

Dearomative [3 + 2] Cycloaddition Reaction of Nitrobenzothiophenes with Nonstabilized Azomethine Ylides

Kai-Kai Wang,^a Yan-Xin Xie,^b Yan-Li Li,^c Yongxiang Chen^a and Zhan-Yong Wang^{*a}

^a School of Pharmacy, Xinxiang University, Xinxiang 453000, P.R. of China

^b School of Chemistry and Materials Engineering, Xinxiang University, Xinxiang 453000, P.R. of China

^c Medical College, Xinxiang University, Xinxiang 453000, P.R. of China

E-mail: zhanyongw@126.com

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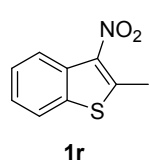
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1. General methods

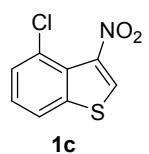
NMR data were obtained for ^1H at 400 MHz, and for ^{13}C at 100 MHz. Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard in CDCl_3 solution. ESI HRMS was recorded on a Waters SYNAPT G2. Column chromatography was performed on silica gel (300-400 mesh) eluting with ethyl acetate/petroleum ether. TLC was performed on glass-backed silica plates. UV light, I_2 , and solution of potassium permanganate were used to visualize products. All chemicals were used without purification as commercially available unless otherwise noted. Petroleum ether and ethyl acetate were distilled. Unless otherwise noted, experiments involving moisture and/or air sensitive components were performed under a positive pressure of argon in oven-dried glassware equipped with a rubber septum inlet. Dried solvents and liquid reagents were transferred by oven-dried syringes. 3-Nitrobenzo[*b*]thiophenes¹ and 2-nitrobenzo[*b*]thiophene² were prepared according to the literature procedures. 2-Nitrobenzofuran was prepared according to the literature procedures.³

- (1)(a) K. Tanemura, T. Suzuki, Y. Nishida, K. Satsumabayashi and T. Horaguchi, *J. Chem. Res-s.*, 2003, 497.
(b) J.-Q. Zhao, L. Yang, Y. You, Z.-H. Wang, K.-X. Xie, X.-M. Zhang, X.-Y. Xu and W.-C. Yuan, *Org. Biomol. Chem.*, 2019, **17**, 5294.
- (2) C. O. Hayes, W. K. Bell, B. R. Cassidy and C. G. Willson, *J. Org. Chem.*, 2015, **80**, 7530.
- (3) (a) F. Yang, K. Rauch, K. Kettelhoit and L. Ackermann, *Angew. Chem., Int. Ed.*, 2014, **53**, 11285; (b) H. Wang, J. Zhang, Y. Tu and J. Zhang, *Angew. Chem., Int. Ed.*, 2019, **58**, 5422.

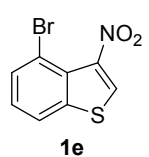
2. Some new substrates of nitrobenzo[*b*]thiophenes



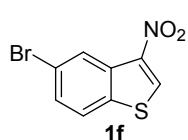
2-methyl-3-nitrobenzo[*b*]thiophene: ^1H NMR (400 MHz, CDCl_3) δ 8.46 (d, $J = 8.0$ Hz, 1H), 7.75 (d, $J = 8.0$ Hz, 1H), 7.54 (t, $J = 7.6$ Hz, 1H), 7.44 (t, $J = 7.6$ Hz, 1H), 2.94 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl_3) δ 149.3, 138.7, 134.4, 132.1, 126.7, 125.9, 123.7, 121.9, 17.2 ppm. ESI-HRMS: calcd. for $\text{C}_9\text{H}_7\text{NO}_2\text{S}+\text{H}^+$ 194.0270, found 194.0269.



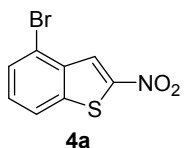
4-chloro-3-nitrobenzo[*b*]thiophene: ^1H NMR (400 MHz, CDCl_3) δ 8.36 (s, 1H), 7.75 – 7.71 (m, 1H), 7.53 – 7.48 (m, 2H) ppm. ^{13}C NMR (100 MHz, CDCl_3) δ 151.6, 141.0, 134.9, 132.0, 129.8, 126.1, 123.8, 121.4 ppm. ESI-HRMS: calcd. for $\text{C}_8\text{H}_4\text{ClNO}_2\text{S}+\text{H}^+$ 213.9724, found 213.9721.



4-bromo-3-nitrobenzo[*b*]thiophene: ^1H NMR (400 MHz, CDCl_3) δ 8.34 (s, 1H), 7.78 (d, $J = 8.0$ Hz, 1H), 7.67 (d, $J = 8.0$ Hz, 1H), 7.43 (t, $J = 8.0$ Hz, 1H) ppm. ^{13}C NMR (100 MHz, CDCl_3) δ 151.5, 140.7, 136.5, 129.9, 129.5, 125.8, 122.0, 120.6 ppm. ESI-HRMS: calcd. for $\text{C}_8\text{H}_4\text{BrNO}_2\text{S}+\text{H}^+$ 257.9219, found 257.9219.

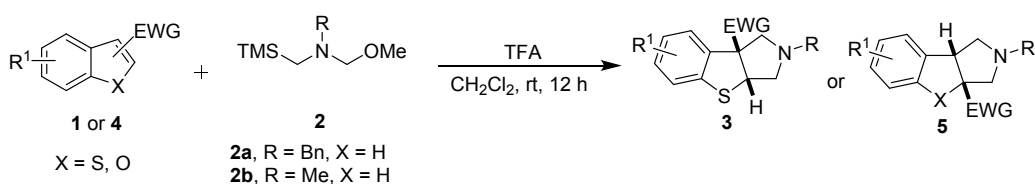


5-bromo-3-nitrobenzo[b]thiophene: ^1H NMR (400 MHz, CDCl_3) δ 8.80 (s, 1H), 8.71 (s, 1H), 7.75 (d, $J = 8.8$ Hz, 1H), 7.63 (d, $J = 8.8$ Hz, 1H) ppm. ^{13}C NMR (100 MHz, CDCl_3) δ 141.8, 137.2, 134.0, 131.5, 129.8, 126.8, 124.2, 121.8 ppm. ESI-HRMS: calcd. for $\text{C}_8\text{H}_4\text{BrNO}_2\text{S}+\text{H}^+$ 257.9219, found 257.9220.

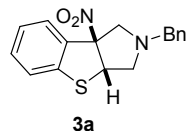


4-bromo-2-nitrobenzo[b]thiophene: ^1H NMR (400 MHz, CDCl_3) δ 8.16 (s, 1H), 7.84 (d, $J = 8.0$ Hz, 1H), 7.73 (d, $J = 7.6$ Hz, 1H), 7.33 (t, $J = 8.0$ Hz, 1H) ppm. ^{13}C NMR (100 MHz, CDCl_3) δ 144.2, 140.4, 132.0, 128.5, 128.0, 127.1, 122.3, 115.6 ppm. ESI-HRMS: calcd. for $\text{C}_8\text{H}_4\text{BrNO}_2\text{S}+\text{H}^+$ 257.9219, found 257.9221.

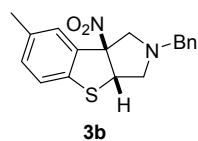
3. General procedure for [3+2] dipolar cycloaddition



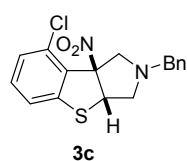
The nitrobenzo[b]thiophenes **1** (0.1 mmol), *N*-(methoxymethyl)-*N*-(trimethyl silylmethyl)alkylamine **2** (0.12 mmol), and the TFA (0.1 mmol) were dissolved in CH_2Cl_2 (1.0 mL). Then the solution was stirred at rt for 12 h. After completion, the mixture was directly purified by column chromatography on silica gel eluting with petroleum ether/ethyl acetate (30:1 to 10:1) to afford the product **3** and **5**.



3a, 28.1 mg, 90% yield, colorless oil. ^1H NMR (400 MHz, CDCl_3) δ 7.40 (d, $J = 7.6$ Hz, 1H), 7.30 (d, $J = 7.6$ Hz, 3H), 7.28 – 7.24 (m, 3H), 7.19 (d, $J = 8.0$ Hz, 1H), 7.14 – 7.10 (m, 1H), 4.99 (t, $J = 7.6$ Hz, 1H), 3.98 (d, $J = 10.8$ Hz, 1H), 3.63 (dd, $J = 31.6, 13.2$ Hz, 2H), 3.46 (t, $J = 8.4$ Hz, 1H), 2.97 (d, $J = 10.4$ Hz, 1H), 2.60 (dd, $J = 9.2, 7.6$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ 142.9, 137.2, 135.1, 131.3, 128.6, 128.5, 127.5, 125.6, 125.2, 122.5, 107.1, 64.5, 63.2, 58.6, 52.4. ESI-HRMS: calcd. for $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_2\text{S}+\text{H}^+$ 313.1005, found 313.1000.

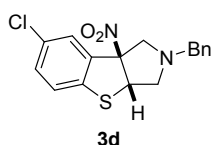


3b, 30.0 mg, 92% yield, colorless oil. ^1H NMR (400 MHz, CDCl_3) δ 7.33 – 7.29 (m, 2H), 7.27 – 7.24 (m, 3H), 7.20 (s, 1H), 7.13 (d, $J = 8.0$ Hz, 1H), 7.06 (d, $J = 8.0$ Hz, 1H), 4.97 (t, $J = 7.2$ Hz, 1H), 4.01 (d, $J = 10.8$ Hz, 1H), 3.67 (d, $J = 13.2$ Hz, 1H), 3.57 (d, $J = 13.2$ Hz, 1H), 3.47 – 3.43 (m, 1H), 2.92 (d, $J = 10.8$ Hz, 1H), 2.55 (dd, $J = 9.2, 8.0$ Hz, 1H), 2.29 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 139.3, 137.3, 135.23, 135.17, 132.3, 128.6, 128.5, 127.5, 126.0, 122.2, 107.1, 64.4, 63.2, 58.7, 52.8, 20.9. ESI-HRMS: calcd. for $\text{C}_{18}\text{H}_{18}\text{N}_2\text{O}_2\text{S}+\text{H}^+$ 327.1162, found 327.1159.

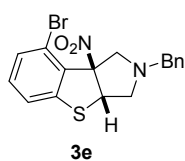


3c, 31.1 mg, 90% yield, pale white solid. ^1H NMR (400 MHz, CDCl_3) δ 7.34 – 7.24 (m, 5H), 7.18 (t, $J = 7.6$ Hz, 1H), 7.10 (d, $J = 8.0$ Hz, 1H), 7.00 (d, $J = 8.0$ Hz, 1H), 5.00 (t, $J = 7.2$ Hz, 1H), 3.72 – 3.66 (m, 3H), 3.55 (t, $J = 8.8$ Hz, 1H), 3.23 (d, $J = 11.4$ Hz, 1H), 2.76 (dd, $J = 9.2, 6.8$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ 140.6, 137.0, 136.0, 131.2, 130.2,

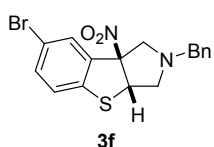
128.58, 128.56, 127.6, 126.0, 119.5, 106.2, 65.6, 59.4, 58.5, 57.7. ESI-HRMS: calcd. for $C_{17}H_{15}ClN_2O_2S+H^+$ 347.0616, found 347.0614.



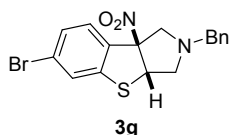
3d, 31.5 mg, 91% yield, pale white solid. 1H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, $J = 2.0$ Hz, 1H), 7.33 – 7.23 (m, 6H), 7.10 (d, $J = 8.4$ Hz, 1H), 5.02 (t, $J = 7.2$ Hz, 1H), 3.91 (d, $J = 10.8$ Hz, 1H), 3.63 (dd, $J = 38.8, 13.2$ Hz, 2H), 3.46 – 3.41 (m, 1H), 2.98 (d, $J = 10.8$ Hz, 1H), 2.61 (dd, $J = 9.6, 7.2$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.5, 137.0, 136.6, 131.5, 130.9, 128.6, 127.6, 125.8, 123.4, 106.5, 64.6, 63.0, 58.5, 53.0. ESI-HRMS: calcd. for $C_{17}H_{15}ClN_2O_2S+H^+$ 347.0616, found 347.0616.



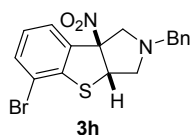
3e, 35.9 mg, 92% yield, pale white solid. 1H NMR (400 MHz, $CDCl_3$) δ 7.34 – 7.24 (m, 6H), 7.09 (t, $J = 7.6$ Hz, 1H), 7.04 (d, $J = 8.0$ Hz, 1H), 4.96 (t, $J = 7.6$ Hz, 1H), 3.72 – 3.68 (m, 2H), 3.63 (d, $J = 10.8$ Hz, 1H), 3.58 (t, $J = 8.8$ Hz, 1H), 3.25 (d, $J = 10.8$ Hz, 1H), 2.79 (dd, $J = 9.2, 6.4$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.4, 137.8, 137.0, 130.3, 129.1, 128.59, 128.56, 127.6, 120.1, 120.0, 105.7, 65.5, 59.6, 59.3, 58.5. ESI-HRMS: calcd. for $C_{17}H_{15}BrN_2O_2S+H^+$ 391.0110 (^{81}Br) and 393.0090 (^{83}Br), found 391.0109, 393.0085.



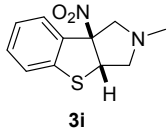
3f, 34.3 mg, 88% yield, pale white solid. 1H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, $J = 1.6$ Hz, 1H), 7.42 (dd, $J = 8.4, 2.0$ Hz, 1H), 7.33 – 7.27 (m, 3H), 7.24 (d, $J = 6.4$ Hz, 2H), 7.05 (d, $J = 8.4$ Hz, 1H), 5.00 (t, $J = 7.2$ Hz, 1H), 3.91 (d, $J = 10.8$ Hz, 1H), 3.63 (dd, $J = 41.2, 12.8$ Hz, 2H), 3.46 – 3.41 (m, 1H), 2.98 (d, $J = 10.8$ Hz, 1H), 2.61 (dd, $J = 9.6, 7.2$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.1, 137.0, 136.9, 134.3, 128.7, 128.6, 127.6, 123.7, 118.2, 106.4, 64.6, 63.0, 58.5, 52.9. ESI-HRMS: calcd. for $C_{17}H_{15}BrN_2O_2S+H^+$ 391.0110 (^{81}Br) and 393.0090 (^{83}Br), found 391.0111, 393.0089.



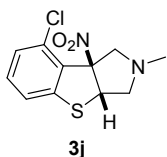
3g, 33.9 mg, 87% yield, pale white solid. 1H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.26 (m, 4H), 7.25 – 7.22 (m, 4H), 4.99 (t, $J = 7.2$ Hz, 1H), 3.87 (d, $J = 10.8$ Hz, 1H), 3.62 (dd, $J = 28.8, 12.8$ Hz, 2H), 3.44 – 3.39 (m, 1H), 2.97 (d, $J = 10.8$ Hz, 1H), 2.63 (dd, $J = 9.6, 6.8$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.3, 137.0, 134.1, 128.6, 128.5, 128.4, 127.6, 126.8, 125.6, 125.2, 106.3, 64.6, 63.0, 58.6, 52.8. ESI-HRMS: calcd. for $C_{17}H_{15}BrN_2O_2S+H^+$ 391.0110 (^{81}Br) and 393.0090 (^{83}Br), found 391.0110, 393.0087.



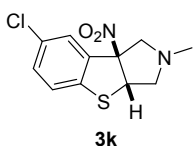
3h, 34.7 mg, 89% yield, pale white solid. 1H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, $J = 8.0$ Hz, 1H), 7.36 – 7.23 (m, 6H), 7.00 (t, $J = 7.6$ Hz, 1H), 4.97 (t, $J = 7.2$ Hz, 1H), 3.91 (d, $J = 10.8$ Hz, 1H), 3.63 (q, $J = 12.8$ Hz, 2H), 3.47 – 3.43 (m, 1H), 2.97 (d, $J = 10.8$ Hz, 1H), 2.66 (dd, $J = 9.2, 6.8$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.3, 137.0, 136.1, 134.1, 128.6, 127.6, 126.6, 124.3, 116.0, 108.0, 64.7, 63.0, 58.5, 51.3. ESI-HRMS: calcd. for $C_{17}H_{15}BrN_2O_2S+H^+$ 391.0110 (^{81}Br) and 393.0090 (^{83}Br), found 391.0110, 393.0087.



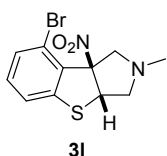
3i, 19.8 mg, 84% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.45 (d, $J = 8.0$ Hz, 1H), 7.32 (t, $J = 7.6$ Hz, 1H), 7.19 (d, $J = 8.0$ Hz, 1H), 7.14 (t, $J = 7.6$ Hz, 1H), 4.99 (t, $J = 6.8$ Hz, 1H), 3.82 (d, $J = 10.4$ Hz, 1H), 3.35 (dd, $J = 9.6, 8.0$ Hz, 1H), 3.08 (d, $J = 10.4$ Hz, 1H), 2.69 (dd, $J = 9.6, 6.4$ Hz, 1H), 2.36 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 143.0, 135.0, 131.3, 125.5, 125.2, 122.4, 107.4, 67.1, 65.7, 52.7, 41.2. ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_2\text{S}+\text{H}^+$ 237.0692, found 237.0692.



3j, 23.2 mg, 86% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.19 (t, $J = 8.0$ Hz, 1H), 7.12 (d, $J = 7.6$ Hz, 1H), 7.01 (d, $J = 7.6$ Hz, 1H), 4.98 (dd, $J = 8.8, 5.6$ Hz, 1H), 3.55 (d, $J = 10.8$ Hz, 1H), 3.38 (t, $J = 8.8$ Hz, 1H), 3.32 (d, $J = 10.8$ Hz, 1H), 2.86 (dd, $J = 9.2, 5.2$ Hz, 1H), 2.40 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 140.5, 136.1, 131.1, 130.3, 126.0, 119.5, 106.5, 68.2, 62.0, 58.0, 41.1. ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{11}\text{ClN}_2\text{O}_2\text{S}+\text{H}^+$ 271.0303, found 271.0303.

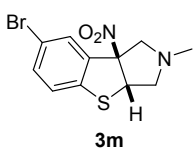


3k, 23.0 mg, 85% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.45 (d, $J = 2.0$ Hz, 1H), 7.29 (dd, $J = 8.4, 2.0$ Hz, 1H), 7.11 (d, $J = 8.4$ Hz, 1H), 5.02 (t, $J = 6.4$ Hz, 1H), 3.73 (d, $J = 10.4$ Hz, 1H), 3.32 (dd, $J = 9.6, 7.6$ Hz, 1H), 3.10 (d, $J = 10.4$ Hz, 1H), 2.71 (dd, $J = 9.6, 6.0$ Hz, 1H), 2.36 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 141.6, 136.5, 131.5, 130.9, 125.8, 123.3, 106.7, 67.1, 65.6, 53.3, 41.1. ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{11}\text{ClN}_2\text{O}_2\text{S}+\text{H}^+$ 271.0303, found 271.0303.

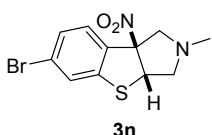


3l, 25.7 mg, 82% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.29 (d, $J = 7.6$ Hz, 1H), 7.10 (t, $J = 8.0$ Hz, 1H), 7.05 (d, $J = 7.6$ Hz, 1H), 4.94 (dd, $J = 8.4, 5.6$ Hz, 1H), 3.53 (d, $J = 10.4$ Hz, 1H), 3.42 – 3.34 (m, 2H), 2.89 (dd, $J = 9.2, 5.2$ Hz, 1H), 2.41 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 140.3, 137.9, 130.3, 129.2, 120.1, 120.0, 105.9, 68.1, 62.2, 59.6, 41.1.

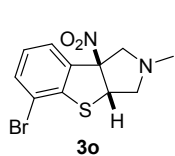
ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{11}\text{BrN}_2\text{O}_2\text{S}+\text{H}^+$ 314.9797 (^{81}Br) and 316.9777 (^{83}Br), found 314.9797, 316.9771.



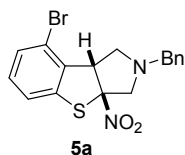
3m, 26.1 mg, 83% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.59 (s, 1H), 7.43 (d, $J = 8.4$ Hz, 1H), 7.06 (d, $J = 8.4$ Hz, 1H), 5.01 (t, $J = 6.4$ Hz, 1H), 3.73 (d, $J = 10.4$ Hz, 1H), 3.35 – 3.30 (m, 1H), 3.10 (d, $J = 10.4$ Hz, 1H), 2.71 (dd, $J = 9.6, 6.0$ Hz, 1H), 2.36 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 142.3, 136.8, 134.3, 128.7, 123.6, 118.2, 106.7, 67.1, 65.6, 53.2, 41.1. ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{11}\text{BrN}_2\text{O}_2\text{S}+\text{H}^+$ 314.9797 (^{81}Br) and 316.9777 (^{83}Br), found 314.9796, 316.9771.



3n, 25.4 mg, 81% yield, colorless oil. $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.34 – 7.26 (m, 3H), 5.00 (t, $J = 6.4$ Hz, 1H), 3.72 (d, $J = 10.4$ Hz, 1H), 3.34 – 3.30 (m, 1H), 3.08 (d, $J = 10.4$ Hz, 1H), 2.72 (dd, $J = 9.6, 5.6$ Hz, 1H), 2.36 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 145.4, 134.0, 128.4, 126.7, 125.7, 125.1, 106.5, 67.1, 65.6, 53.1, 41.1. ESI-HRMS: calcd. for $\text{C}_{11}\text{H}_{11}\text{BrN}_2\text{O}_2\text{S}+\text{H}^+$ 314.9797 (^{81}Br) and 316.9777 (^{83}Br), found 314.9797, 316.9775.

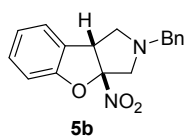


3o, 26.4 mg, 84% yield, colorless oil. ¹H NMR (400 MHz, CDCl₃) δ 7.48 (d, *J* = 8.0 Hz, 1H), 7.42 (d, *J* = 7.6 Hz, 1H), 7.04 (t, *J* = 8.0 Hz, 1H), 4.97 (t, *J* = 6.8 Hz, 1H), 3.74 (d, *J* = 10.4 Hz, 1H), 3.33 (dd, *J* = 9.6, 7.6 Hz, 1H), 3.10 (d, *J* = 10.4 Hz, 1H), 2.76 (dd, *J* = 10.0, 6.0 Hz, 1H), 2.36 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 145.4, 136.0, 134.1, 126.7, 124.2, 115.9, 108.3, 67.3, 65.5, 51.7, 41.1. ESI-HRMS: calcd. for C₁₁H₁₁BrN₂O₂S+H⁺ 314.9797 (⁸¹Br) and 316.9777 (⁸³Br), found 314.9797, 316.9773.



5a, 35.5 mg, 91% yield, pale white solid. ¹H NMR (400 MHz, CDCl₃) δ 7.37 – 7.32 (m, 4H), 7.31 – 7.30 (m, 2H), 7.20 – 7.19 (m, 2H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.42 – 4.38 (m, 1H), 3.74 (q, *J* = 13.2 Hz, 2H), 3.57 – 3.53 (m, 1H), 2.88 (d, *J* = 11.6 Hz, 1H), 2.43 (t, *J* = 9.2 Hz, 1H). ¹³C NMR (100 MHz, CDCl₃) δ 146.3, 137.4, 134.7, 132.2, 129.3, 128.6, 127.5,

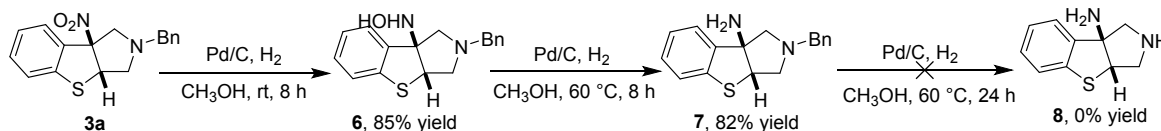
121.9, 121.5, 107.3, 63.6, 62.7, 58.6, 55.9. ESI-HRMS: calcd. for C₁₇H₁₅BrN₂O₂S+H⁺ 391.0110 (⁸¹Br) and 393.0090 (⁸³Br), found 391.0110, 393.0086.



5b, 23.9 mg, 90% yield, pale white solid. ¹H NMR (400 MHz, CDCl₃) δ 7.31 – 7.22 (m, 6H), 7.15 (d, *J* = 7.2 Hz, 1H), 7.01 (t, *J* = 7.0 Hz, 2H), 4.34 (dd, *J* = 7.6, 3.6 Hz, 1H), 3.73 – 3.65 (m, 2H), 3.35 (q, *J* = 10.4 Hz, 2H), 3.18 (t, *J* = 8.6 Hz, 1H), 2.93 (dd, *J* = 9.2, 3.6 Hz, 1H). ¹³C NMR (100 MHz, CDCl₃) δ 158.8, 137.1, 129.4, 128.6, 128.5, 127.5, 126.8, 124.3, 123.0, 122.2,

110.2, 62.8, 60.2, 58.7, 53.7. ESI-HRMS: calcd. for C₁₇H₁₆N₂O₃+H⁺ 297.1234, found 297.1234.

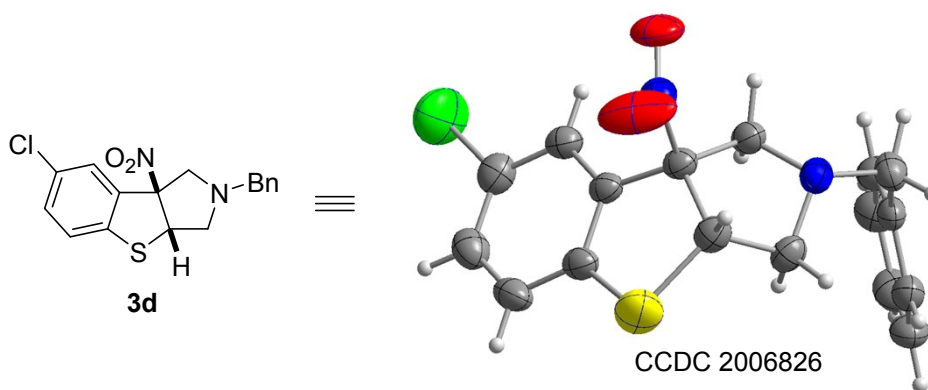
4. Transformations of product 3a



To a solution of compound **3a** (0.5 mmol, 156 mg) in MeOH (5 mL) was added the Pd/C (15.6 mg, 10 wt%), followed by degassing with H₂ for three times at room temperature, and the resultant mixture was then stirred at the room temperature under a balloon pressure of H₂ for 8 h until the reaction was completed as monitored by TLC analysis. Then, the reaction mixture was filtrated off through a celite pad. The filtrate was concentrated under vacuum, and the residue was purified by a flash column chromatography on silica gel (PE /EA = 2:1) to give the product **6** (119.9 mg, 85% yield) as a colourless oil. ¹H NMR (400 MHz, CDCl₃) δ 7.30 – 7.28 (m, 2H), 7.25 – 7.22 (m, 3H), 7.20 – 7.16 (m, 2H), 7.12 (d, *J* = 7.6 Hz, 1H), 7.04 (t, *J* = 7.2 Hz, 1H), 6.08 (br, 1H), 5.52 (br, 1H), 4.24 (t, *J* = 7.2 Hz, 1H), 3.54 (dd, *J* = 31.6, 12.8 Hz, 2H), 3.35 – 3.31 (m, 1H), 3.12 (d, *J* = 10.0 Hz, 1H), 2.60 – 2.51 (m, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 142.3, 139.6, 137.9, 129.5, 128.8, 128.4, 127.3, 125.6, 124.4, 122.1, 84.2, 63.6, 63.1, 59.4, 50.7. ESI-HRMS: calcd. for C₁₇H₁₈N₂OS+H⁺ 299.1213, found 299.1214.

To a solution of compound **6** (0.3 mmol, 90 mg) in MeOH (2 mL) was added the Pd/C (9.0 mg, 10 wt%), followed by degassing with H₂ for three times at room temperature, and the resultant mixture was then stirred at the 60 °C under a balloon pressure of H₂ for 8 h until the reaction was completed as monitored by TLC analysis. Then, the reaction mixture was filtrated off through a celite pad. The filtrate was concentrated under vacuum, and the residue was purified by a flash column chromatography on silica gel (PE /EA = 1:1) to give the product **7** (69.4 mg, 82% yield) as a colourless oil. ¹H NMR (400 MHz, CDCl₃) δ 7.29 – 7.23 (m, 5H), 7.21 – 7.16 (m, 2H), 7.12 – 7.05 (m, 2H), 3.83 (t, *J* = 6.4 Hz, 1H), 3.59 (q, *J* = 13.2 Hz, 2H), 3.33 (dd, *J* = 9.6, 7.2 Hz, 1H), 2.93 (d, *J* = 9.6 Hz, 1H), 2.81 (d, *J* = 9.6 Hz, 1H), 2.65 (dd, *J* = 9.6, 5.6 Hz, 1H), 1.96 (s, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 143.7, 140.6, 138.2, 129.0, 128.7, 128.3, 127.1, 124.9, 124.7, 121.8, 76.5, 67.9, 63.3, 59.5, 59.1. ESI-HRMS: calcd. for C₁₇H₁₈N₂S+H⁺ 283.1263, found 283.1263.

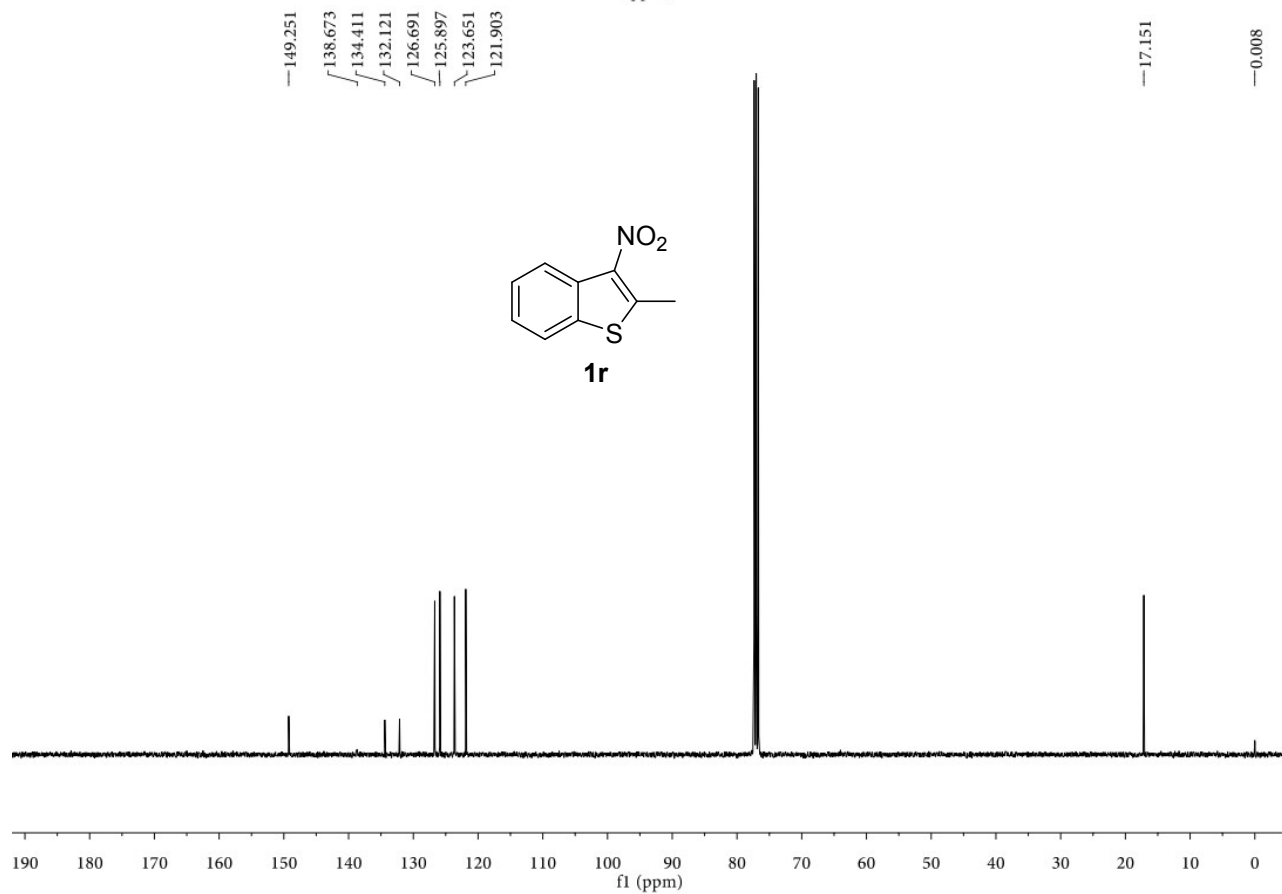
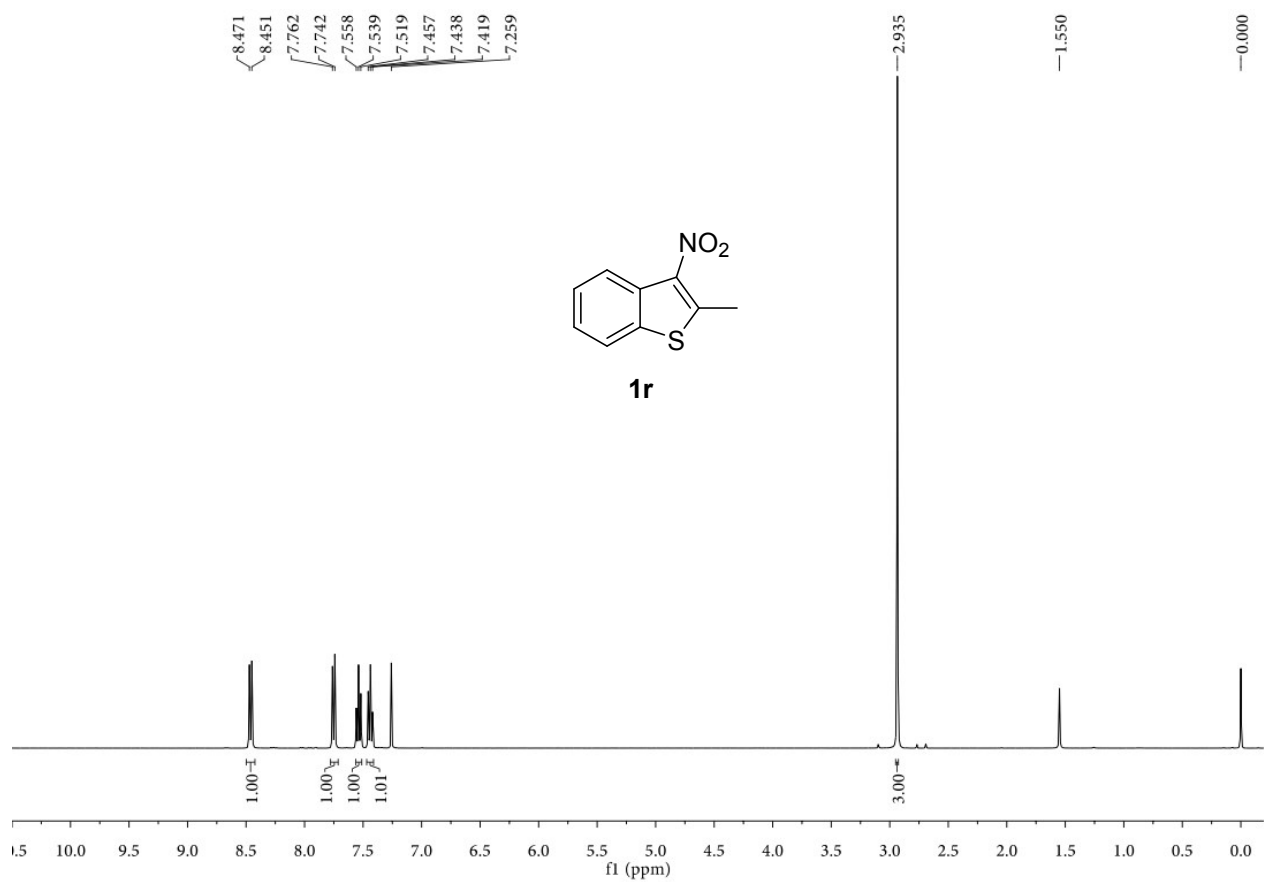
5. X-ray crystal structure of compound **3d**

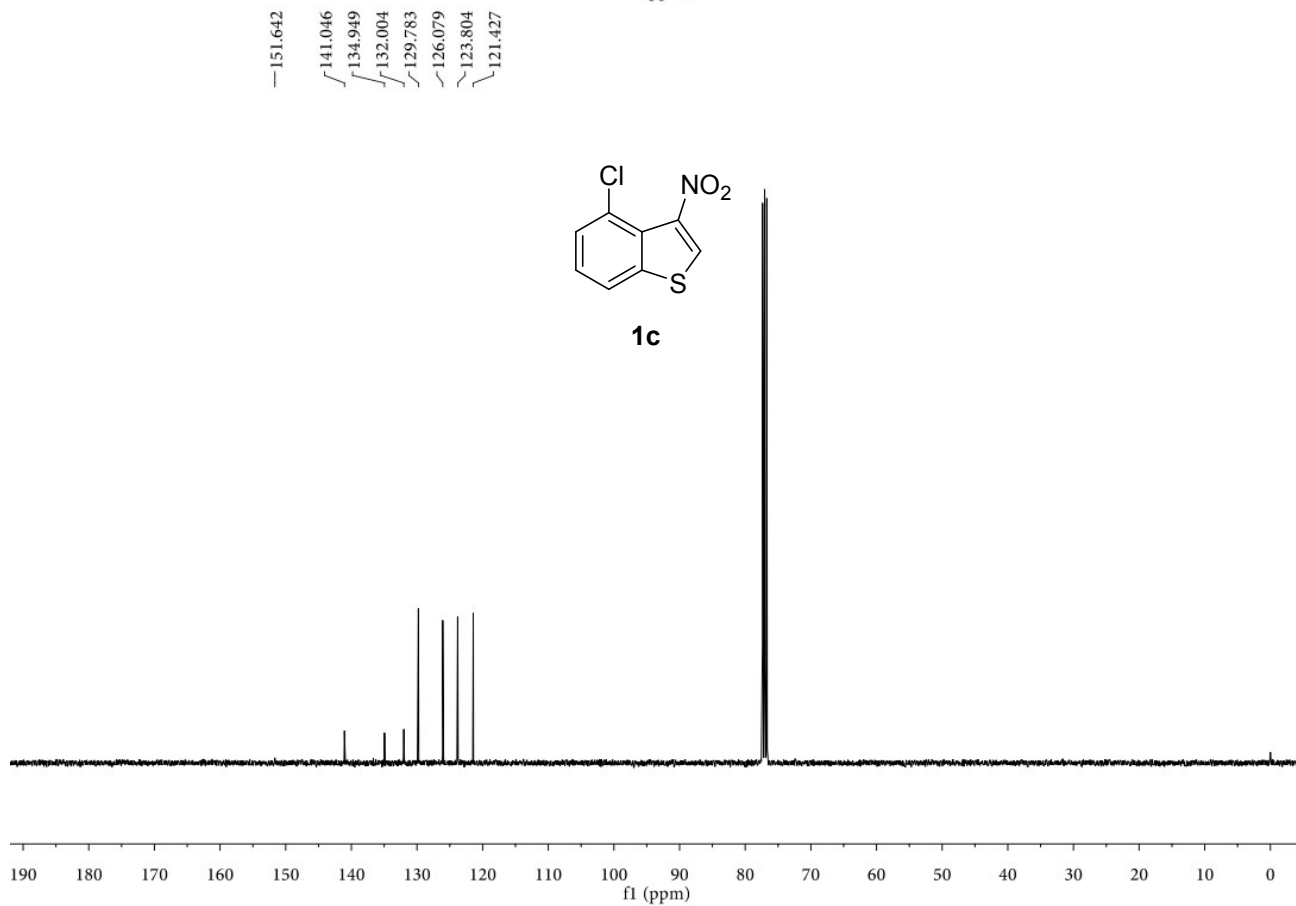
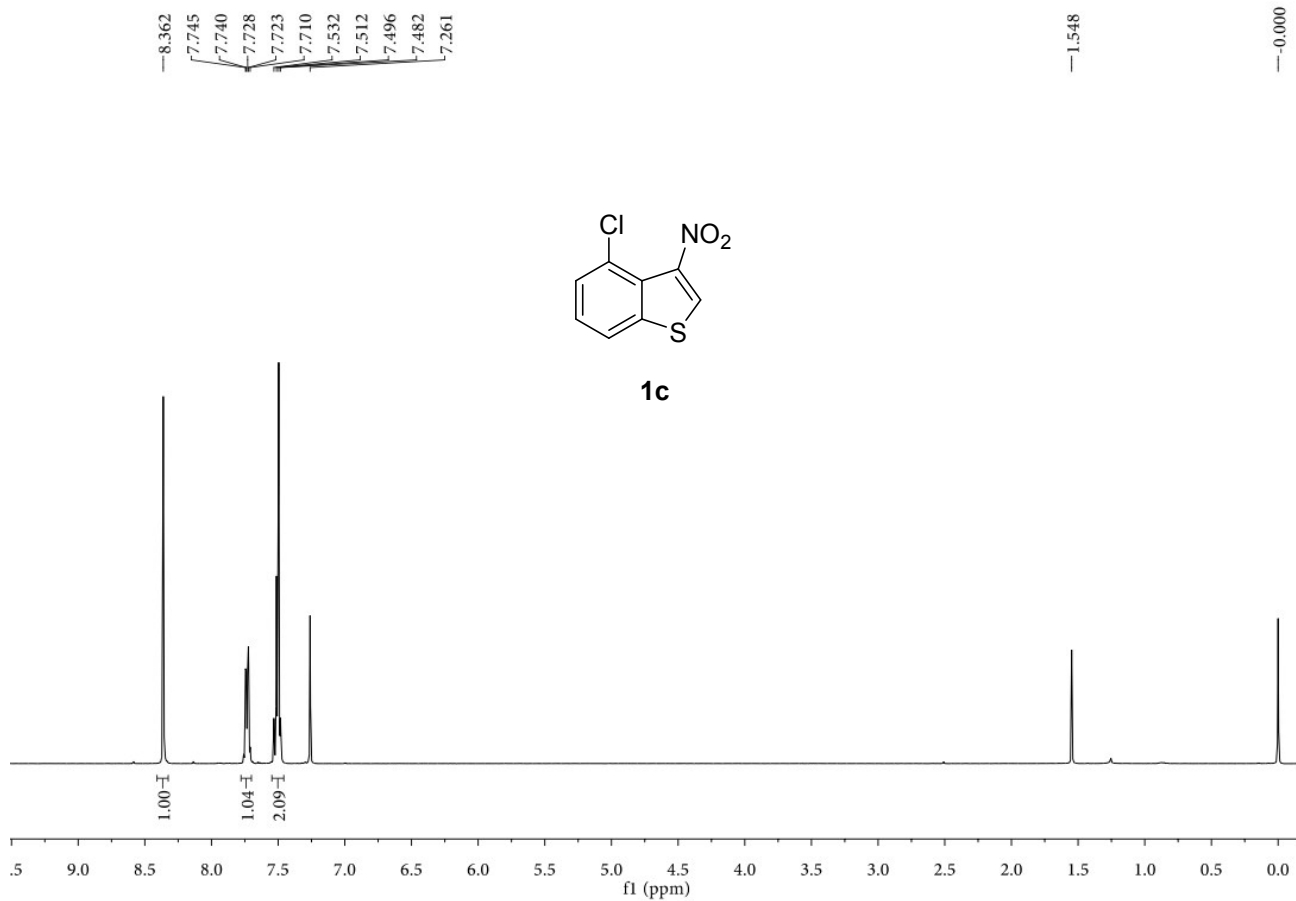


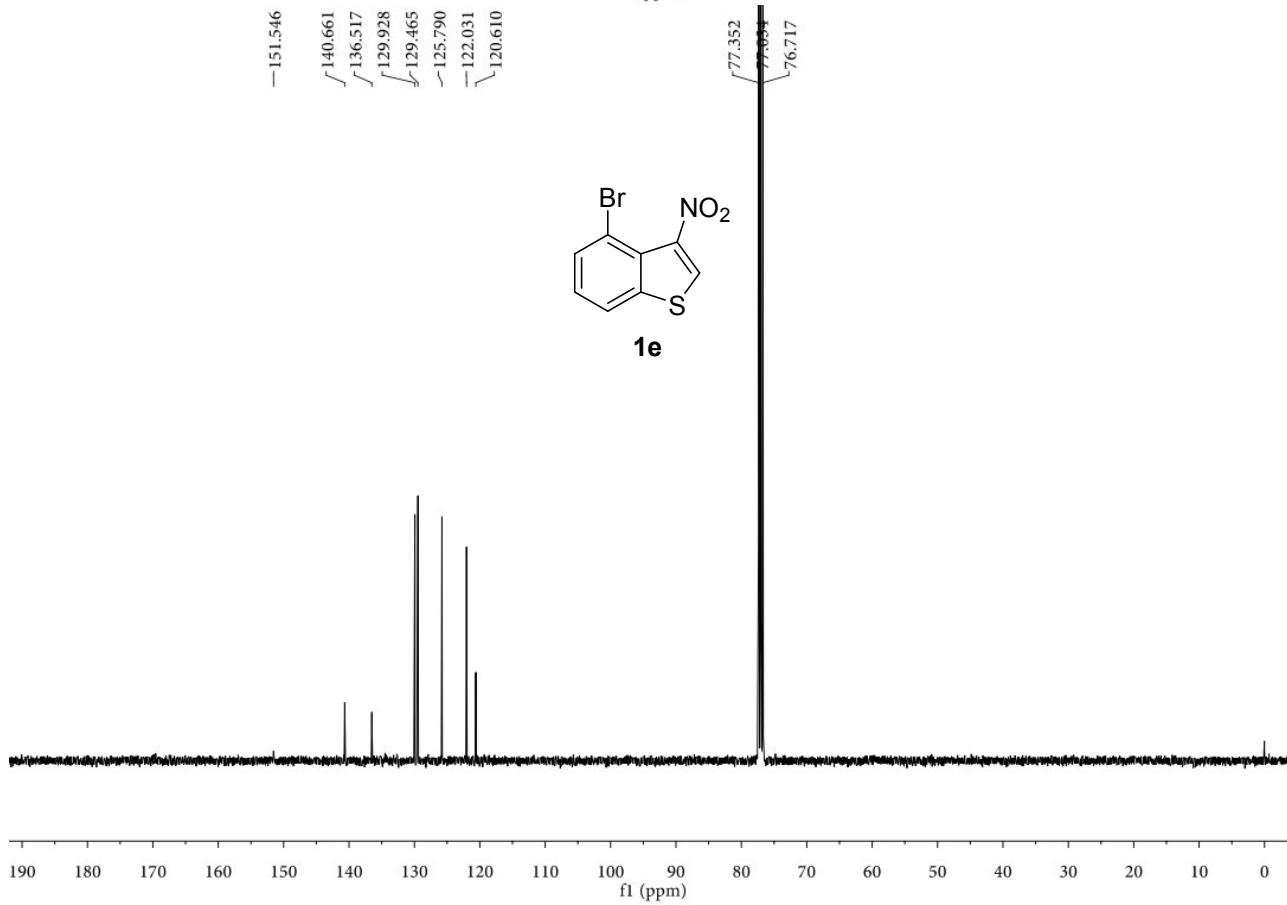
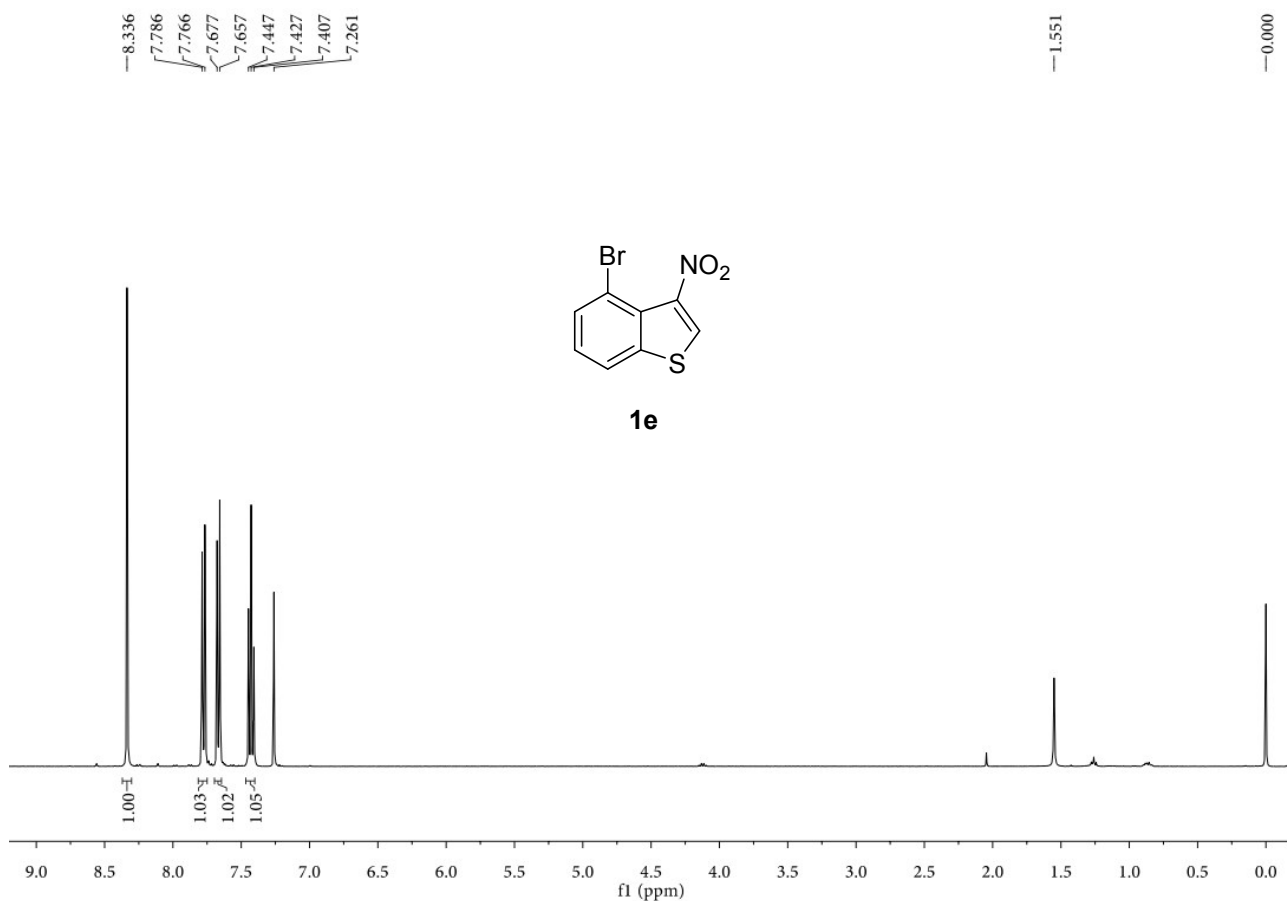
Identification code	3d
Empirical formula	C ₁₇ H ₁₅ ClN ₂ O ₂ S
Formula weight	346.82
Temperature/K	296
Crystal system	Monoclinic
Space group	P 21/c
<i>a</i> /Å	10.768(2)
<i>b</i> /Å	10.433(2)
<i>c</i> /Å	14.800(5)
<i>α</i> /°	90
<i>β</i> /°	103.502(3)
<i>γ</i> /°	90

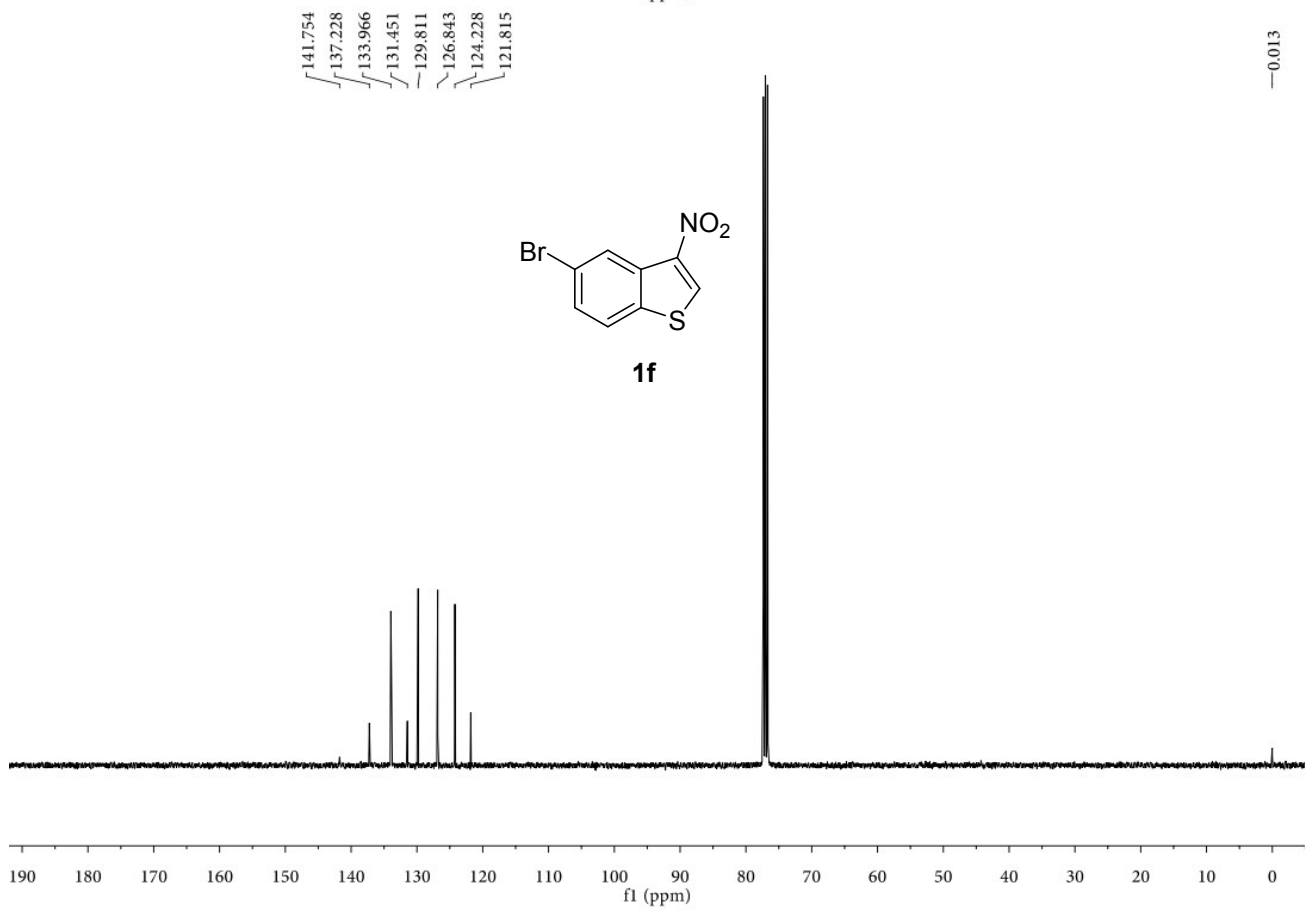
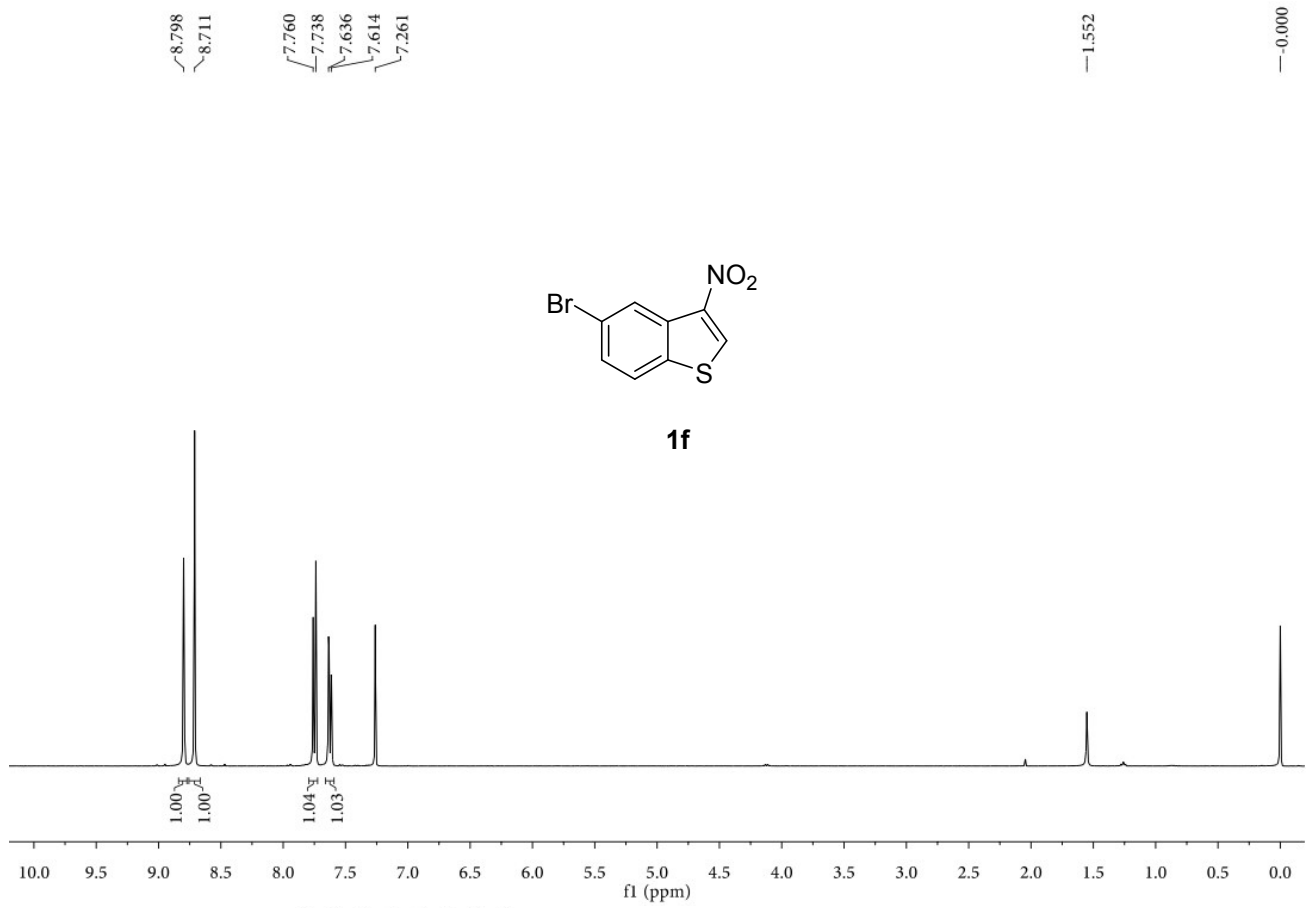
Volume/Å ³	1616.8(6)
Z	4
ρ _{calc} /cm ³	1.425
μ/mm ⁻¹	0.376
F(000)	720.0
Crystal size/mm ³	0.26 × 0.24 × 0.22
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	2.756 to 25.497
Index ranges	-13 ≤ h ≤ 12, -7 ≤ k ≤ 12, -17 ≤ l ≤ 17
Reflections collected	8288
Independent reflections	2411[R _{int} = 0.0393]
Data/restraints/parameters	2990 / 0 / 208
Goodness-of-fit on F ²	1.022
Final R indexes [I ≥ 2σ (I)]	R ₁ = 0.0393, wR ₂ = 0.1041
R indices (all data)	R ₁ = 0.0510, wR ₂ = 0.1106
Largest diff. peak and hole	0.042 / -0.303

6. NMR spectra





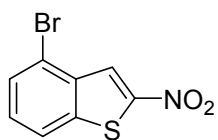




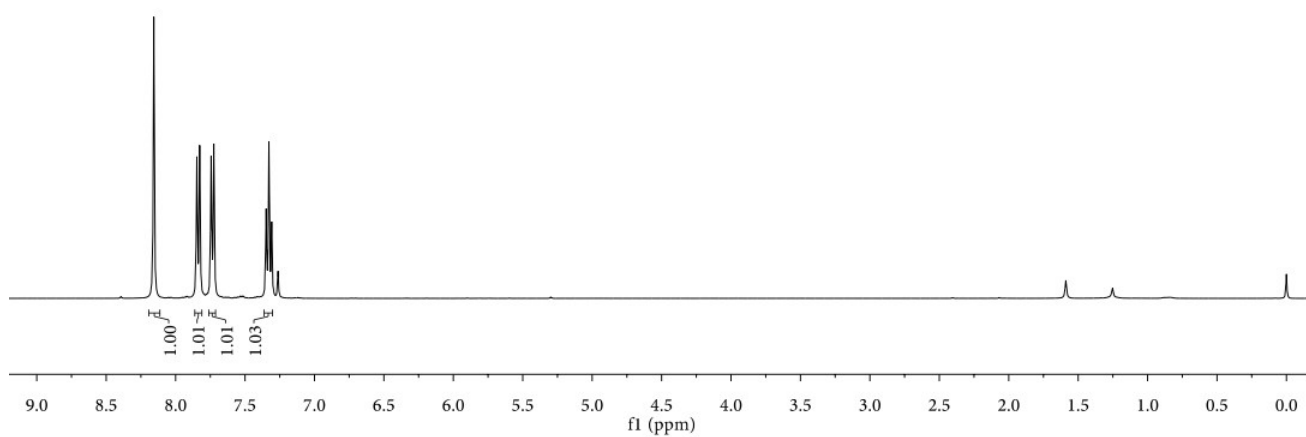
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7.725
7.348
7.328
7.308
7.262

-1.589

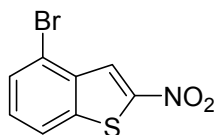
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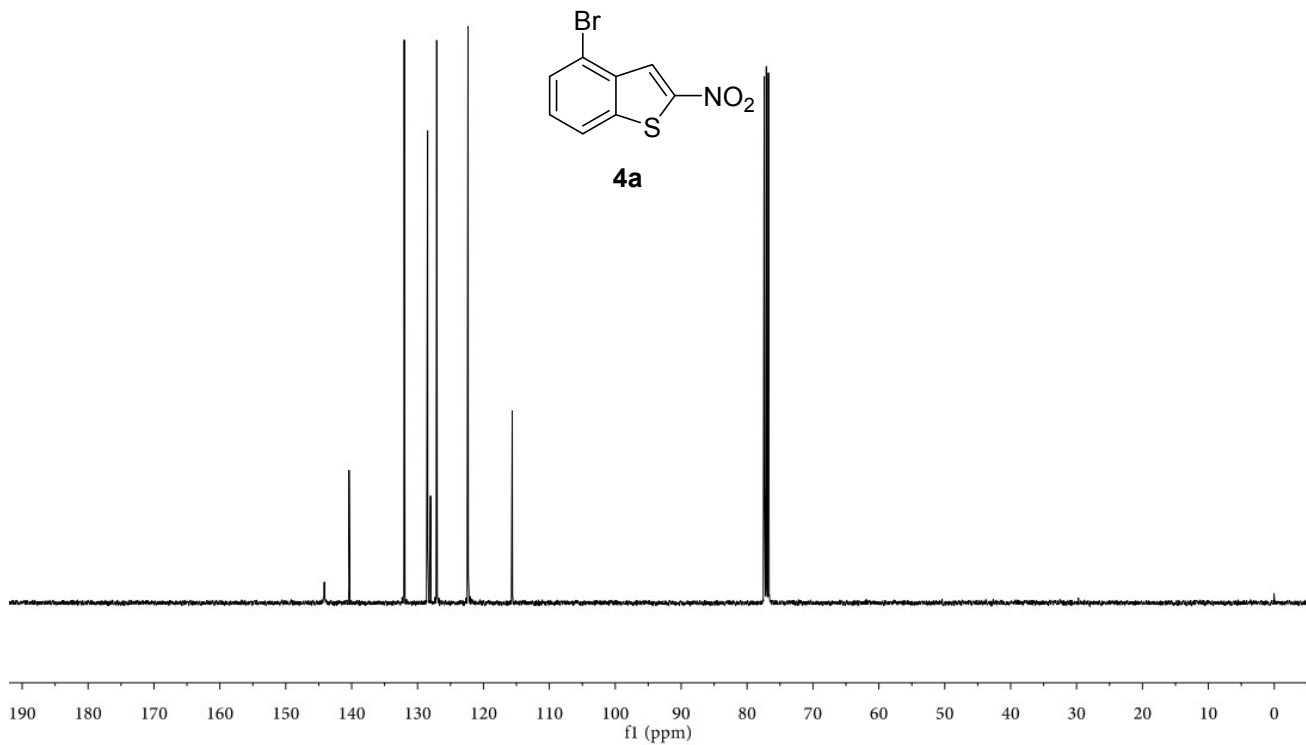
4a



144.150
140.399
132.015
128.478
128.029
127.088
122.337
115.628



4a

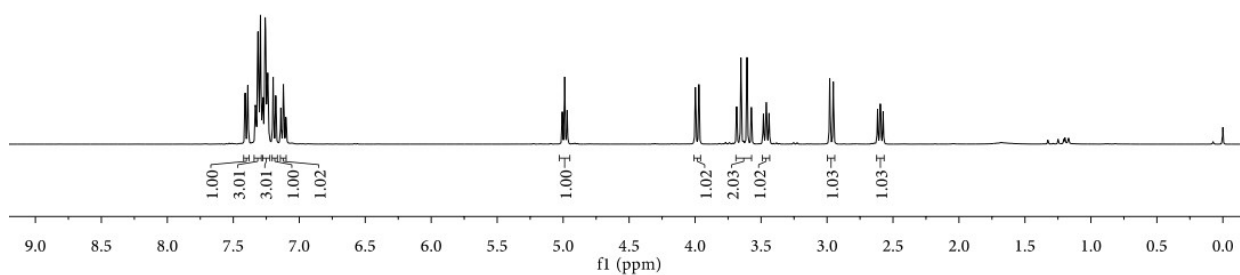
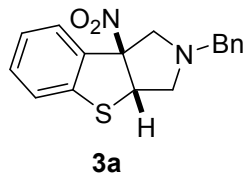


7.409
7.390
7.313
7.294
7.278
7.275
7.258
7.243
7.239
7.198
7.178
7.140
7.138
7.120
7.102
7.100

5.007
4.988
4.970

3.998
3.971
3.685
3.652
3.606
3.574
3.461
2.979
2.953
2.617
2.598
2.594
2.575

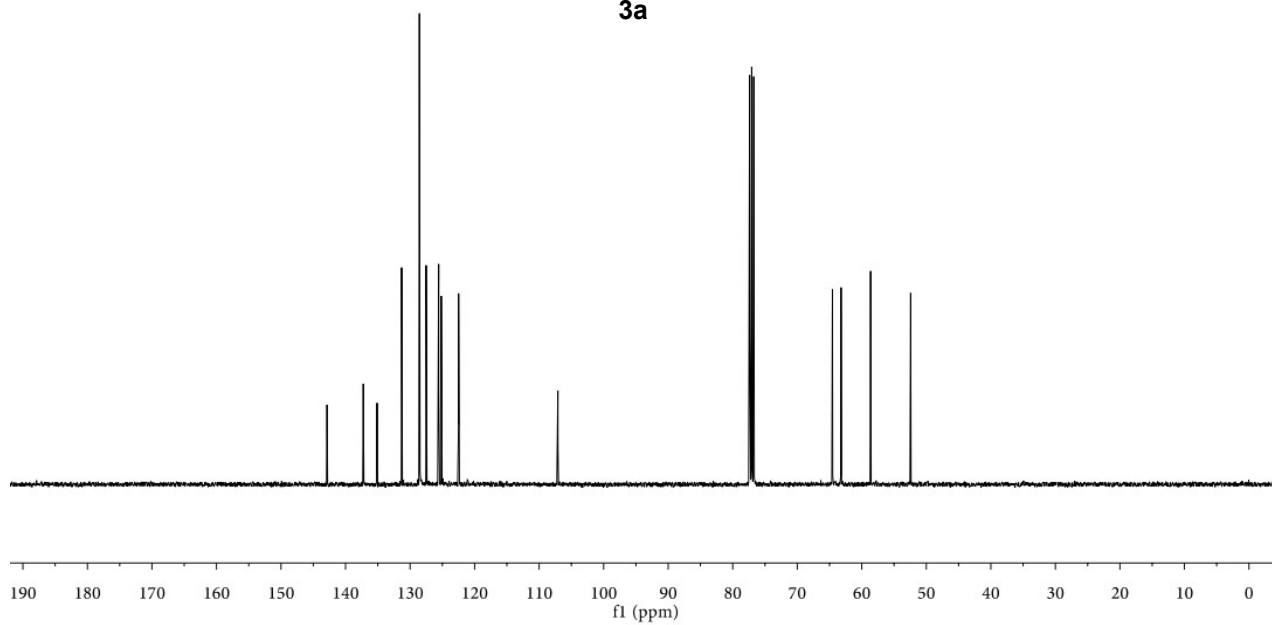
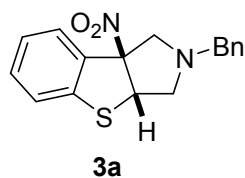
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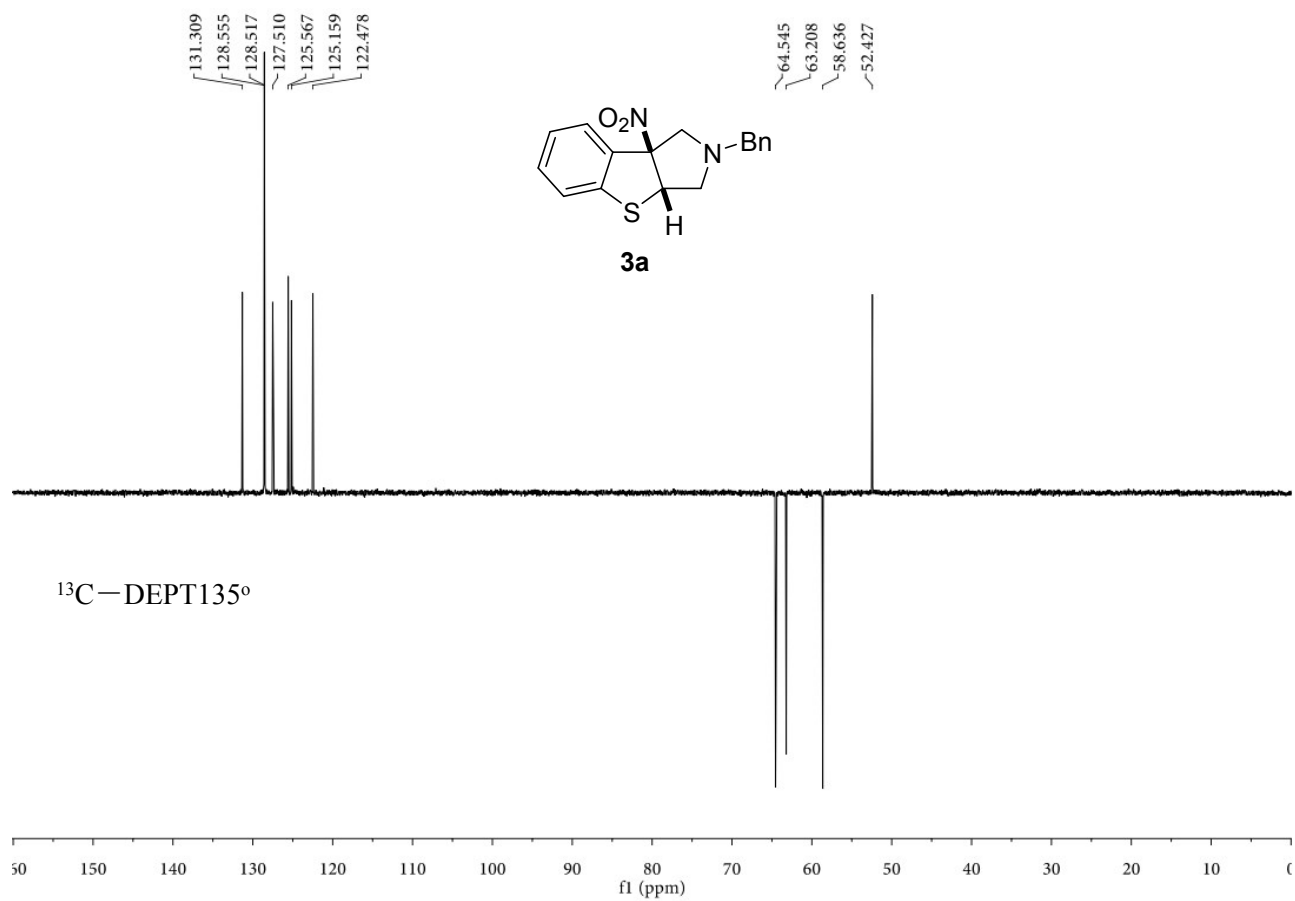


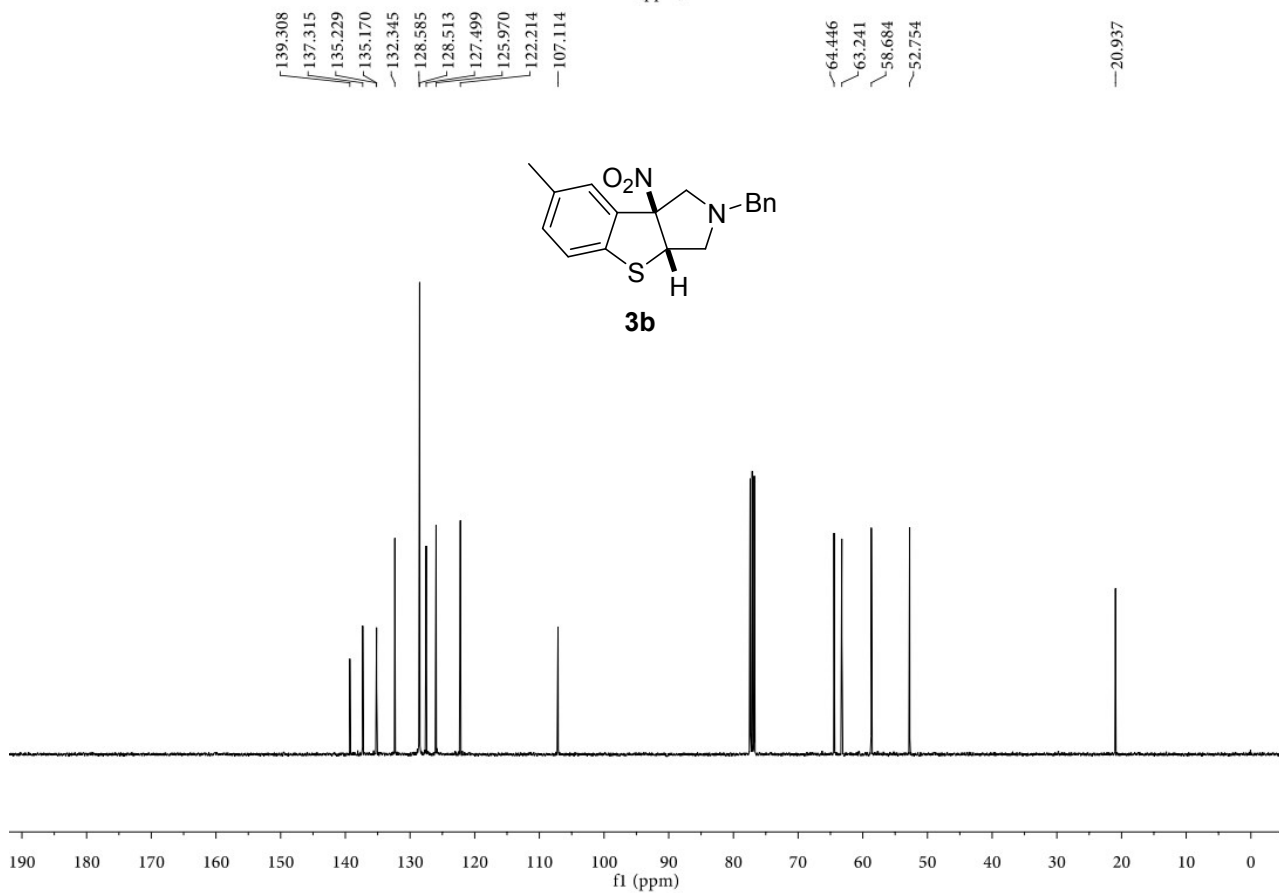
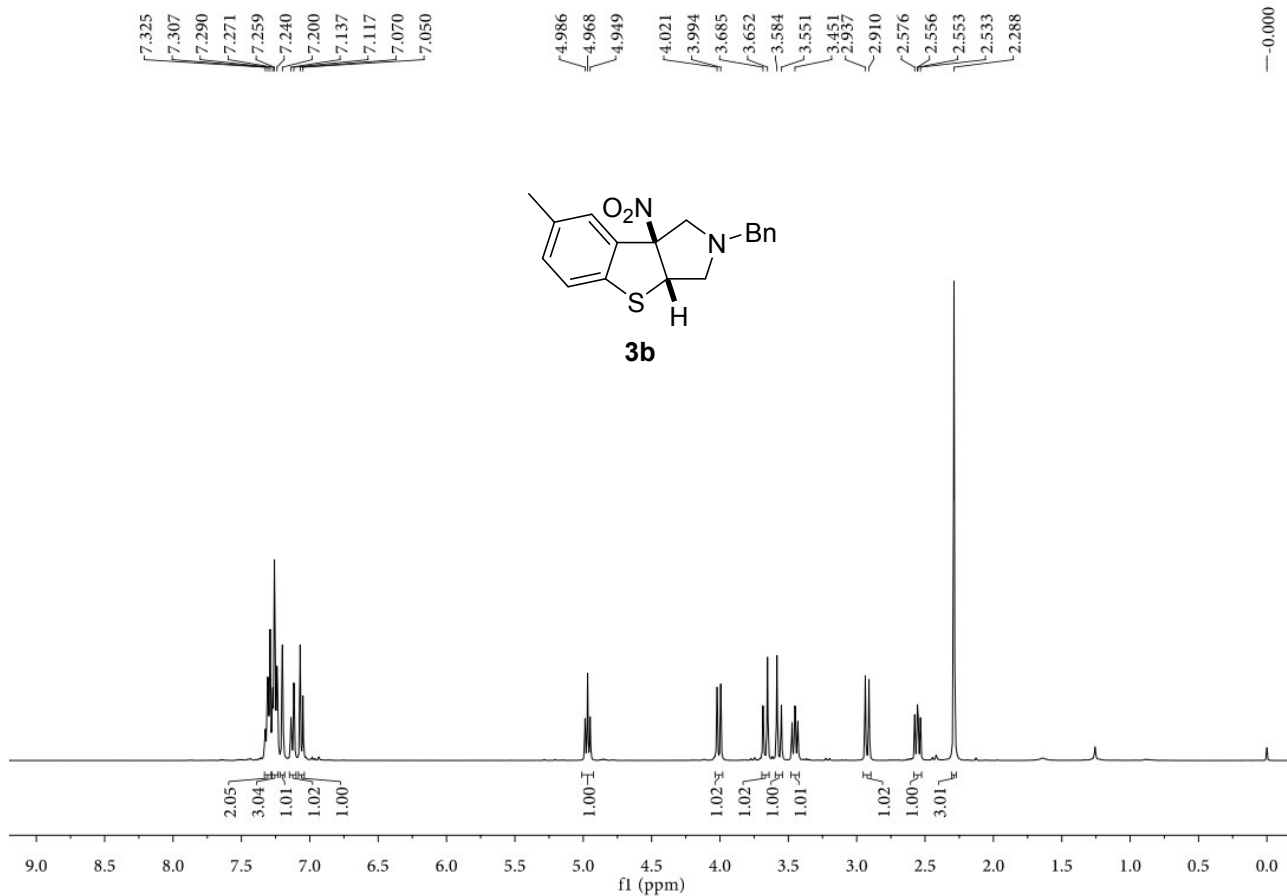
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128.518
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125.158
122.477

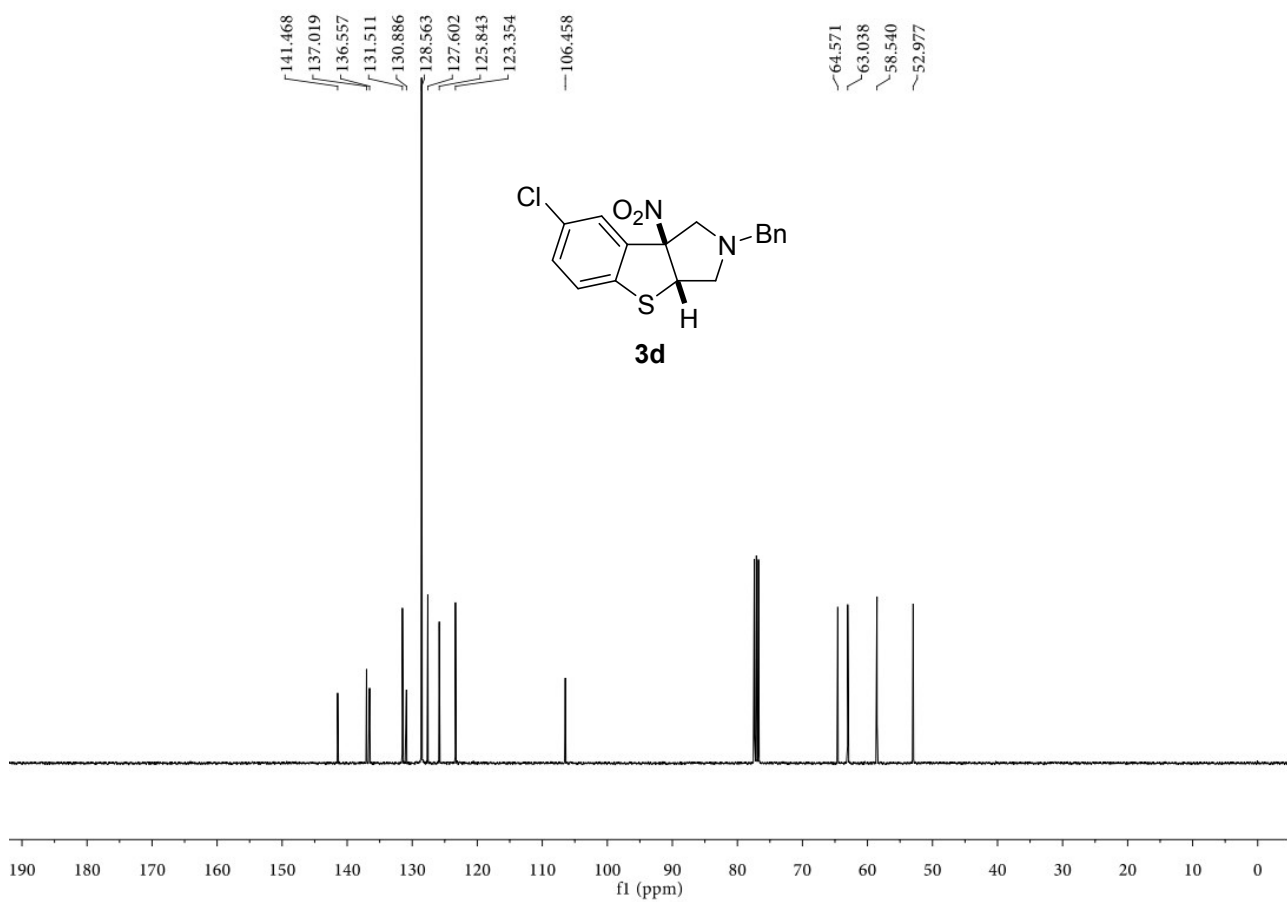
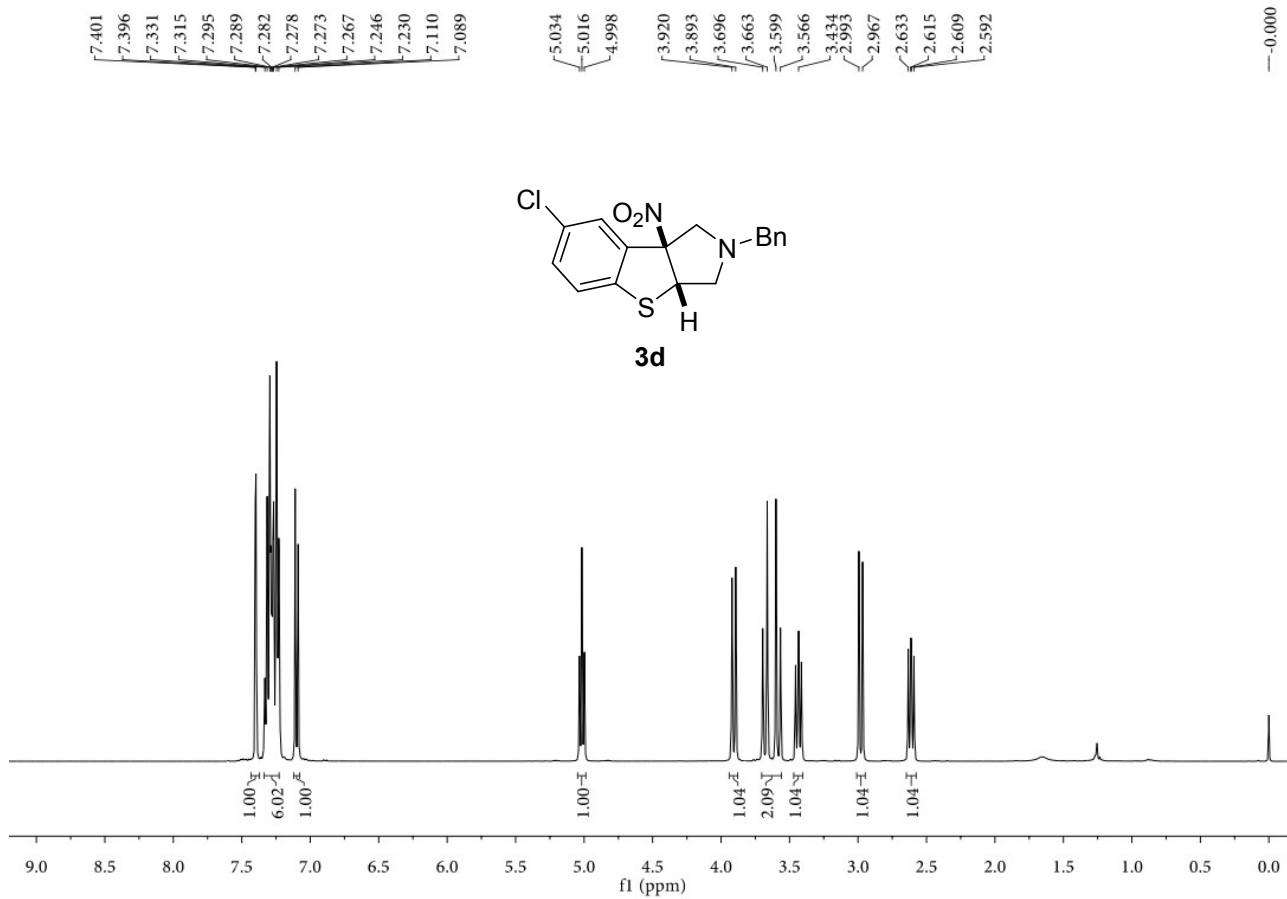
107.089

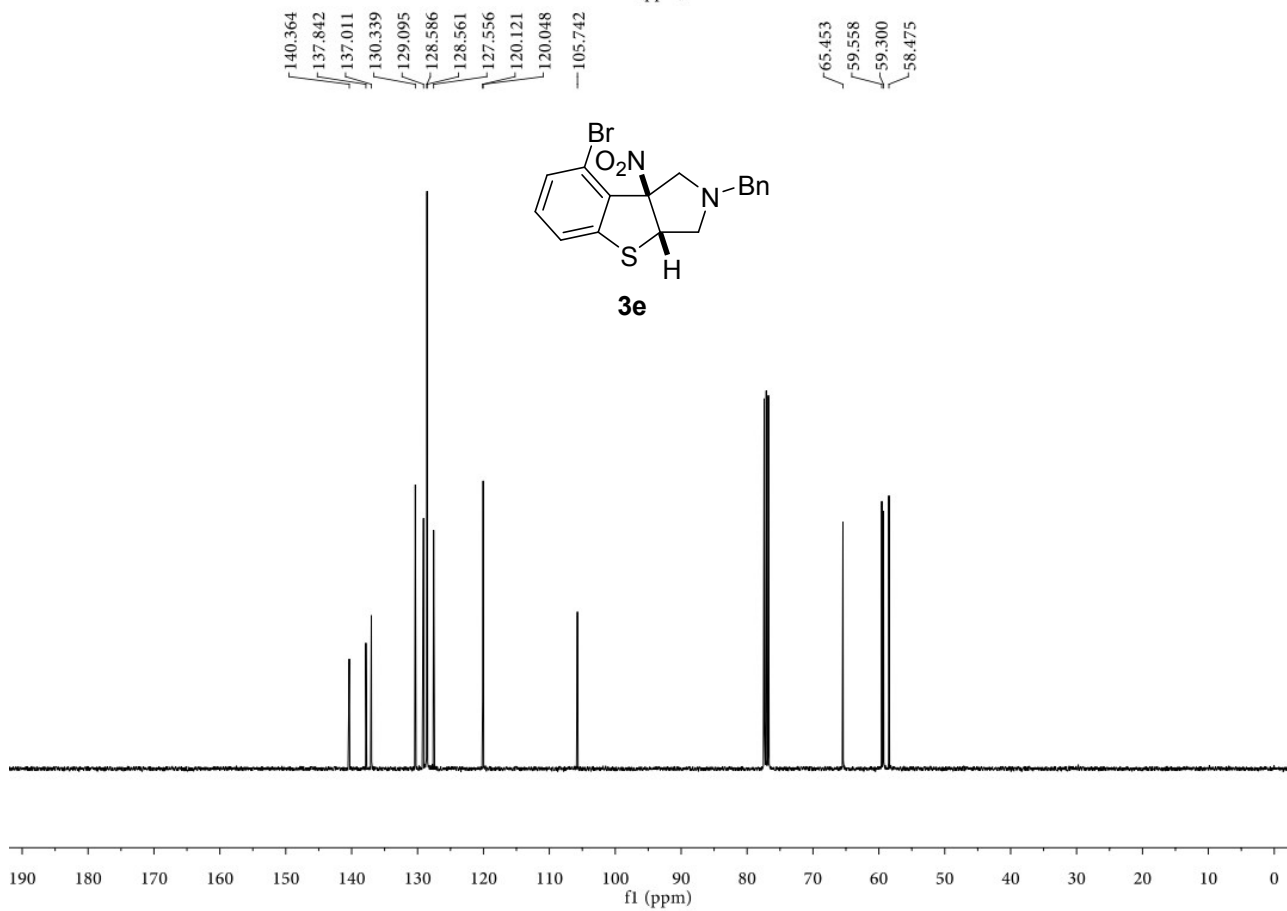
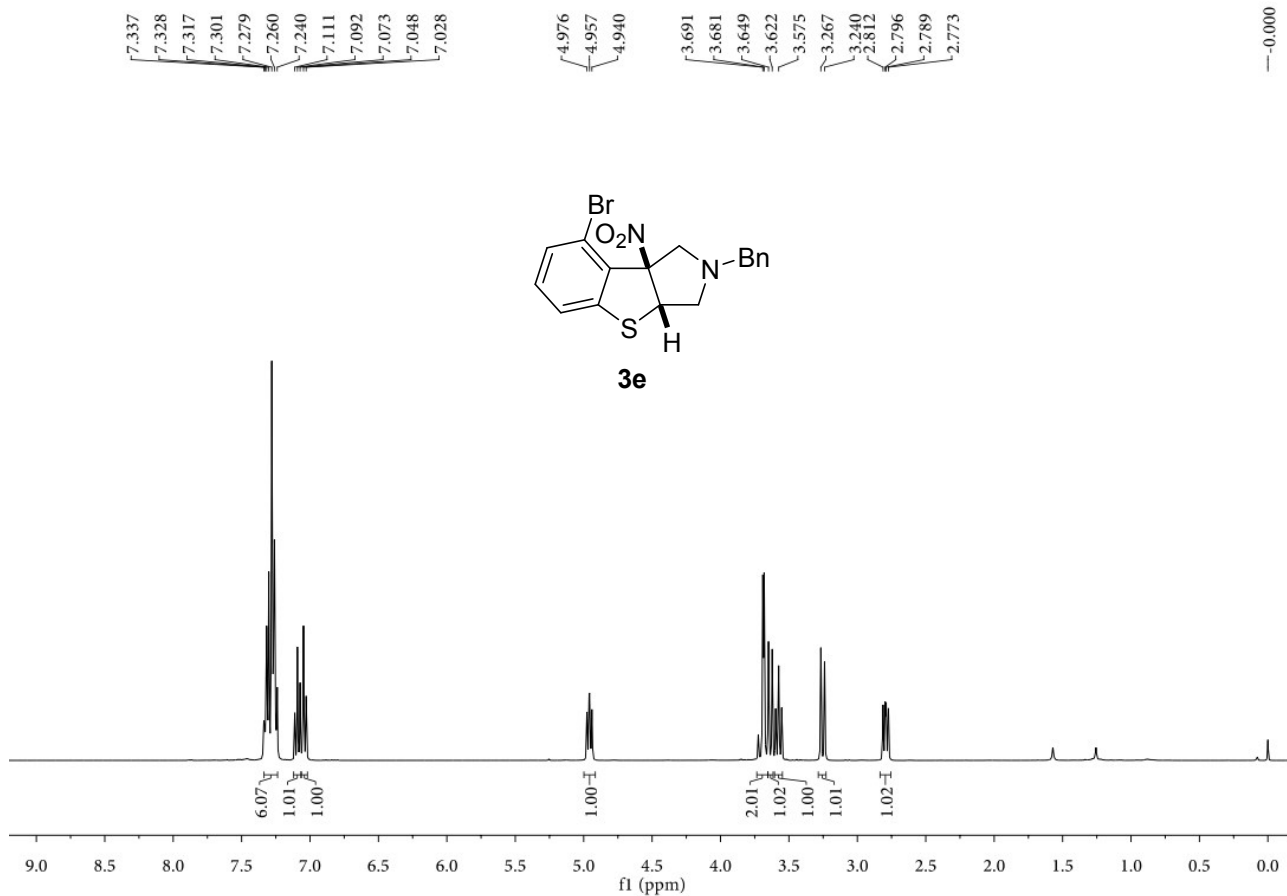
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63.207
58.635
52.427









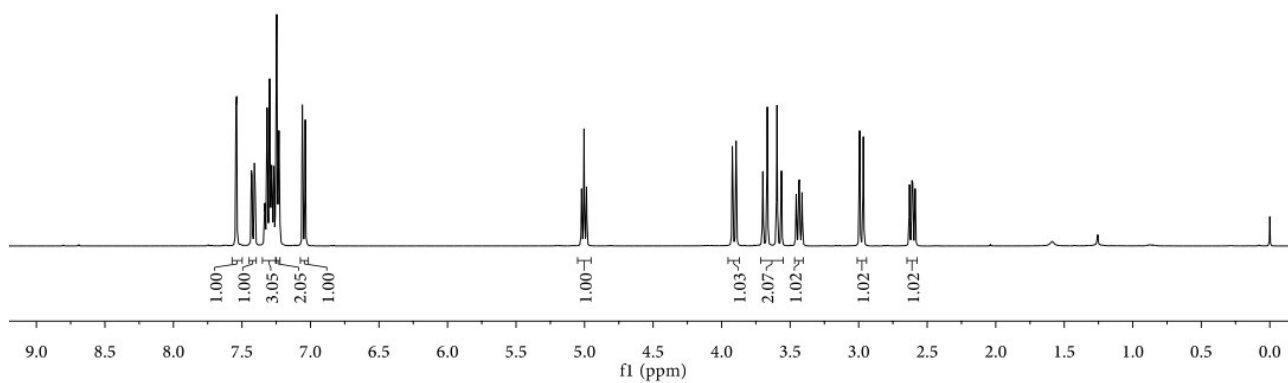
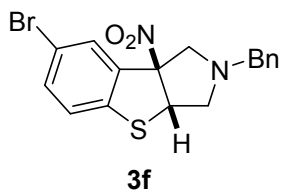


7.543
7.539
7.431
7.426
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7.298
7.283
7.267
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7.230
7.059
7.038

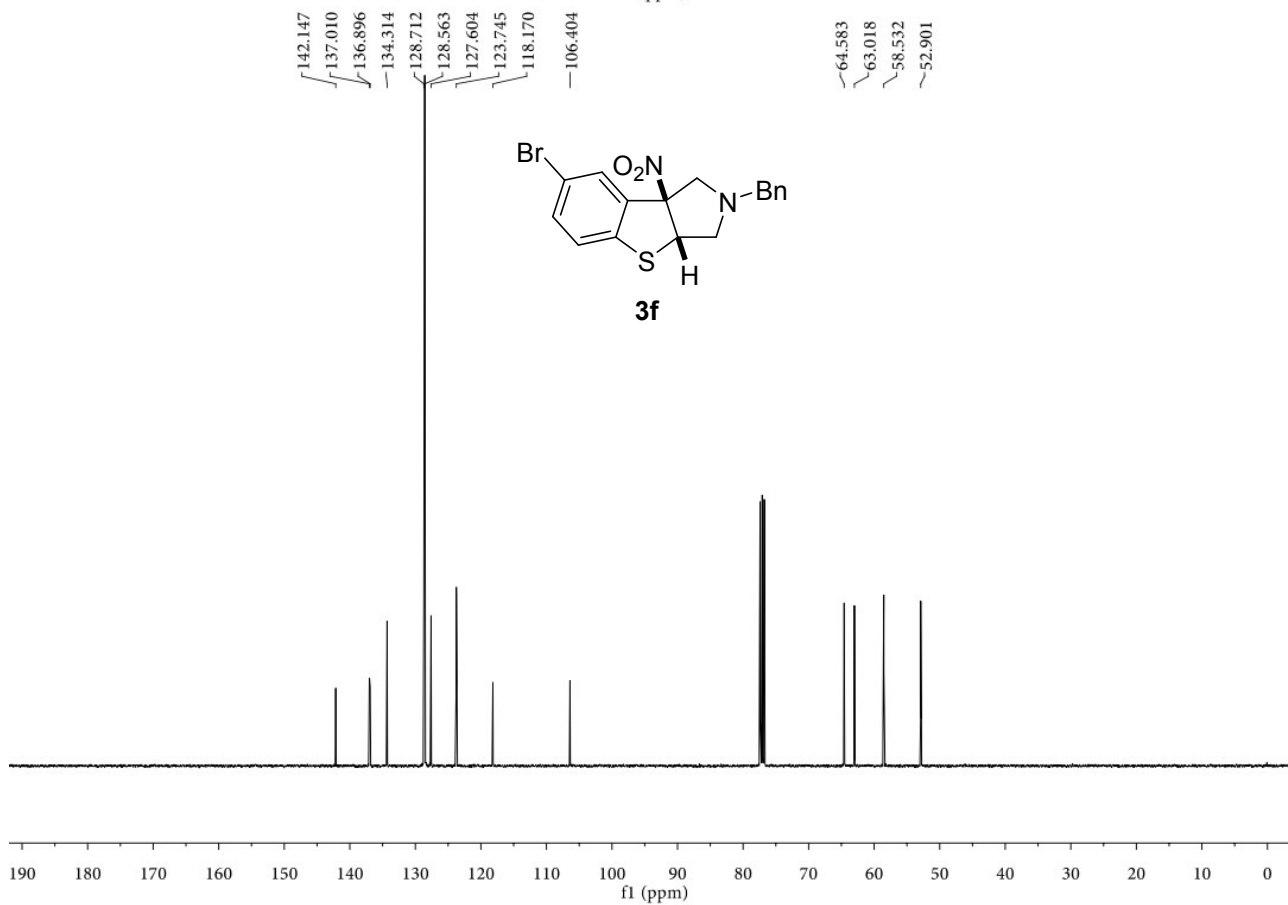
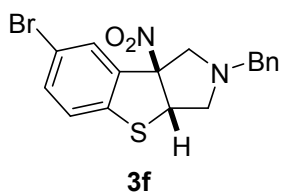
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5.004
4.986

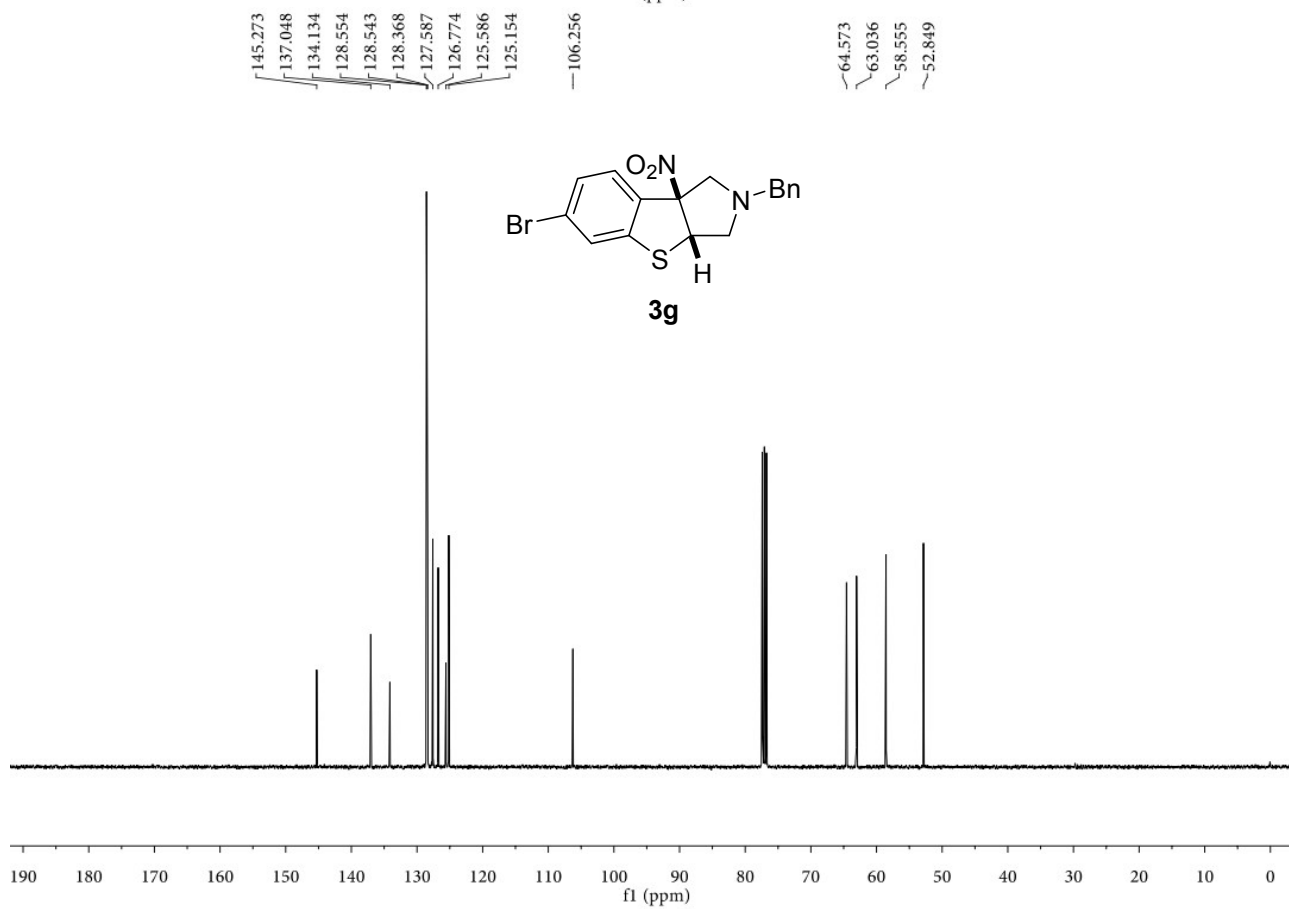
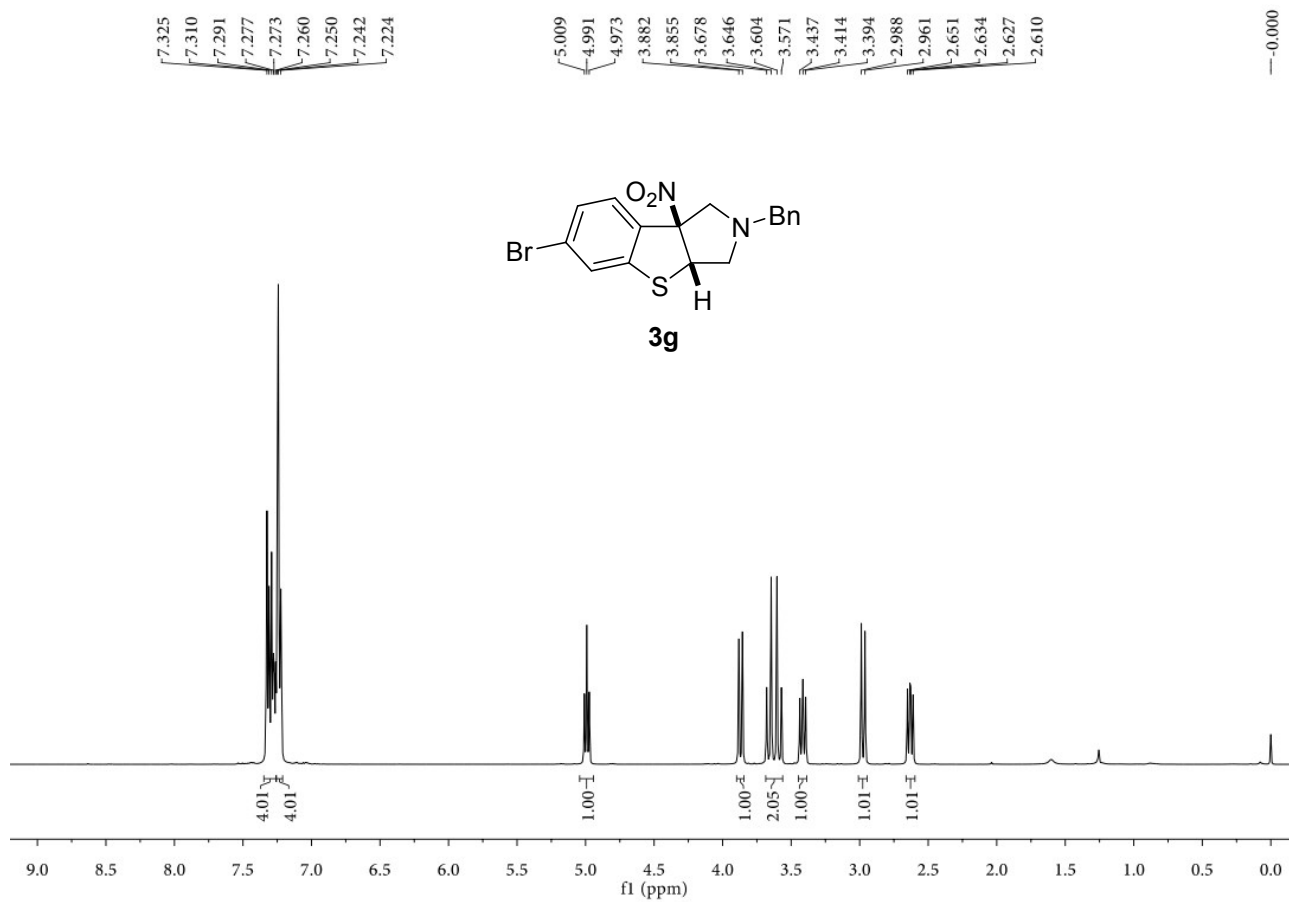
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2.611
2.605
2.588

-0.000



142.147
137.010
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128.563
127.604
123.745
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64.583
63.018
58.532
52.901





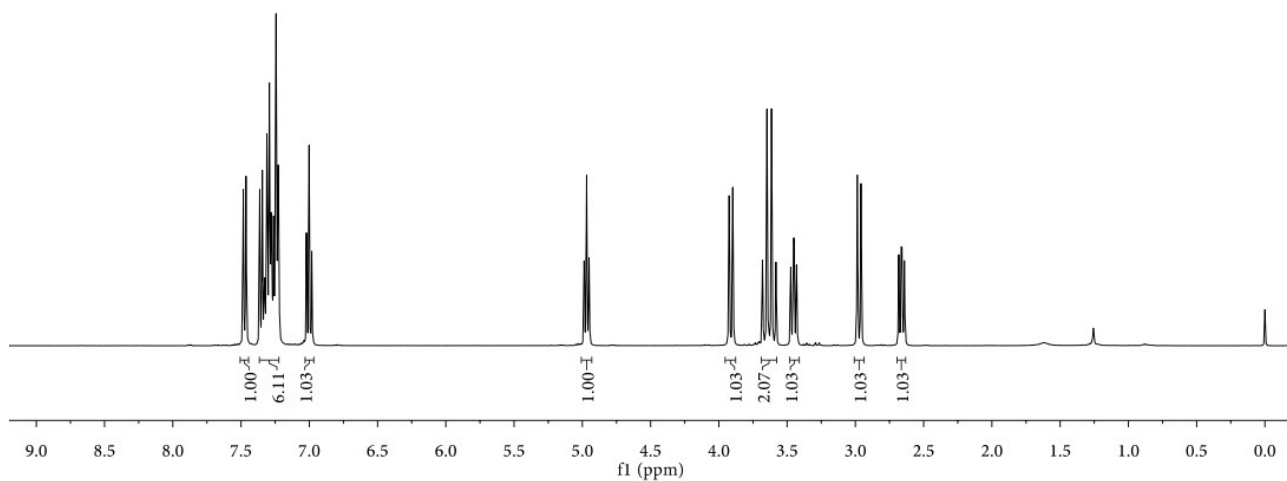
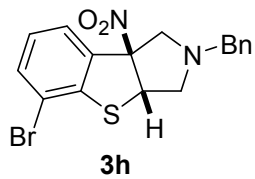
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6.982

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2.959

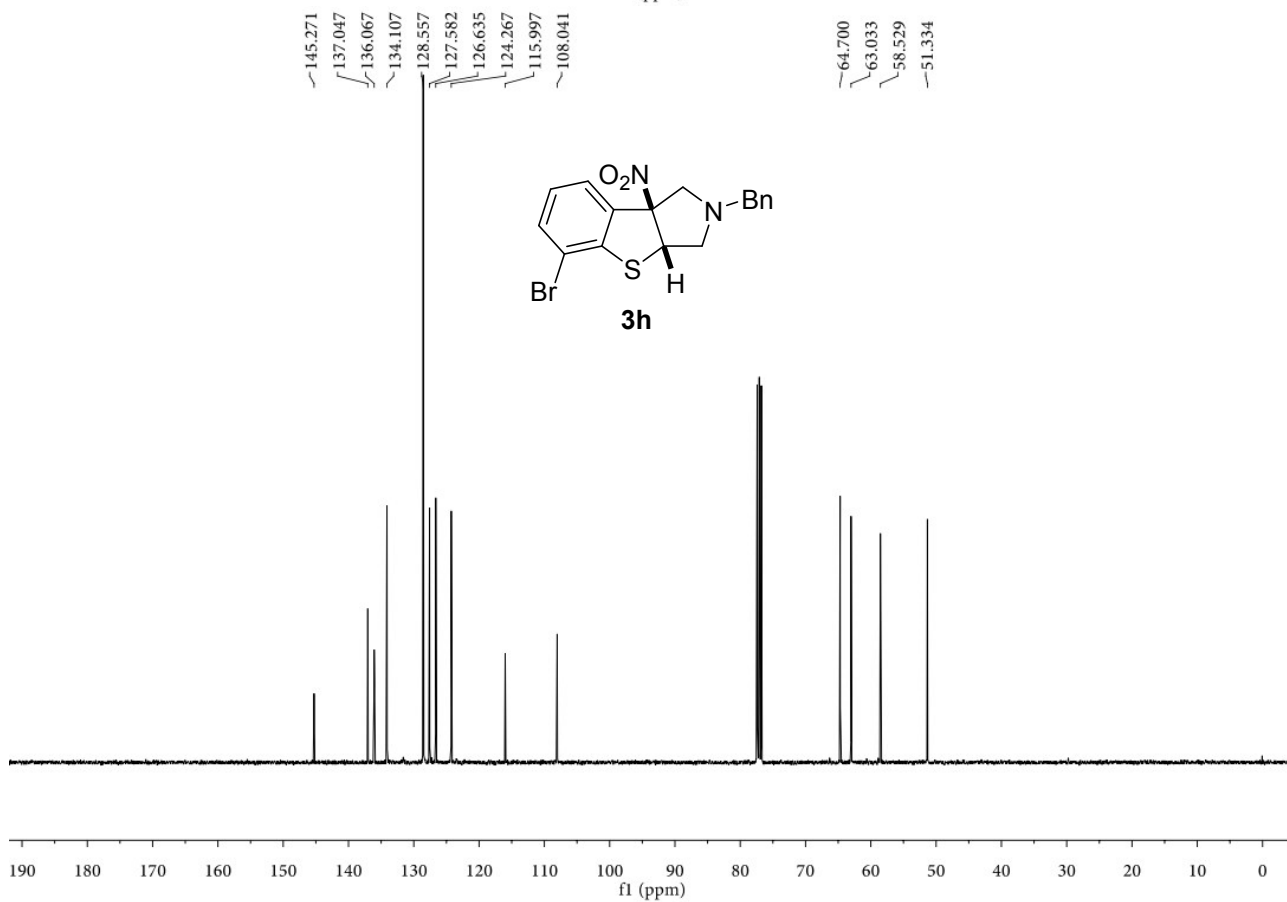
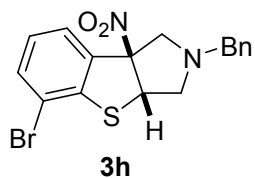
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2.659
2.641

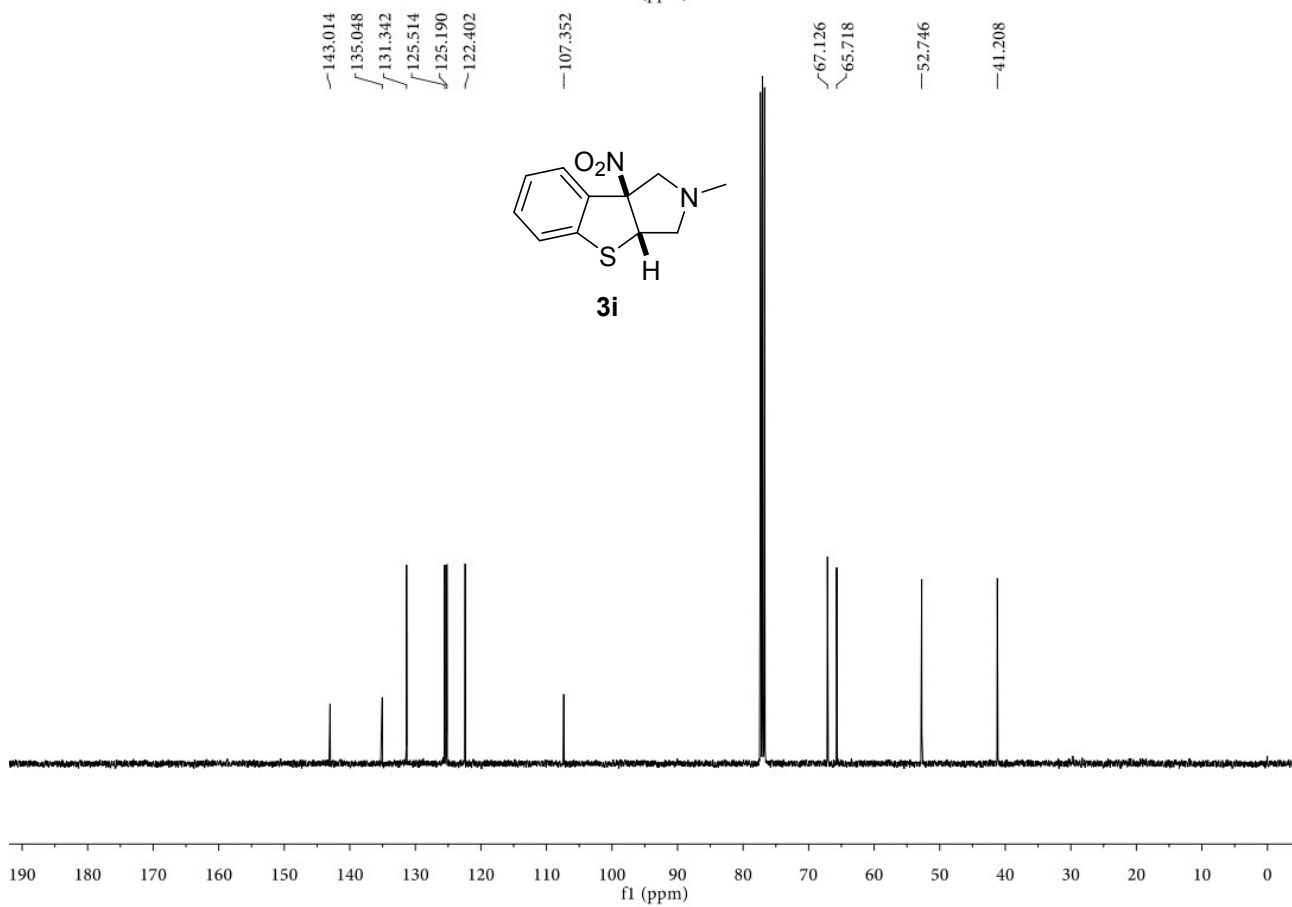
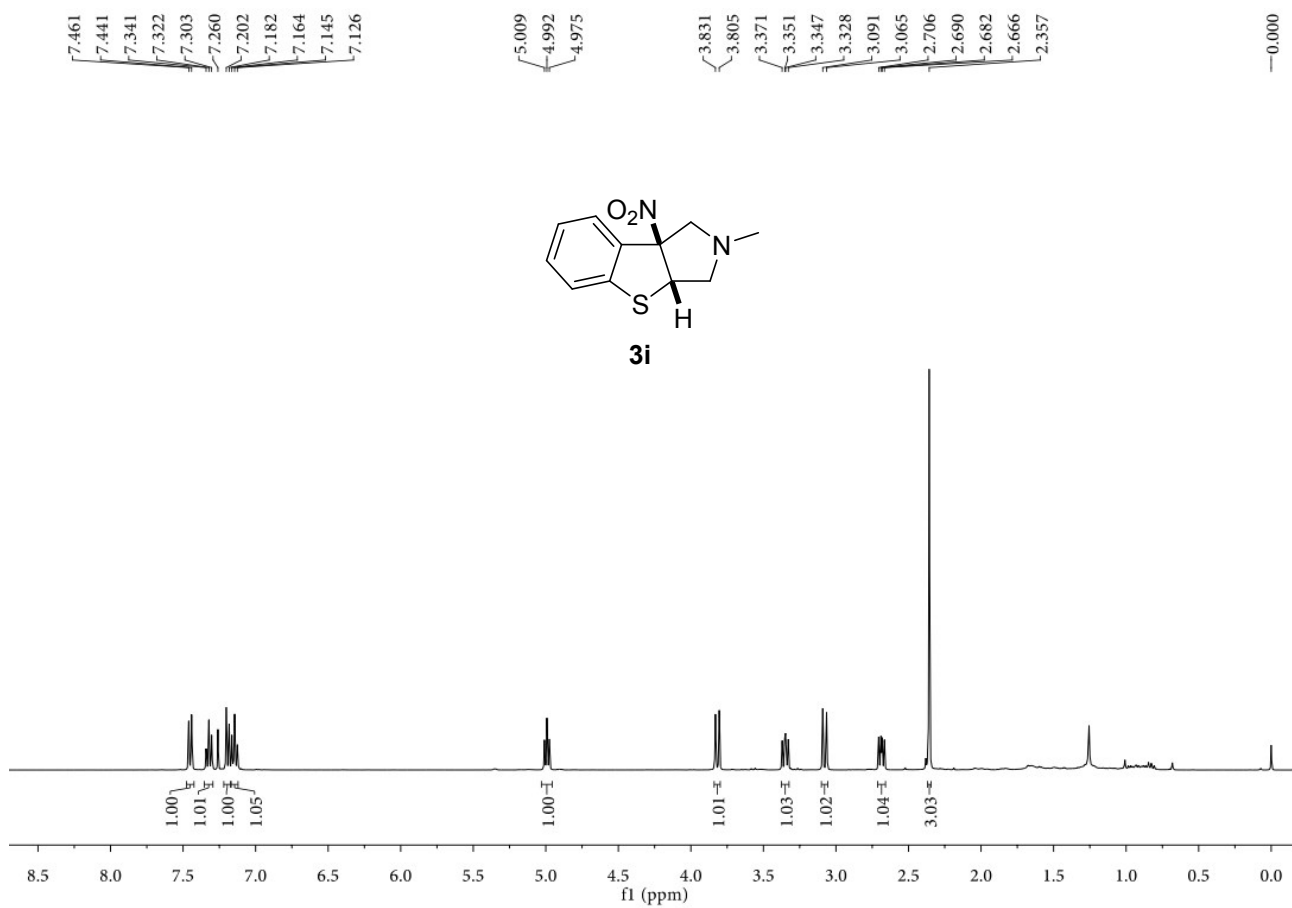
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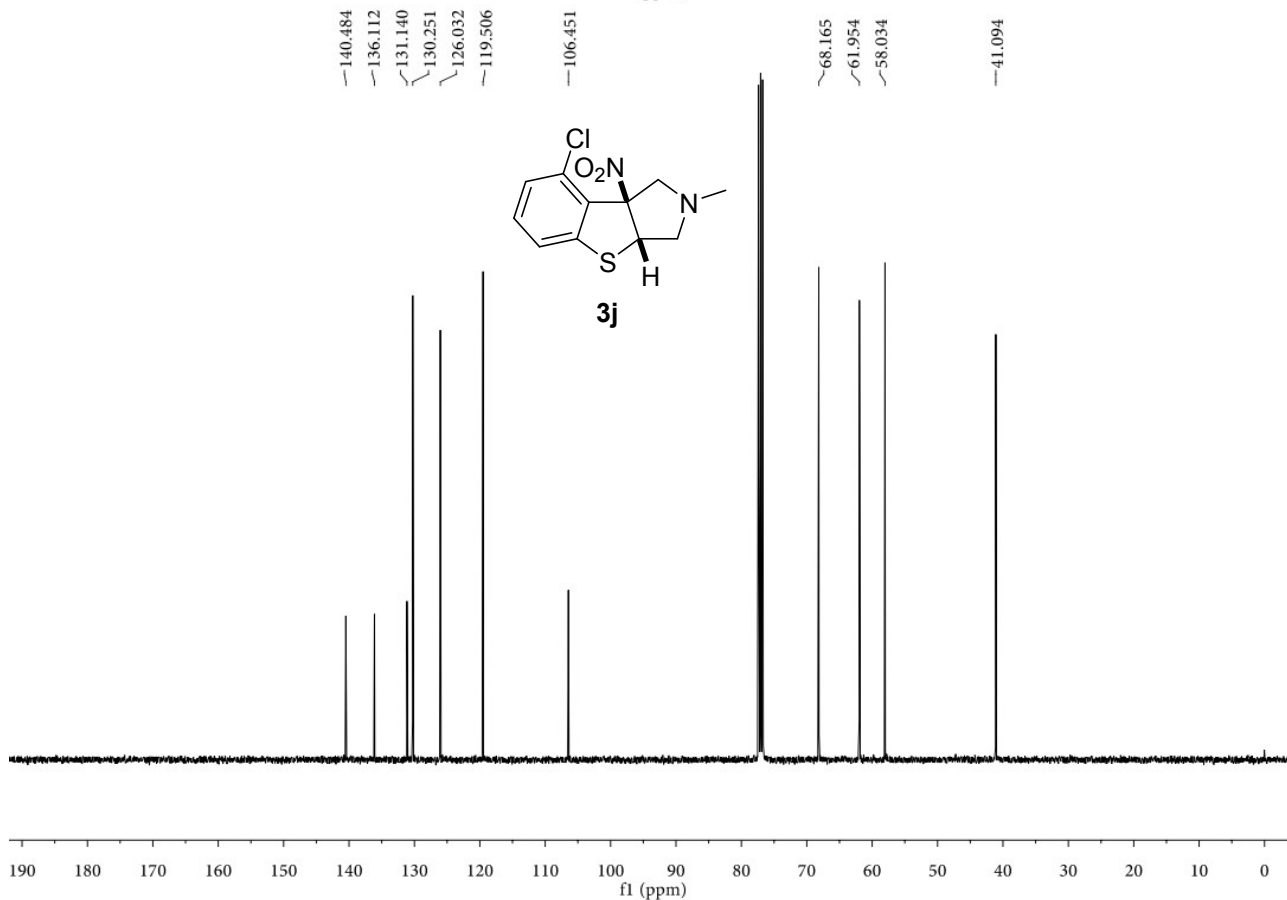
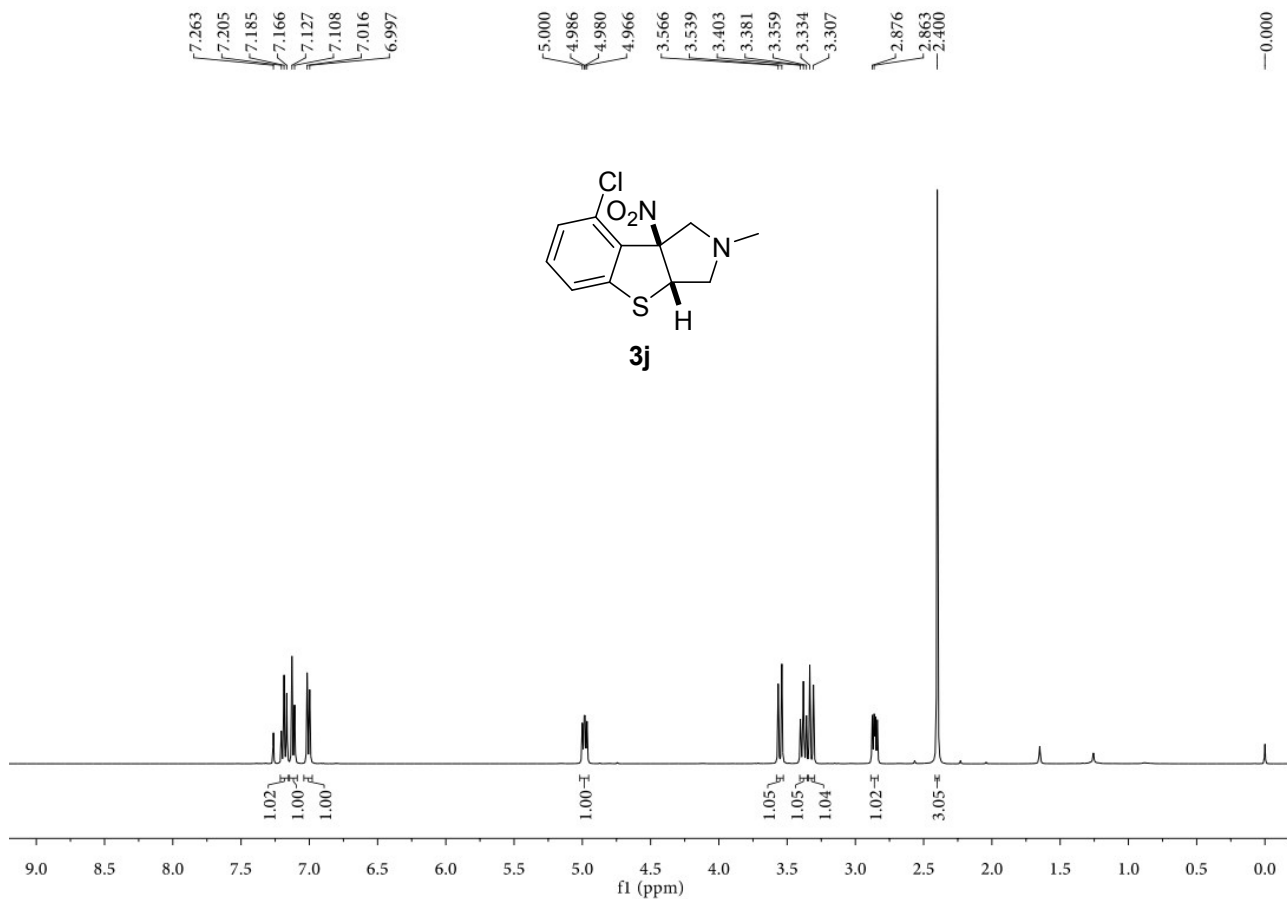


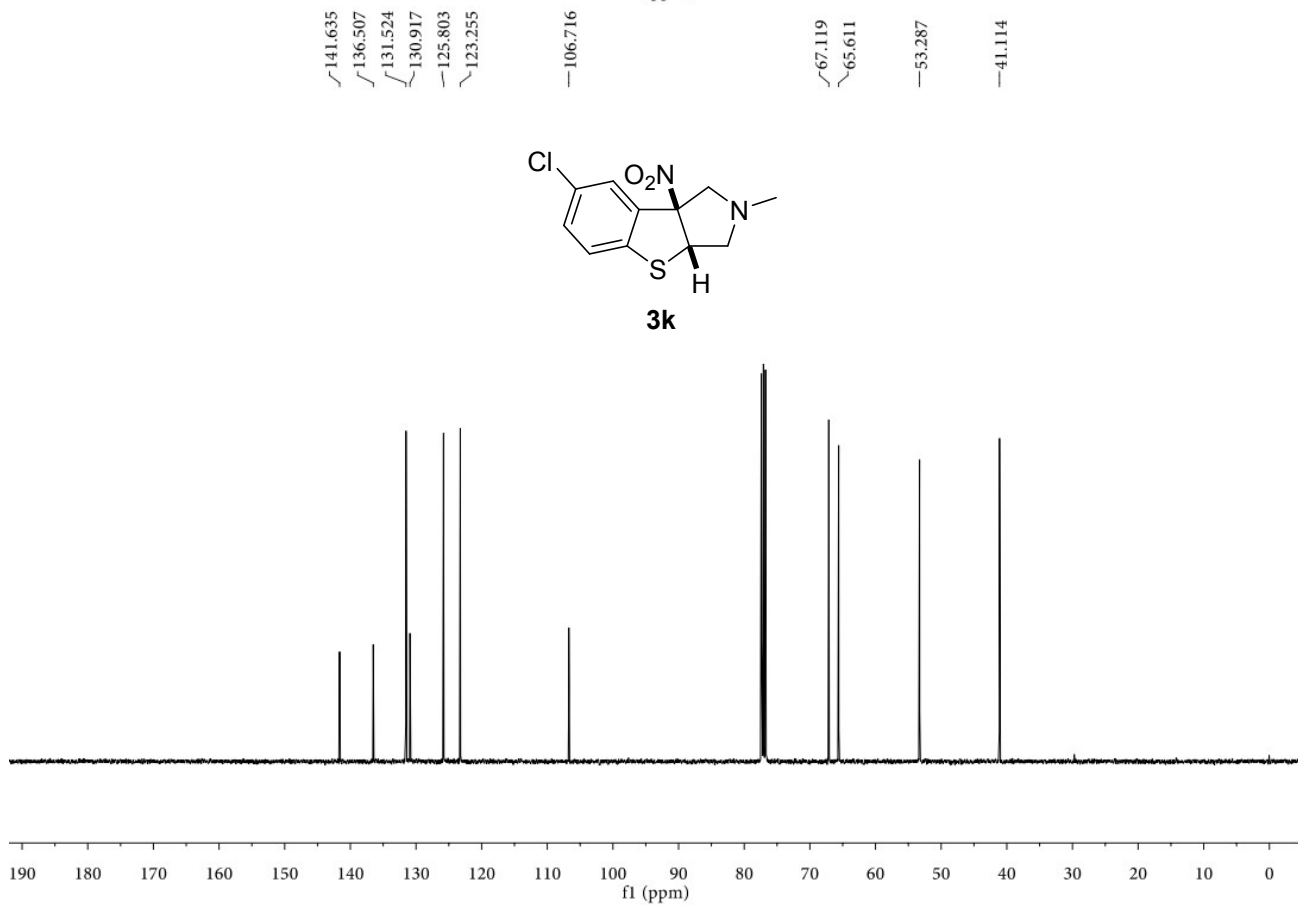
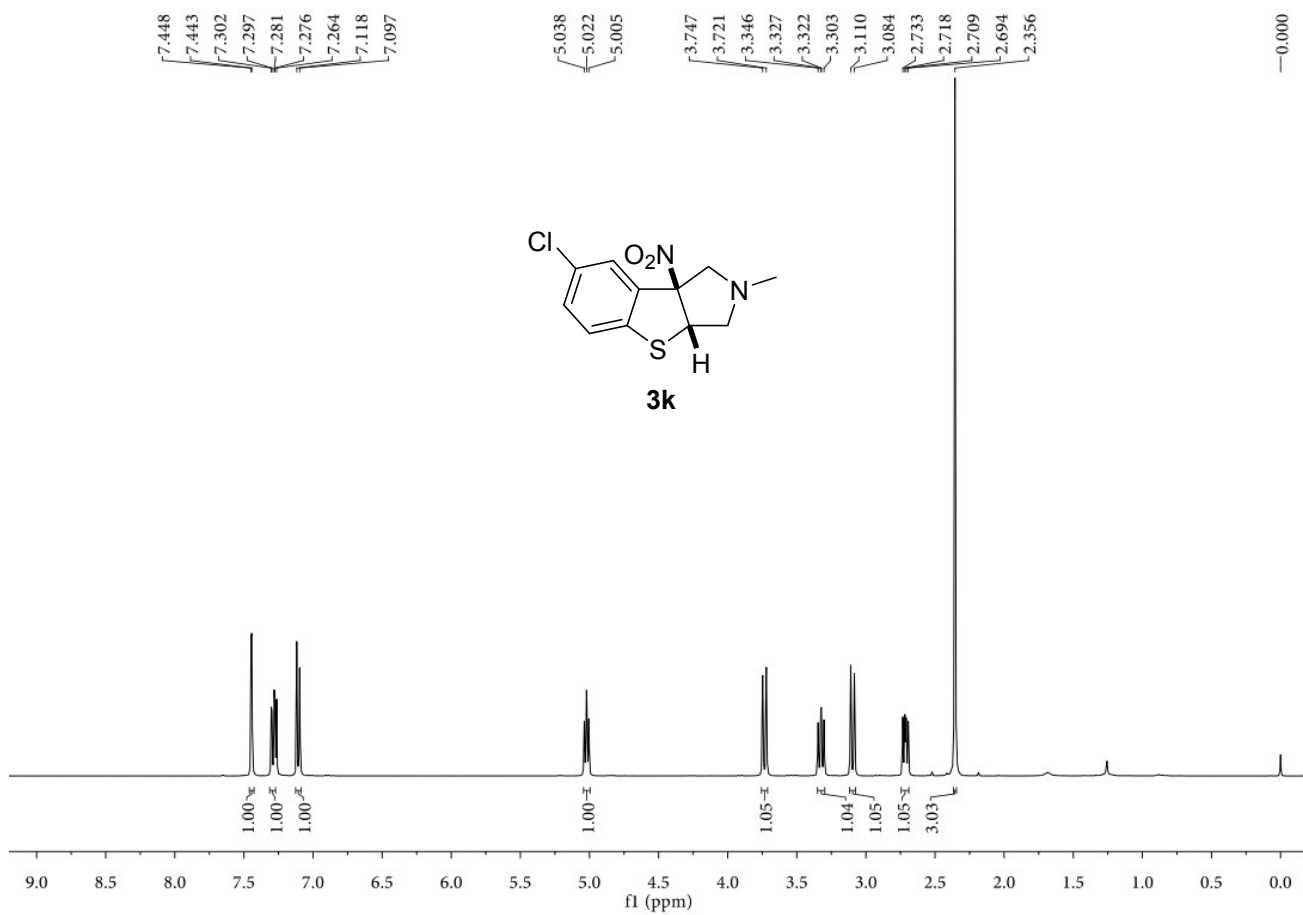
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127.582
126.635
124.267
115.997
108.041

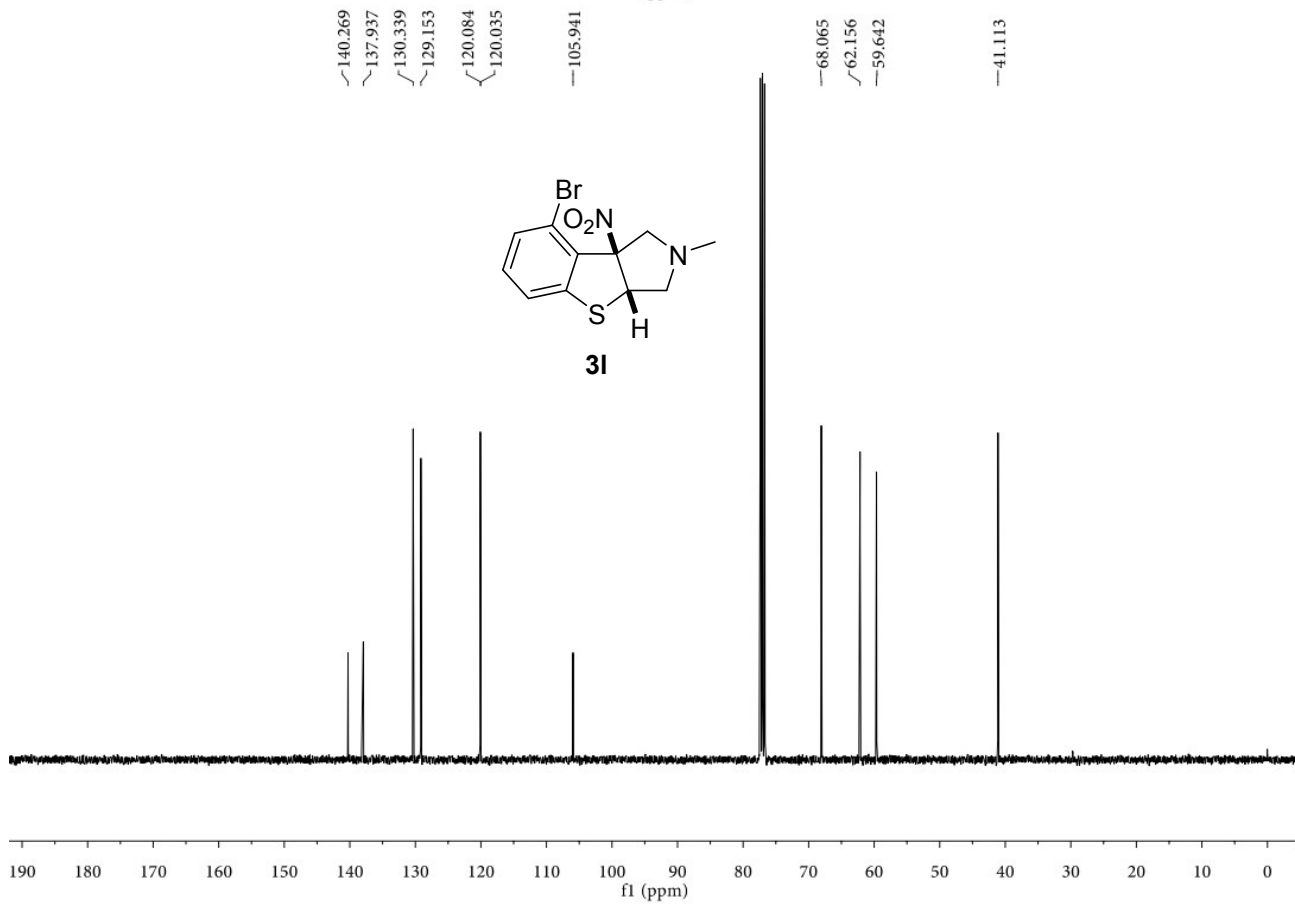
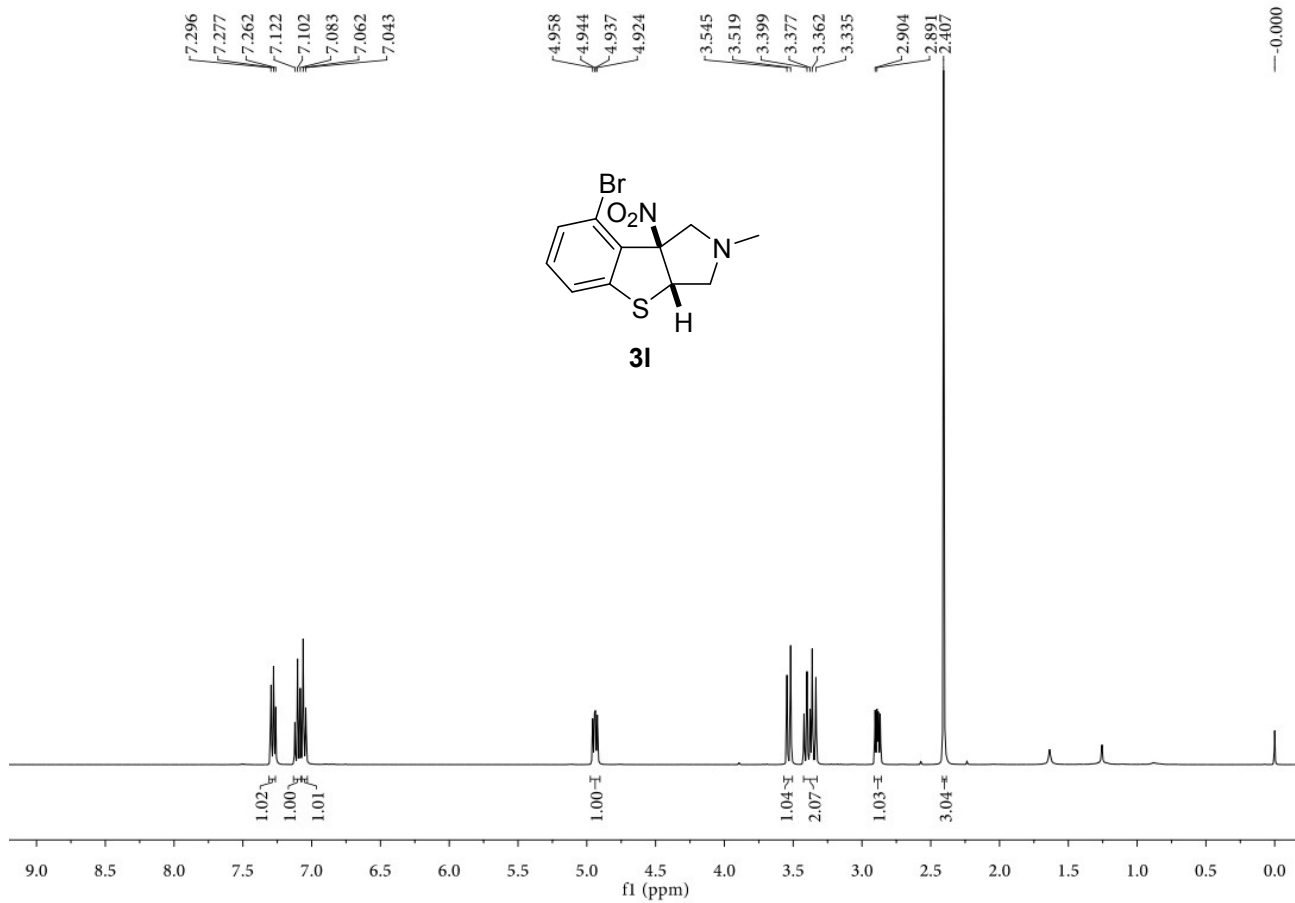
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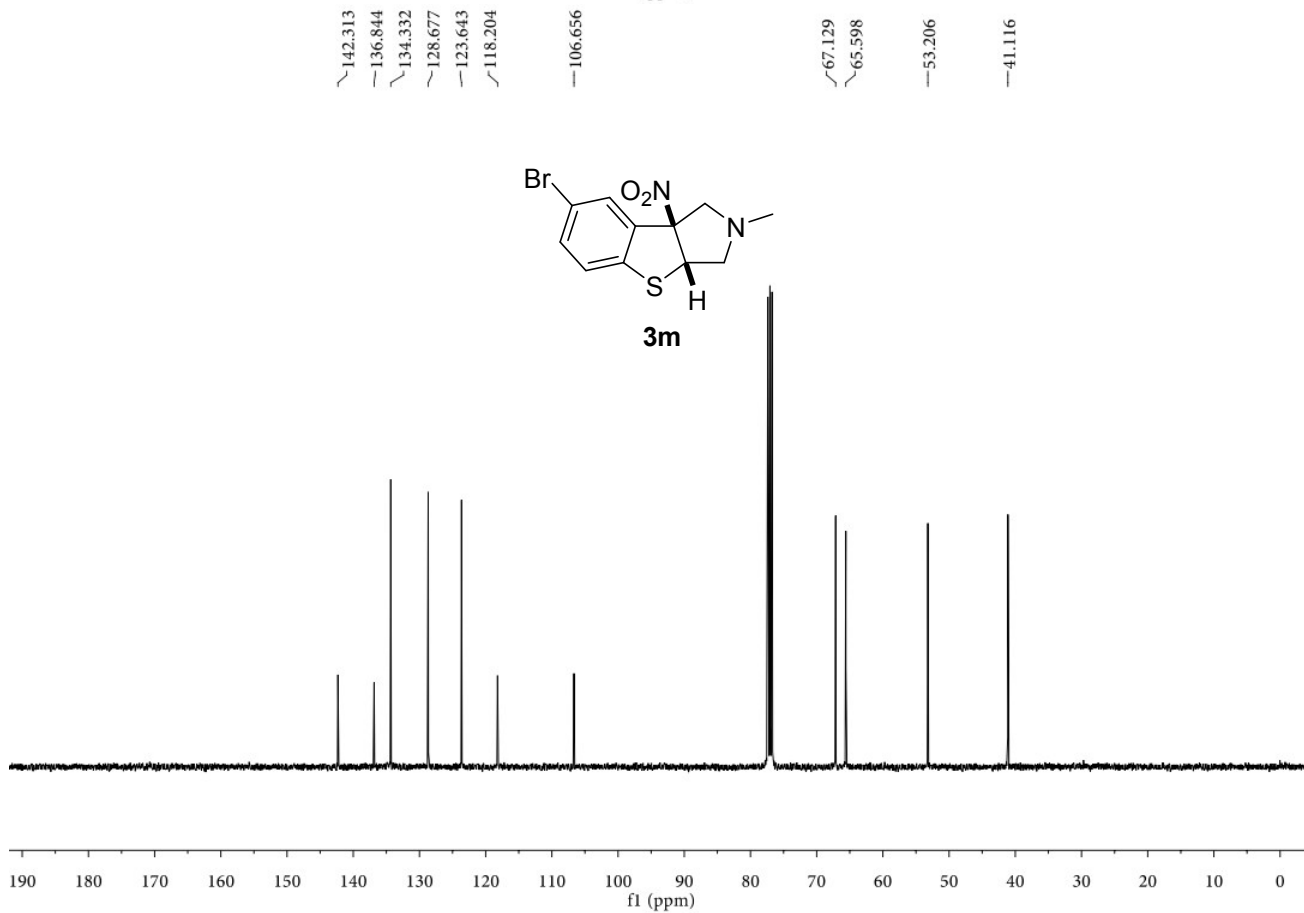
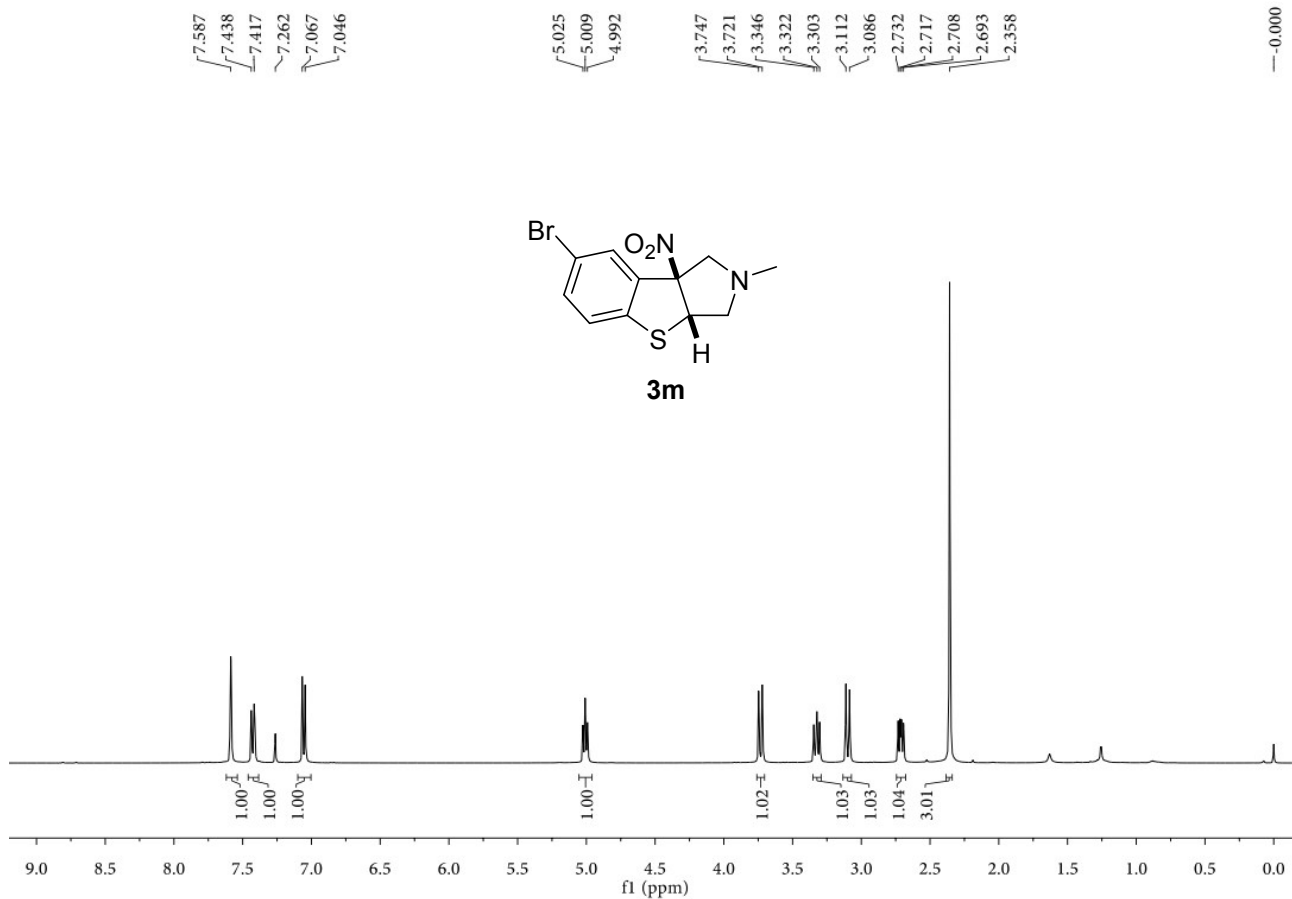


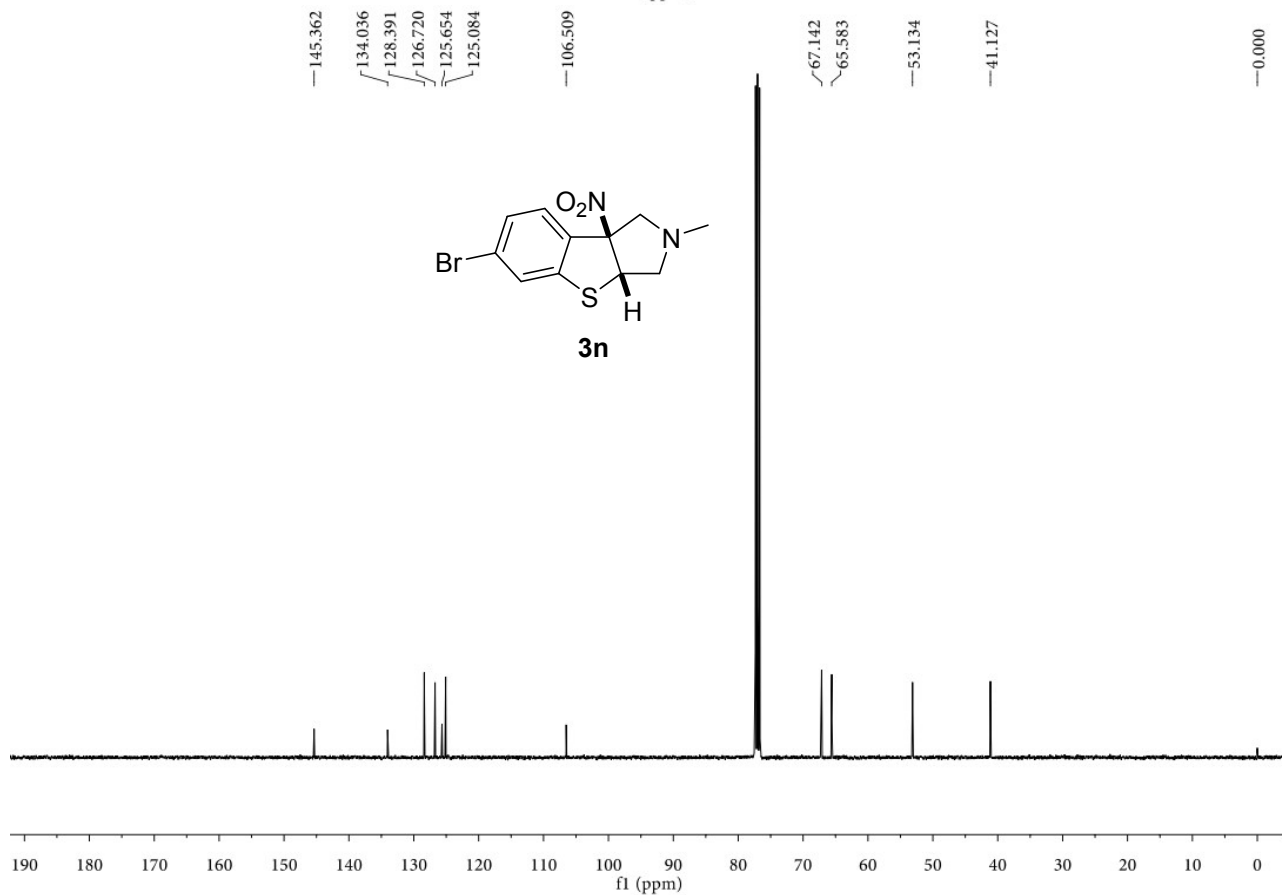
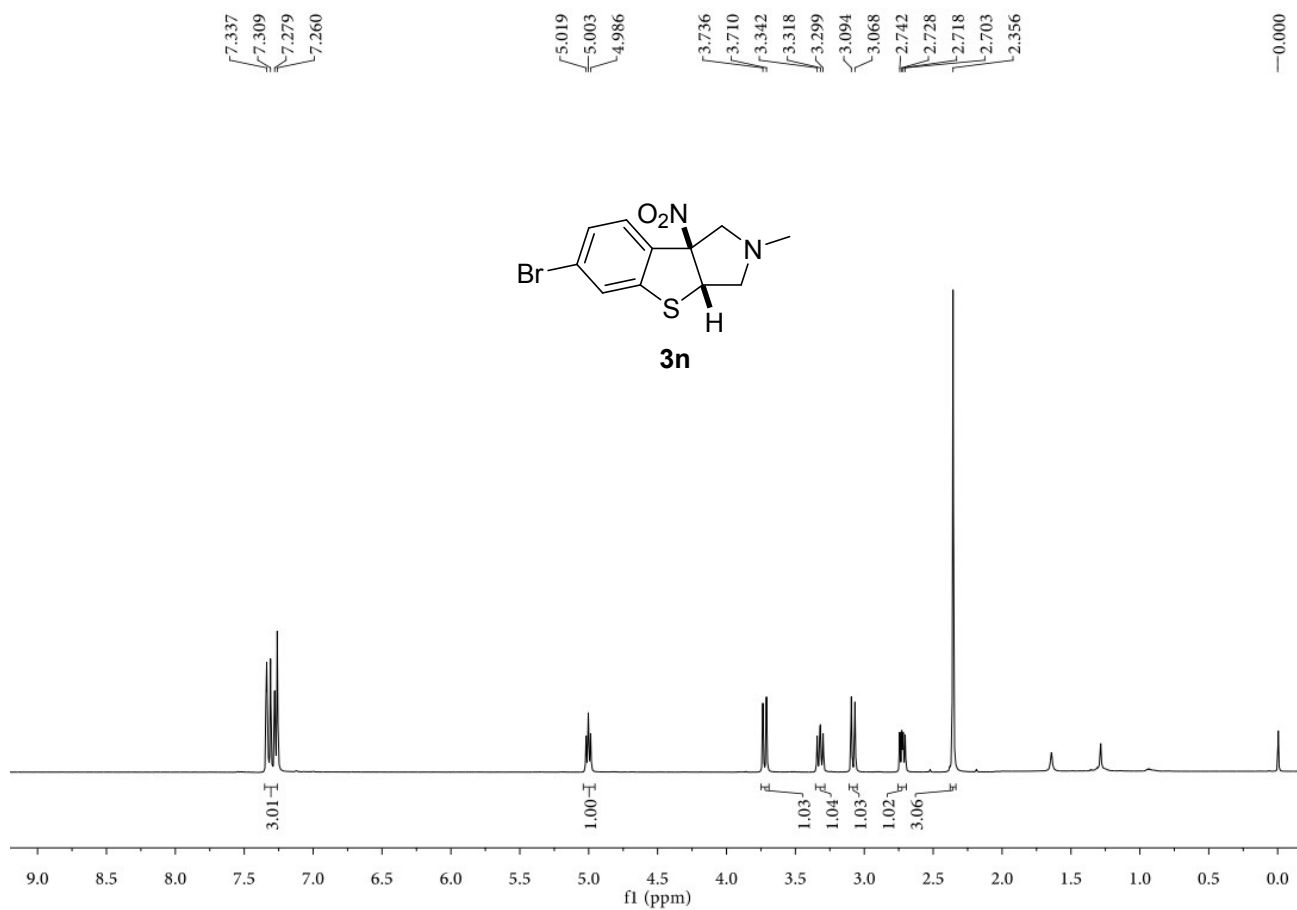


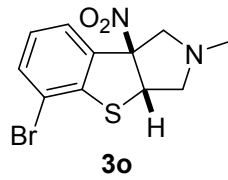
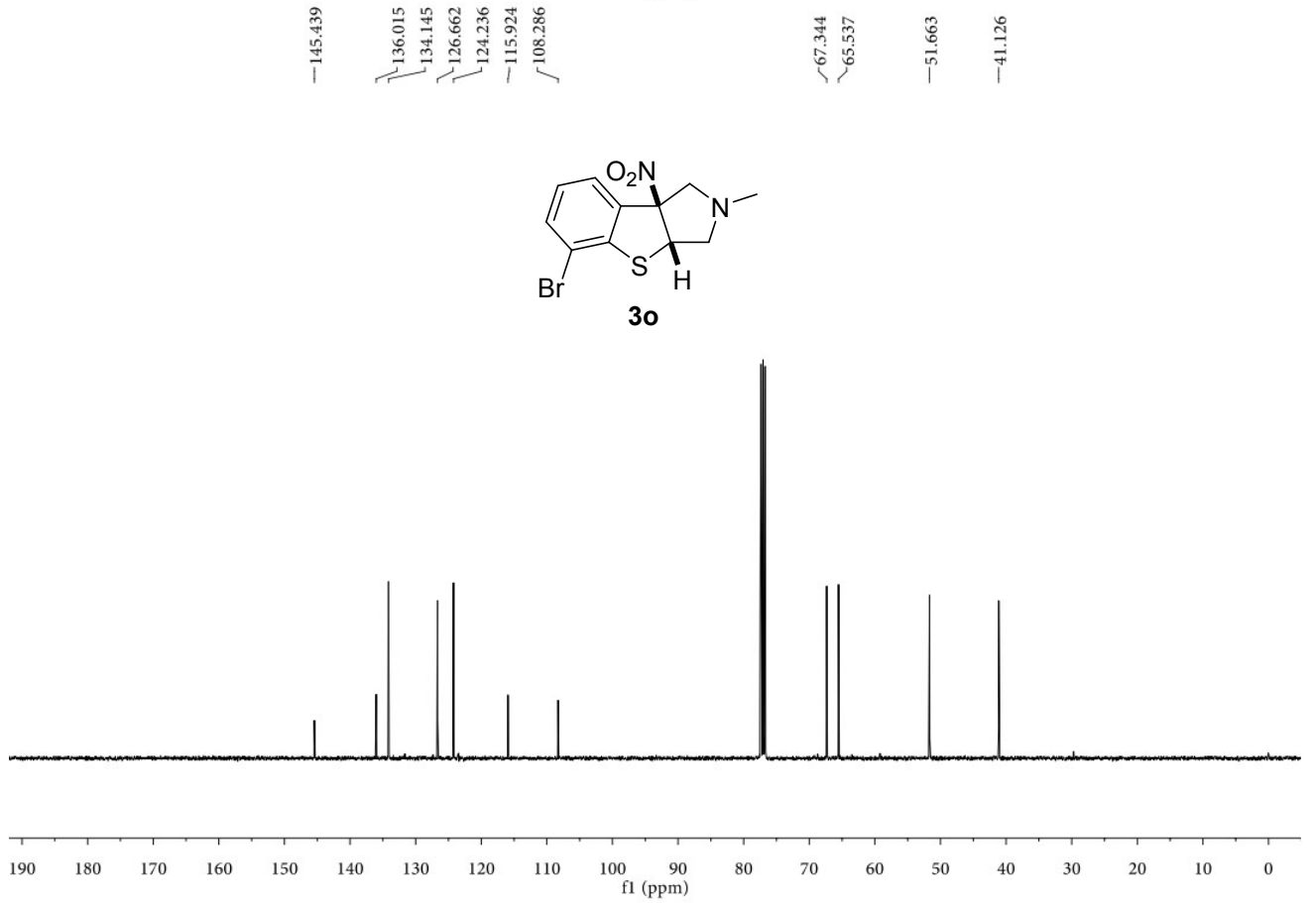
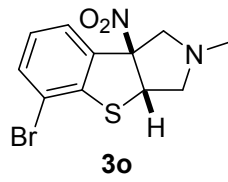
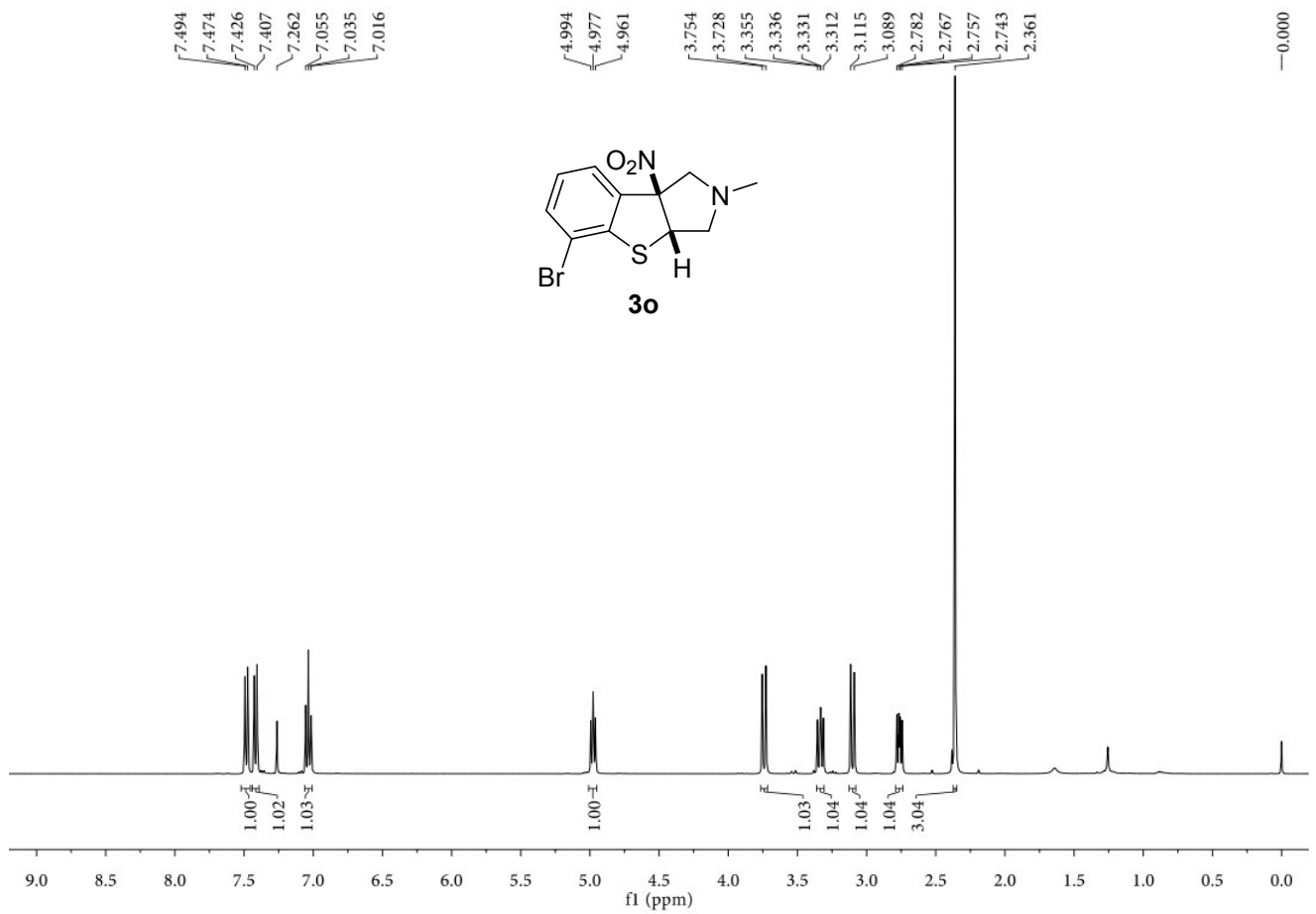


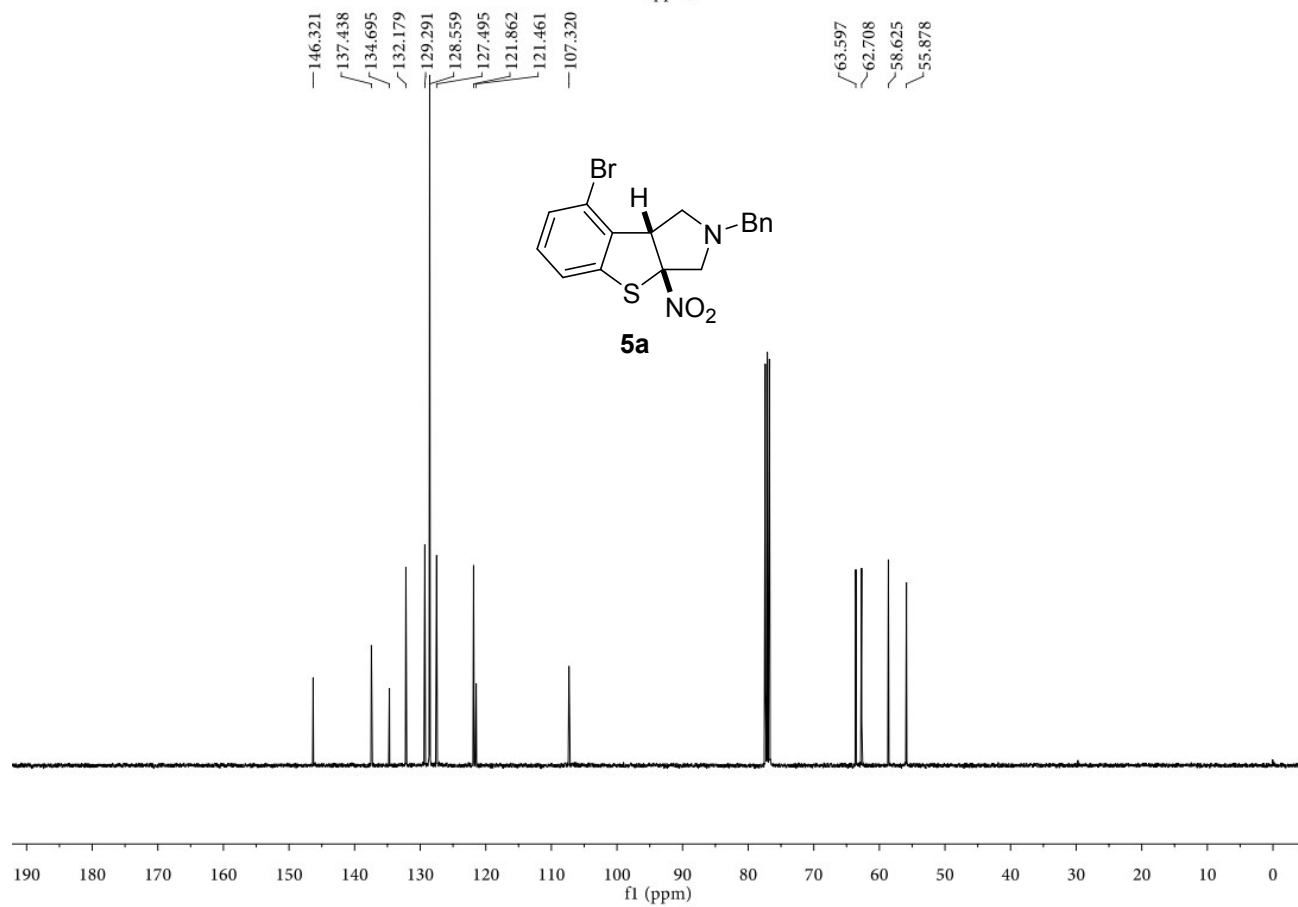
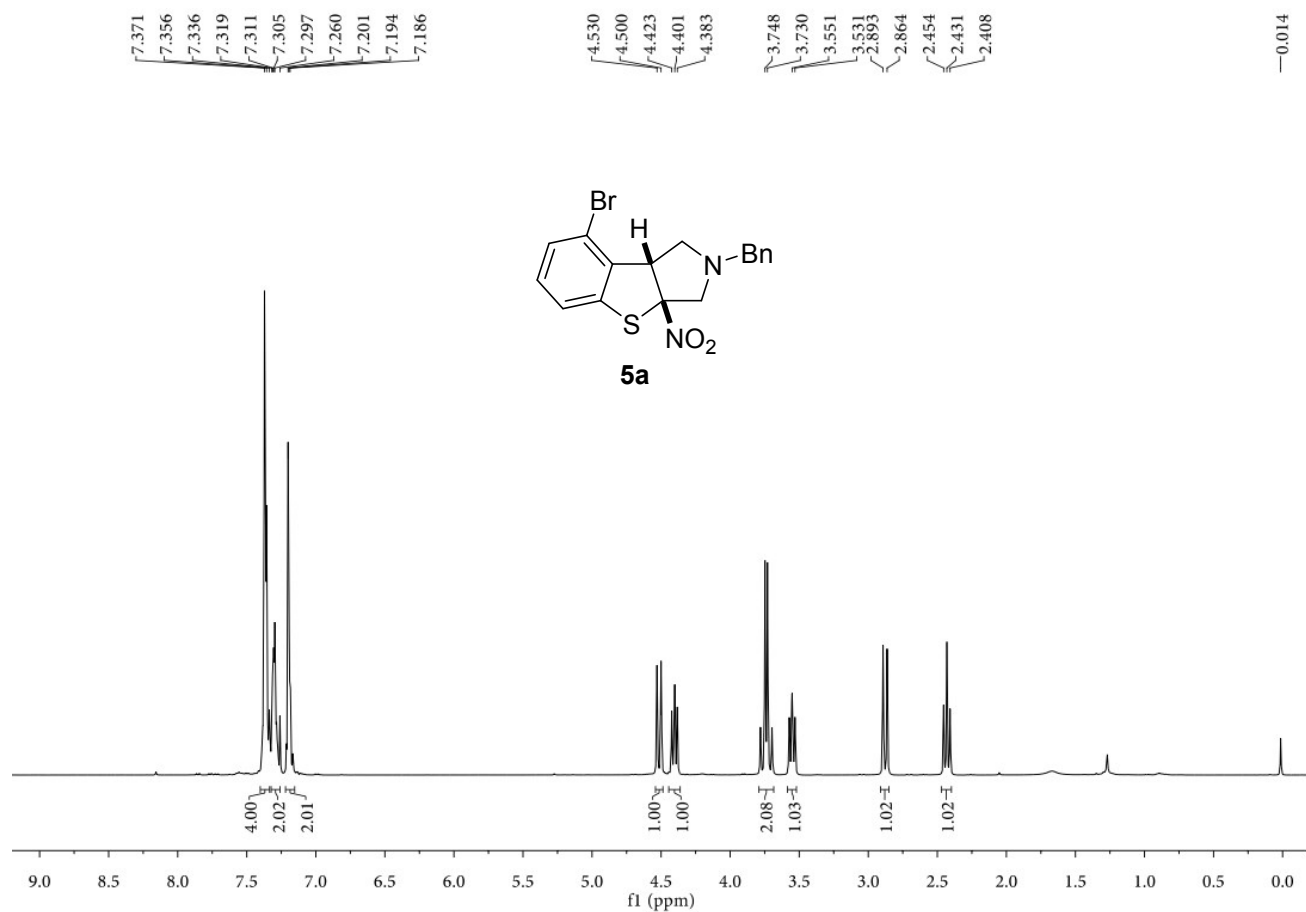


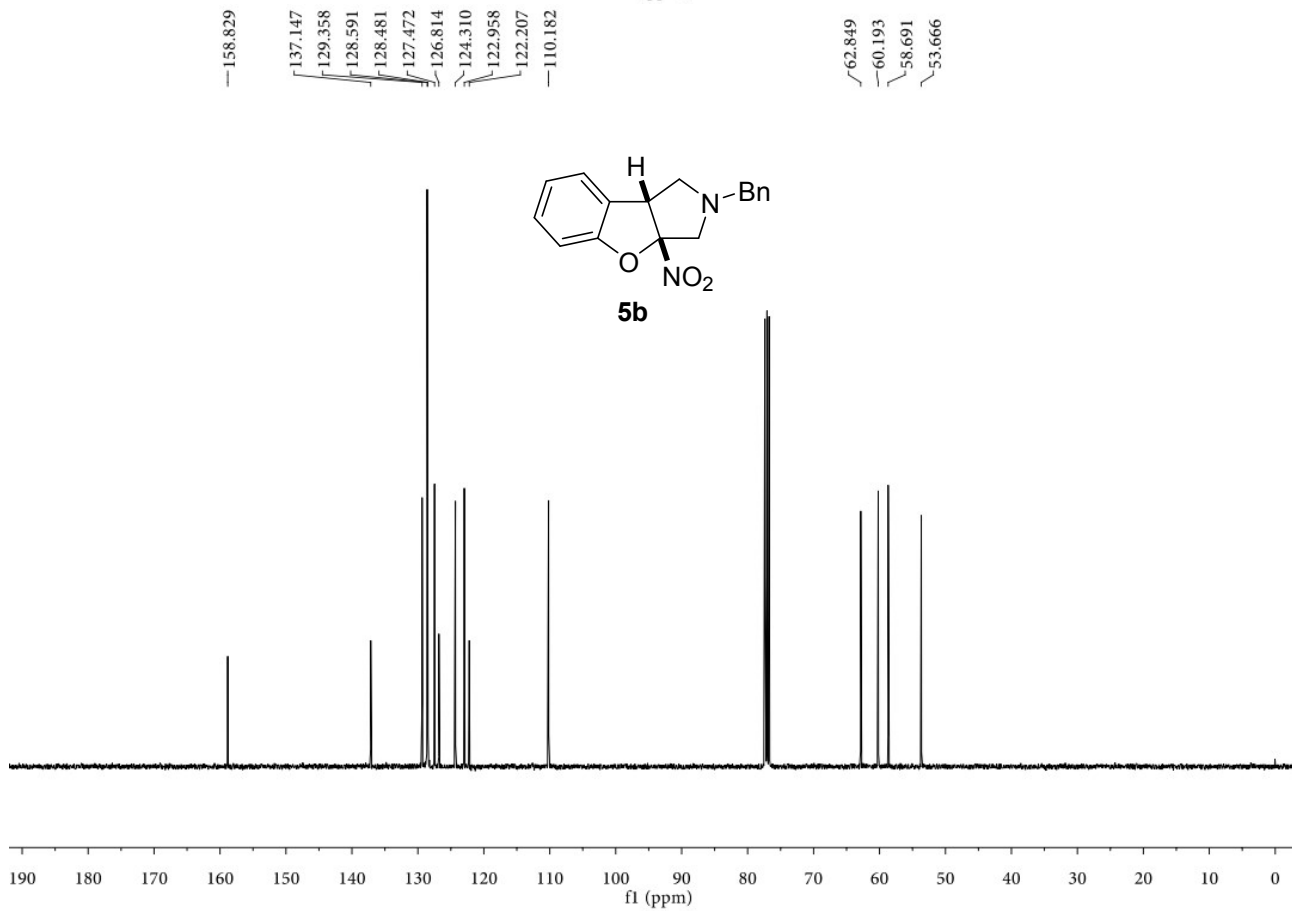
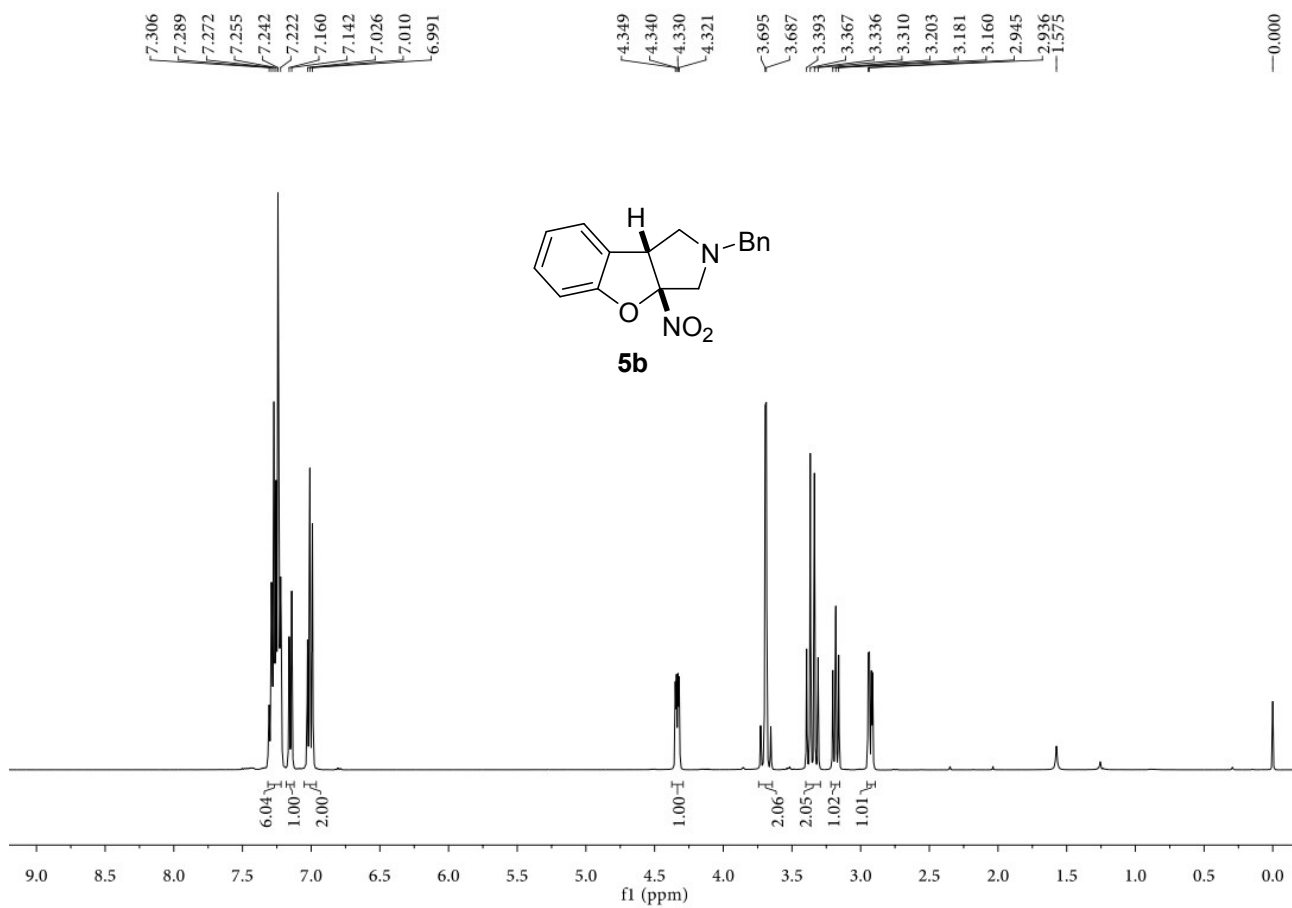


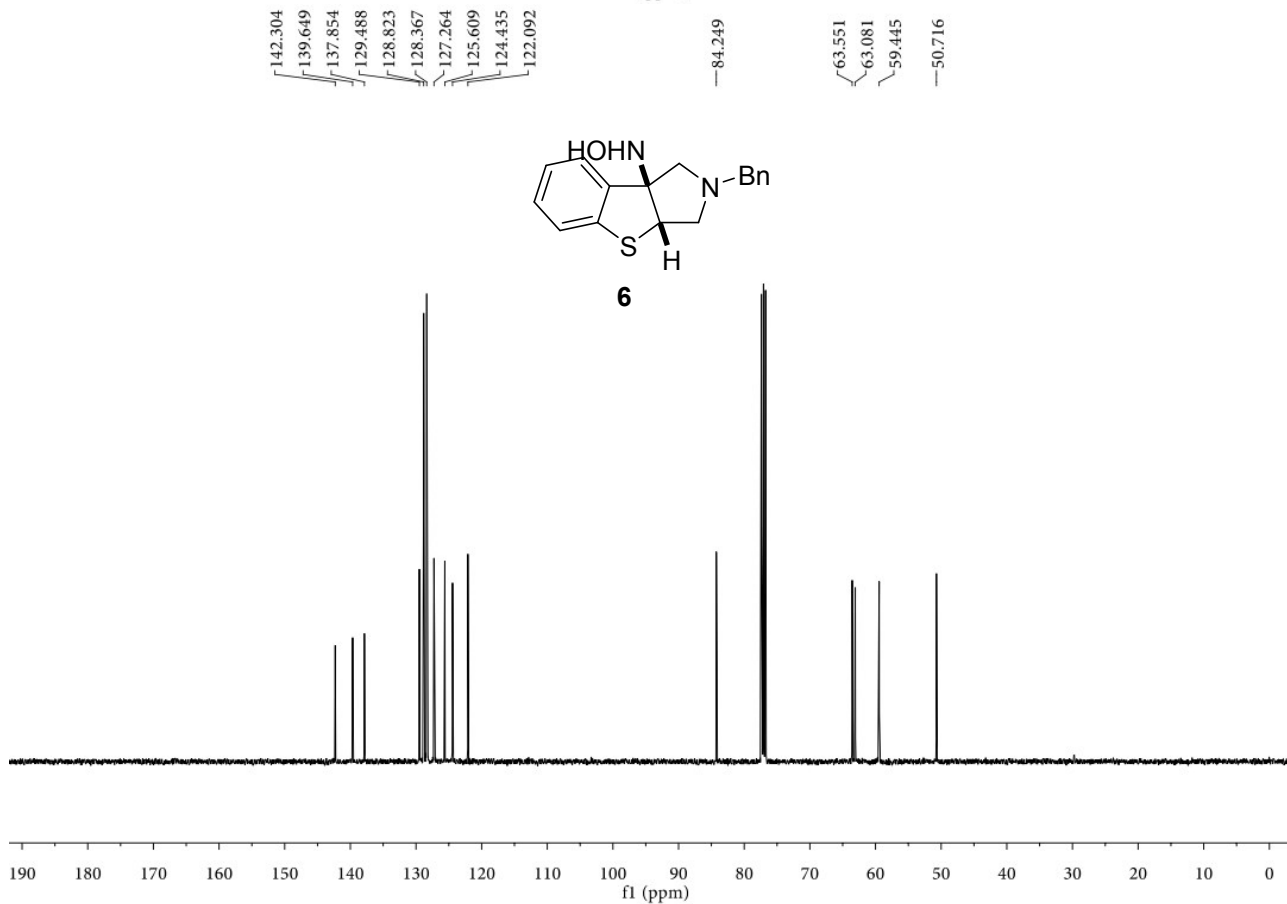
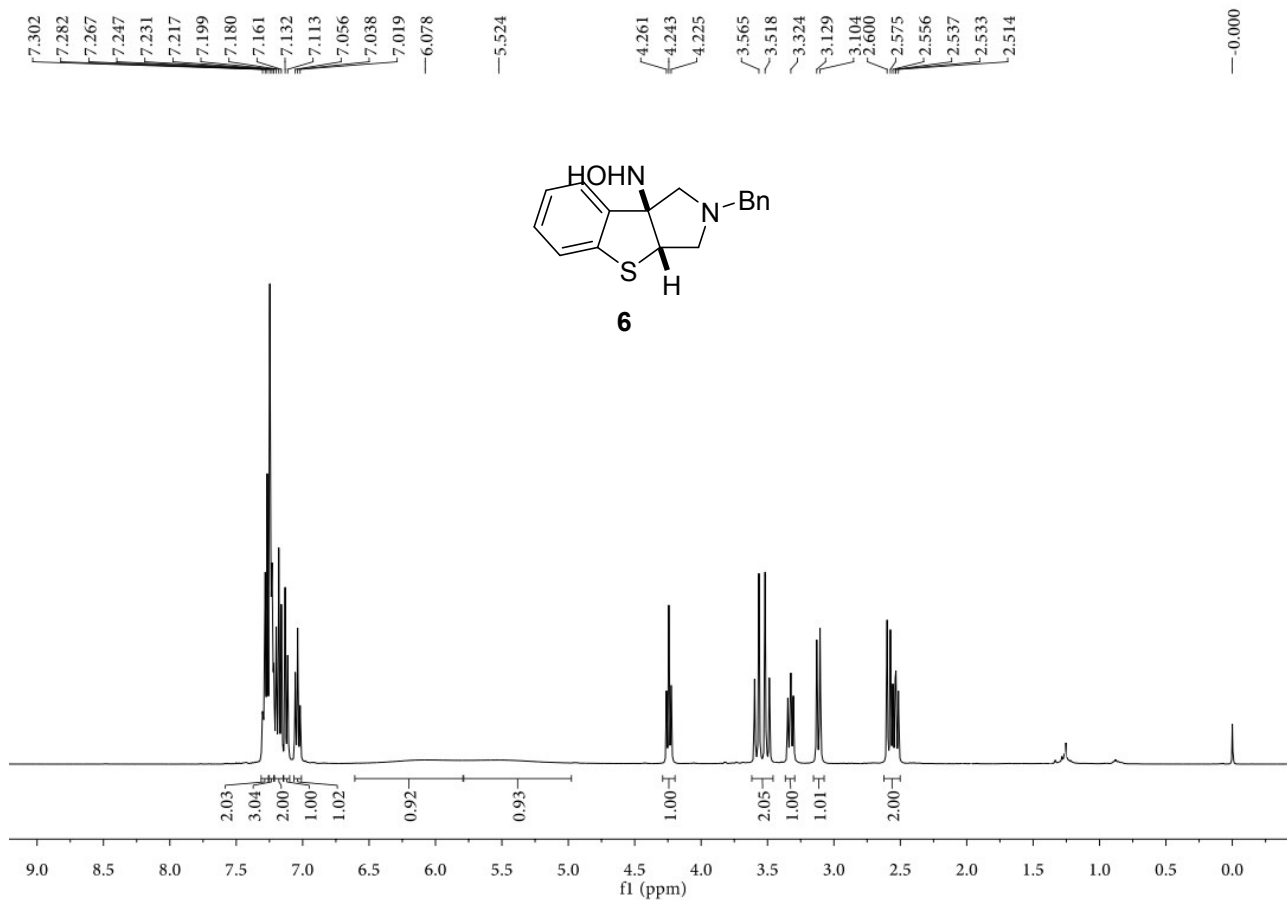








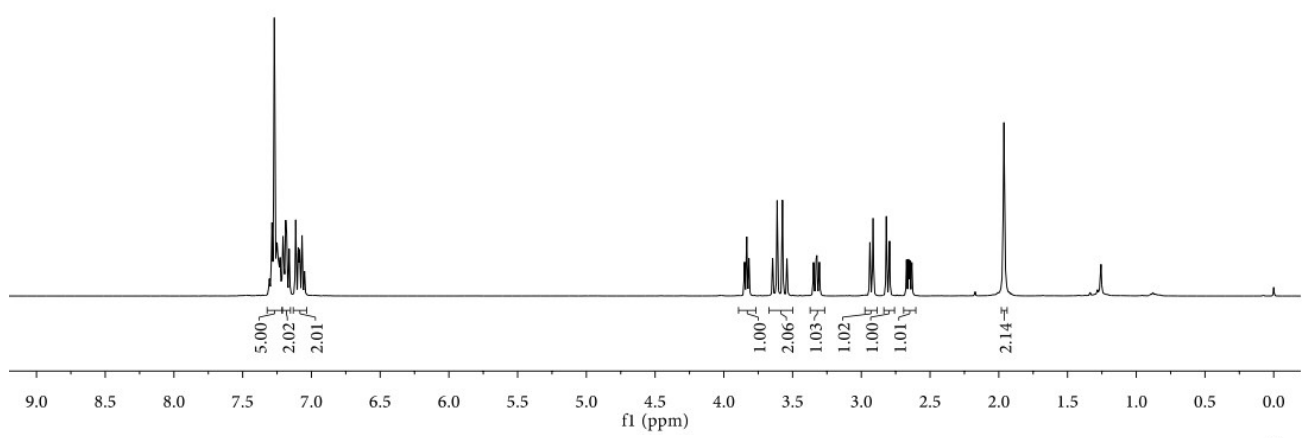
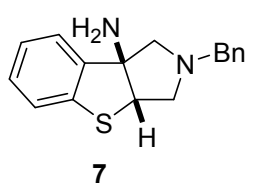




7.287
7.270
7.251
7.239
7.228
7.206
7.187
7.181
7.162
7.115
7.095
7.087
7.068
7.050

3.849
3.833
3.817
3.645
3.612
3.574
3.541
3.329
3.323
3.305
2.938
2.914
2.818
2.795
2.671
2.657
2.647
1.963

-0.000

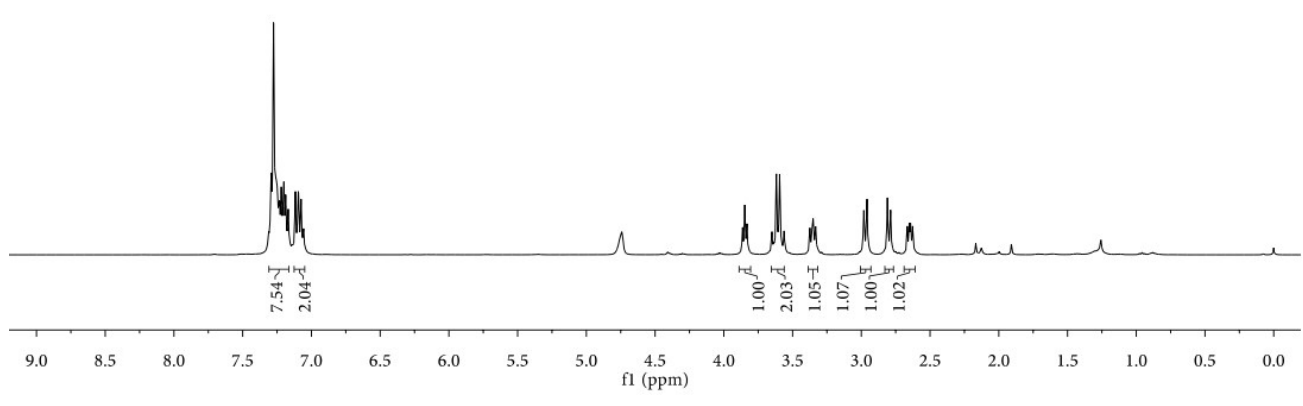
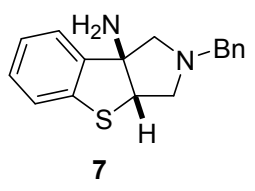


7.292
7.276
7.219
7.201
7.187
7.169
7.117
7.095
7.075
7.057

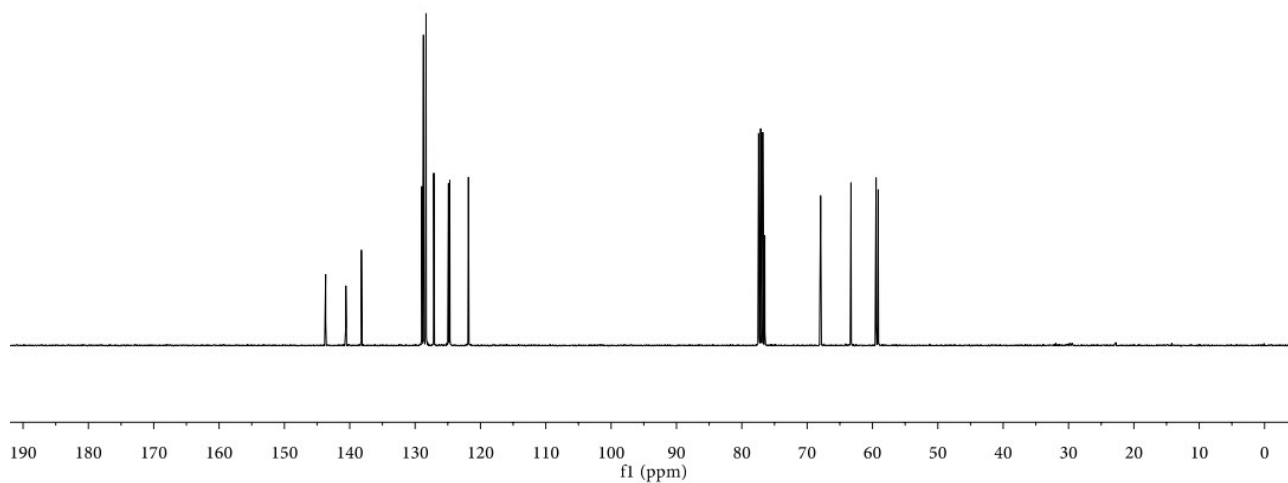
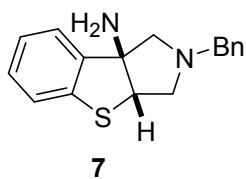
4.742
3.864
3.848
3.832
3.650
3.618
3.594
3.562
3.374
3.350
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2.982
2.958
2.810
2.787
2.666
2.651
2.642
2.627

-0.000

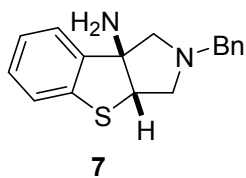
CDCl₃+D₂O



143.686
 140.591
 138.218
 128.973
 128.723
 128.325
 127.140
 124.893
 124.698
 121.838
 76.484
 67.945
 63.292
 59.450
 59.131



128.974
 128.726
 128.327
 127.141
 124.893
 124.699
 121.839
 67.945
 63.294
 59.451
 59.128



$^{13}\text{C-DEPT}135^\circ$

