

Efficient synthesis of β -nitro amides by aminocarbonylation of ethoxycarbonyl-containing nitroalkenes with carbamoylsilane

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I Experimental section

II ^1H NMR data, ^{13}C NMR data and elemental analysis data of 3a-j

III Pictures of ^1H NMR and ^{13}C NMR spectra of 3a-j

I Experimental section

General: Dry toluene, benzene and THF were freshly distilled from sodium benzophenone ketyl under argon before use. Dichloromethane and acetonitrile were distilled from phosphorous pentoxide. Carbamoylsilane was prepared according to our previous reported methods. ^1H (600 MHz) and ^{13}C - $\{^1\text{H}\}$ (150.8 MHz) NMR spectra were recorded on Bruker (AV600) NMR spectrometer with TMS as internal standard. All spectra were recorded at room temperature in CDCl_3 unless otherwise stated. Elemental analysis was performed on an EA-1108 analyzer. Melting points were measured with a STUART SMP 10 melting point apparatus and uncorrected. The monitoring of reaction and checking of purity of the products were done using pre-coated silica gel plates (Merck 60 PF₂₅₄). Column chromatography was performed using Merck silica gel 200-300 mesh and ethyl acetate–petroleum ether elution. Visualization was achieved by UV (254 nm) light detection and iodine staining.

General Procedure for the Reaction of Carbamoylsilane with Nitroalkenes A Schlenk tube fitted with a Teflon vacuum stopcock and micro stirring bar was flame-heated under vacuum and refilled with argon. Nitroalkene **1** (0.5 mmol) and anhydrous toluene (2.0 ml) were added at ice bath temperature. After 20 min, carbamoylsilane **2** (0.6 mmol) was added. The sealed reaction mixture was stirred at 60 °C until no carbamoylsilane could be detected by TLC (using pre-coated silica gel plate). The volatiles were removed *in vacuo* to leave the crude product which was purified by column chromatography on silica gel (petroleum ether/EtOAc combination) to give β -nitro amides **3**.

II ¹H NMR data, ¹³C NMR data, IR and elemental analysis data of compounds 3a-j

Ethyl 4-dimethylamino-3-(4-dimethylaminophenyl)-2-nitro-4-oxobutanoate (3a): Light yellow solid, yield 108 mg (25 h, 64%), mp 90.0–92.0 °C. ¹H NMR (600 MHz, CDCl₃) δ: 7.15–6.63 (m, 4H, C₆H₄), 5.86, 5.81 (dd, *J* = 10.8 Hz, 1H, CHNO₂), 4.65, 4.61 (dd, *J* = 10.8 Hz, 1H, CH), 4.28, 3.97 (qq, *J* = 7.2 Hz, 2H, OCH₂), 2.99–2.92 (m, 12H, N(CH₃)₂, N(CH₃)₂), 1.29, 0.98 (tt, *J* = 7.2 Hz, 3H, CCH₃). ¹³C NMR (151 MHz, CDCl₃) δ: 169.7, 169.4, 164.2, 163.6, 150.6, 150.5, 129.5, 129.1, 118.8, 117.7, 112.7, 112.6, 91.8, 89.0, 63.1, 62.6, 49.5, 49.0, 40.3, 40.2, 37.1, 36.9, 36.1, 35.9, 13.8, 13.6. IR (KBr, ν/cm⁻¹): 1739, 1645, 1570, 1307. Found (%): C, 56.68; H, 6.99; N, 12.27. Calcd. for C₁₆H₂₃N₃O₅ (%): C, 56.96; H, 6.87; N, 12.46.

Ethyl 4-dimethylamino-3-(4-methoxyphenyl)-2-nitro-4-oxobutanoate (3b): Yellowish viscous liquid, yield 123 mg (23 h, 76%). ¹H NMR (600 MHz, CDCl₃) δ: 7.23–6.84 (m, 4H, C₆H₄), 5.86, 5.80 (dd, *J* = 10.8 Hz, 1H, CHNO₂), 4.70, 4.66 (dd, *J* = 10.8 Hz, 1H, CH), 4.27, 3.96 (qq, *J* = 7.2 Hz, 2H, OCH₂), 3.78, 3.77 (ss, 3H, OCH₃), 2.98, 2.96 (ss, 3H, NCH₃), 2.94, 2.92 (ss, 3H, NCH₃), 1.29, 0.96 (tt, *J* = 7.2 Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ: 169.3, 169.0, 164.1, 163.4, 159.9, 130.0, 129.6, 123.9, 122.9, 114.7, 91.7, 88.9, 63.2, 62.7, 55.3, 55.2, 49.4, 49.0, 37.1, 36.9, 36.1, 35.9, 13.7, 13.6. IR (KBr, ν/cm⁻¹): 1747, 1641, 1560, 1254. Found (%): C, 55.31; H, 6.47; N, 8.50. Calcd. for C₁₅H₂₀N₂O₆ (%): C, 55.55; H, 6.22; N, 8.64.

Ethyl 4-dimethylamino-3-(4-methylphenyl)-2-nitro-4-oxobutanoate (3c): White solid yield 116 mg (27 h, 75%), mp 73–75 °C. ¹H NMR (600 MHz, CDCl₃) δ: 7.22–7.16 (m, 4H, C₆H₄), 5.91, 5.84 (dd, *J* = 10.8 Hz, 1H, CHNO₂), 4.73, 4.69 (dd, *J* = 10.8 Hz, 1H, CH), 4.31, 3.97 (qq, *J* = 7.2 Hz, 2H, OCH₂), 3.01, 2.98 (ss, 3H, NCH₃), 2.97, 2.95 (ss, 3H, NCH₃), 2.35, 2.34 (ss, 3H, CH₃Ph), 1.32, 0.96 (tt, *J* = 7.2 Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ: 169.2, 168.9, 164.1, 163.5, 138.8, 130.1, 130.0, 129.1, 128.7, 128.3, 128.1, 91.7, 88.9, 63.3, 62.7, 49.8, 49.5, 37.1, 36.9, 36.2, 36.0, 21.2, 21.1, 13.8, 13.5. IR (KBr, ν/cm⁻¹): 1750, 1651, 1557, 1519, 1353. Found (%): C, 58.18; H, 6.70; N, 9.11. Calcd. for C₁₅H₂₀N₂O₅ (%): C, 58.43; H, 6.54; N, 9.09.

Ethyl 4-dimethylamino-2-nitro-4-oxo-3-phenylbutanoate (3d): Light yellow solid, yield 125 mg (10 h, 85%), mp 74–76 °C. ¹H NMR (600 MHz, CDCl₃) δ: 7.38–7.31 (m, 5H, C₆H₅), 5.92 (d, *J* = 10.8 Hz, 1H, CHNO₂), 4.76 (d, *J* = 10.8 Hz, 1H, CH), 3.94 (q, *J* = 7.2 Hz, 2H, OCH₂), 3.01, 3.00 (ss, 3H, NCH₃), 2.97, 2.96 (ss, 3H, NCH₃), 0.91 (t, *J* = 7.2 Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ: 168.7, 164.1, 131.2, 129.3, 128.9, 88.9, 62.7, 49.8, 36.9, 36.2, 13.5. IR (KBr, ν/cm⁻¹): 1741, 1641, 1560, 1304. Found (%): C, 57.35; H, 6.01; N, 9.30. Calcd. for C₁₄H₁₈N₂O₅ (%): C, 57.13; H, 6.16; N, 9.52.

Ethyl 3-(4-chlorophenyl)-4-dimethylamino-2-nitro-4-oxobutanoate (3e): White solid, yield 156 mg (8 h, 95%), mp 94–96 °C. ¹H NMR (600 MHz, CDCl₃) δ: 7.36–7.28 (m, 4H, C₆H₄), 5.89, 5.83 (dd, *J* = 10.8 Hz, 1H, CHNO₂), 4.75, 4.71 (dd, *J* = 10.8 Hz, 1H, CH), 4.30, 3.99 (qq, *J* = 7.2 Hz, 2H, OCH₂), 3.01, 2.98 (ss, 3H, NCH₃), 2.96, 2.95 (ss, 3H, NCH₃), 1.31, 0.99 (tt, *J* = 7.2 Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ: 168.7, 168.4, 163.8, 163.2, 135.1, 130.7, 130.2, 129.8, 129.7, 129.6, 91.4, 88.7, 63.4, 62.9, 49.3, 49.0, 37.1, 37.0, 36.3, 36.0, 13.7, 13.6. IR (KBr, ν/cm⁻¹): 1739, 1644, 1561, 1311. Found (%): C, 51.30; H, 5.09; N, 8.28. Calcd. for C₁₄H₁₇ClN₂O₅ (%): C, 51.15; H, 5.21; N, 8.52.

Ethyl 4-dimethylamino-2-nitro-3-(3-nitrophenyl)-4-oxobutanoate (3f): Light yellow solid, yield 163 mg (6 h, 96%), mp 96–98 °C. ¹H NMR (600 MHz, CDCl₃) δ: 8.23–7.56 (m, 4H, C₆H₄),

5.94, 5.89 (dd, $J = 10.8$ Hz, 1H, CHNO₂), 4.92, 4.87 (dd, $J = 10.8$ Hz, 1H, CH), 4.30, 4.00 (qq, $J = 7.2$ Hz, 2H, OCH₂), 3.05, 3.04 (ss, 3H, NCH₃), 2.97, 2.95 (ss, 3H, NCH₃), 1.30, 0.96 (tt, $J = 7.2$ Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ : 167.9, 167.7, 163.4, 162.9, 148.7, 148.6, 134.9, 134.5, 134.4, 133.6, 130.5, 124.0, 123.9, 123.5, 91.2, 88.5, 63.7, 63.2, 49.2, 48.9, 37.3, 37.1, 36.4, 36.2, 13.7, 13.6. IR (KBr, ν/cm^{-1}): 1734, 1644, 1541, 1353. Found (%): C, 49.81; H, 5.31; N, 12.19. Calcd. for C₁₄H₁₇N₃O₇ (%): C, 49.56; H, 5.05; N, 12.38.

Ethyl 4-dimethylamino-3-(2-furyl)-2-nitro-4-oxobutanoate (3g): Light brown solid, yield 114 mg (9 h, 80 %), mp 70.0–72.0 °C. ¹H NMR (600 MHz, CDCl₃) δ : 7.40–6.31 (m, 3H, furyl), 5.95, 5.90 (dd, $J = 10.8$ Hz, 1H, CHNO₂), 4.98 (d, $J = 10.8$ Hz, 1H, CH), 4.28, 4.10 (qq, $J = 7.2$ Hz, 2H, OCH₂), 3.05 (s, 3H, NCH₃), 2.97, 2.96 (ss, 3H, NCH₃), 1.29, 1.12 (tt, $J = 7.2$ Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ : 166.7, 166.5, 163.8, 163.0, 145.6, 144.7, 143.7, 143.5, 111.0, 110.9, 110.0, 109.8, 89.2, 86.9, 63.4, 63.1, 44.2, 43.8, 37.2, 37.0, 36.3, 36.0, 13.7. IR (KBr, ν/cm^{-1}): 1743, 1651, 1561, 1322. Found (%): C, 50.90; H, 5.54; N, 9.62. Calc. for C₁₂H₁₆N₂O₆ (%): C, 50.70; H, 5.67; N, 9.85.

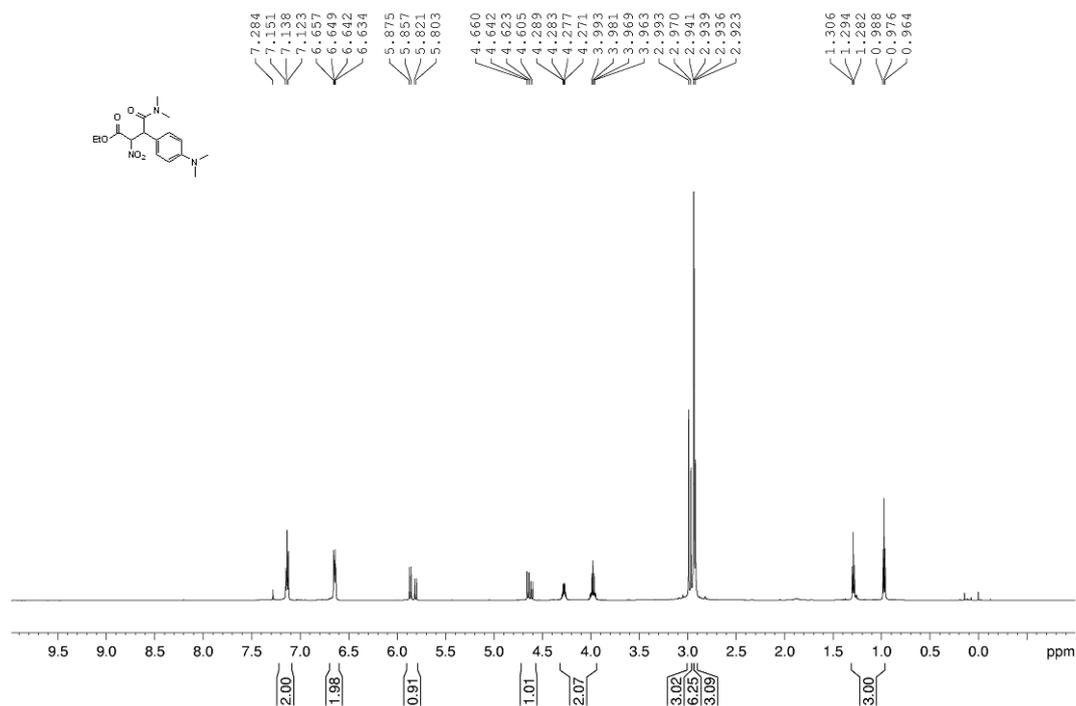
Ethyl 4-dimethylamino-2-nitro-4-oxo-3-(2-thienyl)butanoate (3h): White solid, yield 119 mg (13 h, 79%), mp 110.0–112.0 °C. ¹H NMR (600 MHz, CDCl₃) δ : 7.33–6.98 (m, 3H, thienyl), 5.94, 5.89 (dd, $J = 10.8$ Hz, 1H, CHNO₂), 5.11, 5.07 (dd, $J = 10.8$ Hz, 1H, CH), 4.31, 4.08 (qq, $J = 7.2$ Hz, 2H, OCH₂), 3.11, 3.09 (ss, 3H, NCH₃), 3.00, 2.98 (ss, 3H, NCH₃), 1.32, 1.07 (tt, $J = 7.2$ Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ : 168.5, 168.2, 163.8, 163.1, 133.5, 132.4, 128.2, 128.1, 127.4, 127.3, 127.0, 91.8, 88.8, 63.4, 63.0, 45.1, 44.4, 37.3, 37.2, 36.3, 36.1, 13.7, 13.6. IR (KBr, ν/cm^{-1}): 1743, 1651, 1557, 1311. Found (%): C, 47.70; H, 5.44; N, 9.59. Calcd. for C₁₂H₁₆N₂O₅S (%): C, 47.99; H, 5.37; N, 9.33.

Ethyl 4-dimethylamino-2-nitro-4-oxo-3-(2-pyridyl)butanoate (3i): Yellow viscous liquid yield 121 mg (7 h, 82%). ¹H NMR (600 MHz, CDCl₃) δ : 8.23–7.56 (m, 4H, pyridyl), 5.96 (d, $J = 10.8$ Hz, 1H, CHNO₂), 4.93 (d, $J = 10.8$ Hz, 1H, CH), 4.04–3.97 (m, 2H, OCH₂), 3.08, 3.06 (ss, 3H, NCH₃), 3.00, 2.99 (ss, 3H, NCH₃), 0.98 (t, $J = 7.2$ Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ : 167.7, 163.4, 148.6, 134.8, 133.6, 130.5, 123.9, 88.5, 63.2, 48.9, 37.1, 36.4, 13.6. IR (KBr, ν/cm^{-1}): 1735, 1641, 1566, 1354. Found (%): C, 52.61; H, 5.99; N, 14.09. Calcd. for C₁₃H₁₇N₃O₅ (%): C, 52.88, H, 5.80, N, 14.23.

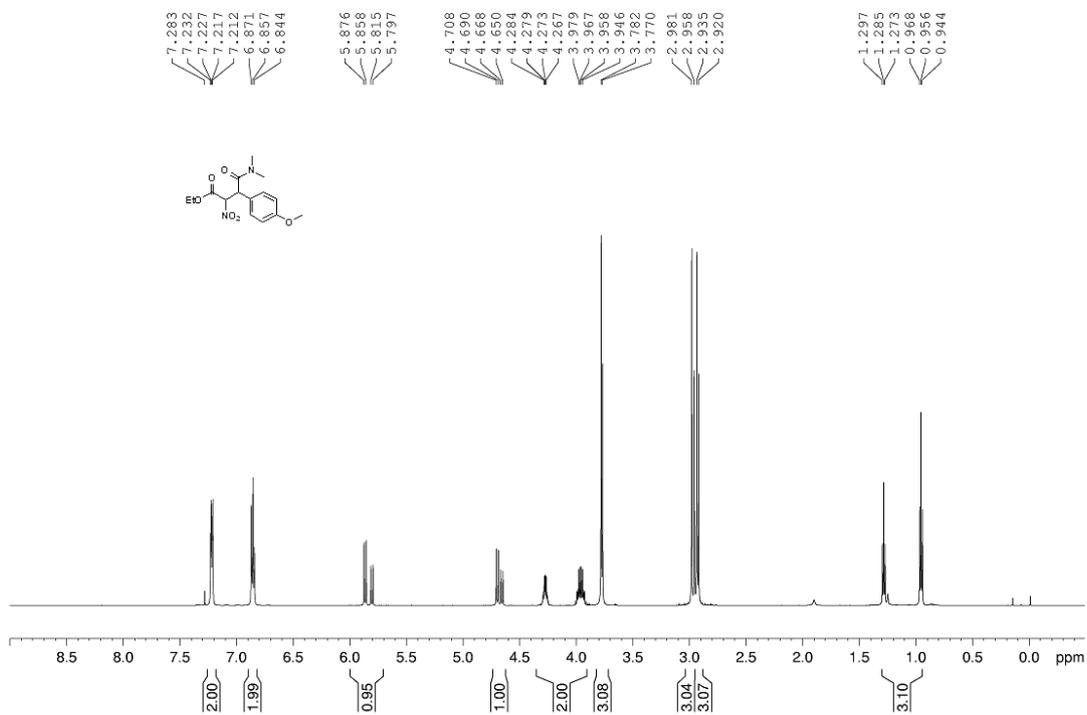
Ethyl 3-dimethylaminocarbonyl-2-nitro-5-phenylpent-4-enoate (3j): Yellowish liquid, yield 136 mg (6 h, 85.1%). ¹H NMR (600 MHz, CDCl₃) δ : 7.35–7.32 (m, 5H, C₆H₅), 6.66–5.98 (m, 2H, CH=CH), 5.80, 5.73 (dd, $J = 10.8$ Hz, 1H, CHNO₂), 4.47–4.20 (m, 3H, CH, OCH₂), 3.18 (s, 3H, NCH₃), 3.01, 3.00 (ss, 3H, NCH₃), 1.31, 1.17 (tt, $J = 7.2$ Hz, 3H, CH₃). ¹³C NMR (151 MHz, CDCl₃) δ : 168.7, 168.5, 164.1, 163.2, 136.9, 135.4, 128.8, 128.7, 126.7, 126.6, 120.1, 119.3, 90.1, 87.7, 63.3, 63.0, 48.1, 47.8, 37.3, 37.1, 36.3, 36.1, 13.9, 13.8. IR (KBr, ν/cm^{-1}): 1747, 1641, 1560, 1398. Found (%): C, 59.70; H, 6.50; N, 8.99. Calcd. for C₁₆H₂₀N₂O₅ (%): C, 59.99; H, 6.29; N, 8.74.

III Pictures of ^1H NMR of compounds 3a-j (600 MHz)

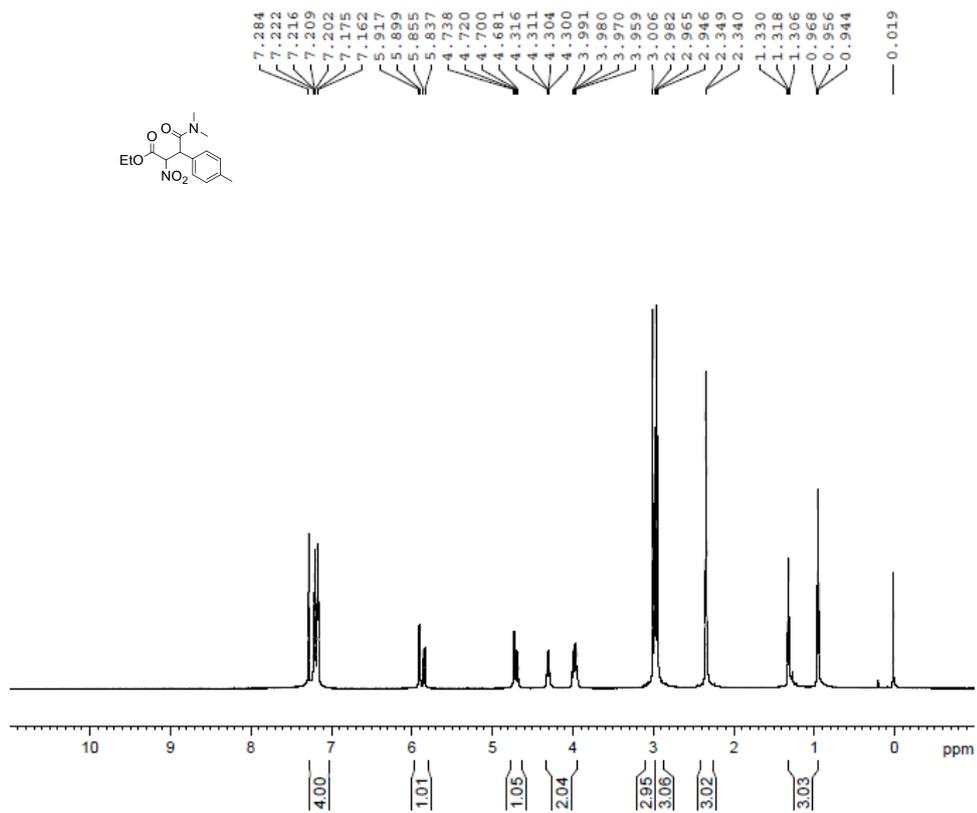
^1H NMR of 3a



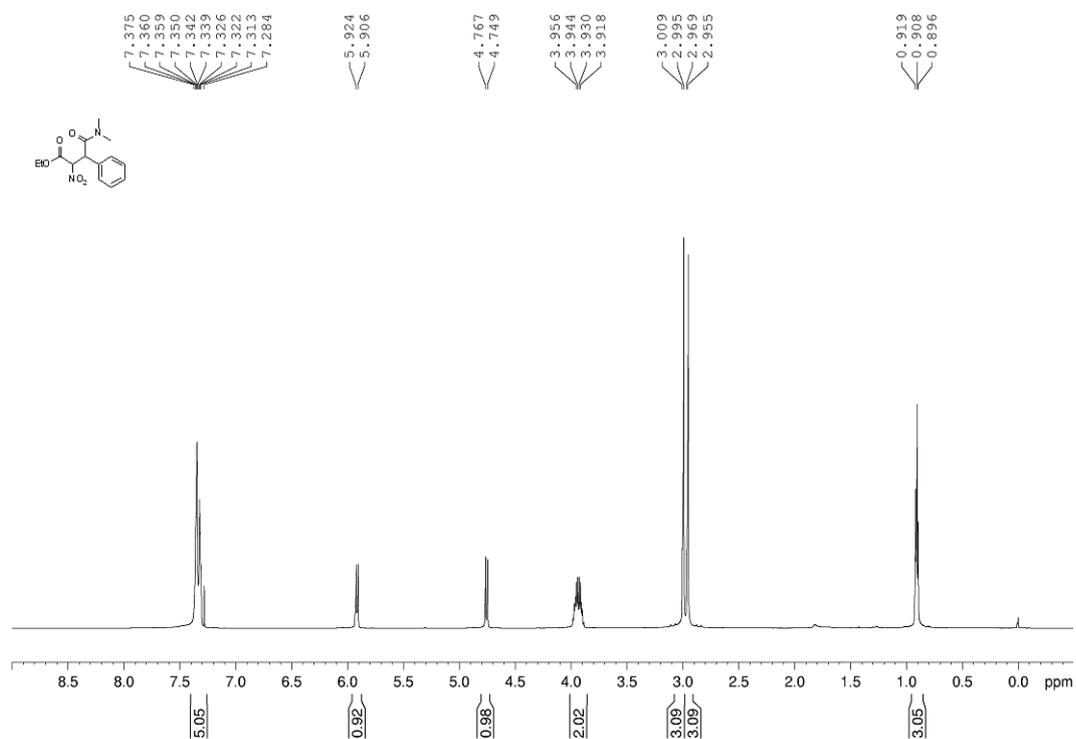
^1H NMR of 3b



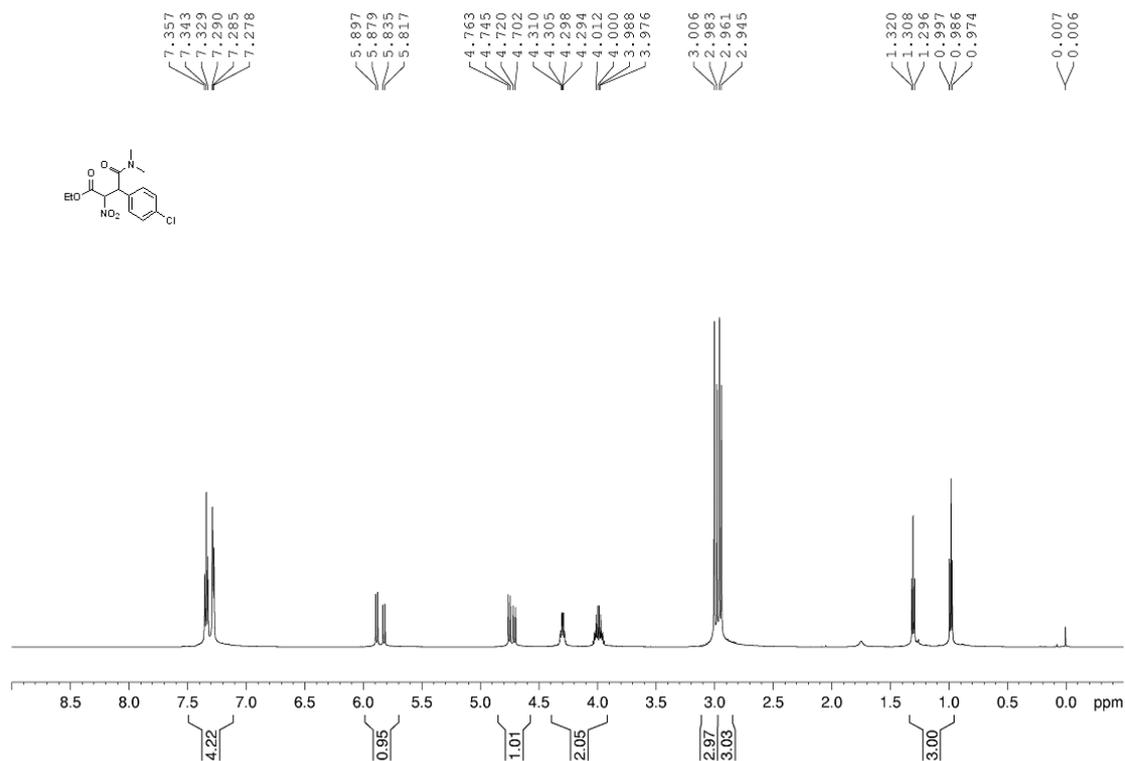
¹H NMR of **3c**



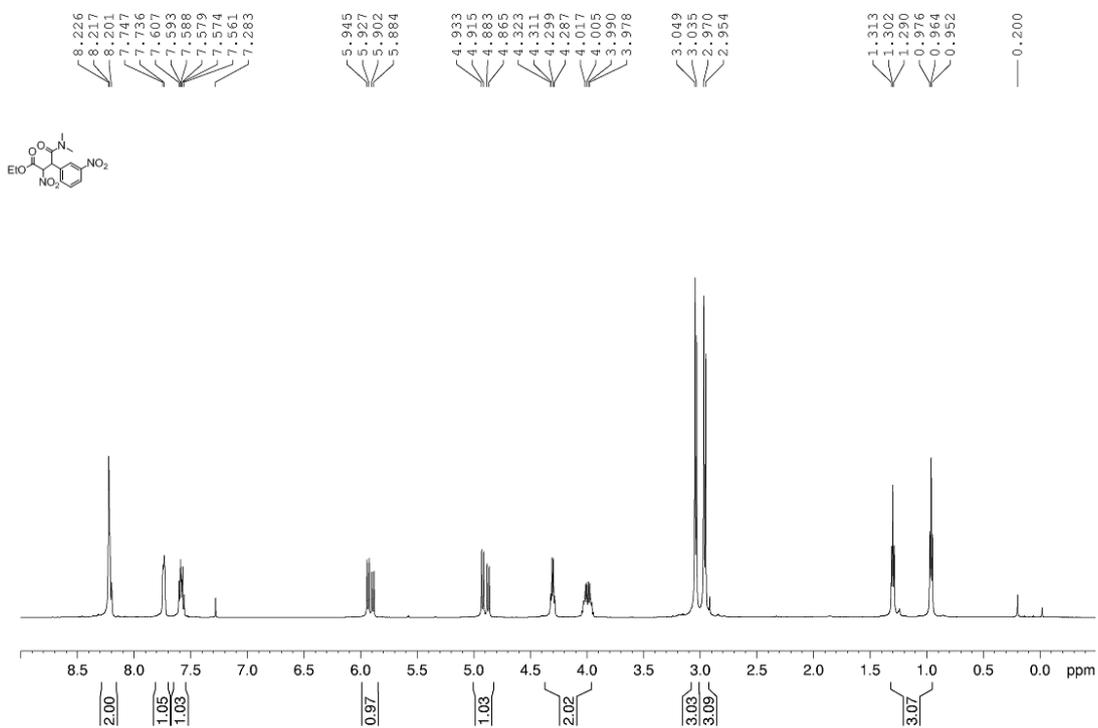
¹H NMR of **3d**



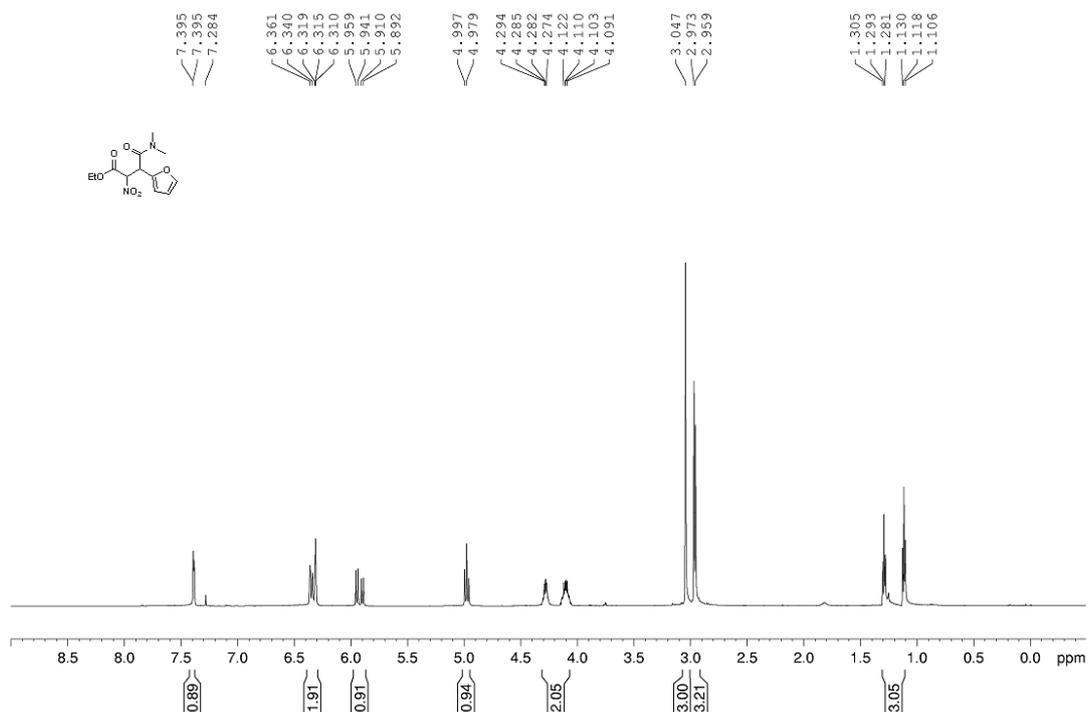
¹H NMR of 3e



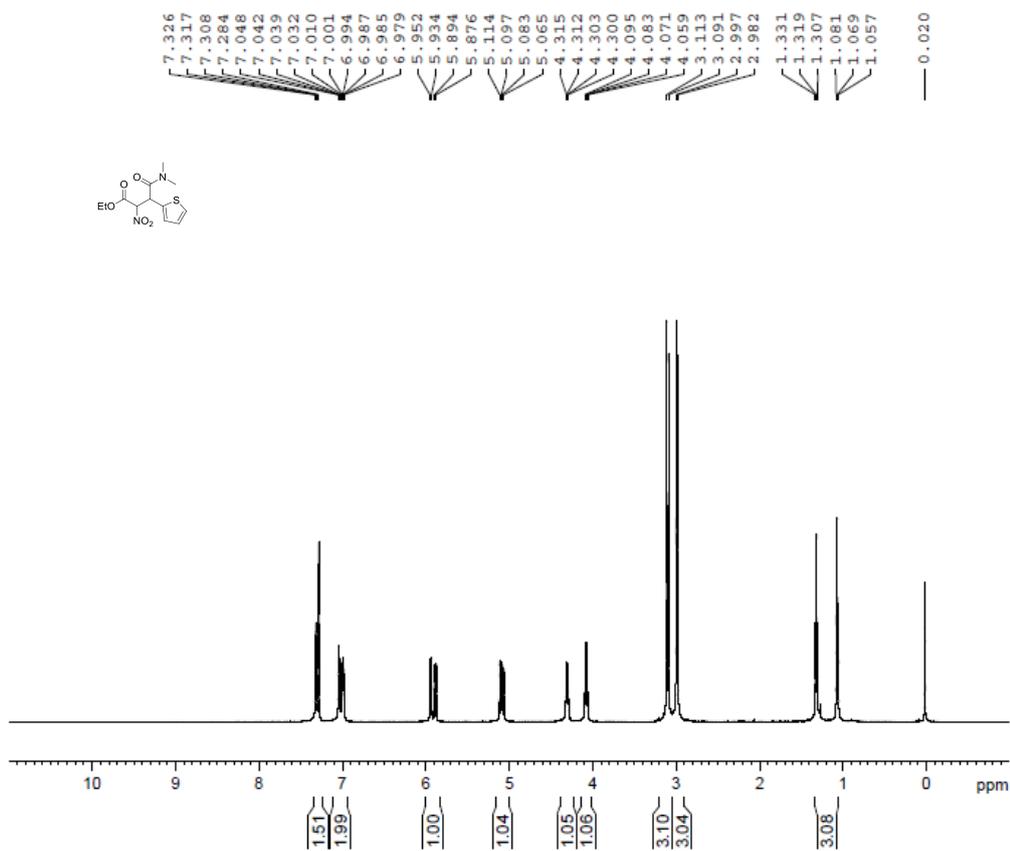
¹H NMR of 3f



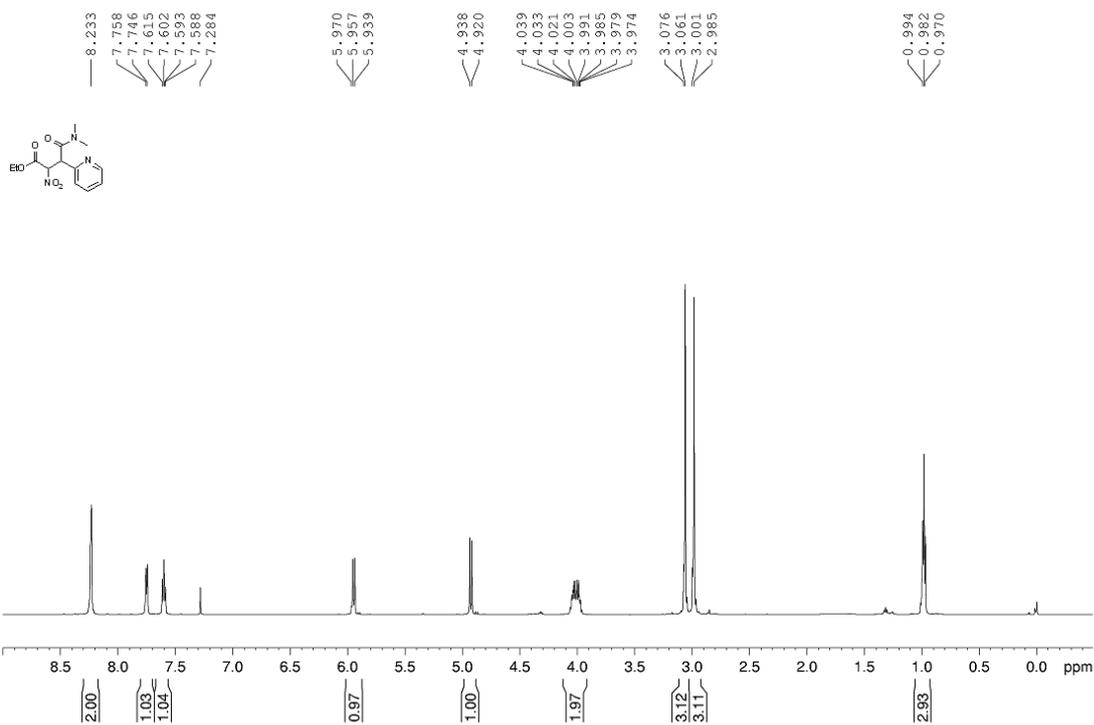
¹H NMR of **3g**



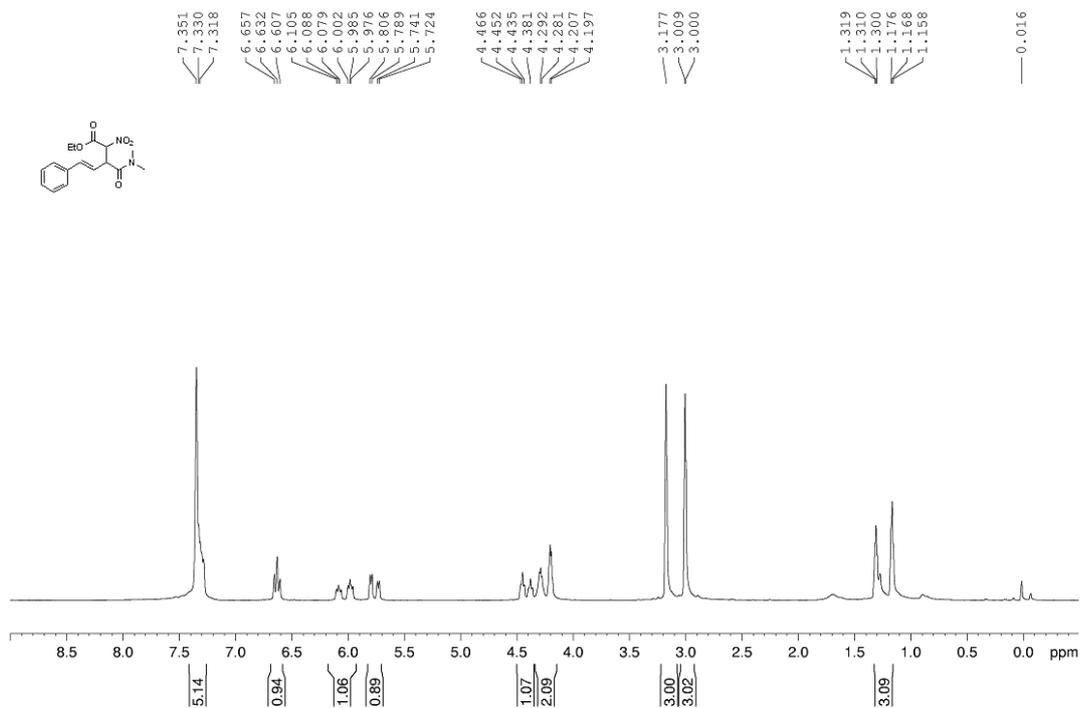
¹H NMR of **3h**



¹H NMR of **3i**

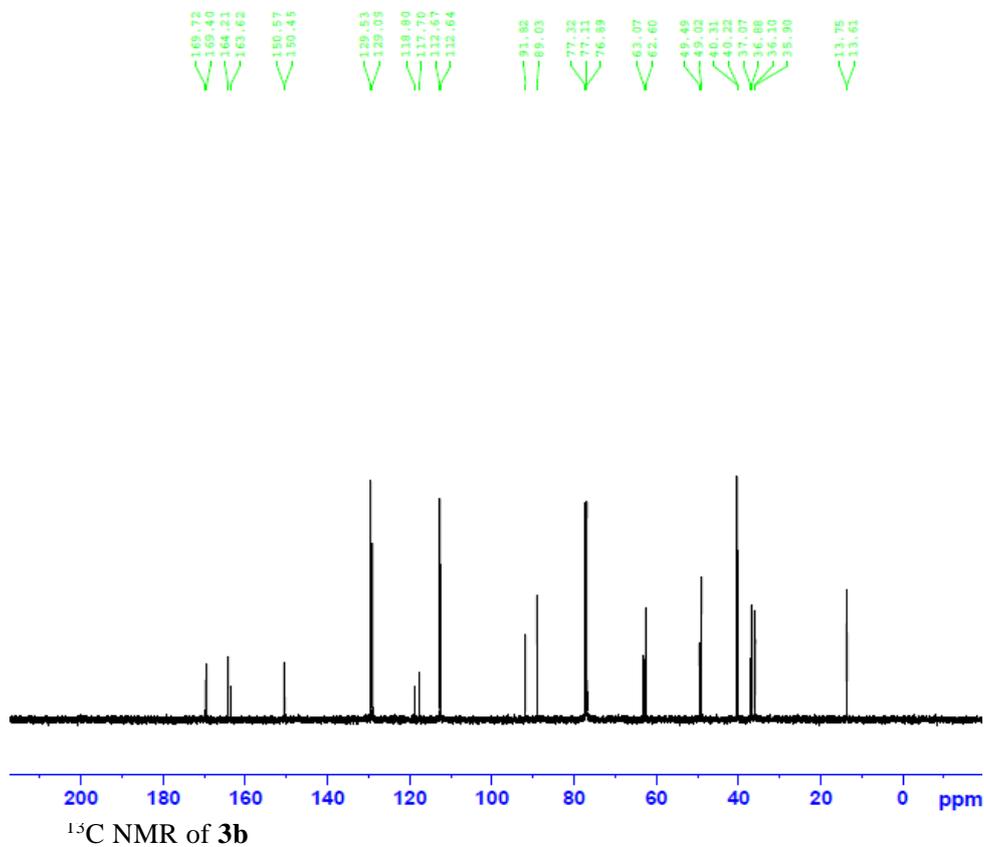


¹H NMR of **3j**

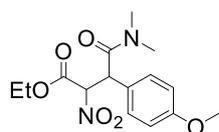
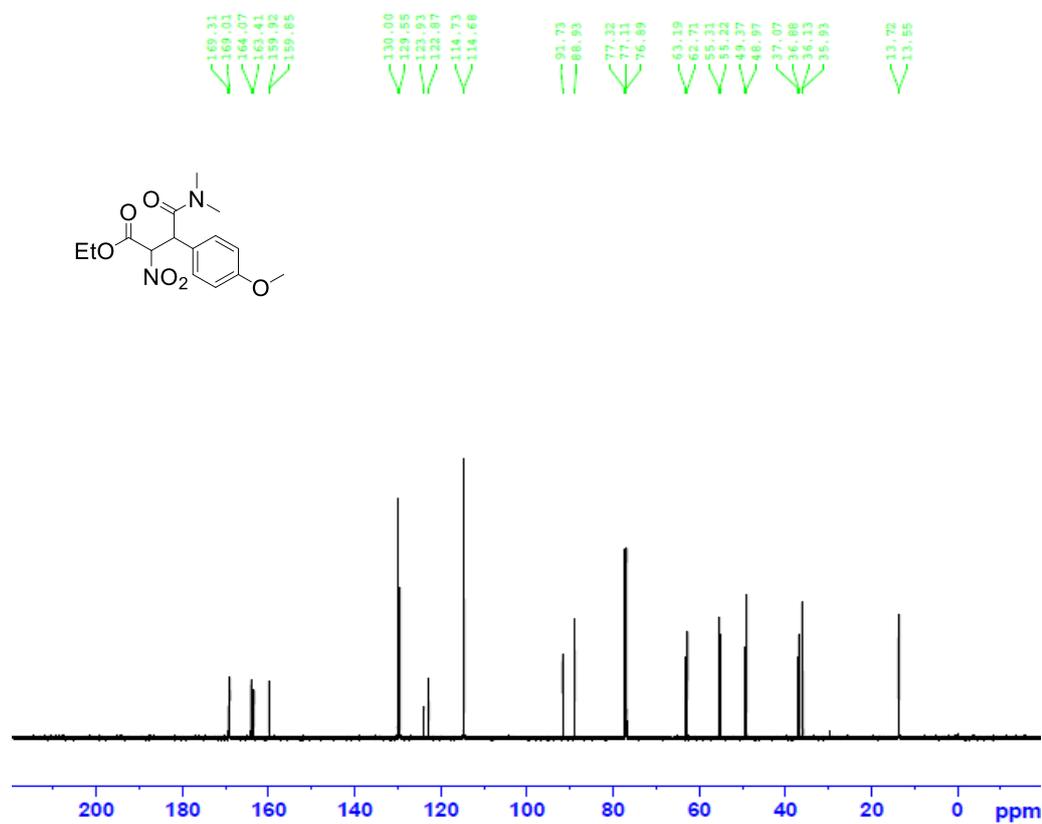


2. ^{13}C NMR spectra of compounds 3a-j (150.8 MHz)

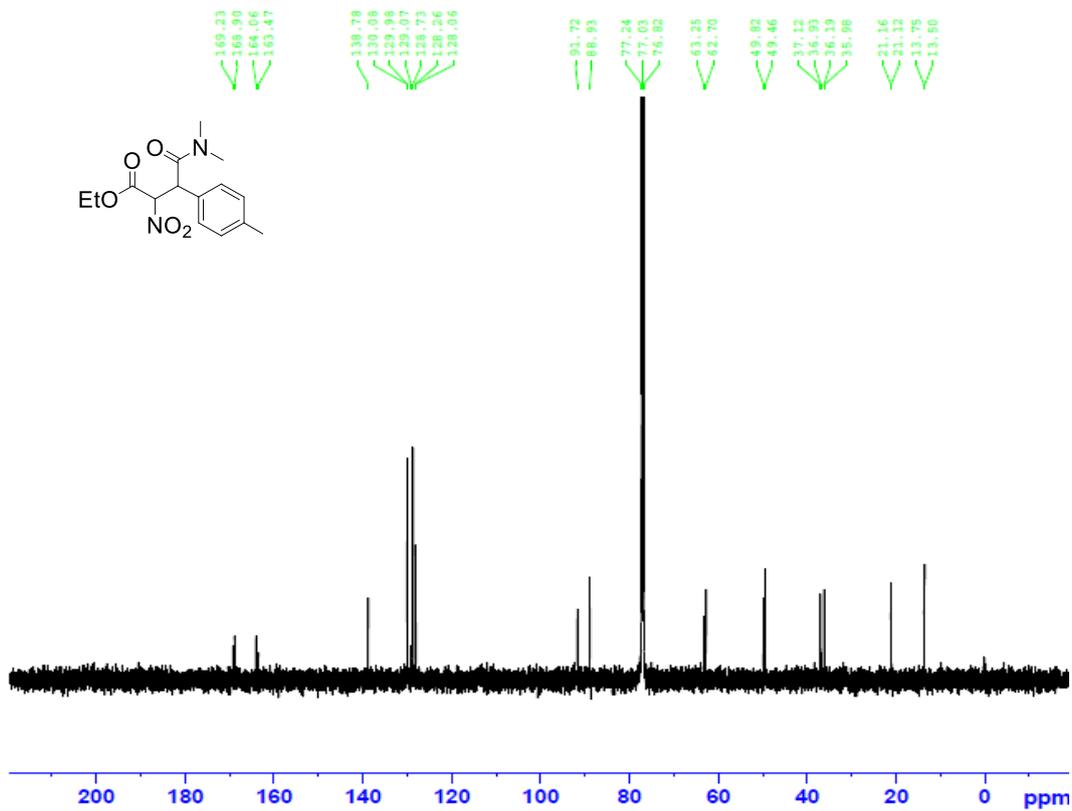
^{13}C NMR of 3a



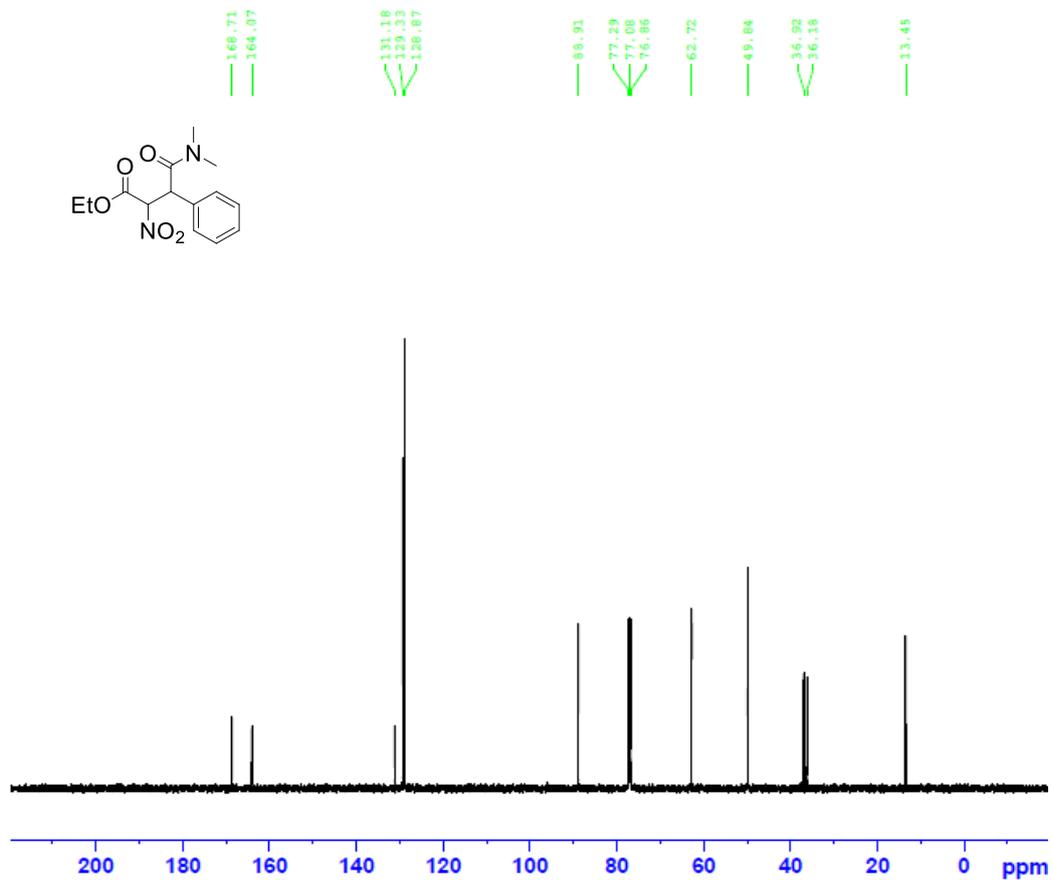
^{13}C NMR of 3b



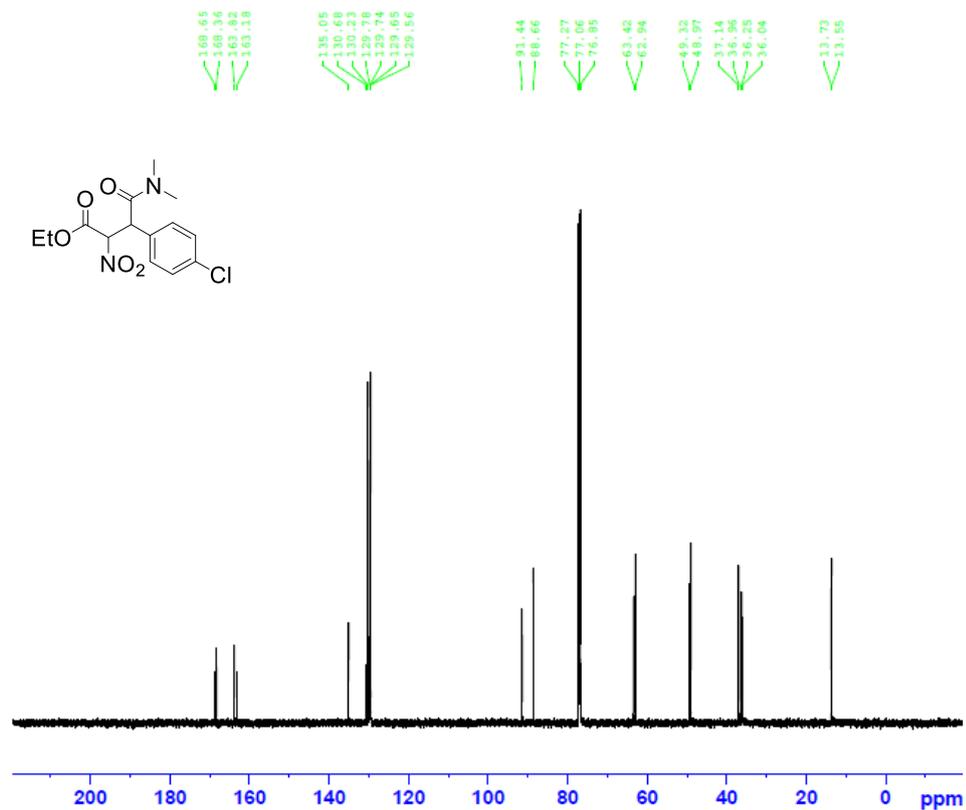
¹³C NMR of **3c**



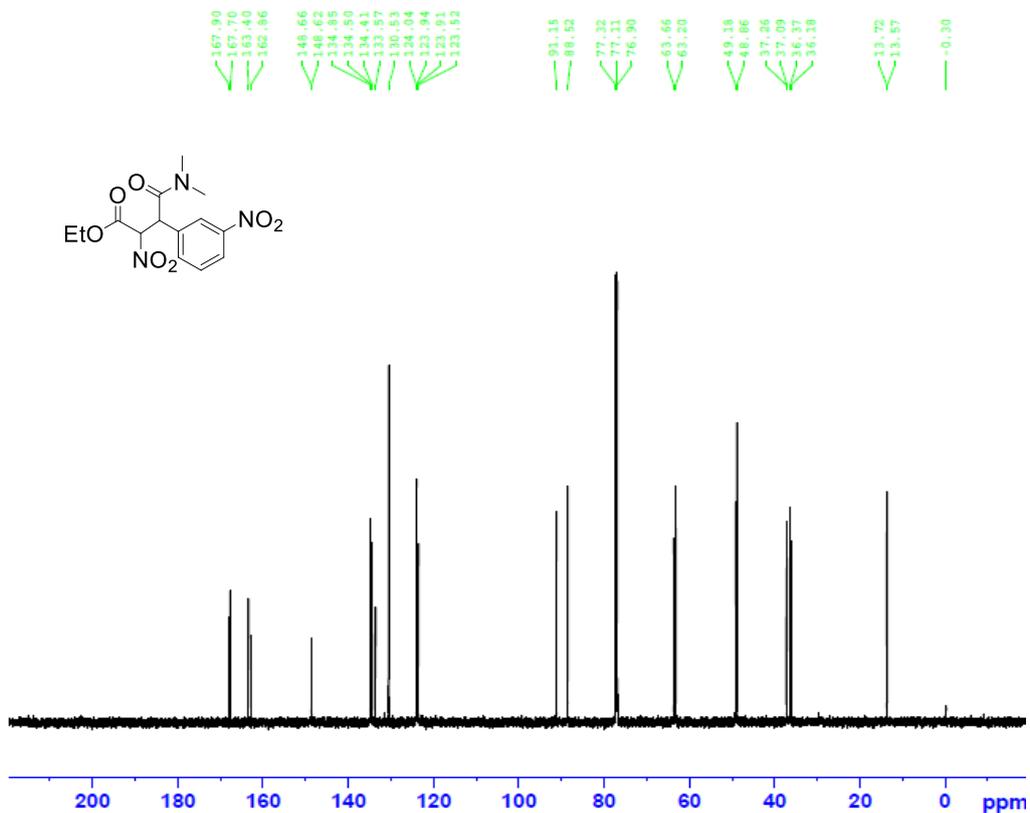
¹³C NMR of **3d**



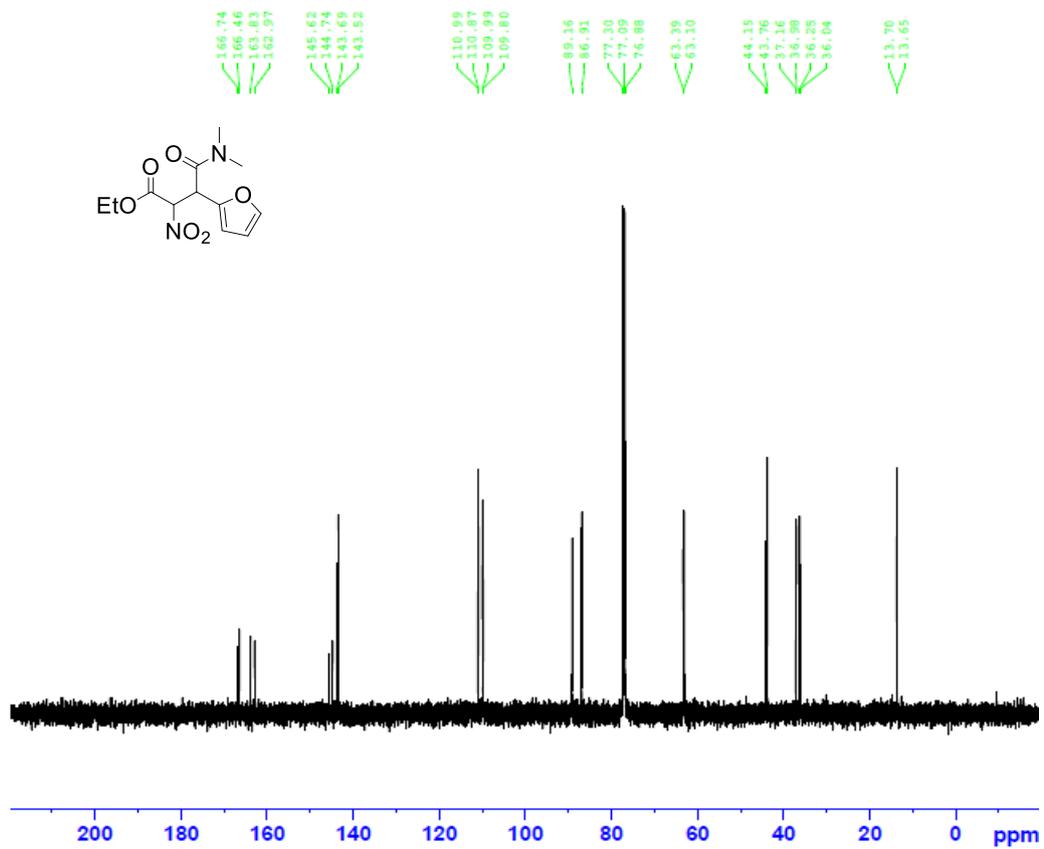
¹³C NMR of **3e**



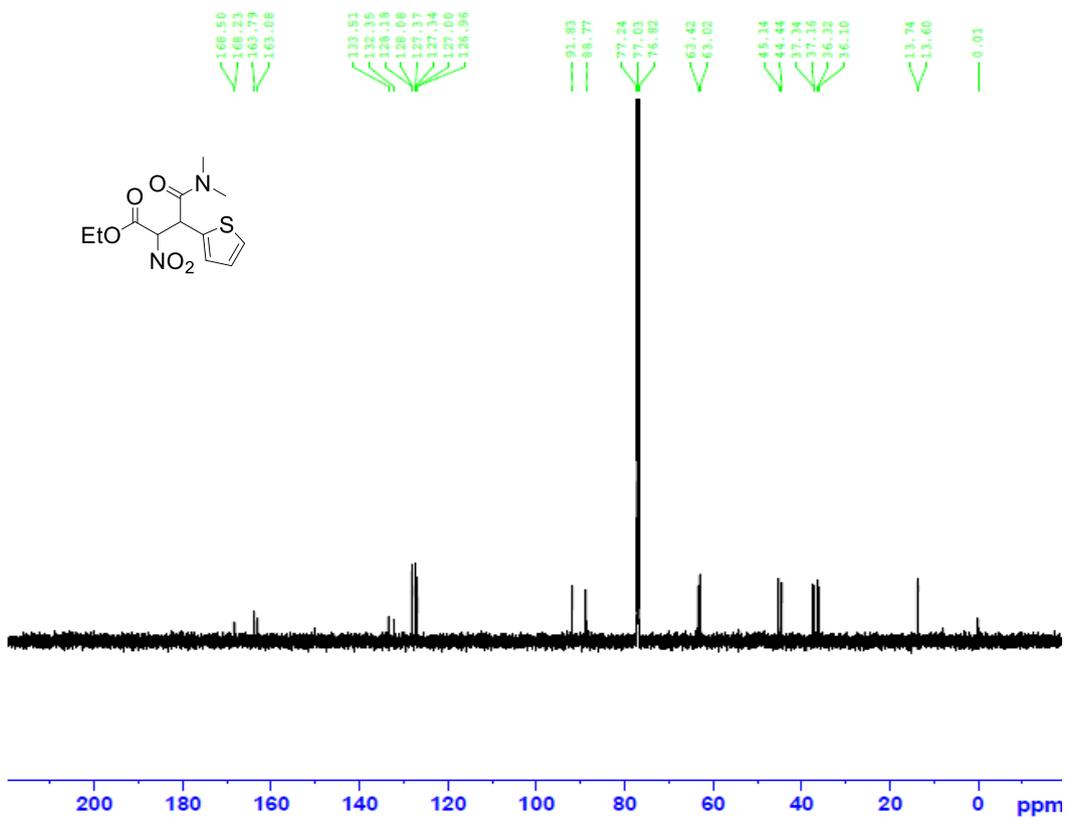
¹³C NMR of **3f**



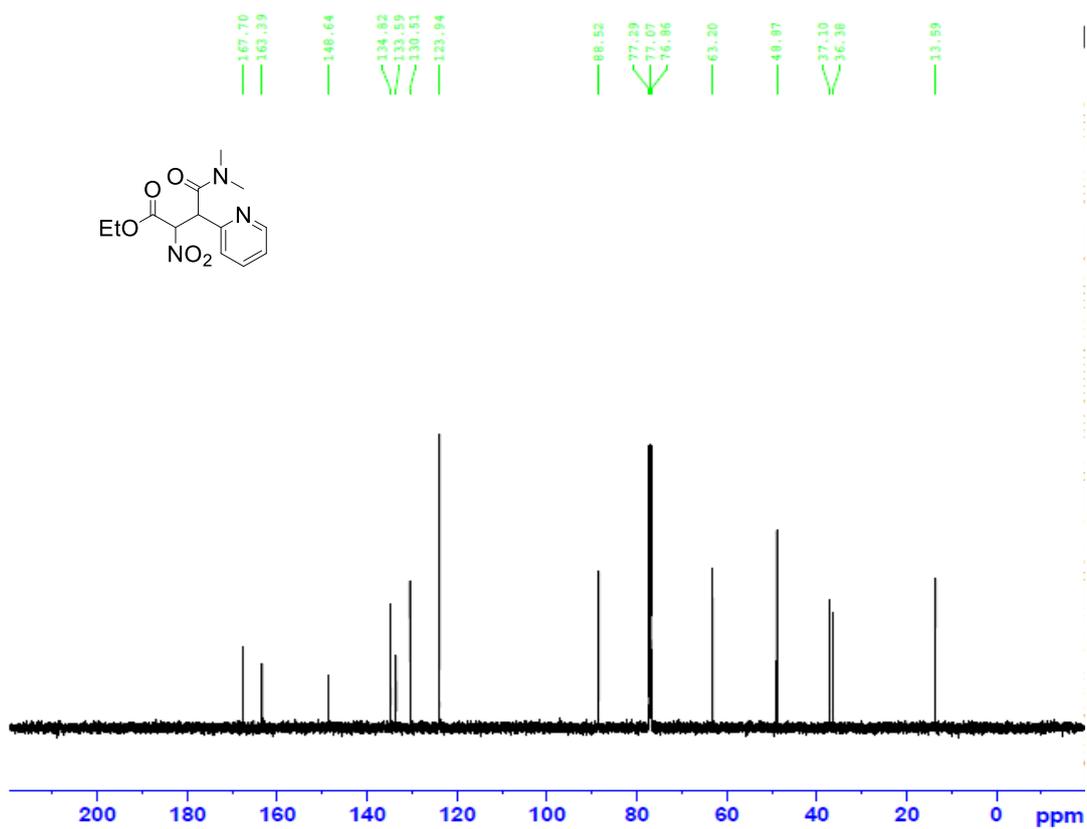
¹³C NMR of **3g**



¹³C NMR of **3h**



¹³C NMR of **3i**



¹³C NMR of **3j**

