Cationic iron-catalyzed intramolecular alkyne-hydroarylation with electron-deficient arenes

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General
Nuclear magnetic resonance spectra were taken on JEOL EX-270 (1H NMR, 270.05 MHz; 13C NMR) spectrometer or JEOL Lambda-400 (1H NMR, 395.75 MHz; 99.5 MHz; 13C NMR) spectrometer using residual chloroform (for 1H NMR, 7.26 ppm) and CDCl3 (for 13C NMR, 77.0 ppm) as an internal standard. Low-resolution mass spectra (EI) were obtained at 70 eV on a Shimazu QP-5050. High-resolution mass experiments (EI) for novel products were performed on JEOL-SX102A at the Natural Science Center for Basic Research and Development (N-BARD) of Hiroshima University. Melting points were recorded on YANAKO micro melting point apparatus, and uncorrected. Column chromatography was performed with silica gel Merck 60 (Merck, type 60, 230-400 mesh). TLC monitoring was performed with silica gel aluminium sheets (Merck, type 60 F254). 1,4-Dioxane and toluene were distilled from Na/benzophenone ketyl. Acetonitrile and nitromethane were distilled from P2O5 and stored over molecular sieves. 1,2-Dichloroethane were distilled from CaH2. Fe(OTf)3 and substrates 1b–1w, 3a–3g were prepared by according to literature method. Unless otherwise noted, commercially available reagents were used without further purification.

Data of products
4-Phenyl-1-tosyl-1,2-dihydroquinoline (2b). 72% isolated as a white solid (Mp. 157.0-158.0 ºC); Rf (SiO2, Hexane:EtOAc = 7:1) = 0.28; 1H NMR (CDCl3, 270.05 MHz) δ 2.27 (3H, s), 4.54 (2H, d, J = 4.4 Hz), 5.58 (1H, t, J = 4.4 Hz), 6.69-6.63 (2H, m), 6.87 (1H, dd, J = 7.7, 1.5 Hz), 7.01-7.04 (2H, m), 7.14 (1H, ddd, J = 7.7, 7.7, 1.3 Hz), 7.20-7.28 (3H, m), 7.30-7.36 (3H, m), 7.80 (1H, dd, J = 7.9, 1.0 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.5, 121.6, 126.0, 126.9, 127.5, 127.6, 128.0, 128.2, 128.5, 129.0, 130.9, 135.5, 136.1, 138.4, 138.6, 143.4, one peak was obscured due to overlap with other peaks. 6-Bromo-4-phenyl-1-tosyl-1,2-dihydroquinoline (2c). 81% isolated as a white solid (Mp. 168.0-169.0 ºC); Rf (SiO2, Hexane:EtOAc = 10:1) = 0.23; 1H NMR (CDCl3, 395.75 MHz) δ 2.29 (3H, s), 4.53 (2H, d, J = 4.4 Hz), 5.61 (1H, t, J = 4.4 Hz), 6.68-6.70 (2H, m), 6.99 (1H, d, J = 2.2 Hz), 7.07 (2H, d, J = 8.2 Hz), 7.23-7.36 (5H, m), 7.45 (1H, dd, J = 8.1, 2.2 Hz), 7.67 (1H, d, J = 8.8 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.3, 120.3, 122.9, 127.5, 127.6, 128.0, 128.2, 128.5, 129.0, 130.9, 131.1, 132.7, 134.5, 135.8, 137.2, 137.8, 143.7; HRMS m/z (EI): M+ calcd for C22H18BrNO2S, 439.0242; found 439.0239.

6-Methoxy-4-phenyl-1-tosyl-1,2-dihydroquinoline (2j). 67% isolated as a yellow oil; Rf (SiO2, Hexane:EtOAc = 7:1) = 0.21; 1H NMR (CDCl3, 270.05 MHz) δ 2.24 (3H, s), 2.34 (3H, s), 4.07 (1H, dd, J = 18.5, 2.5 Hz), 4.84 (1H, dd, J = 18.5, 5.8 Hz), 5.51 (1H, dd, J = 5.8, 2.5 Hz), 6.70 (2H, d, J = 7.9 Hz), 6.91 (1H, d, J = 7.6 Hz), 7.01-7.10 (5H, m), 7.47 (2H, d, J = 7.9 Hz), 7.60-7.63 (1H, m); 13C NMR (CDCl3, 67.80 MHz) δ 21.1, 21.3, 46.0, 123.5, 125.0, 128.1, 128.2, 128.3, 128.6, 128.9, 129.4, 133.6, 134.21, 134.25, 134.5, 136.4, 137.6, 138.6, 144.7; HRMS m/z (EI): M+ calcd for C23H25BrNO2S, 453.0398; found 453.0399.

6-Fluoro-4-phenyl-1-tosyl-1,2-dihydroquinoline (2e). 76% isolated as a white solid (Mp. 140.0-141.0 °C); Rf (SiO2, Hexane:EtOAc = 7:1) = 0.34; 1H NMR (CDCl3, 395.75 MHz) δ 2.28 (3H, s), 4.54 (2H, d, J = 4.2 Hz), 5.63 (1H, t, J = 4.2 Hz), 6.57 (1H, dd, J = 9.6, 2.9 Hz), 6.68 (2H, dd, J = 7.7, 1.9 Hz), 7.00-7.06 (3H, m), 7.22-7.33 (5H, m), 7.75-7.78 (1H, m); 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.5, 112.6 (d, J = 24.6 Hz), 114.9 (d, J = 22.8 Hz), 122.8, 127.6, 127.9, 128.1, 128.4, 129.1, 129.4 (d, J = 8.4 Hz), 131.3 (d, J = 2.8 Hz), 132.8 (d, J = 8.4 Hz), 135.8, 137.3, 138.1 (d, J = 2.2 Hz), 143.6, 160.9 (d, J = 246.2 Hz); HRMS m/z (EI): M+ calcd for C23H18FNO2S, 379.1042; found 379.1039.

4-Phenyl-1,2-dihydroquinoline-6-carboxylic acid methyl ester (2f). 79% isolated as a yellow oil; Rf (SiO2, Hexane:EtOAc = 5:1) = 0.21; 1H NMR (CDCl3, 270.05 MHz) δ 2.27 (3H, s), 3.84 (3H, s), 4.56 (2H, d, J = 4.5 Hz), 5.64 (1H, t, J = 4.5 Hz), 6.72-6.75 (2H, m), 7.04 (2H, d, J = 8.4 Hz), 7.24-7.29 (3H, m), 7.35 (2H, d, J = 8.6 Hz), 7.57 (1H, d, J = 2.0 Hz), 7.87 (1H, d, J = 8.6 Hz), 7.99 (1H, dd, J = 8.2, 2.0 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.4, 52.2, 122.3, 127.2, 127.3, 127.4, 127.9, 128.1, 128.2, 128.3, 129.2, 129.3, 130.8, 135.9, 137.5, 138.3, 139.8, 143.8, one carbon was obscured; HRMS m/z (EI): M+ calcd for C24H21NO2S, 419.1191; found 419.1190.

6-Nitro-1-tosyl-4-p-tolyl-1,2-dihydroquinoline (2g). 71% isolated as a yellow solid (Mp. 200.0-201.0 °C); Rf (SiO2, Hexane:EtOAc = 5:1) = 0.40; 1H NMR (CDCl3, 270.05 MHz) δ 2.31 (3H, s), 2.37 (3H, s), 4.59 (2H, d, J = 4.5 Hz), 5.71 (1H, t, J = 4.5 Hz), 6.64 (2H, d, J = 8.2 Hz), 7.08-7.12 (4H, m), 7.38 (2H, d, J = 8.2 Hz), 7.77 (1H, d, J = 2.6 Hz), 7.95 (1H, d, J = 8.9 Hz), 8.16 (1H, dd, J = 8.9, 2.6 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.2, 21.4, 45.4, 121.2, 122.9, 123.2, 127.3, 127.7, 128.2, 129.2, 129.5, 131.2, 133.7, 135.8, 137.5, 138.3, 141.3, 144.2, 145.6; HRMS m/z (EI): M+ calcd for C25H20NO2S, 420.1144; found 420.1145.

5,7-Difluoro-4-phenyl-1-tosyl-1,2-dihydroquinoline (2h). 76% isolated as a yellow solid (Mp. 119.0-120.0 °C); Rf (SiO2, Hexane:EtOAc = 5:1) = 0.38; 1H NMR (CDCl3, 270.05 MHz) δ 2.18 (3H, s), 4.41 (2H, d, J = 4.8 Hz), 5.53 (1H, t, J = 4.8 Hz), 6.54-6.62 (3H, m), 6.97 (2H, d, J = 8.3 Hz), 7.11-7.19 (3H, m), 7.33 (2H, d, J = 8.2 Hz), 7.37-7.42 (1H, m), 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.3, 103.3 (t, J = 26.0 Hz), 110.8 (d, J = 24.5 Hz), 111.0 (d, J = 24.5 Hz), 123.0 (d, J = 2.5 Hz), 126.70, 126.73, 127.4, 127.6, 129.4, 134.88, 135.9, 138.73, 138.69, 144.0, 155.4 (d, J = 245.0 Hz), 158.0 (d, J = 250.0 Hz); HRMS m/z (EI): M+ calcd for C25H17F2NO2S, 397.0948; found 397.0942.

6-Methyl-4-phenyl-1-tosyl-1,2-dihydroquinoline (2i). 57% isolated as a white solid (Mp. 172.0-173.0 °C); Rf (SiO2, Hexane:EtOAc = 7:1) = 0.36; 1H NMR (CDCl3, 270.05 MHz) δ 2.30 (3H, s), 2.35 (3H, s), 4.43 (2H, d, J = 4.3 Hz), 5.47 (1H, d, J = 4.3 Hz), 6.59-6.64 (3H, m), 6.96 (2H, d, J = 8.2 Hz), 7.07 (1H, d, J = 8.2 Hz), 7.15-7.18 (3H, m), 7.26 (2H, d, J = 8.2 Hz), 7.60 (1H, d, J = 8.2 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.2, 21.3, 45.5, 121.6, 126.4, 127.4, 127.49, 127.54, 127.9, 128.5, 128.95, 129.01, 130.6, 132.9, 136.1, 136.4, 138.2, 138.7, 143.3; HRMS m/z (EI): M+ calcd for C23H21N2O3S, 375.1293; found 375.1290.

6-Methoxy-4-phenyl-1-tosyl-1,2-dihydroquinoline (2j). 19% isolated as a white solid (Mp.
8-Methoxy-4-phenyl-1-tosyl-1,2-dihydroquinoline (2k). 13% isolated as a yellow oil; Rf (SiO2, Hexane:EtOAc = 7:1) = 0.37; 1H NMR (CDCl3, 395.75 MHz) δ 2.27 (3H, s), 3.95-4.09 (2H, m), 4.95 (1H, dd, J = 18.2, 6.0 Hz), 5.57 (1H, dd, J = 6.0, 2.6 Hz), 6.70-6.75 (3H, m), 7.02-7.06 (4H, m), 7.13 (1H, tm, J = 7.6 Hz), 7.31-7.35 (3H, m), 7.79 (1H, d, J = 8.1 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.1, 21.3, 45.5, 122.6, 123.5, 126.8, 127.4, 127.5, 127.8, 128.3, 128.6, 129.1, 132.1, 132.5, 136.3, 137.9, 139.9, 143.3, 148.8; HRMS m/z (EI): M+ calcd for C23H21NO3S, 391.1237.

8-Isopropyl-4-phenyl-1-tosyl-1,2-dihydroquinoline (2l). 46% isolated as a yellow oil; Rf (SiO2, Hexane:EtOAc = 5:1) = 0.54; 1H NMR (CDCl3, 270.05 MHz) δ 1.13 (3H, d, J = 6.8 Hz), 1.47 (3H, d, J = 6.8 Hz), 2.24 (3H, s), 3.95-4.09 (2H, m), 4.95 (1H, dd, J = 18.2, 6.0 Hz), 5.57 (1H, dd, J = 6.0, 2.6 Hz), 6.70-6.75 (3H, m), 7.02-7.06 (4H, m), 7.13 (1H, tm, J = 7.6 Hz), 7.31-7.35 (3H, m), 7.79 (1H, d, J = 8.1 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.3, 45.9, 122.6, 123.5, 126.8, 127.4, 127.5, 127.8, 128.3, 128.6, 129.1, 132.1, 132.5, 136.3, 137.9, 139.9, 143.3, 148.8; HRMS m/z (EI): M+ calcd for C25H25NO2S, 403.1606; found 403.1612.

1-Tosyl-4-p-tolyl-1,2-dihydroquinoline (2s). 83% isolated as a white solid (Mp. 158.5-159.5 ºC); Rf (SiO2, Hexane:EtOAc = 7:1) = 0.37; 1H NMR (CDCl3, 395.75 MHz) δ 2.28 (3H, s), 2.34 (3H, s), 4.53 (2H, d, J = 4.4 Hz), 5.55 (1H, t, J = 4.4 Hz), 6.60 (2H, d, J = 7.7 Hz), 6.89 (1H, dd, J = 7.7 Hz), 7.02-7.06 (4H, m), 7.13 (1H, tm, J = 7.6 Hz), 7.31-7.35 (3H, m), 7.79 (1H, d, J = 8.1 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.1, 21.3, 45.5, 121.2, 126.0, 126.5, 127.51, 127.53, 128.1, 128.4, 128.6, 129.0, 131.1, 135.1, 135.5, 136.0, 137.3, 138.5, 143.3; HRMS m/z (EI): calcd for C23H21NO2S, 375.1293; found 375.1292.

4-(4-Methoxymethylphenyl)-1-tosyl-1,2-dihydroquinoline (2t). 65% isolated as a colorless oil; Rf (SiO2, Hexane:EtOAc = 5:1) = 0.26; 1H NMR (CDCl3, 270.05 MHz) δ 2.27 (3H, s), 3.42 (3H, s), 4.44 (2H, s), 4.53 (2H, d, J = 4.5 Hz), 5.57 (1H, t, J = 4.5 Hz), 6.70 (2H, d, J = 7.7 Hz), 6.85-6.87 (1H, m), 7.02 (2H, d, J = 8.7 Hz), 7.13 (1H, t, J = 7.3 Hz), 7.21 (2H, t, J = 7.7 Hz), 7.31-7.35 (3H, m), 7.79 (1H, d, J = 8.7 Hz); 13C NMR (CDCl3, 67.80 MHz) δ 21.4, 45.4, 58.3, 74.4, 121.6, 126.0, 126.6, 127.4, 127.5, 127.6, 128.2, 128.6, 129.0, 130.9, 135.5, 136.1, 137.5, 137.6, 138.4, 143.4; HRMS m/z (EI): calcd for C23H21NO3S, 405.1399; found 405.1399.

4-(4-anisyl)-1-tosyl-1,2-dihydroquinoline (2u). 75% isolated as a white solid (Mp. 66.0-67.5 ºC); Rf (SiO2, Hexane:EtOAc = 5:1) = 0.37; 1H NMR (CDCl3, 395.75 MHz) δ 2.27 (3H, s), 3.81 (3H, s), 4.51 (2H, d, J = 4.3 Hz), 5.57 (1H, t, J = 4.3 Hz), 6.64 (2H, d, J = 8.9 Hz), 6.77 (2H, d, J = 8.6 Hz), 6.89 (1H, dd, J = 7.8, 1.6 Hz), 7.02 (2H, d, J = 8.6 Hz), 7.12-7.16 (1H, m), 7.31-7.35 (3H, m), 7.79 (1H, d, J = 7.5 Hz); 13C NMR (CDCl3, 99.45 MHz) δ 21.4, 45.5, 55.2, 113.3, 120.8, 126.0, 126.5, 127.4, 127.6, 128.1, 129.0, 130.5, 131.2, 135.6, 136.1, 138.2, 143.3, 159.1; HRMS m/z (EI): M+ calcd for C23H21NO3S, 391.1232; found 391.1232.
4-(2,3,4-Trimethoxyphenyl)-1-tosyl-1,2-dihydroquinoline (2w).  77% isolated as a colorless oil; Rf (SiO\textsubscript{2}, Hexane:EtOAc = 3:1) = 0.21; 1H NMR (CDCl\textsubscript{3}, 270.05 MHz) δ 2.36 (3H, s), 3.53 (3H, s), 3.85 (3H, s), 3.86 (2H, brs), 4.58 (2H, brs), 5.62 (1H, t, J = 4.3 Hz), 5.94 (1H, d, J = 8.7 Hz), 6.49 (1H, d, J = 8.6 Hz), 6.74 (1H, d, J = 7.2 Hz), 7.07-7.13 (3H, m), 7.28-7.31 (1H, m), 7.42 (2H, d, J = 8.0 Hz), 7.79 (1H, d, J = 7.9 Hz); 13C NMR (CDCl\textsubscript{3}, 67.80 MHz) δ 21.4, 45.4, 55.3, 110.8, 120.1, 123.1, 125.8, 126.2, 126.8, 126.9, 127.6, 127.7, 129.0, 129.1, 130.6, 130.7, 134.9, 135.0, 136.7, 143.2, 157.0; HRMS m/z (EI): M\textsuperscript{+} calcd for C\textsubscript{23}H\textsubscript{21}NO\textsubscript{3}S, 391.1242; found 391.1236.

2-Cyano-10-phenylphenanthrene (4a). Isolated in 86% yield as a yellow solid (Mp. 118.0-119.0 ºC); Rf (SiO\textsubscript{2}, Hexane:EtOAc=20:1) = 0.38; 1H NMR (CDCl\textsubscript{3}, 270.05 MHz) δ 2.36 (3H, s), 7.49-7.62 (5H, m), 7.72-7.95 (4H, m), 7.92-7.95 (1H, m), 8.26 (1H, d, J = 8.6 Hz), 8.68-8.71 (1H, m), 8.82 (1H, d, J = 8.6 Hz), 8.68 (1H, s), 8.73 (1H, d, J = 7.7 Hz), 8.82 (1H, d, J = 9.1 Hz); 13C NMR (CDCl\textsubscript{3}, 67.80 MHz) δ 109.8, 119.3, 123.0, 124.0, 127.4, 127.7, 128.0, 128.5, 128.7, 128.88, 128.91, 129.2, 129.9, 130.8, 132.3, 132.5, 133.1, 133.8, 139.2; LRMS m/z: 279 (M\textsuperscript{+}, 100), 250 (15), 139 (15), 125 (94); HRMS m/z (EI): M\textsuperscript{+} calcd for C\textsubscript{25}H\textsubscript{25}NO\textsubscript{5}S, 451.1453; found 451.1455.

2-Methoxycarbonyl-10-phenylphenanthrene (4b). Isolated in 85% yield as a yellow solid (Mp. 138.0-139.0 ºC); Rf (SiO\textsubscript{2}, Hexane:EtOAc=20:1) = 0.24; 1H NMR (CDCl\textsubscript{3}, 395.75 MHz) δ 3.93 (3H, s), 7.50-7.55 (5H, m), 7.66-7.75 (3H, m), 7.92 (1H, d, J = 7.7 Hz), 8.28 (1H, d, J = 8.6 Hz), 8.68 (1H, s), 8.73 (1H, d, J = 7.7 Hz), 8.82 (1H, d, J = 9.1 Hz); 13C NMR (CDCl\textsubscript{3}, 99.45 MHz) δ 52.2, 123.1, 123.2, 126.3, 126.9, 127.6, 127.9, 128.4, 128.5, 128.7, 129.1, 129.3, 130.0, 130.5, 132.4, 133.7, 139.1, 140.0, 167.2, one carbon was obscured due to overlap with other peaks; LRMS m/z (EI): 312 (M\textsuperscript{+}, 30), 281 (40), 140 (20), 126 (100); HRMS m/z (EI): M\textsuperscript{+} calcd for C\textsubscript{22}H\textsubscript{16}O\textsubscript{2}, 312.1150; found 312.1158.

2-Nitro-10-phenylphenanthrene (4c). Isolated in 79% yield as a yellow solid (Mp. 178.0-179.0 ºC); Rf (SiO\textsubscript{2}, Hexane:EtOAc=10:1) = 0.39; 1H NMR (CDCl\textsubscript{3}, 395.75 MHz) δ 7.52-7.57 (5H, m), 7.74-7.76 (2H, m), 7.83 (1H, s), 7.94-7.97 (1H, m), 8.43 (1H, d, J = 9.7 Hz), 8.72-8.74 (1H, m), 8.34-8.88 (2H, m); 13C NMR (CDCl\textsubscript{3}, 67.80 MHz) δ 120.1, 122.9, 123.4, 124.4, 127.5, 128.1, 128.78, 128.83, 129.0, 129.6, 129.9, 130.8, 132.8, 134.6, 139.0, 139.2, 145.9, one carbon was obscured; LRMS m/z (EI): 299 (M\textsuperscript{+}, 48), 282 (8), 252 (91), 125 (100); HRMS m/z (EI): M\textsuperscript{+} calcd for C\textsubscript{20}H\textsubscript{13}N\textsubscript{2}O\textsubscript{2}, 299.0946; found 299.0939.

2-Trifluoromethyl-10-phenylphenanthrene (4d). Isolated in 95% yield as a white solid (Mp. 105.0-106.0 ºC); Rf (SiO\textsubscript{2}, Hexane) = 0.30; 1H NMR (CDCl\textsubscript{3}, 395.75 MHz) δ 7.49-7.62 (5H, m), 7.67-7.76 (2H, m), 7.79 (1H, s), 7.87 (1H, dm, J = 8.8 Hz), 7.92-7.96 (1H, m), 8.25 (1H, s), 8.71-8.75 (1H, m), 8.86 (1H, d, J = 8.8 Hz); 13C NMR (CDCl\textsubscript{3}, 67.80 MHz) δ 122.3 (q, J = 3.6 Hz), 122.9, 123.8, 124.2, (q, J = 4.4 Hz), 124.4 (q, J = 272.2 Hz), 127.1, 127.8, 127.9, 128.2, (q, J = 32.2 Hz), 128.6, 128.8, 128.9, 129.2, 129.9, 130.5, 132.2, 132.68-132.69 (m), 138.6, 139.7; LRMS m/z (EI): 322 (M\textsuperscript{+}, 100), 252 (42), 151 (48), 126 (85); HRMS m/z (EI): M\textsuperscript{+} calcd for C\textsubscript{23}H\textsubscript{13}F\textsubscript{3}, 322.0969; found 322.0956

1,3-Difluoro-10-phenylphenanthrene (4e). Isolated in 91% yield as a white solid (Mp. 172.0-173.0 ºC); Rf (SiO\textsubscript{2}, Hexane) = 0.38; 1H NMR (CDCl\textsubscript{3}, 395.75 MHz) δ 6.99-7.05 (1H, m), 7.42-7.47 (5H, m), 7.57 (1H, s), 7.65-7.71 (2H, m), 7.86-7.89 (1H, m), 8.22 (1H, dm, J = 10.6 Hz),
8.53-8.55 (1H, m); $^{13}$C NMR (CDCl$_3$, 67.80 MHz) $\delta$ 103.1 (t, $J = 26.9$ Hz), 104.3 (dd, $J = 21.8$, 4.5 Hz), 117.4 (dd, $J = 9.8$, 2.5 Hz), 123.0, 126.9, 127.1, 127.5, 128.1, 128.6, 128.66, 128.71, 129.3 (d, $J = 2.2$ Hz), 131.71 (d, $J = 1.1$ Hz), 133.8 (dd, $J = 9.8$, 4.8 Hz), 134.8, 142.8 (d, $J = 3.9$ Hz), 160.3 (dd, $J = 258.1$, 12.7 Hz), 160.7 (dd, $J = 246.9$, 13.6 Hz); LRMS $m/z$ (EI): 290 (M+, 100), 270 (26), 143 (48), 135 (73), 122 (24); HRMS $m/z$ (EI): M$^+$ calcd for C$_{20}$H$_{12}$F$_2$, 290.0907; found 290.0897.

9-Phenylphenanthrene (4f).$^5$ Isolated in 86% yield as a white solid (Mp. 84.0-85.0 °C); R$_f$ (SiO$_2$, Hexane) = 0.41; $^1$H NMR (CDCl$_3$, 270.05 MHz) $\delta$ 7.48-7.71 (10H, m), 7.90-7.97 (2H, m), 8.75 (1H, d, $J = 8.0$ Hz), 8.80 (1H, d, $J = 8.0$ Hz); $^{13}$C NMR (CDCl$_3$, 67.80 MHz) $\delta$ 122.5, 122.9, 126.4, 126.5, 126.6, 126.8, 126.9, 127.3, 127.5, 128.3, 128.6, 129.9, 130.1, 130.6, 131.1, 131.5, 138.7, 140.7; LRMS $m/z$ (EI): 254 (M+, 59), 126 (100), 113 (42), 100 (6).

2-Methoxy-10-phenylphenanthrene (4g)$^6$ and 9-benzylidene-2-methoxy-9$H$-fluorene (4g'). Isolated as a mixture of 4g and 4g' (yellow oil); R$_f$ (SiO$_2$, Hexane:EtOAc=20:1) = 0.26; $^1$H NMR (CDCl$_3$, 270.05 MHz) for 4g: $\delta$ 3.81 (3H, s), 7.19 (1H, dd, $J = 9.1$, 2.6 Hz), 7.30 (1H, d, $J = 2.7$ Hz), 7.34 (1H, s), 7.46-7.65 (6H, m), 7.69 (1H, s), 7.84-7.91 (1H, m), 8.63 (1H, d, $J = 8.2$ Hz), 8.69 (1H, d, $J = 8.7$ Hz); for 4g' (assignable peaks only): $\delta$ 4.04 (3H, s), 8.16 (1H, d, $J = 2.6$ Hz); $^{13}$C NMR (CDCl$_3$, 67.8 MHz) for 4g: $\delta$ 55.3, 107.80, 116.3, 122.0, 124.5, 124.9, 125.8, 126.7, 127.4, 128.1, 128.4, 128.6, 129.9, 130.0, 130.5, 132.5, 138.2, 140.9, 158.2, for 4g': $\delta$ 55.4, 104.2, 122.5, 125.2, 125.7, 126.1, 126.9, 127.3, 128.3, 128.5, 128.7, 129.98, 132.0, 132.1, 140.9, 158.22, three peaks were obscured due to overlap with other peaks.


ESI– 5
6-Cyano-4-(4-Tol)-1-tosyl-1,2-dihydroquinoline (2a).
4-Phenyl-1-tosyl-1,2-dihydroquinoline (2b).
6-Bromo-4-phenyl-1-tosyl-1,2-dihydroquinoline (2c).
8-Bromo-1-tosyl-4-p-tolyl-1,2-dihydroquinoline (2d).
6-Fluoro-4-phenyl-1-tosyl-1,2-dihydroquinoline (2e).
4-Phenyl-1-tosyl-1,2-dihydroquinoline-6-carboxylic acid methyl ester (2f).
6-Nitro-1-tosyl-4-p-tolyl-1,2-dihydroquinoline (2g).
5,7-Difluoro-4-phenyl-1-tosyl-1,2-dihydroquinoline (2h).
6-Methyl-4-phenyl-1-tosyl-1,2-dihydroquinoline (2i).
6-Methoxy-4-phenyl-1-tosyl-1,2-dihydroquinoline (2j).
8-Methoxy-4-phenyl-1-tosyl-1,2-dihydroquinoline (2k).
8-Isopropyl-4-phenyl-1-tosyl-1,2-dihydroquinoline (2l).
1-Tosyl-4-p-tolyl-1,2-dihydroquinoline (2s).
4-(4-Methoxymethylphenyl)-1-tosyl-1,2-dihydroquinoline (2t).
4-(4-anisyl)-1-tosyl-1,2-dihydroquinoline (2u).
4-(2-Anisyl)-1-tosyl-1,2-dihydroquinoline (2v).
4-(2,3,4-Trimethoxyphenyl)-1-tosyl-1,2-dihydroquinoline (2w).
2-Cyano-10-phenylphenanthrene (4a).
2-Methoxycarbonyl-10-phenylphenanthrene (4b).
2-Nitro-10-phenylphenanthrene (4c).
2-Trifluoromethyl-10-phenylphenanthrene (4d).
1,3-Difluoro-10-phenylphenanthrene (4e).
9-Phenylphenanthrene (4f).