CHAPTER 2

A New Method for the Cleavage of Nitrobenzyl Amides and Ethers†

2.1. Introduction

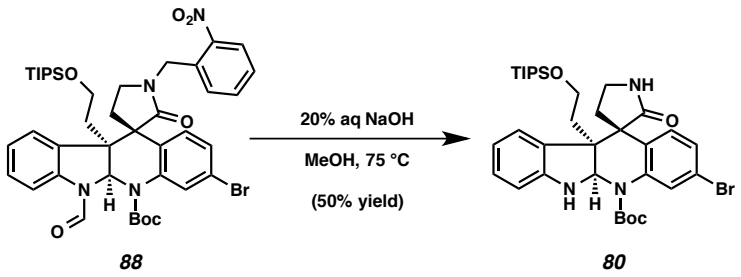
The selection of protection groups is critical to the synthesis of multifunctional complex molecules. Over the past decades, a wide variety of protecting groups have been developed to mask specific functional groups selectively.[1,2] However, despite considerable effort, relatively few protecting groups have been developed for the amide *N–H* (e.g., PMB, TBS, Benzyl, SEM, allyl, etc.).[3] Consequently, limitations associated with cleavage of amide protecting groups often arise.[4] Herein, we report *o*- and *p*-nitrobenzyl groups as easily introducible and removable protecting groups for both R_2N–*H* (including amides) and *RO–H* groups.

† This work was performed in collaboration with Gabriel Fernando de Melo. Additionally, this work has been published and adapted with permission from Han, S.-J.; Fernando de Melo, G.; Stoltz, B. M. *Tetrahedron Lett*. **2014**, *55*, 6467–6469.

2.2. Results and Discussion

In the course of our efforts toward the synthesis of the polycyclic, complex alkaloid perophoramidine, we serendipitously found that the *o*-nitrobenzyl group was easily removed by using 20% aqueous NaOH in methanol at 75 °C (Scheme 1).[5] *o*-Nitrobenzyl groups have been used as photocleavable protecting groups for amides and heterocycles such as indoles, benzimidazole, and 6-chlorouracil as well as the more common hydroxyl group.[6,7] In addition, a method for removing *p*-nitrobenzyl groups on hydroxyl groups in two steps by reduction to a *p*-aminobenzyl group followed by electrochemical oxidation was disclosed by the Kusumoto group.[8] To the best of our knowledge, ours was the first example of using simple aqueous NaOH to remove a nitrobenzyl group from a lactam.

Scheme 2.2.1. *o-Nitrobenzyl group cleavage on perophoramidine intermediate (**88**)*

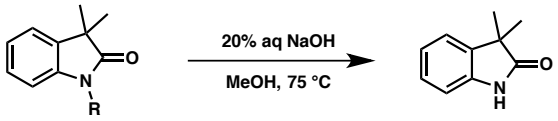


88 ***80***

To explore the general reactivity of nitrobenzyl group cleavage reactions by using simple aqueous NaOH, we initially chose 3,3-dimethyl oxindole as a test substrate (Table 2.2.1). We found that both *ortho*- and *para*-nitrobenzyl groups on oxindoles **137a** and **137c** were smoothly cleaved under our standard conditions (entries 1 and 3). However, a *meta*-nitrobenzyl group as well as a simple benzyl group on the oxindole

nitrogen (**137b** and **137d)** were both unreactive (entries 2 and 4). Notably, the *o*-nitrobenzyl group was also successfully removed even in the absence of light (entry 5). Interestingly, only trace amounts of product were observed when degassed water and methanol were used (entry 6). Furthermore, we discovered that cleavage of the *o*-nitrobenzyl group was successful when the degassed water and methanol were purged with oxygen gas (entry 7). We therefore concluded that oxygen was necessary for the reaction, but light was not.

Table 2.2.1. *Cleavage of nitrobenzyl groups on 3,3-dimethyloxindole*



137 ***138***

Entry	Substrate	R	Time (h)	Yield (%)
1	***137a***	-*o*-nitrobenzyl	5	69
2	***137b***	-*m*-nitrobenzyl	24	0
3	***137c***	-*p*-nitrobenzyl	1.5	63
4	***137d***	-benzyl	24	0
5[a]	***137a***	-*o*-nitrobenzyl	6.5	72
6[b]	***137a***	-*o*-nitrobenzyl	12	trace
7[b,c]	***137a***	-*o*-nitrobenzyl	6.5	66

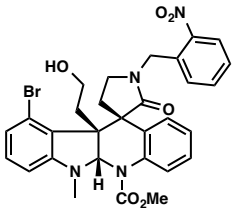
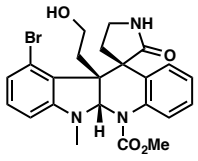
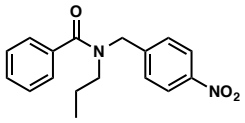
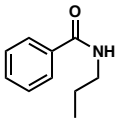
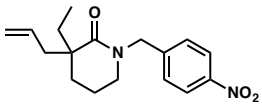
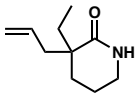
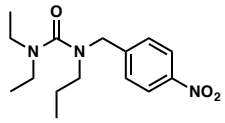
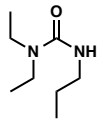
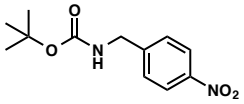
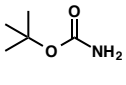
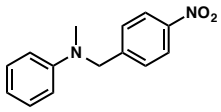
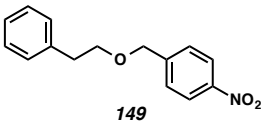
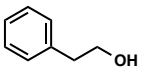
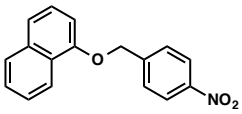
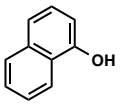
[a] The reaction was performed in the dark.
[b] Degassed water and methanol were used.
[c] Purged with O_2.

With the standard conditions in hand, we explored the scope of the *o*- and *p*-nitrobenzyl group cleavage reactions with various substrates (Table 2.2.2). *o*- and *p*-Nitrobenzyl protected substrates were easily prepared by a variety of methods, including reductive amination, simple alkylation, EDCI coupling, and acylation. The *o*-nitrobenzyl group on a highly functionalized communesin F intermediate **79** was smoothly cleaved

under our standard conditions in good yield (entry 1).[5] *p*-Nitrobenzyl groups on amide **139** and lactam **141** were also cleaved in moderate yields (entries 2 and 3). The *p*-nitrobenzyl group on urea **143** was also successfully cleaved and methyl 4-nitrobenzoate was isolated as a by-product (entry 4). An attempt to remove the *p*-nitrobenzyl group on secondary carbamate **145** proved unsuccessful (entry 5). Additionally, removal of the *p*-nitrobenzyl group on amine **147** was facile, furnishing aniline **148** in 65% yield (entry 6). Interestingly, 4-nitrobenzaldehyde was isolated as a by-product in this reaction, presumably resulting from the oxidation reaction at the benzylic position by oxygen dissolved in the solution. Furthermore, we successfully removed the *p*-nitrobenzyl groups from ethers **149** and **151** in moderate yields (entries 7 and 8). This work offers a one-step alternative to previous work by the Kusumoto group.[8] In the cases of deprotection reactions from urea **143** and ether **149**, the corresponding hemiaminal ether and acetal intermediates were observed (see ref. 9). It is important to note that these deprotection conditions are compatible with free hydroxyl groups, aminals, aryl bromides, methyl carbamates, silyl ethers, and Boc groups present on the substrates.

A representative procedure is as follows: To a 20 mL scintillation vial with a magnetic stir bar were added *p*-nitrobenzyl protected oxindole **137c** (30 mg, 0.10 mmol, 1.0 equiv), MeOH (1.0 mL), and 20% aq NaOH (1.0 mL). The reaction mixture was stirred for 1.5 h at 75 °C. The reaction mixture was then cooled to 23 °C, and extracted with EtOAc (3 x 2 mL). The organic layer was washed with brine, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by column chromatography to afford 3,3-dimethyloxindole **138** (10.3 mg, 63% yield).

Table 2.2.2. *Scope of the o- and p-nitrobenzyl deprotecion reactions*

Entry	Substrate	Product	Time (h)	Yield (%)
1	 ***79***	 ***53***	4	70
2	 ***139***	 ***140***	12	42
3	 ***141***	 ***142***	1	55
4	 ***143***	 ***144***	10.5	94[a,b]
5	 ***145***	 ***146***	6	0
6	 ***147***	 ***148***	2	65[c]
7	 ***149***	 ***150***	32	59[b] (74)[d]
8	 ***151***	 ***152***	48	48

[a] Methyl 4-nitrobenzoate was isolated as a by-product.
[b] See Ref. 9 for detail.
[c] 4-Nitrobenzaldehyde was isolated as a by-product.
[d] Yield based on recovered starting material.

2.3. Conclusion

In summary, a mild and efficient deprotection protocol was discovered for the cleavage of *o*- and *p*-nitrobenzyl ethers, amides, ureas, and anilines. Since relatively few options for protection of the amide *N–H* functionality exist, easily introducible and removable *o*- and *p*-nitrobenzyl groups could prove useful in the synthesis of alkaloids and biologically active molecules, which possess amide functionalities. In our laboratory, this has already been proven to be the case in our formal syntheses of communesin F and perophoramidine. In addition, *p*-nitrobenzyl-protected anilines, ureas, and alcohols were also competent substrates for this transformation, which may further its utility as a mild deprotection method in cases where other conditions fail.

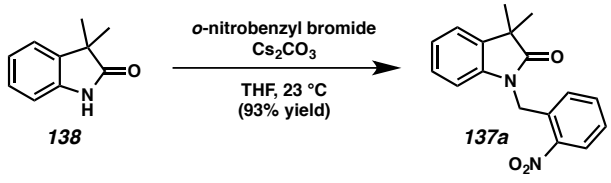
2.4. Experimental Methods and Analytical Data

2.4.1. Materials and Methods

Unless otherwise stated, reactions were performed in flame-dried glassware under an argon or nitrogen atmosphere using dry, deoxygenated solvents. Reaction progress was monitored by thin-layer chromatography (TLC). THF, Et_2O, CH_2Cl_2, toluene, benzene, CH_3CN, and dioxane were dried by passage through an activated alumina column under argon. Triethylamine was distilled over CaH_2 prior to use. Purified water was obtained using a Barnstead NANOpure Infinity UV/UF system. Brine solutions are saturated aqueous solutions of sodium chloride. Commercially available reagents were purchased from Sigma-Aldrich, Acros Organics, Strem, or Alfa Aesar and used as received unless otherwise stated. Reaction temperatures were controlled by an IKAmag temperature modulator unless otherwise indicated. Microwave-assisted reactions were

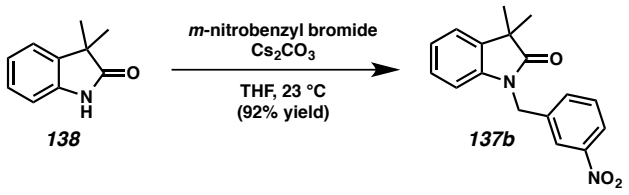
performed in a Biotage Initiator 2.5 microwave reactor. Glove box manipulations were performed under a N_2 atmosphere. TLC was performed using E. Merck silica gel 60 F254 precoated glass plates (0.25 mm) and visualized by UV fluorescence quenching, *p*-anisaldehyde, or PMA (phosphomolybdic acid) staining. Silicycle Silia*Flash* P60 Academic Silica gel (particle size 0.040-0.064 mm) was used for flash column chromatography. ^{1}H NMR spectra were recorded on a Varian Inova 500 MHz spectrometer and were reported relative to residual $CHCl_3$ (δ 7.26 ppm), or $(CD_3)_2CO$ (δ 2.05 ppm). ^{13}C NMR spectra were recorded on a Varian Inova 500 MHz spectrometer (125MHz) and are reported relative to $CHCl_3$ (δ 77.16 ppm), or $(CD_3)_2CO$ (δ 29.84 ppm). Data for ^{1}H NMR are reported as follows: s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, sept = septuplet, m = multiplet, br s = broad singlet, br d= broad doublet, app = apparent. Data for ^{13}C are reported in terms of chemical shifts (δ ppm). IR spectra were obtained using a Perkin Elmer Paragon 1000 spectrometer using thin films deposited on NaCl plates and reported in frequency of absorption (cm^{-1}). High resolution mass spectra (HRMS) were obtained from Agilent 6200 Series TOF with an Agilent G1978A Multimode source in electrospray ionization (ESI+), atmospheric pressure chemical ionization (APCI+), or mixed ionization mode (MM: ESI-APCI+).

2.4.2. Experimental Procedures



***N*–2-nitrobenzyloxindole 137a.** To a mixture of 3,3-dimethyloxindole **138**[1] (150 mg, 0.93 mmol, 1.00 equiv) and Cs_2CO_3 (606 mg, 1.86 mmol, 2.00 equiv) in THF (4.70 mL) was added *o*-nitrobenzyl bromide (302 mg, 1.40 mmol, 1.50 equiv). The reaction mixture was stirred overnight. Then, the reaction mixture was extracted with EtOAc (3 x 6 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:4 → 1:2 EtOAc:hexanes) on silica gel to afford *N*–2-nitrobenzyl-3,3-dimethyloxindole **137a** (258 mg, 93% yield).

R_f = 0.35 (1:2 EtOAc:hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.51 (td, *J* = 7.6, 1.4 Hz, 1H), 7.44 (dddt, *J* = 8.1, 7.4, 1.4, 0.7 Hz, 1H), 7.28 (ddd, *J* = 7.3, 1.3, 0.6 Hz, 1H), 7.17 (td, *J* = 7.7, 1.3 Hz, 1H), 7.12 (dq, J = 7.8, 1.0 Hz, 1H), 7.09 (td, *J* = 7.5, 1.1 Hz, 1H), 6.61 (dt, *J* = 7.8, 0.8 Hz, 1H), 5.33 (d, *J* = 0.8 Hz, 2H), 1.48 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 181.8, 148.2, 141.4, 135.8, 134.2, 132.0, 128.5, 128.0, 127.6, 125.7, 123.2, 122.8, 108.8, 77.2, 44.5, 41.2, 24.8; IR (Neat Film NaCl) 2968, 1721, 1615, 1524, 1489, 1385, 1338, 1177, 1008, 858, 761 cm^{-1}; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{17}H_{17}N_2O_3$ $[M+H]^+$: 297.1234; found: 297.1236.

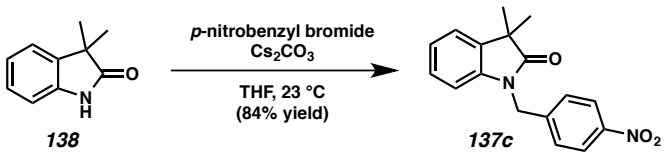


***N*–3-nitrobenzyloxindole 137b.** To a mixture of 3,3-dimethyloxindole **138**[1] (100 mg, 0.62 mmol, 1.00 equiv) and Cs_2CO_3 (403 mg, 1.24 mmol, 2.00 equiv) in THF (3.10 mL)

[1] Vu, A. T.; Cohn, S. T.; Zhang, P.; Kim, C. Y. Mahaney, P. E.; Bray, J. A.; Johnston, G. H.; Koury, E. J.; Cosmi, S. A.; Deecher, D. C.; Smith, V. A.; Harrison, J. E.; Leventhal, L.; Whiteside, G. T.; Kennedy, J. D.; Trybulski, E. J. *J. Med. Chem.* **2010**, *53*, 2051–2062.

was added *m*-nitrobenzyl bromide (335 mg, 1.55 mmol, 2.50 equiv). The reaction mixture was stirred overnight. Then, the reaction mixture was extracted with EtOAc (3 x 4 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:4 → 1:2 EtOAc:hexanes) on silica gel to afford *N*–3-nitrobenzyl-3,3-dimethyloxindole **137b** (170 mg, 92% yield).

R_f = 0.35 (1:2 EtOAc:hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 – 8.11 (m, 2H), 7.60 (ddt, *J* = 7.7, 1.8, 0.9 Hz, 1H), 7.53 – 7.48 (m, 1H), 7.26 – 7.24 (m, 1H), 7.17 (td, *J* = 7.7, 1.3 Hz, 1H), 7.07 (td, *J* = 7.5, 1.0 Hz, 1H), 5.01 (s, 2H), 1.46 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 181.7, 148.6, 141.1, 138.5, 135.9, 133.3, 130.1, 127.9, 123.2, 122.9, 122.8, 122.2, 108.7, 77.2, 44.4, 43.0, 24.7; IR (Neat Film NaCl) 2969, 1652, 1538, 1348, 1011, 933, 761; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{17}H_{17}N_2O_3$ $[M+H]^+$: 297.1234; found: 297.1241.

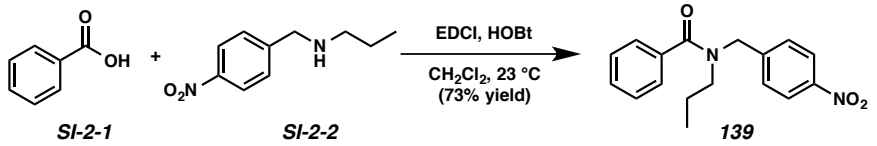


138 *137c*

***N*–4-nitrobenzyloxindole 137c.** To a mixture of 3,3-dimethyloxindole **138**[1] (50 mg, 0.31 mmol, 1.00 equiv) and Cs_2CO_3 (202 mg, 0.62 mmol, 2.00 equiv) in THF (1.60 mL) was added *p*-nitrobenzyl bromide (101 mg, 0.47 mmol, 1.50 equiv). The reaction mixture was stirred overnight. Then, the reaction mixture was extracted with EtOAc (3 x 3 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:4 → 1:2

EtOAc:hexanes) on silica gel to afford *N*–4-nitrobenzyl-3,3-dimethyloxindole **137c** (77.5 mg, 84% yield).

R_f = 0.35 (1:2 EtOAc:hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.8 Hz, 2H), 7.43 (d, *J* = 10.0 Hz, 2H), 7.25 (ddd, *J* = 7.3, 1.5, 0.7 Hz, 1H), 7.16 (td, *J* = 7.7, 1.3 Hz, 1H), 7.07 (td, *J* = 7.5, 1.1 Hz, 1H), 6.65 (dt, *J* = 7.7, 0.7 Hz, 1H), 5.01 (s, 2H), 1.45 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 181.6, 147.6, 143.7, 141.1, 135.8, 128.0, 127.9, 124.2, 123.2, 122.8, 108.7, 77.2, 44.4, 43.1, 24.7; IR (Neat Film NaCl) 2968, 1707, 1613, 1522, 1343, 1173, 1111, 1009, 760; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{17}H_{17}N_2O_3$ $[M+H]^+$: 297.1234; found: 297.1239.



Benzamide 139. To a solution of benzoic acid **SI-2-1** (57.0 mg, 0.463 mmol, 1.00 equiv) and propylamine **SI-2-2**[2] (90.0 mg, 0.463 mmol, 1.00 equiv) in CH_2Cl_2 (2.30 mL) were added EDCI (90.0 mg, 0.579 mmol, 1.25 equiv) and HOBt (78.0 mg, 0.579, 1.25 equiv). The reaction mixture was stirred overnight at 23 °C. Then, the reaction mixture was extracted with CH_2Cl_2 (3 x 3 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:8 → 1:2 EtOAc:hexanes) on silica gel to afford *N*–3-nitrobenzyl-3,3-dimethyloxindole **139** (101 mg, 73% yield).

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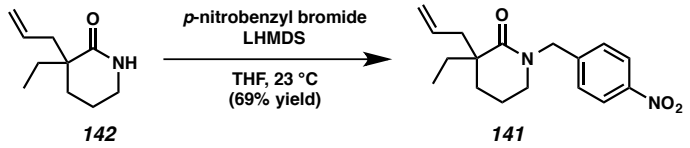
[2] Hajipour, A. R.; Fontanilla, D.; Chu, U. B.; Arbabian, M.; Ruoho, A. E. *Bioorg. Med. Chem.* **2010**, *18*, 4397–4404.

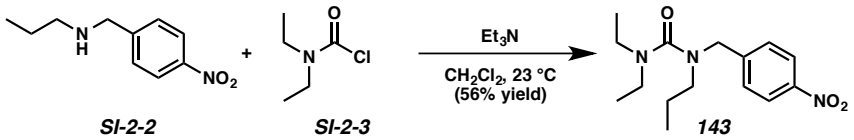
R_f = 0.32 (1:2 EtOAc:hexanes); (due to the distinct presence of rotameric isomers, the ^{1}H NMR and ^{13}C NMR contained extra peaks. See the attached spectrum); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, *J* = 10 Hz 2H), 7.53 – 7.35 (m, br, 7H), 4.84 – 4.61 (m, br, 2H), 3.43 – 3.18 (m, br, 2H), 1.68 –1.53 (m, br, 2H), 0.95 – 0.73 (m, br, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.47, 147.44, 145.42, 136.17, 129.84, 128.71, 127.49, 126.61, 124.06, 77.16, 52.29, 50.82, 47.59, 46.85, 21.87, 20.34, 11.07; IR (Neat Film NaCl) 3060, 2963, 2874, 1633, 1519, 1461, 1412, 1344, 1258, 1098, 859, 791, 736; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{17}H_{19}N_2O_3$ $[M+H]^+$: 299.1390; found: 299.1396.



***N*–4-nitrobenzylpiperidin-2-one 141.** To a solution of lactam **142** (34.0 mg, 0.203 mmol, 1.00 equiv) in THF (1.40 mL) was added LHMDS (41.0 mg, 0.244 mmol, 1.20 equiv) at 0 °C. The reaction mixture was stirred for 1 h, and then, *p*-nitrobenzyl bromide (66.0 mg, 0.305 mmol, 1.50 equiv) was added. The reaction mixture was stirred overnight at 23 °C. Then, the reaction mixture was extracted with EtOAc (3 x 3 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:2 EtOAc:hexanes) on silica gel to afford *N*–4-nitrobenzylpiperidin-2-one **141** (42.0 mg, 69% yield).

R_f = 0.25 (1:2 EtOAc:hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.7 Hz, 2H), 7.41 (d, *J* = 8.7 Hz, 2H), 5.80 – 5.71 (m, 1H), 5.11 – 5.04 (m, 2H), 4.65 (d, *J* = 3.8 Hz, 2H), 3.22 (td, *J* = 6.1, 1.3 Hz, 2H), 2.54 (ddt, *J* = 13.5, 6.9, 1.3 Hz, 1H), 2.21 (ddt, *J* =

13.4, 8.0, 1.1 Hz, 1H), 1.81 (dddd, *J* = 11.9, 6.8, 2.9, 1.4 Hz, 3H), 1.76 – 1.72 (m, 2H), 1.55 (dq, *J* = 13.5, 7.4 Hz, 1H), 0.88 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 174.9, 147.4, 145.6, 134.7, 128.7, 124.0, 118.3, 77.2, 50.5, 48.6, 45.5, 43.3, 31.6, 28.9, 19.9, 8.9; IR (Neat Film NaCl) 2939, 1633, 1519, 1344, 1196, 1109; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{17}H_{23}N_2O_3$ $[M+H]^+$: 303.1703; found: 303.1707.



Urea 11. To a solution of propylamine **SI-2-2**[2] (100 mg, 0.515 mmol, 1.00 equiv) and Et_3N (0.18 mL, 1.29 mmol, 2.50 equiv) in CH_2Cl_2 (2.60 mL) was added diethylcarbamoyl chloride **SI-2-3** (72.0 mL, 0.566 mmol, 1.10 equiv) at 0 °C. The solution was warmed to 23 °C and stirred overnight. Then, the reaction mixture was extracted with CH_2Cl_2 (3 x 3.5 mL) and washed with brine. The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by column chromatography (1:8 → 1:4 EtOAc:hexanes) on silica gel to afford urea **143** (85 mg, 56% yield).

R_f = 0.32 (1:4 EtOAc:hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 8.6 Hz, 2H), 7.42 (d, *J* = 8.6 Hz, 2H), 4.42 (s, 2H), 3.22 (q, *J* = 7.1 Hz, 4H), 3.06 – 3.01 (m, 2H), 1.61 – 1.52 (m, 2H), 1.11 (t, *J* = 7.1 Hz, 6H), 0.86 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.9, 147.2, 146.9, 128.4, 123.8, 51.4, 51.2, 42.5, 21.1, 13.4, 11.4; IR (Neat Film NaCl) 2967, 1644, 1520, 1410, 1344, 1251, 1132, 1108; HRMS (MM: ESI-APCI+) *m/z* calc'd for $C_{15}H_{24}N_3O_3$ $[M+H]^+$: 294.1812; found: 294.1863.

2.5. References and Notes

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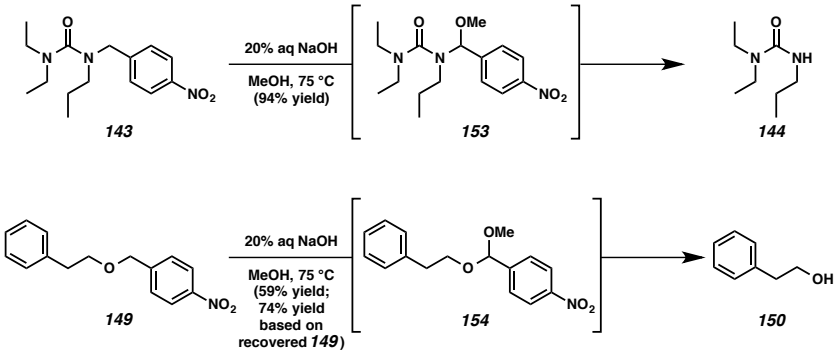
(9) From the deprotection reaction of urea **143**, hemiaminal ether intermediate **153** was observed in 1 hour under the standard reaction conditions and intermediate **153** was converted to propyl urea **144** after 10.5 hours. In addition, acetal **154** was observed in 2 hours during the deprotection reaction of ether **149**, and the desired phenylethyl alcohol **150** was isolated after 32 hours.



APPENDIX 6

Spectra Relevant to Chapter 2:

A New Method for the Cleavage of Nitrobenzyl Amides and Ethers

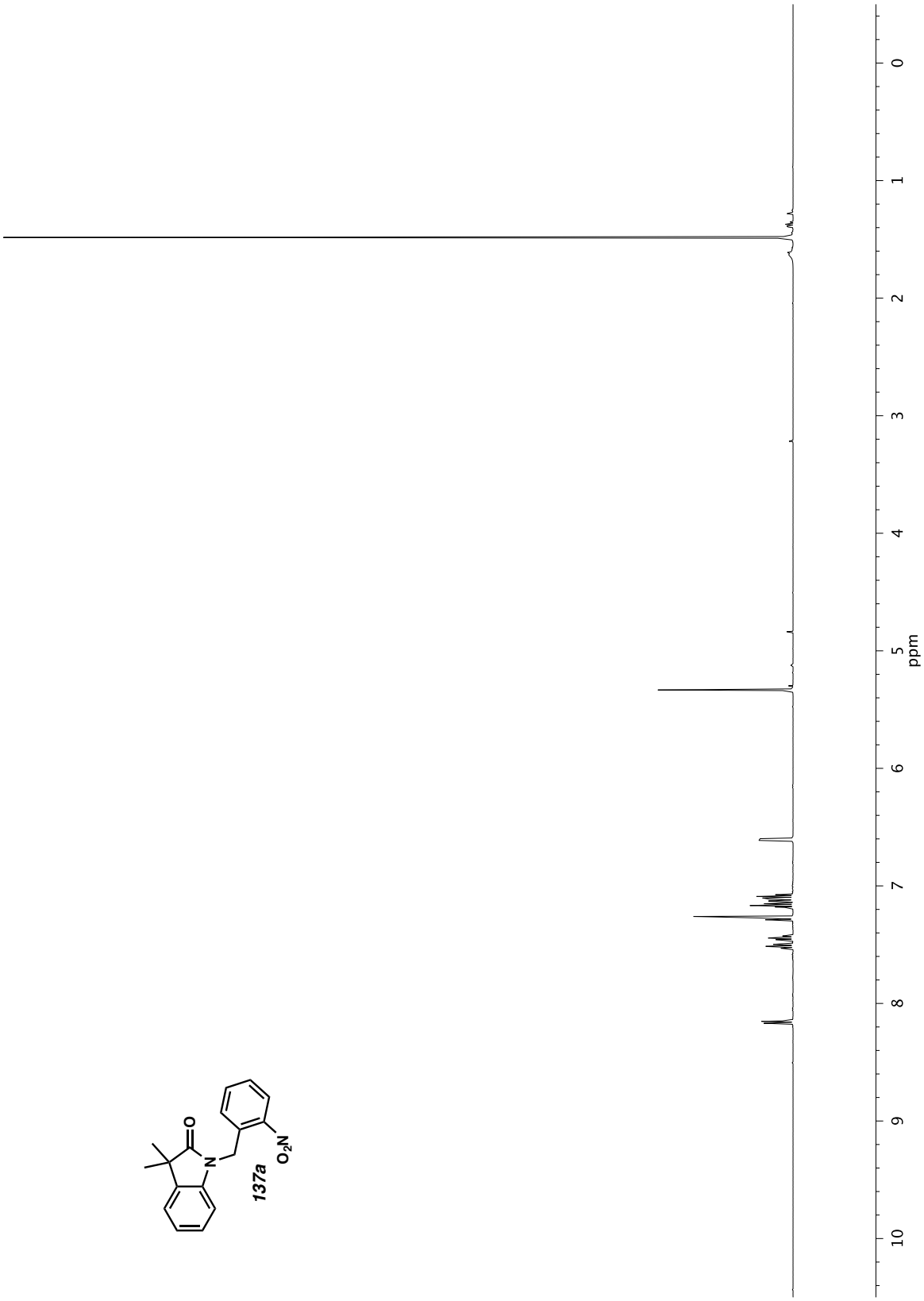


Figure A6.1. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **137a**.

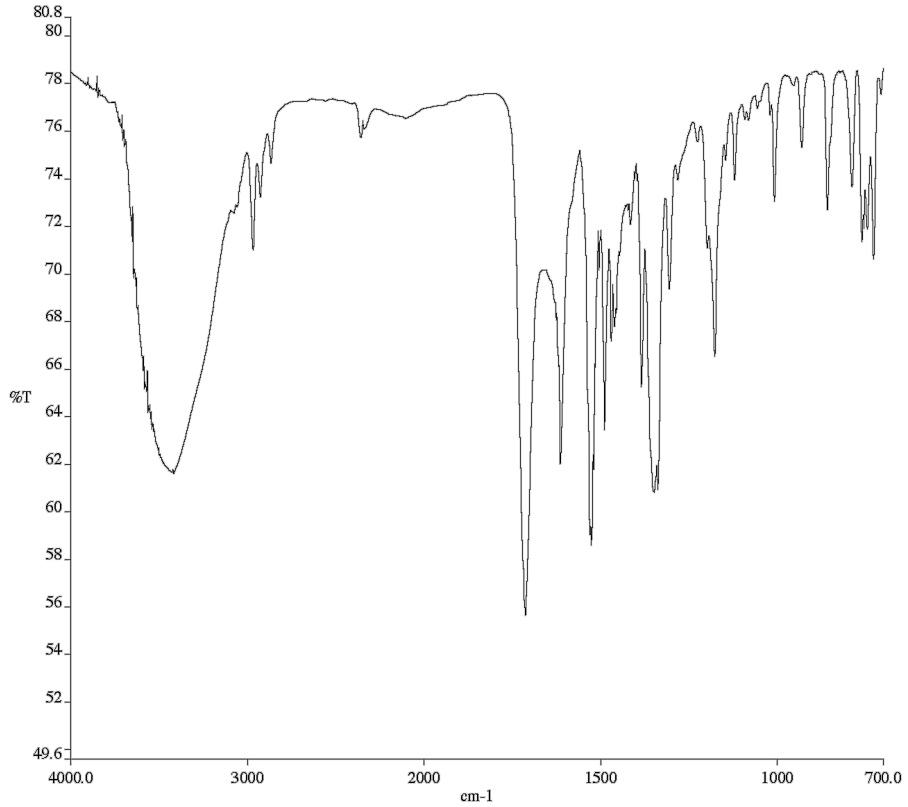


Figure A6.2. Infrared spectrum (Thin Film, NaCl) of compound **137a**.

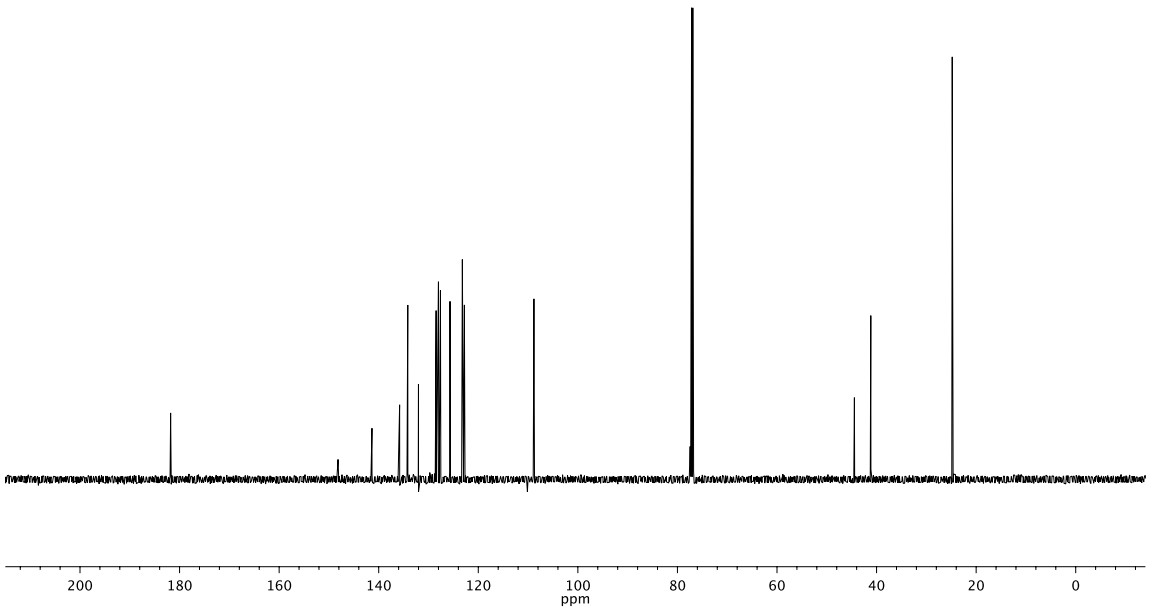


Figure A6.3. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **137a**.

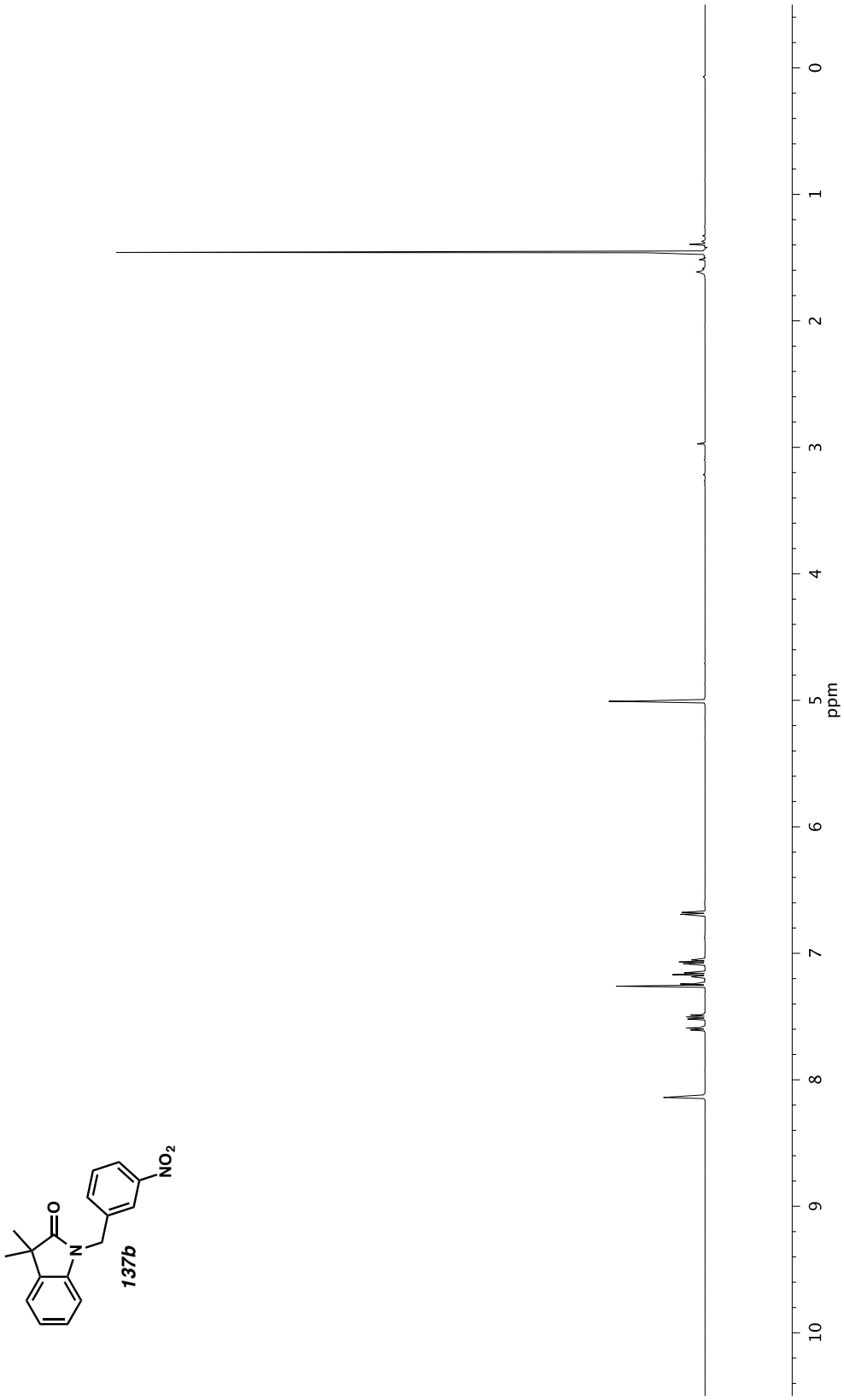


Figure A6.4. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **137b**.

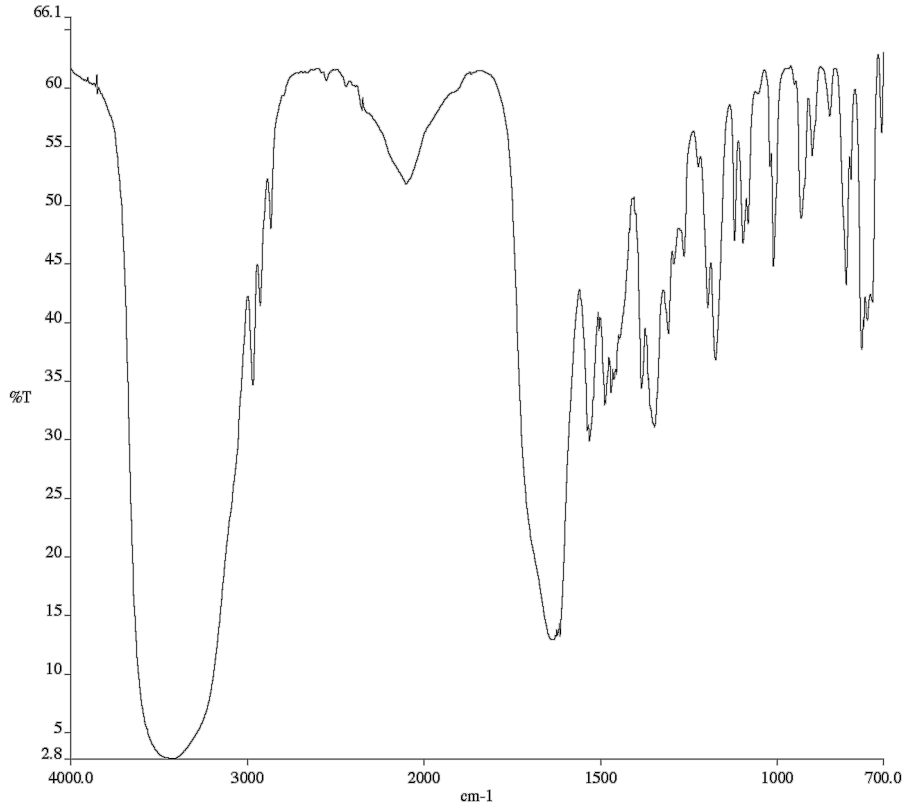


Figure A6.5. Infrared spectrum (Thin Film, NaCl) of compound **137b**.

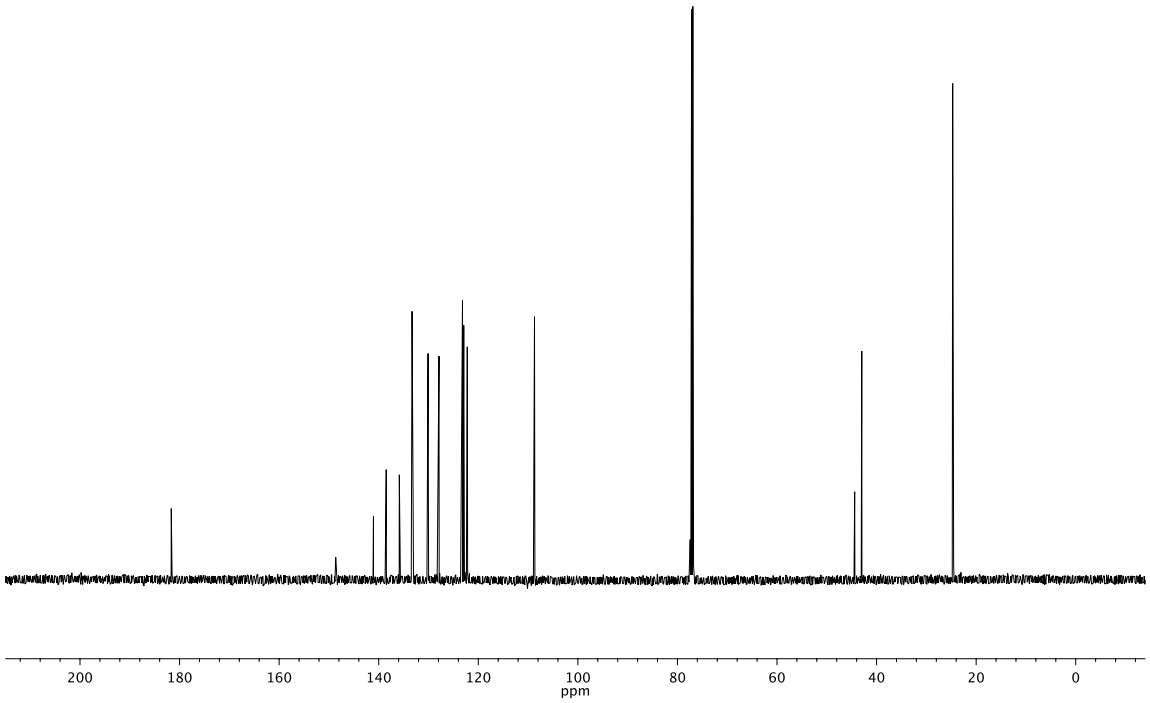


Figure A6.6. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **137b**.

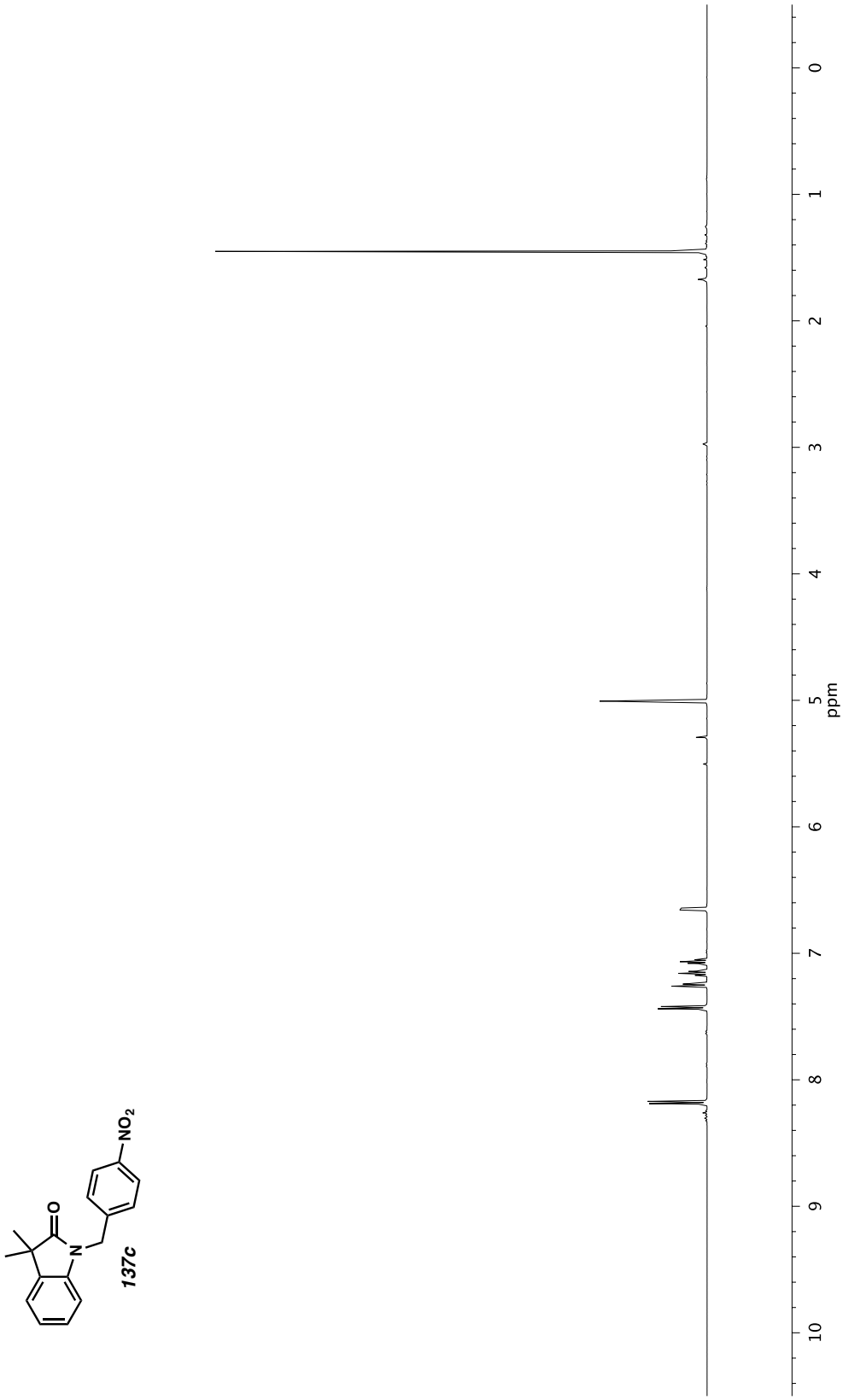


Figure A6.7. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **137c**.

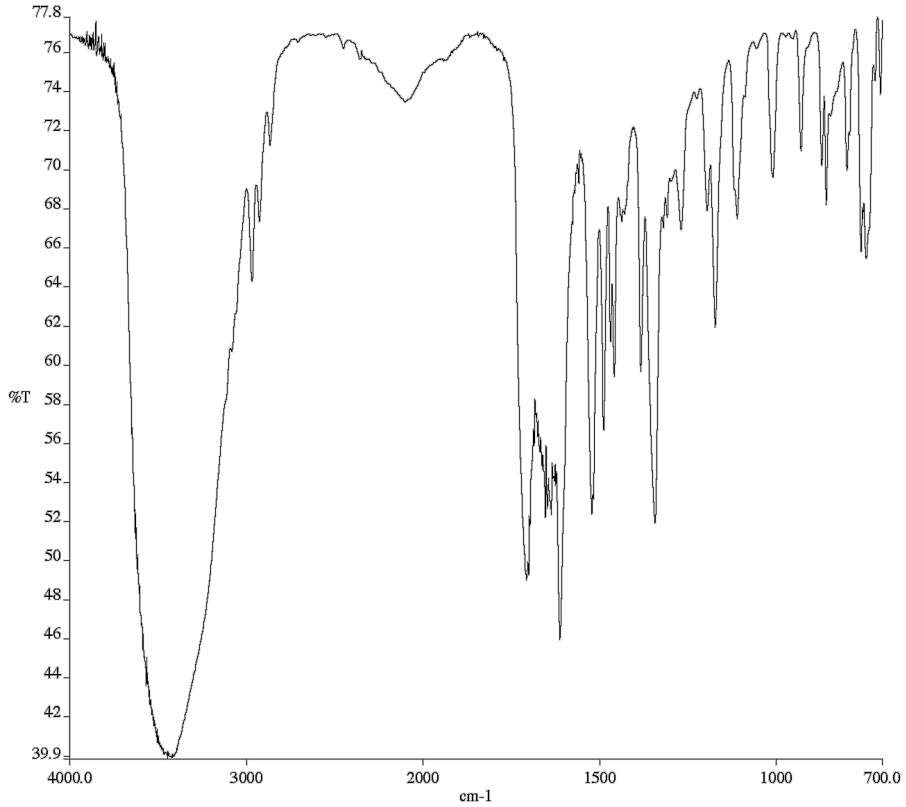


Figure A6.8. Infrared spectrum (Thin Film, NaCl) of compound **137c**.

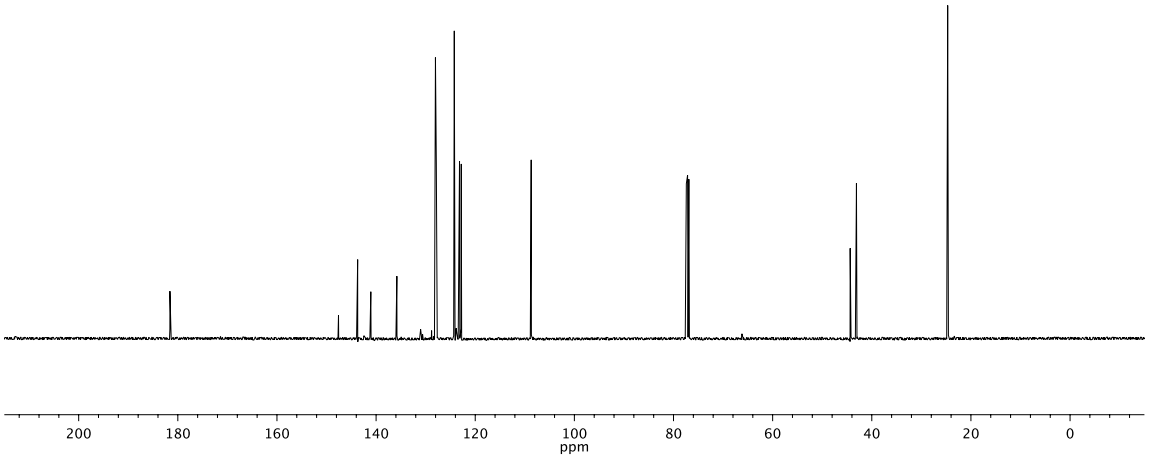


Figure A6.9. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **137c**.

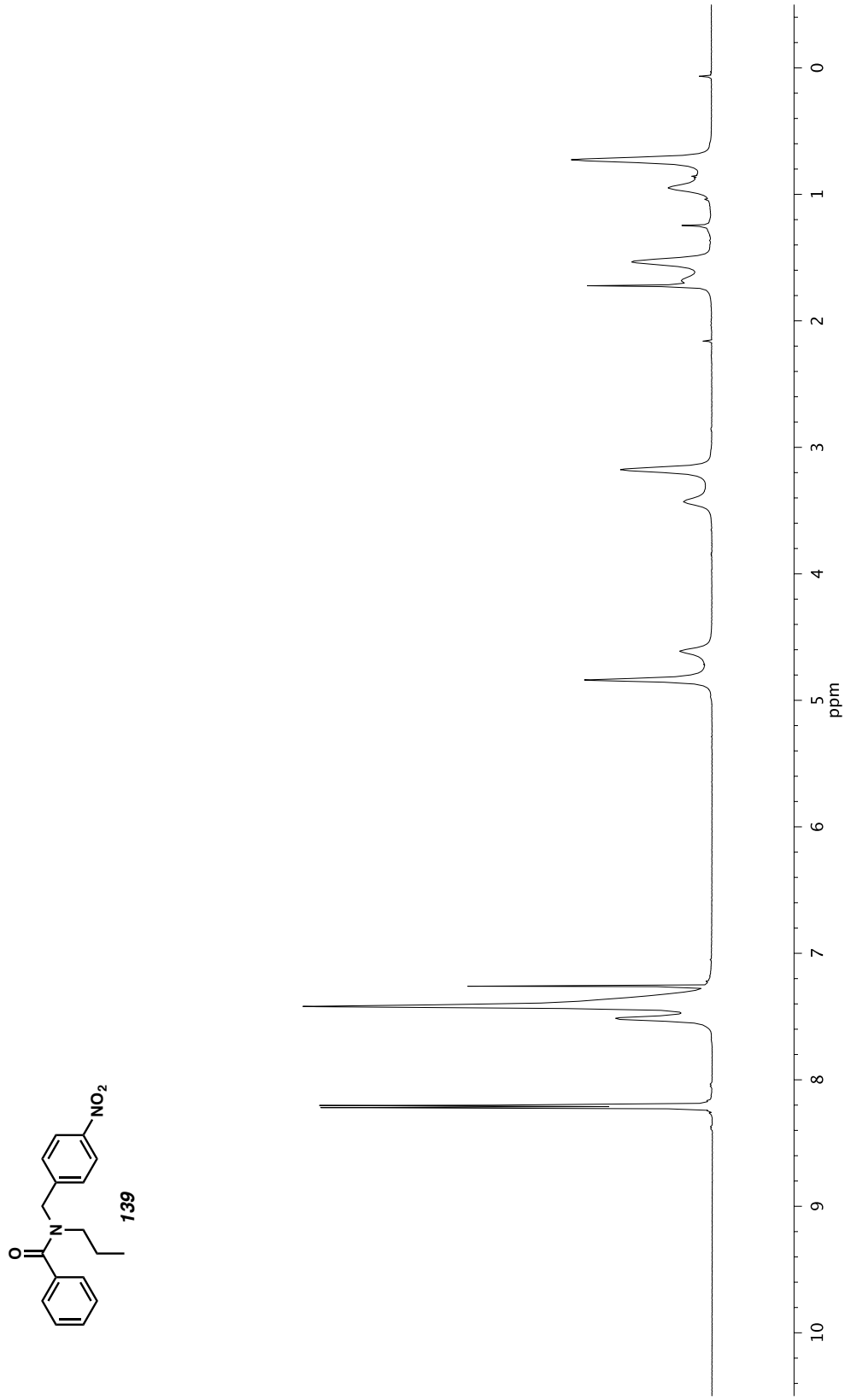


Figure A6.10. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **139**.

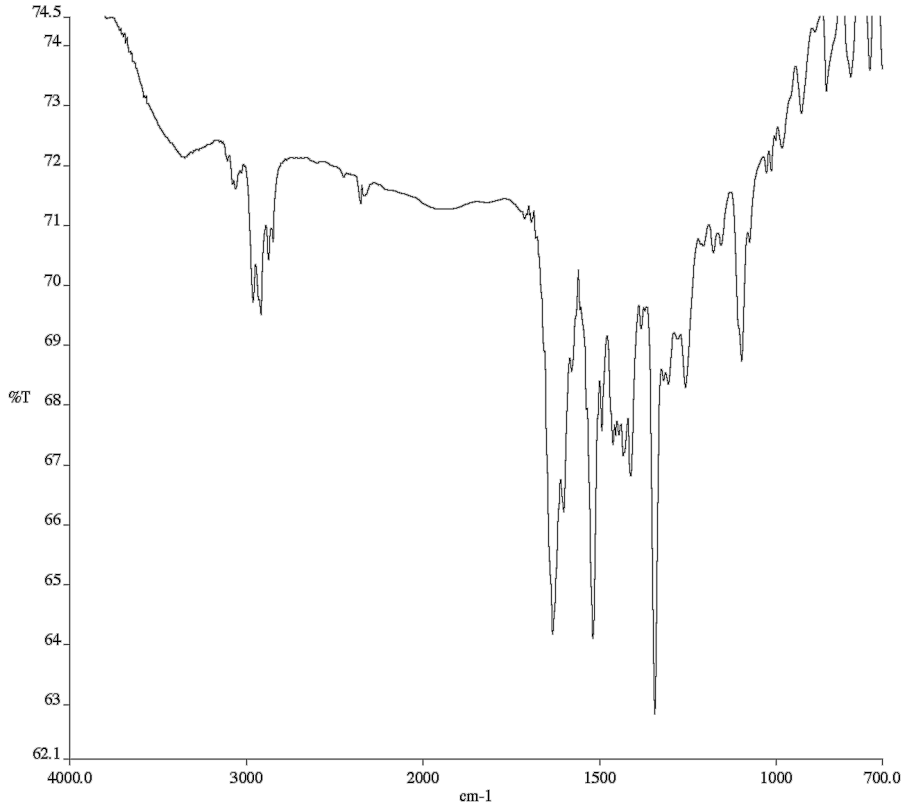


Figure A6.11. Infrared spectrum (Thin Film, NaCl) of compound **139**.

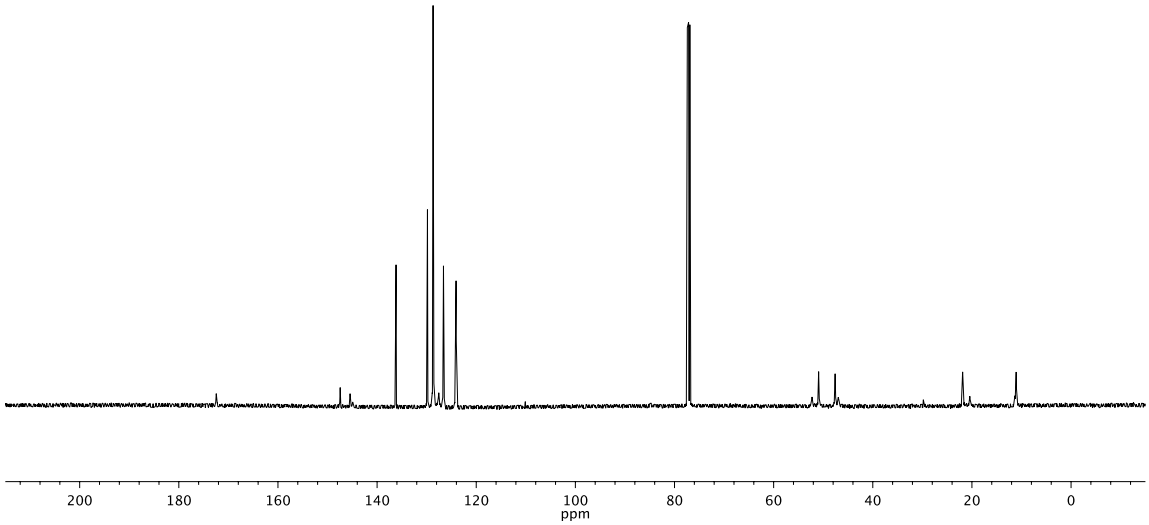


Figure A6.12. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **139**.

Figure A6.13. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **141**.

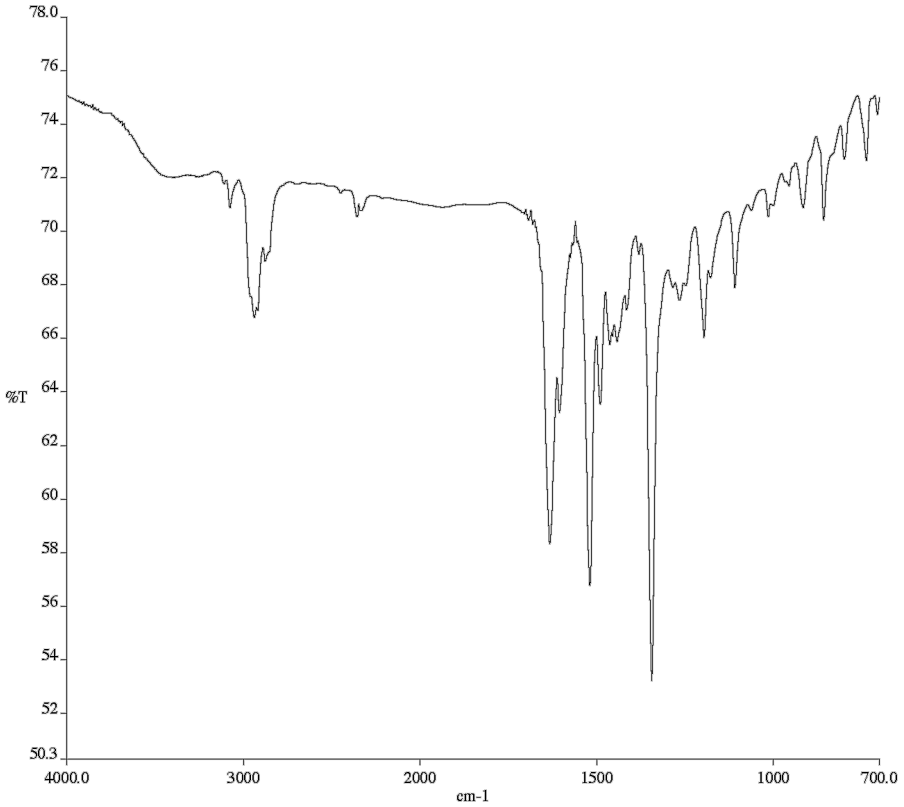


Figure A6.14. Infrared spectrum (Thin Film, NaCl) of compound **141**.

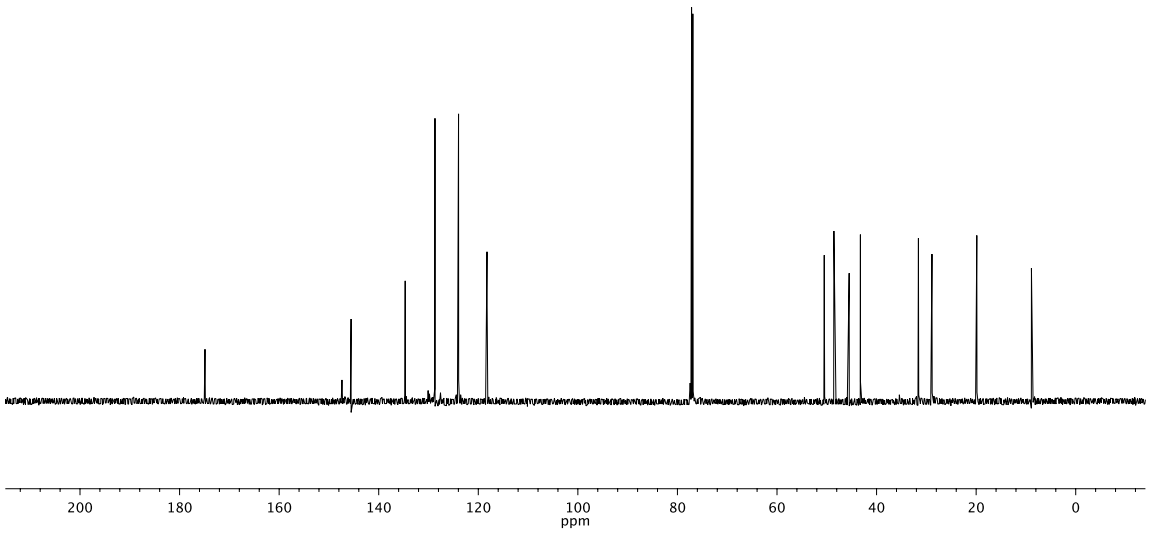


Figure A6.15. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **141**.

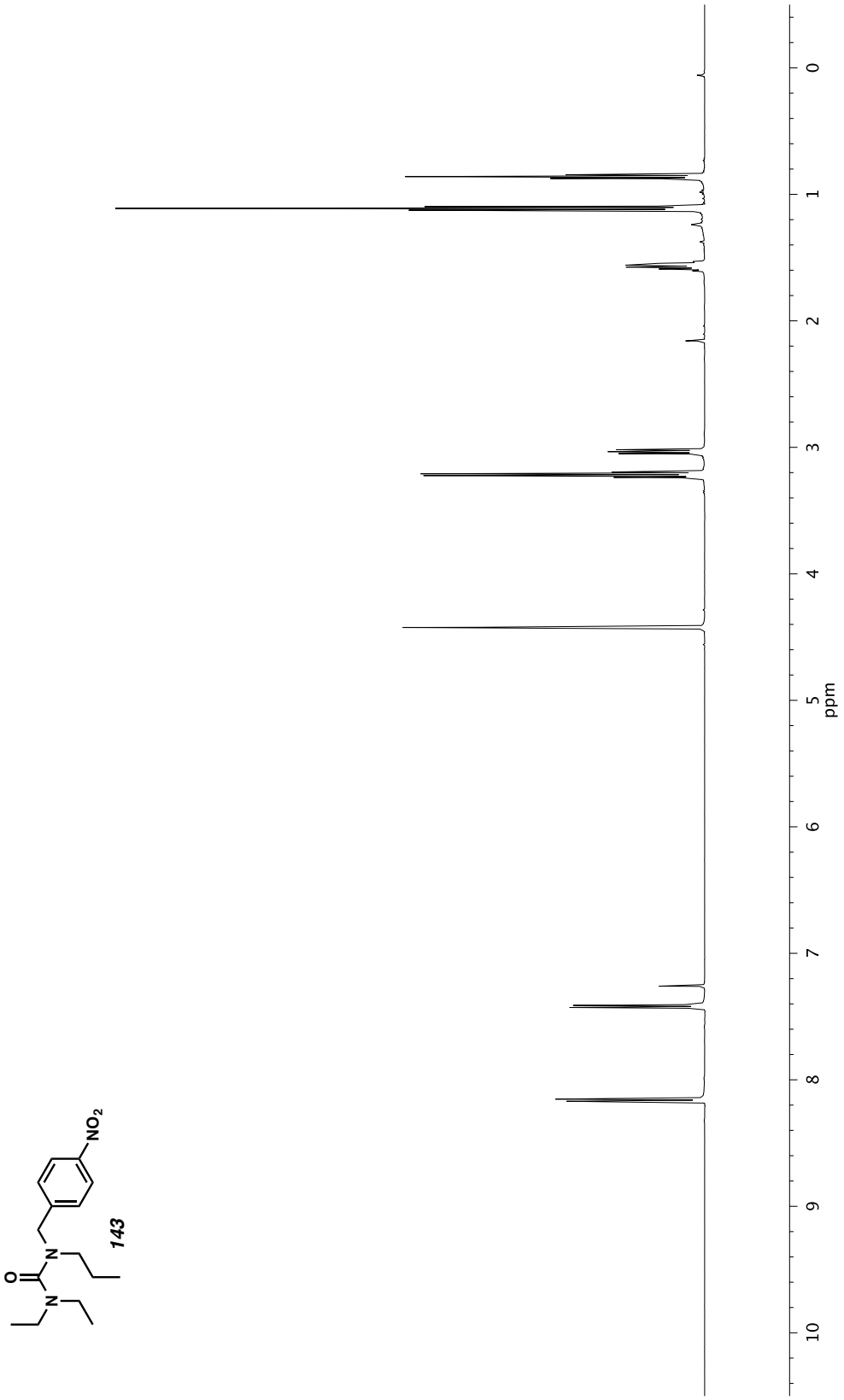


Figure A6.16. ^{1}H NMR (500 MHz, $CDCl_3$) of compound **143**.

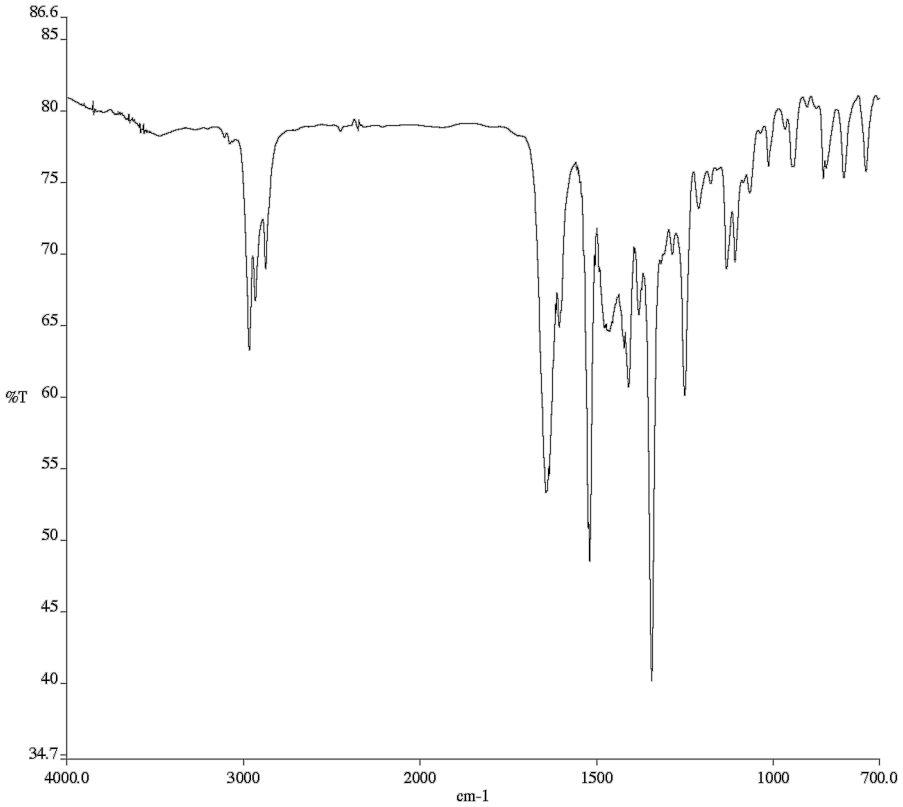


Figure A6.17. Infrared spectrum (Thin Film, NaCl) of compound **143**.

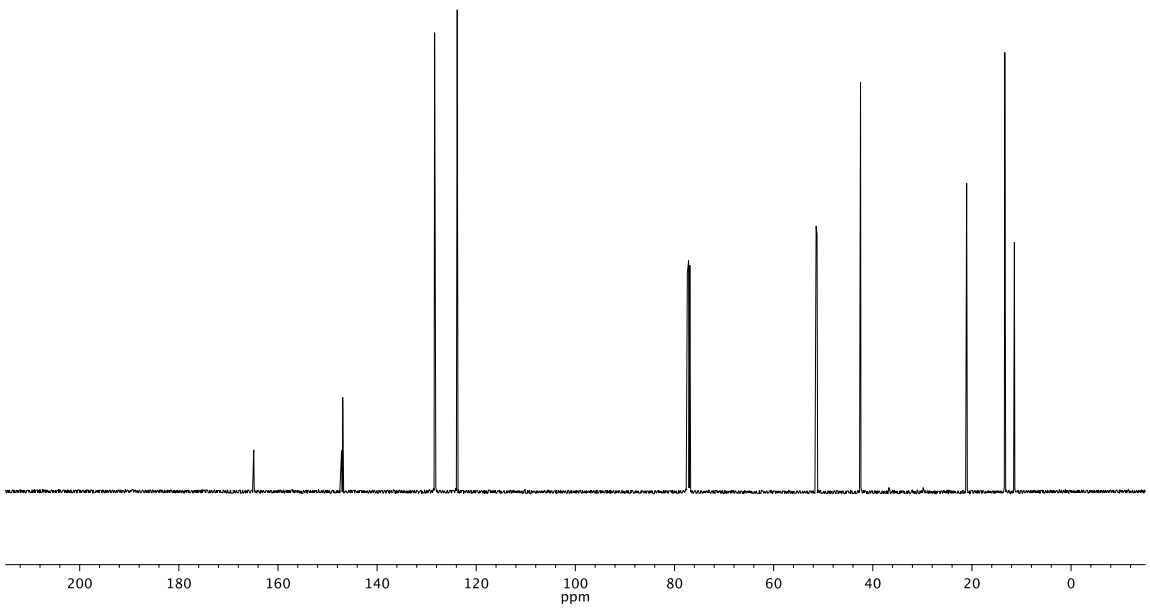


Figure A6.18. ^{13}C NMR (125 MHz, $CDCl_3$) of compound **143**.