Access to 6*H*-Naphtho[2,3-*c*]chromenes by A Palladium-Catalyzed Reaction of 2-Bromoaryl allene with 2-Alkynylphenol

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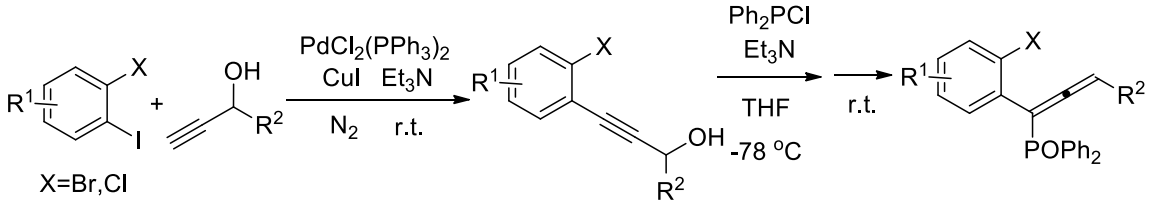
Supporting Information

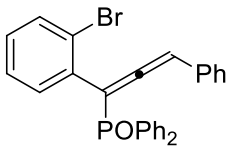
General experimental methods:

Unless otherwise stated, all commercial reagents were used as received. All solvents were dried and distilled according to standard procedures. Flash column chromatography was performed using silica gel (60-Å pore size, 32–63μm, standard grade). Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light. Organic solutions were concentrated on rotary evaporators at ~20 Torr at 25–35°C. Nuclear magnetic resonance (NMR) spectra are recorded in parts per million from internal tetramethylsilane on the δ scale. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker DRX-400 spectrometer operating at 400 MHz and 100 MHz, respectively. All chemical shift values are quoted in ppm and coupling constants quoted in Hz. High resolution mass spectrometry (HRMS) spectra were obtained on a micrOTOF II Instrument.

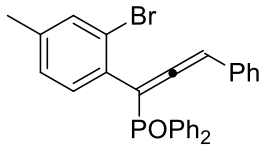
General Procedure for the Synthesis of 2-haloaryl allene 1[12]**:**



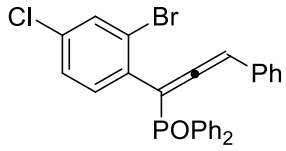
Substituted propargylic alcohols were afforded via typical Sonogashira coupling reaction. Ph_2PCl (2.7 mL, d = 1.229 g/mL, 3.3 g, 15.0 mmol) was added dropwisely to a solution of the above propargylic alcohol (10.0 mmol) and Et_3N (2.1 mL, d = 0.726 g/mL, 1.5 g, 15.1 mmol) in THF (30 mL) at -78 °C. After the addition, the reaction mixture was allowed to stir at room temperature for about 4 hours. After complete conversion of propargylic alcohol as indicated by TLC, the mixture was filtered. Evaporation of the solvent followed by purification on silica gel provided 2-bromoaryl allene **1**.



(1-(2-Bromophenyl)-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**1a**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90-7.77 (m, 5H), 7.50 (d, J = 7.9 Hz, 1H), 7.38-7.29 (m, 6H), 7.21-7.16 (m, 6H), 7.03-7.01 (m, 1H), 6.27 (d, J = 10.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.7 (d, J_{PC} = 4.7 Hz), 133.2, 132.5 (d, J_{PC} = 6.5 Hz), 132.1, 131.8, 131.7, 131.7, 131.6, 131.5, 131.2 (d, J_{PC} = 9.9 Hz), 130.6, 129.1, 128.3, 128.2, 128.1, 127.9, 127.7, 127.4, 127.3, 123.8 (d, J_{PC} = 5.7 Hz), 103.9 (d, J_{PC} = 98.7 Hz), 97.7 (d, J_{PC} = 12.9 Hz). HRMS (ESI) calcd for $C_{27}H_{20}BrOPNa^{+}$: 493.0327 (M + Na^{+}), found: 493.0322.

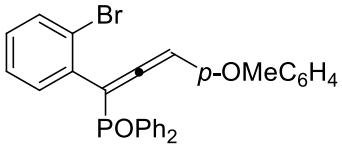


(1-(2-Bromo-4-methylphenyl)-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**1b**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89-7.77 (m, 5H), 7.40-7.29 (m, 7H), 7.22-7.12 (m, 5H), 7.02 (d, J = 7.6 Hz, 1H), 6.25 (d, J = 10.8 Hz, 1H), 2.19 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.7 (d, J_{PC} = 5.2 Hz), 139.5, 133.7, 131.8, 131.7, 131.6, 131.6 (d, J_{PC} = 106.9 Hz), 131.5, 131.0, 129.3 (d, J_{PC} = 6.5 Hz), 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.6, 127.4, 123.5 (d, J_{PC} = 5.9 Hz), 103.6 (d, J_{PC} = 99.2 Hz), 97.5 (d, J_{PC} = 13.0 Hz), 20.5. HRMS (ESI) calcd for $C_{28}H_{22}BrOPNa^{+}$: 507.0484 (M + Na^{+}), found: 507.0491.

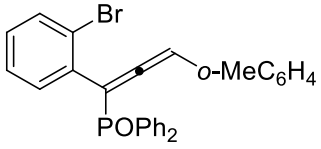


(1-(2-Bromo-4-chlorophenyl)-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**1c**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89-7.76 (m, 5H), 7.54-7.53 (m, 1H), 7.43-7.32 (m, 6H), 7.23-7.18 (m, 4H), 7.11 (d, J = 7.4 Hz, 2H), 6.29 (d, J = 10.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.8 (d, J_{PC} = 4.9 Hz), 134.3, 132.9, 132.0 (d, J_{PC} = 9.3 Hz), 131.6, 131.6, 131.5, 131.1 (d, J_{PC} = 6.7 Hz), 130.8 (d, J_{PC} = 105.7 Hz), 130.6 (d, J_{PC} = 5.5 Hz), 128.4, 128.3, 128.2 (d, J_{PC} = 1.8 Hz), 128.1, 127.9, 127.7, 127.5, 124.2

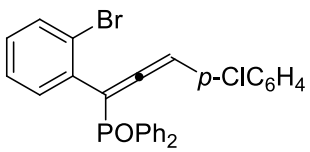
(d, J_{PC} = 5.7 Hz), 103.1 (d, J_{PC} = 98.8 Hz), 98.0 (d, J_{PC} = 12.9 Hz). HRMS (ESI) calcd for $C_{27}H_{19}BrClOPNa^+$: 526.9938 (M + Na^+), found: 526.9929.



(1-(2-Bromophenyl)-3-(4-methoxyphenyl)propa-1,2-dien-1-yl)diphenylphosphine oxide (**1d**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89-7.77 (m, 5H), 7.52 (d, *J* = 7.6 Hz, 1H), 7.40-7.32 (m, 6H), 7.21 (m, 1H), 7.08-7.04 (m, 3H), 6.77 (d, *J* = 8.6 Hz, 2H), 6.25 (d, *J* = 10.6 Hz, 1H), 3.75 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 213.0 (d, J_{PC} = 4.5 Hz), 159.3, 133.2, 132.8 (d, J_{PC} = 6.9 Hz), 132.0, 131.8, 131.8 (d, J_{PC} = 106.0 Hz), 131.7 (d, J_{PC} = 9.0 Hz), 131.6, 131.0, 129.1, 128.8, 128.2, 128.1 (d, J_{PC} = 4.3 Hz), 128.0, 127.4, 123.8 (d, J_{PC} = 5.7 Hz), 123.1 (d, J_{PC} = 6.4 Hz), 113.9, 103.9 (d, J_{PC} = 99.7 Hz), 97.3 (d, J_{PC} = 13.0 Hz), 55.1. HRMS (ESI) calcd for $C_{28}H_{22}BrO_2PNa^+$: 523.0433 (M + Na^+), found: 523.0429.

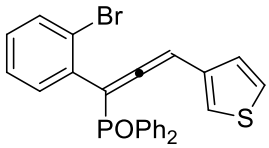


(1-(2-Bromophenyl)-3-(*o*-tolyl)propa-1,2-dien-1-yl)diphenylphosphine oxide (**1e**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88-7.76 (m, 5H), 7.48 (m, 1H), 7.35-7.29 (m, 6H), 7.18-7.16 (m, 2H), 7.06-7.00 (m, 4H), 6.47 (d, *J* = 10.6 Hz, 1H), 2.08 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.7 (d, J_{PC} = 4.8 Hz), 135.0, 133.1, 132.5 (d, J_{PC} = 6.5 Hz), 131.7, 131.5, 131.5, 131.4 (d, J_{PC} = 106.7 Hz), 130.8, 130.7, 130.1, 129.4 (d, J_{PC} = 6.1 Hz), 129.0, 128.0 (d, J_{PC} = 12.9 Hz), 127.8, 127.5, 127.2, 125.8, 123.9 (d, J_{PC} = 5.6 Hz), 102.8 (d, J_{PC} = 99.3 Hz), 95.1 (d, J_{PC} = 12.8 Hz), 19.5. HRMS (ESI) calcd for $C_{28}H_{22}BrOPNa^+$: 507.0484 (M + Na^+), found: 507.0487.

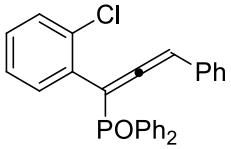


(1-(2-Bromophenyl)-3-(4-chlorophenyl)propa-1,2-dien-1-yl)diphenylphosphine oxide (**1f**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89-7.74 (m, 5H), 7.53-7.52 (m, 1H), 7.37-7.33 (m, 6H), 7.21-7.18 (m, 3H), 7.06-7.04 (m, 3H), 6.23 (d, *J* = 10.4 Hz, 1H). ^{13}C NMR

(100 MHz, $CDCl_3$): δ 212.6, 133.4, 133.3, 132.3 (d, J_{PC} = 6.3 Hz), 132.0 (d, J_{PC} = 9.0 Hz), 131.7, 131.6, 131.5, 131.5 (d, J_{PC} = 103.6 Hz), 130.6, 129.6 (d, J_{PC} = 6.5 Hz), 129.3, 128.6, 128.3, 128.2, 128.1, 127.5, 123.8 (d, J_{PC} = 5.7 Hz), 104.4 (d, J_{PC} = 97.1 Hz), 96.8 (d, J_{PC} = 12.8 Hz). HRMS (ESI) calcd for $C_{27}H_{19}BrClOPNa^+$: 526.9938 (M + Na^+), found: 526.9964.

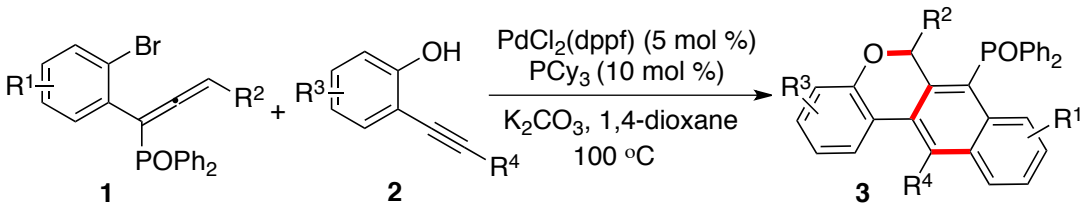


(1-(2-Bromophenyl)-3-(thiophen-3-yl)propa-1,2-dien-1-yl)diphenylphosphine oxide (**1g**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87-7.76 (m, 5H), 7.49 (d, *J* = 8.0 Hz, 1H), 7.36-7.30 (m, 6H), 7.18-7.16 (m, 2H), 7.02-6.96 (m, 3H), 6.34 (d, *J* = 10.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 213.2 (d, J_{PC} = 4.6 Hz), 133.1, 132.5 (d, J_{PC} = 6.7 Hz), 131.7 (d, J_{PC} = 8.6 Hz), 131.6 (d, J_{PC} = 105.7 Hz), 131.5, 131.4, 131.3, 131.2, 130.8, 130.7, 129.4, 128.0 (d, J_{PC} = 4.3 Hz), 127.9 (d, J_{PC} = 4.3 Hz), 127.2, 126.5, 125.7, 123.7 (d, J_{PC} = 5.7 Hz), 122.7, 103.1 (d, J_{PC} = 98.7 Hz), 92.0 (d, J_{PC} = 13.0 Hz). HRMS (ESI) calcd for $C_{25}H_{18}BrOPSNa^+$: 498.9892 (M + Na^+), found: 498.9876.

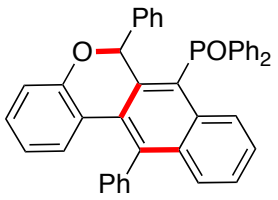


(1-(2-Chlorophenyl)-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**1h**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.93-7.77 (m, 5H), 7.33-7.29 (m, 7H), 7.23-7.19 (m, 2H), 7.16-7.08 (m, 5H), 6.24 (d, *J* = 10.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.9, 133.3 (d, J_{PC} = 5.7 Hz), 131.7, 131.6 (d, J_{PC} = 105.8 Hz), 131.5, 131.4, 131.3, 130.8, 130.7, 130.6 (d, J_{PC} = 6.5 Hz), 129.8, 128.8, 128.3, 128.0 (d, J_{PC} = 5.7 Hz), 127.9, 127.2, 126.7, 101.7 (d, J_{PC} = 98.5 Hz), 97.1 (d, J_{PC} = 13.0 Hz). HRMS (ESI) calcd for $C_{27}H_{20}ClOPNa^+$: 449.0833 (M + Na^+), found: 449.0832.

*General experimental procedure for the synthesis of phosphonated naphtho[2,3-c]chromenes by a palladium-catalyzed reaction of 2-bromoaryl allene **1** with 2-alkynylphenol **2**:*



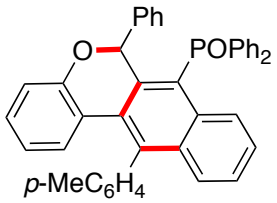
2-Bromoaryl allene **1** (0.44 mmol) was added to a mixture of $PdCl_2(dppf)$ (5 mol %), PCy_3 (10 mol %), K_2CO_3 (0.80 mmol), and 2-alkynylphenol (0.40 mmol) in 1,4-dioxane (4.0 mL). The mixture was stirred at 100 °C for 12-16hrs. After completion of the reaction as indicated by TLC, the reaction was cooled and the solvent was diluted by EtOAc (10 mL). The mixture was washed with saturated brine (2 × 10 mL), and dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification on silica gel provides the phosphonated naphtho[2,3-*c*]chromene **3**.



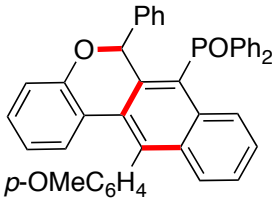
(6,12-Diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3a**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.22 (d, *J* = 8.7 Hz, 1H), 7.90 (s, 1H), 7.69-7.61 (m, 7H), 7.48-7.40 (m, 3H), 7.35-7.26 (m, 6H), 7.15 (t, *J* = 7.4 Hz, 1H), 7.04-6.98 (m, 6H), 6.85 (t, *J* = 7.2 Hz, 1H), 6.74 (d, *J* = 7.5 Hz, 1H), 6.59 (d, *J* = 7.3 Hz, 1H), 6.34 (t, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.4, 143.5 (d, J_{PC} = 7.8 Hz), 141.5, 139.5, 139.0, 134.7 (d, J_{PC} = 103.2 Hz), 134.5 (d, J_{PC} = 102.6 Hz), 133.5 (d, J_{PC} = 9.0 Hz), 132.8 (d, J_{PC} = 9.5 Hz), 131.9, 131.8, 131.6, 131.5, 129.7, 129.5, 129.1, 128.8, 128.6, 128.5, 128.4, 128.1, 128.0, 127.8, 127.7, 127.3, 127.3, 125.9, 125.8, 123.9, 123.8 (d, J_{PC} = 95.7 Hz), 120.6, 118.2, 76.1 (d, J_{PC} = 4.4 Hz). HRMS (ESI) calcd for $C_{41}H_{30}O_2P^+$: 585.1978 ($M + H^+$), found: 585.1988.

Crystallographic data for the structure **3a** has been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC-977123. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [fax.: (internat.) + 44 1223/336-033; e-mail:

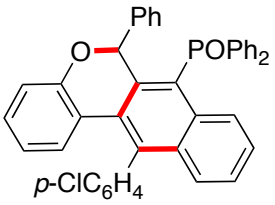
deposit@ccdc.cam.ac.uk].



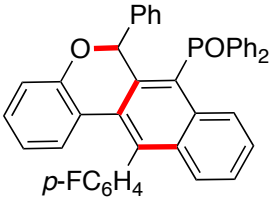
Diphenyl(6-phenyl-12-(*p*-tolyl)-6*H*-naphtho[2,3-*c*]chromen-7-yl)phosphine oxide (**3b**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.20 (d, J = 8.4 Hz, 1H), 7.88 (s, 1H), 7.68-7.54 (m, 6H), 7.40-7.38 (m, 3H), 7.31-7.23 (m, 5H), 7.13-7.12 (m, 2H), 7.03 (m, 2H), 6.95 (m, 3H), 6.87-6.81 (m, 2H), 6.73 (d, J = 7.6 Hz, 1H), 6.66 (d, J = 7.6 Hz, 1H), 6.34 (t, J = 7.1 Hz, 1H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.2, 143.4 (d, J_{PC} = 7.8 Hz), 141.7, 138.8, 137.3, 136.3, 134.4 (d, J_{PC} = 103.3 Hz), 134.1 (d, J_{PC} = 103.1 Hz), 133.5, 132.7 (d, J_{PC} = 9.5 Hz), 131.8, 131.7, 131.5, 131.4, 130.0, 129.4, 129.1, 128.8, 128.6, 128.5, 128.5, 128.4, 128.3, 127.9 (d, J_{PC} = 6.4 Hz), 127.7, 127.2, 127.2, 125.7 (d, J_{PC} = 10.0 Hz), 123.9, 123.2 (d, J_{PC} = 96.5 Hz), 120.5, 118.1, 76.0 (d, J_{PC} = 3.8 Hz), 21.2. HRMS (ESI) calcd for $C_{42}H_{32}O_2P^+$: 599.2134 (M + H^+), found: 599.2148.



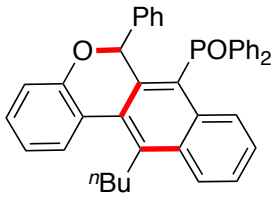
11-(4-Chlorophenyl)-5-methyl-6-phenyl-5*H*-indeno[1,2-*c*]quinoline (**3c**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.19 (d, J = 8.6 Hz, 1H), 7.92 (s, 1H), 7.73-7.55 (m, 6H), 7.40-7.37 (m, 2H), 7.33-7.22 (m, 5H), 7.14-7.09 (m, 2H), 7.03 (m, 2H), 6.90-6.81 (m, 3H), 6.73 (d, J = 7.8 Hz, 1H), 6.67 (d, J = 7.8 Hz, 1H), 6.37 (t, J = 7.4 Hz, 1H), 3.82 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 154.3, 143.5 (d, J_{PC} = 7.7 Hz), 141.3, 138.9, 134.5 (d, J_{PC} = 103.2 Hz), 134.2 (d, J_{PC} = 103.0 Hz), 133.8, 132.7, 132.6, 131.7, 131.6, 131.5, 131.4, 130.8, 129.0, 128.6, 128.4, 128.4, 128.3, 127.9, 127.8, 127.6, 127.2, 127.1, 125.7 (d, J_{PC} = 13.6 Hz), 124.0, 123.2 (d, J_{PC} = 96.1 Hz), 120.6, 118.1, 114.5, 113.9, 76.0 (d, J_{PC} = 3.9 Hz), 55.1. HRMS (ESI) calcd for $C_{42}H_{32}O_3P^+$: 615.2084 (M + H^+), found: 615.2091.



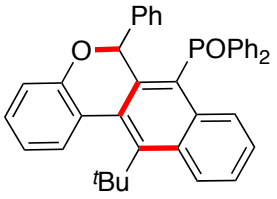
(12-(4-Chlorophenyl)-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3d**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.24 (d, J = 8.9 Hz, 1H), 7.89 (s, 1H), 7.65-7.60 (m, 6H), 7.43-7.26 (m, 9H), 7.15 (t, J = 8.0 Hz, 1H), 7.02-6.92 (m, 6H), 6.87 (t, J = 7.6 Hz, 1H), 6.75 (d, J = 8.0 Hz, 1H), 6.61 (d, J = 8.0 Hz, 1H), 6.40 (t, J = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.5, 143.5 (d, J_{PC} = 7.8 Hz), 140.0, 138.8, 137.9, 134.5 (d, J_{PC} = 103.3 Hz), 134.2 (d, J_{PC} = 102.6 Hz), 133.8, 133.2, 133.1, 132.7 (d, J_{PC} = 9.4 Hz), 131.8, 131.7, 131.7, 131.6, 131.3, 129.7, 129.0, 128.6, 128.5, 128.4, 128.2, 128.1, 127.8 (d, J_{PC} = 11.6 Hz), 126.0 (d, J_{PC} = 23.9 Hz), 124.1 (d, J_{PC} = 100.1 Hz), 120.8, 118.4, 76.1 (d, J_{PC} = 4.3 Hz). HRMS (ESI) calcd for $C_{41}H_{29}ClO_2P^+$: 619.1588 ($M + H^+$), found: 619.1601.



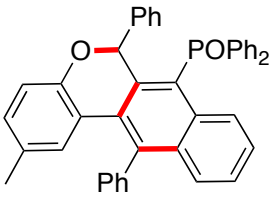
(12-(4-Fluorophenyl)-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3e**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.24 (d, J = 8.7 Hz, 1H), 7.93 (s, 1H), 7.69-7.60 (m, 6H), 7.41-7.39 (m, 2H), 7.33-7.25 (m, 6H), 7.14 (t, J = 7.8 Hz, 1H), 7.03-7.02 (m, 3H), 6.96-6.95 (m, 4H), 6.84 (t, J = 7.3 Hz, 1H), 6.74 (d, J = 7.8 Hz, 1H), 6.58 (d, J = 7.7 Hz, 1H), 6.37 (t, J = 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.3 (d, J_{CF} = 246.4 Hz), 154.4, 143.5 (d, J_{PC} = 7.7 Hz), 140.2, 138.8, 135.3, 135.1 (d, J_{PC} = 103.1 Hz), 134.2 (d, J_{PC} = 102.7 Hz), 133.4, 133.2 (d, J_{CF} = 7.5 Hz), 132.7 (d, J_{PC} = 9.4 Hz), 131.7, 131.6, 131.6, 131.5, 131.4, 128.9, 128.9, 128.5, 128.4, 128.3, 128.1, 128.0, 127.9, 127.2, 125.9 (d, J_{PC} = 22.5 Hz), 124.0 (d, J_{PC} = 95.4 Hz), 123.7, 120.6, 118.3, 116.4 (d, J_{CF} = 21.1 Hz), 115.3 (d, J_{CF} = 21.4 Hz), 76.1 (d, J_{PC} = 4.3 Hz). HRMS (ESI) calcd for $C_{41}H_{29}FO_2P^+$: 603.1884 ($M + H^+$), found: 603.1892.



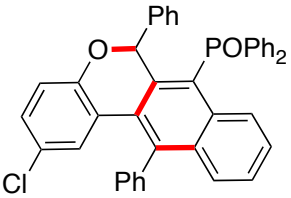
(12-Butyl-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3f**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.23 (d, *J* = 8.5 Hz, 1H), 8.18 (d, *J* = 8.6 Hz, 1H), 7.83 (s, 1H), 7.62-7.54 (m, 5H), 7.45 (t, *J* = 7.4 Hz, 1H), 7.39-7.35 (m, 2H), 7.31-7.23 (m, 4H), 7.15 (t, *J* = 7.8 Hz, 1H), 7.06 (t, *J* = 7.6 Hz, 1H), 6.97-6.91 (m, 6H), 6.85 (d, *J* = 7.8 Hz, 1H), 3.46-3.34 (m, 2H), 1.58-1.57 (m, 2H), 1.26 (m, 2H), 1.02 (t, *J* = 7.0 Hz, 1H) .^{13}C NMR (100 MHz, $CDCl_3$): δ 154.7, 144.3 (d, J_{PC} = 7.7 Hz), 141.2, 138.8, 134.7 (d, J_{PC} = 103.4 Hz), 134.2 (d, J_{PC} = 102.7 Hz), 133.1 (d, J_{PC} = 9.0 Hz), 132.7 (d, J_{PC} = 9.4 Hz), 131.7, 131.6, 131.4, 129.1, 128.5, 128.5, 128.4, 128.3, 128.2, 127.2, 125.9, 125.5, 125.4, 124.8, 122.0, 121.1, 118.7, 76.5 (d, J_{PC} = 4.2 Hz), 33.9, 30.5, 22.8, 13.7. HRMS (ESI) calcd for $C_{39}H_{34}O_2P^+$: 565.2291 ($M + H^+$), found: 565.2302.



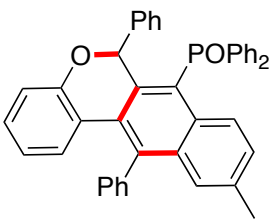
(12-(*tert*-Butyl)-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3g**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (d, *J* = 8.7 Hz, 1H), 8.16 (s, 1H), 7.71 (d, *J* = 8.6 Hz, 1H), 7.50-7.46 (m, 2H), 7.43-7.38 (m, 2H), 7.34-7.28 (m, 4H), 7.24-7.17 (m, 4H), 7.02 (t, *J* = 7.2 Hz, 1H), 6.95 (t, *J* = 7.7 Hz, 1H), 6.87 (t, *J* = 7.4 Hz, 1H), 6.77-6.76 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.0, 148.0 (d, J_{PC} = 6.7 Hz), 138.9, 136.0 (d, J_{PC} = 105.0 Hz), 134.9 (d, J_{PC} = 8.6 Hz), 132.7 (d, J_{PC} = 9.1 Hz), 132.4 (d, J_{PC} = 102.6 Hz), 131.8 (d, J_{PC} = 10.1 Hz), 131.3, 131.1, 131.0, 130.9, 129.3, 128.9, 128.6, 128.3, 128.1 (d, J_{PC} = 7.2 Hz), 128.0, 127.9, 127.8, 127.2, 127.0, 126.5, 123.7 (d, J_{PC} = 25.3 Hz), 121.2, 119.1 (d, J_{PC} = 98.9 Hz), 118.9, 75.6, 38.8, 34.8. HRMS (ESI) calcd for $C_{39}H_{34}O_2P^+$: 565.2291 ($M + H^+$), found: 565.2304.



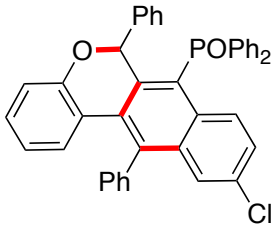
(2-Methyl-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3h**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.26 (d, J = 8.7 Hz, 1H), 7.81 (s, 1H), 7.73-7.60 (m, 7H), 7.48-7.26 (m, 10H), 7.18-7.14 (m, 1H), 7.01-6.99 (m, 5H), 6.68-6.61 (m, 2H), 6.28 (s, 1H), 1.73 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.1, 143.3 (d, J_{PC} = 7.9 Hz), 141.4 (d, J_{PC} = 2.7 Hz), 139.7, 139.2, 134.8 (d, J_{PC} = 102.9 Hz), 134.6 (d, J_{PC} = 102.4 Hz), 129.8 (d, J_{PC} = 27.2 Hz), 129.5 (d, J_{PC} = 4.7 Hz), 129.4, 128.6, 128.6, 128.5, 128.4, 128.1, 128.0, 127.7 (d, J_{PC} = 7.7 Hz), 127.3, 127.2, 125.9, 125.7, 123.8 (d, J_{PC} = 97.0 Hz), 117.5, 75.9 (d, J_{PC} = 4.6 Hz), 20.7. HRMS (ESI) calcd for $C_{42}H_{32}O_2P^+$: 599.2134 (M + H^+), found: 599.2142.



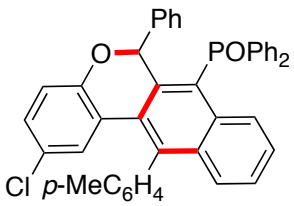
(2-Chloro-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3i**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.19 (d, J = 6.8 Hz, 1H), 7.98 (s, 1H), 7.65 (m, 6H), 7.51-7.16 (m, 11H), 7.00 (m, 6H), 6.80 (m, 1H), 6.67 (d, J = 6.4 Hz, 1H), 6.47 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.0, 142.9 (d, J_{PC} = 7.6 Hz), 142.0, 138.7 (d, J_{PC} = 20.0 Hz), 134.5 (d, J_{PC} = 103.4 Hz), 134.2 (d, J_{PC} = 103.0 Hz), 133.3 (d, J_{PC} = 6.6 Hz), 133.0 (d, J_{PC} = 9.4 Hz), 131.8, 131.7, 131.6, 131.5, 131.1, 129.5 (d, J_{PC} = 34.2 Hz), 129.0, 128.6, 128.5, 128.4, 128.4, 128.2, 128.0, 128.0, 127.8, 127.5, 126.6 (d, J_{PC} = 11.6 Hz), 126.1, 125.5, 125.1, 124.5, 123.0 (d, J_{PC} = 96.5 Hz), 119.3, 76.0 (d, J_{PC} = 3.8 Hz). HRMS (ESI) calcd for $C_{41}H_{29}ClO_2P^+$: 619.1588 (M + H^+), found: 619.1581.



(10-Methyl-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3j**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (d, J = 8.9 Hz, 1H), 7.94 (s, 1H), 7.68-7.62 (m, 5H), 6.34 (t, J = 7.2 Hz, 1H), 7.43-7.35 (m, 4H), 7.32-7.24 (m, 5H), 7.06-7.05 (m, 2H), 6.98-6.93 (m, 5H), 6.82-6.77 (m, 1H), 6.73-6.71 (m, 1H), 6.57 (d, J = 7.2 Hz, 1H), 6.82-6.77 (m, 1H), 2.22 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.3, 142.5 (d, J_{PC} = 7.8 Hz), 140.8, 139.5, 139.0, 135.6, 134.6 (d, J_{PC} = 103.0 Hz), 134.3 (d, J_{PC} = 102.6 Hz), 133.5 (d, J_{PC} = 9.1 Hz), 131.7, 131.6, 131.6, 131.4, 131.3, 130.9 (d, J_{PC} = 9.6 Hz), 129.5 (d, J_{PC} = 27.8 Hz), 129.0, 128.5, 128.4, 128.3, 128.2, 127.9 (d, J_{PC} = 6.9 Hz), 127.7, 127.7, 127.6, 127.2, 127.1, 126.5, 123.9, 123.2 (d, J_{PC} = 96.0 Hz), 120.4, 118.0, 76.8 (d, J_{PC} = 4.2 Hz), 21.4. HRMS (ESI) calcd for $C_{42}H_{32}O_2P^+$: 599.2134 ($M + H^+$), found: 599.2151.

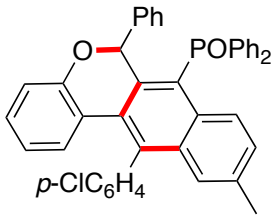


(10-Chloro-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3k**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32 (m, 1H), 7.74-7.60 (m, 8H), 7.42-7.25 (m, 8H), 7.12 (m, 1H), 6.95 (m, 6H), 6.81-6.73 (m, 2H), 6.56 (m, 1H), 6.31 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.3, 143.1 (d, J_{PC} = 7.6 Hz), 140.5, 138.5 (d, J_{PC} = 23.0 Hz), 134.3 (d, J_{PC} = 103.4 Hz), 134.6 (d, J_{PC} = 8.8 Hz), 133.2 (d, J_{PC} = 102.8 Hz), 132.2, 131.8, 131.6, 131.5, 131.4, 131.3, 131.1, 130.0, 129.5, 129.0 (d, J_{PC} = 6.8 Hz), 128.4, 128.3, 128.0, 127.2, 126.3 (d, J_{PC} = 31.6 Hz), 124.1 (d, J_{PC} = 95.5 Hz), 123.4, 120.6, 118.1, 75.9. HRMS (ESI) calcd for $C_{41}H_{29}ClO_2P^+$: 619.1588 ($M + H^+$), found: 619.1555.

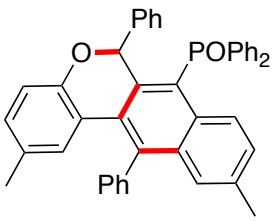


(2-Chloro-6-phenyl-12-(*p*-tolyl)-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3l**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.17 (d, J = 8.7 Hz, 1H), 7.97 (s, 1H), 7.77

(d, J = 8.6 Hz, 1H), 7.68-7.61 (m, 4H), 7.55-7.53 (m, 1H), 7.43-7.43 (m, 3H), 7.38-7.27 (m, 5H), 7.23 (d, J = 8.3 Hz, 1H), 7.18-7.14 (m, 1H), 7.01 (m, 5H), 6.88-6.86 (m, 1H), 6.81 (dd, J = 8.5 Hz, 1H), 6.67 (d, J = 8.6 Hz, 1H), 6.48-6.47 (m, 1H), 2.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.9, 143.0 (d, J_{PC} = 7.9 Hz), 142.2, 138.7, 138.1, 135.7, 135.0 (d, J_{PC} = 103.4 Hz), 134.3 (d, J_{PC} = 102.9 Hz), 133.4 (d, J_{PC} = 9.2 Hz), 133.0 (d, J_{PC} = 9.5 Hz), 131.9, 131.7, 131.6, 131.5, 131.3, 130.4, 129.3, 129.1, 128.6, 128.5, 128.4, 128.0, 128.0, 127.5, 127.3, 126.7 (d, J_{PC} = 11.7 Hz), 126.1 (d, J_{PC} = 6.6 Hz), 125.5, 125.2, 123.7 (d, J_{PC} = 95.8 Hz), 119.2, 76.1 (d, J_{PC} = 4.3 Hz), 21.3. HRMS (ESI) calcd for $C_{42}H_{31}ClO_2P^+$: 633.1745 (M + H^+), found: 633.1743.

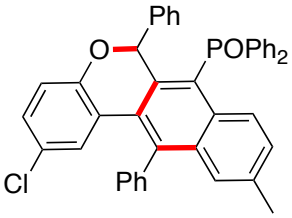


(12-(4-Chlorophenyl)-10-methyl-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3m**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.12 (d, J = 8.9 Hz, 1H), 7.90 (s, 1H), 7.67-7.58 (m, 6H), 7.42-7.29 (m, 8H), 7.04-6.95 (m, 6H), 6.91 (d, J = 8.2 Hz, 1H), 6.84 (d, J = 7.1 Hz, 1H), 6.74 (d, J = 8.0 Hz, 1H), 6.58 (d, J = 8.0 Hz, 1H), 6.41-6.37 (m, 1H), 2.28 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.5, 142.5 (d, J_{PC} = 7.8 Hz), 139.4, 138.9, 138.1, 135.9, 135.0 (d, J_{PC} = 103.1 Hz), 134.4 (d, J_{PC} = 102.6 Hz), 133.7, 133.4 (d, J_{PC} = 9.1 Hz), 133.2, 131.8, 131.7, 131.5, 131.4, 131.3, 131.0 (d, J_{PC} = 9.5 Hz), 129.7, 128.9 (d, J_{PC} = 14.0 Hz), 128.5, 128.5, 128.4, 128.3, 128.1, 127.9 (d, J_{PC} = 6.6 Hz), 127.3, 127.2, 126.2, 123.9 (d, J_{PC} = 95.4 Hz), 123.8, 120.7, 118.3, 76.0 (d, J_{PC} = 4.2 Hz), 21.5. HRMS (ESI) calcd for $C_{42}H_{31}ClO_2P^+$: 633.1745 (M + H^+), found: 633.1748.

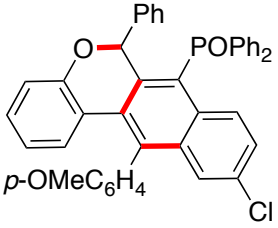


(2,10-Dimethyl-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine

oxide (**3n**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.13 (d, J = 8.8 Hz, 1H), 7.86 (s, 1H), 7.66-7.59 (m, 6H), 7.48-7.26 (m, 9H), 7.04-6.95 (m, 7H), 6.62 (m, 2H), 6.26 (s, 1H), 2.24 (s, 3H), 1.70 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.0, 142.3 (d, J_{PC} = 7.8 Hz), 140.7, 139.7, 139.2, 135.5, 134.7 (d, J_{PC} = 102.9 Hz), 134.5 (d, J_{PC} = 102.5 Hz), 133.5 (d, J_{PC} = 9.2 Hz), 131.7, 131.7, 131.6, 131.5, 131.4, 130.9 (d, J_{PC} = 9.5 Hz), 129.7 (d, J_{PC} = 25.8 Hz), 129.3 (d, J_{PC} = 3.1 Hz), 129.2, 128.5, 128.4 (d, J_{PC} = 7.3 Hz), 128.2, 127.9, 127.7, 127.5, 127.2, 127.0, 126.5, 123.4 (d, J_{PC} = 96.0 Hz), 123.3, 117.4, 75.7 (d, J_{PC} = 4.2 Hz), 21.4, 20.5. HRMS (ESI) calcd for $C_{43}H_{34}O_2P^+$: 613.2291 (M + H^+), found: 613.2301.

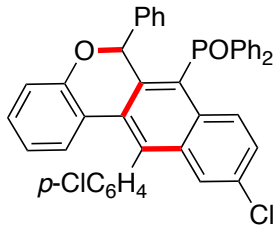


(2-Chloro-10-methyl-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3o**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.08 (d, J = 8.9 Hz, 1H), 8.00 (s, 1H), 7.68-7.61 (m, 6H), 7.53-7.47 (m, 2H), 7.43-7.40 (m, 3H), 7.38-7.28 (m, 4H), 7.02-6.98 (m, 7H), 6.79 (dd, J = 8.6 Hz, 2.2 Hz 1H), 6.68 (d, J = 8.6 Hz, 1H), 6.44-6.43 (m, 1H), 2.26 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.9, 141.0 (d, J_{PC} = 7.9 Hz), 141.4, 138.9 (d, J_{PC} = 16.3 Hz), 135.9, 134.6 (d, J_{PC} = 103.2 Hz), 134.4 (d, J_{PC} = 102.8 Hz), 133.4 (d, J_{PC} = 9.1 Hz), 131.8, 131.7, 131.5, 131.5, 131.4, 131.2 (d, J_{PC} = 9.6 Hz), 129.5 (d, J_{PC} = 29.2 Hz), 129.0, 128.6, 128.5, 128.4, 128.3, 128.1, 127.8 (d, J_{PC} = 6.6 Hz), 127.4, 127.4, 126.7, 126.6 (d, J_{PC} = 11.8 Hz), 125.3, 125.2, 123.6 (d, J_{PC} = 95.4 Hz), 119.2, 76.0 (d, J_{PC} = 4.3 Hz), 21.5. HRMS (ESI) calcd for $C_{42}H_{31}ClO_2P^+$: 633.1745 (M + H^+), found: 633.1768.

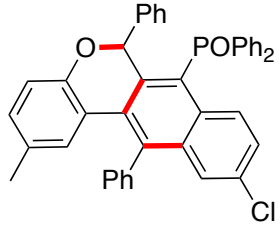


(10-Chloro-12-(4-methoxyphenyl)-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3p**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.31 (d, J = 9.3 Hz, 1H), 7.76

(s, 1H), 7.70-7.54 (m, 6H), 7.43-7.32 (m, 4H), 7.28-7.24 (m, 2H), 7.16-7.09 (m, 2H), 6.99-6.95 (m, 5H), 6.87-6.82 (m, 3H), 6.72 (d, J = 7.4 Hz, 1H), 6.65-6.63 (m, 1H), 6.38 (t, J = 8.0 Hz, 1H), 3.83 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3, 154.3, 143.2 (d, J_{PC} = 7.7 Hz), 140.4, 138.5, 135.0, 134.5 (d, J_{PC} = 116.0 Hz), 133.9 (d, J_{PC} = 102.6 Hz), 132.5, 132.1, 131.8, 131.7, 131.7, 131.6, 131.5 (d, J_{PC} = 10.0 Hz), 131.1 (d, J_{PC} = 9.3 Hz), 130.8, 130.6, 129.5 (d, J_{PC} = 6.2 Hz), 129.0 (d, J_{PC} = 10.2 Hz), 128.6, 128.4, 128.4, 128.3, 127.2, 126.3 (d, J_{PC} = 17.8 Hz), 123.8 (d, J_{PC} = 95.3 Hz), 123.7, 120.7, 118.1, 114.7, 114.1, 76.0 (d, J_{PC} = 4.4 Hz), 55.1. HRMS (ESI) calcd for $C_{42}H_{31}ClO_3P^+$: 649.1694 (M + H^+), found: 649.1696.

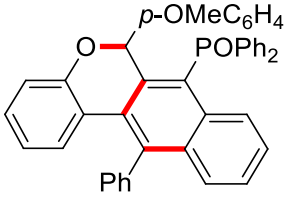


(10-Chloro-12-(4-chlorophenyl)-6-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3q**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.35 (d, J = 9.3 Hz, 1H), 7.72 (s, 1H), 7.68-7.56 (m, 7H), 7.46-7.44 (m, 1H), 7.39-7.28 (m, 3H), 7.28-7.25 (m, 3H), 7.13 (dd, J = 9.3 Hz, 2.2 Hz 1H), 6.96 (m, 5H), 6.91-6.85 (m, 2H), 6.73 (d, J = 7.3 Hz, 1H), 6.58-6.56 (m, 1H), 6.41-6.38 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.5, 143.2 (d, J_{PC} = 7.8 Hz), 139.0, 138.3, 137.2, 134.5, 134.3 (d, J_{PC} = 103.4 Hz), 134.2 (d, J_{PC} = 25.9 Hz) 133.8 (d, J_{PC} = 102.8 Hz), 132.9, 132.5, 131.9 (d, J_{PC} = 5.6 Hz), 131.7, 131.6, 131.5, 131.4, 131.2, 131.1, 129.9, 129.7 (d, J_{PC} = 6.2 Hz), 129.3, 128.7, 128.5 (d, J_{PC} = 5.7 Hz), 128.4, 127.4, 127.3, 126.7, 125.8, 125.2, 123.8 (d, J_{PC} = 95.1 Hz), 120.8, 118.4, 76.1 (d, J_{PC} = 4.4 Hz). HRMS (ESI) calcd for $C_{41}H_{28}Cl_2O_2P^+$: 653.1198 (M + H^+), found: 653.1195.

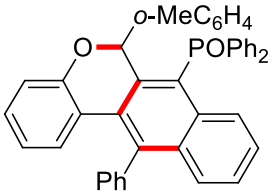


(10-Chloro-2-methyl-6,12-diphenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3r**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.37 (d, J = 9.3 Hz, 1H), 7.70-7.65 (m,

5H), 7.62-7.56 (m, 3H), 7.47-7.42 (m, 2H), 7.37-7.31 (m, 4H), 7.26-7.22 (m, 2H), 7.12 (dd, J = 9.3 Hz, 2.2 Hz, 1H), 6.97-6.95 (m, 6H), 6.65-6.59 (m, 2H), 6.26 (m, 1H), 1.69 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.0, 142.9 (d, J_{PC} = 7.8 Hz), 140.3, 138.7 (d, J_{PC} = 20.7 Hz), 134.5 (d, J_{PC} = 103.0 Hz), 134.5 (d, J_{PC} = 7.5 Hz), 133.9 (d, J_{PC} = 102.5 Hz), 132.1, 131.7, 131.7, 131.6, 131.5, 131.3, 131.1 (d, J_{PC} = 9.3 Hz), 129.8, 129.6, 129.5, 129.4, 128.8, 128.6, 128.5, 128.4, 128.3, 128.3, 128.2, 127.9, 127.2, 126.3 (d, J_{PC} = 26.2 Hz), 124.2 (d, J_{PC} = 95.1 Hz), 122.9, 117.5, 75.8 (d, J_{PC} = 4.6 Hz), 20.5. HRMS (ESI) calcd for $C_{42}H_{31}ClO_2P^+$: 633.1745 (M + H^+), found: 633.1761.

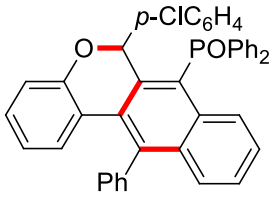


(6-(4-Methoxyphenyl)-12-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3s**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.22 (d, J = 8.2 Hz, 1H), 7.78 (s, 1H), 7.68-7.60 (m, 7H), 7.43-7.33 (m, 9H), 7.14 (m, 1H), 6.99-6.93 (m, 3H), 6.85-6.83 (m, 1H), 6.72 (d, J = 7.2 Hz, 1H), 6.61 (d, J = 7.2 Hz, 1H), 6.50 (d, J = 7.6 Hz, 2H), 6.35 (d, J = 6.8 Hz, 1H), 3.60 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.6, 154.3, 143.6 (d, J_{PC} = 8.0 Hz), 141.5, 139.5, 134.7 (d, J_{PC} = 103.1 Hz), 134.4 (d, J_{PC} = 102.7 Hz), 133.4 (d, J_{PC} = 9.2 Hz), 132.7 (d, J_{PC} = 9.3 Hz), 131.8, 131.7, 131.5, 131.4, 131.2, 129.8, 129.7, 129.4, 129.0, 128.8, 128.6, 128.4, 128.3, 128.0, 127.9, 127.7, 127.6, 125.8 (d, J_{PC} = 11.7 Hz), 123.4 (d, J_{PC} = 102.0 Hz), 120.5, 118.2, 112.7, 75.8 (d, J_{PC} = 4.2 Hz), 54.9. HRMS (ESI) calcd for $C_{42}H_{31}O_3PNa^+$: 637.1903 (M + Na^+), found: 637.1881.

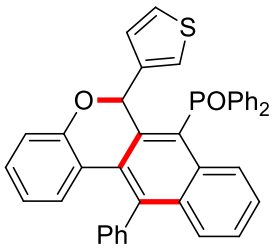


Diphenyl(12-phenyl-6-(*o*-tolyl)-6*H*-naphtho[2,3-*c*]chromen-7-yl)phosphine oxide (**3t**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15-8.13 (m, 2H), 7.74-7.71 (m, 2H), 7.62-7.55 (m, 5H), 7.47-7.24 (m, 9H), 7.13 (t, J = 7.6 Hz, 1H), 7.04 (d, J = 7.3 Hz, 1H), 6.97 (d, J =

7.2 Hz, 1H), 6.91 (t J = 6.8 Hz, 1H), 6.83 (t, J = 7.6 Hz, 1H), 6.69-6.63 (m, 3H), 6.59-6.57 (m, 1H), 6.37 (d, J = 7.6 Hz, 1H), 2.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.4, 144.6 (d, J_{PC} = 7.6 Hz), 141.3, 139.5, 138.4, 136.6, 134.8 (d, J_{PC} = 103.5 Hz), 134.3 (d, J_{PC} = 102.5 Hz), 133.4 (d, J_{PC} = 9.2 Hz), 132.8 (d, J_{PC} = 9.6 Hz), 131.9, 131.7, 131.6, 131.5, 130.4, 129.5, 129.3, 129.1, 128.8, 128.6, 128.5, 128.4, 128.4, 128.1, 128.0, 127.8, 127.7, 125.9, 125.7, 124.3, 124.1, 123.1 (d, J_{PC} = 96.1 Hz), 120.8, 117.3, 74.4 (d, J_{PC} = 4.1 Hz), 19.9. HRMS (ESI) calcd for $C_{42}H_{31}O_2PNa^+$: 621.1954 (M + Na^+), found: 621.1955.



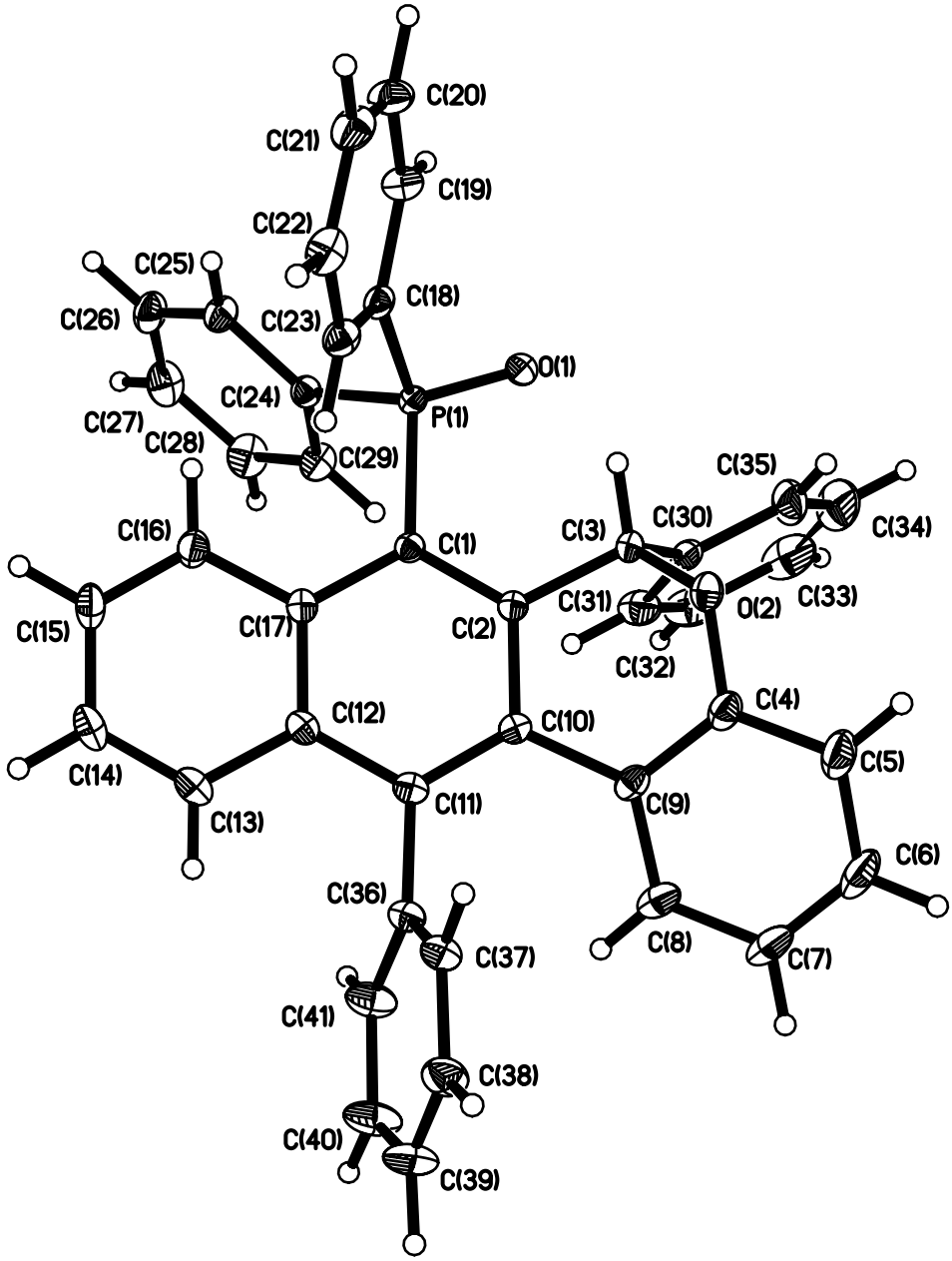
(6-(4-Chlorophenyl)-12-phenyl-6*H*-naphtho[2,3-*c*]chromen-7-yl)diphenylphosphine oxide (**3u**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.09 (d, J = 8.7 Hz, 1H), 8.01 (s, 1H), 7.70-7.59 (m, 7H), 7.48-7.44 (m, 3H), 7.38-7.34 (m, 5H), 7.27 (t, J = 7.1 Hz, 1H), 7.12 (t, J = 7.3 Hz, 1H), 7.04-6.95 (m, 5H), 6.90-6.86 (m, 1H), 6.75 (d, J = 7.0 Hz, 1H), 6.60 (dd, J = 9.6 Hz, 1.2 Hz, 1H), 6.37 (t, J = 7.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.2, 143.5 (d, J_{PC} = 7.6 Hz), 141.7, 139.3, 137.9, 134.4 (d, J_{PC} = 103.0 Hz), 133.4 (d, J_{PC} = 9.2 Hz), 133.0, 132.6 (d, J_{PC} = 9.6 Hz), 131.9, 131.8, 131.7 (d, J_{PC} = 10.0 Hz), 129.9, 129.6 (d, J_{PC} = 21.8 Hz), 129.0 (d, J_{PC} = 17.3 Hz), 128.6 (d, J_{PC} = 9.8 Hz), 128.1, 127.9, 127.8, 127.7, 127.6, 125.9 (d, J_{PC} = 18.8 Hz), 123.8, 123.6 (d, J_{PC} = 95.3 Hz), 120.8, 118.2, 75.4 (d, J_{PC} = 4.0 Hz). HRMS (ESI) calcd for $C_{41}H_{29}ClO_2P^+$: 619.1588 (M + H^+), found: 619.1563.

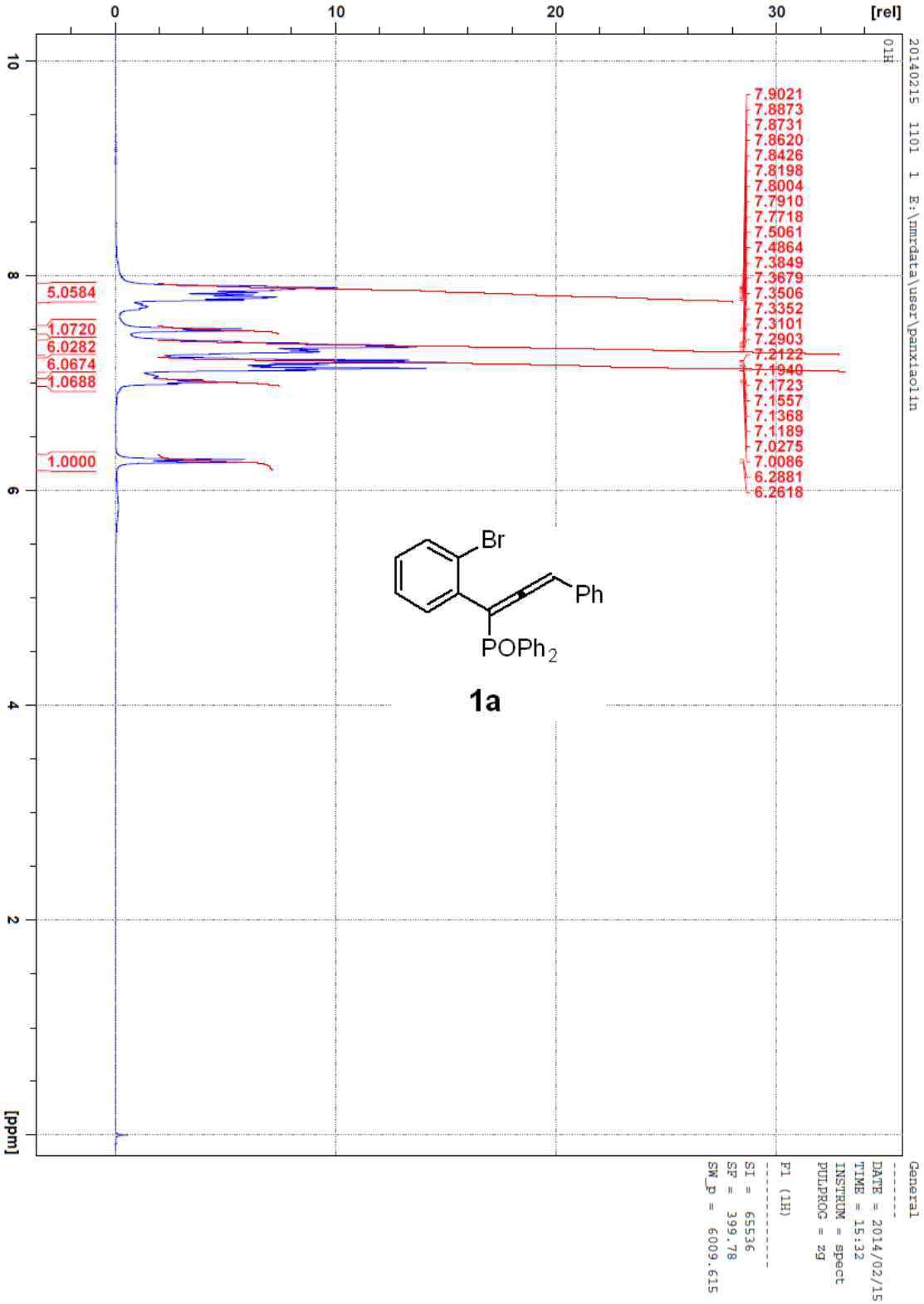


Diphenyl(12-phenyl-6-(thiophen-3-yl)-6*H*-naphtho[2,3-*c*]chromen-7-yl)phosphine oxide (**3v**). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.20 (d, J = 8.6 Hz, 1H), 7.91 (s, 1H), 7.68-7.61 (m, 5H), 7.46-7.25 (m, 10H), 7.16-7.14 (m, 1H), 7.00 (d, J = 7.6 Hz, 1H),

6.92-6.89 (m, 2H), 6.78-6.76 (m, 2H), 6.69 (s, 1H), 6.63 (d, J = 7.6 Hz, 1H), 6.40 (t, J = 7.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.3, 144.1 (d, J_{PC} = 7.7 Hz), 141.6, 140.0 (d, J_{PC} = 97.5 Hz), 135.3 (d, J_{PC} = 32.6 Hz), 134.9 (d, J_{PC} = 106.4 Hz), 133.5 (d, J_{PC} = 17.9 Hz), 133.3, 132.7 (d, J_{PC} = 9.4 Hz), 131.7, 131.6, 131.5, 129.6 (d, J_{PC} = 24.8 Hz), 129.1, 128.8, 128.6, 128.5 (d, J_{PC} = 5.0 Hz), 128.4, 128.1, 128.0, 127.9, 127.8, 127.7, 127.2 (d, J_{PC} = 11.1 Hz), 125.9, 125.8, 125.2, 124.4, 123.8, 122.7 (d, J_{PC} = 96.0 Hz), 122.7, 120.7, 118.0, 72.2 (d, J_{PC} = 3.9 Hz). HRMS (ESI) calcd for $C_{39}H_{28}O_2PS^+$: 591.1542 ($M + H^+$), found: 591.1522.

Figure 1. ORTEP illustration of compound **3a** (30% probability ellipsoids)

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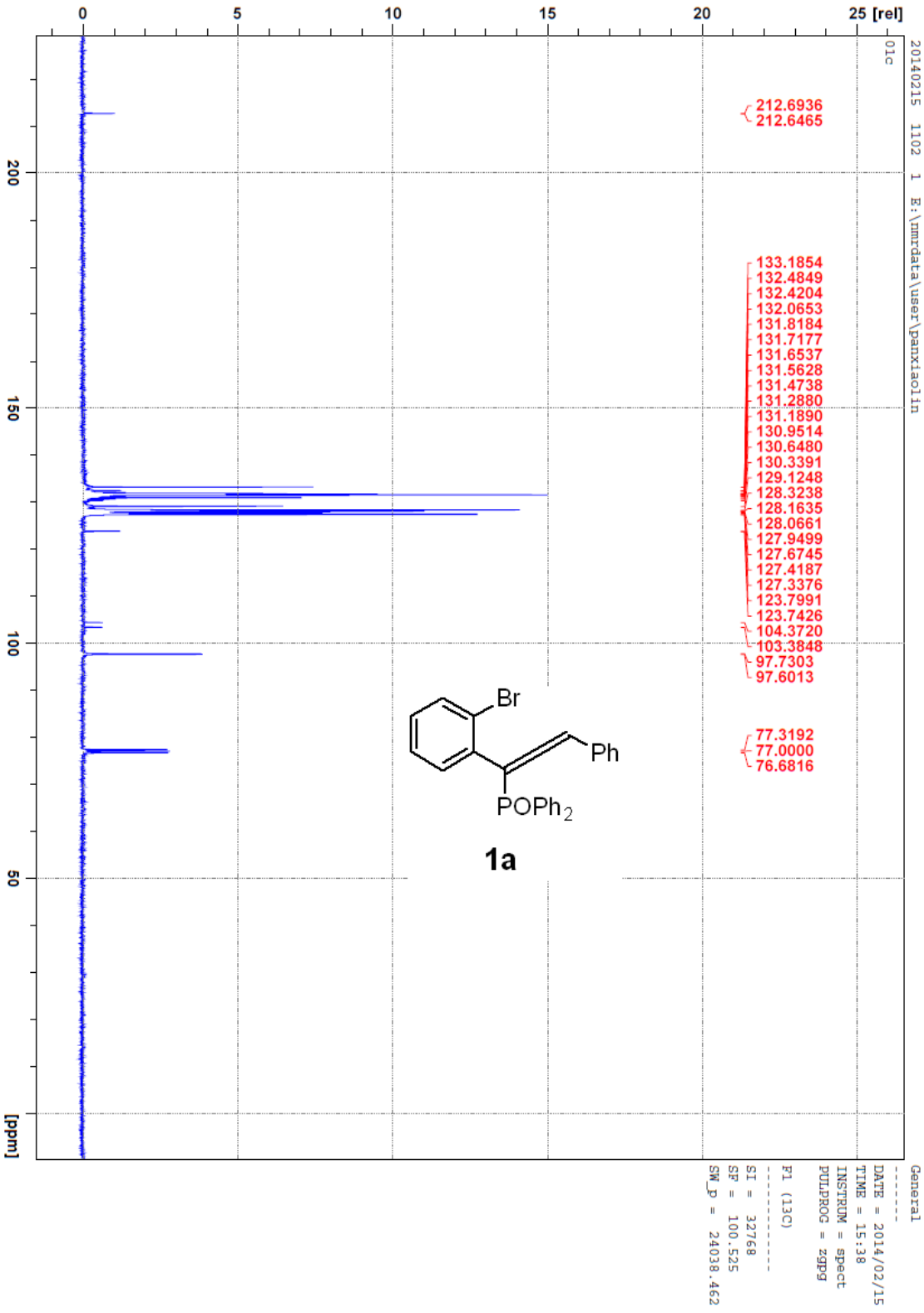
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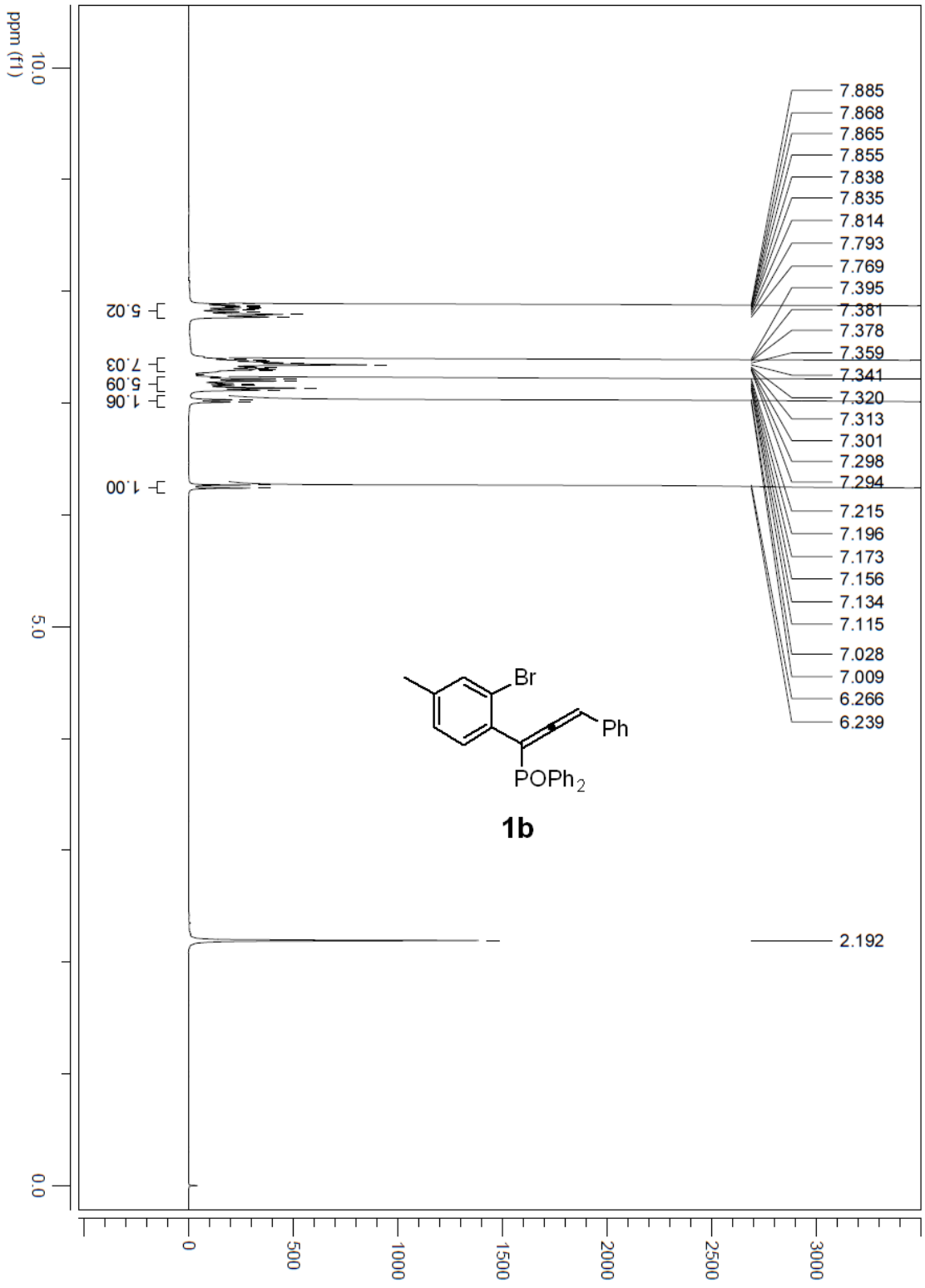
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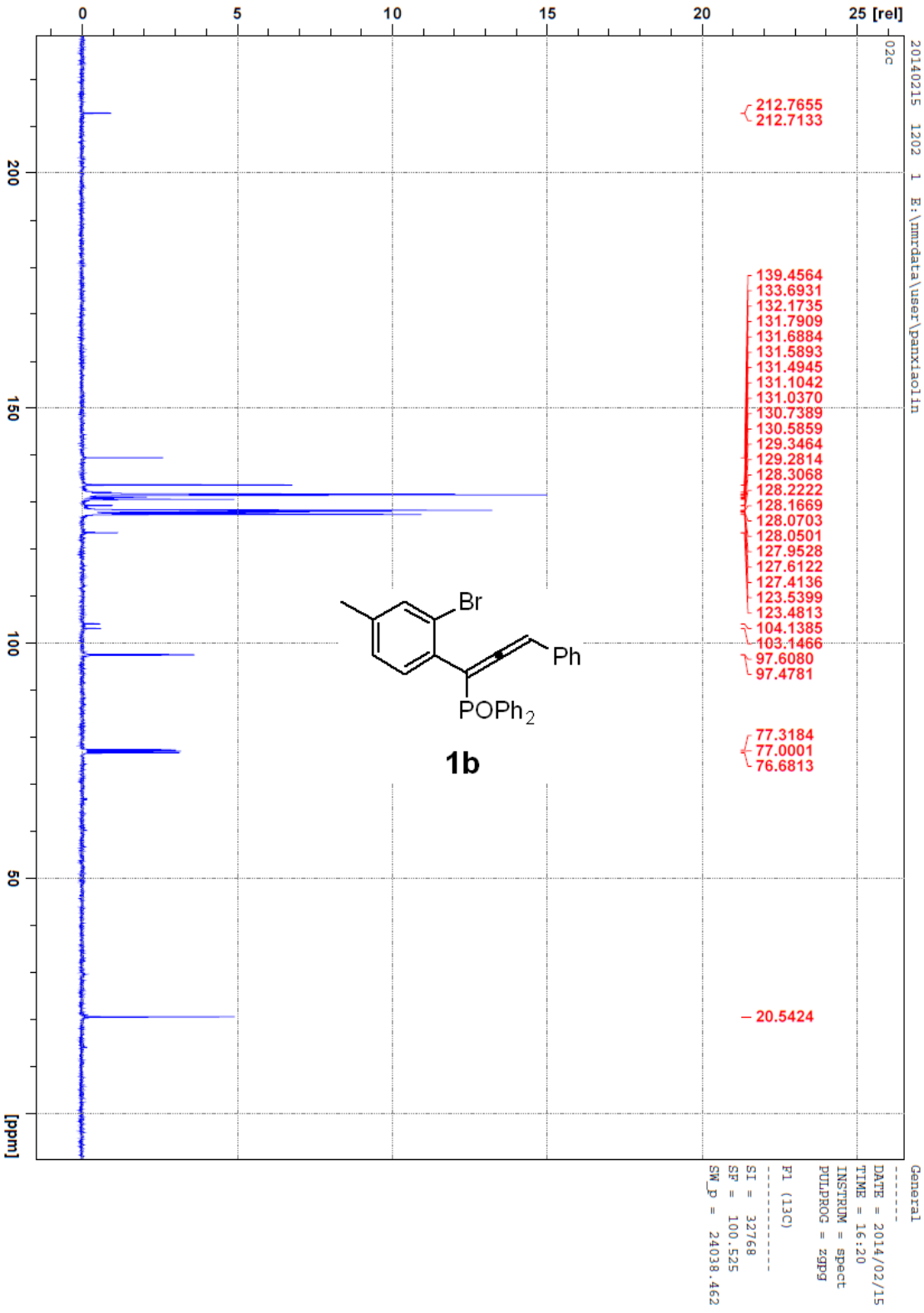
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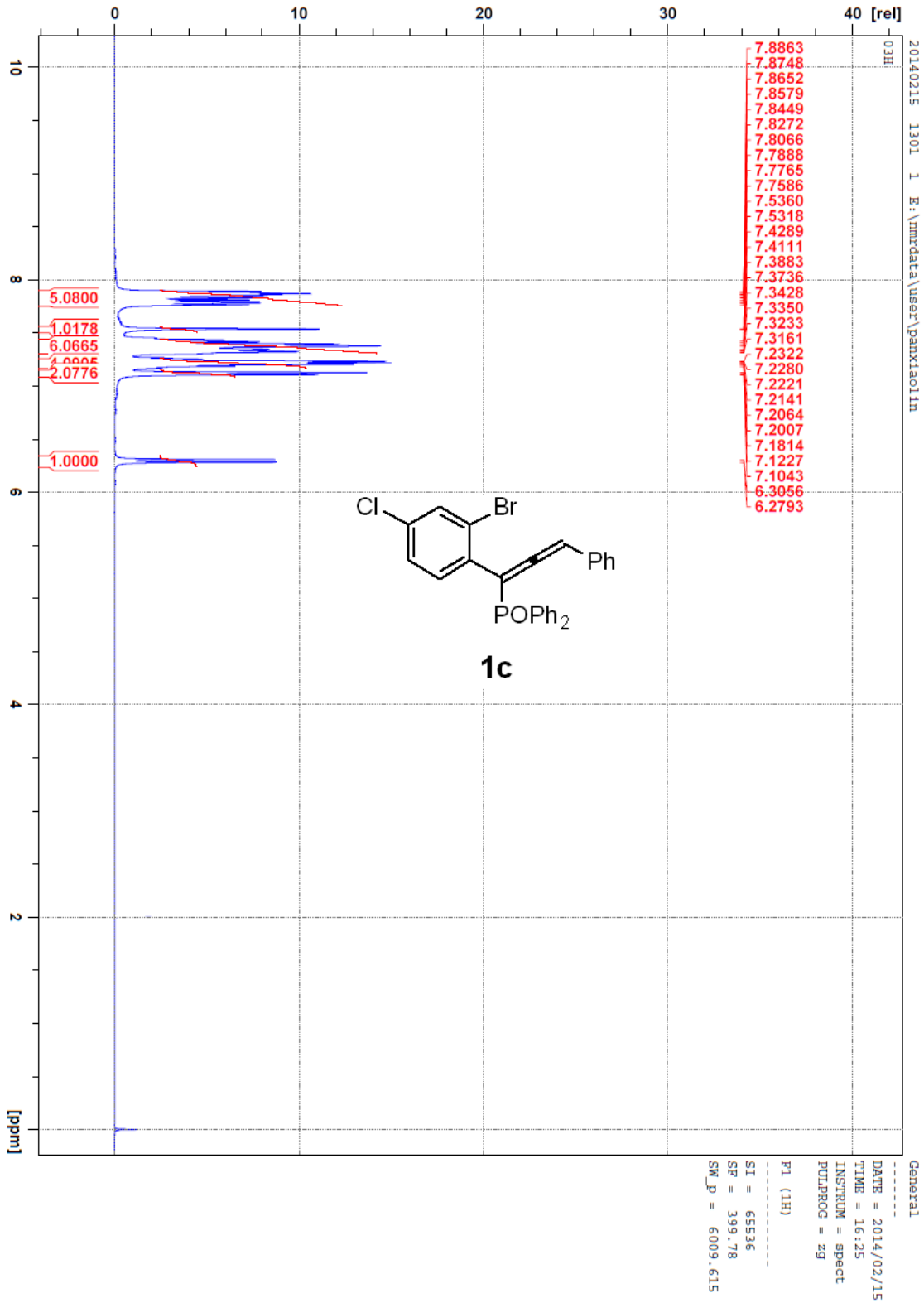
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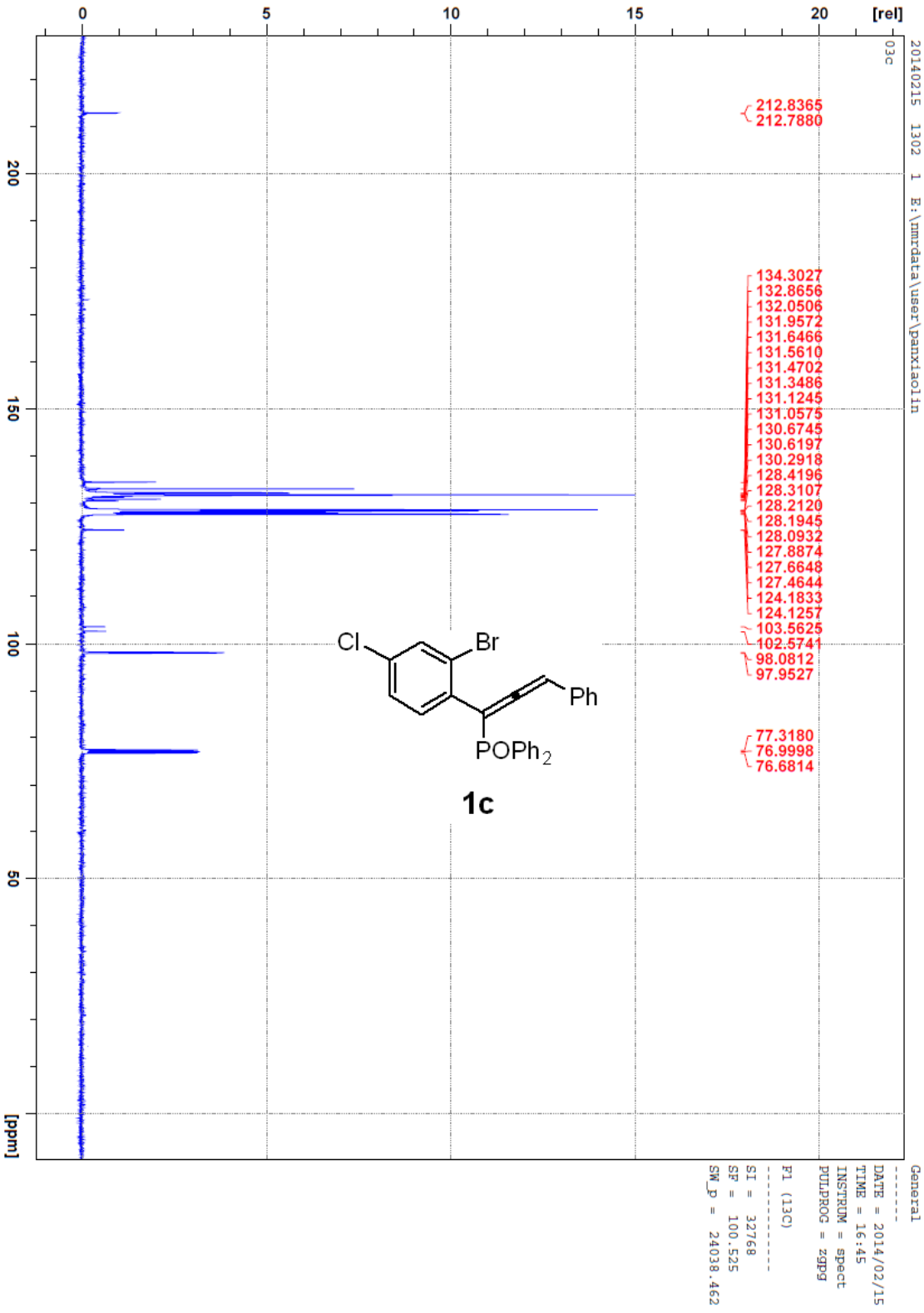
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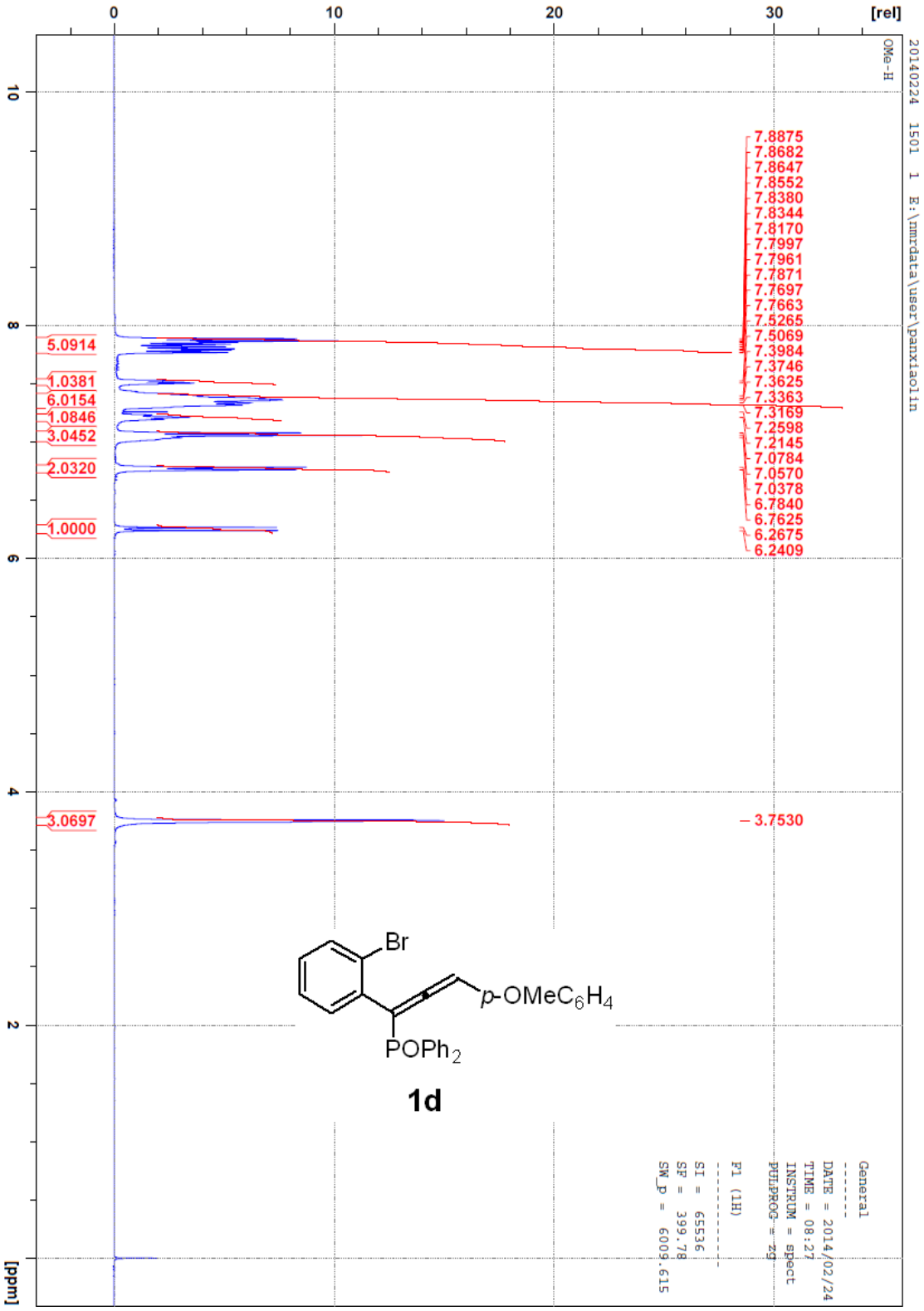
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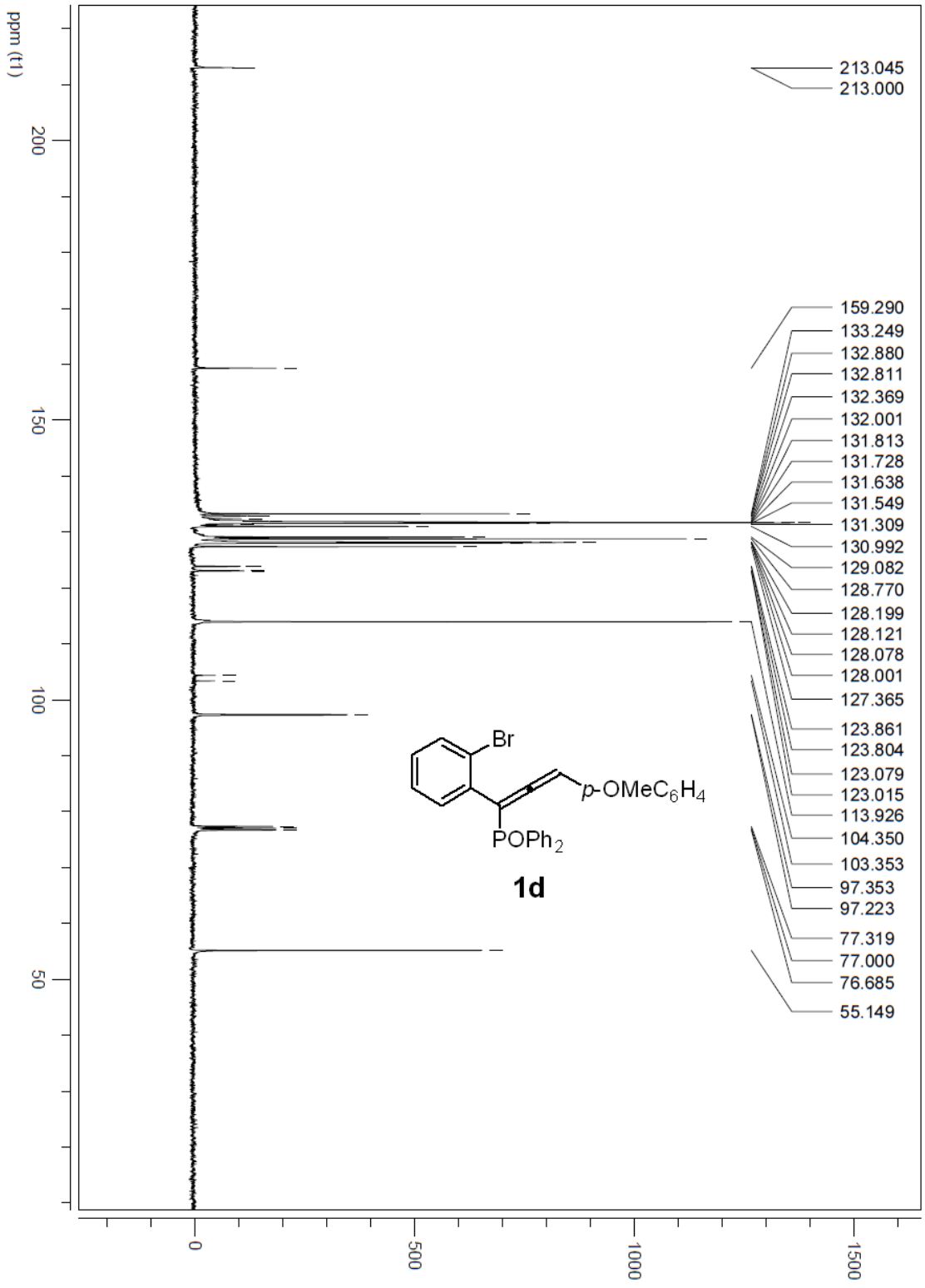
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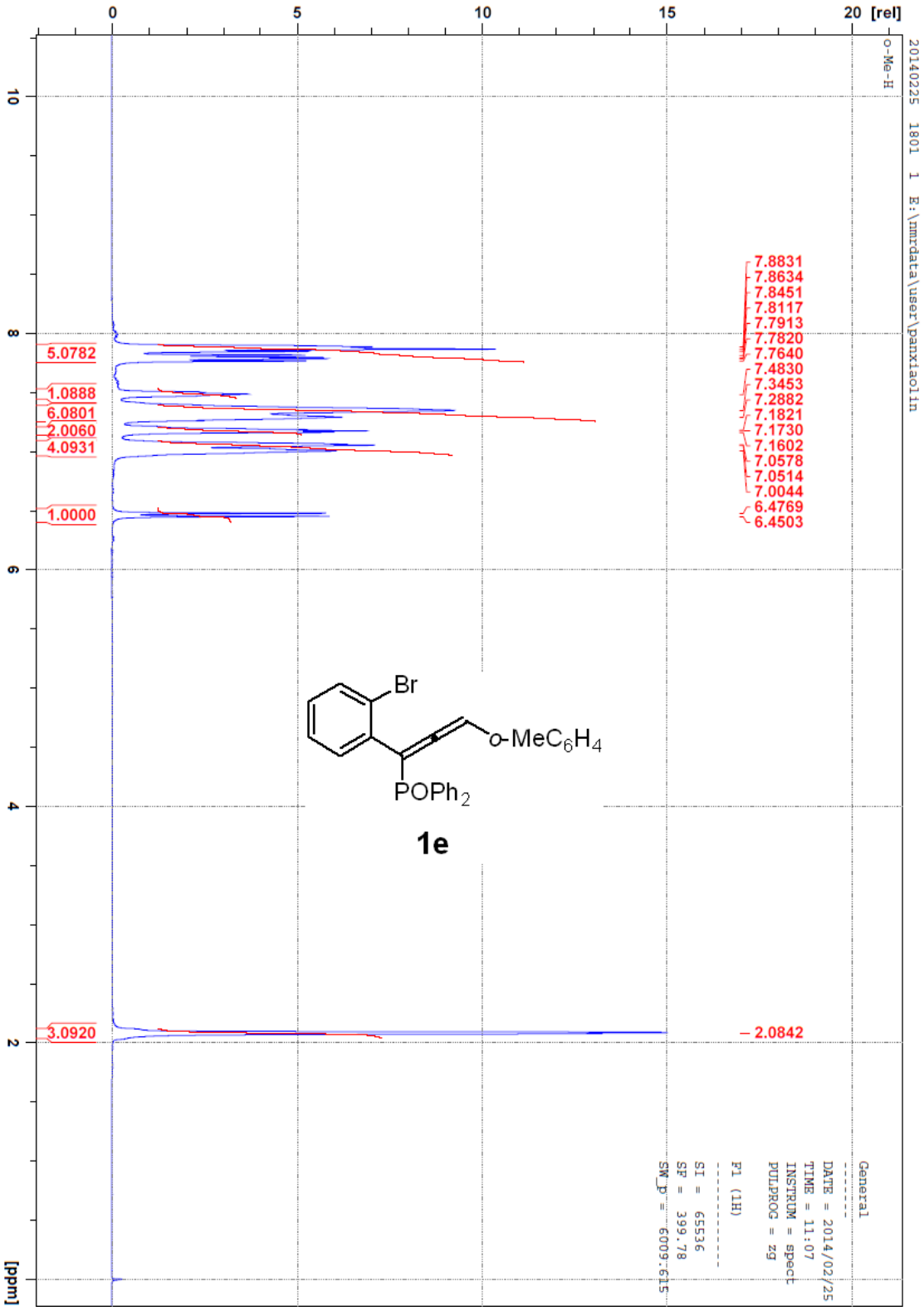
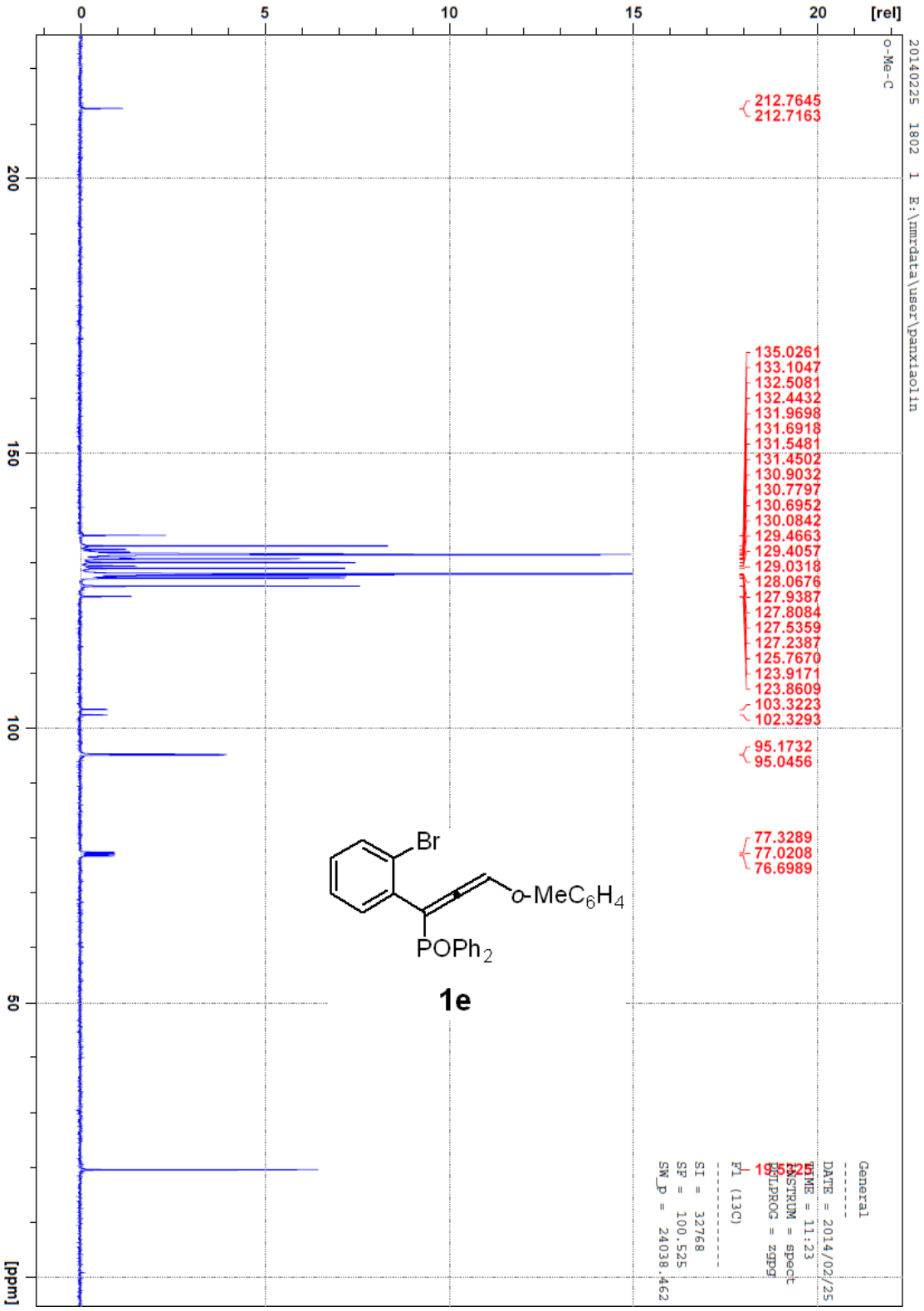
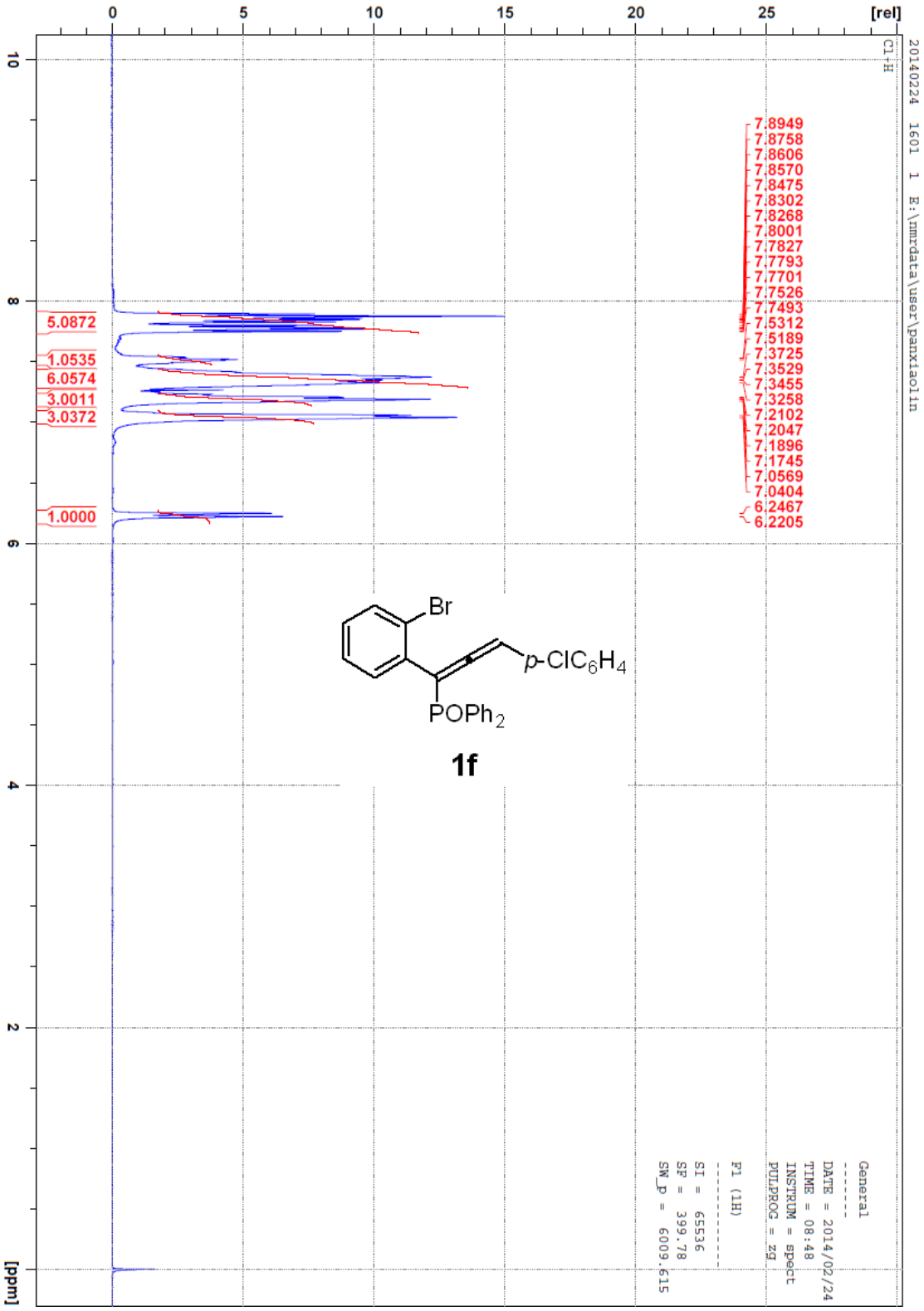
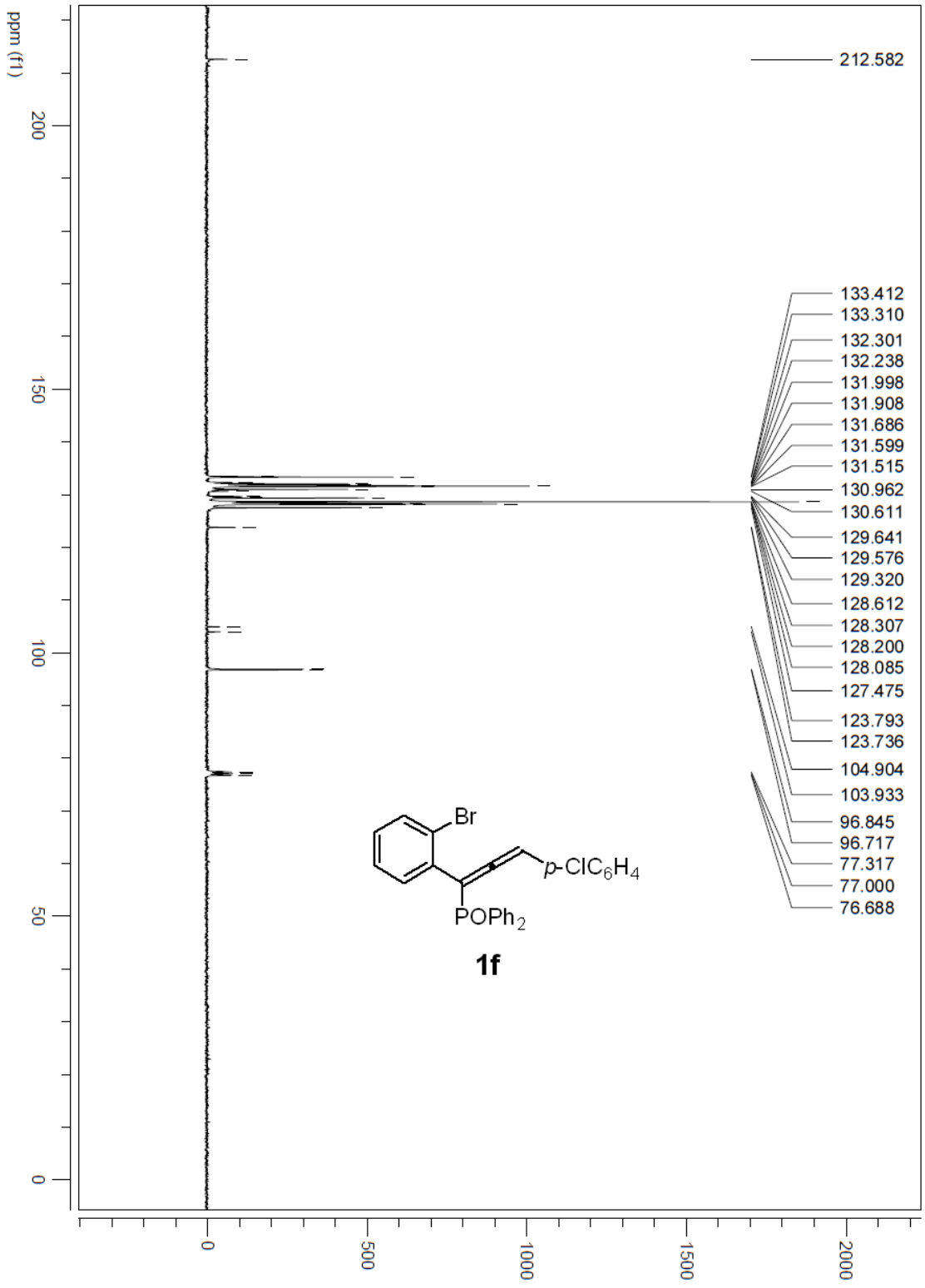
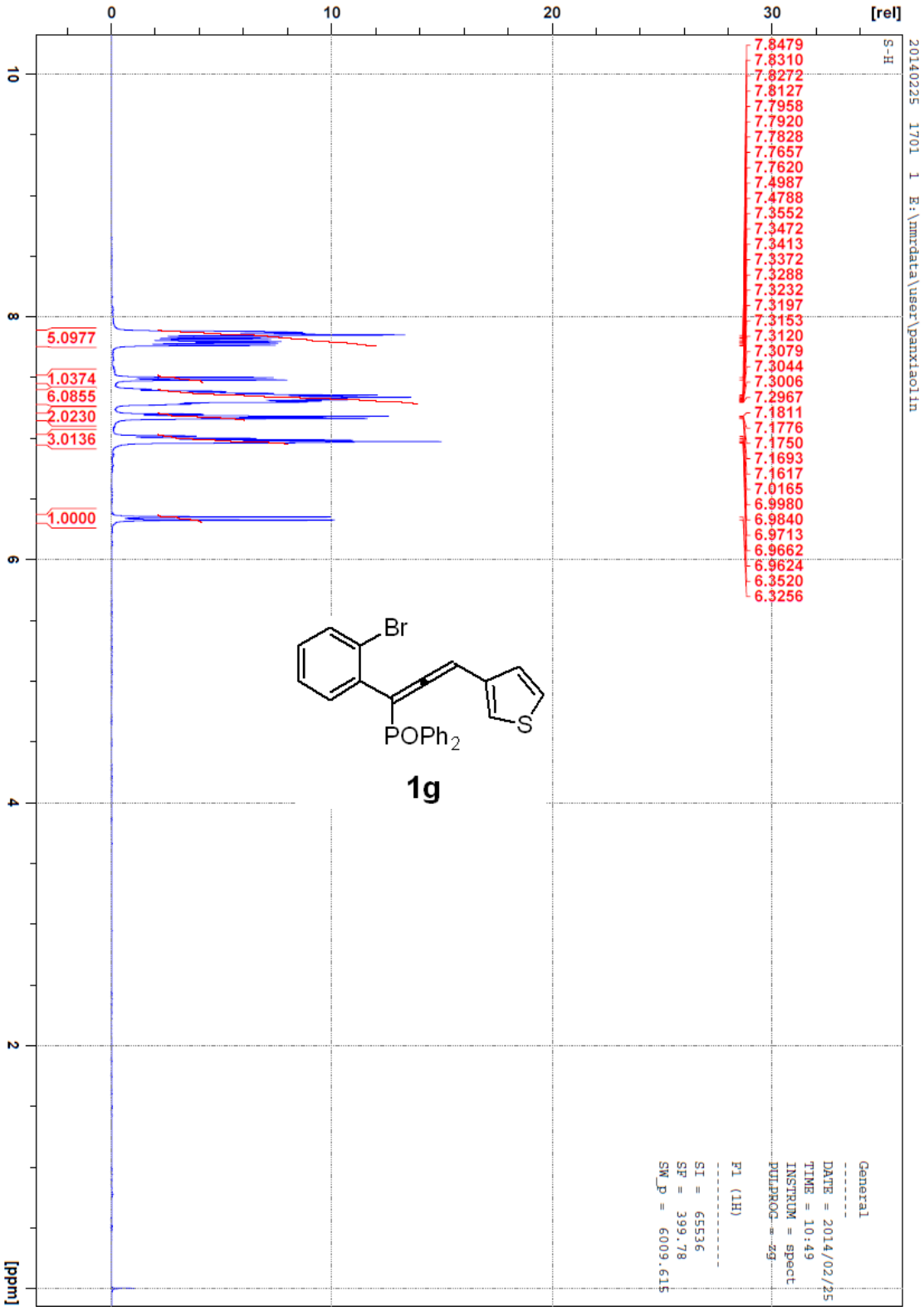
POPh2
1d

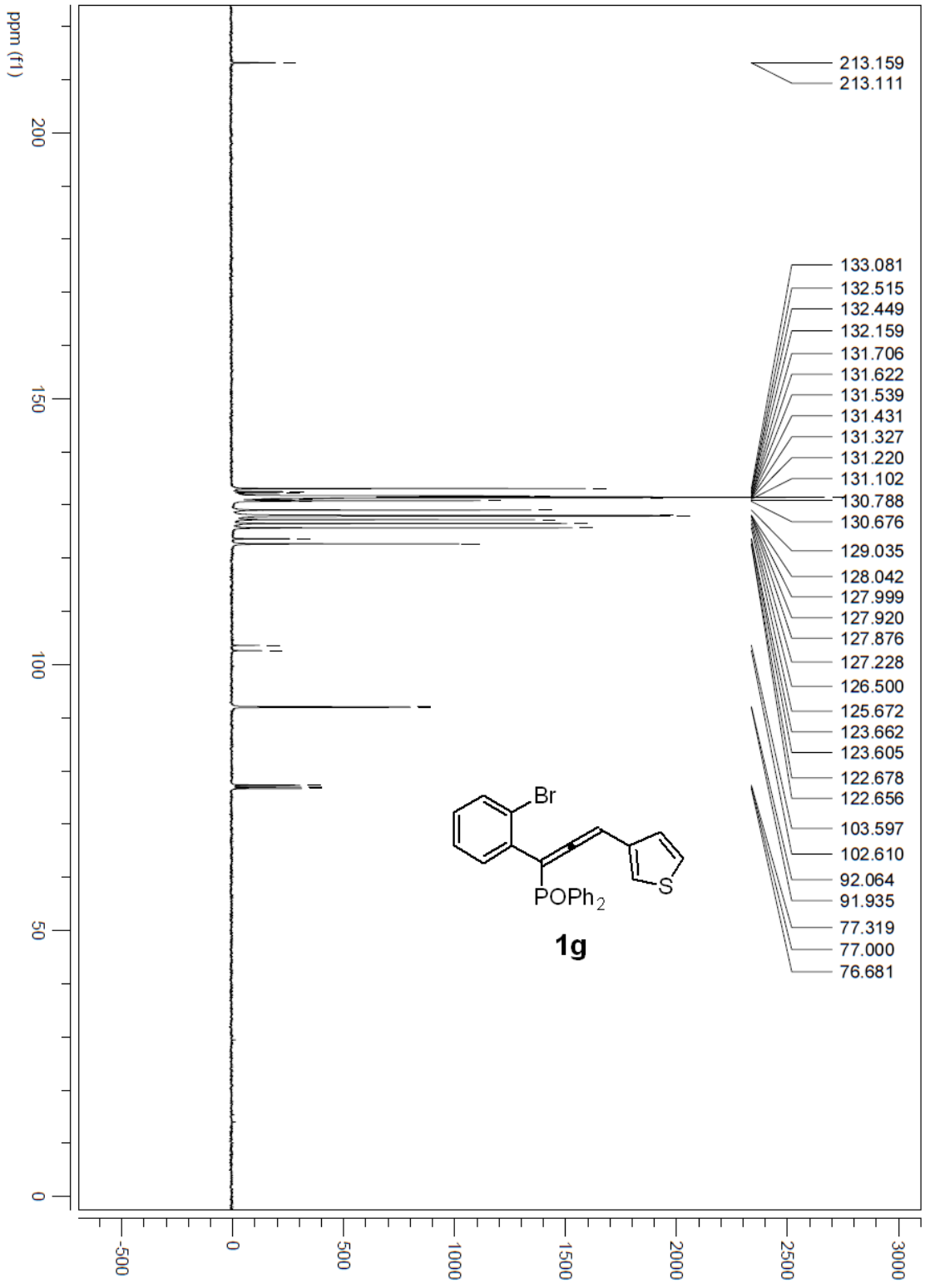

o-Me-H
20140225 1801 1 E:\nmrdata\user\panxiaolin
7.8831
7.8634
7.8451
7.8117
7.7913
7.7820
7.7640
7.4830
7.3453
7.2882
7.1821
7.1730
7.1602
7.0578
7.0514
7.0044
6.4769
6.4503
5.0782
1.0888
6.0801
2.0060
4.0931
1.0000
3.0920
2.0842
Br
o-MeC6H4
POPh2
1e
General
DATE = 2014/02/25
TIME = 11:07
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615
[rel]
[ppm]

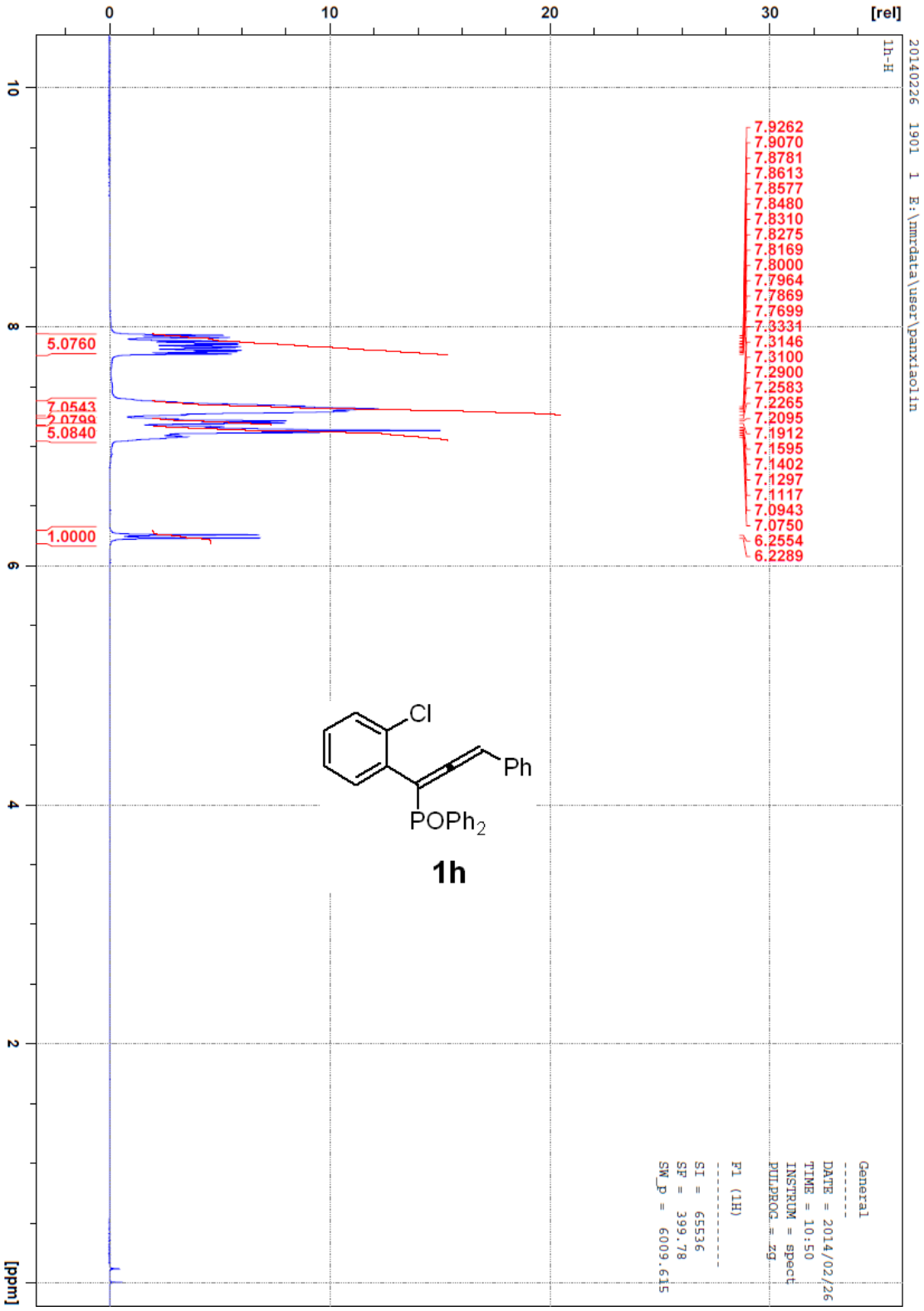

o-Me-C
20140225 1802 1 E:\nmrdata\user\panxiaolin
212.7645
212.7163
135.0261
133.1047
132.5081
132.4432
131.9698
131.6918
131.5481
131.4502
130.9032
130.7797
130.6952
130.0842
129.4663
129.4057
129.0318
128.0676
127.9387
127.8084
127.5359
127.2387
125.7670
123.9171
123.8609
103.3223
102.3293
95.1732
95.0456
77.3289
77.0208
76.6989
19.5322
Br
o-MeC6H4
POPh2
1e
General
DATE = 2014/02/25
TIME = 11:23
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
0
5
10
15
20
[rel]
200
150
100
50
[ppm]

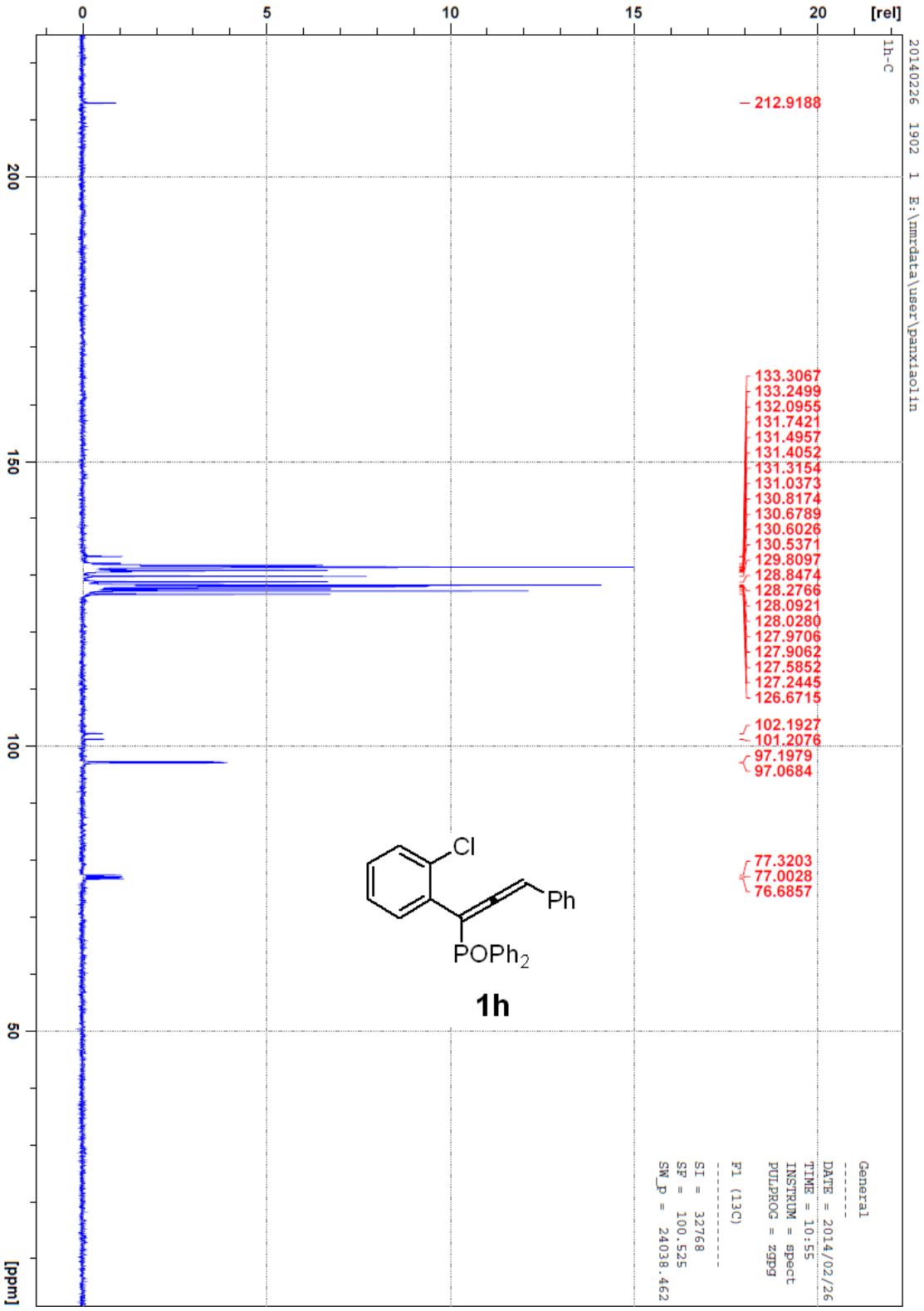

0
5
10
15
20
25
[rel]
10
8
6
4
2
[ppm]
Cl-H
20140224 1601 1 E:\nmrdata\user\panxiaolin
7.8949
7.8758
7.8606
7.8570
7.8475
7.8302
7.8268
7.8001
7.7827
7.7793
7.7701
7.7526
7.7493
7.5312
7.5189
7.3725
7.3529
7.3455
7.3258
7.2102
7.2047
7.1896
7.1745
7.0569
7.0404
6.2467
6.2205
5.0872
1.0535
6.0574
3.0011
3.0372
1.0000
Br
p-ClC6H4
POPh2
1f
General
DATE = 2014/02/24
TIME = 08:48
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615

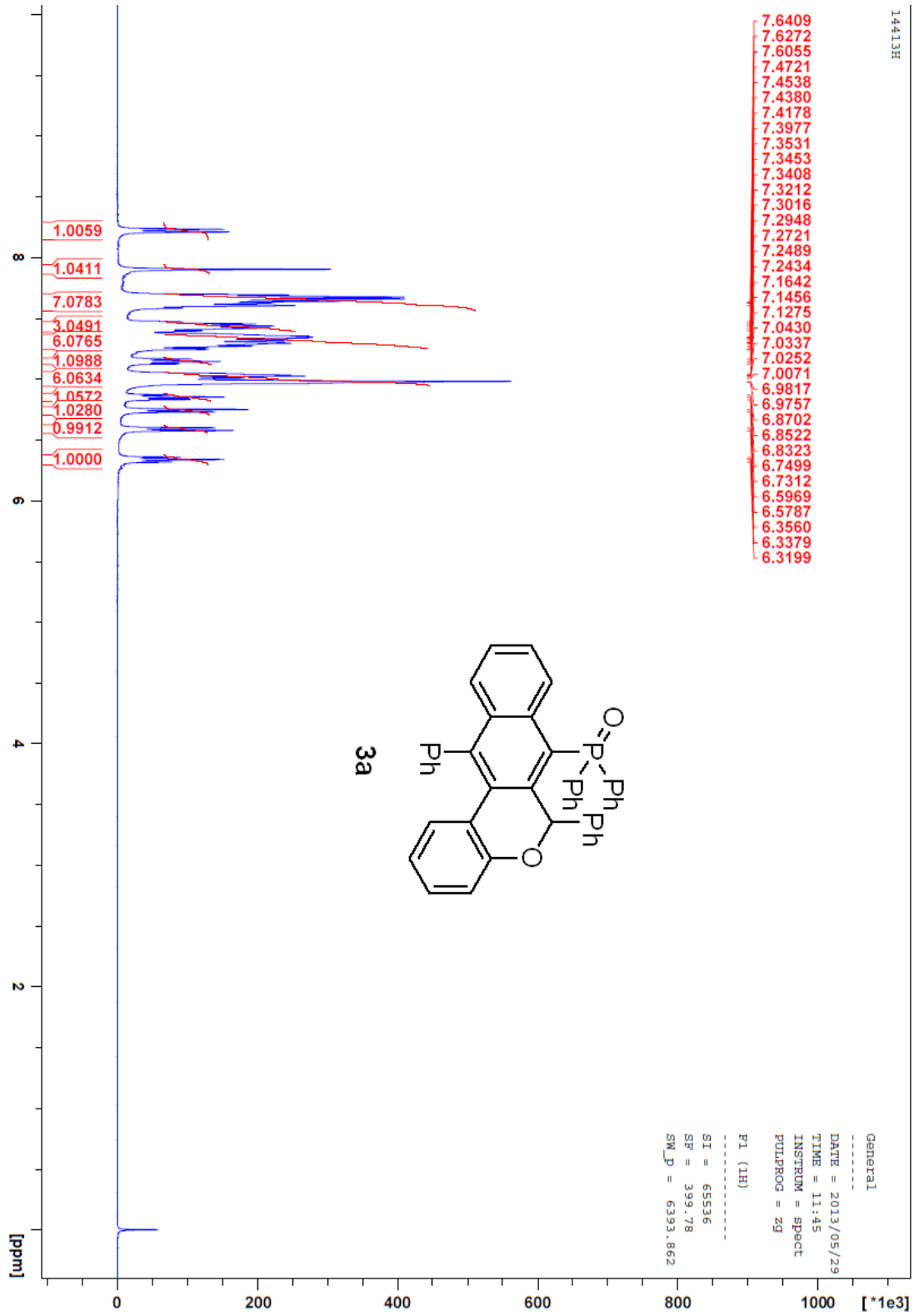

ppm (f1)
212.582
133.412
133.310
132.301
132.238
131.998
131.908
131.686
131.599
131.515
130.962
130.611
129.641
129.576
129.320
128.612
128.307
128.200
128.085
127.475
123.793
123.736
104.904
103.933
96.845
96.717
77.317
77.000
76.688
Br
p-ClC6H4
POPh2
1f

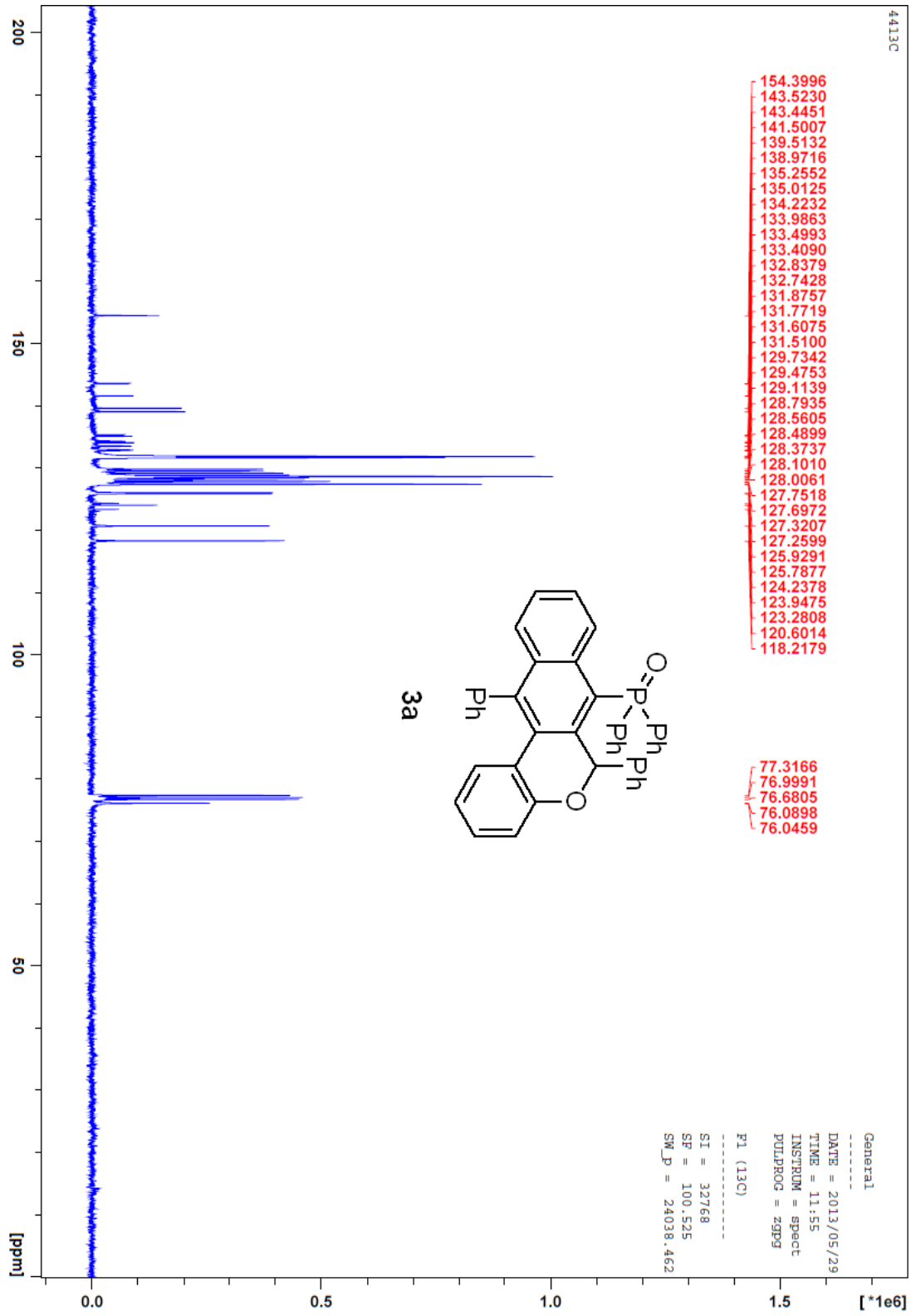

0
10
20
30
[rel]
10
8
6
4
2
[ppm]
S-H
20140225 1701 1 E:\nmrdata\user\panxiaolin
7.8479
7.8310
7.8272
7.8127
7.7958
7.7920
7.7828
7.7657
7.7620
7.4987
7.4788
7.3552
7.3472
7.3413
7.3372
7.3288
7.3232
7.3197
7.3153
7.3120
7.3079
7.3044
7.3006
7.2967
7.1811
7.1776
7.1750
7.1693
7.1617
7.0165
6.9980
6.9840
6.9713
6.9662
6.9624
6.3520
6.3256
5.0977
1.0374
6.0855
2.0230
3.0136
1.0000
Br
POPh2
S
1g
General
DATE = 2014/02/25
TIME = 10:49
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615

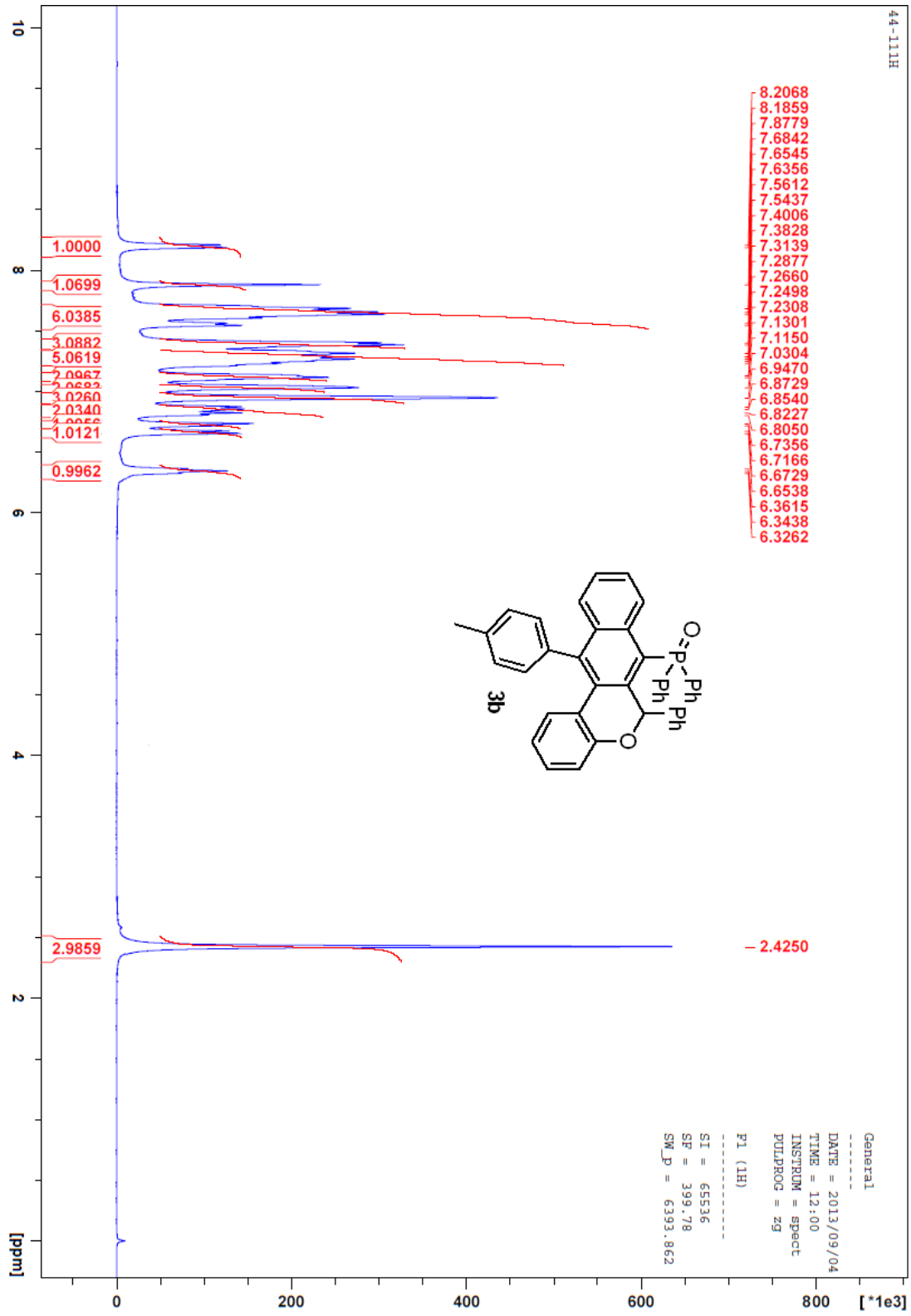

ppm (f1)
213.159
213.111
133.081
132.515
132.449
132.159
131.706
131.622
131.539
131.431
131.327
131.220
131.102
130.788
130.676
129.035
128.042
127.999
127.920
127.876
127.228
126.500
125.672
123.662
123.605
122.678
122.656
103.597
102.610
92.064
91.935
77.319
77.000
76.681
Br
POPh2
S
1g

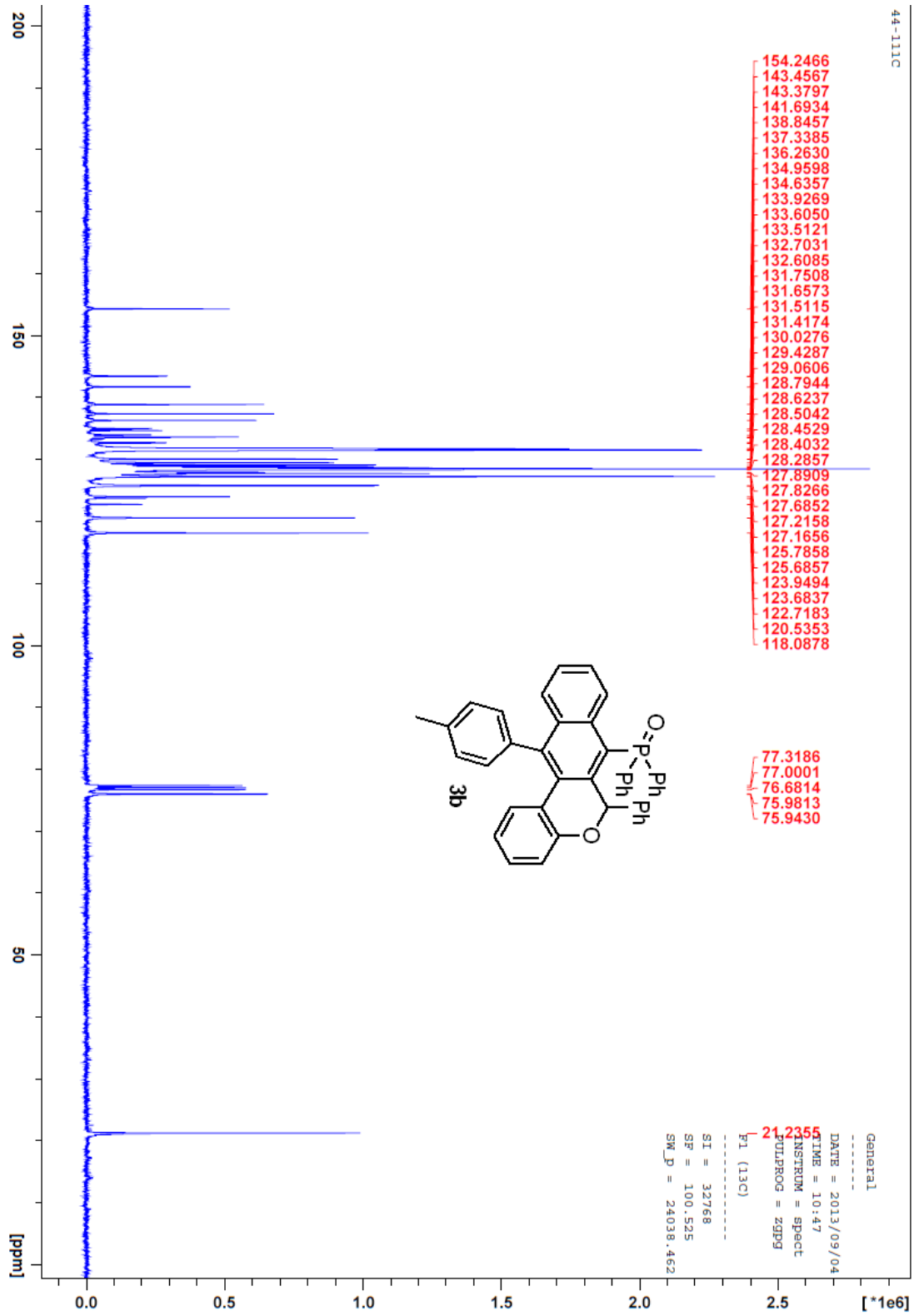

0
10
20
30
[rel]
10
8
6
4
2
[ppm]
1h-H
20140226 1901 1 E:\nmrdata\user\panxiaolin
7.9262
7.9070
7.8781
7.8613
7.8577
7.8480
7.8310
7.8275
7.8169
7.8000
7.7964
7.7869
7.7699
7.3331
7.3146
7.3100
7.2900
7.2583
7.2265
7.2095
7.1912
7.1595
7.1402
7.1297
7.1117
7.0943
7.0750
6.2554
6.2289
5.0760
7.0543
2.0799
5.0840
1.0000
Cl
Ph
POPh2
1h
General
DATE = 2014/02/26
TIME = 10:50
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615

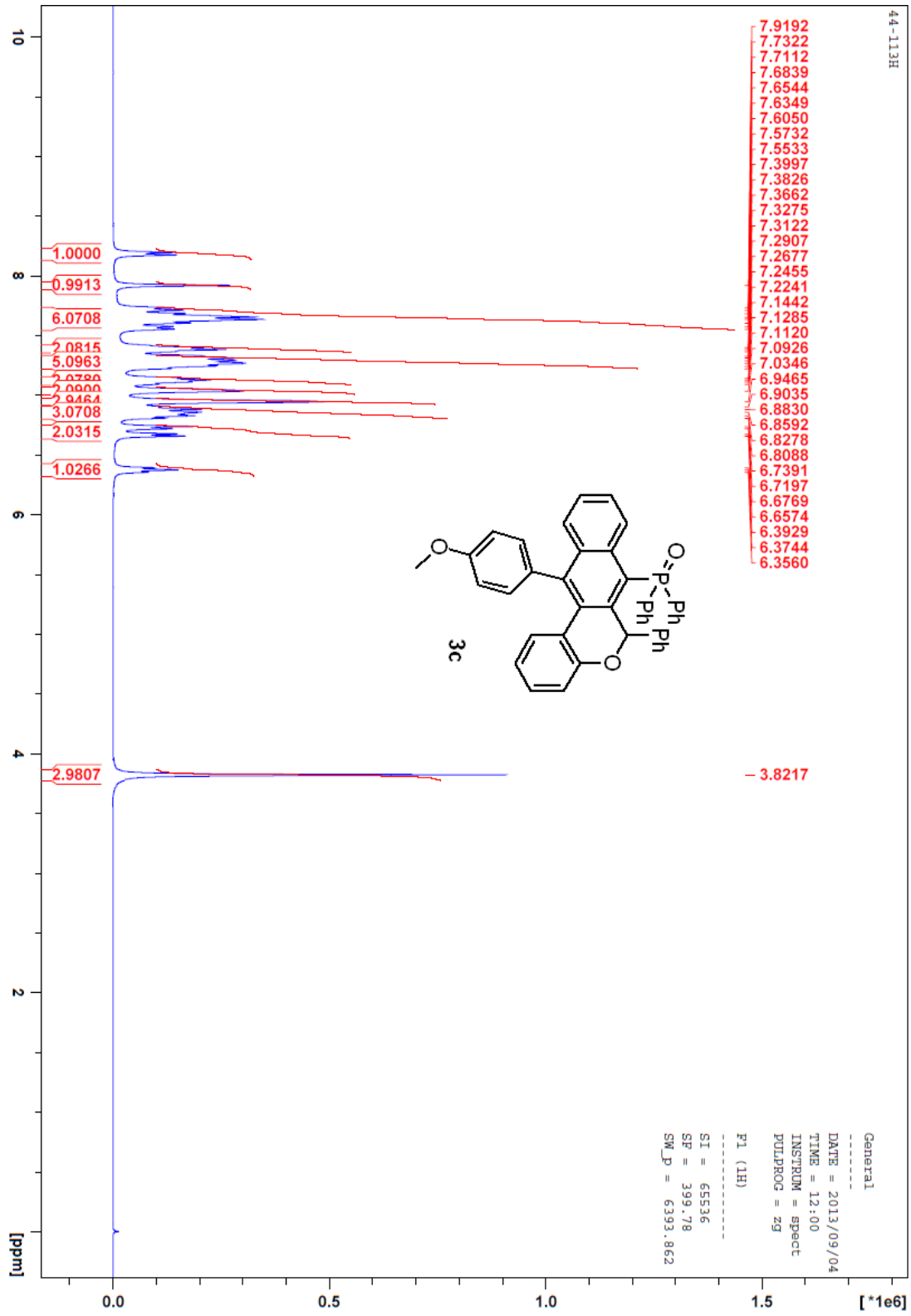

0
5
10
15
20
[rel]
200
150
100
50
[ppm]
1h-C
20140226 1902 1 E:\nmrdata\user\panxiaolin
212.9188
133.3067
133.2499
132.0955
131.7421
131.4957
131.4052
131.3154
131.0373
130.8174
130.6789
130.6026
130.5371
129.8097
128.8474
128.2766
128.0921
128.0280
127.9706
127.9062
127.5852
127.2445
126.6715
102.1927
101.2076
97.1979
97.0684
77.3203
77.0028
76.6857
Cl
Ph
POPh2
1h
General
DATE = 2014/02/26
TIME = 10:55
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462

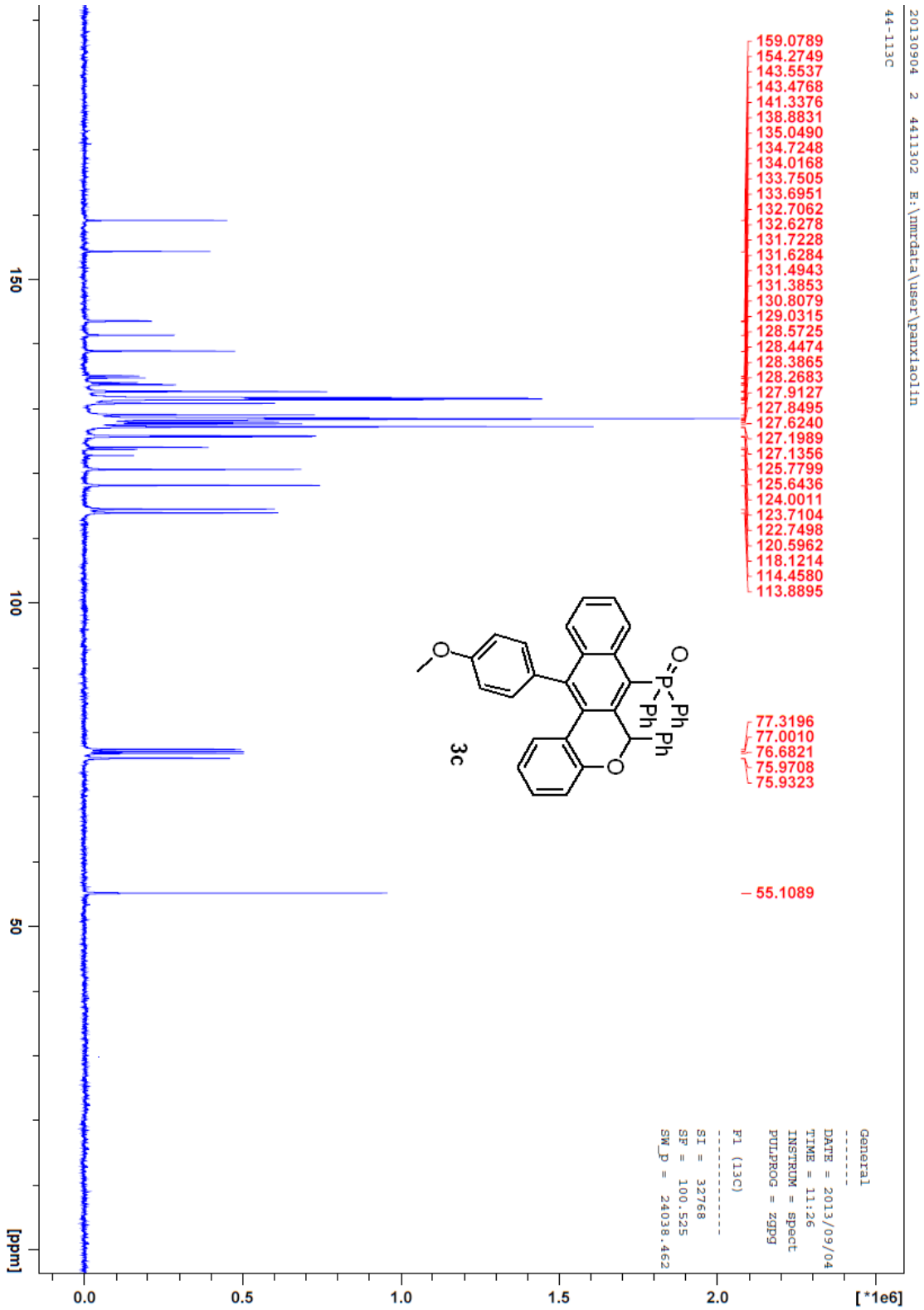

20130529 1441301 1 E:\nmrdata\user\panxiaolin
14413H
7.6409
7.6272
7.6055
7.4721
7.4538
7.4380
7.4178
7.3977
7.3531
7.3453
7.3408
7.3212
7.3016
7.2948
7.2721
7.2489
7.2434
7.1642
7.1456
7.1275
7.0430
7.0337
7.0252
7.0071
6.9817
6.9757
6.8702
6.8522
6.8323
6.7499
6.7312
6.5969
6.5787
6.3560
6.3379
6.3199
1.0059
1.0411
7.0783
3.0491
6.0765
1.0988
6.0634
1.0572
1.0280
0.9912
1.0000
3a
Ph
O
P
Ph
Ph
O
General
DATE = 2013/05/29
TIME = 11:45
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]

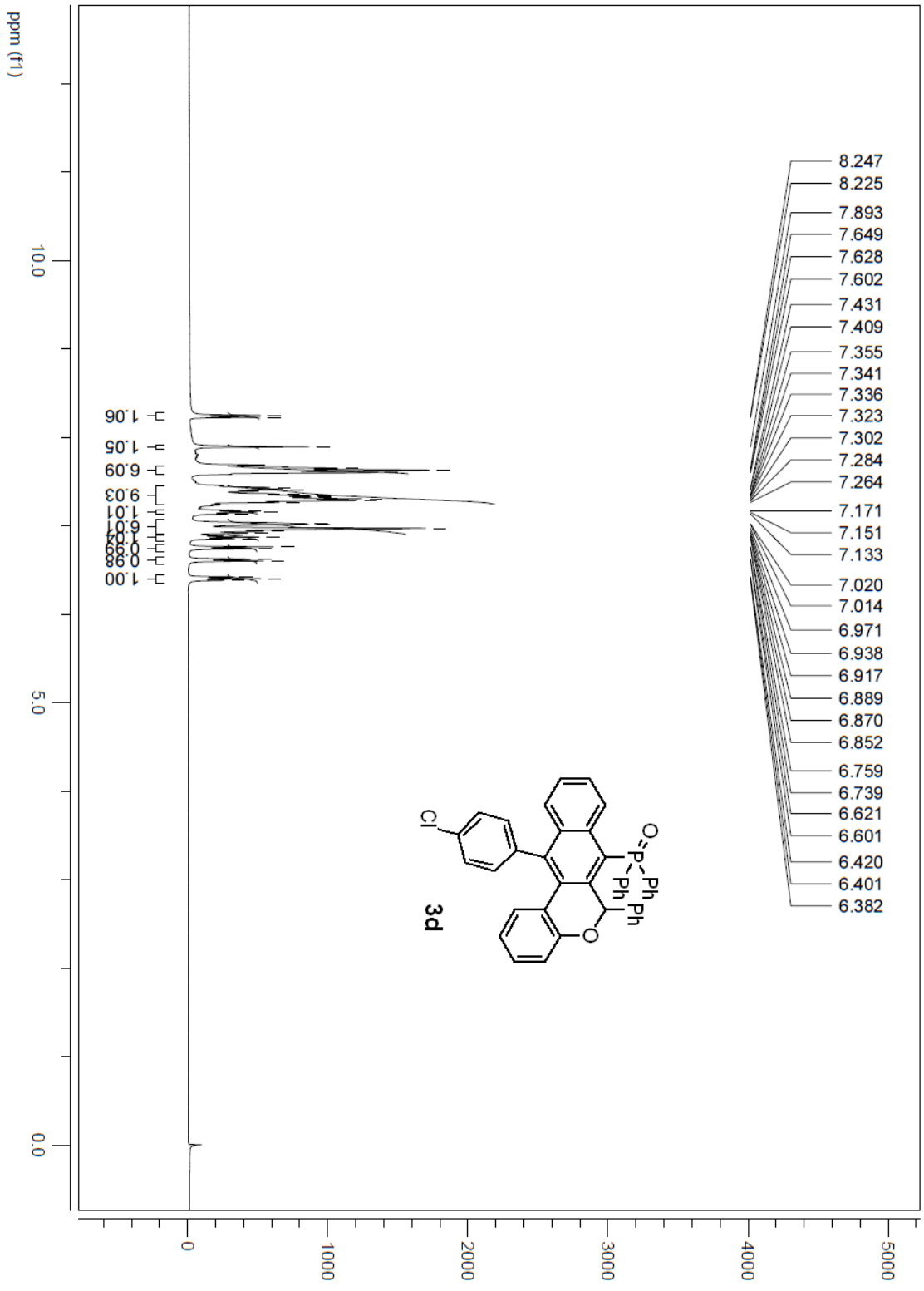

20130529 441302 1 E:\nmrdata\user\panxiaolin
4413C
154.3996
143.5230
143.4451
141.5007
139.5132
138.9716
135.2552
135.0125
134.2232
133.9863
133.4993
133.4090
132.8379
132.7428
131.8757
131.7719
131.6075
131.5100
129.7342
129.4753
129.1139
128.7935
128.5605
128.4899
128.3737
128.1010
128.0061
127.7518
127.6972
127.3207
127.2599
125.9291
125.7877
124.2378
123.9475
123.2808
120.6014
118.2179
77.3166
76.9991
76.6805
76.0898
76.0459
3a
Ph
O
P
Ph
Ph
O
General
DATE = 2013/05/29
TIME = 11:55
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

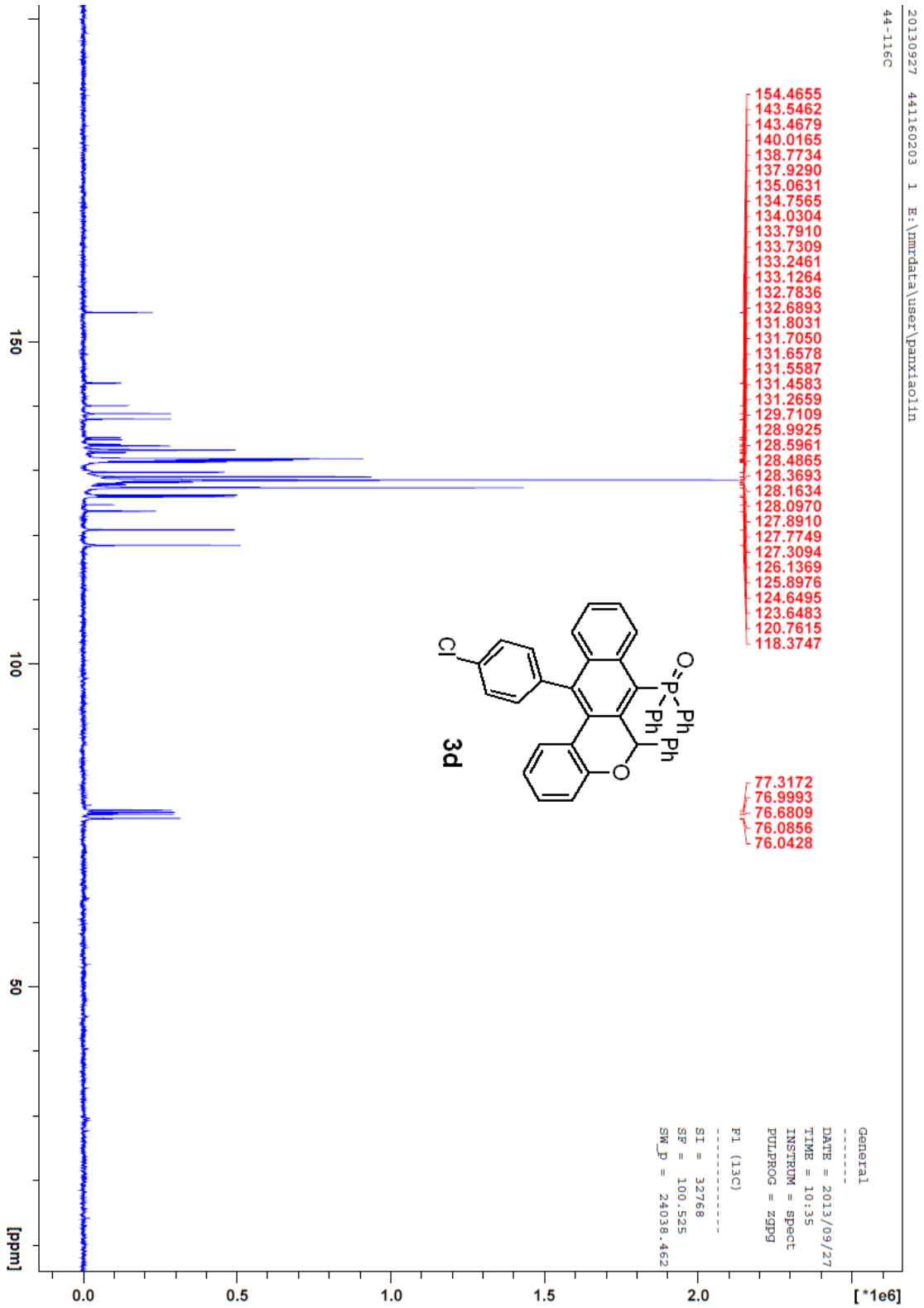

20130904 1 4411101 E:\nmrdata\user\panxiaolin
44-111H
8.2068
8.1859
7.8779
7.6842
7.6545
7.6356
7.5612
7.5437
7.4006
7.3828
7.3139
7.2877
7.2660
7.2498
7.2308
7.1301
7.1150
7.0304
6.9470
6.8729
6.8540
6.8227
6.8050
6.7356
6.7166
6.6729
6.6538
6.3615
6.3438
6.3262
1.0000
1.0699
6.0385
3.0882
5.0619
2.0967
3.0260
2.0340
1.0121
0.9962
2.9859
2.4250
3b
O
P
Ph
Ph
Ph
General
DATE = 2013/09/04
TIME = 12:00
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]
0
200
400
600
800
2
4
6
8
10

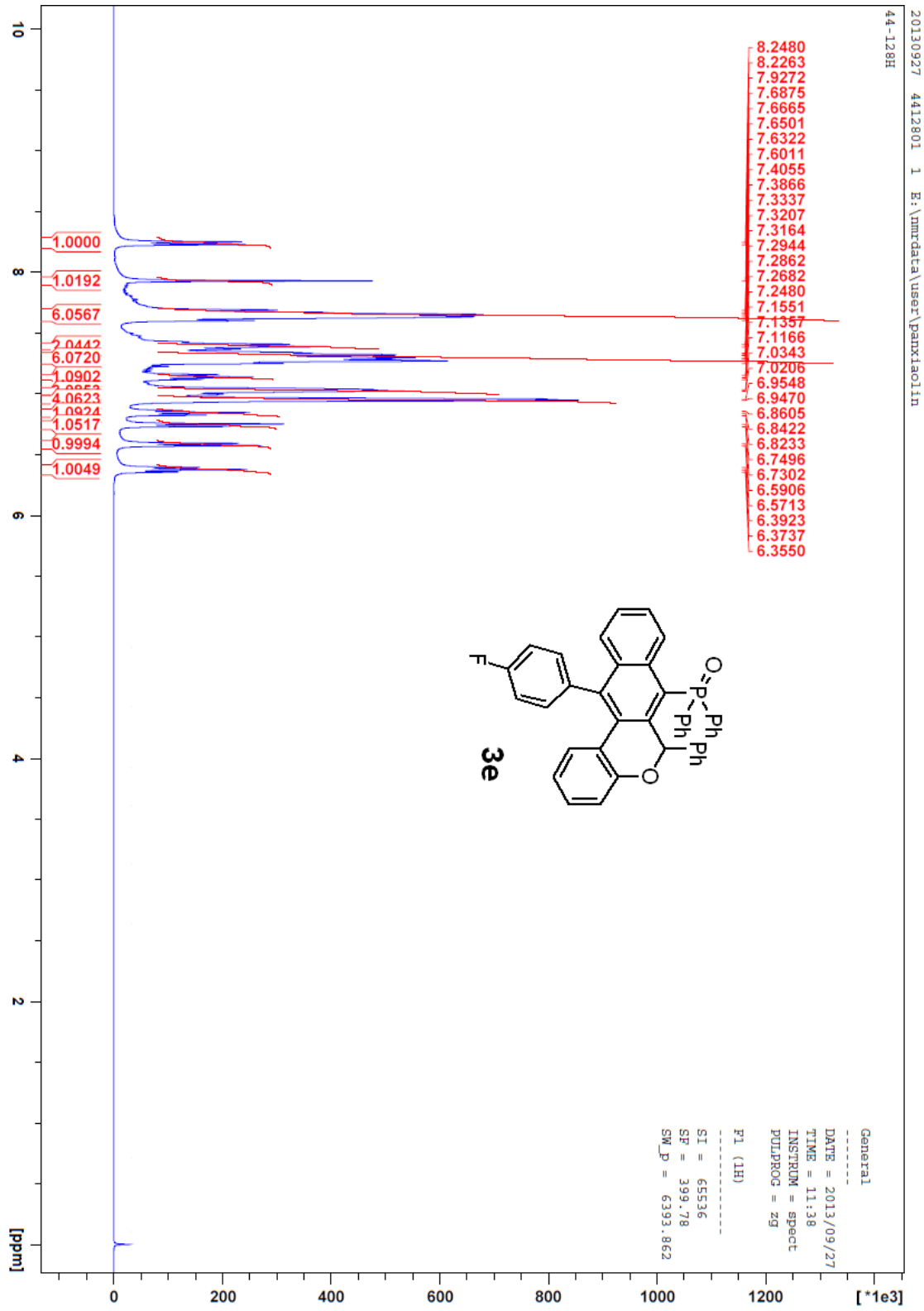

154.2466
143.4567
143.3797
141.6934
138.8457
137.3385
136.2630
134.9598
134.6357
133.9269
133.6050
133.5121
132.7031
132.6085
131.7508
131.6573
131.5115
131.4174
130.0276
129.4287
129.0606
128.7944
128.6237
128.5042
128.4529
128.4032
128.2857
127.8909
127.8266
127.6852
127.2158
127.1656
125.7858
125.6857
123.9494
123.6837
122.7183
120.5353
118.0878
77.3186
77.0001
76.6814
75.9813
75.9430
21.2355
3b
O=P
Ph
Ph
Ph
O
20130904 2 411102 E:\nmrdata\user\panxiaolin
44-111C
General
DATE = 2013/09/04
TIME = 10:47
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
2.5
[*1e6]

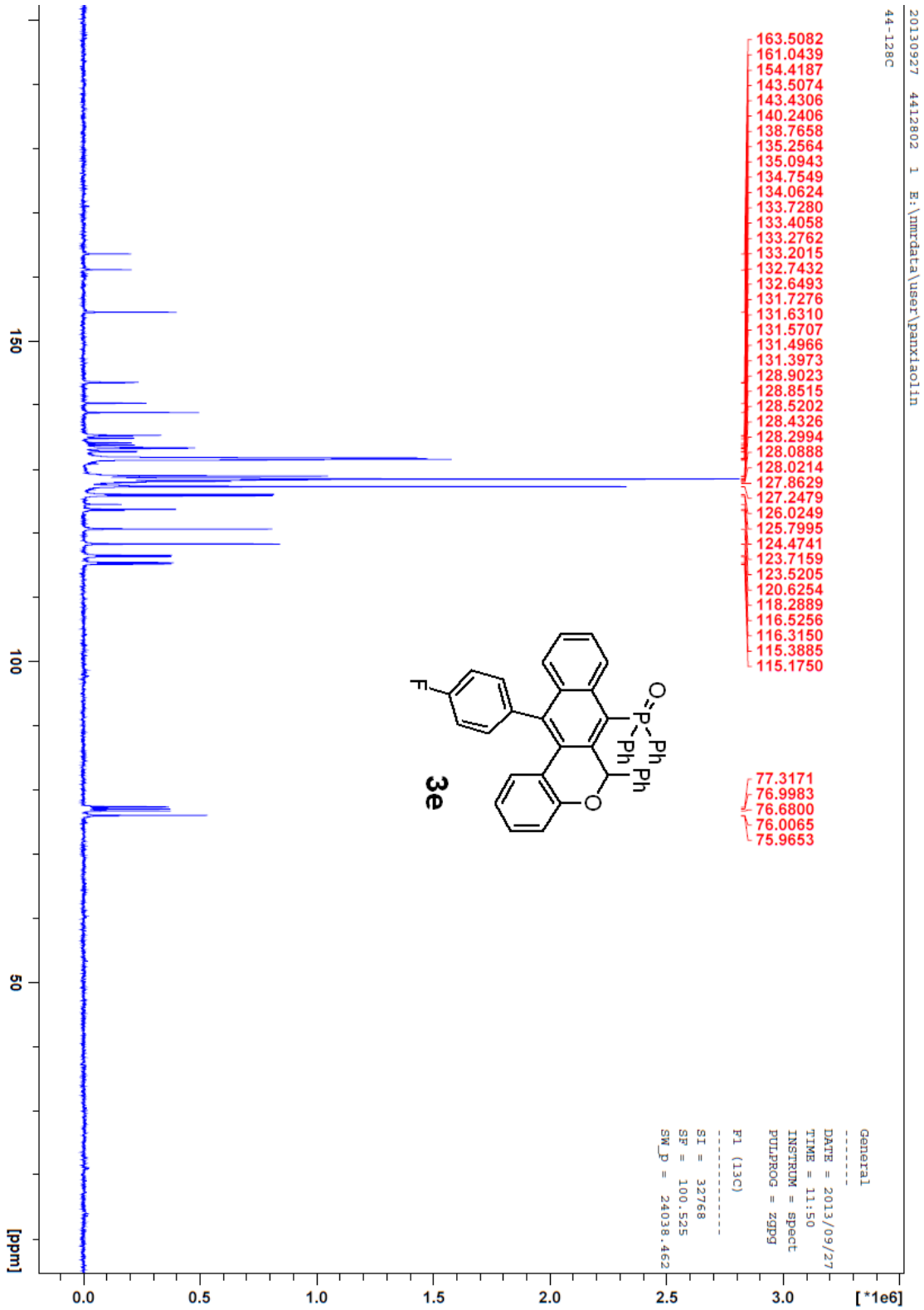

20130904 1 4411301 E:\nmrdata\user\panxiaolin
44-113H
7.9192
7.7322
7.7112
7.6839
7.6544
7.6349
7.6050
7.5732
7.5533
7.3997
7.3826
7.3662
7.3275
7.3122
7.2907
7.2677
7.2455
7.2241
7.1442
7.1285
7.1120
7.0926
7.0346
6.9465
6.9035
6.8830
6.8592
6.8278
6.8088
6.7391
6.7197
6.6769
6.6574
6.3929
6.3744
6.3560
3.8217
1.0000
0.9913
6.0708
2.0815
5.0963
3.0708
2.0315
1.0266
2.9807
3c
O
P
Ph
Ph
Ph
O
O
General
DATE = 2013/09/04
TIME = 12:00
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
10
8
6
4
2
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

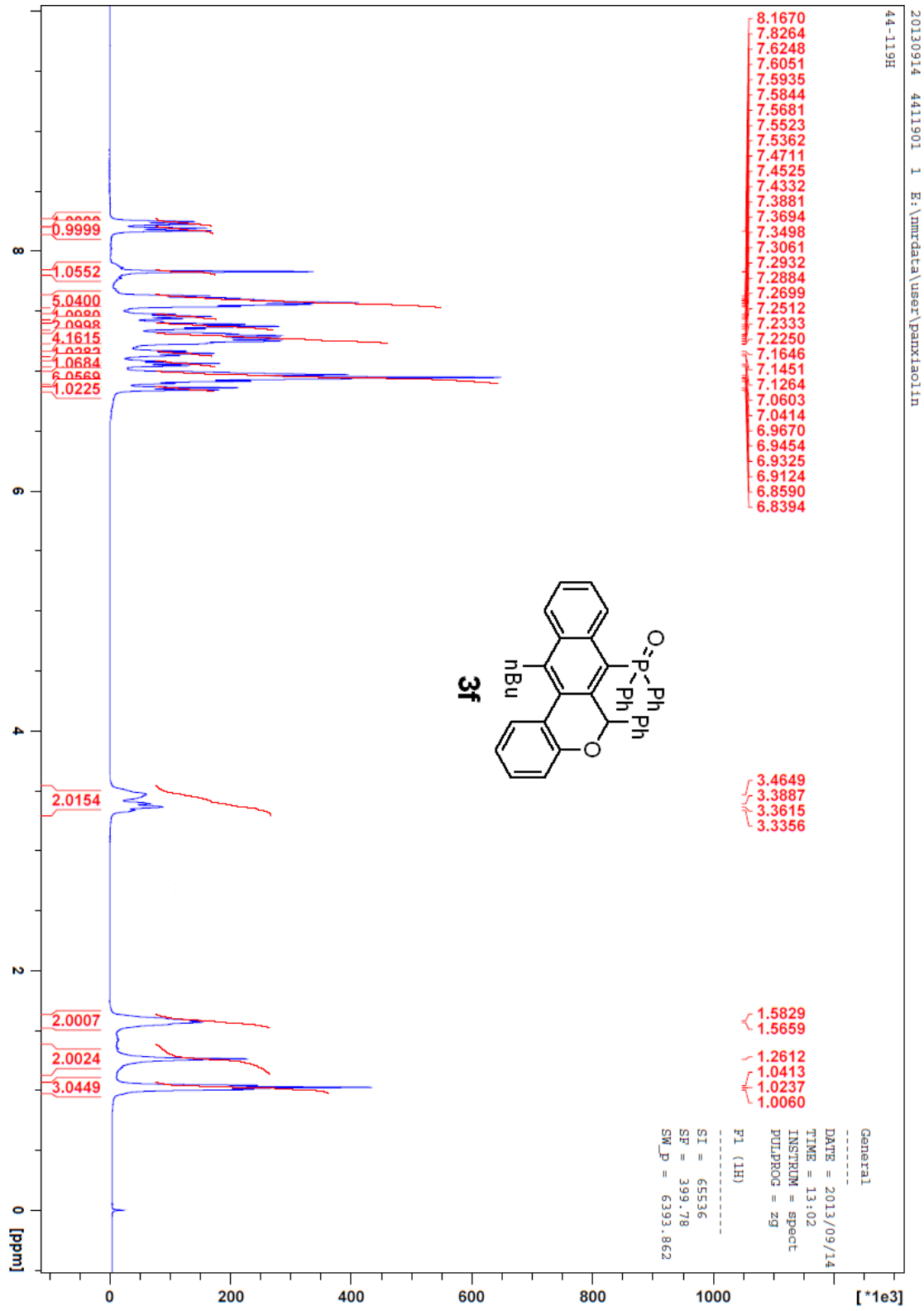

20130904 2 441302 E:\nmrdata\user\panxiaolin
44-113C
159.0789
154.2749
143.5537
143.4768
141.3376
138.8831
135.0490
134.7248
134.0168
133.7505
133.6951
132.7062
132.6278
131.7228
131.6284
131.4943
131.3853
130.8079
129.0315
128.5725
128.4474
128.3865
128.2683
127.9127
127.8495
127.6240
127.1989
127.1356
125.7799
125.6436
124.0011
123.7104
122.7498
120.5962
118.1214
114.4580
113.8895
77.3196
77.0010
76.6821
75.9708
75.9323
55.1089
3c
O=P
Ph
Ph
Ph
O
O
General
DATE = 2013/09/04
TIME = 11:26
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]

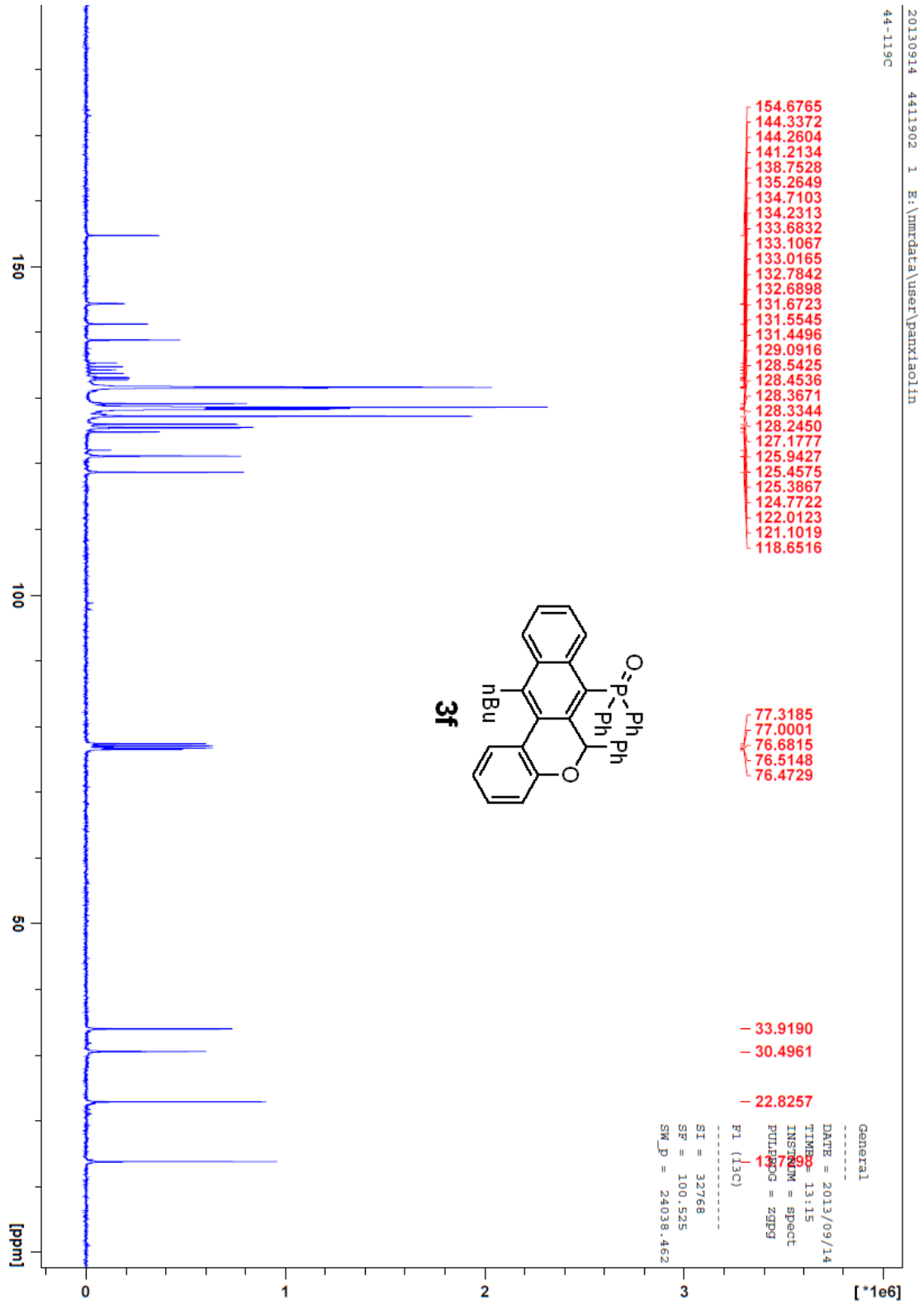

ppm (f1)
10.0
5.0
0.0
0
1000
2000
3000
4000
5000
8.247
8.225
7.893
7.649
7.628
7.602
7.431
7.409
7.355
7.341
7.336
7.323
7.302
7.284
7.264
7.171
7.151
7.133
7.020
7.014
6.971
6.938
6.917
6.889
6.870
6.852
6.759
6.739
6.621
6.601
6.420
6.401
6.382
1.06
1.05
6.09
9.03
1.01
6.01
1.02
0.99
0.98
1.00
Cl
O=P
Ph
Ph
Ph
O
3d

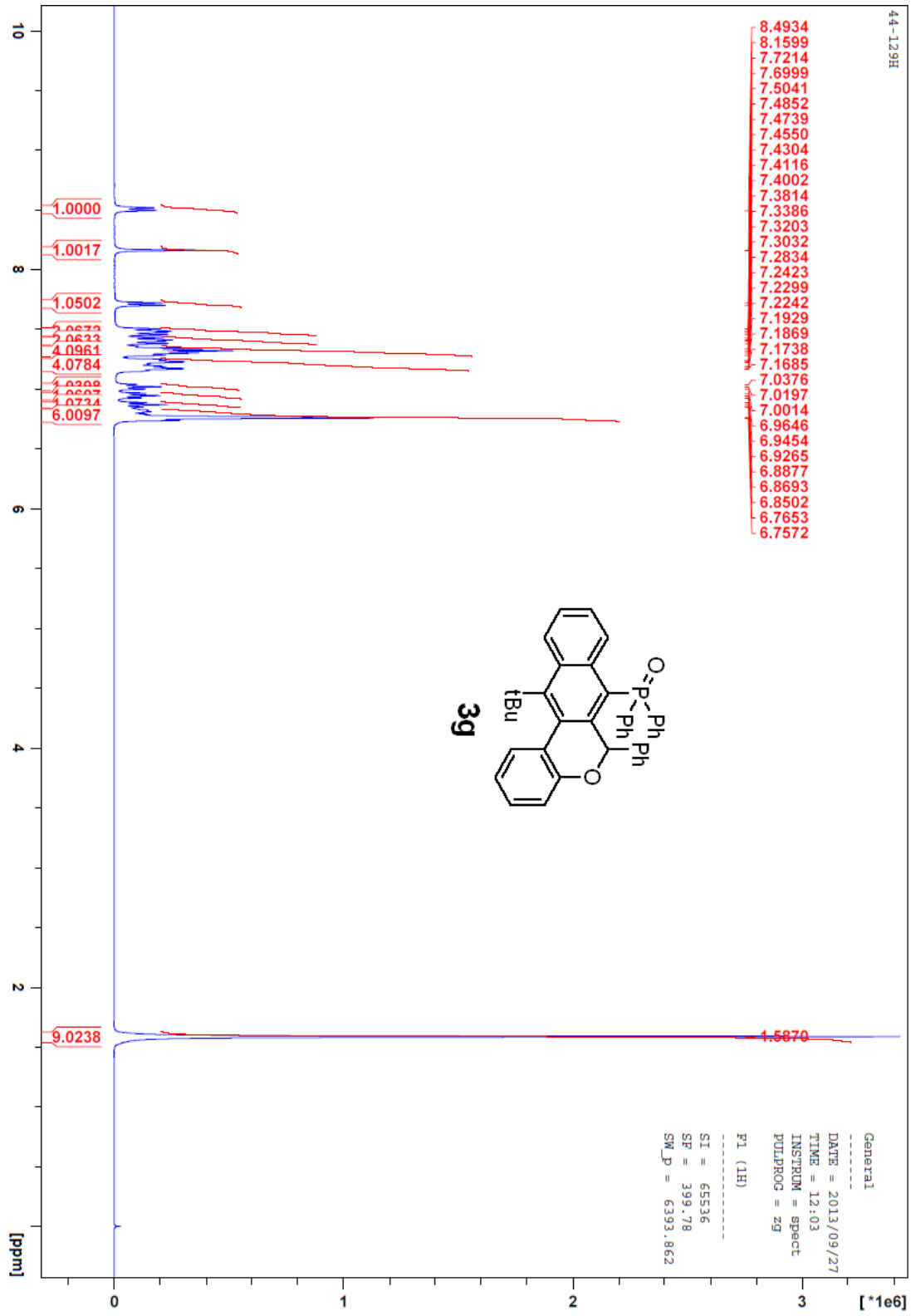

20130927 44160203 1 E:\nmrdata\user\panxiaolin
44-116C
154.4655
143.5462
143.4679
140.0165
138.7734
137.9290
135.0631
134.7565
134.0304
133.7910
133.7309
133.2461
133.1264
132.7836
132.6893
131.8031
131.7050
131.6578
131.5587
131.4583
131.2659
129.7109
128.9925
128.5961
128.4865
128.3693
128.1634
128.0970
127.8910
127.7749
127.3094
126.1369
125.8976
124.6495
123.6483
120.7615
118.3747
77.3172
76.9993
76.6809
76.0856
76.0428
Cl
O
P
Ph
Ph
Ph
O
3d
General
DATE = 2013/09/27
TIME = 10:35
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]

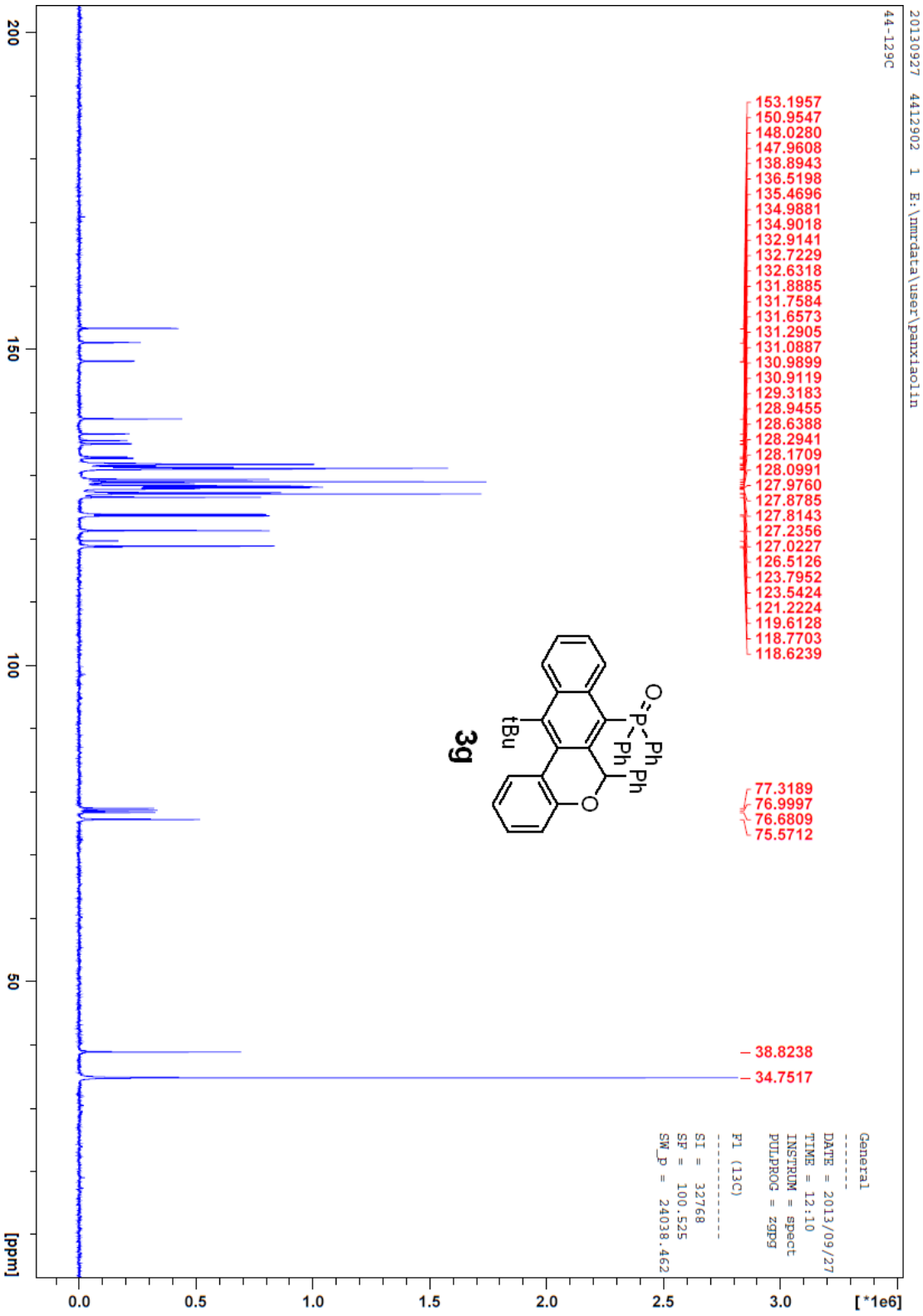

20130927 4412801 1 E:\nmrdata\user\panxiaolin
44-128H
8.2480
8.2263
7.9272
7.6875
7.6665
7.6501
7.6322
7.6011
7.4055
7.3866
7.3337
7.3207
7.3164
7.2944
7.2862
7.2682
7.2480
7.1551
7.1357
7.1166
7.0343
7.0206
6.9548
6.9470
6.8605
6.8422
6.8233
6.7496
6.7302
6.5906
6.5713
6.3923
6.3737
6.3550
1.0000
1.0192
6.0567
2.0442
6.0720
1.0902
4.0623
1.0924
1.0517
0.9994
1.0049
F
O=P
Ph
Ph
Ph
O
3e
General
DATE = 2013/09/27
TIME = 11:38
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]

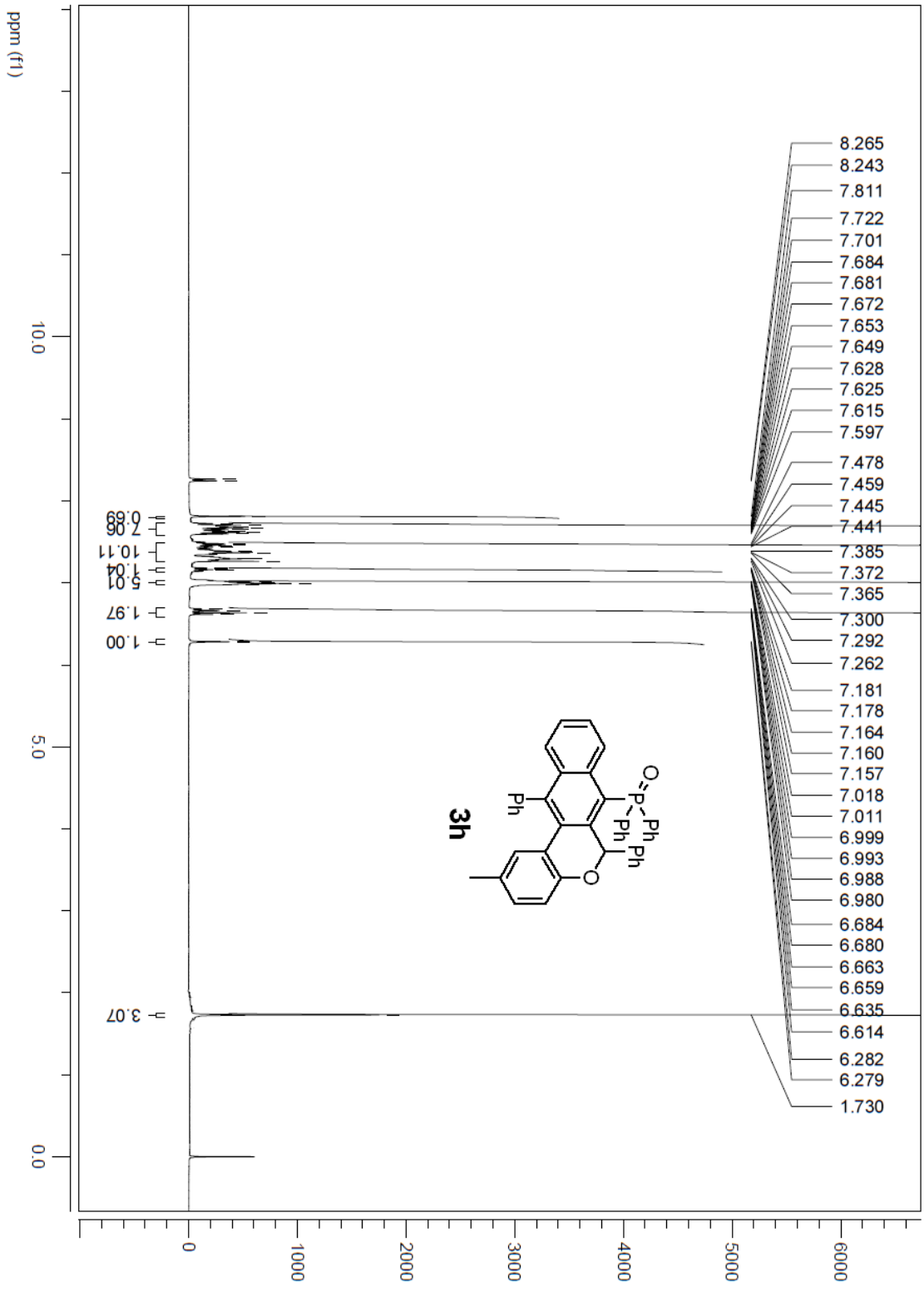

20130927 4412802 1 E:\nmrdata\user\panxiaolin
44-128C
163.5082
161.0439
154.4187
143.5074
143.4306
140.2406
138.7658
135.2564
135.0943
134.7549
134.0624
133.7280
133.4058
133.2762
133.2015
132.7432
132.6493
131.7276
131.6310
131.5707
131.4966
131.3973
128.9023
128.8515
128.5202
128.4326
128.2994
128.0888
128.0214
127.8629
127.2479
126.0249
125.7995
124.4741
123.7159
123.5205
120.6254
118.2889
116.5256
116.3150
115.3885
115.1750
77.3171
76.9983
76.6800
76.0065
75.9653
3e
F
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 11:50
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
[*1e6]

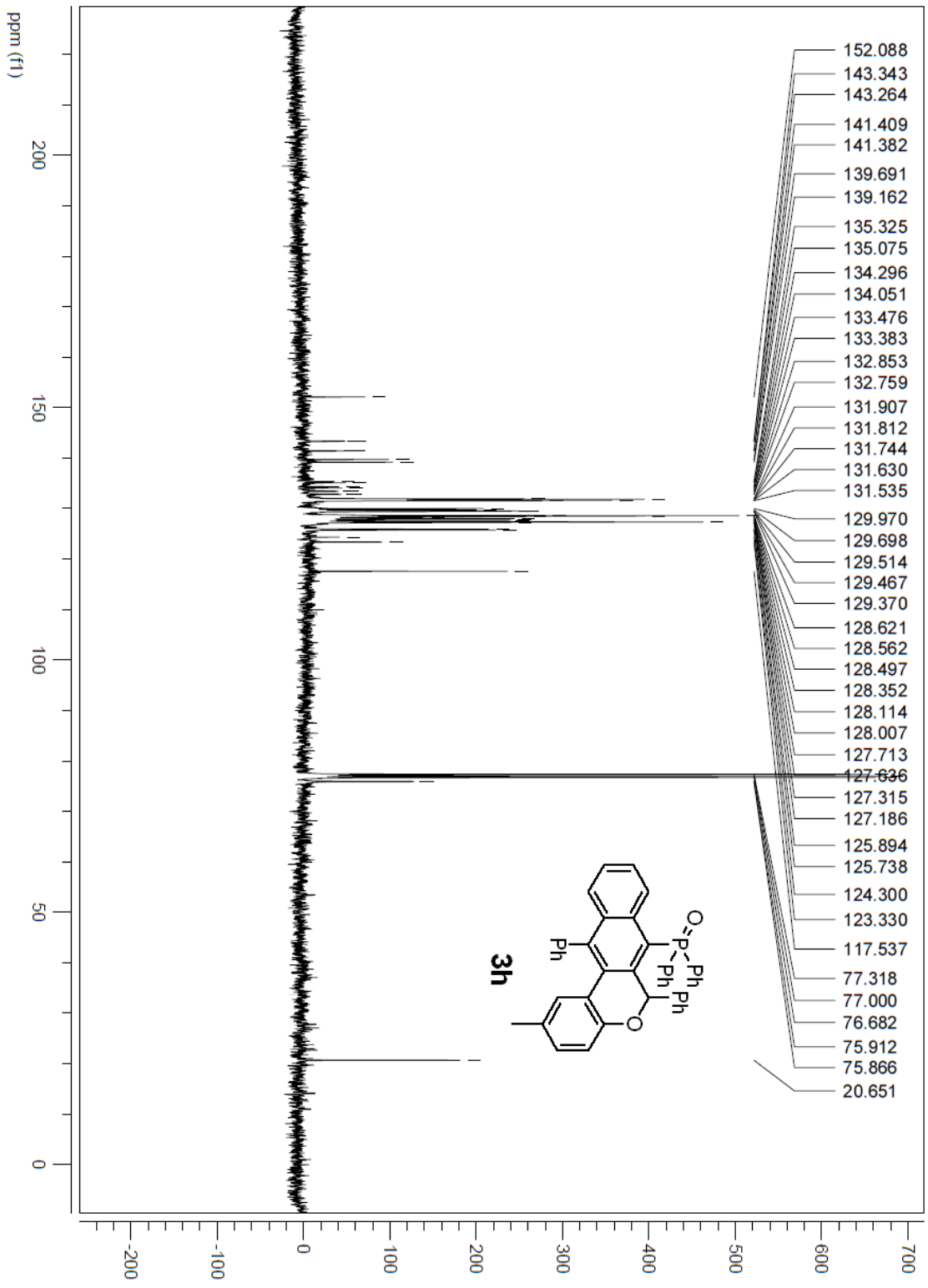

20130914 4411901 1 E:\nmrdata\user\panxiaolin
44-119H
8.1670
7.8264
7.6248
7.6051
7.5935
7.5844
7.5681
7.5523
7.5362
7.4711
7.4525
7.4332
7.3881
7.3694
7.3498
7.3061
7.2932
7.2884
7.2699
7.2512
7.2333
7.2250
7.1646
7.1451
7.1264
7.0603
7.0414
6.9670
6.9454
6.9325
6.9124
6.8590
6.8394
3.4649
3.3887
3.3615
3.3356
1.5829
1.5659
1.2612
1.0413
1.0237
1.0060
0.9999
1.0552
5.0400
4.1615
1.0684
1.0225
2.0154
2.0007
2.0024
3.0449
3f
nBu
Ph
Ph
O
P
O
General
DATE = 2013/09/14
TIME = 13:02
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]

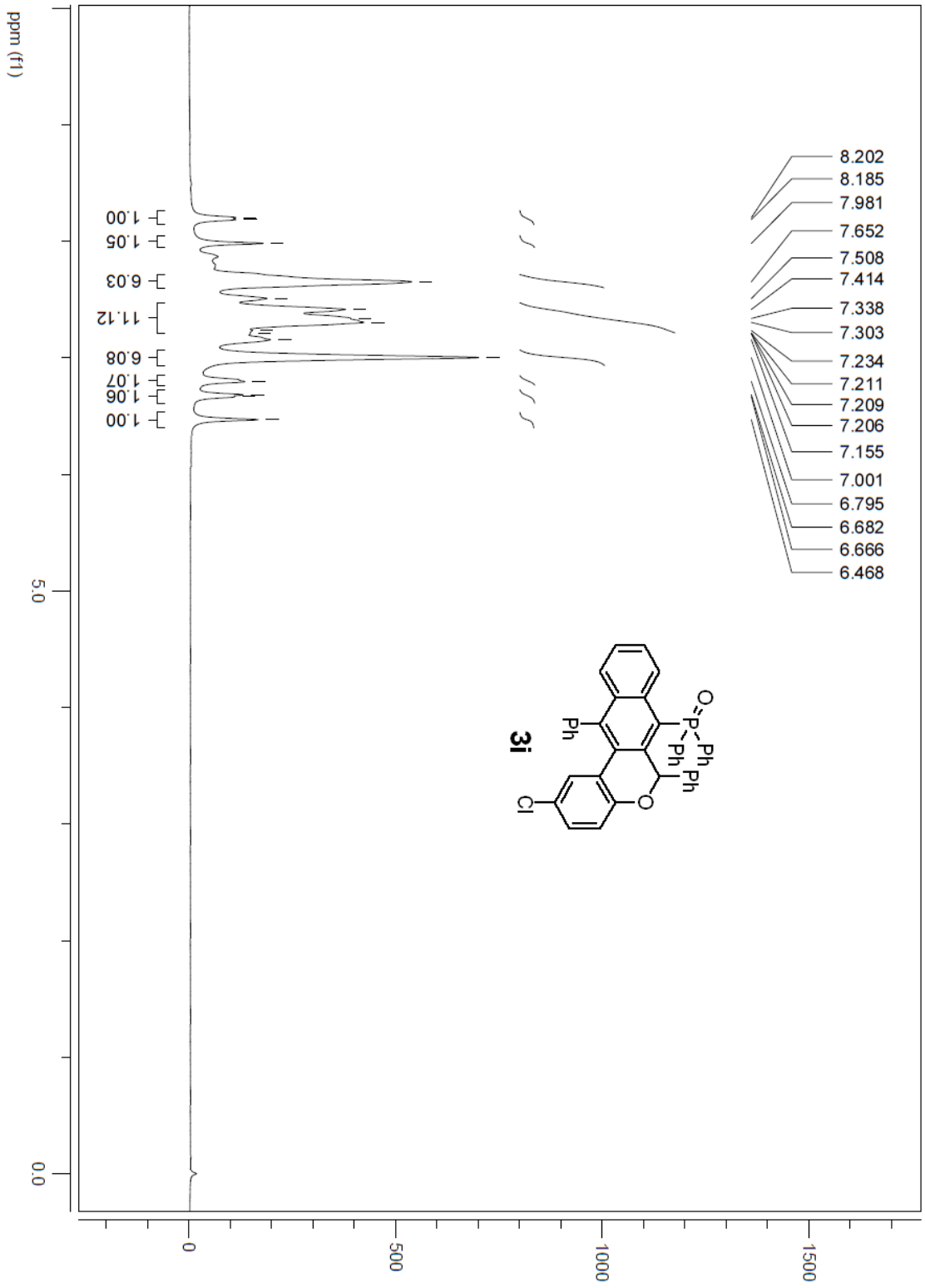

20130914 4411902 1 E:\nmrdata\user\panxiaolin
44-119C
154.6765
144.3372
144.2604
141.2134
138.7528
135.2649
134.7103
134.2313
133.6832
133.1067
133.0165
132.7842
132.6898
131.6723
131.5545
131.4496
129.0916
128.5425
128.4536
128.3671
128.3344
128.2450
127.1777
125.9427
125.4575
125.3867
124.7722
122.0123
121.1019
118.6516
77.3185
77.0001
76.6815
76.5148
76.4729
33.9190
30.4961
22.8257
13.7990
3f
nBu
O=P
Ph
Ph
O
General
DATE = 2013/09/14
TIME = 13:15
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0
1
2
3
[*1e6]

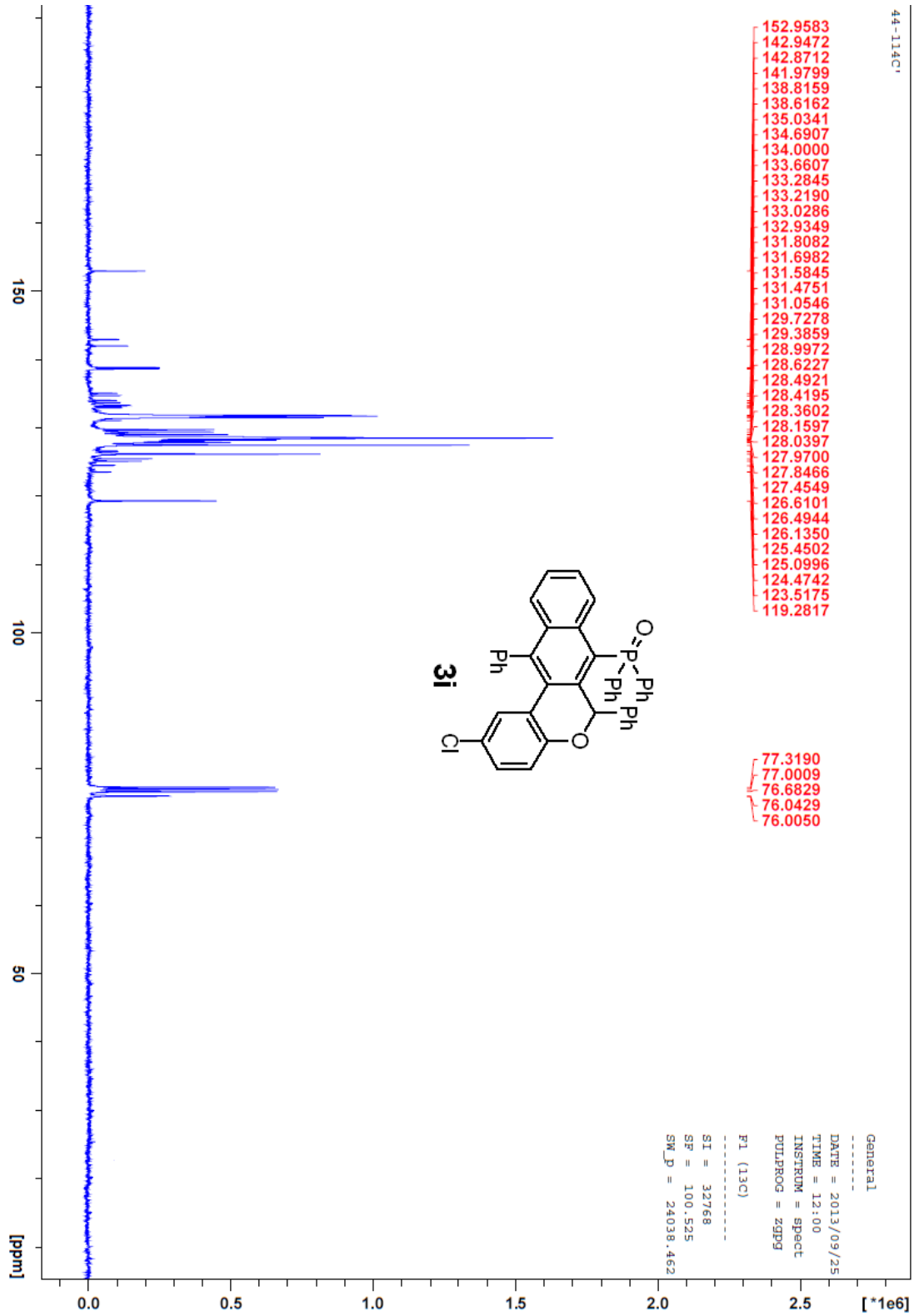

20130927 4412901 1 E:\nmrdata\user\panxiaolin
44-129H
8.4934
8.1599
7.7214
7.6999
7.5041
7.4852
7.4739
7.4550
7.4304
7.4116
7.4002
7.3814
7.3386
7.3203
7.3032
7.2834
7.2423
7.2299
7.2242
7.1929
7.1869
7.1738
7.1685
7.0376
7.0197
7.0014
6.9646
6.9454
6.9265
6.8877
6.8693
6.8502
6.7653
6.7572
1.0000
1.0017
1.0502
4.0961
4.0784
6.0097
9.0238
1.5870
3g
tBu
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 12:03
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e6]

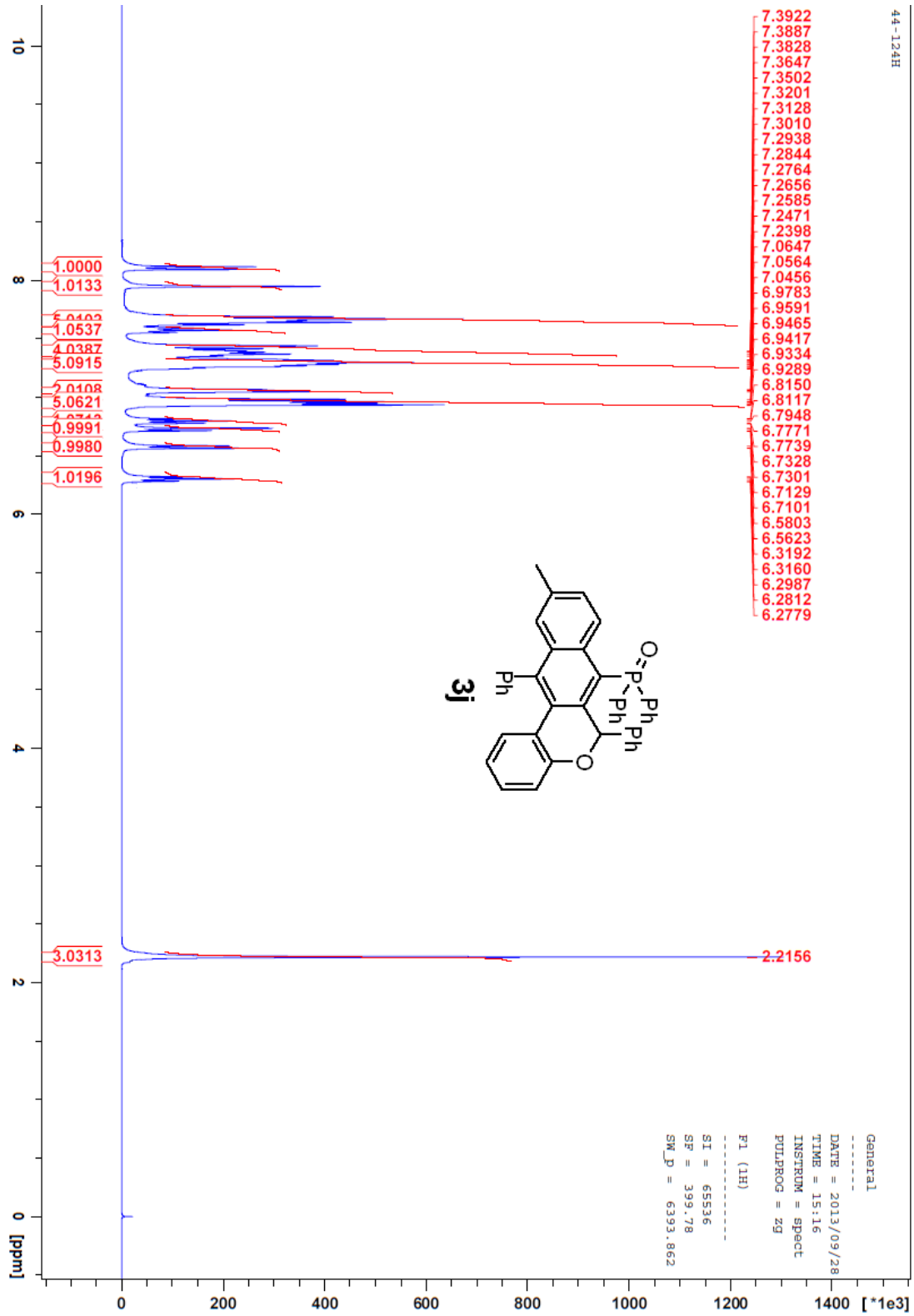

20130927 4412902 1 E:\nmrdata\user\panxiaolin
44-129C
153.1957
150.9547
148.0280
147.9608
138.8943
136.5198
135.4696
134.9881
134.9018
132.9141
132.7229
132.6318
131.8885
131.7584
131.6573
131.2905
131.0887
130.9899
130.9119
129.3183
128.9455
128.6388
128.2941
128.1709
128.0991
127.9760
127.8785
127.8143
127.2356
127.0227
126.5126
123.7952
123.5424
121.2224
119.6128
118.7703
118.6239
77.3189
76.9997
76.6809
75.5712
38.8238
34.7517
3g
tBu
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 12:10
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
[*1e6]

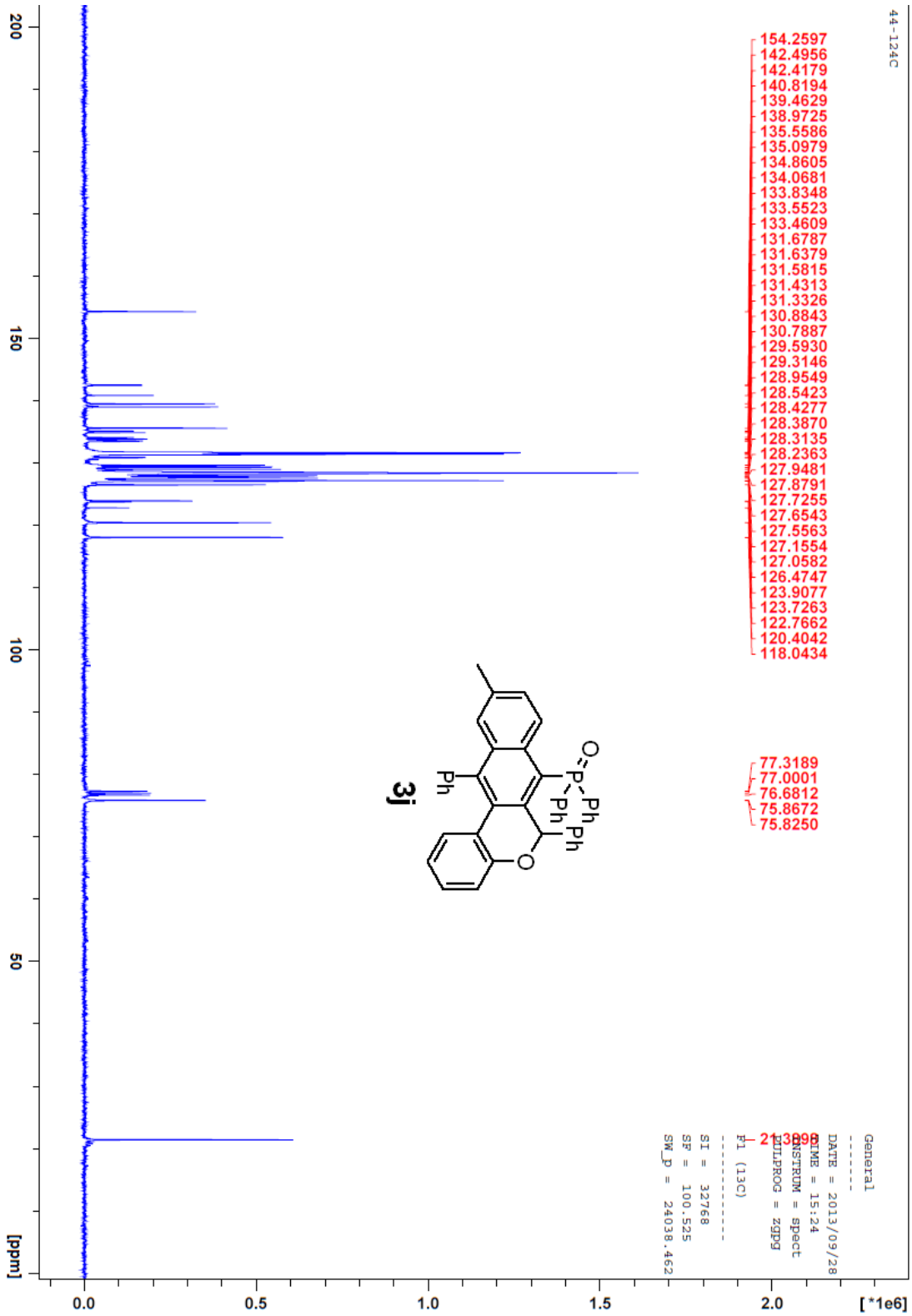

ppm (f1)
10.0
5.0
0.0
0
1000
2000
3000
4000
5000
6000
8.265
8.243
7.811
7.722
7.701
7.684
7.681
7.672
7.653
7.649
7.628
7.625
7.615
7.597
7.478
7.459
7.445
7.441
7.385
7.372
7.365
7.300
7.292
7.262
7.181
7.178
7.164
7.160
7.157
7.018
7.011
6.999
6.993
6.988
6.980
6.684
6.680
6.663
6.659
6.635
6.614
6.282
6.279
1.730
3.07
1.00
1.97
5.01
1.04
10.11
7.06
0.69
3h
Ph
O=P
Ph
Ph
Ph
O

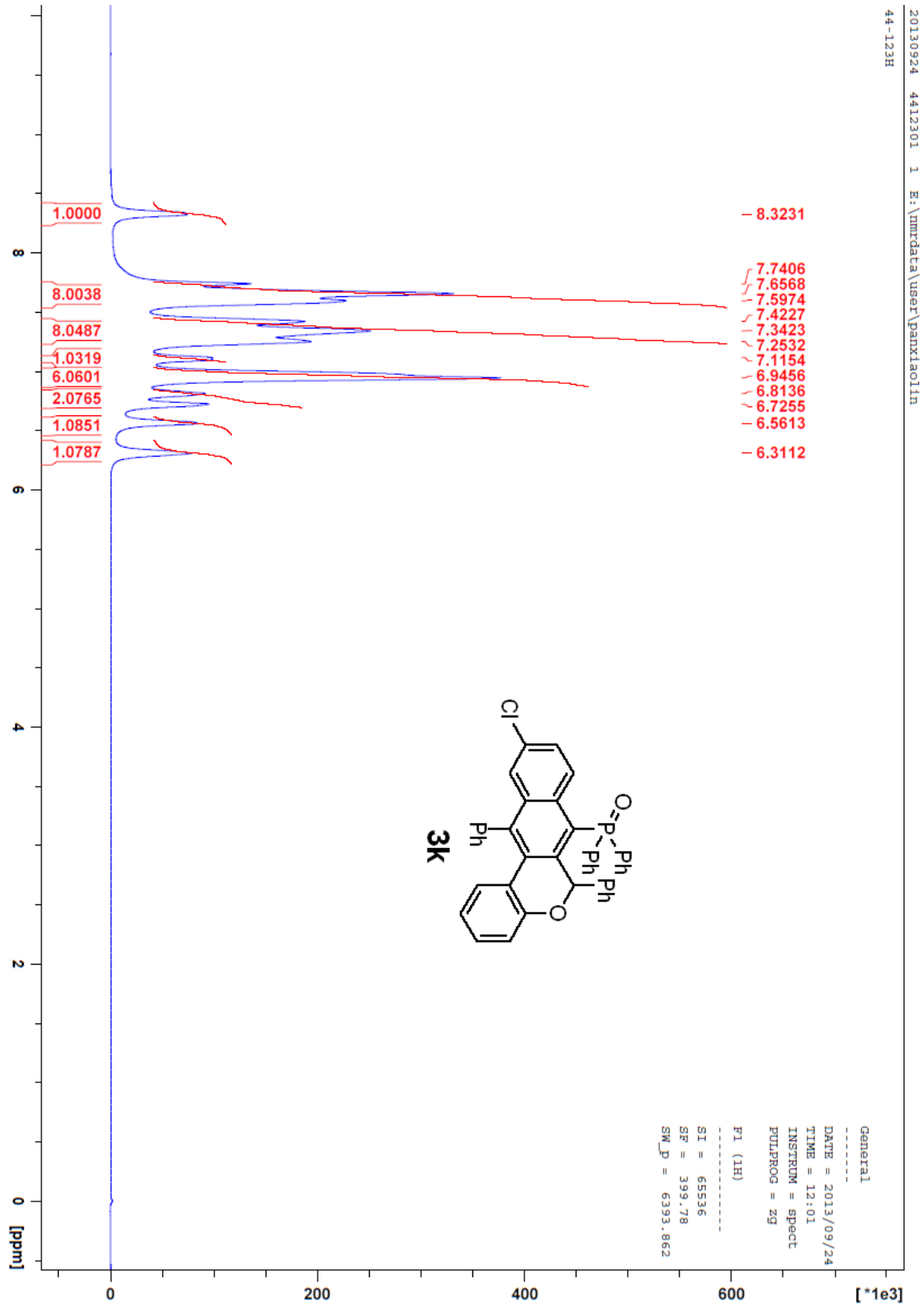

ppm (f1)
200
150
100
50
0
-200
-100
0
100
200
300
400
500
600
700
152.088
143.343
143.264
141.409
141.382
139.691
139.162
135.325
135.075
134.296
134.051
133.476
133.383
132.853
132.759
131.907
131.812
131.744
131.630
131.535
129.970
129.698
129.514
129.467
129.370
128.621
128.562
128.497
128.352
128.114
128.007
127.713
127.636
127.315
127.186
125.894
125.738
124.300
123.330
117.537
77.318
77.000
76.682
75.912
75.866
20.651
3h
Ph
O=P
Ph
Ph
Ph
O

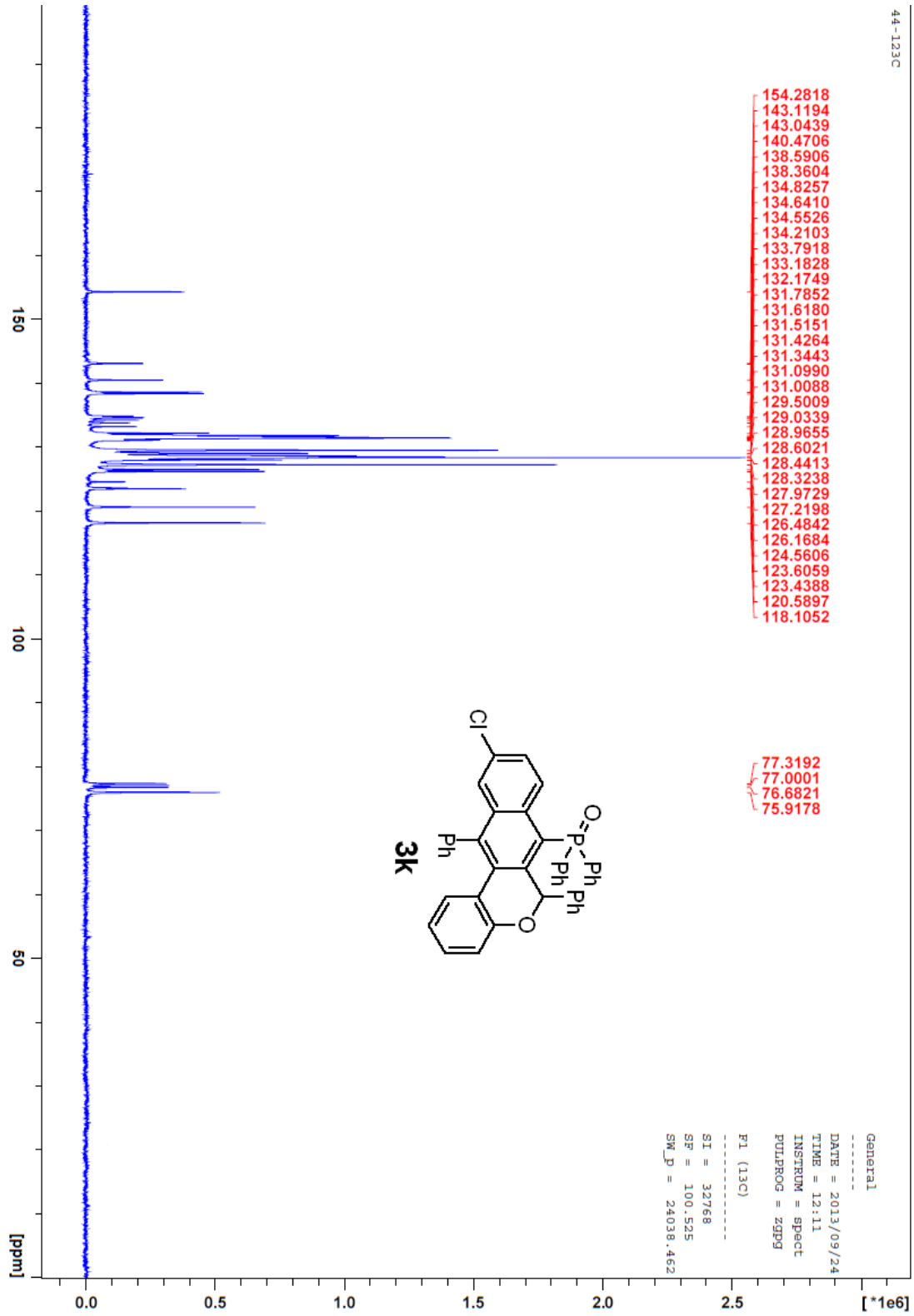

ppm (f1)
5.0
0.0
0
500
1000
1500
1.00
1.05
6.03
11.12
6.08
1.07
1.06
1.00
8.202
8.185
7.981
7.652
7.508
7.414
7.338
7.303
7.234
7.211
7.209
7.206
7.155
7.001
6.795
6.682
6.666
6.468
3i
Ph
Cl
O
P
Ph
Ph
Ph


20130925 44114O203 1 E:\nmrdata\user\panxiaolin
44-114C'
152.9583
142.9472
142.8712
141.9799
138.8159
138.6162
135.0341
134.6907
134.0000
133.6607
133.2845
133.2190
133.0286
132.9349
131.8082
131.6982
131.5845
131.4751
131.0546
129.7278
129.3859
128.9972
128.6227
128.4921
128.4195
128.3602
128.1597
128.0397
127.9700
127.8466
127.4549
126.6101
126.4944
126.1350
125.4502
125.0996
124.4742
123.5175
119.2817
77.3190
77.0009
76.6829
76.0429
76.0050
3i
Ph
Cl
O
O=P
Ph
Ph
Ph
General
DATE = 2013/09/25
TIME = 12:00
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
2.5
[*1e6]


20130928 44124O103 1 E:\nmrdata\user\panxiaoln
44-124H
7.3922
7.3887
7.3828
7.3647
7.3502
7.3201
7.3128
7.3010
7.2938
7.2844
7.2764
7.2656
7.2585
7.2471
7.2398
7.0647
7.0564
7.0456
6.9783
6.9591
6.9465
6.9417
6.9334
6.9289
6.8150
6.8117
6.7948
6.7771
6.7739
6.7328
6.7301
6.7129
6.7101
6.5803
6.5623
6.3192
6.3160
6.2987
6.2812
6.2779
1.0000
1.0133
1.0537
5.0915
5.0621
0.9991
0.9980
1.0196
3.0313
2.2156
3j
Ph
O=P
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 15:16
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]


20130928 44240203 1 E:\nmrdata\user\panxiaolin
44-124C
154.2597
142.4956
142.4179
140.8194
139.4629
138.9725
135.5586
135.0979
134.8605
134.0681
133.8348
133.5523
133.4609
131.6787
131.6379
131.5815
131.4313
131.3326
130.8843
130.7887
129.5930
129.3146
128.9549
128.5423
128.4277
128.3870
128.3135
128.2363
127.9481
127.8791
127.7255
127.6543
127.5563
127.1554
127.0582
126.4747
123.9077
123.7263
122.7662
120.4042
118.0434
77.3189
77.0001
76.6812
75.8672
75.8250
21.3898
3j
Ph
O=P
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 15:24
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]


20130924 4412301 1 E:\nmrdata\user\panxiaolin
44-123H
1.0000
8.0038
8.0487
1.0319
6.0601
2.0765
1.0851
1.0787
8.3231
7.7406
7.6568
7.5974
7.4227
7.3423
7.2532
7.1154
6.9456
6.8136
6.7255
6.5613
6.3112
Cl
Ph
O=P
Ph
Ph
O
3k
General
DATE = 2013/09/24
TIME = 12:01
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e3]


20130924 4412302 1 E:\nmrdata\user\panxiaolin
44-123C
154.2818
143.1194
143.0439
140.4706
138.5906
138.3604
134.8257
134.6410
134.5526
134.2103
133.7918
133.1828
132.1749
131.7852
131.6180
131.5151
131.4264
131.3443
131.0990
131.0088
129.5009
129.0339
128.9655
128.6021
128.4413
128.3238
127.9729
127.2198
126.4842
126.1684
124.5606
123.6059
123.4388
120.5897
118.1052
77.3192
77.0001
76.6821
75.9178
Cl
Ph
O=P
Ph
Ph
Ph
O
3k
General
DATE = 2013/09/24
TIME = 12:11
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
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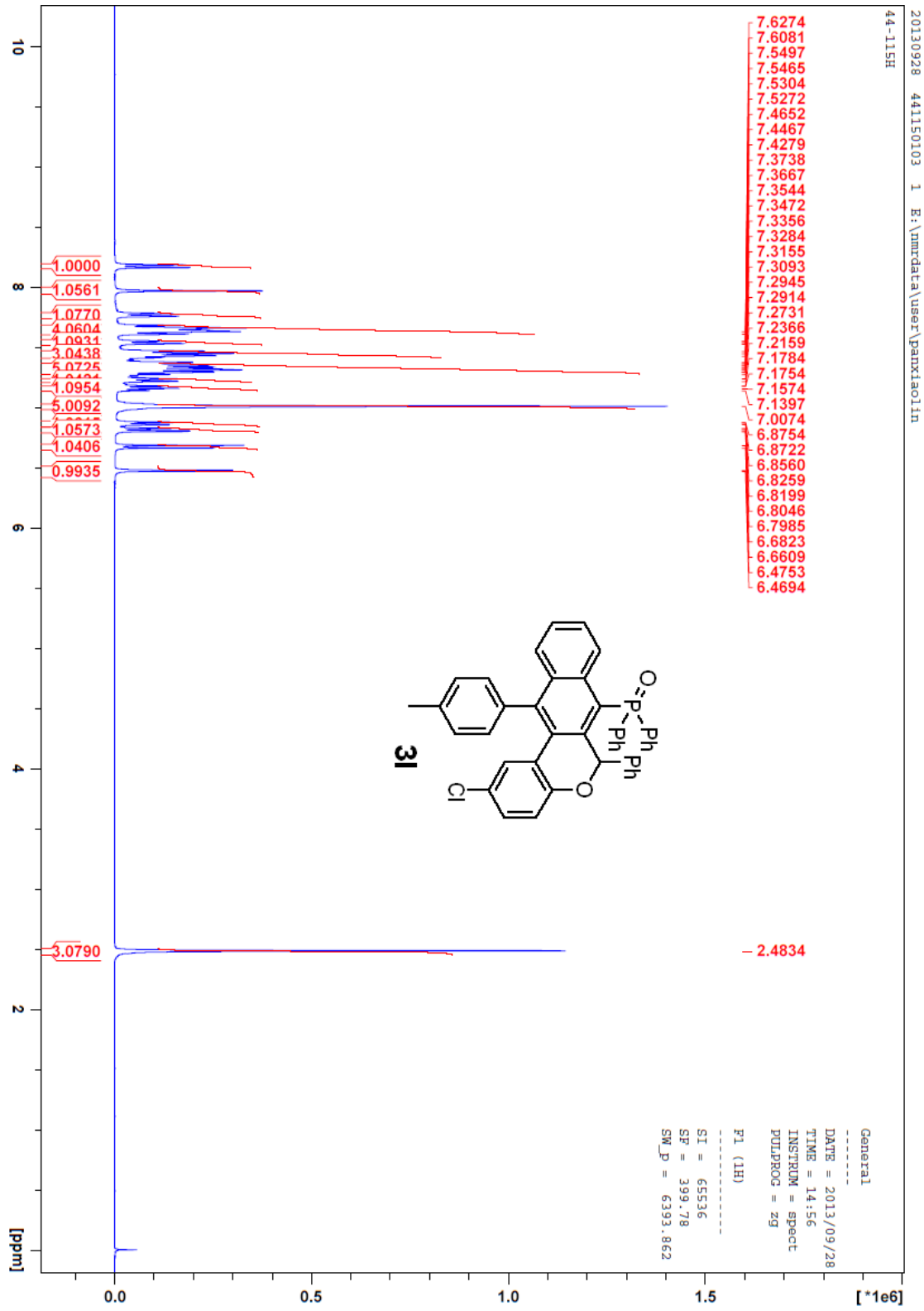
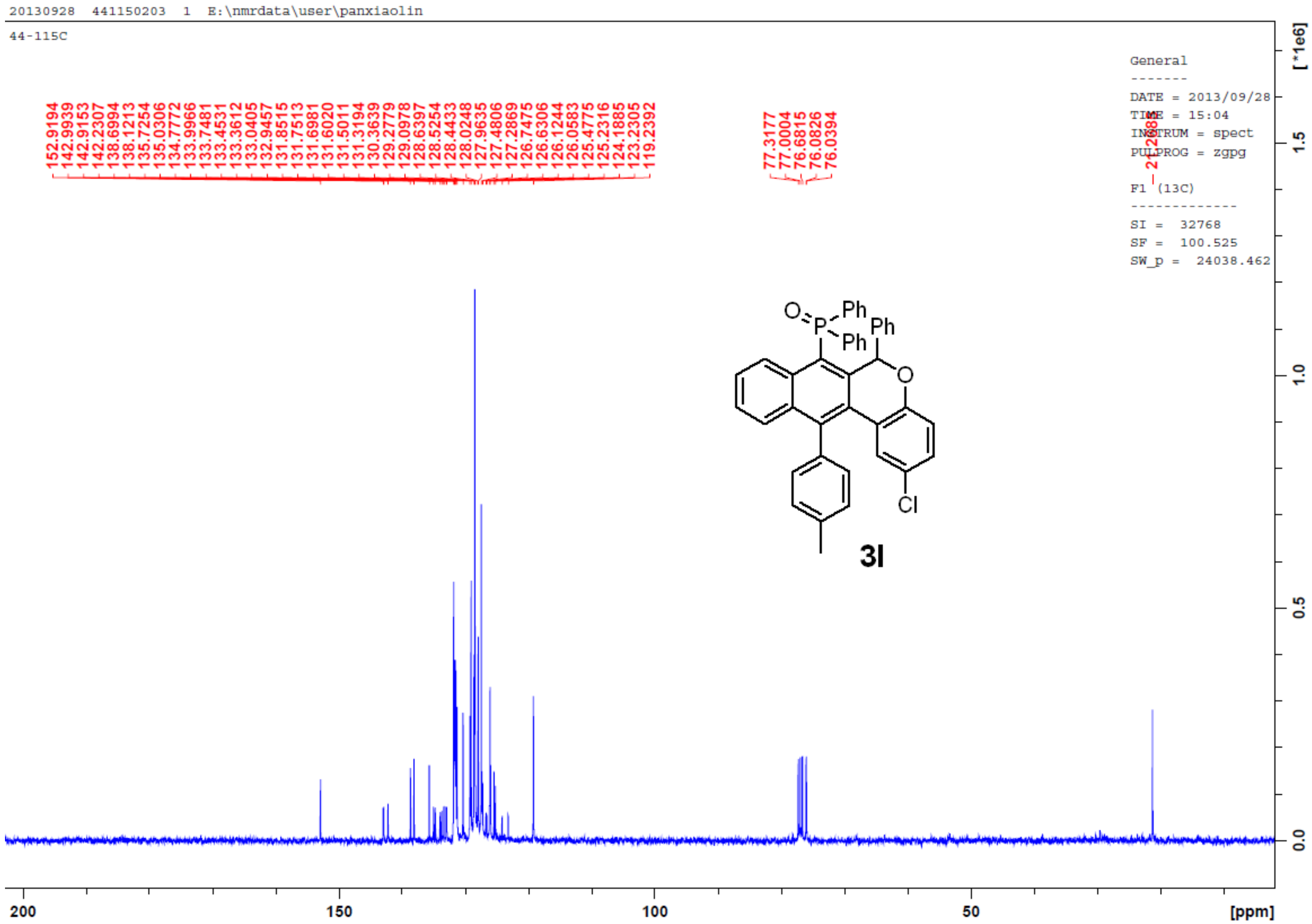
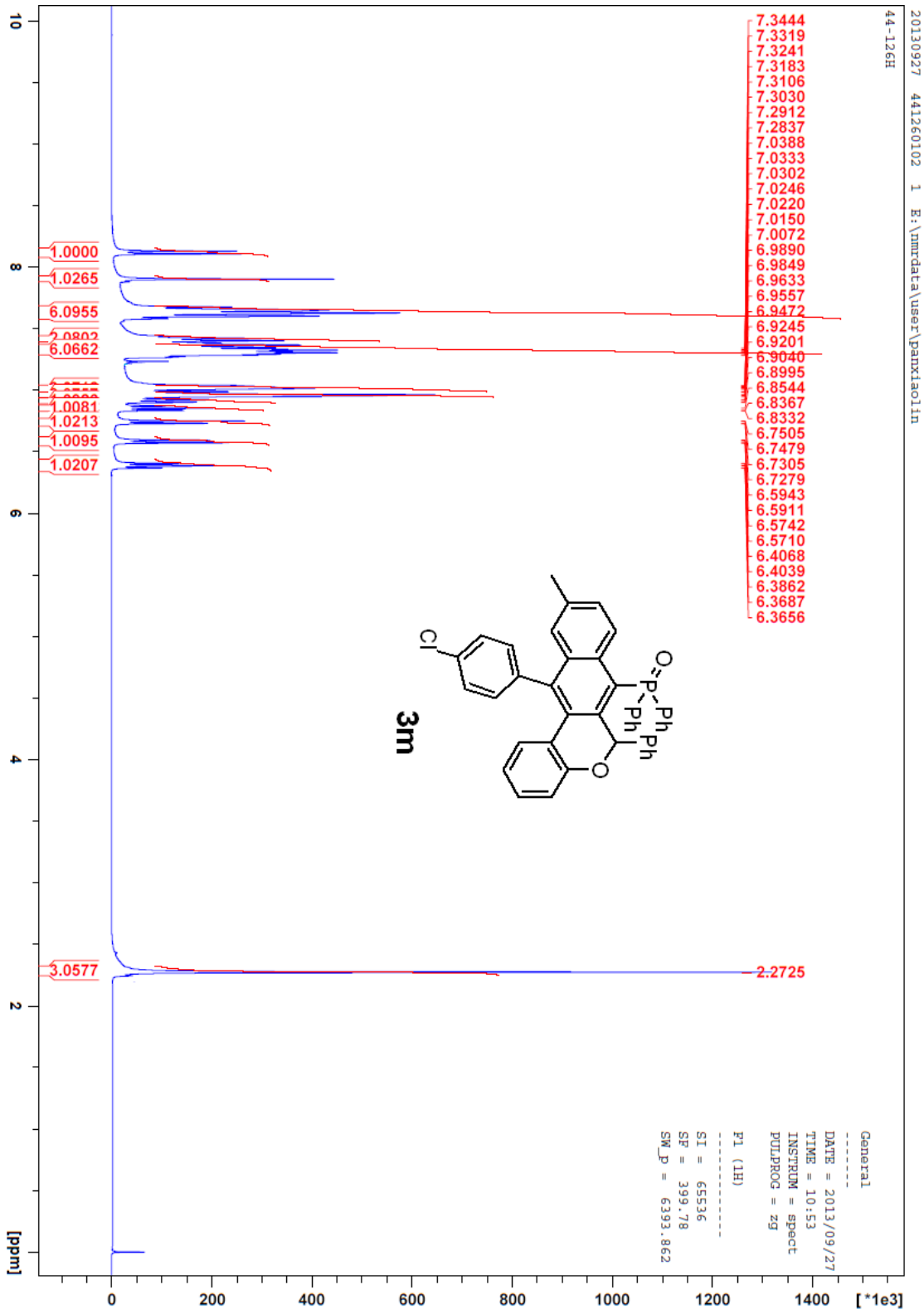
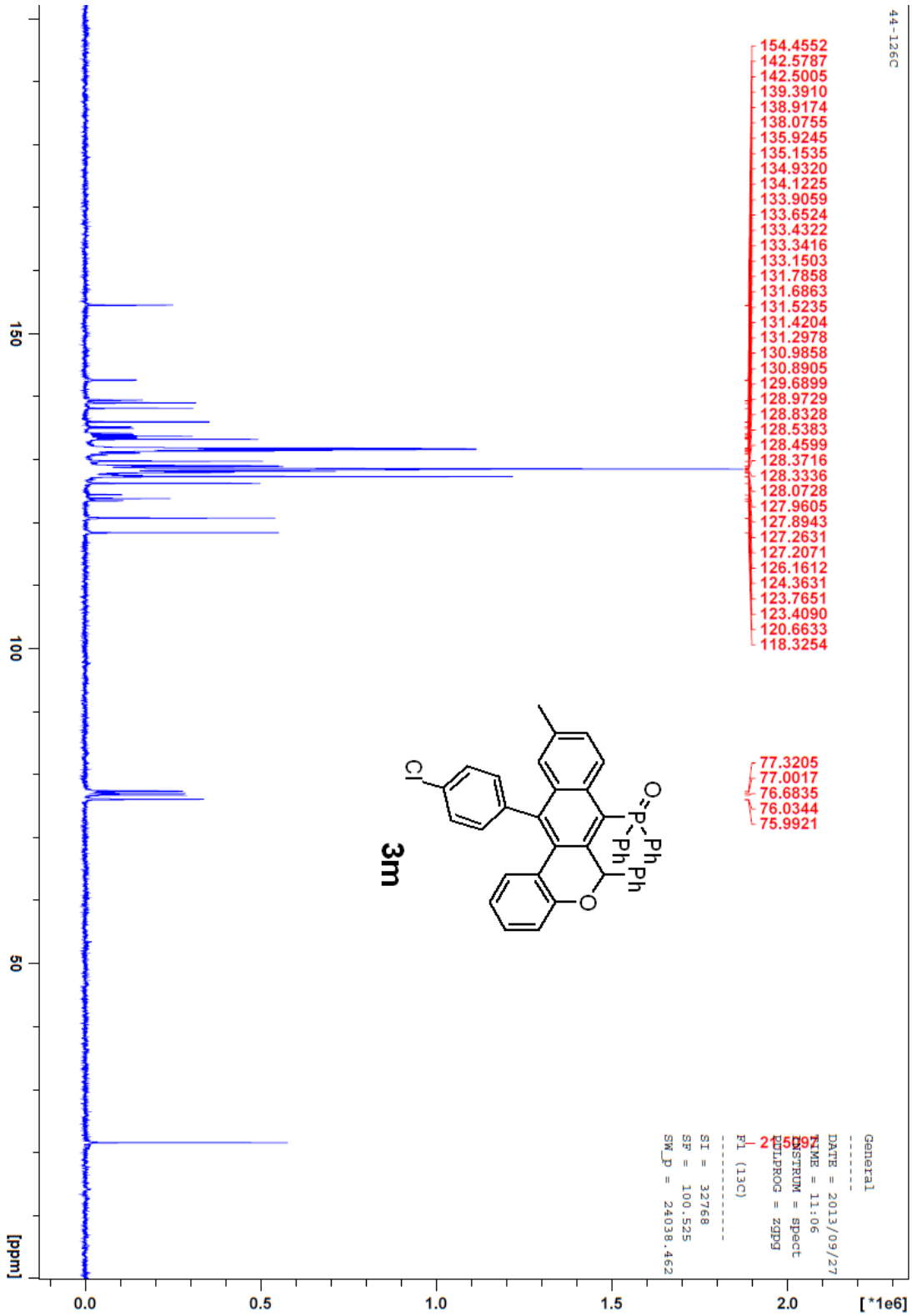
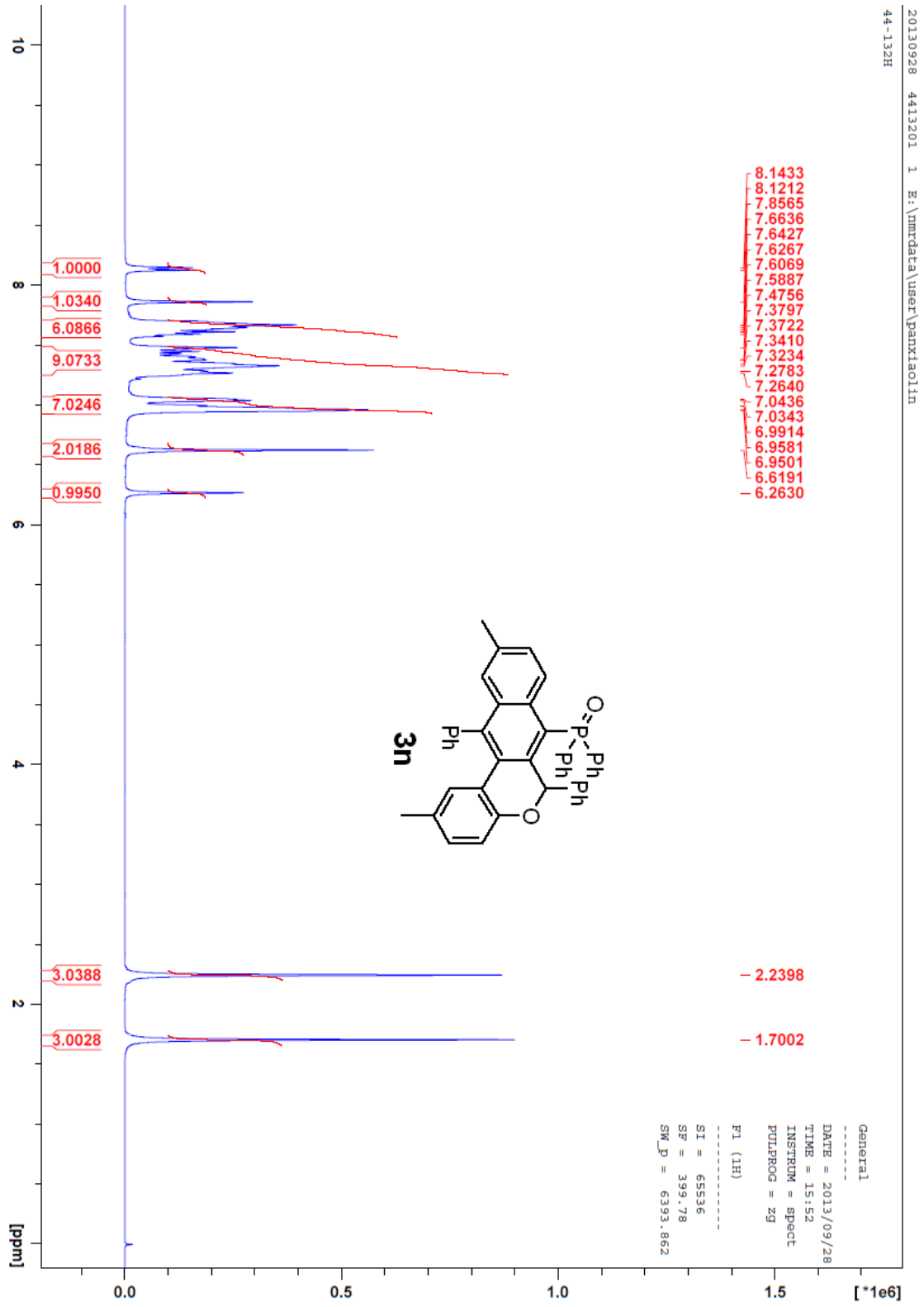
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
2.5
[*1e6]

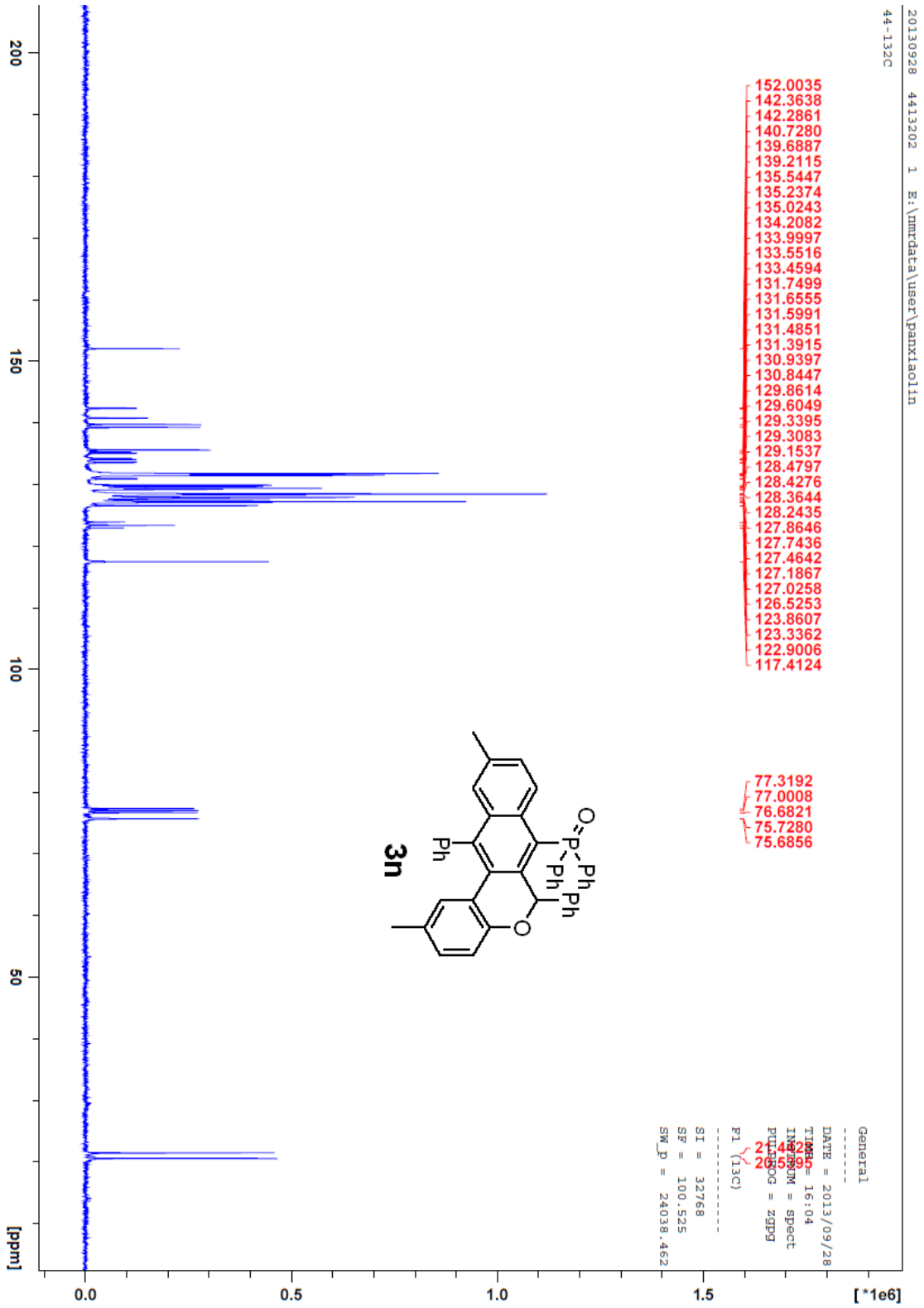

20130928 44150103 1 E:\nmrdata\user\panxiaolin
44-115H
7.6274
7.6081
7.5497
7.5465
7.5304
7.5272
7.4652
7.4467
7.4279
7.3738
7.3667
7.3544
7.3472
7.3356
7.3284
7.3155
7.3093
7.2945
7.2914
7.2731
7.2366
7.2159
7.1784
7.1754
7.1574
7.1397
7.0074
6.8754
6.8722
6.8560
6.8259
6.8199
6.8046
6.7985
6.6823
6.6609
6.4753
6.4694
1.0000
1.0561
1.0770
4.0604
4.0931
3.0438
5.0725
1.0954
5.0092
1.0573
1.0406
0.9935
3.0790
2.4834
3l
O=P
Ph
Ph
Cl
O
General
DATE = 2013/09/28
TIME = 14:56
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e6]
0.0
0.5
1.0
1.5
2
4
6
8
10

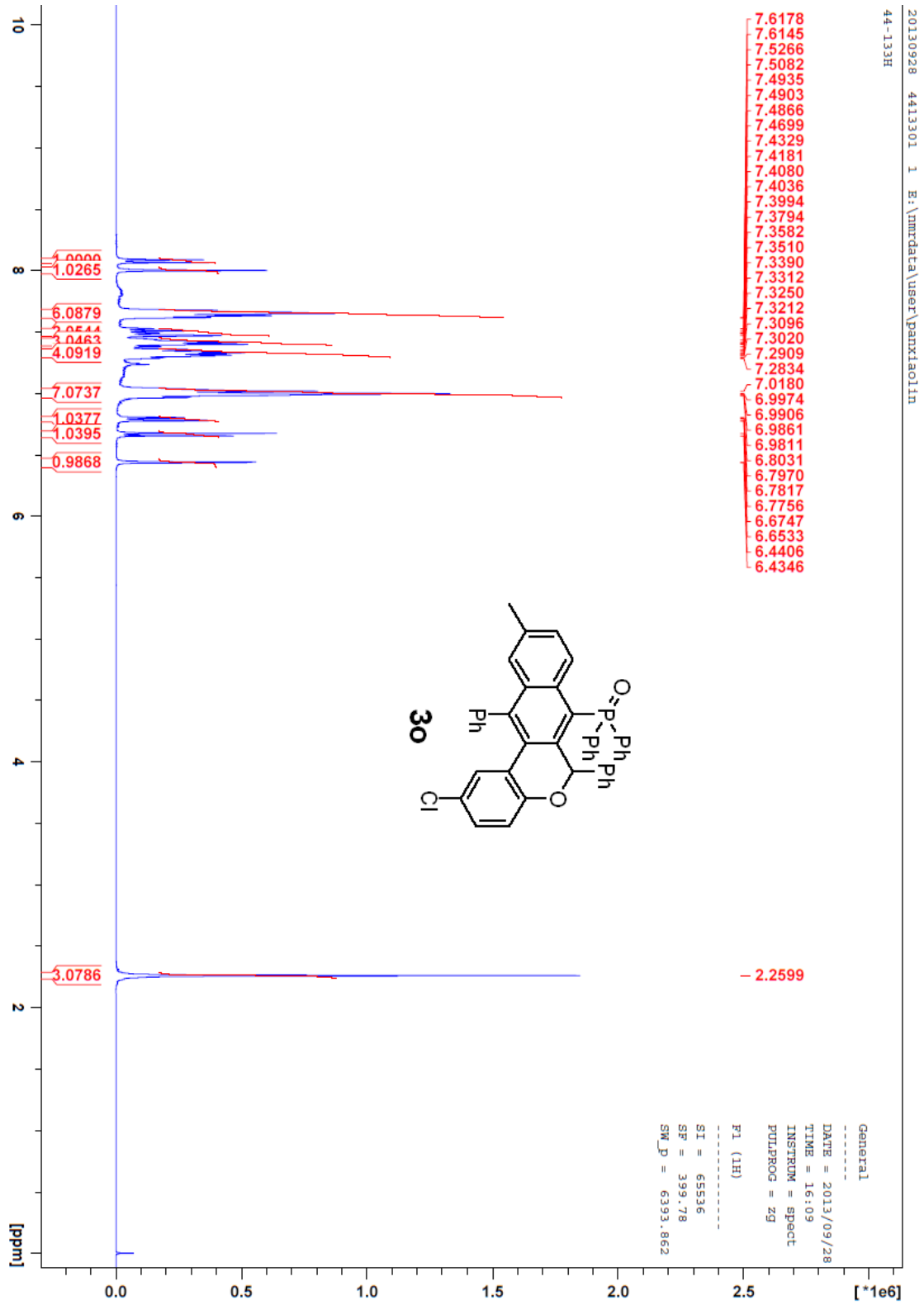

20130928 441150203 1 E:\nmrdata\user\panxiaolin
44-115C
152.9194
142.9939
142.9153
142.2307
138.6994
138.1213
135.7254
135.0306
134.7772
133.9966
133.7481
133.4531
133.3612
133.0405
132.9457
131.8515
131.7513
131.6981
131.6020
131.5011
131.3194
130.3639
129.2779
129.0978
128.6397
128.5254
128.4433
128.0248
127.9635
127.4806
127.2869
126.7475
126.6306
126.1244
126.0583
125.4775
125.2316
124.1885
123.2305
119.2392
77.3177
77.0004
76.6815
76.0826
76.0394
General
DATE = 2013/09/28
TIME = 15:04
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
O
P
Ph
Ph
Ph
O
Cl
3l
[*1e6]
1.5
1.0
0.5
0.0
200
150
100
50
[ppm]

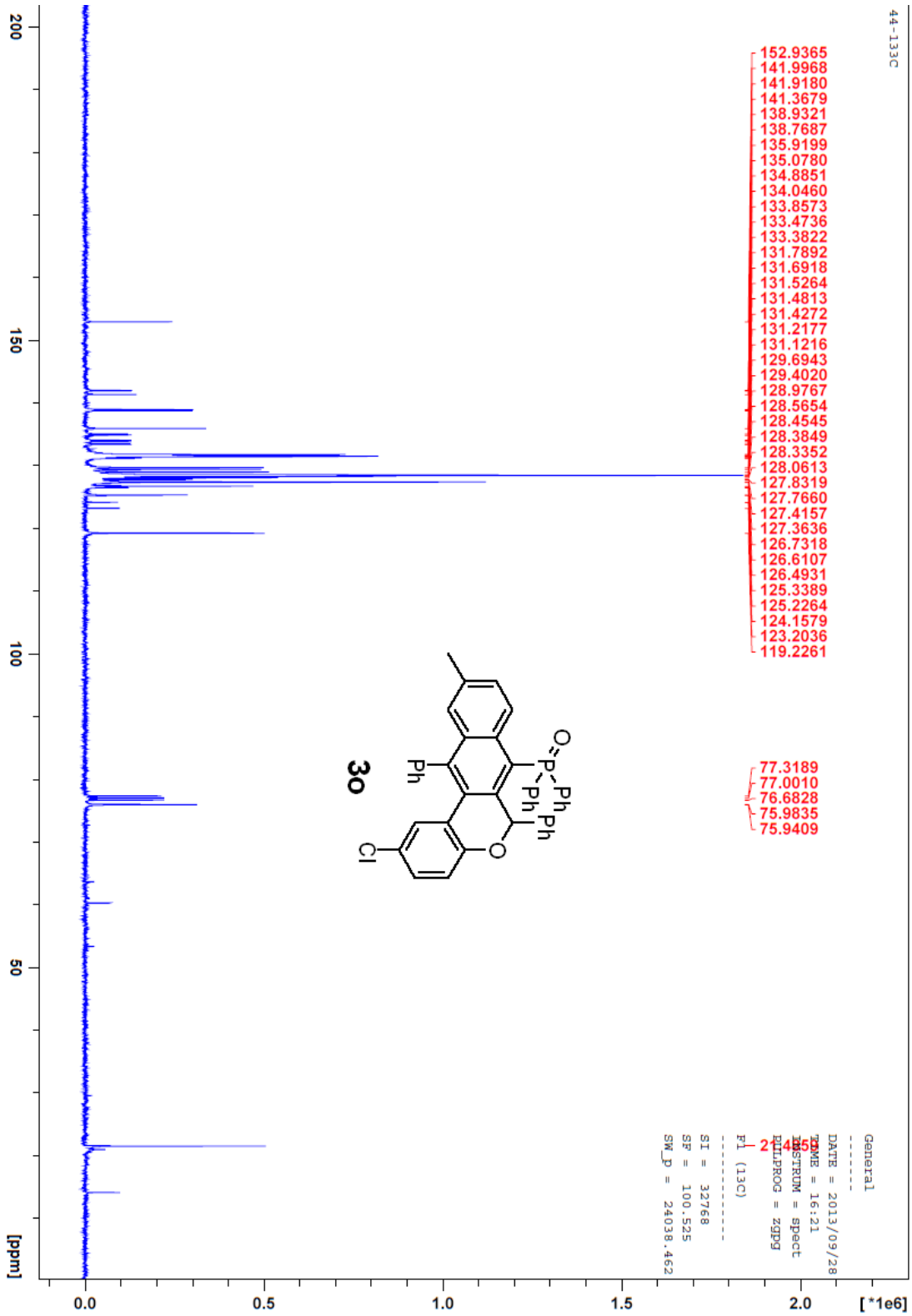

20130927 44126O102 1 E:\nmrdata\user\panxiaolin
44-126H
7.3444
7.3319
7.3241
7.3183
7.3106
7.3030
7.2912
7.2837
7.0388
7.0333
7.0302
7.0246
7.0220
7.0150
7.0072
6.9890
6.9849
6.9633
6.9557
6.9472
6.9245
6.9201
6.9040
6.8995
6.8544
6.8367
6.8332
6.7505
6.7479
6.7305
6.7279
6.5943
6.5911
6.5742
6.5710
6.4068
6.4039
6.3862
6.3687
6.3656
1.0000
1.0265
6.0955
2.0802
6.0662
1.0081
1.0213
1.0095
1.0207
3.0577
2.2725
Cl
O=P
Ph
Ph
O
3m
General
DATE = 2013/09/27
TIME = 10:53
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
10
8
6
4
2
[ppm]
0
200
400
600
800
1000
1200
1400
[*1e3]

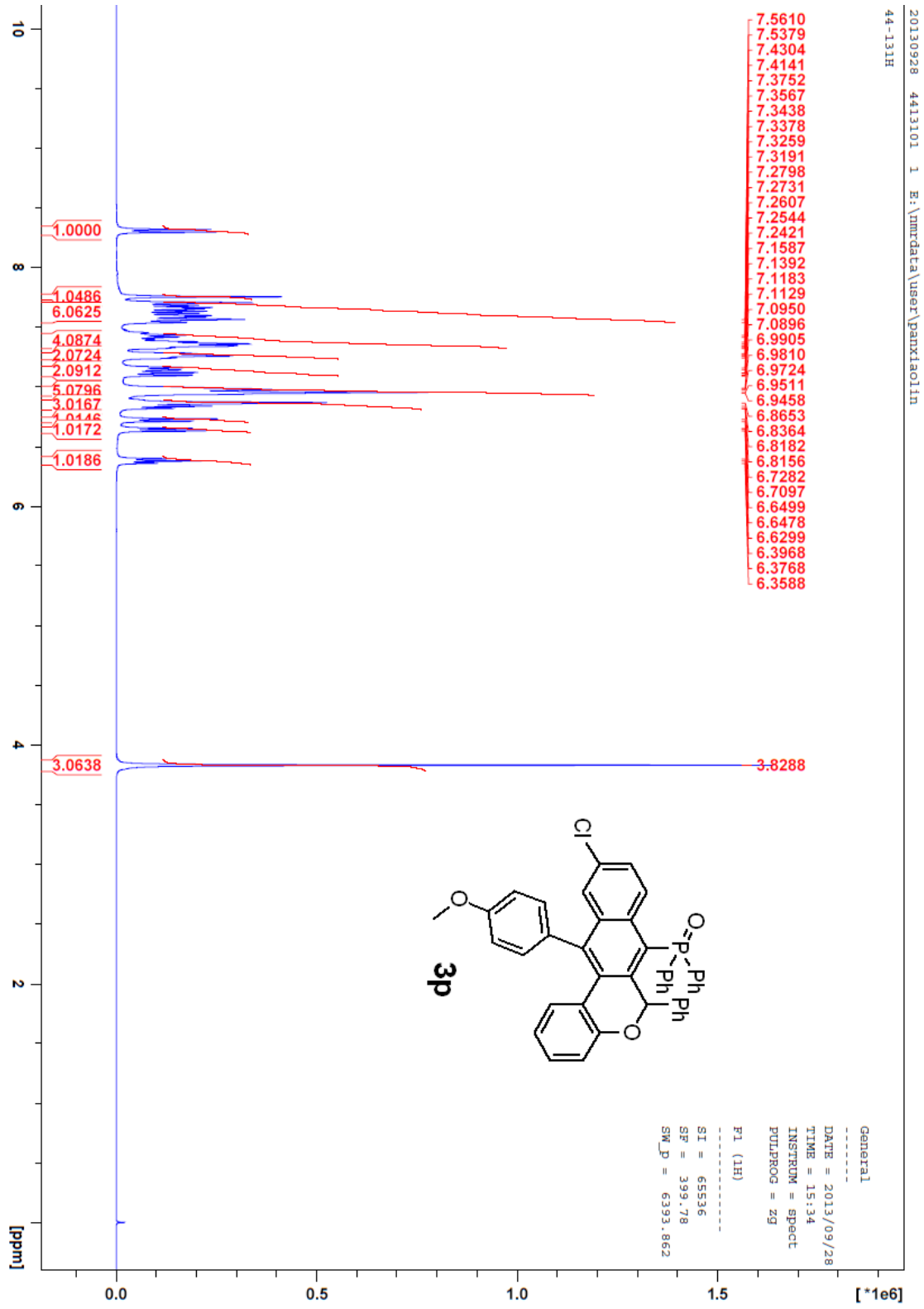

20130927 441260202 1 E:\nmrdata\user\panxiaolin
44-126C
154.4552
142.5787
142.5005
139.3910
138.9174
138.0755
135.9245
135.1535
134.9320
134.1225
133.9059
133.6524
133.4322
133.3416
133.1503
131.7858
131.6863
131.5235
131.4204
131.2978
130.9858
130.8905
129.6899
128.9729
128.8328
128.5383
128.4599
128.3716
128.3336
128.0728
127.9605
127.8943
127.2631
127.2071
126.1612
124.3631
123.7651
123.4090
120.6633
118.3254
77.3205
77.0017
76.6835
76.0344
75.9921
21.5099
Cl
O
P
Ph
Ph
O
3m
General
DATE = 2013/09/27
TIME = 11:06
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]

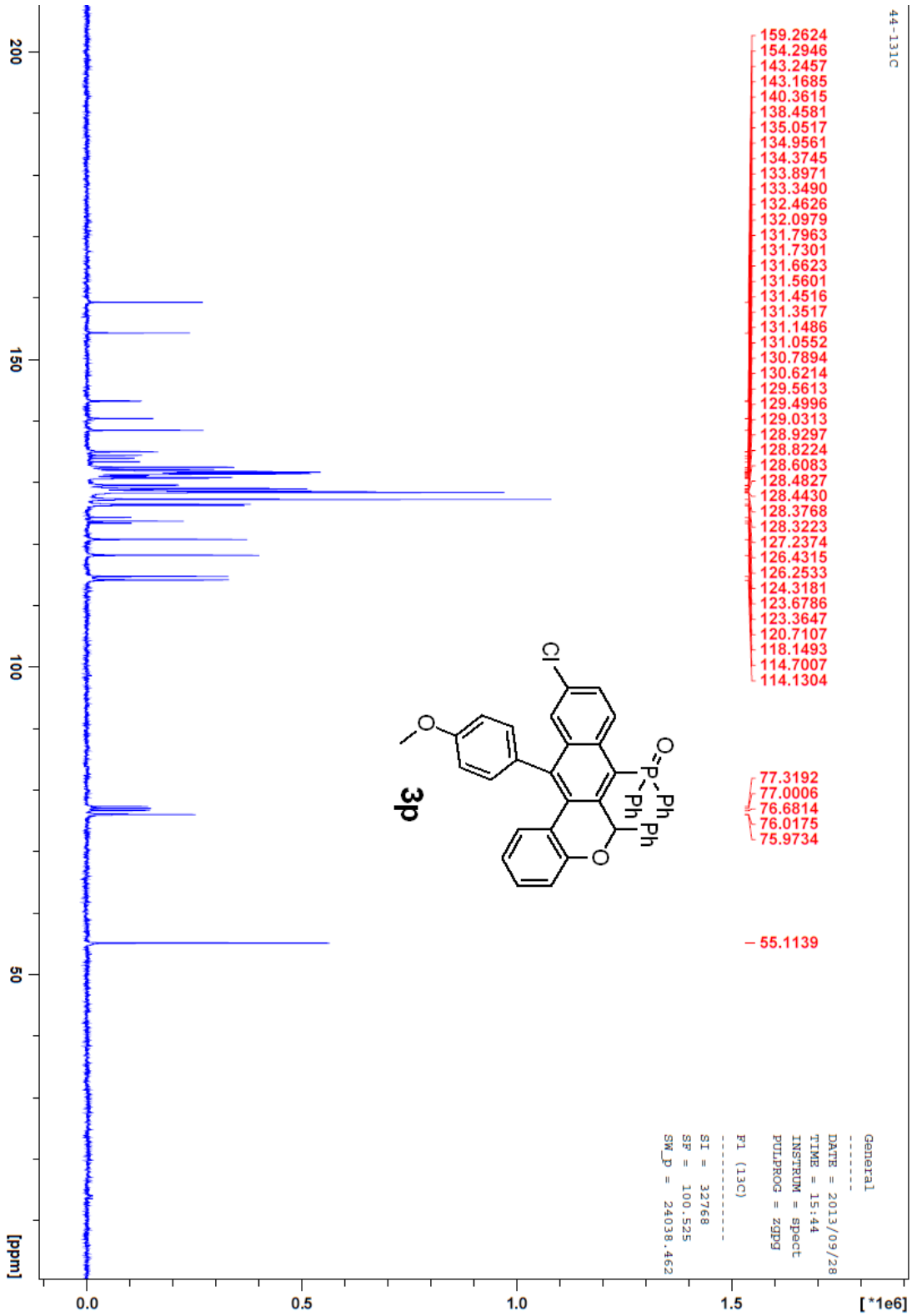

20130928 4413201 1 E:\nmrdata\user\panxiaolin
44-132H
8.1433
8.1212
7.8565
7.6636
7.6427
7.6267
7.6069
7.5887
7.4756
7.3797
7.3722
7.3410
7.3234
7.2783
7.2640
7.0436
7.0343
6.9914
6.9581
6.9501
6.6191
6.6260
1.0000
1.0340
6.0866
9.0733
7.0246
2.0186
0.9950
3.0388
3.0028
2.2398
1.7002
3n
Ph
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 15:52
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
10
8
6
4
2
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

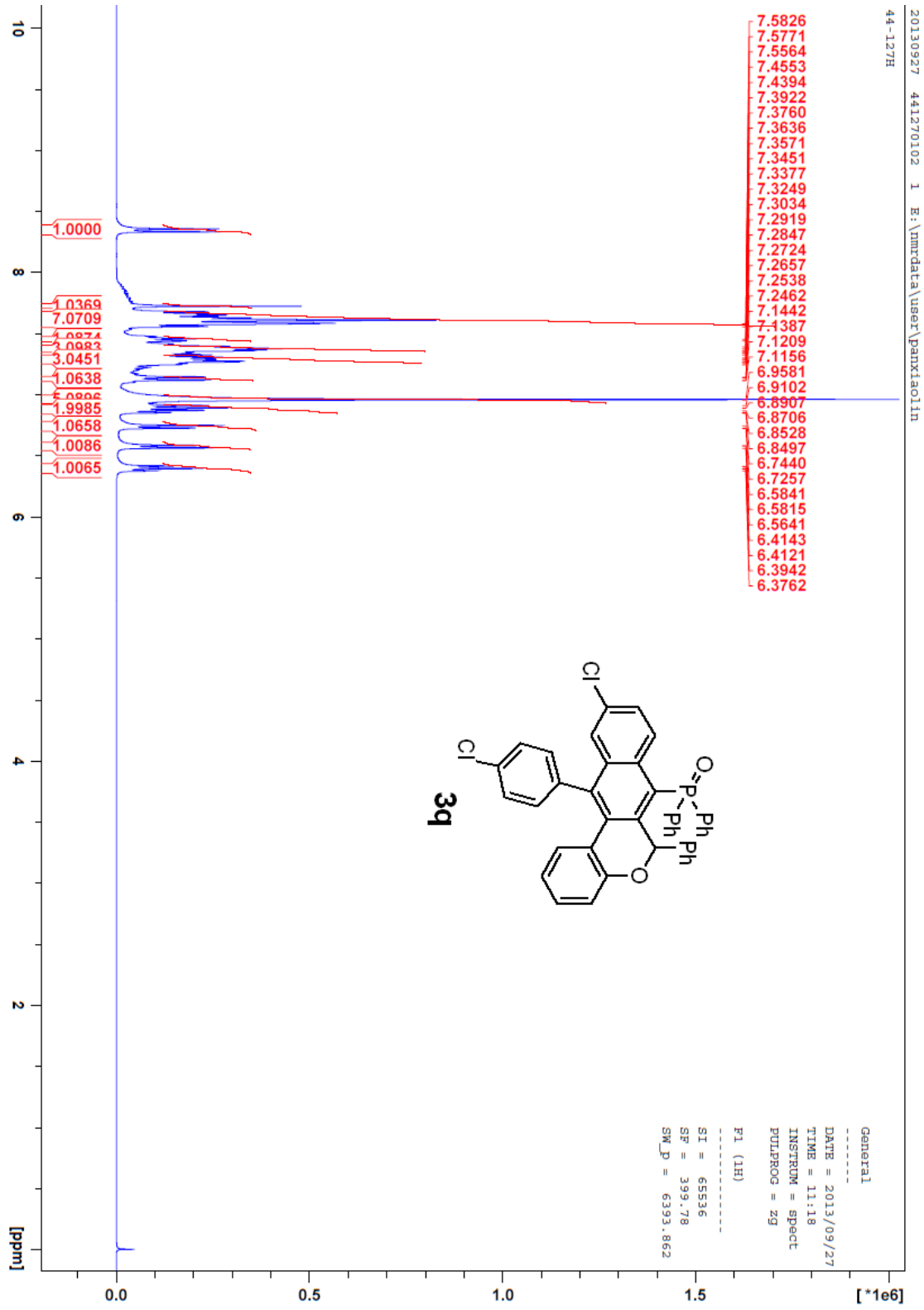

20130928 4413202 1 E:\nmrdata\user\panxiaolin
44-132C
152.0035
142.3638
142.2861
140.7280
139.6887
139.2115
135.5447
135.2374
135.0243
134.2082
133.9997
133.5516
133.4594
131.7499
131.6555
131.5991
131.4851
131.3915
130.9397
130.8447
129.8614
129.6049
129.3395
129.3083
129.1537
128.4797
128.4276
128.3644
128.2435
127.8646
127.7436
127.4642
127.1867
127.0258
126.5253
123.8607
123.3362
122.9006
117.4124
77.3192
77.0008
76.6821
75.7280
75.6856
3n
Ph
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 16:04
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

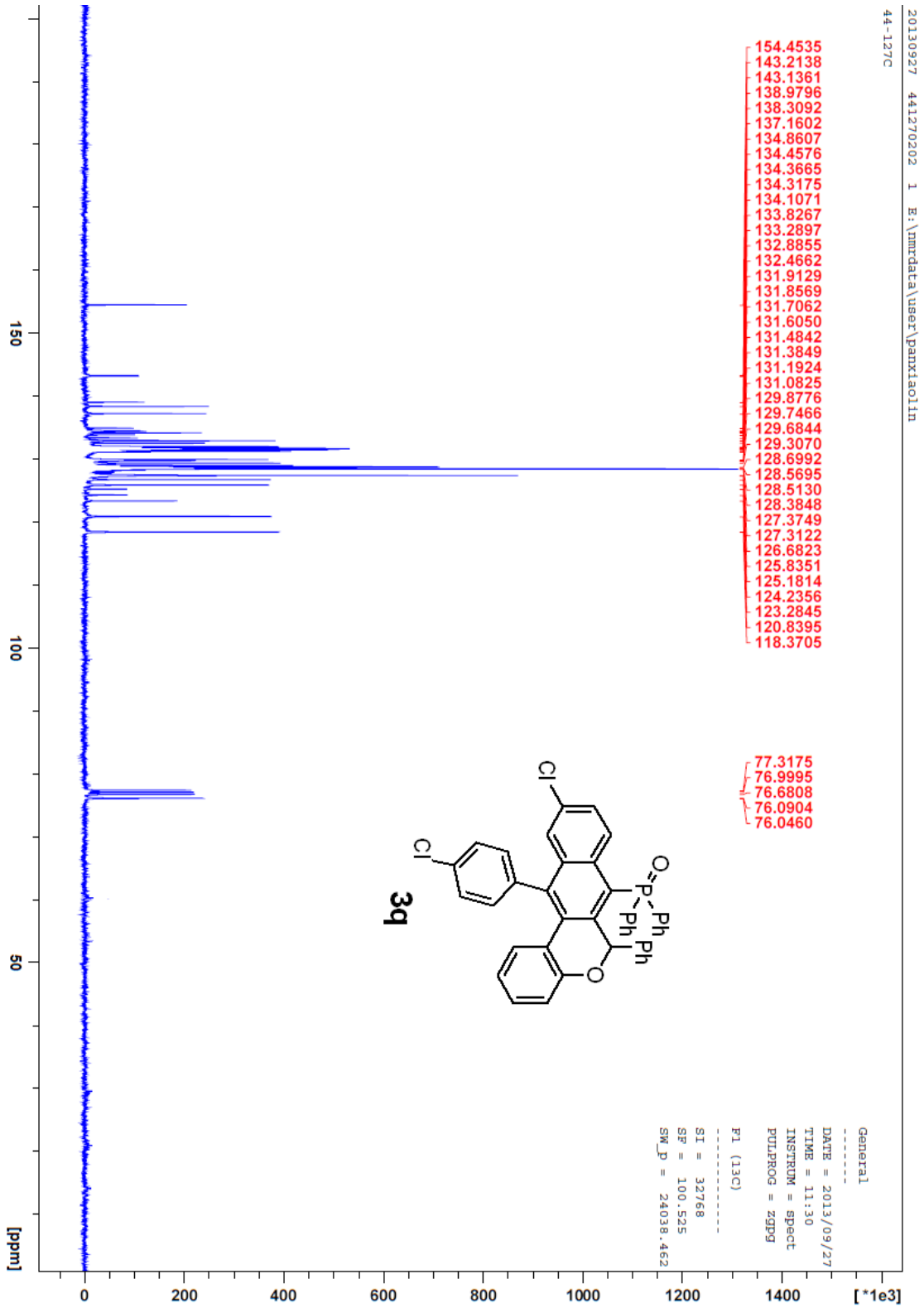

20130928 4413301 1 E:\nmrdata\user\panxiaolin
44-133H
7.6178
7.6145
7.5266
7.5082
7.4935
7.4903
7.4866
7.4699
7.4329
7.4181
7.4080
7.4036
7.3994
7.3794
7.3582
7.3510
7.3390
7.3312
7.3250
7.3212
7.3096
7.3020
7.2909
7.2834
7.0180
6.9974
6.9906
6.9861
6.9811
6.8031
6.7970
6.7817
6.7756
6.6747
6.6533
6.4406
6.4346
1.0265
6.0879
4.0919
7.0737
1.0377
1.0395
0.9868
3.0786
2.2599
3o
Ph
Cl
O=P
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 16:09
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e6]

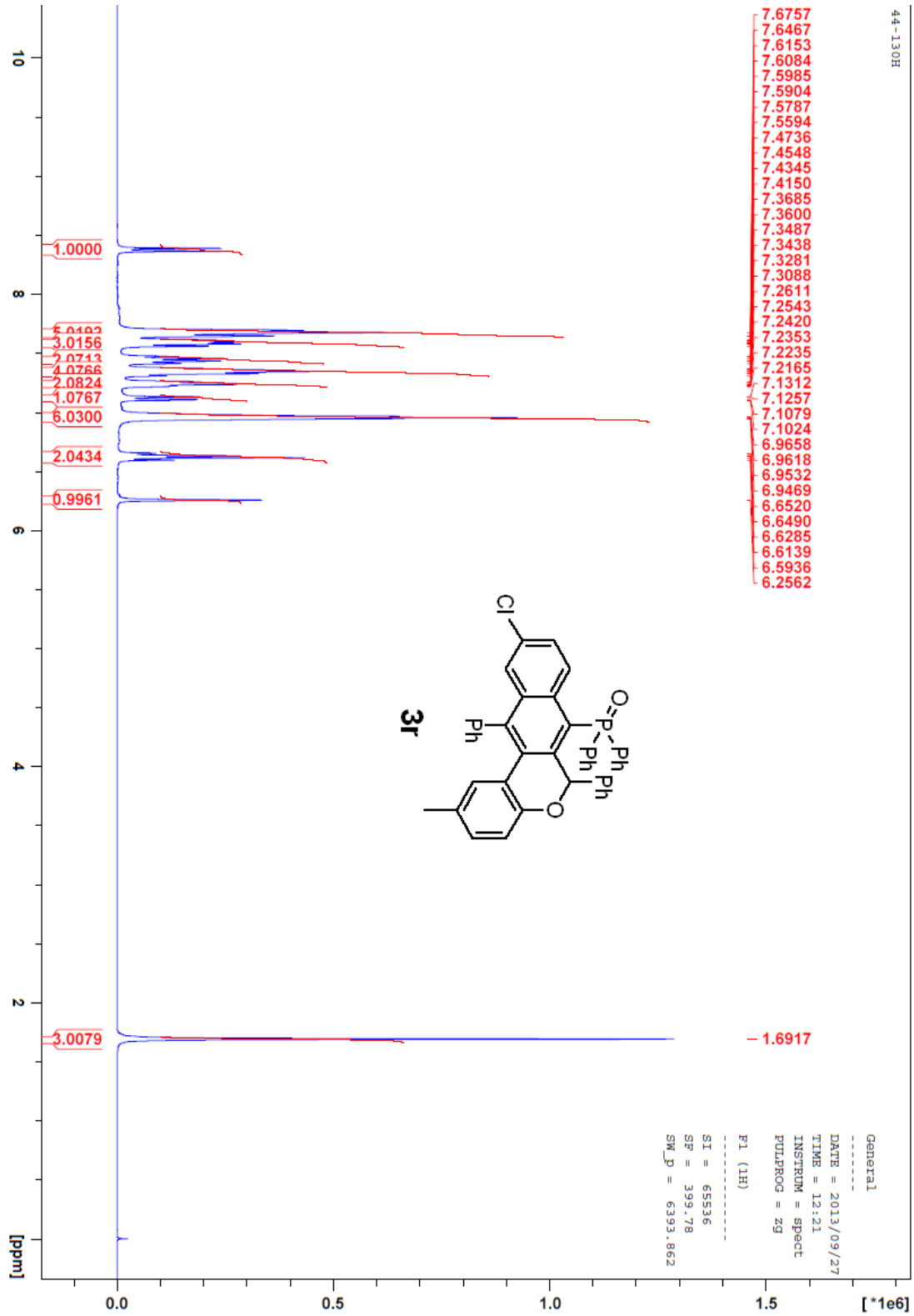

20130928 4413302 1 E:\nmrdata\user\panxiaolin
44-133C
152.9365
141.9968
141.9180
141.3679
138.9321
138.7687
135.9199
135.0780
134.8851
134.0460
133.8573
133.4736
133.3822
131.7892
131.6918
131.5264
131.4813
131.4272
131.2177
131.1216
129.6943
129.4020
128.9767
128.5654
128.4545
128.3849
128.3352
128.0613
127.8319
127.7660
127.4157
127.3636
126.7318
126.6107
126.4931
125.3389
125.2264
124.1579
123.2036
119.2261
77.3189
77.0010
76.6828
75.9835
75.9409
3o
Ph
O=P
Ph
Ph
Ph
Cl
O
General
DATE = 2013/09/28
TIME = 16:21
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]

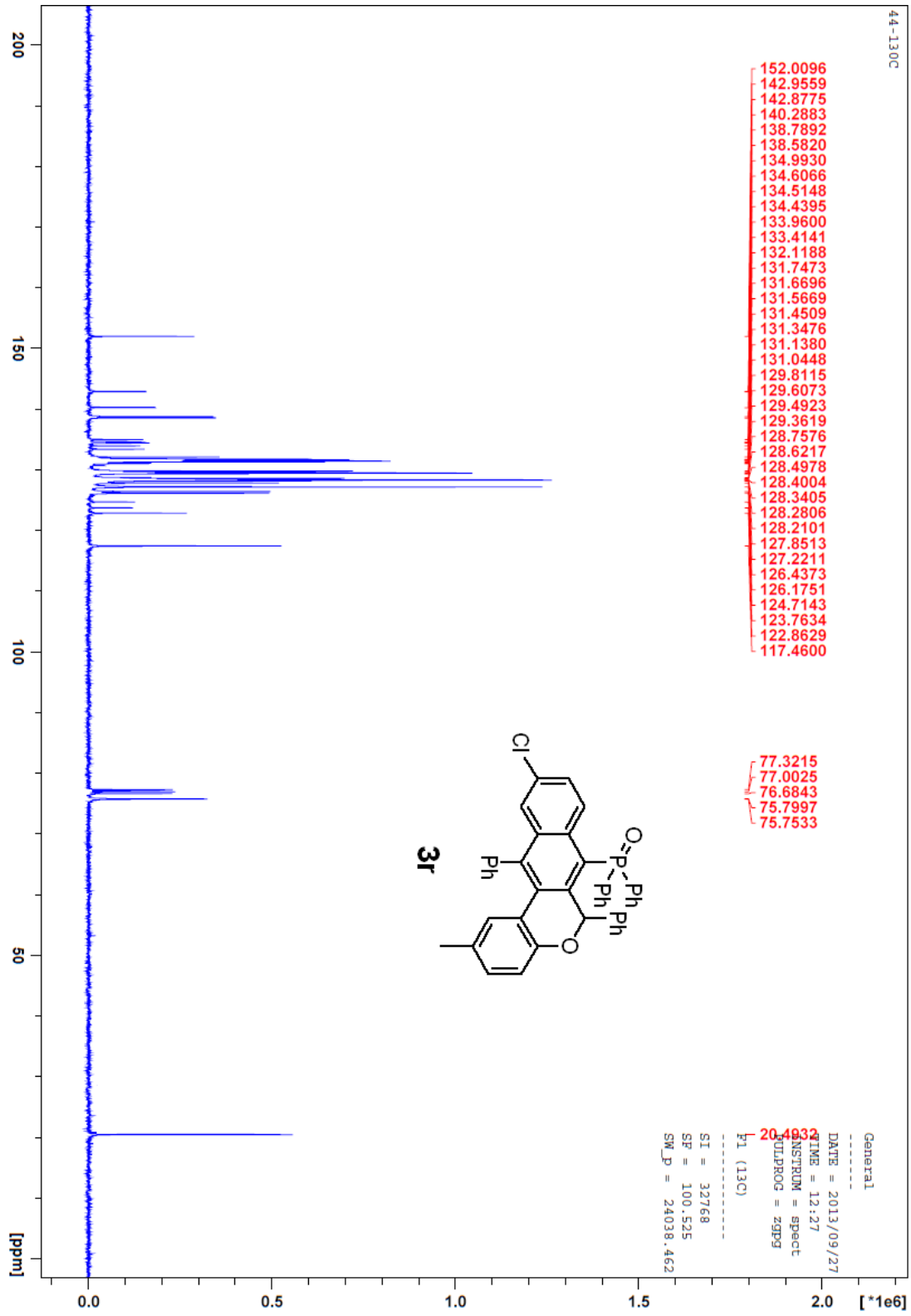

20130928 4413101 1 E:\nmrdata\user\panxiaolin
44-131H
7.5610
7.5379
7.4304
7.4141
7.3752
7.3567
7.3438
7.3378
7.3259
7.3191
7.2798
7.2731
7.2607
7.2544
7.2421
7.1587
7.1392
7.1183
7.1129
7.0950
7.0896
6.9905
6.9810
6.9724
6.9511
6.9458
6.8653
6.8364
6.8182
6.8156
6.7282
6.7097
6.6499
6.6478
6.6299
6.3968
6.3768
6.3588
1.0000
1.0486
6.0625
4.0874
2.0724
2.0912
5.0796
3.0167
1.0172
1.0186
3.0638
3.8288
Cl
O
O=P
Ph
Ph
Ph
O
3p
General
DATE = 2013/09/28
TIME = 15:34
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
10
8
6
4
2
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

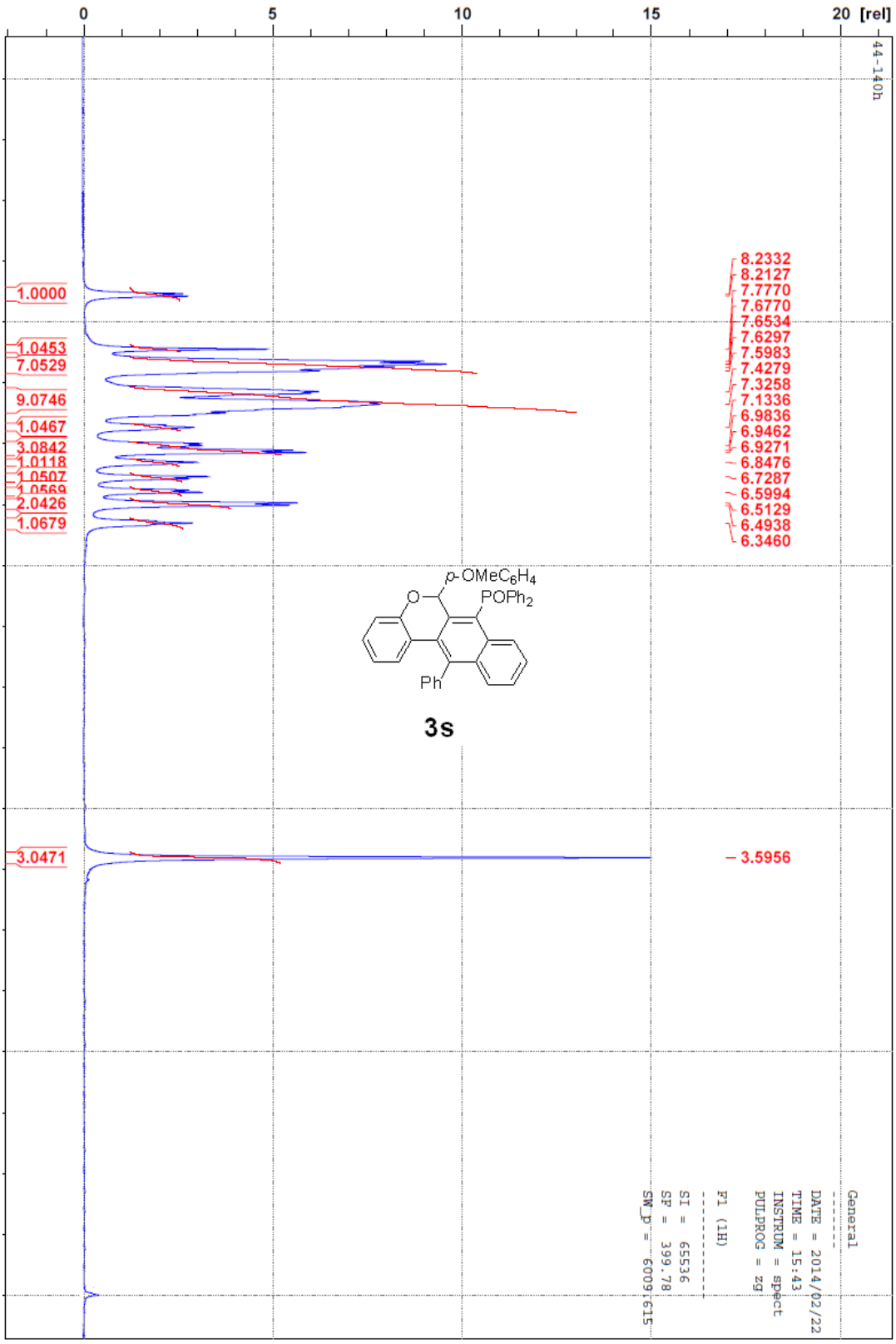

20130928 4413102 1 E:\nmrdata\user\panxiaolin
44-131C
159.2624
154.2946
143.2457
143.1685
140.3615
138.4581
135.0517
134.9561
134.3745
133.8971
133.3490
132.4626
132.0979
131.7963
131.7301
131.6623
131.5601
131.4516
131.3517
131.1486
131.0552
130.7894
130.6214
129.5613
129.4996
129.0313
128.9297
128.8224
128.6083
128.4827
128.4430
128.3768
128.3223
127.2374
126.4315
126.2533
124.3181
123.6786
123.3647
120.7107
118.1493
114.7007
114.1304
77.3192
77.0006
76.6814
76.0175
75.9734
55.1139
3p
Cl
O
O=P
Ph
Ph
O
General
DATE = 2013/09/28
TIME = 15:44
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
[*1e6]

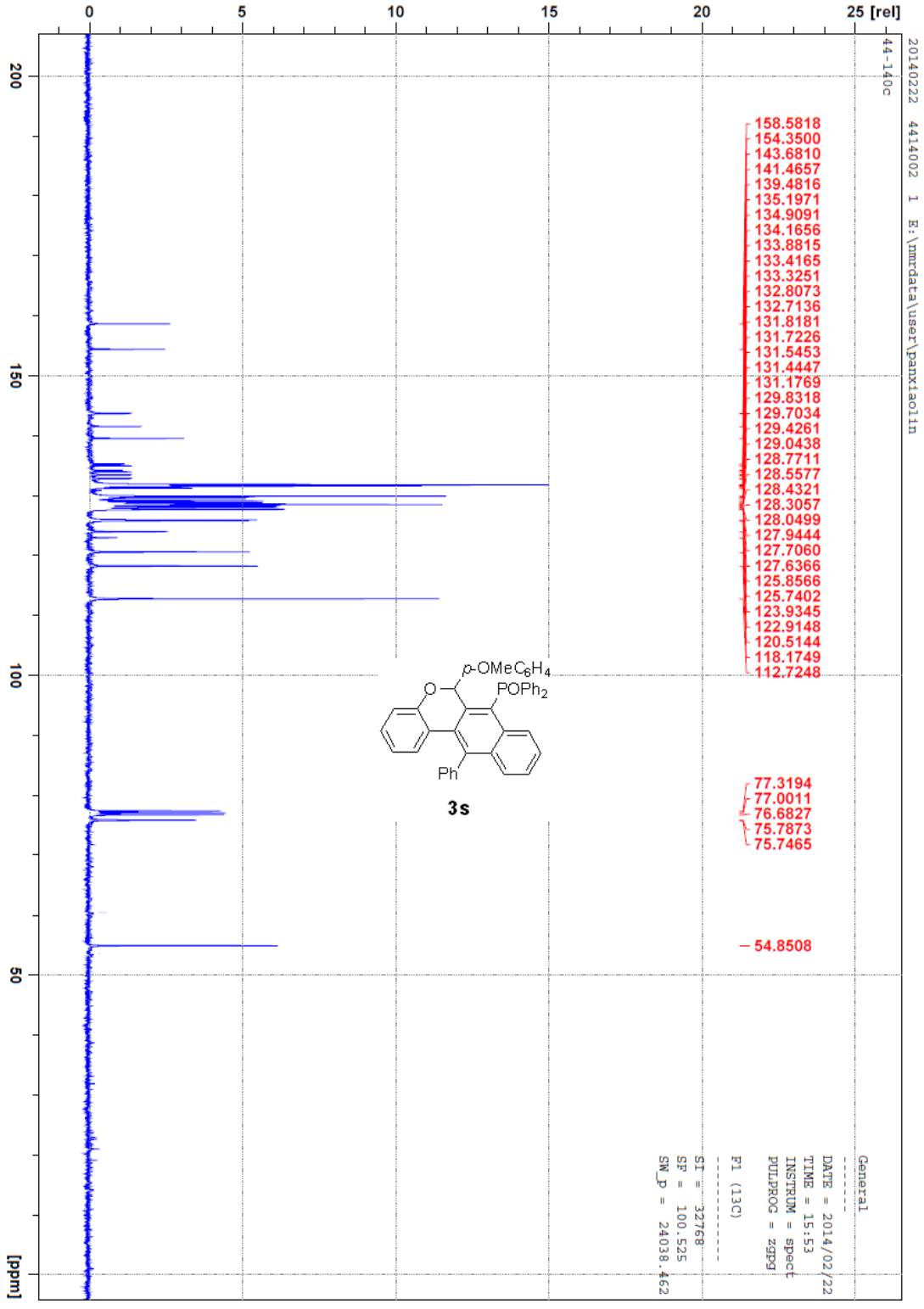

20130927 44127010 1 E:\nmrdata\user\panxiaolin
44-127H
7.5826
7.5771
7.5564
7.4553
7.4394
7.3922
7.3760
7.3636
7.3571
7.3451
7.3377
7.3249
7.3034
7.2919
7.2847
7.2724
7.2657
7.2538
7.2462
7.1442
7.1387
7.1209
7.1156
6.9581
6.9102
6.8907
6.8706
6.8528
6.8497
6.7440
6.7257
6.5841
6.5815
6.5641
6.4143
6.4121
6.3942
6.3762
1.0000
1.0369
7.0709
3.0451
1.0638
1.9985
1.0658
1.0086
1.0065
3q
Cl
Cl
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 11:18
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e6]

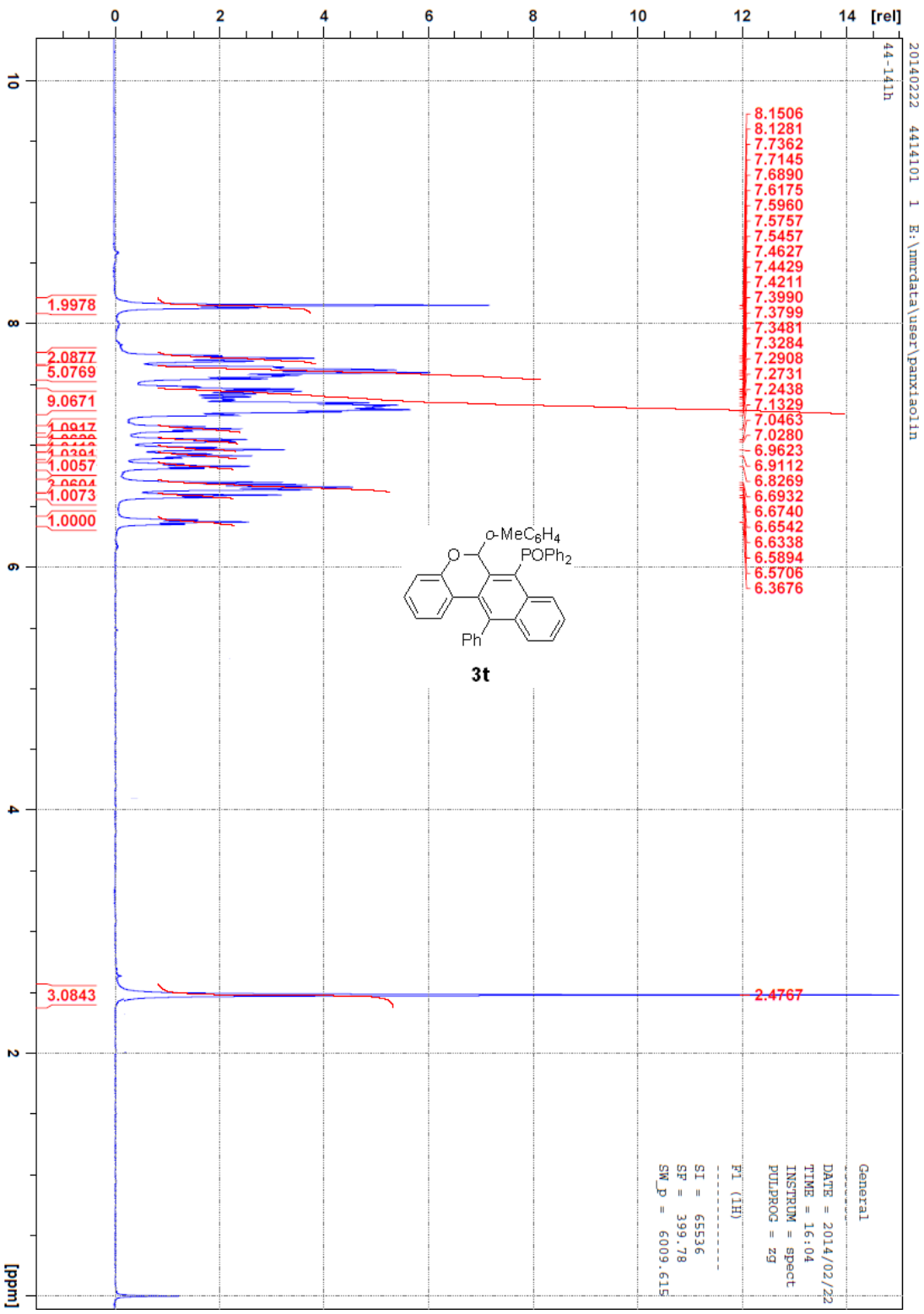

20130927 441270202 1 E:\nmrdata\user\panxiaolin
44-127C
154.4535
143.2138
143.1361
138.9796
138.3092
137.1602
134.8607
134.4576
134.3665
134.3175
134.1071
133.8267
133.2897
132.8855
132.4662
131.9129
131.8569
131.7062
131.6050
131.4842
131.3849
131.1924
131.0825
129.8776
129.7466
129.6844
129.3070
128.6992
128.5695
128.5130
128.3848
127.3749
127.3122
126.6823
125.8351
125.1814
124.2356
123.2845
120.8395
118.3705
77.3175
76.9995
76.6808
76.0904
76.0460
3q
Cl
Cl
O
P
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 11:30
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
150
100
50
[ppm]
0
200
400
600
800
1000
1200
1400
[*1e3]

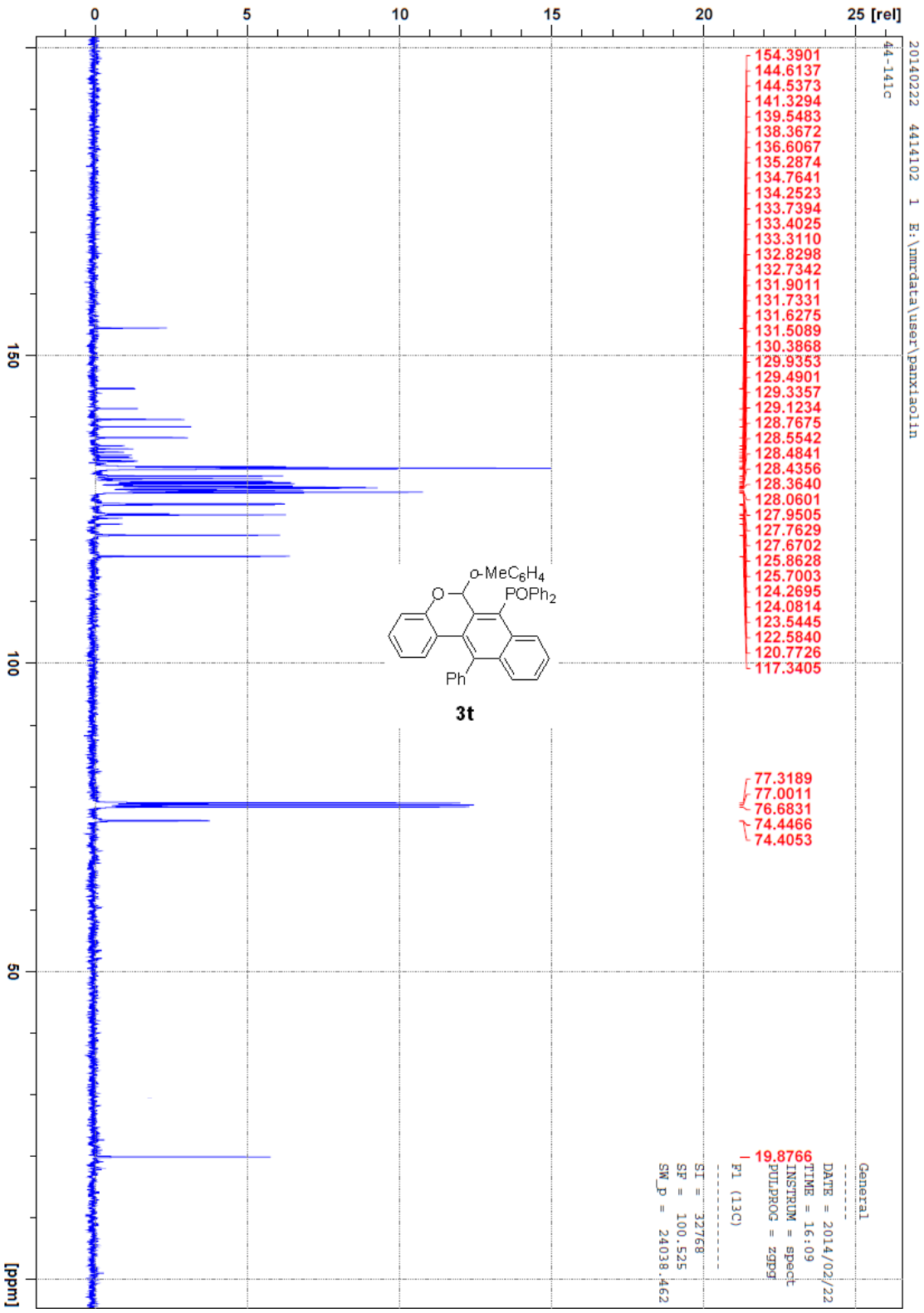

20130927 4413001 1 E:\nmrdata\user\panxiaolin
44-130H
7.6757
7.6467
7.6153
7.6084
7.5985
7.5904
7.5787
7.5594
7.4736
7.4548
7.4345
7.4150
7.3685
7.3600
7.3487
7.3438
7.3281
7.3088
7.2611
7.2543
7.2420
7.2353
7.2235
7.2165
7.1312
7.1257
7.1079
7.1024
6.9658
6.9618
6.9532
6.9469
6.6520
6.6490
6.6285
6.6139
6.5936
6.2562
1.0000
3.0156
2.0824
1.0767
6.0300
2.0434
0.9961
3.0079
1.6917
3r
Cl
Ph
O=P
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 12:21
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6393.862
[ppm]
[*1e6]

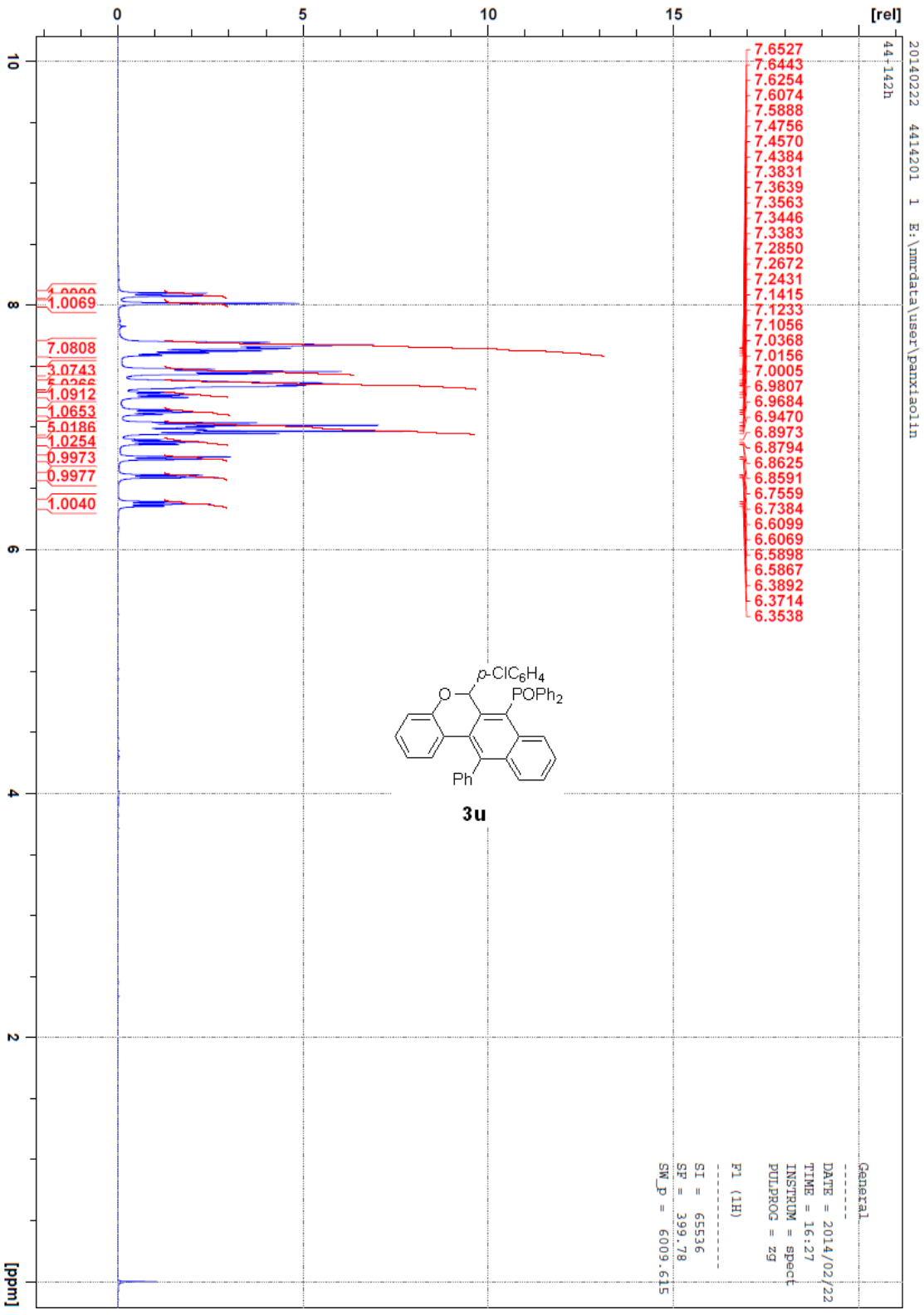

20130927 4413002 1 E:\nmrdata\user\panxiaolin
44-130C
152.0096
142.9559
142.8775
140.2883
138.7892
138.5820
134.9930
134.6066
134.5148
134.4395
133.9600
133.4141
132.1188
131.7473
131.6696
131.5669
131.4509
131.3476
131.1380
131.0448
129.8115
129.6073
129.4923
129.3619
128.7576
128.6217
128.4978
128.4004
128.3405
128.2806
128.2101
127.8513
127.2211
126.4373
126.1751
124.7143
123.7634
122.8629
117.4600
77.3215
77.0025
76.6843
75.7997
75.7533
20.4932
3r
Cl
Ph
O=P
Ph
Ph
Ph
O
General
DATE = 2013/09/27
TIME = 12:27
INSTRUM = spect
PULPROG = zgpg
P1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
200
150
100
50
[ppm]
0.0
0.5
1.0
1.5
2.0
[*1e6]


0
5
10
15
20 [rel]
44-140h
20140222 4414001 1 E:\nmrdata\user\panxiaolin
1.0000
1.0453
7.0529
9.0746
1.0467
3.0842
1.0118
1.0507
1.0569
2.0426
1.0679
3.0471
8.2332
8.2127
7.7770
7.6770
7.6534
7.6297
7.5983
7.4279
7.3258
7.1336
6.9836
6.9462
6.9271
6.8476
6.7287
6.5994
6.5129
6.4938
6.3460
3.5956
p-OMeC6H4
POPh2
O
Ph
3s
General
DATE = 2014/02/22
TIME = 15:43
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615


158.5818
154.3500
143.6810
141.4657
139.4816
135.1971
134.9091
134.1656
133.8815
133.4165
133.3251
132.8073
132.7136
131.8181
131.7226
131.5453
131.4447
131.1769
129.8318
129.7034
129.4261
129.0438
128.7711
128.5577
128.4321
128.3057
128.0499
127.9444
127.7060
127.6366
125.8566
125.7402
123.9345
122.9148
120.5144
118.1749
112.7248
77.3194
77.0011
76.6827
75.7873
75.7465
54.8508
p-OMeC6H4
POPh2
O
Ph
3s
44-140c
20140222 4414002 1 E:\nmrdata\user\panxiaolin
General
DATE = 2014/02/22
TIME = 15:53
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462
0
5
10
15
20
25 [rel]
200
150
100
50
[ppm]


20140222 4414101 1 E:\nmrdata\user\panxiaolin
44-141h
8.1506
8.1281
7.7362
7.7145
7.6890
7.6175
7.5960
7.5757
7.5457
7.4627
7.4429
7.4211
7.3990
7.3799
7.3481
7.3284
7.2908
7.2731
7.2438
7.1329
7.0463
7.0280
6.9623
6.9112
6.8269
6.6932
6.6740
6.6542
6.6338
6.5894
6.5706
6.3676
1.9978
2.0877
5.0769
9.0671
1.0057
1.0073
1.0000
3.0843
2.4767
o-MeC6H4
POPh2
Ph
3t
General
DATE = 2014/02/22
TIME = 16:04
INSTRUM = spect
PULPROG = zg
F1 (1H)
SI = 65536
SF = 399.78
SW_p = 6009.615
[rel]
[ppm]


0
5
10
15
20
25 [rel]
150
100
50
[ppm]
154.3901
144.6137
144.5373
141.3294
139.5483
138.3672
136.6067
135.2874
134.7641
134.2523
133.7394
133.4025
133.3110
132.8298
132.7342
131.9011
131.7331
131.6275
131.5089
130.3868
129.9353
129.4901
129.3357
129.1234
128.7675
128.5542
128.4841
128.4356
128.3640
128.0601
127.9505
127.7629
127.6702
125.8628
125.7003
124.2695
124.0814
123.5445
122.5840
120.7726
117.3405
77.3189
77.0011
76.6831
74.4466
74.4053
19.8766
o-MeC6H4
POPh2
O
Ph
3t
44-141c
20140222 4414102 1 E:\nmrdata\user\panxiaolin
General
DATE = 2014/02/22
TIME = 16:09
INSTRUM = spect
PULPROG = zgpg
F1 (13C)
SI = 32768
SF = 100.525
SW_p = 24038.462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7.4384
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7.3563
7.3446
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7.2850
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7.2431
7.1415
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7.0005
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6.7559
6.7384
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6.6069
6.5898
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6.3714
6.3538
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O
POPh2
Ph
3u
General
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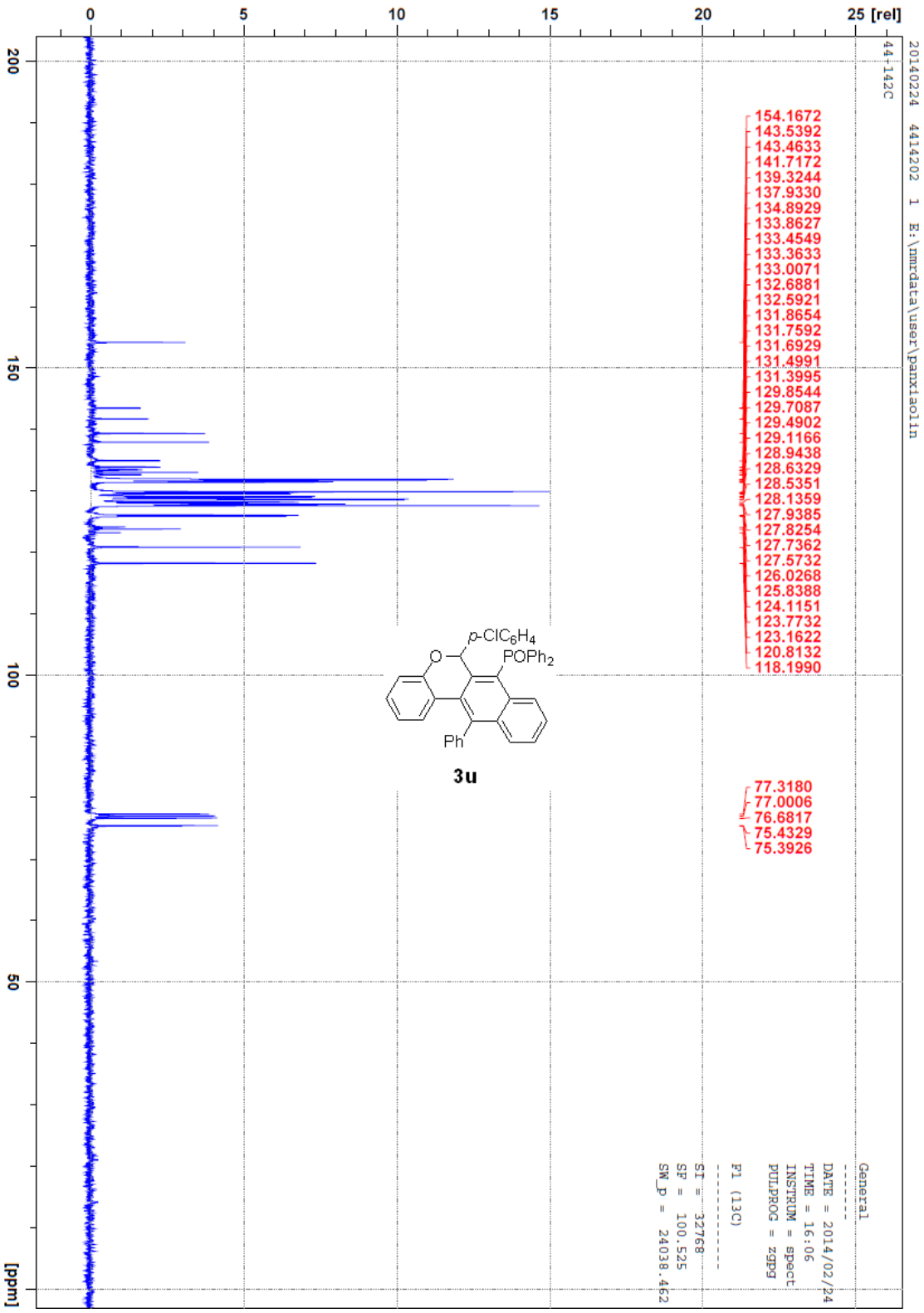
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O
Ph
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100
50
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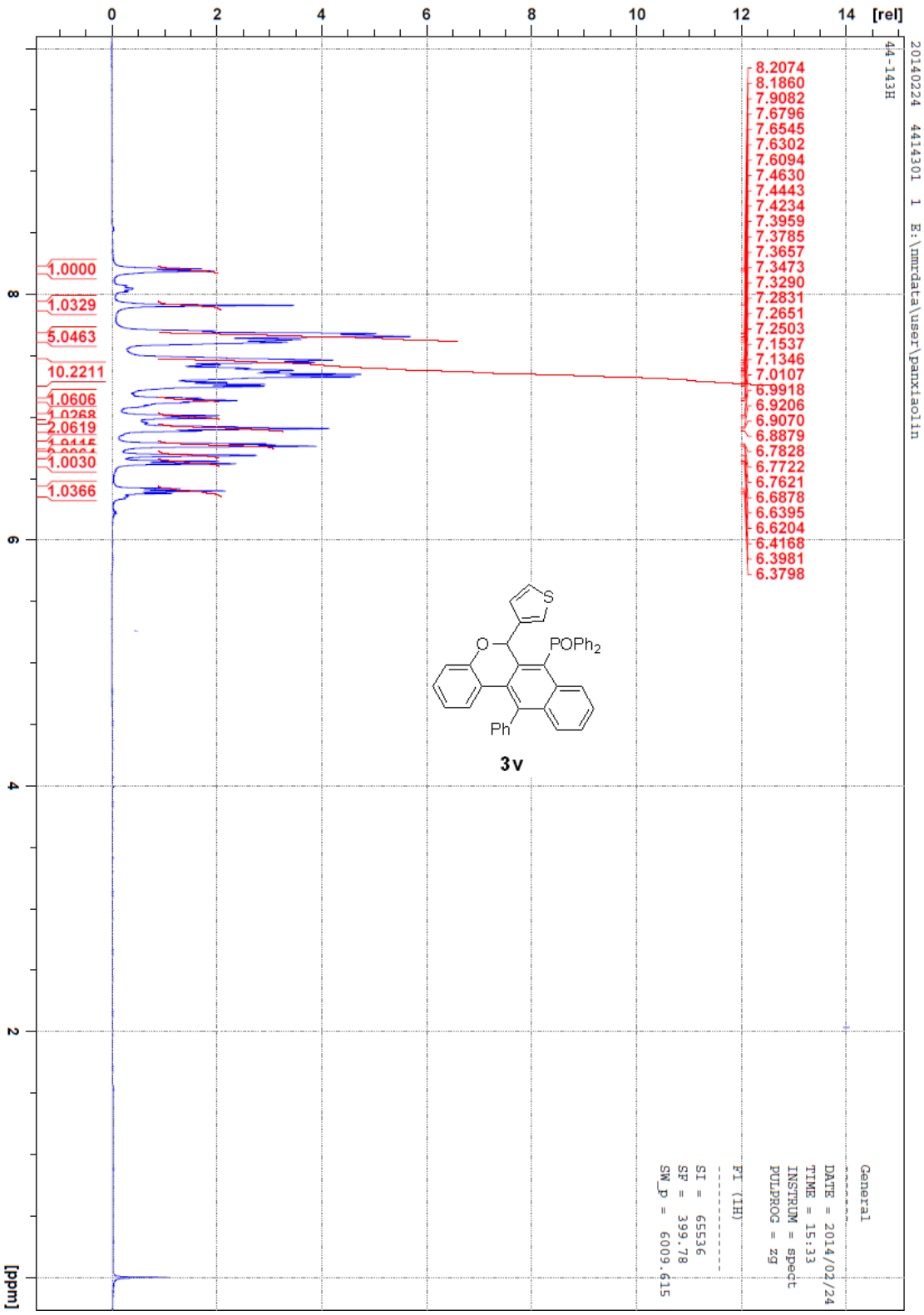
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S
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POPh2
Ph
3v
General
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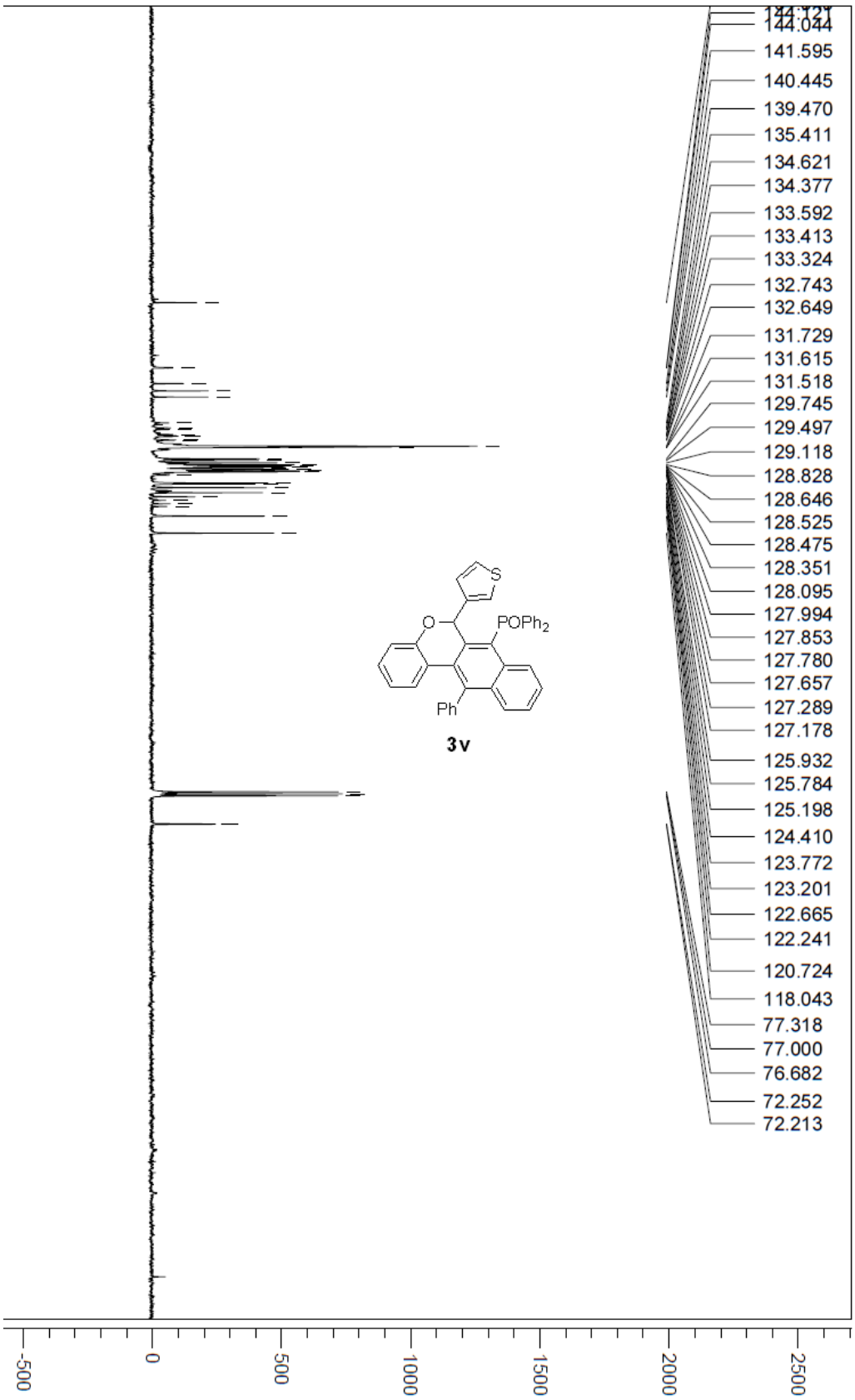
SI = 65536
SF = 399.78
SW_p = 6009.615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72.213
S
O
POPh2
Ph
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0
500
1000
1500
2000
2500

3v