Supporting Information

Intramolecular Reaction of a Phenonium Ion. Novel Lactonization of 4-Aryl-5-tosyloxypentanoates and 4-Aryl-5-tosyloxyhexanoates Concomitant with a Phenyl Rearrangement.

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Experimental Section

General methods

The melting points were determined on a Yanagimoto micro melting point apparatus and were uncorrected. IR spectra were recorded on a JASCO IRA-102 or a JASCO FT/IR-300 spectrometer. NMR spectra were recorded on a JEOL EX-400 or a JEOL GX-270 spectrometer using tetramethylsilane as an internal standard. Chemical shifts are given in ppm. The following abbreviations are used: s, singlet; d, doublet; t, triplet; q, quartet; br, broad. MS spectra were measured on a JEOL JMS-DX303 or a Hitachi M-2000 spectrometer. Optical rotations were measured with a JASCO DIP-370 digital polarimeter. The HPLC system was consisted of two SSC instruments (ultraviolet (UV) detector 3000B and flow system 3100). Column chromatography and lactonization were carried out on Merck's Silica gel 60 (70-230 mesh ASTM).

Typical procedures for silica gel promoted lactonization of 1 or 3

A mixture of **1** or **3** (100 mg), silica gel (500 mg) and hexane (5 ml) was stirred for an adequate time at rt. The reaction mixture was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (10 : 1) to give **2** or **4** and **5**. For the yield and reaction time, see Table 1 or 2.

Typical procedures for thermal lactonization of 3c

A solution **3c** in CH_3NO_2, ^tBuOH or CH_3COOH was stirred for an adequate time at 70°C. The reaction mixture was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (10 : 1) to give **4** and **5**. For the yield and reaction time, see Table 2.

5-[(4-Methoxyphenyl)methyl]-3,4,5-trihydrofuran-2-one 2c

White crystals; m.p. 45-46°C (AcOEt-hexane); IR (nujor) 1779 cm^{-1}; FAB-MS *m/z* 207 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.93 (m, 1H), 2.25 (m, 1H), 2.35-2.47 (m, 2H), 2.88 (dd, *J* = 14.2, 6.4 Hz, 1H), 3.00 (dd, *J* = 14.2, 5.9 Hz, 1H), 3.79 (s, 3H), 4.69 (m, 1H), 6.85 (d, *J* = 8.3 Hz, 2H), 7.14 (d, *J* = 8.3 Hz, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.91, 28.59, 40.33, 55.20, 80.91, 114.00 (x 2), 127.77, 130.43 (x 2), 158.58, 177.02; Anal. Calcd for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 69.56; H, 6.94.

5-[(2-Methoxy-4-methylphenyl)methyl]-3,4,5-trihydrofuran-2-one 2d

White crystals; m.p. 50-51.5°C (AcOEt-hexane); IR (nujor) 1773 cm^{-1}; FAB-MS *m/z* 221 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.95 (m, 1H), 2.18 (m, 1H), 2.33 (s, 3H), 2.41-2.47 (m, 2H), 2.84 (dd, *J* = 13.7, 6.8 Hz, 1H), 3.08 (dd, *J* = 13.7, 6.4 Hz, 1H), 3.81 (s, 3H), 4.77 (m, 1H), 6.69 (dd, *J* = 7.8, 2.0 Hz, 1H), 6.72 (d, *J* =2.0 Hz, 1H), 7.07 (d, *J* = 7.8 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 21.48, 27.13, 28.69, 35.32, 55.16, 80.23, 111.31, 121.13, 121.23, 131.00, 138.26, 157.33, 177.30; Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.87; H, 7.35.

5-[(4-Methoxy-2-methylphenyl)methyl]-3,4,5-trihydrofuran-2-one 2e

White crystals; m.p. 62-63°C (AcOEt-hexane); IR (nujor) 1775 cm^{-1}; FAB-MS *m/z* 221 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.96 (m, 1H), 2.25 (m, 1H), 2.30 (s, 3H), 2.45-2.49 (m, 2H), 2.85 (dd, *J* = 14.2, 6.4 Hz, 1H), 3.05 (dd, *J* = 14.2, 6.4 Hz, 1H), 3.77 (s, 3H), 4.68 (m, 1H), 6.68 (s, 1H), 6.72 (d, *J* = 8.0 Hz, 1H), 7.04 (d, *J* = 8.0 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.88, 27.31, 28.65, 37.58, 55.11, 80.50, 111.27, 116.02, 126.38, 131.02, 137.75, 158.45, 176.89; Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.52; H, 7.36.

5-[(2,4-Dimethoxyphenyl)methyl]-3,4,5-trihydrofuran-2-one 2f

White crystals; m.p. 89-90°C (AcOEt-hexane); IR (nujor) 1776 cm^{-1}; FAB-MS *m/z* 237 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.94 (m, 1H), 2.20 (m, 1H), 2.41-2.48 (m, 2H), 2.84 (dd, *J* = 13.7, 6.8 Hz, 1H), 3.05 (dd, *J* = 13.7, 6.4 Hz, 1H), 3.79 (s, 3H), 3.80 (s, 3H), 4.76 (m, 1H), 6.43 (dd, *J* = 7.8, 2.0 Hz, 1H), 6.45 (d, *J* = 2.0 Hz, 1H), 7.07 (d, *J* = 7.8 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 27.05, 28.69, 34.96, 55.24, 55.31, 80.28, 98.49, 104.10, 116.64, 131.55, 158.36, 159.99, 177.30; Anal. Calcd for $C_{13}H_{16}O_4$: C, 66.08; H, 6.82. Found: C, 65.92; H, 6.78.

5-[(2,6-Dimethoxyphenyl)methyl]-3,4,5-trihydrofuran-2-one 2g

White crystals; m.p. 63.5-64.5°C (AcOEt-hexane); IR (nujor) 1773 cm^{-1}; FAB-MS *m/z* 237 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 2.00 (m, 1H), 2.11 (m, 1H), 2.42 (dd, *J* = 17.5, 6.4 Hz, 1H), 2.65 (dd, *J* = 17.5, 6.4 Hz, 1H), 2.98 (dd, *J* = 12.7, 8.3 Hz, 1H), 3.05 (dd, *J* = 12.7, 5.9 Hz, 1H), 3.81 (s, 6H), 4.78 (m, 1H), 6.54 (d, *J* = 8.3 Hz, 2H), 7.18 (t, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.82, 28.10, 28.47, 55.57 (x 2), 79.86, 103.57 (x 2), 112.32, 128.01, 158.56 (x 2), 177.77; Anal. Calcd for $C_{13}H_{16}O_4$: C, 66.08; H, 6.82. Found: C, 65.81; H, 6.94.

5-[(2,6-Dimethoxy-4-methylphenyl)methyl]-3,4,5-trihydrofuran-2-one 2h

White crystals; m.p. 96-97°C (AcOEt-hexane); IR (nujor) 1766 cm^{-1}; FAB-MS *m/z* 251 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 2.04 (m, 1H), 2.17 (m, 1H), 2.39 (s, 3H), 2.47 (m, 1H), 2.61 (m, 1H), 2.99 (dd, *J* = 12.7, 8.8 Hz, 1H), 3.17 (dd, *J* = 12.7, 5.7 Hz, 1H), 3.85 (s, 6H), 4.81 (m, 1H), 6.62 (s, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 21.99, 26.76, 27.95, 28.47, 55.51 (x 2), 79.92, 104.49 (x 2), 109.27, 138.19, 158.36 (x 2), 177.65; Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 67.28; H, 7.42.

5-[(2,4-Dimethoxy-6-methylphenyl)methyl]-3,4,5-trihydrofuran-2-one 2i

White crystals; m.p. 74-75°C (AcOEt-hexane); IR (nujor) 1759 cm^{-1}; FAB-MS *m/z* 251 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 2.00 (m, 1H), 2.20 (m, 1H), 2.32 (s, 3H), 2.41-2.53 (m, 2H), 2.98 (d, *J* = 6.6 Hz, 2H) 3.78 (s, 6H), 4.71 (quintet, *J* = 6.6 Hz, 1H), 6.32 (d, *J* = 2.2 Hz, 1H), 6.34 (d, *J* = 2.2 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.36, 27.29, 28.74, 31.07, 55.20, 55.33, 80.61, 96.05, 106.76, 115.52, 138.99, 158.69, 159.05, 177.30; Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 66.98; H, 7.46.

5-[(2,4,5-Trimethoxyphenyl)methyl]-3,4,5-trihydrofuran-2-one 2j

White crystals; m.p. 70.5-71.5°C (AcOEt-hexane); IR (nujor) 1758 cm^{-1}; FAB-MS *m/z* 267 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.96 (m, 1H), 2.21 (m, 1H), 2.35-2.50 (m, 2H), 2.72 (dd, *J* = 14.1, 6.3 Hz, 1H), 3.06 (dd, *J* = 14.1, 6.3 Hz, 1H), 3.80 (s, 3H), 3.83 (s, 3H), 3.89 (s, 3H), 4.76 (m, 1H), 6.52 (s, 1H), 6.73 (s, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.94, 28.69, 34.92, 56.13 (x 2), 56.63, 80.37, 97.41, 115.16, 115.56, 142.88, 148.64, 151.70, 177.28; Anal. Calcd for $C_{14}H_{18}O_5$: C, 63.14; H, 6.81. Found: C, 62.99; H, 6.86.

5-[(2,3,4-Trimethoxyphenyl)methyl]-3,4,5-trihydrofuran-2-one 2k

White crystals; m.p. 91-92°C (AcOEt-hexane); IR (nujor) 1773 cm-1; FAB-MS m/z 267 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.98 (m, 1H), 2.23 (m, 1H), 2.43-2.48 (m, 2H), 2.86 (dd, *J* = 13.7, 6.4 Hz, 1H), 3.04 (dd, *J* = 13.7, 6.4 Hz, 1H), 3.85 (s, 3H), 3.86 (s, 3H), 3.90 (s, 3H), 4.73 (m, 1H), 6.61 (d, *J* = 8.3 Hz, 1H), 6.88 (d, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 27.09, 28.65, 35.14, 55.91, 60.64, 60.81, 80.59, 107.20, 121.74, 125.11, 142.09, 151.94, 152.87, 177.19; Anal. Calcd for $C_{14}H_{18}O_5$: C, 63.14; H, 6.81. Found: C, 62.84; H, 6.66.

(*R)-5-[(*R**)-1-(4-Methoxyphenyl)ethyl]-3,4,5-trihydrofuran-2-one 4a**

White crystals; m.p. 42-42.5°C (AcOEt-hexane); IR (nujor) 1770 cm^{-1}; FAB-MS *m/z* 221 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.38 (d, *J* = 6.8 Hz, 3H), 1.82 (m, 1H), 2.00 (m, 1H), 2.30 (td, *J* = 9.8, 4.9 Hz, 1H), 2.41 (ddd, *J* = 9.8, 9.3, 5.4 Hz, 1H), 2.88 (dq, *J* = 8.0, 6.8 Hz, 1H), 3.79 (s, 3H), 4.50 (q, *J* = 8.0 Hz, 1H), 6.86 (d, *J* = 8.8 Hz, 2H), 7.10 (d, *J* = 8.8 Hz, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 18.60, 26.39, 29.20, 44.51, 55.69, 85.25, 114.53 (x 2), 129.18 (x 2), 133.73, 159.11, 177.68; Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.75; H, 7.43.

(*R)-5-[(*R**)-1-(2-Methoxyphenyl)ethyl]-3,4,5-trihydrofuran-2-one 4b**

Colorless oil; IR (neat) 1770 cm^{-1}; EI-MS *m/z* 220 (M^+), 135; HR-MS *m/z* Calcd for $C_{13}H_{16}O_3$: 220.1098. Found: 220.1068; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.38 (d, *J* = 7.0 Hz, 3H), 1.84 (dddd, *J* = 13.0, 7.7, 6.3, 5.7 Hz, 1H), 2.01 (dddd, *J* = 13.0, 8.4, 6.6, 5.5 Hz, 1H), 2.46 (ddd, *J* = 9.2, 6.3, 5.5 Hz, 1H), 2.48 (ddd, *J* = 9.2, 6.6, 5.7 Hz, 1H), 3.35 (qd, *J* = 7.0, 6.8 Hz, 1H), 3.83 (s, 3H), 4.65 (ddd, *J* = 8.4, 7.7, 6.8 Hz, 1H), 6.88 (dd, *J* = 8.2, 1.1 Hz, 1H), 6.94 (td, *J* = 7.5, 1.1 Hz, 1H), 7.17 (dd, *J* = 7.5, 1.1 Hz, 1H), 7.22 (ddd, *J* = 8.2, 7.5, 1.1 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 17.32, 26.34, 28.89, 38.26, 55.33, 84.77, 110.72, 120.84, 127.86, 128.18, 130.30, 156.91, 177.48.

(*R)-5-[(*R**)-1-(3,4-Dimethoxyphenyl)ethyl]-3,4,5-trihydrofuran-2-one 4c**

White crystals; m.p. 70.5-71.5°C (AcOEt-hexane); IR (nujor) 1765 cm^{-1}; FAB-MS *m/z* 251 (MH^+); ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.40 (d, *J* = 7.1 Hz, 3H), 1.84 (m, 1H), 2.02 (m, 1H), 2.28 (ddd, *J* = 17.8, 9.5, 4.9 Hz, 1H), 2.42 (dt, *J* = 17.8, 9.0 Hz, 1H), 2.89 (quintet, *J* = 7.1 Hz, 1H), 3.87 (s, 3H), 3.88 (s, 3H), 4.53 (q, *J* = 7.1 Hz, 1H), 6.72 (d, *J* = 2.0 Hz, 1H), 6.75 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.83 (d, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 18.40, 26.23, 29.09, 44.75, 56.26, 56.34, 85.05, 111.53, 111.73, 120.05, 134.19, 148.49, 149.39, 177.59; Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 67.05; H, 7.28.

(*R)-5-[(*R**)-1-(4-Methoxy-2-methylphenyl)ethyl]-3,4,5-trihydrofuran-2-one 4d**

White crystals; m.p. 67-68.5°C (AcOEt-hexane); IR (nujor) 1775 cm^{-1}; FAB-MS *m/z* 234 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.34 (d, *J* = 6.8 Hz, 3H), 1.74 (m, 1H), 2.05 (m, 1H), 2.32 (s, 3H), 2.40-2.50 (m, 2H), 3.11 (quintet, *J* = 6.8 Hz, 1H), 3.83 (s, 3H), 4.65 (q, *J* = 6.8 Hz, 1H), 6.72 (s, 1H), 6.73 (d, *J* = 8.3 Hz, 1H), 7.06 (d, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 18.73, 20.14, 26.34, 28.85, 39.28, 55.13, 85.18, 111.80, 116.07, 127.17, 132.41, 137.16, 157.93, 177.17; Anal. Calcd for $C_{14}H_{18}O_3$: C, 71.77; H, 7.74. Found: C, 71.88; H, 7.74.

(*R)-5-[(*R**)-1-(2-Methoxy-4-methylphenyl)ethyl]-3,4,5-trihydrofuran-2-one 4e**

colorless oil; IR (neat) 1775 cm^{-1}; EI-MS *m/z* 234 (M^+), 149; HR-MS *m/z* Calcd for $C_{14}H_{18}O_3$ 234.1255, Found 234.1283; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.35 (d, *J* = 6.8 Hz, 3H), 1.84 (m, 1H), 1.97 (m, 1H), 2.33 (s, 3H), 2.43-2.49 (m, 2H), 3.29 (quintet, *J* = 6.8 Hz, 1H), 3.81 (s, 3H), 4.62 (ddd, *J* = 8.8, 7.8, 6.8 Hz, 1H), 6.69 (s, 1H), 6.74 (d, *J* = 7.3 Hz, 1H), 7.03 (d, *J* = 7.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 17.51, 21.45, 26.39, 28.93, 38.08, 55.34, 84.97, 111.76, 121.46, 127.31, 128.02, 137.87, 156.85, 177.58.

(5*R, 6*R**)-Tetrahydro-5-(4-methoxyphenyl)-6-methyl-2H-pyran-2-one 5a**

White crystals; m.p. 83-84°C (AcOEt-hexane); IR (nujor) 1720 cm^{-1}; FAB-MS *m/z* 221 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.18 (d, *J* = 6.2 Hz, 3H), 2.06-2.12 (m, 2H), 2.57-2.69 (m, 2H), 2.78 (ddd, *J* = 10.8, 10.4, 5.9 Hz, 1H), 3.80 (s, 3H), 4.47 (dq, *J* = 10.4, 6.2 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 7.10 (d, *J* = 8.8 Hz, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.16, 27.73, 30.06, 46.23, 55.25, 81.47, 114.31 (x 2), 128.43 (x 2), 132.65, 158.83, 171.19; Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 71.03; H, 7.47.

(5*R, 6*R**)-Tetrahydro-5-(2-methoxyphenyl)-6-methyl-2H-pyran-2-one 5b**

Colorless oil; IR (neat) 1730 cm^{-1}; EI-MS *m/z* 220 (M^+), 176, 155, 134; HR-MS *m/z* Calcd for $C_{13}H_{16}O_3$: 220.1098. Found: 220.1123; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.18 (d, *J* = 6.2 Hz, 3H), 2.02 (dtd, *J* = 13.6, 7.0, 5.8 Hz, 1H), 2.17 (m, 1H), 2.60 (ddd, *J* = 15.3, 7.0 Hz, 1H), 2.79 (dt, *J* = 15.3, 7.0 Hz, 1H), 3.14 (ddd, *J* = 10.4, 7.0, 5.8 Hz, 1H), 3.84 (s, 3H), 4.72 (dq, *J* = 10.4, 6.2 Hz, 1H), 6.90 (d, *J* = 8.4 Hz, 1H), 6.94 (t, *J* = 8.4 Hz, 1H), 7.13 (dd, *J* = 8.4, 1.6 Hz, 1H), 7.25 (td, *J* = 8.4, 1.6 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.94, 25.77, 29.90, 41.26, 55.31, 79.73, 110.96, 120.90, 128.27, 128.54, 129.00, 157.07, 172.20.

(5*R, 6*R**)-Tetrahydro-5-(3,4-dimethoxyphenyl)-6-methyl-2H-pyran-2-one 5c**

White crystals; m.p. 117-118.5°C (AcOEt-hexane); IR (nujor) 1730 cm^{-1}; FAB-MS *m/z* 251 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.21 (d, *J* = 6.4 Hz, 3H), 2.06-2.17 (m, 2H), 2.55-2.70 (m, 2H), 2.79 (dt, *J* = 10.7, 5.4 Hz, 1H), 3.88 (s, 3H), 3.89 (s, 3H), 4.71 (dq, *J* = 10.3, 6.4 Hz, 1H), 6.68 (d, *J* = 1.0 Hz, 1H), 6.74 (dd, *J* = 7.8, 1.0 Hz, 1H), 6.85 (d, *J* = 7.8 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.25, 27.77, 30.04, 46.73, 55.91, 55.97, 81.40, 110.68, 111.56, 119.48, 133.20, 148.35, 149.23, 171.12; Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 66.91; H, 7.50.

(5*R, 6*R**)-Tetrahydro-5-(4-methoxy-2-methylphenyl)-6-methyl-2H-pyran-2-one 5d**

White crystals; m.p. 123-123.5°C (AcOEt-hexane); IR (nujor) 1720 cm^{-1}; FAB-MS *m/z* 234 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.19 (d, *J* = 6.3 Hz, 3H), 1.99-2.05 (m, 2H), 2.34 (s, 3H), 2.62 (dt, *J* = 17.5, 8.5 Hz, 1H), 2.80 (dt, *J* = 17.5, 5.5 Hz, 1H), 3.00 (ddd, *J* = 10.3, 9.8, 6.8 Hz, 1H), 3.78 (s, 3H), 4.58 (dq, *J* = 10.3, 6.3 Hz, 1H), 6.74 (s, 1H), 6.75 (d, *J* = 6.8 Hz, 1H), 7.01 (d, *J* = 6.8 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.70, 20.23, 27.53, 30.08, 40.79, 55.14, 81.73, 111.93, 116.24, 126.60, 131.35, 137.38, 158.06, 171.34; Anal. Calcd for $C_{14}H_{18}O_3$: C, 71.77; H, 7.74. Found: C, 71.38; H, 7.76.

(5*R, 6*R**)-Tetrahydro-5-(2-methoxy-4-methylphenyl)-6-methyl-2H-pyran-2-one 5e**

Colorless oil; IR (neat) 1735 cm^{-1}; EI-MS *m/z* 234 (M^+), 190, 148; HR-MS *m/z* Calcd for $C_{14}H_{18}O_3$ 234.1255, Found 234.1280; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.17 (d, *J* = 5.9 Hz, 3H), 1.95-2.20 (m, 2H), 2.34 (s, 3H), 2.59 (dt, *J* = 18.0, 8.0 Hz, 1H), 2.78 (dt, *J* = 18.0, 6.0 Hz, 1H), 3.07 (td, *J* = 10.2, 5.9 Hz, 1H), 3.82 (s, 3H), 4.68 (dq, *J* = 10.2, 5.9 Hz, 1H), 6.71 (s, 1H), 6.74 (d, *J* = 7.8 Hz, 1H), 6.98 (d, *J* = 7.8 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.92, 21.42, 25.84, 29.91, 40.97, 55.24, 79.84, 111.91, 121.43, 125.96, 128.30, 138.28, 156.93, 172.26.

Typical Procedures for acetolysis of 6 or 7

A solution of **6** or **7** (100 mg) in AcOH (5 ml) was stirred at 70°C. After 1 h, saturated aqueous $NaHCO_3$ was added to the mixture at 0°C, and the whole was extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (8 : 2) to give a mixture of **8** and **9**. Ref. Table 3 for yields and ratios.

(1*R)-1-[(1*R**)-1-(2,3-Dimethoxyphenyl)ethyl]pentyl acetate 8a**

Colorless oil; IR (neat) 1725 cm^{-1}; EI-MS *m/z* 294 (M^+), 234, 165; HR-MS *m/z* Calcd for $C_{17}H_{26}O_4$ 294.1830, Found 294.1856; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.81 (br t, *J* = 6.3 Hz, 3H), 1.23 (d, *J* = 7.1 Hz, 3H), 1.20-1.50 (m, 6H), 2.08 (s, 3H), 2.82 (quintet, *J* = 7.1 Hz, 1H), 3.86 (s, 3H), 3.88 (s, 3H), 5.02 (dt, *J* = 7.1, 4.2 Hz, 1H), 6.68-6.83 (m, 3H) ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.93, 17.78, 21.15, 22.45, 27.49, 31.88, 43.50, 55.82, 55.88, 78.01, 110.83, 111.14, 119.81, 136.19, 147.65, 148.82, 170.92.

(1*R)-1-[(1*R**)-1-(4-Methoxy-2-methylphenyl)ethyl]pentyl acetate 8b**

Colorless oil; IR (neat) 1720 cm^{-1}; EI-MS *m/z* 278 (M^+), 218, 149; HR-MS *m/z* Calcd for $C_{17}H_{26}O_3$: 278.1881. Found: 278.1897; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.81 (t, *J* = 6.8 Hz, 3H), 1.17 (d, *J* = 7.1 Hz, 3H), 1.10-1.48 (m, 6H), 2.06 (s, 3H), 2.30 (s, 3H), 3.09 (quintet, *J* = 7.1 Hz, 1H), 3.77 (s, 3H), 5.09 (q, *J* = 7.1 Hz, 1H), 6.67-6.75 (m, 2H), 7.10 (d, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.91, 17.52, 20.05, 21.09, 22.43, 27.71, 32.04, 37.85, 55.03, 77.83, 111.42, 115.78, 127.41, 134.26, 136.78, 157.53, 170.90.

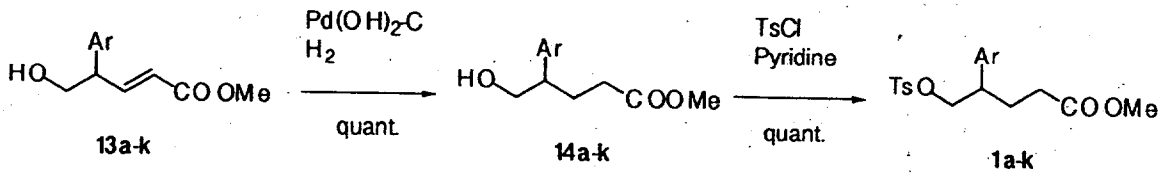
(1*R, 2*R**)-2-(2,3-Dimethoxyphenyl)-1-methylhexyl acetate 9a**

Colorless oil; IR (neat) 1720 cm^{-1}; EI-MS *m/z* 294 (M^+), 234, 207, 151; HR-MS *m/z* Calcd for $C_{17}H_{26}O_4$: 294.1830. Found: 294.1852; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.81 (t, *J* = 7.2 Hz, 3H), 1.01 (d, *J* = 6.4 Hz, 3H), 0.96-1.40 (m, 4H), 1.51 (m, 1H), 1.73 (m, 1H), 2.07 (s, 3H), 2.60 (ddd, *J* = 11.1, 8.5, 3.8 Hz, 1H), 3.868 (s, 3H), 3.874 (s, 3H), 5.01 (dq, *J* = 8.5, 6.4 Hz, 1H), 6.63-6.72 (m, 2H), 6.80 (d, *J* = 8.1 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.89, 18.29, 21.33, 22.60, 29.49, 31.47, 50.84, 55.75, 55.86, 74.32, 111.01, 111.27, 120.71, 134.04, 147.67, 148.86, 170.73.

(1*R, 2*R**)-2-(4-Methoxy-2-methylphenyl)-1-methylhexyl acetate 9b**

Colorless oil; IR (neat) 1720 cm^{-1}; EI-MS *m/z* 278 (M^+), 218, 191, 135; HR-MS *m/z* Calcd for $C_{17}H_{26}O_3$: 278.1881. Found: 278.1883; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.80 (t, *J* = 7.2 Hz, 3H), 1.00 (d, *J* = 6.5 Hz, 3H), 0.97-1.36 (m, 4H), 1.51 (m, 1H), 1.77 (m, 1H), 2.07 (s, 3H), 2.30 (s, 3H), 2.96 (m, 1H), 3.78 (s, 3H), 5.02 (dq, *J* = 8.8, 6.5 Hz, 1H), 6.69-6.76 (m, 2H), 7.05 (d, *J* = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.91, 18.11, 20.47, 21.33, 22.82, 29.27, 32.13, 44.67, 54.98, 74.98, 111.51, 115.63, 127.55, 132.34, 138.02, 157.48, 170.71.

Synthesis of 1a-k



Ref. Preparation of compounds **13a-g** and **1i** has been reported. Compounds **13h, j, k** were synthesized according to the procedure. See (a) Ono, M.; Yamamoto, Y.; Todoriki, R.; Akita, H. *Heterocycles* **1994**, *37*, 181. (b) Ono, M; Todoriki, R.; Yamamoto, Y.; Akita, H. *Chem. Pharm. Bull.* **1994**, *42*, 1590. (c) Ono, M.; Yamamoto, Y.; Akita, H. *Chem. Pharm. Bull.* **1995**, *43*, 553. (d) Ono, M.; Ogura, Y.; Hatogai, K.; Akita, H. *Tetrahedron: Asymmetry* **1995**, *6*, 1829. (e) Nagumo, S.; Irie, S.; Akita, H. *J. Chem. Soc., Chem. Commun.* **1995**, 2001. (f) Nagumo, S.; Irie, S.; Akita, H. *Chem. Pharm. Bull.* **1996**, *44*, 675. (g) Nagumo, S.; Irie, S.; Hayashi, K.; Akita, H. *Heterocycles* **1996**, *43*, 1175.

Compound 14

A mixture of **13** (1.5 mmol), 20% $Pd(OH)_2$-C (30 mg) and MeOH (10 ml) was stirred under H_2 atmosphere for 3 h. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (7 : 3) to give **14** quantitatively.

14a Colorless oil: IR (neat) 3420, 1738cm^{-1}; SIMS *m/z* 209 (MH^+), 191, 177; HR-MS *m/z* Calcd for $C_{12}H_{17}O_3$: 209.1178, Found: 209.1207; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.69 (br s, 1H), 1.89 (m, 1H), 2.10 (m, 1H), 2.18-2.26 (m, 2H), 2.79 (m, 1H), 3.61 (s, 3H), 3.75 (d, J = 6.6 Hz, 2H), 7.16-7.37 (m, 5H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 27.05, 31.82, 47.97, 51.48, 67.12, 126.98, 127.99 (x 2), 128.73 (x 2), 141.16, 173.91.

14b Colorless oil: IR (neat) 3428, 1736cm^{-1}; EI-MS *m/z* 238 (M^+), 220; HR-MS *m/z* Calcd for $C_{13}H_{18}O_4$: 238.1204, Found: 238.1230; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.60 (br s, 1H), 1.87 (m, 1H), 2.08 (m, 1H), 2.19-2.28 (m, 2H), 2.78 (m, 1H), 3.63 (s, 3H), 3.75 (d, J = 7.1 Hz, 2H), 3.81 (s, 3H), 6.74-6.83 (m, 3H), 7.25 (t, J = 7.9 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 27.07, 31.86, 48.08, 51.53, 55.18, 67.15, 112.11, 114.02, 120.31, 129.84, 142.83, 159.97, 173.89.

14c Colorless oil: IR (neat) 3400, 1710cm^{-1}; EI-MS *m/z* 238 (M^+), 220, 207; HR-MS *m/z* Calcd for $C_{13}H_{18}O_4$: 238.1204, Found: 238.1224; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.51 (br s, 1H), 1.84 (m, 1H), 2.07 (m, 1H), 2.17-2.28 (m, 2H), 2.75 (m, 1H), 3.62 (s, 3H), 3.72 (m, 2H), 3.79 (s, 3H), 6.87 (d, J = 8.7 Hz, 2H), 7.12 (d, J = 8.7 Hz, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 27.20, 31.84, 47.15, 51.50, 55.22, 67.26, 114.20 (x 2), 128.95 (x 2), 132.91, 158.59, 173.94.

14d Colorless oil: IR (neat) 3452, 1734cm^{-1}; EI-MS *m/z* 252 (M^+), 234; HR-MS *m/z* Calcd for $C_{14}H_{20}O_4$: 252.1360, Found: 252.1376; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.67 (br s, 1H), 1.91 (m, 1H), 2.09 (m, 1H), 2.20-2.30 (m, 2H), 2.33 (s, 3H), 3.25 (m, 1H), 3.62 (s, 3H), 3.72-3.78 (m, 2H), 3.79 (s, 3H), 6.70 (br s, 1H), 6.75 (br d, J = 7.7 Hz, 1H), 7.03 (d, J = 7.7 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 21.39, 26.19, 31.99, 40.62, 51.42, 55.31, 66.24, 111.75, 121.45, 126.07, 127.88, 137.80, 157.68, 174.16.

14e Colorless oil: IR (neat) 3454, 1738cm^{-1}; EI-MS *m/z* 252 (M^+), 234, 221; HR-MS *m/z* Calcd for $C_{14}H_{20}O_4$: 252.1360, Found: 252.1373; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.41 (br s, 1H), 1.86 (m, 1H), 2.09 (m, 1H), 2.18-2.27 (m, 2H), 2.30 (s, 3H), 3.11 (m, 1H), 3.62 (s, 3H), 3.70 (m, 2H), 3.78 (s, 3H), 6.68-6.80 (m, 2H), 7.09 (d, J = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.53, 27.75, 32.19, 42.03, 51.97, 55.60, 67.54, 112.28, 116.61, 127.30, 131.64, 139.10, 158.41, 174.46.

1 4f Colorless oil: IR (neat) 3450, 1730cm^{-1}; EI-MS *m/z* 268 (M^+), 250, 237; HR-MS *m/z* Calcd for $C_{14}H_{20}O_5$: 268.1310, Found: 268.1331; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.72-1.98 (m, 2H), 2.08 (m, 1H), 2.19-2.28 (m, 2H), 3.20 (m, 1H), 3.62 (s, 3H), 3.70-3.77 (m, 2H), 3.78 (s, 3H), 3.79 (s, 3H), 6.42-6.50 (m, 2H), 7.05 (d, J = 7.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.25, 31.97, 40.46, 51.42, 55.29 (x 2), 66.20, 98.78, 104.43, 121.39, 128.56, 158.76, 159.55, 174.18.

1 4g Colorless oil: IR (neat) 3450, 1736cm^{-1}; EI-MS *m/z* 268 (M^+), 250; HR-MS *m/z* Calcd for $C_{14}H_{20}O_5$: 268.1310, Found: 268.1333; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.75 (br s, 1H), 1.97-2.34 (m, 4H), 3.60 (s, 3H), 3.62 (m, 1H), 3.79 (s, 6H), 3.82-3.99 (m, 2H), 6.53 (d, J = 8.3 Hz, 2H), 7.16 (t, J = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 24.85, 32.52, 37.87, 51.33, 55.64 (x 2), 65.45, 104.25 (x 2), 116.99, 127.94, 159.16 (x 2), 174.36.

1 4h White crystals: m.p. 61.5°C (AcOEt-hexane), IR (neat) 3420, 1720cm^{-1}; EI-MS *m/z* 282 (M^+), 264, 251; HR-MS *m/z* Calcd for $C_{15}H_{22}O_5$: 282.1466, Found: 282.1462; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.81 (br s, 1H), 1.95-2.31 (m, 4H), 2.32 (s, 3H), 3.56 (m, 1H), 3.60 (s, 3H), 3.76 (s, 6H), 3.80-3.98 (m, 2H), 6.36 (s, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 21.86, 24.87, 32.46, 37.63, 51.26, 55.55 (x 2), 65.45, 105.11 (x 2), 113.82, 137.97, 158.89 (x 2), 174.38; Anal. Calcd for $C_{15}H_{22}O_5$: C, 63.80; H, 7.87. Found: C, 63.64; H, 7.93.

1 4i Colorless oil: IR (neat) 3450, 1734cm^{-1}; EI-MS *m/z* 282 (M^+), 264, 251; HR-MS *m/z* Calcd for $C_{15}H_{22}O_5$: 282.1466, Found: 282.1468; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.66 (br s, 1H), 1.95-2.26 (m, 4H), 2.29 (s, 3H), 3.17 (br s, 1H), 3.60 (s, 3H), 3.76 (s, 3H), 3.78 (s, 3H), 3.79-3.98 (m, 2H). 6.32 (s, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 21.75, 25.24, 32.61, 42.16,

51.61, 55.36 (x 2), 65.61, 97.28, 107.57, 119.47, 140.09, 159.09, 159.75, 174.53.

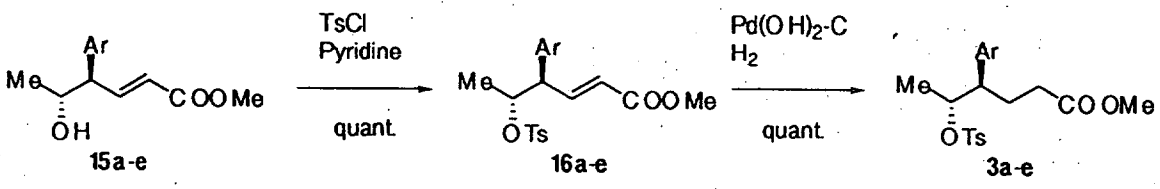
14j Colorless oil: IR (neat) 3450, 1715cm^{-1}; EI-MS *m/z* 298 (M^+), 280, 267; HR-MS *m/z* Calcd for $C_{15}H_{22}O_6$: 298.1415, Found: 298.1389; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.67 (br s, 1H), 1.89 (m, 1H), 2.10 (m, 1H), 2.20-2.34 (m, 2H), 3.23 (m, 1H), 3.63 (s, 3H), 3.75 (d, J = 6.4 Hz, 2H), 3.79 (s, 3H), 3.83 (s, 3H), 3.88 (s, 3H), 6.53 (s, 1H), 6.70 (s, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.28, 31.95, 40.57, 51.42, 56.08, 56.41, 56.70, 66.29, 97.96, 112.17, 120.57, 143.28, 148.29, 152.20, 174.11.

14k Colorless oil: IR (neat) 3450, 1720cm^{-1}; EI-MS *m/z* 298 (M^+), 280, 267; HR-MS *m/z* Calcd for $C_{15}H_{22}O_6$: 298.1415, Found: 298.1419; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 1.77-1.96 (m, 2H), 2.11 (m, 1H), 2.20-2.35 (m, 2H), 3.19 (m, 1H), 3.62 (s, 3H), 3.72 (br, 2H), 3.85 (s, 3H), 3.87 (s, 6H), 6.67 (d, J = 8.5 Hz, 1H), 6.84 (d, J = 8.5 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 26.60, 31.99, 40.44, 51.44, 55.90, 60.63, 61.01, 66.71, 107.60, 121.83, 126.86, 142.28, 152.36, 152.49, 174.02.

Compound 1

To a solution of **14** (0.5 mmol) in pyridine (2 ml) were successively added *p*-toluenesulfonyl chloride (2 mmol) and a trace amount of DMAP. The mixture was stirred at rt for 2 h, then quenched with 2 N HCl, extracted with Et_2O, and washed with saturated aqueous $NaHCO_3$. The extract was dried over $MgSO_4$ and concentrated under reduced pressure to give crude **1**, which was subjected to the silica gel-promoted lactonization without purification.

Synthesis of 3a-e



Ref. Akita, H.; Umezawa, I.; Takano, M.; Matsukura, H.; Oishi, T. *Chem. Pharm. Bull.* **1991**, *39*, 3094 (synthesis of **15**).

Compound 16

To a solution of **15** (1.50 mmol) in pyridine (1 ml) was added TsCl (570 mg, 2.99 mmol) at 0°C. The reaction mixture was stirred at rt for 12 h, then quenched with 2 N HCl, extracted with Et_2O, and washed with saturated aqueous $NaHCO_3$. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (9 : 1) to give **16**.

16a Colorless oil; IR (neat) 1730, 1460 cm^{-1}; FAB-MS *m/z* 405 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.24 (d, *J* = 6.4 Hz, 3H), 2.43 (s, 3H), 3.48 (dd, *J* = 8.3, 8.1 Hz, 1H), 3.70 (s, 3H), 3.77 (s, 3H), 4.81 (dq, *J* = 8.3, 6.4 Hz, 1H), 5.75 (d, *J* = 15.6 Hz, 1H), 6.80 (d, *J* = 8.6 Hz, 2H), 6.94 (dd, *J* = 15.6, 8.1 Hz, 1H), 7.00 (d, *J* = 8.6 Hz, 2H), 7.28 (d, *J* = 8.3 Hz, 2H), 7.70 (d, *J* = 8.3 Hz, 2H); Anal. Calcd for $C_{21}H_{24}O_6S$: C, 62.36; H, 5.98. Found: C, 62.64; H, 6.08.

16b Colorless oil; IR (neat) 1721, 1494 cm^{-1}; FAB-MS *m/z* 405 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.28 (d, *J* = 6.3 Hz, 3H), 2.39 (s, 3H), 3.69 (s, 3H), 3.76 (s, 3H), 3.83 (dd, *J* = 9.3, 7.3 Hz, 1H), 5.05 (dq, *J* = 7.3, 6.3 Hz, 1H), 5.75 (d, *J* = 16.1 Hz, 1H), 6.77 (d, *J* = 7.3 Hz, 1H), 6.84 (t, *J* = 7.3 Hz, 1H), 7.00 (dd, *J* = 16.1, 9.3 Hz, 1H), 7.00 (d, *J* = 7.3 Hz, 1H), 7.19 (t, *J* = 7.3 Hz, 1H), 7.24 (d, *J* = 8.3 Hz, 2H), 7.65 (d, *J* = 8.3 Hz, 2H); Anal. Calcd for $C_{21}H_{24}O_6S$: C, 62.36; H, 5.98. Found: C, 62.60; H, 5.87.

16c Colorless oil; IR (neat) 1725, 1517 cm^{-1}; FAB-MS *m/z* 434 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.18 (d, *J* = 6.4 Hz, 3H), 2.36 (s, 3H), 3.40 (dd, *J* = 8.8, 7.9 Hz, 1H), 3.64 (s, 3H), 3.75 (s, 3H), 3.78 (s, 3H), 4.78 (dq, *J* = 7.9, 6.4 Hz, 1H), 5.71 (d, *J* = 15.6 Hz, 1H), 6.49 (d, *J* = 2.0 Hz, 1H), 6.57 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.69 (d, *J* = 8.3 Hz, 1H), 6.91 (dd, *J* = 15.6, 8.8 Hz, 1H), 7.19 (d, *J* = 8.3 Hz, 2H), 7.61 (d, *J* = 8.3 Hz, 2H); Anal. Calcd for $C_{22}H_{26}O_7S$: C, 60.81; H, 6.03. Found: C, 60.74; H, 6.31.

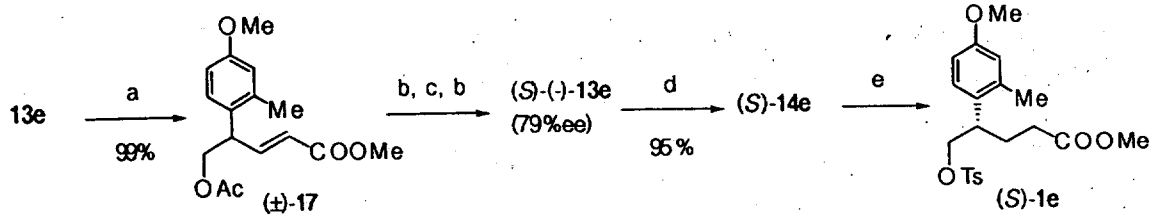
16d Colorless oil; IR (neat) 1714, 1504 cm^{-1}; FAB-MS *m/z* 419 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.25 (d, *J* = 6.4 Hz, 3H), 2.23 (s, 3H), 2.44 (s, 3H), 3.67 (s, 3H), 3.74 (t, *J* = 8.4 Hz, 1H), 3.75 (s, 3H), 4.78 (dq, *J* = 8.4, 6.4 Hz, 1H), 5.68 (d, *J* = 15.6 Hz, 1H), 6.66 (s, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 6.88 (dd, *J* = 15.6, 8.4 Hz, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 7.29 (d, *J* = 8.4 Hz, 2H), 7.73 (d, *J* = 8.4 Hz, 2H); Anal. Calcd for $C_{22}H_{26}O_6S$: C, 63.14; H, 6.23. Found: C, 62.74; H, 6.34.

16e Pale yellow oil; IR (neat) 1715, 1506 cm^{-1}; EI-MS *m/z* 418 (M^+), 246, 219, 159; HR-MS *m/z* Calcd for $C_{22}H_{26}O_6S$: 418.1448. Found: 418.1421; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.28 (d, *J* = 6.4 Hz, 3H), 2.30 (s, 3H), 2.43 (s, 3H), 3.69 (s, 3H), 3.72 (s, 3H), 3.78 (t, *J* = 8.4 Hz, 1H), 5.02 (dq, *J* = 8.4, 6.4 Hz, 1H), 5.73 (d, *J* = 15.8 Hz, 1H), 6.64 (d, *J* = 7.5 Hz, 1H), 6.67 (s, 1H), 6.86 (d, *J* = 7.5 Hz, 1H), 6.99 (dd, *J* = 15.8, 8.4 Hz, 1H), 7.24 (d, *J* = 8.2 Hz, 2H), 7.66 (d, *J* = 8.2 Hz, 2H).

Compound 3

A mixture of **16** (ca. 150 mg), 20% $Pd(OH)_2$-C (10 mg) and AcOEt (3 ml) was stirred under H_2 atmosphere for 15 h. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure to give crude **3**, which was subjected to the silica gel-promoted lactonization without purification.

Synthesis of (*S*)-1e



Reagents and conditions: (a) Ac_2O, pyr, rt, 30 min; (b) lipase OF-360, H_2O, *iso*-Pr_2O, 33°C, 72 h; (c) lipase OF-360, isopropenyl acetate, *iso*-Pr_2O, 33°C, 72 h; (d) H_2, $Pd(OH)_2C$, MeOH, rt, 3 h; (e) TsCl, pyr, rt, 2 h.

Compound 17

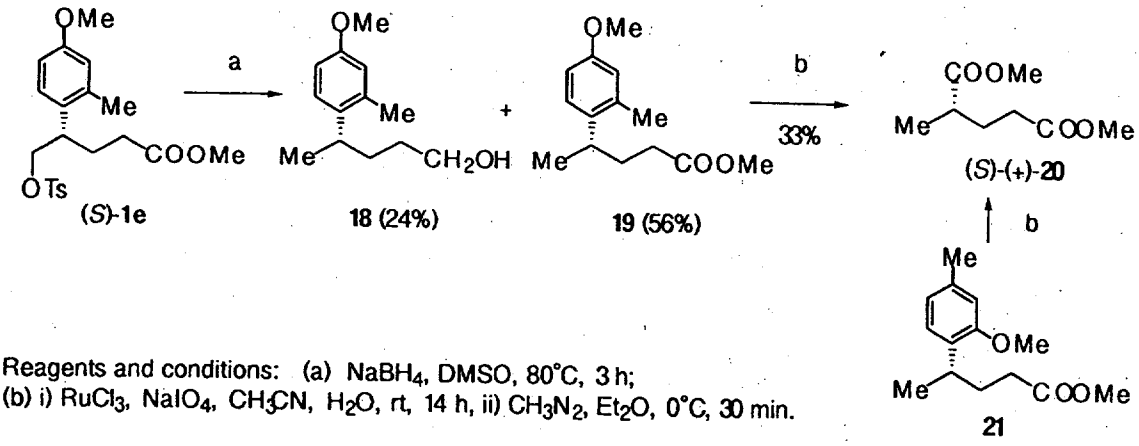
To a solution of **13e** (11.6 g, 46.4 mmol) in pyridine (30 ml) was added acetic anhydride (5 ml, 52.3 mmol) at 0°C. The mixture was stirred at rt for 30 min, then quenched with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (9 : 1) to give **17** (13.4 g, 45.9 mmol, 99%) as a colorless oil: IR (neat) 1739 cm^{-1}; FAB-MS *m/z* 293 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 2.03 (s, 3H), 2.32 (s, 3H), 3.72 (s, 3H), 3.78 (s, 3H), 4.01 (qd, *J* = 6.6, 1.7 Hz, 1H), 4.28-4.33 (m, 2H), 5.81 (dd, *J* = 15.8, 1.7 Hz, 1H), 6.71-6.76 (m, 2H), 7.03 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.08 (dd, *J* = 15.8, 6.6 Hz, 1H); Anal. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90. Found: C, 65.66; H, 7.03; HPLC: Daicel Chiralpak OD, UV at 254 nm, hexane : EtOH : *iso*-PrOH (600 : 10 :10), 1 ml/min, Retention time 8.6 (*S*) and 9.9 (*R*) min.

Compound (*S*)-13e

To a solution of **17** (6.73 g, 23.0 mmol) in saturated aqueous *iso*-Pr_2O (600 ml) was added Lipase OF-360 (*Candida rugosa*, 600 mg). The mixture was stirred at 33°C for 3 d and then filtered. The filtrate was dried over $MgSO_4$ and concentrated under reduced pressure. The experiment was carried out two times. Both residues were combined and purified by column chromatography on silica gel to give (*R*)-**17** (10.0 g, 40.0 mmol, 87%, 15%ee) (hexane/AcOEt (9 : 1)) as a colorless oil and (*S*)-**13e** (1.50 g, 5.98 mmol, 13%, 40%ee) (hexane/AcOEt (7 : 3)) as a colorless oil. To a mixture of (*S*)-**13e** (1.50 g), isopropenyl acetate (3 g, 30 mmol) and *iso*-Pr_2O (200 ml) was added Lipase OF-360 (500 mg). The reaction mixture was stirred at 33°C for 3 d and then filtered. The filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel to give (*S*)-**17** (332 mg, 1.14 mmol, 19%, 67%ee) and **13e** (1.15 g, 4.60 mmol, 77%, 34%ee). To a solution of (*S*)-**17** (332 mg) in saturated aqueous *iso*-Pr_2O (40 ml) was added Lipase OF-360 (200 mg). The mixture was stirred at 33°C for 3 d and then filtered. The filtrate was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel to give **17** (76.2 mg, 0.26 mmol, 23%, 36%ee) and (*S*)-**13e** (170 mg, 0.682 mmol, 60%, 79%ee): **13e** $[\alpha]_D^{27}$ = -4.5 (*c* = 1.08, $CHCl_3$); HPLC: Daicel Chiralpak OD, UV at 254 nm, hexane : EtOH : *iso*-PrOH (600 : 10 :10), 1 ml/min, Retention time 21.8 (*R*) and 26.6 (*S*) min.

Compound (*S*)-14e $[\alpha]_D^{27}$ = +11.4 (c = 1.50, $CHCl_3$).

Determination of Abosolute Configuration of (*S*)-1e



Reagents and conditions: (a) $NaBH_4$, DMSO, 80°C, 3 h;
(b) i) $RuCl_3$, $NaIO_4$, CH_3CN, H_2O, rt, 14 h, ii) CH_3N_2, Et_2O, 0°C, 30 min.

Compound (*S*)-(+)-20

To a solution of crude (*S*)-**1e** (160 mg, 0.394 mmol, 79%ee) in DMSO (2 ml) was added $NaBH_4$ (71.2 mg, 1.87 mmol). The mixture was further stirred at 80°C. After 3 h, a mixture of acetone (1 ml) and MeOH (1 ml) was added dropwise to the reaction mixture at 0°C. To the reaction mixture was added saturated aqueous NaCl, and the whole was extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel to give **19** (52.4 mg, 0.222 mmol, 56% from (*S*)-**1e**) and **18** (19.3 mg, 0.0926 mmol, 24% from (*S*)-**1e**): **19** (colorless oil); $[\alpha]_D^{25}$ = +12.7 (*c* = 1.97, $CHCl_3$); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.19 (d, *J* = 7.0 Hz, 3H), 1.86-1.92 (m, 2H), 2.19-2.23 (m, 2H), 2.28 (s, 3H), 2.94 (sextet, *J* = 7.0 Hz, 1H), 3.62 (s, 3H), 3.76 (s, 3H), 6.68 (d, *J* = 2.8 Hz, 1H), 6.73 (dd, *J* = 8.5, 2.8 Hz, 1H), 7.08 (d, *J* = 8.5 Hz, 1H): **18** (colorless oil); $[\alpha]_D^{23}$ = +7.9 (*c* = 2.24, $CHCl_3$); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.18 (d, *J* = 7.0 Hz, 3H), 1.39-1.64 (m, 4H), 2.29 (s, 3H), 2.91 (sextet, *J* = 7.0 Hz, 1H), 3.56 (t, *J* = 7.0 Hz, 2H), 3.76 (s, 3H), 6.68 (d, *J* = 2.6 Hz, 1H), 6.72 (dd, *J* = 8.6, 2.6 Hz, 1H), 7.08 (d, *J* = 8.6 Hz, 1H). A hydroxy protone was not observed.: To a mixture of **19** (50 mg, 0.212 mmol), $NaIO_4$ (906 mg, 4.24 mmol), CH_3CN (0.4 ml) and H_2O (0.6 ml) was added $RuCl_3 \cdot 3H_2O$ (5 mg) at 0°C, and the whole was further stirred at rt

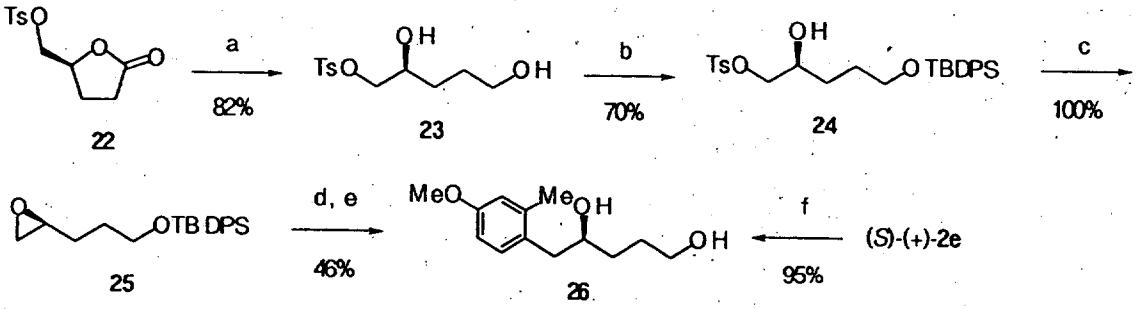
for 14 h. The reaction mixture was filtered. The filtrate was treated with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure to give crude oil. To a solution of the crude was added a solution of CH_3N_2 in Et_2O at 0°C, and the whole was further stirred at 0°C for 30 min and then quenched with a trace amount of AcOH. The mixture was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (40 : 1) to give **20** (12.9 mg, 0.074 mmol, 33%) as a colorless oil: $[\alpha]_D^{24}$ = +13.9 (*c* = 0.78, $CHCl_3$); IR ($CHCl_3$) 1730 cm^{-1}; FAB-MS *m/z* 174 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.18 (d, *J* = 7.0 Hz, 3H), 1.79 (m, 1H), 1.97 (m, 1H), 2.33-2.37 (m, 2H), 2.51 (sextet, *J* = 7.0 Hz, 1H), 3.67 (s, 3H), 3.68 (s, 3H) ; ^{13}C-NMR (100 MHz, $CDCl_3$) δ 17.1, 28.6, 31.7, 38.7, 51.6 (x 2), 173.5, 176.0.

Conversion of 21 into (*S*)-(+)-20

According to the conversion of **19** into **20**, **21** (289 mg, 1.22 mmol, 90%ee) was subjected to a sequence of $RuCl_3$ oxidation and methylation to give **20** (71.0 mg, 0.408 mmol, 33%): $[\alpha]_D^{25}$ = +15.8 (c = 0.72, $CHCl_3$).

Ref. The absolute configuration of **21** has already been determined. Ono, M.; Ogura, Y.; Hatogai, K.; Akita, H. *Tetrahedron: Asymmetry* **1995**, *6*, 1829.

Determination of Abosolute Configuration of (+)-2e



Reagents and conditions: (a) $LiAlH_4$, THF, -78°C, 1 h; (b) TBDPSCl, imidazole, DMF, rt, 2 h; (c) NaH, isopropanol, rt, 1 h; (d) 4-methoxy-2-methylphenylmagnesiumbromide, THF, 0°C-rt, 30 min; (e) TBAF, THF, rt, 1 h, 100%; (f) $LiAlH_4$, THF, 0°C, 30 min.

Ref. Ho, P-T.; Davies, N. *Synthesis* **1983**, 462 (synthesis of **22**).

Compound 25

To a susupension of $LiAlH_4$ (36.8 mg, 1.32 mmol) in THF (2 ml) was added a solution of (*S*)-(+)-**22** (203 mg, 0.749 mmol) in THF (1 ml) at -78°C. The mixture was stirred at -78°C for 1 h, then quenched with 2 N HCl at 0°C and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (1 : 1) to give **23** (169 mg, 0.617 mmol, 82%) as a colorless oil: $[\alpha]_D^{24}$ = +1.2 (*c* = 1.09, $CHCl_3$); IR (neat) 3363 cm^{-1}; FAB-MS *m/z* 275 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.48-1.72 (m, 4H), 2.45 (s, 3H), 2.60 (s, 1H), 3.50 (s, 1H), 3.62-3.72 (m, 2H), 3.88 (m, 1H), 3.92 (dd, *J* = 9.0, 7.0 Hz, 1H)), 4.01 (dd, *J* = 9.0, 3.0 Hz, 1H), 7.36 (d, *J* = 8.2 Hz, 2 H), 7.80 (d, *J* = 8.2 Hz, 2H): To a mixture of **23** (547 mg, 1.99 mmol), imidazole (276 mg, 4.05 mmol) and DMF was added *tert*-butylchlorodiphenylsilane (0.6 ml, 2.31 mmol) at 0°C. The mixture was stirred at rt for 2 h, then quenched with saturated aqueous $NaHCO_3$ and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (4 : 1) to give **24** (718 mg, 1.40 mmol, 70%) as a colorless oil: $[\alpha]_D^{23}$ = +4.0 (*c* = 0.87, $CHCl_3$); IR (neat) 3536 cm^{-1};

FAB-MS *m/z* 513 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.03 (s, 9H), 1.45-1.71 (m, 4H), 2.44 (s, 3H), 2.74 (br s, 1H), 3.65 (t, J = 6.0 Hz, 2H), 3.84 (m, 1 H), 3.92 (dd, J = 10.0, 7.0 Hz, 1 H), 4.01 (dd, J = 10.0, 4.0 Hz, 1 H), 7.33-7.42 (m, 8 H), 7.62-7.64 (m, 4 H), 7.80 (d, J = 9.0 Hz, 2 H): To a solution of NaH (55%, 36.1 mg) in isopropanol (1 ml) was added a solution of **24** (374 mg, 0.691 mmol) in isopropanol (1 ml) at 0°C. The reaction mixture was stirred at rt for 1 h and then the whole was purified by column chromatography on silica gel eluted with hexane to give **25** (234 mg, 0.688 mmol, 100%) as a colorless oil: $[\alpha]_D^{25}$ = -2.1 (c = 0.85, $CHCl_3$); IR (neat) 2930, 1428, 1111 cm^{-1}; EI-MS *m/z* 283 (M^+-^{t}Bu), 199; HR-MS *m/z* Calcd for $C_{17}H_{19}O_2Si$ 283.1154, Found 283.1156; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.05 (s, 9 H), 1.61-1.74 (m, 4 H), 2.45 (dd, J = 5.0, 2.7 Hz, 1 H), 2.73 (dd, J = 5.0, 4.4 Hz, 1 H), 2.92 (m, 1 H), 3.68-3.72 (m, 2 H), 7.35-7.42 (m, 6 H), 7.64-7.67 (m, 4 H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.19, 26.83 (x3), 28.85, 28.98, 47.11, 52.12, 63.36, 127.61 (x4), 129.57 (x2), 133.86 (x2), 135.53 (x4).

Compound 26

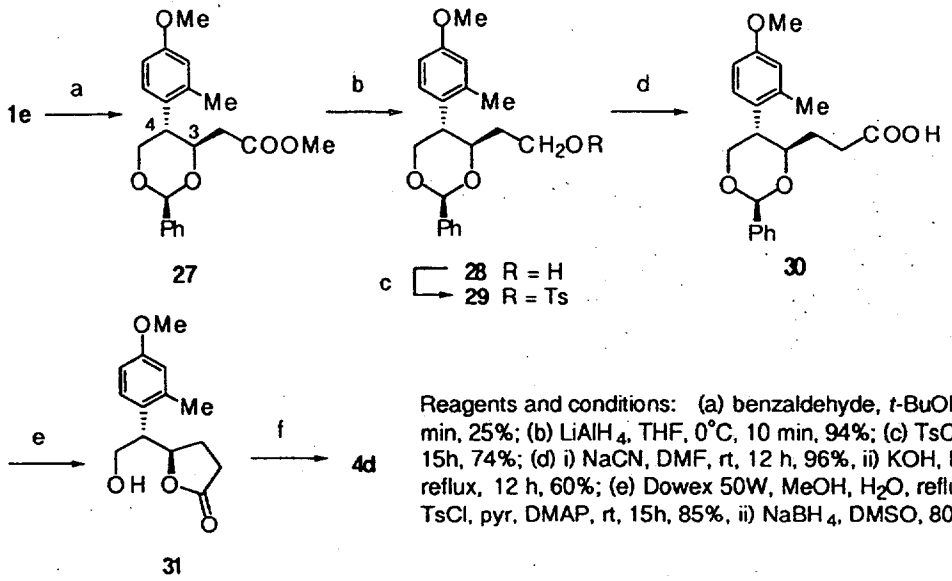
To 2-bromo-5-methoxytoluene (78.6 mg, 0.391 mmol) in THF was added Mg (10.9 mg, 0.448 mmol) in THF (1 ml), and the whole was heated at 90°C for 1 h. To the reaction mixture was added dropwise a solution of (*S*)-**25** (69.6 mg, 0.188 mmol) in THF (2 ml) at 0°C. The mixture was stirred at rt for 30 min, then quenched with 2 N HCl at 0°C and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (15 : 1) to give arylated product (42.8 mg, 0.0926 mmol, 46%) as a colorless oil: $[\alpha]_D^{26}$ = +1.58 (c = 0.70, $CHCl_3$); IR (neat) 3422 cm^{-1}; FAB-MS *m/z* 463 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.05 (s, 9 H), 1.50-1.72 (m, 4 H), 2.02 (d, J = 4.0 Hz, 1 H), 2.30 (s, 3 H), 2.67 (dd, J = 13.8, 8.0 Hz, 1 H), 2.75 (dd, J = 13.8, 5.1 Hz, 1 H), 3.70 (t, J = 10.5 Hz, 2 H), 3.78 (s, 3 H), 3.79 (m, 1 H), 6.69 (dd, J = 8.0, 2.0 Hz, 1 H), 6.73 (d, J = 2.0 Hz, 1 H), 7.06 (d, J = 8.0 Hz, 1 H), 7.35-7.44 (m, 6 H), 7.64-7.67 (m, 4 H);

Anal. Calcd for $C_{29}H_{38}O_3Si$: C, 75.28; H, 8.28. Found: C, 75.03; H, 8.31: To a solution of arylated compound (42.8 mg, 0.0926 mmol) in THF (1 ml) was added tetrabutylammonium fluoride hydrate (103 mg) at 0°C. The reaction mixture was stirred at rt for 1 h, then quenched with saturated aqueous NaCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (1 : 1) to give **26** (20.7 mg, 0.0924 mmol, 100%, 96%ee) as a colorless oil: $[\alpha]_D^{24}$ = +13.1 (*c* = 1.39, $CHCl_3$); IR (neat) 3350 cm^{-1}; EI-MS *m/z* 224 (M^+), 205, 189, 165; HR-MS *m/z* Calcd for $C_{13}H_{20}O_3$ 224.1412, Found 224.1412; ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.50-1.78 (m, 4 H), 2.30 (s, 3 H), 2.66 (dd, *J* = 13.9, 8.6 Hz, 1 H), 2.77 (dd, *J* = 13.9, 4.6 Hz, 1 H), 3.68 (q, *J* = 5.4 Hz, 2 H), 3.78 (s, 3 H), 3.80 (m, 1 H), 6.70 (dd, *J* = 8.0, 2.0 Hz, 1 H), 6.73 (d, *J* = 2.0 Hz, 1 H), 7.07 (d, *J* = 8.0 Hz, 1 H). Hydroxy protones were not observed; ^{13}C-NMR (68 MHz, $CDCl_3$) δ 19.92, 29.35, 33.93, 40.55, 55.16, 62.90, 71.83, 111.14, 116.13, 128.73, 131.09, 137.97, 158.17; HPLC: Daicel Chiralpak OD, UV at 254 nm, hexane : EtOH : *iso*-PrOH (600 : 10 :10), 1 ml/min, Retention time 24.3 (*S*) and 28.2 (*R*) min.

Reduction of (*S*)-(+)-2e

To a susupension of $LiAlH_4$ (32.7 mg, 0.858 mmol) in THF (2ml) was added a solution of (*S*)-(+)-**2e** (95.1 mg, 0.430 mmol) in THF (1 ml) at 0°C. The mixture was stirred at rt for 30 min, then quenched with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (7 : 3) to give **26** (91.5 mg, 0.408 mmol, 95%, 77%ee) as a colorless oil: $[\alpha]_D^{28}$ = +10.9 (*c* = 0.95, $CHCl_3$).

Alternative Synthesis of 4d to Determine its Relative Configuration



Reagents and conditions: (a) benzaldehyde, *t*-BuOK, THF, -20°C, 30 min, 25%; (b) $LiAlH_4$, THF, 0°C, 10 min, 94%; (c) TsCl, pyr, DMAP, rt, 15h, 74%; (d) i) NaCN, DMF, rt, 12 h, 96%, ii) KOH, EtOH, H_2O, reflux, 12 h, 60%; (e) Dowex 50W, MeOH, H_2O, reflux, 3 h, 93%; (f) i) TsCl, pyr, DMAP, rt, 15h, 85%, ii) $NaBH_4$, DMSO, 80°C, 2 h, 37%.

Compound 27

To a solution of **1e** (2.46 g, 9.84 mmol) and benzaldehyde (1.23 g, 11.6 mmol) in THF (20 ml) was added *t*-BuOK (290 mg, 2.58 mmol) at -20°C. The mixture was stirred for 30 min, then quenched with saturated aqueous NH_4Cl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (19 : 1) to give **27** (880 mg, 2.47 mmol, 25%) as a colorless oil: IR (neat) 1745 cm^{-1}; FAB-MS *m/z* 356 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 2.37 (s, 3H), 2.41 (dd, *J* = 15.6, 2.9 Hz, 1H), 2.54 (dd, *J* = 15.6, 9.3 Hz, 1H), 3.25 (td, *J* = 10.7, 4.8 Hz, 1H), 3.59 (s, 3H), 3.78 (s, 3H), 3.92 (dd, *J* = 11.7, 10.7 Hz, 1H), 4.18 (dd, *J* = 11.7, 4.8 Hz, 1H), 4.60 (ddd, *J* = 10.7, 9.3, 2.9 Hz, 1H), 5.73 (s, 1H), 6.74-6.78 (m, 2H), 7.13 (m, 1H), 7.34-7.40 (m, 3H), 7.52 (m, 2H). NOE correlations of the C2-H peak (δ 5.73) were also found with the proton peak at the ortho position of the phenyl group (δ 7.52, 5%), C4-H peak (δ

4.60, 14%) and one proton peak at C6 (δ 3.92, 8%); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.16, 38.33, 40.70, 51.64, 55.14, 71.98, 78.61, 101.15, 111.62, 116.51, 126.01 (x 2), 127.19, 127.41, 128.19 (x 2), 128.78, 138.11, 138.52, 158.34, 171.36; Anal. Calcd for $C_{21}H_{24}O_5$: C, 70.76; H, 6.79. Found: C, 70.69; H, 6.99.

Compound 28

To a solution of **27** (509 mg, 1.43 mmol) in THF (10 ml) was added $LiAlH_4$ (61.6 mg, 1.62 mmol) at 0°C. The mixture was stirred for 10 min, then quenched with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (6 : 4) to give **28** (438 mg, 1.34 mmol, 94%) as white crystals: m.p. 102-103°C; IR (nujor) 3360 cm^{-1}; FAB-MS *m/z* 329 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.66-1.80 (m, 2H), 2.13 (br s, 1H), 2.38 (s, 3H), 3.29 (td, *J* = 10.7, 4.8 Hz, 1H), 3.72-3.77 (m, 2H), 3.78 (s, 3H), 3.91 (dd, *J* = 11.7, 10.7 Hz, 1H), 4.17 (dd, *J* = 11.7, 4.8 Hz, 1H), 4.31 (ddd, *J* = 11.7, 10.7, 7.3 Hz, 1H), 5.71 (s, 1H), 6.73-6.75 (m, 2H), 7.08 (d, *J* = 8.8 Hz, 1H), 7.35-7.41 (m, 3H), 7.53 (dd, *J* = 8.3, 2.0 Hz, 2H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.25, 35.01, 40.97, 55.16, 60.63, 72.20, 81.71, 101.39, 111.64, 116.46, 125.98 (x 2), 127.13, 127.81, 128.36 (x 2), 128.96, 138.17, 138.50, 158.19; Anal. Calcd for $C_{20}H_{24}O_4$: C, 73.14; H, 7.37. Found: C, 73.09; H, 7.52.

Compound 29

To a solution **28** (103 mg, 0.314 mmol) in pyridine (3 ml) was successively added TsCl (141 mg, 0.740 mmol) and a slight amount of DMAP at 0°C. The mixture was stirred for 15 h, then quenched with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (9 : 1) to give **29** (112 mg, 0.232 mmol, 74%) as white crystals: m.p. 161-162°C; IR (nujor) 1177 cm^{-1}; FAB-MS *m/z* 482 (M^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.69 (m, 1H), 1.82

(m, 1H), 2.31 (s, 3H), 2.36 (s, 3H), 3.13 (td, J = 10.7, 4.4 Hz, 1H), 3.78-3.88 (m, 2H), 3.80 (s, 3H), 4.03-4.17 (m, 2H), 4.24 (td, J = 10.7, 4.9 Hz, 1H), 5.54 (s, 1H), 6.73-6.77 (m, 2H), 7.03 (d, J = 8.3 Hz, 1H), 7.13-7.28 (m, 2H), 7.33-7.44 (m, 4H), 7.73 (d, J = 8.3 Hz, 2H), 7.93 (d, J = 8.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.12, 21.57, 32.17, 41.15, 55.16, 66.51, 72.03, 77.48, 100.91, 111.66, 116.59, 125.88 (x 2), 127.17, 127.24, 127.85 (x 2), 128.18 (x 2), 128.80, 129.77 (x 2), 132.94, 138.10, 138.30, 144.68, 158.26; Anal. Calcd for $C_{27}H_{30}O_6S$: C, 67.19; H, 6.26. Found: C, 67.14; H, 6.56.

Compound 30

To a solution of the **29** (93.4 mg, 0.194 mmol) in DMF (2 ml) was added NaCN (20.0 mg, 0.408 mmol) at 0°C. The mixture was stirred at rt for 12 h, then quenched with H_2O and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (19 : 1) to give a cyanate compound (62.9 mg, 0.187 mmol, 96%) as white crystals: m.p. 115-116°C; IR (nujor) 2240 cm^{-1}; FAB-MS *m/z* 338 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.76-1.82 (m, 2H), 2.36 (s, 3H), 2.44-2.56 (m, 2H), 3.20 (td, J = 10.7, 4.4 Hz, 1H), 3.79 (s, 3H), 3.90 (t, J = 10.7 Hz, 1H), 4.11-4.23 (m, 2H), 5.71 (s, 1H), 6.74-6.79 (m, 2H), 7.10 (d, J = 6.4, 2.9 Hz, 1H), 7.35-7.43 (m, 3H), 7.53-7.55 (m, 2H): A mixture of the cyanate compound (55.0 mg, 0.165 mmol), KOH (64.0 mg), EtOH (2.6 ml) and H_2O (1.3 ml) was refluxed for 12 h, then quenched with 2 N HCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (3 : 7) to give **30** (35.3 mg, 0.099 mmol, 60%) as white crystals: m.p. 143.5-144.5°C; IR (nujor) 3200, 1705 cm^{-1}; FAB-MS *m/z* 357 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.71-1.85 (m, 2H), 2.36 (s, 3H), 2.39-2.58 (m, 2H), 3.20 (td, J = 10.7, 4.4 Hz, 1H), 3.78 (s, 3H), 3.86 (t, J = 10.7 Hz, 1H), 4.07-4.20 (m, 2H), 5.67 (s, 1H), 6.73-6.75 (m, 2H), 7.07 (d, J = 9.3 Hz, 1H), 7.30-7.39 (m, 3H), 7.53 (d, J = 6.8 Hz, 2H). A hydroxy protone was not observed; ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.54, 28.05, 30.16, 41.57, 55.45, 72.39, 81.14, 101.49, 111.94, 116.76, 126.28 (x 2),

127.47, 128.06, 128.54 (x 2), 129.10, 138.60, 138.77, 158.50, 179.40; Anal. Calcd for $C_{21}H_{24}O_5$: C, 70.76; H, 6.79. Found: C, 70.66; H, 6.84.

Compound 31

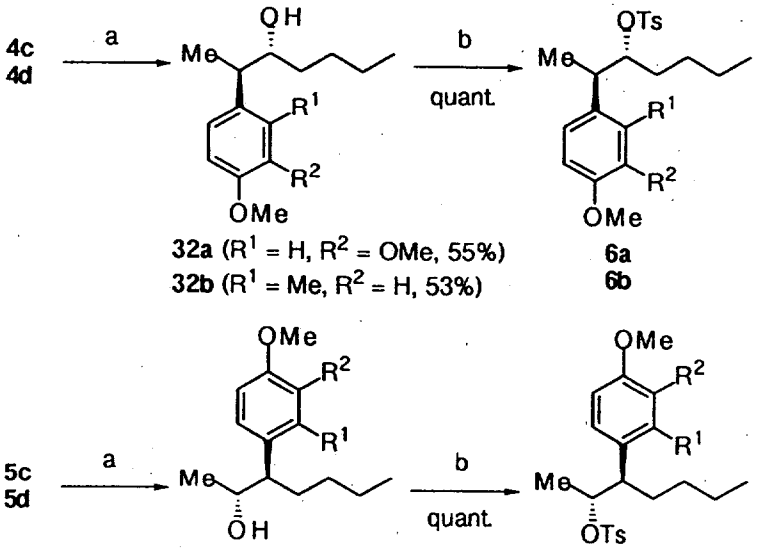
To a solution of **30** (26.3 mg, 0.0739 mmol) in MeOH (0.5 ml) and H_2O (0.5 ml) was added Dowex (50Wx8-400, 50 mg). The mixture was refluxed for 3 h, then filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (6 : 4) to give **31** (17.2 mg, 0.0688 mmol, 93%) as white crystals: m.p. 80.5-81.5°C; IR (nujor) 1770 cm^{-1}; FAB-MS *m/z* 251 (MH^+); ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.76 (m, 1H), 2.10 (m, 1H), 2.35 (s, 3H), 2.45-2.50 (m, 2H), 3.26 (dt, *J* = 10.7, 5.8 Hz, 1H), 3.79 (s, 3H), 3.87 (dd, *J* = 10.7, 5.4 Hz, 1H), 4.16 (dd, *J* = 10.7, 5.8 Hz, 1H), 4.83 (ddd, *J* = 10.7, 6.3, 5.8 Hz, 1H), 6.73-6.77 (m, 2H), 7.06 (d, *J* = 8.3 Hz, 1H). A hydroxy protone was not observed; ^{13}C-NMR (68 MHz, $CDCl_3$) δ 20.29, 26.78, 28.32, 47.37, 55.09, 64.79, 82.01, 111.78, 116.46, 127.61, 127.68, 138.50, 158.36, 176.77; Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 67.30; H, 7.31.

Conversion of 31 into 4d

To a solution of **31** (31.3 mg, 0.125 mmol) in pyridine (1 ml) were successively added TsCl (46.4 mg, 0.244 mmol) and a slight amount of DMAP at 0°C. The mixture was stirred for 15 h, then quenched with 2 N HCl, extracted with Et_2O, and washed with saturated aqueous $NaHCO_3$. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (8.5 : 1.5) to give a tosylate compound (42.9 mg, 0.106 mmol, 85%) as a colorless oil: ^{1}H-NMR (400 MHz, $CDCl_3$) δ 1.68 (m, 1H), 1.99 (m, 1H), 2.19 (s, 3H), 2.36 (s, 3H), 2.34-2.39 (m, 2H), 3.28 (ddd, *J* = 9.0, 6.8, 4.9 Hz, 1H), 3.71 (s, 3H), 4.18 (dd, *J* = 9.8, 6.8 Hz, 1H), 4.29 (dd, *J* = 9.8, 4.9 Hz, 1H), 4.62 (td, *J* = 9.0, 6.8 Hz, 1H), 6.57-6.68 (m, 2H), 6.87 (d, *J* = 8.3 Hz, 1H), 7.21 (d, *J* = 8.3 Hz, 2H), 7.55 (d, *J* = 8.3 Hz, 2H): A mixture of the tosylate (41.4 mg, 0.102 mmol), $NaBH_4$ (9.4 mg, 0.25

mmol) and DMSO (1 ml) was stirred at 80°C for 2 h, then quenched with H_2O at 0°C and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (8.5 : 1.5) to give **4d** (8.8 mg, 0.0376 mmol, 37%) along with recovered substrate (7.9 mg, 0.0196 mmol, 19%). All spectroscopic data of the product were identical with those of **4d** obtained by lactonization *via* a phenonium ion.

Syntheses of 6a,b and 7a,b



[a] Reagents and conditions: (a) i) DIBAH, toluene, -78°C, 30 min, ii) $Ph_3P{=}CH_2$, THF, rt, 1h, iii) H_2, $Pd(OH)_2/C$, AcOEt, rt, 4 h (b) Ts_2O, pyr, DMAP, rt, 5 h.

Compound 32a

To a solution of **4c** (455 mg, 1.82 mmol) in toluene (12 ml) was added dropwise diisobutylaluminium hydride (DIBAH, 1 M toluene sol., 2.2 ml) at -78°C. The mixture was stirred at -78°C for 30 min, then quenched with saturated aqueous NH_4Cl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified

by column chromatography on silica gel eluted with hexane/AcOEt (3 : 1) to give a lactol compound (486 mg, 1.78 mmol, 98%) as a colorless oil. To a suspension of methyltriphenylphosphonium bromide (1.47 g, 4.12 mmol) in THF (25 ml) was added dropwise 1.5 M *n*-BuLi (hexane sol., 2.7 ml, 4.05 mmol) at 0°C. After being stirred for 30 min, a solution of the lactol compound (323 mg, 1.28 mmol) in THF (15 ml) was added to the mixture at 0°C The whole was further stirred at rt for 1 h, then quenched with with saturated aqueous NaCl and extracted with Et_2O. The extract was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (4 : 1) to give a terminal alkene compound (219 mg, 0.877 mmol, 69%) as a colorless oil. A mixture of the alkene compound (59.8 mg, 0.239 mmol), 20% $Pd(OH)_2$-C (10 mg) and AcOEt (2 ml) was stirred under H_2 atmosphere at rt for 4 h. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel eluted with hexane/AcOEt (8 : 2) to give **32a** (49.4 mg, 0.196 mmol, 82%) as a colorless oil: IR (neat) 3400 cm^{-1}; EI-MS *m/z* 252 (M^+), 165; HR-MS *m/z* Calcd for $C_{15}H_{24}O_3$: 252.1725. Found: 252.1751; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.87 (t, J = 7.0 Hz, 3H), 1.29 (d, J = 7.1 Hz, 3H), 1.20-1.57 (m, 7H), 2.73 (quintet, J = 7.1 Hz, 1H), 3.63 (br s, 1H), 3.86 (s, 3H), 3.88 (s, 3H), 6.73-6.85 (m, 3H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.98, 15.34, 22.60, 28.21, 34.24, 45.02, 55.80 (x 2), 76.18, 111.11, 111.18, 119.50, 137.27, 147.48, 148.80.

Compound 32b

Colorless oil: IR (neat) 3350 cm^{-1}; EI-MS *m/z* 236 (M^+), 149; HR-MS *m/z* Calcd for $C_{15}H_{24}O_2$: 236.1775. Found: 236.1793; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.87 (t, J = 7.1 Hz, 3H), 1.25 (d, J = 6.8 Hz, 3H), 1.20-1.48 (m, 7H), 2.30 (s, 3H), 2.99 (quintet, J = 6.8 Hz, 1H), 3.64 (br s, 1H), 3.78 (s, 3H), 6.70-6.76 (m, 2H), 7.11 (d, J = 7.3 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 14.04, 15.30, 20.01, 22.65, 28.37, 34.44, 39.43, 55.13, 75.37, 111.22, 116.07, 127.33, 135.33, 136.92, 157.49.

Compound 33a

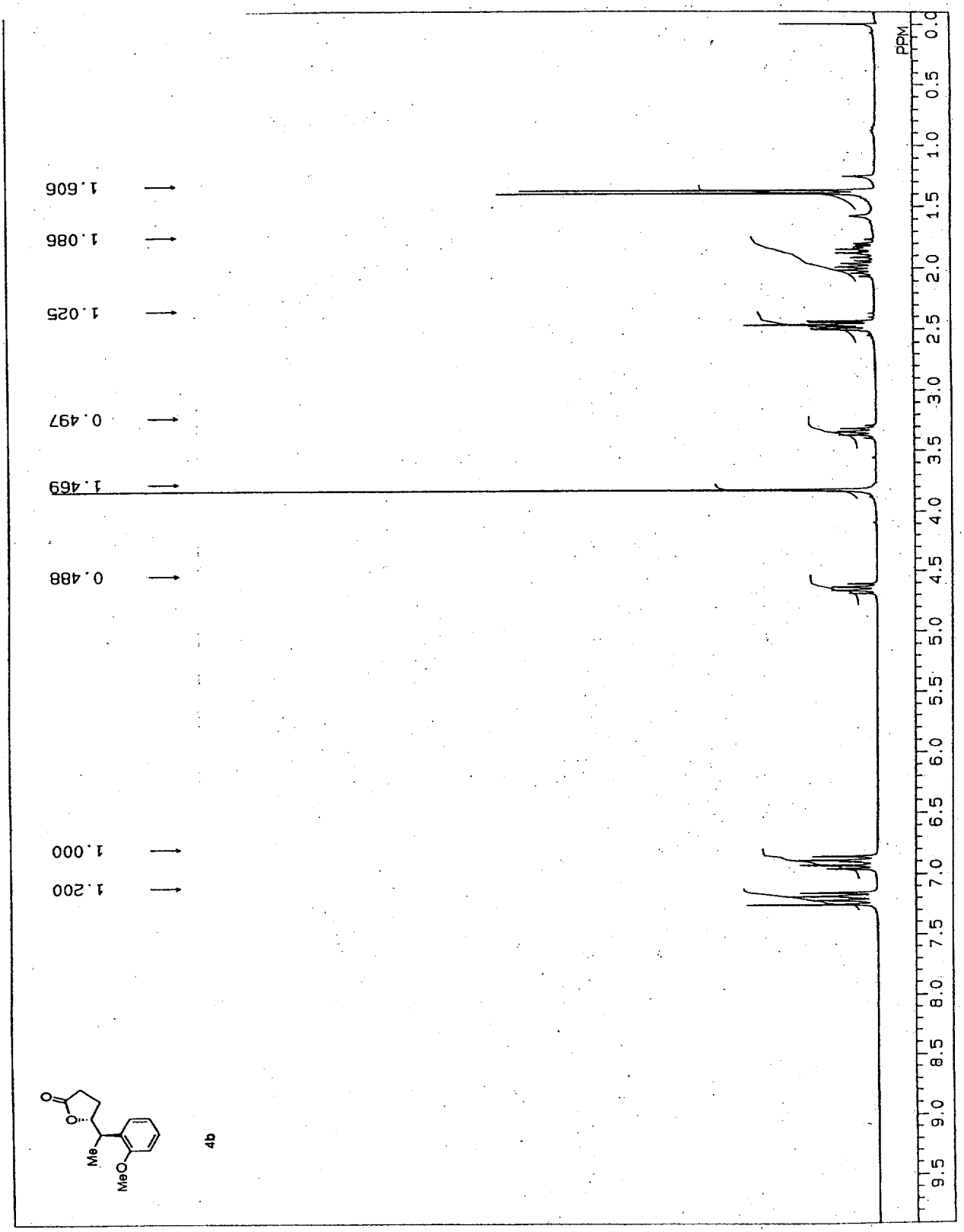
Colorless oil: IR (neat) 3400 cm^{-1}; EI-MS *m/z* 252 (M^+), 207, 151; HR-MS *m/z* Calcd for $C_{15}H_{24}O_3$: 252.1725. Found: 252.1711; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.83 (t, *J* = 7.1 Hz, 3H), 1.04 (d, *J* = 6.4 Hz, 3H), 1.02-1.40 (m, 4H), 1.50-1.66 (m, 2H), 1.88 (m, 1H), 2.49 (m, 1H), 3.84 (m, 1H), 3.87 (s, 3H), 3.88 (s, 3H), 6.66-6.72 (m, 2H), 6.82 (d, *J* = 8.1 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.94, 21.09, 22.73, 29.79, 30.68, 53.27, 55.79, 55.86, 71.83, 111.09, 111.69, 120.49, 134.74, 147.54, 148.79.

Compound 33b

Colorless oil: IR (neat) 3350 cm^{-1}; EI-MS *m/z* 236 (M^+), 191, 135; HR-MS *m/z* Calcd for $C_{15}H_{24}O_2$: 236.1776. Found: 236.1750; ^{1}H-NMR (270 MHz, $CDCl_3$) δ 0.82 (t, *J* = 7.2 Hz, 3H), 1.04 (d, *J* = 6.3 Hz, 3H), 1.00-1.34 (m, 4 H), 1.43-1.66 (m, 2H), 1.95 (m, 1H), 2.31 (s, 3H), 2.82 (m, 1H), 3.78 (s, 3H), 3.83 (m, 1H), 6.71-6.75 (m, 2H), 7.02 (dd, *J* = 7.3, 1.7 Hz, 1H); ^{13}C-NMR (68 MHz, $CDCl_3$) δ 13.89, 20.45, 21.20, 22.87, 29.47, 31.36, 47.22, 54.89, 72.29, 111.29, 115.60, 127.22, 133.38, 138.00, 157.16.

Typical Procedures for tosylation of 32 or 33

To a solution of 32 or 34 (0.480 mmol) in pyridine (1 ml) were successively added *p*-toluenesulfonic anhydride (1.45 mmol) and DMAP (1.45 mmol). The mixture was stirred at rt for 5 h, then quenched with 2 N HCl, extracted with Et_2O, and washed with saturated aqueous $NaHCO_3$. The extract was dried over $MgSO_4$ and concentrated under reduced pressure to give crude 8 or 9, which was subjected to the acetolysis without purification.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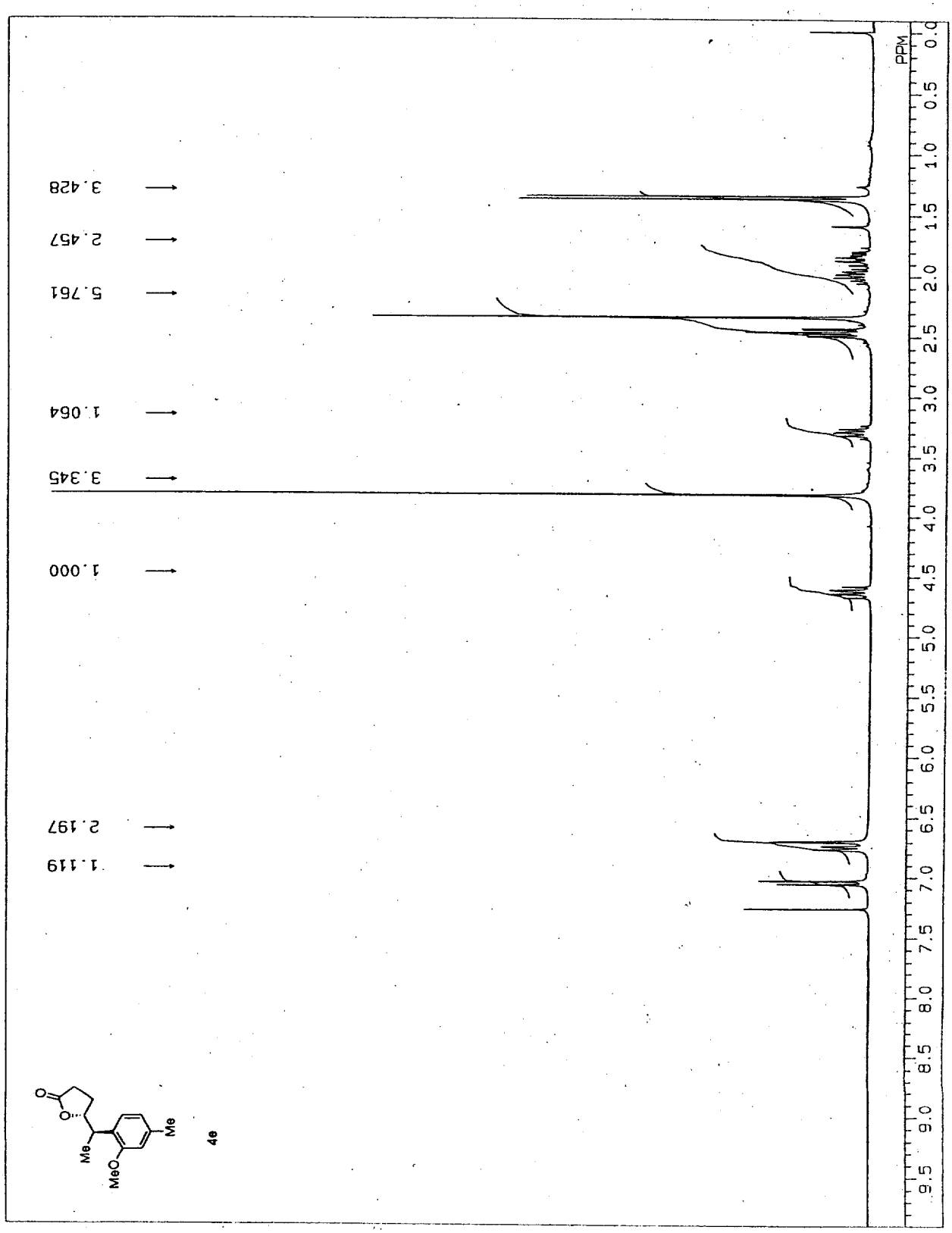

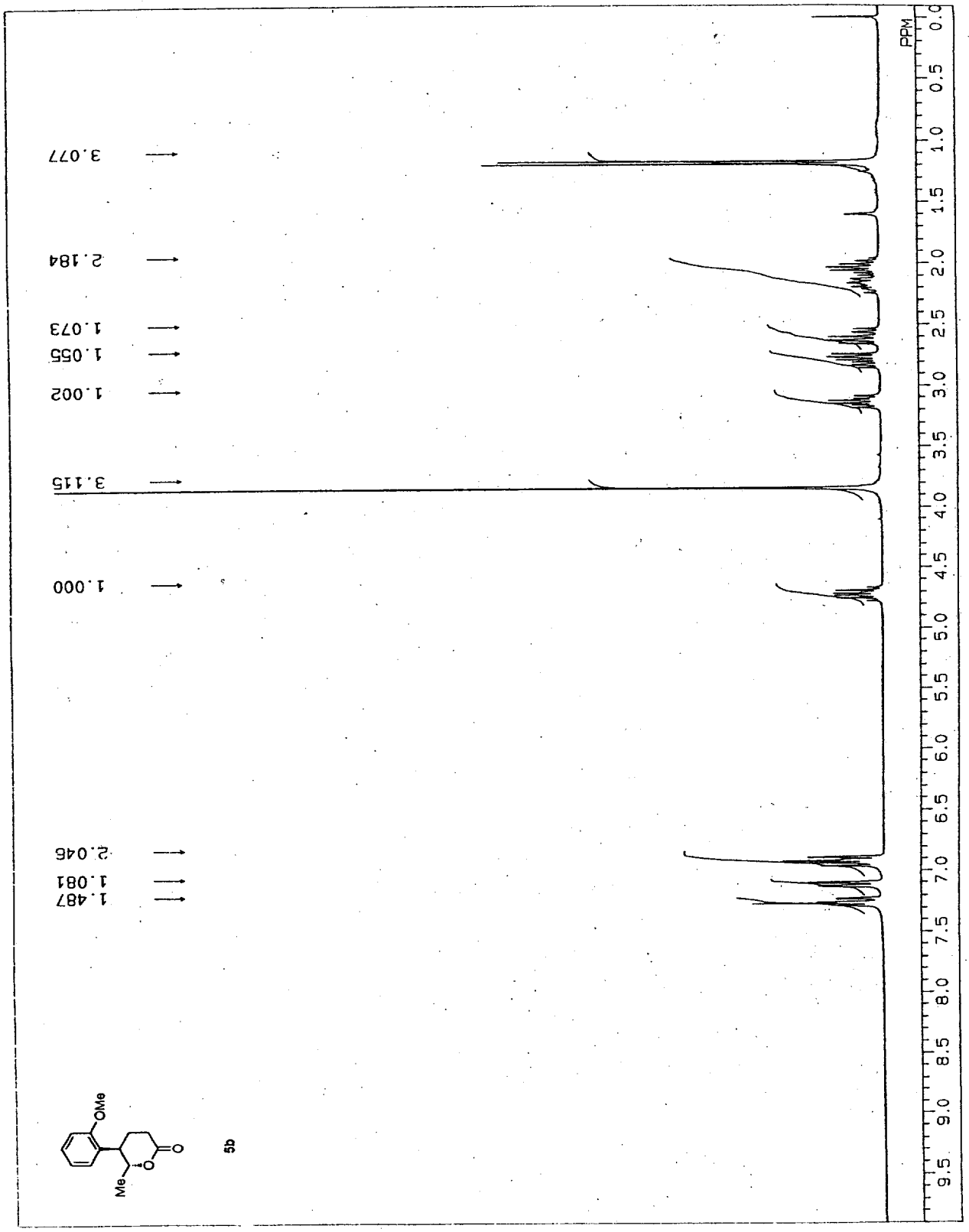
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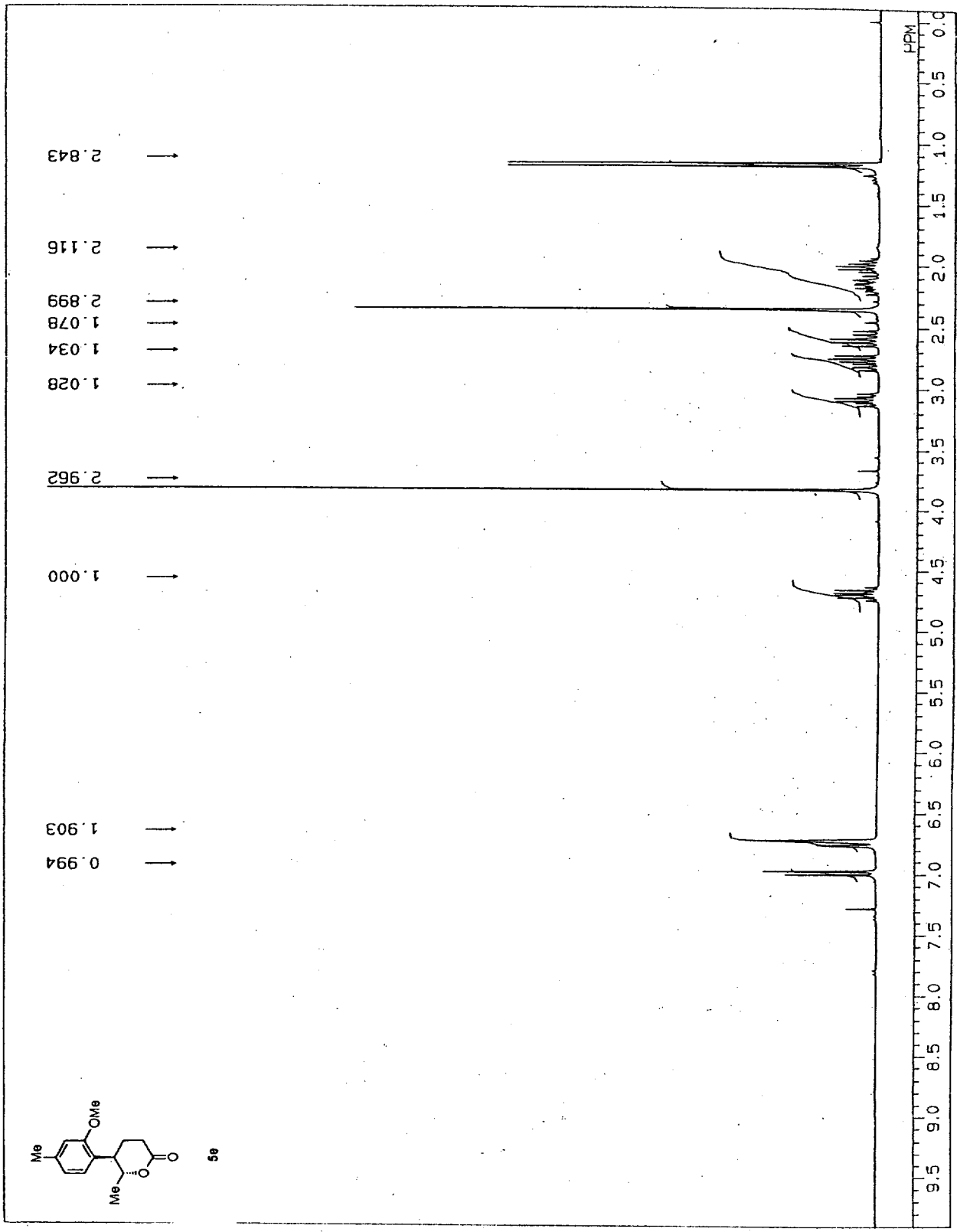
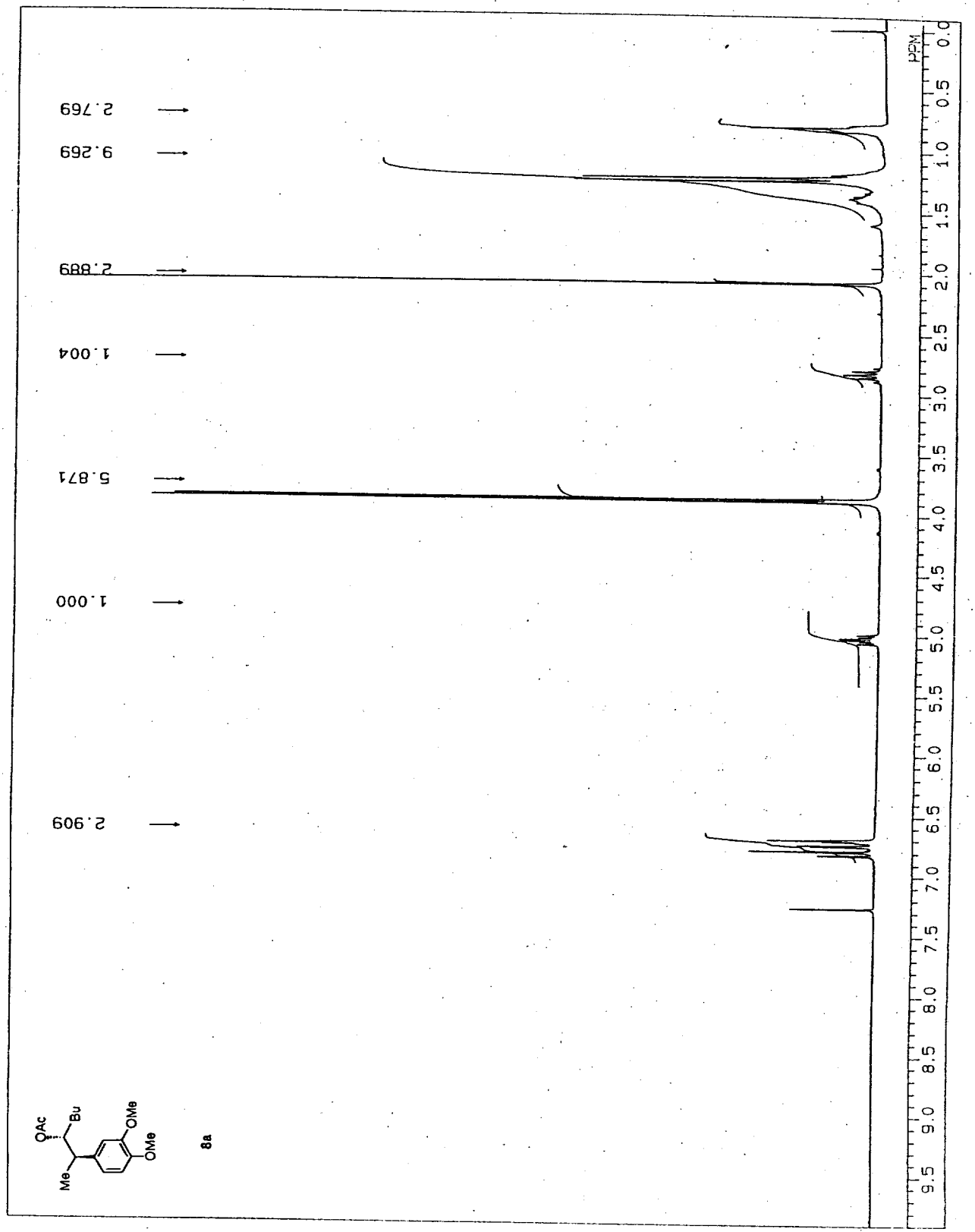
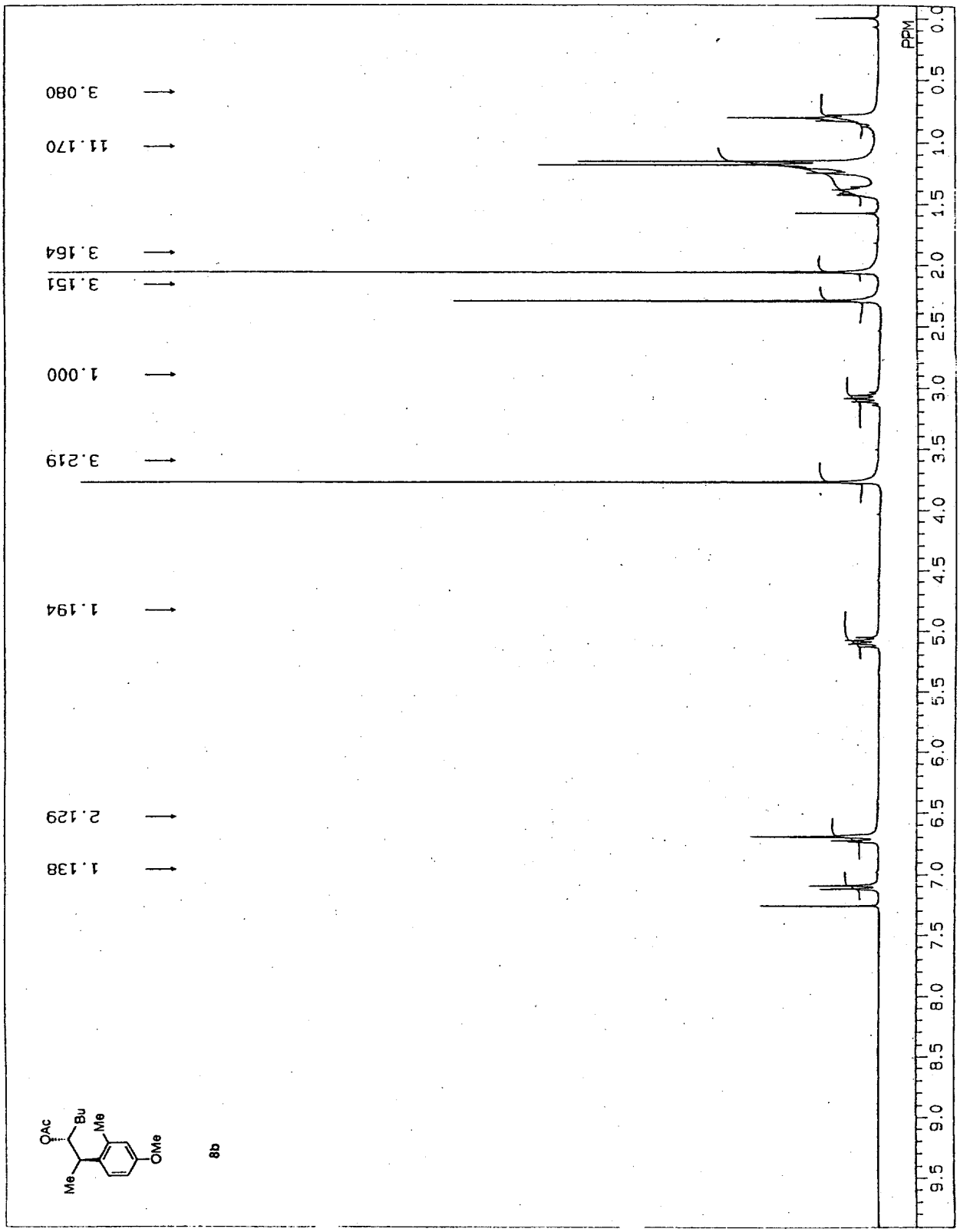
O
O
5b



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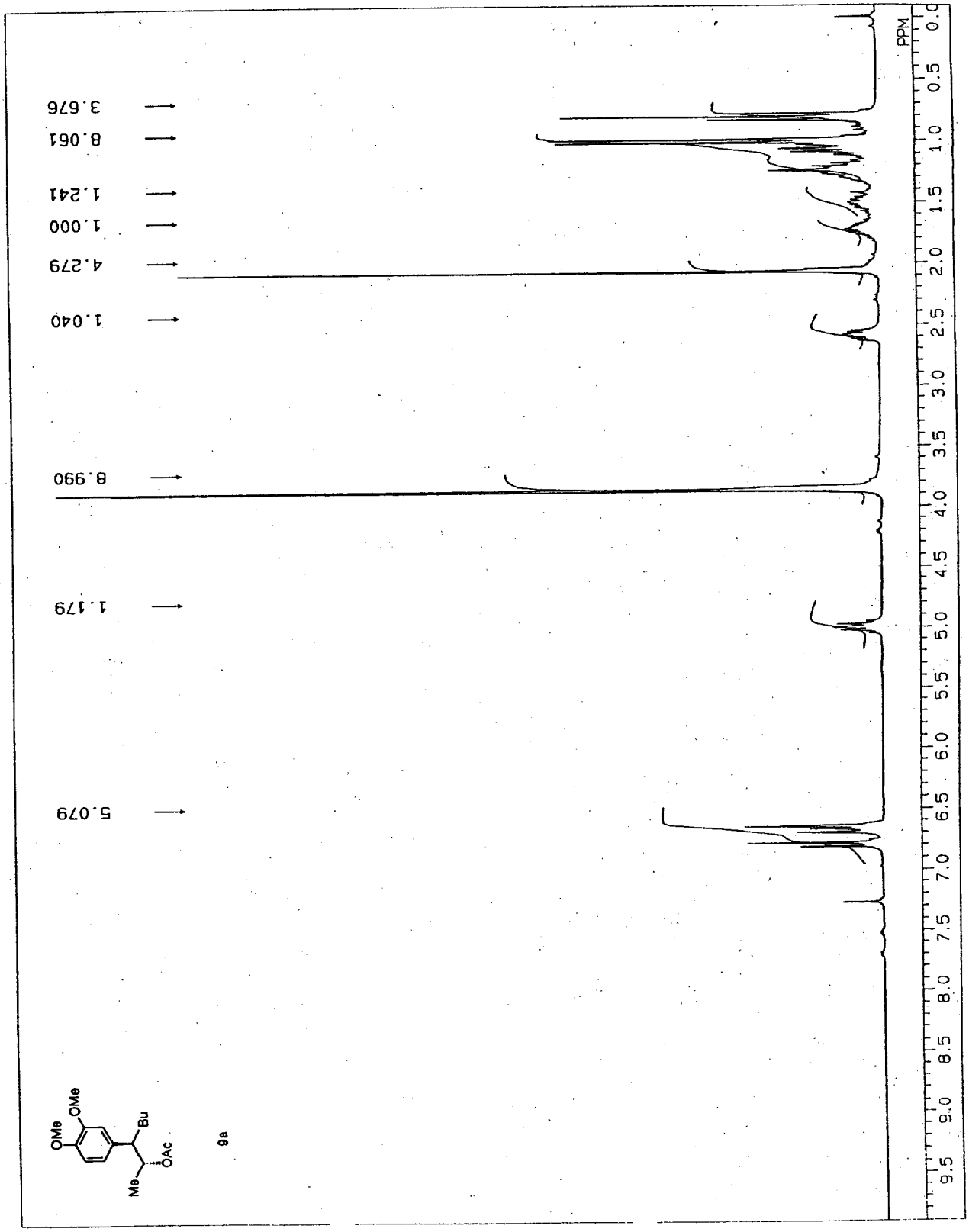
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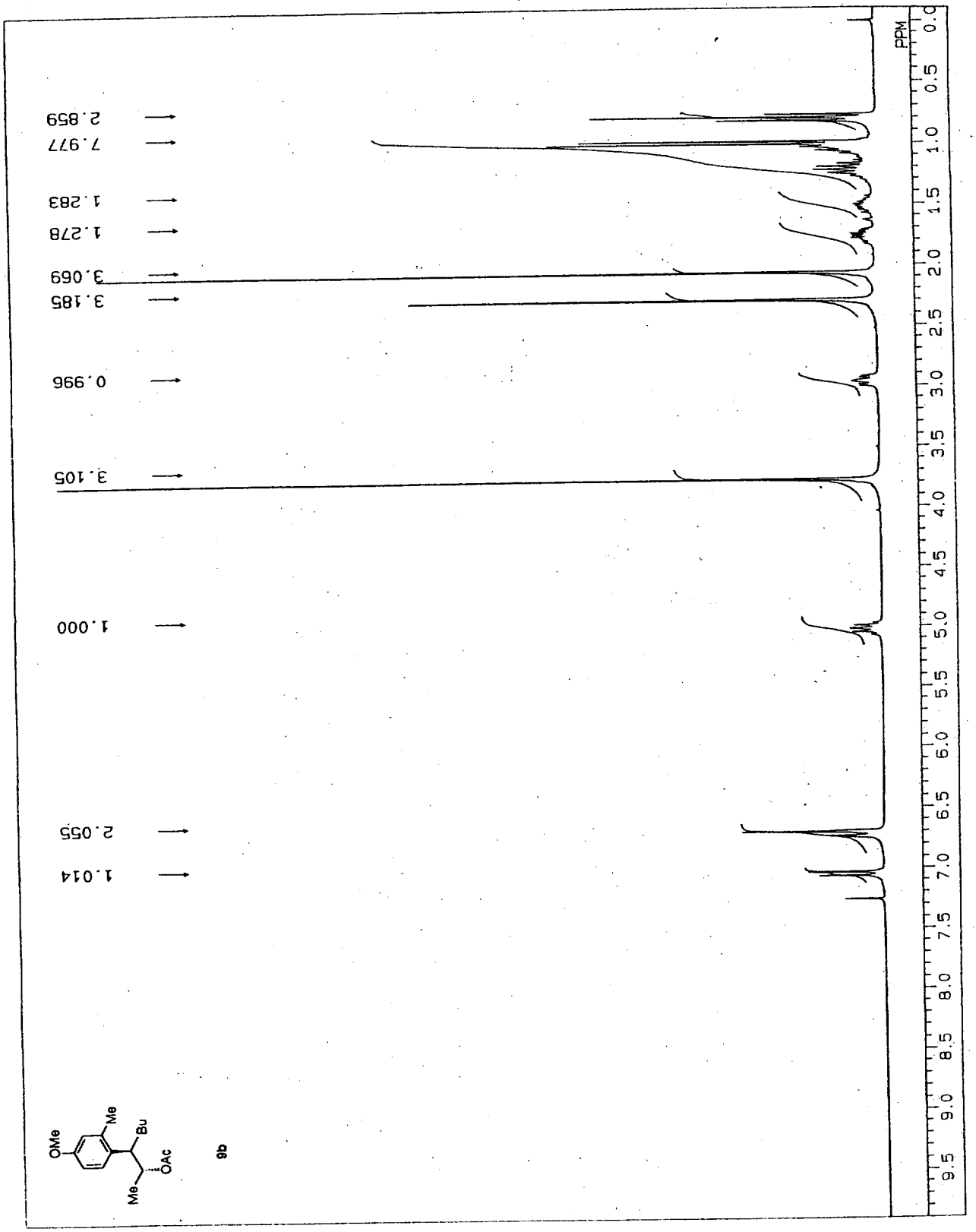

S40