Supporting Information

Practical synthesis of unsymmetrical disulfides promoted by bromodimethylsulfonium bromide

Bo Dong[a], Yifeng Chen[a], Shubing Xie[c], Jieying Zhang[a], Jian Shen[a,b,*] and Lan-Gui Xie[a,*]

[a] National and Local Joint Engineering Research Center of Biomedical Functional Materials, School of Chemistry and Materials Science, Nanjing Normal University, Nanjing 210023, China.

[b] Jiangsu Engineering Research Center of Interfacial Chemistry, Nanjing University, Nanjing 210023, China.

[c] Anhui Changjiang Institute of Metrology, Hefei 230088, China.

Email: jshen@njnu.edu.cn

xielg@njnu.edu.cn

Supporting Information

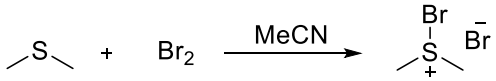
Table of contents

1 General Information

All reactions involving air or moisture sensitive reagents were carried out in flame-dried glassware under argon atmosphere using standard Schlenk techniques. Solvents were either freshly distilled or obtained in extra-dry grade from commercial sources, and store over molecular sieve (3 Å). Dichloromethane (CH_2Cl_2), N,N-Dimethylformamide (DMF) and Acetonitrile (MeCN) was refluxed over CaH_2 and used as freshly distilled. Tetrahydrofuran (THF) (extra dry over molecular sieves) was purchased commercially and used directly. Otherwise noted, commercially available chemicals were purchased from Energy Chemical. Column chromatography was performed with silica gel (300−400 mesh). Column chromatography was performed with silica gel (300−400 mesh). Merck silica gel 60 F254 plates were used for thin layer chromatography (TLC) with UV light (254/366 nm) or $KMnO_4$ as stains. The NMR spectra were recorded on a Bruker Avance 400 spectrometer at 400 MHz (^{1}H), 101 MHz (^{13}C) and 376 MHz (^{19}F) in $CDCl_3$ with tetramethylsilane as the internal standard. Chemical shifts (δ) were reported in parts per million (ppm). Splitting patterns were designated as s, singlet; d, doublet; t, triplet; q, quartet; dd, doublet of doublets; m, multiplet. HR-ESI-MS was recorded on a Bruker MTQ III q-TOF instrument.

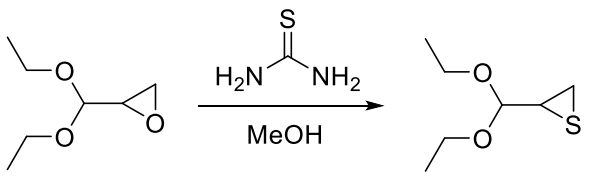
2 Experimental Procedures

Preparation of (Bromodimethyl)sulfonium bromide (BDMS)



Dimethyl sulfide (12.4 g, 200 mmol, 1 equiv) were diluted in 40 mL dry acetonitrile (MeCN) in a dry 250 mL flask. A solution of bromine (10.3 mL, 200 mmol, 1 equiv) in 40 mL MeCN was added dropwise over 15 min at room temperature. The resulting orange powder was washed with hexane (10 mL X 3) and dried in vacuo (40.3 g, 180 mmol, 92%).

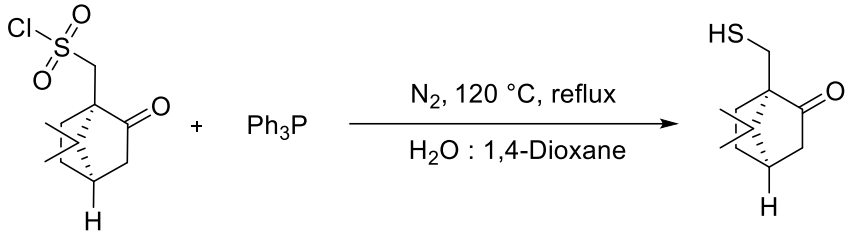
Preparation of 2-(diethoxymethyl)thiirane (39)



To a flask containing 10 mL of anhydrous methanol were added thiourea (0.3 g, 4 mmol,

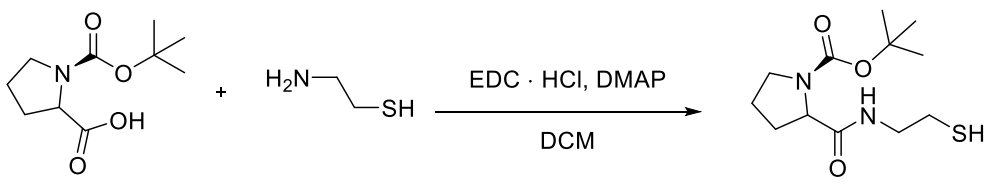
1 equiv) and 2-(diethoxymethyl)oxirane (0.6 g, 4 mmol, 1 equiv). The mixture was stirred at 23 °C under N_2 for 3 days.[11] The methanol was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (EtOAc/petroleum ether 1:100), the title compound was obtained as a colorless oil (394 mg, 61% yield). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 4.08 (d, *J* = 6.0 Hz, 1H), 3.76–3.66 (m, 2H), 3.63–3.52 (m, 2H), 3.10-3.05 (m, 1H), 2.45 (dd, *J* = 6.4, 1.6 Hz, 1H), 2.29 (dd, *J* = 5.2, 1.2 Hz, 1H), 1.21 (q, *J* = 7.2 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 105.3, 62.3, 34.3, 21.1, 15.2.

Preparation of (1*S*,4*R*)-1-(mercaptomethyl)-7,7-dimethylbicyclo[2.2.1]heptan-2-one



To a flask containing 5 mL of H_2O:1,4-dioxane (1:4) were added ((1*S*,4*R*)-7,7-dimethyl-2-oxobicyclo[2.2.1]heptan-1-yl)methanesulfonyl chloride (0.5 g, 2 mmol, 1 equiv) and triphenylphosphine (1.6 g, 6 mmol, 3 equiv). The mixture was refluxed at 120 °C under N_2 for 2 h.[12] After the extraction with EtOAc (10 mL X 3), the combined organic layers were washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:100), the title compound was obtained as a white solid (737 mg, 67% yield). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 2.84 (q, *J* = 6.8 Hz, 1H), 2.37–2.31 (m, 2H), 2.06 (t, *J* = 4.0 Hz, 1H), 2.00–1.83 (m, 4H), 1.71–1.65 (m, 1H), 1.40–1.26 (m, 1H), 1.00 (s, 3H), 0.88 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 217.8, 60.6, 47.8, 43.6, 43.2, 27.0, 26.6, 21.3, 20.2, 19.8.

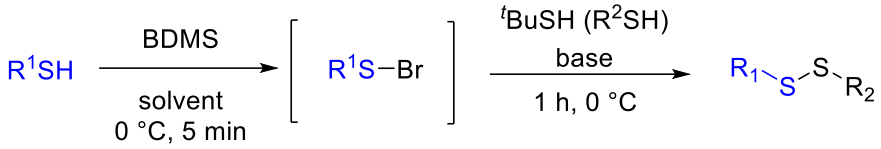
Preparation of *tert*-butyl 2-((2-mercaptoethyl)carbamoyl)pyrrolidine-1-carboxylate



To a flask containing 20 mL of DCM were added N-(3-dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride (1.25 g, 6.5 mmol, 1.3 equiv), 4-dimethylaminopyridine (6 mg, 0.5 mmol, 0.1 equiv), Boc-L-proline (1.30 g, 6 mmol,

1.2 equiv) and 2-aminoethanethiol (0.39 g, 5 mmol, 1 equiv). The mixture was stirred for 12 h at 23 °C. After the extraction with EtOAc (10 mL X 3), the combined organic layer was washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:1), the title compound was obtained as a white solid (767 mg, 56% yield). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.15–6.39 (m, 1H), 4.42–4.08 (m, 1H), 3.54–3.23 (m, 4H), 2.96–2.60 (m, 1H), 2.28–1.70 (m, 5H), 1.53–1.33 (m, 10H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 202.4, 153.7, 80.4, 66.1, 46.5, 42.1, 31.5, 28.3, 24.5.23.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{12}H_{23}N_2O_3S$ 275.1424; Found 275.1422.

General procedure for the synthesis of unsymmetrical disulfides



A dry flask, charged with BDMS (100 mg, 0.45 mmol, 1.5 equiv) and R^1SH (0.45 mmol, 1.5 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry DMF (3 mL) were injected to the flask at 0 ℃ with an ice bath. After a stirring of 5 min, K_2CO_3 (62 mg, 0.45 mmol, 1.5 equiv) (Et_3N in the case of compound **8**) and corresponding R^2SH (0.3 mmol, 1.0 equiv) were added to the flask. The reaction mixture was then stirred at 0 ℃ for 1 h, before quenching with H_2O. After the extraction with Et_2O (10 mL X 3), the combined organic layer was washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. The crude product was then purified by column chromatography on silica gel using petroleum ether and ethyl acetate as the eluent.

Procedure for multi-gram scale synthesis

A dry flask charged with BDMS (3.33 g, 15 mmol, 1.5 equiv) was vacuumed and refilled with nitrogen (3 cycles). Dry DMF (60 mL) were injected to the flask at 0 ℃ with an ice bath and R^1SH (15 mmol, 1.5 equiv) dissolved in DMF (20 mL) were injected to the flask. After a stirring of 5 min, K_2CO_3 (2.07 g, 15 mmol, 1.5 equiv) (Et_3N in the case of compound **8**) and the corresponding R^2SH (10 mmol, 1.0 equiv) dissolved in DMF (20 mL) were added to the flask. The reaction mixture was then stirred at 0 ℃ for 1 h, before quenching with H_2O. After the extraction with Et_2O (20 mL X 3), the combined organic layer was washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. The crude product was then purified by column chromatography on silica gel using petroleum ether and ethyl acetate as the eluent.

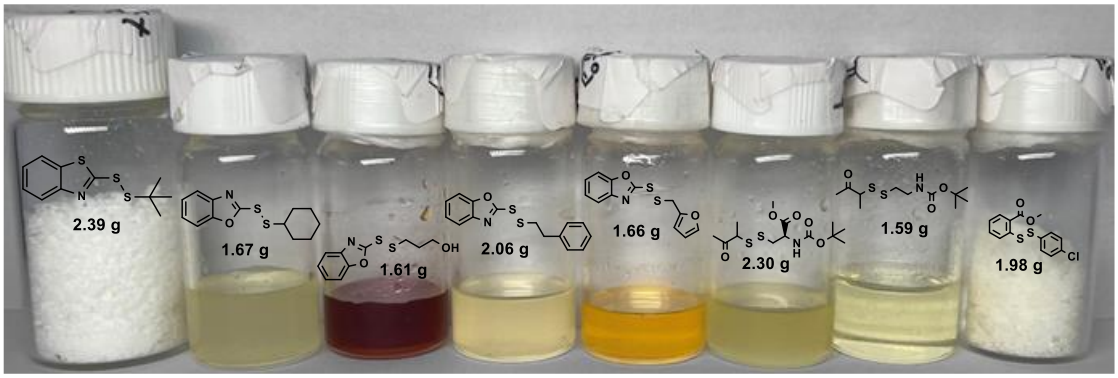
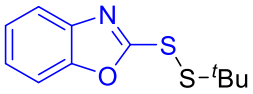


Figure S1. Picture of the isolated disulfides

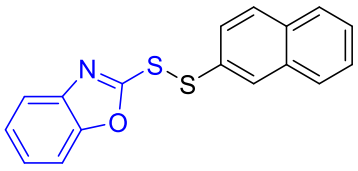
3 Characterization of products

2-(*tert*-Butyldisulfanyl)benzo[*d*]oxazole (1)[1]



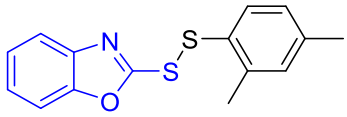
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and *tert*-butylthiol (27 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (71 mg, 99%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66–7.63 (m, 1H), 7.49–7.46 (m, 1H), 7.32–7.27 (m, 2H), 1.40 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.8, 152.1, 142.0, 124.6, 124.5, 119.3, 110.2, 49.5, 29.5.

2-(Naphthalen-2-yldisulfanyl)benzo[*d*]oxazole (2)



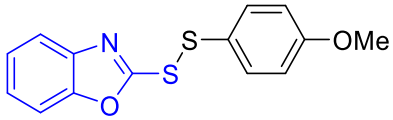
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and naphthalene-2-thiol (48 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a light yellow solid (61 mg, 66%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, J = 1.6 Hz, 1H), 7.85–7.79 (m, 3H), 7.77–7.75 (m, 1H), 7.72–7.70 (m, 1H), 7.53–7.48 (m, 3H), 7.35–7.29 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.7, 152.5 141.9, 133.3, 133.0, 132.3, 129.7, 129.3, 127.8, 127.2, 127.0, 126.9, 124.9, 124.7, 119.5, 110.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{17}H_{12}NOS_2$ 310.0355 Found 310.0354.

2-((2,4-Dimethylphenyl)disulfanyl)benzo[*d*]oxazole (3)



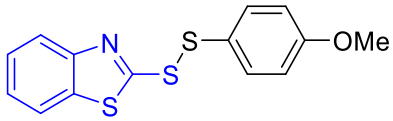
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and 2,4-dimethylbenzenethiol (42 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a yellow oil (68 mg, 79%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70–7.66 (m, 2H), 7.52–7.47 (m, 1H), 7.34–7.28 (m, 2H), 7.005–6.98 (m, 2H), 2.51 (s, 3H), 2.30 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.9, 152.3, 142.0, 140.0, 139.9, 133.1, 131.5, 130.4, 127.7, 124.7, 124.5, 119.4, 110.2, 21.1, 20.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{15}H_{14}NOS_2$ 288.0511; Found 288.0510.

2-((4-Methoxyphenyl)disulfanyl)benzo[*d*]oxazole (4)[2]



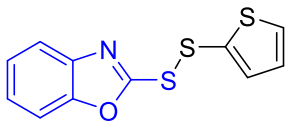
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and 4-methoxybenzenethiol (43 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a yellow oil (73 mg, 84%). ^{1}H NMR (400 MHz, $CDCl_3$) δ ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71–7.67 (m, 3H), 7.51–7.48 (m, 1H), 7.34–7.27 (m, 2H), 6.87–6.84 (m, 2H), 3.78 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.4, 161.0, 152.5, 142.0, 134.8, 125.9, 124.8, 124.6, 119.5, 114.9, 110.3, 55.4.

2-((4-Methoxyphenyl)disulfanyl)benzo[*d*]thiazole (5)[2]



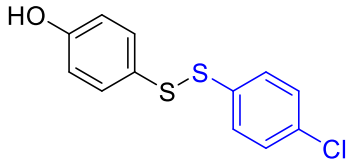
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]thiazole-2-thiol (75 mg, 0.45 mmol, 1.5 equiv) and 4-methoxybenzenethiol (43 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a white solid (67 mg, 73%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88–7.86 (m, 1H), 7.82–7.80 (m, 1H), 7.65–7.61 (m, 2H), 7.45–7.41 (m, 1H), 7.35–7.31 (m, 1H), 6.88–6.84 (m, 2H), 3.79 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.0, 160.7, 154.9, 135.8, 133.3, 126.2, 125.7, 124.6, 122.2, 121.1, 114.9, 55.4.

2-(Thiophen-2-yldisulfanyl)benzo[*d*]oxazole (6)



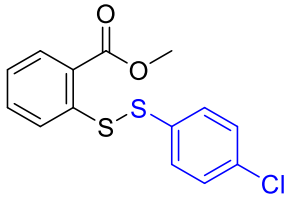
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and thiophene-2-thiol (35 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a yellow oil (40 mg, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74–7.70 (m, 1H), 7.57–7.44 (m, 3H), 7.36–7.32 (m, 2H), 7.04–6.99 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.6, 152.5, 142.0, 137.3, 133.2, 133.1, 127.8, 124.9, 124.7, 119.6, 110.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{11}H_8NOS_3$ 265.9763; Found 265.9762.

4-((4-Chlorophenyl)disulfanyl)phenol (7)



According to the general procedure for the synthesis of unsymmetrical disulfides, 4-chlorobenzenethiol (65 mg, 0.45 mmol, 1.5 equiv) and 4-mercaptophenol (38 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:10), the title compound was obtained as a yellow oil (62 mg, 65%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44–7.41 (m, 2H), 7.38–7.34 (m, 2H), 7.29–7.26 (m, 2H), 6.79–6.74 (m, 2H), 5.21 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.9, 135.9, 133.3, 132.2, 129.7, 129.1, 127.8, 116.2. HRMS (ESI) m/z: $[M - H]^+$ Calcd for $C_{12}H_8ClOS_2$ 266.9705; Found 266.9709.

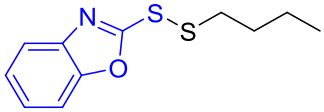
Methyl 2-((4-chlorophenyl)disulfanyl)benzoate (8)



A dry flask, charged with BDMS (100 mg, 0.45 mmol, 1.5 equiv) and 4-chlorobenzenethiol (65 mg, 0.45 mmol, 1.5 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry DCM (3 mL) were injected to the flask at 0 ℃ with an ice bath. After a stirring of 5 min, Et_3N (46 mg, 0.45 mmol, 1.5 equiv) and corresponding 2-mercaptobenzoate (51 mg, 0.3 mmol, 1.0 equiv) were added to the flask. The reaction mixture was then stirred at 0 ℃ for 1 h, before quenching with H_2O. After the extraction

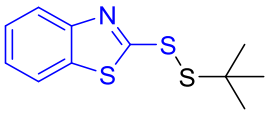
with Et_2O (10 mL X 3), the combined organic layer was washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:10), the title compound was obtained as a white solid (73 mg, 78%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06–8.03 (m, 1H), 7.99–7.93 (m, 1H), 7.51–7.47 (m, 1H), 7.41–7.37 (m, 2H), 7.27–7.21 (m, 3H), 3.96 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.7, 140.7, 134.6, 133.1, 132.8, 131.4, 129.1, 128.3, 126.9, 125.6, 125.5, 52.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{14}H_{12}ClO_2S_2$ 310.9962; Found 310.9961.

2-(Butyldisulfanyl)benzo[*d*]oxazole (9) [2]



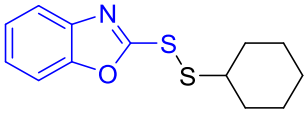
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and butane-1-thiol (28 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (66 mg, 92%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69–7.64 (m, 1H), 7.50–7.45 (m, 1H), 7.32–7.26 (m, 2H), 2.98 (t, *J* =7.6 Hz, 2H), 1.77–1.70 (m, 2H), 1.49–1.39 (m, 2H), 0.91 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.6, 152.3, 141.9, 124.6, 124.5, 119.3, 110.2, 39.0, 30.6, 21.4, 13.5.

2-(*tert*-Butyldisulfanyl)benzo[*d*]thiazole (10)[3]



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]thiazole-2-thiol (75 mg, 0.45 mmol, 1.5 equiv) and *tert*-butylthiol (27 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a white solid (64 mg, 93%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, *J* = 22.4 Hz, 1H), 7.76 (d, *J* = 9.2 Hz, 1H), 7.43–7.39 (m, 1H), 7.32–7.28 (m, 1H), 1.41 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 174. 3, 154.7, 135.6, 126.1, 124.4, 121.9, 121.0, 50.2, 29.7.

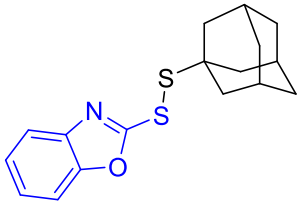
2-(Cyclohexyldisulfanyl)benzo[*d*]oxazole (11)[4]



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and cyclohexanethiol (35 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on

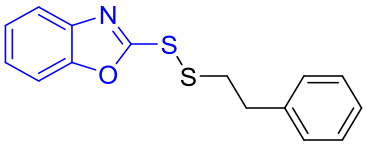
silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a yellow oil (66 mg, 83%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68–7.64 (m, 1H), 7.50–7.45 (m, 1H), 7.32–7.25 (m, 2H), 3.10–3.03 (m, 1H), 2.12–2.07 (m, 2H), 1.81–1.76 (m, 2H), 1.63–1.58 (m, 1H), 1.48–1.39 (m, 2H), 1.36–1.19 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.9, 152.2, 141.9, 124.5, 124.4, 119.2, 110.1, 49.9, 32.2, 25.8, 25.3.

2-((Adamantan-1-yl)disulfanyl)benzo[*d*]oxazole (12)



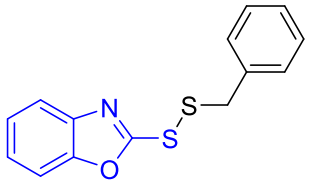
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and adamantane-1-thiol (53 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (92 mg, 96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66–7.62 (m, 1H), 7.49–7.45 (m, 1H), 7.30–7.24 (m, 2H), 2.07–2.04 (m, 3H), 1.94–1.91 (m, 6H), 1.67–1.61 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.2, 152.1, 142.0, 124.4 (2), 119.1, 110.1, 51.0, 41.9, 35.7, 29.8. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{17}H_{20}NOS_2$ 318.0981; Found 318.0981.

2-(Phenethyldisulfanyl)benzo[*d*]oxazole (13)



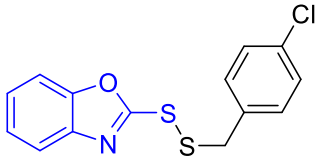
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and 2-phenylethane-1-thiol (42 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a yellow oil (81 mg, 94%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73–7.69 (m, 1H), 7.53–7.48 (m, 1H), 7.36–7.29 (m, 4H), 7.26–7.20 (m, 3H), 3.29–3.24 (m, 2H), 3.13–3.09 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.3, 152.3, 141.8, 139.1, 128.5 (2C), 126.5, 124.7, 124.6, 119.3, 110.2, 40.3, 35.0. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{15}H_{14}NOS_2$ 288.0511; Found 288.0510.

2-(Benzyldisulfanyl)benzo[*d*]oxazole (14)[5]



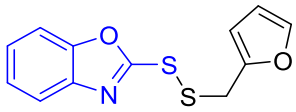
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and phenylmethanethiol (37 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (73 mg, 88%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70–7.65 (m, 1H), 7.48–7.44 (m, 1H), 7.37–7.19 (m, 7H), 4.22 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 152.2, 141.8, 135.5, 129.5, 128.5, 127.8, 124.7, 124.5, 119.3, 110.2, 43.6.

2-((4-Chlorobenzyl)disulfanyl)benzo[*d*]oxazole (15)



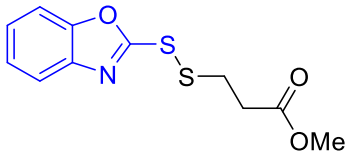
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and (4-chlorophenyl)methanethiol (37 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (57 mg, 62%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69–7.64 (m, 1H), 7.47–7.43 (m, 1H), 7.34–7.30 (m, 2H), 7.27–7.21 (m, 4H), 4.16 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.6, 152.2, 141.7, 134.1, 133.8, 130.8, 128.7, 124.9, 124.6, 119.3, 110.2, 42.7. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{14}H_{11}ClNOS_2$ 307.9965; Found 307.9965.

2-((Furan-2-ylmethyl)disulfanyl)benzo[*d*]oxazole (16)



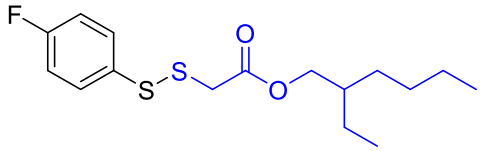
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and furan-2-ylmethanethiol (35 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as an orange oil (62 mg, 79%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67–7.63 (m, 1H), 7.48–7.43 (m, 1H), 7.32–7.26 (m, 3H), 6.30–6.26 (m, 1H), 6. 21–6.17 (m, 1H), 4.21 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.8, 152.3, 148.5, 143.0, 141.8, 124.6, 124.5, 119.2, 110.5, 110.1, 109.9, 35.8. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{12}H_{10}NO_2S_2$ 264.0147; Found 264.0147.

Methyl 3-(benzo[*d*]oxazol-2-yldisulfanyl)propanoate (17)



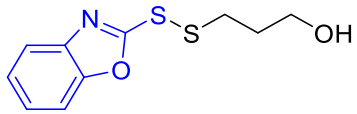
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and methyl 3-mercaptopropanoate (37 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a yellow oil (66 mg, 83%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69–7.62 (m, 1H), 7.50–7.46 (m, 1H), 7.33–7.27 (m, 2H), 3.67 (s, 3H), 3.23 (t, *J* = 7.2 Hz, 2H), 2.85 (t, *J* = 7.2 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.6, 162.8, 152.3, 141.7, 124.8, 124.6, 119.3, 110.2, 51.9, 33.9, 33.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{11}H_{12}NO_3S_2$ 270.0253; Found 270.0254.

2-Ethylhexyl 2-((4-fluorophenyl)disulfanyl)acetate (18)



According to the general procedure for the synthesis of unsymmetrical disulfides, 2-ethylhexyl 2-mercaptoacetate (92 mg, 0.45 mmol, 1.5 equiv) and 4-fluorobenzenethiol (39 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (53 mg, 54%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56–7.51 (m, 2H), 7.06–7.00 (m, 2H), 3.98–3.93 (m, 2H), 3.49 (s, 2H), 1.58–1.48 (m, 1H), 1.37–1.26 (m, 8H), 0.91–0.85 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0, 162.6 (d, $J_{C\text{-}F}$ = 249.0 Hz), 131.7 (d, $J_{C\text{-}F}$ = 8.1 Hz), 131.4 (d, $J_{C\text{-}F}$ = 3.4 Hz), 116.2 (d, $J_{C\text{-}F}$ = 22.2 Hz), 68.0, 40.8, 38.6, 30.2, 28.8, 23.6, 22.9, 14.0, 10.9. ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.5. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{16}H_{24}FO_2S_2$ 331.1196; Found 331.1193.

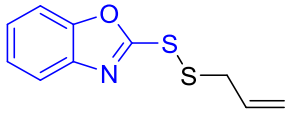
3-(Benzo[*d*]oxazol-2-yldisulfanyl)propan-1-ol (19)[6]



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and methyl 3-mercaptopropan-1-ol (28 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:2), the title compound was obtained as a rufous oil (58 mg, 80%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67–7.63 (m, 1H), 7.49–7.44 (m, 1H), 7.33–7.26 (m, 2H), 3.82 (t, *J* = 6.0 Hz, 2H), 3.15 (t, *J* = 6.8

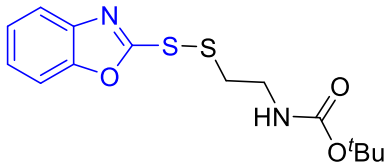
Hz, 2H), 2.03–1.96 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.0, 152.3, 141.4, 124.8, 124.7, 119.1, 110.2, 60.2, 36.0, 31.0.

2-(Allyldisulfanyl)benzo[*d*]oxazole (20)



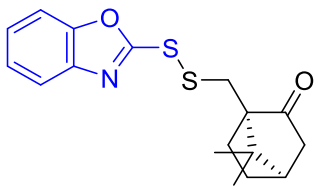
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and prop-2-ene-1-thiol (22 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (34 mg, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70–7.66 (m, 1H), 7.53–7.47 (m, 1H), 7.34–7.28 (m, 2H), 5.92–5.82 (m, 1H), 5.24–5.17 (m, 2H), 3.62 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.4, 152.3, 141.8, 131.4, 124.7, 124.6, 120.2, 119.3, 110.2, 42.0. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{10}H_{10}NOS_2$ 224.0198; Found 224.0198.

***tert*-Butyl (2-(benzo[*d*]oxazol-2-yldisulfanyl)ethyl)carbamate (21)**



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl (2-mercaptoethyl)carbamate (53 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (66 mg, 57%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67–7.65 (m, 1H), 7.49–7.46 (m, 1H), 7.34–7.28 (m, 2H), 6.03 (s, 1H), 3.53–3.47 (m, 2H), 3.08 (t, *J* = 5.6 Hz, 2H), 1.44 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.3, 155.9, 152.6, 141.4, 124.8, 124.7, 119.2, 110.3, 79.4, 39.7, 38.3, 28.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{14}H_{19}N_2O_3S_2$ 327.0832; Found 327.0831.

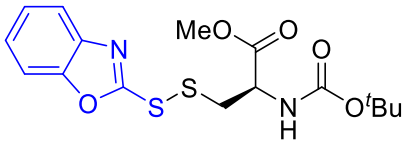
(1*S*,4*R*)-1-((Benzo[*d*]oxazol-2-yldisulfanyl)methyl)-7,7-dimethylbicyclo[2.2.1]heptan-2-one (22)



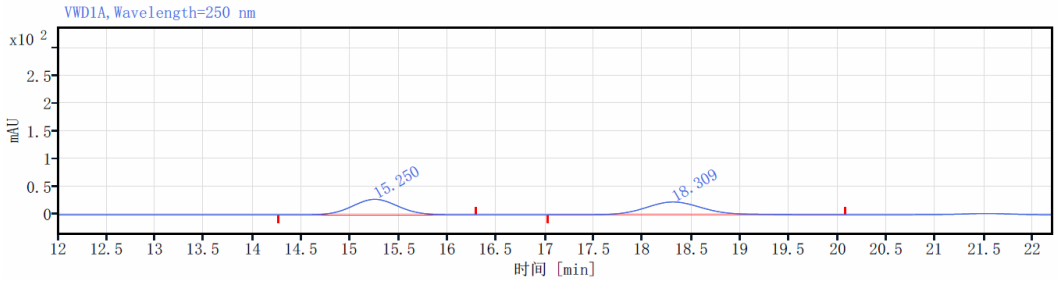
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and (1*S*,4*R*)-1-

(mercaptomethyl)-7,7-dimethylbicyclo[2.2.1]heptan-2-one (55 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:10), the title compound was obtained as a yellow oil (50 mg, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70–7.66 (m, 1H), 7.54–7.49 (m, 1H), 7.35–7.29 (m, 2H), 3.52 (d, *J* = 13.2 Hz, 1H), 3.03 (d, *J* = 13.2 Hz, 1H), 2.43–2.36 (m, 1H), 2.13–2.11 (m, 1H), 2.09–2.05 (m, 1H), 1.91 (d, *J* = 18.4 Hz, 1H), 1.73–1.70 (m, 2H), 1.46–1.40 (m, 1H), 1.06 (s, 3H), 0.94 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.7, 163.5, 152.4, 142.0, 124.7, 124.6, 119.4, 110.3, 61.6, 48.0, 43.6, 43.0, 39.8, 26.8, 26.6, 20.2, 19.9. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{17}H_{20}NO_2S_2$ 334.0930; Found 334.0931.

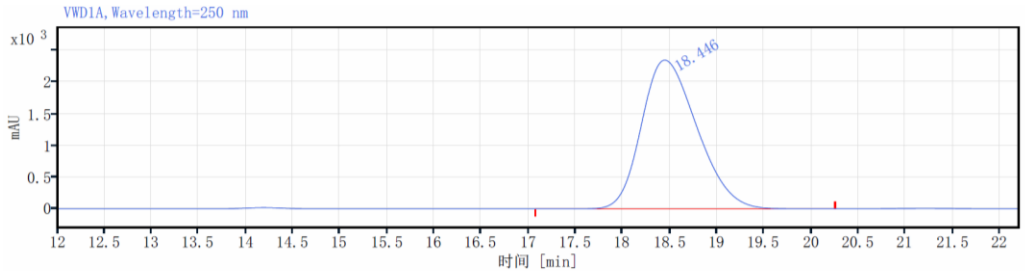
Methyl S-(benzo[*d*]oxazol-2-ylthio)-N-(*tert*-butoxycarbonyl)-L-cysteinate (23)



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl methyl (tert-butoxycarbonyl)-L-cysteinate (78 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:5), the title compound was obtained as a colorless oil (90 mg, 78%), > 99% e.e.. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69–7.66 (m, 1H), 7.48–7.44 (m, 1H), 7.32–7.25 (m, 2H), 6.20 (d, *J* = 8.4 Hz, 1H), 4.71–4.64 (m, 1H), 3.70 (s, 3H), 3.57–3.41 (m, 2H), 1.39 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 163.5, 155.2, 152.5, 141.5, 124.9, 124.7, 119.4, 110.3, 80.2, 52.7, 42.1, 29.7, 28.2. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{16}H_{21}N_2O_5S_2$ 385.0886; Found 385.0886. $[\alpha]D^{15}$ = 1.92° (c = 0.05, $CHCl_3$). HPLC analysis: The enantiomeric excess was determined on a CHIRALPAK AD-H column (10% ^{i}PrOH in hexane, 1.0 mL/min, 25 ℃, λ = 250 nm), tR (major) = 18.466 min.

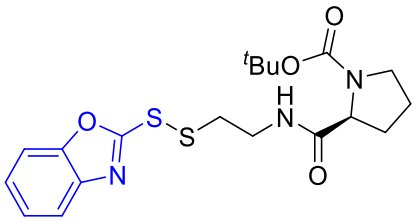


Resolution Time (min)	Width (min)	Area	Height	Area %
15.250	2.019	916.6	28.0	48.87
18.309	3.053	958.8	23.2	51.13
		Total VWD1A	1875.4	

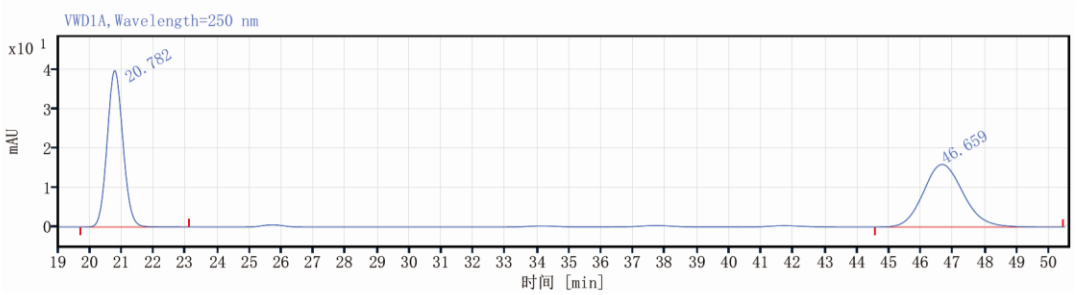


Resolution Time (min)	Width (min)	Area	Height	Area %
18.446	3.180	96605.9	2354.2	100.00
		Total VWD1A	96605.9	

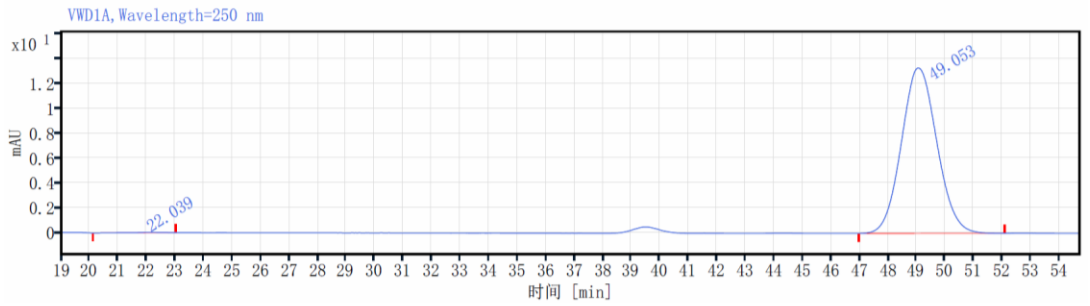
tert-Butyl 2-((2-(benzo[_d_]oxazol-2-yldisulfanyl)ethyl)carbamoyl)pyrrolidine-1-carboxylate (24)



According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl 2-((2-mercaptoethyl)carbamoyl)pyrrolidine-1-carboxylate (82 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:2), the title compound was obtained as a colorless oil (75 mg, 56%), > 99% e.e.. Rotamers, the integrations are given as observed. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01–8.00 (m, 0.3H), 7.75–7.67 (m, 0.3H), 7.52–7.46 (m, 0.4H), 7.35–7.26 (m, 5H), 6.78–6.68 (m, 0.4H), 5.60–5.36 (m, 1H), 4.57–4.24 (m, 3.3H), 4.02–3.54 (m, 3H), 3.50–3.36 (m, 0.8H), 3.12–2.98 (m, 1.3H), 1.49–1.38 (m, 9H). ^{13}C NMR (101 MHz, CDCl3) δ 170.5, 155.3, 152.5, 141.3, 137.2, 128.4, 127.7, 124.9, 110.3, 80.5, 73.3, 70.0, 69.8, 60.4, 39.0, 37.1, 28.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{19}H_{26}N_3O_4S_2$ 424.1359; Found 424.1359. $[\alpha]D^{15}$ = -12.57° (c = 0.1, $CHCl_3$). HPLC analysis: The enantiomeric excess was determined on a CHIRALPAK AD-H column (5% ^{i}PrOH in hexane, 1.0 mL/min, 25 ℃, λ = 250 nm), tR (major) = 49.053 min, tR (minor) = 22.039 min.

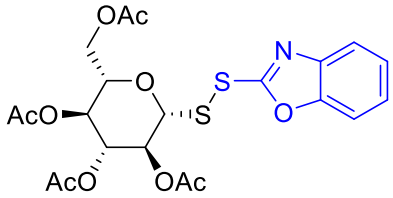


Resolution Time (min)	Width (min)	Area	Height	Area %
20.782	3.403	1369.6	39.9	49.53
46.659	5.880	1395.4	16.0	50.47
		Total VWD1A	2765.0	



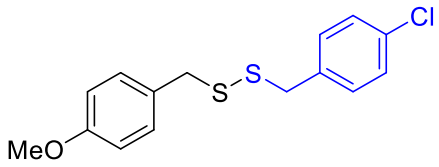
Resolution Time (min)	Width (min)	Area	Height	Area %
22.039	0.719	2.2	0.0	0.19
49.053	5.112	1148.5	13.3	99.81
		Total VWD1A	1150.7	

(2*S*,3*S*,4*R*,5*S*,6*R*)-2-(Acetoxymethyl)-6-(benzo[*d*]oxazol-2-yldisulfanyl)tetrahydro-2H-pyran-3,4,5-triyl triacetate (25)[7]



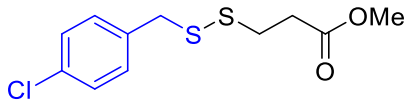
According to the general procedure for the synthesis of unsymmetrical disulfides, benzo[*d*]oxazole-2-thiol (67 mg, 0.45 mmol, 1.5 equiv) and (2*S*,3*S*,4*R*,5*S*,6*R*)-2-(acetoxymethyl)-6-mercaptotetrahydro-2H-pyran-3,4,5-triyl triacetate (110 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:2), the title compound was obtained as a white solid (112 mg, 73%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65–7.60 (m, 1H), 7.50–7.45 (m, 1H), 7.32–7.28 (m, 2H), 5.29–5.21 (m, 2H), 5.10–5.02 (m, 1H), 4.77–4.70 (m, 1H), 4.04–3.99 (m, 1H), 3.94–3.91 (m, 1H), 3.73–3.69 (m, 1H), 2.03 (s, 3H), 1.98–1.95 (m, 6H), 1.79 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3, 170.0, 169.2 (2C), 161.7, 152.1, 141.8, 125.0, 124.7, 119.4, 110.2, 86.3, 76.0, 73.4, 69.1, 67.6, 61.5, 20.6, 20.5 (2C), 20.3.

1-(4-Chlorobenzyl)-2-(4-methoxybenzyl)disulfide (26)[8]



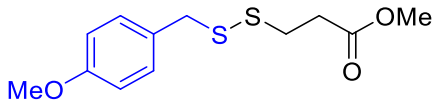
According to the general procedure for the synthesis of unsymmetrical disulfides, (4-chlorophenyl)methanethiol (68 mg, 0.45 mmol, 1.5 equiv) and (4-methoxyphenyl)methanethiol (46 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:100), the title compound was obtained as a white solid (32 mg, 35%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31–7.27 (m, 2H), 7.20–7.14 (m, 4H), 6.89–6.85 (m, 2H), 3.81 (s, 3H), 3.62 (s, 2H), 3.55 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 135.9, 133.2, 130.7, 130.5, 129.1, 128.5, 76.7,55.3, 42.7, 42.3.

Methyl 3-((4-chlorobenzyl)disulfanyl)propanoate (27)[9]



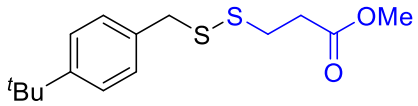
According to the general procedure for the synthesis of unsymmetrical disulfides, (4-chlorophenyl)methanethiol (68 mg, 0.45 mmol, 1.5 equiv) and methyl 3-mercaptopropanoate (37 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (38 mg, 46%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33–7.27 (m, 4H), 3.86 (s, 2H), 3.71 (s, 3H), 2.72–2.68 (m, 2H), 2.66–2.62 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.0, 135.8, 133.3, 130.5, 128.7, 51.8, 42.6, 33.8, 32.8.

Methyl 3-((4-methoxybenzyl)disulfanyl)propanoate (28)



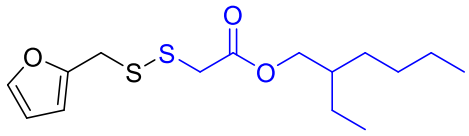
According to the general procedure for the synthesis of unsymmetrical disulfides, (4-methoxyphenyl)methanethiol (69 mg, 0.45 mmol, 1.5 equiv) and methyl 3-mercaptopropanoate (37 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:10), the title compound was obtained as a colorless oil (29 mg, 36%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26–7.22 (m, 2H), 6.87–6.83 (m, 2H), 3.86 (s, 2H), 3.80 (s, 3H), 3.68 (s, 3H), 2.69–2.60 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.2, 159.0, 130.4, 129.1, 113.9, 55.2, 51.8, 42.9, 33.8, 32.8. HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{12}H_{16}NaO_3S_2$ 295.0433; Found 295.0434.

Methyl 3-((4-(*tert*-butyl)benzyl)disulfanyl)propanoate (29)



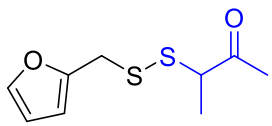
According to the general procedure for the synthesis of unsymmetrical disulfides, methyl 3-mercaptopropanoate (54 mg, 0.45 mmol, 1.5 equiv) and (4-(*tert*-butyl)phenyl)methanethiol (54 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (45 mg, 51%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36–7.33 (m, 2H), 7.27–7.24 (m, 2H), 3.88 (s, 2H), 3.67 (s, 3H), 2.67–2.57 (m, 4H), 1.31 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.2, 150.6, 134.0, 128.9, 125.5, 51.8, 43.2, 34.5, 33.8, 32.8, 31.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{15}H_{23}O_2S_2$ 299.1134; Found 299.1134.

2-Ethylhexyl 2-((furan-2-ylmethyl)disulfanyl)acetate (30)



According to the general procedure for the synthesis of unsymmetrical disulfides, 2-ethylhexyl 2-mercaptoacetate (92 mg, 0.45 mmol, 1.5 equiv) and furan-2-ylmethanethiol (35 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (48 mg, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.38 (m, 1H), 6.35–6.33 (m, 1H), 6.29–6.26 (m, 1H), 4.06–4.04 (m, 2H), 3.98 (s, 2H), 3.26 (s, 2H), 1.63–1.58 (m, 1H), 1.39–1.35 (m, 2H), 1.32–1.28 (m, 6H), 0.91–0.87 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.6, 149.9, 142.6, 110.8, 109.1, 67.9, 41.4, 38.7, 35.7, 30.3, 28.9, 23.7, 23.0, 14.0, 11.0. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{15}H_{25}O_3S_2$ 317.1240; Found 317.1240.

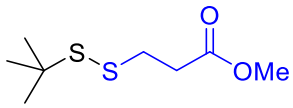
3-((Furan-2-ylmethyl)disulfanyl)butan-2-one (31)



According to the general procedure for the synthesis of unsymmetrical disulfides, 3-mercaptobutan-2-one (47 mg, 0.45 mmol, 1.5 equiv) and furan-2-ylmethanethiol (35 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:10), the title compound was obtained as a yellow oil (36 mg, 56%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.37 (m, 1H), 6.33–6.32 (m, 1H), 6.26–6.25 (m, 1H), 3.89 (s, 2H), 3.28 (q, J = 7.2 Hz, 1H), 2.26 (s, 3H), 1.35 (d, J = 7.0 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 205.0, 149.8, 142.6, 110.7, 109.2, 53.6, 35.7,

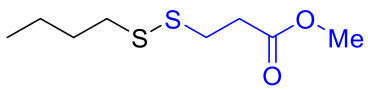
27.4, 15.4. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_9H_{13}O_2S_2$ 217.0351; Found 217.0351.

Methyl 3-(*tert*-butyldisulfanyl)propanoate (32)[9]



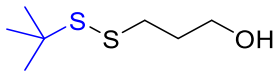
According to the general procedure for the synthesis of unsymmetrical disulfides, methyl 3-mercaptopropanoate (54 mg, 0.45 mmol, 1.5 equiv) and *tert*-butylthiol (27 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (27 mg, 42%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.69 (s, 3H), 2.92 (t, *J* = 7.2 Hz, 2H), 2.72 (t, *J* = 7.2 Hz, 2H), 1.33 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.3, 51.8, 48.0, 34.8, 34.1, 29.9.

Methyl 3-(butyldisulfanyl)propanoate (33)



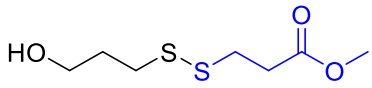
According to the general procedure for the synthesis of unsymmetrical disulfides, methyl 3-mercaptopropanoate (54 mg, 0.45 mmol, 1.5 equiv) and butane-1-thiol (28 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a colorless oil (24 mg, 39%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.70 (s, 3H), 2.90 (t, *J* = 7.2 Hz, 2H), 2.75 (t, *J* = 7.2 Hz, 2H), 2.69 (t, *J* = 7.2 Hz, 2H), 1.68–1.61 (m, 2H), 1.45–1.36 (m, 2H), 0.92 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.3, 51.8, 38.7, 34.0, 33.1, 31.2, 21.6, 13.7. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_8H_{17}O_2S_2$ 209.0664; Found 209.0665.

3-(*tert*-Butyldisulfanyl)propan-1-ol (34)[9]



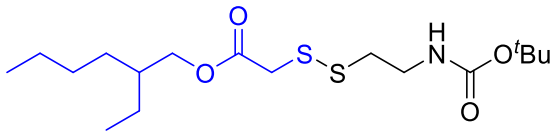
According to the general procedure for the synthesis of unsymmetrical disulfides, *tert*-butylthiol (36 mg, 0.45 mmol, 1.5 equiv) and 3-mercaptopropan-1-ol (28 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:5), the title compound was obtained as a colorless oil (24 mg, 45%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.74 (t, *J* = 6.1 Hz, 2H), 2.81 (t, *J* = 7.1 Hz, 2H), 1.95–1.89 (m, 2H), 1.33 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 61.0, 47.9, 36.9, 31.9, 29.9.

Methyl 3-((3-hydroxypropyl)disulfanyl)propanoate (35)



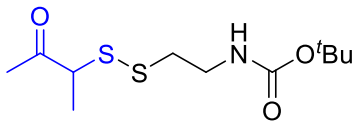
According to the general procedure for the synthesis of unsymmetrical disulfides, methyl 3-mercaptopropanoate (54 mg, 0.45 mmol, 1.5 equiv) and 3-mercaptopropan-1-ol (28 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:3), the title compound was obtained as a colorless oil (41 mg, 65%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.73 (t, *J* = 6.1 Hz, 2H), 3.69 (s, 3H), 2.91 (t, *J* = 7.3 Hz, 2H), 2.79 (t, *J* = 7.1 Hz, 2H), 2.74 (t, *J* = 7.2 Hz, 2H), 1.96–1.90 (m, 2H), 1.87 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.3, 60.8, 51.9, 35.0, 33.9, 33.0, 31.7. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_7H_{15}O_3S_2$ 211.0457; Found 211.0456.

2-Ethylhexyl 2-((2-((tert-butoxycarbonyl)amino)ethyl)disulfanyl)acetate (36)



According to the general procedure for the synthesis of unsymmetrical disulfides, 2-ethylhexyl 2-mercaptoacetate (92 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl (2-mercaptoethyl)carbamate (53 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:5), the title compound was obtained as a colorless oil (63 mg, 55%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.00 (s, 1H), 4.10–4.00 (m, 2H), 3.48–3.42 (m, 3H), 2.84 (t, *J* = 6.0 Hz, 2H), 1.61–1.55 (m, 1H), 1.42 (s, 9H), 1.37–1.33 (m, 2H), 1.31–1.21 (m, 6H), 0.89–0.85 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.6, 155.7, 79.4, 68.0, 41.3, 39.0, 38.6, 38.4, 30.2, 28.8, 28.3, 23.6, 22.9, 14.0, 10.9. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{17}H_{34}NO_4S_2$ 380.1924; Found 380.1924.

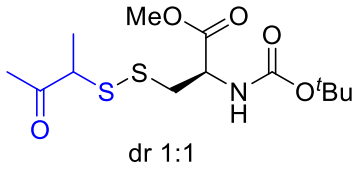
***tert*-Butyl (2-((3-oxobutan-2-yl)disulfanyl)ethyl)carbamate (37)**



According to the general procedure for the synthesis of unsymmetrical disulfides, 3-mercaptobutan-2-one (47 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl (2-mercaptoethyl)carbamate (53 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:5), the title compound was obtained as a colorless oil (52 mg, 62%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.99 (s, 1H), 3.51 (q, *J* = 7.2 Hz, 1H), 3.44–3.33 (m, 2H), 2.79–2.70 (m, 2H), 2.27 (s, 3H), 1.41–1.39 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 204.8, 155.6, 79.4, 53.2, 39.1, 38.7, 28.3, 26.9, 15.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{11}H_{22}NO_3S_2$ 280.1036;

Found 280.1035.

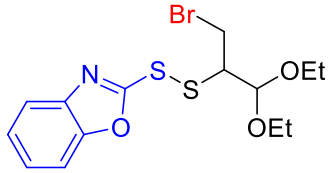
Methyl *N*-(*tert*-butoxycarbonyl)-((3-oxobutan-2-yl)thio)-L-cysteinate (38)



dr 1:1

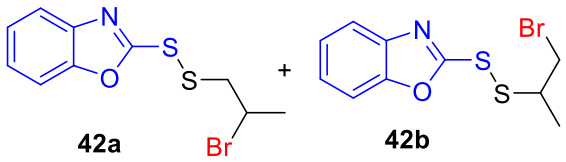
According to the general procedure for the synthesis of unsymmetrical disulfides, 3-mercaptobutan-2-one (47 mg, 0.45 mmol, 1.5 equiv) and *tert*-butyl methyl (tert-butoxycarbonyl)-L-cysteinate (78 mg, 0.3 mmol, 1.0 equiv) were applied. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:3), the title compound was obtained as a colorless oil (72 mg, 71%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.46–5.23 (m, 1H), 4.66–4.53 (m, 1H), 3.74 (s, 3H), 3.57–3.50 (m, 1H), 3.16–2.96 (m, 2H), 2.26 (d, *J* = 5.2 Hz, 3H), 1.46–1.38 (m, 12H). ^{13}C NMR (101 MHz, Chloroform-*d*) (one isomer) δ 204.5, 171.0, 170.9, 154.9, 80.2, 53.5, 52.8, 41.4, 28.2, 27.0, 15.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{13}H_{24}NO_5S_2$ 338.1090; Found 338.1091. $[\alpha]D^{15}$ = 1.7° (c = 0.1, $CHCl_3$).

2-((3-Bromo-1,1-diethoxypropan-2-yl)disulfanyl)benzo[*d*]oxazole (40)



A dry flask charged with BDMS (100 mg, 0.45mmol, 1.5 equiv) and benzo[*d*]oxazole-2-thiol (67 mg, 0.45mmol, 1.5 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry DMF (3 mL) were injected to the flask at 0 ℃ with an ice bath. After a stirring of 5 min, K_2CO_3 (62 mg, 0.45mmol, 1.5 equiv) and 2-(diethoxymethyl)thiirane (49 mg, 0.3mmol, 1.0 equiv) were added to the flask. The reaction mixture was then stirred at 0 ℃ for 1 h, before quenching with H_2O. After the extraction with Et_2O (10 mL X 3), the combined organic layers were washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:20), the title compound was obtained as a colorless oil (63 mg, 56%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67–7.63 (m, 1H), 7.51–7.46 (m, 1H), 7.34–7.28 (m, 2H), 4.88 (d, *J* = 4.0 Hz, 1H), 3.92–3.83 (m, 2H), 3.81–3.71 (m, 2H), 3.64–3.55 (m, 3H), 1.24–1.20 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.8, 152.3, 141.8, 125.0, 124.6, 119.5, 110.3, 102.0, 64.2, 64.1, 57.9, 31.7, 15.2, 15.1. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{14}H_{19}BrNO_3S_2$ 391.9984; Found 391.9983.

2-((2-Bromopropyl)disulfanyl)benzo[*d*]oxazole (42a)
2-((1-Bromopropan-2-yl)disulfanyl)benzo[*d*]oxazole (42b)

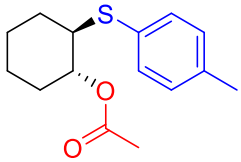


42a **42b**

50% (2 : 1)

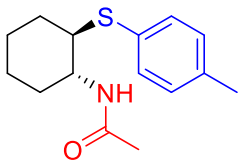
A dry flask charged with BDMS (100 mg, 0.45mmol, 1.5 equiv) and benzo[*d*]oxazole-2-thiol (67 mg, 0.45mmol, 1.5 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry DMF (3 mL) were injected to the flask at 0 ℃ with an ice bath. After a stirring of 5 min, K_2CO_3 (62 mg, 0.45mmol, 1.5 equiv) and 2-methylthiirane (22 mg, 0.3mmol, 1.0 equiv) were added to the flask. The reaction mixture was then stirred at 0 ℃ for 1 h, before quenching with H_2O. After the extraction with Et_2O (10 mL X 3), the combined organic layers were washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure (NMR yield with Anisole as the internal standard, 50%). After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:100), the title compound was obtained as a colorless oil. The major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71–7.66 (m, 1H), 7.53–7.49 (m, 1H), 7.37–7.31 (m, 2H), 3.93–3.85 (m, 1H), 3.53–3.46 (m, 2H), 1.56–1.50 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.7, 152.4, 141.8, 125.0, 124.8, 119.5, 110.4, 47.3, 36.9, 18.3. HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{10}H_{11}BrNOS_2$ 303.9460; Found 303.9460.

2-(*p*-Tolylthio)cyclohexyl acetate (43)[10]



A dry flask, charged with BDMS (221 mg, 1 mmol, 2 equiv) and 4-methylbenzenethiol (124 mg, 1 mmol, 2 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry DCM (5 mL) were injected to the flask at 0 ℃ with an oil bath. After a stirring of 5 min, Et_3N (152 mg, 1.5 mmol, 3.0 equiv), cyclohexene (41 mg, 0.5 mmol, 1.0 equiv) and acetic acid (60 mg. 1 mmol, 2.0 equiv) were added to the flask. The reaction mixture was then stirred and refluxed at 85 ℃ for 10 h, before quenching with H_2O. After the extraction with Et_2O (10 mL X 3), the combined organic layers were washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:50), the title compound was obtained as a yellow oil (116 mg, 88%).^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36–7.32 (m, 2H), 7.10–7.08 (m, 2H), 4.78–4.72 (m, 1H), 3.07–3.01 (m, 1H), 2.31 (s, 3H), 2.11–2.02 (m, 2H)1.95 (s, 3H), 1.71–1.63 (m, 2H), 1.42–1.28 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.2, 137.1, 133.1, 130.3, 129.4, 74.8, 50.4, 31.5, 31.2, 24.9, 23.4, 21.0, 20.9.

***N*-(2-(*p*-Tolylthio)cyclohexyl)acetamide (44)** [10]



A dry flask charged with BDMS (221 mg, 1 mmol, 2 equiv) and 4-methylbenzenethiol (221 mg, 1 mmol, 2 equiv), was vacuumed and refilled with nitrogen (3 cycles). Dry MeCN (5 mL) were injected to the flask at 0 ℃ with an oil bath. After a stirring of 5 min, cyclohexene (41 mg, 0.5 mmol, 1.0 equiv) and H_2O (18 mg, 1 mmol, 2.0 equiv) were added to the flask. The reaction mixture was then stirred and refluxed at 100 ℃ for 10 h, before quenching with H_2O. After the extraction with Et_2O (10 mL X 3), the combined organic layers were washed with brine, dried over Na_2SO_4, filtrated and concentrated under reduced pressure. After purification by column chromatography on silica gel (EtOAc/petroleum ether 1:1), the title compound was obtained as a white solid (21 mg, 16%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34–7.32 (m, 2H), 7.11–7.09 (m, 2H), 5.62 (s, 1H), 3.72–3.64 (m, 1H), 2.82–2.72 (m, 1H), 2.31 (s, 3H), 2.19–2.03 (m, 2H), 1.93 (s, 3H), 1.74–1.62 (m, 2H), 1.36–1.18 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.4, 137.6, 133.8, 129.6, 129.5, 52.7, 51.8, 33.5, 33.0, 25.8, 24.4, 23.5, 21.1.

4 References

[1] P. F. Huang, P. Wang, S. Tang, Z. J. Fu, A. W. Lei, *Angew. Chem. Int. Ed.* **2018**, *57*, 8115.

[2] N. Stellenboom, R. Hunter, M. R. Caira, *Tetrahedron.* **2010**, *66*, 3228.

[3] J. M. Guo, J. J. Zha, T. Zhang, C. H. Ding, Q. T. Tan, B. Xu, *Org. Lett.* **2021**, *23*, 3167.

[4] T. R. DiRaimondo, N. M. Plugis, J. Xi, C. Khosla, *J. Med. Chem.* **2013**, *56*, 1301.

[5] M. Krumb, L. M. Kammer, R. Forster, C. Grundke, T. Opatz, *ChemPhotoChem.* **2020**, *4*, 101.

[6] J. K. Vandavasi, W. P. Hu, C. Y. Chen, J. J. Wang, *Tetrahedron* **2011**, *67*, 8895.

[7] G. R. Morais, R. A. Falconer, *Tetrahedron Lett.* **2007**, *48*, 7637.

[8] D. G. Wang, Q. He, K. Q. Shi, M. T. Xiong, Y. F. Zhou, Y. J. Pan, *Adv. Synth. Catal.* **2021**, *363*, 2767.

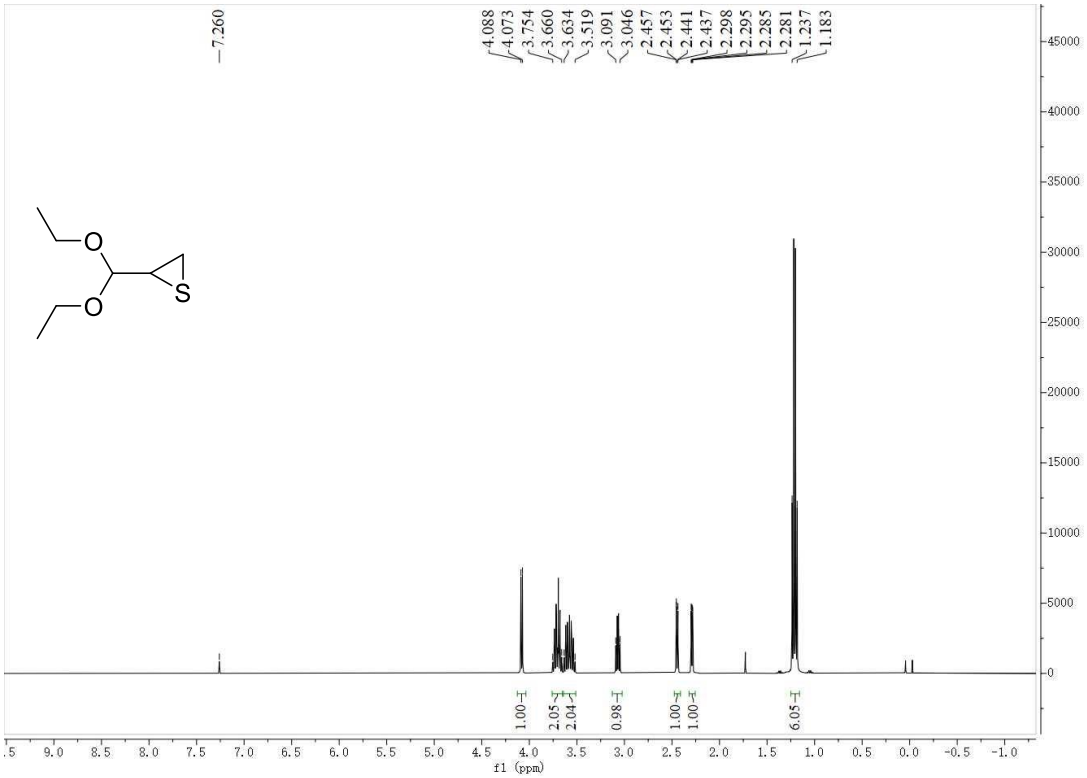
[9] X. Qiu, X. X. Yang, Y. Q. Zhang, S. Song, N. Jiao, *Org. Chem. Front.* **2019**, *6*, 2220.

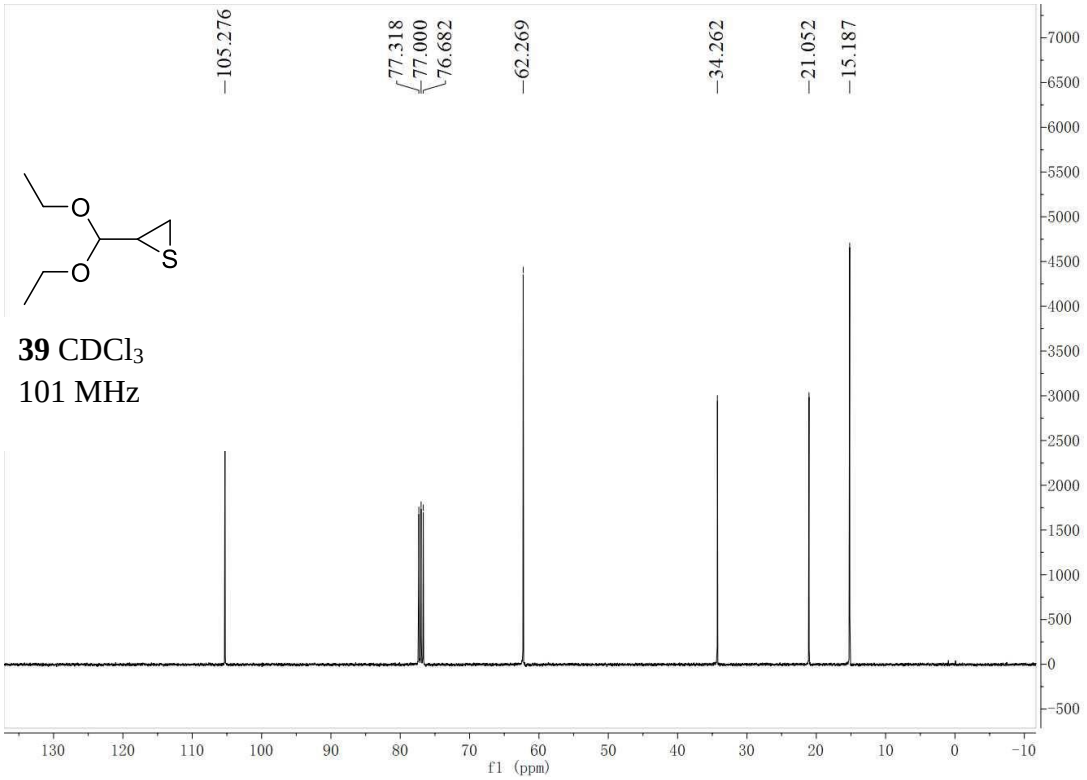
[10] D. Y. Wang, Z. H. Yan, Q. H. Xie, R. X. Zhang, S. Lin, Y. X. Wang, *Org. Biomol. Chem.* **2017**, *15*, 1998.

[11] M. G. Silvestri, C. H. Wong, *J. Org. Chem.* **2001,** *66*, 910.

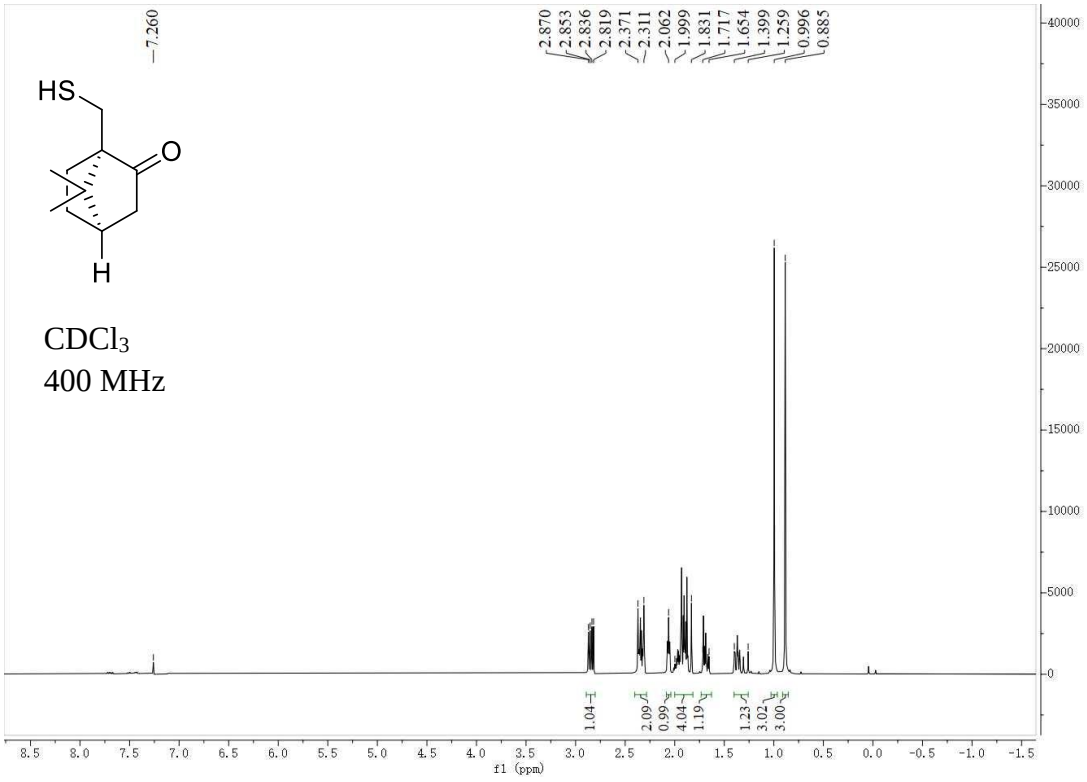
[12] S. Knoppe, N. Kothalawala, V. R. Jupally, A. Dass, T. Bürgi, *Chem. Commun.* **2012**, *48*, 4630.

5 NMR spectra

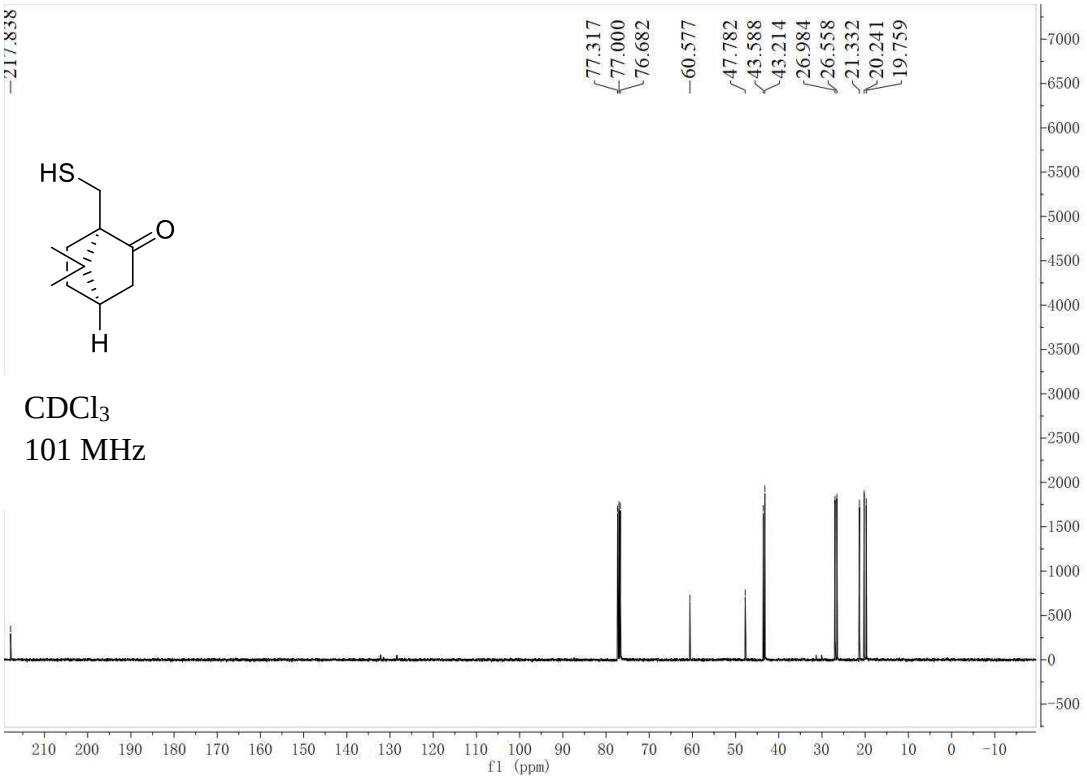




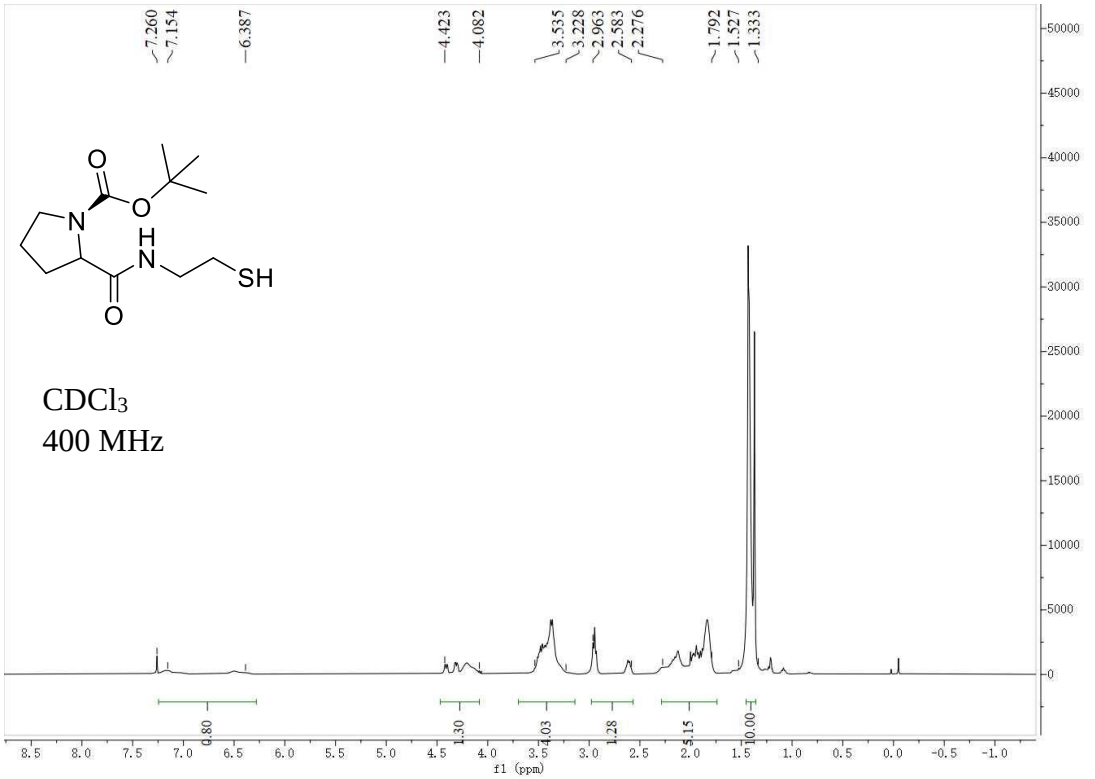
39 $CDCl_3$
101 MHz

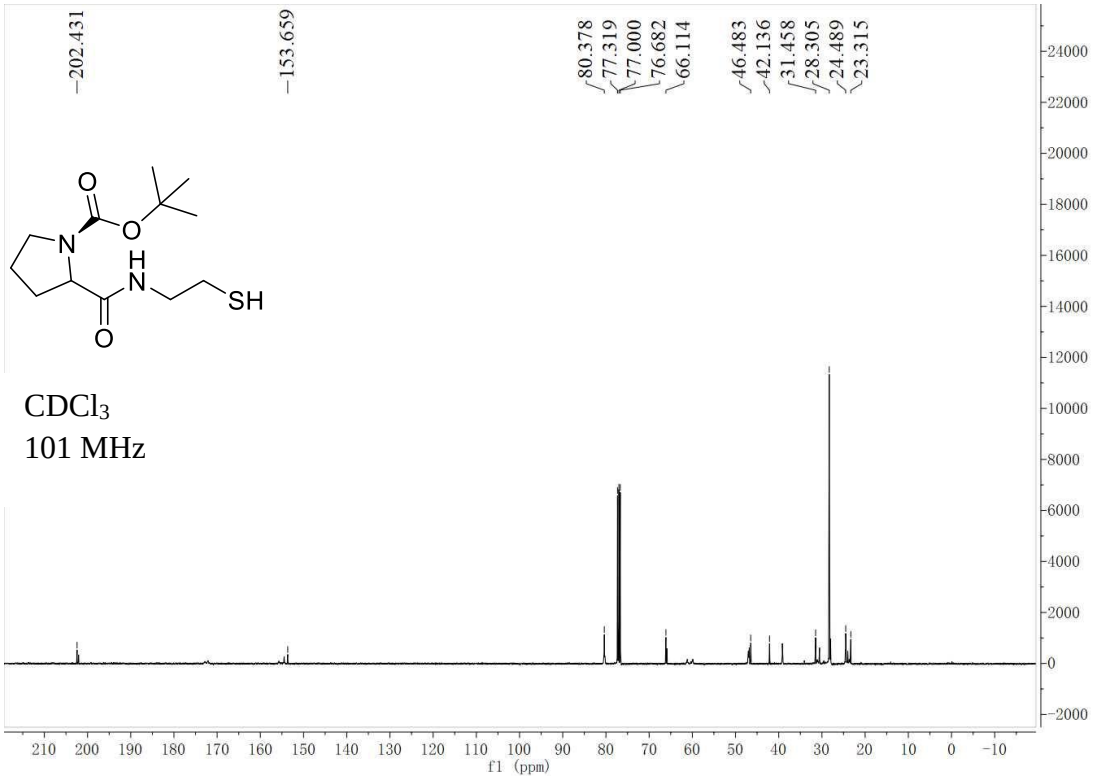


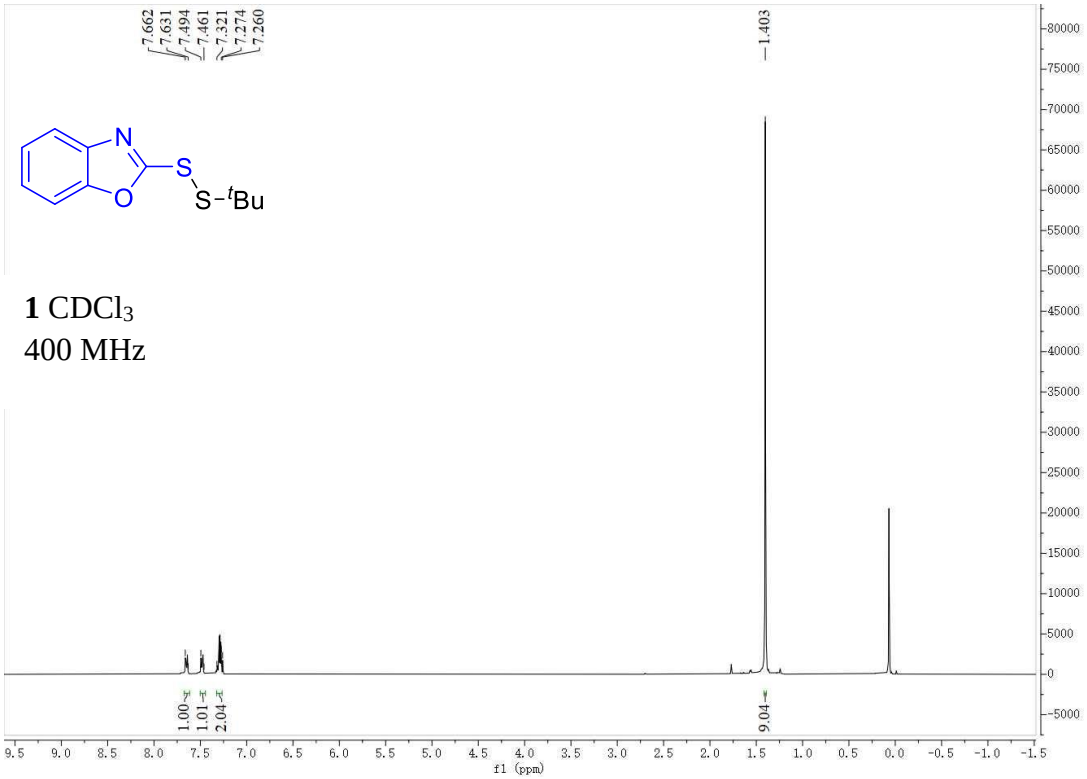
$CDCl_3$
400 MHz



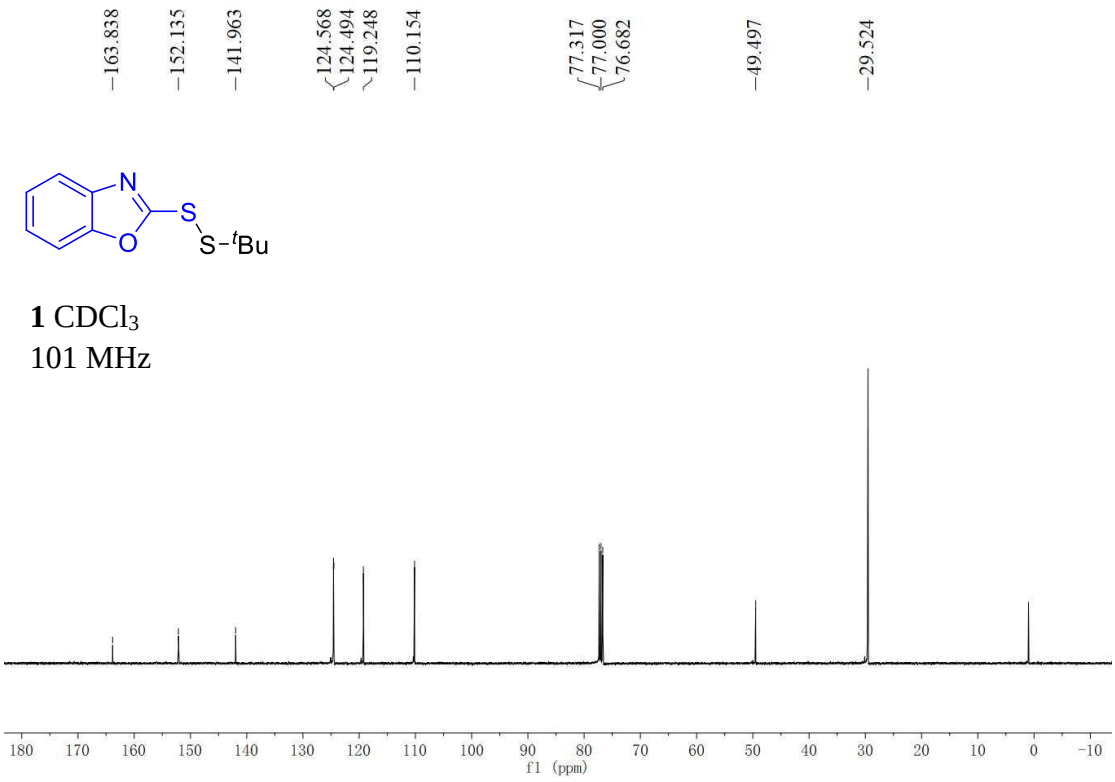
$CDCl_3$
101 MHz


7.260
7.154
6.387
4.423
4.082
3.535
3.228
2.963
2.583
2.276
1.792
1.527
1.333
O
O
N
H
N
SH
O
CDCl3
400 MHz
0.80
1.30
4.03
1.28
3.15
10.00
f1 (ppm)

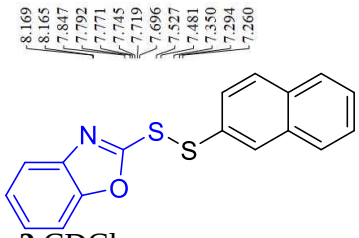

202.431
153.659
80.378
77.319
77.000
76.682
66.114
46.483
42.136
31.458
28.305
24.489
23.315
O
O
N
H
N
SH
O
CDCl3
101 MHz
f1 (ppm)



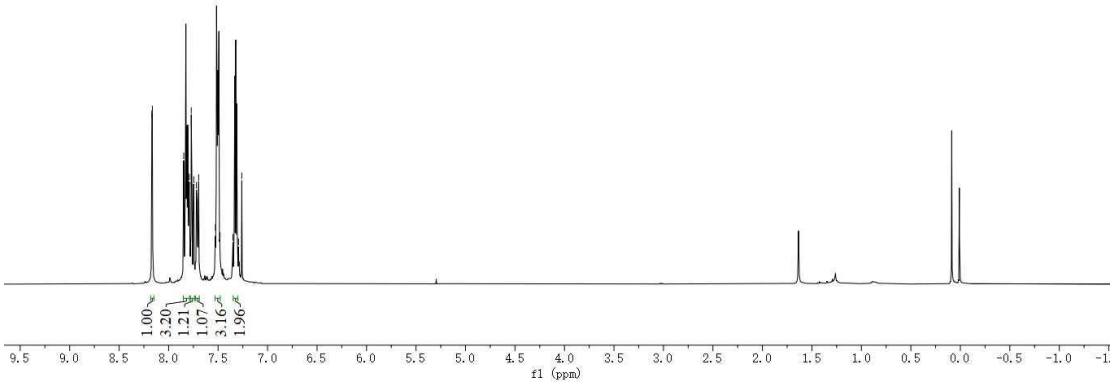
1 $CDCl_3$
400 MHz

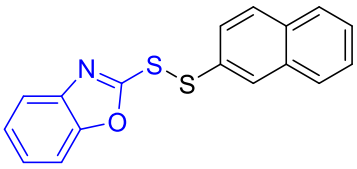


1 $CDCl_3$
101 MHz

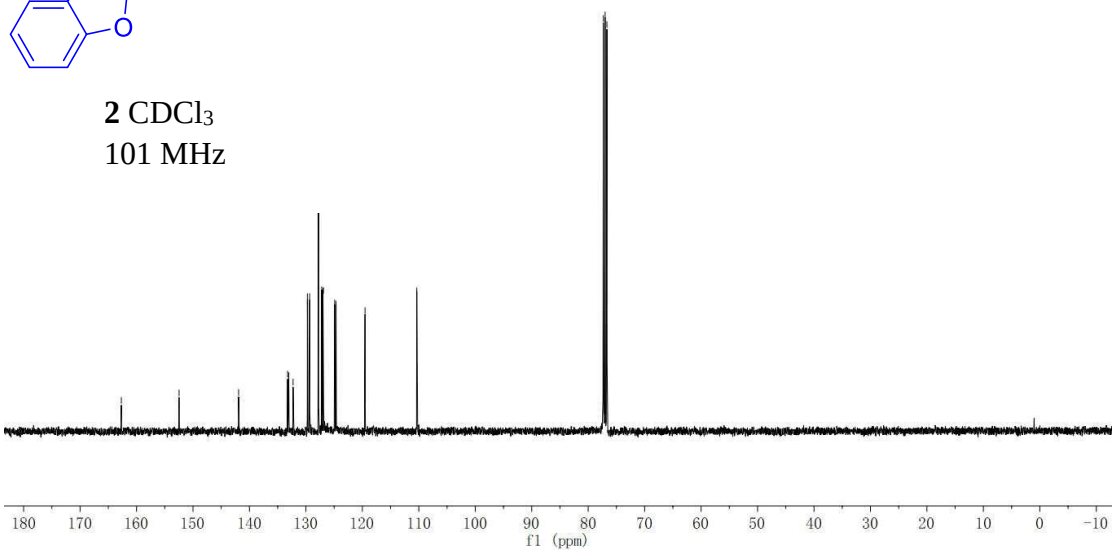


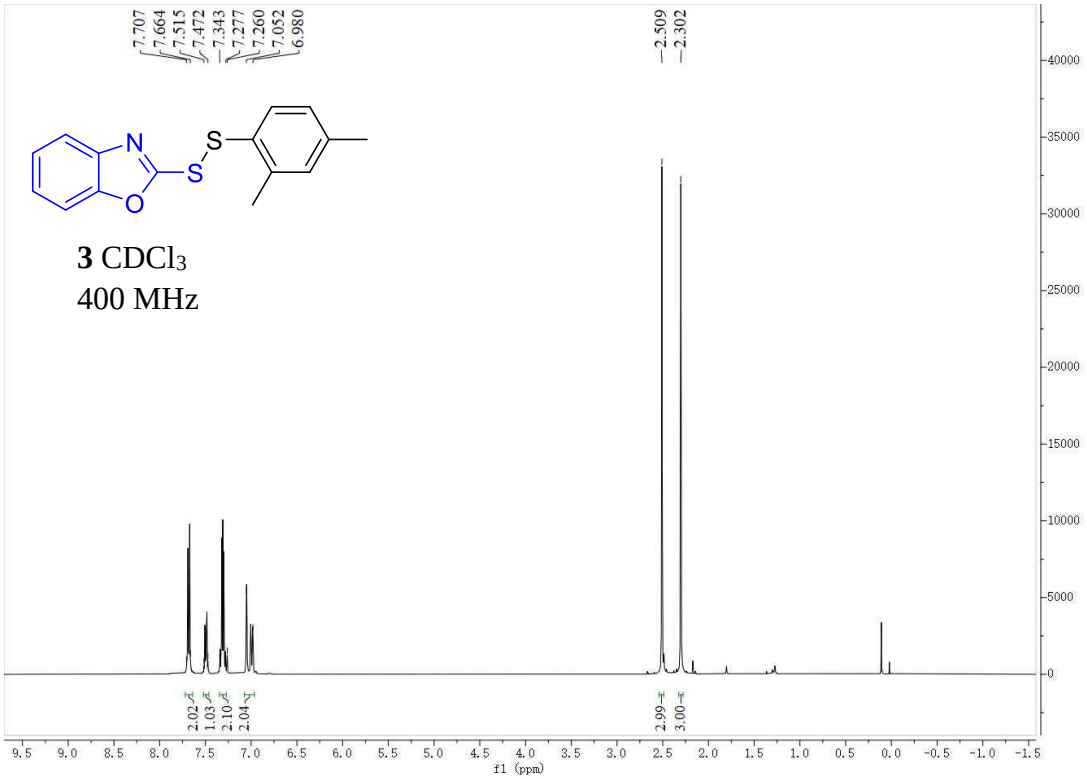
2 $CDCl_3$
400 MHz



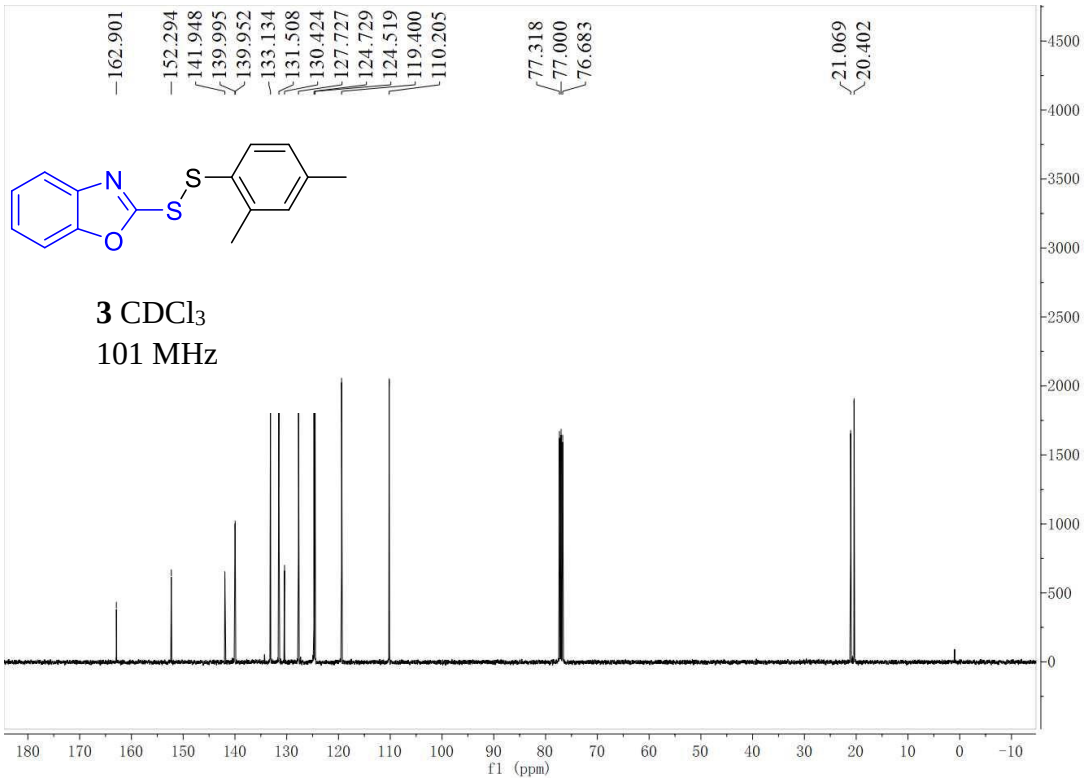


2 $CDCl_3$
101 MHz

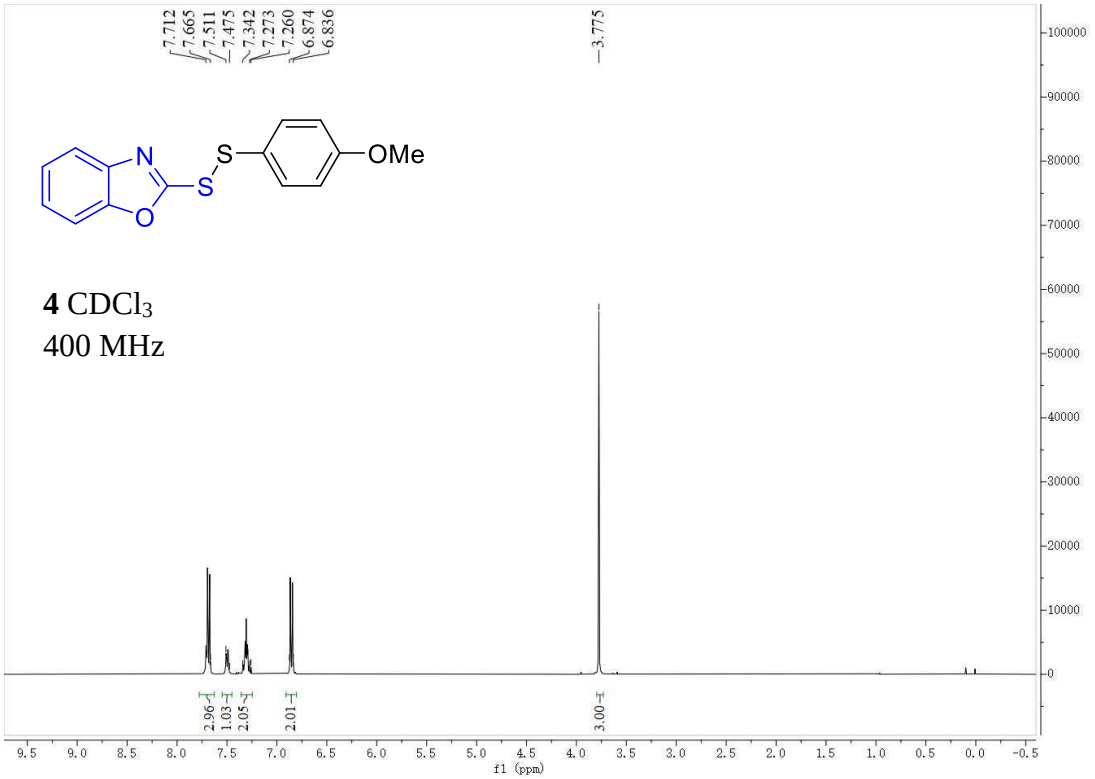


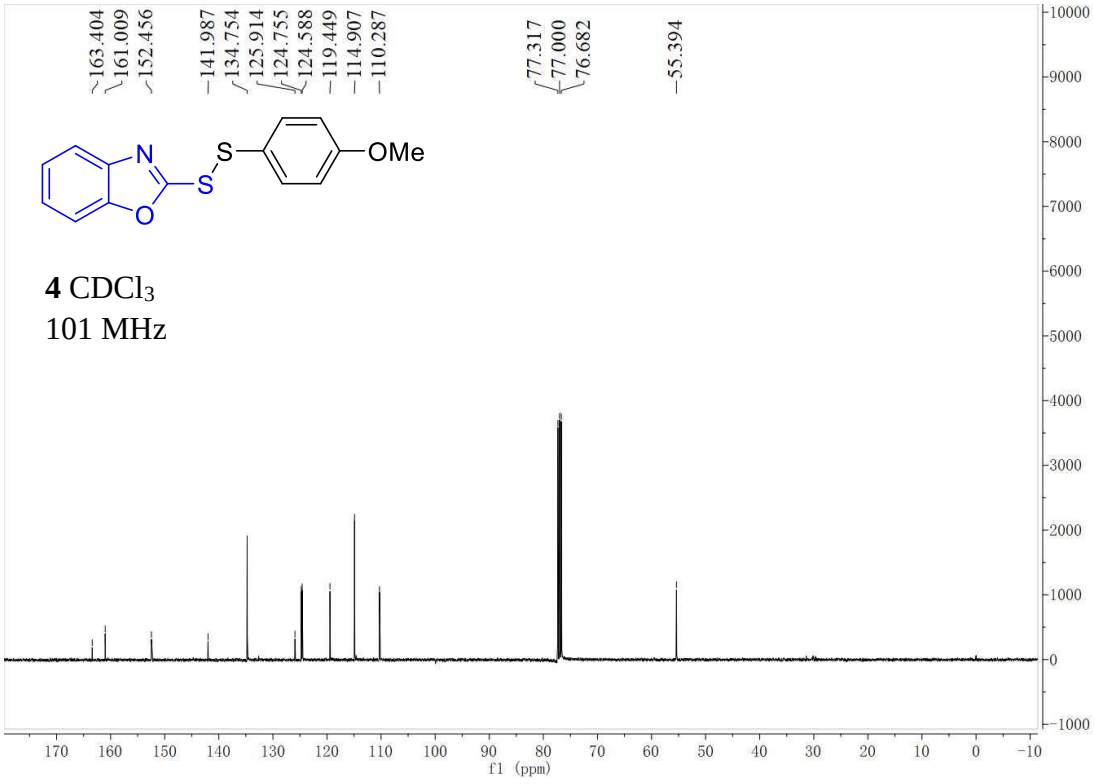


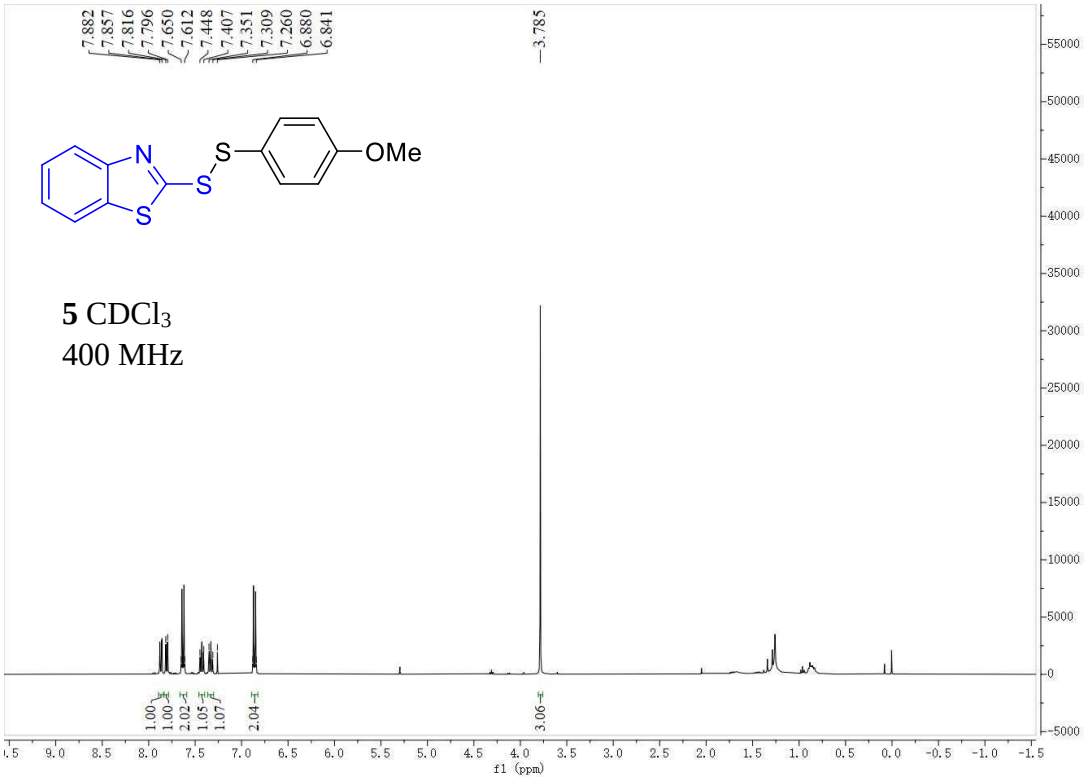
3 $CDCl_3$
400 MHz

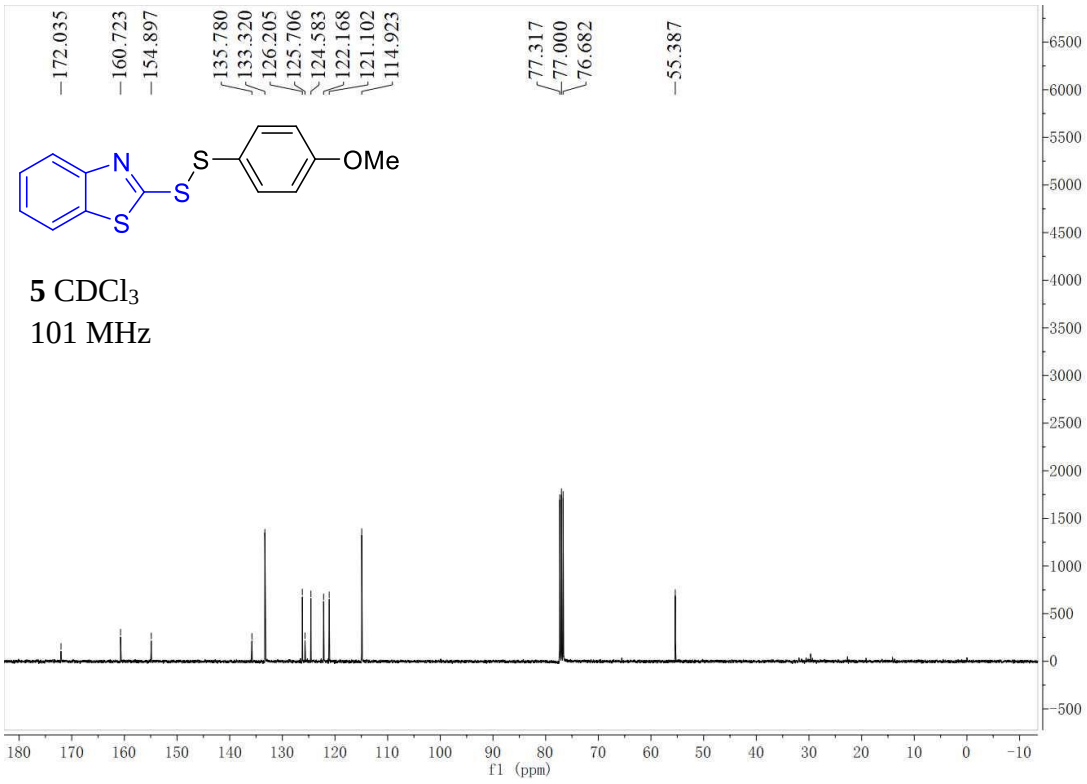


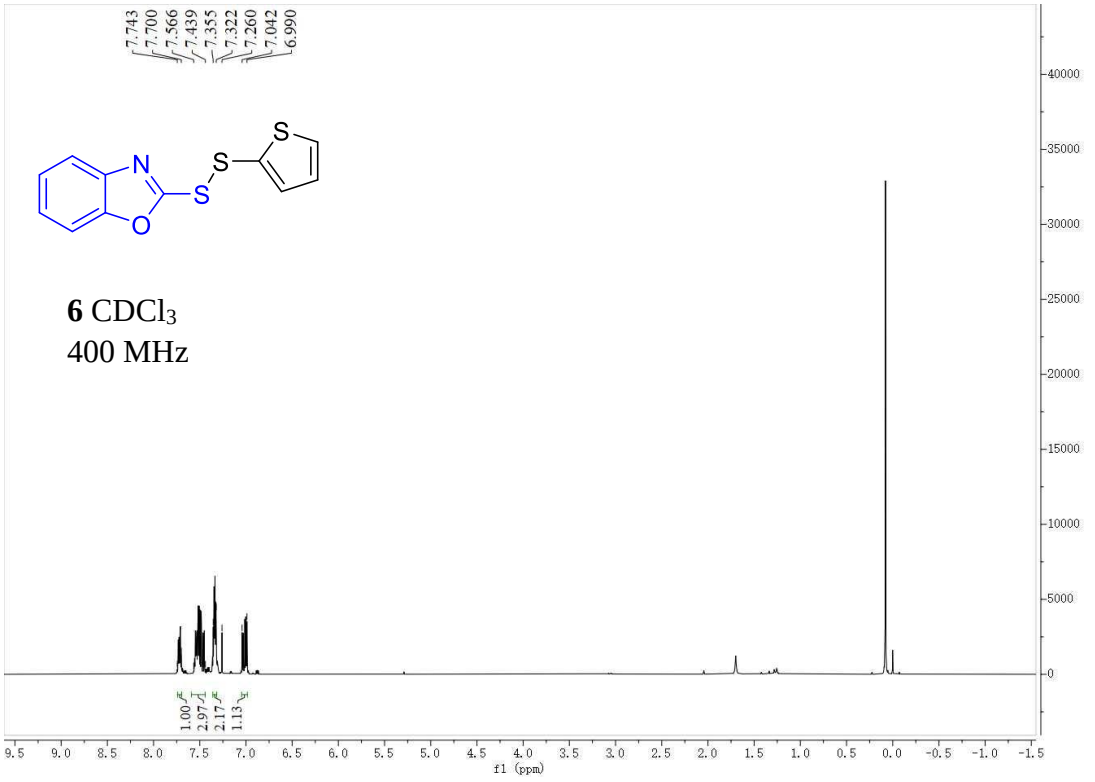
3 $CDCl_3$
101 MHz


7.712
7.665
7.511
7.475
7.342
7.273
7.260
6.874
6.836
3.775
N
S
S
O
OMe
4 CDCl3
400 MHz
2.96
1.03
2.05
2.01
3.00
f1 (ppm)

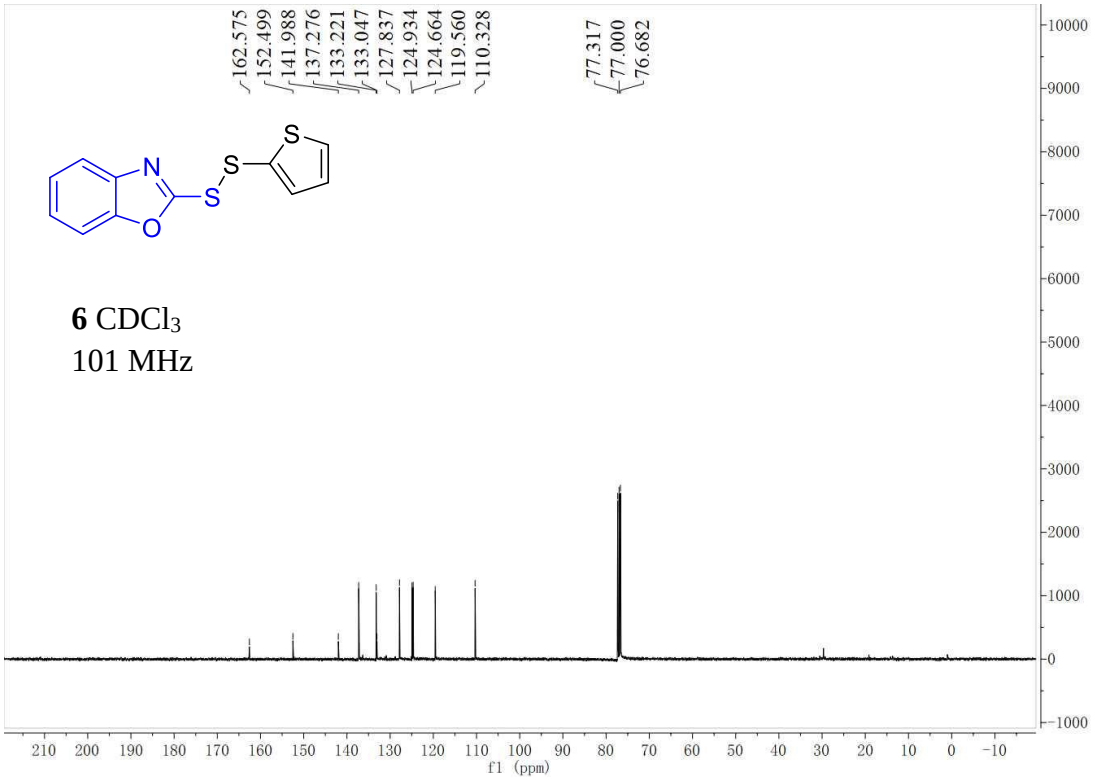

163.404
161.009
152.456
141.987
134.754
125.914
124.755
124.588
119.449
114.907
110.287
77.317
77.000
76.682
55.394
N
S
S
O
OMe
4 CDCl3
101 MHz
f1 (ppm)


7.882
7.857
7.816
7.796
7.650
7.612
7.448
7.407
7.351
7.309
7.260
6.880
6.841
3.785
N
S
S
S
OMe
5 CDCl3
400 MHz
1.00
1.00
2.02
1.05
1.07
2.04
3.06
f1 (ppm)

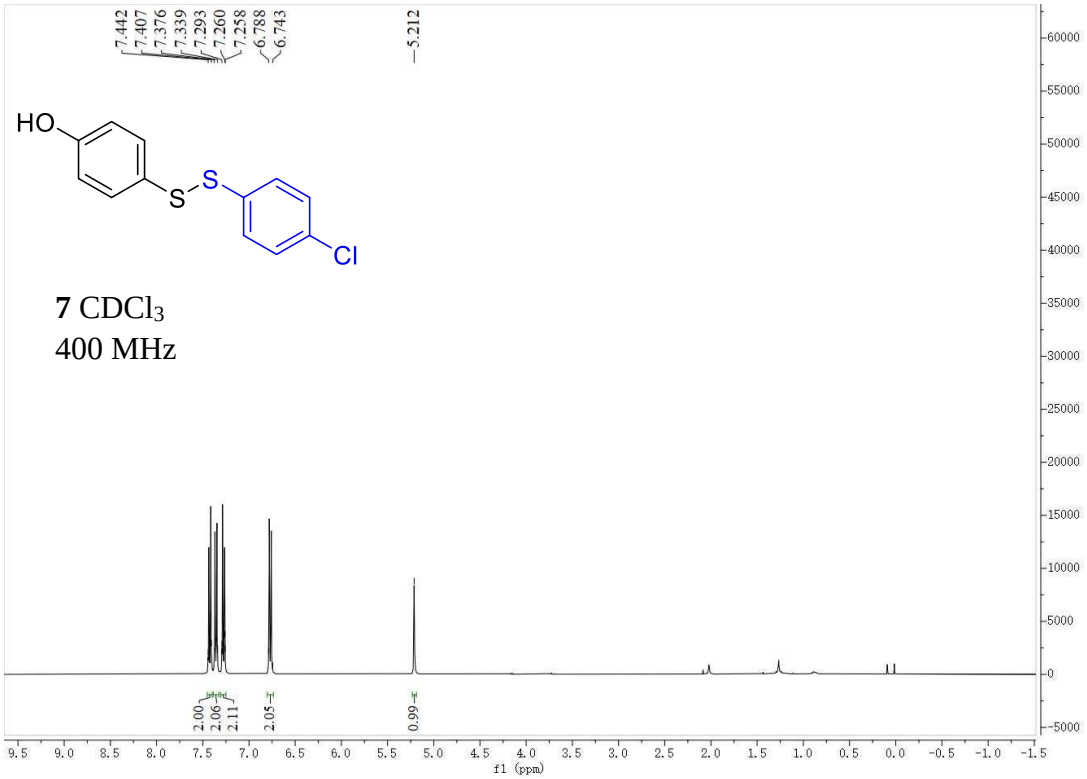

172.035
160.723
154.897
135.780
133.320
126.205
125.706
124.583
122.168
121.102
114.923
77.317
77.000
76.682
55.387
N
S
S
S
OMe
5 CDCl3
101 MHz
f1 (ppm)



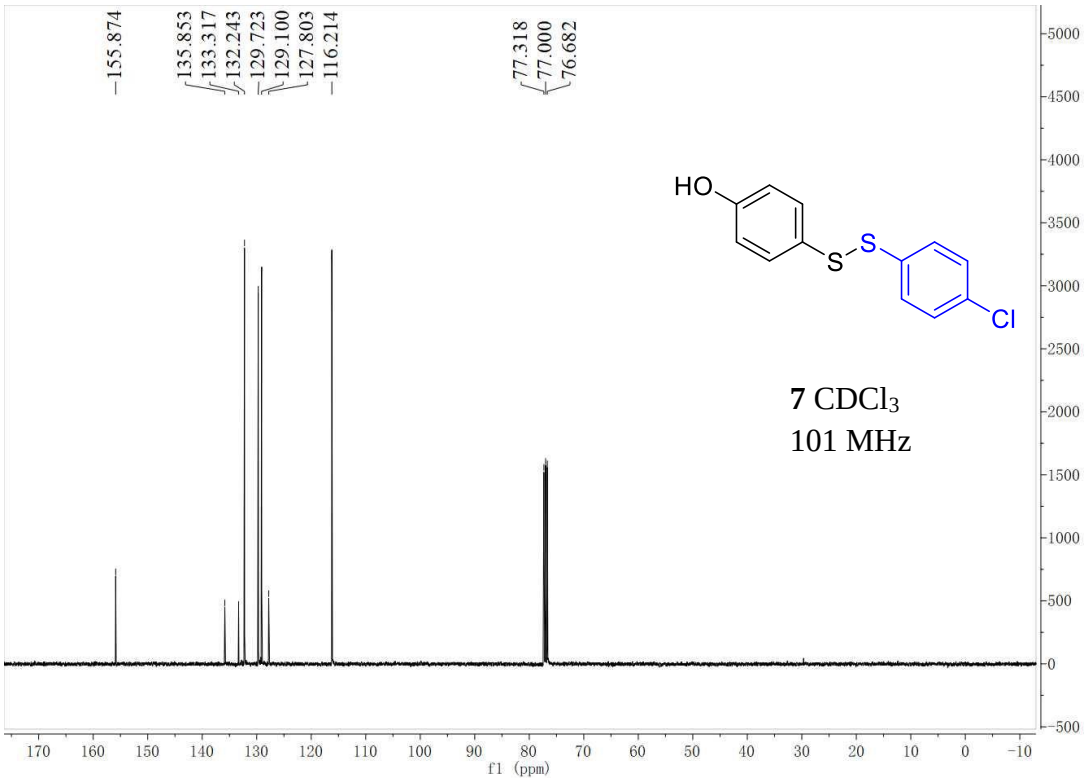
6 $CDCl_3$
400 MHz



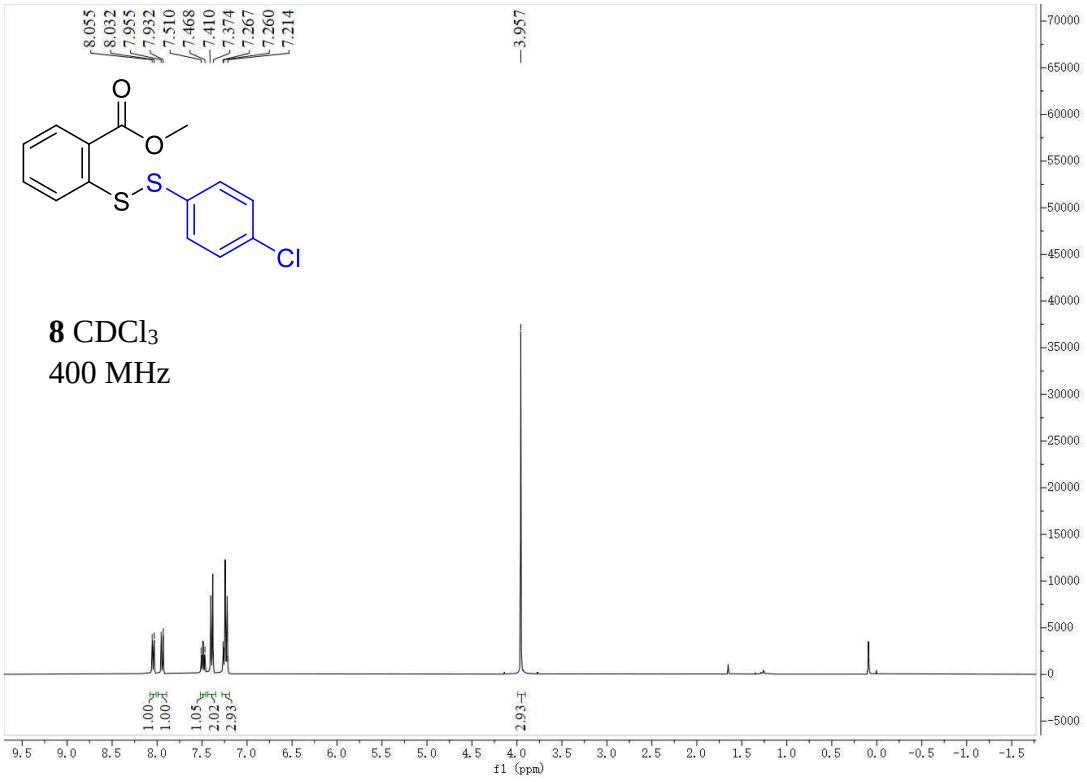
6 $CDCl_3$
101 MHz

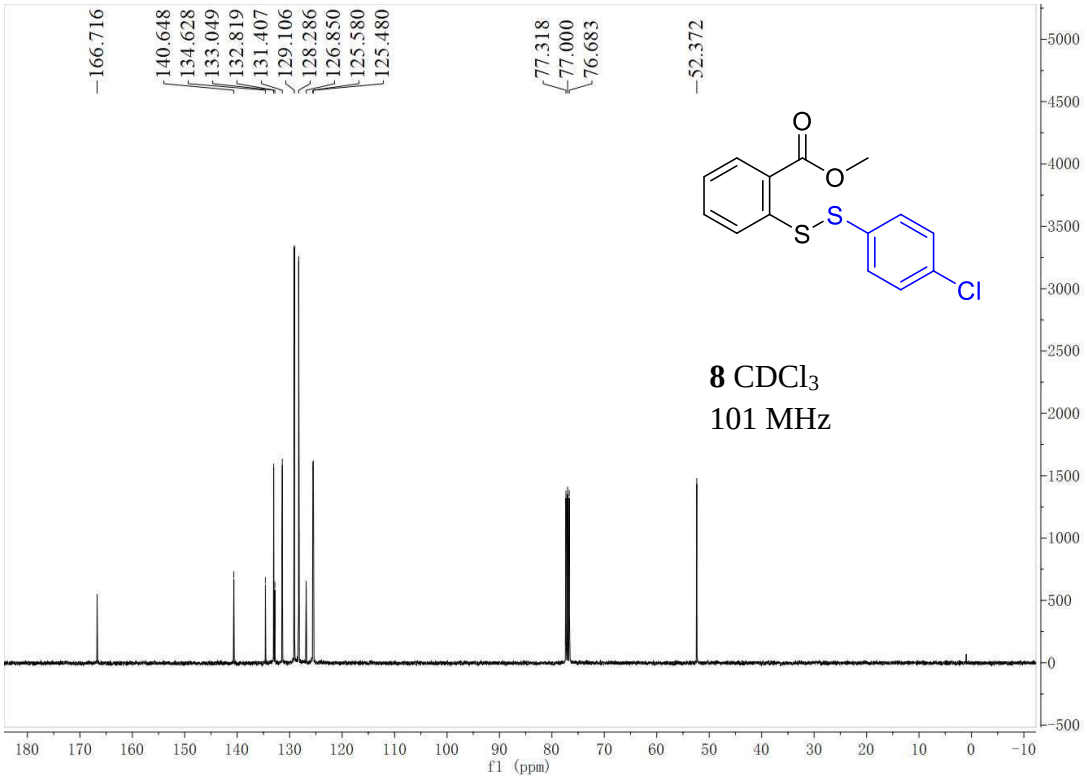


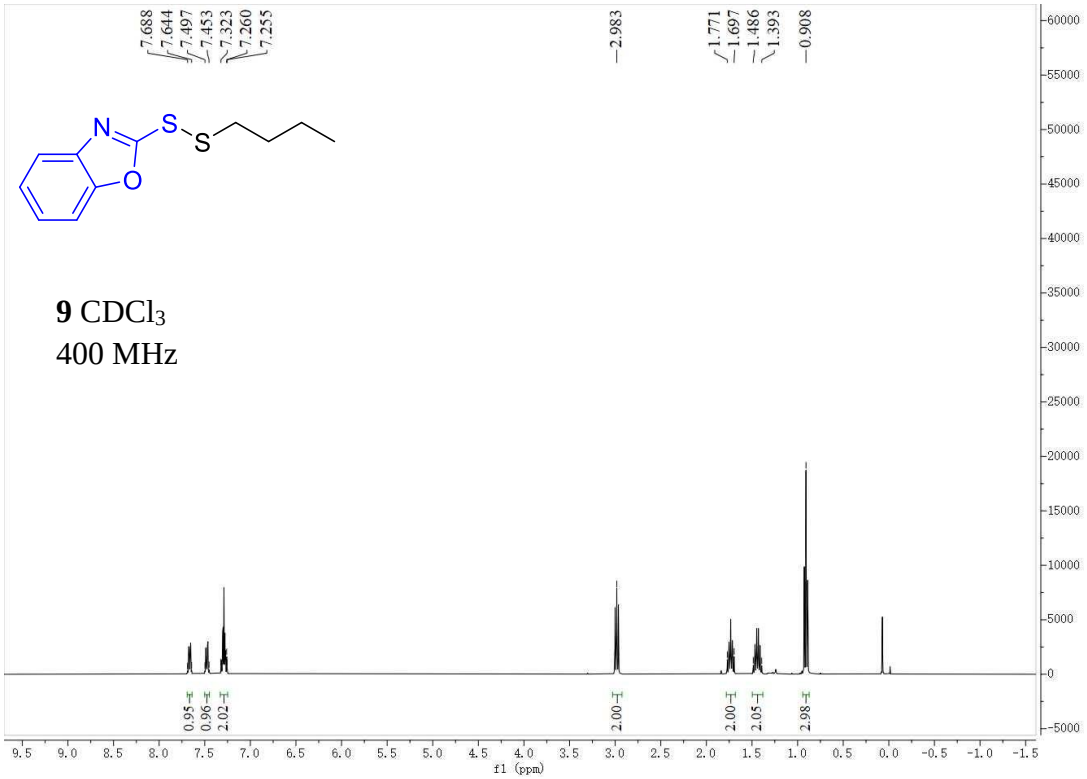
7 $CDCl_3$
400 MHz



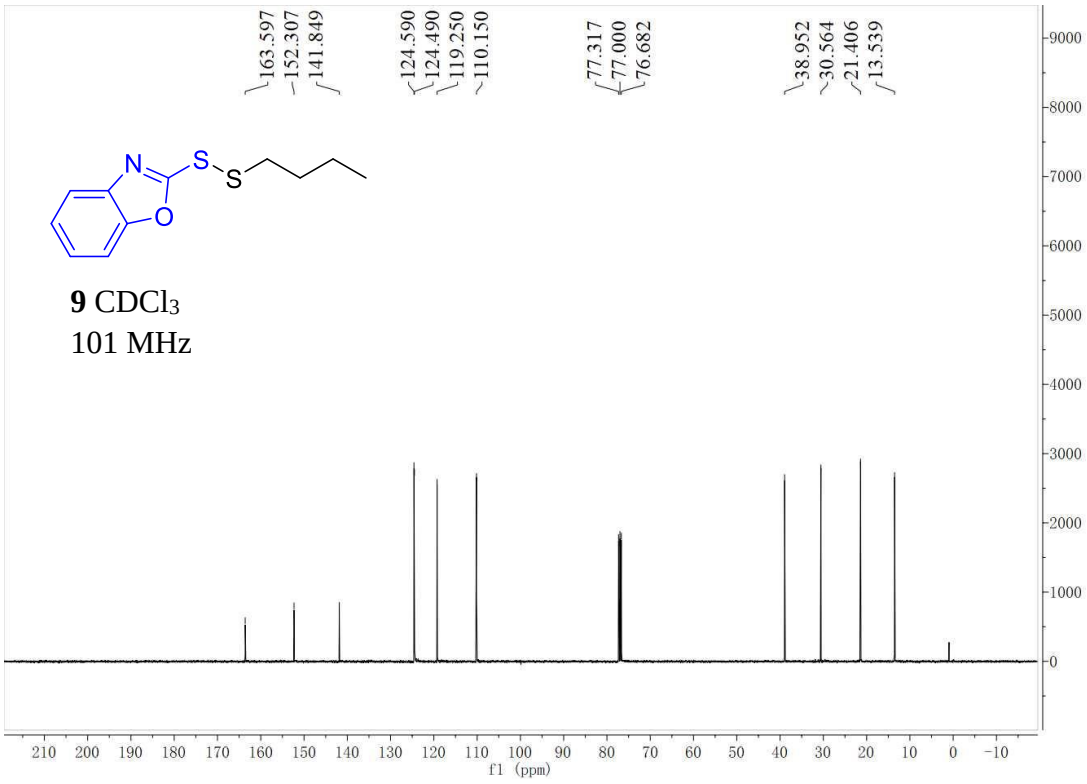
7 $CDCl_3$
101 MHz


8.055
8.032
7.955
7.932
7.510
7.468
7.410
7.374
7.267
7.260
7.214
3.957
O
O
S
S
Cl
8 CDCl3
400 MHz
1.00
1.00
1.05
2.02
2.93
2.93
f1 (ppm)

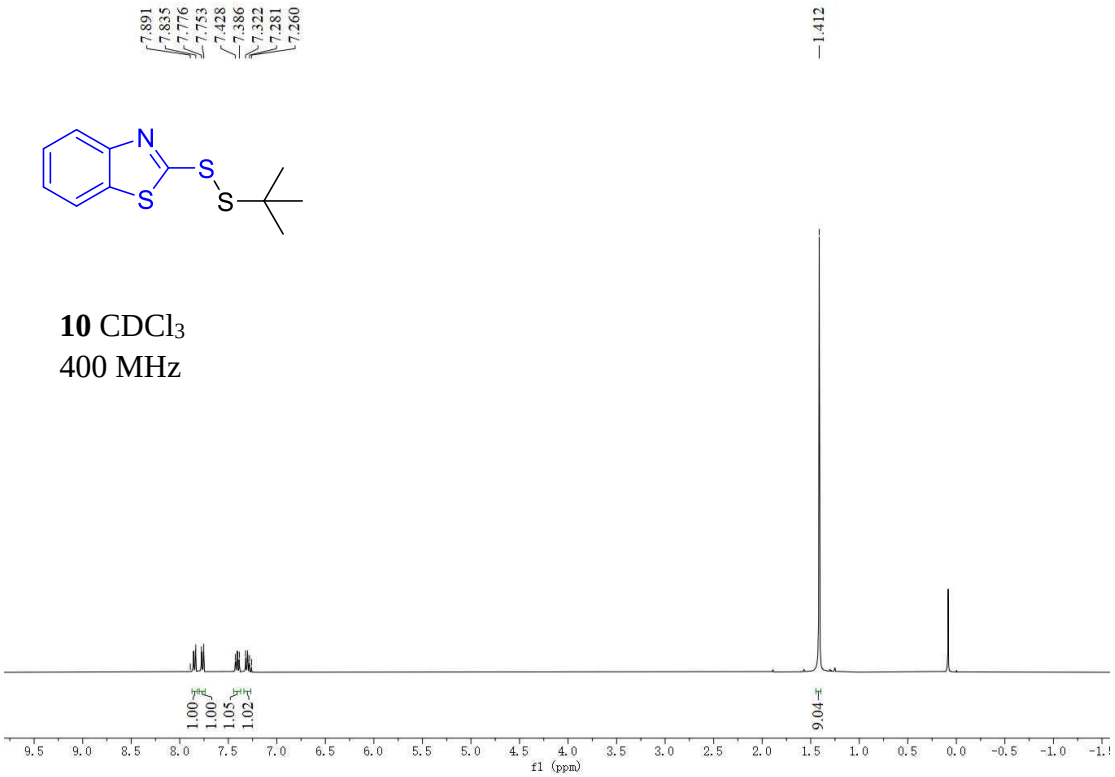

166.716
140.648
134.628
133.049
132.819
131.407
129.106
128.286
126.850
125.580
125.480
77.318
77.000
76.683
52.372
O
O
S
S
Cl
8 CDCl3
101 MHz
f1 (ppm)



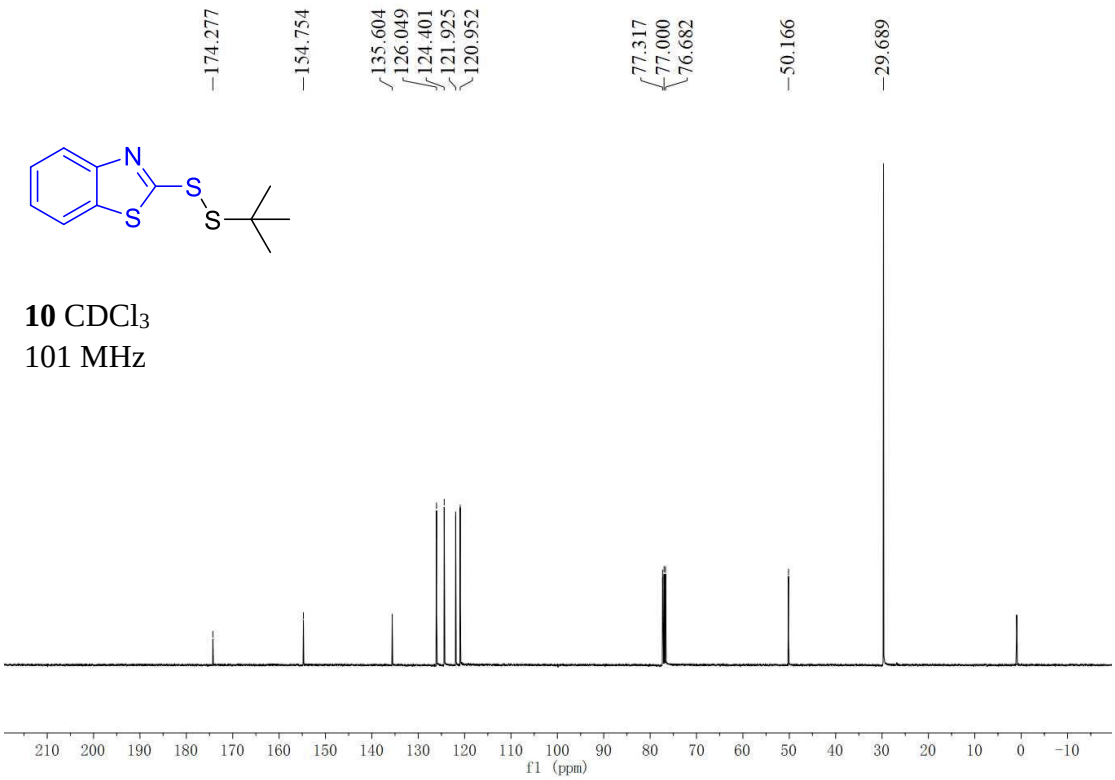
9 $CDCl_3$
400 MHz



9 $CDCl_3$
101 MHz

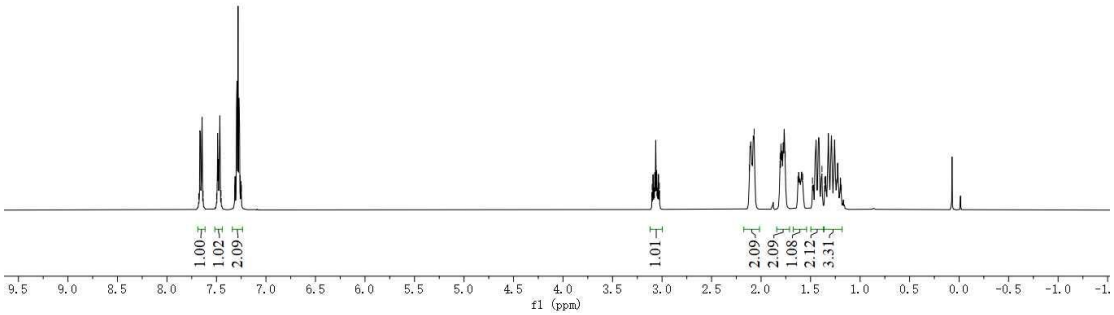


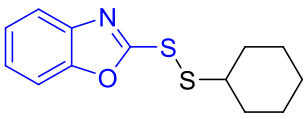
10 $CDCl_3$
400 MHz



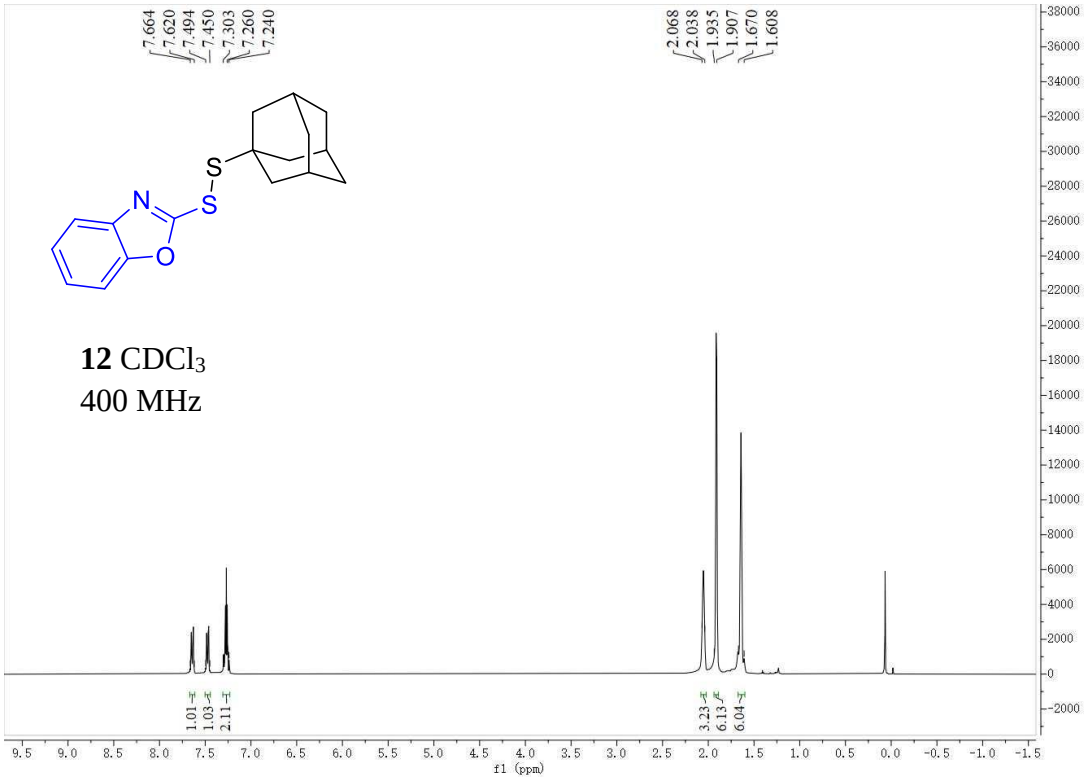
10 $CDCl_3$
101 MHz

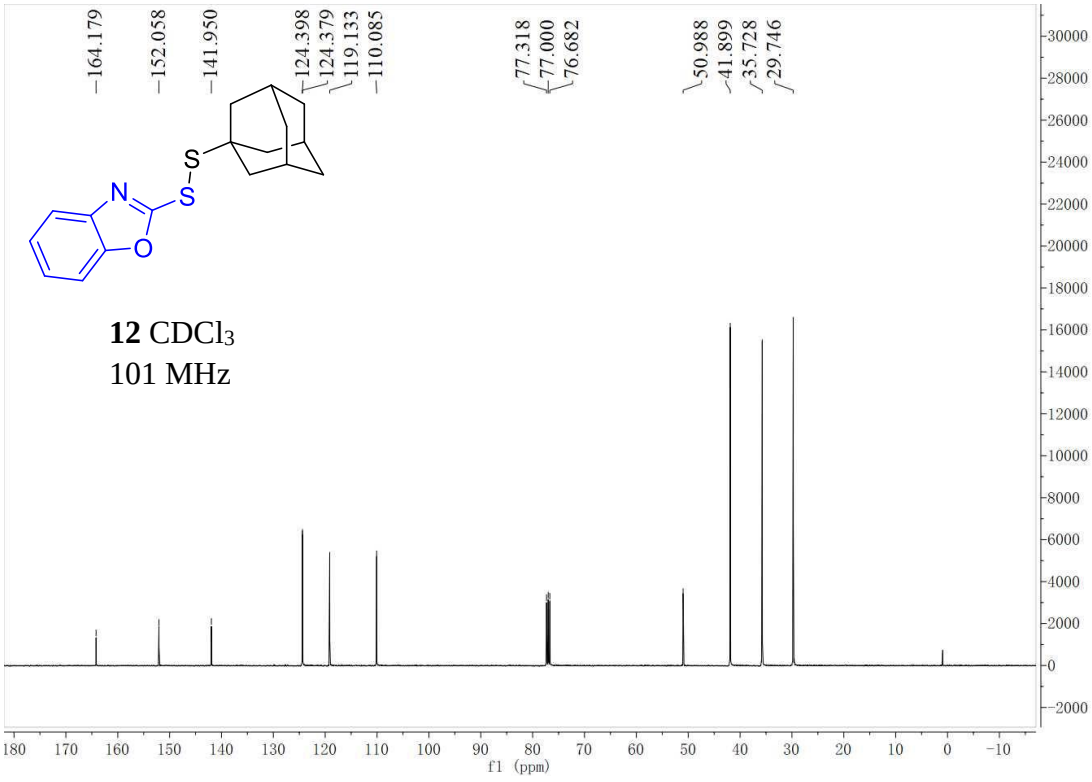
11 $CDCl_3$
400 MHz

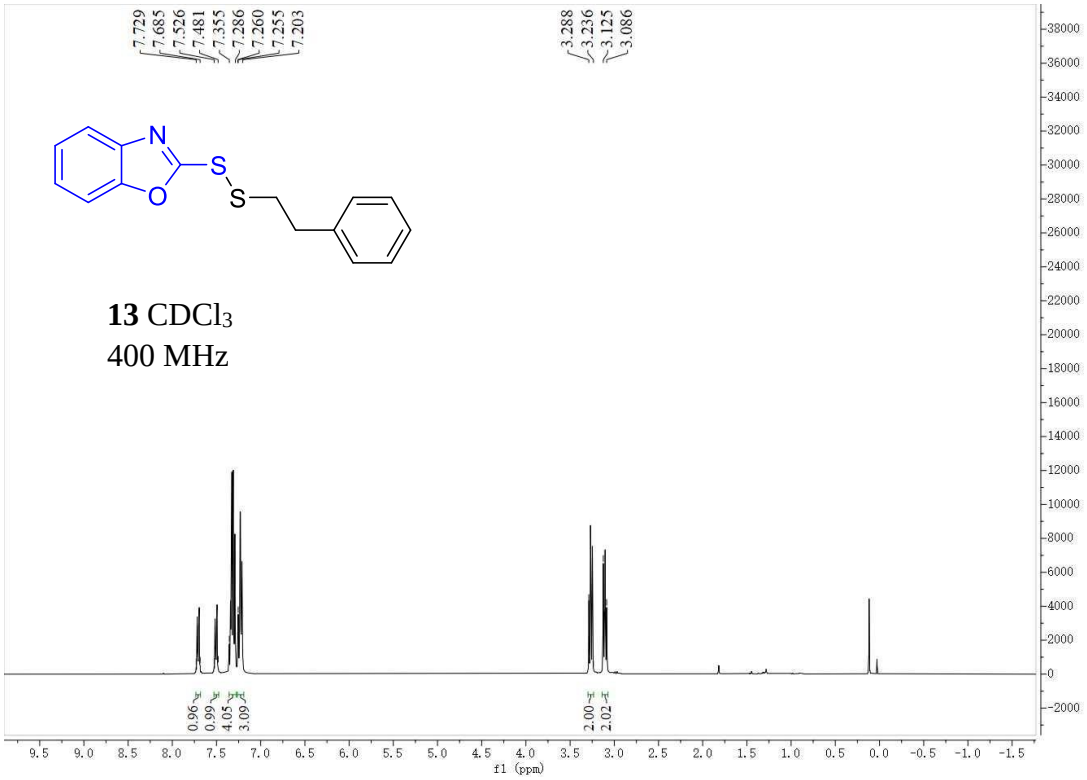


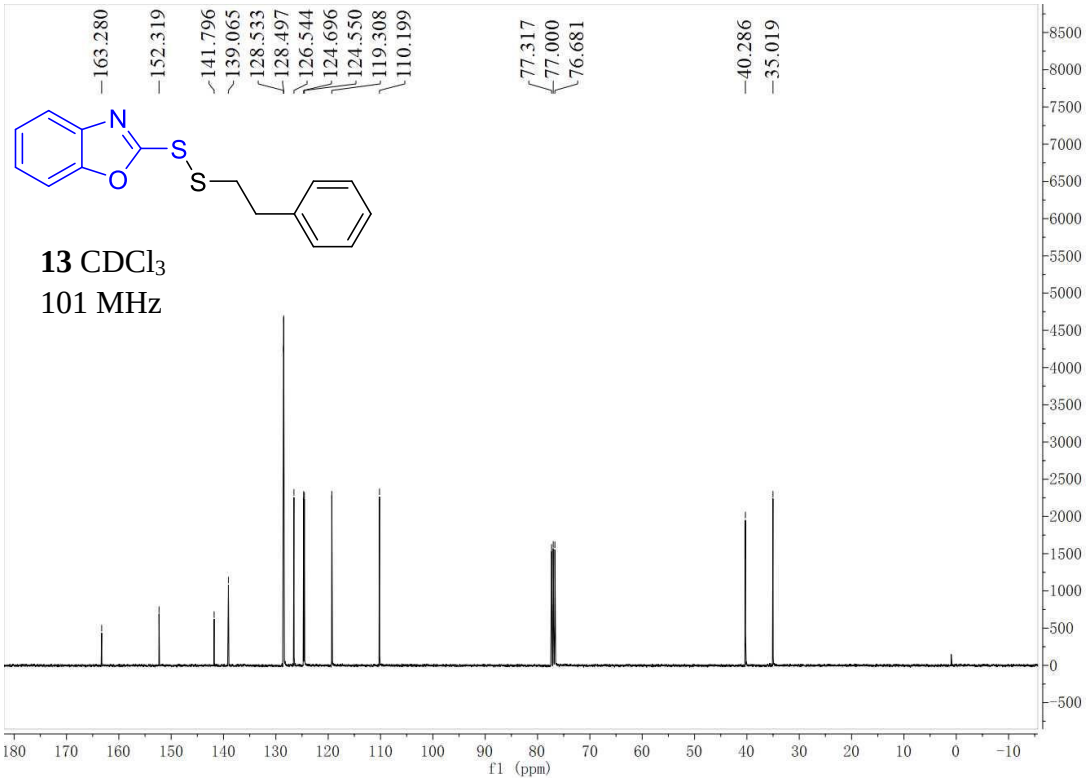


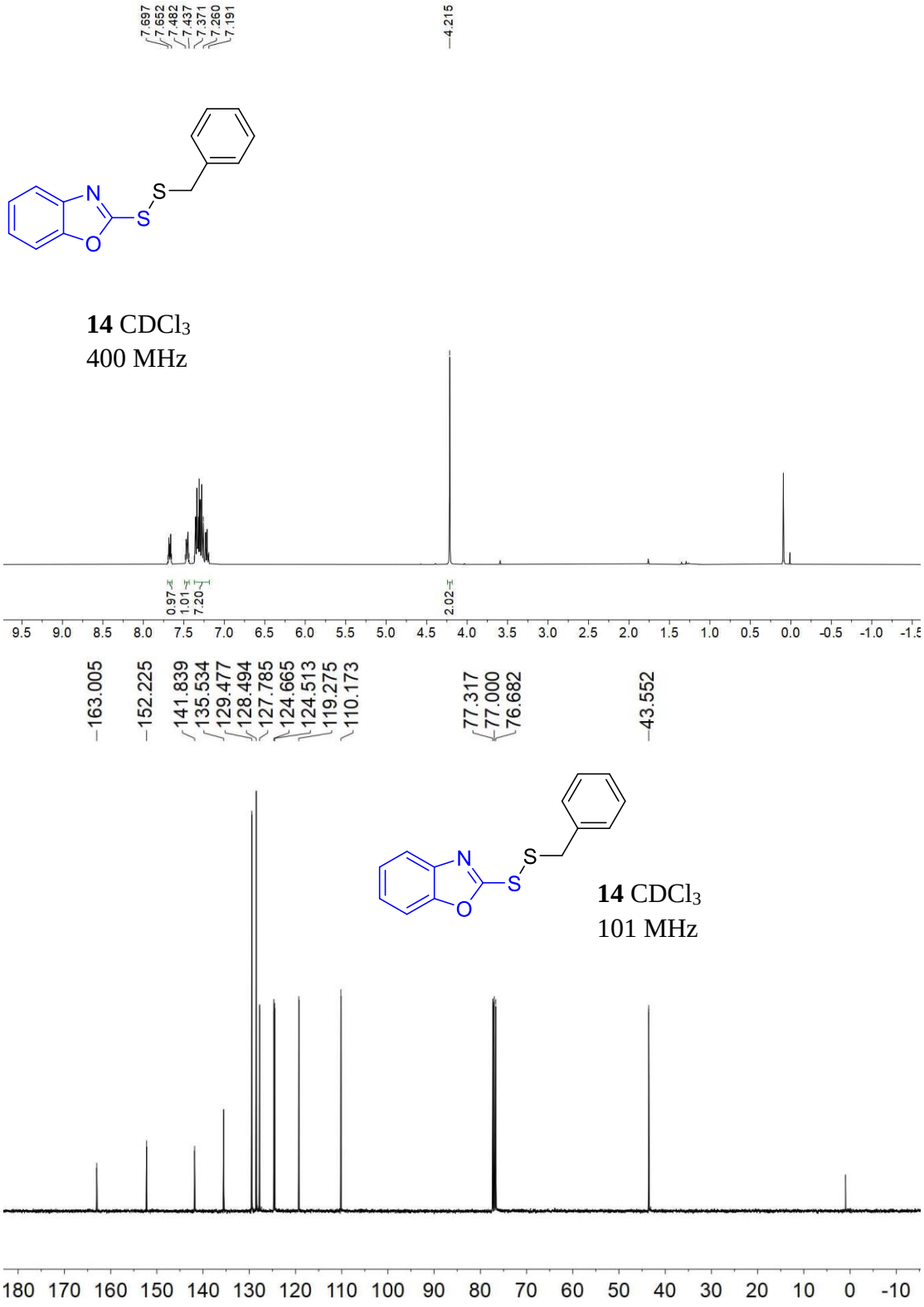
11 $CDCl_3$
101 MHz


7.664
7.620
7.494
7.450
7.303
7.260
7.240
2.068
2.038
1.935
1.907
1.670
1.608
S
N
S
O
12 CDCl3
400 MHz
1.01
1.03
2.11
3.23
6.13
6.04
f1 (ppm)


164.179
152.058
141.950
124.398
124.379
119.133
110.085
77.318
77.000
76.682
50.988
41.899
35.728
29.746
S
N
S
O
12 CDCl3
101 MHz
f1 (ppm)

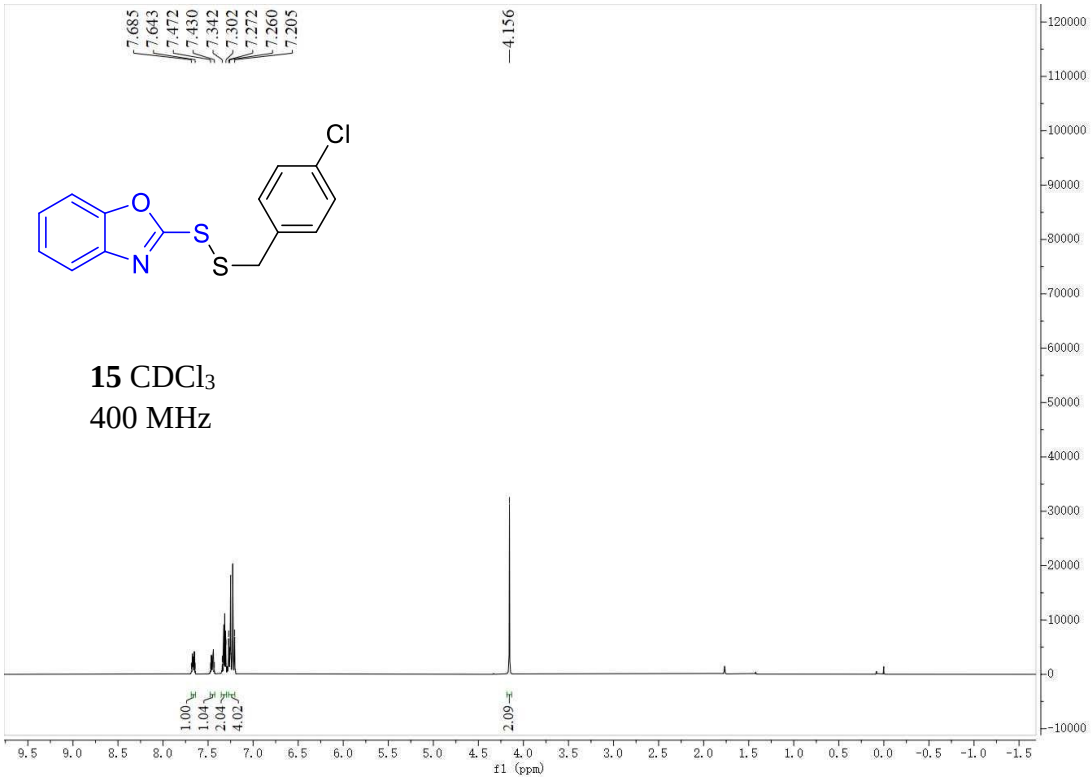

7.729
7.685
7.526
7.481
7.355
7.286
7.260
7.255
7.203
3.288
3.236
3.125
3.086
N
O
S
S
13 CDCl3
400 MHz
0.96
0.99
4.05
3.09
2.00
2.02
f1 (ppm)

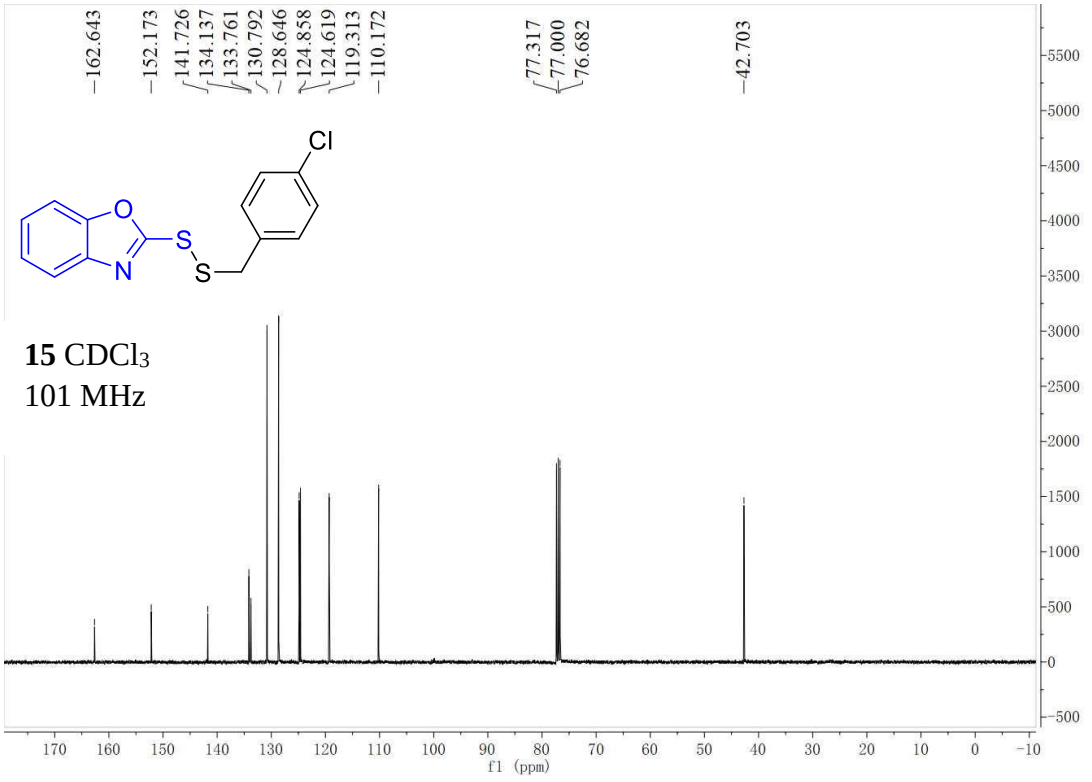

163.280
152.319
141.796
139.065
128.533
128.497
126.544
124.696
124.550
119.308
110.199
77.317
77.000
76.681
40.286
35.019
N
O
S
S
13 CDCl3
101 MHz
f1 (ppm)

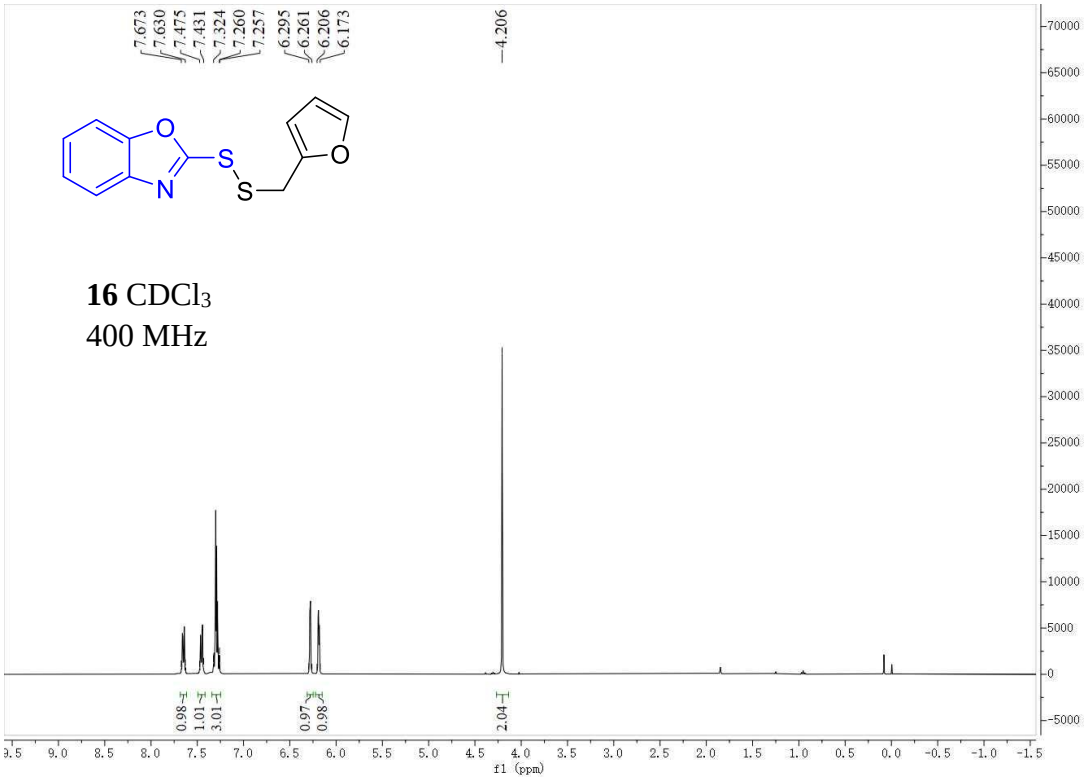


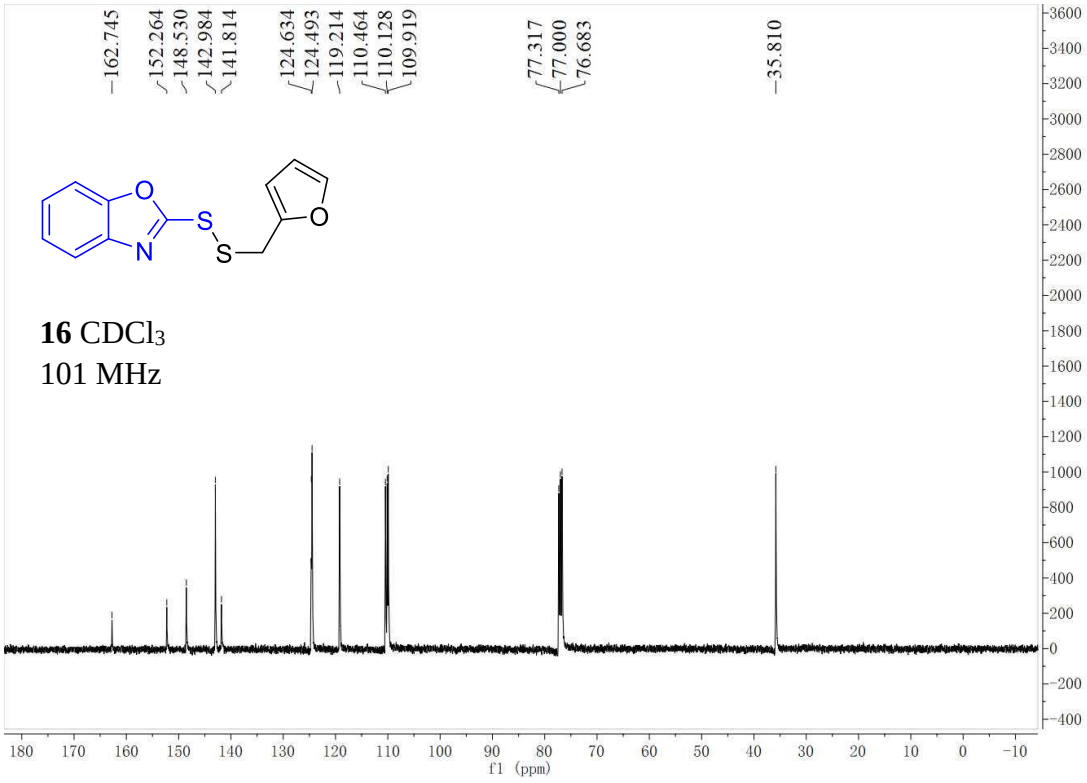
14 $CDCl_3$
400 MHz

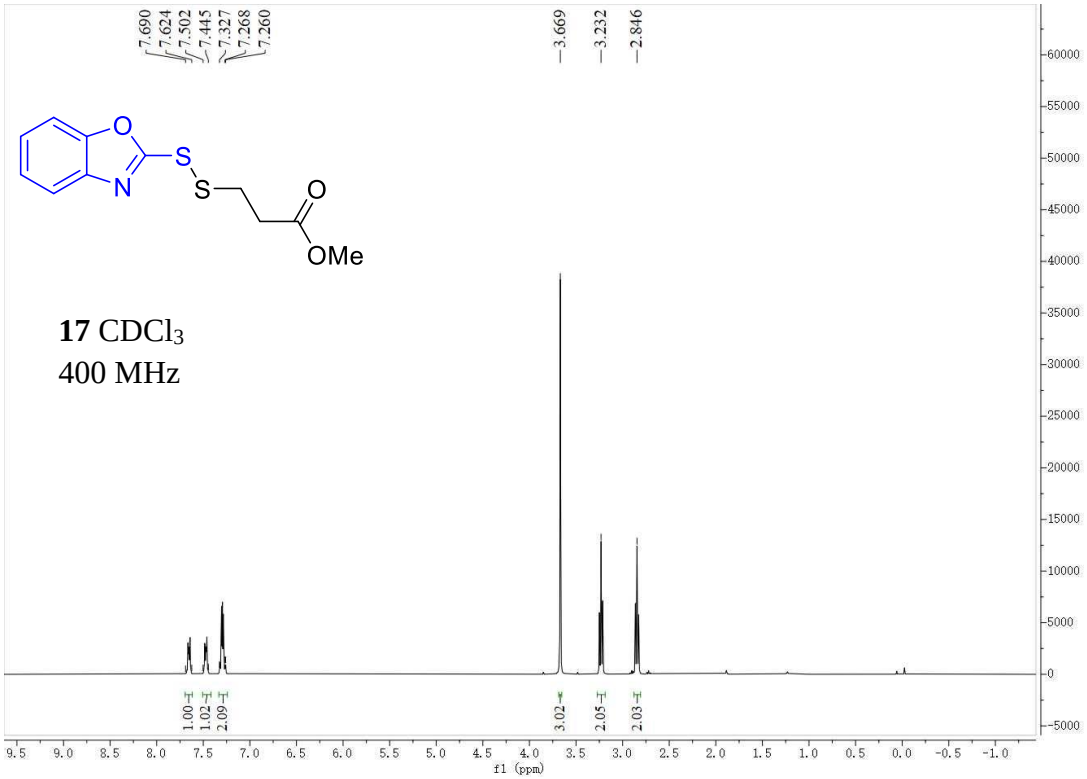
14 $CDCl_3$
101 MHz

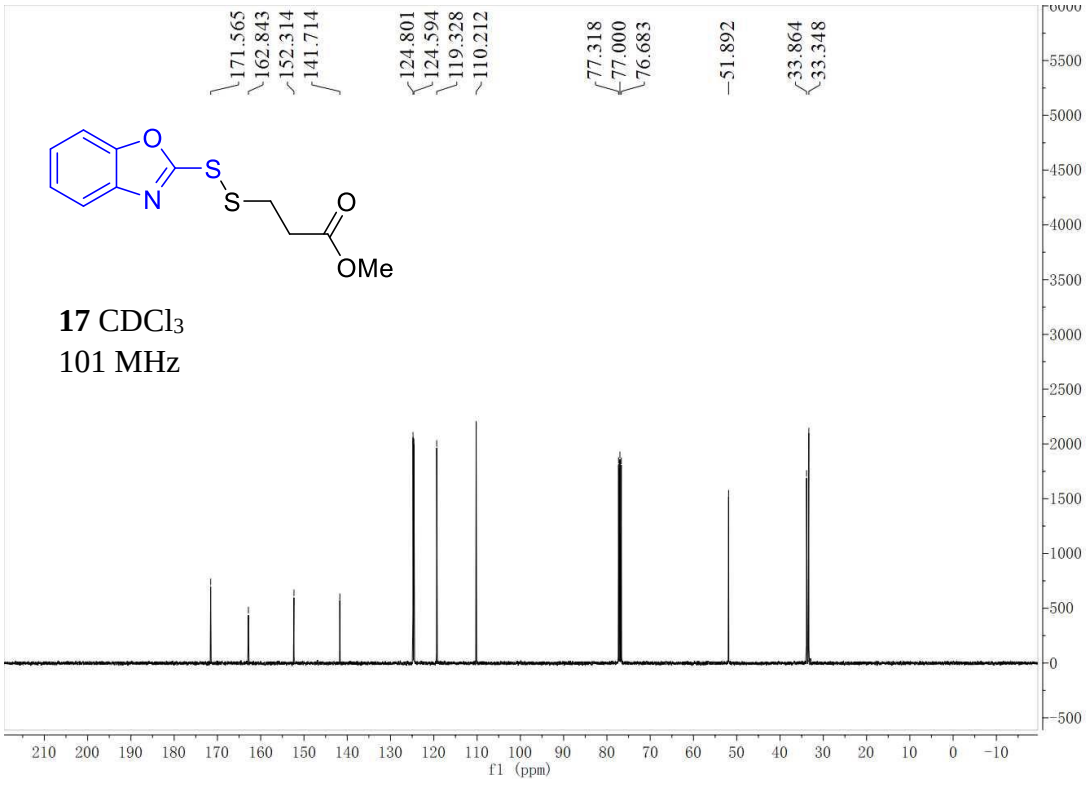

7.685
7.643
7.472
7.430
7.342
7.302
7.272
7.260
7.205
4.156
Cl
O
S
N
S
15 CDCl3
400 MHz
1.00
1.04
2.04
4.02
2.09
f1 (ppm)

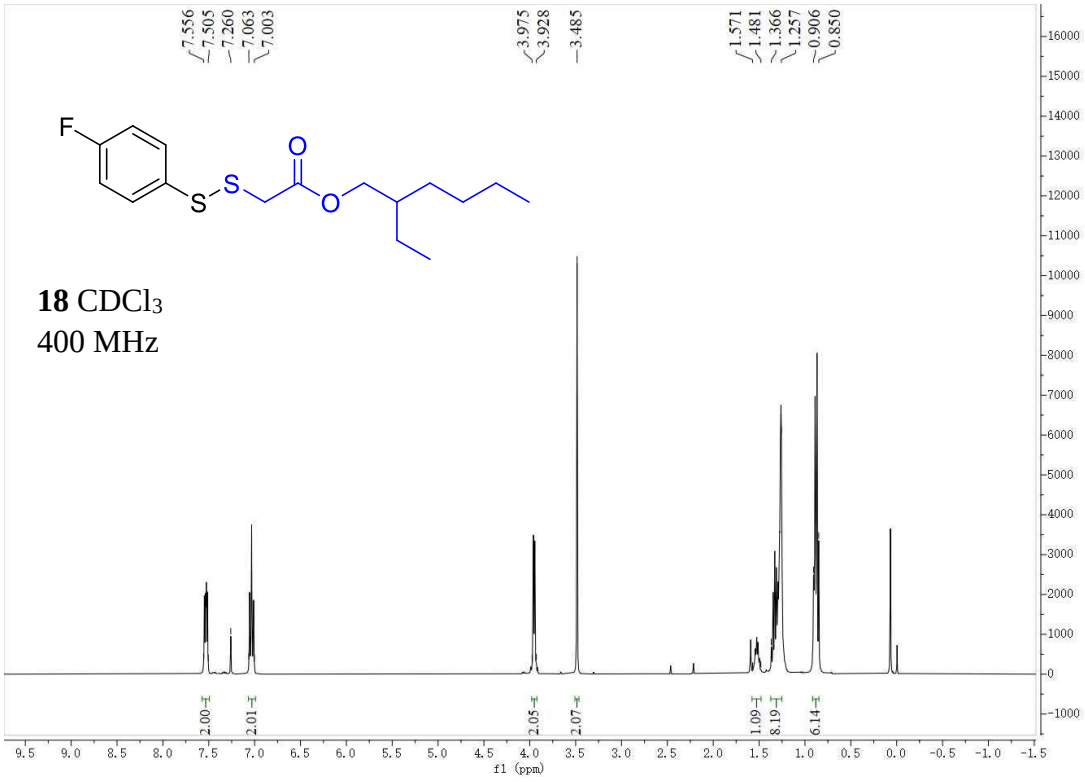

162.643
152.173
141.726
134.137
133.761
130.792
128.646
124.858
124.619
119.313
110.172
77.317
77.000
76.682
42.703
Cl
O
S
N
S
15 CDCl3
101 MHz
f1 (ppm)

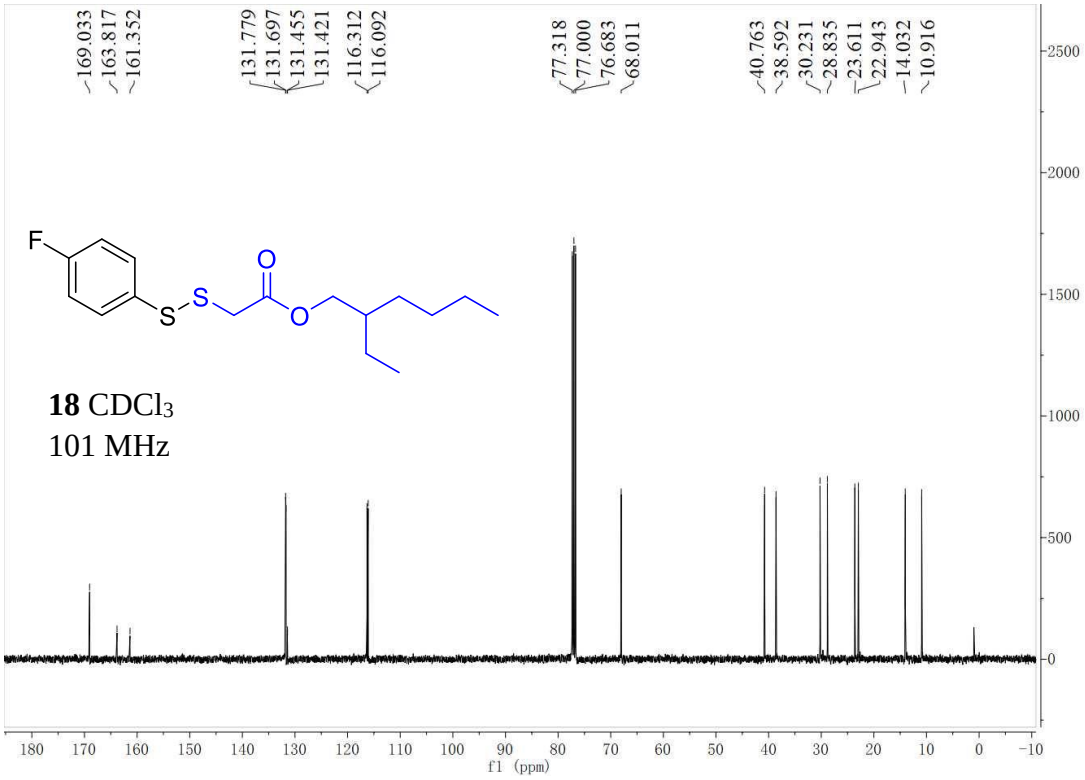

7.673
7.630
7.475
7.431
7.324
7.260
7.257
6.295
6.261
6.206
6.173
4.206
O
S
S
N
O
16 CDCl3
400 MHz
0.98
1.01
3.01
0.97
0.98
2.04
f1 (ppm)

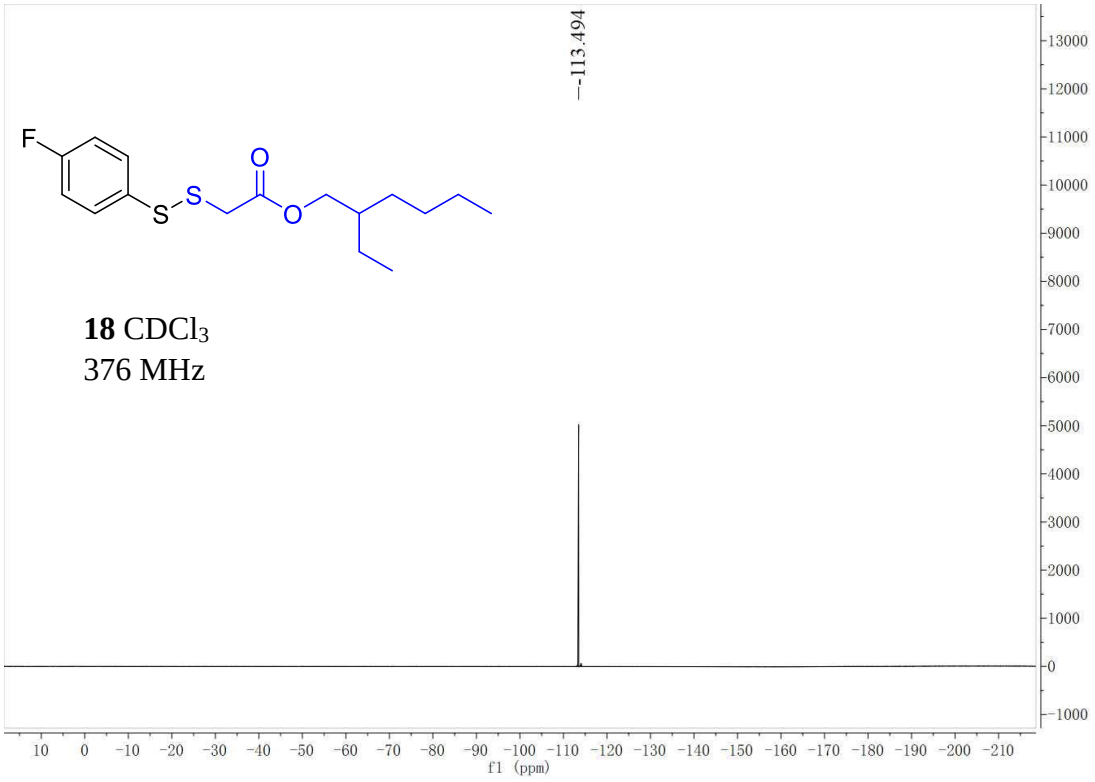

162.745
152.264
148.530
142.984
141.814
124.634
124.493
119.214
110.464
110.128
109.919
77.317
77.000
76.683
35.810
O
S
S
N
O
16 CDCl3
101 MHz
f1 (ppm)

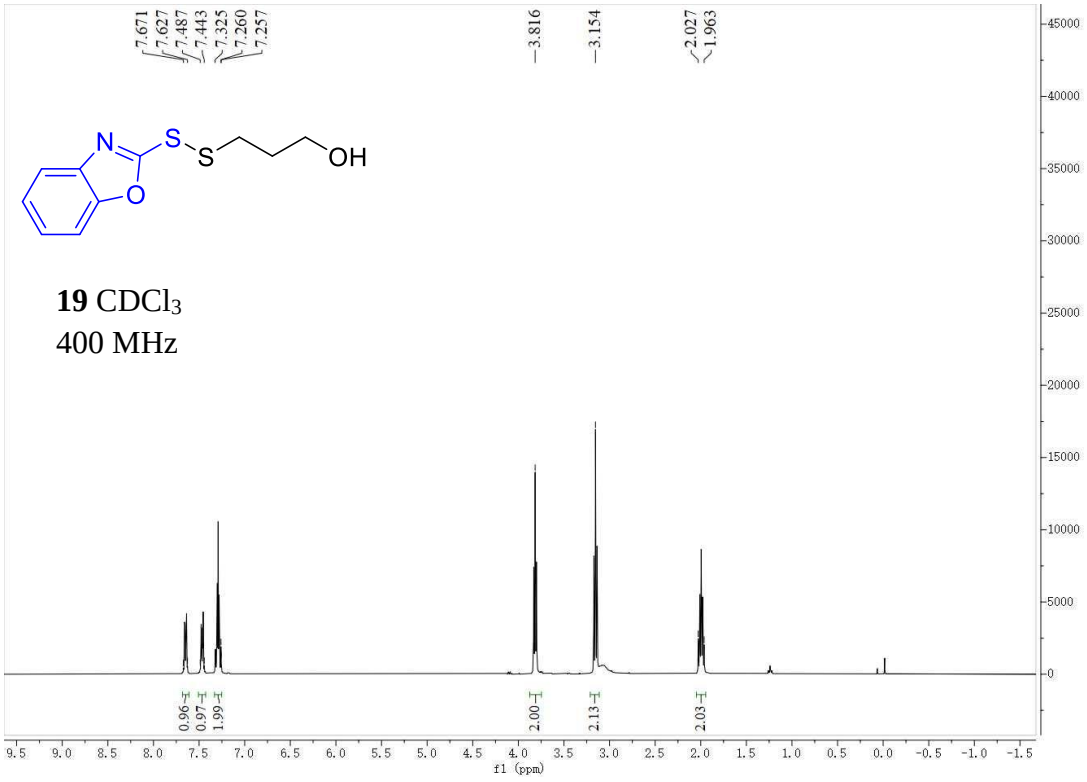

7.690
7.624
7.502
7.445
7.327
7.268
7.260
3.669
3.232
2.846
O
S
N
S
O
OMe
17 CDCl3
400 MHz
1.00
1.02
2.09
3.02
2.05
2.03
f1 (ppm)


171.565
162.843
152.314
141.714
124.801
124.594
119.328
110.212
77.318
77.000
76.683
51.892
33.864
33.348
O
S
N
S
O
OMe
17 CDCl3
101 MHz
f1 (ppm)

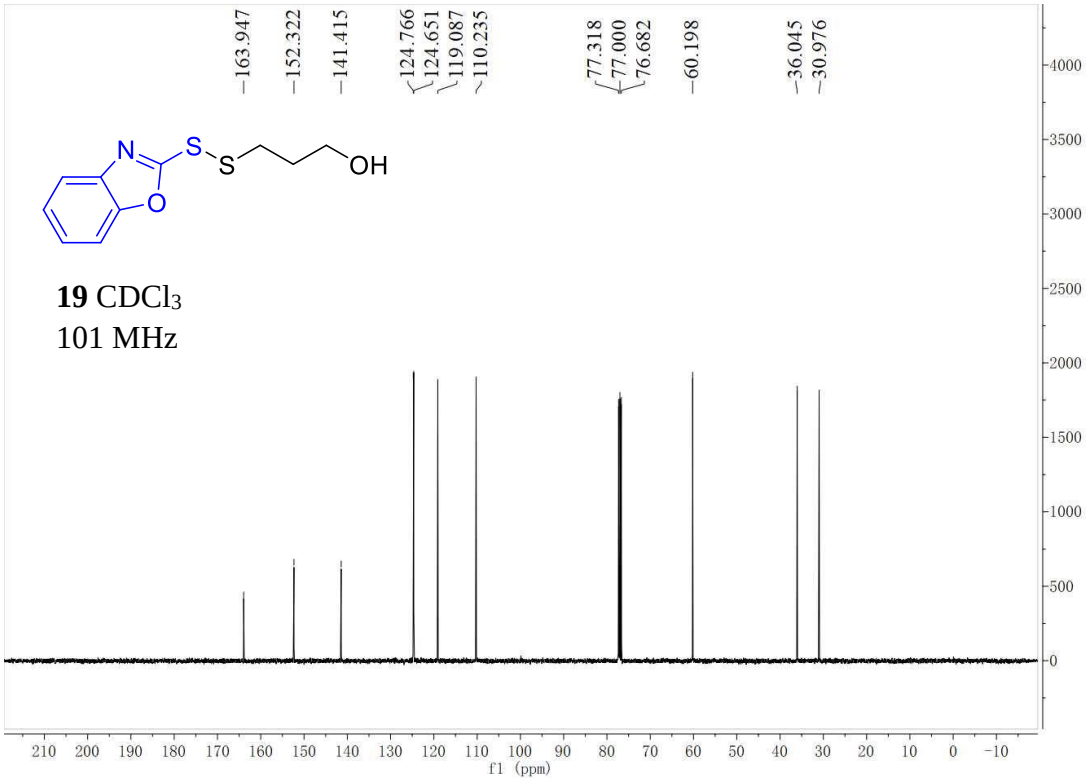

7.556
7.505
7.260
7.063
7.003
3.975
3.928
3.485
1.571
1.481
1.366
1.257
0.906
0.850
F
S
S
O
O
18 CDCl3
400 MHz
2.00
2.01
2.05
2.07
1.09
8.19
6.14
f1 (ppm)


169.033
163.817
161.352
131.779
131.697
131.455
131.421
116.312
116.092
77.318
77.000
76.683
68.011
40.763
38.592
30.231
28.835
23.611
22.943
14.032
10.916
F
S
S
O
O
18 CDCl3
101 MHz
f1 (ppm)

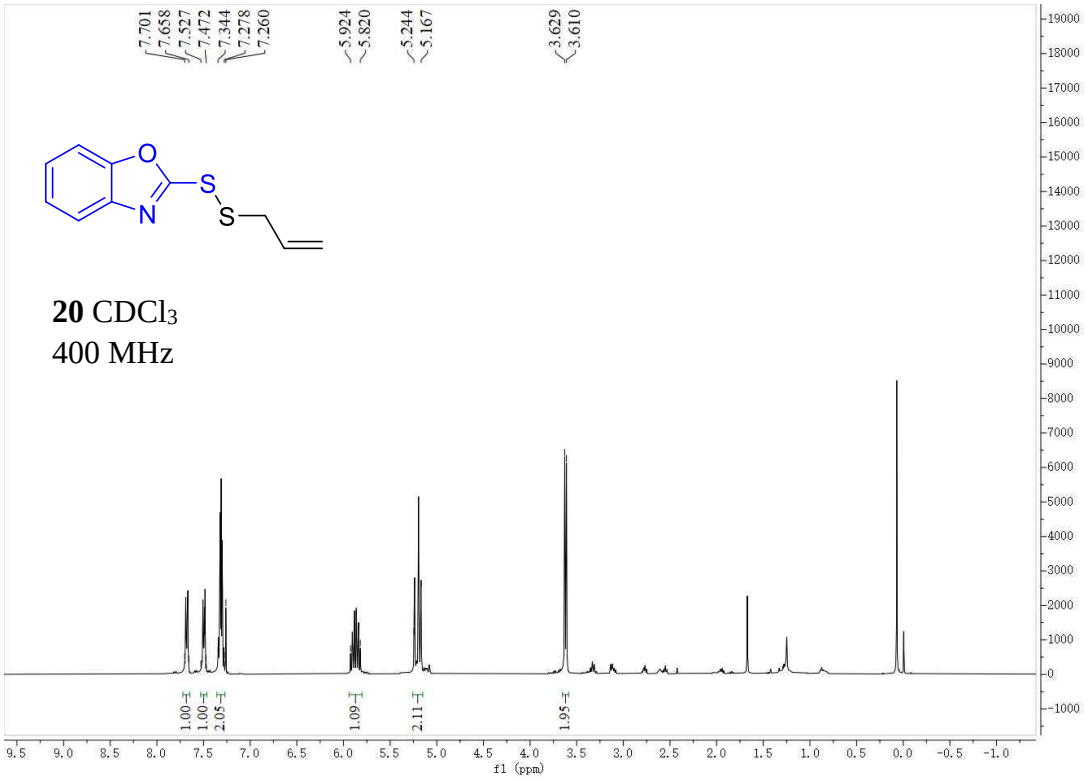

-113.494
F
S
S
O
O
18 CDCl3
376 MHz
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

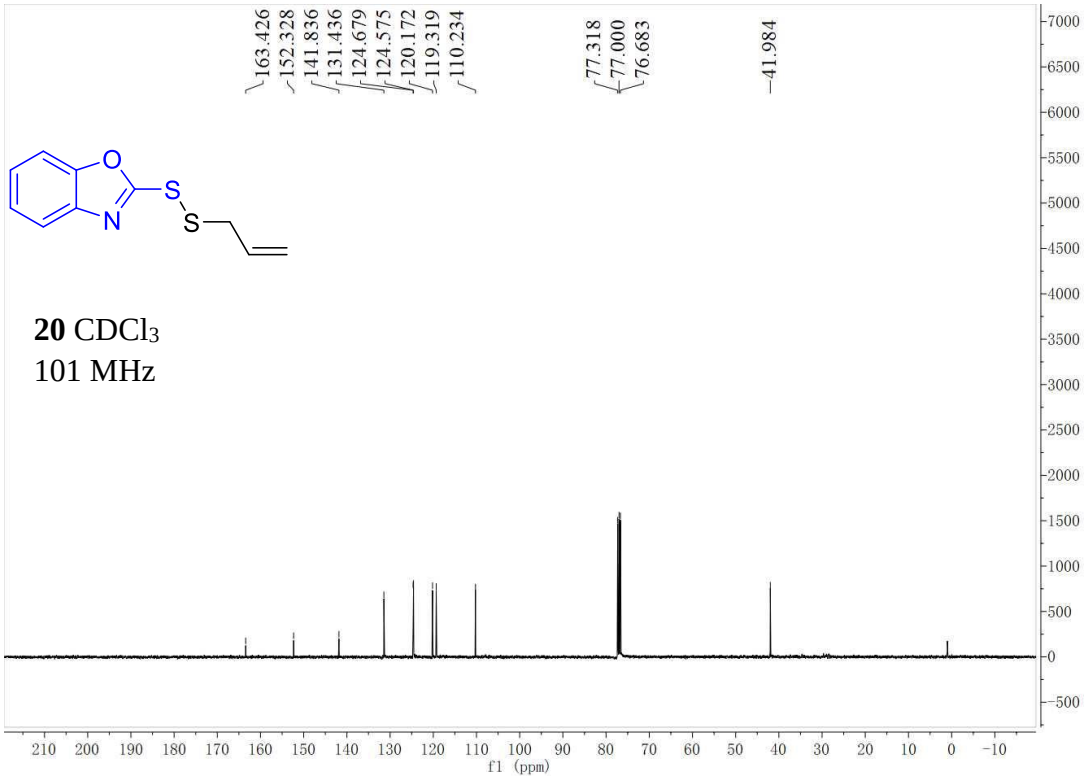


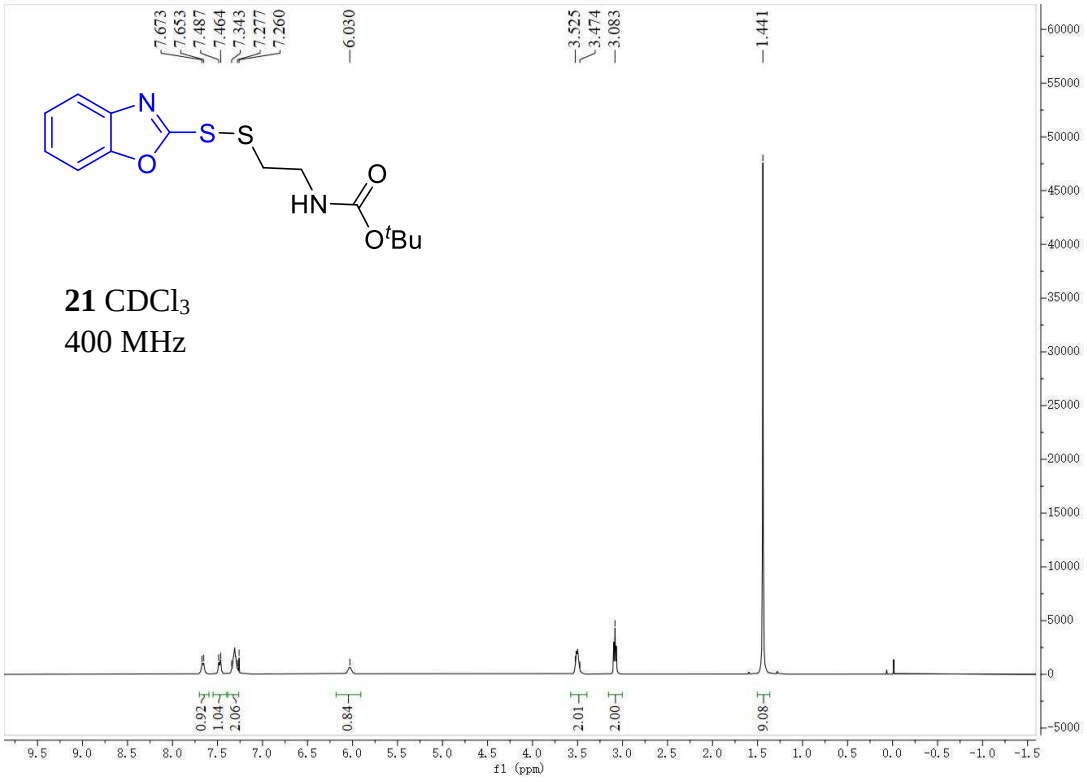
19 $CDCl_3$
400 MHz



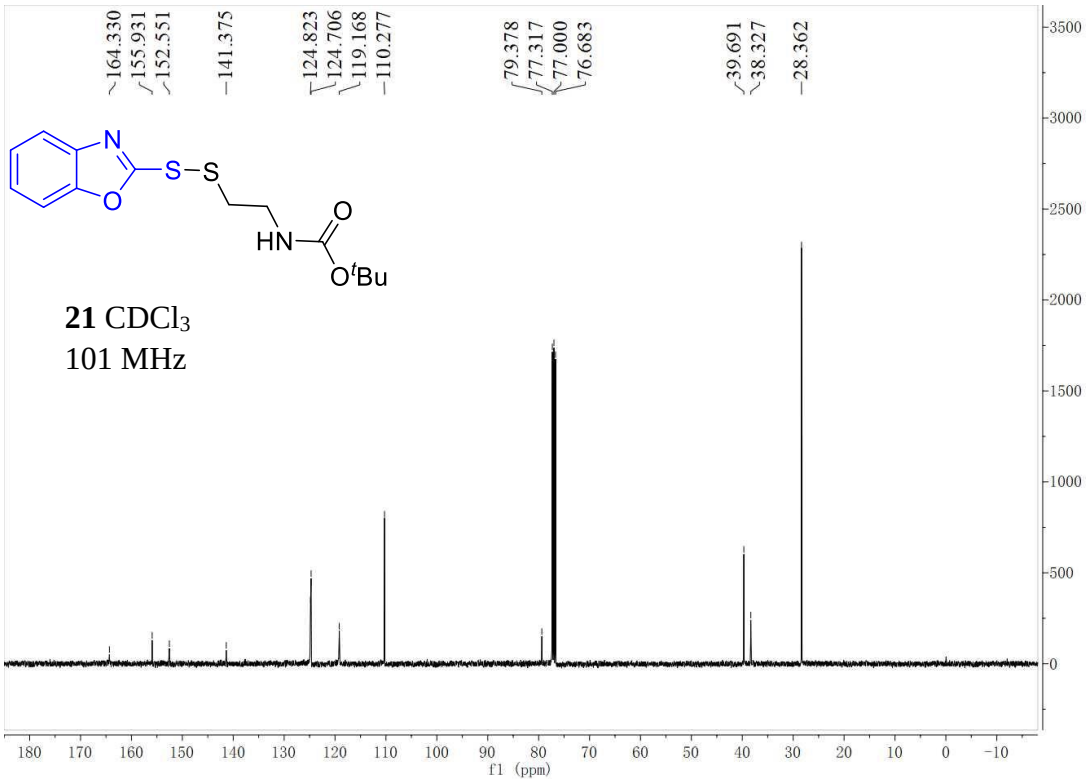
19 $CDCl_3$
101 MHz


7.701
7.658
7.527
7.472
7.344
7.278
7.260
5.924
5.820
5.244
5.167
3.629
3.610
O
S
N
S
20 $CDCl_3$
400 MHz
1.00
1.00
2.05
1.09
2.11
1.95
f1 (ppm)

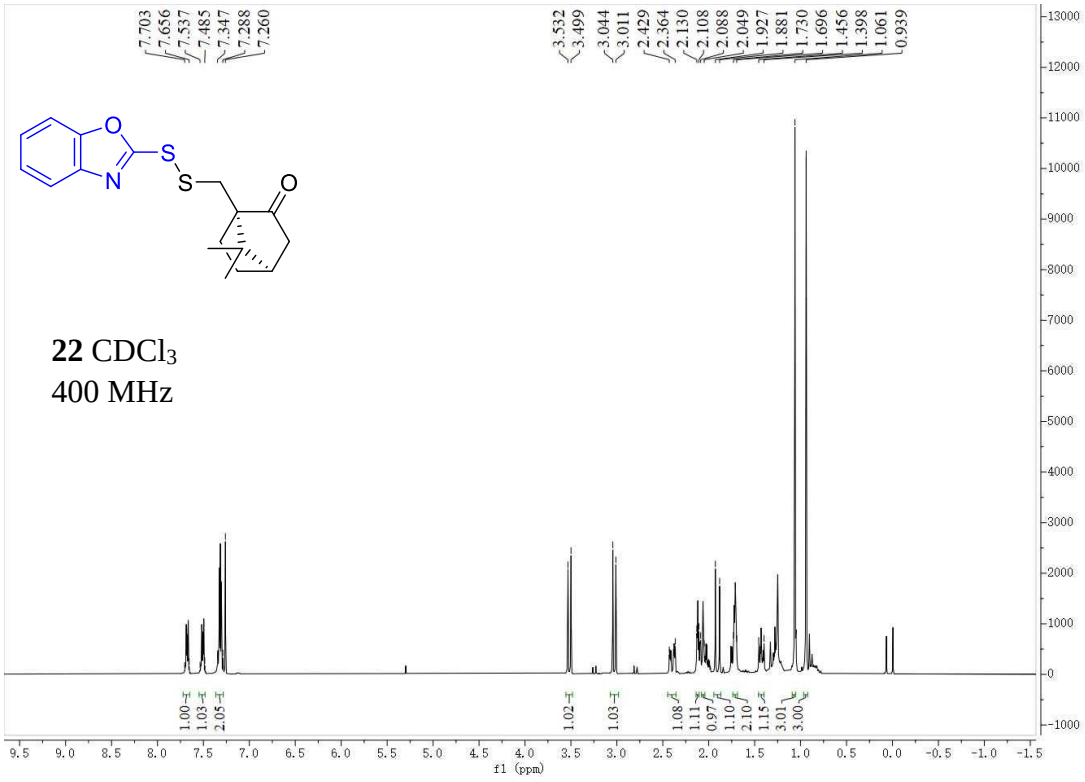

163.426
152.328
141.836
131.436
124.679
124.575
120.172
119.319
110.234
77.318
77.000
76.683
41.984
O
S
N
S
20 $CDCl_3$
101 MHz
f1 (ppm)

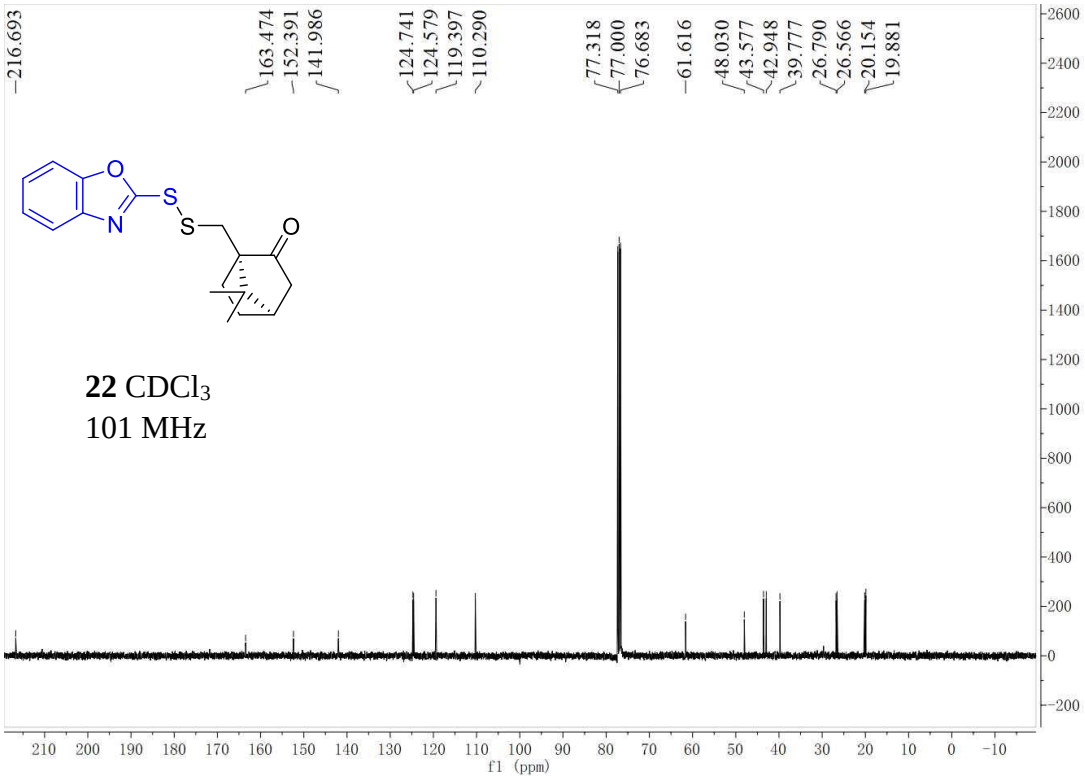


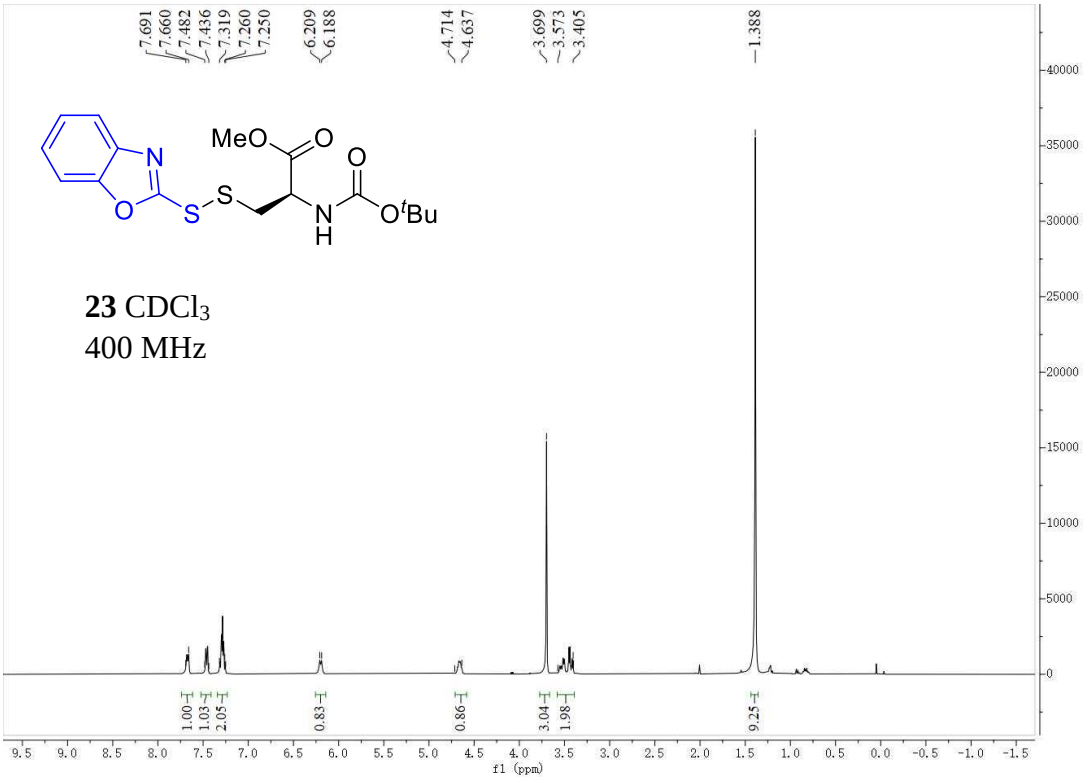
21 $CDCl_3$
400 MHz



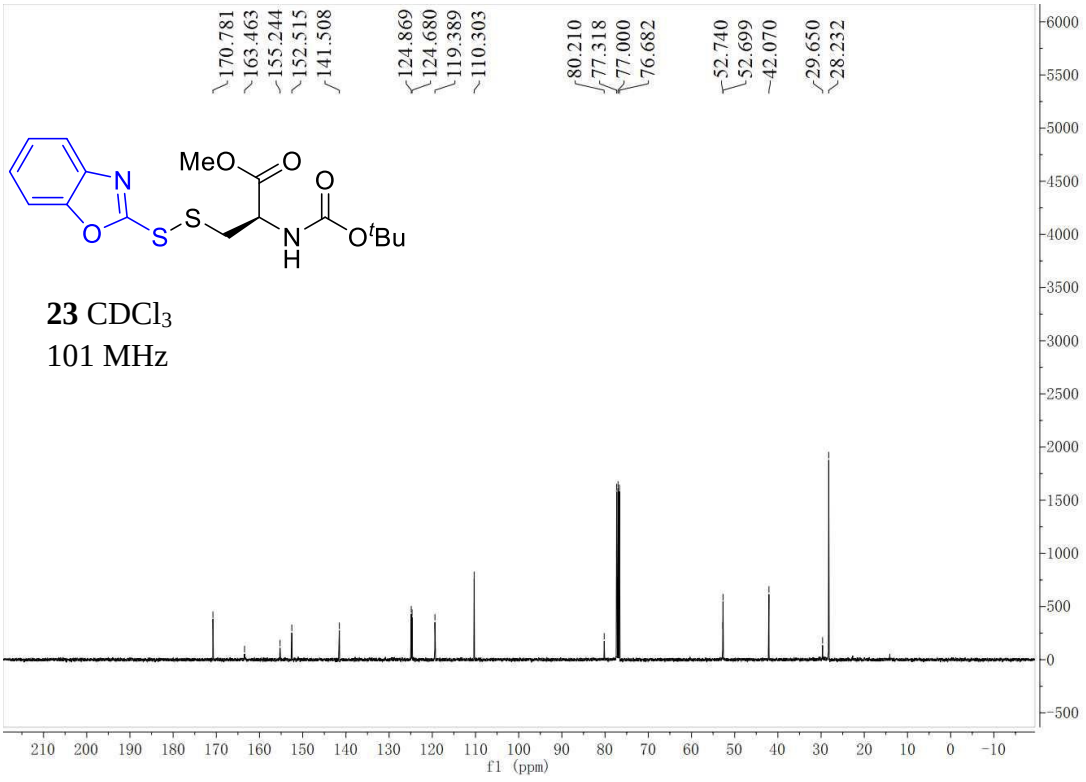
21 $CDCl_3$
101 MHz


7.703
7.656
7.537
7.485
7.347
7.288
7.260
3.532
3.499
3.044
3.011
2.429
2.364
2.130
2.108
2.088
2.049
1.927
1.881
1.730
1.696
1.456
1.398
1.061
0.939
O
S
S
N
O
22 CDCl3
400 MHz
1.00
1.03
2.05
1.02
1.03
1.08
1.11
0.97
1.10
2.10
1.15
3.01
3.00
f1 (ppm)

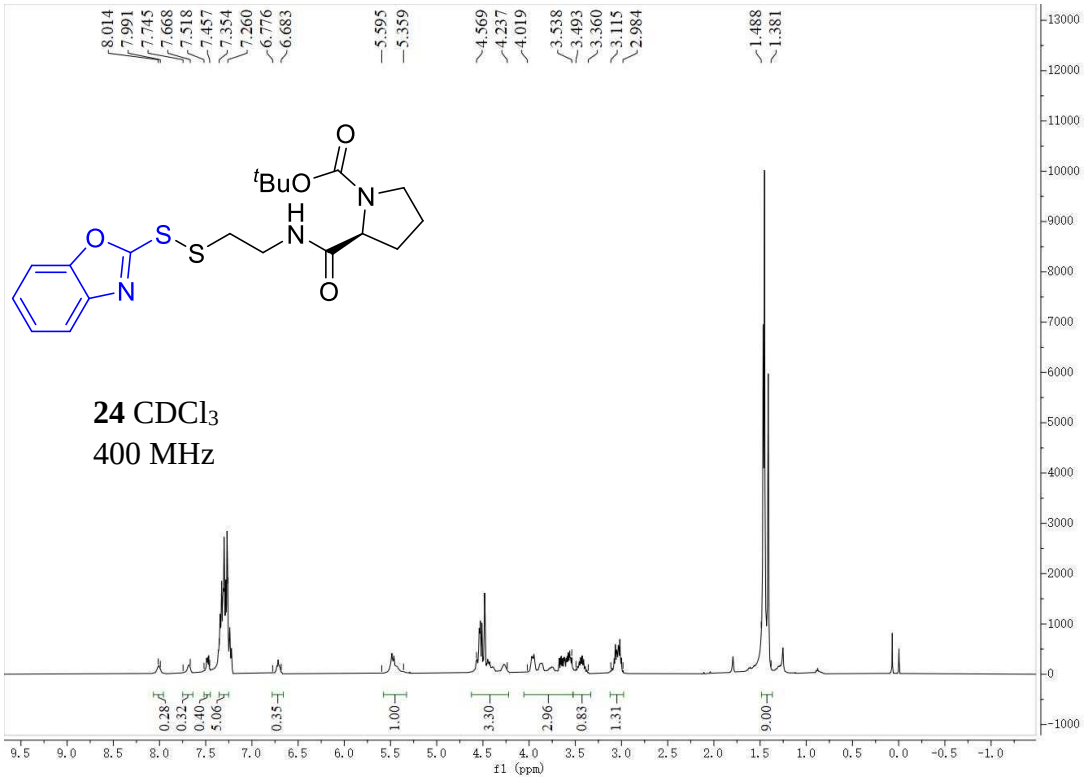

216.693
163.474
152.391
141.986
124.741
124.579
119.397
110.290
77.318
77.000
76.683
61.616
48.030
43.577
42.948
39.777
26.790
26.566
20.154
19.881
O
S
S
N
O
22 CDCl3
101 MHz
f1 (ppm)

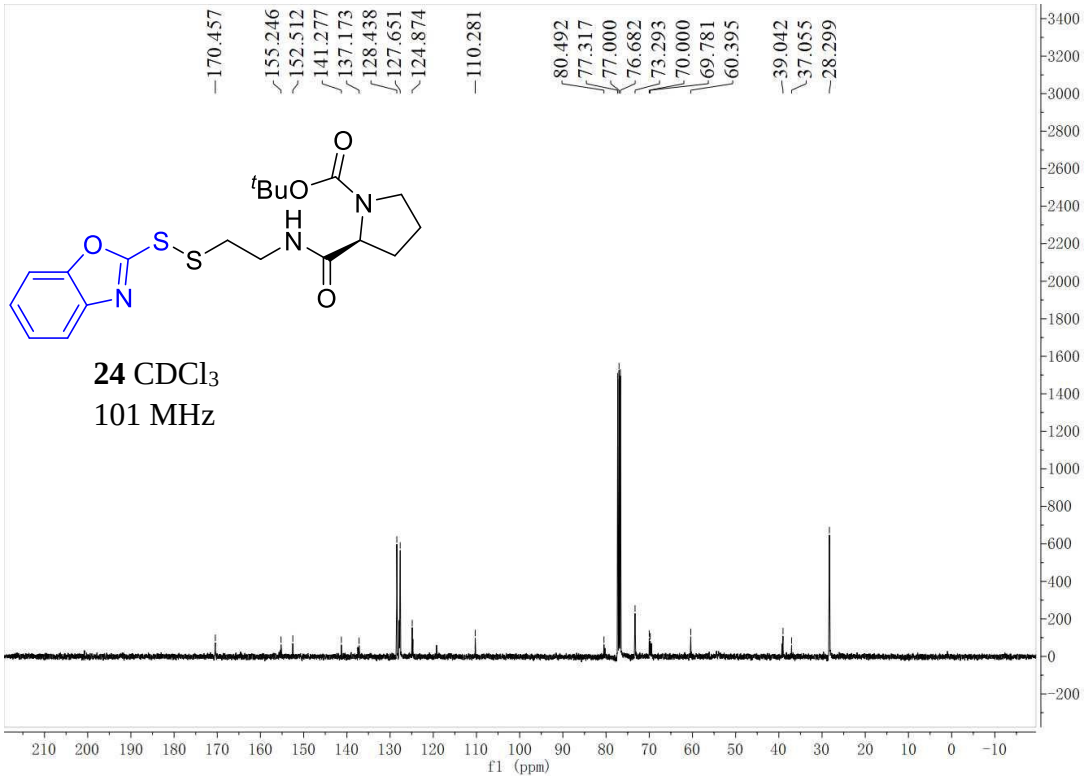


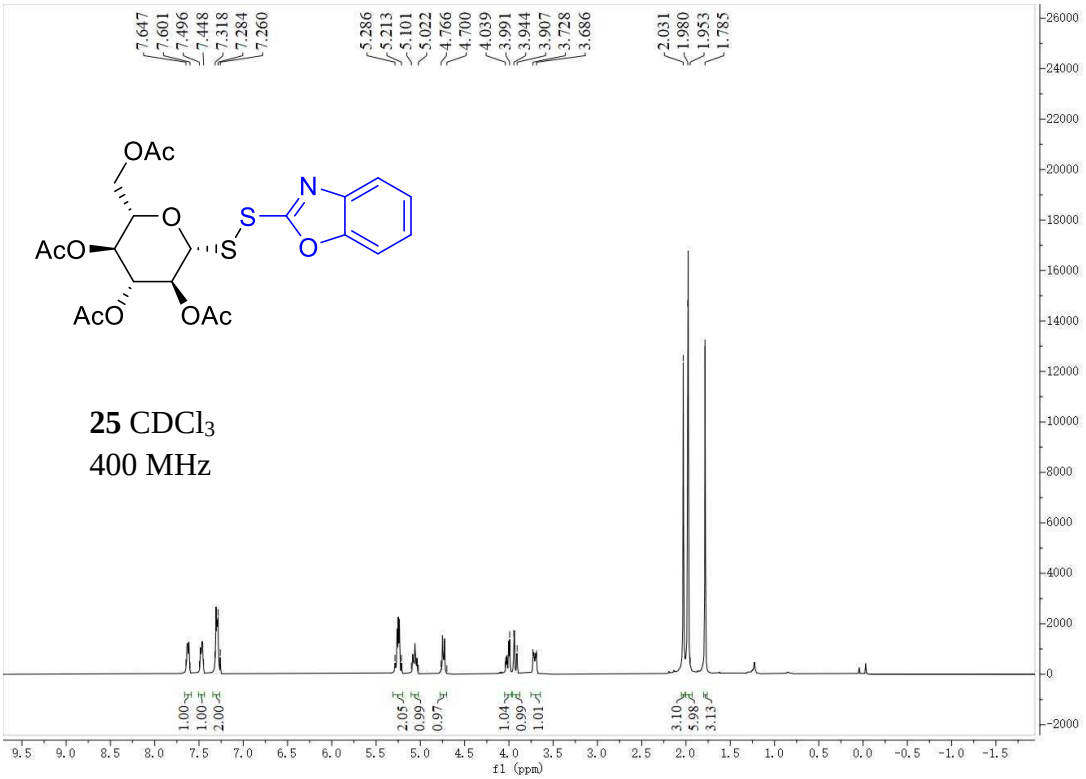
23 $CDCl_3$
400 MHz

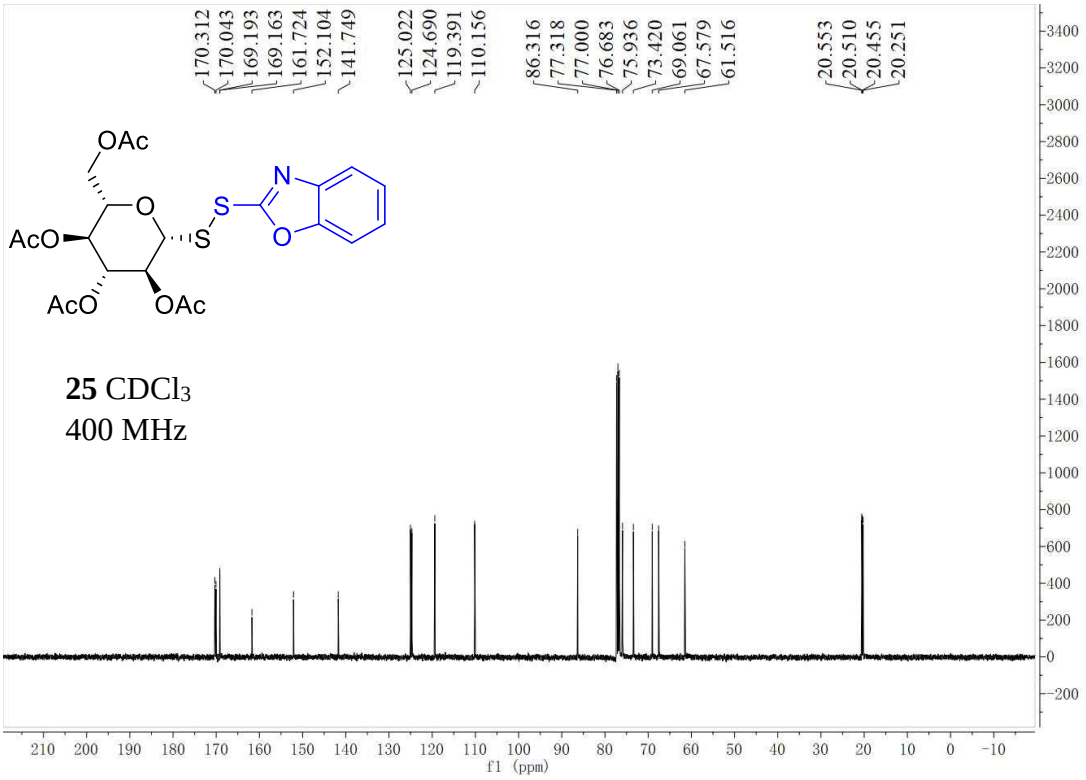


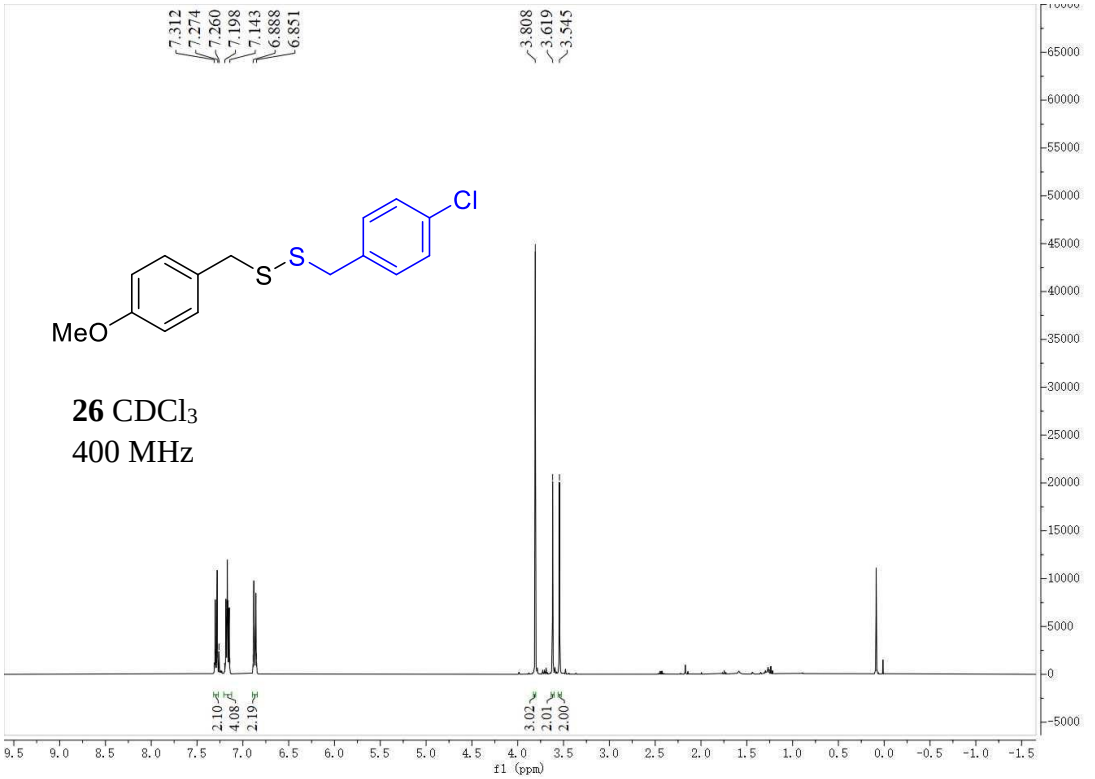
23 $CDCl_3$
101 MHz

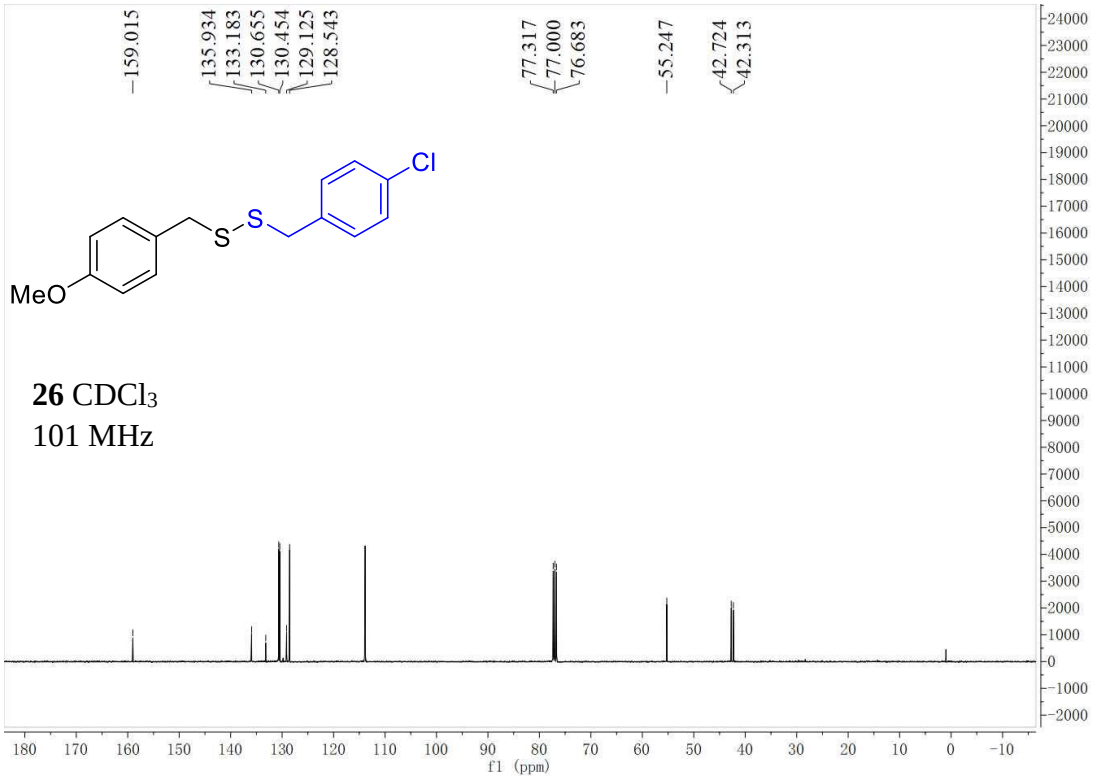

8.014
7.991
7.745
7.668
7.518
7.457
7.354
7.260
6.776
6.683
5.595
5.359
4.569
4.237
4.019
3.538
3.493
3.360
3.115
2.984
1.488
1.381
tBuO
O
N
H
N
O
S
S
O
N
24 CDCl3
400 MHz
0.28
0.32
0.40
5.06
0.35
1.00
3.30
2.96
0.83
1.31
9.00
f1 (ppm)

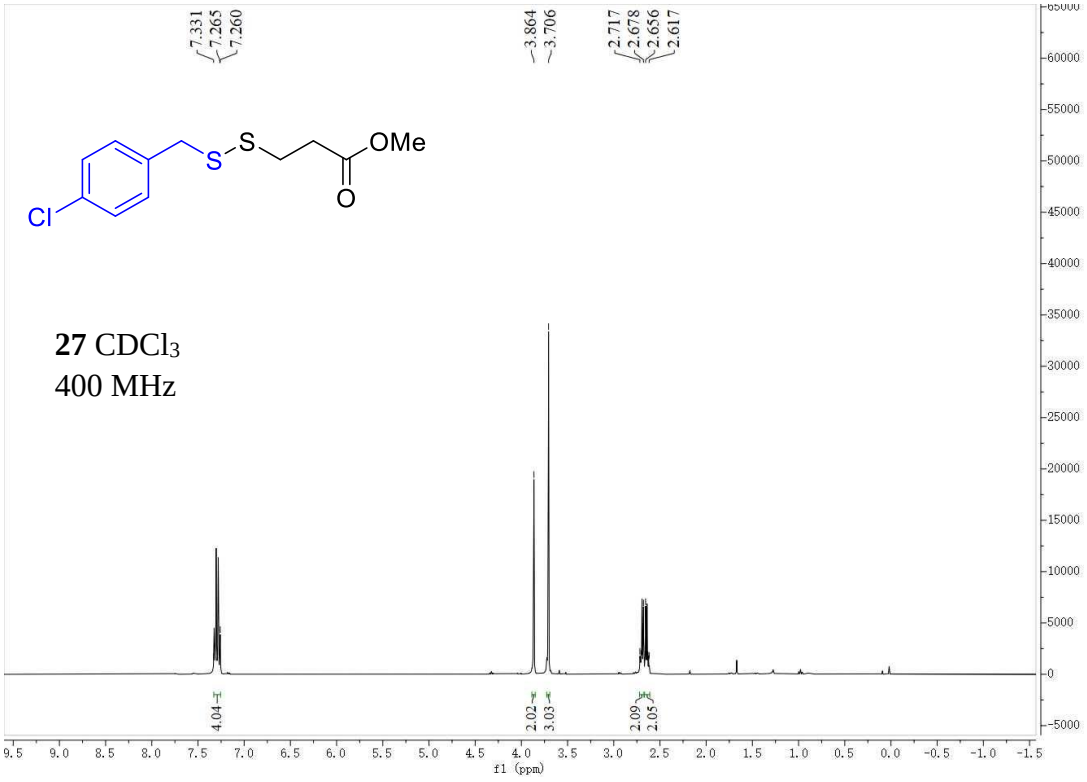

170.457
155.246
152.512
141.277
137.173
128.438
127.651
124.874
110.281
80.492
77.317
77.000
76.682
73.293
70.000
69.781
60.395
39.042
37.055
28.299
tBuO
O
N
H
N
O
S
S
O
N
24 CDCl3
101 MHz
f1 (ppm)

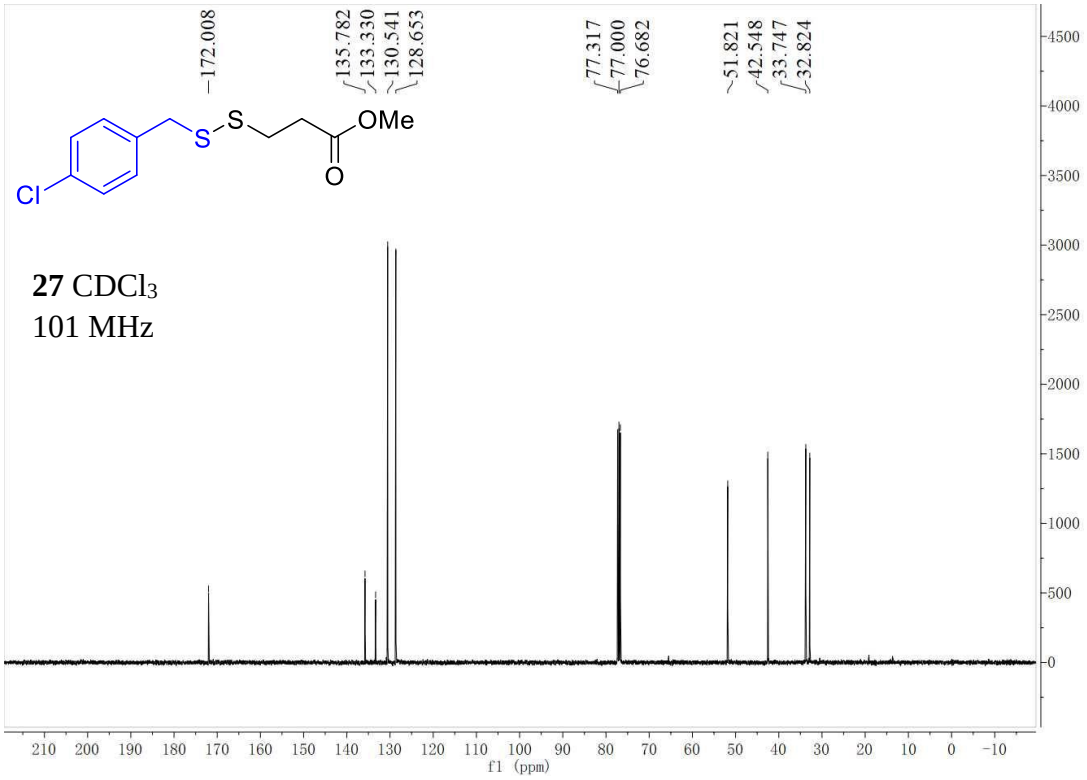

7.647
7.601
7.496
7.448
7.318
7.284
7.260
5.286
5.213
5.101
5.022
4.766
4.700
4.039
3.991
3.944
3.907
3.728
3.686
2.031
1.980
1.953
1.785
OAc
AcO
AcO
OAc
O
S
S
N
O
25 CDCl3
400 MHz
1.00
1.00
2.00
2.05
0.99
0.97
1.04
0.99
1.01
3.10
5.98
3.13
f1 (ppm)

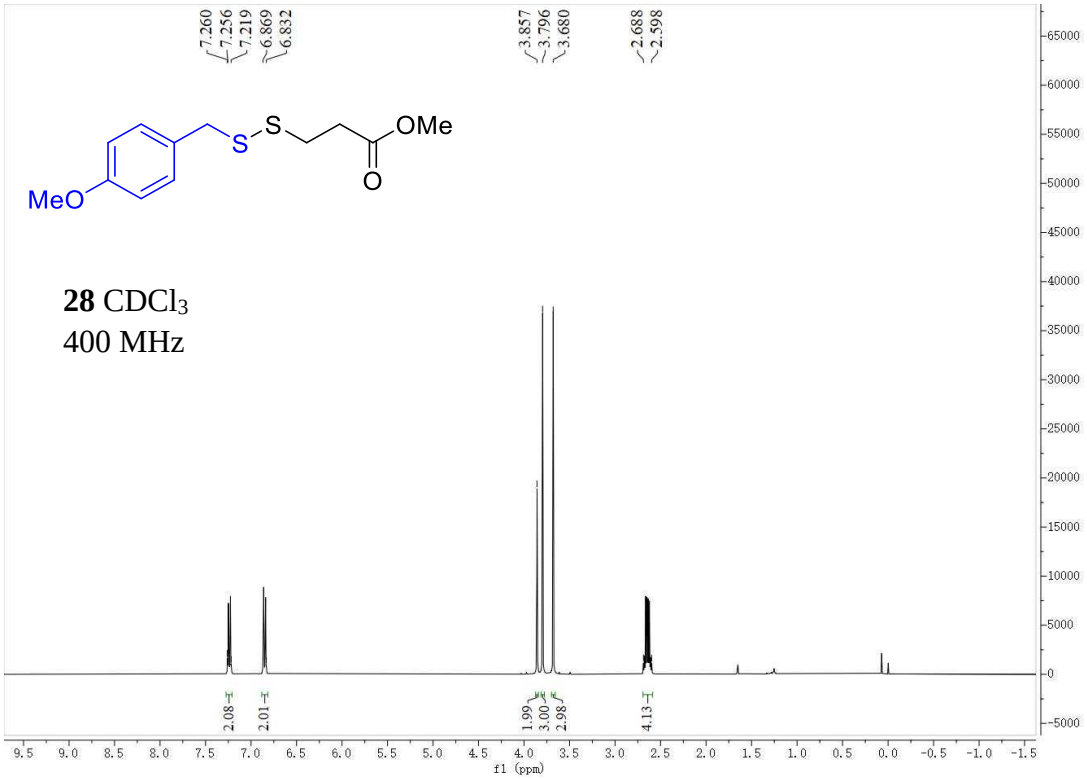

170.312
170.043
169.193
169.163
161.724
152.104
141.749
125.022
124.690
119.391
110.156
86.316
77.318
77.000
76.683
75.936
73.420
69.061
67.579
61.516
20.553
20.510
20.455
20.251
OAc
AcO
AcO
OAc
O
S
S
N
O
25 CDCl3
400 MHz
f1 (ppm)

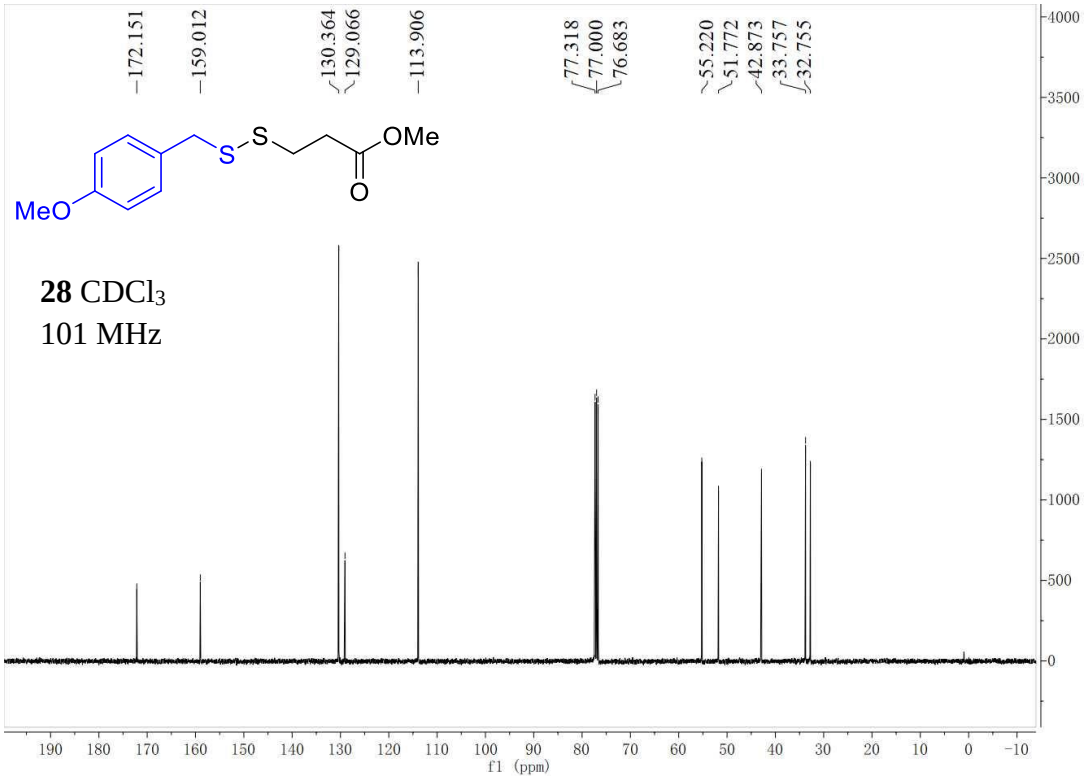

7.312
7.274
7.260
7.198
7.143
6.888
6.851
3.808
3.619
3.545
Cl
S
S
MeO
26 CDCl3
400 MHz
2.10
4.08
2.19
3.02
2.01
2.00
f1 (ppm)

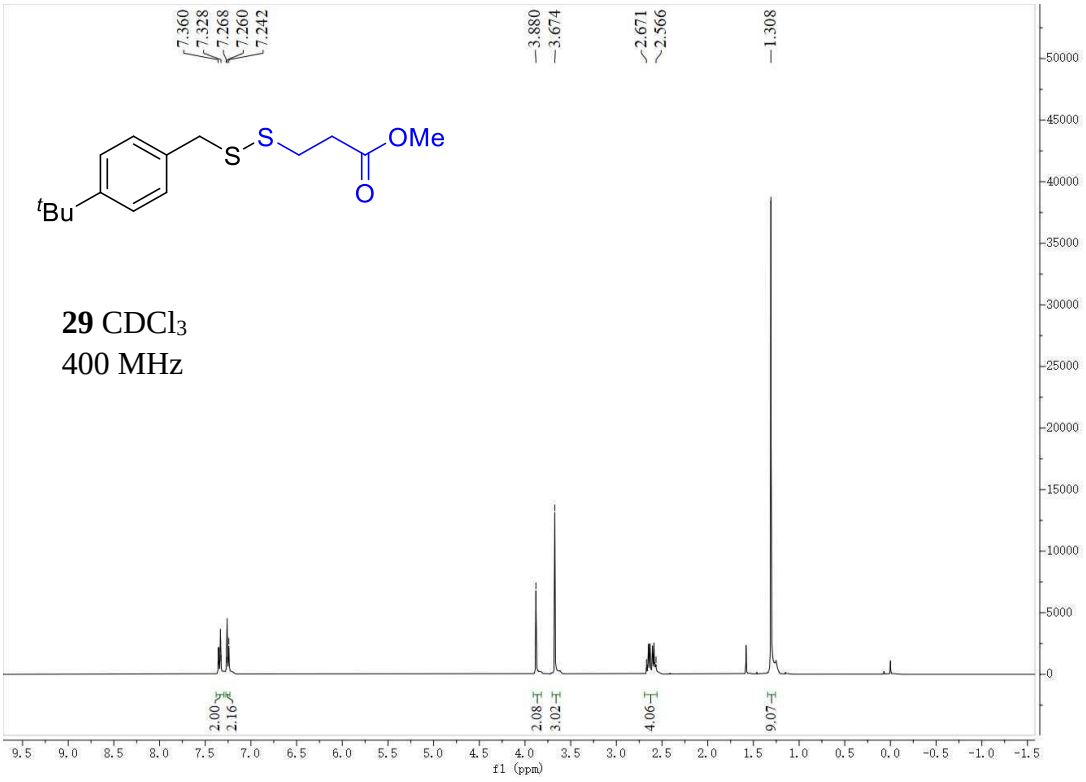

159.015
135.934
133.183
130.655
130.454
129.125
128.543
77.317
77.000
76.683
55.247
42.724
42.313
Cl
S
S
MeO
26 CDCl3
101 MHz
f1 (ppm)

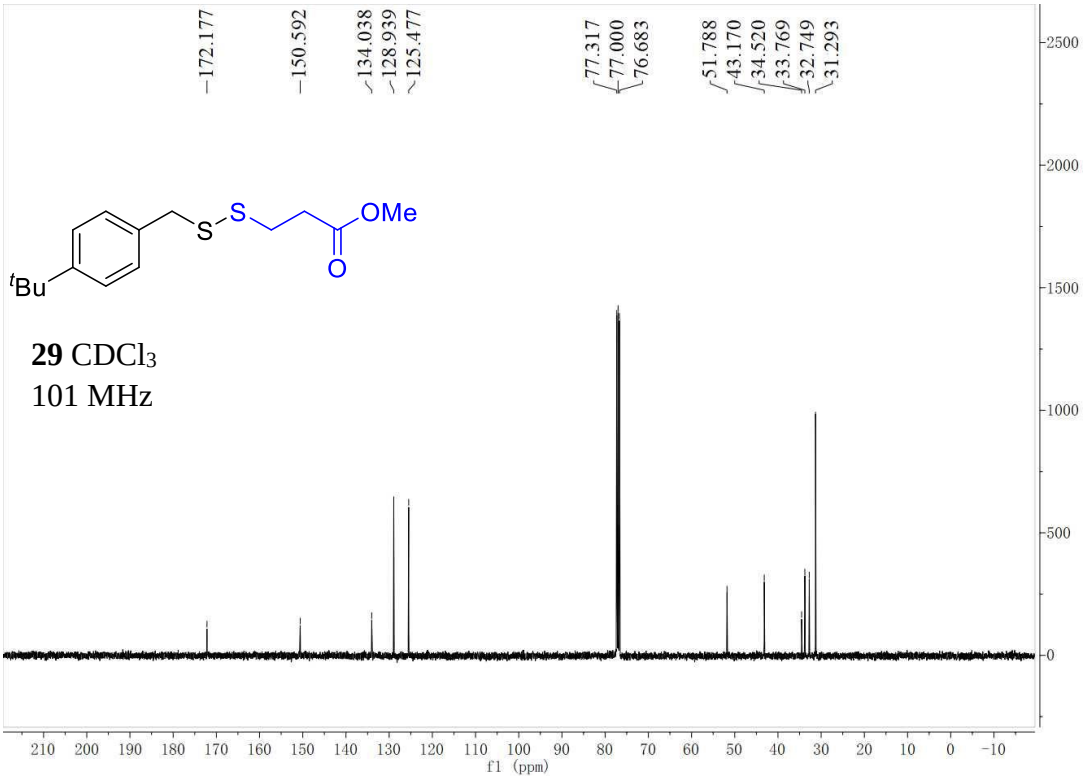

7.331
7.265
7.260
3.864
3.706
2.717
2.678
2.656
2.617
S
S
OMe
O
Cl
27 CDCl3
400 MHz
4.04
2.02
3.03
2.09
2.05
f1 (ppm)

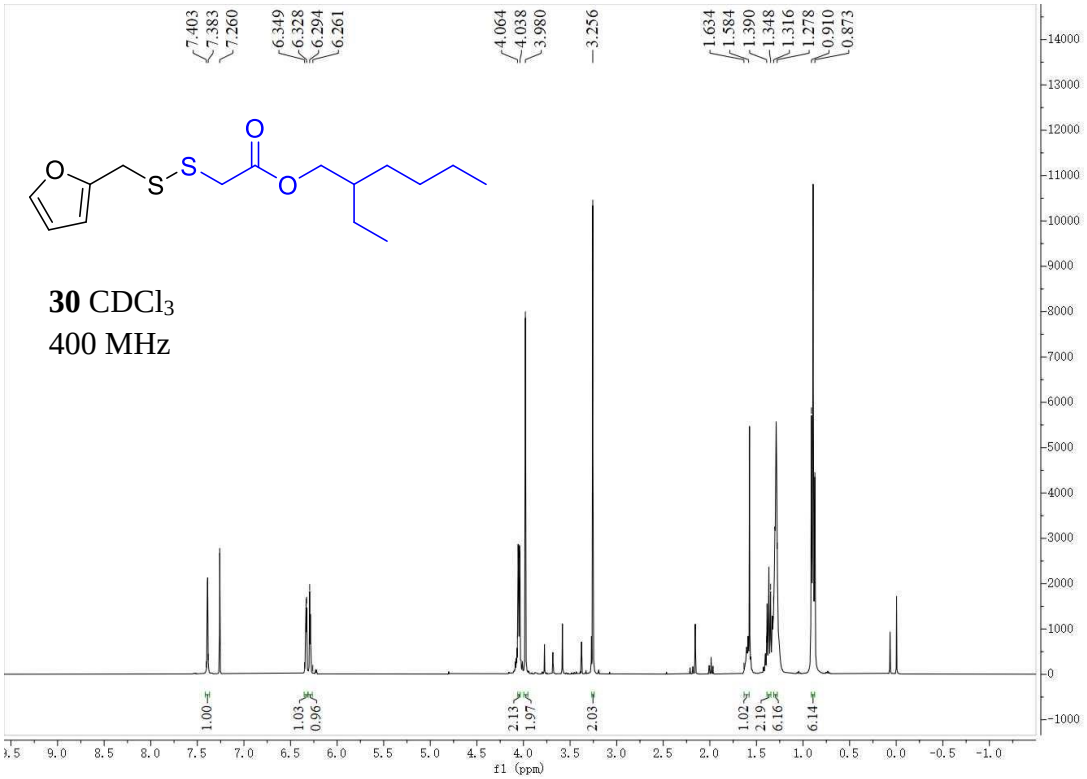

172.008
135.782
133.330
130.541
128.653
77.317
77.000
76.682
51.821
42.548
33.747
32.824
S
S
OMe
O
Cl
27 CDCl3
101 MHz
f1 (ppm)


7.260
7.256
7.219
6.869
6.832
3.857
3.796
3.680
2.688
2.598
MeO
S
S
OMe
O
28 CDCl3
400 MHz
2.08
2.01
1.99
3.00
2.98
4.13
f1 (ppm)

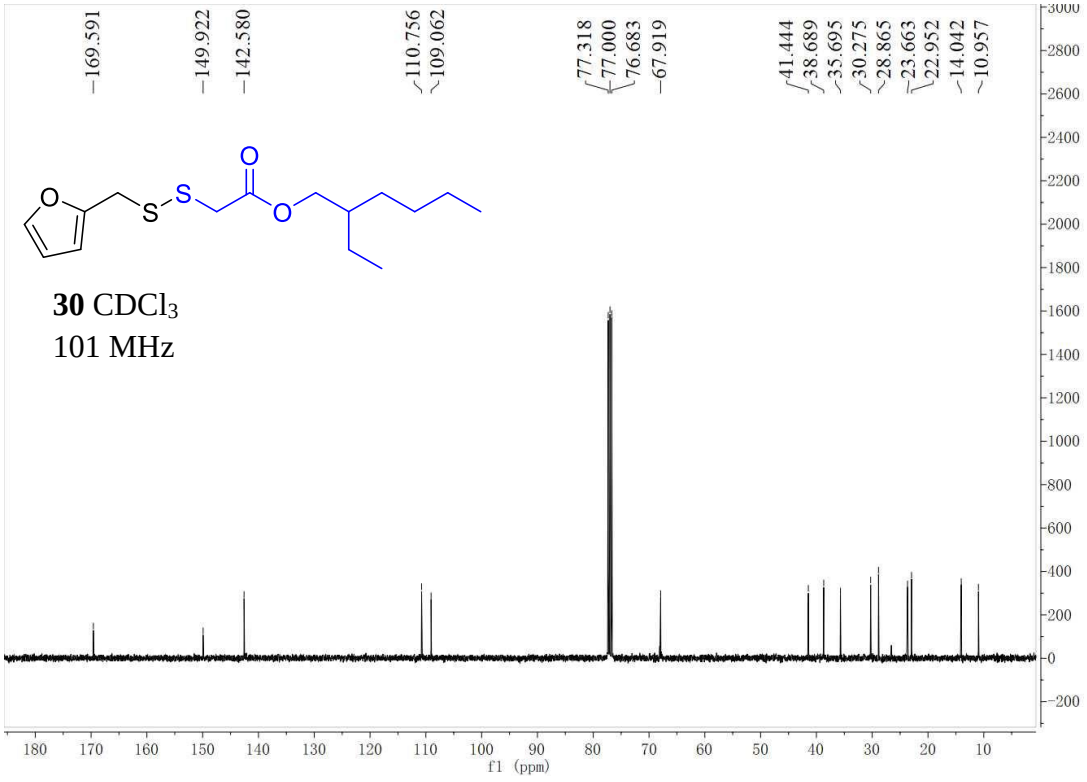

172.151
159.012
130.364
129.066
113.906
77.318
77.000
76.683
55.220
51.772
42.873
33.757
32.755
MeO
S
S
OMe
O
28 CDCl3
101 MHz
f1 (ppm)


7.360
7.328
7.268
7.260
7.242
3.880
3.674
2.671
2.566
1.308
S
S
OMe
O
tBu
29 CDCl3
400 MHz
2.00
2.16
2.08
3.02
4.06
9.07
f1 (ppm)

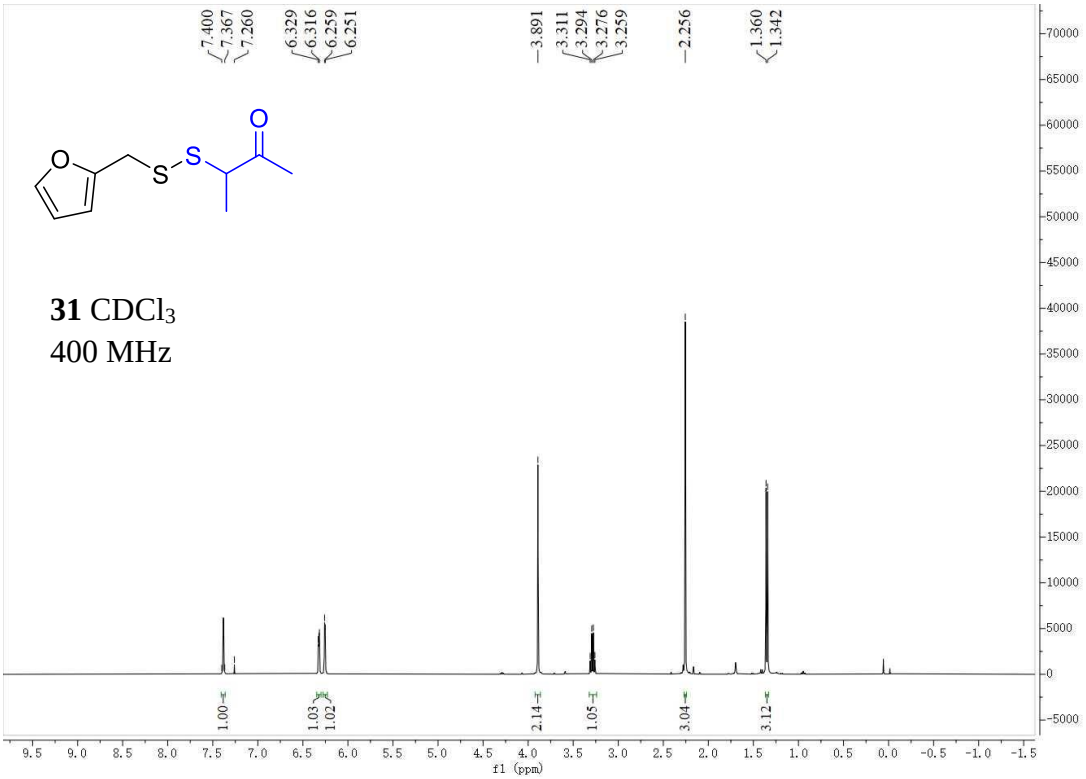

172.177
150.592
134.038
128.939
125.477
77.317
77.000
76.683
51.788
43.170
34.520
33.769
32.749
31.293
S
S
OMe
O
tBu
29 CDCl3
101 MHz
f1 (ppm)



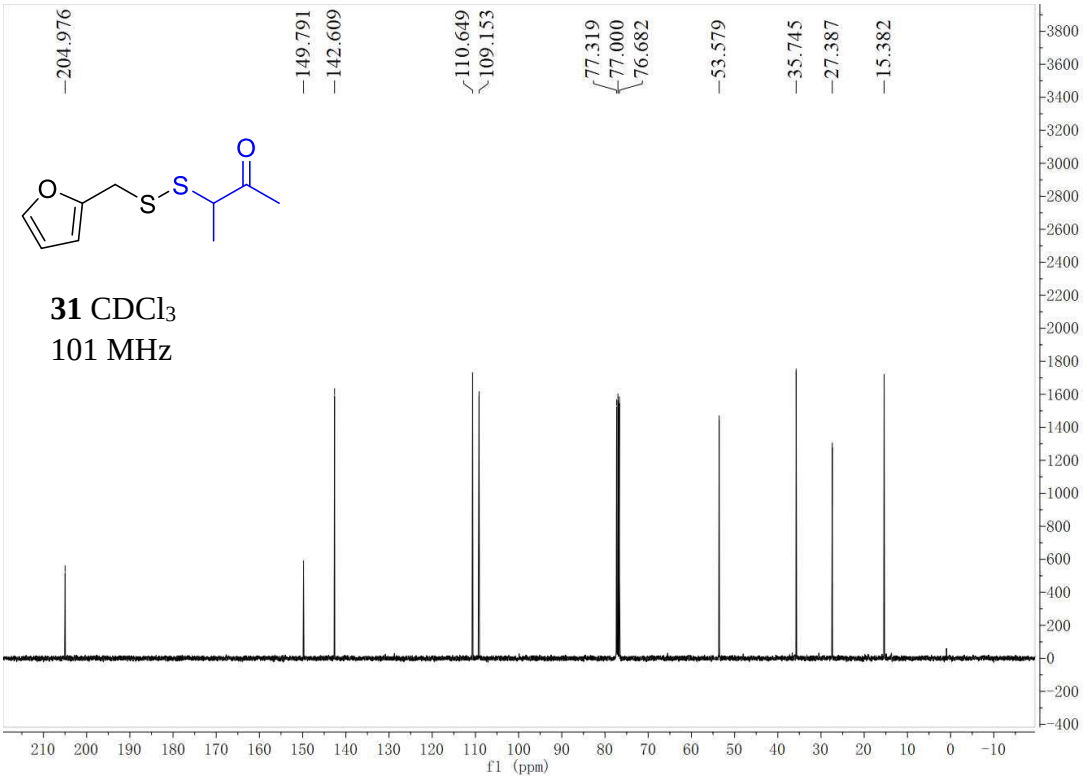
30 $CDCl_3$
400 MHz



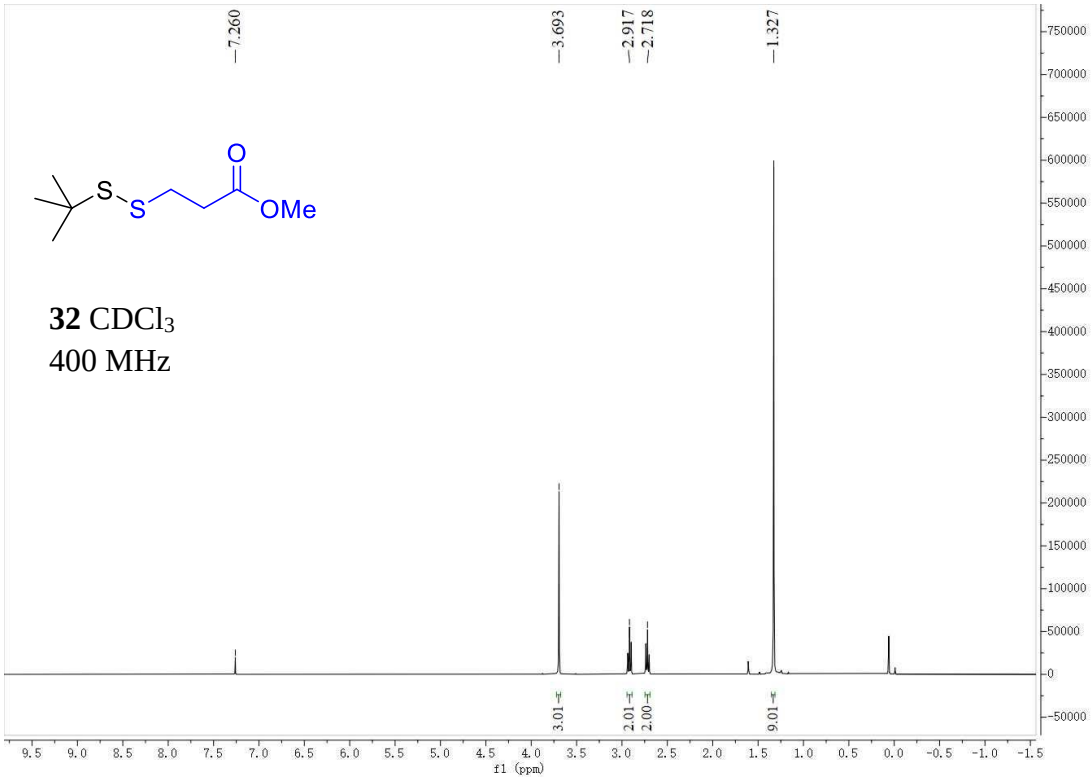
30 $CDCl_3$
101 MHz



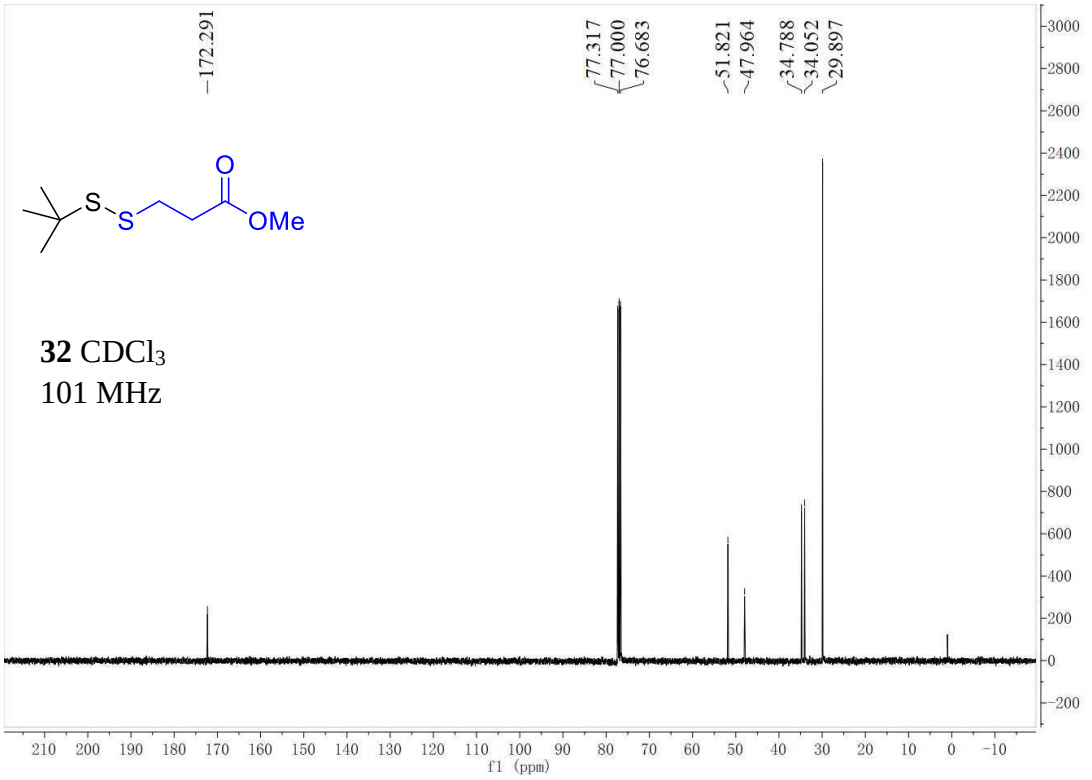
31 $CDCl_3$
400 MHz



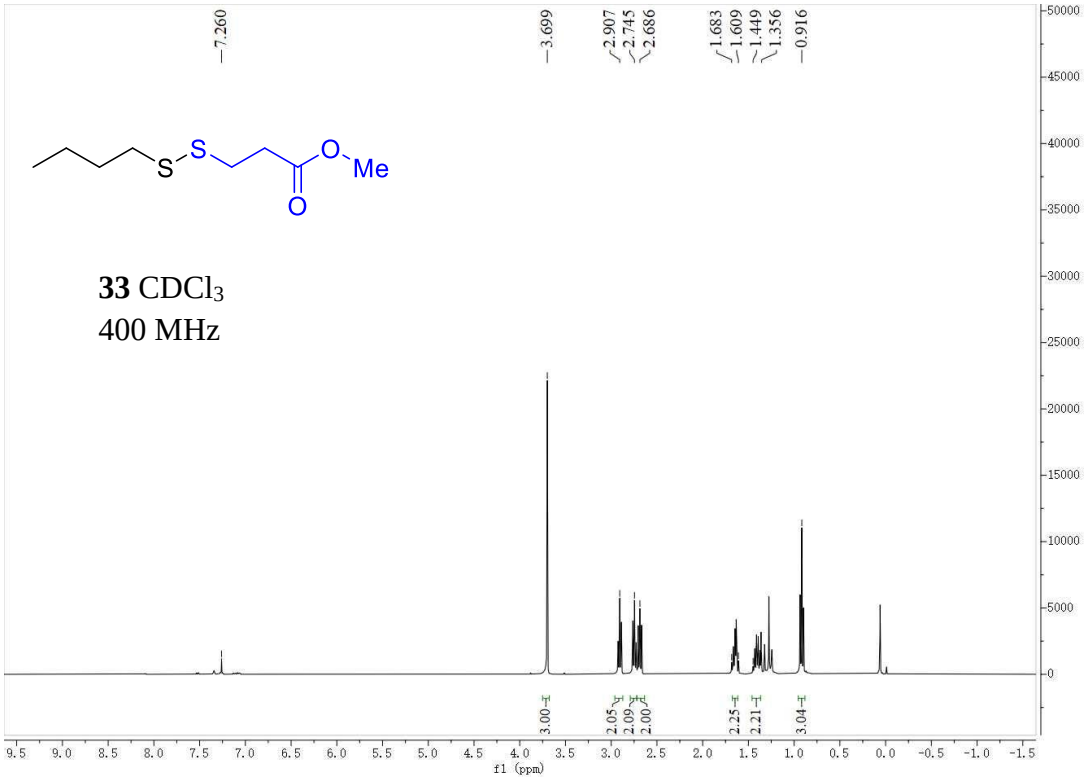
31 $CDCl_3$
101 MHz



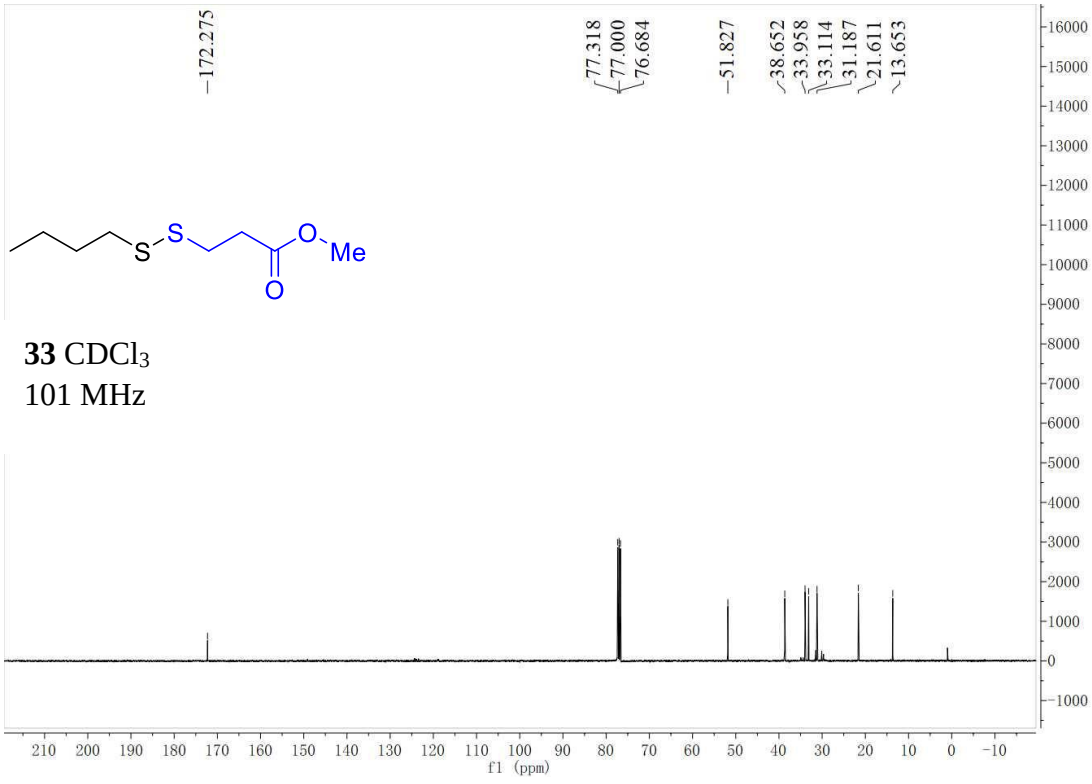
32 $CDCl_3$
400 MHz



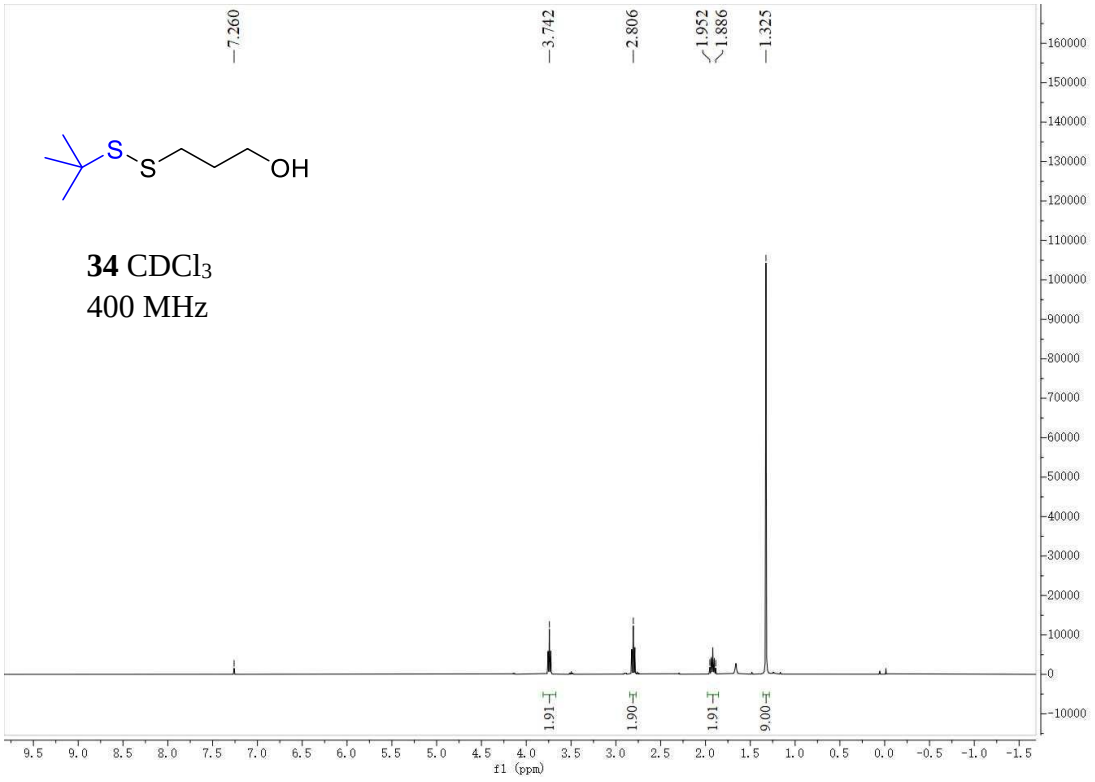
32 $CDCl_3$
101 MHz

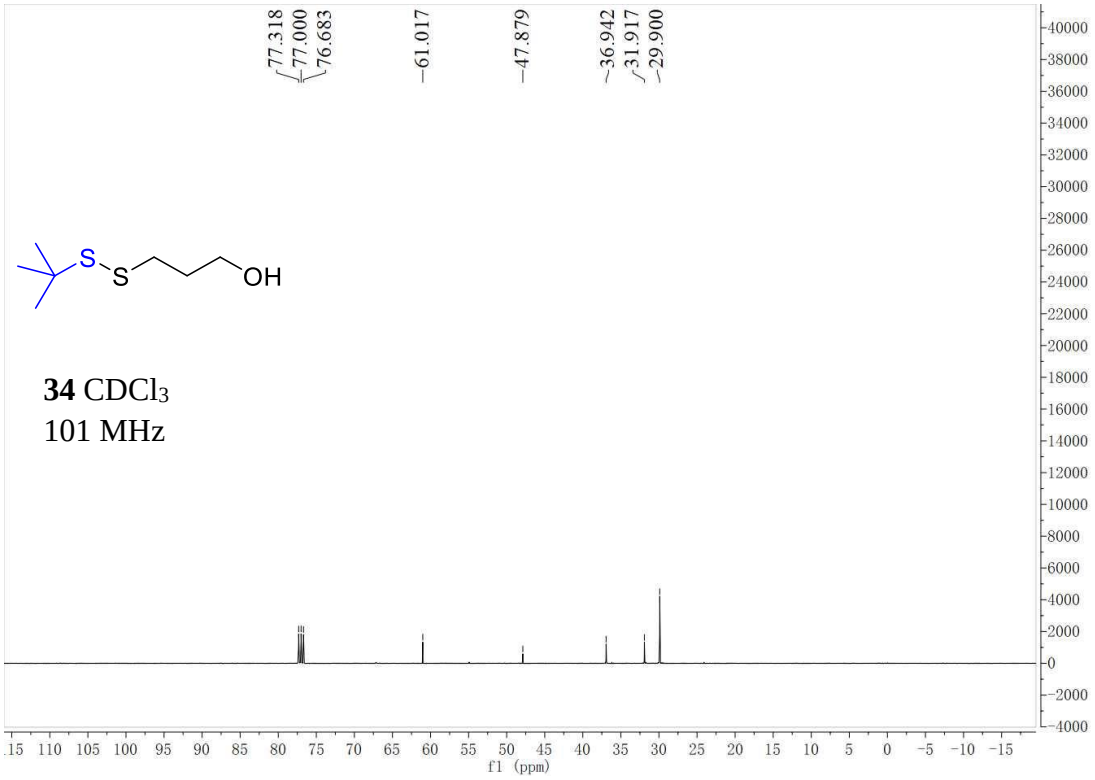


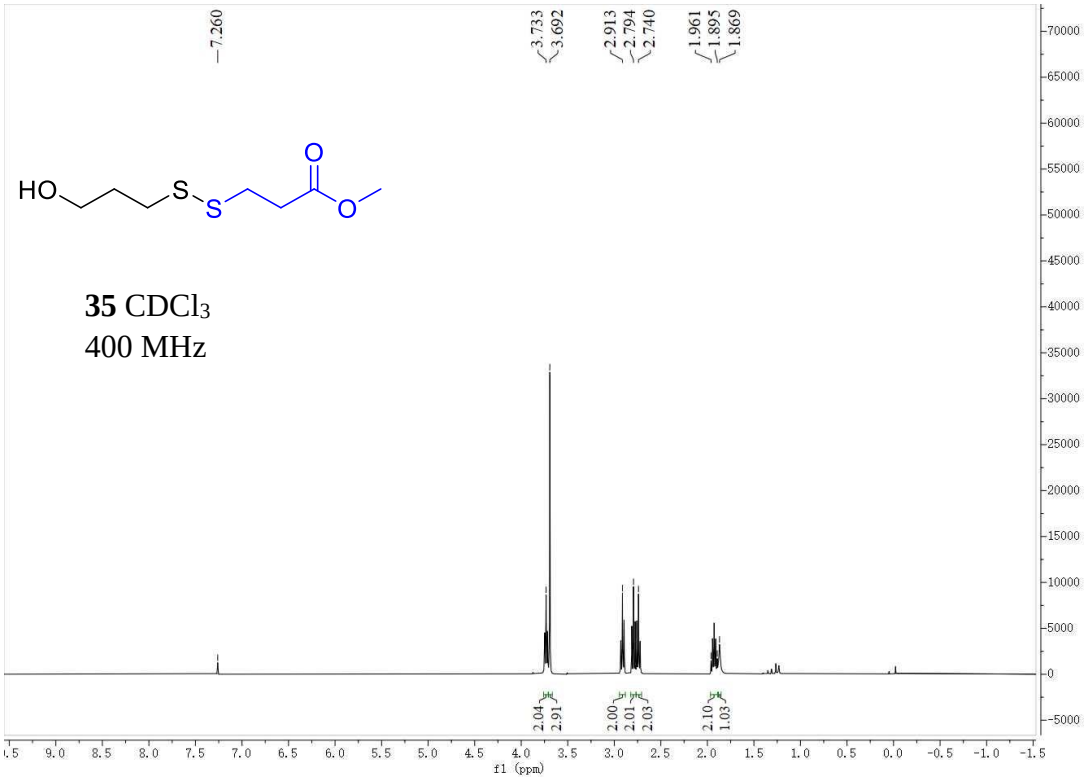
33 $CDCl_3$
400 MHz

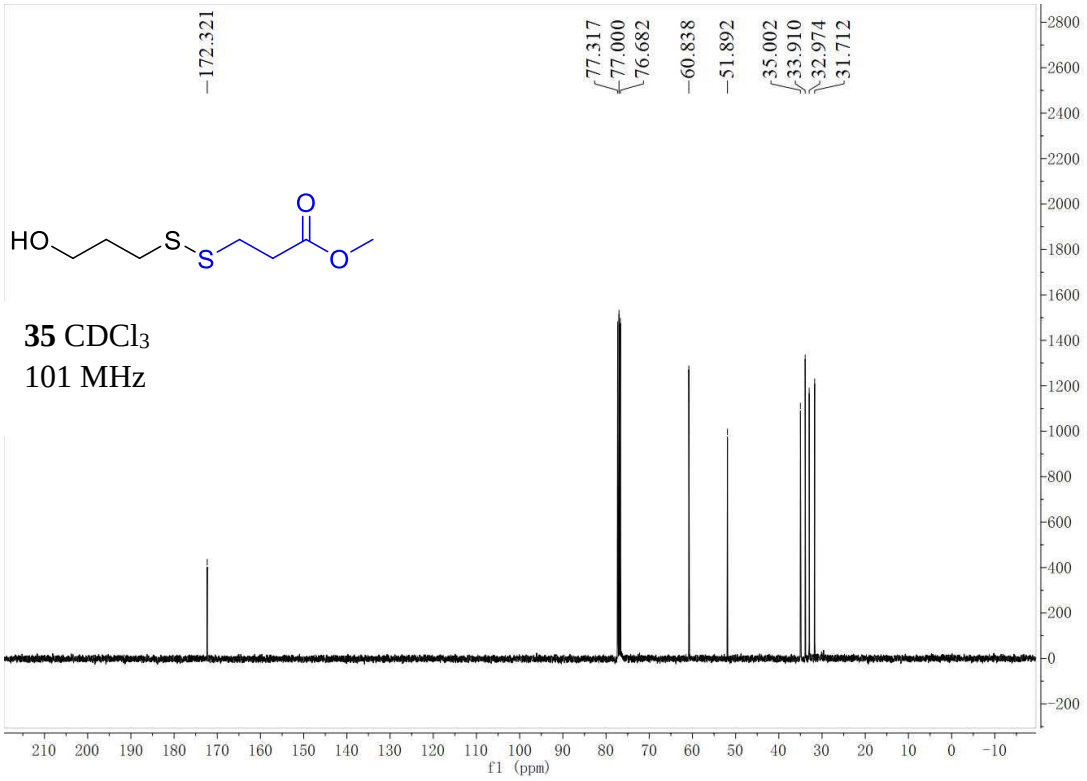


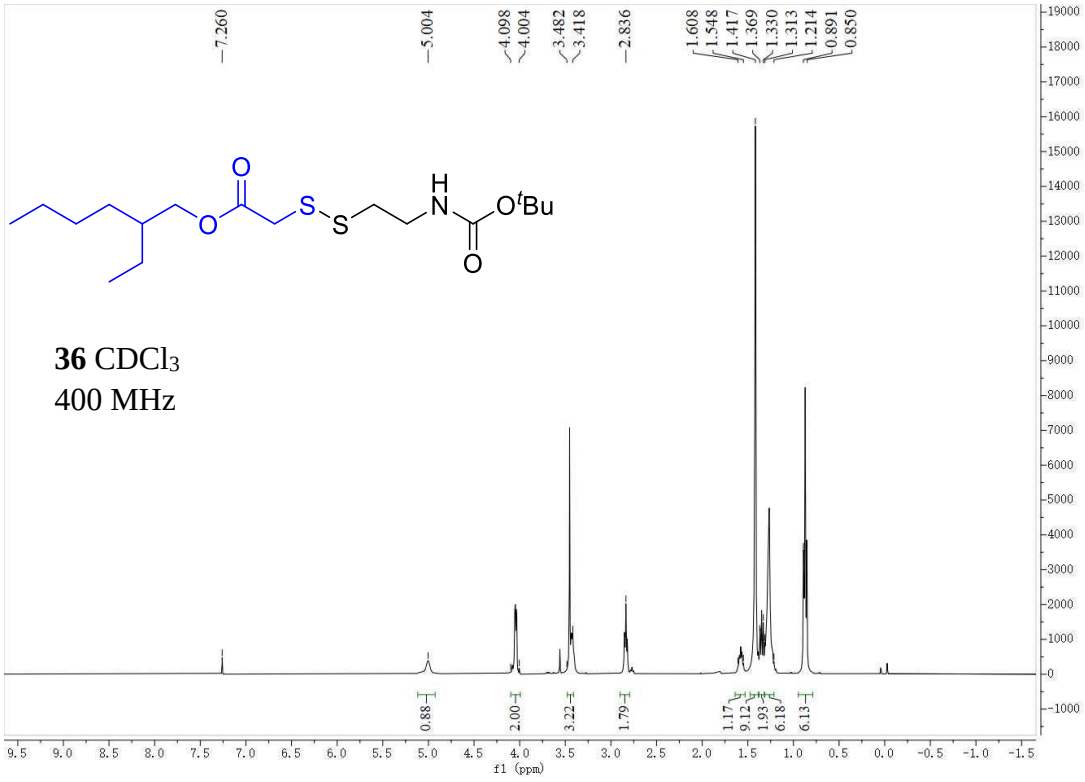
33 $CDCl_3$
101 MHz

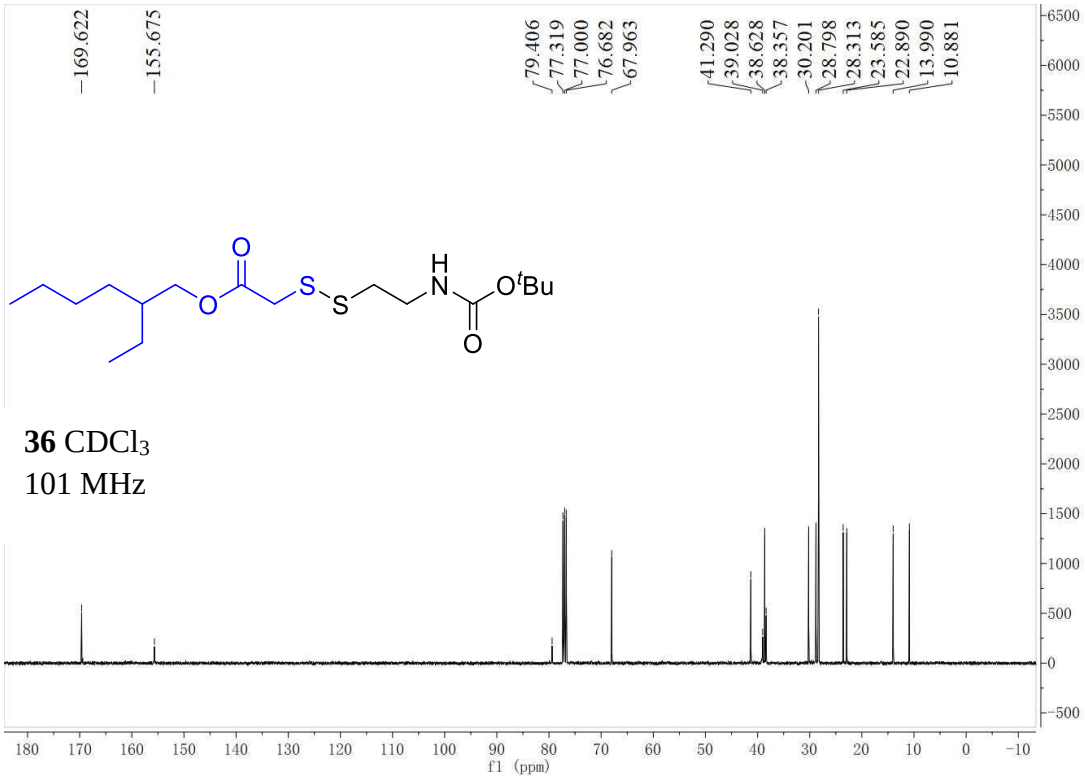

7.260
3.742
2.806
1.952
1.886
1.325
S
S
OH
34 CDCl3
400 MHz
1.91
1.90
1.91
9.00
f1 (ppm)

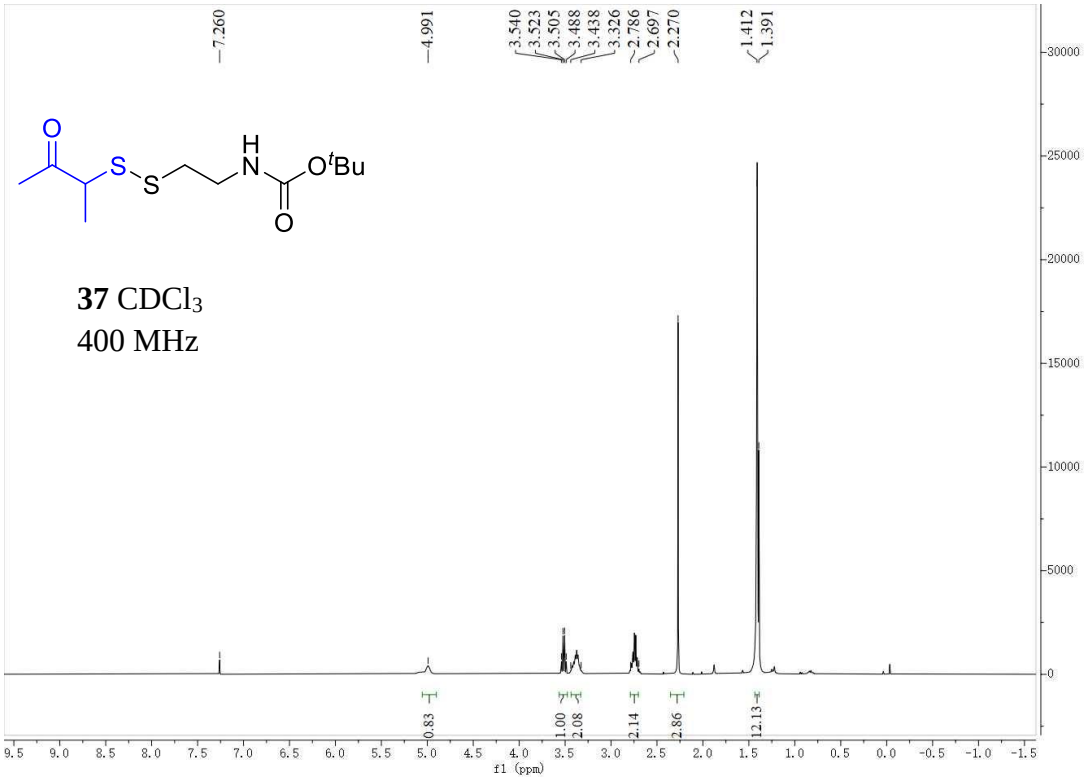

77.318
77.000
76.683
61.017
47.879
36.942
31.917
29.900
S
S
OH
34 CDCl3
101 MHz
f1 (ppm)


7.260
3.733
3.692
2.913
2.794
2.740
1.961
1.895
1.869
HO
S
S
O
O
35 CDCl3
400 MHz
2.04
2.91
2.00
2.01
2.03
2.10
1.03
f1 (ppm)

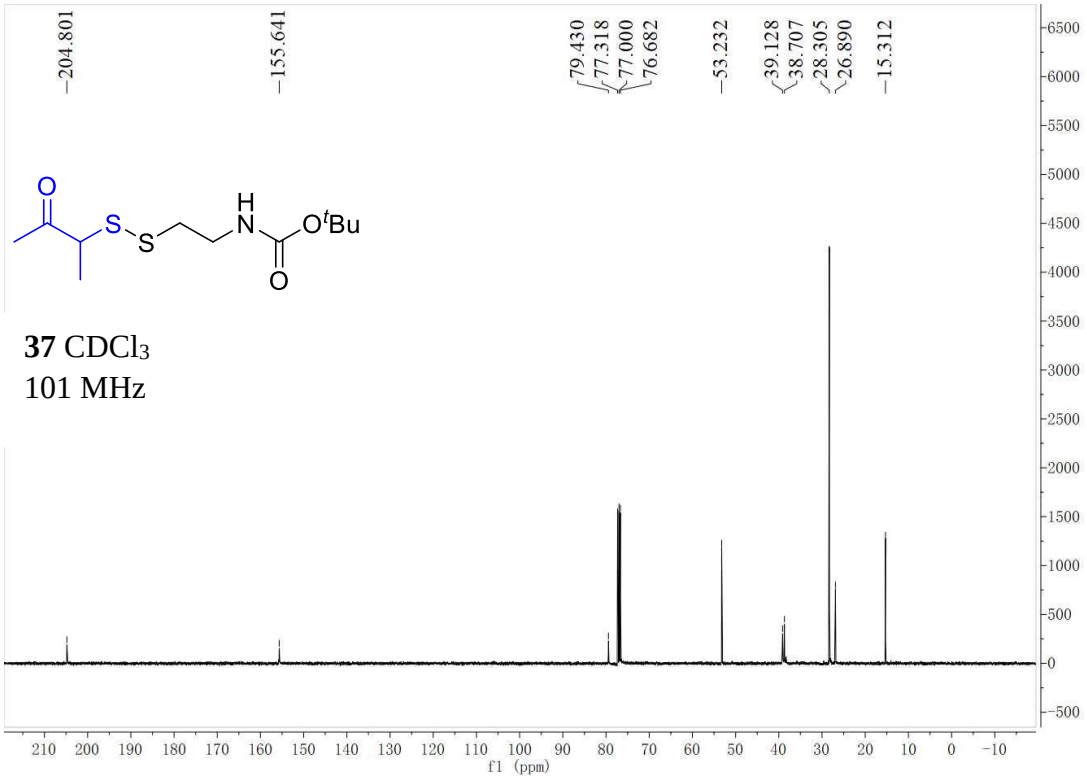

172.321
77.317
77.000
76.682
60.838
51.892
35.002
33.910
32.974
31.712
HO
S
S
O
O
35 CDCl3
101 MHz
f1 (ppm)


7.260
5.004
4.098
4.004
3.482
3.418
2.836
1.608
1.548
1.417
1.369
1.330
1.313
1.214
0.891
0.850
O
S
S
O
H
N
O
O
O'Bu
36 CDCl3
400 MHz
0.88
2.00
3.22
1.79
1.17
9.12
1.93
6.18
6.13
f1 (ppm)

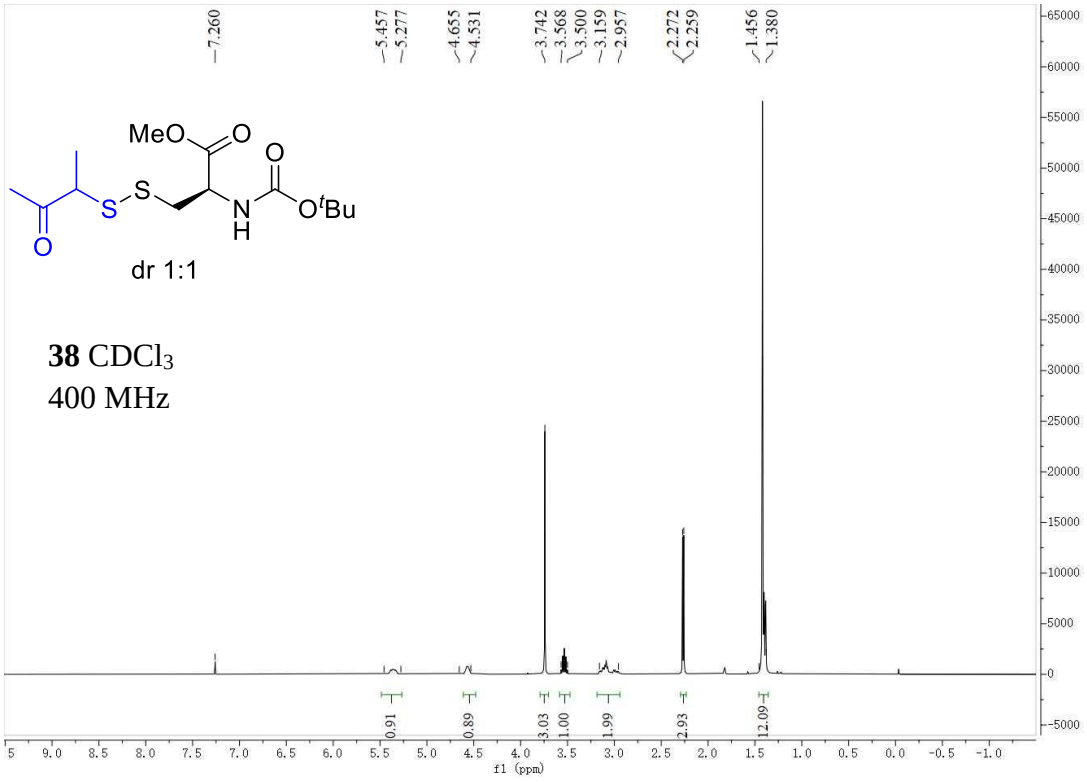

169.622
155.675
79.406
77.319
77.000
76.682
67.963
41.290
39.028
38.628
38.357
30.201
28.798
28.313
23.585
22.890
13.990
10.881
O
S
S
O
H
N
O
O
O'Bu
36 CDCl3
101 MHz
f1 (ppm)

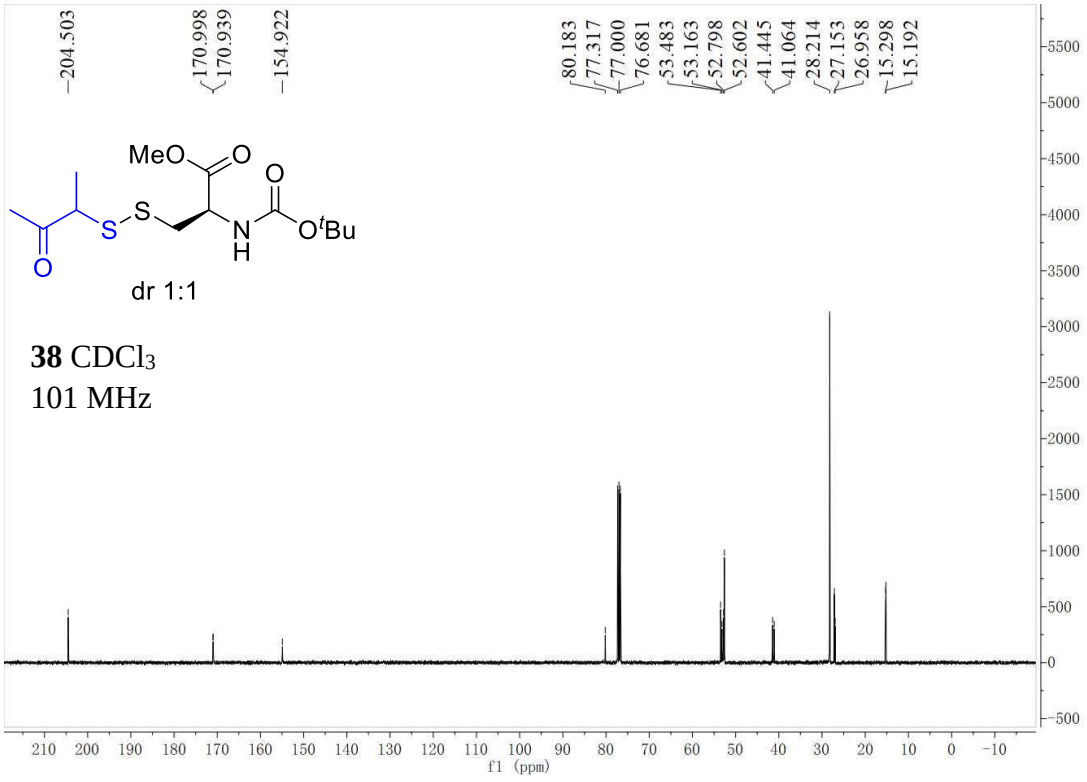


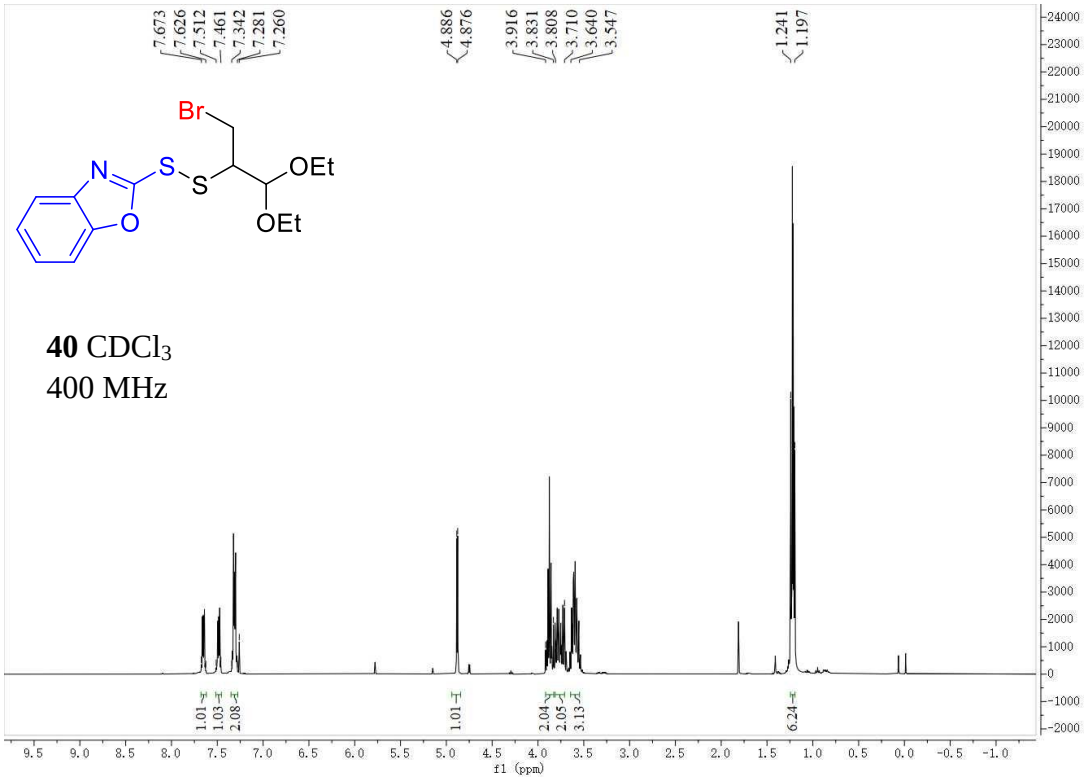
37 $CDCl_3$
400 MHz

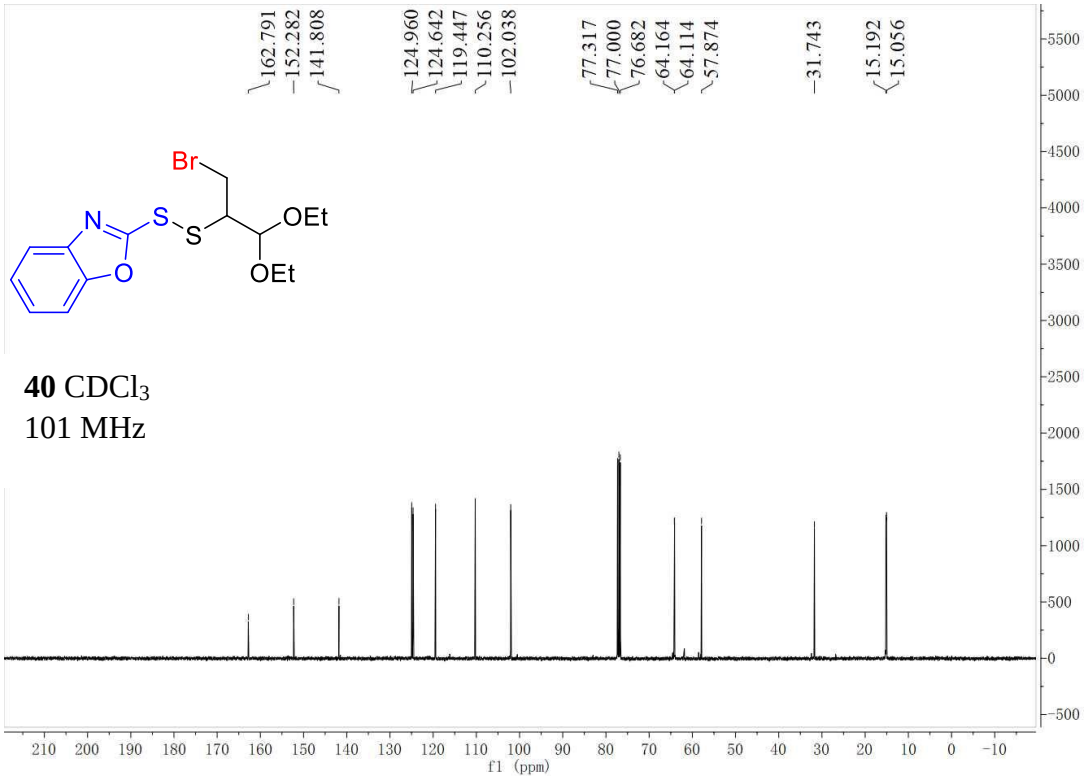


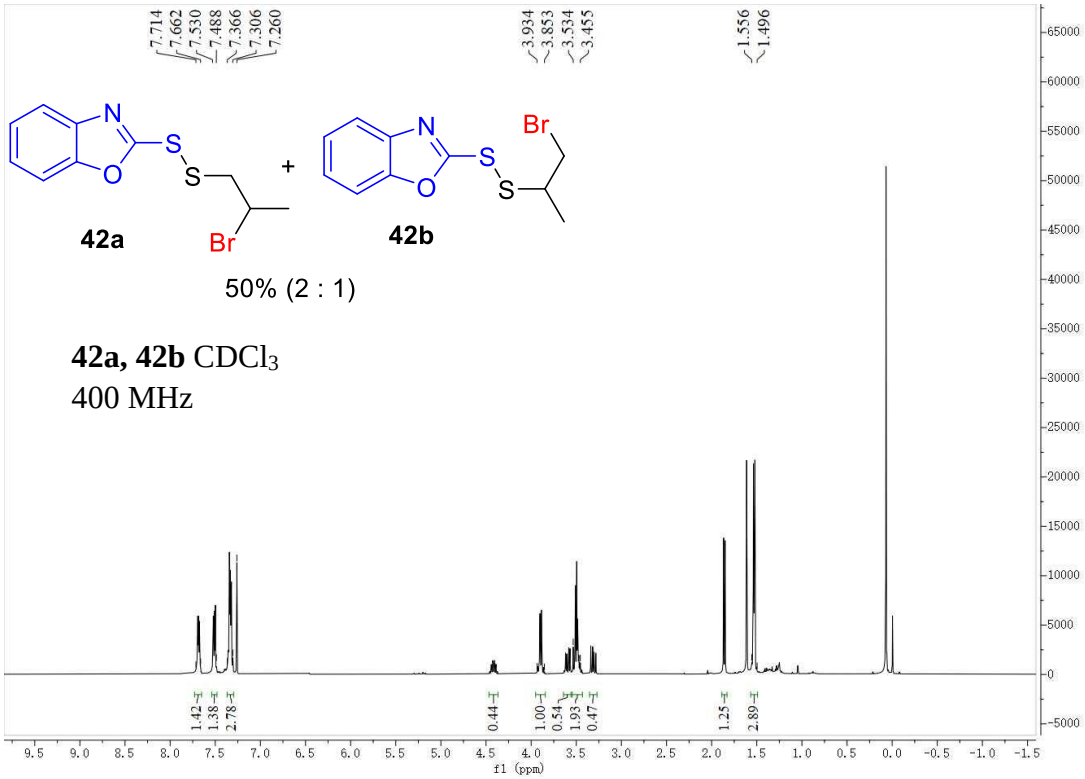
37 $CDCl_3$
101 MHz

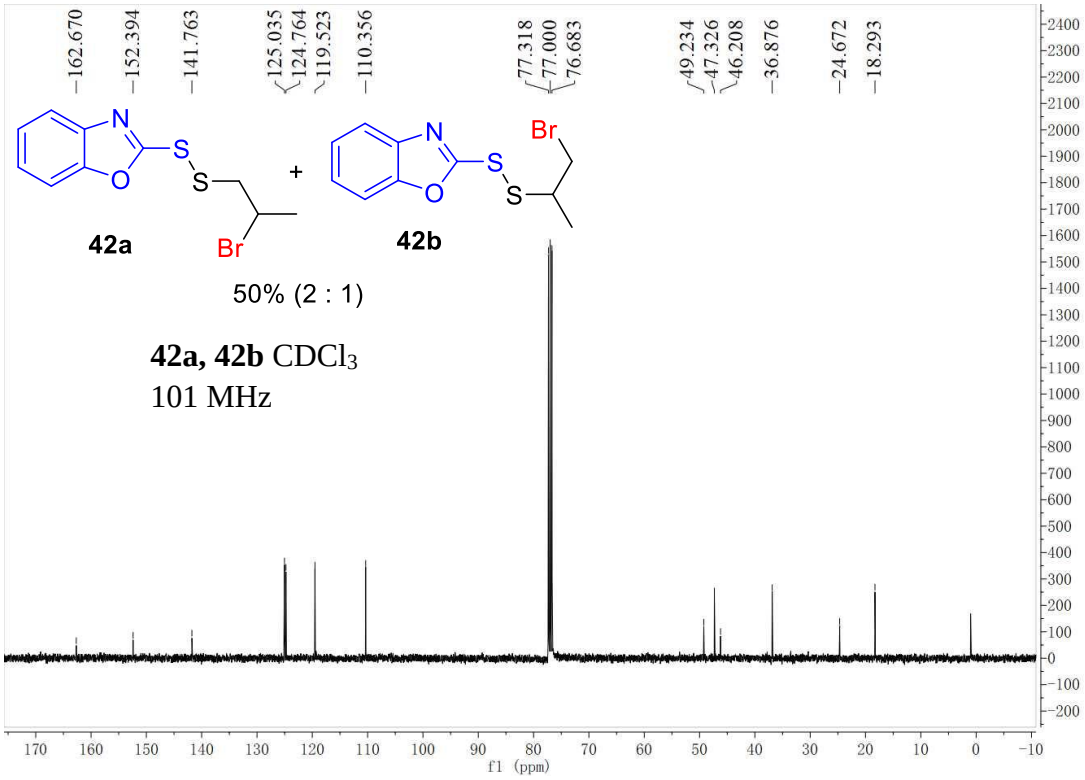

7.260
5.457
5.277
4.655
4.531
3.742
3.568
3.500
3.159
2.957
2.272
2.259
1.456
1.380
MeO
O
O
S
S
N
H
O
O
tBu
dr 1:1
38 CDCl3
400 MHz
0.91
0.89
3.03
1.00
1.99
2.93
12.09
f1 (ppm)

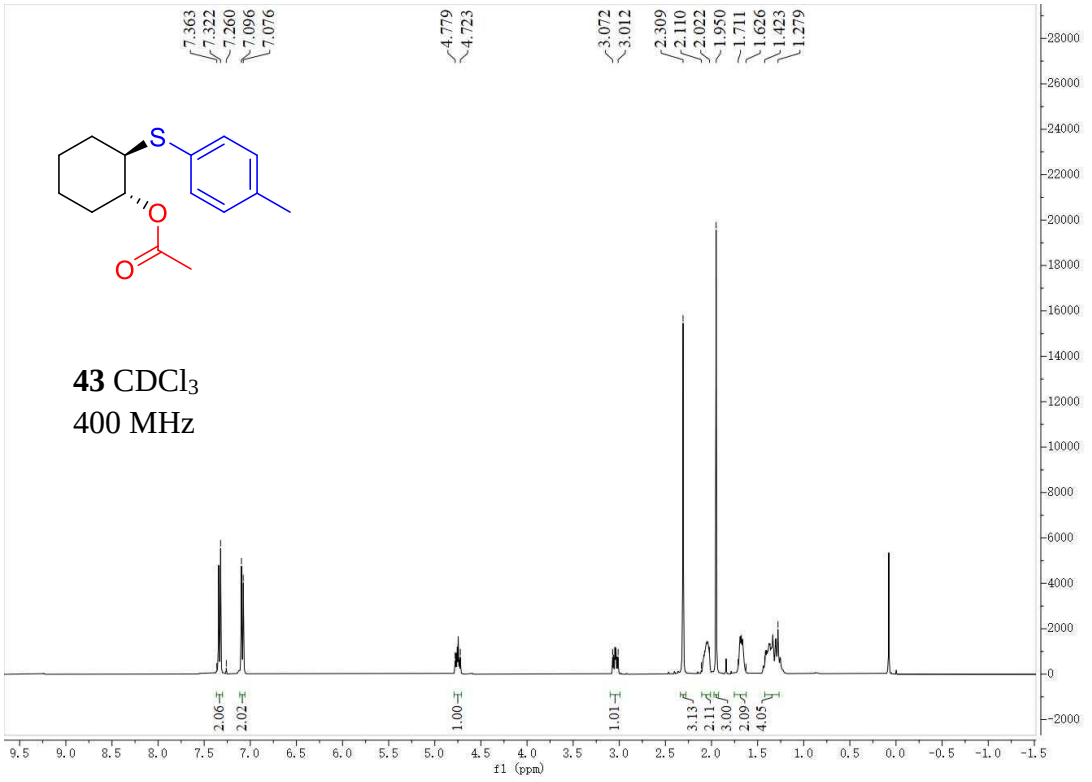

204.503
170.998
170.939
154.922
80.183
77.317
77.000
76.681
53.483
53.163
52.798
52.602
41.445
41.064
28.214
27.153
26.958
15.298
15.192
MeO
O
O
S
S
N
H
O
O
tBu
dr 1:1
38 CDCl3
101 MHz
f1 (ppm)

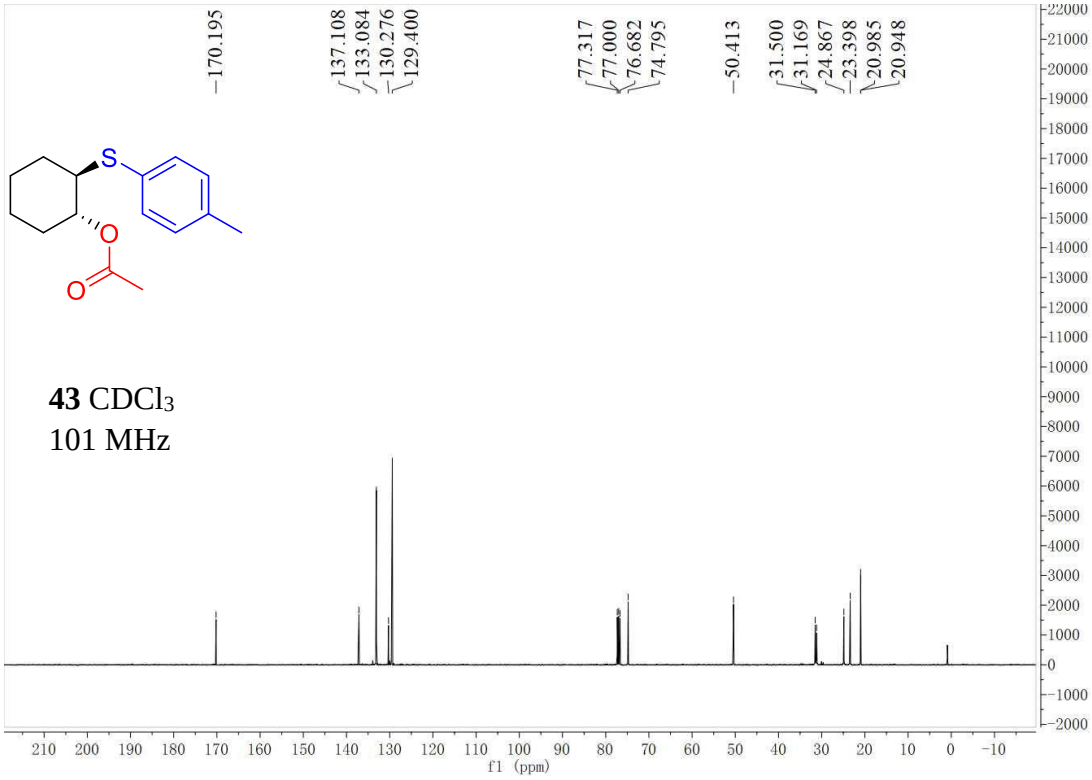

7.673
7.626
7.512
7.461
7.342
7.281
7.260
4.886
4.876
3.916
3.831
3.808
3.710
3.640
3.547
1.241
1.197
Br
N
S
S
O
OEt
OEt
40 CDCl3
400 MHz
1.01
1.03
2.08
1.01
2.04
2.05
3.13
6.24
f1 (ppm)

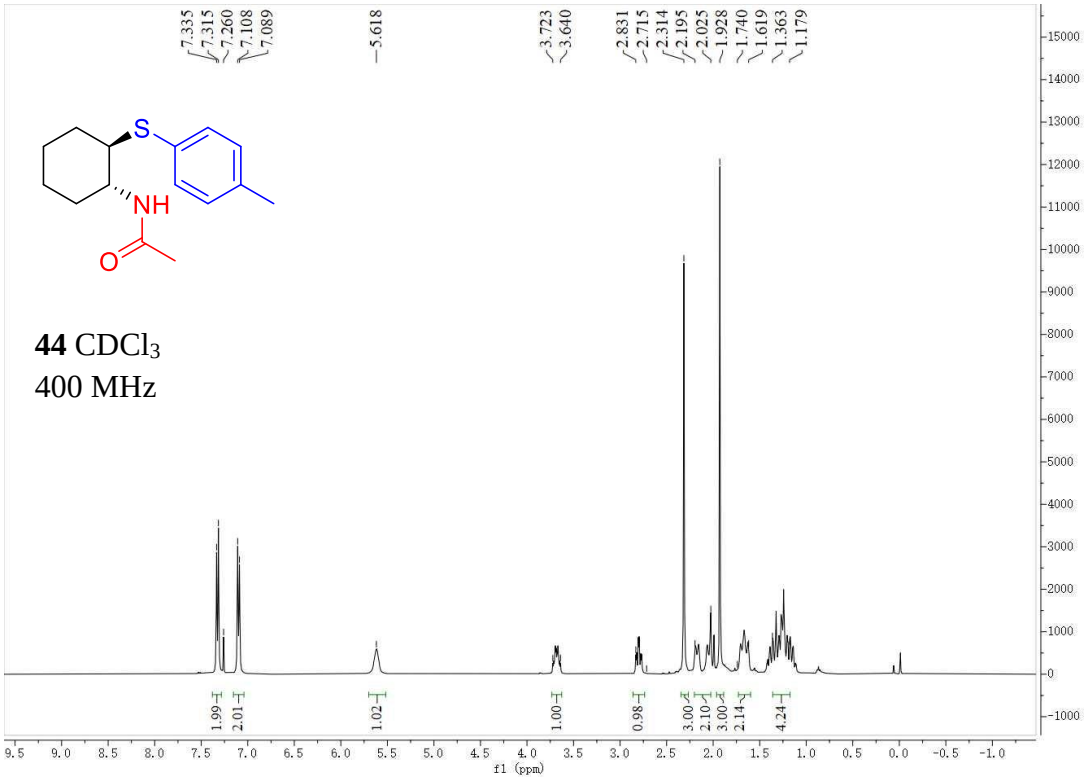

162.791
152.282
141.808
124.960
124.642
119.447
110.256
102.038
77.317
77.000
76.682
64.164
64.114
57.874
31.743
15.192
15.056
Br
N
S
S
O
OEt
OEt
40 CDCl3
101 MHz
f1 (ppm)

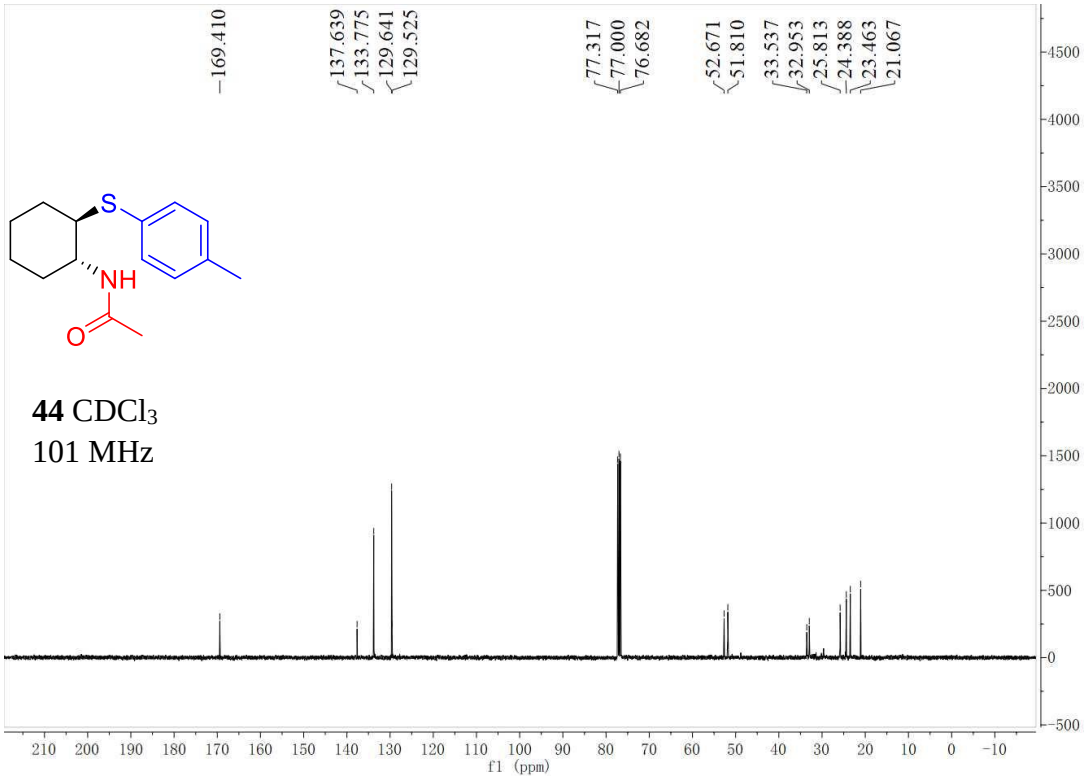

7.714
7.662
7.530
7.488
7.366
7.306
7.260
3.934
3.853
3.534
3.455
1.556
1.496
42a
42b
50% (2 : 1)
42a, 42b CDCl3
400 MHz
f1 (ppm)


162.670
152.394
141.763
125.035
124.764
119.523
110.356
77.318
77.000
76.683
49.234
47.326
46.208
36.876
24.672
18.293
42a
42b
50% (2 : 1)
42a, 42b CDCl3
101 MHz
f1 (ppm)


7.363
7.322
7.260
7.096
7.076
4.779
4.723
3.072
3.012
2.309
2.110
2.022
1.950
1.711
1.626
1.423
1.279
S
O
O
43 CDCl3
400 MHz
2.06
2.02
1.00
1.01
3.13
2.11
3.00
2.09
4.05
f1 (ppm)


170.195
137.108
133.084
130.276
129.400
77.317
77.000
76.682
74.795
50.413
31.500
31.169
24.867
23.398
20.985
20.948
S
O
O
43 CDCl3
101 MHz
f1 (ppm)


7.335
7.315
7.260
7.108
7.089
5.618
3.723
3.640
2.831
2.715
2.314
2.195
2.025
1.928
1.740
1.619
1.363
1.179
S
NH
O
44 CDCl3
400 MHz
1.99
2.01
1.02
1.00
0.98
3.00
2.10
3.00
2.14
4.24
f1 (ppm)


169.410
137.639
133.775
129.641
129.525
77.317
77.000
76.682
52.671
51.810
33.537
32.953
25.813
24.388
23.463
21.067
S
NH
O
44 CDCl3
101 MHz
f1 (ppm)