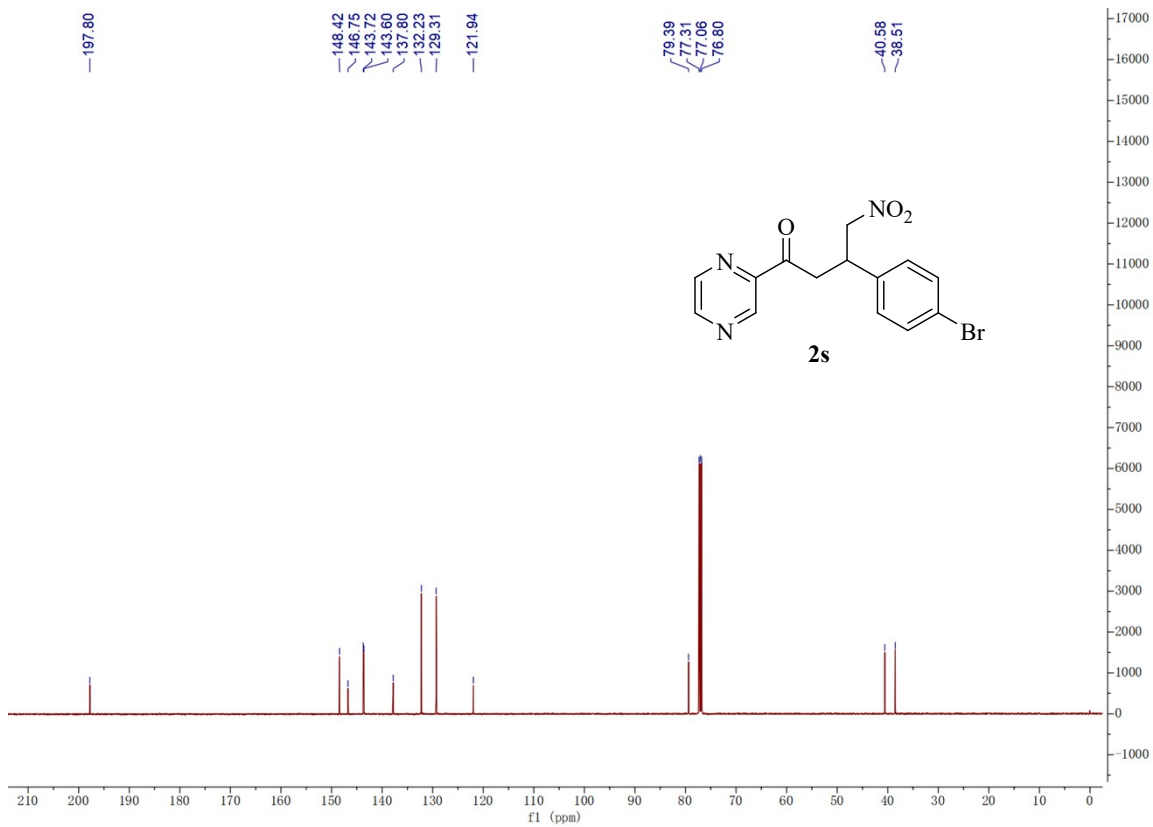
¹³C NMR of compound **2r** (in CDCl₃):



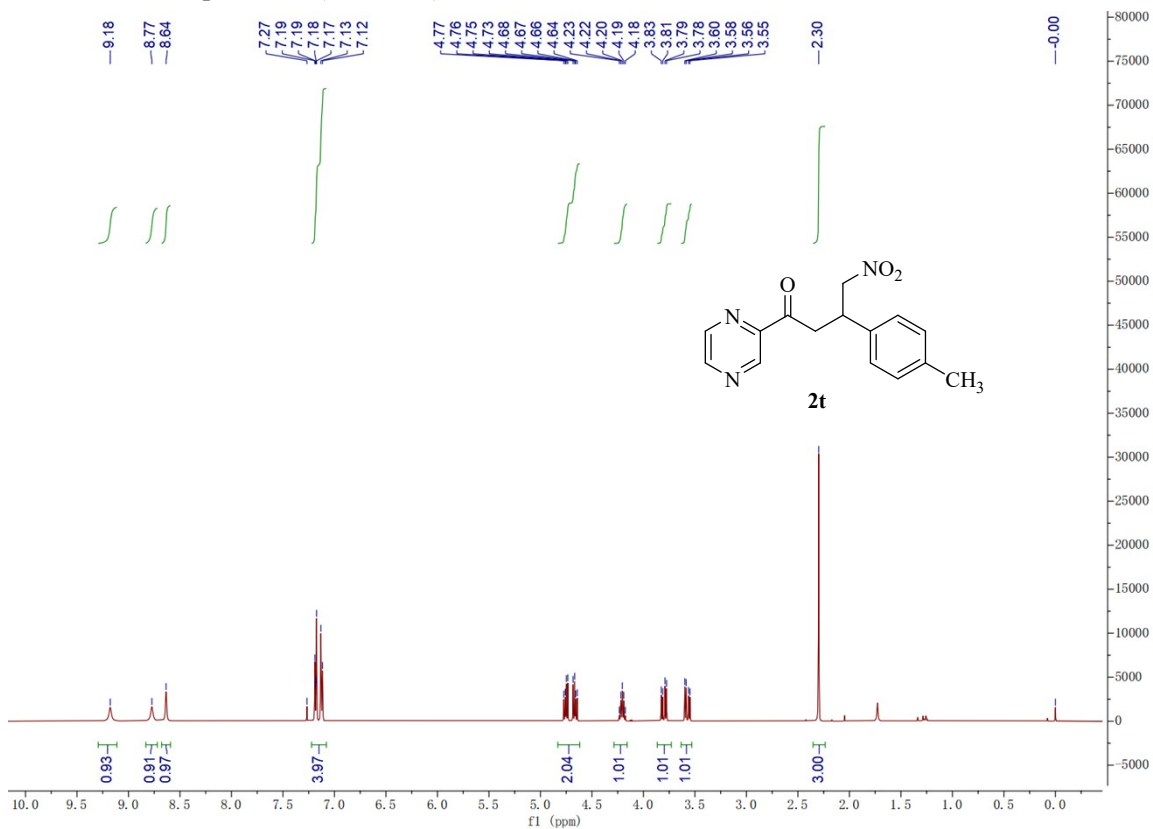
¹H NMR of compound **2s** (in CDCl₃):



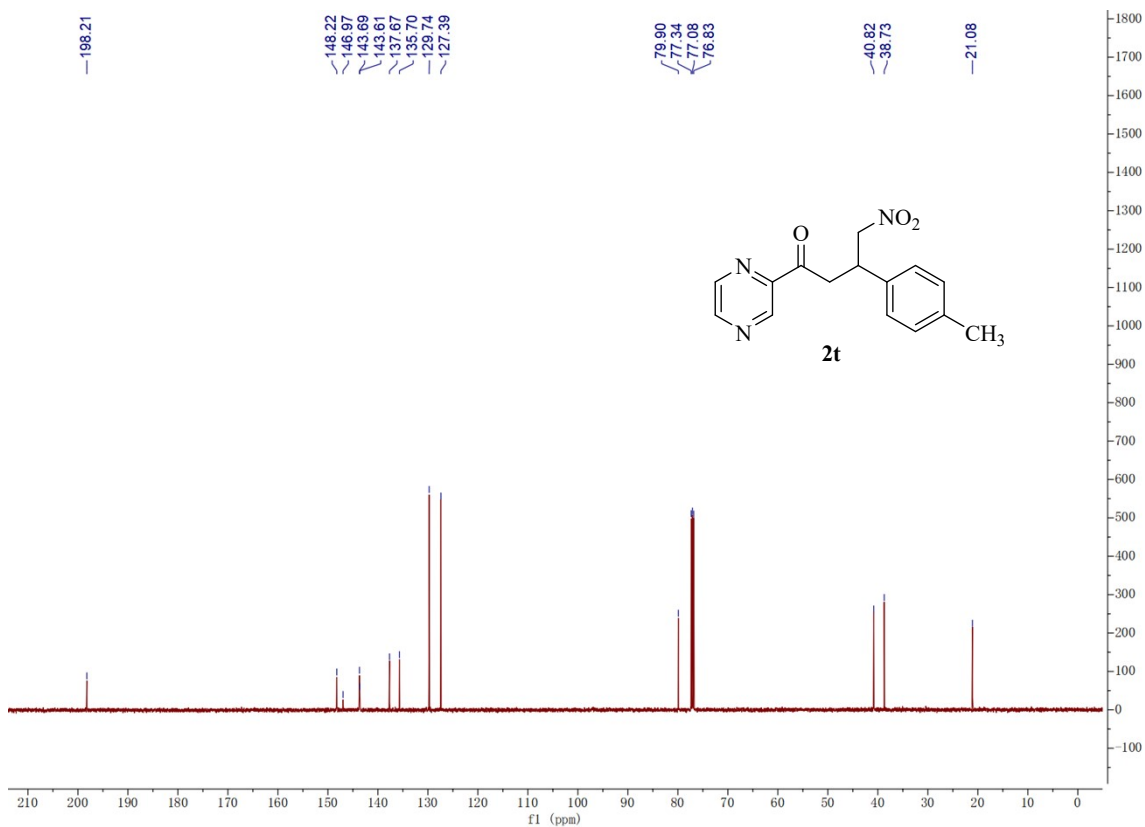
¹³C NMR of compound **2s** (in CDCl₃):



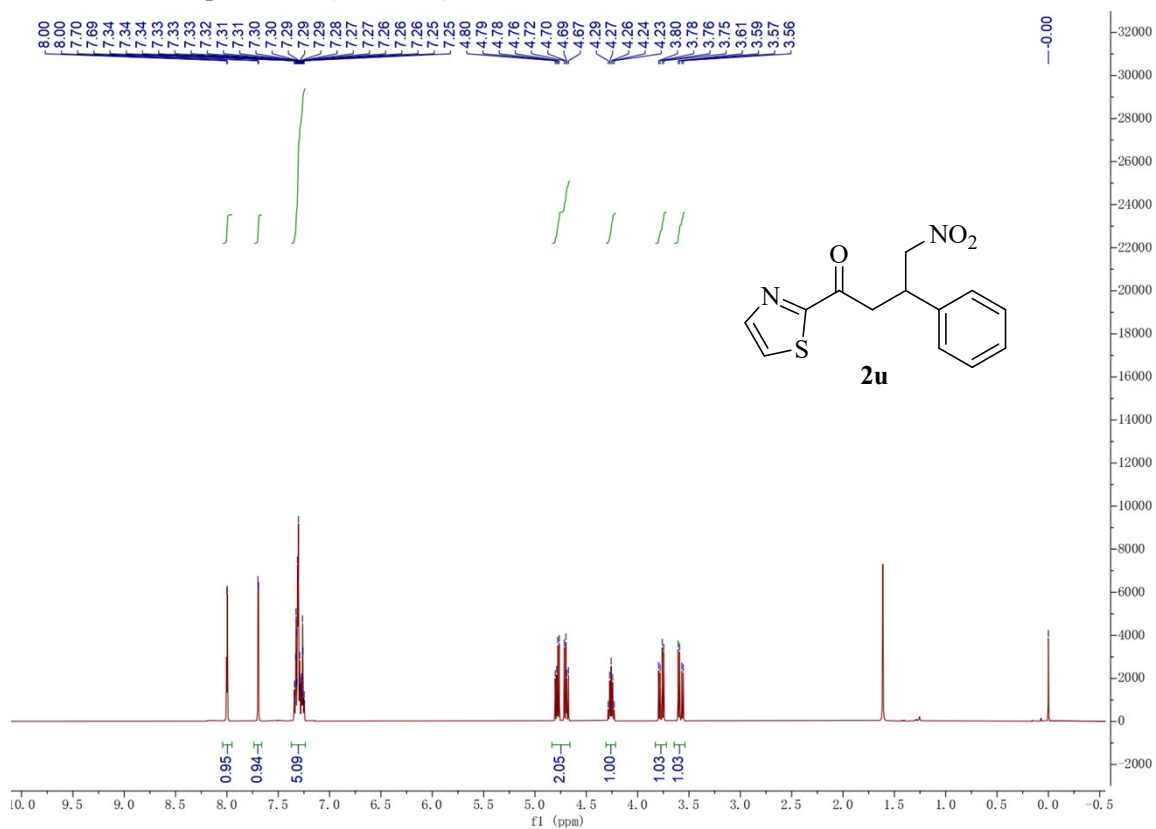
^1H NMR of compound **2t** (in CDCl_3):



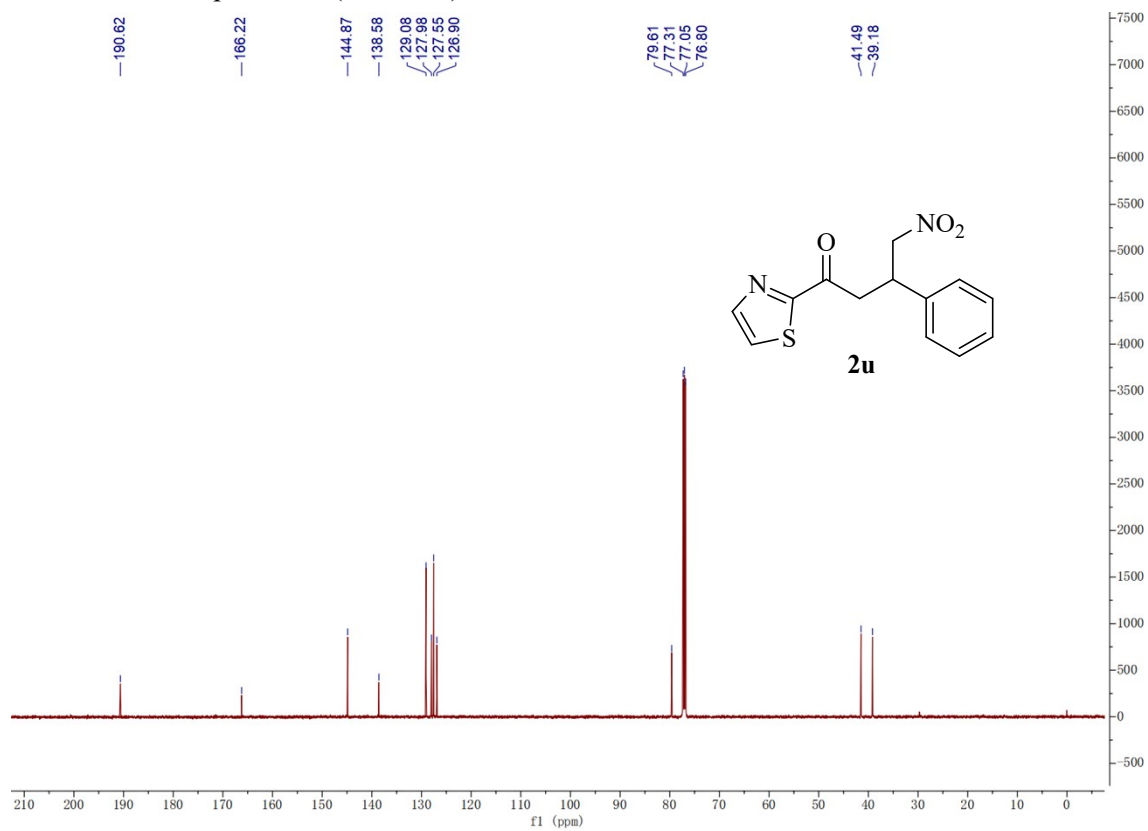
^{13}C NMR of compound **2t** (in CDCl_3):



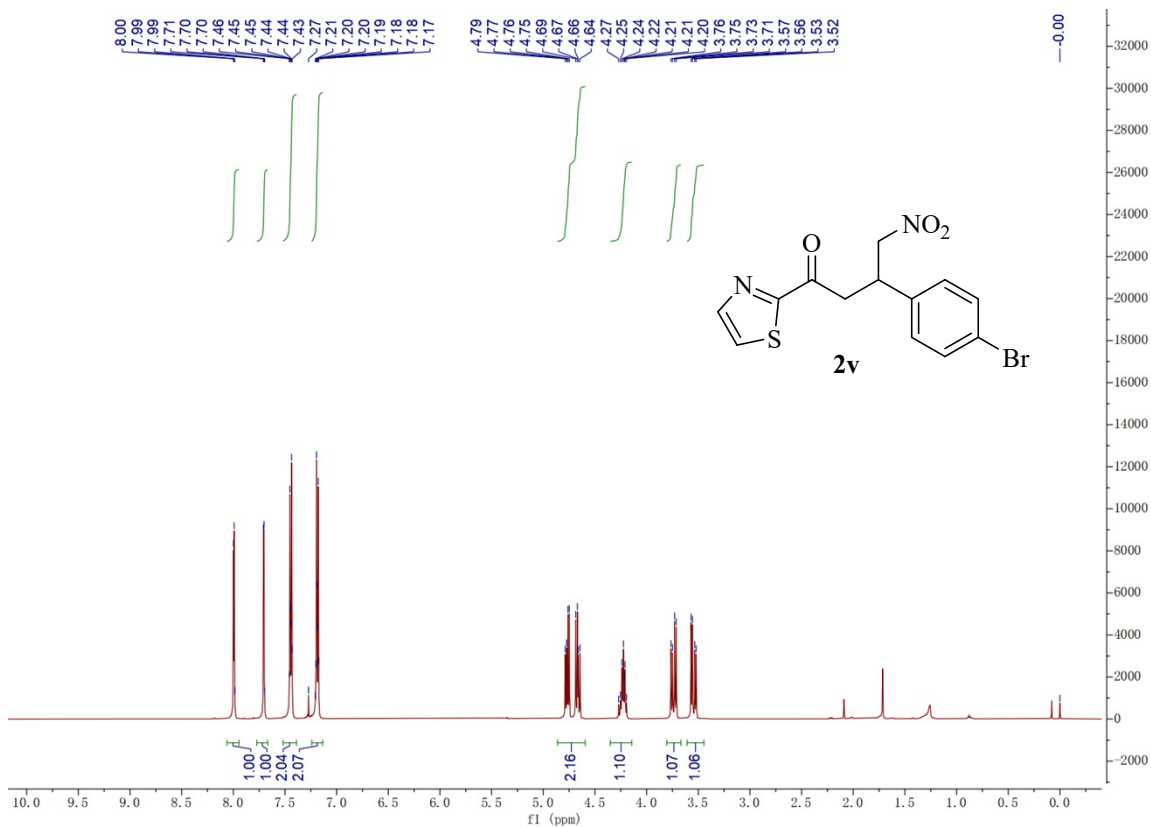
^1H NMR of compound **2u** (in CDCl_3):



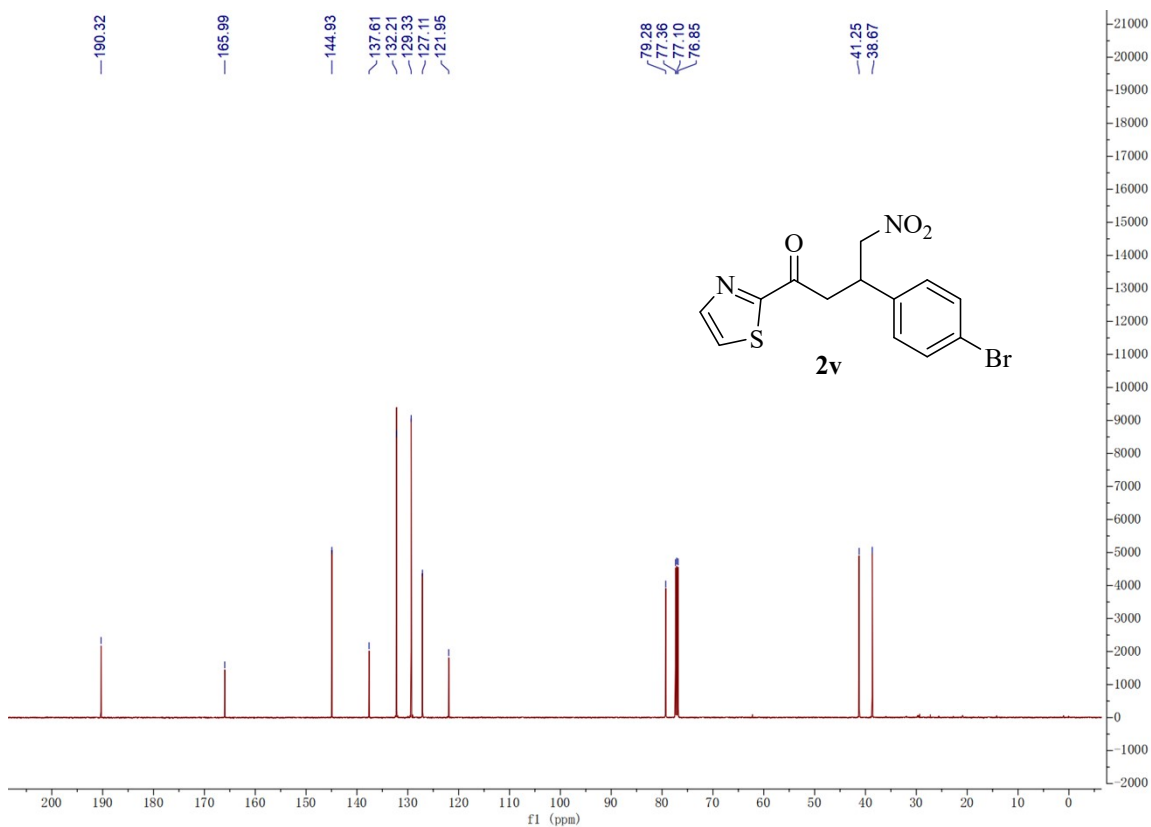
^{13}C NMR of compound **2u** (in CDCl_3):



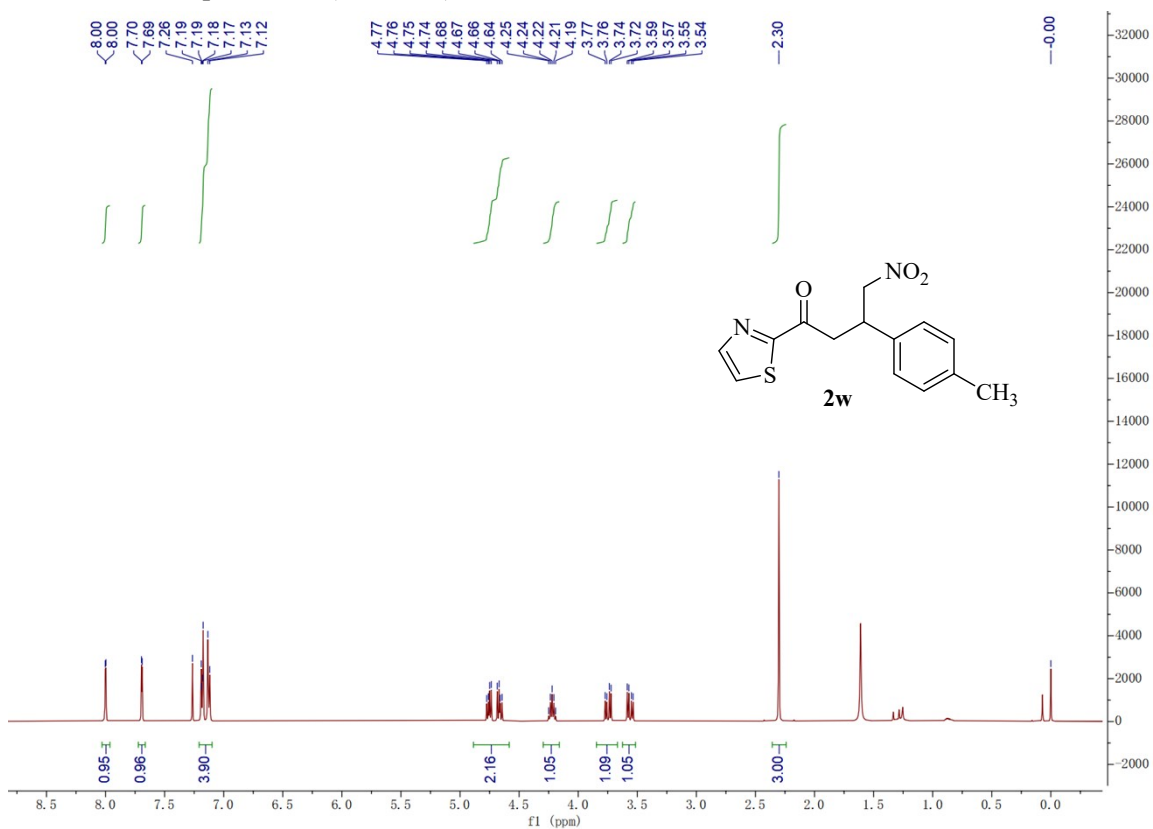
^1H NMR of compound **2v** (in CDCl_3):



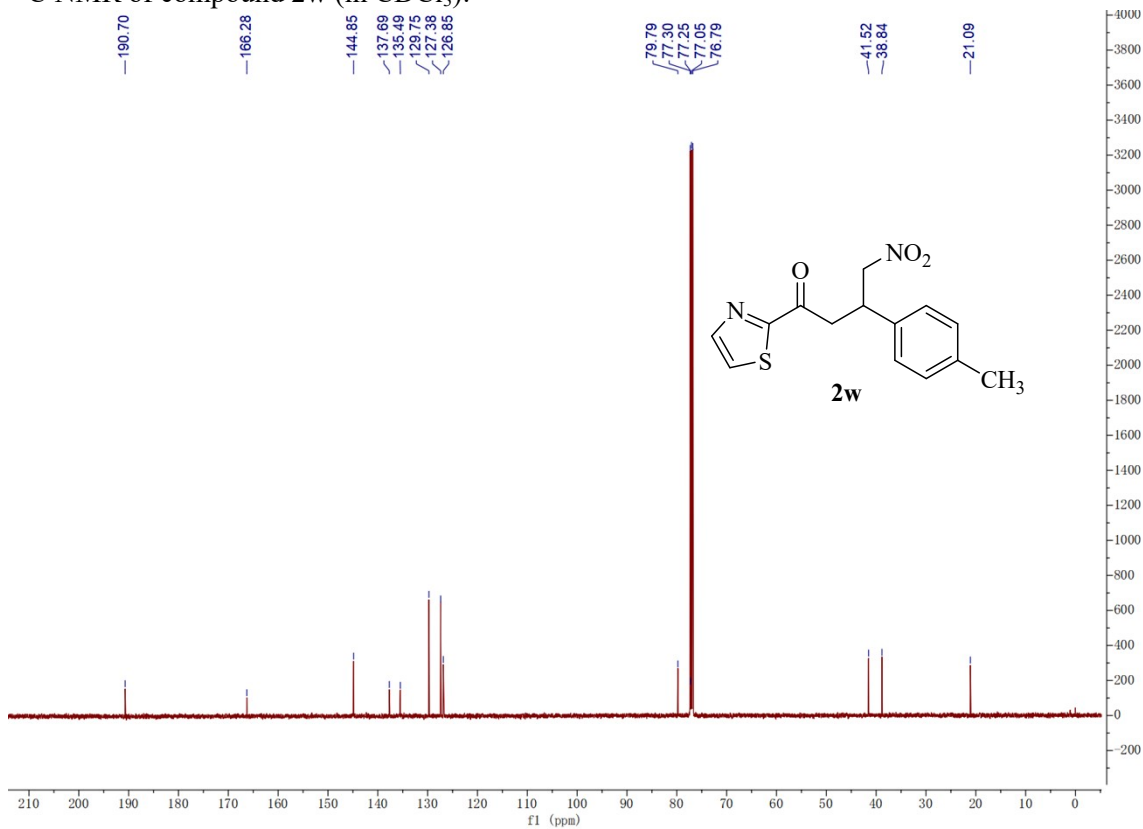
^{13}C NMR of compound **2v** (in CDCl_3):



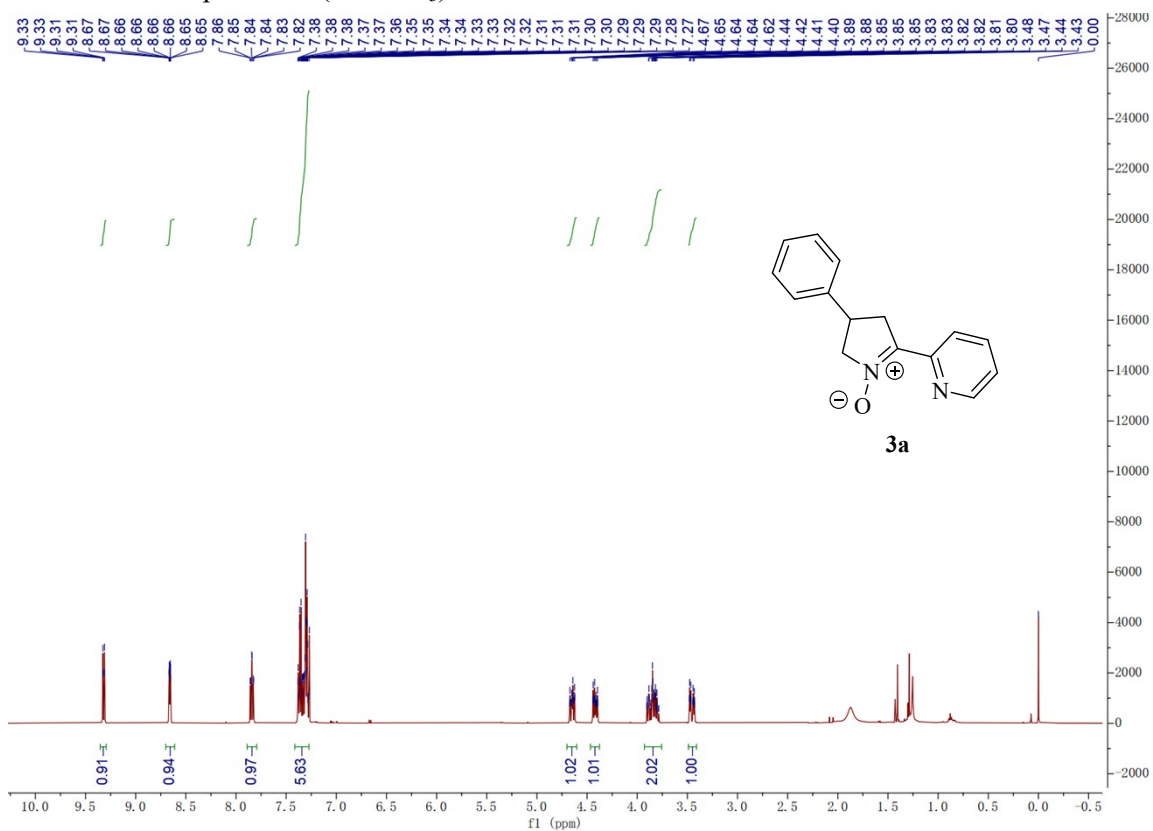
^1H NMR of compound **2w** (in CDCl_3):



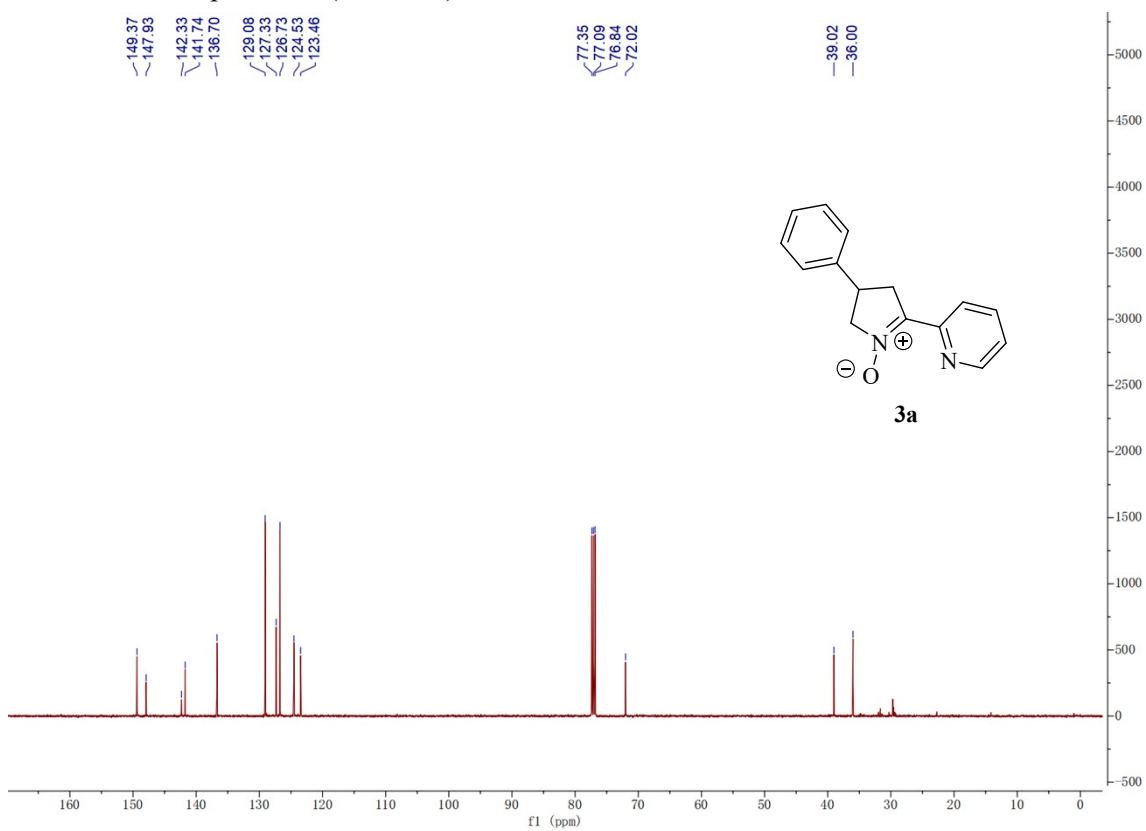
^{13}C NMR of compound **2w** (in CDCl_3):



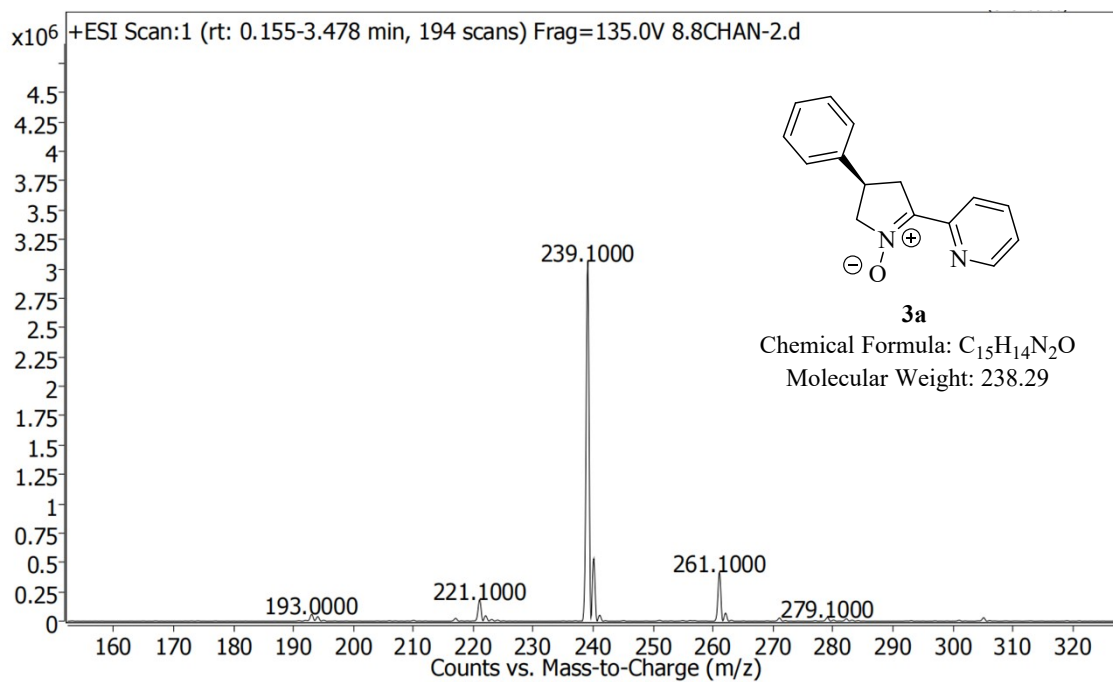
¹H NMR of compound **3a** (in CDCl₃):



¹³C NMR of compound **3a** (in CDCl₃):

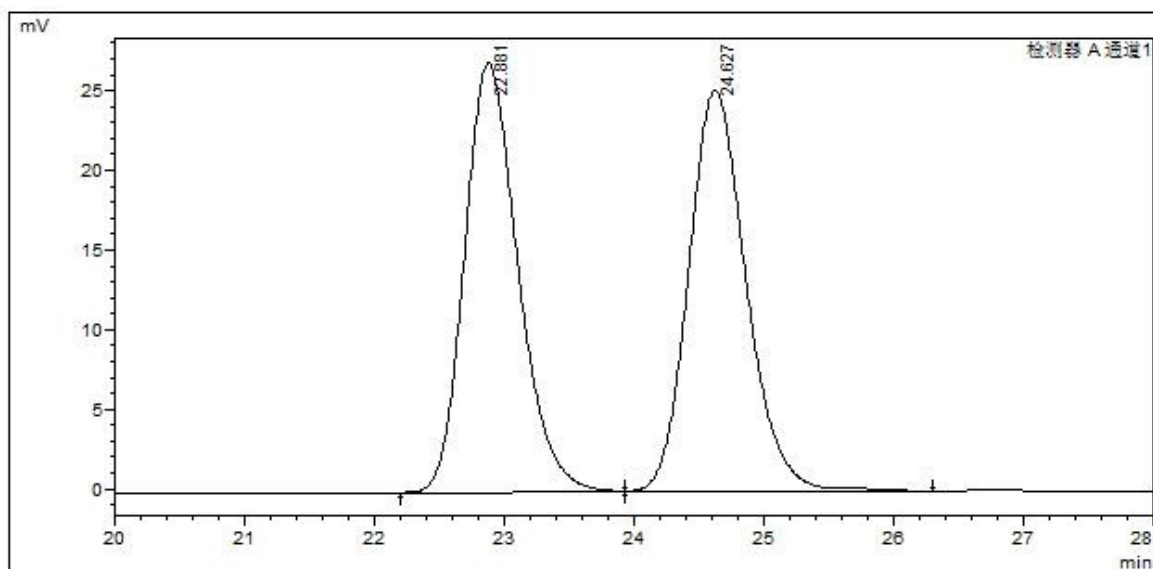
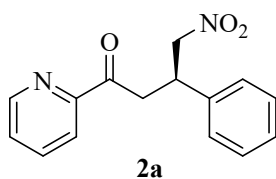


Mass spectrum of compound **3a**:



3. HPLC traces of racemic and chiral products 2a-2w and 3a

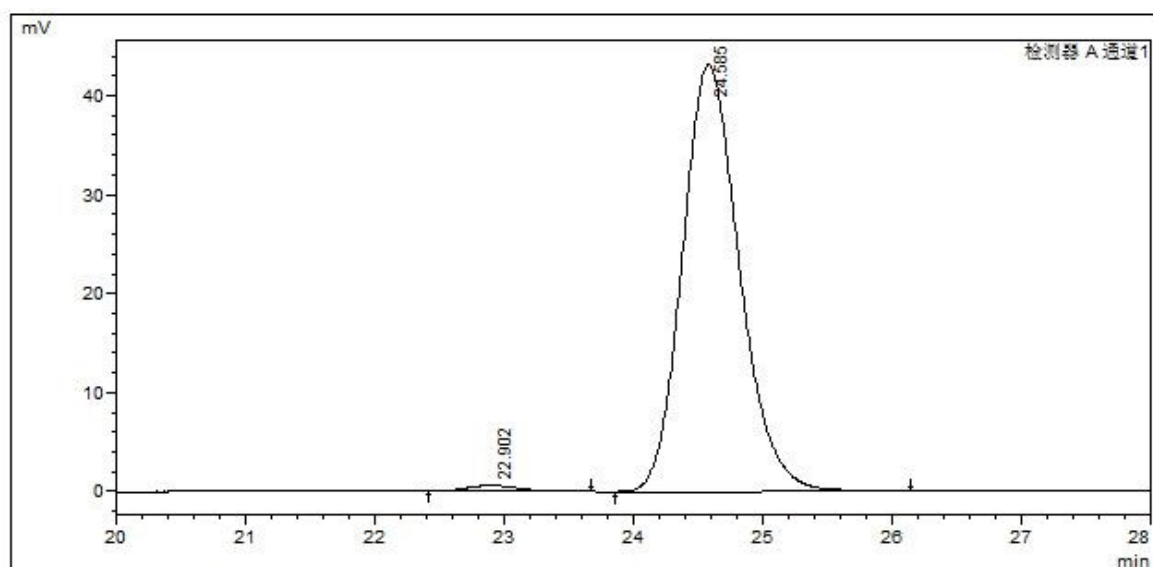
HPLC spectra of compound **2a** (racemic and chiral product):



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	22.881	772764	0.749	26940	49.785
2	24.627	779446	0.803	25229	50.215

检测器 A Ch1 254nm

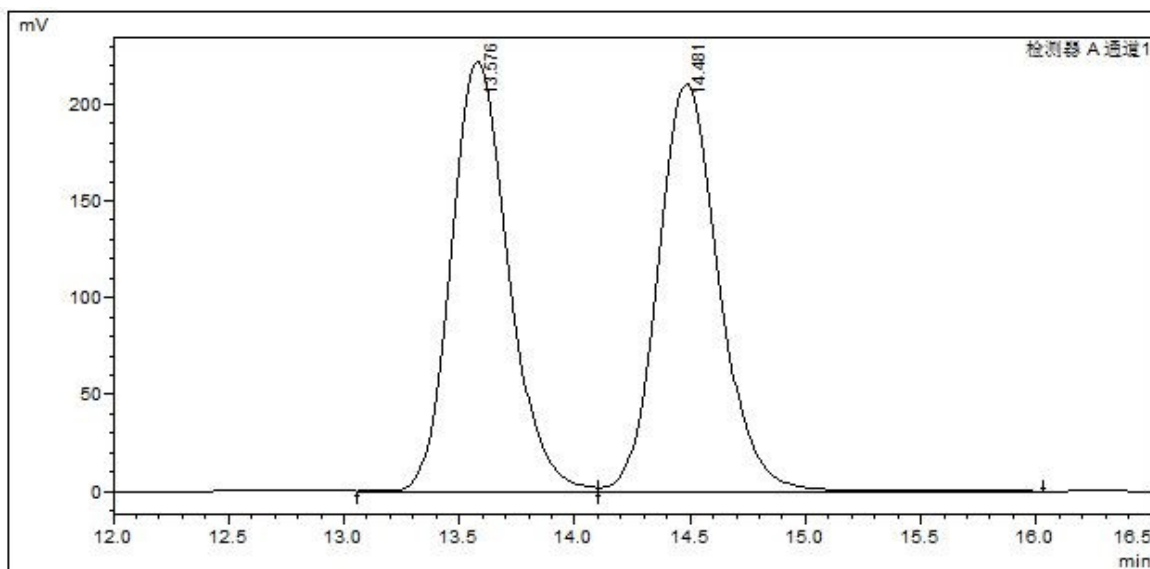
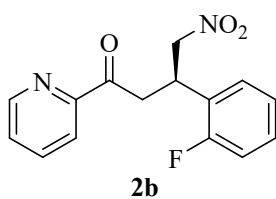


峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	22.902	16941	0.727	606	1.266
2	24.585	1321646	0.802	43096	98.734

检测器 A Ch1 254nm

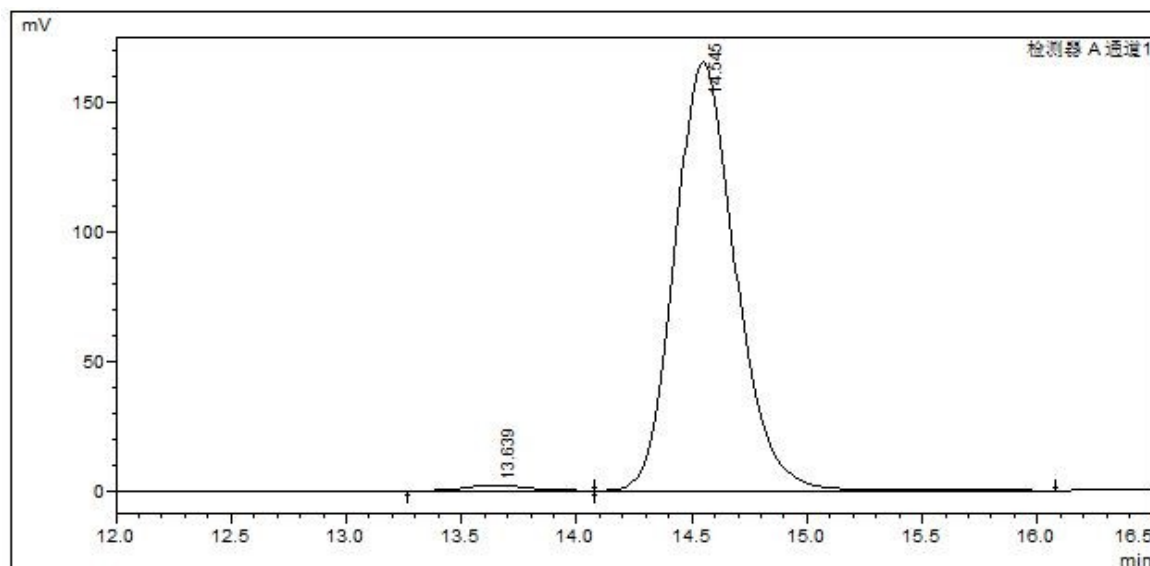
HPLC spectra of compound **2b** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.576	3816781	0.455	221400	49.759
2	14.481	3853734	0.480	210220	50.241

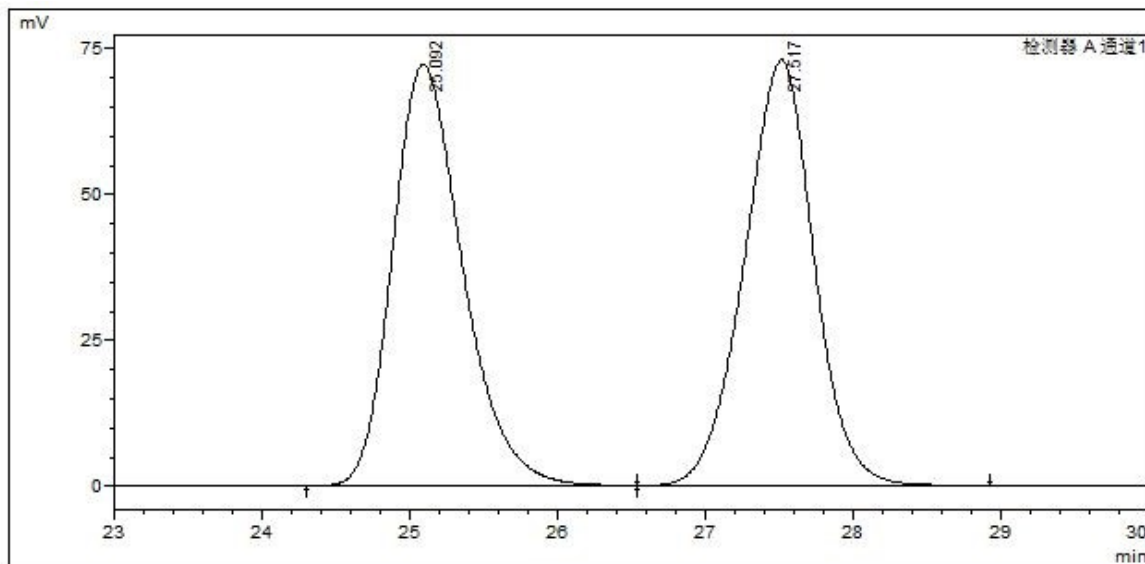
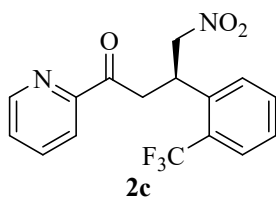


峰表

检测器 A Ch1 254nm

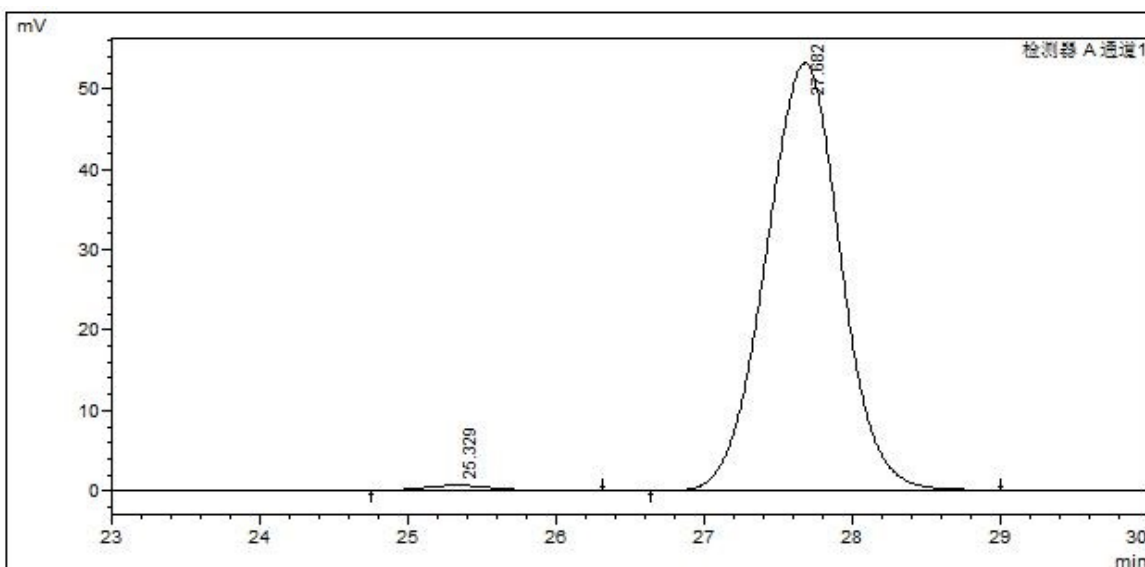
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.639	37297	0.450	2206	1.212
2	14.545	3039657	0.483	165466	98.788

HPLC spectra of compound **2c** (racemic and chiral product):



峰表

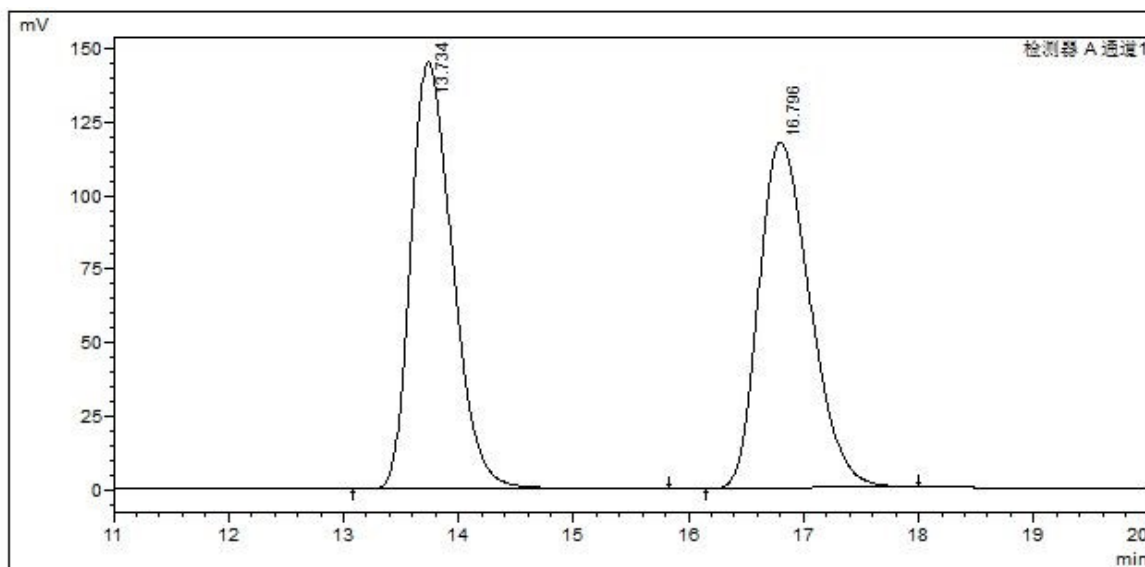
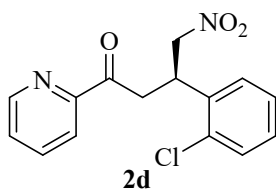
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	25.092	2380743	0.860	72104	50.009
2	27.517	2379880	0.862	72934	49.991



峰表

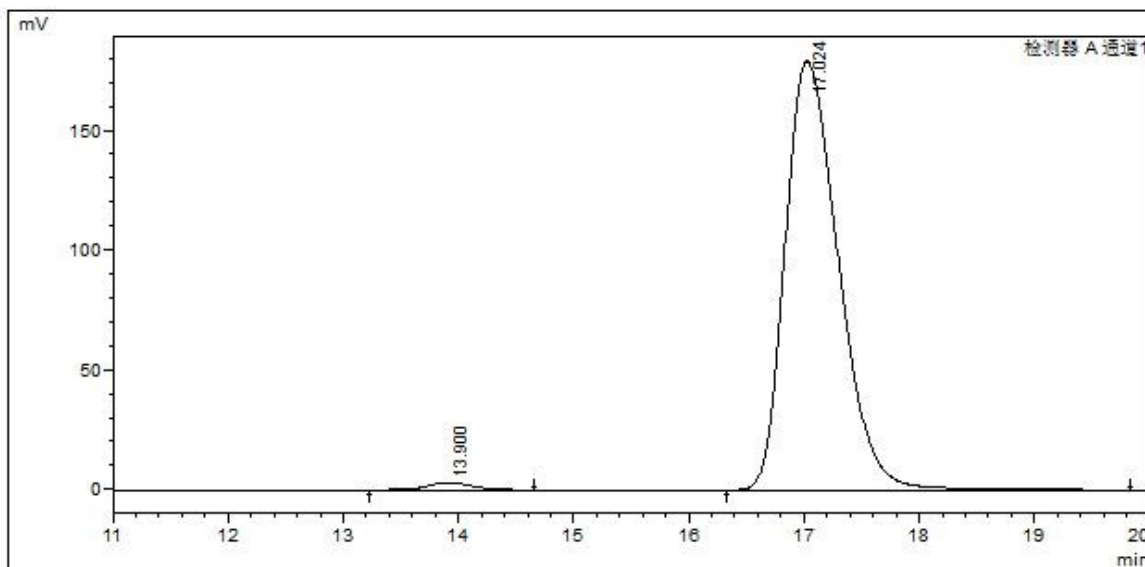
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	25.329	21526	0.850	663	1.138
2	27.682	1870457	0.922	53218	98.862

HPLC spectra of compound **2d** (racemic and chiral product):



峰表

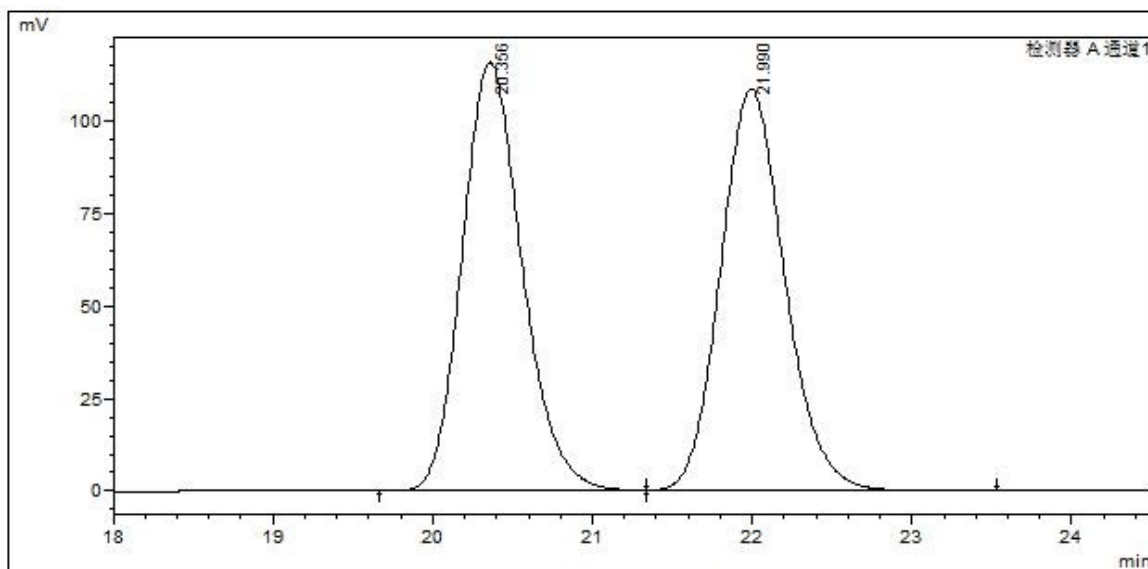
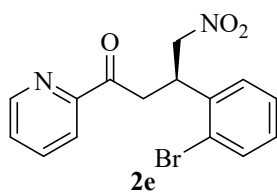
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.734	3679746	0.670	145350	50.190
2	16.796	3651905	0.825	117915	49.810



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.900	79683	0.676	3107	1.366
2	17.024	5755058	0.849	179044	98.634

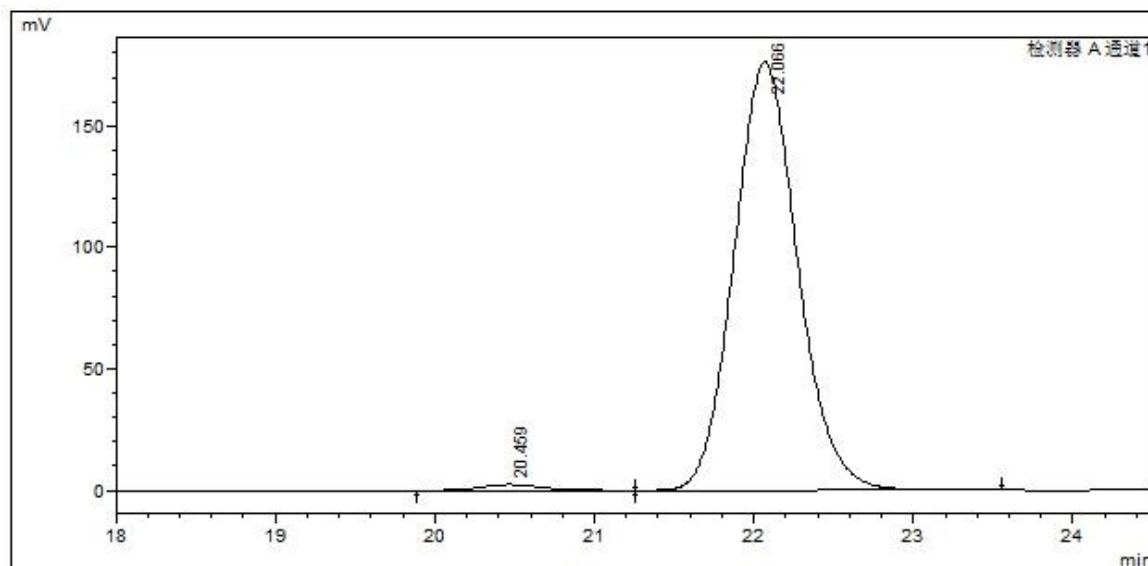
HPLC spectra of compound **2e** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	20.356	3031382	0.685	115890	49.878
2	21.990	3046188	0.735	108611	50.122

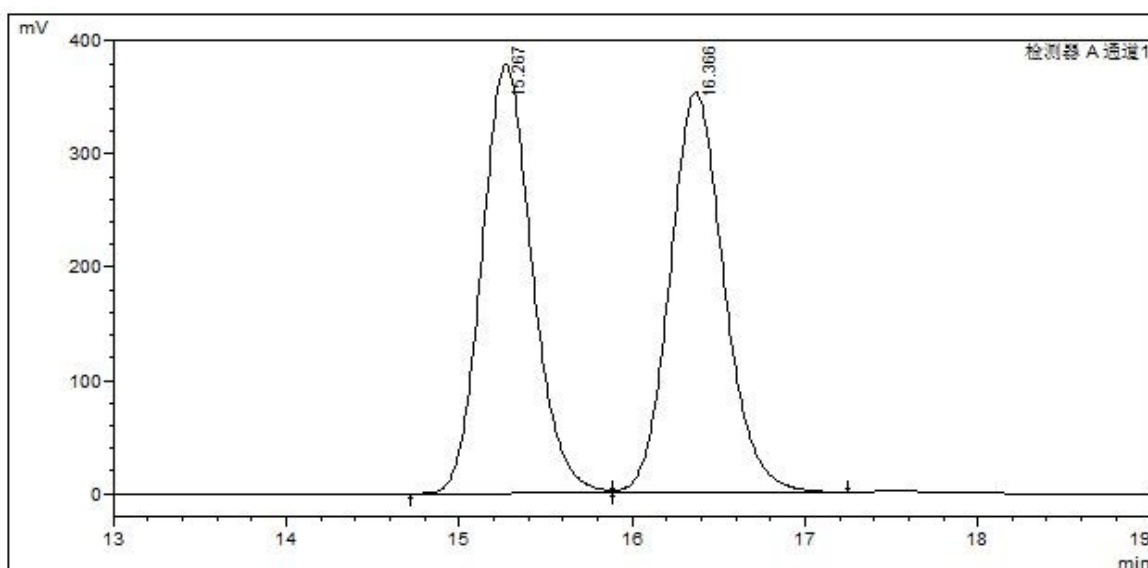
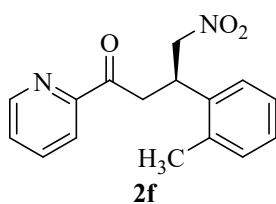


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	20.459	60645	0.676	2361	1.224
2	22.066	4895548	0.729	176180	98.776

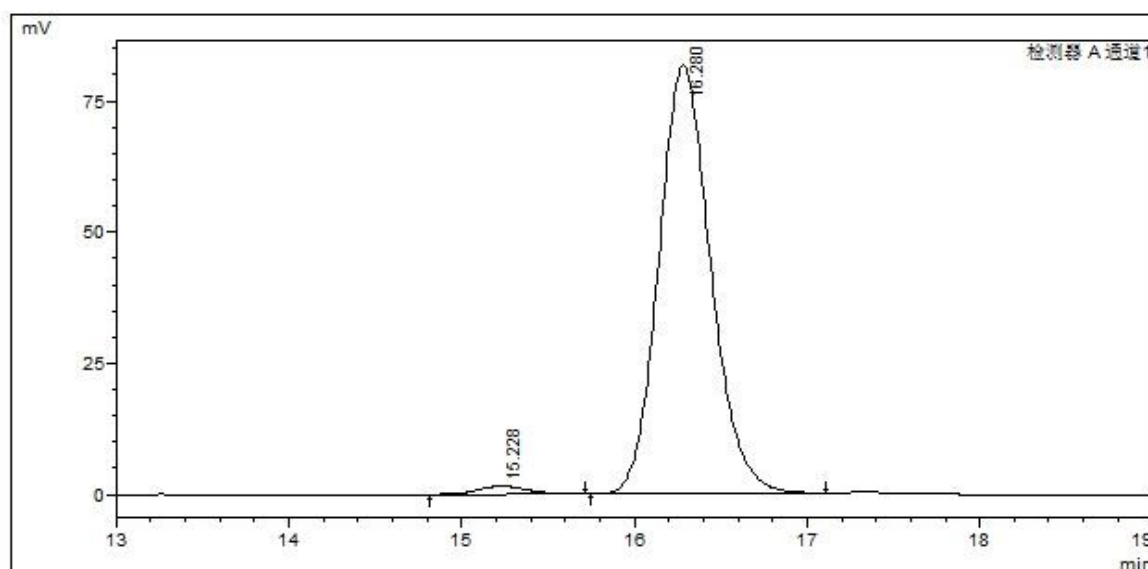
HPLC spectra of compound **2f** (racemic and chiral product):



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.267	7686046	0.534	378292	49.943
2	16.366	7703713	0.570	353975	50.057

检测器 A Ch1 254nm

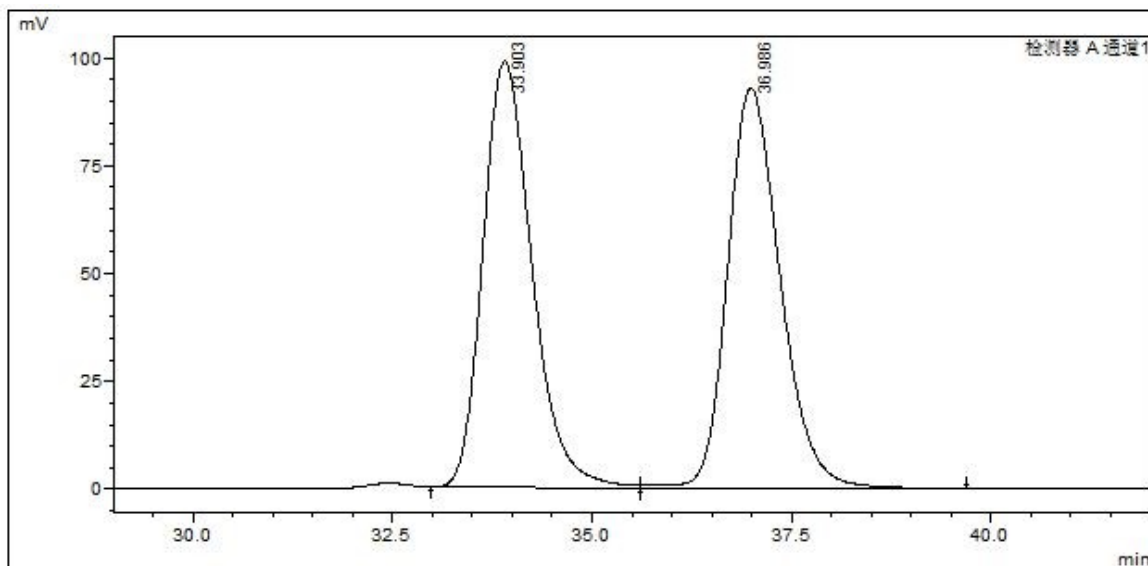
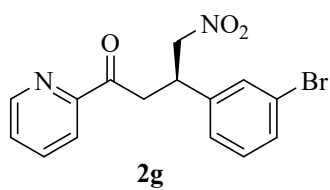


峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.228	30308	0.515	1570	1.746
2	16.280	1705492	0.549	81634	98.254

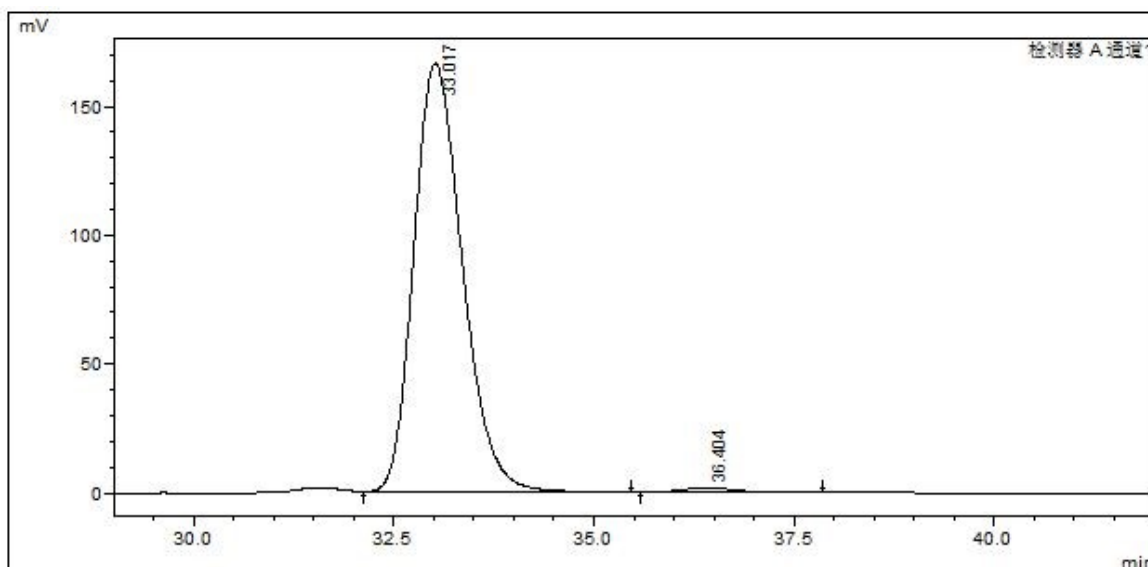
检测器 A Ch1 254nm

HPLC spectra of compound **2g** (racemic and chiral product):



峰表

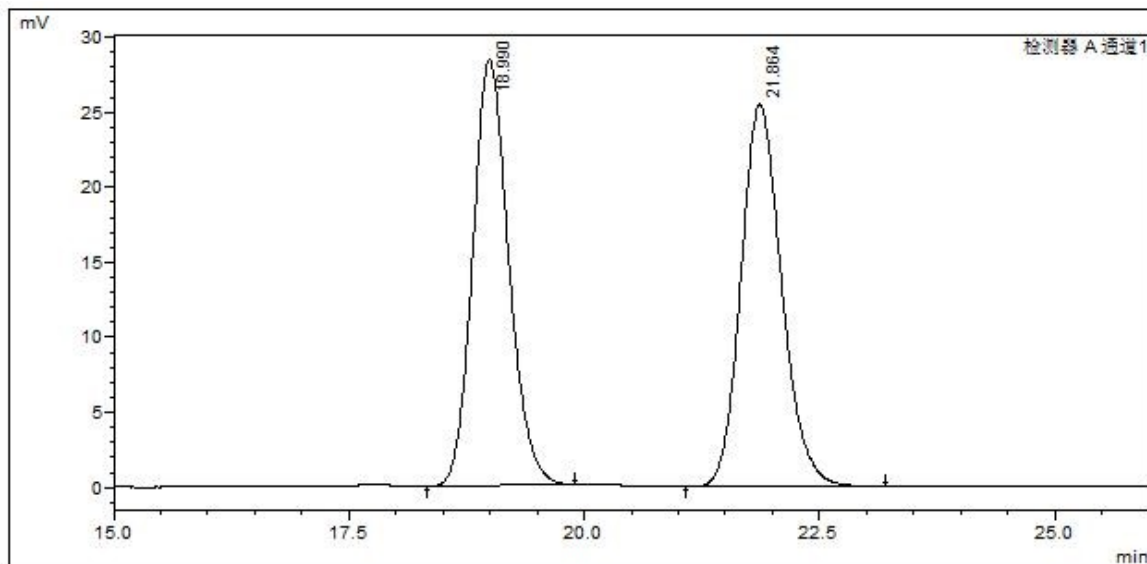
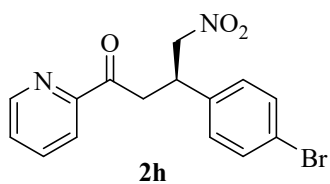
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	33.903	4231276	1.107	98827	49.879
2	36.986	4251800	1.188	92686	50.121



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	33.017	7020800	1.106	166304	98.882
2	36.404	79407	1.200	1739	1.118

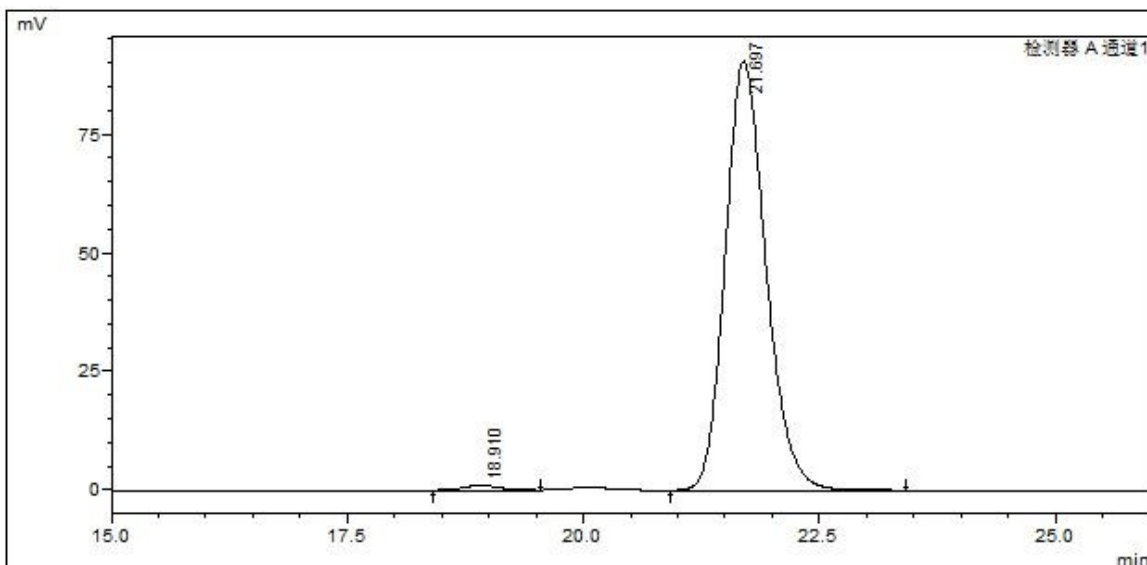
HPLC spectra of compound **2h** (racemic and chiral product):



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	18.990	759110	0.701	28391	49.752
2	21.864	766689	0.787	25467	50.248

检测器 A Ch1 254nm

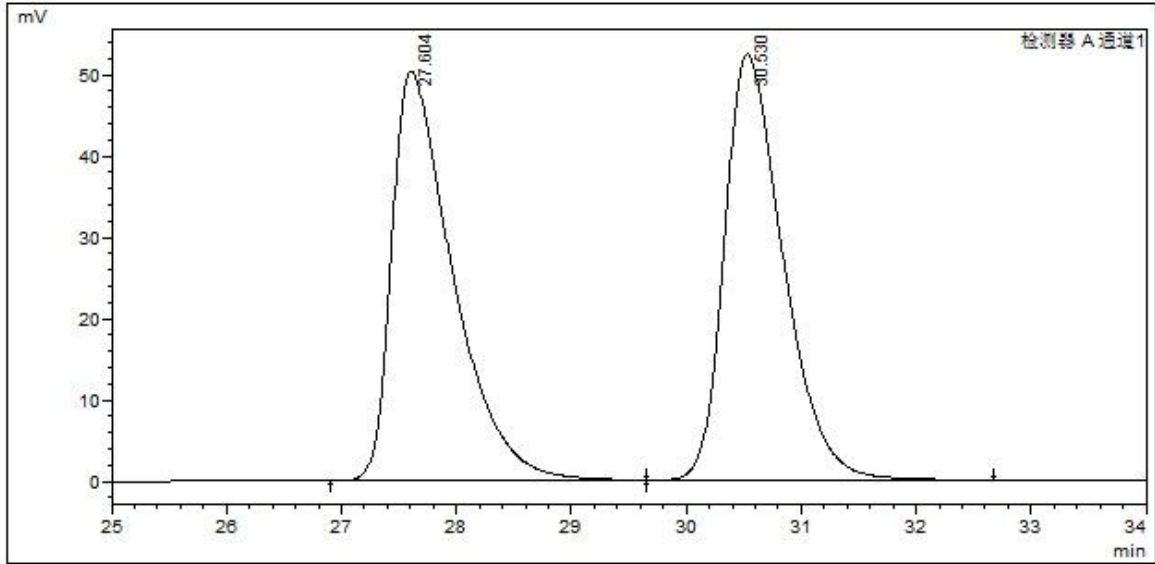
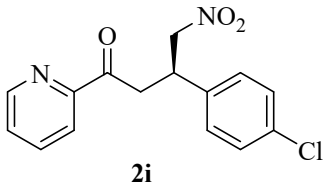


峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	18.910	25194	0.679	986	0.920
2	21.697	2712396	0.785	90355	99.080

检测器 A Ch1 254nm

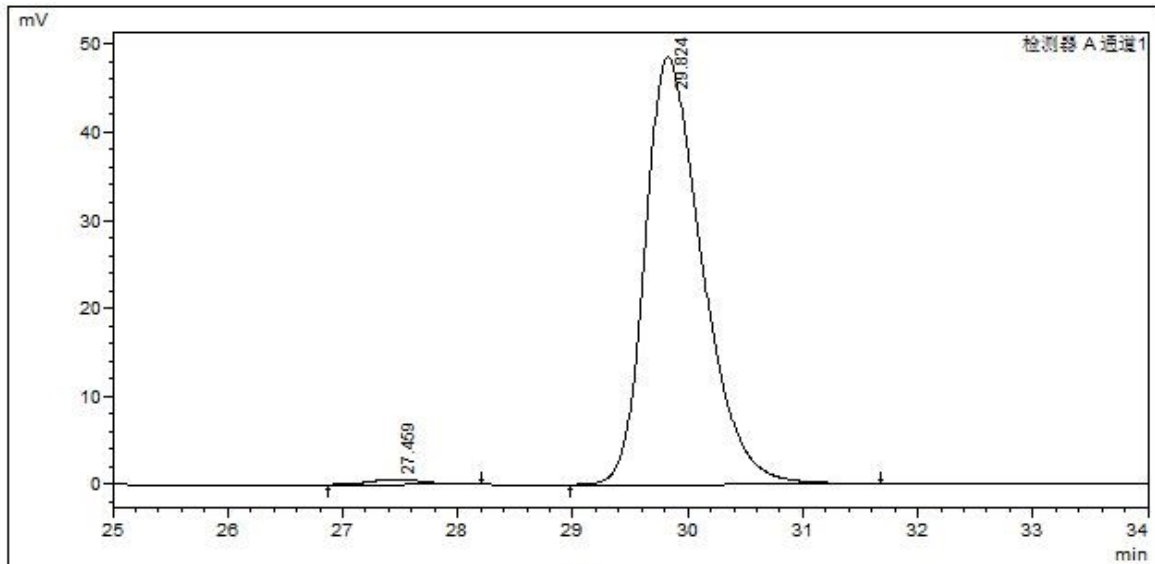
HPLC spectra of compound **2i** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	27.604	1876385	0.954	50438	49.928
2	30.530	1881804	0.930	52513	50.072

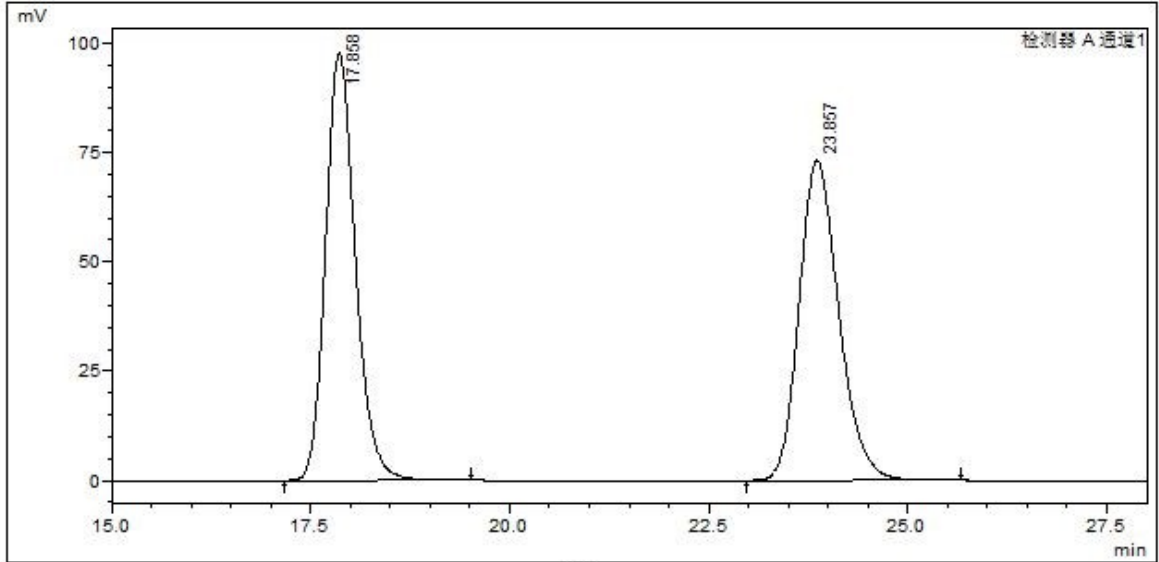
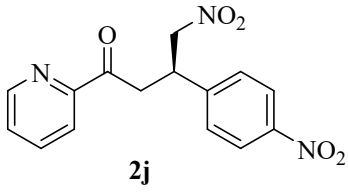


峰表

检测器 A Ch1 254nm

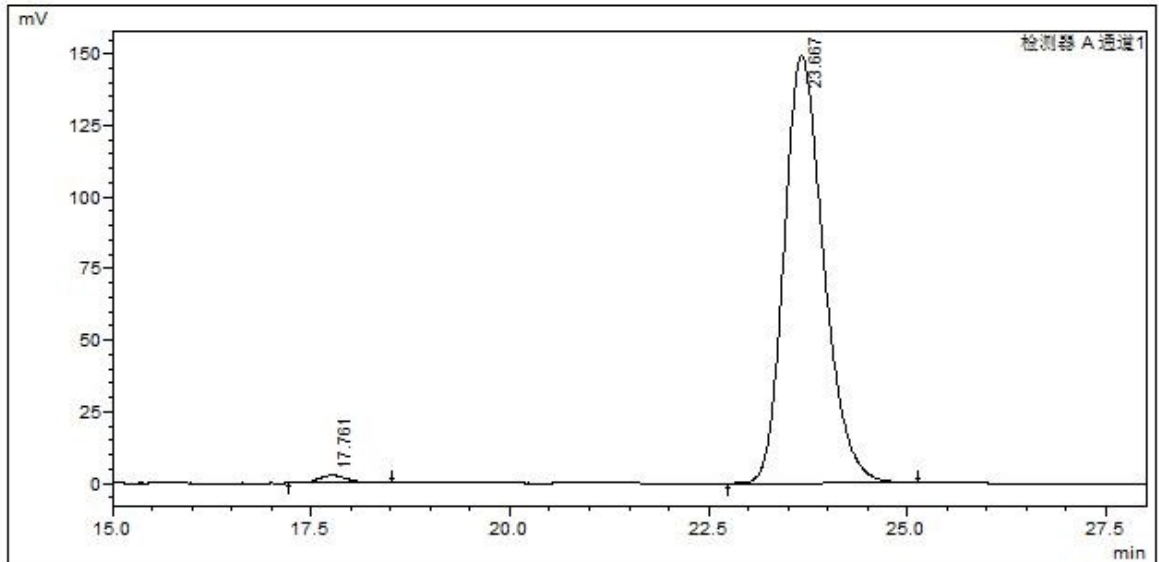
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	27.459	20038	0.838	630	1.182
2	29.824	1675966	0.900	48501	98.818

HPLC spectra of compound **2j** (racemic and chiral product):



峰表

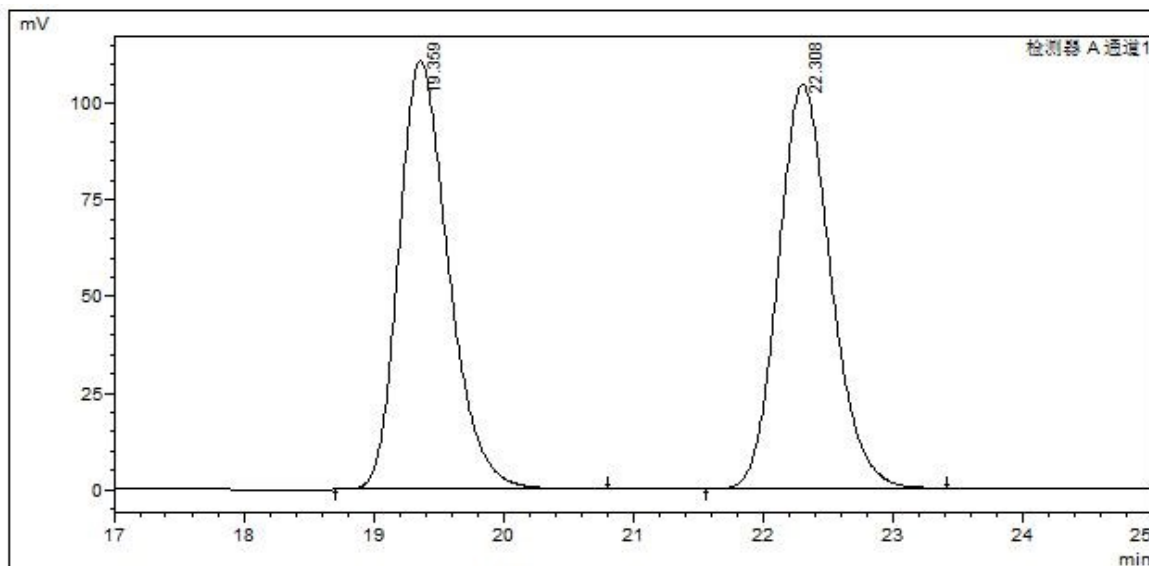
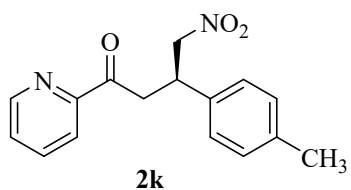
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	17.858	2543665	0.676	97672	50.068
2	23.857	2536734	0.905	73158	49.932



峰表

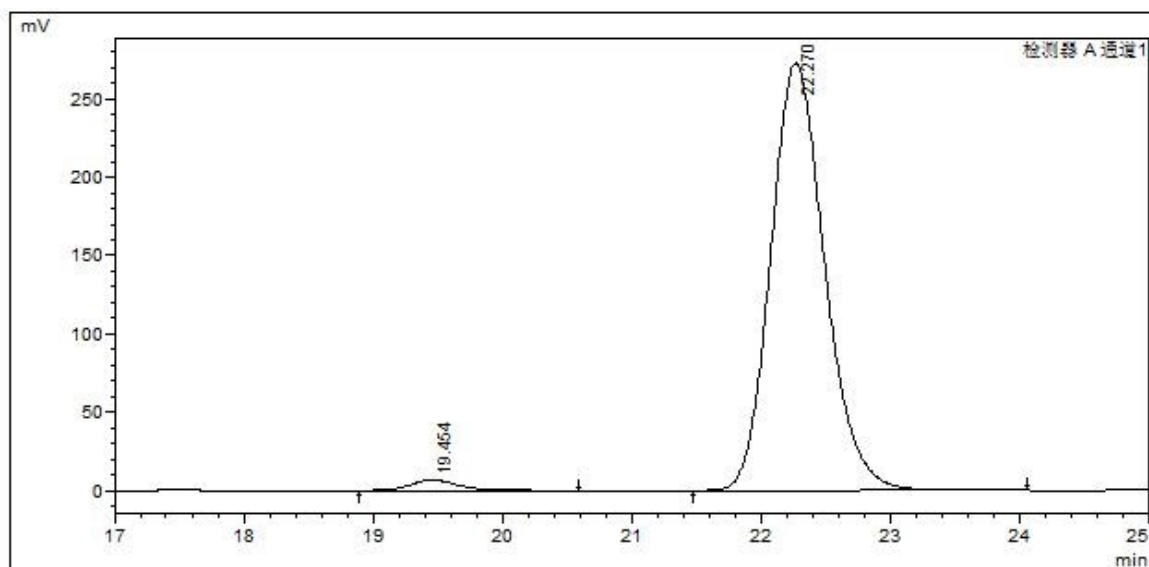
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	17.761	69369	0.667	2732	1.326
2	23.667	5160361	0.905	149130	98.674

HPLC spectra of compound **2k** (racemic and chiral product):



峰表

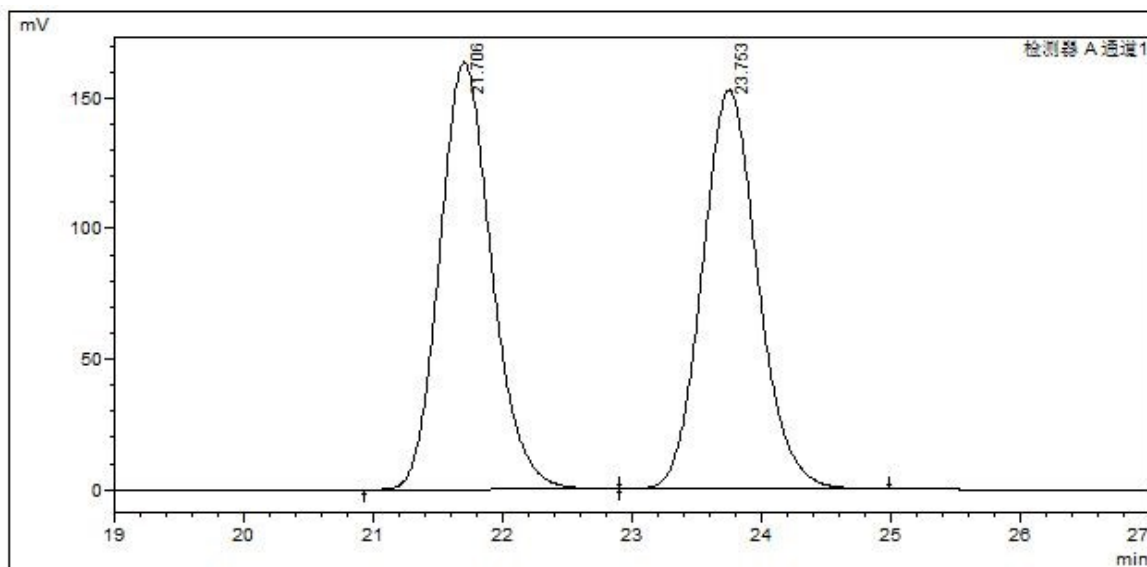
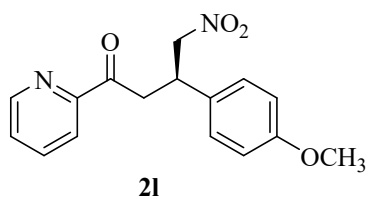
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	19.359	2958926	0.697	110863	50.047
2	22.308	2953389	0.740	104780	49.953



峰表

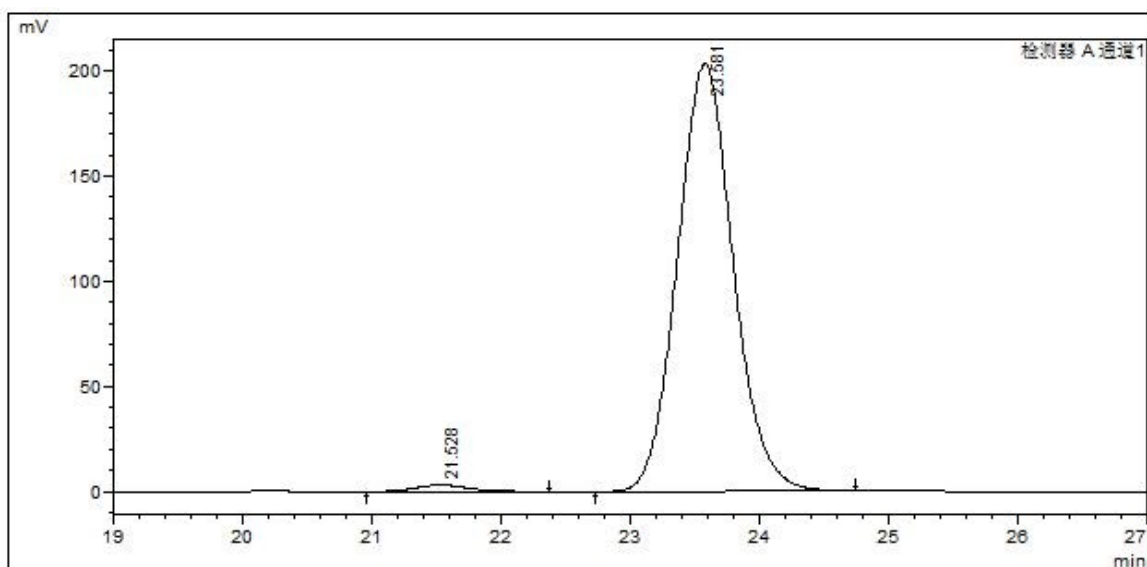
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	19.454	166059	0.652	6646	2.050
2	22.270	7935978	0.761	272774	97.950

HPLC spectra of compound **21** (racemic and chiral product):



峰表

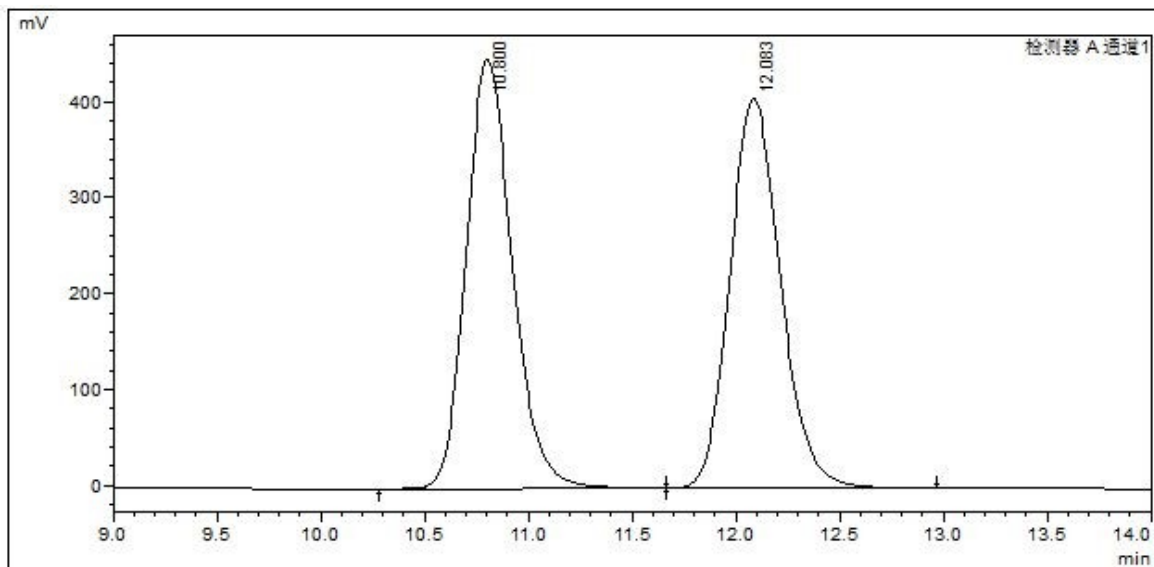
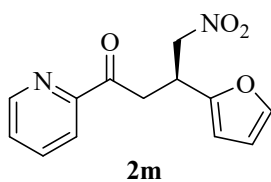
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	21.706	4580500	0.733	163731	50.042
2	23.753	4572902	0.784	152894	49.958



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	21.528	85022	0.726	3085	1.373
2	23.581	6106939	0.790	203208	98.627

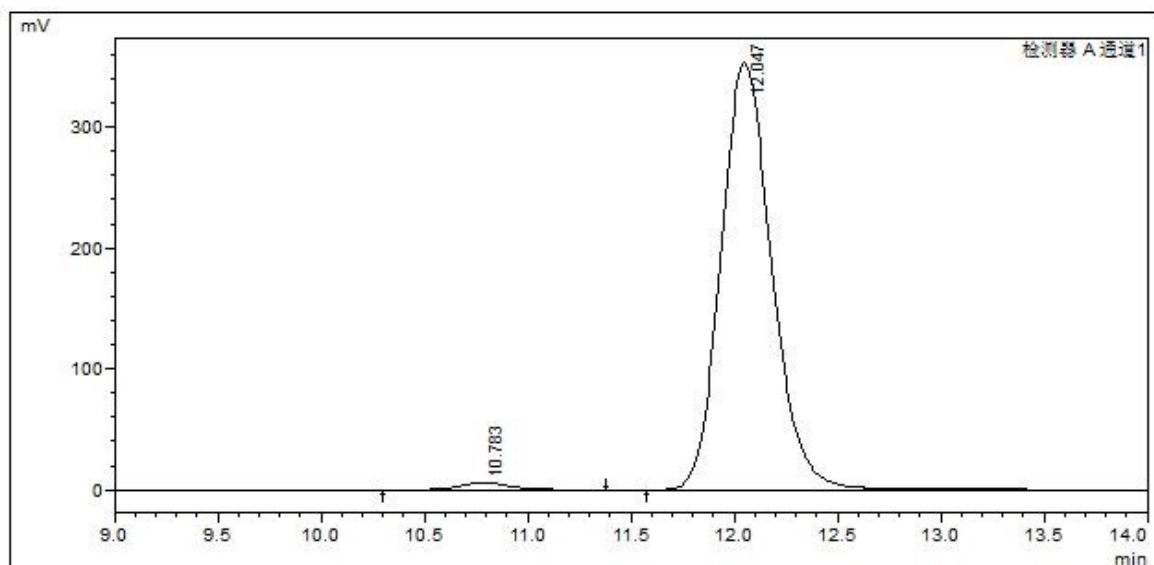
HPLC spectra of compound **2m** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	10.800	6957924	0.409	447020	50.104
2	12.083	6929059	0.449	406378	49.896

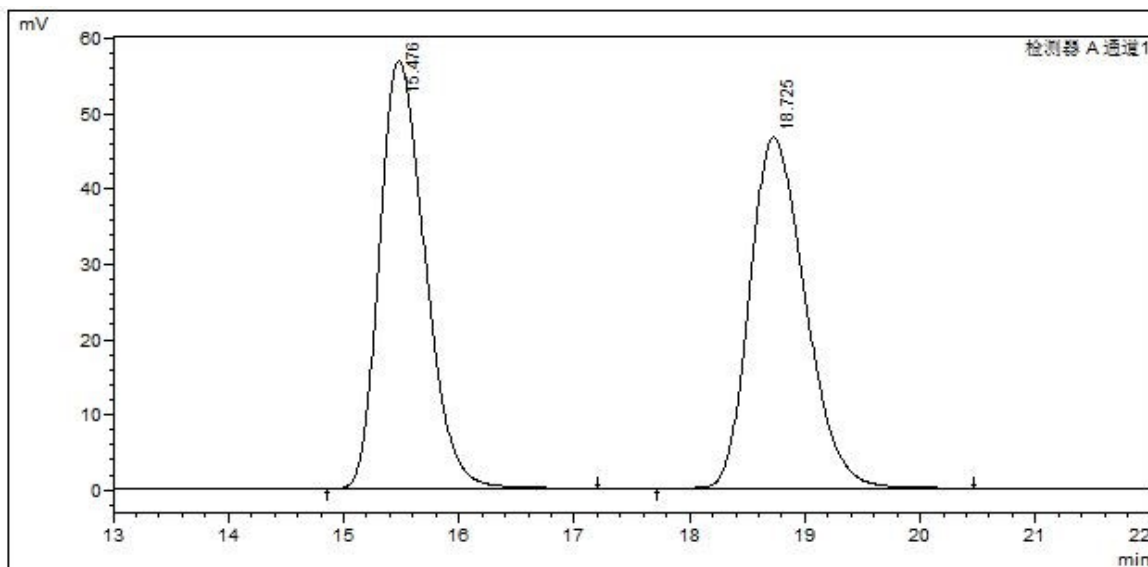
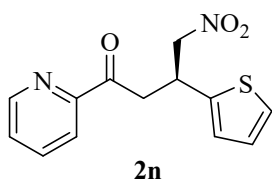


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	10.783	93915	0.414	5959	1.529
2	12.047	6048857	0.450	353206	98.471

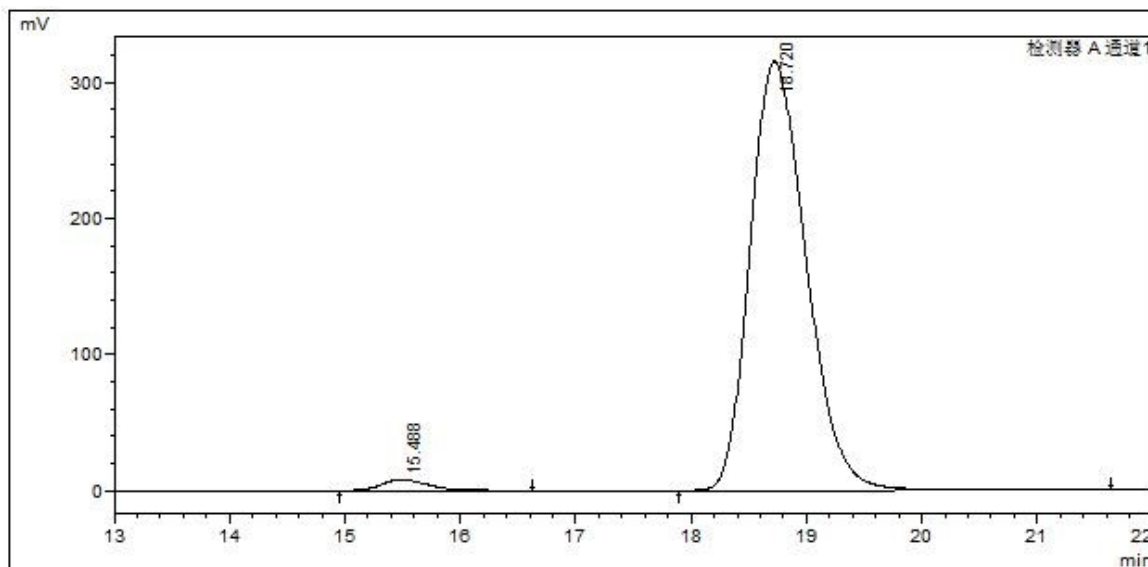
HPLC spectra of compound **2n** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.476	1565340	0.729	56852	50.002
2	18.725	1565215	0.889	46663	49.998

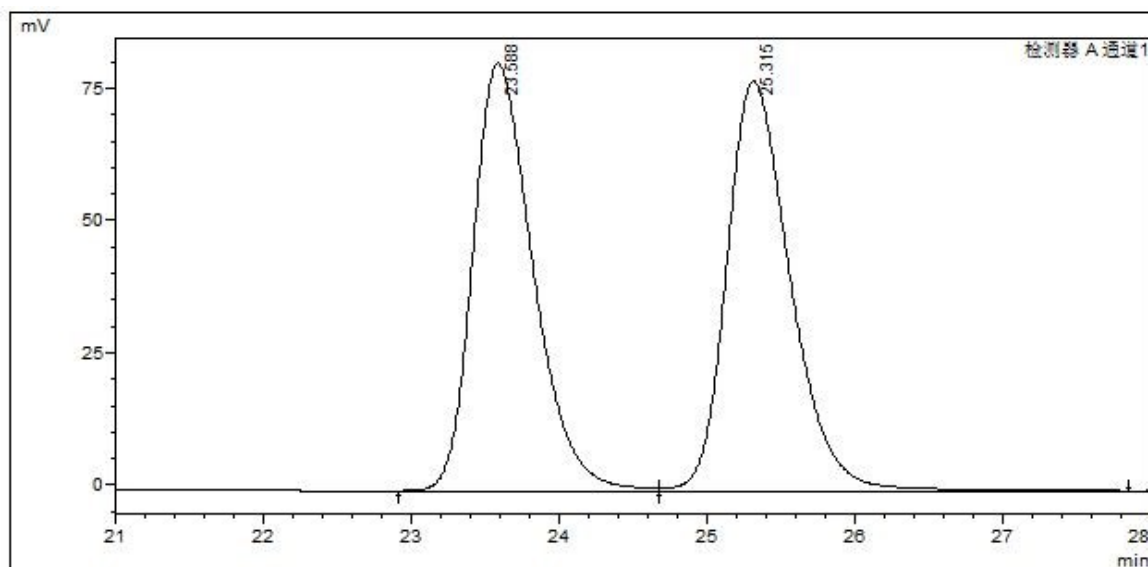
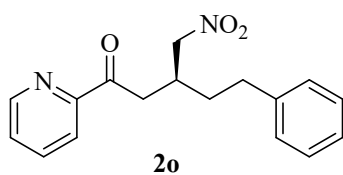


峰表

检测器 A Ch1 254nm

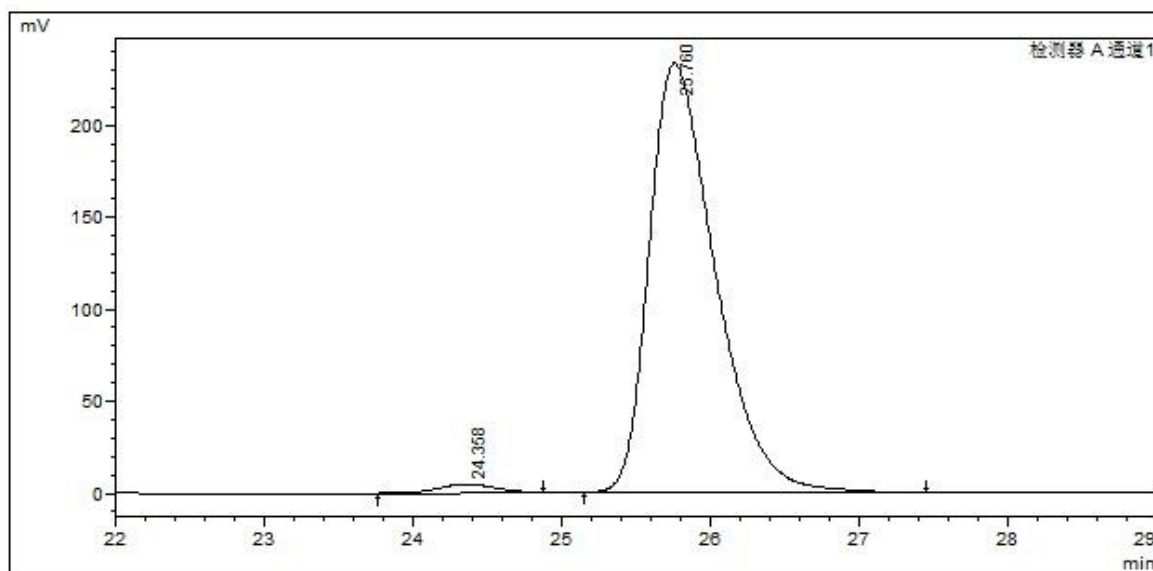
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.488	214991	0.726	7846	1.976
2	18.720	10665007	0.894	315545	98.024

HPLC spectra of compound **20** (racemic and chiral product):



峰表

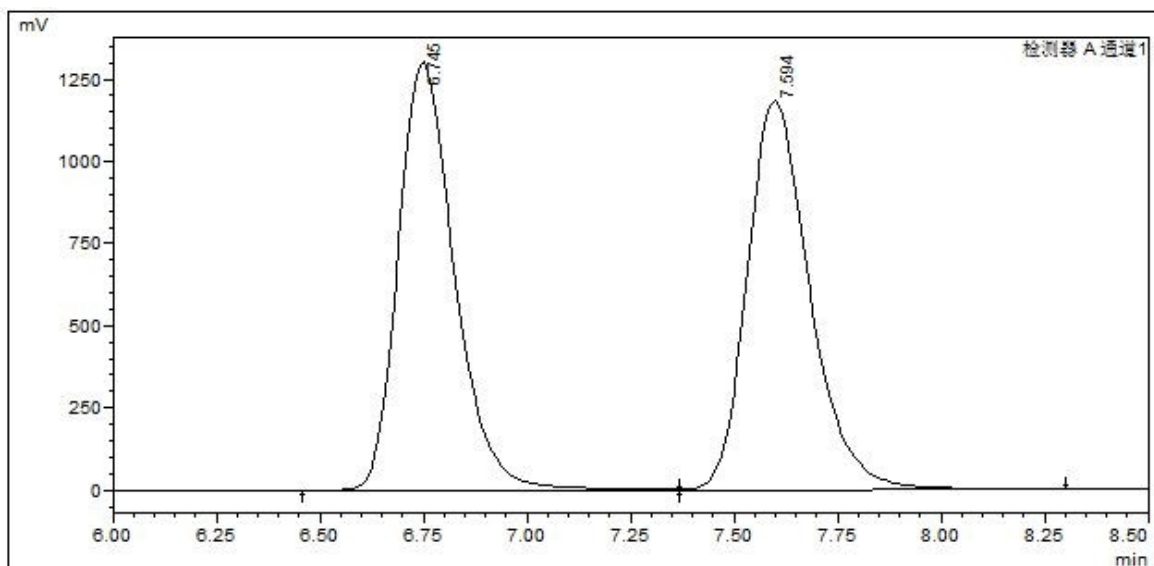
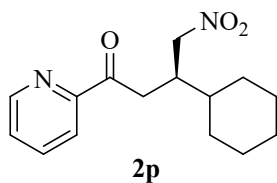
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	23.588	2288644	0.737	80910	49.720
2	25.315	2314390	0.773	77410	50.280



峰表

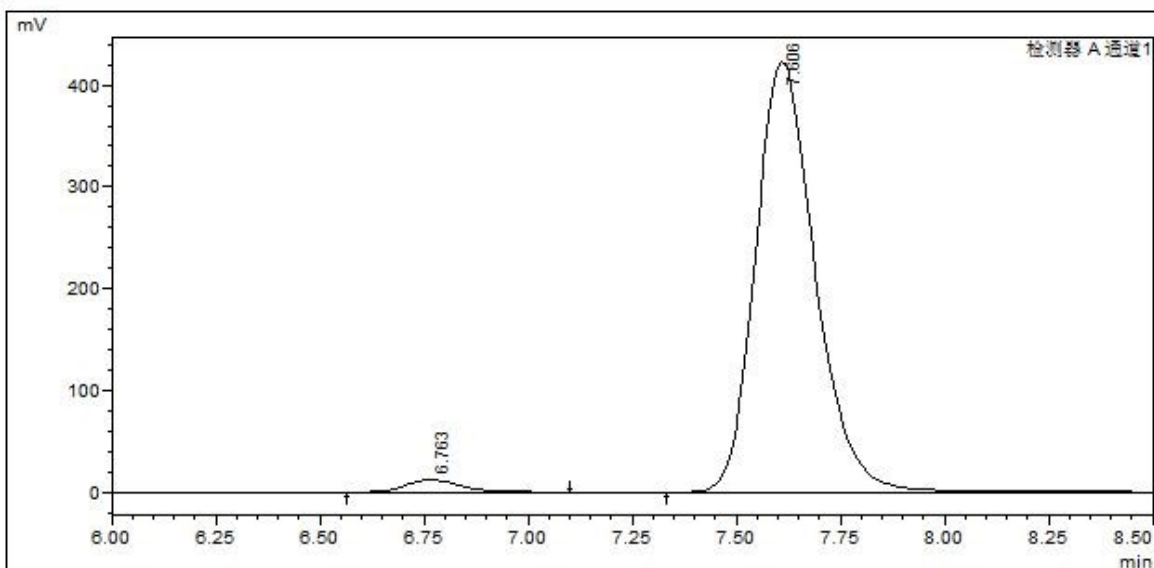
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	24.358	115486	0.679	4589	1.580
2	25.760	7193449	0.802	232999	98.420

HPLC spectra of compound **2p** (racemic and chiral product):



峰表

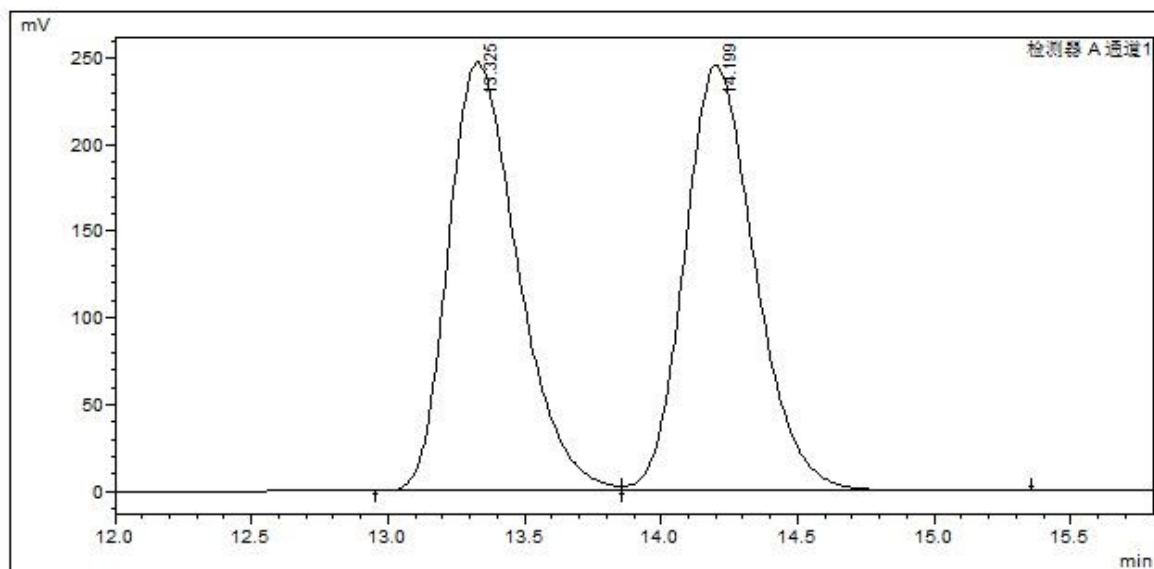
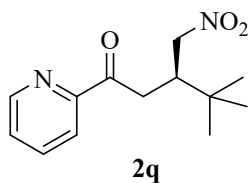
峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	6.745	12287803	0.253	1301790	49.689
2	7.594	12441477	0.279	1182392	50.311



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	6.763	106574	0.242	12016	2.467
2	7.606	4214051	0.267	422382	97.533

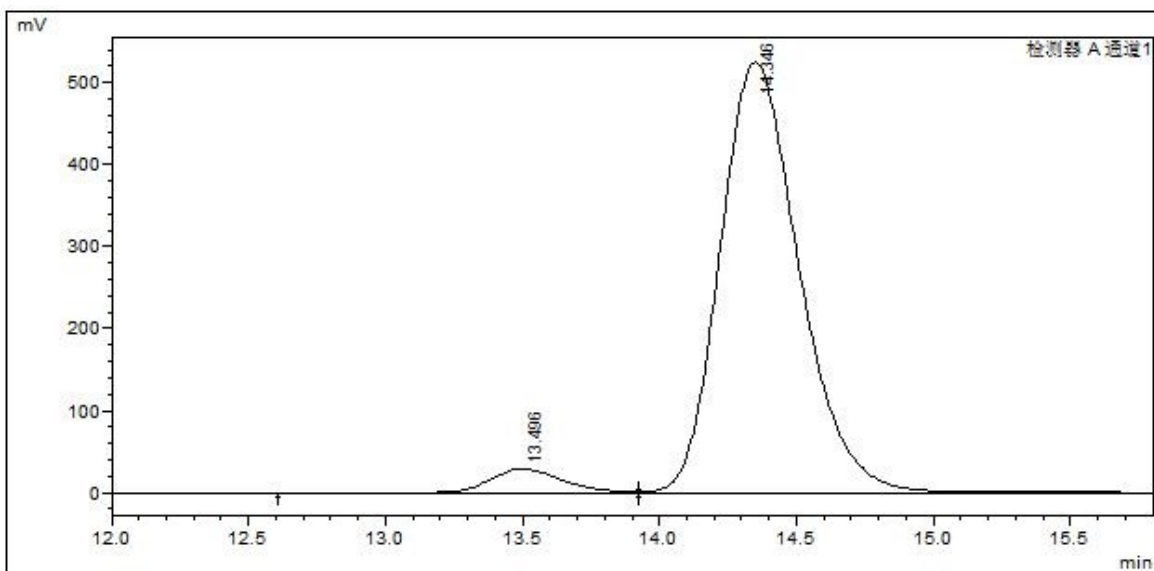
HPLC spectra of compound **2q** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.325	4392073	0.469	247235	49.843
2	14.199	4419728	0.475	245341	50.157

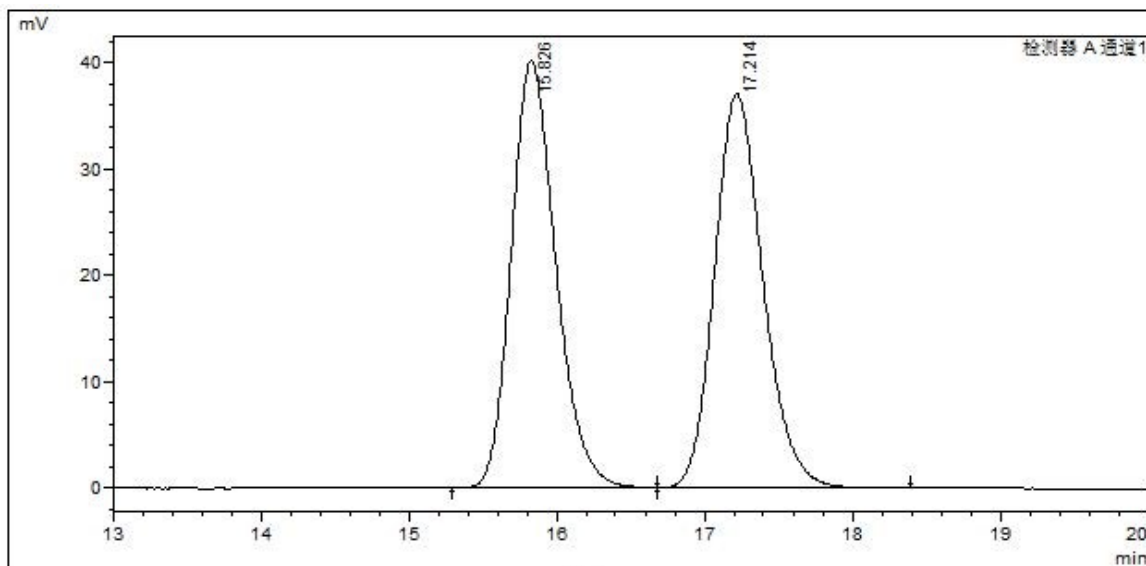
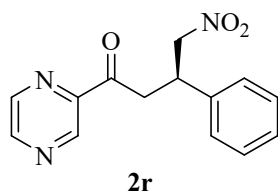


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	13.496	521567	0.477	28855	4.728
2	14.346	10509650	0.527	524435	95.272

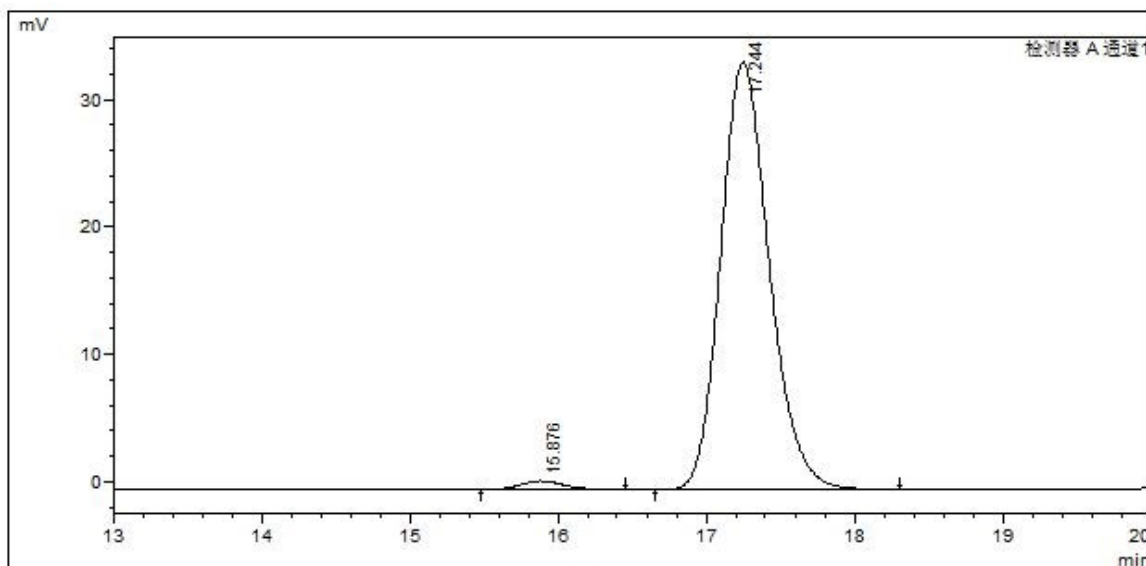
HPLC spectra of compound **2r** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.826	844165	0.551	40160	49.911
2	17.214	847173	0.598	37046	50.089

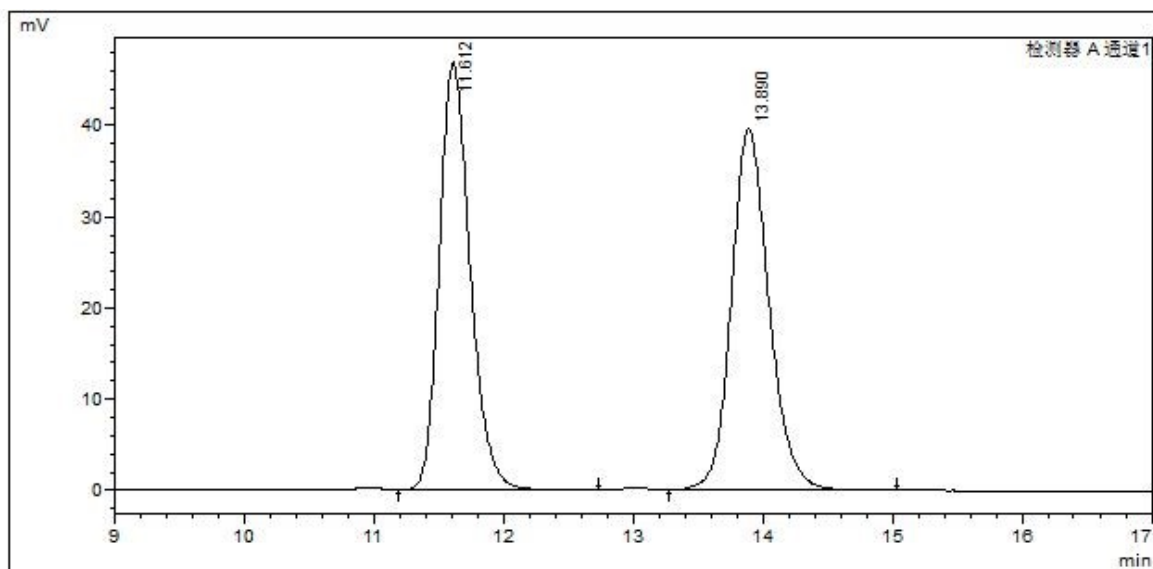
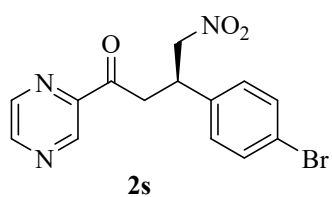


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	15.876	13932	0.539	679	1.788
2	17.244	765179	0.597	33569	98.212

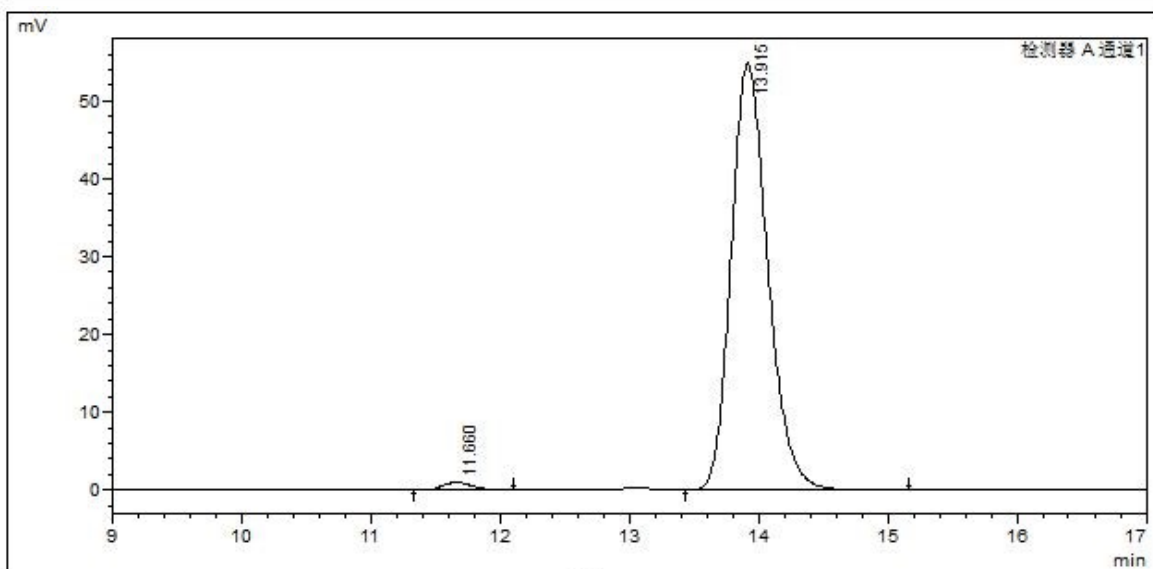
HPLC spectra of compound **2s** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	11.612	776653	0.435	46879	49.277
2	13.890	799440	0.523	39589	50.723

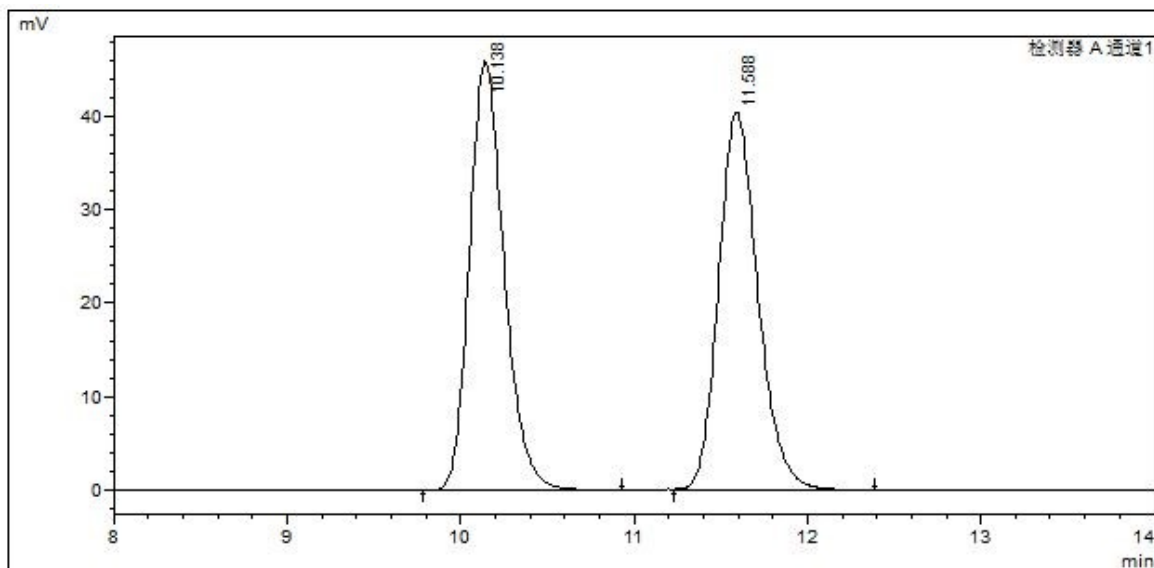
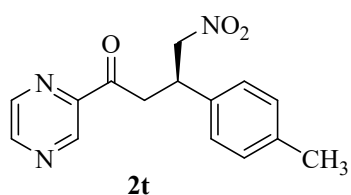


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	11.660	16740	0.433	1033	1.518
2	13.915	1086095	0.518	54917	98.482

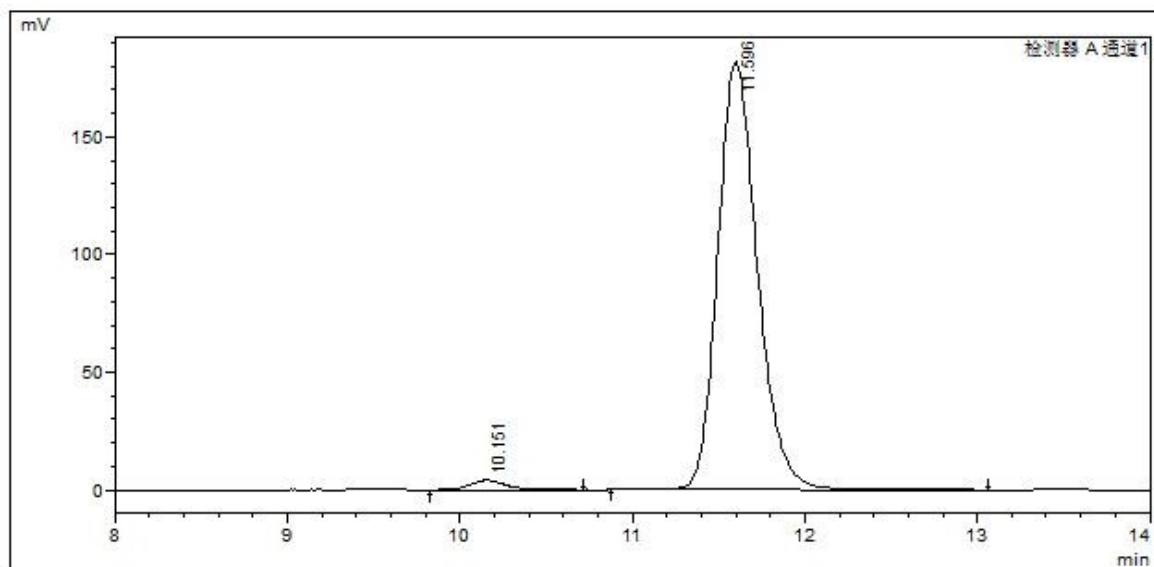
HPLC spectra of compound **2t** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	10.138	639546	0.368	45919	50.155
2	11.588	635593	0.415	40391	49.845

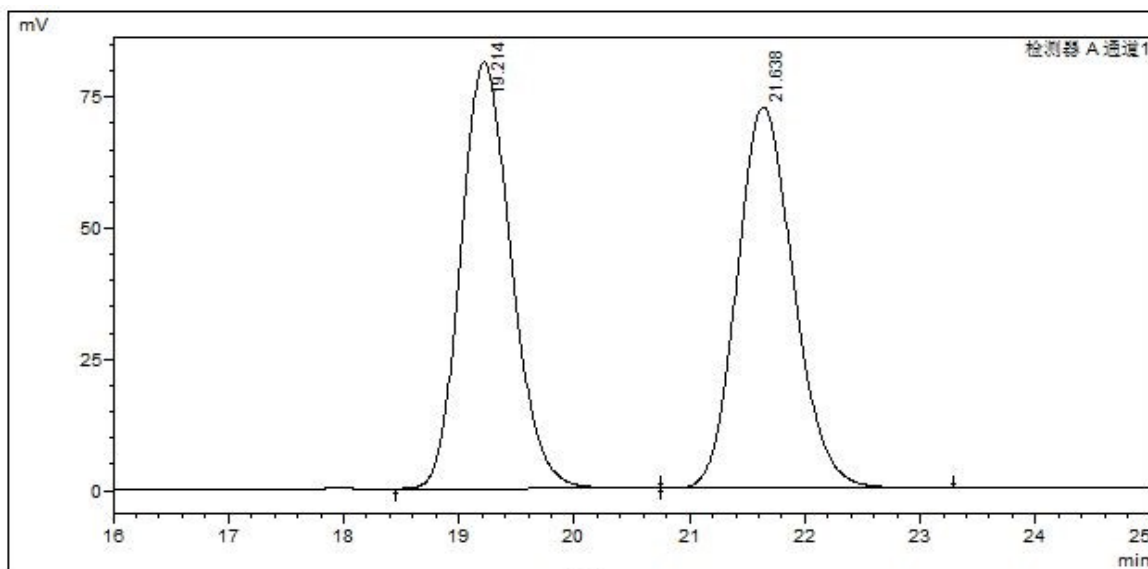
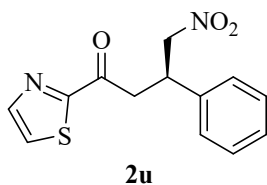


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	10.151	55938	0.368	4029	1.883
2	11.596	2915304	0.419	181857	98.117

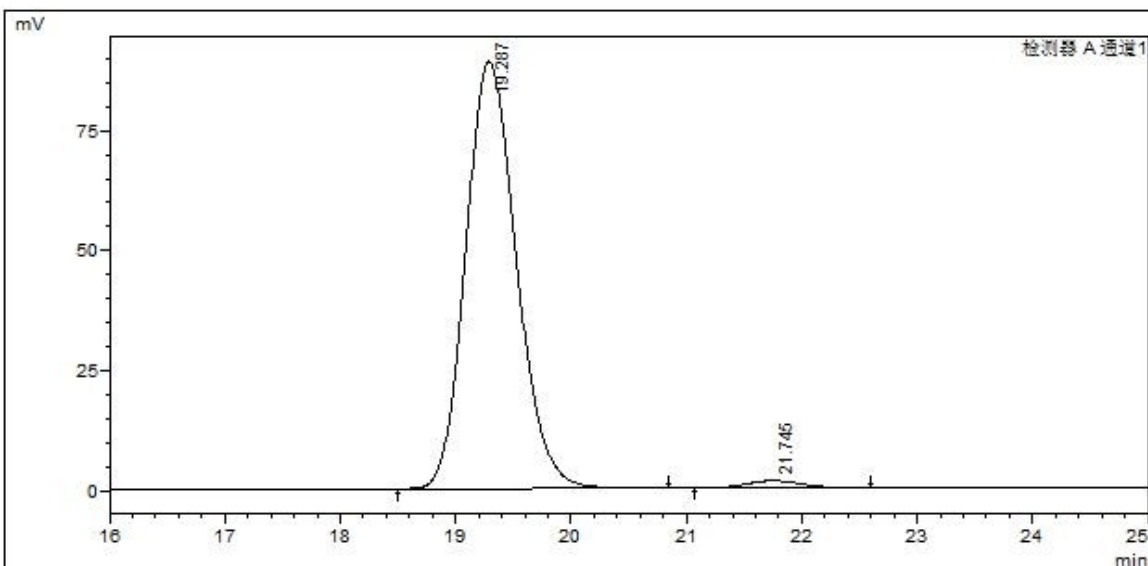
HPLC spectra of compound **2u** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	19.214	2477688	0.803	81316	49.929
2	21.638	2484717	0.902	72667	50.071

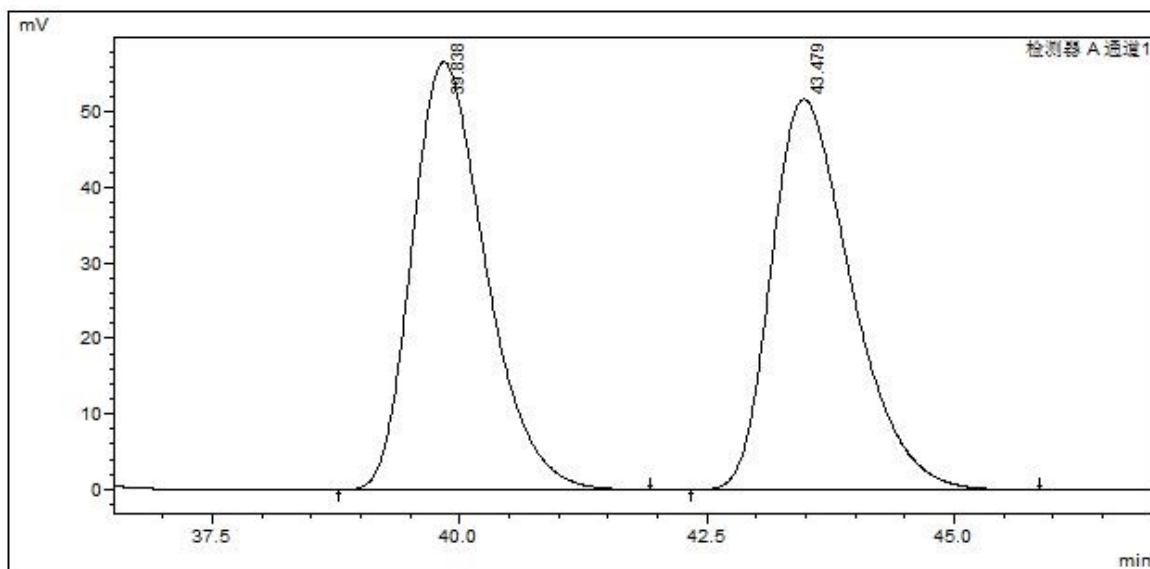
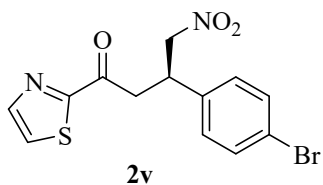


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	19.287	2709957	0.803	88993	98.158
2	21.745	50841	0.881	1532	1.842

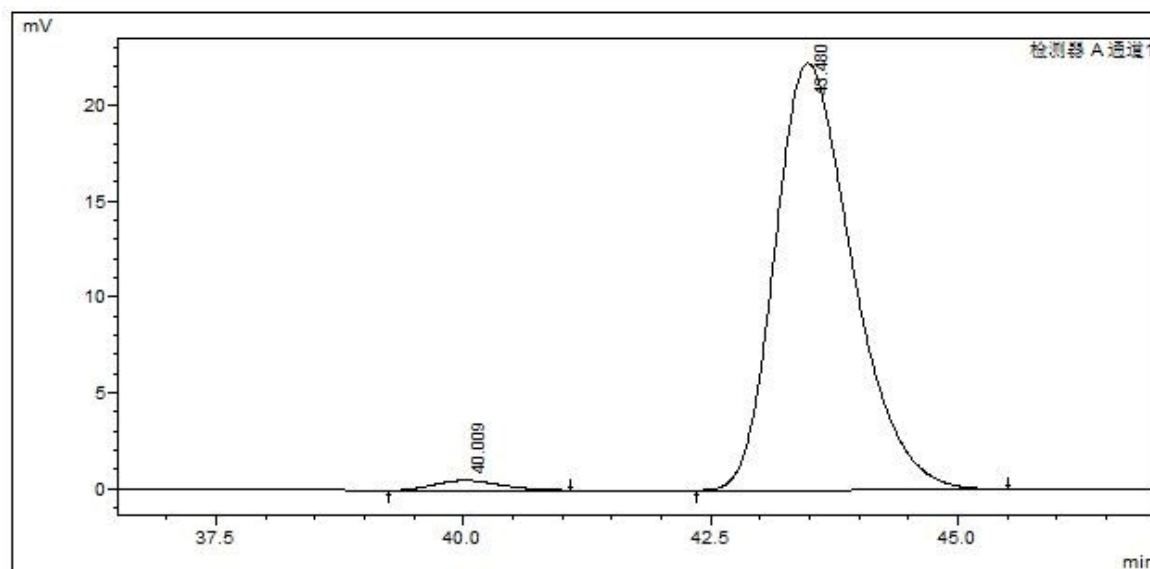
HPLC spectra of compound **2v** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	39.838	2939685	1.357	56642	50.128
2	43.479	2924630	1.482	51718	49.872

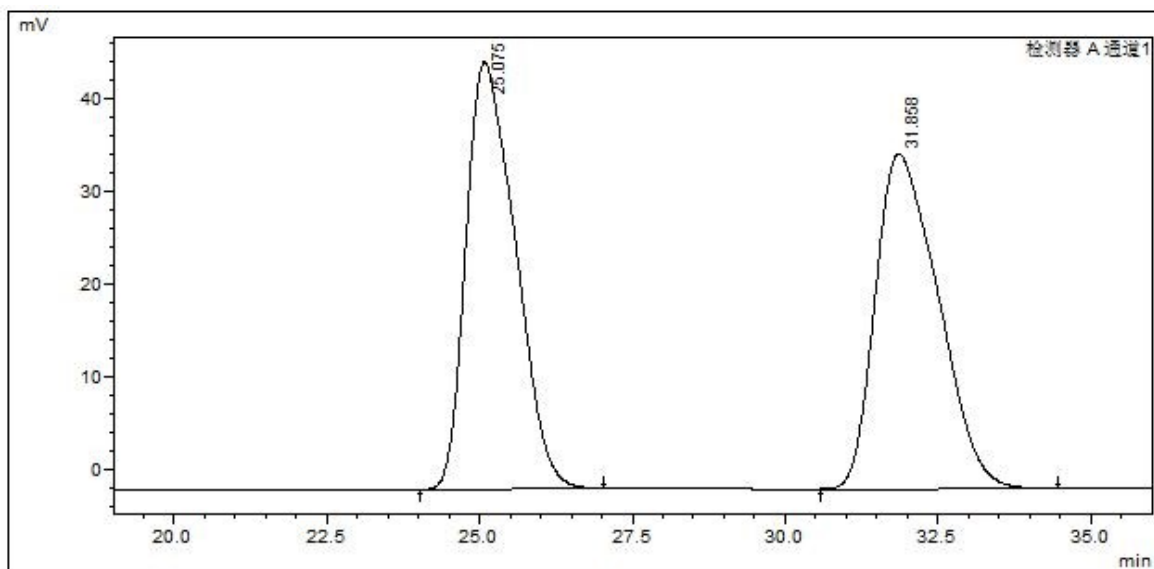
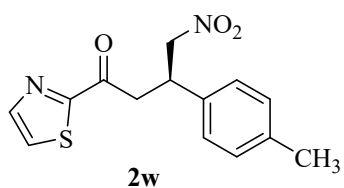


峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	40.009	24496	1.252	522	1.975
2	43.480	1215572	1.429	22283	98.025

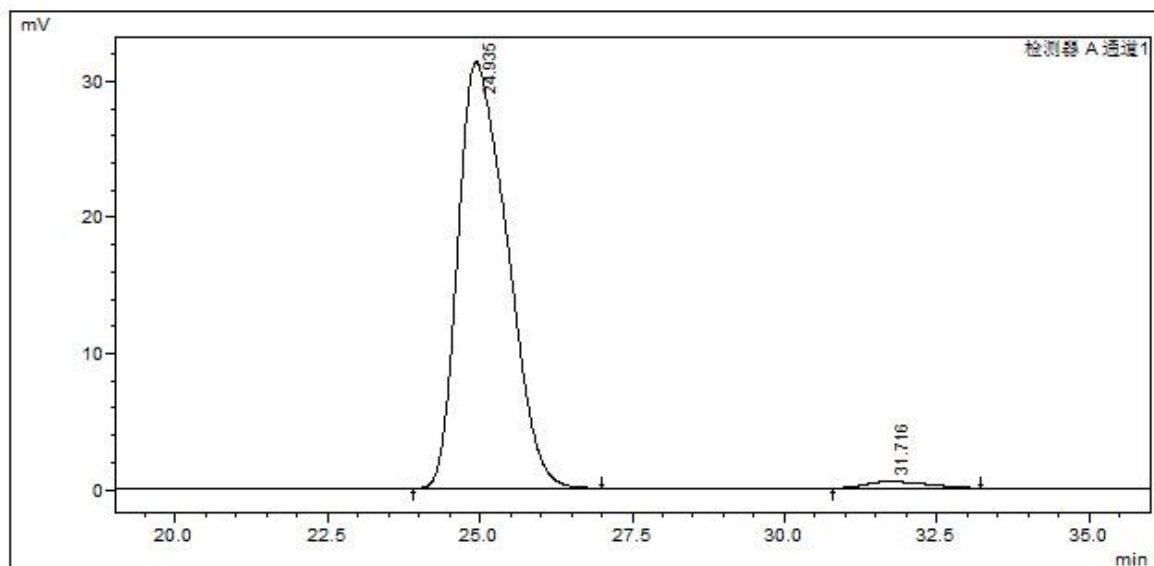
HPLC spectra of compound **2w** (racemic and chiral product):



峰表

检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	25.075	2584628	1.539	46013	49.966
2	31.858	2588098	1.961	36136	50.034

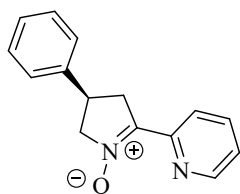


峰表

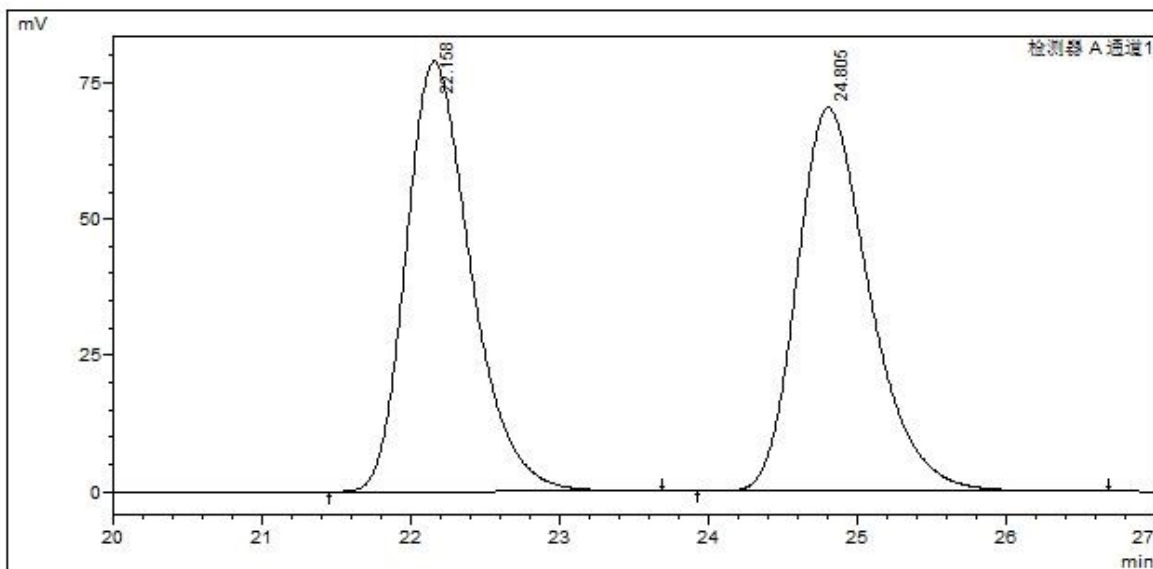
检测器 A Ch1 254nm

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	24.935	1757554	1.532	31318	98.132
2	31.716	33459	1.950	486	1.868

HPLC spectra of compound **3a** (racemic and chiral product):

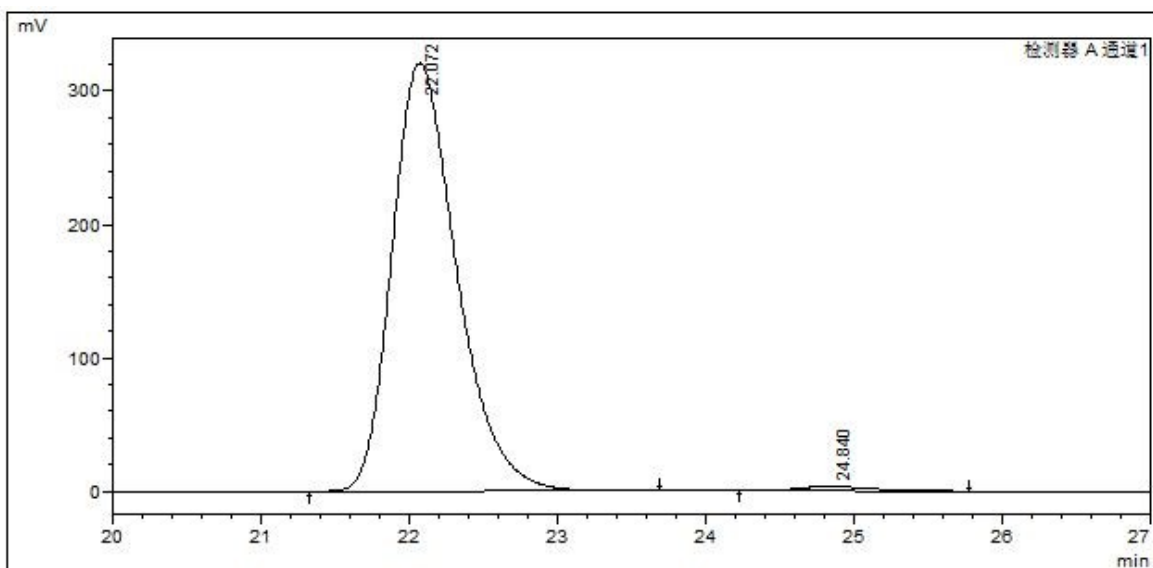


3a



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	22.158	2398585	0.788	78967	49.962
2	24.805	2402189	0.885	70383	50.038



峰表

峰#	保留时间	面积	USP 峰宽	高度	面积 %
1	22.072	9726199	0.789	320915	98.871
2	24.840	111034	0.873	3375	1.129

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