Sustainable Photoredoxchemistry of Transient Ternary Complex: An Unconventional Approach to Trifluoromethylated Hydroquinones

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Supporting Information

General Considerations

General Reagent Information

Commercially available benzoquinones are purchased from TCI, Alfa Aesar, and Sigma-Aldrich companies. Benzoquinones **1d, 1e**, and **1g-1l** were synthesized by a known method.[S1] CF_3SO_2Na (Langlois reagent) and vinyl arenes were purchased from TCI or Sigma-Aldrich. 2,2,2-Trifluoroethanol and acetonitrile were purchased from Alfa Aesar and Sigma-Aldrich, respectively. Flash column chromatography was performed using ZEOCHEM ZEOprep silica gel 60 (60-200 mesh).

General Analytical Information

The synthesized compounds (**2**, **3**, **5**, and **6**) were characterized by ^{1}H NMR, ^{13}C NMR, ^{19}F NMR, and FT-IR spectroscopy. NMR spectra were recorded on a Varian 600 MHz instrument (600 MHz for ^{1}H NMR, 151 MHz for ^{13}C NMR, and 564 MHz for ^{19}F NMR). Copies of ^{1}H and ^{13}C spectra can be found at the end of the Supporting Information. ^{1}H NMR experiments are reported in units, parts per million (ppm), and were measured relative to residual chloroform (7.26 ppm) in the deuterated solvent. ^{13}C NMR spectra are reported in ppm relative to deuterochloroform (77.23 ppm), and all were obtained with ^{1}H decoupling. ^{19}F NMR spectra are reported in ppm, and all were taken composite pulse decoupling (CPD) mode. Coupling constants were reported in Hz. FT-IR spectra were recorded on a Nicolet 6700 Thermo Scientific FT-IR spectrometer. Mass spectral data of unknown compounds were acquired at the Korea Basic Science Institute (Daegu) on a Jeol JMS 700 high-resolution mass spectrometer. A quadrupole mass analyzer was used for HRMS measurements.

Experimental Details

Steady-State UV−vis Absorption Measurements. UV−vis absorption spectra were collected on an Agilent, Cary 300 spectrophotometer at 298 K. Sample solutions were prepared prior to measurements at a concentration of 10 mM or 100 μM in acetonitrile, unless otherwise stated. The solution was transferred to a quartz cell (Hellma, beam path length = 1 cm).

Steady-State Photoluminescence Measurements. Photoluminescence spectra were obtained at 298 K using a Photon Technology International, Quanta Master 400 scanning spectrofluorometer. The solutions used for the steady-state UV−vis absorption studies were used for the photoluminescence measurements. A quartz cell (Hellma, beam path length = 1.0 cm) was used. The excitation wavelengths were 315 nm for HQ and 422 nm for BQ and QH. The spectra were recorded in the emission range 300−650 nm.

Determination of Photoluminescence Lifetime. Photoluminescence decay traces were acquired on the basis of time-correlated single-photon counting (TCSPC) techniques, using a PicoQuant, FluoTime 200 instrument after pulsed laser excitation at 377 nm (pulse duration = 25 ps). Transient photon signals were collected at λ_{obs} = 466 nm through an automated motorized monochromator. The photon acquisition was terminated when the accumulated photon count reached 105. Photoluminescence decay traces were analyzed using a monoexponential decay models embedded in the OriginLab, OriginPro 2018 software.

Photoluminescence Quenching Experiments. Photoluminescence quenching experiments were performed for acetonitrile solution containing 100 μM QH with added CF_3SO_2Na (0–1.0 mM). A photoexcitation at a wavelength of 420 nm was used. The photoluminescence changes were quantified as the photoluminescence intensity ratio at wavelengths of 428 nm and 466 nm, which was analyzed using the Stern–Volmer equation described in the main text. The photoluminescence quenching of QH was further monitored by the transient photoluminescence experiments for 100 μM QH (acetonitrile) performed with an increased concentration of CF_3SO_2Na. The quenching rate was quantitated as $1/\tau - 1//\tau_0$, where τ and τ_0 are the photoluminescence lifetime of QH in the presence and absence of the CF_3SO_2Na, respectively. The initial three points of $1/\tau - 1/\tau_0$ values were analyzed for the pseudo first–order kinetics analysis.

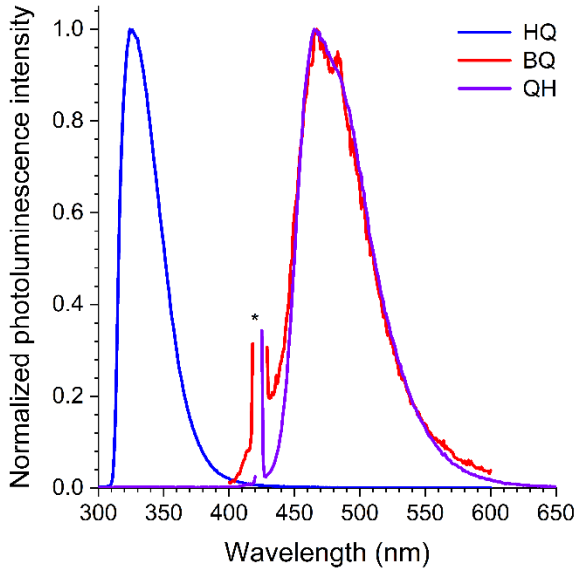


Figure S1. Photoluminescence spectra of HQ, BQ and QH recorded in MeCN (10 mM) at 298 K. Excitation wavelengths = 315 nm (HQ) and 422 nm (BQ and QH). The signals marked with an asterisk (*) are due to the excitation beam.

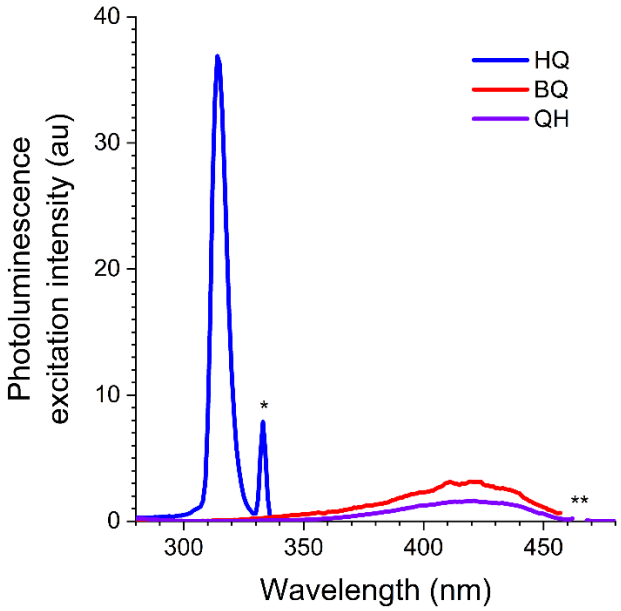


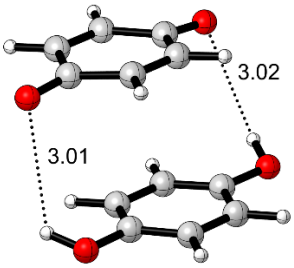
Figure S2. Photoluminescence excitation spectra of HQ, BQ and QH recorded in MeCN (10 mM) at 298 K. Observation wavelengths = 326 nm (HQ), 468 nm (BQ) and 466 nm (QH). The signals marked with asterisks (* and **) are due to the emission.

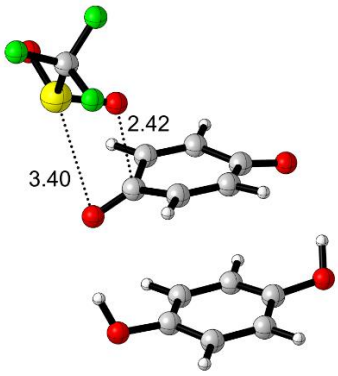
Computational Details

All calculations were performed by using the density functional theory (DFT) and time dependent-density functional theory (TD-DFT) with the GAUSSIAN 09 program package.[S2] Geometry optimizations for TD-DFT calculation and potential energy surface diagram were performed in the gas phase with B3LYP functional[S3] with 6-31+G(d). Frequency calculation and transition state structures were performed for all stationary points to confirm the local minima, thermodynamic parameters including Gibbs free energies at 298 K. Electronic energies of optimized structures were further calculated by single point calculation of B3LYP with 6-311+G(d,p) basis set with solvent effects for TD-DFT calculation (polarizable continuum model method[S4] in 2,2,2-trifluoroethanol solvent (ε = 26.726)). All optimized structures, molecular orbitals and electrostatic potential were visualized by CYLview[S5] and GaussView.[S2] Spin density isosurface of radical intermediates were visualized by Chemcraft software.[S6]

TD-DFT Calculation

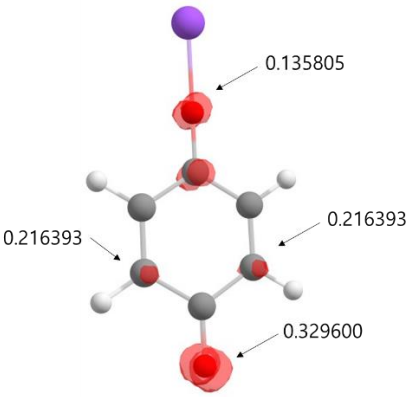
Excitation Energies and Oscillator Strengths of Compounds



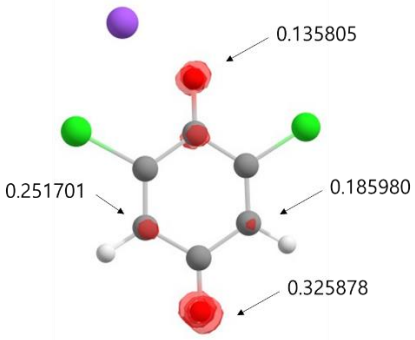


	QH	Ternary complex
Singlet Excited state	57 → 58	90 → 91
Oscillator strength	f = 0.0558	f = 0.0638
Energy	**1.7626 eV (703.41 nm)**	**2.2750 eV (545.00 nm)**

Spin Density Isosurface and Values of Optimized Radical Intermediates



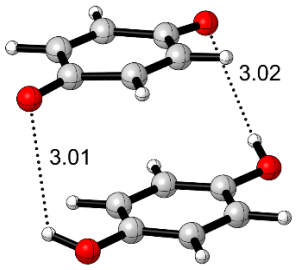
Radical Intermediate A



Radical Intermediate B

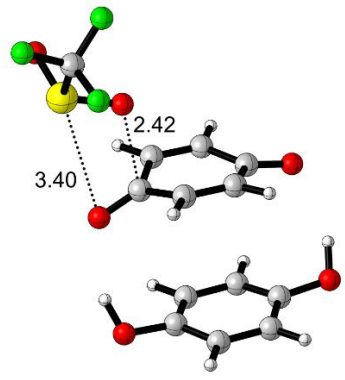
Spin density isosurfaces were given by 0.02

Cartesian Coordinates and Energies of All Optimized Geometries



Quinhydrone

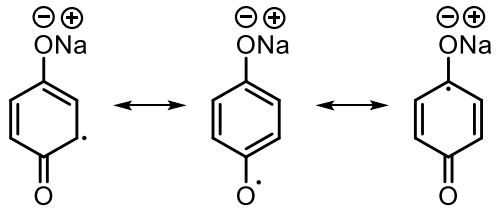
C	-1.84052600	1.43818200	0.25617700
C	-1.20898100	0.66996000	1.35455300
C	-1.20758000	-0.67125000	1.35438500
C	-1.83750800	-1.44050200	0.25580600
C	-2.57761000	-0.67146900	-0.77761100
C	-2.57903400	0.66786400	-0.77742800
H	-0.72427800	1.25455900	2.12785400
H	-0.72165000	-1.25502900	2.12753300
H	-3.08840400	-1.25848200	-1.53330800
H	-3.09107700	1.25400300	-1.53296000
O	-1.75212100	2.65611800	0.18999500
O	-1.74651700	-2.65823500	0.18927600
C	1.78564400	1.40043100	-0.24253100
C	2.48601600	0.69521300	0.74164000
C	2.48678500	-0.69186600	0.74185900
C	1.78720500	-1.39818000	-0.24209100
C	1.12694800	-0.69709000	-1.25049400
C	1.12615500	0.69830000	-1.25070100
H	3.01032500	1.25118600	1.50956200
H	3.01170600	-1.24701700	1.50995800
H	0.61270900	-1.23565100	-2.04010400
H	0.61128900	1.23603800	-2.04046700
O	1.80481900	2.76822300	-0.17190500
H	1.08927000	3.13818400	-0.70076100
O	1.80788300	-2.76591600	-0.17102000
H	1.09251800	-3.13686400	-0.69944500



Ternary complex

C	1.45885100	-2.08413300	0.02875200

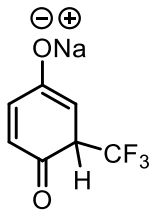
C	1.05414600	-1.10829900	-1.00109600
C	0.36455400	-0.00676300	-0.67349000
C	0.04092100	0.28799100	0.74260000
C	0.14530800	-0.84906900	1.69032500
C	0.83941700	-1.94847400	1.36216400
H	1.38892300	-1.30657200	-2.01284800
H	0.09705500	0.75398200	-1.39669400
H	-0.28779400	-0.69719300	2.67184000
H	1.01083300	-2.76106200	2.05961300
O	2.29268500	-2.96381400	-0.20724300
O	-0.08885100	1.44432100	1.14626500
C	4.37164700	-0.30823200	-0.52334200
C	4.25208700	0.72928400	-1.44784300
C	3.57848700	1.89923100	-1.10336300
C	3.02055800	2.04129000	0.16823100
C	3.24725300	1.05195500	1.12711000
C	3.91759500	-0.11721400	0.78236900
H	4.63140500	0.58178000	-2.45249600
H	3.42022000	2.68443800	-1.83360600
H	2.85261900	1.18202800	2.12821000
H	4.05119000	-0.90670100	1.51345200
O	4.92654700	-1.50690700	-0.92230100
H	4.31628000	-2.21692600	-0.66502100
O	2.25007300	3.14624600	0.44622300
H	1.40735700	2.83493700	0.82210800
S	-3.27156000	0.31651100	0.71580200
O	-4.14605400	-0.26919600	1.78907500
O	-2.14670500	-0.63112800	0.27102300
C	-4.39966600	0.12467200	-0.86065800
F	-5.53010000	0.86330400	-0.73017600
F	-4.77420700	-1.14112900	-1.10617700
F	-3.76142800	0.58421400	-1.96612400



Radical Intermediate A

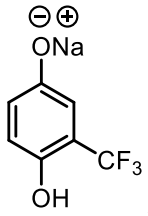
C	1.46387310	1.23156233	0.00000538
C	2.23652733	0.00002613	-0.00009173
C	1.46393982	-1.23155520	0.00000637
C	0.09033233	-1.22527286	0.00017134
C	-0.65603127	-0.00003918	0.00023965
C	0.09025894	1.22522042	0.00017048
H	2.02478792	2.16313792	-0.00005816
H	2.02489575	-2.16310619	-0.00005626
H	-0.47415640	-2.15633509	0.00024308
H	-0.47423812	2.15627815	0.00025164
O	-1.95791044	-0.00009277	0.00033792

O	3.49849670	0.00006342	-0.00027621
Na	-3.95994371	0.00005548	-0.00035299



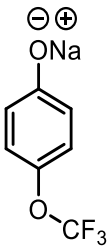
A-1

C	0.24900811	0.82991868	-0.47674659
C	-2.01196041	2.02300313	-0.43879139
C	-2.63547697	0.82332932	-0.56800709
H	-2.61642444	2.89223166	-0.28398505
O	-4.04632529	0.78509149	-0.79810465
O	1.49325245	0.79629404	-0.66193831
C	-1.85654783	-0.49650428	-0.42422898
H	-2.38495009	-1.42688034	-0.41466634
C	-0.51267851	-0.48856993	-0.31151441
H	0.01910116	-1.40080131	-0.13847021
C	-0.47237386	2.19372226	-0.46448400
H	-0.20727280	2.75689538	0.40583633
C	-0.02357664	2.94583480	-1.73117567
F	-0.61766043	4.15749034	-1.76932374
F	-0.37678459	2.23685550	-2.82437854
F	1.31714125	3.10247797	-1.71023628
Na	-5.72321958	0.74202841	-1.07465371



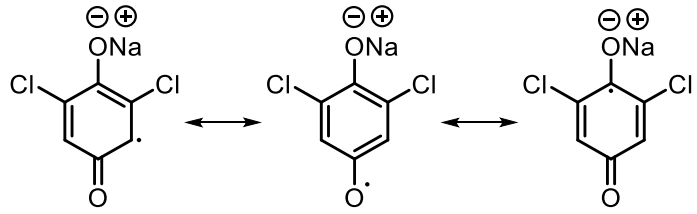
A-2

C	-0.09703465	-0.18548750	-0.07481249
C	1.30433750	-0.18871197	-0.06658831
C	2.00735758	1.02086577	0.01469159
C	1.30900549	2.23366780	0.08775017
C	-0.09236668	2.23689213	0.07952816
C	-0.79538675	1.02731456	-0.00175436
H	-0.63380609	-1.10902695	-0.13687137
H	1.84577692	3.15720721	0.14980967
H	-1.86536549	1.02977649	-0.00803340
O	-0.80497087	3.47444509	0.15407972
O	2.01694167	-1.42626524	-0.14113498
H	2.17097228	-1.76073797	0.74543288
C	3.54732701	1.01732260	0.02372601
F	4.00325683	2.15678207	-0.53864406
F	3.98968015	0.93537332	1.29656065
F	3.99901723	-0.04329363	-0.67881876
Na	-1.14453173	4.64105010	-0.14165543



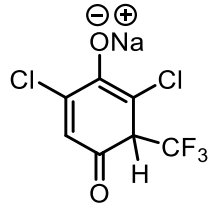
A'-1

C	-0.75234465	-0.09009214	-0.00926063
C	0.64905532	-0.09009453	-0.00899366
C	1.34975766	1.12355134	-0.01036992
C	0.64906004	2.33719959	-0.01201527
C	-0.75233994	2.33720198	-0.01228335
C	-1.45304228	1.12355611	-0.01090454
H	-1.28734644	-1.01673769	-0.00820940
H	2.41975765	1.12354951	-0.01016597
H	1.18406183	3.26384514	-0.01306745
H	-2.52304226	1.12355794	-0.01110777
O	-1.46733752	3.57561856	-0.01396214
O	1.36405290	-1.32851112	-0.00731690
C	1.60212860	-1.73963951	1.34145788
F	2.33160333	-0.79800320	1.97682208
F	0.42241292	-1.90026947	1.97782957
F	2.27712631	-2.90877405	1.34304084
Na	-1.48835059	4.58365923	-0.18169204



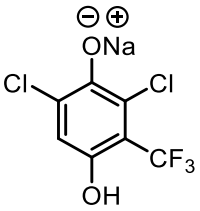
Radical Intermediate B

C	1.48205922	0.35101404	0.00000000
C	2.87721922	0.35101404	0.00000000
C	3.57475722	1.55876504	0.00000000
C	2.87710322	2.76727404	-0.00119900
C	1.48227822	2.76719604	-0.00167800
C	0.78467722	1.55899004	-0.00068200
H	0.93230022	-0.60130296	0.00045000
H	4.67443722	1.55884504	0.00063400
O	0.76696419	4.00543039	-0.00291717
O	3.59180354	-0.88764101	0.00171004
Cl	3.75767930	4.29114600	-0.00129343
Cl	-0.97532274	1.55928294	-0.00097010
Na	0.63252192	4.85788105	-0.53036842



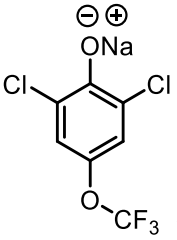
B-1

C	-0.47681234	-1.33866804	-0.05638003
C	1.05561426	-1.39788585	-0.00516027
C	1.82749546	-0.08766076	0.15112998
C	1.03314326	1.22402725	0.08388891
C	-0.32728529	1.19846200	0.04165199
C	-1.11439847	-0.13699143	-0.01729832
H	-1.04464621	-2.24300747	-0.12446015
O	-1.04848092	2.43326574	0.04770047
O	1.66167101	-2.49770898	-0.08673754
Cl	1.88321825	2.76498747	0.06353912
Cl	-2.87377123	-0.09681518	-0.04165699
C	3.35765715	-0.04027053	-0.01608060
F	3.66161713	0.41684449	-1.24943140
F	3.88647924	0.78465128	0.91254807
F	3.86625059	-1.28076399	0.14206083
H	1.80867580	-0.13705628	-0.91756357
Na	-1.40051535	3.41285838	-0.58620037



B-2

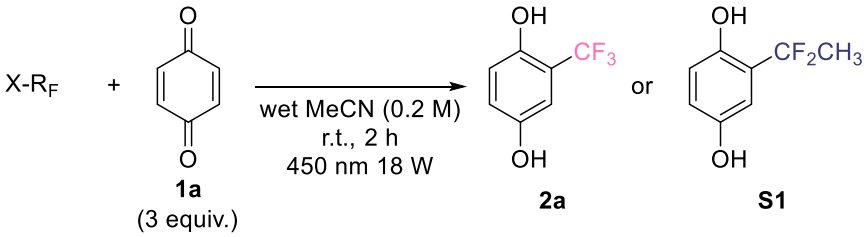
C	0.88290580	1.24490978	0.08572054
C	2.28430462	1.24653587	0.08491264
C	2.98354526	2.45725779	-0.01067461
C	2.28138708	3.66635359	-0.10545432
C	0.87998826	3.66472759	-0.10464524
C	0.18074762	2.45400560	-0.00905895
H	0.34902005	0.32049680	0.15870440
Cl	-1.57925091	2.45196349	-0.00804344
Cl	3.15955430	5.18688327	-0.22550365
O	0.16350032	4.89849897	-0.20135728
O	3.00079256	0.01276462	0.18162628
H	3.16156333	-0.19233907	1.10557716
C	4.52354397	2.45904473	-0.01156201
F	4.97415893	2.55938970	1.25705024
F	4.97191103	3.50852986	-0.73270550
F	4.97456082	1.31078109	-0.55980869
Na	-0.51079607	6.02008680	0.55373727



B'-1

C	-0.63800022	-0.21016294	0.00050138
C	0.76339972	-0.21017155	0.00092435
C	1.46410762	1.00347108	-0.00047704
C	0.76341559	2.21712231	-0.00230072
C	-0.63798435	2.21713092	-0.00272319
C	-1.33869225	1.00348829	-0.00132263
H	-1.17300626	-1.13680602	0.00157209
H	2.53410757	1.00346451	-0.00015365
O	-1.35297621	3.45555055	-0.00458154
O	1.47839158	-1.44859117	0.00278593
C	1.71631530	-1.85960600	1.35162214
Cl	-3.09869217	1.00349910	-0.00185223
Cl	1.64342552	3.74132028	-0.00405820
Na	-2.19280491	4.29211765	0.12433487
F	0.53652807	-2.02017664	1.98787615
F	2.39130762	-3.02874341	1.35337958
F	2.44572350	-0.91791895	1.98698752

Fluoroalkylation of BQ with other nucleophilic fluoroalkyl reagents

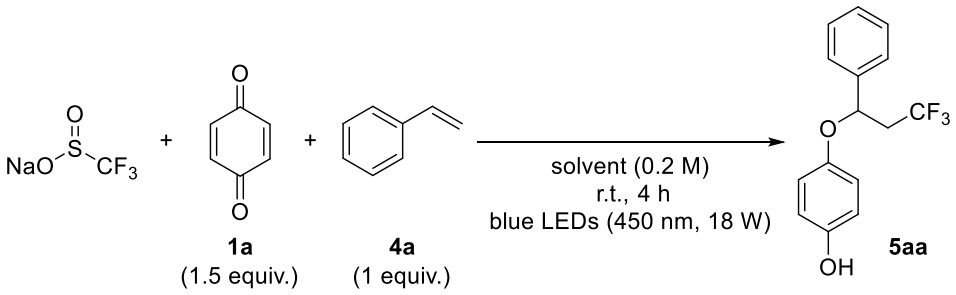


fluoroalkyl reagent (X-R_F)	yield (%)
R_F = -CF_3	
CF_3SO_2Na	**2a**, 66%
$(CF_3SO_2)_2Zn$	**2a**, 61%
CF_3CO_2Na	**2a**, 0%
R_F = -CF_2CH_3	
$CH_3CF_2SO_2Na$	**S1**, 0%

Scheme S1. All the reactions were carried out on a 0.1 mmol scale of X-R_F under an argon atmosphere. Yields were determined by ^{19}F NMR spectrometry using α,α,α-trifluorotoluene as an internal standard.

Optimization for Three-Component Trifluoromethylation

Table S1. Optimization of C-O Bond Forming Trifluoromethylation of BQ with Vinyl Arenes (4).[a]



Entry	Solvent[b]	Variations	Yield (%)[c]
1	TFE/H_2O (1/1)	-	-
2	TFE	-	-
3	wet MeCN	-	55%
4	MeOH	-	-
5	wet DMF	-	-
6	wet DMSO	-	-
7	wet MeCN	**4a** (1.5 equiv.)	63%
8	wet MeCN	**4a** (2 equiv.)	23%
9	wet MeCN	**4a** (1.5 equiv.) **1a** (3 equiv.)	51%

[a]All the reactions were carried out on a 0.1 mmol scale of CF_3SO_2Na under an argon atmosphere. [b]Solvent was used without drying. [c]Yields were determined by ^{19}F NMR spectrometry using α,α,α-trifluorotoluene as an internal standard.

Structure Determination by NMR spectra

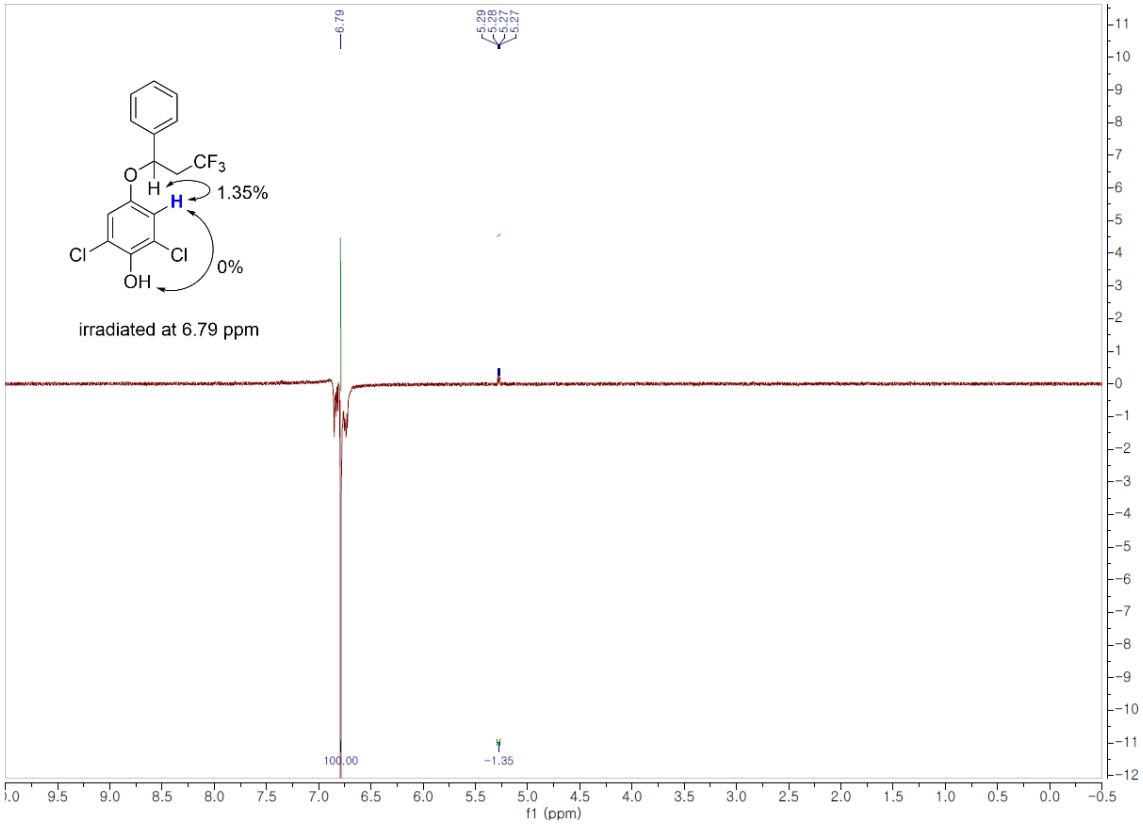
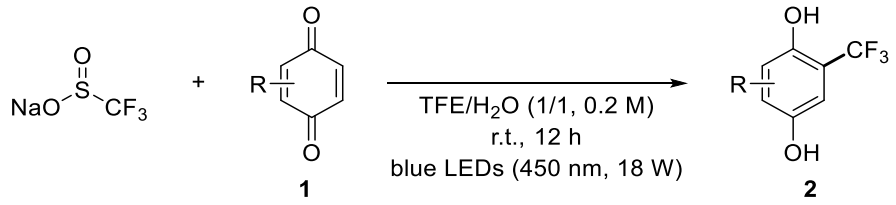
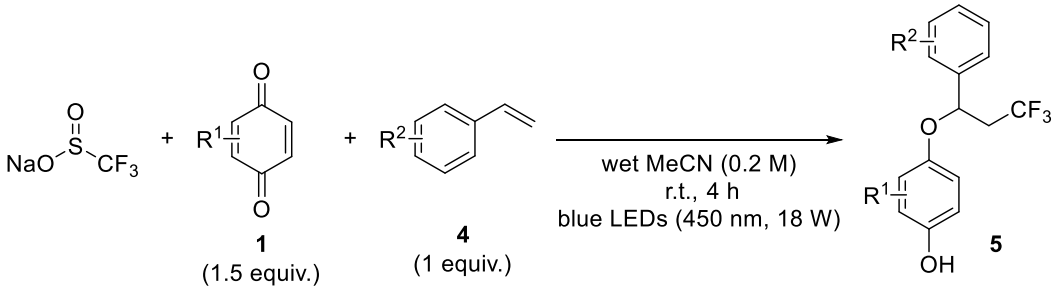


Figure S3. 1D NOESY spectrum of **6qa**.

Experimental Procedure

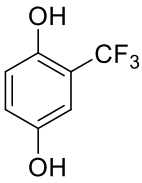


To an oven-dried reaction test tube charged with argon, CF_3SO_2Na (1.0 mmol), benzoquinone **1** (3 equiv., 3.0 mmol), and 2,2,2-trifluoroethanol/water (1/1, 0.2 M, 5 mL) were added. The reaction mixture was argon-bubbled for 3 minutes and allowed to stir at room temperature under 450 nm (18 W) irradiation for 12 hours. The reaction progress was monitored using thin layer chromatography and gas chromatography. After completion, reaction was concentrated under reduced pressure and purified by silica gel flash column chromatography using a petroleum ether-ethyl acetate mixture as the eluent to give the corresponding trifluoromethylated hydroquinone **2**.

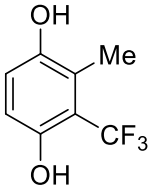


To an oven-dried reaction test tube charged with argon, CF_3SO_2Na (1.0 mmol), benzoquinone **1** (1.5 equiv., 1.5 mmol), vinyl arene **4** (1.5 equiv., 1.5 mmol) and acetonitrile (0.2 M, 5 mL) were added. The reaction mixture was argon-bubbled for 3 minutes and allowed to stir at room temperature under 450 nm (18 W) irradiation for 4 hours. The reaction progress was monitored using thin layer chromatography and gas chromatography. After completion, reaction was concentrated under reduced pressure and purified by silica gel flash column chromatography using a hexane-ethyl acetate mixture as the eluent to give the corresponding product, **5**.

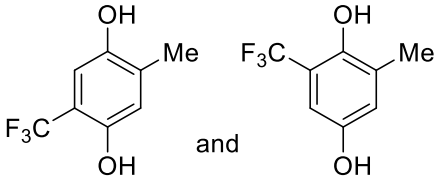
Analytic Data for Synthesized Compounds



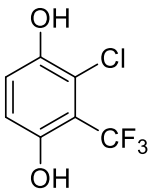
2-(trifluoromethyl)benzene-1,4-diol, **2a**[S7]: white solid; **^{1}H NMR (600 MHz, CD_3CN)** δ 6.95 (d, *J* = 3.0 Hz, 1H), 6.89 (dd, *J* = 8.8, 3.0 Hz, 1H), 6.84 (d, *J* = 8.8 Hz, 1H); **^{13}C NMR (151 MHz, CD_3CN)** δ 150.57, 148.83 (q, *J* = 2.0 Hz), 124.81 (q, *J* = 271.7 Hz), 121.20, 119.01, 117.53 (q, *J* = 30.6 Hz), 113.82 (q, *J* = 5.2 Hz); **^{19}F NMR (564 MHz, CD_3CN)** δ -62.80; **IR (neat)**: ν_{max} = 3326, 1212, 1163, 1118 cm^{-1}; ***R*$_f$** 0.48 (Hex/EtOAc, 2/1).



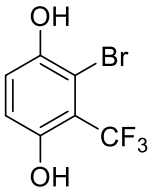
2-methyl-3-(trifluoromethyl)benzene-1,4-diol (mixed with 2-methylhydroquinone), **2b**: white solid; m.p. 115 – 117 °C; **^{1}H NMR (600 MHz, CD_3CN)** δ 6.87 (d, *J* = 8.8 Hz, 1H), 6.67 (d, *J* = 8.8 Hz, 1H), 2.25 (q, *J* = 3.0 Hz, 3H); **^{13}C NMR (151 MHz, CD_3CN)** δ 149.66 (q, *J* = 2.0 Hz), 149.13, 126.26 (q, *J* = 275.1 Hz), 125.21 (q, *J* = 2.0 Hz), 120.35, 120.14, 116.42 (q, *J* = 28.0 Hz), 12.61 (q, *J* = 4.0 Hz); **^{19}F NMR (564 MHz, CD_3CN)** δ -54.67 (q, *J* = 3.0 Hz); **IR (neat)**: ν_{max} = 3317, 2945, 1115, 1020 cm^{-1}; **HRMS** m/z (EI) calc. for $C_8H_7F_3O_2$ [M^+] 192.0398, found 192.0399; ***R*$_f$** 0.34 (Hex/EtOAc, 2/1).



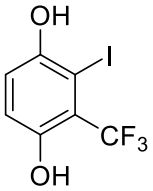
2-methyl-5-(trifluoromethyl)benzene-1,4-diol / 2-methyl-6-(trifluoromethyl) benzene-1,4-diol, **2b**: white solid; **^{1}H NMR (600 MHz, CD_3CN)** δ 6.89 (s, 1H), 6.74 (s, 1H), 2.16 (s, 3H) / 6.83 (d, *J* = 3.2 Hz, 1H), 6.80 (d, *J* = 3.2 Hz, 1H), 2.20 (s, 3H); **^{13}C NMR (151 MHz, CD_3CN)** δ 150.69, 148.62 (q, *J* = 2.0 Hz), 131.76, 125.02 (q, *J* = 271.1 Hz), 122.39, 113.01 (q, *J* = 4.9 Hz), 16.57 (one peak is overlapped with CD_3CN peak) / 148.57, 146.56 (q, *J* = 2.1 Hz), 129.41, 125.00 (q, *J* = 271.1 Hz), 120.14, 111.17 (q, *J* = 5.4 Hz), 16.21 (one peak is overlapped with CD_3CN peak); **^{19}F NMR (564 MHz, CD_3CN)** δ -62.13 / -62.36; **IR (neat)**: ν_{max} = 3371, 1632, 1129, 1037 cm^{-1}; **HRMS** m/z (EI) calc. for $C_8H_7F_3O_2$ [M^+] 192.0398, found 192.0399; ***R*$_f$** 0.56 (Hex/EtOAc, 2/1).



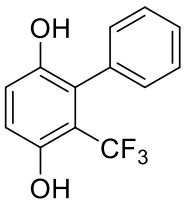
2-chloro-3-(trifluoromethyl)benzene-1,4-diol, **2c**[S8]: white solid; **^{1}H NMR (600 MHz, $(CD_3)_2CO$)** δ 8.88 (bs, 1H), 8.46 (bs, 1H), 7.12 (d, *J* = 8.9 Hz, 1H), 6.93 (d, *J* = 8.9 Hz, 1H); **^{13}C NMR (151 MHz, $(CD_3)_2CO$)** δ 150.01, 147.01, 123.82 (q, *J* = 274.8 Hz), 120.78, 118.71, 117.23, 114.22 (q, *J* = 29.8 Hz); **^{19}F NMR (564 MHz, $(CD_3)_2CO$)** δ -50.45; **IR (neat)**: ν_{max} = 3394, 2956, 2925, 1122, 1074 cm^{-1}; ***R*$_f$** 0.28 (Hex/EtOAc, 2/1).



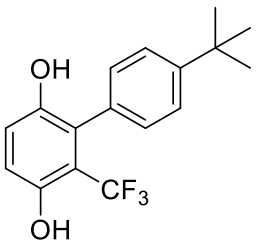
2-bromo-3-(trifluoromethyl)benzene-1,4-diol, **2d**: pale-green oil; **^{1}H NMR (600 MHz, CD_3CN)** δ 7.35 (bs, 1H), 7.07 (d, *J* = 8.9 Hz, 1H), 7.04 (bs, 1H), 6.91 (d, *J* =8.9 Hz, 1H); **^{13}C NMR (151 MHz, CD_3CN)** δ 150.86, 148.71, 132.20, 124.63 (q, *J* = 274.9 Hz), 121.40, 119.26, 108.75 (q, *J* = 2.3 Hz); **^{19}F NMR (564 MHz, CD_3CN)** δ -54.83; **IR (neat)**: ν_{max} = 3370, 3093, 1494, 1309, 1124, 1037, 833 cm^{-1}; **HRMS** m/z (EI) calc. for $C_7H_4BrF_3O_2$ [M$^+$] 255.9347, found 255.9349; ***R*$_f$** 0.64 (Hex/EtOAc, 1/1).



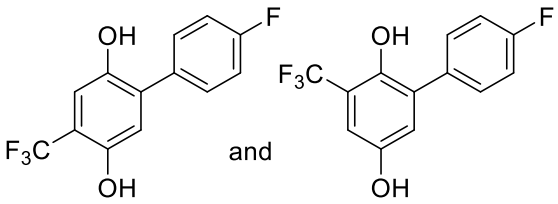
2-iodo-3-(trifluoromethyl)benzene-1,4-diol, **2e**: pale-green oil; **^{1}H NMR (600 MHz, CD_3CN)** δ 7.35 (bs, 2H), 7.03 (d, *J* = 8.9 Hz, 1H), 6.93 (d, *J* = 8.9 Hz, 1H); **^{13}C NMR (151 MHz, CD_3CN)** δ 151.33, 150.82, 124.10 (q, *J* = 273.5 Hz), 120.28, 119.64, 119.54 (q, *J* = 29.5), 83.04 (q, *J* = 1.7 Hz); **^{19}F NMR (564 MHz, CD_3CN)** δ -55.37; **IR (neat)**: ν_{max} = 3299, 2926, 1483, 1297, 1120, 489 cm^{-1}; **HRMS** m/z (EI) calc. for $C_7H_4F_3IO_2$ [M$^+$] 303.9208, found 303.9206; ***R*$_f$** 0.33 (Hex/EtOAc, 1/1).



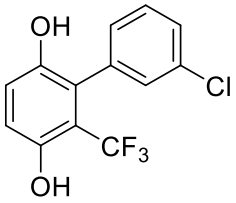
6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol / 2-phenylhydroquinone, **2f**: yellow oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.50 (dd, *J* = 7.4, 6.7 Hz, 2H), 7.46 (t, *J* = 7.4 Hz, 1H), 7.27 (d, *J* = 6.7 Hz, 2H), 7.08 (d, *J* = 9.0 Hz, 1H), 6.96 (d, *J* = 9.0 Hz, 1H), 5.63 (bs, 1H), 4.52 (bs, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 148.05 (q, *J* = 1.8 Hz), 147.39, 133.46, 130.12 (q, *J* = 1.4 Hz), 129.42, 129.10, 126.70, 124.80 (q, *J* = 275.1 Hz), 120.47, 119.54, 114.53 (q, *J* = 27.5 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -52.15; **IR (neat)**: ν_{max} = 3376, 1455, 1298, 1162, 1113, 1068 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{13}H_9F_3O_2$ [M$^+$] 254.0555, found 254.0554; ***R*$_f$** 0.29 (Hex/EtOAc, 2/1).



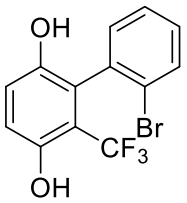
4'-(tert-butyl)-6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol / 2-(tert-butyl)-hydroquinone (mixed), **2g**: pale-green oil; **^{1}H NMR (600 MHz, CD_3CN)** δ 7.48 (d, *J* = 8.9 Hz, 2H), 7.14 (d, *J* = 8.9 Hz, 2H), 7.00 (d, *J* = 8.9 Hz, 1H), 6.91 (d, *J* = 8.9 Hz, 1H), 6.32 (bs, 1H), 6.08 (bs, 1H), 1.35 (s, 9H) / δ 7.48 (d, *J* = 8.9 Hz, 2H), δ 7.47 (bs, 1H) 7.14 (d, *J* = 8.9 Hz, 2H), 6.78 (d, *J* = 8.7 Hz, 1H), 6.75 (d, *J* = 2.1 Hz, 1H), 6.67 (dd, *J* = 8.7, 2.1 Hz, 1H), 6.48 (bs, 1H), 1.35 (s, 9H); **^{13}C NMR (151 MHz, CD_3CN)** δ 151.24, 149.72 (q, *J* = 1.7 Hz), 148.57, 130.10, 129.26 (q, *J* = 2.3 Hz), 126.03, 125.88, 123.50 (q, *J* = 275.0 Hz), 117.73, 117.68, 116.22 (q, *J* = 28.0 Hz), 35.17, 31.60 / δ 151.32, 150.88, 147.75, 136.46, 133.74, 130.03, 129.82, 120.73, 115.81, 35.11, 31.57. (one peak is overlapped); **^{19}F NMR (564 MHz, CD_3CN)** δ -48.37; **IR (neat)**: ν_{max} = 3621, 3092, 1459, 1295, 1193, 1037 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{17}H_{17}F_3O_2$ [M$^+$] 310.1181, found 310.1177; ***R*$_f$** 0.39 (Hex/EtOAc, 4/1).



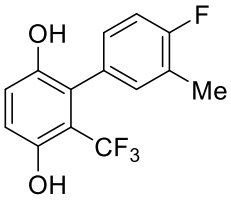
4'-fluoro-4-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol / 4'-fluoro-3-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol, **2h**: pale-green oil; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 7.55 (dd, *J* = 8.9, 5.5 Hz, 2H), 7.18 (dd, *J* = 8.9, 8.9 Hz, 2H), 7.07 (s, 1H), 6.88 (s, 1H) / δ 7.46 (dd, *J* = 8.8, 5.4 Hz, 2H), 7.23 (dd, *J* = 8.8, 8.8 Hz, 2H), 7.00 (d, *J* = 3.1 Hz, 1H), 6.89 (d, *J* = 3.1 Hz, 1H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 163.30 (d, *J* = 245.3), 150.87, 148.88 (q, *J* = 2.0 Hz), 134.18 (d, *J* = 3.5 Hz), 133.49, 132.53 (d, *J* = 2.0 Hz), 124.84 (q, *J* = 272.0 Hz), 122.04, 119.44 (d, *J* = 30.8 Hz), 116.60 (d, *J* = 21.7 Hz), 114.84 (q, *J* = 5.2 Hz) / δ 163.30 (d, *J* = 245.0 Hz) 146.35, 145.34 (d, *J* = 1.6 Hz), 133.69 (d, *J* = 3.5 Hz), 131.68, 132.14 (d, *J* = 8.4 Hz), 124.74 (q, *J* = 271.5 Hz), 118.82, 116.65 (d, *J* = 31.3 Hz), 115.98 (d, *J* = 21.4 Hz), 113.46 (q, *J* = 5.2 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -57.21 / -57.17; **IR (neat)**: ν_{max} = 3374, 2930, 1434, 1225, 1118, 1058 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{13}H_8F_4O_2$ [M$^+$] 272.0460, found 272.0460; ***R$_f$*** 0.58 (Hex/EtOAc, 2/1).



3'-chloro-6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol, **2i**: pale-green oil; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 7.42 (m, 2H), 7.27 (s, 1H), 7.23 (bs, 1H), 7.16 (m, 1H), 7.02 (d, *J* = 8.9 Hz, 1H), 6.94 (d, *J* = 8.9 Hz, 1H), 6.34 (bs, 1H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 148.83, 147.45, 138.20, 133.25, 129.60, 129.40, 128.20, 127.41, 126.70, 124.23 (q, *J* = 275.1 Hz), 120.22, 117.96, 115.07 (q, *J* = 28.1 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -53.85; **IR (neat)**: ν_{max} = 3377, 1453, 1287, 1162, 1114, 1068, 760 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{13}H_8ClF_3O_2$ [M$^+$] 288.0165, found 288.0167; ***R$_f$*** 0.43 (Hex/EtOAc, 2/1).

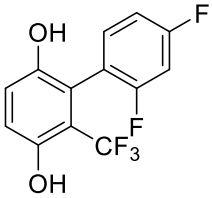


2'-bromo-6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol, **2j**: pale-green oil; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 7.67 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.40 (ddd, *J* = 7.6, 7.5, 1.2 Hz, 1H), 7.28 (ddd, *J* = 8.1, 7.5, 1.8 Hz, 1H), 7.22 (bs, 1H), 7.20 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.01 (dd, *J* = 8.9, 0.8 Hz, 1H), 6.95 (dd, *J* = 8.8, 0.9 Hz, 1H), 6.39 (bs, 1H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 149.72, 148.27, 138.33, 133.12, 132.09, 130.37, 128.28, 128.00, 125.09 (q, *J* = 274.8 Hz), 124.78, 121.09, 118.98, 116.09 (q, *J* = 28.3 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -53.57; **IR (neat)**: ν_{max} = 3355, 2929, 1492, 1298, 1161, 1123, 752 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{13}H_8BrF_3O_2$ [M$^+$] 331.9660, found 331.9659; ***R$_f$*** 0.27 (Hex/EtOAc, 2/1).

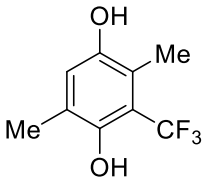


4'-fluoro-3'-methyl-6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol, **2k**: pale-green oil; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 7.17 (bs, 1H), 7.12 – 7.08 (m, 2H), 7.02 (dq, *J* = 8.4, 2.5 Hz, 1H), 6.99 (d, *J* = 9.0 Hz, 1H), 6.91 (d, *J* = 9.0 Hz, 1H), 6.12 (bs, 1H) 2.30 (d, *J* = 2.2 Hz, 3H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 161.79 (d, *J* =

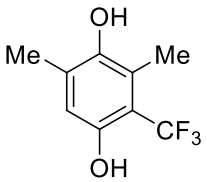
243.3 Hz), 149.73 (q, *J* = 2.0 Hz), 148.59, 133.65 (m), 132.58, 130.80, 130.73, 129.71 (dq, *J* = 8.39, 1.76 Hz), 128.28 (q, *J* = 2.61 Hz), 125.28 (q, *J* = 275.1 Hz), 125.43 (d, *J* = 18.0 Hz), 120.91, 118.59, 115.46 (d, *J* = 22.9 Hz), 14.46 (d, *J* = 3.8 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -48.52, -115.99; **IR (neat)**: ν_{max} = 3370, 3093, 1493, 1299, 1120, 1037 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{14}H_{10}F_4O_2$ [M$^+$] 286.0617, found 286.0619; ***R*$_f$** 0.62 (Hex/EtOAc, 2/1).



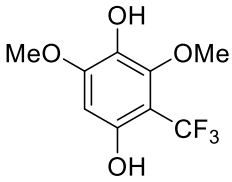
2',4'-difluoro-6-(trifluoromethyl)-[1,1'-biphenyl]-2,5-diol, **2l**: pale-green oil; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 7.26 (bs, 1H), 7.24 – 7.20 (m, 1H), 7.03 – 7.00 (m, 3H), 6.95 (d, *J* = 8.8 Hz, 1H), 6.57 (bs, 1H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 163.74 (dd, *J* = 246.8, 11.9 Hz), 160.93 (dd, *J* = 245.9, 12.4 Hz), 149.90 (q, *J* = 1.7 Hz), 148.89, 133.72 (m), 125.09 (q, *J* = 274.5 Hz), 121.55 (q, *J* = 2.1 Hz), 121.14, 120.80 (dd, *J* = 18.3, 4.3 Hz), 119.53, 116.69 (q, *J* = 28.3 Hz), 111.91 (dd, *J* = 21.7, 3.8 Hz), 104.35 (dd, *J* = 26.3, 26.3 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -50.52, -106.81, -107.37; **IR (neat)**: ν_{max} = 3349, 2925, 1491, 1457, 1287, 1118, 1061 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{13}H_7F_5O_2$ [M$^+$] 290.0366, found 290.0364; ***R*$_f$** 0.27 (Hex/EtOAc, 2/1).



2,5-dimethyl-3-(trifluoromethyl)benzene-1,4-diol, **2m**: white solid; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 6.82 (s, 1H), 6.64 (bs, 1H), 6.10 (bs, 1H), 2.22 (q, *J* = 2.9 Hz, 3H), 2.18 (s, 3H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 149.12, 147.28 (q, *J* = 2.0 Hz), 126.59 (q, *J* = 274.8 Hz), 126.20, 122.19 (q, *J* = 1.8 Hz), 121.76, 117.21 (q, *J* = 27.4 Hz), 16.47, 12.36 (q, *J* = 4.0 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -54.28 (q, *J* = 2.9 Hz); **IR (neat)**: ν_{max} = 3392, 2948, 1450, 1017 cm^{-1}; **HRMS** m/z (EI) calc. for $C_9H_9F_3O_2$ [M$^+$] 206.0555, found 206.0557; ***R*$_f$** 0.39 (Hex/EtOAc, 2/1).

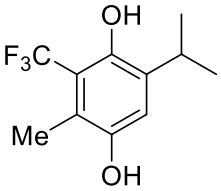


3,5-dimethyl-2-(trifluoromethyl)benzene-1,4-diol, **2n**: white solid; m.p. 133 – 137 °C; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 6.59 (s, 1H), 2.30 (s, 3H), 2.26 (q, *J* = 2.7 Hz, 3H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 149.56 (q, *J* = 8.1 Hz), 147.20, 131.50, 126.40 (q, *J* = 274.3 Hz), 125.43 (q, *J* = 2.0 Hz), 117.62, 113.71 (q, *J* = 28.4 Hz), 17.06, 13.18 (q, *J* = 4.0 Hz); **^{19}F NMR (564 MHz, CD$_3$CN)** δ -54.14; **IR (neat)**: ν_{max} = 3292, 1228, 1141, 1104 cm^{-1}; **HRMS** m/z (EI) calc. for $C_9H_9F_3O_2$ [M$^+$] 206.0555, found 206.0554; ***R*$_f$** 0.38 (Hex/EtOAc, 2/1).

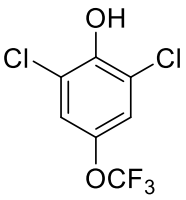


3,5-dimethoxy-2-(trifluoromethyl)benzene-1,4-diol, **2o**: white solid; m.p. 78 – 81 °C; **^{1}H NMR (600 MHz, CD$_3$CN)** δ 6.35 (s, 1H), 3.85 (s, 3H), 3.82 (s, 3H); **^{13}C NMR (151 MHz, CD$_3$CN)** δ 152.46, 149.34 (q, *J* = 1.7 Hz), 134.04, 125.50 (q, *J* = 272.5 Hz), 108.01, 103.17 (q, *J* = 29.2 Hz), 97.58, 61.67, 56.69; **^{19}F NMR**

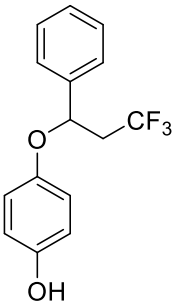
(564 MHz, CD_3CN) δ -54.96; **IR (neat)**: ν_{max} = 3393, 2949, 1206, 1098, 1064 cm^{-1}; **HRMS** m/z (EI) calc. for $C_9H_9F_3O_4$ [M^+] 238.0453, found 238.0450; ***R_f*** 0.47 (Hex/EtOAc, 1/1).



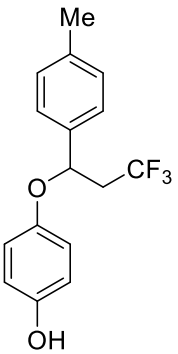
5-isopropyl-2-methyl-3-(trifluoromethyl)benzene-1,4-diol, **2p**: pale-green oil; **^{1}H NMR (600 MHz, CD_3CN)** δ 6.90 (s, 1H), 6.76 (bs, 1H), 6.12 (bs, 1H), 3.20 (hept, *J* = 6.9 Hz, 1H), 2.22 (q, *J* = 3.0 Hz, 3H), 1.17 (d, *J* = 6.9 Hz, 6H); **^{13}C NMR (151 MHz, CD_3CN)** δ 149.76, 145.94, 137.29, 126.67 (q, *J* = 275.1 Hz), 121.92, 117.75 (q, *J* = 27.2 Hz), 117.47, 27.16, 22.89, 12.35 (q, *J* = 4.0 Hz); **^{19}F NMR (564 MHz, CD_3CN)** δ -48.70 (q, *J* = 3.0 Hz); **IR (neat)**: ν_{max} = 3402, 2968, 1280, 1111, 1028 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{11}H_{13}F_3O_2$ [M^+] 234.0866, found 234.0868; ***R_f*** 0.63 (Hex/EtOAc, 2/1).



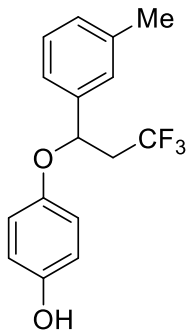
3,5-dichloro-4-(trifluoromethoxy)phenol, **3q**[S9]: white solid; **^{1}H NMR (600 MHz, CD_3OD)** δ 6.72 (s, 2H); **^{13}C NMR (151 MHz, CD_3OD)** δ 151.88, 143.46, 123.92, 117.18 (q, *J* = 248.2 Hz), 116.36; **^{19}F NMR (564 MHz, CD_3OD)** δ –56.83; **IR (neat)**: ν_{max} = 3458, 2928, 1270, 1161, 1127 cm^{-1}; ***R_f*** 0.45 (Hex/EtOAc, 2/1).



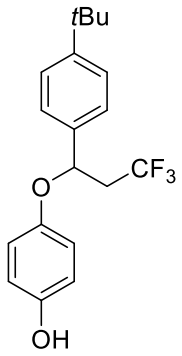
4-(3,3,3-trifluoro-1-phenylpropoxy)phenol, **5aa**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.37 – 7.36 (m, 4H), 7.31 (m, 1H), 6.72 (d, *J* = 9.1 Hz, 2H), 6.65 (d, *J* = 9.1 Hz, 2H), 5.29 (dd, *J* = 9.1, 3.7 Hz, 1H), 4.40 (bs, 1H), 2.92 – 2.82 (m, 1H), 2.57 – 2.48 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.87, 150.33, 140.24, 129.14, 128.61, 126.21, 125.72 (q, *J* = 278.0 Hz),118.02, 116.14, 76.06 (q, *J* = 3.2 Hz), 42.80 (q, *J* = 27.8 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.77; **IR (neat)**: ν_{max} = 3393, 3033, 1508, 1253, 1204, 1134 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{15}H_{13}F_3O_2$ [M^+] 282.0868, found 282.0865; ***R_f*** 0.55 (Hex/EtOAc, 2/1).



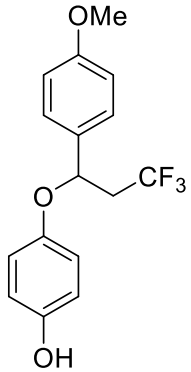
4-(3,3,3-trifluoro-1-(p-tolyl)propoxy)phenol, **5ab**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.25 (d, *J* = 7.9 Hz, 2H), 7.17 (d, *J* = 7.9 Hz, 2H), 6.72 (d, *J* = 8.9 Hz, 2H), 6.65 (d, *J* = 8.9 Hz, 2H), 5.26 (dd, *J* = 9.0, 3.7 Hz, 1H), 4.54 (bs, 1H), 2.90 - 2.81 (m, 1H), 2.55 – 2.46 (m, 1H), 2.34 (s, 3H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.88, 150.29, 138.38, 137.22, 129.79, 126.15, 125.74 (q, *J* = 278.0 Hz) 118.03, 116.12, 75.90 (q, *J* = 3.2 Hz), 42.85 (q, *J* = 27.8 Hz) , 21.36; **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.75; **IR (neat)**: ν_{max} = 3365, 2924, 1507, 1251, 1203, 1132, 1108 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{16}H_{15}F_3O_2$ [M^+] 296.1024, found 296.1022; ***R_f*** 0.71 (Hex/EtOAc, 2/1).



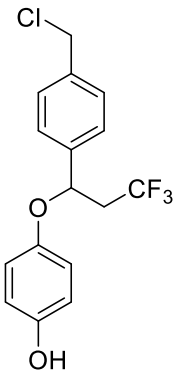
4-(3,3,3-trifluoro-1-(m-tolyl)propoxy)phenol, **5ac**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.25 (dd, *J* = 7.8, 7.6 Hz, 1H), 7.17 (s, 1H), 7.16 (d, *J* = 7.8 Hz, 1H), 7.11 (d, *J* = 7.6 Hz, 1H), 6.72 (d, *J* = 9.1 Hz, 2H), 6.65 (d, *J* = 9.1 Hz, 2H), 5.24 (dd, *J* = 9.1, 3.5 Hz, 1H), 4.61 (bs, 1H), 2.89 – 2.80 (m, 1H), 2.55 – 2.45 (m, 1H), 2.35 (s, 3H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.96, 150.32, 140.27, 138.89, 129.35, 129.01, 126.74, 125.75 (q, *J* = 277.7 Hz), 123.24, 117.96, 116.13, 76.09 (q, *J* = 3.2 Hz), 42.85 (q, *J* = 27.8 Hz), 21.65; **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.80; **IR (neat)**: ν_{max} = 2926, 2855, 1371, 1221, 1164 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{16}H_{15}F_3O_2$ [M^+] 296.1024, found 296.1021; ***R*$_f$** 0.59 (Hex/EtOAc, 2/1).



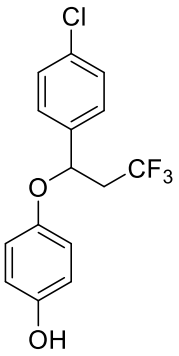
4-(1-(4-(tert-butyl)phenyl)-3,3,3-trifluoropropoxy)phenol, **5ad**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.37 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 8.4 Hz, 2H), 6.73 (d, *J* = 8.9 Hz, 2H), 6.66 (d, *J* = 8.9 Hz, 2H), 5.27 (dd, *J* = 9.2, 3.6 Hz, 1H), 4.43 (s, 1H), 2.90 - 2.81 (m, 1H), 2.54 - 2.46 (m, 1H), 1.30 (s, 9H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 152.03, 151.56, 150.23, 137.17, 126.03, 125.81, 125.78 (q, *J* = 278.0 Hz), 117.92, 116.13, 75.79 (q, *J* = 2.9 Hz), 42.84 (q, *J* = 27.8 Hz), 34.80, 31.51; **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.83; **IR (neat)**: ν_{max} = 3393, 2967, 1509, 1253, 1226, 1137 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{19}H_{21}F_3O_2$ [M^+] 338.1494, found 338.1496; ***R*$_f$** 0.53 (Hex/EtOAc, 2/1).



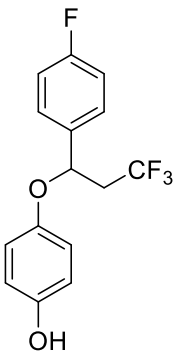
4-(3,3,3-trifluoro-1-(4-methoxyphenyl)propoxy)phenol, **5ae**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.27 (d, *J* = 8.8 Hz, 2H), 6.88 (d, *J* = 8.8 Hz, 2H), 6.71 (d, *J* = 8.9 Hz, 2H), 6.64 (d, *J* = 8.9 Hz, 2H), 5.23 (dd, *J* = 8.8, 3.8 Hz, 1H), 4.47 (bs, 1H), 3.79 (s, 3H), 2.90 – 2.81 (m, 1H), 2.54 – 2.44 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 159.53, 151.59, 150.11, 147.18, 131.95, 128.81, 127.31, 125.49 (q, *J* = 277.5 Hz), 117.95, 115.88, 114.24, 75.76 (q, *J* = 3.0 Hz), 55.25, 42.77 (q, *J* = 26.3 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.72; **IR (neat)**: ν_{max} = 3394, 2923, 1509, 1246, 1176, 1134, 1107 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{16}H_{15}F_3O_3$ [M^+] 312.0973, found 312.0976; ***R*$_f$** 0.48 (Hex/EtOAc, 2/1).



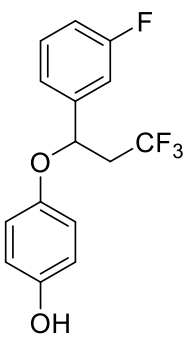
4-(1-(4-(chloromethyl)phenyl)-3,3,3-trifluoropropoxy)phenol, **5af**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.39 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.4 Hz, 2H), 6.71 (d, *J* = 9.1 Hz, 2H), 6.65 (d, *J* = 9.1 Hz, 2H), 5.30 (dd, *J* = 8.9, 3.7 Hz, 1H), 4.57 (s, 2H), 4.54 (bs, 1H), 2.91 – 2.81 (m, 1H), 2.55 – 2.46 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.69, 150.44, 140.49, 137.89, 129.38, 126.61, 125.63 (q, *J* = 278.0 Hz), 117.95, 116.19, 75.67 (q, *J* = 3.2 Hz), 45.89, 42.70 (q, *J* = 27.7 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.72; **IR (neat)**: ν_{max} = 3392, 1507, 1252, 1206, 1133, 1106 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{16}H_{14}ClF_3O_2$ [M^+] 330.0634, found 330.0633; ***R*$_f$** 0.65 (Hex/EtOAc, 2/1).



4-(1-(4-chlorophenyl)-3,3,3-trifluoropropoxy)phenol, **5ag**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.34 (d, *J* = 8.7 Hz, 2H), 7.31 (d, *J* = 8.7 Hz, 2H), 6.69 (d, *J* = 9.1 Hz, 2H), 6.66 (d, *J* = 9.1 Hz, 2H), 5.26 (dd, *J* = 8.7, 4.0 Hz, 1H), 4.45 (bs, 1H), 2.91 – 2.80 (m, 1H), 2.54 – 2.45 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.54, 150.54, 138.69, 134.48, 129.40, 128.12, 125.55 (q, *J* = 278.0 Hz), 118.05, 116.22, 75.47 (q, *J* = 3.2 Hz), 42.64 (q, *J* = 28.0 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.83; **IR (neat)**: ν_{max} = 3352, 2923, 1506, 1129, 1092 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{15}H_{12}ClF_3O_2$ [M^+] 316.0478, found 316.0478; ***R*$_f$** 0.43 (Hex/EtOAc, 2/1).

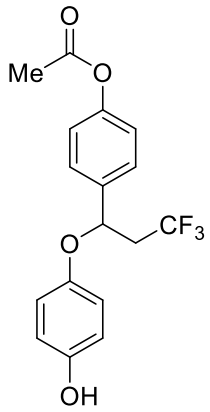


4-(3,3,3-trifluoro-1-(4-fluorophenyl)propoxy)phenol, **5ah**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.34 (dd, *J* = 8.7, 5.2 Hz, 2H), 7.05 (dd, *J* = 8.7, 8.6 Hz, 2H), 6.70 (d, *J* = 9.1 Hz, 2H), 6.66 (d, *J* = 9.1 Hz, 2H), 5.27 (dd, *J* = 8.7, 4.1 Hz, 1H), 4.54 (s, 1H), 2.91 – 2.82 (m, 1H), 2.55 – 2.46 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 162.79 (d, *J* = 247.4 Hz), 151.58, 150.50, 135.94 (d, *J* = 3.2 Hz), 128.05 (d, *J* = 8.4 Hz), 125.59 (q, *J* = 277.7 Hz), 118.13, 116.20, 116.06, 75.51 (q, *J* = 3.1 Hz), 42.72 (q, *J* = 28.9 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.68; **IR (neat)**: ν_{max} = 3393, 2987, 1511, 1251, 1226, 1134, 1066 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{15}H_{12}F_4O_2$ [M^+] 300.0773, found 300.0777; ***R*$_f$** 0.58 (Hex/EtOAc, 2/1).

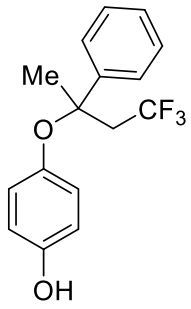


4-(3,3,3-trifluoro-1-(3-fluorophenyl)propoxy)phenol, **5ai**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.34 (ddd, *J* = 8.2, 7.8, 5.8 Hz, 1H), 7.15 (d, *J* = 7.8 Hz, 1H), 7.10 (dd, *J* = 9.4, 2.5 Hz, 1H), 7.00 (ddd, *J* = 8.4, 8.2, 2.5 Hz, 1H), 6.71 (d, *J* = 9.1 Hz, 2H), 6.66 (d, *J* = 9.1 Hz, 2H), 5.27 (dd, *J* = 8.9, 3.7 Hz, 1H), 2.90 – 2.81 (m, 1H), 2.56 – 2.47 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 163.35 (d, *J* = 247.7 Hz), 151.60, 150.54, 142.89 (d, *J* = 7.0 Hz), 130.83 (d, *J* = 8.4 Hz) 125.55 (q, *J* = 278.0 Hz), 121.88 (d, *J* = 3.2 Hz), 117.96, 116.23, 115.67 (d, *J* = 21.1 Hz), 113.28 (d, *J* = 22.3

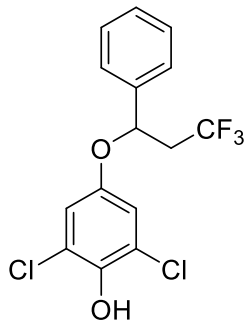
Hz), 75.45, 42.66 (q, *J* = 28.1 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -63.74, -111.72; **IR (neat)**: ν_{max} = 3366, 1507, 1250, 1210, 1120 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{15}H_{12}F_4O_2$ [M^+] 300.0773, found 300.0775; ***R*$_f$** 0.54 (Hex/EtOAc, 2/1).



4-(3,3,3-trifluoro-1-(4-hydroxyphenoxy)propyl)phenyl acetate, **5aj**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.37 (d, *J* = 8.6 Hz, 2H), 7.09 (d, *J* = 8.6 Hz, 2H), 6.69 (d, *J* = 8.9 Hz, 2H), 6.63 (d, *J* = 8.9 Hz, 2H), 5.28 (dd, *J* = 9.0, 3.5 Hz, 1H), 2.89 – 2.78 (m, 1H), 2.54 – 2.44 (m, 1H), 2.29 (s, 3H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 169.80, 151.58, 150.70, 150.61, 137.81, 127.31, 125.63 (q, *J* = 278.2 Hz), 122.27, 118.02, 116.18, 75.59 (q, *J* = 3.2 Hz), 42.73 (q, *J* = 27.8 Hz), 21.31; **^{19}F NMR (564 MHz, $CDCl_3$)** δ –63.74; **IR (neat)**: ν_{max} = 2988, 1760, 1504, 1371, 1215, 1192 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{17}H_{15}F_3O_4$ [M^+] 340.0922, found 340.0925; ***R*$_f$** 0.46 (Hex/EtOAc, 2/1).



4-((4,4,4-trifluoro-2-phenylbutan-2-yl)oxy)phenol, **5ak**: colorless oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.52 (d, *J* = 8.1 Hz, 2H), 7.40 (dd, *J* = 8.1, 7.3Hz, 2H), 7.34 (t, *J* = 7.3 Hz, 1H), 6.58 (d, *J* = 9.1 Hz, 2H), 6.53 (d, *J* = 9.1 Hz, 2H), 4.53 (s, 1H), 2.87 (dq, *J* = 15.4, 11.0 Hz, 1H), 2.65 (dq, *J* = 15.4, 10.6 Hz, 1H), 1.75 (s, 3H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 151.12, 148.75, 144.61, 128.78, 128.12, 126.10, 125.5 (q, *J* = 278.6 Hz), 122.63, 115.67, 79.26 (q, *J* = 2.3 Hz), 47.91 (q, *J* = 26.3 Hz), 22.41; **^{19}F NMR (564 MHz, $CDCl_3$)** δ -60.00; **IR (neat)**: ν_{max} = 3366, 2925, 1505, 1260, 1209, 1151, 1123 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{16}H_{15}F_3O_2$ [M^+] 296.1024, found 296.1021; ***R*$_f$** 0.53 (Hex/EtOAc, 2/1).



3,5-dichloro-4-(3,3,3-trifluoro-1-phenylpropoxy)phenol, **6qa**: yellow oil; **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.40 (dd, *J* = 7.5, 7.0 Hz, 2H), 7.35 - 7.32 (m, 3H), 6.79 (s, 2H), 5.43 (bs, 1H), 5.27 (dd, *J* = 9.2, 3.4 Hz, 1H), 2.91 – 2.81 (m, 1H), 2.56 - 2.48 (m, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 150.82, 143.14, 139.02, 129.41, 129.07, 126.05, 125.5 (*J* = 278.0 Hz), 121.24, 117.03, 76.28, 42.72 (*J* = 28.1 Hz); **^{19}F NMR (564 MHz, $CDCl_3$)** δ -62.28; **IR (neat)**: ν_{max} = 3520, 3065, 1483, 1252, 1205, 1135, 701 cm^{-1}; **HRMS** m/z (EI) calc. for $C_{15}H_{11}Cl_2F_3O_2$ [M^+] 350.0088, found 350.0086; ***R*$_f$** 0.45 (Hex/EtOAc, 2/1).

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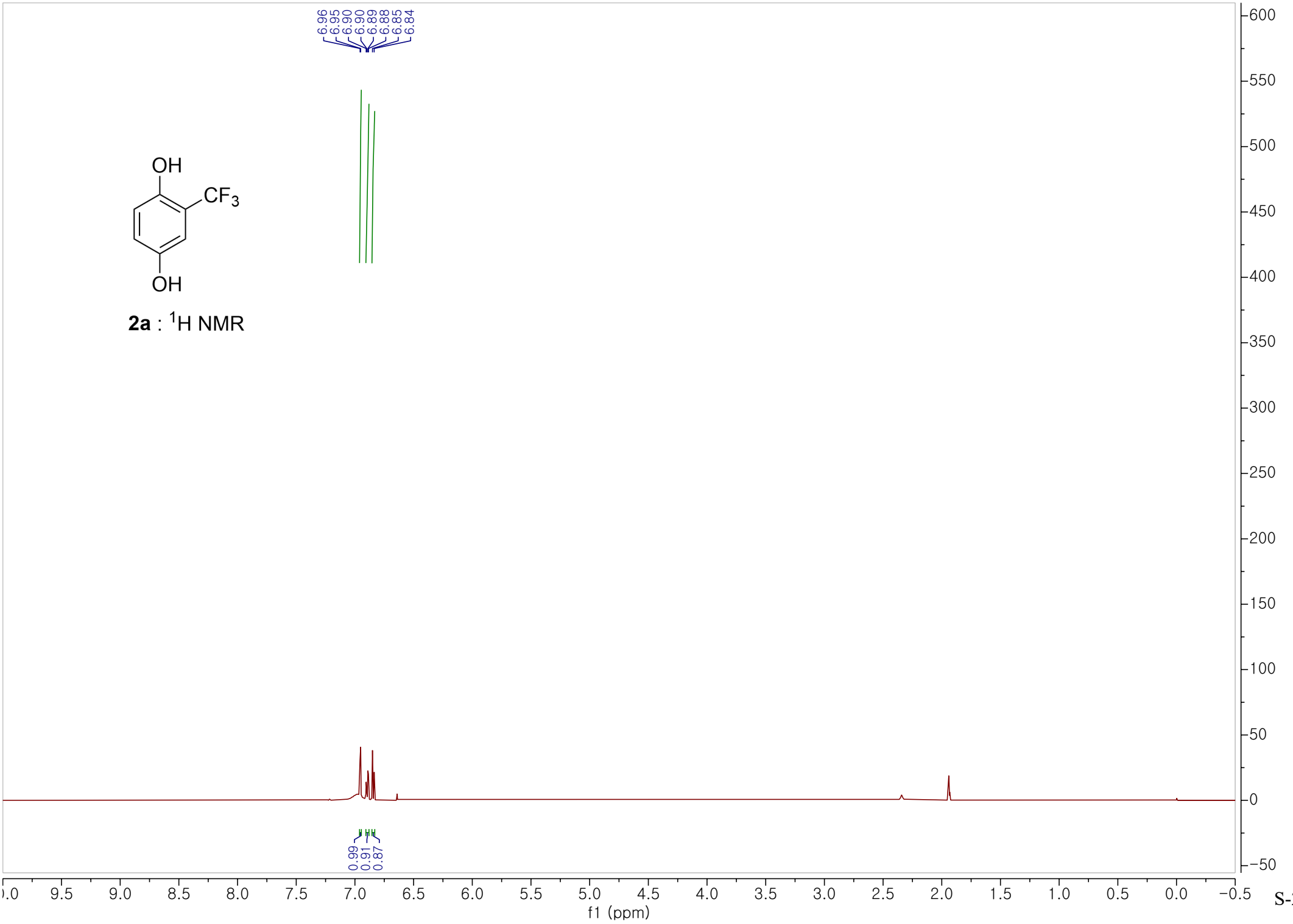
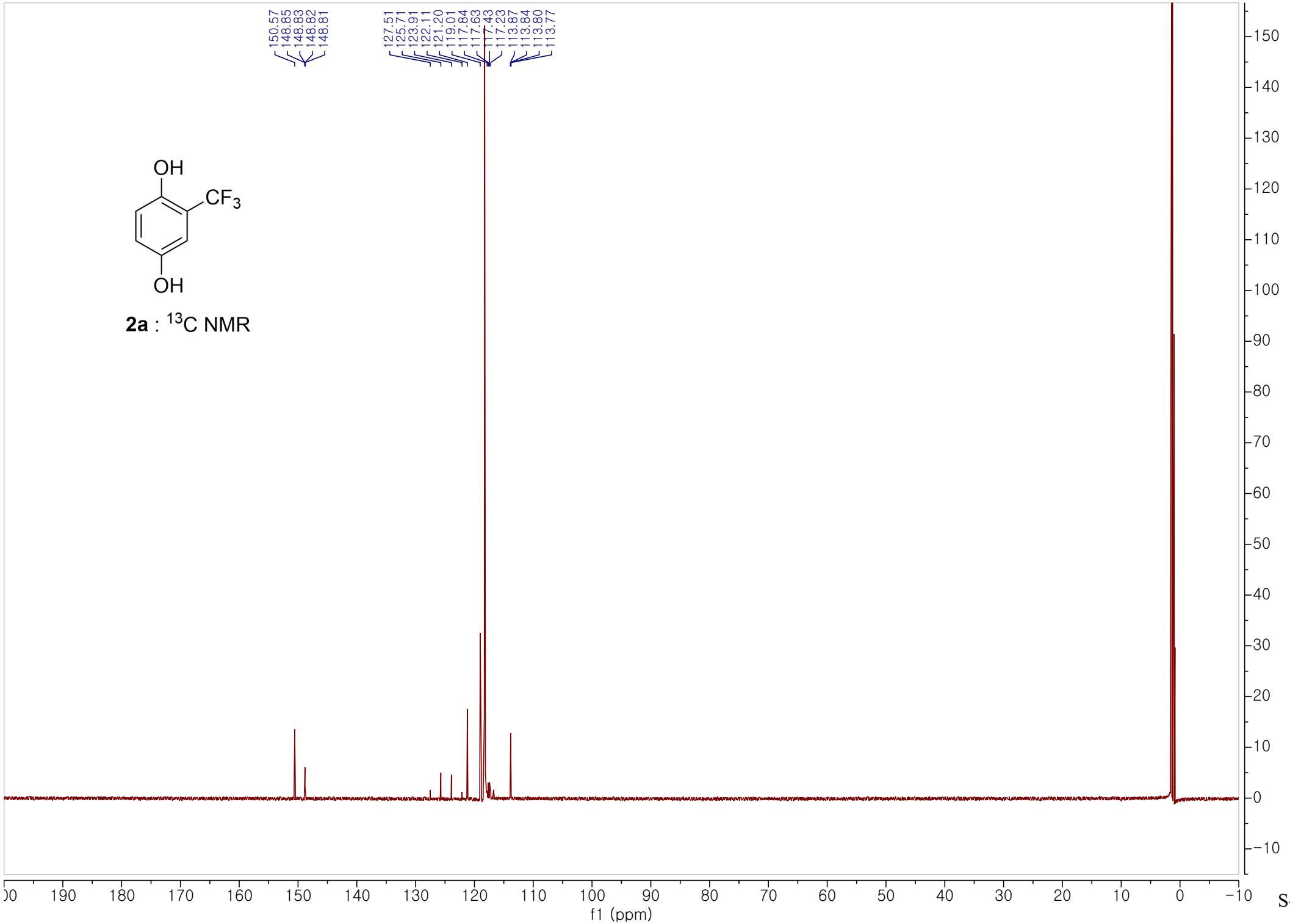
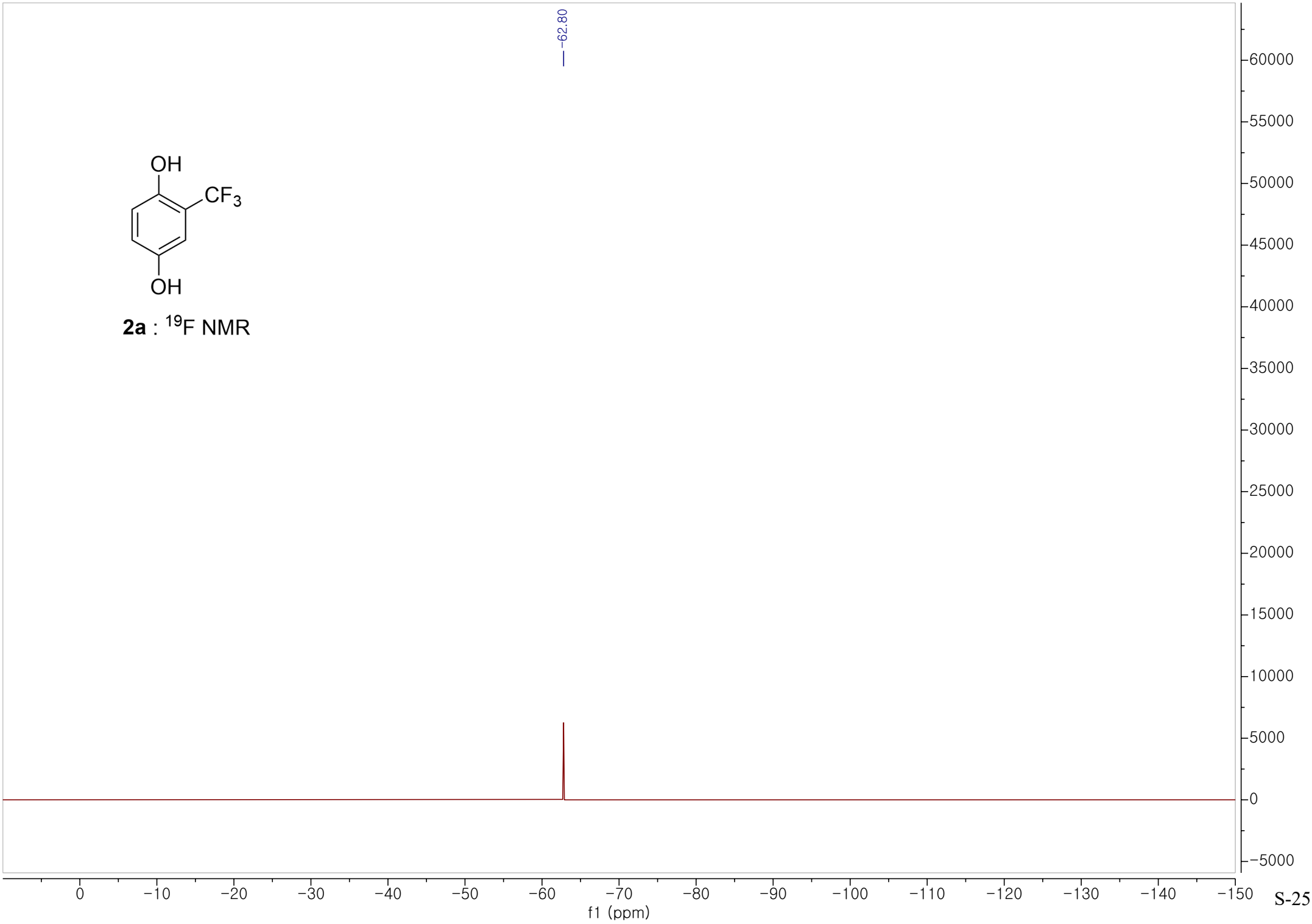
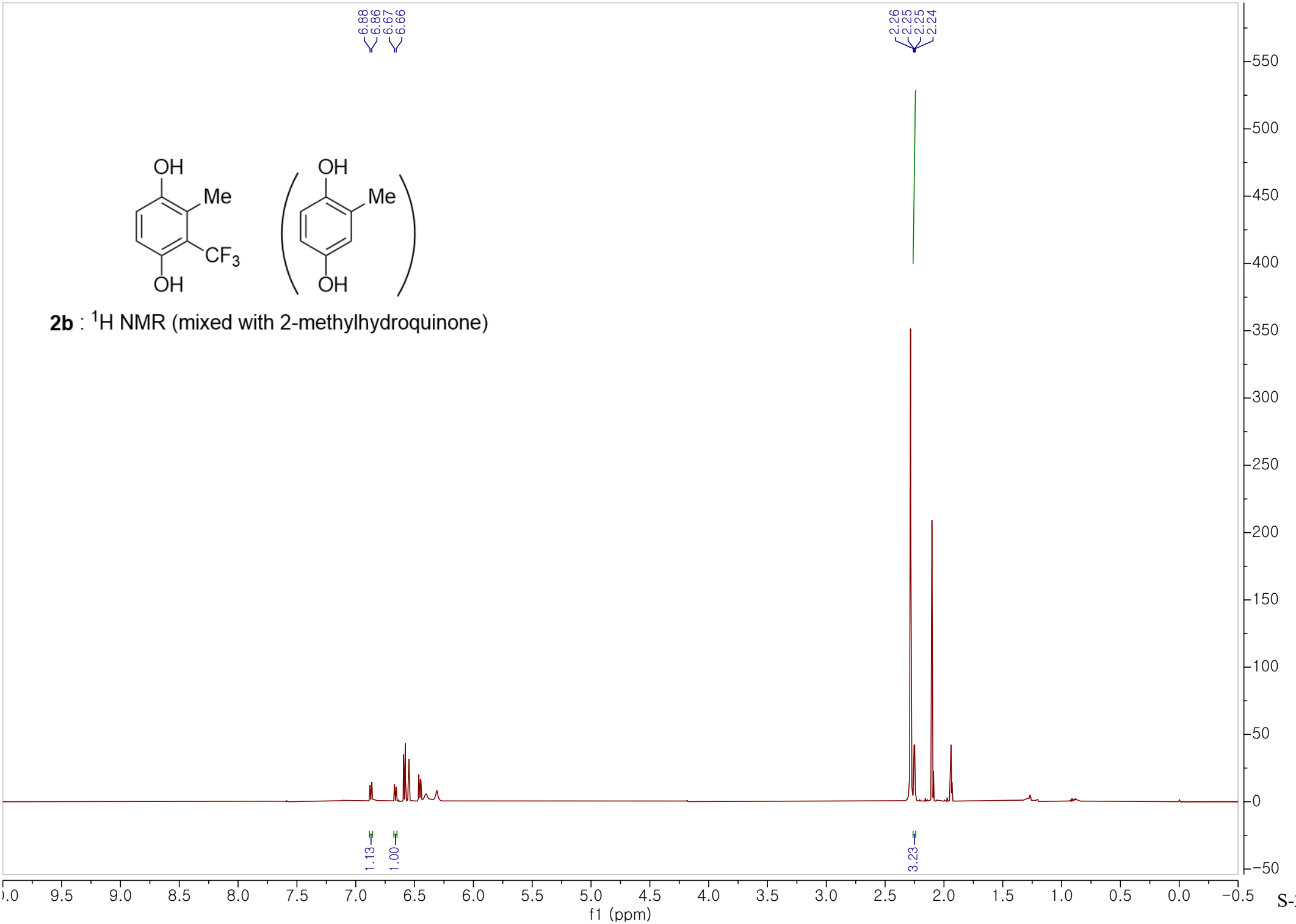
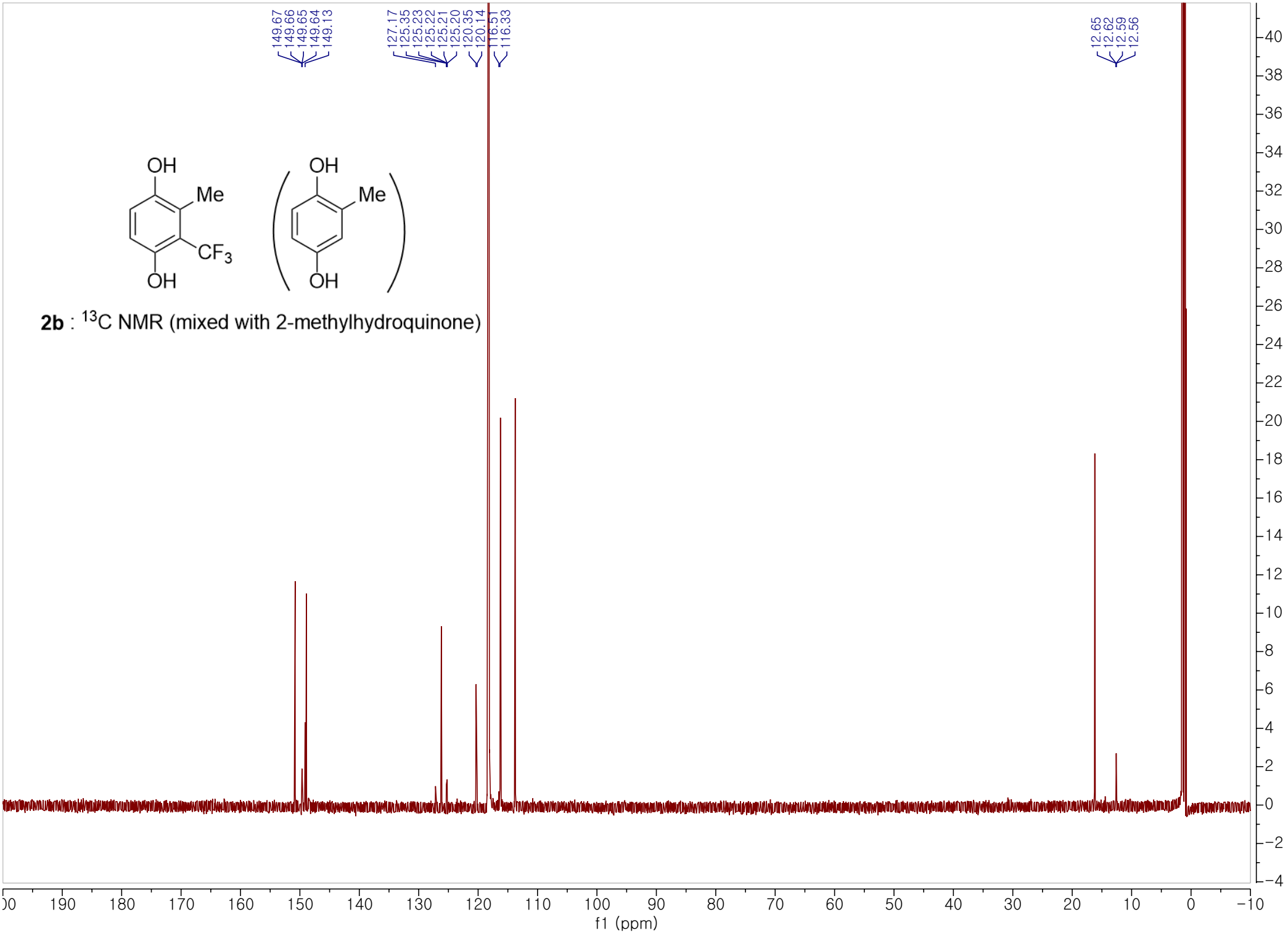

6.96
6.95
6.90
6.90
6.89
6.88
6.85
6.84
OH
CF3
OH
2a : 1H NMR
0.99
0.91
0.87
f1 (ppm)

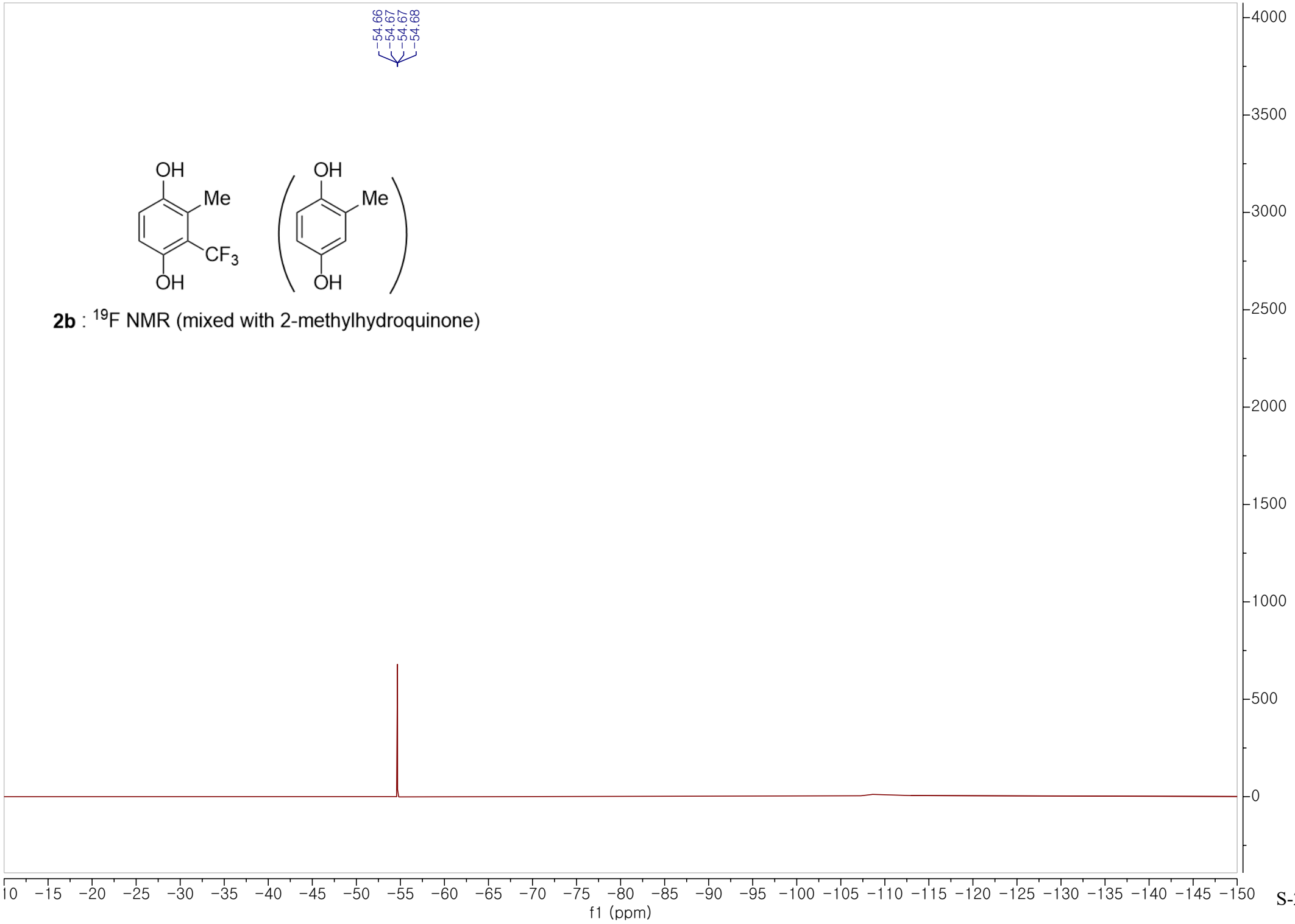

150.57
148.85
148.83
148.82
148.81
127.51
125.71
123.91
122.11
121.20
119.01
117.84
117.63
117.43
117.23
113.87
113.84
113.80
113.77
OH
CF3
OH
2a : 13C NMR
f1 (ppm)


-62.80
OH
CF3
OH
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

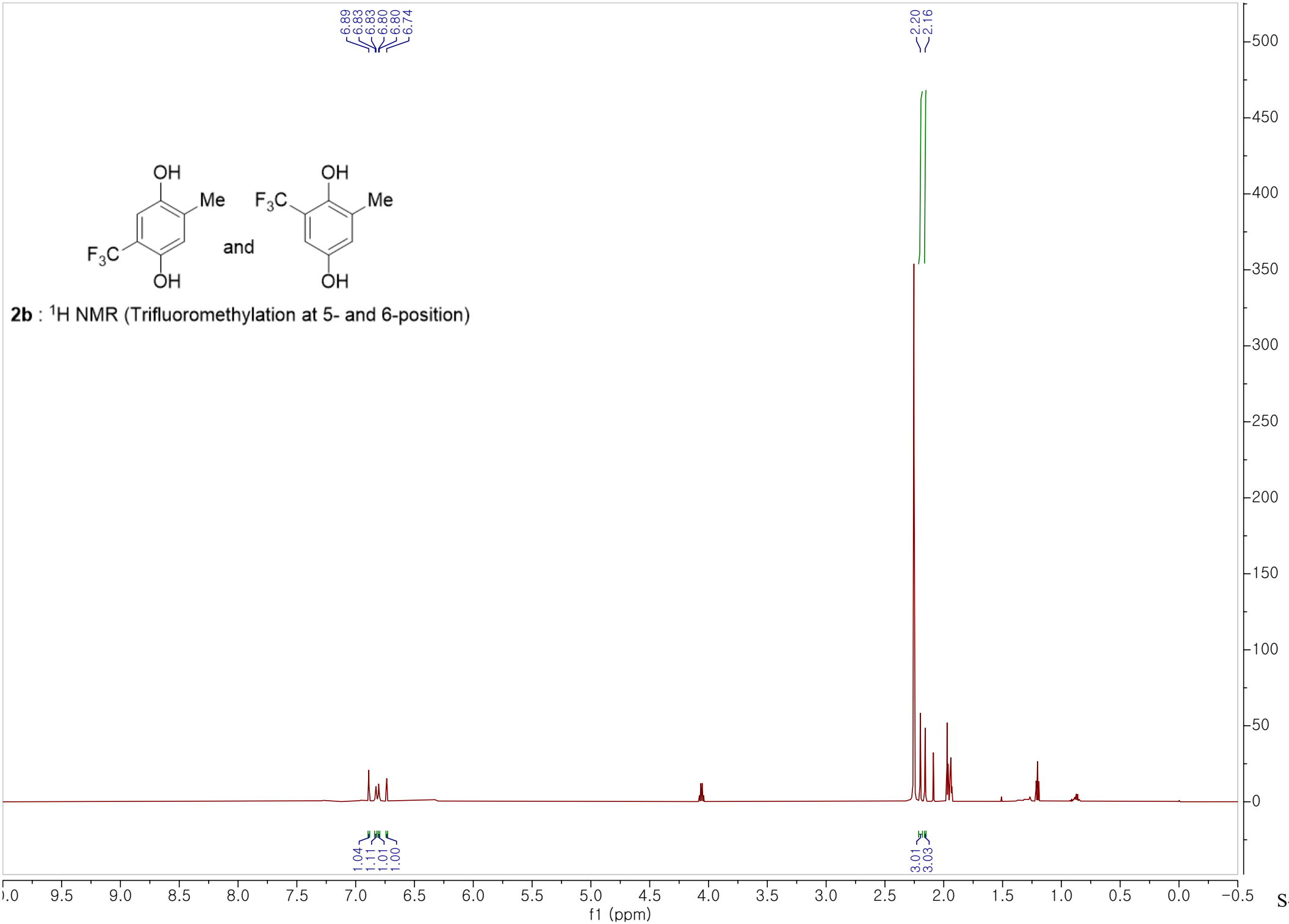
2a : ^{19}F NMR

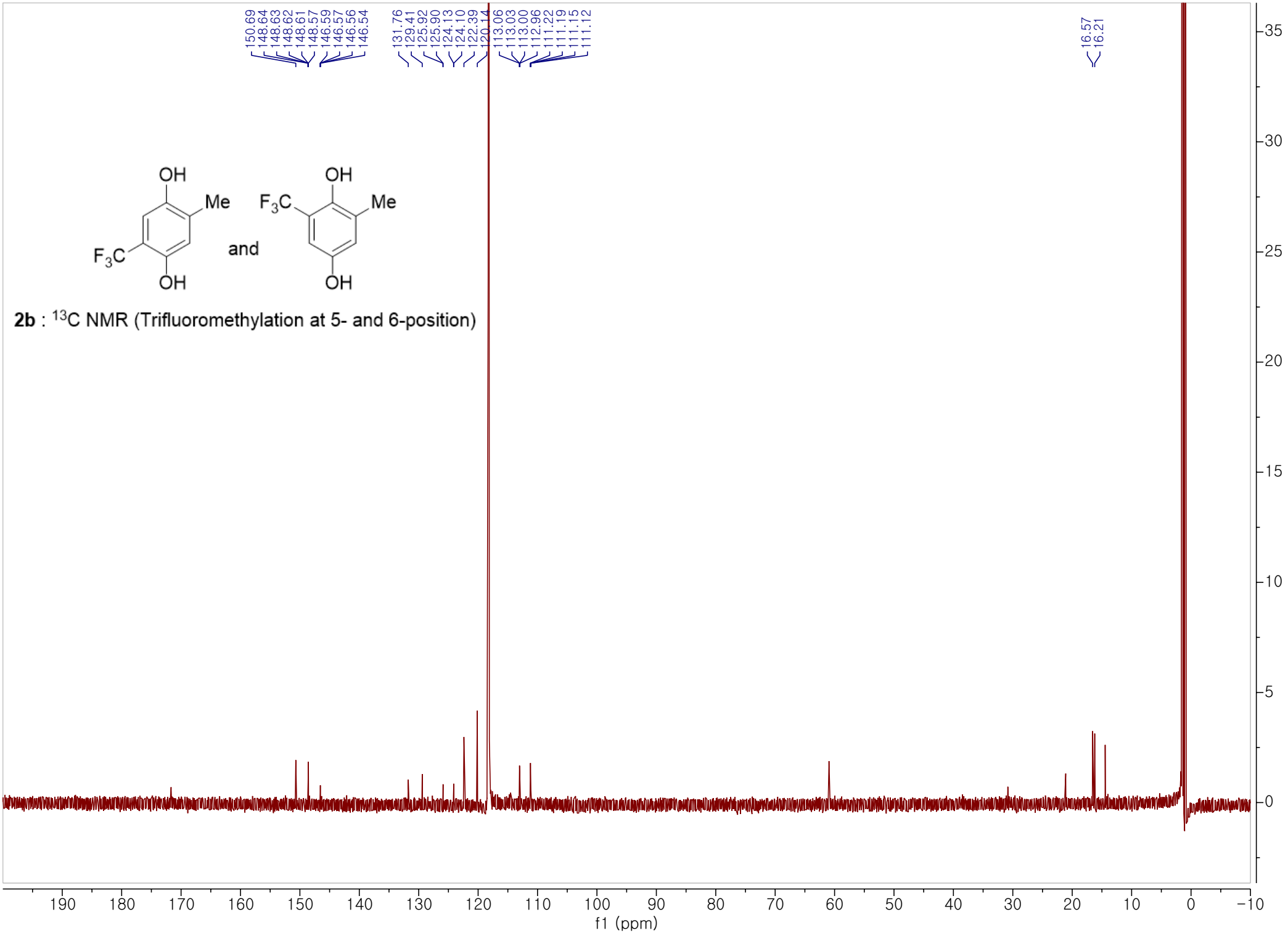

6.88
6.86
6.67
6.66
2.26
2.25
2.25
2.24
OH
Me
CF3
OH
OH
Me
OH
2b : 1H NMR (mixed with 2-methylhydroquinone)
1.13
1.00
3.23
f1 (ppm)

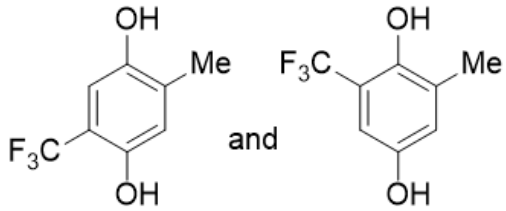

149.67
149.66
149.65
149.64
149.13
127.17
125.35
125.23
125.22
125.21
125.20
120.35
120.14
116.51
116.33
12.65
12.62
12.59
12.56
OH
Me
CF3
OH
OH
Me
OH
2b : 13C NMR (mixed with 2-methylhydroquinone)
f1 (ppm)



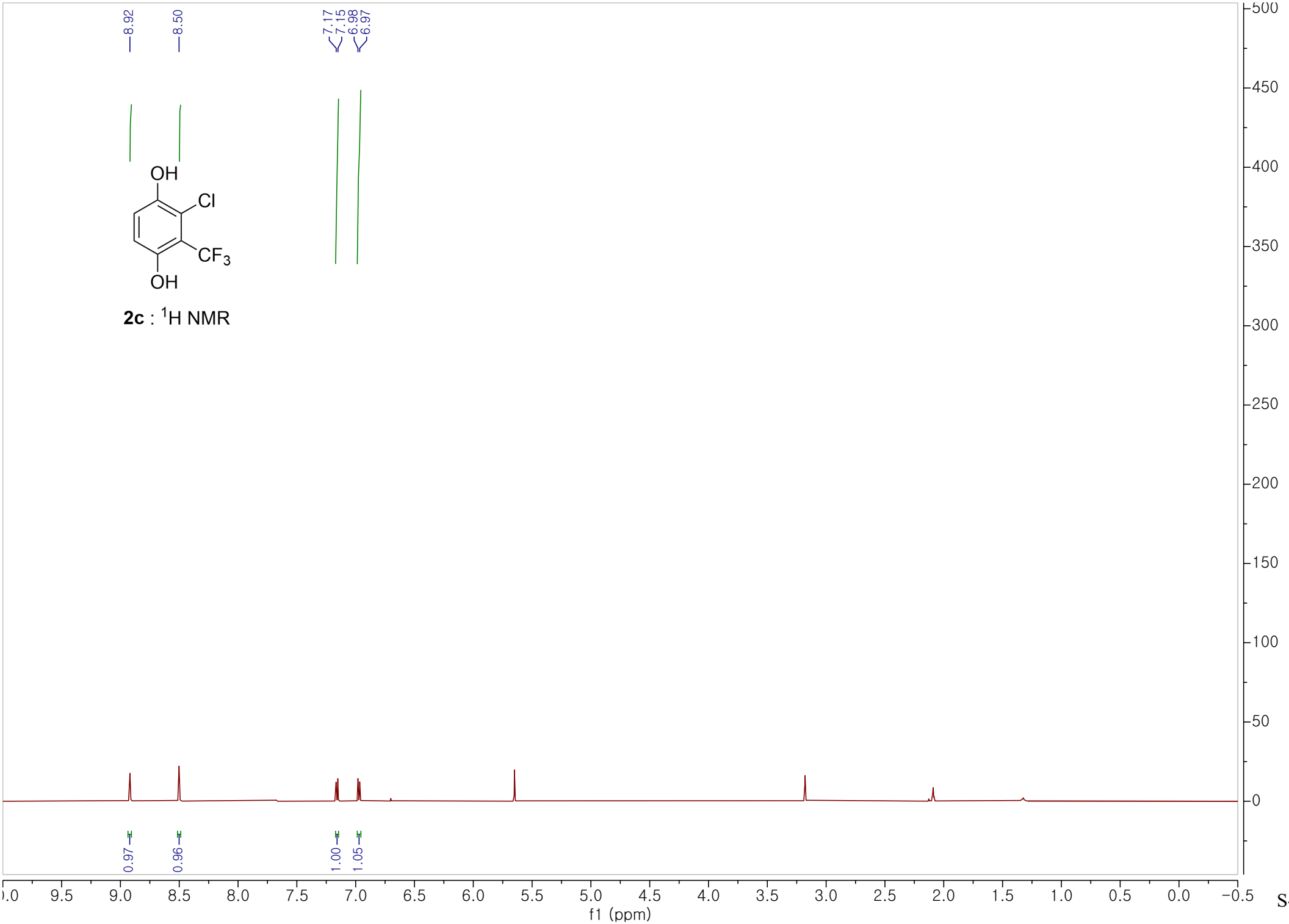
2b : ^{19}F NMR (mixed with 2-methylhydroquinone)

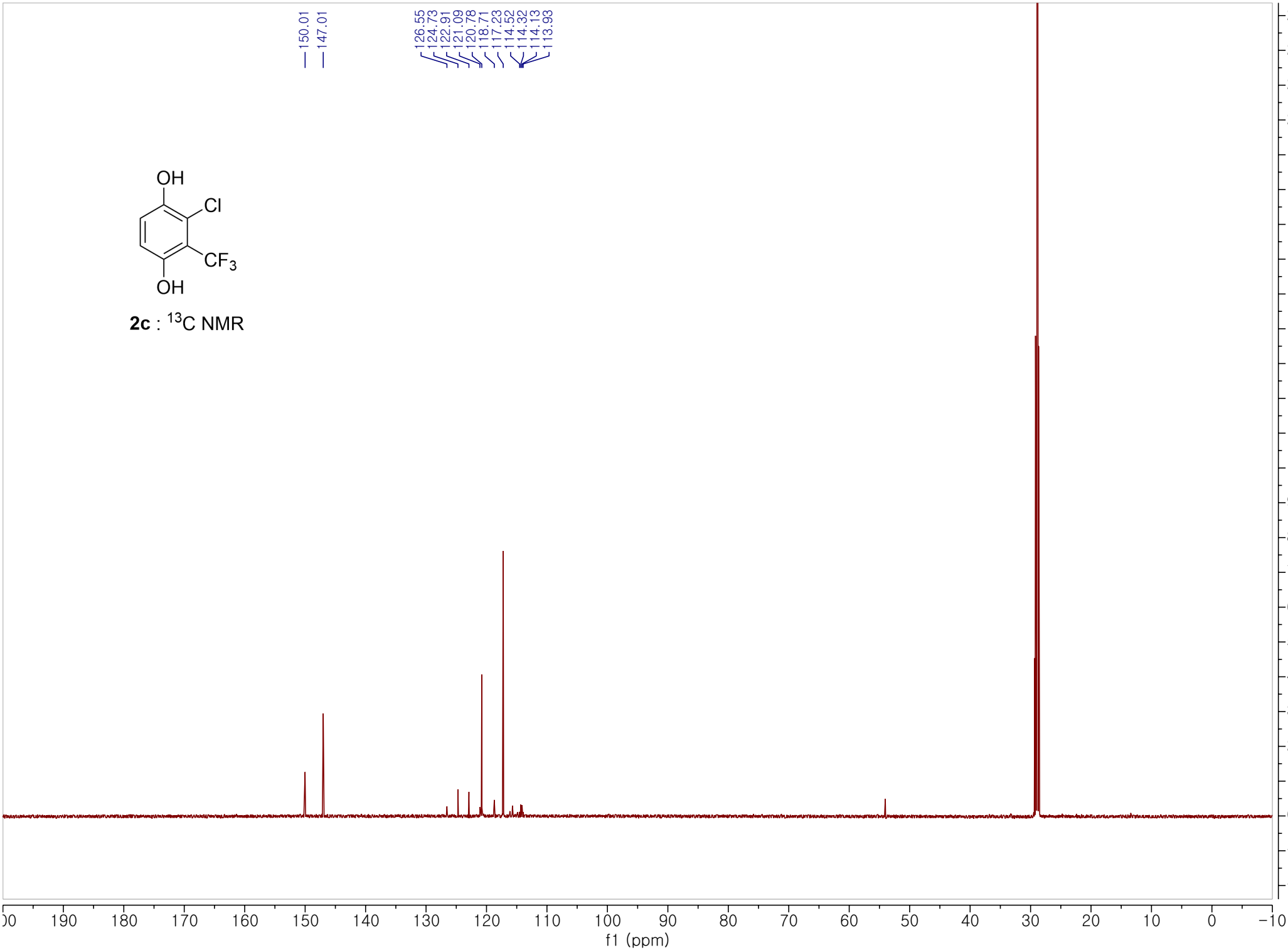

6.89
6.83
6.83
6.80
6.80
6.74
2.20
2.16
OH
Me
F3C
OH
and
OH
F3C
Me
OH
2b : 1H NMR (Trifluoromethylation at 5- and 6-position)
1.04
1.11
1.01
1.00
3.01
3.03
f1 (ppm)

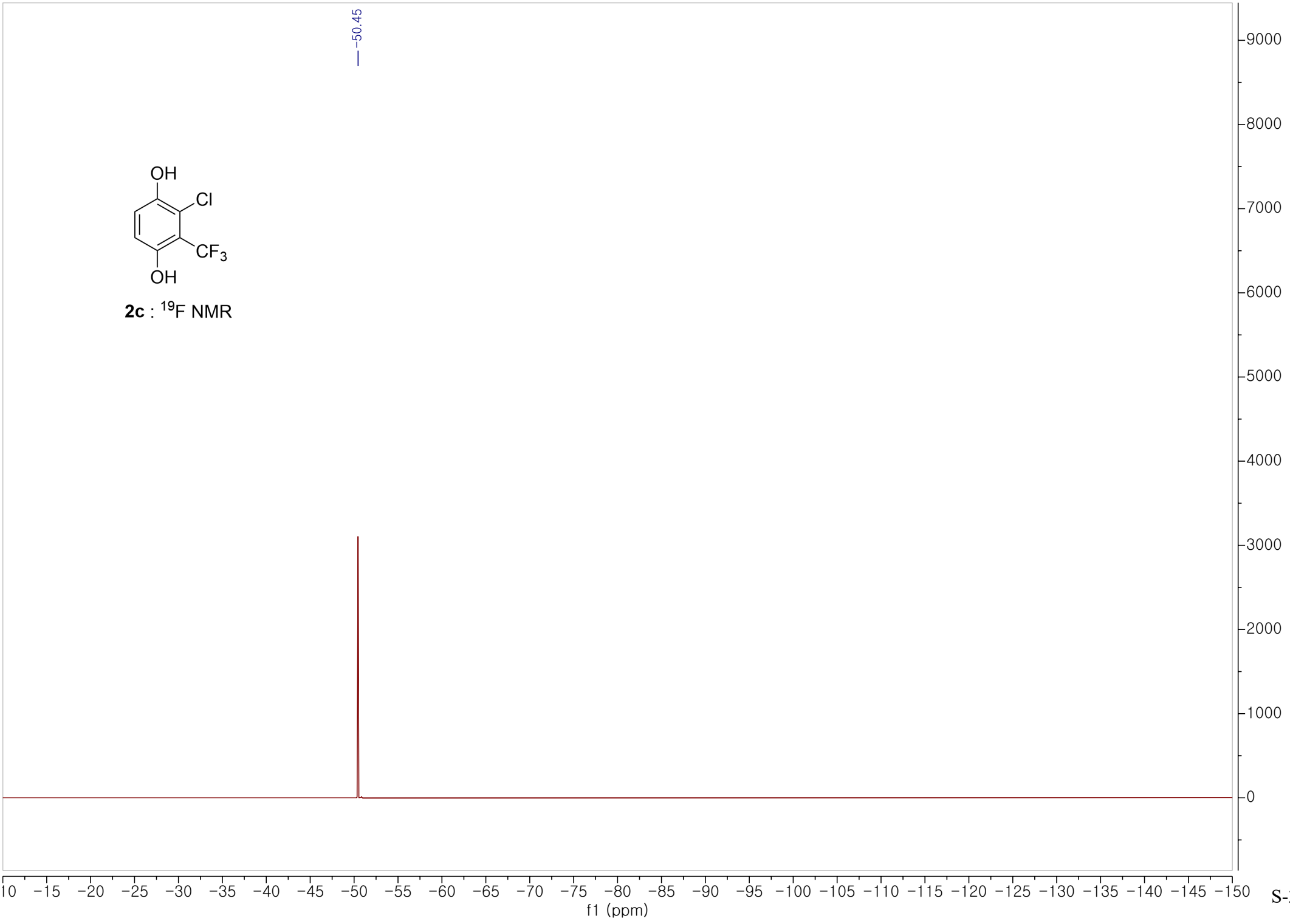

150.69
148.64
148.63
148.62
148.61
148.57
146.59
146.57
146.56
146.54
131.76
129.41
125.92
125.90
124.13
124.10
122.39
120.14
113.06
113.03
113.00
112.96
111.22
111.19
111.15
111.12
16.57
16.21
OH
Me
F3C
OH
and
OH
F3C
Me
OH
2b : 13C NMR (Trifluoromethylation at 5- and 6-position)
35
30
25
20
15
10
5
0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)



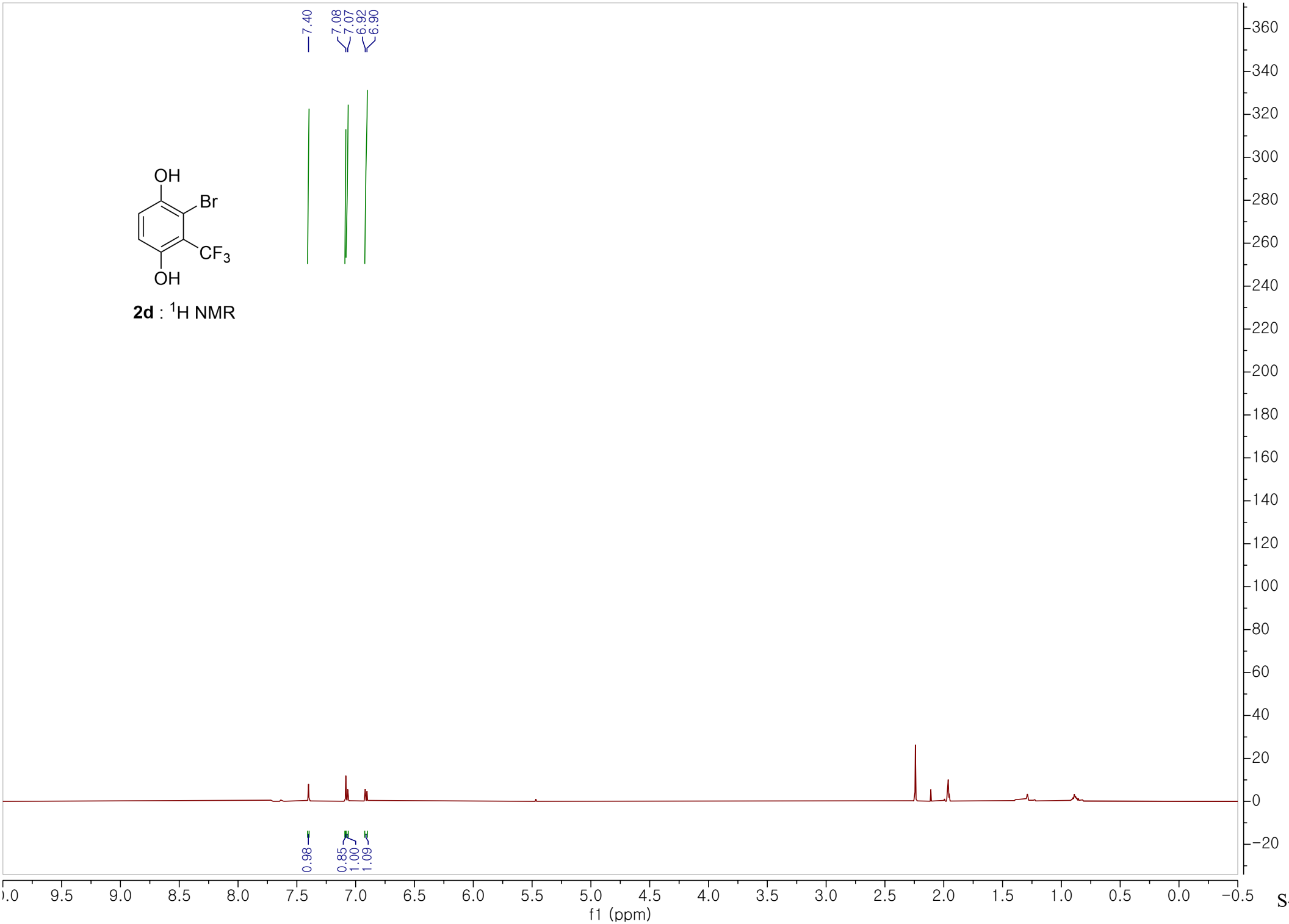
2b : ^{19}F NMR (Trifluoromethylation at 5- and 6-position)

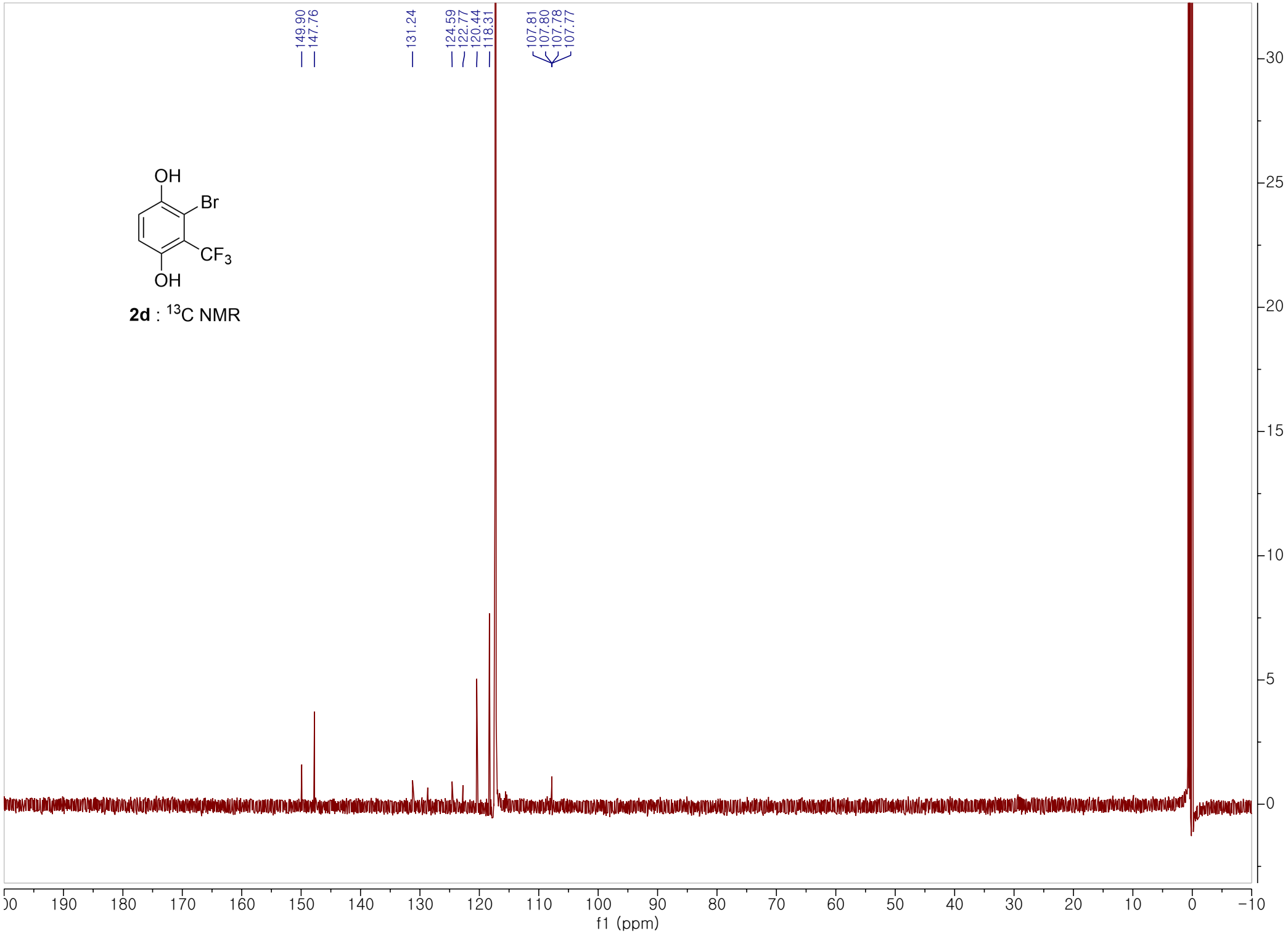

8.92
8.50
7.17
7.15
6.98
6.97
OH
Cl
CF3
OH
2c : 1H NMR
0.97
0.96
1.00
1.05
f1 (ppm)

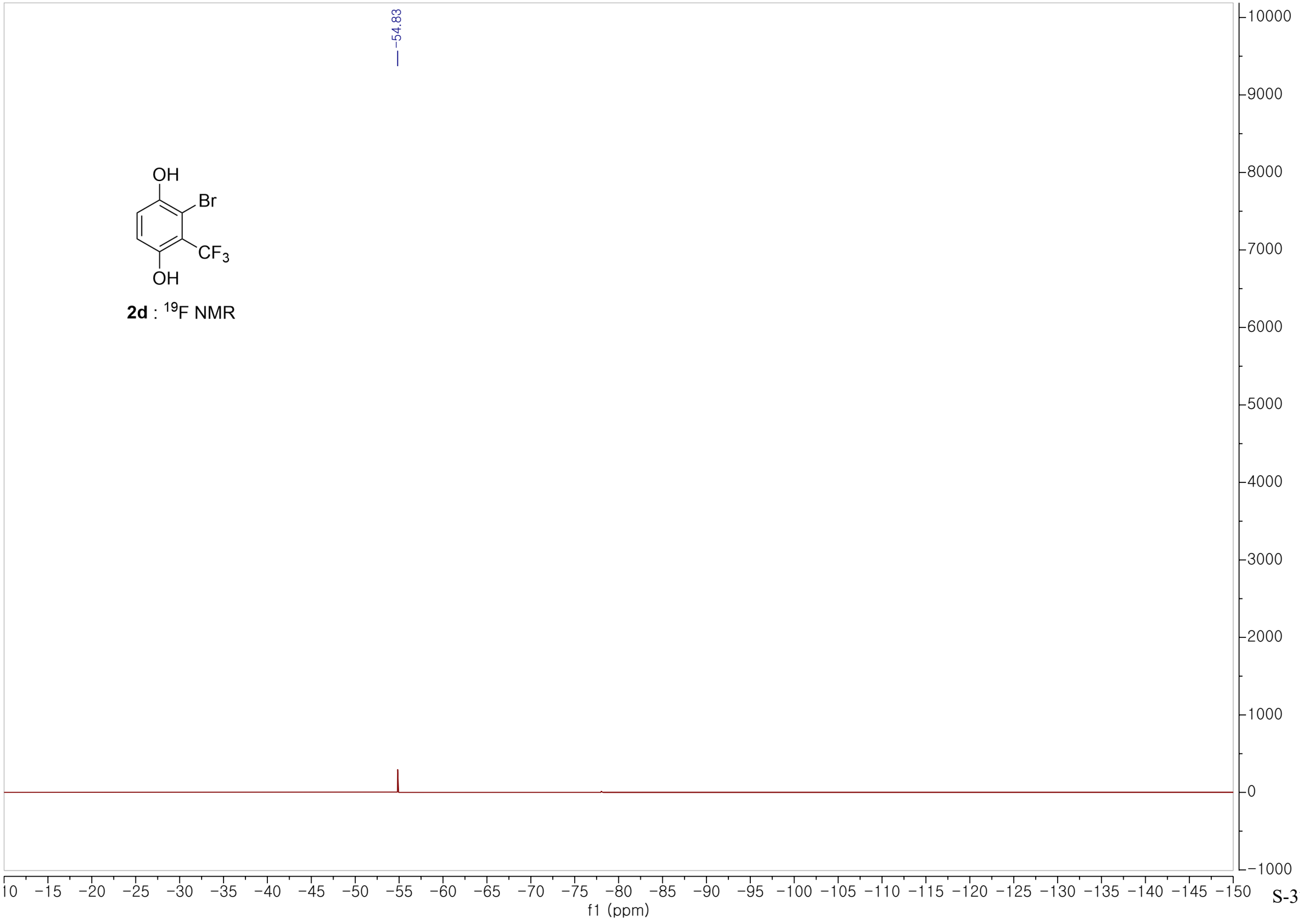

150.01
147.01
126.55
124.73
122.91
121.09
120.78
118.71
117.23
114.52
114.32
114.13
113.93
OH
Cl
CF3
OH
2c : 13C NMR
f1 (ppm)


−50.45
OH
Cl
CF3
OH
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
10 −15 −20 −25 −30 −35 −40 −45 −50 −55 −60 −65 −70 −75 −80 −85 −90 −95 −100 −105 −110 −115 −120 −125 −130 −135 −140 −145 −150
f1 (ppm)

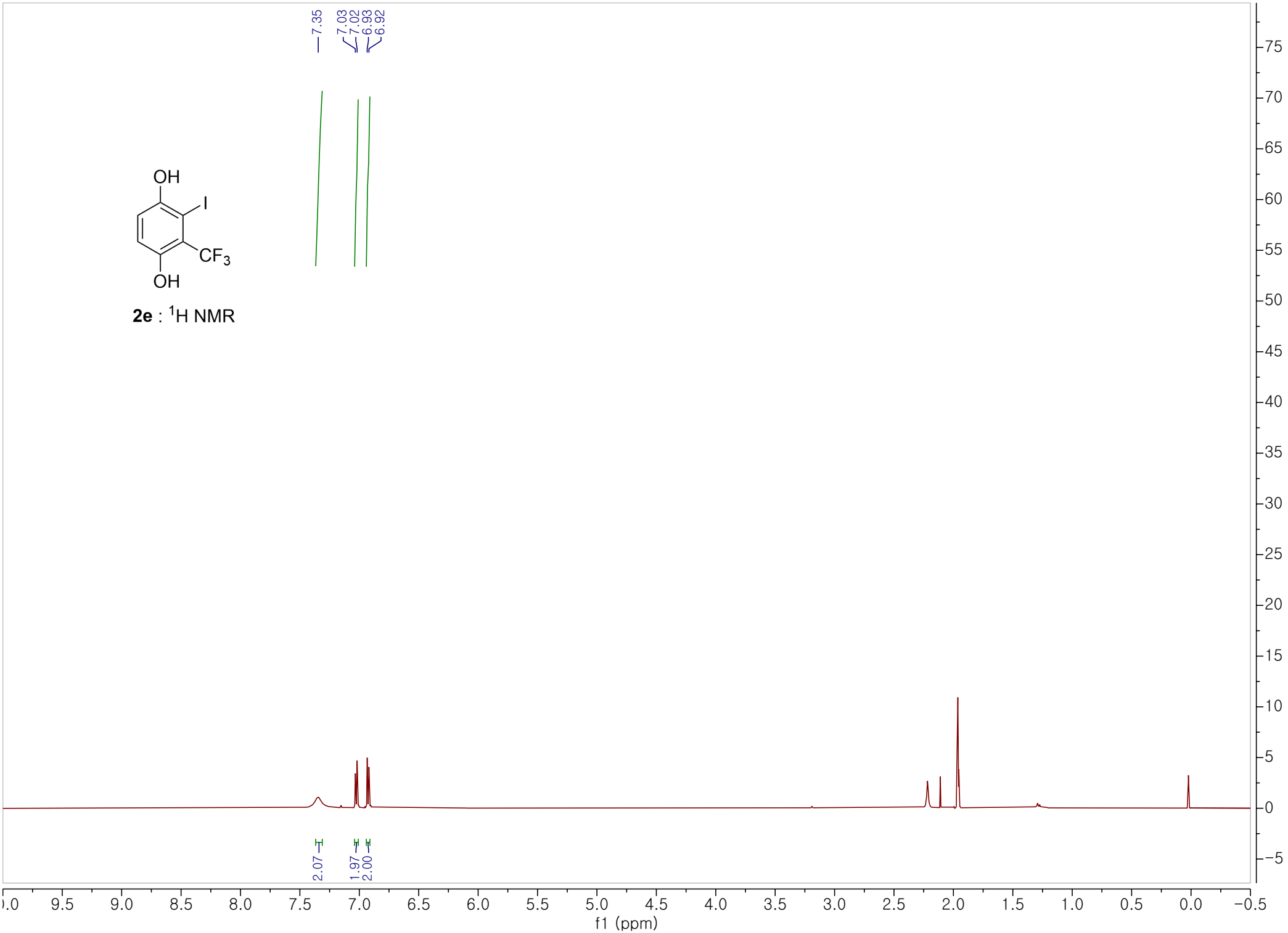
2c : ^{19}F NMR

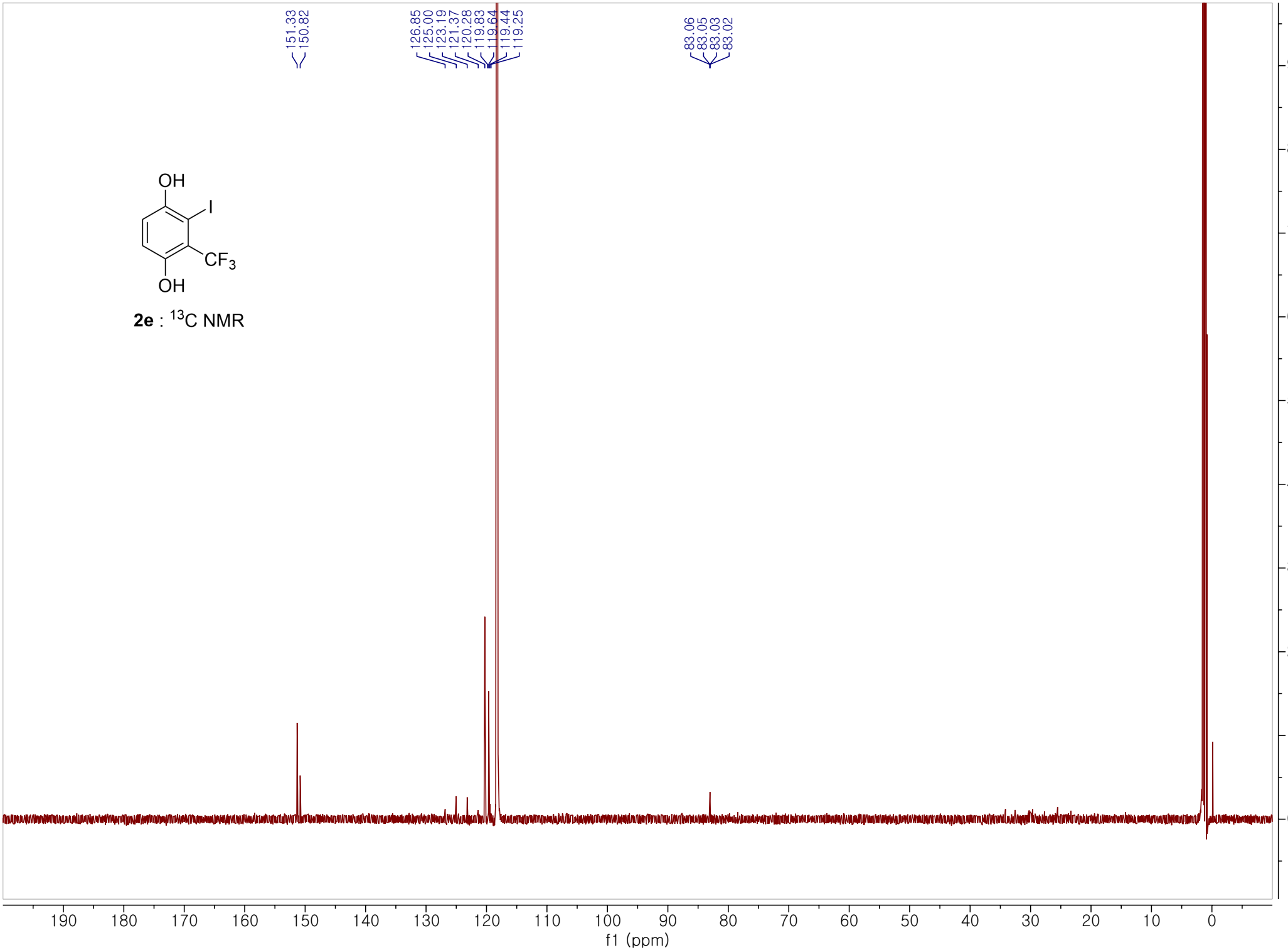

7.40
7.08
7.07
6.92
6.90
OH
Br
CF3
OH
2d : 1H NMR
0.98
0.85
1.00
1.09
f1 (ppm)

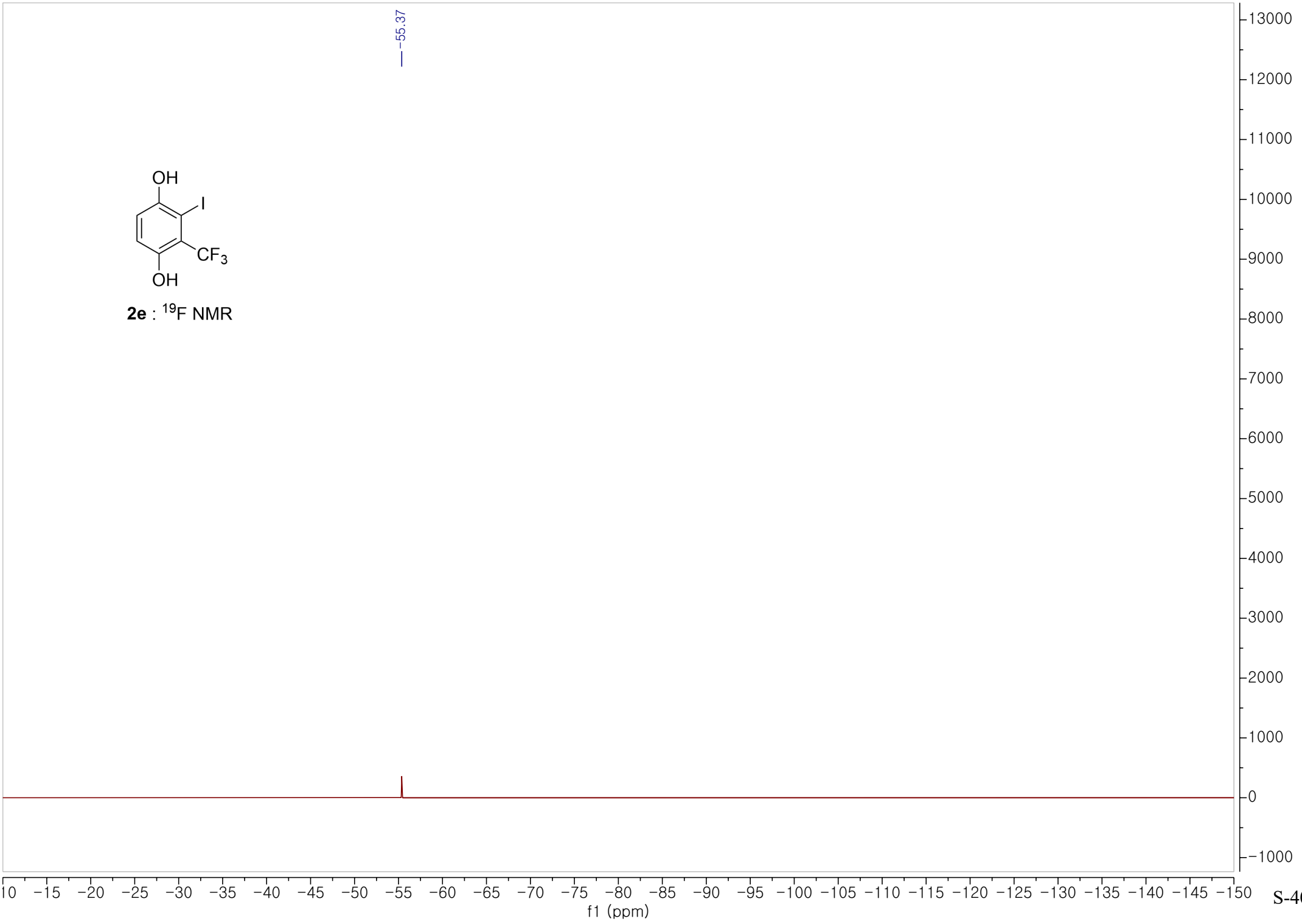

149.90
147.76
131.24
124.59
122.77
120.44
118.31
107.81
107.80
107.78
107.77
OH
Br
CF3
OH
2d : 13C NMR
30
25
20
15
10
5
0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

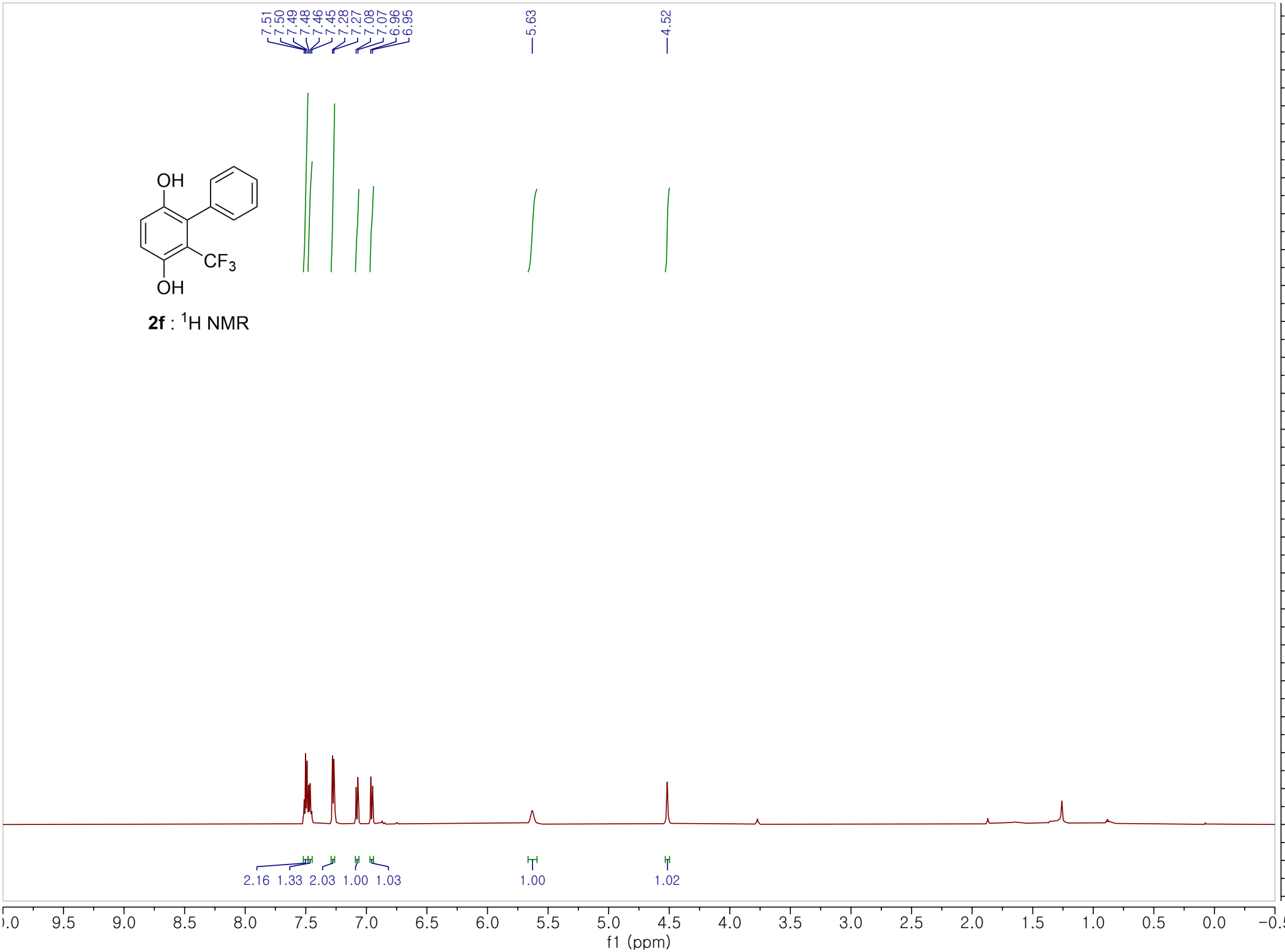

-54.83
OH
Br
CF3
OH
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

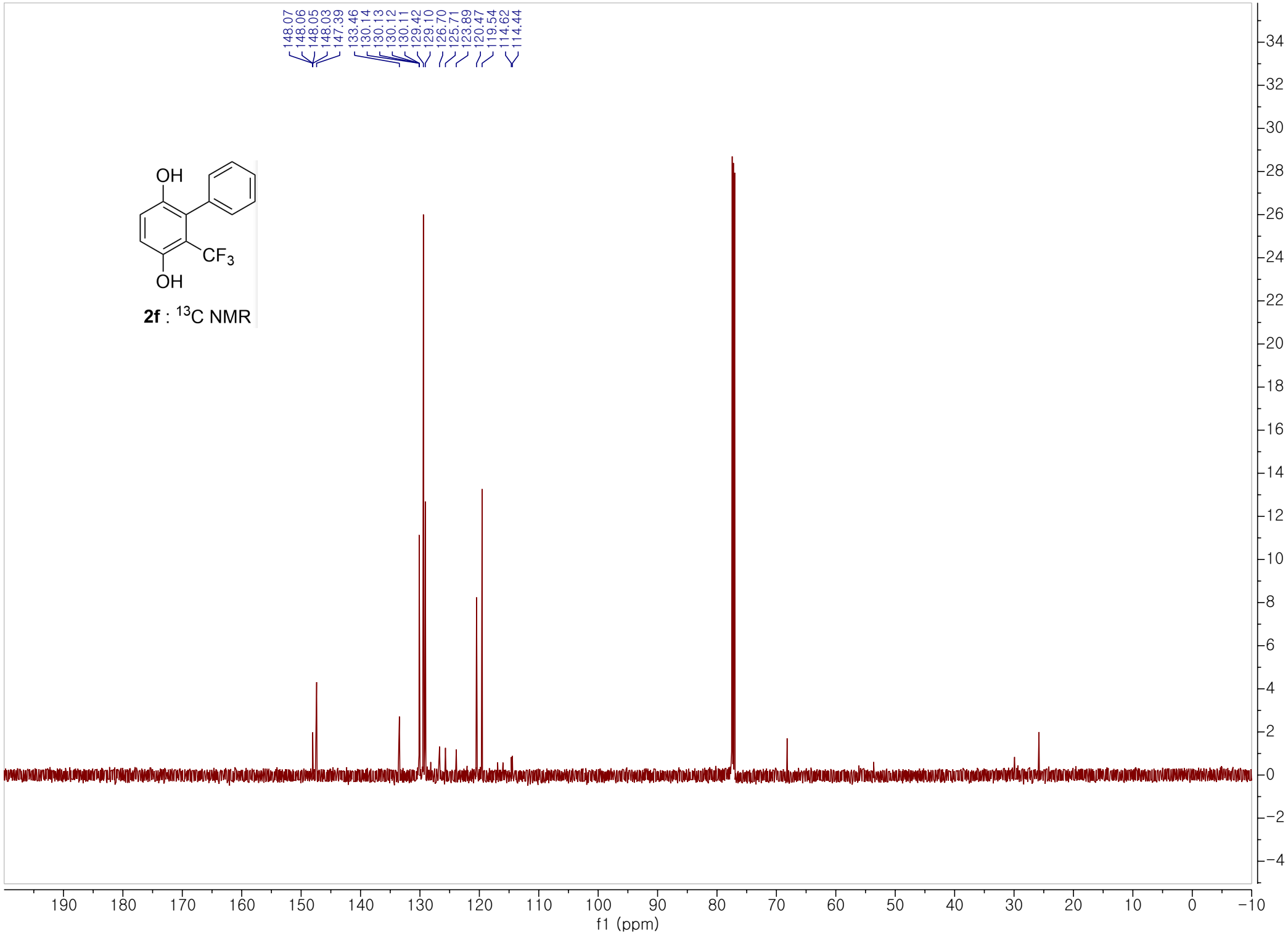
2d : ^{19}F NMR

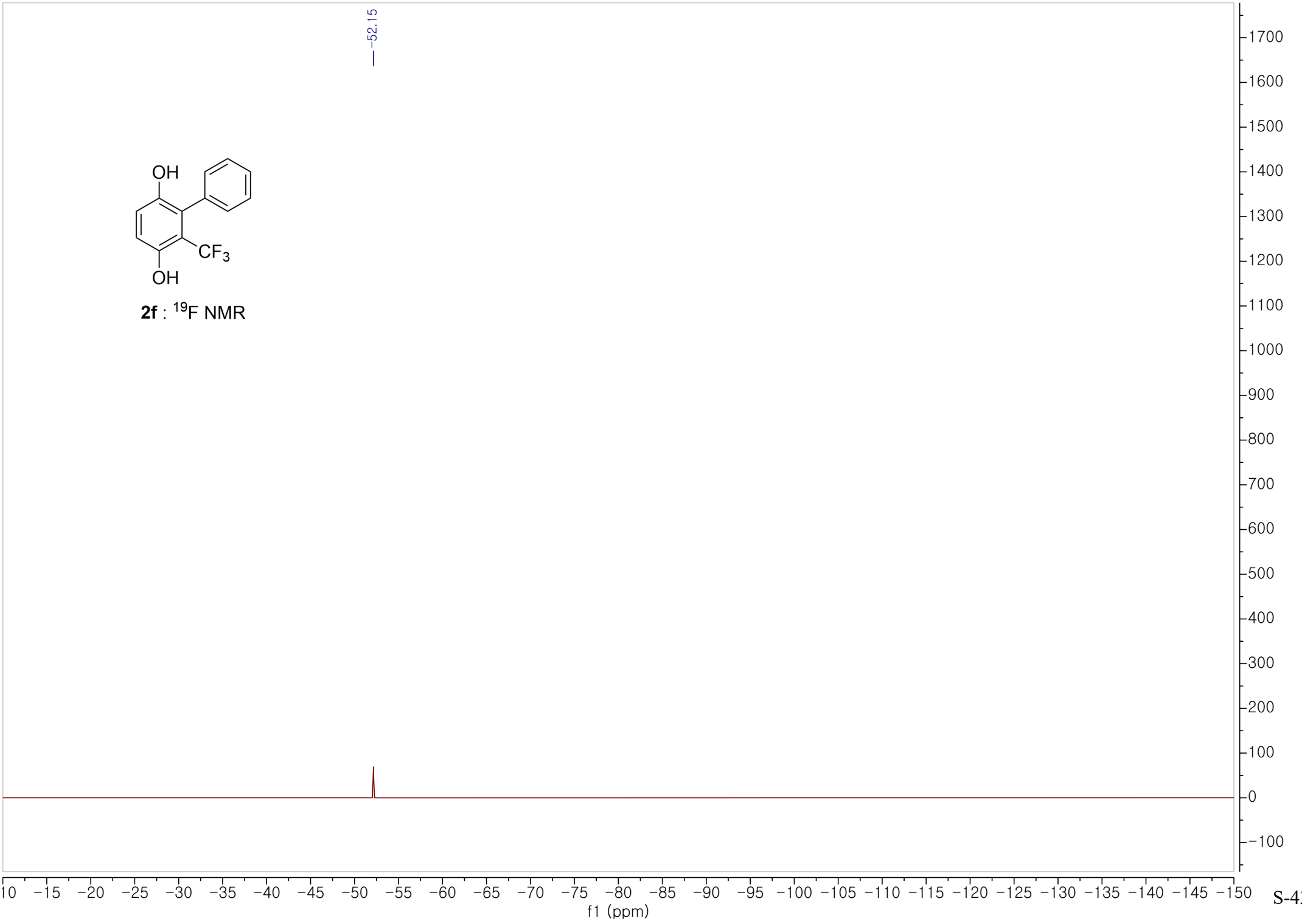

7.35
7.03
7.02
6.93
6.92
OH
I
CF3
OH
2e : 1H NMR
2.07
1.97
2.00
f1 (ppm)

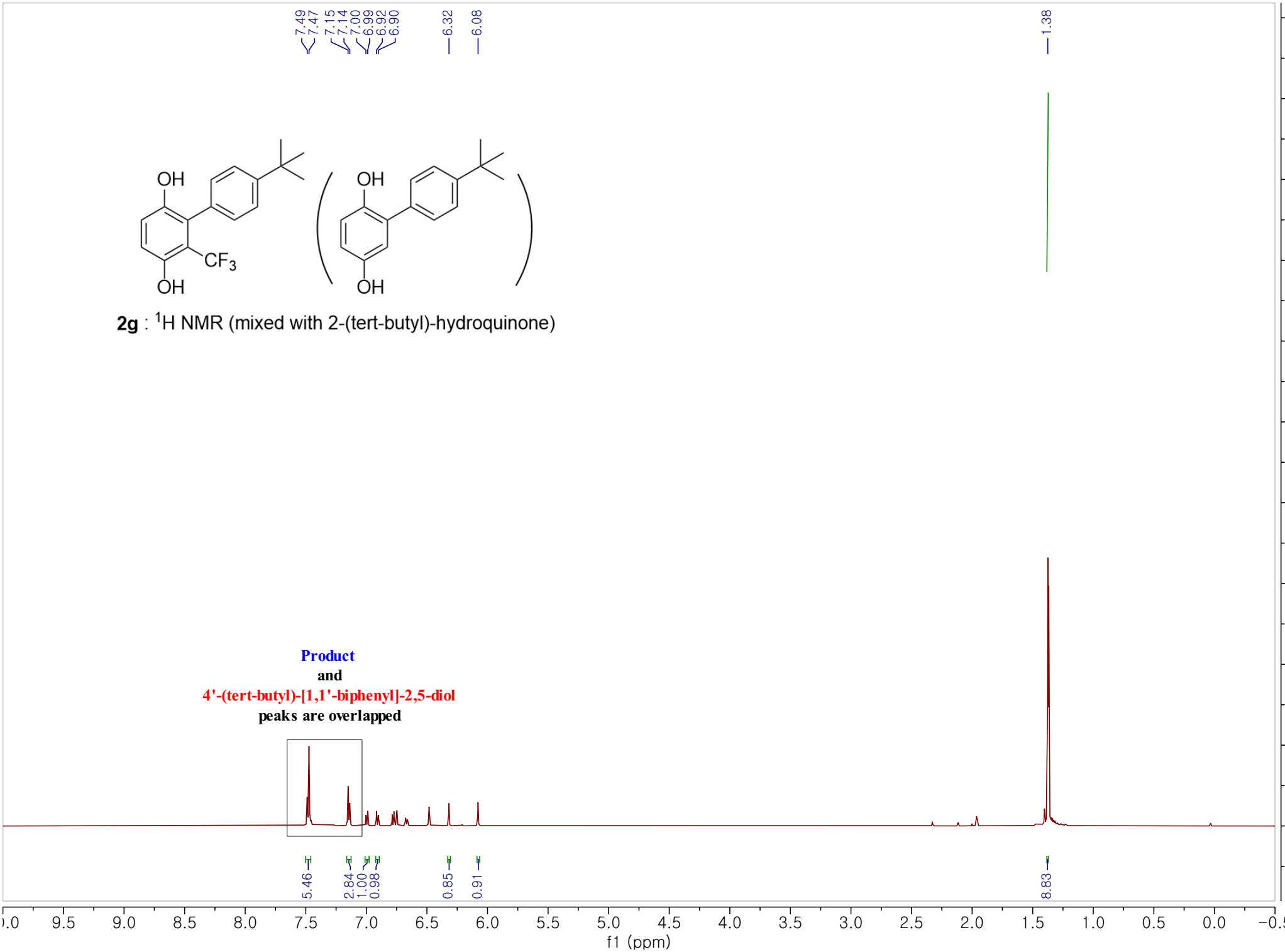

151.33
150.82
126.85
125.00
123.19
121.37
120.28
119.83
119.64
119.44
119.25
83.06
83.05
83.03
83.02
OH
I
CF3
OH
2e : 13C NMR
f1 (ppm)

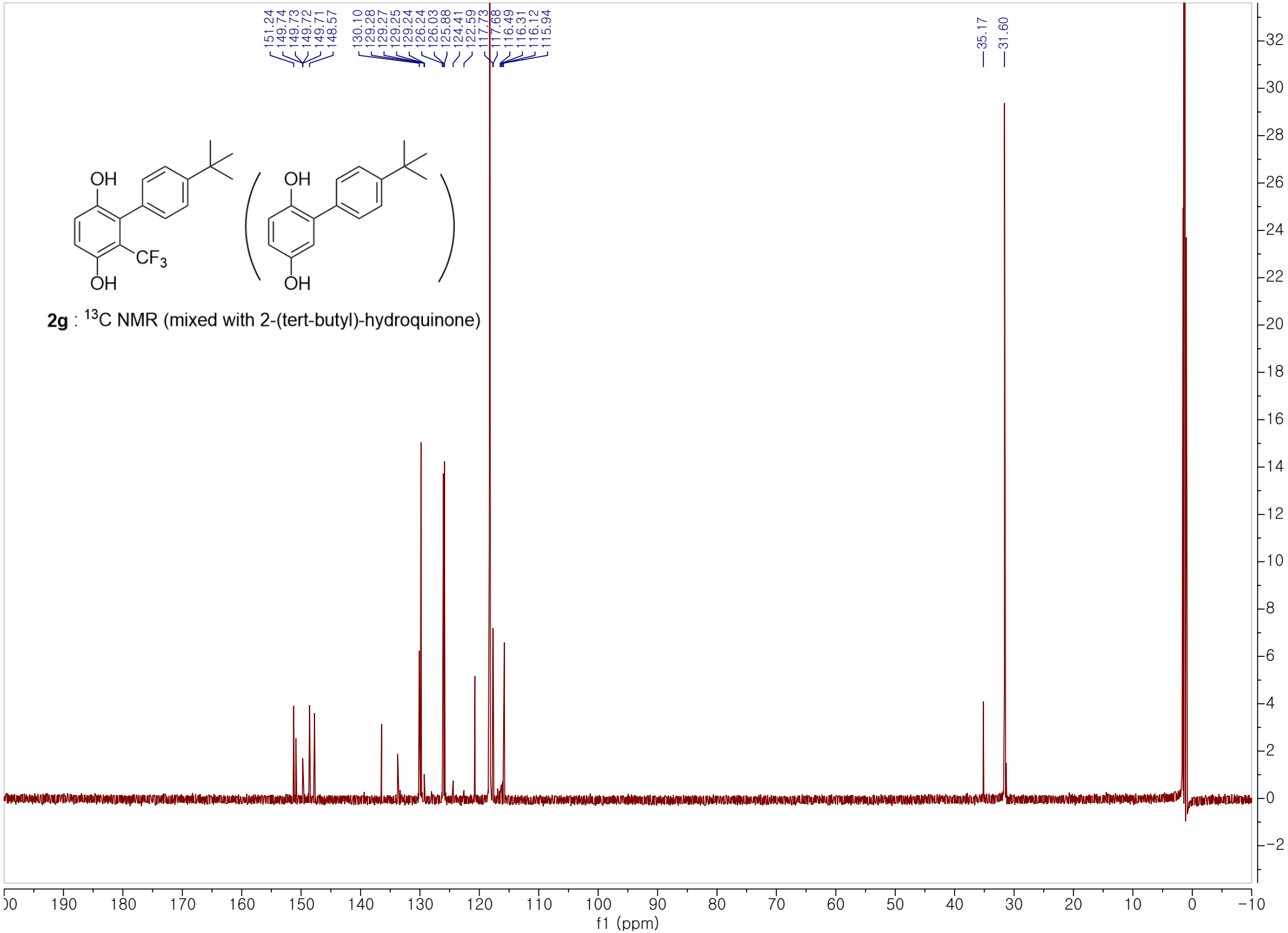

-55.37
OH
I
CF3
OH
2e : 19F NMR
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)


7.51
7.50
7.49
7.48
7.46
7.45
7.28
7.27
7.08
7.07
6.96
6.95
5.63
4.52
OH
CF3
OH
2f : 1H NMR
2.16 1.33 2.03 1.00 1.03
1.00
1.02
f1 (ppm)

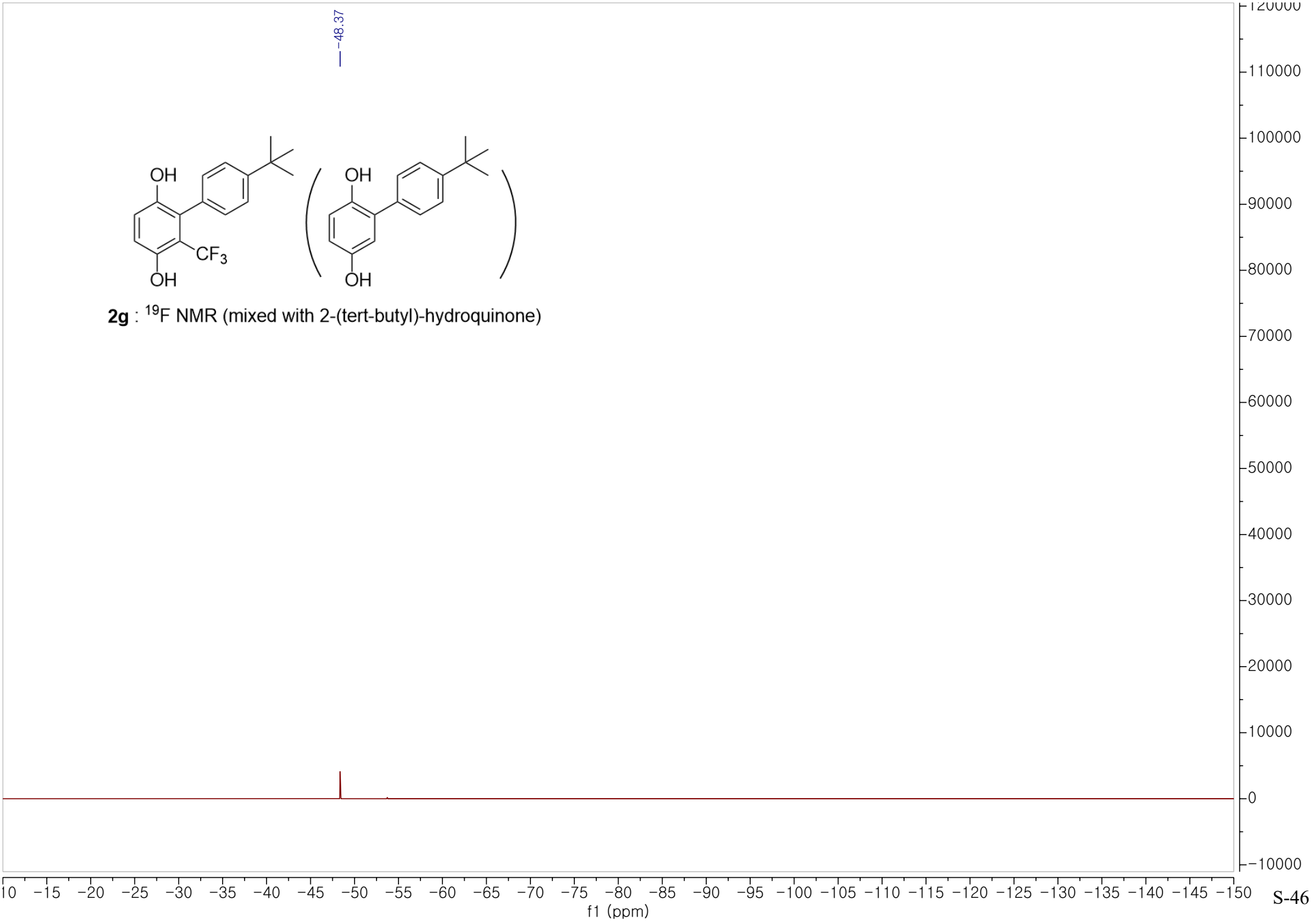

148.07
148.06
148.05
148.03
147.39
133.46
130.14
130.13
130.12
130.11
129.42
129.10
126.70
125.71
123.89
120.47
119.54
114.62
114.44
OH
CF3
OH
2f : 13C NMR
f1 (ppm)


-52.15
OH
CF3
OH
2f : 19F NMR
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

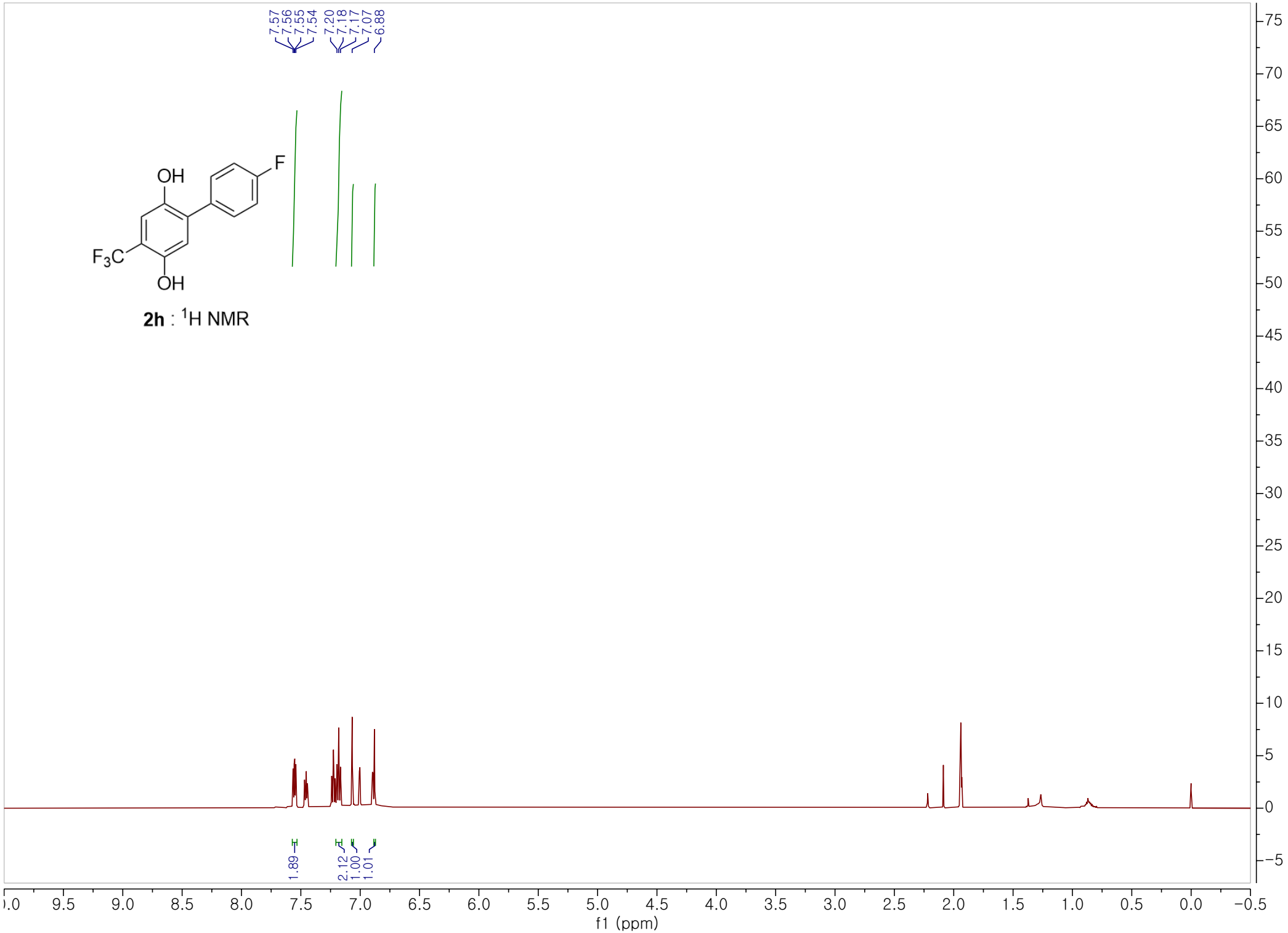

7.49
7.47
7.15
7.14
7.00
6.99
6.92
6.90
6.32
6.08
1.38
OH
CF3
OH
OH
OH
2g : 1H NMR (mixed with 2-(tert-butyl)-hydroquinone)
Product
and
4'-(tert-butyl)-[1,1'-biphenyl]-2,5-diol
peaks are overlapped
5.46
2.84
1.00
0.98
0.85
0.91
8.83
f1 (ppm)

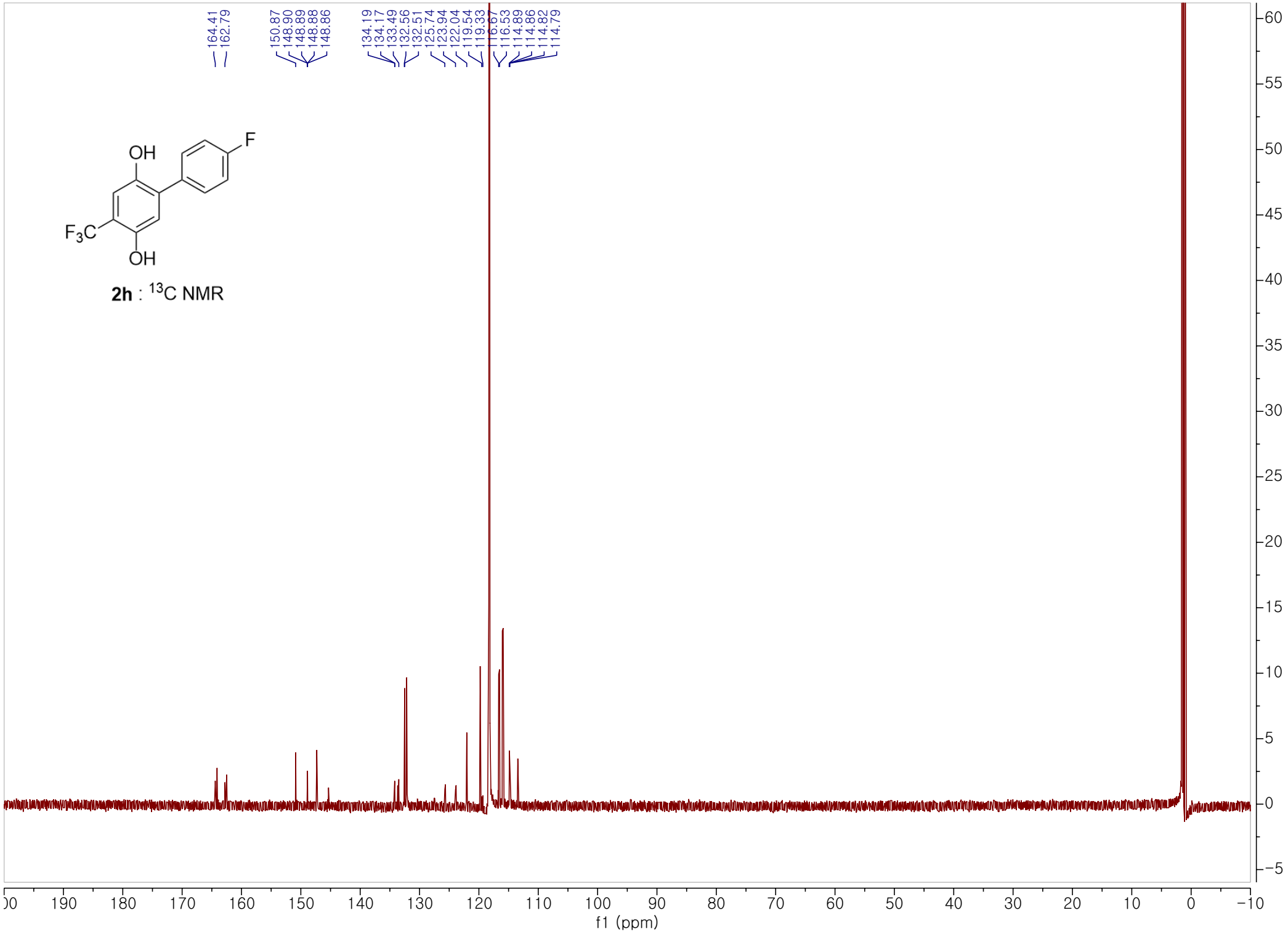


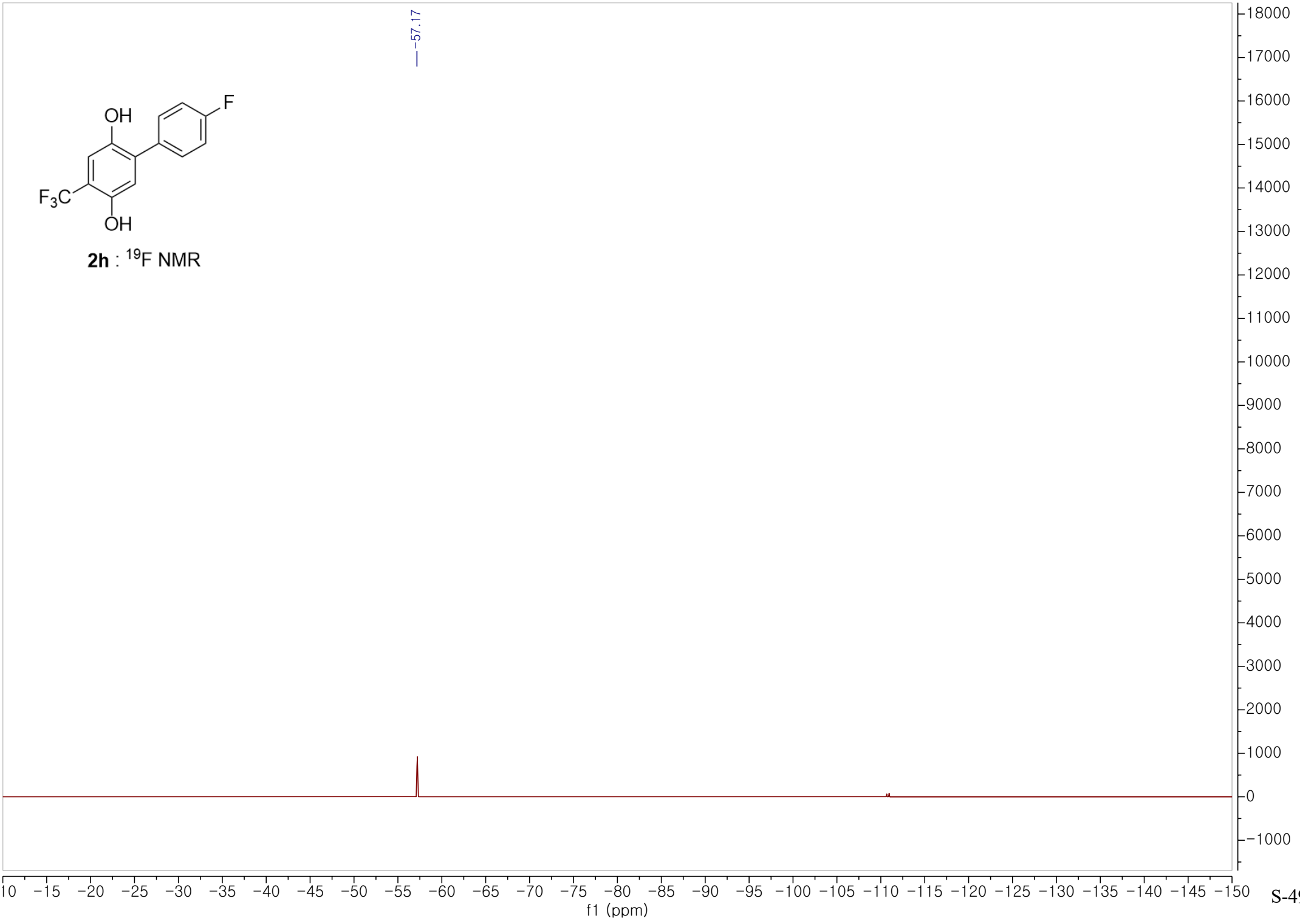
2g : ^{13}C NMR (mixed with 2-(tert-butyl)-hydroquinone)

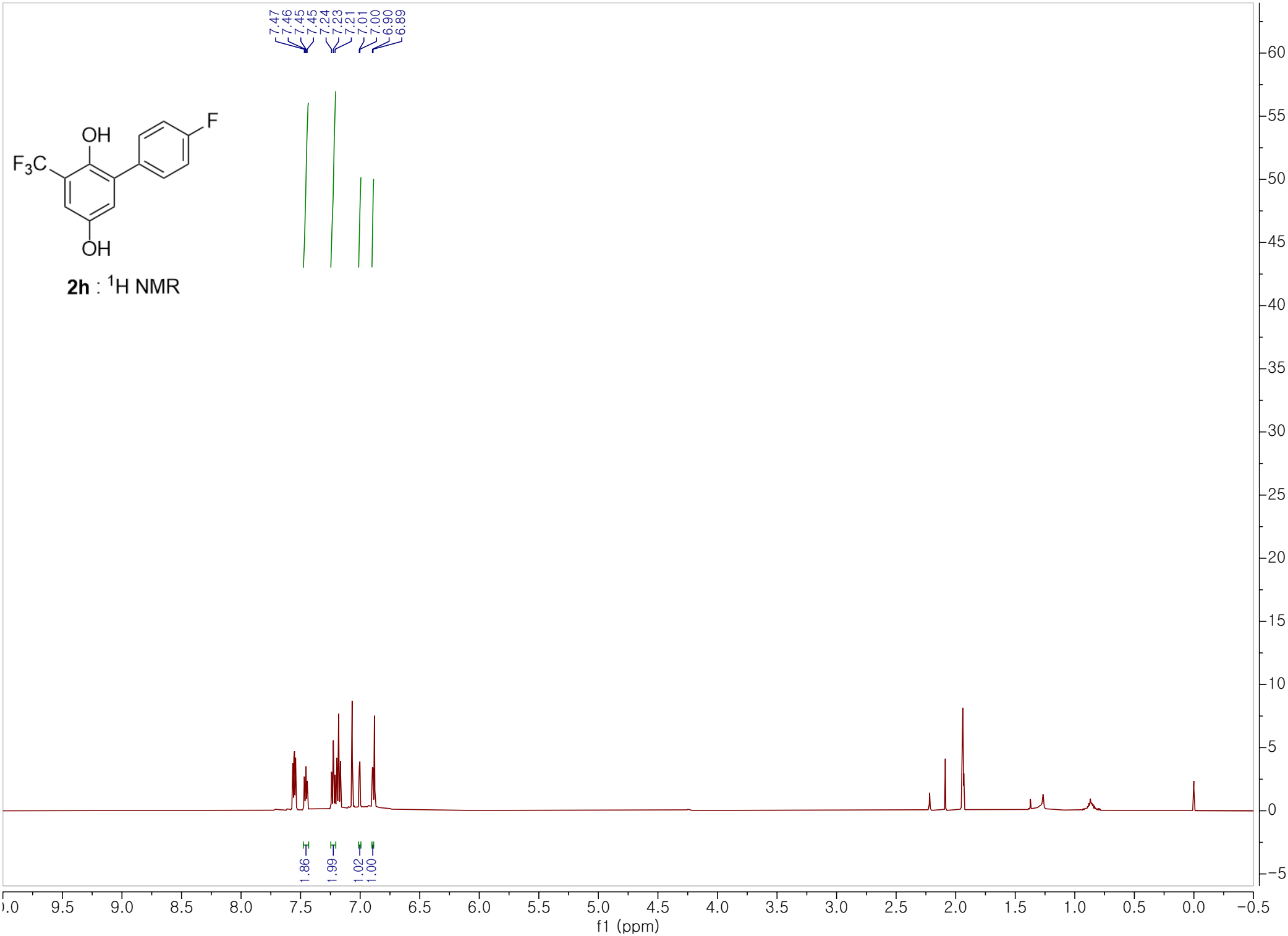


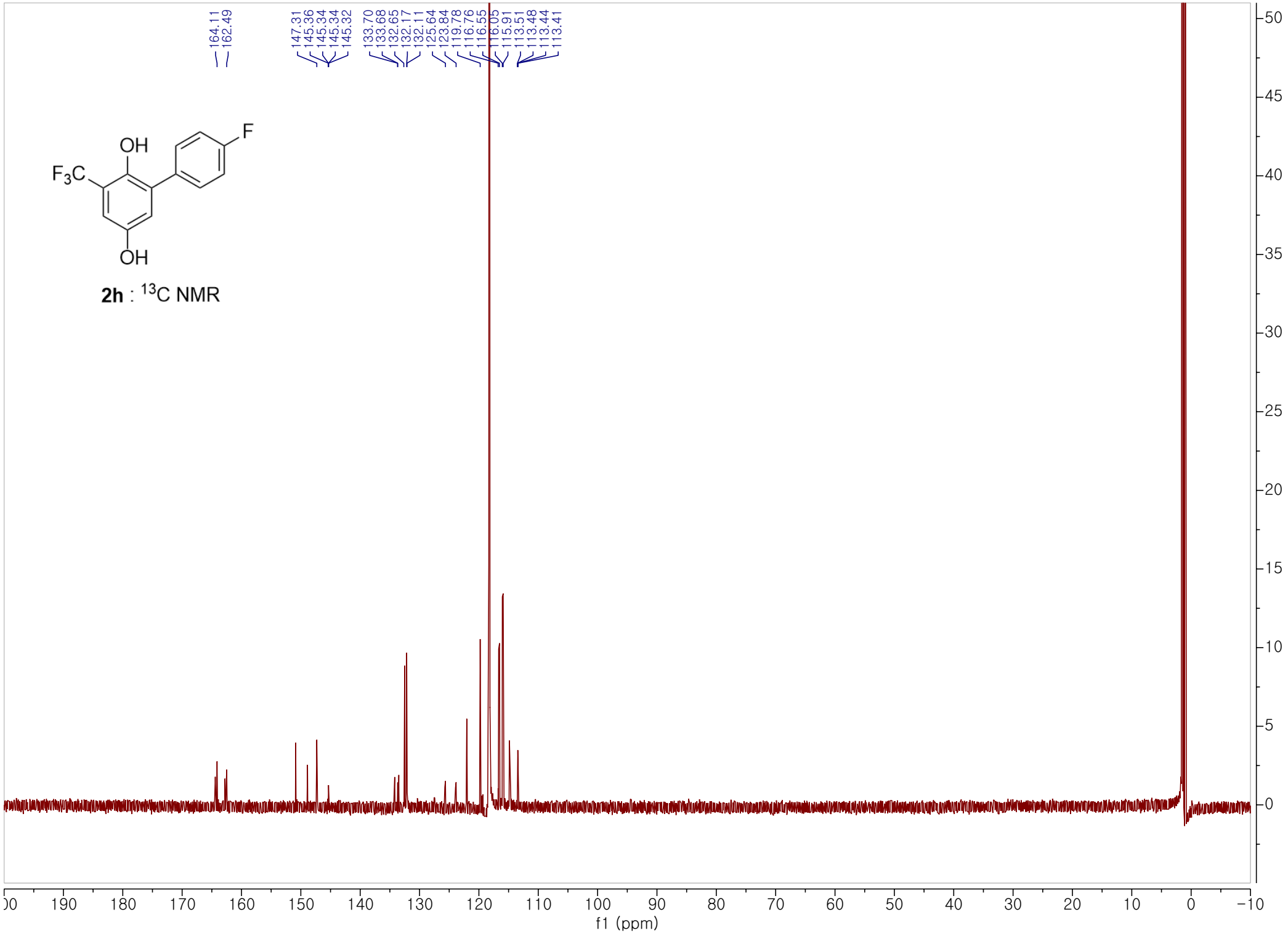
2g : ^{19}F NMR (mixed with 2-(tert-butyl)-hydroquinone)

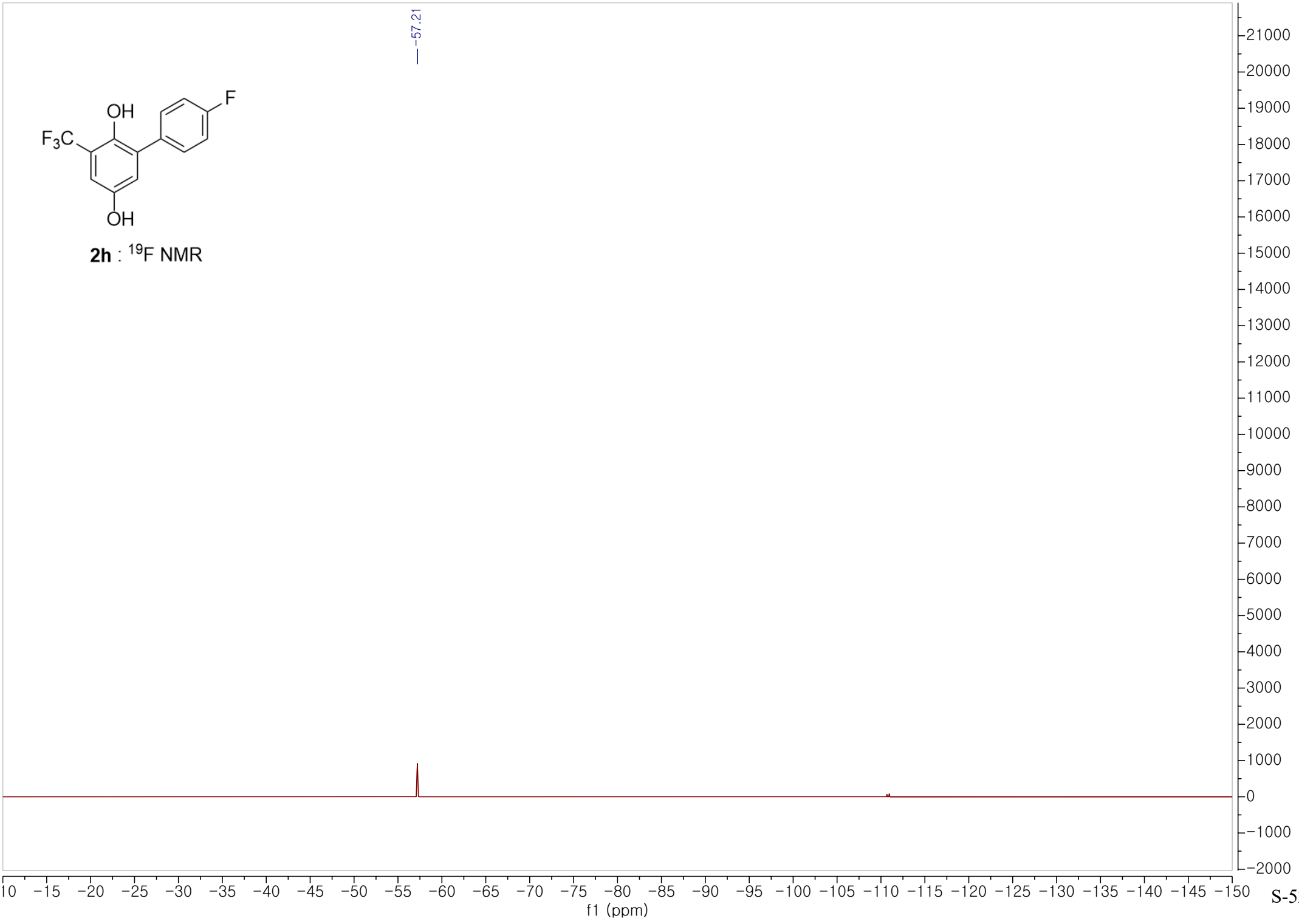

7.57
7.56
7.55
7.54
7.20
7.18
7.17
7.07
6.88
OH
F
F3C
OH
2h : 1H NMR
1.89
2.12
1.00
1.01
f1 (ppm)

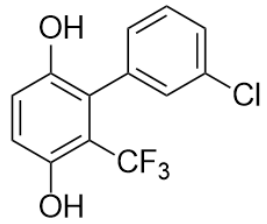

164.41
162.79
150.87
148.90
148.89
148.88
148.86
134.19
134.17
133.49
132.56
132.51
125.74
123.94
122.04
119.54
119.33
116.67
116.53
114.89
114.86
114.82
114.79
OH
F
F3C
OH
2h : 13C NMR
f1 (ppm)


OH
F
F3C
OH
2h : 19F NMR
-57.17
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

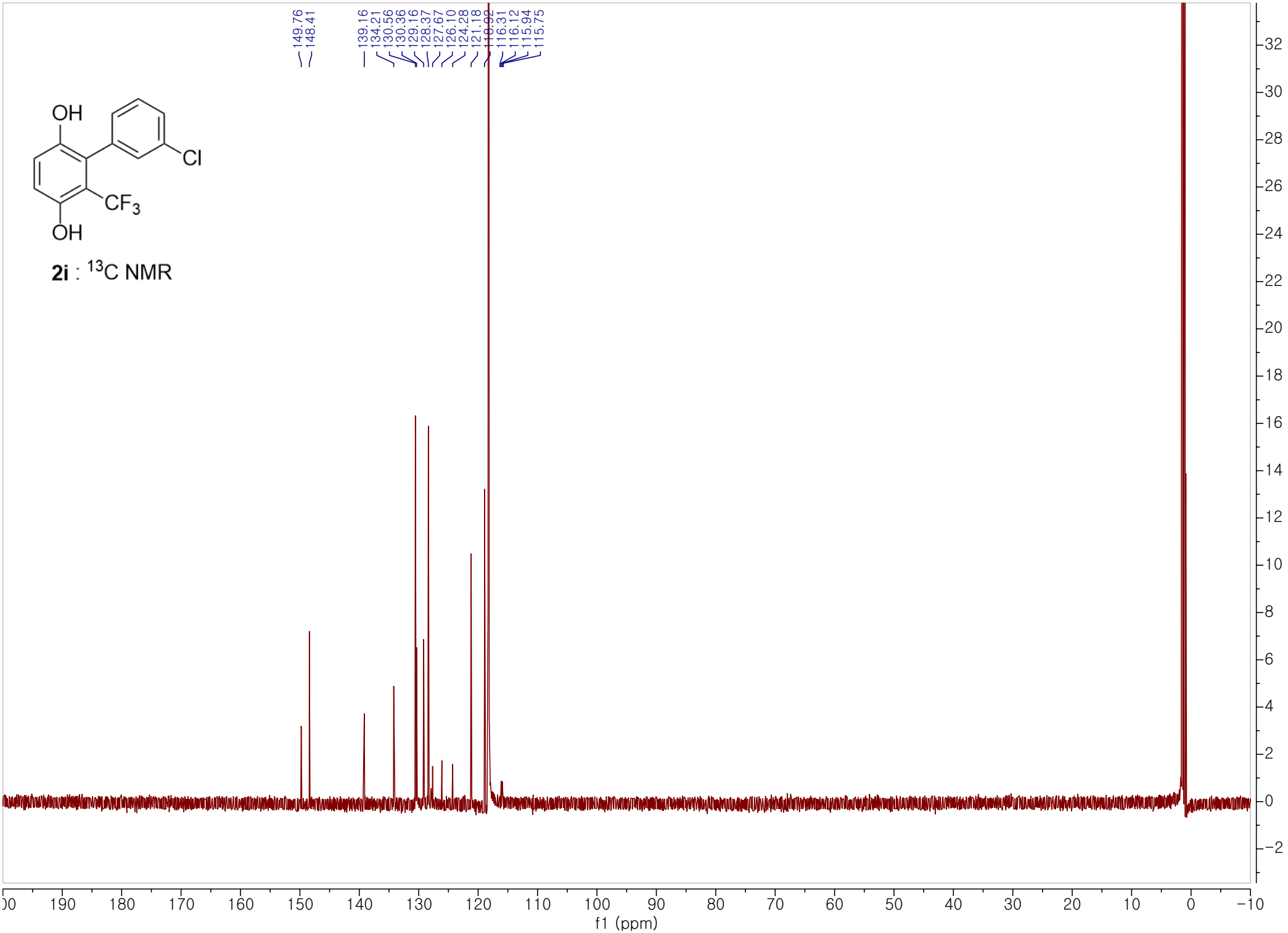

7.47
7.46
7.45
7.45
7.24
7.23
7.21
7.01
7.00
6.90
6.89
OH
F
F3C
OH
2h : 1H NMR
1.86
1.99
1.02
1.00
f1 (ppm)

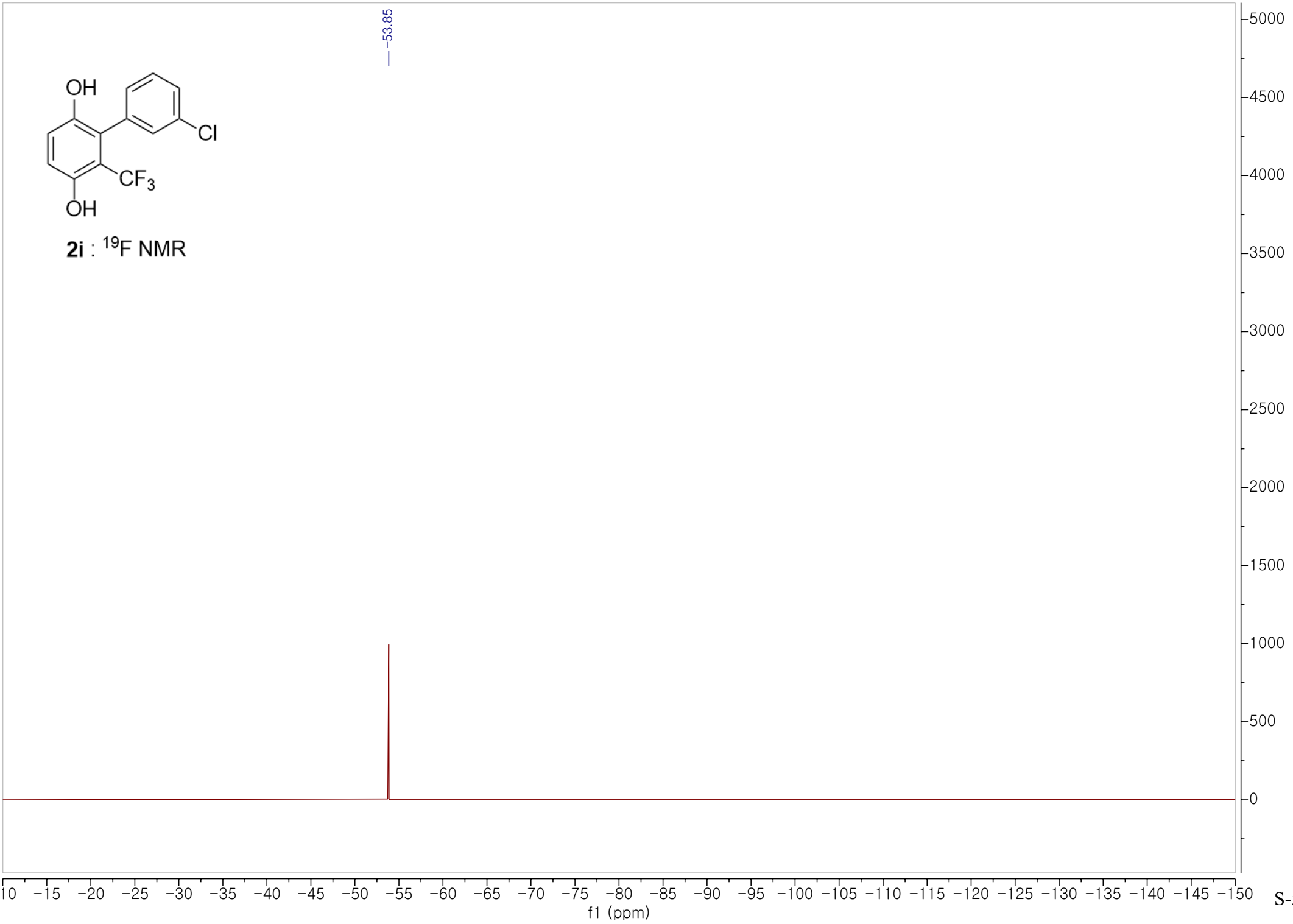

164.11
162.49
147.31
145.36
145.34
145.34
145.32
133.70
133.68
132.65
132.17
132.11
125.64
123.84
119.78
116.76
116.55
116.05
115.91
113.51
113.48
113.44
113.41
OH
F
F3C
OH
2h : 13C NMR
50
45
40
35
30
25
20
15
10
5
0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

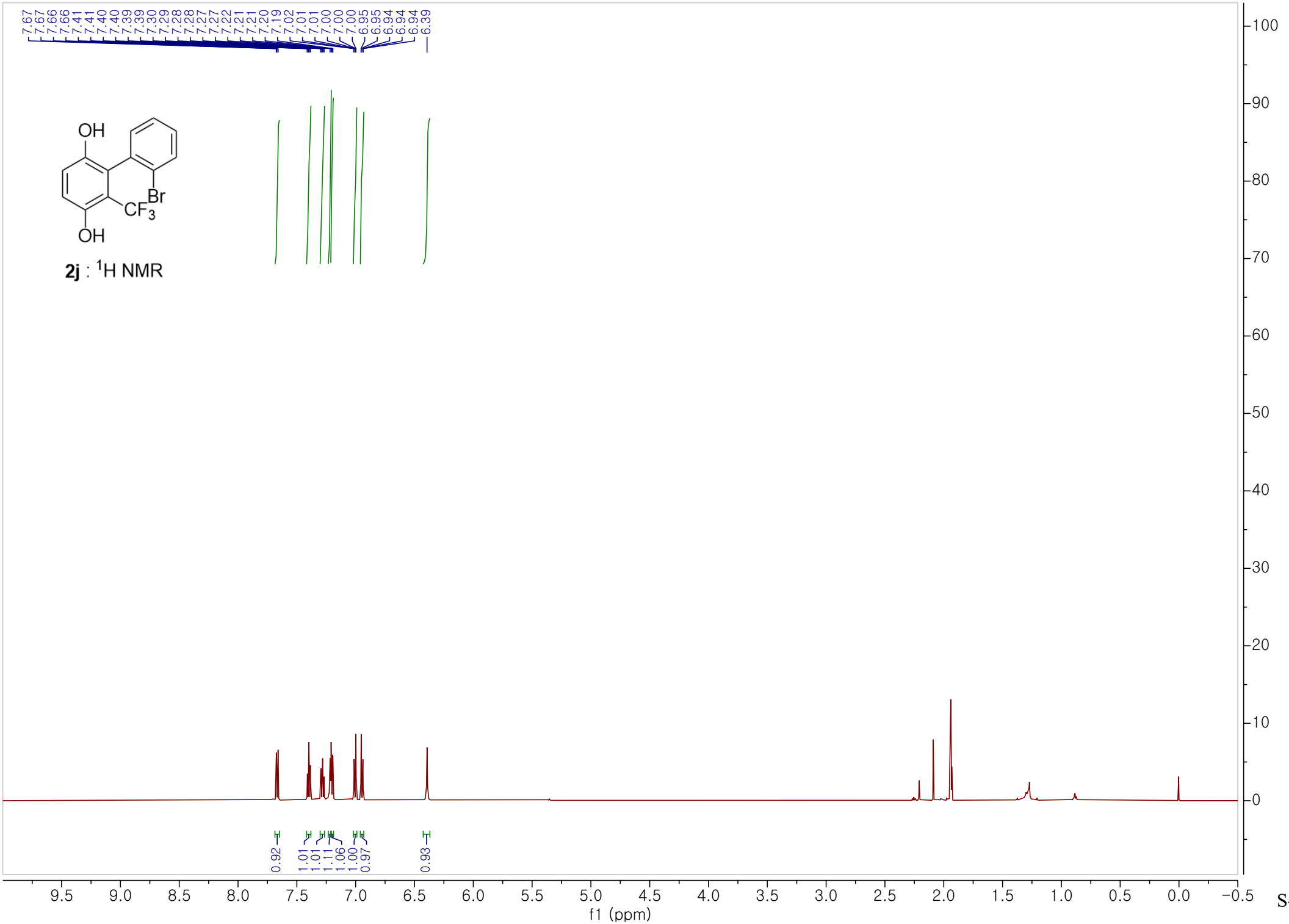

-57.21
OH
F
F3C
OH
2h : 19F NMR
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

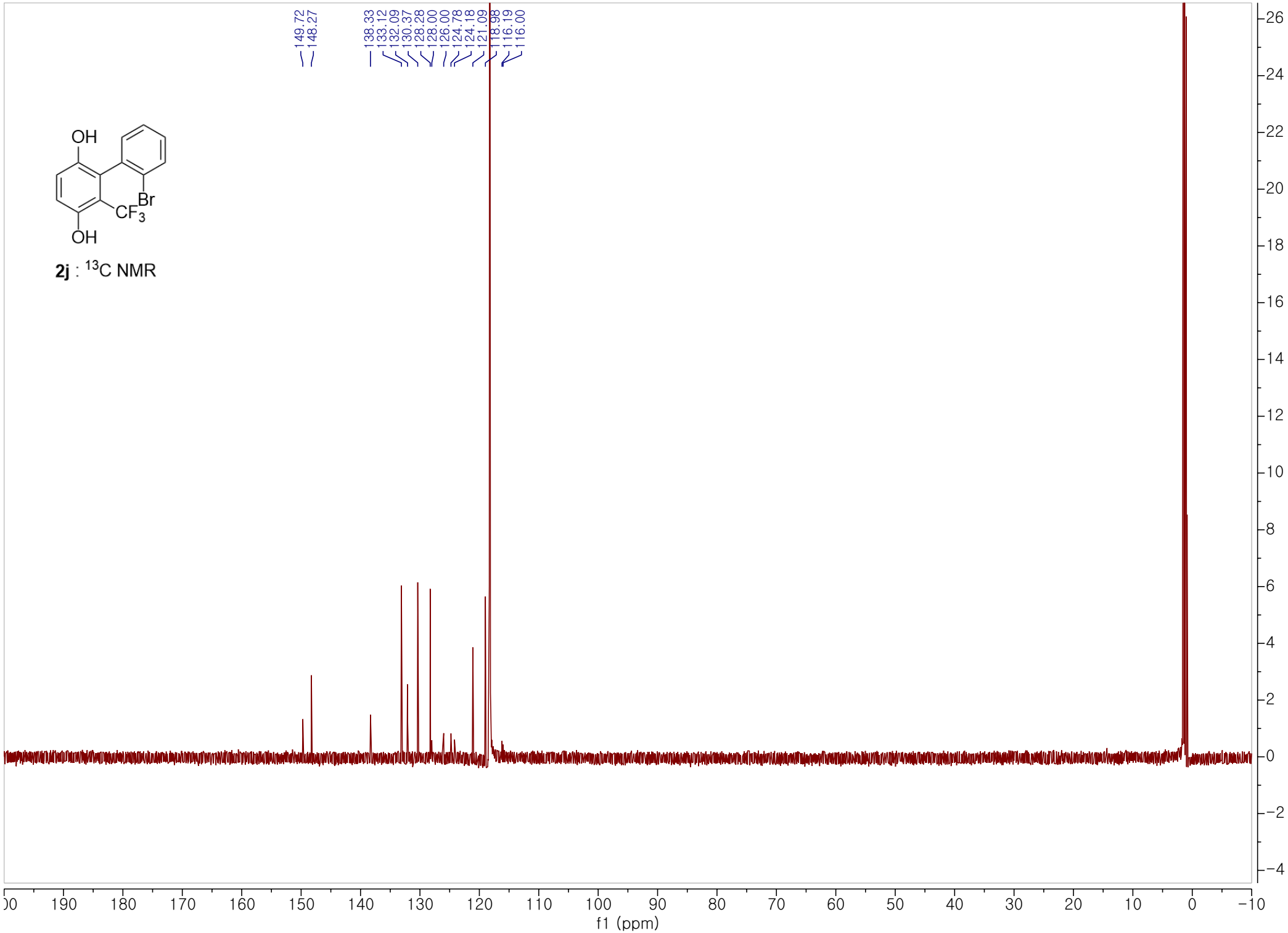


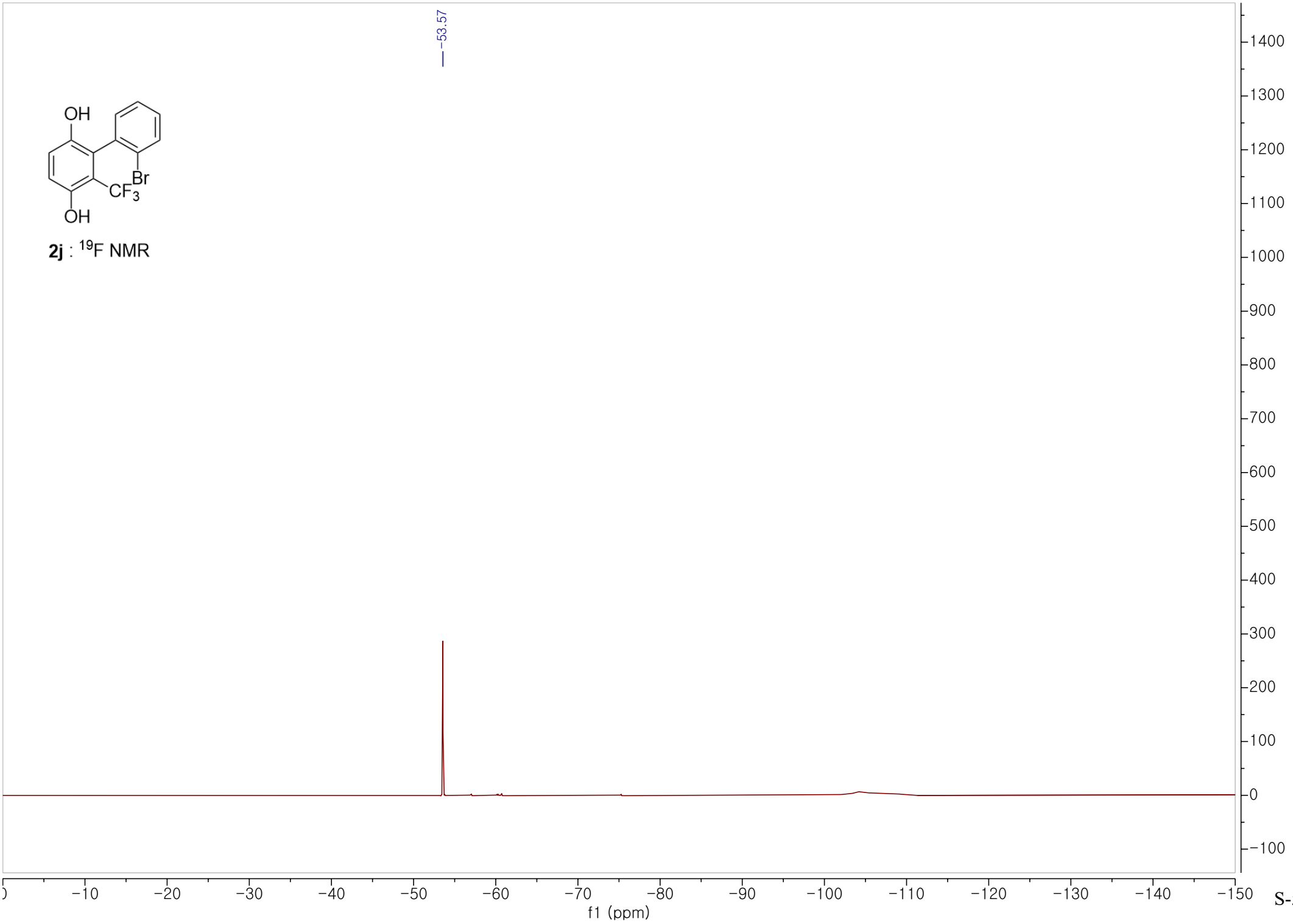
2i : ^{1}H NMR

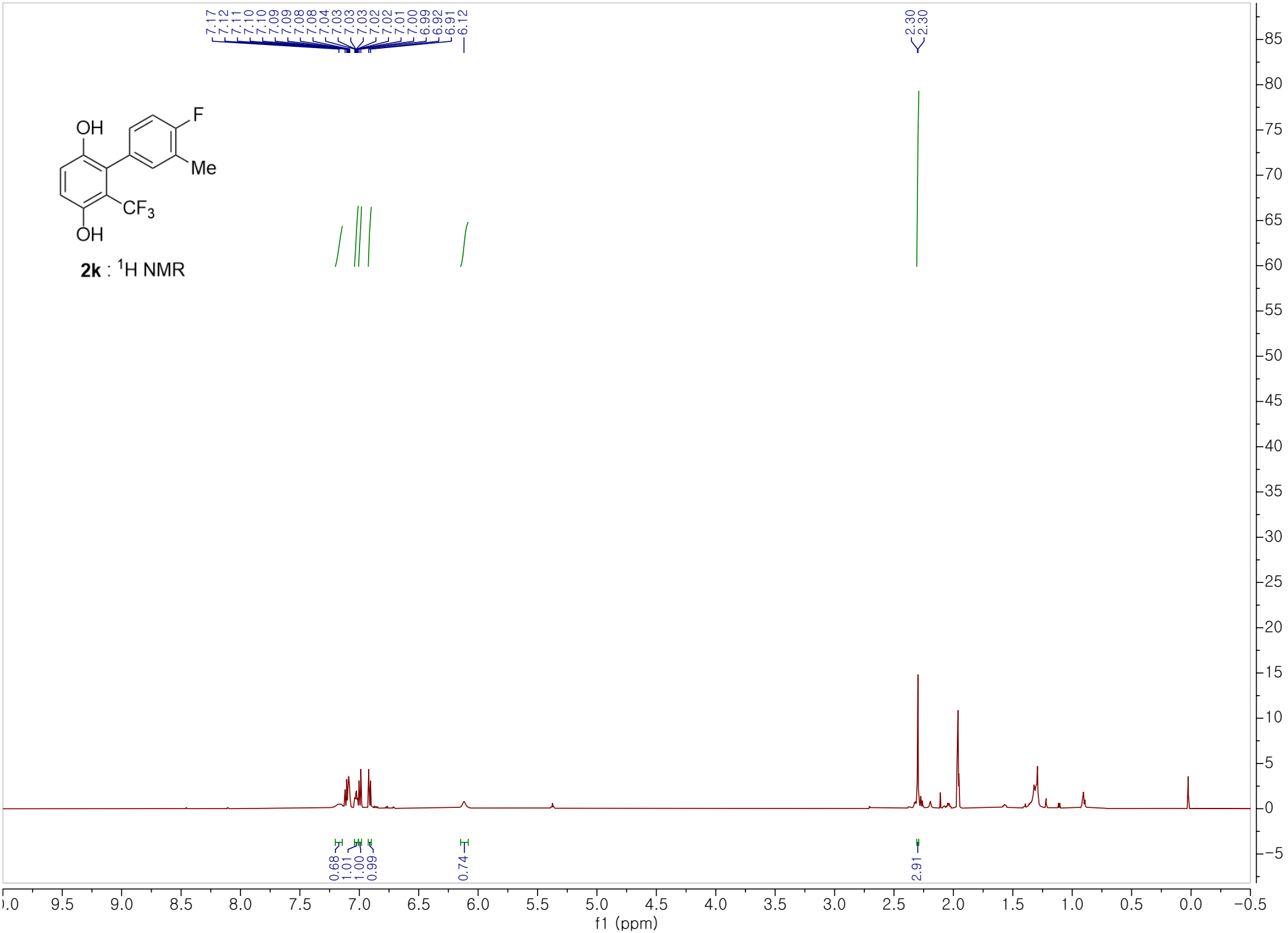

149.76
148.41
139.16
134.21
130.56
130.36
129.16
128.37
127.67
126.10
124.28
121.18
116.31
116.12
115.94
115.75
OH
Cl
CF3
OH
2i : 13C NMR
f1 (ppm)

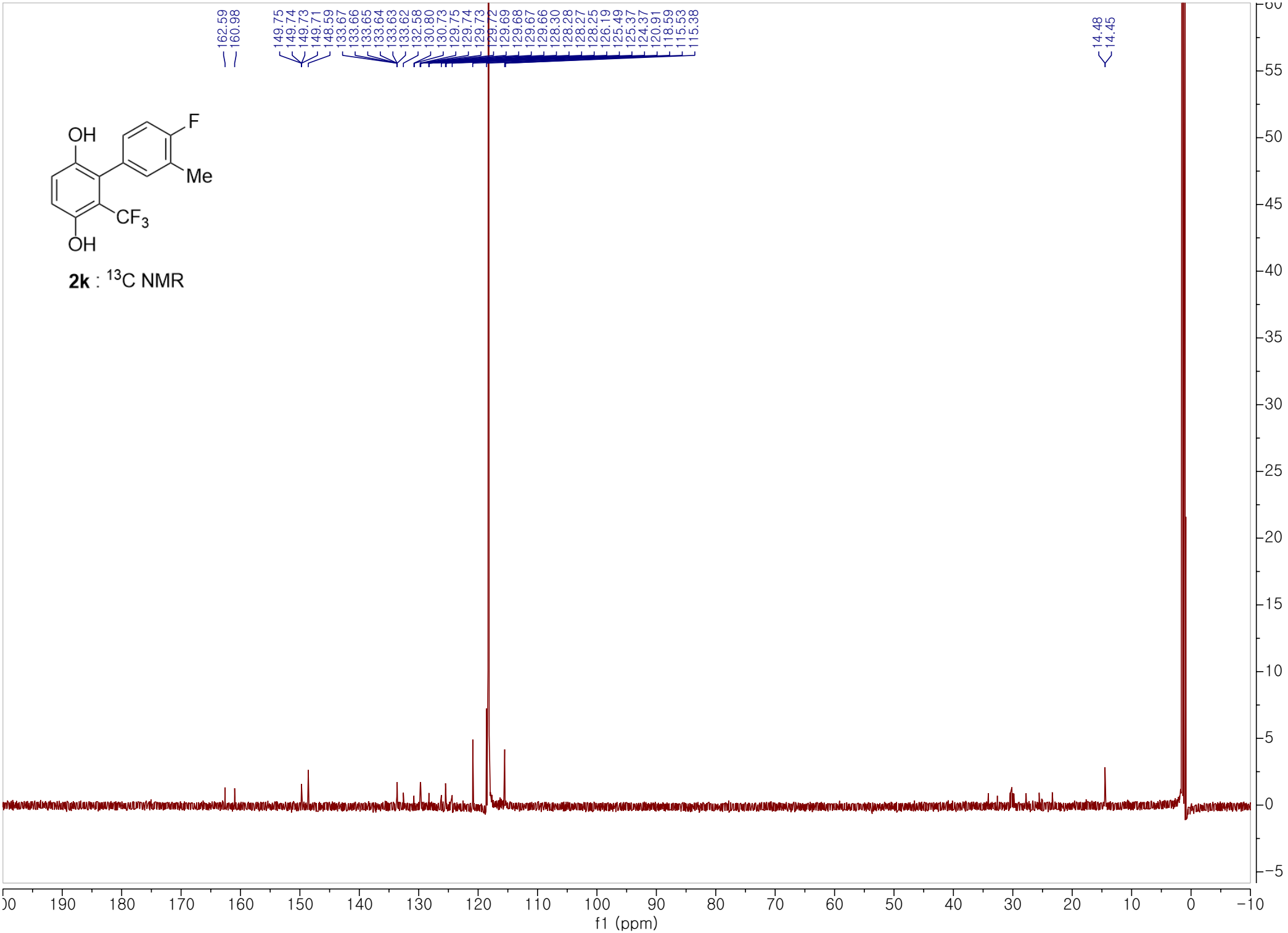

OH
Cl
CF3
OH
2i : 19F NMR
-53.85
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

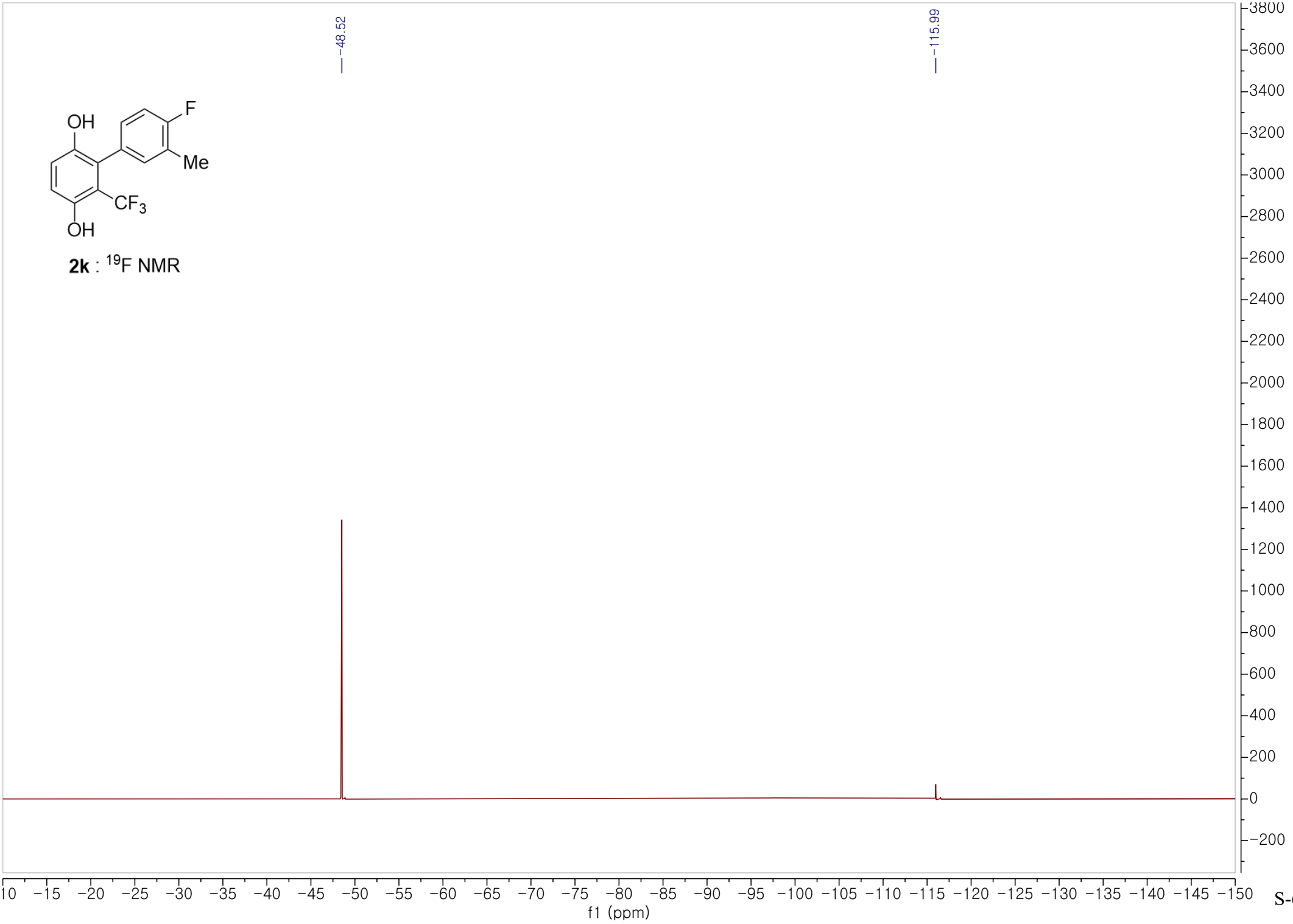

7.67
7.67
7.66
7.66
7.41
7.41
7.40
7.40
7.39
7.39
7.30
7.29
7.28
7.28
7.27
7.27
7.22
7.21
7.21
7.20
7.19
7.02
7.01
7.01
7.00
7.00
7.00
6.95
6.94
6.94
6.94
6.39
OH
Br
CF3
OH
2j : 1H NMR
0.92
1.01
1.01
1.11
1.06
1.00
0.97
0.93
f1 (ppm)

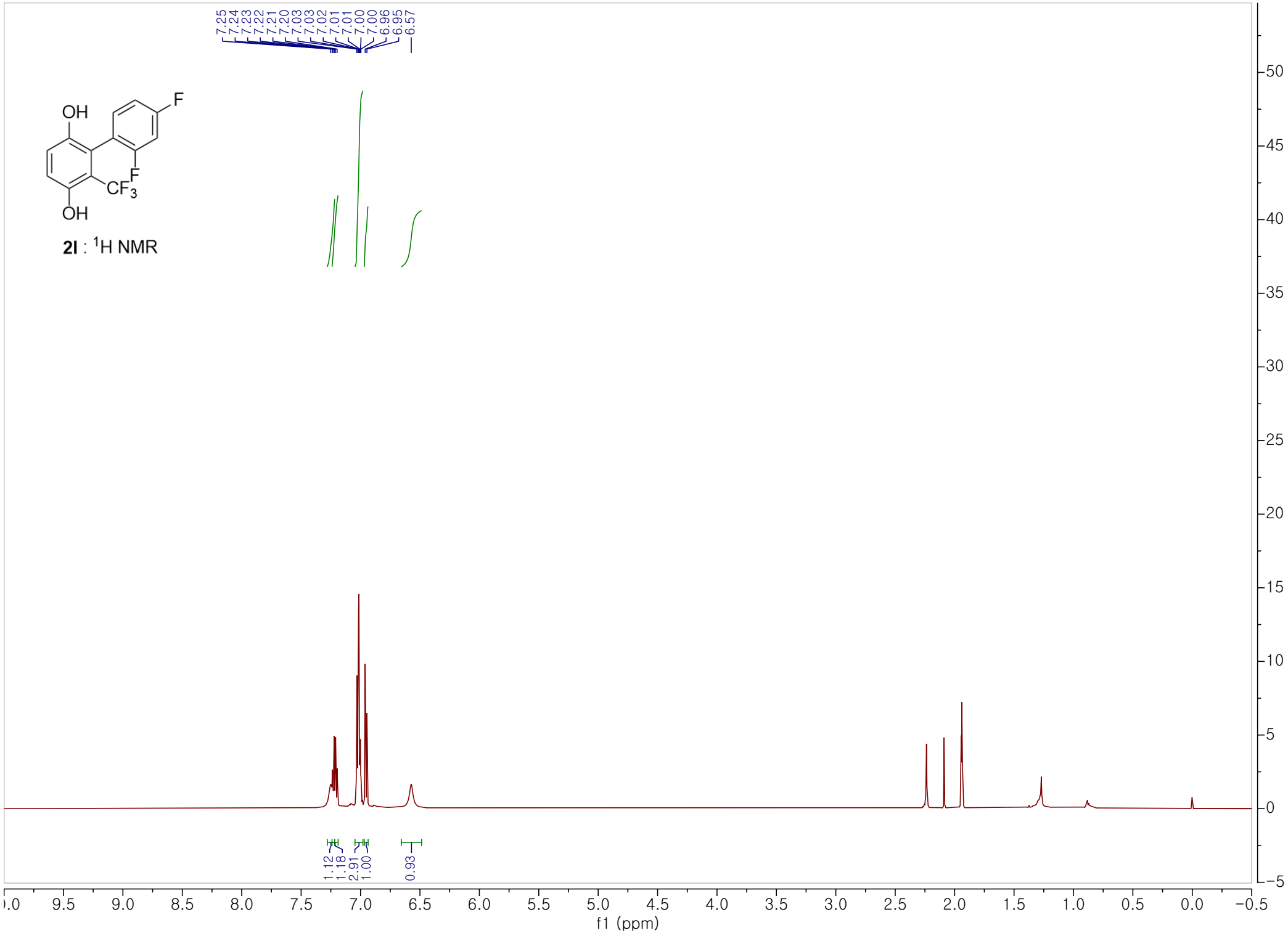

149.72
148.27
138.33
133.12
132.09
130.37
128.28
128.00
126.00
124.78
124.18
121.09
118.98
116.19
116.00
OH
Br
CF3
OH
2j : 13C NMR
f1 (ppm)

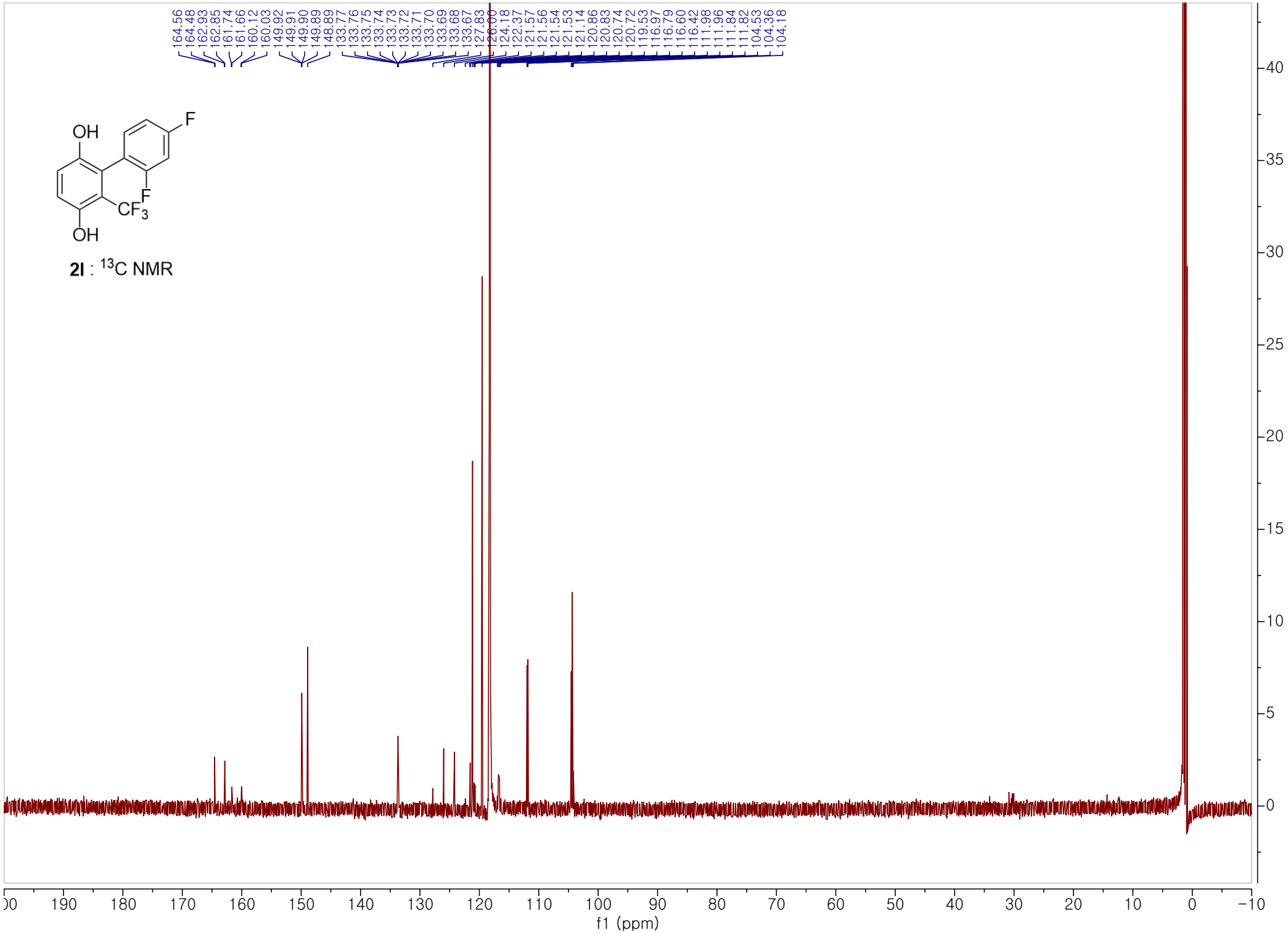

-53.57
OH
Br
CF3
OH
2j : 19F NMR
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

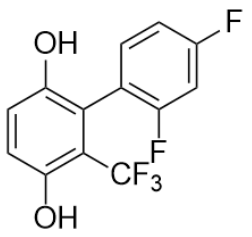

7.17
7.12
7.11
7.10
7.10
7.09
7.09
7.08
7.08
7.04
7.03
7.03
7.03
7.02
7.02
7.01
7.00
6.99
6.92
6.91
6.12
2.30
2.30
OH
F
Me
CF3
OH
2k : 1H NMR
0.68
1.01
1.00
0.99
0.74
2.91
f1 (ppm)


162.59
160.98
149.75
149.74
149.73
149.71
148.59
133.67
133.66
133.65
133.64
133.63
133.62
132.58
130.80
130.73
129.75
129.74
129.73
129.72
129.69
129.68
129.67
129.66
128.30
128.28
128.27
128.25
126.19
125.49
125.37
124.37
120.91
118.59
115.53
115.38
14.48
14.45
OH
F
Me
CF3
OH
2k : 13C NMR
f1 (ppm)


-48.52
-115.99
OH
F
Me
CF3
OH
2k : 19F NMR
f1 (ppm)

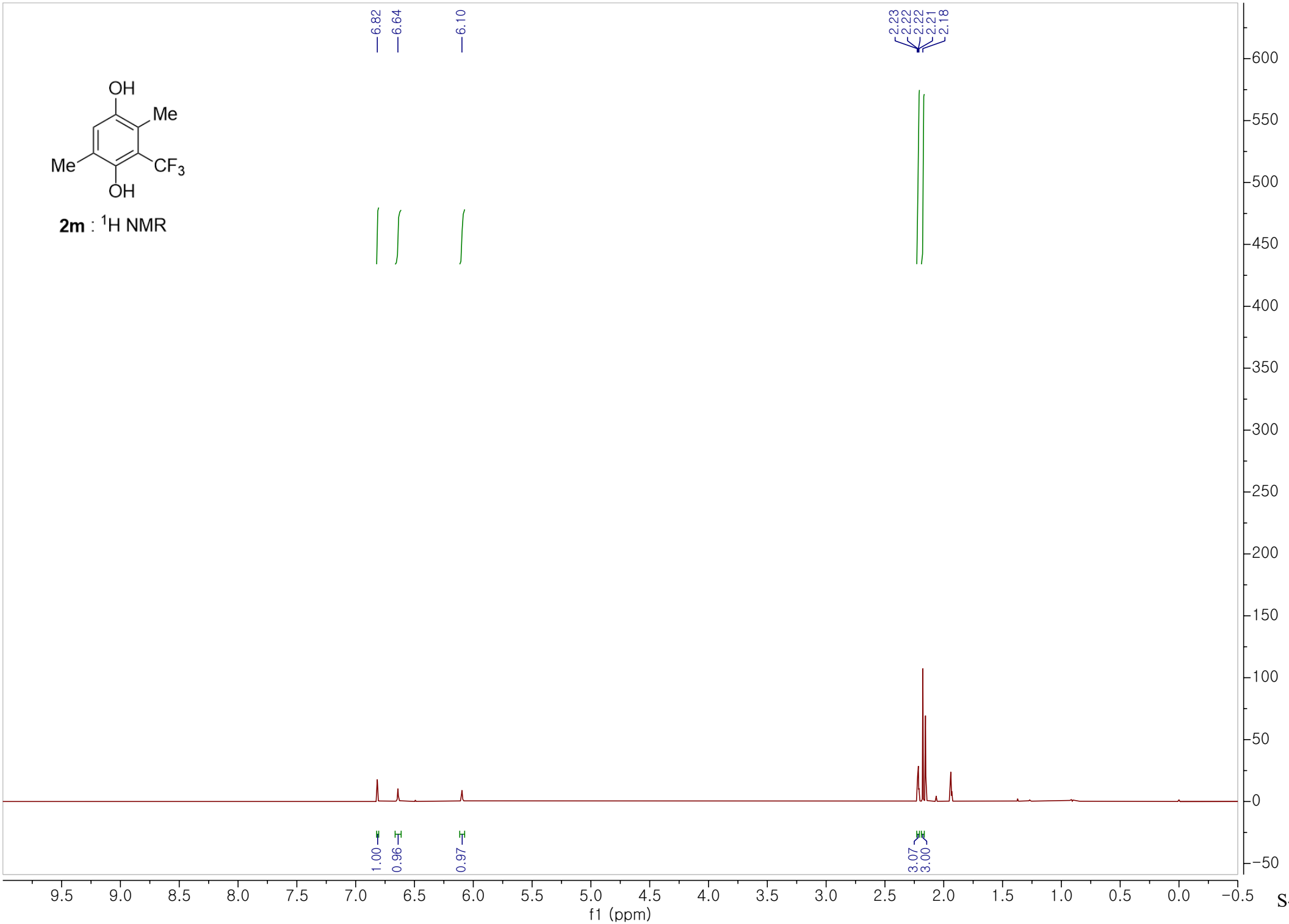

7.25
7.24
7.23
7.22
7.21
7.20
7.03
7.03
7.02
7.01
7.01
7.00
7.00
6.96
6.95
6.57
OH
F
F
CF3
OH
2l : 1H NMR
1.12
1.18
2.91
1.00
0.93
f1 (ppm)

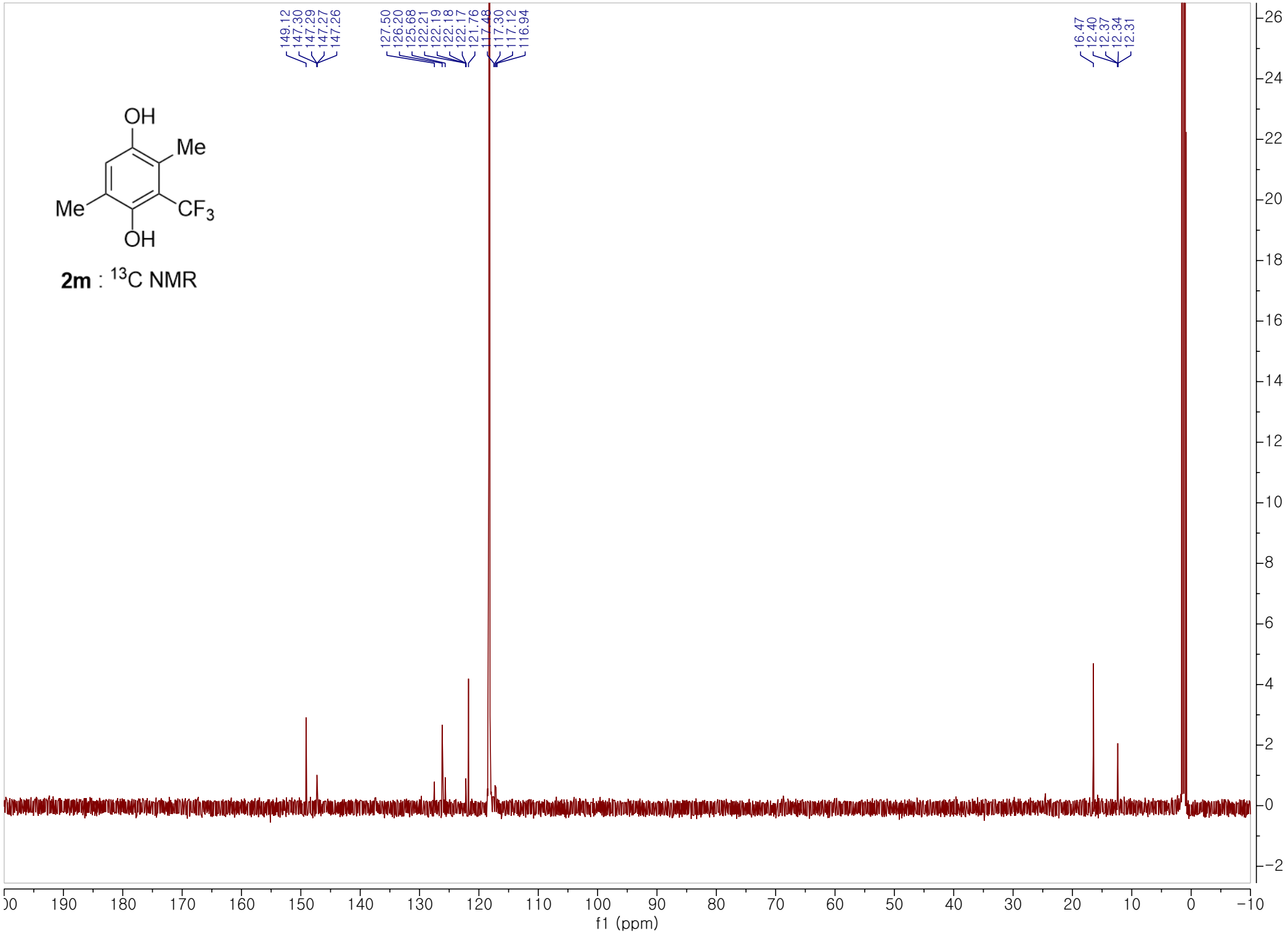

164.56
164.48
162.93
162.85
161.74
161.66
160.12
160.03
149.92
149.91
149.90
149.89
148.89
133.77
133.76
133.75
133.74
133.73
133.72
133.71
133.70
133.69
133.68
133.67
127.83
126.00
124.18
122.37
121.57
121.56
121.54
121.53
121.14
120.86
120.83
120.74
120.72
119.53
116.97
116.79
116.60
116.42
111.98
111.96
111.84
111.82
104.53
104.36
104.18
OH
F
F
CF3
OH
2l : 13C NMR
40
35
30
25
20
15
10
5
0
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

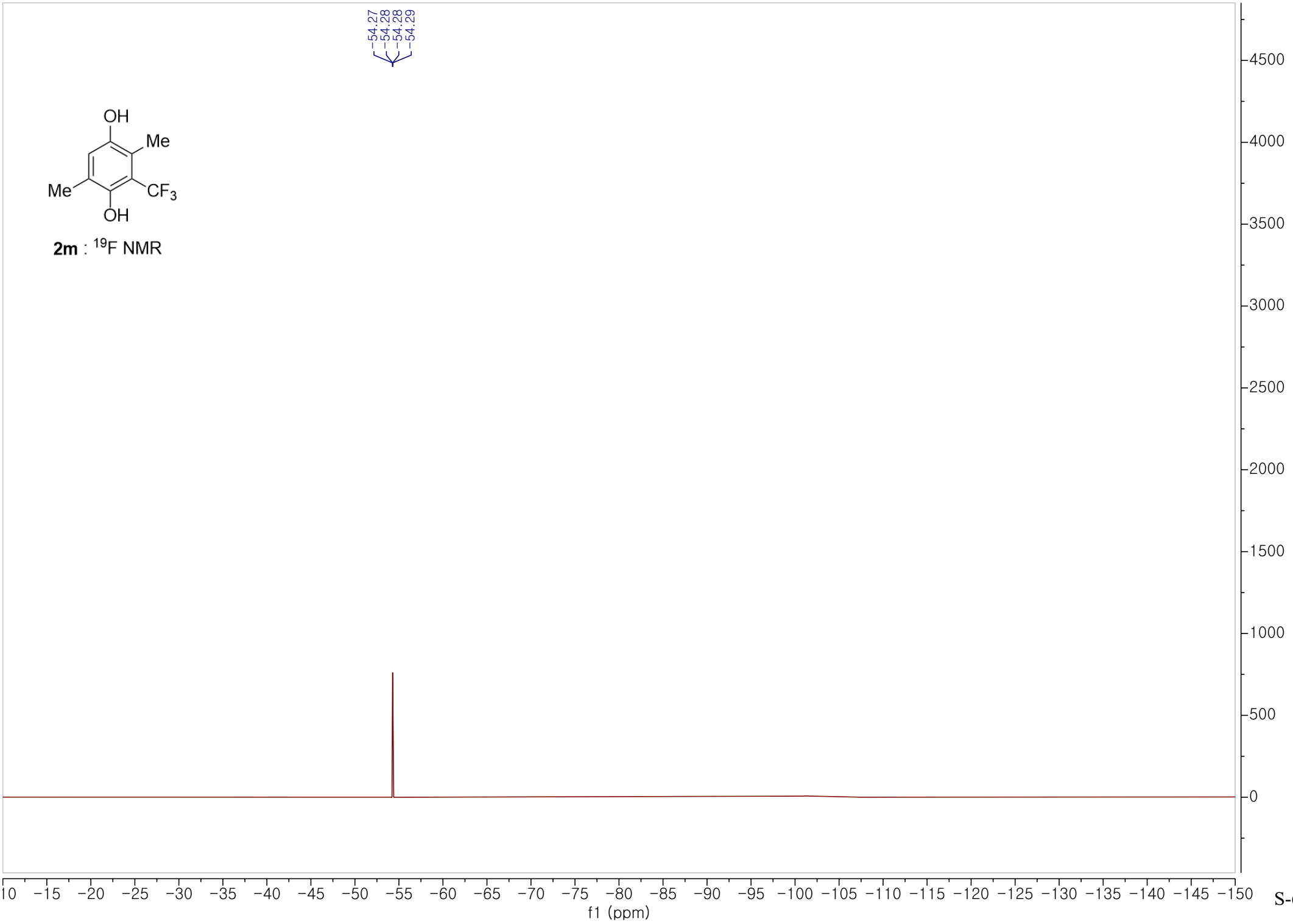

OH
F
F
CF3
OH

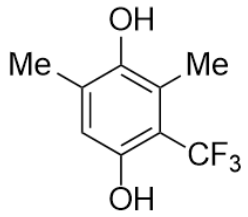
2l : ^{19}F NMR

-50.52
-106.81
-107.37
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

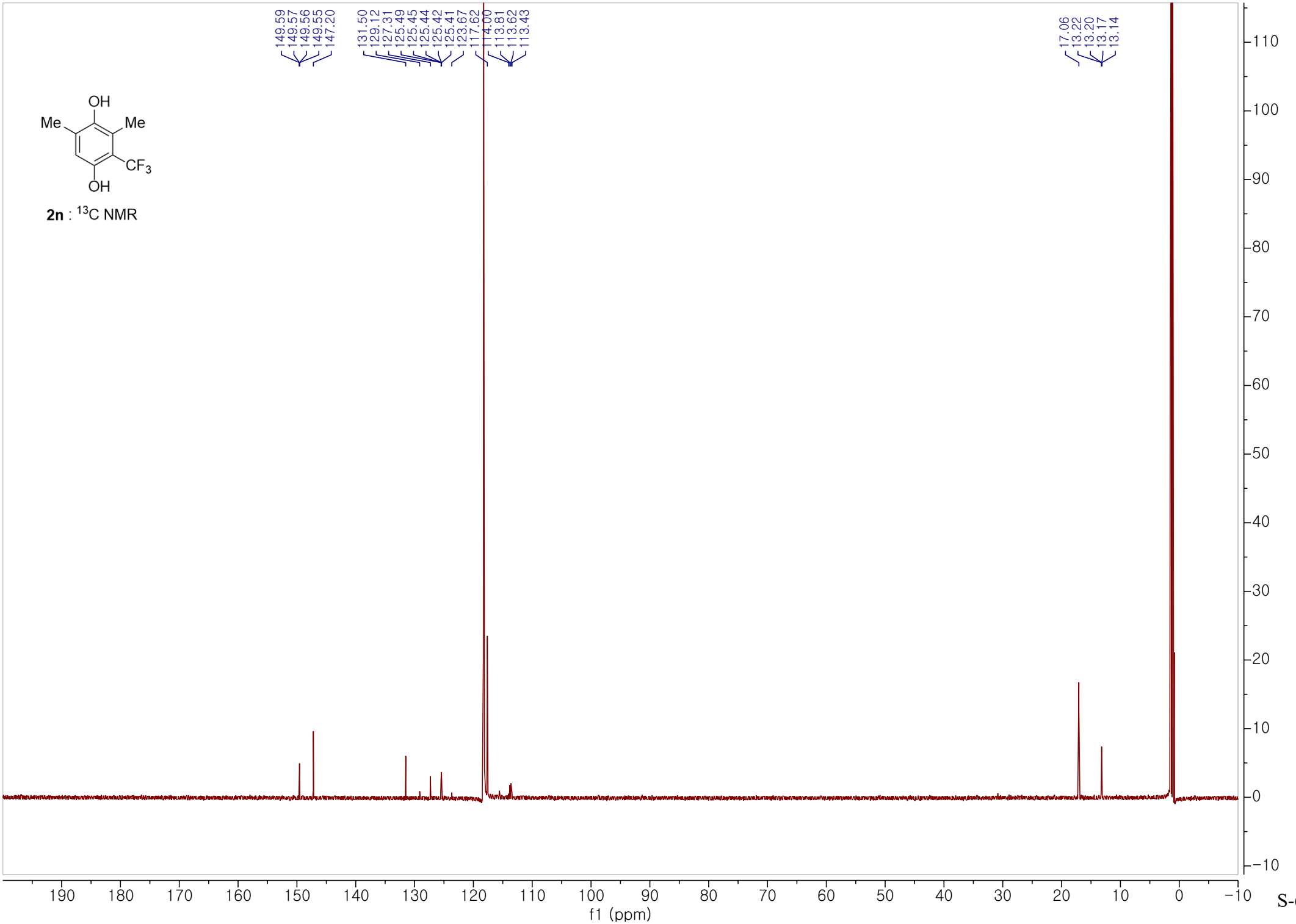

OH
Me
Me
CF3
OH
2m : 1H NMR
6.82
6.64
6.10
2.23
2.22
2.22
2.21
2.18
1.00
0.96
0.97
3.07
3.00
f1 (ppm)

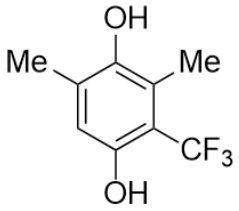

149.12
147.30
147.29
147.27
147.26
127.50
126.20
125.68
122.21
122.19
122.18
122.17
121.76
117.48
117.30
117.12
116.94
16.47
12.40
12.37
12.34
12.31
OH
Me
Me
CF3
OH
2m : 13C NMR
f1 (ppm)


-54.27
-54.28
-54.28
-54.29
OH
Me
Me
CF3
OH
2m : 19F NMR
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)



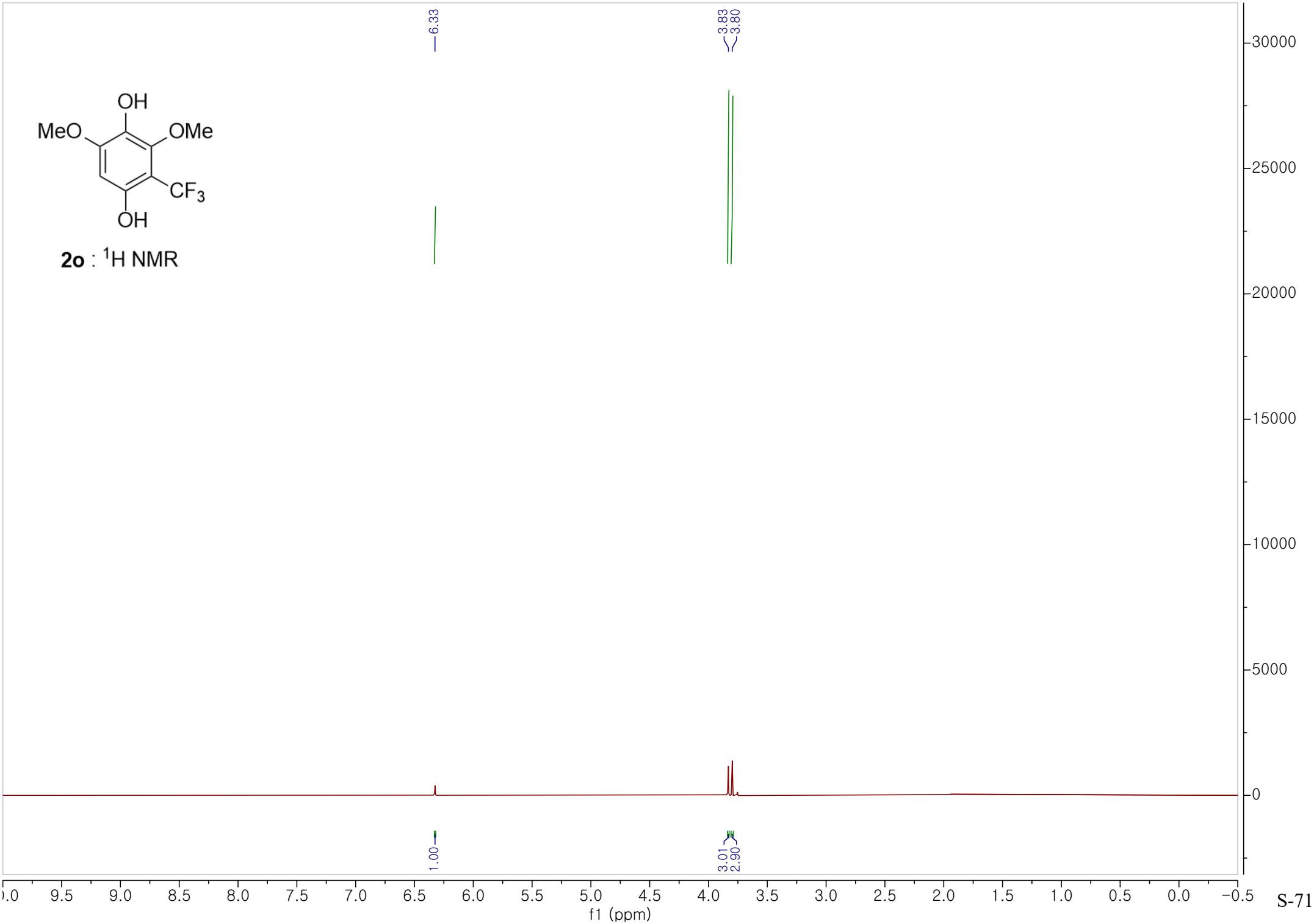
2n : ^{1}H NMR

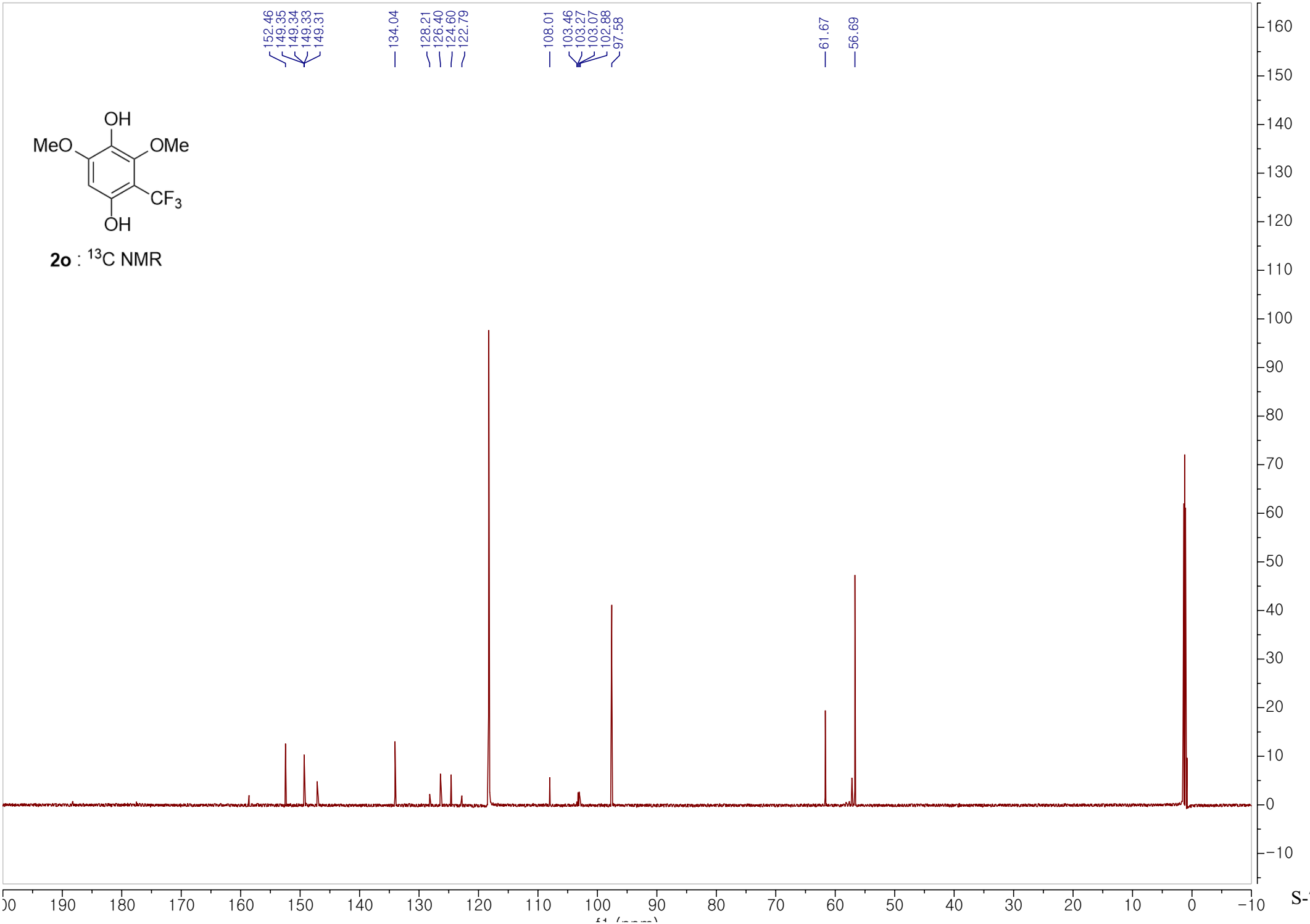

149.59
149.57
149.56
149.55
147.20
131.50
129.12
127.31
125.49
125.45
125.44
125.42
125.41
123.67
117.62
114.00
113.81
113.62
113.43
17.06
13.22
13.20
13.17
13.14
OH
Me
Me
CF3
OH
2n : 13C NMR
f1 (ppm)

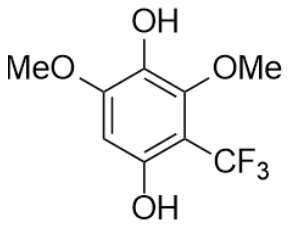

OH
Me
Me
CF3
OH

2n : ^{19}F NMR

-54.14
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

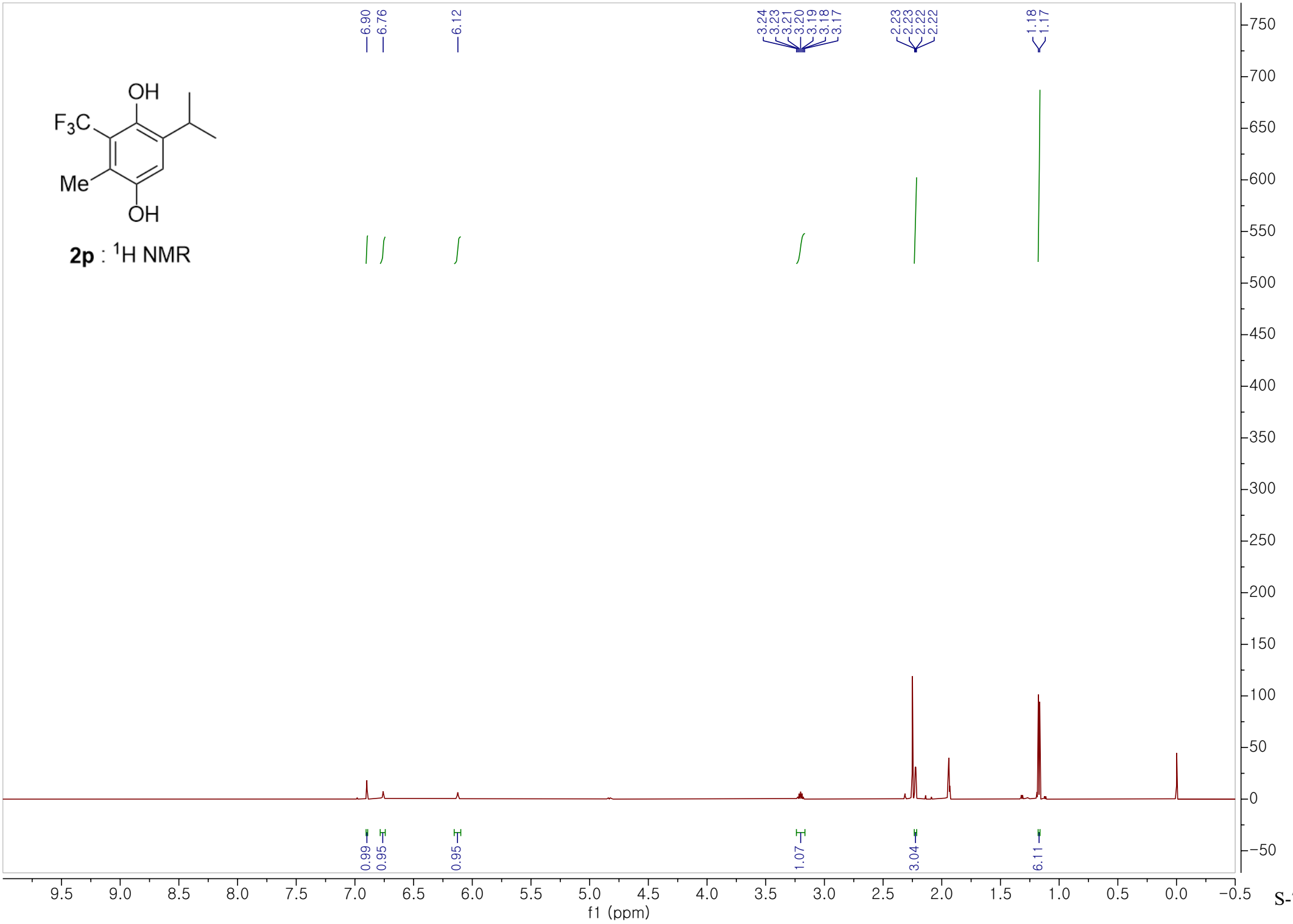

6.33
3.83
3.80
OH
MeO
OMe
CF3
OH
2o : 1H NMR
30000
25000
20000
15000
10000
5000
0
1.00
3.01
2.90
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

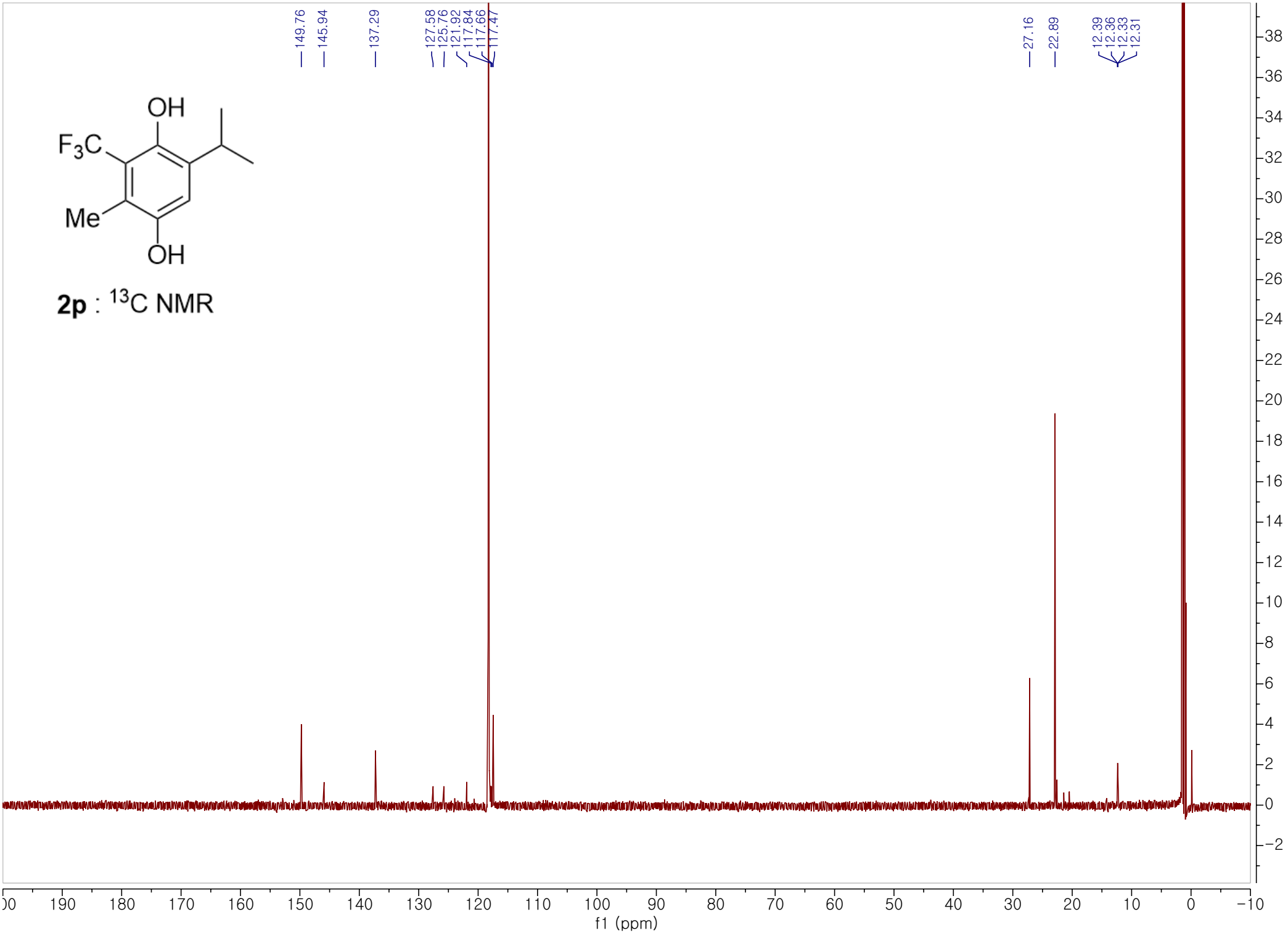

152.46
149.35
149.34
149.33
149.31
134.04
128.21
126.40
124.60
122.79
108.01
103.46
103.27
103.07
102.88
97.58
61.67
56.69
OH
MeO
OMe
CF3
OH
2o : 13C NMR

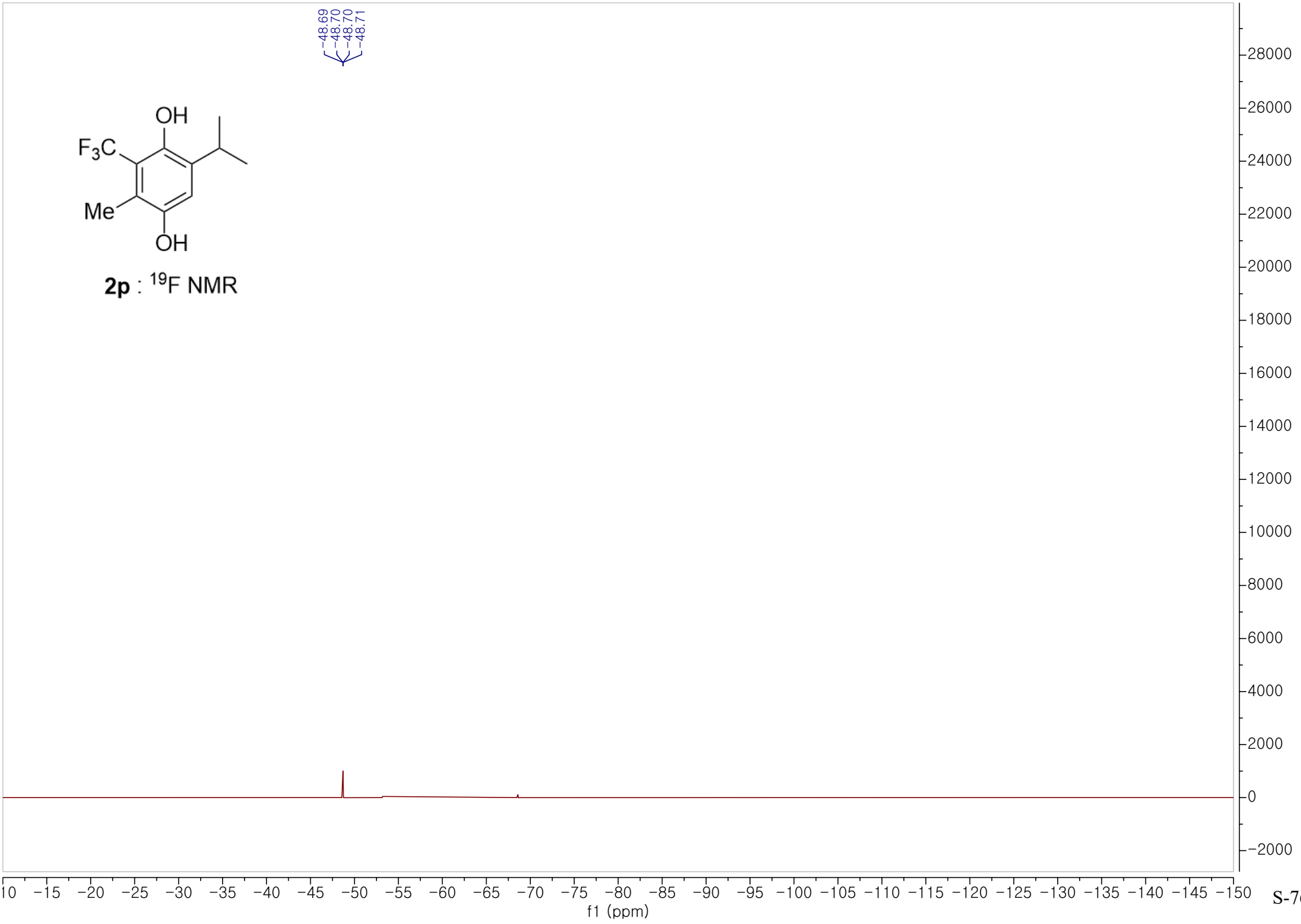

OH
MeO
OMe
CF3
OH

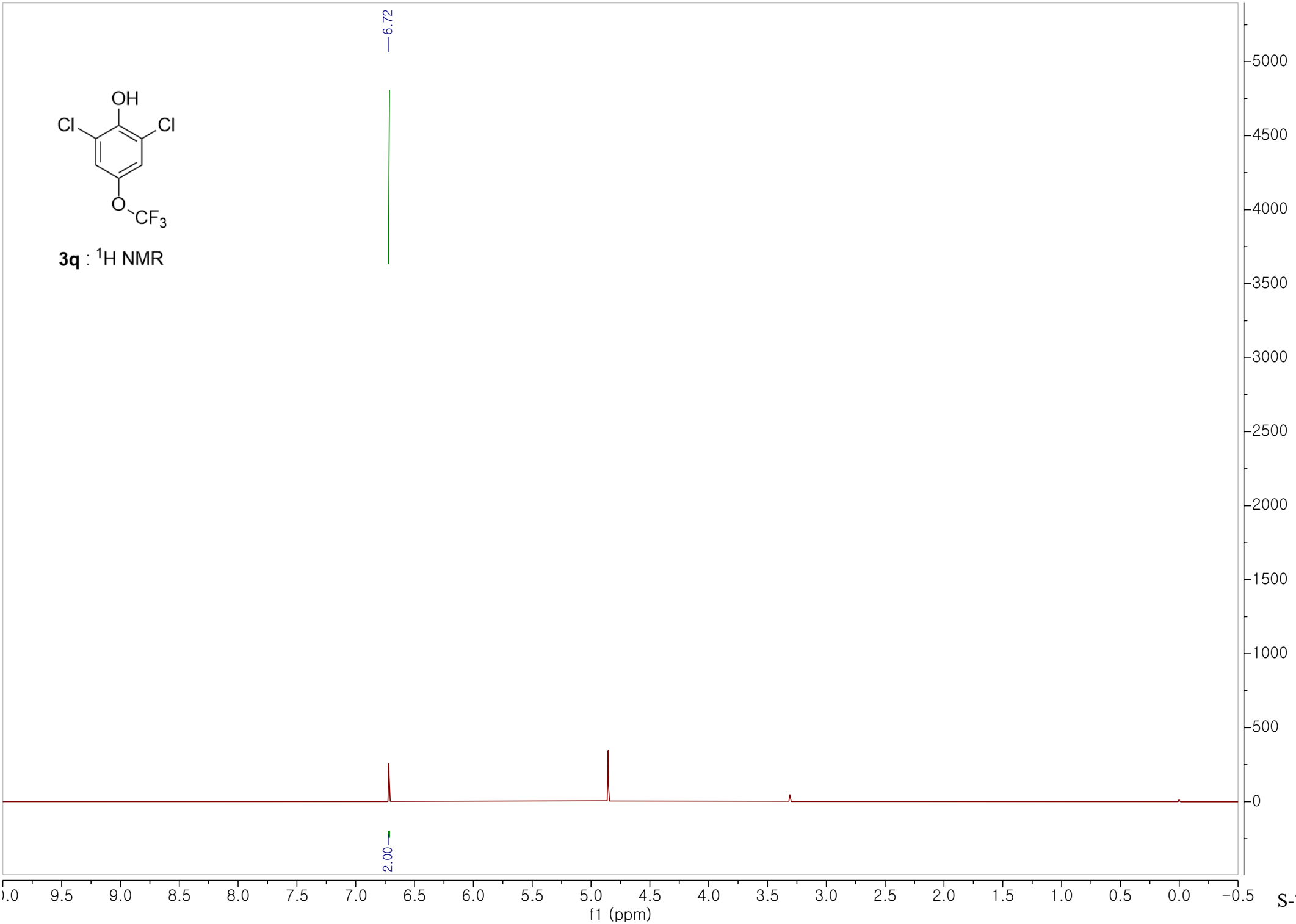
2o : ^{19}F NMR

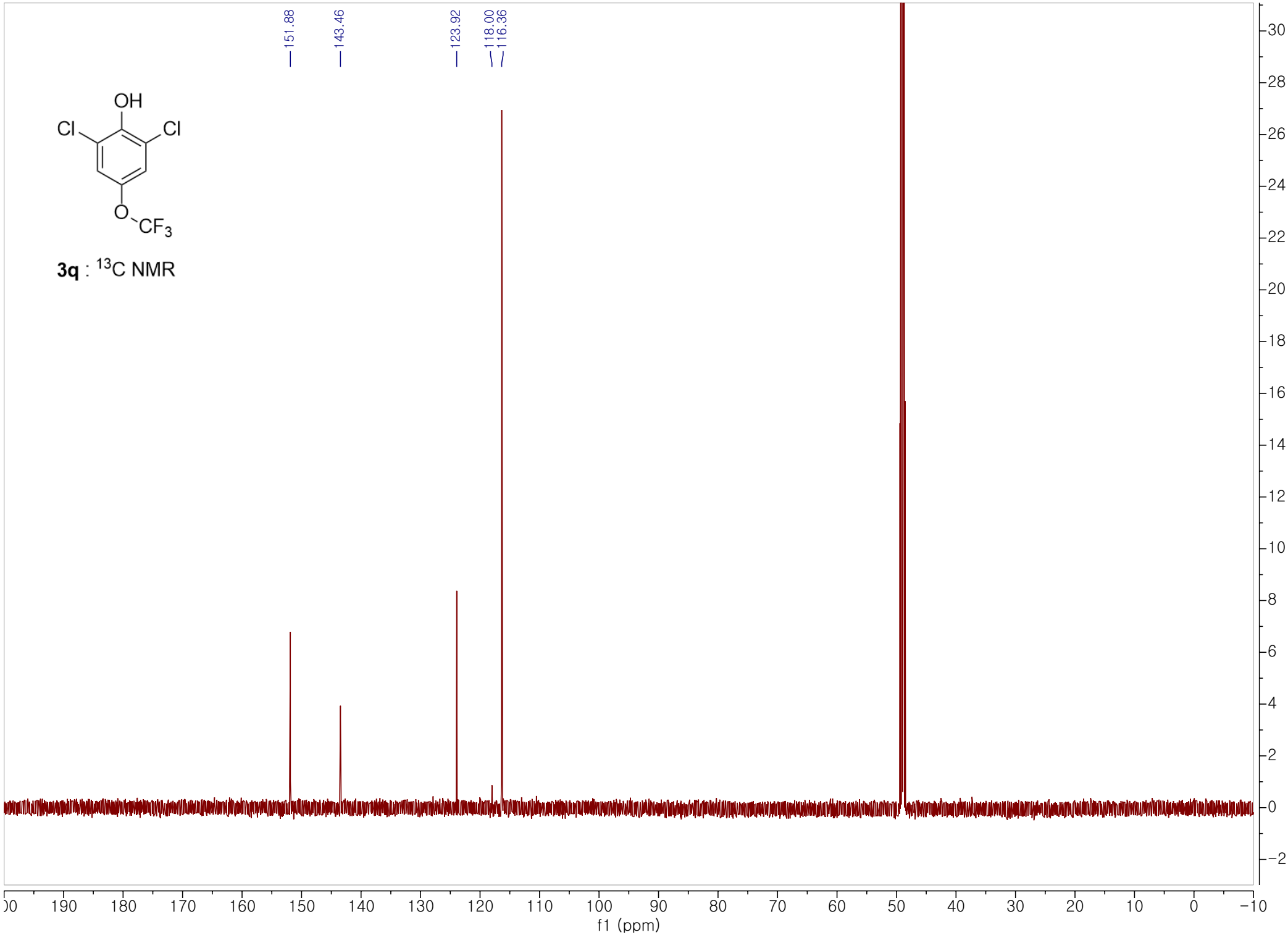
-54.96
90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

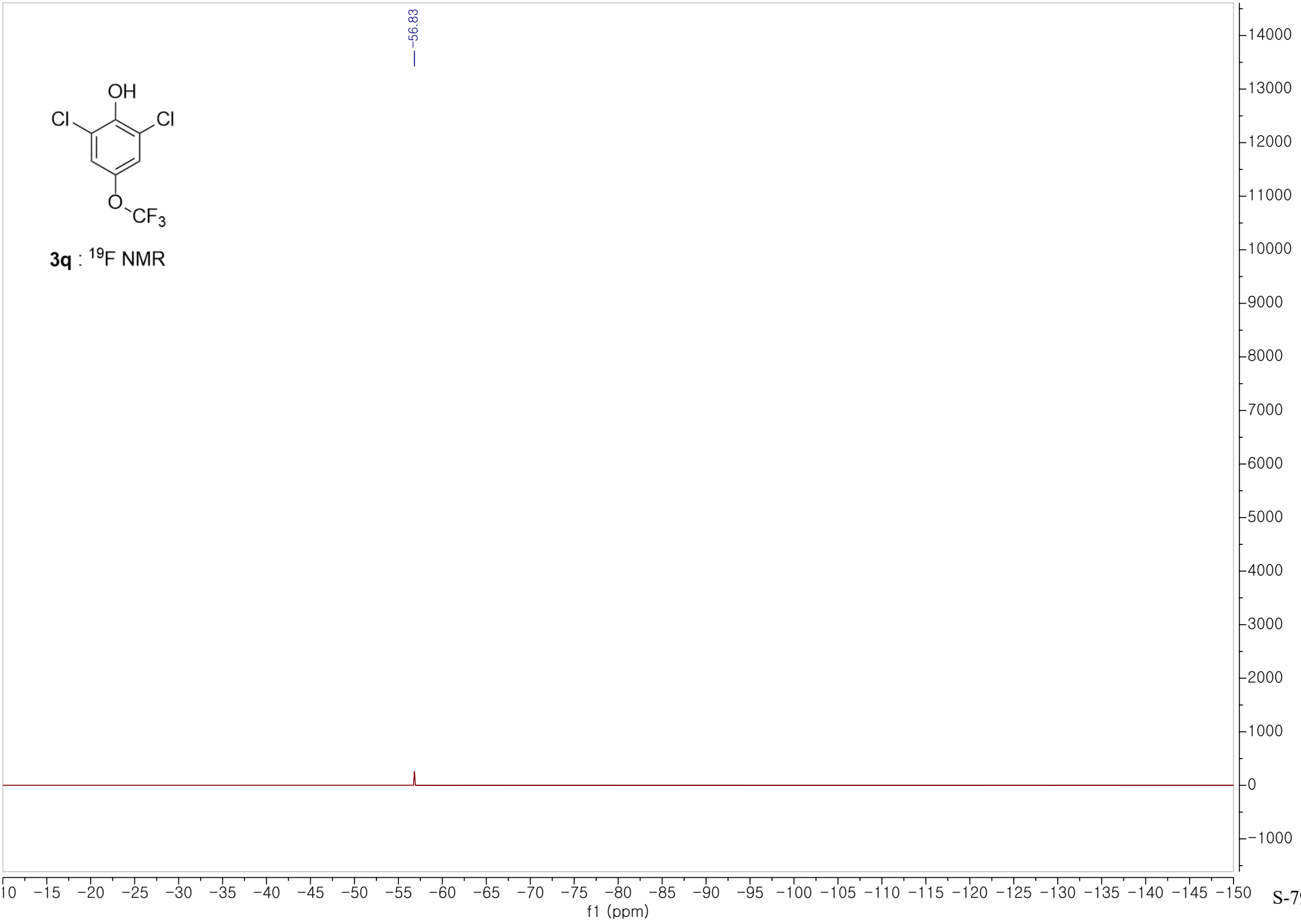

OH
F3C
Me
OH
2p : 1H NMR
6.90
6.76
6.12
3.24
3.23
3.21
3.20
3.19
3.18
3.17
2.23
2.23
2.22
2.22
1.18
1.17
0.99
0.95
0.95
1.07
3.04
6.11
f1 (ppm)

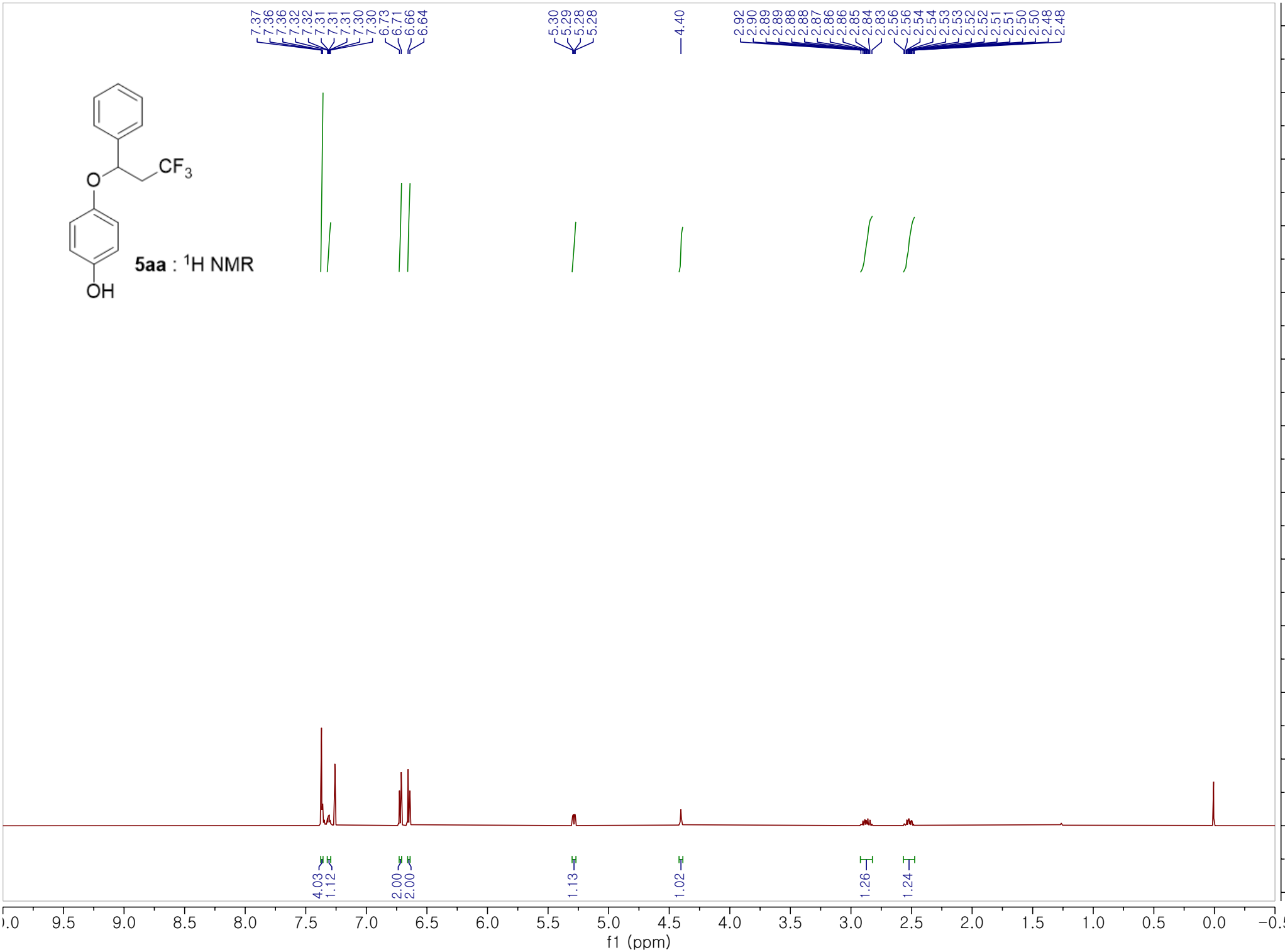

149.76
145.94
137.29
127.58
125.76
121.92
117.84
117.66
117.47
27.16
22.89
12.39
12.36
12.33
12.31
OH
F3C
Me
OH
2p : 13C NMR
f1 (ppm)

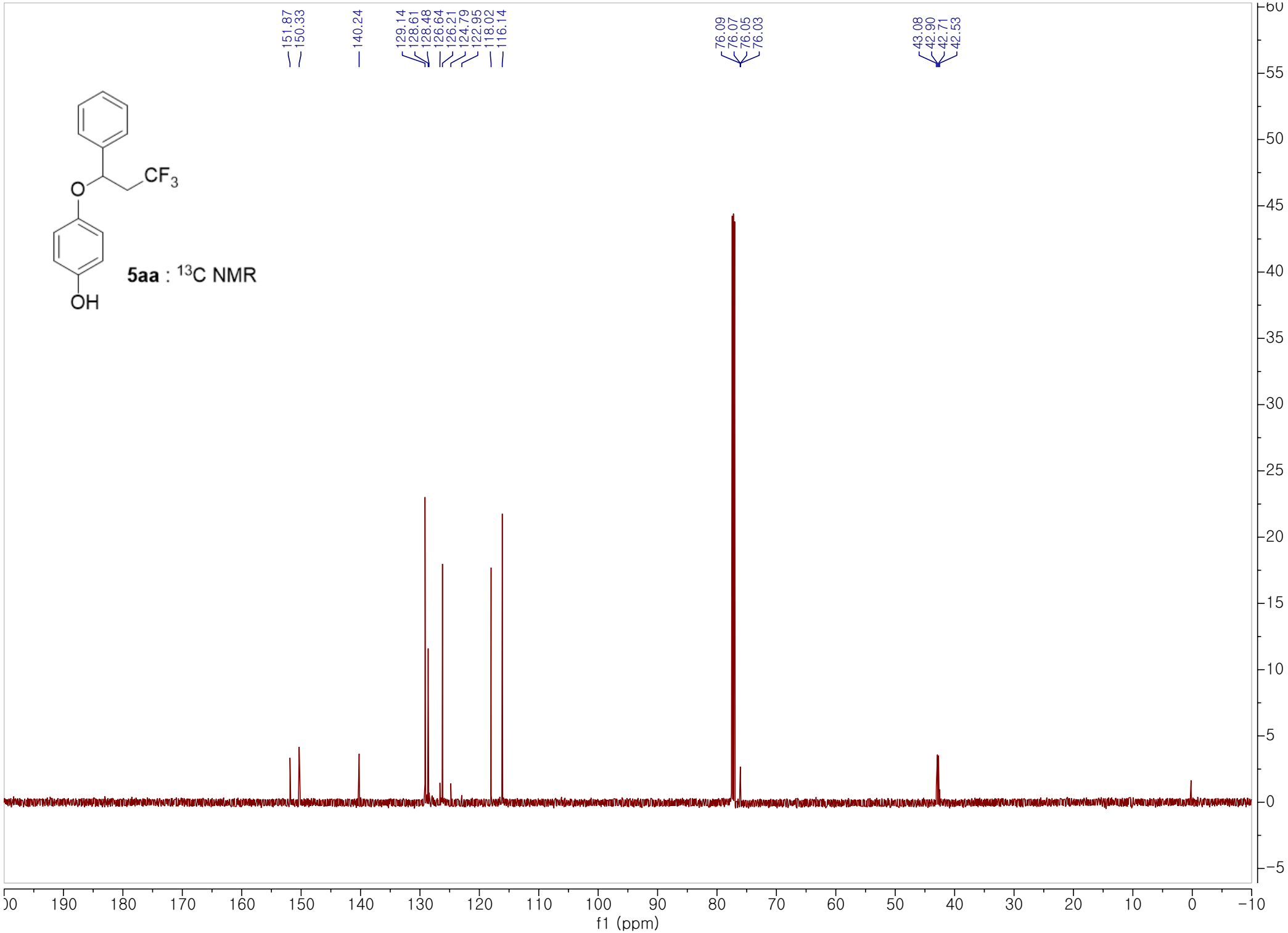

-48.69
-48.70
-48.70
-48.71
OH
F3C
Me
OH
2p : 19F NMR
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

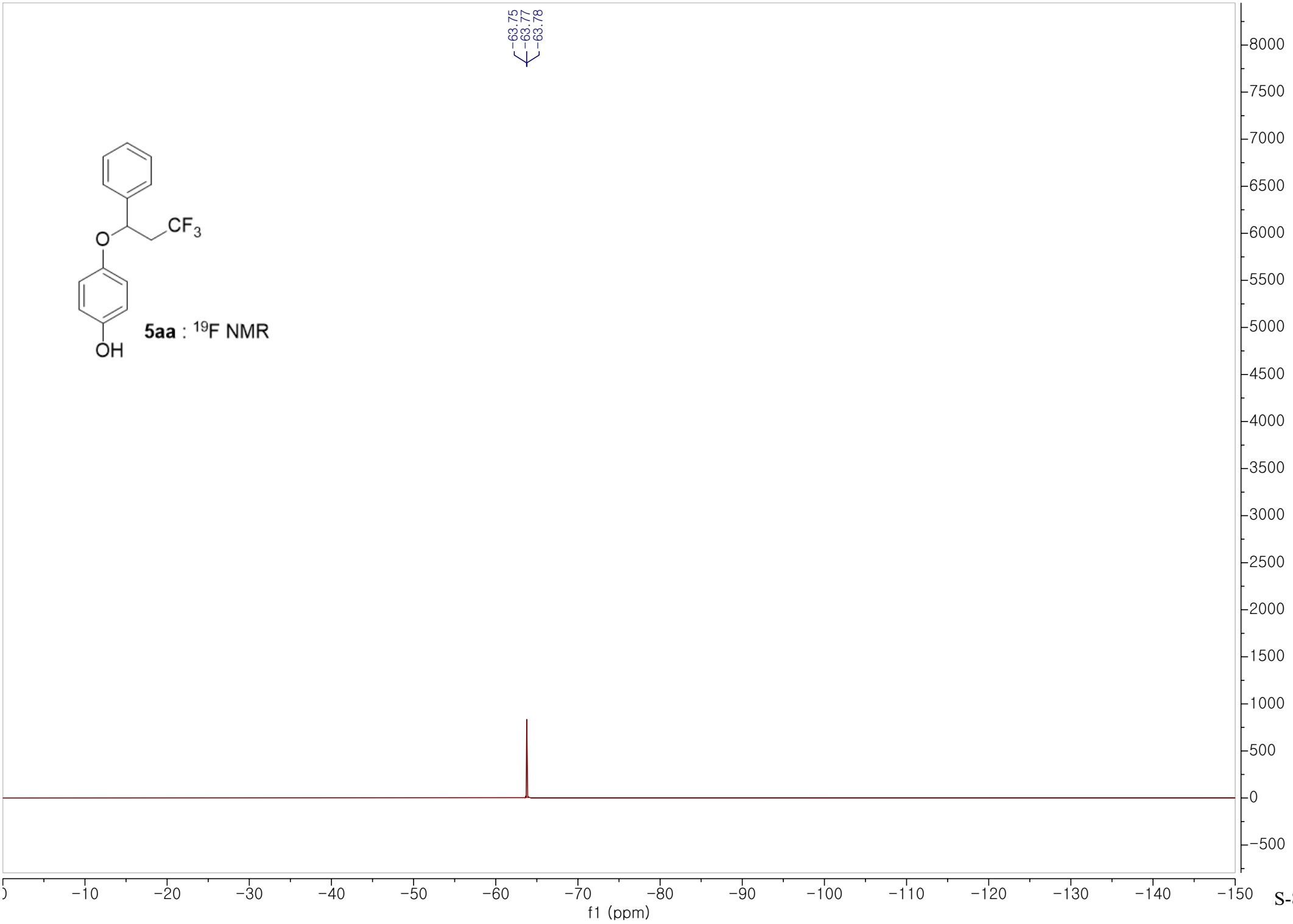

6.72
OH
Cl
Cl
O
CF3
3q : 1H NMR
2.00
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
f1 (ppm)

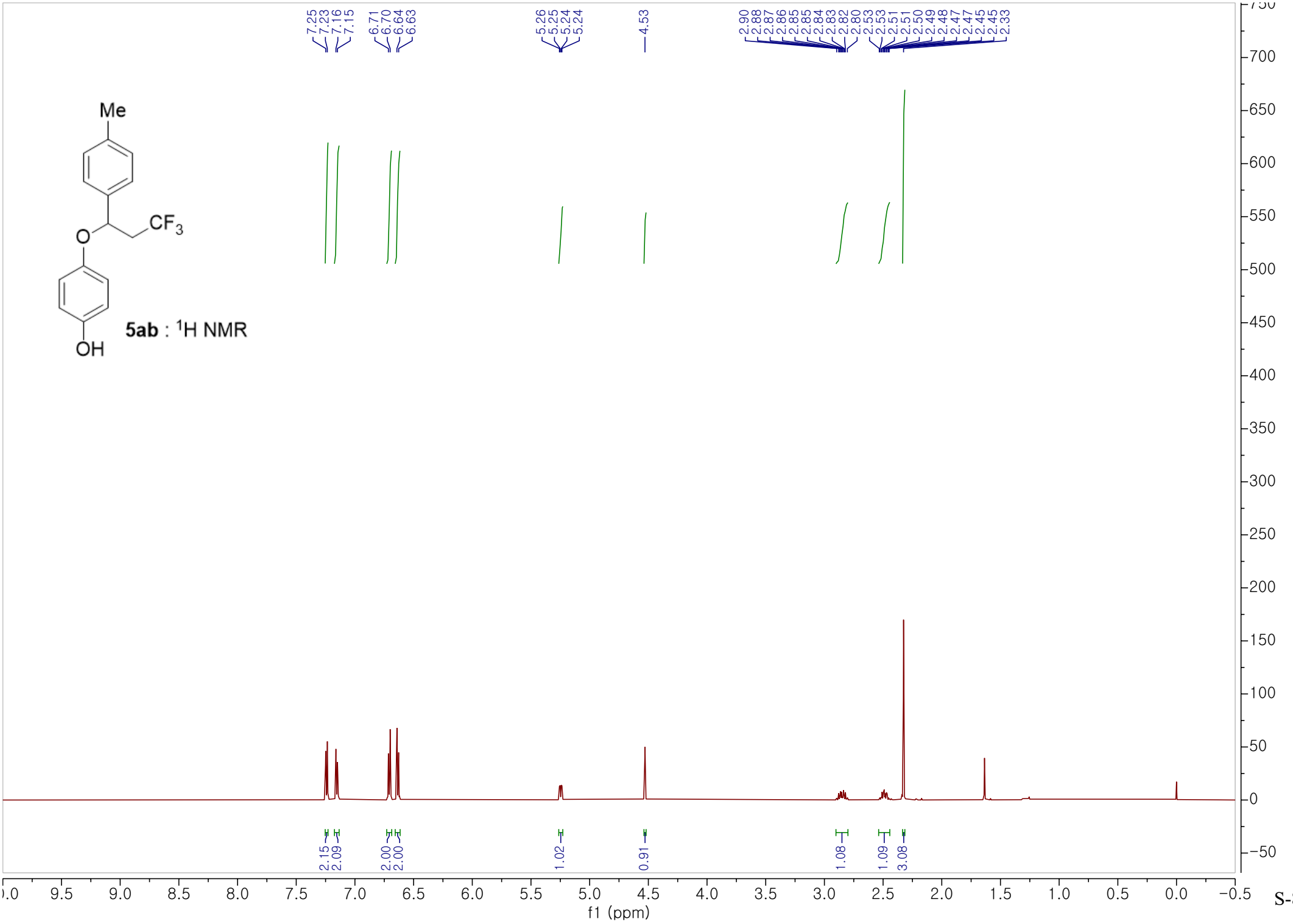

151.88
143.46
123.92
118.00
116.36
OH
Cl
Cl
O
CF3
3q : 13C NMR
f1 (ppm)

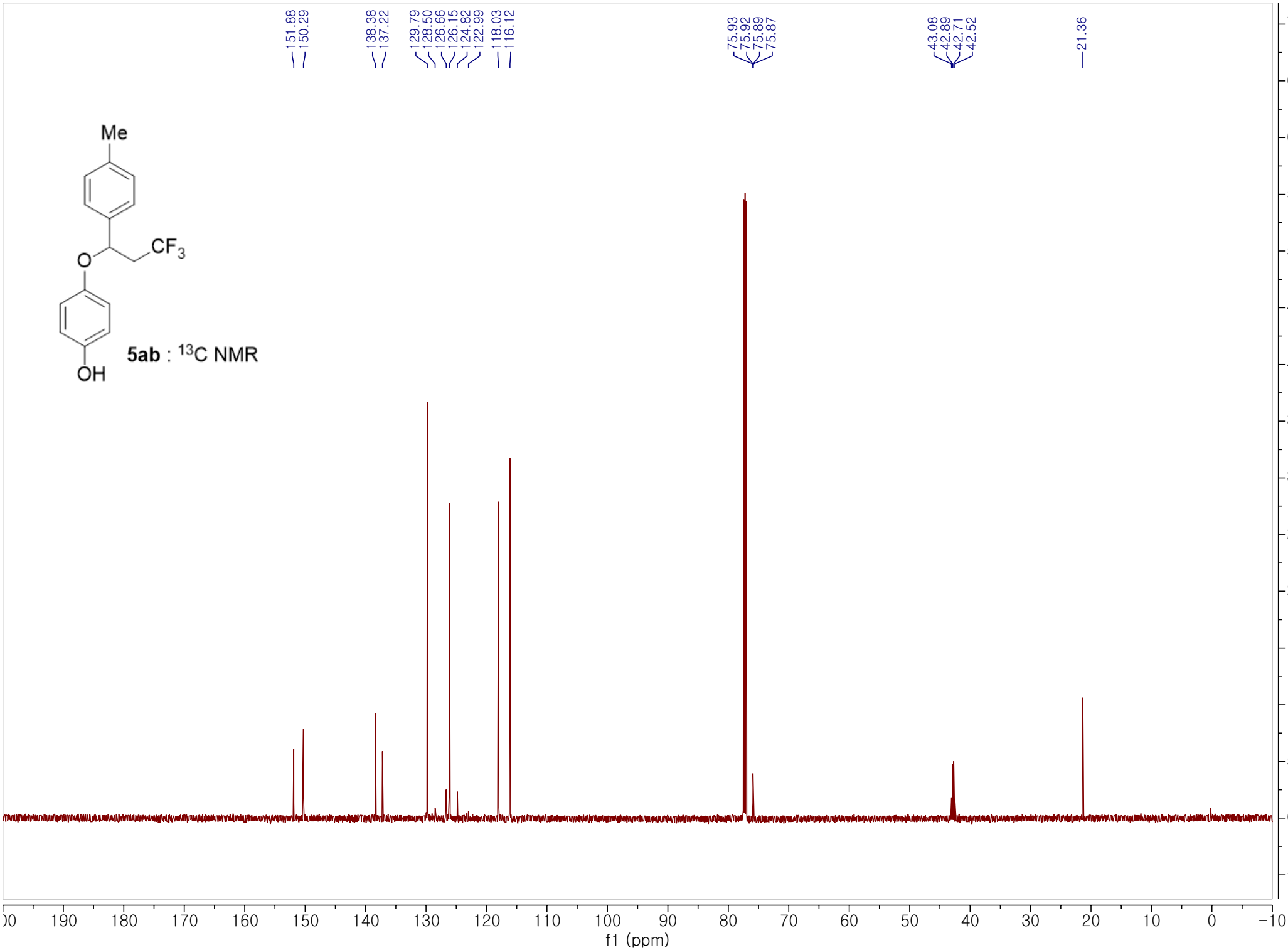

-56.83
OH
Cl
Cl
O
CF3
3q : 19F NMR
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150
f1 (ppm)

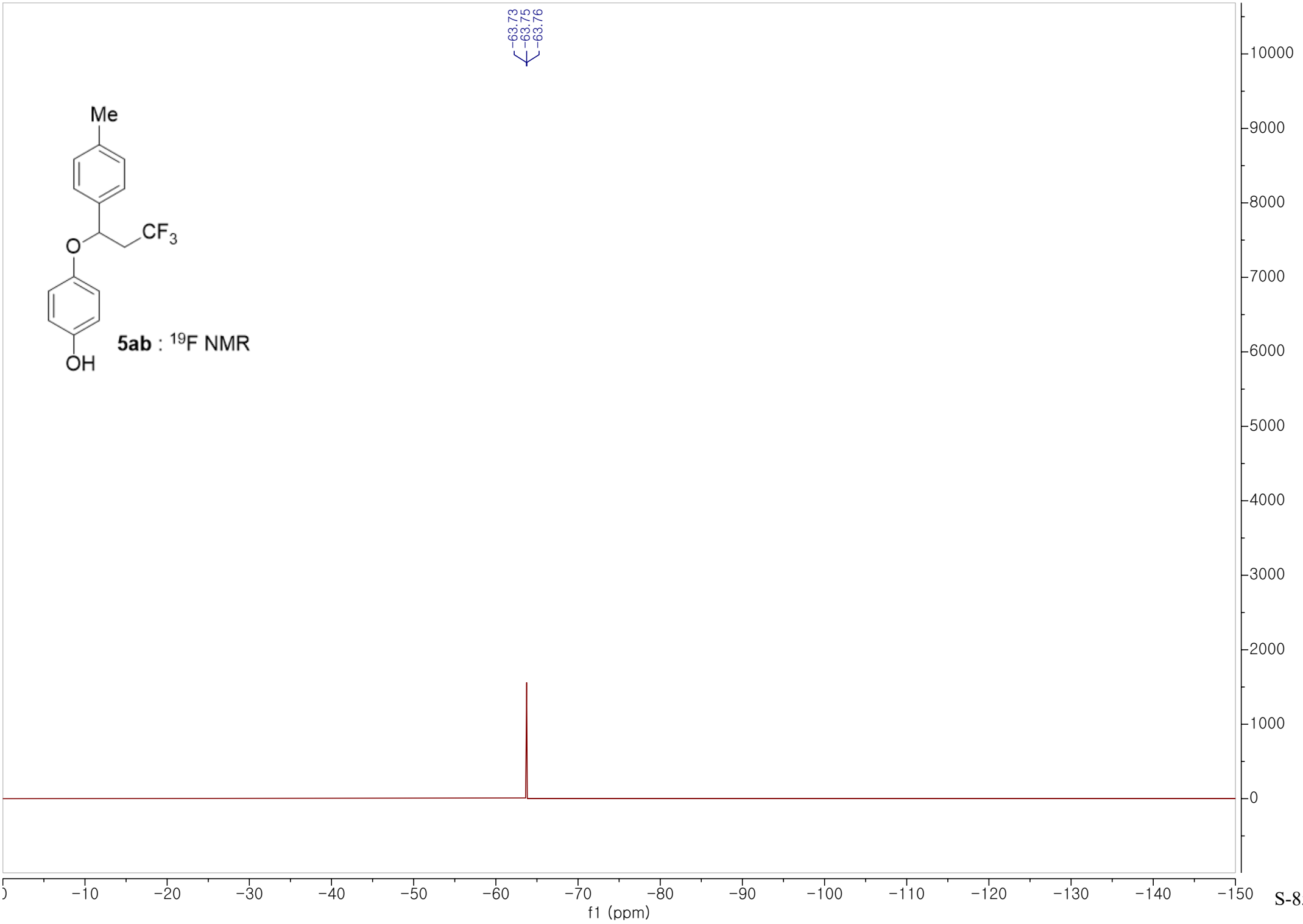

7.37
7.36
7.36
7.32
7.32
7.31
7.31
7.31
7.30
7.30
6.73
6.71
6.66
6.64
5.30
5.29
5.28
5.28
4.40
2.92
2.90
2.89
2.89
2.88
2.88
2.87
2.86
2.86
2.85
2.84
2.83
2.56
2.56
2.54
2.54
2.53
2.53
2.52
2.52
2.51
2.51
2.50
2.50
2.48
2.48
CF3
O
OH
5aa : 1H NMR
4.03
1.12
2.00
2.00
1.13
1.02
1.26
1.24
f1 (ppm)

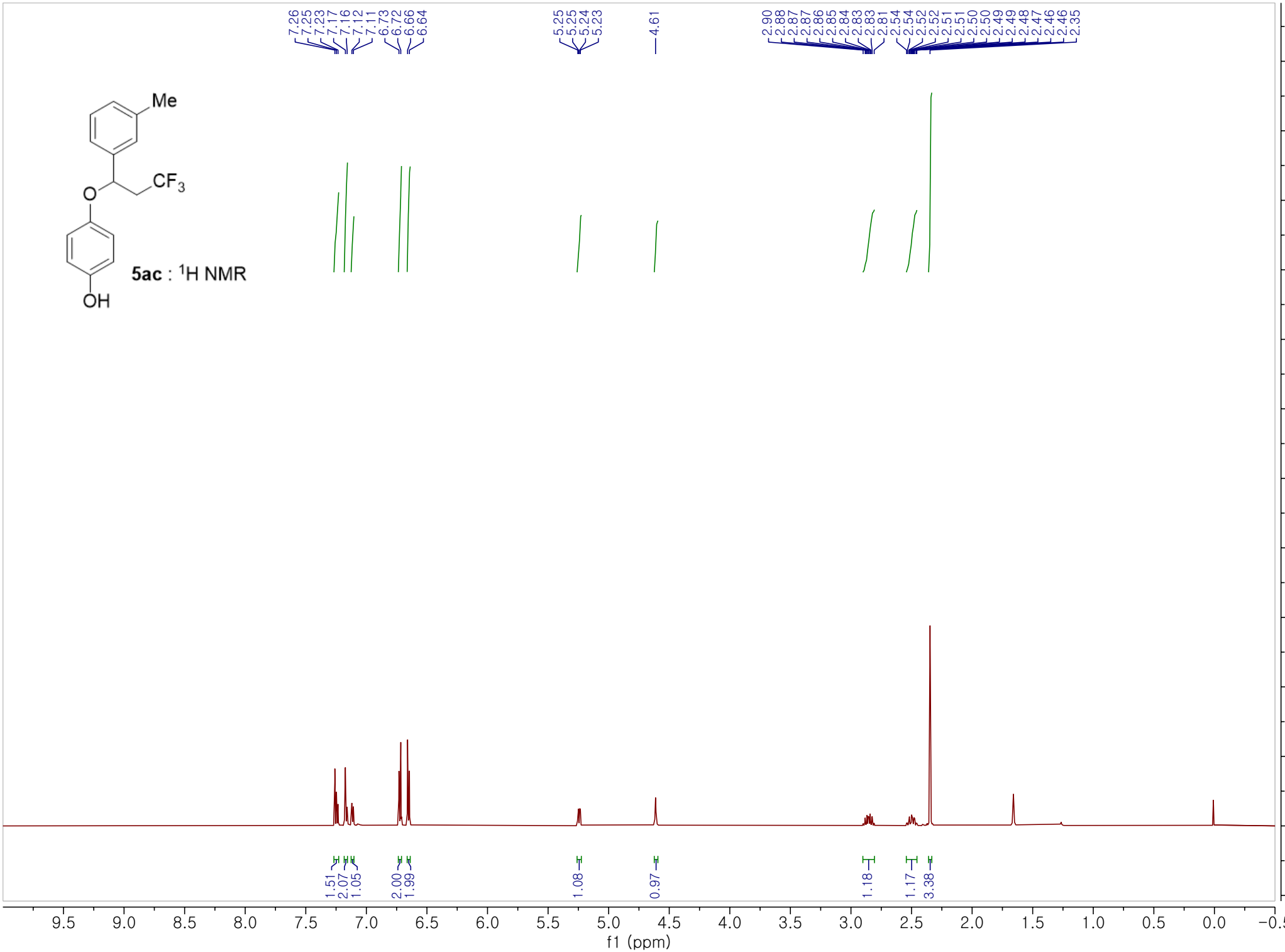

151.87
150.33
140.24
129.14
128.61
128.48
126.64
126.21
124.79
122.95
118.02
116.14
76.09
76.07
76.05
76.03
43.08
42.90
42.71
42.53
CF3
O
OH
5aa : 13C NMR
f1 (ppm)

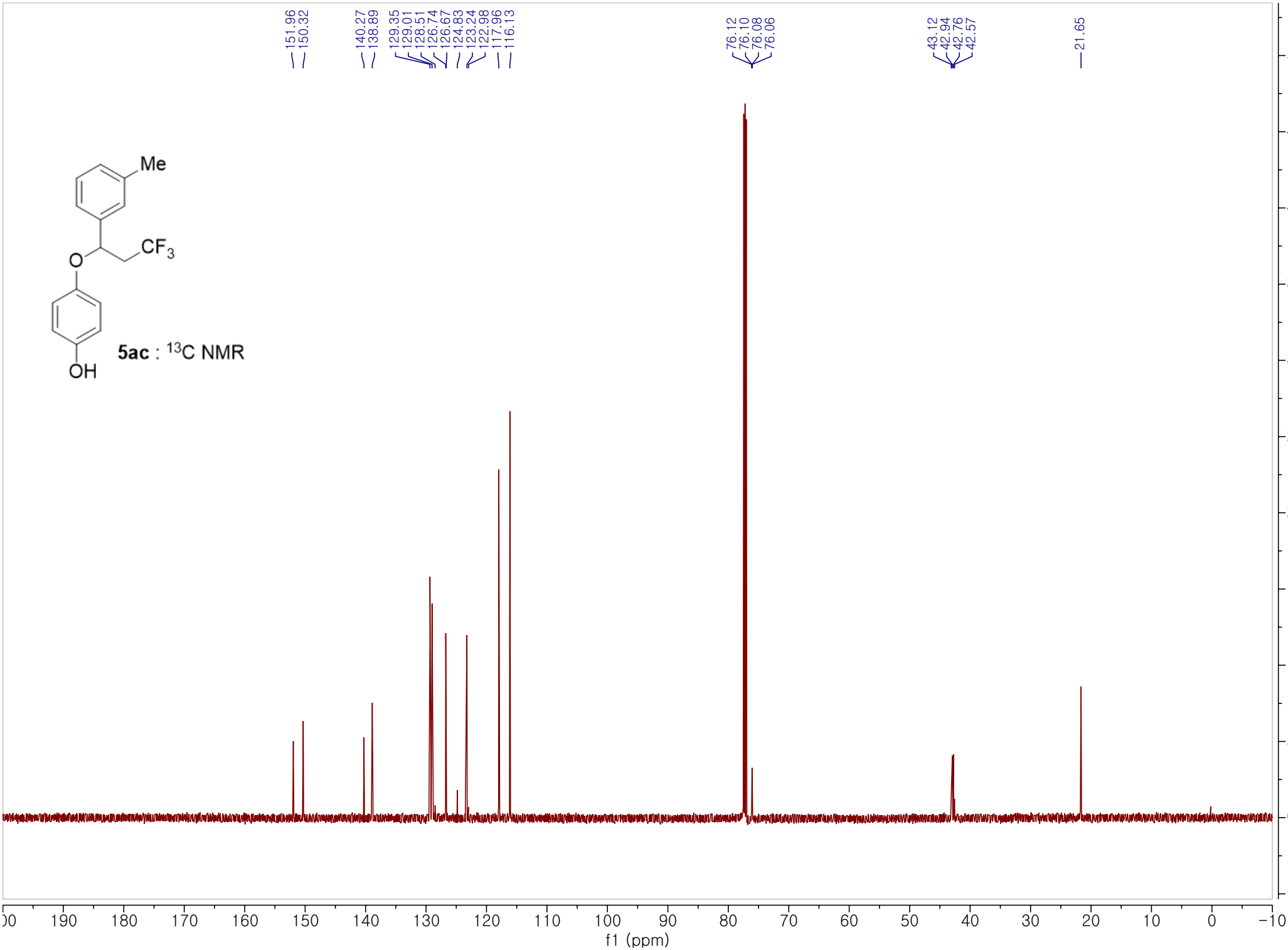

-63.75
-63.77
-63.78
CF3
O
OH
5aa : 19F NMR
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

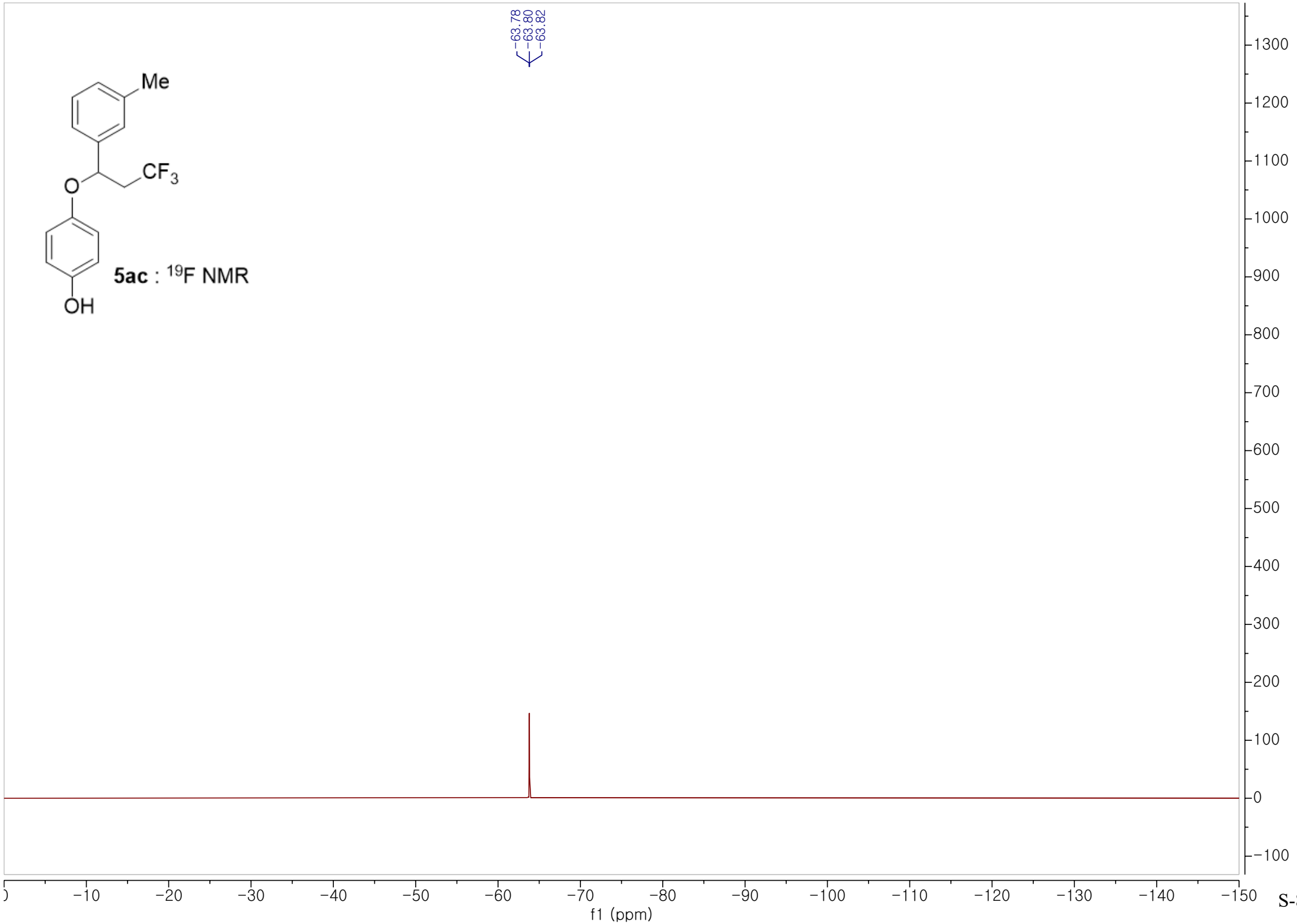

Me
CF3
O
OH
5ab : 1H NMR
7.25
7.23
7.16
7.15
6.71
6.70
6.64
6.63
5.26
5.25
5.24
5.24
4.53
2.90
2.88
2.87
2.86
2.85
2.85
2.84
2.83
2.82
2.80
2.53
2.53
2.51
2.51
2.50
2.49
2.48
2.47
2.47
2.45
2.45
2.33
2.15
2.09
2.00
2.00
1.02
0.91
1.08
1.09
3.08
f1 (ppm)

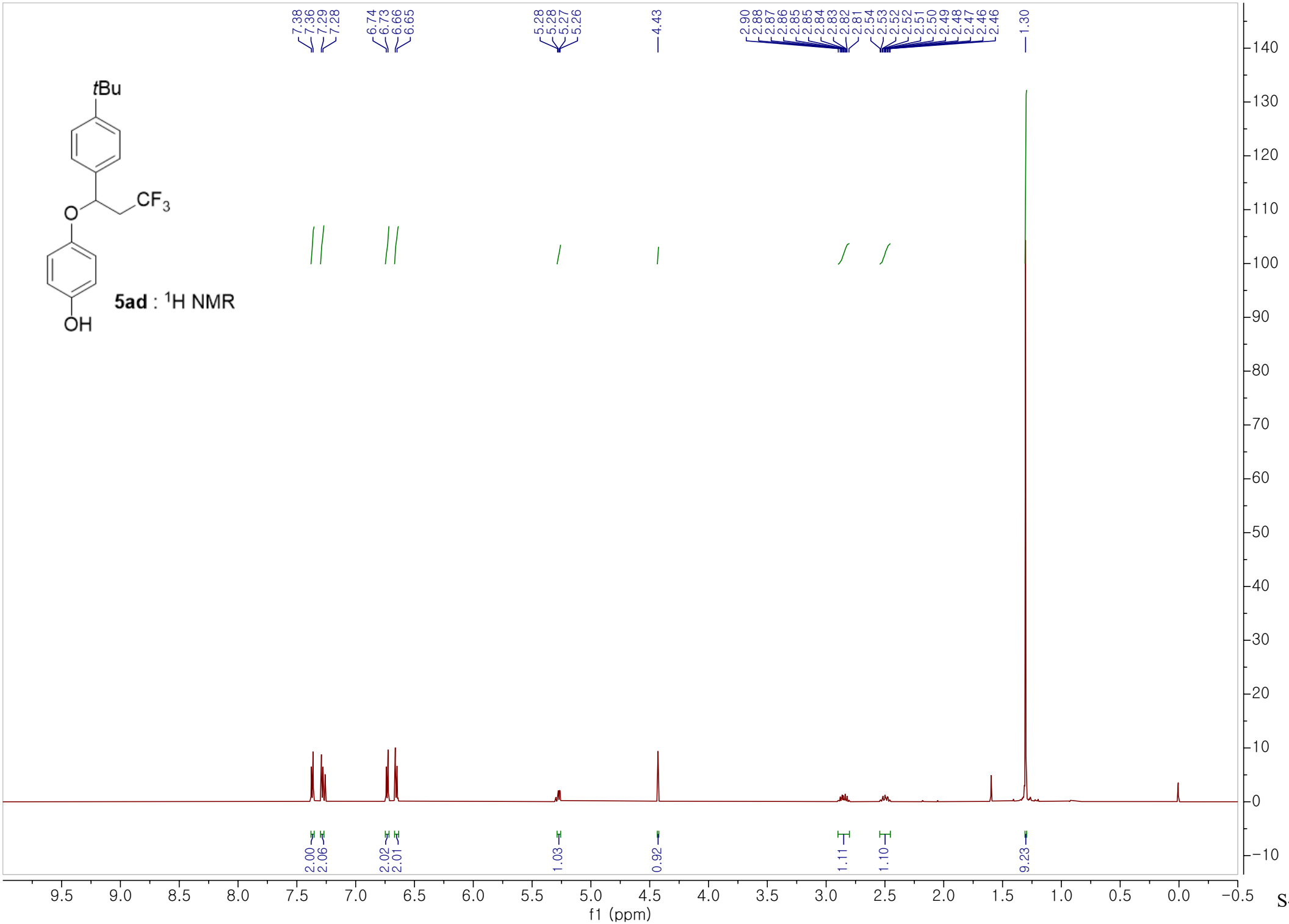

151.88
150.29
138.38
137.22
129.79
128.50
126.66
126.15
124.82
122.99
118.03
116.12
75.93
75.92
75.89
75.87
43.08
42.89
42.71
42.52
21.36
Me
CF3
O
OH
5ab : 13C NMR
f1 (ppm)

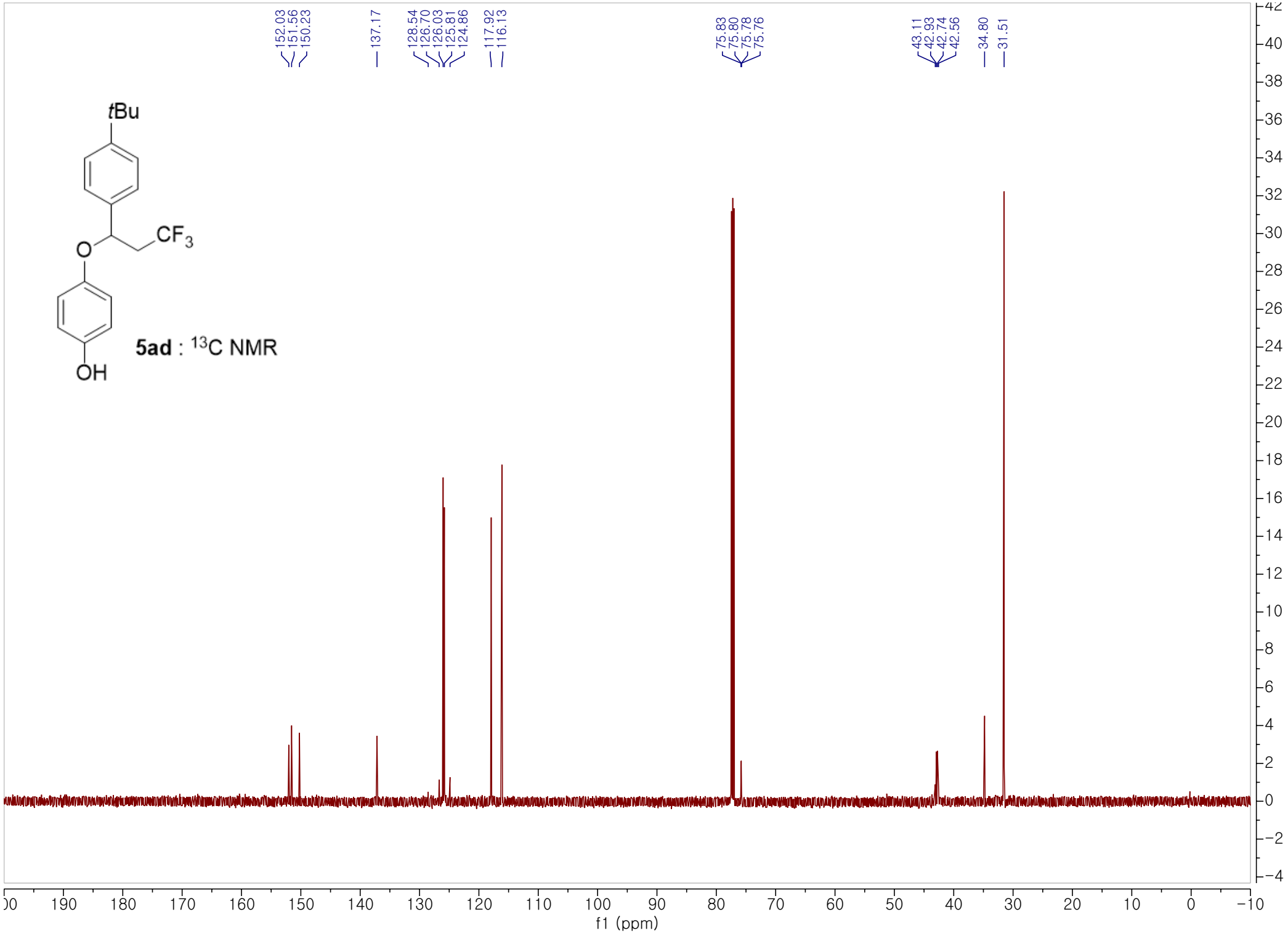

-63.73
-63.75
-63.76
Me
CF3
O
OH
5ab : 19F NMR
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

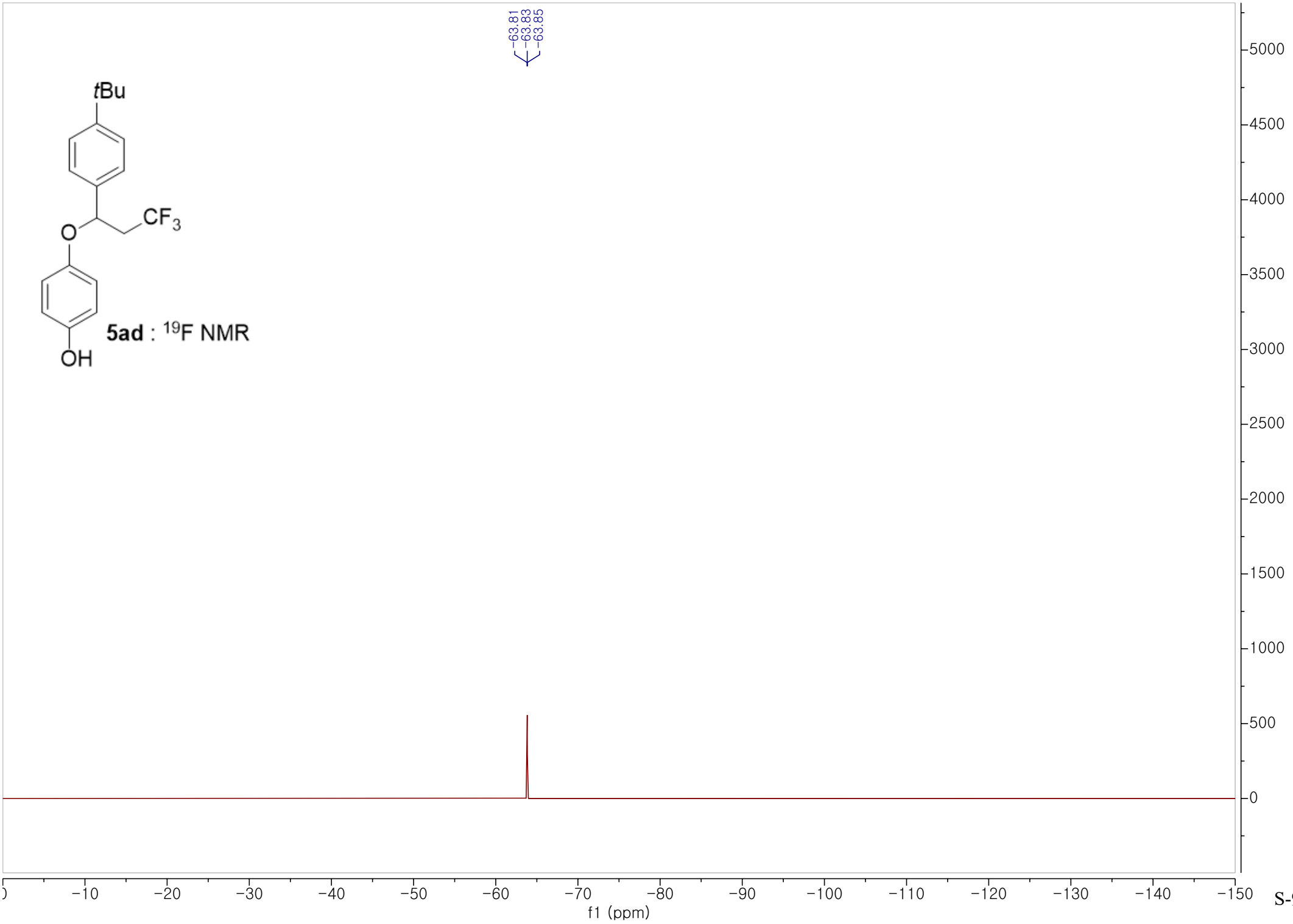

Me
CF3
O
OH
5ac : 1H NMR
7.26
7.25
7.23
7.17
7.16
7.12
7.11
6.73
6.72
6.66
6.64
5.25
5.25
5.24
5.23
4.61
2.90
2.88
2.87
2.87
2.86
2.85
2.84
2.83
2.83
2.81
2.54
2.54
2.52
2.52
2.51
2.51
2.50
2.50
2.49
2.49
2.48
2.47
2.46
2.46
2.35
1.51
2.07
1.05
2.00
1.99
1.08
0.97
1.18
1.17
3.38
f1 (ppm)

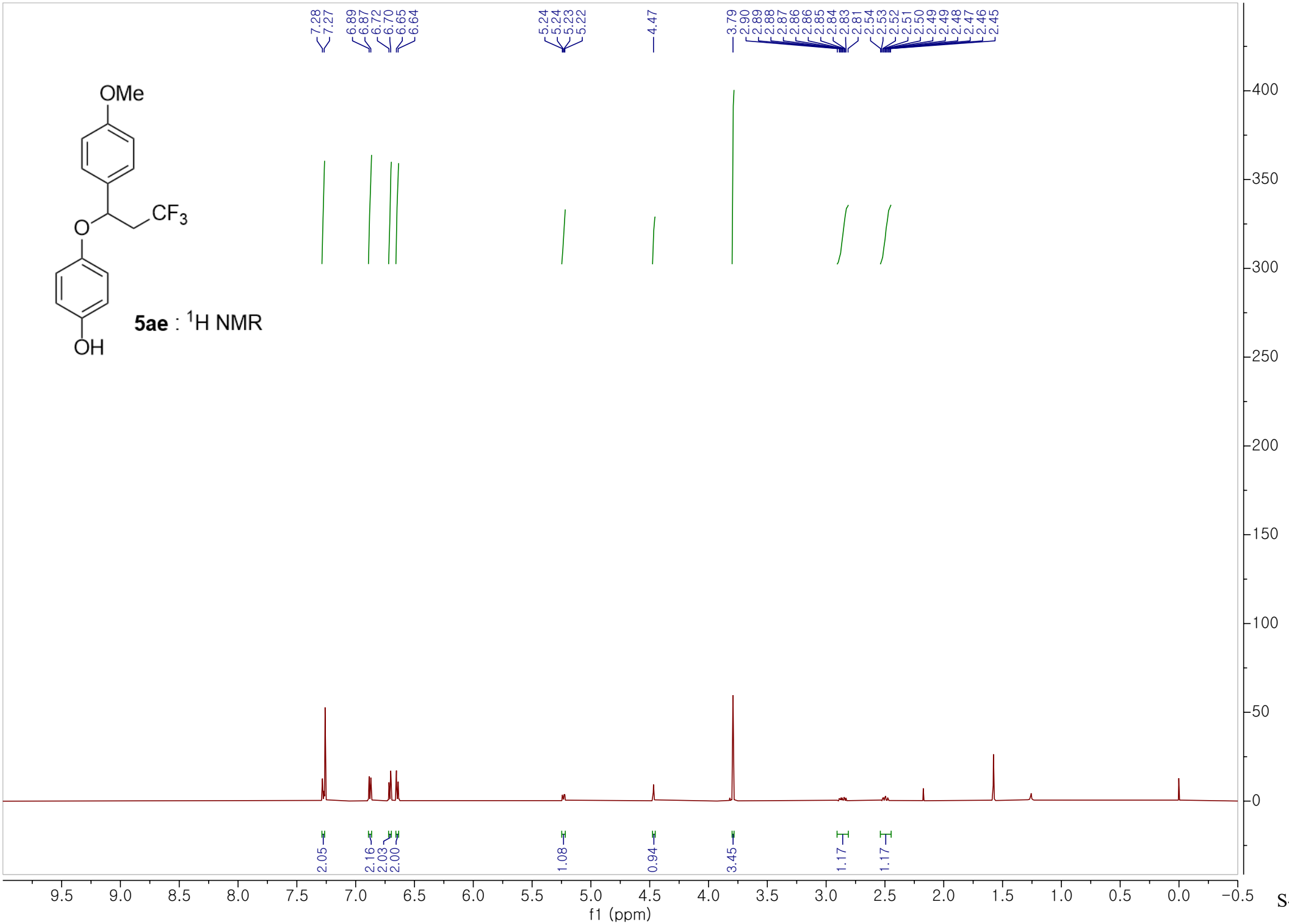

151.96
150.32
140.27
138.89
129.35
129.01
128.51
126.74
126.67
124.83
123.24
122.98
117.96
116.13
76.12
76.10
76.08
76.06
43.12
42.94
42.76
42.57
21.65
Me
CF3
O
OH
5ac : 13C NMR
f1 (ppm)

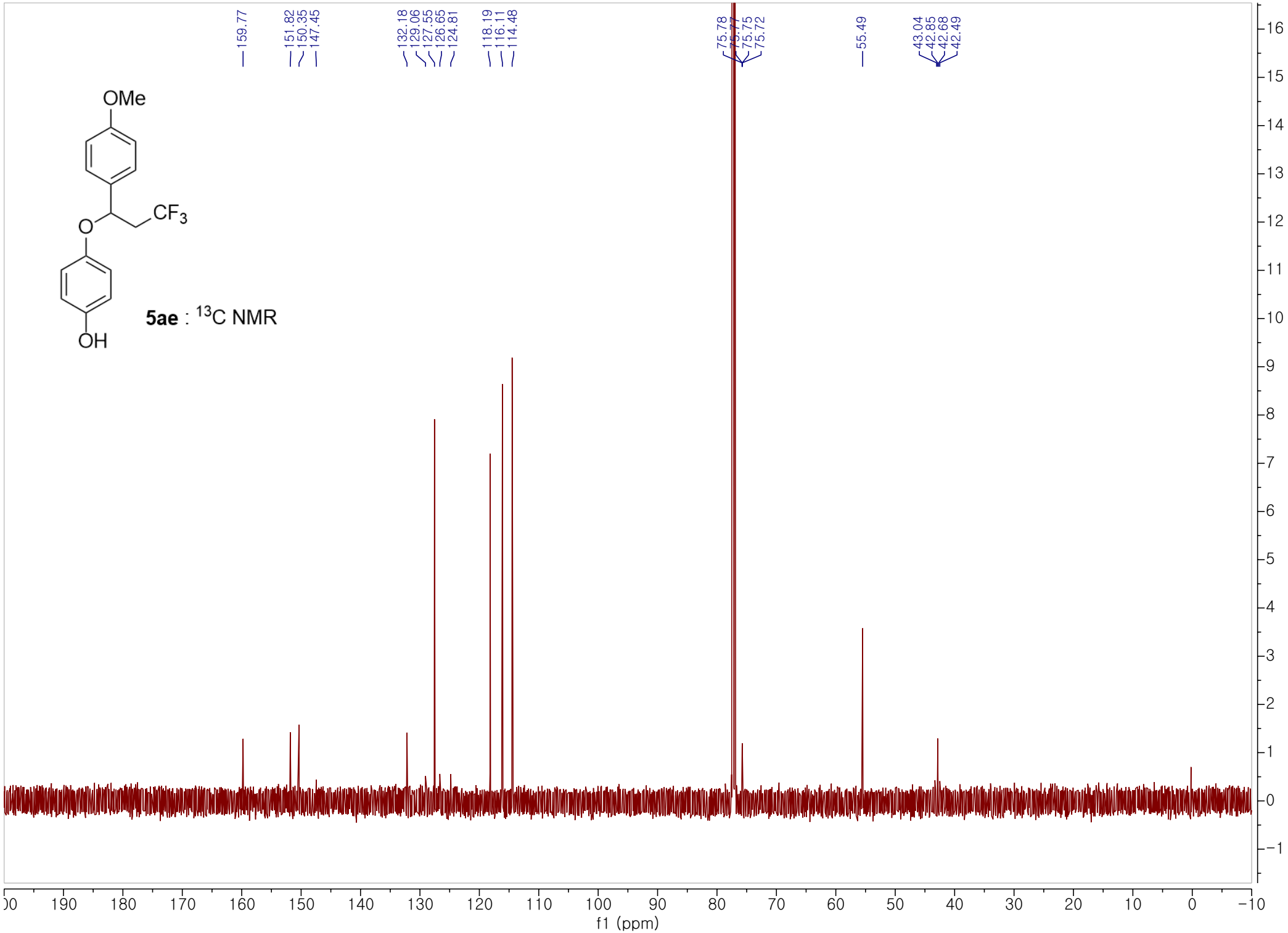

-63.78
-63.80
-63.82
Me
CF3
O
OH
5ac : 19F NMR
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

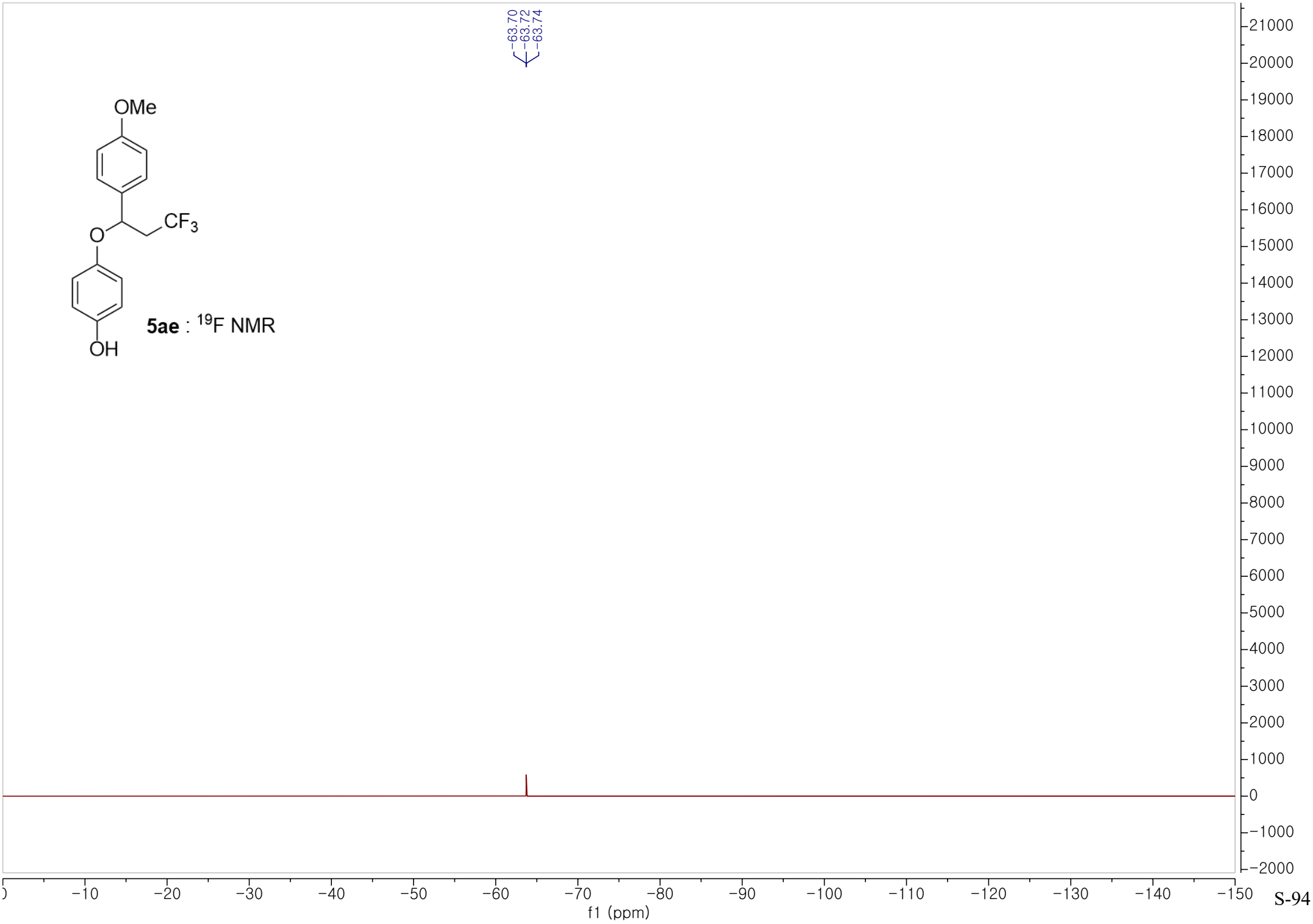

tBu
CF3
O
OH
5ad : 1H NMR
7.38
7.36
7.29
7.28
6.74
6.73
6.66
6.65
5.28
5.27
5.26
4.43
2.90
2.88
2.87
2.86
2.85
2.84
2.83
2.82
2.81
2.54
2.53
2.52
2.51
2.50
2.49
2.48
2.47
2.46
2.46
1.30
2.00
2.06
2.02
2.01
1.03
0.92
1.11
1.10
9.23
f1 (ppm)

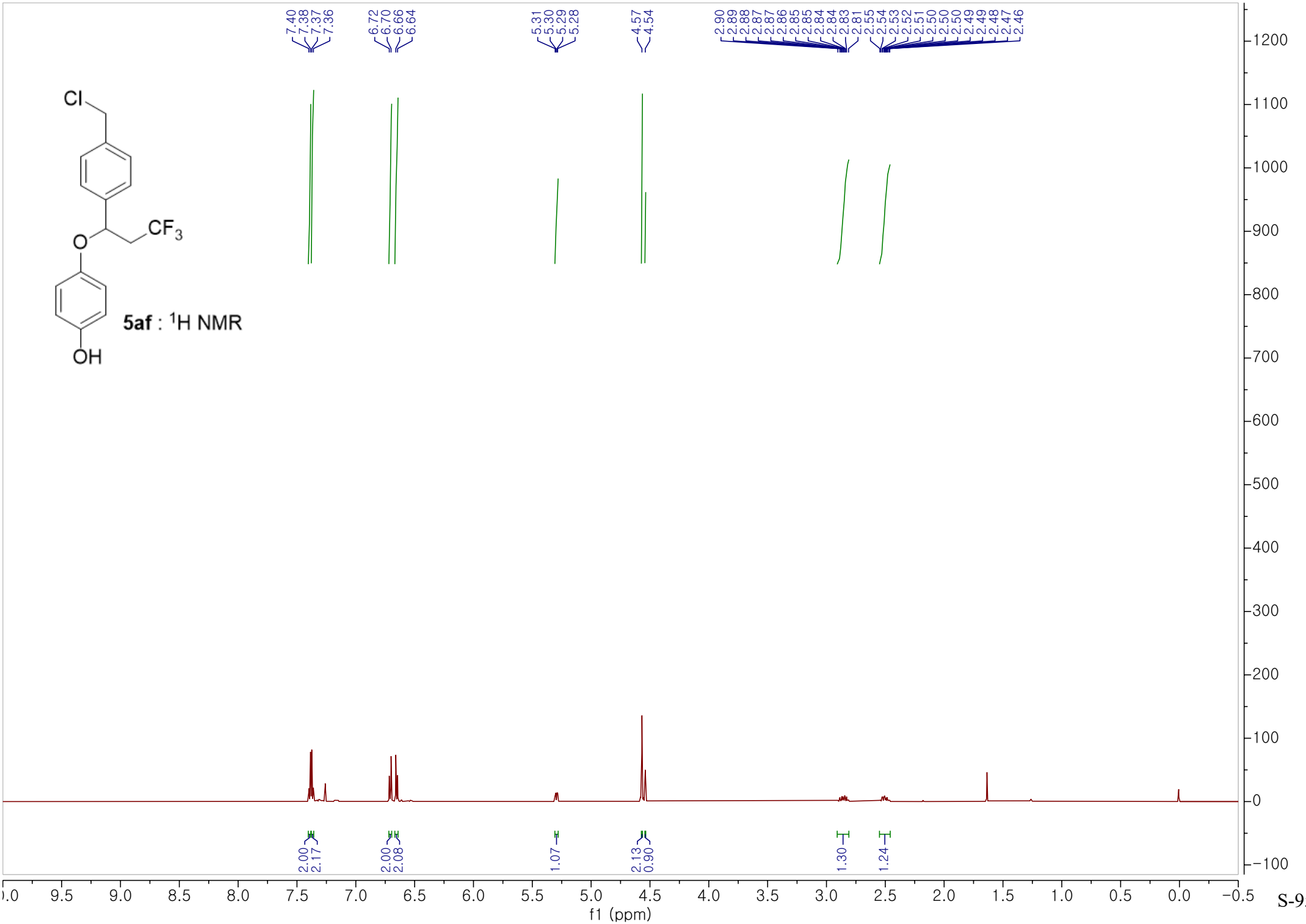

152.03
151.56
150.23
137.17
128.54
126.70
126.03
125.81
124.86
117.92
116.13
75.83
75.80
75.78
75.76
43.11
42.93
42.74
42.56
34.80
31.51
tBu
CF3
O
OH
5ad : 13C NMR
f1 (ppm)

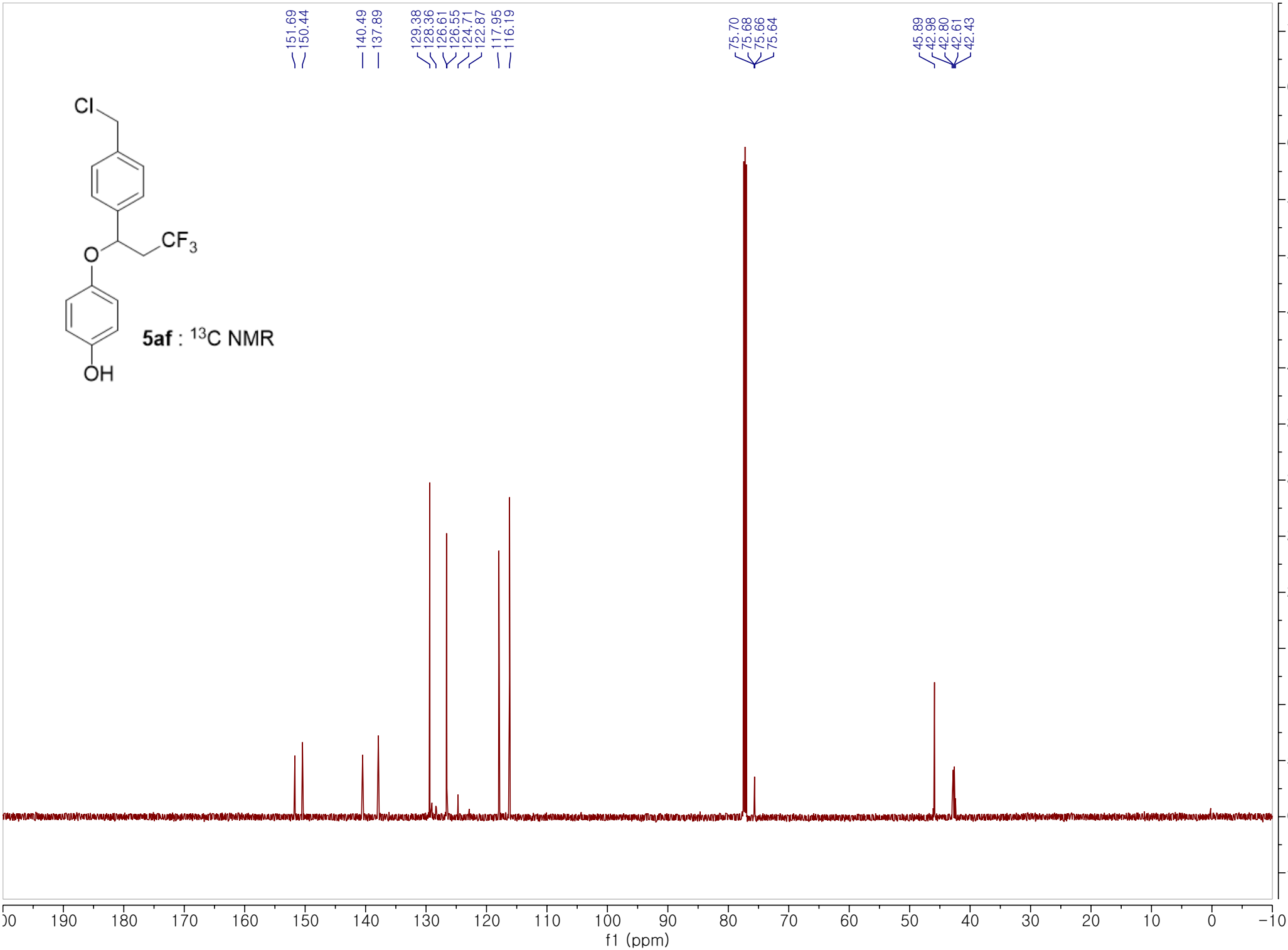

-63.81
-63.83
-63.85
tBu
CF3
O
OH
5ad : 19F NMR
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

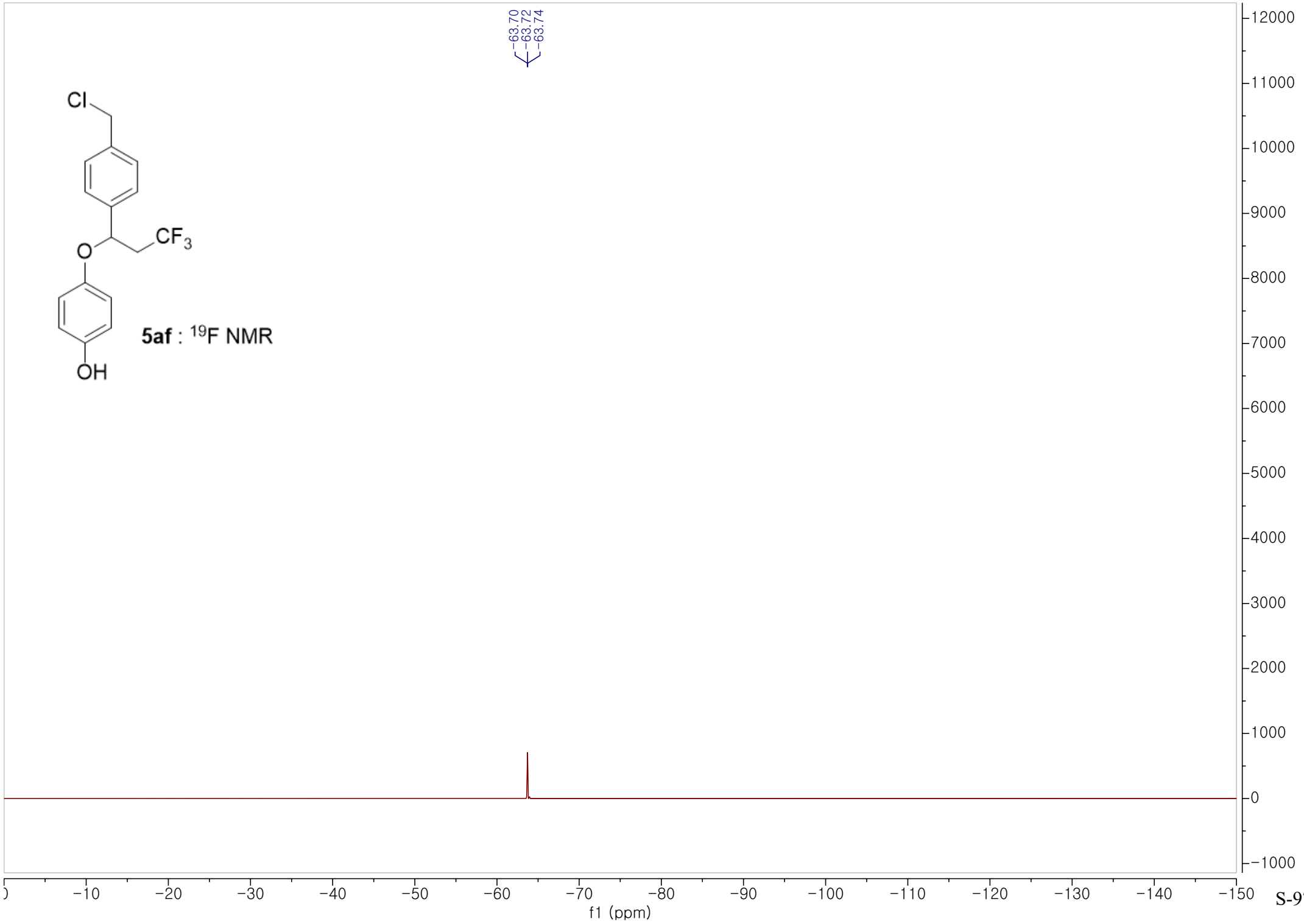

OMe
CF3
O
OH
5ae : 1H NMR
7.28
7.27
6.89
6.87
6.72
6.70
6.65
6.64
5.24
5.24
5.23
5.22
4.47
3.79
2.90
2.89
2.88
2.87
2.86
2.86
2.85
2.84
2.83
2.81
2.54
2.53
2.52
2.51
2.50
2.49
2.49
2.48
2.47
2.46
2.45
2.05
2.16
2.03
2.00
1.08
0.94
3.45
1.17
1.17
f1 (ppm)

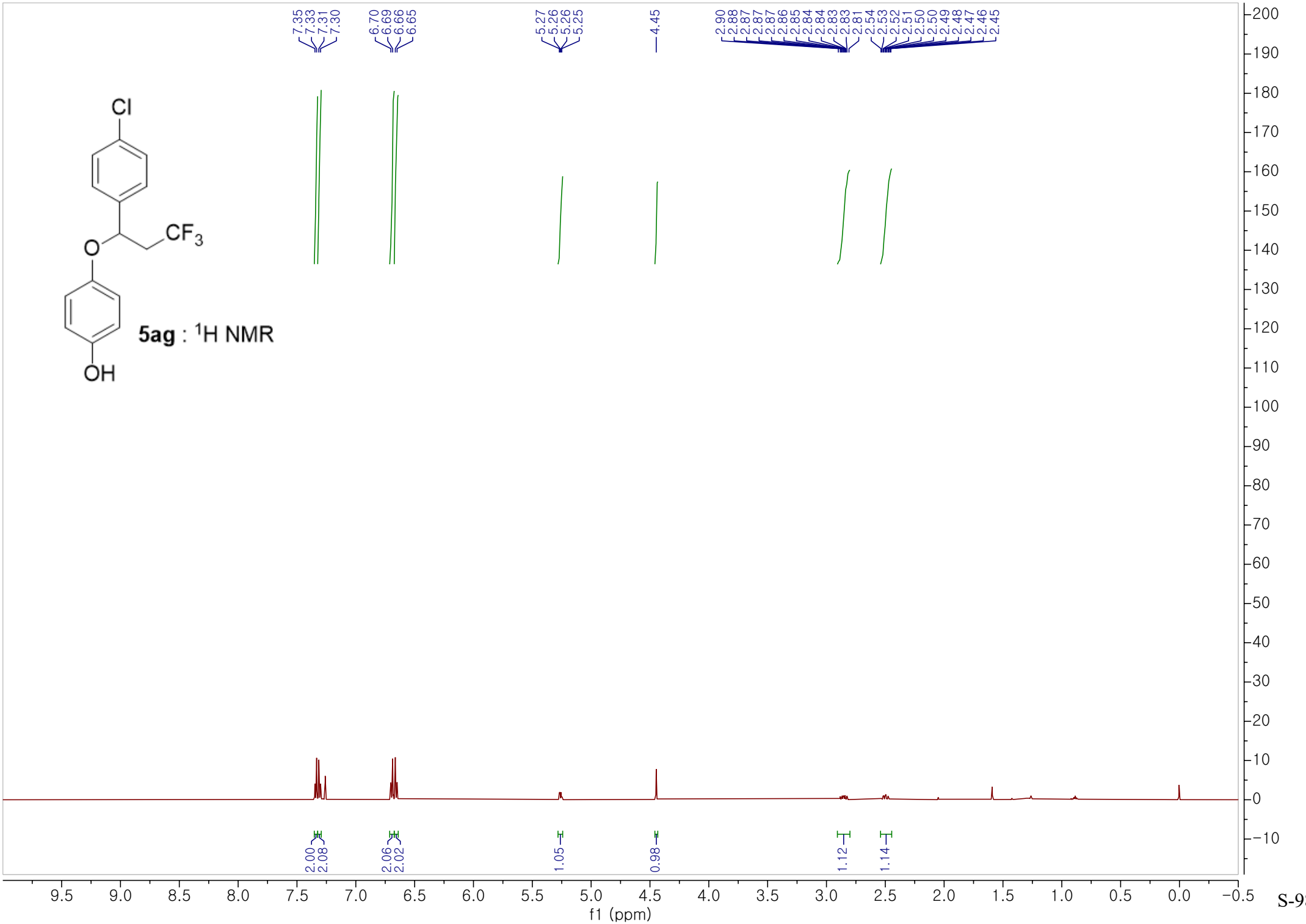

159.77
151.82
150.35
147.45
132.18
129.06
127.55
126.65
124.81
118.19
116.11
114.48
75.78
75.77
75.75
75.72
55.49
43.04
42.85
42.68
42.49
OMe
CF3
O
OH
5ae : 13C NMR
f1 (ppm)

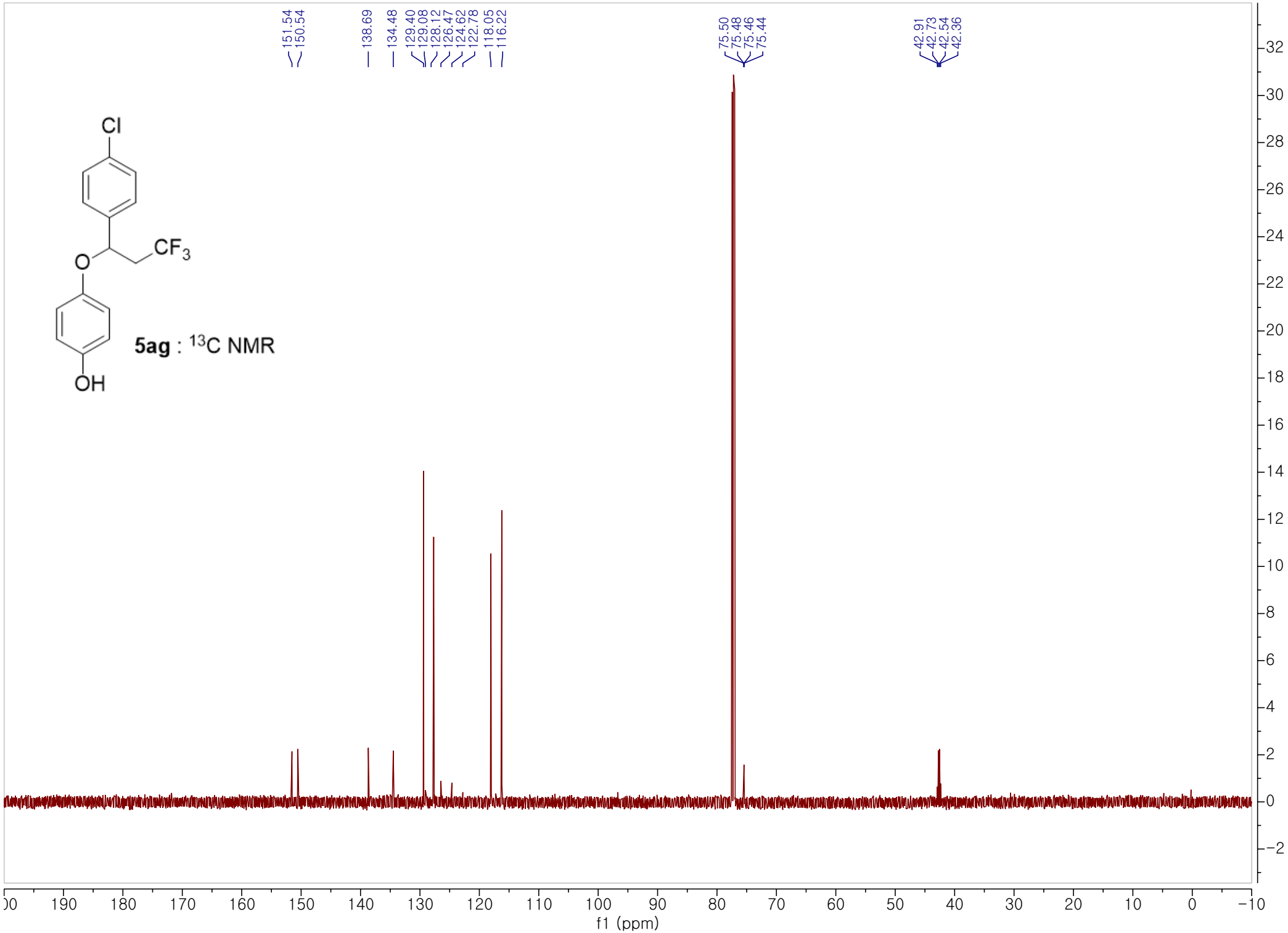

-63.70
-63.72
-63.74
OMe
CF3
O
OH
5ae : 19F NMR
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

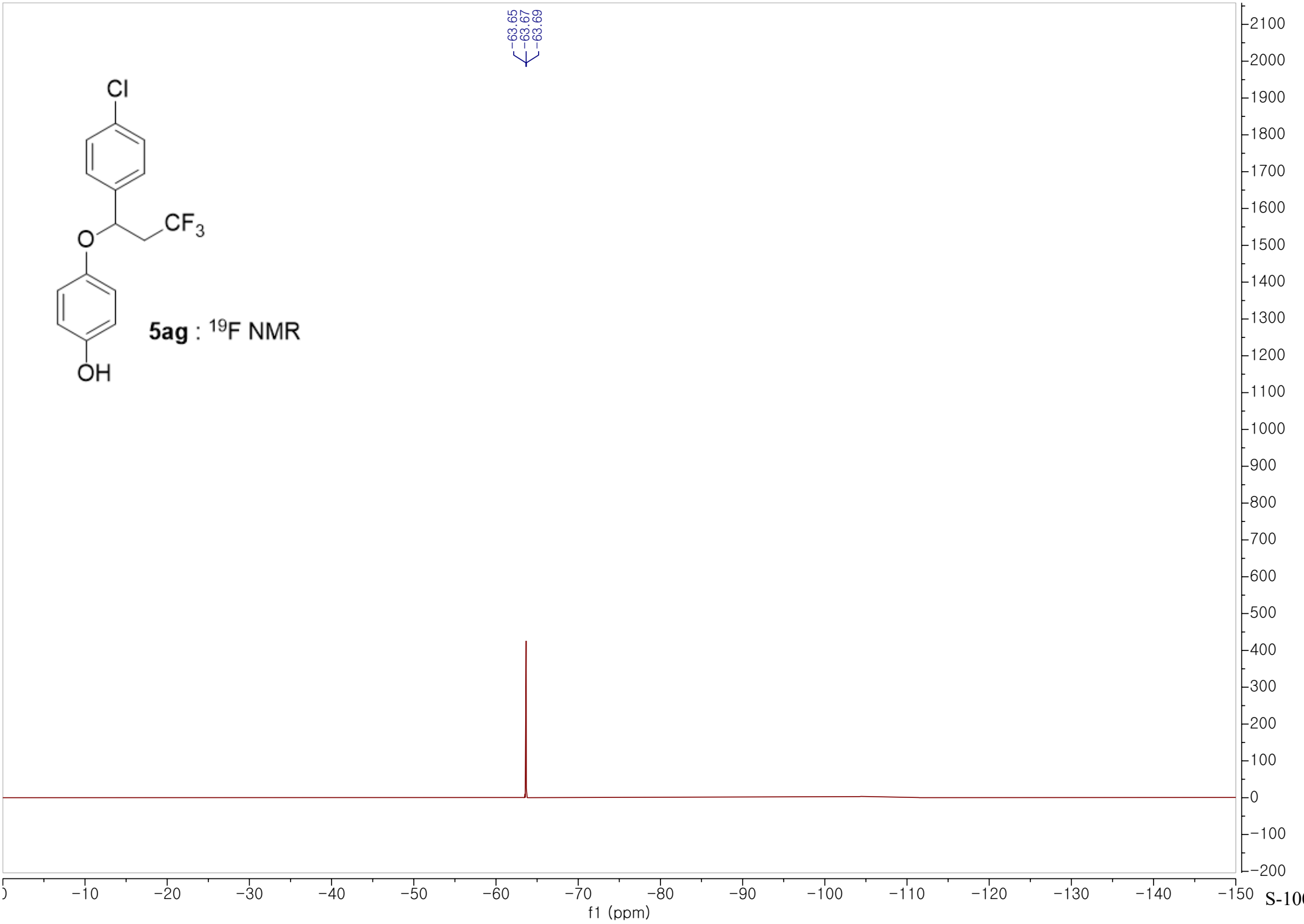

7.40
7.38
7.37
7.36
6.72
6.70
6.66
6.64
5.31
5.30
5.29
5.28
4.57
4.54
2.90
2.89
2.88
2.87
2.87
2.86
2.85
2.85
2.84
2.84
2.83
2.81
2.55
2.54
2.53
2.52
2.51
2.50
2.50
2.50
2.49
2.49
2.48
2.47
2.46
Cl
CF3
O
OH
5af : 1H NMR
2.00
2.17
2.00
2.08
1.07
2.13
0.90
1.30
1.24
f1 (ppm)

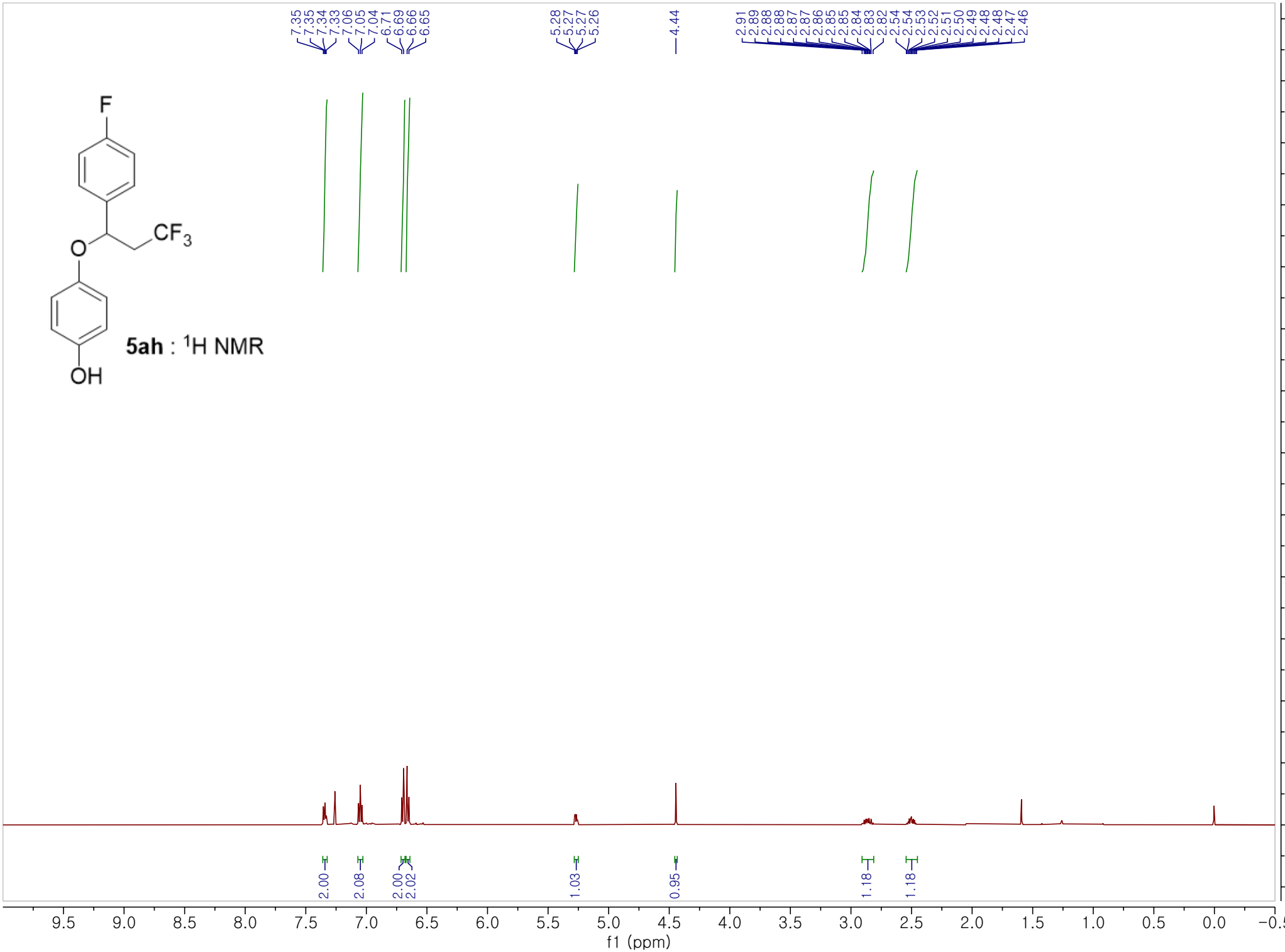

151.69
150.44
140.49
137.89
129.38
128.36
126.61
126.55
124.71
122.87
117.95
116.19
75.70
75.68
75.66
75.64
45.89
42.98
42.80
42.61
42.43
Cl
CF3
O
OH
5af : 13C NMR
f1 (ppm)

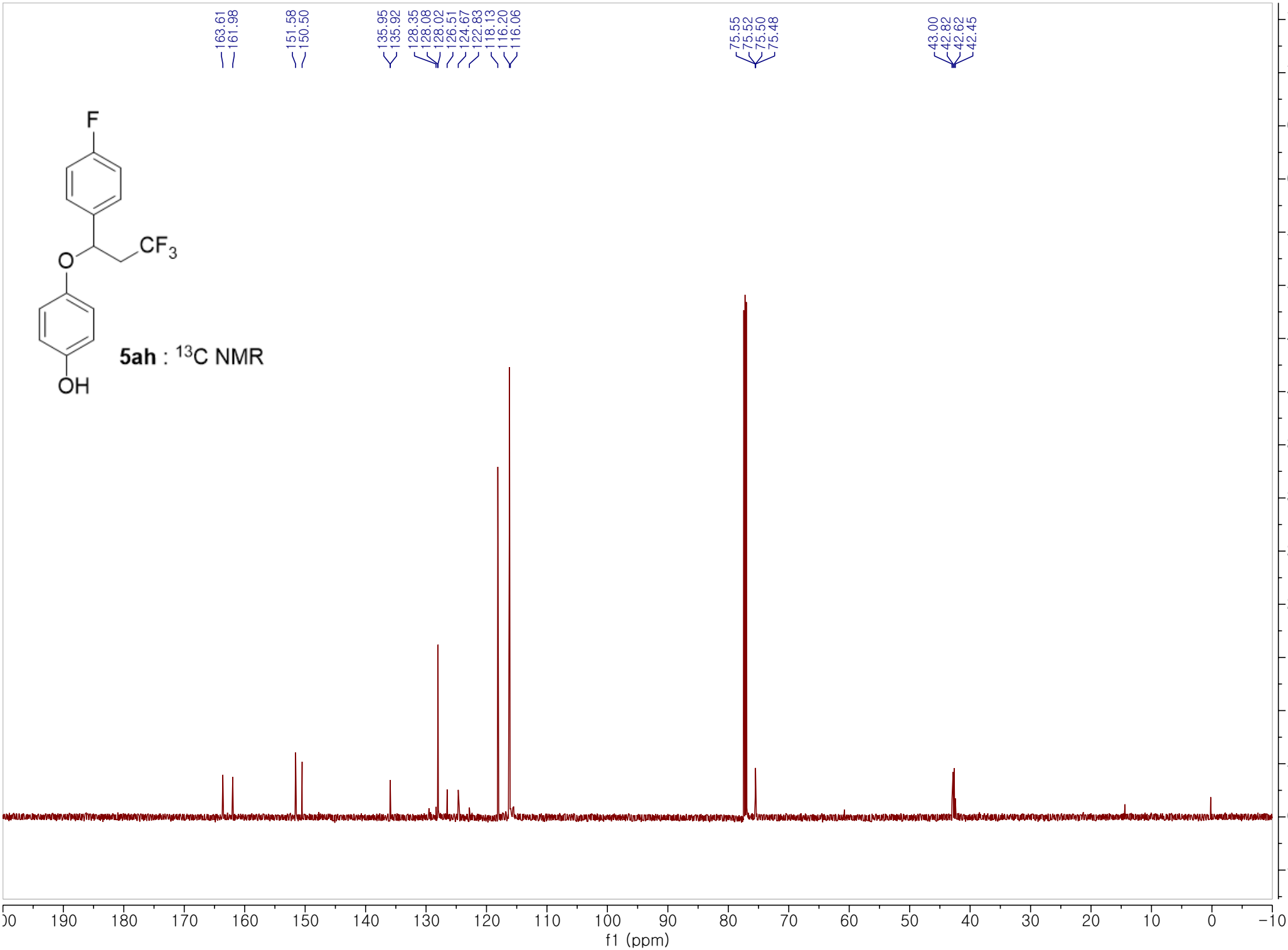

-63.70
-63.72
-63.74
Cl
CF3
O
OH
5af : 19F NMR
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

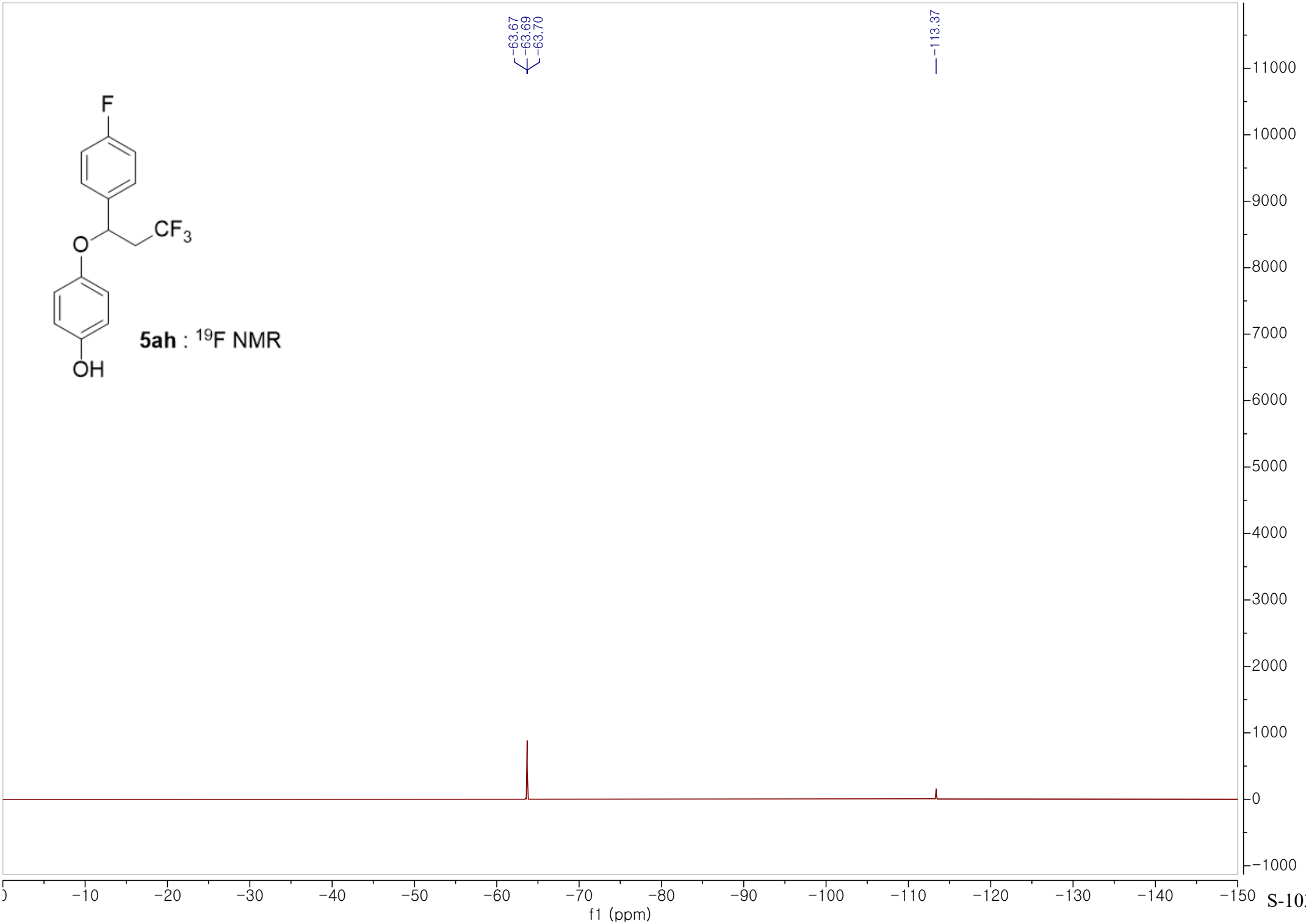

Cl
CF3
O
OH
5ag : 1H NMR
7.35
7.33
7.31
7.30
6.70
6.69
6.66
6.65
5.27
5.26
5.26
5.25
4.45
2.90
2.88
2.87
2.87
2.87
2.86
2.85
2.84
2.84
2.83
2.83
2.81
2.54
2.53
2.52
2.51
2.50
2.50
2.49
2.48
2.47
2.46
2.45
2.00
2.08
2.06
2.02
1.05
0.98
1.12
1.14
f1 (ppm)

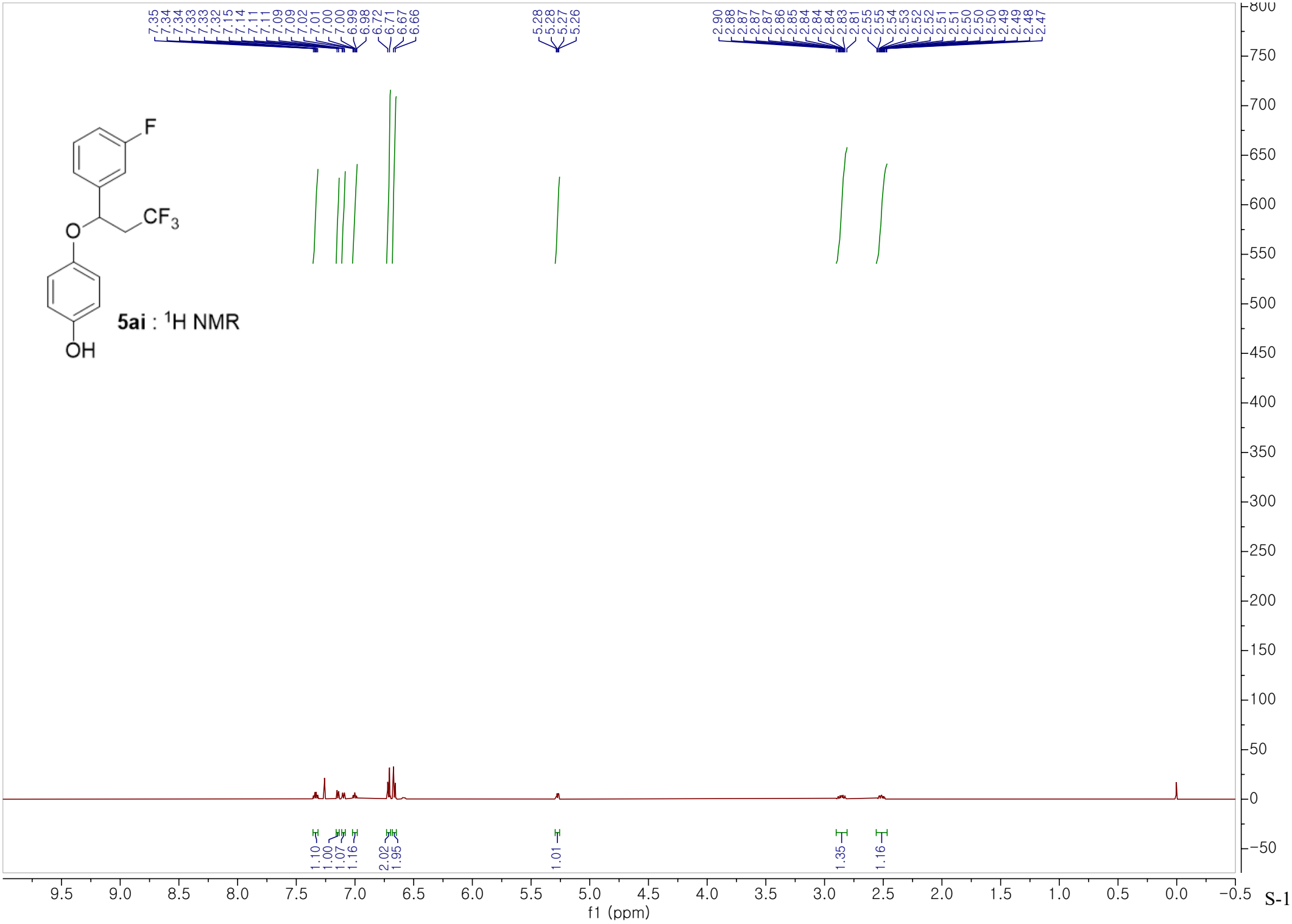

151.54
150.54
138.69
134.48
129.40
129.08
128.12
126.47
124.62
122.78
118.05
116.22
75.50
75.48
75.46
75.44
42.91
42.73
42.54
42.36
Cl
CF3
O
OH
5ag : 13C NMR
f1 (ppm)

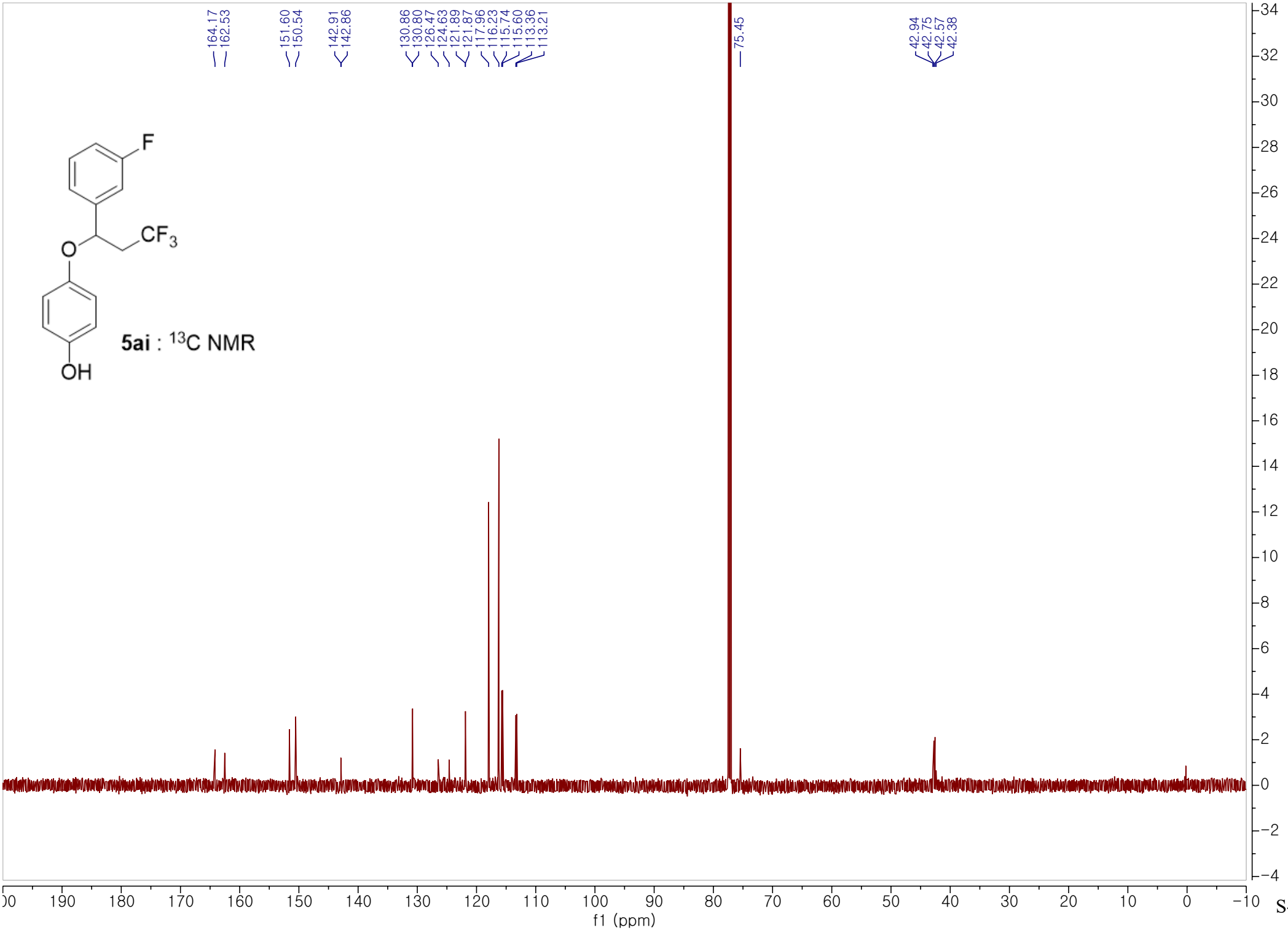

-63.65
-63.67
-63.69
Cl
CF3
O
OH
5ag : 19F NMR
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

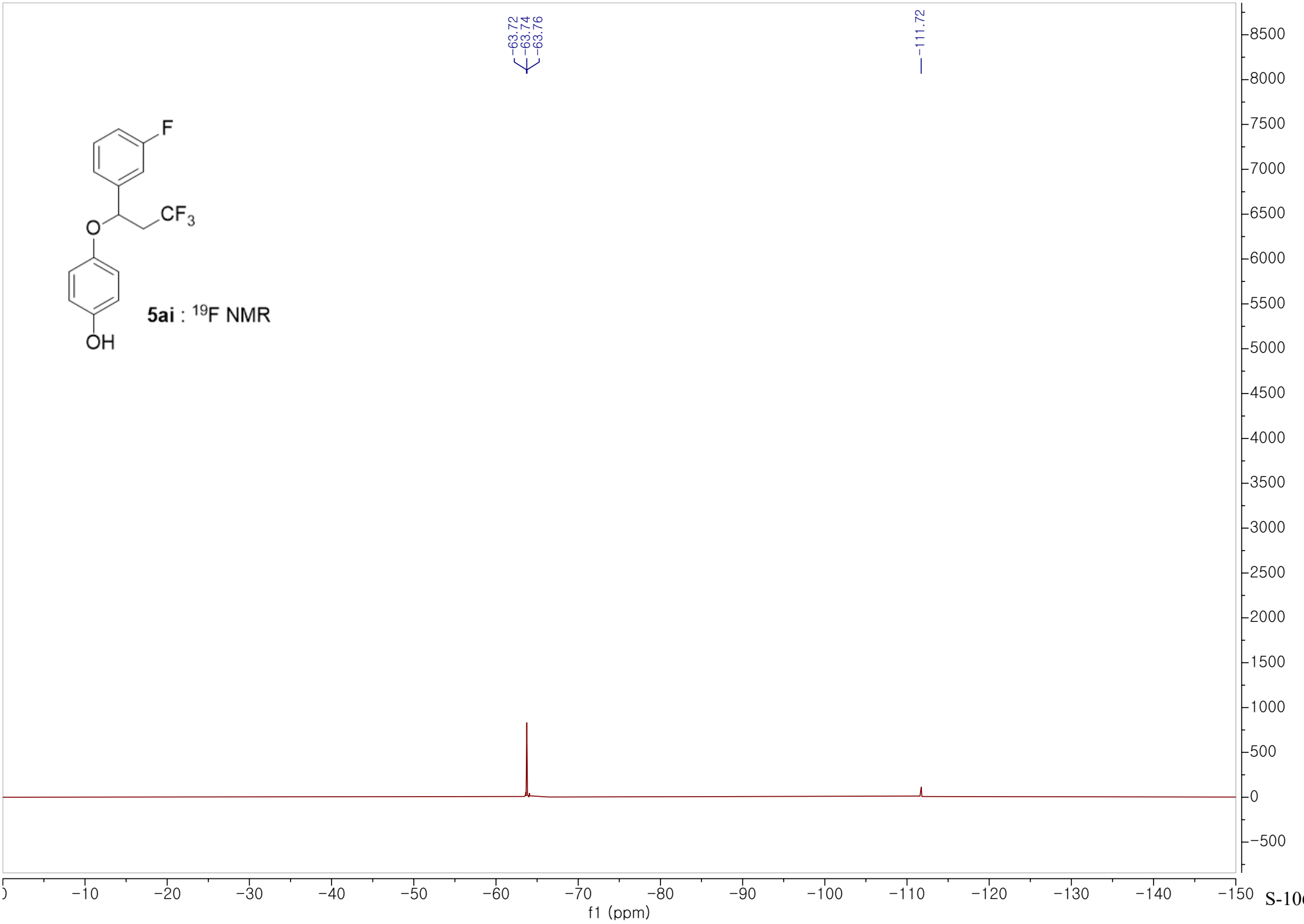

F
CF3
O
OH
5ah : 1H NMR
7.35
7.35
7.34
7.33
7.06
7.05
7.04
6.71
6.69
6.66
6.65
5.28
5.27
5.27
5.26
4.44
2.91
2.89
2.88
2.88
2.87
2.87
2.86
2.85
2.85
2.84
2.83
2.82
2.54
2.54
2.53
2.52
2.51
2.50
2.49
2.48
2.48
2.47
2.46
2.00
2.08
2.00
2.02
1.03
0.95
1.18
1.18
f1 (ppm)

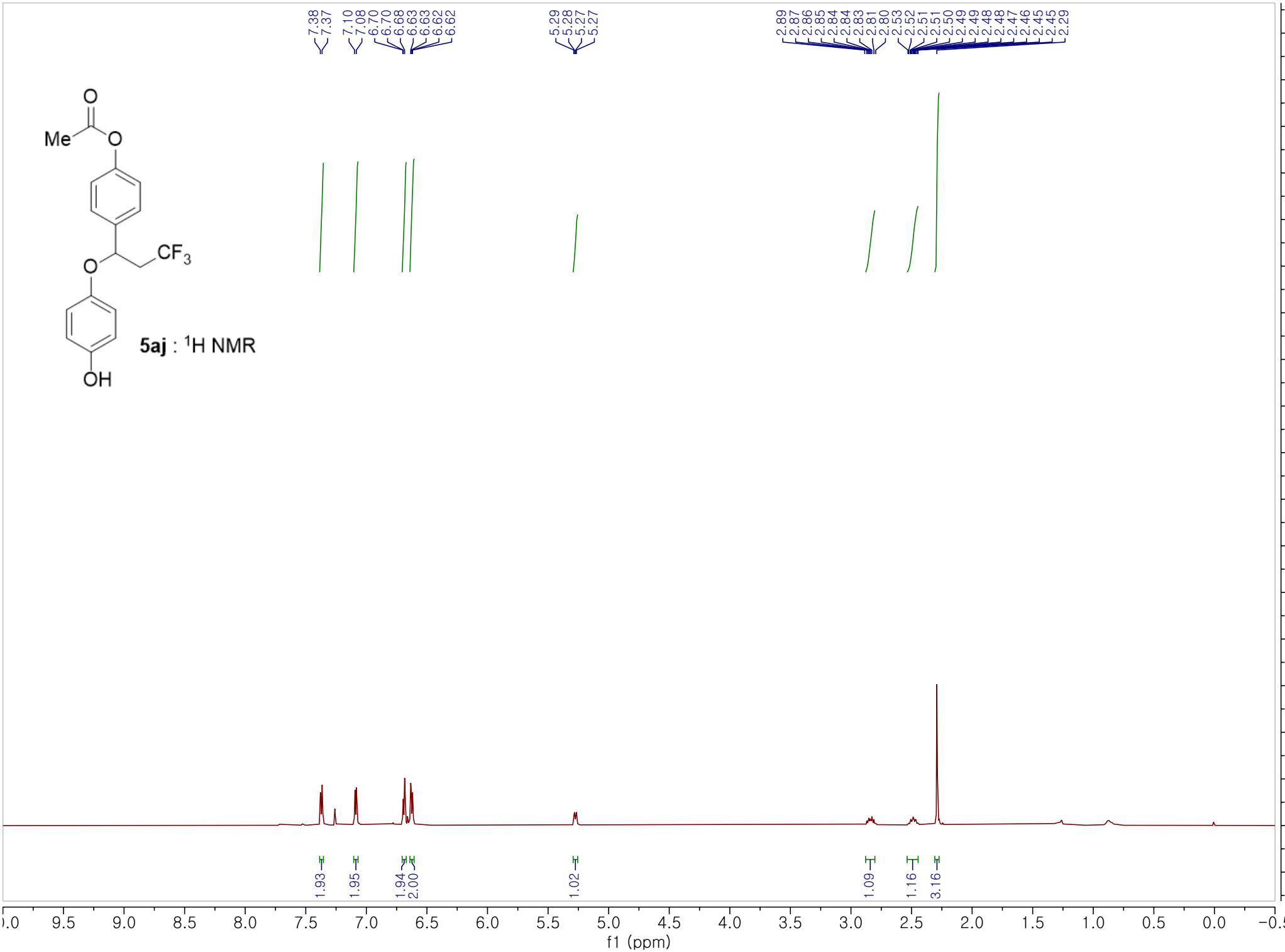

163.61
161.98
151.58
150.50
135.95
135.92
128.35
128.08
128.02
126.51
124.67
122.83
118.13
116.20
116.06
75.55
75.52
75.50
75.48
43.00
42.82
42.62
42.45
F
CF3
O
OH
5ah : 13C NMR
f1 (ppm)

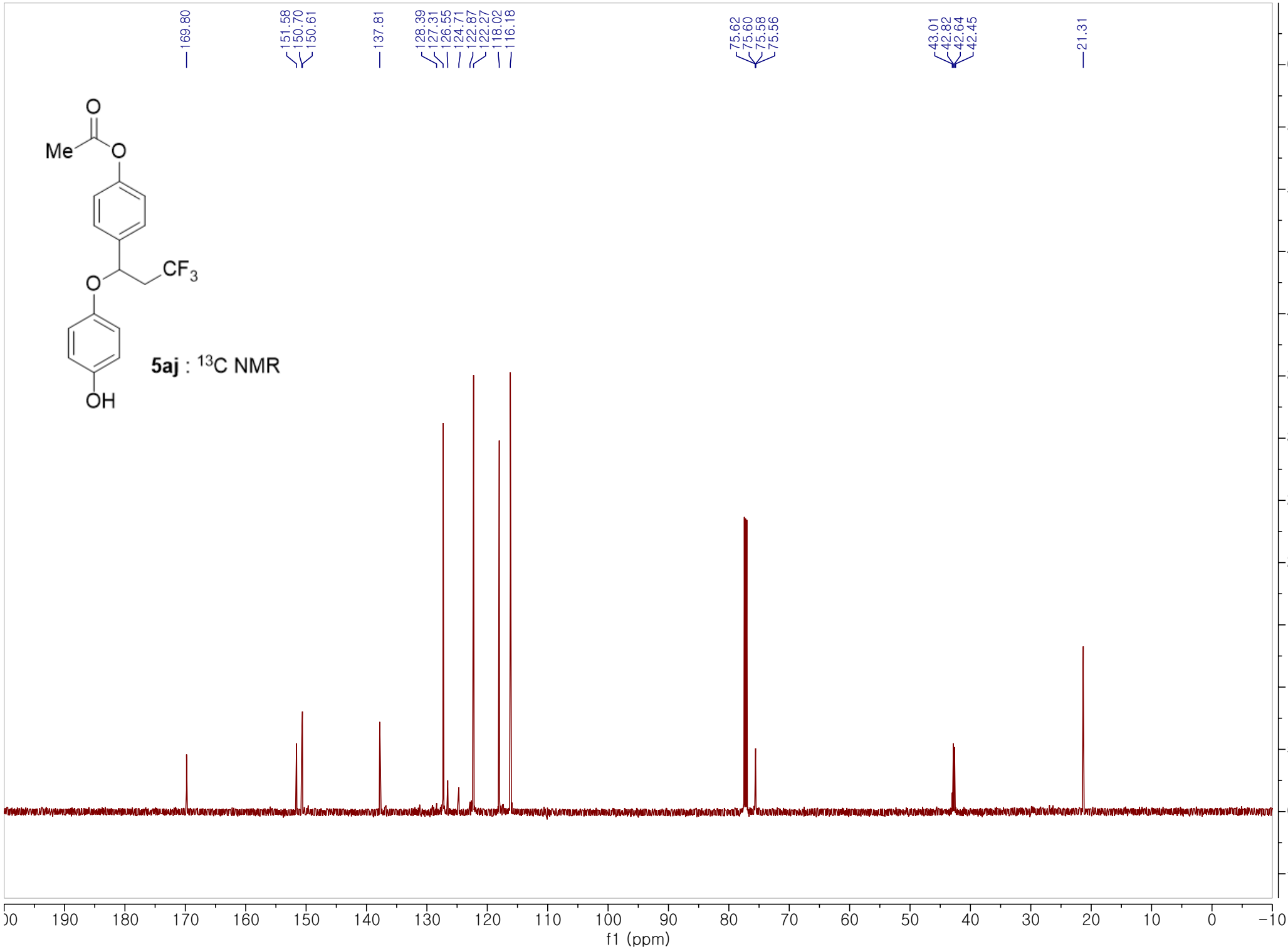

-63.67
-63.69
-63.70
-113.37
F
CF3
O
OH
5ah : 19F NMR
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

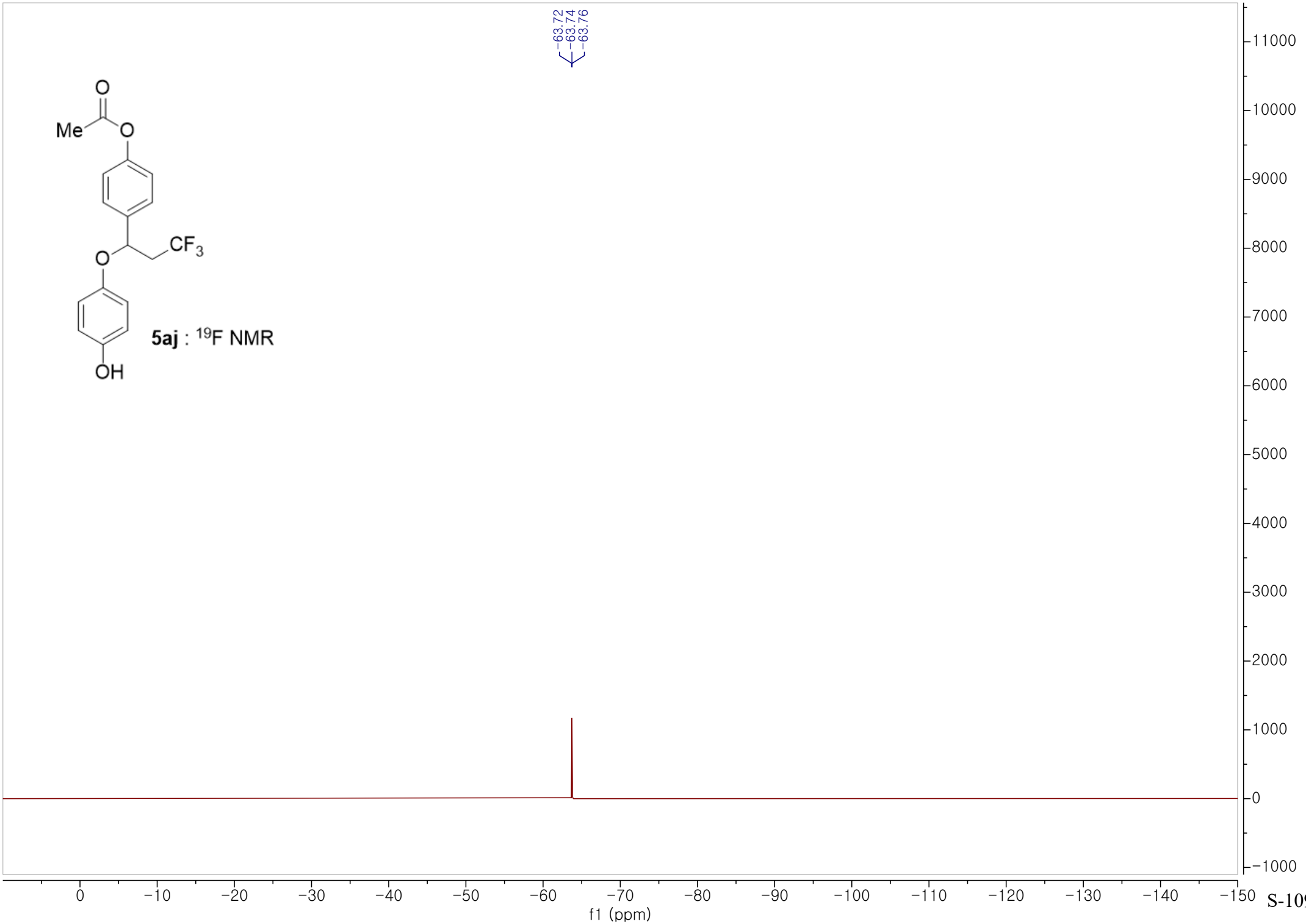

F
CF3
O
OH
5ai : 1H NMR
7.35 7.34 7.34 7.33 7.33 7.32 7.15 7.14 7.11 7.11 7.09 7.09 7.02 7.01 7.00 7.00 6.99 6.98 6.72 6.71 6.67 6.66
5.28 5.28 5.27 5.26
2.90 2.88 2.87 2.87 2.87 2.86 2.85 2.84 2.84 2.84 2.83 2.81 2.55 2.55 2.54 2.53 2.52 2.52 2.51 2.51 2.50 2.50 2.50 2.49 2.49 2.48 2.47
1.10 1.00 1.07 1.16 2.02 1.95 1.01 1.35 1.16
f1 (ppm)

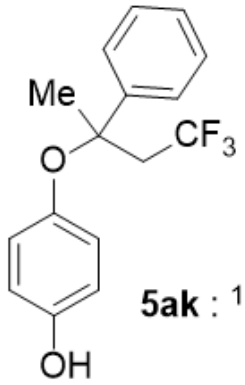

164.17
162.53
151.60
150.54
142.91
142.86
130.86
130.80
126.47
124.63
121.89
121.87
117.96
116.23
115.74
115.60
113.36
113.21
75.45
42.94
42.75
42.57
42.38
F
CF3
O
OH
5ai : 13C NMR
f1 (ppm)


-63.72
-63.74
-63.76
-111.72
F
O
CF3
OH
5ai : 19F NMR
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

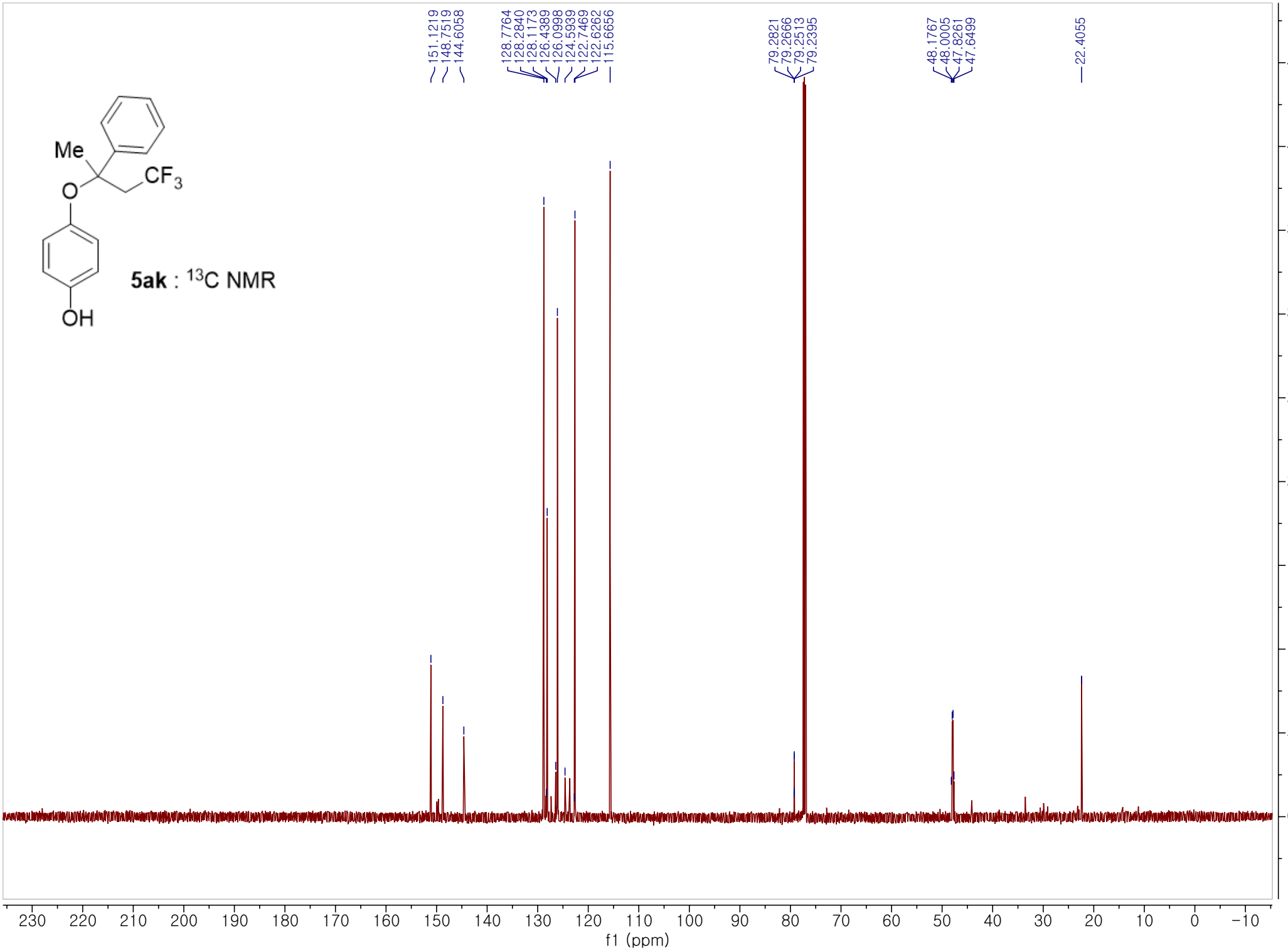

7.38
7.37
7.10
7.08
6.70
6.70
6.68
6.63
6.63
6.62
6.62
5.29
5.28
5.27
5.27
2.89
2.87
2.86
2.85
2.84
2.84
2.83
2.81
2.80
2.53
2.52
2.51
2.51
2.50
2.49
2.49
2.48
2.48
2.47
2.46
2.45
2.45
2.29
Me
O
O
CF3
O
OH
5aj : 1H NMR
1.93
1.95
1.94
2.00
1.02
1.09
1.16
3.16
f1 (ppm)

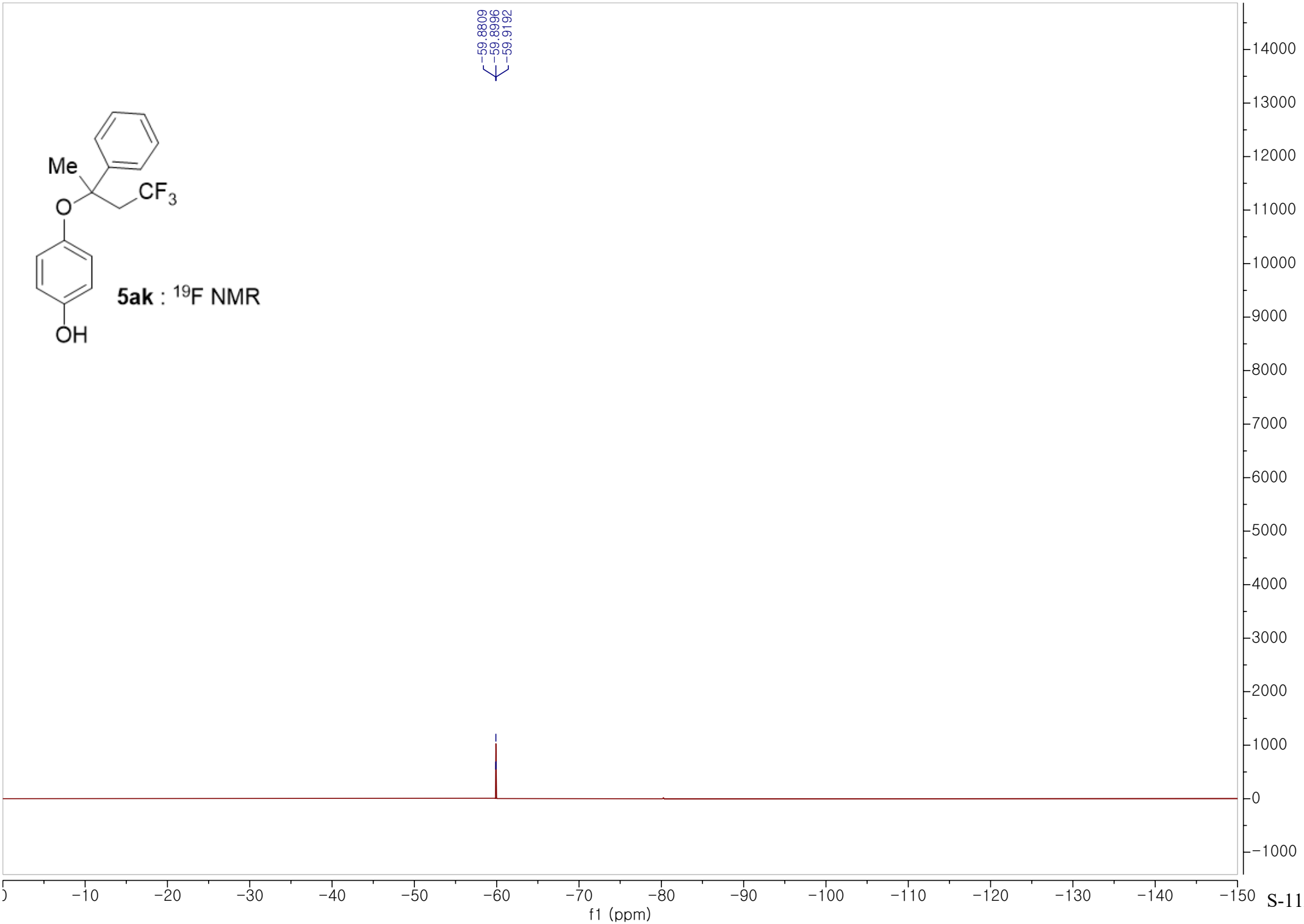

169.80
151.58
150.70
150.61
137.81
128.39
127.31
126.55
124.71
122.87
122.27
118.02
116.18
75.62
75.60
75.58
75.56
43.01
42.82
42.64
42.45
21.31
Me
O
O
CF3
O
OH
5aj : 13C NMR
f1 (ppm)

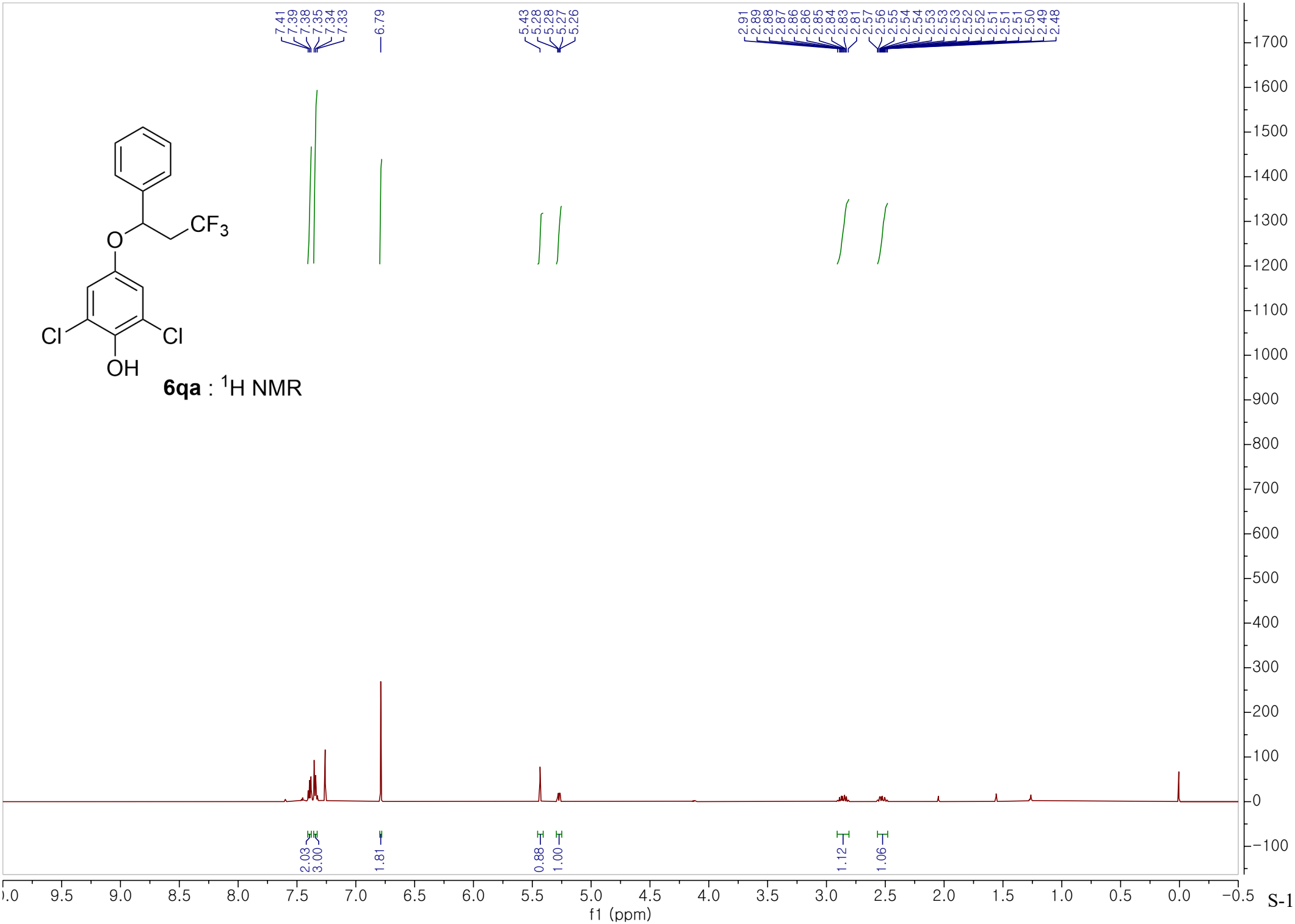

-63.72
-63.74
-63.76
Me
O
O
O
CF3
OH
5aj : 19F NMR
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

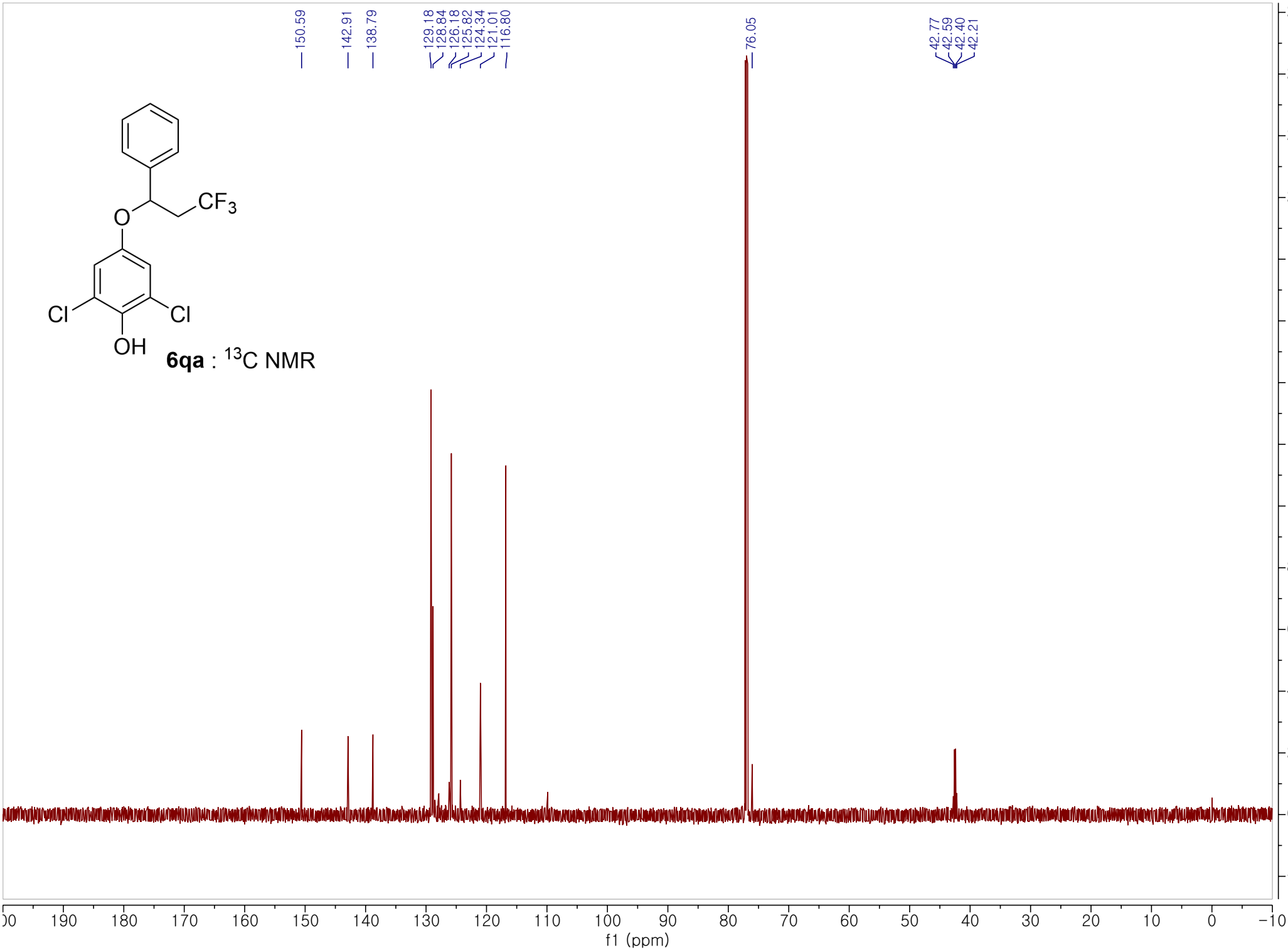


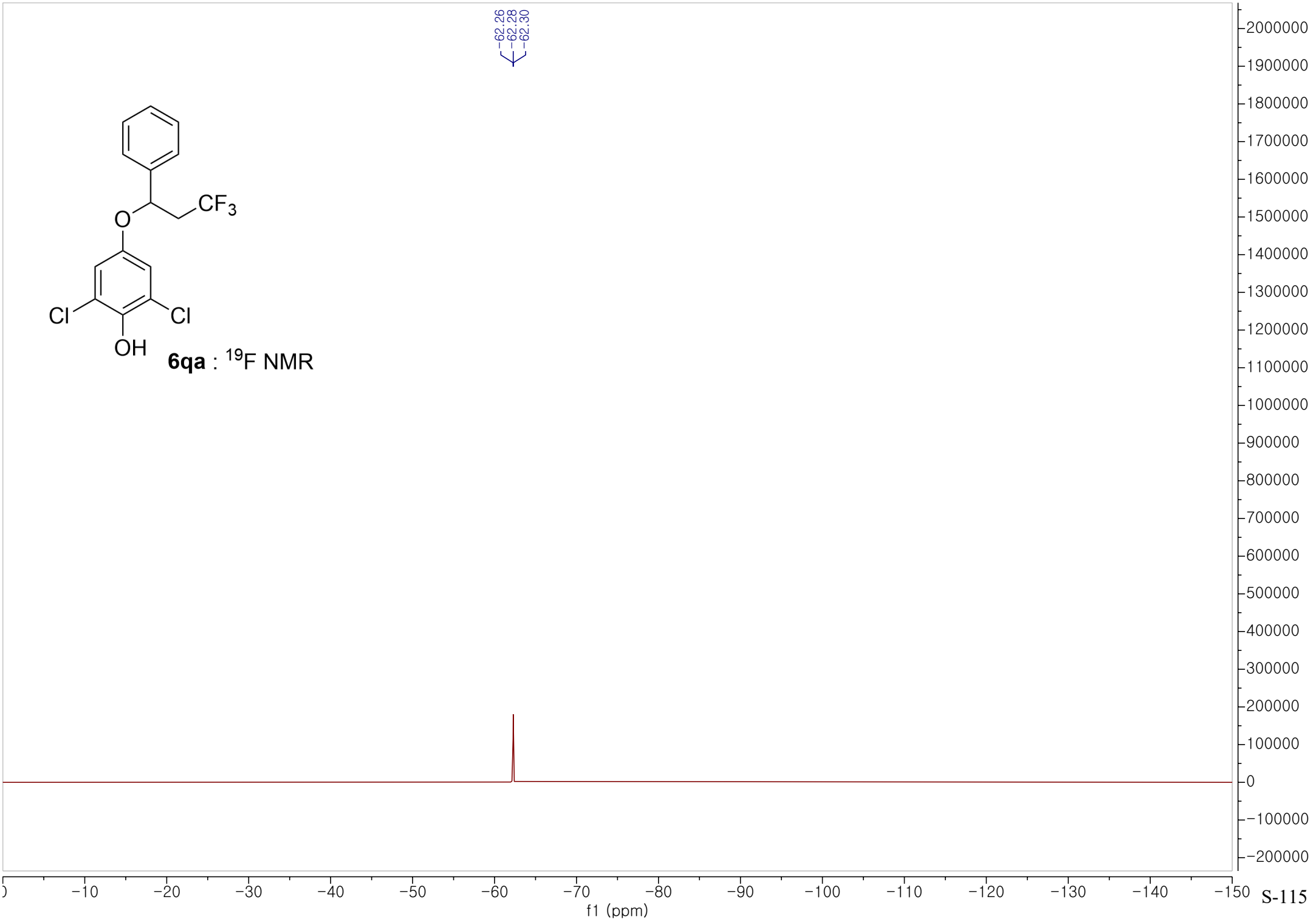
5ak : ^{1}H NMR


151.1219
148.7519
144.6058
128.7764
128.2840
128.1173
126.4389
126.0998
124.5939
122.7469
122.6262
115.6656
79.2821
79.2666
79.2513
79.2395
48.1767
48.0005
47.8261
47.6499
22.4055
Me
CF3
O
OH
5ak : 13C NMR
f1 (ppm)


-59.8809
-59.8996
-59.9192
Me
CF3
O
OH
5ak : 19F NMR
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)


7.41
7.39
7.38
7.35
7.34
7.33
6.79
5.43
5.28
5.27
5.26
2.91
2.89
2.88
2.87
2.86
2.86
2.85
2.84
2.83
2.81
2.57
2.56
2.55
2.54
2.54
2.53
2.53
2.52
2.52
2.51
2.51
2.50
2.49
2.48
CF3
O
Cl
Cl
OH
6qa : 1H NMR
2.03
3.00
1.81
0.88
1.00
1.12
1.06
f1 (ppm)


150.59
142.91
138.79
129.18
128.84
126.18
125.82
124.34
121.01
116.80
76.05
42.77
42.59
42.40
42.21
CF3
O
Cl
Cl
OH
6qa : 13C NMR
f1 (ppm)


-62.26
-62.28
-62.30
CF3
O
Cl
Cl
OH
6qa : 19F NMR
2000000
1900000
1800000
1700000
1600000
1500000
1400000
1300000
1200000
1100000
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)