Gold-Catalyzed Tandem Cyclization/Friedel-Crafts Type

Reactions toward Furan Derivatives

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General Remarks

Column chromatography was carried out on silica gel. $^1$H NMR spectra were recorded on 300/400 MHz in CDCl$_3$ and $^{13}$C NMR spectra were recorded on 75/100 MHz in CDCl$_3$. IR spectra were recorded on a FT-IR spectrometer and only major peaks are reported in cm$^{-1}$. Melting points were determined on a microscopic apparatus and were uncorrected. All compounds were further characterized by elemental analysis; copies of their $^1$H NMR and $^{13}$C NMR spectra are provided in the Supporting Information. Room temperature is 23–25°C. Commercially available reagents and solvents were used without further purification. THF was distilled immediately before use from Na/benzophenone.

The known substrates 1a-11 were prepared according to the literature.$^1$

The known nucleophiles were prepared according to the literature.$^2$

General procedure A: Gold (III)-catalyzed reaction of 1-oxiranyl-2-alkynyl ester 1 with nucleophiles for synthesis of 4.
To a solution of esters of 1-oxiranyl-2-alkyn-1-ols 1 (0.50 mmol), 5 mmol of nucleophiles (10 equivs) in wet 1,4-dioxane (2.0 mL) was added 4.00 mg (0.01 mmol, 2 mol %) of HAuCl₄·4H₂O under air at room temperature. When the reaction was considered complete as determined by TLC analysis, the reaction mixture was diluted with ethyl ether (40 mL), washed with water, saturated brine, dried over Na₂SO₄ and evaporated under reduced pressure. The residue was purified by chromatography on silica gel to afford corresponding furan derivatives 4.

**Characterization Data of 4.**

2-(furan-2-yl(phenyl)methyl)-5-phenylfuran (4a): Compound 4a was isolated in 71 % yield as an oil following the general procedure A. Reaction time: 20 min.; ¹H NMR (300 MHz, CDCl₃) δ 7.68-7.66 (d, J = 7.5 Hz, 2H), 7.43-7.24 (m, 9 H), 6.65-6.63 (d, J = 3.6 Hz, 1 H), 6.39-6.38 (dd, J =3.3, 1.8 Hz, 1 H), 6.15 (s, 2H), 5.58 (s, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 154.3, 153.9, 153.3, 141.9, 139.4, 130.8, 128.5, 128.3, 127.2, 127.1, 123.5, 110.2, 109.7, 107.6, 105.7, 45.1. IR (neat, cm⁻¹) 2924, 1450, 1163, 1018, 694. Anal.Calcd for C₂₁H₁₆O₂: C, 83.98; H, 5.37. Found: C, 83.82; H, 5.30.

2-(furan-2-yl(p-tolyl)methyl)-5-phenylfuran (4b): Compound 4b was isolated in 73 % yield as an oil following the general procedure A. Reaction time: 10 min.; ¹H NMR (300 MHz, CDCl₃) δ 7.61-7.58 (d, J = 7.5 Hz, 2H), 7.35-7.11 (m, 8 H), 6.57-6.55 (t, J = 3.0 Hz, 1 H), 6.31-6.30 (dd, J = 3.0, 1.2 Hz, 1 H), 6.08-6.06 (t, J = 3.0 Hz, 2 H), 5.47 (s, 1H), 2.32 (s, 3H) ¹³C NMR (75 MHz, CDCl₃) δ 154.6, 154.2, 153.2, 141.9, 136.8, 136.4, 130.9, 129.2, 128.6, 128.2, 127.1, 123.6, 110.2, 109.6, 107.5, 105.7, 44.8, 21.1. IR (neat, cm⁻¹) 2921, 1509, 1208, 1018, 762. Anal.Calcd for C₂₂H₁₈O₂: C, 84.05; H, 5.77. Found: C, 84.02; H, 5.73.

2-((4-chlorophenyl)(furan-2-yl)methyl)-5-phenylfuran (4c): Compound 4c was isolated in 70 % yield as an oil following the general procedure A. Reaction time: 10 min.; ¹H NMR (300 MHz, CDCl₃) δ 7.51-7.49 (d, J = 7.8 Hz, 2H), 7.26-7.18 (m, 5 H),
7.14-7.09(m, 3 H), 6.48-6.47(d, J = 3.0 Hz, 1 H), 6.24-6.22(t, J = 3.0 Hz, 1 H), 6.00-5.99(d, J = 2.4 Hz, 2 H), 5.38(s, 1H) 13C NMR (75 MHz, CDCl3) δ 153.7, 153.5, 153.3, 142.1, 137.9, 133.0, 130.7, 129.7, 128.7, 128.6, 127.2, 123.5, 110.3, 109.8, 107.7, 105.6, 44.5. IR (neat, cm\(^{-1}\)) 2926, 1594, 1543, 1488, 1488, 1017, 761. Anal.Calcd for C\(_{21}\)H\(_{15}\)ClO\(_2\): C, 75.34; H, 4.52. Found: C, 75.39; H, 4.63.

2-(1-(furan-2-yl)ethyl)-5-phenylfuran (4d): Compound 4d was isolated in 50 % yield as an oil following the general procedure A. Reaction time: 20 min.; \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ 7.64-7.61(dd, J = 7.6, 1.6 Hz, 2H), 7.37-7.33(m, 3 H), 7.24-7.20 (m, 1 H), 6.57-6.56 (d, J = 3.2 Hz, 1 H), 6.32-6.30(dd, J = 3.2, 2.0 Hz, 2H), 6.12-6.09 (m, 2 H), 4.31-4.25 (q, J = 7.2 Hz, 1 H), 1.66-1.65 (d, J = 7.2 Hz, 3 H). 13C NMR (100 MHz, CDCl\(_3\)) δ 156.4, 156.2, 152.7, 141.3, 131.1, 128.6, 127.0, 123.5, 110.1, 107.1, 105.6, 105.1, 33.3, 18.1. IR (neat, cm\(^{-1}\)) 2980, 2935, 1545, 1485, 1015, 760. Anal.Calcd for C\(_{16}\)H\(_{14}\)O\(_2\): C, 80.65; H, 5.92. Found: C, 80.60; H, 4.88.

2-(furan-2-ylmethyl)-5-phenylfuran (4e): Compound 4e was isolated in 43 % yield as an oil following the general procedure A. Reaction time: 20 min.; \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ 7.64-7.61(d, J = 7.6 Hz, 2 H), 7.36-7.33(t, J = 7.6 Hz, 3 H) 7.25-7.20 (m, 1 H),6.57-6.56 (d, J = 3.2 Hz, 1 H), 6.31(s, 1 H), 6.16-6.13 (dd, J = 8.0, 3.2 Hz, 2H), 4.07(s, 2 H). 13C NMR (100 MHz, CDCl\(_3\)) δ 153.1, 151.5, 151.3, 141.6, 131.0, 128.6, 127.0, 123.5, 110.4, 108.6, 106.6, 105.8, 28.4. IR (neat, cm\(^{-1}\)) 2924, 2935, 1549, 1017, 758. Anal.Calcd for C\(_{16}\)H\(_{14}\)O\(_2\): C, 80.34; H, 5.39. Found: C, 80.50; H, 4.51.

2-(furan-2-yl(phenyl)methyl)-5-p-tolylfuran (4f): Compound 4f was isolated in 68 % yield as an oil following the general procedure A. Reaction time: 10 min.; \(^1\)H NMR (300 MHz, CDCl\(_3\)) δ 7.51-7.48(d, J = 8.1 Hz, 2 H), 7.36-7.35(d, J = 1.2 Hz, 1 H), 7.32-7.30 (m, 5 H), 7.14-7.12 (d, J = 8.1 Hz, 2 H), 6.51-6.50 (d, J = 2.7 Hz, 1 H), 6.32-6.30 (dd, J = 3.0, 1.8 Hz, 1 H), 6.08-6.06 (t, J = 3.0 Hz, 2 H), 5.50(s, 1H), 2.32 (s, 3H). 13C NMR (75 MHz, CDCl\(_3\)) δ 154.4, 153.5, 153.5, 141.9, 139.5, 136.9, 129.2, 128.5, 128.4, 128.2, 127.1, 123.6, 110.2, 109.6, 107.6, 104.9, 45.1, 21.2. IR (neat, cm\(^{-1}\)) 3027, 2921, 1498, 1016, 736. Anal.Calcd for C\(_{22}\)H\(_{18}\)O\(_2\): C, 84.05; H, 5.77. Found: C, 84.01; H, 5.70.
1-(4-(5-(furan-2-yl(phenyl)methyl)furan-2-yl)phenyl)ethanone (4g): Compound 4g was isolated in 58 % yield as an oil following the general procedure A. Reaction time: 50 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.94-7.91 (dd, $J = 9.0, 1.2$ Hz, 2 H), 7.68-7.64 (dd, $J = 8.7, 1.2$ Hz, 2 H), 7.38 (s, 1 H), 7.34-7.24 (m, 5 H), 6.73-6.72 (t, 1 H), 6.34-6.33 (dd, $J = 2.7, 1.8$ Hz, 1 H), 6.15-6.14 (d, $J = 3.0$ Hz, 1 H), 6.09-6.08 (t, 1 H), 5.53 (s, 1 H), 2.57 (s, 3 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 197.3, 155.4, 153.9, 152.2, 142.1, 139.1, 135.3, 134.8, 128.9, 128.6, 128.3, 127.3, 123.3, 110.3, 110.2, 108.3, 107.7, 45.2, 26.5. IR (neat, cm$^{-1}$) 2922, 1679, 1607, 1266, 1016, 731. Anal.Calcd for C$_{22}$H$_{18}$O$_2$: C, 80.68; H, 5.30. Found: C, 80.60; H, 5.22.

2-(furan-2-yl(phenyl)methyl)-5-(thiophen-2-yl)furan (4h): Compound 4h was isolated in 60 % yield as an oil following the general procedure A. Reaction time: 10 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.36 (s, 1 H), 7.33-7.23 (m, 5 H), 7.18-7.15 (m, 2 H), 7.00-6.97 (m, 1 H), 6.42-6.41 (d, $J = 3.6$ Hz, 1 H), 6.33-6.31 (dd, $J = 3.0, 1.8$ Hz, 1 H), 6.08-6.04 (m, 2 H), 5.48 (s, 1 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 154.2, 153.6, 148.8, 142.0, 128.5, 128.4, 127.5, 127.2, 123.8, 122.4, 110.3, 109.7, 107.7, 105.8, 45.1. IR (neat, cm$^{-1}$) 3114, 1598, 1499, 1013, 730, 697. Anal.Calcd for C$_{14}$H$_{19}$O$_2$S: C, 74.48; H, 4.61. Found: C, 74.40; H, 4.55.

2-(furan-2-yl(phenyl)methyl)-5-pentylfuran (4i): Compound 4i was isolated in 41 % yield as an oil following the general procedure A. Reaction time: 60 min.; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.34-7.23 (m, 6 H), 6.31-6.29 (dd, $J = 2.8, 2.0$ Hz, 1 H), 6.01-6.00 (d, $J = 3.2$ Hz, 1 H), 5.89-5.86 (dd, $J = 8.4, 3.2$ Hz, 2 H), 5.39 (s, 1 H), 2.58-2.54 (t, $J = 7.6$ Hz, 2 H), 1.68-1.61 (m, 2 H), 1.48-1.32 (m, 4 H), 0.95-0.91 (t, $J = 7.2$ Hz, 3 H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 156.1, 154.8, 152.2, 141.8, 139.8, 128.4, 128.4, 127.0, 110.2, 108.0, 107.4, 105.2, 45.1, 31.9, 29.7, 27.7, 22.7, 14.1. IR (neat, cm$^{-1}$) 2926, 1560, 1499, 1458, 1013, 800, 730. Anal.Calcd for C$_{20}$H$_{22}$O$_2$: C, 81.60; H, 7.53. Found: C, 81.70; H, 7.66.

2-(furan-2-yl(phenyl)methyl)-3-methyl-5-phenylfuran (4j): Compound 4j was isolated in 72 % yield as an oil following the general procedure A. Reaction time: 10 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.58-7.55 (dd, $J = 8.1, 1.2$ Hz, 2 H), 7.35-7.17 (m, 9 H), 6.46 (s, 1 H), 6.31-6.29 (dd, $J = 3.0, 1.8$ Hz, 1 H), 6.09-6.08 (d, $J = 3.3$ Hz, 1 H), 5.50 (s, 1 H), 1.93 (s, 3 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 154.5, 151.9, 148.2, 141.7, 139.7, 130.9, 128.5, 128.5, 128.3, 126.9, 126.9, 123.4, 117.9, 110.2, 108.7, 107.8,
2-methyl-5-(phenyl(5-phenylfuran-2-yl)methyl)furan (4aa): Compound 4aa was isolated in 73% yield as an oil following the general procedure A. Reaction time: 30 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.61-7.58 (dd, $J = 8.7, 1.5$ Hz, 2 H), 6.56-6.55 (d, $J = 3.6$ Hz, 1 H), 6.08-6.07 (d, $J = 3.6$ Hz, 1 H), 5.93-5.91 (d, $J = 3.6$ Hz, 1 H), 5.89-5.88 (d, $J = 3.6$ Hz, 1 H), 5.45 (s, 1 H), 2.24 (s, 3 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 154.3, 153.2, 152.5, 151.5, 139.7, 130.9, 128.5, 128.4, 127.0, 123.6, 109.6, 108.4, 106.1, 105.7, 45.2, 13.6. IR (neat, cm$^{-1}$) 3029, 1544, 1489, 1450, 1215, 1022, 760, 695. Anal. Calcd for C$_{22}$H$_{18}$O$_2$: C, 84.05; H, 5.77. Found: C, 83.97; H, 5.68.

1-benzyl-2-(phenyl(5-phenylfuran-2-yl)methyl)-1H-pyrrole (4ab): Compound 4ab was isolated in 81% yield as an oil following the general procedure A. Reaction time: 15 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.57-7.55 (d, $J = 6.9$ Hz, 2 H), 7.33-7.12 (m, 11 H), 6.95-6.93 (d, $J = 7.2$ Hz, 2 H), 6.65-6.64 (d, $J = 2.4$ Hz, 1 H), 6.52-6.51 (d, $J = 3.6$ Hz, 1 H), 6.14-6.12 (t, 1 H), 5.91-5.90 (d, $J = 3.6$ Hz, 1 H), 5.84-5.83 (d, $J = 1.8$ Hz, 1 H), 5.26 (s, 1 H), 4.90 (s, 1 H), 4.88 (s, 1 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 155.3, 153.1, 140.4, 138.1, 132.4, 131.3, 128.7, 128.5, 127.4, 127.0, 126.9, 126.4, 123.5, 122.0, 109.9, 109.4, 107.1, 105.6, 50.5, 43.3. IR (neat, cm$^{-1}$) 3029, 2925, 1711, 1543, 1489, 1450, 1293, 1074, 1022, 760, 714, 697. Anal. Calcd for C$_{28}$H$_{23}$NO: C, 86.34; H, 5.95; N, 3.60; Found: C, 86.22; H, 5.88; N, 3.48.

phenyl(2-(phenyl(5-phenylfuran-2-yl)methyl)-1H-pyrrol-1-yl)methanone (4ac): Compound 4ac was isolated in 57% yield as an oil following the general procedure A. Reaction time: 60 min.; $^1$H NMR (300 MHz, CDCl$_3$) δ 169.1, 155.6, 153.0, 140.6, 136.4, 134.0, 132.3, 130.9, 129.7, 128.6, 128.5, 128.3, 128.2, 126.9, 126.8, 124.2, 123.5, 115.2, 110.2, 109.7, 105.6, 44.2. IR (neat, cm$^{-1}$) 3030, 1696, 1598, 1487, 1325, 1128, 1023, 876, 696. Anal. Calcd for C$_{28}$H$_{21}$NO: C, 83.35; H, 5.25; N, 3.47; Found: C, 83.30; H, 5.22; N, 3.41.

General procedure B: Gold (III)-catalyzed reaction of 1-oxiranyl-2-alkynyl ester 1 with nucleophiles in water at 80 °C for
synthesis of 4ad-4af.

\[
\text{Ph} \quad \text{O} \quad \text{Ph} \\
\text{1} + \text{Nu} \quad \xrightarrow{\text{cat.} \text{H}_2\text{O} 80^\circ \text{C}} \quad \text{Ph} \quad \text{O} \quad \text{Nu} \\
\]

\text{Nu: 1H-indole, pentane-2,4-dione, NaN}_3

To a solution of esters of 1-oxiranyl-2-alkyn-1-ols 1a (0.50 mmol), 0.60 mmol of nucleophiles (1.2 equivs) in water (0.8 mL) was added 10.00 mg (0.01 mmol, 5 mol %) of HAuCl₄·4H₂O at 80°C. When the reaction was considered complete as determined by TLC analysis, the reaction mixture was diluted with ethyl ether (40 mL), washed with water, saturated brine, dried over Na₂SO₄ and evaporated under reduced pressure. The residue was purified by chromatography on silica gel to afford corresponding furan derivatives 4.

3-(phenyl(5-phenylfuran-2-yl)methyl)-1H-indole(4ad): Compound 4ad was isolated in 51 % yield as an oil following the general procedure B. Reaction time: 10h. 

\[\text{^1H NMR (300 MHz, CDCl}_3 \delta 7.85 (s, 1 H), 7.60-7.58 (d, J = 7.8 Hz, 2 H), 7.40-7.37 (d, J = 8.1 Hz, 1 H), 7.34-7.12 (m, 10 H), 7.04-6.99(t, J = 7.5 Hz, 1 H), 6.77-6.76 (d, J = 2.1 Hz, 1 H), 6.56-6.54 (d, J = 3.3 Hz, 1 H), 6.02-6.01(d, J = 3.0 Hz, 1 H), 5.71(s, 1 H).\]

\[\text{^13C NMR (75 MHz, CDCl}_3 \delta 156.6, 152.9, 141.8, 136.5, 131.1, 128.6, 128.5, 128.4, 126.9, 126.7, 126.6, 123.5, 123.3, 122.1, 119.6, 119.5, 117.4, 111.1, 109.6, 105.7, 42.8.} \]

IR (neat, cm⁻¹) 3422, 1739, 1453, 1021, 740. Anal. Calcd for C₂₅H₁₉NO: C, 85.93; H, 5.48; N, 4.01; Found: C, 85.88; H, 5.39; N, 3.97.

3-(phenyl(5-phenylfuran-2-yl)methyl)pentane-2,4-dione(4ae): Compound 4ae was isolated in 38 % yield as a solid following the general procedure B, along with 20 % 6a was isolated. Reaction time: 8h. 

\[\text{mp = 97-99 °C; ^1H NMR (300 MHz, CDCl}_3 \delta 7.58-7.55 (d, J = 7.5 Hz, 2 H), 7.38-7.20 (m, 8 H), 6.51-6.49 (d, J = 3.6 Hz, 1 H), 6.08-6.07 (d, J = 3.6 Hz, 1 H), 4.94-4.90 (d, J = 12.3 Hz, 1 H), 4.69-4.65 (d, J = 11.7 Hz, 1 H), 2.21(s, 3 H), 1.96(s, 3 H).} \]

\[\text{^13C NMR (75 MHz, CDCl}_3 \delta 202.1, 202.0, 153.8, 153.4, 138.6, 130.6, 128.9, 128.7, 128.3, 127.5, 127.3, 123.5, 109.1, 105.8, 73.4, 45.2, 30.1, 29.1.} \]

IR (neat, cm⁻¹) 2921, 1732, 1700, 1356, 1022, 761, 697. Anal. Calcd for C₂₃H₂₀O₃: C, 79.50; H, 6.06; Found: C, 79.45; H, 5.98.
2-(azido(phenyl)methyl)-5-phenylfuran (4af): Compound 4af was isolated in 46% yield as an oil following the general procedure B. Reaction time: 8h.; $^1$H NMR (300 MHz, CDCl$_3$) δ 7.57-7.55 (d, $J = 7.5$ Hz, 2 H), 7.50-7.47 (d, $J = 6.9$ Hz, 1 H), 7.34-7.29 (m, 5 H), 7.20-7.14 (m, 2 H), 6.51-6.50 (d, $J = 3.3$ Hz, 1 H), 6.16-6.15 (d, $J = 3.0$ Hz, 1 H), 5.62 (s, 1 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 154.6, 151.7, 136.7, 130.4, 128.7, 128.5, 127.7, 127.4, 125.3, 123.9, 111.0, 105.5, 62.3 IR (neat, cm$^{-1}$) 3062, 2096, 1600, 1487, 1451, 1238, 1024, 761, 696. Anal. Calcd for C$_{17}$H$_{13}$N$_3$O: C, 74.17; H, 4.76; N, 15.26; Found: C, 74.03; H, 4.66; N, 15.11.

1-benzyl-2-((4-chlorophenyl)(5-phenylfuran-2-yl)methyl)-1H-pyrrole (4ag): Compound 4ag was isolated in 79% yield as an oil following the general procedure A. $^1$H NMR (300 MHz, CDCl$_3$) δ 7.49-7.46 (d, $J = 7.5$ Hz, 2 H), 7.23-7.09 (m, 9 H), 6.97-6.94 (d, $J = 8.4$ Hz, 2 H), 6.86-6.84 (d, $J = 6.3$ Hz, 1 H), 6.59 (s, 1 H), 6.44-6.32 (d, $J = 3.6$ Hz, 1 H), 6.05-6.04 (d, $J = 2.7$ Hz, 1 H), 5.83-5.81 (d, $J = 4.2$ Hz, 1 H), 5.74-5.73 (t, $J = 1.8$ Hz, 1 H), 5.14 (s, 1 H), 4.83 (s, 1 H), 4.81 (s, 1 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 154.7, 153.3, 139.0, 138.0, 132.7, 131.9, 130.8, 129.8, 128.7, 128.6, 127.5, 127.1, 126.5, 126.3, 123.5, 122.3, 110.0, 109.6, 107.2, 105.6, 50.6, 42.7. IR (neat, cm$^{-1}$) 2923, 1489, 1451, 1292, 1019, 760, 714. Anal. Calcd for C$_{28}$H$_{22}$ClNO: C, 79.33; H, 5.23; N, 3.30; Found: C, 79.10; H, 5.12; N, 3.18.

1-benzyl-2-(phenyl(5-(thiophen-2-yl)furan-2-yl)methyl)-1H-pyrrole (4ah): Compound 4ah was isolated in 63% yield as an oil following the general procedure A. $^1$H NMR (300 MHz, CDCl$_3$) δ 7.29-7.11 (m, 11 H), 6.97-6.93 (m, 2 H), 6.64 (d, $J = 2.4$ Hz, 1 H), 6.36-6.35 (d, $J = 3.0$ Hz, 1 H), 6.12-6.11 (d, $J = 3.0$ Hz, 1 H), 5.87-5.86 (d, $J = 3.0$ Hz, 1 H), 5.83-5.82 (d, $J = 1.8$ Hz, 1 H), 5.23 (s, 1 H), 4.90 (s, 1 H), 4.89 (s, 1 H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 155.0, 148.6, 140.3, 138.1, 135.6, 133.9, 132.3, 128.7, 128.5, 128.4, 127.4, 127.2, 126.9, 126.5, 123.7, 122.2, 109.8, 109.4, 107.1, 105.7, 50.5, 43.2. IR (neat, cm$^{-1}$) 3028, 2924, 1493, 1451, 1298, 1074, 1015, 782, 699. Anal. Calcd for C$_{26}$H$_{21}$NOS: C, 78.95; H, 5.35; N, 3.54; Found: C, 78.99; H, 5.19; N, 3.38.
phenyl(5-phenylfuran-2-yl)methanol (3a): $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.63-7.61 (d, $J = 7.8$ Hz, 2H), 7.47-7.45 (d, $J = 7.2$ Hz, 2 H), 7.38-7.20 (m, 6 H), 6.55-6.54 (d, $J = 3.6$ Hz, 1 H), 6.15-6.14 (d, $J = 3.0$ Hz, 1 H), 5.84 (s), 2.64 (s); $^{13}$C NMR(75 MHz, CDCl$_3$) $\delta$ 155.4, 153.9, 140.7, 130.6, 128.6, 128.4, 128.0, 127.4, 126.6, 123.7, 109.6, 105.5, 70.2. IR (neat, cm$^{-1}$) 2924, 1457, 1187, 1018, 689. Anal.Calcd for C$_{17}$H$_{14}$O$_2$: C, 81.58; H, 5.64. Found: C, 81.62; H, 5.67.
4ad
4ah