SYNTHESIS OF 6-ACYL-2, 2-DIMETHYL-2-SILATETRALINS

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Abstract — Friedel-Crafts reaction of 2-silatetralin (4) with acid anhydrides (acetic anhydride, succinic anhydride, glutaric anhydride, phthalic anhydride, cis-1, 2-cyclohexanedicarboxylic anhydride, and diphenic anhydride) or benzoyl chloride in the presence of AlCl3 in CH2Cl2 at room temperature gave exclusively the corresponding 6-acyl-2-silatetralins in fair to good yield. This findings were supported by the MNDO molecular orbital calculations of 2-silatetralin (4).

Previously, we have reported syntheses of 2-silatetralins (1) having oxygen functional groups, tetracyclic organosilicon compounds (2), and 1-alkyl-2-silatetralins (3). In our continuous investigation on synthesis and reaction of 2-silatetralin derivatives, we found that Friedel-Crafts reaction of 2-silatetralin (4) gave exclusively 6-acyl-2-silatetralins. This paper deals with formation of 6-acyl-2-silatetralins.

\[
\begin{align*}
1: & \quad R = \text{OMe, OH} \\
2: & \quad R = \text{OMe, H} \\
3: & \quad R^1 = \text{OMe, t-BuMe}_2\text{SiO} \\
& \quad R^2 = \text{Me, CH}_2\text{Ph}
\end{align*}
\]
At first, Friedel-Crafts reaction of 2-silatetralin (4) with acetic anhydride in the presence of AlCl₃ (3.5 eq.) in CH₂Cl₂ at room temperature gave acetyl-2-silatetralin in 84 % yield. The ¹H-nmr spectrum showed one proton due to aromatic proton at the 8-position at δ 7.14 (d, J = 8.6 Hz) and two protons due to aromatic protons at the 5 and 7-positions at δ 7.59-7.79 (m). IR spectrum indicated an absorption due to α, β-unsaturated carbonyl group at 1685 cm⁻¹, and in the ms a molecular peak (M⁺) was measured at m/z 218. From these spectral data, the structure of acetylated product was presumed to be 6-acetyl-2-silatetralin (5a). Moreover, the position of acetyl group was determined as follows. Baeyer-Villiger reaction of the 6-acetyl-2-silatetralin (5a) with m-chloroperbenzoic acid (m-CPBA) in CH₂Cl₂ at room temperature gave 6-acetoxy-2-silatetralin in 56 % yield, which was identical with 6-acetoxy-2-silatetralin (7) derived from 6-hydroxy-2-silatetralin (6). From this results, the position of acetyl group introduced was confirmed to be the 6-position.

Based on the above results, Friedel-Crafts reaction of 4 with benzoyl chloride, succinic anhydride, glutaric anhydride, phthalic anhydride, cis-1,2-cyclohexanedicarboxylic anhydride, and diphenic anhydride was performed under reaction conditions similar to those noted for 5a to give 6-acyl-2-silatetralins (5b-g) in fair to good yield.
In order to prove again the position of acyl group introduced among the products, 6-(3'-carboxypropanoyl)-2-silatetralin (5c) was converted to 6 in unequivocal reaction sequences (esterification, Baeyer-Villiger oxidation, and reduction).

\[
\begin{align*}
5c & \xrightarrow{\text{ether \ 85\%}} \text{CH}_2\text{N}_2 \\
& \xrightarrow{\text{m-CPBA \ CH}_2\text{Cl}_2 \ 42\%} \text{CO}_2\text{Me} \\
& \xrightarrow{\text{LiAlH}_4 \ \text{THF \ 83\%}} \ 6
\end{align*}
\]

In the present reaction, formation of 6-acyl-2-silatetralins (5) would be explained by considering that the reaction intermediate (A) is preferable to intermediate (B) by 3-effect of a silicon atom.

This assumption was also supported by the molecular orbital calculation of 4 using the MNDO method, showing the maximum value of \( \pi \) HOMO coefficient at the 6-position.

<table>
<thead>
<tr>
<th>Position</th>
<th>( \pi ) HOMO Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>4a</td>
<td>-0.426</td>
</tr>
<tr>
<td>5</td>
<td>0.101</td>
</tr>
<tr>
<td>6</td>
<td><strong>0.511</strong></td>
</tr>
<tr>
<td>7</td>
<td>0.367</td>
</tr>
<tr>
<td>8</td>
<td>-0.175</td>
</tr>
<tr>
<td>8a</td>
<td>-0.540</td>
</tr>
</tbody>
</table>

In conclusion, Friedel-Crafts reaction of 2-silatetralin (4) afforded exclusively 6-acyl-2-silatetralins (5).
ACKNOWLEDGEMENT

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EXPERIMENTAL

General — All melting points were measured on Büchi or Yanagimoto (hot plate) melting point apparatus and are uncorrected. Ir spectra were taken with a Hitachi model 260-10 spectrophotometer in CHCl$_3$ solution, unless otherwise noted. $^1$H-Nmr spectra were recorded on a JEOL model FX-100 or JEOL model JUM-EX270 spectrometer in CDCl$_3$ solution using CHCl$_3$ or CH$_2$Cl$_2$ as internal standard. Ms were measured on a Hitachi M-80 or M-80A spectrometer. HRms was measured on a Hitachi M-80 spectrometer. Elemental analysis was measured on a Heraeus CHN-O-PAPID. Ball-to-ball distillation was carried out by use of a Sibata glass tube oven model GTO-250RS. Preparative tlc was performed with Kieselgel 60 F$_{254}$ Art. 5744 (Merck) or Kieselgel 60 GF$_{254}$ Art. 7730 (Merck). For column chromatography, silica gel [ Wako gel C-200 or Silica Gel 60 (Cica-Merck) ] was used. CH$_2$Cl$_2$ was distilled from CaH$_2$ prior to use, after treatment in a usual manner.

General Procedure for Preparation of 6-Acyl-2,2-dimethyl-2-silatetralins (5). A mixture of 4, AlCl$_3$, and acid anhydrides or benzoyl chloride in CH$_2$Cl$_2$ was stirred at room temperature for 45 min. The reaction was quenched with addition of water. The organic layer was separated and the aqueous layer was extracted with CH$_2$Cl$_2$. The combined organic layers were washed with saturated NaHCO$_3$ and brine (for 5a, b) or only brine (for 5c-g) and dried (MgSO$_4$). Removal of the solvent in vacuo gave a residue, which was purified by column chromatography, preparative tlc, or ball-to-ball distillation under reduced pressure.

6-Acetyl-2, 2-dimethyl-2-silatetralin (5a) : Compound (4) (212 mg, 1.2 mmol), AlCl$_3$ (560 mg, 4.2 mmol), acetic anhydride (184 mg, 1.8 mmol), and CH$_2$Cl$_2$ (32 ml) were used. The residue (252 mg) was purified by preparative tlc (three developments with hexane : AcOEt = 20 : 1) to afford 5a (219 mg, 84 %) as a colorless oil, 70-100 °C / 2 Torr. $^1$H-Nmr $\delta$: 
0.08 (6H, s, SiMe<sub>2</sub>), 0.76 (2H, t, J = 7.1 Hz, C<sub>3</sub>-H), 2.05 (2H, s, C<sub>1</sub>-H), 2.58 (3H, s, MeCO), 2.79 (2H, t, J = 7.1 Hz, C<sub>4</sub>-H), 7.14 (1H, d, J = 8.6 Hz, C<sub>8</sub>-H), 7.59-7.79 (2H, m, C<sub>5</sub>-H, C<sub>7</sub>-H).

I<sub>r</i> : 1685 (CO) cm<sup>-1</sup>. HRms m/z calcld for C<sub>13</sub>H<sub>18</sub>O<sub>2</sub>Si (M<sup>+</sup>) : 218.1126, found : 218.1122; ms m/z : 218 (M<sup>+</sup>).

6-Benzoyl-2, 2-dimethyl-2-silatetralin (5b) : Compound (4) (212 mg, 1.2 mmol), AlCl<sub>3</sub> (272 mg, 2.04 mmol), benzoyl chloride (253 mg, 1.8 mmol), and CH<sub>2</sub>Cl<sub>2</sub> (32 ml) were used. The residue (382 mg) was purified by preparative tlc (two developments with hexane : AcOEt = 20 : 1) to afford 5b (249 mg, 74%) as a colorless oily 130-160 °C 1 Torr.

I<sub>r</i> : 1685 (CO) cm<sup>-1</sup>. HRms m/z calcld for C<sub>18</sub>H<sub>20</sub>O<sub>2</sub>Si (M<sup>+</sup>) : 280.1282, found : 280.1279; ms m/z : 280 (M<sup>+</sup>).

6-(3'-Carboxypropanoyl)-2, 2-dimethyl-2-silatetralin (5c) : Compound (4) (212 g, 1.2 mmol), AlCl<sub>3</sub> (3.2 g, 24 mmol), succinic anhydride (1.08 g, 10.8 mmol), and CH<sub>2</sub>Cl<sub>2</sub> (270 ml) were used. The light yellow crystals (2.44 g) were recrystallized from hexane-AcOEt to afford 5c (1.81 g, 61%, mp 113-115 °C) as colorless needles. Anal. Calcd for C<sub>15</sub>H<sub>21</sub>O<sub>3</sub>Si : C, 65.18; H, 7.29. Found : C, 65.20; H, 7.29. 1H-Nmr δ : 0.06 (6H, s, SiMe<sub>2</sub>), 0.76 (2H, t, J = 7.1 Hz, C<sub>3</sub>-H), 2.05 (2H, s, C<sub>1</sub>-H), 2.79 (2H, t, J = 7.1 Hz, C<sub>4</sub>-H), 7.15 (1H, d, J = 8.6 Hz, C<sub>8</sub>-H), 7.35-7.64 (5H, m, 5xAr-H), 7.78 (2H, dd, J = 1.4, 7.1 Hz, Ar<sub>2</sub>-H, Ar<sub>6</sub>-H). I<sub>r</i> : 1650 (CO) cm<sup>-1</sup>. HRms m/z calcld for C<sub>18</sub>H<sub>20</sub>O<sub>3</sub>Si (M<sup>+</sup>) : 280.1282, found : 280.1279; ms m/z : 280 (M<sup>+</sup>).
6-(2'-Carboxybenzoyl)-2, 2-dimethyl-2-silatetralin (5e): Compound (4) (212 mg, 1.2 mmol), AlCl₃ (320 mg, 2.4 mmol), phthalic anhydride (160 mg, 1.08 mmol), and CH₂Cl₂ (32 ml) were used. The residue (623 mg) was purified three times by column chromatography [two times, CHCl₃ and CHCl₃-MeOH (100 : 1 ~ 5 : 1); third, CHCl₃ and CHCl₃-MeOH (200 : 1)] to afford 5e (91 mg, 26 %, mp 140-144 °C) as light yellow crystals, mp 144.5-148.5 °C (hexane-AcOEt). Anal. Calcd for C₁₉H₂₀O₃Si: C, 70.34; H, 6.21. Found: C, 70.03; H, 6.25.

₁H-Nmr: δ: 0.05 (6H, s, SiMe₂), 0.74 (2H, t, J = 7.1 Hz, C₃-H), 2.02 (2H, s, C₁-H), 2.75 (2H, t, J = 7.1 Hz, C₄-H), 4.36-4.78 (1 H, br, COOH), 7.06 (1H, d, J = 8.6 Hz, C₈-H), 7.28-7.72 (5H, m, 5xAr-H), 7.95-8.12 (1H, m, Ar-H). IR (KBr): 3700-2200 (OH), 1695 (CO), 1675 (CO) cm⁻¹; ms m/z: 324 (M⁺).

6-(1', 2'-cis-2'-Carboxycyclohexane-1'-carbonyl)-2, 2-dimethyl-2-silatetralin (5f): Compound (4) (212 mg, 1.2 mmol), AlCl₃ (320 mg, 2.4 mmol), cis-1,2-cyclohexanedicarboxylic anhydride (167 mg, 1.08 mmol), and CH₂Cl₂ (32 ml) were used. The residue (415 mg) was purified by column chromatography with hexane-AcOEt (5 : 1) to afford 5f (247 mg, 69 %, mp 50-52.5 °C) as light yellow crystals, mp 115-118 °C (hexane). Anal. Calcd for C₁₉H₂₆O₃Si: C, 69.05; H, 7.93. Found: C, 69.29; H, 7.92. ₁H-Nmr δ: 0.06 (6H, s, SiMe₂), 0.75 (2H, t, J = 7.1 Hz, C₃-H), 1.15-2.35 (8H, br, 4xCH₂), 2.02 (2H, s, C₁-H), 2.65 (1H, dt, J = 4.3, 4.3 Hz, CHCO₂H), 2.76 (2H, t, J = 7.1 Hz, C₄-H), 3.89 (1H, dt, J = 4.3, 4.3 Hz, CHCO), 7.09 (1H, d, J = 8.6 Hz, C₈-H), 7.51-7.68 (2H, m, C₅-H, C₇-H). IR (KBr): 3650-2450 (OH), 1710 (CO), 1685 (CO) cm⁻¹; ms m/z: 330 (M⁺).

6-[2'-(2''-Carboxyphenyl)benzoyl]-2, 2-dimethyl-2-silatetralin (5g): Compound (4) (106 mg, 0.6 mmol), AlCl₃ (160 mg, 1.2 mmol), diphenic anhydride (121 mg, 0.54 mmol), and CH₂Cl₂ (16 ml) were used. The residue (237 mg) was purified two times by column chromatography [first, CHCl₃ and CHCl₃-MeOH (300 : 1 ~ 5 : 1); second, CHCl₃ and CHCl₃-MeOH (100 : 1)] to afford 5g (91 mg, 42 %) as a light yellow amorphous solid. ₁H-Nmr δ: 0.05 (6H, s, SiMe₂), 0.73 (2H, t, J = 6.9 Hz, C₃-H), 2.04 (2H, s, C₁-H), 2.73 (2H, t, J = 6.9 Hz, C₄-H), 7.04-7.17 (2H, m, 2xAr-H), 7.27-7.66 (8H, m, 8xAr-H), 7.76-7.82 (1H, m, Ar-H). IR: 3500-2500 (OH), 1740 (CO), 1705 (CO) cm⁻¹. HRms m/z calcd for C₂₅H₂₄O₃Si (M⁺): 400.1495, found: 400.1490; ms m/z: 400 (M⁺).
Baeyer-Villiger Reaction of 6-Acetyl-2, 2-dimethyl-2-silatetralin (5a). A mixture of 5a (102 mg, 0.47 mmol) and 80 % m-CPBA (609 mg, 2.82 mmol) in CH₂Cl₂ (2.5 ml) was stirred at room temperature for 3.5 h. The reaction was quenched with saturated Na₂S₂O₃. The organic layer was separated and the aqueous layer was extracted with CH₂Cl₂. The combined organic layers were washed with saturated NaHCO₃ and brine, and dried (MgSO₄). Removal of the solvent in vacuo gave a residue (130 mg), which was purified by preparative tlc (five developments with hexane : AcOEt = 40 : 1) to give 7 (62 mg, 56 %) as a colorless oil, spectral data (¹H-nmr, lr, and ms) of which were in agreement with those of 6-acetoxy-2-silatetralin (7) obtained from 6.

6-Acetoxy-2, 2-dimethyl-2-silatetralin (7). A mixture of 6 (187 mg, 0.97 mmol), acetic anhydride (149 mg, 1.46 mmol), and pyridine (231 mg, 2.92 mmol) in CH₂Cl₂ (10 ml) was stirred at room temperature for 1 h. Usual work-up of the reaction mixture gave a residue, which was purified two times by preparative tlc (development with hexane : AcOEt = 3 : 1) to give 7 (143 mg, 63 %) as a colorless oil. ¹H-Nmr δ : 0.06 (6H, s, SiMe₂), 0.75 (2H, t, J = 7.1 Hz, C₃-H), 1.95 (2H, s, C₁-H), 2.29 (3H, s, MeCO), 2.72 (2H, t, J = 7.1 Hz, C₄-H), 6.68-6.88 (2H, m, C₅-H, C₇-H), 7.06 (1H, d, J = 8.6 Hz, C₈-H). lr : 1760 (CO) cm⁻¹. HRms m/z calcd for C₁₃H₁₈O₂Si (M⁺) : 234.1074, found : 234.1072; ms m/z : 234 (M⁺).

6-(3'-Methoxycarbonylpropanoyl)-2, 2-dimethyl-2-silatetralin (8). A solution of 5c (387 mg, 1.40 mmol) in ether (14 ml) was treated with excess of diazomethane-ether under stirring in an ice bath. Removal of the solvent in vacuo gave a residue (408 mg), which was purified by column chromatography with CHCl₃-hexane (1 : 1) to give 8 (344 mg, 85 %) as a colorless oil. ¹H-Nmr δ : 0.06 (6H, s, SiMe₂), 0.75 (2H, t, J = 7.1 Hz, C₃-H), 2.04 (2H, s, C₁-H), 2.62-2.86 (4H, m, C₄-H, CH₂CO₂Me), 3.29 (2H, t, J = 7.1 Hz, CH₂CO), 3.69 (3H, s, OMe), 7.14 (1H, d, J = 8.6 Hz, C₈-H), 7.64-7.79 (2H, m, C₅-H, C₇-H). lr : 1735 (COOMe), 1680 (CO) cm⁻¹. HRms m/z calcd for C₁₆H₂₂O₃Si (M⁺) : 290.1337, found : 290.1337; ms m/z : 290 (M⁺).

6-(3'-Methoxycarbonylpropanoyloxy)-2, 2-dimethyl-2-silatetralin (9). A mixture of 8 (122 mg, 0.42 mmol) and 80 % m-CPBA (906 mg, 4.2 mmol) in CH₂Cl₂ (6 ml) was stirred at room temperature for 72 h. The reaction mixture was treated in a manner similar to that noted for 5b gave light yellow crystals (144 mg), which were purified by preparative tlc (two
developments with CHCl₃) to give 9 (54 mg, 42 %) as a light yellow oil. ¹H-Nmr δ : 0.04 (6H, s, SiMe₂), 0.69-0.78 (2H, m, C₃-H), 1.93 (2H, s, C₁-H), 2.67-2.78 (4H, m, C₄-H, CH₂CO₂Me), 2.82-2.91 (2H, m, CH₂CO₂), 3.73 (3H, s, OMe), 6.79-6.86 (2H, m, C₅-H, C₇-H), 7.05 (1H, d, J = 8.6 Hz, C₈-H). Ir : 1750 (COOAr), 1740 (COOMe) cm⁻¹. HRms m/z calcd for C₁₆H₂₂O₄Si (M⁺) 306.1287, found : 306.1294; ms m/z : 306 (M⁺).

6-Hydroxy-2, 2-dimethyl-2-silatetralin (6). A mixture of 9 (110 mg, 0.36 mmol) and LiAlH₄ (68 mg, 1.8 mmol) in THF (10 ml) was refluxed for 1 h under stirring. The reaction was quenched with water under ice-cooling. The reaction mixture was extracted with ether and organic layers were washed with brine, and dried (MgSO₄). Removal of the solvent in vacuo gave colorless crystals (64 mg), which were purified by preparative tlc (two developments with hexane : AcOEt = 10 : 1) to give 6 (57 mg, 83 %), mp 75.5-76 °C (petroleum ether) as colorless crystals, spectral data (¹H-nmr, ir, ms) of which were identical with those of authentic sample.¹

REFERENCES

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