Supplementary Information for

A new microwave-assisted thionation-heterocyclization process leading to benzo[*c*]thiophene-1(3*H*)-thione and 1*H*-isothiochromene-1-thione derivatives

Salvatore V. Giofrè,*[a] Roberto Romeo,[a] Raffaella Mancuso,*[b] Nicola Cicero,[c] Nicola Corriero,[d] Ugo Chiacchio,[e] Giovanni Romeo[a] and Bartolo Gabriele*[b]

a *Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche ed Ambientali, Università di Messina, Via S.S. Annunziata, 98168 Messina, Italy. E-mail: sgiofre@unime.it*

b *Laboratory of Industrial and Synthetic Organic Chemistry (LISOC), Dipartimento di Chimica e Tecnologie Chimiche, Università della Calabria, Via P. Bucci, 12/C, 87036 Arcavacata di Rende (CS), Italy. E-mail: raffaella.mancuso@unical.it; bartolo.gabriele@unical.it*

c *Dipartimento di Scienze biomediche, odontoiatriche e delle immagini morfologiche e funzionali, Università di Messina, Via Consolare Valeria, 98125 Messina, Italy.*

d *Istituto di Cristallografia, CNR, Via Amendola 122, 70126 Bari, Italy.*

e *Dipartimento di Chimica, Università di Catania, Viale A. Doria, 95100 Catania, Italy*

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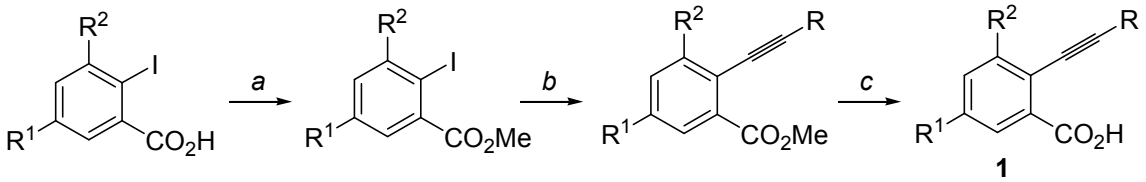
General Information

Solvents and reagents were commercially available. Microwave assisted syntheses were performed using a microwave oven CEM Discover in sealed reaction vessels. The temperature was monitored using a vertically focused IR temperature sensor. In order to have a homogenous system, all the batches were started with a ramp time of 120 seconds, and when the temperature program was completed a cooling period of 10 minutes was included. ESI-HRMS were determined with a Thermo Fischer Scientific LTQ Orbitrap XL. NMR spectra (^{1}H NMR at 500 MHz, ^{13}C NMR at 126 MHz) were recorded with Varian instruments; chemical shifts are reported in ppm relative to $CDCl_3$ (7.26 ppm). Merck silica gel 60-F254 precoated aluminum plates were used for thin-layer chromatographic separations. Flash chromatography was performed on Merck silica gel (200–400 mesh). Preparative separations were carried out by a MPLC Büchi C-601 by using Merck silica gel 0.040–0.063 mm.

Experimental Procedures and Characterization Data for Products

Synthesis of 2-alkynylbenzoic acid derivatives 1

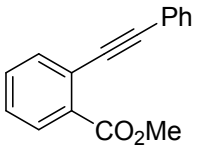
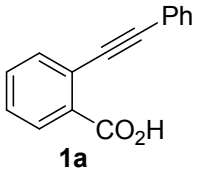
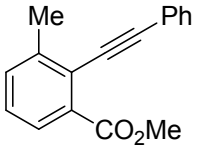
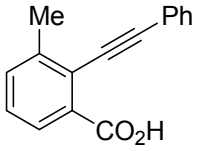
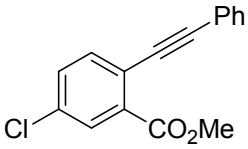
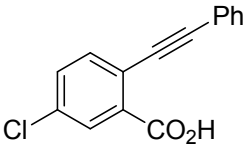
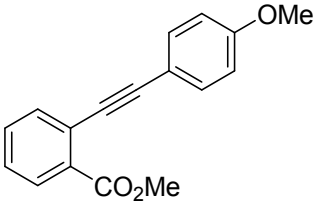
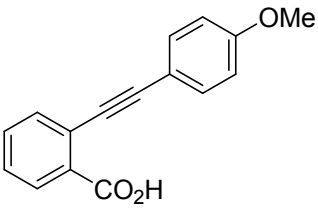
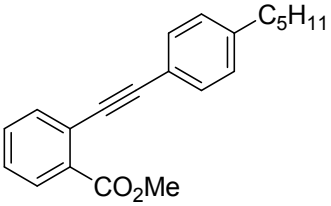
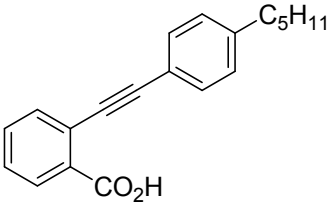
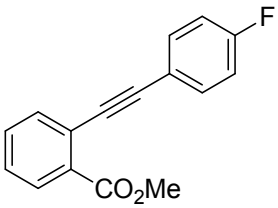
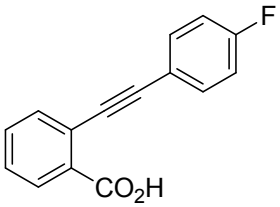
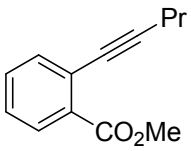
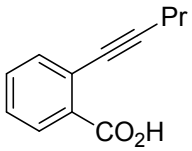
Starting materials **1** were prepared by Sonogashira coupling between methyl 2-iodobenzoates (prepared by esterification of commercially available 2-iodobenzoic acids) followed by hydrolysis, according to Scheme S1.



Scheme S1. Preparation of starting materials **1**. Reagents and conditions: *a*) MeOH, H_2SO_4, 2.5 h, reflux; *b*) 1-alkyne (1.5 eq.), Et_3N (1.5 eq.), $Pd(PPh_3)_4$ (0.12 eq.), CuI (0.2 eq), THF, 4 h, 50 °C; yield 80-90%; c) 2 N NaOH, 2 h, rt.

The intermediate methyl 2-alkynylbenzoates, purified by flash chromatography using cyclohexane/ethyl acetate 95:5 as eluent, were obtained in good yields (80-90%, Table S1). Different experimental conditions were then tested for their hydrolysis, to avoid the formation of the cyclic derivatives originated from *O*-heterocyclization. The best results were obtained by treatment with 2N NaOH at r.t and subsequent acidification. In this way, pure 2-alkynylbenzoic acids **1** were obtained in good to excellent yields, by crystallization from ethyl acetate/hexane (1:4) (82-93%, Table S1).

Table S1. Isolated yields of methyl 2-alkynylbenzoates and 2-alkynylbenzoic acids **1**

Entry	R	Methyl 2-alkynylbenzoate	Yield (%)	2-Alkynylbenzoic acid **1**	Yield (%)
1	Ph		90	 **1a**	93
2	Ph		89	 **1b**	90
3	Ph		90	 **1c**	92
4	4-MeO-C_6H_4		90	 **1d**	90
5	4-pentyl-C_6H_4		89	 **1e**	85
6	4-FC_6H_4		85	 **1f**	82
7	Propyl		80	 **1g**	86

Sonogashira coupling of methyl 2-iodobenzoates with 1-alkynes to give methyl 2-alkynylbenzoates

A stirred suspension of the methyl 2-iodobenzoate (3.80 mmol), $Pd(PPh_3)_4$ (0.46 mmol), CuI (0.76 mmol), the 1-alkyne (5.70 mmol), and Et_3N (5.70 mmol) in anhydrous and deoxygenated THF (15.0 mL) was heated under nitrogen at 50 °C for 4 h. The volatiles were evaporated, and the residue was purified by flash chromatography (cyclohexane/ethyl acetate, 95:5) to give methyl 2-alkynylbenzoates, purified by flash chromatography using cyclohexane/ethyl acetate 95:5 as eluent, in 80-90% yields (Table S1).

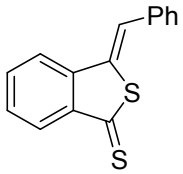
General procedure for hydrolysis of methyl 2-alkynylbenzoates to 2-alkynylbenzoic acids 1

To a solution of the methyl 2-alkynylbenzoate (1.0 mmol, 1.0 equiv.), dissolved in a mixture of methanol (20 mL) and ethanol (10 mL), was added 2N NaOH (7 mL). After stirring for 2 h at rt, TLC analysis showed that all the starting material was converted, and the solution was concentrated under reduced pressure. The residue was dissolved in water (30 mL) and washed with diethyl ether (2 x 20 mL). After acidification to pH = 4-5, the aqueous layer was extracted with ethyl acetate (3 x 30 mL). The combined organic layers were dried (Na_2SO_4) and concentrated under reduced pressure to give 2-alkynylbenzoic acids **1** in high yields (82-93%, Table S1).

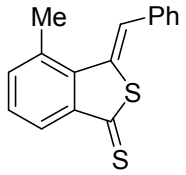
General procedure for the tandem thionation-heterocyclization of 2-alkynylbenzoic acids 1 to benzo[*c*]thiophene-1(3*H*)-thiones 2 and 1*H*-isothiochromene-1-thiones 3

A sealed tube (10 mL) was charged with a solution of **1** (0.45 mmol) and the Lawesson's reagent (0.182 g, 0.45 mmol) in CH_2Cl_2 (3 mL). The mixture was irradiated under microwave conditions at 300 W and 100 °C for 1 h. After cooling, the reaction mixture was concentrated under reduced pressure and the product purified by MPLC (medium pressure liquid chromatography) using 9:1 cyclohexane/CH_2Cl_2 as eluent.

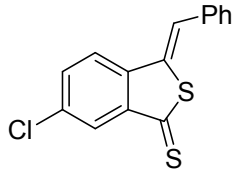
Characterization data for products 2 and 3



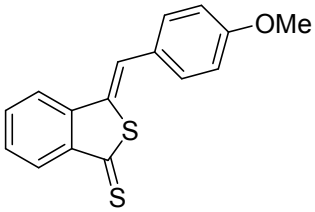
*(Z)-3-Benzylidenebenzo[c]thiophene-1(3H)-thione (**2a**)* Red crystals (Yield: 103 mg, 90%) mp 121-123 °C; R_f 0.51 cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.11 (d, *J* = 7.9, 1H), 7.94 (d, *J* = 8.0, 1H), 7.71 (t, *J* = 7.7, 1H), 7.62 (d, *J*=7.7, 2H), 7.53 (s, 1H), 7.50 (d, *J* = 7.8, 1H), 7.46 (t, *J* = 7.6, 2H), 7.38 (t, *J* = 7.4, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 219.54, 143.47, 141.87, 137.06, 135.49, 132.81, 130.05, 129.37, 129.28, 129.12, 128.85, 124.16, 123.09, 120.61. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{15}H_{11}S_2$: 255.0302; found 255.0299.



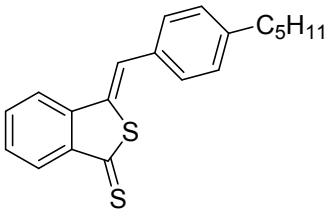
*(Z)-3-Benzylidene-4-methylbenzo[c]thiophen-1(3H)-thione (**2b**)* Red crystals (Yield:103 mg, 91%) mp 107-109 °C; R_f 0.47 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.06 (d, *J* = 7.9, 1H), 7.69 (s, 1H), 7.58 (d, *J* = 7.7, 2H), 7.52 (d, *J* = 7.3, 1H), 7.45 (t, *J* = 7.6, 2H), 7.41 – 7.33 (m, 2H), 2.84 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 220.00, 143.38, 140.00, 139.89, 136.57, 136.50, 134.45, 129.91, 129.09, 128.96, 128.56, 128.12, 122.81, 23.19. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{16}H_{13}S_2$: 269.0459; found: 269.0456.



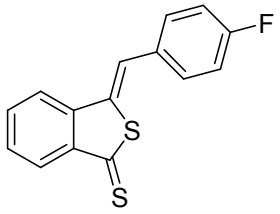
*(Z)-3-Benzylidene-6-chlorobenzo[c]thiophene-1(3H)-thione (**2c**)* Red crystals (Yield: 96 mg, 85%) mp 186-188 °C; R_f 0.60 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.05 (d, *J* = 1.6, 1H), 7.87 (d, *J* = 8.5, 2H), 7.65 (dd, *J* = 8.5, 1.6, 2H), 7.60 (d, *J* = 7.8, 3H), 7.49 (s, 2H), 7.48 – 7.44 (m, 3H), 7.39 (t, *J* = 7.2, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 217.36, 142.72, 141.63, 136.17, 136.04, 135.25, 132.66, 130.05, 129.37, 123.77, 123.71, 121.71. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{15}H_{10}ClS_2$: 288.9912; found: 288.9903.



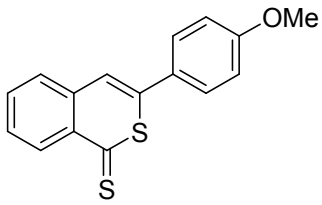
*(Z)-3-(4-Methoxybenzylidene)benzo[c]thiophene-1(3H)-thione (**2d**)* Amorphous red solid (Yield: 6 mg, 5%) mp 135-137 °C; R_f 0.23 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.11 (d, *J*=7.9, 1H), 7.92 (d, *J*=8.0, 1H), 7.69 (ddd, *J*=8.1, 7.2, 1.2, 1H), 7.58 (d, *J*=8.8, 2H), 7.51 – 7.46 (m, 2H), 6.99 (d, *J*=8.8, 2H), 3.87 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 219.08, 160.50, 143.83, 1.41.77, 134.54, 132.69, 131.83, 128.89, 128.22, 124.19, 123.16, 120.42, 114.85, 55.56. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{16}H_{13}OS_2$: 285.0408; found: 285.0404.



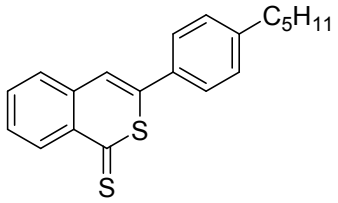
*(Z)-3-(4-Pentylbenzylidene)benzo[c]thiophene-1(3H)-thione (**2e**)* Red oil (Yield: 78 mg, 70%); R_f 0.61 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.11 (ddd, *J* = 7.9, 1.0, 0.6, 1H), 7.93 (d, *J* = 8.1, 1H), 7.69 (ddd, *J* = 8.1, 7.2, 1.2, 1H), 7.54 (d, *J* = 8.1, 2H), 7.51 (s, 1H), 7.50 – 7.47 (m, 1H), 7.27 (d, *J* = 8.3, 2H), 2.72 – 2.58 (m, 3H), 1.70 – 1.60 (m, 3H), 1.38 – 1.32 (m, 4H), 0.91 (t, *J*=7.0, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 219.41, 144.68, 143.66, 141.83, 135.93, 132.90, 132.73, 130.15, 129.43, 129.12, 124.14, 123.35, 120.54, 35.98, 31.64, 31.01, 22.68, 14.17. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{20}H_{21}S_2$: 325.1085; found: 325.1081.



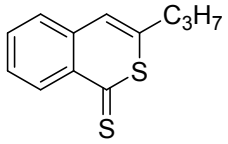
*(Z)-3-(4-Fluorobenzylidene)benzo[c]thiophene-1(3H)-thione (**2f**)* Orange solid (Yield: 100 mg, 88%) mp 147-149 °C; R_f 0.43 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.10 (d, *J* = 7.9, 1H), 7.91 (d, *J* = 8.1, 2H), 7.70 (t, *J* = 7.8, 1H), 7.59 (dd, *J* = 8.5, 5.4, 2H), 7.54 – 7.49 (m, 1H), 7.47 (s, 1H), 7.15 (t, *J* = 8.6, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 219.15, 163.94, 162.96 (d, *J* = 258.7), 143.38, 141.83, 136.78 (d, *J* = 2.5), 135.32, 132.86, 131.83 (d, *J* = 8.5), 129.41, 124.17 (d, *J* = 6.2), 121.73 (d, *J* = 8.2), 120.53, 116.55 (d, *J* = 21.2). HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{15}H_{10}FS_2$: 273.0208; found: 273.0205.



*3-(4-Methoxyphenyl)-1H-isothiochromene-1-thione (**3d**)* Amorphous coral solid (Yield: 101 mg, 90%) mp 128-130 °C; R_f 0.17 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.90 – 8.85 (m, 1H), 7.76 – 7.71 (m, 1H), 7.63 – 7.60 (m, 1H), 7.58 (d, *J* = 8.5, 2H), 7.56 – 7.53 (m, 1H), 7.52 (s, 1H), 7.00 (d, *J* = 8.9, 2H), 3.87 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 212.03, 161.16, 144.72, 135.36, 134.33, 133.93, 131.13, 129.37, 128.03, 121.85, 114.83, 55.58. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{16}H_{13}OS_2$: 285.0408; found: 285.0401.



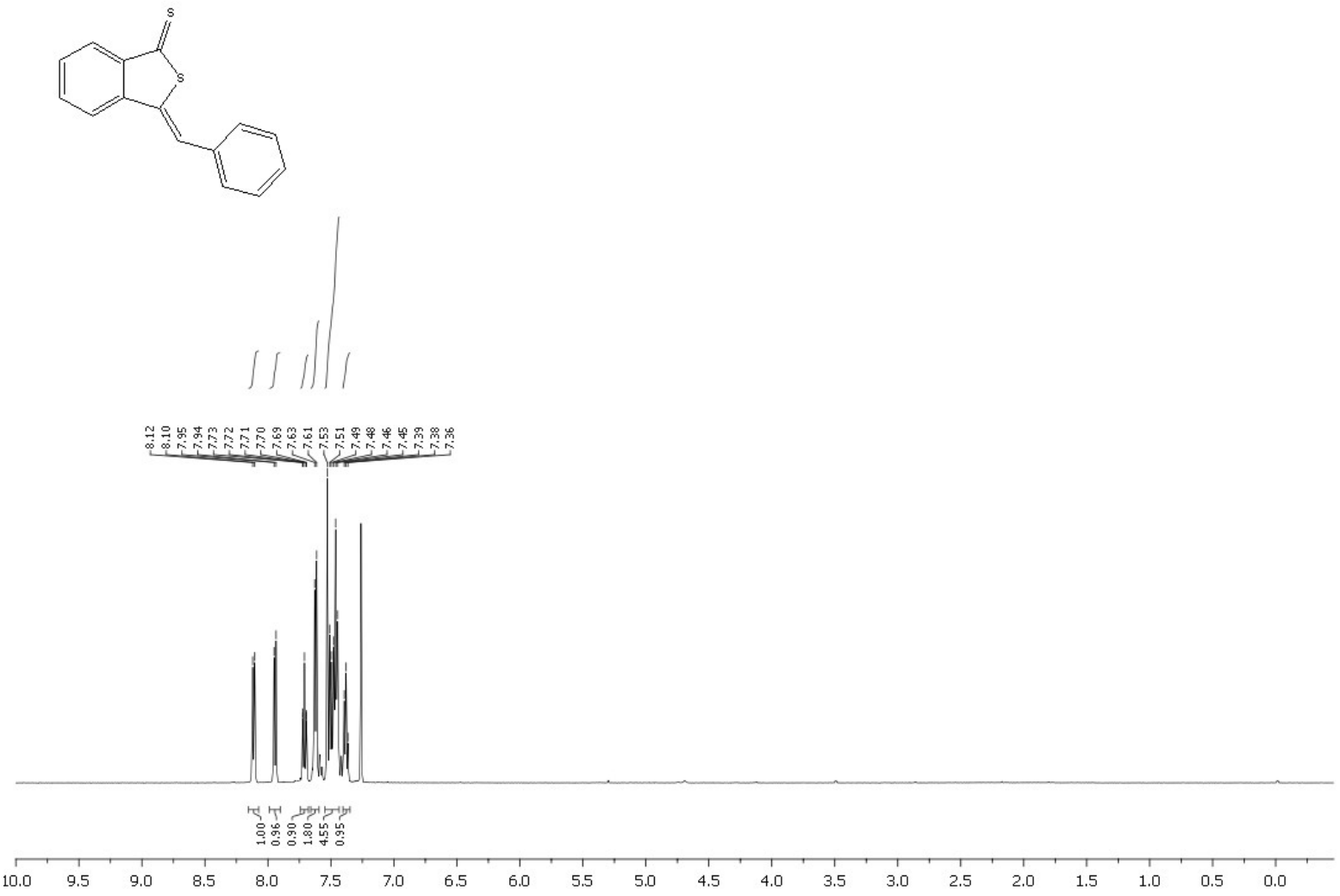
*3-(4-Pentylphenyl)-1H-isothiochromene-1-thione (**3e**)* Red oil (Yield: 22 mg, 20%); R_f 0.45 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.90 – 8.86 (m, 1H), 7.74 (ddd, *J* = 8.2, 7.1, 1.3, 1H), 7.65 – 7.61 (m, 1H), 7.60 – 7.55 (m, 4H), 7.54 (s, 1H), 7.29 (d, *J* = 8.3, 2H), 2.68 – 2.63 (m, 2H), 1.70 – 1.61 (m, 2H), 1.39 – 1.31 (m, 4H), 0.91 (t, *J* = 7.0, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 212.10, 145.36, 145.00, 135.48, 134.31, 133.76, 132.96, 131.22, 129.51, 128.03, 126.56, 122.44, 35.84, 31.61, 31.10, 22.67, 14.16. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{20}H_{21}S_2$: 325.1085; found: 325.1079.



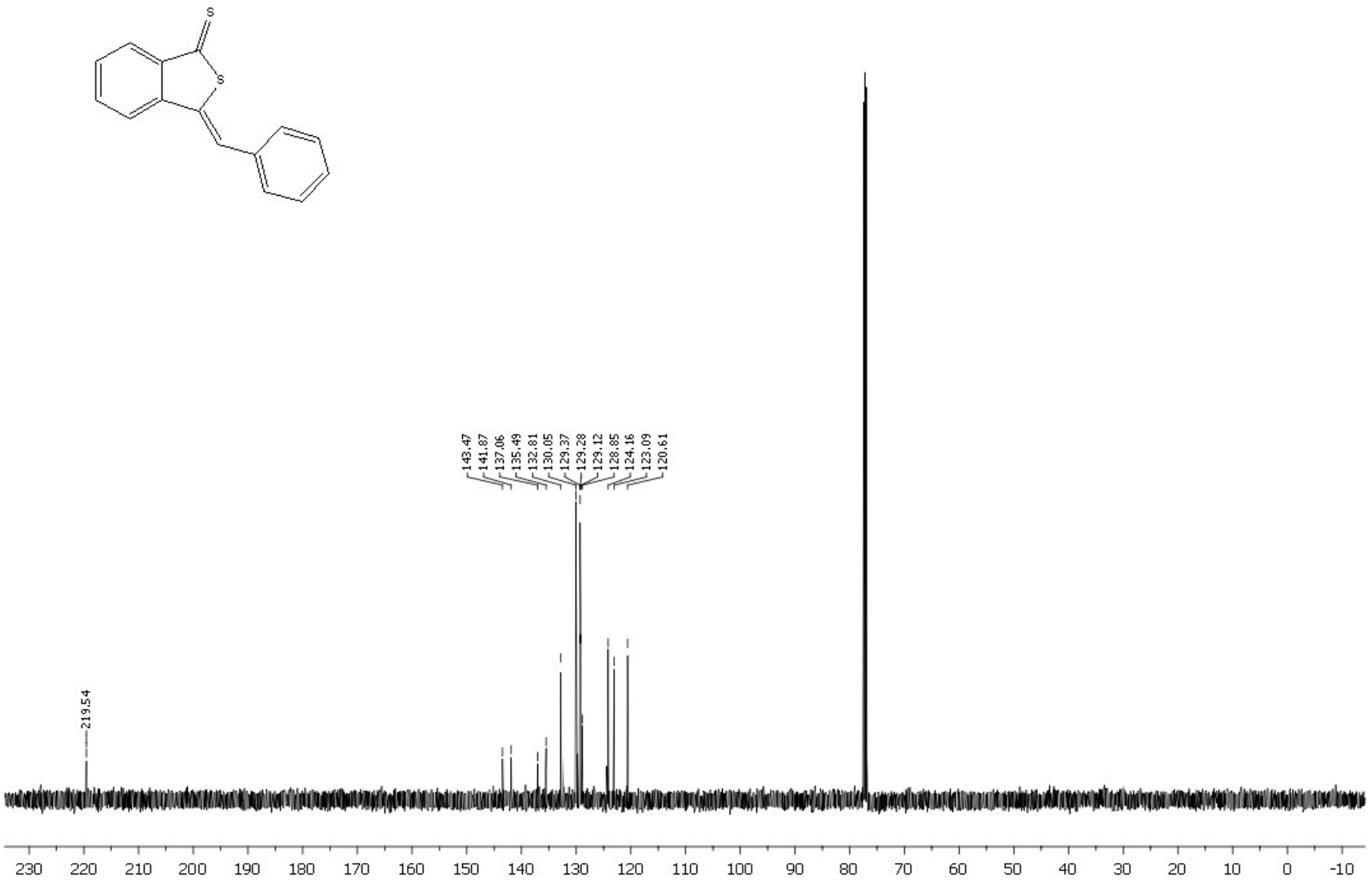
*3-Propyl-1H-isothiochromene-1-thione (**3g**)* Red brown oil (Yield: 100 mg, 86%); R_f 0.37 Cyclohexane/CH_2Cl_2 (8:2). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.85 (d, *J* = 8.3, 1H), 7.71 (t, *J* = 7.4, 1H), 7.57 – 7.44 (m, 2H), 7.19 (s, 1H), 2.59 (t, *J* = 7.5, 2H), 1.77 – 1.69 (m, 2H), 1.00 (t, *J* = 7.3, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 212.53, 147.11, 135.51, 134.21, 133.53, 130.46, 129.09, 127.96, 123.23, 37.59, 23.23, 13.57. HRMS-ESI: *m/z* $[M+H]^+$ calcd for $C_{12}H_{13}S_2$: 221.0459; found: 221.0456.

Copy of ^{1}H and ^{13}C NMR spectra

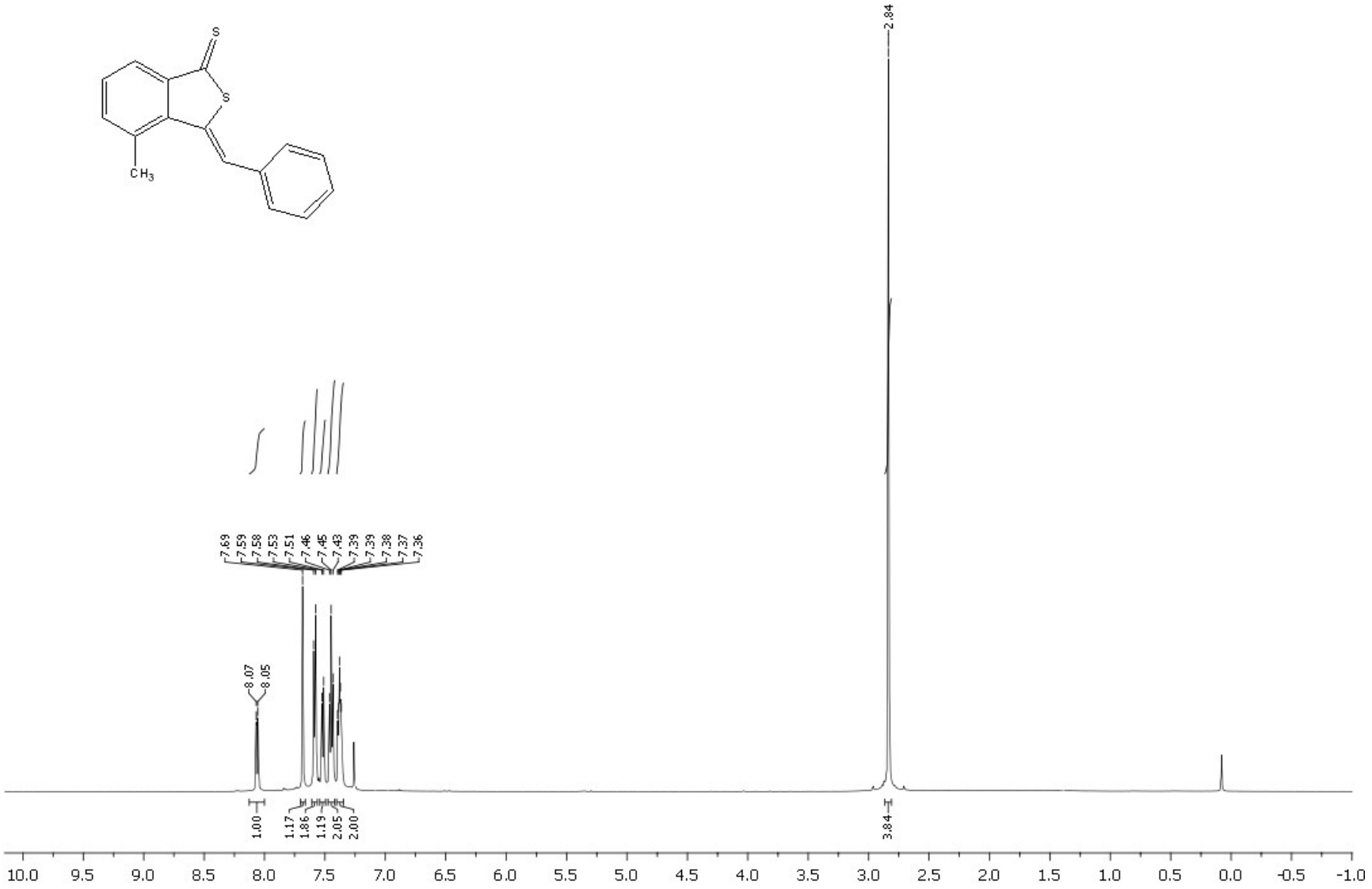
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2a**



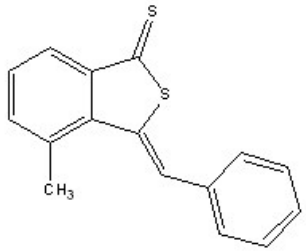
^{13}C NMR (126 MHz, $CDCl_3$) of compound **2a**

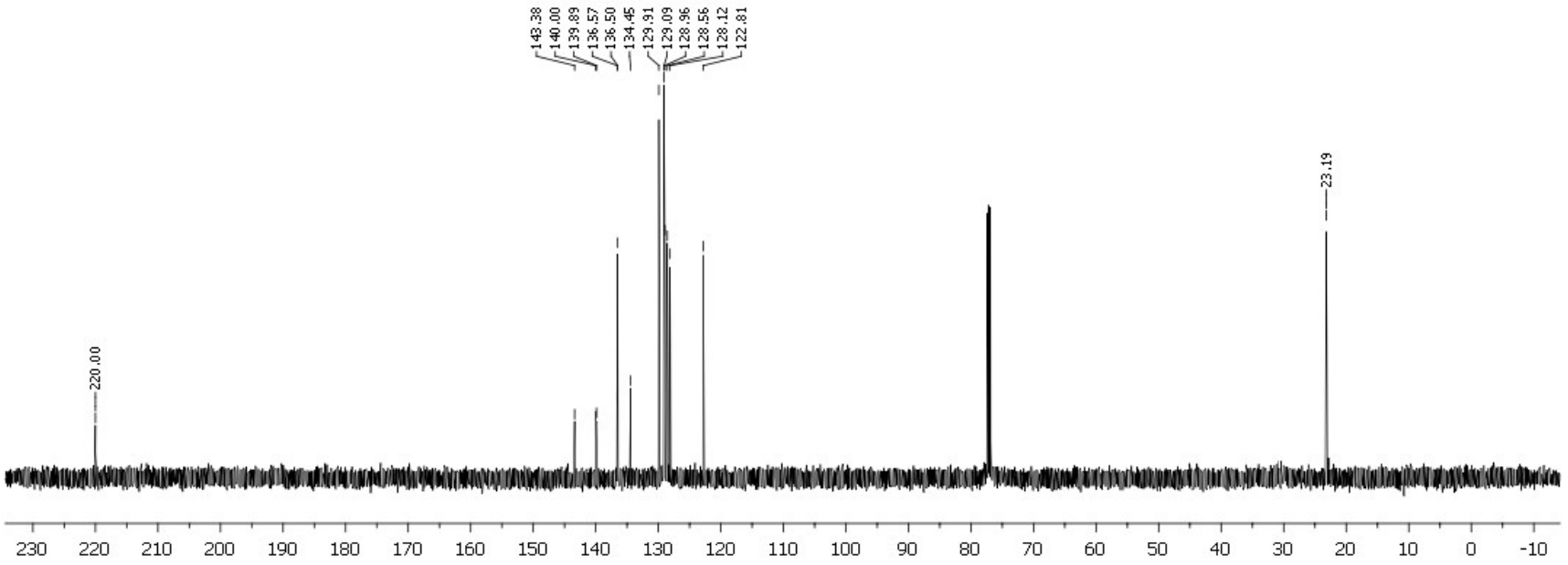


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2b**

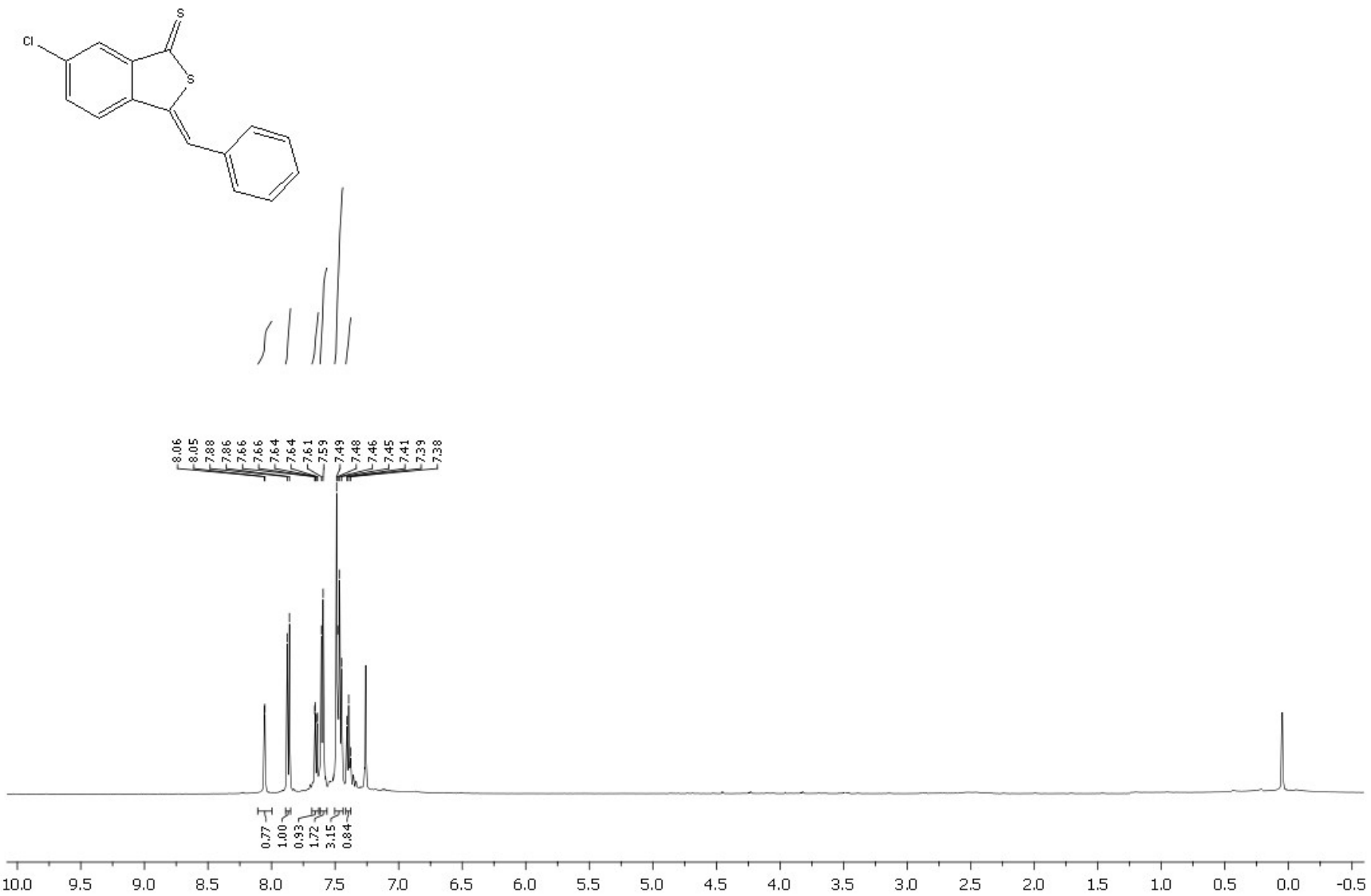


^{13}C NMR (126 MHz, $CDCl_3$) of compound **2b**

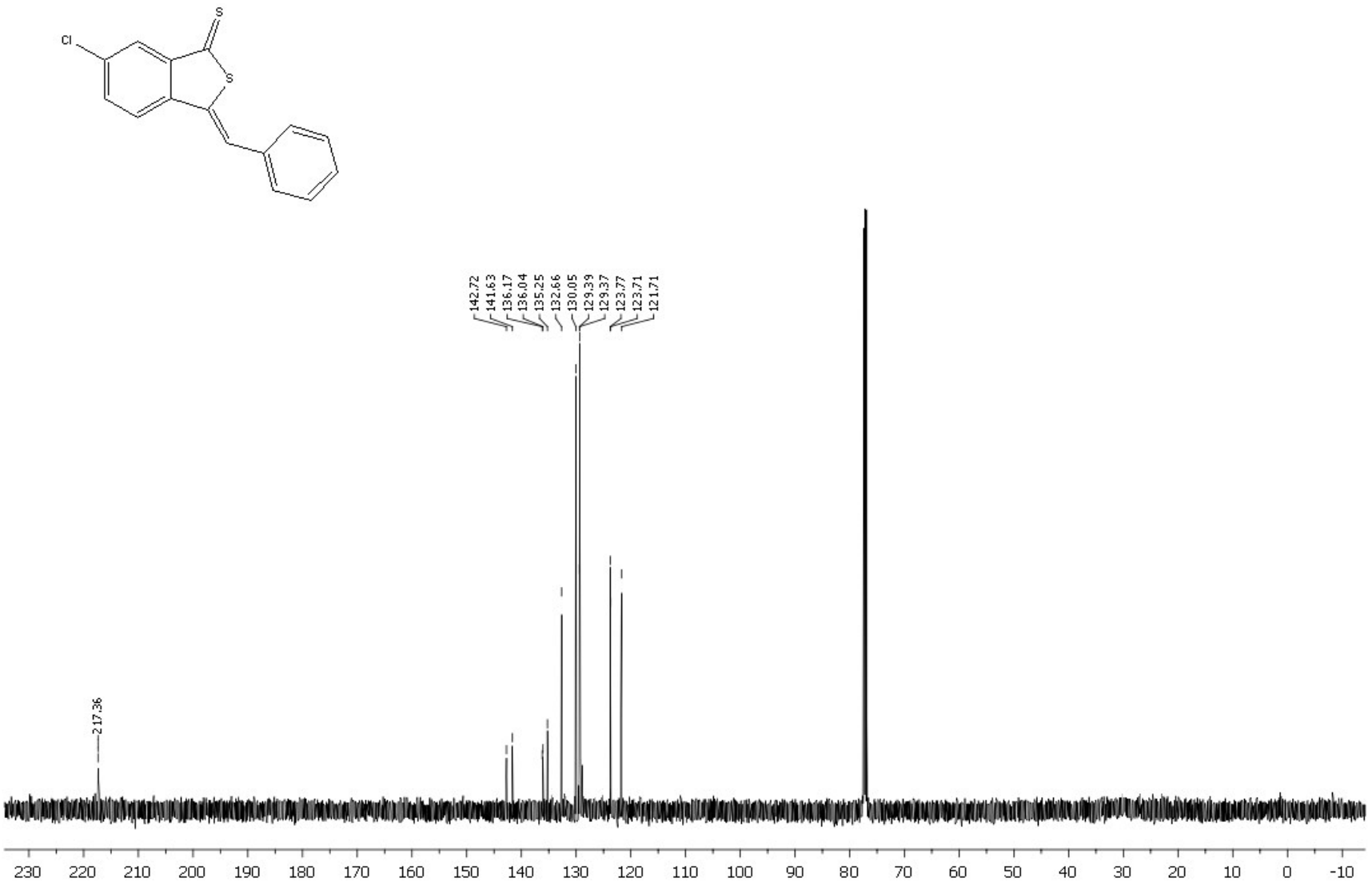




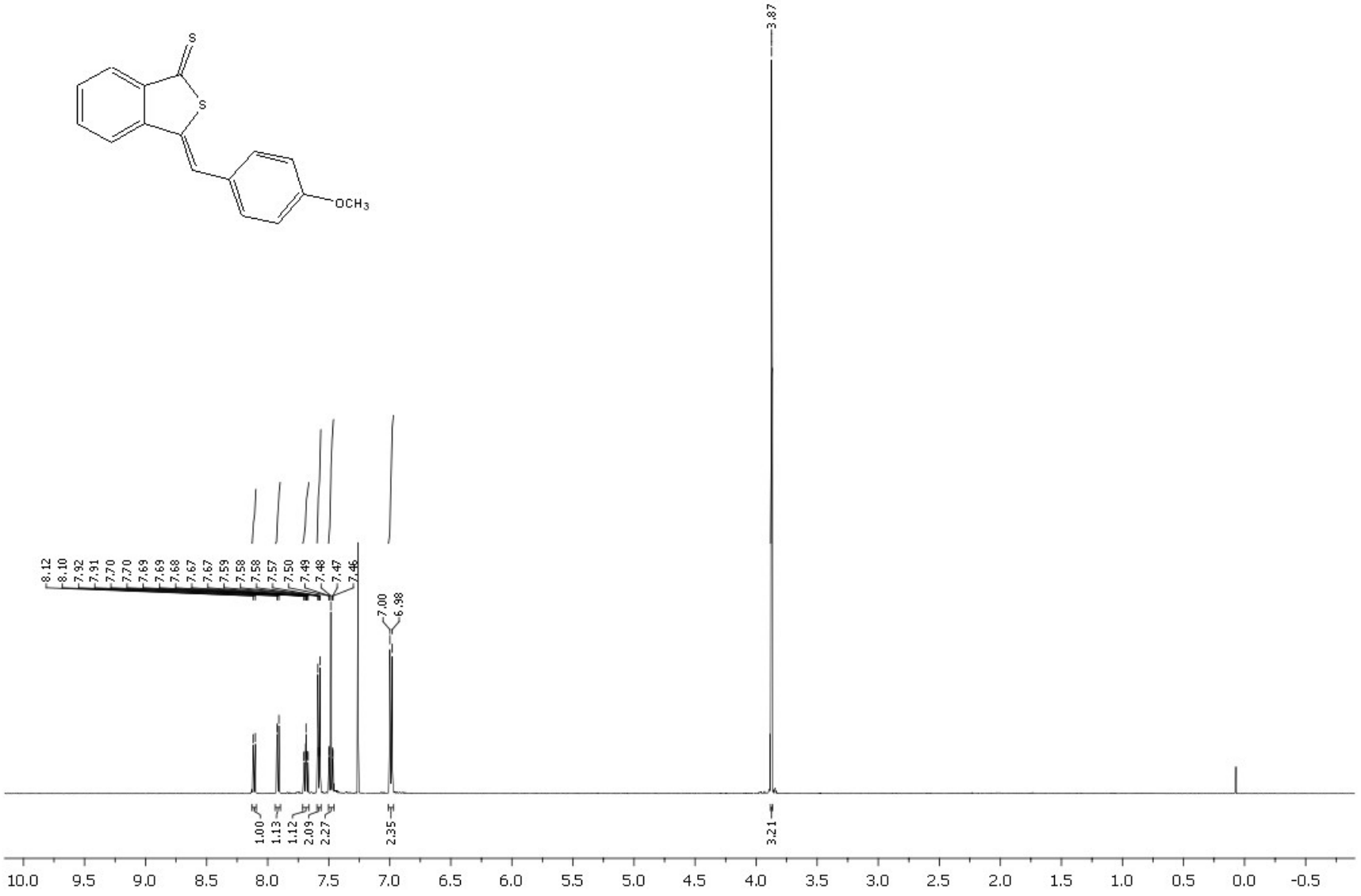
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2c**



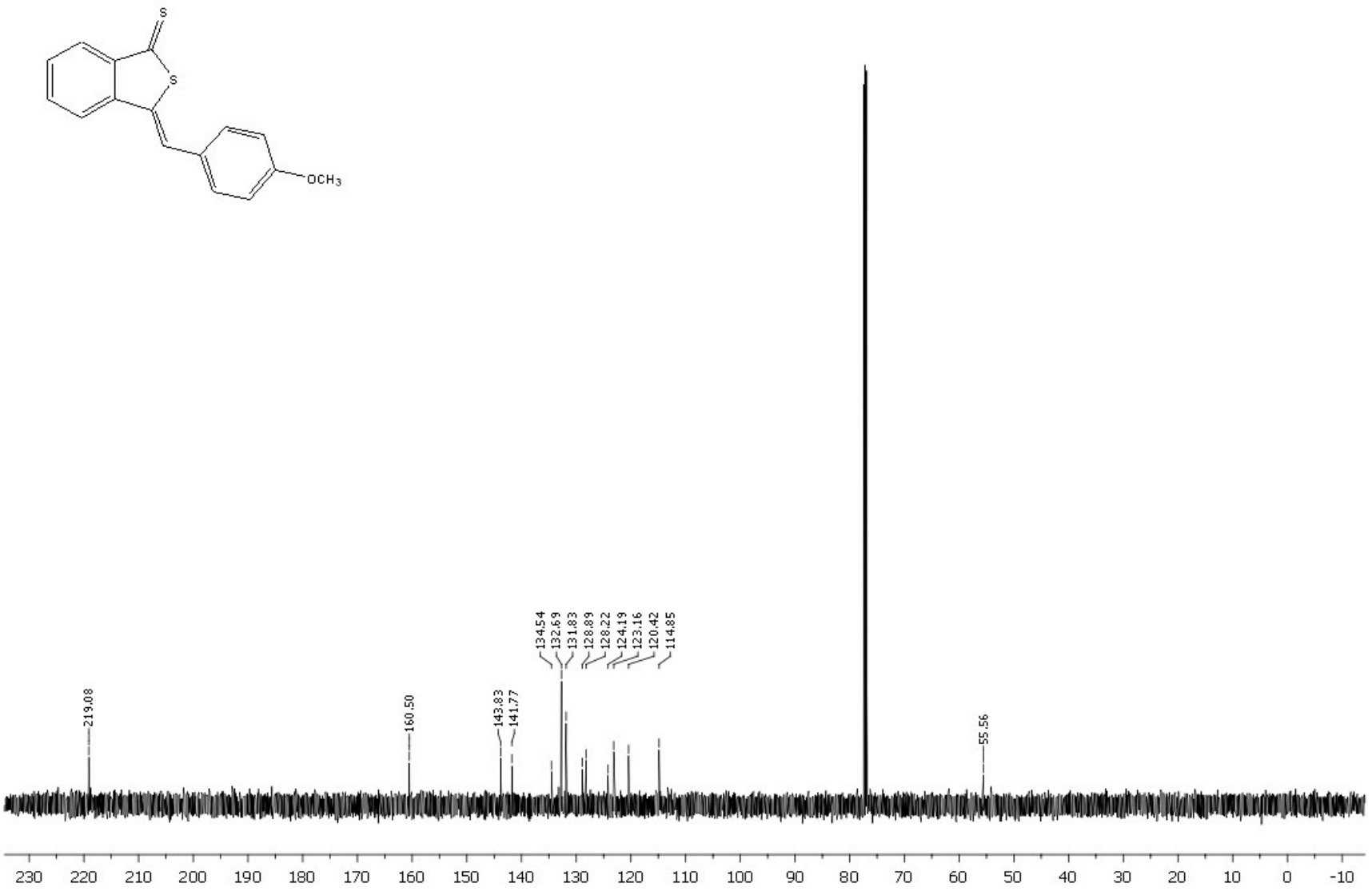
^{13}C NMR (126 MHz, $CDCl_3$) of compound **2c**



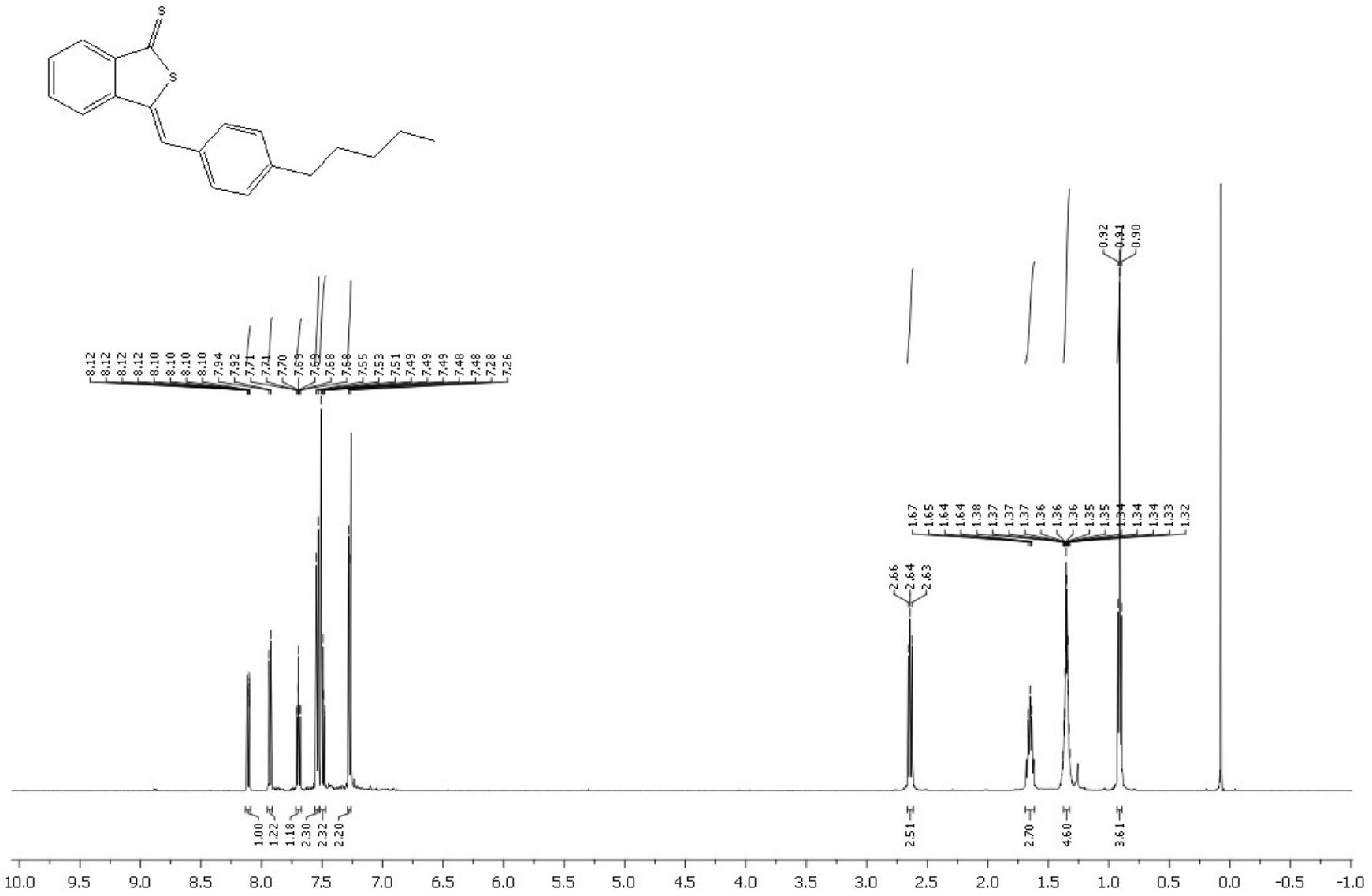
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2d**



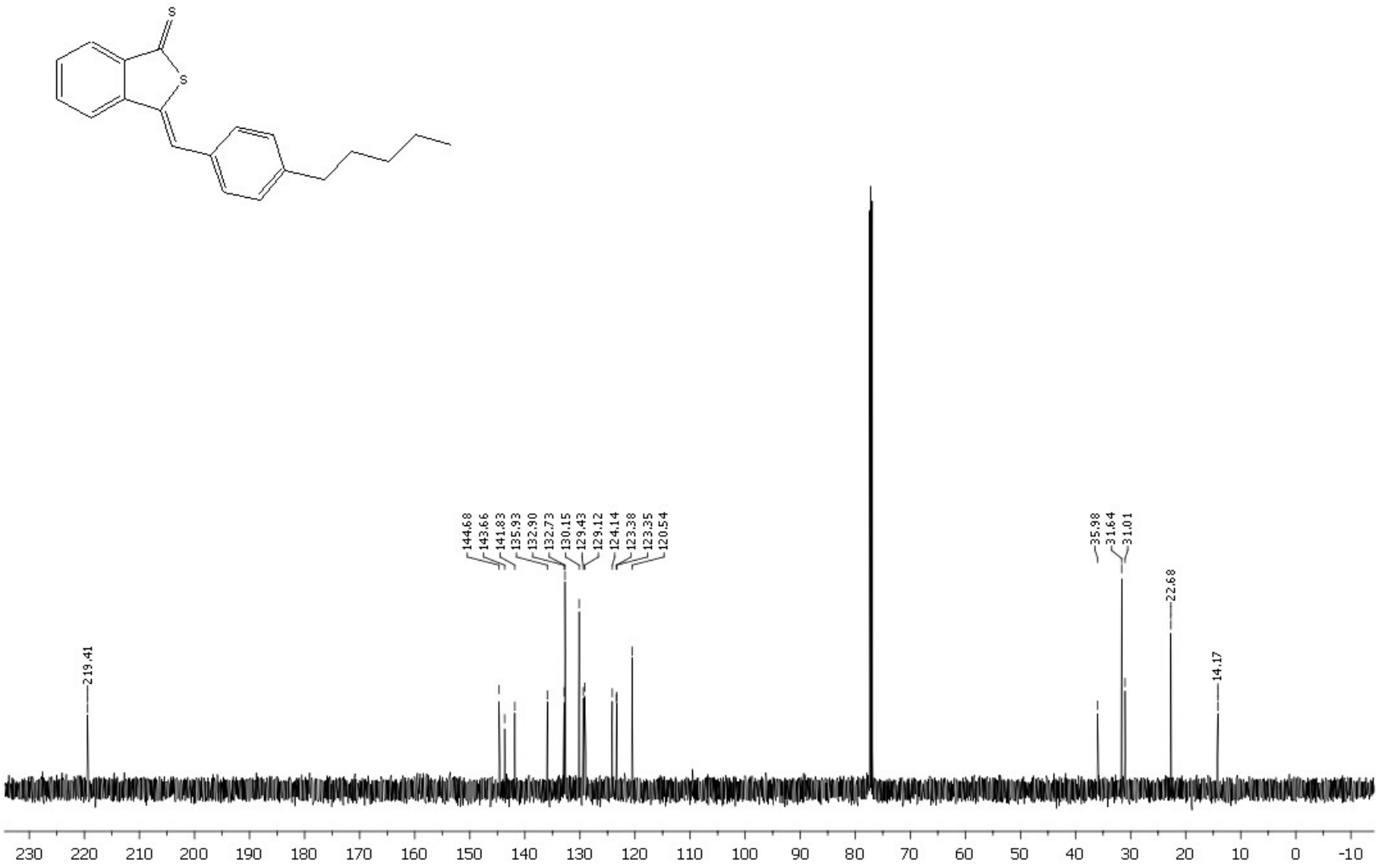
^{13}C NMR (126 MHz, $CDCl_3$) of compound **2d**



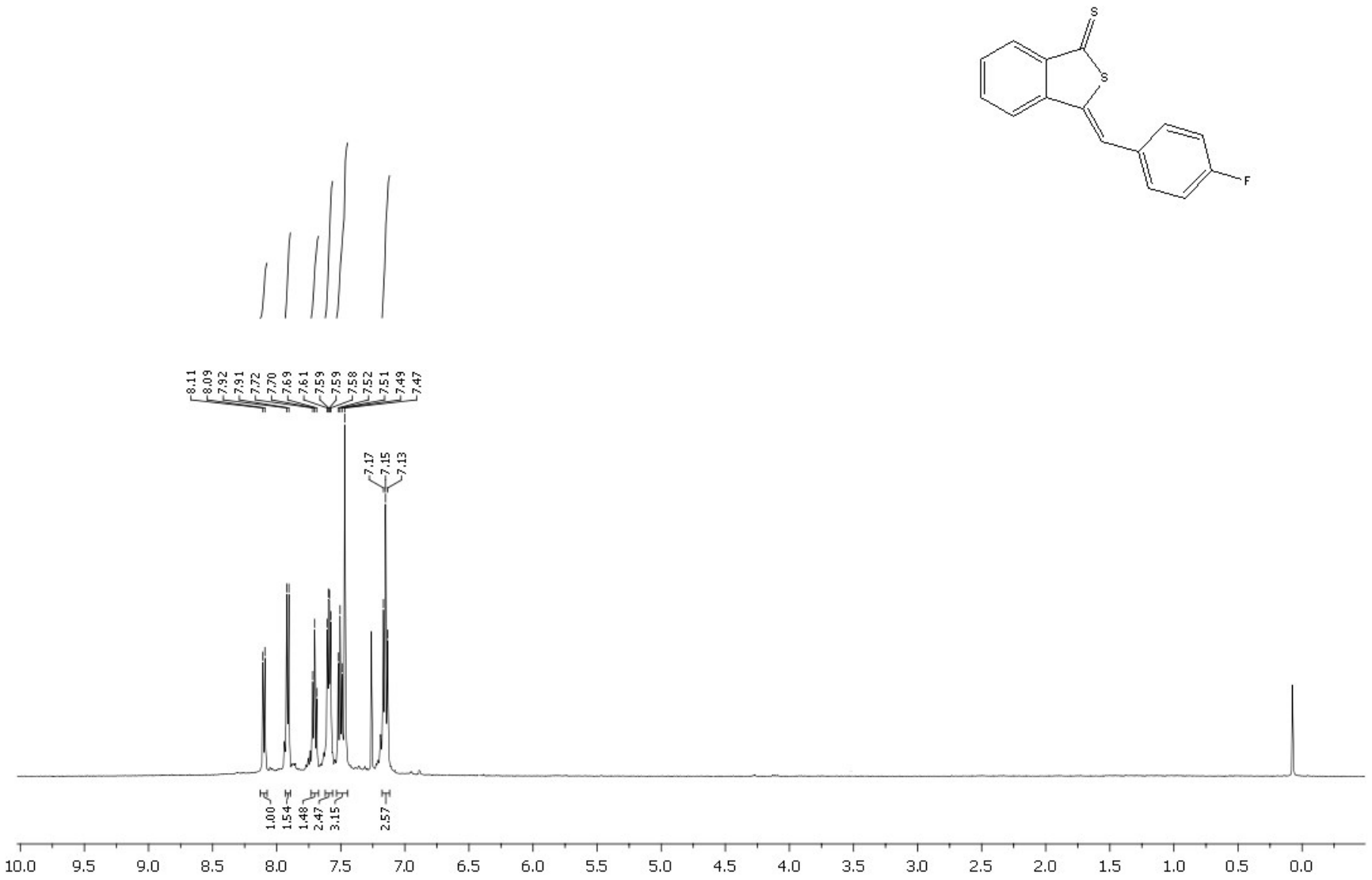
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2e**



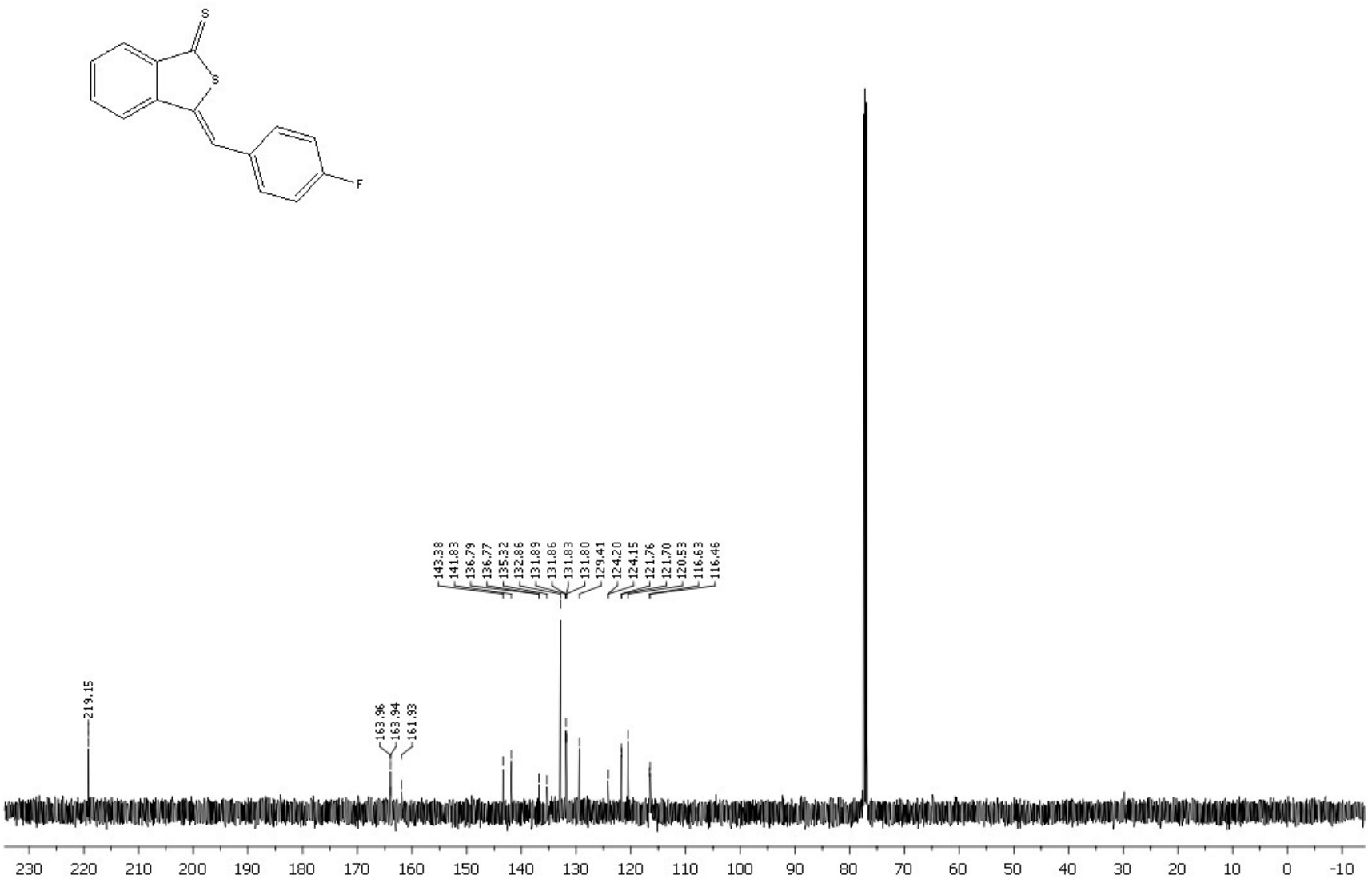
^{13}C NMR (126 MHz, $CDCl_3$) of compound **2e**



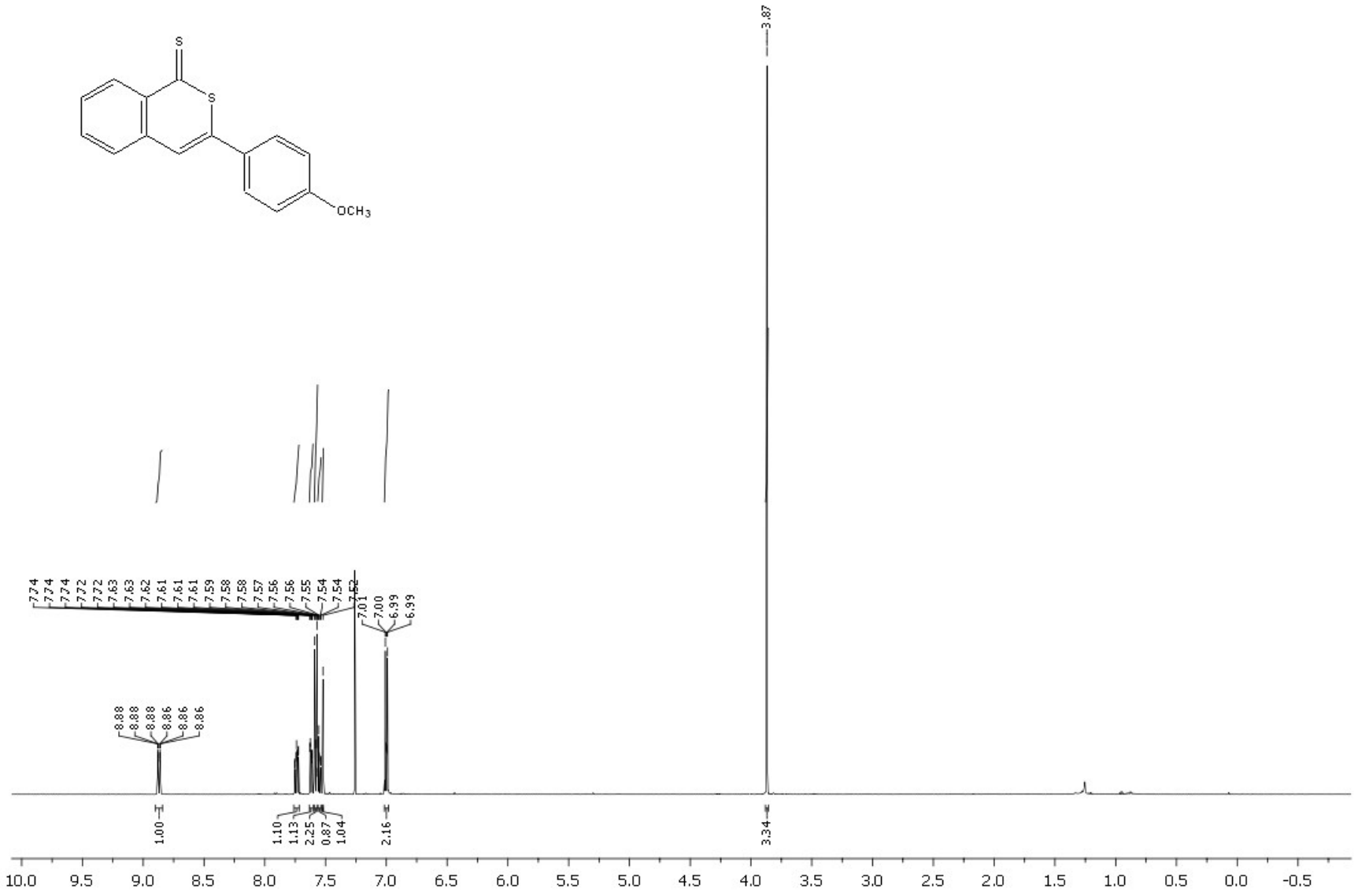
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2f**



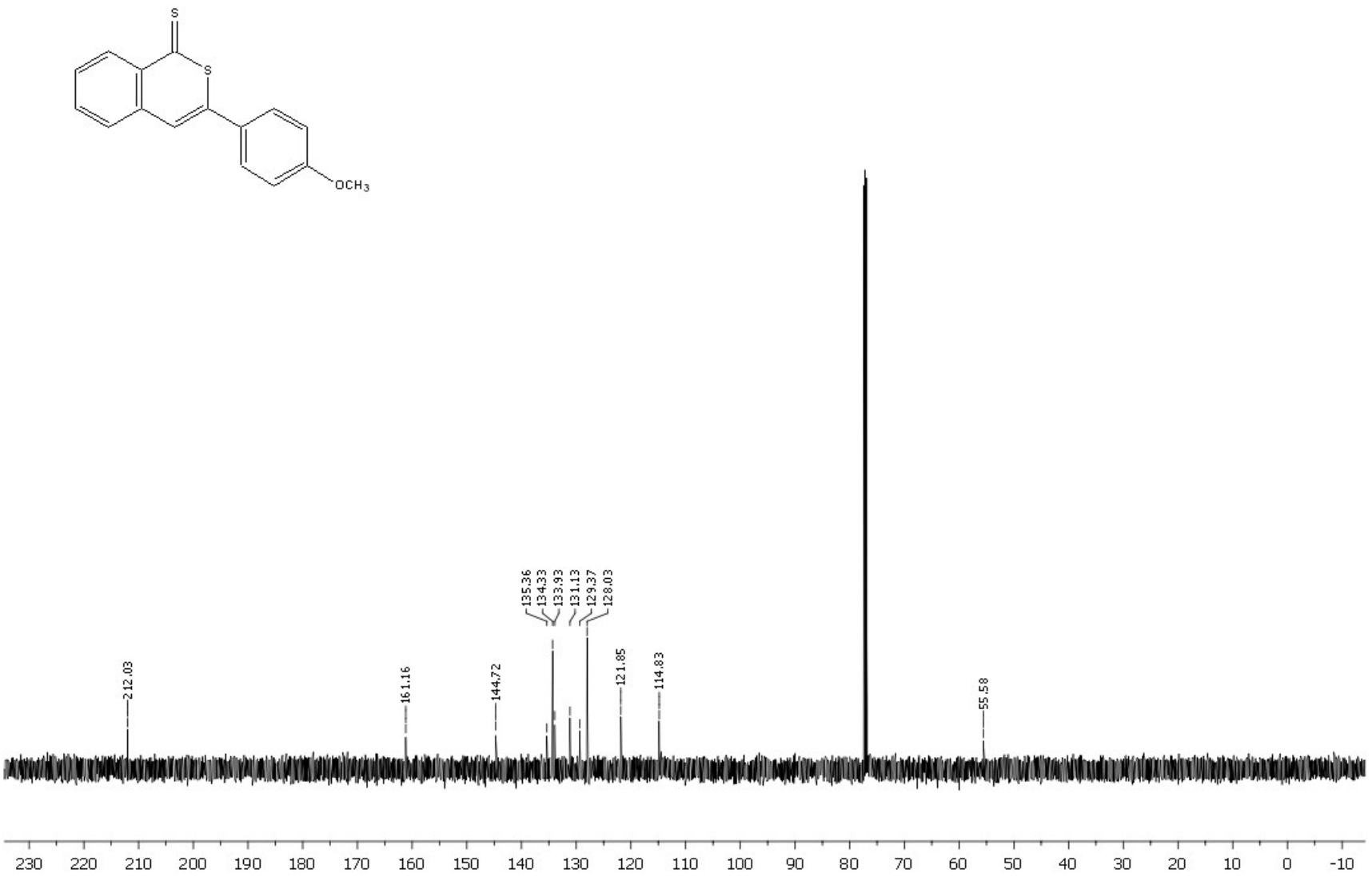
^{13}C NMR (126 MHz, $CDCl_3$) of compound **2f**



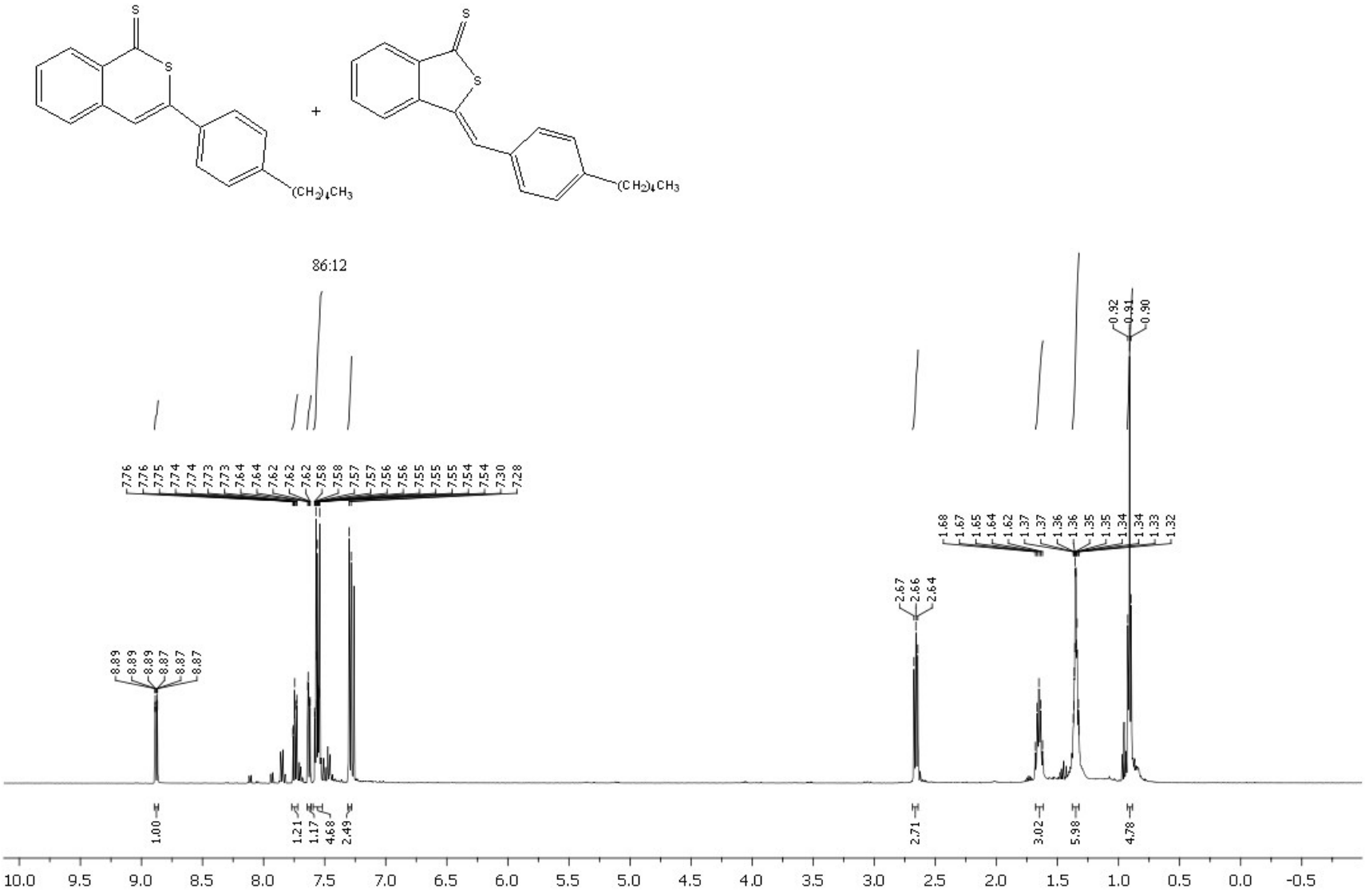
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3d**



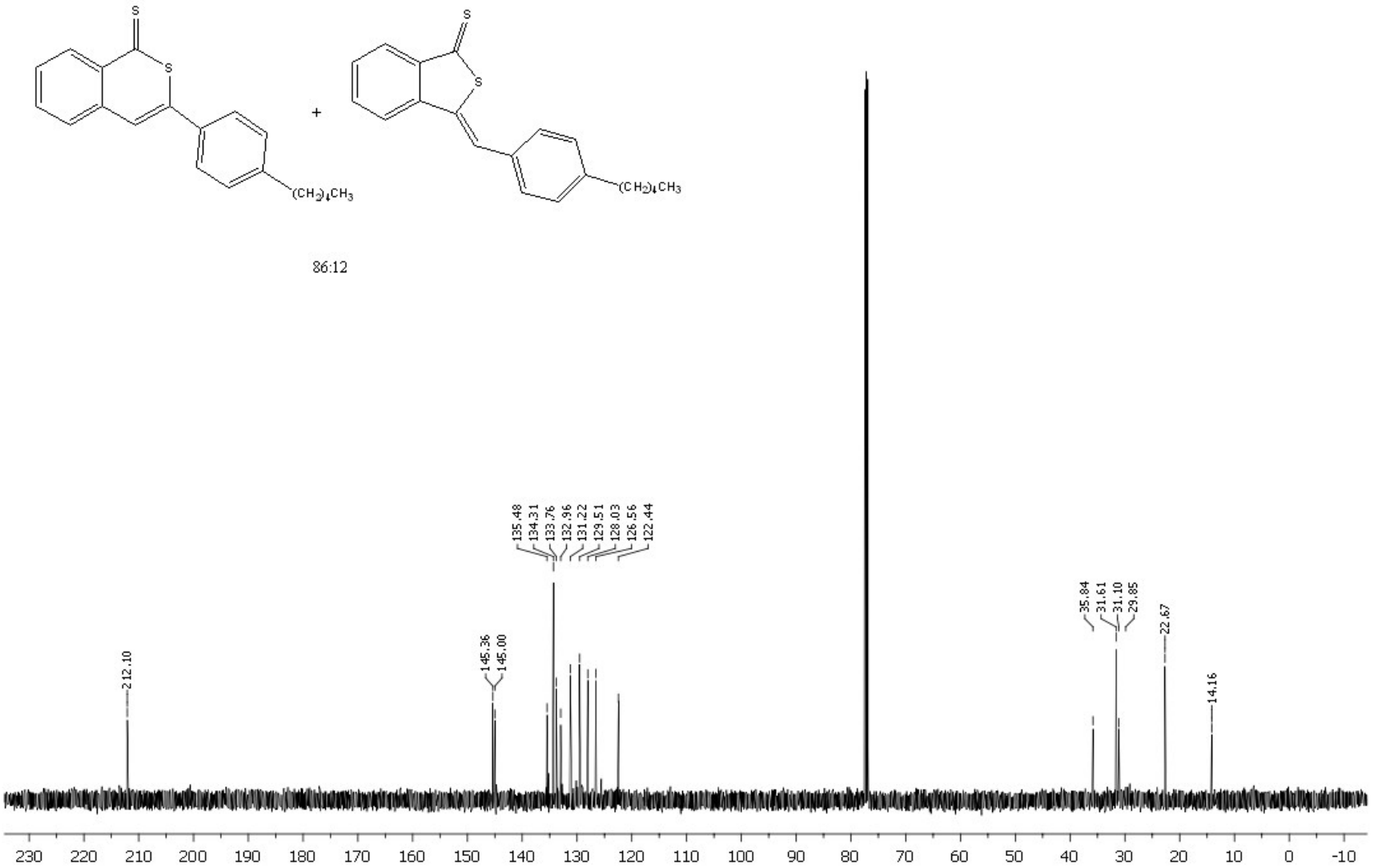
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3d**



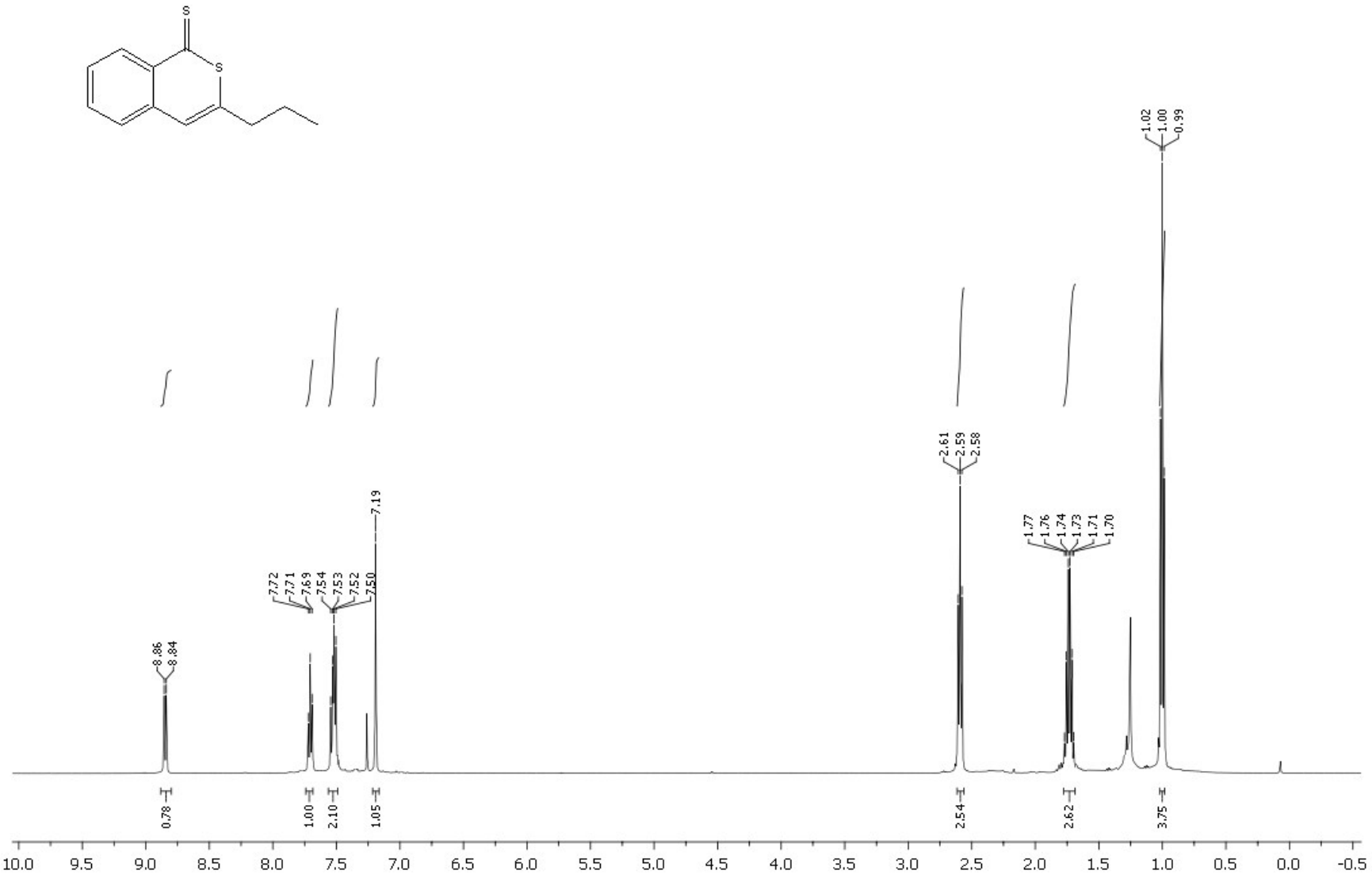
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3e**



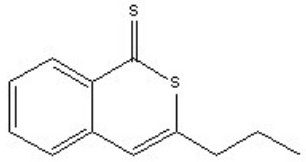
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3e**

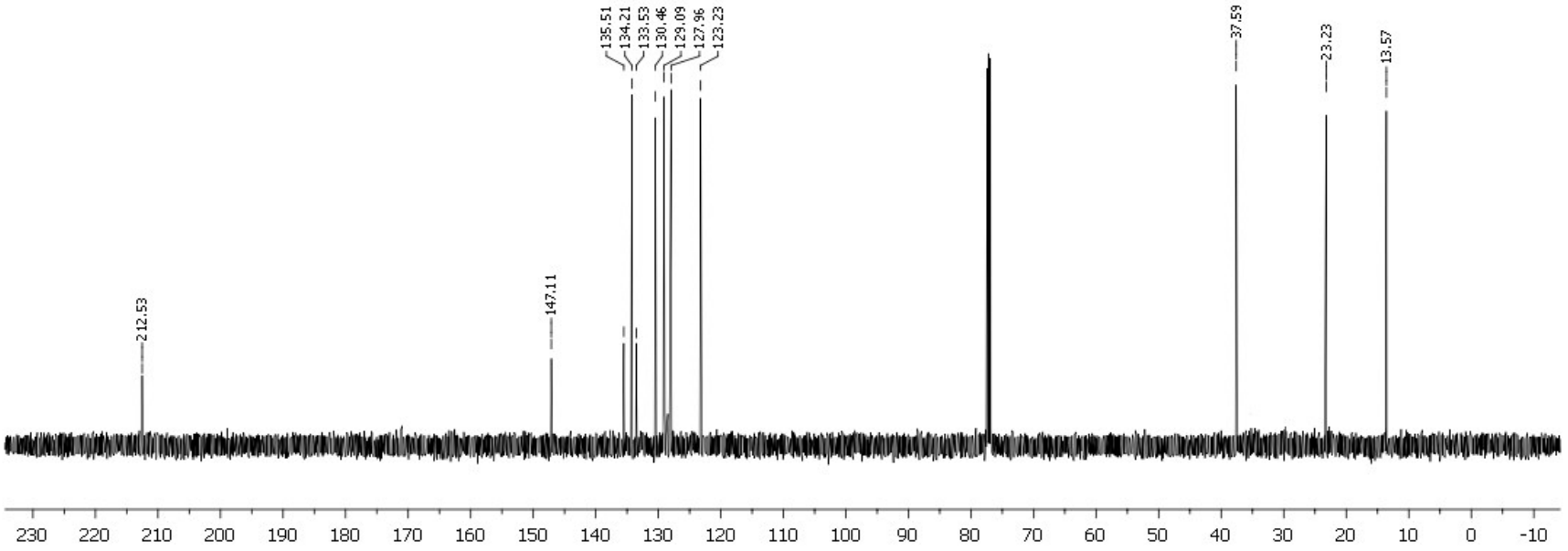


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3g**



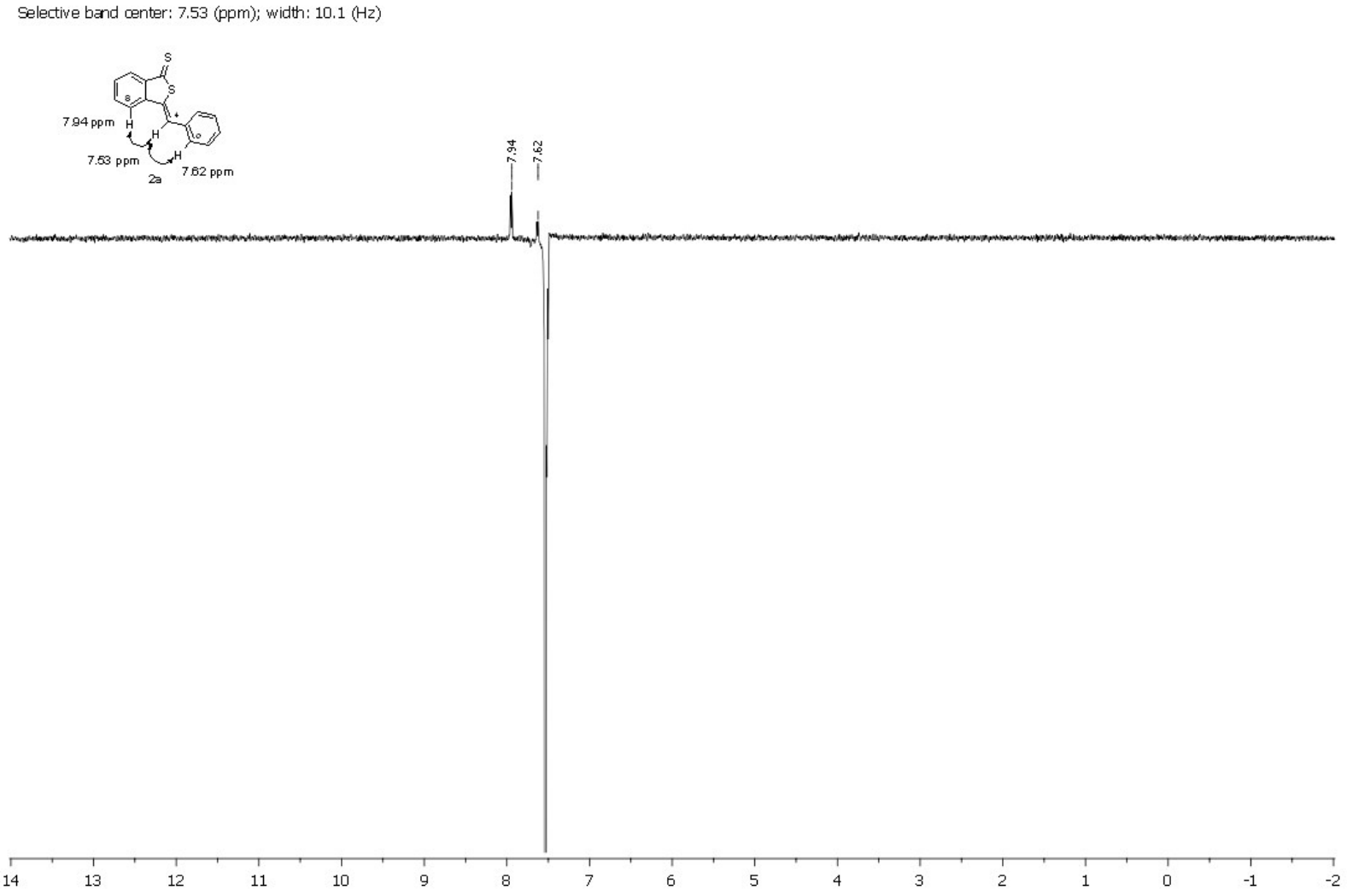
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3g**



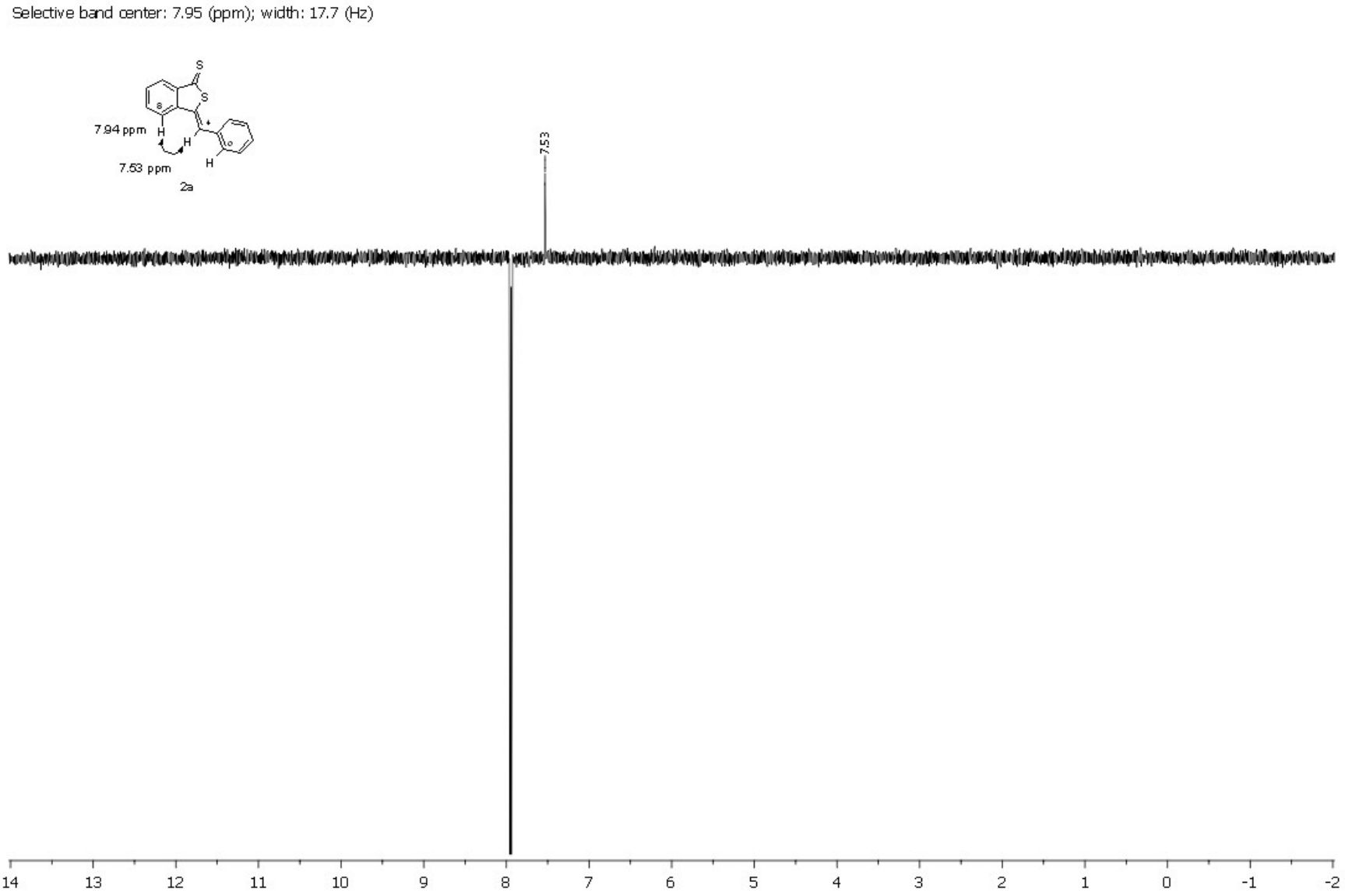


1D Selective NOESY spectra for products 2a, 2d, and 3d

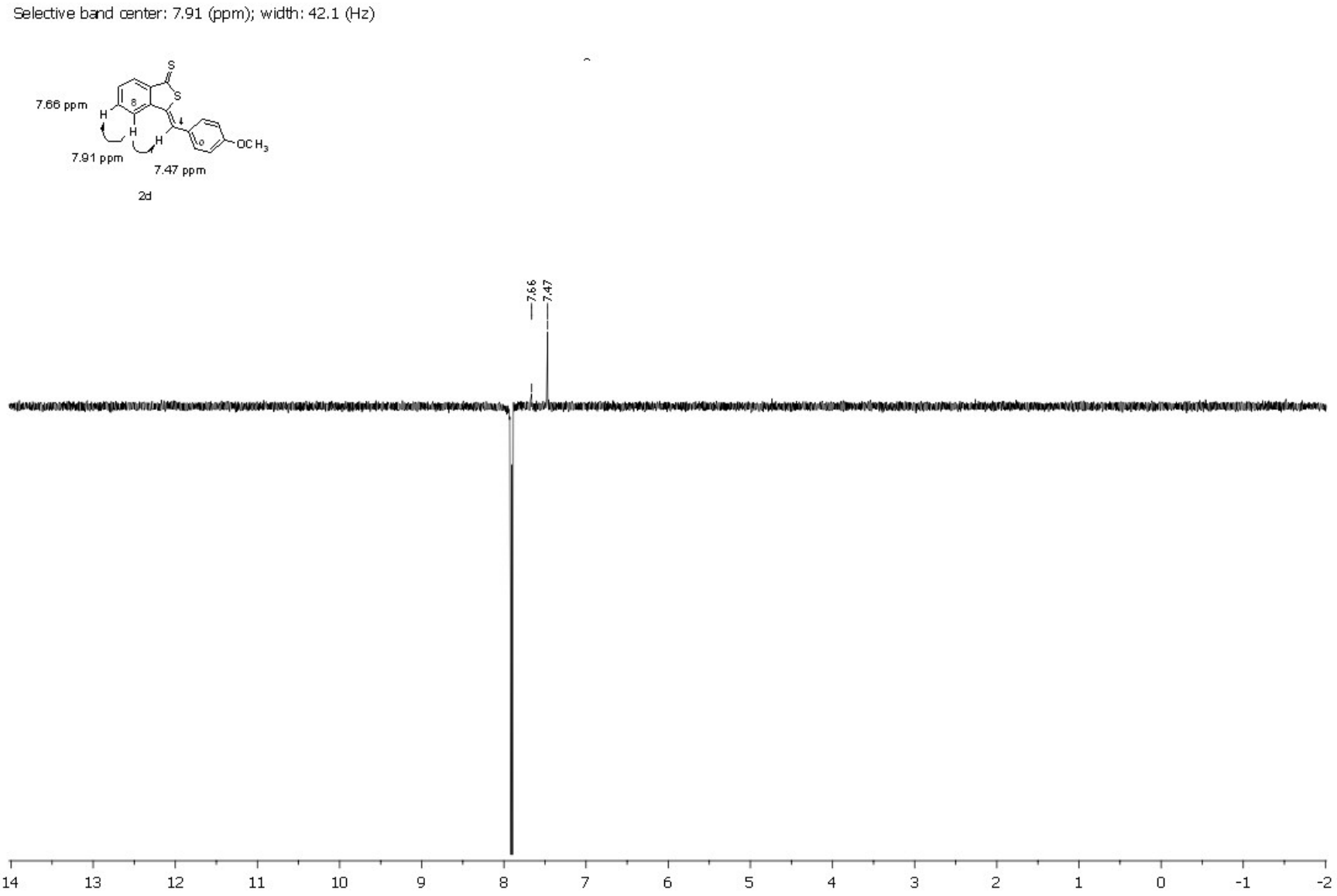
1D selective NOESY (500 ms) of compound **2a**



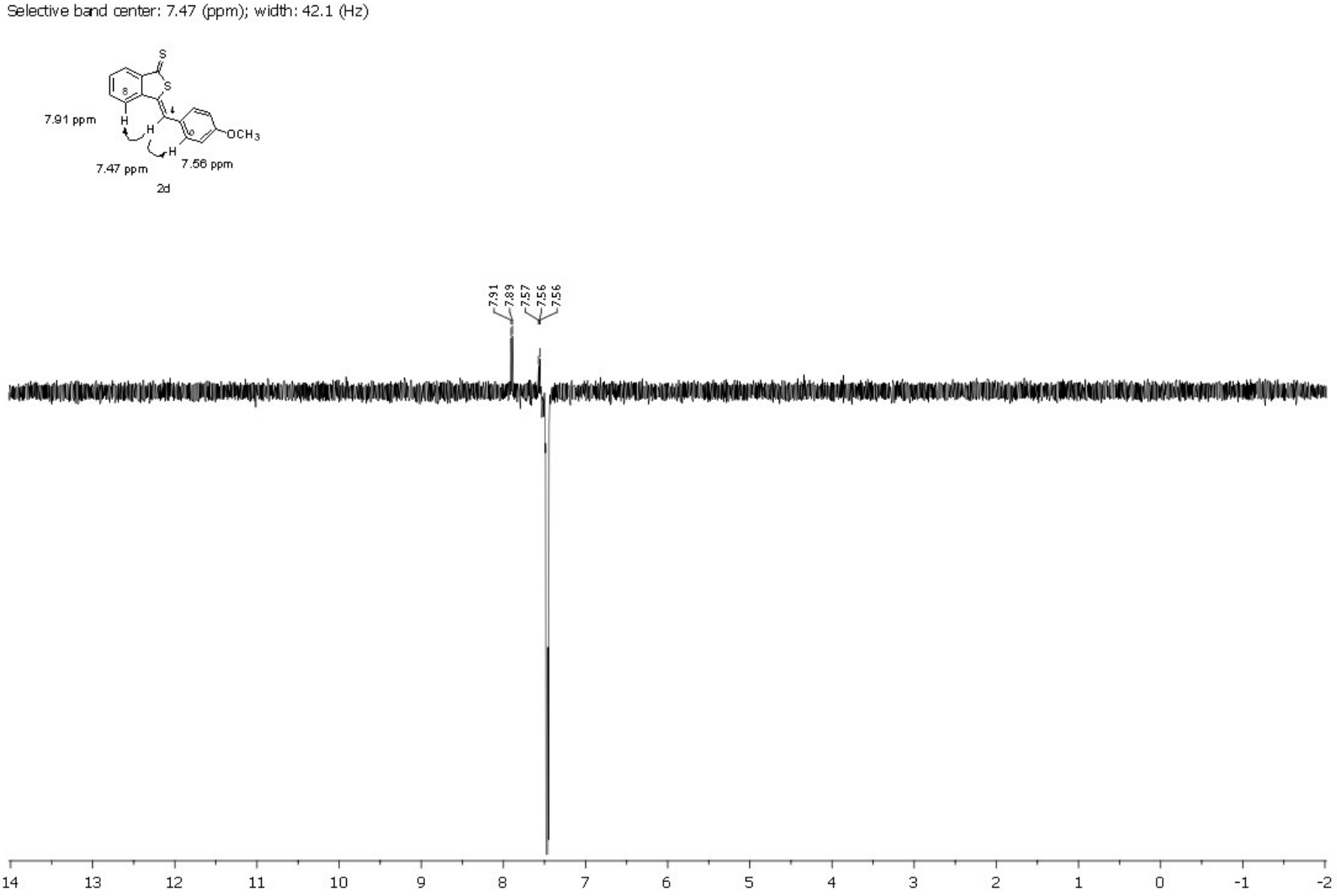
1D selective NOESY (500 ms) of compound **2a**



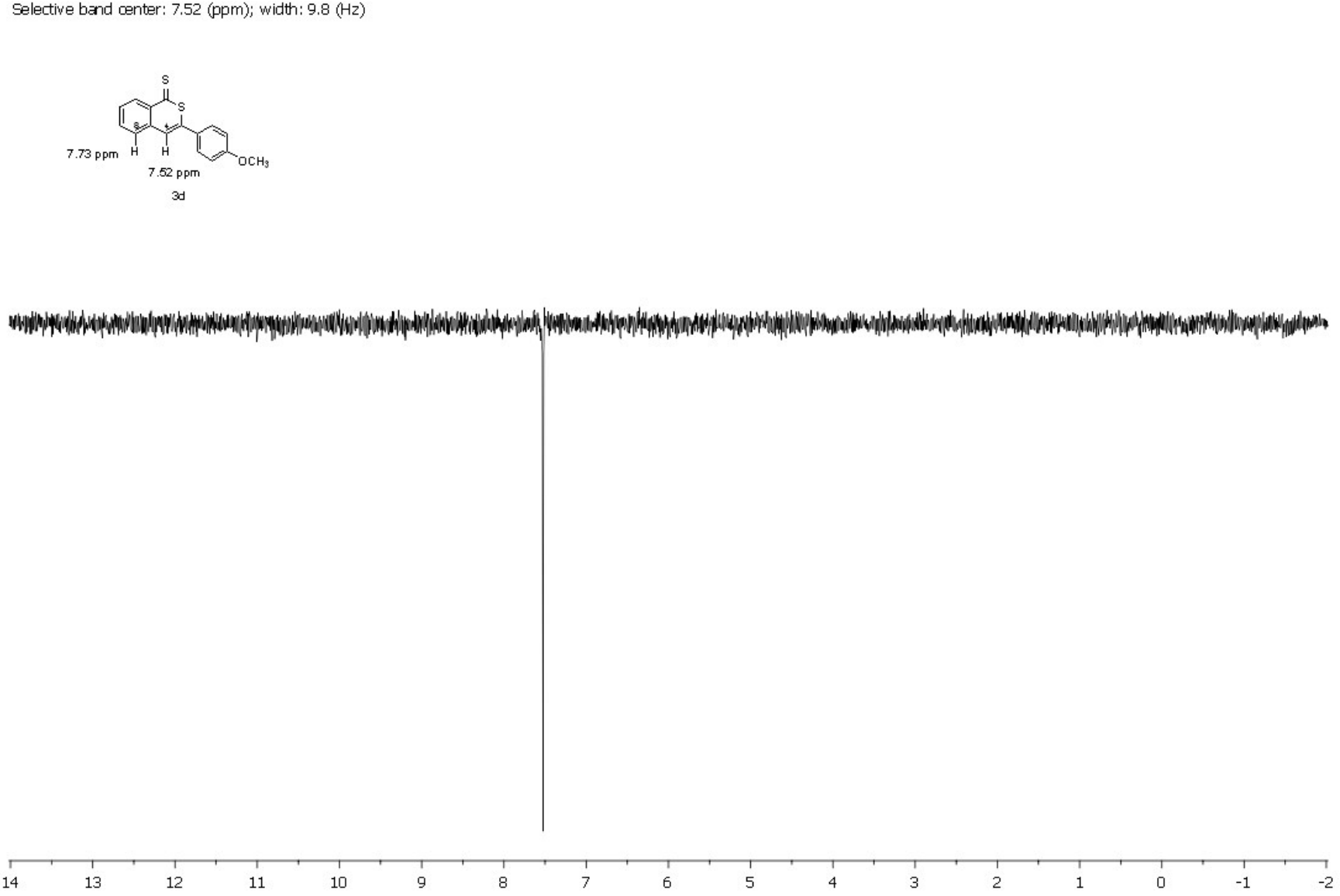
1D selective NOESY (500 ms) of compound **2d**



1D selective NOESY (500 ms) of compound **2d**



1D selective NOESY of compound **3d**



Computational methods

All calculations were performed using Gaussian 03.[1] Density functional theory (DFT) calculations were carried out with B3LYP[2] functional and the 6-31 G* set. The geometries were optimized by standard gradient techniques and characterized by evaluation of the Hessian matrix and the associated harmonic vibrational frequencies.

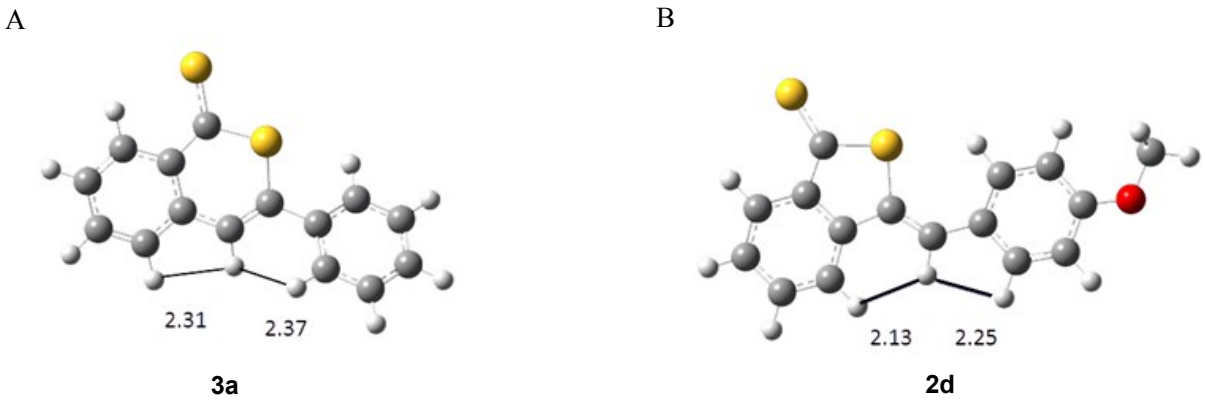


Figure S1. Molecular structure of compounds **3a** and **2d** optimized by Gaussian at 6-31g**b3lyp level.

B3LYP76-31G** optimized Cartesian coordinates of the:

Compound 2a

C -5.282027 -0.349656 -0.028163

C -4.936484 0.978023 -0.288894

C -3.602976 1.369808 -0.250251

C -2.573535 0.447401 0.036123

C -2.944297 -0.885371 0.311101

C -4.280424 -1.273931 0.276836

C -1.204674 0.950530 0.040181

C	-0.004397	0.317006	0.037767
S	0.259047	-1.444211	-0.028198
C	2.025936	-1.312930	-0.054223
C	2.396534	0.100070	-0.006836
C	1.300810	0.988777	0.045574
S	3.015967	-2.628559	-0.121941
C	3.713741	0.580790	-0.011322
C	3.936267	1.949643	0.039381
C	2.850254	2.838430	0.095745
C	1.541077	2.369720	0.100672
H	-5.706717	1.707914	-0.519473
H	-3.341249	2.404806	-0.453928
H	-2.194523	-1.619353	0.580598
H	-4.541042	-2.305003	0.496030
H	-1.143977	2.036860	0.018618
H	4.532474	-0.129977	-0.052807
H	4.950617	2.335908	0.037774
H	3.033317	3.908015	0.137965
H	0.718250	3.075146	0.149943
H	-6.322195	-0.659860	-0.054649

Compound 3a

C	-4.198419	-1.387107	-0.076574
C	-3.417342	-2.545441	-0.207473
C	-2.035281	-2.455316	-0.239634
C	-1.369517	-1.221417	-0.056733

C	-2.174481	-0.045220	-0.010452
C	-3.577462	-0.152156	0.018962
C	2.333318	-0.155855	-0.042226
C	3.134863	0.787958	-0.707284
C	4.524542	0.691876	-0.669175
C	5.140266	-0.343060	0.035985
C	4.354995	-1.281738	0.707985
C	2.965851	-1.187293	0.674328
C	0.068336	-1.183975	-0.185112
C	0.853733	-0.082904	-0.088513
S	0.178011	1.537009	0.114437
C	-1.623751	1.318017	0.095844
H	-5.281311	-1.457323	-0.052150
H	-3.895640	-3.517447	-0.284800
H	-1.435492	-3.355190	-0.342940
H	-4.151277	0.762368	0.118789
H	2.666436	1.587074	-1.273039
H	5.126507	1.425648	-1.196763
H	6.223286	-0.414538	0.066844
H	4.824877	-2.082297	1.271670
H	2.361801	-1.900396	1.226253
H	0.556832	-2.129092	-0.405918
S	-2.482631	2.621928	0.221343

Compound 2d

C	4.555280	-0.238993	-0.000150
C	4.076496	-1.559159	-0.000055
C	2.715166	-1.799902	-0.000089
C	1.766210	-0.749011	-0.000175
C	2.272737	0.565524	-0.000271
C	3.640604	0.823230	-0.000273
C	0.360312	-1.116405	-0.000197
C	-0.785353	-0.384878	-0.000044
S	-0.905359	1.391745	0.000015
C	-2.677067	1.408227	-0.000049
C	-3.160055	0.030295	-0.000038
C	-2.139411	-0.946578	0.000002
S	-3.555871	2.804067	0.000005
C	-4.512805	-0.340804	0.000003
C	-4.847111	-1.687067	0.000115
C	-3.836644	-2.663463	0.000212
C	-2.493743	-2.304870	0.000170
O	5.906810	-0.099059	-0.000237
C	6.454209	1.213488	0.000681
H	4.794474	-2.372232	0.000043
H	2.361821	-2.827669	-0.000003
H	1.601184	1.415054	-0.000400
H	3.981671	1.851263	-0.000358
H	0.202545	-2.193167	-0.000247
H	-5.269654	0.436565	-0.000047

H	-5.889706	-1.988999	0.000145
H	-4.106962	-3.715341	0.000351
H	-1.732038	-3.077541	0.000291
H	7.537110	1.085488	0.001198
H	6.156410	1.774562	-0.893474
H	6.155401	1.773695	0.895040

Compound 3d

C	-3.750573	0.718447	0.523595
C	-2.358262	0.793578	0.535740
C	-1.563965	-0.201221	-0.053260
C	-2.220207	-1.283331	-0.675048
C	-3.602254	-1.371521	-0.690859
C	-4.382084	-0.369892	-0.090248
C	-0.088839	-0.135846	-0.029749
C	0.709989	-1.224427	0.106040
C	2.149568	-1.216217	0.115962
C	2.934904	-0.026979	0.025123
C	2.347805	1.308886	-0.093265
S	0.597764	1.478160	-0.217170
S	3.187559	2.747176	-0.159817
C	2.815541	-2.457599	0.239795
C	4.195139	-2.541046	0.265620
C	4.966940	-1.371571	0.171215

C	4.343404	-0.142988	0.056044
O	-5.728923	-0.546667	-0.162818
C	-6.572581	0.443550	0.409800
H	-4.325810	1.503626	0.998763
H	-1.886083	1.633696	1.035316
H	-1.633455	-2.049009	-1.172462
H	-4.107380	-2.199446	-1.176822
H	0.229238	-2.188810	0.246362
H	2.215348	-3.359989	0.313762
H	4.678484	-3.509063	0.358843
H	6.050738	-1.429040	0.190123
H	4.924988	0.768701	-0.014602
H	-7.594155	0.107633	0.228821
H	-6.408957	0.536773	1.490569
H	-6.423898	1.421949	-0.063367

X-ray crystallographic data for (*Z*)-3-benzylidenebenzo[*c*]thiophene-1(3*H*)-thione (2a)[2]

Table S2. Crystallographic data

Crystal data	
Chemical formula: $C_{15}H_{10}S_2$	Mr = 254.35
Orthorhombic, $P2_12_12_1$	Dx = 1.367 Mg m−3
Hall symbol: P 2ac 2ab	Mo $K\alpha$ radiation, λ = 0.71073 Å
a = 5.7002 (4) Å	Cell parameters from 124 reflections
b = 13.2911 (16) Å	μ = 0.40 mm−1
c = 16.3160 (17) Å	T = 293 K
V = 1236.1 (2) Å^3	Crystal: white block
Z = 4	Crystal size: 0.25 × 0.13 × 0.03 mm
F(000) = 528	
Data collection	
Diffractometer: Bruker-Nonius KappaCCD	R_{int} = 0.114
Radiation source: Mo Kα, λ = 0.71073 Å	θ_{max} = 27.5°, θ_{min} = 3.8°
Scan mode: φ/ω	H= −6 → 7
15019 measured reflections	K = −16 → 17
2829 independent reflections	L= −21 → 21
Refinement	
Refinement on F^2	Hydrogen site location: mixed. H atoms treated by a mixture of independent and constrained refinement
$R[F^2 > 2\sigma(F^2)]$ = 0.048	$\Delta\rho_{max}$ = 0.16 e Å−3
$wR(F^2)$ = 0.123	$\Delta\rho_{min}$ = −0.21 e Å−3
S = 0.97	Absolute structure: Flack x determined using 604 quotients [(I+)-(I-)]/[(I+)+(I-)] (Parsons, Flack and Wagner, Acta Cryst. B69 (2013) 249-259).
2829 reflections	
157 refined parameters	
Programs: SIR2014,[3] SHELXL-2014[4]	

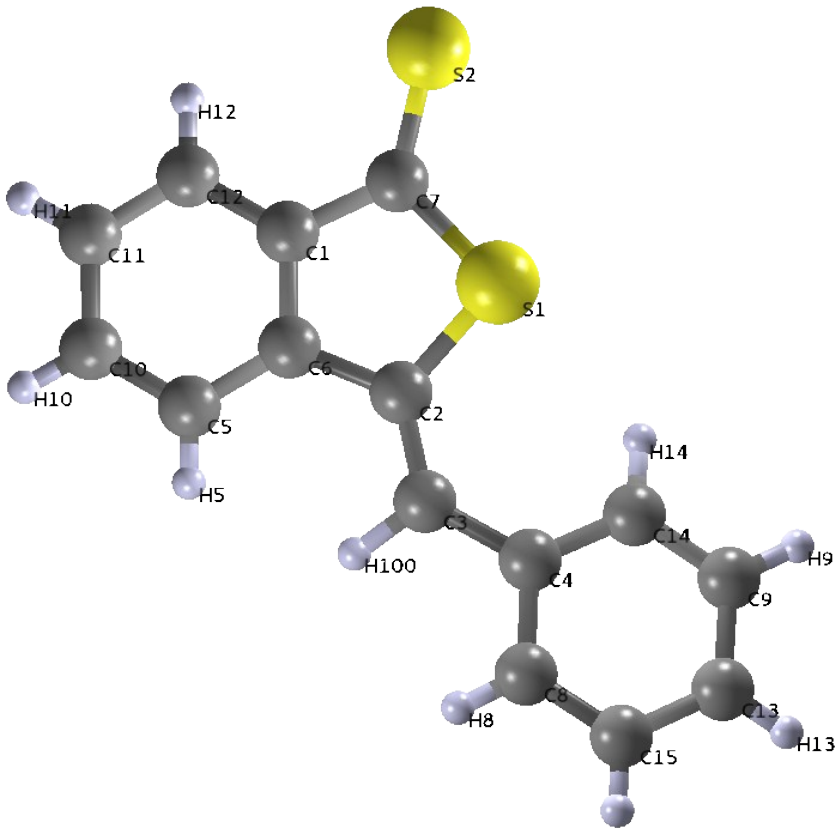


Figure S2. Asymmetric unit of (*Z*)-3-Benzylidenebenzo[*c*]thiophene-1(3*H*)-thione **2a**

Table S3. Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	***y***	***z***	***U*iso*/*U*eq**
S1	0.0994 (2)	0.11137 (9)	0.22447 (7)	0.0539 (3)
S2	−0.3030 (3)	0.02626 (11)	0.13206 (9)	0.0710 (4)
C1	−0.1476 (7)	0.2258 (3)	0.1261 (2)	0.0452 (10)
C2	0.1854 (7)	0.2389 (3)	0.2149 (2)	0.0463 (9)
C3	0.3660 (8)	0.2842 (4)	0.2545 (2)	0.0489 (10)
C4	0.5274 (7)	0.2474 (4)	0.3167 (2)	0.0475 (10)
C5	0.0325 (8)	0.3907 (4)	0.1334 (3)	0.0545 (11)
H5	0.1478	0.4338	0.1532	0.065*
C6	0.0273 (8)	0.2889 (3)	0.1572 (3)	0.0446 (10)

C7	−0.1339 (8)	0.1223 (3)	0.1563 (2)	0.0493 (10)
C8	0.7145 (8)	0.3118 (4)	0.3392 (3)	0.0553 (11)
H8	0.7313	0.3738	0.3134	0.066*
C9	0.6677 (9)	0.1293 (4)	0.4186 (3)	0.0594 (12)
H9	0.6519	0.0680	0.4455	0.071*
C10	−0.1387 (9)	0.4257 (4)	0.0794 (3)	0.0588 (12)
H10	−0.1365	0.4928	0.0632	0.071*
C11	−0.3115 (9)	0.3627 (4)	0.0494 (3)	0.0587 (12)
H11	−0.4239	0.3879	0.0135	0.070*
C12	−0.3186 (8)	0.2626 (4)	0.0724 (3)	0.0533 (11)
H12	−0.4354	0.2203	0.0524	0.064*
C13	0.8492 (9)	0.1933 (4)	0.4392 (3)	0.0626 (13)
H13	0.9554	0.1754	0.4799	0.075*
C14	0.5098 (8)	0.1558 (4)	0.3584 (3)	0.0559 (11)
H14	0.3888	0.1118	0.3451	0.067*
C15	0.8718 (9)	0.2836 (4)	0.3990 (3)	0.0607 (13)
H15	0.9953	0.3262	0.4123	0.073*
H100	0.378 (9)	0.363 (4)	0.243 (3)	0.073*

Table S4. Atomic displacement parameters (Å^2)

	***U*11**	***U*22**	***U*33**	***U*12**	***U*13**	***U*23**
S1	0.0569 (6)	0.0467 (6)	0.0583 (6)	−0.0033 (5)	−0.0036 (6)	0.0026 (5)
S2	0.0771 (9)	0.0592 (8)	0.0767 (9)	−0.0224 (7)	−0.0090 (7)	0.0002 (6)
C1	0.044 (2)	0.049 (2)	0.043 (2)	−0.0007 (18)	0.0077 (19)	−0.0042 (18)
C2	0.046 (2)	0.049 (2)	0.044 (2)	0.0008 (19)	0.008 (2)	−0.0016 (18)
C3	0.046 (2)	0.055 (3)	0.045 (2)	0.000 (2)	0.0065 (18)	−0.0036 (19)
C4	0.043 (2)	0.057 (3)	0.043 (2)	0.001 (2)	0.0053 (18)	−0.004 (2)
C5	0.059 (3)	0.050 (2)	0.055 (2)	−0.003 (2)	0.001 (2)	−0.001 (2)
C6	0.046 (2)	0.047 (2)	0.041 (2)	−0.0004 (18)	0.0085 (17)	−0.0028 (17)
C7	0.052 (3)	0.052 (2)	0.044 (2)	−0.003 (2)	0.0055 (19)	−0.0054 (19)
C8	0.054 (3)	0.056 (3)	0.056 (3)	−0.006 (2)	0.007 (2)	−0.005 (2)
C9	0.062 (3)	0.063 (3)	0.053 (3)	0.007 (2)	−0.002 (2)	−0.002 (2)

C10	0.072 (3)	0.046 (2)	0.058 (3)	0.007 (2)	0.002 (3)	0.000 (2)
C11	0.060 (3)	0.064 (3)	0.052 (3)	0.013 (2)	−0.008 (2)	−0.003 (2)
C12	0.049 (2)	0.060 (3)	0.050 (2)	−0.001 (2)	0.000 (2)	−0.005 (2)
C13	0.059 (3)	0.077 (4)	0.051 (3)	0.011 (3)	−0.008 (2)	−0.005 (2)
C14	0.052 (3)	0.060 (3)	0.056 (3)	−0.004 (2)	0.000 (2)	0.000 (2)
C15	0.047 (3)	0.075 (3)	0.060 (3)	−0.007 (2)	−0.003 (2)	−0.013 (2)

Table S5. Geometric parameters (Å, °)

S1—C7	1.740 (5)	C4—C8	1.416 (6)
S1—C2	1.772 (4)	C5—C10	1.394 (7)
S2—C7	1.647 (5)	C5—C6	1.408 (6)
C1—C6	1.398 (6)	C8—C15	1.376 (7)
C1—C12	1.400 (6)	C9—C14	1.379 (6)
C1—C7	1.463 (6)	C9—C13	1.381 (7)
C2—C3	1.357 (6)	C10—C11	1.382 (7)
C2—C6	1.462 (6)	C11—C12	1.384 (7)
C3—C4	1.455 (6)	C13—C15	1.373 (7)
C4—C14	1.397 (6)		
C7—S1—C2	94.3 (2)	C1—C6—C2	113.6 (4)
C6—C1—C12	120.9 (4)	C5—C6—C2	127.0 (4)
C6—C1—C7	113.8 (4)	C1—C7—S2	128.0 (3)
C12—C1—C7	125.2 (4)	C1—C7—S1	109.5 (3)
C3—C2—C6	125.0 (4)	S2—C7—S1	122.5 (3)
C3—C2—S1	126.3 (3)	C15—C8—C4	120.6 (5)
C6—C2—S1	108.7 (3)	C14—C9—C13	120.3 (5)
C2—C3—C4	131.6 (4)	C11—C10—C5	121.4 (4)
C14—C4—C8	117.0 (4)	C12—C11—C10	120.5 (5)
C14—C4—C3	125.9 (4)	C11—C12—C1	119.1 (4)
C8—C4—C3	117.0 (4)	C15—C13—C9	119.5 (5)
C10—C5—C6	118.7 (4)	C9—C14—C4	121.5 (4)
C1—C6—C5	119.4 (4)	C13—C15—C8	121.0 (5)

X-ray crystallographic data for 3-(4-methoxyphenyl)-1*H*-isothiochromene-1-thione (3d)[5]

Table S6. Crystallographic data

Crystal data	
Chemical formula: $C_{16}H_{12}OS_2$	Mr = 284.38
Monoclinic, $P2_1/n$	Dx = 1.422 Mg m−3
Hall symbol: -P2yn	Mo $K\alpha$ radiation, λ = 0.71073 Å
a = 3.9659 (5) Å	Cell parameters from 126 reflections
c = 20.518 (5) Å	μ = 0.39 mm−1
β = 91.920 (16)°	T = 293 K
V = 1328.7 (4) Å3	Crystal: yellow needle
Z = 4	Crystal size: 0.35 × 0.08 × 0.03 mm
F(000) = 592	
Data collection	
Diffractometer: Bruker-Nonius KappaCCD	R_{int} = 0.135
Radiation source: Mo Kα, λ = 0.71073 Å	θ_{max} = 27.6°, θ_{min} = 2.4°
Scan mode: φ/ω	H = −5 → 5 K = −20 → 21 L = −26 → 26
26857 measured reflections	
3085 independent reflections	
1719 reflections with I >2σ(I)]	
Refinement	
Refinement on F^2	Hydrogen site location: mixed H atoms treated by a mixture of independent and constrained refinement
$R[F^2 > 2\sigma(F^2)]$ = 0.054	$\Delta\rho_{max}$ = 0.20 e Å^{-3}
$wR(F^2)$ = 0.128	$\Delta\rho_{min}$ = −0.24 e Å^{-3}
S = 1.02	Programs: SIR2014,[3] SHELXL-2014[4]
3085 reflections	
177 refined parameters	

Figure S3. Asymmetric unit of 3-(4-methoxyphenyl)-1*H*-isothiochromene-1-thione **3d**

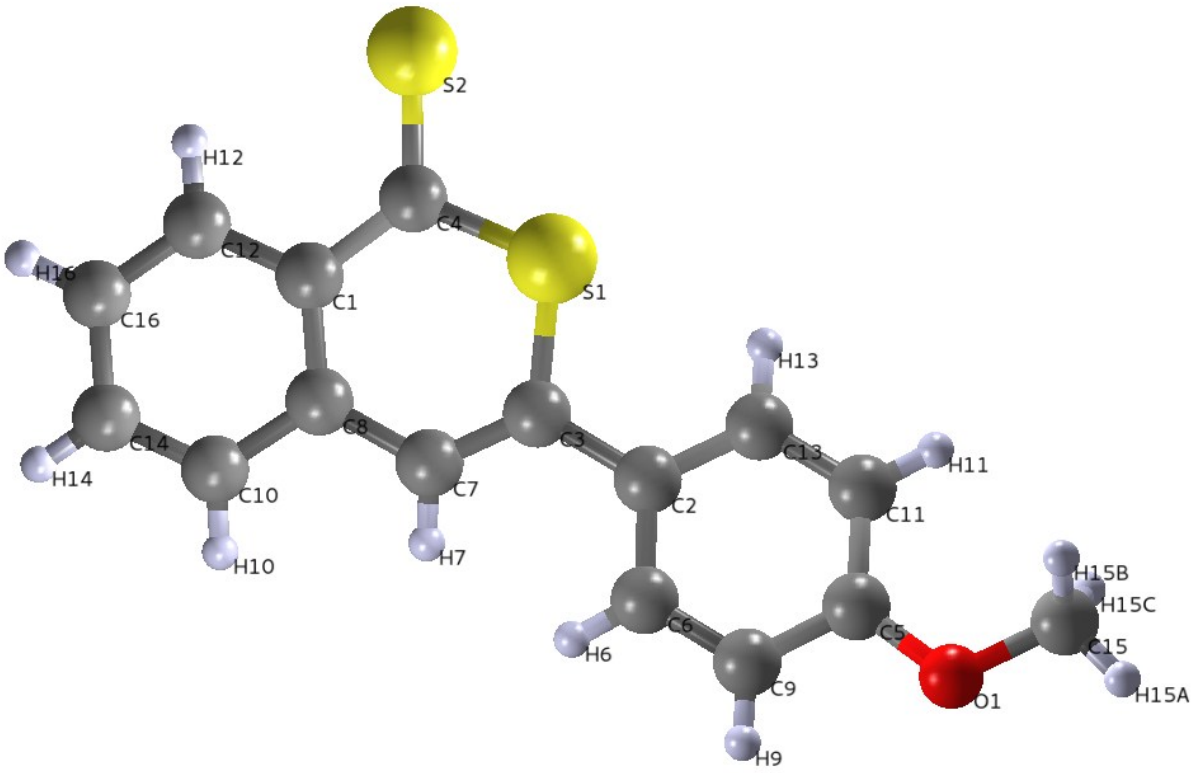


Table S7. Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	*y*	*z*	*U*iso*/*U*eq
S1	0.0949 (2)	0.03568 (5)	0.17373 (4)	0.0419 (2)
S2	0.0283 (2)	0.17908 (5)	0.25078 (5)	0.0569 (3)
O1	0.3940 (6)	−0.25688 (14)	−0.03908 (11)	0.0550 (6)
C1	−0.1919 (7)	0.02816 (19)	0.29484 (14)	0.0406 (7)
C2	0.0863 (7)	−0.11496 (17)	0.11732 (14)	0.0355 (7)
C3	−0.0144 (7)	−0.06791 (18)	0.17493 (14)	0.0357 (7)
C4	−0.0396 (7)	0.07925 (18)	0.24530 (15)	0.0396 (7)
C5	0.2954 (7)	−0.20637 (19)	0.00987 (14)	0.0406 (7)
C6	0.0840 (8)	−0.20005 (19)	0.11795 (16)	0.0491 (8)
H6	0.0111	−0.2273	0.1547	0.059*

C7	−0.1695 (8)	−0.0992 (2)	0.22673 (16)	0.0422 (7)
H7	−0.236 (7)	−0.152 (2)	0.2240 (15)	0.048 (9)*
C8	−0.2550 (7)	−0.05616 (19)	0.28481 (14)	0.0385 (7)
C9	0.1877 (9)	−0.2451 (2)	0.06518 (16)	0.0546 (9)
H9	0.1848	−0.3020	0.0670	0.066*
C10	−0.4051 (8)	−0.1006 (2)	0.33503 (16)	0.0505 (8)
H10	−0.4498	−0.1560	0.3289	0.061*
C11	0.2958 (8)	−0.1227 (2)	0.00741 (16)	0.0493 (8)
H11	0.3648	−0.0959	−0.0299	0.059*
C12	−0.2779 (9)	0.0638 (2)	0.35413 (16)	0.0523 (9)
H12	−0.2373	0.1193	0.3611	0.063*
C13	0.1933 (8)	−0.0779 (2)	0.06056 (16)	0.0493 (8)
H13	0.1960	−0.0211	0.0582	0.059*
C14	−0.4867 (9)	−0.0646 (2)	0.39246 (17)	0.0591 (10)
H14	−0.5854	−0.0954	0.4248	0.071*
C15	0.5327 (8)	−0.2205 (2)	−0.09518 (15)	0.0524 (9)
H15A	0.6036	−0.2626	−0.1243	0.079*
H15B	0.7231	−0.1873	−0.0822	0.079*
H15C	0.3649	−0.1869	−0.1169	0.079*
C16	−0.4216 (10)	0.0181 (2)	0.40234 (17)	0.0627 (10)
H16	−0.4751	0.0427	0.4416	0.075*

Table S8. Atomic displacement parameters (Å²)

	***U*11**	***U*22**	***U*33**	***U*12**	***U*13**	***U*23**
S1	0.0510 (5)	0.0353 (4)	0.0398 (4)	−0.0017 (4)	0.0089 (3)	0.0003 (4)
S2	0.0780 (6)	0.0371 (5)	0.0559 (6)	−0.0023 (4)	0.0079 (5)	−0.0059 (4)
O1	0.0710 (15)	0.0491 (14)	0.0461 (14)	−0.0005 (11)	0.0189 (11)	−0.0064 (11)
C1	0.0406 (17)	0.0457 (19)	0.0355 (17)	0.0056 (14)	0.0014 (13)	0.0032 (15)
C2	0.0356 (15)	0.0380 (17)	0.0328 (16)	−0.0015 (13)	−0.0010 (12)	−0.0005 (13)
C3	0.0334 (15)	0.0361 (16)	0.0374 (17)	0.0026 (12)	−0.0007 (13)	0.0016 (13)
C4	0.0409 (17)	0.0397 (17)	0.0380 (17)	0.0041 (13)	−0.0001 (13)	−0.0028 (14)
C5	0.0413 (17)	0.0458 (18)	0.0349 (17)	−0.0004 (14)	0.0044 (13)	−0.0033 (14)

C6	0.063 (2)	0.0401 (19)	0.045 (2)	0.0023 (15)	0.0160 (16)	0.0088 (15)
C7	0.0485 (18)	0.0388 (19)	0.0394 (19)	−0.0032 (15)	0.0038 (14)	0.0004 (15)
C8	0.0396 (17)	0.0436 (19)	0.0324 (17)	0.0051 (13)	0.0022 (13)	0.0022 (14)
C9	0.080 (3)	0.0350 (18)	0.050 (2)	0.0016 (17)	0.0177 (18)	0.0014 (16)
C10	0.061 (2)	0.047 (2)	0.044 (2)	0.0029 (16)	0.0119 (16)	0.0075 (16)
C11	0.065 (2)	0.049 (2)	0.0344 (18)	−0.0082 (17)	0.0150 (16)	0.0002 (15)
C12	0.070 (2)	0.046 (2)	0.042 (2)	0.0107 (17)	0.0064 (17)	−0.0037 (16)
C13	0.068 (2)	0.0348 (18)	0.046 (2)	−0.0074 (15)	0.0140 (17)	0.0005 (15)
C14	0.073 (2)	0.064 (2)	0.041 (2)	0.0067 (19)	0.0162 (18)	0.0091 (18)
C15	0.055 (2)	0.064 (2)	0.0390 (19)	0.0046 (17)	0.0133 (16)	−0.0037 (17)
C16	0.083 (3)	0.069 (3)	0.037 (2)	0.016 (2)	0.0157 (18)	−0.0041 (18)

Table S9. Geometric parameters (Å, °)

S1—C4	1.732 (3)	C3—C7	1.347 (4)
S1—C3	1.747 (3)	C5—C11	1.368 (4)
S2—C4	1.656 (3)	C5—C9	1.380 (4)
O1—C5	1.367 (3)	C6—C9	1.383 (4)
O1—C15	1.422 (4)	C7—C8	1.434 (4)
C1—C12	1.401 (4)	C8—C10	1.409 (4)
C1—C8	1.414 (4)	C10—C14	1.365 (4)
C1—C4	1.462 (4)	C11—C13	1.386 (4)
C2—C6	1.390 (4)	C12—C16	1.378 (5)
C2—C13	1.391 (4)	C14—C16	1.390 (5)
C2—C3	1.476 (4)		
C4—S1—C3	107.61 (15)	O1—C5—C9	115.5 (3)
C5—O1—C15	118.0 (2)	C11—C5—C9	119.3 (3)
C12—C1—C8	119.0 (3)	C9—C6—C2	121.5 (3)
C12—C1—C4	119.0 (3)	C3—C7—C8	126.7 (3)
C8—C1—C4	122.0 (3)	C10—C8—C1	118.2 (3)
C6—C2—C13	116.4 (3)	C10—C8—C7	118.2 (3)
C6—C2—C3	120.7 (3)	C1—C8—C7	123.6 (3)
C13—C2—C3	122.8 (3)	C5—C9—C6	120.5 (3)

C7—C3—C2	125.3 (3)	C14—C10—C8	121.8 (3)
C7—C3—S1	119.9 (2)	C5—C11—C13	119.9 (3)
C2—C3—S1	114.8 (2)	C16—C12—C1	121.1 (3)
C1—C4—S2	125.8 (2)	C11—C13—C2	122.3 (3)
C1—C4—S1	120.1 (2)	C10—C14—C16	119.8 (3)
S2—C4—S1	114.10 (18)	C12—C16—C14	120.1 (3)
O1—C5—C11	125.1 (3)		

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