Supporting Information

Ruthenium-catalyzed oxidative coupling of 2-aryl-4-quinazolinones with olefins: synthesis of pyrrolo[2,1-b]quinazolin-9(1H)-one motifs

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1. Experimental Section

1.1 General

$^1$H and $^{13}$C NMR spectra were recorded on a Bruker NMR spectrometer with CDCl$_3$ as the solvent and TMS as an internal standard. HRESIMS was measured on an Agilent G6224A TOF spectrometer. TLC was performed on precoated silica gel GF254 plates (Qingdao Marine Chemical Factory). Column chromatography was performed on silica gel (200–300 mesh, Qingdao Marine Chemical Factory). Petroleum was distilled prior to use.

1.2 General procedure for synthesis of 3a-3s:

1 (0.25 mmol), 2 (0.5 mmol), [RuCl$_2$(pcymene)]$_2$ (5 % mol), Cu(OAc)$_2$·H$_2$O (2.2 equiv) and DCE (2 ml) were added in a sealed tube. The reaction mixture was allowed to stir at 100°C for 10 h. After cooling at room temperature, the mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate) to afford the pure product.
2. Data Characterisation:

*Methyl 2-(10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3a).*

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.37 (ddd, $J = 7.9, 1.6, 0.7$ Hz, 1H), 8.19 (dt, $J = 7.1, 1.2$ Hz, 1H), 7.87 – 7.77 (m, 2H), 7.66 – 7.58 (m, 3H), 7.51 (ddd, $J = 8.2, 6.8, 1.6$ Hz, 1H), 5.89 (dd, $J = 7.9, 3.7$ Hz, 1H), 3.72 (dd, $J = 16.5, 3.8$ Hz, 1H), 3.69 (s, 3H), 3.01 (dd, $J = 16.5, 7.9$ Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.4, 160.8, 154.4, 151.5, 149.3, 143.3, 134.4, 132.7, 129.4, 127.4, 126.6, 126.5, 123.5, 123.2, 121.0, 58.5, 52.0, 35.8. HRMS (ESI): m/z [M+H]$^+$ calcld for C$_{18}$H$_{15}$N$_2$O$_3$, 307.1077; found: 307.1086.

*Methyl 2-(2-methyl-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3b).*

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.35 (ddd, $J = 8.0, 1.5, 0.7$ Hz, 1H), 8.05 (d, $J = 7.9$ Hz, 1H), 7.84 – 7.75 (m, 2H), 7.48 (ddd, $J = 8.1, 5.7, 2.6$ Hz, 1H), 7.14 (s, 1H), 7.11 (m, 1H), 5.82 (dd, $J = 7.9, 3.7$ Hz, 1H), 3.73-3.65 (dd, $J = 16.5, 3.8$ Hz, 1H), 3.69 (s, 3H), 3.00 (dd, $J = 16.6, 7.9$ Hz, 1H), 2.50 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.5, 160.7, 154.6, 149.2, 143.7, 143.7, 134.4, 130.5, 129.2, 127.2, 126.5, 126.3, 123.6, 123.3, 120.9, 58.4, 52.0, 35.8, 22.2. HRMS (ESI): m/z [M+H]$^+$ calcld for C$_{19}$H$_{17}$N$_2$O$_3$, 321.1234; found: 321.1228.

*Methyl 2-(2-methoxy-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3c).*

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.35 (dt, $J = 7.9, 1.0$ Hz, 1H), 8.09 (d, $J = 8.3$ Hz, 1H), 7.82 – 7.77 (m, 2H), 7.48 (ddd, $J = 8.1, 5.7, 2.6$ Hz, 1H), 7.14 (s, 1H), 7.11 (m, 1H), 5.83 (dd, $J = 8.2, 3.7$ Hz, 1H), 3.93 (s, 3H), 3.72 (dd, $J = 16.8, 3.7$ Hz, 1H), 3.71 (s, 3H), 2.95 (dd, $J = 16.6, 8.2$ Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.5, 163.6, 160.7, 154.3, 149.4, 145.7, 134.4, 130.5, 129.2, 127.2, 126.5, 126.3, 123.6, 123.3, 120.9, 58.4, 55.8, 52.0, 35.9. HRMS (ESI): m/z [M+H]$^+$ calcld for C$_{19}$H$_{17}$N$_2$O$_4$, 337.1183; found: 337.1184.

*Methyl 2-(2-(diethylamino)-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3d).*

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.31 (dt, $J = 7.9, 1.0$ Hz, 1H), 7.96 (d, $J = 8.8$ Hz, 1H), 7.78 – 7.71 (m, 2H), 7.40 (ddd, $J = 8.1, 5.8, 2.4$ Hz, 1H), 6.82 (ddd, $J = 8.8, 2.3$ Hz, 1H), 6.76 (d, $J = 2.3$ Hz, 1H), 5.77 (dd, $J = 8.3, 3.9$ Hz, 1H), 3.74 (dd, $J = 16.5, 3.8$ Hz, 1H), 3.73 (s, 3H), 3.46 (m, 4H), 2.83 (dd, $J = 16.3, 8.3$ Hz, 1H), 1.24 (t, $J = 7.1$ Hz, 6H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.9, 160.8, 151.1, 146.2, 143.2, 128.4, 126.6, 126.4, 125.3, 125.1, 120.2, 112.7, 111.2, 104.1, 58.2, 52.0, 44.9, 36.6, 12.4. HRMS (ESI): m/z [M+H]$^+$ calcld for C$_{22}$H$_{24}$N$_3$O$_3$, 378.1812; found: 378.1824.

*Methyl 2-(2-bromo-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3e).*

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.40 – 8.35 (m, 1H), 8.07 (d, $J = 8.2$ Hz, 1H), 7.87 – 7.82 (m, 3H), 7.78 – 7.74 (m, 1H), 7.54 (ddt, $J = 8.2, 6.5, 2.2$ Hz, 1H), 5.87 (dd, $J = 8.2, 3.5$ Hz, 1H), 3.73 (dd, $J = 16.5, 3.6$ Hz, 1H), 3.72 (s, 3H), 3.02 (dd, $J = 16.9, 8.1$ Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.2, 160.4, 153.7, 145.1, 135.0, 133.1, 129.2, 128.8, 127.2, 126.9, 126.8, 126.7, 126.4, 125.1, 120.8, 58.3, 52.2, 35.4. HRMS (ESI): m/z [M+Na]$^+$ calcld for C$_{18}$H$_{13}$BrN$_2$NaO$_3$, 407.0007; found: 400.0002.

*Methyl 2-(2-fluoro-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3f).*
**Methyl 2-(2-nitro-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3g).**

\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.57 \text{– 8.54 (m, 1H), 8.50 (dd, } J = 8.4, 2.0 \text{ Hz, 1H), 8.43 \text{– 8.36 (m, 2H), 7.94 \text{– 7.83 (m, 2H), 7.60 (ddd, } J = 8.4, 2.0, 1.6 \text{ Hz, 1H), 5.98 (dd, } J = 7.9, 3.4 \text{ Hz, 1H), 3.78 (dd, } J = 17.1, 3.5 \text{ Hz, 1H), 3.70 (s, 3H), 2.97 (dd, } J = 16.4, 8.0 \text{ Hz, 1H). } ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 169.9, 160.3, 152.3, 150.6, 148.5, 144.3, 137.6, 134.9, 127.8, 126.7, 125.1, 124.6, 121.0, 119.0, 58.6, 52.3, 35.0. } \text{HRMS (ESI): } m/z [M+Na]^+ \text{ calcd for C}_{18}H_{13}N_3NaO_5, 374.0747; \text{ found: 374.0751.} \]

**Methyl 2-(3-nitro-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3j).**

\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.38 \text{– 8.32 (m, 1H), 7.94 \text{– 7.89 (m, 1H), 7.87 \text{– 7.74 (m, 4H), 7.56 (ddd, } J = 8.2, 3.5 \text{ Hz, 1H), 3.72 (dd, } J = 16.9, 3.5 \text{ Hz, 1H). } ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.2, 165.8 \text{ (d, } J_{C-F} = 255 \text{ Hz), 160.4, 153.6, 145.9 (d, } J_{C-F} = 9.9 \text{ Hz), 135.1, 134.7, 129.6 (d, } J_{C-F} = 9.5 \text{ Hz), 127.9, 127.0, 126.8, 126.7, 116.3 (d, } J_{C-F} = 21.9 \text{ Hz), 111.1 (d, } J_{C-F} = 25.0 \text{ Hz), 58.5, 52.1, 35.4. } \text{HRMS (ESI): } m/z [M+H]^+ \text{ calcd for C}_{18}H_{13}FN_2O_3, 325.0983; \text{ found: 325.0997.} \]
Methyl 2-(4-fluoro-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3l).
\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.19 (d, J = 6.9 Hz, 1H), 7.80 (d, J = 8.9 Hz, 1H), 7.76 (d, J = 3.0 Hz, 1H), 7.63 (m, 3H), 7.42 (dd, J = 8.9, 3.0 Hz, 1H), 5.91 (dd, J = 7.9, 3.8 Hz, 1H), 3.97 (s, 3H), 3.71 (dd, J = 16.9, 3.8 Hz, 1H), 3.70 (s, 3H), 3.03 (dd, J = 16.5, 7.9 Hz, 1H).\]
\[ ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.4, 160.5, 158.4, 152.6, 142.9, 132.4, 129.5, 128.8, 124.6, 123.3, 123.2, 121.7, 106.2, 58.6, 55.9, 52.0, 35.8. HRMS (ESI): m/z [M+H]^+ calecd for C_{18}H_{17}N_{2}O_{5}, 337.1183; found: 337.1176.\]

Methyl 2-(6-methoxy-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3m).
\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.22 – 8.14 (m, 2H), 7.59 (m, 4H), 7.36 (t, J = 7.6 Hz, 1H), 5.84 (dd, J = 8.0, 3.7 Hz, 1H), 3.71 (dd, J = 16.6, 3.8 Hz, 1H), 3.67 (s, 3H), 2.96 (dd, J = 16.5, 8.0 Hz, 1H), 2.71 (s, 3H). \]
\[ ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.5, 161.1, 153.1, 147.9, 143.2, 136.1, 134.9, 132.4, 129.3, 126.0, 124.2, 123.5, 123.1, 120.9, 58.4, 51.9, 35.8, 17.5. HRMS (ESI): m/z [M+H]^+ calecd for C_{19}H_{18}N_{2}O_{5}, 321.1234; found: 321.1245.\]

Methyl 2-(7-chloro-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3o).
\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.28 (d, J = 8.5 Hz, 1H), 8.16 (dt, J = 7.4, 1.1 Hz, 1H), 7.82 (d, J = 2.0 Hz, 1H), 7.67 – 7.59 (m, 3H), 7.44 (dd, J = 8.5, 2.0 Hz, 1H), 5.86 (dd, J = 7.9, 3.7 Hz, 1H), 3.67 (dd, J = 16.4, 3.8 Hz, 1H), 3.66 (s, 3H), 3.02 (dd, J = 16.5, 7.8 Hz, 1H). \]
\[ ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.2, 160.2, 155.6, 150.3, 143.4, 140.6, 133.0, 131.7, 129.6, 128.0, 127.1, 127.0, 123.2, 119.5, 58.7, 52.0, 35.7. HRMS (ESI): m/z [M+H]^+ calecd for C_{18}H_{14}ClN_{2}O_{3}, 341.0687; found: 341.0680.\]

Methyl 2-(8-bromo-10-oxo-10,12-dihydroisoindolo[1,2-b]quinazolin-12-yl)acetate (3p).
\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.46 (d, J = 2.3 Hz, 1H), 8.14 (d, J = 7.4 Hz, 1H), 7.85 (dd, J = 8.7, 2.3 Hz, 1H), 7.68 (d, J = 8.7 Hz, 1H), 7.65 – 7.56 (m, 3H), 5.85 (dd, J = 7.8, 3.8 Hz, 1H), 3.66 (s, 3H), 3.65 (dd, J = 16.5, 3.8 Hz, 1H), 3.02 (dd, J = 16.5, 7.8 Hz, 1H). \]
\[ ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.2, 159.5, 154.8, 148.1, 143.3, 137.5, 132.9, 131.7, 129.5, 129.2, 123.6, 122.4, 120.0, 58.7, 52.0, 35.6. HRMS (ESI): m/z [M+H]^+ calecd for C_{18}H_{14}BrN_{2}O_{3}, 407.0002; found: 407.0005.\]

\[ ^1H \text{NMR (400 MHz, CDCl}_3 \delta 8.37 – 8.33 (m, 1H), 7.82 – 7.77 (m, 2H), 7.76 (d, J = 4.9 Hz, 1H), 7.54 – 7.48 (m, 1H), 7.24 (d, J = 4.9 Hz, 1H), 5.77 (dd, J = 9.8, 3.9 Hz, 1H), 3.98 (dd, J = 16.6, 3.9 Hz, 1H), 3.77 (s, 3H), 2.65 (dd, J = 16.6, 9.8 Hz, 1H). \]
\[ ^{13}C \text{NMR (100 MHz, CDCl}_3 \delta 170.5, \text{ etc.}\]

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160.5, 153.4, 151.3, 136.3, 134.5, 131.3, 128.4, 127.0, 126.6, 126.5, 122.4, 120.1, 57.5, 52.1, 35.1. HRMS (ESI): m/z [M+H]^+ caleed for C_{10}H_{13}N_{2}O_{3}S, 313.0641; found: 313.0649.

(E)-2-(3-(2-(phenylsulfonyl)vinyl)thiophen-2-yl)quinazolin-4(3H)-one (3s).

1^H NMR (400 MHz, CDCl_3) δ 8.62 (d, J = 15.5 Hz, 1H), 8.35 – 8.27 (m, 1H), 8.02 – 7.92 (m, 2H), 7.92 – 7.82 (m, 2H), 7.65 – 7.47 (m, 6H), 7.37 (d, J = 5.2 Hz, 1H), 6.89 (d, J = 15.4 Hz, 1H). 13C NMR (100 MHz, CDCl_3) δ 162.8, 148.6, 146.2, 140.5, 136.5, 135.8, 135.4, 135.3, 133.4, 130.0, 129.3, 128.5, 128.2, 128.1, 127.8, 127.7, 127.6, 126.5, 77.3. HRMS (ESI): m/z [M+Na]^+ caleed for C_{20}H_{18}N_{2}Na_{2}O_{3}, 417.0344; found: 417.0345.

Methyl 2-(6-oxo-4,6-dihydrofuro[2',3':2,1]pyrrolo[2,1-b]quinazolin-4-yl)acetate (3t).

1^H NMR (400 MHz, CDCl_3) δ 9.77 (br s, 1H, NH), 8.85 (d, J = 16.2 Hz, 1H), 8.31 (dd, J = 7.9, 1.5 Hz, 1H), 7.95 – 7.70 (m, 2H), 7.60 (d, J = 2.1 Hz, 1H), 7.55 – 7.49 (m, 1H), 6.87 (d, J = 2.1 Hz, 1H), 6.42 (d, J = 16.2 Hz, 1H), 3.88 (s, 3H). 13C NMR (100 MHz, CDCl_3) δ 167.0, 161.2, 148.8, 144.5, 143.2, 143.1, 134.9, 128.2, 127.3, 126.6, 125.7, 121.7, 119.4, 111.0, 51.9. HRMS (ESI): m/z [M+Na]^+ caleed for C_{16}H_{13}N_{2}Na_{2}O_{4}, 319.0689; found: 319.0689.


1^H NMR (400 MHz, CDCl_3) δ 10.11 (br s, 1H, NH), 8.76 (d, J = 16.2 Hz, 1H), 8.45 – 8.16 (m, 1H), 8.00 – 7.72 (m, 2H), 7.66 – 7.54 (m, 1H), 7.50 (m, 1H), 6.85 (d, J = 1.9 Hz, 1H), 6.33 (d, J = 16.1 Hz, 1H), 1.60 (s, 9H). 13C NMR (100 MHz, CDCl_3) δ 165.8, 161.5, 148.9, 144.4, 143.4, 143.0, 134.9, 133.9, 128.1, 127.2, 126.5, 126.0, 124.1, 121.2, 110.9, 80.7, 28.2. HRMS (ESI): m/z [M+Na]^+ caleed for C_{16}H_{18}N_{2}Na_{2}O_{4}, 361.1156; found: 361.1156.

(E)-2-(3-(2-(phenylsulfonyl)furan-2-yl)quinazolin-4(3H)-one (3v).

1^H NMR (400 MHz, CDCl_3) δ 9.54 (br s, 1H, NH), 8.88 (d, J = 15.6 Hz, 1H), 8.41 – 8.26 (m, 1H), 8.04 (dd, J = 8.4, 1.4 Hz, 2H), 7.89 – 7.81 (m, 2H), 7.72 – 7.65 (m, 1H), 7.64 – 7.58 (m, 3H), 7.56 (dd, J = 8.0, 2.7 Hz, 1H), 6.93 (d, J = 15.6 Hz, 1H), 6.77 (d, J = 1.9 Hz, 1H). 13C NMR (100 MHz, CDCl_3) δ 161.0, 148.6, 144.6, 144.1, 142.8, 140.4, 135.1, 133.6, 132.9, 131.1, 129.4, 128.4, 128.0, 127.6, 126.6, 123.5, 111.2. HRMS (ESI): m/z [M+Na]^+ caleed for C_{20}H_{18}N_{2}Na_{2}O_{4}, 401.0566; found: 401.0568.

1,1'-2-(4-Oxo-3,4-dihydroquinazolin-2-yl)-1,3-phenylene)bis(pentan-3-one) (5a).

1^H NMR (400 MHz, CDCl_3) δ 11.14 (br s, 1H, NH), 8.31 (dd, J = 8.1, 1.5 Hz, 1H), 7.80 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.73 (dd, J = 8.3, 1.4 Hz, 1H), 7.53 (td, J = 7.5, 6.9, 1.3 Hz, 1H), 7.34 (t, J = 7.7 Hz, 1H), 7.15 (d, J = 7.7 Hz, 2H), 2.95 – 2.64 (m, 8H), 2.32 (q, J = 7.0 Hz, 4H), 0.95 (t, J = 7.3 Hz, 6H). 13C NMR (100 MHz, CDCl_3) δ 210.9, 189.8, 162.2, 153.2, 148.6, 139.7, 134.7, 133.7, 133.0, 127.5, 127.2, 126.8, 126.6, 121.2, 43.1, 40.3, 36.0, 26.9, 7.7. HRMS (ESI): m/z [M+Na]^+ caleed for C_{20}H_{20}N_{2}Na_{2}O_{5}, 413.1836; found: 413.1848.

1,1'-2-(4-Oxo-3-(3-oxopentyl)-3,4-dihydroquinazolin-2-yl)-1,3-phenylene)bis(pentan-3-one) (5a').

1^H NMR (400 MHz, CDCl_3) δ 8.34 (dd, J = 8.1, 1.5 Hz, 1H), 7.78 (dd, J = 8.4, 7.1, 1.5 Hz, 1H), 7.69 – 7.65 (m, 1H), 7.55 (ddd, J = 8.0, 7.1, 1.2 Hz, 1H), 7.37 (t, J = 7.7 Hz, 1H), 7.18 (d, J = 7.7 Hz, 2H), 4.07 – 3.98 (m, 2H), 2.80 (m, 6H), 2.74 – 2.62 (m, 2H), 2.58 – 2.46 (m, 2H), 2.42 – 2.26
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(1H, 6H), 0.97 (t, J = 7.3 Hz, 3H), 0.96 (t, J = 7.3 Hz, 3H). 13C NMR (100 MHz, CDCl3) δ 209.9, 208.3, 161.9, 154.4, 146.8, 138.7, 134.6, 133.7, 130.3, 127.4, 127.3, 127.0, 126.9, 120.9, 42.8, 41.2, 39.9, 35.9, 35.9, 30.3, 29.7, 27.4, 14.2, 7.7, 7.6. HRMS (ESI): m/z [M+Na]+ calsd for C29H34N2NaO4, 497.2411; found: 497.2426.

2-(3-(3-Oxopentyl)thiophen-2-yl)quinazolin-4(3H)-one (5o).

1H NMR (400 MHz, CDCl3) δ 12.12 (br s, 1H, NH), 8.32 (d, J = 8.0 Hz, 1H), 7.74 (dd, J = 3.9, 1.5 Hz, 2H), 7.50 – 7.41 (m, 2H), 6.94 (d, J = 5.1 Hz, 1H), 3.11 (dd, J = 6.9, 5.0 Hz, 2H), 3.03 (dd, J = 6.9, 5.1 Hz, 2H), 2.48 (q, J = 7.4 Hz, 2H), 1.06 (t, J = 7.3 Hz, 3H). 13C NMR (100 MHz, CDCl3) δ 213.2, 162.5, 149.3, 148.4, 141.4, 134.5, 131.8, 129.3, 129.0, 127.5, 126.6, 121.0, 42.1, 36.1, 22.9, 7.8. HRMS (ESI): m/z [M+Na]+ calsd for C17H16N2O2S, 335.0825; found: 335.0825.
$^1$H and $^{13}$C NMR spectra of 3a:
$^1$H and $^{13}$C NMR spectra of 3b:
$^1$H and $^{13}$C NMR spectra of 3c:
$^1$H and $^{13}$C NMR spectra of 3d:
$^1$H and $^{13}$C NMR spectra of 3e:
$^1$H and $^{13}$C NMR spectra of 3f:
$^1$H and $^{13}$C NMR spectra of $3g$: 
$^1$H and $^{13}$C NMR spectra of 3h:
$^1$H and $^{13}$C NMR spectra of 3i:
$^1$H and $^{13}$C NMR spectra of 3j:
$^1$H and $^{13}$C NMR spectra of 3k:
$^1$H and $^{13}$C NMR spectra of 3l:
$^1$H and $^{13}$C NMR spectra of 3m:
$^1$H and $^{13}$C NMR spectra of 3n:
$^1$H and $^{13}$C NMR spectra of 3o:
$^1$H and $^{13}$C NMR spectra of 3p:
$^1$H and $^{13}$C NMR spectra of 3r:
$^1$H and $^{13}$C NMR spectra of 3s:
$^1$H and $^{13}$C NMR spectra of 3t:
$^1$H and $^{13}$C NMR spectra of 3u:
$^1$H and $^{13}$C NMR spectra of 3r:
$^1$H and $^{13}$C NMR spectra of 5a:
$^1$H and $^{13}$C NMR spectra of 5a':
$^1$H and $^{13}$C NMR spectra of 5o: