A Highly Regio- and Stereoselective Nickel-Catalyzed Ring-Opening Reaction of Alkyl and Allyl Zirconium Reagents to 7-Oxabenzonorbornadienes

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Supporting Information

Table of Contents
Page S2  Experimental Section
Page S2 – S9  $^1$H and $^{13}$C NMR Data
Page S10 – S47  $^1$H and $^{13}$CNMR Spectra
Experimental Section

**General:** All reactions were conducted under nitrogen atmosphere on a dual-manifold Schlenk line by using purified deoxygenated solvents and standard inert atmosphere techniques, unless otherwise stated. Reagents and chemicals were used as purchased without further purification. The purity of each product was checked by NMR analysis.

**Synthesis of Alkyl Zirconium Reagent:** To a suspension of Cp₂ZrHCl (1.00 mmol) in THF (1.0 mL) under nitrogen was added a mixture of THF (0.50 mL) and alkene CH₂=CHR (2.00 mmol) and the reaction mixture was stirred at 40 °C for 30 min. During the reaction, light yellow color of the solution was developed. The solution was evacuated to remove the excess alkene and solvent. Then freshly distilled THF (2.0 mL) was added and this resulting mixture (Cp₂ZrClCH₂CH₂R) was used for the subsequent nickel-catalyzed reaction. This procedure of generating alkyl zirconium reagent (Cp₂ZrClCH₂CH₂R) was used for all alkenes except (R = (CH₂)₃-CH=C(CH₃)₂, cyclohexyl, cyclopentyl, -CH₂Ph, and -(CH₂)₃Br). The alkyl zirconium reagents from these alkenes were generated using 1.00 mmol of the alkene and no further evacuation or addition of THF was done.

**Synthesis of Allyl Zirconium Reagent:** To a suspension of Cp₂ZrHCl (1.00 mmol) in THF (1.0 mL) under nitrogen was added a solution of CH₂Cl₂ (0.5 mL) and allene (2.00 mmol). The mixture was stirred at room temperature for 5 min. During the reaction, red color of the solution was developed. The solution was evacuated to remove the excess allene and solvent. Then freshly distilled THF (2.0 mL) was added and this resulting mixture was used for the subsequent nickel-catalyzed reaction.

**2-(3,3-Dimethylbutyl)-1,2-dihydro-1-naphthalenol (3a):** Colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 0.95 (9 H, s), 1.33-1.39 (2 H, m), 1.41-1.57 (2 H, m), 1.74-1.77
(1 H, m), 2.34-2.36 (1 H, m), 4.56 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.82 (1 H, dd, $J_1 = 4.8$ Hz, $J_2 = 9.6$ Hz), 6.51 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 10.0$ Hz), 7.09-7.11 (1 H, m), 7.19-7.25 (2 H, m), 7.26-7.32 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 24.2, 29.4, 30.4, 41.4, 41.7, 70.5, 126.5, 126.7, 127.6, 128.5, 131.3, 132.7, 136.8; HRMS (m/e): calcd for C$_{16}$H$_{22}$O 230.1671, found 230.1672.

2-Hexyl-1,2-dihydro-1-naphthalenol (3b): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): δ 0.88 (3 H, t, $J = 6.4$ Hz), 1.31-1.50 (6 H, m), 1.51-1.60 (4 H, m), 1.75-1.80 (1 H, m), 2.44-2.46 (1 H, m), 4.57 (1 H, dd, $J_1 = 4.4$ Hz, $J_2 = 7.6$ Hz), 5.81 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 6.53 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 9.6$ Hz), 7.10-7.12 (1 H, m), 7.19-7.25 (2 H, m), 7.26-7.33 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 14.1, 22.7, 27.2, 29.1, 29.5, 31.8, 40.5, 70.4, 126.5, 126.7, 127.6, 128.5, 131.4, 132.7, 136.8; HRMS (m/e): calcd for C$_{16}$H$_{22}$O 230.1671, found 230.1672.

2-Heptyl-1,2-dihydro-1-naphthalenol (3c): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): δ 0.87 (3 H, t, $J = 6.4$ Hz), 1.24-1.59 (12 H, m), 1.75-1.79 (1 H, m), 2.43-2.46 (1 H, m), 4.57 (1 H, dd, $J_1 = 3.2$ Hz, $J_2 = 6.0$ Hz), 5.82 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 9.6$ Hz), 6.52 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.10-7.19 (1 H, m), 7.21-7.25 (2 H, m), 7.26-7.33 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 14.1, 22.7, 27.2, 29.1, 29.3, 29.8, 31.9, 40.5, 70.4, 126.5, 126.7, 127.6, 128.5, 131.4, 132.7, 136.8; HRMS (m/e): calcd for C$_{17}$H$_{24}$O 244.1827, found 244.1825.

2-(7-Methyl-6-octenyl)-1,2-dihydro-1-naphthalenol (3d): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): δ 1.25-1.57 (7 H, m), 1.60 (3 H, s), 1.65 (3 H, s), 1.68-1.78 (2 H, m), 1.80-1.98 (2 H, m), 2.44-2.47 (1 H, m), 4.58 (1 H, dd, $J_1 = 4.0$ Hz, $J_2 = 6.4$ Hz), 5.11 (1 H, t, $J = 6.8$ Hz), 5.82 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 10.0$ Hz), 6.53 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 10.0$ Hz), 7.11-7.12 (1 H, m), 7.20-7.26 (2 H, m), 7.28-7.34 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 17.7, 25.7, 27.1, 28.0, 29.1, 29.5, 29.8, 40.4, 70.3, 122.1,
124.8, 126.5, 126.7, 127.6, 128.5, 131.3, 132.7, 136.7; HRMS (m/e): calcd for 
C_{19}H_{26}O 270.1984, found 270.1987.

2-[2-(1,1,1-Trimethylsilyl)ethyl]-1,2-dihydro-1-naphthalenol (3e): solid; m.p.: 
50-51 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta \) 0.00 (9 H, s), 0.64-0.70 (2 H, m), 1.52-1.59 
(2 H, m), 1.78-1.80 (1 H, m), 2.35-2.37 (1 H, m), 4.61 (1 H, dd, \(J_1 = 4.4 \) Hz, \(J_2 = 7.6 \) 
Hz), 5.83 (1 H, dd, \(J_1 = 2.0 \) Hz, \(J_2 = 9.6 \) Hz), 6.53 (1 H, dd, \(J_1 = 2.8 \) Hz, \(J_2 = 9.6 \) Hz), 
7.10-7.12 (1 H, m), 7.21-7.25 (2 H, m), 7.27-7.32 (1 H, m); \(^{13}\)C NMR (100 MHz, 
CDCl\(_3\)): \(\delta \) -1.7, 14.1, 23.5, 43.6, 70.1, 126.5, 126.7, 127.6, 128.6, 131.1, 
132.8, 136.8; HRMS (m/e): calcd for C\(_{15}\)H\(_{22}\)OSi 246.1440, found 246.1436.

2-[3-(1,1,1-Trimethylsilyl)ethyl]-1,2-dihydro-1-naphthalenol (3f): Colorless oil; 
\(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta \) -0.02 (9 H, s), 0.51-0.57 (2 H, m), 1.47-1.59 (4 H, 
m), 1.78-1.80 (1 H, m), 2.41-2.45 (1 H, m), 4.55 (1 H, dd, \(J_1 = 4.0 \) Hz, \(J_2 = 7.6 \) Hz), 
5.81 (1 H, dd, \(J_1 = 2.0 \) Hz, \(J_2 = 9.6 \) Hz), 6.52 (1 H, dd, \(J_1 = 2.8 \) Hz, \(J_2 = 9.6 \) Hz), 7.10- 
7.12 (1 H, m), 7.21-7.25 (2 H, m), 7.26-7.33 (1 H, m); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): 
\(\delta \) -1.6, 16.8, 21.5, 32.9, 40.2, 70.3, 126.5, 126.7, 127.6, 128.5, 131.3, 132.7, 136.8; 
HRMS (m/e): calcd for C\(_{16}\)H\(_{24}\)OSi 260.1590, found 260.1588.

2-(5-Bromopentyl)-1,2-dihydro-1-naphthalenol (3g): Colorless oil; \(^1\)H NMR (400 
MHz, CDCl\(_3\)): \(\delta \) 1.50-1.55 (5 H, m), 1.80-2.01 (4 H, m), 2.41-2.45 (1 H, m), 3.42 (2 
H, t, \(J = 6.8 \) Hz), 4.57 (1 H, dd, \(J_1 = 4.0 \) Hz, \(J_2 = 7.6 \) Hz), 5.80 (1 H, dd, \(J_1 = 2.4 \) Hz, 
\(J_2 = 9.6 \) Hz), 6.52 (1 H, dd, \(J_1 = 2.4 \) Hz, \(J_2 = 9.6 \) Hz), 7.10-7.14 (1 H, m), 7.22-7.25 (2 
H, m), 7.27-7.33 (1 H, m); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta \) 26.3, 28.3, 28.9, 32.7, 
33.9, 40.3, 70.2, 126.5, 126.9, 127.6, 127.7, 128.6, 131.0, 132.6, 136.7; HRMS (m/e): 
calcd for C\(_{15}\)H\(_{19}\)OBr 294.0619, found 294.0617.

2-(2-Cyclopentylethyl)-1,2-dihydro-1-naphthalenol (3h): Colorless oil; \(^1\)H NMR 
(400 MHz, CDCl\(_3\)): \(\delta \) 1.12-1.19 (2 H, m), 1.47-1.61 (8 H, m), 1.76-1.79 (4 H, m),

S4
2.39-2.43 (1 H, m), 4.57 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.82 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 9.6$ Hz), 6.52 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 9.6$ Hz), 7.10-7.12 (1 H, m), 7.21-7.25 (2 H, m), 7.26-7.33 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 25.2, 28.3, 32.8, 33.7, 40.3, 40.7, 70.4, 126.5, 126.7, 127.5, 127.6, 128.5, 131.4, 132.7, 136.8; HRMS (m/e): calcld for C$_{17}$H$_{22}$O 242.1671, found 242.1673.

2-(2-Cyclohexylethyl)-1,2-dihydro-1-naphthalenol (3i): Colorless solid; m.p.: 79-81 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 0.92-0.95 (2 H, m), 1.10-1.36 (4 H, m), 1.36-1.41 (2 H, m), 1.43-1.83 (8 H, m), 2.37-2.42 (1 H, m), 4.58 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.80 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 9.6$ Hz), 6.52 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.09-7.11 (1 H, m), 7.19-7.23 (2 H, m), 7.28-7.34 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 26.4, 26.7, 33.4, 34.9, 37.9, 40.7, 70.3, 126.5, 126.7, 127.6, 128.5, 131.4, 132.7, 136.8; HRMS (m/e): calcld for C$_{18}$H$_{24}$O 256.1827, found 256.1830.

2-(3-Penylpropyl)-1,2-dihydro-1-naphthalenol (3j): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.60-1.65 (2 H, m), 1.80-1.88 (3 H, m), 2.44-2.49 (1 H, m), 2.66-2.69 (2 H, m), 4.57 (1 H, dd, $J_1 = 4.0$ Hz, $J_2 = 7.6$ Hz), 5.80 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 9.6$ Hz), 6.52 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 10.0$ Hz), 7.12-7.15 (1 H, m), 7.17-7.32 (8 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 29.0, 36.1, 40.4, 41.8, 70.2, 125.7, 126.5, 126.7, 126.8, 127.5, 127.6, 128.3, 128.4, 128.6, 131.0, 132.6, 136.7; HRMS (m/e): calcld for C$_{19}$H$_{24}$O 264.1514, found 264.1517.

6-(3,3-Dimethylbutyl)naphtho[2,3-d][1,3]dioxole (3k): Colorless solid; m.p.: 96-98 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 0.99 (9 H, s), 1.56 (2 H, t, $J = 4.8$ Hz), 2.67 (2 H, t, $J = 4.8$ Hz), 6.00 (2 H, s), 7.05 (1 H, s), 7.07 (1 H, s), 7.17 (1 H, d, $J = 8.4$ Hz), 7.44 (1 H, s), 7.57 (1 H, d, $J = 8.4$ Hz); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 29.4, 30.6, 31.2, 46.4, 100.8, 103.5, 103.7, 125.6, 125.8, 126.9, 128.6, 130.7, 139.6, 146.9, 147.6; HRMS (m/e): calcld for C$_{17}$H$_{20}$O$_2$ 256.1463, found 256.1467.
2-(3,3-Dimethylbutyl)-1,2-dihydro-1-triphenylenol (3l): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): δ 1.00 (9 H, s), 1.45-1.59 (3 H, m), 1.77-1.80 (1 H, m), 1.94-1.97 (1 H, m), 2.42-2.49 (1 H, m), 5.35 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 6.13 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 8.8$ Hz), 7.38 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.61-7.68 (4 H, m), 8.23-8.25 (1 H, m), 8.33-8.35 (1 H, m), 8.70-8.73 (2 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 24.6, 29.5, 30.5, 41.4, 41.8, 66.0, 122.6, 123.0, 123.1, 123.3, 123.7, 124.1, 126.3, 126.7, 126.8, 127.0, 127.2, 129.8, 130.0, 130.5, 130.6, 132.4; HRMS (m/e): calcd for C$_{24}$H$_{26}$O 330.1984, found 330.1980.

2-Heptyl-1,2-dihydro-1-triphenylenol (3m): Colorless oil; $^1$H NMR (600 MHz, CDCl$_3$): δ 0.90 (3 H, t, $J = 7.0$ Hz), 1.31-1.43 (8 H, m), 1.54-1.64 (3 H, m), 1.80-1.83 (1 H, m), 2.00-2.08 (1 H, m), 2.58-2.59 (1 H, m), 5.33 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 6.0$ Hz), 6.12 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.38 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.62-7.66 (4 H, m), 8.24-8.25 (1 H, m), 8.33-8.34 (1 H, m), 8.70-8.73 (2 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 14.1, 22.7, 27.4, 29.3, 29.6, 29.8, 31.9, 40.6, 65.9, 122.6, 123.0, 123.1, 123.7, 124.1, 126.3, 126.7, 126.8, 127.3, 128.8, 129.9, 130.0, 130.5, 130.6, 132.5; HRMS (m/e): calcd for C$_{25}$H$_{28}$O 344.2140, found 344.2143.

2-[(E)-3-Cyclohexyl-2-propenyl]-1,2-dihydro-1-naphthalenol (5a): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): δ 1.01-1.30 (5 H, m), 1.56-1.71 (6 H, m), 1.93-1.97 (1 H, m), 2.23-2.30 (1 H, m), 2.41-2.50 (2 H, m), 4.57 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.43-5.56 (2 H, m), 5.81 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 6.52 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.09-7.11 (1 H, m), 7.21-7.26 (2 H, m), 7.28-7.32 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 26.1, 26.2, 32.4, 33.1, 40.7, 40.8, 70.5, 125.1, 126.5, 126.9, 127.5, 127.6, 128.5, 130.6, 132.7, 136.7, 139.1; HRMS (m/e): calcd for C$_{19}$H$_{24}$O 268.1827, found 268.1827.
2-[(E)-3-Cycloheptyl-2-propenyl]-1,2-dihydro-1-naphthalenol (5b): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.31-1.75 (13 H, m), 2.14-2.20 (1 H, m), 2.23-2.38 (1 H, m), 2.41-2.58 (2 H, m), 4.58 (1 H, dd, $J_1 = 3.6$ Hz, $J_2 = 7.6$ Hz), 5.46 (1 H, dt, $J_1 = 6.4$ Hz, $J_2 = 15.6$ Hz), 5.58 (1 H, dd, $J_1 = 7.2$ Hz, $J_2 = 15.6$ Hz), 5.83 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 9.6$ Hz), 6.53 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.11-7.13 (1 H, m), 7.21-7.26 (2 H, m), 7.27-7.32 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 26.2, 28.4, 32.3, 34.9, 40.8, 42.8, 70.5, 124.4, 126.5, 126.9, 127.5, 127.6, 128.5, 130.6, 132.7, 136.7, 140.0; HRMS (m/e): calcd for C$_{26}$H$_{28}$O 282.1984, found 282.1983.

2-(2-Cyclohexylidenethyl)-1,2-dihydro-1-naphthalenol (5c): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.41-1.63 (7 H, m), 2.03-2.21 (4 H, m), 2.21-2.58 (3 H, m), 4.59 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.20 (1 H, t, $J = 6.8$ Hz), 5.81 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 9.6$ Hz), 6.51 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 9.6$ Hz), 7.09-7.11 (1 H, m), 7.19-7.26 (2 H, m), 7.27-7.33 (1 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 26.8, 27.8, 28.7, 37.3, 41.2, 70.6, 118.9, 126.5, 126.9, 127.5, 127.6, 128.4, 130.9, 132.7, 136.8, 142.0; HRMS (m/e): calcd for C$_{19}$H$_{22}$O 254.1671, found 254.1669.

2-[(E)-3-Cycloheptyl-2-propenyl]-1,2-dihydro-1-triphenylenol (5d): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.24-1.82 (13 H, m), 2.18-2.23 (1 H, m), 2.41-2.55 (1 H, m), 2.60-2.73 (2 H, m), 5.35 (1 H, dd, $J_1 = 2.0$ Hz, $J_2 = 6.0$ Hz), 5.59 (1 H, dt, $J_1 = 7.2$ Hz, $J_2 = 15.6$ Hz), 5.68 (1 H, dd, $J_1 = 7.2$ Hz, $J_2 = 15.6$ Hz), 6.14 (1 H, dd, $J_1 = 2.4$ Hz, $J_2 = 9.6$ Hz), 7.38 (1 H, dd, $J_1 = 2.8$ Hz, $J_2 = 10.0$ Hz), 7.61-7.68 (4 H, m), 8.23-8.31 (2 H, m), 8.70-8.73 (2 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 26.3, 28.4, 32.7, 35.0, 40.9, 42.9, 65.8, 122.8, 123.0, 123.1, 123.3, 123.7, 124.1, 124.4, 126.3, 126.8, 127.0, 127.3, 129.8, 130.0, 130.5, 130.6, 131.6, 132.4, 140.4; HRMS (m/e): calcd for C$_{28}$H$_{30}$O 382.2297, found 382.2293.
**Procedure for Dehydration Reaction:** To a 50-ml round-bottom flask containing 3a (1.00 mmol) in THF (2 mL) was added 6 N HCl (3 mL). The reaction mixture was stirred at room temperature for 3 h. Water (3 mL) was added to the reaction mixture and the system was extracted with ether (~ 10 mL each) twice. The extracts were combined together, washed with brine solution and dried with Na$_2$SO$_4$. The extract was concentrated and the residue was purified on a silica-gel column using hexane as eluent to afford the dehydration product 6a in 96 % yield. Compounds 6b-c was synthesized according to this procedure and the spectral data of the representative compounds are as follows.

2-(3,3-Dimethylbutyl)naphthalene (6a): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 0.98 (9 H, s), 1.58 (2 H, t, $J$ = 8.4 Hz), 2.72 (2 H, t, $J$ = 8.4 Hz), 7.31 (1 H, d, $J$ = 1.6 Hz), 7.33-7.43 (2 H, m), 7.60 (1 H, s), 7.73-7.79 (3 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 29.4, 30.6, 31.4, 46.3, 124.9, 125.8, 126.0, 127.3, 127.5, 127.6, 127.8, 131.9, 133.7, 141.1; HRMS (m/e): calcd for C$_{16}$H$_{20}$212.1565, found 212.1573.

2-(7-Methyl-6-octenyl)naphthalene (6b): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.34-1.38 (4 H, m), 1.53-1.57 (4 H, m), 1.61-1.68 (4 H, m), 1.95 (2 H, dt, $J_1$ = 1.2 Hz, $J_2$ = 6.0 Hz), 2.75 (2 H, t, $J$ = 7.6 Hz), 5.10 (1 H, t, $J$ = 6.4 Hz ), 7.32 (1 H, d, $J$ = 1.6 Hz), 7.38-7.42 (2 H, m), 7.59 (1 H, s), 7.73-7.79 (3 H, m); $^{13}$C NMR (150 MHz, CDCl$_3$): $\delta$ 17.7, 25.7, 28.0, 29.2, 29.7, 31.3, 36.1, 124.8, 125.0, 125.8, 126.3, 127.4, 127.5, 127.6, 127.7, 131.3, 131.9, 133.6, 140.4; HRMS (m/e): calcd for C$_{19}$H$_{24}$ 252.1878, found 252.1877.

2-(2-Cyclohexylethyl)naphthalene (6c): Colorless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 0.93-1.02 (2 H, m), 1.13-1.39 (4 H, m), 1.47-1.91 (7 H, m), 2.76 (2 H, t, $J$ = 8.4 Hz), 7.31 (1 H, d, $J$ = 1.6 Hz ), 7.32-7.43 (2 H, m), 7.59 (1 H, s), 7.73-7.79 (3 H, m); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 26.3, 26.7, 33.3, 37.3, 39.2, 124.9, 125.8,
126.2, 127.4, 127.5, 127.6, 127.7, 131.9, 133.7, 140.8; HRMS (m/e): calcd for C_{18}H_{22} 238.1721, found 238.1716.
$^1$H NMR spectrum of compound 3a:
$^{13}$C NMR spectrum of compound 3a:
$^{1}$H NMR spectrum of compound 3b:
$^{13}$C NMR spectrum of compound 3b:
"H NMR spectrum of compound 3c:
$^{13}$C NMR spectrum of compound 3c:
$^1$H NMR spectrum of compound 3d:
$^{13}$C NMR spectrum of compound 3d:
$^1$H NMR spectrum of compound 3e:
$^{13}$C NMR spectrum of compound 3e:
$^1$H NMR spectrum of compound 3f:
$^{13}$C NMR spectrum of compound 3f:
$^1$H NMR spectrum of compound 3g:
$^{13}$C NMR spectrum of compound 3g:
$^1$H NMR spectrum of compound 3h:
$^{13}$C NMR spectrum of compound 3h:
$^1$H NMR spectrum of compound 3i:
$^{13}$C NMR spectrum of compound 3i:
$^1$H NMR spectrum of compound 3j:
$^{13}$C NMR spectrum of compound 3j:
$^1$H NMR spectrum of compound 3k:
$^{13}$C NMR spectrum of compound 3k:
$^1$H NMR spectrum of compound 3I:
$^{13}$C NMR spectrum of compound 3l:
$^{13}$C NMR spectrum of compound 3m:
$^1$H NMR spectrum of compound 3m:
$^1$H NMR spectrum of compound 5a:
$^{13}$C NMR spectrum of compound 5a:
$^1$H NMR spectrum of compound 5b:
$^{13}$C NMR spectrum of compound 5b:
$^1$H NMR spectrum of compound 5c:
$^{13}$C NMR spectrum of compound 5c:
$^1$H NMR spectrum of compound 6a:
$^{13}$C NMR spectrum of compound 6a:
$^1$H NMR spectrum of compound 6b:
$^{13}$C NMR spectrum of compound 6b:
$^1$H NMR spectrum of compound 6c:
$^{13}$C NMR spectrum of compound 6c: