Supplement Materials

Brønsted Acid Catalyzed Transoximation Reaction: synthesis of Aldoximes and Ketoximes without use of hydroxylamine salts

Kengo Hyodo,* Kosuke Togashi, Naoki Oishi, Genna Hasegawa and Kingo Uchida

Department of Material Chemistry, Faculty of Science and Technology,

Ryukoku University,

1-5 Yokotani, Oe-cho,Seta, Otsu, Shiga 520-2194, Japan

Fax: +81-77-543-7483; Tel: +81-77-543-7462; E-mail: hyodo@rins.ryukoku.ac.jp

Content

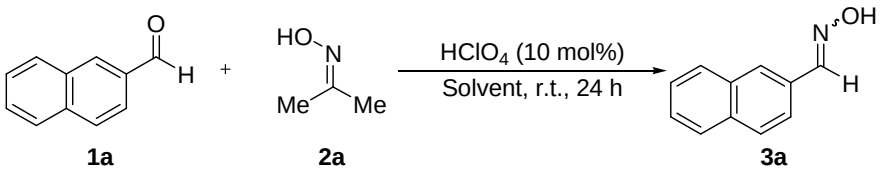
1. General Methods:

All reactions were performed in oven-dried glassware under a positive pressure of argon. Solvents were transferred via syringe and were introduced into the reaction vessels through a rubber septum. All reactions were monitored by thin-layer chromatography (TLC) carried out on 0.25 mm Merck silica-gel (60-F254). The TLC plates were visualized with UV light and 7% phosphomolybdic acid or basic $KMnO_4$ in H_2O/heat. Column chromatography was carried out on a column packed with silica-gel 60N spherical neutral size 63-210 μm. ^1H NMR (400 MHz), ^{19}F NMR (376 MHz) and ^{13}C NMR (100 MHz) spectra for solution in $CDCl_3$, or CD_2Cl_2 or CD_3CD d_6-DMSO were recorded on a JEOL RESONANCE JNM-ECS-400. Chemical shifts (δ) are expressed in ppm downfield from internal TMS or $CHCl_3$ or CH_2Cl_2 or CH_3CN or DMSO or C_6F_6. EI-MS were recorded on a SHIMADZU GC-MS QP-2010 Plus (Column: Frontier Lab UltraALLOY-5(MS/HT) (30 m, 0.25 mmID, 0.25 μm film), He: 30 psi mL/min, condition: 70 °C to 120 °C, 5 °C/min). ESI-MS were recorded on a SHIMADZU LC-MS-2020 or Agilent G1956B LCMS system with 1100 Series HPLC. Infrared spectra were recorded on a JASCO FT/IR-660 Plus. CH_2Cl_2 was used after distillation from CaH_2. The amount of water contented in distilled CH_2Cl_2 was measured by Karl-Fisher Moisture Titrator MKC 510N, Kyoto Electronics Manufacturing Co., Ltd. All aldehydes and ketones are commercial available. 70 wt% perchloric acid aqueous solution was purchased from Nacalai Tesque, Inc. Iron (II) perchlorate hexahydrate was purchased from Wako Pure Chemical Industries, Ltd. 2-Butanone oxime and ethyl acetohydroxamate were purchased from Tokyo Chemical Industry Co., Ltd. Anhydrous $HClO_4 \cdot NH_2OH$ ethanol solution was purchased from Nacalai Tesque, Inc. All aldoximes and ketoximes were characterized by ^1H NMR to compare to previous report.[1-11]

2. Optimization of Reaction Conditions

Solvent effect

Table S1. Screening of solvents[a]



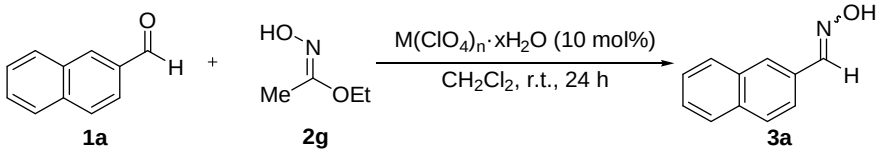
1a **2a** **3a**

Entry	Solvent	E/Z (-)[b]	Yield (%)[c]
1	CH_2Cl_2	99/1	65
2	THF	-	0
3	Toluene	96/4	37
4	CH_3CN	92/8	52
5	Et_2O	97/3	33
6	Acetone	-	31
7	EtOH	87/13	47
8	H_2O	99/1	90

a) Reaction conditions: 1a (0.16 mmol), 2a (0.24 mmol), 70 wt% $HClO_4$ (10 mol%) in CH_2Cl_2 at r.t. for 24 h. b) *E*/*Z* ratio was determined by ^{1}H NMR from crude mixtures. c) Isolated yield.

Catalyst effect

Table S2. Screening of perchloric acid and metal perchlorate salts[a]



1a **2g** **3a**

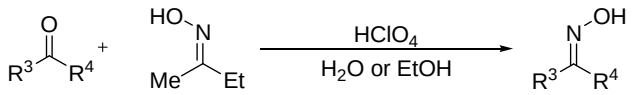
Periodic table of the $M(ClO_4)_n \cdot xH_2O$

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**H** 96% yield E/Z=97/3 n=1, x=2.4													
2	**Li** 0% yield n=1, x=3	Be										B	C	**NH_4** 0% yield n=1, x=0
3	Na	Mg										**Al** 90%yield E/Z=96/4 n=3, x=9	Si	P
4	**K** 0% yield n=1, x=0	**Ca** 65% yield E/Z=93/7 n=2, x=4	**Sc** 98% E/Z= 97/3 n=3, x=6	Ti	V	Cr	**Mn** 20% yield E/Z= 89/11 n=2, x=6	**Fe** 99% yield E/Z=96/4 n=2, x=6	**Co** 83% yield E/Z=99/1 n=2, x=6	**Ni** 62% yield E/Z=100/0 n=2, x=6	**Cu** 36% yield E/Z=86/14 n=2, x=6	**Zn** 70% yield E/Z= 99/1 n=2, x=6	Ga	Ge
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	**Ag** 0% yield n=1, x=0	Cd	In	Sn

a)Reaction conditions: **1a** (0.16 mmol), **2g** (0.24 mmol), catalyst (10 mol%) in CH_2Cl_2 at r.t. for 24 h. E/Z ratio was determined by ^{1}H NMR from crude mixtures. Isolated yield.

3. Synthetic Procedures

General procedure for aldoxime synthesis via transoxoimation

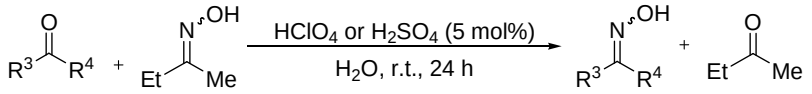


1 **2d** **3**

To a 50 mL flask were added to aldehyde or ketone (11 mmol, 1.0 eq.), H_2O or EtOH (0.2 M), 70 wt% $HClO_4$ aq (5-30 mol%) under N_2 at indicated temperature in Table 3. Then methyl ethyl ketone (1.5 equiv.) was added to stirred reaction mixtures. After reaction mixtures turned to white suspension for 24 h, the white solid was collected by filtration and washed using water (10 mL). The collected product was dried over P_2O_5 under vacuum for 12 h to remove water.

If white suspension was not observed in the reaction mixtures after 24 hours, the reaction mixtures were extracted with AcOEt (50 mL×3). The combined organic layer was washed with brine (50 mL) and dried over Na_2SO_4. After removal of Na_2SO_4 from organic layer, solvent was evaporated under reduced pressure. The remained crude mixtures was purified by silica gel column chromatography (hexane/Ethyl acetate = 90/10 or hexane/Ethyl acetate = 50/50 or hexane/dichloromethane = 2/8 to dichloromethane/Et_2O = 95/5) and white solid product or colorless oil was obtained.

Table S3. Scope of Substrates catalyzed by $HClO_4$ or H_2SO_4

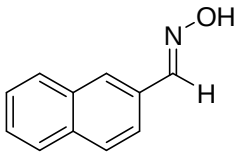


1 **2d** **3** **4d**

Entry	**1**	**3**	$HClO_4$ *E*/*Z*[b]	$HClO_4$ Yield (%)[c]	H_2SO_4 *E*/*Z*[b]	H_2SO_4 Yield (%)[c]
1	**1a**	**3a**	99/1	95	99/1	94
2	**1b**	**3b**	99/1	91	99/1	94
3	**1c**	**3c**	92/8	99	99/1	81
4	**1d**	**3d**	99/1	92	99/1	91
5	**1e**	**3e**	99/1	90	99/1	87
6	**1f**	**3f**	99/1	90	99/1	89
7	**1g**	**3g**	99/1	97	99/1	90
8	**1h**	**3h**	99/1	95	99/1	86
9	**1i**	**3i**	52/48	98	19/81	91
10	**1j**	**3j**	99/1[e]	93	99/1[e]	85
11[d]	**1k**	**3k**	54/46[e]	85	32/68[e]	99
12	**1l**	**3l**	99/1	95	99/1	85
13[f]	**1m**	**3m**	99/1	74(93)[g]	99/1	58
14[h]	**1n**	**3n**	76/24[e]	82	71/29[e]	76
15[f]	**1o**	**3o**	88/12[e]	70(97)[g]	89/11[e]	52
16[f]	**1p**	**3p**	-	41(97)[i]	-	31
17[h]	**1q**	**3q**	-	93	-	90
18	**1r**	**3r**	64/36	84	66/34	80

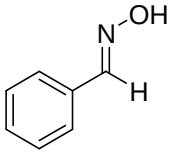
a) Reaction conditions: **1** (11 mmol, gram scale), **2d** (1.5 equiv.), $HClO_4$ (5 mol%) in H_2O (0.20 M) at r.t. b) *E*/*Z* ratio was determined by ^1H NMR. c) Isolated yield. d) 10 mol% catalyst was used at 40°C. e) This means the ratio of major and minor isomer. f) 30 mol% catalyst was used in EtOH at reflux. g) **2g** was used instead of **2d** with 5 mol% $HClO_4$ at r.t. h) 10 mol% catalyst was used at reflux. i) **2g** was used instead of **2d** at 40°C.

(*E*)-2- Naphthaldoxime (3a)[1)]



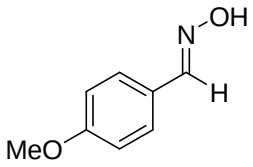
^1H NMR (400 MHz, $CDCl_3$) δ 7.48-7.52 (m, 2H), 7.84-7.86 (m, 4H), 7.87 (s, 1H), 8.29 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 122.9, 126.8, 127.2, 128.0, 128.5, 128.8, 128.9, 129.8, 133.3, 134.3, 150.7; MS (ESI, negative) m/z calcd. for $C_{11}H_8NO$ [M-H]: 170.06, Found 170.10.

(*E*)-Benzaldoxime (3b)[2)]



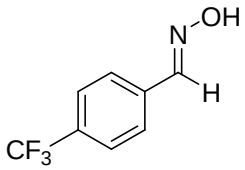
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.41 (m, 3H), 7.57-7.59 (m, 2H), 8.16 (s, 1H), 8.38 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 127.2, 128.9, 130.2, 132.0, 150.5; MS (APCI, negative) m/z calcd. for C_7H_6NO [M-H]: 120.05, Found 120.05.

(*E*)-4-Anisaldoxime (3c)[2)]



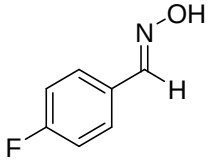
^{1}H NMR (400 MHz, $CDCl_3$) δ 3.83 (s, 3H), 6.90 (d, J = 8.5 Hz, 2H), 7.52 (d, J = 8.5 Hz, 2H), 8.11 (s, 1H), 8.67 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 55.4, 114.4, 124.6, 128.7, 150.0, 161.2; MS (ESI, negative) m/z calcd. for $C_8H_8NO_2$ [M-H]: 150.06, Found 150.10.

(*E*)-α,α,α-Trifluoro-4-tolubenzaldoxime (3d)[3)]



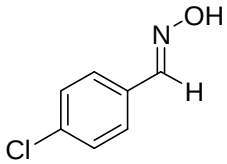
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.5 Hz, 2H), 7.70 (d, J = 8.5 Hz, 2H), 8.18 (br, 1H), 8.19 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -66.0 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 124.0 (q, $J_{C\text{-}F}$ = 271 Hz), 125.9 (q, $J_{C\text{-}F}$ = 3.8 Hz), 127.4, 131.9 (q, $J_{C\text{-}F}$ = 32 Hz), 135.4, 149.3; MS (ESI, negative) m/z calcd. for $C_8H_5F_3NO$ [M-H]: 188.03, Found 188.05.

(*E*)-4-Fluorobenzaldoxime (3e)[2)]



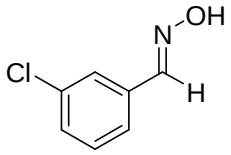
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (m, 2H), 7.57 (m, 2H), 8.13 (s, 1H), 8.29 (br, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.23 (s, 1F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 116.1 (d, $J_{C\text{-}F}$ = 21.9 Hz), 128.2 (d, $J_{C\text{-}F}$ = 3.3 Hz), 129.1 (d, $J_{C\text{-}F}$ = 8.3 Hz), 149.5 (d, $J_{C\text{-}F}$ = 1.2 Hz), 164.0 (d, $J_{C\text{-}F}$ = 249 Hz); MS (ESI, negative) m/z calcd. for C_7H_5FNO [M-H]: 138.04, Found 138.10.

(*E*)-4-Chlorobenzaldoxime (3f)[2)]



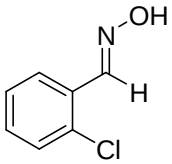
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, J = 8.5 Hz, 2H), 7.51 (d, J = 8.5 Hz, 2H), 8.12 (s, 1H), 8.40 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 128.4, 129.2, 130.4, 136.2, 149.5; MS (ESI, negative) m/z calcd. for C_7H_5ClNO [M-H]: 154.01, Found 154.05.

(*E*)-3-Chlorobenzaldoxime (3g)[3)]



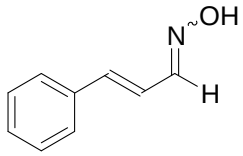
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.38 (m, 2H), 7.44 (d, J = 7.3 Hz, 1H), 7.59 (s, 1H), 8.10 (s, 1H), 8.24 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 125.4, 127.0, 130.2, 130.2, 133.7, 135.0, 149.4; MS (ESI, negative) m/z calcd. for C_7H_5ClNO [M-H]: 154.01, Found 154.00.

(*E*)-2-Chlorobenzaldoxime (3h)[2)]



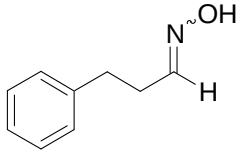
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25-7.34 (m, 2H), 7.39 (d, J = 8.0 Hz, 1H), 7.82 (dd, J = 1.8, 7.7 Hz, 1H), 8.42 (br, 1H), 8.58 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 127.2, 127.3, 129.7, 130.1, 131.2, 134.1, 147.8; MS (ESI, negative) m/z calcd. for C_7H_5ClNO [M-H]: 154.01, Found 154.00.

***trans*-Cinnamaldoxime (3i)**[2)]



(*E*)-**3i**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.84 (d, J = 5.4 Hz, 2H), 7.28-7.38 (m, 3H), 7.46 (d, J = 7.0 Hz, 2H), 7.95 (t, J = 4.6 Hz, 1H), 8.50 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 121.8, 127.1, 128.9, 129.1, 135.9, 139.2, 152.1; MS (ESI, negative) m/z calcd. for C_9H_8NO [M-H]: 146.06, Found 146.10.
(*Z*)-**3i**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.88 (d, J = 16.0 Hz, 1H), 7.27-7.47 (m, 5H), 7.50-7.54 (m, 2H), 8.52 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 115.8, 127.7, 128.9, 129.5, 135.9, 140.3, 149.1; MS (ESI, positive) m/z calcd. for $C_9H_{10}NO$ [M+H]: 148.08, Found 148.10.

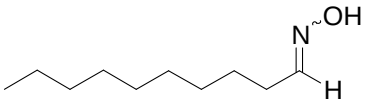
3-Phenylpropionaldoxime (3j)[6)]



3j (minor): ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.51-2.56 (m, 2H), 2.81-2.84 (m, 2H), 7.19-7.31 (m, 5H), 7.46 (dt, J = 1.8, 5.9 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 31.3, 32.9, 126.3, 128.5, 128.6, 140.6, 151.5. These NMR data for **3j** was obtained from E and Z mixtures NMR chart because we cannot isolate only **3j** (minor) which was easily isomerize **3j** (major).

3j (major): ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.68-2.73 (m, 2H), 2.80-2.84 (m, 2H), 6.75 (t, J = 5.3 Hz, 1H), 7.19-7.32 (m, 5H), 8.93 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.5, 32.1, 126.4, 128.4, 128.7, 140.8, 151.9; MS (APCI, positive) m/z calcd. for $C_9H_{12}NO$ [M+H]: 150.08, Found 150.10.

Decanal oxime (3k)[7)]



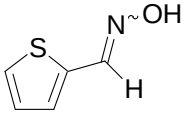
3k (major): ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, J = 6.6 Hz, 3H), 1.22-1.39 (m, 12H), 1.49 (quin, J = 7.4 Hz, 2H), 2.20 (td, J = 7.4, 6.3 Hz, 2H), 7.42 (t, J = 6.3 Hz, 1H), 8.38 (br, 1H).

3k (minor): ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, J = 6.6 Hz, 3H), 1.22-1.39 (m, 12H), 1.49 (quin, J = 7.4 Hz, 2H), 2.38 (td, J = 7.4 Hz, 5.5 Hz, 2H), 6.72 (t, J = 5.5 Hz, 1H), 8.81(br, 1H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 14.2, 22.8, 25.1, 26.2, 29.40, 29.44, 29.5, 29.6, 32.0, 153.1

MS (APCI, positive) m/z calcd for $C_{10}H_{22}NO$ [M+H]: 172.16, Found 172.20.

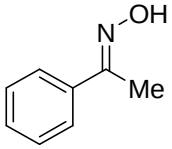
2-Thiophenecarbaldoxime (3l)[2)]



(*E*)-**3l**: ^{1}H NMR (400 MHz, d_6-DMSO) δ 7.12 (dd, J = 1.3, 0.9 Hz, 1H), 7.47 (d, J = 0.9 Hz, 1H), 7.73 (dd, J = 1.3, 0.2 Hz, 1H), 7.84 (s, 1H), 11.9 (s, 1H); ^{13}C NMR (100 MHz, d_6-DMSO) δ 139.8, 131.1, 131.08, 131.04, 126.2; MS (APCI, positive) m/z calcd for C_5H_6NOS [M+H]: 128.01, Found 128.10.

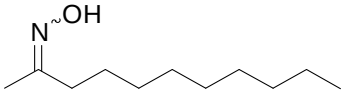
(*Z*)-**3l**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11 (dd, J = 1.3, 3.6 Hz, 1H), 7.42 (d, J = 3.6 Hz, 1H), 7.59 (d, J = 5.1 Hz, 1H), 7.76 (s, 1H), 9.38 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 126.4, 131.0, 131.9, 132.1, 141.3; MS (ESI, negative) m/z calcd. for C_5H_4NOS [M-H]: 126.002, Found 126.05.

Acetophenoxime (3m)[8)]



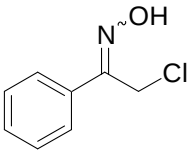
(*E*)-**3m**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 3H), 7.37-7.41 (m, 3H), 7.60-7.63 (m, 2H), 9.69 (br, 1H); MS (ESI, positive) m/z calcld. for $C_8H_{10}NO$ [M+H]: 136.08, Found 136.1.

2-Undecanoxime (3n)[9)]



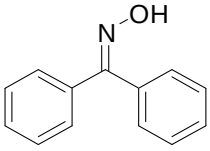
3n (major): ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, J = 7.0 Hz, 3H), 1.26 (m, 12H), 1.50 (t, J = 7.2 Hz, 2H), 1.88 (s, 3H), 2.18 (t, J = 7.8 Hz, 2H), 9.19 (br, 1H): ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.5, 14.2, 22.8, 26.4, 29.3, 29.4, 29.5, 29.6, 32.0, 36.0, 158.8; MS (ESI, positive) m/z calcld. for $C_{11}H_{24}NO$ [M+H]: 186.19, Found 186.2.
3n (minor): ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, J = 7.1 Hz, 3H), 1.26-1.30 (m, 12H), 1.50 (t, J = 7.7 Hz, 2H), 1.86 (s, 3H), 2.36 (t, J = 7.6 Hz, 2H), 8.36 (br, 1H): ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.3, 20.0, 22.8, 25.7, 28.7, 29.44, 29.54, 29.63, 29.86, 32.0, 159.5; MS (ESI, positive) m/z calcld. for $C_{11}H_{24}NO$ [M+H]: 186.19, Found 186.2.

Phenacyl Chloride oxime (3o)[10)]



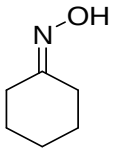
3o (major) : ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.62 (s, 2H), 7.42-7.44 (m, 3H), 7.67-7.70 (m, 2H), 9.50 (br, 1H): ^{13}C NMR (100 MHz, $CDCl_3$) δ 32.4, 126.4, 128.9, 130.2, 133.4, 154.4; MS (ESI, positive) m/z calcld. for C_8H_9ClNO [M+H]: 170.04, Found 170.0.

Benzophenoxime (3p)[11)]



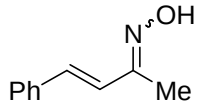
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.50 (m, 10H), 8.50 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 128.0, 128.4, 128.5, 129.26, 129.35, 129.7, 132.8, 136.3, 158.2; MS (ESI, positive) m/z calcld. for $C_{13}H_{12}NO$ [M+H]: 198.09, Found 198.1.

Cyclohexanone oxime (3q)[8)]



^{1}H NMR (400 MHz, $CDCl_3$) δ 1.61-1.67 (m, 6H), 2.22 (t, J = 5.8 Hz, 2H), 2.51 (t, J = 5.8 Hz), 9.32 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 24.5, 25.7, 25.9, 26.9, 32.2, 160.8; MS (ESI, positive) m/z calcld. for $C_6H_{12}NO$ [M+H]: 114.09, Found 114.20.

Benzylideneacetone oxime (3r)[12)]

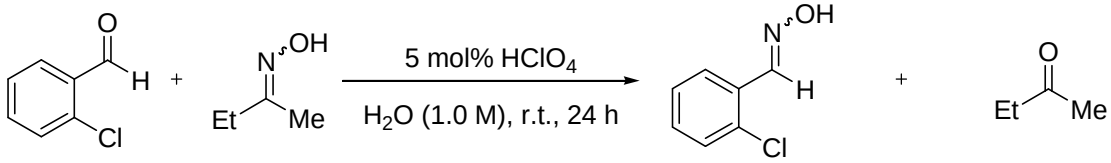


3r (major) : ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, J = 7.3, 2H), 7.35 (t, J = 7.7, 2H), 7.30-7.25 (m, 1H), 6.91 (d, J = 16.4 Hz, 1H), 6.86 (d, J = 16.4 Hz, 1H), 2.16 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9, 136.4, 133.6, 128.9, 128.8, 128.6, 127.0, 125.9, 9.9; MS (ESI, positive) m/z calcld. for $C_{10}H_{12}NO$ [M+H]:162.09, Found 162.10.

3r (minor) : ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, J = 16.6 Hz, 1H), 7.59-7.53 (d, J = 7.4, 2H), 7.38-7.30 (m, 3H), 6.95 (d, J = 16.6 Hz, 1H), 2.15 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.5, 136.7, 136.4, 129.3, 128.9, 128.6, 127.7, 117.0, 17.0.MS (ESI, positive) m/z calcld. for $C_{10}H_{12}NO$ [M+H]:162.09, Found 162.10.

Scalability and synthetic application

Preparation of the 2-Chlorobenzaldoxime (3h) on 100 g scale



100 g scale

To a three necked 2 L flask were added to 2-chloroaldehyde (100 g, 0.711 mol, 1.0 eq.), H_2O (0.71 L, 1.0 M), methyl ethyl ketone (76.4 mL, 0.853 mol, 1.2 eq.) under argon at room temperature (23–25°C). Then, 70 wt% $HClO_4$ aq (2.92 mL, 36.0 mmol, 5 mol%) was dropwised to stirred reaction mixtures vigorously. After 24 hours, the reaction mixture was cooling to 15°C in order to solidify product, the white solid appeared was collected by filtration and washed using water (0.75 L). The collected product was dried over KOH under vacuum at r.t. for 24 h to remove water. The white product was obtained 103 g (94% yield). The remained filtrate aqueous solution was distilled by evaporator (pressure: 77 mmHg, bath temp.: 40°C) and methyl ethyl ketone was recovered 24 mL (37% recovery).

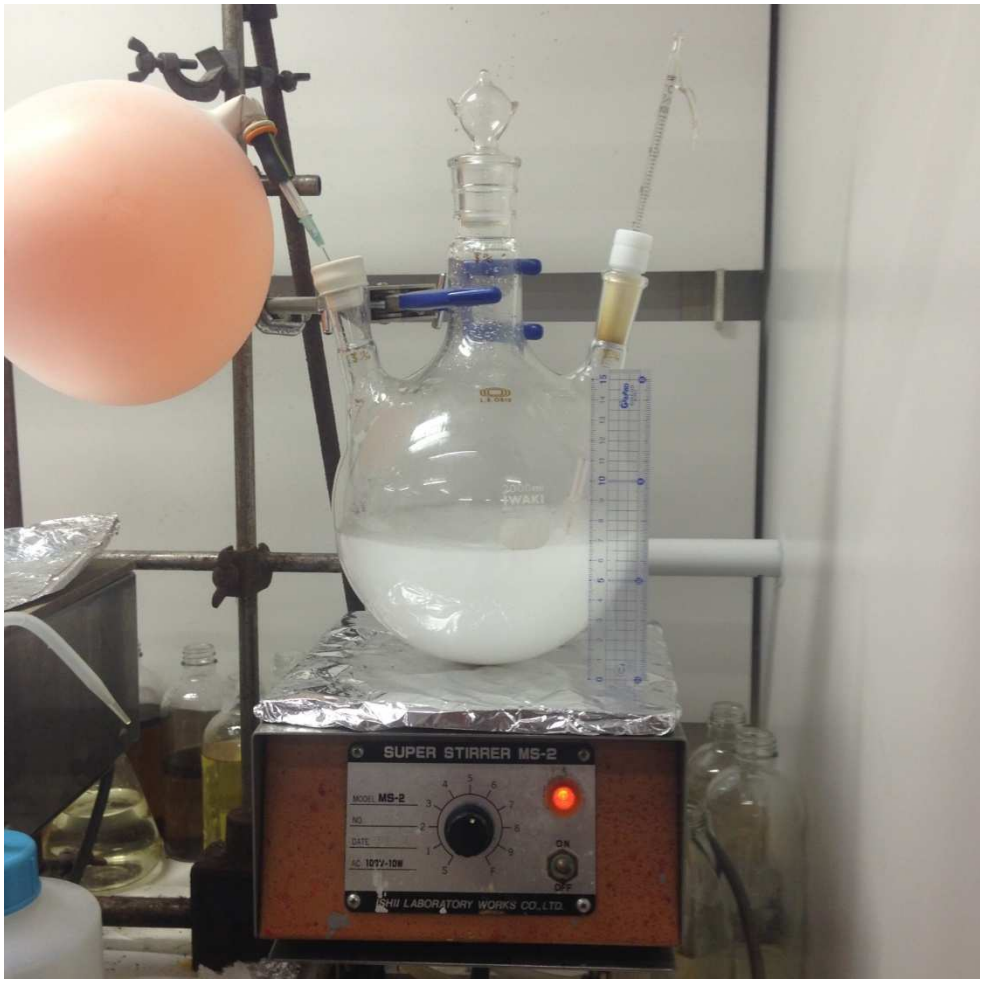
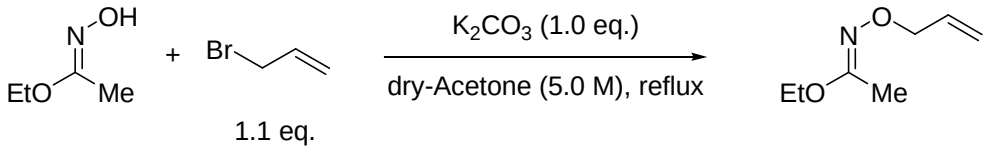


Figure S1. 100 g scale reaction in 2 L flask

Preparation of ethyl *O*-allyl-acetohydroxamate (6)[13)]

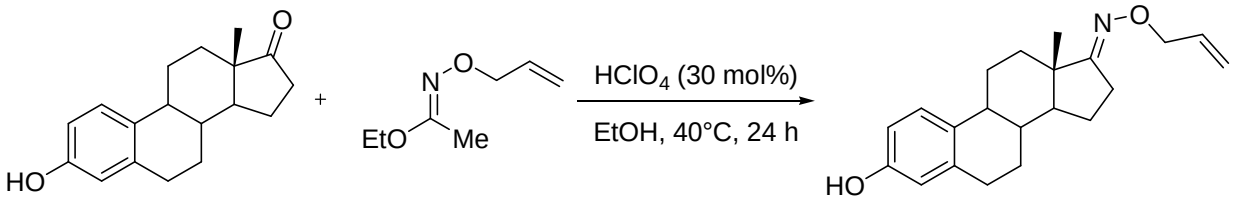


Allyl bromide (0.93 mL, 9.70 mmol, 1.1 equiv.) was added to a solution of ethyl acetohydroxamate (7.5 g, 72.8 mmol) and K_2CO_3 (10.2 g, 72.8 mmol, 1.0 equiv.) in Acetone (14.6 ml, 5.0 M) with stirring at r.t. After addition was complete, the reaction mixtures was stirred under reflux for 24 h. After the starting materials was consumed, the reaction mixtures was cooling to r.t. and water (3.9 mL) was added. After removal of acetone by evaporator, water phase was extracted with Et_2O (20 mL×3). The combined organic layer was washed with 10% NaOH aq. (20 mL) and dried over K_2CO_3. After removal of K_2CO_3 from organic layer, solvent was evaporated under reduced pressure. The remained crude mixtures was purified by silica gel column chromatography (pentane only to pentane /Et_2O = 90/10) and yellow solid product was obtained (4.13 g, 64%).

^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 1.27 (t, J = 7.1 Hz, 3H), 1.95 (s, J = 7.1 Hz, 3H), 4.01 (q, J = 7.1 Hz, 2H),

4.41 (d, J = 4.4 Hz, 2H), 5.18 (d, J = 15.4 Hz, 1H), 5.27 (d, J = 15.4 Hz, 1H), 5.94-6.03 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 13.9, 14.5, 62.3, 74.6, 117.3, 134.8, 162.7; MS (ESI, positive) m/z calcd for $C_7H_{14}NO_2$ [M+H]: 144.10, Found 144.20.

3-Hydroxy-17-*O*-allyl-oximino-estra-1, 3, 5(10)-triene (7)[14)]

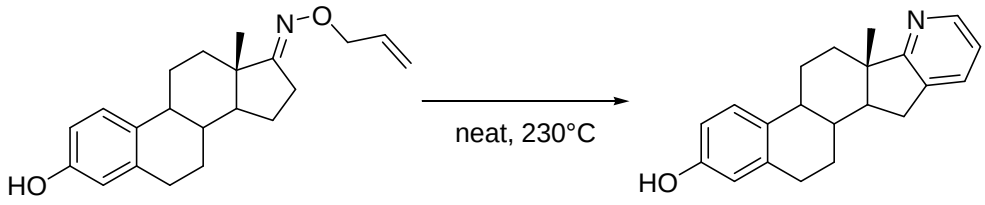


5 **6** **7**

To a 50 mL flask were added to estrone **5** (2.5 g, 9.24 mmol, 1.0 eq.), EtOH (9.2 mL, 1.0 M), 70 wt% $HClO_4$ aq. (0.24 mL, 2.77 mmol, 30 mol%) under N_2 at room temperature. Then ethyl *O*-allyl-acetohydroxamate **6** (1.73 g, 13.9 mmol, 1.5 equiv.) was dropwised to stirred reaction mixtures at 40 °C. After 18 hours, the reaction mixtures was passing through silica/celite® pad and washed with Et_2O (20 mL). The collected solution was evaporated and dried under vacuum. The crude mixture was purified by silica gel column chromatography (hexane/Et_2O = 70/30 to 60/40) and white solid product was obtained (2.6 g, 93% yield).

^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 0.94 (s, 3H), 2.83-1.41 (m, 15H), 4.55 (d, J = 5.6 Hz, 2H), 5.19 (d, J = 10.5 Hz, 1H), 5.27 (d, J = 17.3 Hz, 1H), 5.68 (s, 1H), 5.93-6.03 (m, 1H), 6.23 (d, J = 8.4 Hz, 1H), 6.57 (s, 1H), 7.13 (d, J = 8.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 18.1, 23.8, 26.9, 27.1, 28.1, 30.4, 35.0, 39.0, 44.8, 45.3, 53.8, 113.7, 116.2, 118.0, 127.3, 133.0, 135.3, 138.9, 154.5, 172.3; MS (ESI, positive) m/z calcd for $C_{21}H_{28}NO_2$ [M+H]: 326.21, Found 326.30.

3-Hydroxy-estra-1,3,5(10)-triene-[17,16-*b*]-pyridine (8)[14)]



7 **8**

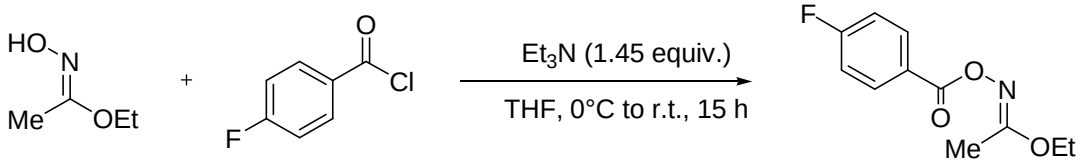
To a 30 mL flask were added to *O*-allyl oxime **7** (2.00 g, 6.14 mmol, 1.0 eq.) under argon at 230°C and stirred for 24 h. Then the mixtures were cooling to r.t. and dissolved in EtOH. The unsolved solid was removed by filtration and the filtrate solution was evaporated to remove EtOH after the solution was added to silica gel. The crude mixture was purified by silica gel column chromatography (chloroform/ethyl acetate = 90/10) and orange solid product was obtained (282 mg, 15% yield).

^{1}H NMR (d_6-DMSO, 400 MHz, ppm) δ 0.89 (s, 3H), 1.39-2.80 (m, 13H), 6.46 (s, 1H), 6.53 (dd, J = 2.2 Hz, 1H), 7.05-7.09 (m, 2H), 7.59 (d, J = 7.4 Hz, 1H), 8.24 (d, J = 4.6 Hz, 1H), 9.02 (s, 1H); ^{13}C NMR (d_6-DMSO,

100 MHz, ppm) δ 17.6, 26.0, 27.0, 29.0, 29.5, 33.6, 37.3, 43.9, 45.5, 54.7, 112.8, 115.0, 121.1, 125.8, 130.3, 132.5, 135.8, 137.1, 146.6, 155.0, 172.6; MS (ESI, positive) m/z calcd for $C_{21}H_{24}NO$ [M+H]: 306.19, Found 306.20.

Preparation of ethyl *O*-(4-fluorobenzoyl)acetohydroxamate and *O*-(4-fluorobenzoyl) -2-naphthaldoxime

Ethyl *O*-(4-fluorobenzoyl)acetohydroxamate

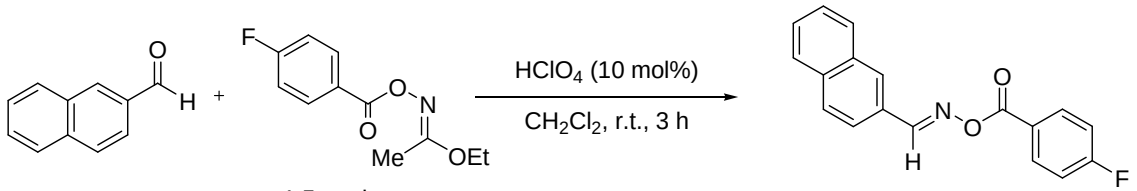


2g 1.35 equiv.

4-Fluorobenzoylchloride (155 μL, 1.31 mmol, 1.35 equiv.) was added to a solution of ethyl acetohydroxamate (100 mg, 0.970 mmol) and triethylamine (196 μL, 1.41 mmol, 1.45 equiv.) in THF (3.2 ml, 0.30 M) with stirring under ice cooling. After addition was complete, the reaction mixtures was stirred for 15 h at room temperature. Then saturated NH_4Cl aq. (3 mL) was added to quench the reaction and remove THF by evaporator, and the remained aqueous layer was extracted with Et_2O (10 mL×3). The combined organic layer was washed with brine (10 mL) and dried over $MgSO_4$. After removal of $MgSO_4$ from organic layer, solvent was evaporated under reduced pressure. The remained crude mixtures was purified by silica gel column chromatography (hexane/Ethyl acetate = 90/10) and yellow solid product was obtained (191 mg, 88%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 1.36 (t, J = 7.1 Hz, 3H), 2.15 (s, 3H), 4.28 (q, J = 7.1 Hz, 2H), 7.11-7.16 (m, 2H), 8.05-8.08 (m, 2H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -108.4 (s, 1F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.2, 15.1, 63.8, 115.6 (d, $J_{C\text{-}F}$ = 22 Hz), 125.4 (d, $J_{C\text{-}F}$ = 3 Hz), 131.9 (d, $J_{C\text{-}F}$ = 9 Hz), 162.9, 165.8 (d, $J_{C\text{-}F}$ = 253 Hz), 169.6; IR (neat) 3068, 2989, 1747, 1635, 1508, 1379, 1319, 1271, 1159, 1095, 1045, 972, 860, 760, 606 cm^{-1}; MS (ESI, positive) m/z calcd for $C_{11}H_{13}FNO_3$ [M+H]: 226.09, Found 226.50; Anal. Calcd. for $C_{11}H_{12}FNO_3$: C, 58.7; H, 5.37; N, 6.22; found C, 58.6; H, 5.45; N, 6.13.

***O*-(4-fluorobenzoyl) -2-naphthaldoxime**



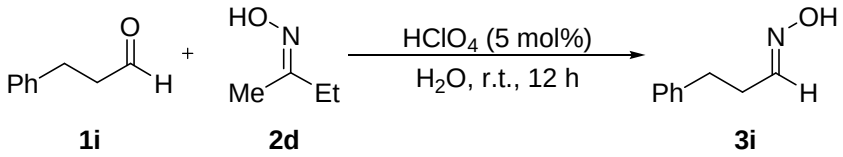
1a 1.5 equiv.

To a flame dried test tube were added to 2-naphthaldehyde (13.3 mg, 0.085 mmol, 1.0 eq.), CH_2Cl_2 (0.9 mL, 0.1 M), 70 wt% $HClO_4$ aq (0.7 μL, 8.50 μmmol, 10 mol%) under argon at room temperature. Then ethyl *O*-(4-fluorobenzoyl)acetohydroxamate (28.7 mg, 0.128 mmol, 1.5 equiv.) was added to stirred reaction mixtures. After 3 hours, reaction mixtures were filtrated through silica/Celite® pad to remove acid-catalyst. The filtrate solution were evaporated and removed under vacuum. Then, crude mixture was purified by

column chromatography (hexane/benzene = 4/6) giving the corresponding oximes as a white solid (24.4 mg, 98%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16 (t, J = 8.4 Hz, 2H), 7.51-7.58 (m, 2H), 7.85-7.90 (m, 3H), 8.03-8.09 (m, 2H), 8.17 (dd, J = 8.4, 5.5 Hz, 2H), 8.67 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -107.7 (s, 1F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 123.6, 124.9 (d, J_{C-F} = 2.9 Hz), 127.0, 127.8, 128.0, 128.1, 128.9 (d, J_{C-F} = 27 Hz), 130.9, 132.4 (d, J_{C-F} = 9.3 Hz), 133.0, 135.1, 163.1, 166.1 (d, J_{C-F} = 253 Hz); IR (neat) 3060, 3022, 1747, 1601, 1504, 1255, 1155, 1078, 974, 893, 850, 758 cm^{-1}; MS (ESI, positive) m/z calcd for $C_{18}H_{13}FNO_2$ [M+H]: 294.09, Found 294.60; Anal. Calcd. for $C_{18}H_{12}FNO_2$: C, 73.7; H, 4.12; N, 4.78; found C, 73.5; H, 4.28; N, 4.86.

Procedure for recovery and reuse of reaction filtrate solution



1i **2d** **3i**

1) To a flame dried 50 mL flask were added to 3-Phenylpropionaldehyde **3i** (0.98 mL (1.0 g), 7.45 mmol, 1.0 eq.), H_2O (37 mL, 0.2 M), 70 wt% $HClO_4$ aq (32.1 μL, 0.373 mmol, 5 mol%) under argon at room temperature. Then methylethyl ketone **2d** (1.05 mL, 11.2 mmol, 1.5 equiv.) was dropwised to stirred reaction mixtures. After reaction mixtures turned to white suspension for 12 h, the white solid was collected by filtration and filtrate solution was received to a 100 mL round bottom flask. Furthermore, the above solid was washed using water (10 mL×3) after receiver flask was changed. The collected product was dried over P_2O_5 under vacuum for 12 h to remove water. Aldoxime **3i** was obtained in 79% yield (0.88 g).

2) The previous receiver 100 mL flask which contained filtration reaction solution, was charged argon gas. To the solution was added stirrer bar, 3-Phenylpropionaldehyde **3i** (0.98 mL (1.0 g), 7.45 mmol, 1.0 eq.), methylethyl ketone **2d** (0.70 mL, 7.45 mmol, 1.0 equiv.) and stirred at room temperature for 12 hours. After starting materials was consumed (determined by TLC), the reaction mixtures was filtrated and the filtrate solution was received to another 100 mL round bottom flask. The collected solid was further washed with H_2O (10 mL×3) and dried over P_2O_5 under vacuum at room temperature for 12 h. The desired product was obtained in 86% yield (0.96 g).

3-11) Above procedure 2) was repeated total nine times.

(a) (b) (c)

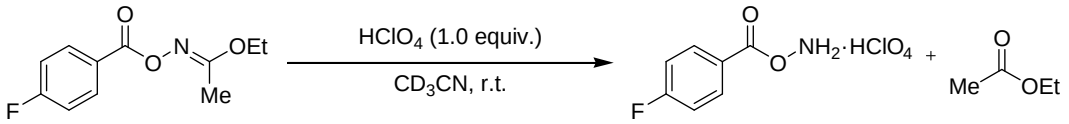
Figure S2. Appearance of catalytic transoximation to **1i** from **2d** in H_2O. (a) 10 min. (b) 3 hours. (c) 12 hours.

Table S4. The result for synthesis of **3i** using reusable reaction filtrate

Cycle	Isolated yield (%)
	Oxime (**3i**)
1st	85
2nd	98
3th	84
4th	80
5th	99
6th	86
7th	71
8th	73
9th	80
10th	83
11th	80

4. Observation Experiments about Existence of Hydroxylamine Derivatives in-situ

Pre-experiments to check hydroxylamine derivatives by ^{1}H & ^{19}F NMR[15)]



To a flame dried test tube ethyl *O*-(4-fluorobenzoyl)acetohydroxamate (15.8 mg, 0.0700 mmol), 1, 1, 2, 2-tetrachloroethane (5.9 mg, 0.0350 mmol) as internal standard for ^{1}H NMR, perfluorobenzene (2.2 mg, 0.0119 mmol) as internal standard for ^{19}F NMR, d_3-CD_3CN (0.7 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then the solution was directly transferred to the NMR tube and taken ^{1}H & ^{19}F NMR (before starting reaction: 0 min, Figure S3 (a), S4 (a)). After the measurement of NMR, the solution was returned to the test tube and 70 wt% $HClO_4$ aq. (23.8 μL, 0.0350 mmol, 0.50 equiv.) was added there under stirring. Further 70 wt% $HClO_4$ aq. (23.8 μL, 0.0350 mmol, 0.50 equiv., total 1.0 equiv.) was added to the reaction mixtures after 1.5 h. Starting material was consumed after 3 h, followed by taken ^{1}H & ^{19}F NMR (after finished reaction: 180 min, Figure S3 (b), S4 (b)). We can observe AcOEt and new peaks (8.11, 7.35 ppm) from ^{1}H NMR, one peak (-102 ppm) from ^{19}F NMR.

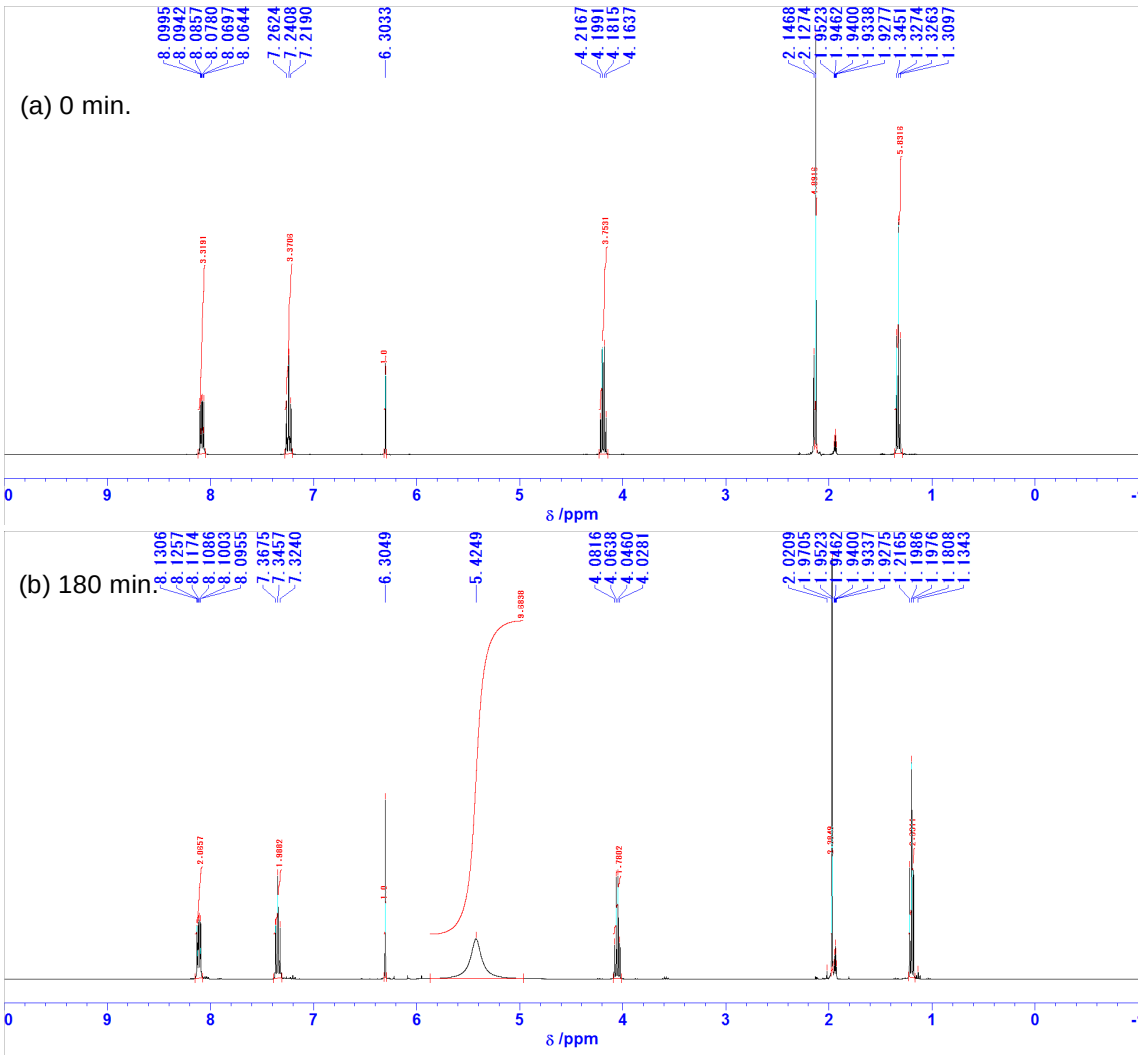


Figure S3. ^{1}H NMR

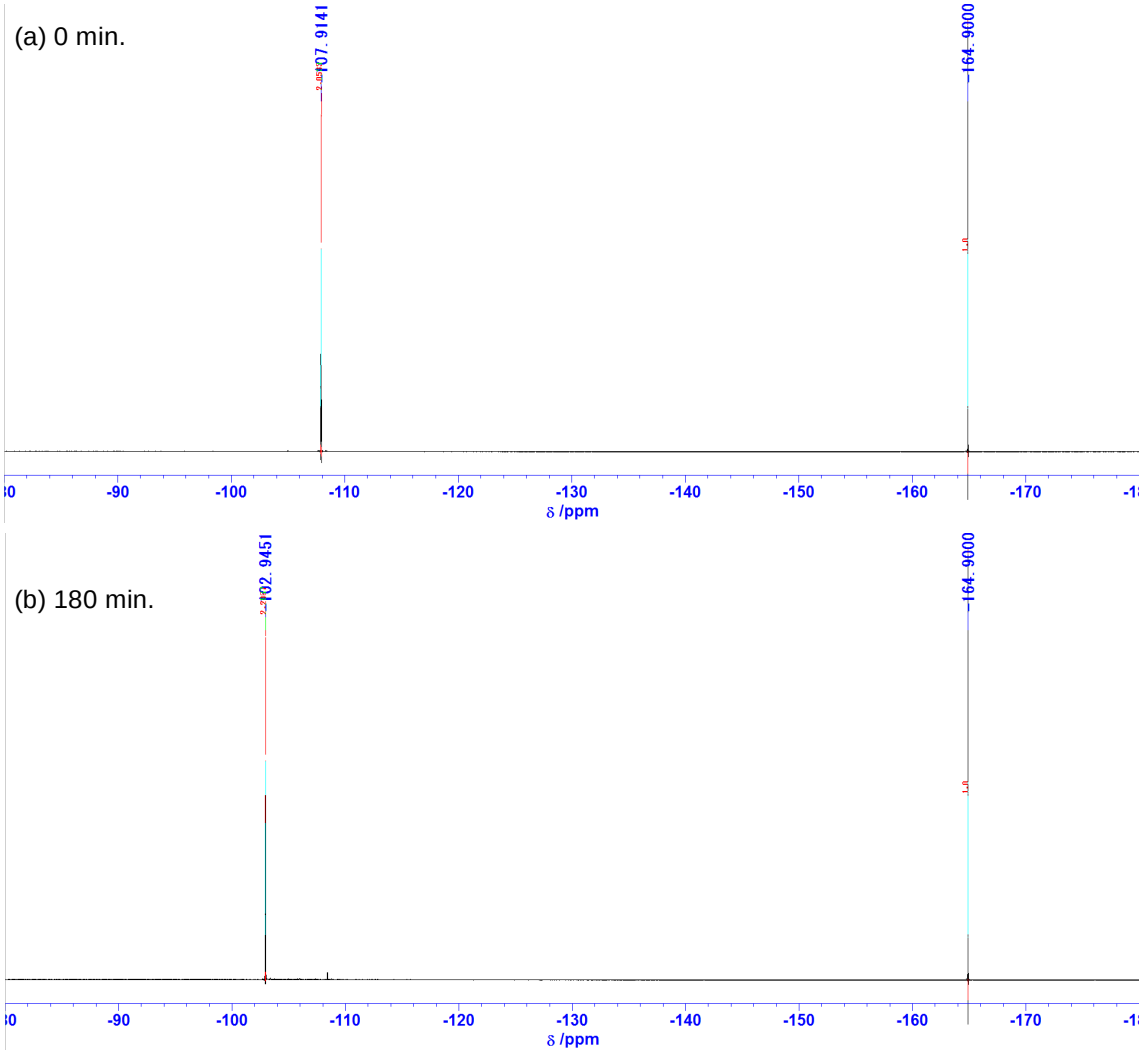
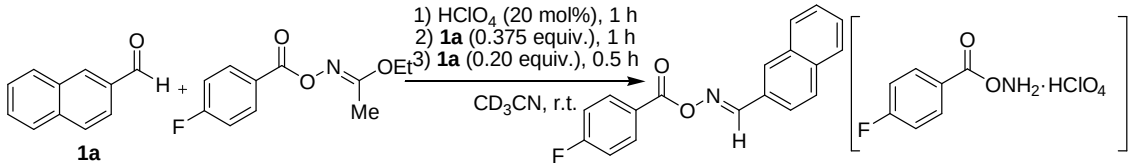


Figure S4. ^{19}F NMR

Experiments for the observation of hydroxylamine derivatives in-situ under transoximation reaction



1) To a flame dried test tube 2-naphthaldehyde **1a** (10.9 mg, 0.0700 mmol), ethyl *O*-(4-fluorobenzoyl)acetohydroxamate (23.7 mg, 0.105 mmol, 1.5 equiv.), 1, 1, 2, 2-tetrachloroethane (5.9 mg, 0.0350 mmol) as internal standard for ^{1}H NMR, perfluorobenzene (2.2 mg, 0.0119 mmol) as internal standard for ^{19}F NMR, d_3-CD_3CN (0.7 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then the solution was directly transferred to the NMR tube and taken ^{1}H & ^{19}F NMR (before starting reaction: 0 min, Figure S5 (a), S6 (a)). After the measurement of NMR, the solution was returned to the test tube and 70 wt% $HClO_4$ aq. (1.2 μL, 0.0140 mmol, 20 mol%) was added there under stirring. After 15, 60 minutes, the reaction mixtures was taken ^{1}H & ^{19}F NMR as well as previous methods (Figure S6 (b) (c), S6 (b) (c)).

2) After 60 minutes **1a** was disappeared from ^{1}H NMR, therefore **1a** (4.1 mg, 0.0263 mmol) was added to the reaction mixtures again.

3) Further 60 minutes, the reaction mixturtes was taken ^{1}H & ^{19}F NMR, which showed no peaks of ethyl *O*-(4-fluorobenzoyl)acetohydroxamate, however two peaks which seemed hydroxylamine derivatives and aldoxime, was confirmed on the ^{19}F NMR (Figure S5 (d), S6 (d)). Moreover **1a** (2.2 mg, 0.0140 mmol) was added to the reaction mixtures and stirred further 1 hour. As a result, one peak (-102 ppm) was disappeared and another peak (-107 ppm) derived from product was remained on the ^{19}F NMR chart (Figure S6 (e)).

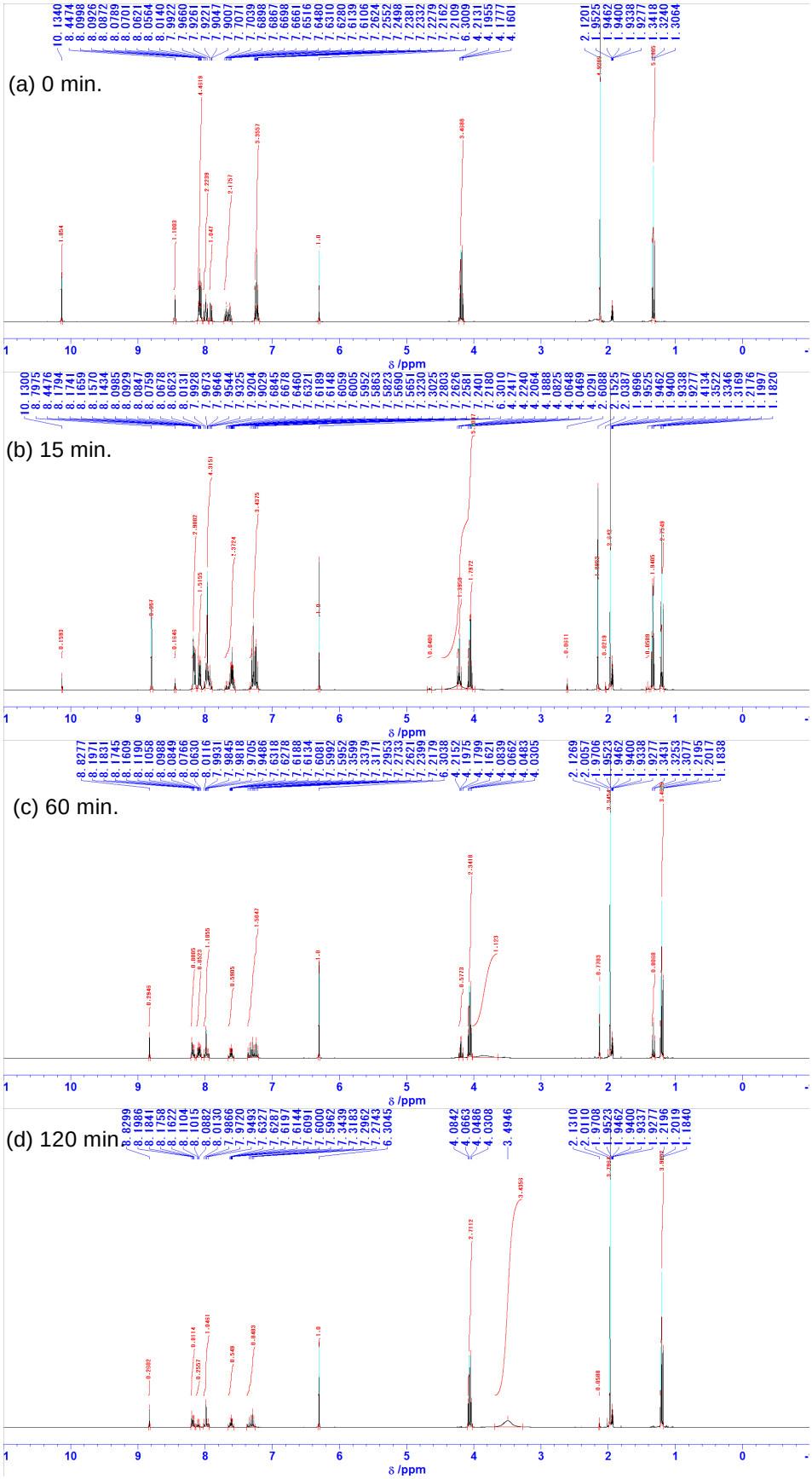
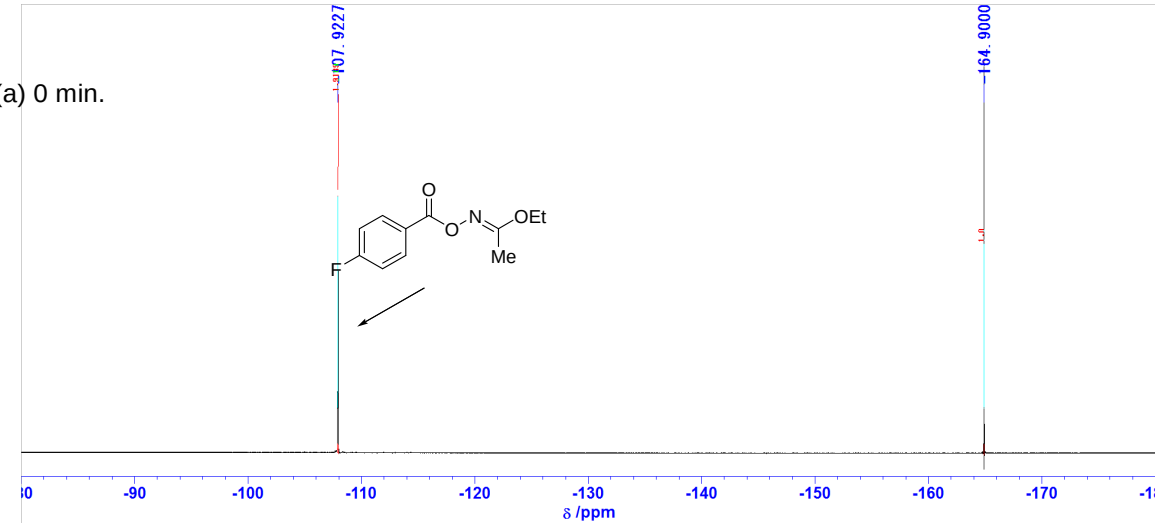
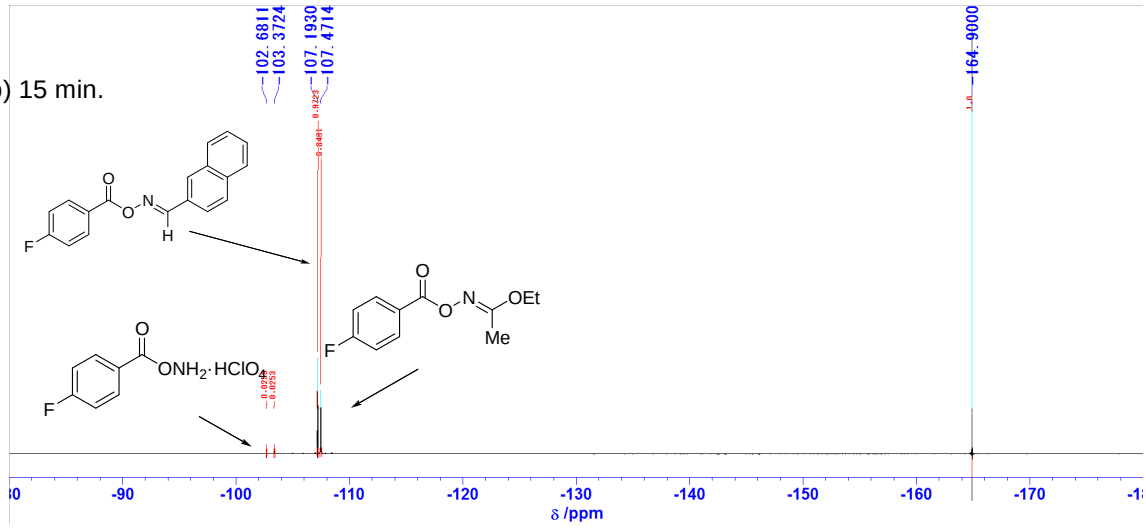


Figure S5. ^{1}H NMR

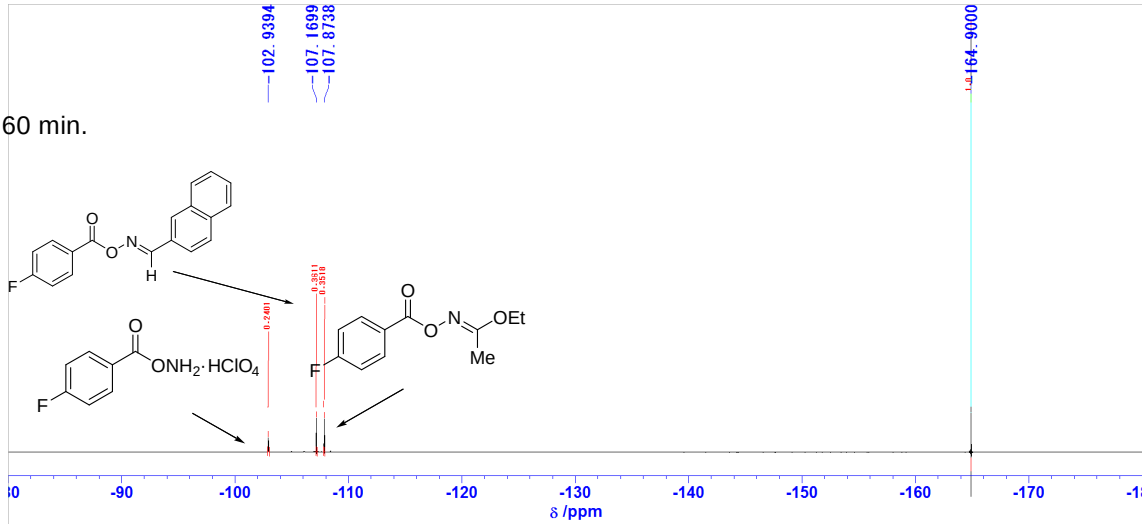
(a) 0 min.



(b) 15 min.



(c) 60 min.



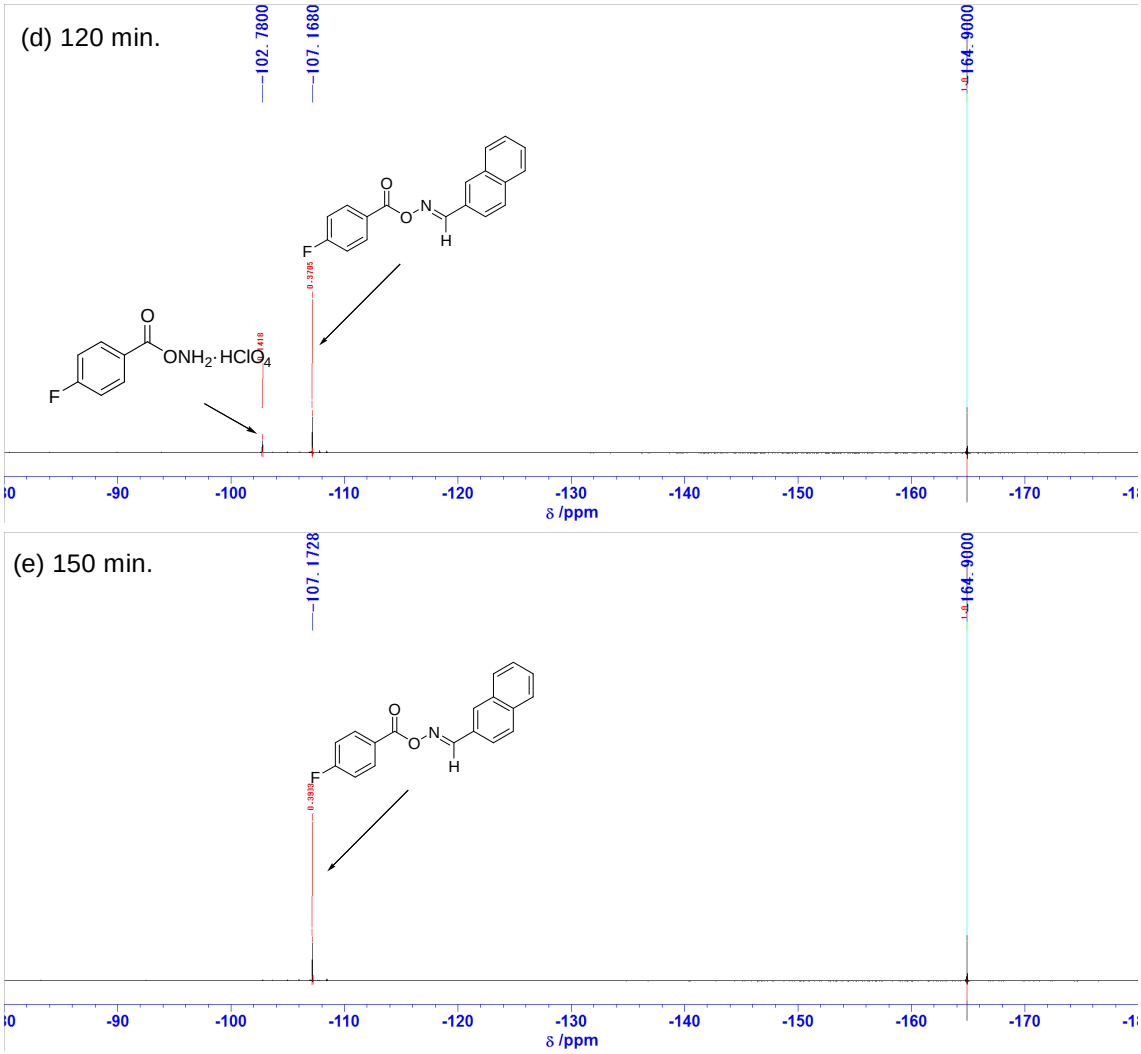
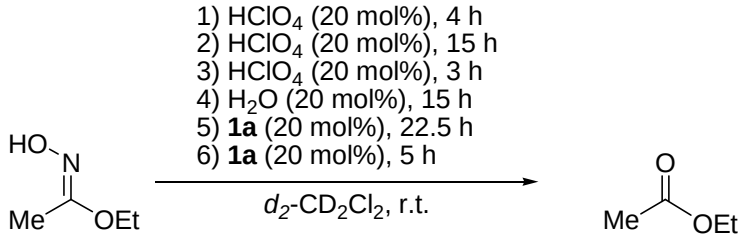


Figure S6. ^{19}F NMR

5. NMR Experiments for Hydrolysis of 2g

In d_2-CD_2Cl_2 solution (Figure 3 and Table 3 entry 1)



2g **4g**

1) To a flame dried test tube ethyl acetohydroxamate **2g** (14.5 μL, 0.140 mmol), 1, 1, 2, 2-tetrachloroethane (11.7 mg, 0.0697 mmol) as internal standard, d_2-CD_2Cl_2 (1.4 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (2.4 μL, 0.0280 mmol, 20 mol%) was added to the reaction mixtures. After 1, 2, 3, 4 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine the yield of AcOEt **4g** from internal standard. After the measurement of ^{1}H NMR, the solution was returned to the test tube and started the reaction under stirring again.

2) After 4 hours, 70 wt% $HClO_4$ aq. (2.4 μL, 0.0280 mmol, 20 mol%) was added to the reaction mixtures (total 40 mol% $HClO_4$). The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (5, 6, 19 h).

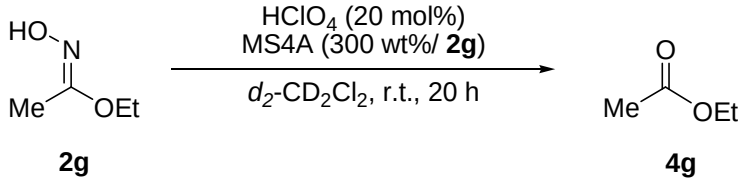
3) After 19 hours, 70 wt% $HClO_4$ aq. (2.4 μL, 0.0280 mmol, 20 mol%) was added to the reaction mixtures (total 60 mol% $HClO_4$) again. The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (20, 21, 22 h).

4) After 22 hours, H_2O (0.5 mg, 0.0278 mmol, 20 mol%) was added to the reaction mixtures (reaction was almost not proceeding). The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (23, 24, 25, 37 h).

5) After 37 hours, 2-naphthaldehyde (4.4 mg, 0.0280 mmol, 20 mol%) **1a** was added to the reaction mixtures (the reaction was restarted). The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (38, 39, 40, 41, 42, 60.5 h).

6) After 60.5 hours (**1a** was consumed by ^{1}H NMR), 2-naphthaldehyde (4.4 mg, 0.0280 mmol, 20 mol%) **1a** was added to the reaction mixtures again (total 40 mol% **1a**). The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (61.5, 62.5, 66.5 h) (All **2g** disappeared on the ^{1}H NMR).

In d_2-CD_2Cl_2 solution in the presence of molecular sieve 4A (MS4A) (Figure S7, Table 3 entry 2)



2g **4g**

To a flame dried test tube ethyl acetohydroxamate **2g** (14.5 μL, 0.140 mmol), 1, 1, 2, 2-tetrachloroethane (13.2 mg, 0.0786 mmol) as internal standard, MS4A (43.3 mg, 300 wt/wt% for **2g**, it was dried under 2

mmHg/150°C with P_2O_5 for 1 hour before use), d_2-CD_2Cl_2 (1.4 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (2.4 μL, 0.0280 mmol, 20 mol%) was added to the reaction mixtures. After 1, 2, 3, 4, 5, 6, 7, 20 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine the yield of AcOEt **4g** from internal standard. After the measurement of ^{1}H NMR, the solution was returned to the test tube and started the reaction under stirring again.

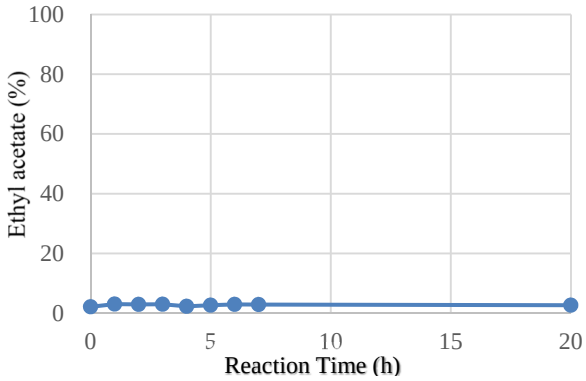
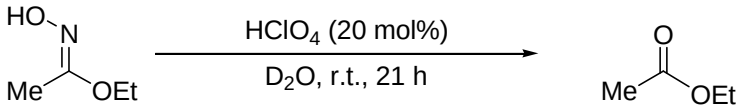


Figure S7. Hydrolysis of **2g** in d_2-CD_2Cl_2 in the presence of MS4A

In D_2O solution (Figure S8, Table 3 entry 3)



2g **4g**

To a flame dried test tube ethyl acetohydroxamate **2g** (14.5 μL, 0.140 mmol), 1, 1, 2, 2-tetrachloroethane (11.7 mg, 0.0697 mmol) as internal standard, D_2O (1.4 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (2.4 μL, 0.0280 mmol, 20 mol%) was added to the reaction mixtures. After 1, 2, 3, 17.5, 21 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine the yield of AcOEt **4g** from internal standard. After the measurement of ^{1}H NMR, the solution was returned to the test tube and started the reaction under stirring again.

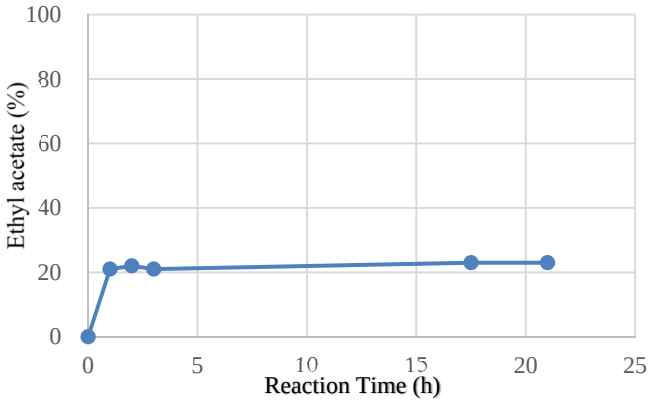
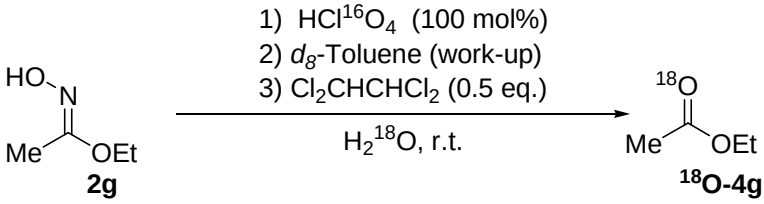


Figure S8. Hydrolysis of **2g** in D_2O

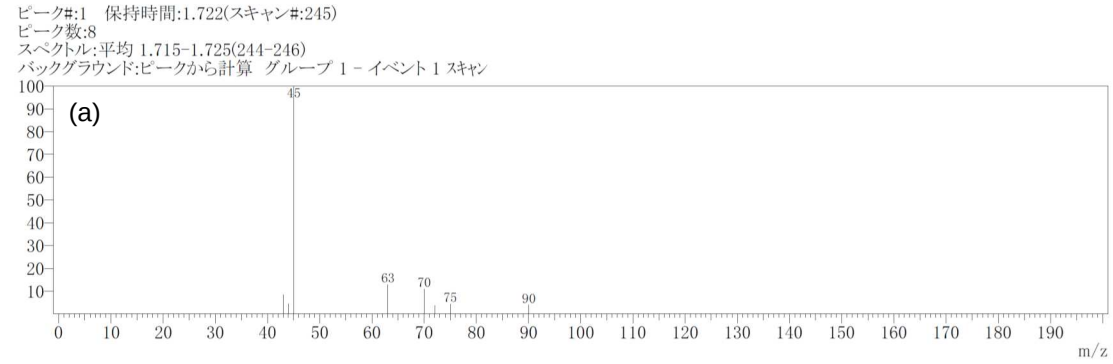
In $H_2{}^{18}O$ solution (Figure S9, Table 3 entry 4)

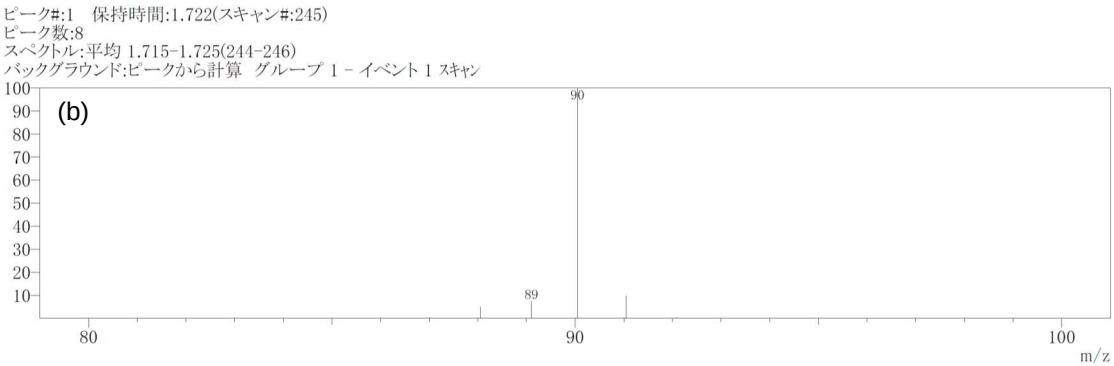


1) To a flame dried test tube, 70 wt% $HClO_4$ aq. (2.1 μL, 0.0250 mmol, 100 mol%) $H_2{}^{18}O$ (0.25 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then ethyl acetohydroxamate **2g** (2.6 μL, 0.025 mmol) was added to the reaction mixtures.

2) After 10 minutes, the reaction mixtures was extracted with d_8-toluene (1.0 mL). The obtained organic layer was directly measured by ^{1}H NMR to check the production of AcOEt and the consumption of all **2g**. Next in order to determine whether ^{18}O-labeled AcOEt **4g** or ^{16}O-AcOEt **4g**, the solution was directly measured by the GC-MS (Figure S8). We can confirmed that the obtained **4g** had one ^{18}O labeled oxgen atom. According to the theoretical calculations, the ratio of $C_4H_8{}^{16}O_2$ (MW: 88.05): $C_4H_8{}^{16}O^{18}O$ (MW: 90.06) = 100: 0.20. Following to literature[16], we can calculated the ^{18}O% of **4g**: (100-5.01*0.20%)/(100-5.01*0.20%+5.01)= 95% (We can conclude the oxygen of carbonyl group of AcOEt mostly came from oxygen of water, not from $HClO_4$).

3) After GC-MS measurement, the solution was added to 1, 1, 2, 2-tetrachloroethane (2.0 mg, 0.0119 mmol) as internal standard and taken ^{1}H NMR to determine the yield of AcOEt **4g** from internal standard (84% yield).





(c)

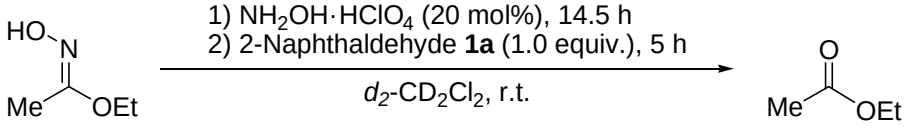
マステーブル
ピーク#:1　保持時間:1.720(スキャン#:245)
ピーク数:8
グループ 1 - イベント 1　スキャン

#	m/z	絶対強度	相対強度
1	86.00	96	0.13
2	87.00	165	0.23
3	88.05	3572	5.01
4	89.10	5369	7.53
5	90.05	71303	100.00
6	91.05	6968	9.77
7	92.10	386	0.54
8	93.10	3	0.00

Figure S9. GC-MS chart of the obtained ^{18}O-labeled AcOEt

(a) total MS chart, (b) expansion MS chart between M.W. 80 and 100, (c) peak intensity

In CD_2Cl_2 with $HClO_4 \cdot NH_2OH$ as a catalyst (Figure S10, Table 3 entry 5)



2g **4g**

1) To a flame dried test tube ethyl acetohydroxamate **2g** (14.5 μL, 0.140 mmol), 1, 1, 2, 2-tetrachloroethane (14.0 mg, 0.0834 mmol) as internal standard, d_2-CD_2Cl_2 (1.4 mL, 0.1 M) was added and stirred under argon atmosphere at room temperature. Then 0.7% anhydrous $NH_2OH \cdot HClO_4$-EtOH solution (534 mg, 0.0280 mmol, 20 mol%) was added to the reaction mixtures. After 1, 2, 3, 14.5 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine the yield of AcOEt **4g** from internal standard. After the measurement of ^{1}H NMR, the solution was returned to the test tube and started the reaction under stirring again (The hydrolysis reaction was not almost proceeding).

2) After 14.5 hours, 2-naphthaldehyde **1a** (21.9 mg, 0.140 mmol, 1.0 equiv.) was added to the reaction mixtures. The reaction was monitored by ^{1}H NMR and calculated the yield of AcOEt **4g** every hours (15.5, 18.5, 19.5 h) (Once aldehyde was added, the reaction was drastically proceeding. This result indicated free $HClO_4$ was re-generated by aldehyde and started the hydrolysis reaction).

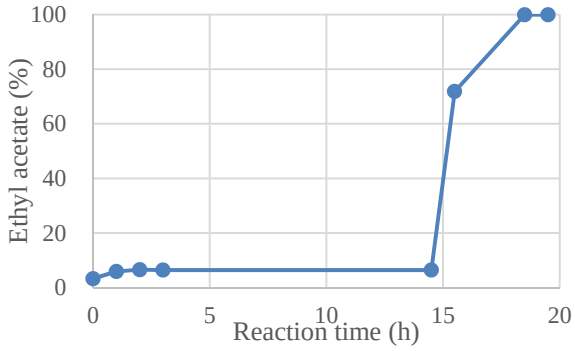


Figure S10. Hydrolysis of **2g** in CD_2Cl_2 with $HClO_4 \cdot NH_2OH$ as a catalyst

6. Kinetic Studies[17)]

Experiments for ethyl acetohydroxamate

To every flame dried 30 mL flask aldehyde **1a** (0.80 mmol), tetralin (0.20 mmol, as an internal standard), CH_2Cl_2 (4.0 mL, 0.20 M) was added and stirred under Ar atmosphere. 70 wt% $HClO_4$ aq. (0.040 mmol, 5 mol%) was added to the reaction mixtures, followed by added ethyl acetohydroxamate **2g** (x [mmol], x = 0.60, 0.80, 1.0, 1.2) at room temperatures. After 20, 40, 60 min, an aliquot part of the reaction mixtures was taken (ca 0.50 mL) and quenched with Et_3N (0.025 mmol). The solvent was evaporated under reduced pressure (ca 200 mmHg) to give the crude mixtures. The yield of aldoxime **3a** was directly determined by ^{1}H NMR from internal standard.

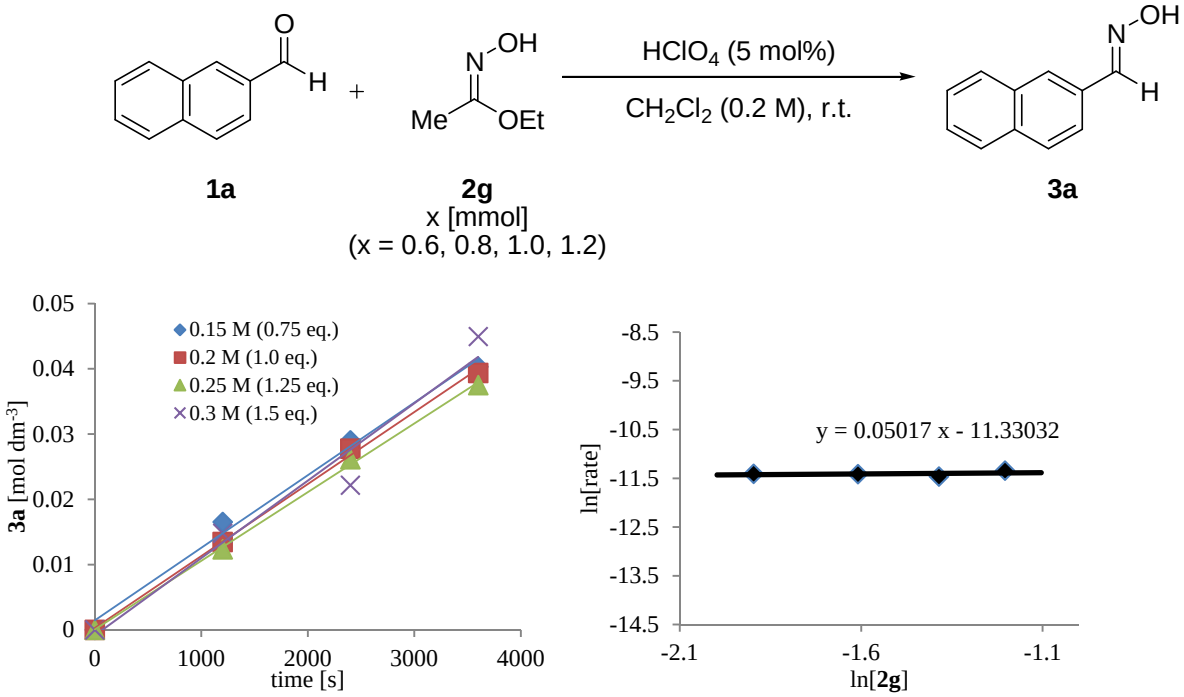


Figure S11. Kinetic study for ethyl acetohydroxamate

Experiments for 2-naphthaldehyde

To every flame dried 30 mL flask aldehyde **1a** (y [mmol], y = 0.40, 0.60, 0.80, 1.2), tetralin (0.20 mmol, as an internal standard), CH_2Cl_2 (4.0 mL, 0.20 M) was added and stirred under Ar atmosphere. 70 wt% $HClO_4$ aq. (0.040 mmol) was added to the reaction mixtures, followed by added ethyl acetohydroxamate **2g** (1.2 mmol) at room temperatures. After 20, 40, 60 min, an aliquot part of the reaction mixtures was taken (ca 0.50 mL) and quenched with Et_3N (0.025 mmol). The solvent was evaporated under reduced pressure (ca 200 mmHg) to give the crude mixtures. The yield of aldoxime **3a** was directly determined by ^{1}H NMR from internal standard.

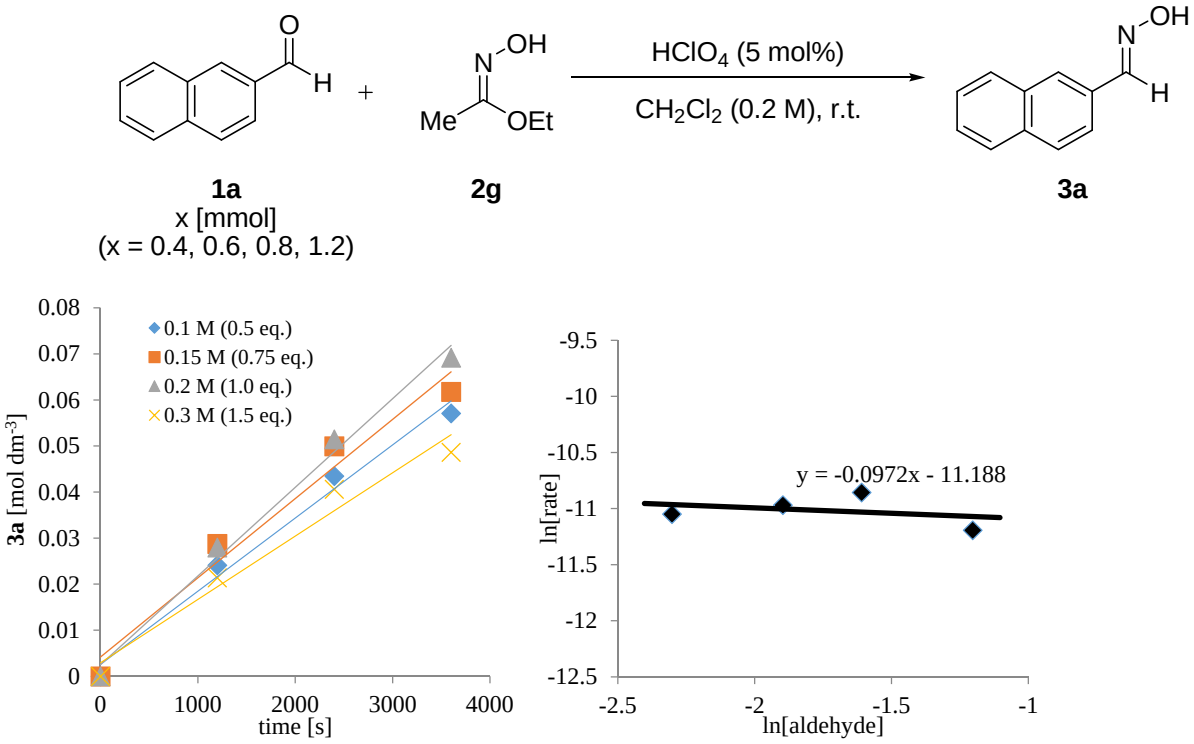
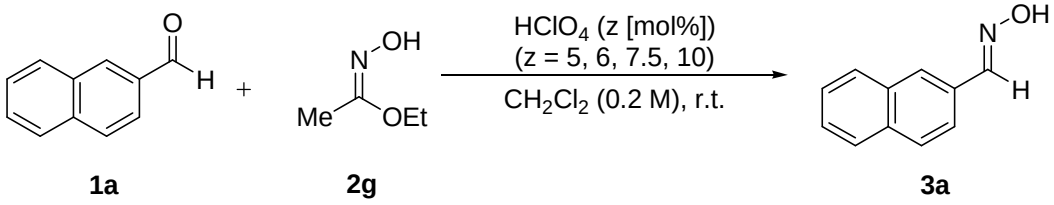


Figure S12. Kinetic study for 2-naphthaldehyde

Experiments for perchloric acid

To every flame dried 30 mL flask aldehyde **1a** (0.80 mmol), tetralin (0.20 mmol, as an internal standard), CH_2Cl_2 (4.0 mL, 0.20 M) was added and stirred under Ar atmosphere. 70 wt% $HClO_4$ aq. (z [mmol], z = 0.040, 0.048, 0.060, 0.080) was added to the reaction mixtures, followed by added ethyl acetohydroxamate **2g** (1.2 mmol) at room temperatures. After 20, 40, 60 min, an aliquot part of the reaction mixtures was taken (ca 0.50 mL) and quenched with Et_3N (0.025 mmol). The solvent was evaporated under reduced pressure (ca 200 mmHg) to give the crude mixtures. The yield of aldoxime **3a** was directly determined by ^1H NMR from internal standard.



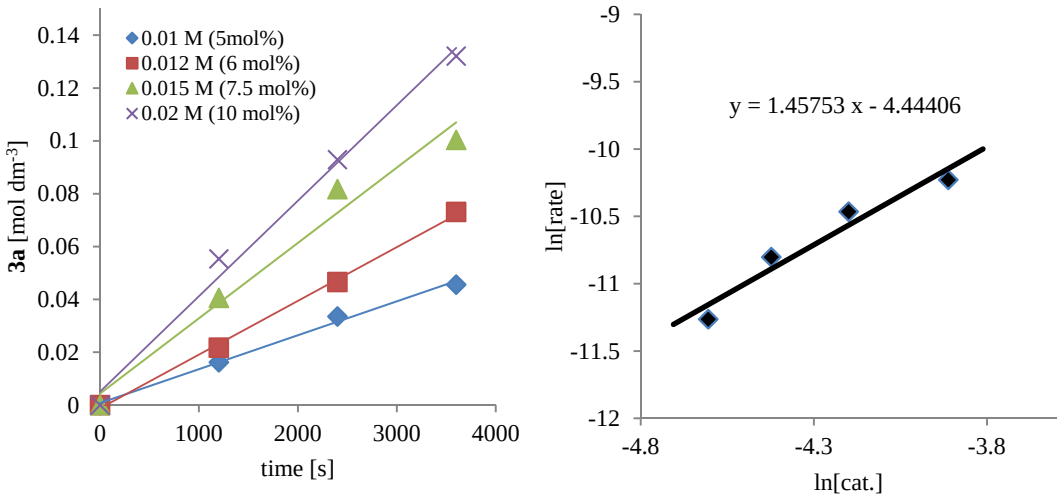
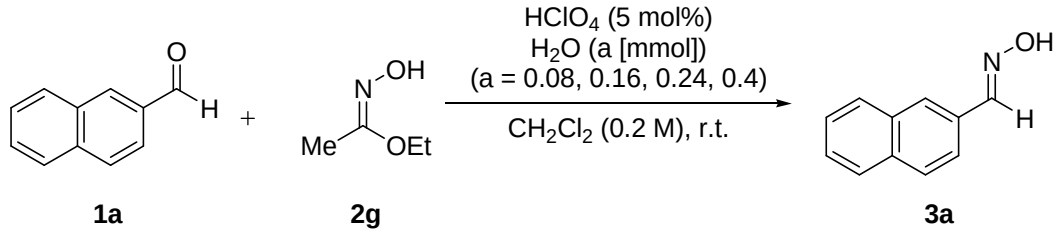


Figure S13. Kinetic study for perchloric acid

Experiments for water

To every flame dried 30 mL flask aldehyde **1a** (0.80 mmol), tetralin (0.20 mmol, as an internal standard), CH_2Cl_2 (4.0 mL, 0.20 M), H_2O (a [mmol], a = 0.080, 0.16, 0.24, 0.40) was added and stirred under Ar atmosphere. 70 wt% $HClO_4$ aq. (0.040 mmol, 5 mol%) was added to the reaction mixtures, followed by added ethyl acetohydroxamate **2g** (1.2 mmol) at room temperatures. After 20, 40, 60 min, an aliquot part of the reaction mixtures was taken (ca 0.50 mL) and quenched with Et_3N (0.025 mmol). The solvent was evaporated under reduced pressure (ca 200 mmHg) to give the crude mixtures. The yield of aldoxime **3a** was directly determined by ^{1}H NMR from internal standard.



1a **2g** **3a**

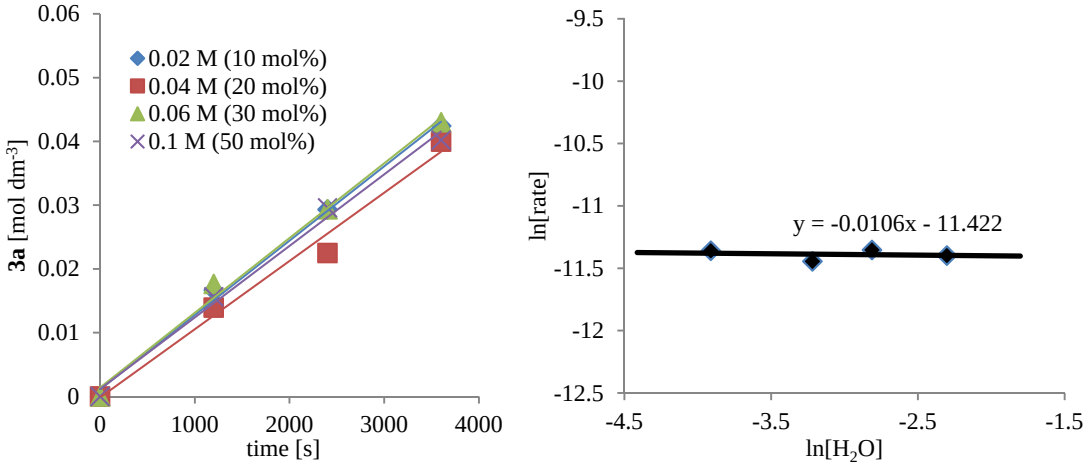
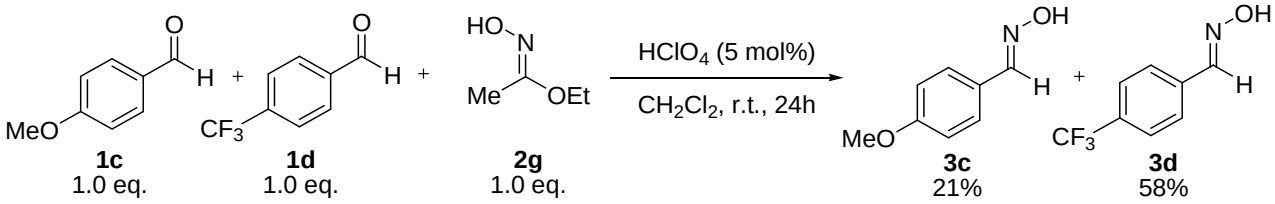


Figure S14. Kinetic study for water

7. Cross-over Reaction

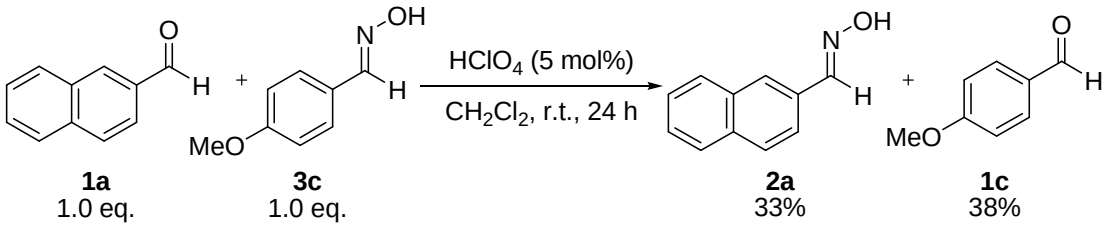
Reaction with 1c and 1d, 2g



Scheme S1. Cross-over reaction with **1c** and **1d** in the presence of **2g**

To a flame dried test tube **1c** (20.7 μL, 0.170 mmol), **1d** (23.2 μL, 0.170 mmol), CH_2Cl_2 (0.9 mL, 0.20 M) was added and stirred under argon atmosphere. 70 wt% $HClO_4$ aqueous solution (0.7 μL, 8.50 μmol) was added to the reaction mixtures, followed by added **2g** (17.5 μL, 0.170 mmol) at room temperature. After 24 hours, the reaction mixtures was passed through silica/Celite® pad to remove catalyst and washed with CH_2Cl_2 (10 mL). The collected solution was evaporated to remove solvent and dried over under vacuum pump to give crude mixtures. 1, 1, 2, 2-Tetrachloroethane (14.8 mg, 0.0883 mmol) was added to the crude mixtures as an internal standard. The yield of both **3c** and **3d** were determined by ^{1}H NMR from the peak of internal standard.

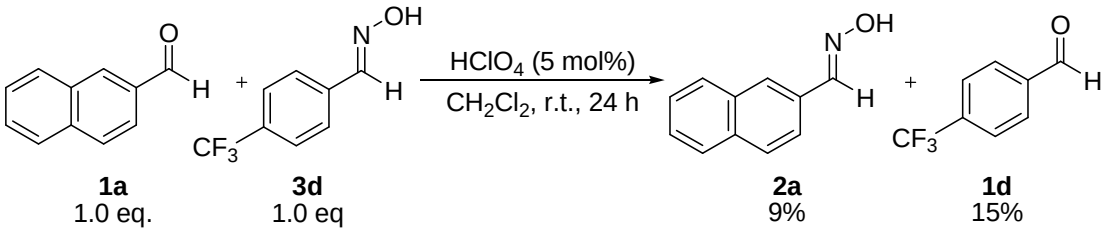
Reaction with 1a and 3c



Scheme S2. Cross-over reaction with **1a** and **3c**

To a flame dried test tube **1a** (26.6 mg, 0.170 mmol), **3c** (25.7 mg, 0.170 mmol), CH_2Cl_2 (0.9 mL, 0.20 M) was added and stirred under argon atmosphere. 70 wt% $HClO_4$ aqueous solution (0.7 μL, 8.50 μmol) was added to the reaction mixtures at room temperature. After 24 hours, the reaction mixtures was passed through silica/Celite® pad to remove catalyst and washed with CH_2Cl_2 (10 mL). The collected solution was evaporated to remove solvent and dried over under vacuum pump to give crude mixtures. 1, 1, 2, 2-Tetrachloroethane (15.5 mg, 0.0925 mmol) was added to the crude mixtures as an internal standard. The yield of both **2a** and **1c** were determined by ^{1}H NMR from the peak of internal standard.

Reaction with 1a and 3d

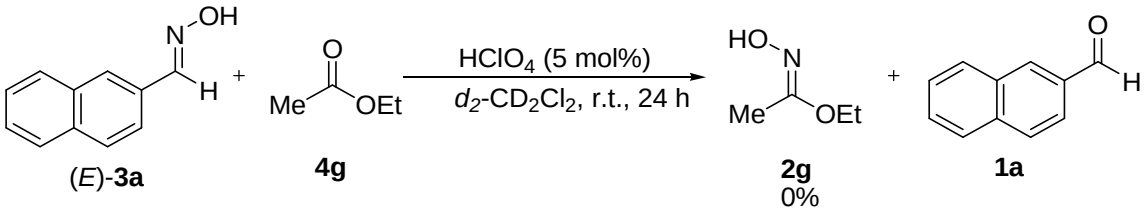


Scheme S3. Cross-over reaction with **1a** and **3d**

To a flame dried test tube **1a** (26.6 mg, 0.170 mmol), **3d** (32.2 mg, 0.170 mmol), CH_2Cl_2 (0.9 mL, 0.20 M) was added and stirred under argon atmosphere. 70 wt% $HClO_4$ aqueous solution (0.7 μL, 8.50 μmol) was added to the reaction mixtures at room temperature. After 24 hours, the reaction mixtures was passed through silica/Celite® pad to remove catalyst and washed with CH_2Cl_2 (10 mL). The collected solution was evaporated to remove solvent and dried over under vacuum pump to give crude mixtures. 1, 1, 2, 2-Tetrachloroethane (14.3 mg, 0.0852 mmol) was added to the crude mixtures as an internal standard. The yield of both **2a** and **1d** were determined by ^{1}H NMR from the peak of internal standard.

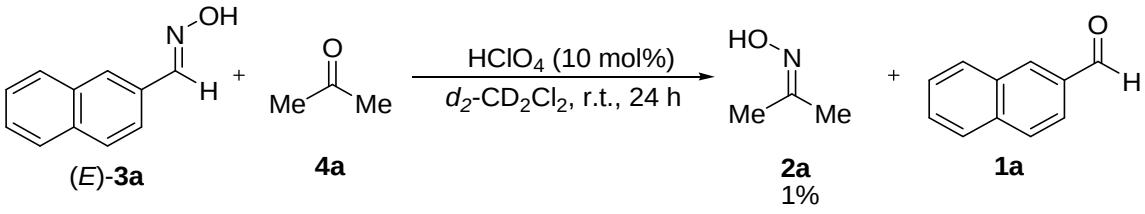
8. Retro Reaction

Transoximation from aldoxime to ethyl acetate in d_2-CD_2Cl_2



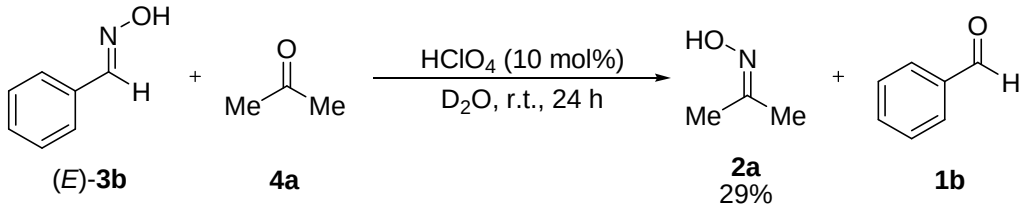
To a flame dried test tube ethyl acetate **4g** (9.1 μL, 0.0930 mmol, 1.0 equiv.), (*E*)-2- naphthaldoxime **3a** (24.0 mg, 0.140 mmol, 1.5 equiv.), d_2-CD_2Cl_2 (1.4 mL) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (0.4 μL, 4.70 μmol, 5 mol%) was added to the reaction mixtures. After 24 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine **2g**. However the reaction was not occurred and peaks of **2g** was nothing on the ^{1}H NMR chart.

Transoximation from aldoxime to acetone in d_2-CD_2Cl_2



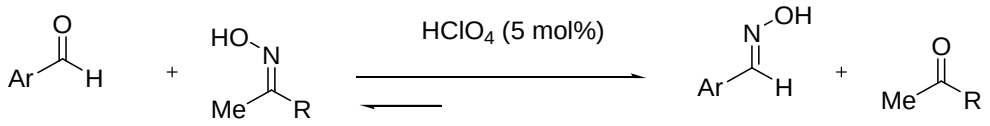
To a flame dried test tube acetone **4a** (10.3 μL, 0.140 mmol, 1.0 equiv.), (*E*)-2- naphthaldoxime **3a** (36.0 mg, 0.210 mmol, 1.5 equiv.), 1, 1, 2, 2-tetrachloroethane (10.9 mg, 0.0649 mmol) as internal standard d_2-CD_2Cl_2 (1.4 mL, 0.10 M) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (1.2 μL, 14.0 μmol, 10 mol%) was added to the reaction mixtures. After 24 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine yield of **2a** from an internal standard (**2a**: 1% yield). We found retro reaction (**3a** to **4a**) was not almost occurred in this condition.

Transoximation from aldoxime to acetone in D_2O



To a flame dried test tube acetone **4a** (24.9 μL, 0.340 mmol, 1.0 equiv.), (*E*)-2- benzaldoxime **3b** (61.8 mg, 0.510 mmol, 1.5 equiv.), dioxane (3.7 mg, 0.0425 mmol) as internal standard D_2O (1.7 mL, 0.20 M) was added and stirred under argon atmosphere at room temperature. Then 70 wt% $HClO_4$ aq. (2.9 μL, 34.0 μmol, 10 mol%) was added to the reaction mixtures. After 24 hours, the solution was directly transferred to the NMR tube and taken ^{1}H NMR to determine yield of **2a** from an internal standard (**2a**: 29% yield). We found retro reaction (**3b** to **4a**) was slightly occurred in this condition.

These results indicated that retro-reaction which **3a** reacted with **4a, g** generated from **2a, g** in d_2-CD_2Cl_2 was not occurred under process of transoximation in our catalytic system. Thus retro-reaction which **3b** reacted with **4a** generated from **2a** in D_2O did not occur so much under process of transoximation in our catalytic system. This will be one of the reason our transoximation system gave aldoxime products in high yields.



1a, b **2a, g** (*E*)-**3a, b** **4a, g**

9. References

1) Kainuma, M.; Makishima, M.; Hashimoto, Y.; Miyachi, H. *Bioorg. Med. Chem.* **2007**, *15*, 2587-2600.

2) Yu, J.; Jin, Y.; Lu, M. *Adv. Synth. Catal.* **2015**, *357*, 1175 –1180.

3) Zhang, L.; Chen, H.; Zha, Z.; Wang, Z. *Chem. Commun*. **2012**, *48*, 6574–6576.

4) Sharghi, H.; Sarvari, M. H. *Synlett*, **2001**, 99-101.

5) Li, J.-T.; Li, X.-L.; Li, T.-S. *Ultrasonics Sonochemistry*, **2006**, *13*, 200-202.

6) Vo, Q. V.; Trenerry, C.; Rochfort, S.; Wadeson, J.; Leyton, C.; Hughes, A. B. B*ioorg. Med. Chem.* **2013**, *21*, 5945-5954.

7) Crandall, J. K.; Reix, T. *J. Org. Chem.* **1992**, *57*, 6759-6764.

8) Furuya, Y.; Ishihara, K.; Yamamoto, H. *J. Am. Chem. Soc.* **2005**, *127*, 11240-11241.

9) Blay, G.; Benach, E.; Fernández, I, Galletero, S.; Pedro, J. R.; Ruiz, R. *Synthesis*, **2000**, 403-406.

10) Pavlishchuk, V.; Birkelbach, F.; Weyhermüller, T.; Wieghardt, K.; Chaudhuri, P. *Inorg. Chem.* **2002**, *41*, 4405-4416.

11) Liu, S.; Yu, Y.; Liebeskind, L. S. *Org. Lett.* **2007**, *9*, 1947-1950.

12) (a) El-Gamal, M.; Bayomi, S. M.; El-Ashry, S. M.; Said, S. A.; Abdel-Aziz, A. A.-M.; Abdel-Aziz, N. I. *Eur. J. Med. Chem.* **2010**, *45*, 1403-1414; (b) Jerzy, S.; Czeslawa, T. *Zesz. Nauk. Politech. Slask. Chem.* **1967**, *39*, 43.

13) Khomutov, A. R.; Khurs, E. N.; Khomutov, R. V. *Russ. J. Bioorg. Chem.* **1988**, *14*, 385-391.

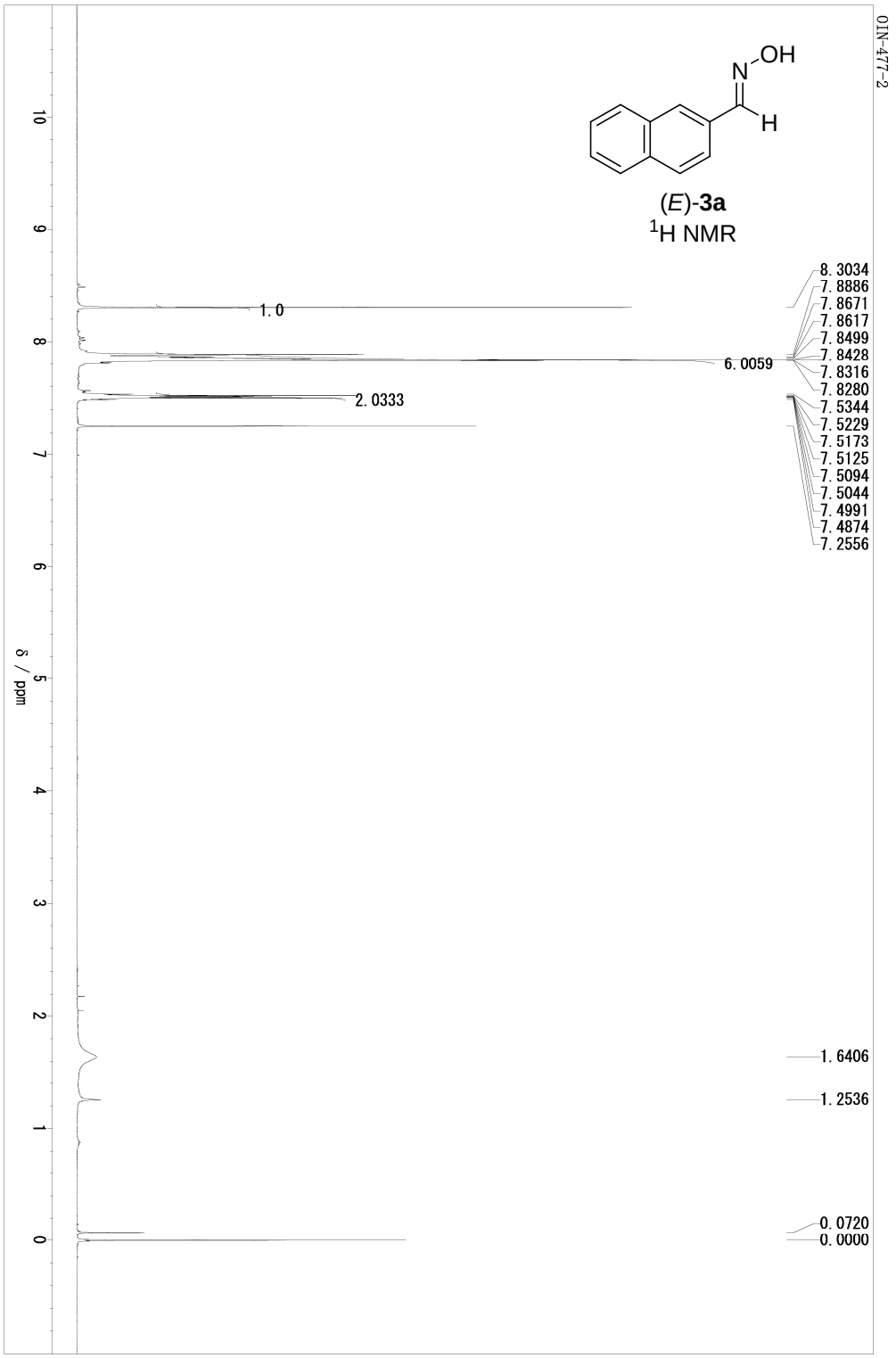
14) Fischer, D. S.; Allan, G. M.; Bubert, C.; Vicker, N.; Smith, A.; Tutill, H. J.; Purohit, A.; Wood, L.; Packham, G.; Mahon, M. F.; Reed, M. J.; Potter, B. V. L. *J. Med. Chem.* **2005**, *48*, 5749−5770.

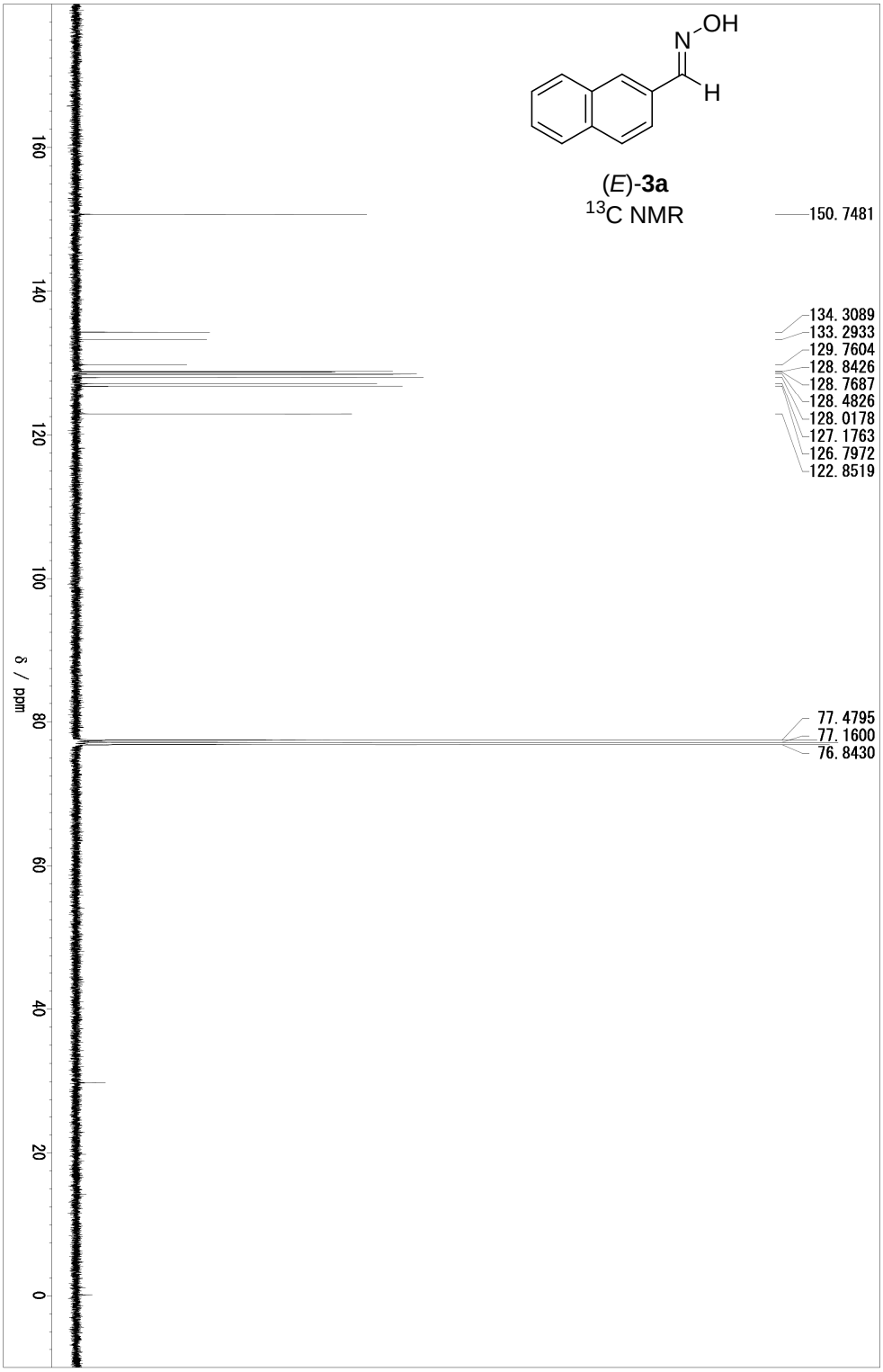
15) Parlanti, L.; Discordia, R. P.; Hynes, Jr., J.; Miller, M. M.; O'Grady, H. R.; Shi, Z. *Org. Lett.* **2007**, *9*, 3821-3824.

16) Kang, Q.-K.; Wang, L.; Liu, Q.-J.; Li, J.-F.; Tang, Y. *J. Am. Chem. Soc.* **2015**, *137*, 14594-14597.

17) Yukawa, T.; Seelig, B.; Xu, Y.; Morimoto, H.; Matsunaga, S.; Berkessel, A.; Shibasaki, M. *J. Am. Chem. Soc.* **2010**, *132*, 11988-11992.

10. NMR chart


OIN-477-2
OH
N
H
(E)-3a
1H NMR
δ / ppm
8.3034
7.8886
7.8671
7.8617
7.8499
7.8428
7.8316
7.8280
7.5344
7.5229
7.5173
7.5125
7.5094
7.5044
7.4991
7.4874
7.2556
1.0
6.0059
2.0333
1.6406
1.2536
0.0720
0.0000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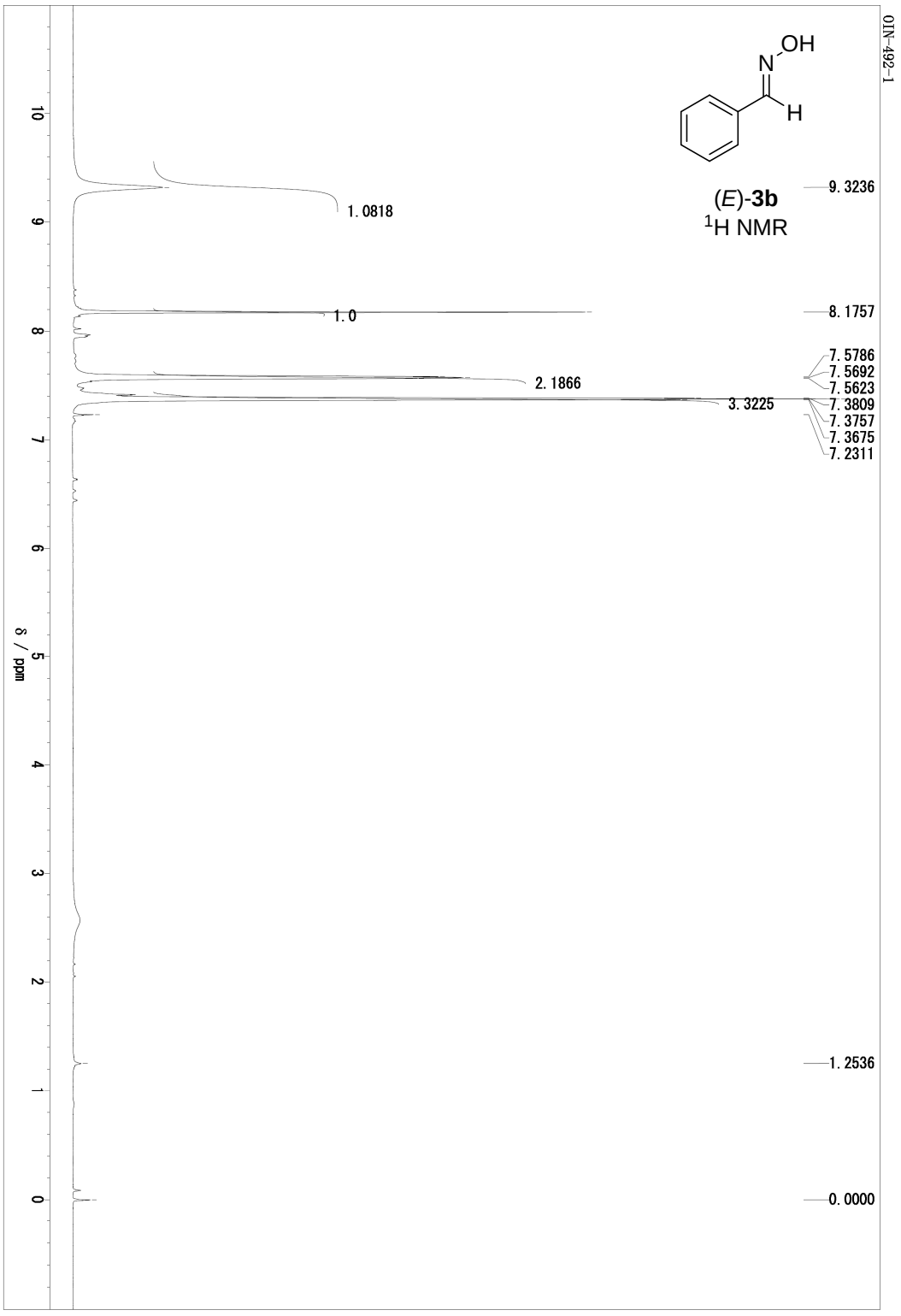
OH
N
H
(E)-3a
13C NMR
150.7481
134.3089
133.2933
129.7604
128.8426
128.7687
128.4826
128.0178
127.1763
126.7972
122.8519
77.4795
77.1600
76.8430
δ / ppm
160
140
120
100
80
60
40
20
0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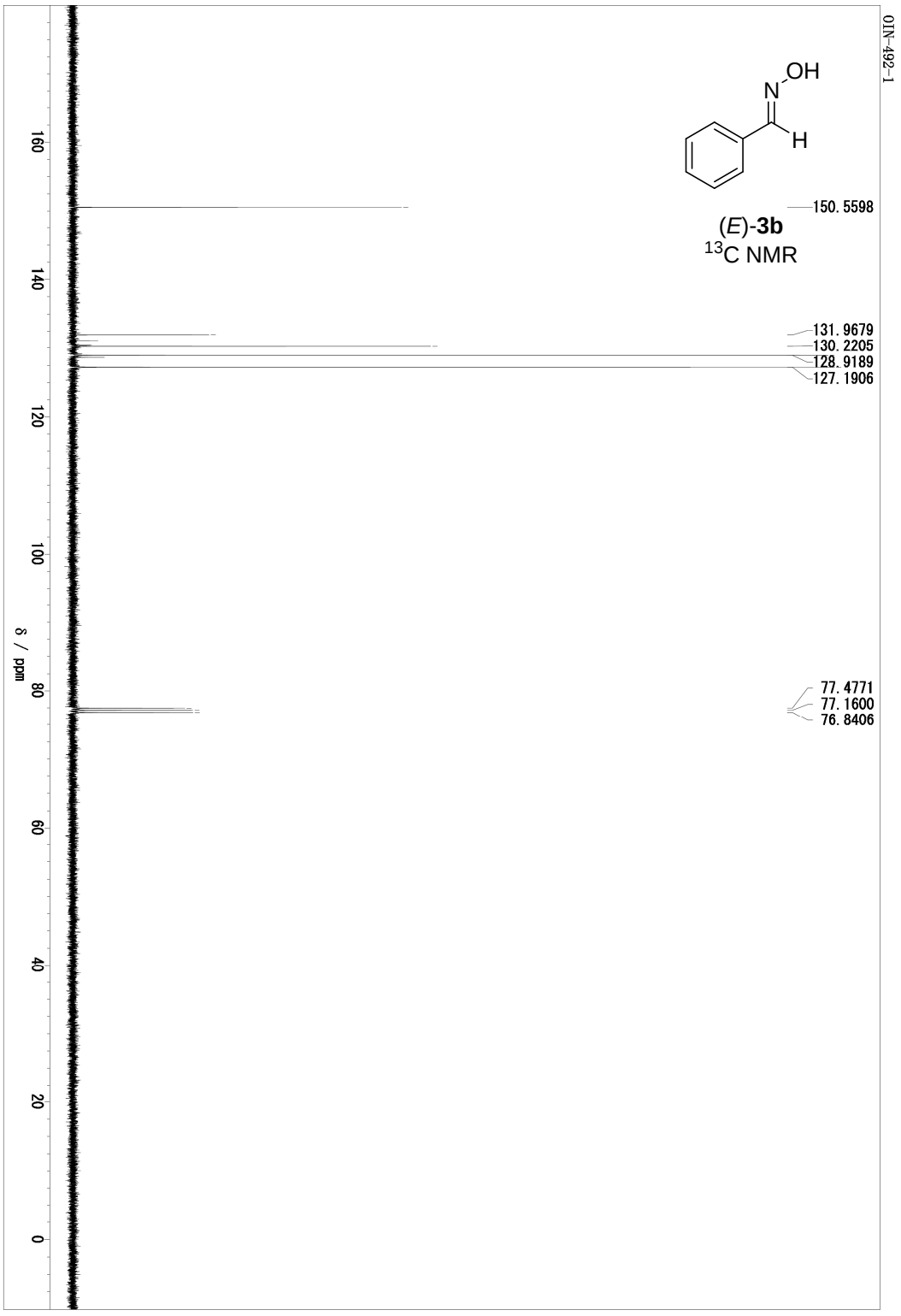
N
H
(E)-3b
1H NMR
9.3236
8.1757
7.5786
7.5692
7.5623
7.3809
7.3757
7.3675
7.2311
1.2536
0.0000
1.0818
1.0
2.1866
3.3225
δ / ppm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H
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(E)-3b
13C NMR
131.9679
130.2205
128.9189
127.1906
77.4771
77.1600
76.8406
δ / ppm
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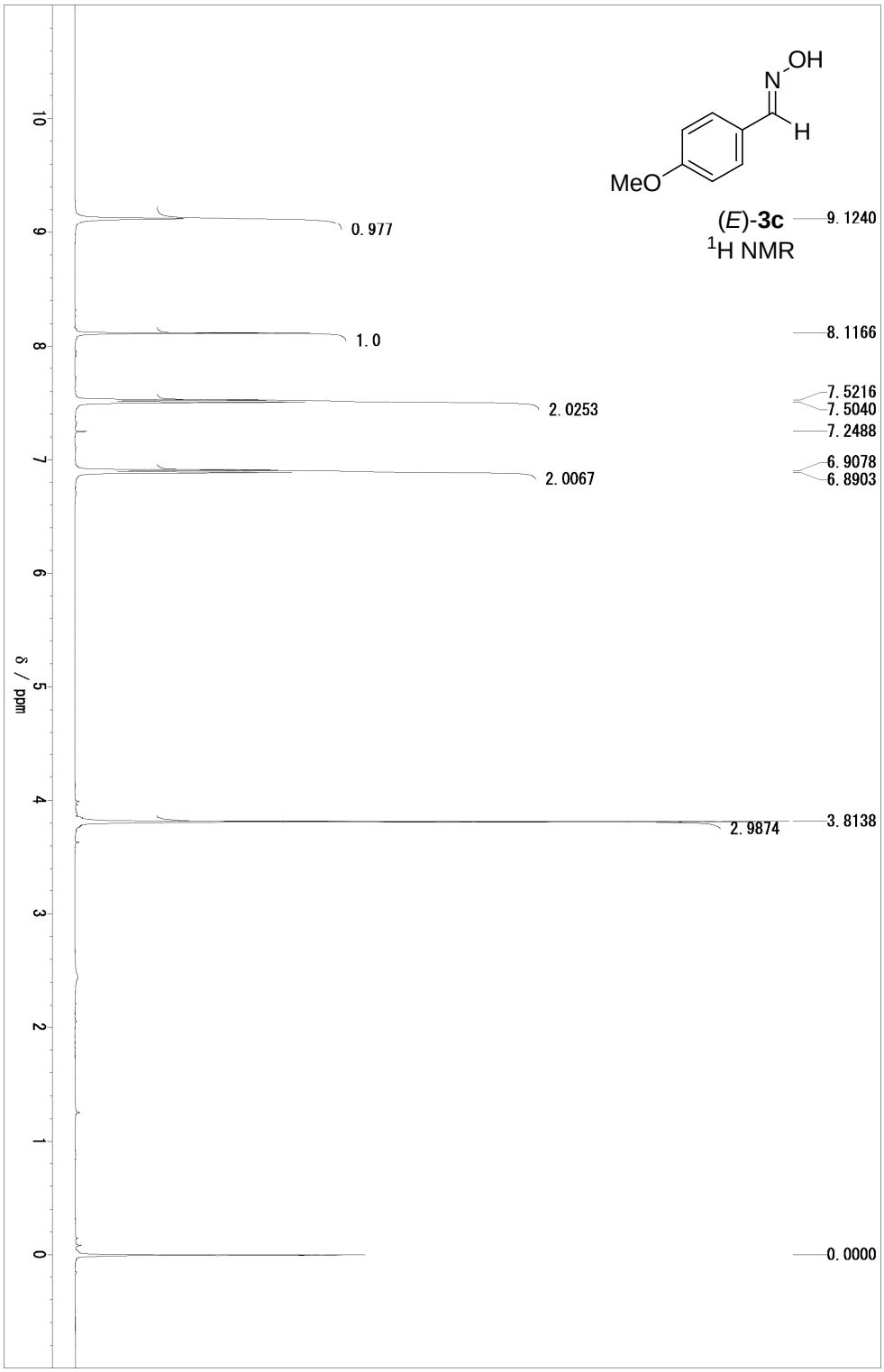
140
120
100
80
60
40
20
0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OH
N
H
MeO
(E)-3c
1H NMR
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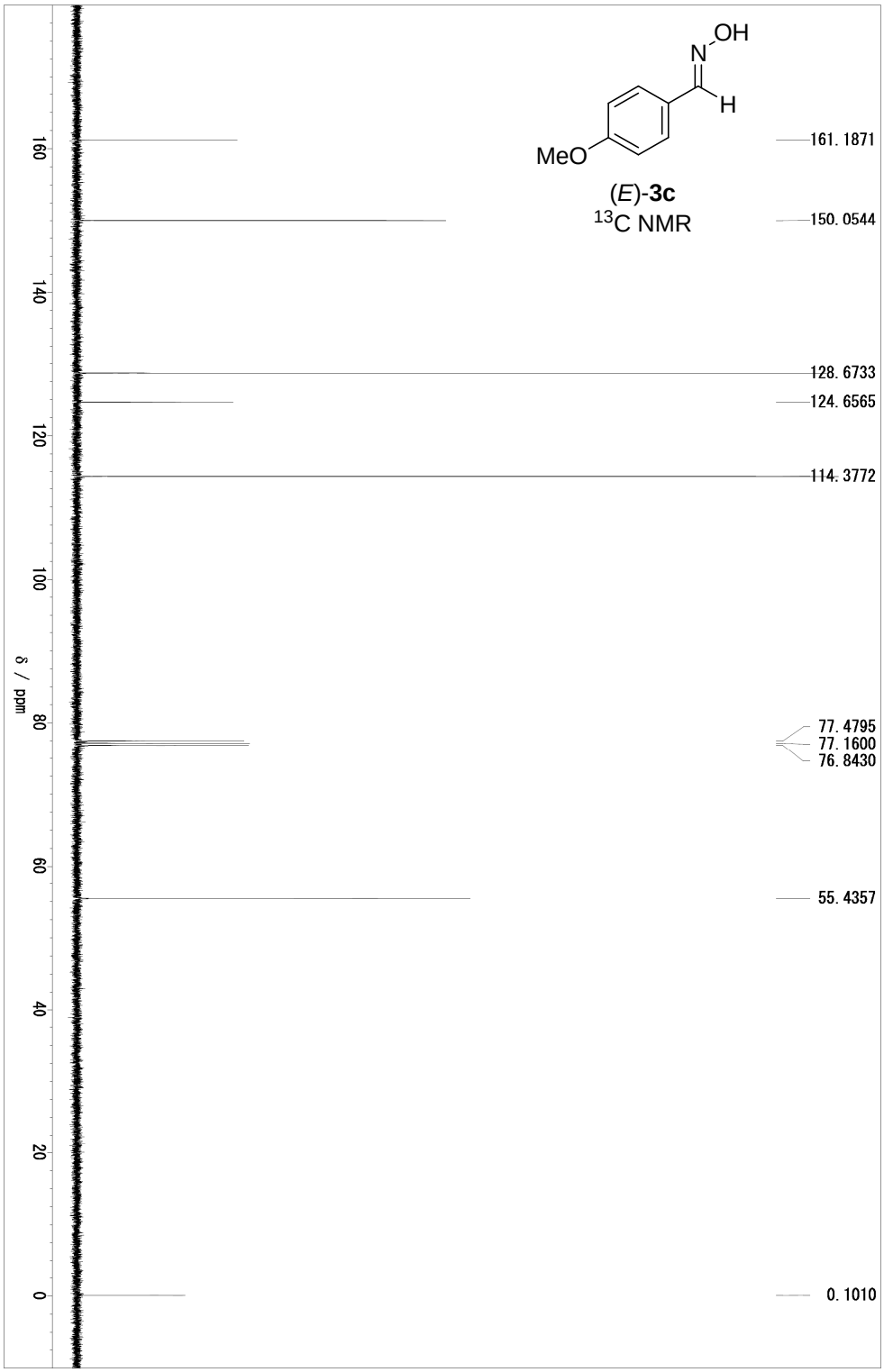
8.1166
7.5216
7.5040
7.2488
6.9078
6.8903
3.8138
0.0000
0.977
1.0
2.0253
2.0067
2.9874
δ / ppm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N
H
MeO
(E)-3c
13C NMR
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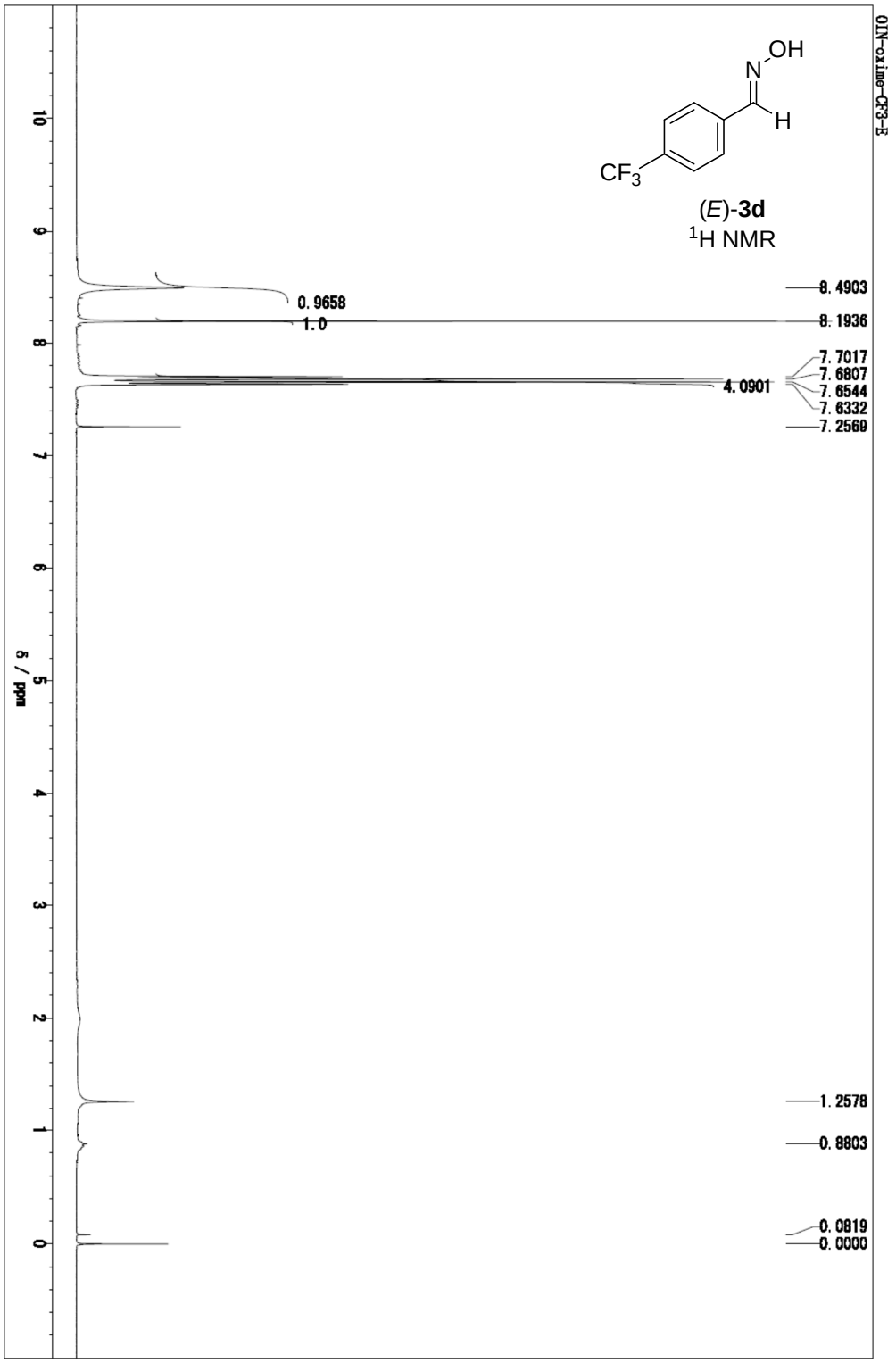
150.0544
128.6733
124.6565
114.3772
77.4795
77.1600
76.8430
55.4357
0.1010
δ / ppm
160
140
120
100
80
60
40
20
0
01N-oxime-4MeO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N
H
CF3
(E)-3d
1H NMR
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8.4903
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7.7017
7.6807
7.6544
7.6332
4.0901
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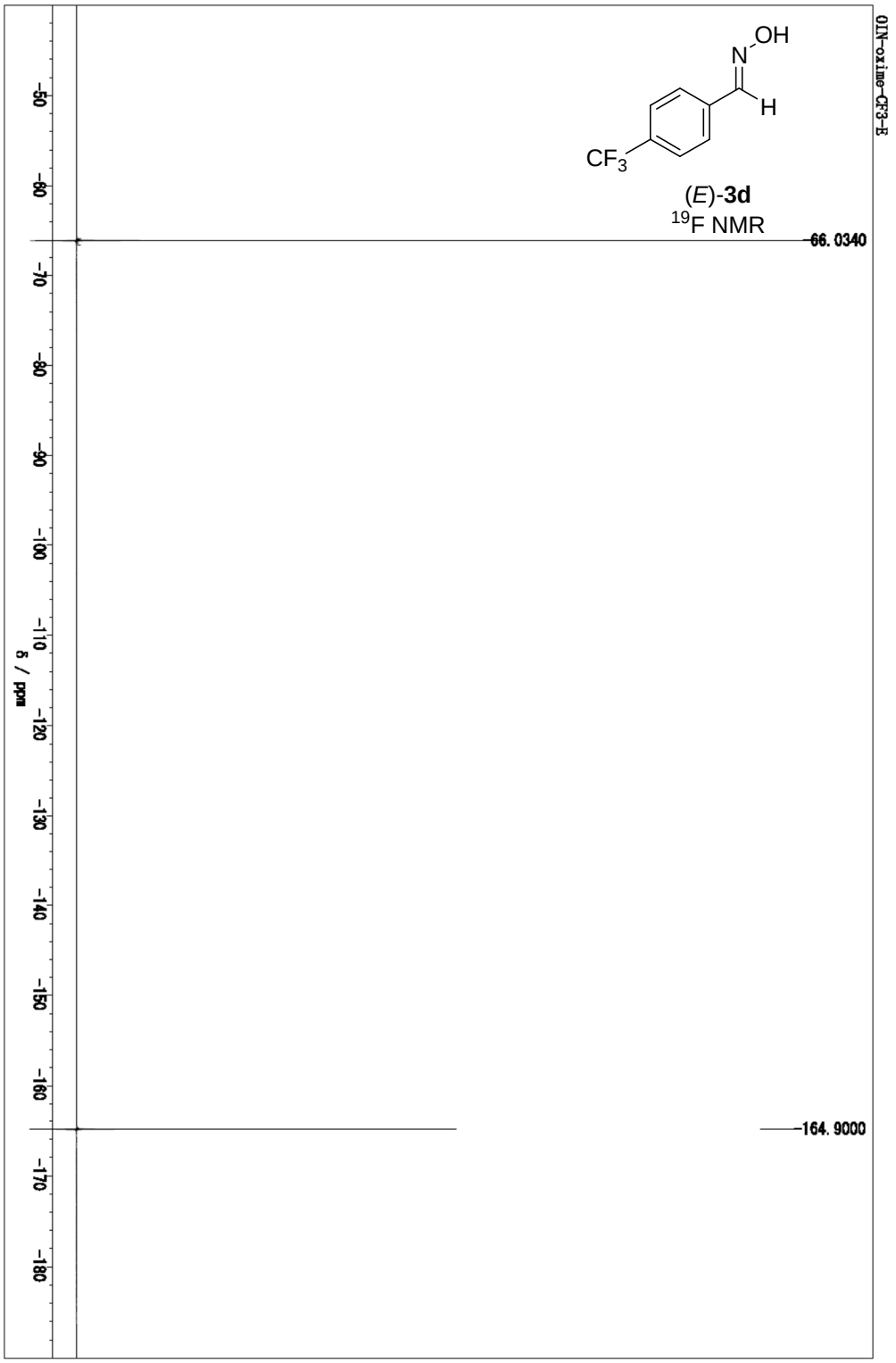
1.2578
0.8803
0.0819
0.0000
δ / ppm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N
H
CF3
(E)-3d
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δ / ppm
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-60
-70
-80
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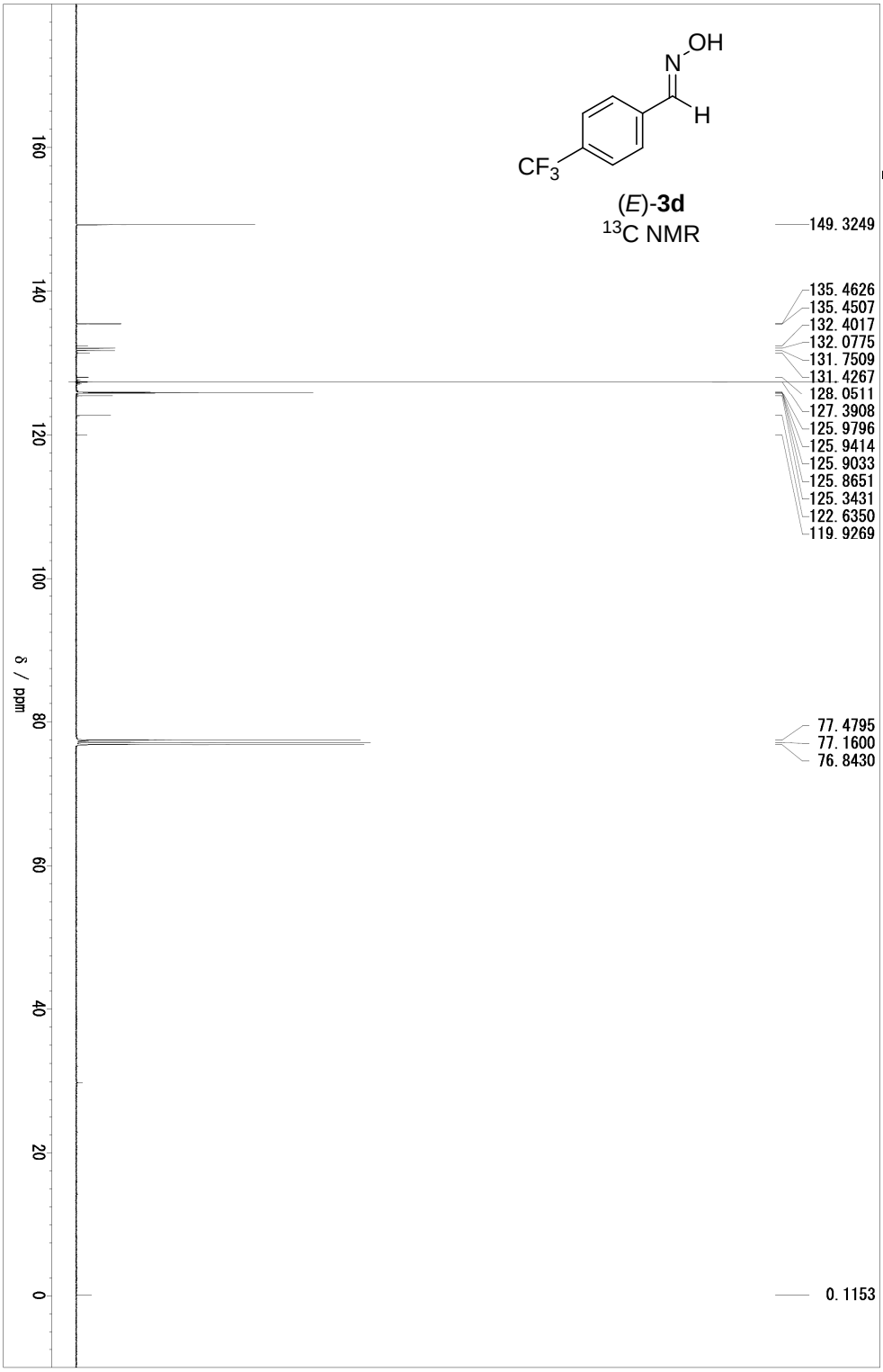
-120
-130
-140
-150
-160
-170
-180


OIN-oxime-Trifluoro_E
OH
N
H
CF3
(E)-3d
13C NMR
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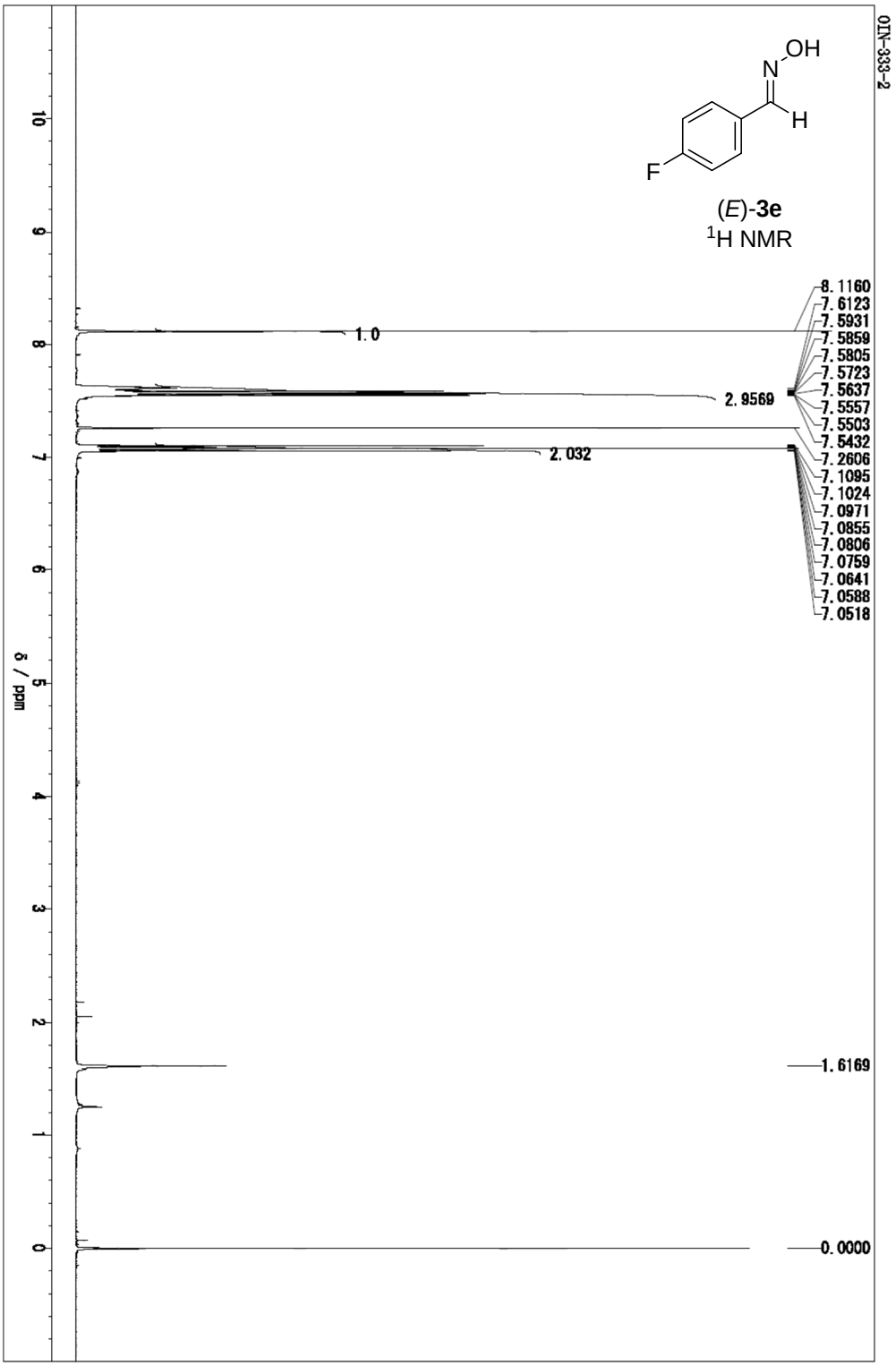
135.4626
135.4507
132.4017
132.0775
131.7509
131.4267
128.0511
127.3908
125.9796
125.9414
125.9033
125.8651
125.3431
122.6350
119.9269
77.4795
77.1600
76.8430
0.1153
δ / ppm
160
140
120
100
80
60
40
20
0


OIN-333-2
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N
H
F
(E)-3e
1H NMR
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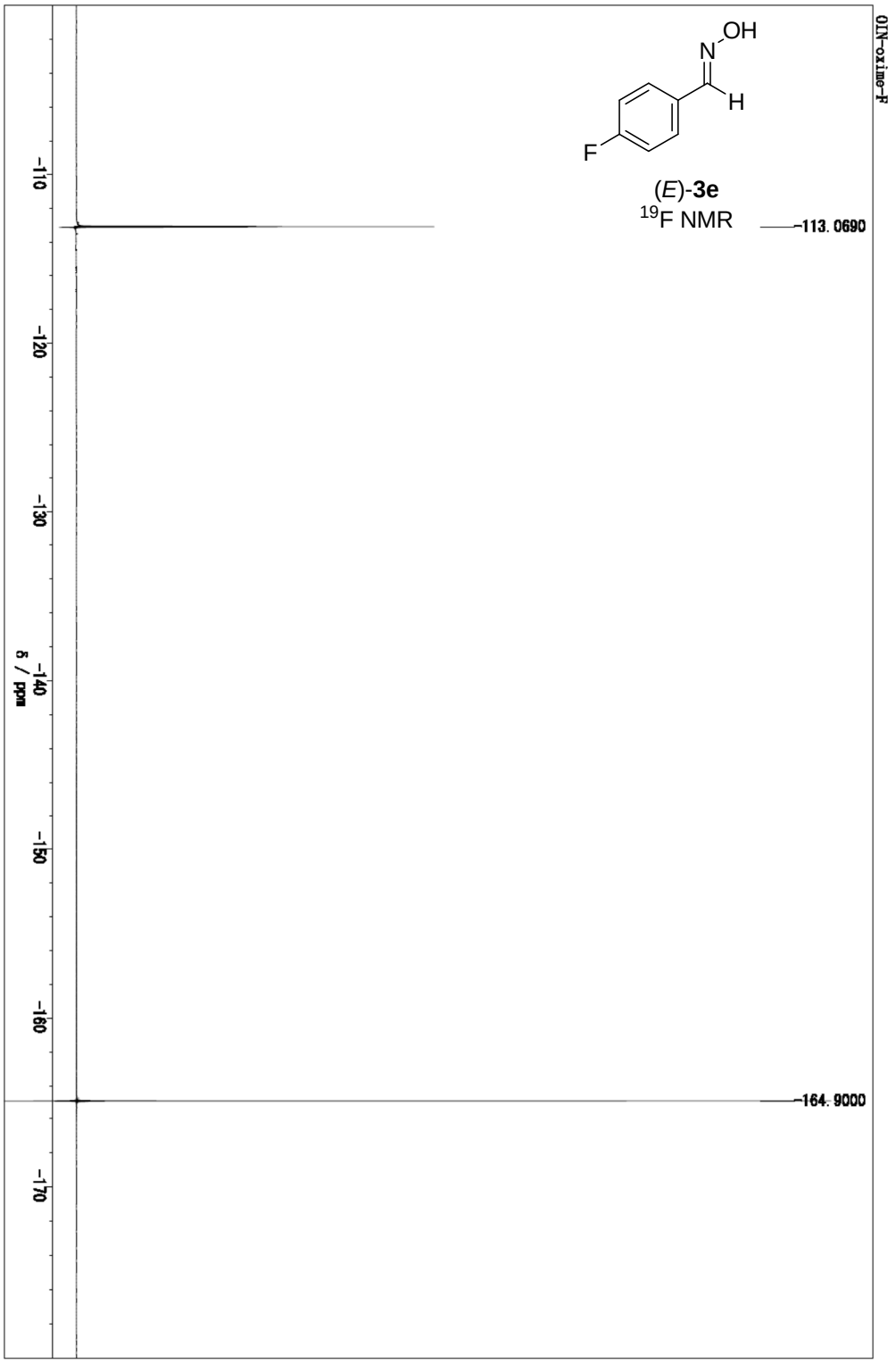
7.5805
7.5723
7.5637
7.5557
7.5503
7.5432
7.2606
7.1095
7.1024
7.0971
7.0855
7.0806
7.0759
7.0641
7.0588
7.0518
1.0
2.9569
2.032
1.6169
0.0000
δ / ppm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N
H
F
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δ / ppm
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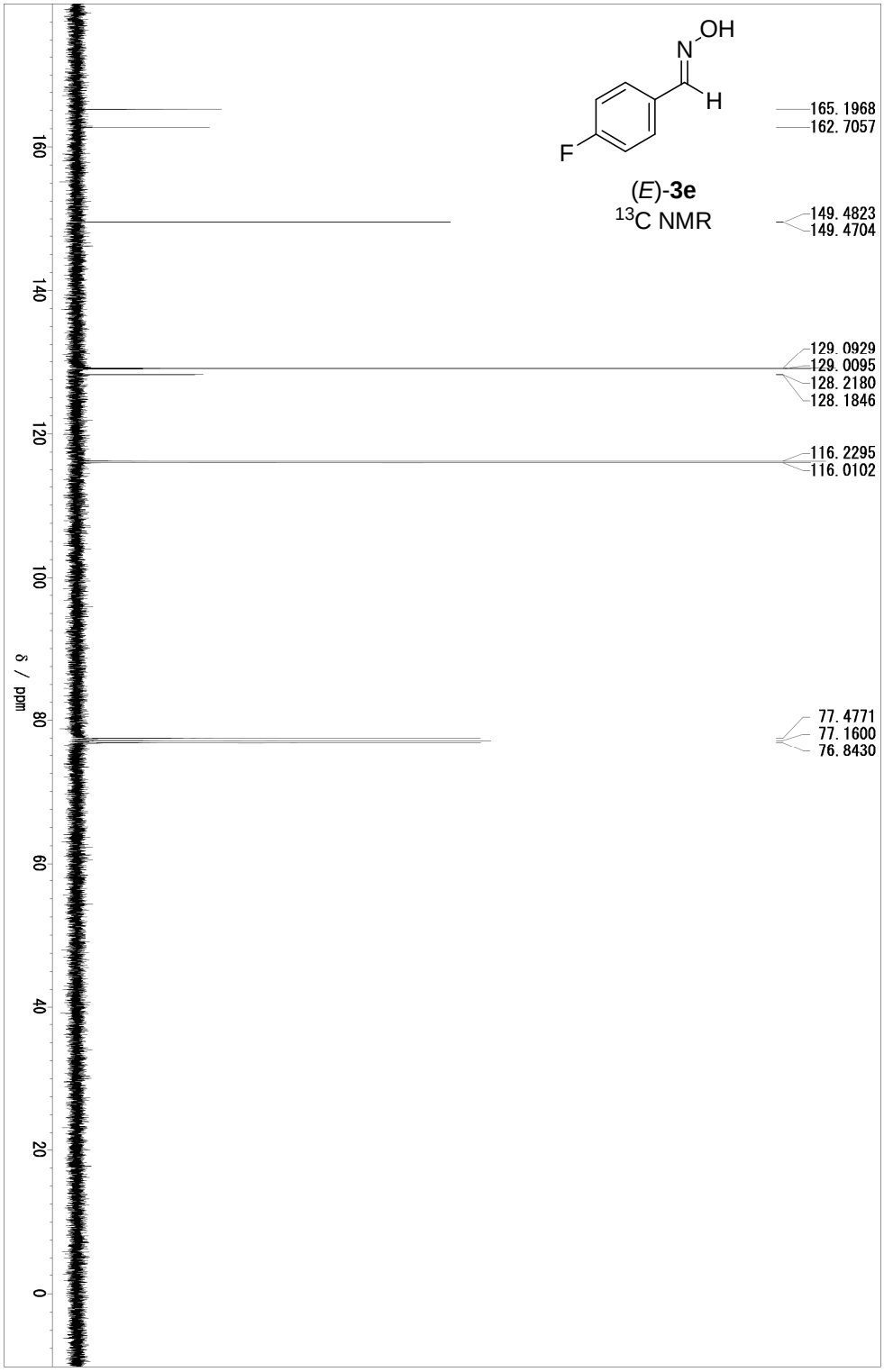
-120
-130
-140
-150
-160
-170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N
H
F
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13C NMR
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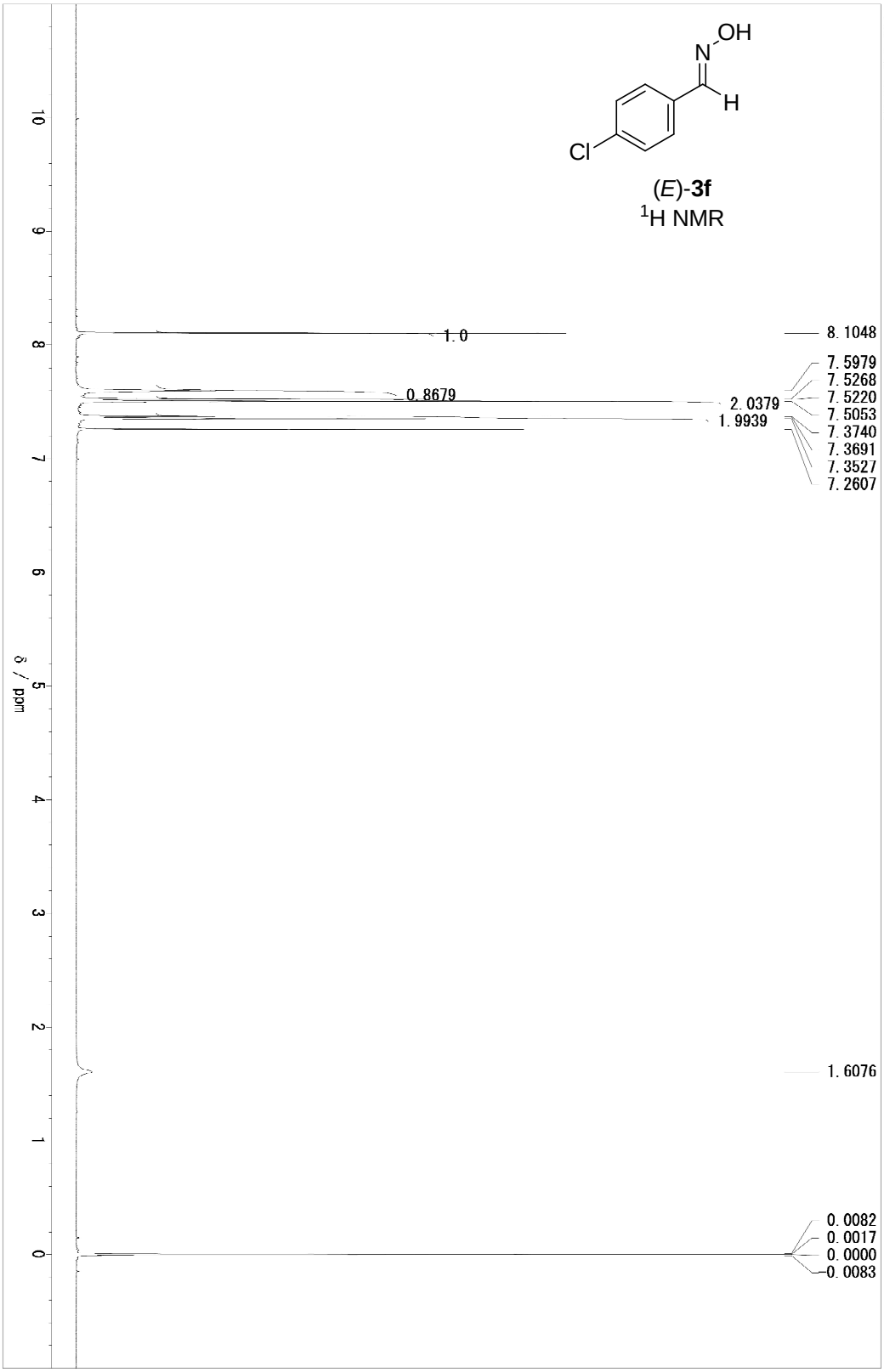
129.0929
129.0095
128.2180
128.1846
116.2295
116.0102
77.4771
77.1600
76.8430
δ / ppm
160
140
120
100
80
60
40
20
0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N
H
Cl
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0.8679
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1.9939
8.1048
7.5979
7.5268
7.5220
7.5053
7.3740
7.3691
7.3527
7.2607
1.6076
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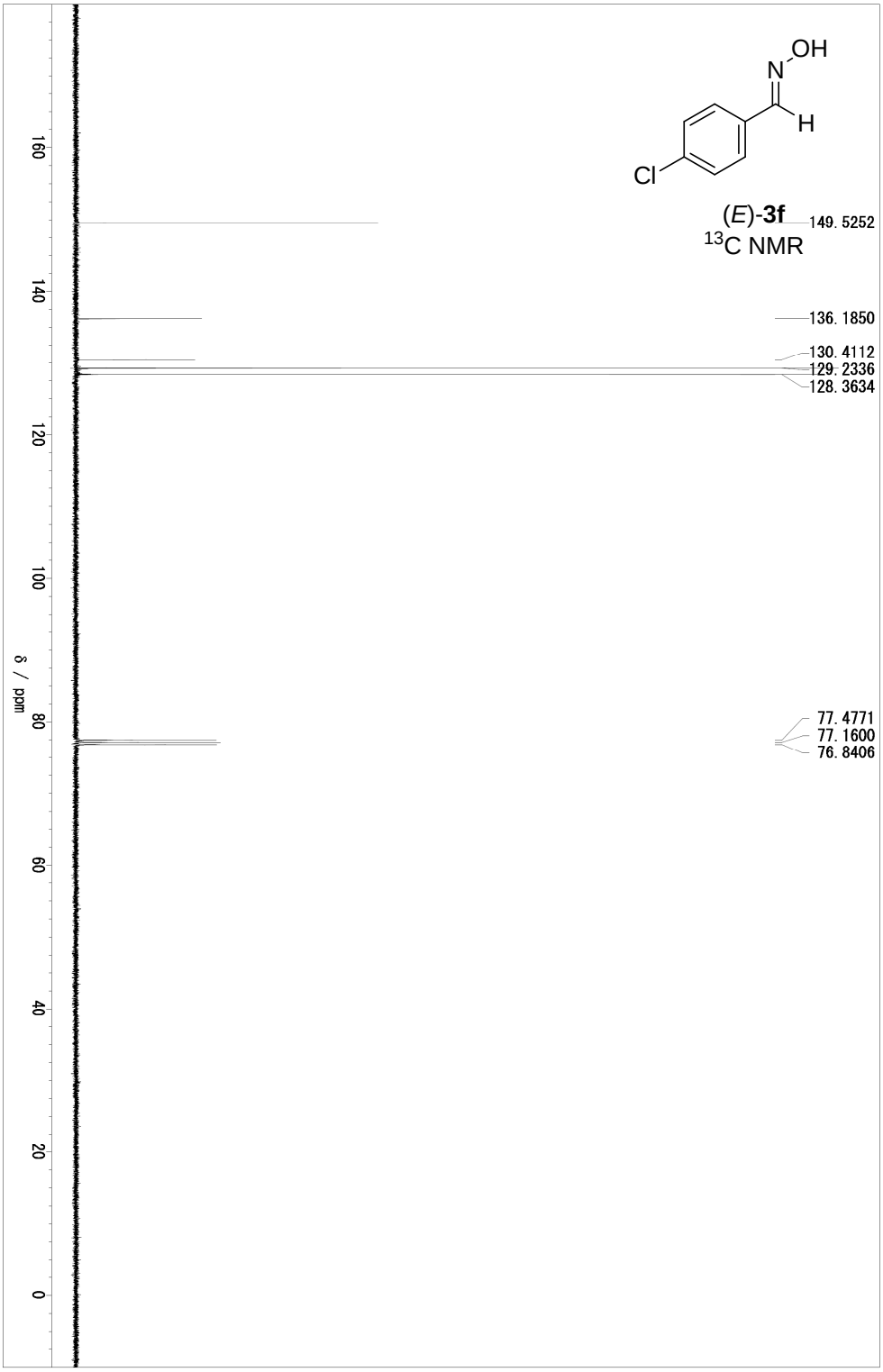
0.0017
0.0000
0.0083
δ / ppm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H
Cl
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77.1600
76.8406
δ / ppm
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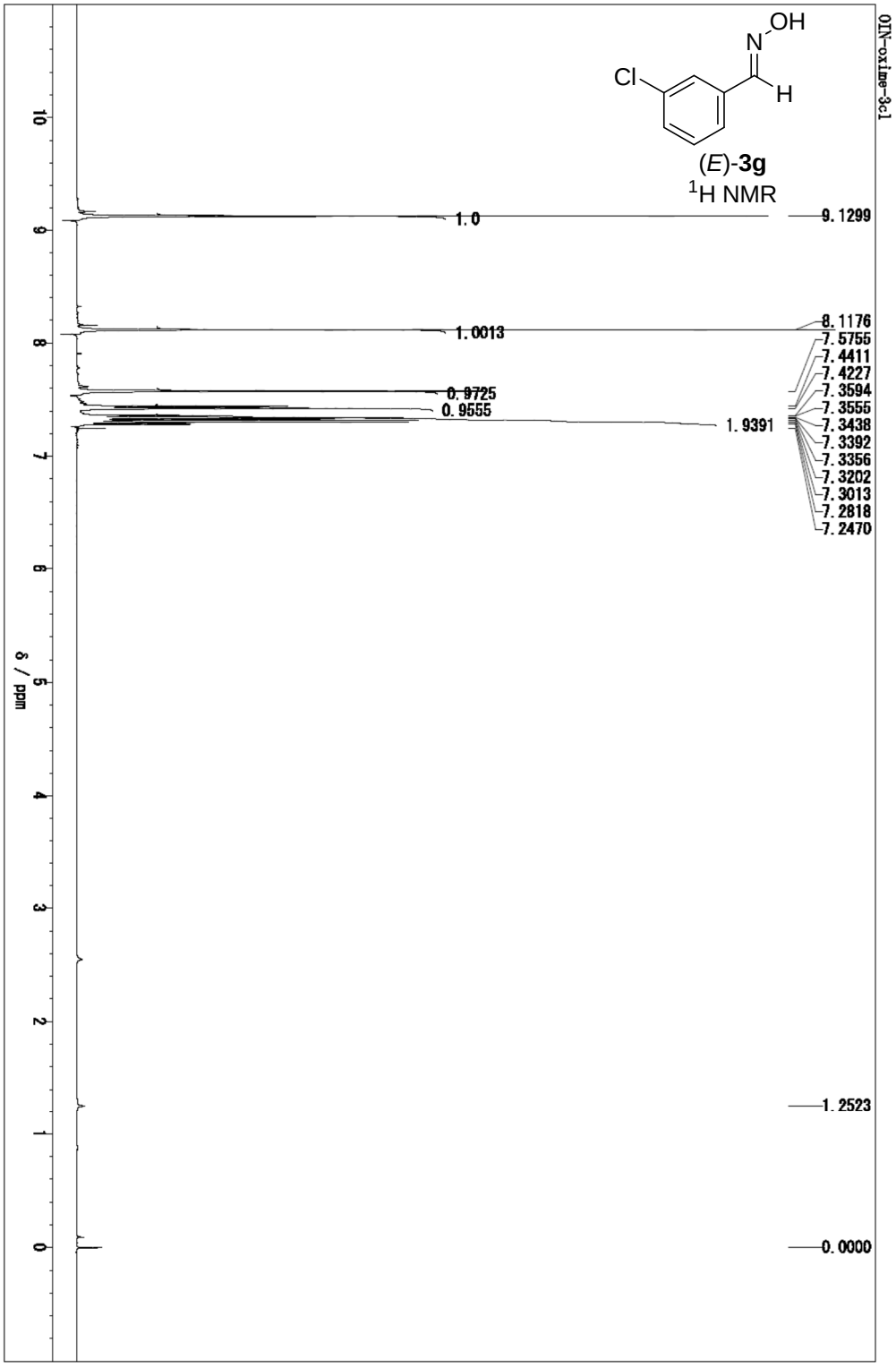
140
120
100
80
60
40
20
0


OIN-oxime-3c1
OH
N
Cl
H
(E)-3g
1H NMR
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9.1299
1.0013
8.1176
7.5755
7.4411
7.4227
7.3594
0.9725
7.3555
0.9555
1.9391
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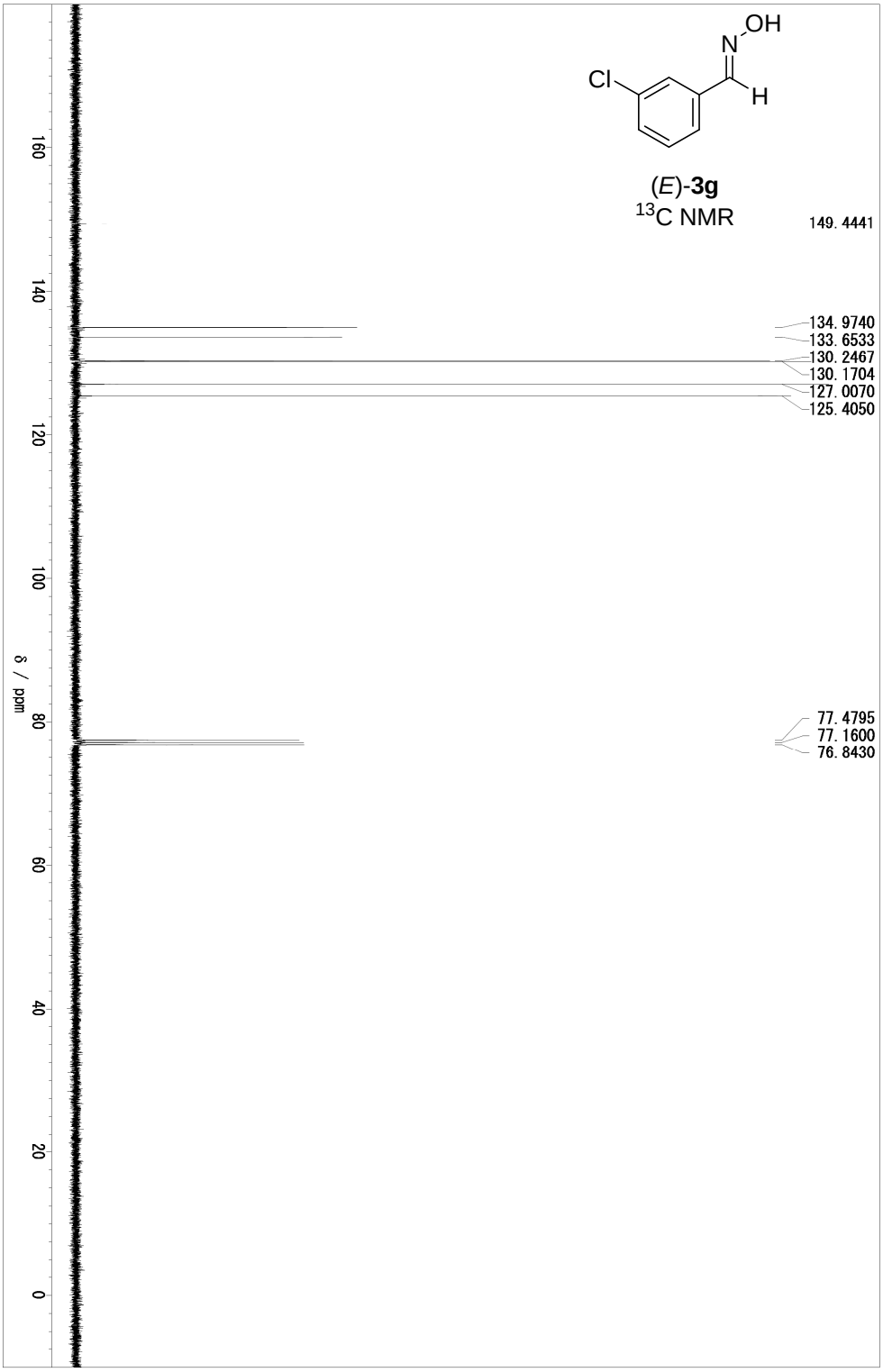
7.3392
7.3356
7.3202
7.3013
7.2818
7.2470
1.2523
0.0000
δ / ppm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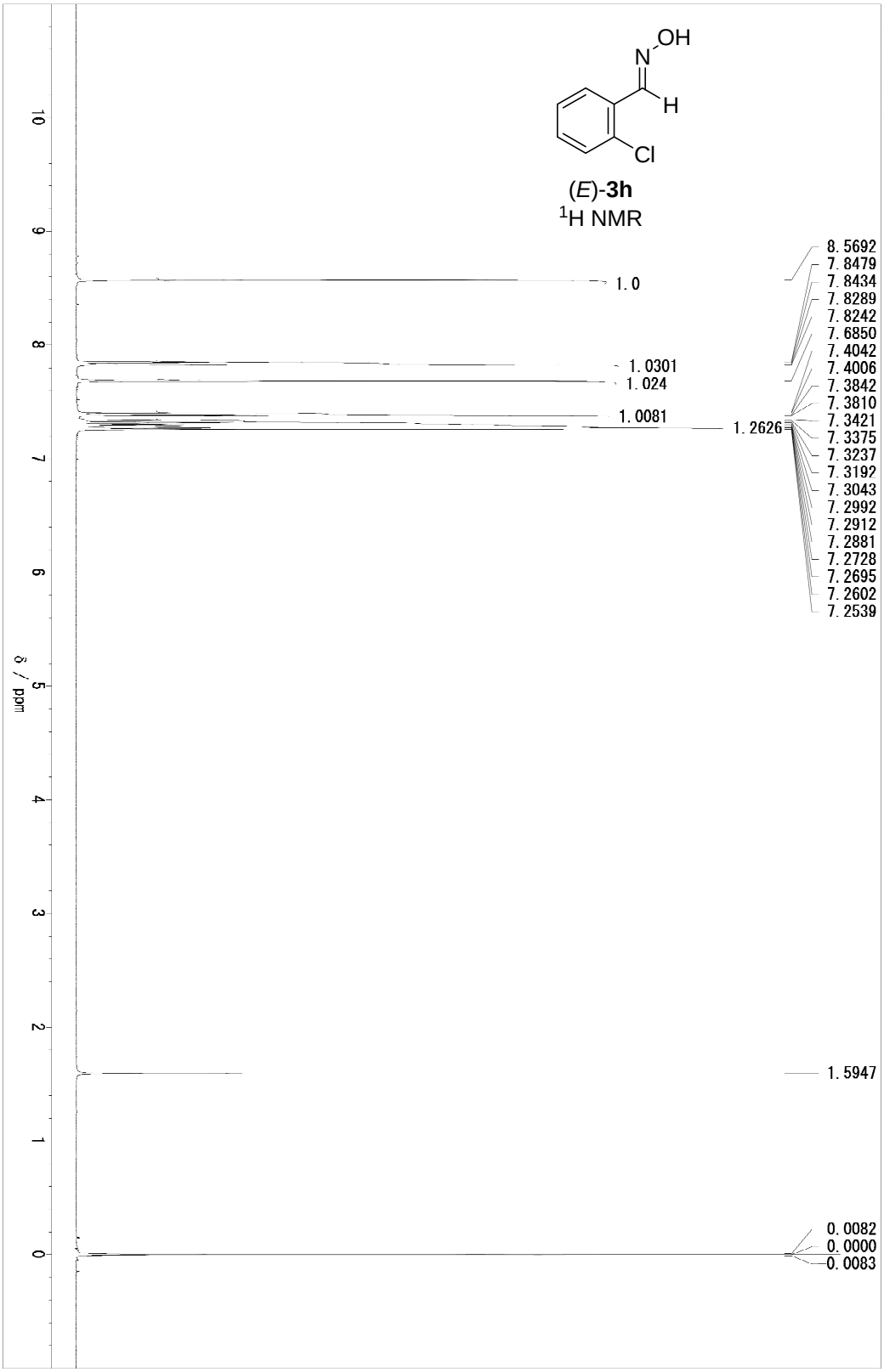
N
Cl
H
(E)-3g
13C NMR
149.4441
134.9740
133.6533
130.2467
130.1704
127.0070
125.4050
77.4795
77.1600
76.8430
δ / ppm
160
140
120
100
80
60
40
20
0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N
H
Cl
(E)-3h
1H NMR
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7.8434
7.8289
7.8242
7.6850
7.4042
7.4006
7.3842
7.3810
7.3421
7.3375
7.3237
7.3192
7.3043
7.2992
7.2912
7.2881
7.2728
7.2695
7.2602
7.2539
1.0
1.0301
1.024
1.0081
1.2626
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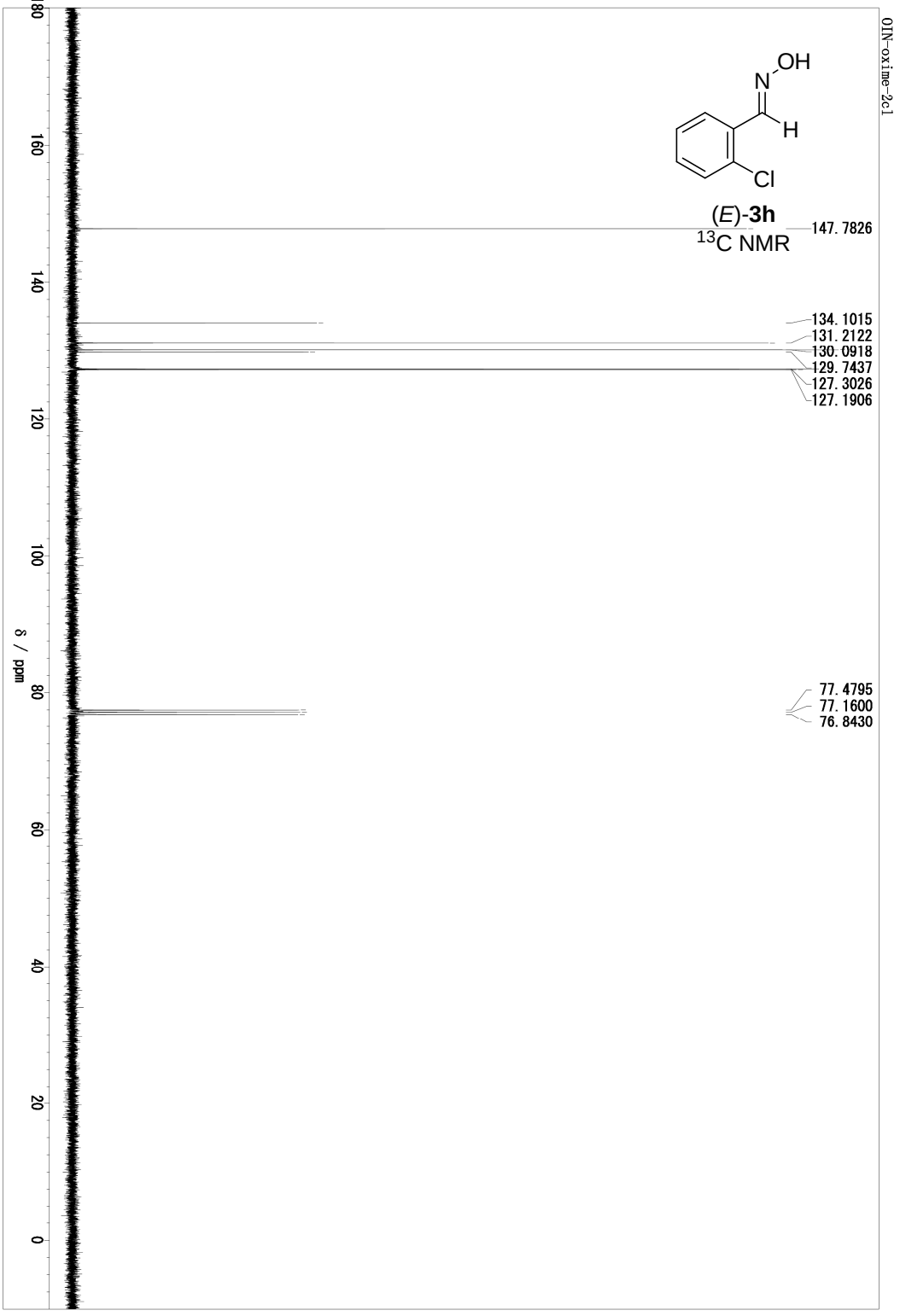
0.0000
0.0083
δ / ppm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H
Cl
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131.2122
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127.3026
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77.1600
76.8430
δ / ppm
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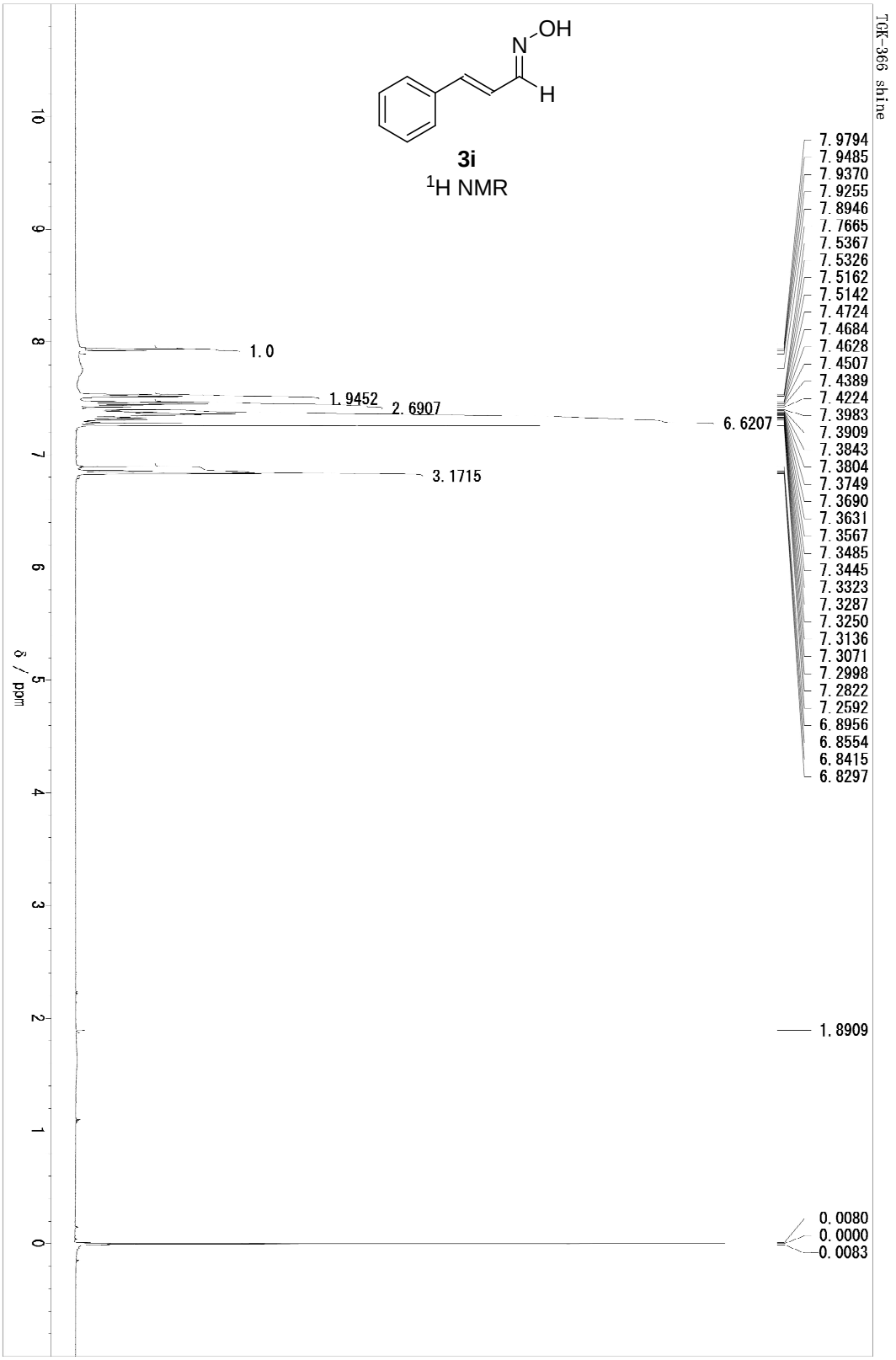
160
140
120
100
80
60
40
20
0


TGK-366 shine
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N
H
3i
1H NMR
δ / ppm
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2.6907
3.1715
6.6207
1.8909
0.0080
0.0000
0.0083
7.9794
7.9485
7.9370
7.9255
7.8946
7.7665
7.5367
7.5326
7.5162
7.5142
7.4724
7.4684
7.4628
7.4507
7.4389
7.4224
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7.3485
7.3445
7.3323
7.3287
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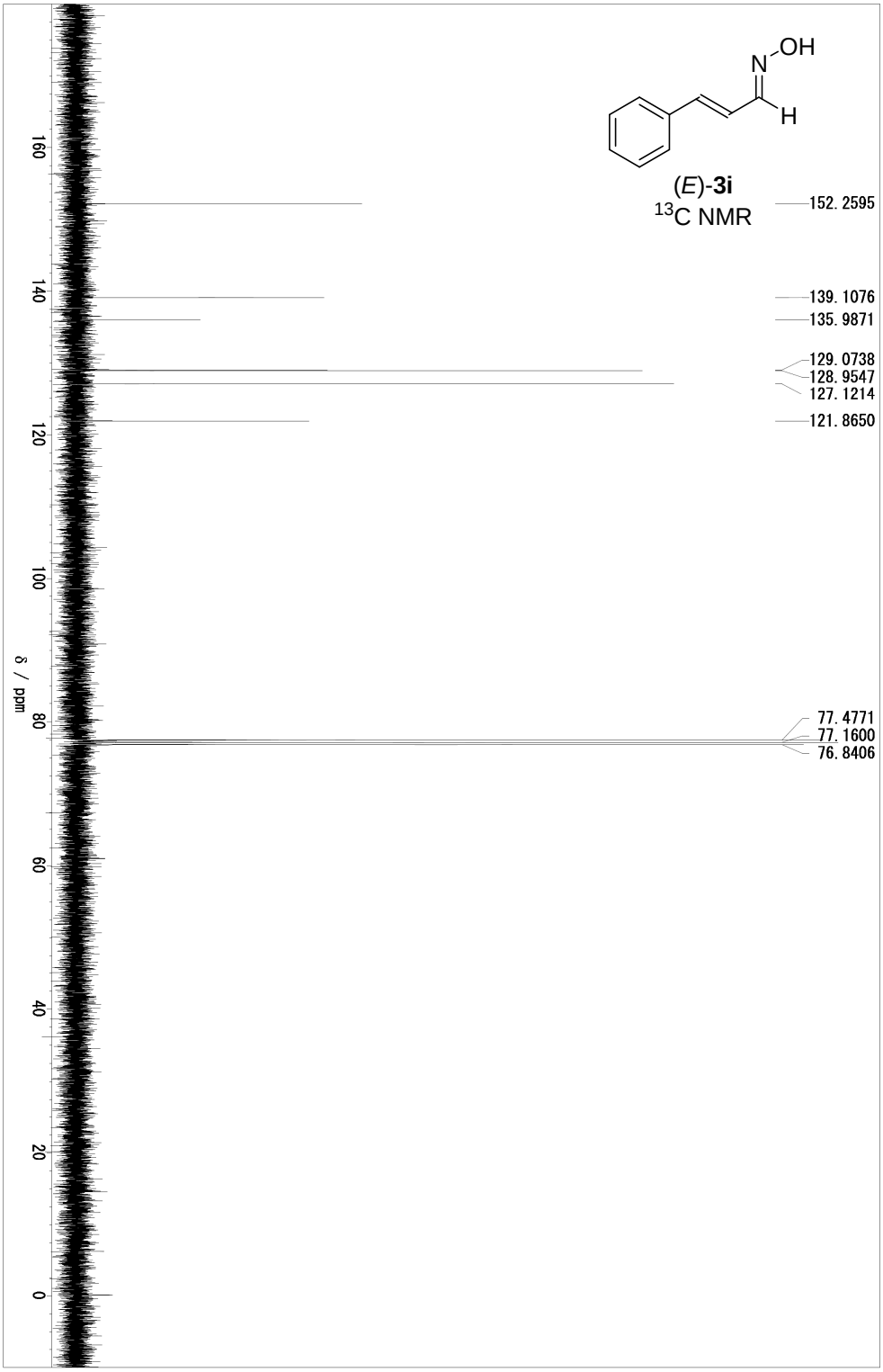
6.8297


OIN-oxime-trans E
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13C NMR
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128.9547
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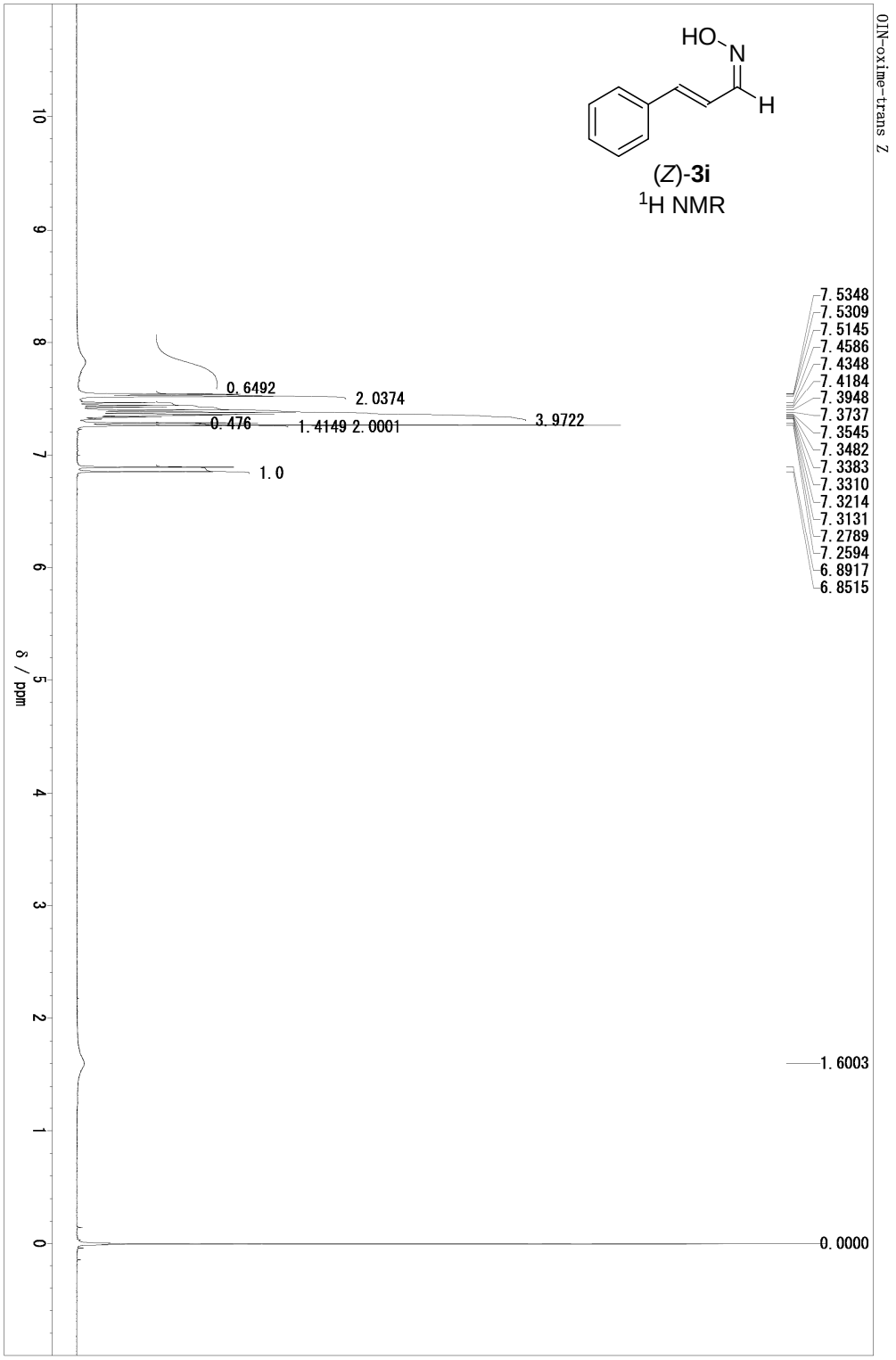
77.1600
76.8406
δ / ppm
160
140
120
100
80
60
40
20
0


HO
N
H
(Z)-3i
1H NMR
01N-oxime-trans Z
δ / ppm
0.6492
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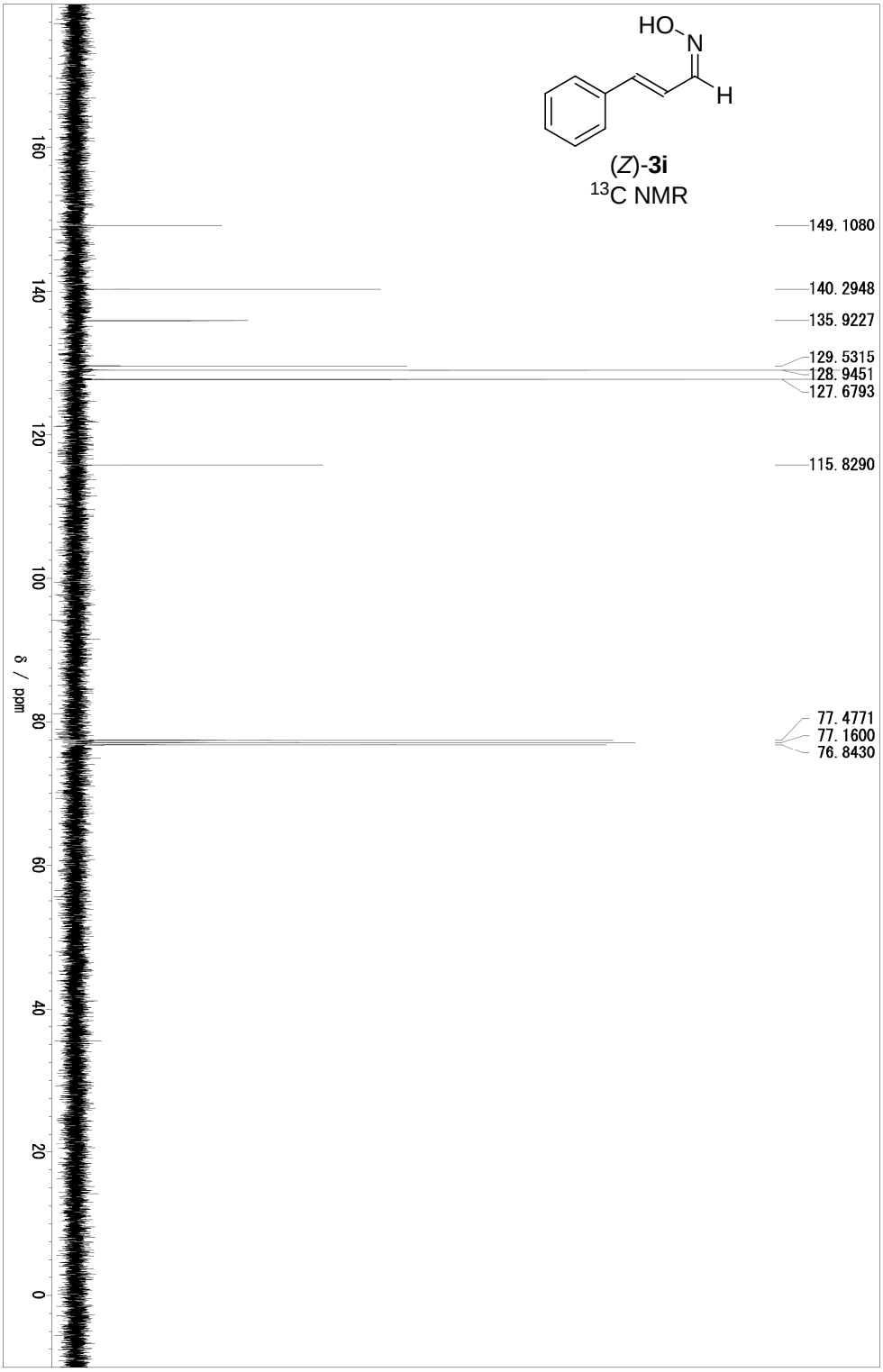
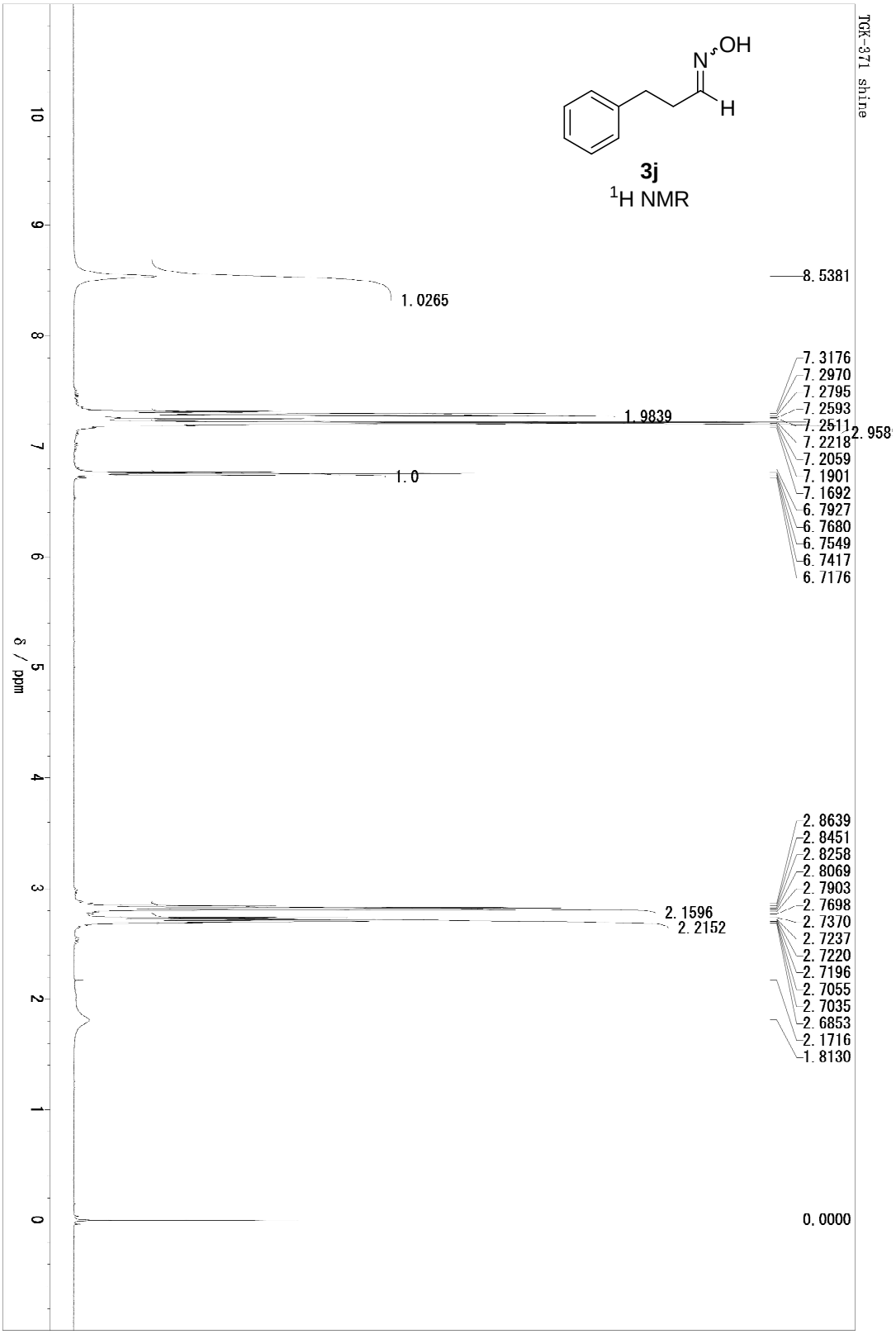
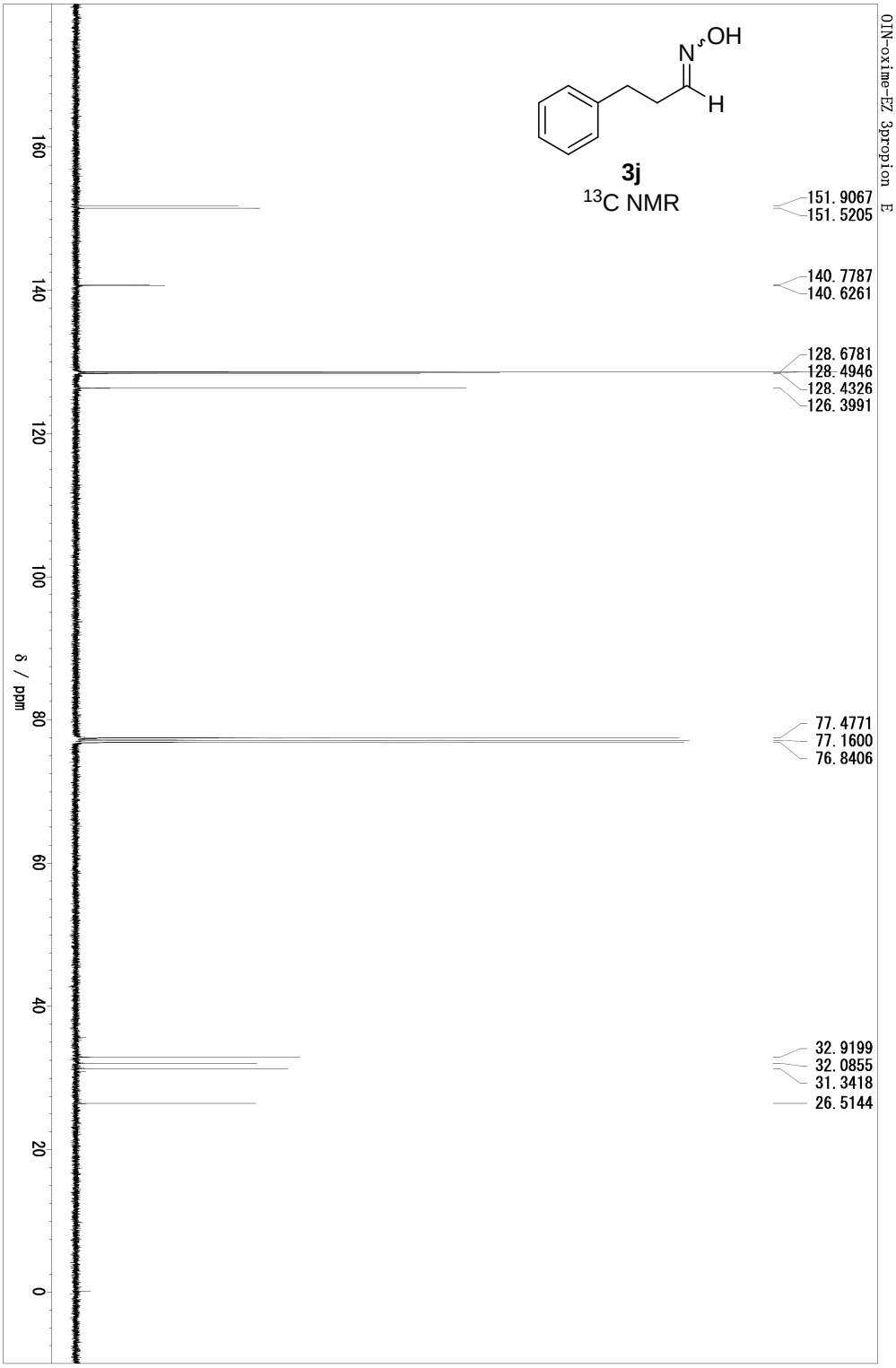
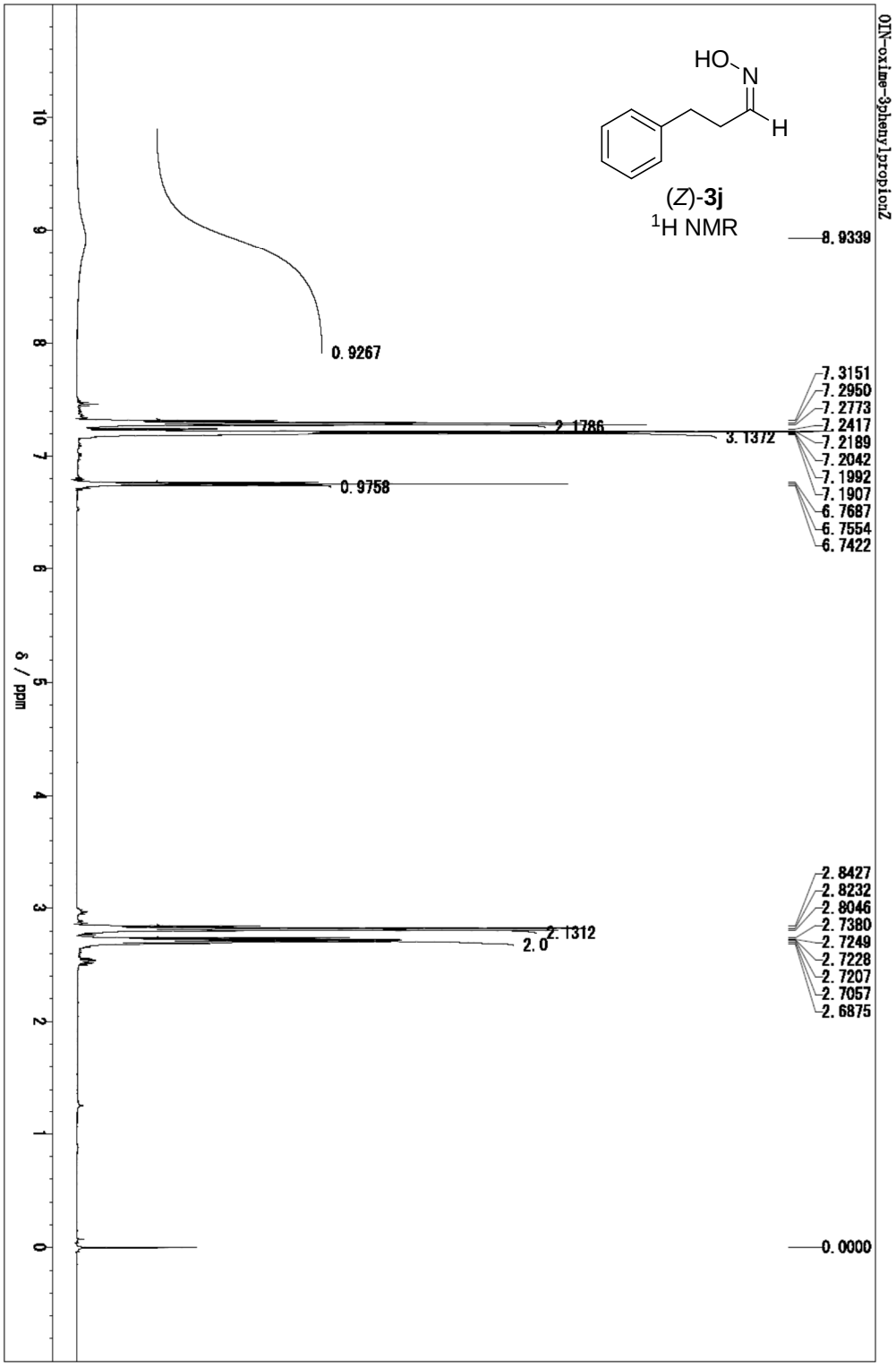
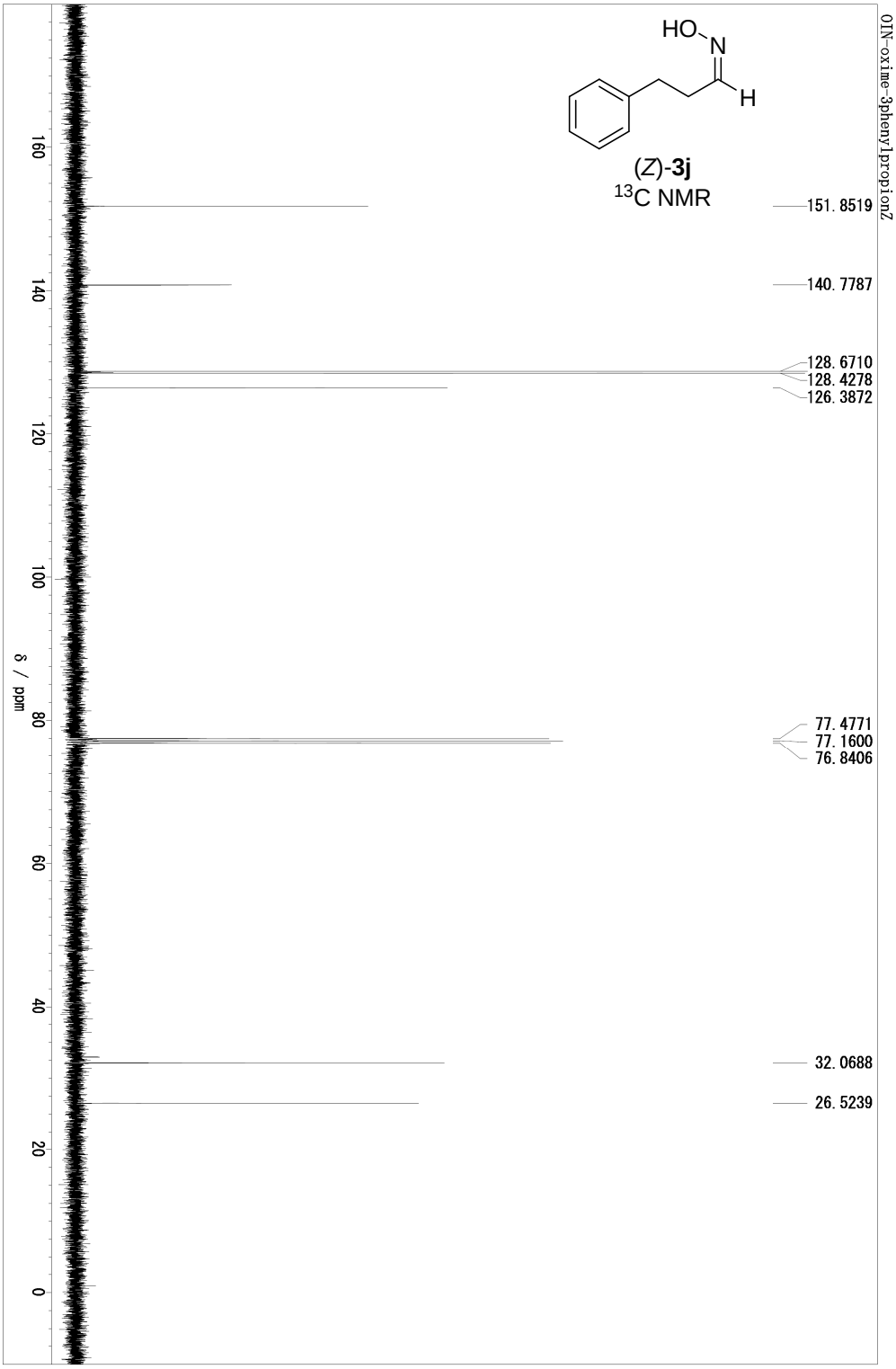
0.476
1.4149
2.0001
3.9722
1.0
7.5348
7.5309
7.5145
7.4586
7.4348
7.4184
7.3948
7.3737
7.3545
7.3482
7.3383
7.3310
7.3214
7.3131
7.2789
7.2594
6.8917
6.8515
1.6003
0.0000

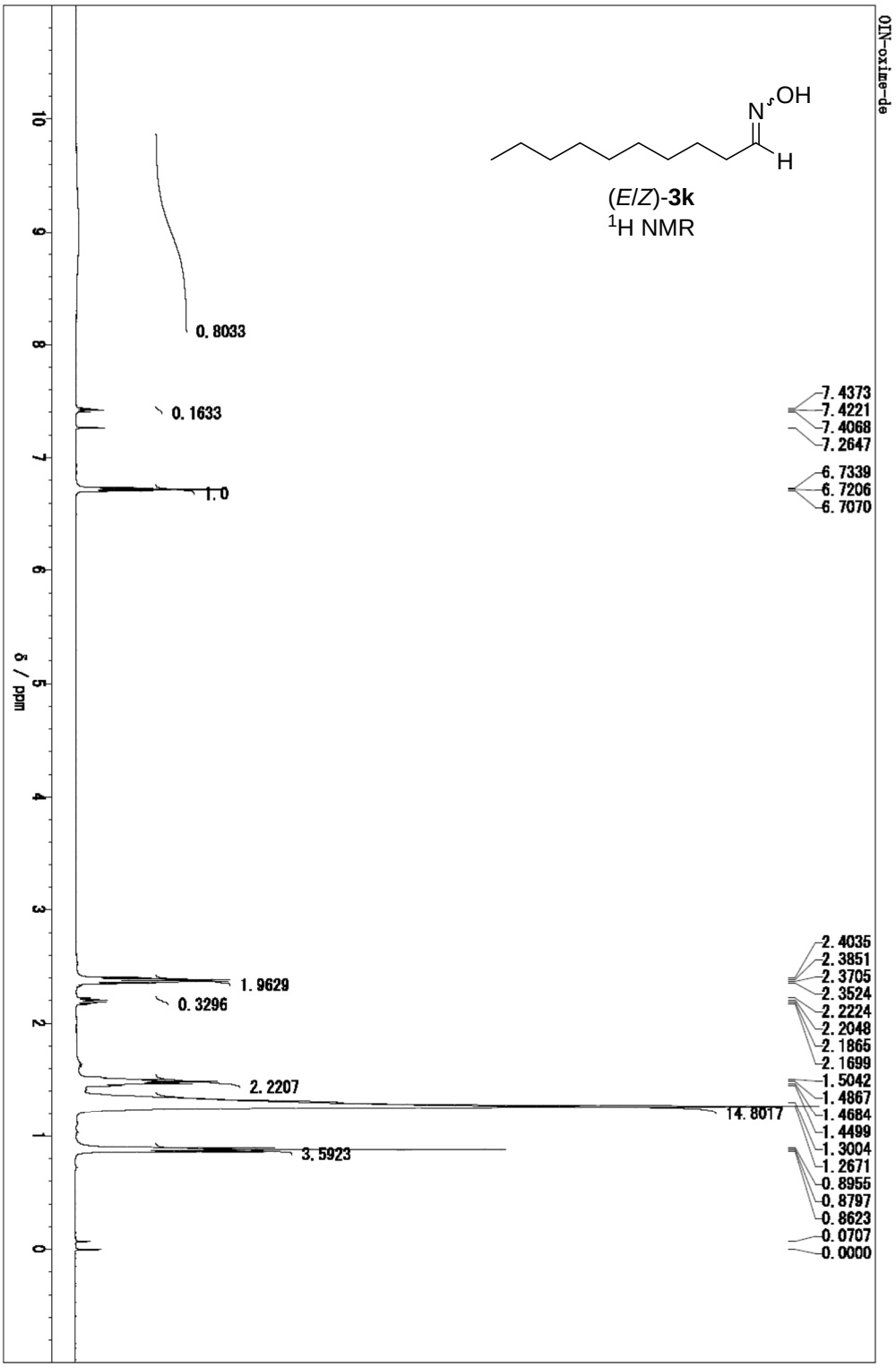

OIN-oxime-transZ
HO
N
H
(Z)-3i
13C NMR
149.1080
140.2948
135.9227
129.5315
128.9451
127.6793
115.8290
77.4771
77.1600
76.8430
δ / ppm
160
140
120
100
80
60
40
20
0

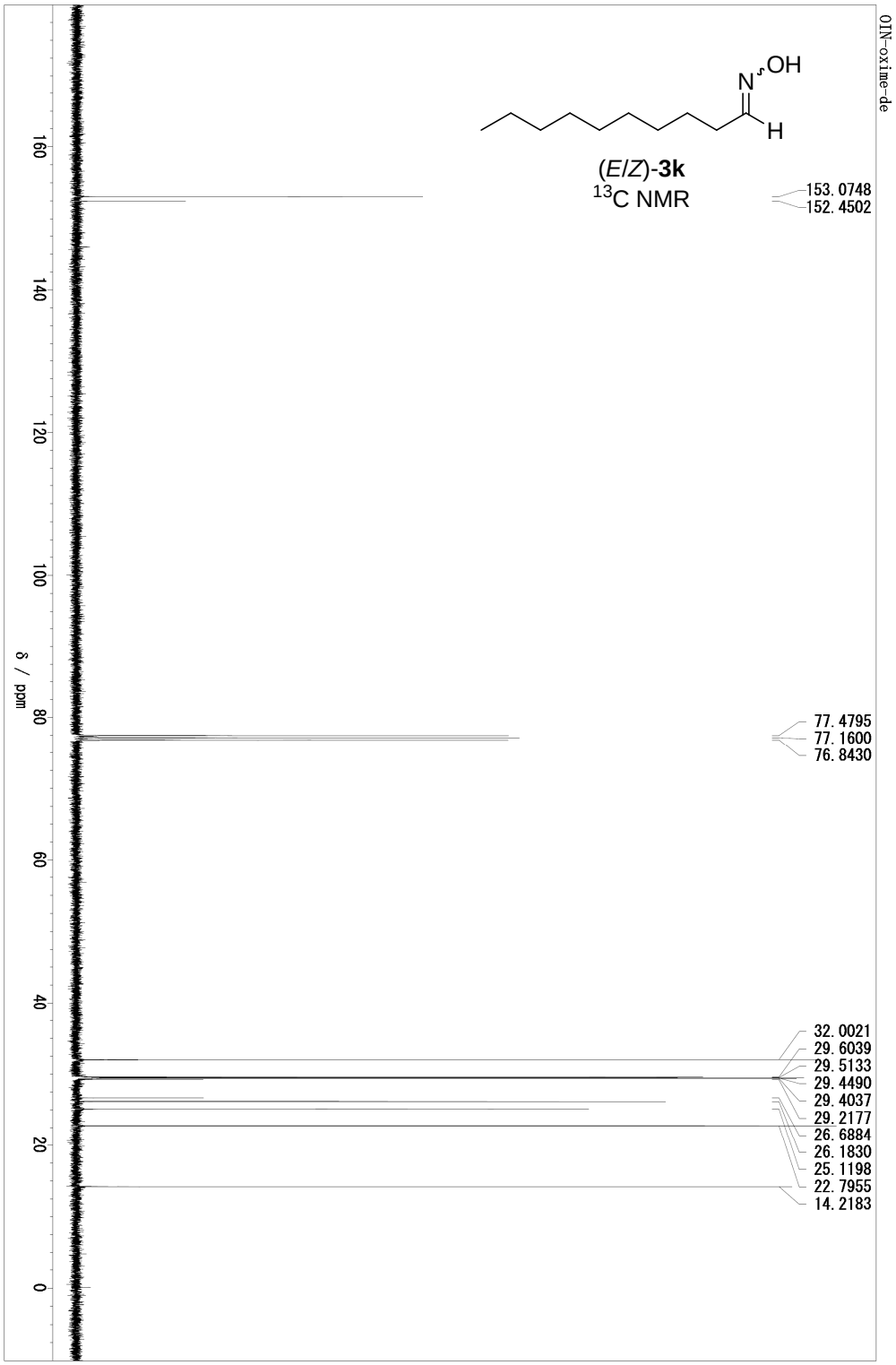

TGK-371 shine
N
OH
H
3j
1H NMR
8.5381
1.0265
7.3176
7.2970
7.2795
7.2593
7.2511
7.2218
7.2059
7.1901
7.1692
6.7927
6.7680
6.7549
6.7417
6.7176
1.9839
2.958
1.0
2.8639
2.8451
2.8258
2.8069
2.7903
2.7698
2.7370
2.7237
2.7220
2.7196
2.7055
2.7035
2.6853
2.1716
1.8130
2.1596
2.2152
0.0000
δ / ppm

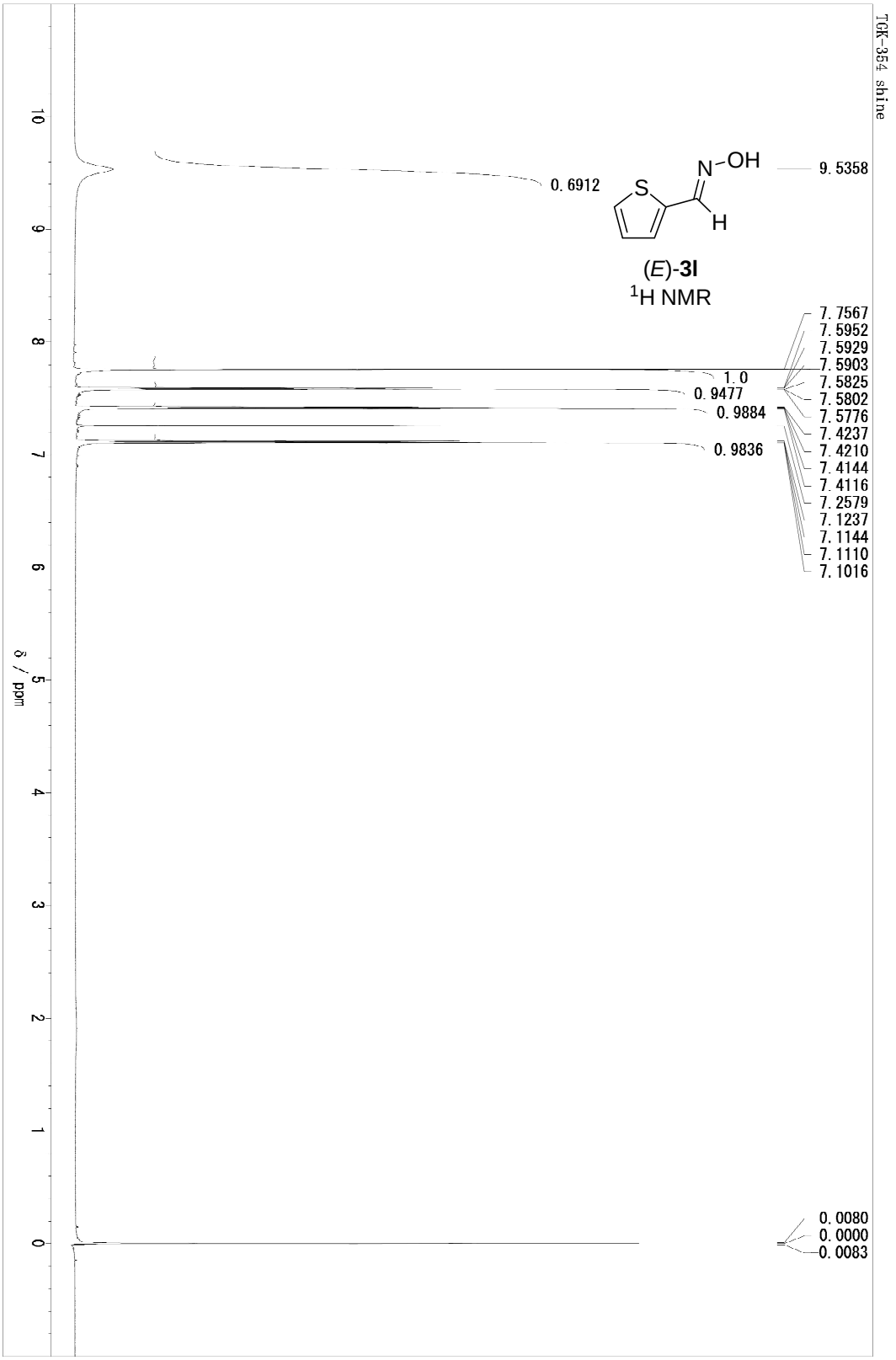

0IN-oxime-EZ 3propion E
3j
13C NMR
151.9067
151.5205
140.7787
140.6261
128.6781
128.4946
128.4326
126.3991
77.4771
77.1600
76.8406
32.9199
32.0855
31.3418
26.5144
δ / ppm
160
140
120
100
80
60
40
20
0

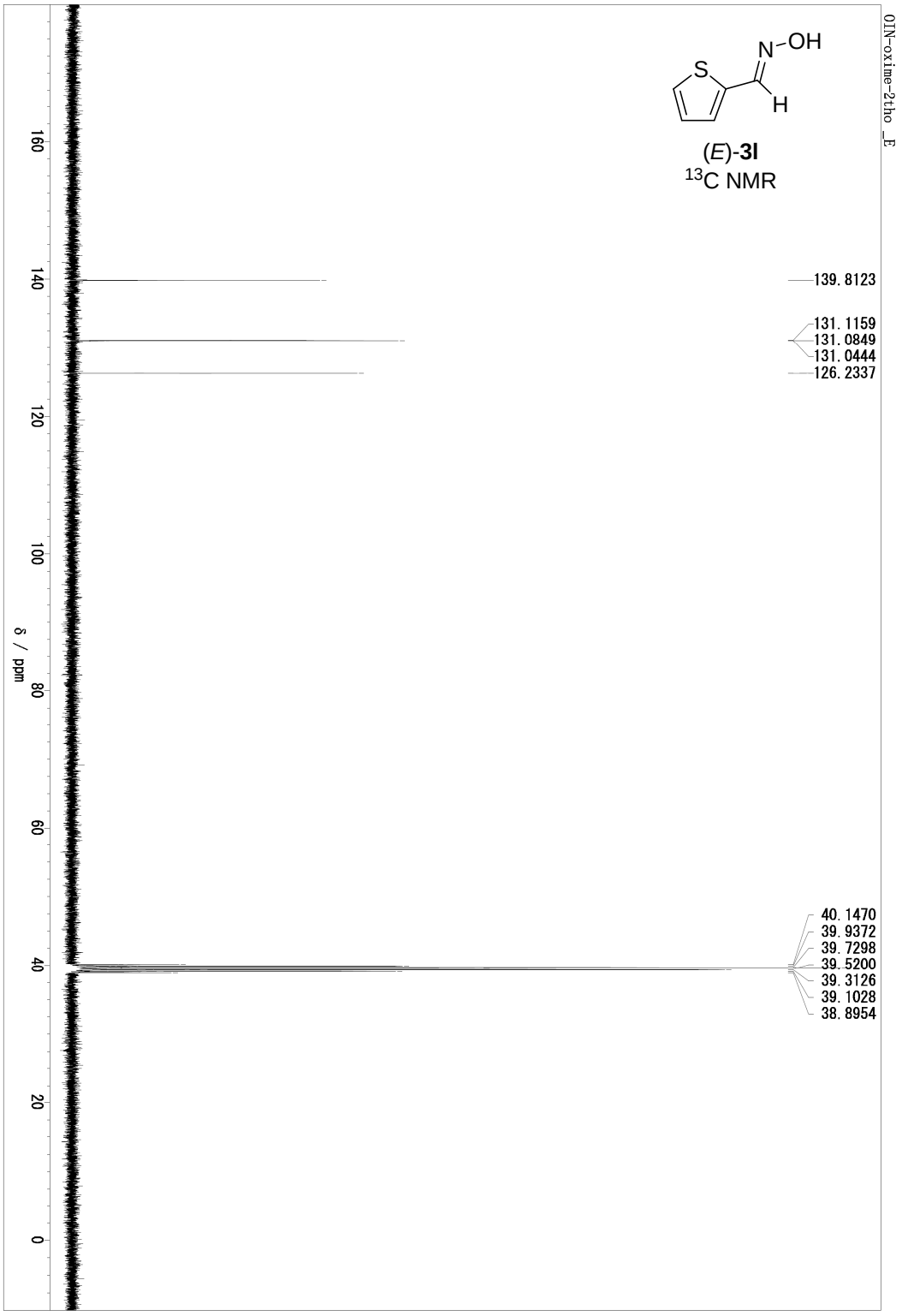

OLV-oxime-3phenylpropionZ
HO
N
H
(Z)-3j
1H NMR
8.9339
0.9267
7.3151
7.2950
7.2773
7.2417
2.1786
3.1372
7.2189
7.2042
7.1992
7.1907
0.9758
6.7687
6.7554
6.7422
2.8427
2.8232
2.8046
2.7380
2.1312
2.0
2.7249
2.7228
2.7207
2.7057
2.6875
0.0000
δ / ppm

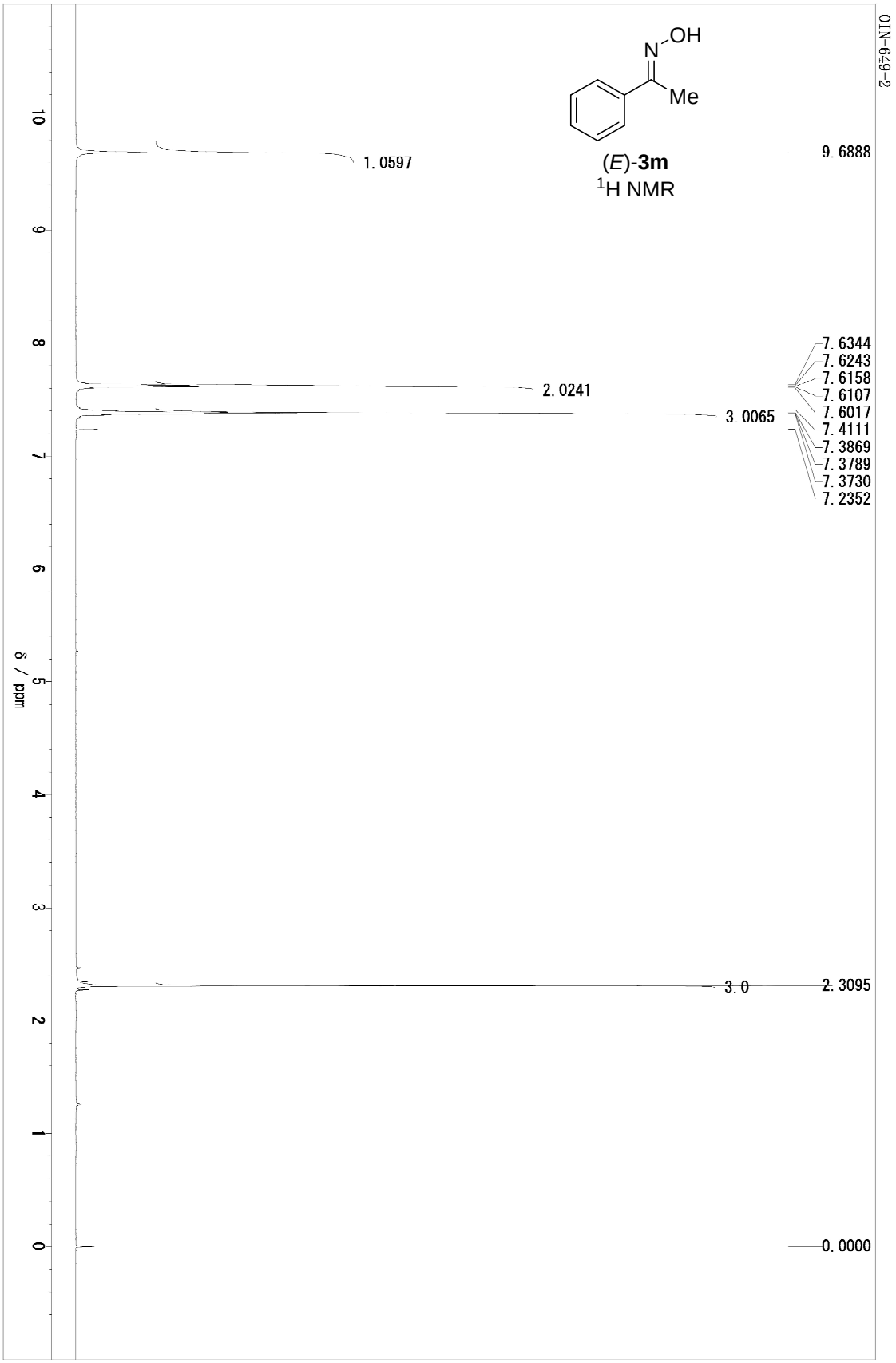

HO
N
H
(Z)-3j
13C NMR
0IN-oxime-3phenylpropionZ
151.8519
140.7787
128.6710
128.4278
126.3872
77.4771
77.1600
76.8406
32.0688
26.5239
δ / ppm
160
140
120
100
80
60
40
20
0

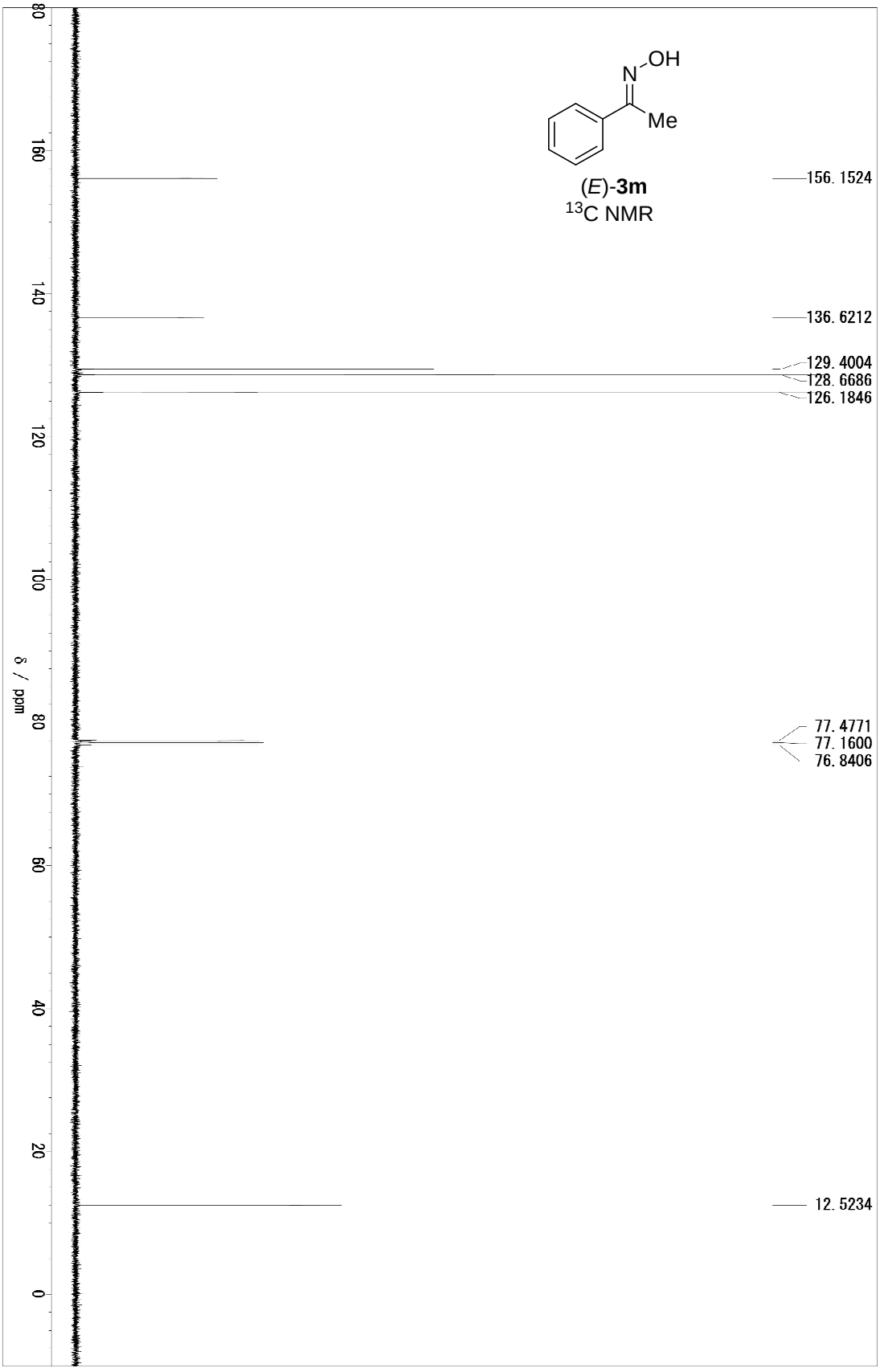

OTN-oxime-de
N
OH
H
(E/Z)-3k
1H NMR
δ / ppm
0.8033
0.1633
1.0
1.9629
0.3296
2.2207
14.8017
3.5923
7.4373
7.4221
7.4068
7.2647
6.7339
6.7206
6.7070
2.4035
2.3851
2.3705
2.3524
2.2224
2.2048
2.1865
2.1699
1.5042
1.4867
1.4684
1.4499
1.3004
1.2671
0.8955
0.8797
0.8623
0.0707
0.0000

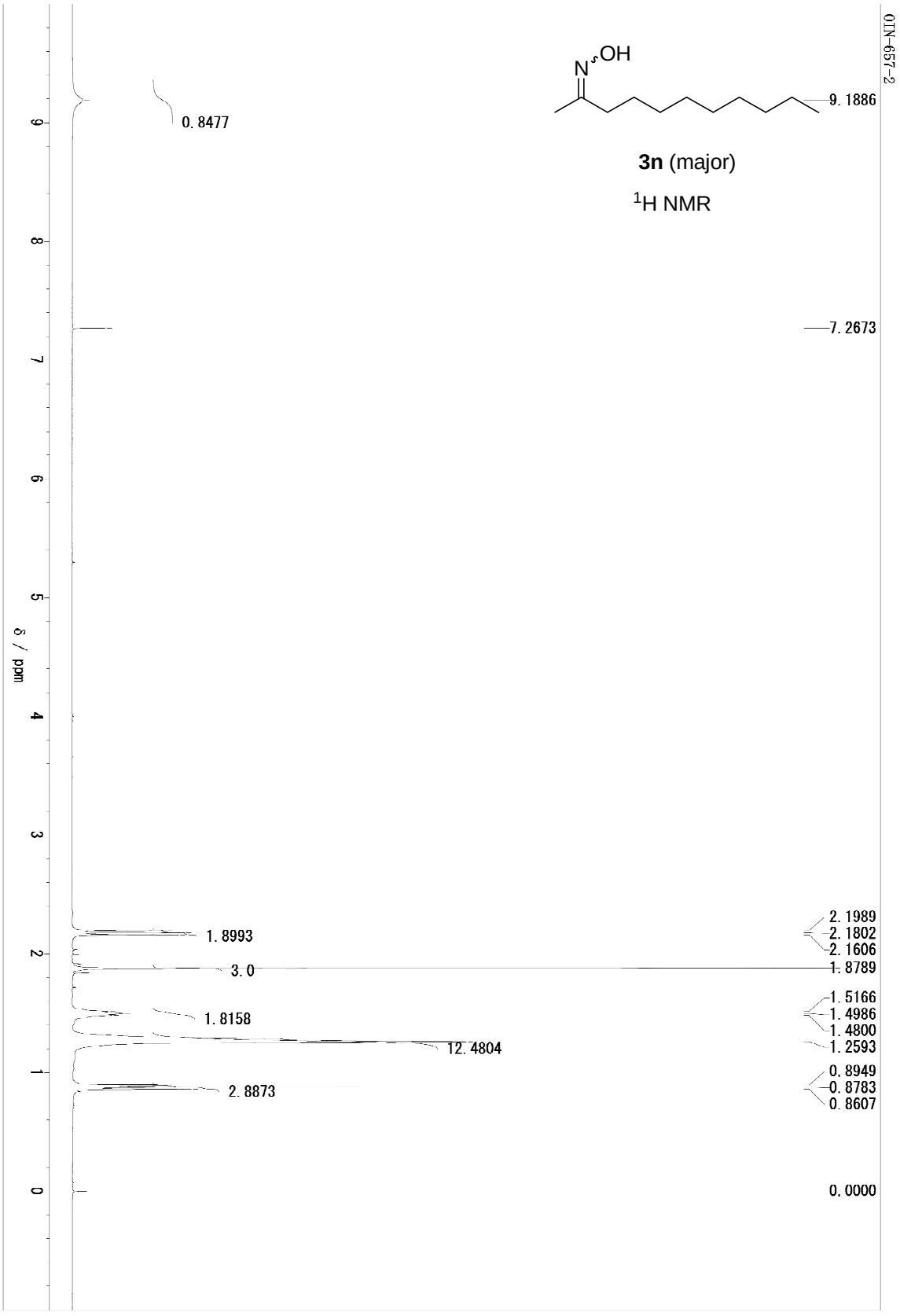

OIN-oxime-de
N
OH
H
(E/Z)-3k
13C NMR
153.0748
152.4502
77.4795
77.1600
76.8430
32.0021
29.6039
29.5133
29.4490
29.4037
29.2177
26.6884
26.1830
25.1198
22.7955
14.2183
δ / ppm
160
140
120
100
80
60
40
20
0

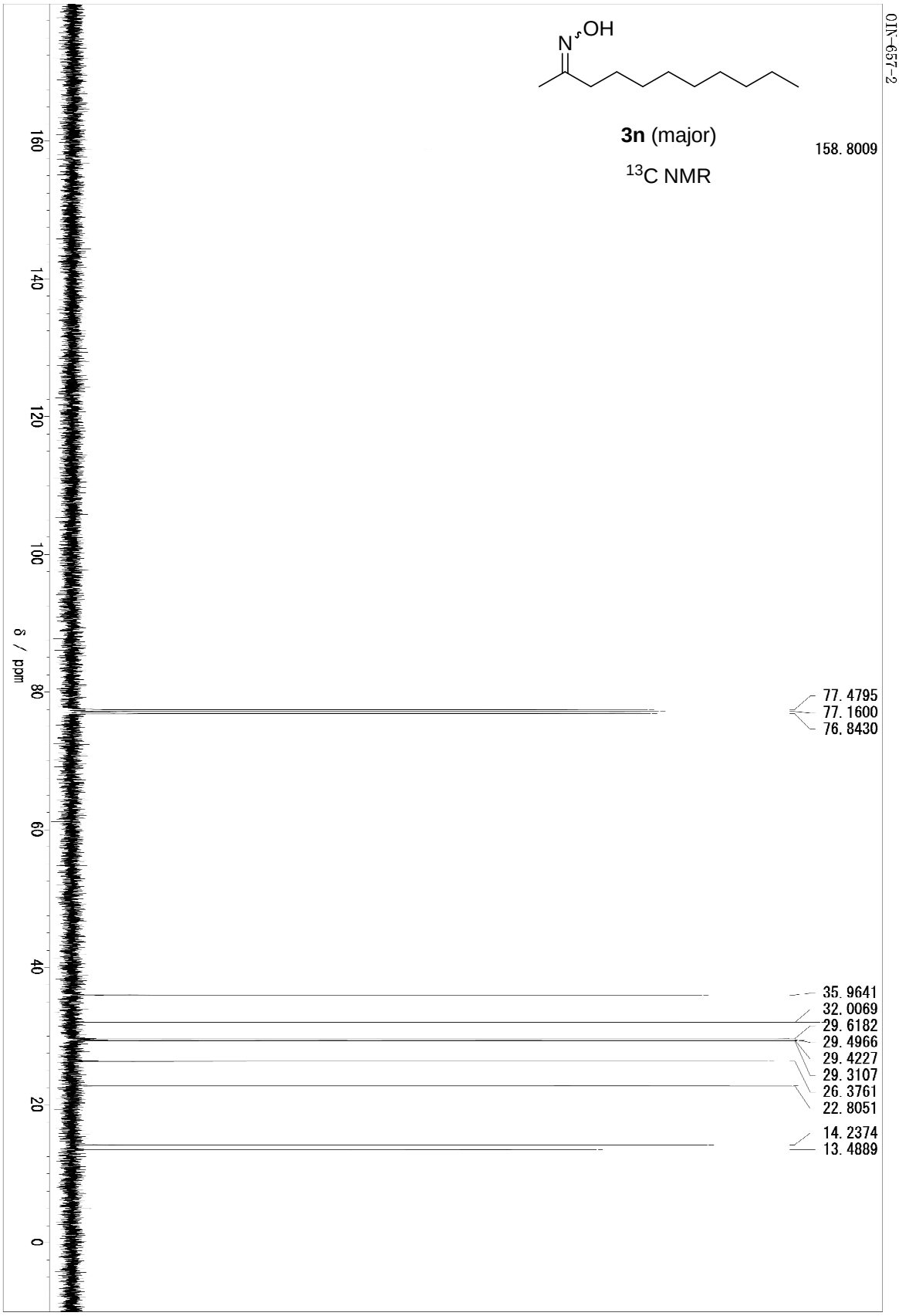

TGK-354 shine
(E)-3l
1H NMR
9.5358
0.6912
7.7567
7.5952
7.5929
7.5903
7.5825
7.5802
7.5776
7.4237
7.4210
7.4144
7.4116
7.2579
7.1237
7.1144
7.1110
7.1016
1.0
0.9477
0.9884
0.9836
0.0080
0.0000
0.0083
δ / ppm

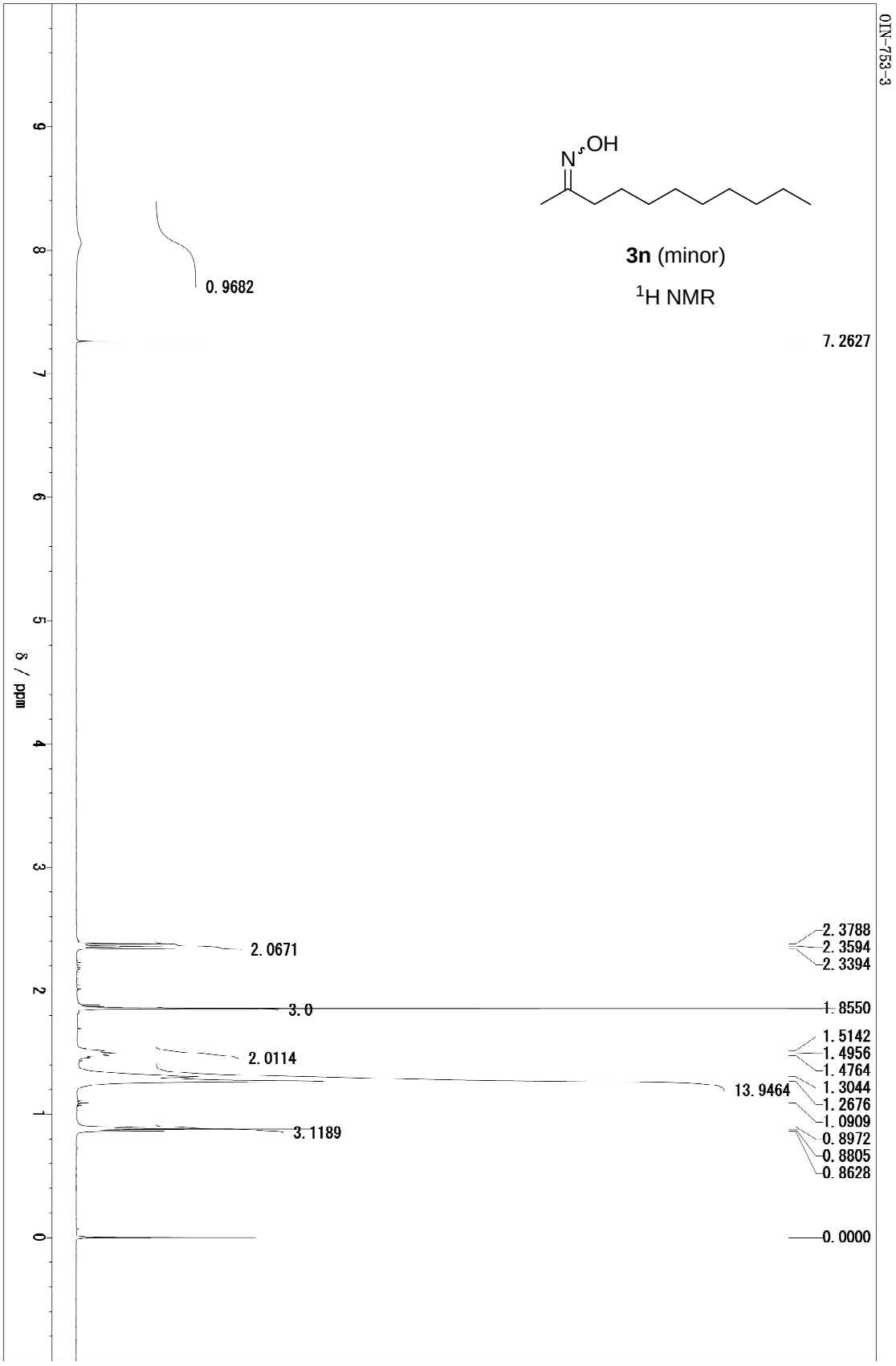

0IN-oxime-2tho _E
N-OH
S
H
(E)-3l
13C NMR
139.8123
131.1159
131.0849
131.0444
126.2337
40.1470
39.9372
39.7298
39.5200
39.3126
39.1028
38.8954
δ / ppm
160
140
120
100
80
60
40
20
0

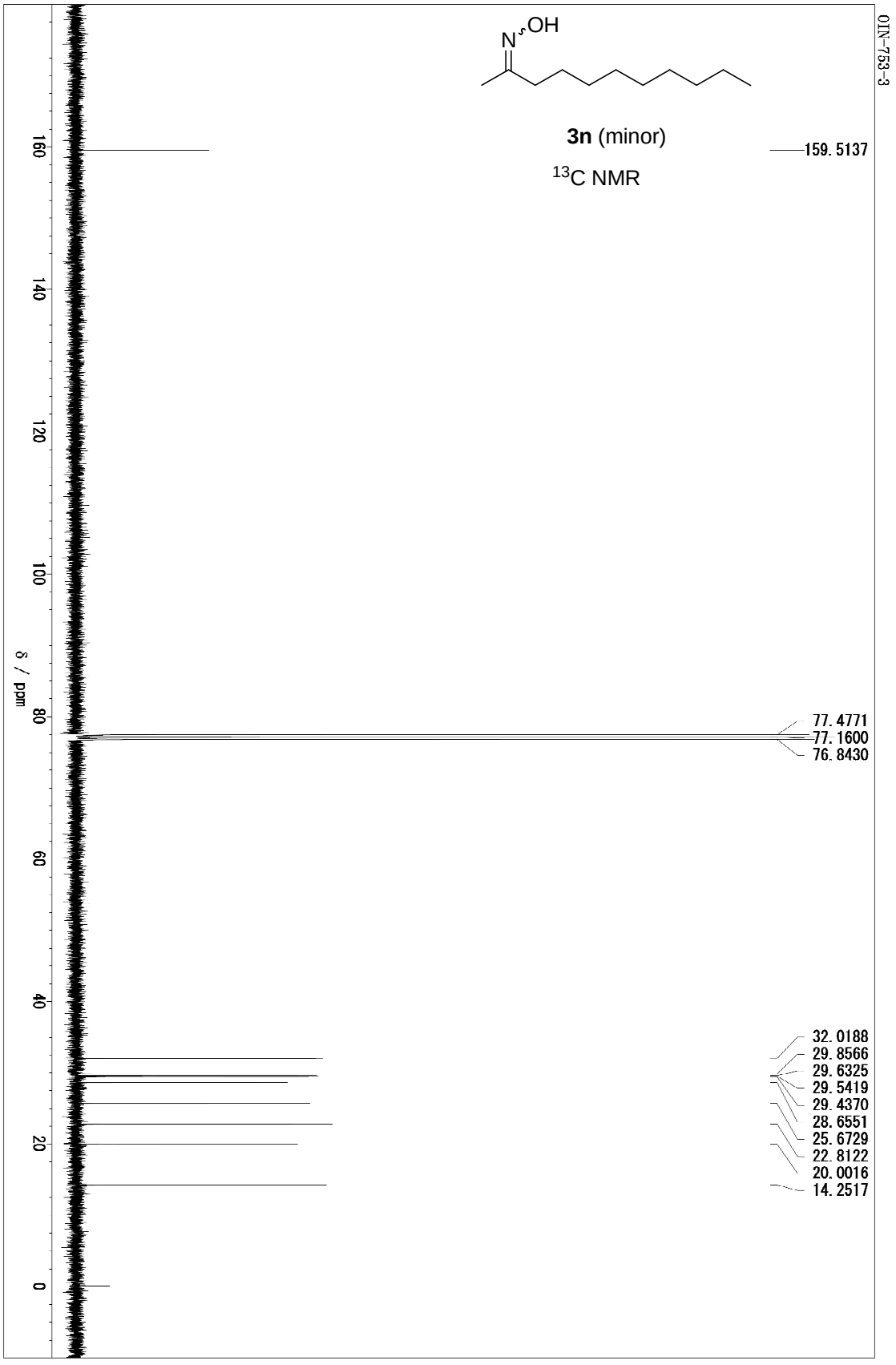

OIN-649-2
OH
N
Me
(E)-3m
1H NMR
9.6888
7.6344
7.6243
7.6158
7.6107
7.6017
7.4111
7.3869
7.3789
7.3730
7.2352
2.3095
0.0000
1.0597
2.0241
3.0065
3.0
δ / ppm

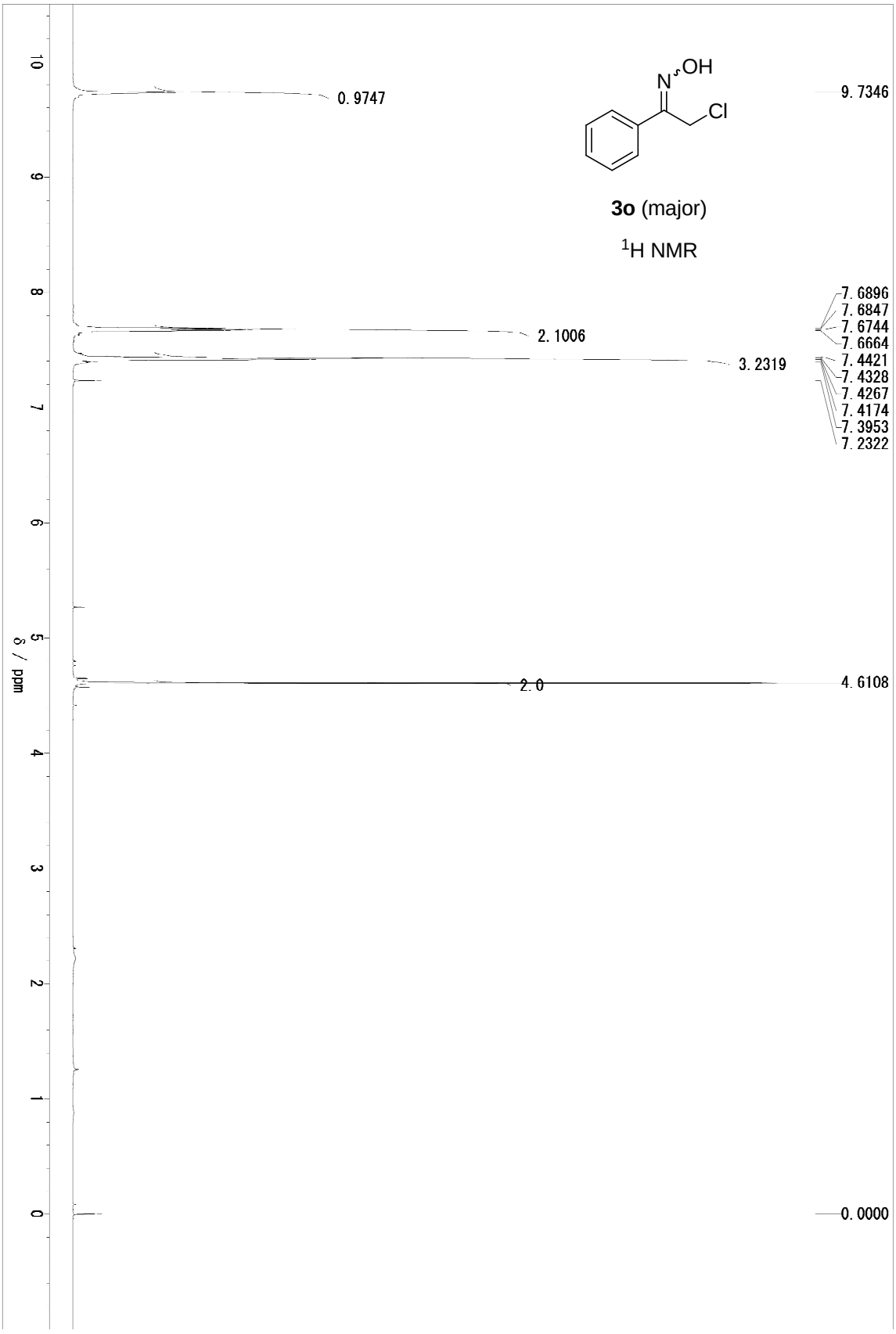

HSG144 F8-20
OH
N
Me
(E)-3m
13C NMR
156.1524
136.6212
129.4004
128.6686
126.1846
77.4771
77.1600
76.8406
12.5234
δ / ppm
80
160
140
120
100
80
60
40
20
0

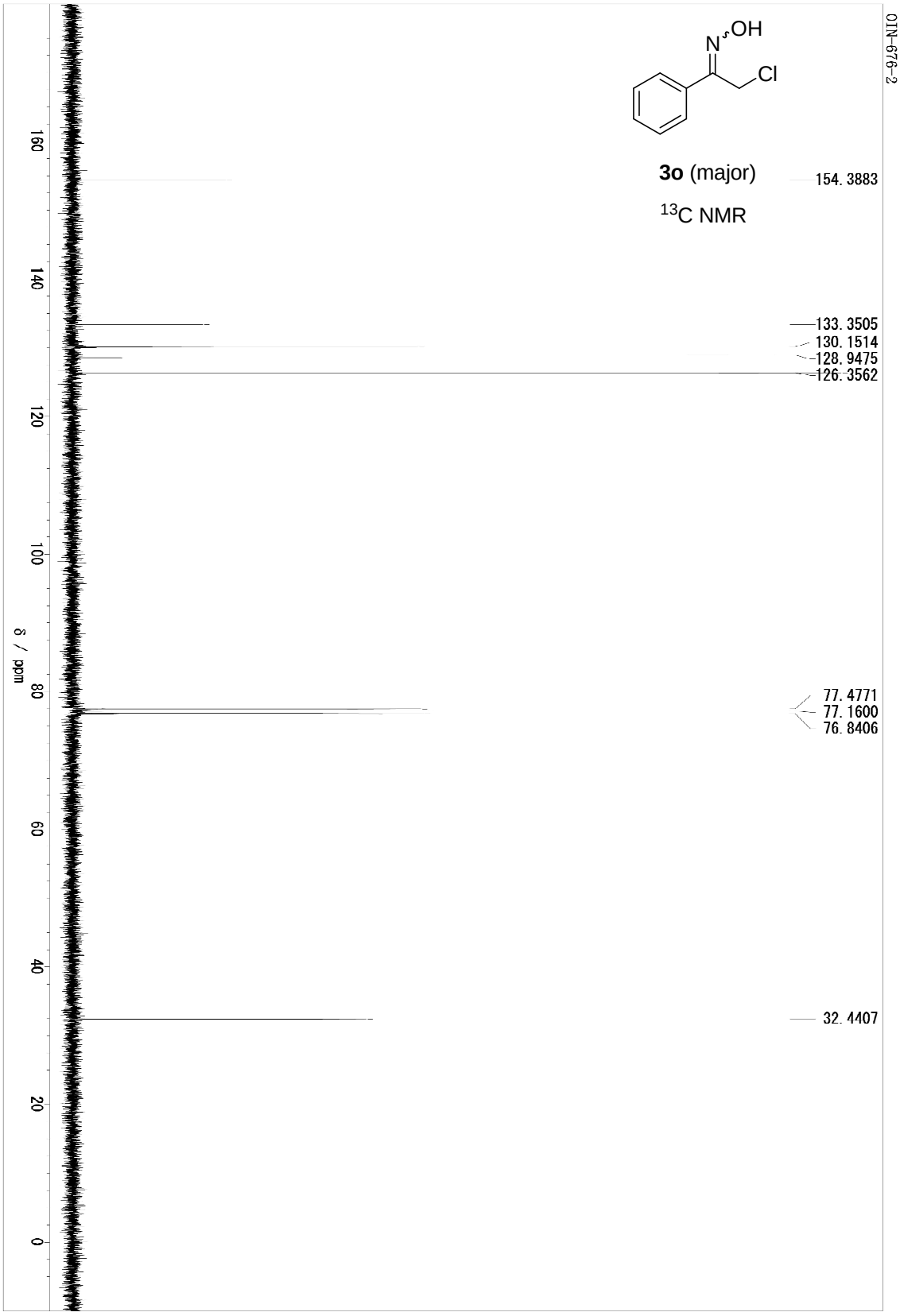

OTN-657-2
N
OH
9.1886
0.8477
3n (major)
1H NMR
7.2673
δ / ppm
9
8
7
6
5
4
3
2
1
0
1.8993
3.0
1.8158
12.4804
2.8873
2.1989
2.1802
2.1606
1.8789
1.5166
1.4986
1.4800
1.2593
0.8949
0.8783
0.8607
0.0000

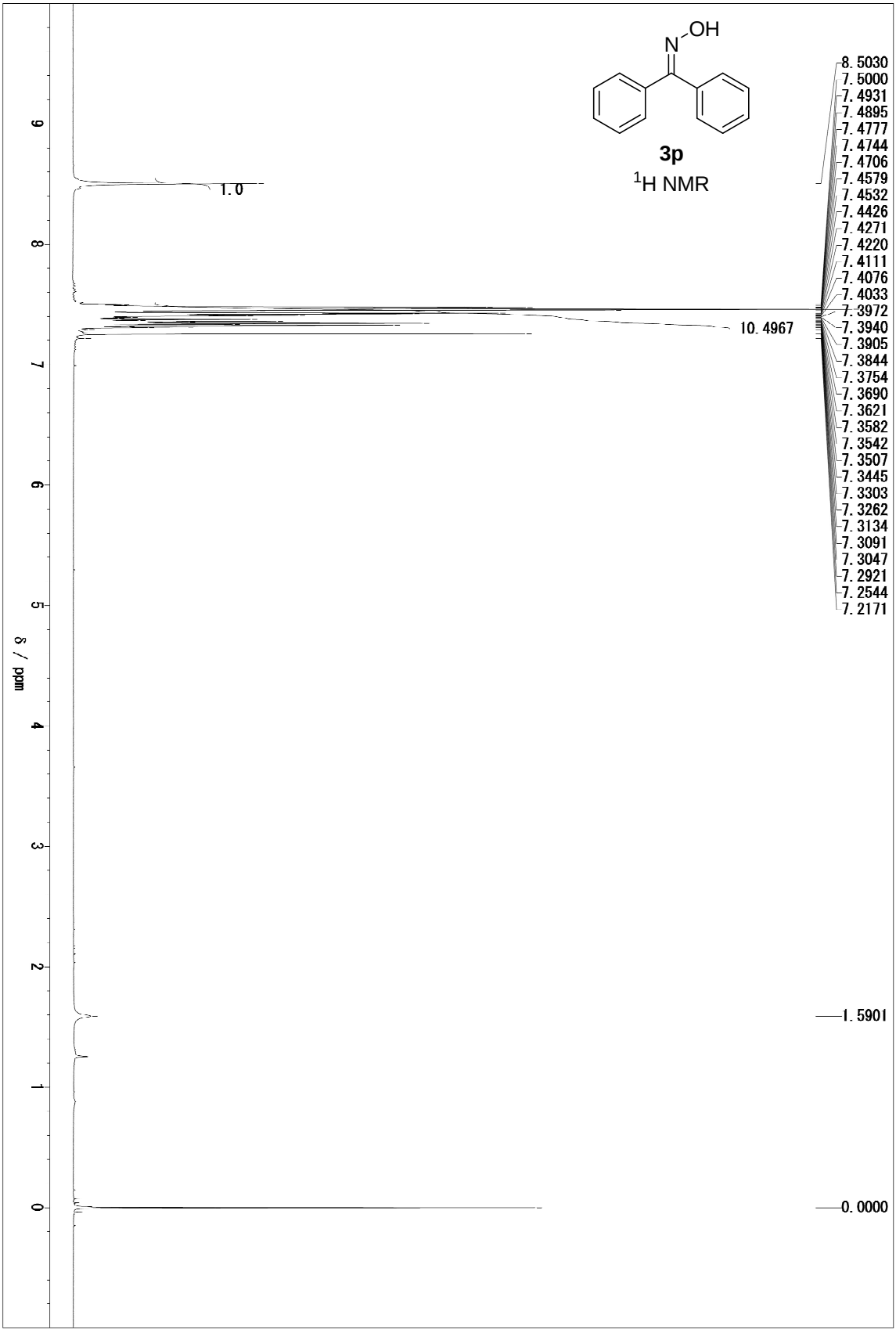

OIN-657-2
N
OH
3n (major)
13C NMR
158.8009
77.4795
77.1600
76.8430
35.9641
32.0069
29.6182
29.4966
29.4227
29.3107
26.3761
22.8051
14.2374
13.4889
δ / ppm
160
140
120
100
80
60
40
20
0

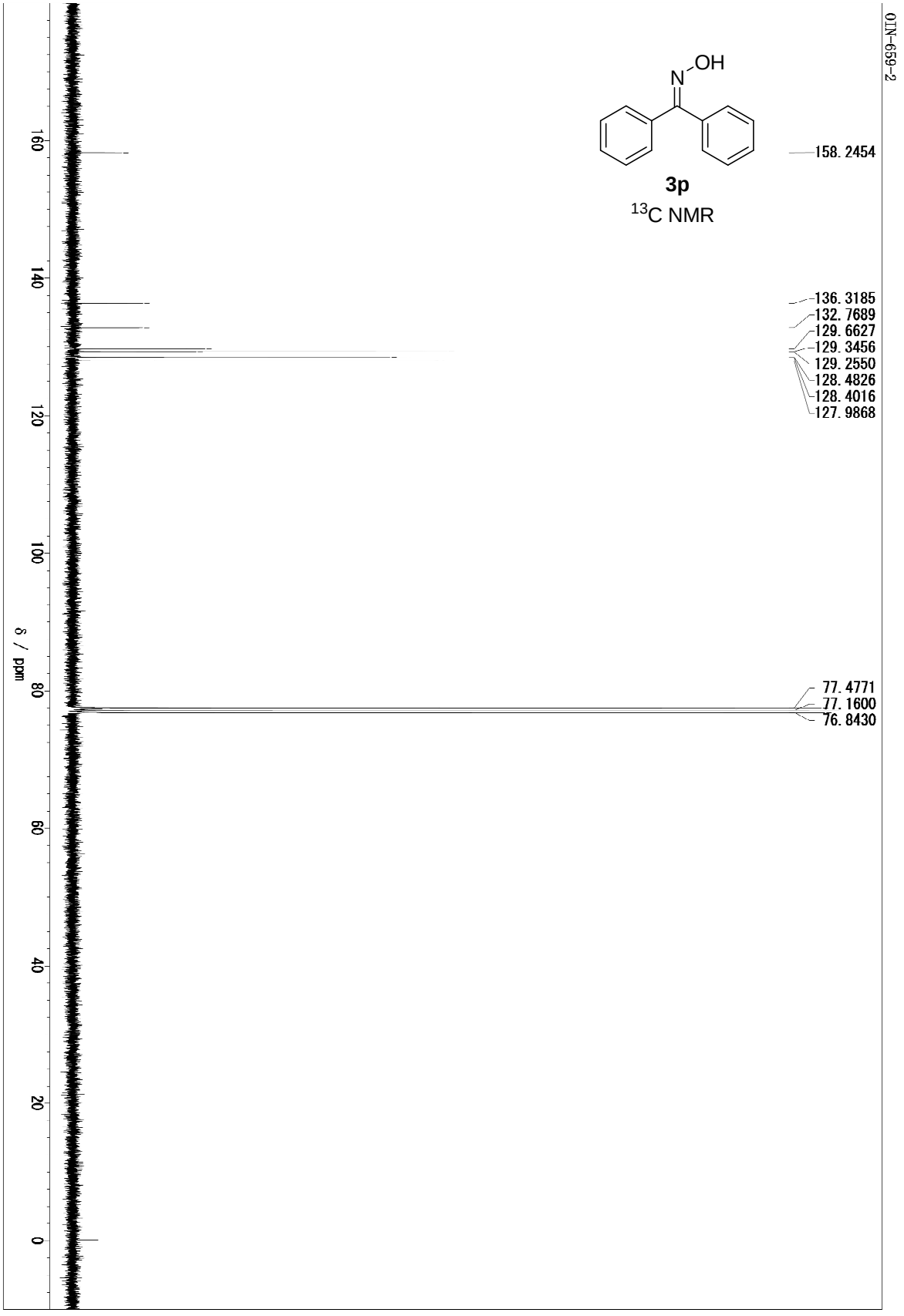

OIN-753-3
N
OH
3n (minor)
1H NMR
δ / ppm
0.9682
7.2627
2.0671
3.0
2.0114
3.1189
2.3788
2.3594
2.3394
1.8550
1.5142
1.4956
1.4764
13.9464
1.3044
1.2676
1.0909
0.8972
0.8805
0.8628
0.0000

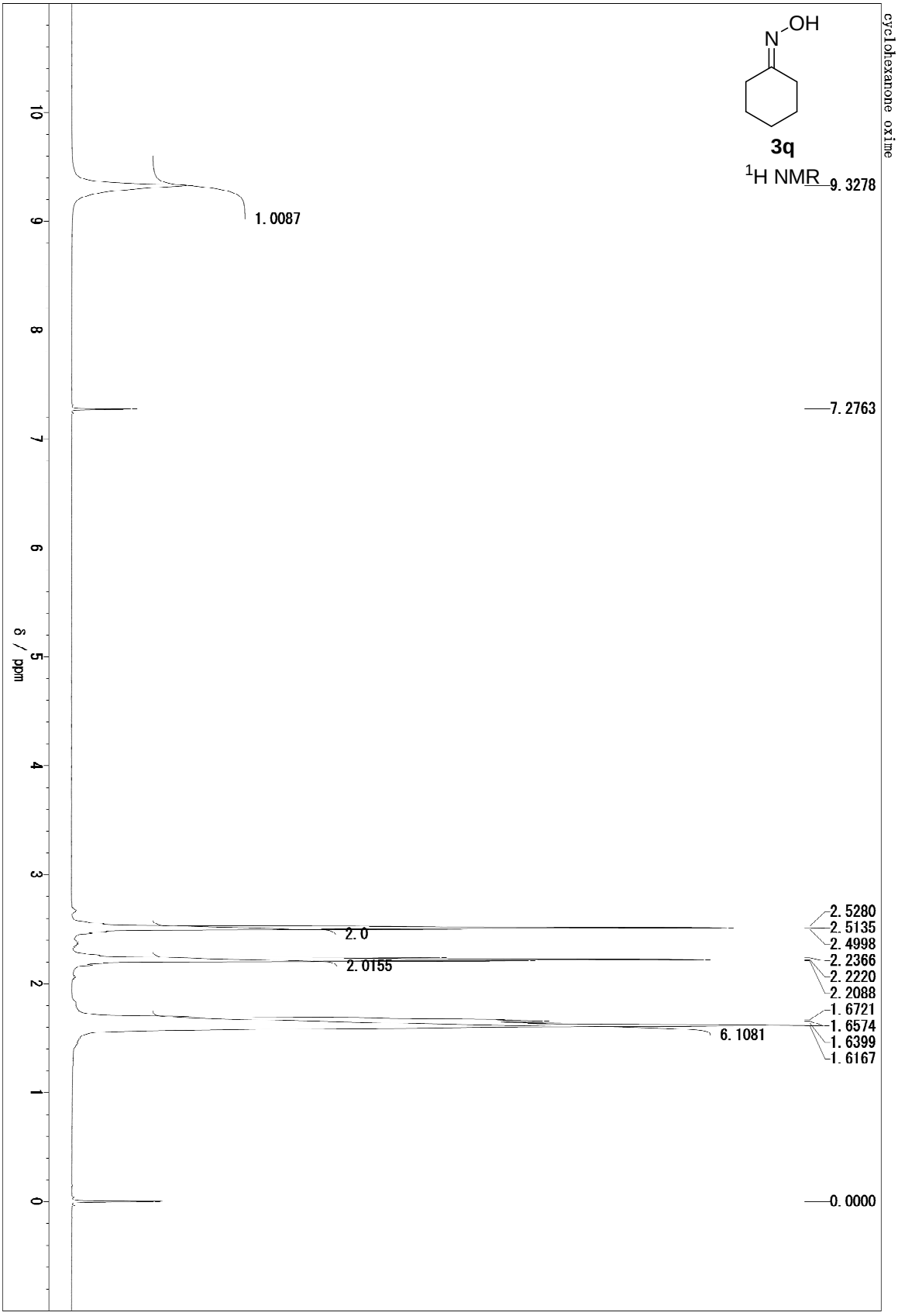

OIN-753-3
N
OH
3n (minor)
13C NMR
159.5137
77.4771
77.1600
76.8430
32.0188
29.8566
29.6325
29.5419
29.4370
28.6551
25.6729
22.8122
20.0016
14.2517
δ / ppm
160
140
120
100
80
60
40
20
0

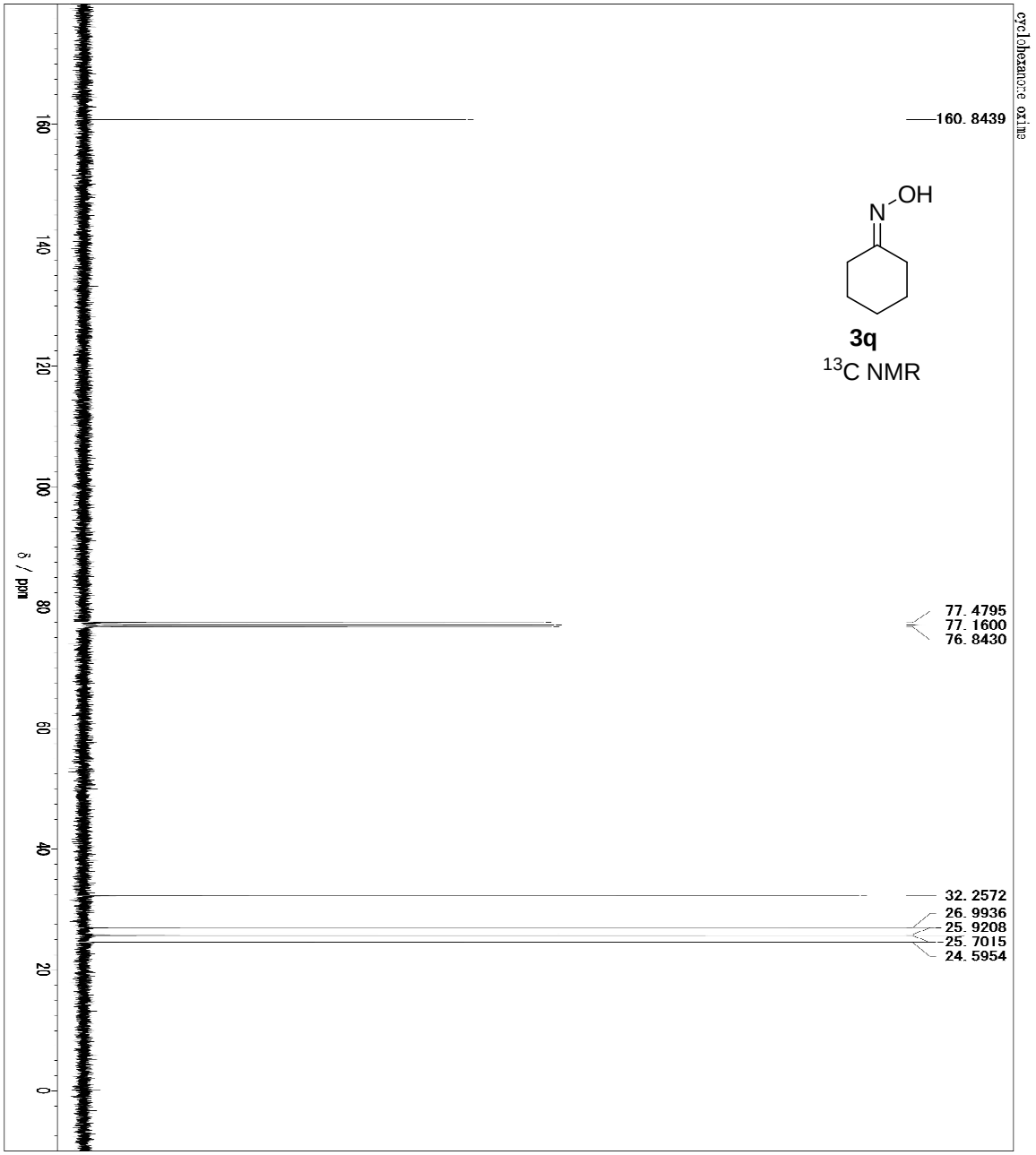

HSG152 F15-29
N
OH
Cl
3o (major)
1H NMR
0.9747
2.1006
3.2319
2.0
9.7346
7.6896
7.6847
7.6744
7.6664
7.4421
7.4328
7.4267
7.4174
7.3953
7.2322
4.6108
0.0000
δ / ppm

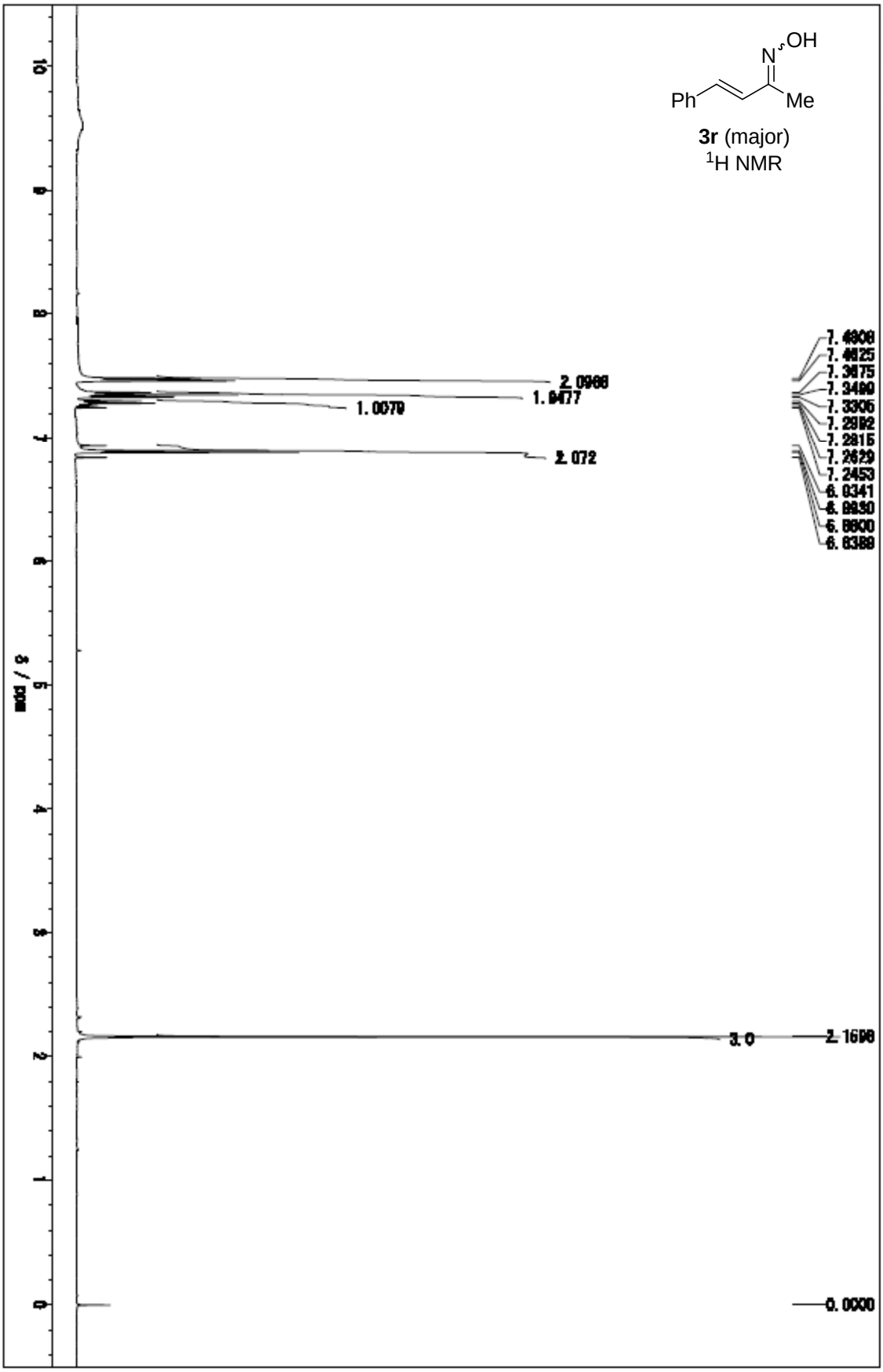

OIN-676-2
N
OH
Cl
3o (major)
13C NMR
154.3883
133.3505
130.1514
128.9475
126.3562
77.4771
77.1600
76.8406
32.4407
δ / ppm
160
140
120
100
80
60
40
20
0

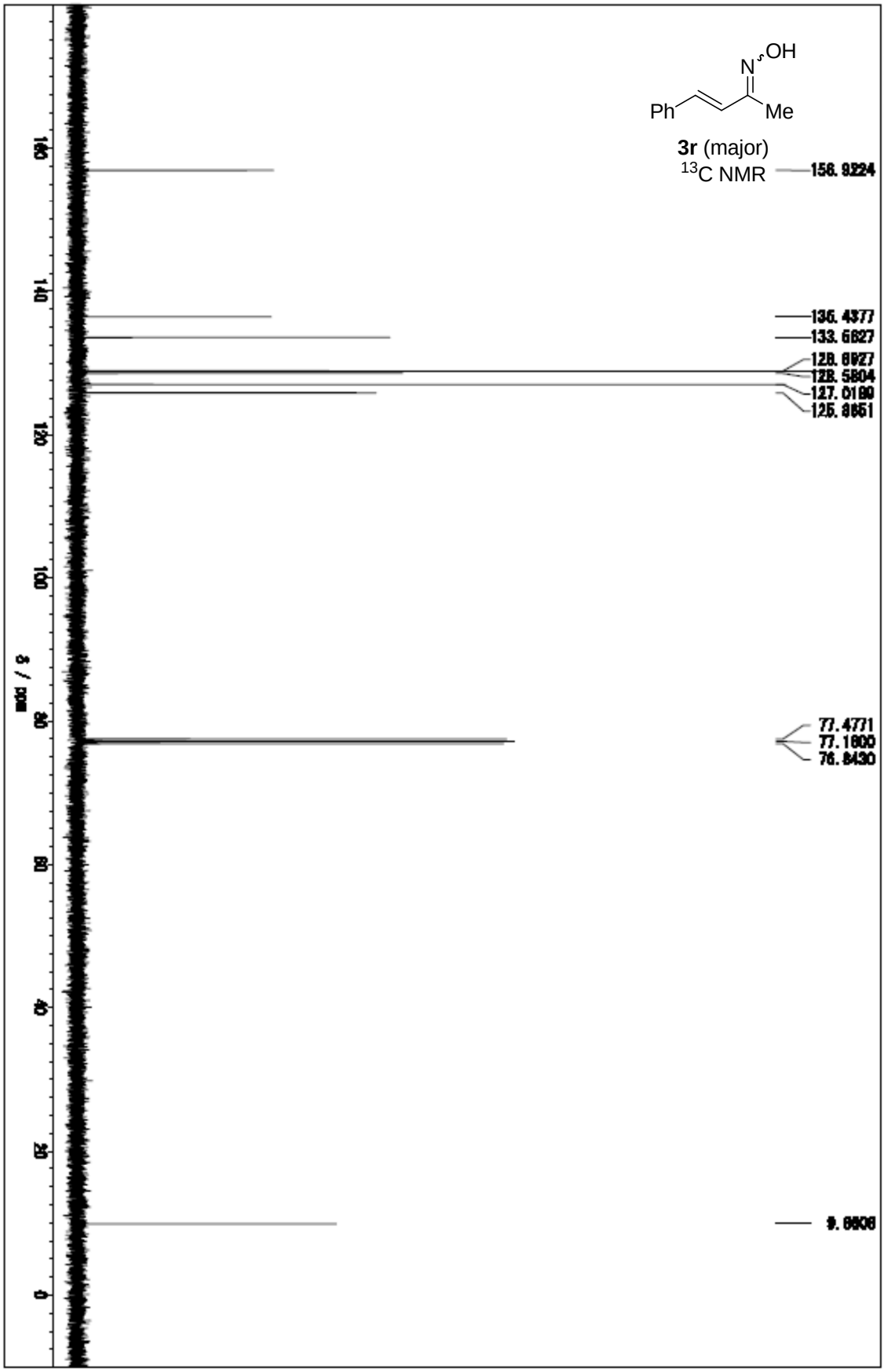

OIN-659-2
OH
N
3p
1H NMR
8.5030
7.5000
7.4931
7.4895
7.4777
7.4744
7.4706
7.4579
7.4532
7.4426
7.4271
7.4220
7.4111
7.4076
7.4033
7.3972
7.3940
7.3905
7.3844
7.3754
7.3690
7.3621
7.3582
7.3542
7.3507
7.3445
7.3303
7.3262
7.3134
7.3091
7.3047
7.2921
7.2544
7.2171
1.0
10.4967
1.5901
0.0000
δ / ppm

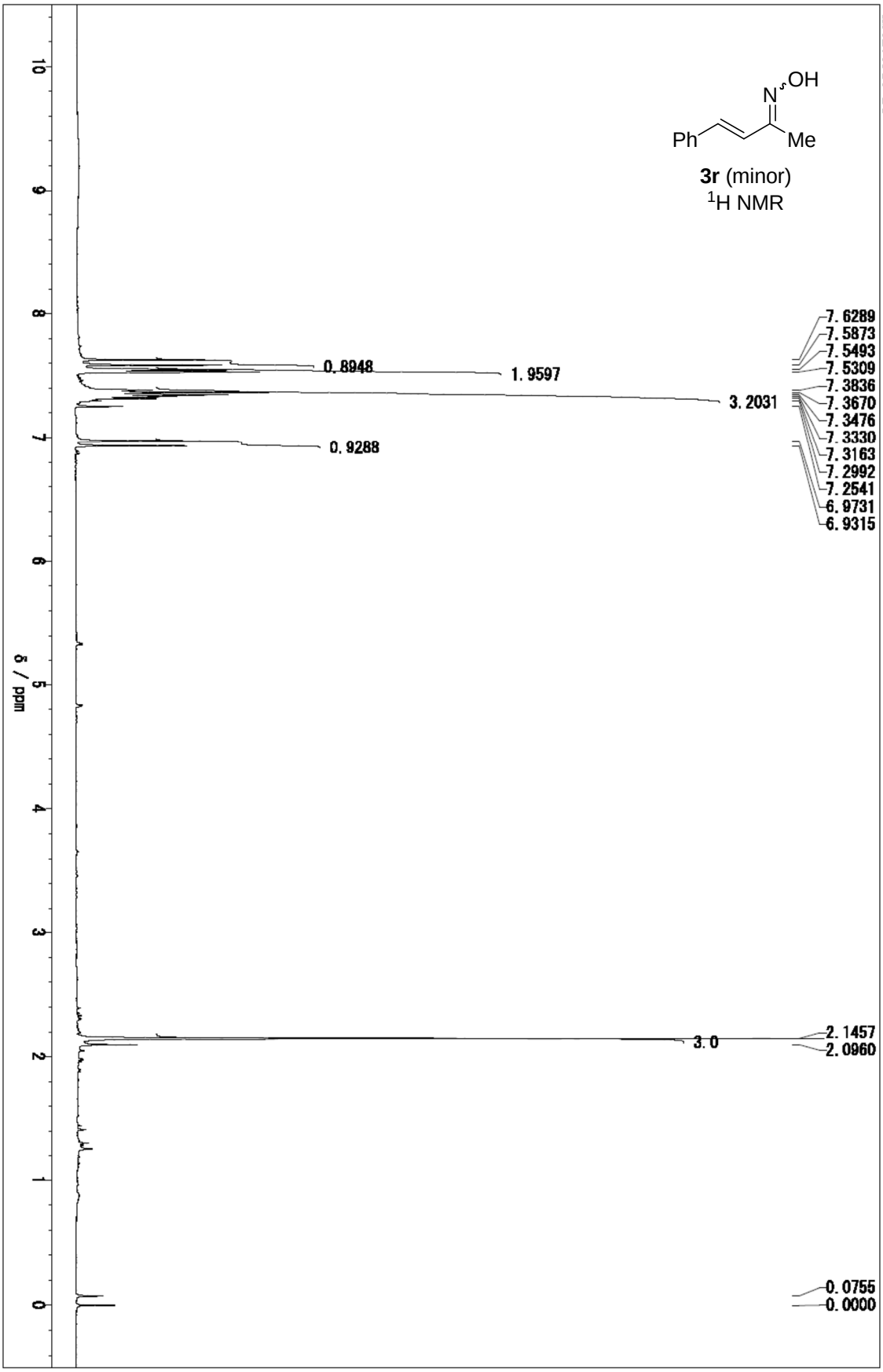

OTN-659-2
OH
N
158.2454
3p
13C NMR
136.3185
132.7689
129.6627
129.3456
129.2550
128.4826
128.4016
127.9868
77.4771
77.1600
76.8430
δ / ppm
160
140
120
100
80
60
40
20
0

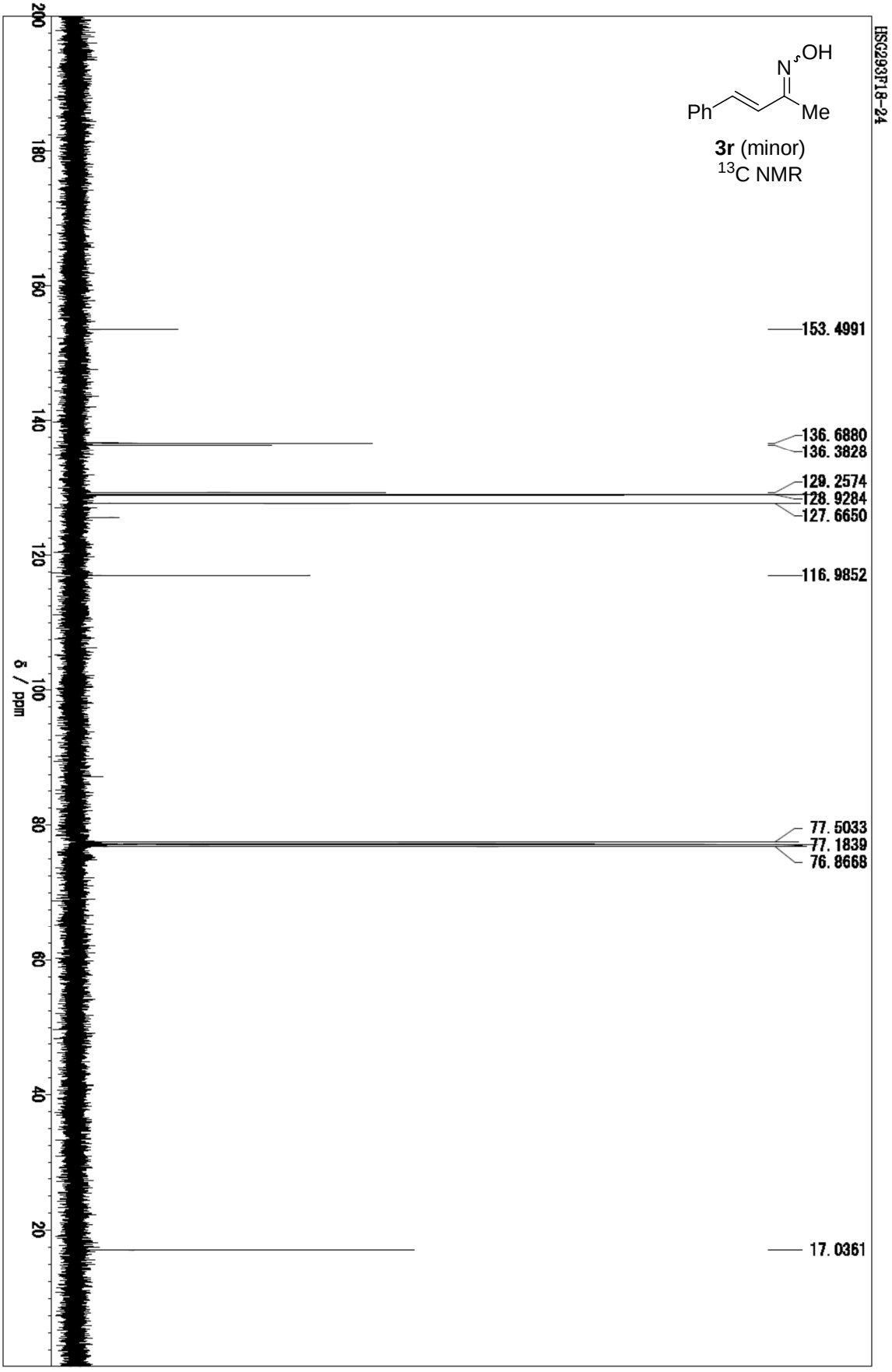

cyclohexanone oxime
3q
1H NMR
9.3278
7.2763
2.5280
2.5135
2.4998
2.2366
2.2220
2.2088
1.6721
1.6574
1.6399
1.6167
0.0000
1.0087
2.0
2.0155
6.1081
δ / ppm

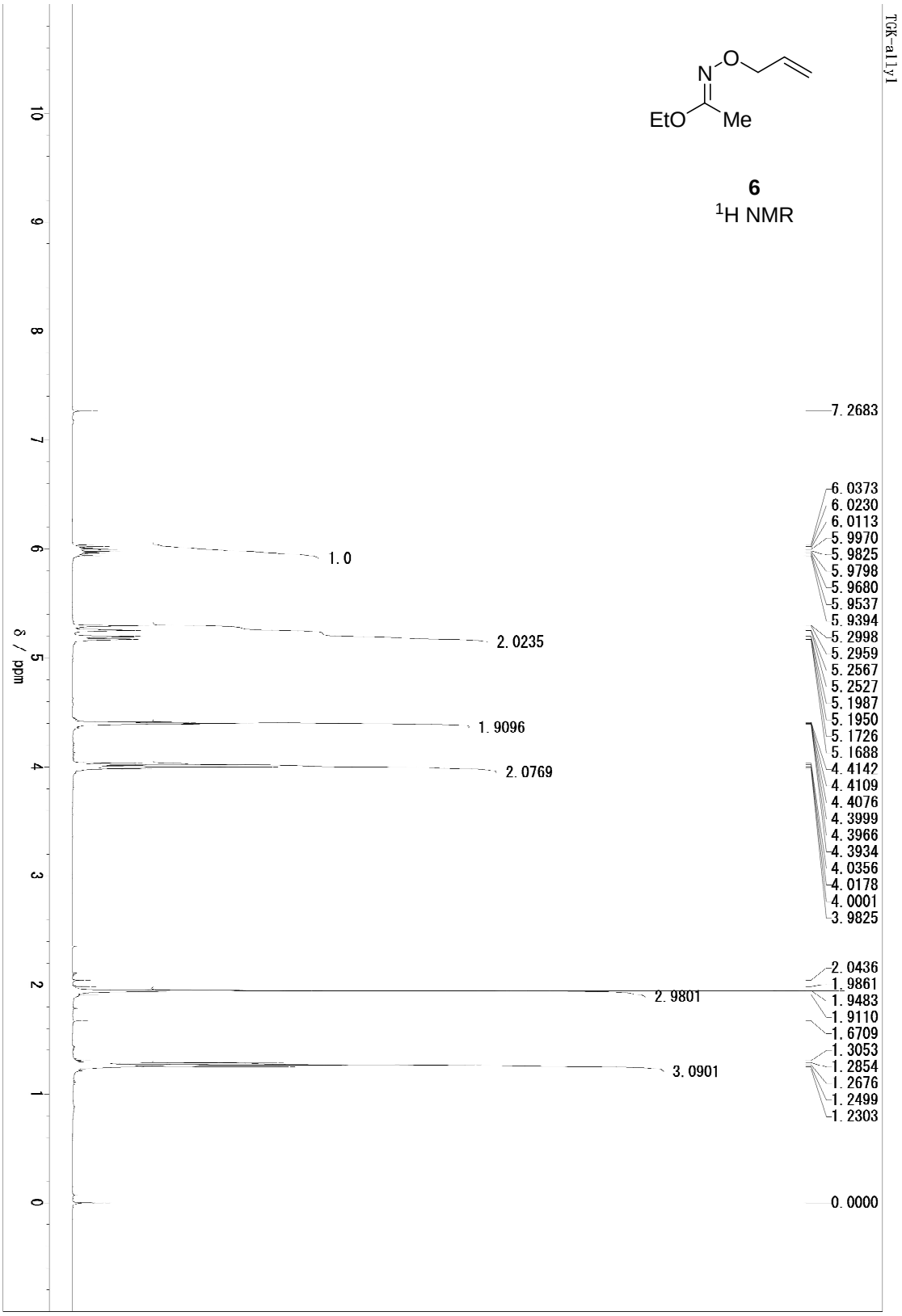

cyclohexanone oxime
160.8439
77.4795
77.1600
76.8430
32.2572
26.9936
25.9208
25.7015
24.5954
δ / ppm
160
140
120
100
80
60
40
20
0
N
OH
3q
13C NMR

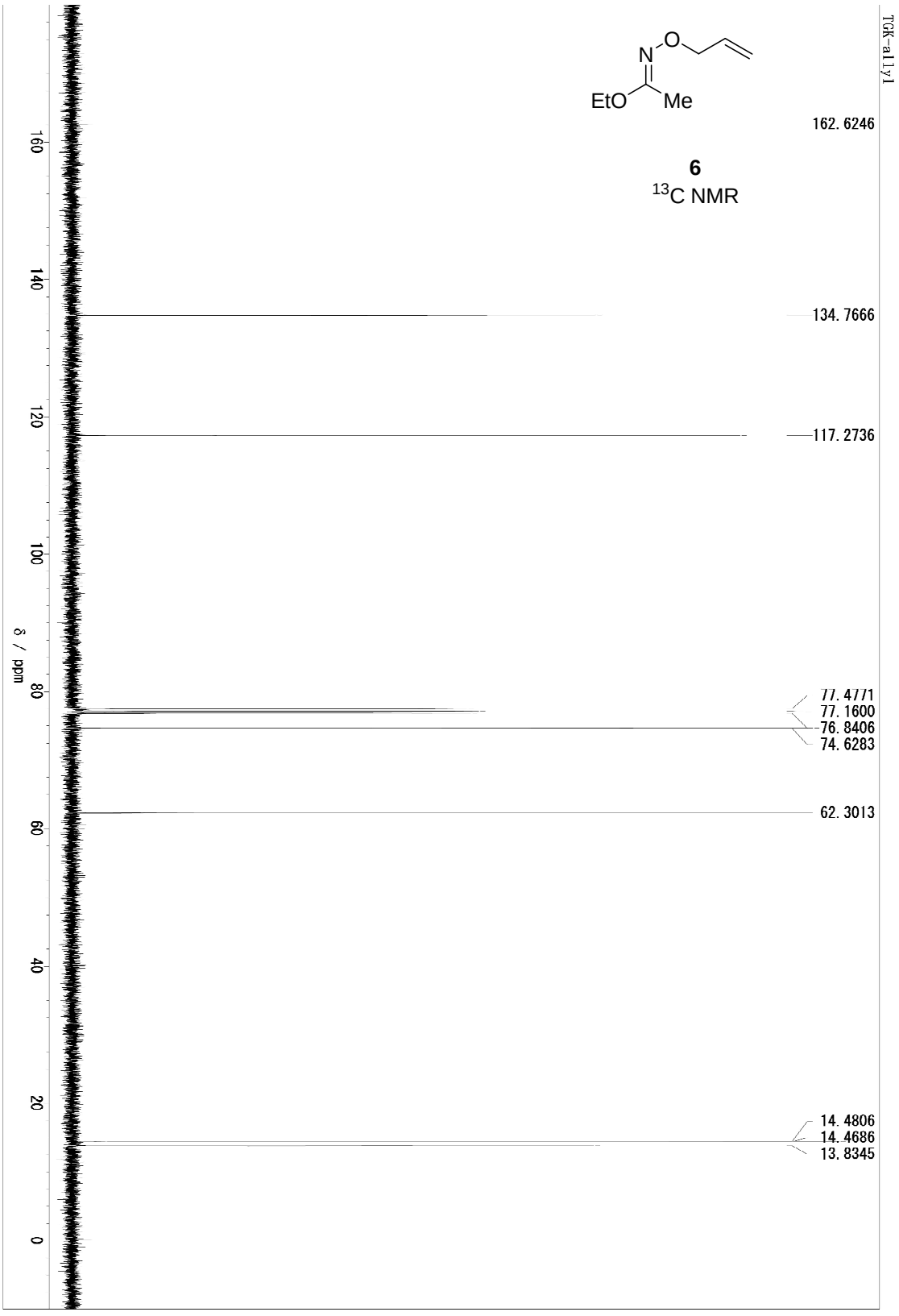

OH
N
Ph
Me
3r (major)
1H NMR
2.0988
1.9477
1.0079
2.072
7.4908
7.4825
7.3675
7.3490
7.3306
7.2992
7.2815
7.2629
7.2453
6.9341
6.9150
6.8800
6.8389
3.0
2.1698
0.0000
ppm

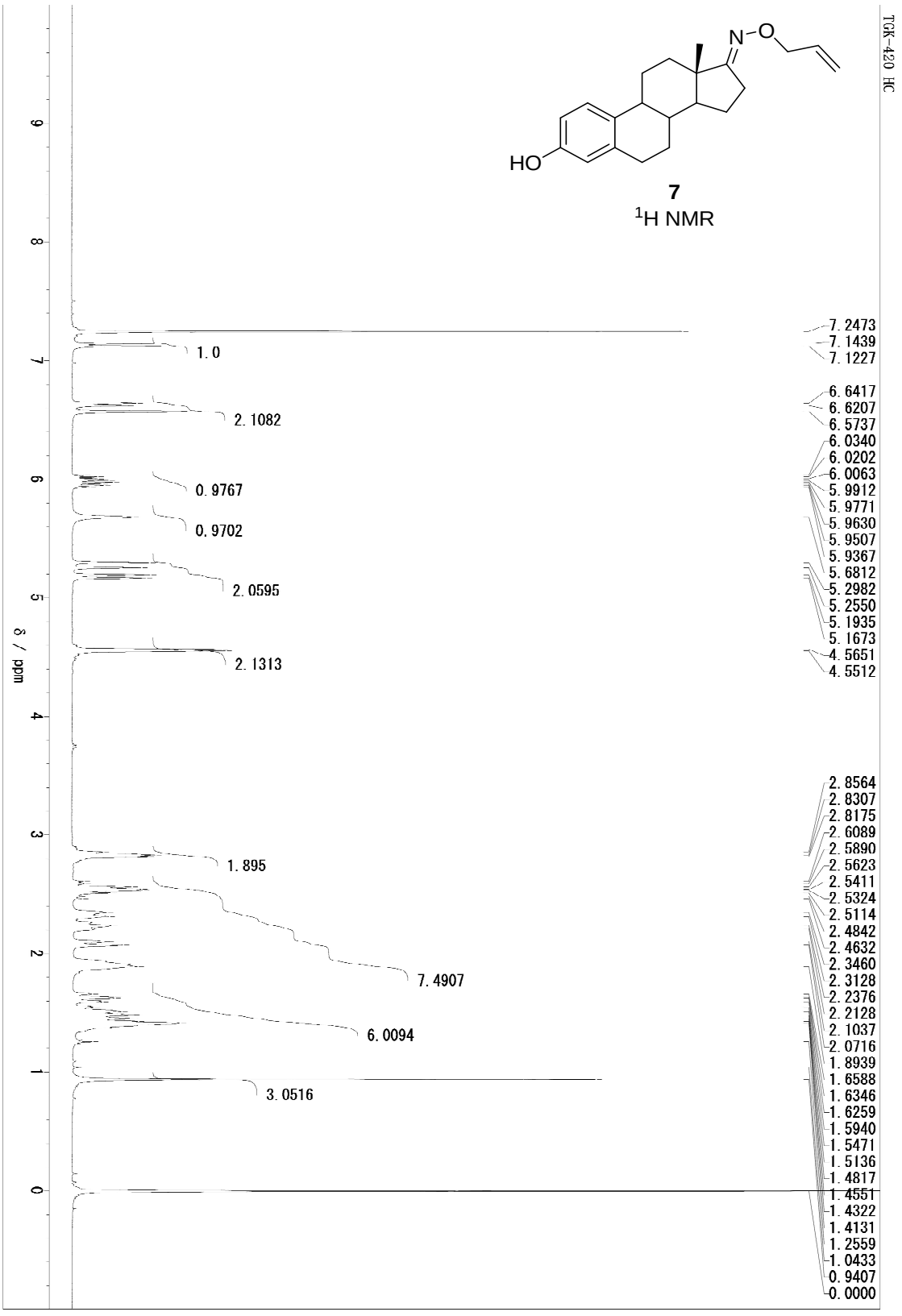

OH
N
Ph
Me
3r (major)
13C NMR
158.9224
136.4377
133.6627
128.6927
128.5804
127.0180
125.8651
77.4771
77.1600
76.8430
9.6608
δ / ppm
160
140
120
100
80
60
40
20
0

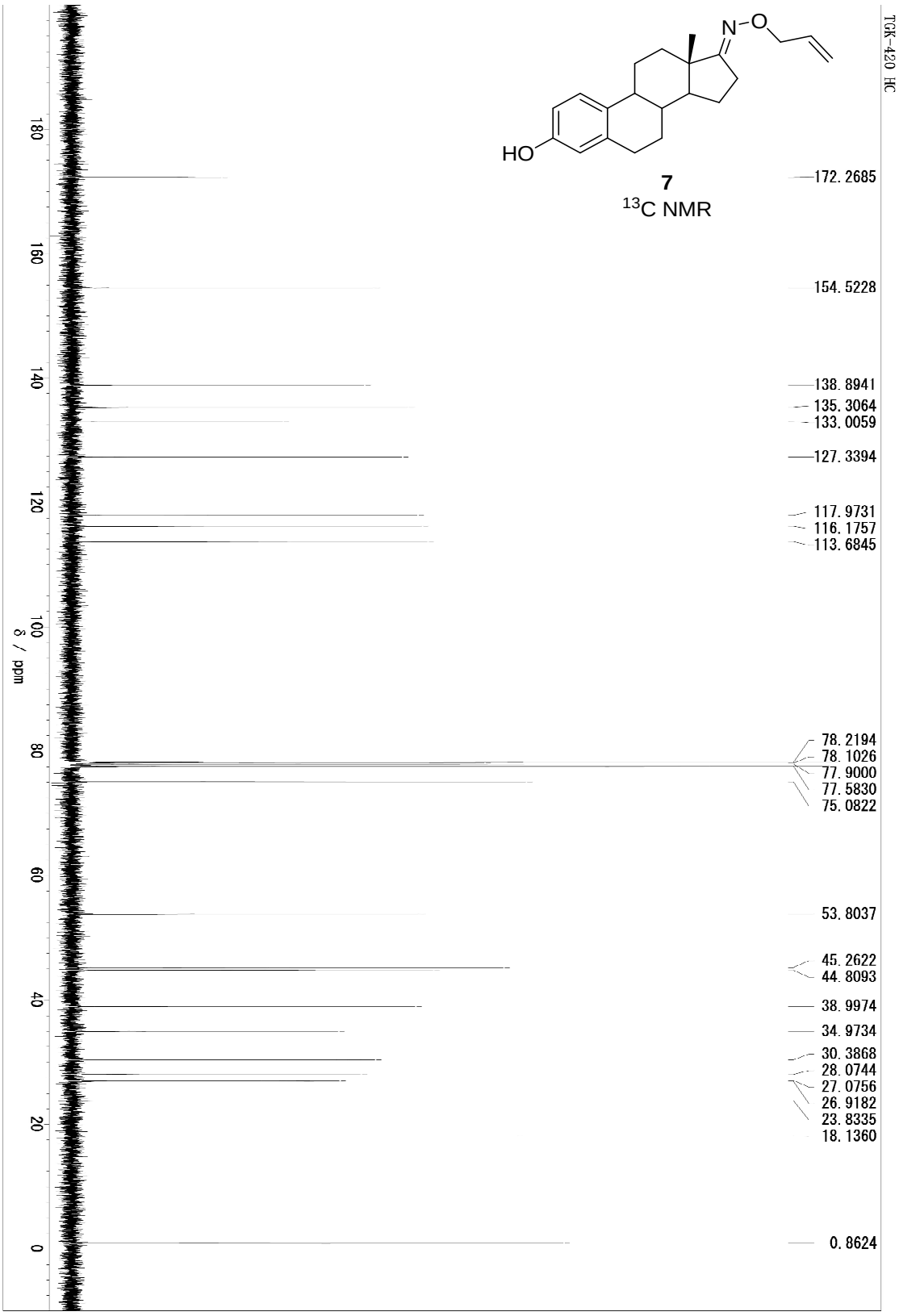

HSG293F18-24
OH
N
Ph
Me
3r (minor)
1H NMR
7.6289
7.5873
7.5493
7.5309
7.3836
7.3670
7.3476
7.3330
7.3163
7.2992
7.2541
6.9731
6.9315
0.8948
1.9597
3.2031
0.9288
3.0
2.1457
2.0960
0.0755
0.0000
δ / ppm

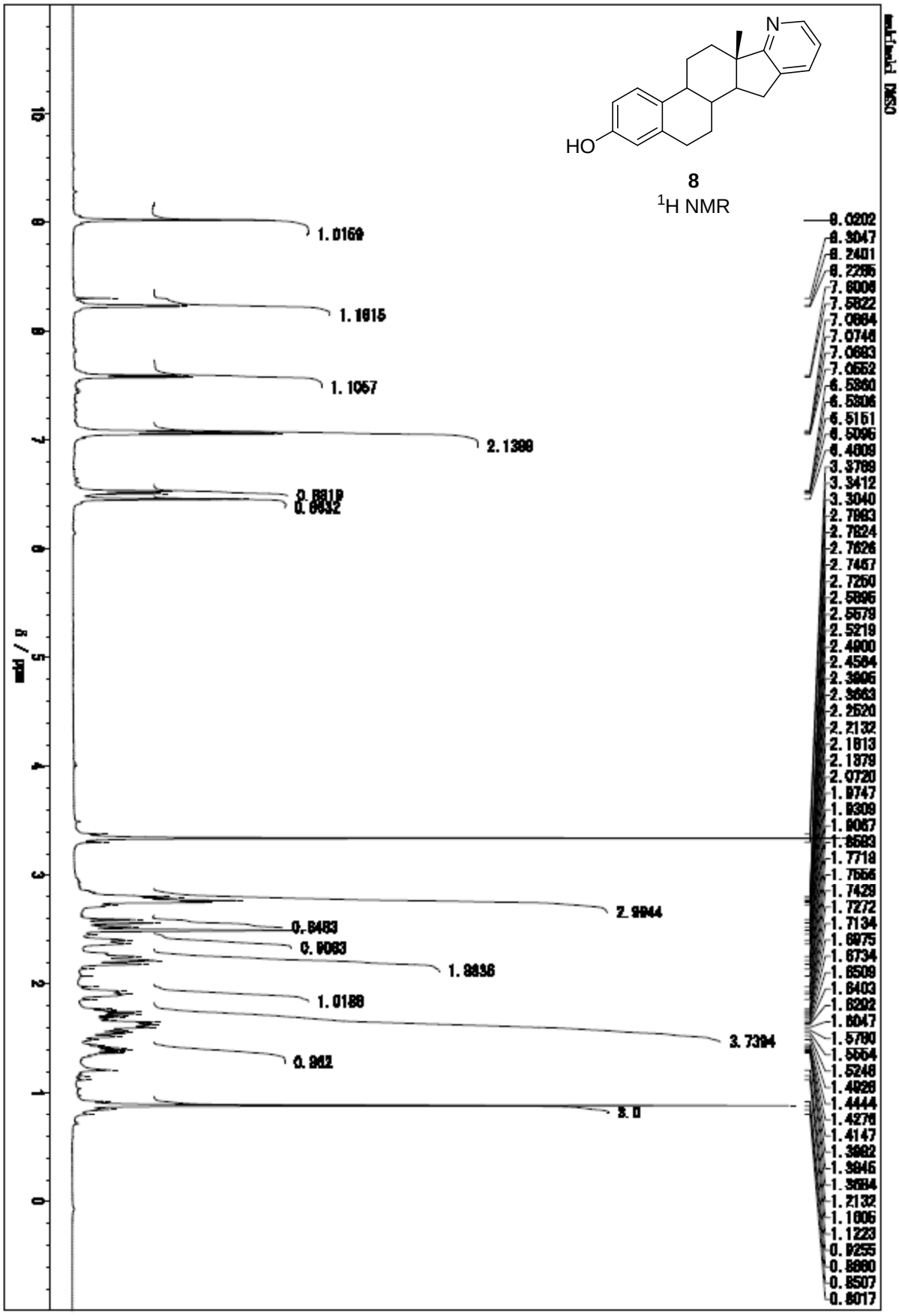

HSG293F18-24
OH
N
Ph
Me
3r (minor)
13C NMR
153.4991
136.6880
136.3828
129.2574
128.9284
127.6650
116.9852
77.5033
77.1839
76.8668
17.0361
δ / ppm
200
180
160
140
120
100
80
60
40
20

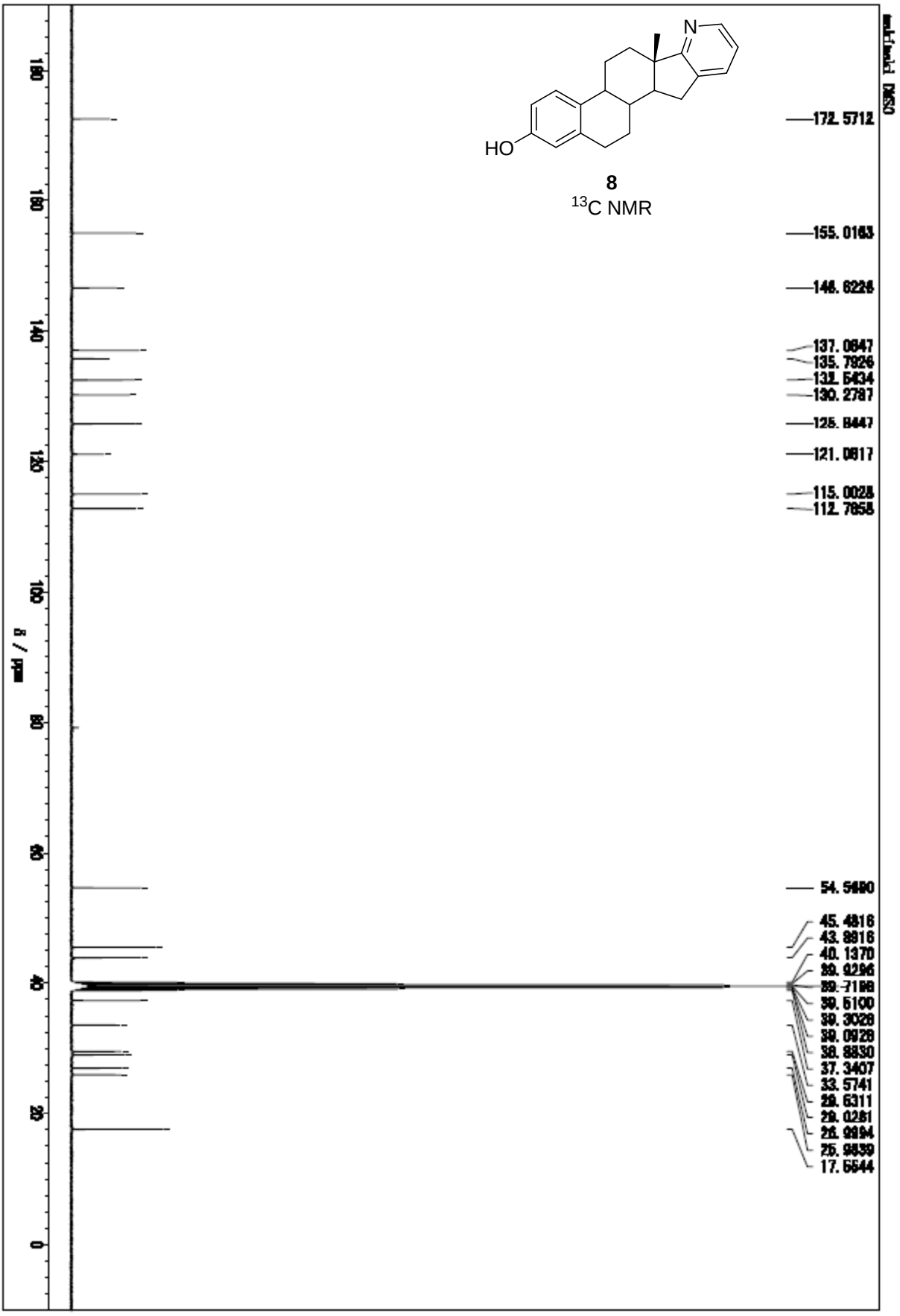

TGK-allyl
N
O
EtO
Me
6
1H NMR
δ / ppm
10
9
8
7
6
5
4
3
2
1
0
1.0
2.0235
1.9096
2.0769
2.9801
3.0901
7.2683
6.0373
6.0230
6.0113
5.9970
5.9825
5.9798
5.9680
5.9537
5.9394
5.2998
5.2959
5.2567
5.2527
5.1987
5.1950
5.1726
5.1688
4.4142
4.4109
4.4076
4.3999
4.3966
4.3934
4.0356
4.0178
4.0001
3.9825
2.0436
1.9861
1.9483
1.9110
1.6709
1.3053
1.2854
1.2676
1.2499
1.2303
0.0000

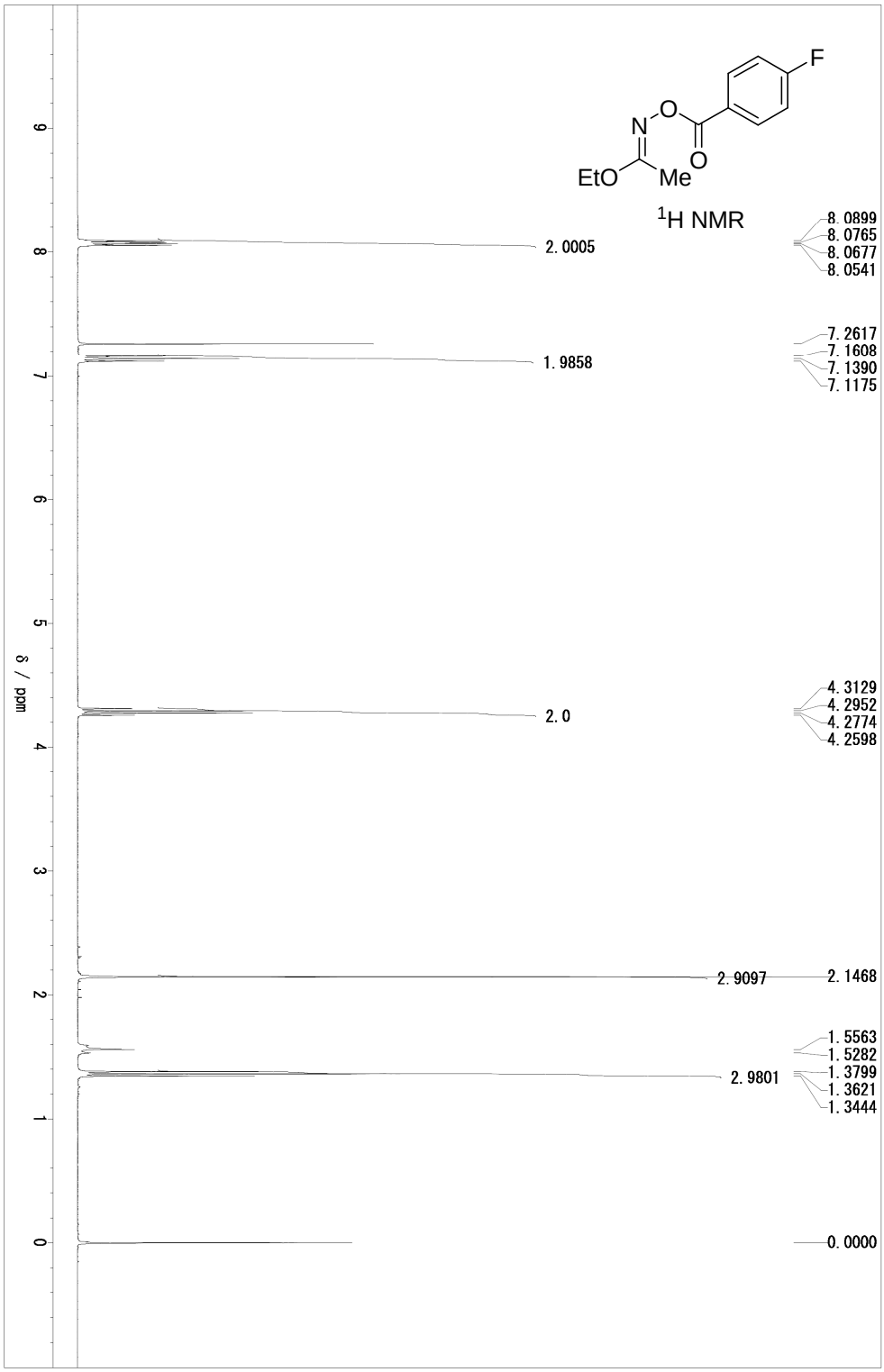

TGK-allyl
N
O
EtO
Me
6
13C NMR
162.6246
134.7666
117.2736
77.4771
77.1600
76.8406
74.6283
62.3013
14.4806
14.4686
13.8345
δ / ppm
160
140
120
100
80
60
40
20
0

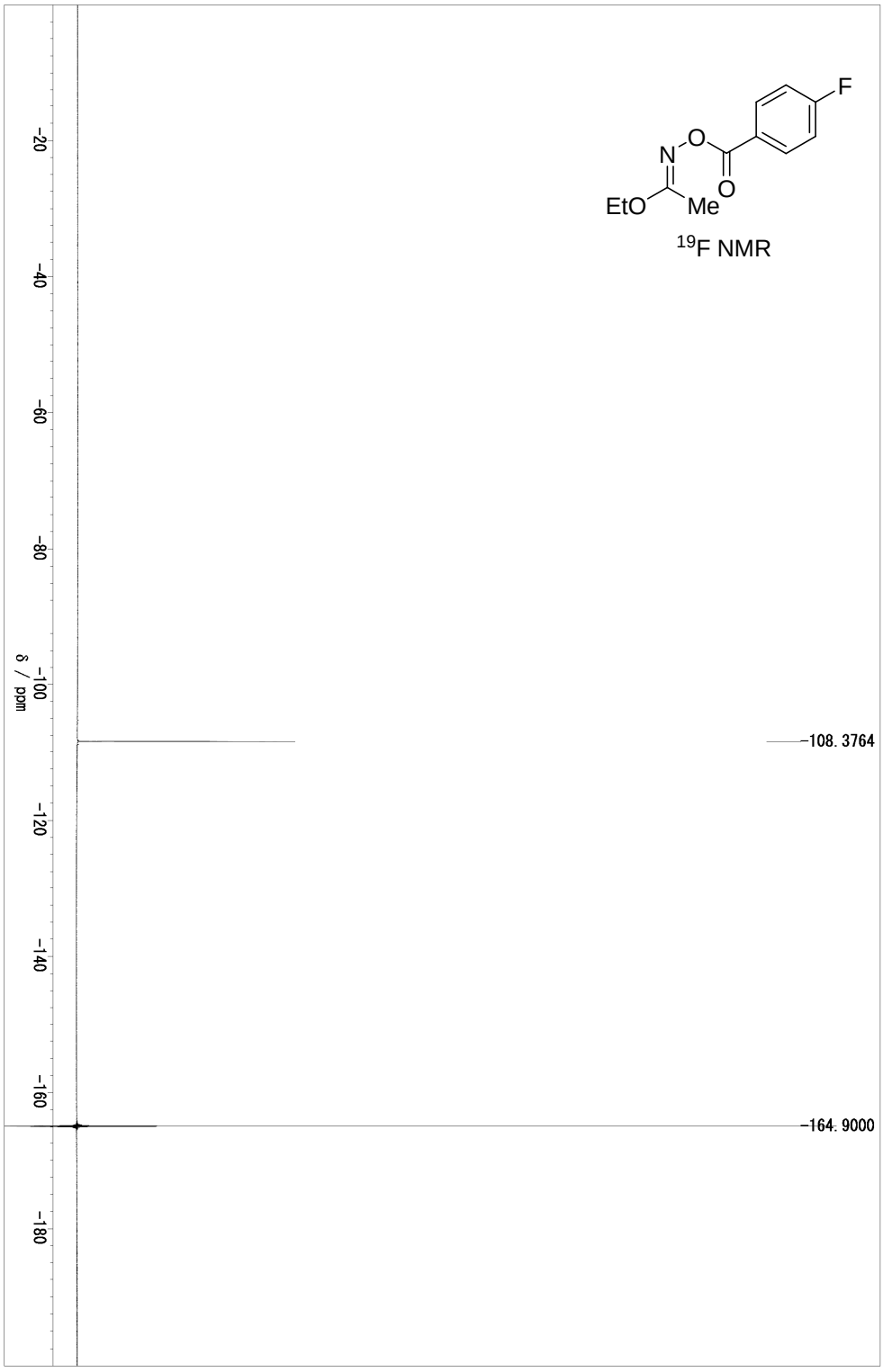

TGK-420 HC
N
O
HO
7
1H NMR
δ / ppm
9
8
7
6
5
4
3
2
1
0
1.0
2.1082
0.9767
0.9702
2.0595
2.1313
1.895
7.4907
6.0094
3.0516
7.2473
7.1439
7.1227
6.6417
6.6207
6.5737
6.0340
6.0202
6.0063
5.9912
5.9771
5.9630
5.9507
5.9367
5.6812
5.2982
5.2550
5.1935
5.1673
4.5651
4.5512
2.8564
2.8307
2.8175
2.6089
2.5890
2.5623
2.5411
2.5324
2.5114
2.4842
2.4632
2.3460
2.3128
2.2376
2.2128
2.1037
2.0716
1.8939
1.6588
1.6346
1.6259
1.5940
1.5471
1.5136
1.4817
1.4551
1.4322
1.4131
1.2559
1.0433
0.9407
0.0000

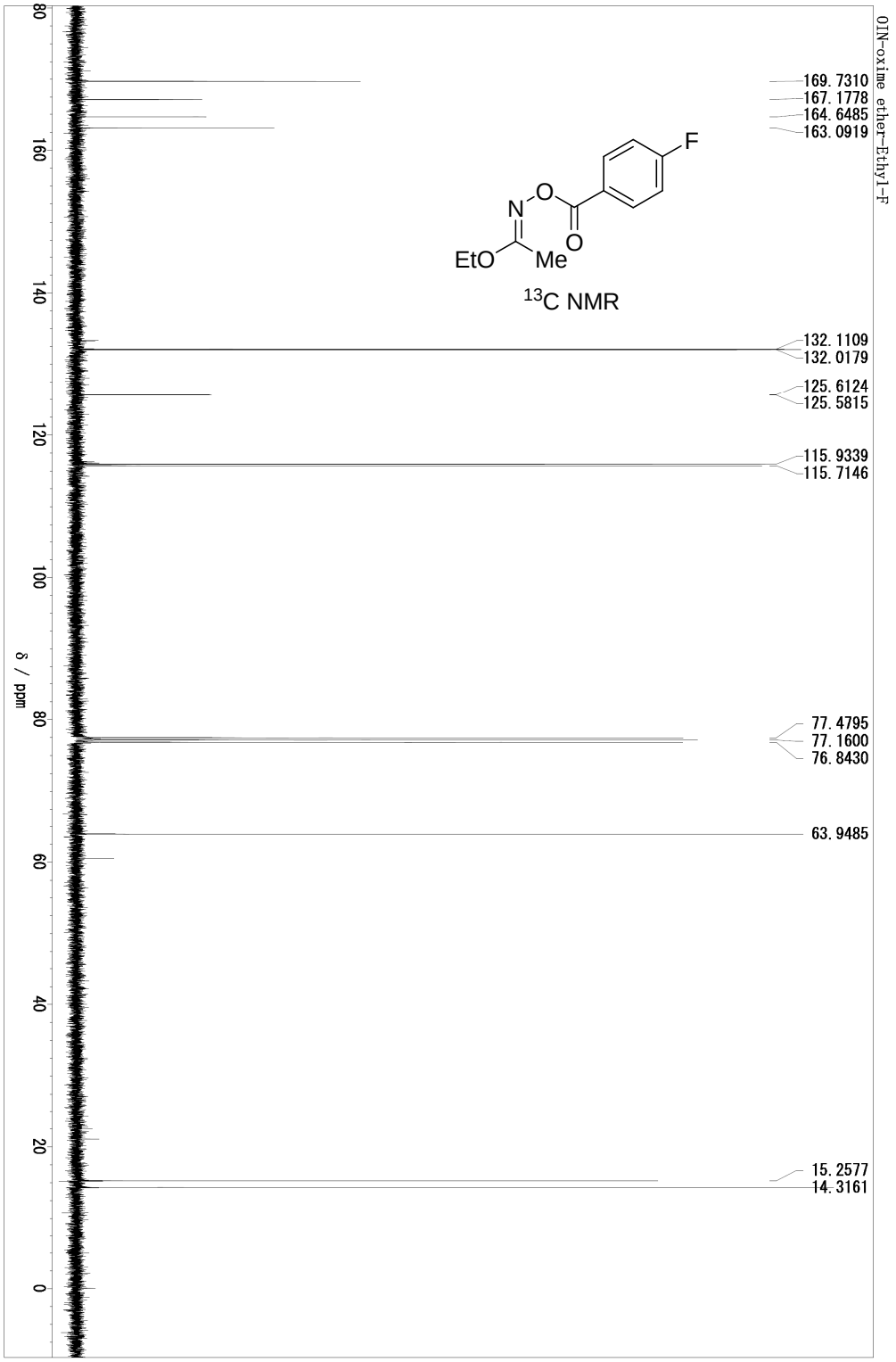

TGK-420 HC
HO
N
O
7
13C NMR
δ / ppm
180
160
140
120
100
80
60
40
20
0
172.2685
154.5228
138.8941
135.3064
133.0059
127.3394
117.9731
116.1757
113.6845
78.2194
78.1026
77.9000
77.5830
75.0822
53.8037
45.2622
44.8093
38.9974
34.9734
30.3868
28.0744
27.0756
26.9182
23.8335
18.1360
0.8624

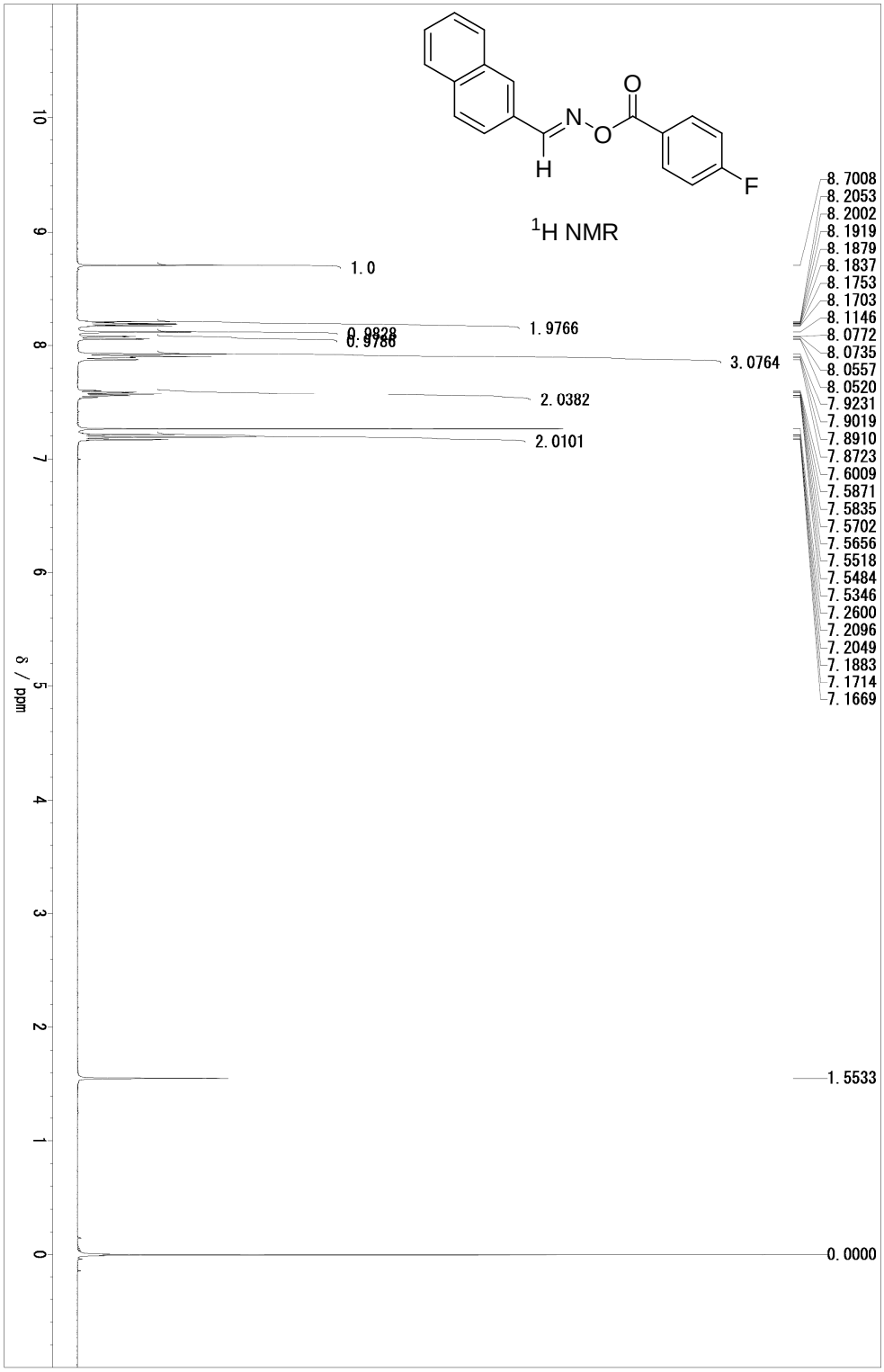

N
HO
8
1H NMR
DMSO
1.0169
1.1615
1.1057
2.1399
2.9944
0.8483
0.9063
1.9836
1.0188
3.7394
0.962
3.0
ppm

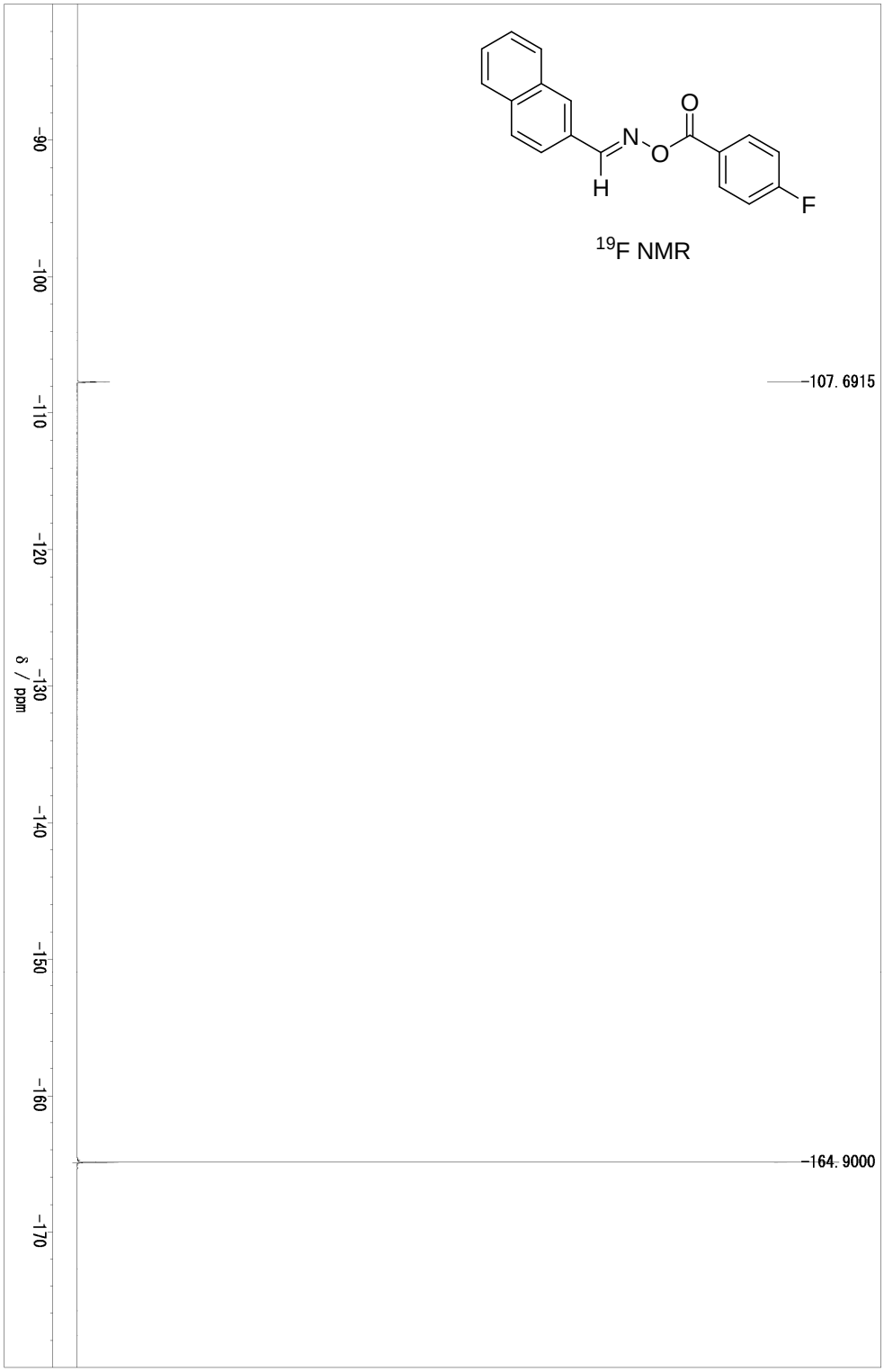

N
HO
8
13C NMR
172.5712
155.0163
146.6226
137.0847
135.7926
132.5434
130.2787
125.8447
121.0817
115.0025
112.7858
54.5490
45.4816
43.8816
40.1370
39.9296
39.7198
39.5100
39.3026
39.0928
38.8830
37.3407
33.5741
29.6311
29.0261
26.9894
25.9839
17.6544
ppm

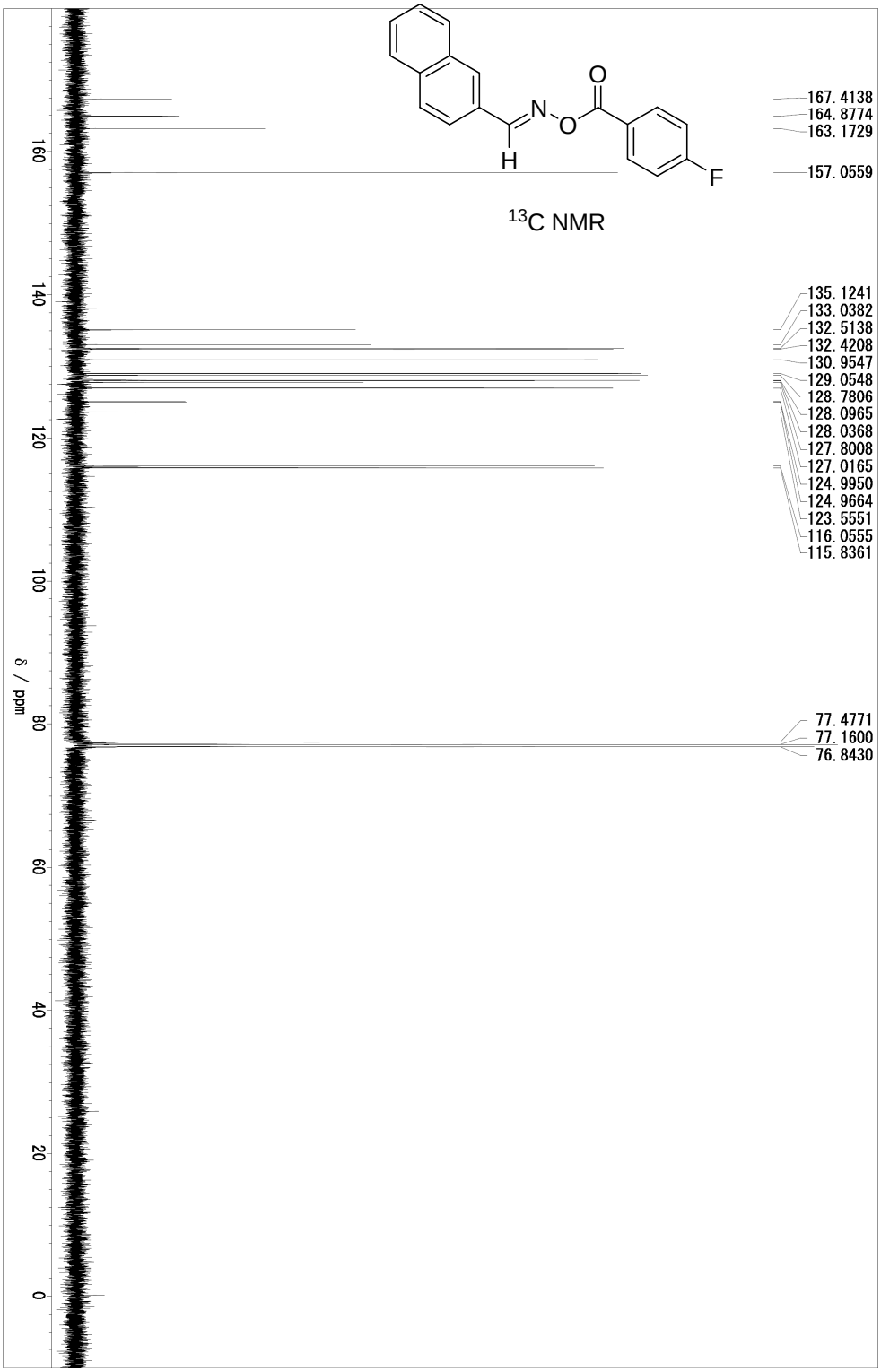

OIN-479-2
F
O
N
O
O
EtO
Me
^{1}H NMR
8.0899
8.0765
8.0677
8.0541
2.0005
7.2617
7.1608
7.1390
7.1175
1.9858
4.3129
4.2952
4.2774
4.2598
2.0
2.9097
2.1468
1.5563
1.5282
1.3799
1.3621
1.3444
2.9801
0.0000
δ / ppm
9
8
7
6
5
4
3
2
1
0


01N-479-2
F
O
N
O
EtO
Me
O
19F NMR
-20
-40
-60
-80
-100
-120
-140
-160
-180
δ / ppm
-108.3764
-164.9000


OIN-oxime ether-Ethyl-F
169.7310
167.1778
164.6485
163.0919
F
O
N
O
O
EtO
Me
13C NMR
132.1109
132.0179
125.6124
125.5815
115.9339
115.7146
77.4795
77.1600
76.8430
63.9485
15.2577
14.3161
δ / ppm
180
160
140
120
100
80
60
40
20
0


OIN-oxime ether-2NathF
O
N
O
H
F
^{1}H NMR
δ / ppm
10
9
8
7
6
5
4
3
2
1
0
1.0
1.9766
0.9828
0.9786
3.0764
2.0382
2.0101
1.5533
0.0000
8.7008
8.2053
8.2002
8.1919
8.1879
8.1837
8.1753
8.1703
8.1146
8.0772
8.0735
8.0557
8.0520
7.9231
7.9019
7.8910
7.8723
7.6009
7.5871
7.5835
7.5702
7.5656
7.5518
7.5484
7.5346
7.2600
7.2096
7.2049
7.1883
7.1714
7.1669


01N-485-3
O
N
O
H
F
19F NMR
-107.6915
-164.9000
-90
-100
-110
-120
-130
-140
-150
-160
-170
δ / ppm


OIN-oxime ether-2Nath-F
167.4138
164.8774
163.1729
157.0559
135.1241
133.0382
132.5138
132.4208
130.9547
129.0548
128.7806
128.0965
128.0368
127.8008
127.0165
124.9950
124.9664
123.5551
116.0555
115.8361
77.4771
77.1600
76.8430
O
N
O
H
F
13C NMR
δ / ppm
160
140
120
100
80
60
40
20
0