Synthesis of Highly Functionalized Furanones via Aldol Reaction of 3-Silyloxyfurans

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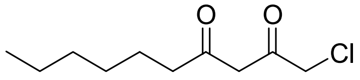
Data of products



1-Chloro-decane-2,4-dione (6)

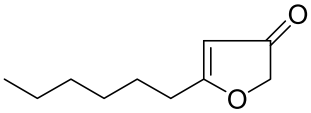
To a stirred solution of lithium diisopropylamide (120 mmol) in dry tetrahydrofuran (50ml) at -30^{o}C, was added octan-2-one (18.8 ml, 120 mmol) dropwise. The resulting mixture was stirred for 30 minutes at same temperature then ethyl chloroacetate (6.39 ml, 60 mmol) was introduced at -50^{o}C. The stirring was continued until the mixture was warmed to ambient temperature. and the mixture was acidified (pH 4-5) with 10% hydrochloric acid solution. The mixture was poured into water and diethyl ether, and extracted with diethyl ether (50 ml×3). The combined organic solution was washed with saturated brine and then dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was purified by flash chromatography on silica gel (eluent 95/5 hexanes/ethyl acetate) to give the diketone **6** as a clear oil (4.8 g, 40%).

IR (neat) 2956, 2930, 2858, 1707, 1603, 1458;

^{1}H NMR (500MHz, CDCl$_3$): A 8:1 mixture of enol and diketone, 5.82 (1H, s, enol form), 4.16 (2H, s, keto form), 4.02 (2H, enol form), 3.75 (2H, keto form), 2.52 (2H, t, 7.3Hz, keto form), 2.33 (2H, t, 7.4Hz, enol form), 1.62 (4H, m), 1.30 (12H, m), 0.88 (6H, m);

^{13}C NMR (125MHz, CDCl$_3$): Enol form: 194.2, 188.0, 97.4, 44.4, 38.0, 31.46, 28.8, 25.6, 22.4, 13.9;

HRMS calcd for $C_{10}H_{18}O_2Cl$ 205.0995, found 205.0989 (MH$^+$)



5-Hexyl-furan-3-one (7)

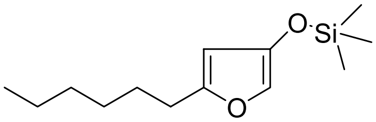
To a stirred solution of the diketone **6** (1.0 g, 4.89 mmol) in dry tetrahydrofuran (25 ml) at ambient temperature, was added 1,8-diazabicyclo[5.4.0]undec-7-ene (1.47 ml, 9.77 mmol) dropwise. Immediate precipitation was observed in two minutes after the addition. After stirring for another hour, the reaction was quenched by addition of saturated ammonium chloride solution and extracted with diethyl ether (50 ml×3). The combined organic layers were washed with saturated brine and dried over magnesium sulfate and concentrated in vacuo. The residue was purified by flash chromatography on silica gel (eluent 80/20 hexanes/ethyl acetate) to give the furanone **7** as a yellow oil (0.82 g, 100 %).

IR (neat) 2930, 2860, 1700, 1597;

^{1}H NMR (500MHz, $CDCl_3$): 5.50 (1H, d, 0.6Hz), 4.51 (2H, d, 0.6Hz), 2.52 (2H, t, 7.7Hz), 1.67 (2H, m), 1.38-1.31(6H, m), 0.92 (3H, t, 7.0Hz);

^{13}C NMR (125MHz, $CDCl_3$): 203.0, 195.7, 103.9, 75.2, 31.3, 30.7, 28.7, 25.9, 22.4, 13.9;

HRMS calcd for $C_{10}H_{16}O_2$ 168.1150, found 168.1152 (M^+)



(5-Hexyl-furan-3-yloxy)-trimethyl-silane (8)

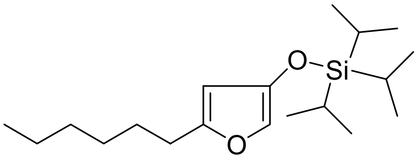
To a stirred solution of lithium diisopropylamide (6.95 mmol) in dry tetrahydrofuran (12 ml) at -78°C, was added the furanone **7** (1.0 g, 5.9 mmol) in dry tetrahydrofuran (25 ml) dropwise. The resulting mixture was stirred for 30 minutes at same temperature and trimethylsilyl chloride (0.75 ml, 5.9 ml) was added. The mixture was allowed to warm up to ambient temperature slowly then dry pentane was added to precipitate the lithium salt. After centrifuging the resulting solution, the deep red solution was collected and the solvent was removed to give the furan **8** as a reddish oil (1.40 g, 98 %).

IR (neat) 2957, 2929, 2858, 1702, 1615, 1601, 1552, 1466;

^{1}H NMR (500MHz, $CDCl_3$): 6.96 (1H, d, 0.8Hz), 5.75 (1H, d, 0.8Hz), 2.50 (2H, t, 7.5Hz), 1.59 (2H, m), 1.30 (6H, m), 0.88(3H, t, 7.0Hz);

^{13}C NMR (125MHz, $CDCl_3$): 155.3, 143.4, 126.0, 102.2, 31.5, 28.7, 28.5, 27.7, 22.5, 14.0, -0.28;

HRMS calcd for $C_{13}H_{25}O_2Si$ 241.1624, found 241.1613 (MH^+)



(5-Hexyl-furan-3-yloxy)-triisopropyl-silane (9)

To a stirred solution of the furanone **7** (0.200 g, 1.18 mmol) in dry dichlomethane (6 ml) at 0°C, was added triethylamine (0.18 ml, 1.30 mmol) followed by triisopropylsilyl trifluoromethanesulfonate (0.35 ml, 1.30 mmol) dropwise. The resulting mixture was stirred for one hour at 0°C and another 30minutes at ambient temperature. The solvent was removed under reduced pressure then the resulting oil was purified by flash chromatography on silica gel (eluent hexanes) to give the furan **9** as a clear oil (0.367 g, 100 %).

IR (neat) 2931, 2866, 1615, 1551, 1463;

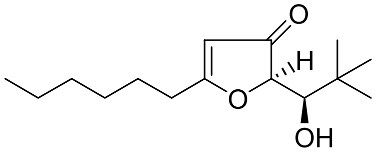
^{1}H NMR (500MHz, $CDCl_3$): 6.96 (1H, s), 5.77 (1H, s), 2.49 (2H, t, 7.4Hz), 1.57 (2H, m), 1.29 (6H, m), 1.18 (3H, m), 1.09 (18H, m), 0.88 (3H, t, 7.1Hz);

^{13}C NMR (125MHz, $CDCl_3$): 155.0, 144.3, 126.1, 102.5, 31.5, 28.7, 28.5, 27.7, 22.5, 17.7, 14.0, 12.3;

HRMS calcd for $C_{19}H_{36}O_2Si$ 324.2484, found 324.2474 (M^+)

Typical procedure for Aldol reaction

To a stirred solution of the furan **8** or **9** (0.42 mmol) and pivaldehyde (0.039 ml, 0.33 mmol) in dry dichloromethane at -78°C, was added boron trifluoride diethyl etherate (0.042 ml, 0.33 mmol) dropwise. The resulting mixture was stirred for 1 hour at same temperature then saturated sodium bicarbonate solution was added. The solution was warmed to ambient temperature and extracted with diethyl ether (20 ml×3). The combined organic layers were washed with saturated brine and then dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was purified by flash chromatography (eluent 70/30 hexanes/diethyl ether) to give the alcohol **10d** as a clear oil, solidified in refrigerator to white crystals (0.088 g, 100 %).



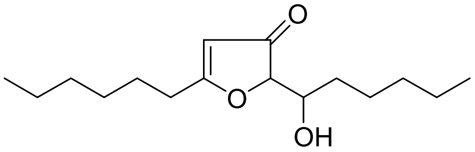
5-Hexyl-2-(1-hydroxy-2,2-dimethyl-propyl)-furan-3-one (10d)

IR (neat) 3406, 2957, 2867, 1686, 1593, 1466;

^{1}H NMR (500MHz, $CDCl_3$): 5.47 (1H, s), 4.56 (1H, s), 3.78 (1H, d, 7.2Hz), 2.53 (2H, t, 7.5Hz), 1.73 (1H, d, 7.8 Hz), 1.66 (2H, m), 1.37 (2H, m), 1.30 (4H, m), 1.04 (9H,s), 0.89 (3H, t, 6.8Hz);

^{13}C NMR (125MHz, $CDCl_3$): 204.9, 196.0, 104.3, 85.6, 78.3, 35.4, 31.7, 31.0, 28.9, 26.6, 26.1, 22.6, 14.1;

HRMS calcd for $C_{15}H_{26}O_3Na$ 277.1780, found 277.1777 (MNa^+)



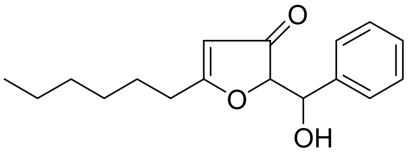
5-Hexyl-2-(1-hydroxy-hexyl)-furan-3-one (10a)

IR (neat) 3425, 2929, 2859, 1692, 1592, 1461;

^{1}H NMR (500MHz, $CDCl_3$): A 1:1 mixture of *threo*/*erythro*; 5.46 (1H, t, 0.6Hz), 5.45 (1H, t, 0.6Hz), 4.42 (1H, dt, 3.7Hz, 0.7Hz), 4.31 (1H, dt, 6.9Hz, 0.7Hz), 4.04 (1H, td, 8.7Hz, 4.2Hz), 3.77 (1H, ddd, 8.2Hz, 7.0Hz, 3.4Hz), 3.16 (1H, OH), 2.52 (4H, m), 2.05 (1H, OH), 1.45-1.70 (10H, m), 1.20-1.45 (22H, m), 0.89 (12H, m);

^{13}C NMR (125MHz, $CDCl_3$): 204.9, 203.9, 195.5, 195.4, 104.7, 104.0, 87.2, 86.5, 71.3, 71.1, 33.0, 32.7, 31.8, 31.7, 31.5, 31.0, 30.9, 30.5, 28.9, 28.9, 26.2, 26.2, 25.4, 25.4, 24.8, 24.8, 22.7, 22.7, 22.6, 22.6, 14.1, 14.1, 14.1, 14.1;

HRMS calcd for $C_{16}H_{26}O_2$ 250.1933, found 250.1938 ($[M-H_2O]^+$)



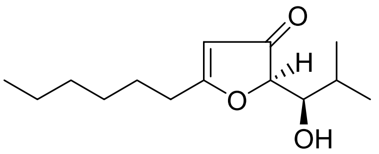
5-Hexyl-2-(hydroxy-phenyl-methyl)-furan-3-one (10b)

IR (neat) 3410, 2928, 2860, 1683, 1589, 1454;

^{1}H NMR (500MHz, $CDCl_3$): A 1:1 mixture of *threo/erythro*; 7.36 (10H, m), 5.40 (1H, s), 5.37 (1H, s), 5.21 (1H, m), 4.86 (1H, d, 6.7Hz), 4.65 (1H, d, 3.5Hz), 4.57 (1H, dd, 6.7Hz, 0.7Hz), 3.76 (1H, OH), 3.07 (1H, OH), 2.42 (4H, m), 1.56 (4H, m), 1.28 (10H, m), 0.88 (6H, m);

^{13}C NMR (125MHz, $CDCl_3$): 203.9, 203.4, 195.9, 195.7, 139.1, 138.3, 128.4, 128.2, 128.1, 128.1, 126.8, 126.4, 104.5, 103.9, 86.7, 86.7, 73.6, 72.6, 31.3, 31.2, 30.7, 30.6, 28.6, 28.6, 25.9, 25.9, 22.3, 22.3, 13.9, 13.9;

HRMS calcd for $C_{17}H_{20}O_2$ 256.1463, found 256.1452 ($[M-H_2O]^+$)



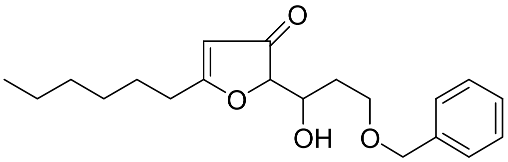
5-Hexyl-2-(1-hydroxy-2-methyl-propyl)-furan-3-one (10c)

IR (neat) 3417, 2956, 2928, 2870, 1681, 1591, 1454;

^{1}H NMR (500MHz, $CDCl_3$): 5.46 (1H, d, 0.6Hz), 4.52 (1H, dd, 2.5Hz, 0.5Hz), 3.74 (1H, d, 6.3Hz), 2.53 (2H, t, 7.6Hz), 2.11 (1H, OH), 2.02 (1H, m, 6.8Hz), 1.65 (2H, m), 1.37 (2H, m), 1.29 (4H, m), 1.05 (3H, d, 6.6Hz), 1.02 (3H, 6.6Hz), 0.88 (3H, t, 7.0Hz);

^{13}C NMR (125MHz, $CDCl_3$): 204.2, 195.6, 104.3, 86.2, 75.7, 31.3, 31.1, 30.8, 28.7, 26.0, 22.4, 19.1, 18.5, 13.9;

HRMS calcd for $C_{14}H_{25}O_3$ 241.1804, found 241.1811 for (MH^+)



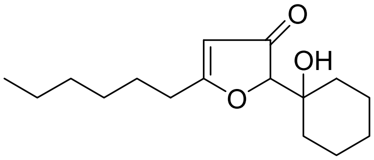
2-(3-Benzyloxy-1-hydroxy-propyl)-5-hexyl-furan-3-one (10e)

IR (neat) 3422, 2928, 2854, 1687, 1590, 1448;

^{1}H NMR (500MHz, $CDCl_3$): A 1:1 mixture of *threo/erythro*; 7.30 (10H, m), 5.46 (1H, s), 5.44 (1H, s), 4.51 (4H, s), 4.45 (1H, d, 5.3Hz), 4.28 (1H, d, 3.8Hz), 4.27 (1H, br. s), 4.13 (1H, m), 3.75 (1H, m), 3.70 (3H, m), 3.12 (1H, OH), 2.51 (4H, t, 7.8Hz), 2.00 (2H, m), 1.95 (1H, m), 1.80 (1H, m), 1.68 (4H, m), 1.37 (4H, m), 1.30 (8H, m), 0.88 (6H, m, 6.9Hz);

^{13}C NMR (125MHz, $CDCl_3$): 203.6, 203.2, 137.8, 137.7, 128.4, 128.4, 127.7, 127.7, 127.6, 127.6, 104.3, 103.9, 87.4, 86.9, 73.3, 73.2, 70.1, 69.2, 68.0, 67.6, 32.2, 31.3, 31.3, 31.1, 30.7, 30.7, 28.7, 28.7, 25.9, 25.9, 22.4, 22.4, 13.9, 13.9;

HRMS calcd for $C_{20}H_{28}O_4Na$ 355.1885, found 355.1878 for (MNa^+)



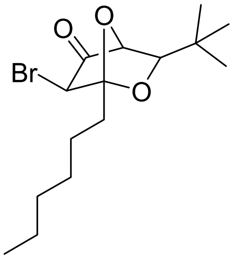
5-Hexyl-2-(1-hydroxy-cyclohexyl)-furan-3-one (10f)

IR (neat) 3442, 2930, 2858, 1685, 1592, 1448;

^{1}H NMR (500MHz, CDCl$_3$): 5.45 (1H, s), 4.19 (1H, s), 3.27 (1H, OH), 2.52 (2H, t, 7.6Hz), 1.65 (7H, m), 1.55 (2H, m), 1.38 (4H, m), 1.33 (4H, m), 1.10 (1H, m), 0.89 (3H, t, 7.0Hz);

^{13}C NMR (125MHz, CDCl$_3$): 204.9, 195.2, 104.8, 89.2, 73.0, 34.2, 31.3, 30.8, 28.7, 26.0, 25.4, 22.4, 20.8, 13.9;

HRMS calcd for $C_{16}H_{27}O_3$ 267.1960, found 267.1967 for (MH$^+$)



6-Bromo-3-*tert*-butyl-1-hexyl-2,7-dioxa-bicyclo[2.2.1]heptan-5-one (11)

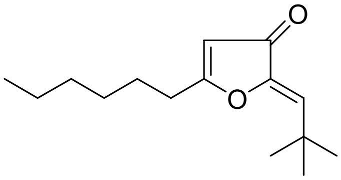
To a stirred solution of the alcohol **10d** (0.100 g, 0.39 mmol) in dry dichloromethane (3 ml) at -20°C, was added *N*-bromosuccinimide (0.081g, 0.45 mmol) portionwise. The resulting mixture was stirred until no starting material was observed by thin layer chromatography then saturated ice-cold sodium bicarbonate solution was added. Extraction using diethyl ether (20 ml×3) and the combined organic layers were washed with saturated brine and dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was purified by flash chromatography (eluent 80/20 hexanes/diethyl ether) to give the bromo-ether **11** as a yellowish oil (0.111 g, 85 %)

IR (neat) 2956, 1710, 1595;

^{1}H NMR (500MHz, CDCl$_3$): 4.70 (1H, t, 0.5Hz), 3.83 (1H, s), 2.73 (1H, m, 7.5Hz), 2.65 (1H, m, 7.3Hz), 1.80 (2H, m), 1.70 (1H, m), 1.40 (2H, m), 1.31 (4H, m), 1.05 (9H, s), 0.89 (3H, t, 7.0Hz);

^{13}C NMR (125MHz, $CDCl_3$): 191.1, 97.3, 85.4, 78.3, 35.5, 31.5, 29.8, 28.8, 26.6, 26.1, 25.8, 22.6, 14.1;

HRMS calcd for $C_{15}H_{23}O_2Br$ 314.0881, found 314.0861 ($[M-H_2O]^+$ using ^{79}Br) and 316.0868 ($[M-H_2O]^+$ using ^{81}Br)



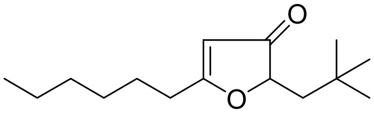
2-(2,2-Dimethyl-propylidene)-5-hexyl-furan-3-one (12)

IR (neat) 2957, 2931, 2865, 1704, 1663, 1604, 1461, 1362;

^{1}H NMR (500MHz, $CDCl_3$): 5.90 (1H, s), 5.57 (1H, s), 2.54 (2H, t, 7.5Hz), 1.66 (2H, tt, 7.5Hz, 7.5Hz), 1.37 (2H, m), 1.30 (4H, m), 1.22 (9H, s), 0.87 (3H, t, 7.0Hz);

^{13}C NMR (125MHz, $CDCl_3$): 188.3, 184.8, 146.3, 124.9, 104.7, 32.5, 31.3, 29.9, 29.8, 28.7, 25.8, 22.4, 13.9;

HRMS calcd for $C_{15}H_{24}O_2$ 236.1776, found 236.1777 (M^+)



2-(2,2-Dimethyl-propyl)-5-hexyl-furan-3-one (13)

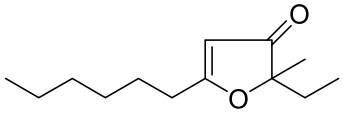
To a stirred solution of the unsaturated ketone **12** (0.200g, 0.85mmol) in dry methanol (4ml) at ambient temperature, was added 10 % palladium on activated carbon (9 mg). The resulting solution was stirred under the atmosphere of hydrogen using a balloon. The stirring was continued for 18 hours then the solution was diluted with diethyl ether. Filtration of the solid residue using diethyl ether (20 ml×3) and the filtrate was concentrated in vacuo. The residue was purified by flash chromatography (eluent 80/20 hexanes/diethyl ether) to give the reduced furanone **13** as an oil (0.161 g, 80 %)

IR (neat) 2957, 2868, 1711, 1598, 1466;

^{1}H NMR (500MHz, $CDCl_3$): 5.40 (1H, s), 4.44 (1H, d, 10.9Hz), 2.48 (2H, t, 7.6Hz), 1.83 (1H, d, 14.9Hz), 1.62 (2H, m), 1.31 (9H, m), 1.01 (9H, s), 0.88 (3H, t, 7.1Hz);

^{13}C NMR (125MHz, $CDCl_3$): 206.0, 194.0, 102.9, 84.9, 45.7, 31.5, 30.9, 30.5, 29.9, 28.9, 26.1, 22.6, 14.1;

HRMS calcd for $C_{15}H_{26}O_2$ 238.1933, found 238.1939 (M^+)



2-Ethyl-5-hexyl-2-methyl-furan-3-one (16)

To a stirred solution of the furanone **14** (0.300 g, 1.65 mmol) in dry tetrahydrofuran at -78°C, was added sodium bis(trimethylsilyl)amide (0.90 ml, 1.81 mmol) dropwise. The resulting yellow solution was stirred for 10 minutes then Iodoethane (0.26 ml, 3.29 mmol) was introduced. The reaction mixture was warmed up to ambient temperature over one hour and stirred for two hours at same temperature. The reaction was quenched by addition of saturated ammonium chloride solution and diluted with diethyl ether. Extraction using diethyl ether (20 ml×3) was performed and the combined organic layer were washed with saturated brine and dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was purified by flash chromatography (eluent 90/10 hexanes/diethyl ether) to give the furanone **16** as an oil (0.294 g, 85 %)

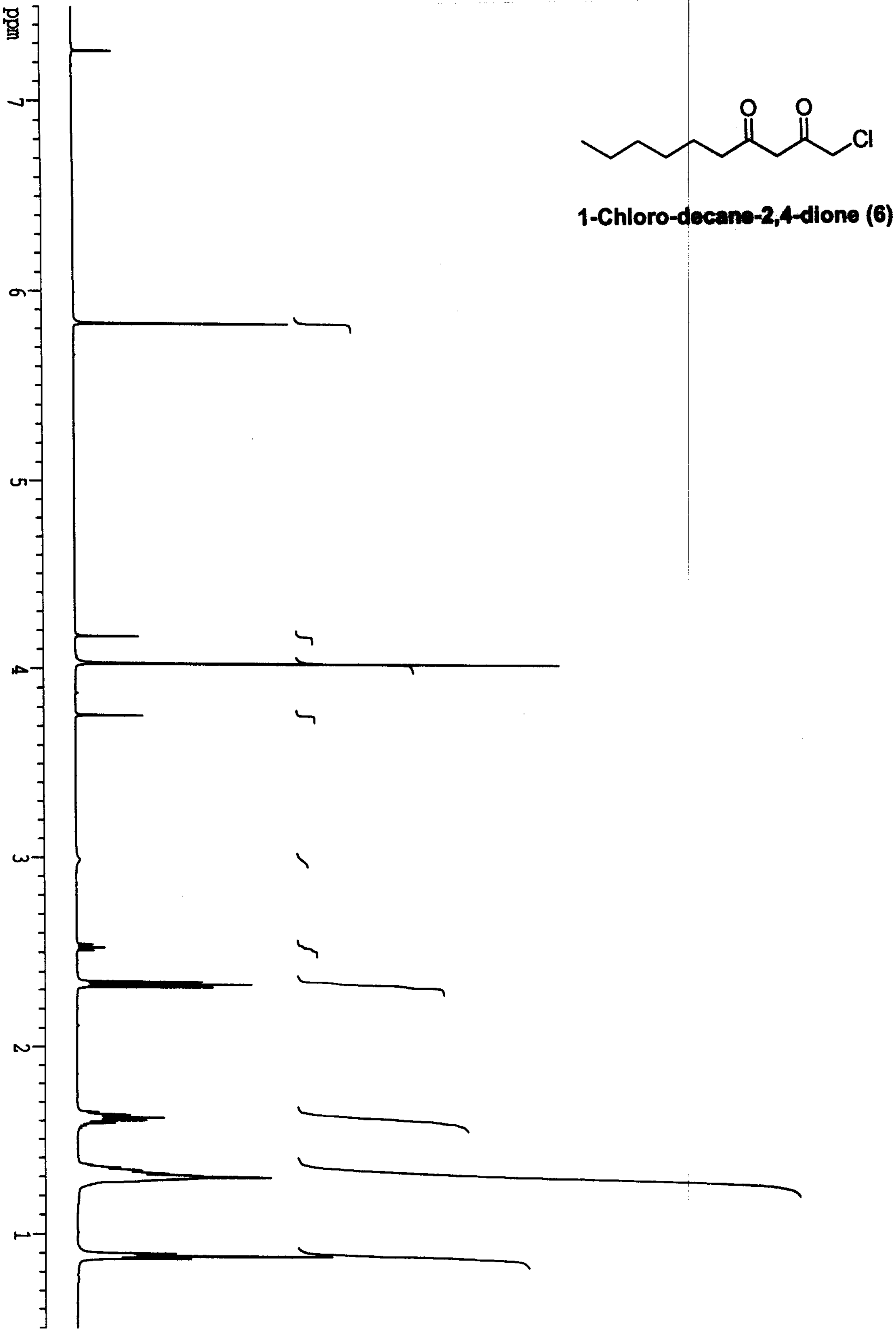
IR (neat) 2957, 2931, 2860, 1703, 1595, 1456;

^{1}H NMR (500MHz, $CDCl_3$):5.35 (1H, s), 2.47 (2H, t, 7.6Hz), 1.75 (2H, m), 1.64 (2H, m), 1.36 (2H, m), 1.36 (3H, s), 1.30 (4H, m), 0.88 (3H, t, 7.0Hz), 0.80 (3H, t, 7.4Hz);

^{13}C NMR (125MHz, $CDCl_3$): 207.3, 192.6, 102.4, 91.2, 31.3, 30.8, 29.6, 28.7, 26.1, 22.4, 21.5, 13.9, 7.4;

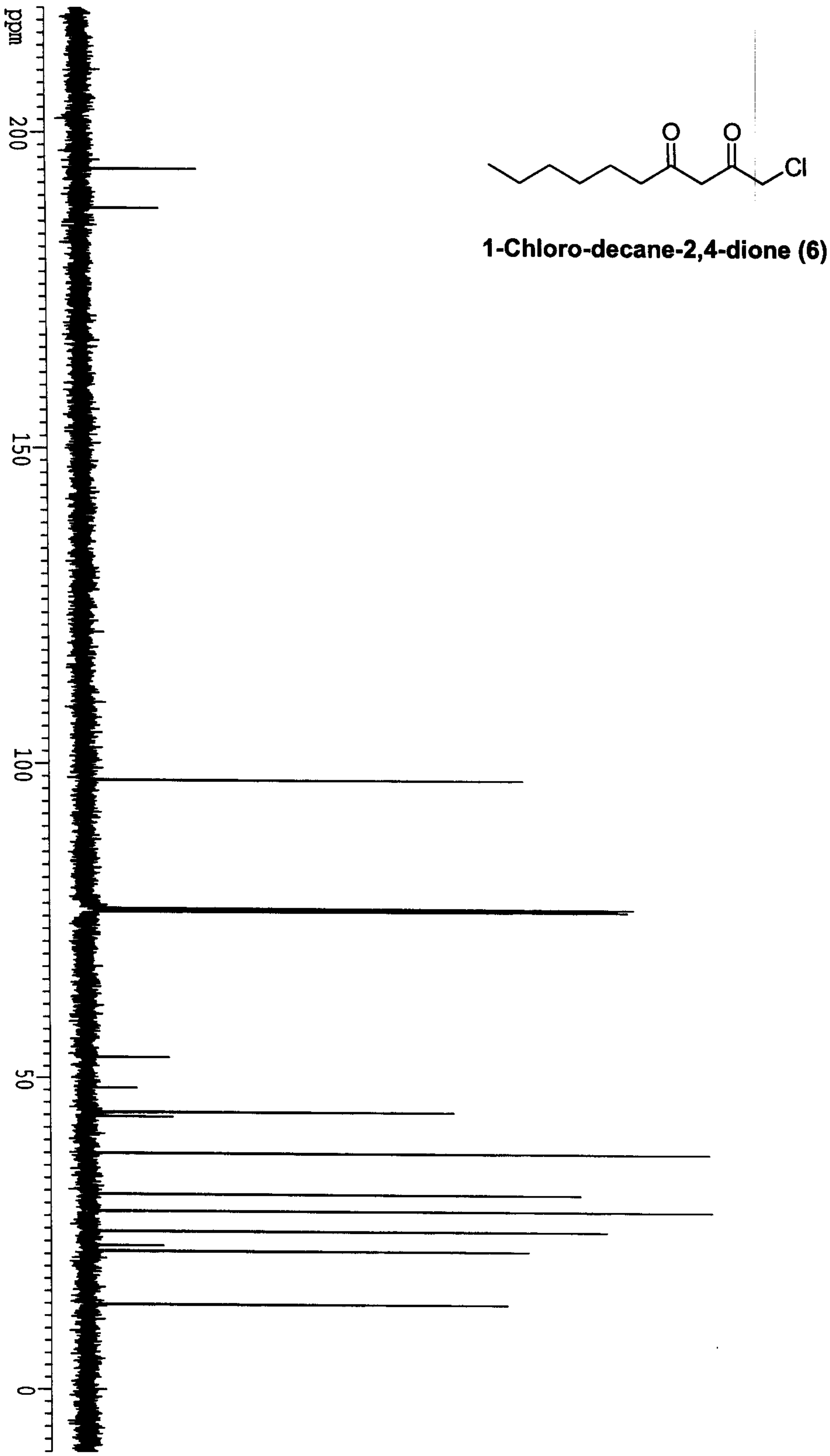
HRMS calcd for $C_{13}H_{23}O_2$ 211.1698, found 211.1688 (MH^+)

^{1}H NMR Spectrum of 6



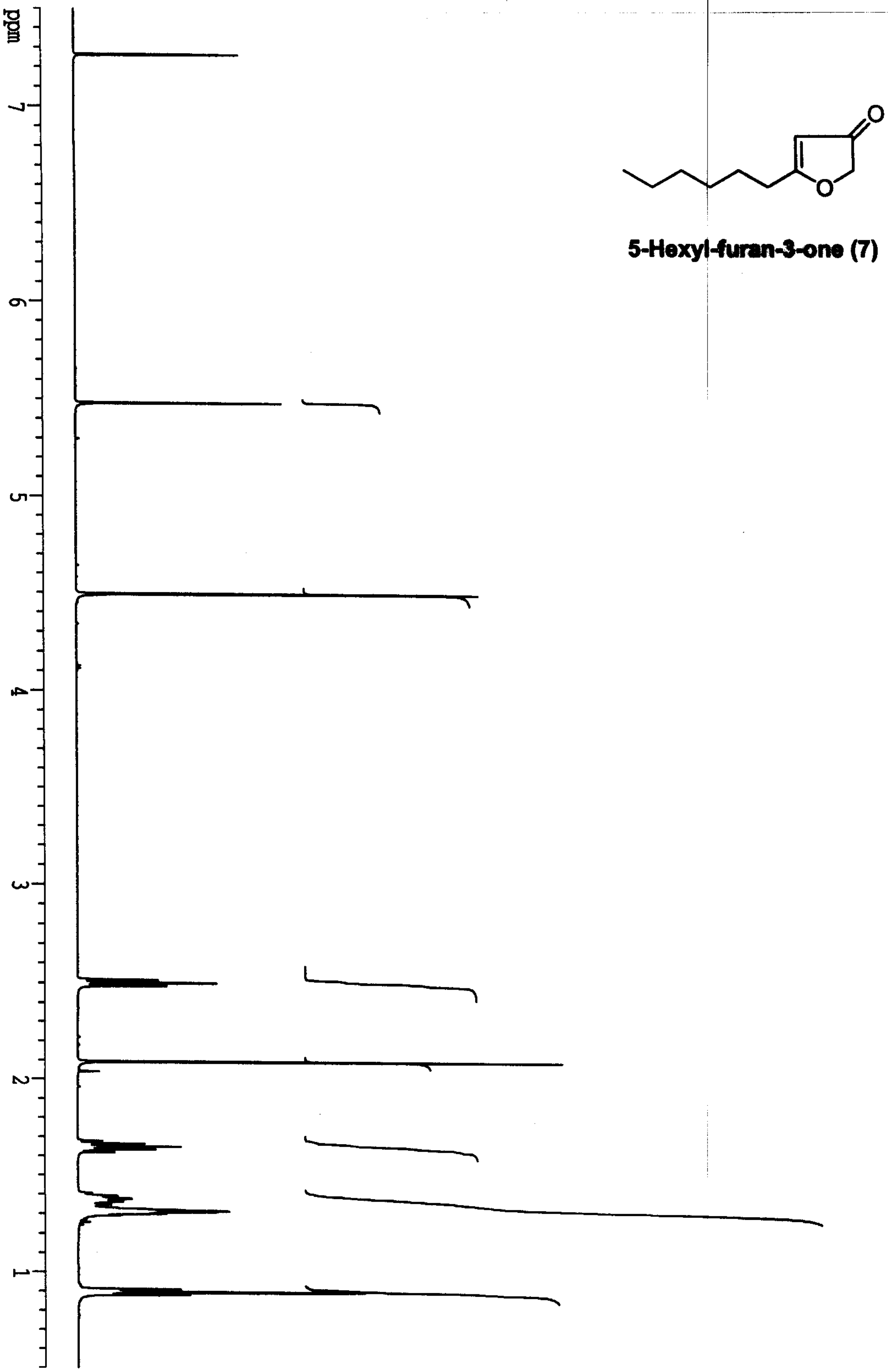
1-Chloro-decane-2,4-dione (6)

^{13}C NMR Spectrum of 6



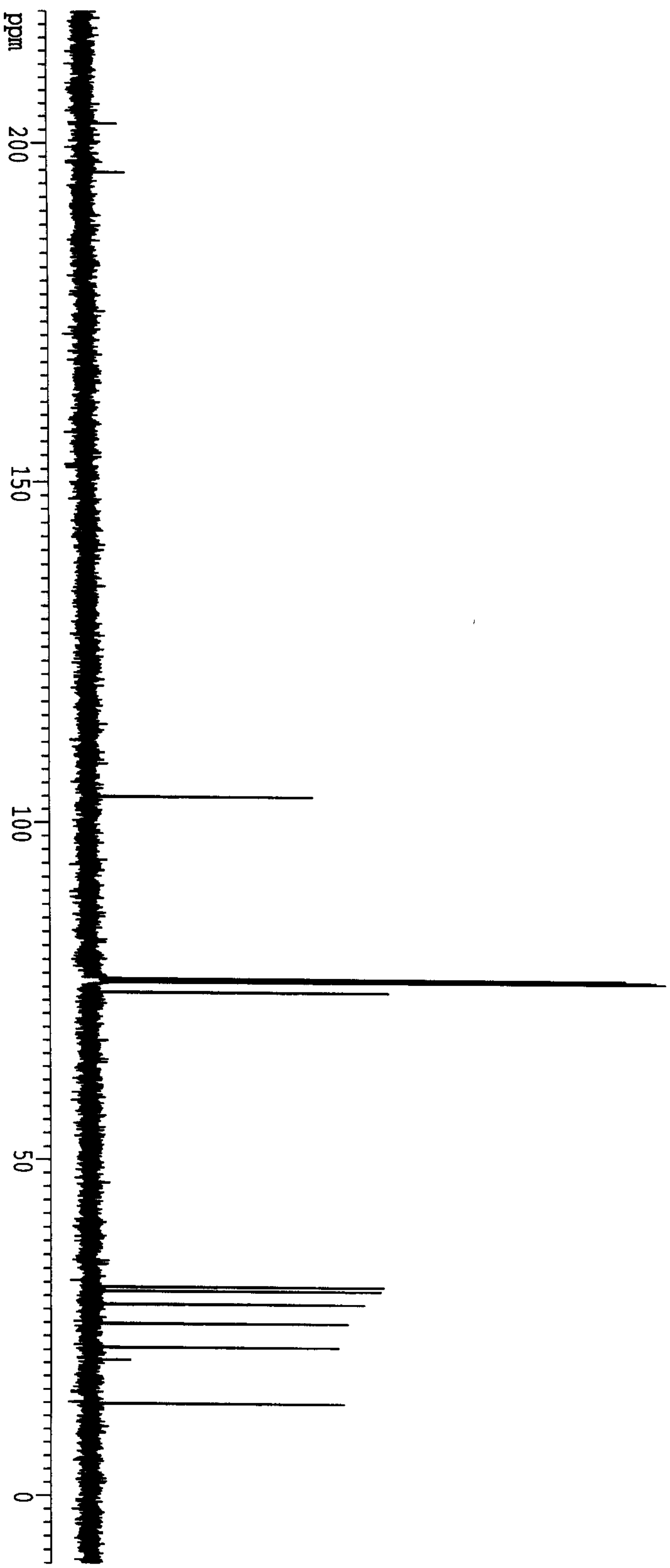
1-Chloro-decane-2,4-dione (6)

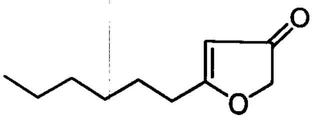
^{1}H NMR Spectrum of 7



5-Hexyl-furan-3-one (7)

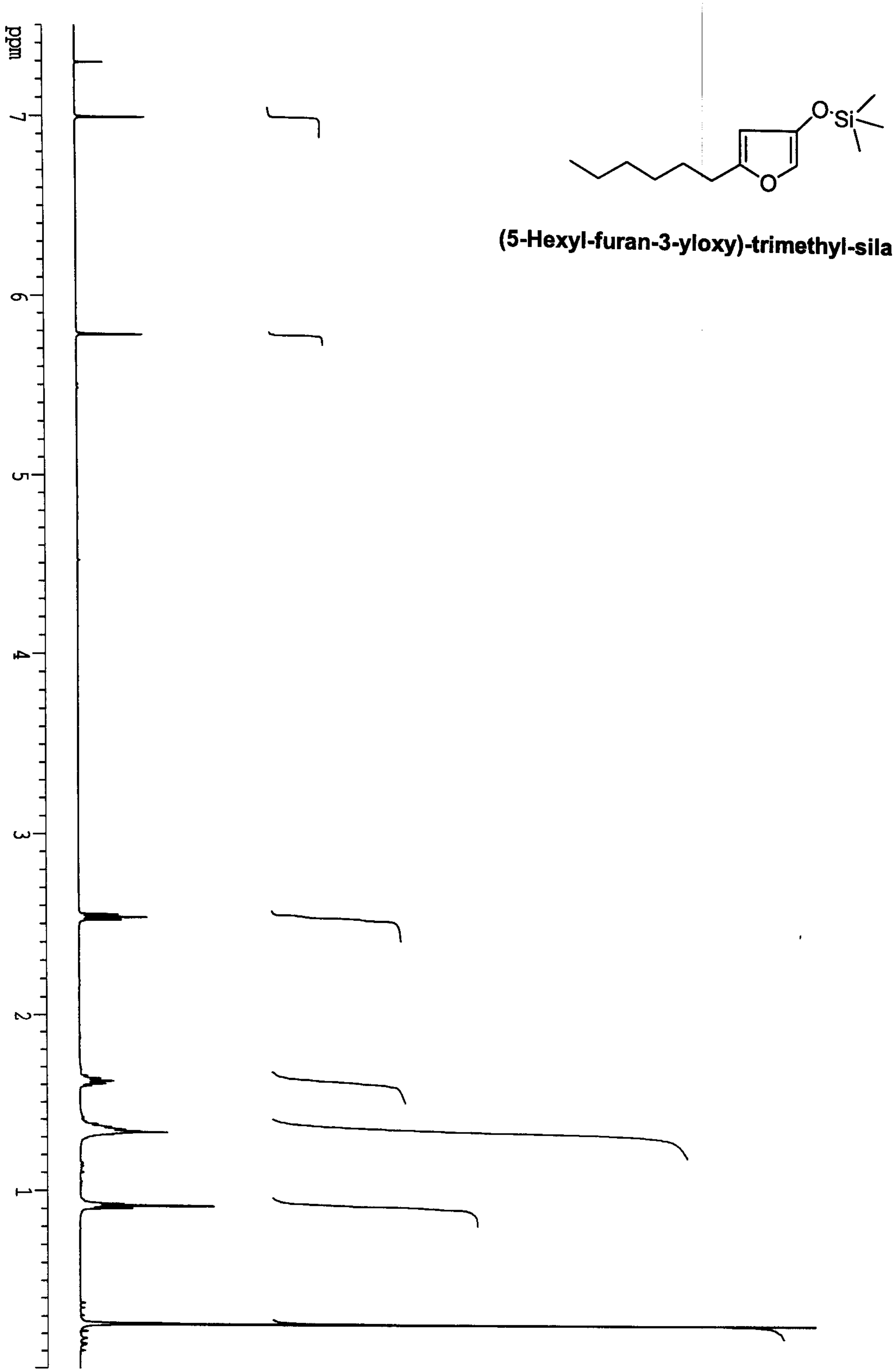
^{13}C NMR Spectrum of 7





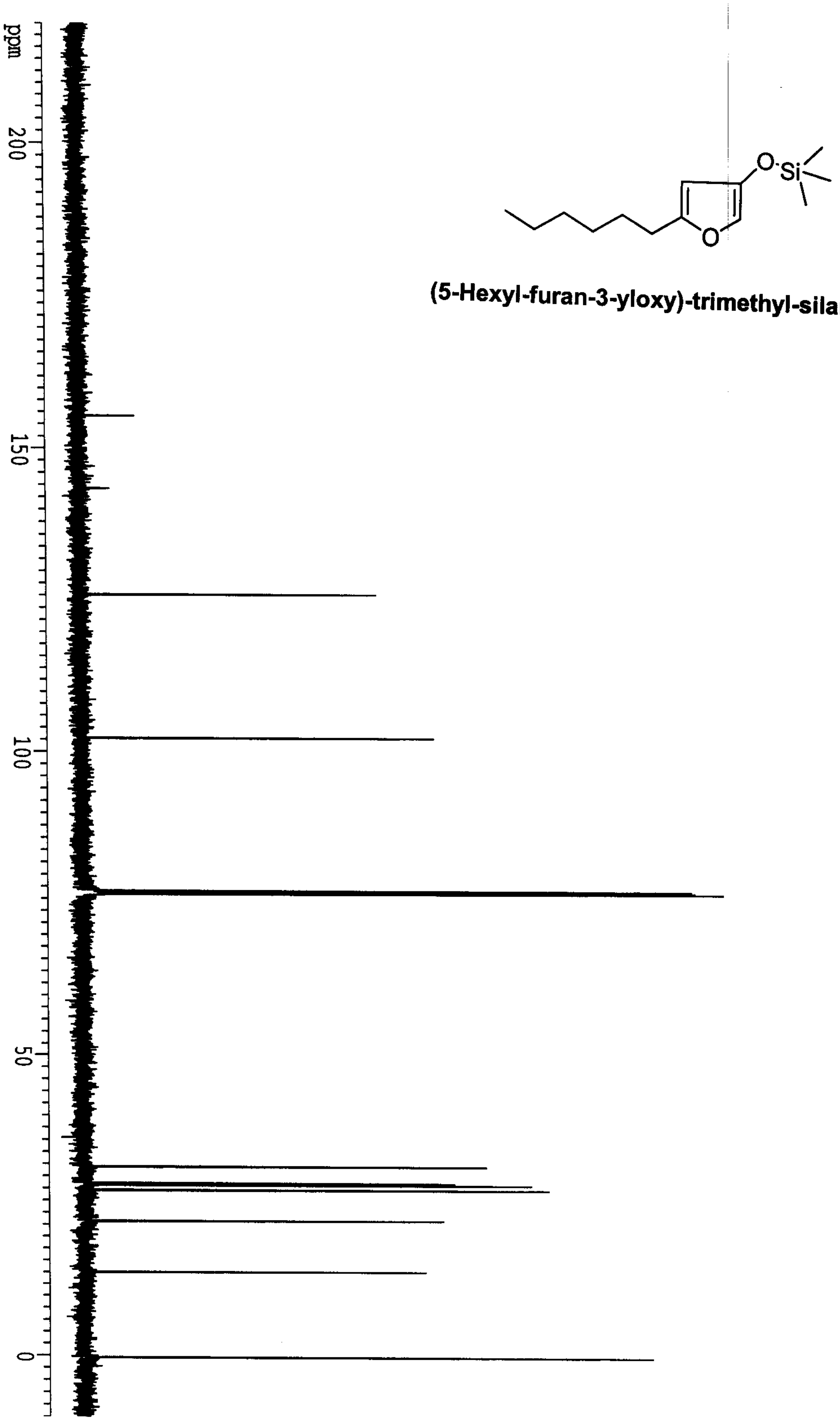
5-Hexyl-furan-3-one (7)

^1H NMR Spectrum of 8



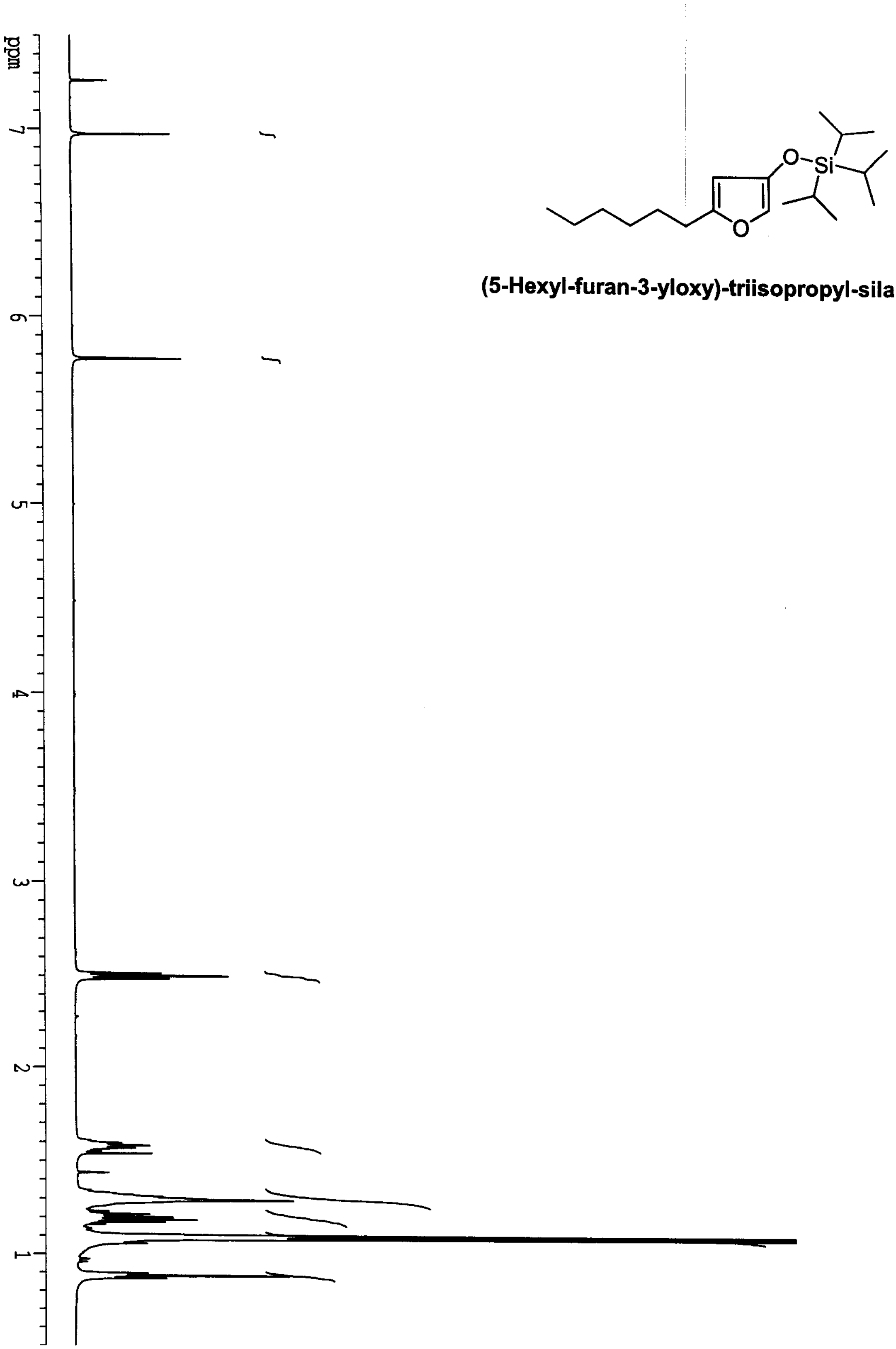
(5-Hexyl-furan-3-yloxy)-trimethyl-silane (8)

^{13}C NMR Spectrum of 8



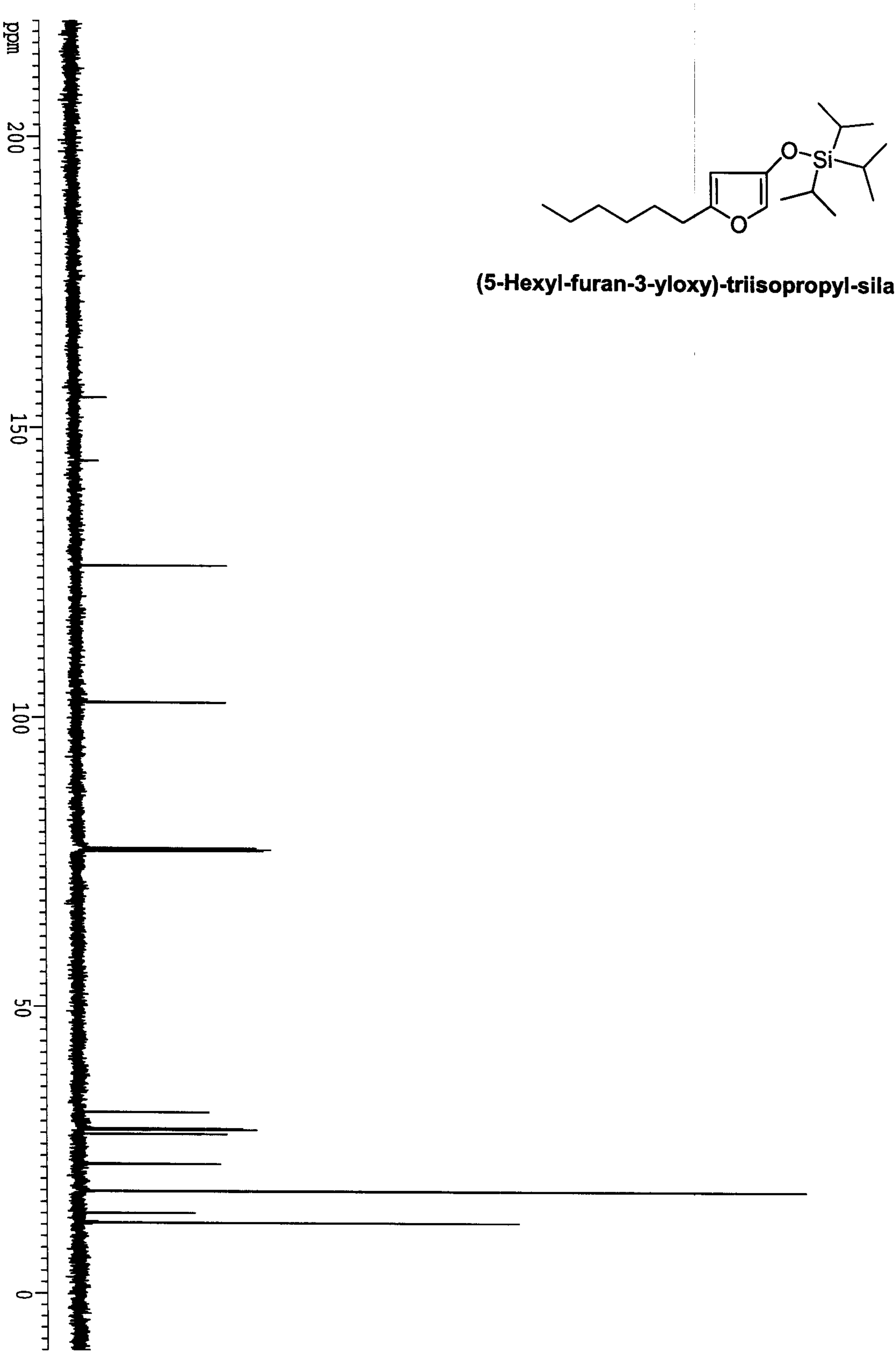
(5-Hexyl-furan-3-yloxy)-trimethyl-silane (8)

^{1}H NMR Spectrum of 9



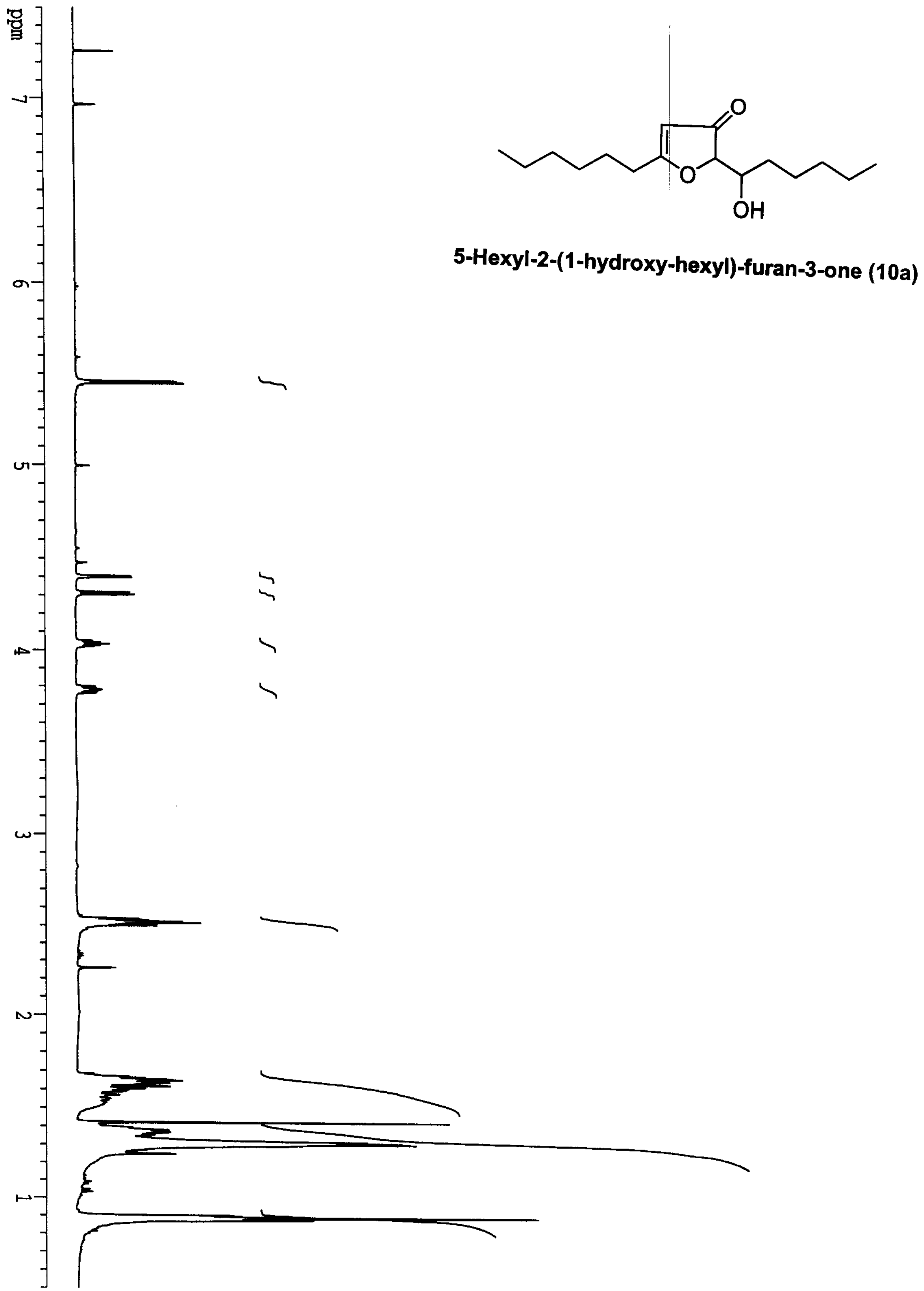
(5-Hexyl-furan-3-yloxy)-triisopropyl-silane (9)

^{13}C NMR Spectrum of 9



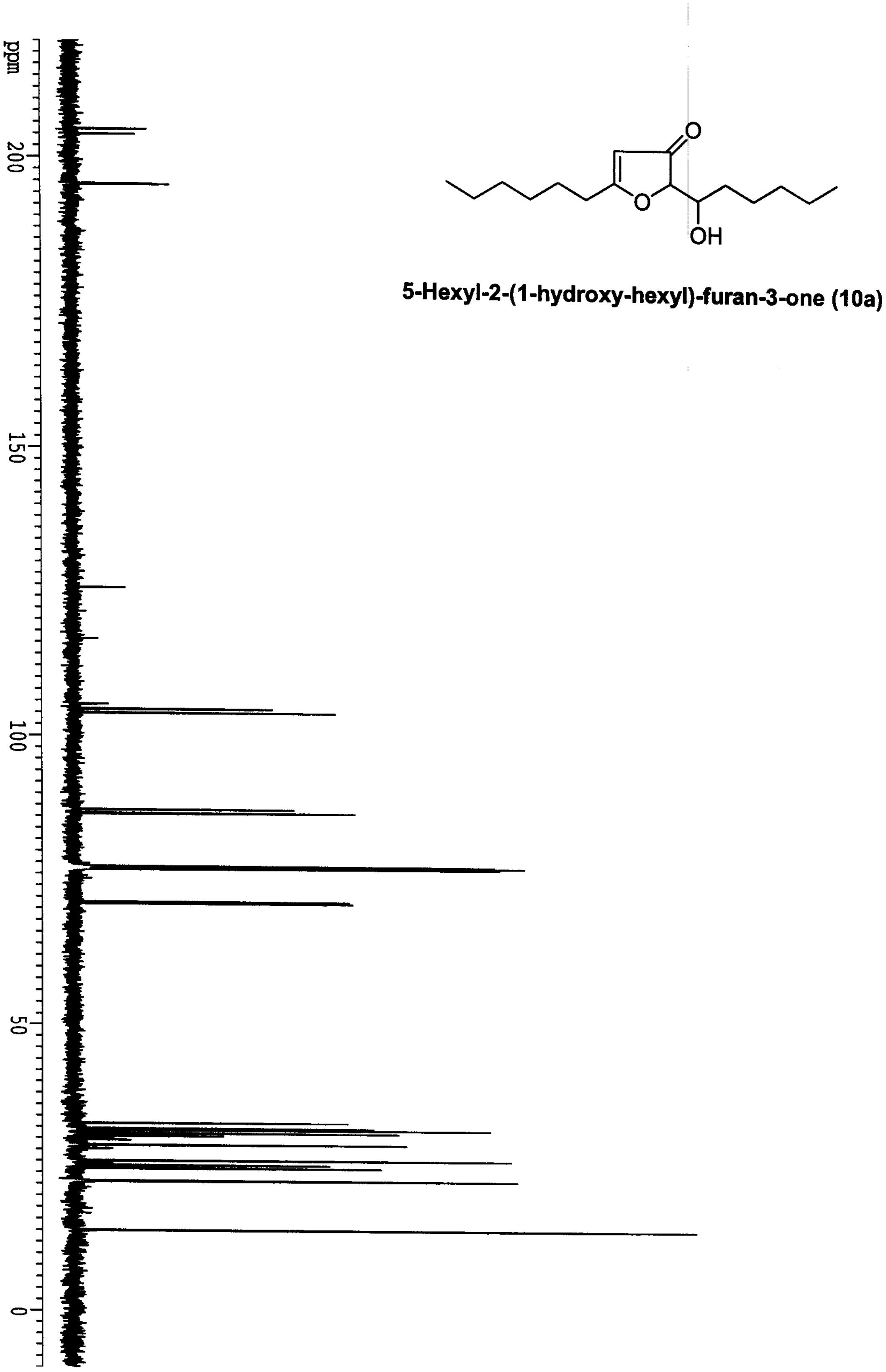
(5-Hexyl-furan-3-yloxy)-triisopropyl-silane (9)

^{1}H NMR Spectrum of 10a



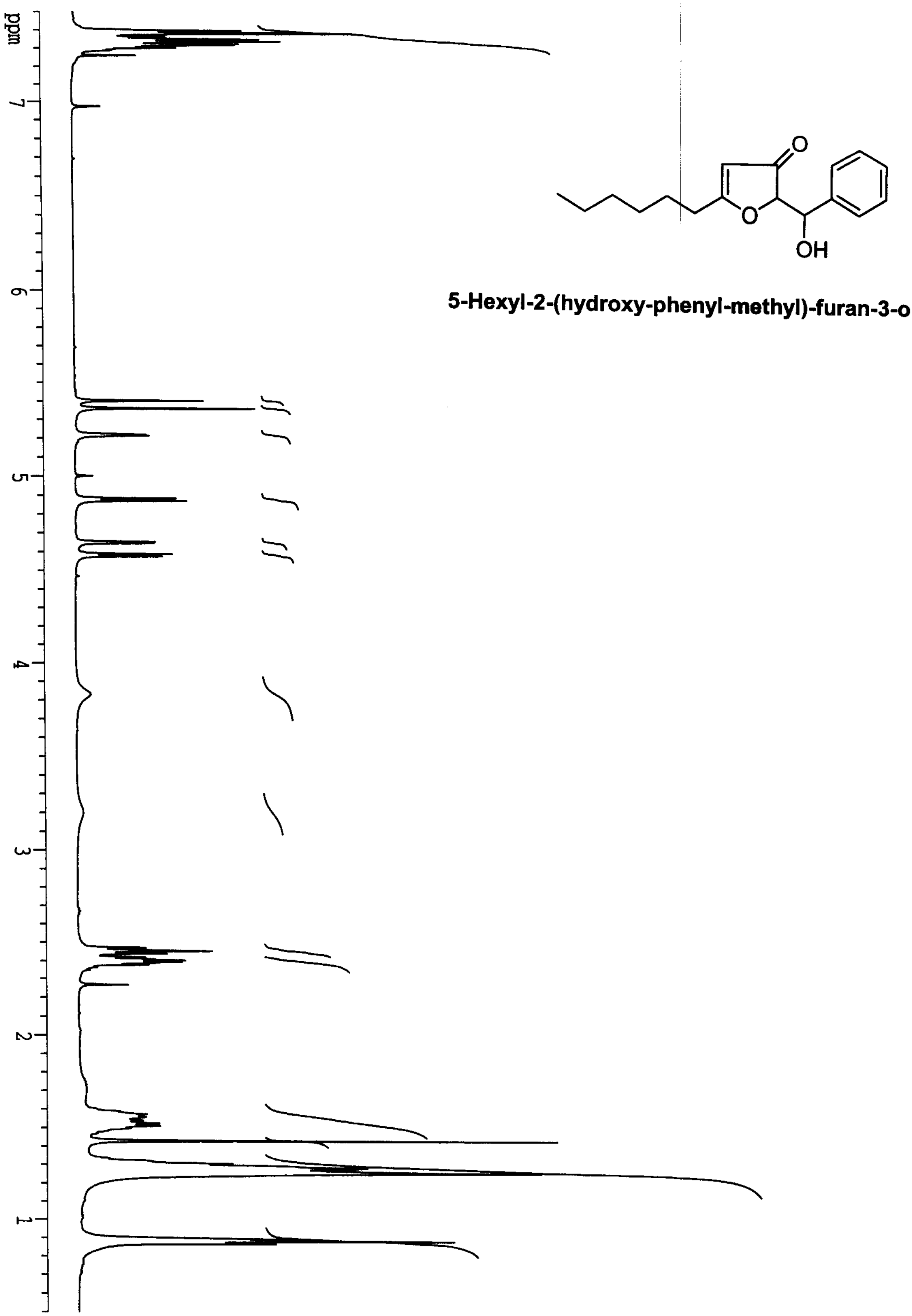
5-Hexyl-2-(1-hydroxy-hexyl)-furan-3-one (10a)

^{13}C NMR Spectrum of 10a



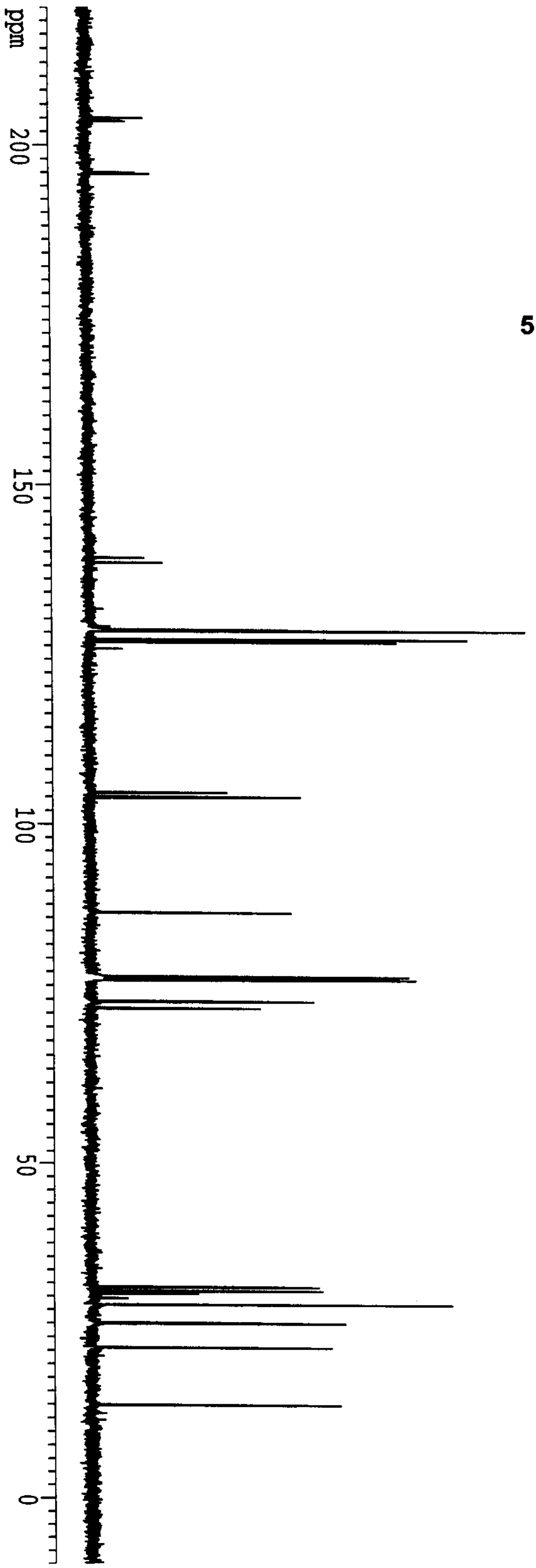
5-Hexyl-2-(1-hydroxy-hexyl)-furan-3-one (10a)

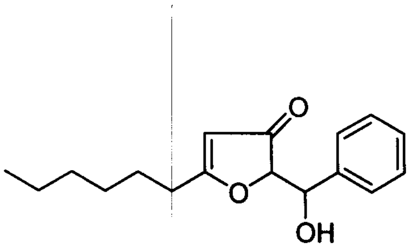
^{1}H NMR Spectrum of 10b



5-Hexyl-2-(hydroxy-phenyl-methyl)-furan-3-one (10b)

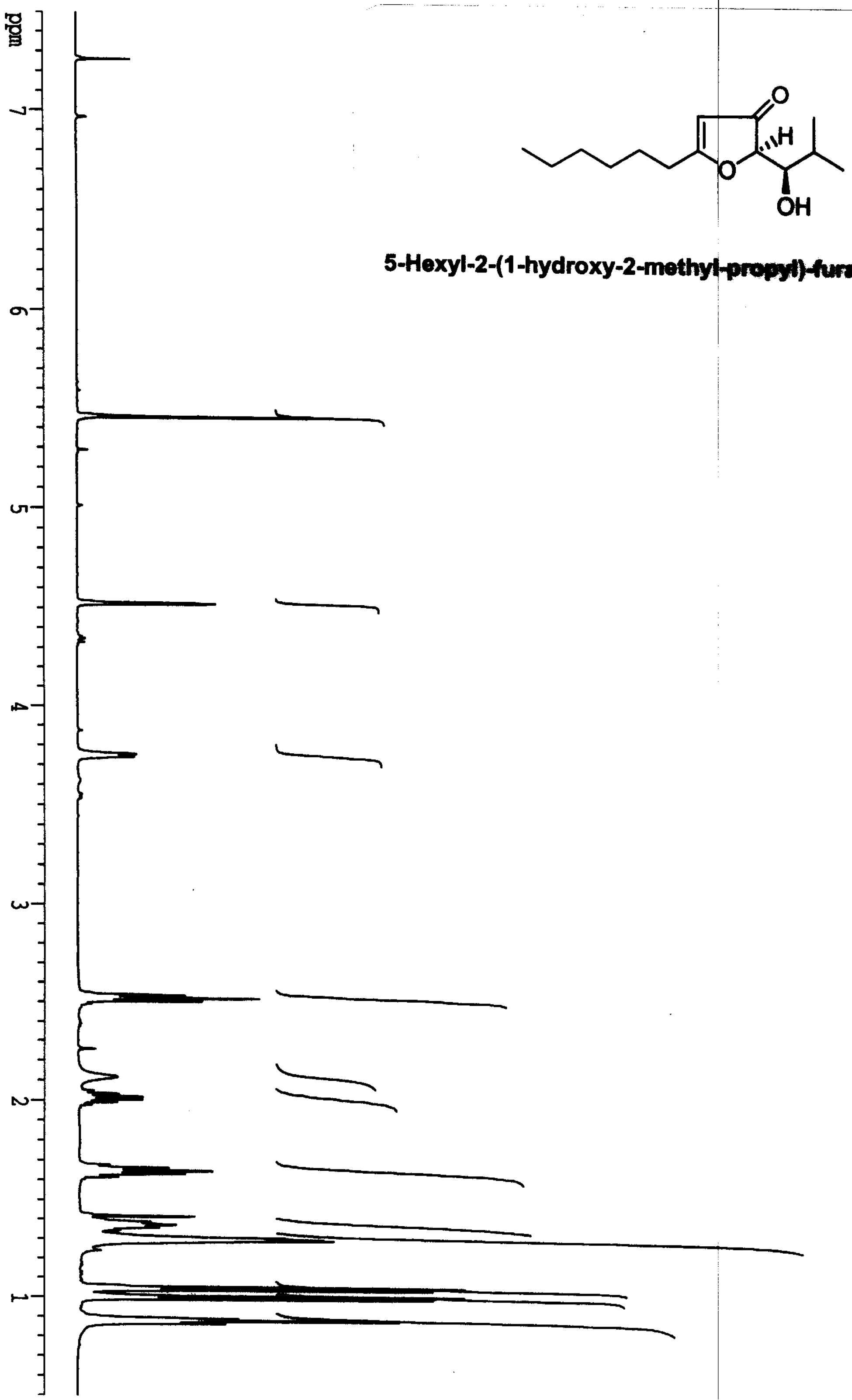
^{13}C NMR Spectrum of 10b





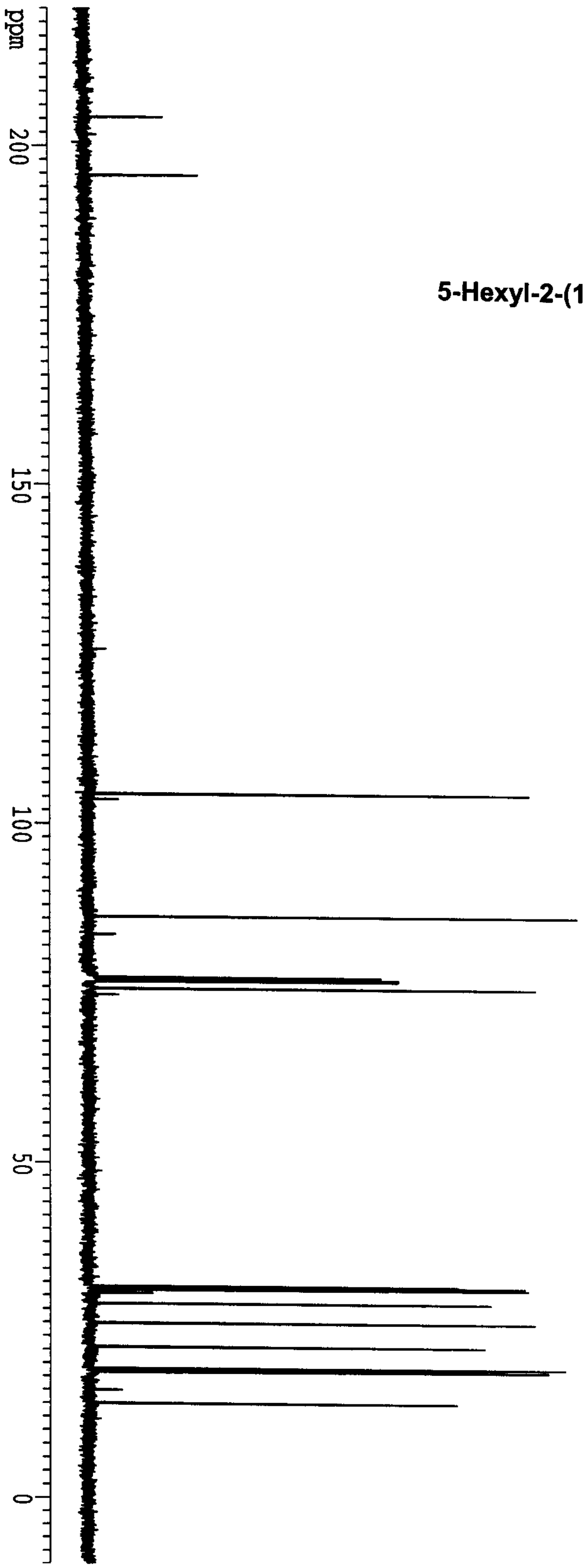
5-Hexyl-2-(hydroxy-phenyl-methyl)-furan-3-one (10b)

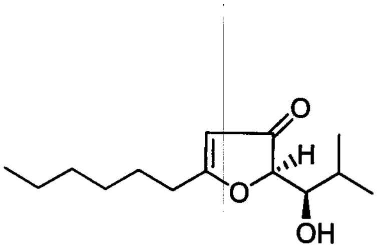
^1H NMR Spectrum of 10c



5-Hexyl-2-(1-hydroxy-2-methyl-propyl)-furan-3-one (10c)

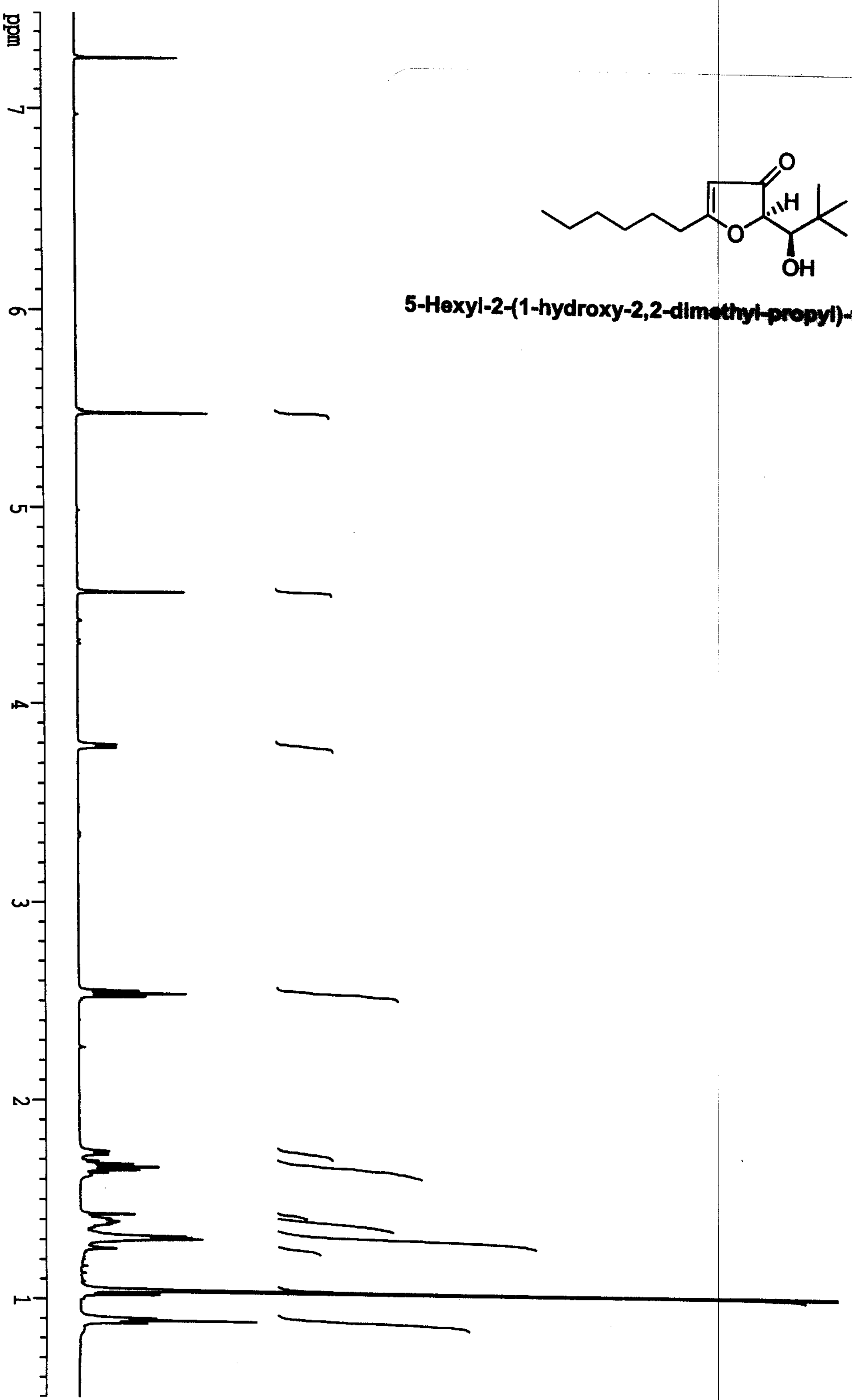
^{13}C NMR Spectrum of 10c





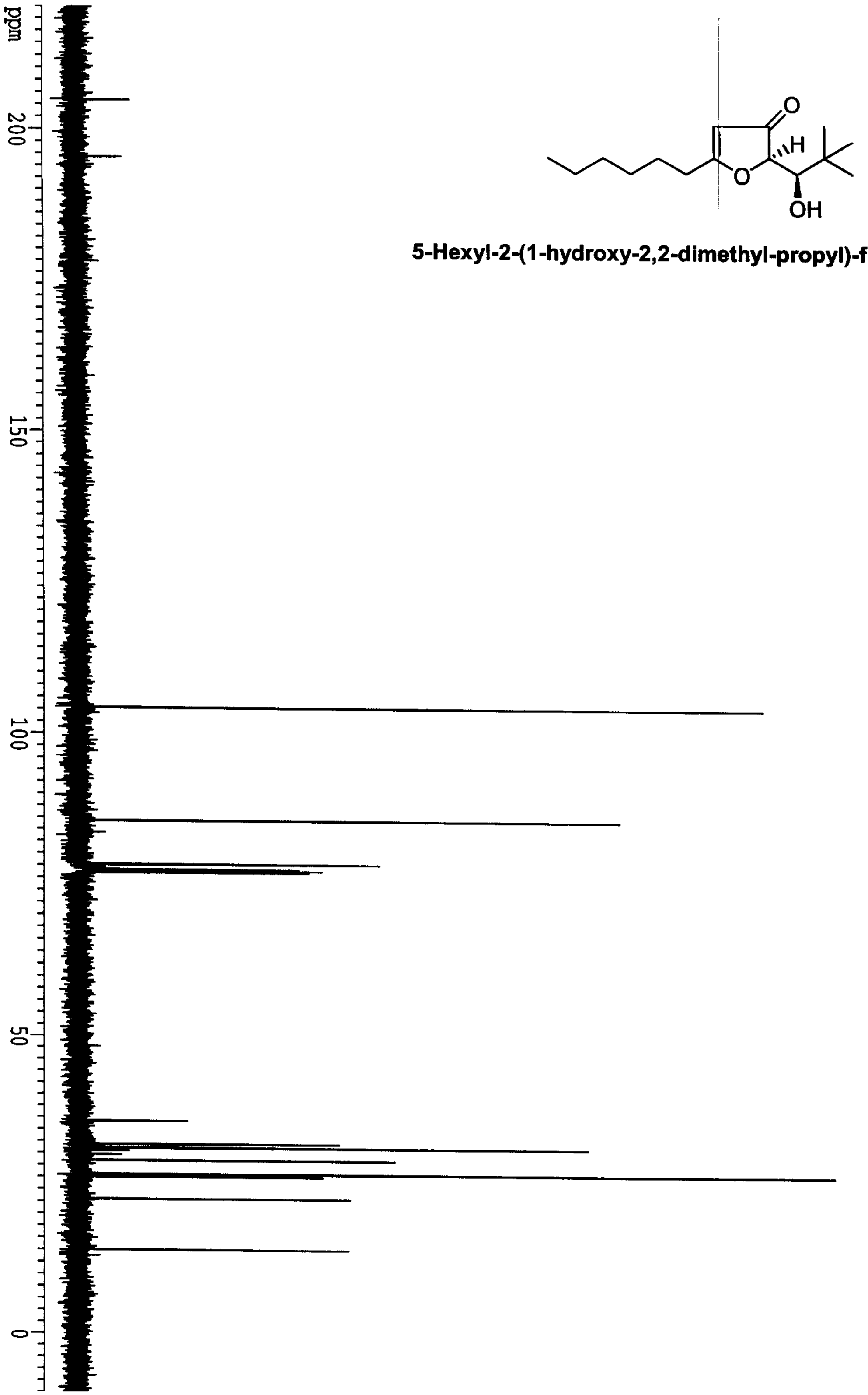
5-Hexyl-2-(1-hydroxy-2-methyl-propyl)-furan-3-one (10c)

^{1}H NMR Spectrum of 10d



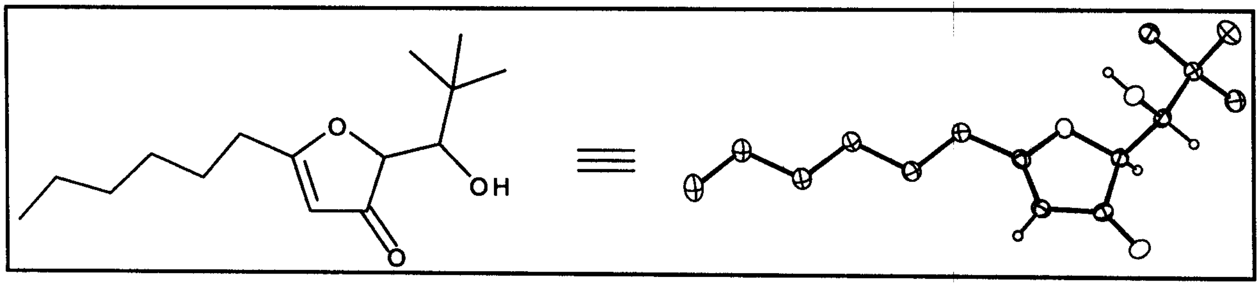
5-Hexyl-2-(1-hydroxy-2,2-dimethyl-propyl)-furan-3-one (10d)

^{13}C NMR Spectrum of 10d



5-Hexyl-2-(1-hydroxy-2,2-dimethyl-propyl)-furan-3-one (10d)

X-Ray Structure Determination of 10d



Compound 2018, $C_{15}H_{26}O_3$, crystallizes in the triclinic space group $P\bar{1}$ with $a=5.7876(9)$Å, $b=9.3219(11)$Å, $c=14.716(2)$Å, $\alpha=72.903(7)°$, $\beta=85.327(9)°$, $\gamma=83.290(8)°$, $V=752.8(2)$Å^3, $Z=2$ and $d_{calc}=1.122$ g/cm^3. X-ray intensity data were collected on a Rigaku Mercury CCD area detector employing graphite-monochromated Mo-K_α radiation ($\lambda=0.71069$ Å) at a temperature of 143°K. Preliminary indexing was performed from a series of twelve 0.5° rotation images with exposures of 30 seconds. A total of 824 rotation images were collected with a crystal to detector distance of 36 mm, a 2θ swing angle of -12°, rotation widths of 0.5° and exposures of 30 seconds: scan no. 1 was a ϕ-scan from 135° to 315° at $\omega = 10°$ and $\chi = 20°$; scan no. 2 was a ϕ-scan from 180° to 360° at $\omega = 0°$ and $\chi = -30°$; scan no. 3 was an ω-scan from -14° to 10° at $\chi = -90°$ and $\phi = 135°$; scan no. 4 was an ω-scan from -20° to 8° at $\chi = -90°$ and $\phi = 0°$. Rotation images were processed using CrystalClear[1], producing a listing of unaveraged F^2 and $\sigma(F^2)$ values which were then passed to the CrystalStructure[2] program package for further processing and structure solution on a Dell Pentium III computer. A total of 7619 reflections were measured over the ranges $5.8 \leq 2\theta \leq 50.7$ °, $-6 \leq h \leq 6$, $-10 \leq k \leq 11$, $-15 \leq l \leq 17$ yielding 2670 unique reflections ($R_{int} = 0.0350$). The intensity data were corrected for Lorentz and polarization effects and for absorption. using REQAB[3] (minimum and maximum transmission 0.543, 1.000).

The structure was solved by direct methods (SIR97[4]). Refinement was by full-matrix least squares based on F^2 using SHELXL-97[5]. All reflections were used during refinement (F^2's that were experimentally negative were replaced by $F^2 = 0$). The weighting scheme used was $w=1/[\sigma^2(F_o^2)+0.0703P^2 + 0.0671P]$ where $P = (F_o^2 + 2F_c^2)/3$. Non-hydrogen atoms were refined anisotropically and hydrogen atoms were refined using a ":riding" model. Refinement converged to R_1=0.0517 and wR_2=0.1248 for 2052 reflections for which F > 4σ(F) and R_1=0.0644, wR_2=0.1417 and GOF = 1.055 for all 2670 unique, non-zero reflections and 168 variables[6]. The maximum Δ/σ in the final cycle of least squares was 0.000 and the two most prominent peaks in the final difference Fourier were +0.202 and -0.263 e/Å^3.

Table 1. lists cell information, data collection parameters, and refinement data. Final positional and equivalent isotropic thermal parameters are given in Table 2. Anisotropic thermal parameters are in Table 3. Tables 4. and 5. list bond distances and bond angles. Figure 1. is an ORTEP[7] representation of the molecule with 30% probability thermal ellipsoids displayed.

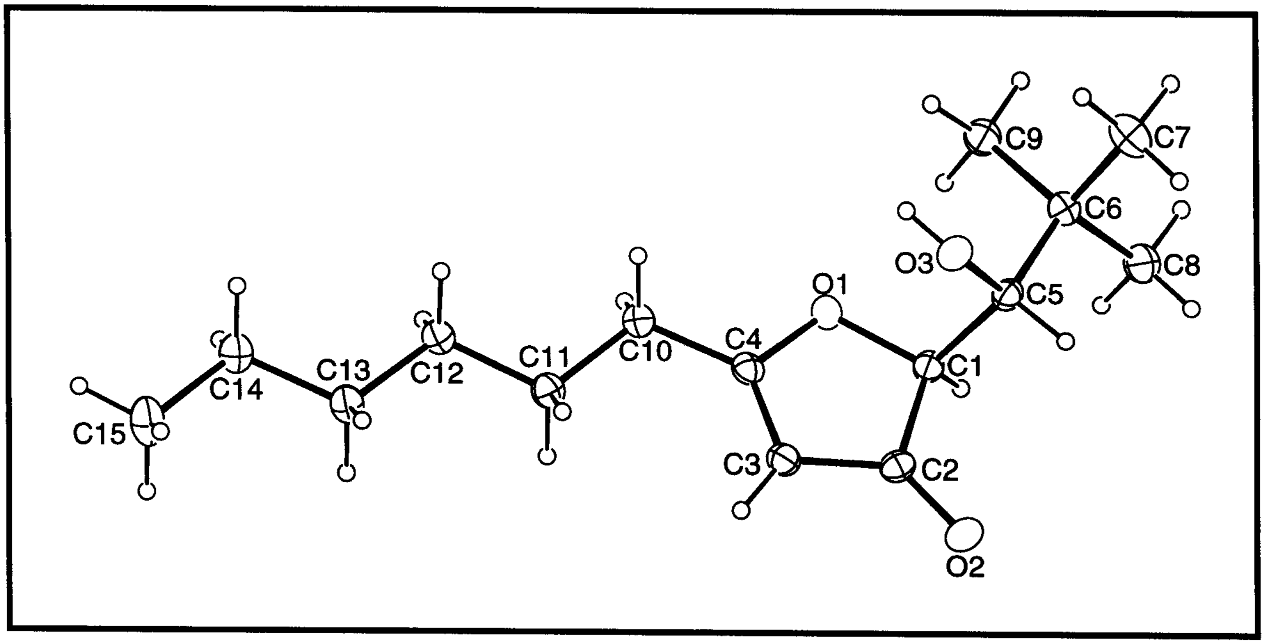


Figure 1. ORTEP drawing of the title compound with 30% probability thermal ellipsoids.

References

1. CrystalClear: Rigaku Corporation, 1999.
2. CrystalStructure: Crystal Structure Analysis Package, Rigaku Corp. Rigaku/MSC (2002).
3. REQAB4: R.A. Jacobsen, (1994). Private Communication.
4. SIR97: Altomare, A., M. Burla, M. Camalli, G. Cascarano, C. Giacovazzo, A. Guagliardi, A. Moliterni, G. Polidori & R. Spagna (1999). *J. Appl. Cryst.*, **32**, 115-119.

5. SHELXL-97: Program for the Refinement of Crystal Structures, Sheldrick, G.M. (1997), University of Göttingen, Germany.

6. $R_1 = \Sigma \, ||F_o| - |F_c|| \, / \, \Sigma \, |F_o|$

   $wR_2 = \{ \Sigma \, w \, (F_o^2 - F_c^2)^2 / \Sigma \, w(F_o^2)^2 \}^{1/2}$

   $GOF = \{ \Sigma \, w \, (F_o^2 - F_c^2)^2 / (n - p) \}^{1/2}$
   where n = the number of reflections and p = the number of parameters refined.

7. "ORTEP-II: A Fortran Thermal Ellipsoid Plot Program for Crystal Structure Illustrations". C.K. Johnson (1976) ORNL-5138.

Table 1. Summary of Structure Determination of Compound 2018

Formula:	$C_{15}H_{26}O_3$
Formula weight:	254.36
Crystal class:	triclinic
Space group:	$P\bar{1}$ (#2)
Z	2
Cell constants:	
a	5.7876(9)Å
b	9.3219(11)Å
c	14.716(2)Å
α	72.903(7)°
β	85.327(9)°
γ	83.290(8)°
V	752.8(2)Å^3
μ	0.76 cm^{-1}
crystal size, mm	0.28 x 0.28 x 0.16
D_{calc}	1.122 g/cm^3
F(000)	280
Radiation:	Mo-K_α (λ=0.71069Å)
2θ range	5.8 – 50.7 °
hkl collected:	$-6\leq h \leq 6$; $-10\leq k \leq 11$; $-15\leq l \leq 17$
No. reflections measured:	7619
No. unique reflections:	2670 (R_{int}=0.0350)
No. observed reflections	2052 (F>4σ)
No. reflections used in refinement	2670
No. parameters	168
R indices (F>4σ)	R_1=0.0517
	wR_2=0.1248
R indices (all data)	R_1=0.0644
	wR_2=0.1417
GOF:	1.055
Final Difference Peaks, e/Å^3	+0.202, -0.263

Table 2. Refined Positional Parameters for Compound 2018

Atom	x	y	z	U_{eq}, Å^2
C1	0.6151(3)	0.5100(2)	0.27698(11)	0.0270(4)
H1	0.7153	0.4800	0.2274	0.036
C2	0.7568(3)	0.4941(2)	0.36284(11)	0.0283(4)
C3	0.6534(3)	0.3857(2)	0.43972(11)	0.0289(4)
H3	0.7027	0.3517	0.5017	0.038
C4	0.4718(3)	0.3407(2)	0.40729(11)	0.0276(4)
C5	0.4994(3)	0.6704(2)	0.23623(10)	0.0280(4)
H5	0.6225	0.7372	0.2295	0.037
C6	0.4042(3)	0.7063(2)	0.13624(11)	0.0312(4)
C7	0.2765(3)	0.8652(2)	0.11199(13)	0.0488(5)
H7a	0.3798	0.9354	0.1175	0.073
H7b	0.1435	0.8669	0.1553	0.073
H7c	0.2262	0.8930	0.0480	0.073
C8	0.6068(3)	0.7043(2)	0.06313(12)	0.0434(5)
H8a	0.6843	0.6041	0.0757	0.065
H8b	0.7148	0.7724	0.0674	0.065
H8c	0.5485	0.7350	0.0004	0.065
C9	0.2381(3)	0.5930(2)	0.13126(12)	0.0384(4)
H9a	0.1751	0.6227	0.0694	0.058
H9b	0.1136	0.5906	0.1788	0.058
H9c	0.3214	0.4946	0.1425	0.058
C10	0.2981(3)	0.2359(2)	0.45685(11)	0.0328(4)
H10a	0.2844	0.1668	0.4199	0.044
H10b	0.1479	0.2936	0.4585	0.044
C11	0.3524(3)	0.1445(2)	0.55760(11)	0.0305(4)
H11a	0.5004	0.0842	0.5564	0.041
H11b	0.3684	0.2129	0.5947	0.041
C12	0.1674(3)	0.0415(2)	0.60586(11)	0.0323(4)
H12a	0.1568	-0.0298	0.5702	0.043
H12b	0.0182	0.1015	0.6041	0.043
C13	0.2131(3)	-0.0452(2)	0.70830(11)	0.0338(4)
H13a	0.3646	-0.1026	0.7101	0.045
H13b	0.2196	0.0263	0.7441	0.045
C14	0.0339(3)	-0.1520(2)	0.75691(11)	0.0365(4)
H14a	0.0308	-0.2262	0.7227	0.049
H14b	-0.1186	-0.0956	0.7538	0.049
C15	0.0808(4)	-0.2329(2)	0.85995(12)	0.0465(5)
H15a	0.2327	-0.2875	0.8637	0.070
H15b	-0.0345	-0.3020	0.8863	0.070

H15c	0.0739	-0.1606	0.8952	0.070
O1	0.4411(2)	0.40507(11)	0.31278(7)	0.0299(3)
O2	0.9221(2)	0.56748(13)	0.36011(7)	0.0372(3)
O3	0.3338(2)	0.70589(12)	0.30504(7)	0.0317(3)
H3a	0.2240	0.6549	0.3117	0.048

$U_{eq} = {}^1/_3[U_{11}(aa^*)^2 + U_{22}(bb^*)^2 + U_{33}(cc^*)^2 + 2U_{12}aa^*bb^*\cos\gamma + 2U_{13}aa^*cc^*\cos\beta + 2U_{23}bb^*cc^*\cos\alpha]$

Table 3. Refined Thermal Parameters (U's) for Compound 2018

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
C1	0.0262(9)	0.0255(8)	0.0285(9)	-0.0066(7)	0.0007(6)	-0.0042(7)
C2	0.0222(8)	0.0309(9)	0.0321(10)	-0.0116(7)	0.0013(7)	0.0004(7)
C3	0.0272(9)	0.0320(9)	0.0258(9)	-0.0066(7)	-0.0019(7)	0.0003(7)
C4	0.0282(9)	0.0235(8)	0.0290(10)	-0.0064(7)	-0.0008(7)	0.0026(7)
C5	0.0251(9)	0.0256(9)	0.0330(9)	-0.0074(7)	0.0002(7)	-0.0055(7)
C6	0.0291(9)	0.0331(9)	0.0286(9)	-0.0039(7)	-0.0025(7)	-0.0039(7)
C7	0.0551(12)	0.0395(11)	0.0456(12)	-0.0045(8)	-0.0104(9)	0.0058(9)
C8	0.0401(11)	0.0542(12)	0.0302(10)	-0.0031(8)	0.0006(8)	-0.0075(9)
C9	0.0370(10)	0.0477(11)	0.0292(10)	-0.0054(8)	-0.0066(7)	-0.0099(8)
C10	0.0321(10)	0.0288(9)	0.0349(10)	-0.0035(7)	-0.0038(7)	-0.0050(7)
C11	0.0333(9)	0.0284(9)	0.0300(10)	-0.0087(7)	-0.0018(7)	-0.0030(7)
C12	0.0336(10)	0.0290(9)	0.0318(10)	-0.0048(7)	-0.0020(7)	-0.0024(7)
C13	0.0398(10)	0.0305(9)	0.0306(10)	-0.0071(7)	-0.0016(7)	-0.0056(8)
C14	0.0435(10)	0.0340(10)	0.0317(10)	-0.0083(7)	0.0018(7)	-0.0082(8)
C15	0.0654(13)	0.0390(11)	0.0338(11)	-0.0065(8)	0.0036(9)	-0.0148(9)
O1	0.0346(7)	0.0265(6)	0.0281(7)	-0.0046(5)	-0.0041(5)	-0.0079(5)
O2	0.0267(6)	0.0436(7)	0.0413(7)	-0.0106(6)	-0.0015(5)	-0.0077(5)
O3	0.0286(7)	0.0313(7)	0.0375(7)	-0.0134(5)	0.0013(5)	-0.0054(5)

The form of the anisotropic displacement parameter is:
$\exp[-2\pi^2(a^{*2}U_{11}h^2 + b^{*2}U_{22}k^2 + c^{*2}U_{33}l^2 + 2b^*c^*U_{23}kl + 2a^*c^*U_{13}hl + 2a^*b^*U_{12}hk)]$.

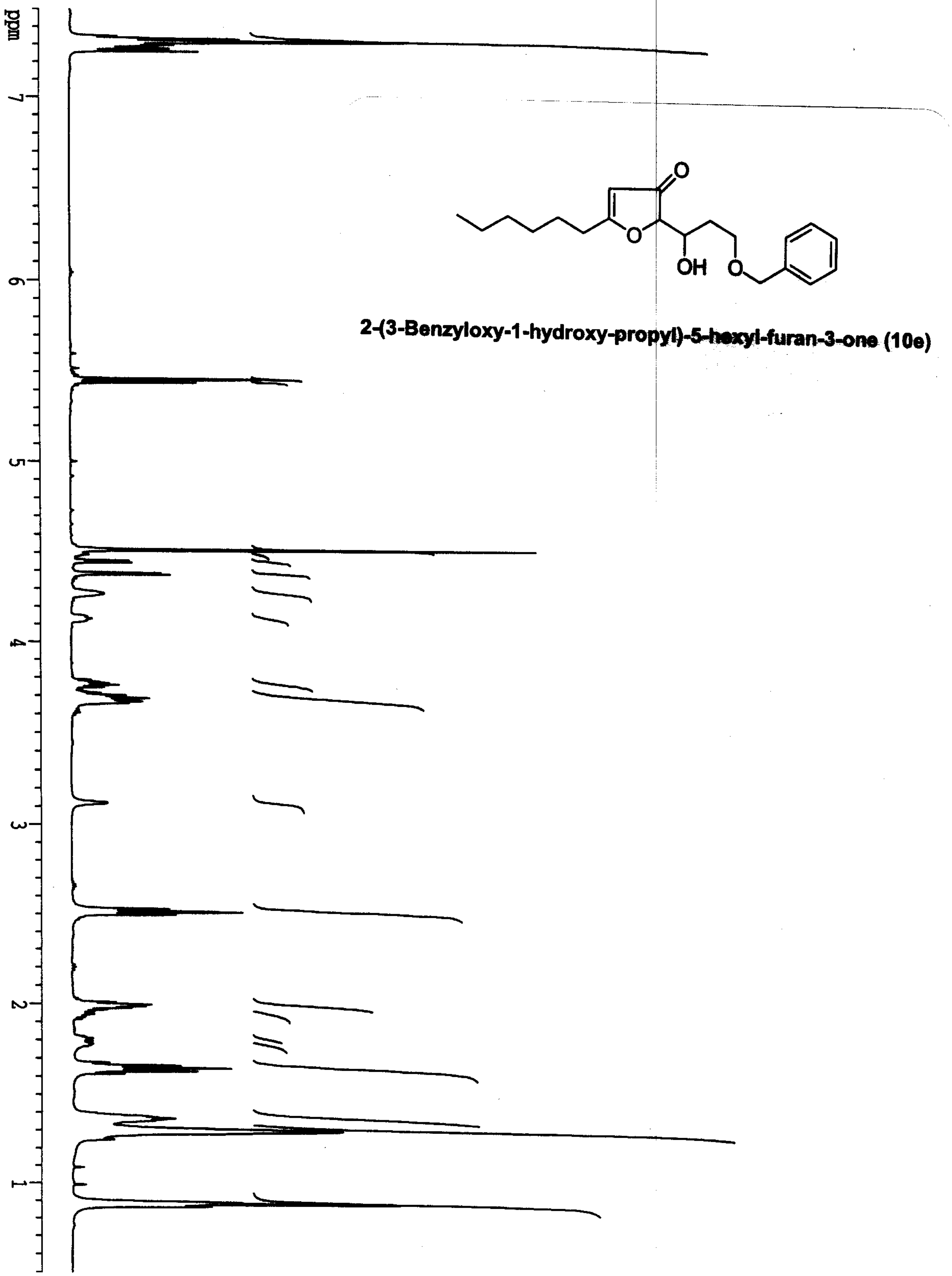
Table 4. Bond Distances in Compound 2018, Å

C1-O1	1.445(2)	C1-C2	1.524(2)	C1-C5	1.532(2)
C2-O2	1.231(2)	C2-C3	1.421(2)	C3-C4	1.345(2)
C4-O1	1.360(2)	C4-C10	1.480(2)	C5-O3	1.421(2)
C5-C6	1.543(2)	C6-C8	1.528(2)	C6-C9	1.529(2)
C6-C7	1.531(2)	C10-C11	1.514(2)	C11-C12	1.512(2)
C12-C13	1.515(2)	C13-C14	1.510(2)	C14-C15	1.513(2)

Table 5. Bond Angles in Compound 2018, °

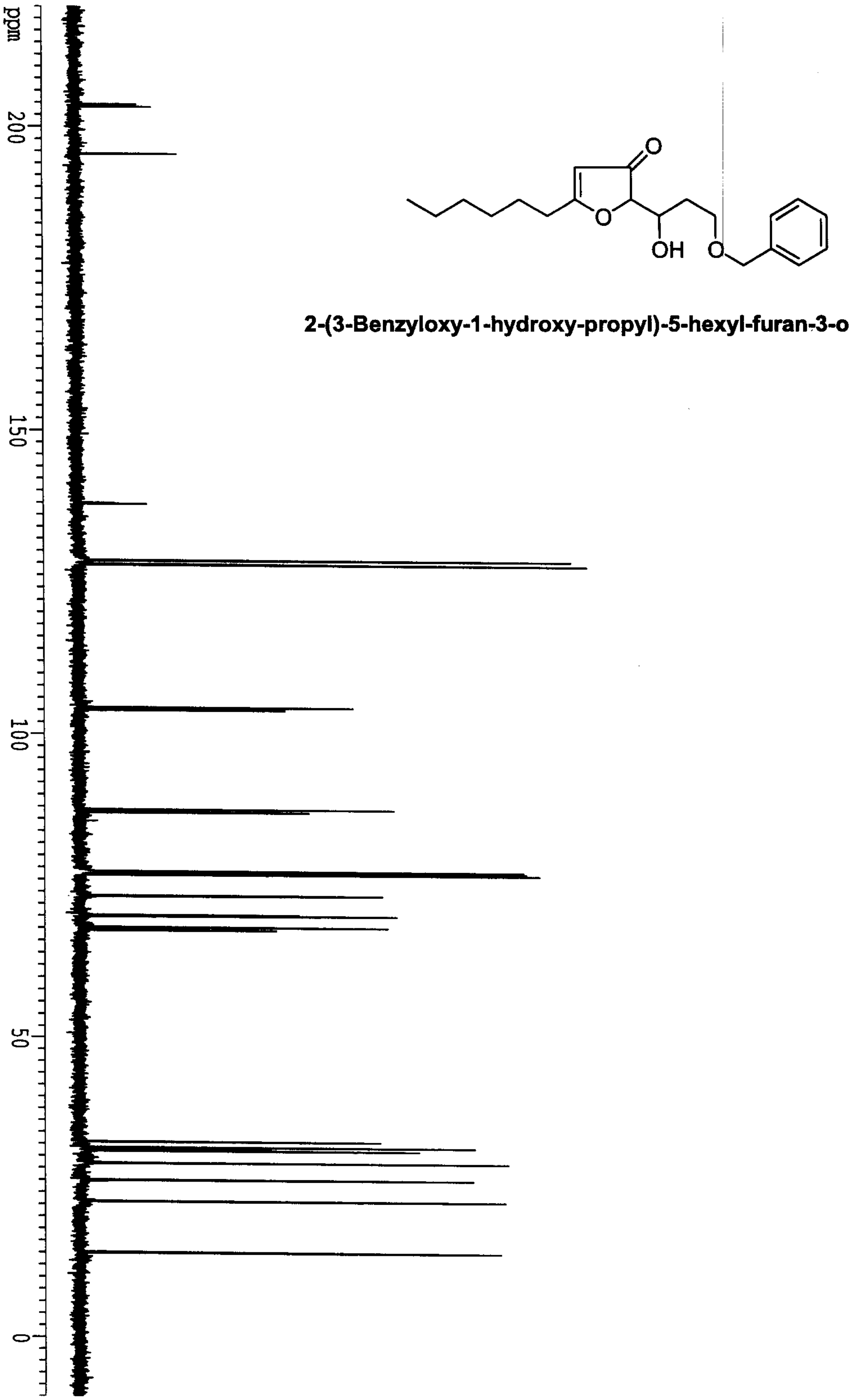
O1-C1-C2	104.36(11)	O1-C1-C5	110.62(11)	C2-C1-C5	112.71(12)
O2-C2-C3	130.71(14)	O2-C2-C1	123.42(13)	C3-C2-C1	105.86(13)
C4-C3-C2	108.13(14)	C3-C4-O1	114.10(14)	C3-C4-C10	131.2(2)
O1-C4-C10	114.68(13)	O3-C5-C1	109.15(12)	O3-C5-C6	113.77(12)
C1-C5-C6	115.85(12)	C8-C6-C9	108.97(13)	C8-C6-C7	108.47(14)
C9-C6-C7	109.78(13)	C8-C6-C5	109.51(13)	C9-C6-C5	111.98(12)
C7-C6-C5	108.06(13)	C4-C10-C11	115.08(13)	C12-C11-C10	113.07(13)
C11-C12-C13	113.81(13)	C14-C13-C12	114.63(13)	C13-C14-C15	113.18(14)
C4-O1-C1	107.51(11)				

^{1}H NMR Spectrum of 10e



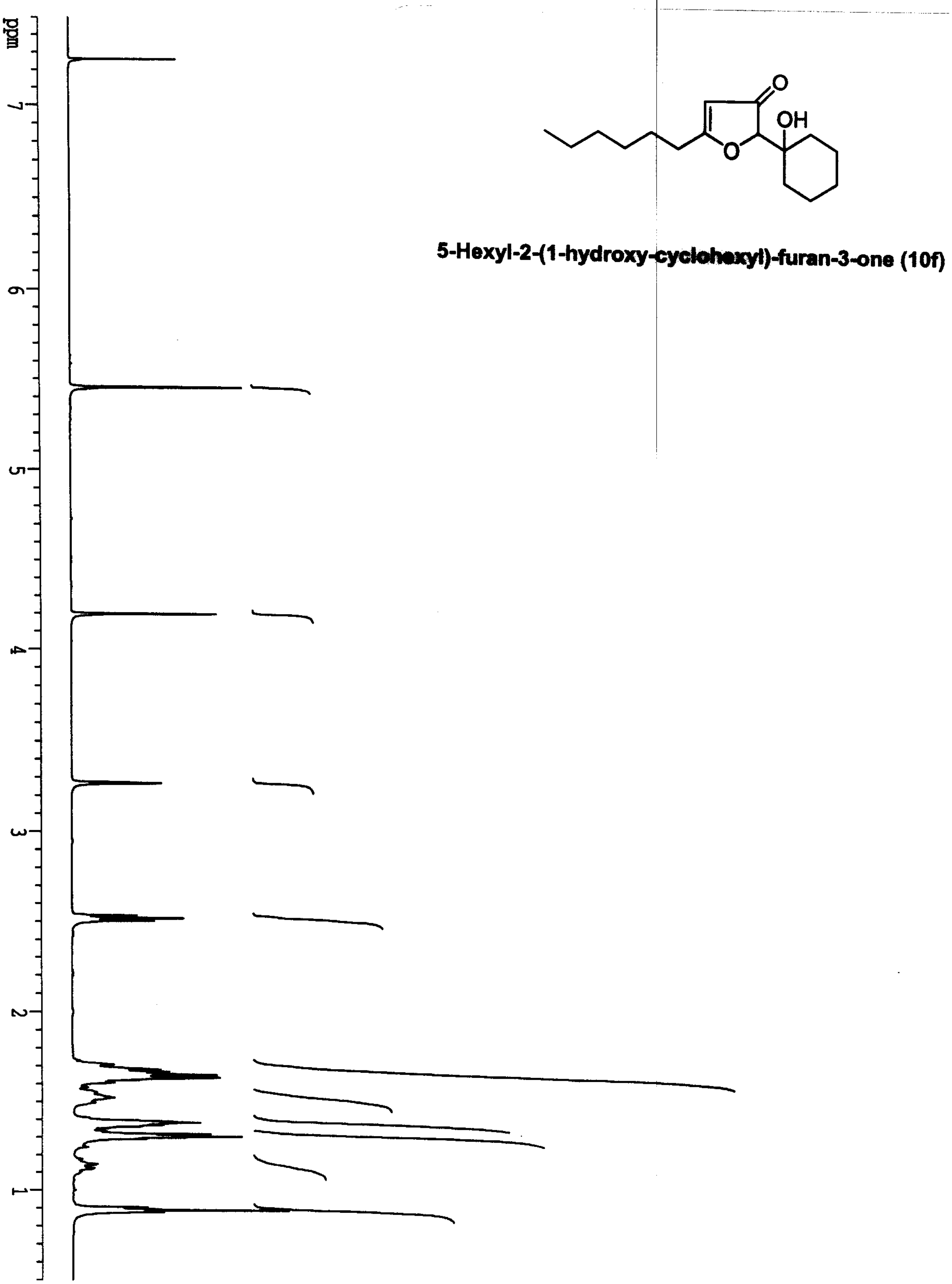
2-(3-Benzyloxy-1-hydroxy-propyl)-5-hexyl-furan-3-one (10e)

^{13}C NMR Spectrum of 10e



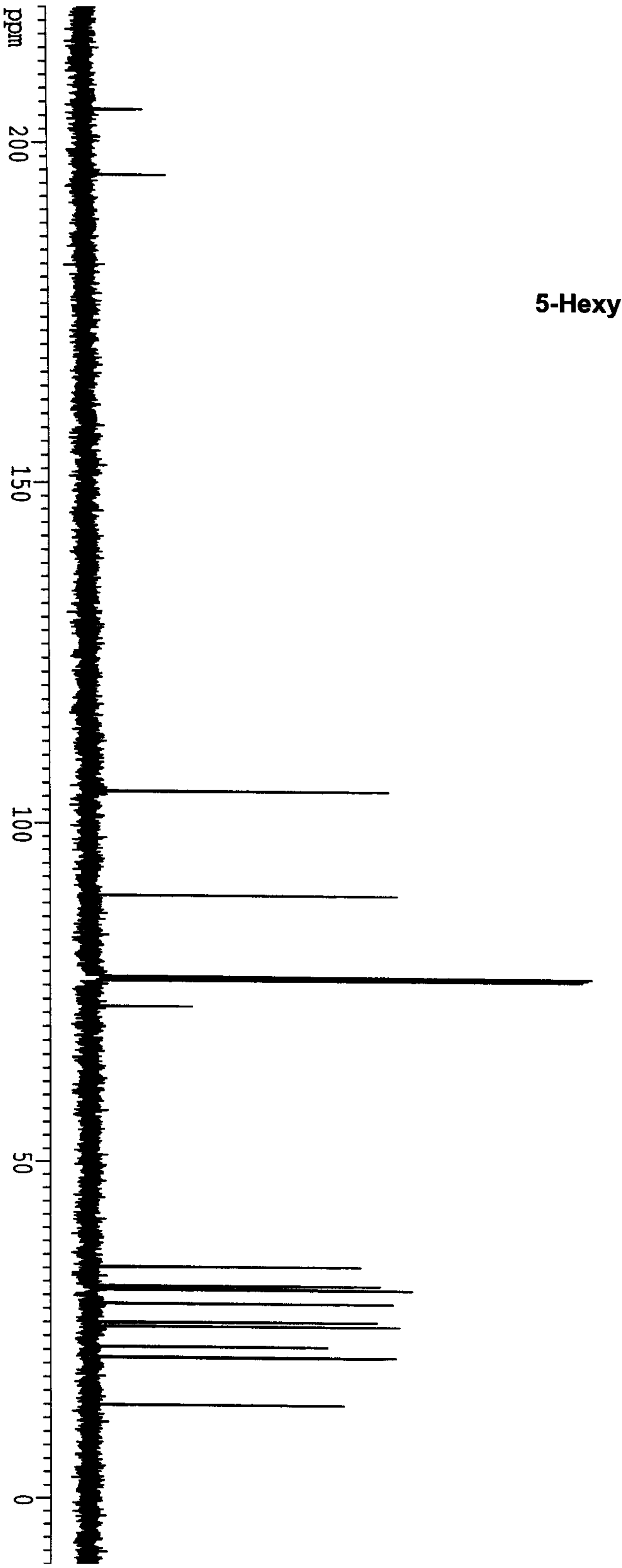
2-(3-Benzyloxy-1-hydroxy-propyl)-5-hexyl-furan-3-one (10e)

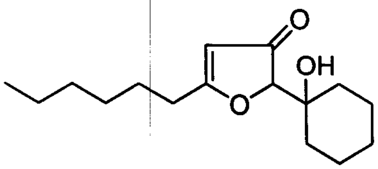
^{1}H NMR Spectrum of 10f



5-Hexyl-2-(1-hydroxy-cyclohexyl)-furan-3-one (10f)

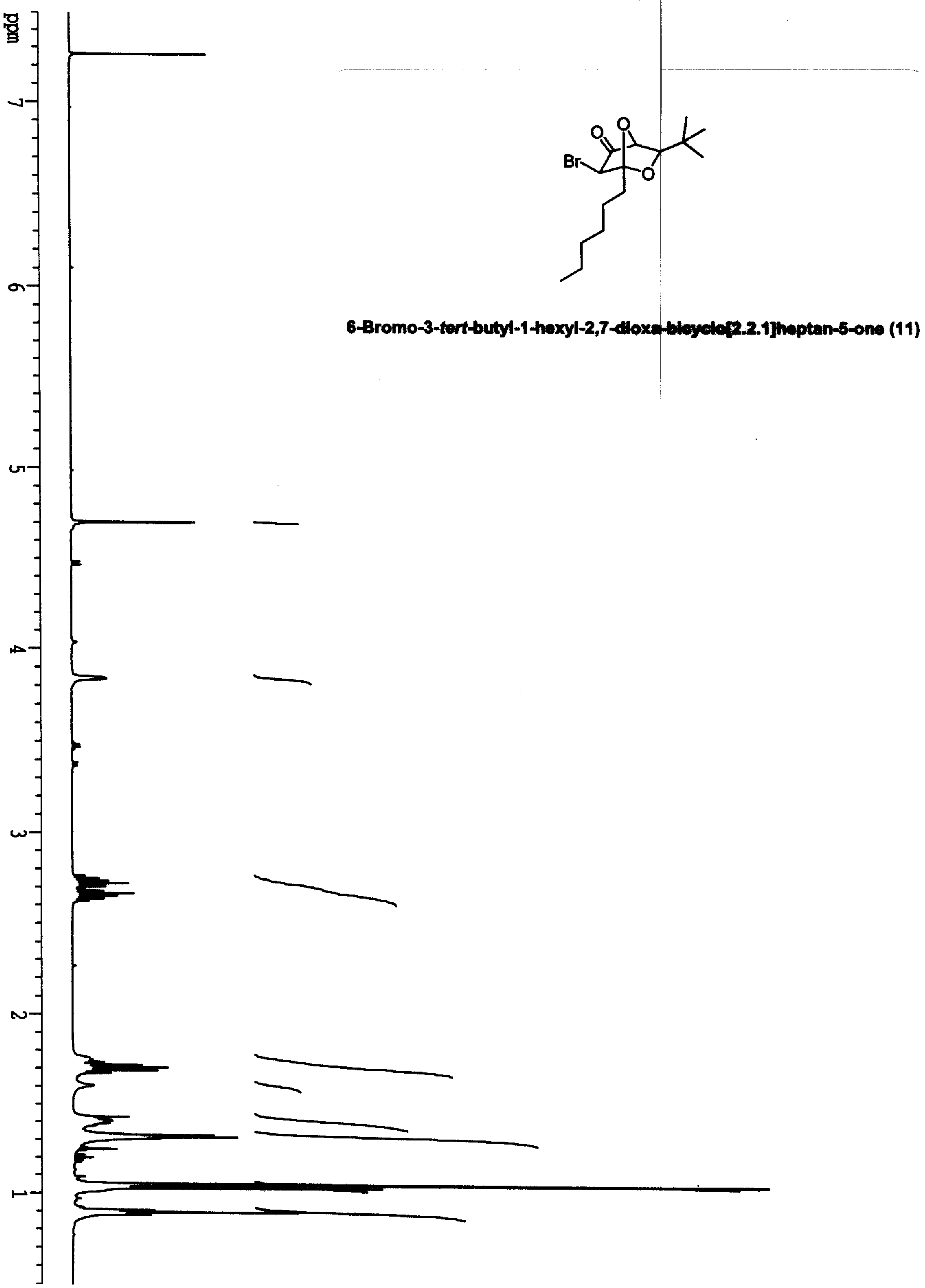
^{13}C NMR Spectrum of 10f





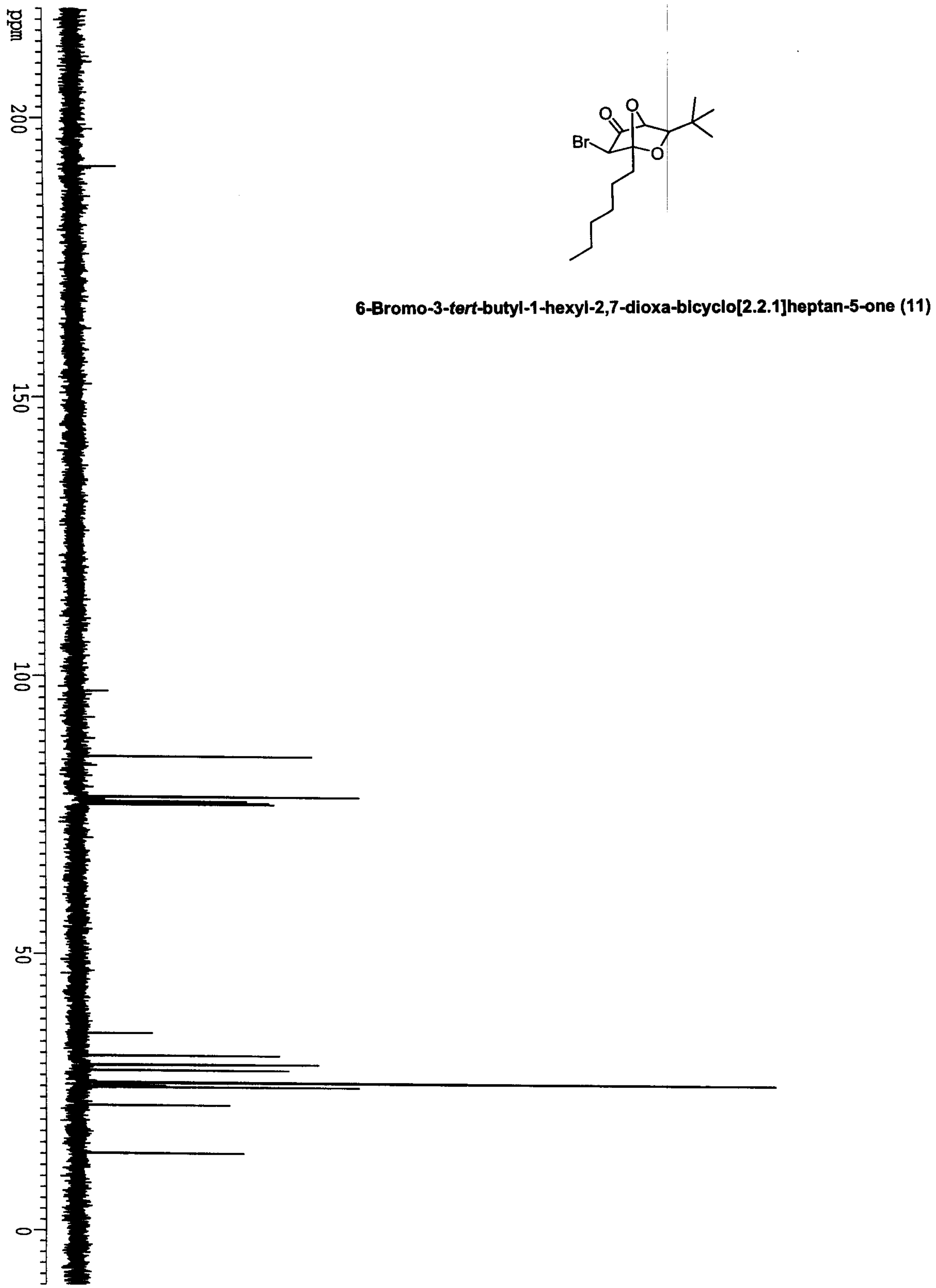
5-Hexyl-2-(1-hydroxy-cyclohexyl)-furan-3-one (10f)

^{1}H NMR Spectrum of 11



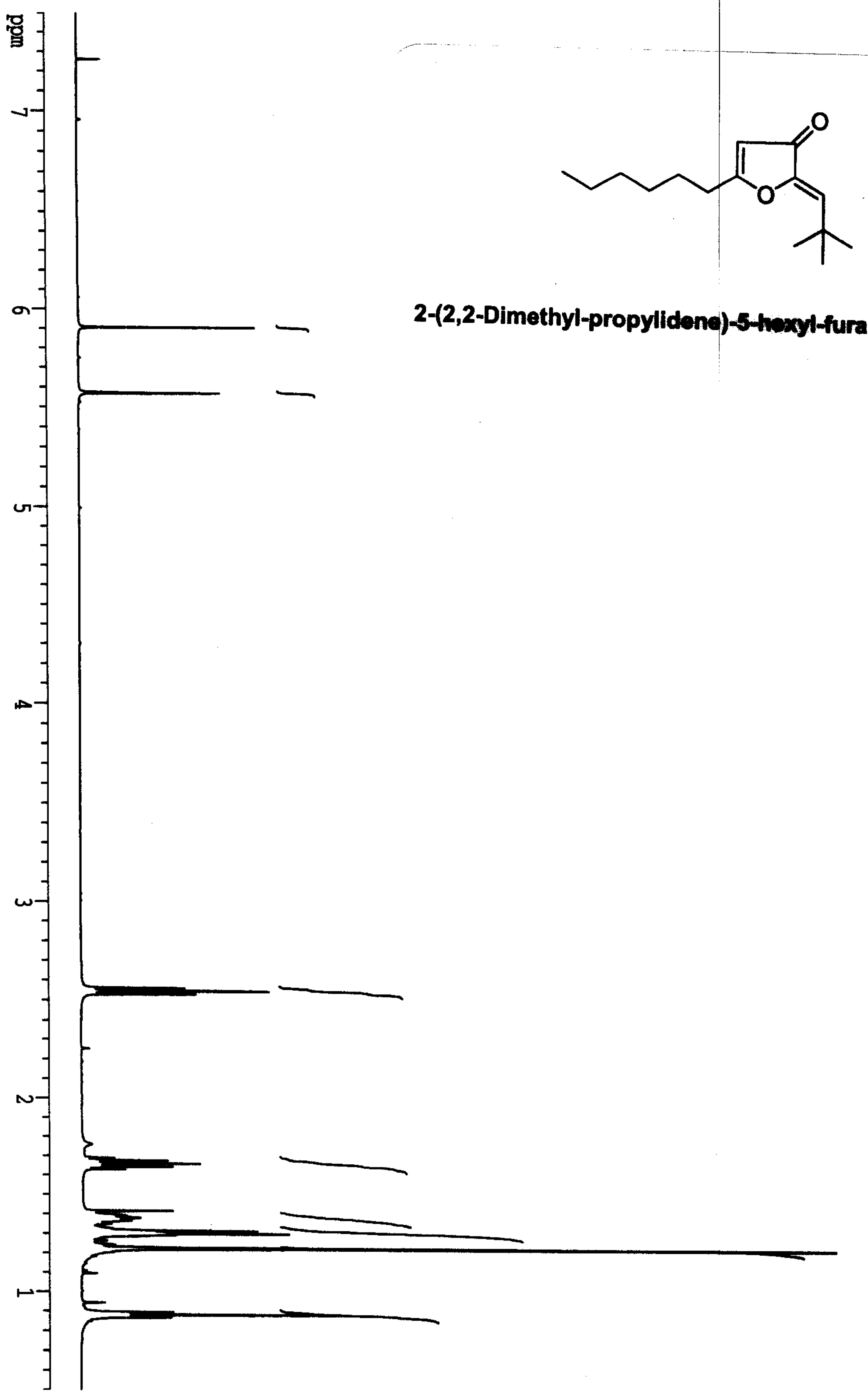
6-Bromo-3-*tert*-butyl-1-hexyl-2,7-dioxa-bicyclo[2.2.1]heptan-5-one (11)

^{13}C NMR Spectrum of 11



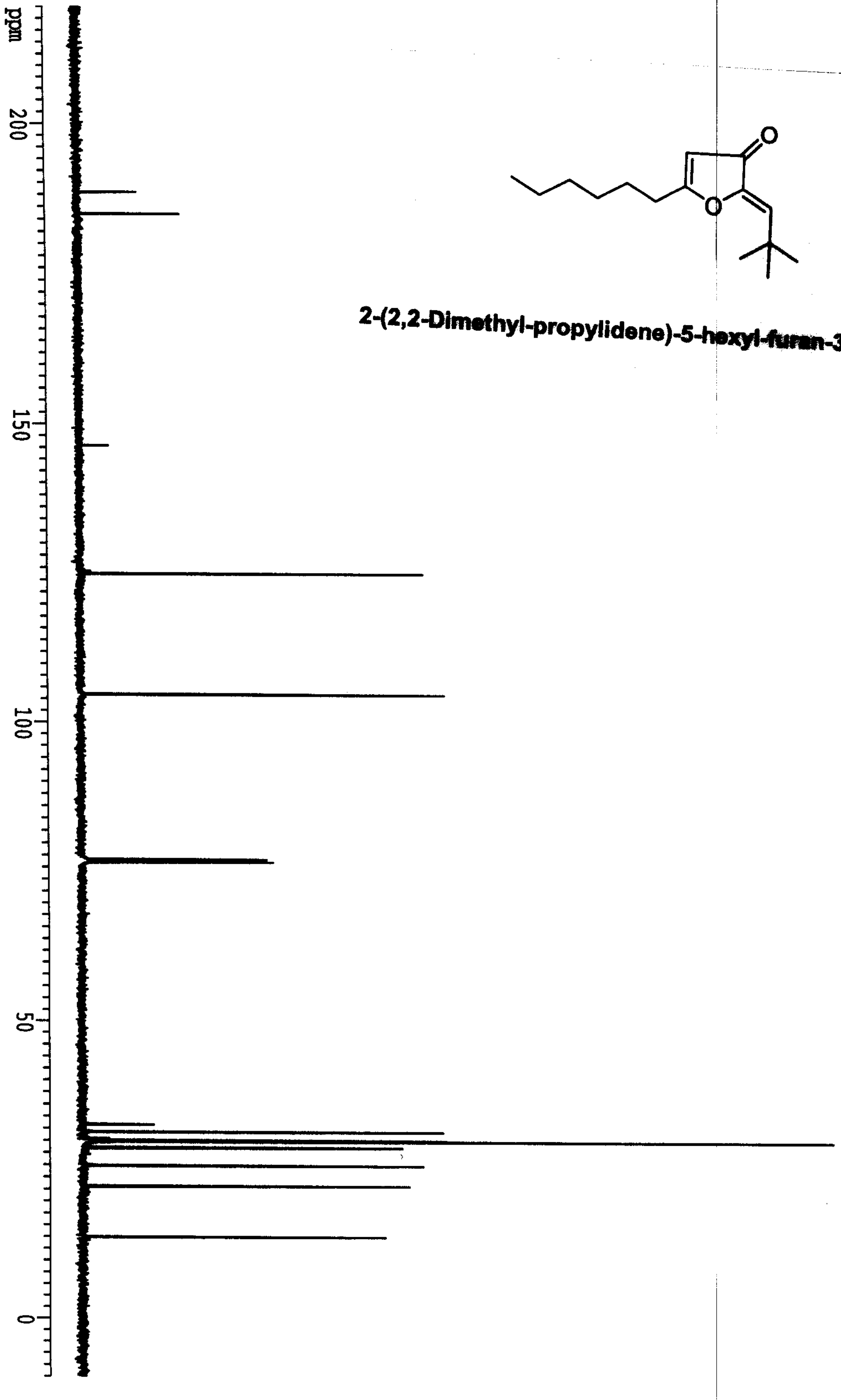
6-Bromo-3-*tert*-butyl-1-hexyl-2,7-dioxa-bicyclo[2.2.1]heptan-5-one (11)

¹H NMR Spectrum of 12



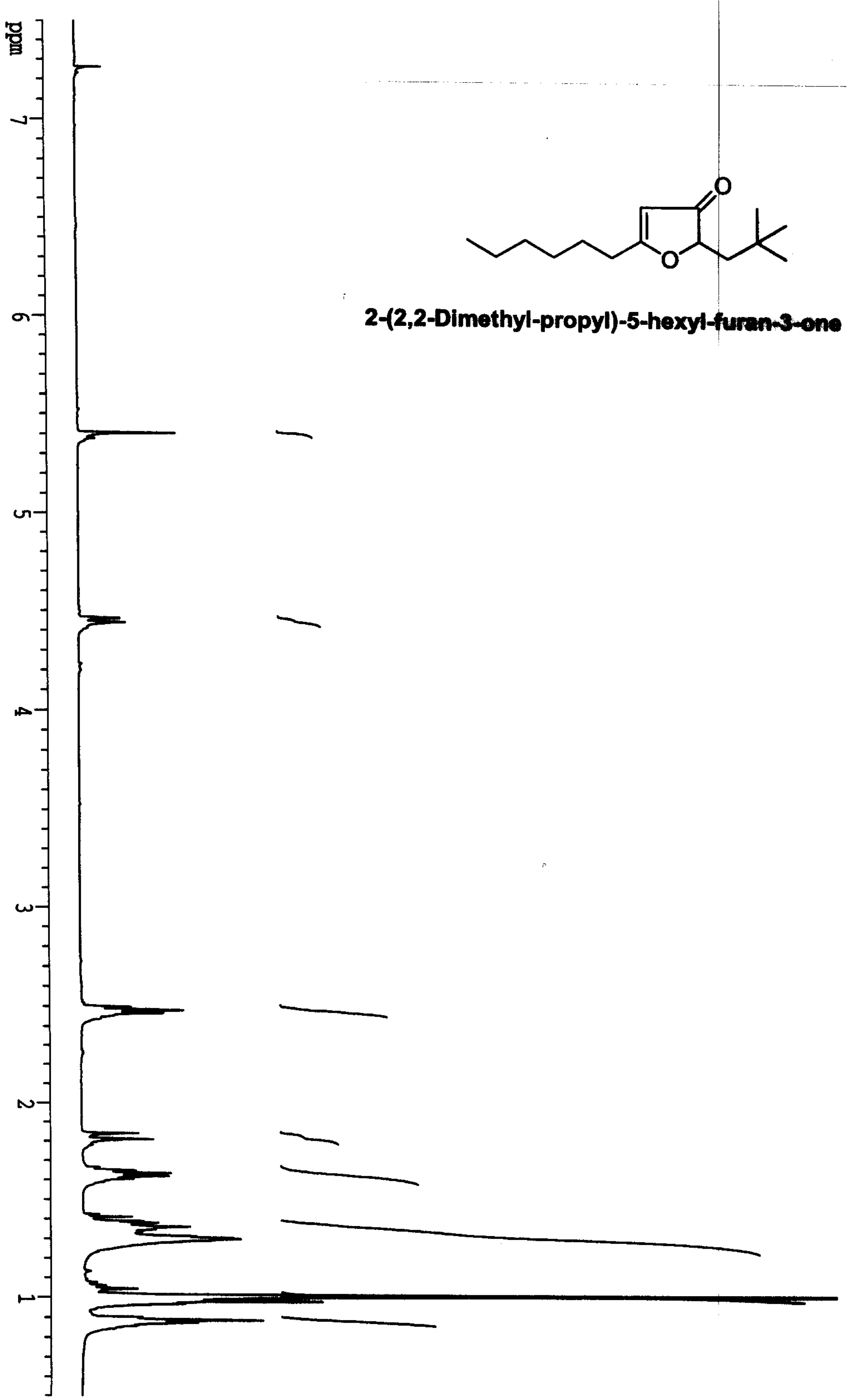
2-(2,2-Dimethyl-propylidene)-5-hexyl-furan-3-one (12)

^{13}C NMR Spectrum of 12



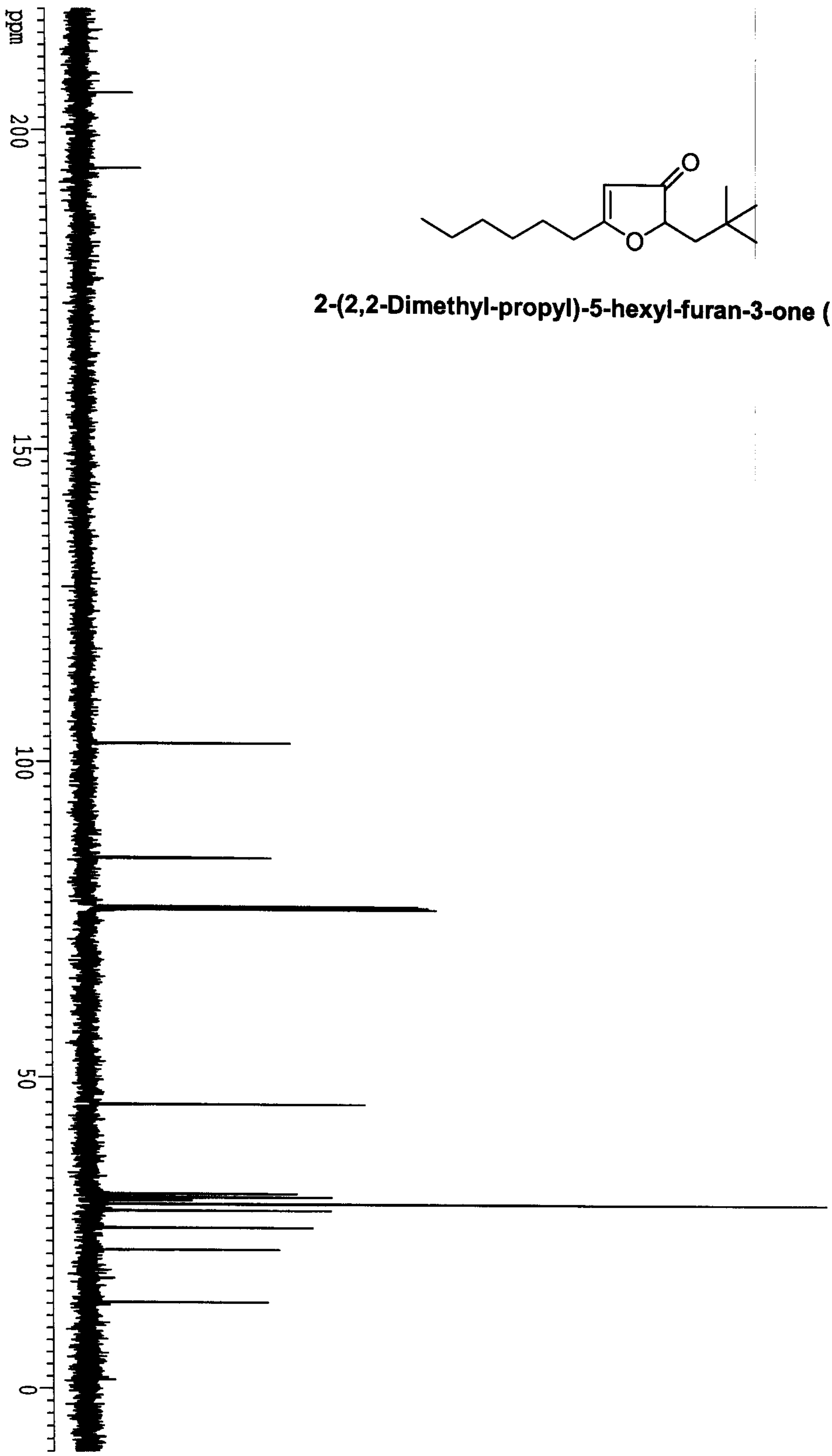
2-(2,2-Dimethyl-propylidene)-5-hexyl-furan-3-one (12)

^{1}H NMR Spectrum of 13



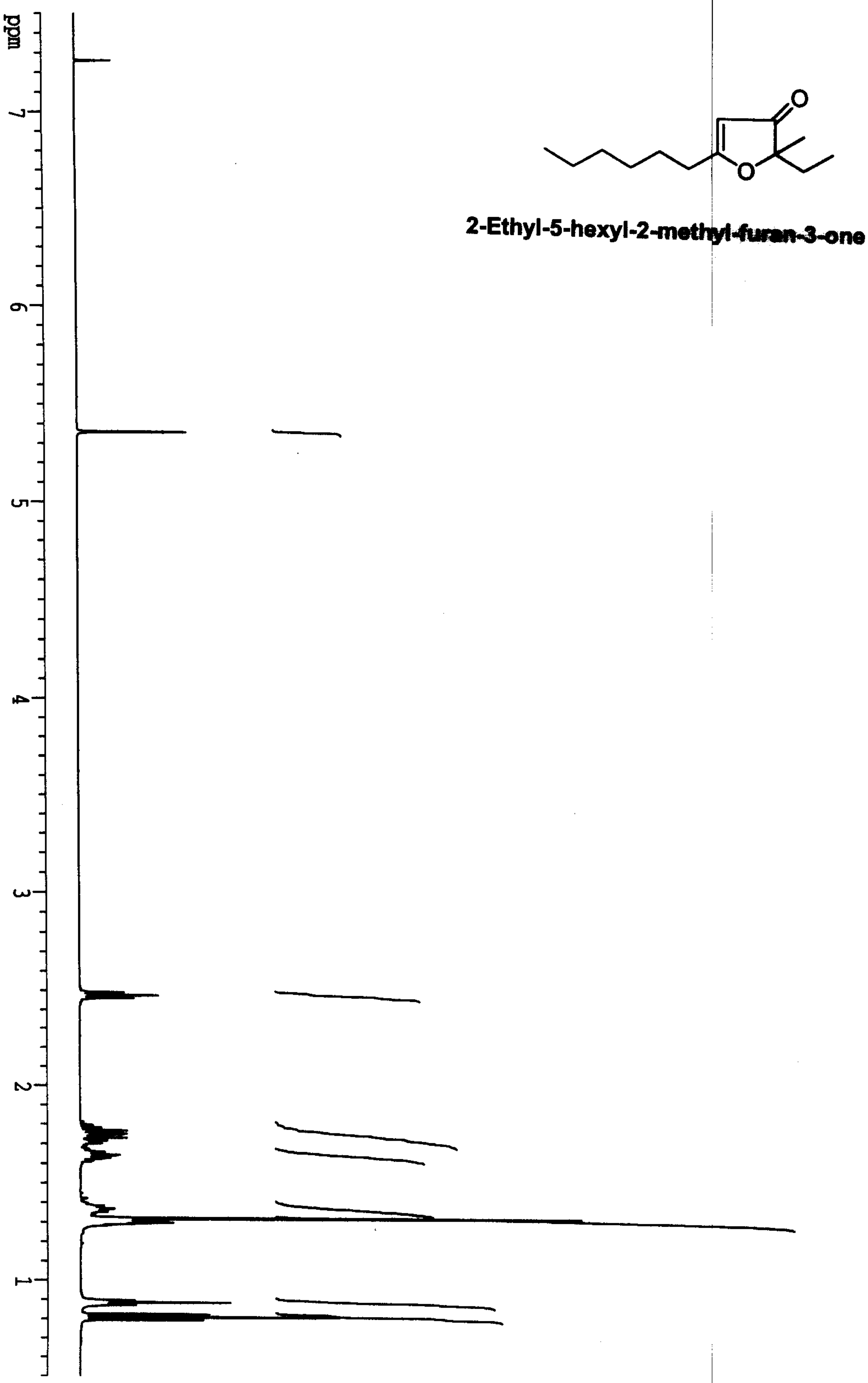
2-(2,2-Dimethyl-propyl)-5-hexyl-furan-3-one (13)

^{13}C NMR Spectrum of 13



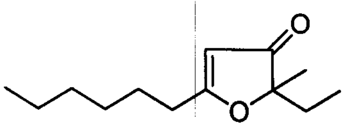
2-(2,2-Dimethyl-propyl)-5-hexyl-furan-3-one (13)

^{1}H NMR Spectrum of 16



2-Ethyl-5-hexyl-2-methyl-furan-3-one (16)

^{13}C NMR Spectrum of 16



2-Ethyl-5-hexyl-2-methyl-furan-3-one (16)