Supporting Information

Catalytic Asymmetric Intermolecular Stetter Reaction of Enals with Nitroalkenes: Enhancement of Catalytic Efficiency Through Bifunctional Additives

Daniel A. DiRocco and Tomislav Rovis*

Department of Chemistry, Colorado State University
Fort Collins, Colorado 80523

Table of Contents:

Materials and Methods

All reactions were carried out under an atmosphere of argon in flame-dried glassware with magnetic stirring. Dichloromethane was degassed with argon and passed through two columns of neutral alumina. Toluene was degassed with argon and passed through one column of neutral alumina and one column of Q5 reactant. Methanol was purchased from Fisher Scientific and dried with activated 3Å molecular sieves. N,N-Diisopropylethylamine was purchased from Aldrich and distilled from Calcium hydride prior to use. Column chromatography was performed on SiliCycle®Silica*Flash*® P60, 40-63μm 60A. Thin layer chromatography was performed on SiliCycle® 250μm 60A plates. Visualization was accomplished with UV light or $KMnO_4$ stain followed by heating.

^1H NMR spectra were recorded on Varian 300 or 400 MHz spectrometers at ambient temperature. Data is reported as follows: chemical shift in parts per million (δ, ppm) from $CDCl_3$ (7.26 ppm) or acetone-D_6 (2.03 ppm), multiplicity (s = singlet, bs = broad singlet, d = doublet, t = triplet, q = quartet, and m = multiplet), coupling constants (Hz). ^{13}C NMR were recorded Varian 300 or 400 MHz spectrometers (at 75 or 100 MHz) at ambient temperature. Chemical shifts are reported in ppm from $CDCl_3$ (77.36 ppm) or acetone-D_6 (205.87, 30.6 ppm).

Aldehydes were either purchased from Aldrich or prepared via literature procedures. Nitroalkenes were prepared according to the general procedure as described within.

General Procedure for the Asymmetric Intermolecular Stetter Reaction[1]

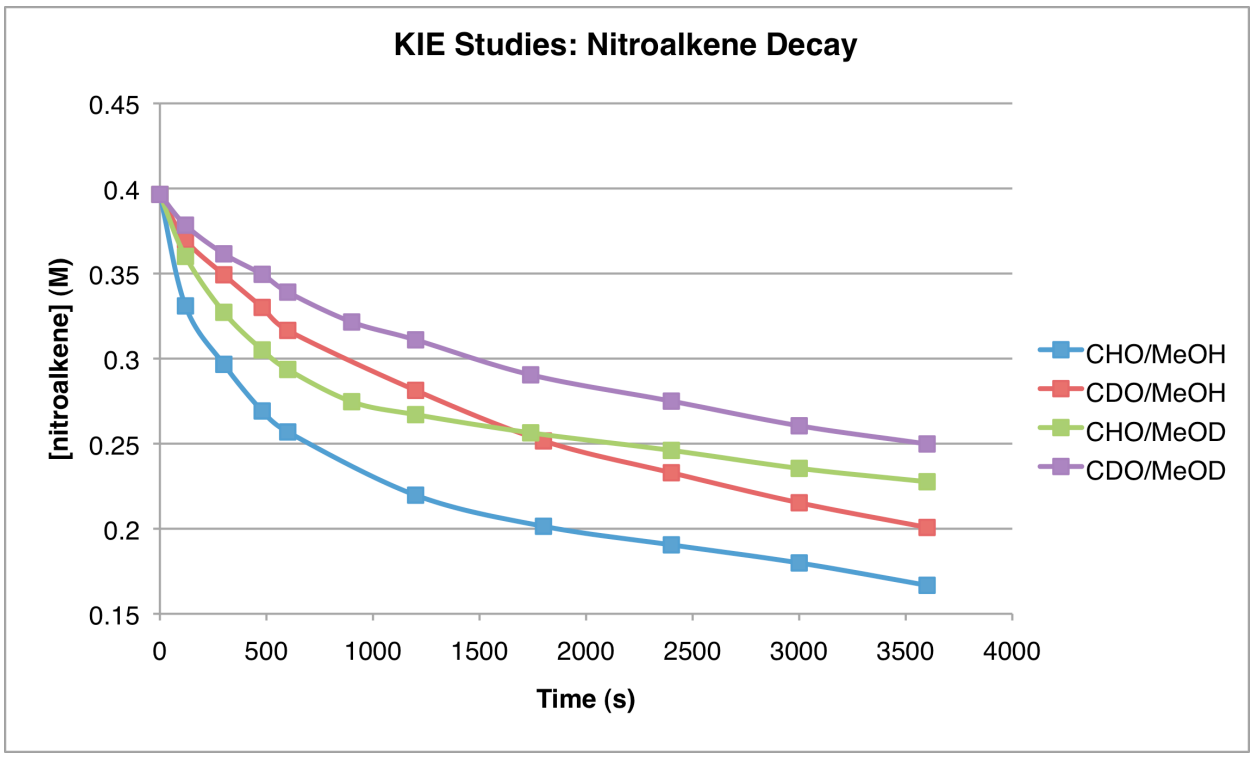
To a dry 4 mL vial, with a magnetic stir bar, was added triazolium salt **4** (16 mg, 0.0378 mmol, 0.1 equiv), catechol (42 mg, 0.378 mmol, 1.0 equiv) and anhydrous methanol (0.8 mL). The vial was cooled to 0 ºC in an ice/water bath with stirring undsr argon. N,N-diisopropylethylamine (66 μl, 0.378 mmol) was added dropwise and the reaction was stirred at 0 ºC for 5 min. A solution of the aldehyde (0.378 mmol, 1.0 equiv), and nitroalkene (0.567 mmol, 1.5 equiv), in methanol (0.2 mL) was then added dropwise. After approximately 4 h, or complete consumption of aldehyde, as indicated by TLC, AcOH (100 μl) was added to quench the reaction followed by concentration *in vacuo*. Column chromatography (hexanes:ether) of the resulting residue gave the desired β-nitro ketone.

Kinetic Isotope Effect Experiments:

General Procedure for the Asymmetric Intermolecular Stetter Reaction Monitored by Gas Chromatography:

To a dry 4 mL vial, with a magnetic stir bar, was added triazolium salt **4** (32 mg, 0.0756 mmol, 0.1 equiv), catechol (83 mg, 0.756 mmol, 1.0 equiv), trimethoxy benzene (25.4 mg, 0.151 mmol. 0.2 equiv) (internal standard) and anhydrous methanol (1.6 mL). The vial was cooled to 0 ºC in an ice/water bath with stirring under argon. N,N-diisopropylethylamine (132 μl, 0.756 mmol) was added dropwise and the reaction was stirred at 0 ºC for 5 min. A cooled (0 ºC) solution of the aldehyde (0.756 mmol, 1.0 equiv), and nitroalkene (0.794 mmol, 1.05 equiv), in methanol (0.4 mL) was then added via syringe. The reaction was stirred at 0 ºC, and aliquots (50 μl) were removed from the reactions at the indicated time intervals and quenched by placing them directly into 1.5 mL vials containing DCM (1 mL) and AcOH (50 μl). GC analysis – CP Wax 52CB col-

umn 80 °C at 1mL/min for 5 min ramp to 110 ºC at 20 ºC/min. Nitroalkene **2a** 5.0 min, trimethoxy benzene (internal standard): 6.1 min.



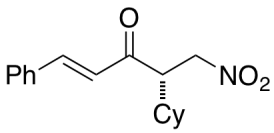
Initial rates were extrapolated from the slopes at low conversion.

CHO/MeOH		CDO/MeOH		CHO/MeOD		CDO/MeOD	
[alkene]M	Time (s)	[alkene]M	Time (s)	[alkene]M	Time (s)	[alkene]M	Time (s)
0.397	0	0.397	0	0.397	0	0.397	0
0.331	120	0.370	120	0.360	120	0.378	120
0.297	300	0.349	300	0.327	300	0.362	300
0.269	480	0.330	480	0.305	480	0.350	480
0.257	600	0.317	600	0.294	600	0.339	600
0.220	1200	0.281	1200	0.275	900	0.322	900
0.201	1800	0.252	1800	0.267	1200	0.311	1200
0.191	2400	0.233	2400	0.256	1740	0.290	1740
0.180	3000	0.215	3000	0.246	2400	0.275	2400
0.167	3600	0.201	3600	0.235	3000	0.261	3000
				0.228	3600	0.250	3600

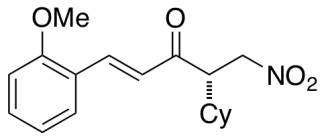
Substrate/Solvent	kobs($M\ s^{-1}$)
CHO/MeOH	5.20E-04
CDO/MeOH	1.92E-04
CHO/MeOD	2.95E-04
CDO/MeOD	1.23E-04

k_{obs} (CHO/MeOH)/k_{obs} (CDO/MeOD) = 4.2
k_{obs} (CHO/MeOH)/k_{obs} (CDO/MeOH) = 2.7
k_{obs} (CHO/MeOH)/k_{obs} (CHO/MeOD) = 1.8

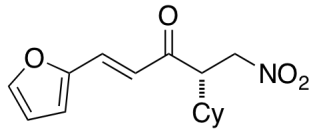
Characterization Data



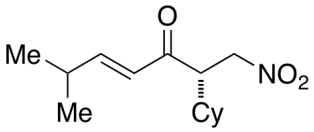
(*S*,*E*)-4-cyclohexyl-5-nitro-1-phenylpent-1-en-3-one (3a): White solid; R_f= 0.29 (4:1 hexanes:ether); 80% yield, 93% ee; $[\alpha]_D^{21}$ = -106.7 (c = 0.006 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 15.17 min, minor: 10.66 min; **m.p.** (ºC): 94-97; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 16.0 Hz, 1H), 7.61-7.58 (m, 2H), 7.44-7.41 (m, 3H), 6.86 (d, *J* = 16.0 Hz, 1H), 4.99 (dd, *J* = 14.6, 10.2 Hz, 1H), 4.45 (dd, *J* = 14.6, 3.6 Hz, 1H), 3.58 (ddd, *J* = 10.2, 5.1, 3.7 Hz, 1H), 1.79-1.59 (m, 6H), 1.32-0.93 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 144.3, 134.7, 131.3, 129.4, 129.0, 125.7, 73.9, 53.2, 39.3, 31.7, 30.3, 26.8, 26.7, 26.3; **IR** (NaCl, neat) 2929, 2854, 1685, 1657, 1608, 1576, 1450, 1375 cm^{-1}; **HRMS** (ESI+) calcd for $C_{17}H_{22}NO_3$, 287.1521. Found 287.1515.



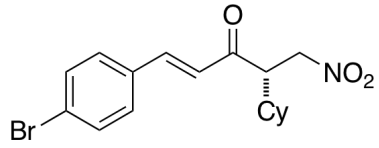
(*S*,*E*)-4-cyclohexyl-1-(2-methoxyphenyl)-5-nitropent-1-en-3-one (3b): Amorphous solid; R_f= 0.25 (4:1 hexanes:ether); 97% yield, 93% ee; $[\alpha]_D^{21}$ = -64.1 (c = 0.013 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 16.24 min, minor: 13.62 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.00 (d, *J* = 16.2 Hz, 1H), 7.58 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.39 (ddd, *J* = 8.3, 7.4, 1.7 Hz, 1H), 7.01-6.90 (m, 3H), 4.98 (dd, *J* = 14.4, 10.1 Hz, 1H), 4.45 (dd, *J* = 14.4, 3.8 Hz, 1H), 3.91 (s, 1H), 3.66-3.58 (m, 1H), 1.80-1.64 (m, 6H), 1.32-0.93 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.0, 158.9, 139.3, 132.2, 129.0, 125.8, 123.2, 120.8, 111.3, 73.6, 55.6, 52.5, 39.0, 31.2, 29.9, 26.4, 26.4, 26.0; **IR** (NaCl, neat) 2930, 2864, 1682, 1654, 1598, 1555, 1465, 1419, 1375, 1316, 1248 cm^{-1}; **HRMS** (ESI+) calcd for $C_{18}H_{24}NO_4$, 317.1627. Found 317.1628.



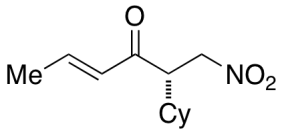
(*S*,*E*)-4-cyclohexyl-1-(furan-2-yl)-5-nitropent-1-en-3-one (3c): Colorless oil; R_f= 0.28 (4:1 hexanes:ether); 98% yield, 93% ee; $[\alpha]_D^{21}$ = -82.7 (c = 0.009 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 16.30 min, minor: 11.39 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 1.8, 0.5 Hz, 1H), 7.41 (d, *J* = 15.6 Hz, 1H), 6.78-6.72 (m, 2H), 6.51 (dd, *J* = 3.5, 1.8 Hz, 1H), 4.97 (dd, *J* = 14.5, 10.3 Hz, 1H), 4.43 (dd, *J* = 14.5, 3.6 Hz, 1H), 3.48 (ddd, *J* = 10.2, 5.1, 3.7 Hz, 1H), 1.81-1.58 (m, 6H), 1.33-0.92 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.1, 151.1, 145.4, 129.8, 122.6, 117.0, 112.9, 73.5, 53.2, 39.0, 31.3, 29.9, 26.5, 26.4, 26.0; **IR** (NaCl, neat) 2930, 2855, 1682, 1655, 1608, 1555, 1376, 1018 cm^{-1}; **HRMS** (ESI+) calcd for $C_{15}H_{20}NO_4$, 277.1314. Found 277.1318.



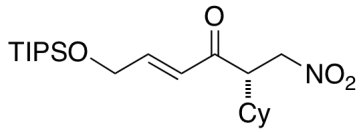
(*S*,*E*)-2-cyclohexyl-6-methyl-1-nitrohept-4-en-3-one (3d): Colorless oil; R_f= 0.41 (4:1 hexanes:ether); 70% yield, 83% ee; $[\alpha]_D^{21}$ = -90.1 (c = 0.008 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 9.98 min, minor: 7.62 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 6.91 (dd, *J* = 15.8, 6.6 Hz, 1H), 6.16 (dd, *J* = 15.8, 1.4 Hz, 1H), 4.90 (dd, *J* = 14.4, 10.2 Hz, 1H), 4.39 (dd, *J* = 14.4, 3.7 Hz, 1H), 3.47 (ddd, *J* = 10.2, 4.9, 3.8 Hz, 1H), 2.56-2.44 (m, 1H), 1.78-1.57 (m, 6H), 1.09 (d, *J* = 6.8 Hz, 6H), 1.27-0.87 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.1, 155.3, 126.8, 73.6, 52.0, 38.9, 31.3, 31.2, 29.8, 26.5, 26.4, 26.0, 21.3, 21.3; **IR** (NaCl, neat) 2963, 2930, 2856, 1692, 1667, 1625, 1450, 1420, 1375 cm^{-1}; **HRMS** (ESI+) calcd for $C_{14}H_{23}NNaO_3$, 253.1678. Found 253.1675.



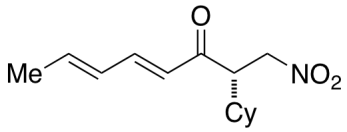
(*S*,*E*)-1-(4-bromophenyl)-4-cyclohexyl-5-nitropent-1-en-3-one (3e): Off-white solid; R_f= 0.27 (4:1 hexanes:ether); 57% yield, 98% ee; $[\alpha]_D^{21}$ = -84.1 (c = 0.011 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 15.95 min, minor: 11.55 min; **m.p.** (ºC): 141-143; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.61-7.53 (m, 3H), 7.46-7.44 (m, 2H), 6.84 (d, *J* = 16.0 Hz, 1H), 4.98 (dd, *J* = 14.6, 10.4 Hz, 1H), 4.45 (dd, *J* = 14.6, 3.5 Hz, 1H), 3.55 (ddd, *J* = 10.3, 5.2, 3.6 Hz, 1H), 1.80-1.63 (m, 6H), 1.33-0.92 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.4, 142.6, 133.3, 132.4, 130.1, 125.8, 125.3, 73.5, 53.0, 39.0, 31.4, 29.9, 26.5, 26.4, 26.0; **IR** (NaCl, neat) 2929, 2854, 1686, 1658, 1608, 1554, 1487, 1449, 1402, 1375, 1063, 1009; **HRMS** (ESI+) calcd for $C_{17}H_{21}BrNO_3$, 365.0627. Found 365.0629.



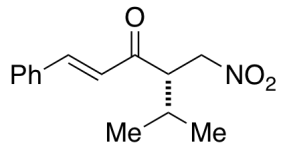
(*S*,*E*)-2-cyclohexyl-1-nitrohex-4-en-3-one (3f): Colorless oil; R_f= 0.35 (4:1 hexanes:ether); 67% yield, 86% ee; $[\alpha]_D^{21}$ = -100.3 (c = 0.007 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 14.00 min, minor: 10.91 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 6.97 (dq, *J* = 15.6, 6.9 Hz, 1H), 6.26 (dq, *J* = 15.6, 1.7 Hz, 1H), 4.91 (dd, *J* = 14.5, 10.3 Hz, 1H), 4.39 (dd, *J* = 14.5, 3.6 Hz, 1H), 3.45 (ddd, *J* = 10.3, 4.9, 3.7 Hz, 1H), 1.95 (dd, *J* = 6.9, 1.7 Hz, 3H), 1.80-1.57 (m, 6H), 1.31-0.87 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.5, 144.5, 131.2, 73.5, 52.0, 38.9, 31.3, 29.8, 26.5, 26.4, 26.0, 18.5; **IR** (NaCl, neat) 2928, 2855, 1692, 1665, 1629, 1553, 1444, 1375, 1286, 1201, 1065 cm^{-1}; **HRMS** (ESI+) calcd for $C_{12}H_{20}NO_3$, 225.1365. Found 253.1397.



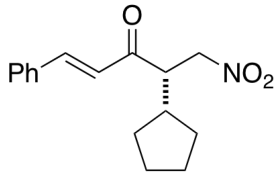
(*S*,*E*)-2-cyclohexyl-1-nitro-6-((triisopropylsilyl)oxy)hex-4-en-3-one (3g): Colorless oil; R_f= 0.42 (4:1 hexanes:ether); 60% yield, 82% ee; $[\alpha]_D^{21}$ = -24.0 (c = 0.006 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 9.74 min, minor: 7.44 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 6.99 (dt, *J* = 15.5, 3.2 Hz, 1H), 6.60 (dt, *J* = 15.4, 2.3 Hz, 1H), 4.92 (dd, *J* = 14.5, 10.1 Hz, 1H), 4.49 (dd, *J* = 3.2, 2.3 Hz, 2H), 4.39 (dd, *J* = 14.5, 3.8 Hz, 1H), 3.48 (ddd, *J* = 10.1, 5.0, 3.9 Hz, 1H), 1.82-1.58 (m, 6H), 1.33-0.86 (m, 26H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.5, 147.3, 126.9, 73.5, 62.8, 52.7, 38.9, 31.3, 30.0, 26.5, 26.5, 26.1, 18.1, 12.1; **IR** (NaCl, neat) 2932, 2866, 1737, 1694, 1671, 1556, 1463, 1450, 1420, 1375, 1267, 1138, 1069 cm^{-1}; **HRMS** ESI/APCI or APCI failed to produce the parent or related ions.



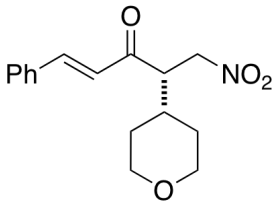
(*S*,*4E*,*6E*)-2-cyclohexyl-1-nitrooct-4,6-dien-3-one (3h): Colorless oil; R_f= 0.28 (4:1 hexanes:ether); 90% yield, 94% ee; $[\alpha]_D^{21}$ = -124.8 (c = 0.005 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 17.33 min, minor: 12.05 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.23 (m, 1H), 6.33-6.11 (m, 3H), 4.91 (dd, *J* = 14.4, 10.2 Hz, 1H), 4.39 (dd, *J* = 14.4, 3.7 Hz, 1H), 3.44 (ddd, *J* = 10.1, 5.0, 3.8 Hz, 1H), 1.89 (d, *J* = 5.3 Hz, 3H), 1.81-1.54 (m, 6H), 1.30-0.86 (m, 5H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 144.4, 142.1, 130.3, 126.9, 73.7, 52.5, 39.1, 31.3, 30.0, 26.5, 26.4, 26.1, 19.0; **IR** (NaCl, neat) 2930, 2855, 1683, 1657, 1636, 1594, 1555, 1449, 1419, 1375, 1058 cm^{-1}; **HRMS** (ESI+) calcd for $C_{14}H_{22}NO_3$, 251.1521. Found 251.1524.



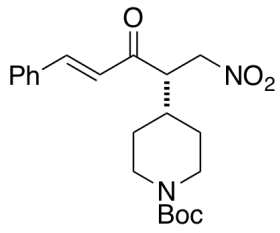
(*S*,*E*)-5-methyl-4-(nitromethyl)-1-phenylhex-1-en-3-one (3i): Colorless oil; R_f= 0.25 (4:1 hexanes:ether); 75% yield, 91% ee; $[\alpha]_D^{21}$ = -108.5 (c = 0.010 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 15.98 min, minor: 10.31 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 16.0 Hz, 1H), 7.61-7.57 (m, 2H), 7.43-7.40 (m, 2H), 6.87 (d, *J* = 16.0 Hz, 1H), 4.99 (dd, *J* = 14.6, 10.2 Hz, 1H), 4.43 (dd, *J* = 14.6, 3.6 Hz, 1H), 3.58 (ddd, *J* = 10.2, 5.1, 3.6 Hz, 1H), 2.24-2.09 (m, 1H), 1.07 (d, *J* = 6.9 Hz, 3H), 0.94 (d, *J* = 6.9 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.4, 144.1, 134.3, 131.0, 129.1, 128.7, 125.1, 73.0, 53.1, 29.0, 20.8, 19.1; **IR** (NaCl, neat) 2967, 1686, 1658, 1608, 1556, 1450, 1419, 1375, 1332, 1193, 1077 cm^{-1}; **HRMS** (ESI+) calcd for $C_{14}H_{18}NO_3$, 247.1208. Found 247.1211.



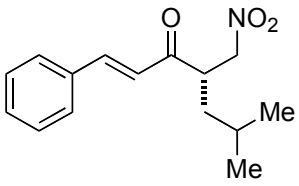
(*S*,*E*)-4-cyclopentyl-5-nitro-1-phenylpent-1-en-3-one (3j): Colorless oil; R_f= 0.24 (4:1 hexanes:ether); 84% yield, 88% ee; $[\alpha]_D^{21}$ = -90.7 (c = 0.009 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 15.24 min, minor: 11.60 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 16.0 Hz, 1H), 7.61-7.58 (m, 2H), 7.43-7.40 (m, 3H), 6.88 (d, *J* = 16.0 Hz, 1H), 4.99 (dd, *J* = 14.6, 10.5 Hz, 1H), 4.47 (dd, *J* = 14.6, 3.5 Hz, 1H), 3.59 (ddd, *J* = 10.4, 8.6, 3.5 Hz, 1H), 2.05-1.91 (m, 1H), 1.85-1.72 (m, 2H), 1.71-1.60 (m, 2H), 1.59-1.49 (m, 2H), 1.38-1.22 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.2, 144.1, 134.4, 131.0, 129.1, 128.7, 125.8, 75.2, 51.7, 41.0, 31.0, 30.5, 24.9, 24.5; **IR** (NaCl, neat) 2948, 2871, 1690, 1656, 1555, 1451, 1412, 1378, 1196 cm^{-1}; **HRMS** (ESI+) calcd for $C_{16}H_{20}NO_3$, 273.1365. Found 273.1365.



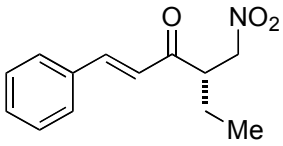
(*S*,*E*)-5-nitro-1-phenyl-4-(tetrahydro-2*H*-pyran-4-yl)pent-1-en-3-one (3k): Amorphous solid; R_f= 0.13 (1:1 hexanes:ether); 82% yield, 90% ee; $[\alpha]_D^{21}$ = -100.2 (c = 0.011 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 60:40 hexanes/*iso*-propanol, 1.0 mL/min. Major: 22.68 min, minor: 20.04 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.68 (d, *J* = 16.0 Hz, 1H), 7.62-7.59 (m, 2H), 7.43 (dd, *J* = 5.0, 2.0 Hz, 3H), 6.87 (d, *J* = 16.0 Hz, 1H), 4.98 (dd, *J* = 14.5, 10.1 Hz, 1H), 4.49 (dd, *J* = 14.5, 3.8 Hz, 1H), 4.00-3.95 (m, 2H), 3.62 (ddd, *J* = 10.1, 6.2, 3.8 Hz, 1H), 3.39-3.29 (m, 2H), 2.00-1.93 (m, 1H), 1.60-1.40 (m, 4H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.2, 144.7, 134.1, 131.2, 129.2, 128.8, 125.3, 73.5, 67.8, 67.7, 52.0, 36.3, 30.9, 30.0; **IR** (NaCl, neat) 2941, 2848, 1685, 1656, 1607, 1554, 1450, 1375, 1183, 1151, 1090 cm^{-1}; **HRMS** (ESI+) calcd for $C_{16}H_{20}NO_4$, 289.1314. Found 289.1314.



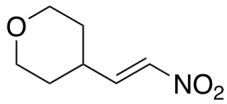
(*S*,*E*)-*tert*-butyl 4-(1-nitro-3-oxo-5-phenylpent-4-en-2-yl)piperidine-1-carboxylate (3l): Amorphous solid; R_f= 0.23 (3:2 hexanes:ether); 78% yield, 90% ee; $[\alpha]_D^{21}$ = -50.4 (c = 0.008 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 60:40 hexanes/*iso*-propanol, 1.0 mL/min. Major: 36.28 min, minor: 22.87 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.68 (d, *J* = 16.0 Hz, 1H), 7.62-7.59 (m, 2H), 7.43 (dd, *J* = 5.1, 1.9 Hz, 3H), 6.87 (d, *J* = 16.0 Hz, 1H), 4.98 (dd, *J* = 14.5, 10.1 Hz, 1H), 4.47 (dd, *J* = 14.5, 3.8 Hz, 1H), 4.18-4.14 (m, 2H), 3.63 (ddd, *J* = 10.0, 6.0, 3.9 Hz, 1H), 2.69-2.57 (m, 2H), 1.94-1.81 (m, 1H), 1.70-1.58 (m, 2H), 1.44 (s, 9H), 1.40-1.14 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.1, 154.5, 144.6, 134.1, 131.2, 129.1, 128.8, 125.2, 79.8, 73.5, 51.8, 37.3, 30.1, 29.1, 28.5; **IR** (NaCl, neat) 2933, 2860, 1684, 1607, 1558, 1426, 1367, 1250, 1170, 1066 cm^{-1}; **HRMS** (ESI+) calcd for $C_{21}H_{28}N_2NaO_5$, 388.1998. Found 388.1997.



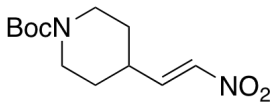
(*S*,*E*)-6-methyl-4-(nitromethyl)-1-phenylhept-1-en-3-one (3m): Colorless oil; R_f= 0.26 (9:1 hexanes:EtOAc); 84% yield, 42% ee; $[\alpha]_D^{21}$ = -28.6 (c = 0.019 g/ml, $CHCl_3$); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 11.24 min, minor: 8.95 min; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.69 (d, *J* = 16.0 Hz, 1H), 7.59 (dd, *J* = 6.5, 3.1 Hz, 2H), 7.42 (dd, *J* = 5.0, 1.8 Hz, 3H), 6.84 (d, *J* = 16.0 Hz, 1H), 4.90 (dd, *J* = 14.4, 9.6 Hz, 1H), 4.39 (dd, *J* = 14.4, 4.3 Hz, 1H), 3.76-3.70 (m, 1H), 1.68-1.57 (m, 2H), 1.37-1.26 (m, 1H), 1.01-0.88 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 144.5, 134.3, 131.1, 129.2, 128.7, 124.6, 75.3, 45.5, 38.9, 26.0, 22.9, 22.5; **IR** (NaCl, neat) 3028, 2959, 2872, 1687, 1662, 1610, 1554, 1450, 1376, 1204, 1054 cm^{-1}; **HRMS** (ESI+) calcd for $C_{15}H_{19}NO_3$, 261.1365. Found 261.1361.



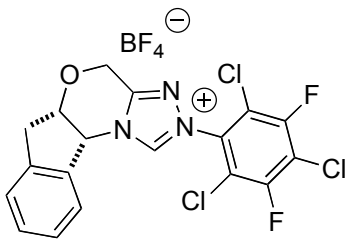
(*S*,*E*)-4-(nitromethyl)-1-phenylhex-1-en-3-one: Colorless oil; R_f= 0.18 (9:1 hexanes:EtOAc); 66% yield, 52% ee; $[\alpha]_D^{21}$ = -34.2 (c = 0.011 g/ml, CH_2Cl_2); HPLC analysis – Chiracel IC column, 70:30 hexanes/*iso*-propanol, 1.0 mL/min. Major: 12.66 min, minor: 9.56 min; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.61 (d, *J* = 16.0 Hz, 1H), 7.52 (dd, *J* = 6.5, 3.1 Hz, 2H), 7.35 (m, 3H), 6.79 (d, *J* = 16.0 Hz, 1H), 4.85 (dd, *J* = 14.3, 9.1 Hz, 1H), 4.36 (dd, *J* = 14.3, 4.9 Hz, 1H), 3.59 (m, 1H), 1.76-1.68 (m, 1H), 1.60 (m, 1H), 0.91 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.6, 144.5, 134.2, 131.1, 129.2, 128.7, 124.5, 74.7, 48.4, 22.9, 11.1; **IR** (NaCl, neat) 2922, 1736, 1687, 1657, 1608, 1549, 1415, 1157, 1074 cm^{-1}. **HRMS** (ESI+) calcd for $C_{13}H_{15}NO_3$, 233.1052. Found 233.1051.



(*E*)-4-(2-nitrovinyl)tetrahydro-2*H*-pyran (2k): Prepared according to the general procedure. Amorphous solid; R_f= 0.30 (1:1 hexanes:ether); 31% yield; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.20 (dd, *J* = 13.5, 6.9 Hz, 1H), 6.95 (dd, *J* = 13.5, 1.4 Hz, 1H), 4.04-3.98 (m, 2H), 3.45 (td, *J* = 11.7, 2.4 Hz, 2H), 2.57-2.46 (m, 1H), 1.74-1.68 (m, 2H), 1.64-1.50 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 145.1, 138.9, 67.1, 34.9, 31.1; IR (NaCl, neat) 3107, 2944, 2849, 1648, 1524, 1389, 1352, 1239, 1146, 1122, 1093 cm^{-1}; **HRMS** ESI/APCI or APCI failed to produce the parent or related ions.



(*E*)-*tert*-butyl 4-(2-nitrovinyl)piperidine-1-carboxylate (2l): Prepared according to the general procedure. Amorphous solid; R_f= 0.35 (1:1 hexanes:ether); 40% yield; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.20 (dd, *J* = 13.5, 7.1 Hz, 1H), 6.95 (dd, *J* = 13.5, 1.3 Hz, 1H), 4.16 (m, 2H), 2.82-2.72 (m, 2H), 2.47-2.35 (m, 1H), 1.79-1.74 (m, 2H), 1.45 (s, 9H), 1.54-1.24 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.7, 145.0, 139.1, 79.9, 36.0, 30.5, 28.5; **IR** (NaCl, neat) 2977, 2934, 2858, 1690, 1648, 1525, 1424, 1366, 1351, 1234, 1171 cm^{-1}; **HRMS** (ESI+) calcd for $C_7H_{13}N_2O_2$ (-Boc), 157.0977. Found 157.0971.



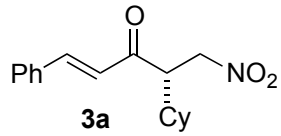
Triazolium Salt 8: Prepared according to the general procedure.[1] White solid; **m.p.** (ºC): 267-269; $[\alpha]_D^{21}$ = -79.1 (c = 0.005 g/ml, acetone/DMSO); **^{1}H NMR** (400 MHz, acetone-d_4+10% DMSO-d_6) δ 11.53 (s, 1H), 7.61 (d, *J* = 7.5 Hz, 1H), 7.42 (ddt, *J* = 20.3, 13.1, 6.8 Hz, 3H), 6.36 (d, *J* = 4.1 Hz, 1H), 5.40-5.22 (m, 2H), 5.18 (t, *J* = 4.5 Hz, 1H), 3.56 (dd, *J* = 17.1, 4.9 Hz, 1H), 3.24 (m, 1H); **^{13}C NMR** (100 MHz, acetone-d_4+10% DMSO-d_6) δ 156.3,

153.8, 152.6, 147.9, 141.8, 131.6, 130.5, 128.3, 126.6, 124.9, 78.2, 63.6, 60.9, 38.1; **IR** (NaCl, neat) 3133, 3101, 2951, 2907, 1678, 1587. 1531, 1483, 1080 cm^{-1}; **HRMS** (ESI+) calcd for $C_{18}H_{11}Cl_3F_2N_3O$, 427.9936. Found 427.9948.

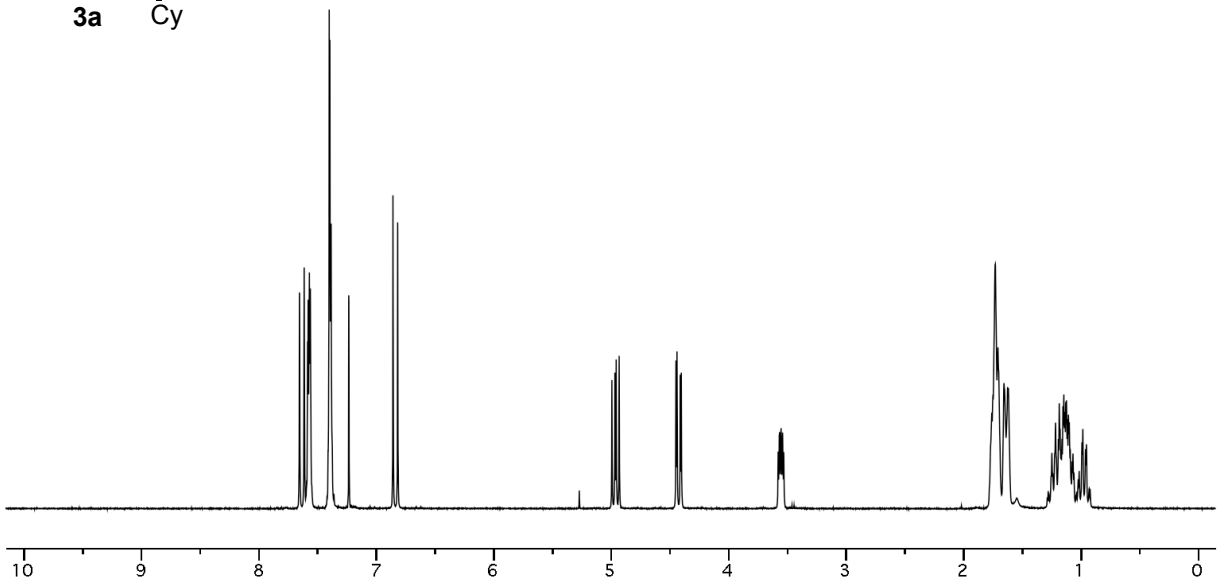
General Procedure for the Synthesis of Nitroalkenes

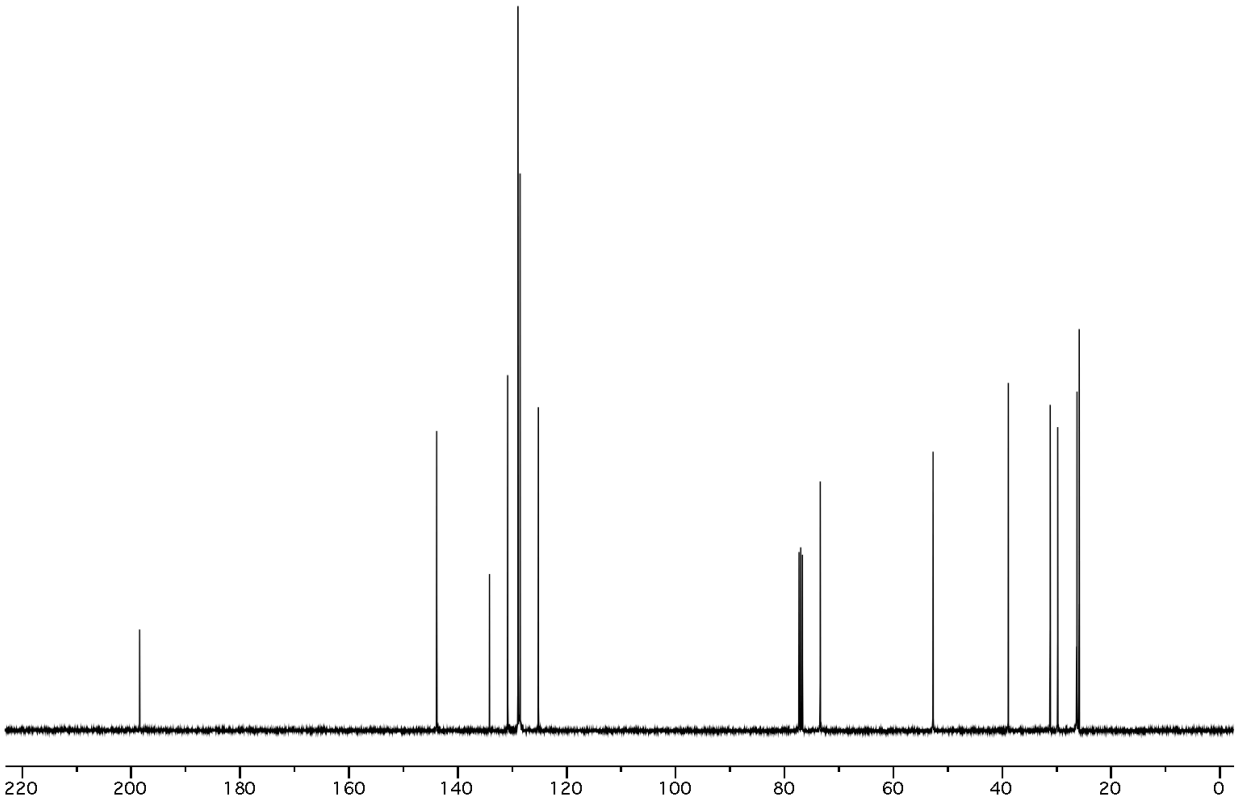
To a dry round bottom flask was added cyclopentane carboxaldehyde (1.02 g, 10.4 mmol), nitromethane (840 μl, 15.6 mmol), and 1:1 THF/*t*-BuOH (10 mL). This solution was cooled to 0 ºC and potassium tert-butoxide (0.233 g, 2.08 mmol) added in one portion. The reaction was then stirred at 0 ºC for 1 h then warmed to room temperature and stirred for 12 h. After completion, saturated aqueous NH_4Cl solution (20 mL) was added to quench the reaction and then extracted with CH_2Cl_2 (3 x 20 mL). The combined organic extracts were then dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. After drying the crude residue under vacuum (4 mm) for 1 h, CH_2Cl_2 (20 mL) was added followed by cooling to 0 ºC. Trifluoroacetic anhydride (1.52 mL, 10.9 mmol) was added followed by the slow dropwise addition of Et_3N (3.04 mL, 21.8 mmol). After stirring for 1 h at 0 ºC the reaction was allowed to warm to room temperature and stirred an additional 2 h. The reaction was diluted with CH_2Cl_2 (20 mL) followed by the addition of water (20 mL). The organic layer was separated and washed with saturated aqueous NH_4Cl solution (3 x 20 mL), dried (Na_2SO_4) and concentrated *in vacuo* to give a yellow oil that was purified by column chromatography (20:1 hexanes:ether) yielding 0.779 g (53%) of (*E*)-(2-nitrovinyl)cyclopentane as a pale yellow oil.

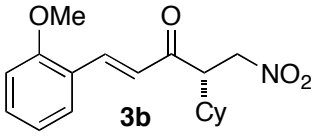
^{1}H and ^{13}C NMR Spectra for New Compounds



3a

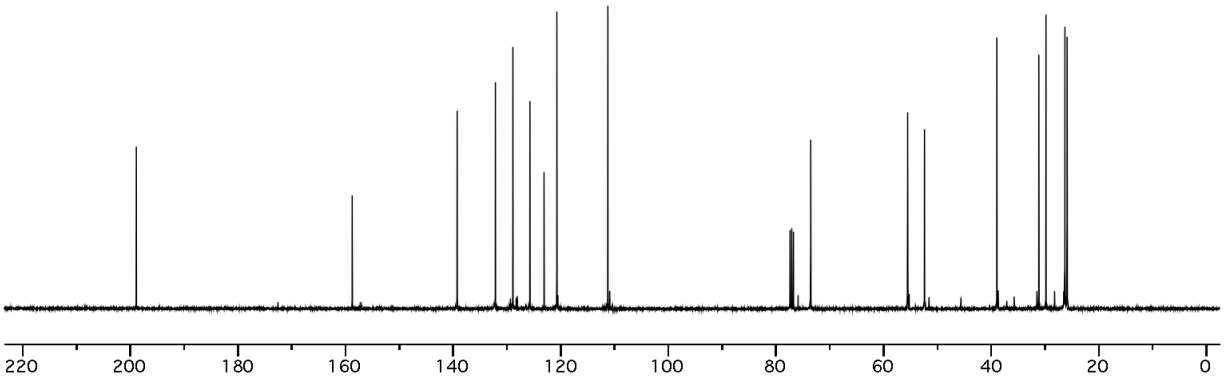


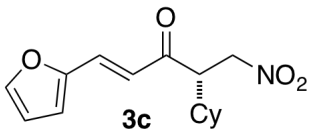



OMe
O
NO2
Cy

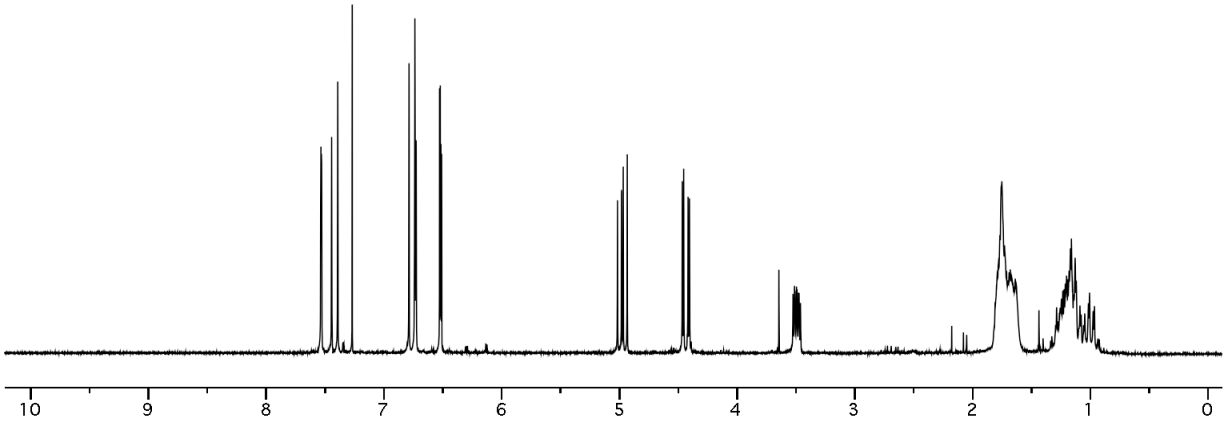
3b

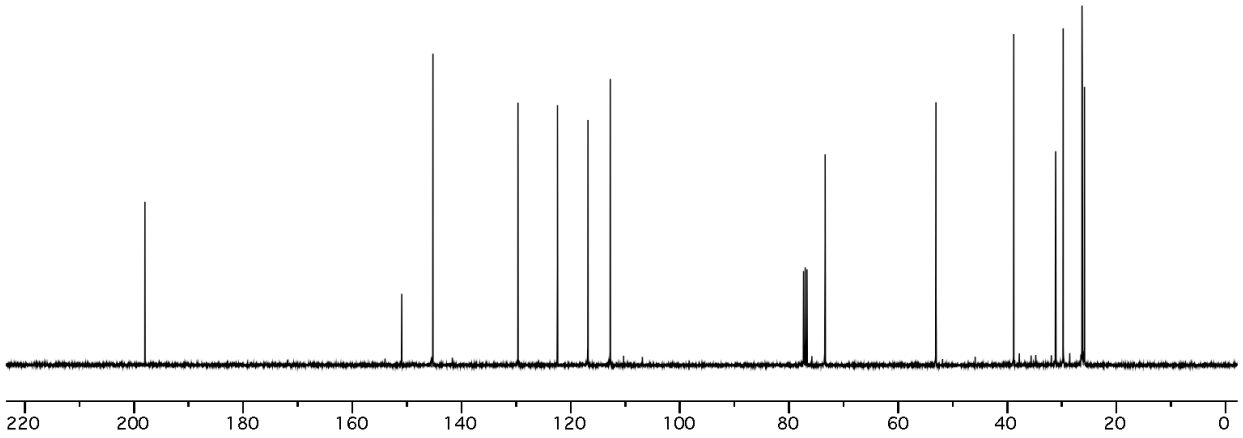
10
9
8
7
6
5
4
3
2
1
0

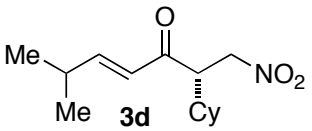

220
200
180
160
140
120
100
80
60
40
20
0



3c

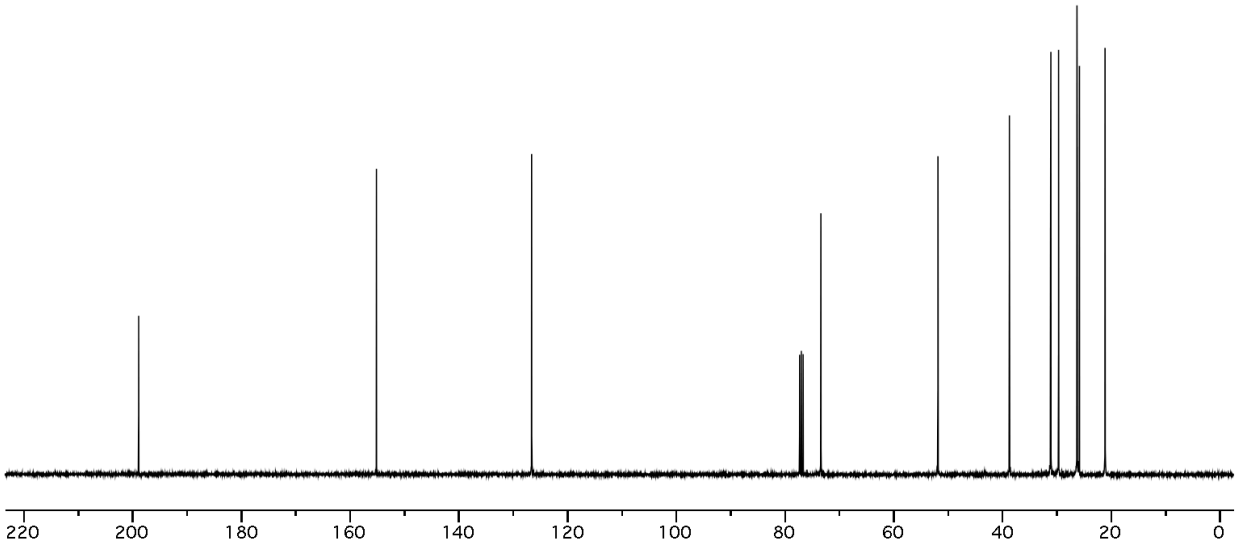


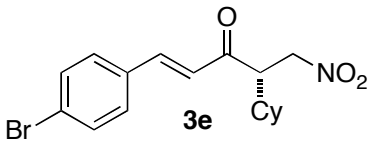



O
Me
NO2
Me
Cy

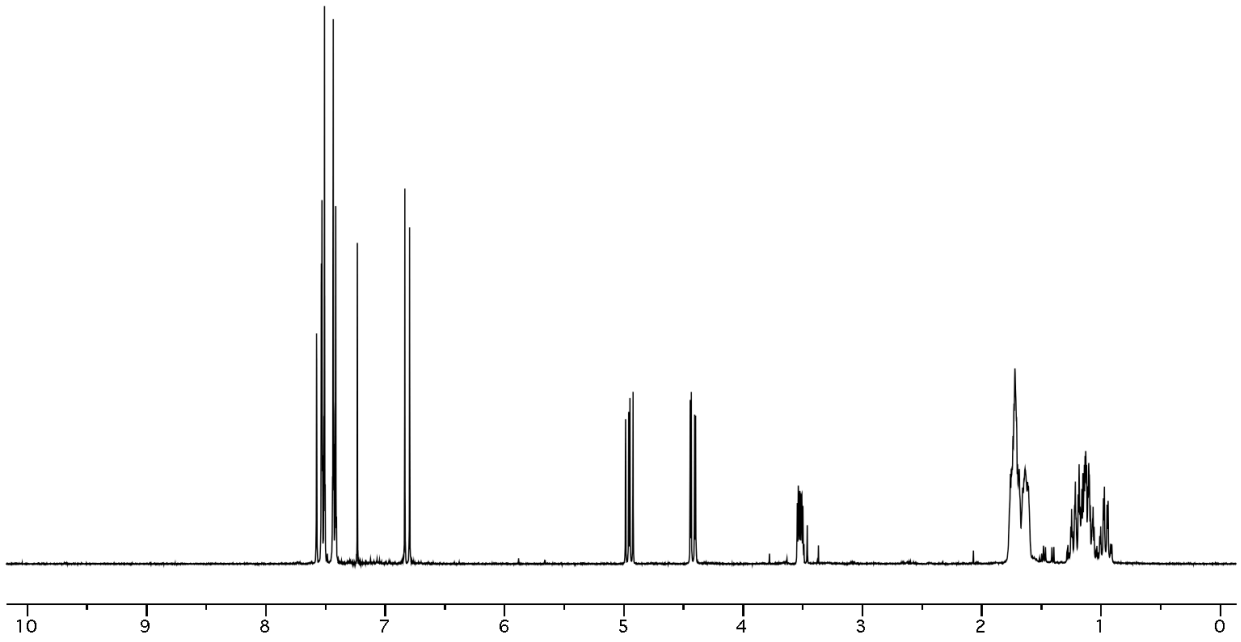
3d

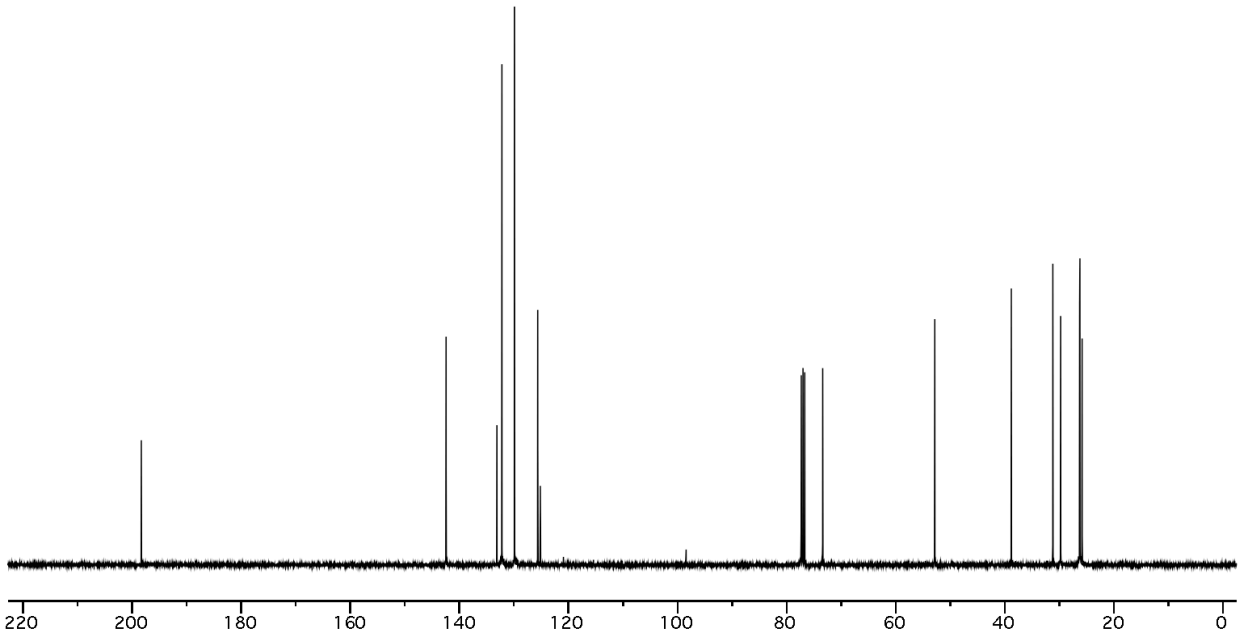
10
9
8
7
6
5
4
3
2
1
0

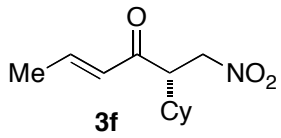

220
200
180
160
140
120
100
80
60
40
20
0


O
NO2
Cy
Br

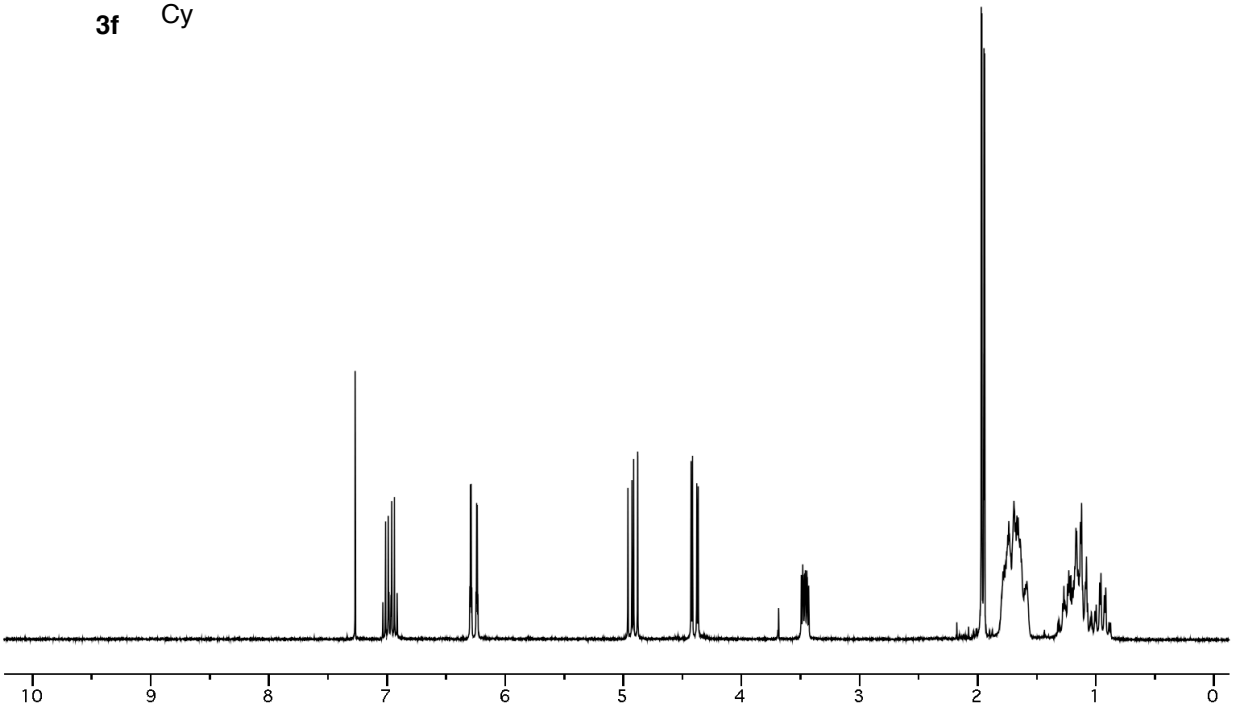
3e

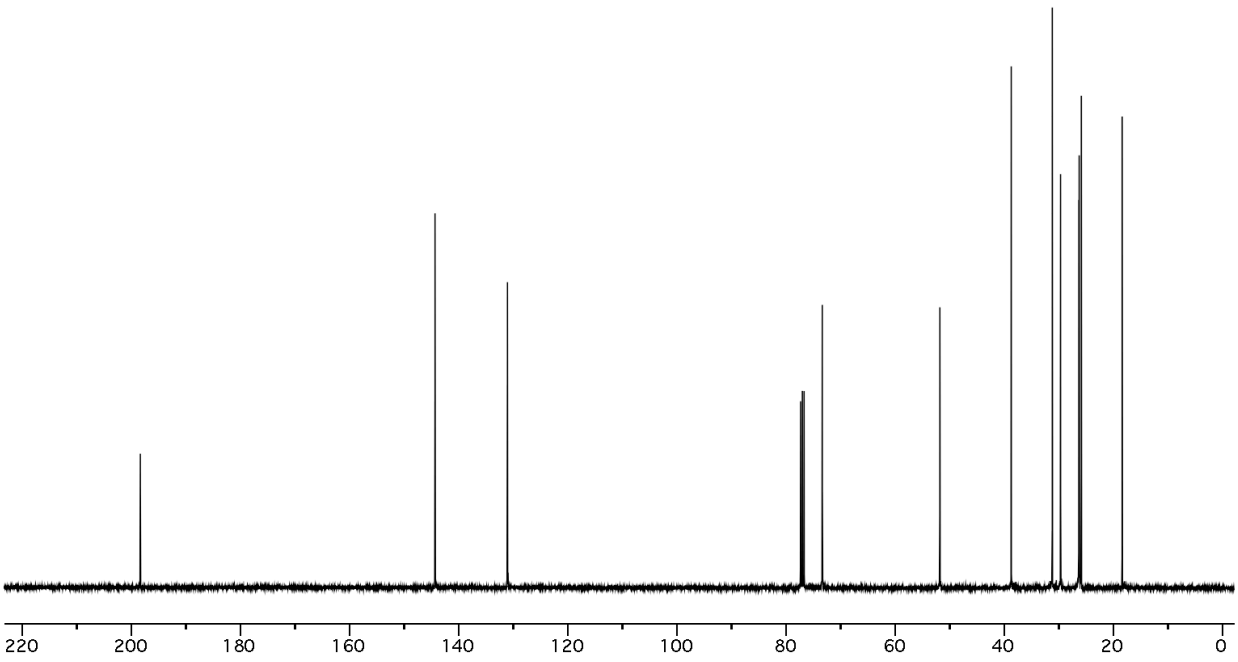

10
9
8
7
6
5
4
3
2
1
0

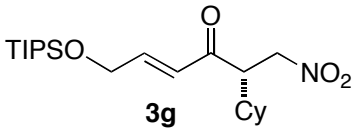

220
200
180
160
140
120
100
80
60
40
20
0


O
Me
NO2
Cy

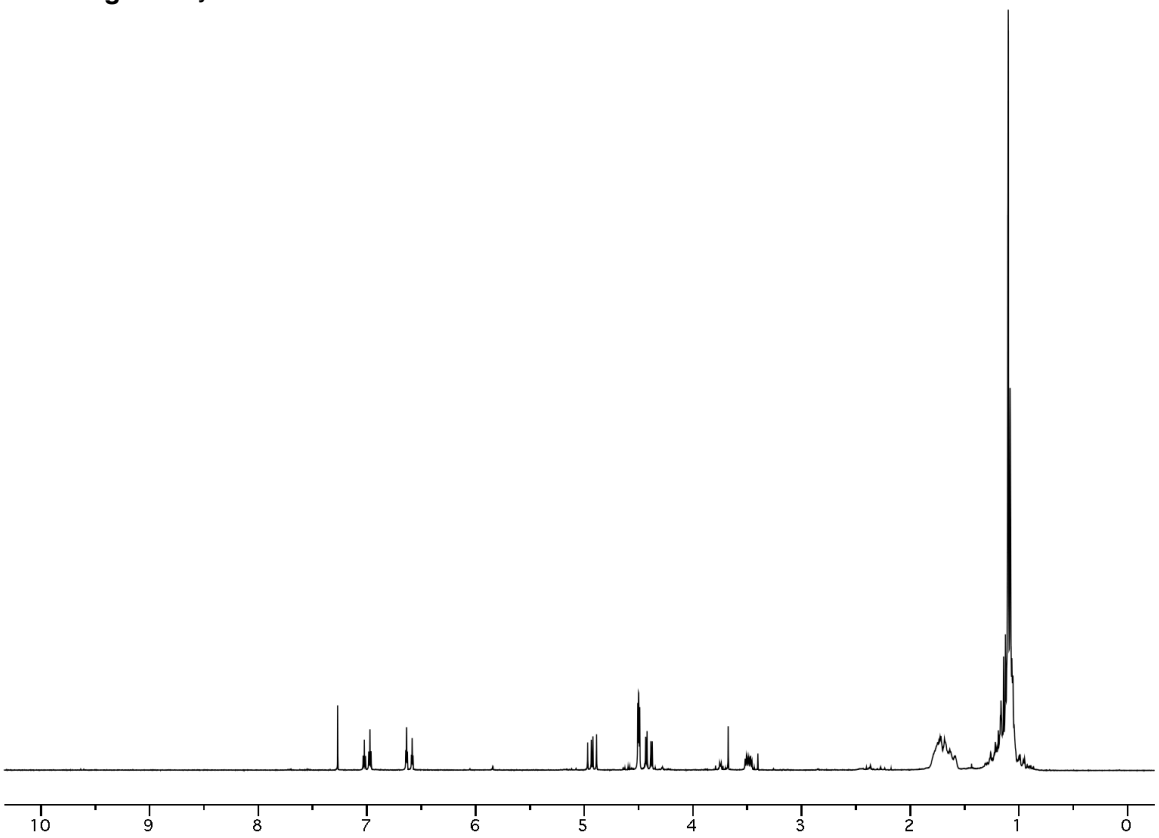
3f

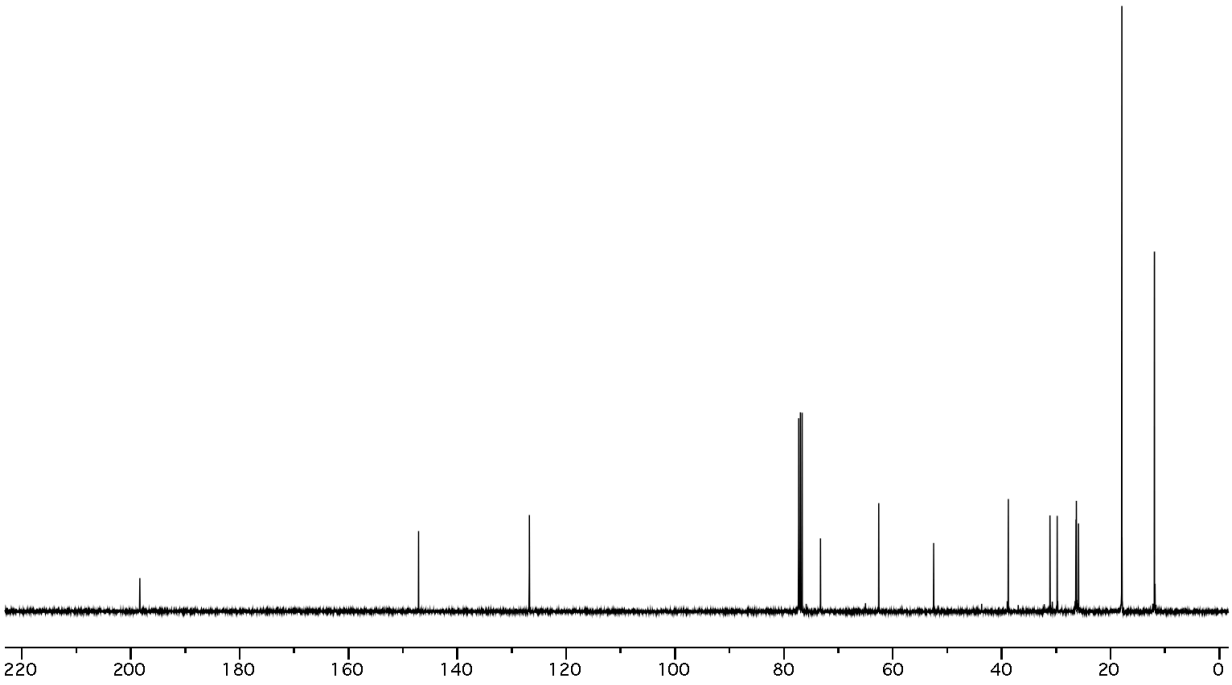

10
9
8
7
6
5
4
3
2
1
0

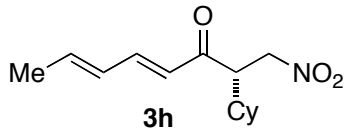

220
200
180
160
140
120
100
80
60
40
20
0


TIPSO
O
NO2
Cy

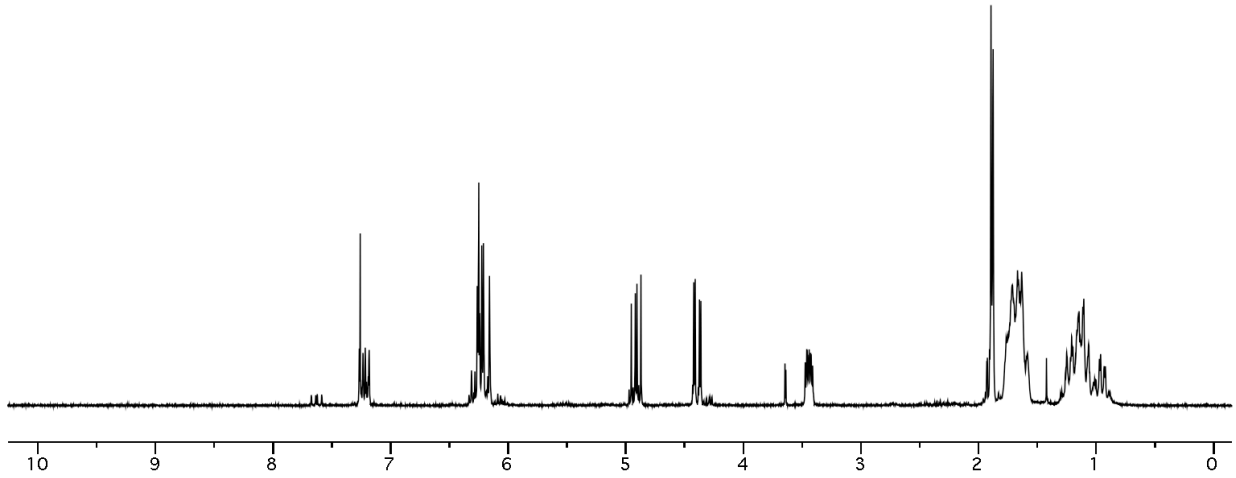
3g

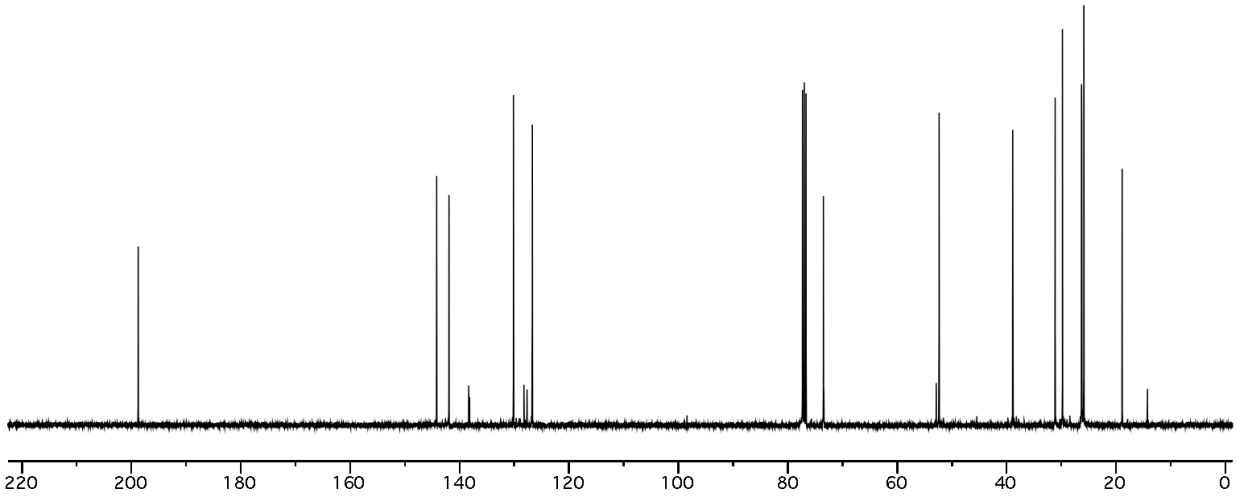

10
9
8
7
6
5
4
3
2
1
0

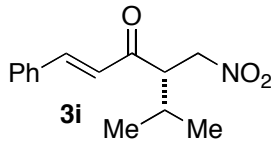

220
200
180
160
140
120
100
80
60
40
20
0


O
Me
NO2
Cy

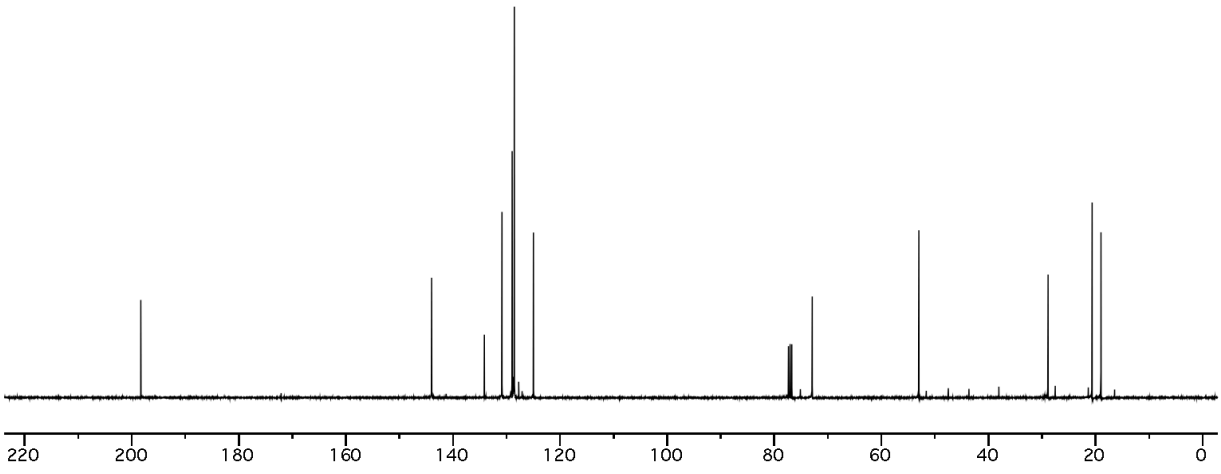
3h

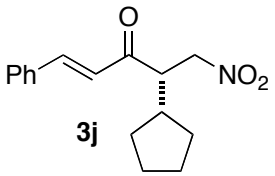

10
9
8
7
6
5
4
3
2
1
0


220
200
180
160
140
120
100
80
60
40
20
0

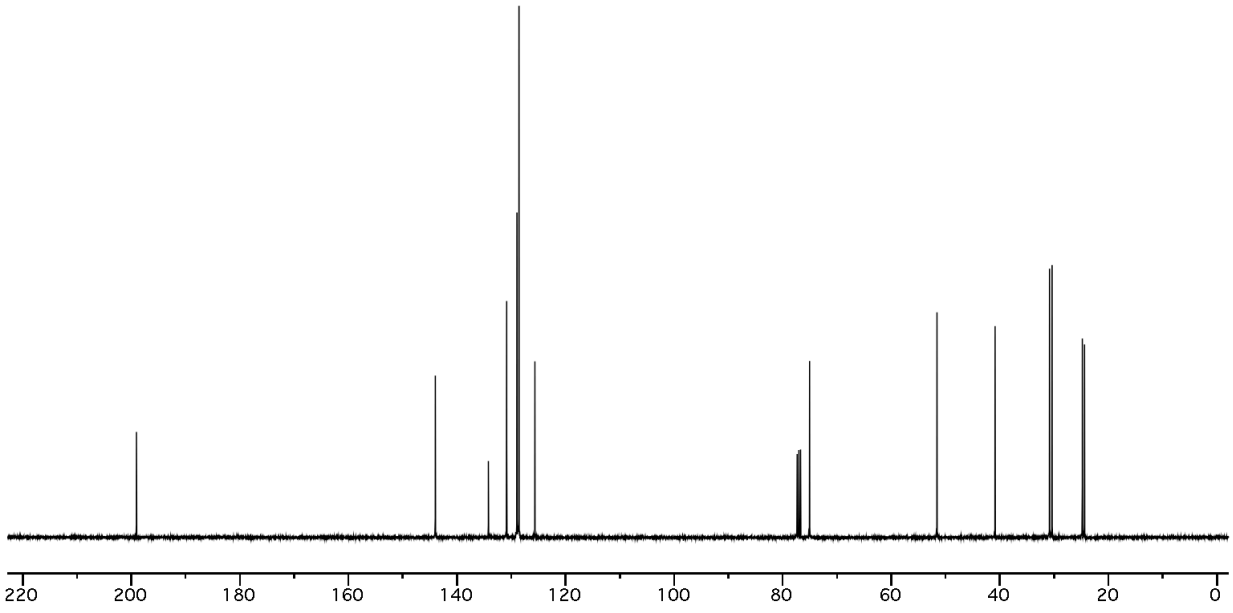

O
Ph
NO2
3i
Me
Me

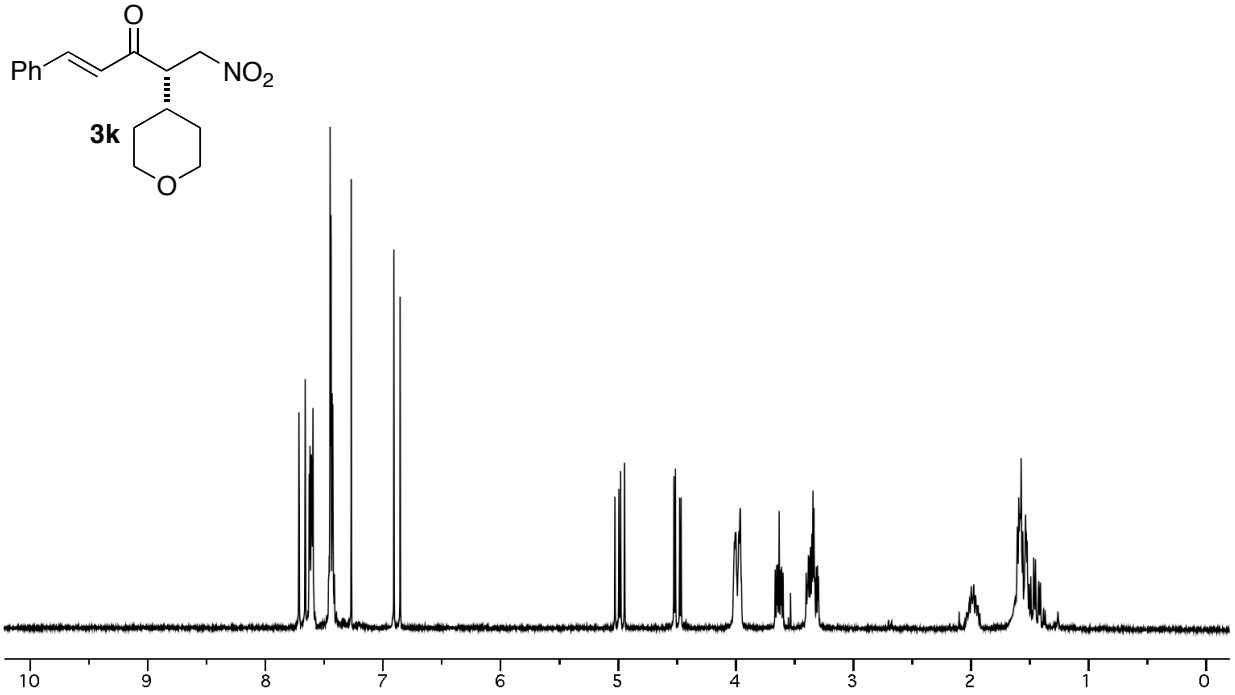
10
9
8
7
6
5
4
3
2
1
0

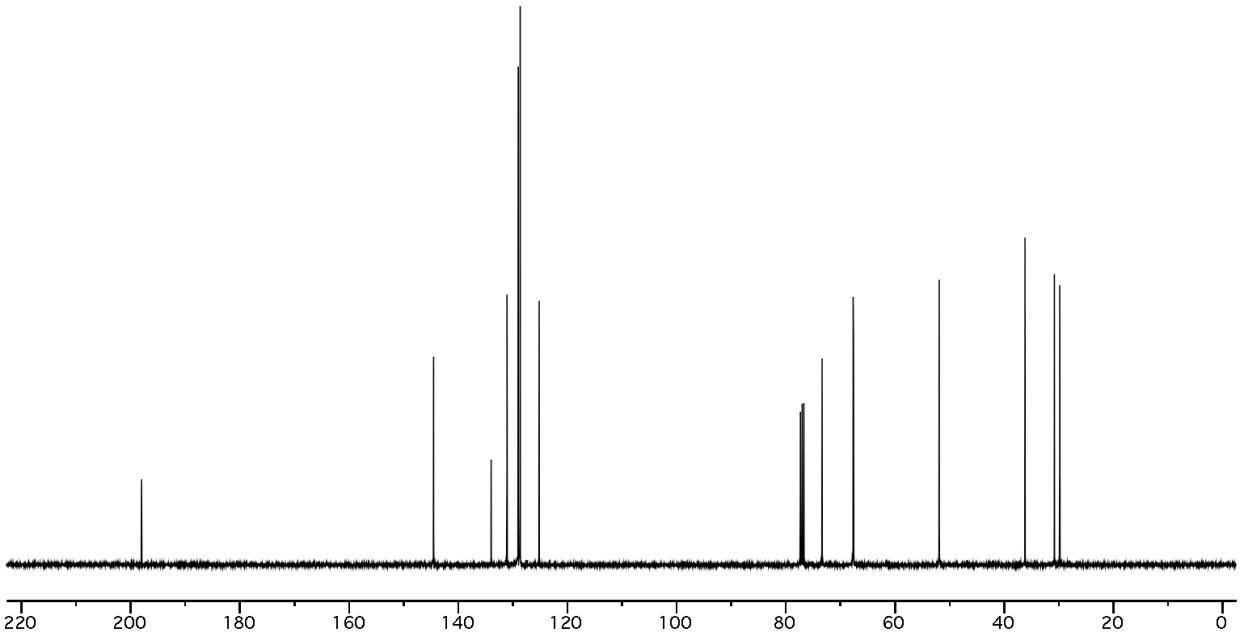

220
200
180
160
140
120
100
80
60
40
20
0

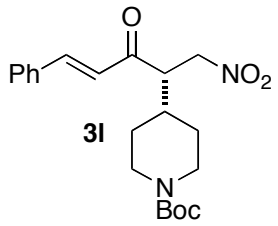


3j



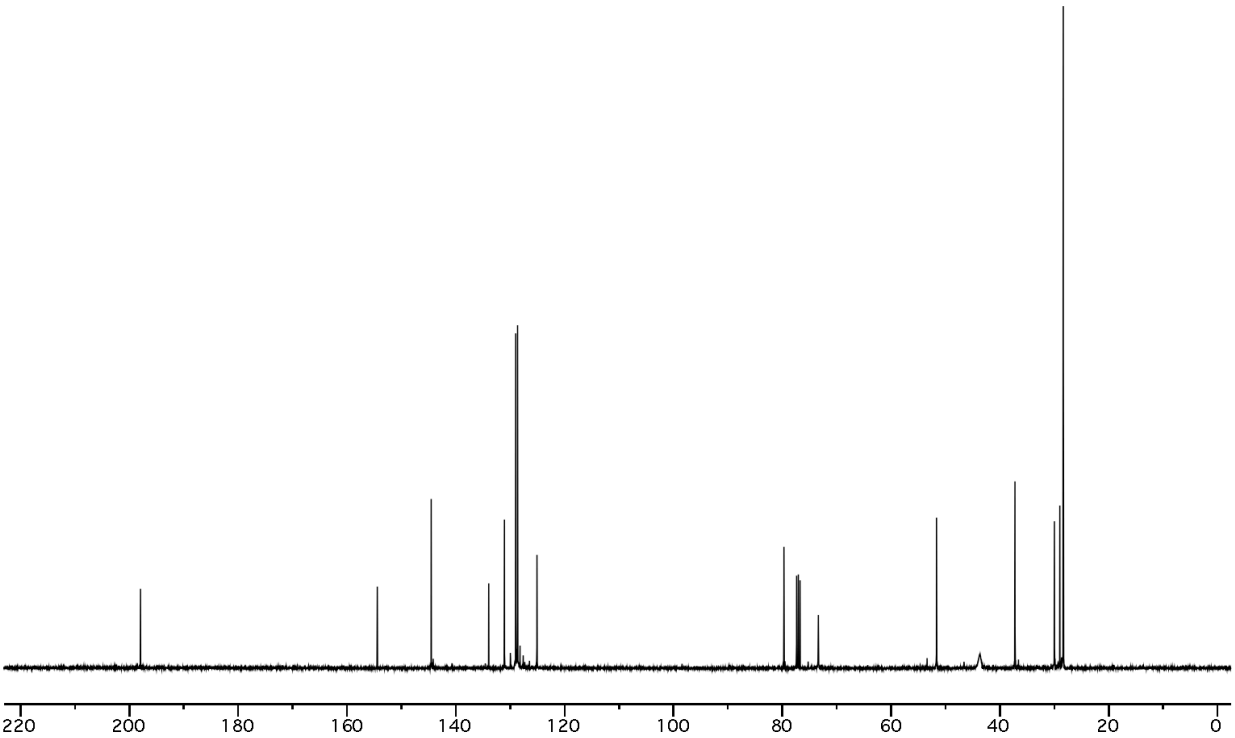

O
Ph
NO2
3k
O
10
9
8
7
6
5
4
3
2
1
0

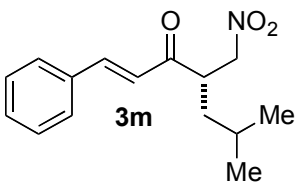

220
200
180
160
140
120
100
80
60
40
20
0


O
Ph
NO2
N
Boc

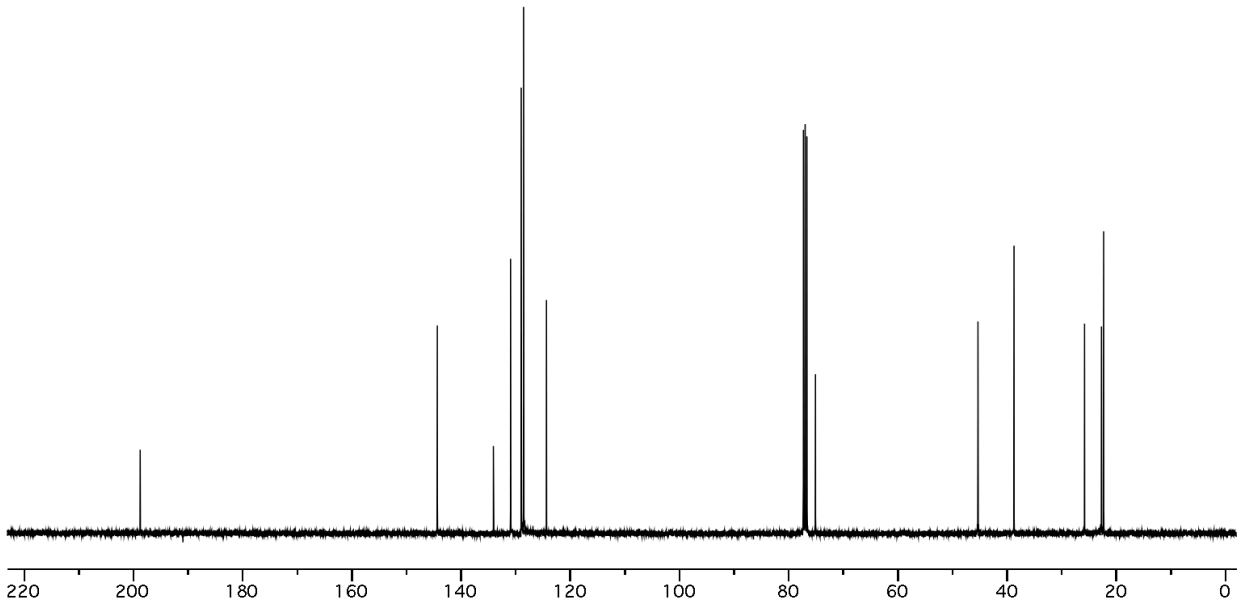
3l

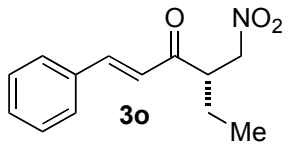
10
9
8
7
6
5
4
3
2
1
0


220
200
180
160
140
120
100
80
60
40
20
0

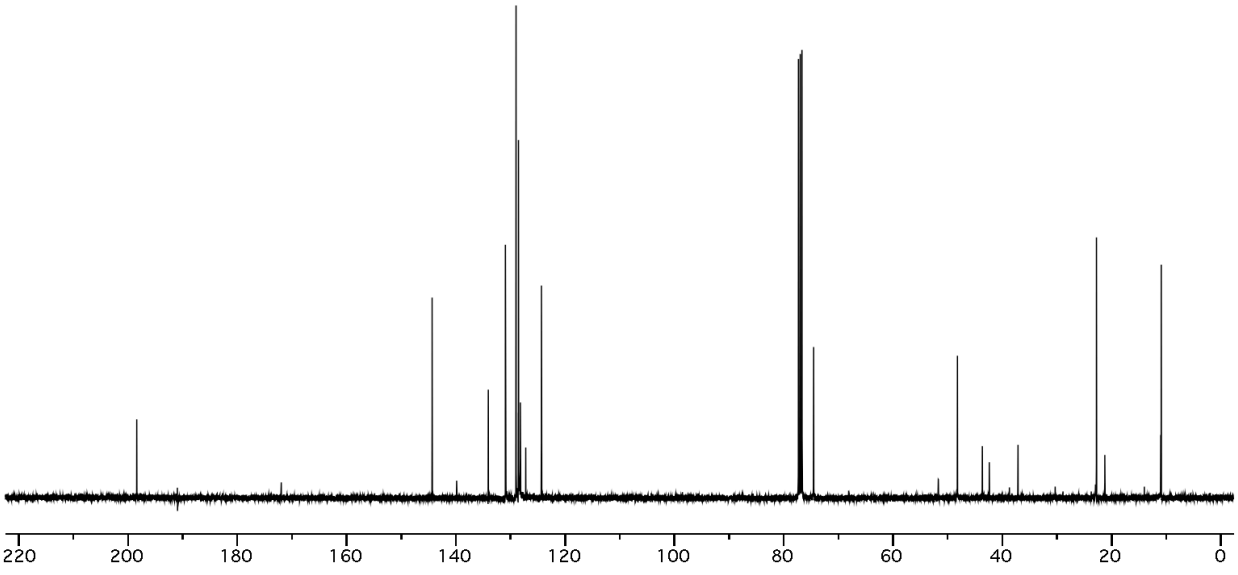

O
NO2
3m
Me
Me

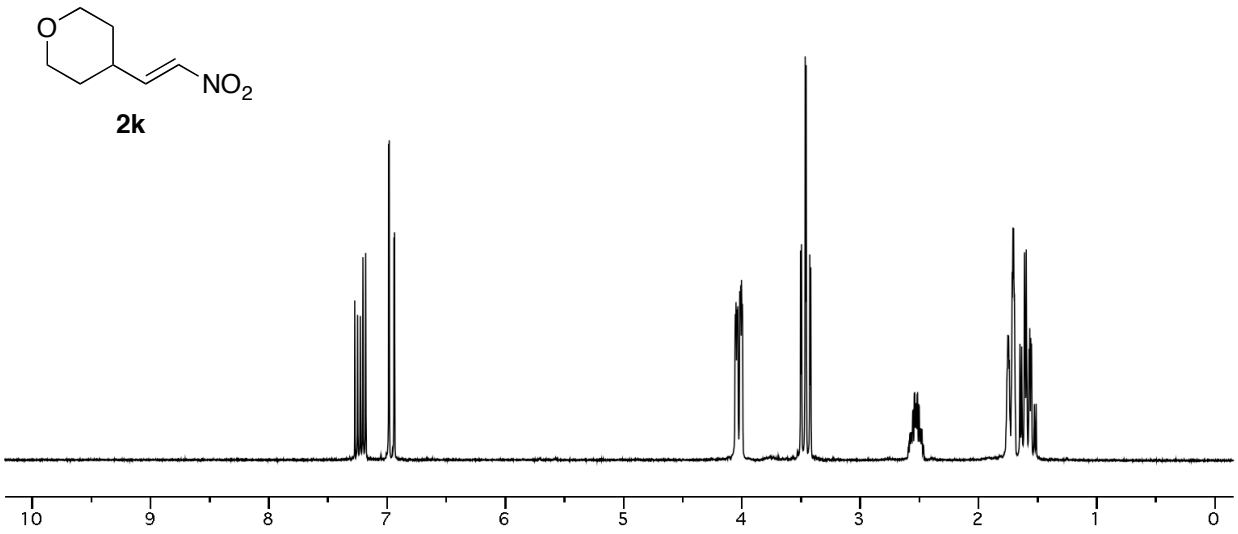
10
9
8
7
6
5
4
3
2
1
0

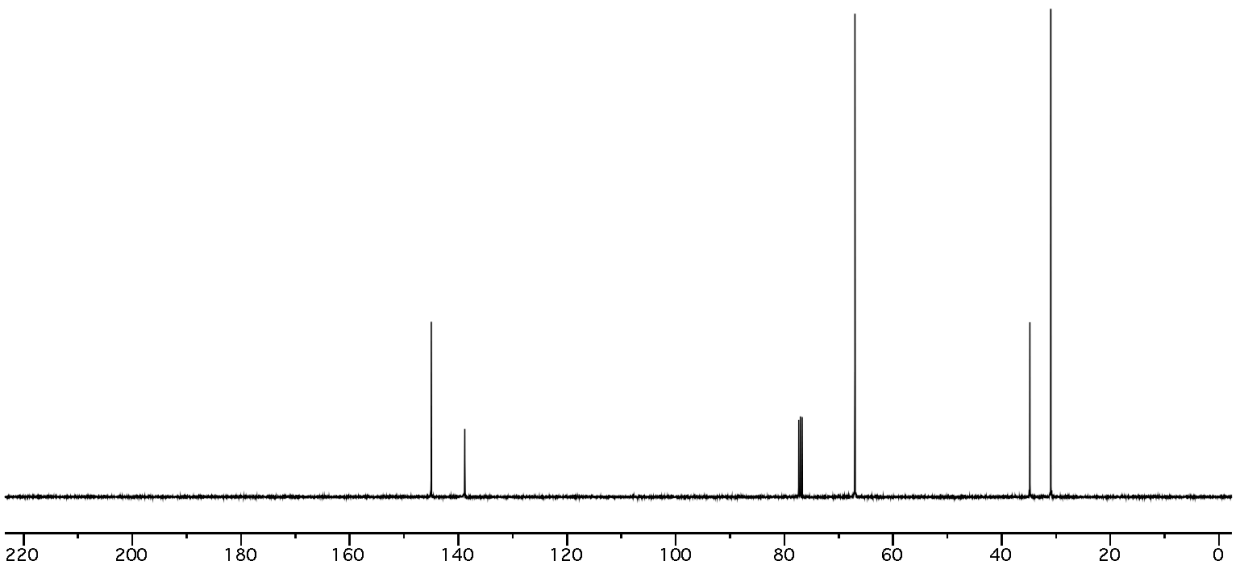

220
200
180
160
140
120
100
80
60
40
20
0

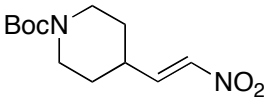

O
NO2
3o
Me

10
9
8
7
6
5
4
3
2
1
0

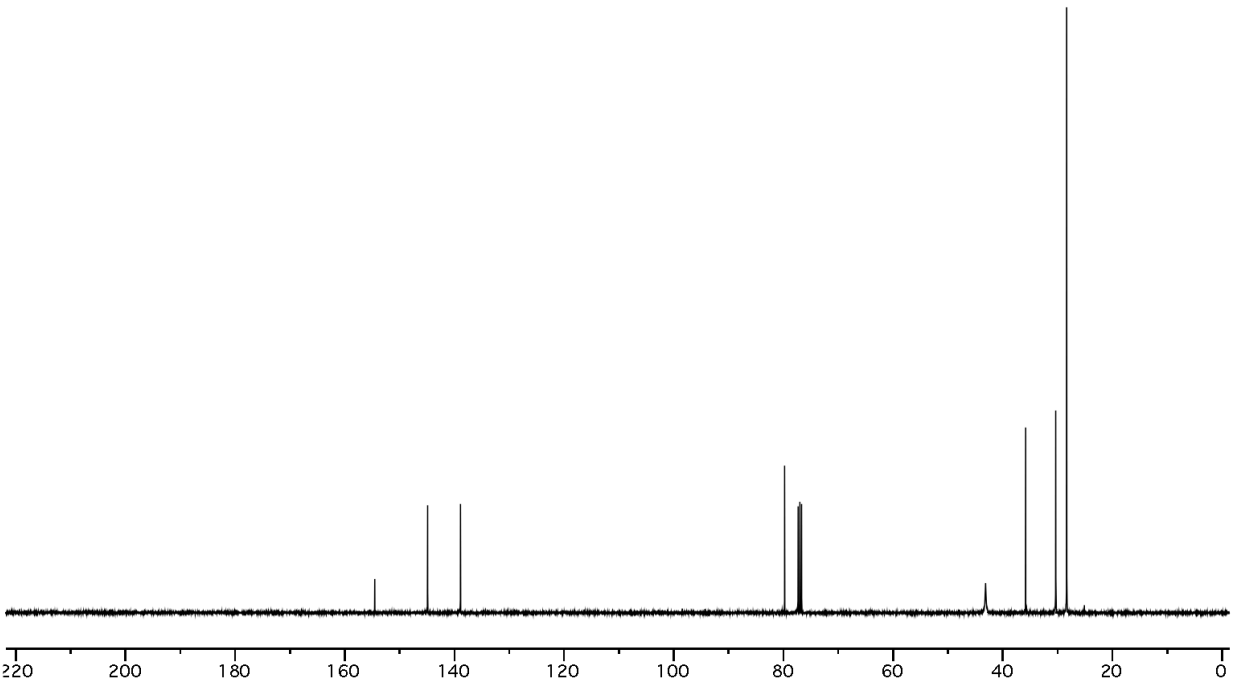

220
200
180
160
140
120
100
80
60
40
20
0

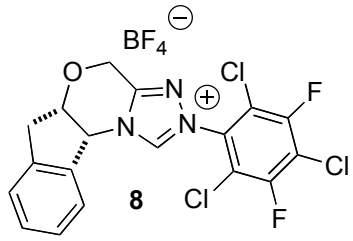

O
NO2
2k
10
9
8
7
6
5
4
3
2
1
0


220
200
180
160
140
120
100
80
60
40
20
0

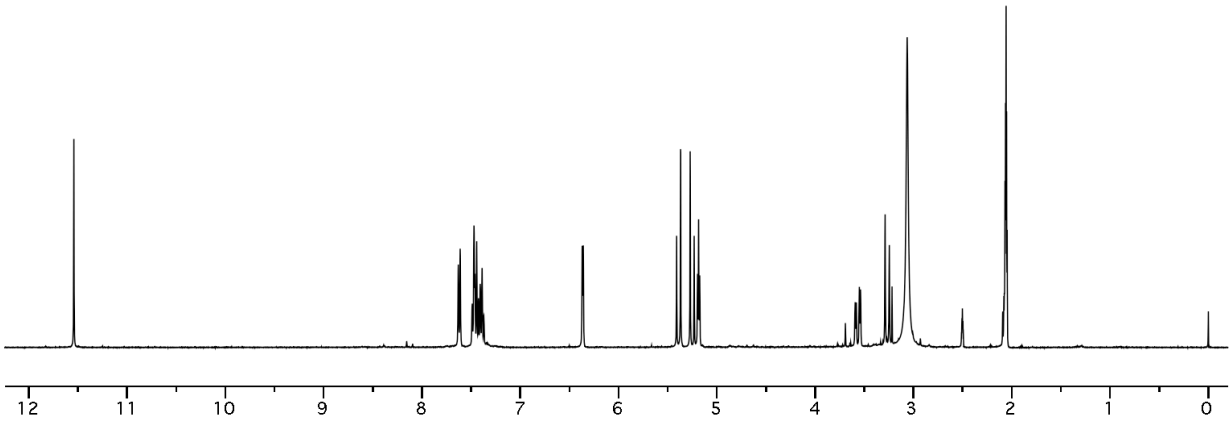


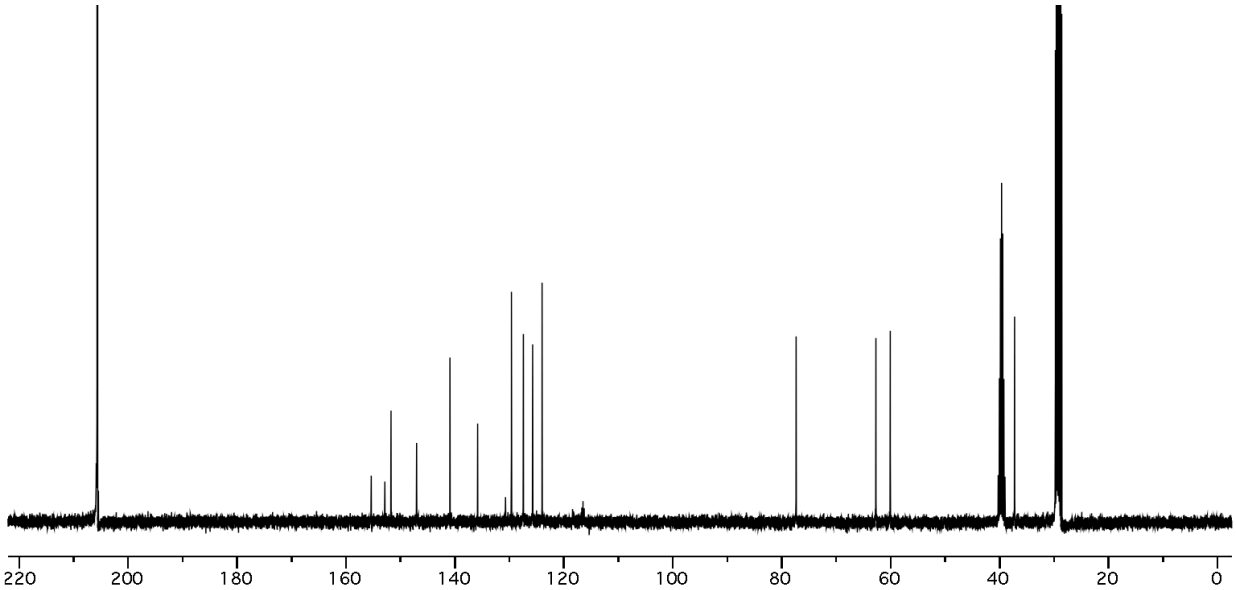
2l




BF4
O
N
N
Cl
F
Cl
Cl
F

8


12
11
10
9
8
7
6
5
4
3
2
1
0


220
200
180
160
140
120
100
80
60
40
20
0

Crystallographic Data

Table S-1. Crystal data and structure refinement for **3e**.

Identification code	rovis101_0m	
Empirical formula	$C_{17}H_{20}BrNO_3$	
Formula weight	366.25	
Temperature	120 K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	$P\,2_12_12_1$	
Unit cell dimensions	a = 5.8072(3) Å	α= 90°
	b = 12.3826(5) Å	β= 90°
	c = 22.3700(9) Å	γ = 90°
Volume	1608.59(12) Å^3	
Z	4	
Density (calculated)	1.512 Mg/m^3	
Absorption coefficient	2.567 mm^{-1}	
F(000)	752	
Crystal size	0.25 x 0.22 x 0.08 mm^3	
Theta range for data collection	1.82 to 33.31°.	
Index ranges	-8<=h<=8, -19<=k<=19, -34<=l<=34	
Reflections collected	43252	
Independent reflections	6182 [R(int) = 0.0569]	
Completeness to theta = 33.31°	99.8 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.8209 and 0.5628	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	6182 / 0 / 200	
Goodness-of-fit on F^2	1.179	
Final R indices [I>2sigma(I)]	R1 = 0.0379, wR2 = 0.0931	
R indices (all data)	R1 = 0.0619, wR2 = 0.1594	
Absolute structure parameter	-0.003(11)	
Largest diff. peak and hole	1.320 and -1.802 e.Å^{-3}	

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for **3e**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
Br(1)	7169(1)	254(1)	-374(1)	24(1)
C(1)	6344(6)	1143(2)	280(1)	15(1)
C(2)	4216(6)	992(3)	560(1)	17(1)
C(3)	3635(6)	1669(2)	1032(1)	16(1)
C(4)	5115(5)	2489(2)	1226(1)	13(1)
C(5)	7239(6)	2625(2)	932(1)	16(1)
C(6)	7857(6)	1954(2)	459(1)	16(1)
C(7)	4390(6)	3138(2)	1742(1)	15(1)
C(8)	5602(6)	3918(2)	2011(1)	15(1)
C(9)	4865(5)	4510(2)	2547(1)	13(1)
C(10)	2629(5)	4230(2)	2875(1)	12(1)
C(11)	3196(5)	3571(2)	3448(1)	13(1)
C(12)	998(6)	3288(3)	3799(1)	18(1)
C(13)	1541(6)	2617(3)	4354(2)	20(1)
C(14)	2896(7)	1601(3)	4198(1)	22(1)
C(15)	5087(7)	1887(3)	3858(2)	24(1)
C(16)	4551(6)	2545(3)	3296(2)	18(1)
C(17)	1415(5)	5262(2)	3056(1)	14(1)
N(1)	942(5)	5999(2)	2543(1)	16(1)
O(1)	6083(4)	5231(2)	2746(1)	19(1)
O(2)	999(5)	5633(2)	2032(1)	24(1)
O(3)	471(5)	6943(2)	2660(1)	24(1)

Table 3. Bond lengths [Å] and angles [°] for **3e**.

Br(1)-C(1)	1.893(3)	C(2)-C(3)-C(4)	121.6(3)
C(1)-C(6)	1.393(5)	C(3)-C(4)-C(5)	118.7(3)
C(1)-C(2)	1.398(5)	C(3)-C(4)-C(7)	117.7(3)
C(2)-C(3)	1.391(4)	C(5)-C(4)-C(7)	123.5(3)
C(3)-C(4)	1.399(4)	C(6)-C(5)-C(4)	120.6(3)
C(4)-C(5)	1.408(5)	C(5)-C(6)-C(1)	119.1(3)
C(4)-C(7)	1.468(4)	C(8)-C(7)-C(4)	126.7(3)
C(5)-C(6)	1.392(4)	C(7)-C(8)-C(9)	125.0(3)
C(7)-C(8)	1.338(4)	O(1)-C(9)-C(8)	119.5(3)
C(8)-C(9)	1.470(4)	O(1)-C(9)-C(10)	118.8(3)
C(9)-O(1)	1.223(4)	C(8)-C(9)-C(10)	121.7(3)
C(9)-C(10)	1.531(4)	C(17)-C(10)-C(9)	109.4(2)
C(10)-C(17)	1.514(4)	C(17)-C(10)-C(11)	108.8(2)
C(10)-C(11)	1.554(4)	C(9)-C(10)-C(11)	109.5(2)
C(11)-C(16)	1.532(4)	C(16)-C(11)-C(12)	110.5(2)
C(11)-C(12)	1.539(4)	C(16)-C(11)-C(10)	111.2(2)
C(12)-C(13)	1.528(5)	C(12)-C(11)-C(10)	111.4(2)
C(13)-C(14)	1.524(5)	C(13)-C(12)-C(11)	111.6(3)
C(14)-C(15)	1.524(5)	C(14)-C(13)-C(12)	111.6(3)
C(15)-C(16)	1.530(5)	C(15)-C(14)-C(13)	110.7(3)
C(17)-N(1)	1.492(4)	C(14)-C(15)-C(16)	111.3(3)
N(1)-O(3)	1.228(3)	C(15)-C(16)-C(11)	111.3(3)
N(1)-O(2)	1.230(4)	N(1)-C(17)-C(10)	113.4(2)
C(6)-C(1)-C(2)	121.7(3)	O(3)-N(1)-O(2)	123.7(3)
C(6)-C(1)-Br(1)	118.8(2)	O(3)-N(1)-C(17)	117.3(3)
C(2)-C(1)-Br(1)	119.5(2)	O(2)-N(1)-C(17)	119.0(3)
C(3)-C(2)-C(1)	118.3(3)		

Symmetry transformations used to generate equivalent atoms:

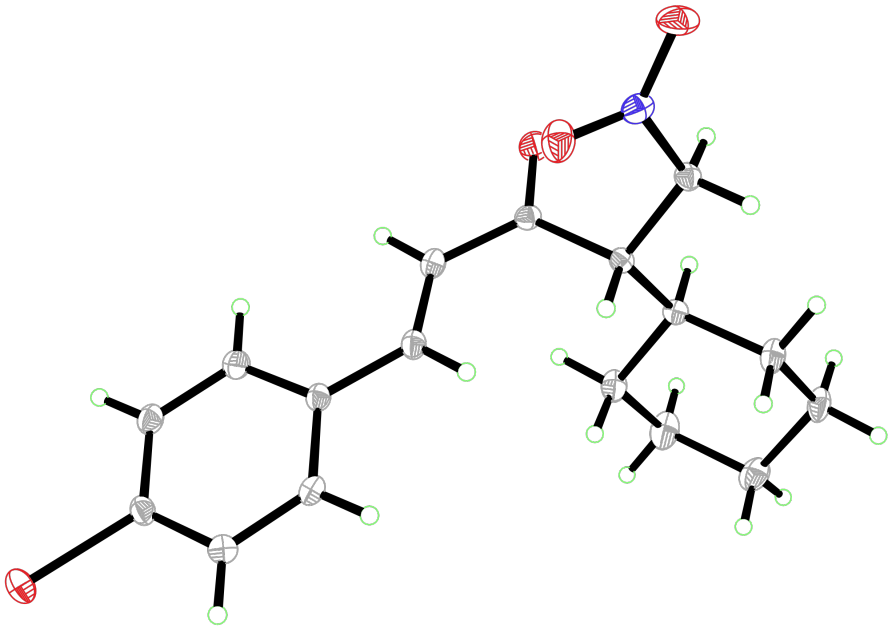
Table 4. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for **3e**. The anisotropic displacement factor exponent takes the form: $-2\pi^2[\ h^2 a^{*2} U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
Br(1)	30(1)	20(1)	22(1)	-7(1)	8(1)	2(1)
C(1)	19(1)	14(1)	13(1)	0(1)	2(1)	4(1)
C(2)	19(2)	16(1)	17(1)	-1(1)	2(1)	-2(1)
C(3)	16(1)	17(1)	14(1)	2(1)	4(1)	-2(1)
C(4)	12(1)	14(1)	12(1)	1(1)	1(1)	2(1)
C(5)	15(1)	17(1)	16(1)	0(1)	2(1)	0(1)
C(6)	15(1)	17(1)	16(1)	2(1)	4(1)	1(1)
C(7)	14(1)	16(1)	13(1)	1(1)	2(1)	2(1)
C(8)	13(1)	18(1)	14(1)	1(1)	2(1)	0(1)
C(9)	10(1)	13(1)	16(1)	1(1)	0(1)	-1(1)
C(10)	10(1)	12(1)	13(1)	-1(1)	0(1)	1(1)
C(11)	13(1)	13(1)	12(1)	1(1)	-1(1)	1(1)
C(12)	15(2)	23(1)	16(1)	4(1)	3(1)	4(1)
C(13)	22(2)	25(2)	13(1)	6(1)	6(1)	3(1)
C(14)	23(2)	22(1)	20(1)	9(1)	1(1)	2(1)
C(15)	21(2)	28(2)	23(2)	11(1)	4(1)	11(1)
C(16)	18(2)	19(1)	16(1)	4(1)	3(1)	7(1)
C(17)	14(1)	14(1)	13(1)	0(1)	0(1)	2(1)
N(1)	11(1)	16(1)	22(1)	4(1)	0(1)	1(1)
O(1)	16(1)	21(1)	22(1)	-4(1)	1(1)	-6(1)
O(2)	25(1)	29(1)	17(1)	5(1)	2(1)	6(1)
O(3)	21(1)	14(1)	37(1)	4(1)	-1(1)	3(1)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for **3e**.

	x	y	z	U(eq)
H(2)	3214	452	433	21
H(3)	2229	1574	1224	19
H(5)	8238	3168	1055	19
H(6)	9261	2046	266	19
H(7)	2939	2991	1898	18
H(8)	7019	4099	1846	18
H(10)	1628	3805	2613	14
H(11)	4167	4021	3705	15
H(12A)	228	3949	3918	21
H(12B)	-42	2886	3542	21
H(13A)	2427	3050	4633	24
H(13B)	114	2413	4549	24
H(14A)	3293	1218	4562	26
H(14B)	1949	1129	3955	26
H(15A)	5883	1229	3746	29
H(15B)	6099	2301	4116	29
H(16A)	3661	2106	3021	21
H(16B)	5980	2741	3100	21
H(17A)	-32	5079	3247	17
H(17B)	2356	5641	3346	17

Figure S-1. X-ray crystal structure of compound **3e**.



References:

1. For the synthesis of triazolium salts see: DiRocco, D. A.; Oberg, K. M.; Dalton, D. M.; Rovis, T. *J. Am. Chem. Soc.* **2009**, *131*, 10872-10874.