A Ligand-Enabled Copper(II)-Catalyzed Highly Selective and Efficient for Synthesis of 2*E*-Alkenylfurans from Ynenones

Shao-Yu Zouÿ, Fang Yangÿ, Xin Zhao, Xin-Ge Ren, Zi-Sheng Chen, Kegong Ji *

College of Chemistry and Pharmacy, Northwest A&F University, 3 Taicheng Road, Yangling, Shaanxi 712100, China.

*E-mail: jikegong@nwsuaf.edu.cn

Supporting Information

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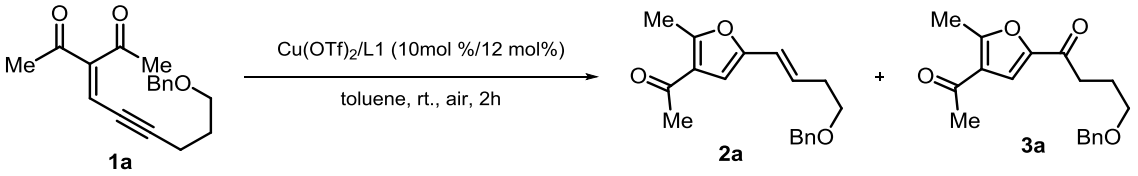
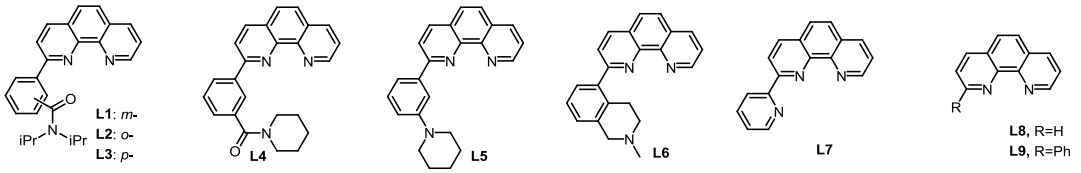
1. General information

All reactions were carried out in a round flask with magnetic stirring. Unless otherwise noted, all reagents were purchased from Aladdin, Energy Chemical for direct use, or prepared as described in the literature. Anhydrous tetrahydrofuran (THF) and toluene were heated over sodium under N_2 for at least four hours before distilled to use. Anhydrous DCM was heated over calcium hydride for two hours before distilled to use. The reactions that sensitive to air or moisture were conducted under nitrogen atmosphere in dry solvents. For chromatographic purification, 200-300 mesh silica gel (Qingdao, China) was employed. For thin layer chromatography (TLC) analysis, Merck 25 TLC aluminium sheets (silica gel 60 GF254, 0.25 mm) were used. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker Advance spectrometer at 500 MHz and 126 MHz or 400 MHz and 101 MHz, respectively. The chemical shift were reported in parts per million (δ) relative to internal standard TMS (0 ppm) and coupling constants are reported as Hertz (Hz). Splitting patterns are designated as singlet (s), doublet (d), triplet (t), doublet of doublets(dd), triplet double(td), multiplet(m). Splitting patterns that could not be interpreted or easily visualized are designated as multiple (m). High resolution mass spectrometry (HRMS) was performed with a Thermo Scientific LTQ Orbitrap XL and AB SCIEX Triple TOF5600+, among them, **1q** and **2q** were analyzed by Life Instrument Sharing Platform of NWAFU and others were analyzed by KeeCloud Biotech. The ene-yne-ketones **1** were prepared according to the literature procedures[1]. The ene-yne-ketones (**1d**, **1e**, **1h-1j**, **1l, 1n-1p**) were new compounds.

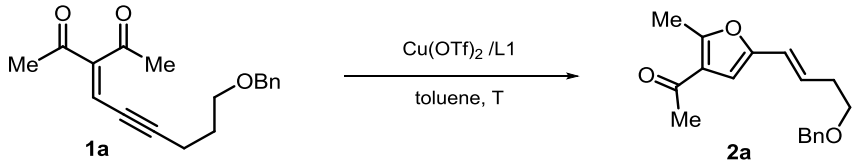
2. Catalyst Screening and Optimization of the Reaction Conditions[a]



Entry	Conditions	**2a** (%)[b]	**3a** (%)[b]
1	**none**	**99**	-
2	without **L1**	<2	97
3	without $Cu(OTf)_2$	-	-
4	**L2** instead of **L1**	73	17
5	**L3** instead of **L1**	70	23
6	**L4** instead of **L1**	77	19
7	**L5** instead of **L1**	8	-
8	**L6** instead of **L1**	-	-
9	**L7** instead of **L1**	-	-
10	**L8** instead of **L1**	<2	-
11	**L9** instead of **L1**	<2	-
12	CuBr instead of $Cu(OTf)_2$	<2	15
13	CuOTf instead of $Cu(OTf)_2$	<2	-
14	$Cu(OAc)_2$ instead of $Cu(OTf)_2$	-	-
15	DCM as the solvent	92	5
16	DCE as the solvent	94	<2
17	MeCN as the solvent	16	8
18	THF as the solvent	18	<2
19	DMSO as the solvent	-	-
20	DMF as the solvent	-	-
21	Acetone as the solvent	89	8



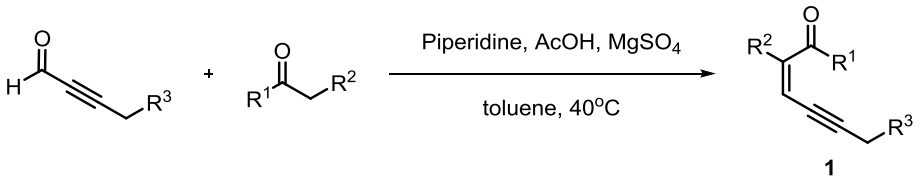
[a] The reactions were conducted with everything in a vial under an air atmosphere. Initially, [1a] = 0.1 M. [b] Isolated yield.



Entry	[Cu]/ L	temperature, concentration	**2a**(%)	TONs
1	$Cu(OTf)_2$/**L1**(10%/12%)	rt., 0.1M	99	9.9
2	$Cu(OTf)_2$/**L1**(5%/6%)	rt., 0.1M	99	19.8
3	$Cu(OTf)_2$/**L1** (1%/1.2%)	rt., 0.1M	99	99
4	$Cu(OTf)_2$/**L1** (0.5%/0.6%)	rt., 0.3M	91	182
5	$Cu(OTf)_2$/**L1** (0.5%/0.6%)	rt., 0.5M	98	196
6	$Cu(OTf)_2$/**L1** (0.5%/0.6%)	rt., 0.8M	49	98
7	$Cu(OTf)_2$/**L1** (0.1%/0.12%)	rt., 0.5M	<2	
8	$Cu(OTf)_2$/**L1** (0.1%/0.12%)	rt., 1M	<2	
9	$Cu(OTf)_2$/**L1** (0.1%/0.12%)	60℃, 0.5M	97	970
10	$Cu(OTf)_2$/**L1** (500ppm/600ppm.)	60℃, 0.75M	82	1640
11	$Cu(OTf)_2$/**L1** (100ppm/120ppm.)	60℃, 0.5M	<2	
12	**$Cu(OTf)_2$/L1 (100ppm/120ppm.)**	**Reflux, 1M**	**86**	**8600**
13	$Cu(OTf)_2$/**L1** (100ppm/120ppm.)	Reflux, 1.5M	81	8100
14	$Cu(OTf)_2$/**L1** (50ppm/60ppm.)	Reflux, 0.75M	40	8000
15	$Cu(OTf)_2$/**L1** (50ppm/60ppm.)	Reflux, 1M	40	8000

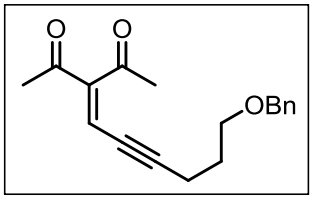
Experiment Producers:

3. General Procedure A for the Synthesis of Ene-yne-ketone 1:



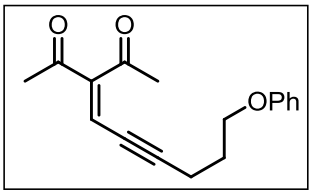
Piperidine (85.1 mg, 1.0 mmol, 0.1 eq), acetic acid (360.3 mg, 6.0 mmol, 0.6 eq), and magnesium sulfate (204.7 mg, 2.0 mmol, 0.2 eq) were added to a stirred solution of aldehyde (10.0 mmol, 1.0 eq) and ketone (10.1 mmol, 1.01 eq) in toluene (30 mL) at ambient temperature. The reaction mixture was stirred at 40 ℃ with an oil bath and the progress of the reaction was monitored by TLC. Upon completion, the reaction was quenched by the addition of water (30 cm^3). The aqueous layer was extract the reaction with EtOAc, dried over Na_2SO_4, filtered, and concentrated to get the residue which was purified by chromatography to get the desired substrate **1**.

3-(6-(benzyloxy)hex-2-yn-1-ylidene)pentane-2,4-dione(1a)



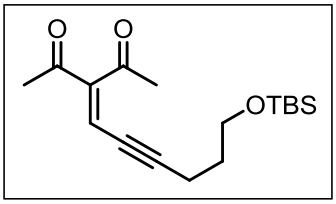
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.31 (m, 4H), 7.30-7.26 (m,1H), 6.66 (t, *J* = 2.5 Hz, 1H), 4.51 (s, 2H), 3.55 (t, *J* = 6.0 Hz, 2H), 2.57 (td, *J* = 7.1, 2.5 Hz, 2H), 2.44 (s, 3H), 2.31 (s, 3H), 1.91-1.80 (m, 2H).

3-(6-phenoxyhex-2-yn-1-ylidene)pentane-2,4-dione(1b)



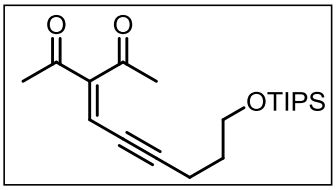
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 (dd, *J* = 8.8, 7.5 Hz, 2H), 6.94 (tt, *J* = 7.5, 1.1 Hz, 1H), 6.89 (dd, *J* = 8.8, 1.1 Hz, 2H), 6.65 (t, *J* = 2.5 Hz, 1H), 4.03 (t, *J* = 5.9 Hz, 2H), 2.67 (td, *J* = 7.0, 2.4 Hz, 2H), 2.41 (s, 3H), 2.29 (s, 3H), 2.08- 1.99 (m, 2H).

3-(6-((tert-butyldimethylsilyl)oxy)hex-2-yn-1-ylidene)pentane-2,4-dione(1c)



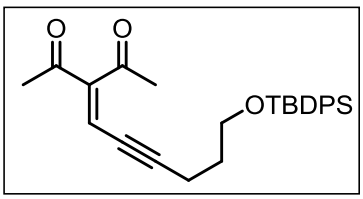
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid.· ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.68 (t, *J* = 2.5 Hz, 1H), 3.66 (t, *J* = 5.9 Hz, 2H), 2.52 (td, *J* = 7.1, 2.5 Hz, 2H), 2.46 (s, 3H), 2.30 (s, 3H), 1.79-1.70 (m, 2H), 0.88 (s, 9H), 0.04 (s, 6H).

3-(6-((triisopropylsilyl)oxy)hex-2-yn-1-ylidene)pentane-2,4-dione(1d)



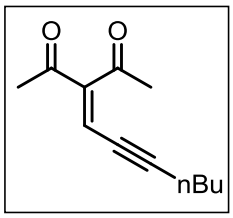
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 30：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.67 (t, *J* = 2.5 Hz, 1H), 3.74 (t, *J* = 5.9 Hz, 2H), 2.55 (td, *J* = 7.1, 2.5 Hz, 2H), 2.44 (s, 3H), 2.29 (s, 3H), 1.80-1.72 (m, 2H), 1.05 (d, *J* = 5.0 Hz, 3H), 1.03 (d, *J* = 5.0 Hz, 18H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.3, 195.9, 149.6, 123.3, 110.3, 76.9, 61.7, 31.5, 31.0, 27.3, 18.1, 16.8, 12.0. HRMS (ESI)：calcd for $C_{20}H_{35}O_3Si^+$ $[M+H]^+$ 351.2350, found 351.2350.

3-(6-((tert-butyldiphenylsilyl)oxy)hex-2-yn-1-ylidene)pentane-2,4-dione(1e)



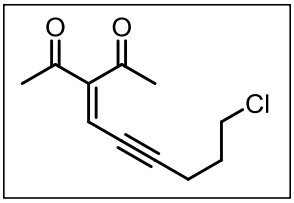
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70-7.62 (m, 4H), 7.47-7.35 (m, 6H), 6.67 (t, *J* = 2.5 Hz, 1H), 3.74 (t, *J* = 5.9 Hz, 2H), 2.61 (td, *J* = 7.1, 2.5 Hz, 2H), 2.43 (s, 3H), 2.32 (s, 3H), 1.87-1.75 (m, 2H), 1.06 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.3, 195.9, 149.5, 135.6, 133.7, 129.8, 127.8, 123.3, 110.1, 77.1, 62.2, 31.1, 31.0, 27.4, 26.9, 19.3, 16.9. HRMS (ESI): calcd for $C_{27}H_{33}O_3Si^+$ $[M+H]^+$ 433.2193, found 433.2195.

3-(hept-2-yn-1-ylidene)pentane-2,4-dione (1f)



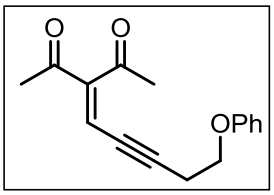
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 30：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.69-6.66 (m, 1H), 2.45 (d, *J* = 1.0 Hz, 3H), 2.42 (td, *J* = 7.5, 2.3 Hz, 2H), 2.29 (d, *J* = 1.0 Hz, 3H), 1.56-1.50 (m, 2H), 1.46-1.34 (m, 2H), 0.91 (td, *J* = 7.5, 1.0 Hz, 3H).

3-(6-chlorohex-2-yn-1-ylidene)pentane-2,4-dione(1g)



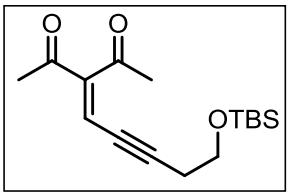
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 30：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.64 (t, *J* = 2.5 Hz, 1H), 3.62 (t, *J* = 6.2 Hz, 2H), 2.63 (td, *J* = 6.9, 2.5 Hz, 2H), 2.44 (s, 3H), 2.30 (s, 3H), 2.04-1.95 (m, 2H).

3-(5-phenoxypent-2-yn-1-ylidene)pentane-2,4-dione(1h)



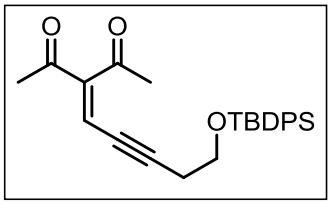
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27 (t, *J* = 8.0 Hz, 2H), 6.95 (t, *J* = 7.5 Hz, 1H), 6.87 (d, *J* = 8.0 Hz, 2H), 6.66 (t, *J* = 2.5 Hz, 1H), 4.08 (t, *J* = 6.5 Hz, 2H), 2.89 (td, *J* = 6.5, 2.5 Hz, 2H), 2.44 (s, 3H), 2.28 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.2, 195.7, 158.2, 150.1, 129.5, 122.3, 121.2, 114.6, 105.5, 77.9, 65.2, 30.9, 27.2, 21.3. HRMS (ESI): calcd for $C_{16}H_{17}O_3^+$ $[M+H]^+$ 257.1172, found 257.1179.

3-(5-((tert-butyldimethylsilyl)oxy)pent-2-yn-1-ylidene)pentane-2,4-dione(1i)



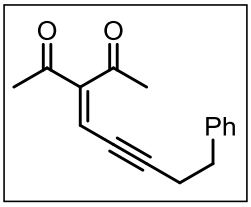
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.68 (s, 1H), 3.75 (t, *J* = 5.7 Hz, 2H), 2.68-2.61 (m, 2H), 2.47 (s, 3H), 2.30 (s, 3H), 0.88 (s, 9H), 0.06 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.3, 195.8, 149.8, 123.0, 107.3, 77.8, 61.2, 31.1, 27.5, 26.0, 24.8, 18.4, -5.2. HRMS (ESI): calcd for $C_{16}H_{27}O_3Si^+$ $[M+H]^+$ 295.1724, found 295.1725.

3-(5-((tert-butyldiphenylsilyl)oxy)pent-2-yn-1-ylidene)pentane-2,4-dione(1j)



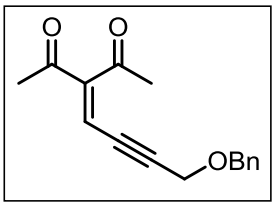
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70-7.62 (m, 4H), 7.47-7.36 (m, 6H), 6.68 (t, *J* = 2.5 Hz, 1H), 3.83 (t, *J* = 6.6 Hz, 2H), 2.69 (td, *J* = 6.6, 2.5 Hz, 2H), 2.45 (s, 3H), 2.31 (s, 3H), 1.08 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.2, 195.8, 149.7, 135.6, 133.3, 129.9, 127.8, 122.9, 107.3, 77.8, 61.8, 31.0, 27.4, 26.8, 24.5, 19.2. HRMS (ESI): calcd for $C_{26}H_{31}O_3Si^+$ $[M+H]^+$ 419.2037, found 419.2036.

3-(5-phenylpent-2-yn-1-ylidene)pentane-2,4-dione(1k)



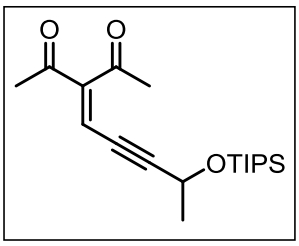
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (t, *J* = 7.5 Hz, 2H), 7.25-7.17 (m, 3H), 6.65 (t, *J* = 2.5 Hz, 1H), 2.87 (t, *J* = 7.5 Hz, 2H), 2.75 (td, *J* = 7.5, 2.5 Hz, 2H), 2.34 (s, 3H), 2.29 (s, 3H).

3-(4-(benzyloxy)but-2-yn-1-ylidene)pentane-2,4-dione (1l)



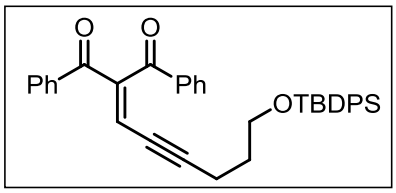
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 10：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38-7.31 (m, 5H), 6.70 (t, *J* = 2.0 Hz, 1H), 4.59 (s, 2H), 4.37 (d, *J* = 2.0 Hz, 2H), 2.47 (s, 3H), 2.33 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 200.9, 195.6, 150.7, 137.0, 128.6, 128.2, 128.2, 121.2, 103.4, 82.0, 72.1, 57.8, 31.0, 27.3. HRMS (ESI): calcd for $C_{16}H_{17}O_3^+$ $[M+H]^+$ 257.1172, found 257.1171.

3-(4-((triisopropylsilyl)oxy)pent-2-yn-1-ylidene)pentane-2,4-dione (1m)



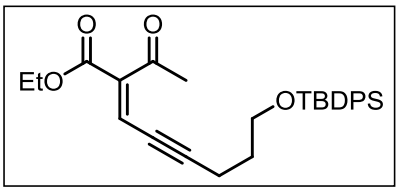
Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.71 (s, 1H), 4.79 (q, *J* = 6.5 Hz, 1H), 2.47 (s, 3H), 2.31 (s, 3H), 1.48 (d, *J* = 6.5 Hz, 3H), 1.07 (d, *J* = 3.9 Hz, 21H).

2-(6-((tert-butyldiphenylsilyl)oxy)hex-2-yn-1-ylidene)-1,3-diphenylpropane-1,3-dione(1n)



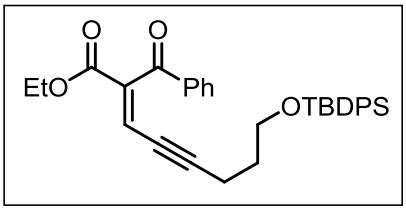
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.5 Hz, 2H), 7.82 (d, *J* = 8.0 Hz, 2H), 7.65 (d, *J* = 7.5 Hz, 4H), 7.53 (dt, *J* = 24.0, 7.5 Hz, 2H), 7.47-7.37 (m, 10H), 6.73 (t, *J* = 2.5 Hz, 1H), 3.53 (t, *J* = 5.8 Hz, 2H), 2.39 (td, *J* = 7.5, 2.5 Hz, 2H), 1.56-1.48 (m, 2H), 1.06 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.3, 193.2, 147.9, 137.0, 136.5, 135.6, 133.8, 133.6, 132.9, 129.7, 129.6, 129.4, 128.7, 128.6, 127.7, 125.5, 109.3, 77.0, 62.1, 31.0, 26.9, 19.3, 16.7. HRMS (ESI): calcd for $C_{37}H_{37}O_3Si^+$ $[M+H]^+$ 557.2506, found 557.2509.

ethyl *(E)*-2-acetyl-8-((tert-butyldiphenylsilyl)oxy)oct-2-en-4-ynoate(1o)



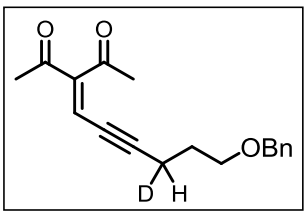
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 50：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.1 Hz, 4H), 7.49-7.32 (m, 6H), 6.78 (s, 1H), 4.27 (q, *J* = 7.5 Hz, 2H), 3.75 (t, *J* = 6.0 Hz, 2H), 2.59 (t, *J* = 6.8 Hz, 2H), 2.41 (s, 3H), 1.91-1.70 (m, 2H), 1.31 (t, *J* = 7.5 Hz, 3H), 1.07 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 199.0, 164.1, 142.3, 135.7, 133.8, 129.8, 127.8, 124.0, 107.9, 76.8, 62.3, 61.6, 31.2, 30.5, 27.0, 19.4, 16.9, 14.2. HRMS (ESI): calcd for $C_{28}H_{35}O_4Si^+$ $[M+H]^+$ 463.2299, found 463.2295.

ethyl *(E)*-2-benzoyl-8-((tert-butyldiphenylsilyl)oxy)oct-2-en-4-ynoate(1p)



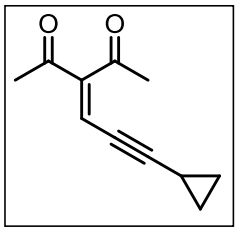
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 20：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.0 Hz, 2H), 7.64 (d, *J* = 7.5 Hz, 4H), 7.50 (t, *J* = 7.5 Hz, 1H), 7.44 (d, *J* = 7.0 Hz, 2H), 7.40 (t, *J* = 7.5 Hz, 6H), 7.03 (t, *J* = 2.5 Hz, 1H), 4.23 (q, *J* = 7.2 Hz, 2H), 3.50 (t, *J* = 5.5 Hz, 2H), 2.36 (td, *J* = 7.0, 2.5 Hz, 2H), 1.53-1.46 (m, 2H), 1.20 (t, *J* = 7.2 Hz, 3H), 1.04 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.0, 164.2, 141.0, 136.2, 135.6, 133.8, 133.6, 129.7, 129.4, 128.6, 127.7, 124.6, 107.4, 76.6, 62.0, 61.6, 31.0, 26.9, 19.3, 16.5, 14.1. HRMS (ESI): calcd for $C_{33}H_{37}O_4Si^+$ $[M+H]^+$ 525.2456, found 525.2459.

3-(6-(benzyloxy)hex-2-yn-1-ylidene-4-d)pentane-2,4-dione(1q)



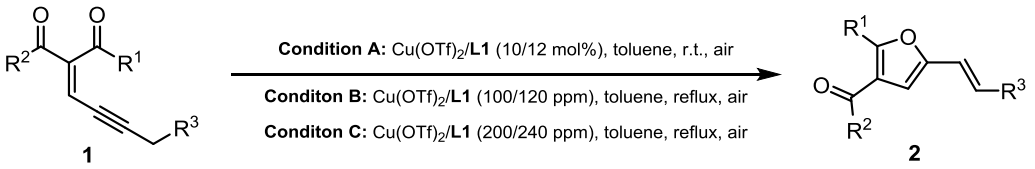
New compound, was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.25 (m, 5H), 6.66 (d, *J* = 2.4 Hz, 1H), 4.51 (s, 2H), 3.54 (t, *J* = 6.0 Hz, 2H), 2.55 (td, *J* = 6.8, 2.4 Hz, 1H), 2.43 (s, 3H), 2.30 (s, 3H), 1.85 (q, *J* = 6.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 201.4, 195.9, 149.7, 138.4, 128.5, 128.5, 127.7, 109.6, 77.4, 73.1, 68.5, 31.0, 28.3, 27.3, 17.0 (t). HRMS (ESI): calcd for $C_{18}H_{19}DO_3^+$ $[M+H]^+$ 286.1548, found 286.1548.

3-(3-cyclopropylprop-2-yn-1-ylidene)pentane-2,4-dione(1r)



Reported compound,[2] was synthesized according to the general procedure A. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.65 (s, 1H), 2.41 (s, 3H), 2.26 (s, 3H), 1.59-1.28 (m, 1H), 0.99-0.90 (m, 2H), 0.86-0.76 (m, 2H).

4.General Procedure B for the Synthesis of 2-Alkenylfuran 2:

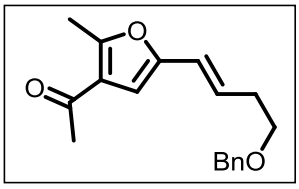


Condition A: Ynenones (0.2 mmol), $Cu(OTf)_2$ (10 mol%, 7.2 mg), **L1** (12 mol%, 9.2 mg) and anhydrous toluene (2 mL) was stirred under air at room temperature for 1-18 h and and the progress of the reaction was monitored by TLC. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel to afford the desired product **2**.

Condition B: An oven-dried flask (200 mL) was charged with $Cu(OTf)_2$ (1.8 mg) and **L1** (2.3 mg) in acetone (100 mL) and stirred at room temperature for 1 h. The solution (2 mL) was added to the reaction flask with a syringe and was concentrated under vacuum. The solution of **1** (1 mmol, 1.0 eq) in toluene (1 mL) was added to the flask. The resulting mixture was refluxed for about 3-11 hours and the progress of the reaction was monitored by TLC. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel to afford the desired product **2**.

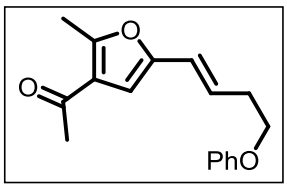
Condition C: An oven-dried flask (200 mL) was charged with $Cu(OTf)_2$ (1.8 mg) and **L1** (2.3 mg) in acetone (100 mL) and stirred at room temperature for 1 h. The solution (4 mL) was added to the reaction flask with a syringe and was concentrated under vacuum. The solution of **1g** (1 mmol, 1.0 eq) in toluene (1 mL) was added to the flask. The resulting mixture was refluxed for about 3 hours and the progress of the reaction was monitored by TLC. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel to afford the desired product **2g**.

***(E)*-1-(5-(4-(benzyloxy)but-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2a)**



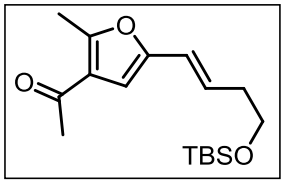
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 56.1 mg, yield 99%; condition B in 244.5 mg, yield 86% with 8600 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 12：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 (d, *J* = 4.5 Hz, 4H), 7.31-7.27 (m, 1H), 6.33 (s, 1H), 6.23-6.16 (m, 2H), 4.54 (s, 2H), 3.58 (t, *J* = 6.5 Hz, 2H), 2.58 (s, 3H), 2.53-2.47 (m, 2H), 2.38 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.2, 157.7, 150.8, 138.5, 128.5, 127.8, 127.7, 127.1, 122.8, 119.5, 106.6, 73.1, 69.6, 33.4, 29.2, 14.5. HRMS (ESI): calcd for $C_{18}H_{21}O_3^+$ $[M+H]^+$ 285.1485, found 285.1487.

***(E)*-1-(2-methyl-5-(4-phenoxybut-1-en-1-yl)furan-3-yl)ethan-1-one(2b)**



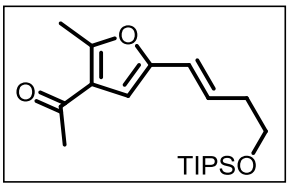
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 53.1 mg, yield 99%; condition B in 243.3 mg, yield 90% with 9000 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (t, *J* = 8.0 Hz, 2H), 6.98-6.90 (m, 3H), 6.37 (s, 1H), 6.28-6.20 (m, 2H), 4.07 (t, *J* = 6.5 Hz, 2H), 2.71-2.65 (m, 2H), 2.59 (s, 3H), 2.38 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.2, 158.9, 157.8, 150.6, 129.6, 126.2, 122.8, 120.9, 120.0, 114.7, 107.0, 67.1, 32.8, 29.2, 14.6. HRMS (ESI): calcd for $C_{17}H_{19}O_3^+$ $[M+H]^+$ 271.1329, found 271.1331.

***(E)*-1-(5-(4-((tert-butyldimethylsilyl)oxy)but-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2c)**



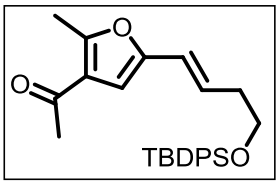
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 60.9 mg, yield 99%; condition B in 246.8 mg, yield 80% with 8000 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.32 (s, 1H), 6.21-6.12 (m, 2H), 3.70 (t, *J* = 6.7 Hz, 2H), 2.57 (s, 3H), 2.44-2.38 (m, 2H), 2.37 (s, 3H), 0.89 (s, 9H), 0.05 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.2, 157.6, 150.9, 127.3, 122.8, 119.5, 106.4, 62.8, 36.5, 29.2, 26.1, 18.5, 14.5, -5.1. HRMS (ESI): calcd for $C_{17}H_{28}O_3SiNa^+$ $[M+Na]^+$ 331.1700, found 331.1699.

***(E)*-1-(2-methyl-5-(4-((triisopropylsilyl)oxy)but-1-en-1-yl)furan-3-yl)ethan-1-one(2d)**



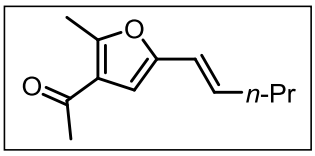
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 69.1 mg, yield 99%; condition B in 305.0 mg, yield 87% with 8700 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.29 (s, 1H), 6.19-6.14 (m, 2H), 3.76 (t, *J* = 6.5 Hz, 2H), 2.54 (s, 3H), 2.40 (q, *J* = 6.5 Hz, 2H), 2.34 (s, 3H), 1.08-1.05 (m, 3H), 1.06-1.00 (m, 18H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.1, 157.5, 150.9, 127.3, 122.7, 119.4, 106.3, 63.0, 36.6, 29.1, 18.1, 14.4, 12.1. HRMS (ESI): calcd for $C_{20}H_{34}O_3SiNa^+$ $[M+Na]^+$ 373.2169, found 373.2171.

***(E)*-1-(5-(4-((tert-butyldiphenylsilyl)oxy)but-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2e)**



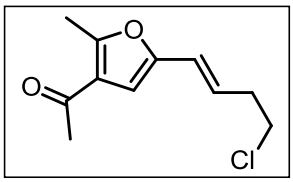
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 85.3 mg, yield 99%; condition B in 402.4 mg, yield 93% with 9300 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72-7.68 (m, 4H), 7.46-7.36 (m, 6H), 6.33 (s, 1H), 6.24-6.13 (m, 2H), 3.79 (t, *J* = 6.5 Hz, 2H), 2.60 (s, 3H), 2.48-2.43 (m, 2H), 2.40 (s, 3H), 1.08 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.3, 157.6, 150.9, 135.7, 133.9, 129.7, 127.7, 127.3, 122.8, 119.6, 106.4, 63.5, 36.2, 29.2, 27.0, 19.3, 14.5. HRMS (ESI): calcd for $C_{28}H_{34}O_4SiNa^+$ $[M+Na]^+$ 455.2013, found 455.2015.

***(E)*-1-(2-methyl-5-(pent-1-en-1-yl)furan-3-yl)ethan-1-one(2f)**



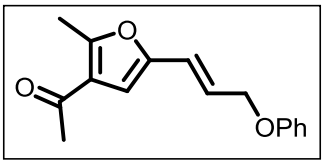
Reported compound,[2] was synthesized according to the general procedure B. The product was obtained by condition A in 37.8 mg, yield 99%; condition B in 128.9 mg, yield 67% with 6700 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.31 (s, 1H), 6.18 (dt, *J* = 16.0, 6.6 Hz, 1H), 6.11 (d, *J* = 16.0 Hz, 1H), 2.58 (s, 3H), 2.38 (s, 3H), 2.16 (q, *J* = 7.0 Hz, 2H), 1.54-1.42 (m, 2H), 0.94 (t, *J* = 7.5 Hz, 3H).

***(E)*-1-(5-(4-chlorobut-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2g)**



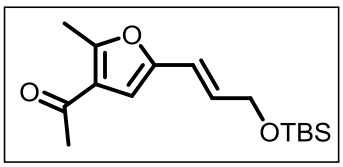
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 42.0 mg, yield 99%; condition C in 165.6 mg, yield 78% with 3900 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.38 (s, 1H), 6.22 (d, *J* = 15.5 Hz, 1H), 6.17-6.09 (m, 1H), 3.60 (t, *J* = 7.0 Hz, 2H), 2.64 (q, *J* = 7.0 Hz, 2H), 2.58 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.1, 158.0, 150.2, 125.6, 122.8, 120.5, 107.5, 43.8, 36.0, 29.2, 14.6. HRMS (ESI): calcd for $C_{11}H_{14}ClO_2^+$ $[M+H]^+$ 213.0677, found 213.0675.

***(E)*-1-(2-methyl-5-(3-phenoxyprop-1-en-1-yl)furan-3-yl)ethan-1-one(2h)**



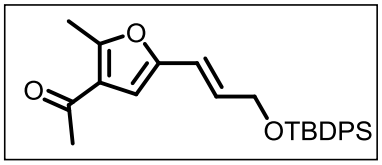
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 50.6 mg, yield 99%; condition B in 171.7 mg, yield 67% with 6700 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (t, *J* =8.0 Hz, 2H), 6.99-6.92 (m, 3H), 6.47 (d, *J* = 17.0 Hz, 2H), 6.36 (dt, *J* = 17.0, 5.5 Hz, 1H), 4.68 (dd, *J* = 5.5, 1.5 Hz, 2H), 2.60 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.1, 158.6, 158.4, 150.0, 129.7, 124.1, 123.0, 121.2, 120.0, 114.9, 108.6, 67.9, 29.2, 14.6. HRMS (ESI): calcd for $C_{16}H_{16}O_3Na^+$ $[M+Na]^+$ 279.0992, found 279.0993.

***(E)*-1-(5-(3-((tert-butyldimethylsilyl)oxy)prop-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2i)**



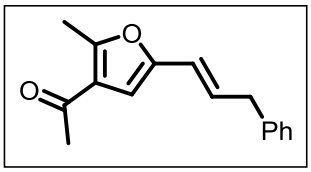
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 58.1 mg, yield 99%; condition B in 176.7 mg, yield 60% with 6000 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.32 (s, 1H), 6.29 (dt, *J* = 15.5, 2.0 Hz, 1H), 6.16 (dt, *J* = 15.5, 4.5 Hz, 1H), 4.25 (dd, *J* = 4.5, 2.0 Hz, 2H), 2.50 (s, 3H), 2.30 (s, 3H), 0.87 (s, 9H), 0.03 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.8, 157.6, 150.5, 128.8, 122.7, 116.6, 107.3, 62.9, 29.0, 25.9, 18.4, 14.3, -5.3. HRMS (ESI): calcd for $C_{16}H_{26}O_3SiNa^+$ $[M+Na]^+$ 317.1543, found 317.1542.

***(E)*-1-(5-(3-((tert-butyldiphenylsilyl)oxy)prop-1-en-1-yl)-2-methylfuran-3-yl)ethan-1-one(2j)**



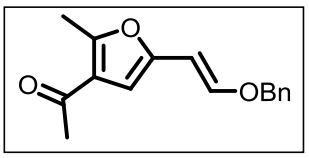
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 82.5 mg, yield 99%; condition B in 293.0 mg, yield 70% with 7000 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (dd, *J* = 8.0, 2.0 Hz, 4H), 7.48-7.39 (m, 6H), 6.54 (dt, *J* = 15.5, 2.0 Hz, 1H), 6.45 (s, 1H), 6.30 (dt, *J* = 15.5, 4.5 Hz, 1H), 4.41 (dd, *J* = 4.5, 2.0 Hz, 2H), 2.63 (s, 3H), 2.42 (s, 3H), 1.15 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.1, 157.8, 150.6, 135.5, 133.5, 129.8, 128.5, 127.8, 122.8, 116.7, 107.5, 63.7, 29.1, 26.9, 19.3, 14.5. HRMS (ESI): calcd for $C_{26}H_{30}O_3SiNa^+$ $[M+Na]^+$ 441.1856, found 441.1859.

***(E)*-1-(2-methyl-5-(3-phenylprop-1-en-1-yl)furan-3-yl)ethan-1-one(2k)**



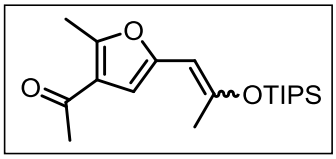
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 47.3 mg, yield 99%; condition B in 153.8 mg, yield 64% with 6400 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 (t, *J* = 8.2 Hz, 2H), 7.23 (t, *J* = 6.8 Hz, 3H), 6.37-6.29 (m, 2H), 6.15 (d, *J* = 15.5 Hz, 1H), 3.52 (dd, *J* = 7.0, 1.5 Hz, 2H), 2.57 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.2, 157.7, 150.8, 139.7, 129.3, 128.8, 128.7, 126.4, 122.8, 118.9, 106.9, 39.2, 29.2, 14.5. HRMS (ESI): calcd for $C_{16}H_{17}O_2^+$ $[M+H]^+$ 241.1223, found 241.1224.

***(E)*-1-(5-(2-(benzyloxy)vinyl)-2-methylfuran-3-yl)ethan-1-one(2l)**



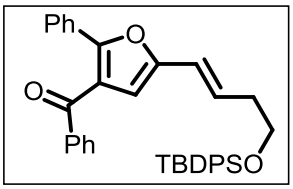
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 50.5 mg, yield 99% (E:Z=5:1); condition B in 184.5 mg, yield 72% (E:Z=3:1) with 7200 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 100:1-20:1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43-7.29 (m, 5H), 7.09 (d, *J* = 12.5 Hz, 1H), 6.20 (s, 1H), 5.72 (d, *J* = 12.5 Hz, 1H), 4.86 (s, 2H), 2.55 (s, 3H), 2.35 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.0, 156.4, 149.3, 148.1, 136.4, 128.6, 128.2, 127.6, 122.7, 104.4, 96.3, 72.2, 29.1, 14.3. HRMS (ESI): calcd for $C_{16}H_{16}O_3Na^+$ $[M+Na]^+$ 279.0992, found 279.0996.

1-(2-methyl-5-(2-((triisopropylsilyl)oxy)prop-1-en-1-yl)furan-3-yl)ethan-1-one(2m)



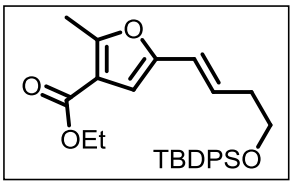
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 66.4 mg, yield 99% (E:Z=11:1); condition B in 171.6 mg, yield 51% (E:Z=1:1) with 5100 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.62 (s, 1H), 6.18 (s, 1H), 5.54 (s, 1H), 5.31 (s, 1H), 2.55 (s, 3H), 2.53 (s, 3H), 2.37 (s, 3H), 2.35 (s, 3H), 2.11 (s, 3H), 2.01 (s, 3H), 1.29-1.24 (m, 3H), 1.22-1.17 (m, 3H), 1.13 (d, *J* = 7.1 Hz, 18H), 1.10 (d, *J* = 7.1 Hz, 18H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.7, 194.3, 156.1, 155.3, 153.5, 150.5, 150.1, 150.0, 122.8, 122.5, 106.2, 105.4, 98.7, 97.7, 29.2, 29.1, 23.6, 20.6, 18.1, 18.0, 14.5, 14.2, 13.7, 12.7. HRMS (ESI): calcd for $C_{19}H_{33}O_3Si^+$ $[M+H]^+$ 337.2193, found 337.2193.

***(E)*-(5-(4-((tert-butyldiphenylsilyl)oxy)but-1-en-1-yl)-2-phenylfuran-3-yl)(phenyl)methanone(2n)**



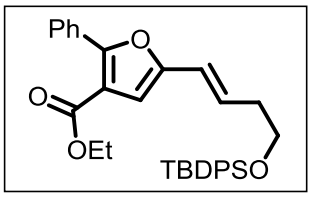
New compound, was synthesized according to the general procedure B. The product was obtained by condition B in 412.0 mg, yield 74% with 7400 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92-7.86 (m, 2H), 7.80-7.74 (m, 2H), 7.77-7.71 (m, 4H), 7.53 (t, *J* = 7.5 Hz, 1H), 7.47-7.38 (m, 9H), 7.35-7.29 (m, 2H), 6.45 (s, 1H), 6.45-6.37 (m, 1H), 6.30 (d, *J* = 15.5 Hz, 1H), 3.86 (t, *J* = 6.5 Hz, 2H), 2.53 (q, *J* = 7.0 Hz, 2H), 1.13 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 191.9, 154.6, 151.7, 138.2, 135.7, 134.0, 132.9, 129.9, 129.8, 129.8, 129.0, 128.8, 128.4, 128.4, 127.8, 127.5, 122.5, 119.5, 110.1, 63.5, 36.3, 27.0, 19.4. HRMS (ESI): calcd for $C_{37}H_{36}O_3SiNa^+$ $[M+Na]^+$ 579.2326, found 579.2329.

ethyl *(E)*-5-(4-((tert-butyldiphenylsilyl)oxy)but-1-en-1-yl)-2-methylfuran-3-carboxylate(2o)



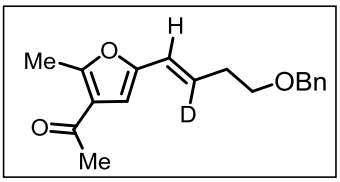
New compound, was synthesized according to the general procedure B. The product was obtained by condition B in 351.6 mg, yield 76% with 7600 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 30：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77-7.71 (m, 4H), 7.49-7.35 (m, 6H), 6.42 (s, 1H), 6.25-6.16 (m, 2H), 4.33 (q, *J* = 7.5 Hz, 2H), 3.83 (t, *J* = 6.5 Hz, 2H), 2.62 (s, 3H), 2.48 (q, *J* = 4.5 Hz, 2H), 1.38 (t, *J* = 7.5 Hz, 3H), 1.13 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.1, 158.2, 151.0, 135.7, 133.9, 129.7, 127.7, 126.9, 119.7, 114.9, 106.8, 63.5, 60.1, 36.2, 26.9, 19.3, 14.4, 13.9. HRMS (ESI): calcd for $C_{28}H_{34}O_4SiNa^+$ $[M+Na]^+$ 485.2119, found 485.2120.

ethyl *(E)*-5-(4-((tert-butyldiphenylsilyl)oxy)but-1-en-1-yl)-2-phenylfuran-3-carboxylate(2p)



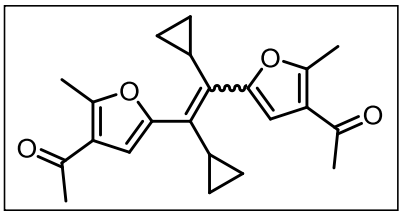
New compound, was synthesized according to the general procedure B. The product was obtained by condition B in 446.0 mg, yield 85% with 8500 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07-8.02 (m, 2H), 7.71 (dd, *J* = 7.8, 1.7 Hz, 4H), 7.50-7.34 (m, 9H), 6.60 (s, 1H), 6.37-6.30 (m, 1H), 6.26 (d, *J* = 16.0 Hz, 1H), 4.33 (q, *J* = 7.1 Hz, 2H), 3.83 (t, *J* = 6.5 Hz, 2H), 2.50 (q, *J* = 6.5 Hz, 2H), 1.36 (t, *J* = 7.1 Hz, 3H), 1.10 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.7, 156.1, 151.7, 135.7, 134.0, 130.0, 129.8, 129.3, 128.6, 128.4, 128.2, 127.8, 119.6, 115.4, 109.2, 63.5, 60.6, 36.3, 27.0, 19.4, 14.4. HRMS (ESI): calcd for $C_{33}H_{36}O_4SiNa^+$ $[M+Na]^+$ 547.2275, found 547.2278.

***(E)*-1-(5-(5-(benzyloxy)pent-1-en-1-yl-2-d)-2-methylfuran-3-yl)ethan-1-one(2q)**



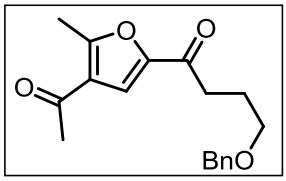
New compound, was synthesized according to the general procedure B. The product was obtained by condition A in 47.3 mg, yield 79%. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.28 (m, 5H), 6.33 (s, 1H), 6.20-6.16 (m, 1H), 4.54 (s, 2H), 3.58 (t, *J* = 6.6 Hz, 2H), 2.58 (s, 3H), 2.49 (td, *J* = 6.6, 1.7 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.3, 157.7, 150.8, 138.4, 128.5, 127.8, 127.7, 122.8, 119.3, 106.6, 73.1, 69.5, 33.2, 29.2, 14.5. HRMS (ESI): calcd for $C_{18}H_{19}DO_3^+$ $[M+H]^+$ 286.1548, found 286.1547.

1,1'-((1,2-dicyclopropylethene-1,2-diyl)bis(2-methylfuran-5,3-diyl))bis(ethan-1-one) (2r)



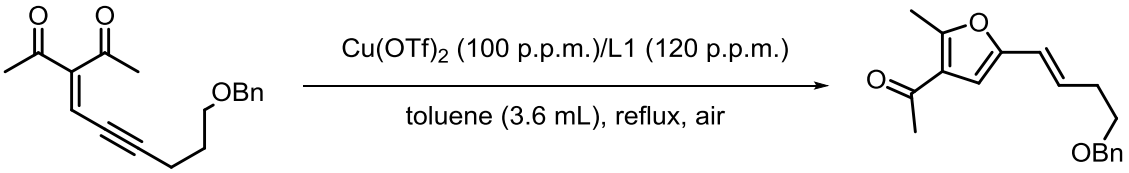
Reported compound,[1] was synthesized according to the general procedure B. The product was obtained by condition A in 34.7 mg, yield 99% (E:Z=1:1); condition B in 172.4 mg, yield 98% (E:Z=1:1) with 9800 TONs. Isolated by column chromatography (hexanes/ethyl acetate = 15：1), yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.61 (s, 1H), 6.24 (s, 1H), 2.59 (s, 3H), 2.41 (s, 6H), 2.31 (s, 3H), 2.04-1.94 (m, 1H), 1.77-1.68 (m, 1H), 0.91-0.85 (m, 2H), 0.70-0.64 (m, 2H), 0.59-0.53 (m, 2H), 0.36-0.29 (m, 2H).

1-(4-acetyl-5-methylfuran-2-yl)-4-(benzyloxy)butan-1-one (3a)



Reported compound,[1] was synthesized according to the general procedure A without **L1**. Isolated by column chromatography (hexanes/ethyl acetate = 8：1) in 58.2 mg, 97%, yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36 (s, 1H), 7.35-7.29 (m, 4H), 7.29-7.26 (m, 1H), 4.48 (s, 2H), 3.55 (t, *J* = 6.0 Hz, 2H), 2.91 (t, *J* = 7.2 Hz, 2H), 2.66 (s, 3H), 2.42 (s, 3H), 2.07-2.00 (m, 2H).

5. A Gram-Scale Synthesis of 2-Alkenylfuran 2a from 1a:

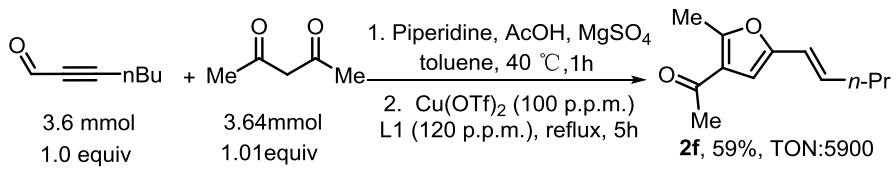


1a, 1.0 g, 3.6 mmol

2a, 895.5 mg, 87%
TON:8700

General procedure C: An oven-dried flask (200 mL) was charged with $Cu(OTf)_2$ (1.8 mg) and **L1** (2.3 mg) in acetone (100 mL) and stirred at room temperature for 1 h. The solution (7.2 mL) was added to the reaction flask with a syringe and was concentrated under vacuum. The solution of **1a** (1.0 g, 3.6 mmol, 1.0 eq) in toluene (3.6 mL) was added to the flask. The resulting mixture was refluxed for 7 h, and the progress of the reaction was monitored by TLC. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel (eluant: hexanes/ethyl acetate = 15:1) to afford the desired product **2a** (895.5 mg) in 87% yield as a yellow liquid.

6. A One-Pot Synthesis of 2f from Hept-2-ynal:



3.6 mmol
1.0 equiv

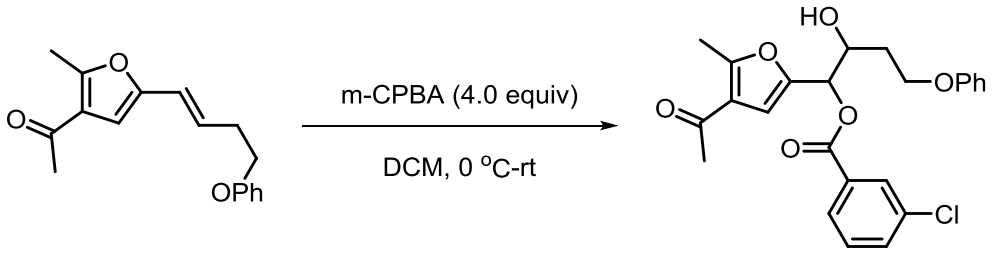
3.64mmol
1.01equiv

2f, 59%, TON:5900

General procedure D: Hept-2-ynal (396.6 mg, 3.6 mmol, 1.0 eq) was added to a mixture of HOAc (129.7 mg, 2.2 mmol, 0.6 eq), piperidine (30.7 mg, 0.36 mmol, 0.1 eq) and acetylacetone

(364.0 mg, 3.64 mmol, 1.01 eq) in toluene (12 mL). $MgSO_4$ (86.7 mg, 0.72 mmol, 0.2 eq) was introduced and the suspension was stirred at 40℃ for 1 h. Then $Cu(OTf)_2$ (0.13 mg) and **L1** (0.14 mg) were added to the reaction. The resulting mixture was refluxed for about 5 hours, and the progress of the reaction was monitored by TLC. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel (eluant: hexanes/ethyl acetate = 15:1) to afford the desired product **2f** (408.4 mg) in 59% yield.

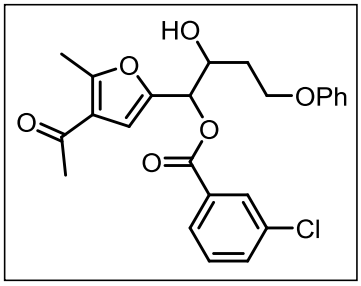
7. Synthesis of 1-(4-acetyl-5-methylfuran-2-yl)-1-hydroxy-4-phenoxybutan-2-yl 3-chlorobenzoate(4a)[3]:



2b **4a**

General procedure E: To a DCM (5 mL) solution of *(E)*-1-(2-methyl-5-(4-phenoxybut-1-en-1-yl)furan-3-yl)ethan-1-one **2b** (135.2 mg, 0.5 mmol, 1.0 eq) was added a m-CPBA (138.1 mg, 2 mmol, 4.0 eq) at 0℃ and the reaction is stirred at room temperature for 2 h. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by chromatography on silica gel (eluant: hexanes/ethyl acetate = 4:1) to afford the desired product **4a** (143.9 mg, 0.33 mmol) in 65% yield as a yellow liquid.

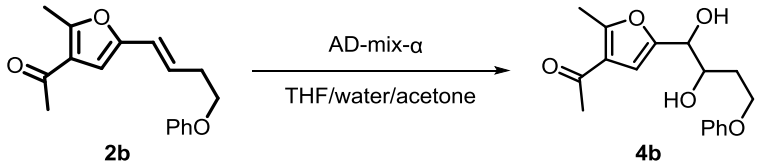
1-(4-acetyl-5-methylfuran-2-yl)-1-hydroxy-4-phenoxybutan-2-yl 3-chlorobenzoate(4a)



New compound, was synthesized according to the general procedure E. Isolated by column chromatography (hexanes/ethyl acetate = 3：1) in 143.9 mg, 65%, yellow liquid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (t, *J* = 1.5 Hz, 1H), 7.96 (dt, *J* = 8.0, 1.5 Hz, 1H), 7.55 (d, *J* = 8.0 Hz, 1H), 7.39 (t, *J* = 8.0 Hz, 1H), 7.29 (d, *J* = 7.8 Hz, 2H), 6.95 (t, *J* = 7.5 Hz, 1 H), 6.90 (d, *J* = 8.0 Hz, 2H), 6.73 (s, 1H), 6.01 (d, *J* = 7.0 Hz, 1H), 4.54 (s, 1H), 4.25-4.19 (m, 1H), 4. 18-4.11 (m, 1H), 2.68 (s, 1H), 2.57 (s, 3H), 2.38 (s, 3H), 2.03-1.90 (m, 2H). ^{13}C NMR (126 MHz, CD Cl_3) δ 193.9, 164.7, 159.1, 158.6, 147.9, 134.8, 133.6, 131.5, 130.0, 129.7, 128.1, 122.2, 121.2, 114.6, 111.2, 72.8, 69.6, 64.6, 32.6, 29.2, 14.6. HRMS (ESI): calcd for $C_{24}H_{23}ClO_6Na^+$ $[M+Na]^+$ 465.1075,

found 465.1076.

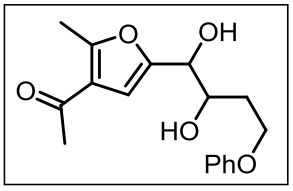
8. Synthesis of 1-(5-(1,2-dihydroxy-4-phenoxybutyl)-2-methylfuran-3-yl)ethan-1-one(4b)[4]:



2b **4b**

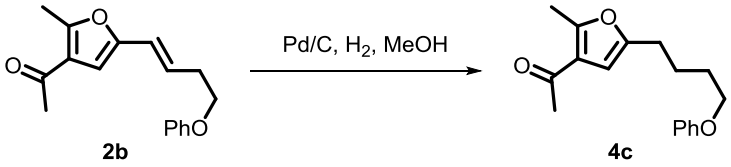
General procedure F: A solution of **2b** (135.2 mg, 0.5 mmol, 1.0 eq), from above, in THF (0.2 mL) was added dropwise to a stirred suspension of comcerical AD-mix-α (840 mg, 0.6 mmol, 1.2 eq) in 1:1:1 water:THF:acetone (3.6 mL) and the mixture was then stirred at room temperature overnight. The mixture was quenched with sat. Na_2SO_3 solution (2 mL) and then extracted with EtOAc (3 x 3 mL), The combinded organic extracts were washed with sat. Na_2SO_3 solution and brine, and then dried over $MgSO_4$. The solvents were removed in vacuo and the residue was purified by flash chromatography on silica gel (eluant: petroleum ether:diethyl ether = 2:1 to Et_2O) to give the title compound **4b** as a white solid (129.3 mg, 85%).

1-(5-(1,2-dihydroxy-4-phenoxybutyl)-2-methylfuran-3-yl)ethan-1-one(4b)



New compound, was synthesized according to the general procedure F. Isolated by column chromatography (hexanes/ethyl acetate = 1：1) in 129.3 mg, 85%, white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (t, *J* = 8.0 Hz, 2H), 6.94 (t, *J* = 7.2 Hz, 1H), 6.87 (d, *J* = 8.0 Hz, 2H), 4.51 (t, *J* = 5.6 Hz, 1H), 4.23-4.05 (m, 3H), 3.58 (d, *J* = 5.2 Hz, 1H), 3.39 (d, *J* = 4.0 Hz, 1H), 2.53 (s, 3H), 2.34 (s, 3H), 2.00-1.89 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.5, 158.5, 151.9, 129.6, 122.0, 121.1, 114.5, 108.4, 70.9, 70.8, 64.9, 32.6, 29.2, 14.5. HRMS (ESI): calcd for $C_{17}H_{20}O_5Na^+$ $[M+Na]^+$ 327.1203, found 327.1202.

9. Synthesis of 1-(2-methyl-5-(4-phenoxybutyl)furan-3-yl)ethan-1-one(4c)[5]:

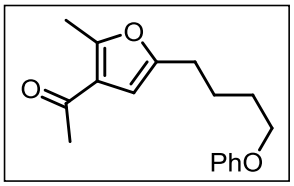


2b **4c**

General procedure G: A solution of **2b** (135.2 mg, 0.5 mmol 1.0 eq) in methanol (1 mL) was added Pd/C (10 %, 7.0 mg, 0.05 mmol, 0.1 eq) in methanol (4 mL). The flask was evacuated, placed under an hydrogen atmosphere (balloon) and stirred for 3 h at rt. The mixture was then filtered over

celite and the filter cake was washed several times with methanol. The solvents were removed in vacuo and the residue was purified by flash chromatography on silica gel (eluant: hexanes/ethyl acetate = 10:1) to give the title compound **4c** (129.4 mg, 0.48 mmol, 95%) as a yellow liquid .

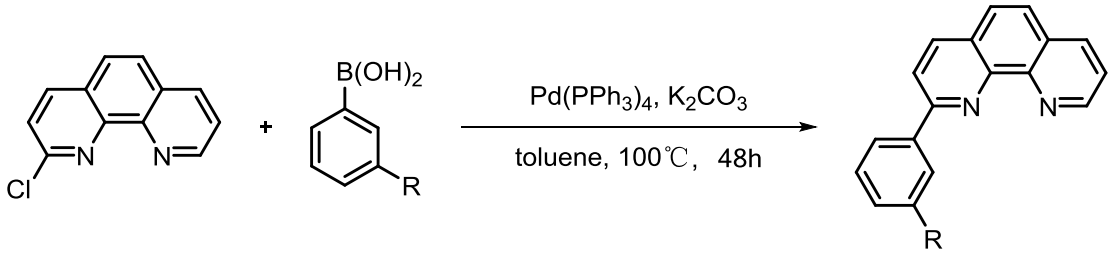
1-(2-methyl-5-(4-phenoxybutyl)furan-3-yl)ethan-1-one(4c)



New compound, was synthesized according to the general procedure G. Isolated by column chromatography (hexanes/ethyl acetate = 10：1) in 129.4 mg, 95%, yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (t, *J* = 8.8 Hz, 2H), 6.94 (t, *J* = 7.3 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 2H), 6.23 (s, 1H), 3.98 (t, *J* = 5.7 Hz, 2H), 2.65 (t, *J* = 6.6 Hz, 2H), 2.55 (s, 3H), 2.37 (s, 3H), 1.90-1.73 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.5, 159.0, 157.1, 153.8, 129.6, 122.1, 120.7, 114.5, 105.7, 67.4, 29.2, 28.7, 27.5, 24.5, 14.5. HRMS (ESI): calcd for $C_{17}H_{20}O_3Na^+$ $[M+Na]^+$ 295.1305, found 295.1309.

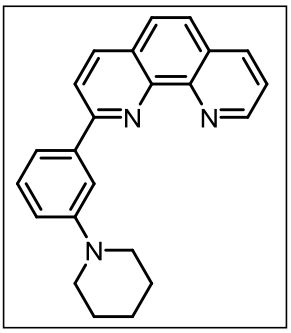
10. Synthesis of Ligands:

Ligands **L1-L4, L7, L9** are known in the literature[6].



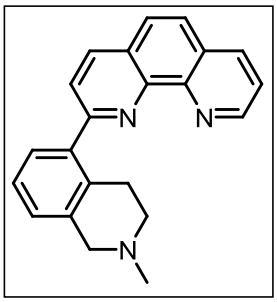
General procedure H: An oven-dried flask (25 mL) was charged with 3-chlorophenanthrene (214.0 mg, 1.0 mmol, 1.1 eq) and phenylboronic acid (0.92 mmol, 1.0 eq). The mixture was dissolved in toluene (8 mL) and purged with N_2 for 10 min. Aq. K_2CO_3 (1M, 4 mL) was added under N_2 purging, followed by $Pd(PPh_3)_4$ (53.2 mg, 5 mol%). After purging with N_2 for an additional 10 min, the pressure tube was closed and heated at 100℃ for 48 h. Upon cooling to room temperature, the reaction mixture was filtered to remove insoluble impurities. The filtrate was then extracted with CH_2Cl_2 (3×5 mL). The organic layers were collected, dried over Na_2SO_4 purified by chromatography on neutral Al_2O_3 (eluant: hexanes/ethyl acetate = 1:1) to give product.

1-(3-(phenanthren-3-yl)phenyl)piperidine (L4)



New compound, was synthesized according to the general procedure H. Isolated by column chromatography (hexanes/ethyl acetate = 1：1) in 133.5 mg, 43%, yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.20 (dd, *J* = 4.4, 1.6 Hz, 1H), 8.23 (d, *J* = 8.4 Hz, 1H), 8.20 (dd, *J* = 8.0, 1.6 Hz, 1H), 8.03 (d, *J* = 8.4 Hz, 1H), 7.87 (t, *J* = 2.0 Hz, 1H), 7.78-7.68 (m, 3H), 7.59 (dd, *J* = 8.0, 4.4 Hz, 1H), 7.40 (t, *J* = 8.4 Hz, 1H), 7.07-7.02 (m, 1H), 3.29 (t, *J* = 5.2 Hz, 4H), 1.81-1.69 (m, 4H), 1.64-1.54 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.5, 152.9, 150.3, 146.5, 146.1, 140.7, 136.7, 136.1, 129.4, 129.1, 127.5, 126.4, 126.1, 122.9, 121.1, 119.3, 117.7, 116.2, 50.9, 26.0, 24.4. HRMS (ESI): calcd for $C_{13}H_{22}N_3^+$ $[M+H]^+$ 340.1808, found 340.1807.

2-(2-methyl-1,2,3,4-tetrahydroisoquinolin-5-yl)-1,10-phenanthroline (L5)



New compound, was synthesized according to the general procedure H. Isolated by column chromatography (hexanes/ethyl acetate = 1：1) in 163.7 mg, 55%, yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.16 (d, *J* = 4.5 Hz, 1H), 8.21 (dd, *J* = 15.0, 8.1 Hz, 2H), 7.76 (q, *J* = 8.7 Hz, 2H), 7.66 (d, *J* = 8.5 Hz, 1H), 7.57 (dd, *J* = 8.1, 4.3 Hz, 1H), 7.37 (d, *J* = 7.5 Hz, 1H), 7.20 (t, *J* = 7.5 Hz, 1H), 7.05 (d, *J* = 7.5 Hz, 1H), 3.64 (s, 2H), 2.96 (t, *J* = 6.0 Hz, 2H), 2.60 (t, *J* = 6.0 Hz, 2H), 2.41 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.4, 150.6, 146.5, 146.1, 141.1, 136.1, 136.1, 135.2, 132.1, 129.0, 128.3, 127.3, 126.9, 126.5, 125.8, 124.3, 123.0, 58.6, 53.1, 46.1, 28.0. HRMS (ESI): calcd for $C_{22}H_{19}N_3Na^+$ $[M+Na]^+$ 348.1471, found 348.1474.

Reference

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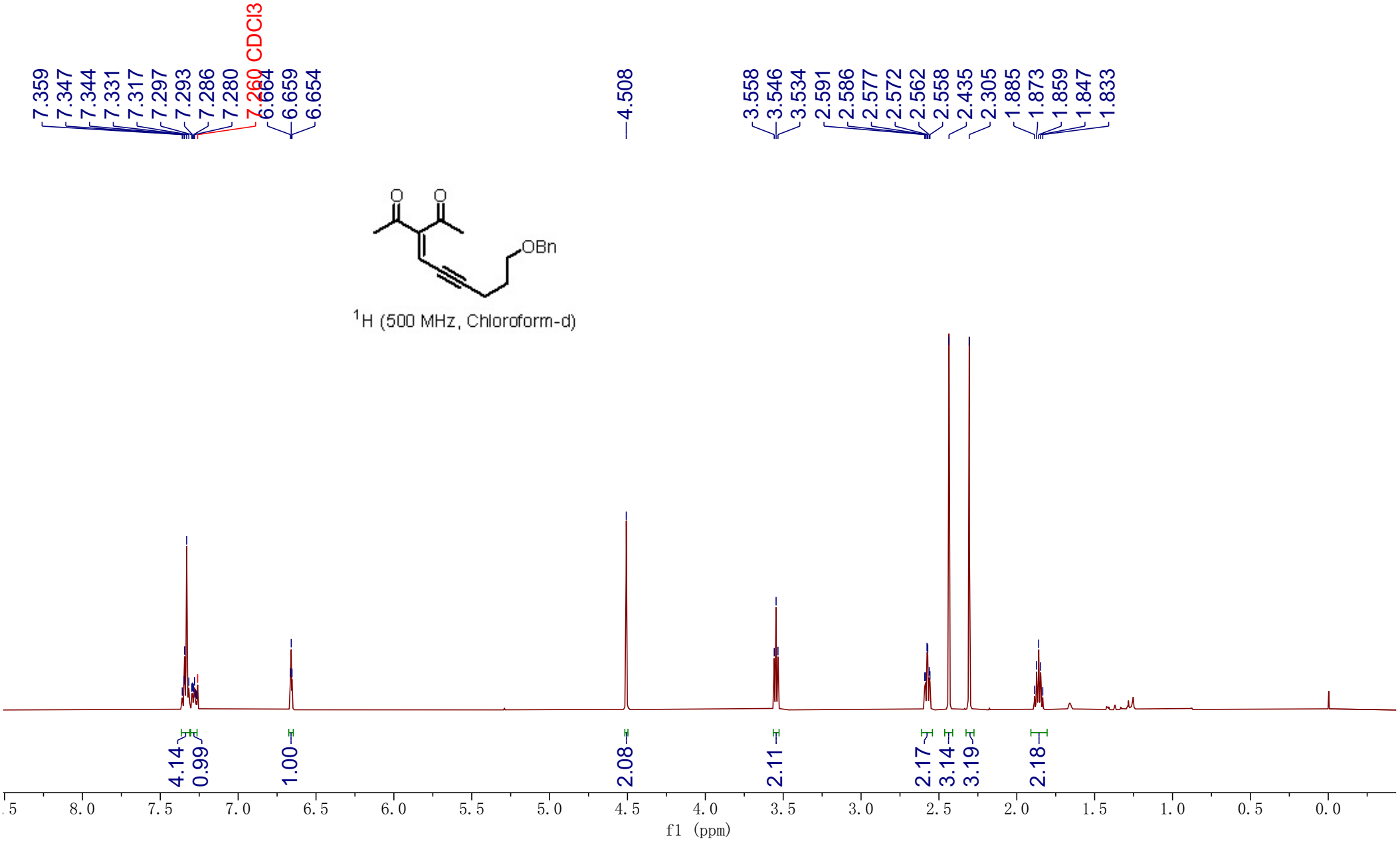
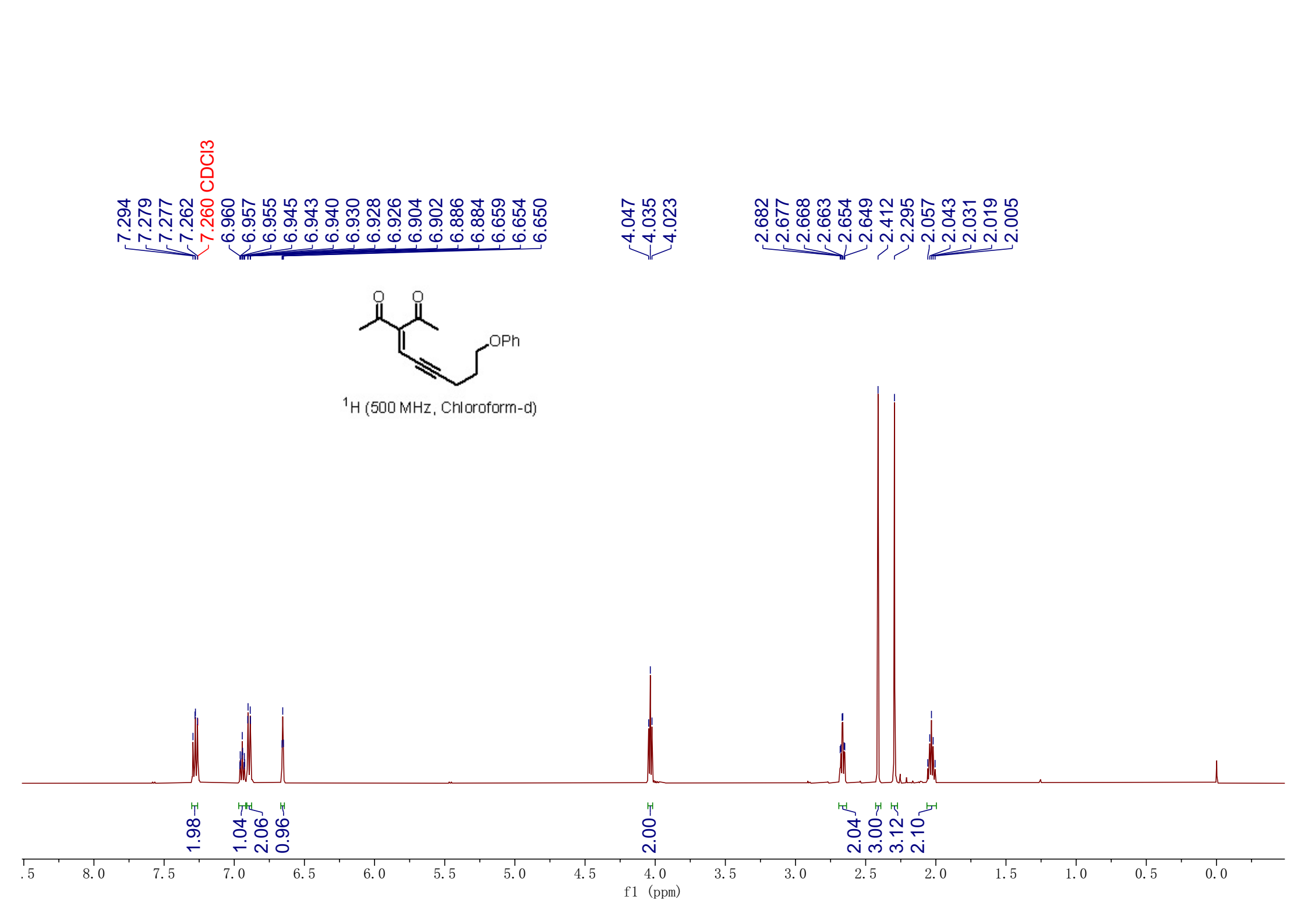
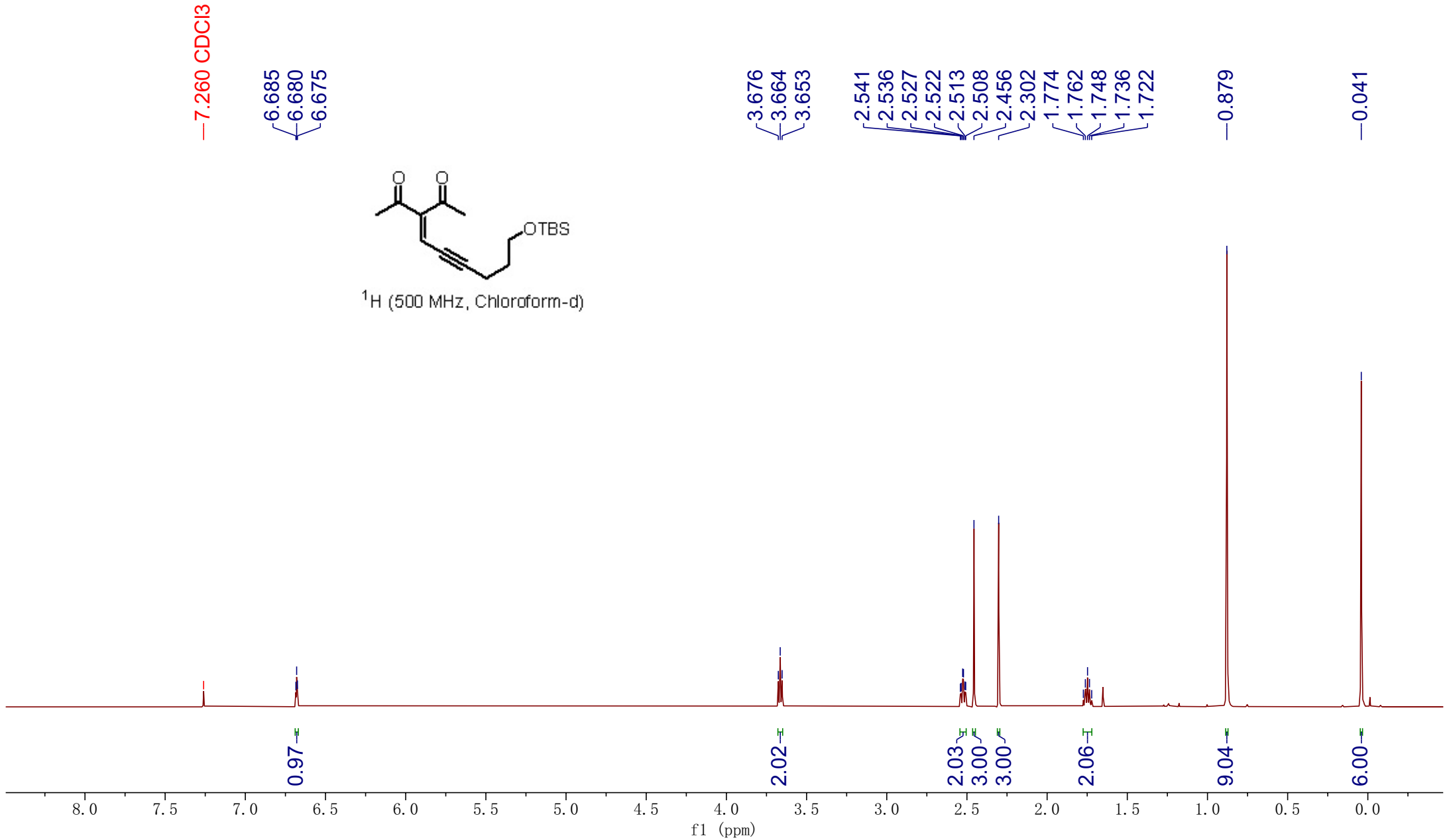
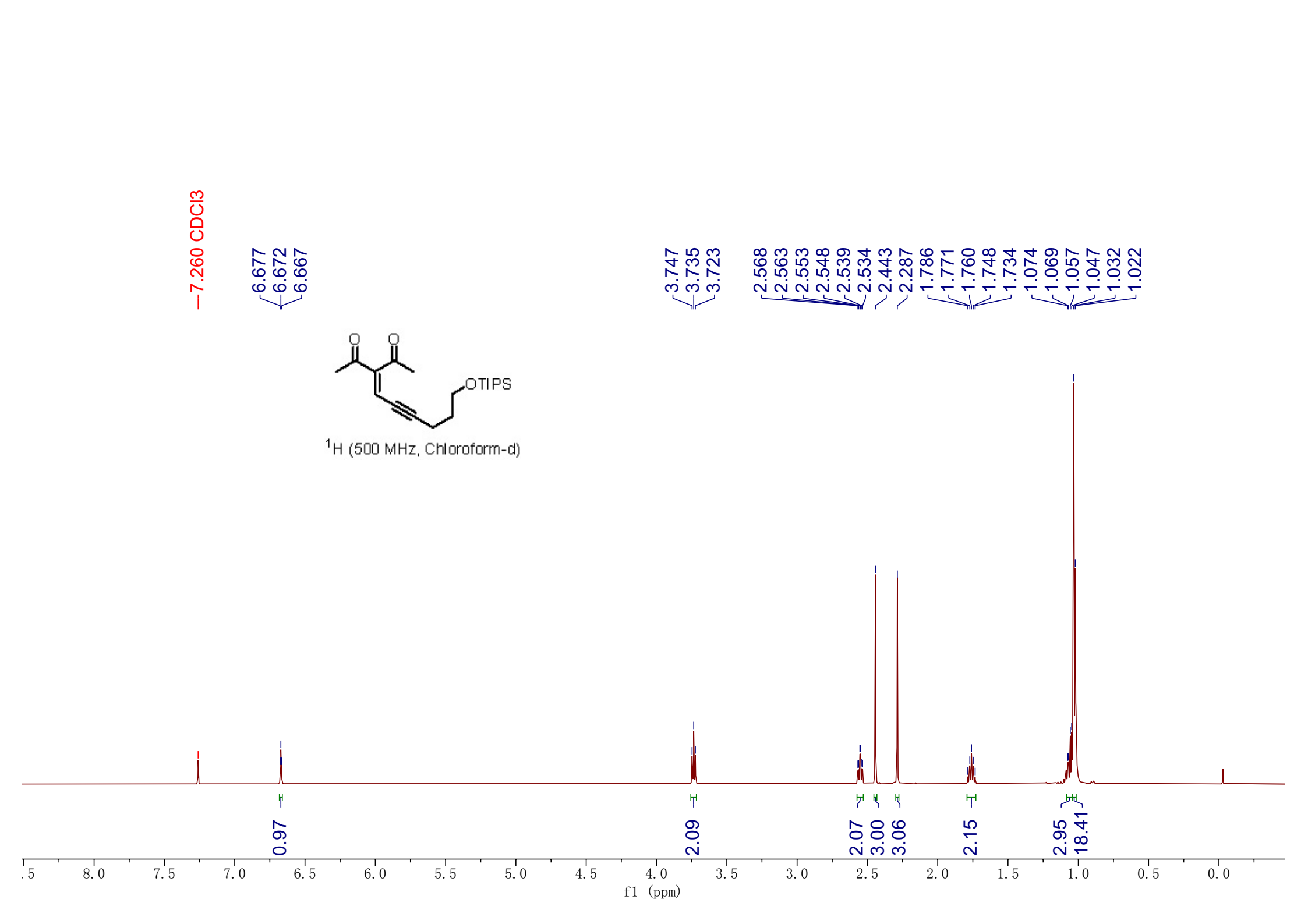
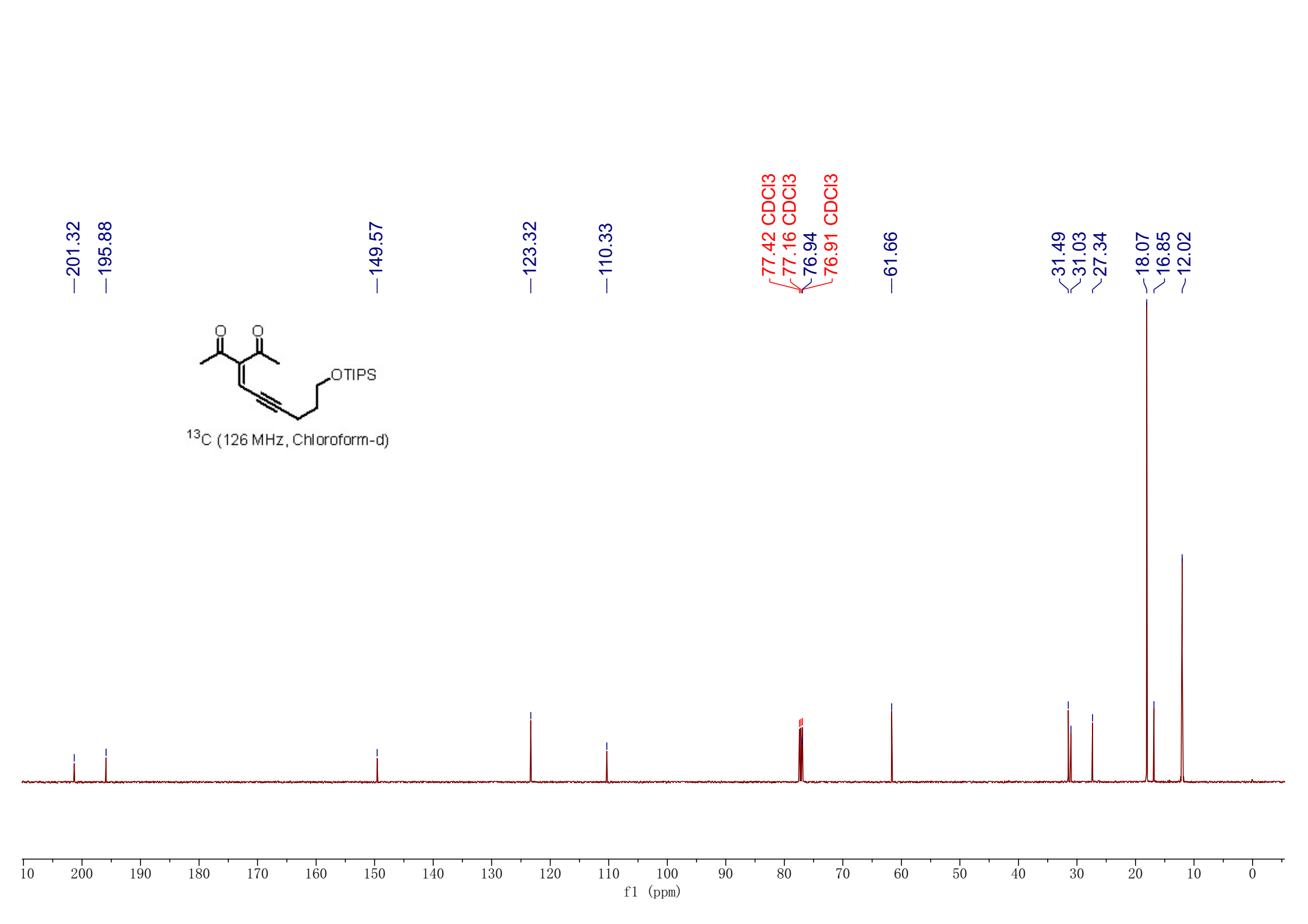
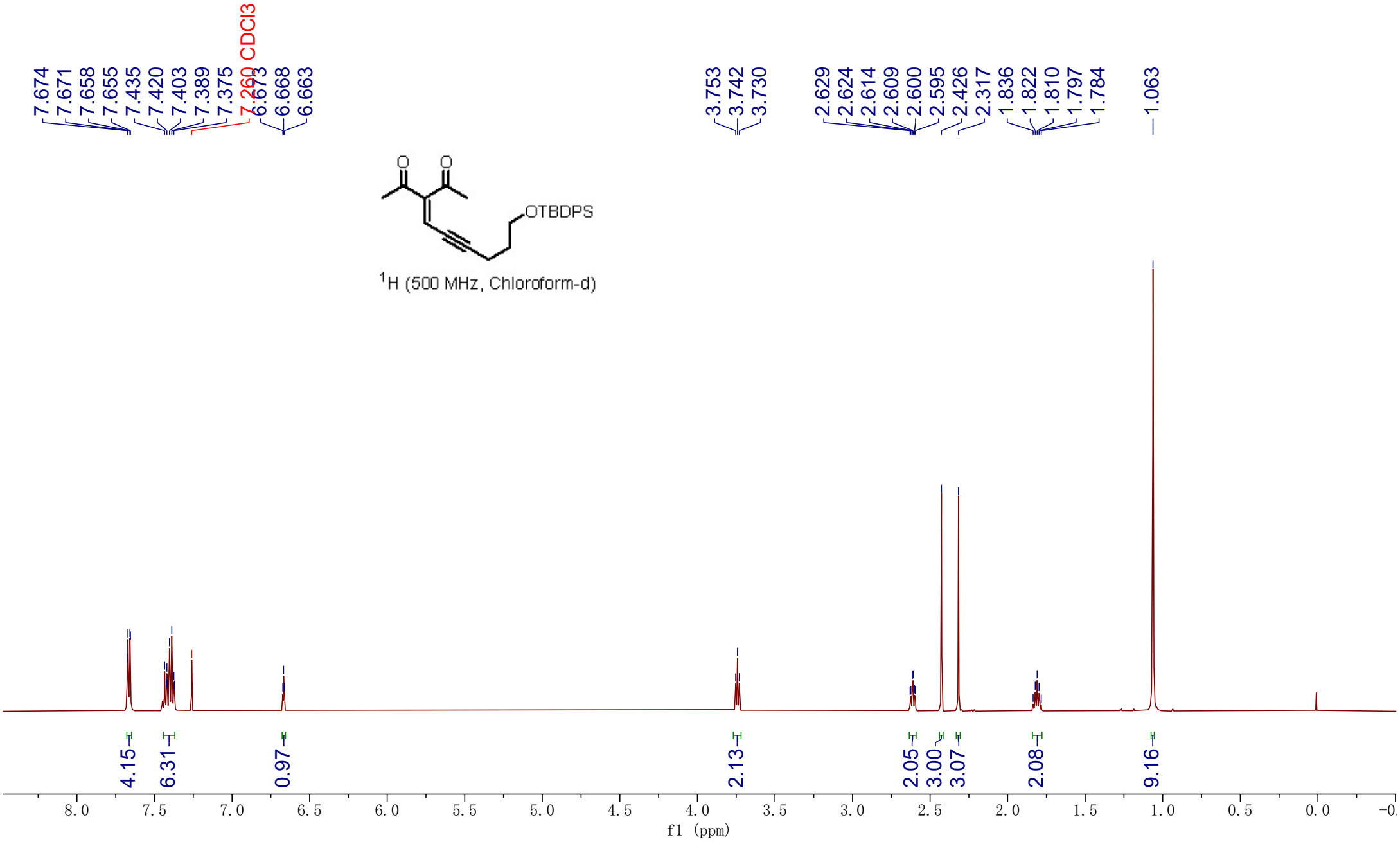

7.359
7.347
7.344
7.331
7.317
7.297
7.293
7.286
7.280
7.260 CDCl3
6.664
6.659
6.654
4.508
3.558
3.546
3.534
2.591
2.586
2.577
2.572
2.562
2.558
2.435
2.305
1.885
1.873
1.859
1.847
1.833
O
O
OBn
1H (500 MHz, Chloroform-d)
4.14
0.99
1.00
2.08
2.11
2.17
3.14
3.19
2.18
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

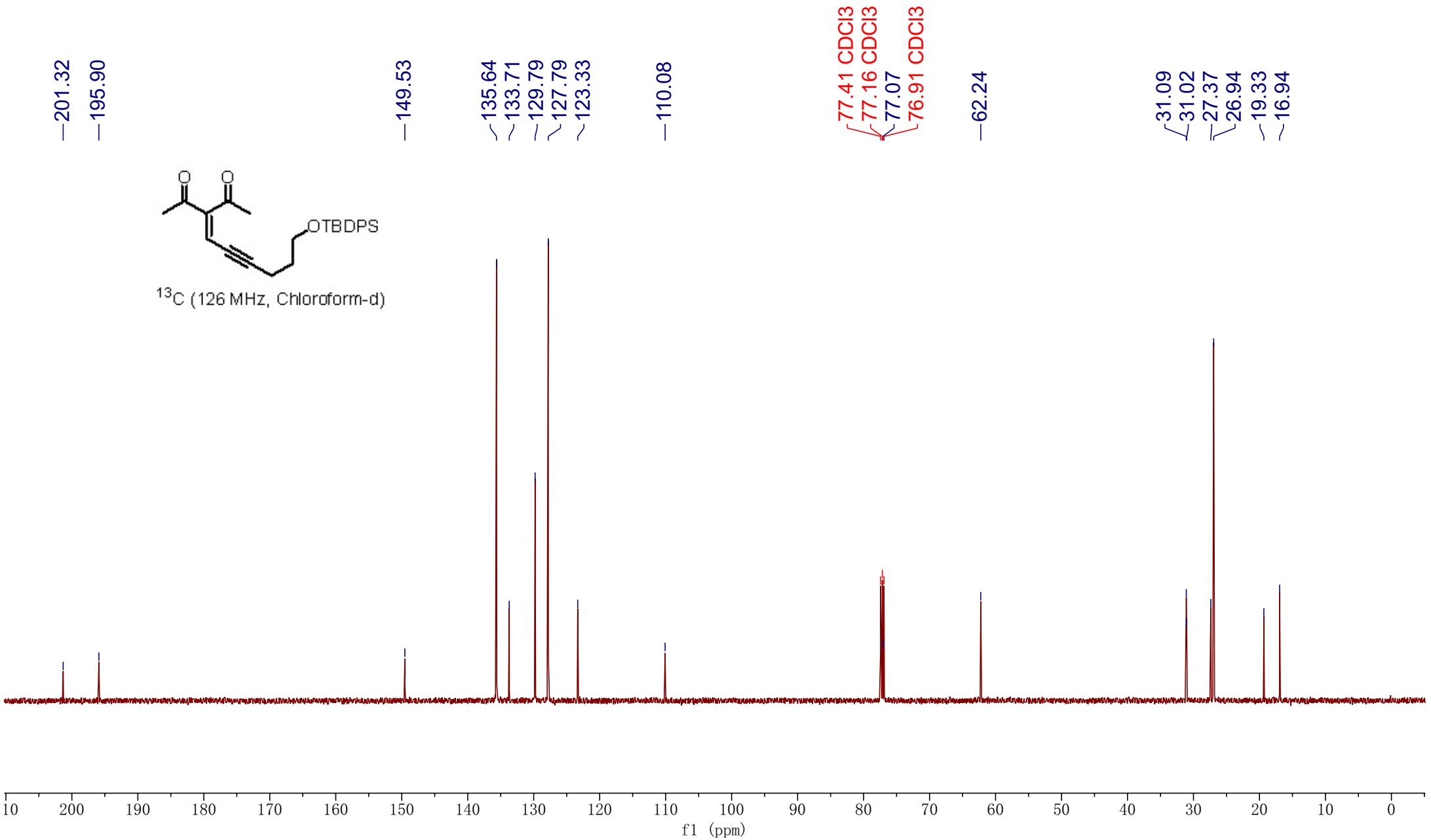

7.294
7.279
7.277
7.262
7.260 CDCl3
6.960
6.957
6.955
6.945
6.943
6.940
6.930
6.928
6.926
6.904
6.902
6.886
6.884
6.659
6.654
6.650
4.047
4.035
4.023
2.682
2.677
2.668
2.663
2.654
2.649
2.412
2.295
2.057
2.043
2.031
2.019
2.005
O
O
OPh
1H (500 MHz, Chloroform-d)
1.98
1.04
2.06
0.96
2.00
2.04
3.00
3.12
2.10
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


7.260 CDCl3
6.685
6.680
6.675
3.676
3.664
3.653
2.541
2.536
2.527
2.522
2.513
2.508
2.456
2.302
1.774
1.762
1.748
1.736
1.722
0.879
0.041
OTBS
1H (500 MHz, Chloroform-d)
0.97
2.02
2.03
3.00
3.00
2.06
9.04
6.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


7.260 CDCl3
6.677
6.672
6.667
3.747
3.735
3.723
2.568
2.563
2.553
2.548
2.539
2.534
2.443
2.287
1.786
1.771
1.760
1.748
1.734
1.074
1.069
1.057
1.047
1.032
1.022
O
O
OTIPS
1H (500 MHz, Chloroform-d)
0.97
2.09
2.07
3.00
3.06
2.15
2.95
18.41
f1 (ppm)


201.32
195.88
149.57
123.32
110.33
77.42 CDCl3
77.16 CDCl3
76.94
76.91 CDCl3
61.66
31.49
31.03
27.34
18.07
16.85
12.02
O
O
OTIPS
13C (126 MHz, Chloroform-d)
f1 (ppm)


7.674
7.671
7.658
7.655
7.435
7.420
7.403
7.389
7.375
7.260 CDCl3
6.673
6.668
6.663
3.753
3.742
3.730
2.629
2.624
2.614
2.609
2.600
2.595
2.426
2.317
1.836
1.822
1.810
1.797
1.784
1.063
O
O
OTBDPS
1H (500 MHz, Chloroform-d)
4.15
6.31
0.97
2.13
2.05
3.00
3.07
2.08
9.16
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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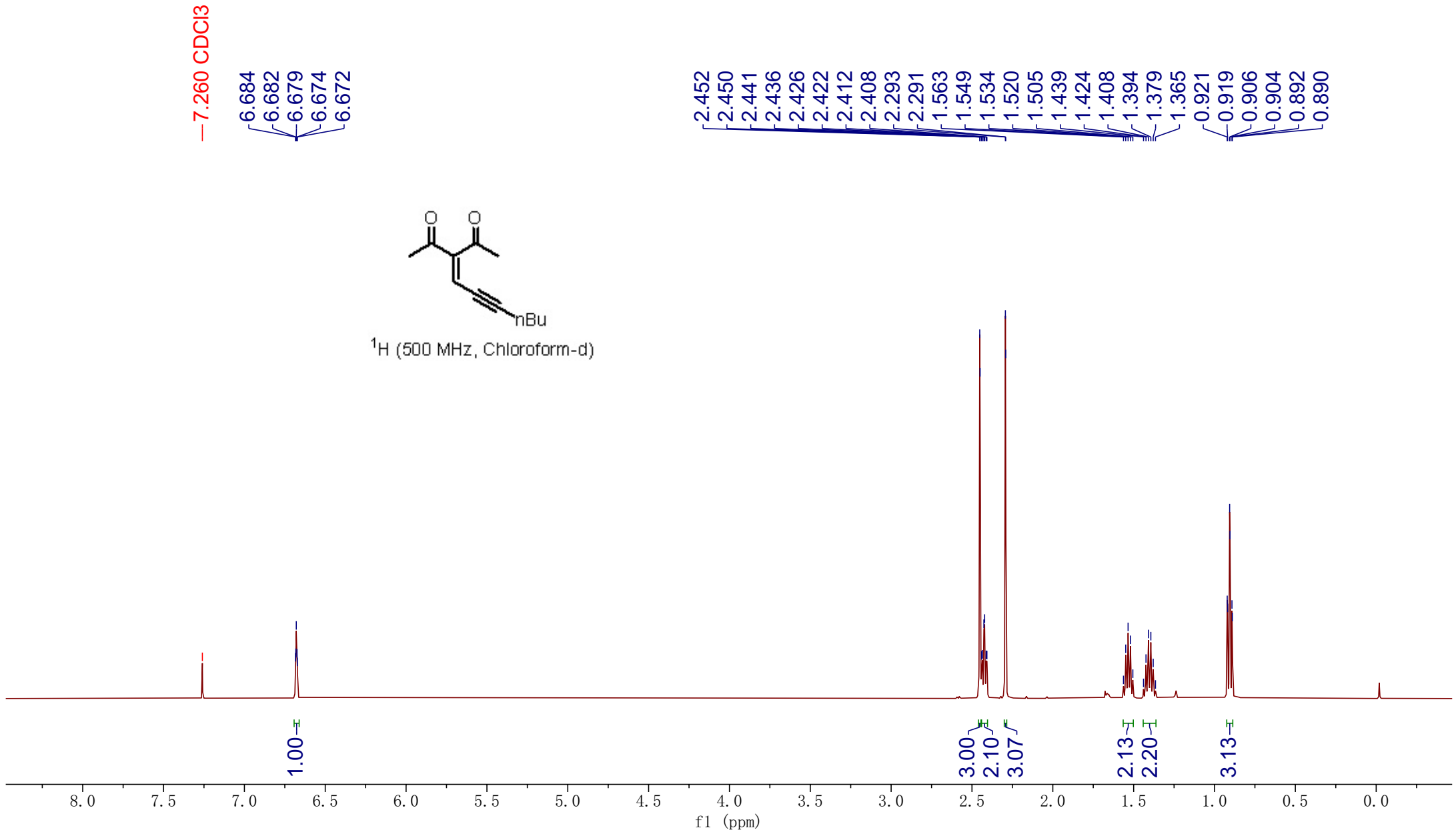
195.90
149.53
135.64
133.71
129.79
127.79
123.33
110.08
77.41 CDCl3
77.16 CDCl3
77.07
76.91 CDCl3
62.24
31.09
31.02
27.37
26.94
19.33
16.94
OTBDPS
13C (126 MHz, Chloroform-d)
f1 (ppm)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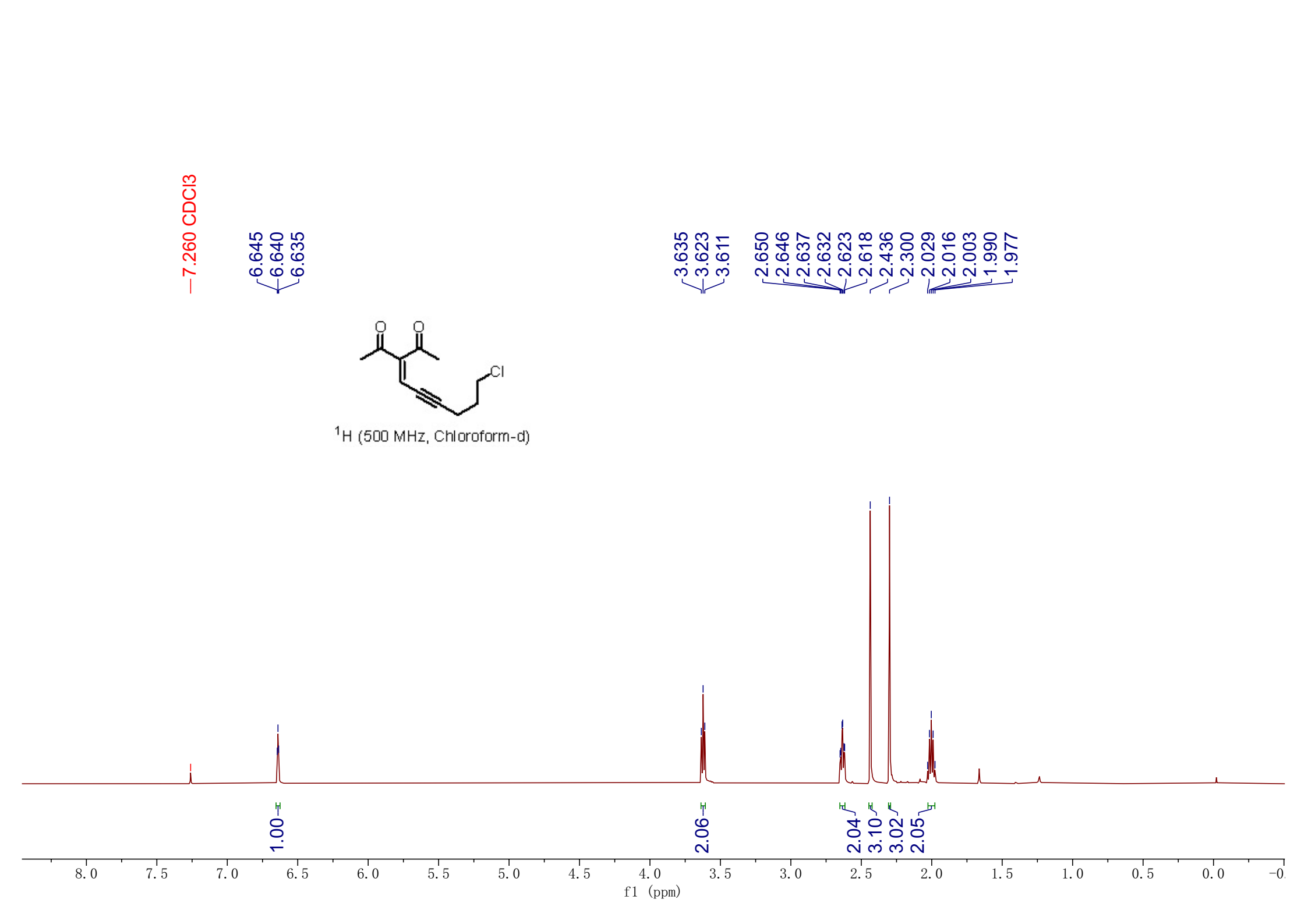
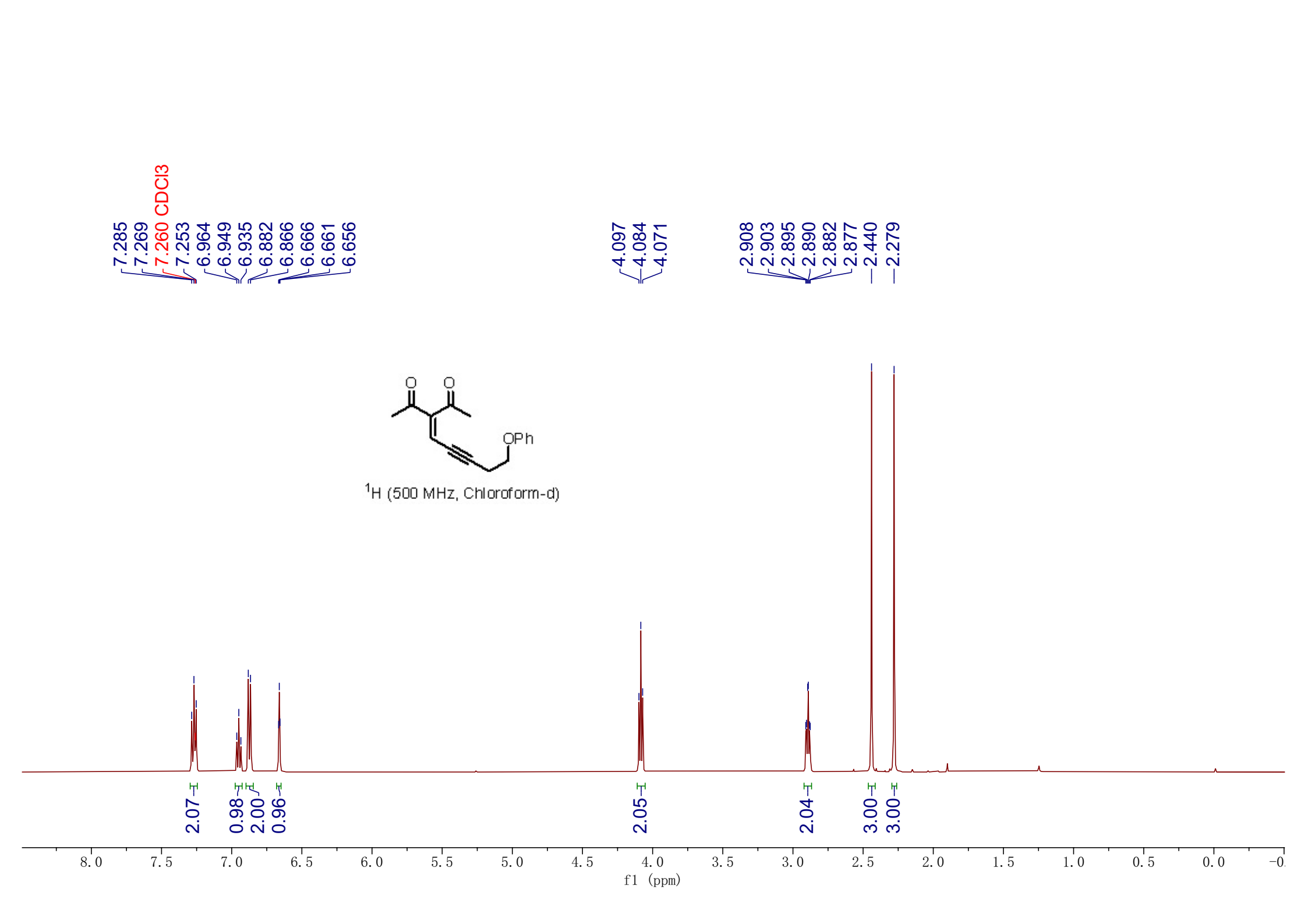
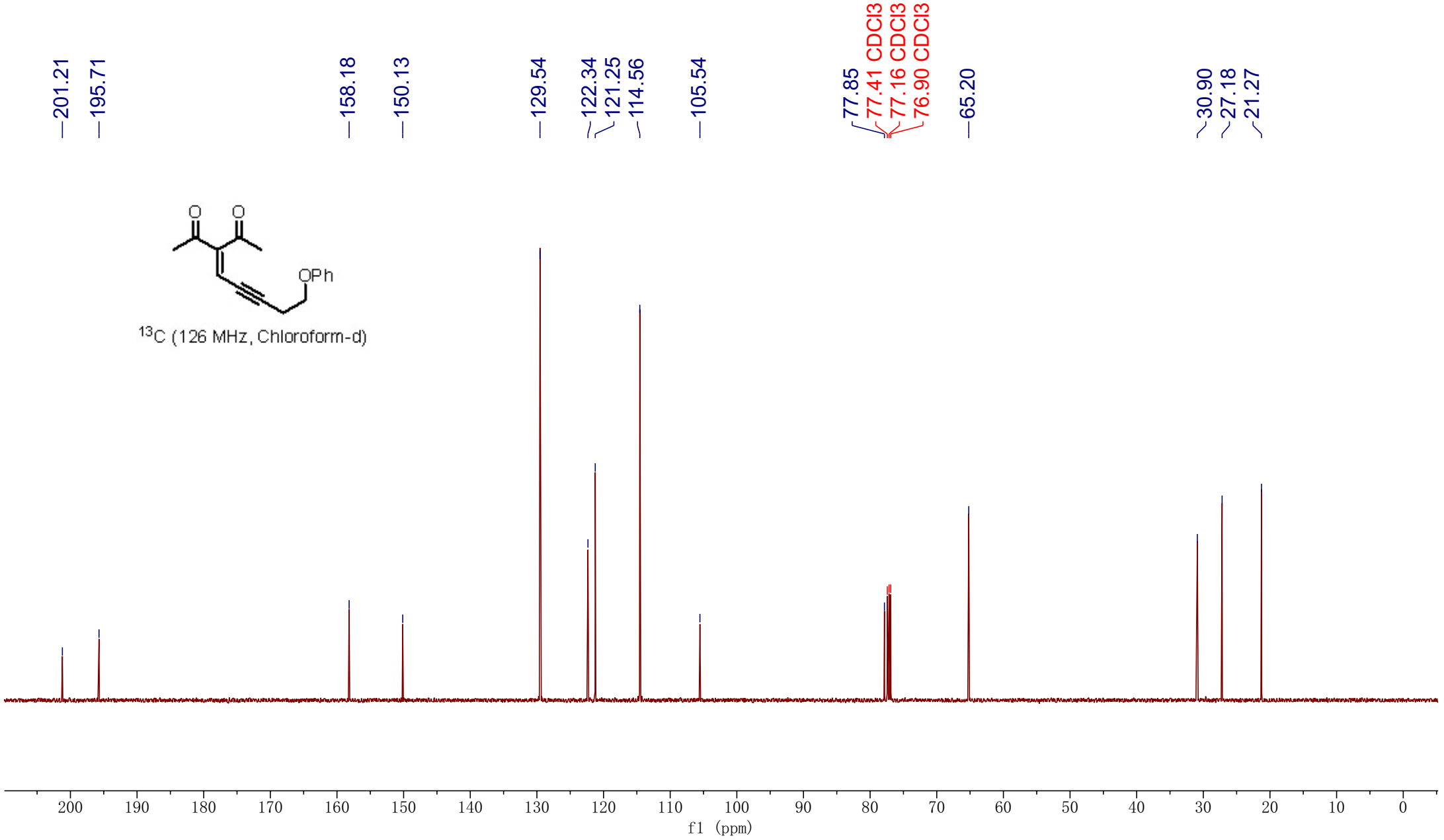
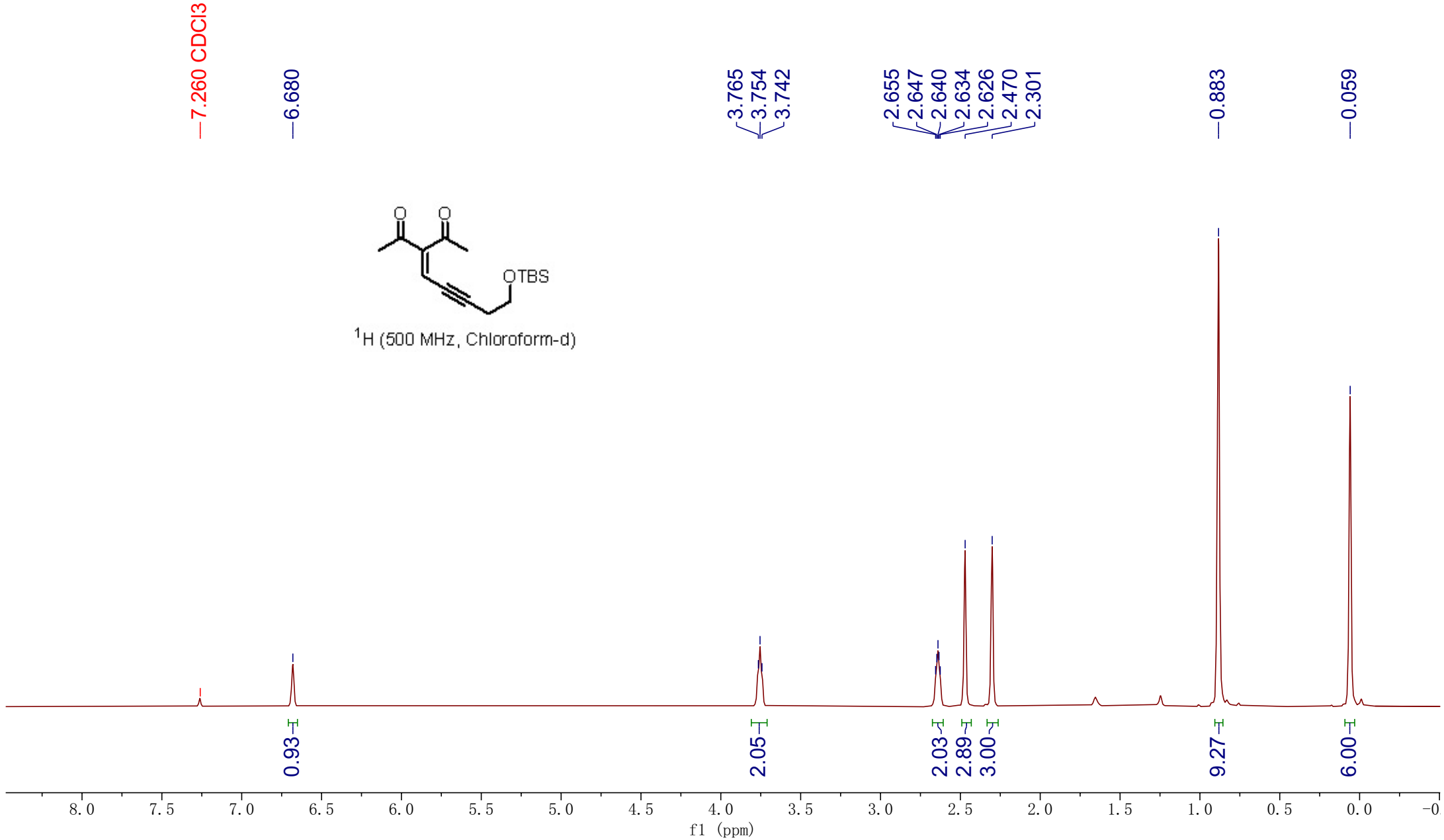
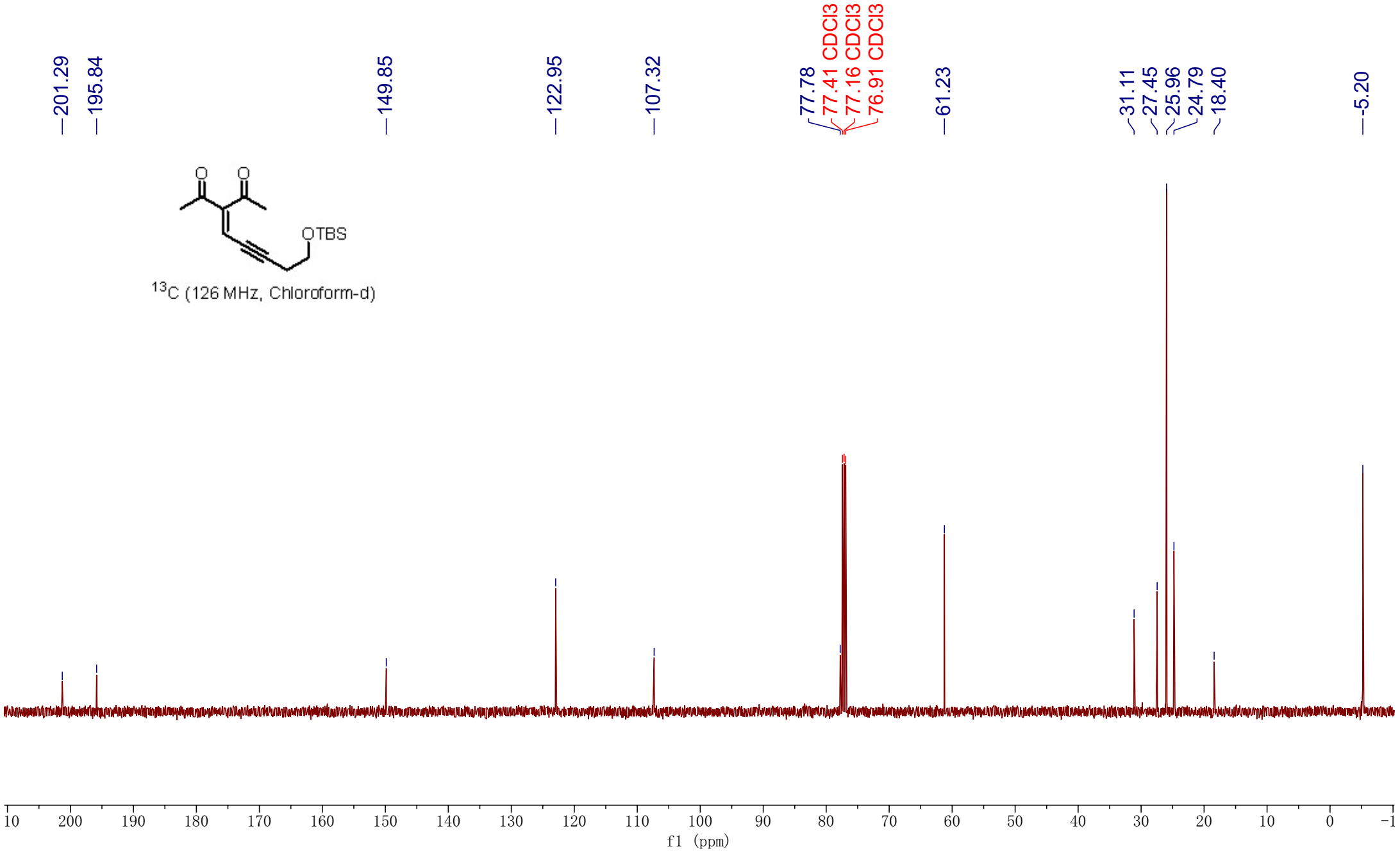
6.684
6.682
6.679
6.674
6.672
2.452
2.450
2.441
2.436
2.426
2.422
2.412
2.408
2.293
2.291
1.563
1.549
1.534
1.520
1.505
1.439
1.424
1.408
1.394
1.379
1.365
0.921
0.919
0.906
0.904
0.892
0.890
O
O
nBu
1H (500 MHz, Chloroform-d)
1.00
3.00
2.10
3.07
2.13
2.20
3.13
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

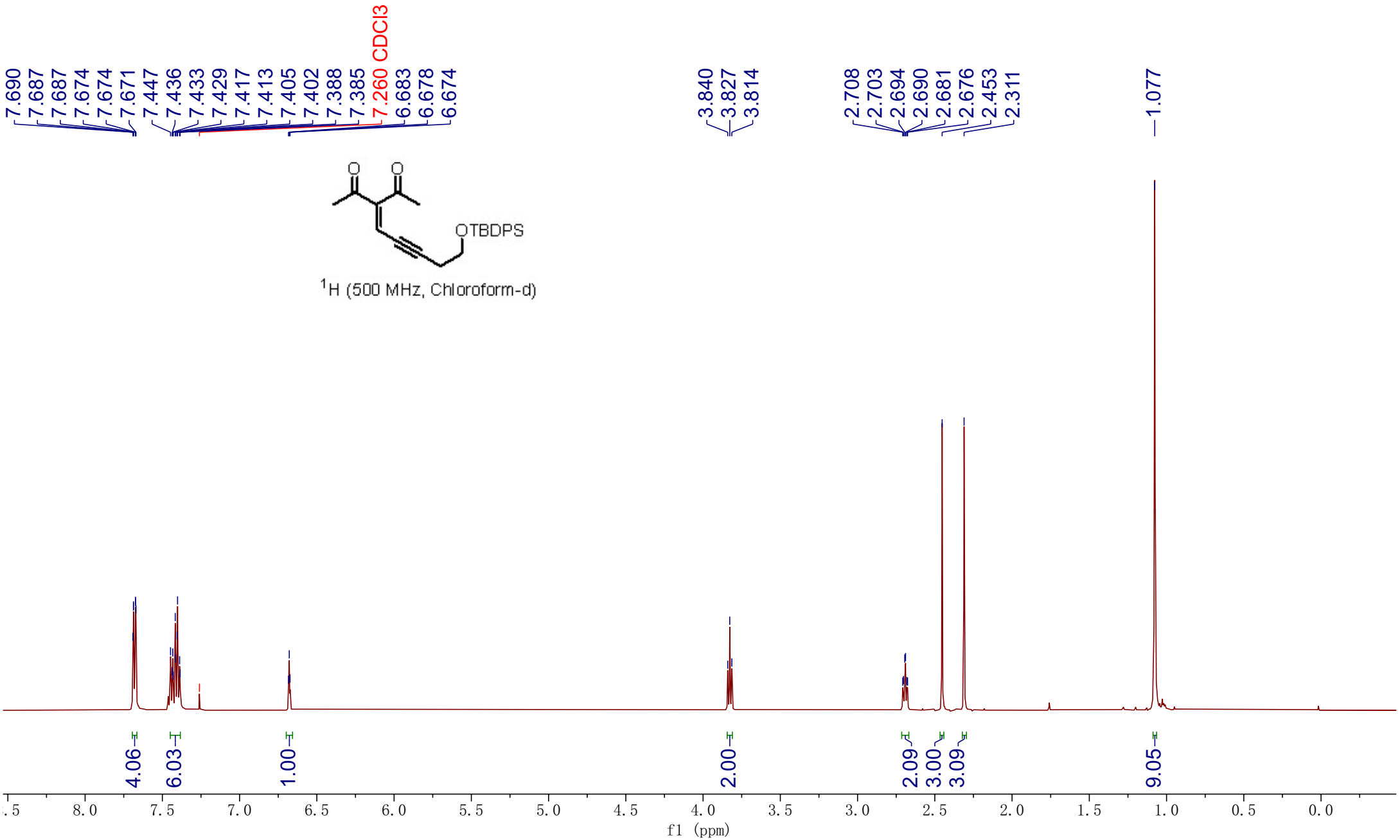

7.260 CDCl3
6.645
6.640
6.635
3.635
3.623
3.611
2.650
2.646
2.637
2.632
2.623
2.618
2.436
2.300
2.029
2.016
2.003
1.990
1.977
O
O
Cl
1H (500 MHz, Chloroform-d)
1.00
2.06
2.04
3.10
3.02
2.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

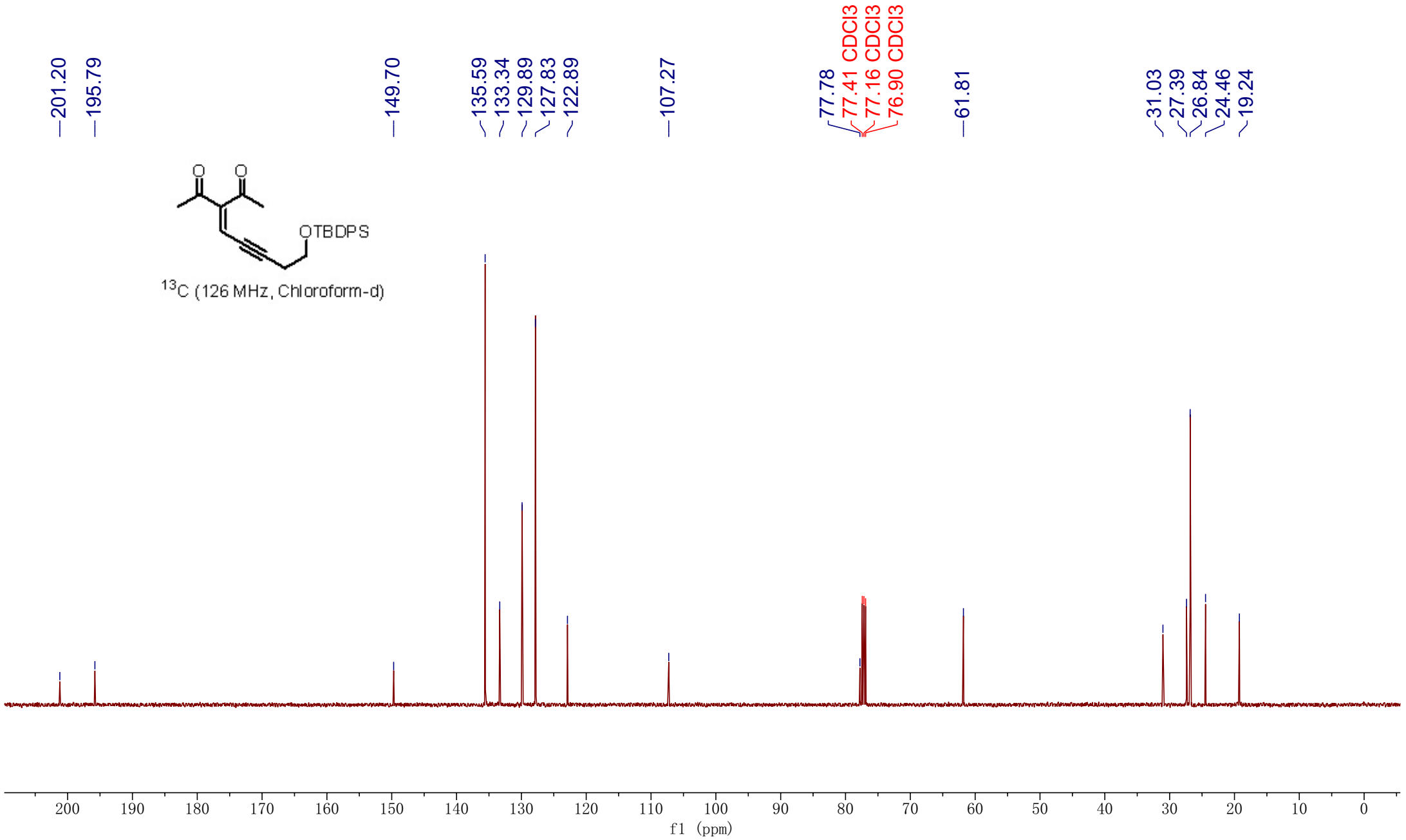

7.285
7.269
7.260 CDCl3
7.253
6.964
6.949
6.935
6.882
6.866
6.666
6.661
6.656
4.097
4.084
4.071
2.908
2.903
2.895
2.890
2.882
2.877
2.440
2.279
O
O
OPh
1H (500 MHz, Chloroform-d)
2.07
0.98
2.00
0.96
2.05
2.04
3.00
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

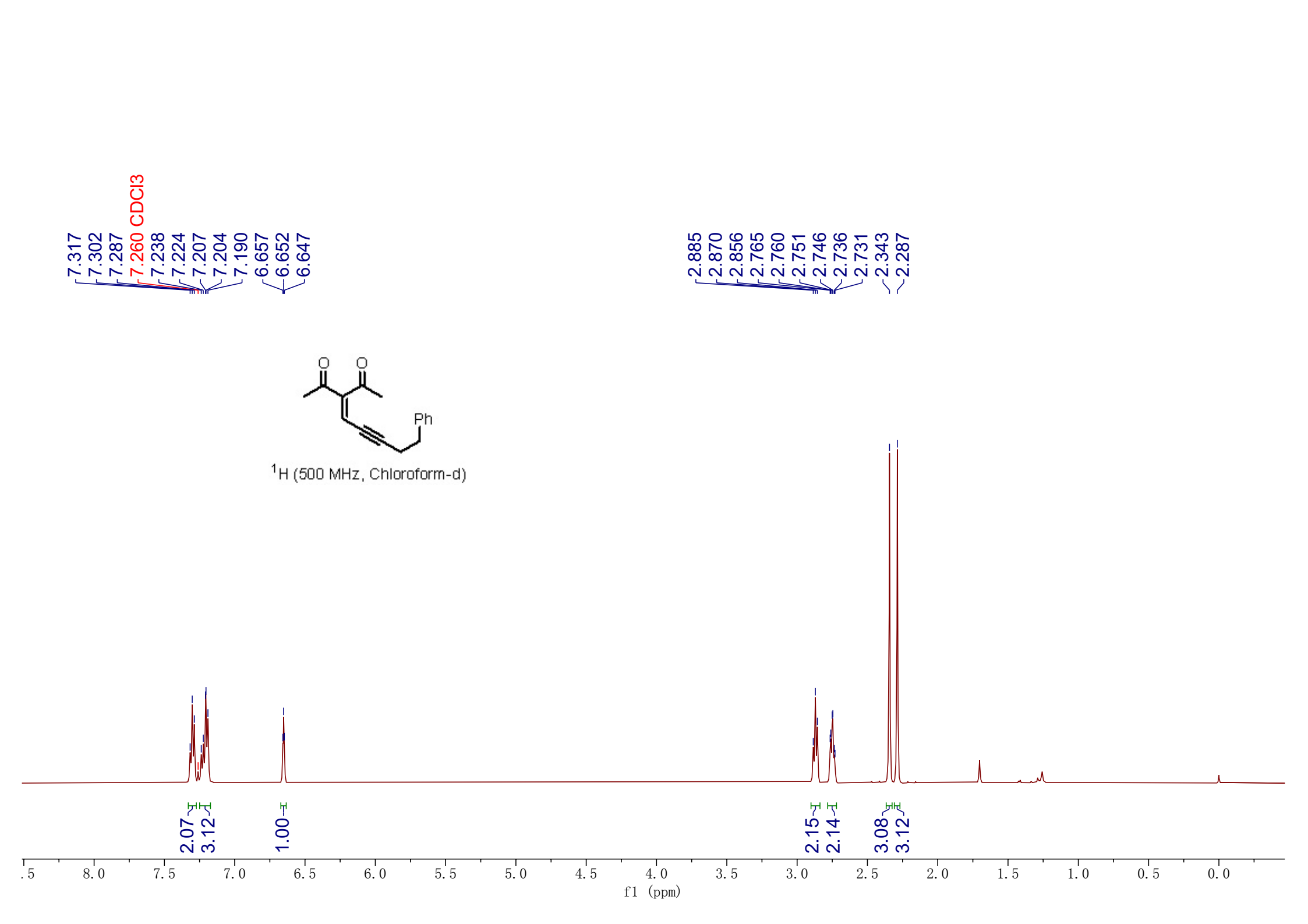

201.21
195.71
158.18
150.13
129.54
122.34
121.25
114.56
105.54
77.85
77.41 CDCl3
77.16 CDCl3
76.90 CDCl3
65.20
30.90
27.18
21.27
O
O
OPh
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

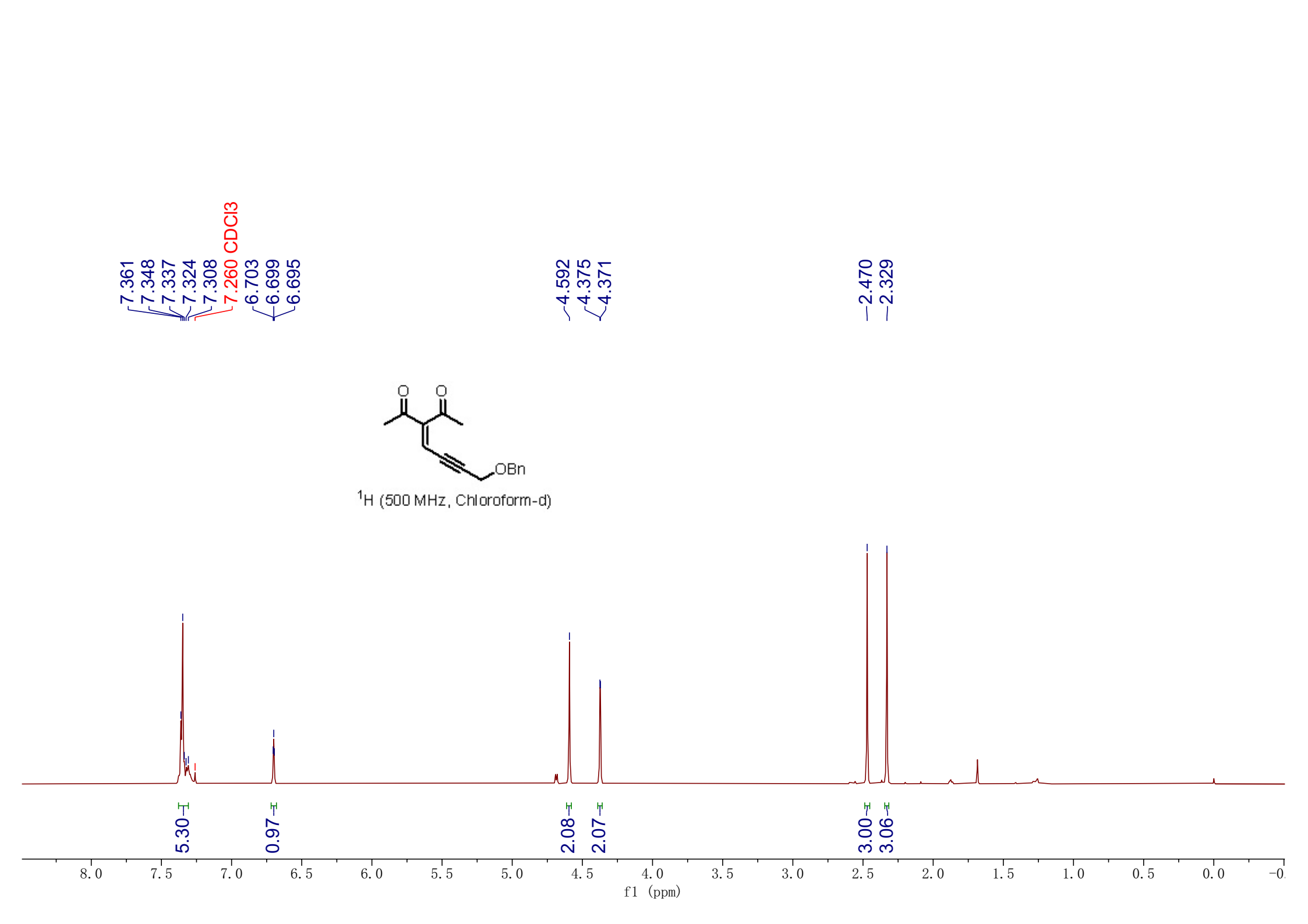

7.260 CDCl3
6.680
3.765
3.754
3.742
2.655
2.647
2.640
2.634
2.626
2.470
2.301
0.883
0.059
OTBS
1H (500 MHz, Chloroform-d)
0.93
2.05
2.03
2.89
3.00
9.27
6.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

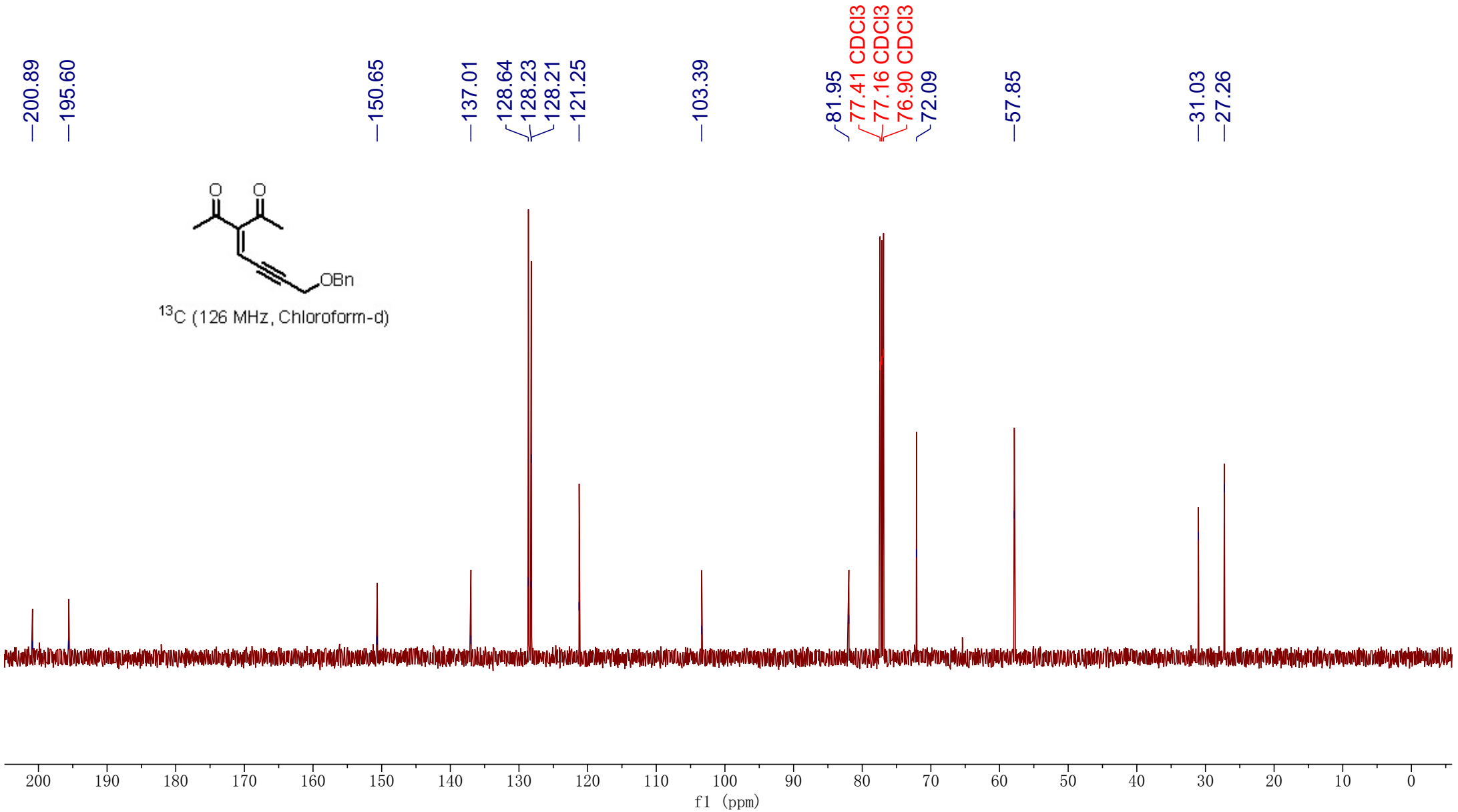

201.29
195.84
149.85
122.95
107.32
77.78
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
61.23
31.11
27.45
25.96
24.79
18.40
-5.20
OTBS
13C (126 MHz, Chloroform-d)
f1 (ppm)

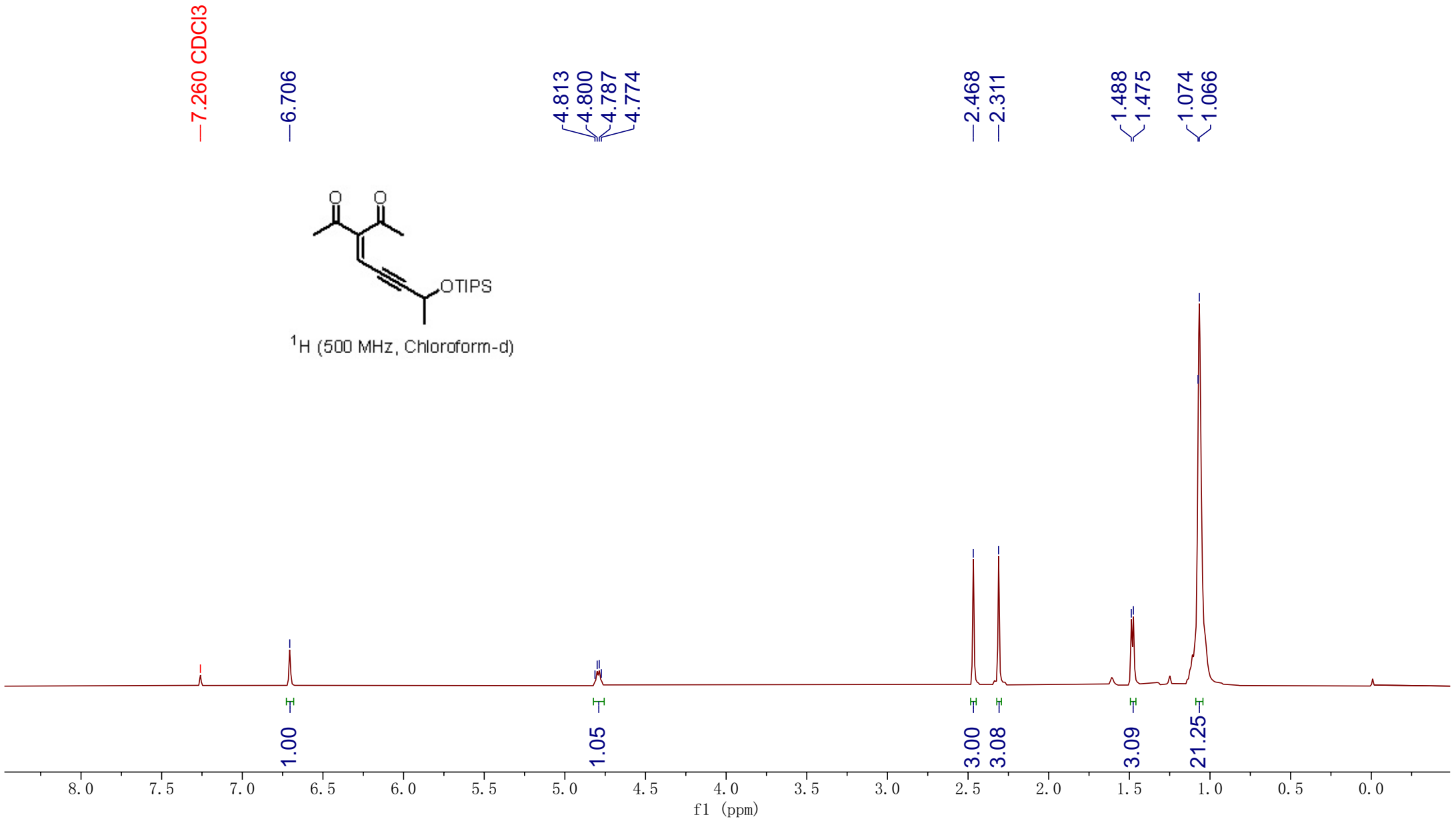

7.690
7.687
7.687
7.674
7.674
7.671
7.447
7.436
7.433
7.429
7.417
7.413
7.405
7.402
7.388
7.385
7.260 CDCl3
6.683
6.678
6.674
3.840
3.827
3.814
2.708
2.703
2.694
2.690
2.681
2.676
2.453
2.311
1.077
O
O
OTBDPS
1H (500 MHz, Chloroform-d)
4.06
6.03
1.00
2.00
2.09
3.00
3.09
9.05
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

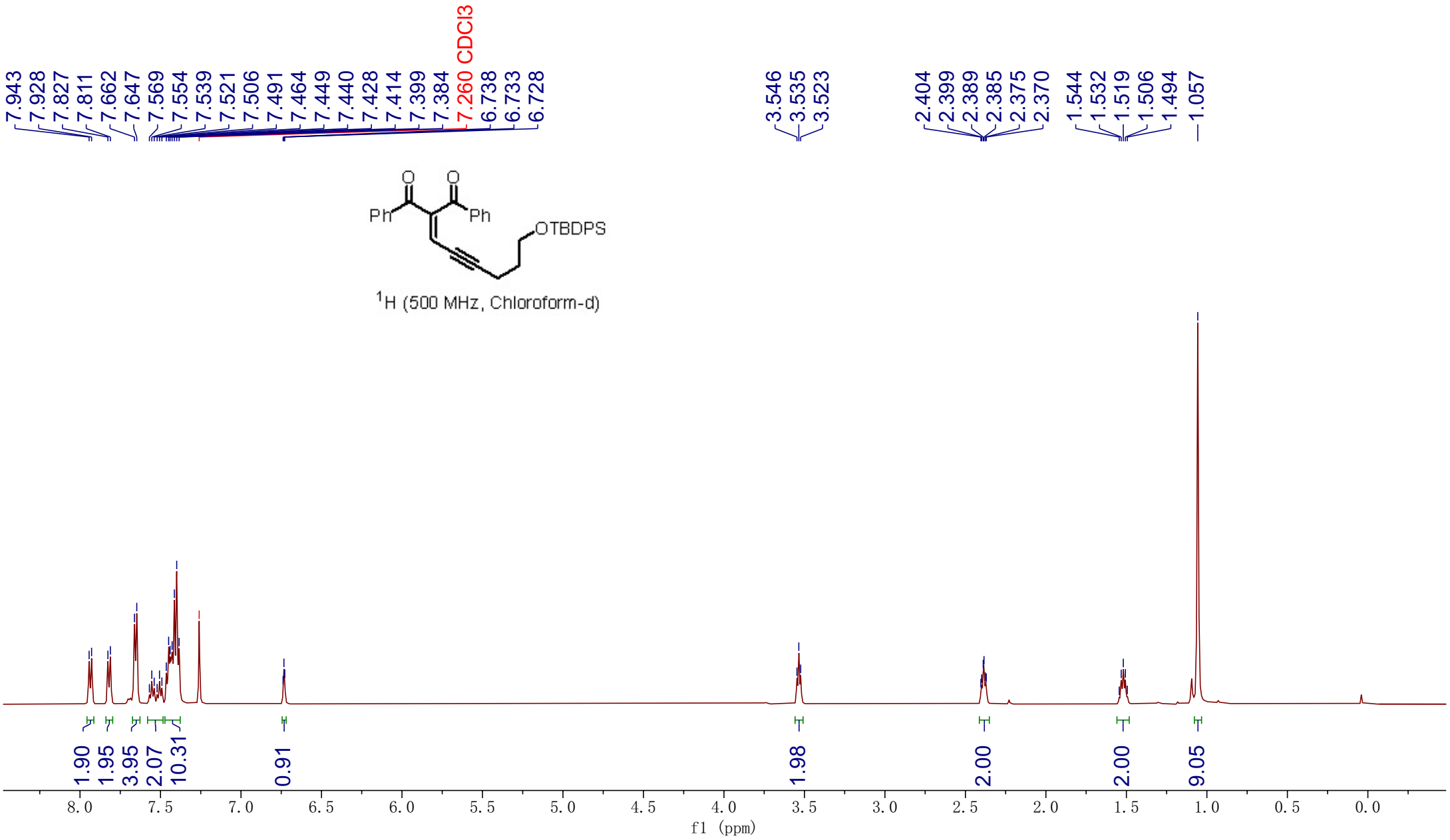

201.20
195.79
149.70
135.59
133.34
129.89
127.83
122.89
107.27
77.78
77.41 CDCl3
77.16 CDCl3
76.90 CDCl3
61.81
31.03
27.39
26.84
24.46
19.24
OTBDPS
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

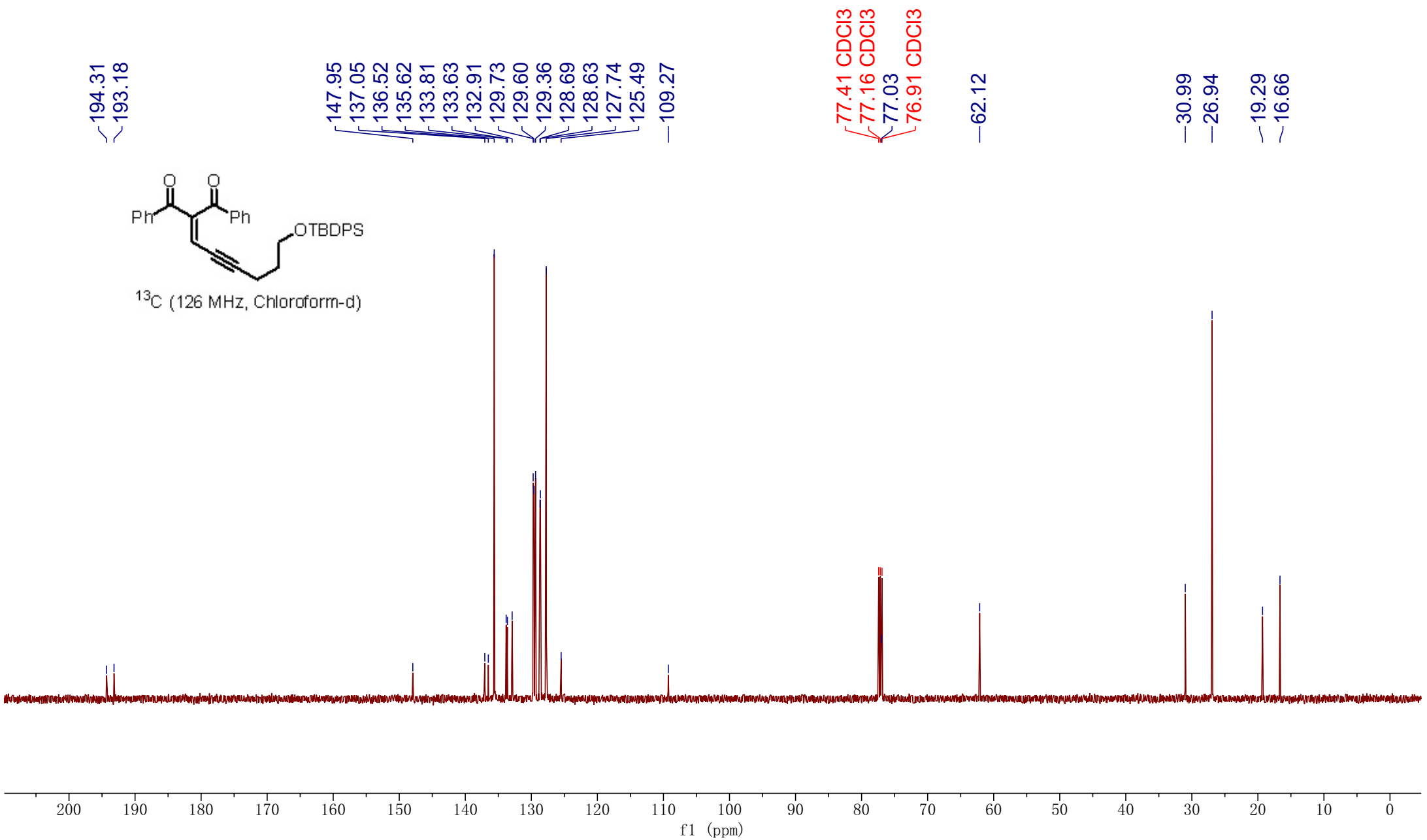

7.317
7.302
7.287
7.260 CDCl3
7.238
7.224
7.207
7.204
7.190
6.657
6.652
6.647
2.885
2.870
2.856
2.765
2.760
2.751
2.746
2.736
2.731
2.343
2.287
O
O
Ph
1H (500 MHz, Chloroform-d)
2.07
3.12
1.00
2.15
2.14
3.08
3.12
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

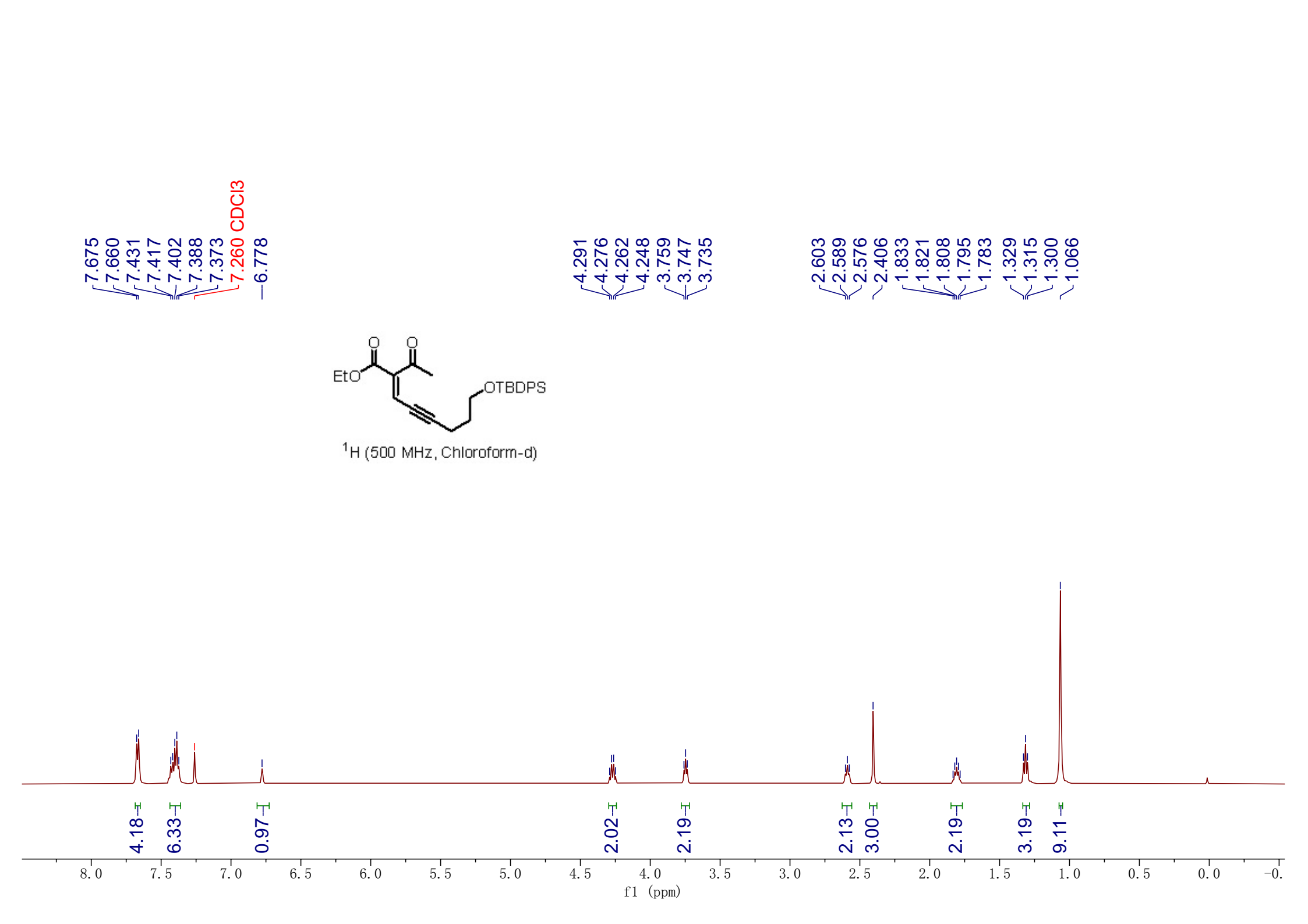

7.361
7.348
7.337
7.324
7.308
7.260 CDCl3
6.703
6.699
6.695
4.592
4.375
4.371
2.470
2.329
O
O
OBn
1H (500 MHz, Chloroform-d)
5.30
0.97
2.08
2.07
3.00
3.06
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

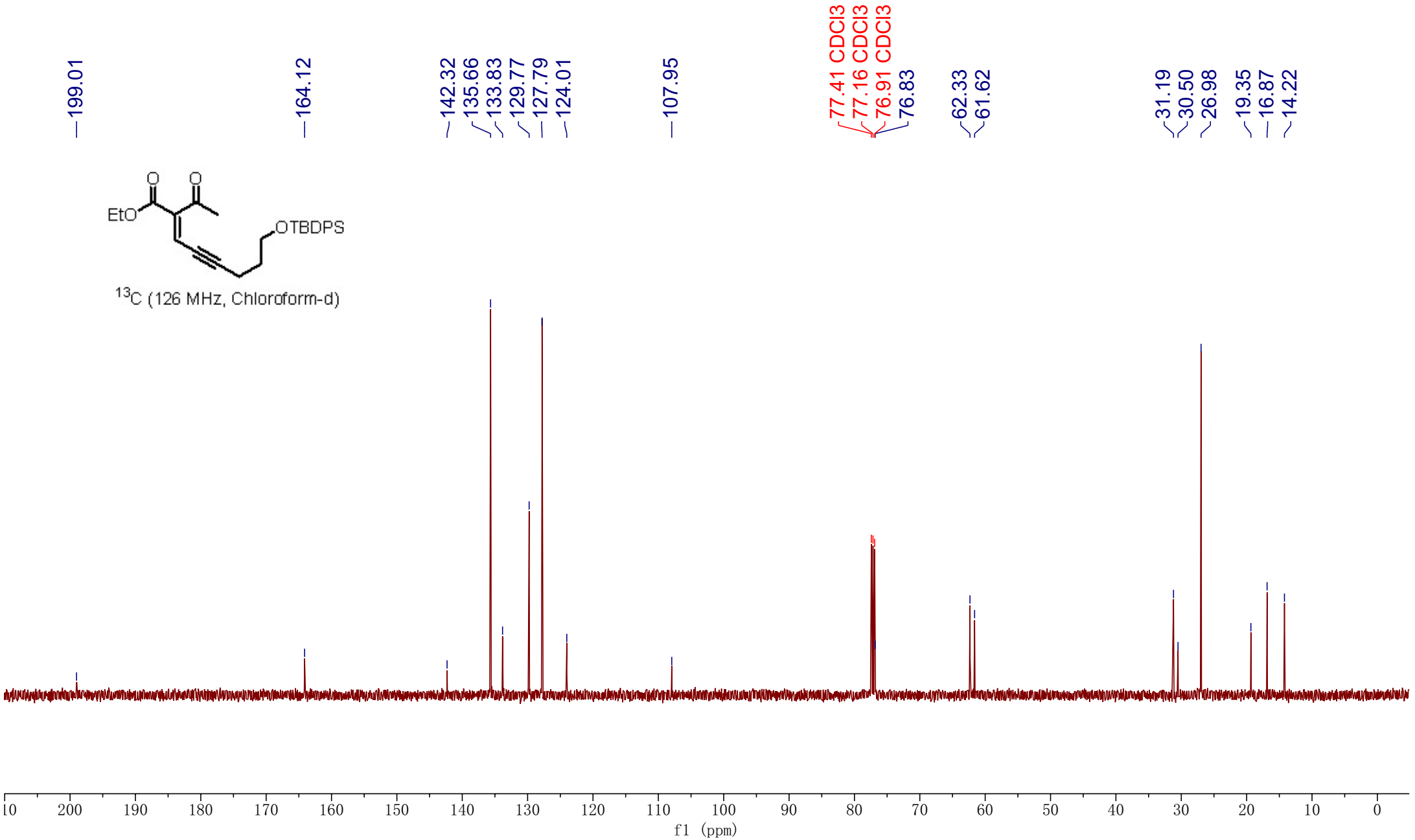

200.89
195.60
150.65
137.01
128.64
128.23
128.21
121.25
103.39
81.95
77.41 CDCl3
77.16 CDCl3
76.90 CDCl3
72.09
57.85
31.03
27.26
O
O
OBn
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

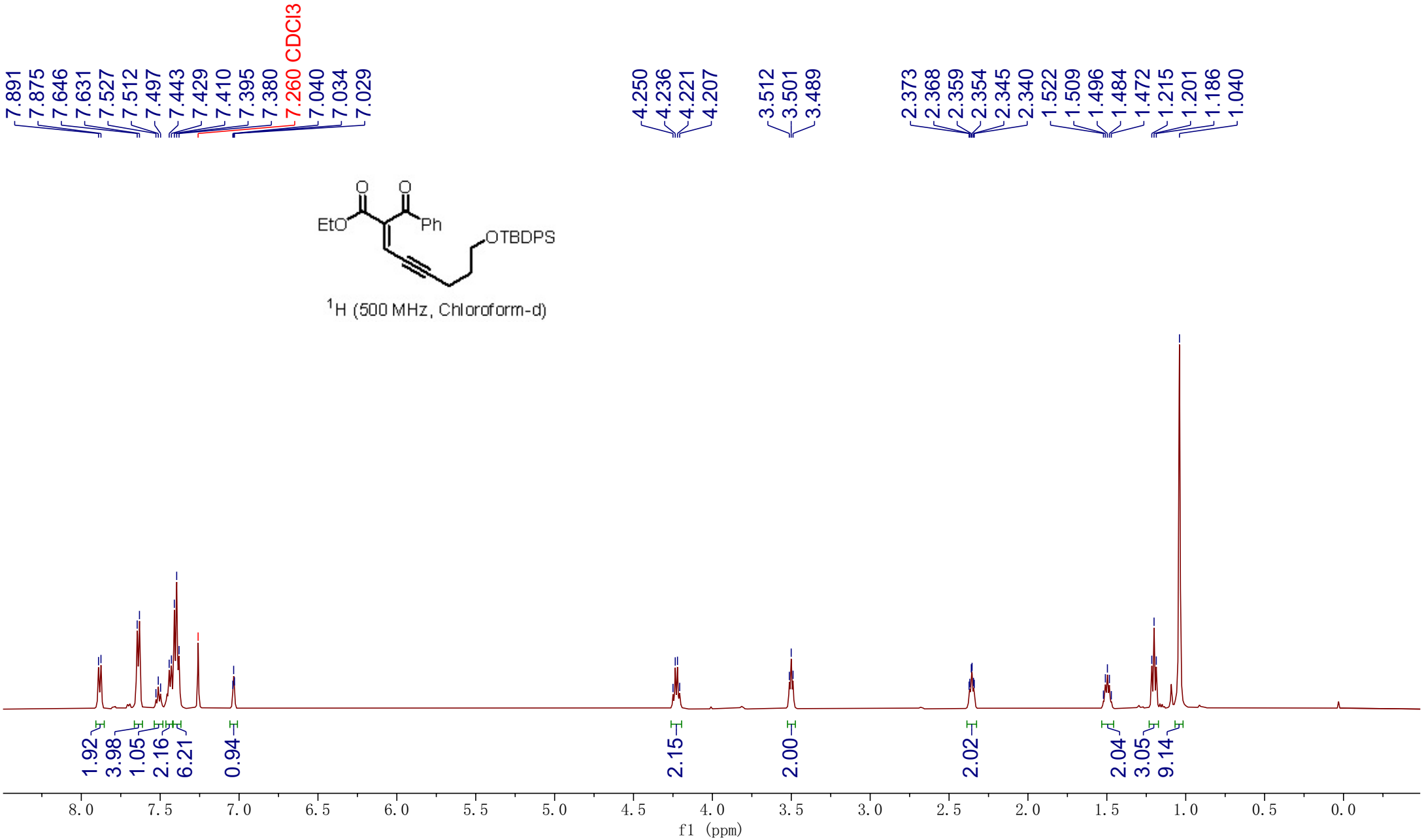

7.260 CDCl3
6.706
4.813
4.800
4.787
4.774
2.468
2.311
1.488
1.475
1.074
1.066
OTIPS
1H (500 MHz, Chloroform-d)
1.00
1.05
3.00
3.08
3.09
21.25
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

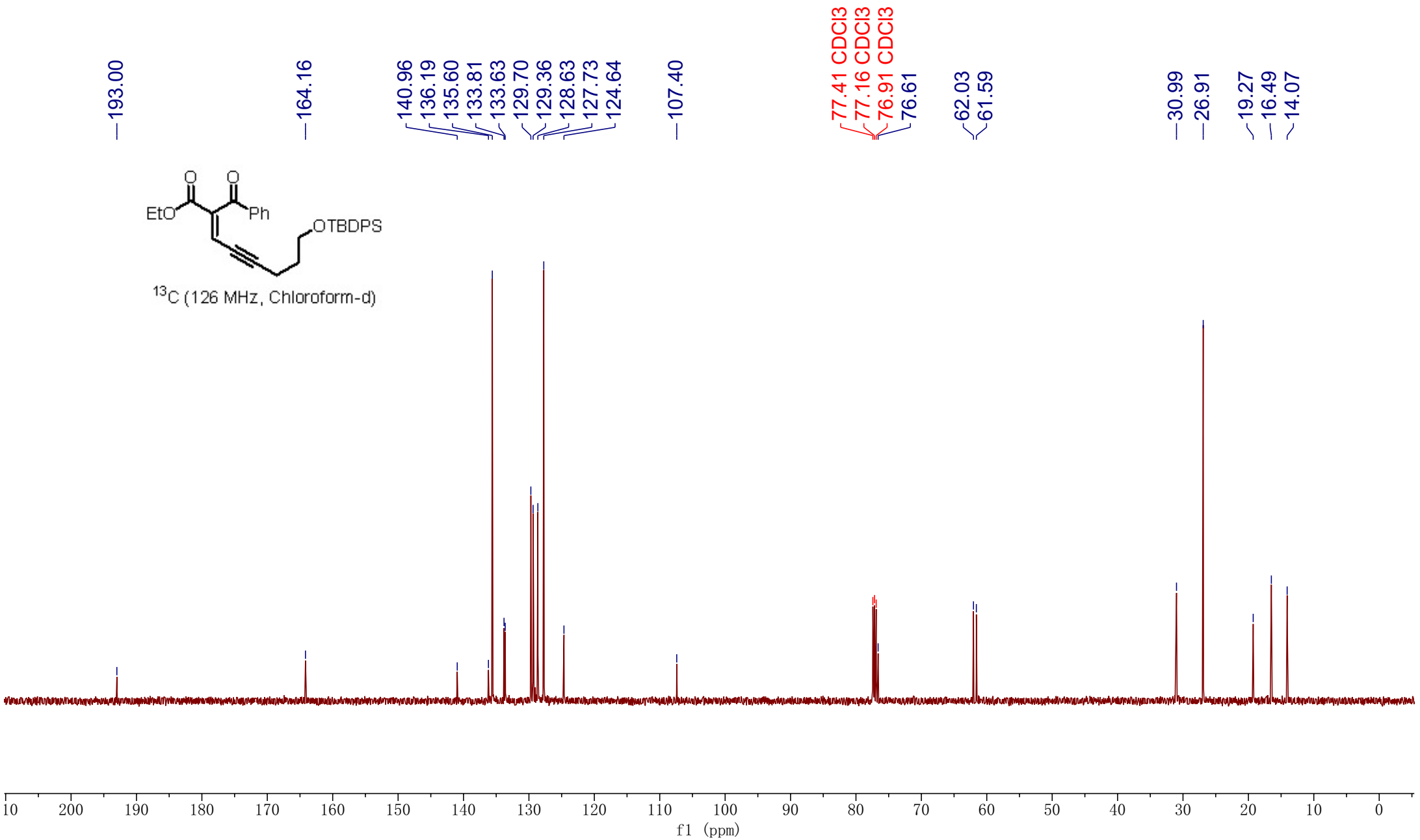

7.943
7.928
7.827
7.811
7.662
7.647
7.569
7.554
7.539
7.521
7.506
7.491
7.464
7.449
7.440
7.428
7.414
7.399
7.384
7.260 CDCl3
6.738
6.733
6.728
3.546
3.535
3.523
2.404
2.399
2.389
2.385
2.375
2.370
1.544
1.532
1.519
1.506
1.494
1.057
Ph
Ph
OTBDPS
1H (500 MHz, Chloroform-d)
1.90
1.95
3.95
2.07
10.31
0.91
1.98
2.00
2.00
9.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

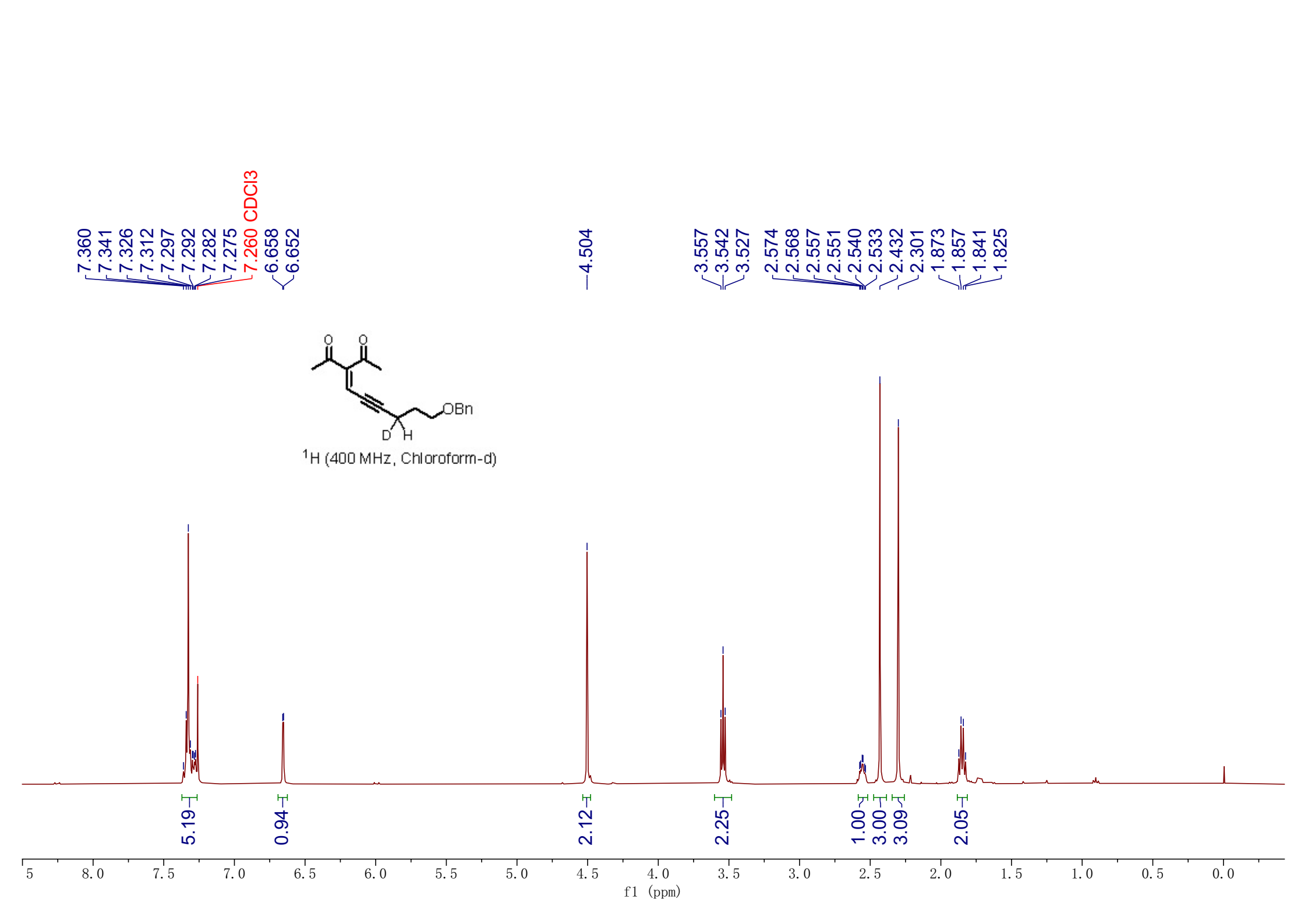

194.31
193.18
147.95
137.05
136.52
135.62
133.81
133.63
132.91
129.73
129.60
129.36
128.69
128.63
127.74
125.49
109.27
77.41 CDCl3
77.16 CDCl3
77.03
76.91 CDCl3
62.12
30.99
26.94
19.29
16.66
Ph
Ph
OTBDPS
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

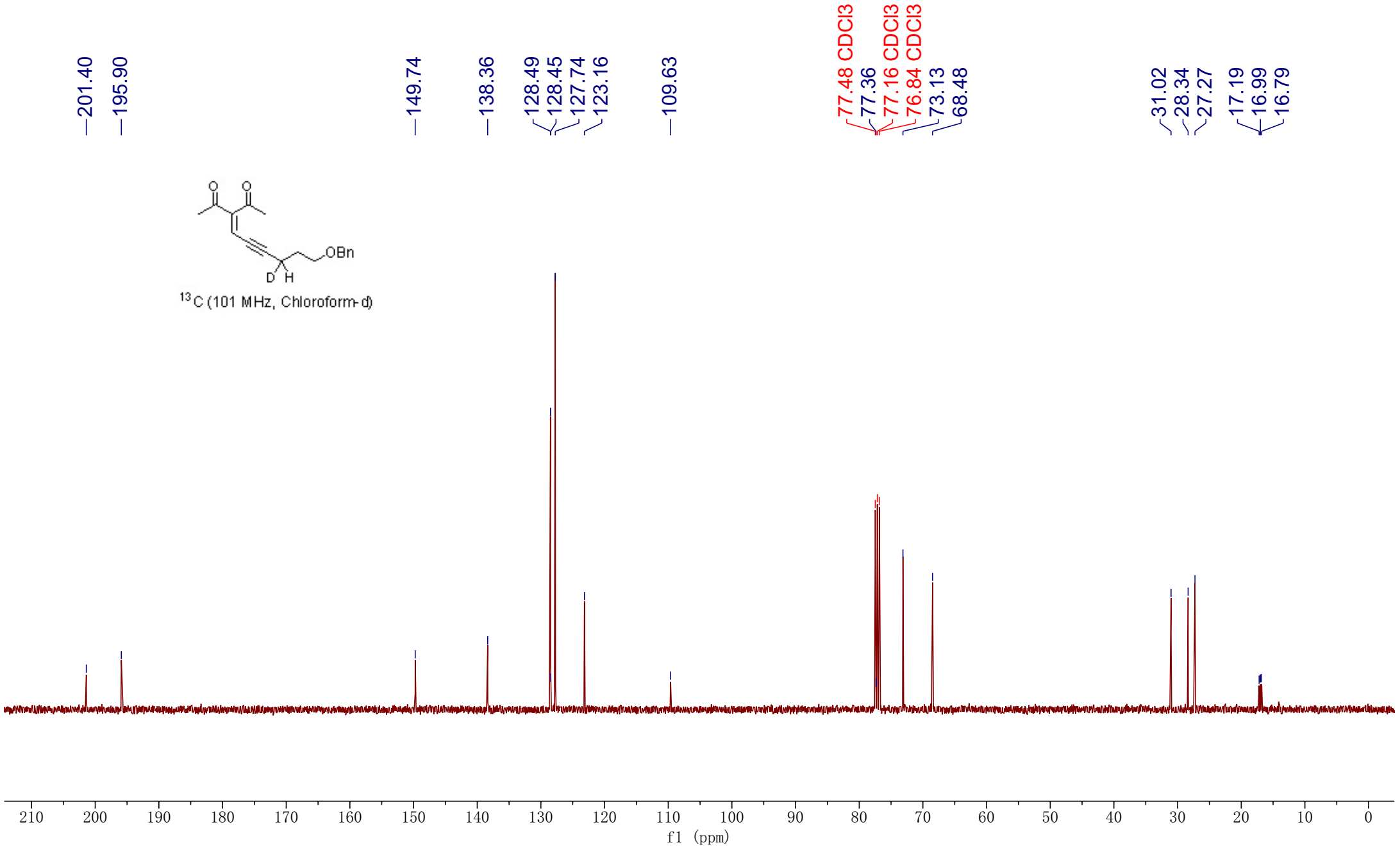

7.675
7.660
7.431
7.417
7.402
7.388
7.373
7.260 CDCl3
6.778
4.291
4.276
4.262
4.248
3.759
3.747
3.735
2.603
2.589
2.576
2.406
1.833
1.821
1.808
1.795
1.783
1.329
1.315
1.300
1.066
EtO
O
O
OTBDPS
1H (500 MHz, Chloroform-d)
4.18
6.33
0.97
2.02
2.19
2.13
3.00
2.19
3.19
9.11
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.
f1 (ppm)

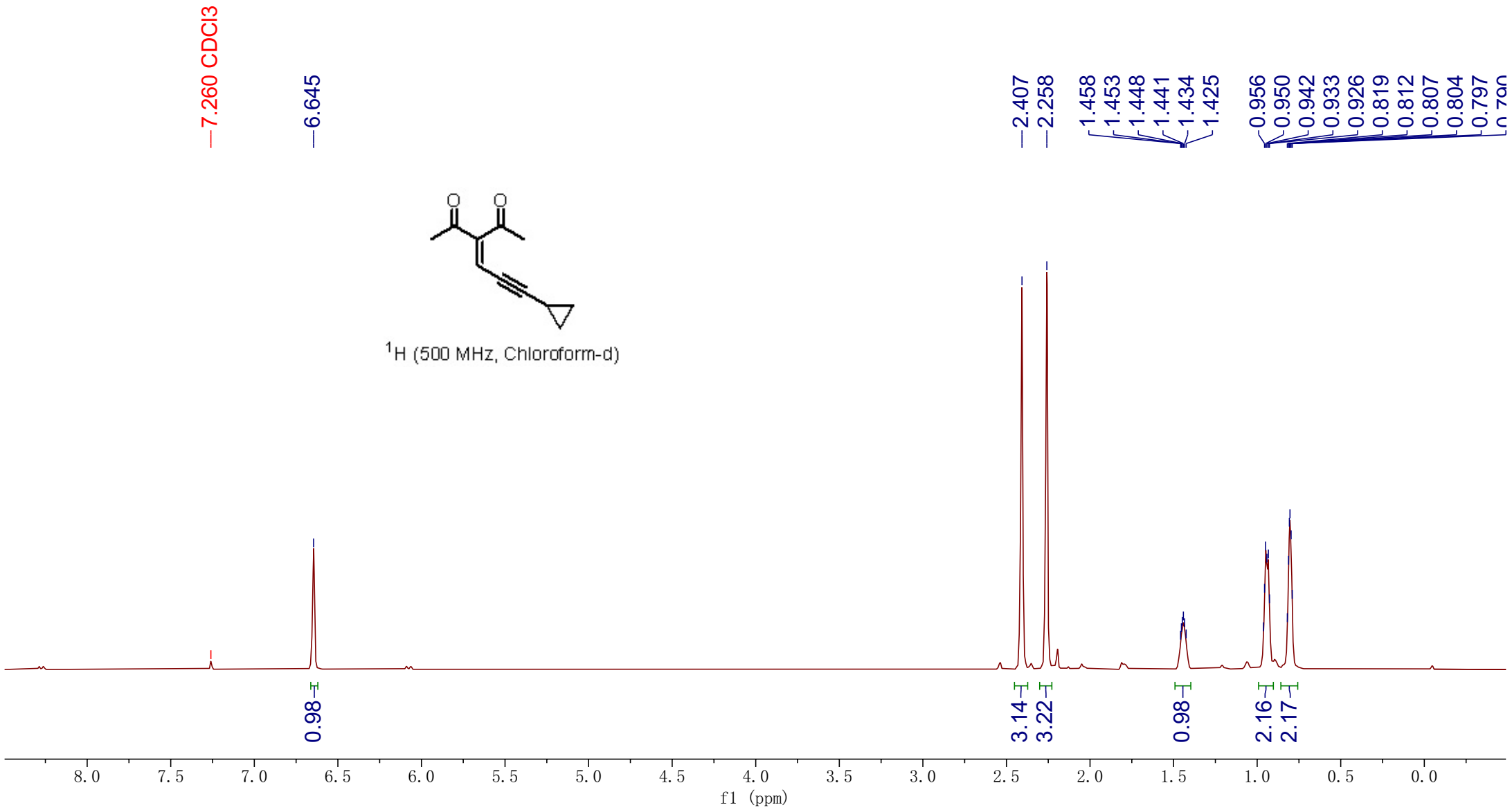

199.01
164.12
142.32
135.66
133.83
129.77
127.79
124.01
107.95
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
76.83
62.33
61.62
31.19
30.50
26.98
19.35
16.87
14.22
EtO
O
O
OTBDPS
13C (126 MHz, Chloroform-d)
f1 (ppm)

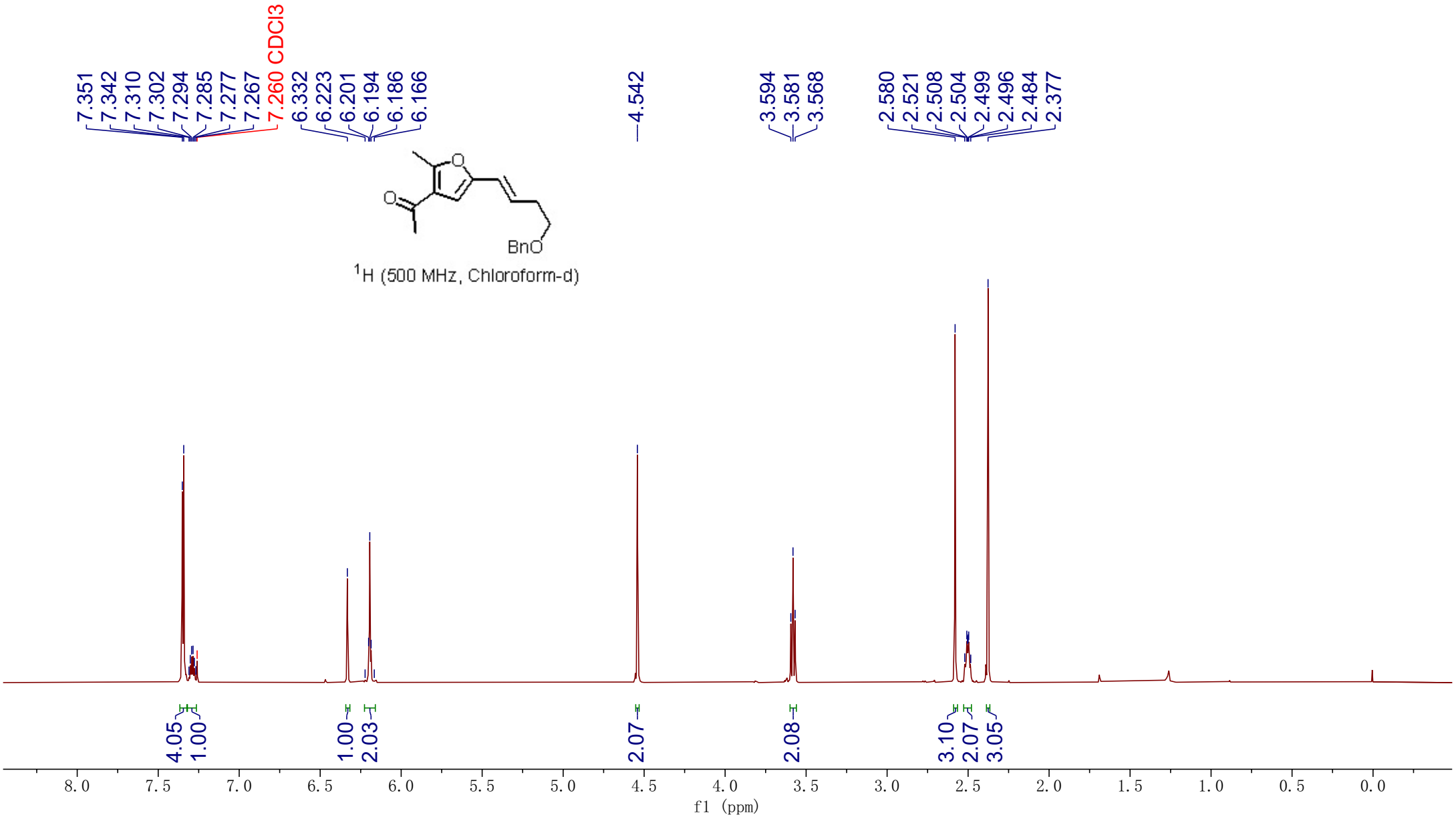

7.891
7.875
7.646
7.631
7.527
7.512
7.497
7.443
7.429
7.410
7.395
7.380
7.260 CDCl3
7.040
7.034
7.029
4.250
4.236
4.221
4.207
3.512
3.501
3.489
2.373
2.368
2.359
2.354
2.345
2.340
1.522
1.509
1.496
1.484
1.472
1.215
1.201
1.186
1.040
O
O
EtO
Ph
OTBDPS
1H (500 MHz, Chloroform-d)
1.92
3.98
1.05
2.16
6.21
0.94
2.15
2.00
2.02
2.04
3.05
9.14
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

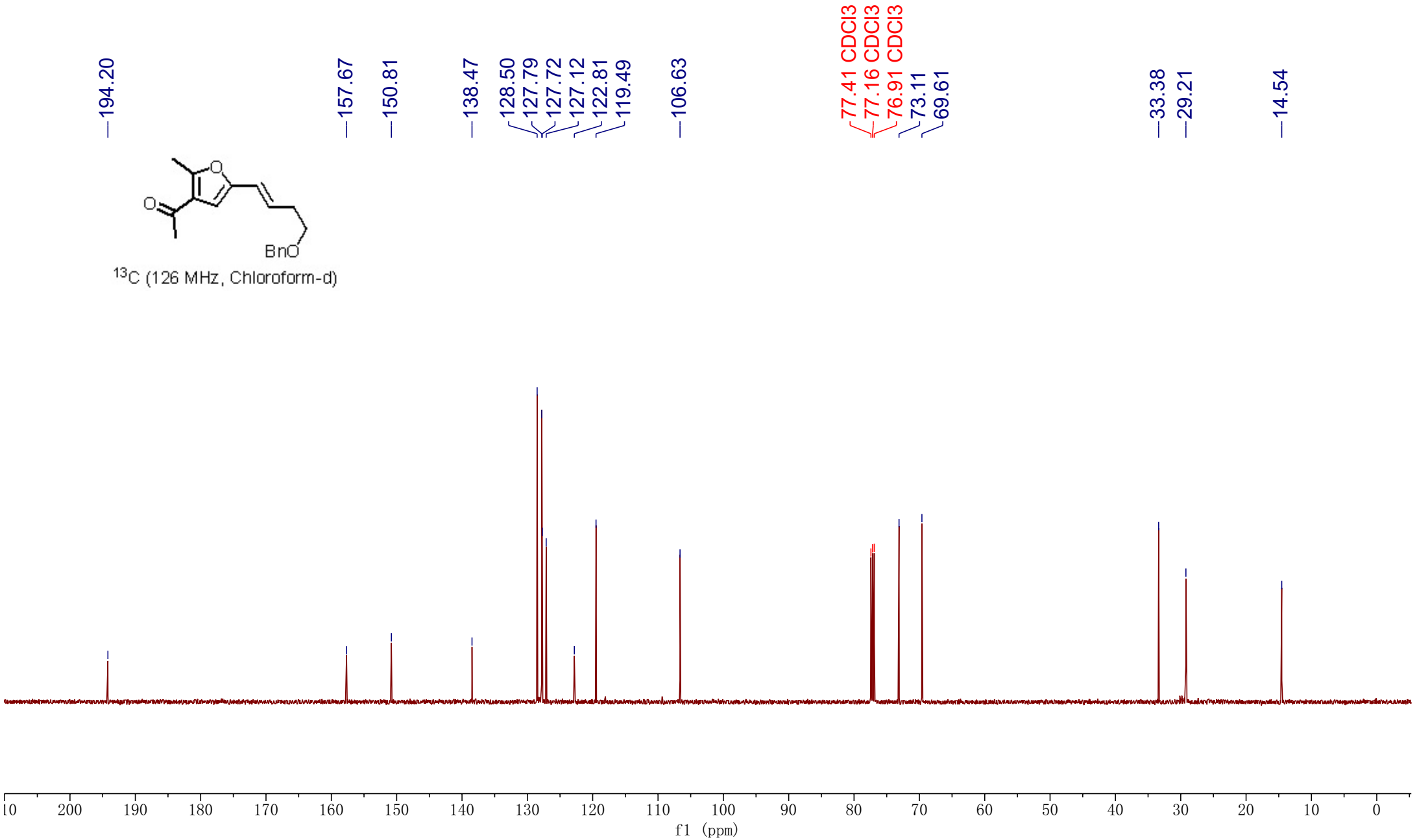

193.00
164.16
140.96
136.19
135.60
133.81
133.63
129.70
129.36
128.63
127.73
124.64
107.40
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
76.61
62.03
61.59
30.99
26.91
19.27
16.49
14.07
EtO
O
O
Ph
OTBDPS
13C (126 MHz, Chloroform-d)
f1 (ppm)

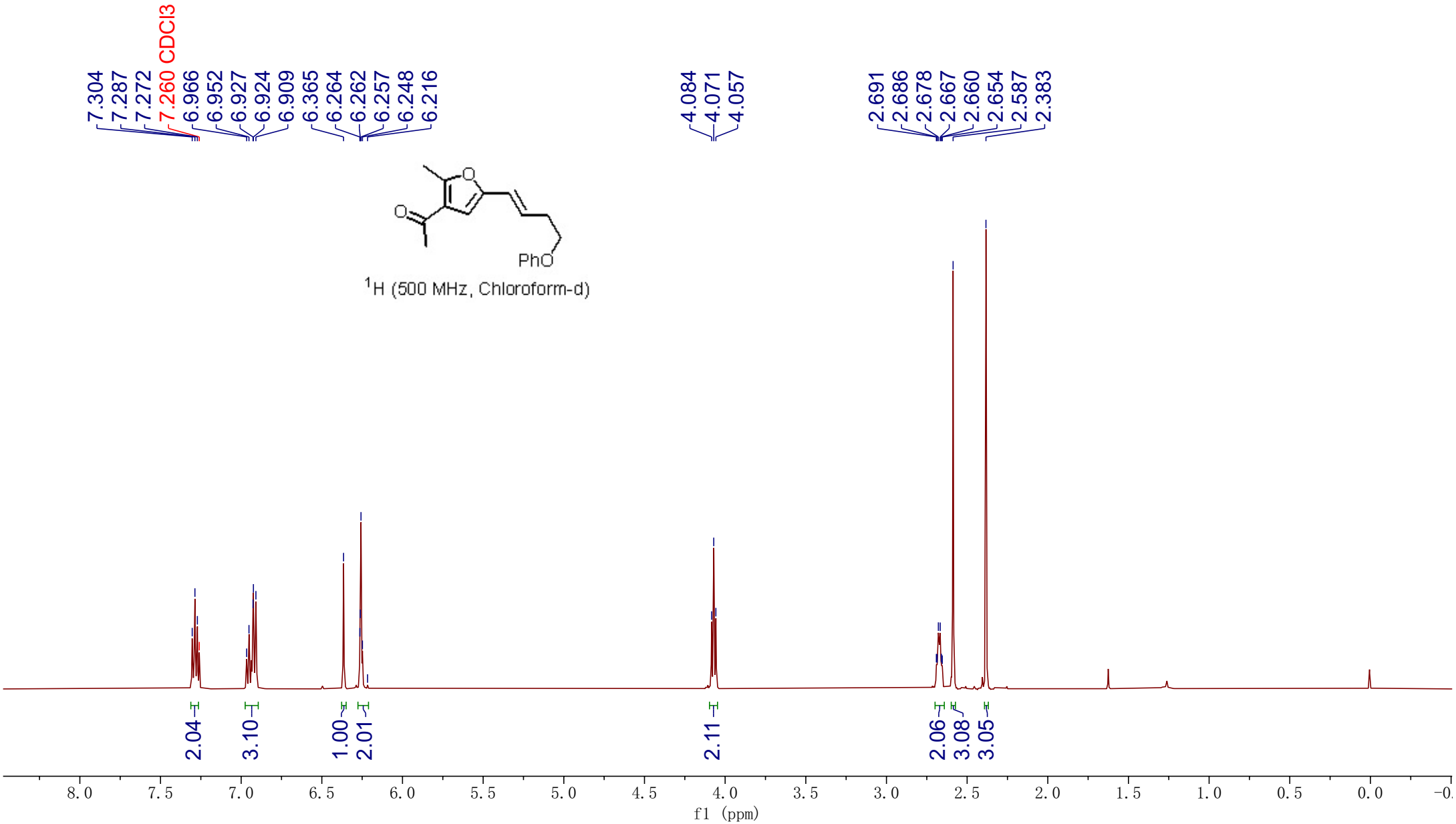

7.360
7.341
7.326
7.312
7.297
7.292
7.282
7.275
7.260 CDCl3
6.658
6.652
4.504
3.557
3.542
3.527
2.574
2.568
2.557
2.551
2.540
2.533
2.432
2.301
1.873
1.857
1.841
1.825
O
O
OBn
D
H
1H (400 MHz, Chloroform-d)
5.19
0.94
2.12
2.25
1.00
3.00
3.09
2.05
f1 (ppm)

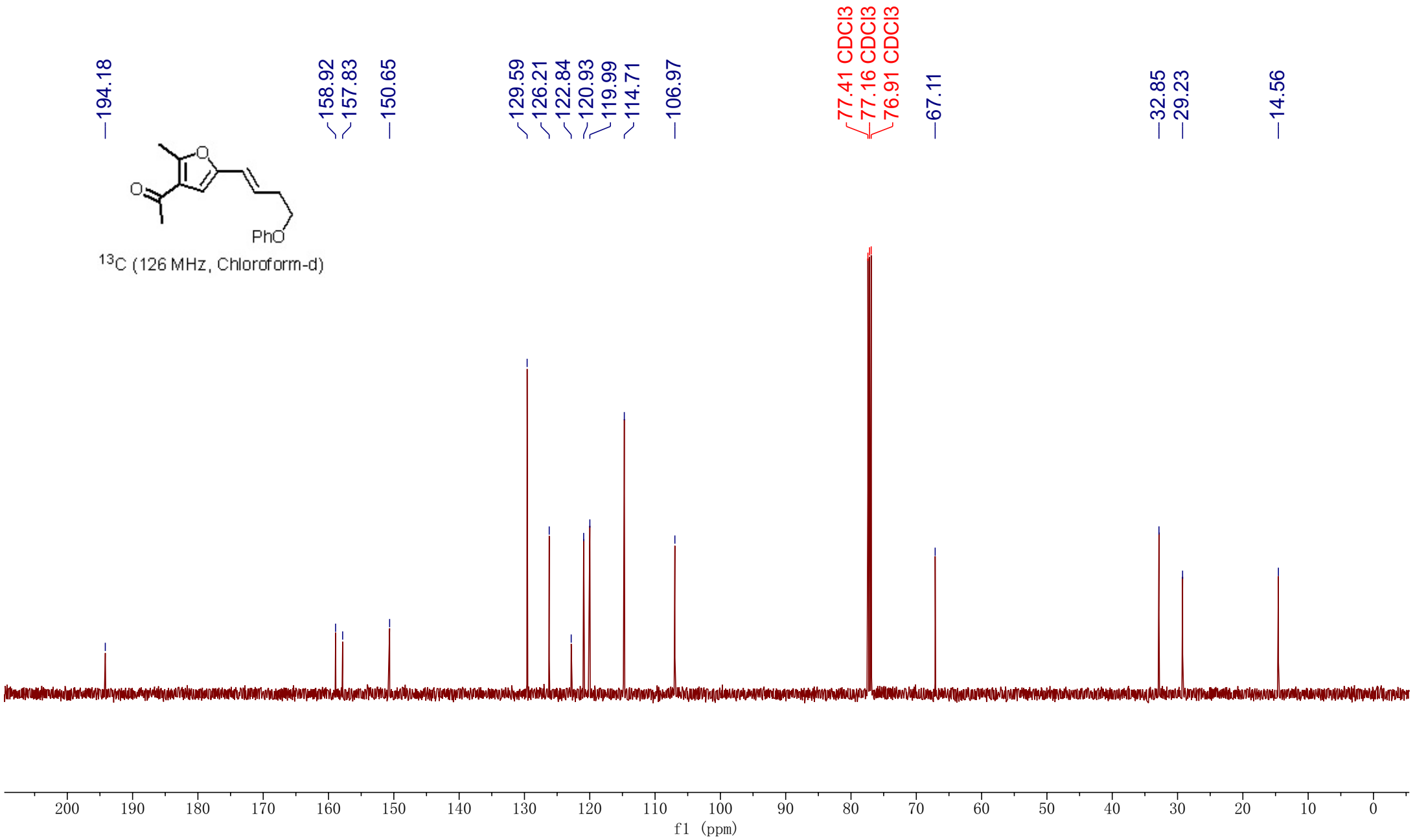

201.40
195.90
149.74
138.36
128.49
128.45
127.74
123.16
109.63
77.48 CDCl3
77.36
77.16 CDCl3
76.84 CDCl3
73.13
68.48
31.02
28.34
27.27
17.19
16.99
16.79
OBn
D
H
13C (101 MHz, Chloroform-d)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

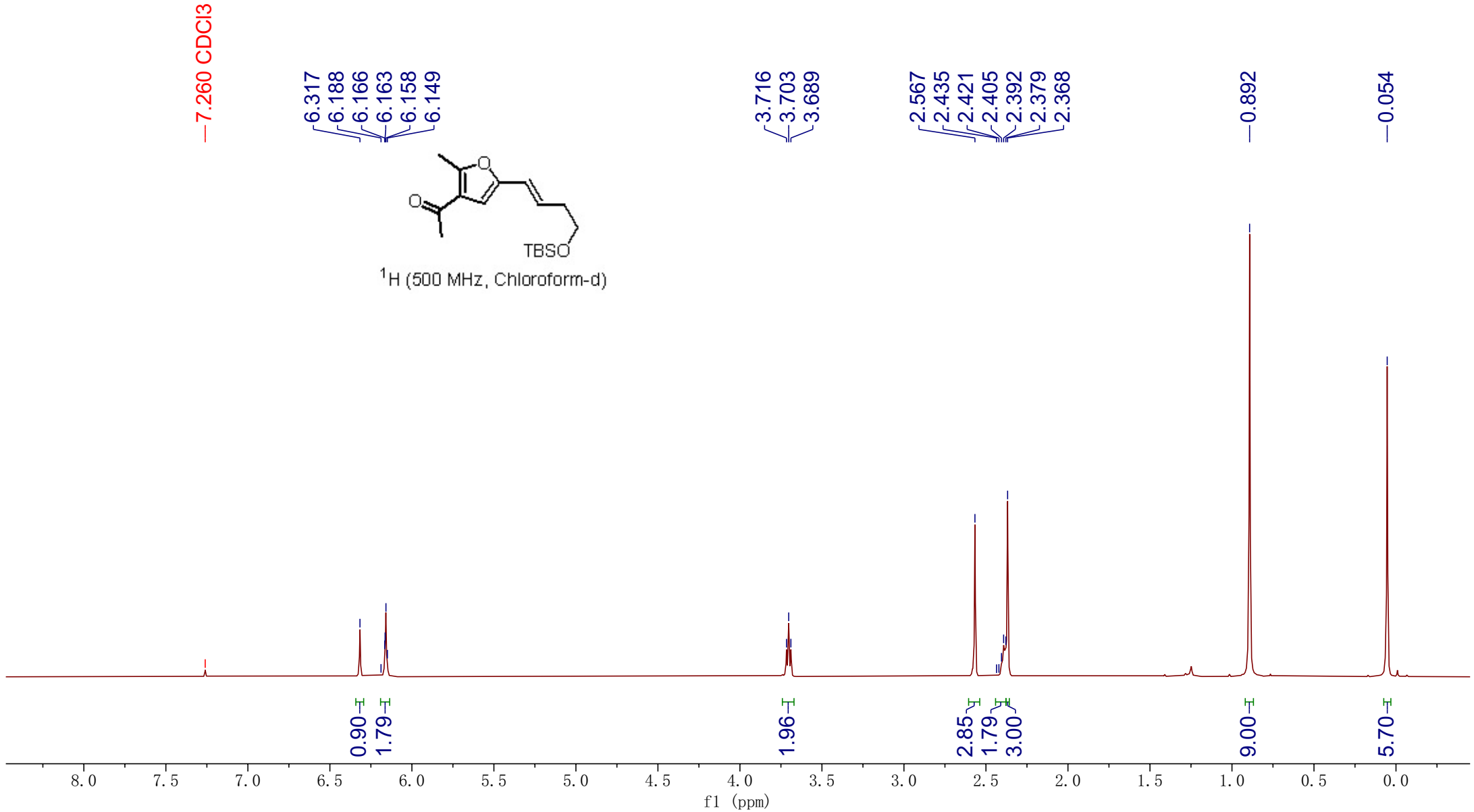

7.260 CDCl3
6.645
2.407
2.258
1.458
1.453
1.448
1.441
1.434
1.425
0.956
0.950
0.942
0.933
0.926
0.819
0.812
0.807
0.804
0.797
O
O
1H (500 MHz, Chloroform-d)
0.98
3.14
3.22
0.98
2.16
2.17
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

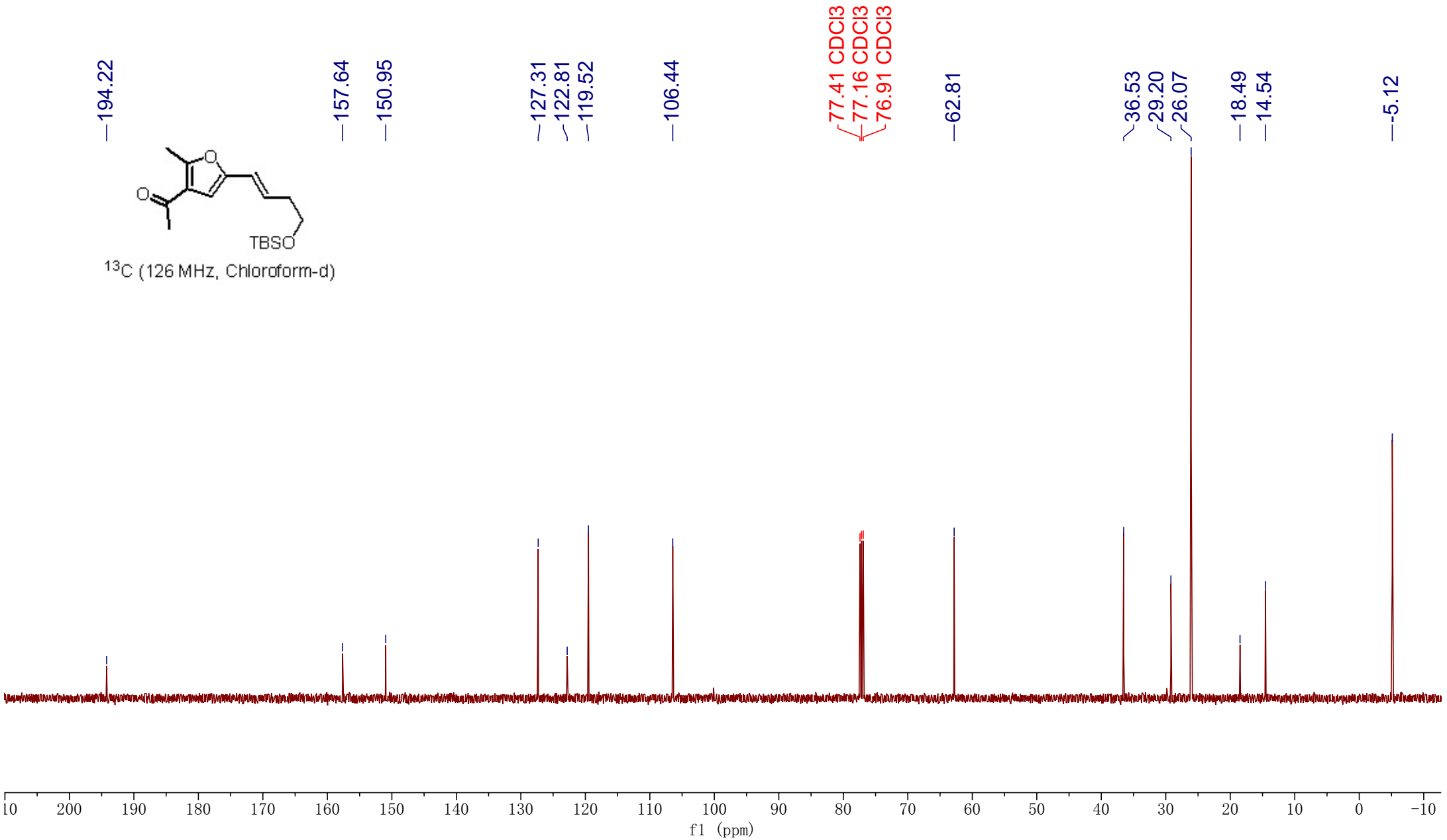

7.351
7.342
7.310
7.302
7.294
7.285
7.277
7.267
7.260 CDCl3
6.332
6.223
6.201
6.194
6.186
6.166
4.542
3.594
3.581
3.568
2.580
2.521
2.508
2.504
2.499
2.496
2.484
2.377
O
O
BnO
1H (500 MHz, Chloroform-d)
4.05
1.00
1.00
2.03
2.07
2.08
3.10
2.07
3.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

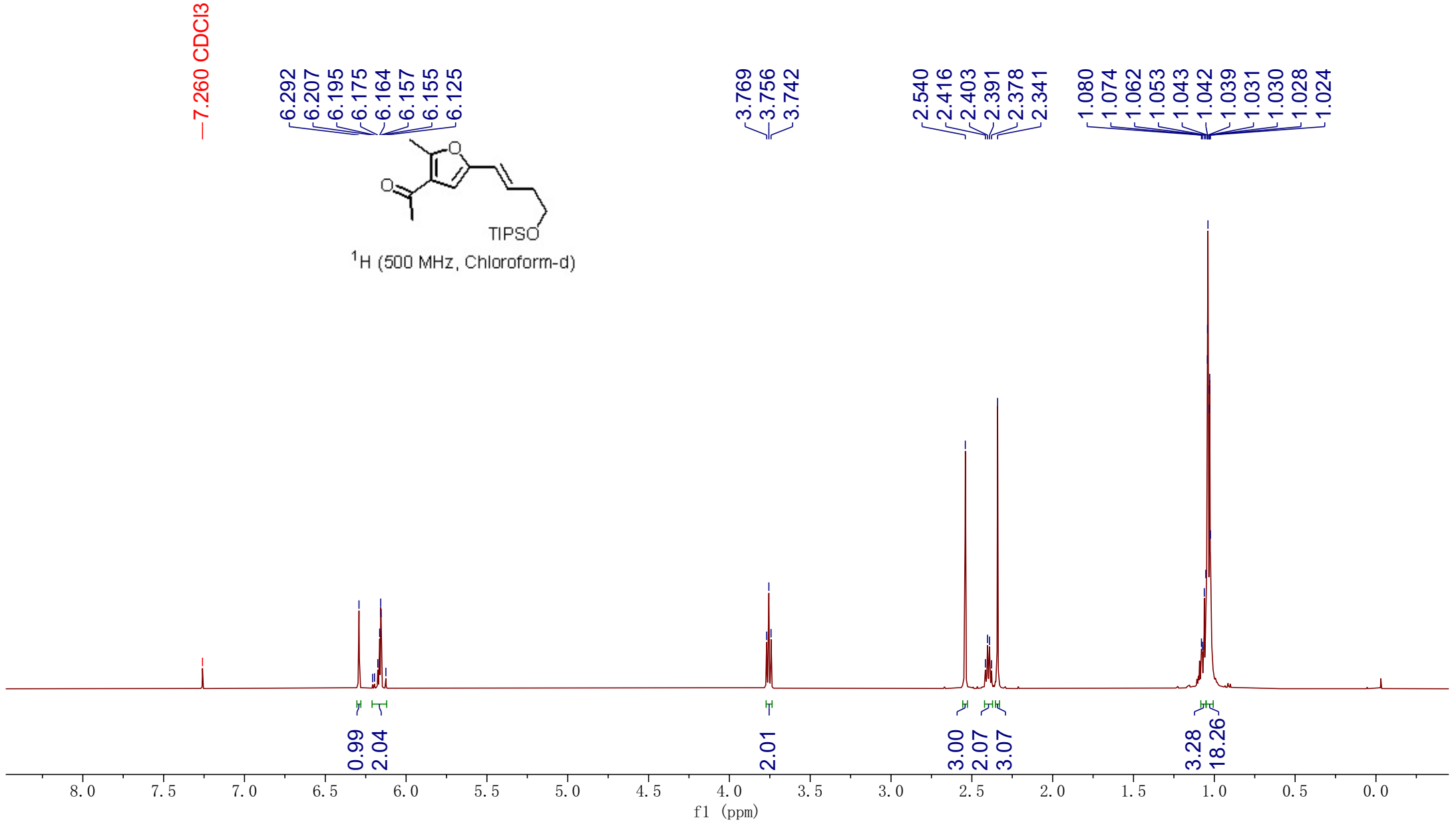

194.20
157.67
150.81
138.47
128.50
127.79
127.72
127.12
122.81
119.49
106.63
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
73.11
69.61
33.38
29.21
14.54
O
O
BnO
13C (126 MHz, Chloroform-d)
f1 (ppm)

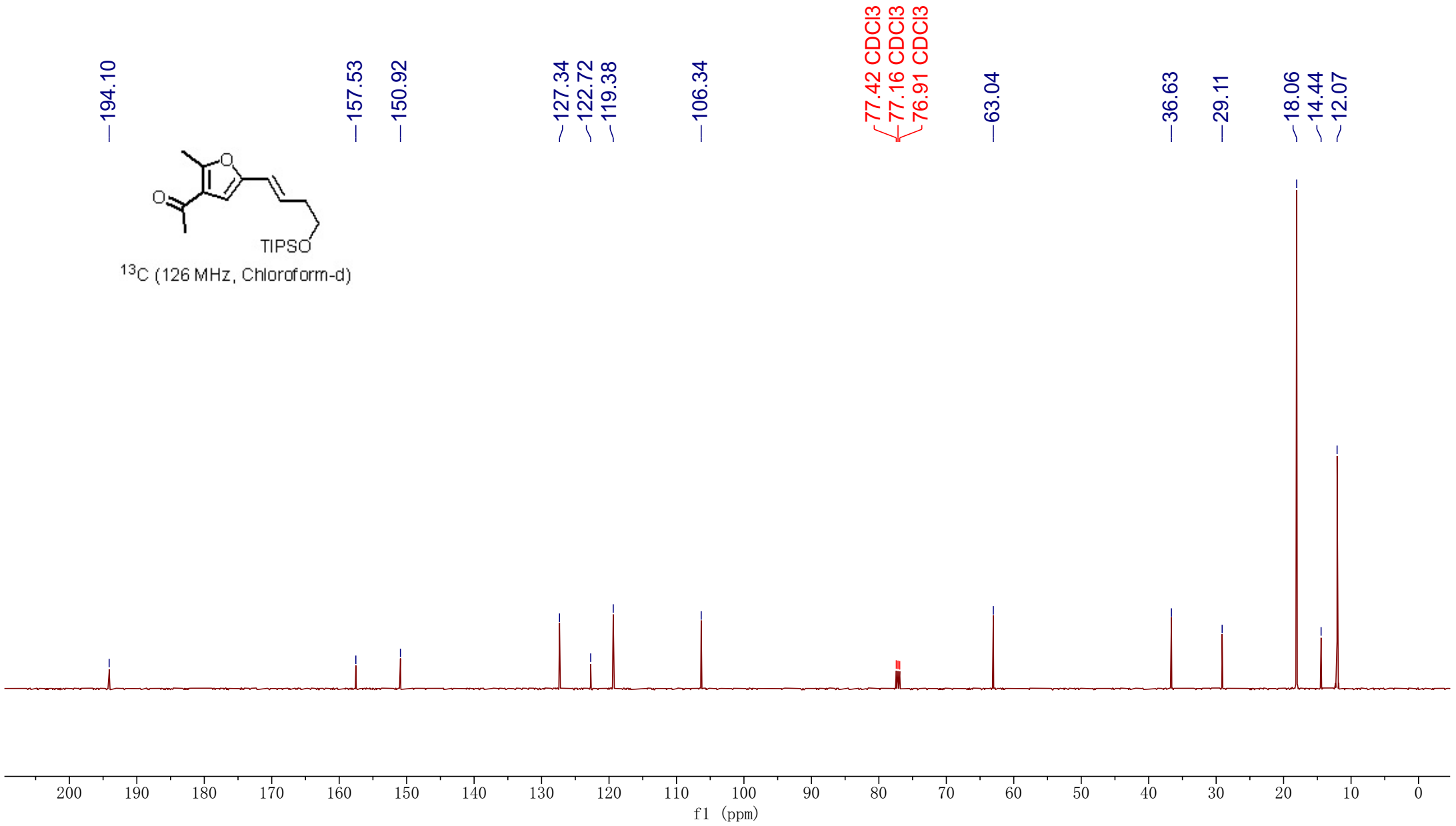

7.304
7.287
7.272
7.260 CDCl3
6.966
6.952
6.927
6.924
6.909
6.365
6.264
6.262
6.257
6.248
6.216
4.084
4.071
4.057
2.691
2.686
2.678
2.667
2.660
2.654
2.587
2.383
O
O
PhO
1H (500 MHz, Chloroform-d)
2.04
3.10
1.00
2.01
2.11
2.06
3.08
3.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

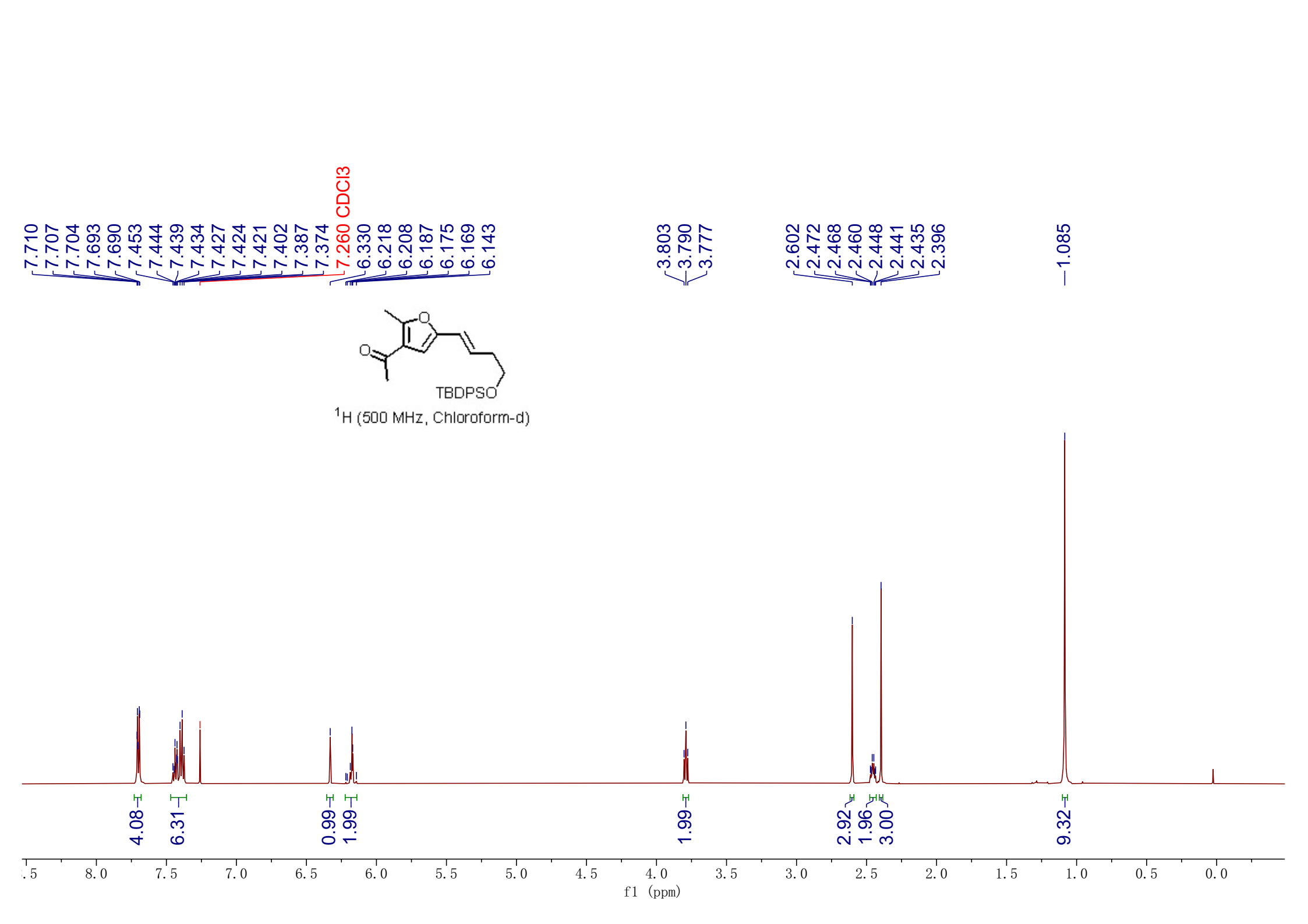

194.18
158.92
157.83
150.65
129.59
126.21
122.84
120.93
119.99
114.71
106.97
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
67.11
32.85
29.23
14.56
O
O
PhO
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

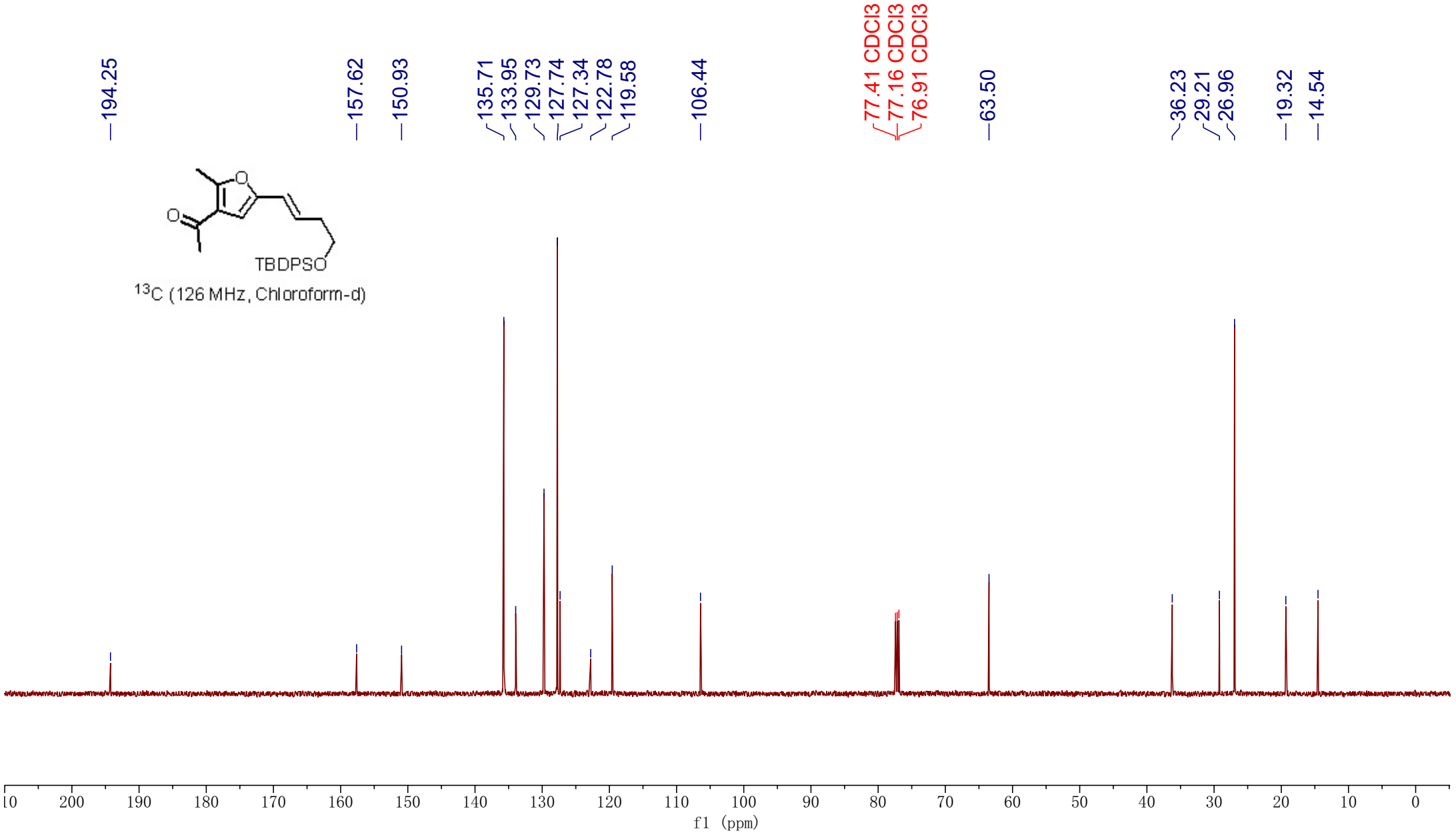

7.260 CDCl3
6.317
6.188
6.166
6.163
6.158
6.149
3.716
3.703
3.689
2.567
2.435
2.421
2.405
2.392
2.379
2.368
0.892
0.054
O
O
TBSO
1H (500 MHz, Chloroform-d)
0.90
1.79
1.96
2.85
1.79
3.00
9.00
5.70
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

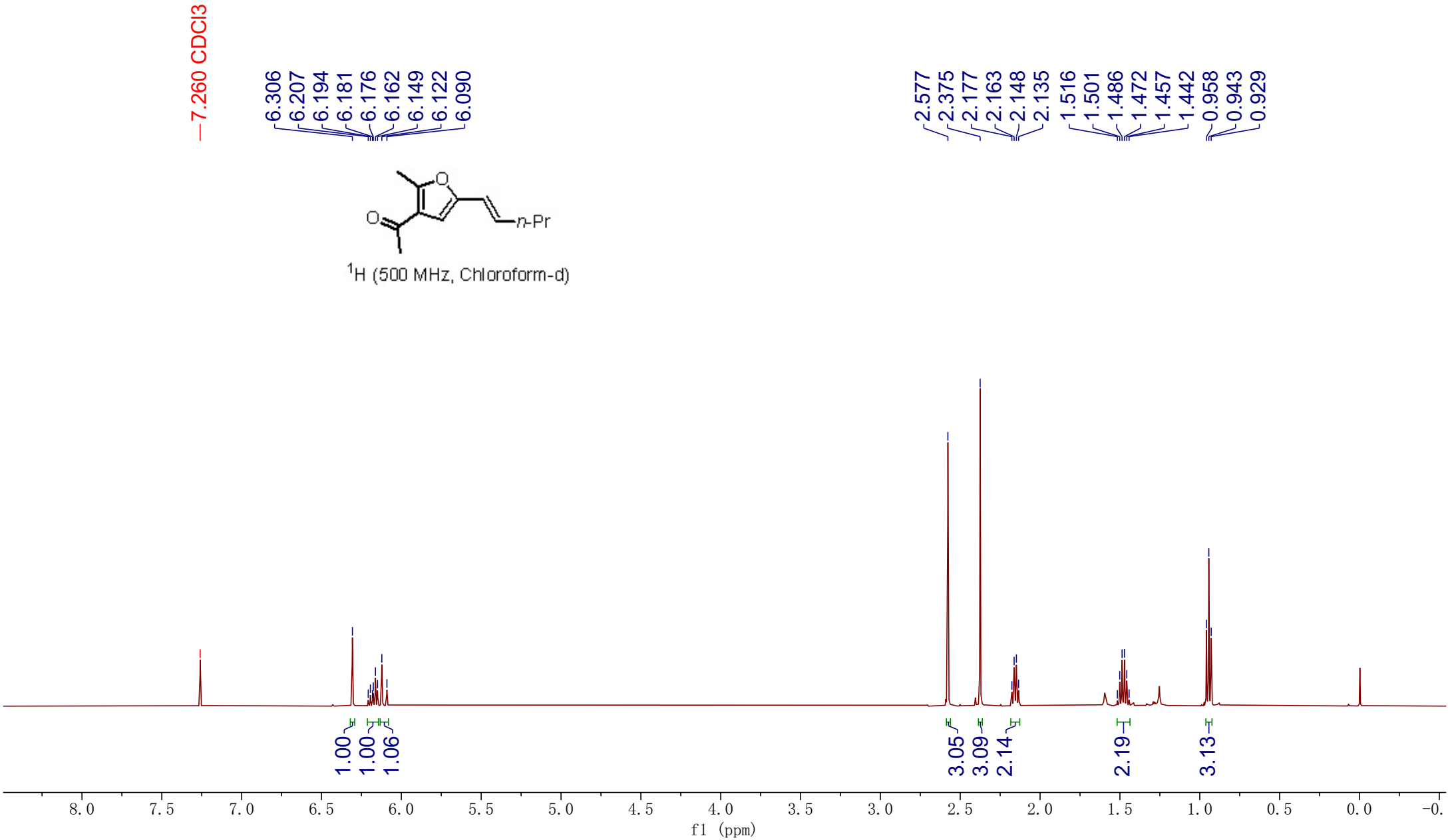

194.22
157.64
150.95
127.31
122.81
119.52
106.44
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
62.81
36.53
29.20
26.07
18.49
14.54
-5.12
O
O
TBSO
13C (126 MHz, Chloroform-d)
f1 (ppm)

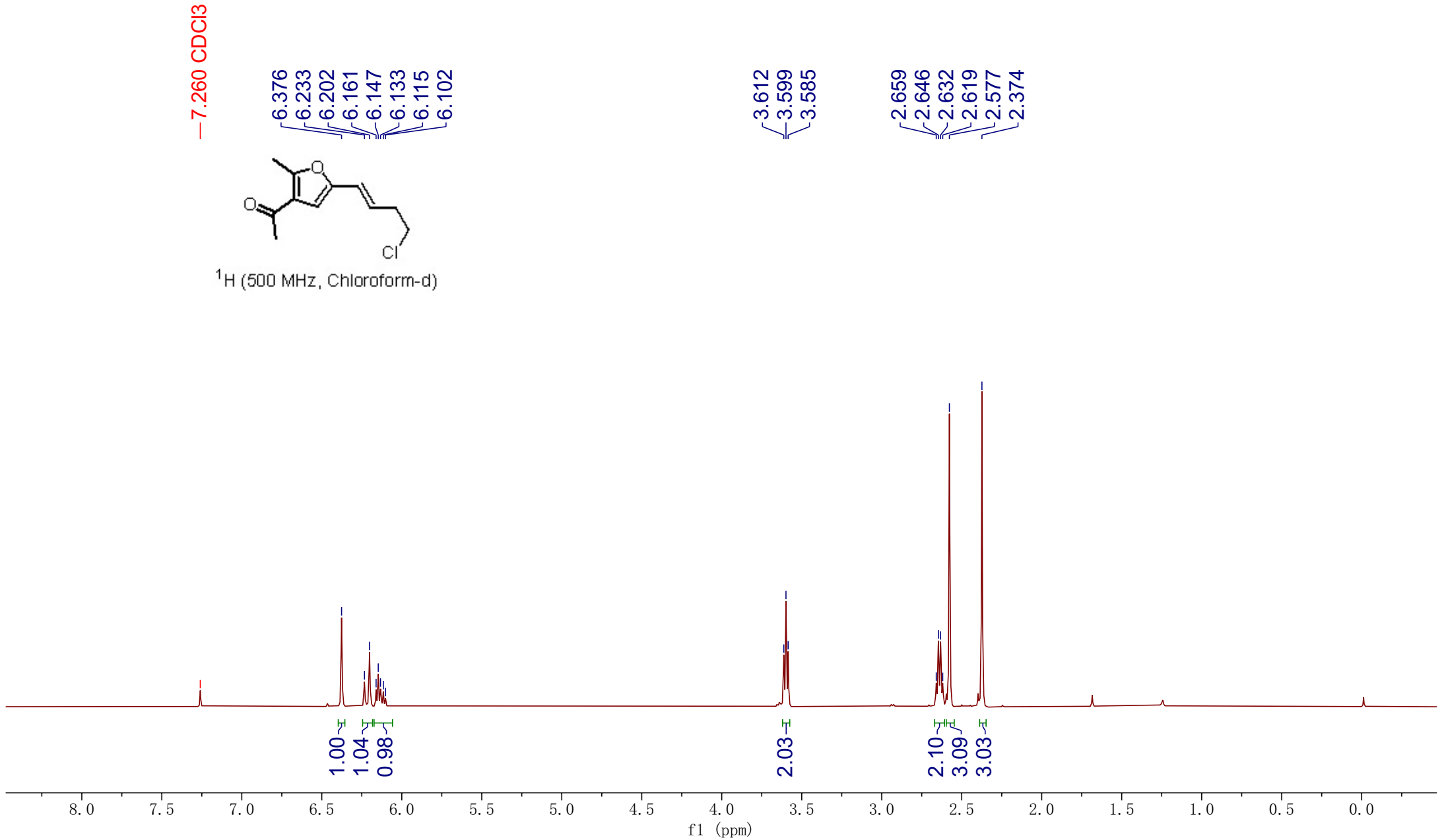

7.260 CDCl3
6.292
6.207
6.195
6.175
6.164
6.157
6.155
6.125
3.769
3.756
3.742
2.540
2.416
2.403
2.391
2.378
2.341
1.080
1.074
1.062
1.053
1.043
1.042
1.039
1.031
1.030
1.028
1.024
TIPSO
1H (500 MHz, Chloroform-d)
0.99
2.04
2.01
3.00
2.07
3.07
3.28
18.26
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

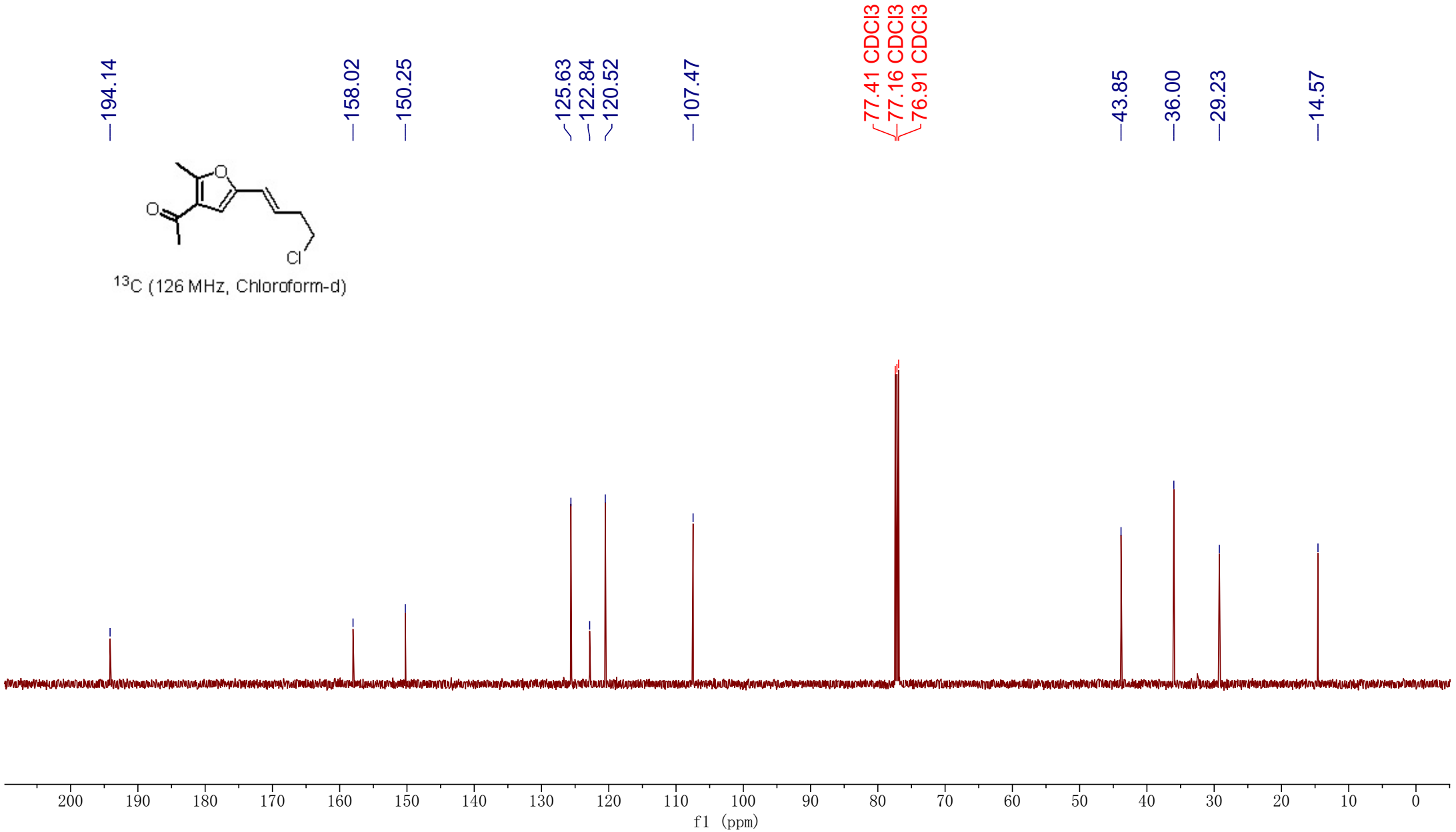

194.10
157.53
150.92
127.34
122.72
119.38
106.34
77.42 CDCl3
77.16 CDCl3
76.91 CDCl3
63.04
36.63
29.11
18.06
14.44
12.07
O
O
TIPSO
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

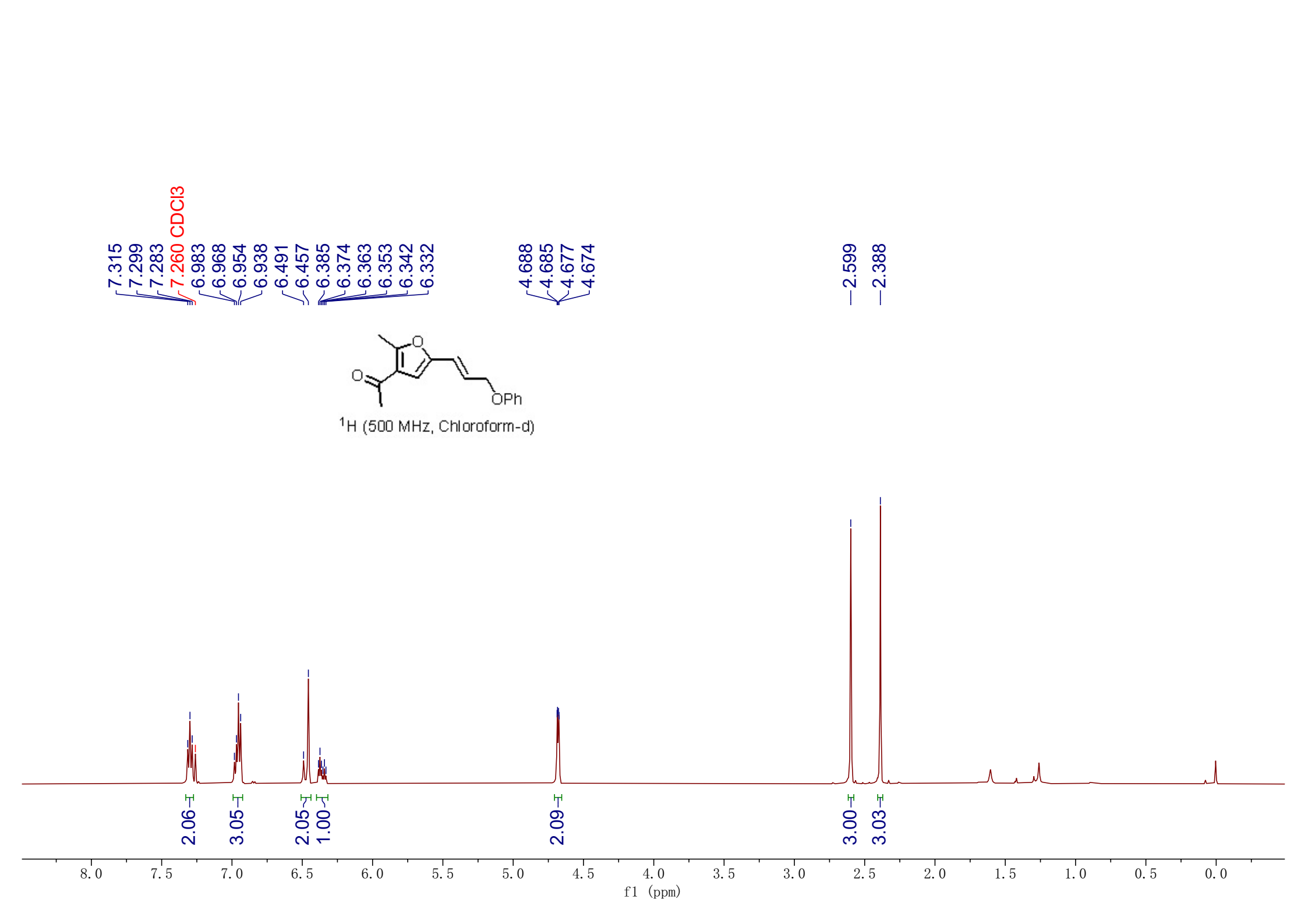

7.710
7.707
7.704
7.693
7.690
7.453
7.444
7.439
7.434
7.427
7.424
7.421
7.402
7.387
7.374
7.260 CDCl3
6.330
6.218
6.208
6.187
6.175
6.169
6.143
3.803
3.790
3.777
2.602
2.472
2.468
2.460
2.448
2.441
2.435
2.396
1.085
O
O
TBDPSO
1H (500 MHz, Chloroform-d)
4.08
6.31
0.99
1.99
1.99
2.92
1.96
3.00
9.32
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

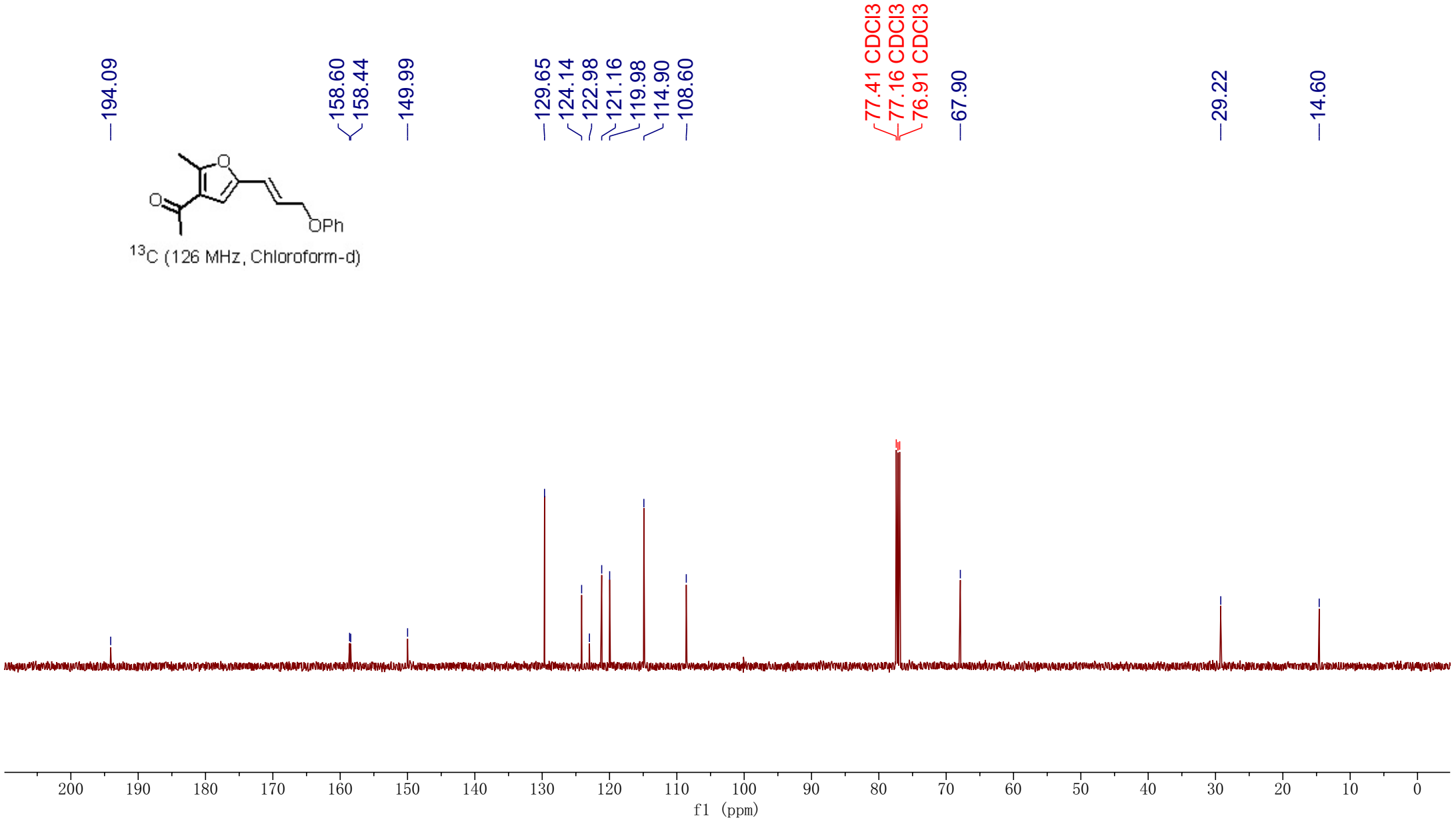

194.25
157.62
150.93
135.71
133.95
129.73
127.74
127.34
122.78
119.58
106.44
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
63.50
36.23
29.21
26.96
19.32
14.54
O
O
TBDPSO
13C (126 MHz, Chloroform-d)
f1 (ppm)

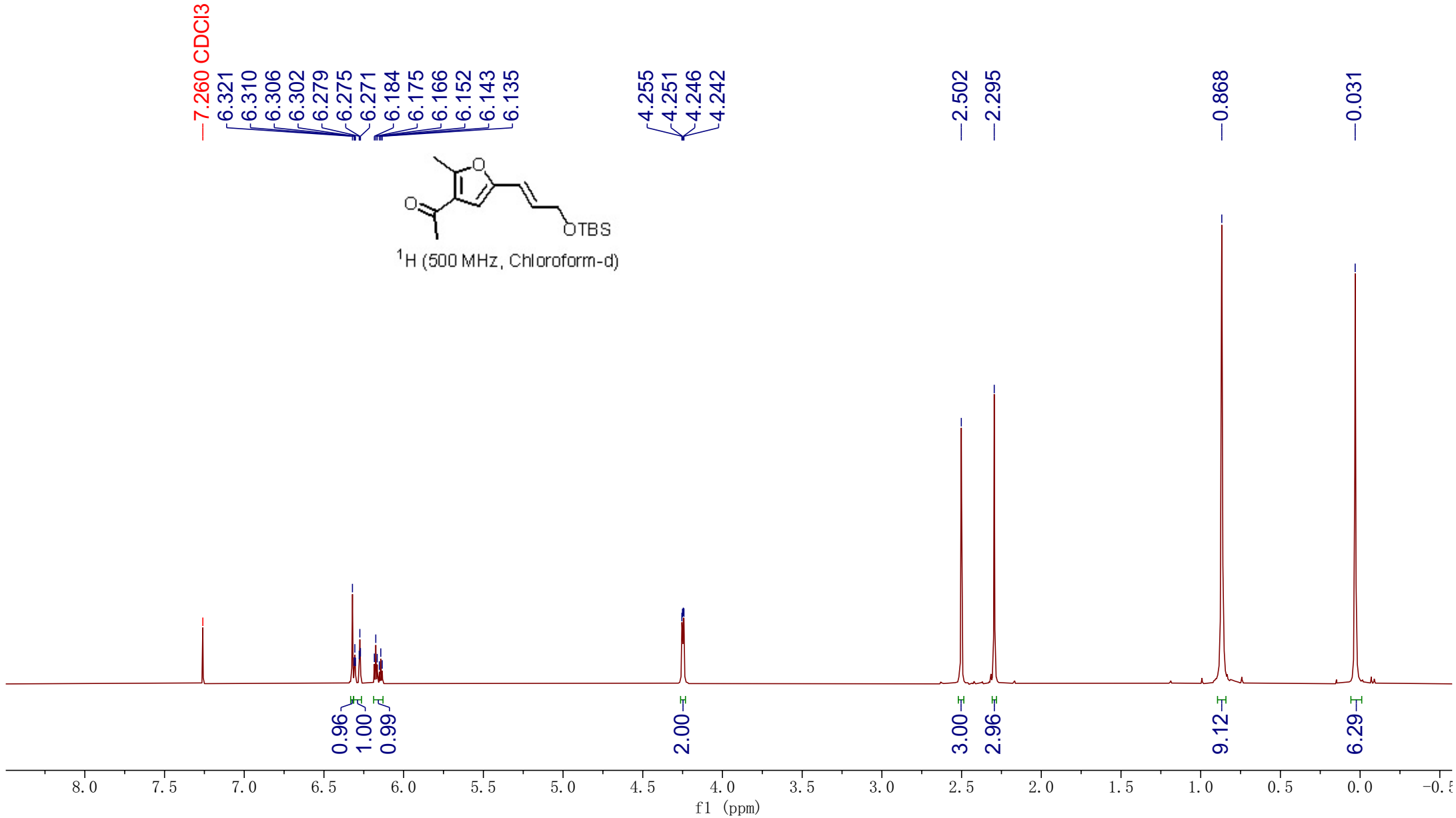

7.260 CDCl3
6.306
6.207
6.194
6.181
6.176
6.162
6.149
6.122
6.090
2.577
2.375
2.177
2.163
2.148
2.135
1.516
1.501
1.486
1.472
1.457
1.442
0.958
0.943
0.929
O
O
n-Pr
1H (500 MHz, Chloroform-d)
1.00
1.00
1.06
3.05
3.09
2.14
2.19
3.13
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.
f1 (ppm)

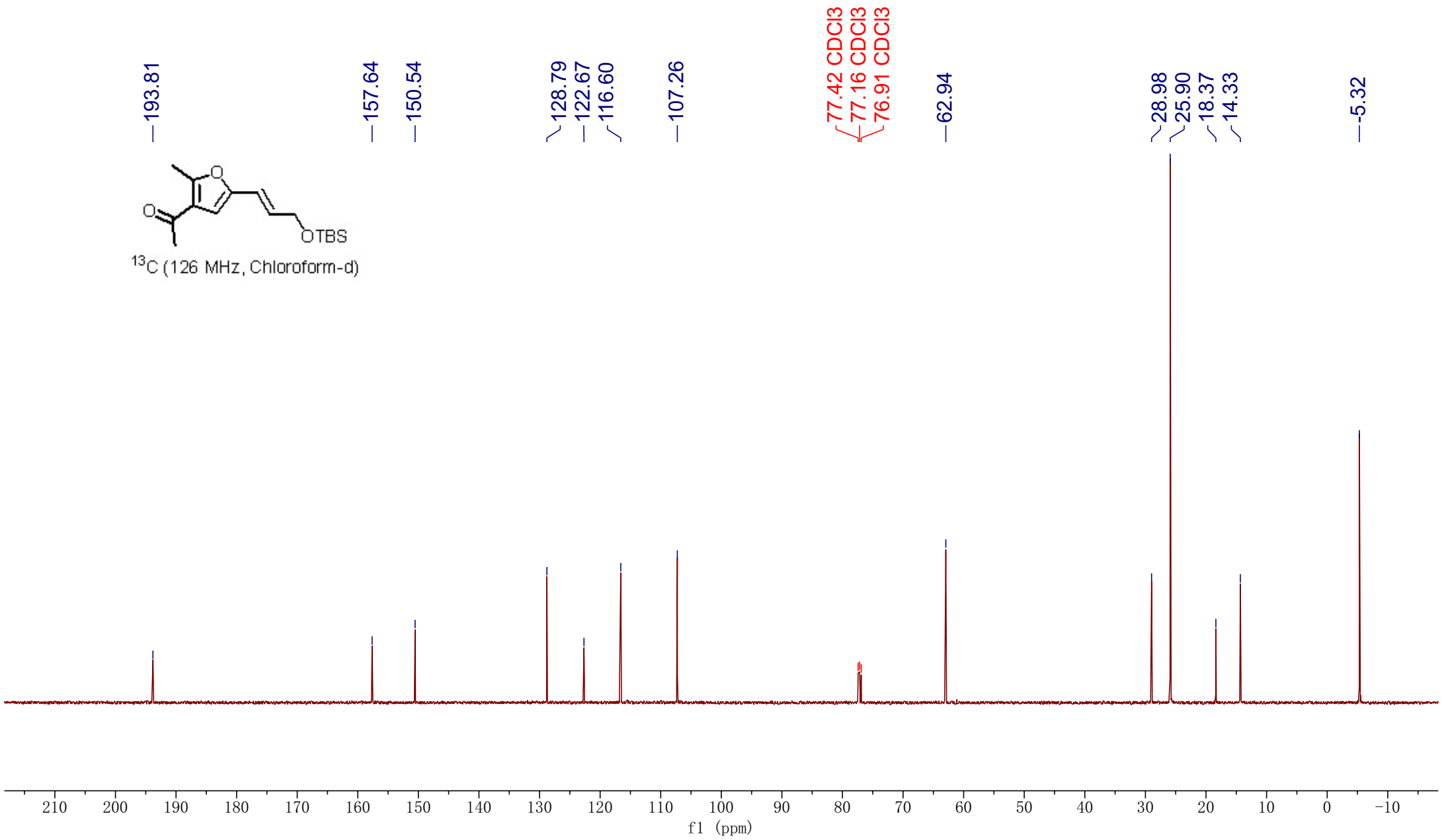

7.260 CDCl3
6.376
6.233
6.202
6.161
6.147
6.133
6.115
6.102
3.612
3.599
3.585
2.659
2.646
2.632
2.619
2.577
2.374
O
O
Cl
1H (500 MHz, Chloroform-d)
1.00
1.04
0.98
2.03
2.10
3.09
3.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

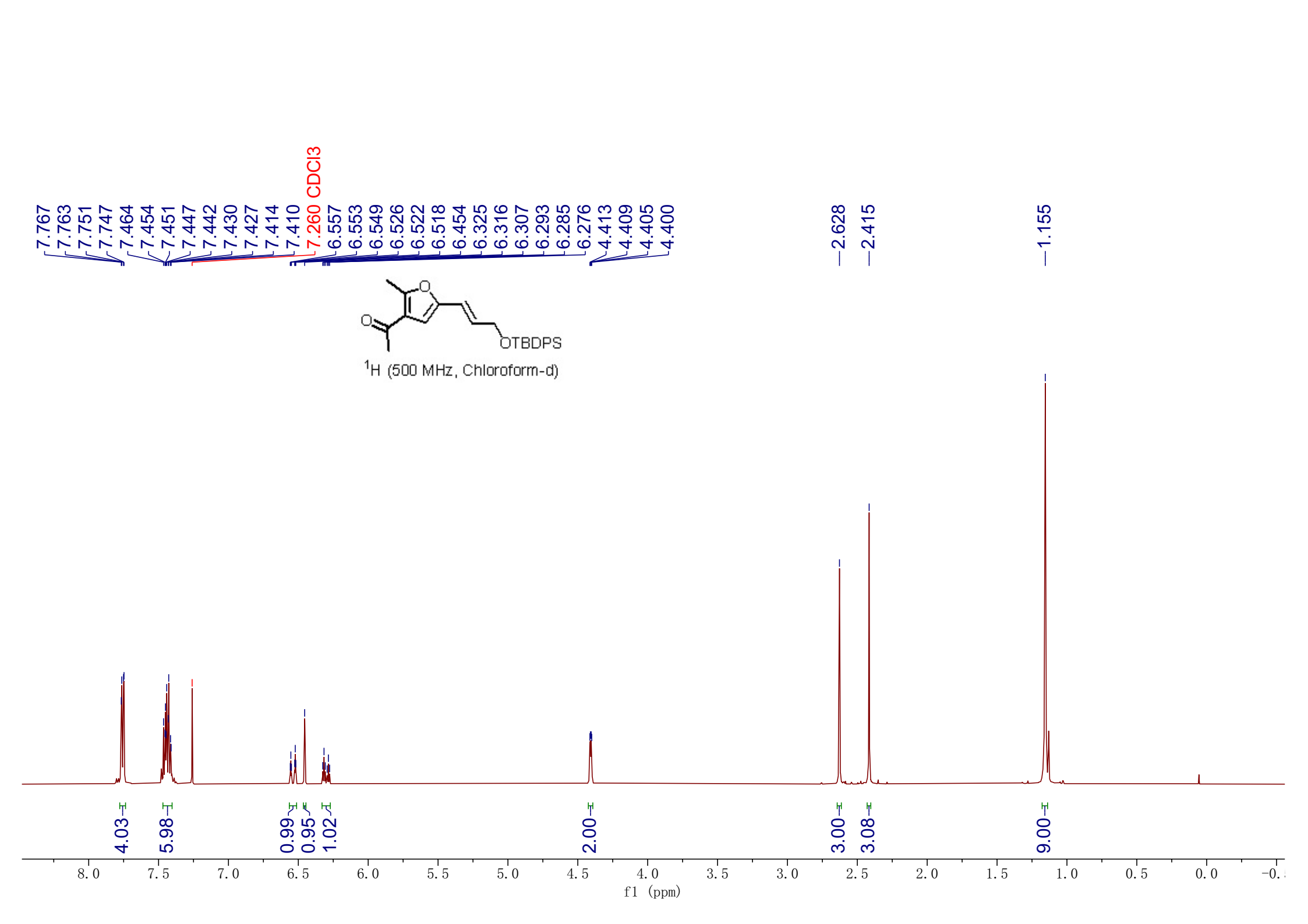

194.14
158.02
150.25
125.63
122.84
120.52
107.47
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
43.85
36.00
29.23
14.57
O
O
Cl
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

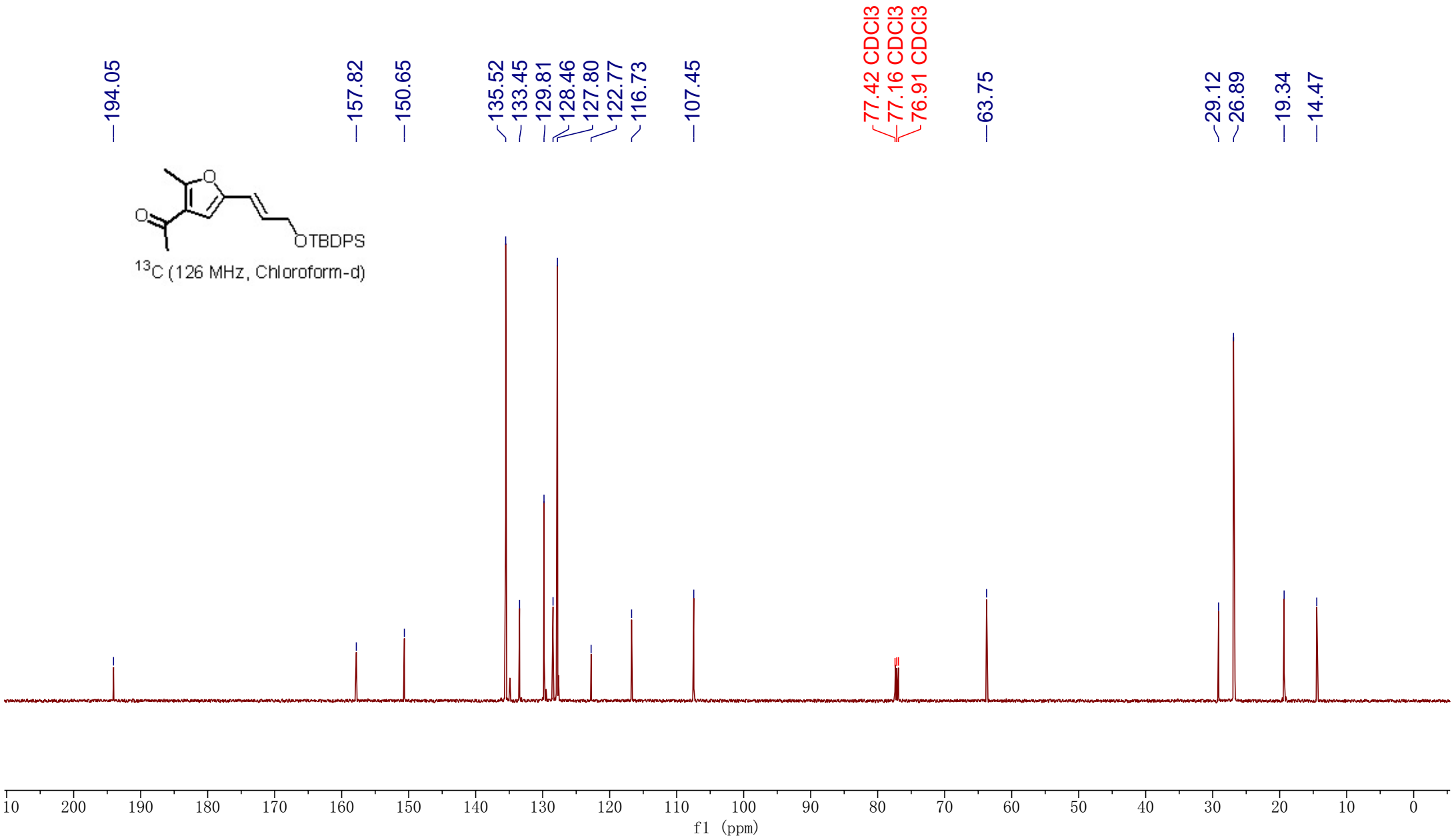

7.315
7.299
7.283
7.260 CDCl3
6.983
6.968
6.954
6.938
6.491
6.457
6.385
6.374
6.363
6.353
6.342
6.332
4.688
4.685
4.677
4.674
2.599
2.388
O
O
OPh
1H (500 MHz, Chloroform-d)
2.06
3.05
2.05
1.00
2.09
3.00
3.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

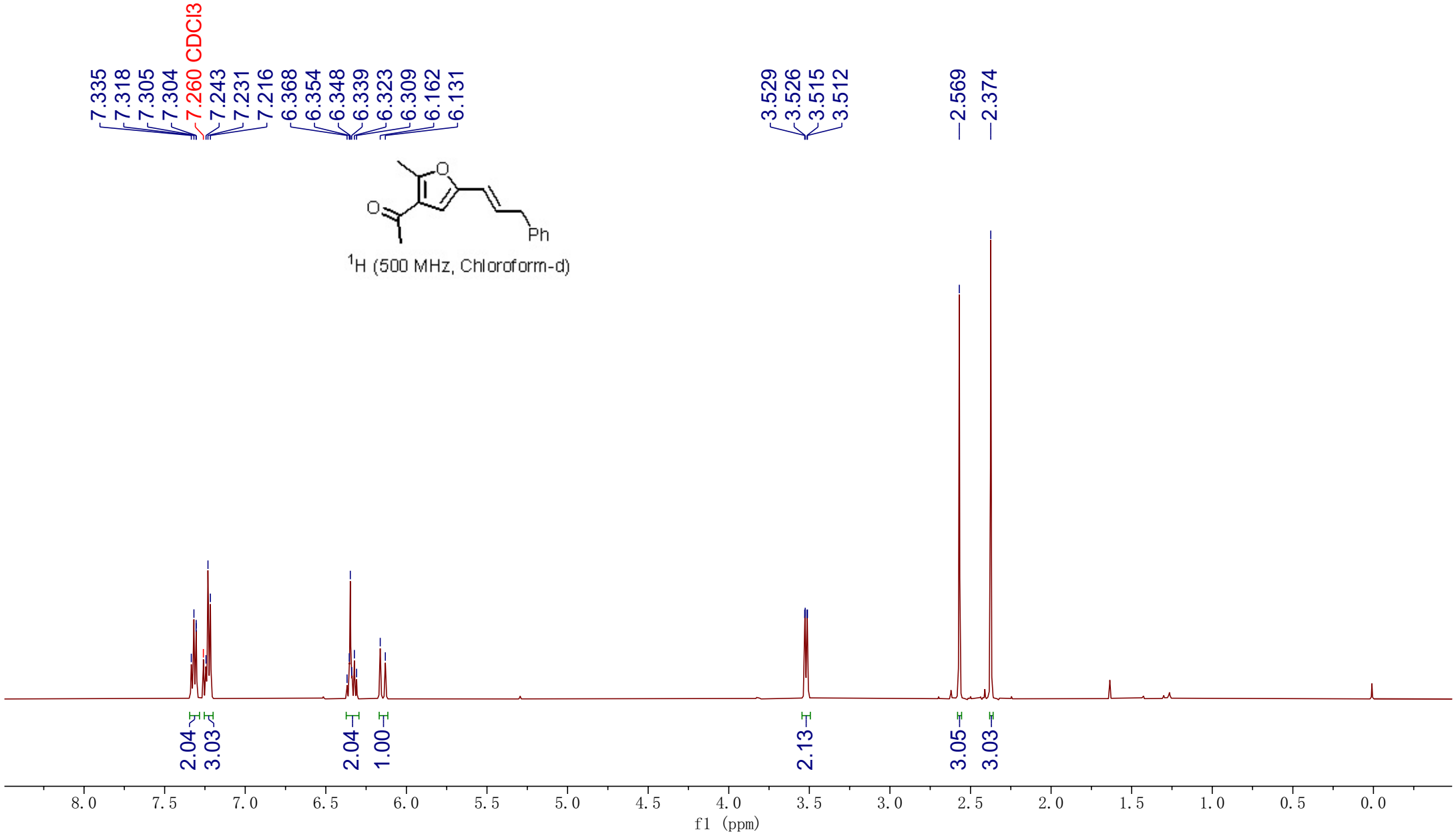

194.09
158.60
158.44
149.99
129.65
124.14
122.98
121.16
119.98
114.90
108.60
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
67.90
29.22
14.60
O
O
OPh
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

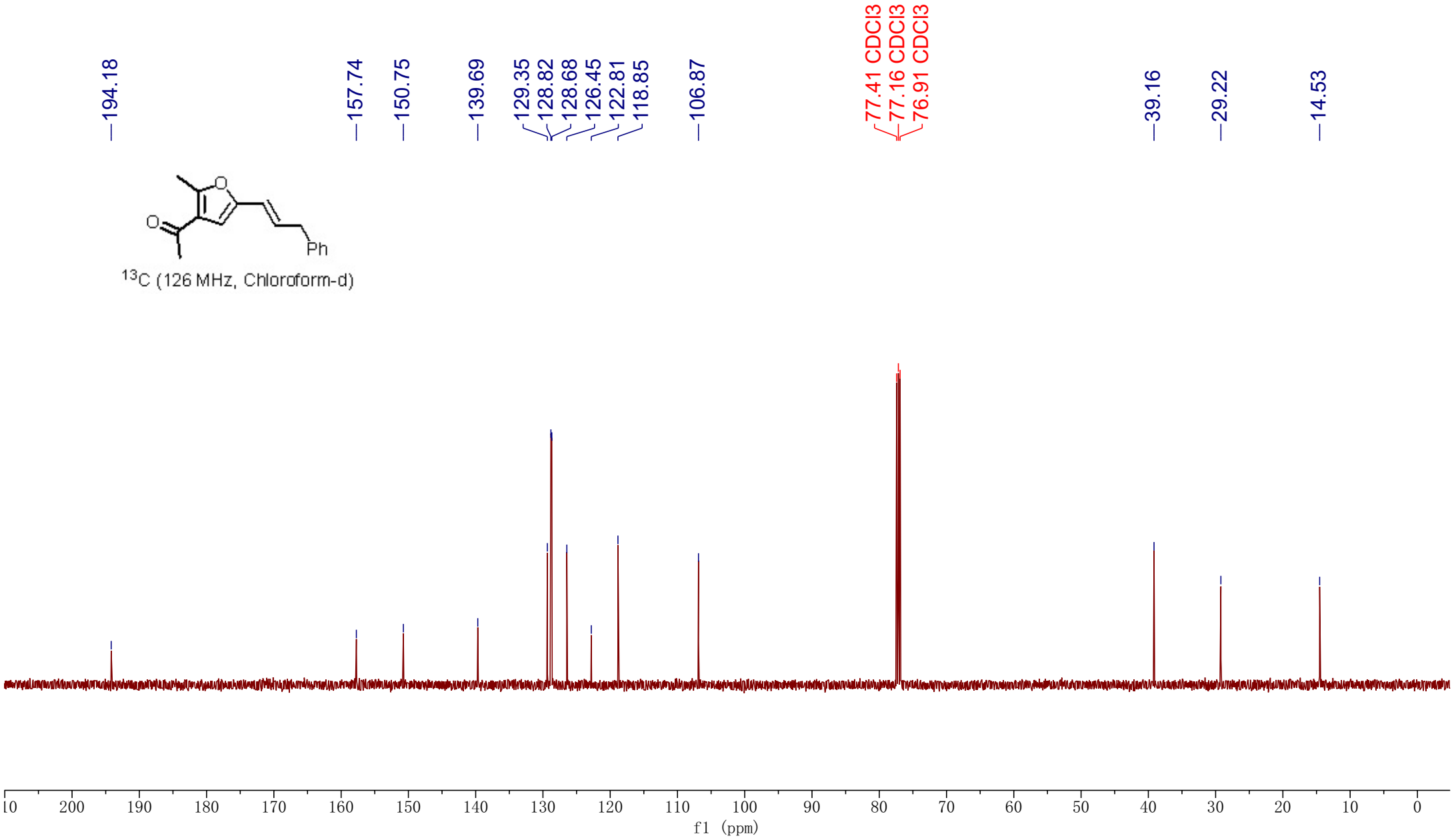

7.260 CDCl3
6.321
6.310
6.306
6.302
6.279
6.275
6.271
6.184
6.175
6.166
6.152
6.143
6.135
4.255
4.251
4.246
4.242
2.502
2.295
0.868
0.031
O
O
OTBS
1H (500 MHz, Chloroform-d)
0.96
1.00
0.99
2.00
3.00
2.96
9.12
6.29
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

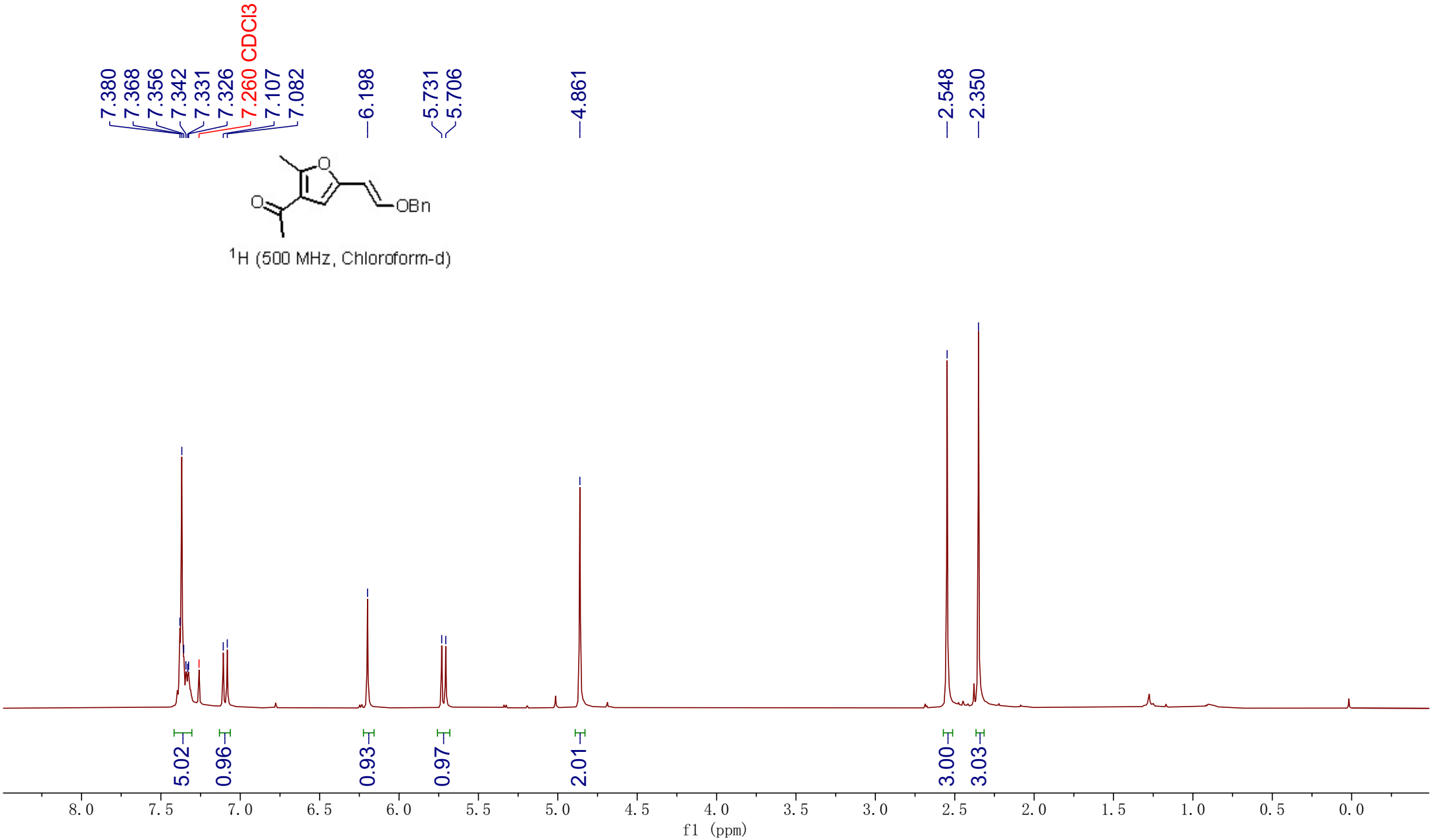

193.81
157.64
150.54
128.79
122.67
116.60
107.26
77.42 CDCl3
77.16 CDCl3
76.91 CDCl3
62.94
28.98
25.90
18.37
14.33
-5.32
O
O
OTBS
13C (126 MHz, Chloroform-d)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

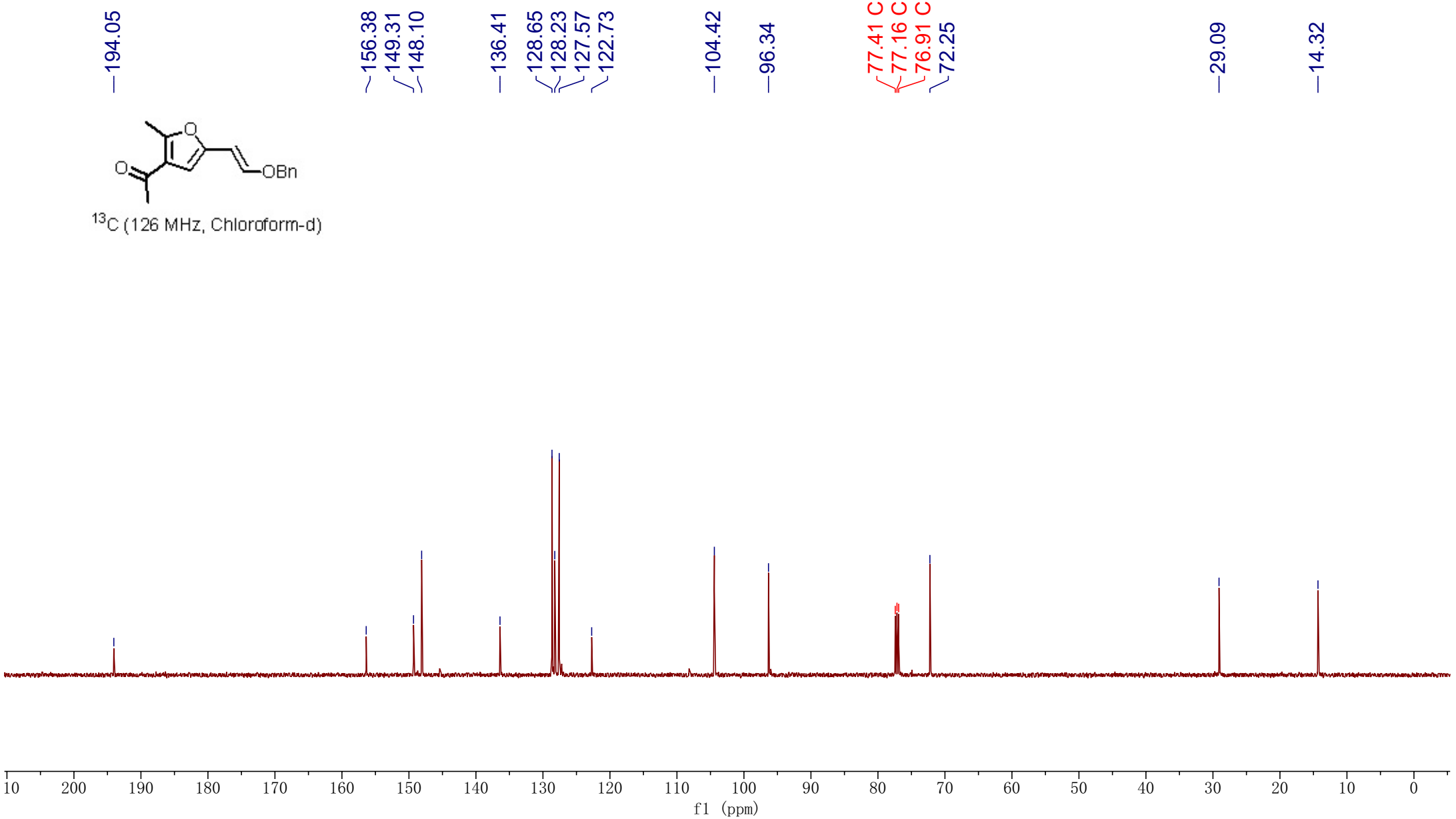

7.767
7.763
7.751
7.747
7.464
7.454
7.451
7.447
7.442
7.430
7.427
7.414
7.410
7.260 CDCl3
6.557
6.553
6.549
6.526
6.522
6.518
6.454
6.325
6.316
6.307
6.293
6.285
6.276
4.413
4.409
4.405
4.400
2.628
2.415
1.155
O
O
OTBDPS
1H (500 MHz, Chloroform-d)
4.03
5.98
0.99
0.95
1.02
2.00
3.00
3.08
9.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

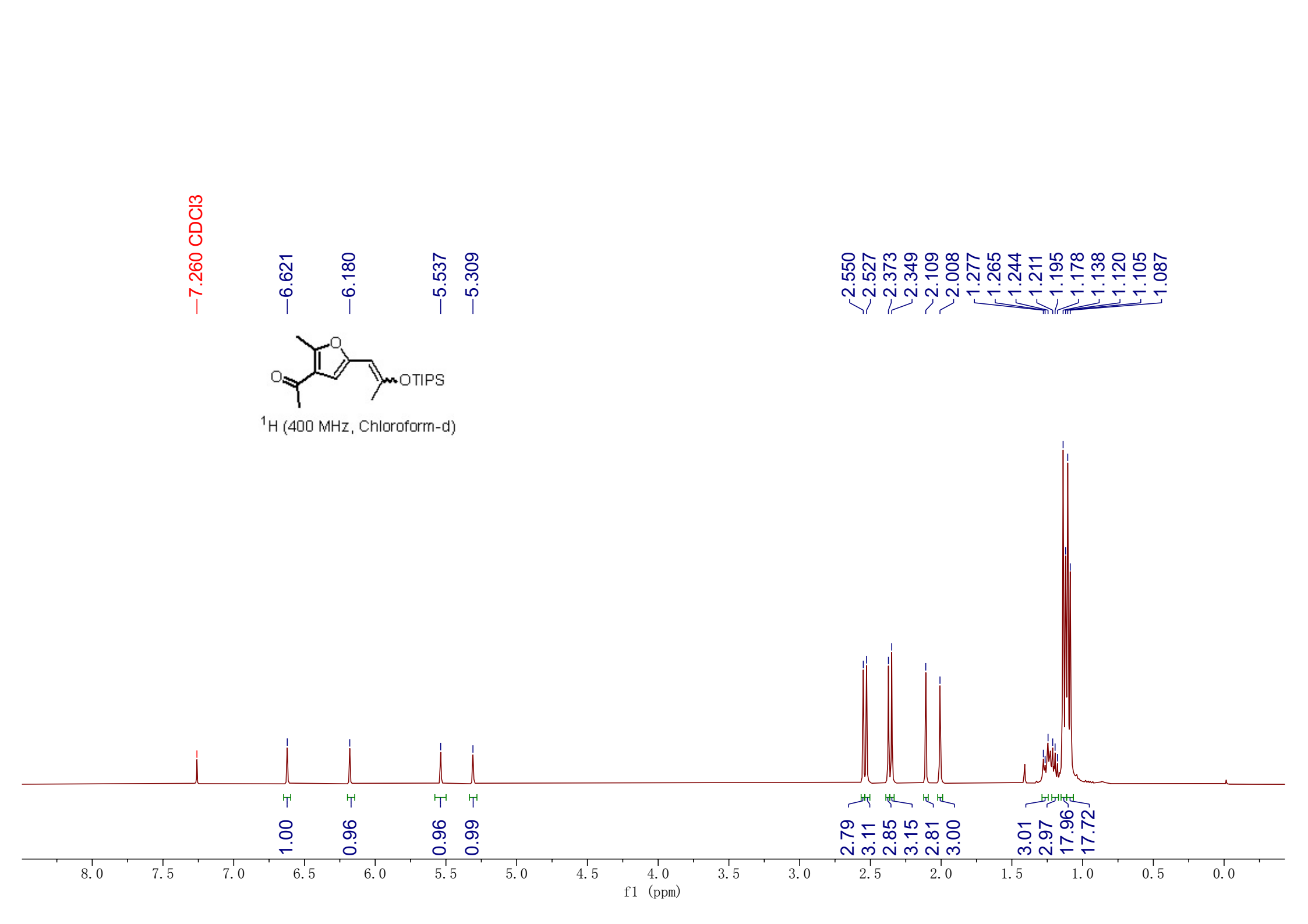

194.05
157.82
150.65
135.52
133.45
129.81
128.46
127.80
122.77
116.73
107.45
77.42 CDCl3
77.16 CDCl3
76.91 CDCl3
63.75
29.12
26.89
19.34
14.47
O
O
OTBDPS
13C (126 MHz, Chloroform-d)
f1 (ppm)

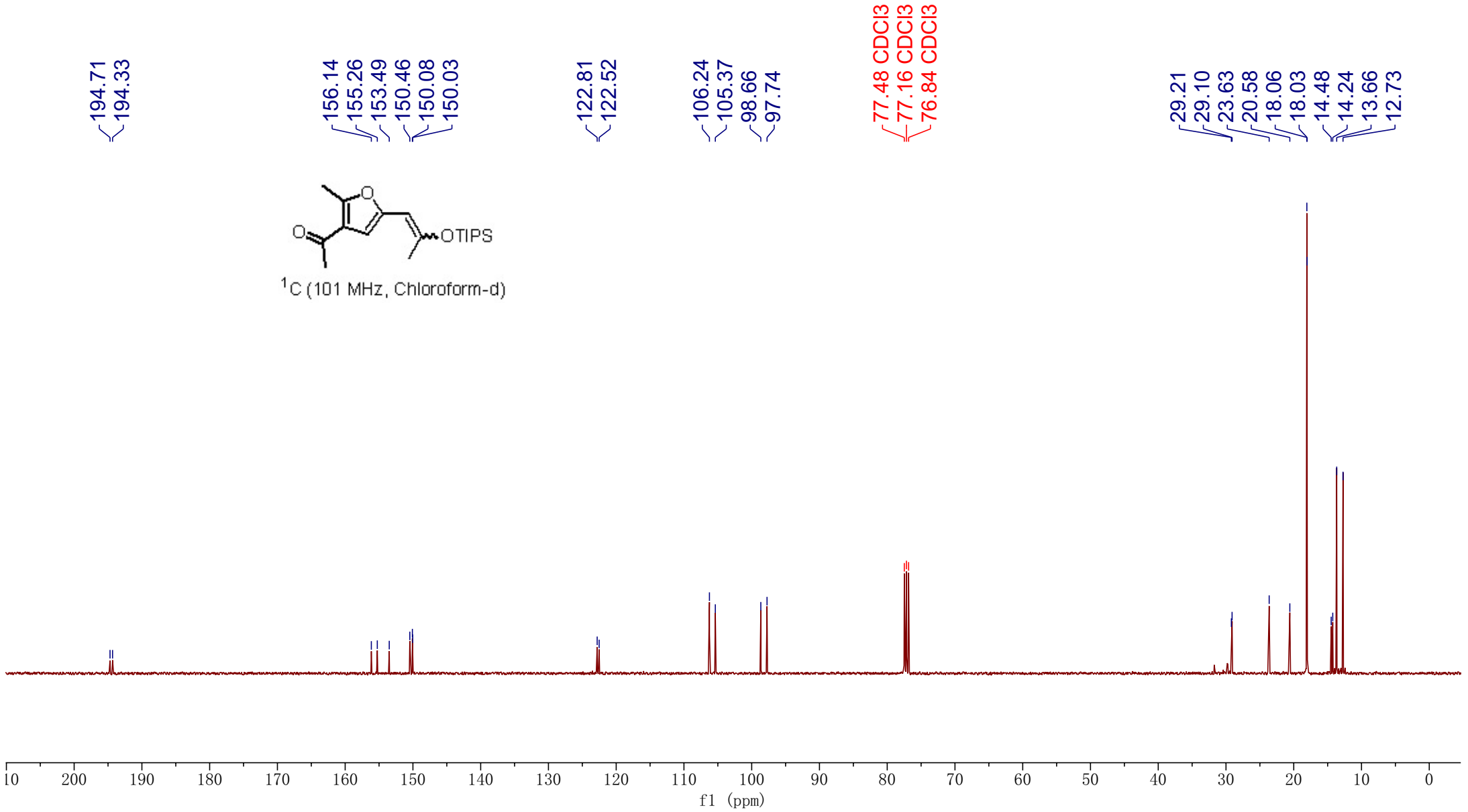

7.335
7.318
7.305
7.304
7.260 CDCl3
7.243
7.231
7.216
6.368
6.354
6.348
6.339
6.323
6.309
6.162
6.131
3.529
3.526
3.515
3.512
2.569
2.374
O
O
Ph
1H (500 MHz, Chloroform-d)
2.04
3.03
2.04
1.00
2.13
3.05
3.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

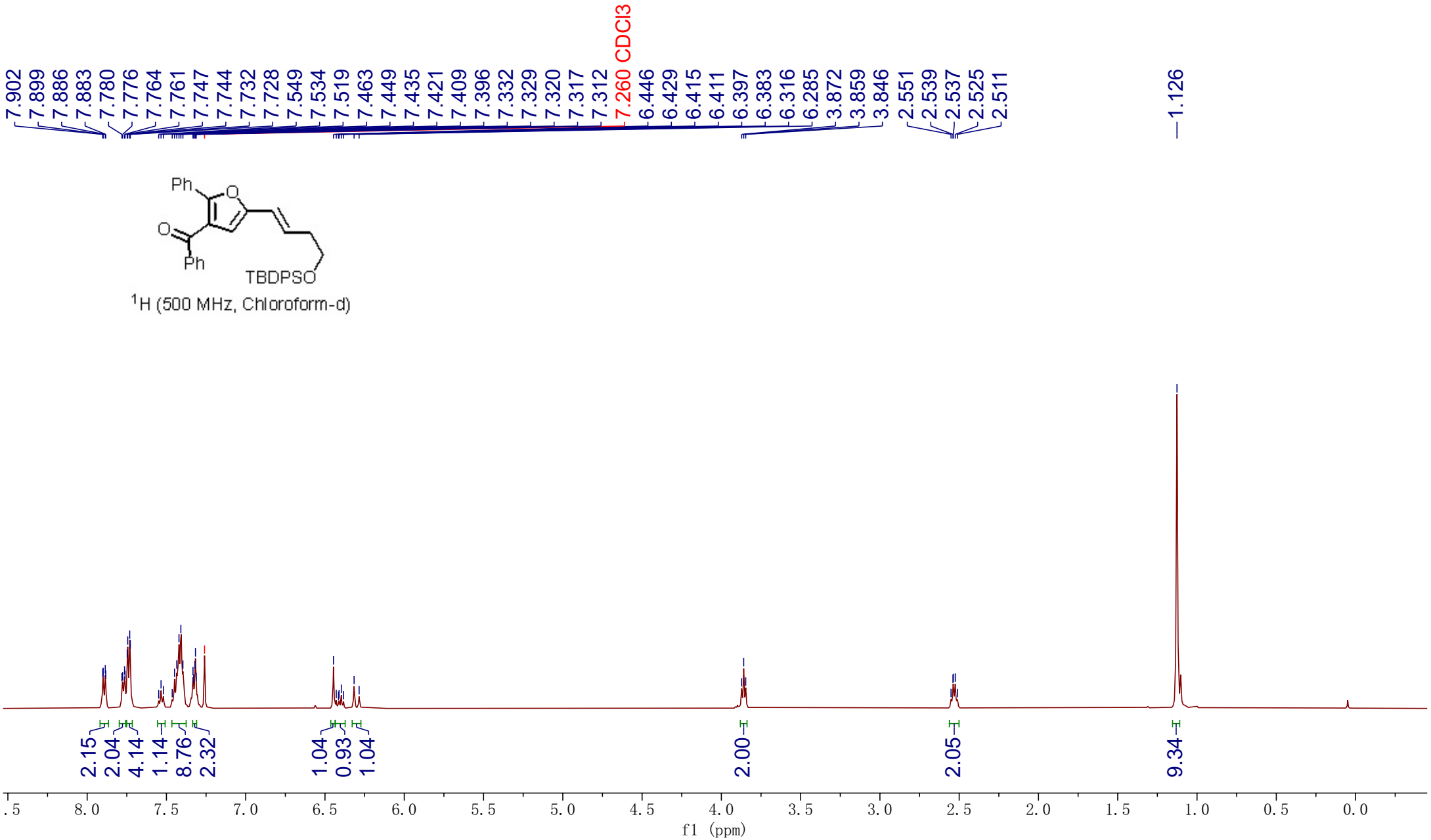

194.18
157.74
150.75
139.69
129.35
128.82
128.68
126.45
122.81
118.85
106.87
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
39.16
29.22
14.53
O
O
Ph
13C (126 MHz, Chloroform-d)
f1 (ppm)

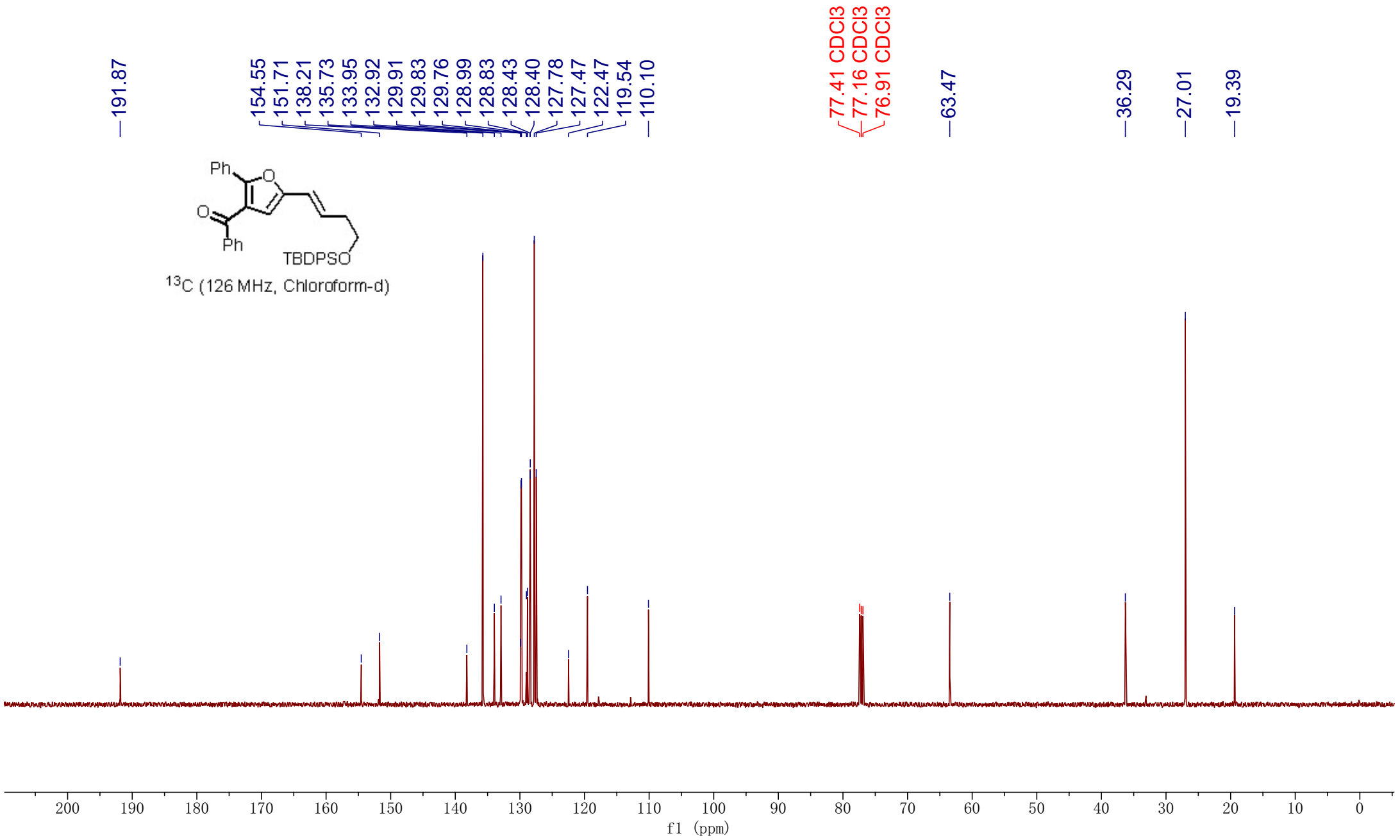

7.380
7.368
7.356
7.342
7.331
7.326
7.260 CDCl3
7.107
7.082
6.198
5.731
5.706
4.861
2.548
2.350
O
O
OBn
1H (500 MHz, Chloroform-d)
5.02
0.96
0.93
0.97
2.01
3.00
3.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

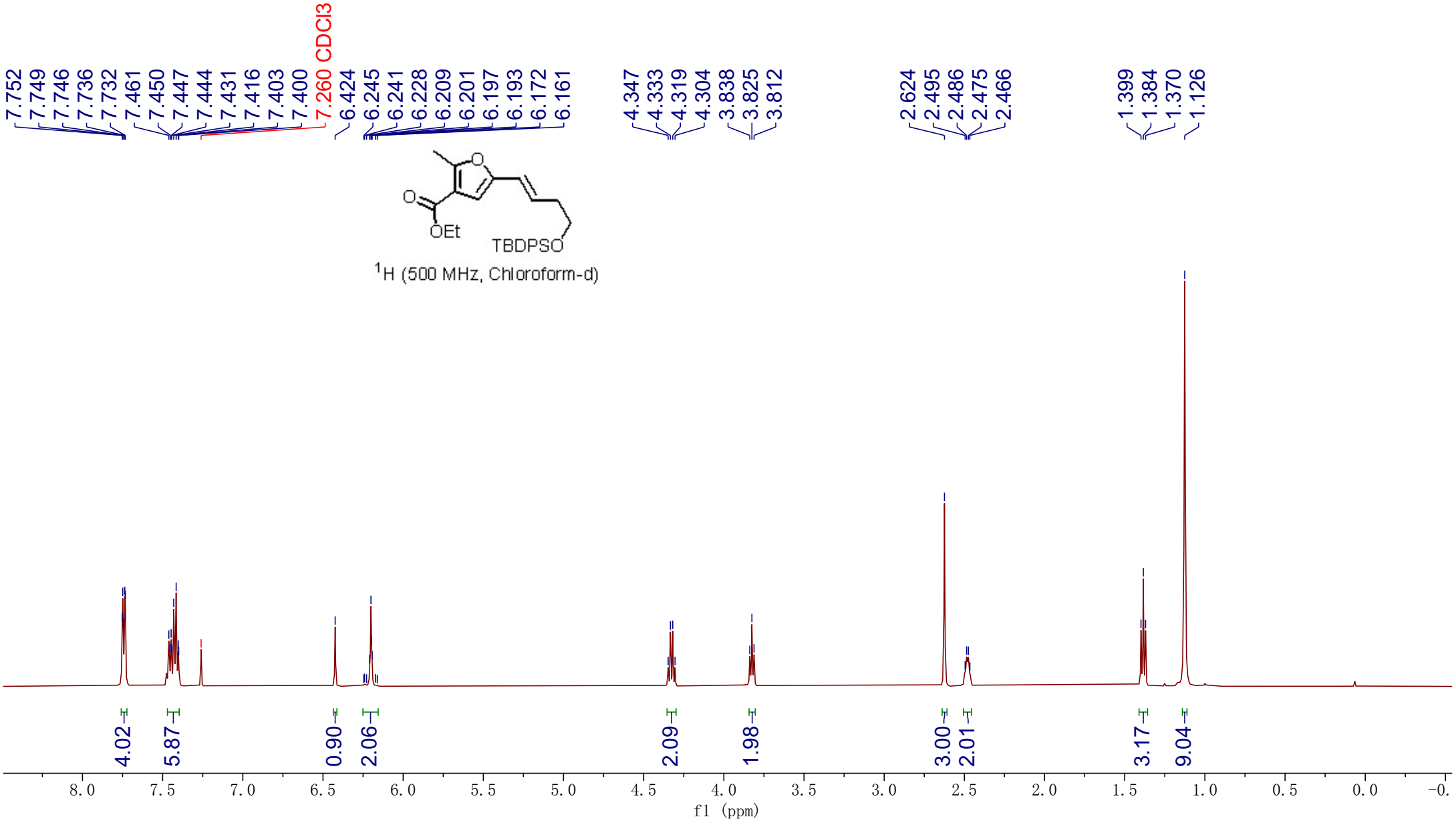

194.05
156.38
149.31
148.10
136.41
128.65
128.23
127.57
122.73
104.42
96.34
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
72.25
29.09
14.32
O
O
OBn
13C (126 MHz, Chloroform-d)
f1 (ppm)

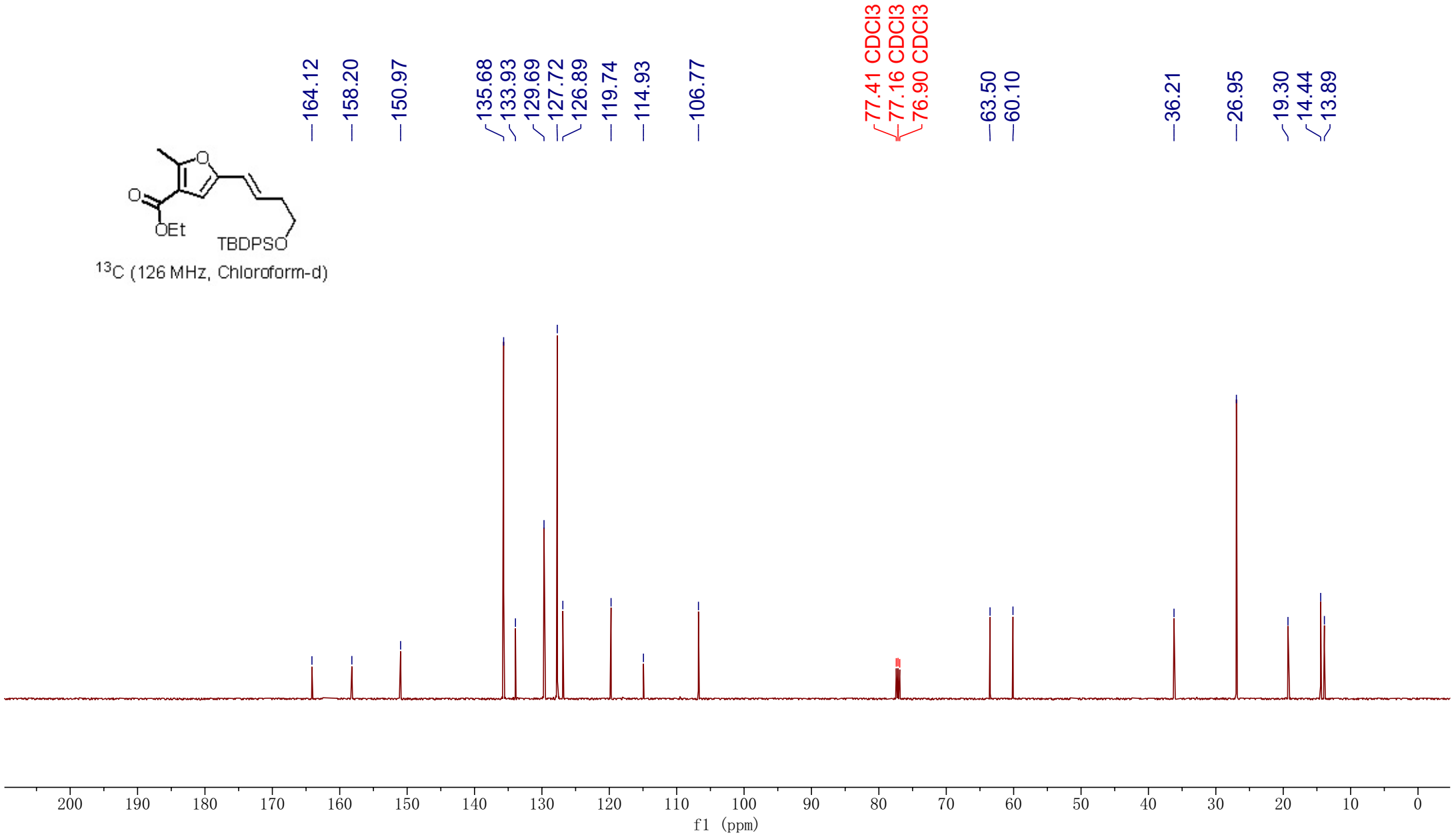

7.260 CDCl3
6.621
6.180
5.537
5.309
2.550
2.527
2.373
2.349
2.109
2.008
1.277
1.265
1.244
1.211
1.195
1.178
1.138
1.120
1.105
1.087
O
O
OTIPS
1H (400 MHz, Chloroform-d)
1.00
0.96
0.96
0.99
2.79
3.11
2.85
3.15
2.81
3.00
3.01
2.97
17.96
17.72
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

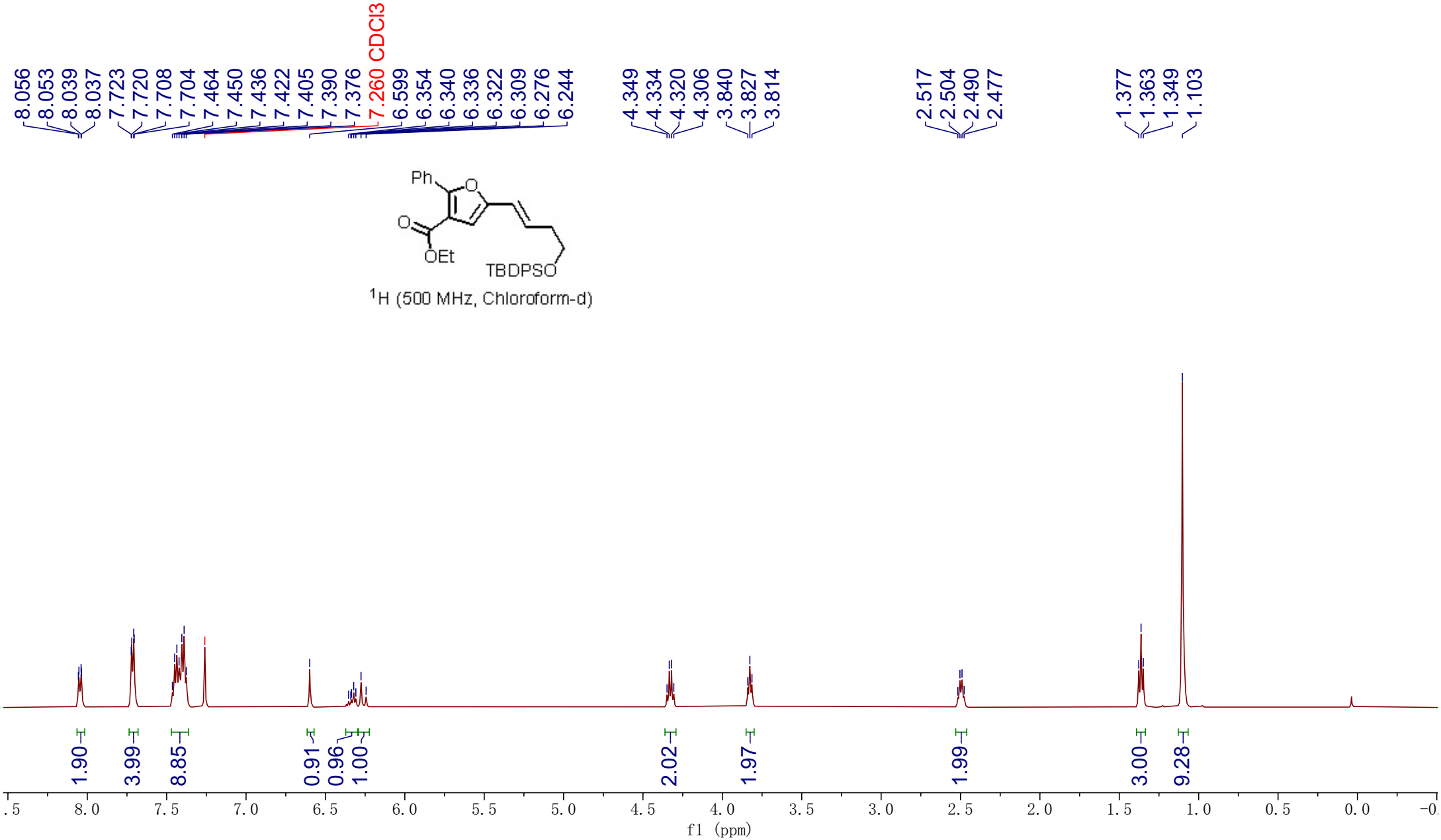

194.71
194.33
156.14
155.26
153.49
150.46
150.08
150.03
122.81
122.52
106.24
105.37
98.66
97.74
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
29.21
29.10
23.63
20.58
18.06
18.03
14.48
14.24
13.66
12.73
O
O
OTIPS
1C (101 MHz, Chloroform-d)
f1 (ppm)

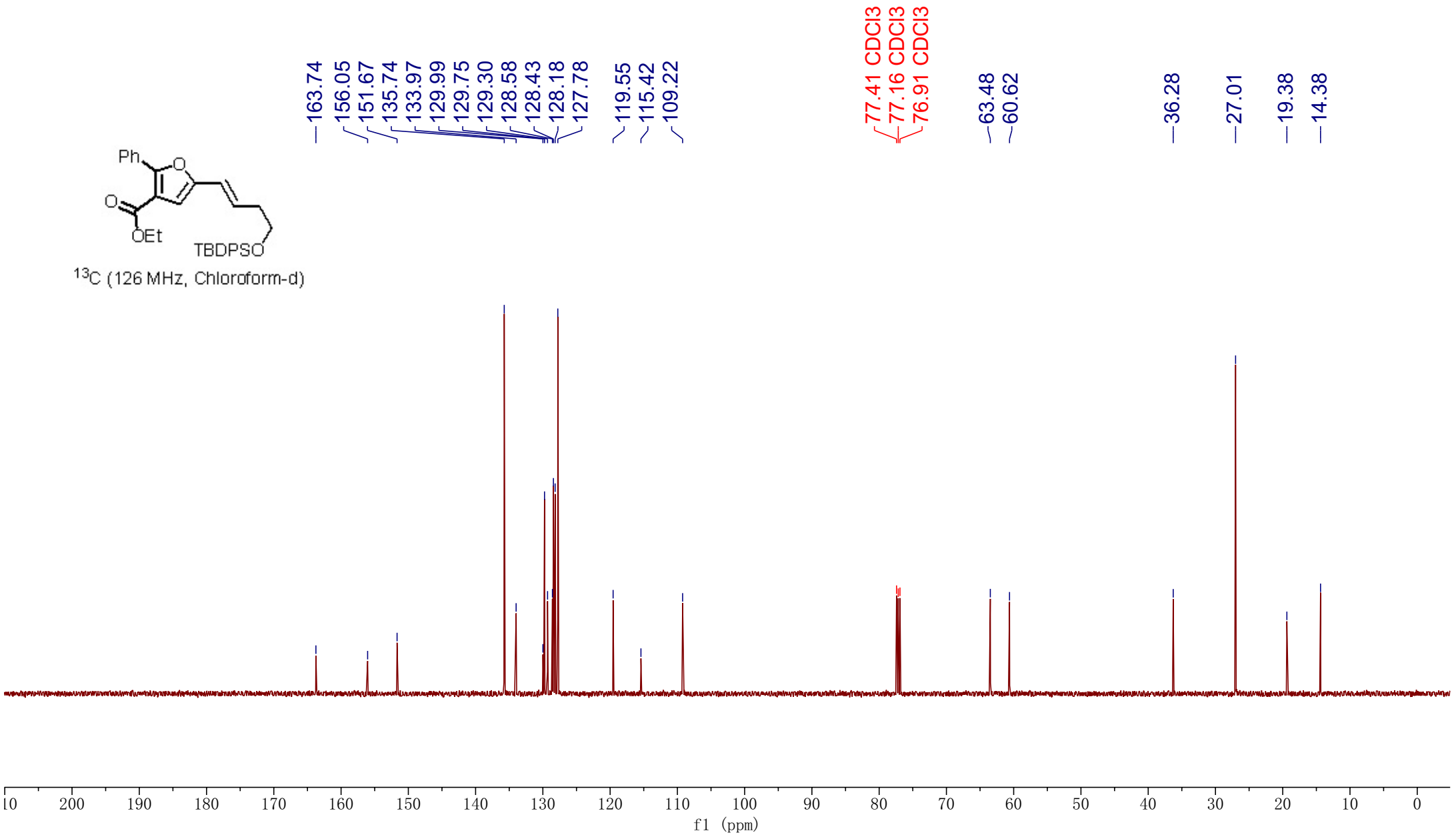

7.902
7.899
7.886
7.883
7.780
7.776
7.764
7.761
7.747
7.744
7.732
7.728
7.549
7.534
7.519
7.463
7.449
7.435
7.421
7.409
7.396
7.332
7.329
7.320
7.317
7.312
7.260 CDCl3
6.446
6.429
6.415
6.411
6.397
6.383
6.316
6.285
3.872
3.859
3.846
2.551
2.539
2.537
2.525
2.511
1.126
Ph
O
O
Ph
TBDPSO
1H (500 MHz, Chloroform-d)
2.15
2.04
4.14
1.14
8.76
2.32
1.04
0.93
1.04
2.00
2.05
9.34
f1 (ppm)

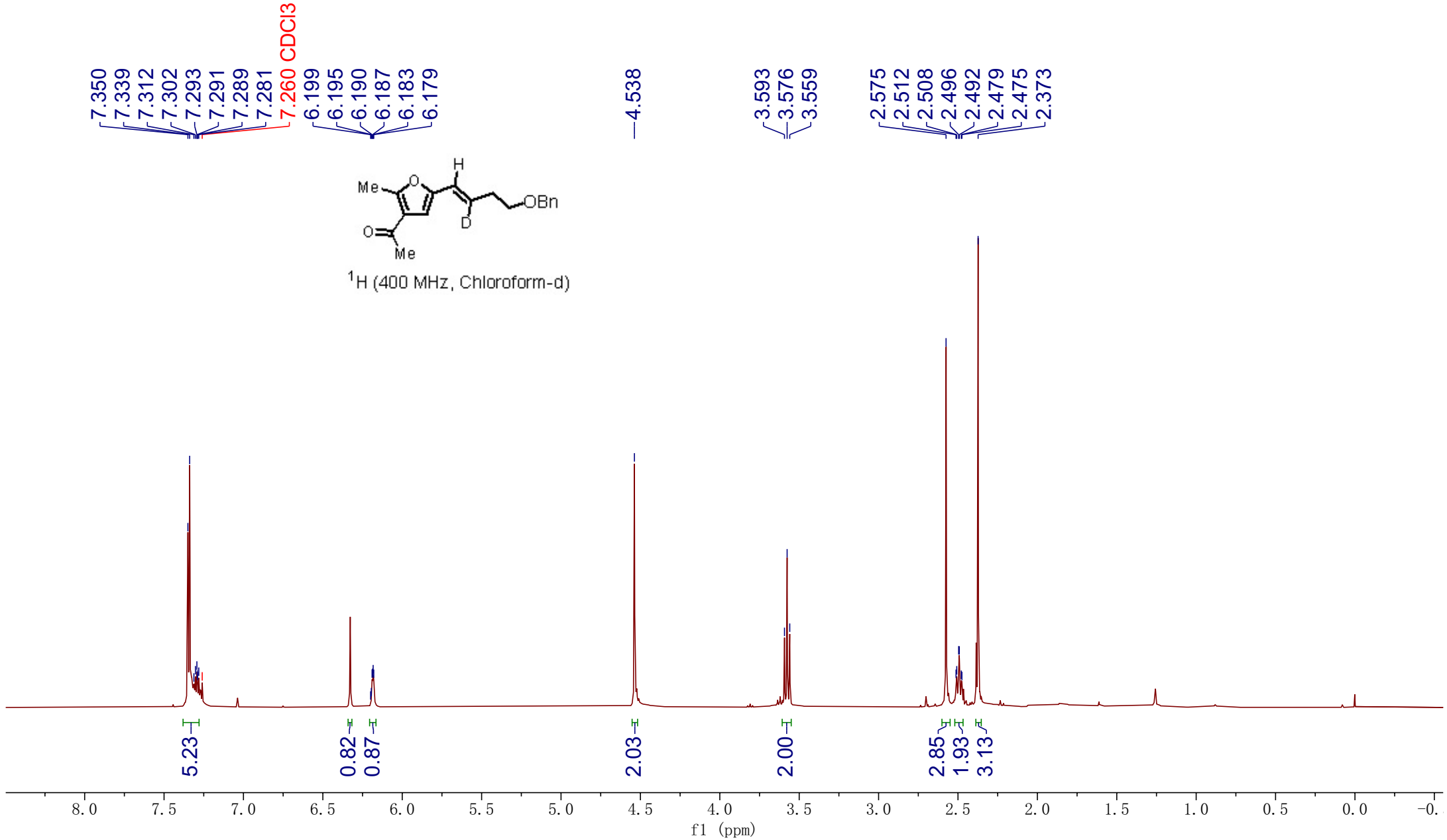

191.87
154.55
151.71
138.21
135.73
133.95
132.92
129.91
129.83
129.76
128.99
128.83
128.43
128.40
127.78
127.47
122.47
119.54
110.10
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
63.47
36.29
27.01
19.39
Ph
O
O
Ph
TBDPSO
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

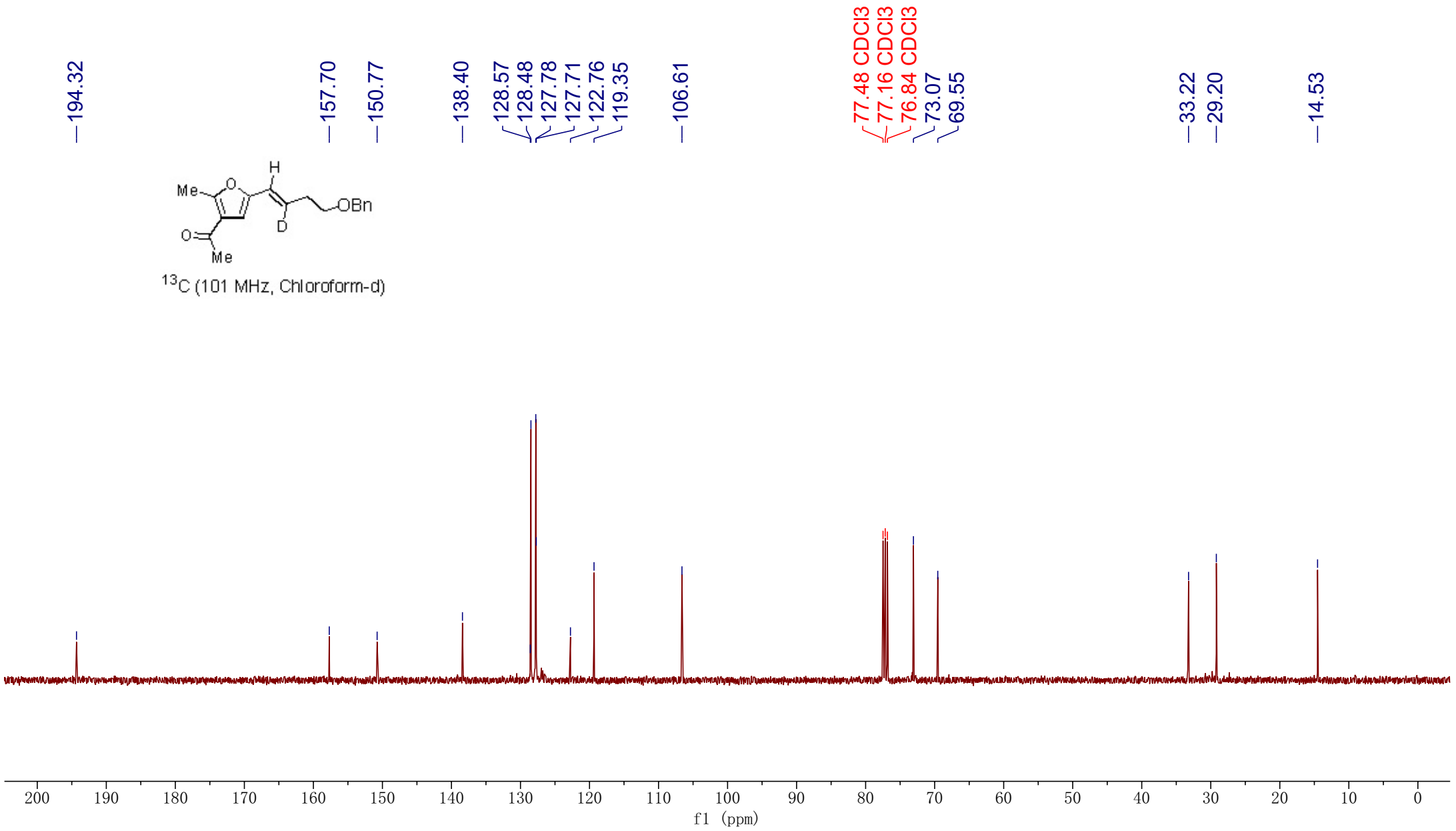

7.752
7.749
7.746
7.736
7.732
7.461
7.450
7.447
7.444
7.431
7.416
7.403
7.400
7.260 CDCl3
6.424
6.245
6.241
6.228
6.209
6.201
6.197
6.193
6.172
6.161
4.347
4.333
4.319
4.304
3.838
3.825
3.812
2.624
2.495
2.486
2.475
2.466
1.399
1.384
1.370
1.126
OEt
TBDPSO
1H (500 MHz, Chloroform-d)
4.02
5.87
0.90
2.06
2.09
1.98
3.00
2.01
3.17
9.04
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.
f1 (ppm)

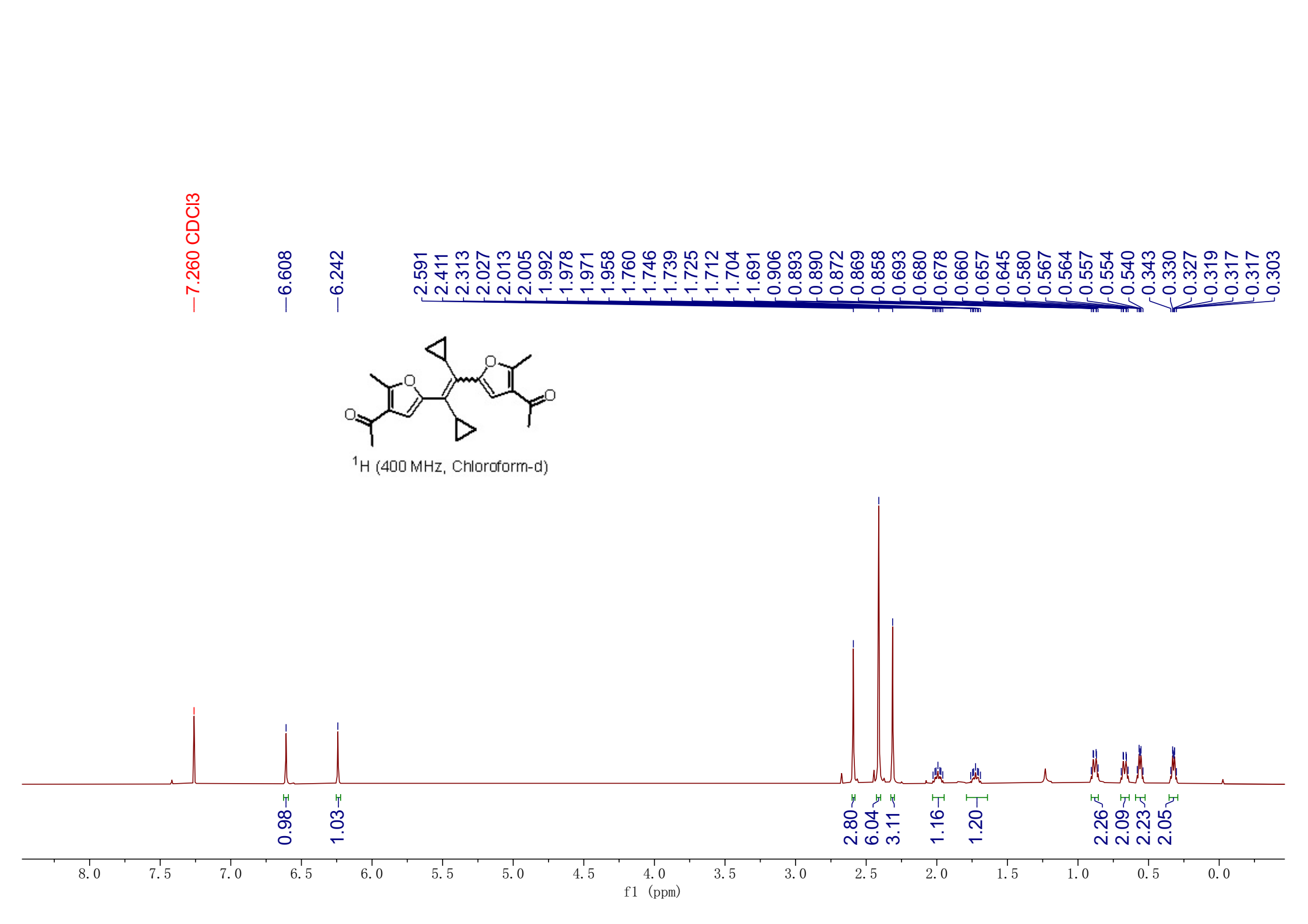

164.12
158.20
150.97
135.68
133.93
129.69
127.72
126.89
119.74
114.93
106.77
77.41 CDCl3
77.16 CDCl3
76.90 CDCl3
63.50
60.10
36.21
26.95
19.30
14.44
13.89
O
O
OEt
TBDPSO
13C (126 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

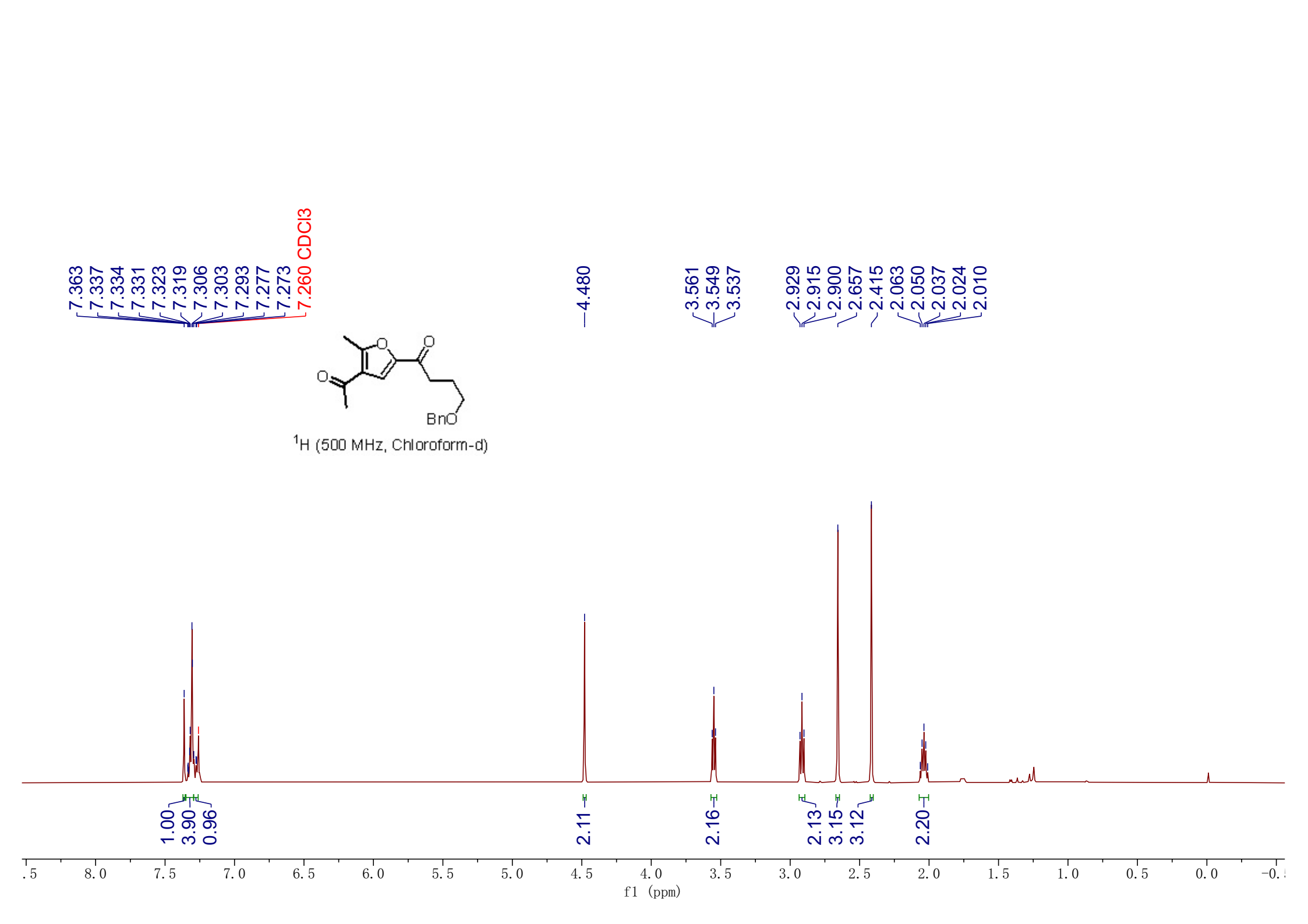

8.056
8.053
8.039
8.037
7.723
7.720
7.708
7.704
7.464
7.450
7.436
7.422
7.405
7.390
7.376
7.260 CDCl3
6.599
6.354
6.340
6.336
6.322
6.309
6.276
6.244
4.349
4.334
4.320
4.306
3.840
3.827
3.814
2.517
2.504
2.490
2.477
1.377
1.363
1.349
1.103
Ph
O
O
OEt
TBDPSO
1H (500 MHz, Chloroform-d)
1.90
3.99
8.85
0.91
0.96
1.00
2.02
1.97
1.99
3.00
9.28
f1 (ppm)

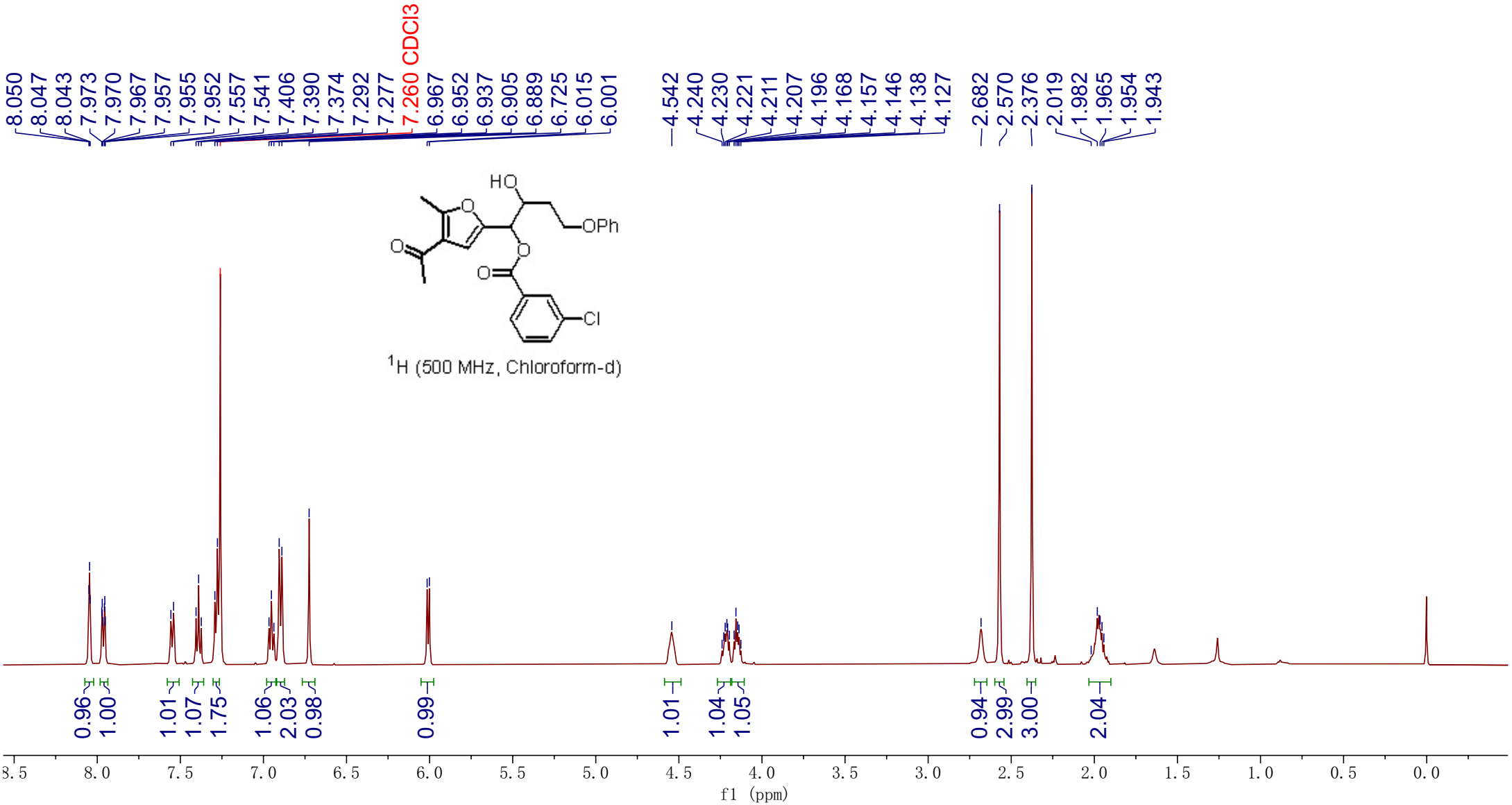

163.74
156.05
151.67
135.74
133.97
129.99
129.75
129.30
128.58
128.43
128.18
127.78
119.55
115.42
109.22
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
63.48
60.62
36.28
27.01
19.38
14.38
Ph
O
O
OEt
TBDPSO
13C (126 MHz, Chloroform-d)
f1 (ppm)

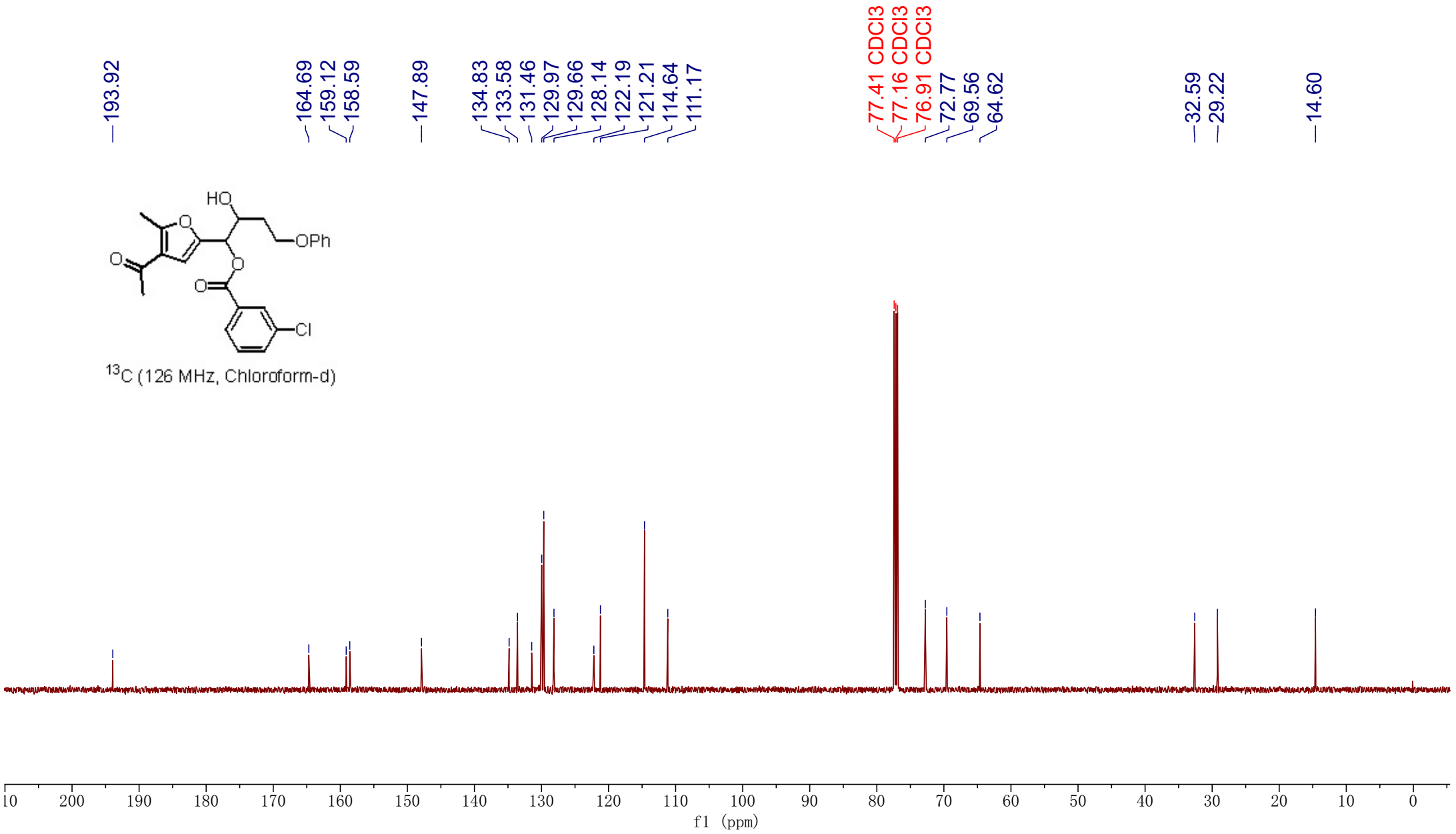

7.350
7.339
7.312
7.302
7.293
7.291
7.289
7.281
7.260 CDCl3
6.199
6.195
6.190
6.187
6.183
6.179
4.538
3.593
3.576
3.559
2.575
2.512
2.508
2.496
2.492
2.479
2.475
2.373
Me
O
H
OBn
D
O
Me
1H (400 MHz, Chloroform-d)
5.23
0.82
0.87
2.03
2.00
2.85
1.93
3.13
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

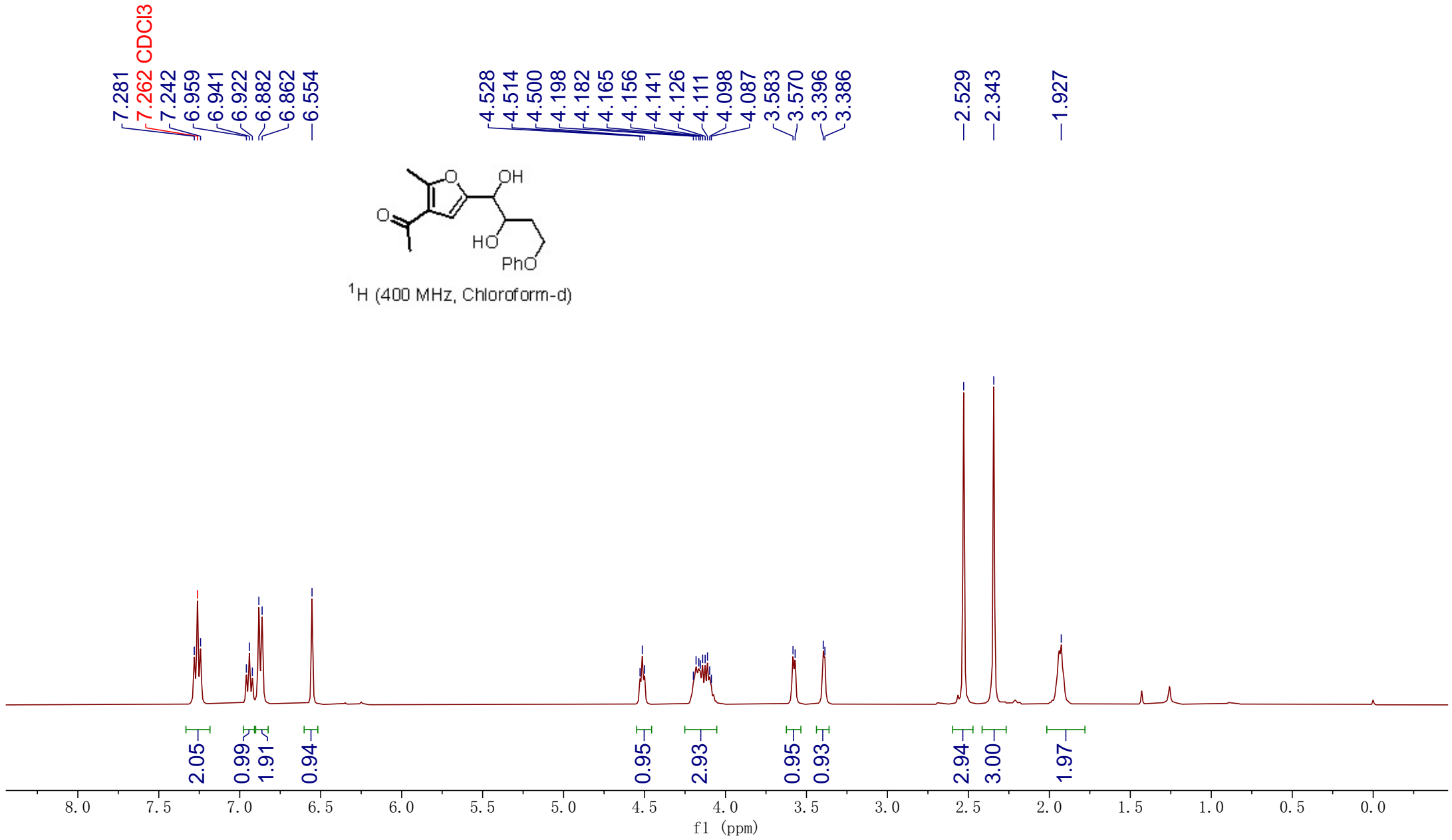

194.32
157.70
150.77
138.40
128.57
128.48
127.78
127.71
122.76
119.35
106.61
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
73.07
69.55
33.22
29.20
14.53
Me
O
H
OBn
D
O
Me
13C (101 MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

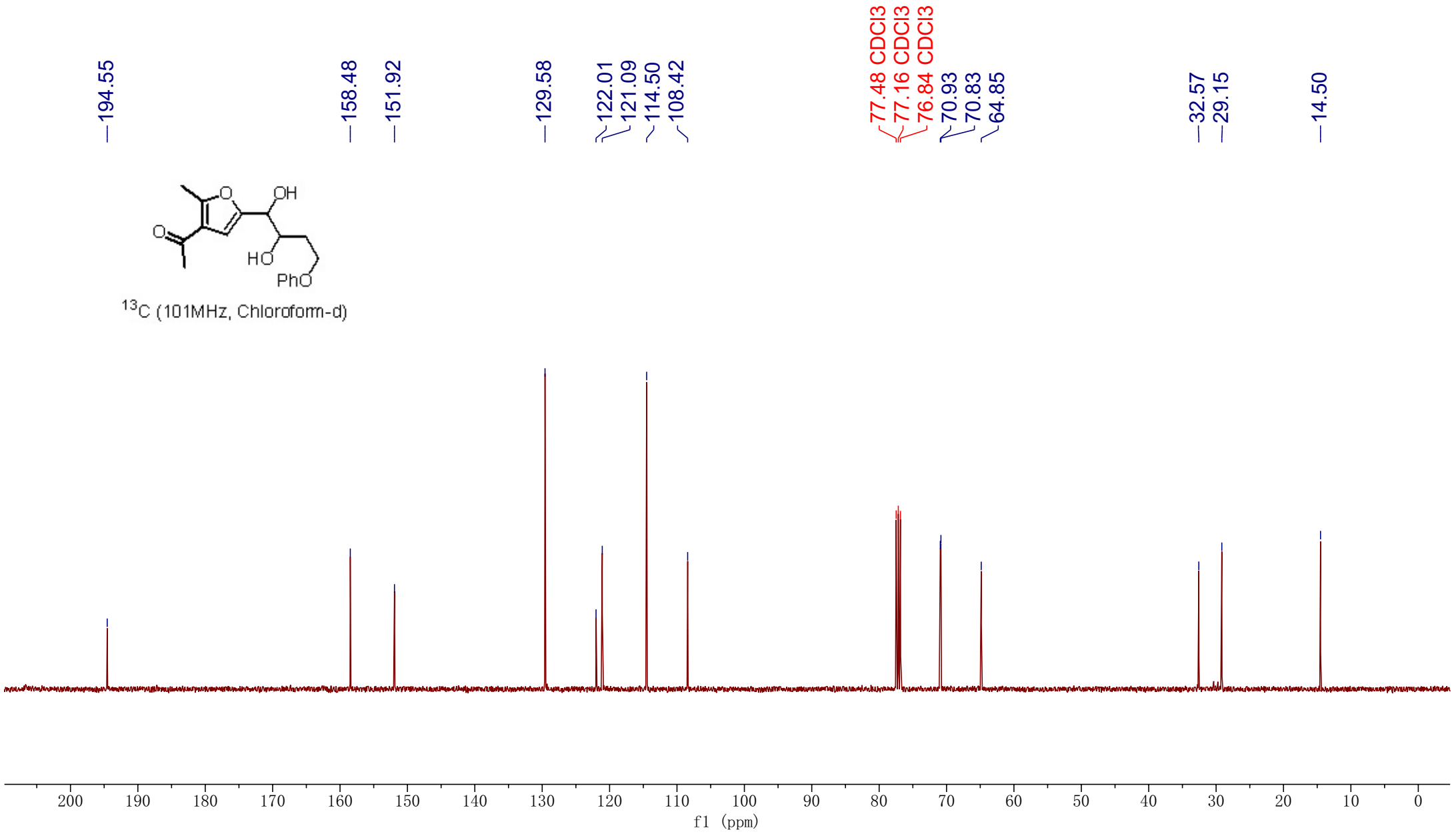

7.260 CDCl3
6.608
6.242
2.591
2.411
2.313
2.027
2.013
2.005
1.992
1.978
1.971
1.958
1.760
1.746
1.739
1.725
1.712
1.704
1.691
0.906
0.893
0.890
0.872
0.869
0.858
0.693
0.680
0.678
0.660
0.657
0.645
0.580
0.567
0.564
0.557
0.554
0.540
0.343
0.330
0.327
0.319
0.317
0.317
0.303
O
O
O
O
1H (400 MHz, Chloroform-d)
0.98
1.03
2.80
6.04
3.11
1.16
1.20
2.26
2.09
2.23
2.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

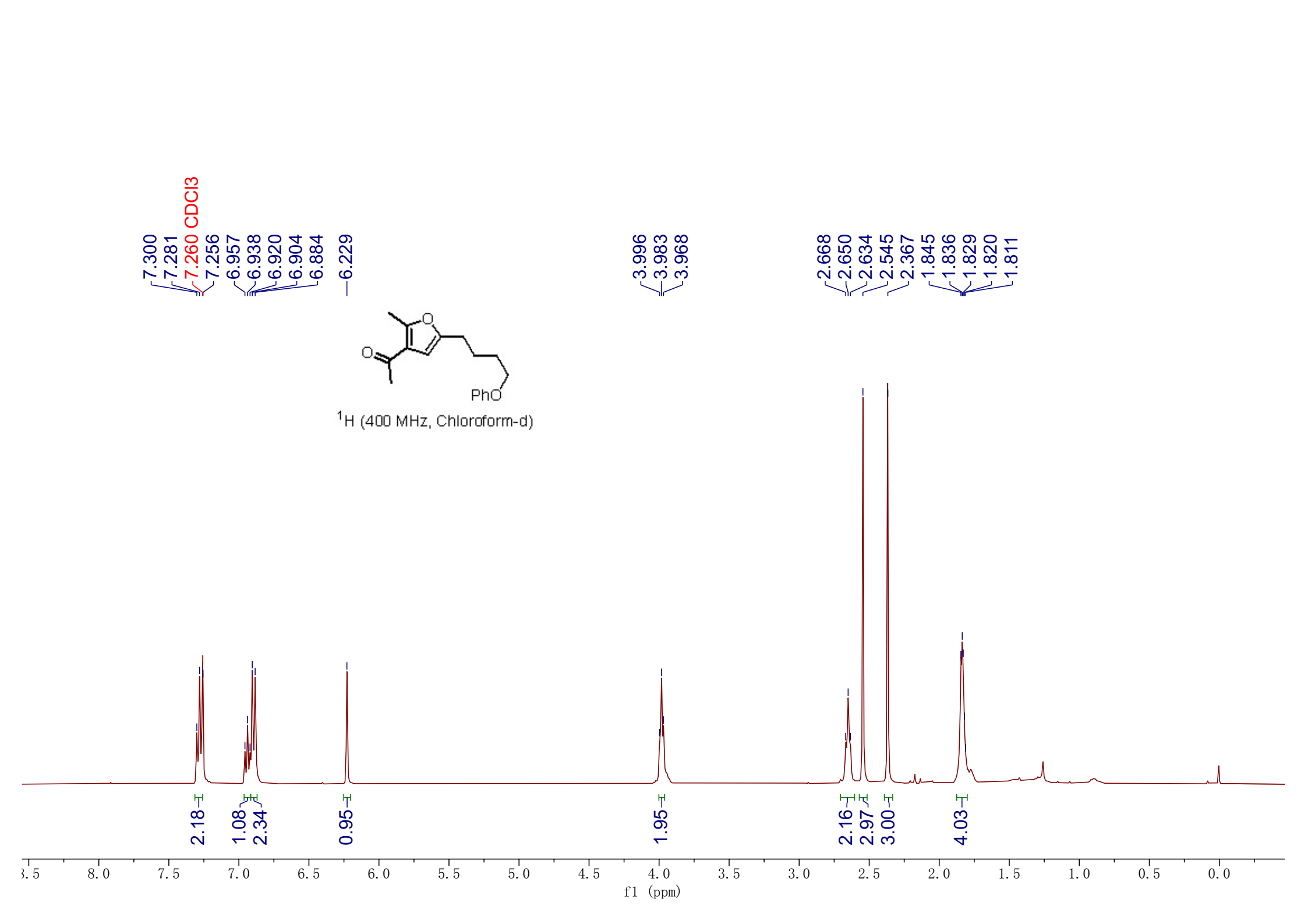

7.363
7.337
7.334
7.331
7.323
7.319
7.306
7.303
7.293
7.277
7.273
7.260 CDCl3
4.480
3.561
3.549
3.537
2.929
2.915
2.900
2.657
2.415
2.063
2.050
2.037
2.024
2.010
O
O
O
BnO
1H (500 MHz, Chloroform-d)
1.00
3.90
0.96
2.11
2.16
2.13
3.15
3.12
2.20
f1 (ppm)

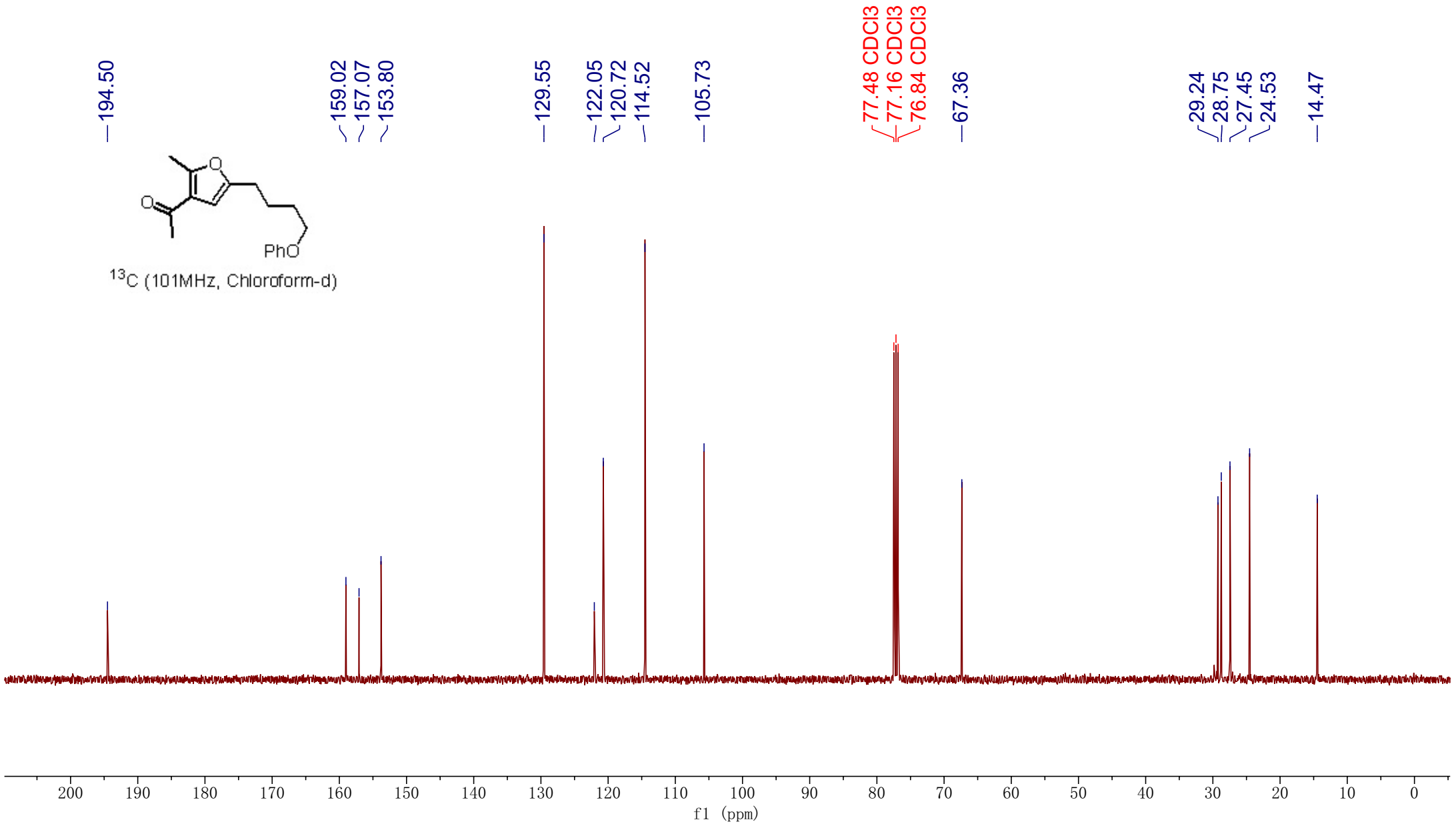

8.050
8.047
8.043
7.973
7.970
7.967
7.957
7.955
7.952
7.557
7.541
7.406
7.390
7.374
7.292
7.277
7.260 CDCl3
6.967
6.952
6.937
6.905
6.889
6.725
6.015
6.001
4.542
4.240
4.230
4.221
4.211
4.207
4.196
4.168
4.157
4.146
4.138
4.127
2.682
2.570
2.376
2.019
1.982
1.965
1.954
1.943
HO
OPh
O
O
O
O
Cl
1H (500 MHz, Chloroform-d)
0.96
1.00
1.01
1.07
1.75
1.06
2.03
0.98
0.99
1.01
1.04
1.05
0.94
2.99
3.00
2.04
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

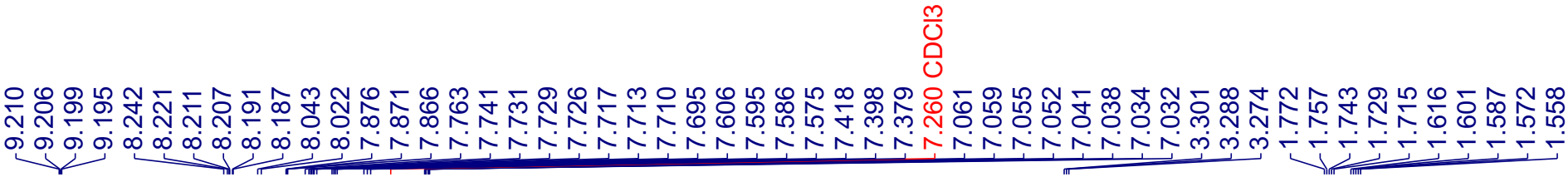

193.92
164.69
159.12
158.59
147.89
134.83
133.58
131.46
129.97
129.66
128.14
122.19
121.21
114.64
111.17
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
72.77
69.56
64.62
32.59
29.22
14.60
HO
O
OPh
O
O
O
Cl
13C (126 MHz, Chloroform-d)
f1 (ppm)

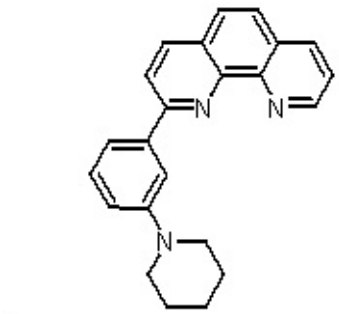

7.281
7.262 CDCl3
7.242
6.959
6.941
6.922
6.882
6.862
6.554
4.528
4.514
4.500
4.198
4.182
4.165
4.156
4.141
4.126
4.111
4.098
4.087
3.583
3.570
3.396
3.386
2.529
2.343
1.927
O
OH
O
HO
PhO
1H (400 MHz, Chloroform-d)
2.05
0.99
1.91
0.94
0.95
2.93
0.95
0.93
2.94
3.00
1.97
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


194.55
158.48
151.92
129.58
122.01
121.09
114.50
108.42
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
70.93
70.83
64.85
32.57
29.15
14.50
O
OH
O
HO
PhO
13C (101MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

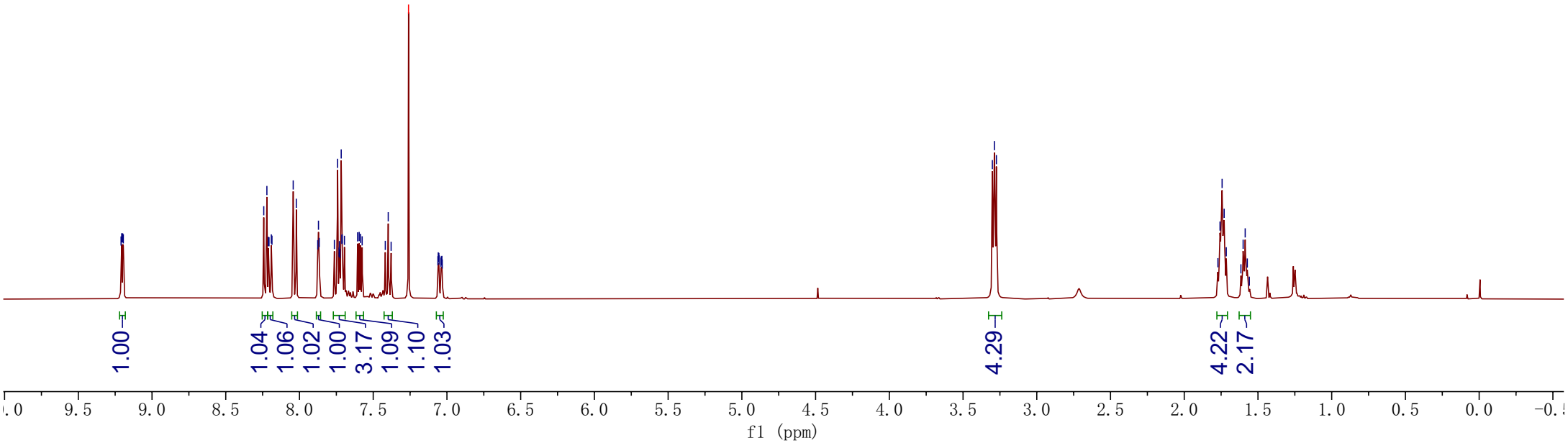

7.300
7.281
7.260 CDCl3
7.256
6.957
6.938
6.920
6.904
6.884
6.229
3.996
3.983
3.968
2.668
2.650
2.634
2.545
2.367
1.845
1.836
1.829
1.820
1.811
O
O
PhO
1H (400 MHz, Chloroform-d)
2.18
1.08
2.34
0.95
1.95
2.16
2.97
3.00
4.03
f1 (ppm)

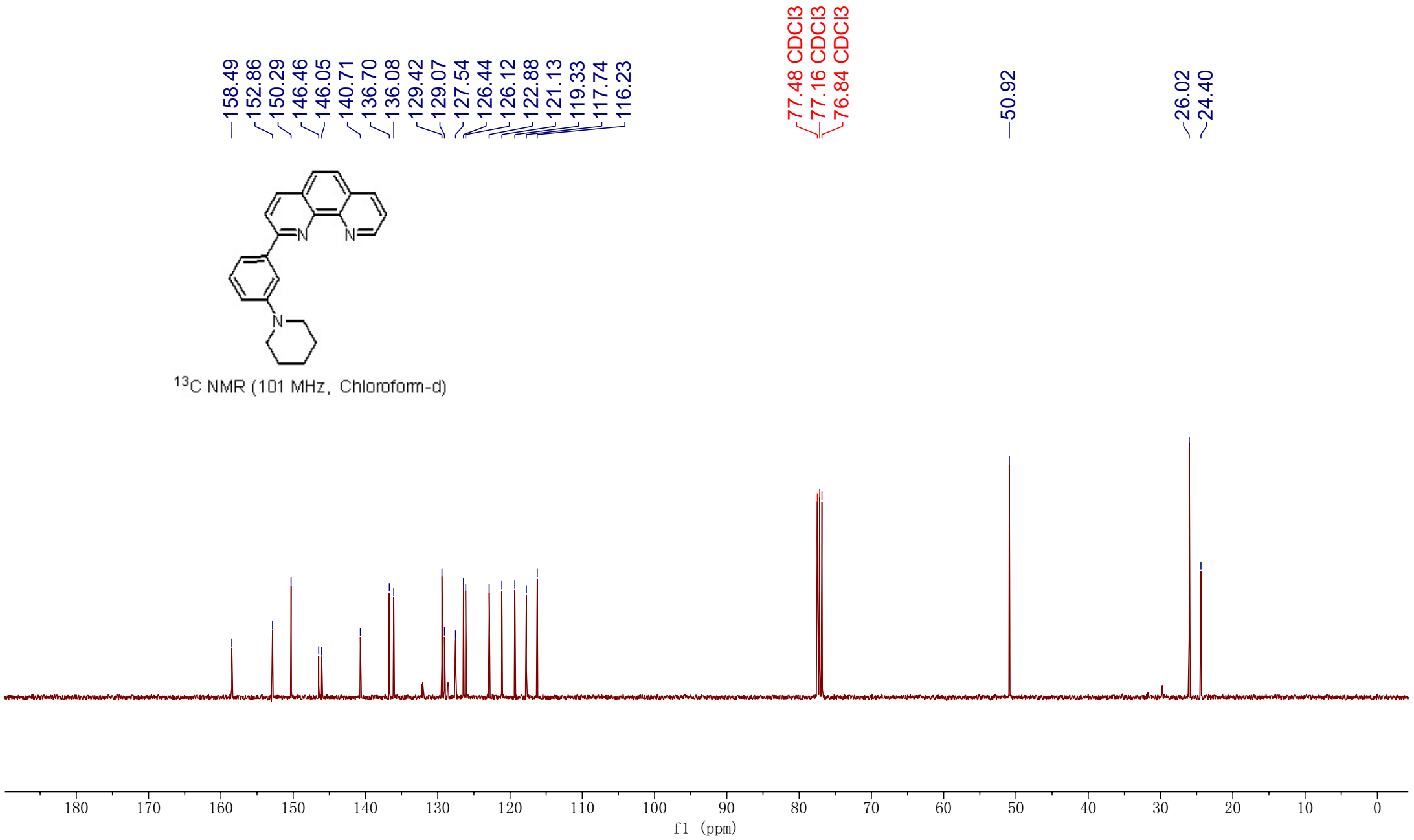

194.50
159.02
157.07
153.80
129.55
122.05
120.72
114.52
105.73
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
67.36
29.24
28.75
27.45
24.53
14.47
O
O
PhO
13C (101MHz, Chloroform-d)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

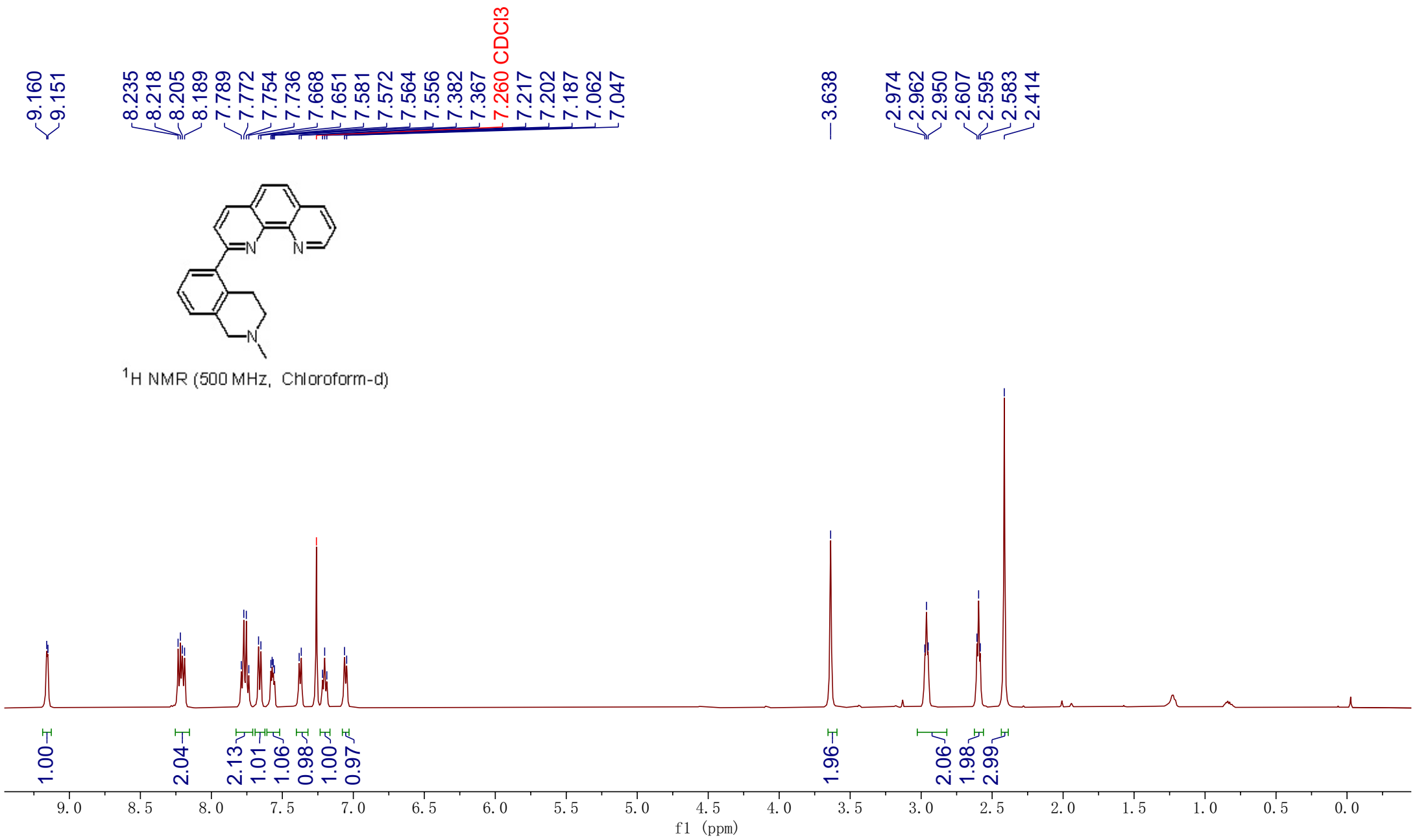


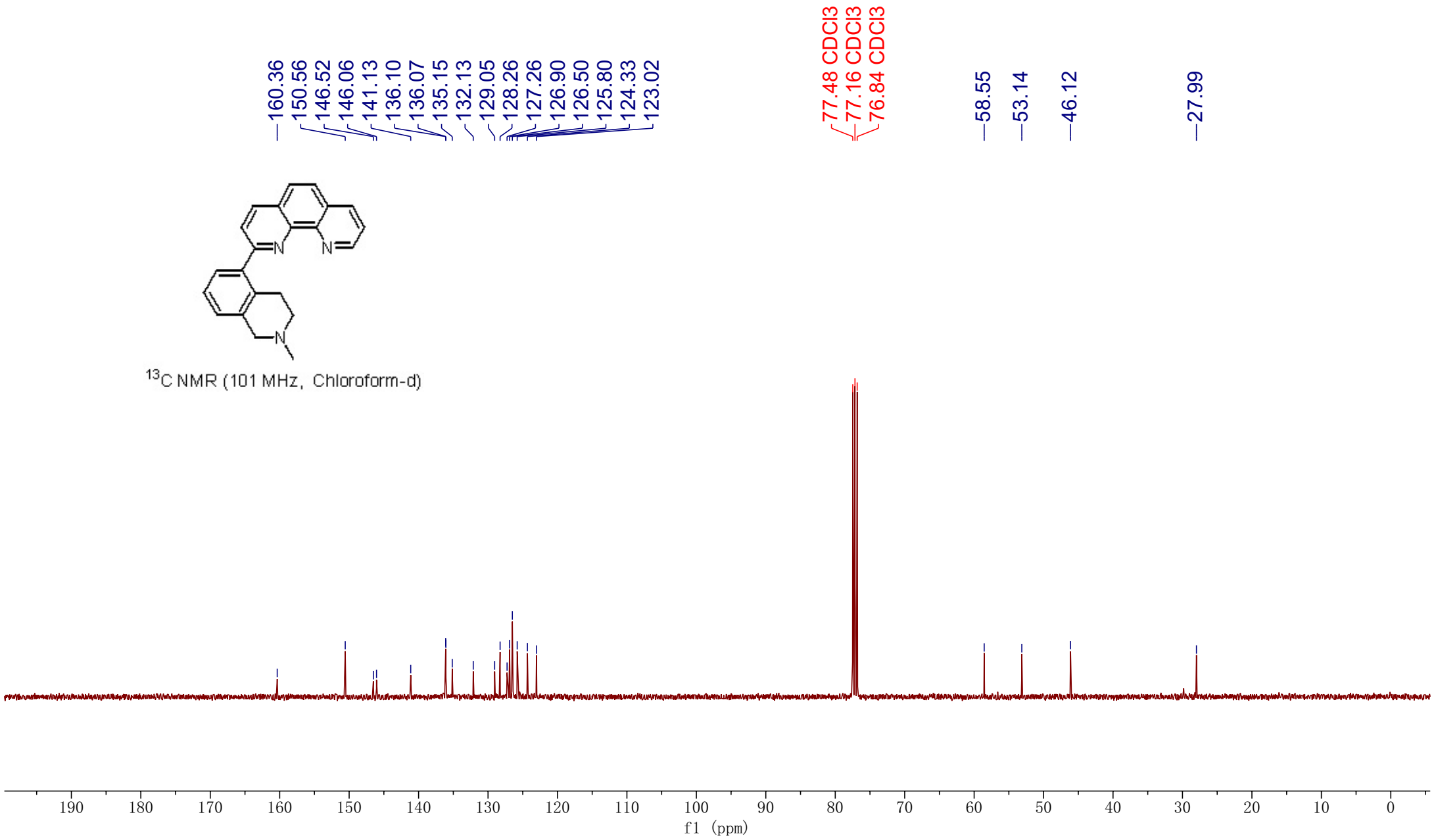


^{1}H NMR (400 MHz, Chloroform-d)




158.49
152.86
150.29
146.46
146.05
140.71
136.70
136.08
129.42
129.07
127.54
126.44
126.12
122.88
121.13
119.33
117.74
116.23
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
50.92
26.02
24.40
N
N
N
13C NMR (101 MHz, Chloroform-d)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


9.160
9.151
8.235
8.218
8.205
8.189
7.789
7.772
7.754
7.736
7.668
7.651
7.581
7.572
7.564
7.556
7.382
7.367
7.260 CDCl3
7.217
7.202
7.187
7.062
7.047
3.638
2.974
2.962
2.950
2.607
2.595
2.583
2.414
N
N
N
1H NMR (500 MHz, Chloroform-d)
1.00
2.04
2.13
1.01
1.06
0.98
1.00
0.97
1.96
2.06
1.98
2.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


160.36
150.56
146.52
146.06
141.13
136.10
136.07
135.15
132.13
129.05
128.26
127.26
126.90
126.50
125.80
124.33
123.02
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
58.55
53.14
46.12
27.99
N
N
N
13C NMR (101 MHz, Chloroform-d)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)