

Supporting Information

Double Isocyanide Cyclization: A Synthetic Strategy for Two-carbon Tethered Pyrrole/Oxazole Pairs

Yifei Li, Xianxiu Xu,* Jing Tan, Chunyu Xia, Dawei Zhang and Qun Liu*

Department of Chemistry, Northeast Normal University, Changchun 130024, China

E-mail: xuux677@nenu.edu.cn; liuqun@nenu.edu.cn

Contents

Table of contents	S1
I. General.....	S2
II. Synthesis and analytical data of 2a-l	S2
III. Synthesis and analytical data of 3m	S6
IV. Preparation of intermediate 4c	S7
V. Copies of NMR spectra for compounds 2a-l , 3m , 4c	S8
VI. ORTEP drawing of compound 2a , 3 and 4c	S22
VII. Crystal data for 2a , 3 and 4c	S22

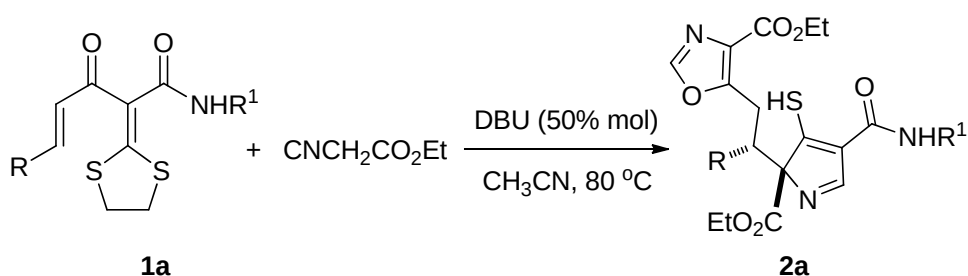
I. General

All reagents were purchased from commercial sources and used without treatment, unless otherwise indicated. The products were purified by column chromatography over silica gel. ^1H NMR and ^{13}C NMR spectra were recorded at 25°C on a Varian 500 MHz and 125 MHz, respectively, and TMS as internal standard.

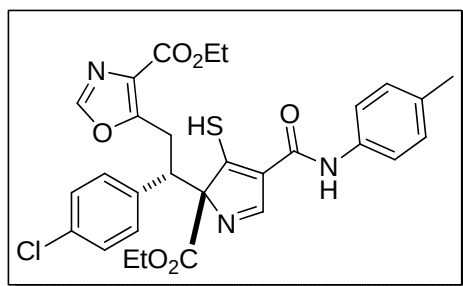
High-resolution mass spectra (HRMS) were obtained using a Bruker microTOF II focus spectrometer (ESI).

Melting points were uncorrected. The substrates, (*E*)-3-oxo-5-substituted -pent-4-enamides **1**, were prepared by the similar method as our previously reported papers¹.

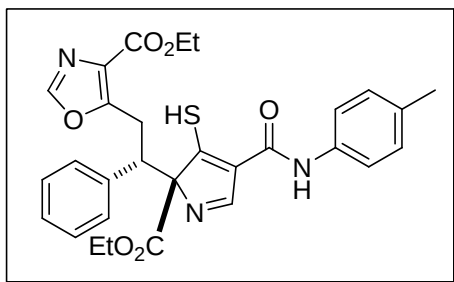
II. Synthesis and analytical data of 2a-l



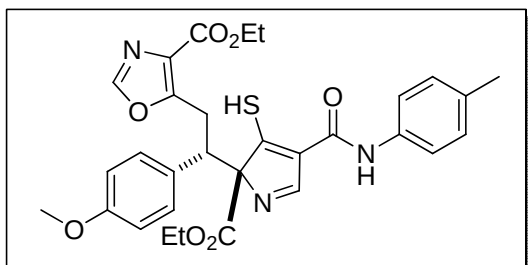
Typical procedure (**2a** as an example): To the mixture of **1a** (414 mg, 1.0 mmol) and ethyl isocyanoacetate (0.226 mL, 2.0 mmol) in CH_3CN (5 mL) was added 1,8-diazabicyclo [5.4.0.]undec-7-ene (DBU) (0.076 mL, 0.5 mmol) in one portion at room temperature. The reaction mixture was heated to 80 °C and stirred for 5 h, then the substrate **1a** was consumed as indicated by TLC. The resulting mixture was cooled to room temperature and poured into ice-water (50 mL) under stirring. The precipitated solid was collected by filtration, washed with water (3×10 mL), and dried in vacuo to afford the crude product **2a**, which was purified by flash chromatography (silica gel, petroleum ether : ethyl acetate = 2 : 3, V/V) to give **2a** (488 mg, 84 %).



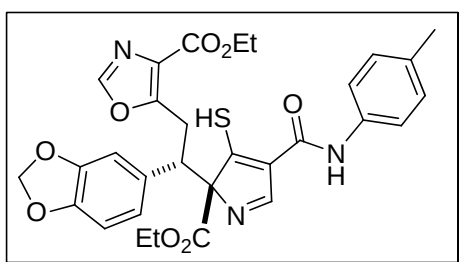
2a, yellow solid, m.p. 140–142 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.12 (t, J = 7.0 Hz, 3H), 1.33 (t, J = 7.5 Hz, 3H), 2.33 (s, 3H), 3.09 (dd, J = 16.0, 5.0 Hz, 1H), 3.53 (dd, J = 16.0, 12.0 Hz, 1H), 4.01–4.07 (m, 2H), 4.28–4.32 (m, 2H), 4.53 (dd, J = 12.0, 5.0 Hz, 1H), 7.14 (d, J = 8.5 Hz, 2H), 7.19 (d, J = 8.5 Hz, 2H), 7.31 (d, J = 8.5 Hz, 2H), 7.54 (d, J = 8.5 Hz, 2H), 7.60 (s, 1H), 8.21 (br, 1H), 9.23 (s, 1H), 11.16 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.4, 51.7, 61.3, 63.3, 90.9, 120.4, 126.0, 128.2, 128.7, 129.5, 130.8, 133.9, 134.1, 134.2, 135.2, 149.4, 156.0, 160.8, 161.6, 162.7, 169.8, 207.3. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{29}\text{ClN}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 582.1460. Found 582.1476.



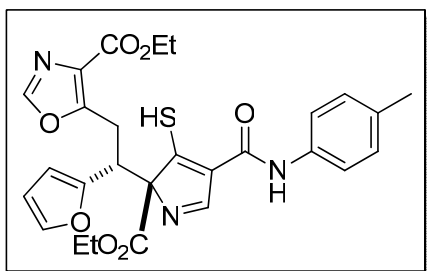
2b, yellow solid, m.p. 136–138 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.10 (t, $J = 7.0$ Hz, 3H), 1.32 (t, $J = 6.5$ Hz, 3H), 2.32 (s, 3H), 3.08 (dd, $J = 16.0, 4.5$ Hz, 1H), 3.53 (dd, $J = 16.0, 12.0$ Hz, 1H), 4.00–4.04 (m, 2H), 4.29 (d, $J = 7.0$ Hz, 2H), 4.51 (dd, $J = 12.0, 4.5$ Hz, 1H), 7.00 (d, $J = 6.5$ Hz, 2H), 7.13 (d, $J = 8.0$ Hz, 2H), 7.21 (d, $J = 8.0$ Hz, 2H), 7.55 (d, $J = 8.0$ Hz, 3H), 9.20 (s, 1H), 11.23 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.3, 52.0, 61.2, 63.3, 91.2, 120.3, 126.6, 128.2, 128.8, 129.4, 129.5, 132.3, 133.7, 135.4, 138.3, 149.2, 156.4, 160.3, 161.8, 162.9, 168.9, 207.7.



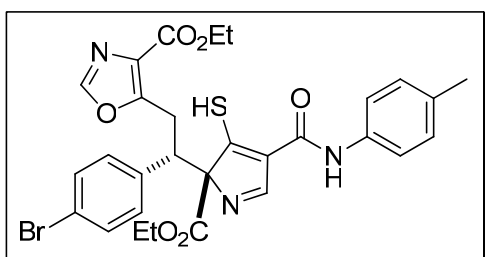
2c, yellow solid, m.p. 129–131 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.13 (t, $J = 7.0$ Hz, 3H), 1.34 (t, $J = 7.0$ Hz, 3H), 2.33 (s, 3H), 3.07 (dd, $J = 15.0, 5.0$ Hz, 1H), 3.53 (dd, $J = 15.0, 12.0$ Hz, 1H), 3.74 (s, 3H), 4.03–4.06 (m, 2H), 4.29–4.32 (m, 2H), 4.50 (dd, $J = 12.0, 4.5$ Hz, 1H), 6.75 (d, $J = 8.5$ Hz, 2H), 7.14 (d, $J = 8.5$ Hz, 2H), 7.27 (d, $J = 8.5$ Hz, 2H), 7.56 (d, $J = 7.5$ Hz, 2H), 7.61 (s, 1H), 7.78 (br, 1H), 9.22 (s, 1H), 11.18 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.3, 51.7, 55.1, 61.2, 63.3, 91.3, 114.1, 120.3, 126.6, 127.2, 128.3, 129.4, 130.1, 133.7, 135.4, 149.2, 156.4, 159.4, 160.3, 161.8, 162.8, 168.8, 207.8. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{29}\text{N}_3\text{O}_6\text{S}^-$ ($[\text{M}-\text{H}]^-$) 576.1798. Found 576.1796.



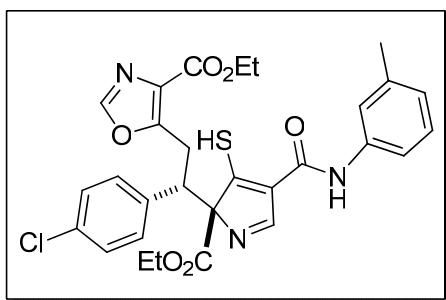
2d, yellow solid, m.p. 148–150 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.16 (t, $J = 7.0$ Hz, 3H), 1.33 (t, $J = 7.0$ Hz, 3H), 2.32 (s, 3H), 3.04 (dd, $J = 15.0, 5.0$ Hz, 1H), 3.48 (dd, $J = 15.0, 11.5$ Hz, 1H), 3.46–3.51 (m, 2H), 4.29–4.33 (m, 2H), 4.45 (dd, $J = 11.5, 5.0$ Hz, 1H), 5.88 (d, $J = 4.5$ Hz, 2H), 6.62 (d, $J = 8.0$ Hz, 1H), 6.80 (d, $J = 8.5$ Hz, 1H), 6.84 (s, 1H), 7.13 (d, $J = 8.0$ Hz, 2H), 7.55 (d, $J = 8.0$ Hz, 2H), 7.63 (s, 1H), 8.25 (br, 1H), 9.19 (s, 1H), 11.20 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.4, 52.1, 61.2, 63.3, 91.2, 101.3, 108.3, 109.1, 120.3, 122.7, 126.5, 128.3, 128.9, 129.4, 133.7, 135.4, 147.5, 147.8, 149.3, 156.3, 160.3, 161.7, 162.9, 169.1, 207.5.



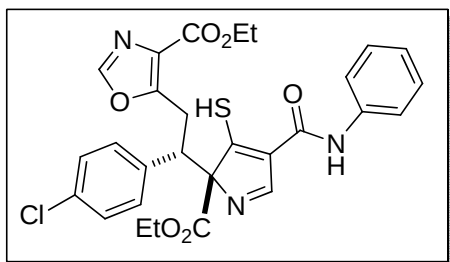
2e, yellow solid, m.p. 147–149 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.14 (t, J = 7.0 Hz, 3H), 1.32 (t, J = 7.0 Hz, 3H), 2.32 (s, 3H), 3.04 (dd, J = 14.0, 5.0 Hz, 1H), 3.38 (dd, J = 14.0, 11.0 Hz, 1H), 4.06–4.14 (m, 2H), 4.26–4.30 (m, 2H), 4.57 (dd, J = 11.0, 5.0 Hz, 1H), 6.09 (s, 1H), 6.24 (s, 1H), 7.14 (d, J = 8.0 Hz, 2H), 7.34 (s, 1H), 7.56 (d, J = 8.5 Hz, 2H), 7.71 (s, 1H), 8.42 (br, 1H), 9.26 (s, 1H), 11.11 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.1, 45.7, 61.2, 63.4, 89.8, 109.8, 110.7, 120.2, 126.5, 129.4, 133.6, 135.4, 142.8, 149.4, 150.4, 155.4, 160.1, 161.5, 162.5, 168.7, 206.6.



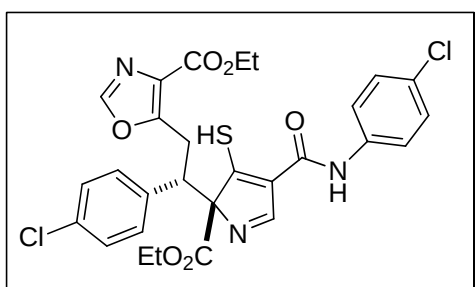
2f, yellow solid, m.p. 124–126 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.12 (t, J = 7.0 Hz, 3H), 1.34 (t, J = 7.0 Hz, 3H), 2.33 (s, 3H), 3.08 (dd, J = 15.0, 4.5 Hz, 1H), 3.53 (dd, J = 14.0, 13.0 Hz, 1H), 4.02–4.05 (m, 2H), 4.28–4.32 (m, 2H), 4.51 (dd, J = 13.0, 4.5 Hz, 1H), 7.14 (d, J = 7.5 Hz, 2H), 7.25 (d, J = 8.0 Hz, 2H), 7.34 (d, J = 7.5 Hz, 2H), 7.54 (d, J = 8.0 Hz, 2H), 7.61 (s, 1H), 8.33 (br, 1H), 9.23 (s, 1H), 11.18 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 20.9, 24.1, 51.7, 61.3, 63.5, 90.6, 120.3, 122.7, 126.8, 128.4, 129.4, 130.8, 131.9, 133.8, 134.6, 135.3, 149.3, 155.9, 160.1, 161.8, 162.6, 169.2, 207.9. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{29}\text{BrN}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 626.0954. Found 626.0936.



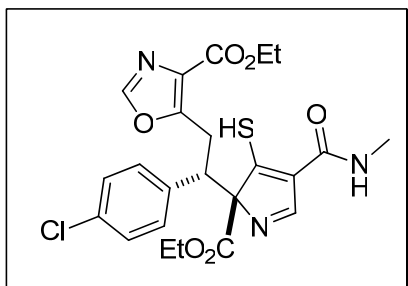
2g, yellow solid, m.p. 131–133 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.13 (t, J = 7.5 Hz, 3H), 1.34 (t, J = 7.0 Hz, 3H), 2.38 (s, 3H), 3.09 (dd, J = 15.0, 5.0 Hz, 1H), 3.54 (dd, J = 15.0, 12.0 Hz, 1H), 4.02–4.07 (m, 2H), 4.29–4.33 (m, 2H), 4.53 (dd, J = 12.0, 5.0 Hz, 1H), 6.93 (d, J = 7.5 Hz, 2H), 7.22 (d, J = 8.0 Hz, 3H), 7.32 (d, J = 8.0 Hz, 2H), 7.48 (s, 1H), 7.49 (d, J = 7.5 Hz, 1H), 7.62 (s, 1H), 7.88 (s, 1H), 8.22 (br, 1H), 9.23 (s, 1H), 11.13 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 21.5, 24.1, 51.7, 61.3, 63.5, 90.7, 117.4, 120.9, 125.0, 126.9, 128.5, 129.1, 130.4, 134.0, 134.6, 137.8, 138.8, 149.3, 155.9, 160.1, 161.8, 162.6, 169.1, 207.8. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{29}\text{ClN}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 582.1460. Found 582.1463.



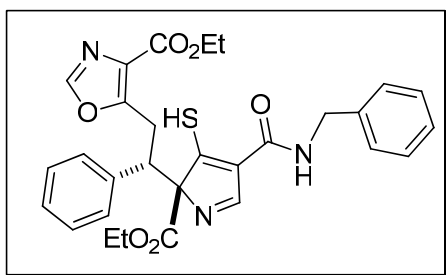
2h, yellow solid, m.p.150–152 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.12 (t, J = 7.0 Hz, 3H), 1.33 (t, J = 7.5 Hz, 3H), 3.10 (dd, J = 15.0, 5.0 Hz, 1H), 3.52 (dd, J = 15.0, 12.0 Hz, 1H), 4.00–4.07 (m, 2H), 4.28–4.32 (m, 2H), 4.53 (dd, J = 12.0, 5.0 Hz, 1H), 7.11 (t, J = 7.5 Hz, 1H), 7.20 (d, J = 8.0 Hz, 2H), 7.31–7.35 (m, 4H), 7.60 (s, 1H), 7.66 (d, J = 8.0 Hz, 2H), 9.24 (s, 1H), 11.13 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 24.3, 51.8, 61.3, 63.4, 90.8, 120.4, 124.3, 126.6, 128.4, 129.0 (2C), 130.6, 134.2, 134.5, 137.9, 149.3, 156.0, 160.4, 161.8, 162.7, 169.4, 207.9. HRMS (ESI-TOF) Calcd for $\text{C}_{28}\text{H}_{27}\text{ClN}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 568.1303. Found 568.1278.



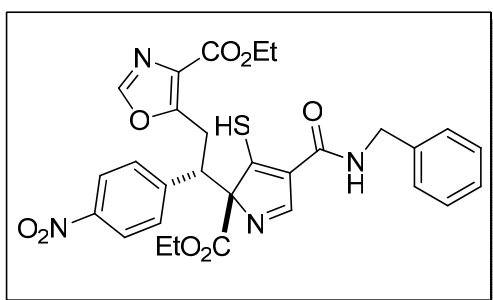
2i, yellow solid, m.p.201–203 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.13 (t, J = 7.0 Hz, 3H), 1.33 (t, J = 7.5 Hz, 3H), 3.11 (dd, J = 15.0, 5.0 Hz, 1H), 3.52 (dd, J = 15.0, 12.0 Hz, 1H), 4.01–4.07 (m, 2H), 4.28–4.32 (m, 2H), 4.53 (dd, J = 12.0, 5.0 Hz, 1H), 7.21 (d, J = 8.5 Hz, 2H), 7.29 (d, J = 8.5 Hz, 2H), 7.31 (d, J = 8.5 Hz, 2H), 7.61 (d, J = 8.5 Hz, 2H), 7.62 (s, 1H), 8.06 (br, 1H), 9.25 (s, 1H), 11.25 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 24.3, 51.7, 61.3, 63.5, 90.9, 121.5, 126.2, 128.4, 128.9, 129.0, 129.1, 130.5, 134.0, 134.5, 136.5, 149.4, 155.9, 160.4, 161.8, 162.6, 169.4, 207.9. HRMS (ESI-TOF) Calcd for $\text{C}_{28}\text{H}_{26}\text{Cl}_2\text{N}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 602.0913. Found 602.0917.



2j, yellow solid, m.p.190–192 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.11 (t, J = 7.0 Hz, 3H), 1.37 (t, J = 7.5 Hz, 3H), 2.87 (d, J = 5.0 Hz, 3H), 3.02 (dd, J = 15.0, 4.5 Hz, 1H), 3.51 (dd, J = 15.0, 12.0 Hz, 1H), 3.98–4.05 (m, 2H), 4.28–4.35 (m, 2H), 4.49 (dd, J = 12.0, 5.0 Hz, 1H), 7.19 (d, J = 8.5 Hz, 2H), 7.32 (d, J = 8.5 Hz, 2H), 7.60 (s, 1H), 8.69 (br, 1H), 9.14 (d, J = 5.0 Hz, 1H), 9.19 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 24.2, 25.4, 51.6, 61.3, 63.3, 90.6, 126.3, 128.3, 128.8, 130.7, 134.2, 134.3, 149.4, 156.1, 161.7, 162.7, 163.3, 169.4. HRMS (ESI-TOF) Calcd for $\text{C}_{23}\text{H}_{25}\text{ClN}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 506.1147. Found 506.1149.

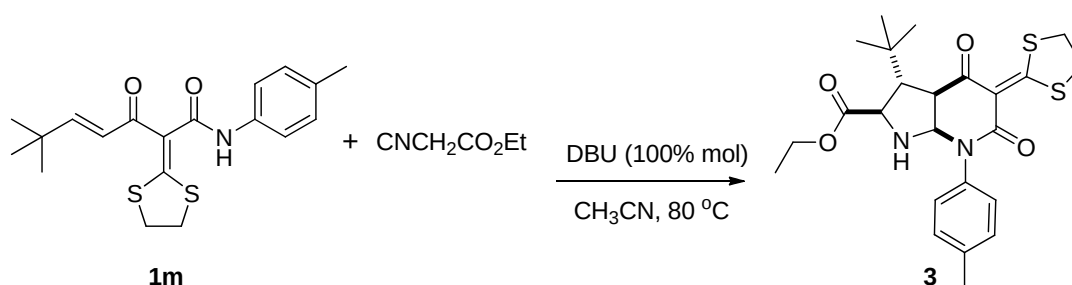


2k, yellow solid, m.p.126–128°C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.06 (t, $J = 7.0$ Hz, 3H), 1.34 (t, $J = 7.0$ Hz, 3H), 3.05 (dd, $J = 15.0, 5.0$ Hz, 1H), 3.54 (dd, $J = 15.0, 12.0$ Hz, 1H), 3.92–4.04 (m, 2H), 4.27–4.34 (m, 2H), 4.50 (dd, $J = 12.5, 5.0$ Hz, 1H), 4.54–4.66 (m, 2H), 7.18–7.19 (m, 3H), 7.24–7.27 (m, 1H), 7.31–7.38 (m, 6H), 7.54 (s, 1H), 8.21 (br, 1H), 9.15 (s, 1H), 9.61 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.3, 24.3, 42.9, 52.4, 61.1, 63.2, 90.8, 126.4, 127.2, 127.6, 128.3, 128.5, 128.6, 128.7, 129.0, 135.6, 138.3, 149.2, 156.3, 161.7, 162.6, 162.8, 168.9, 208.3. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{30}\text{N}_3\text{O}_6\text{S}^+$ ($[\text{M}+\text{H}]^+$) 548.1849. Found 548.1845.

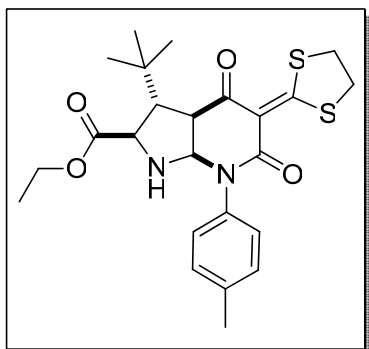


2l, yellow solid, m.p.154–156°C. ^1H NMR (CDCl_3 , 500 Hz) δ 1.10 (t, $J = 7.0$ Hz, 3H), 1.35 (t, $J = 7.0$ Hz, 3H), 3.08 (dd, $J = 15.0, 4.0$ Hz, 1H), 3.61 (dd, $J = 15.0, 12.0$ Hz, 1H), 3.99–4.03 (m, 2H), 4.31–4.36 (m, 2H), 4.58–4.65 (m, 3H), 7.34–7.36 (m, 4H), 7.58 (d, $J = 8.5$, 2H), 7.59 (s, 1H), 7.90 (br, 1H), 8.09 (d, $J = 8.5$, 2H), 9.23 (s, 1H), 9.49 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz), δ 13.7, 14.2, 24.3, 43.0, 52.0, 61.4, 63.6, 90.0, 123.6, 126.3, 127.4, 127.5, 128.6, 128.7, 130.5, 138.0, 143.4, 147.7, 149.5, 155.5, 161.7, 162.5, 162.6, 170.0, 208.2. HRMS (ESI-TOF) Calcd for $\text{C}_{29}\text{H}_{29}\text{N}_4\text{O}_8\text{S}^+$ ($[\text{M}+\text{H}]^+$) 593.1700. Found 593.1701.

III. Synthesis and analytical data of **3**

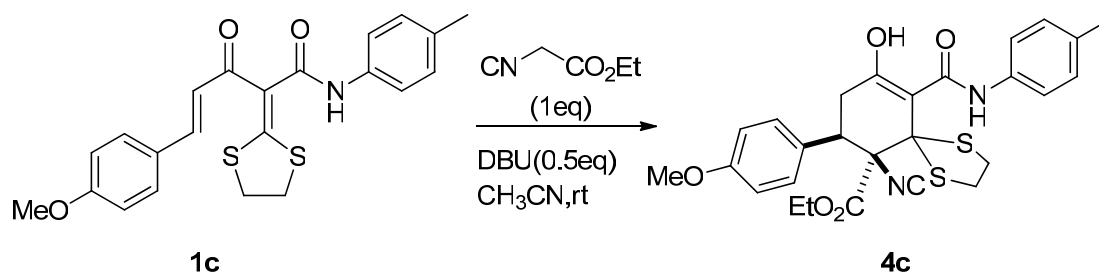


To the mixture of **1m** (361 mg, 1.0 mmol) and ethyl isocynoacetate (0.136 mL, 1.2 mmol) in CH_3CN (5 mL) was added DBU (0.152 mL, 1.0 mmol) in one portion at room temperature. The reaction mixture was heated to 80 °C and stirred for 7 h, the substrate **1m** was consumed as indicated by TLC. Then the resulting mixture was cooled to room temperature and poured into ice-water (50 mL) under stirring. The precipitated solid was collected by filtration, washed with water (3×10 mL), and dried in vacuo to afford the crude product **3**, which was purified by flash chromatography (silica gel, petroleum ether : ethyl acetate = 2 : 1, V/V) to give **3** (290 mg, 61 %).

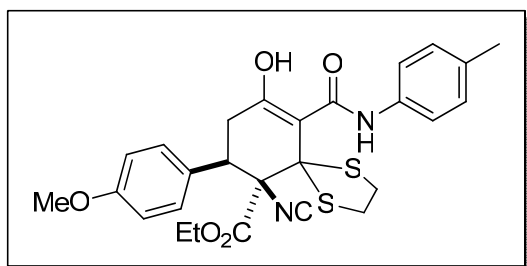


3, white solid, m.p. 286–288 °C. ^1H NMR (CDCl_3 , 500 Hz) δ 0.99 (s, 9H), 1.23 (t, $J = 7.5$ Hz, 3H), 2.37 (s, 3H), 2.94 (dd, $J = 6.0, 2.5$ Hz, 1H), 3.06 (dd, $J = 6.0, 2.5$ Hz, 1H), 3.22–3.41 (m, 4H), 3.53 (d, $J = 6.0$ Hz, 1H), 4.11–4.16 (m, 2H), 4.82 (d, $J = 6.0$ Hz, 1H), 7.23–7.27 (m, 4H); ^{13}C NMR (CDCl_3 , 125 Hz) δ 14.0, 21.1, 27.9, 32.8, 37.0, 37.4, 49.8, 54.3, 58.5, 61.3, 74.8, 114.8, 127.2, 130.0, 137.3, 139.2, 163.5, 173.2, 185.5, 190.7. HRMS (ESI-TOF) Calcd for $\text{C}_{24}\text{H}_{31}\text{N}_2\text{O}_4\text{S}_2^+$ ($[\text{M}+\text{H}]^+$) 475.1719. Found 475.1714.

IV. Preparation of intermediate **4c**



To the mixture of **1c** (411 mg, 1.0 mmol) and ethyl isocyanoacetate (0.113 mL, 1.0 mmol) in CH_3CN (5 mL) was added DBU (0.076 mL, 0.5 mmol) in one portion at room temperature. Then stirred for about 1 h, the substrate **1c** was not consumed as indicated by TLC, quenching the reaction. Then the resulting mixture was poured into saturated aqueous NH_4Cl solution (50 mL) under stirring. The precipitated solid was collected by filtration, washed with water (3×10 mL), and dried in vacuo to afford the crude product **4c**, which was purified by flash chromatography (silica gel, petroleum ether : ethyl acetate = 2 : 1, V/V) to give **4c** (162 mg, 31 %).



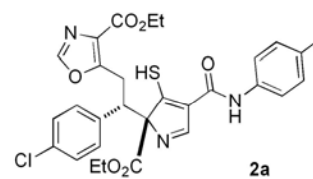
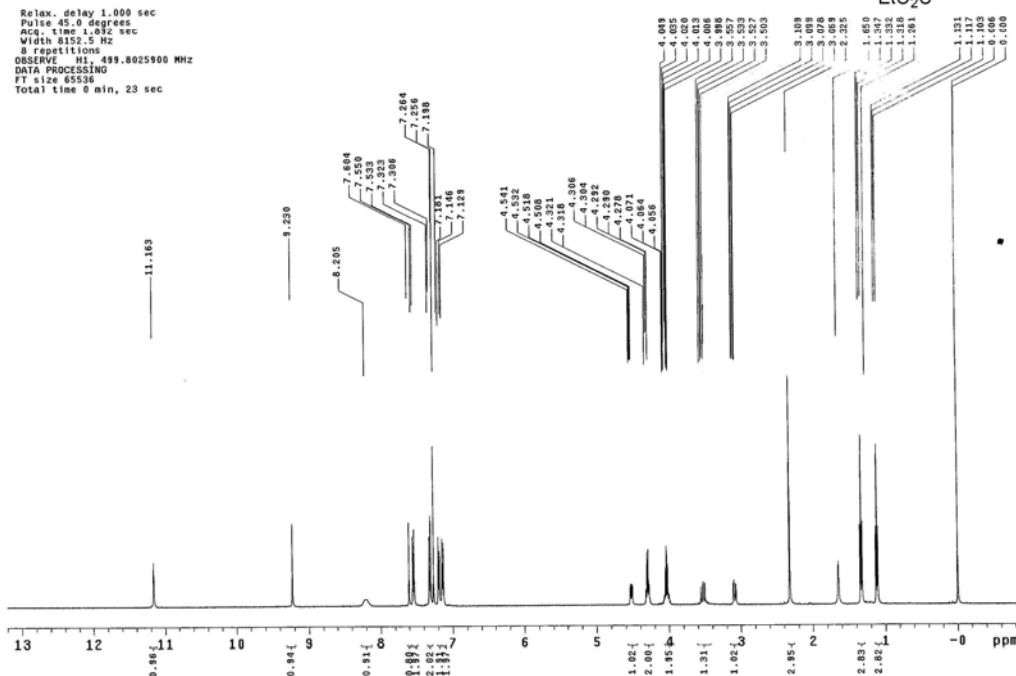
4c, yellowish solid. ^1H NMR (CDCl_3 , 500 Hz) δ 0.92 (t, $J = 7.5$ Hz, 3H), 2.34 (s, 3H), 2.69 (dd, $J = 19.0, 6.0$ Hz, 1H), 3.03 (dd, $J = 19.0, 12.0$ Hz, 1H), 3.26–3.28 (m, 1H), 3.46–3.49 (m, 3H), 3.80 (s, 3H), 3.89–3.97 (m, 3H), 6.86 (d, $J = 8.5$ Hz, 2H), 7.17 (d, $J = 8.0$ Hz, 2H), 7.36–7.38 (m, 4H), 9.53 (s, 1H), 14.63 (s, 1H); ^{13}C NMR (CDCl_3 , 125 Hz) δ 13.5, 20.9, 34.4, 41.5, 41.7, 42.9, 55.3, 62.9, 74.6, 78.0, 99.4, 113.8, 121.0, 128.6, 129.7, 129.9, 134.2, 134.7, 159.6, 164.6, 164.9, 169.3, 171.0.

V. Copies of NMR spectra for compounds 2a-2l, 3m, 4c

STANDARD PROTON PARAMETERS

Archive directory: /export/home/11uy/vnmrsys/data
Sample directory:
Pulse Sequence: s2pu1
Solvent: CDCl3
Ambient temperature
File: m500
INOVA-500 "NENUS00"

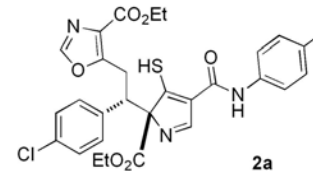
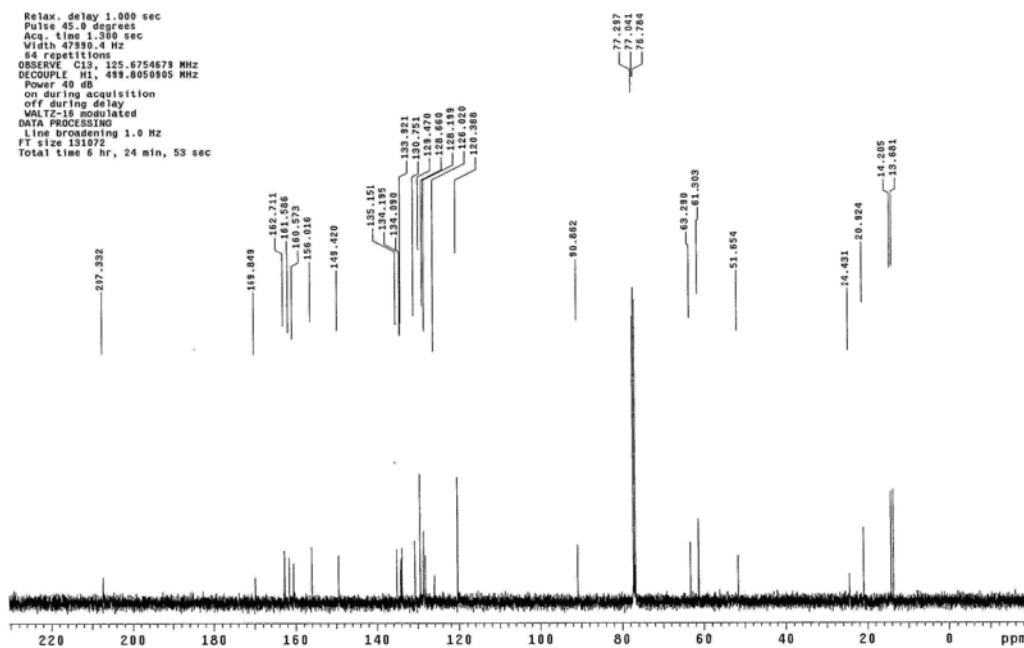
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.032 sec
Width 6152.5 Hz
8 repetitions
OBSERVE H1, 499.8025900 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/11uy/vnmrsys/data
Sample directory:
Pulse Sequence: s2pu1
Solvent: CDCl3
Temp. 7.5 C / 280.6 K
User: 1-14-87
INOVA-500 "NENUS00"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.380 sec
Width 47990.4 Hz
64 repetitions
OBSERVE C13, 125.6754679 MHz
DECOUPLE H1, 499.8050865 MHz
Power 40 dB
on during acquisition
off during delay
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 6 hr, 24 min, 53 sec

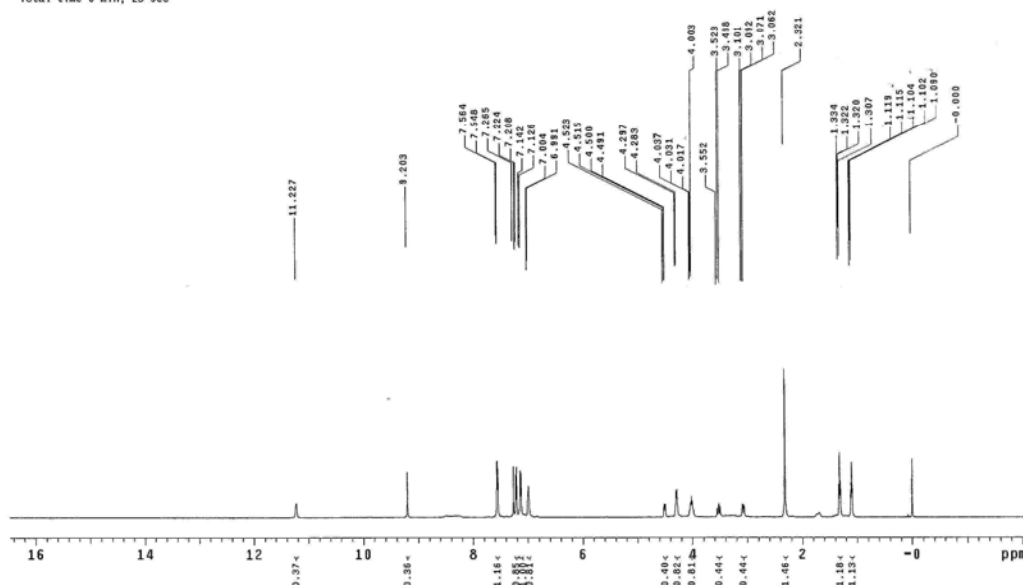
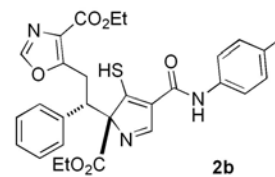


STANDARD PROTON PARAMETERS

Archive directory: /export/home/liuy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pu1
Solvent: CDCl3
Ambient temperature
File: 1836
INOVA-500 "NENU500"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.852 sec
Width 8313.2 Hz
8 repetitions
OBSERVE H1, 499.8025896 MHz
DATA PROCESSING
FT size 85536
Total time 0 min, 23 sec

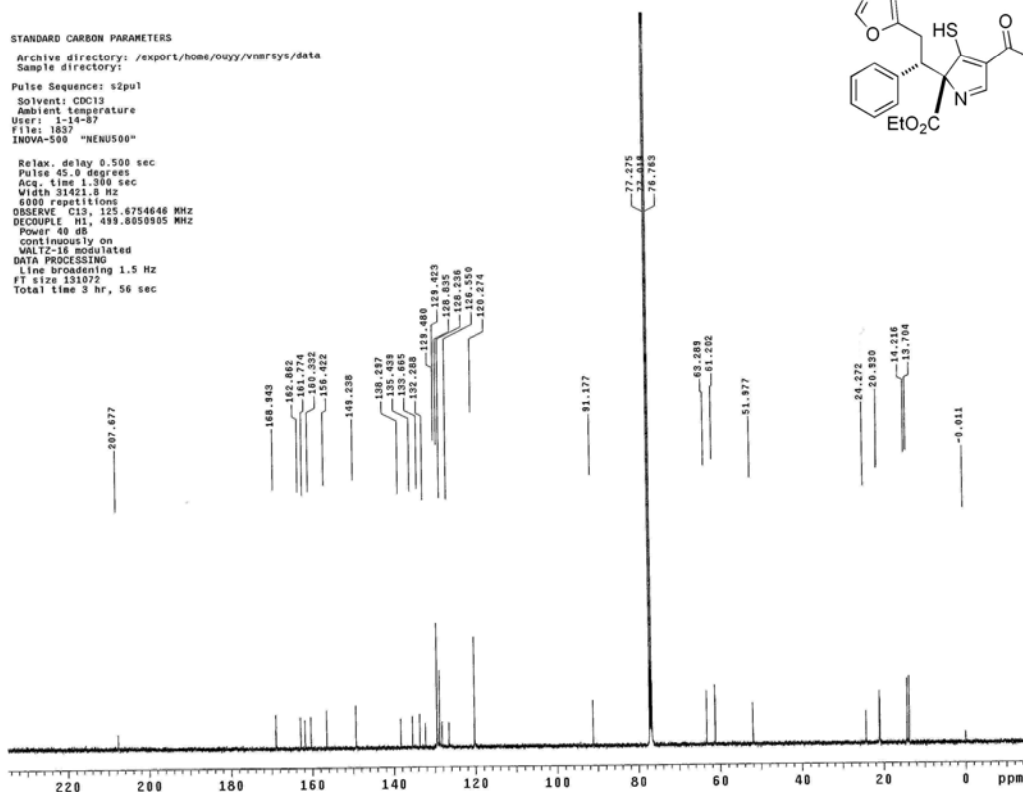
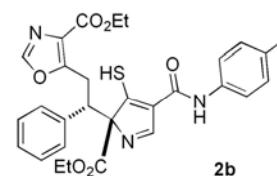


STANDARD CARBON PARAMETERS

Archive directory: /export/home/ougy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pu1
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: 1837
INOVA-500 "NENU500"

Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.380 sec
Width 31421.8 Hz
6000 repetitions
OBSERVE C13, 125.6754646 MHz
DECOUPLE H1, 499.8058955 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec



STANDARD PROTON PARAMETERS

Archive directory: /export/home/110y/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

Solvent: CDCl₃

Ambient temperature

File: 1750

INOVA-500 "NENUS00"

Relax. delay 1.000 sec

Pulse 45.0 degrees

Acq. time 1.892 sec

Width 9313.2 Hz

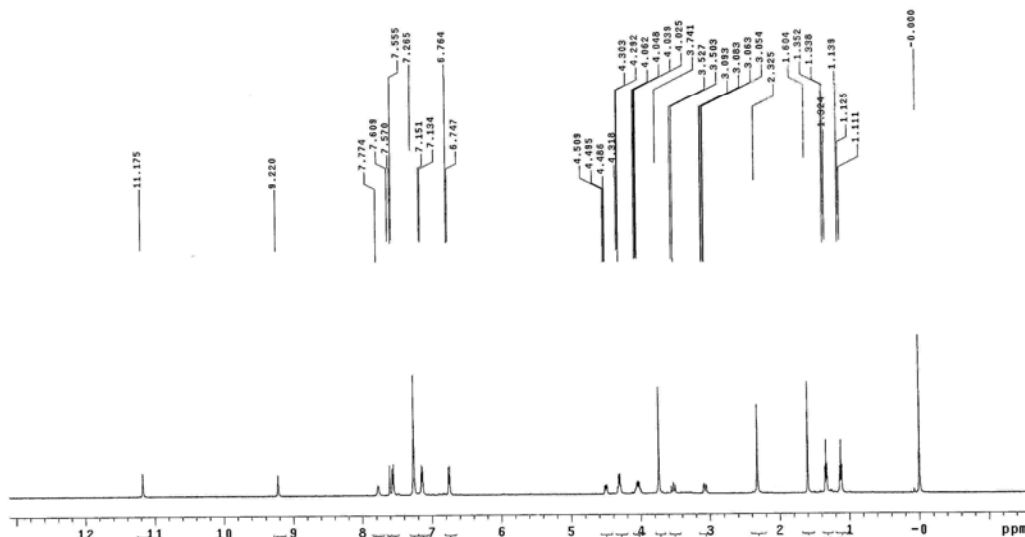
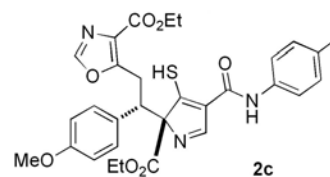
8 repetitions

OBSERVE H1, 499.8025899 MHz

DATA PROCESSING

FT size 85536

Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

Solvent: CDCl₃

Ambient temperature

User: 1-14-87

File: 1770

INOVA-500 "NENUS00"

Relax. delay 0.500 sec

Pulse 45.0 degrees

Acq. time 1.300 sec

Width 31421.8 Hz

784 repetitions

OBSERVE C13, 125.8754668 MHz

DECOUPLE H1, 499.8050905 MHz

Power 40 dB

Continuously on

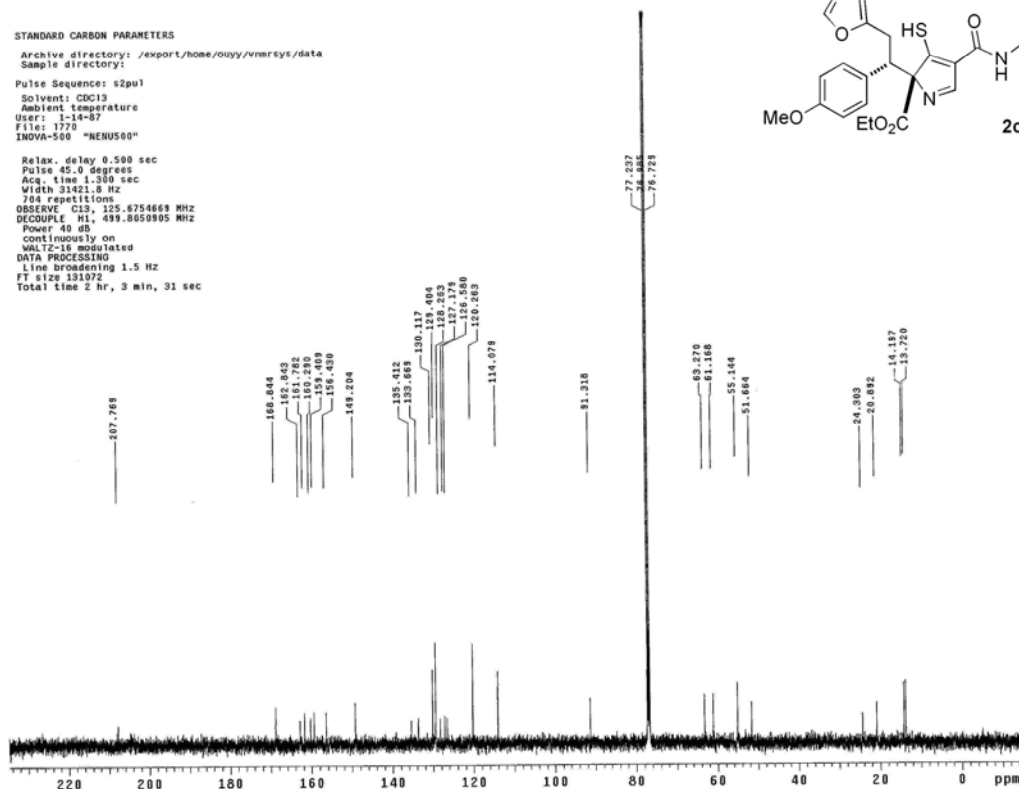
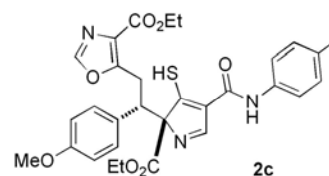
WALTZ-16 modulated

DATA PROCESSING

Line broadening 1.5 Hz

FT size 131072

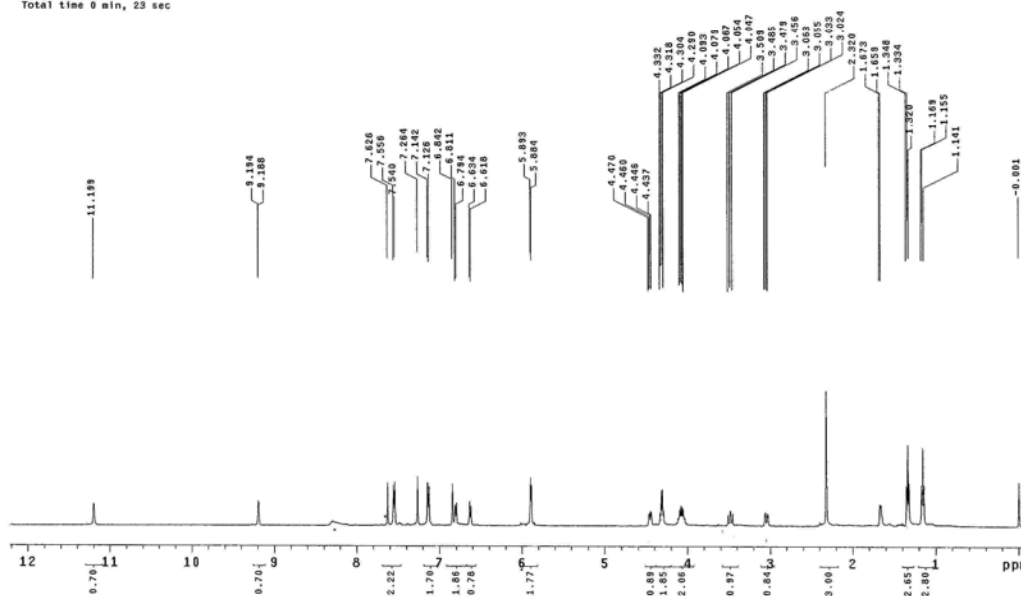
Total time 2 hr, 3 min, 31 sec



```
Archive directory: /export/home/liuy/vmmsys/data
Sample directory:
File: PROTON
```

Pulse Sequence: s2pu1
Solvent: CDCl3
Temp. 7.5 C / 280.6 K
INOVA-500 "MENU500"

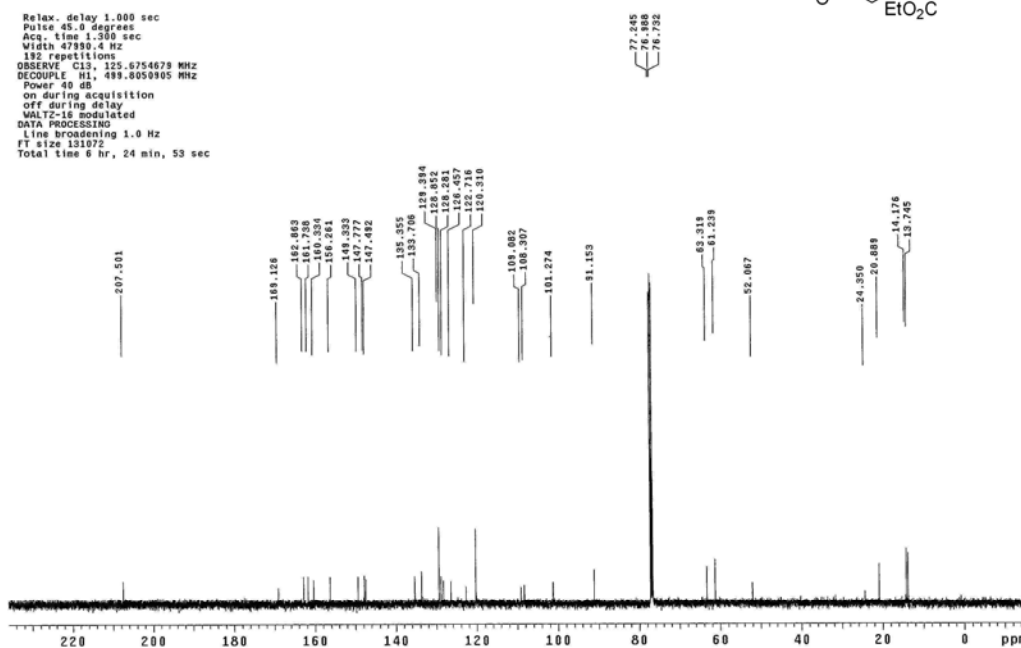
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.892 sec
Width 7896.8 Hz
8 repetitions
OBSERVE H1, 499.8025902 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 23 sec



```
Archive directory: /export/home/liuy/vnmrsys/data
Sample directory:
File: CARBON
```

```
Pulse Sequence: s2pul
Solvent: CDCl3
Temp.: 25.5 C 280.6 K
User: 1-14-87
INOVA-500 "NENU500"

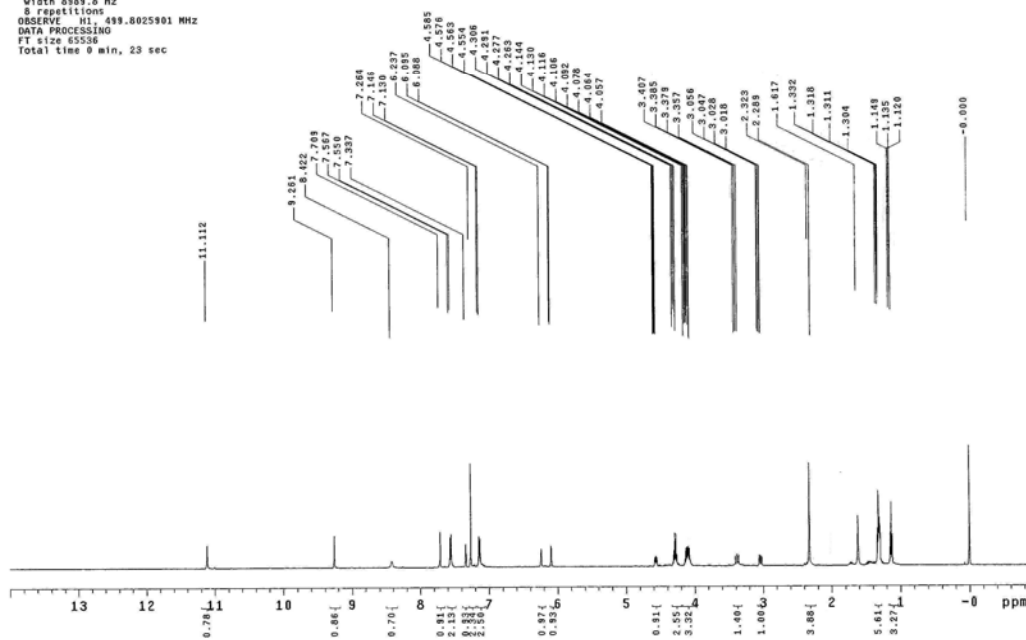
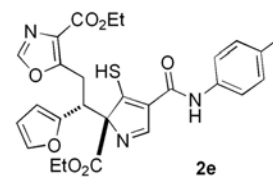
Relax. delay 1.800 sec
Pulse 45.0 degrees
Acq. time 1.360 sec
Width 12.890 sec
192 repetitions
OBSERVE C13, 125.6754679 MHz
F2 101.6261199 MHz
Power 40 dB
on during acquisition
off during delay
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.1 Hz
F1 101.6261197 MHz
Total time 6 hr, 24 min, 53 sec
```



STANDARD PROTON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:
Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
File: r67
INOVA-500 "NENUS00"

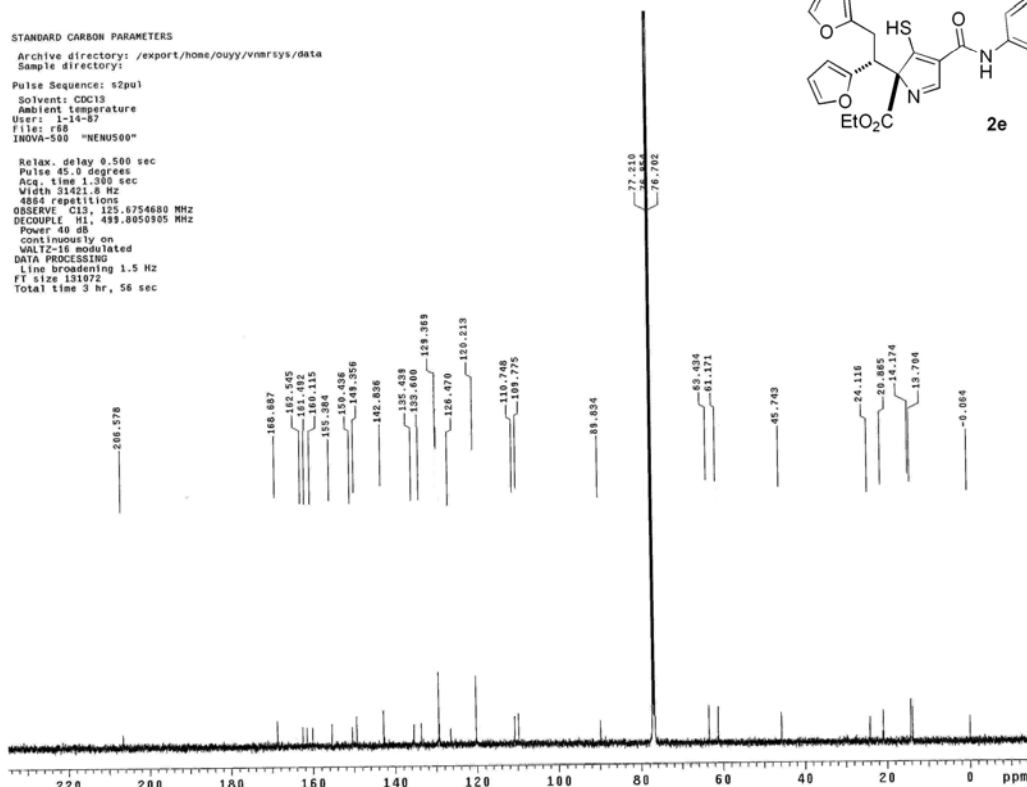
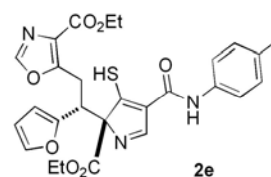
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.882 sec
Width 8888.8 Hz
8 repetitions
OBSERVE H1, 499.8025901 MHz
DATA PROCESSING
FT size 65536
Total time 9 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:
Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: r68
INOVA-500 "NENUS00"

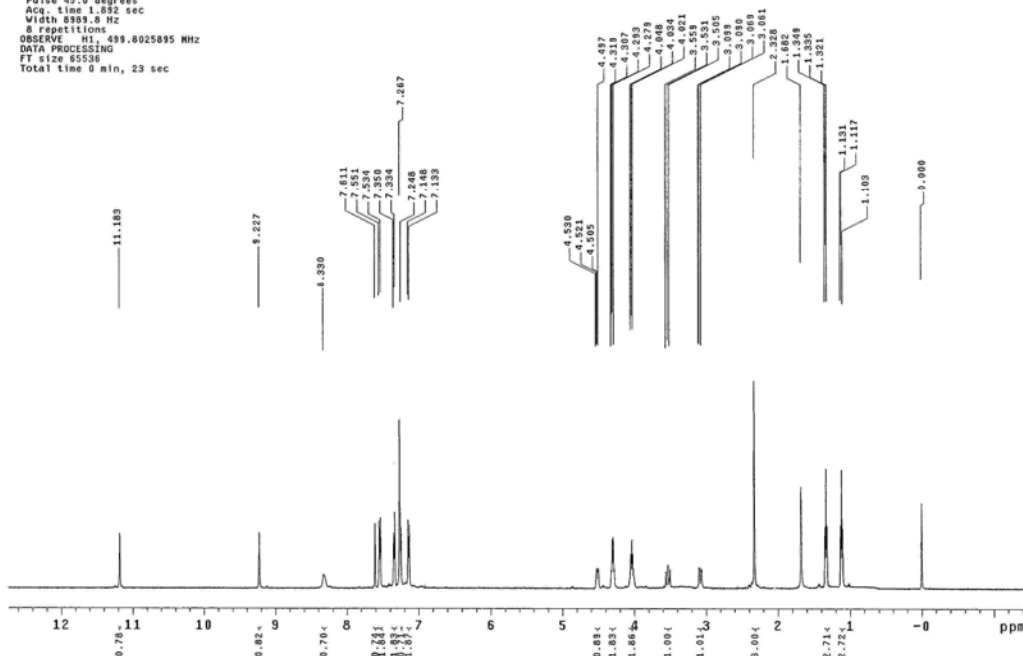
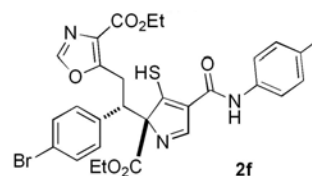
Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.380 sec
Width 31421.0 Hz
4864 repetitions
OBSERVE C13, 125.0754680 MHz
DECOUPLE H1, 499.8050305 MHz
Power 40 dB
continuously on
VOLTAGE-16 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec



STANDARD PROTON PARAMETERS

Archive directory: /export/home/ouyy/vnmr/5ys/data
Sample directory:
Pulse Sequence: s2pu1
Solvent: CDCl3
Ambient temperature
File: g582
INOVA-500 "NENU500"

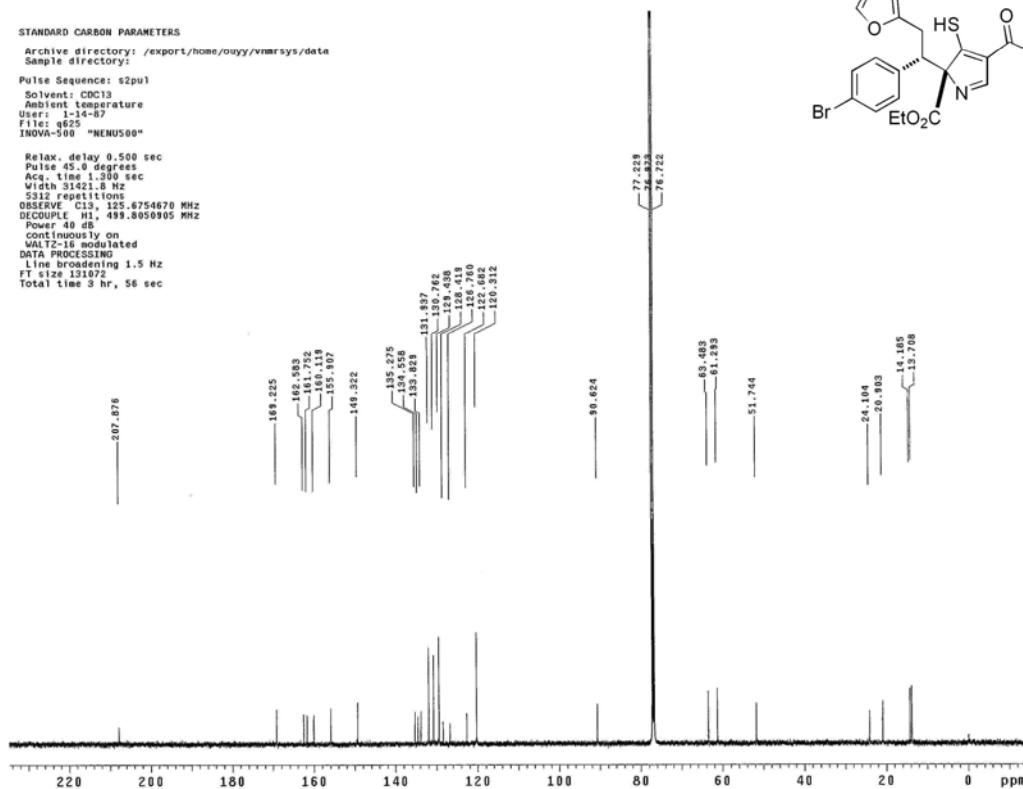
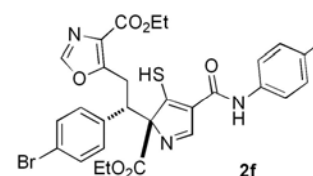
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.882 sec
Width 8903.8 Hz
8 repetitions
OBSERVE H1, 499.8025895 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmr/5ys/data
Sample directory:
Pulse Sequence: s2pu1
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: g625
INOVA-500 "NENU500"

Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.390 sec
Width 31421.8 Hz
5312 repetitions
OBSERVE C13, 125.6754670 MHz
DECOUPLE H1, 499.8050905 MHz
Power 40 dB
continuously on
MULTI-18 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec



S14

STANDARD PROTON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

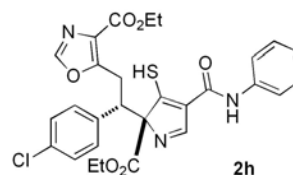
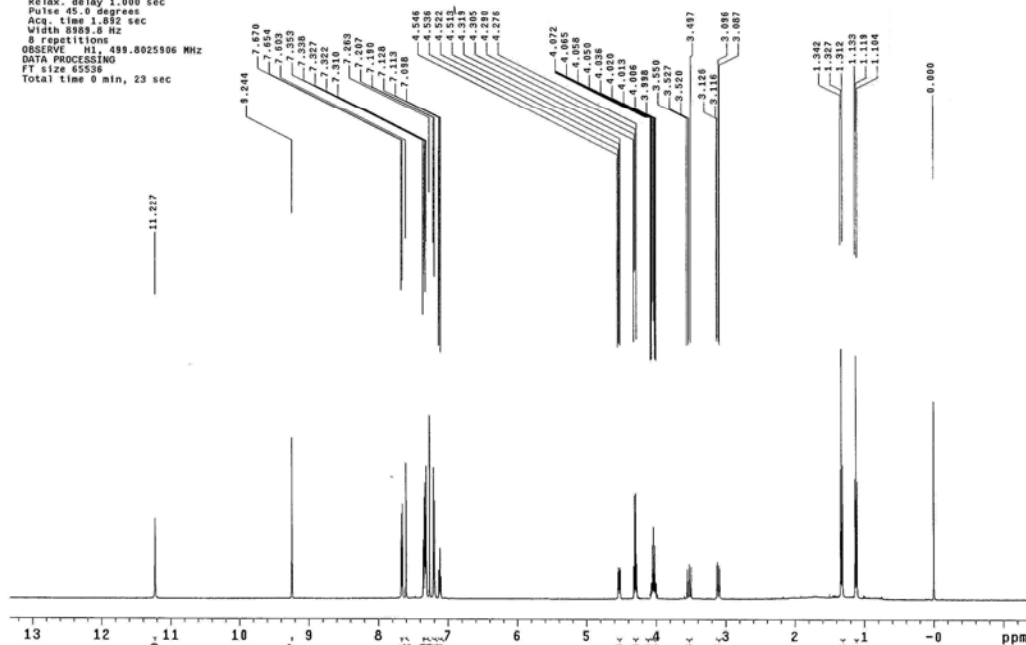
Solvent: CDCl₃

Ambient temperature

File: p636

INOVA-500 "NENU500"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.852 sec
Width 8989.8 Hz
8 repetitions
OBSERVE H1, 499.8025906 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

Solvent: CDCl₃

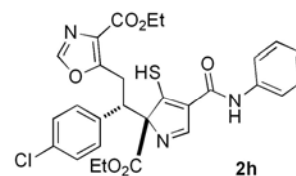
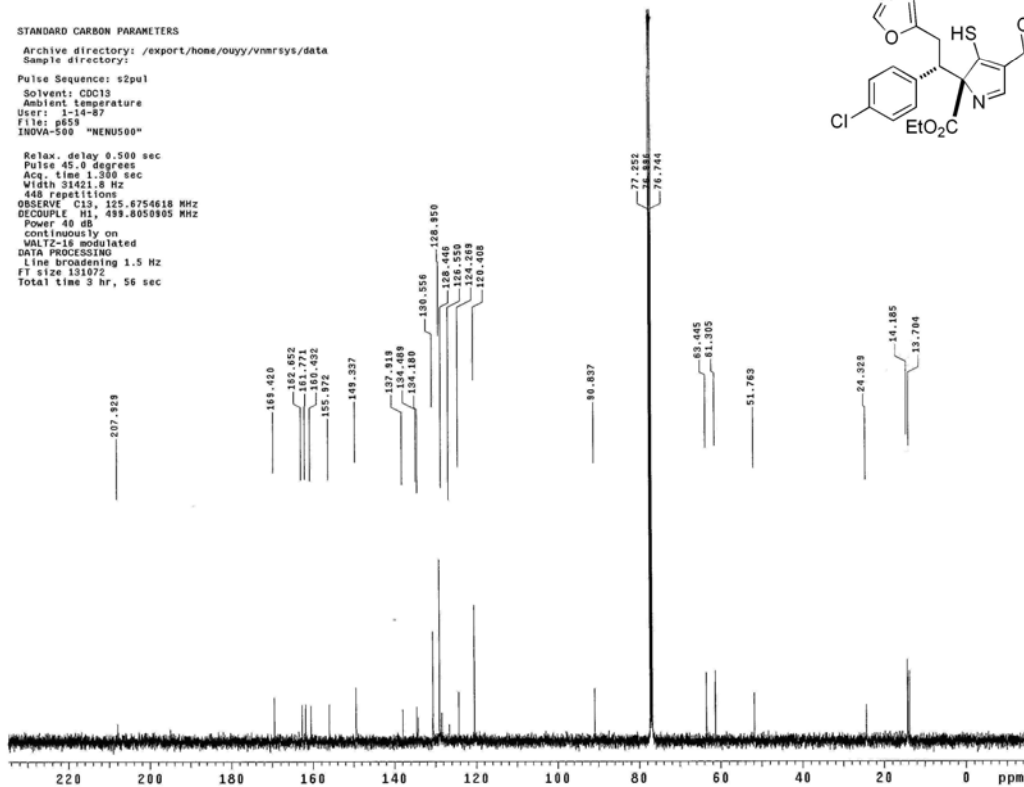
Ambient temperature

User: 1-14-87

File: p659

INOVA-500 "NENU500"

Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.396 sec
Width 31421.8 Hz
448 repetitions
OBSERVE C13, 125.0754618 MHz
DECOUPLE H1, 499.8050905 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec



STANDARD PROTON PARAMETERS

Archive directory: /export/home/ouyy/vnmrSYS/data
Sample directory:

Pulse Sequence: s2pu1

Solvent: CDCl₃

Ambient temperature

File: p494

INOVA-500 "NENU500"

Relax. delay 1.000 sec

Pulse 45.0 degrees

Acq. time 1.892 sec

Width 8589.8 Hz

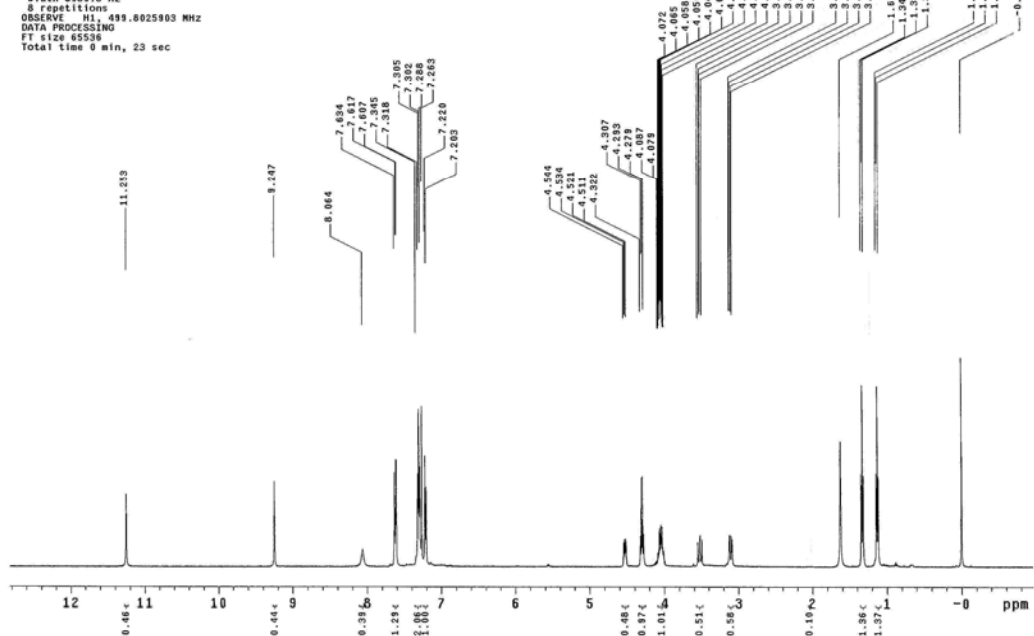
8 repetitions

OBSERVE H1, 499.8025903 MHz

DATA PROCESSING

FT size 65536

Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmrSYS/data
Sample directory:

Pulse Sequence: s2pu1

Solvent: CDCl₃

Ambient temperature

User: 1-14-07

File: p507

INOVA-500 "NENU500"

Relax. delay 0.500 sec

Pulse 45.0 degrees

Acq. time 1.380 sec

Width 31421.6 Hz

350 repetitions

OBSERVE C13, 125.6754632 MHz

DECOUPLE H1, 499.8050905 MHz

Power 40 dB

continuously on

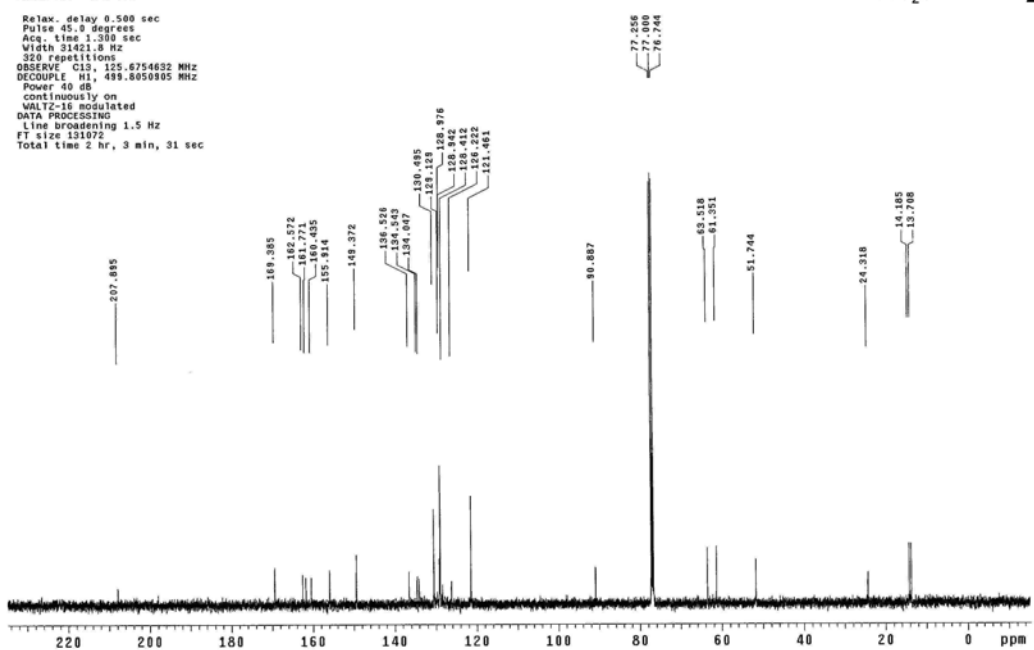
WALTZ-16 modulated

DATA PROCESSING

Line broadening 1.5 Hz

FT size 131072

Total time 2 hr, 3 min, 31 sec



STANDARD PROTON PARAMETERS

Archive directory: /export/home/liuy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pu1

Solvent: CDCl₃

Ambient temperature

File: m048

INOVA-500 "NENU500"

Relax. delay 1.000 sec

Pulse 45.0 degrees

Acq. time 1.892 sec

Width 8313.2 Hz

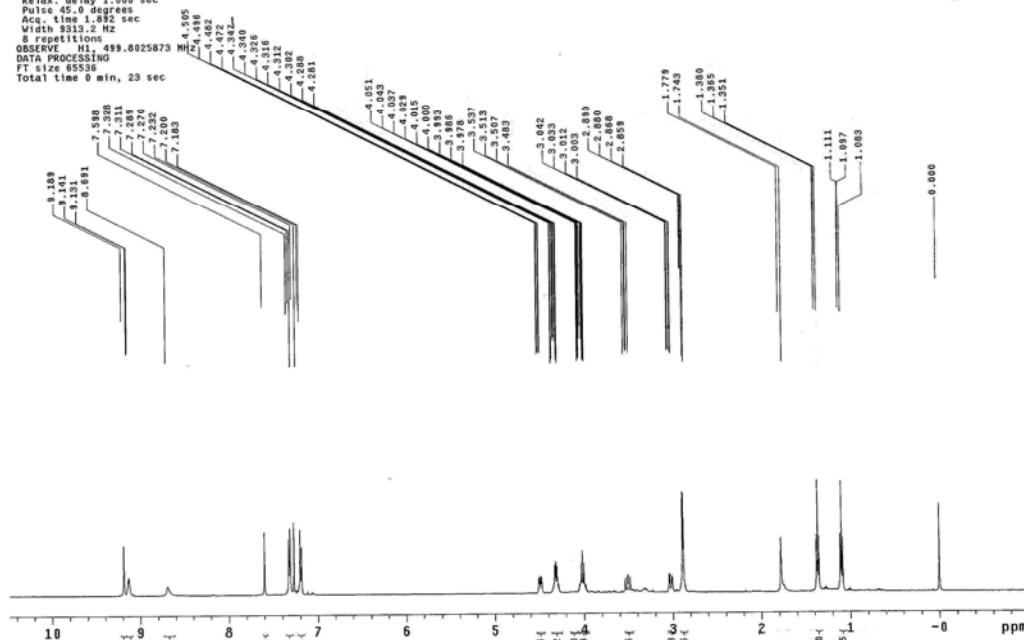
6 repetitions

OBSERVE H1 499.8025873 MHz

DATA PROCESSING

FT size 85336

Total time 0 min, 23 sec



STANDARD CARBON PARAMETERS

Archive directory: /export/home/liuy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pu1

Solvent: CDCl₃

Ambient temperature

User: 1-14-87

File: m11

INOVA-500 "NENU500"

Relax. delay 0.500 sec

Pulse 45.0 degrees

Acq. time 1.390 sec

Width 31421.8 Hz

256 repetitions

OBSERVE C13 125.6754655 MHz

DECOUPLE H1 499.8053935 MHz

Power 40 dB

continuously on

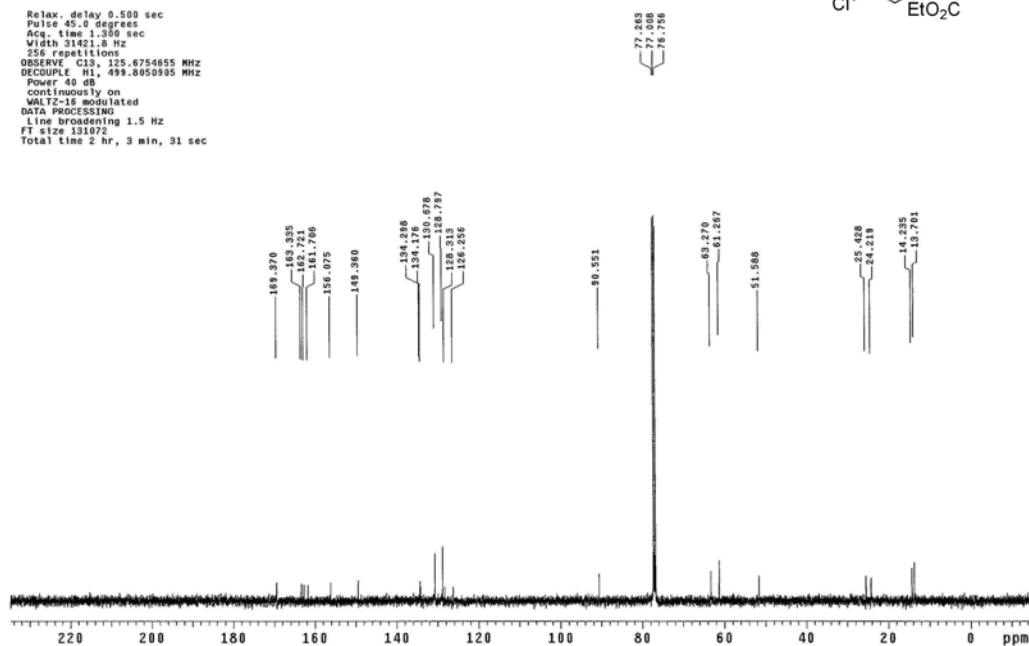
WALTZ-16 modulated

DATA PROCESSING

Line broadening 1.5 Hz

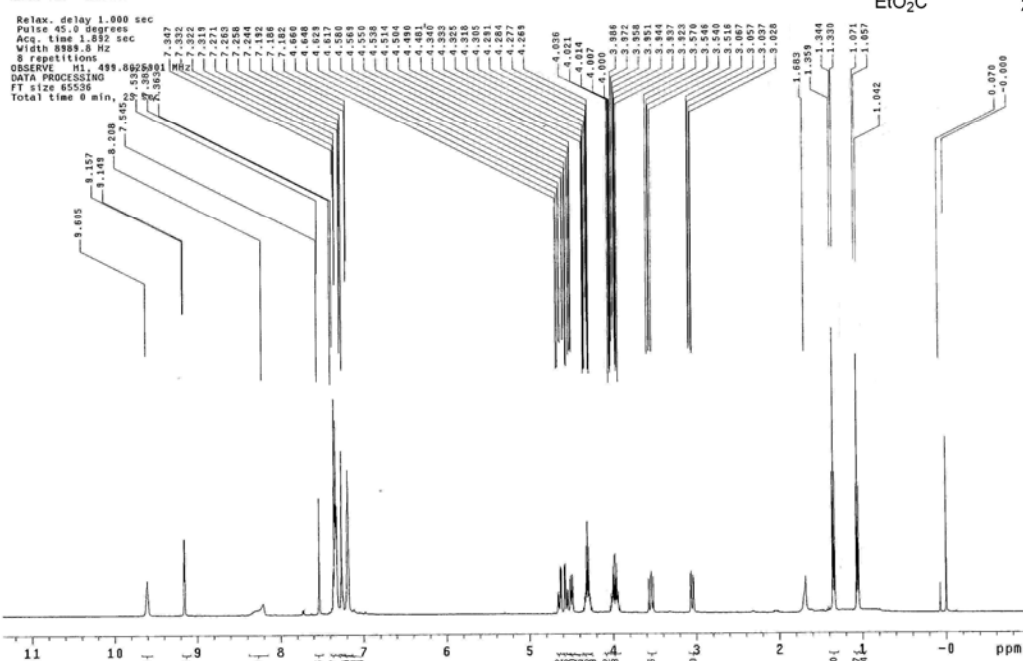
FT size 131072

Total time 2 hr, 3 min, 31 sec



STANDARD PROTON PARAMETERS

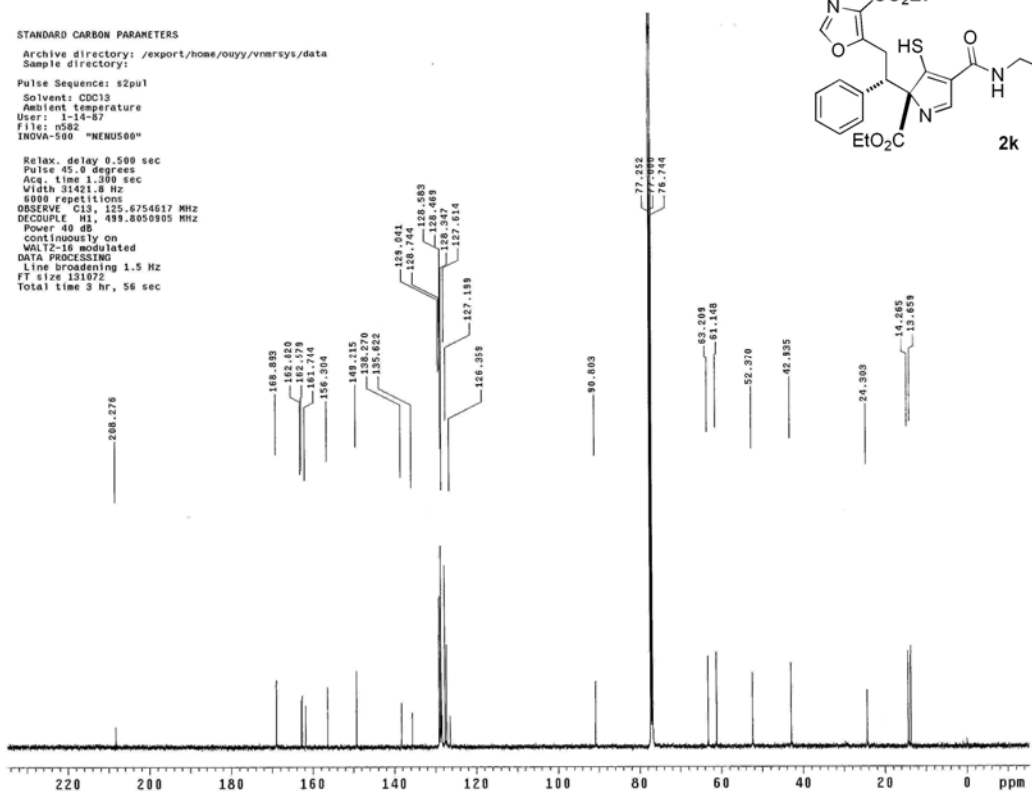
Archive directory: /export/home/ouyy/vmr/sys/data
Sample directory:
Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
File: n582
INOVA-500 "NENU500"



STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vmr/sys/data
Sample directory:
Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: n582
INOVA-500 "NENU500"

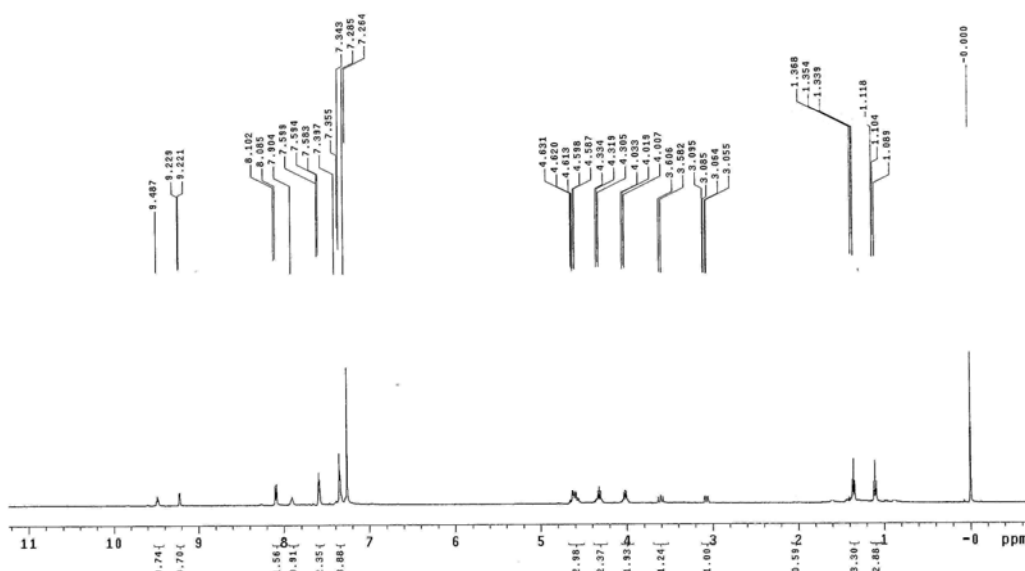
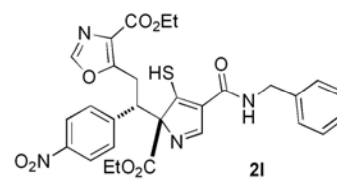
Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.309 sec
Width 31421.8 Hz
8000 repetitions
OBSERVE C13: 125.6754617 MHz
DECOUPLE H1: 499.805901 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec



STANDARD PROTON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
 Sample directory:
 Pulse Sequence: s2pul
 Solvent: CDCl₃
 Ambient temperature
 File: q706
 INOVA-500 "NENU500"

Relax. delay 1.000 sec
 Pulse 45.0 degrees
 Acq. time 1.892 sec
 Width 8889.8 Hz
 5 repetitions
 OBSERVE H1, 499.8025912 MHz
 DATA PROCESSING
 FT size 65536
 Total time 0 min, 23 sec



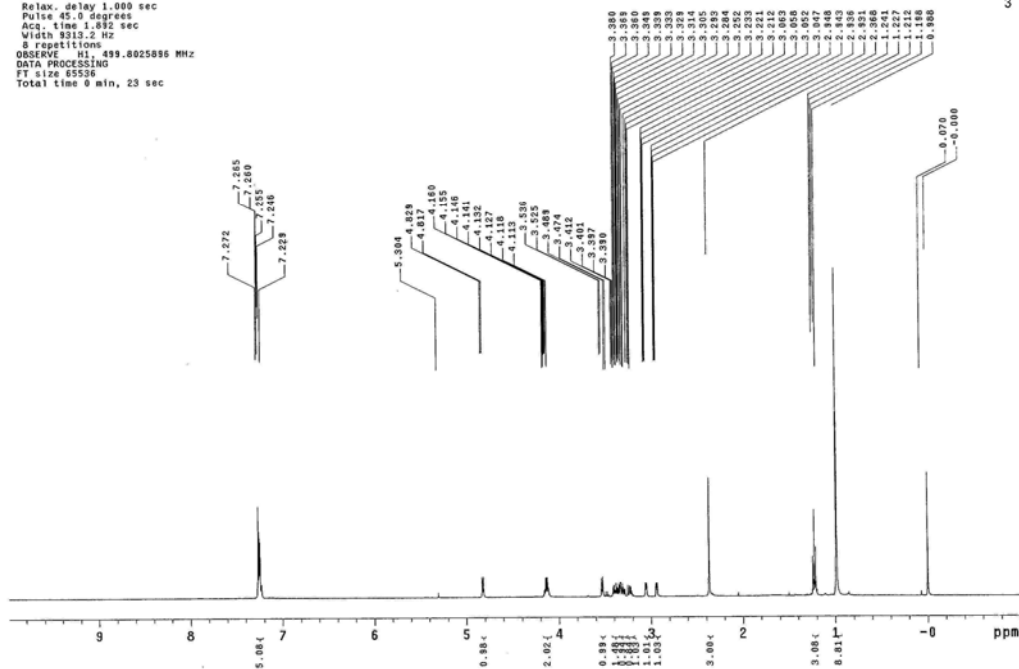
STANDARD PROTON PARAMETERS

Archive directory: /export/home/liuy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

Solvent: CDCl₃
Ambient temperature
File: 1564
INNOVA-500 "NENUS00"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.892 sec
Width 8515.2 Hz
8 repetitions
OBSERVE H1, 499.8025896 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 23 sec



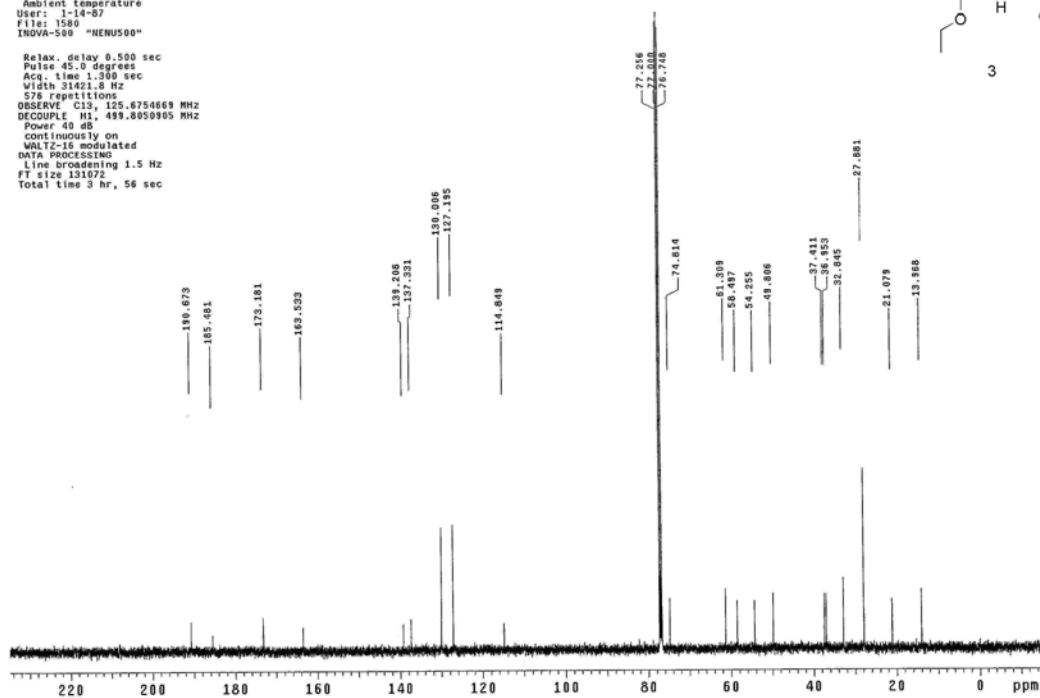
STANDARD CARBON PARAMETERS

Archive directory: /export/home/ouyy/vnmrsys/data
Sample directory:

Pulse Sequence: s2pul

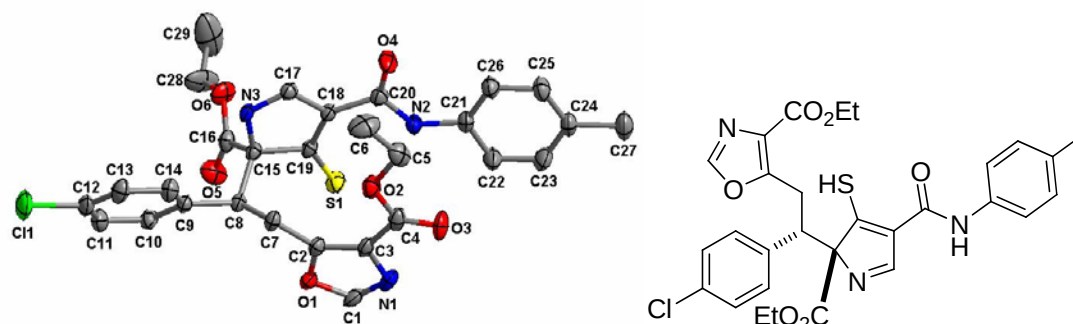
Solvent: CDCl₃
Ambient temperature
User: 1-14-07
File: 1560
INNOVA-500 "NENUS00"

Relax. delay 0.500 sec
Pulse 45.0 degrees
Acq. time 1.300 sec
Width 31621.8 Hz
576 repetitions
OBSERVE C13, 125.6754669 MHz
DECOUPLE H1, 499.8050905 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.5 Hz
FT size 131072
Total time 3 hr, 56 sec

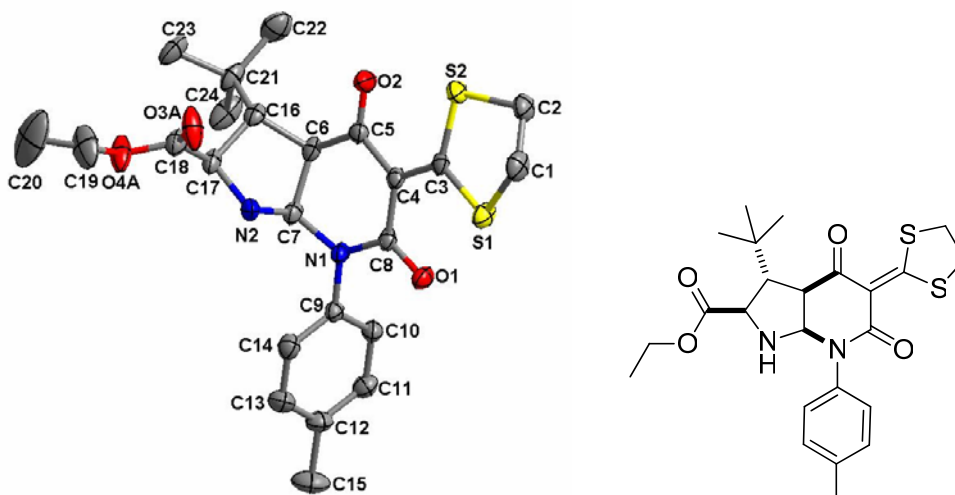


VI. ORTEP drawing of compound 2a, 3 and 4c

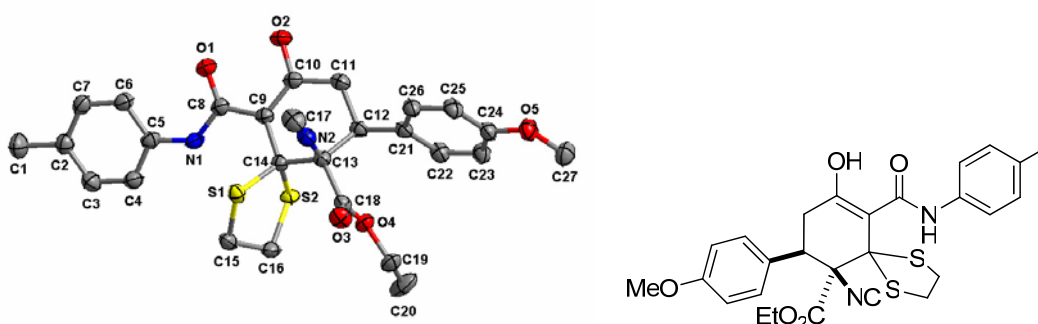
1. FIGURE S1 ORTEP drawing of compound 2a



2. FIGURE S1 ORTEP drawing of compound 3



3. FIGURE S1 ORTEP drawing of compound 4c



VII. Crystal data for 2a, 3 and 4c

2a: C₅₈H₅₆Cl₂N₆O₁₂S₂, yellow, Mr = 1164.11, monoclinic, space group C2/c, a = 19.816(3), b = 8.6000(13), c = 32.975(5) Å, α = 90.00, β = 94.488(3), γ = 90.00°, V = 5602.3(15) Å³, Z = 4, pcalcd = 1.380, T = 293(2) K, 15290 reflections (5543 unique), 370 refined parameters, R = 0.0656 (5543 data with I > 2σ(I)), wR2(F2) = 0.1462. The hydrogen atoms were refined as rigid groups. CCDC

deposition number: 801575 (**2a**). These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Center, 12 Union Road, Cambridge CB21EZ, UK; fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk).

3: $C_{72}H_{90}N_6O_{12}S_6$, yellow, $M_r = 1423.86$, triclinic, space group R-3, $a = 19.425(4)$, $b = 19.425(4)$, $c = 33.628(4)$ Å, $\alpha = 90.00^\circ$, $\beta = 90.00^\circ$, $\gamma = 120.00^\circ$, $V = 10989(3)$ Å³, $Z = 6$, $\rho_{\text{calcd}} = 1.291$, $T = 293(2)$ K, 18636 reflections (4343 unique), 312 refined parameters, $R = 0.0547$ (4343 data with $I > 2\sigma(I)$), $wR2(F2) = 0.1060$. The hydrogen atoms were refined as rigid groups. CCDC deposition number: 801574 (**3**). These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Center, 12 Union Road, Cambridge CB21EZ, UK; fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk).

4c: $C_{27}H_{28}N_2O_5S_2$, white, $M_r = 524.63$, monoclinic, space group P21/n, $a = 15.0260(16)$, $b = 11.9842(13)$, $c = 15.5208(16)$ Å, $\alpha = 90.00^\circ$, $\beta = 111.297(2)^\circ$, $\gamma = 90.00^\circ$, $V = 2604.0(5)$ Å³, $Z = 4$, $\rho_{\text{calcd}} = 1.338$, $T = 293(2)$ K, 14319 reflections (3854 unique), 336 refined parameters, $R = 0.0411$ (3854 data with $I > 2\sigma(I)$), $wR2(F2) = 0.1022$. The hydrogen atoms were refined as rigid groups. CCDC deposition number: 798180 (**4c**). These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Center, 12 Union Road, Cambridge CB21EZ, UK; fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk).