Electronic Supplementary Material (ESI) for Chemical Communications

2,5-*cis*-2,3,5-Trisubstituted tetrahydrofurans from the diastereomixture of 2,4-disubstituted 1,3-dioxepines via stereomutation

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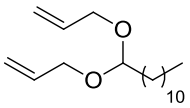
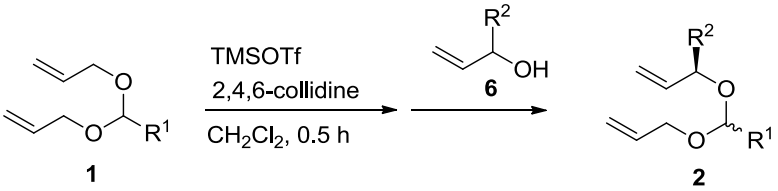
General Techniques

The ^{1}H and ^{13}C NMR spectra were measured by JEOL JNM-LA 500 or JEOL JNM-ECS 400 or JEOL JNM-AL 300 spectrometers with tetramethylsilane as an internal standard at 20-25 ^{o}C. IR spectra were recorded by Shimadzu FTIR 8400 using a diffuse reflectance measurement of samples dispersed in KBr powder. HRMS spectra were recorded by JEOL LMS-D 300 spectrometers. Merck silica gel 60 was used for column chromatography.



1a: (±)-CSA (1.26 g, 5.43 mmol) was added to a solution of dodecanal (5.0 g, 27.13 mmol) and allylalcohol (9.2 mL, 136.65 mmol) in CH_2Cl_2 (27 mL) at room temperature under N_2. The mixture was stirred at the same temperature for 21 h. The mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. EtOH (100 mL) was added to the residue and cooled to $0^{o}C$, then $NaBH_4$ (1.0 g, 26.43 mmol) was added to a solution. The mixture was stirred at the same temperature for 1 h. The mixture was quenched with saturated aqueous NH_4Cl and extracted with AcOEt. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/AcOEt = 40/1) to give **1a** (2.87 g, 37%). colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88 (3 H, t, J = 6.9 Hz), 1.26-1.38 (18 H, m), 1.62-1.67 (2H, m), 3.98-4.12 (4H, m), 4.60 (1H, t, J = 5.7 Hz), 5.15-5.18 (2H, m), 5.26-5.32 (2H, m), 5.88-5.97 (2H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 22.7, 24.7, 29.32, 29.34, 29.42, 29.44, 29.5, 29.6, 31.9, 33.3, 66.0, 102.1, 116.6, 134.8; IR (KBr): 2924, 2855, 2249, 1466, 1038 cm^{-1}; HRMS (EI): Calcd for $C_{18}H_{34}O_2$ (M^{+}) 282.2559 found 282.2541.

General Procedure for Preparation of Mixed Allylacetal 2a-2d.

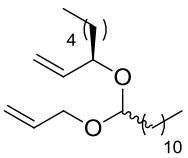


1a ($R^1 = C_{11}H_{23}$)
1b (R^1 = Cy)

6a ($R^2 = C_5H_{11}$)
6b (R^2 = *i*Pr)
6c (R^2 = Ph)

2a ($R^1 = C_{11}H_{23}$, $R^2 = C_5H_{11}$)
2b (R^1 = Cy, $R^2 = C_5H_{11}$)
2c ($R^1 = C_{11}H_{23}$, R^2 = *i*Pr)
2d ($R^1 = C_{11}H_{23}$, R^2 = Ph)

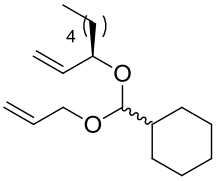
TMSOTf (2.0 equiv) was added dropwise to a solution of 2,4,6-collidine (3.0 equiv) and an acetal **1** in CH_2Cl_2 (0.2 M) at 0 °C under N_2. The mixture was stirred at the same temperature. After checking disappearance of **1** on TLC, an allyalcohol **6** (3.0-5.0 equiv) was added to the resulting mixture, and the solution was stirred at rt. After disappearance of the polar component on TLC, the mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography using neutralized SiO_2 [purchased from KANTO CHEMICAL CO., INC.; Silica Gel 60 N (spherical, neutral)] to give a mixed allylacetal. **1b**[1], **6b**[2], **12**[3] and (*R*)-1-(benzyloxy)but-3-en-2-ol[4]are known compounds. **6a**, **6c**, **13a**, **13b** and RuHCl(CO)(PPh_3)$_3$ are commercially available.



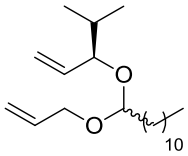
2a：According to the general procedure, **2a** (801.2 mg, 79%) was obtained as 4:5 (= *cis* : *trans*) of diastereomeric mixture from **1a** (811.9 mg, 2.87 mmol), TMSOTf (1.00 mL, 5.74 mmol), 2,4,6-collidine (1.14 mL, 8.62 mmol), and 1-octene-2-ol (**6a)** (1.30 mL, 8.62 mmol). Eluent: hexane/benzene= 1/1 to AcOEt. The relative stereochemistry of **2a** was determined by NOE experiments after transformation of **2a** into **4a**.

cis-**2a**; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88 (6H, t, *J* = 6.6 Hz), 1.26-1.50 (26H, m), 1.57-1.64 (2H, m), 3.87 (1H, q, *J* = 6.7 Hz), 3.92-3.97 (1H, m), 4.07-4.12 (1H, m), 4.55 (1H, t, *J* = 5.5 Hz), 5.10-5.28 (4H, m), 5.75-5.94 (2H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 14.1, 22.6, 22.7, 24.6, 24.8, 29.3, 29.57, 29.61, 31.8, 31.9, 34.1, 35.3, 66.1, 78.1, 101.8, 115.5, 116.4, 134.9, 139.8; IR (KBr): 2926, 2855, 1466, 1115, 1028 cm^{-1}; HRMS (EI): Calcd for $C_{23}H_{44}O_2$ (M^+) 352.3341, found 352.3346.

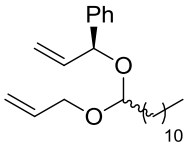
trans-**2a**; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88 (6H, t, *J* = 6.6 Hz), 1.25-1.66 (28H, m), 3.97-4.03 (3H, m), 4.59 (1H, t, *J* = 5.7 Hz), 5.13-5.18 (3H, m), 5.26-5.31 (1H, m), 5.58-5.67 (1H, m), 5.87-5.97 (1H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 14.1, 22.6, 22.7, 24.7, 25.0, 29.3, 29.4, 29.5, 29.56, 29.60, 29.62, 31.7, 31.9, 33.8, 35.6, 64.5, 77.5, 99.9, 116.1, 116.9, 135.1, 139.2 ; IR (KBr): 2924, 2855, 1464, 1115, 1026 cm^{-1}; HRMS (EI): Calcd for $C_{23}H_{44}O_2$ (M^+) 352.3341, found 352.3339.



2b：According to the general procedure, **2b** (390 mg, 48%) was obtained as 3:4 of diastereomeric mixture from **1b** (613.0 mg, 2.91 mmol), TMSOTf (1.1 mL, 5.82 mmol), 2,4,6-collidine (1.1 mL, 8.73 mmol), and 1-octene-2-ol (**6a)** (1.3 mL, 8.73 mmol). Eluent: hexane/CH_2Cl_2= 2/1; colorless oil; ^{1}H NMR (400 MHz, C_6D_6) δ: 0.87-0.91 (3H, m), 1.03-1.77 (17H, m), 1.89-2.03 (2H, m), 3.88-4.15 (3H, m), 4.32 (3/7H, d, *J* = 6.0 Hz), 4.42 (4/7H, d, *J* = 6.9 Hz), 5.00-5.17 (3H, m), 5.32 (3/7H, dq, *J* = 15.1, 1.8 Hz), 5.37 (4/7H, dq, *J* = 15.1, 1.8 Hz), 5.59-5.68 (4/7H, m), 5.79-5.98 (10/7H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 22.6, 24.8, 25.0, 25.8, 25.87, 25.94, 26.4, 26.5, 27.6, 28.0, 28.4, 28.5, 31.80, 31.83, 35.2, 35.6, 40.8, 41.4, 65.2, 66.3, 77.8, 79.0, 103.2, 105.1, 115.7, 116.2, 116.4, 117.2, 135.0, 135.2, 139.3, 139.9 ; IR (KBr): 2928, 2855, 2251, 1645, 1466, 1452, 1379 cm^{-1}; HRMS (FAB): Calcd for $C_{18}H_{32}NaO_2$ ($M+Na^+$): 303.2300, found 303.2318.

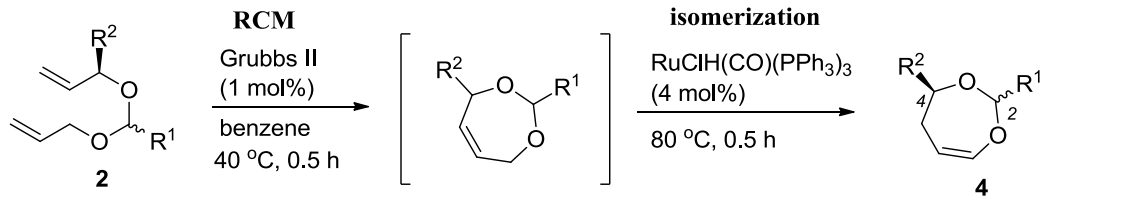


2c：According to the general procedure, **2c** (233.3 mg, 68%) was obtained as 5:6 of diastereomeric mixture from **1a** (297.0 mg, 1.05 mmol), TMSOTf (0.38 mL, 2.10 mmol), 2,4,6-collidine (0.42 mL, 3.15 mmol), and **6b**[2] (526.4 mg, 5.26 mmol). Eluent: hexane/benzene= 1/1; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.96 (9H, m), 1.27-1.37 (18H, m), 1.59-1.64 (2H, m), 1.72-1.83 (1H, m), 3.57-3.60 (5/11H, m), 3.72 (6/11H, dd, *J* = 8.2, 6.4 Hz), 3.91-4.11 (2H, m), 4.53 (5/11H, t, *J* = 5.3 Hz), 4.58 (6/11H, t, *J* = 5.7 Hz), 5.11-5.30 (4H, m), 5.57-5.66 (6/11H, m), 5.74-5.96 (16/11H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 17.9, 18.3, 18.6, 18.7, 22.7, 24.6, 24.7, 29.3, 29.47, 29.55, 29.57, 29.61, 29.64, 31.9, 32.4, 32.6, 33.8, 34.1, 64.5, 66.3, 82.6, 83.6, 99.8, 102.1, 116.2, 116.4, 116.8, 118.2, 135.0, 135.3, 137.2, 137.7; IR (KBr): 2924, 2855, 2247, 1645, 1468 cm^{-1}; HRMS (EI): Calcd for $C_{21}H_{40}O_2$ (M^+) 324.3028, found 324.3048.



2d：According to the general procedure, **2d** (243.2 mg, 47%) was obtained as 7:8 of diastereomeric mixture from **1a** (408.6 mg, 1.45 mmol), TMSOTf (0.52 mL, 2.89 mmol), 2,4,6-collidine (0.57 mL, 4.34 mmol), and **6c** (0.57 mL, 4.34 mmol). Eluent: hexane/benzene= 1/1; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88 (3H, t, *J* = 6.9 Hz), 1.22-1.38 (18H, m), 1.60-1.69 (2H, m), 3.89-3.94 (8/15H, m), 3.99-4.04 (22/15H, m), 4.52 (7/15H, t, *J* = 5.7 Hz), 4.75 (8/15H, t, *J* = 5.7 Hz), 5.07-5.33 (5H, m), 5.79-6.06 (2H, m), 7.24-7.38 (5H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 22.7, 24.6, 24.7, 29.3, 29.37, 29.43, 29.49, 29.53, 29.57, 29.61, 29.63, 31.9, 33.68, 33.72, 65.05, 65.10, 78.3, 78.5, 100.6, 100.7, 115.3, 116.5, 116.7, 126.7, 127.3, 127.4, 127.6, 128.3, 128.4, 134.9, 135.0, 138.6, 139.3, 140.9, 141.4; IR (KBr): 2924, 2853, 1643, 1454, 1115 cm^{-1}; HRMS (EI): Calcd for $C_{24}H_{38}O_2$ (M^+) 358.2872, found 358.2898.

General Procedure A for Preparation of 2,4-disubstituted-1,3-dioxepin 4a-4d.



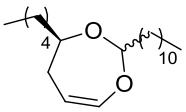
2

2a (R^1 = $C_{11}H_{23}$, R^2 = C_5H_{11})
2b (R^1 = Cy, R^2 = C_5H_{11})
2c (R^1 = $C_{11}H_{23}$, R^2 = *i*Pr)
2d (R^1 = $C_{11}H_{23}$, R^2 = Ph)

4

4a (R^1 = $C_{11}H_{23}$, R^2 = C_5H_{11})
4b (R^1 = Cy, R^2 = C_5H_{11})
4e (R^1 = $C_{11}H_{23}$, R^2 = *i*Pr)
4f (R^1 = $C_{11}H_{23}$, R^2 = Ph)

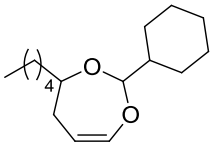
Grubbs' 2nd cat. (1 mol%) was added to a solution of mixed allylacetal **2** in benzene (0.05 M) at room temperature under N_2. The mixture was stirred at 40 °C. After checking disappearance of **2** and completion of RCM on TLC, $RuClH(CO)(PPh_3)_3$ (4 mol%) was added to the resulting mixture, and the solution was stirred at 80 °C. After disappearance of RCM product on TLC, the mixture was evaporated in vacuo. The residue was purified by flash column chromatography using neutralized SiO_2 [purchased from KANTO CHEMICAL CO., INC.; Silica Gel 60 N (spherical, neutral)] to give a 2,4-disubstituted-1,3-dioxepin **4**. The relative stereochemistry of 2,4-disubstituted-1,3-dioxepin **4** between H-2 and H-4 was determined by NOE experiments.



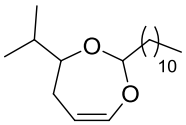
4a: According to the general procedure, **4a** (149.0 mg, 76%) was obtained as 1:1 (= *cis* : *trans*) of diastereomeric mixture from **2a** (212.9 mg, 0.604 mmol), Grubbs' 2nd cat. (5.2 mg, 0.0061 mmol), $RuClH(CO)(PPh_3)_3$ (23.0 mg, 0.024 mmol). Eluent: hexane/benzene= 3/2.

cis-**4a**; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.91 (6H, m), 1.26-1.48 (25H, m), 1.57-1.64 (1H, m), 1.71-1.76 (2H, m), 2.10-2.29 (2H, m), 3.23-3.29 (1H, m), 4.49 (1H, t, *J* = 5.7 Hz), 4.72 (1H, td, *J* = 7.6, 2.6 Hz), 6.32 (1H, dd, *J* = 7.6, 2.6 Hz). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.05, 14.13, 22.6, 22.7, 24.7, 25.9, 29.4, 29.59, 29.64, 29.7, 31.7, 31.9, 35.7, 35.86, 35.91, 80.2, 106.1, 106.3, 145.8; IR (KBr): 2924, 2855, 1653, 1466, 1123 cm^{-1}; HRMS (EI): Calcd for $C_{21}H_{40}O_2$ (M^+) 324.3028, found 324.3053.

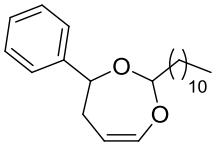
trans-**4a**; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (6H, m), 1.19-1.46 (25H, m), 1.51-1.66 (3H, m), 2.02-2.10 (1H, m), 2.50-2.59 (1H, m), 4.24-4.31 (1H, m), 4.67 (1H, td, *J* = 7.2, 3.6 Hz), 5.43 (1H, t, *J* = 5.3 Hz), 6.24 (1H, dd, *J* = 7.2, 2.1 Hz).^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.05, 14.13, 22.6, 22.7, 24.5, 25.2, 29.38, 29.40, 29.6, 29.65, 29.68, 30.8, 31.8, 31.9, 35.3, 36.1, 77.9, 99.9, 103.9, 146.5; IR (KBr): 2924, 2855, 1651, 1466, 1258 cm^{-1}; HRMS (EI): Calcd for $C_{21}H_{40}O_2$ (M^+) 324.3028, found 324.3033.



4b: According to the general procedure, **4b** (218.0 mg, 73%) was obtained as 1:1 (= *cis* : *trans*) of diastereomeric mixture from **2b** (334.7 mg, 1.19 mmol), Grubbs' 2nd cat. (10.1 mg, 0.0119 mmol), $RuClH(CO)(PPh_3)_3$ (45.3 mg, 0.048 mmol). Eluent: hexane/CH_2Cl_2= 2/1; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.87-0.91 (3H, m), 0.99-1.90 (21H, m), 2.00-2.08 (1/2H, m), 2.13 (1/2H, ddd, *J* = 16.5, 7.8, 2.7 Hz), 2.20-2.28 (1/2H, m), 2.51-2.59 (1/2H, m), 3.20-3.26 (1/2H, m), 4.22 (1/2H, d, *J* = 6.0 Hz), 4.24-4.31 (1/2H, m), 4.62-4.72 (1H, m), 5.17 (1/2H, d, *J* = 5.5 Hz), 6.23 (1/2H, dd, *J* = 6.6, 2.1 Hz), 6.33 (1/2H, dd, *J* = 7.5, 3.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 22.6, 25.2, 25.87, 25.90, 26.5, 27.60, 27.62, 27.7, 28.4, 30.7, 31.7, 31.8, 35.91, 35.95, 36.3, 42.6, 43.2, 78.2, 80.2, 102.4, 103.4, 105.9, 109.3, 145.9, 146.5; IR (KBr): 2926, 1651, 1452, 1263 cm^{-1}; HRMS (FAB): Calcd for $C_{16}H_{28}NaO_2$ ($M+Na^+$): 275.1987, found 275.1977.



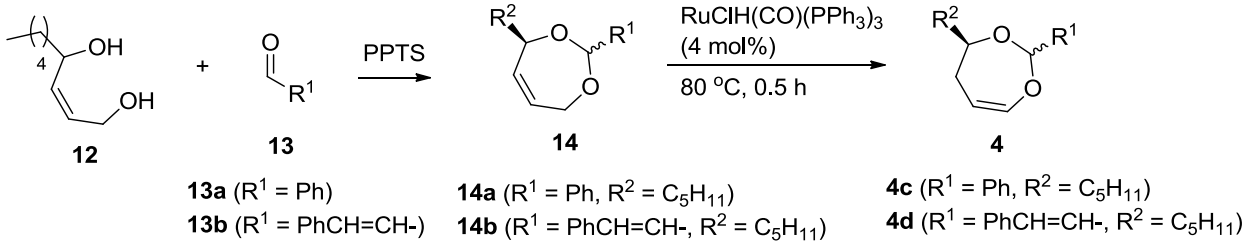
4e: According to the general procedure, **4e** (168.6 mg, 89%) was obtained as 5:6 (= *cis* : *trans*) of diastereomeric mixture from **2c** (206.4 mg, 0.64 mmol), Grubbs' 2nd cat. (5.3 mg, 0.0062 mmol), $RuClH(CO)(PPh_3)_3$ (24.2 mg, 0.025 mmol). Eluent: hexane/CH_2Cl_2= 4/1; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.99 (9H, m), 1.26-1.43 (18H, m), 1.62-1.67 (1H, m), 1.71-1.80 (2H, m), 1.97 (6/11H, ddd, *J* = 17.3, 8.1, 2.6 Hz), 2.14-2.31 (10/11H, m), 2.57-2.65 (6/11H, m), 2.98-3.03 (5/11H, m), 4.07-4.12 (6/11H, m), 4.49 (5/11H, t, *J* = 5.5 Hz), 4.65-4.74 (1H, m), 5.47 (6/11H, t, *J* = 5.3 Hz), 6.24 (6/11H, dd, *J* = 6.4, 2.3 Hz), 6.31 (5/11H, dd, *J* = 7.3, 2.7 Hz).^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 17.9, 18.3, 18.8, 19.5, 22.7, 24.5, 24.6, 27.0, 29.3, 29.38, 29.39, 29.5, 29.61, 29.64, 31.9, 32.8, 33.1, 33.2, 35.2, 35.7, 83.0, 85.4, 100.2, 103.6, 105.9, 106.4, 145.4, 146.4; IR (KBr): 2955, 2924, 2855, 1653, 1466 cm^{-1}; HRMS (FAB): Calcd for $C_{19}H_{37}O_2$ (M^++H): 297.2794, found 297.2783.



4f: According to the general procedure, **4f** (158.5 mg, 76%) was obtained as 1:1 (= *cis* : *trans*) of diastereomeric mixture from **2d** (225.7 mg, 0.63 mmol), Grubbs' 2nd cat. (5.4 mg, 0.0064 mmol), $RuClH(CO)(PPh_3)_3$ (23.8 mg, 0.025 mmol). Eluent: hexane/CH_2Cl_2= 3/1 to hexane/AcOEt= 10/1; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (3H, m), 1.24-1.47 (18H, m), 1.69-1.85 (2H, m), 2.27 (1/2H, ddd, *J* = 17.5, 7.7, 2.4 Hz), 2.41 (1/2H, ddd, *J* = 16.6, 7.9, 2.4 Hz), 2.55-2.63 (1/2H, m), 2.87-2.95 (1/2H, m), 4.38 (1/2H, dd, *J* = 11.0, 2.3 Hz), 4.69 (1/2H, t, *J* = 5.3 Hz), 4.78-4.87 (1H, m), 5.40 (1/2H, dd, *J* = 10.5, 2.7 Hz), 5.61 (1/2H, t, *J* = 5.5 Hz), 6.36 (1/2H, dd, *J* = 6.9, 1.8 Hz), 6.43 (1/2H, dd, *J* = 7.3, 2.7 Hz), 7.26-7.40 (5H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 22.7, 24.5, 24.6, 29.3, 29.4, 29.49, 29.55, 29.6, 31.9, 33.2, 35.2, 35.7, 37.7, 37.9, 79.8, 81.8, 101.3, 104.6, 106.3, 106.4, 125.8, 126.2, 127.4, 127.5, 128.2, 128.4, 142.3, 142.5, 146.4, 147.4; IR (KBr): 3034, 2924, 2853, 2251, 1651 cm^{-1}; HRMS

(FAB): Calcd for $C_{22}H_{35}O_2$ (M^++H): 331.2637, found 331.2660.

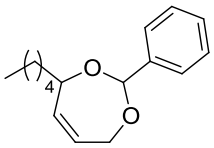
General Procedure B for Preparation of 2,4-disubstituted-1,3-dioxepin 4e and 4f.



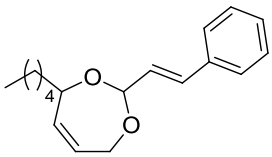
13a (R^1 = Ph)
13b (R^1 = PhCH=CH-)

14a (R^1 = Ph, R^2 = C_5H_{11})
14b (R^1 = PhCH=CH-, R^2 = C_5H_{11})

4c (R^1 = Ph, R^2 = C_5H_{11})
4d (R^1 = PhCH=CH-, R^2 = C_5H_{11})

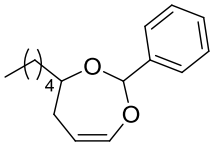


14a: PPTS (21.2 mg, 0.084 mmol)) was added to a solution of **12**[3] (64.3 mg, 0.41 mmol) and benzaldehyde (**13a**) (0.21 mL, 2.03 mmol) in CH_2Cl_2 (2.0 mL) at room temperature under N_2. The mixture was stirred at the same temperature for 12.5 h. The mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. MeOH (10 mL) was added to the residue and cooled to 0°C, then $NaBH_4$ (77.8 mg, 2.06 mmol) was added to a solution. The mixture was stirred at the same temperature for 15 min. The mixture was quenched with saturated aqueous NH_4Cl and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/AcOEt = 10/1) to give **14a** (76.5 mg, 76%) as 7:4 of diastereomeric mixture; colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 0.80 (12/11H, t, *J* = 7.3 Hz), 0.92 (21/11H, t, *J* = 7.0 Hz), 0.99-1.80 (8H, m), 4.03-4.07 (7/11H, m), 4.30-4.34 (1H, m), 4.43-4.55 (15/11H, m), 5.58-5.77 (2H, m), 5.87 (7/11H, s), 5.92 (4/11H, s), 7.32-7.39 (3H, m), 7.54-7.57 (2H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 13.9, 14.0, 22.5, 22.6, 25.0, 25.3, 31.4, 31.7, 35.3, 35.7, 62.2, 66.6, 69.7, 77.1, 100.7, 101.6, 126.4, 126.6, 127.9, 128.1, 128.2, 128.3, 129.2, 129.8, 134.2, 134.6, 139.0, 139.2; IR (KBr): 2932, 2859, 1450, 1346, 1207 cm^{-1}; HRMS (FAB): Calcd for $C_{16}H_{23}O_2$ (M^++H): 247.1698, found 247.1706.

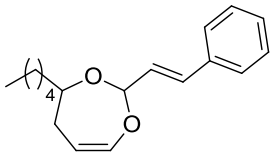


14b: PPTS (103.9 mg, 0.41 mmol) was added to a solution of **12**[3] (327.8 mg, 2.07 mmol) and cinnamaldehyde (**13b**) (1.3 mL, 10.35 mmol) in CH_2Cl_2 (5.2 mL) at room temperature under N_2. The mixture was stirred at the same temperature for 17 h. The mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. MeOH (21 mL) was added to the residue and cooled to 0°C, then $NaBH_4$ (391.9 mg, 10.36 mmol) was added to a solution. The mixture was stirred at the same temperature for 30 min. The mixture was quenched with saturated aqueous NH_4Cl and extracted with Et_2O. The organic layer was dried over Na_2SO_4,

filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/AcOEt = 15/1) to give **14b** (258.0 mg, 43%) as 6:7 of diastereomeric mixture; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.84 (18/13H, t, *J* = 6.9 Hz), 0.90 (21/13H, t, *J* = 6.9 Hz), 1.26-1.74 (8H, m), 4.05-4.11 (7/13H, m), 4.35-4.54 (32/13H, m), 5.45 (7/13H, dd, *J* = 4.0, 1.2 Hz), 5.50 (6/13H, dd, *J* = 4.0, 1.2 Hz), 5.59-5.75 (2H, m), 6.21-6.28 (1H, m), 6.80 (1H, t, *J* = 16.0 Hz), 7.23-7.43 (5H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 14.1, 22.58, 22.60, 25.27, 25.33, 31.6, 31.7, 35.4, 35.6, 62.2, 66.7, 70.0, 77.1, 100.3, 101.3, 126.0, 126.1, 126.7, 126.8, 127.95, 128.00, 128.5, 128.6, 129.3, 129.8, 132.6, 133.0, 134.1, 134.6, 136.2; IR (KBr): 2930, 2857, 1449, 1346, 1138 cm^{-1}; HRMS (FAB): Calcd for $C_{18}H_{25}O_2$ (M^++H): 273.1855, found 273.1853.

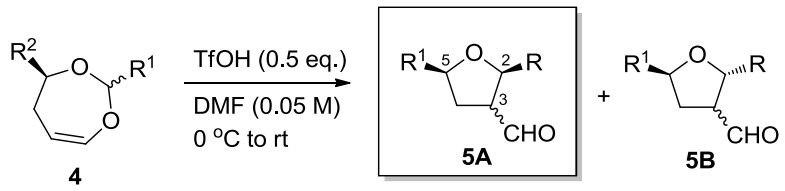


4c: According to the general procedure A, **4c** (55.9 mg, 77%) was obtained as 2:1 (= *cis* : *trans*) of diastereomeric mixture from **14a** (72.2 mg, 0.29 mmol) and $RuClH(CO)(PPh_3)_3$ (11.0 mg, 0.024 mmol). Eluent: hexane/benzene= 2/1. The relative stereochemistry of **4c** was determined by NOE experiments; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (3 H, m), 1.19-1.77 (8 H, m), 2.17-2.29 (1H, m), 2.35-2.43 (2/3 H, m), 2.62-2.71 (1/3H, m), 3.45-3.55 (2/3H, m), 4.43-4.50 (1/3H, m), 4.83 (1/3H, td, *J* = 7.1, 3.2 Hz), 4.89 (2/3H, td, *J* = 7.7, 2.6 Hz), 5.51 (2/3H, s), 6.40-6.42 (2/3 H, m), 6.49 (2/3H, dd, *J* = 7.4, 1.7 Hz), 7.30-7.40 (3H, m), 7.50-7.56 (2H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 22.6, 25.3, 26.0, 31.0, 31.7, 31.8, 35.8, 35.86, 35.89, 78.0, 80.7, 99.4, 104.6, 105.2, 107.1, 126.0, 126.2, 128.1, 128.2, 128.4, 128.6, 138.9, 139.2, 145.9, 146.7; IR (KBr): 2930, 1651, 1452, 1277, 1115 cm^{-1}; HRMS (FAB): Calcd for $C_{16}H_{23}O_2$ (M^++H): 247.1698, found 247.1680.



4d: According to the general procedure A, **4d** (24.9 mg, 59%) was obtained as 5:3 (= *cis* : *trans*) of diastereomeric mixture from **14b** (42.4 mg, 0.15 mmol) and $RuClH(CO)(PPh_3)_3$ (5.6 mg, 0.0059 mmol). Eluent: hexane/benzene= 1/1. The relative stereochemistry of **4d** was determined by NOE experiments; colorless oil; ^{1}H NMR (400 MHz, ACETONE-D_6) δ: 0.73-0.78 (3H, m), 1.16-1.54 (8H, m), 2.12-2.31 (13/8H, m), 2.61-2.69 (3/8H, m), 3.43-3.50 (5/8H, m), 4.28-4.35 (3/8H, m), 4.76-4.84 (1H, m), 5.17 (5/8H, dd, *J* = 4.4, 1.1 Hz), 6.07 (3/8H, dd, *J* = 5.0, 0.9 Hz), 6.24-6.31 (1H, m), 6.37 (1H, td, *J* = 7.7, 3.2 Hz), 6.79 (1H, dd like, *J* = 15.3, 14.0 Hz), 7.26-7.37 (3H, m), 7.47-7.50 (2H, m); ^{13}C NMR (100 MHz, ACETONE-D_6) δ: 14.3, 23.2, 26.0, 26.5, 31.9, 32.4, 32.5, 36.5, 36.7, 78.4, 81.0, 99.5, 105.0, 105.6, 107.3, 127.5, 127.8, 128.8, 129.5, 132.5, 132.9, 137.18, 137.24, 146.3, 146.8; IR (KBr): 2930, 2859, 1651, 1265 cm^{-1}; HRMS (FAB): Calcd for $C_{18}H_{25}O_2$ (M^++H): 273.1855, found 273.1826.

General Procedure for Preparation of 2,3,5-trisubstituted-THF 5aA-5fA.

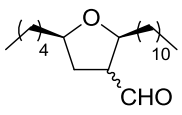


TfOH (0.5 equiv) was added dropwise to a solution of 1,3-dioxepin (1.0 equiv) in DMF (0.05 M) at 0 °C under N_2. The mixture was stirred at room temperature. After checking disappearance of 1,3-dioxepin on TLC, the mixture was quenched with saturated aqueous $NaHCO_3$ at 0 °C. AcOEt and Et_2O were added to the mixture, which was washed by water. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography to give a 2,3,5-trisubstituted-THF.

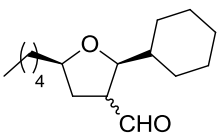
The diastereomeric ratio was determined by integration value of α-proton of aldehyde in ^1H NMR.

The relative stereochemistry between H2 and H5 was determined by NOE experiments.

The relative stereochemistry between H2 and H3 was determined by DBU-mediated isomerization.

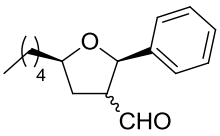


5aA and 5aB: According to the general procedure, **5aA** and **5aB** (52.2mg, 89%) were obtained as 95:5 of diastereomeric mixture from **4a** (58.7 mg, 0.181 mmol) and TfOH (8.0 μL, 0.091 mmol). Eluent: hexane/CH_2Cl_2 = 1/1; pale yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.91 (7H, m), 1.25-1.75 (29H, m), 2.16 (1H, ddd, *J* = 14.3, 7.7, 5.6 Hz), 2.87-2.94 (1H, m), 3.78-3.85 (1H, m), 3.91-3.96 (1H, m), 9.61 (2/100H, d, *J* = 3.2 Hz for minor isomer of **5aB**), 9.65 (88/100H, d, *J* = 4.1 Hz for major isomer of **5aA**), 9.67 (7/100H, d, *J* = 2.8 Hz for minor isomer of **5aA**), 9.74 (3/100H, d, *J* = 3.7 Hz for major isomer of **5aB**); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 14.1, 22.6, 22.7, 25.9, 26.7, 29.3, 29.4, 29.5, 29.6, 31.2, 31.86, 31.89, 32.3, 35.5, 53.9, 79.3, 81.4, 203.0; IR (KBr): 2926, 2855, 1722, 1466, 1261 cm^{-1}; HRMS (FAB): Calcd for $C_{21}H_{40}NaO_2$ ($M+Na^+$): 347.2926, found 347.2915.

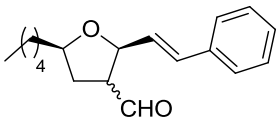


5bA and 5bB: According to the general procedure, **5bA** and **5bB** (15.5mg, 88%) were obtained as 90:10 of diastereomeric mixture from **4b** (17.7 mg, 0.070 mmol) and TfOH (3.1 μL, 0.035 mmol). Eluent: hexane/AcOEt= 4/1; pale yellow oil; ^1H NMR (400 MHz, C_6D_6) δ: 0.78-1.72 (23H, m), 2.21-2.26 (1H, m), 2.49-2.55 (1H, m), 3.23 (1H, dd, *J* = 9.6, 6.0 Hz), 3.48-3.55 (1H, m), 9.27 (3/100H, d, *J* = 3.9 Hz for minor isomer of **5bB**), 9.30 (10/100H, d, *J* = 2.8 Hz for minor isomer of **5bA**), 9.57 (80/100H, d, *J* = 4.6 Hz for major isomer of **5bA**), 9.60 (7/100H, d, *J* = 4.1 Hz for major

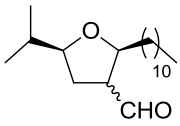
isomer of **5bB**); ^{13}C NMR (100 MHz, C_6D_6) δ: 14.2, 23.0, 25.78, 25.84, 26.4, 26.7, 29.2, 31.4, 32.2, 32.4, 36.0, 38.8, 52.8, 78.7, 86.6, 201.2; IR (KBr): 2924, 2853, 1721, 1466, 1458, 1449 cm^{-1}; HRMS (FAB): Calcd for $C_{16}H_{29}O_2$ (M^++H): 253.2168, found 253.2164.



5cA and 5cB: According to the general procedure, **5cA** and **5cB** (26.7 mg, 95%) were obtained as 96:4 of diastereomeric mixture from **4c** (28.0 mg, 0.114 mmol) and TfOH (5.0 μL, 0.057 mmol). Eluent: hexane/AcOEt= 8/1; pale yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.90-0.93 (3H, m), 1.33-1.56 (6H, m), 1.65-1.73 (1H, m), 1.80-1.90 (1H, m), 2.00 (1H, ddd, *J* = 14.2, 7.8, 5.3 Hz), 2.22 (1H, ddd, *J* = 14.2, 7.8, 5.3 Hz), 3.23-3.29 (1H, m), 3.99-4.06 (1H, m), 5.17 (1H, d, *J* = 8.2 Hz), 7.24-7.36 (5H, m), 9.07 (90/100H, d, *J* = 3.2 Hz for major isomer of **5cA**), 9.17 (3/100H, d, *J* = 2.8 Hz for major isomer of **5cB**), 9.78 (1/100H, d, *J* = 2.3 Hz for minor isomer of **5cB**), 9.81 (6/100H, d, *J* = 2.3 Hz for minor isomer of **5cA**); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 22.6, 25.9, 31.9, 32.1, 35.1, 55.5, 79.7, 81.5, 126.1, 127.9, 128.6, 137.5, 201.7; IR (KBr): 2955, 2930, 2859, 1724, 1454 cm^{-1}; HRMS (FAB): Calcd for $C_{16}H_{23}O_2$ (M^++H): 247.1698, found 247.1708.

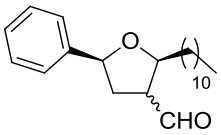


5dA and 5dB: According to the general procedure, **5dA** and **5dB** (21.1mg, 94%) were obtained as 89:11 of diastereomeric mixture from **4d** (22.4 mg, 0.078 mmol) and TfOH (3.4 μL, 0.039 mmol). Eluent: hexane/AcOEt= 8/1; pale yellow oil; ^{1}H NMR (400 MHz, CD_3CN) δ: 0.89-0.93 (3H, m), 1.31-1.92 (9H, m), 2.13-2.20 (1H, m), 3.18-3.25 (1H, m), 3.88-3.95 (1H, m), 4.69-4.73 (1H, m), 6.30 (1H, dd, *J* = 15.6, 6.8 Hz), 6.71 (1H, dd, *J* = 15.6, 0.9 Hz), 7.24-7.44 (5H, m), 9.61 (78/100H, d, *J* = 3.2 Hz for major isomer of **5dA**), 9.66 (4/100H, d, *J* = 2.3 Hz for minor isomer of **5dB**), 9.69 (7/100H, d, *J* = 2.8 Hz for major isomer of **5bB**), 9.69 (11/100H, d, *J* = 2.3Hz for minor isomer of **5dA**); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.0, 22.6, 25.9, 31.8, 32.1, 35.4, 55.5, 79.8, 80.6, 125.1, 126.6, 128.0, 128.5, 132.8, 136.1, 201.7; IR (KBr): 2957, 2932, 2861, 1722, 970 cm^{-1}; HRMS (FAB): Calcd for $C_{18}H_{25}O_2$ (M^++H): 273.1855, found 273.1804.



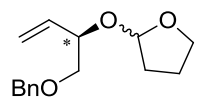
5eA and 5eB: According to the general procedure, **5eA** and **5eB** (19.0mg, 85%) were obtained as 92:8 of diastereomeric mixture from **4e** (22.4 mg, 0.076 mmol) and TfOH (3.4 μL, 0.038 mmol). Eluent: hexane/AcOEt= 30/1 to 20/1; pale yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (3H, m), 0.92 (3H, d, *J* = 6.4 Hz), 1.01 (3H, d, *J* = 6.4 Hz), 1.25-1.37 (21H, m), 1.73-1.82 (1H, m), 1.83-1.90 (1H, m), 2.04-2.11 (1H, m), 2.89-2.95 (1H, m), 3.48-3.54 (1H, m), 3.93-3.98 (1H, m), 9.60 (5/100H, d, *J* = 3.2 Hz for the major isomer of **5eB**), 9.64 (82/100H, d, *J* = 4.1 Hz for major isomer of **5eA**), 9.67 (8/100H, d, *J* = 2.7 Hz for the minor isomer of **5eA**), 9.75 (5/100H, d, *J* = 3.9 Hz for minor isomer of **5eB**); ^{13}C NMR (100 MHz,

$CDCl_3$) δ: 14.1, 18.4, 19.6, 22.7, 26.6, 29.3, 29.4, 29.52, 29.54, 29.6, 29.9, 31.3, 31.9, 33.1, 53.8, 81.1, 84.6, 202.9; IR (KBr): 2957, 2926, 2853, 1724, 1468 cm^{-1}; HRMS (FAB): Calcd for $C_{19}H_{37}O_2$ (M^++H): 297.2794, found 297.2783.

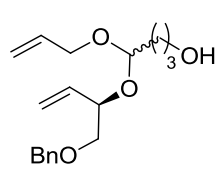


5fA and 5fB: According to the general procedure, **5fA** and **5fB** (19.2 mg, 82%) were obtained as 98:2 of diastereomeric mixture from **4e** (23.3 mg, 0.070 mmol) and TfOH (3.1 μL, 0.035 mmol). Eluent: hexane/AcOEt= 15/1 to 10/1; pale yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88 (3H, t, *J* = 6.9 Hz), 1.26-1.46 (17H, m), 1.52-1.62 (1H, m), 1.65-1.83 (1H, m), 2.18 (1H, ddd, *J* = 14.4, 7.1, 5.2 Hz), 2.49 (1H, ddd, *J* = 14.4, 7.1, 5.2 Hz), 3.06-3.12 (1H, m), 4.14-4.20 (1H, m), 4.87 (1H, dd, *J* = 8.9, 7.1 Hz), 7.26-7.40 (5H, m), 9.73 (88/100H, d, *J* = 4.1 Hz for major isomer of **5fA**), 9.76 (10/100H, d, *J* = 2.3 Hz for minor isomer of **5fA**) 9.85 (2/100H, d, *J* = 3.2Hz for **5fB**); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.1, 22.7, 26.8, 29.3, 29.46, 29.55, 29.58, 29.62, 29.64, 31.4, 31.9, 35.1, 54.3, 80.6, 81.8, 126.0, 127.7, 128.5, 141.3, 202.3; IR (KBr): 2924, 2853, 1724, 1493, 1456 cm^{-1}; HRMS (FAB): Calcd for $C_{22}H_{35}O_2$ (M^++H): 331.2637, found 331.2660.

Experiments in Scheme 5

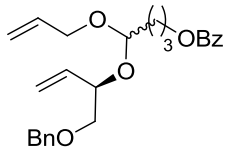


7: PPTS (108.7 mg, 0.433 mmol) was added to a solution of (*R*)-1-(benzyloxy)but-3-en-2-ol[4] (773.7 mg, 4.34 mmol) and 2,3-dihydrofuran (0.59 mL, 7.81 mmol) in CH_2Cl_2 (11 mL) at room temperature under N_2. The mixture was stirred at the same temperature for 10 min. The mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/AcOEt = 4/1) to give **7** (1.05 g, 97%) as 1:1 of diastereomeric mixture; colorless oil; ^{1}H NMR (400 MHz, C_6D_6) δ: 1.35-1.45 (1H, m), 1.53-1.65 (1H, m), 1.71-1.93 (2H, m), 3.36-3.49 (3/2H, m), 3.58-3.71 (3/2H, m), 3.80-3.91 (1H, m), 4.33 (1H, s), 4.40 (1H, s), 4.50-4.57 (1H, m), 5.07-5.13 (1H, m), 5.26-5.31 (1H, m), 5.38 (1/2H, dt, *J* = 17.4, 1.8 Hz), 5.53 (1/2H, d, *J* = 4.1 Hz), 5.74-5.94 (1H, m), 7.07-7.19 (3H, m), 7.26-7.32 (2H, m). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 23.21, 23.24, 32.0, 32.4, 66.5, 66.8, 72.7, 72.8, 73.0, 75.2, 75.9, 100.7, 103.5, 115.6, 117.9, 127.27, 127.33, 128.1, 128.2, 135.4, 136.6, 138.1, 138.3; IR (KBr): 2930, 2359, 2340, 1454, 1186 cm^{-1}; HRMS (FAB): Calcd for $C_{15}H_{21}O_3$ (M^++H): 249.1491, found 249.1479.

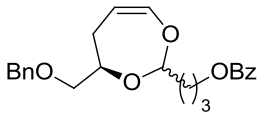


8: According to the literature[5], TESOTf (0.63 mL, 2.800 mmol) and 2,4,6-collidine (0.55 mL, 4.200 mmol) were added to a solution of **7** (347.7 mg, 1.400 mmol) in CH_2Cl_2 (14 mL) at 0 °C under N_2. After 0.5 h stirring

at the same temperature, allylalcohol (0.48 ml, 7.00 mmol) was added to the mixture which was then stirred at the same temperature for 2 h. The mixture was quenched with saturated aqueous $NaHCO_3$ and extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. MeOH (30 mL) was added to the residue then K_2CO_3 (971.0 mg, 7.02 mmol) was added to a solution. The mixture was stirred at the same temperature for 1 h. K_2CO_3 (963.0 mg, 6.97 mmol) was added to a solution again and stirred for another 1 h. The mixture was quenched with saturated aqueous NH_4Cl and extracted with AcOEt. The organic layer was dried over Na_2SO_4, filtered, and evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/AcOEt = 2/1) to give **8** (368.6 mg, 86% over 2 steps) as 1:1 of diastereomeric mixture; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.61-1.87 (5H, m), 3.45-3.67 (4H, m), 3.94-4.16 (2H, m), 4.22-4.34 (1H, m), 4.55-4.57 (2H, m), 4.67 (1/2H, t, *J* = 5.3 Hz), 4.76 (1/2H, t, *J* = 5.0 Hz), 5.12-5.35 (4H, m), 5.71-5.96 (2H, m), 7.26-7.37 (5H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 27.4, 27.5, 30.3, 30.7, 62.29, 62.32, 65.1, 66.5, 72.7, 73.1, 73.2, 73.3, 76.3, 76.7, 100.3, 102.5, 116.5, 116.6, 116.8, 117.0, 118.5, 127.4, 127.5, 127.6, 128.18, 128.24, 134.4, 134.6, 135.5, 136.1, 137.9, 138.0; IR (KBr): 3406, 3383, 2864, 1454, 1117 cm^{-1}; HRMS (FAB): Calcd for $C_{18}H_{27}O_4$ (M^++H): 307.1909, found 307.1907.

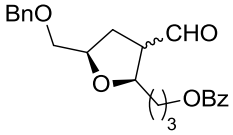


9: *i*Pr$_2$NEt (0.3 mL, 1.775 mmol), benzoyl chloride (0.1 mL, 0.887 mmol) and DMAP (11.2 mg, 0.092 mmol) were successively added to a solution of **8** (151.2 mg, 0.493 mmol) in CH_2Cl_2 (1.6 mL) at room temperature under N_2. The mixture was stirred at the same temperature for 3.5 h. The mixture was evaporated in vacuo. The residue was purified by flash SiO_2 column chromatography (hexane/benzene = 1/10 to hexane/AcOEt = 5/1) to give **9** (201.3 mg, quant.) as 1:1 of diastereomeric mixture; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.77-1.87 (4H, m), 3.45-3.61 (2H, m), 3.95-4.16 (2H, m), 4.24-4.36 (3H, m), 4.54 (1H, d, *J* = 1.8 Hz), 4.57 (1H, d, *J* = 1.8 Hz), 4.70 (1/2H, t, *J* = 5.3 Hz), 4.78 (1/2H, t, *J* = 5.3 Hz), 5.12-5.35 (4H, m), 5.71-5.96 (2H, m), 7.26-7.58 (8H, m), 8.03 (2H, d, *J* = 8.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 23.9, 30.3, 30.7, 64.5, 64.6, 64.9, 66.3, 72.7, 73.1, 73.2, 73.4, 76.4, 76.5, 99.9, 102.2, 116.4, 116.5, 116.8, 118.4, 127.37, 127.42, 127.44, 128.1, 128.2, 129.4, 130.18, 130.22, 132.66, 132.68, 134.5, 134.7, 135.6, 136.1, 137.9, 138.1, 166.3; IR (KBr): 2860, 1717, 1452, 1275, 1113 cm^{-1}; HRMS (FAB): Calcd for $C_{25}H_{30}O_5Na$ (M^++Na): 433.1991, found 433.1993.



10: According to the general procedure A, **10** (21.7 mg, 57%) was obtained as 1:1 (= *cis* : *trans*) of diastereomeric mixture from **9** (41.1 mg, 0.100 mmol), Grubbs' 2nd cat. (3.5 mg, 0.0041 mmol), $RuClH(CO)(PPh_3)_3$ (4.6 mg, 0.0097 mmol). Eluent: hexane/AcOEt= 10/1 to 8/1; pale yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.80-1.97 (4H, m), 2.15 (1/2H, ddd, *J* = 17.4, 8.0, 3.0 Hz), 2.21-2.31 (1H, m), 2.70-2.78 (1/2H, m), 3.44-3.63 (5/2H, m), 4.32-4.36 (2H, m), 4.48-4.63

(3H, m), 4.71 (1/2H, td, *J* = 7.4, 2.1 Hz), 4.79 (1/2H, td, *J* = 7.2, 3.4 Hz), 5.61 (1/2H, t, *J* = 5.0 Hz), 6.24 (1/2H, dd, *J* = 6.9, 2.3 Hz), 6.34 (1/2H, dd, *J* = 7.1, 2.5 Hz), 7.26-7.35 (5H, m), 7.41-7.45 (2H, m), 7.52-7.57 (1H, m), 8.03-8.05 (2H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 23.7, 23.9, 27.5, 31.7, 32.1, 32.2, 64.65, 64.67, 72.67, 72.75, 73.3, 73.4, 77.1, 79.1, 99.9, 103.6, 105.4, 105.9, 127.57, 127.60, 127.61, 128.28, 128.34, 129.5, 130.4, 132.8, 138.1, 145.7, 145.8, 146.3, 146.4, 166.5; IR (KBr): 2928, 1717, 1651, 1275, 1115 cm^{-1}; HRMS (FAB): Calcd for $C_{23}H_{27}O_5$ (M^++H): 383.1858, found 383.1832.

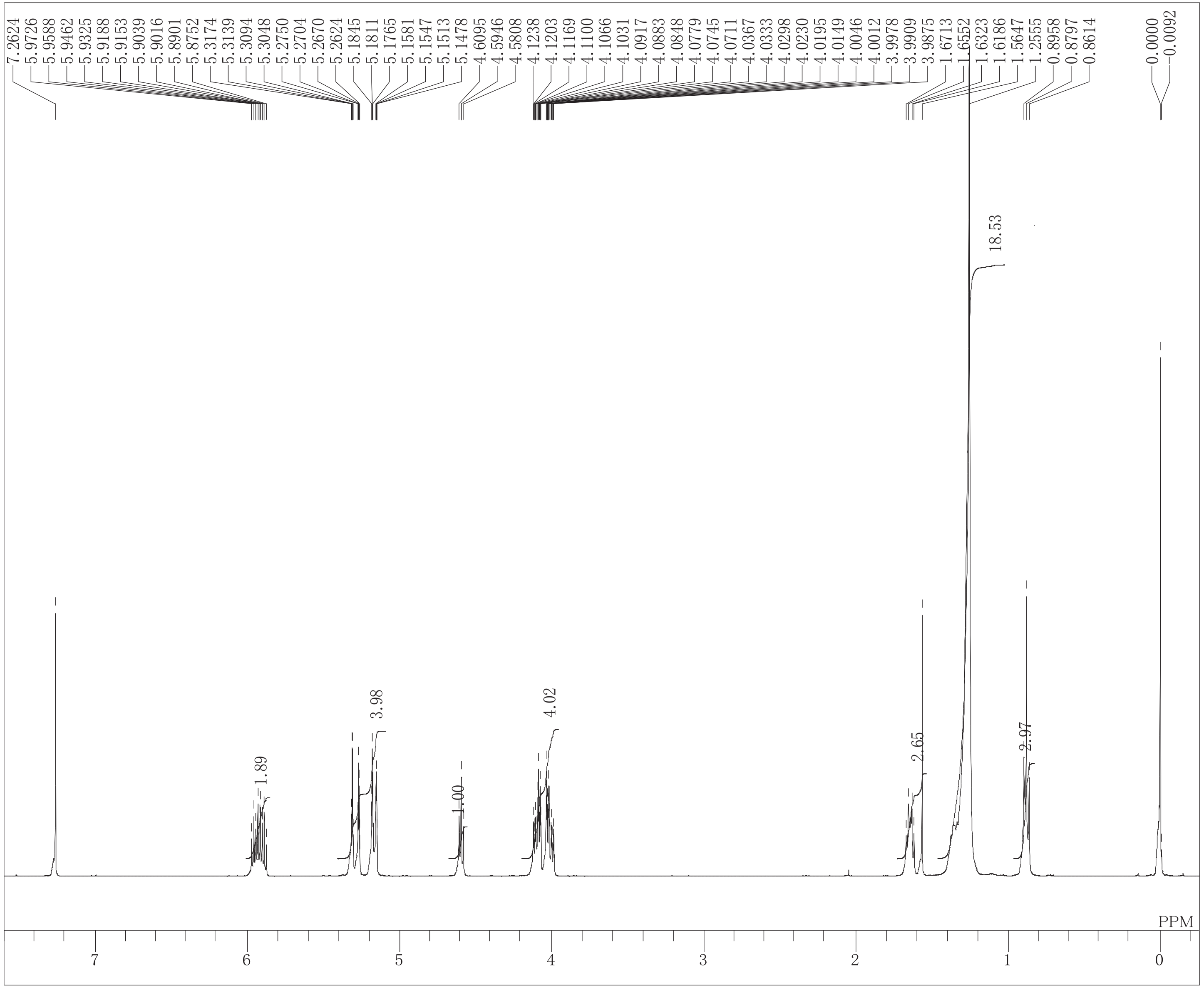


11: According to the general procedure for Preparation of 2,3,5-trisubstituted-THF, **11** (16.0 mg, 55%) was obtained as 30 : 1 of diastereomeric mixture from **10** (29.2 mg, 0.076 mmol) and TfOH (3.4 μl, 0.038 mmol). Eluent: hexane/AcOEt= 2/1; pale yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.78-2.19 (6H, m), 2.93-2.99 (1H, m), 3.51-3.64 (2H, m), 4.06-4.18 (2H, m), 4.28-4.40 (2H, m), 4.56-4.63 (2H, m), 7.26-7.35 (5H, m), 7.44 (2H, t like, *J* = 7.3 Hz), 7.56 (1H, t like, *J* = 7.3 Hz), 8.01-8.03 (2H, m), 9.70 (97/100H, d, *J* = 3.7 Hz for *cis*-isomer of **11**) 9.77 (3/100H, d, *J* = 3.6 Hz for *trans*-isomer of **11**); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 26.0, 27.8, 28.8, 53.4, 64.4, 71.9, 73.4, 78.0, 81.2, 127.66, 127.71, 128.3, 128.4, 129.5, 130.2, 132.9, 138.0, 166.5, 202.5; IR (KBr): 2860, 1719, 1275, 1113 cm^{-1}; HRMS (FAB): Calcd for $C_{23}H_{27}O_5$ (M^++H): 383.1858, found 383.1842.

References

1) H. O. House, J. Lubinkowski, J. J. Good, *J. Org. Chem.*, 1975, **40**, 86.
2) D. M. Hodgson, M. J. Fleming, S. J. Stanway, *J. Org. Chem.*, 2007, **72**, 4763.
3) R. W. Bates, D. Diezmartin, W. J. Kerr, J. G. Knight, S. V. Ley, A. Sakellaridis, *Tetrahedron*, 1990, **46**, 4063.
4) A. K. Ghosh, S. Leshchenko, M. Noetzel, *J. Org. Chem.*, 2004, **69**, 7822.
5) H. Fujioka, T. Okitsu, T. Ohnaka, Y. Sawama, O. Kubo, K. Okamoto, Y. Kita, *Adv. Synth. Cat.*, 2007, **349**, 636.

^{1}H NMR of **1a**



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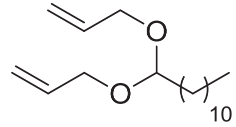
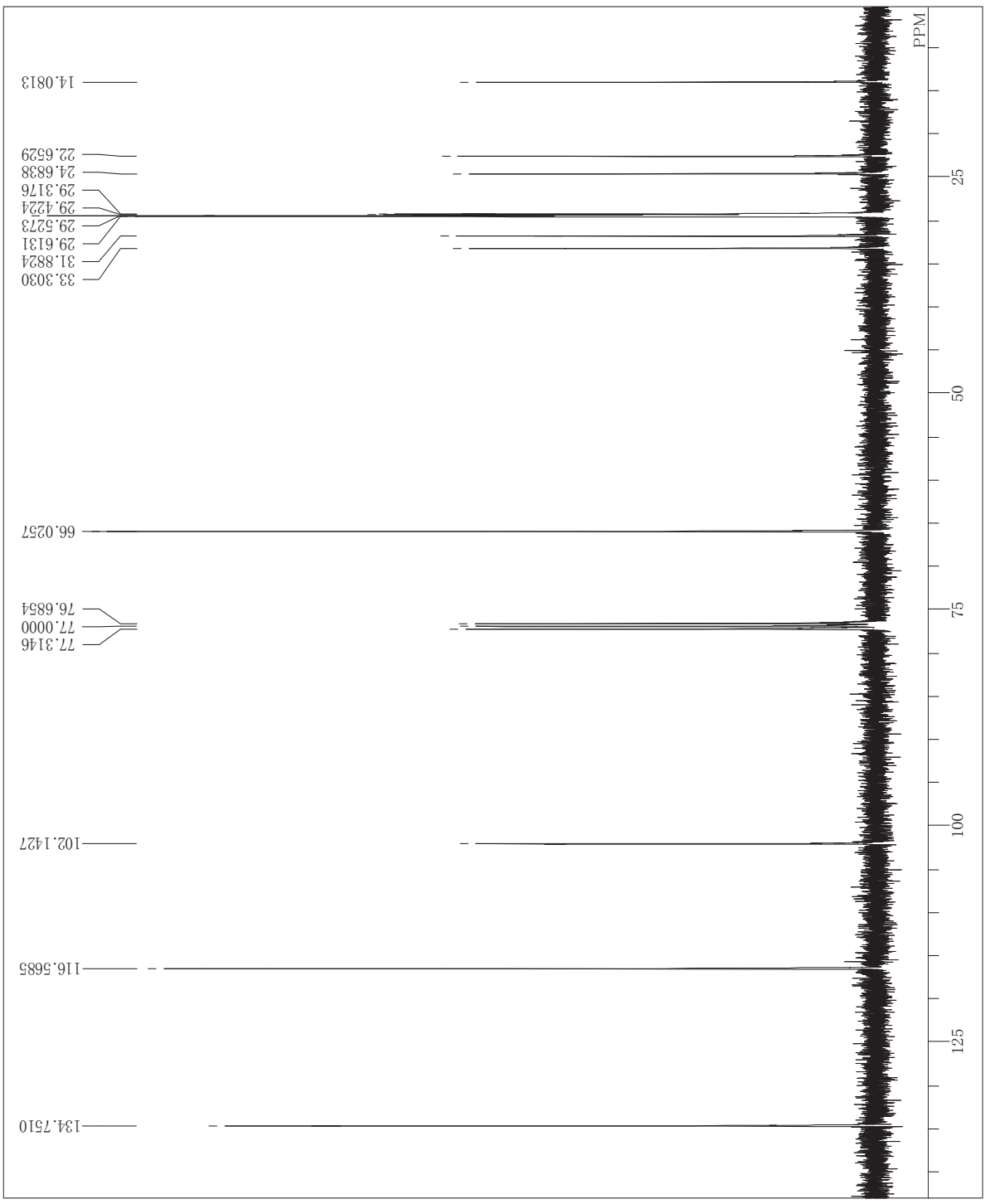
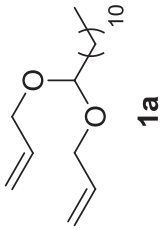


1a

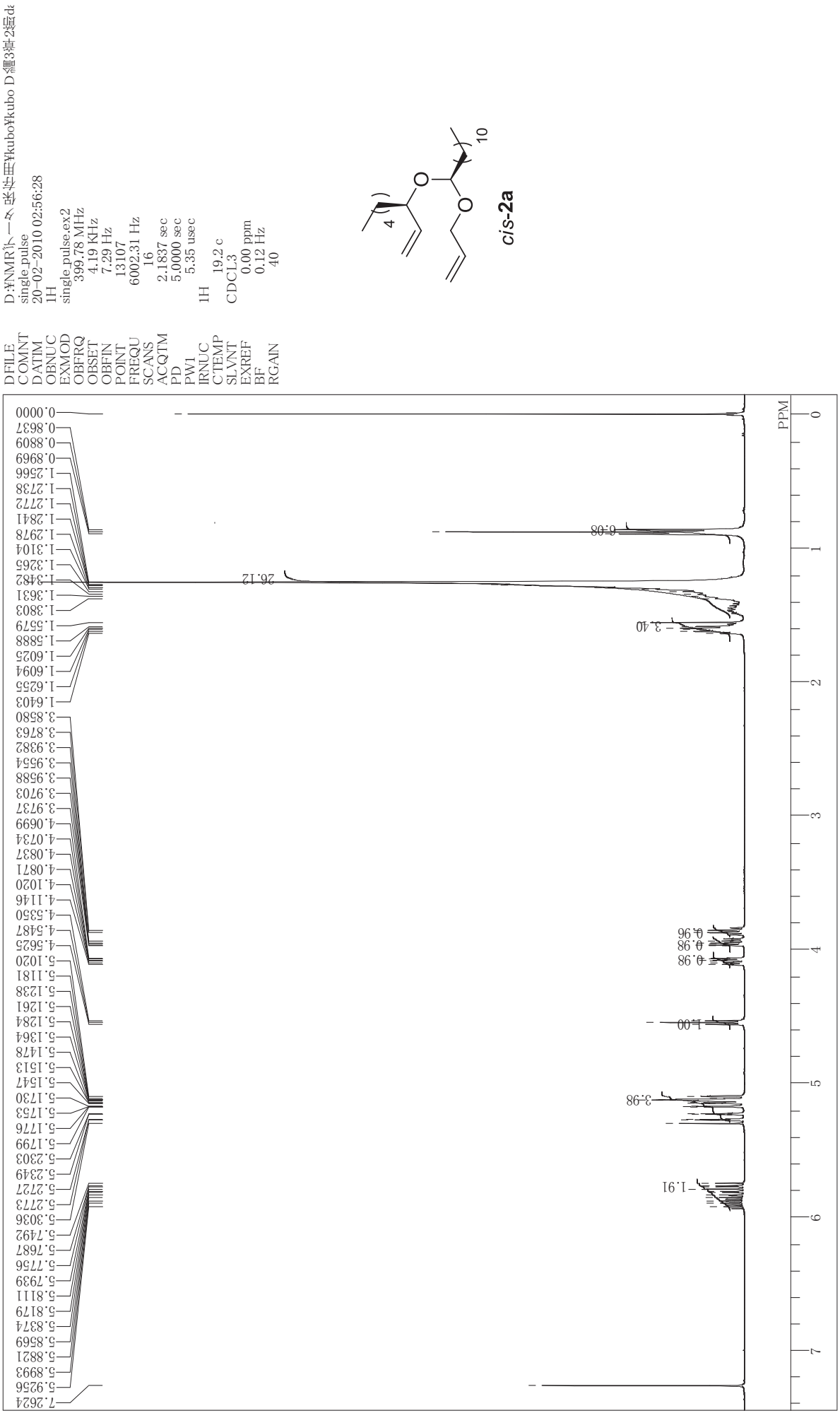
^{13}C NMR of **1a**



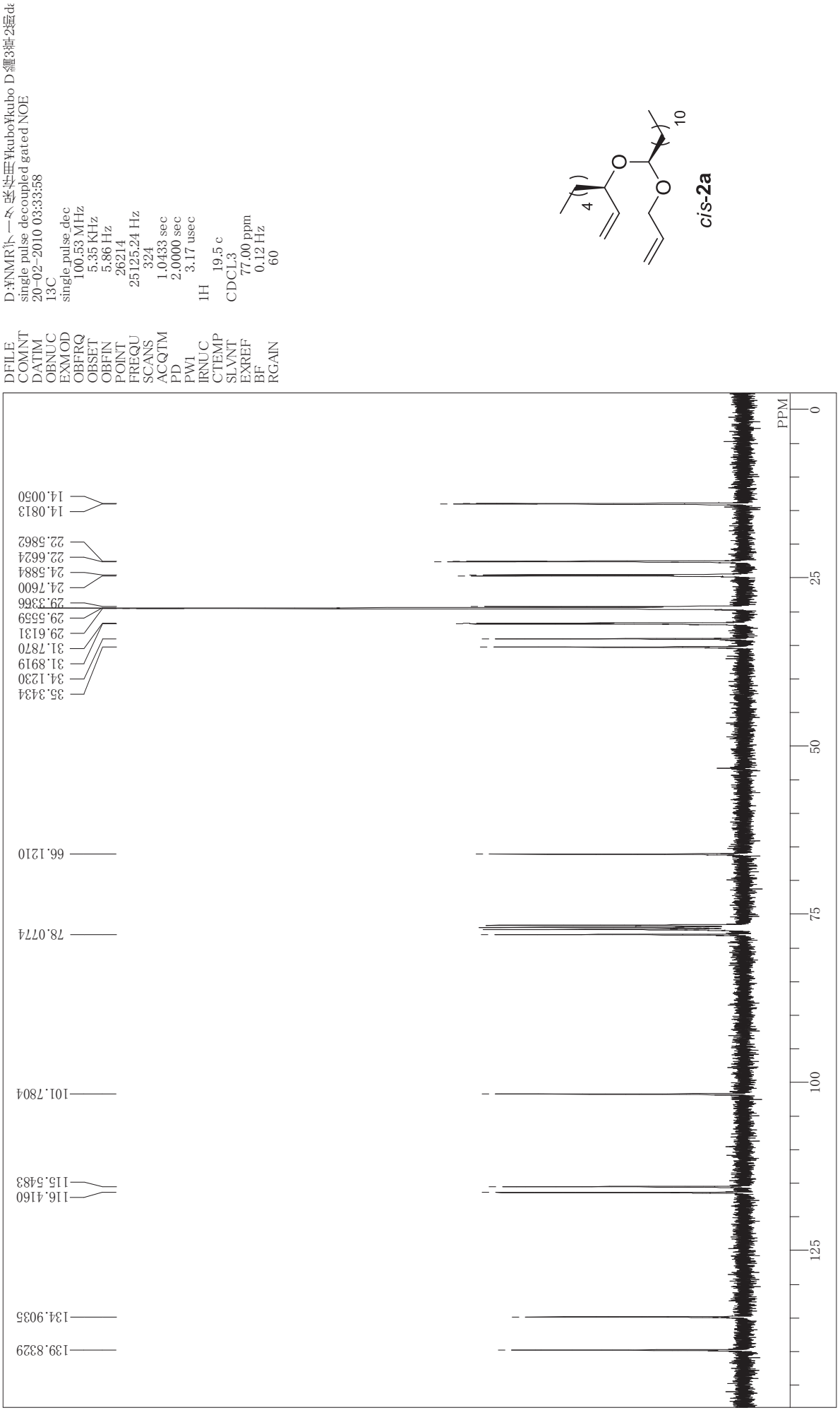


1a

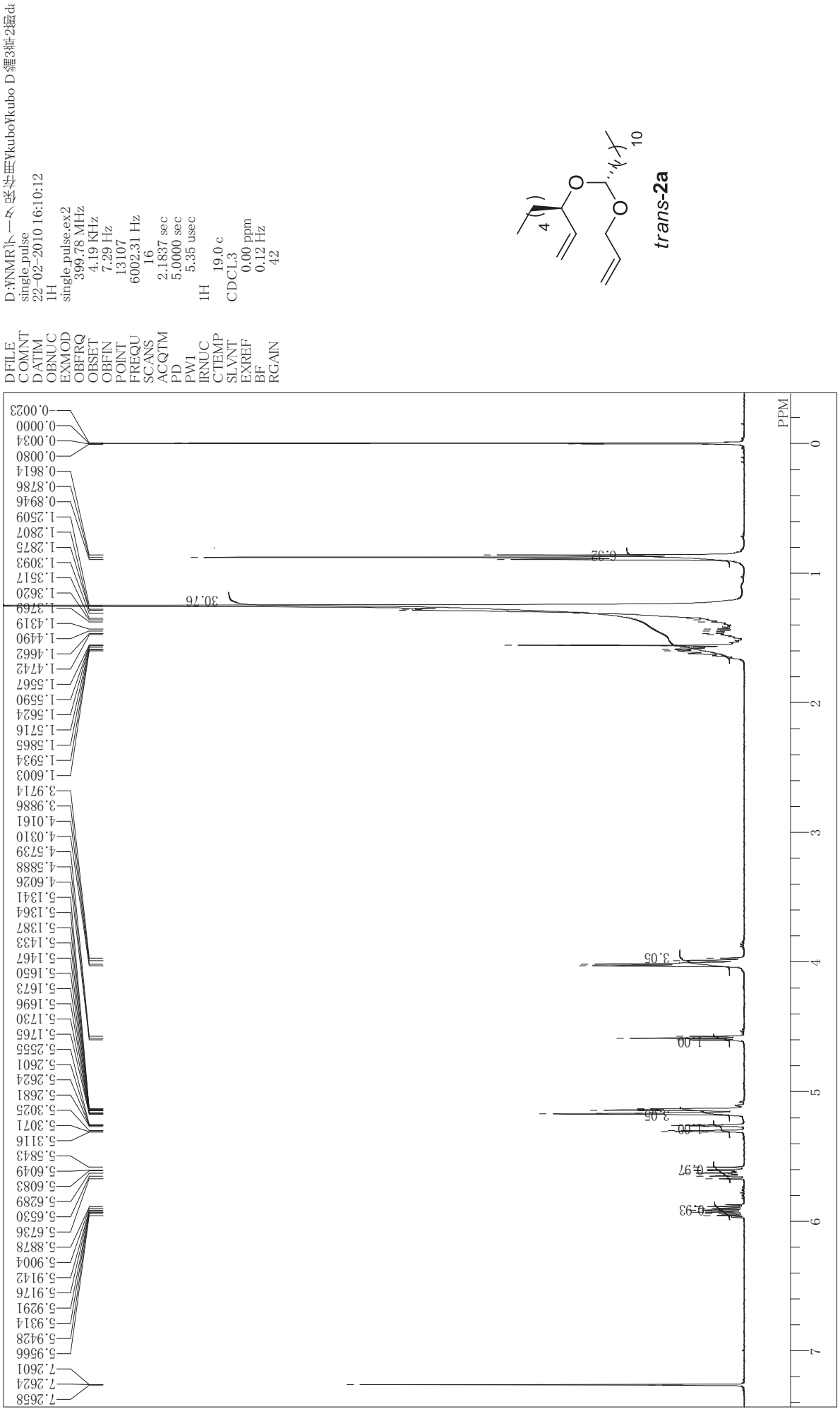
^{1}H NMR of *cis*-**2a**



^{13}C NMR of *cis*-**2a**



^{1}H NMR of *trans*-**2a**



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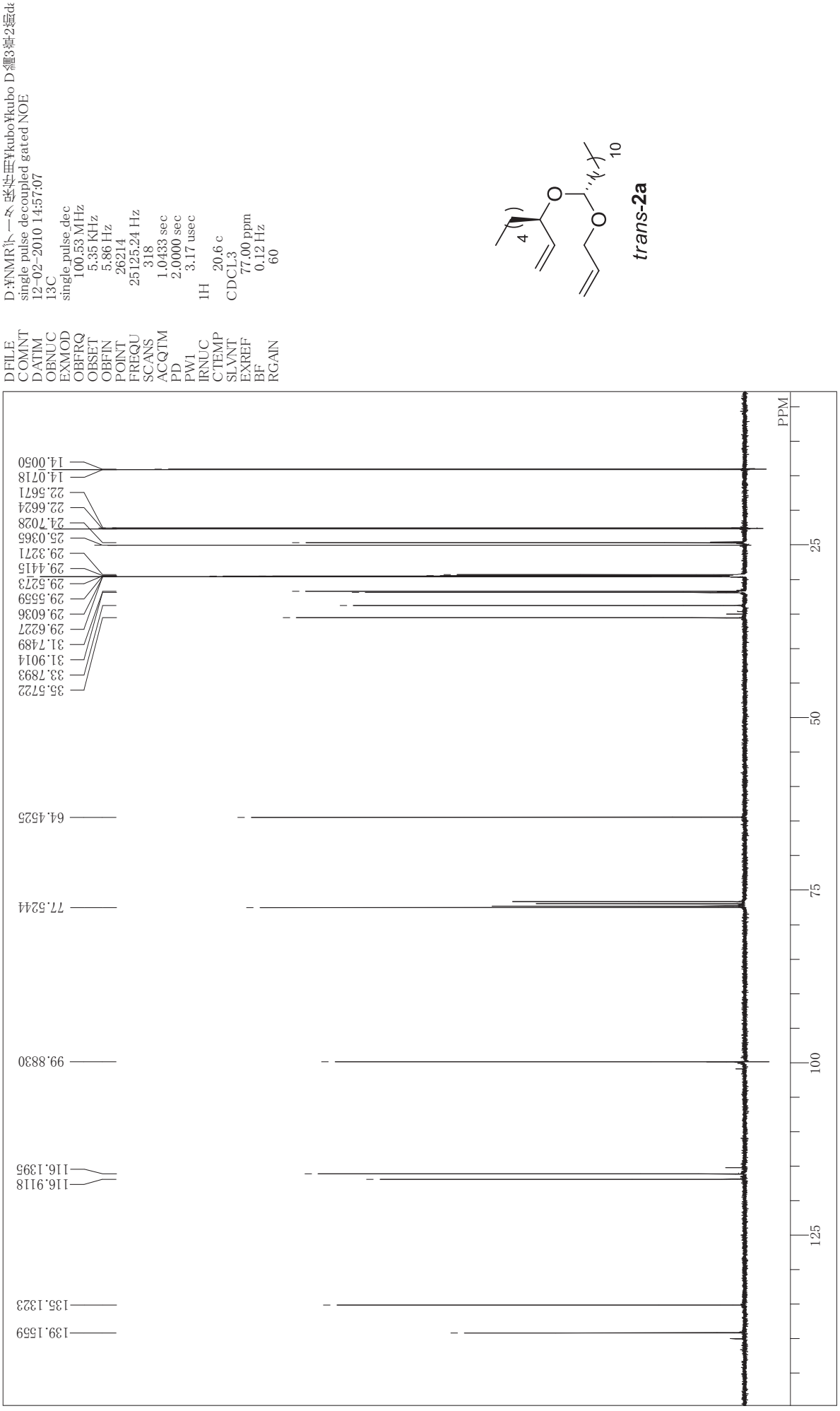
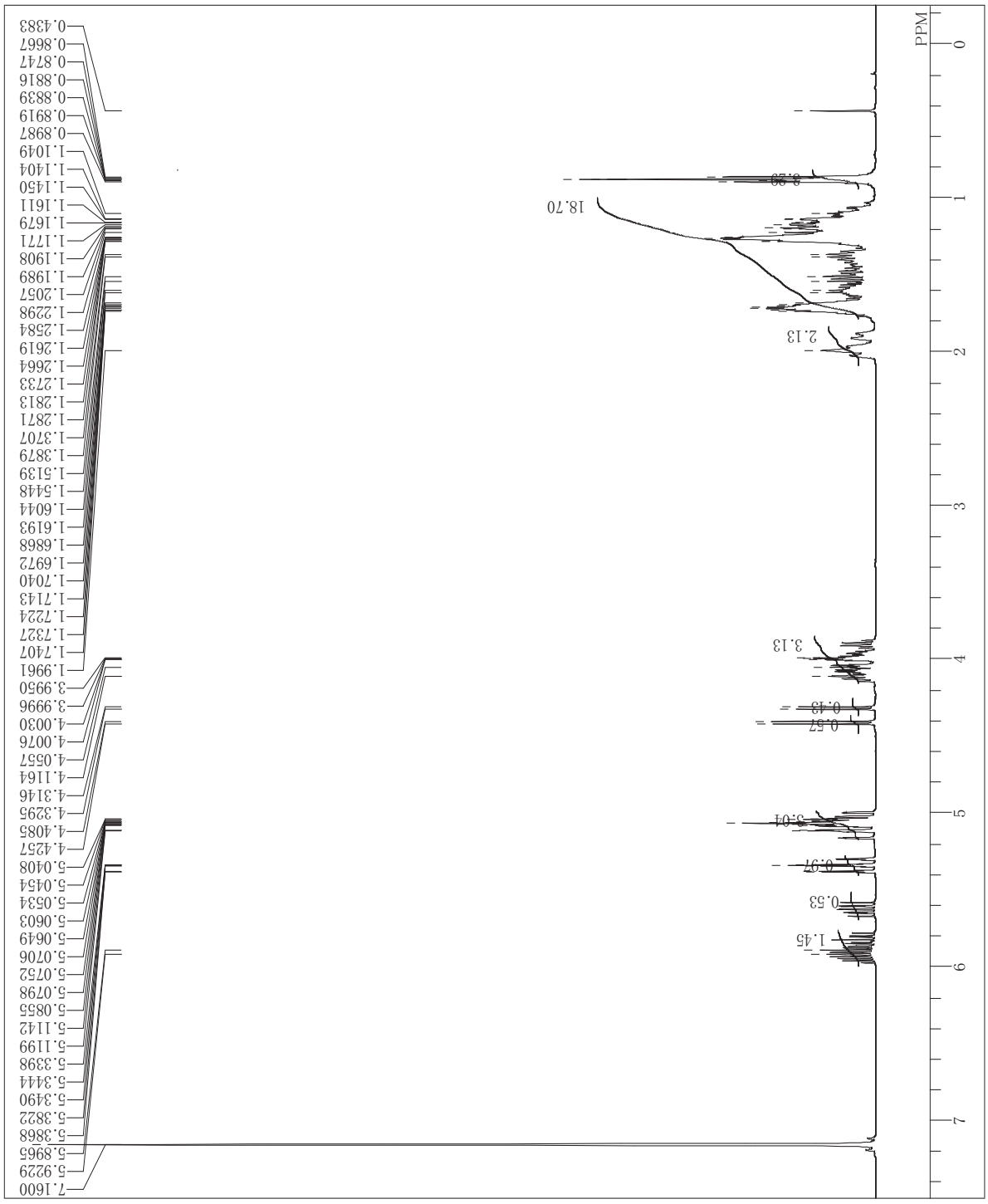
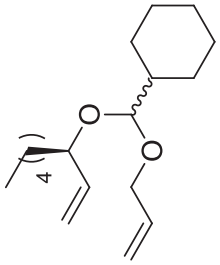


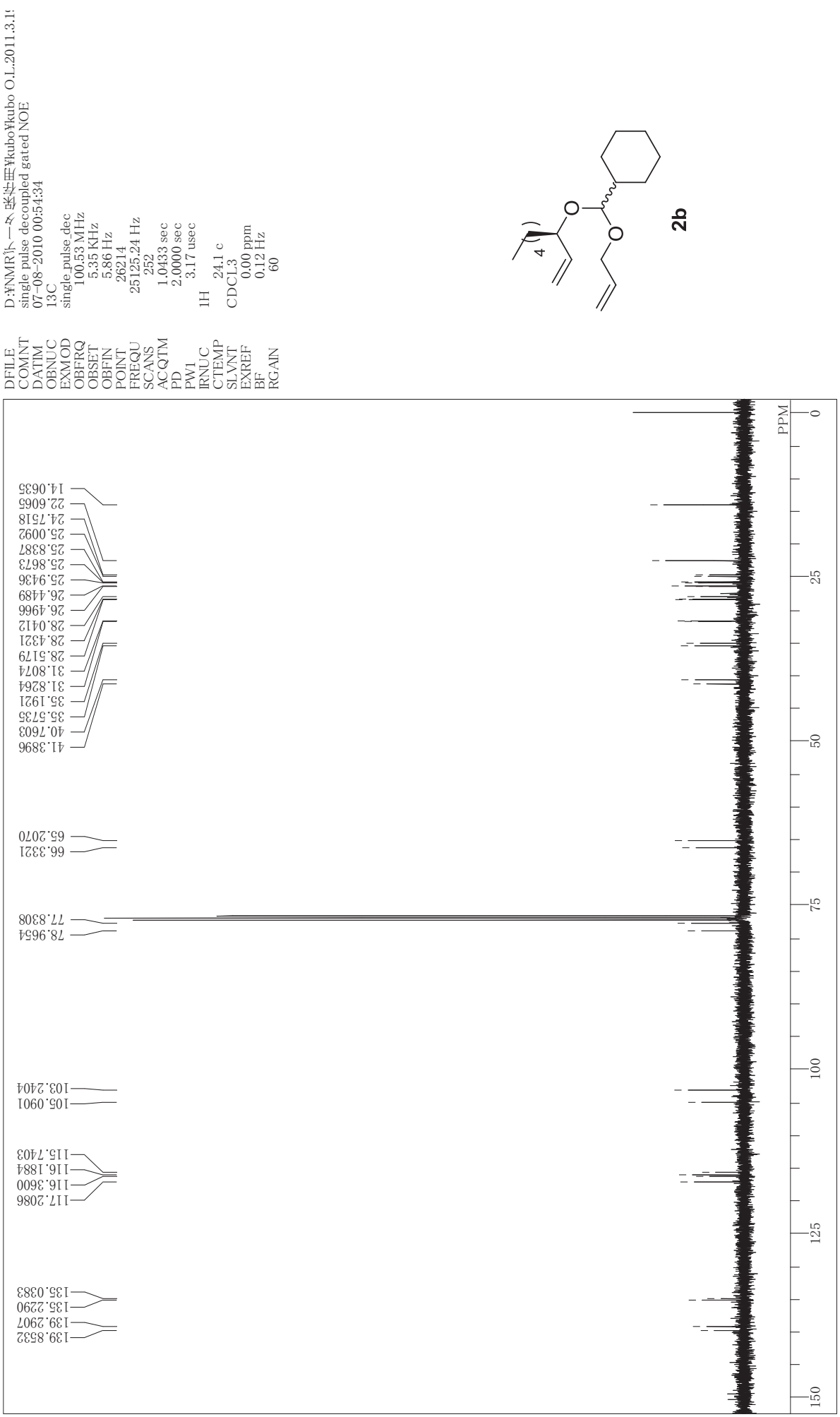
^{1}H NMR of **2b**





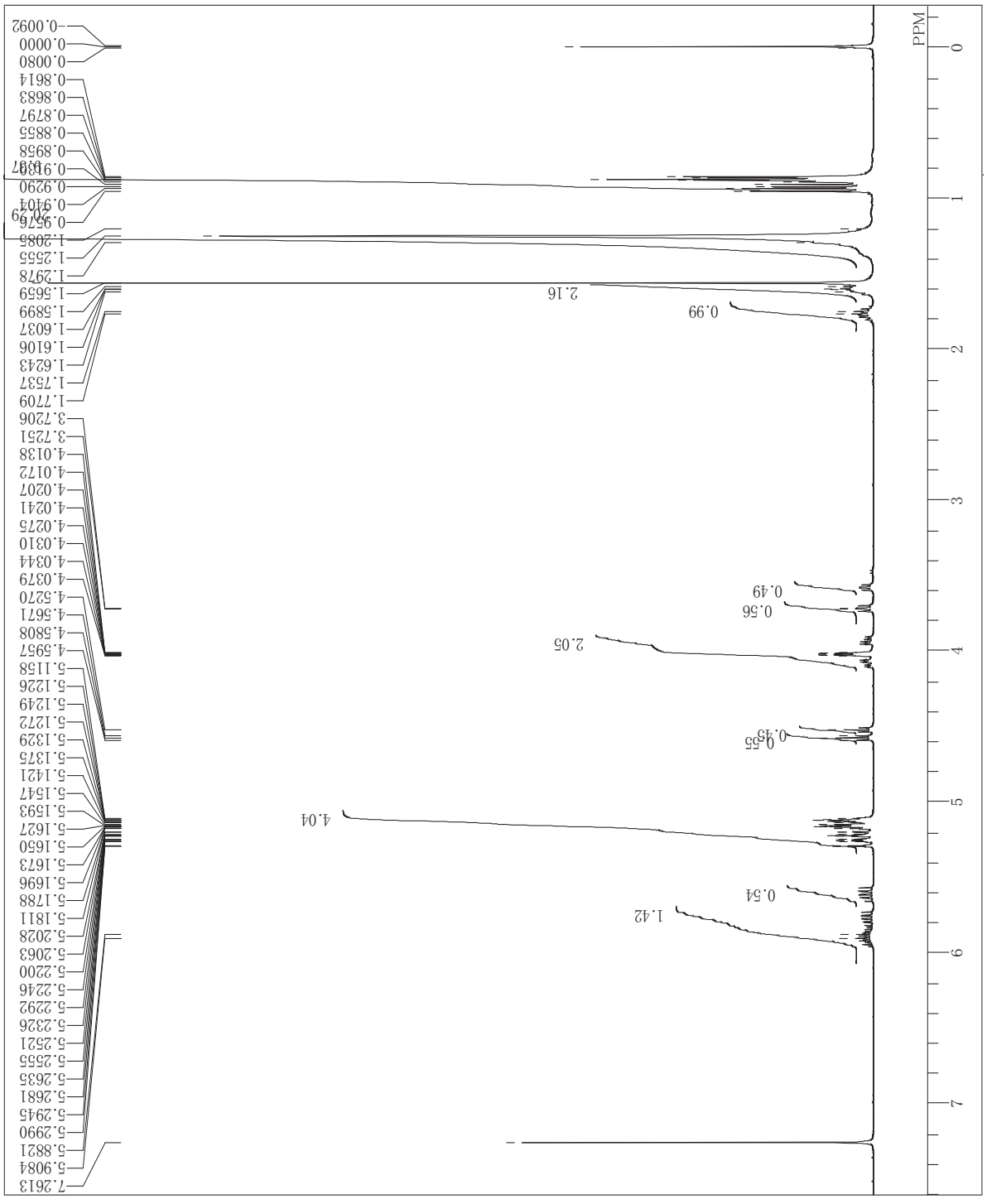
2b

^{13}C NMR of **2b**



2b

^{1}H NMR of **2c**



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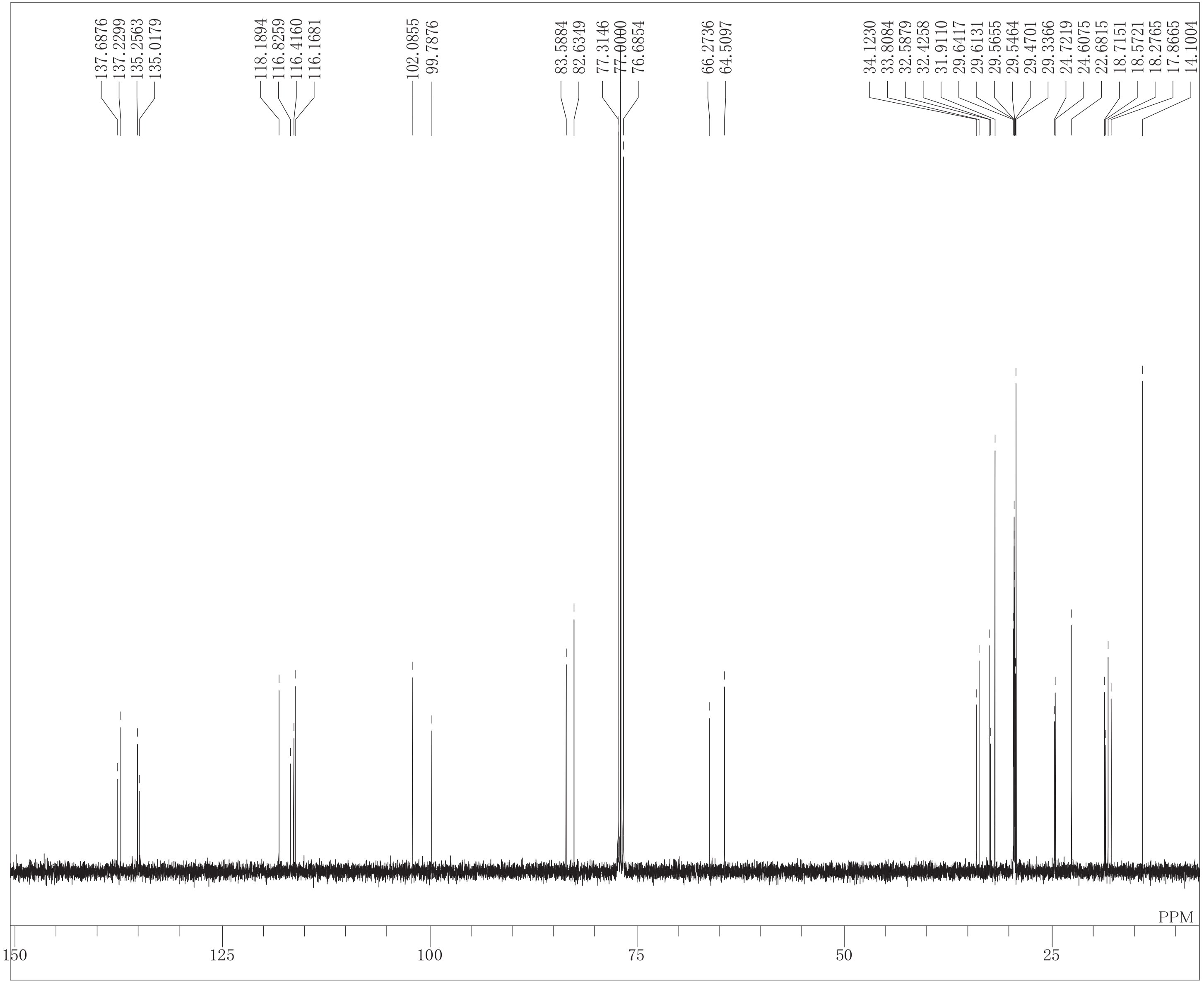

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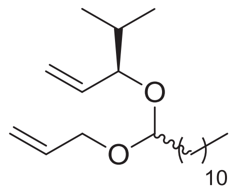
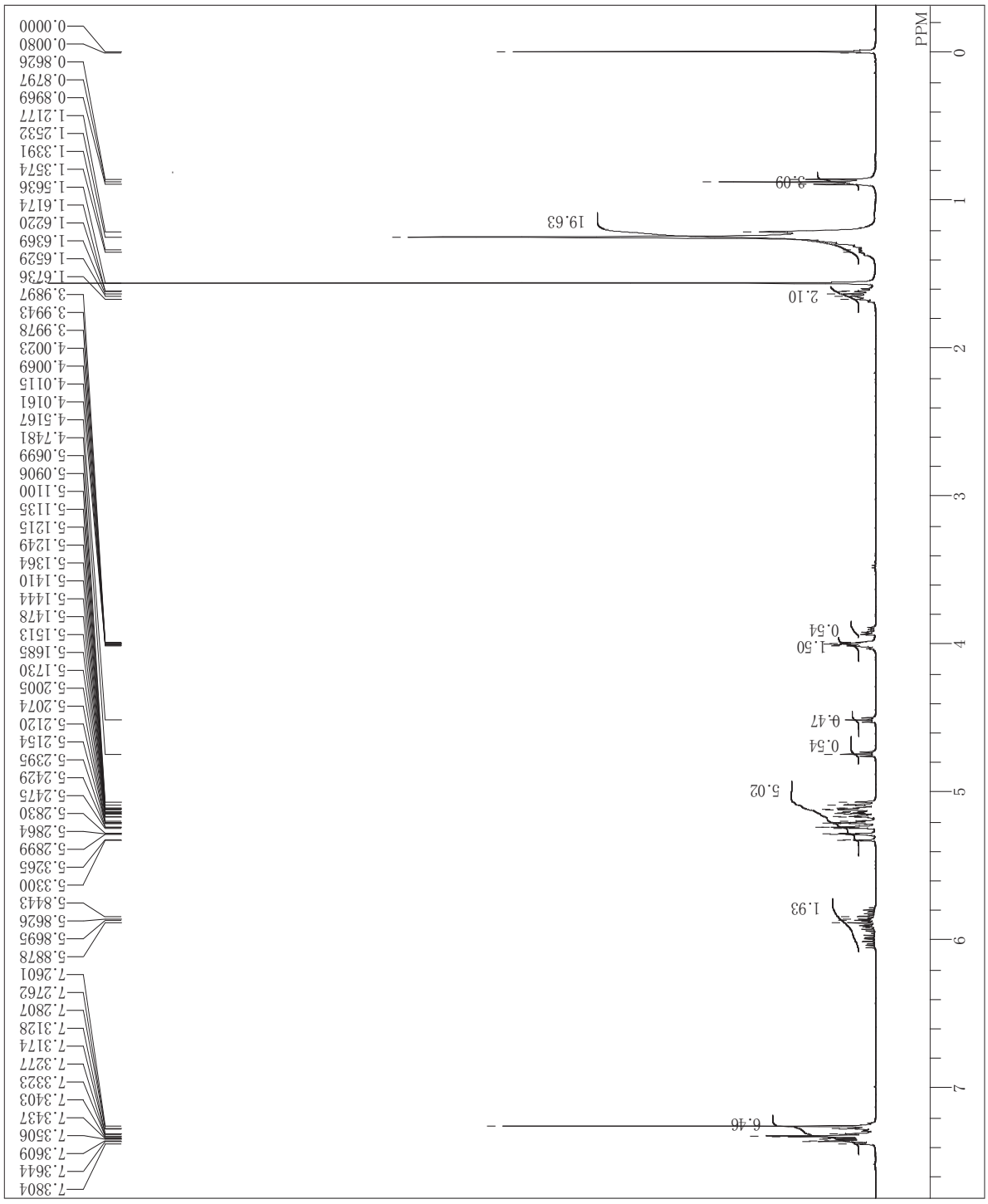


2c

^{1}H NMR of **2d**



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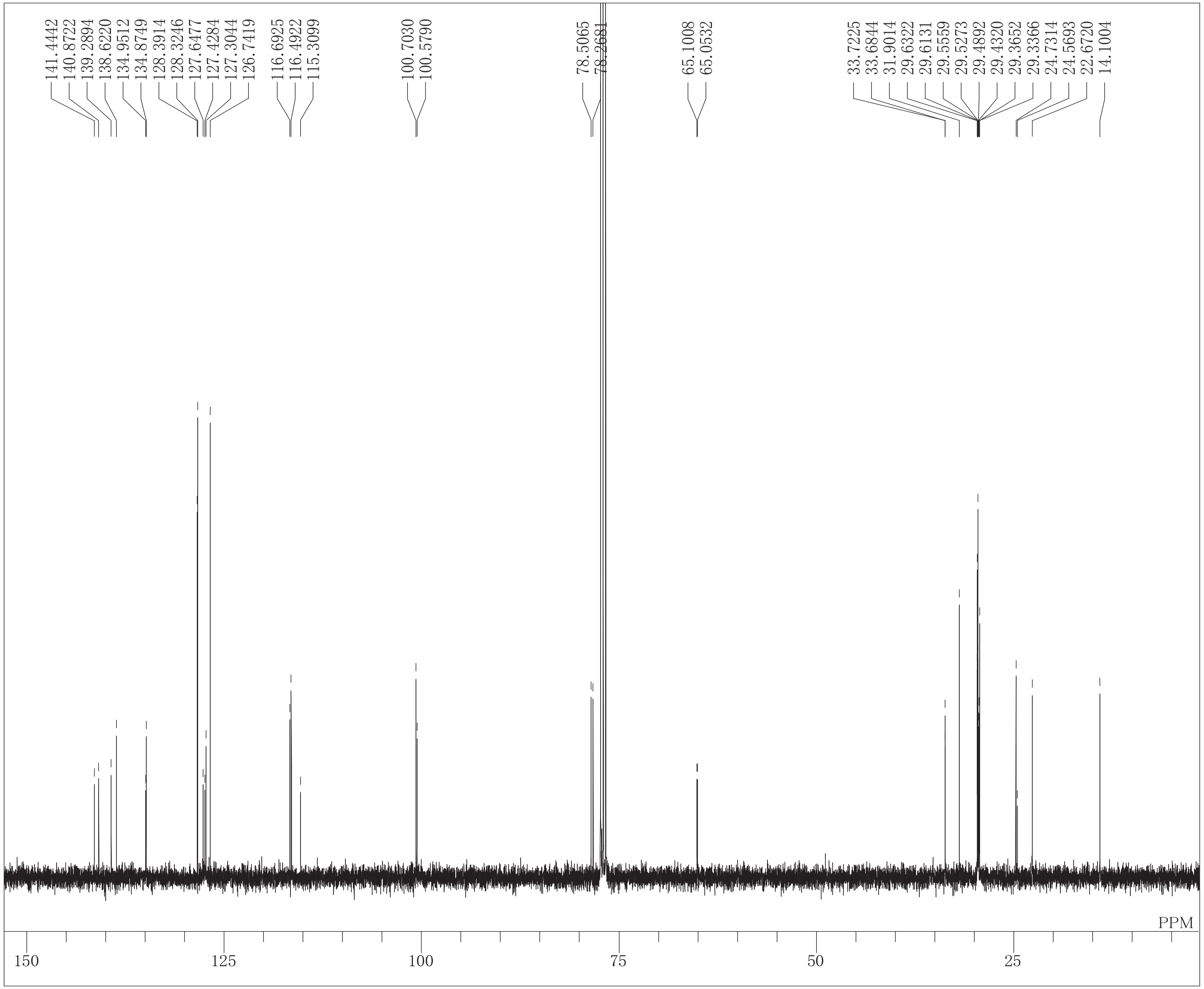

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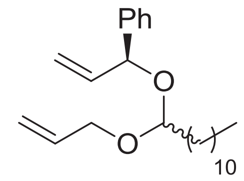
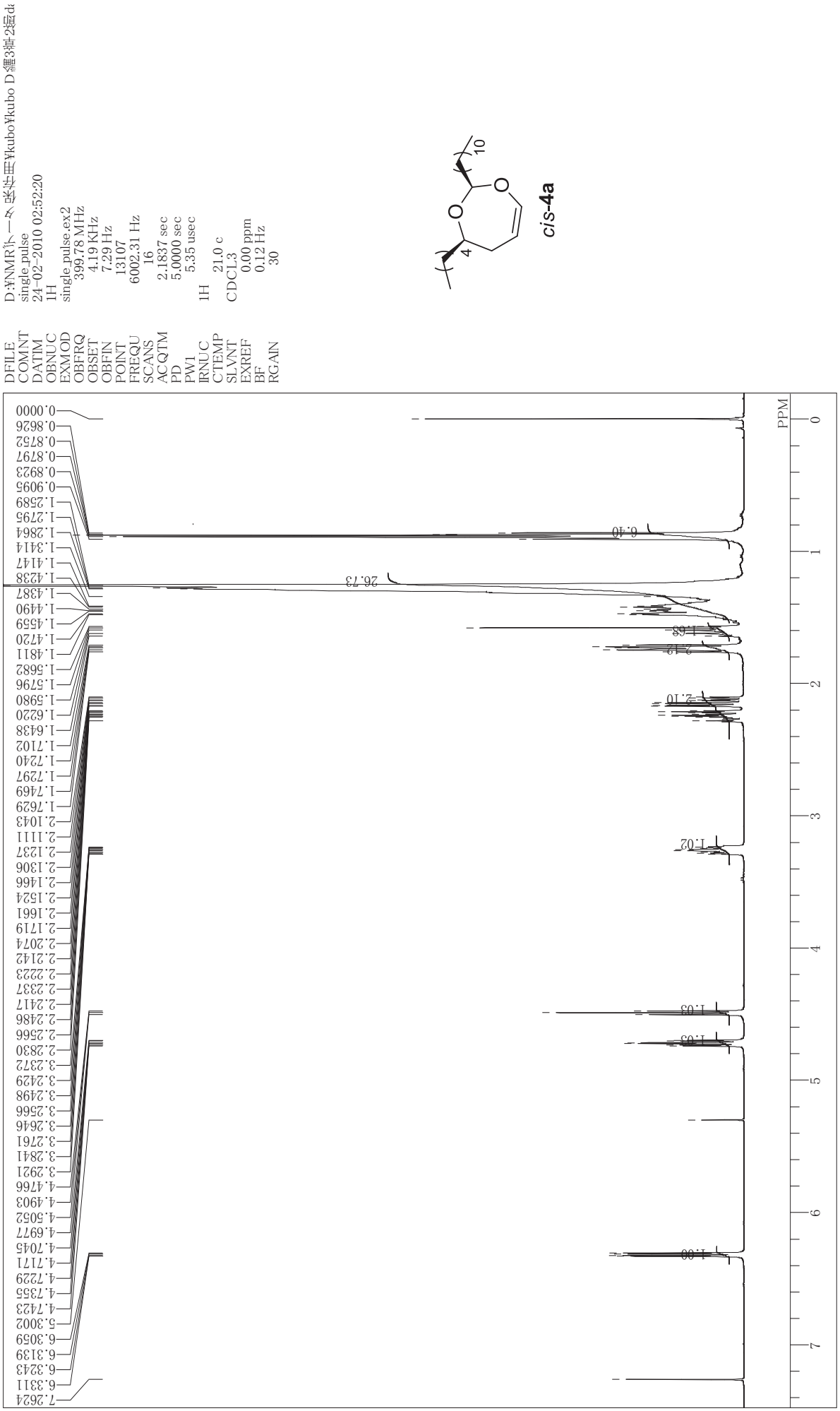
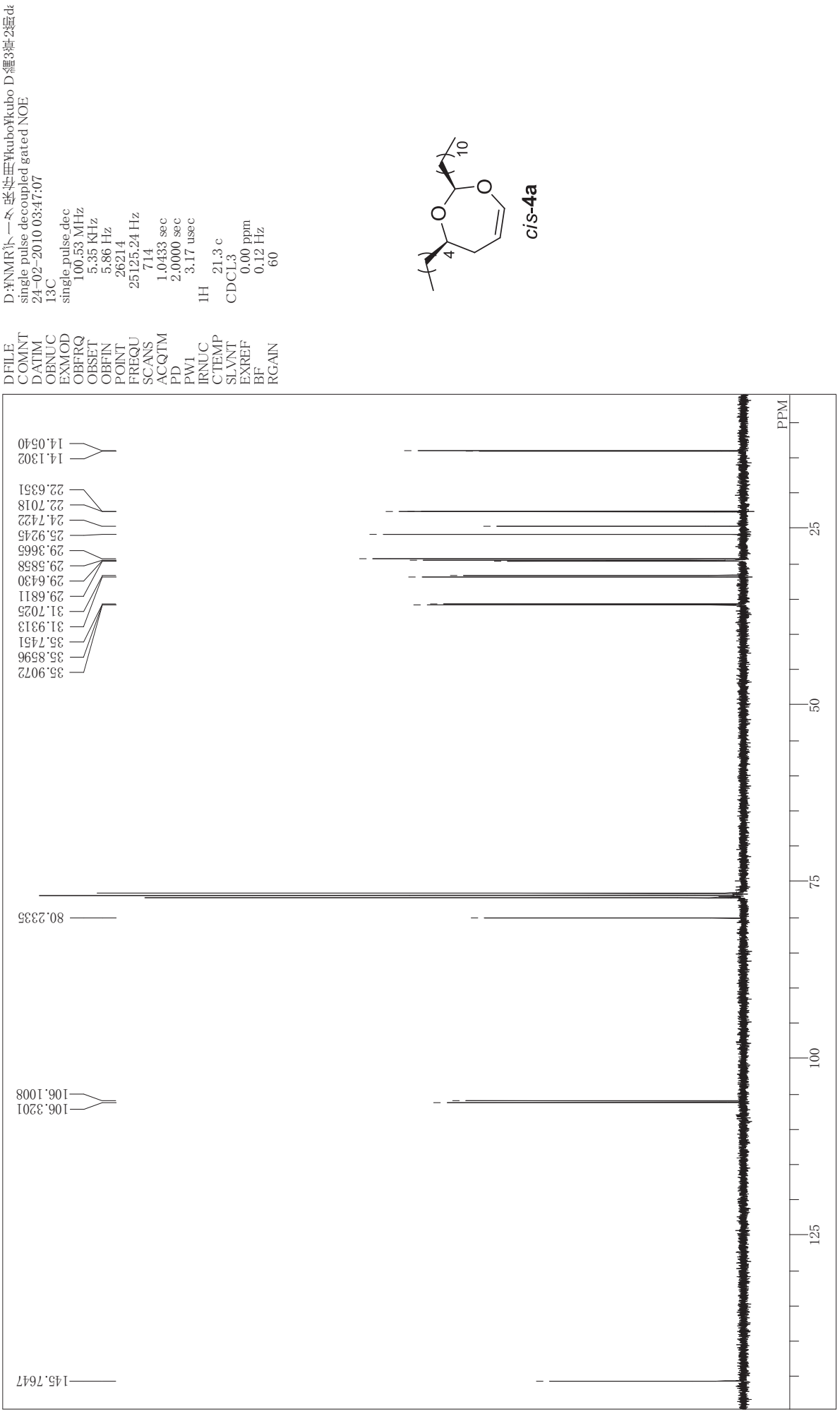


2d

^{1}H NMR of cis-**4a**

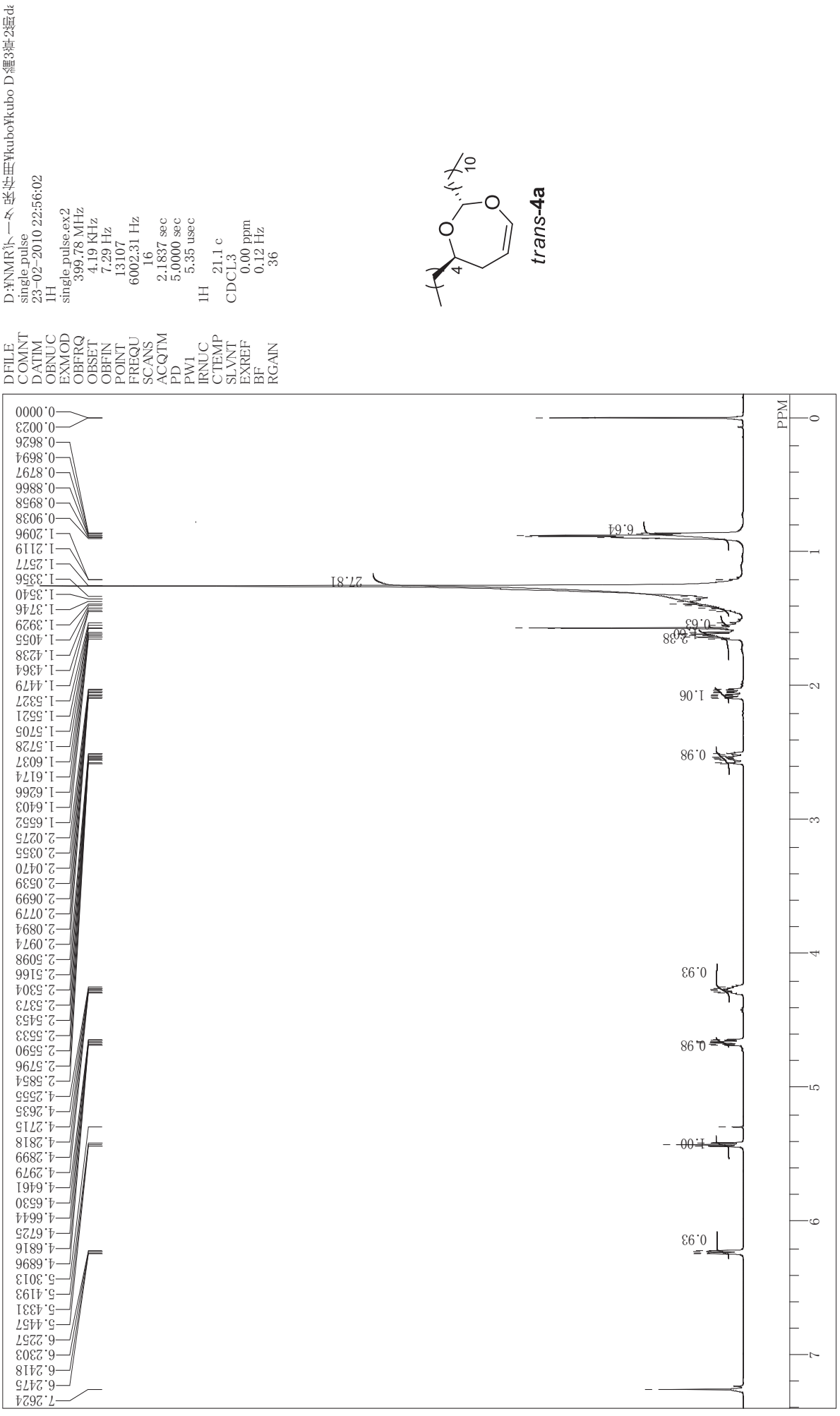


^{13}C NMR of *cis*-**4a**



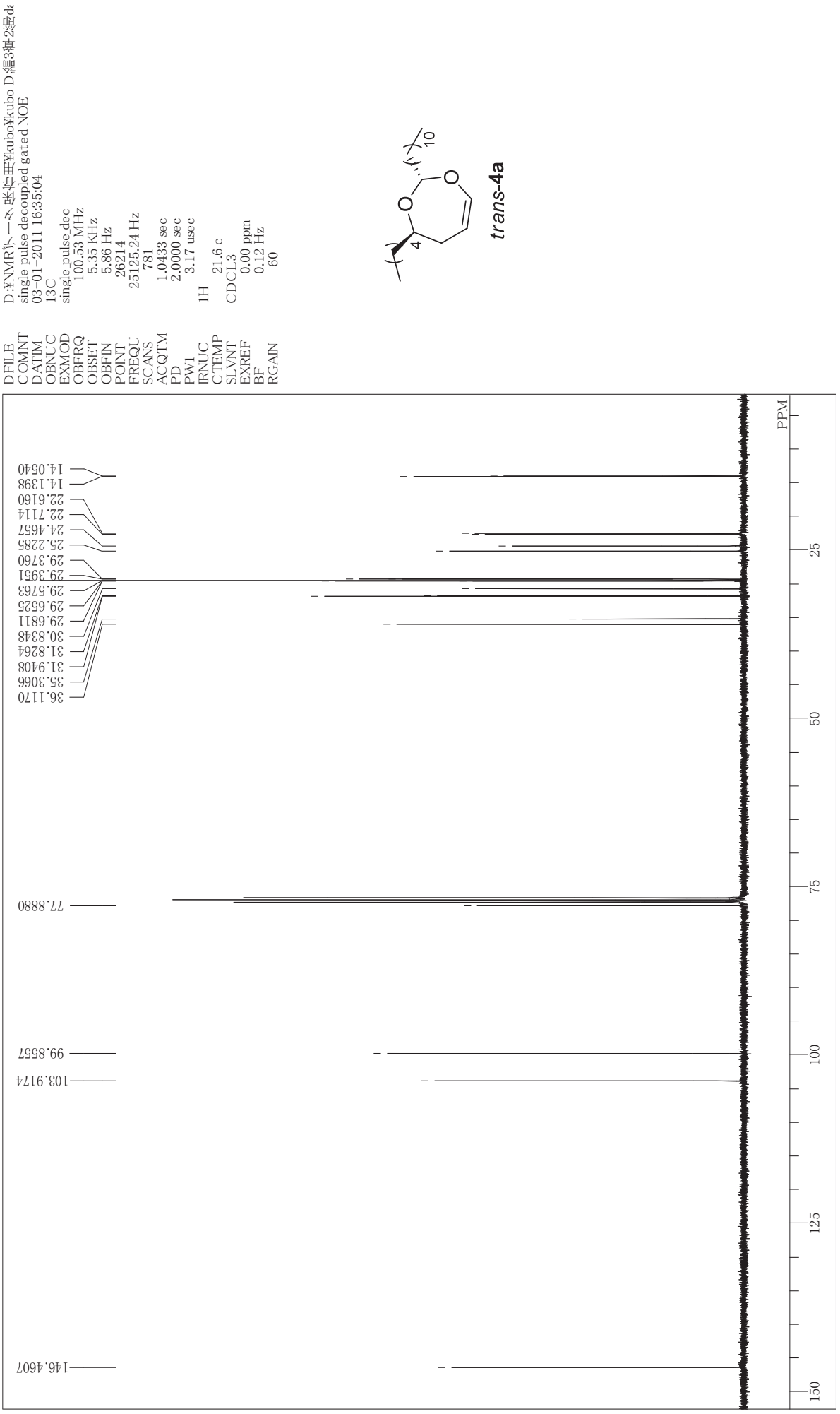
cis-**4a**

^{1}H NMR of *trans*-**4a**



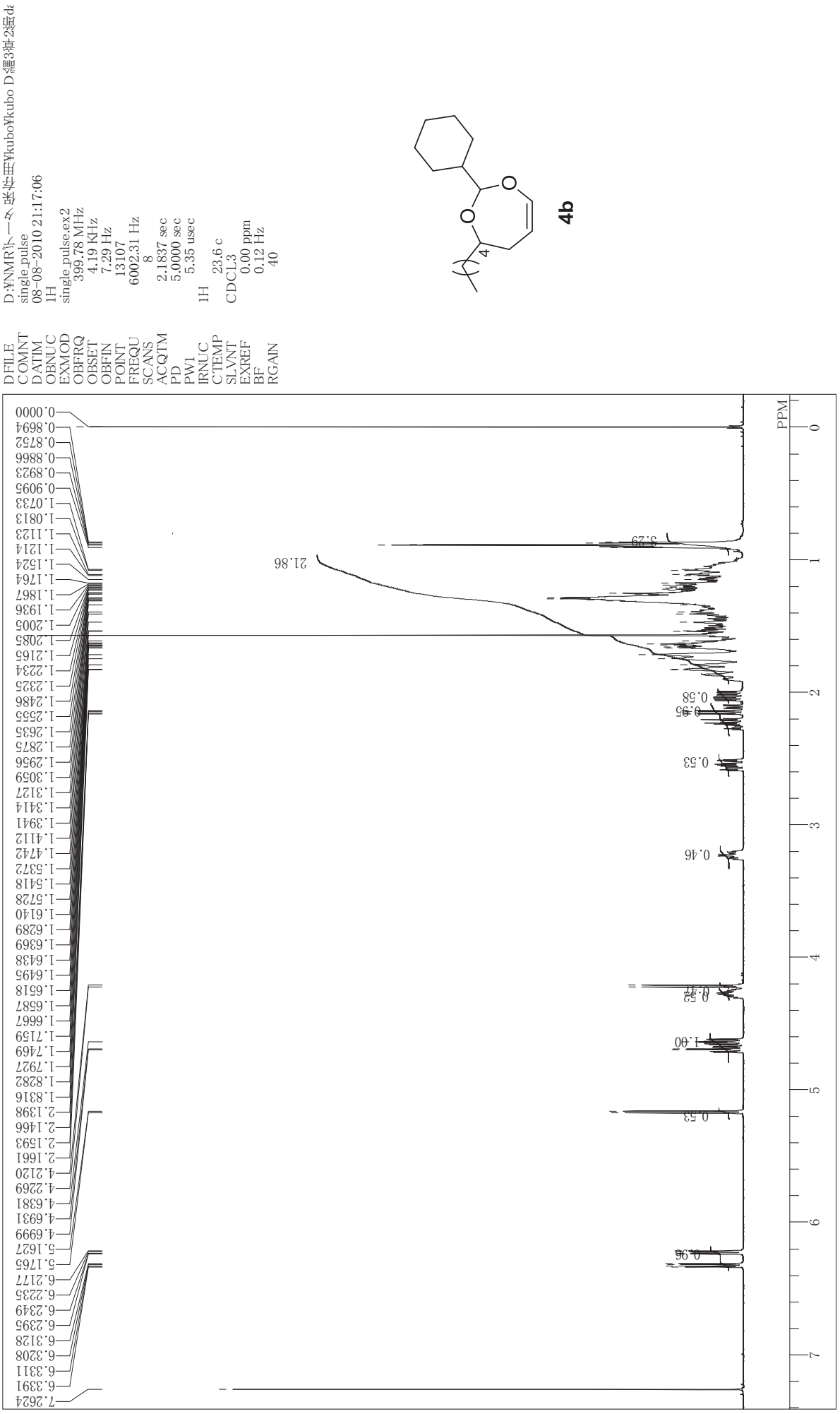
***trans*-4a**

^{13}C NMR of *trans*-**4a**



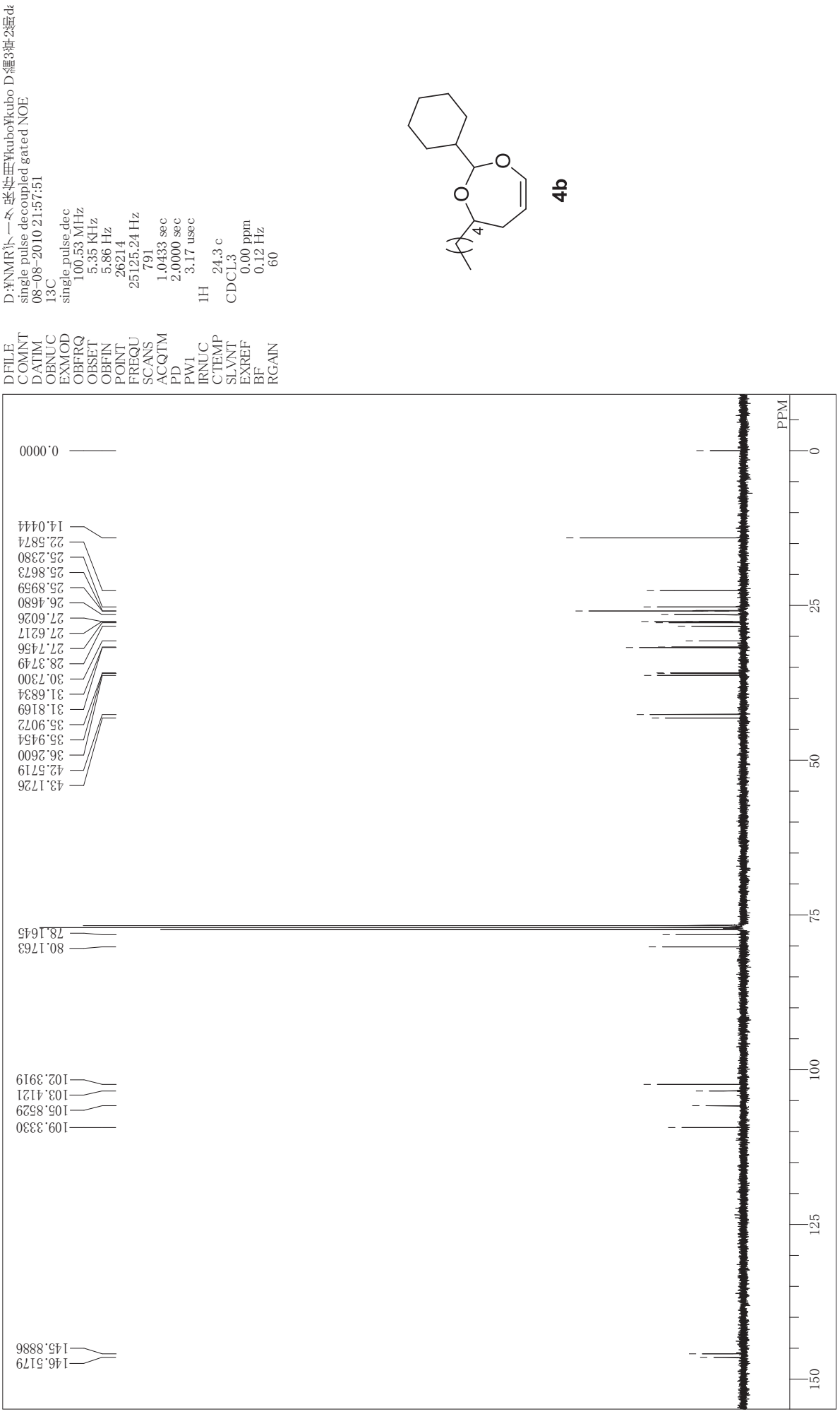
trans-**4a**

^{1}H NMR of **4b**



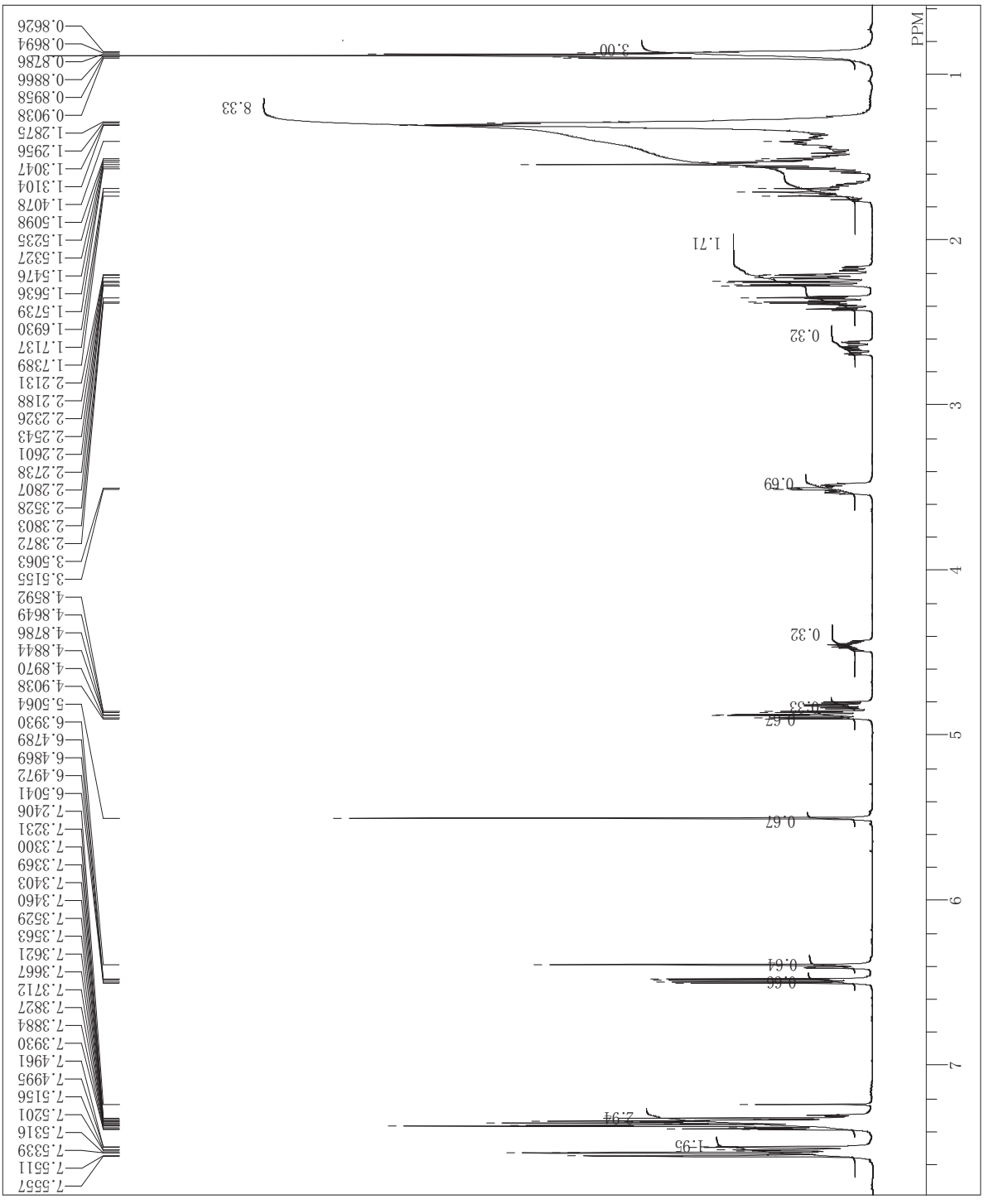
4b

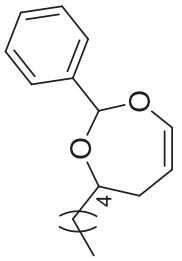
^{13}C NMR of **4b**



4b

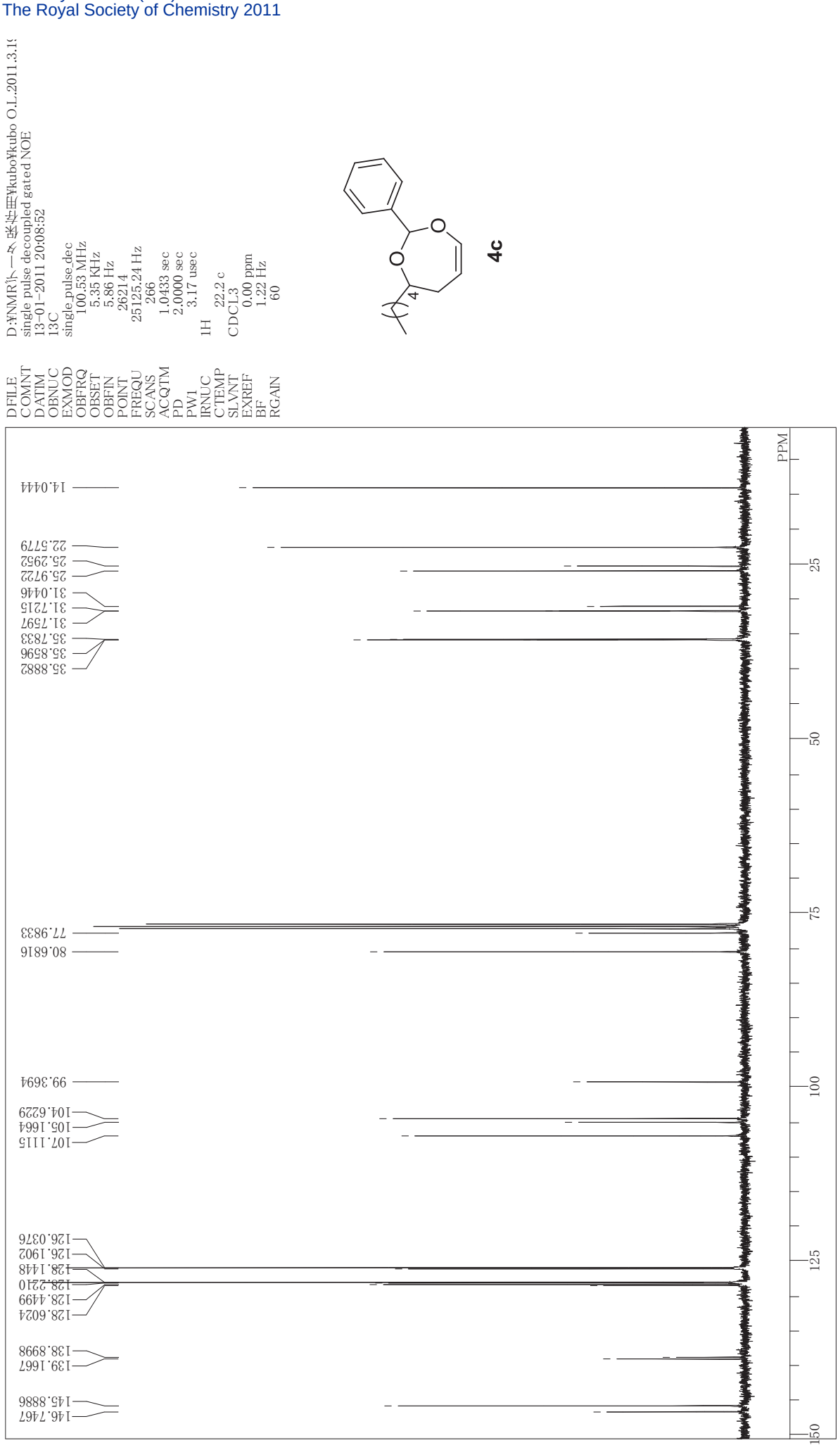
^{1}H NMR of **4c**





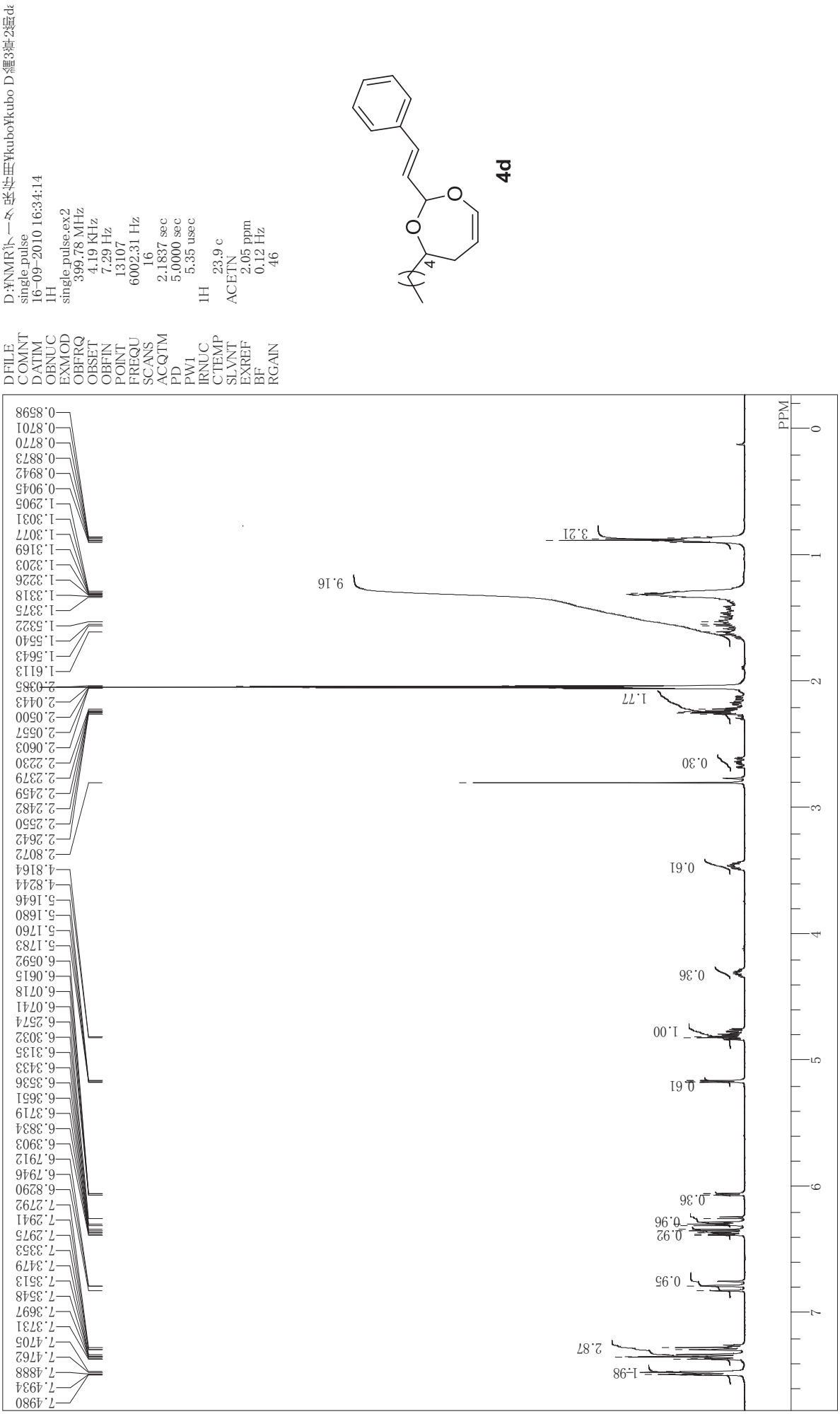
4c

^{13}C NMR of **4c**



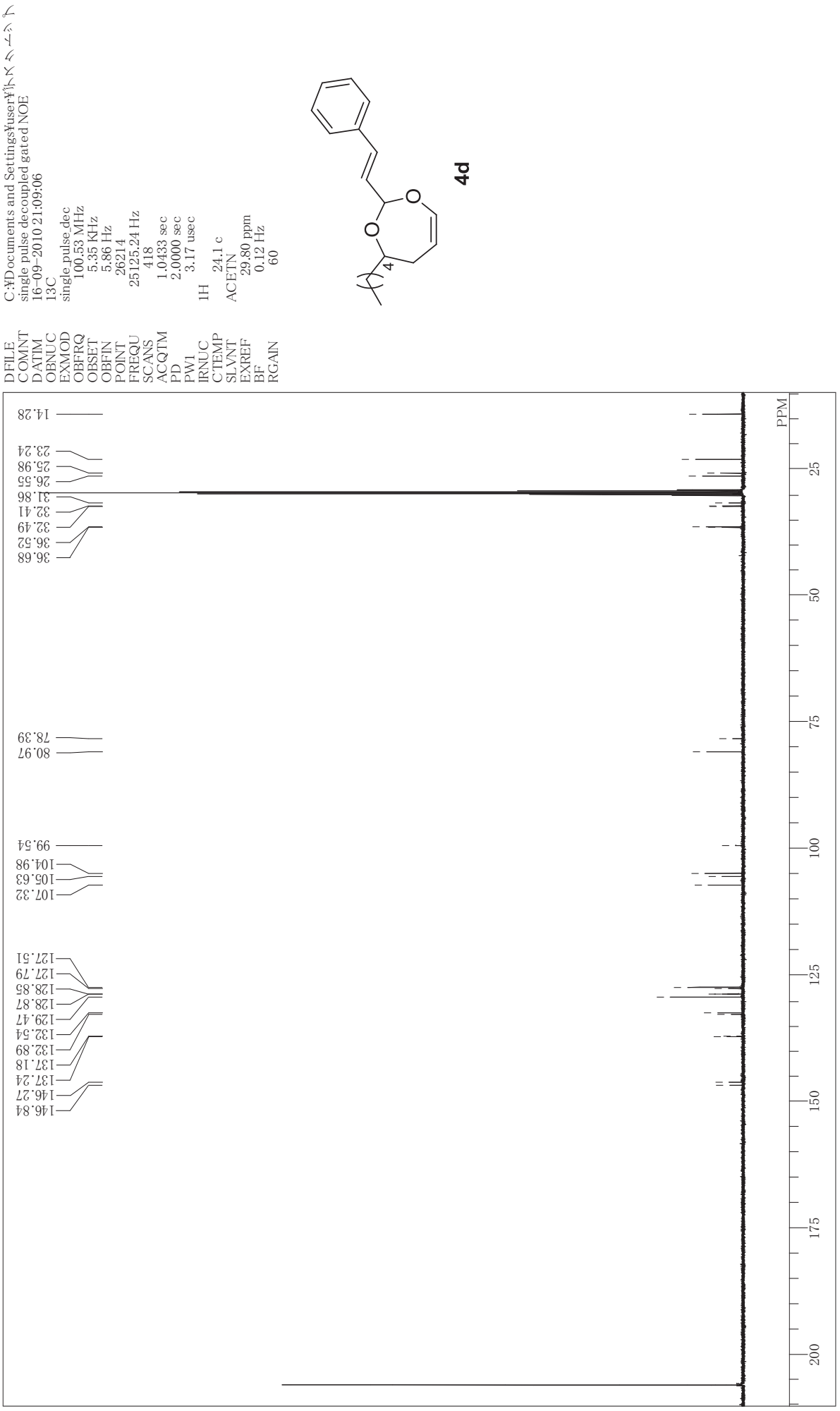
4c

^{1}H NMR of **4d**

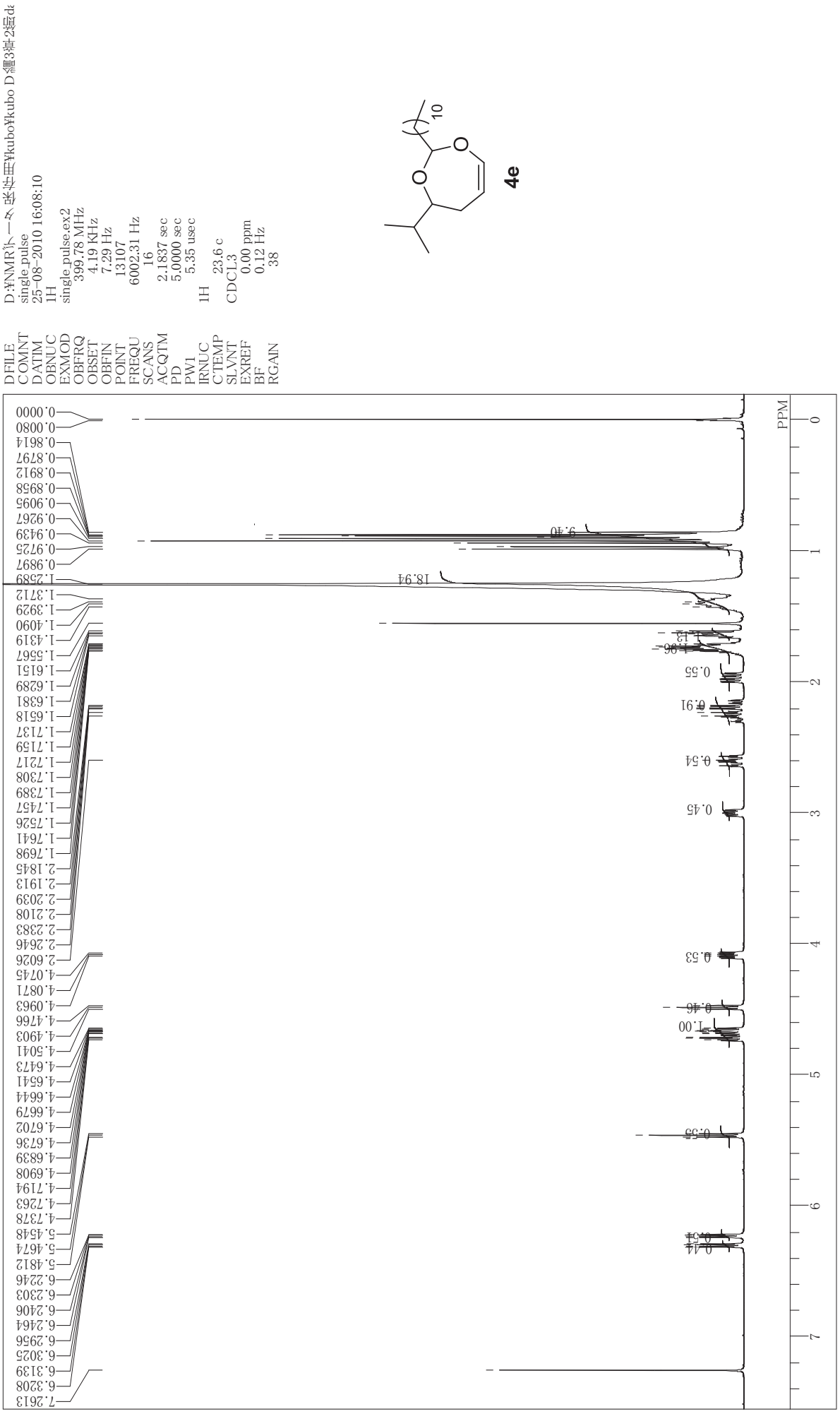


4d

^{13}C NMR of **4d**

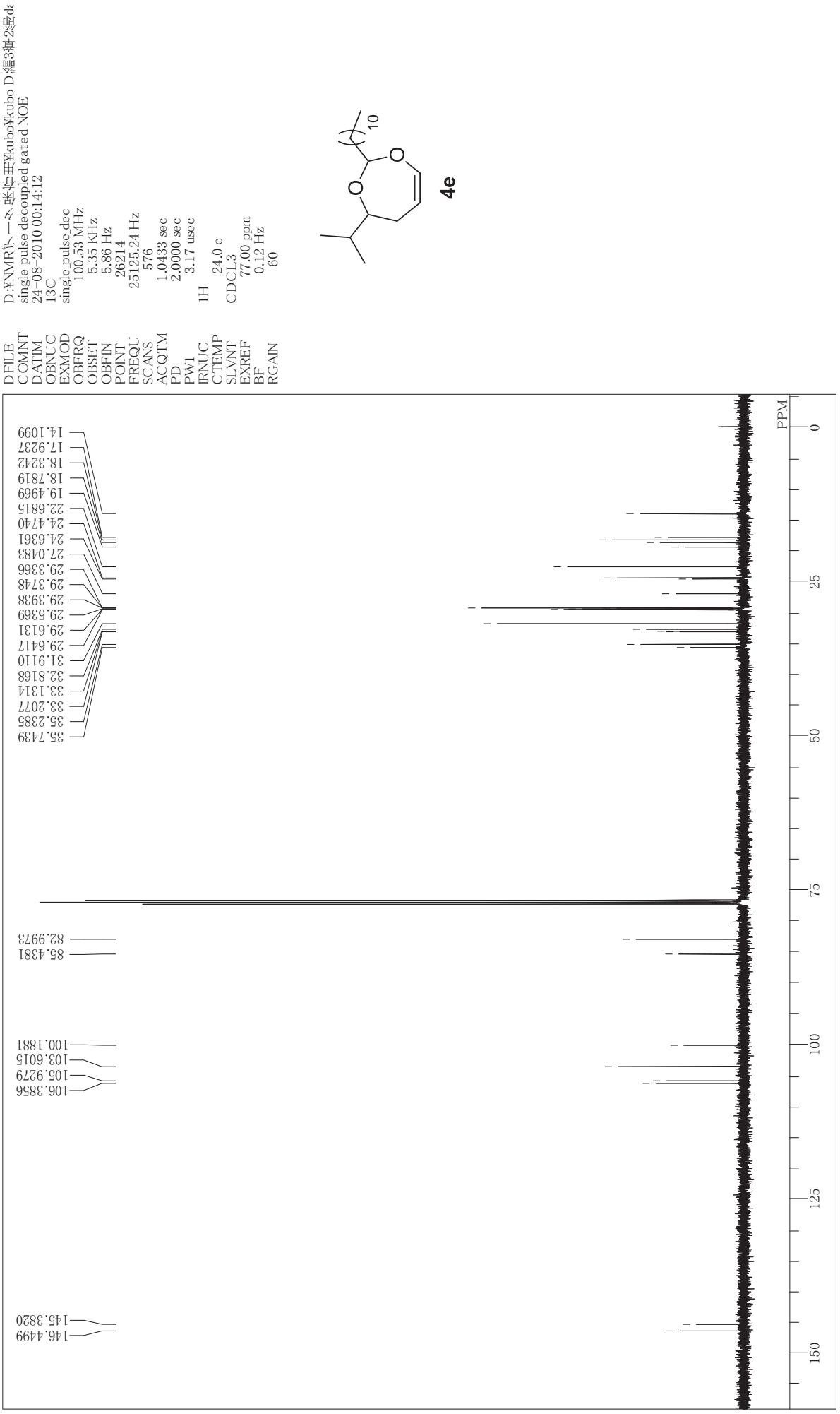


^{1}H NMR of **4e**



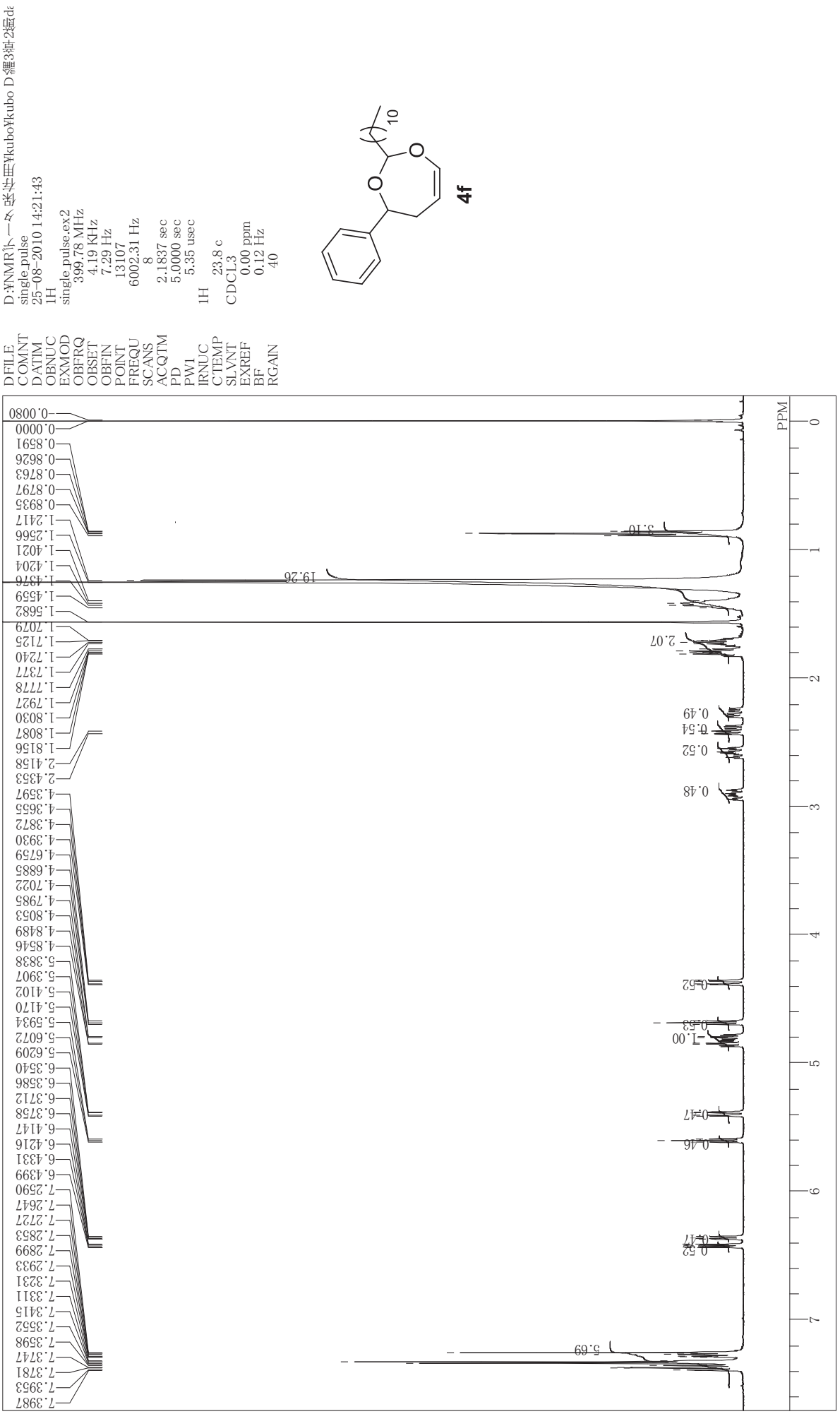
4e

^{13}C NMR of **4e**

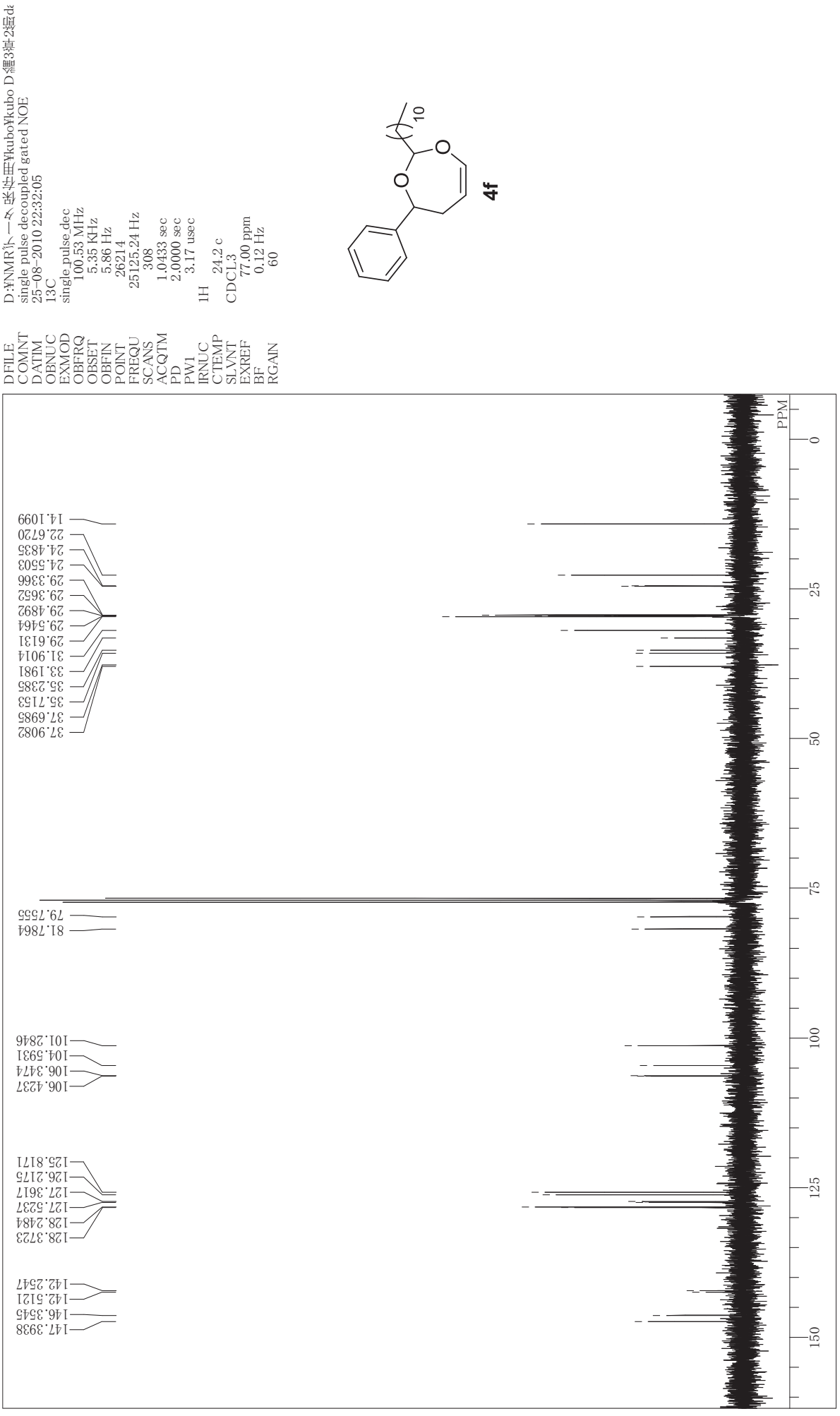


4e

^{1}H NMR of **4f**

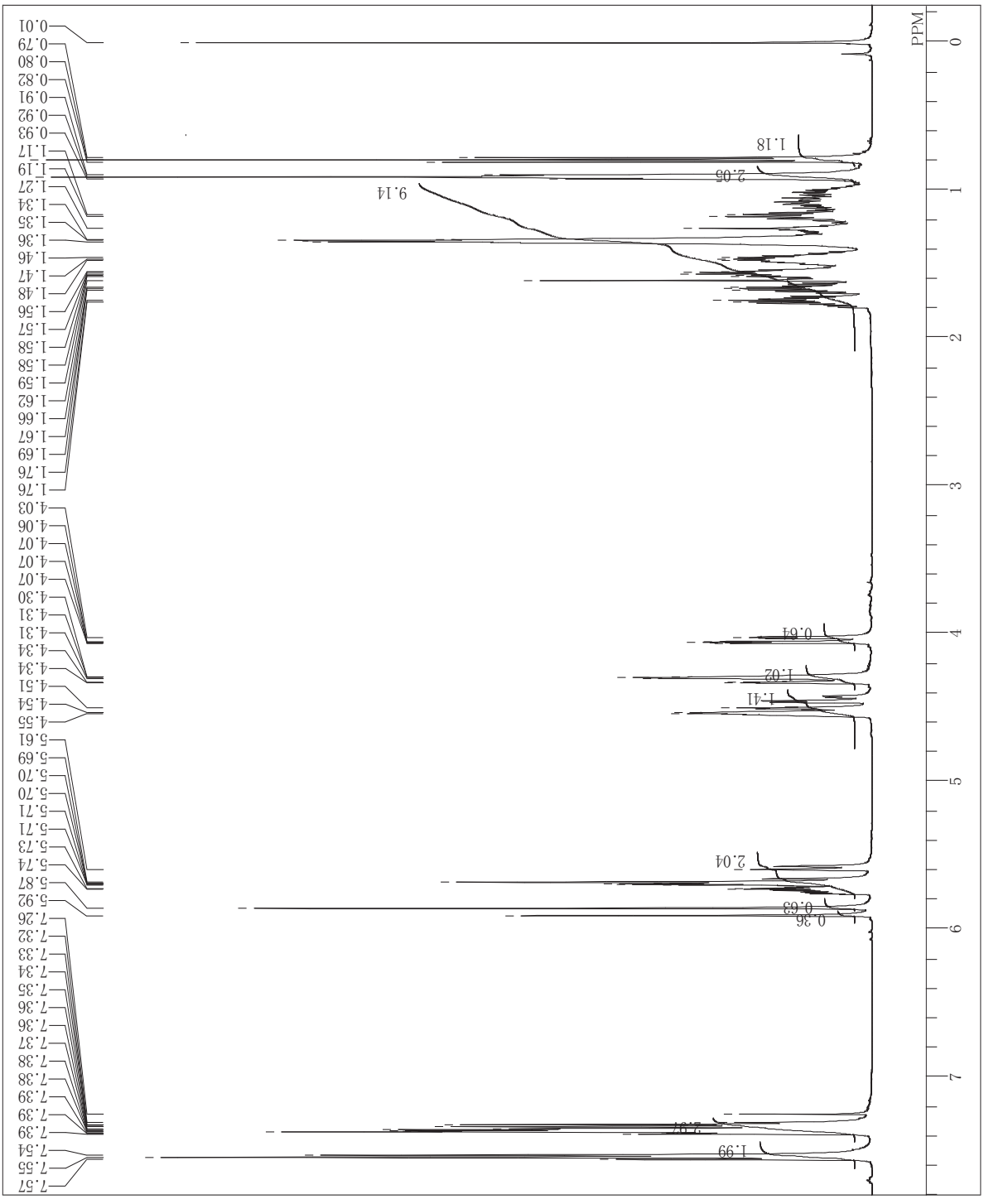


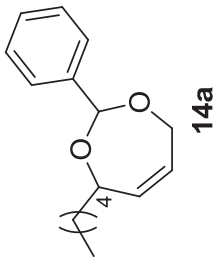
^{13}C NMR of **4f**



4f

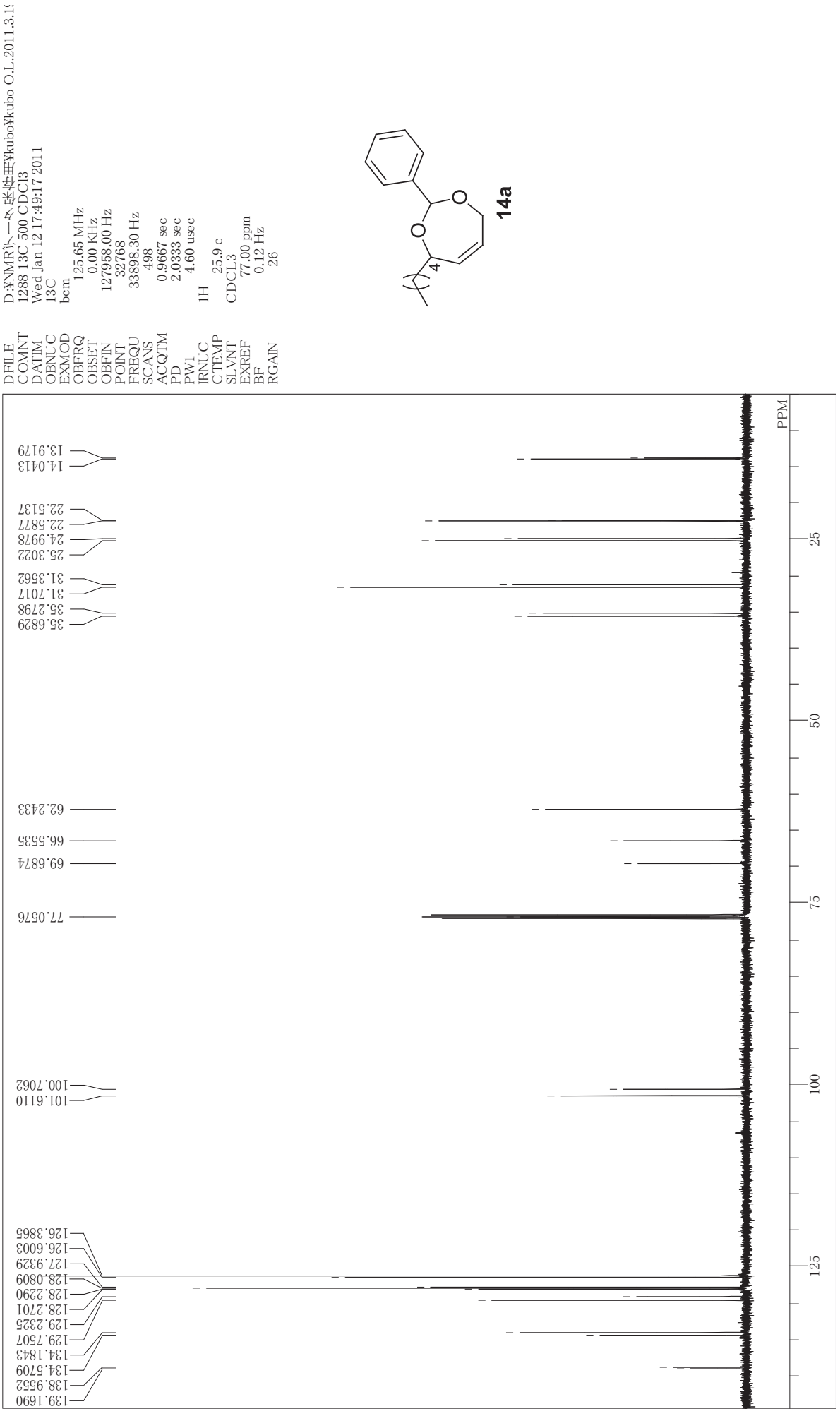
^{1}H NMR of **14a**



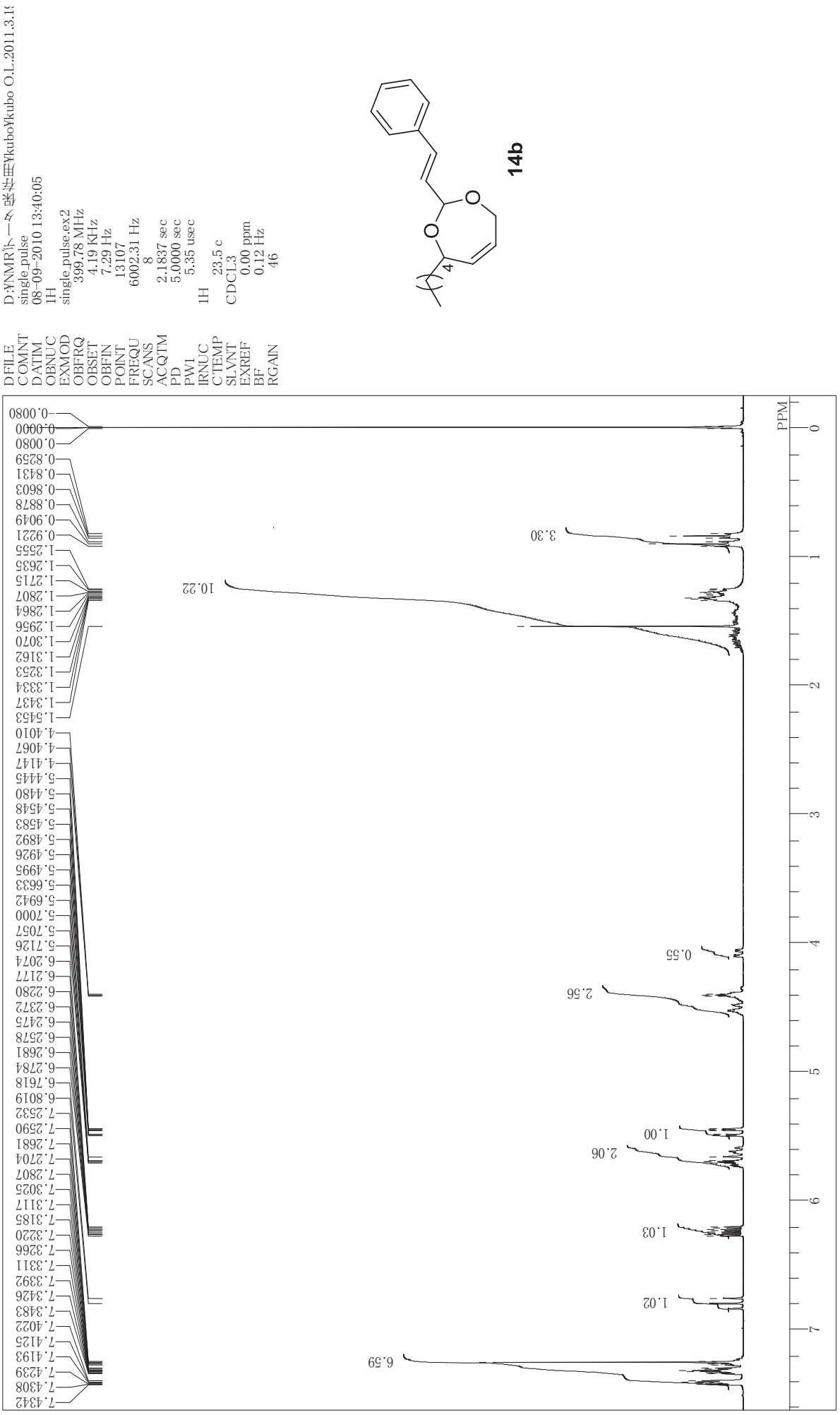


14a

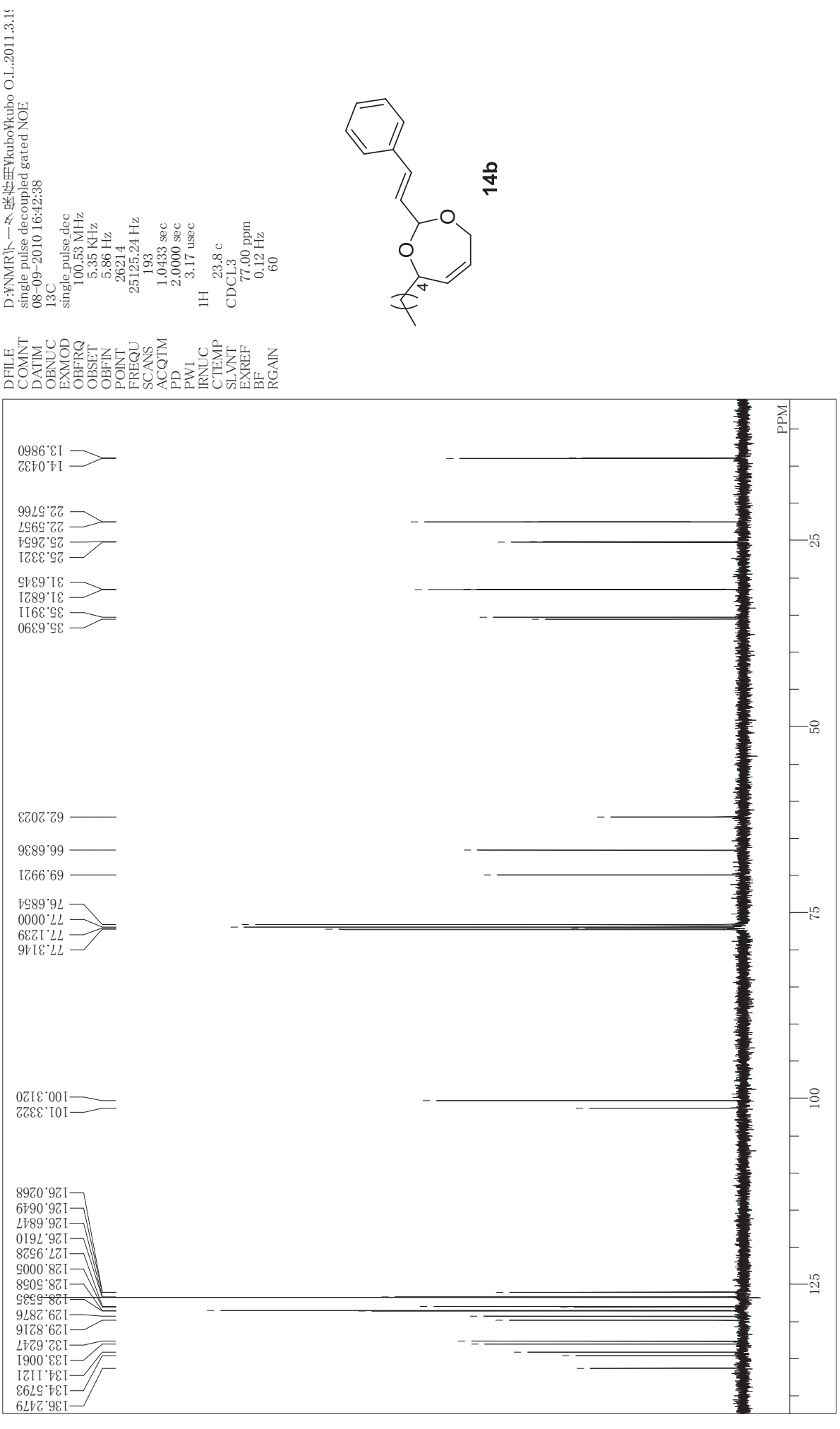
^{13}C NMR of **14a**



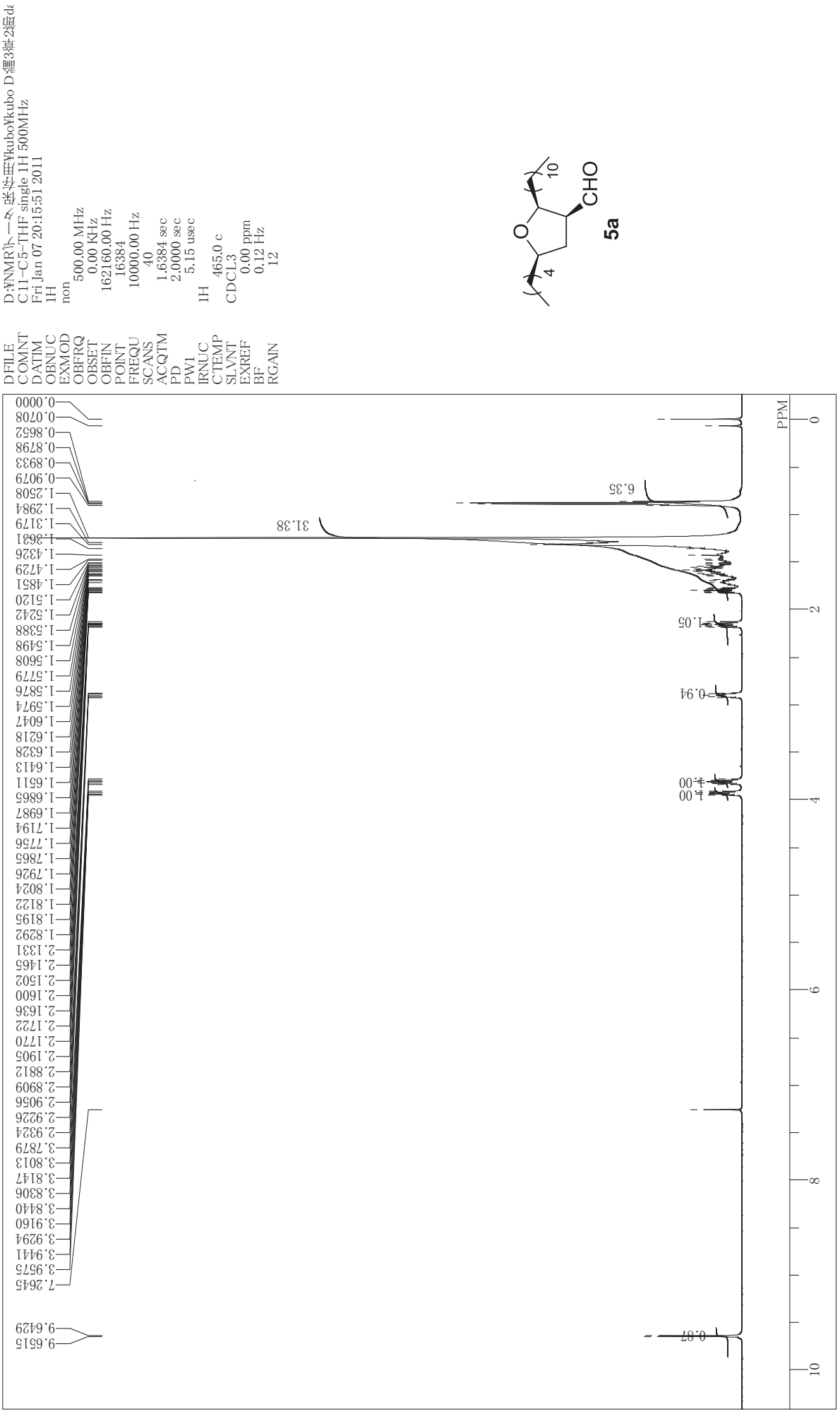
^{1}H NMR of **14b**


D:¥NMR¥ﾙｰﾁﾝ堅牢田¥kubo¥kubo O.L.2011.3.1
single_pulse
08-09-2010 13:40:05
1H
single_pulse.ex2
399.78 MHz
4.19 KHz
7.29 Hz
13107
6002.31 Hz
8
2.1837 sec
5.0000 sec
5.35 usec
1H
23.5 c
CDCL3
0.00 ppm
0.12 Hz
46
DFILE
COMNT
DATIM
OBNUC
EXMOD
OBFRQ
OBSET
OBFIN
POINT
FREQU
SCANS
ACQTM
PD
PW1
IRNUC
CTEMP
SLVNT
EXREF
BF
RGAIN
14b
PPM
10.22
6.59
3.30
2.56
2.06
1.03
1.02
1.00
0.55

^{13}C NMR of **14b**



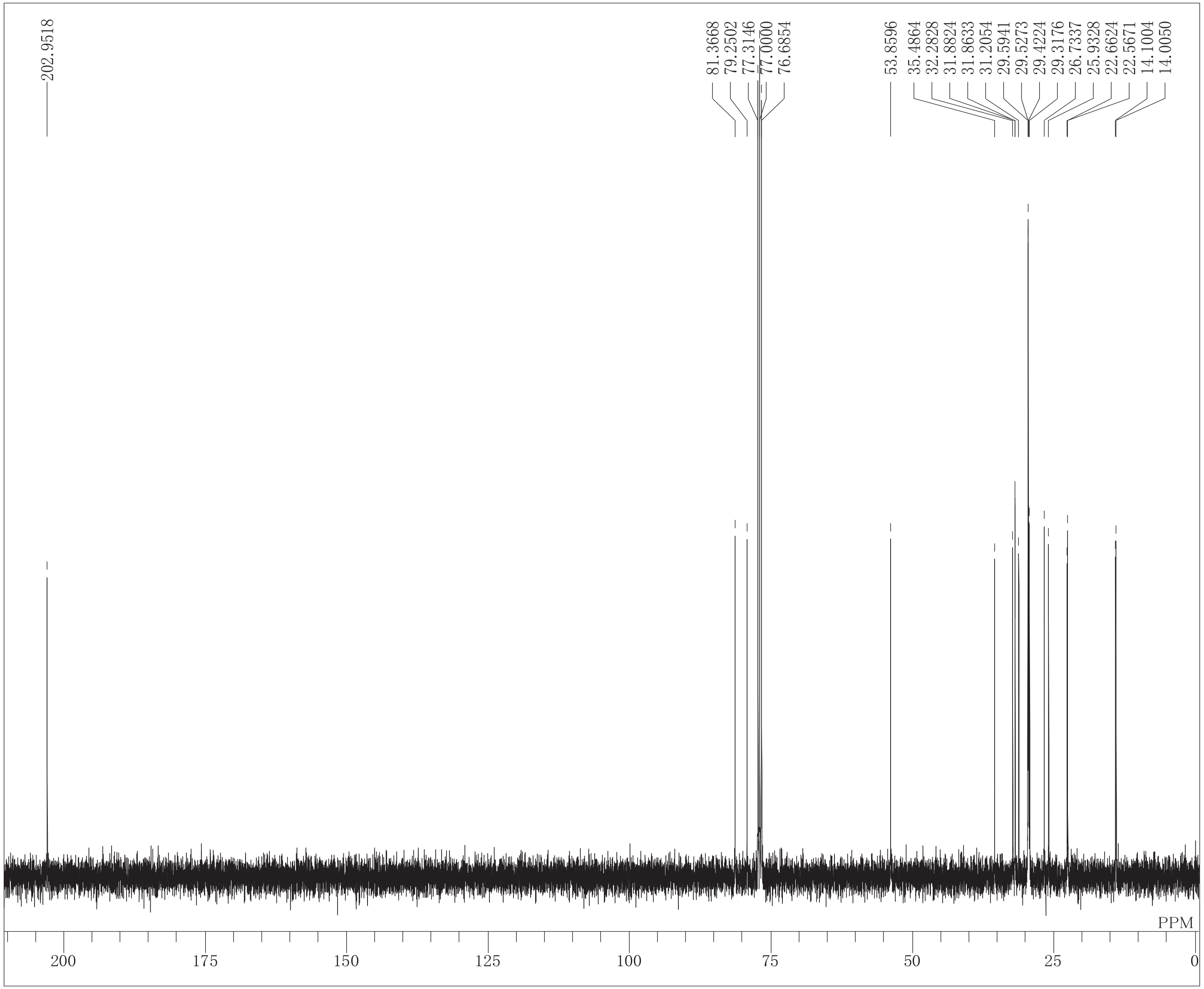
^{1}H NMR of **5a**



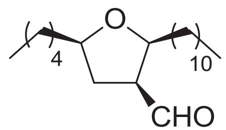
5a

Electronic Supplementary Material (ESI) for Chemical Communications

^{13}C NMR of **5a**

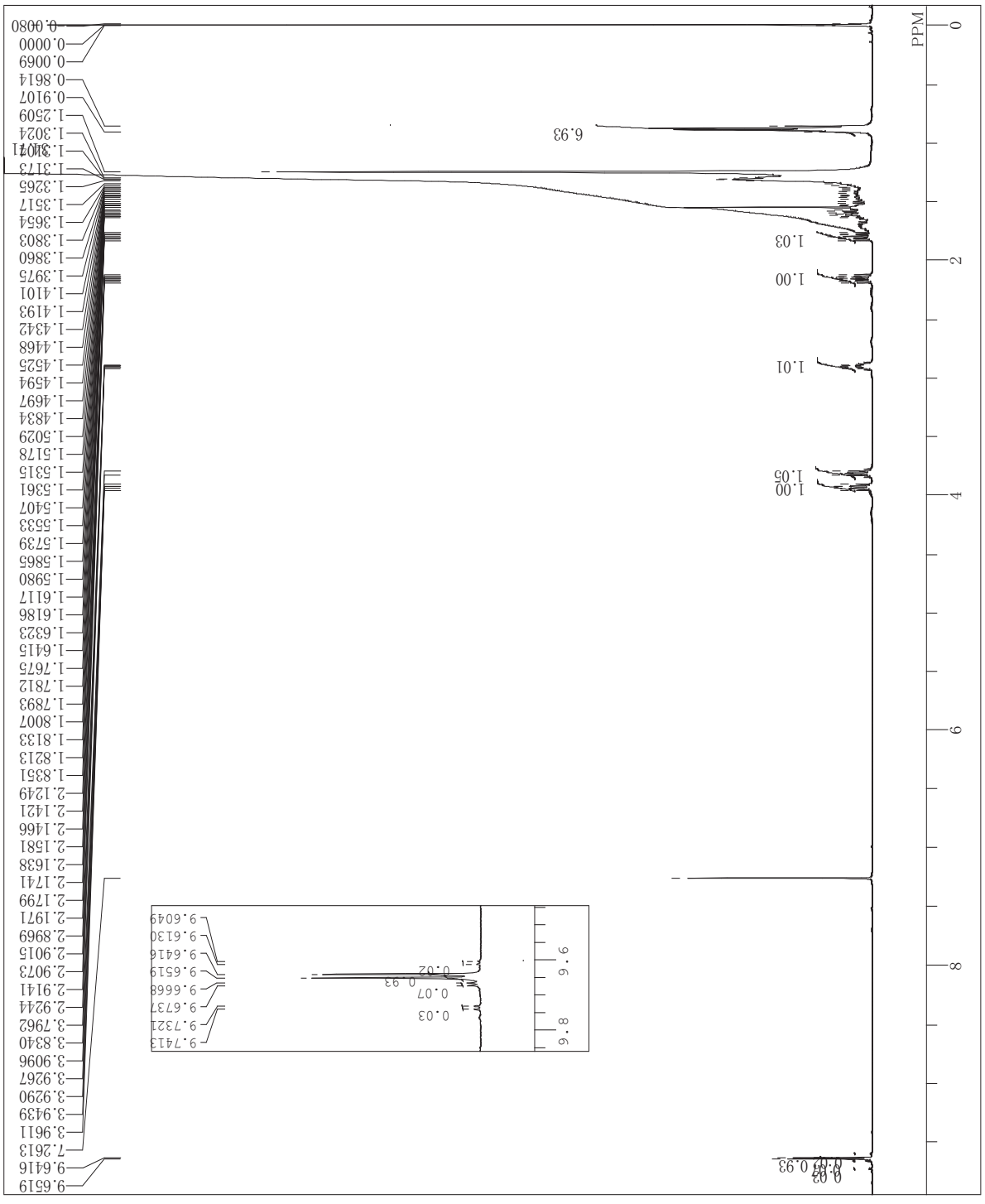


DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single pulse decoupled gated NOE
DATIM	07-01-2011 19:24:29
OBNUC	13C
EXMOD	single_pulse_dec
OBFRQ	100.53 MHz
OBSET	5.35 KHz
OBFIN	5.86 Hz
POINT	32768
FREQU	31407.03 Hz
SCANS	416
ACQTM	1.0433 sec
PD	2.0000 sec
PW1	3.17 usec
IRNUC	1H
CTEMP	22.3 c
SLVNT	CDCL3
EXREF	77.00 ppm
BF	0.32 Hz
RGAIN	30

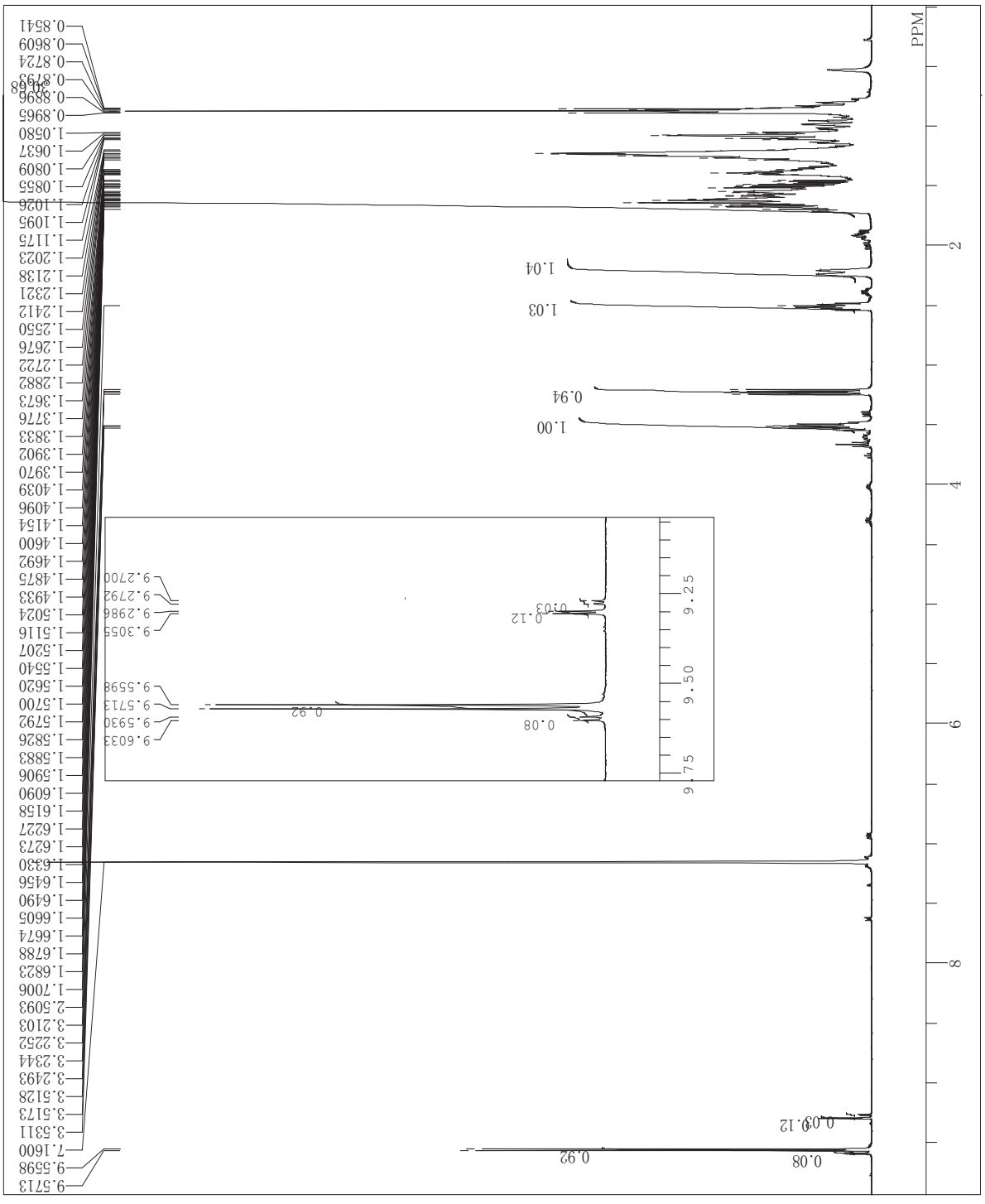


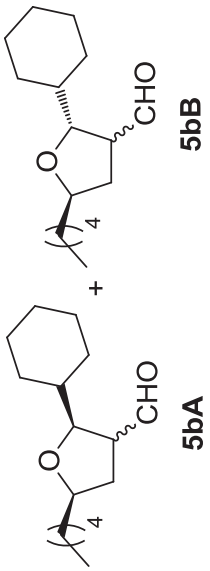
5a

^{1}H NMR of **5aA** and **5aB**

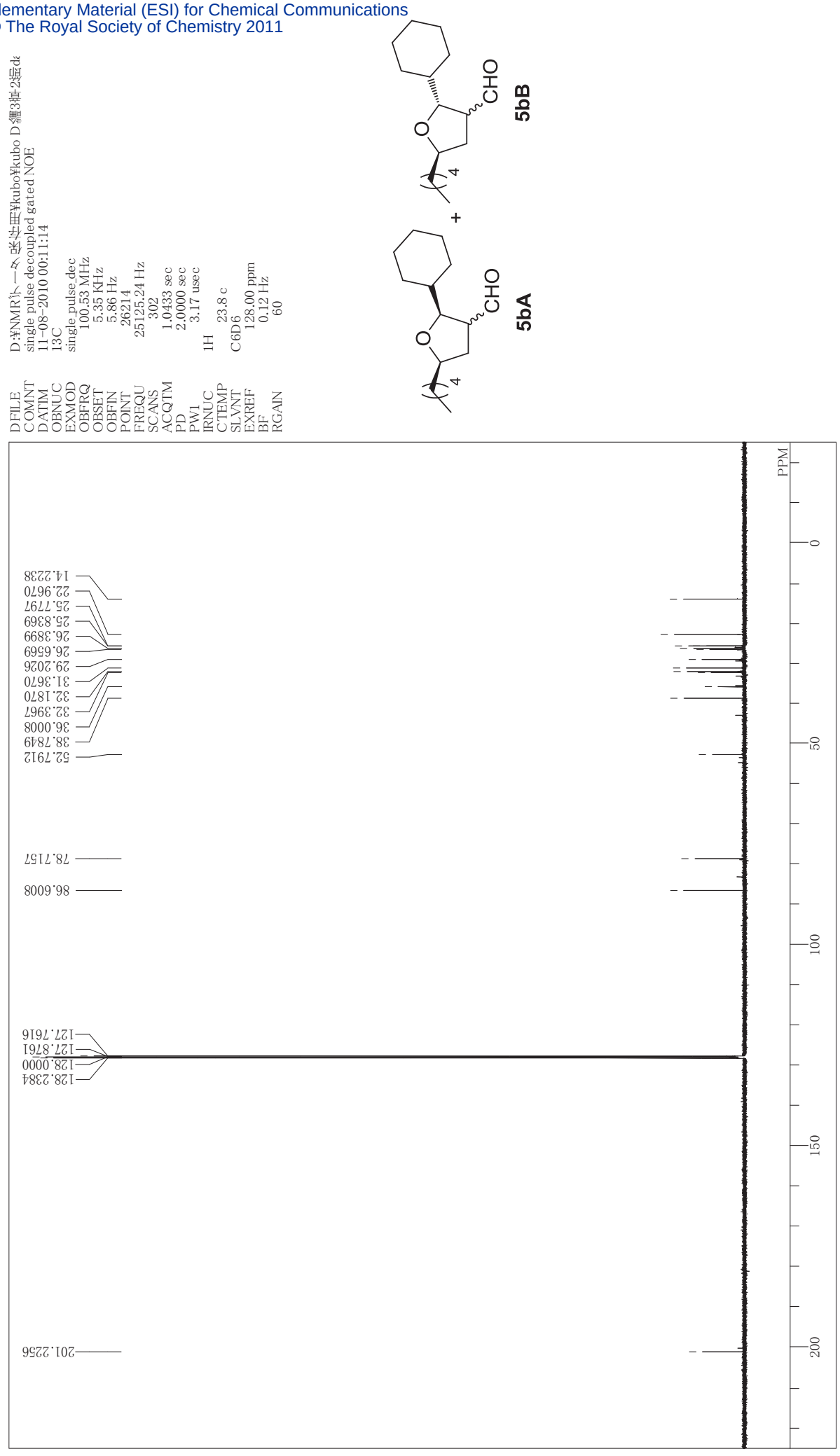


^{1}H NMR of **5bA** and **5bB**

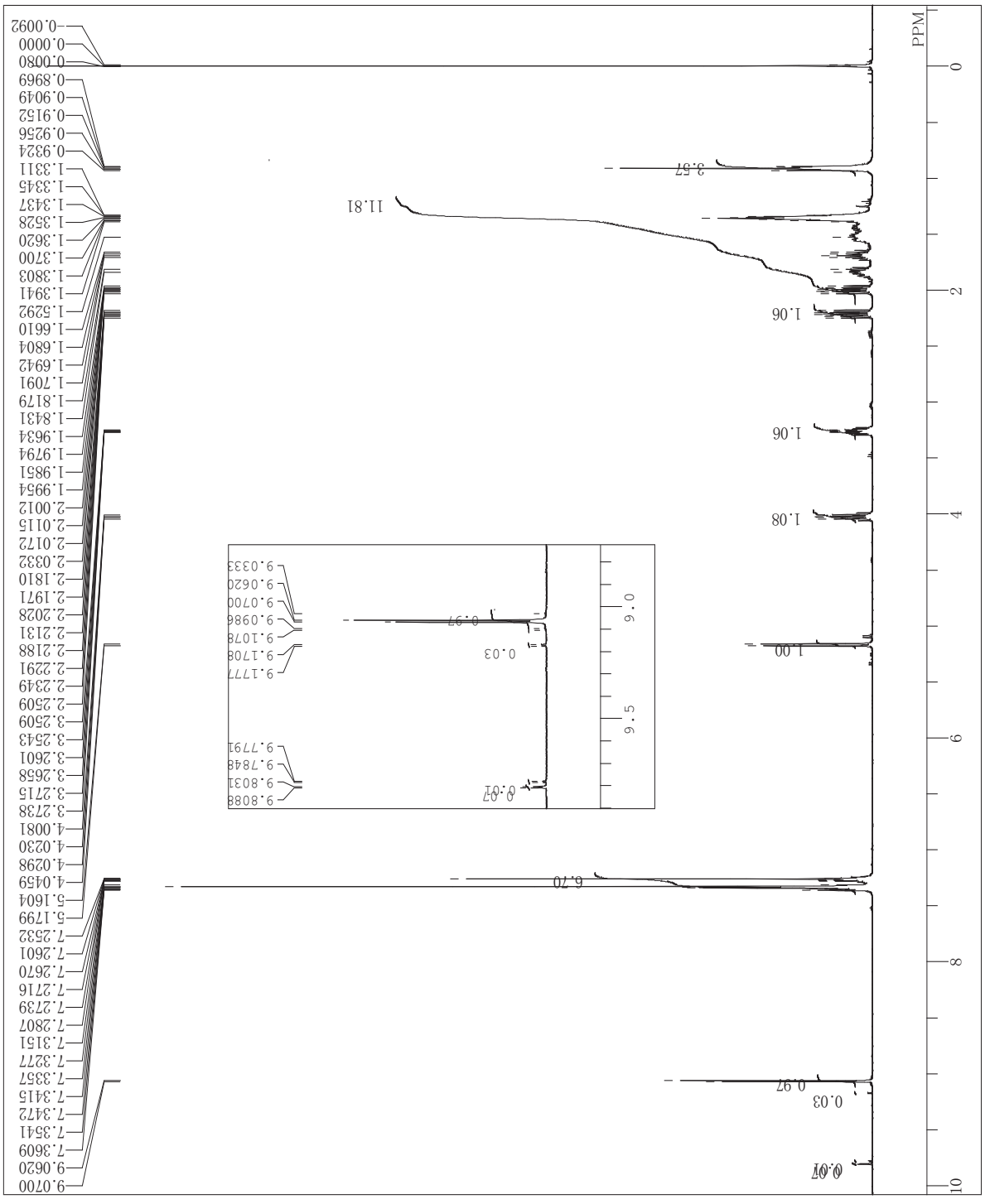


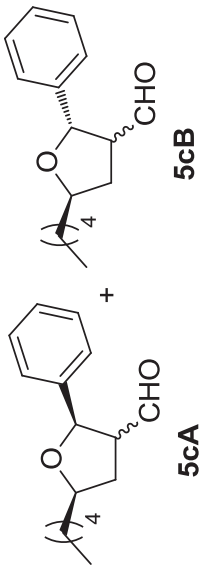


^{13}C NMR of **5bA**

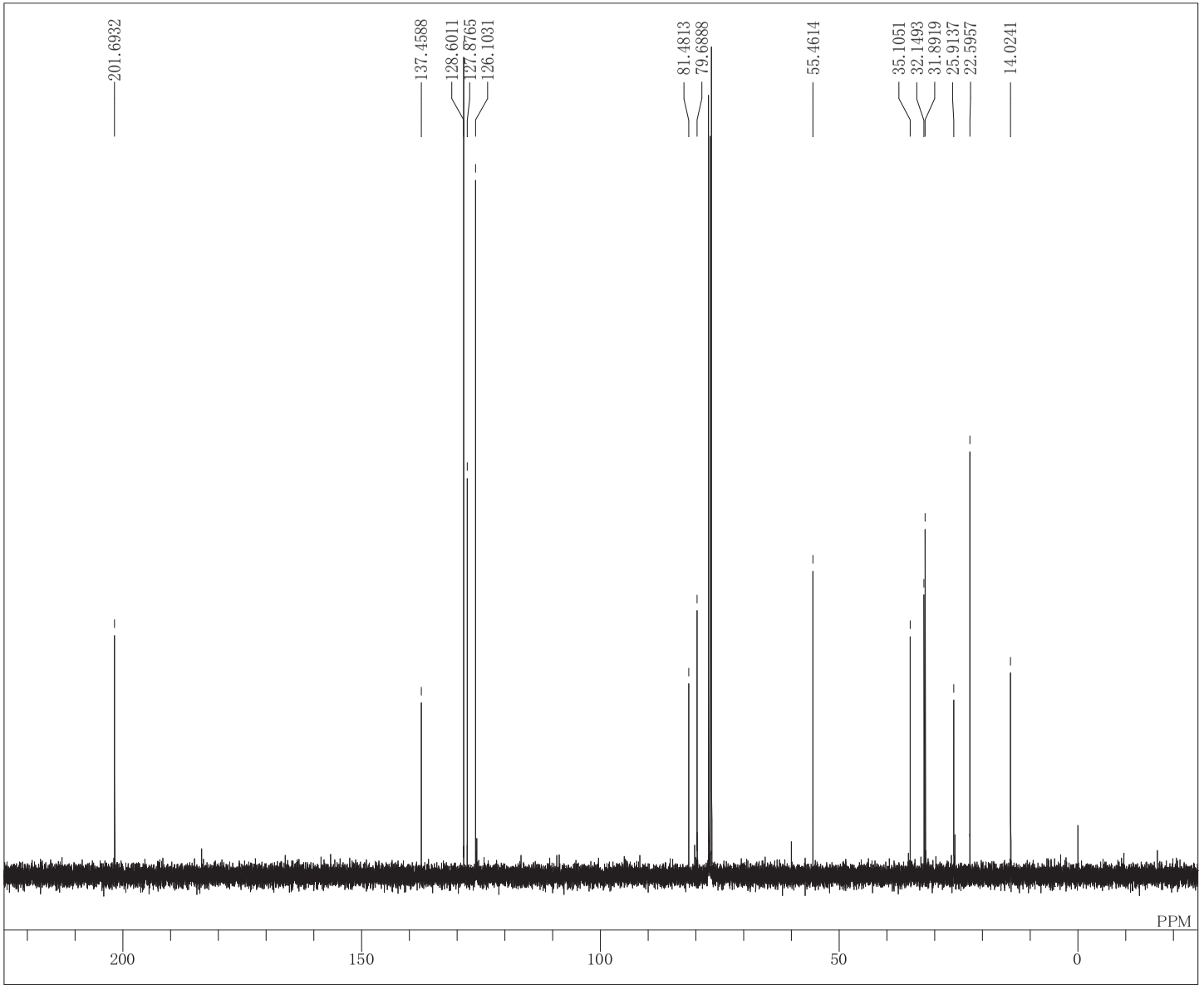


^{1}H NMR of **5cA** and **5cB**

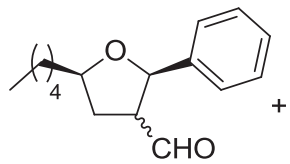




^{13}C NMR of **5cA** and **5cB**

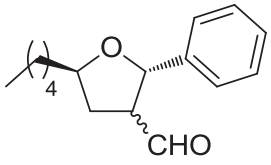


DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single pulse decoupled gated NOE
DATIM	09-08-2010 20:08:31
OBNUC	13C
EXMOD	single_pulse_dec
OBFRQ	100.53 MHz
OBSET	5.35 KHz
OBFIN	5.86 Hz
POINT	26214
FREQU	25125.24 Hz
SCANS	350
ACQTM	1.0433 sec
PD	2.0000 sec
PW1	3.17 usec
IRNUC	1H
CTEMP	24.1 c
SLVNT	CDCL3
EXREF	77.00 ppm
BF	0.12 Hz
RGAIN	60



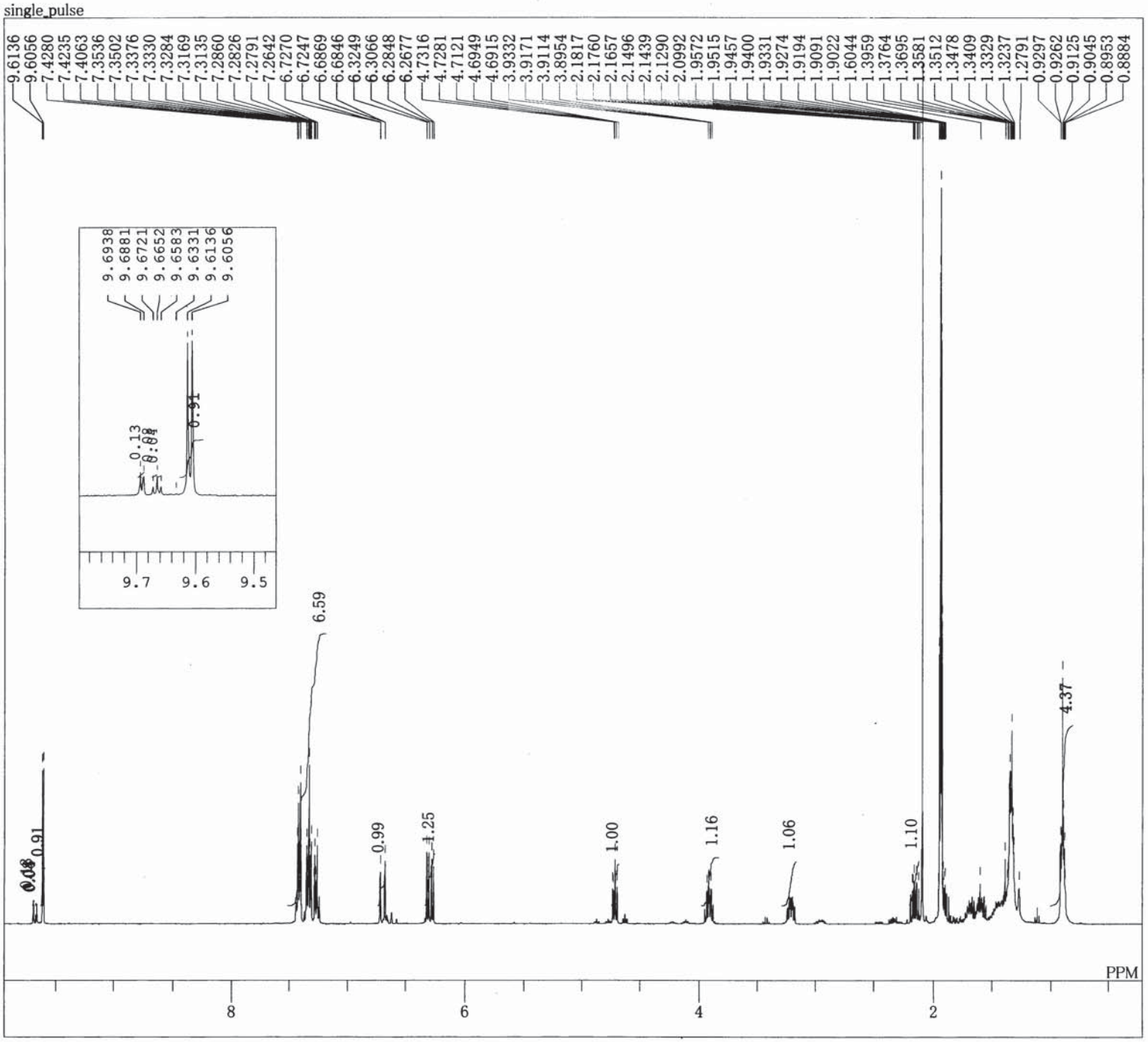
5cA

+

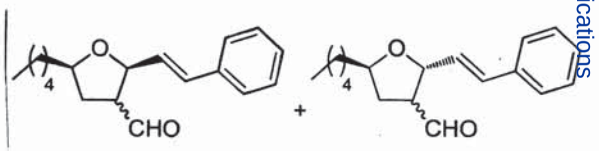


5cB

^{1}H NMR of **5dA** and **5dB**

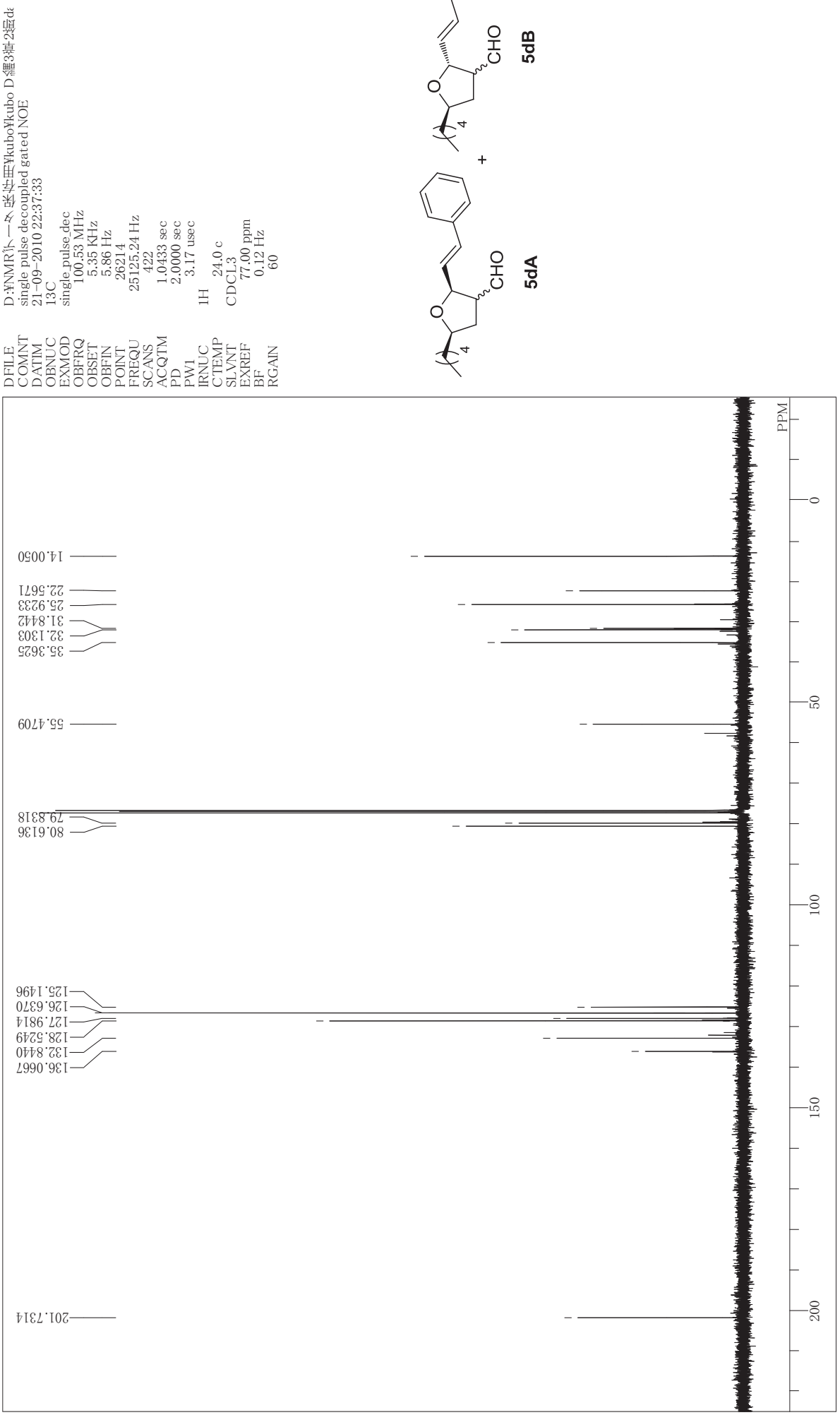


DFILE	D:¥NMRデータ保存用¥kubo¥kubo NMR¥Orgal
COMNT	single_pulse
DATIM	21-09-2010 16:35:04
OBNUC	1H
EXMOD	single_pulse.ex2
OBFRQ	399.78 MHz
OBSET	4.19 KHz
OBFIN	7.29 Hz
POINT	13107
FREQU	6002.31 Hz
SCANS	16
ACQTM	2.1837 sec
PD	5.0000 sec
PW1	5.35 usec
IRNUC	1H
CTEMP	35.0 c
SLVNT	CD3CN
EXREF	1.94 ppm
BF	0.12 Hz
RGAIN	44

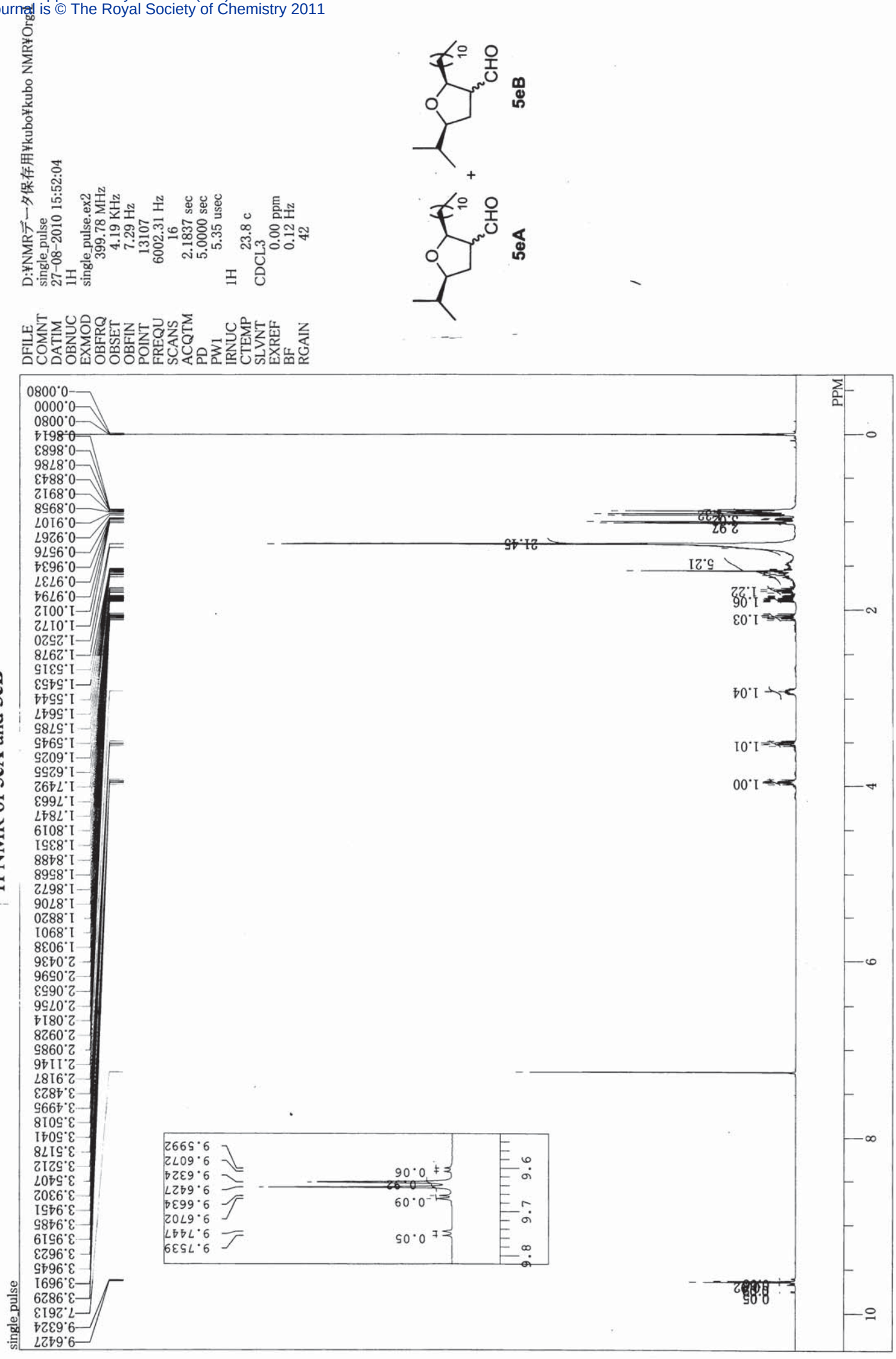


5dA **5dB**

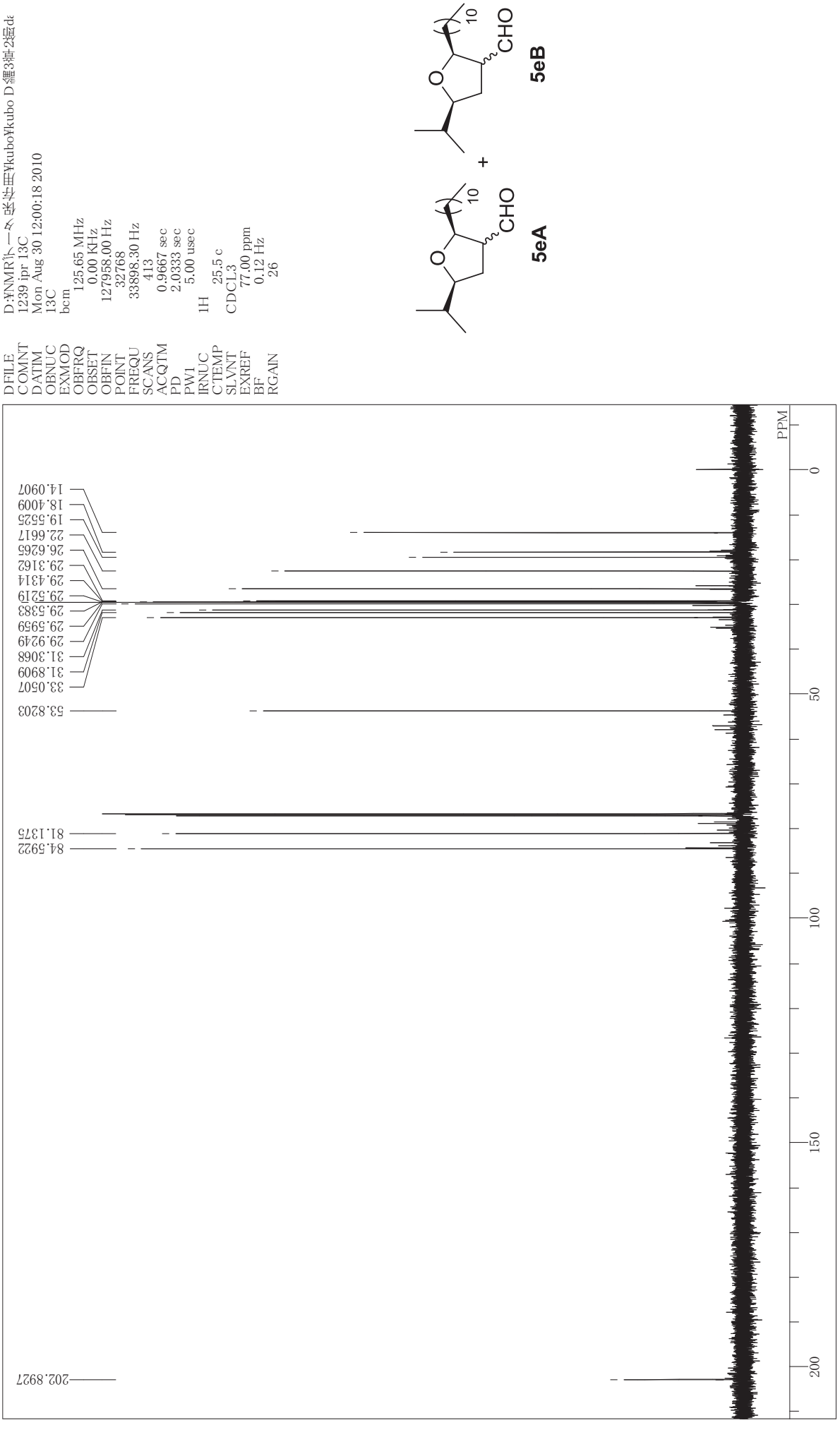
^{13}C NMR of **5dA** and **5dB**



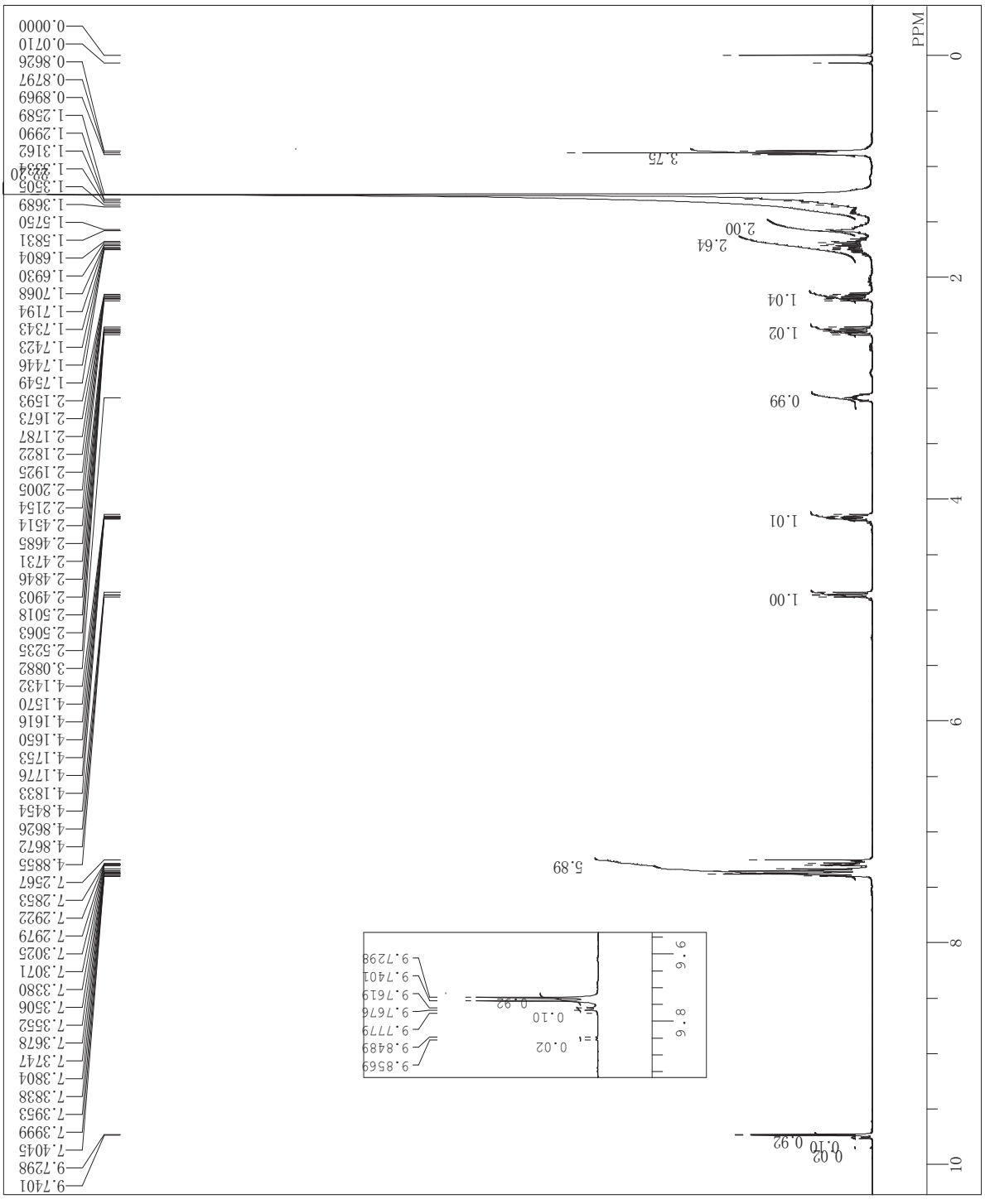
^{1}H NMR of **5eA** and **5eB**

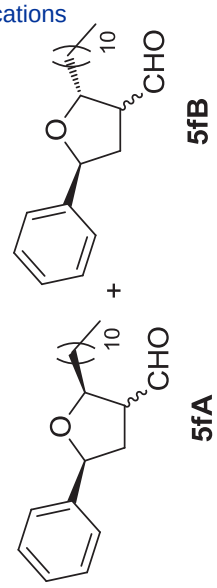


^{13}C NMR of **5eA** and **5eB**

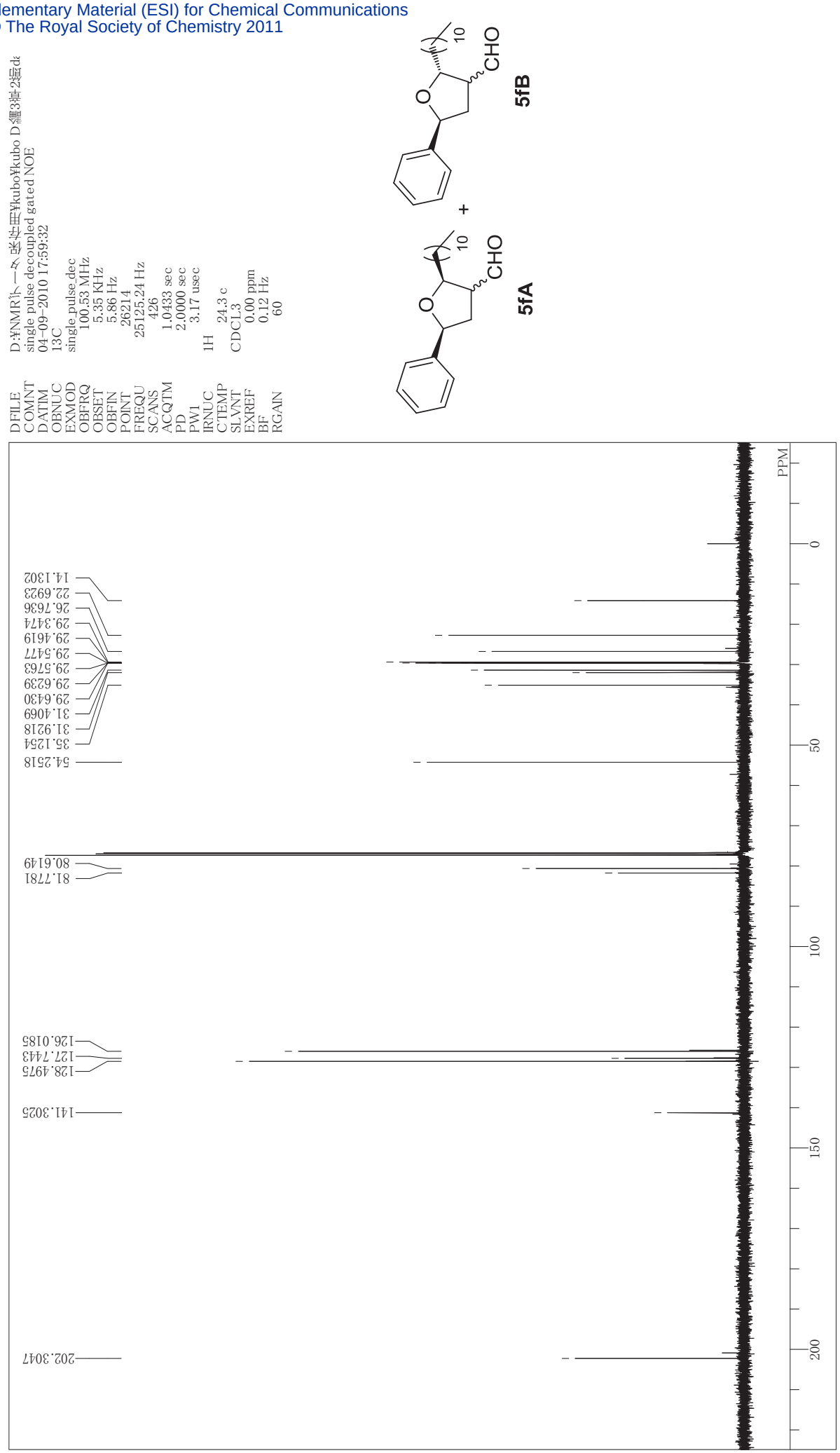


^{1}H NMR of **5fA** and **5fB**

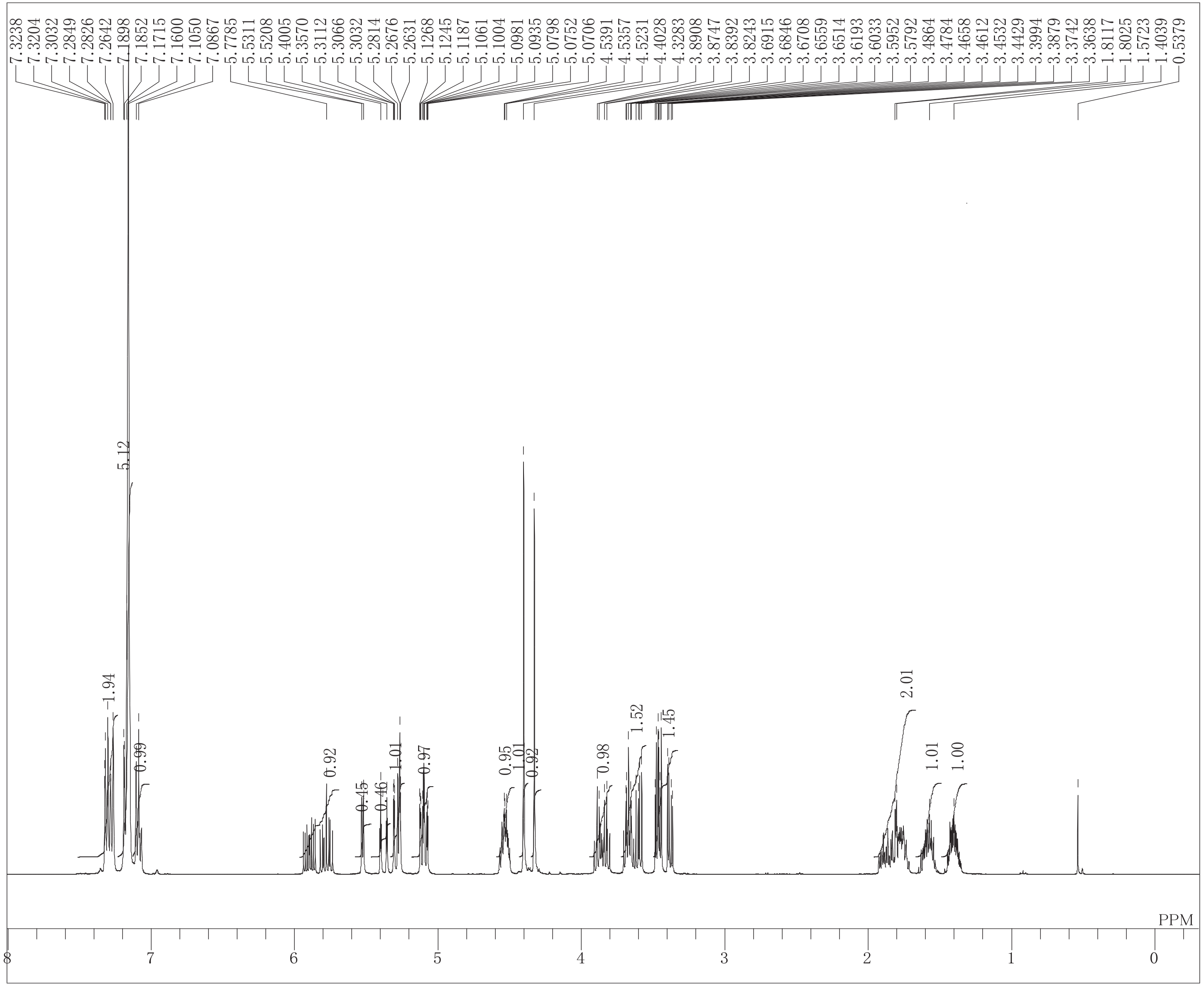




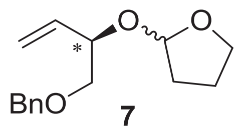
^{13}C NMR of **5fA** and **5fB**



^{1}H NMR of **7**

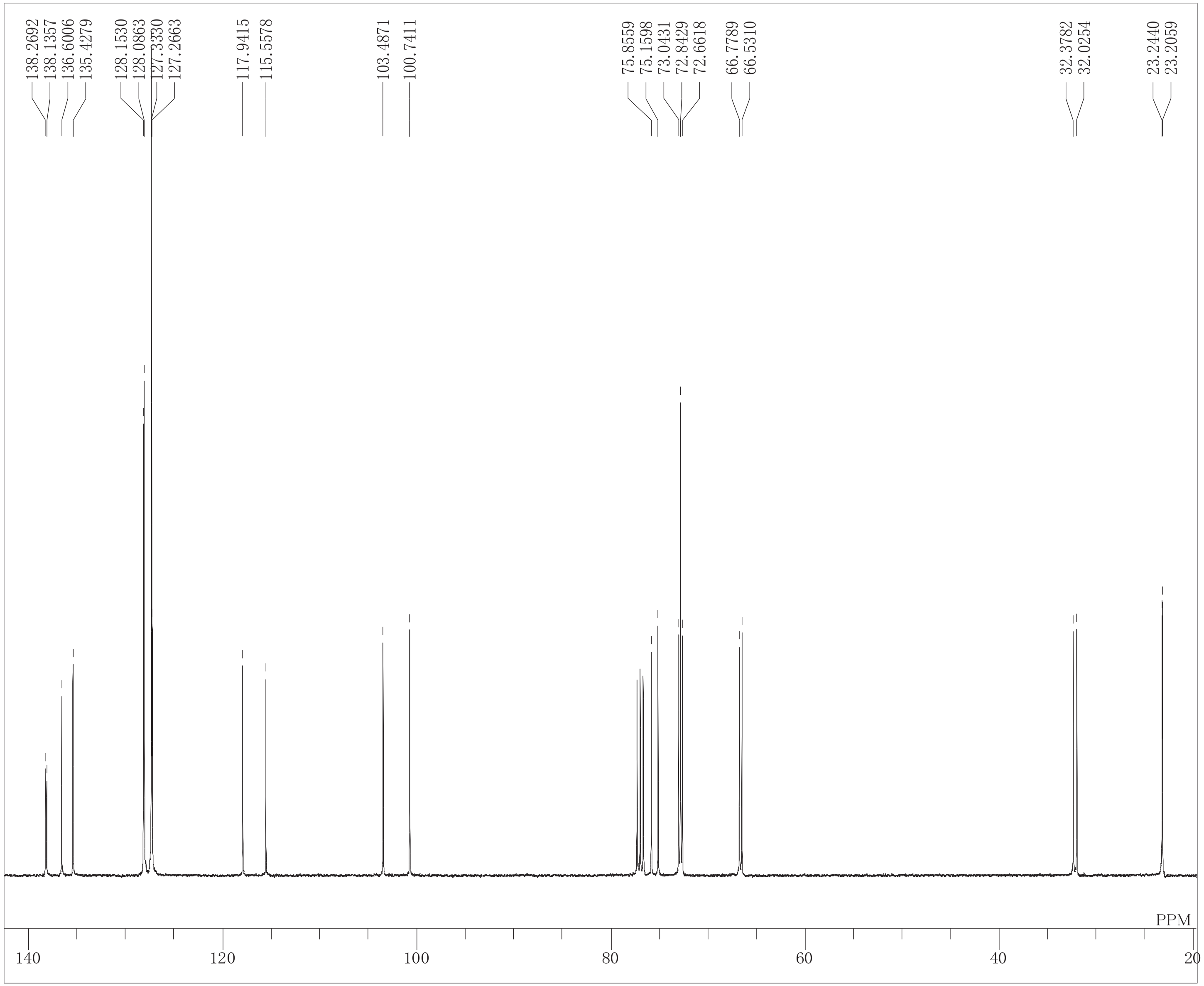


DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single_pulse
DATIM	03-01-2011 23:06:31
OBNUC	1H
EXMOD	single_pulse.ex2
OBFRQ	399.78 MHz
OBSET	4.19 KHz
OBFIN	7.29 Hz
POINT	13107
FREQU	6002.31 Hz
SCANS	16
ACQTM	2.1837 sec
PD	5.0000 sec
PW1	5.35 usec
IRNUC	1H
CTEMP	21.1 c
SLVNT	C6D6
EXREF	7.16 ppm
BF	0.12 Hz
RGAIN	38

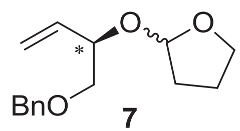


7

^{13}C NMR of **7**

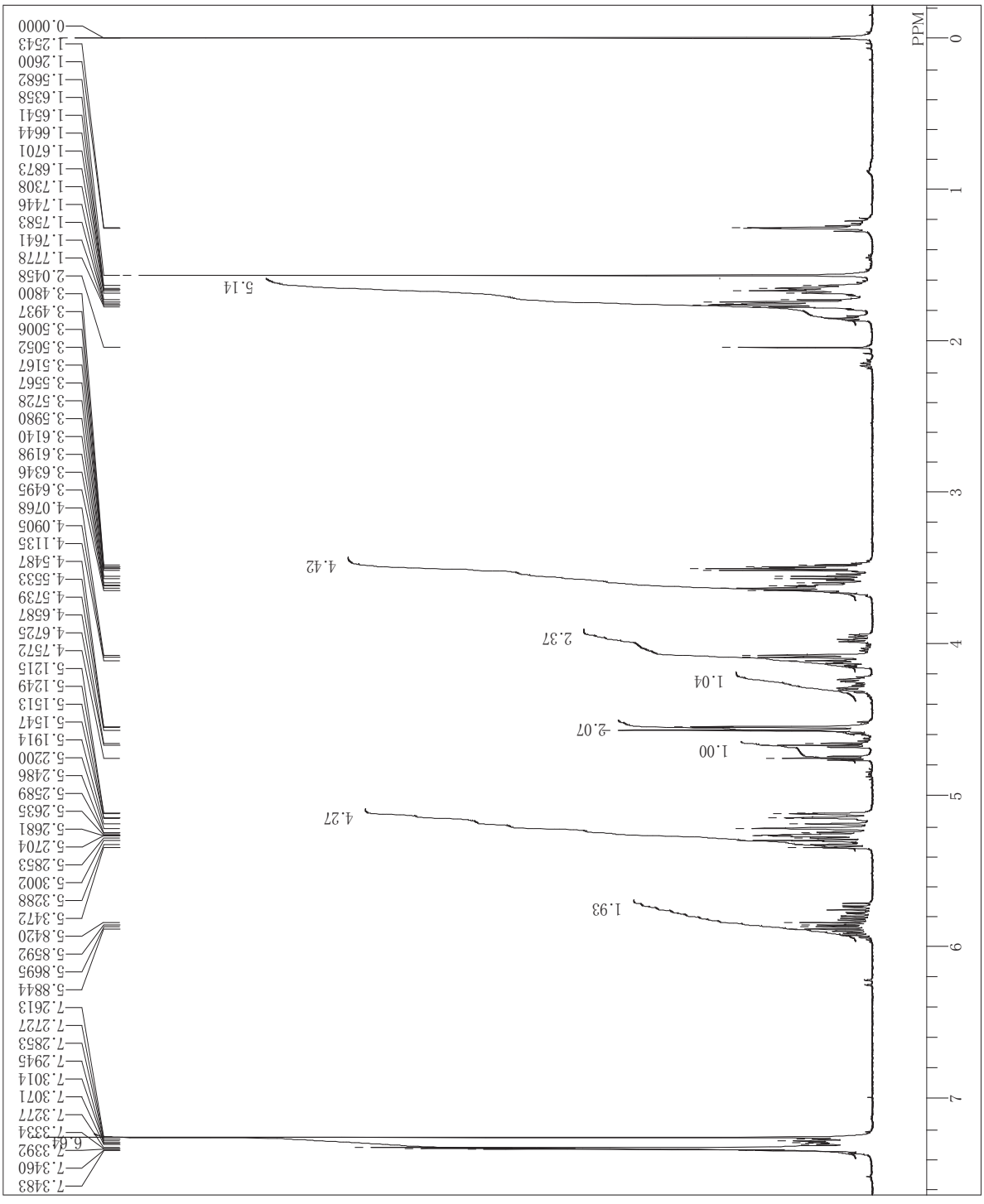


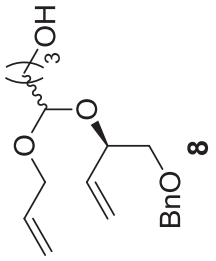
DFILE D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT single pulse decoupled gated NOE
DATIM 03-01-2011 20:31:30
OBNUC 13C
EXMOD single_pulse_dec
OBFRQ 100.53 MHz
OBSET 5.35 KHz
OBFIN 5.86 Hz
POINT 32768
FREQU 31407.04 Hz
SCANS 470
ACQTM 1.0433 sec
PD 2.0000 sec
PW1 3.17 usec
IRNUC 1H
CTEMP 21.5 c
SLVNT CDCL3
EXREF 77.00 ppm
BF 0.12 Hz
RGAIN 60



7

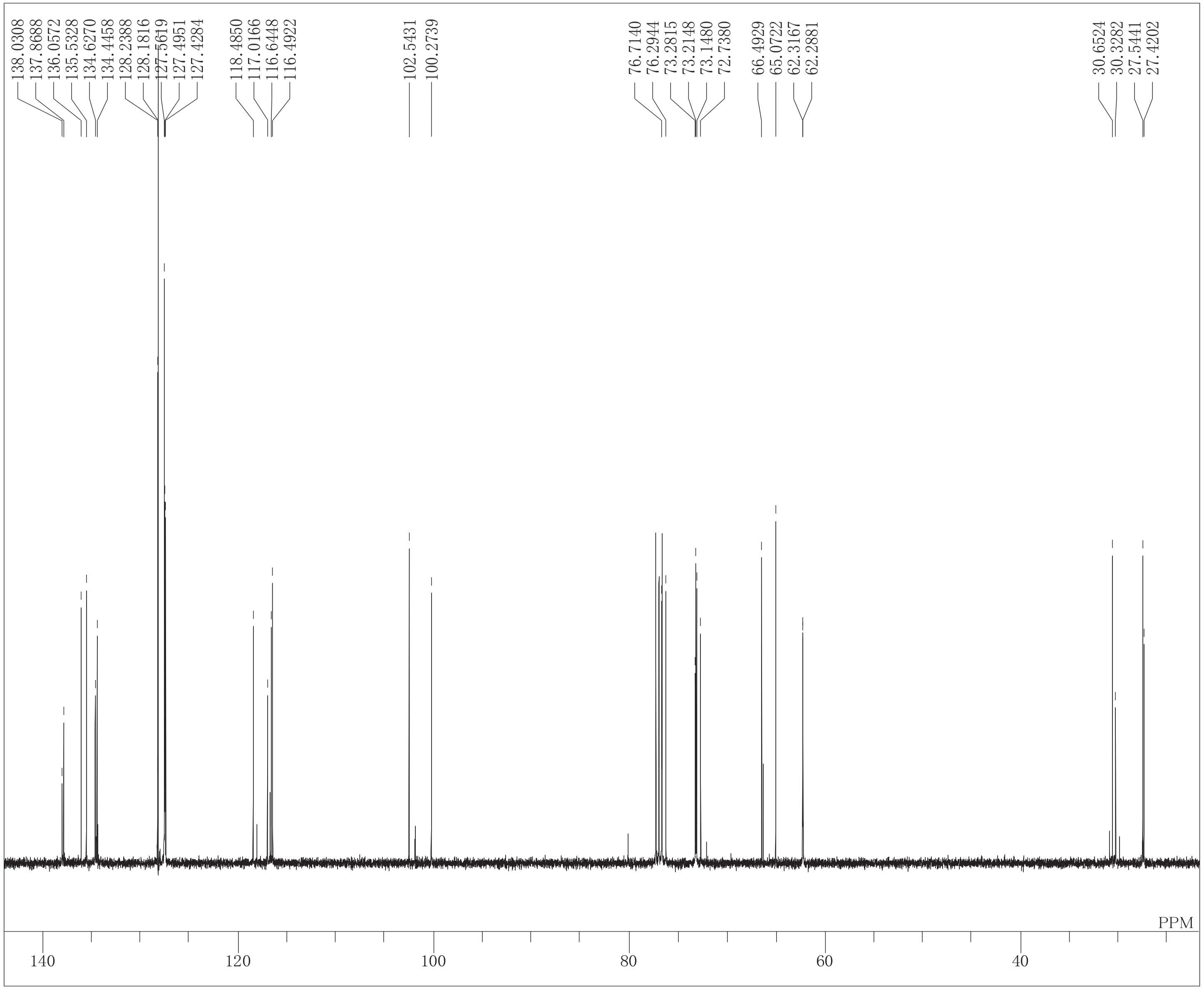
^{1}H NMR of **8**



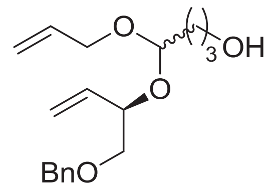


8

^{13}C NMR of **8**

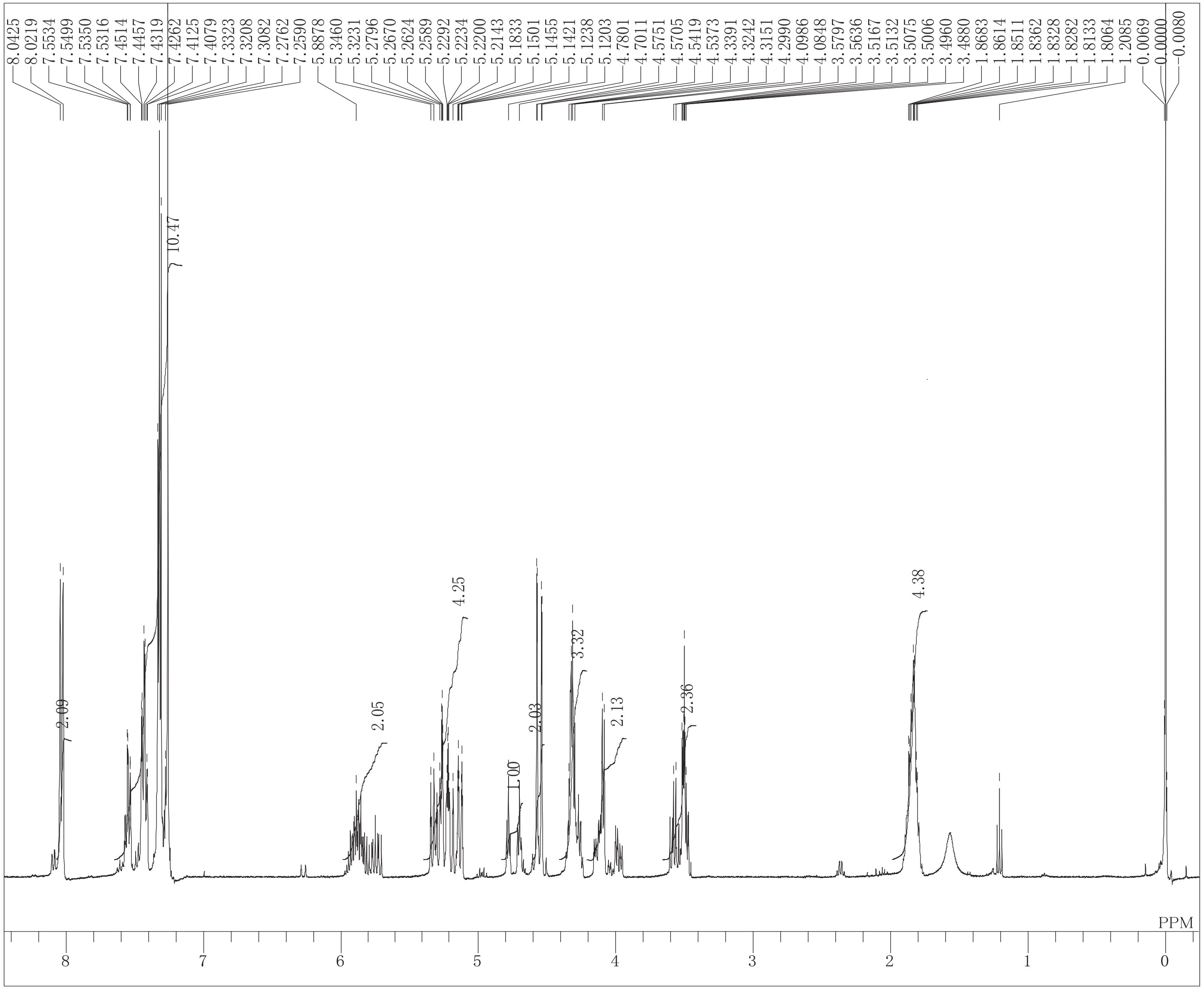


DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single pulse decoupled gated NOE
DATIM	03-01-2011 20:43:49
OBNUC	13C
EXMOD	single_pulse_dec
OBFRQ	100.53 MHz
OBSET	5.35 KHz
OBFIN	5.86 Hz
POINT	26214
FREQU	25125.24 Hz
SCANS	143
ACQTM	1.0433 sec
PD	2.0000 sec
PW1	3.17 usec
IRNUC	1H
CTEMP	21.5 c
SLVNT	CDCL3
EXREF	77.00 ppm
BF	0.12 Hz
RGAIN	60

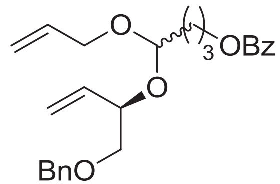


8

^{1}H NMR of **9**

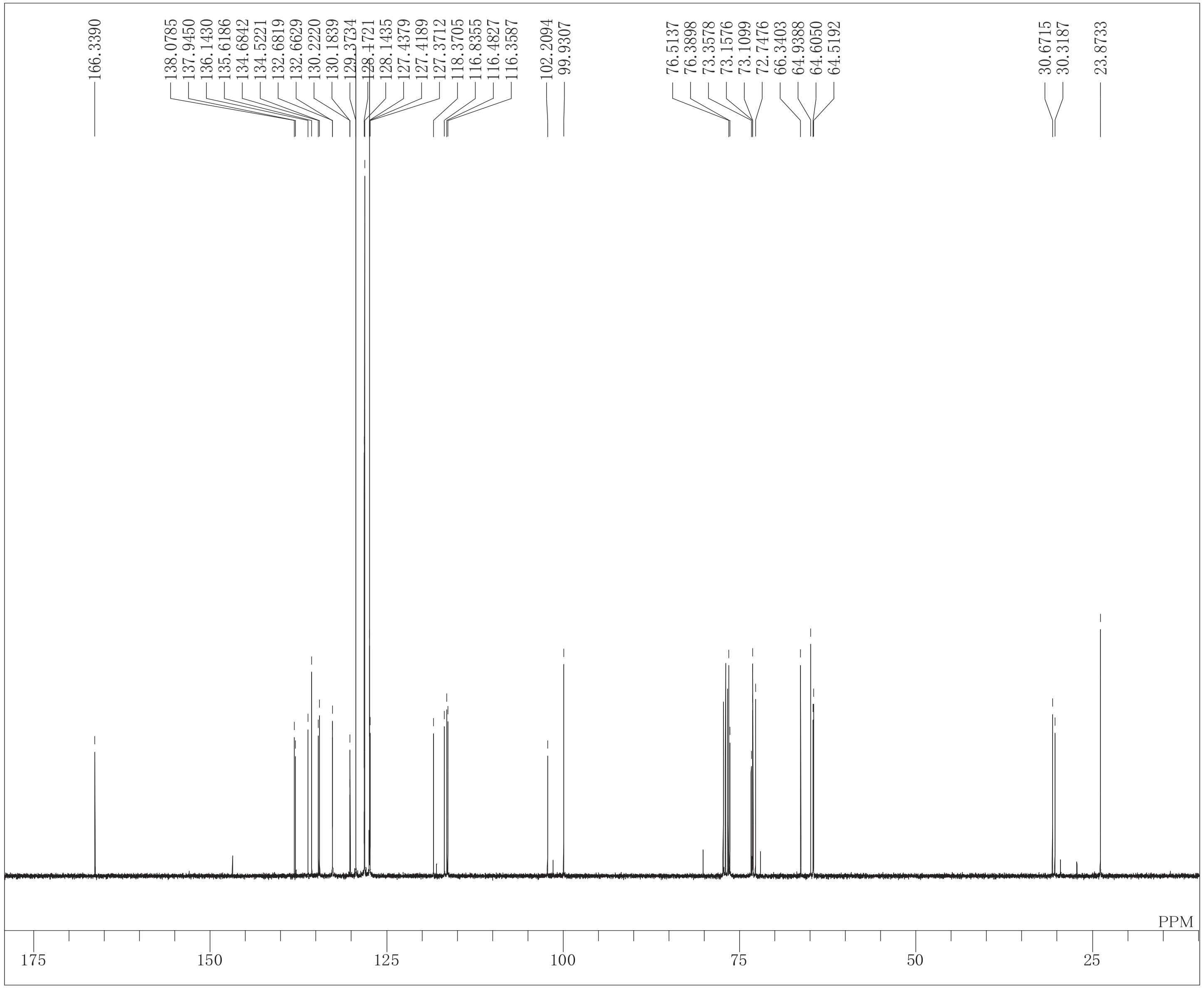


DFILE D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT single_pulse
DATIM 12-10-2010 07:45:06
OBNUC 1H
EXMOD single_pulse.ex2
OBFRQ 399.78 MHz
OBSET 4.19 KHz
OBFIN 7.29 Hz
POINT 13107
FREQU 6002.31 Hz
SCANS 16
ACQTM 2.1837 sec
PD 5.0000 sec
PW1 5.35 usec
IRNUC 1H
CTEMP 23.6 c
SLVNT CDCL3
EXREF 0.00 ppm
BF 0.12 Hz
RGAIN 44

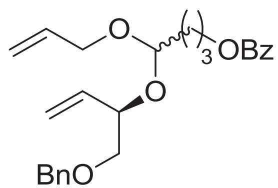


9

^{13}C NMR of **9**

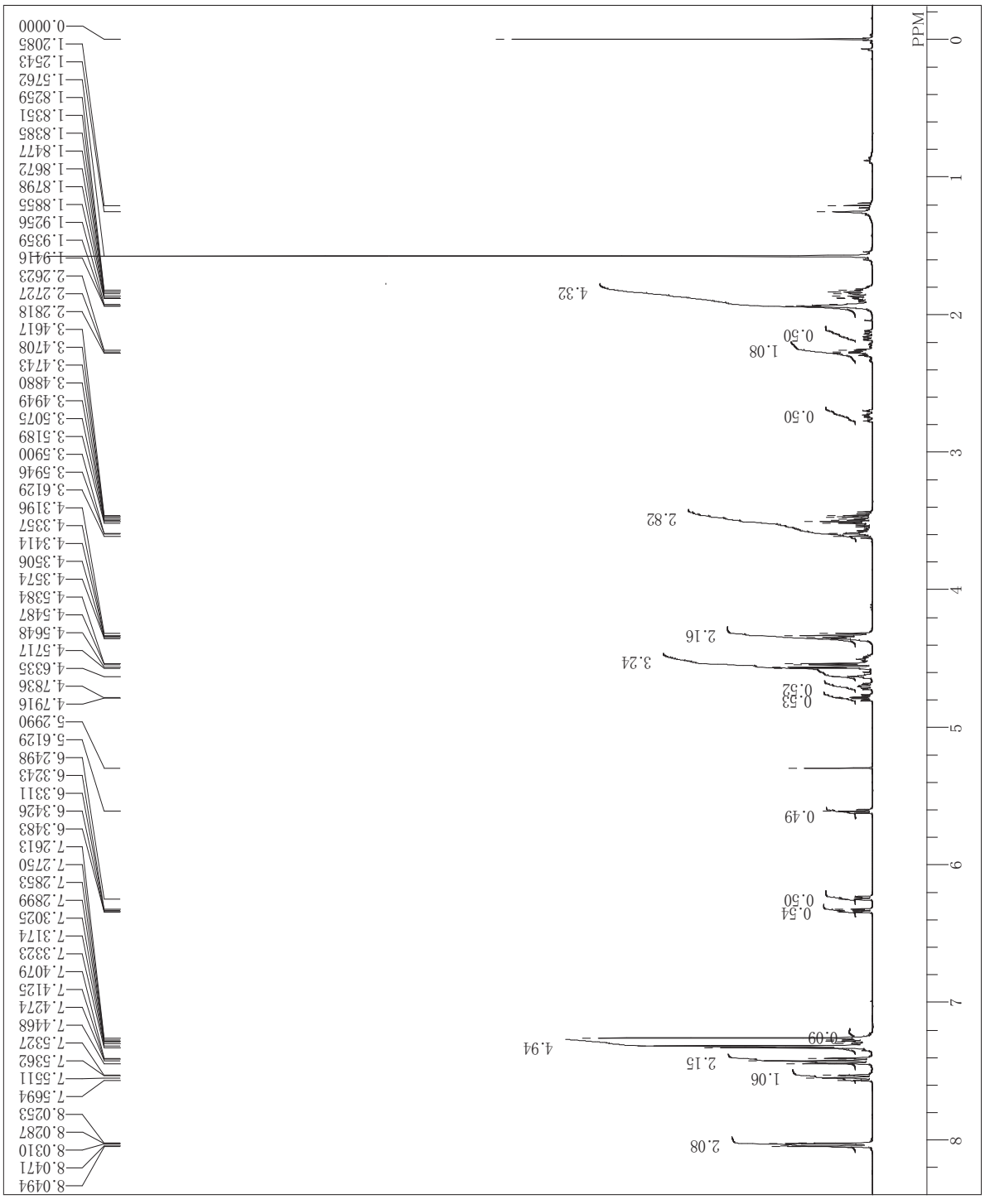


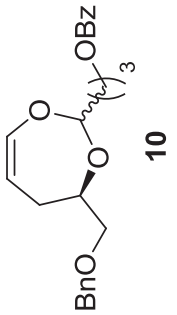
DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single pulse decoupled gated NOE
DATIM	03-01-2011 22:39:56
OBNUC	13C
EXMOD	single_pulse_dec
OBFRQ	100.53 MHz
OBSET	5.35 KHz
OBFIN	5.86 Hz
POINT	26214
FREQU	25125.24 Hz
SCANS	313
ACQTM	1.0433 sec
PD	2.0000 sec
PW1	3.17 usec
IRNUC	1H
CTEMP	21.3 c
SLVNT	CDCL3
EXREF	77.00 ppm
BF	0.12 Hz
RGAIN	60



9

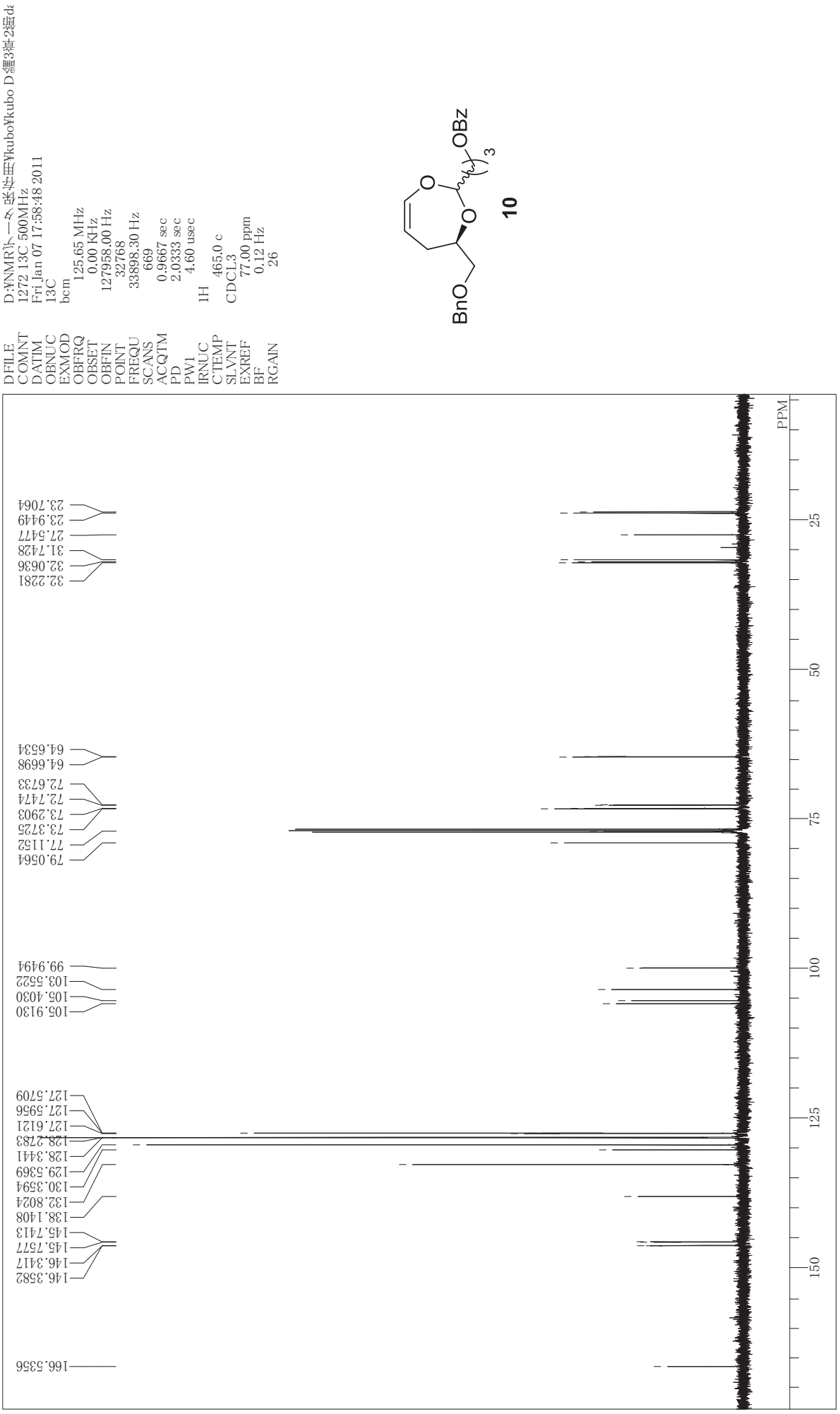
^{1}H NMR of **10**



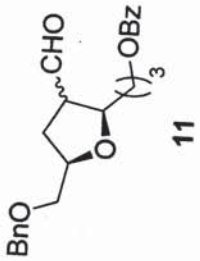


10

^{13}C NMR of **10**



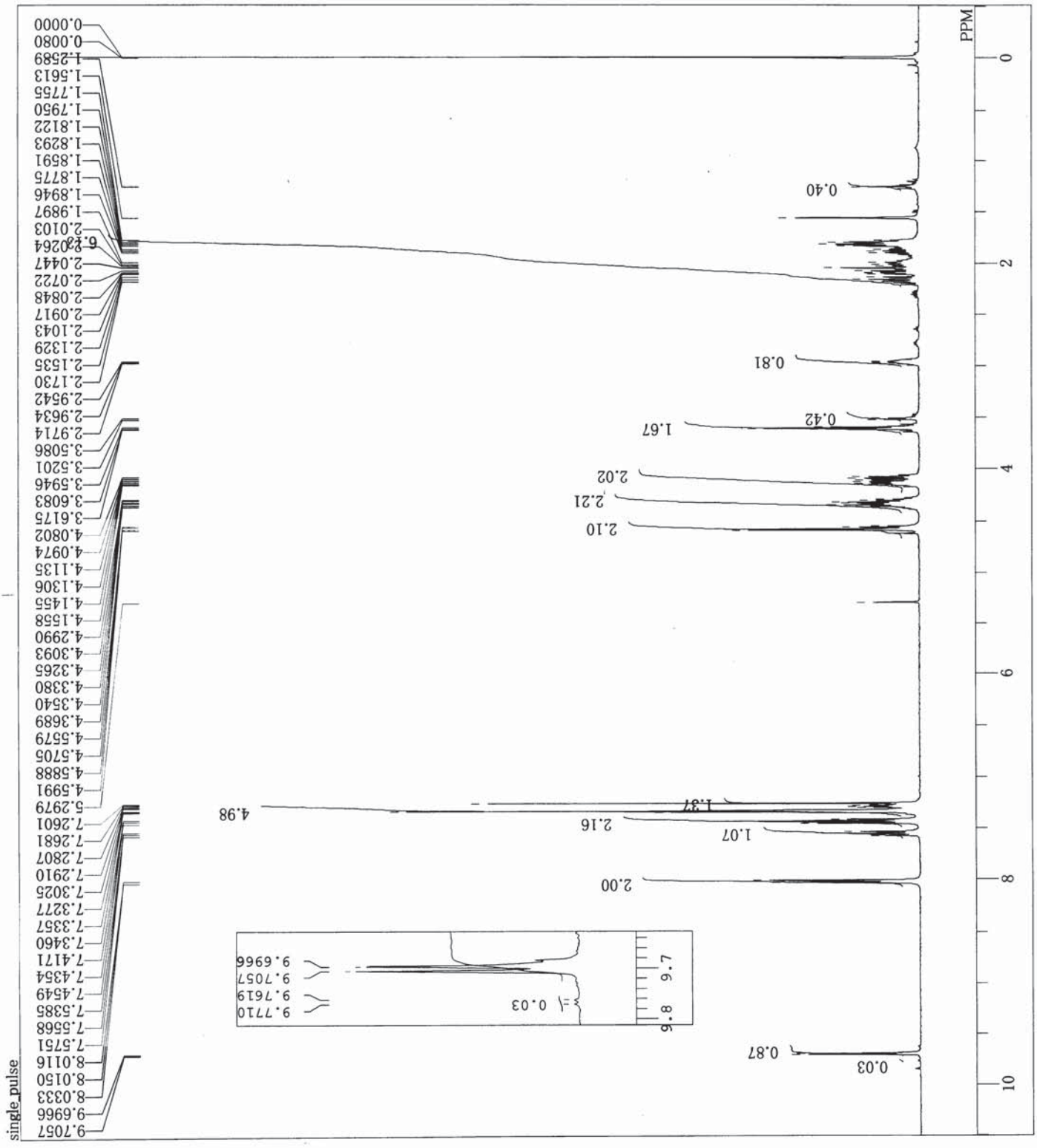
^{1}H NMR of 11



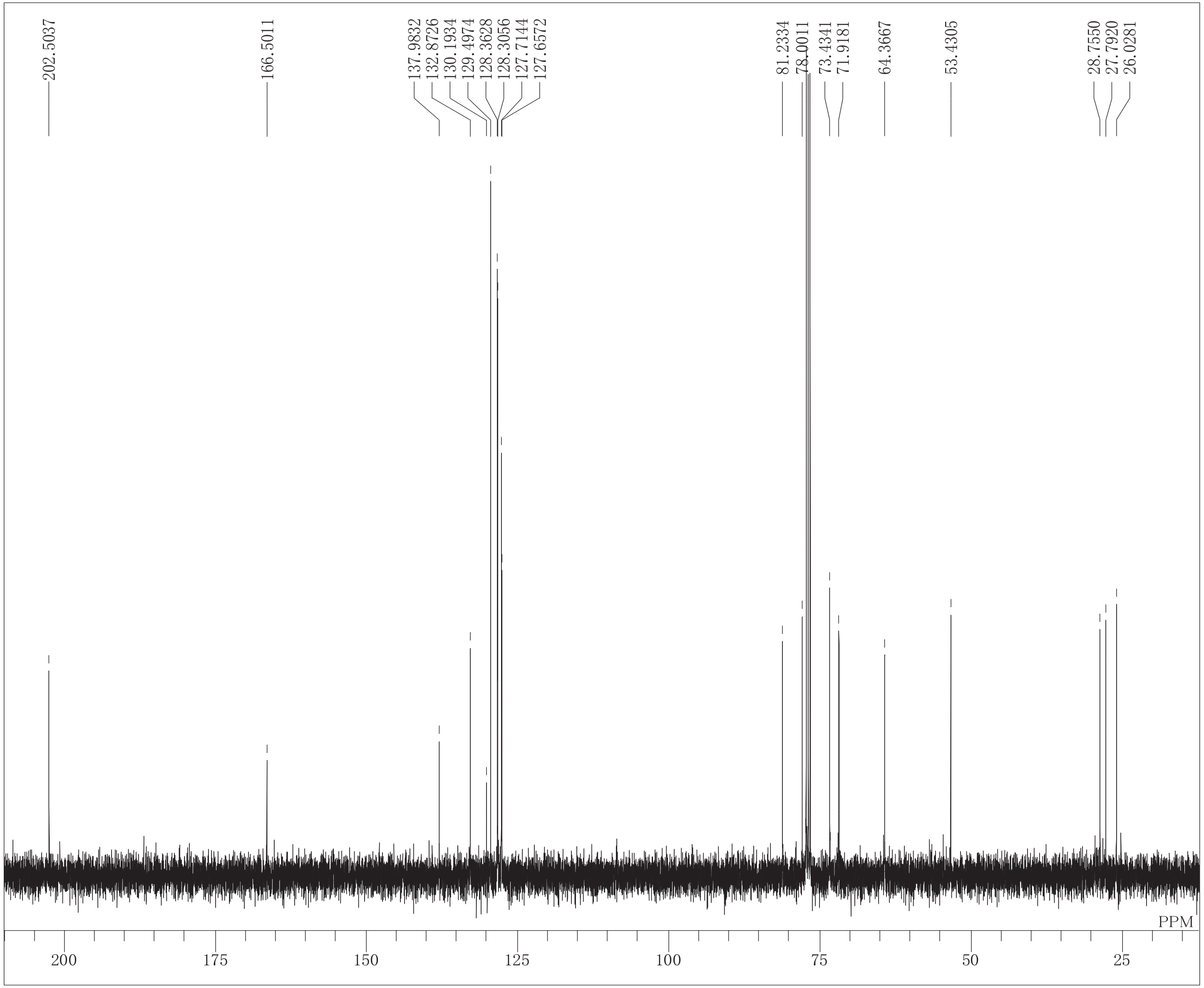
11

D:¥NMRデータ保存用¥kubo¥kubo NMR¥Original
single_pulse
13-10-2010 21:40:34
1H
single_pulse.ex2
399.78 MHz
4.19 KHz
7.29 Hz
13107
6002.31 Hz
16
2.1837 sec
5.0000 sec
5.35 usec
1H 23.9 c
CDCL3
0.00 ppm
0.12 Hz
44

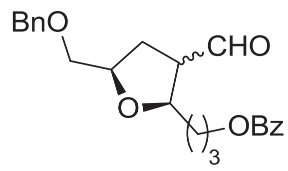
DFILE
COMNT
DATIM
OBNUC
EXMOD
OBFRQ
OBSET
OBFIN
POINT
FREQU
SCANS
ACQTM
PD
PW1
IRNUC
CTEMP
SLVNT
EXREF
BF
RGAIN



^{13}C NMR of **11**



DFILE	D:¥NMRデータ保存用¥kubo¥kubo D論3章2節da
COMNT	single pulse decoupled gated NOE
DATIM	07-01-2011 10:30:23
OBNUC	13C
EXMOD	single_pulse_dec
OBFRQ	100.53 MHz
OBSET	5.35 KHz
OBFIN	5.86 Hz
POINT	26214
FREQU	25125.24 Hz
SCANS	474
ACQTM	1.0433 sec
PD	2.0000 sec
PW1	3.17 usec
IRNUC	1H
CTEMP	21.9 c
SLVNT	CDCL3
EXREF	77.00 ppm
BF	0.12 Hz
RGAIN	60



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