Supporting Information

Photocatalytic difunctionalization of arylalkenes with quinoxalinones and dialkyl dithiophosphoric acids

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Table of Content

1. General information

Unless otherwise special noted, all reagents were purchased from commercial supplies and were used without further purification. Flash column chromatography was performed using silica gel (100-200 mesh). NMR spectra were obtained on a Bruker 400 MHz NMR using $CDCl_3$ as the solvent. Chemical shifts are given in ppm and coupling constants (*J*) in Hz. CV were performed on a CHI 600e potentiostat.

2. The general procedure for the photocatalysis

To a glass tube (8 mL) was added N-methyl quinoxalinone (0.2 mmol, 32 mg), styrene (0.4 mmol, 41 mg), diethyl dithiophosphoric acid (0.5 mmol, 94 mg), Eosin Y (0.002 mmol, 1.3 mg) and CH_3CN (2 mL) sequentially. The glass tube was then sealed with a rubber stopper and a O_2 balloon was attached. Finally, the resulting solution was irradiated by Kessil light (456 nm, 10 W) at rt for 4 h. A fan was necessary to cool down the reaction tube. After the reaction, the solvent was evaporated and the resulting crude was purified by SiO_2 (elute: petroleum ether/ethyl ether 10:1 to 4:1) to give the corresponding product **4** as a yellow oil (67 mg, 75%).

3. The general procedure for the scale-up synthesis

To a round-bottom flask (100 mL) was added N-methyl quinoxalinone (2 mmol, 320 mg), styrene (4 mmol, 410 mg), diethyl dithiophosphoric acid (5 mmol, 940 mg), Eosin Y (0.02 mmol, 13 mg) and CH_3CN (20 mL) sequentially. The glass tube was then sealed with a rubber stopper and a O_2 balloon was attached. Finally, the resulting solution was irradiated by two Kessil lights (456 nm, 10 W) at rt for 10 h. A fan was necessary to cool down the reaction tube. After the reaction, the solvent was evaporated and the resulting crude was purified by SiO_2 (elute: petroleum ether/ethyl ether 10:1 to 4:1) to give the corresponding product **4** as a yellow oil (473 mg, 53%).

4. The general procedure for the control experiment

To a glass tube (8 mL) was added N-methyl quinoxalinone (0.2 mmol, 32 mg), styrene (0.4 mmol, 41 mg), diethyl dithiophosphoric acid (0.5 mmol, 94 mg), Eosin Y (0.002 mmol, 1.3 mg) and CH_3CN (2 mL) sequentially. Then, BHT (0.4 mmol, 88 mg) was added to the reaction tube. The glass tube was then sealed with a rubber stopper and a O_2 balloon was attached. Finally, the resulting solution was irradiated by Kessil light (456 nm, 10 W) at rt for 4 h. A fan was necessary to cool down the reaction tube. After the reaction, the solvent was evaporated. The TLC analysis showed that only trace amount of product **4** was generated. However, the adduct between S-centered radical and BHT was observed by HRMS.

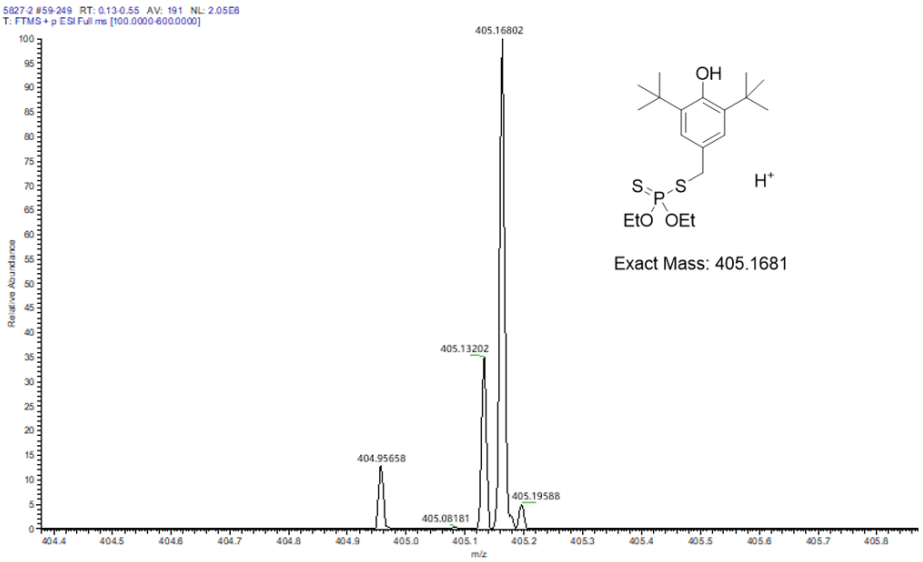


Fig S1. The HRMS of the radical adduct

5. The detection of in situ generated H_2O_2 by potassium iodide-starch test paper

To a glass tube (8 mL) was added N-methyl quinoxalinone (0.2 mmol, 32 mg), styrene (0.4 mmol, 41 mg), diethyl dithiophosphoric acid (0.5 mmol, 94 mg), Eosin Y (0.002 mmol, 1.3 mg) and CH_3CN (2 mL) sequentially. The glass tube was then sealed with a rubber stopper and a O_2 balloon was attached. Finally, the resulting red solution was

irradiated by Kessil light (456 nm, 10 W) at rt for 4 h. A fan was necessary to cool down the reaction tube. After the reaction, potassium iodide-starch test paper was immersed into the reaction mixture. As expected, the blue color change is clearly visible.

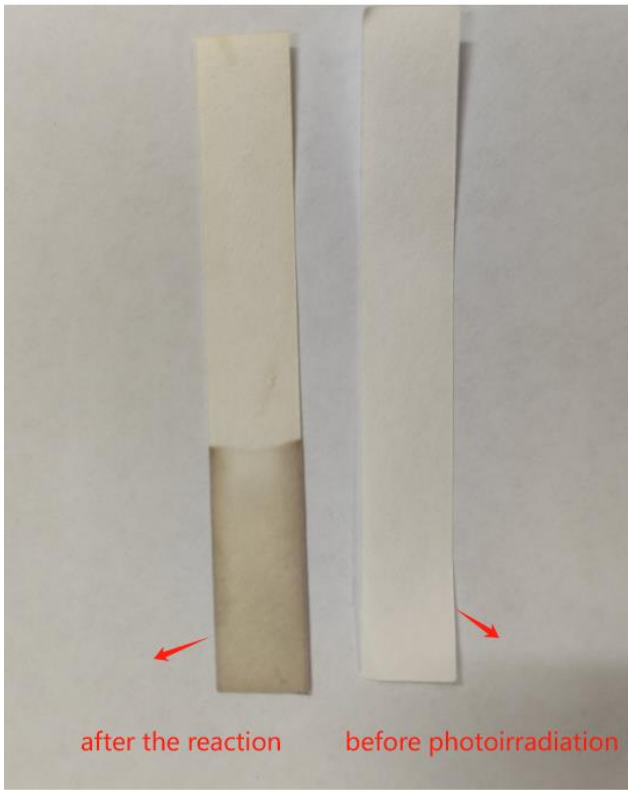
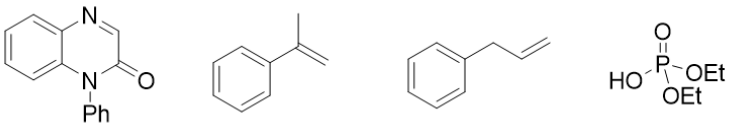


Fig S2. Potassium iodide starch paper test

6. The unsuccessful substrates



7. The general procedure for the CV experiments

All the CV experiments were performed in a three-electrode cell at room temperature. During CV analysis, Pt disk was employed as the working electrode; Pt wire was employed as the counter electrode; SCE was employed as the reference electrode. The

scan rete is 100 mV/s. The blank solution is 0.1 M $LiClO_4$ in CH_3CN. The concentration of the substrates is 5 mM in blank solution.

8. The Stern-Volmer quenching experiments

The UV-Vis spectrum of the cat. (eosin Y) in CH_3CN was recorded on a Shimadzu spectrophotometer. The concentration of cat. is $1*10^{-6}$ mol/L. The absorption was collected and the spectrum was shown in Fig. S3.

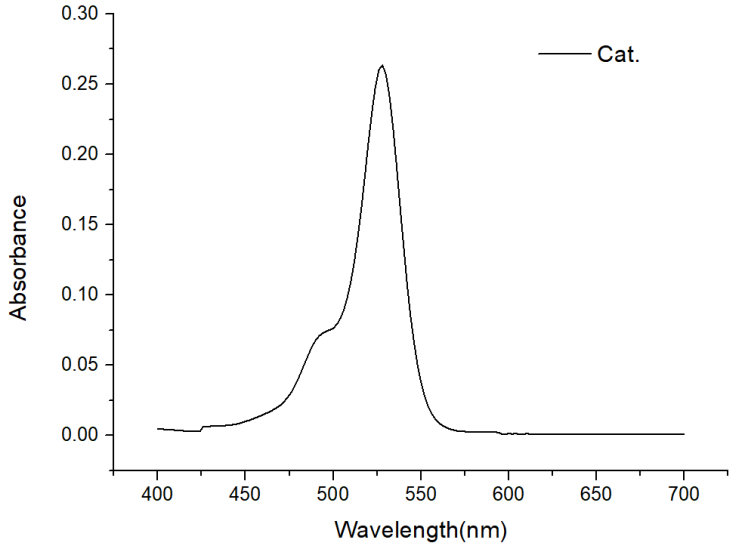


Fig. S3. UV-Vis spectrum of eosin Y (cat.)

The following luminescence quenching experiments were conducted in CH_3CN. The excitation wavelength was 528 nm. The concentration of cat. is $1*10^{-6}$ mol/L. We can conclude that substrate **3a** can't quench the excited state of eosin Y (Fig. S4). This result ruled out the electro- or energy transfer process thereby supported our hypothesized HAT mechanism to generate S-centered radical from **3a**.

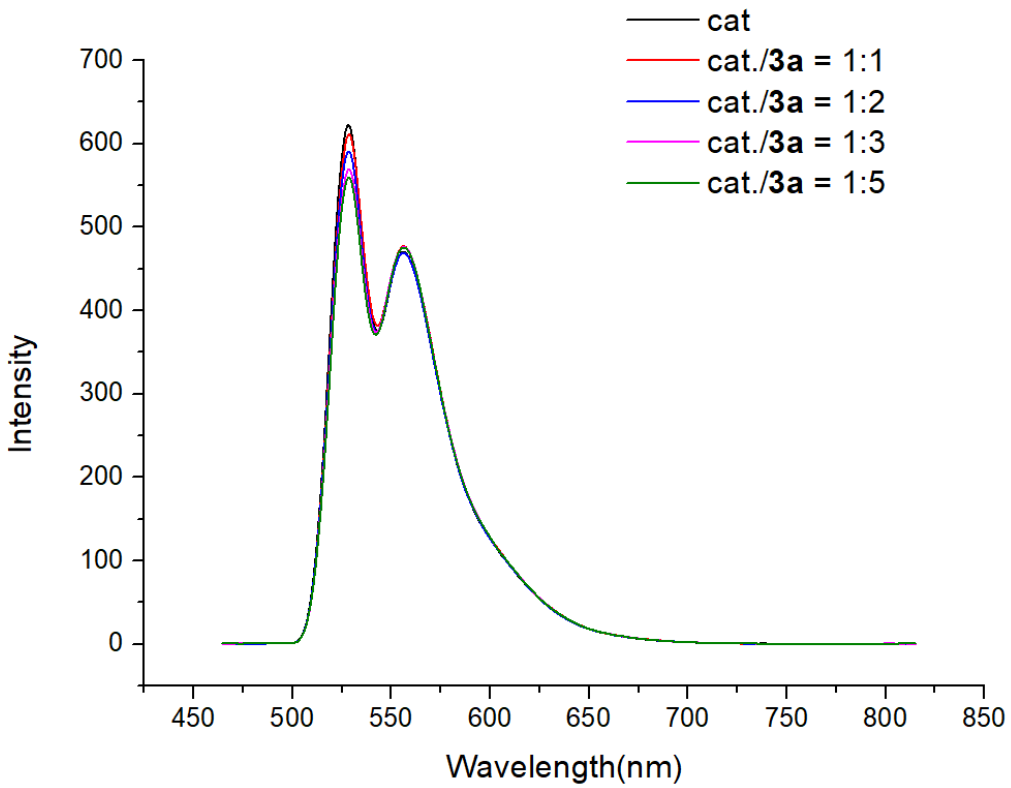
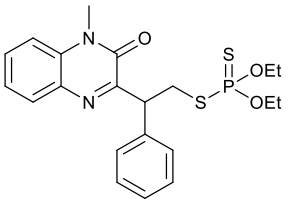


Fig. S4. The Stern-Volmer quenching experiments

9. The characterization data

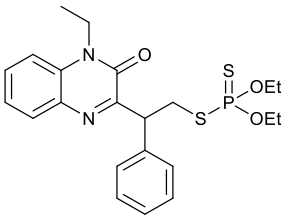
***O,O*-diethyl *S*-(2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (4)**



Yellow oil (67 mg, 75%), R_f = 0.32 (petroleum ether/EtOAc, 4:1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.60 – 7.55 (m, 1H), 7.45 (dd, *J* = 5.2, 3.4 Hz, 2H), 7.42 – 7.37 (m, 1H), 7.34 – 7.28 (m, 3H), 7.27 – 7.21 (m, 1H), 5.03 (dd, *J* = 9.7, 6.0 Hz, 1H), 4.26 – 4.10 (m, 4H), 3.87 (m, 1H), 3.65 (s, 3H), 3.47 (m, 1H), 1.45 – 1.34 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 154.3, 139.6, 133.3, 132.6, 130.4, 128.8, 128.6, 127.6, 123.8, 113.8, 64.0 (t, *J* = 5.6 Hz), 48.5 (d, *J* = 4.1 Hz), 36.5 (d, *J* = 3.8

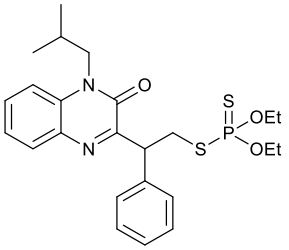
Hz), 29.3, 16.0 (dd, J = 8.5, 4.3 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ 94.6. **HRMS** (ESI) calculated for $C_{21}H_{26}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 449.1117; found: 449.1113.

***O,O*-diethyl *S*-(2-(4-ethyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (5)**



Yellow oil (68 mg, 74%), R_f = 0.33 (petroleum ether/EtOAc, 4:1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, J = 8.0, 1.4 Hz, 1H), 7.60 – 7.55 (m, 1H), 7.48 – 7.42 (m, 2H), 7.41 – 7.35 (m, 1H), 7.35 – 7.28 (m, 3H), 7.25 (m, 1H), 5.03 (dd, J = 9.7, 6.1 Hz, 1H), 4.40 – 4.03 (m, 6H), 3.86 (m, 1H), 3.47 (m, 1H), 1.40 (dd, J = 15.6, 7.3 Hz, 6H), 1.34 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 153.8, 139.7, 132.9, 132.3, 130.6, 130.3, 128.8, 128.6, 127.5, 123.5, 113.6, 64.0 (t, J = 5.5 Hz), 48.3 (d, J = 4.1 Hz), 37.6, 36.5 (d, J = 3.8 Hz), 16.0 (dd, J = 8.5, 4.2 Hz), 12.5. ^{31}P NMR (162 MHz, $CDCl_3$) δ 94.6. **HRMS** (ESI) calculated for $C_{22}H_{28}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 463.1273; found: 463.1269.

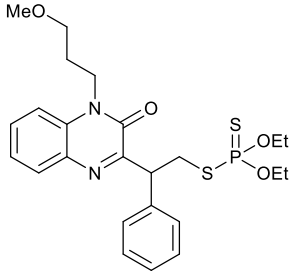
***O,O*-diethyl *S*-(2-(4-isobutyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (6)**



Yellow oil (70.6 mg, 72%), R_f = 0.32 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, J = 8.0, 1.5 Hz, 1H), 7.54 (m, 1H), 7.47 – 7.16 (m, 7H), 5.02 (dd, J = 9.7, 6.0 Hz, 1H), 4.29 – 4.05 (m, 5H), 4.04 – 3.78 (m, 2H), 3.51 – 3.42 (m, 1H),

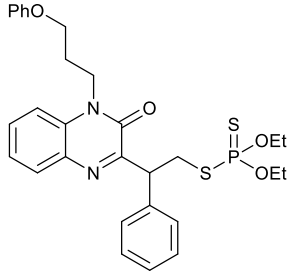
2.21 (m, 1H), 1.40 (m, 6H), 0.94 (dd, *J* = 26.7, 6.7 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 154.5, 139.7, 132.8, 132.8, 130.6, 130.1, 128.8, 128.5, 127.5, 123.5, 114.2, 64.0 (t, *J* = 5.6 Hz), 49.1, 48.5 (d, *J* = 4.0 Hz), 36.6 (d, *J* = 3.8 Hz), 27.3, 20.2 (d, *J* = 3.0 Hz), 16.0 (dd, *J* = 8.6, 4.3 Hz). **HRMS** (ESI) calculated for $C_{24}H_{32}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 491.1586; found: 491.1582.

***O,O*-diethyl *S*-(2-(4-(3-methoxypropyl)-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (7)**



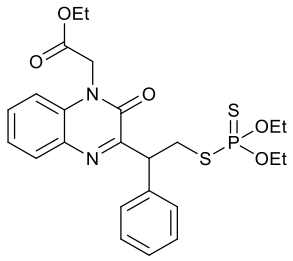
Yellow oil (69.8 mg, 69%), R_f = 0.26 (petroleum ether/EtOAc, 3:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.59 – 7.54 (m, 1H), 7.47 – 7.41 (m, 3H), 7.41 – 7.35 (m, 1H), 7.34 – 7.28 (m, 2H), 7.24 (m, 1H), 5.01 (dd, *J* = 9.6, 6.1 Hz, 1H), 4.41 – 4.06 (m, 6H), 3.86 (m, 1H), 3.52 – 3.45 (m, 1H), 3.43 (t, *J* = 5.7 Hz, 2H), 3.33 (s, 3H), 2.04 – 1.90 (m, 2H), 1.40 (dd, *J* = 15.5, 7.3 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.8, 154.2, 139.7, 132.8, 132.7, 130.5, 130.4, 128.8, 128.6, 127.5, 123.6, 113.9, 69.9, 64.0 (t, *J* = 5.5 Hz), 58.9, 48.4 (d, *J* = 4.2 Hz), 40.2, 36.5 (d, *J* = 3.8 Hz), 27.7, 16.0 (dd, *J* = 8.6, 4.3 Hz). **HRMS** (ESI) calculated for $C_{24}H_{32}N_2O_4PS_2^+$ Exact Mass: $[M+H]^+$: 507.1536; found: 507.1530.

***O,O*-diethyl *S*-(2-(3-oxo-4-(3-phenoxypropyl)-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (8)**



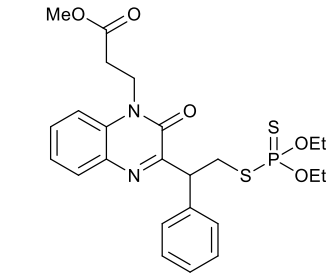
Yellow oil (72.7 mg, 64%), R_f = 0.22 (petroleum ether/EtOAc, 3:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.52 – 7.49 (m, 1H), 7.46 – 7.41 (m, 4H), 7.40 – 7.37 (m, 1H), 7.34 – 7.30 (m, 3H), 7.27 – 7.25 (m, 1H), 7.00 – 6.96 (m, 1H), 6.91 – 6.88 (m, 2H), 5.02 (dd, *J* = 9.6, 6.1 Hz, 1H), 4.47 – 4.37 (m, 2H), 4.26 – 4.14 (m, 4H), 4.06 – 4.04 (m, 2H), 3.86 (m, 1H), 3.47 (m, 1H), 2.31 – 2.06 (m, 2H), 1.42 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.8, 158.6, 154.2, 139.7, 132.8, 132.6, 130.6, 130.5, 129.7, 128.8, 128.6, 127.6, 123.7, 121.2, 114.6, 113.8, 65.2, 64.0 (d, *J* = 5.5 Hz), 48.4 (d, *J* = 4.1 Hz), 40.0, 36.5, 27.3, 16.0 (dd, *J* = 8.5, 3.5 Hz). **HRMS** (ESI) calculated for $C_{29}H_{34}N_2O_4PS_2^+$ Exact Mass: $[M+H]^+$: 569.1692; found: 569.1687.

ethyl 2-(3-(2-((diethoxyphosphorothioyl)thio)-1-phenylethyl)-2-oxoquinoxalin-1(2H)-yl)acetate (9)



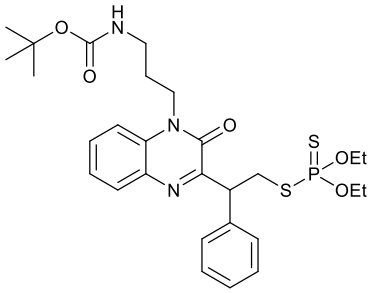
Yellow oil (73.8 mg, 71%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.59 – 7.49 (m, 1H), 7.43 – 7.38 (m, 3H), 7.33 – 7.31 (m, 2H), 7.27 – 7.21 (m, 1H), 7.13 – 7.03 (m, 1H), 5.08 – 4.95 (m, 2H), 4.89 (d, *J* = 17.3 Hz, 1H), 4.27 – 4.15 (m, 4H), 4.15 – 4.04 (m, 2H), 3.85 (m, 1H), 3.48 (m, 1H), 1.42 – 1.35 (m, 6H), 1.23 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 158.8, 153.9, 139.4, 132.7, 132.5, 130.8, 130.5, 128.9, 128.6, 127.6, 124.1, 113.3, 64.0 (d, *J* = 3.3 Hz), 62.2, 48.5 (d, *J* = 4.2 Hz), 43.8, 36.6, 16.0 (dd, *J* = 8.5, 3.6 Hz), 14.2. **HRMS** (ESI) calculated for $C_{24}H_{30}N_2O_5PS_2^+$ Exact Mass: $[M+H]^+$: 521.1328; found: 521.1322.

methyl 3-(3-(2-((diethoxyphosphorothioyl)thio)-1-phenylethyl)-2-oxoquinoxalin-1(2H)-yl)propanoate (10)



Yellow oil (76 mg, 73%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.66 – 7.55 (m, 1H), 7.47 – 7.15 (m, 8H), 5.00 (dd, *J* = 9.7, 6.1 Hz, 1H), 4.49 (dd, *J* = 9.5, 6.0 Hz, 2H), 4.33 – 4.05 (m, 4H), 3.90 – 3.80 (m, 1H), 3.65 (s, 3H), 3.50 – 3.42 (m, 1H), 2.80 – 2.65 (m, 2H), 1.45 – 1.35 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.3, 158.8, 154.0, 139.5, 132.9, 132.2, 130.8, 130.6, 128.8, 128.6, 127.6, 123.9, 113.4, 64.0 (t, *J* = 5.5 Hz), 52.1, 48.4 (d, *J* = 4.1 Hz), 38.4, 36.5, 31.7, 16.0 (dd, *J* = 8.5, 4.2 Hz). **HRMS** (ESI) calculated for $C_{24}H_{30}N_2O_5PS_2^+$ Exact Mass: $[M+H]^+$: 521.1328; found: 521.1323.

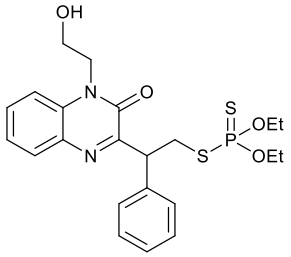
***tert*-butyl (3-(3-(2-((diethoxyphosphorothioyl)thio)-1-phenylethyl)-2-oxoquinoxalin-1(2H)-yl)propyl)carbamate (11)**



Yellow oil (61.5 mg, 52%), R_f = 0.21 (petroleum ether/EtOAc, 2:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.62 – 7.51 (m, 1H), 7.43 – 7.40 (m, 3H), 7.34 – 7.29 (m, 3H), 7.26 – 7.22 (m, 1H), 5.25 (s, 1H), 5.03 (dd, *J* = 9.7, 6.0 Hz, 1H), 4.35 (dd, *J* = 13.4, 6.6 Hz, 1H), 4.29 – 4.05 (m, 5H), 3.94 – 3.75 (m, 1H), 3.46 (m, 1H), 3.19 – 2.92 (m, 2H), 1.94 – 1.88 (m, 2H), 1.46 (s, 9H), 1.42 – 1.34 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.7, 156.2, 154.5, 139.6, 133.0, 132.2, 130.7, 130.5, 128.8, 128.5, 127.6), 123.9, 113.7, 79.4, 64.0 (t, *J* = 5.6 Hz), 48.4 (d, *J* = 4.0 Hz), 39.8, 37.3,

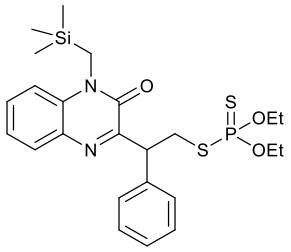
36.6, 28.6, 27.7, 16.0 (dd, J = 8.5, 3.6 Hz). **HRMS** (ESI) calculated for $C_{28}H_{39}N_3O_5PS_2^+$ Exact Mass: $[M+H]^+$: 592.2063; found: 592.2059.

***O,O*-diethyl *S*-(2-(4-(2-hydroxyethyl)-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (12)**



Yellow oil (37.3 mg, 39%), R_f = 0.32 (petroleum ether/EtOAc, 1:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, J = 8.0, 1.4 Hz, 1H), 7.62 – 7.52 (m, 1H), 7.47 – 7.37 (m, 5H), 7.31 (dd, J = 10.1, 4.7 Hz, 2H), 7.25 (d, J = 7.3 Hz, 1H), 5.01 (dd, J = 9.6, 6.1 Hz, 1H), 4.51 – 4.30 (m, 2H), 4.29 – 4.05 (m, 4H), 3.99 (t, J = 5.5 Hz, 2H), 3.90 – 3.81 (m, 1H), 3.51-3.43 (m, 1H), 1.44 – 1.33 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.7, 155.2, 139.5, 132.9, 132.8, 130.7, 130.4, 128.8, 128.6, 127.6, 124.0, 114.0, 64.0 (t, J = 5.2 Hz), 60.6, 48.4 (d, J = 4.0 Hz), 45.2, 36.6 (d, J = 3.8 Hz), 16.0 (dd, J = 8.5, 4.0 Hz). **HRMS** (ESI) calculated for $C_{22}H_{28}N_2O_4PS_2^+$ Exact Mass: $[M+H]^+$: 479.1223; found: 479.1217.

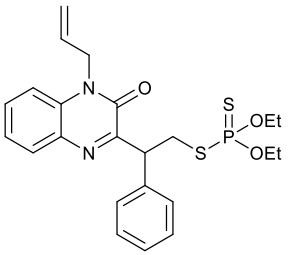
***O,O*-diethyl *S*-(2-(3-oxo-4-((trimethylsilyl)methyl)-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (13)**



Yellow oil (76 mg, 73%), R_f = 0.41 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, J = 8.0, 1.5 Hz, 1H), 7.55 (m, 1H), 7.47 – 7.17 (m, 7H), 5.02 (dd, J = 9.8, 5.9 Hz, 1H), 4.33 – 4.05 (m, 4H), 3.98 – 3.81 (m, 2H), 3.75 (d, J = 14.9 Hz, 1H), 3.51 – 3.43 (m, 1H), 1.49 – 1.34 (m, 6H), 0.07 – -0.05 (m, 9H). ^{13}C NMR (100 MHz,

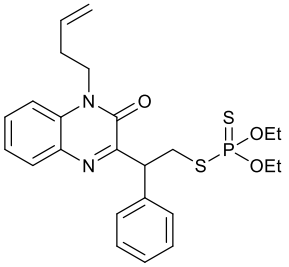
$CDCl_3$) δ 158.4, 153.9, 139.8, 133.2, 132.9, 130.5, 129.9, 128.7, 128.5, 127.4, 123.4, 114.5, 63.9 (t, *J* = 5.8 Hz), 48.6 (d, *J* = 4.1 Hz), 36.5 (d, *J* = 3.9 Hz), 34.2, 16.0 (dd, *J* = 8.6, 4.1 Hz), -1.3. **HRMS** (ESI) calculated for $C_{24}H_{34}N_2O_3PS_2Si^+$ Exact Mass: $[M+H]^+$: 521.1512; found: 521.1506.

_S_-(2-(4-allyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) _O,O_-diethyl phosphorodithioate (14)



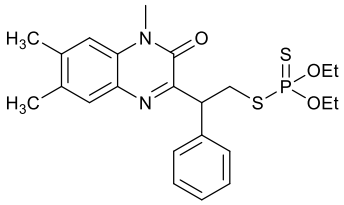
Yellow oil (62.5 mg, 66%), R_f = 0.36 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.56 – 7.52 (m, 1H), 7.47 – 7.41 (m, 2H), 7.41 – 7.35 (m, 1H), 7.33 – 7.23 (m, 4H), 5.89 (m, 1H), 5.24 (m, 1H), 5.14 (dd, *J* = 17.3, 0.6 Hz, 1H), 5.03 (dd, *J* = 9.7, 6.1 Hz, 1H), 4.95 – 4.89 (m, 1H), 4.82 – 4.71 (m, 1H), 4.28 – 4.04 (m, 4H), 3.91 – 3.81 (m, 1H), 3.51 – 3.43 (m, 1H), 1.40 (dd, *J* = 14.9, 7.5 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 153.9, 139.6, 132.8, 132.6, 130.7, 130.5, 130.3, 128.8, 128.6, 127.6, 123.7, 118.3, 114.3, 64.0 (t, *J* = 5.2 Hz), 48.4 (d, *J* = 4.2 Hz), 44.8, 36.6, 16.0 (dd, *J* = 8.6, 3.8 Hz). **HRMS** (ESI) calculated for $C_{23}H_{28}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 475.1273; found: 475.1269.

_S_-(2-(4-(but-3-en-1-yl)-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) _O,O_-diethyl phosphorodithioate (15)



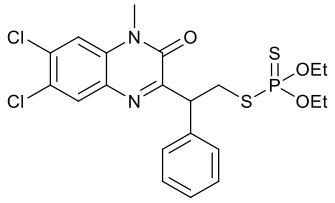
Yellow oil (66.4 mg, 68%), R_f = 0.36 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.57 – 7.55 (m, 1H), 7.44 – 7.37 (m, 3H), 7.35 – 7.27 (m, 3H), 7.27 – 7.21 (m, 1H), 5.82 (m, 1H), 5.12 – 4.95 (m, 3H), 4.36 – 4.08 (m, 6H), 3.85 (m, 1H), 3.46 m, 1H), 2.46 (dd, *J* = 14.8, 7.4 Hz, 2H), 1.47 – 1.34 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 154.0, 139.6, 133.9, 132.8, 132.4, 130.7, 130.3, 128.8, 128.6, 127.5, 123.6, 117.8, 113.7, 64.0 (t, *J* = 5.6 Hz), 48.4 (d, *J* = 4.2 Hz), 41.8, 36.5, 31.5, 16.0 (dd, *J* = 8.6, 4.1 Hz). **HRMS** (ESI) calculated for $C_{24}H_{30}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 489.1430; found: 489.1425.

***O,O*-diethyl *S*-(2-phenyl-2-(4,6,7-trimethyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl) phosphorodithioate (16)**



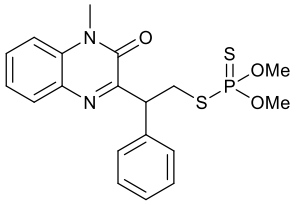
Yellow oil (67.6 mg, 71%), R_f = 0.35 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (s, 1H), 7.44 – 7.40 (m, 2H), 7.32 – 7.28 (m, 2H), 7.26 – 7.19 (m, 1H), 7.06 (s, 1H), 4.99 (dd, *J* = 9.7, 6.1 Hz, 1H), 4.26 – 4.10 (m, 4H), 3.84 (m, 1H), 3.62 (s, 3H), 3.44 (m, 1H), 2.44 (s, 3H), 2.40 (s, 3H), 1.43 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.6, 154.4, 140.2, 139.9, 132.7, 131.4, 131.0, 130.5, 128.8, 128.6, 127.5, 114.3, 64.0 (t, *J* = 5.7 Hz), 48.4 (d, *J* = 4.2 Hz), 36.6, 29.2, 20.7, 19.3, 16.0 (dd, *J* = 8.5, 4.3 Hz). **HRMS** (ESI) calculated for $C_{23}H_{30}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 477.1430; found: 477.1425.

***S*-(2-(6,7-dichloro-4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) *O,O*-diethyl phosphorodithioate (17)**



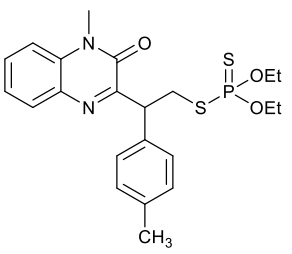
Yellow oil (64 mg, 62%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.43 – 7.38 (m, 3H), 7.34 – 7.30 (m, 2H), 7.28 – 7.23 (m, 1H), 5.01 (dd, *J* = 9.7, 6.0 Hz, 1H), 4.27 – 4.09 (m, 4H), 3.86 – 3.72 (m, 1H), 3.63 (s, 3H), 3.48 – 3.39 (m, 1H), 1.43 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.6, 153.8, 139.0, 134.5, 132.8, 131.6, 131.1, 128.9, 128.6, 127.8, 127.6, 115.3, 64.1 (t, *J* = 5.8 Hz), 48.7 (d, *J* = 3.8 Hz), 36.4 (d, *J* = 3.6 Hz), 29.5, 16.0 (dd, *J* = 8.4, 4.6 Hz). **HRMS** (ESI) calculated for $C_{21}H_{24}Cl_2N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 517.0338; found: 517.0333.

***O,O*-dimethyl *S*-(2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorodithioate (18)**



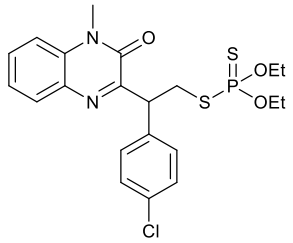
Yellow oil (64 mg, 76%), R_f = 0.33 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.60 – 7.58 (m, 1H), 7.46 – 7.38 (m, 3H), 7.35 – 7.29 (m, 3H), 7.27 – 7.21 (m, 1H), 5.01 (dd, *J* = 9.6, 6.1 Hz, 1H), 3.93 – 3.82 (m, 1H), 3.80 (s, 3H), 3.77 (s, 3H), 3.65 (s, 3H), 3.45 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.8, 154.4, 139.4, 133.3, 132.6, 130.4, 130.4, 128.8, 128.6, 127.6, 123.8, 113.8, 54.1 (t, *J* = 5.1 Hz), 48.4 (d, *J* = 4.0 Hz), 36.6 (d, *J* = 3.8 Hz), 29.3. **HRMS** (ESI) calculated for $C_{19}H_{22}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 421.0804; found: 421.0801.

***O,O*-diethyl *S*-(2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-(p-tolyl)ethyl) phosphorodithioate (19)**



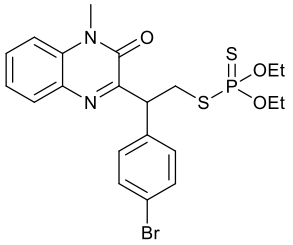
Yellow oil (68.4 mg, 74%), R_f = 0.33 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.61 – 7.53 (m, 1H), 7.42 – 7.36 (m, 1H), 7.31 (dd, *J* = 11.3, 8.8 Hz, 3H), 7.12 (d, *J* = 7.9 Hz, 2H), 4.98 (dd, *J* = 9.7, 6.1 Hz, 1H), 4.30 – 4.08 (m, 4H), 3.85 (m, 1H), 3.64 (s, 3H), 3.45 (m, 1H), 2.31 (s, 3H), 1.47 – 1.35 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 154.3, 137.3, 136.5, 133.3, 132.6, 130.3, 130.3, 129.5, 128.4, 123.7, 113.7, 64.0 (t, *J* = 5.7 Hz), 48.1 (d, *J* = 4.0 Hz), 36.4 (d, *J* = 3.7 Hz), 29.2, 21.2, 16.0 (dd, *J* = 8.6, 4.4 Hz). **HRMS** (ESI) calculated for $C_{22}H_{28}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 463.1273; found: 463.1267.

_S_-(2-(4-chlorophenyl)-2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl) _O,O_-diethyl phosphorodithioate (20)



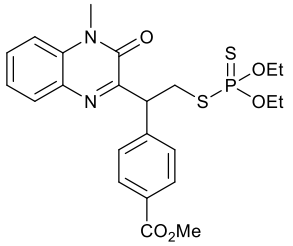
Yellow oil (73.2 mg, 73%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.61 – 7.57 (m, 1H), 7.44 – 7.36 (m, 3H), 7.33 – 7.26 (m, 3H), 5.00 (dd, *J* = 9.4, 6.3 Hz, 1H), 4.24 – 4.12 (m, 4H), 3.83 (m, 1H), 3.65 (s, 3H), 3.44 (m, 1H), 1.43 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.5, 154.3, 138.1, 133.5, 133.3, 132.5, 130.6, 130.4, 130.0, 129.0, 123.9, 113.8, 64.1 (dd, *J* = 5.7, 4.0 Hz), 47.9 (d, *J* = 4.0 Hz), 36.5 (d, *J* = 3.7 Hz), 29.3, 16.0 (dd, *J* = 8.5, 4.5 Hz). **HRMS** (ESI) calculated for $C_{21}H_{25}ClN_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 483.0727; found: 483.0724.

_S_-(2-(4-bromophenyl)-2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl) _O,O_-diethyl phosphorodithioate (21)



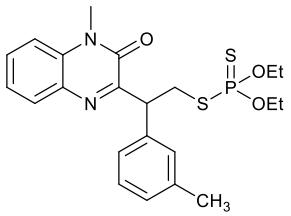
Yellow oil (74.2 mg, 71%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.63 – 7.54 (m, 1H), 7.46 – 7.37 (m, 3H), 7.32 (d, *J* = 8.5 Hz, 3H), 4.99 (dd, *J* = 9.3, 6.3 Hz, 1H), 4.32 – 4.04 (m, 4H), 3.83 (m, 1H), 3.65 (s, 3H), 3.44 (m, 1H), 1.42 – 1.36 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.5, 154.3, 138.6, 133.3, 132.5, 131.9, 130.6, 130.5, 130.4, 123.9, 121.7, 113.8, 64.1 (dd, *J* = 5.7, 4.0 Hz), 48.0 (d, *J* = 4.0 Hz), 36.4 (d, *J* = 3.6 Hz), 29.3, 16.0 (dd, *J* = 8.4, 4.5 Hz). **HRMS** (ESI) calculated for $C_{21}H_{25}BrN_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 527.0222; found: 527.0219.

methyl 4-(2-((diethoxyphosphorothioyl)thio)-1-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl)benzoate (22)



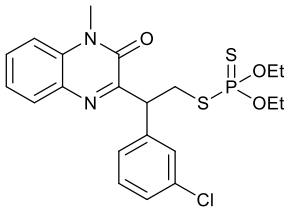
Yellow oil (67.8 mg, 67%), R_f = 0.29 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 – 7.94 (m, 3H), 7.62 – 7.57 (m, 1H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.45 – 7.37 (m, 1H), 7.32 (dd, *J* = 8.4, 0.8 Hz, 1H), 5.08 (dd, *J* = 9.4, 6.3 Hz, 1H), 4.27 – 4.07 (m, 4H), 3.95 – 3.80 (m, 4H), 3.65 (s, 3H), 3.47 (m, 1H), 1.44 – 1.34 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.9, 158.3, 154.3, 144.8, 133.4, 132.6, 130.6, 130.5, 130.1, 129.5, 128.7, 123.9, 113.8, 64.1 (t, *J* = 5 Hz), 52.2, 48.5 (d, *J* = 3.9 Hz), 36.3 (d, *J* = 3.6 Hz), 29.3, 16.0 (dd, *J* = 8.4, 4.9 Hz). **HRMS** (ESI) calculated for $C_{23}H_{28}N_2O_5PS_2^+$ Exact Mass: $[M+H]^+$: 507.1172; found: 507.1166.

***O,O*-diethyl *S*-(2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-(m-tolyl)ethyl) phosphorodithioate (23)**



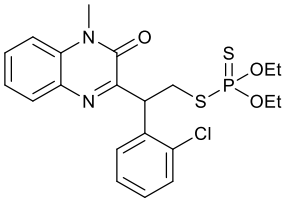
Yellow oil (65.6 mg, 71%), R_f = 0.31 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.60 – 7.56 (m, 1H), 7.44 – 7.36 (m, 1H), 7.31 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.20 (dd, *J* = 13.4, 6.3 Hz, 3H), 7.06 (d, *J* = 7.0 Hz, 1H), 4.98 (dd, *J* = 9.8, 5.9 Hz, 1H), 4.26 – 4.12 (m, 4H), 3.85 (m, 1H), 3.65 (s, 3H), 3.44 (m, 1H), 2.33 (s, 3H), 1.44 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 154.4, 139.5, 138.4, 133.4, 132.6, 130.4, 130.3, 129.3, 128.7, 128.4, 125.6, 123.7, 113.7, 64.0 (t, *J* = 5.9 Hz), 48.5 (d, *J* = 4.1 Hz), 36.5 (d, *J* = 3.7 Hz), 29.3, 21.6, 16.0 (dd, *J* = 8.5, 4.4 Hz). **HRMS** (ESI) calculated for $C_{22}H_{28}N_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 463.1273; found: 463.1270.

***S*-(2-(3-chlorophenyl)-2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl) *O,O*-diethyl phosphorodithioate (24)**



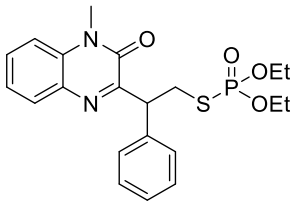
Yellow oil (67.5 mg, 70%), R_f = 0.31 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.62 – 7.58 (m, 1H), 7.45 – 7.31 (m, 4H), 7.28 – 7.20 (m, 2H), 5.00 (dd, *J* = 9.5, 6.2 Hz, 1H), 4.30 – 4.07 (m, 4H), 3.83 (m, 1H), 3.66 (s, 3H), 3.44 (m, 1H), 1.43 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.3, 154.3, 141.6, 134.6, 133.4, 132.6, 130.6, 130.5, 130.1, 128.4, 127.9 127.2, 123.9, 113.8, 64.1 (t, *J* = 5.5 Hz), 48.2 (d, *J* = 4.0 Hz), 36.5, 29.3, 16.0 (dd, *J* = 8.4, 4.9 Hz). **HRMS** (ESI) calculated for $C_{21}H_{25}ClN_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 483.0727; found: 483.0723.

***S*-(2-(2-chlorophenyl)-2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)ethyl) *O,O*-diethyl phosphorodithioate (25)**



Yellow oil (60.7 mg, 63%), R_f = 0.30 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.63 – 7.59 (m, 1H), 7.48 – 7.39 (m, 2H), 7.34 (dd, *J* = 8.4, 0.9 Hz, 1H), 7.22 – 7.10 (m, 3H), 5.51 (dd, *J* = 10.0, 5.4 Hz, 1H), 4.27 – 4.12 (m, 4H), 3.82 – 3.68 (m, 1H), 3.66 (d, *J* = 2.7 Hz, 3H), 3.40 (m, 1H), 1.43 – 1.37 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.3, 154.2, 137.4, 135.0, 133.4, 132.4, 130.7, 130.5, 130.3, 128.7, 128.5, 127.0, 123.8, 113.8, 64.0 (dd, *J* = 15.7, 5.5 Hz), 45.0 (d, *J* = 4.4 Hz), 35.3 (d, *J* = 4.1 Hz), 29.3, 16.0 (dd, *J* = 8.4, 5.2 Hz). **HRMS** (ESI) calculated for $C_{21}H_{25}ClN_2O_3PS_2^+$ Exact Mass: $[M+H]^+$: 483.0727; found: 483.0722.

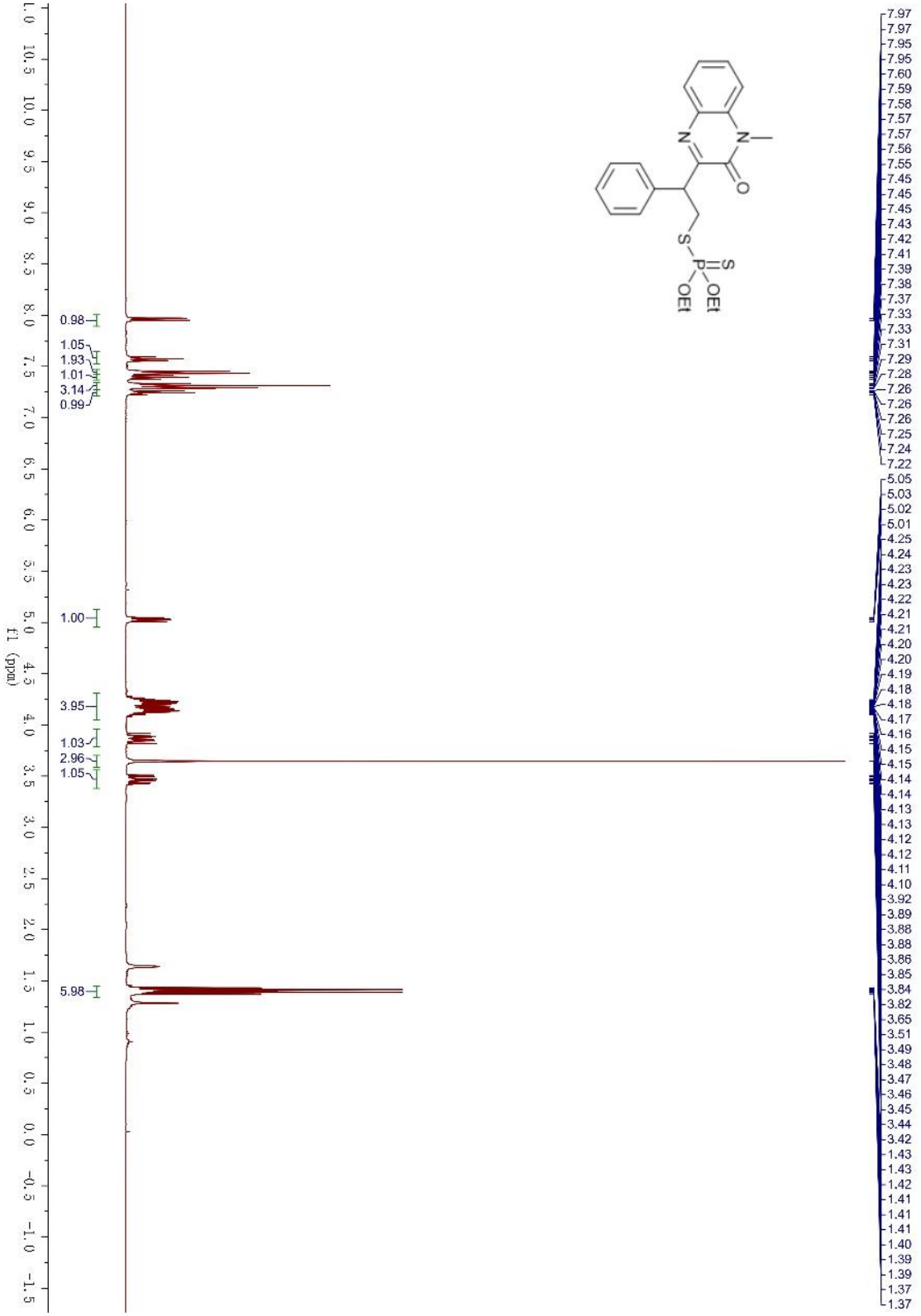
***O,O*-diethyl *S*-(2-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2-yl)-2-phenylethyl) phosphorothioate （27）**



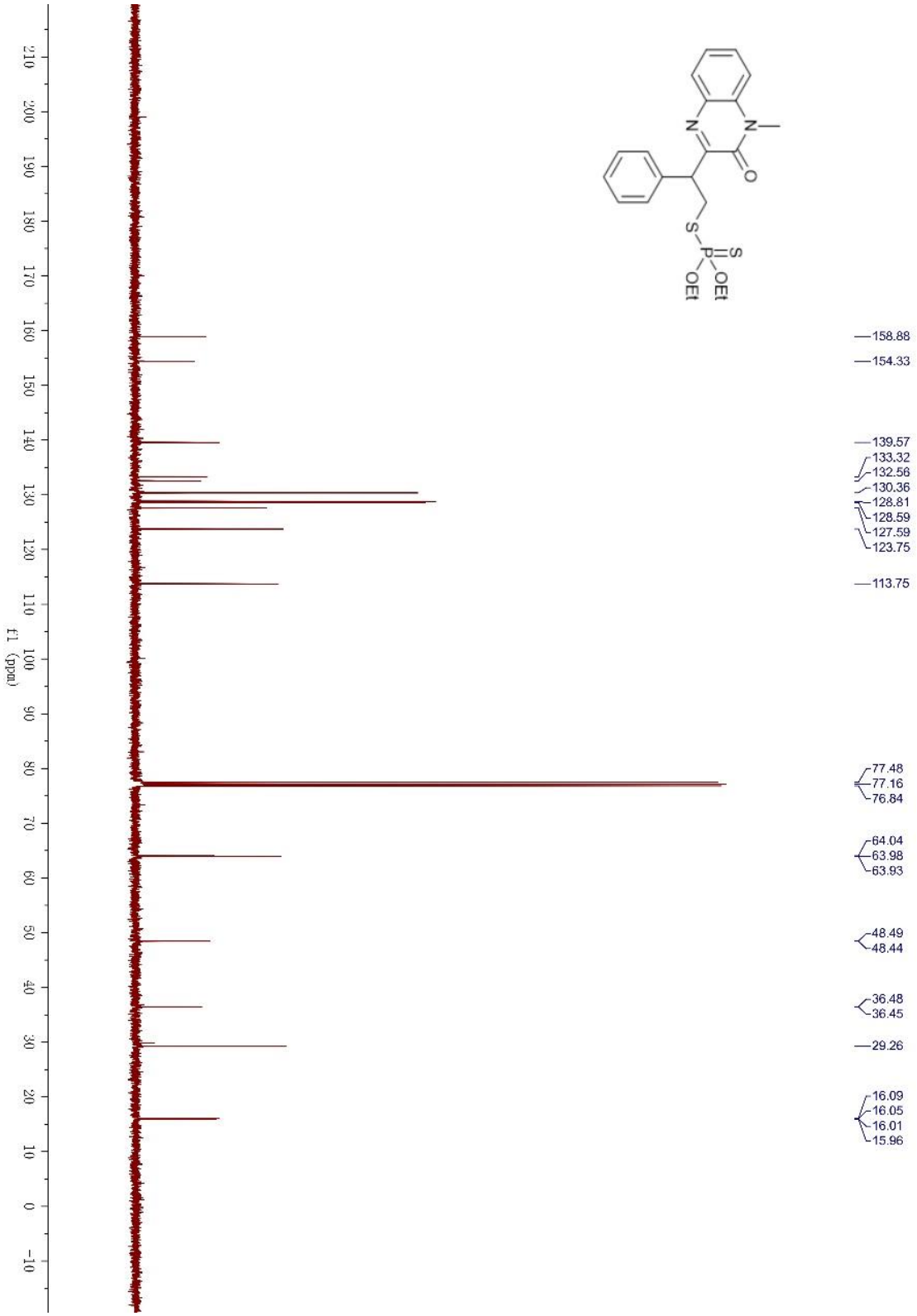
Yellow oil (26.8 mg, 31%), R_f = 0.25 (petroleum ether/EtOAc, 4:1), ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.57 (ddd, *J* = 8.6, 7.5, 1.5 Hz, 1H), 7.46 – 7.37 (m, 3H), 7.34 – 7.15 (m, 5H), 5.01 (dd, *J* = 9.3, 6.4 Hz, 1H), 4.27 – 4.05 (m, 4H), 3.90 – 3.81 (m, 1H), 3.65 (s, 3H), 3.49 – 3.41 (m, 1H), 1.46 – 1.33 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 154.3, 139.4, 133.3, 132.6, 130.4, 128.8, 128.7, 127.6, 123.8, 113.8, 63.6 (t, *J* = 5.3 Hz), 48.7 (d, *J* = 5.0 Hz), 34.1 (d, *J* = 3.6 Hz), 29.3, 16.2 (dd, *J* = 7.3, 2.2 Hz). **HRMS** (ESI) calculated for $C_{21}H_{26}N_2O_4PS^+$ Exact Mass: $[M+H]^+$: 433.1345; found: 433.1341.

10. The NMR spectra

^{1}H NMR of **4**



^{13}C NMR of **4**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128.59
127.59
123.75
113.75
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76.84
64.04
63.98
63.93
48.49
48.44
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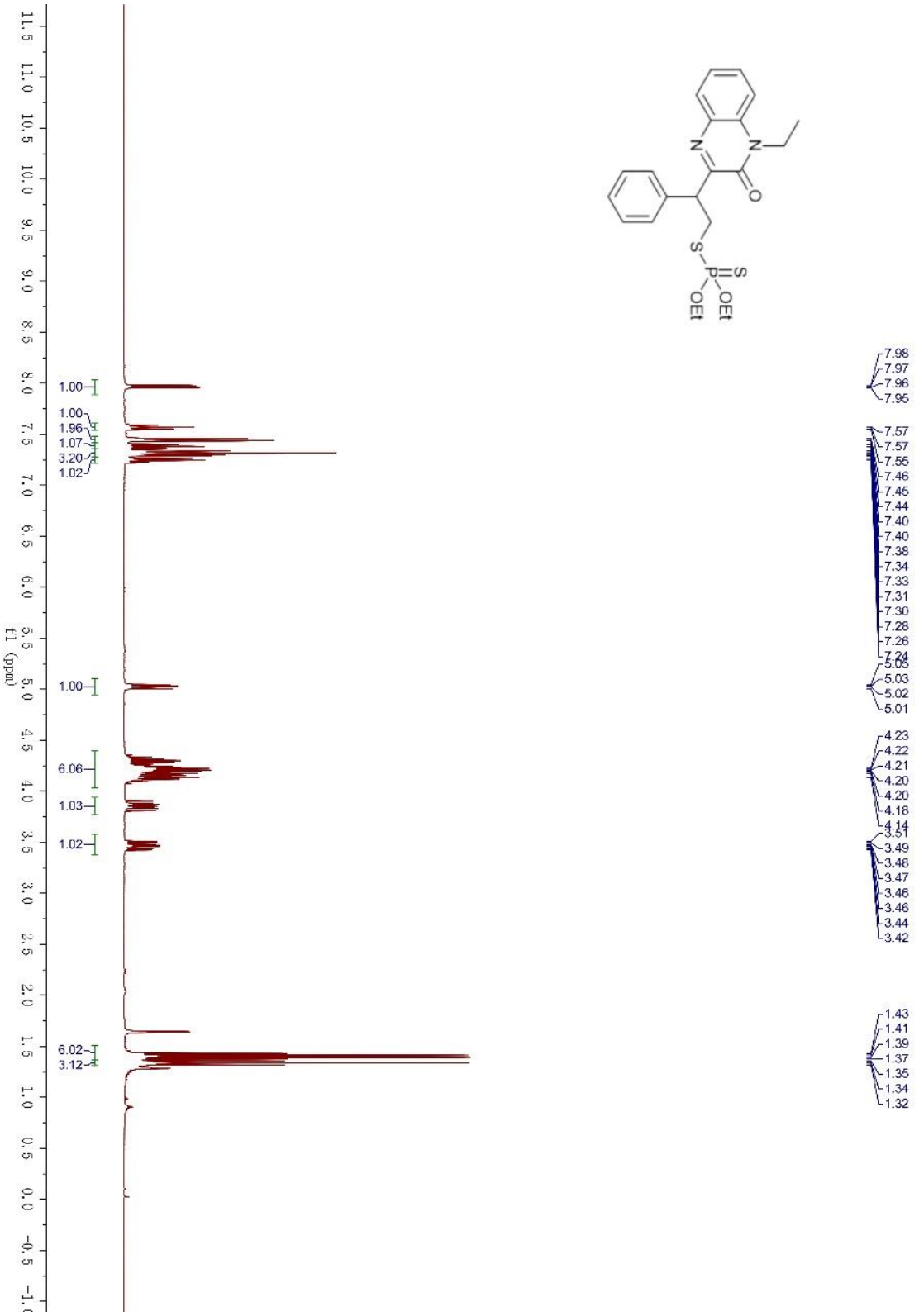
36.45
29.26
16.09
16.05
16.01
15.96
f1 (ppm)

^{1}H NMR of **5**


f1 (ppm)
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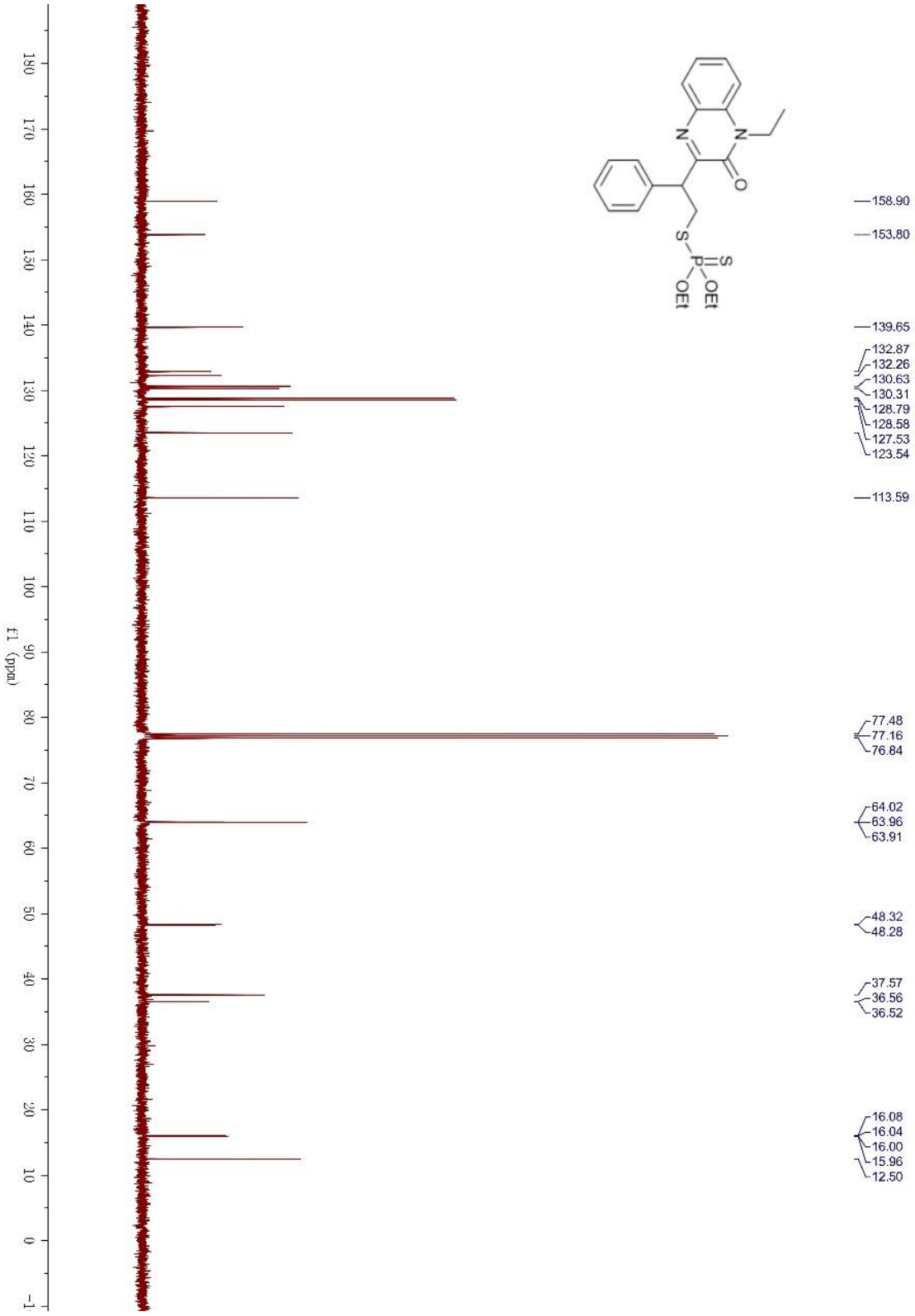
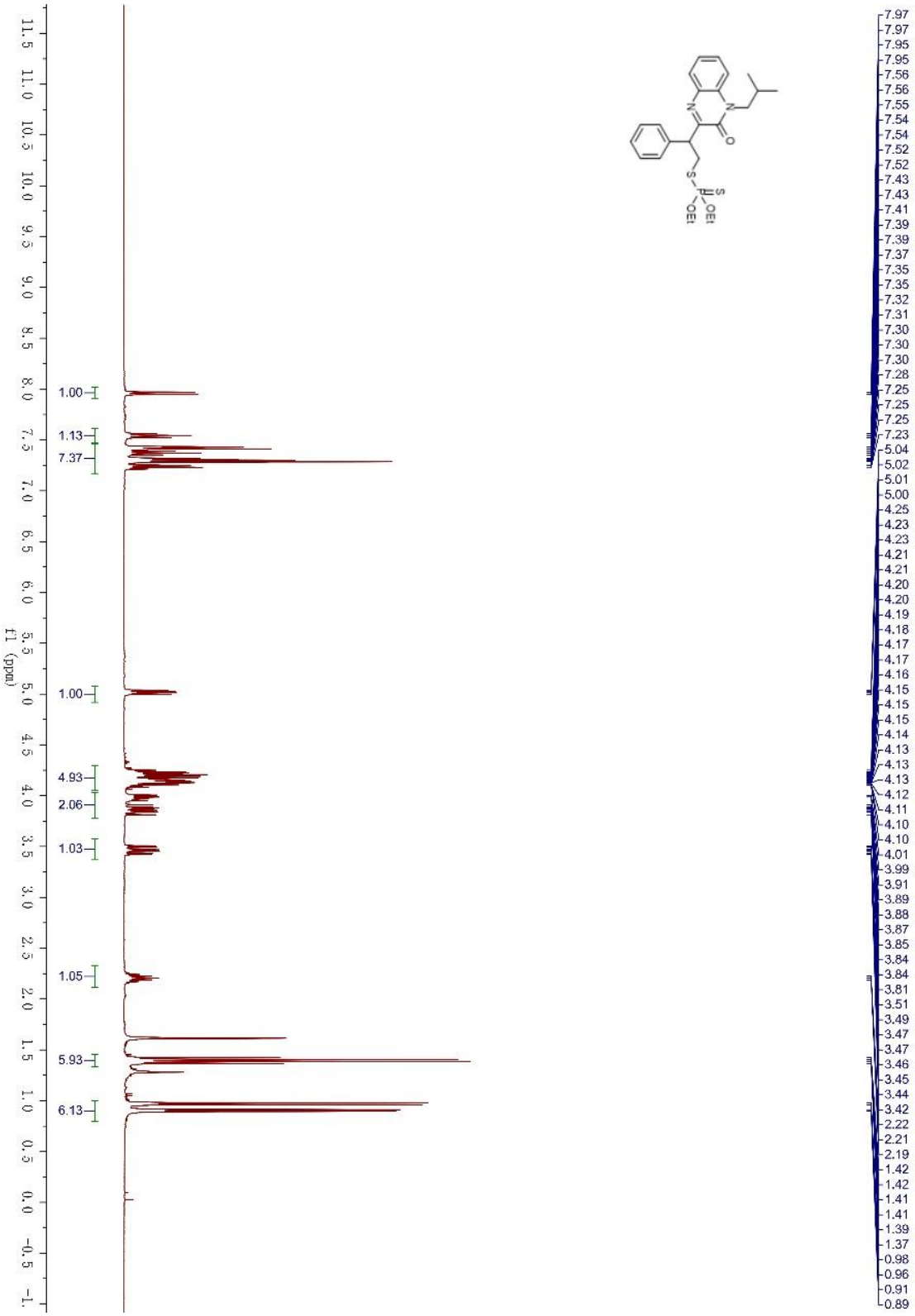
3.20
1.02
1.00
6.06
1.03
1.02
6.02
3.12
7.98
7.97
7.96
7.95
7.57
7.57
7.55
7.46
7.45
7.44
7.40
7.40
7.38
7.34
7.33
7.31
7.30
7.28
7.26
5.05
5.03
5.02
5.01
4.23
4.22
4.21
4.20
4.20
4.18
4.14
3.51
3.49
3.48
3.47
3.46
3.46
3.44
3.42
1.43
1.41
1.39
1.37
1.35
1.34
1.32
N
N
O
S
P
OEt
OEt

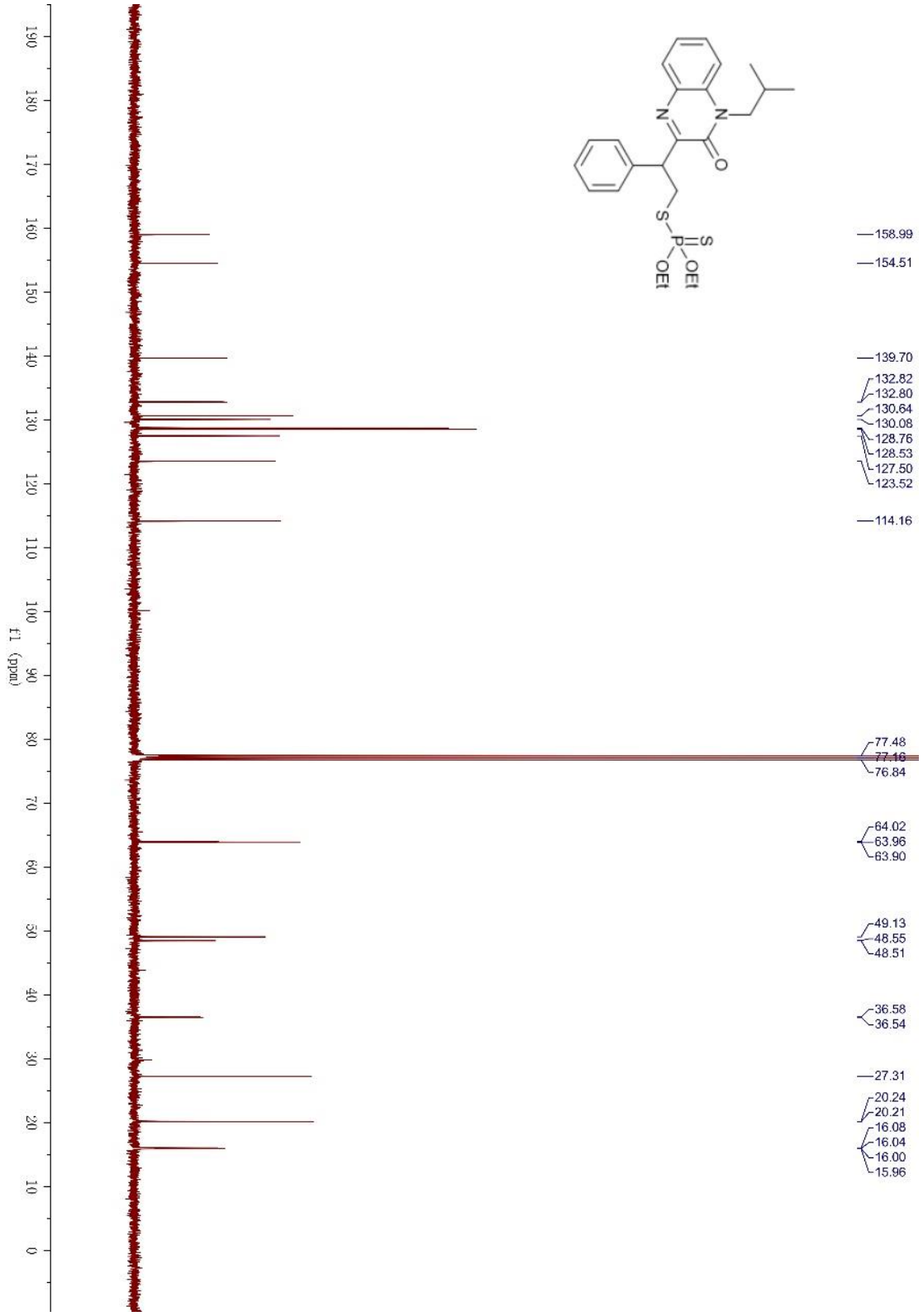
^{13}C NMR of **5**


158.90
153.80
139.65
132.87
132.26
130.63
130.31
128.79
128.58
127.53
123.54
113.59
77.48
77.16
76.84
64.02
63.96
63.91
48.32
48.28
37.57
36.56
36.52
16.08
16.04
16.00
15.96
12.50
f1 (ppm)

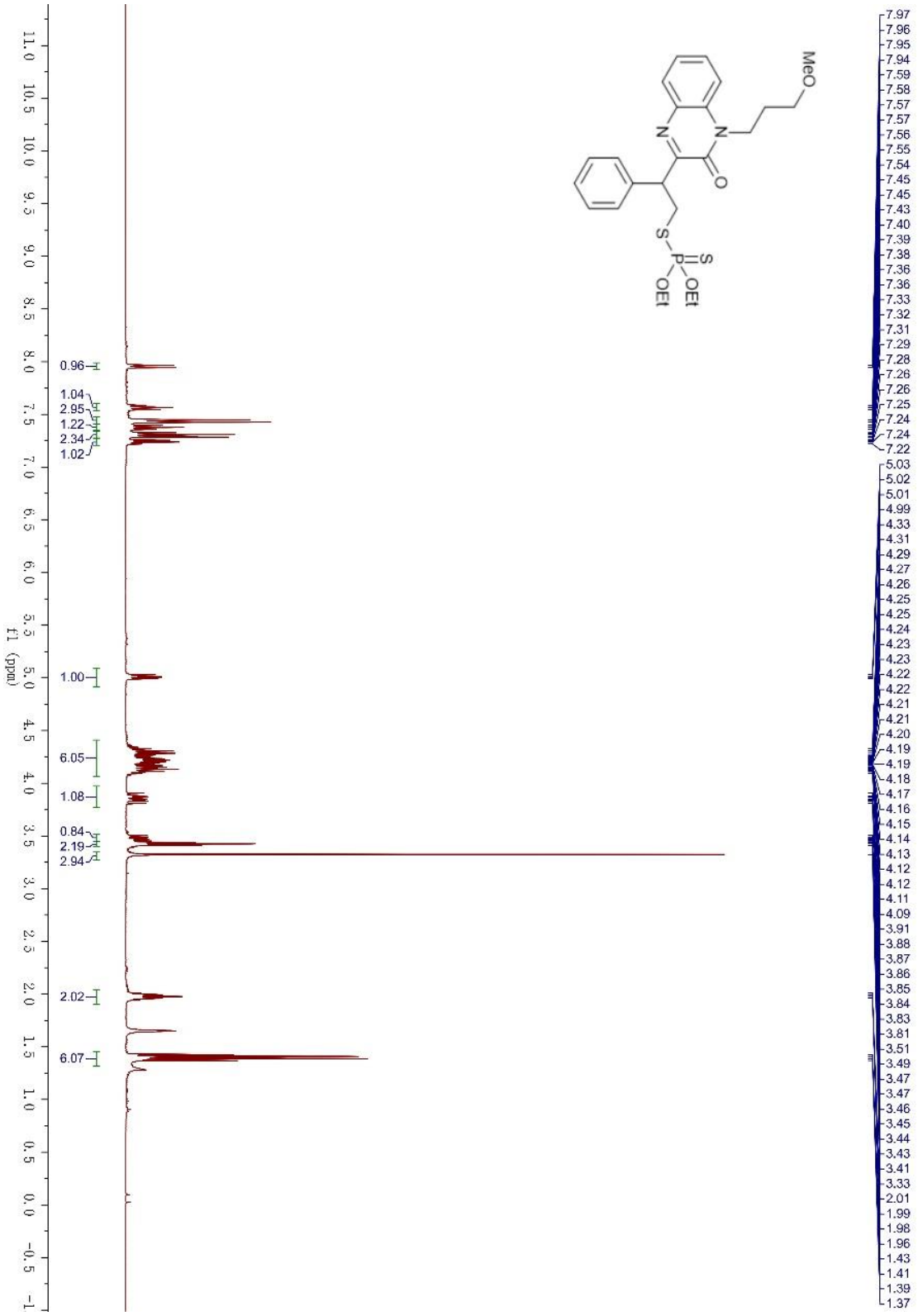
^{1}H NMR of **6**



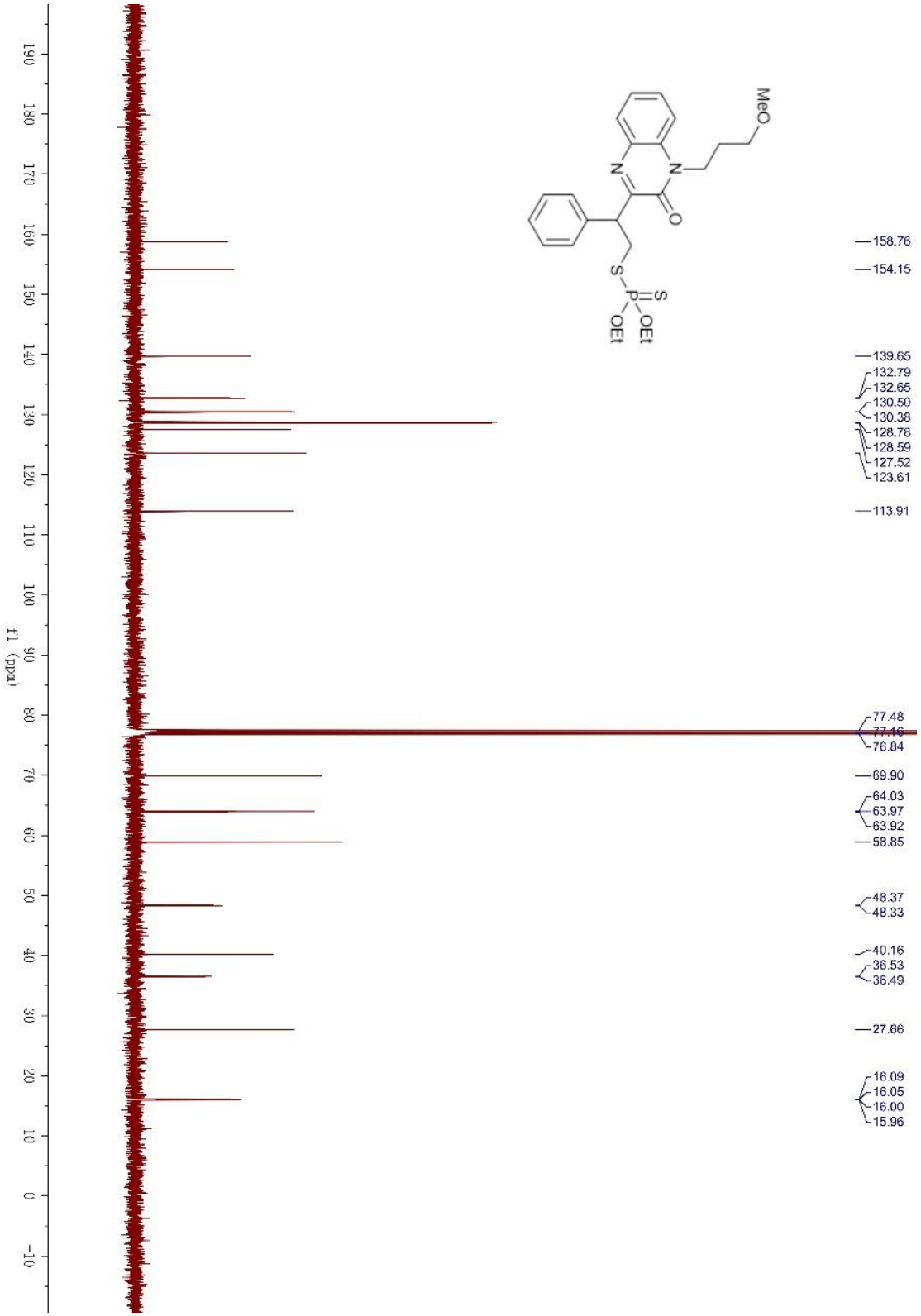
^{13}C NMR of **6**


158.99
154.51
139.70
132.82
132.80
130.64
130.08
128.76
128.53
127.50
123.52
114.16
77.48
77.16
76.84
64.02
63.96
63.90
49.13
48.55
48.51
36.58
36.54
27.31
20.24
20.21
16.08
16.04
16.00
15.96
f1 (ppm)

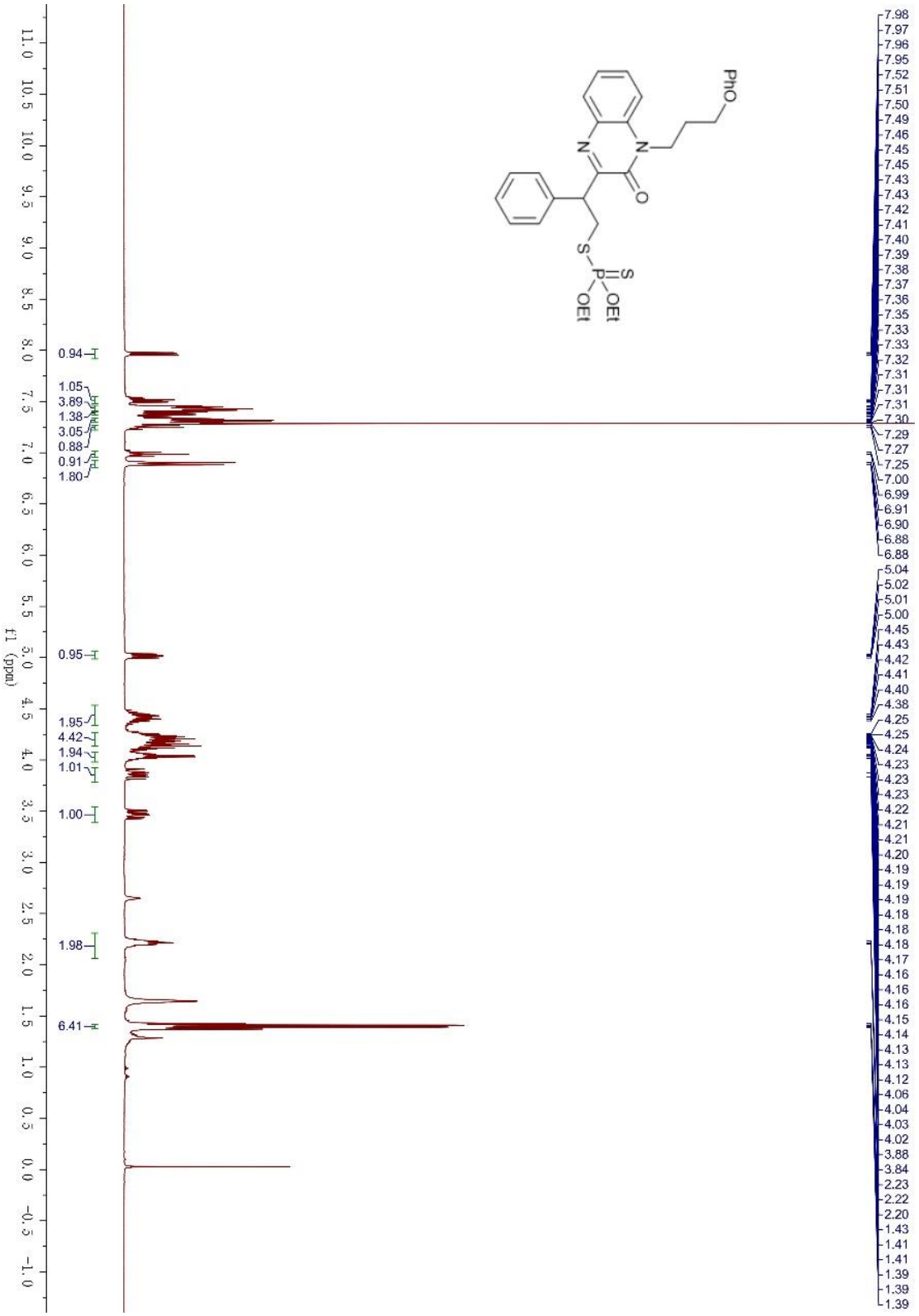
^{1}H NMR of **7**


MeO
N
N
O
S
P
OEt
OEt
S
f1 (ppm)
0.96
1.04
2.95
1.22
2.34
1.02
1.00
6.05
1.08
0.84
2.19
2.94
2.02
6.07

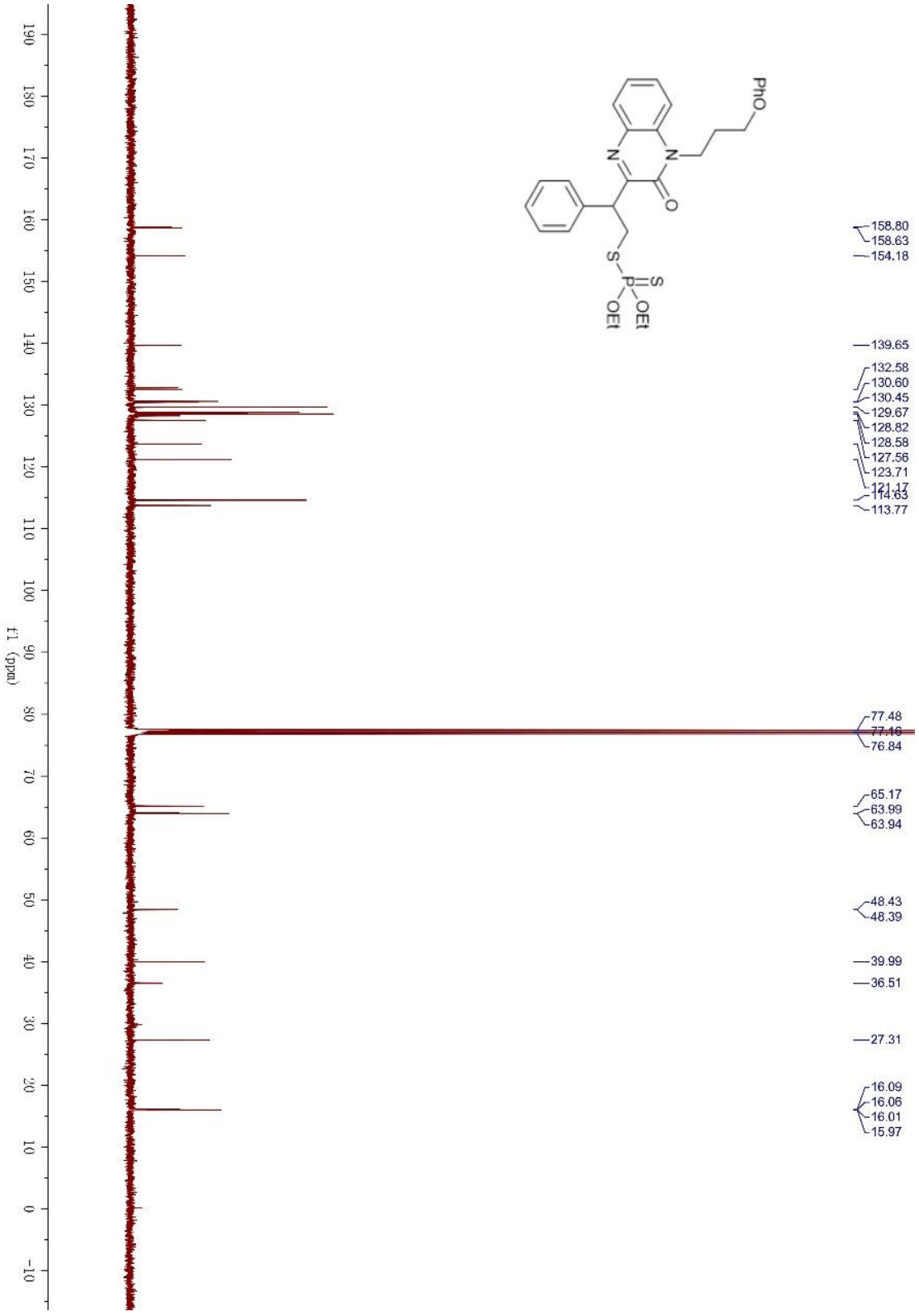
^{13}C NMR of **7**


MeO
N
N
O
S
S
P
OEt
OEt
158.76
154.15
139.65
132.79
132.65
130.50
130.38
128.78
128.59
127.52
123.61
113.91
77.48
77.16
76.84
69.90
64.03
63.97
63.92
58.85
48.37
48.33
40.16
36.53
36.49
27.66
16.09
16.05
16.00
15.96
f1 (ppm)

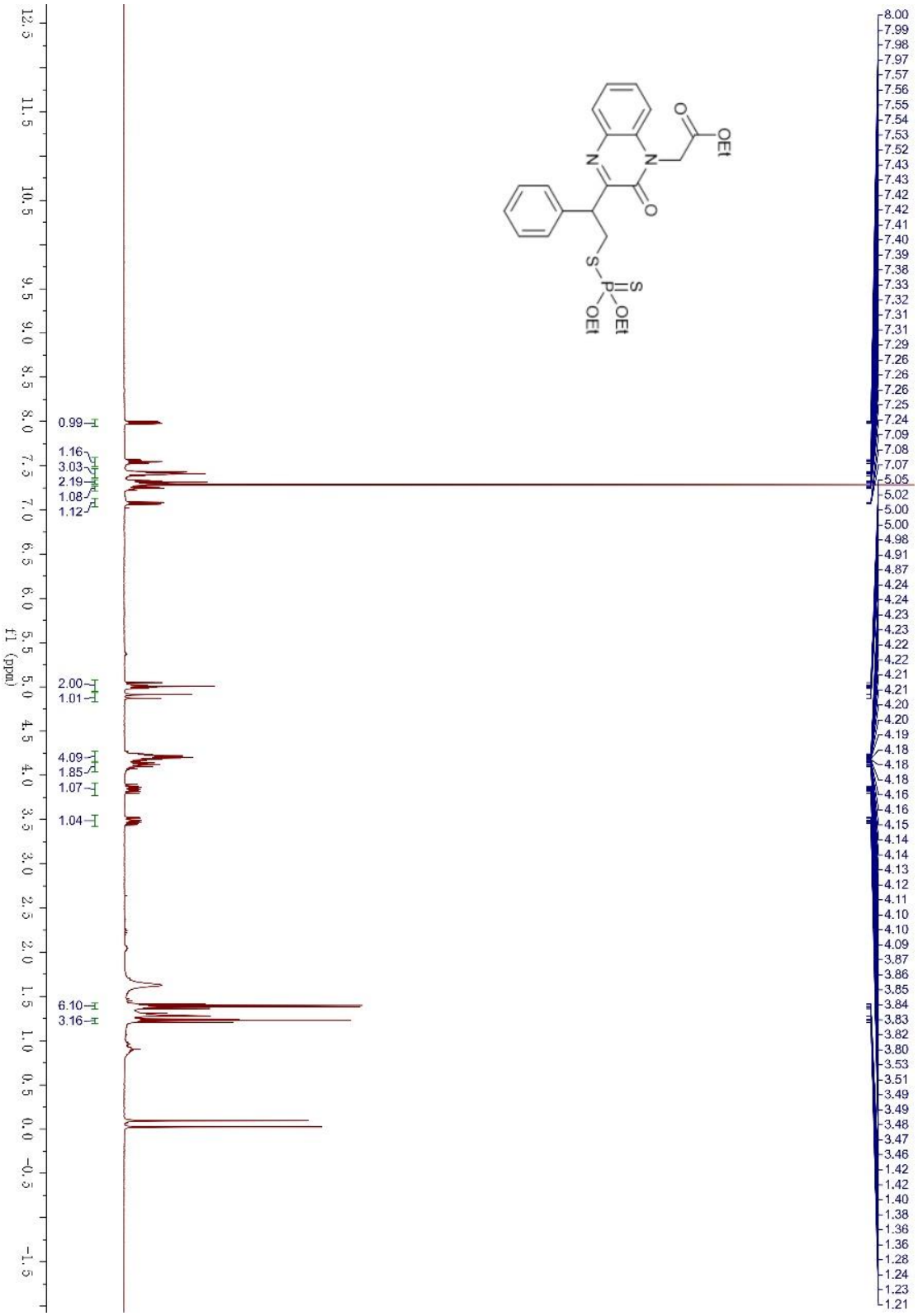
^{1}H NMR of **8**


PhO
N
N
O
S
P
S
OEt
OEt
f1 (ppm)
0.94
1.05
3.89
1.38
3.05
0.88
0.91
1.80
0.95
1.95
4.42
1.94
1.01
1.00
1.98
6.41

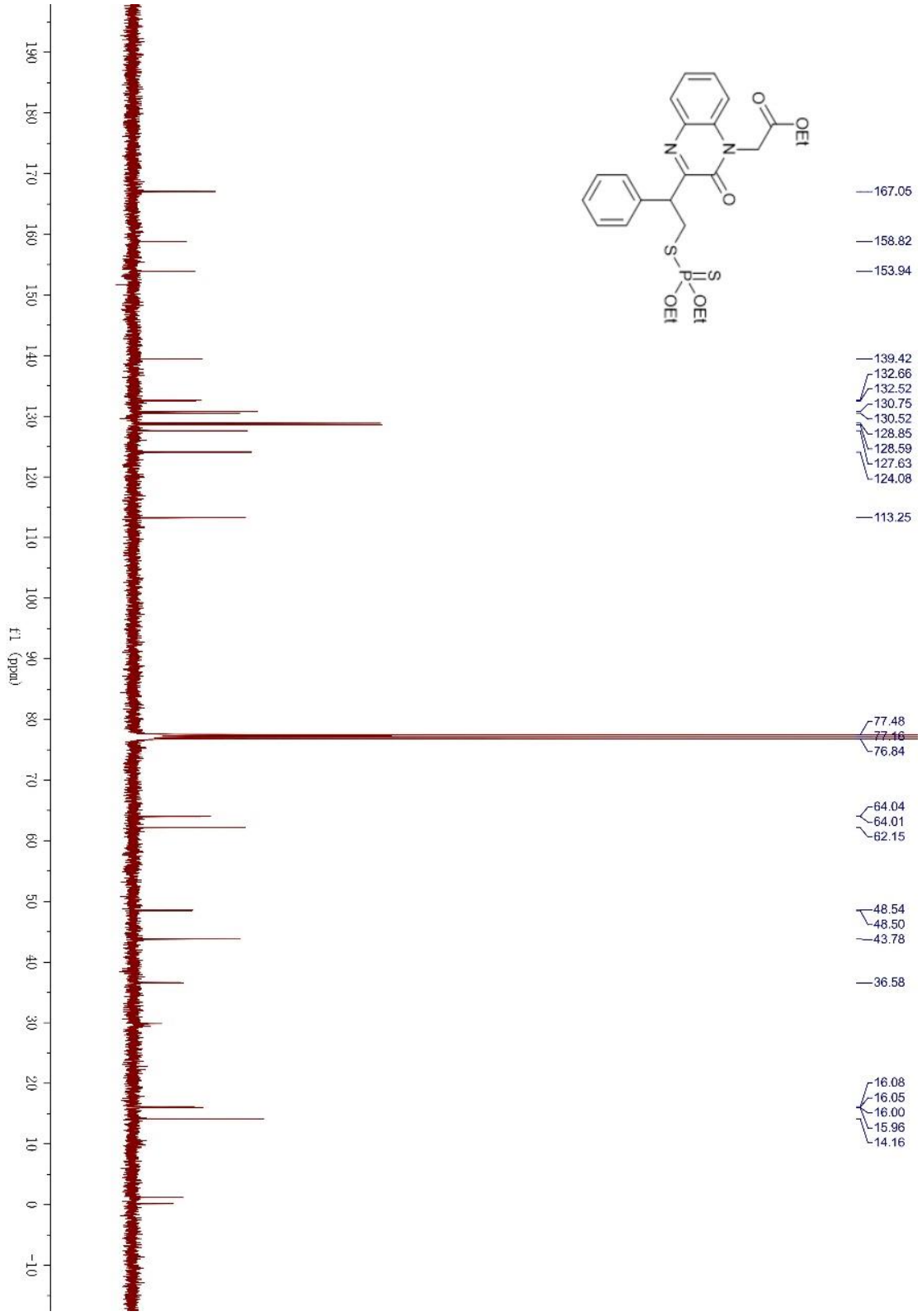
^{13}C NMR of **8**


PhO
N
N
O
S
S
P
OEt
OEt
158.80
158.63
154.18
139.65
132.58
130.60
130.45
129.67
128.82
128.58
127.56
123.71
121.17
114.63
113.77
77.48
77.16
76.84
65.17
63.99
63.94
48.43
48.39
39.99
36.51
27.31
16.09
16.06
16.01
15.97
f1 (ppm)

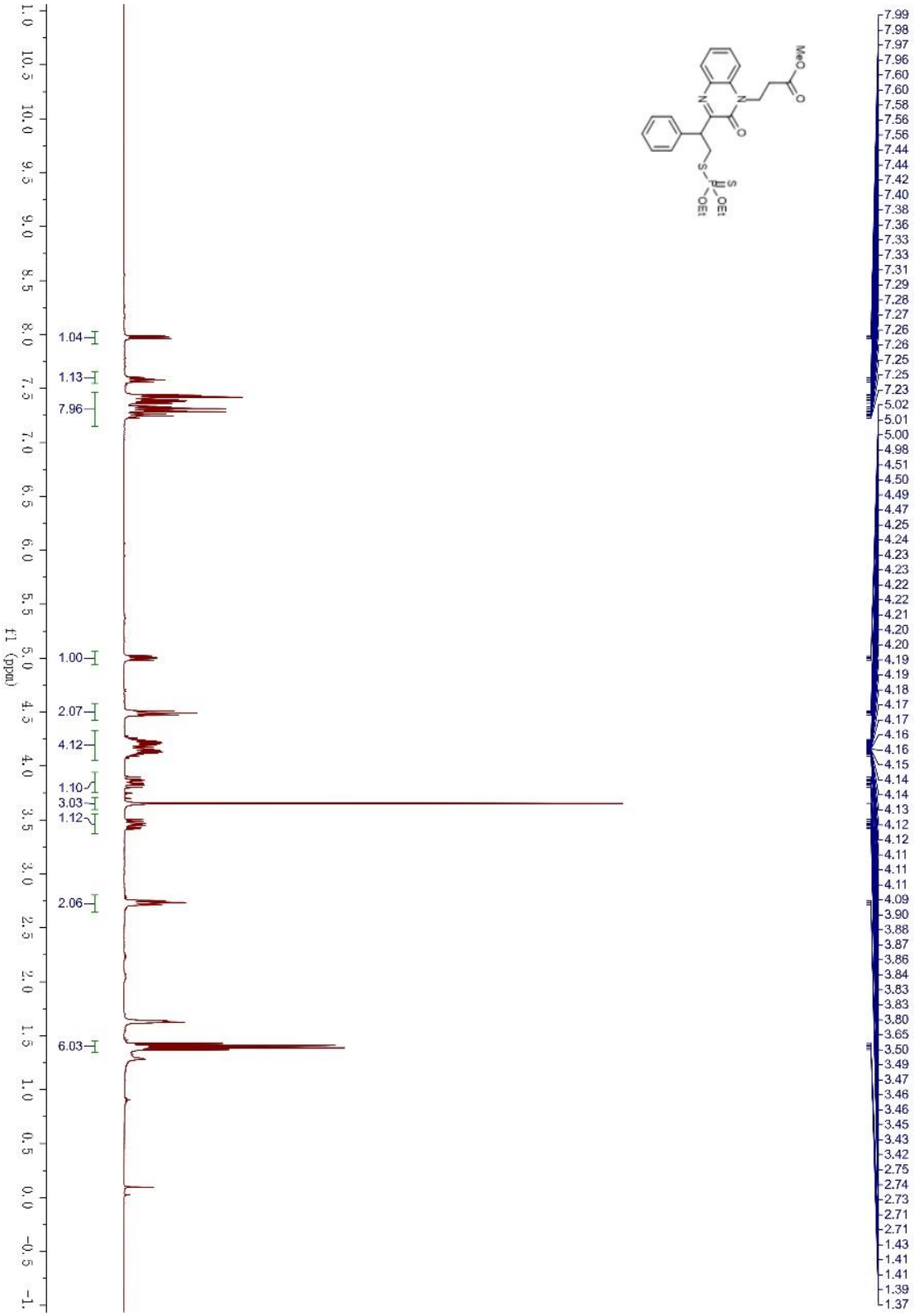
^{1}H NMR of **9**


f1 (ppm)
0.99
1.16
3.03
2.19
1.08
1.12
2.00
1.01
4.09
1.85
1.07
1.04
6.10
3.16
OEt
OEt
OEt

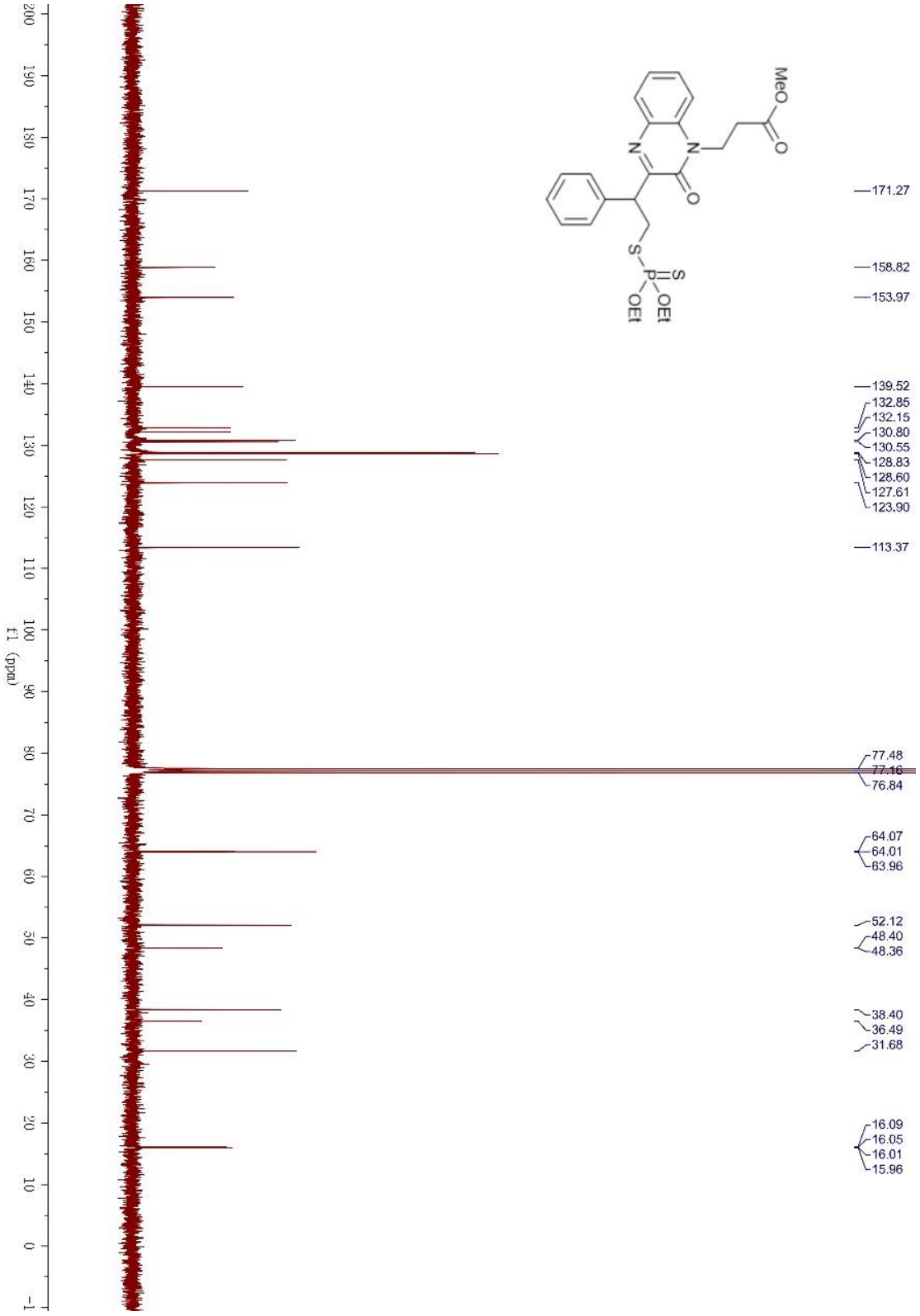
^{13}C NMR of **9**


167.05
158.82
153.94
139.42
132.66
132.52
130.75
130.52
128.85
128.59
127.63
124.08
113.25
77.48
77.16
76.84
64.04
64.01
62.15
48.54
48.50
43.78
36.58
16.08
16.05
16.00
15.96
14.16
f1 (ppm)

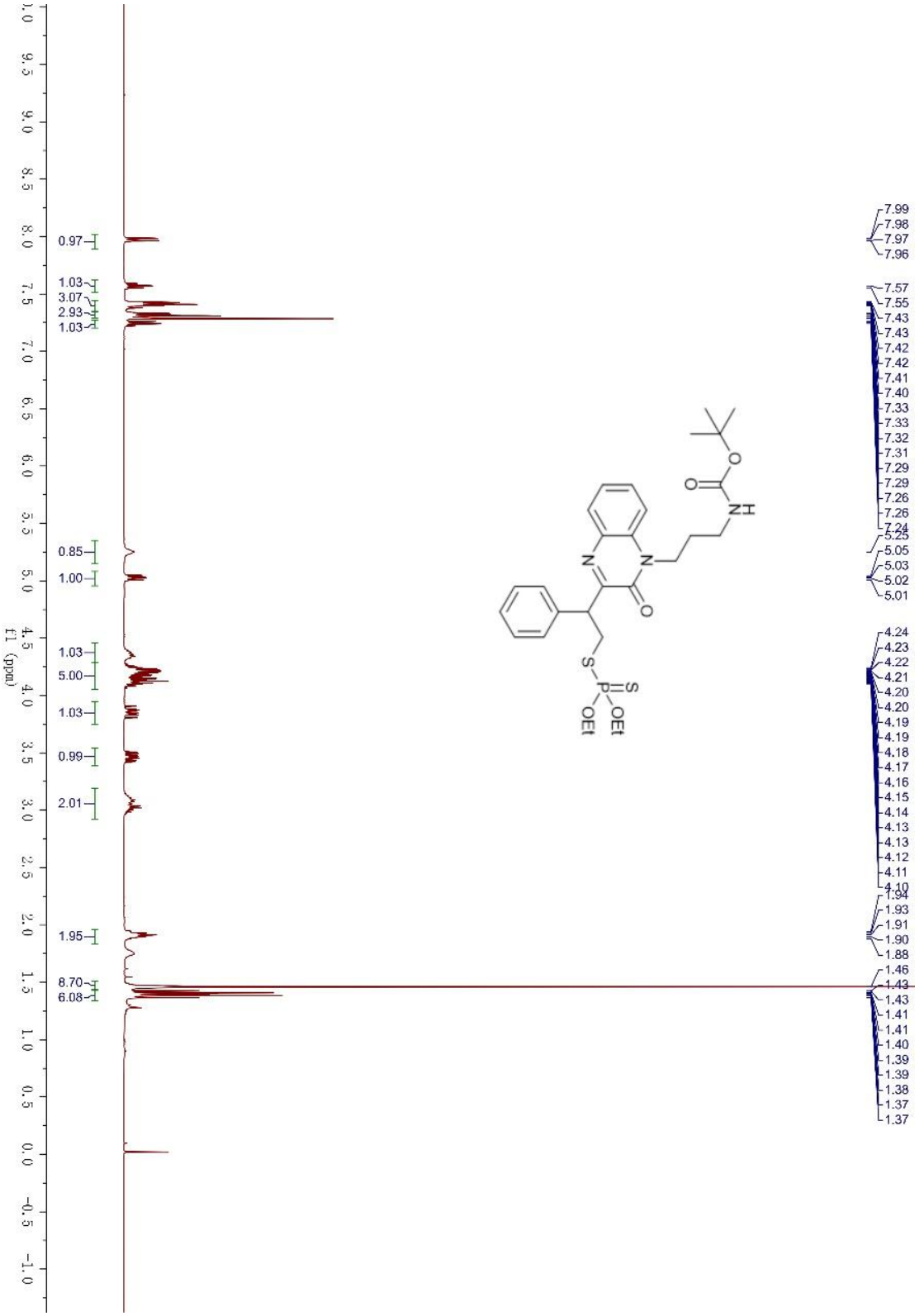
^{1}H NMR of **10**



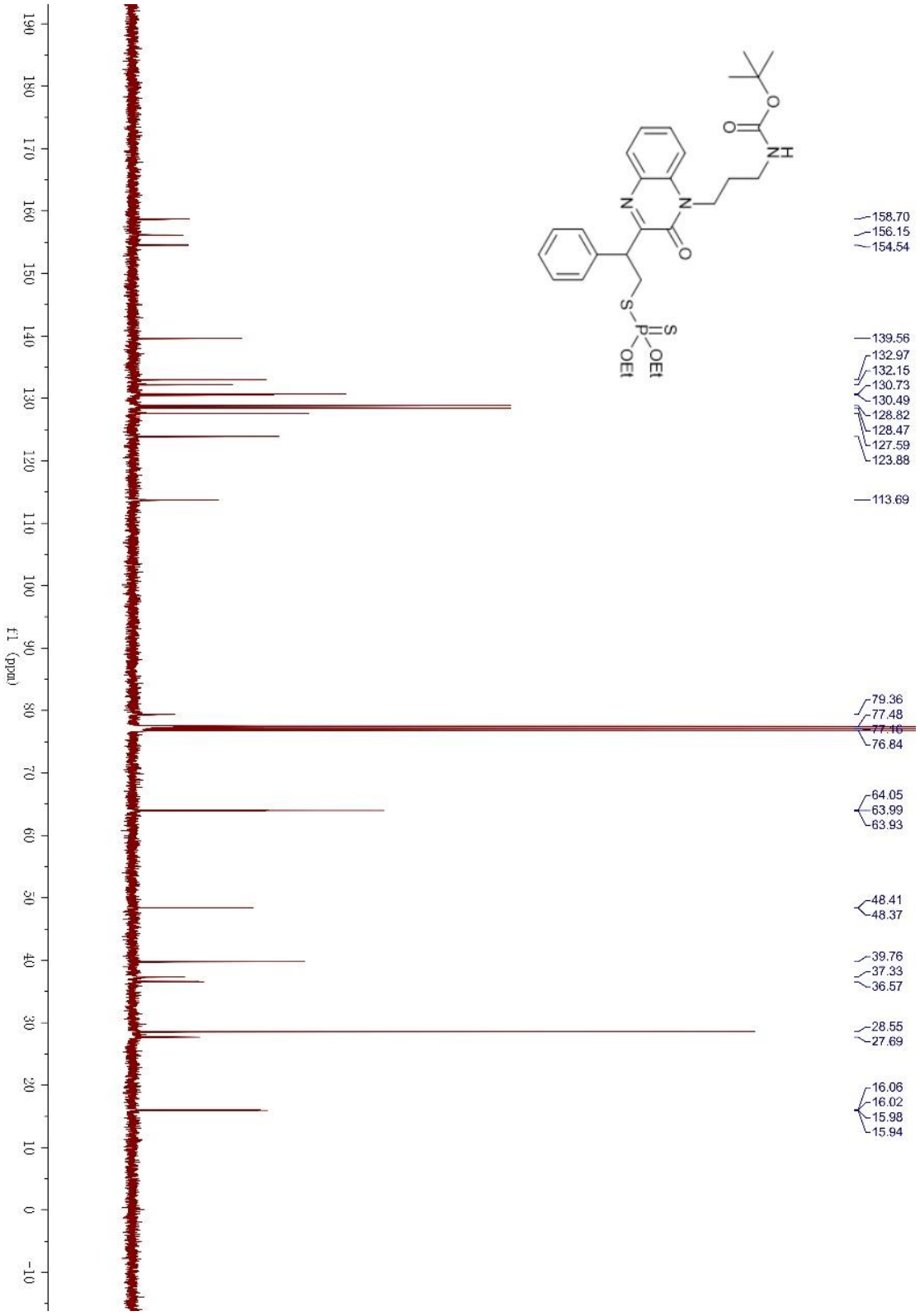
^{13}C NMR of **10**


MeO
O
N
N
O
S
S
P
OEt
OEt
171.27
158.82
153.97
139.52
132.85
132.15
130.80
130.55
128.83
128.60
127.61
123.90
113.37
77.48
77.16
76.84
64.07
64.01
63.96
52.12
48.40
48.36
38.40
36.49
31.68
16.09
16.05
16.01
15.96
f1 (ppm)

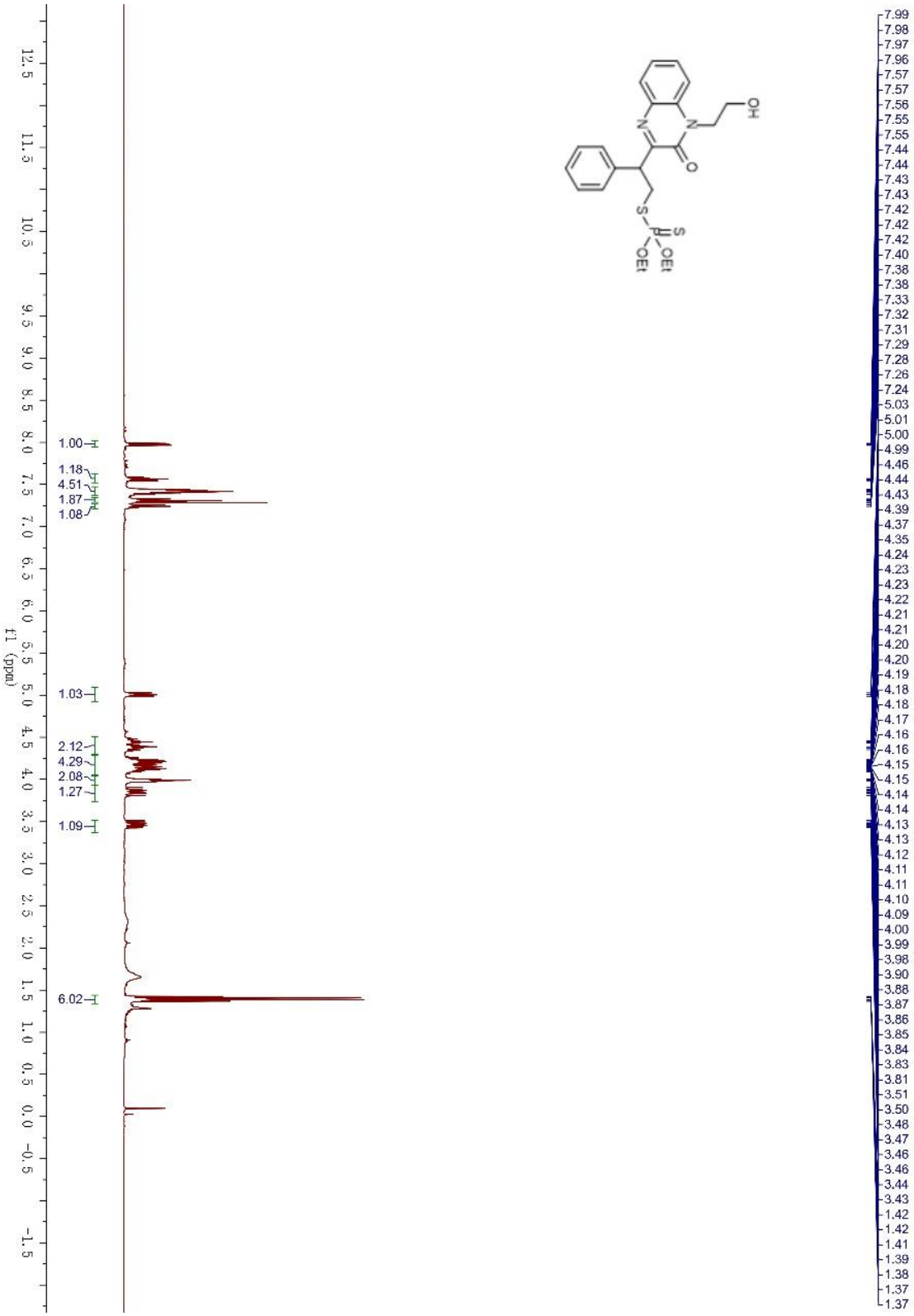
^{1}H NMR of **11**


f1 (ppm)
0.97
1.03
3.07
2.93
1.03
0.85
1.00
1.03
5.00
1.03
0.99
2.01
1.95
8.70
6.08
7.99
7.98
7.97
7.96
7.57
7.55
7.43
7.43
7.42
7.42
7.41
7.40
7.33
7.33
7.32
7.31
7.29
7.29
7.26
7.26
7.24
5.25
5.05
5.03
5.02
5.01
4.24
4.23
4.22
4.21
4.20
4.20
4.19
4.19
4.18
4.17
4.16
4.15
4.14
4.13
4.13
4.12
4.11
4.10
1.94
1.93
1.91
1.90
1.88
1.46
1.43
1.43
1.41
1.41
1.40
1.39
1.39
1.38
1.37
1.37

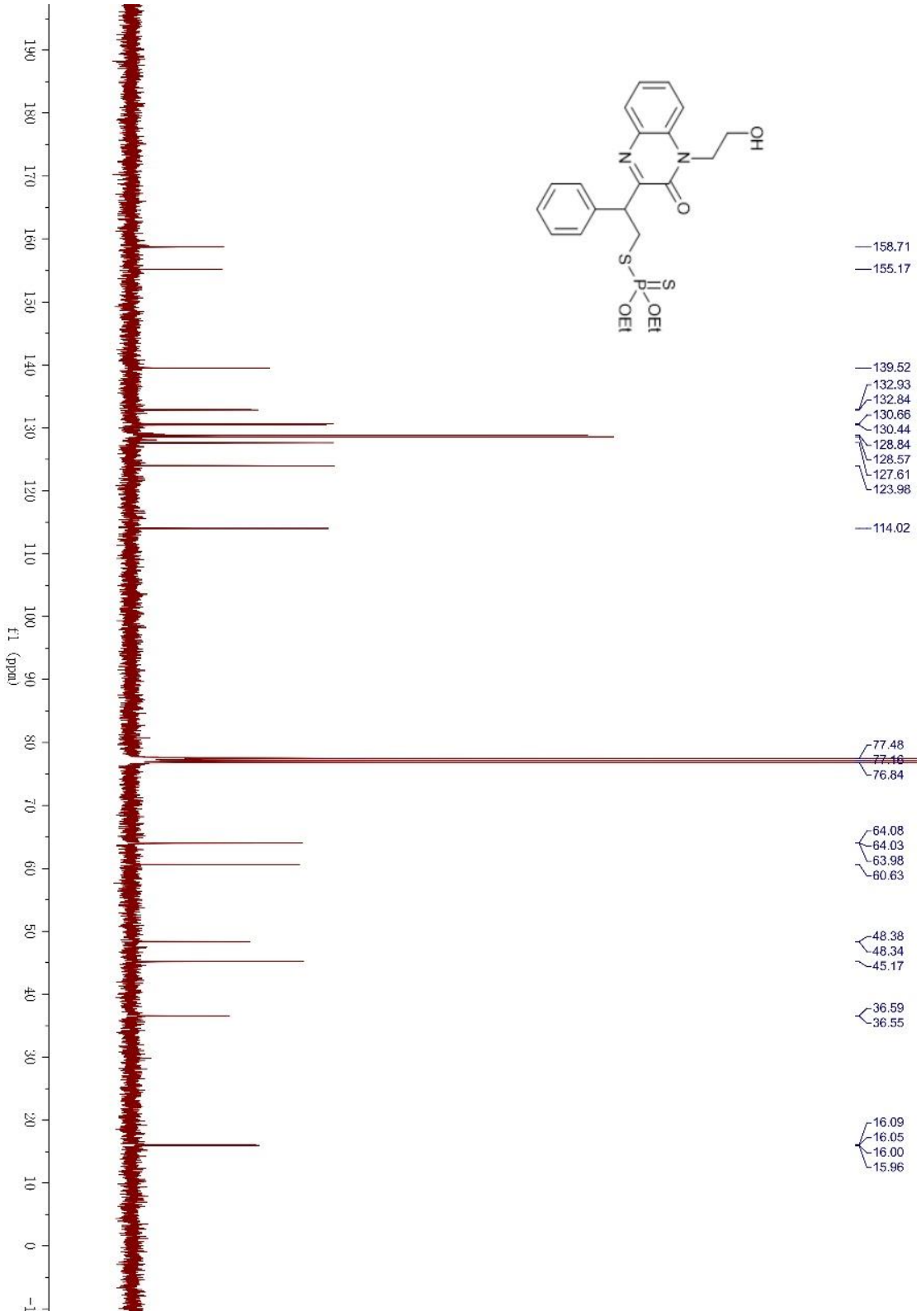
^{13}C NMR of **11**


158.70
156.15
154.54
139.56
132.97
132.15
130.73
130.49
128.82
128.47
127.59
123.88
113.69
79.36
77.48
77.16
76.84
64.05
63.99
63.93
48.41
48.37
39.76
37.33
36.57
28.55
27.69
16.06
16.02
15.98
15.94
f1 (ppm)

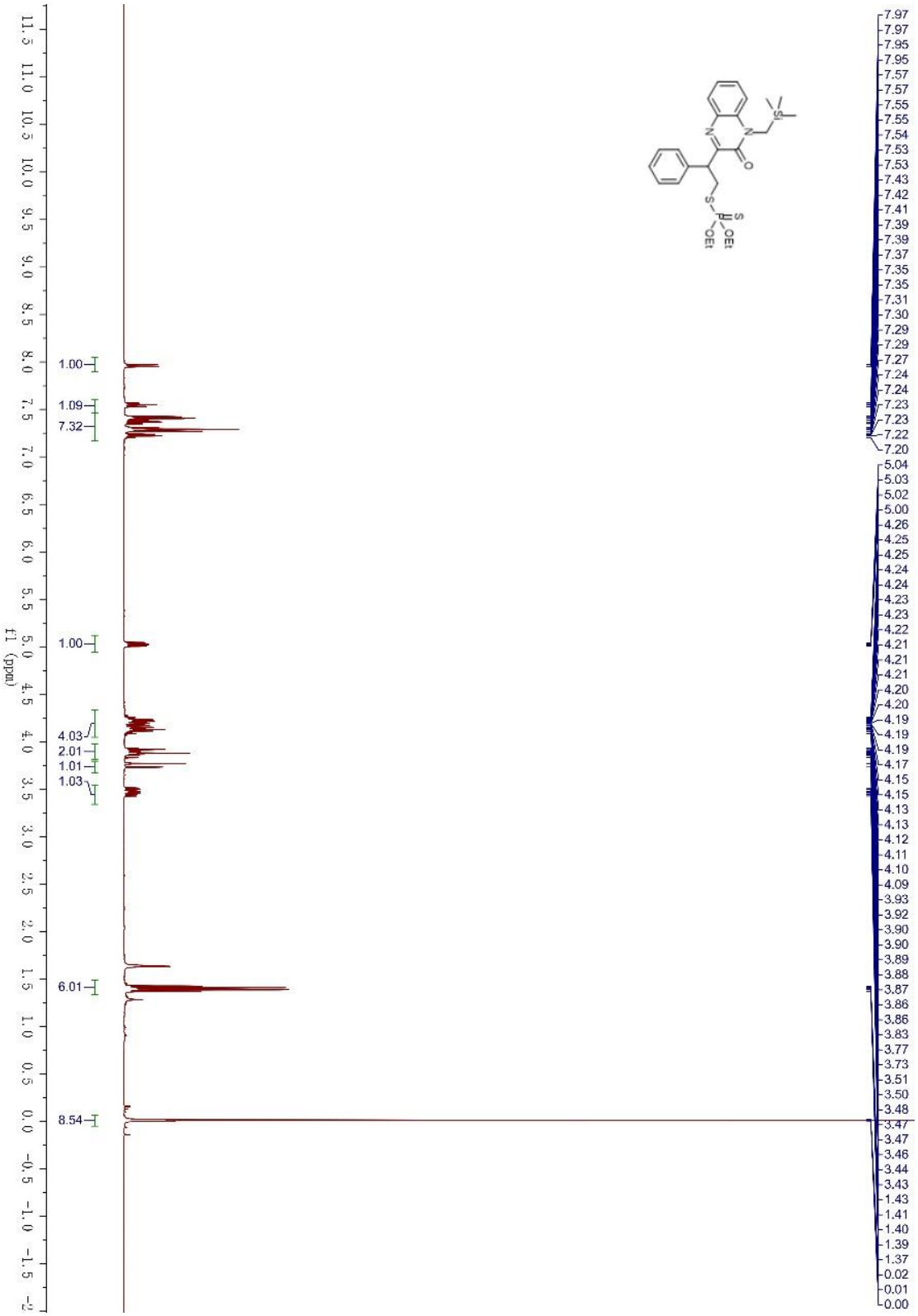
^{1}H NMR of **12**


f1 (ppm)
1.00
1.18
4.51
1.87
1.08
1.03
2.12
4.29
2.08
1.27
1.09
6.02
OH
O
N
S
P
OEt
OEt

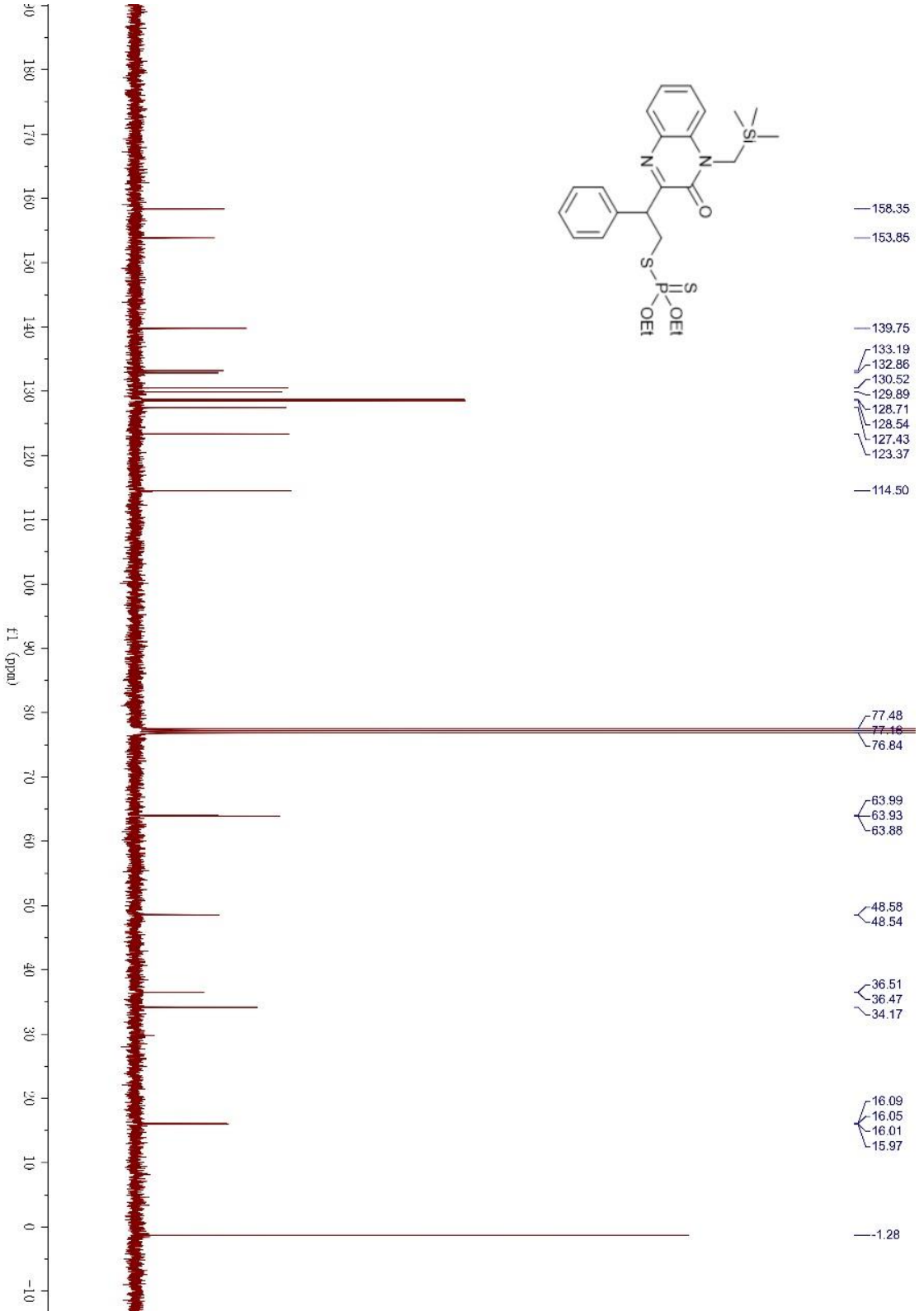
^{13}C NMR of **12**


158.71
155.17
139.52
132.93
132.84
130.66
130.44
128.84
128.57
127.61
123.98
114.02
77.48
77.16
76.84
64.08
64.03
63.98
60.63
48.38
48.34
45.17
36.59
36.55
16.09
16.05
16.00
15.96
f1 (ppm)

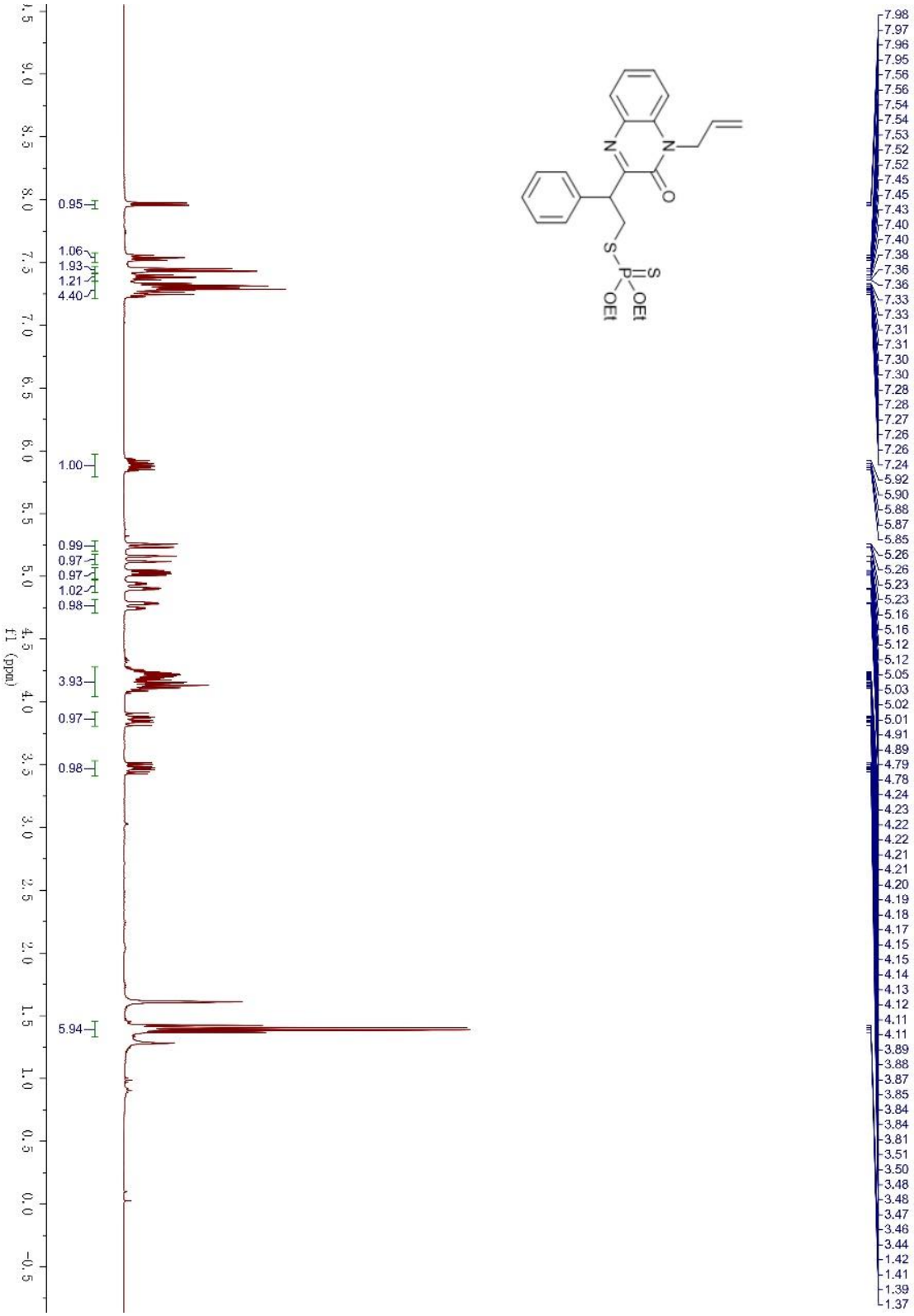
^{1}H NMR of **13**



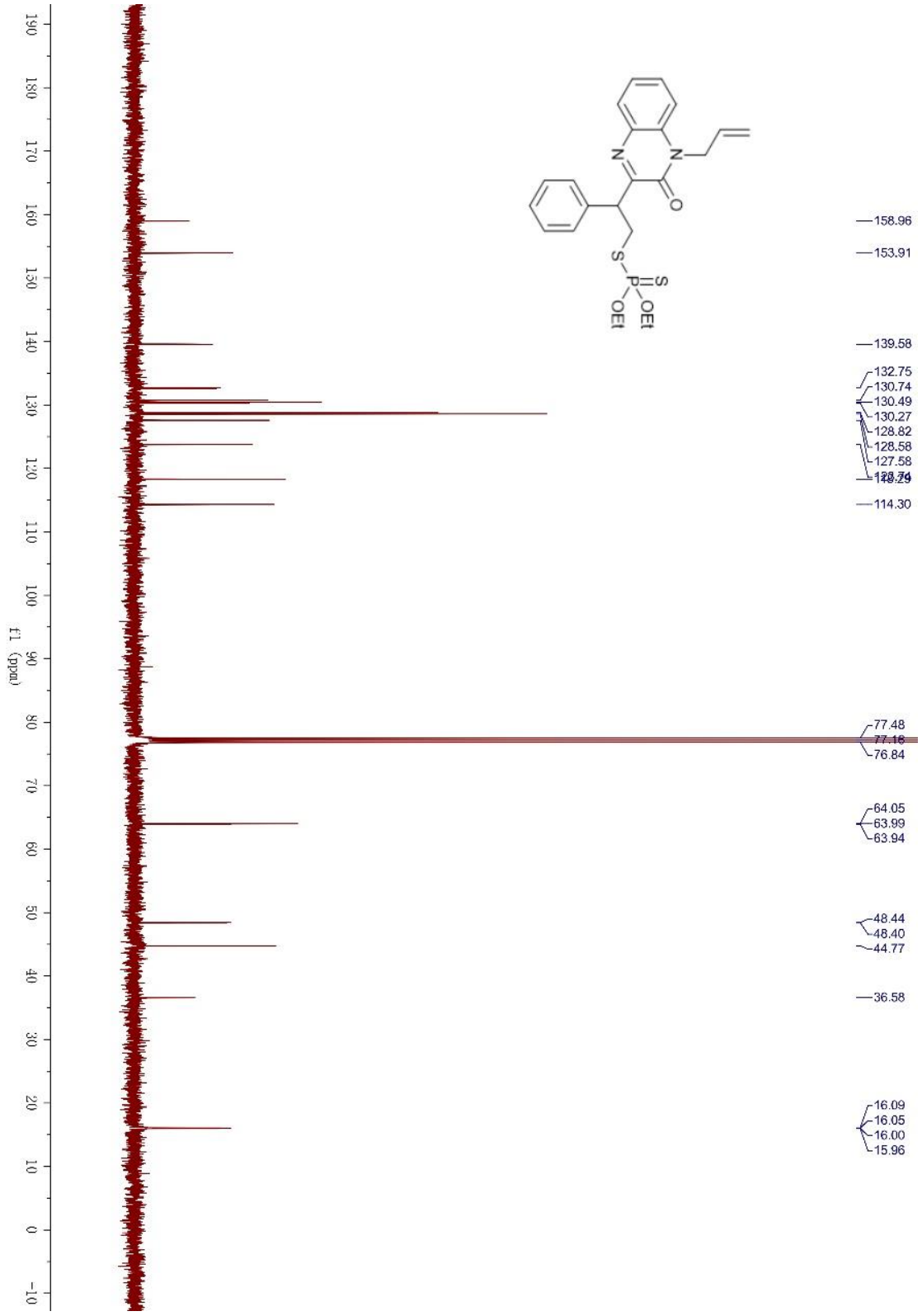
^{13}C NMR of **13**


158.35
153.85
139.75
133.19
132.86
130.52
129.89
128.71
128.54
127.43
123.37
114.50
77.48
77.18
76.84
63.99
63.93
63.88
48.58
48.54
36.51
36.47
34.17
16.09
16.05
16.01
15.97
-1.28
f1 (ppm)

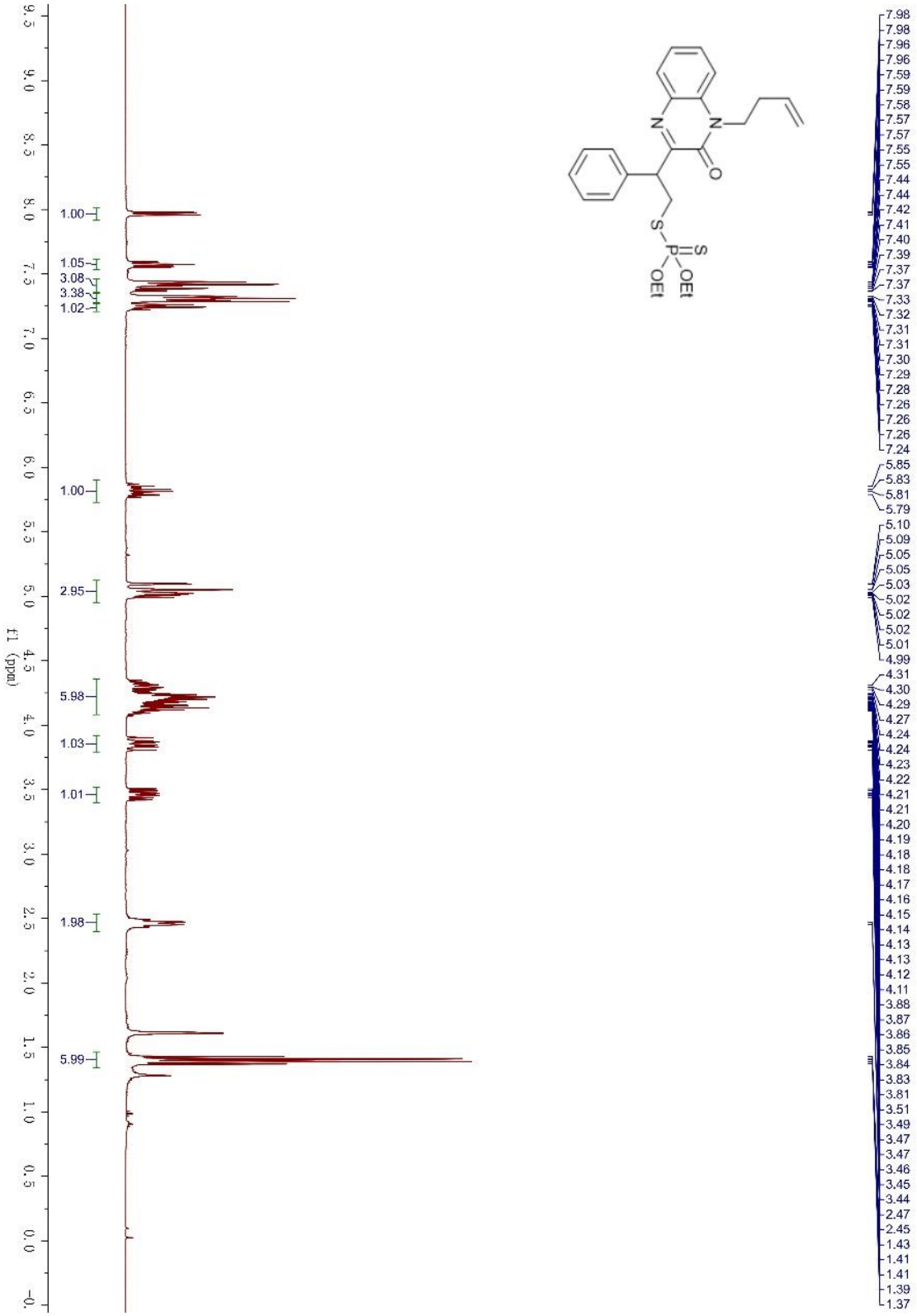
^{1}H NMR of **14**


0.95
1.06
1.93
1.21
4.40
1.00
0.99
0.97
0.97
1.02
0.98
3.93
0.97
0.98
5.94
f1 (ppm)
S
OEt
OEt

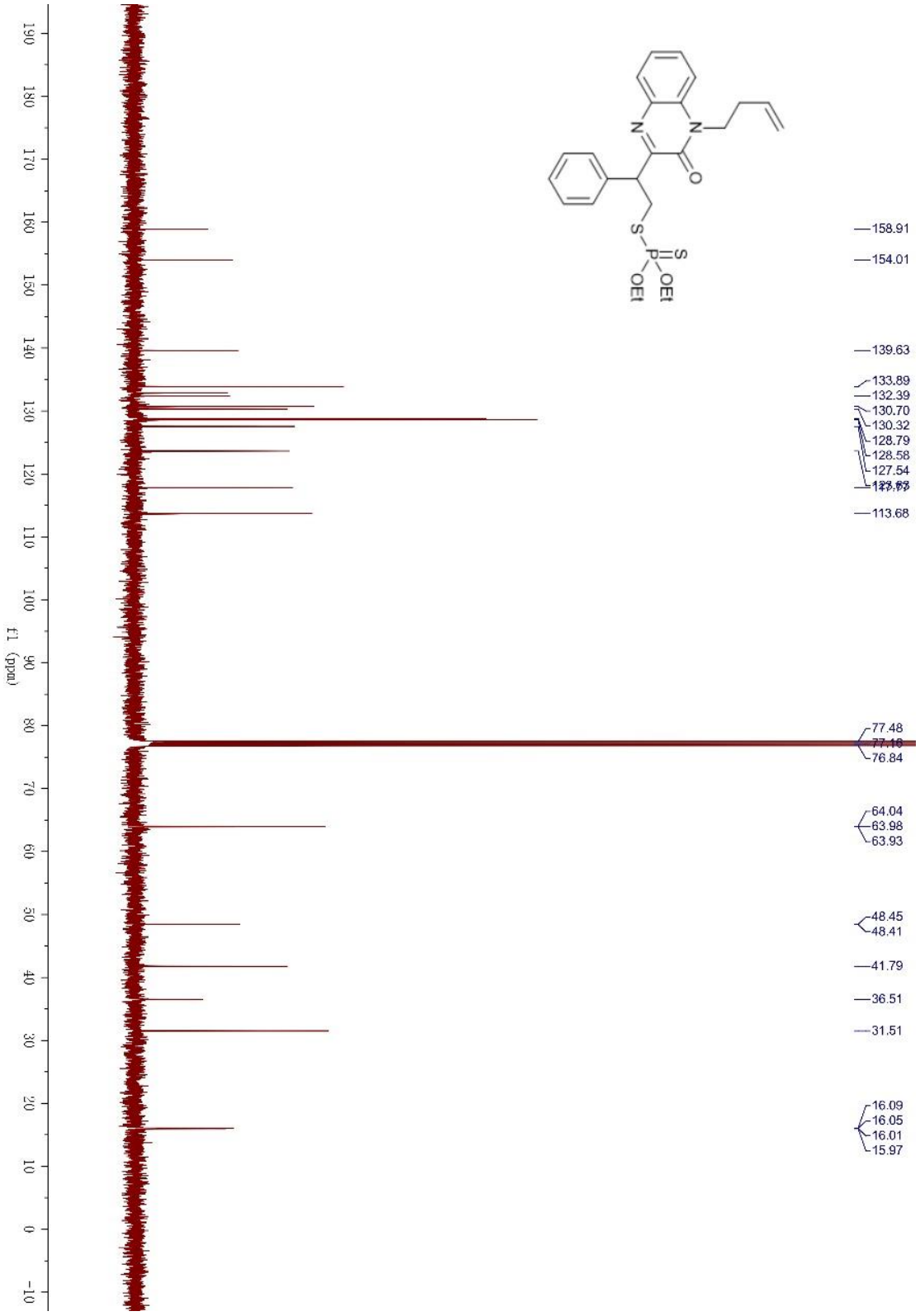
^{13}C NMR of **14**


158.96
153.91
139.58
132.75
130.74
130.49
130.27
128.82
128.58
127.58
114.30
77.48
76.84
64.05
63.99
63.94
48.44
48.40
44.77
36.58
16.09
16.05
16.00
15.96
f1 (ppm)

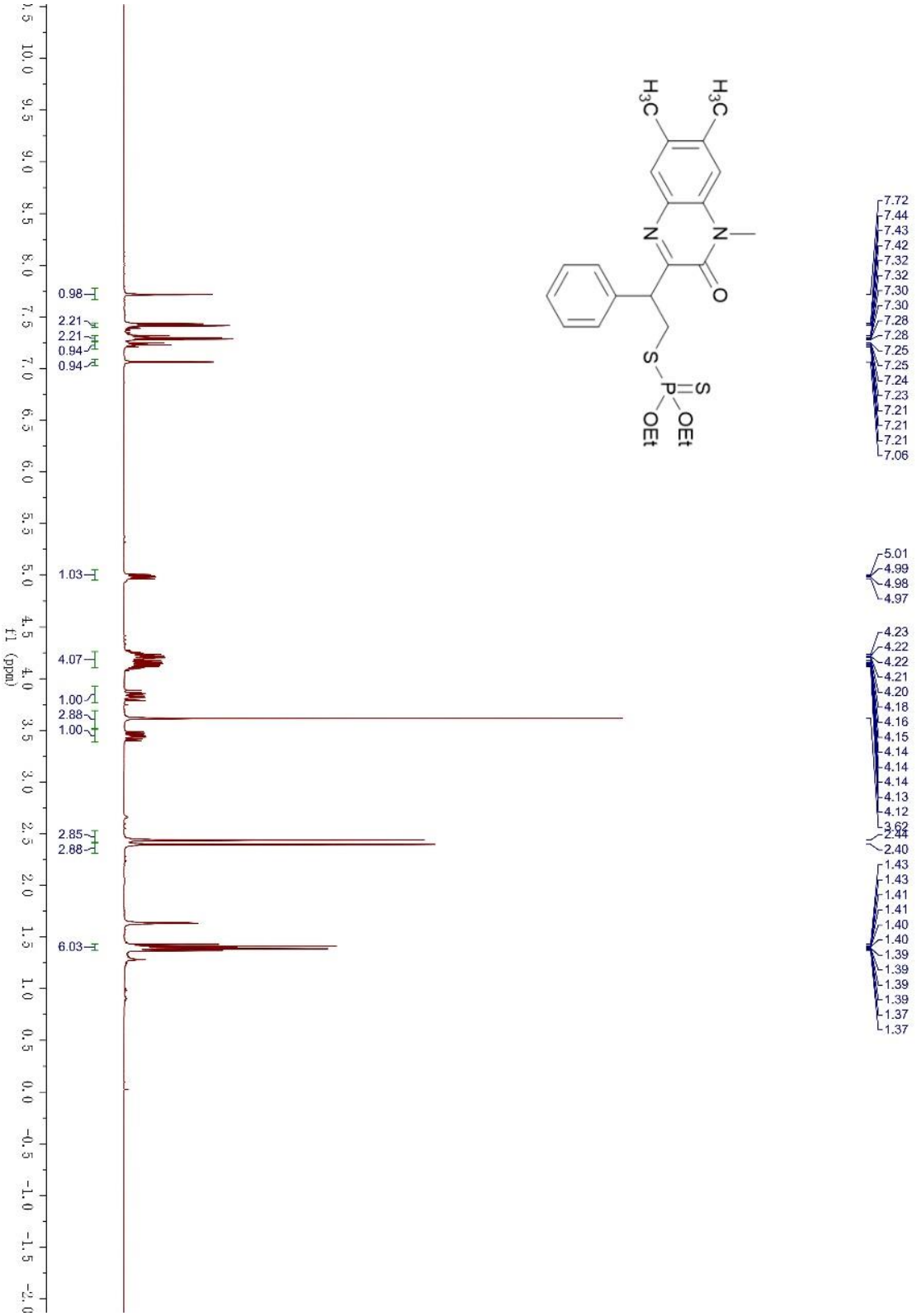
^{1}H NMR of **15**


f1 (ppm)
1.00
1.05
3.08
3.38
1.02
1.00
2.95
5.98
1.03
1.01
1.98
5.99
S
P
OEt
OEt
7.98
7.98
7.96
7.96
7.59
7.59
7.58
7.57
7.57
7.55
7.55
7.44
7.44
7.42
7.41
7.40
7.39
7.37
7.37
7.33
7.32
7.31
7.31
7.30
7.29
7.28
7.26
7.26
7.26
7.24
5.85
5.83
5.81
5.79
5.10
5.09
5.05
5.05
5.03
5.02
5.02
5.02
5.01
4.99
4.31
4.30
4.29
4.27
4.24
4.24
4.23
4.22
4.21
4.21
4.20
4.19
4.18
4.18
4.17
4.16
4.15
4.14
4.13
4.13
4.12
4.11
3.88
3.87
3.86
3.85
3.84
3.83
3.81
3.51
3.49
3.47
3.47
3.46
3.45
3.44
2.47
2.45
1.43
1.41
1.41
1.39
1.37

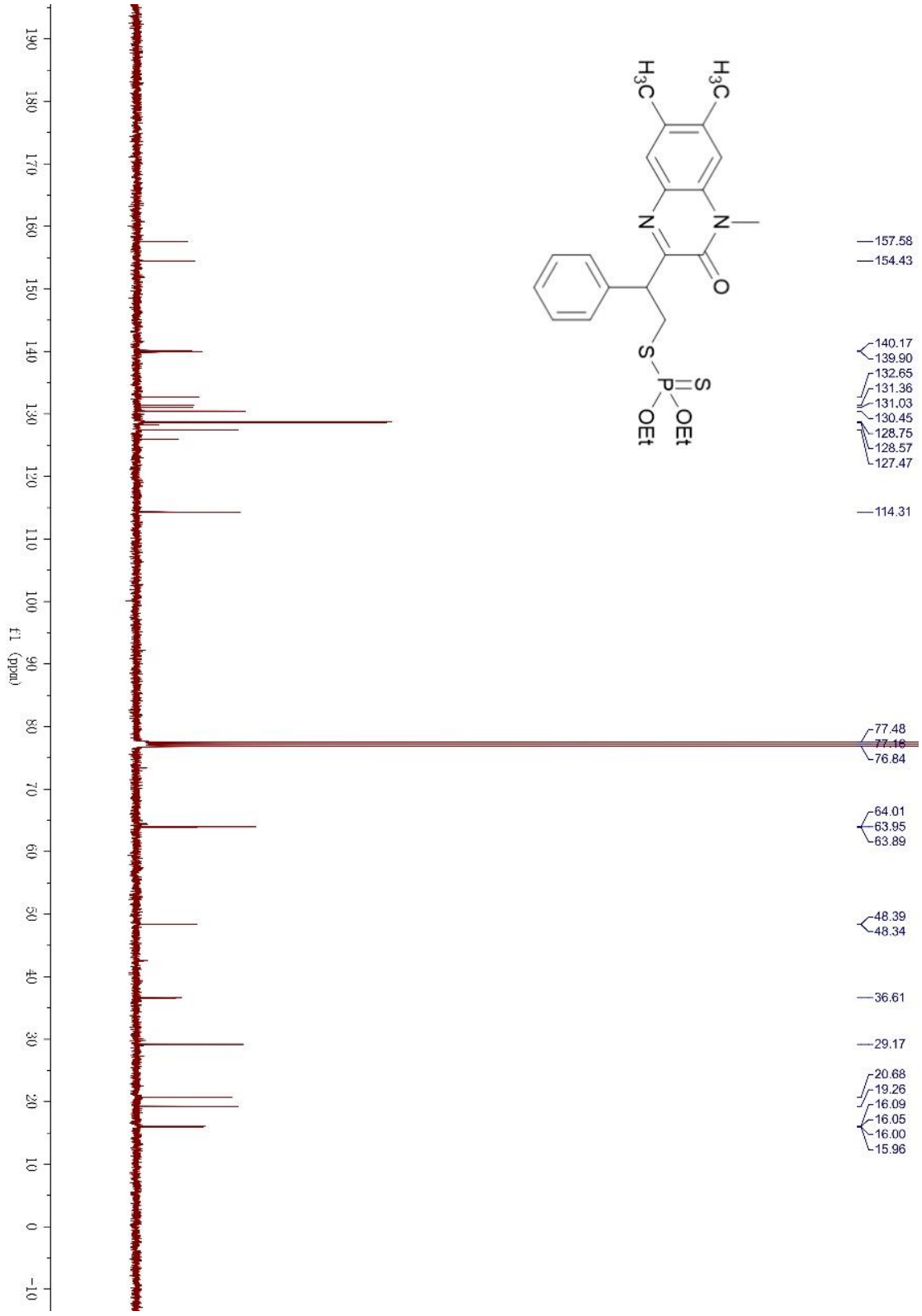
^{13}C NMR of **15**


158.91
154.01
139.63
133.89
132.39
130.70
130.32
128.79
128.58
127.54
113.68
77.48
76.84
64.04
63.98
63.93
48.45
48.41
41.79
36.51
31.51
16.09
16.05
16.01
15.97
f1 (ppm)

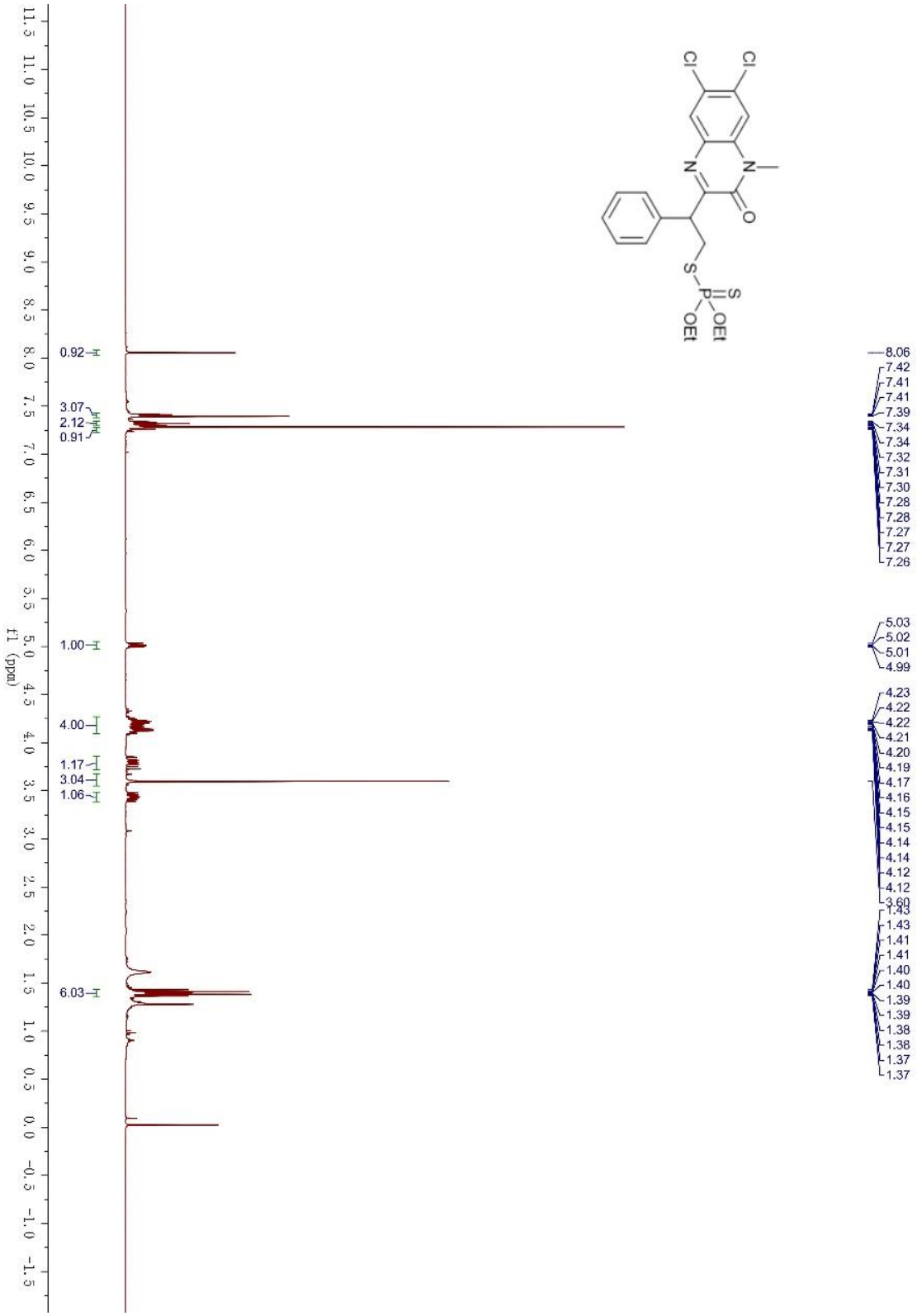
^{1}H NMR of **16**


H3C
H3C
N
N
O
S
P
S
OEt
OEt
0.98
2.21
2.21
0.94
0.94
1.03
4.07
1.00
2.88
1.00
2.85
2.88
6.03
f1 (ppm)
7.72
7.44
7.43
7.42
7.32
7.32
7.30
7.30
7.28
7.28
7.25
7.25
7.24
7.23
7.21
7.21
7.21
7.06
5.01
4.99
4.98
4.97
4.23
4.22
4.22
4.21
4.20
4.18
4.16
4.15
4.14
4.14
4.14
4.13
4.12
3.62
2.44
2.40
1.43
1.43
1.41
1.41
1.40
1.40
1.39
1.39
1.39
1.39
1.37
1.37

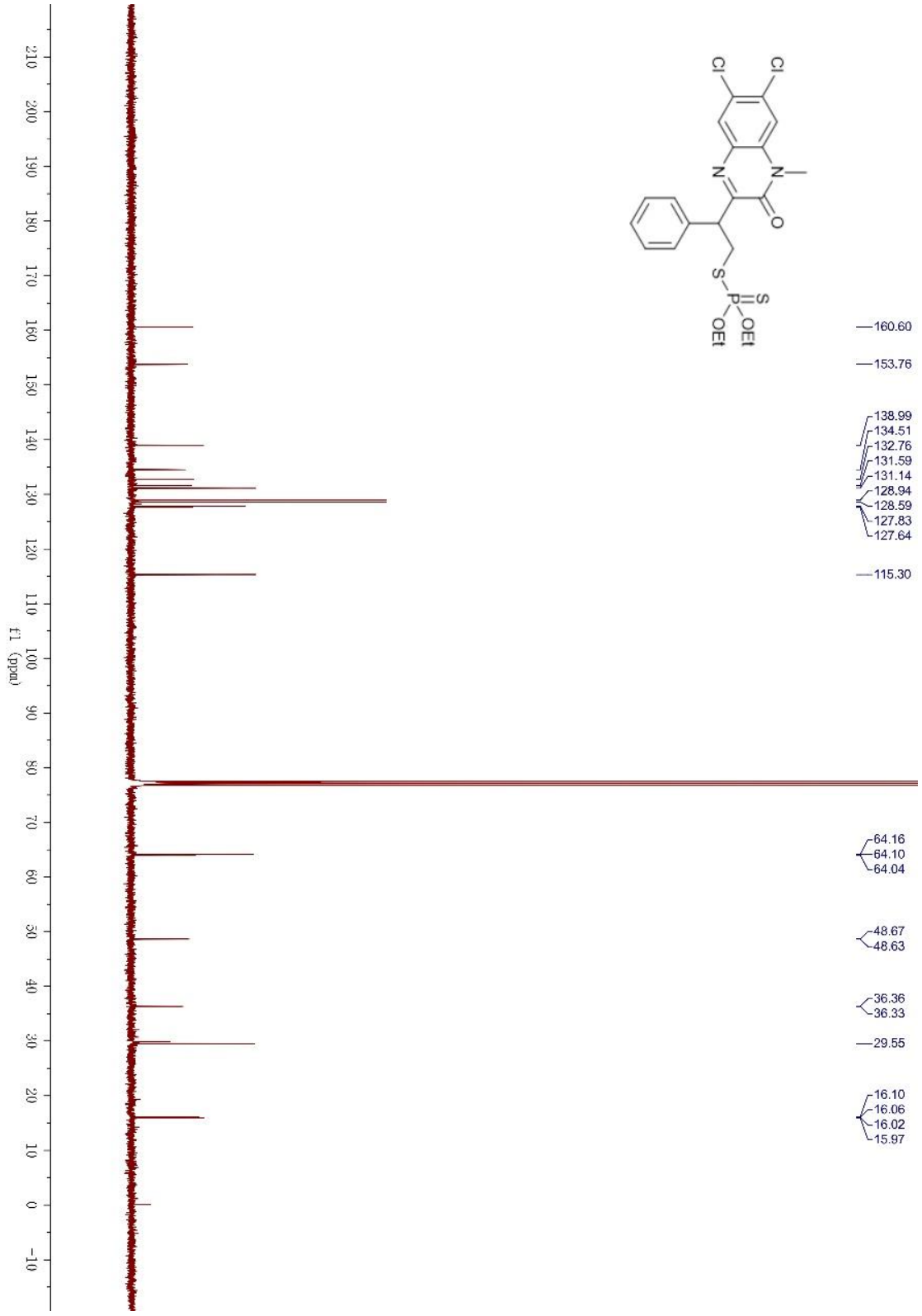
^{13}C NMR of **16**


157.58
154.43
140.17
139.90
132.65
131.36
131.03
130.45
128.75
128.57
127.47
114.31
77.48
77.16
76.84
64.01
63.95
63.89
48.39
48.34
36.61
29.17
20.68
19.26
16.09
16.05
16.00
15.96
f1 (ppm)

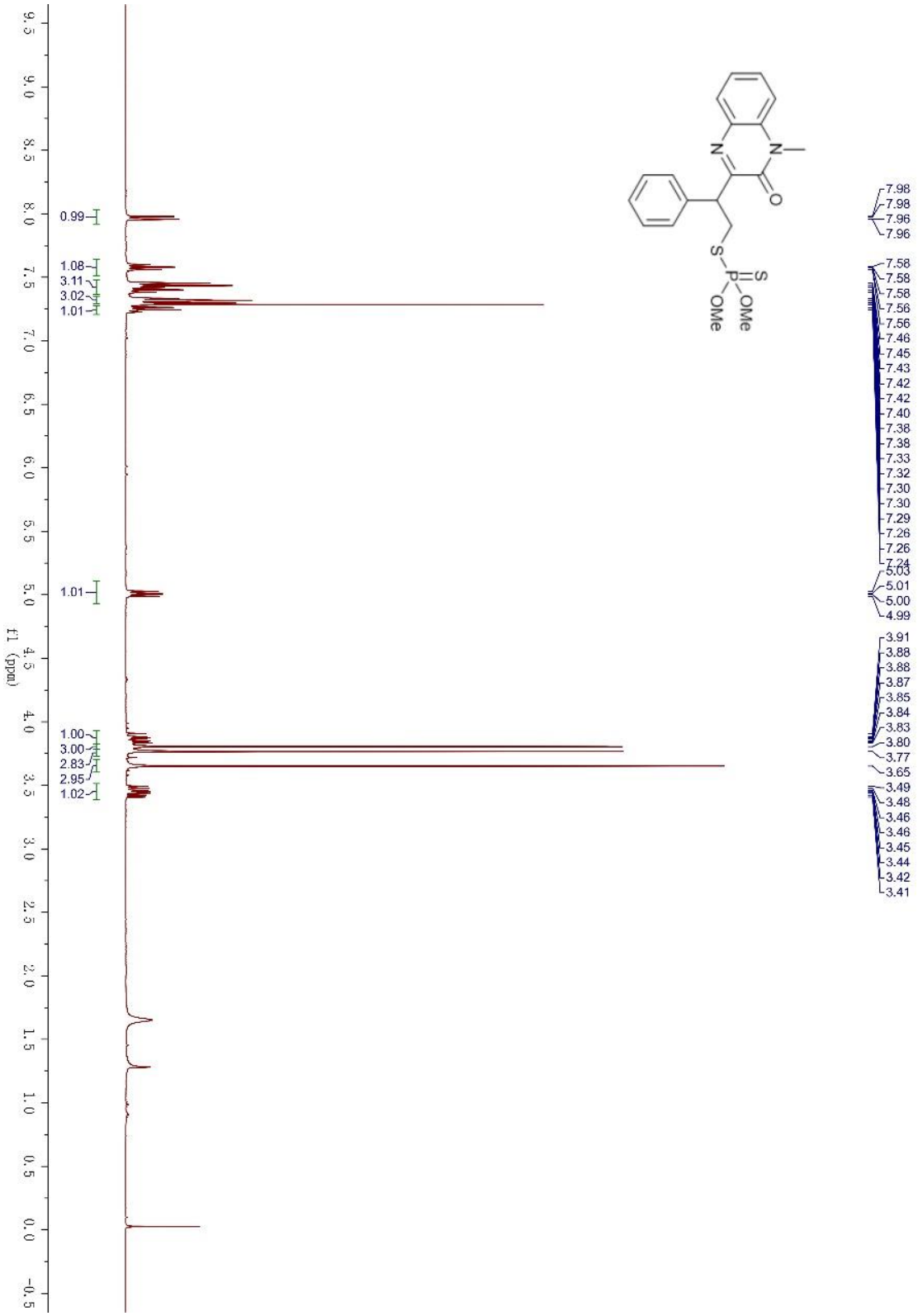
^{1}H NMR of **17**


Cl
Cl
N
N
O
S
P
S
OEt
OEt
f1 (ppm)
0.92
3.07
2.12
0.91
1.00
4.00
1.17
3.04
1.06
6.03
8.06
7.42
7.41
7.41
7.39
7.34
7.34
7.32
7.31
7.30
7.28
7.28
7.27
7.27
7.26
5.03
5.02
5.01
4.99
4.23
4.22
4.22
4.21
4.20
4.19
4.17
4.16
4.15
4.15
4.14
4.14
4.12
4.12
3.60
1.43
1.43
1.41
1.41
1.40
1.40
1.39
1.39
1.38
1.38
1.37
1.37

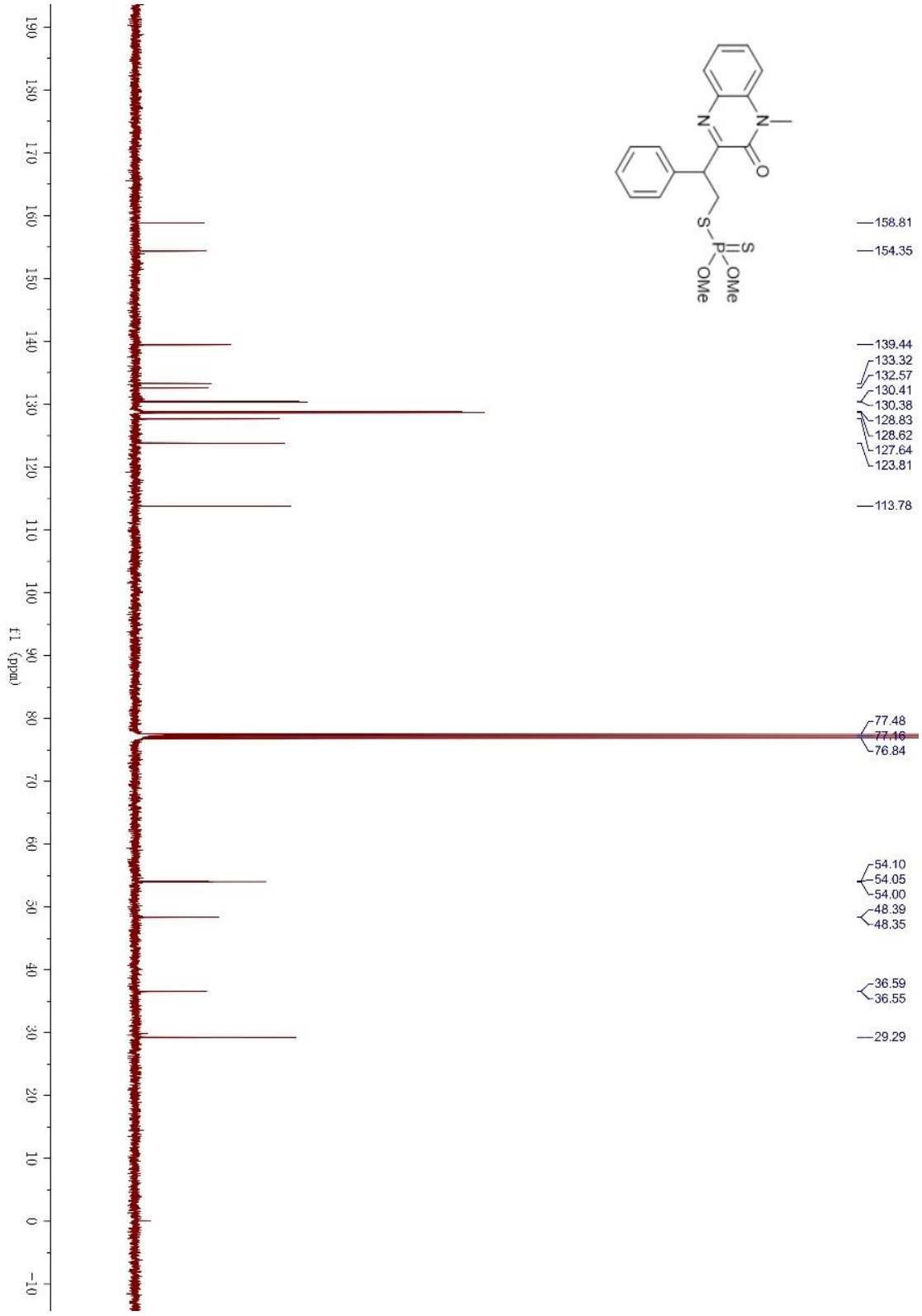
^{13}C NMR of **17**


160.60
153.76
138.99
134.51
132.76
131.59
131.14
128.94
128.59
127.83
127.64
115.30
64.16
64.10
64.04
48.67
48.63
36.36
36.33
29.55
16.10
16.06
16.02
15.97
f1 (ppm)

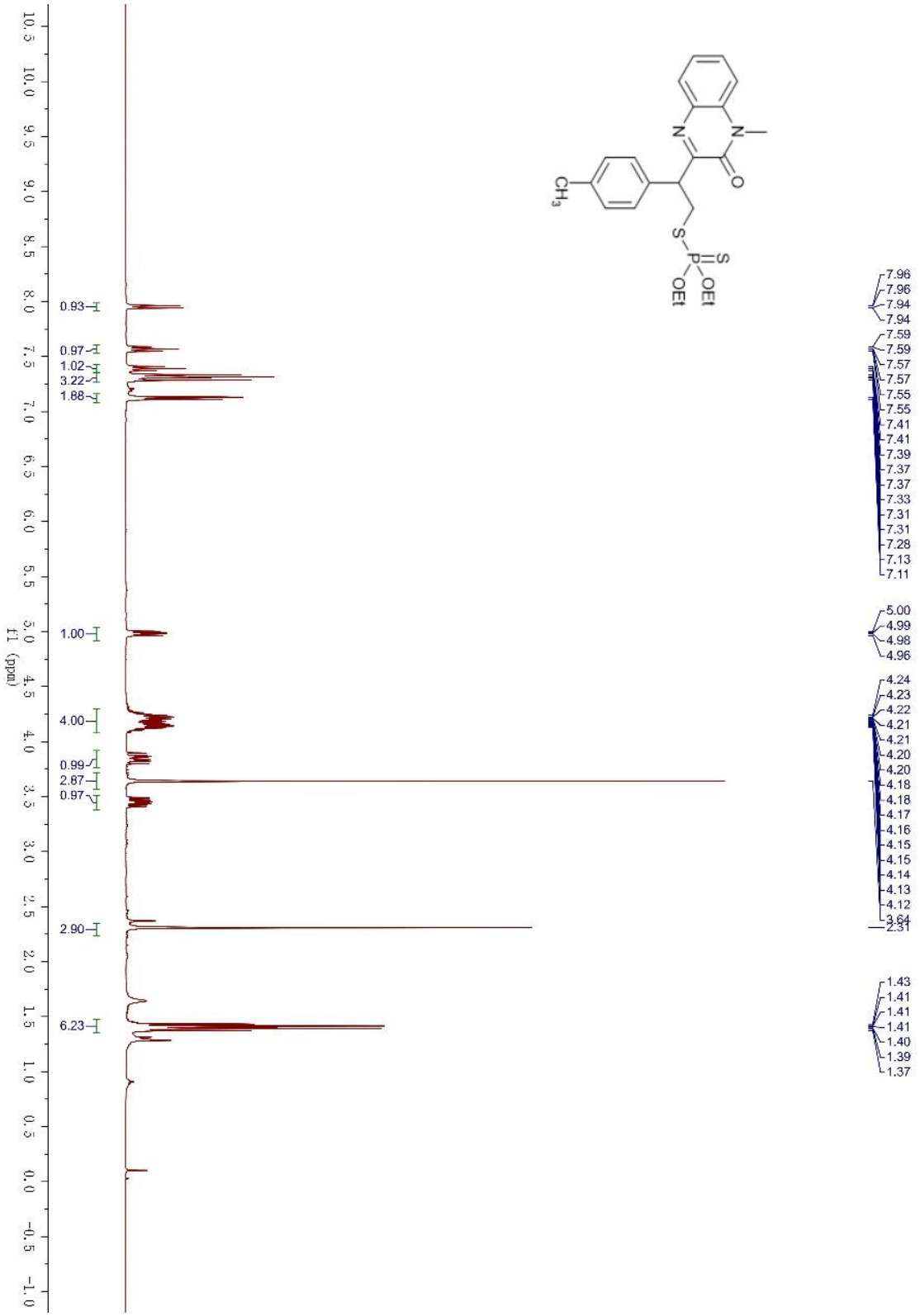
^{1}H NMR of **18**


f1 (ppm)
0.99
1.08
3.11
3.02
1.01
1.01
1.00
3.00
2.83
2.95
1.02
7.98
7.98
7.96
7.96
7.58
7.58
7.58
7.56
7.56
7.46
7.45
7.43
7.42
7.42
7.40
7.38
7.38
7.33
7.32
7.30
7.30
7.29
7.26
7.26
7.24
5.03
5.01
5.00
4.99
3.91
3.88
3.88
3.87
3.85
3.84
3.83
3.80
3.77
3.65
3.49
3.48
3.46
3.46
3.45
3.44
3.42
3.41
N
N
O
S
S
P
OMe
OMe

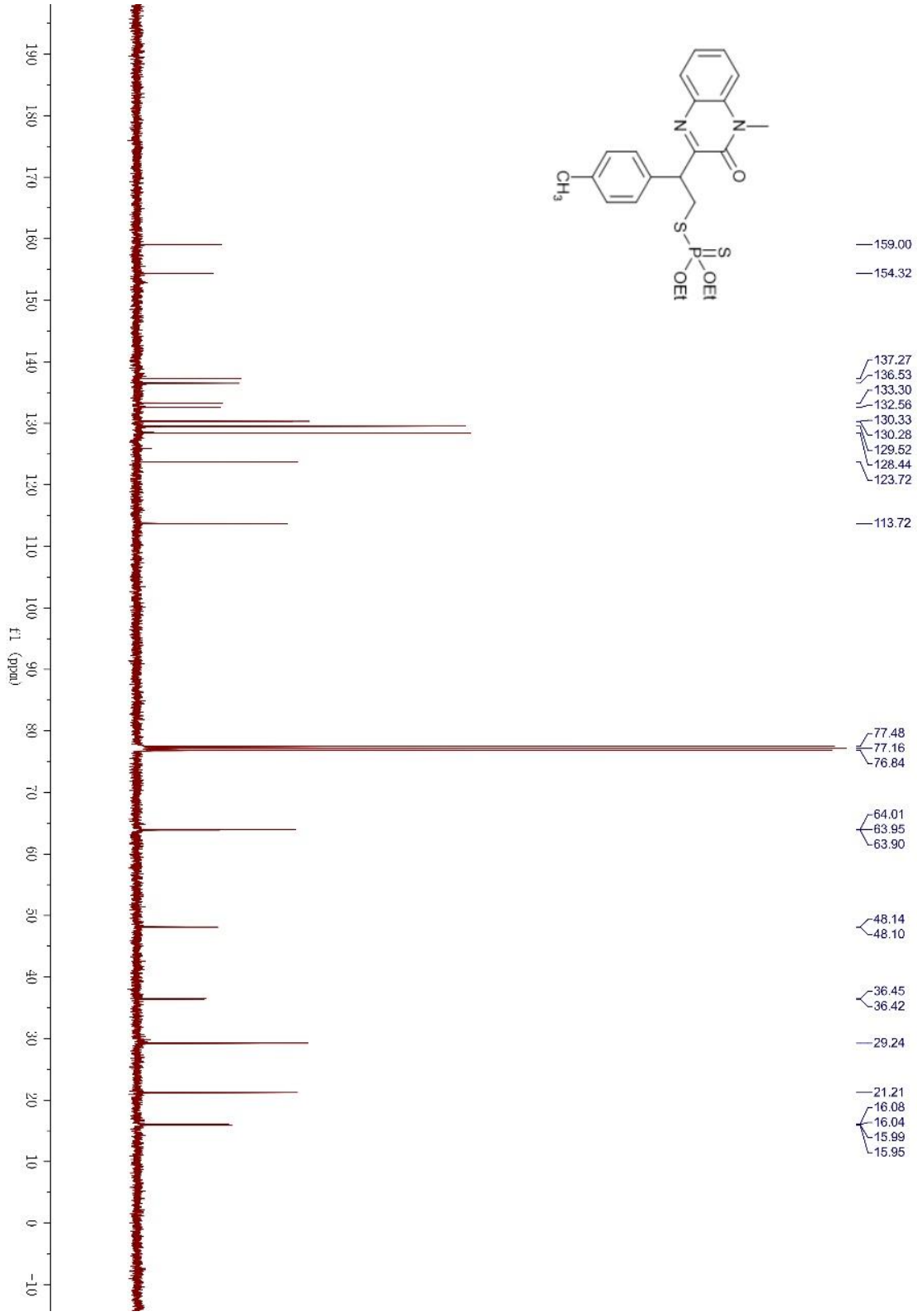
^{13}C NMR of **18**


158.81
154.35
139.44
133.32
132.57
130.41
130.38
128.83
128.62
127.64
123.81
113.78
77.48
77.16
76.84
54.10
54.05
54.00
48.39
48.35
36.59
36.55
29.29
f1 (ppm)

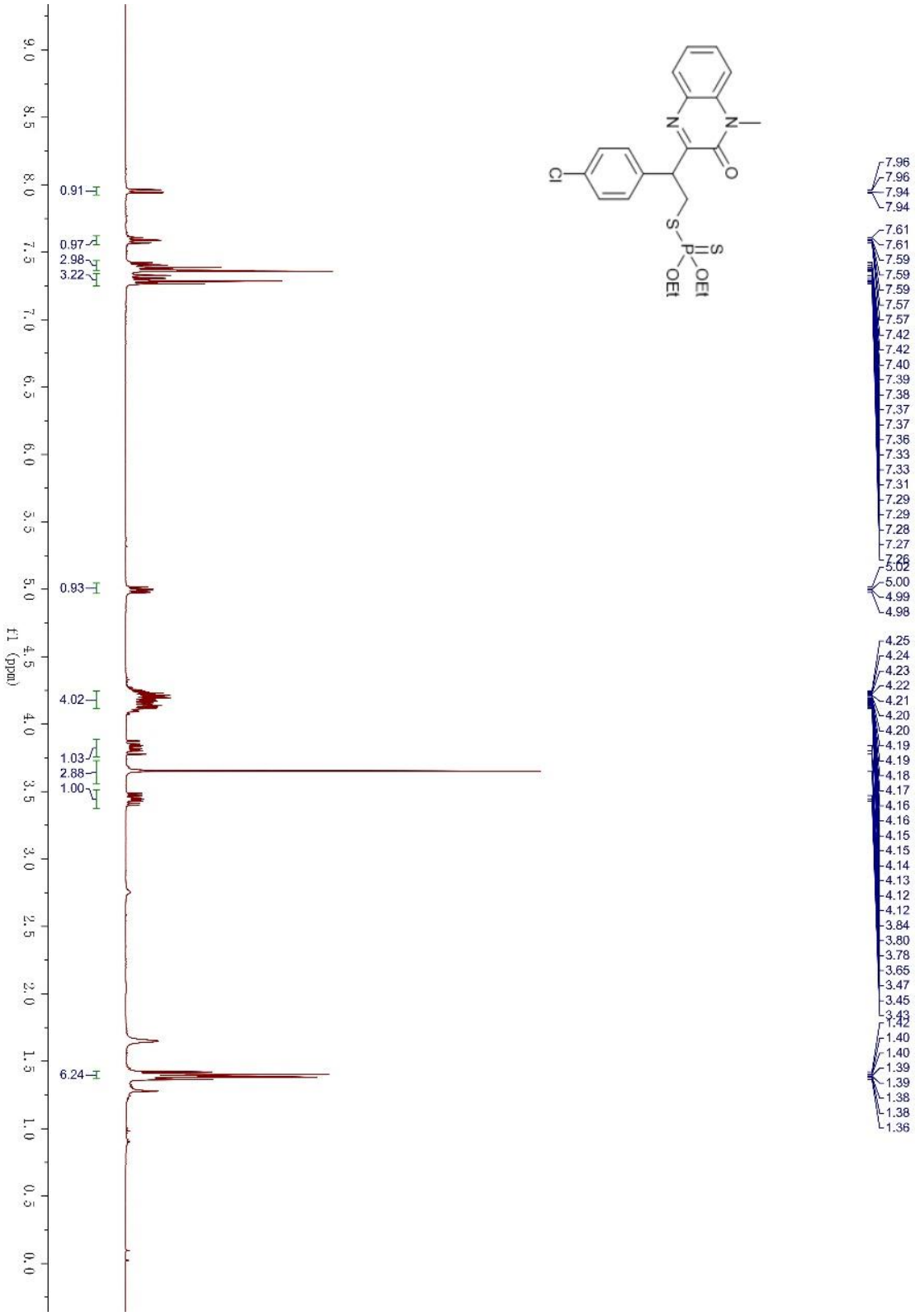
^{1}H NMR of **19**


f1 (ppm)
0.93
0.97
1.02
3.22
1.88
1.00
4.00
0.99
2.87
0.97
2.90
6.23
CH3
N
O
S
P
OEt
OEt
7.96
7.94
7.59
7.57
7.55
7.41
7.39
7.37
7.33
7.31
7.28
7.13
7.11
5.00
4.99
4.98
4.96
4.24
4.23
4.22
4.21
4.20
4.18
4.17
4.16
4.15
4.14
4.13
4.12
3.64
2.31
1.43
1.41
1.40
1.39
1.37

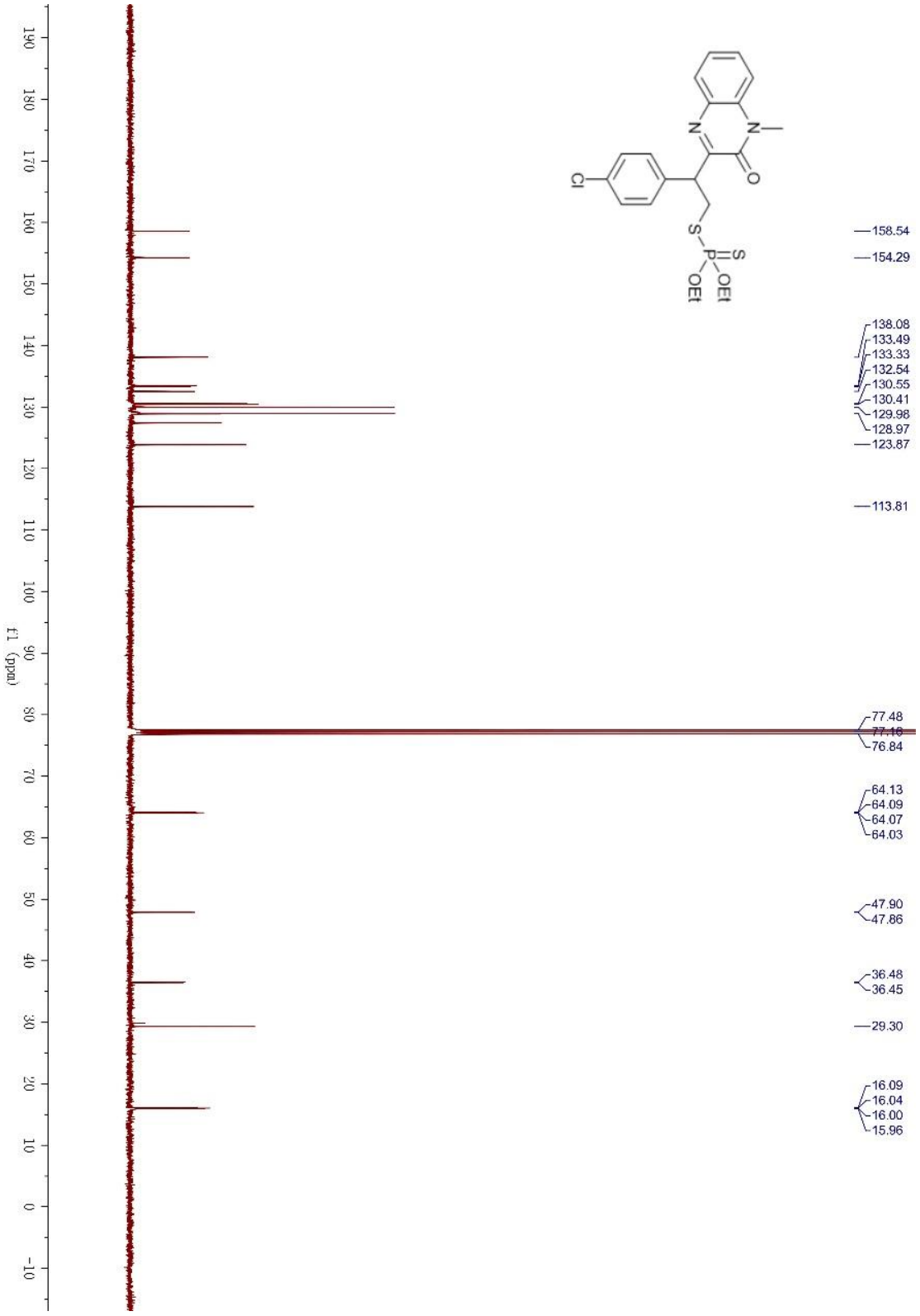
^{13}C NMR of **19**


159.00
154.32
137.27
136.53
133.30
132.56
130.33
130.28
129.52
128.44
123.72
113.72
77.48
77.16
76.84
64.01
63.95
63.90
48.14
48.10
36.45
36.42
29.24
21.21
16.08
16.04
15.99
15.95
f1 (ppm)

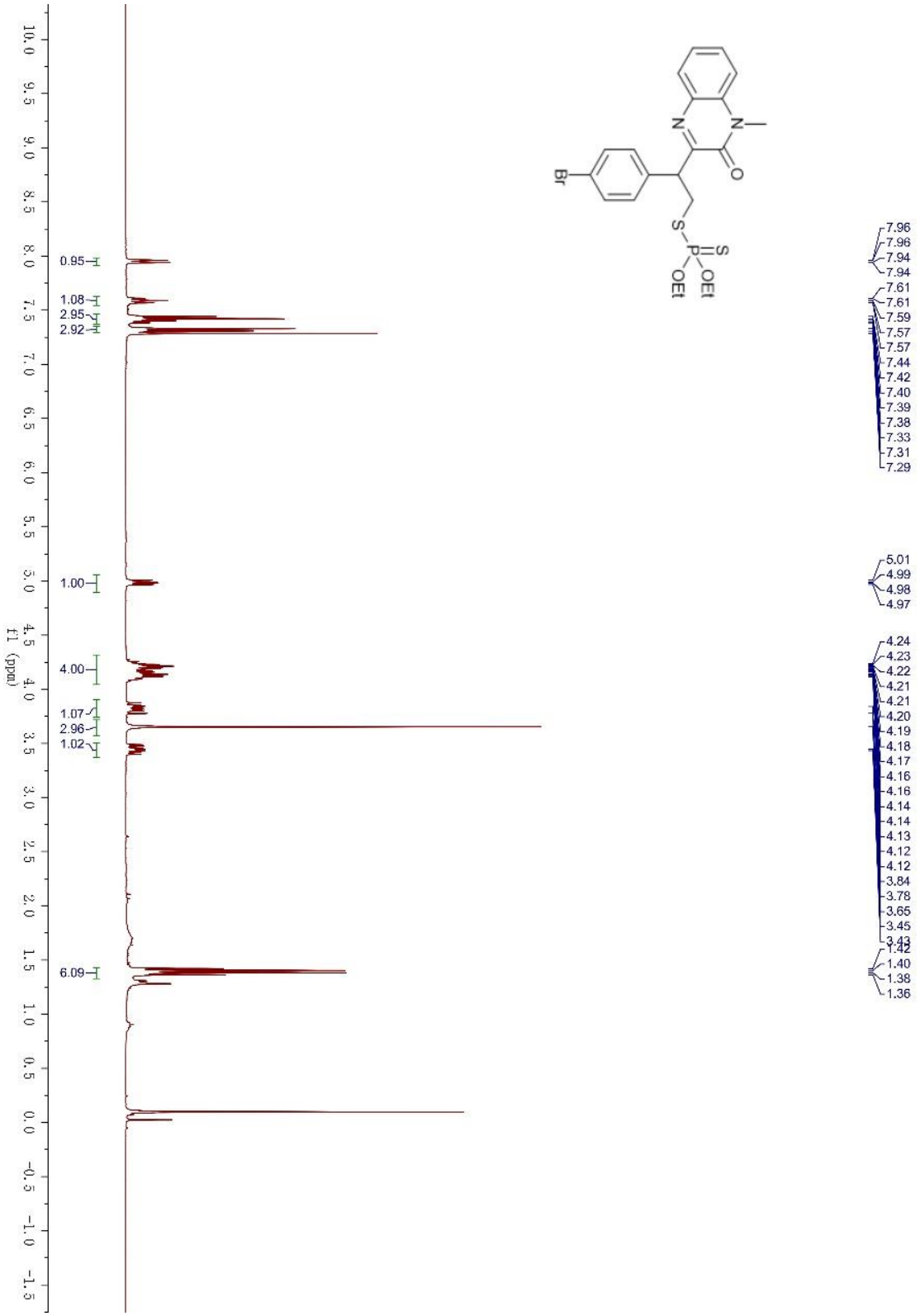
^{1}H NMR of **20**


0.91
0.97
2.98
3.22
0.93
4.02
1.03
2.88
1.00
6.24
f1 (ppm)
Cl
N
N
O
S
P
S
OEt
OEt
7.96
7.96
7.94
7.94
7.61
7.61
7.59
7.59
7.59
7.57
7.57
7.42
7.42
7.40
7.39
7.38
7.37
7.37
7.36
7.33
7.33
7.31
7.29
7.29
7.28
7.27
5.02
5.00
4.99
4.98
4.25
4.24
4.23
4.22
4.21
4.20
4.20
4.19
4.19
4.18
4.17
4.16
4.16
4.15
4.15
4.14
4.13
4.12
4.12
3.84
3.80
3.78
3.65
3.47
3.45
1.42
1.40
1.40
1.39
1.39
1.38
1.38
1.36

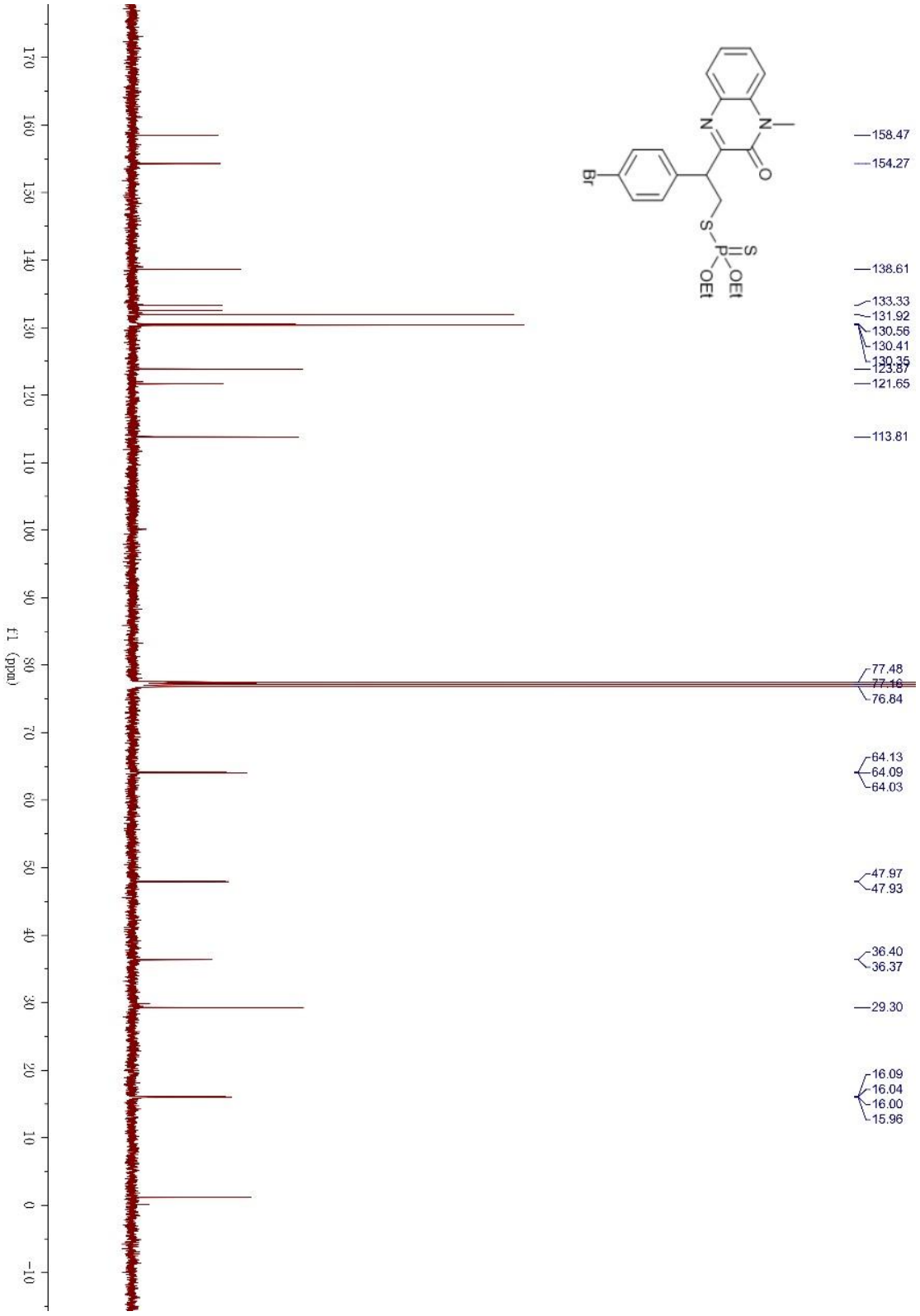
^{13}C NMR of **20**


158.54
154.29
138.08
133.49
133.33
132.54
130.55
130.41
129.98
128.97
123.87
113.81
77.48
77.16
76.84
64.13
64.09
64.07
64.03
47.90
47.86
36.48
36.45
29.30
16.09
16.04
16.00
15.96
f1 (ppm)

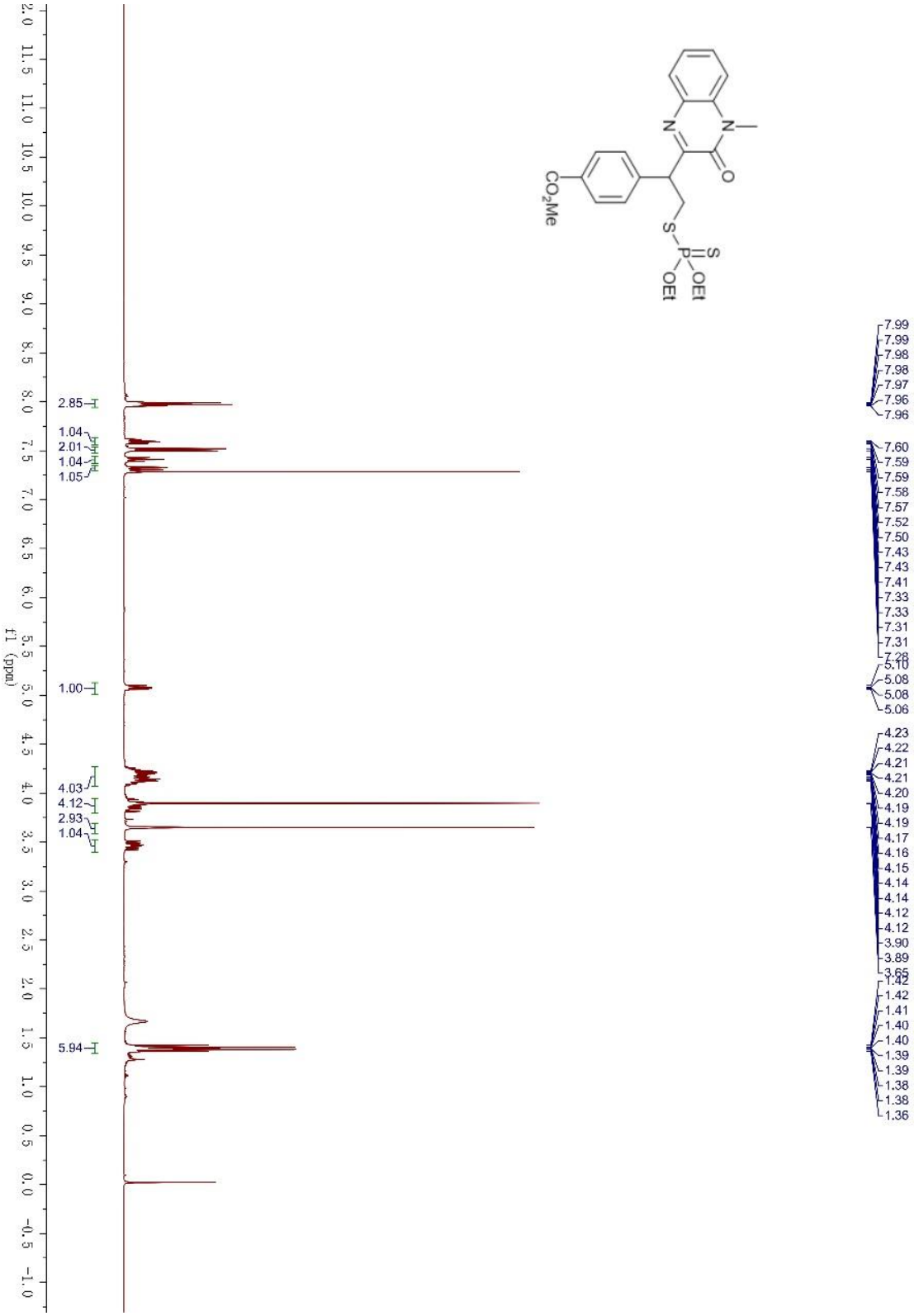
^{1}H NMR of **21**


0.95
1.08
2.95
2.92
1.00
4.00
1.07
2.96
1.02
6.09
f1 (ppm)
Br
N
O
S
P
OEt
OEt
7.96
7.96
7.94
7.94
7.61
7.61
7.59
7.57
7.57
7.44
7.42
7.40
7.39
7.38
7.33
7.31
7.29
5.01
4.99
4.98
4.97
4.24
4.23
4.22
4.21
4.21
4.20
4.19
4.18
4.17
4.16
4.16
4.14
4.14
4.13
4.12
4.12
3.84
3.78
3.65
3.45
1.42
1.40
1.38
1.36

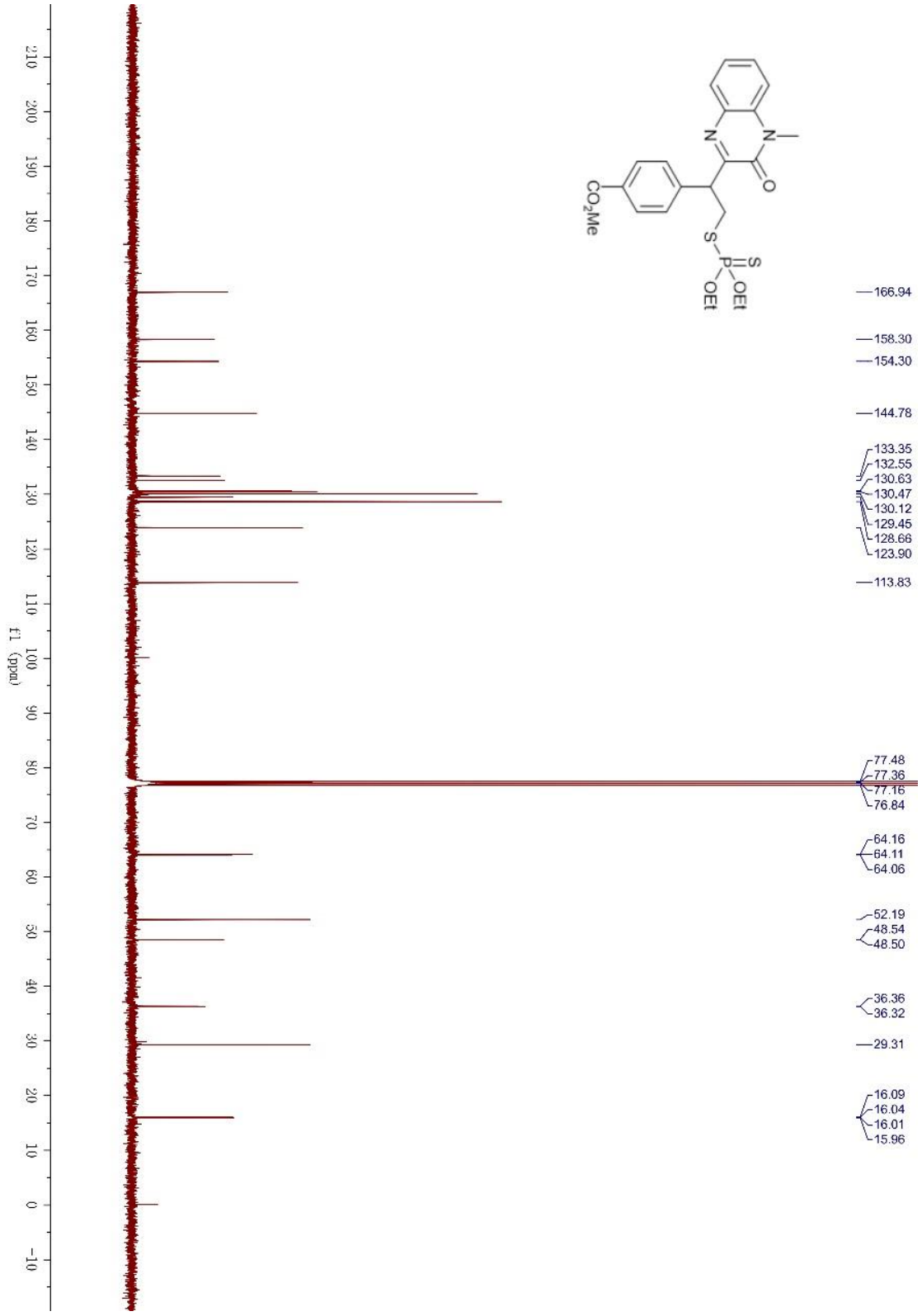
^{13}C NMR of **21**


158.47
154.27
138.61
133.33
131.92
130.56
130.41
130.35
123.87
121.65
113.81
77.48
77.16
76.84
64.13
64.09
64.03
47.97
47.93
36.40
36.37
29.30
16.09
16.04
16.00
15.96
f1 (ppm)

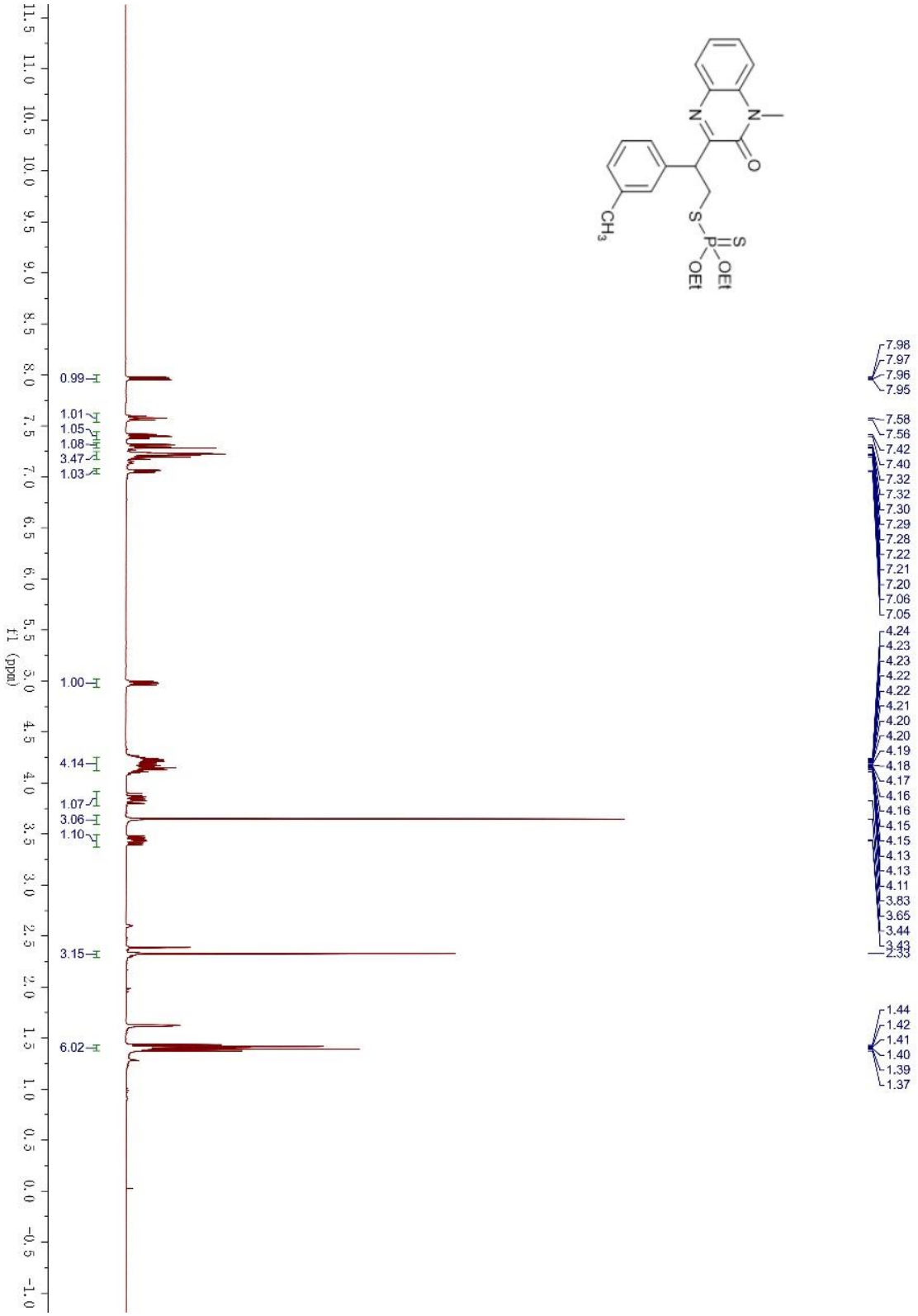
^{1}H NMR of **22**


CO2Me
N
O
S
P
OEt
OEt
2.85
1.04
2.01
1.04
1.05
1.00
4.03
4.12
2.93
1.04
5.94
f1 (ppm)

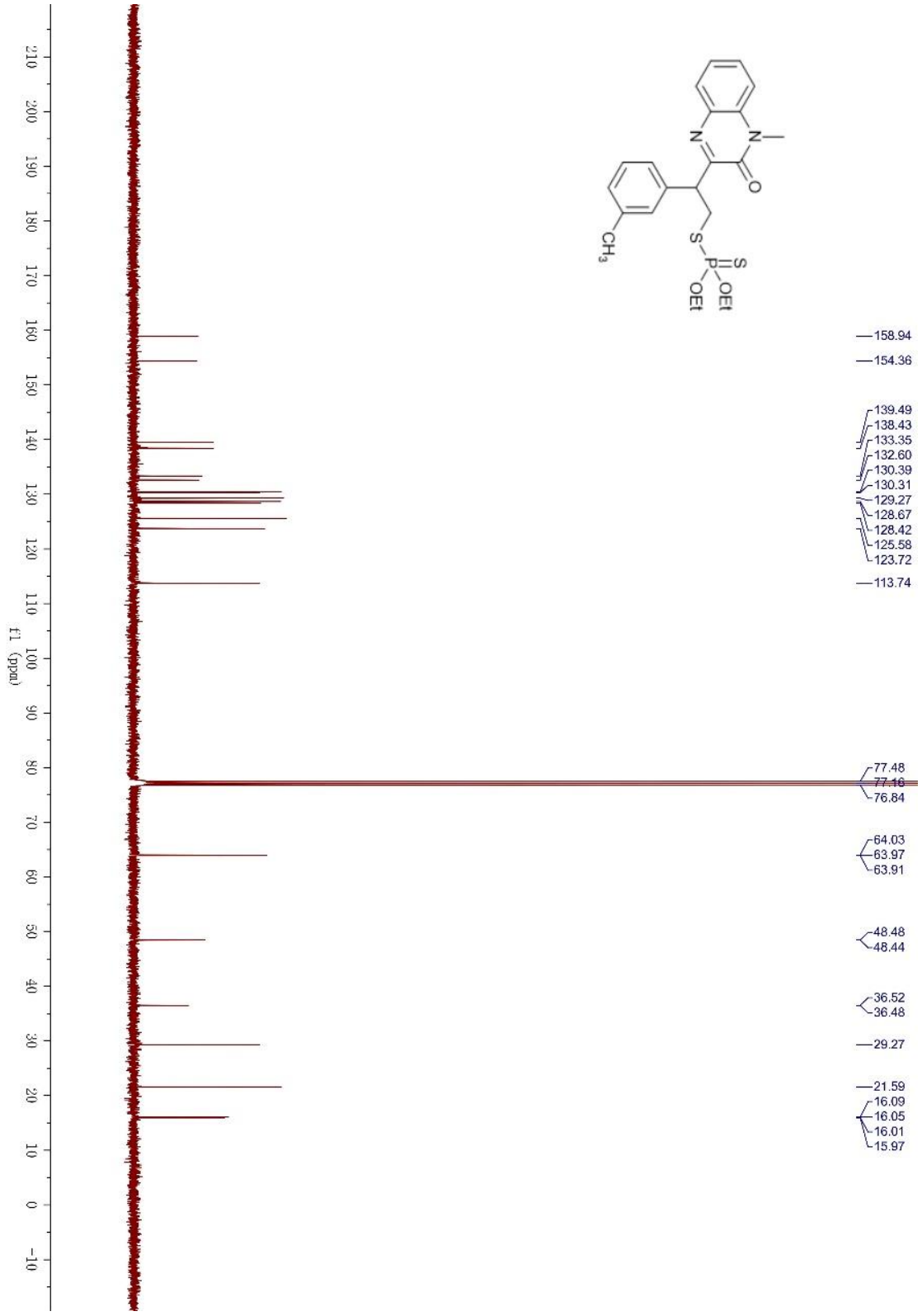
^{13}C NMR of **22**


166.94
158.30
154.30
144.78
133.35
132.55
130.63
130.47
130.12
129.45
128.66
123.90
113.83
77.48
77.36
77.16
76.84
64.16
64.11
64.06
52.19
48.54
48.50
36.36
36.32
29.31
16.09
16.04
16.01
15.96
f1 (ppm)
CO2Me
OEt
OEt

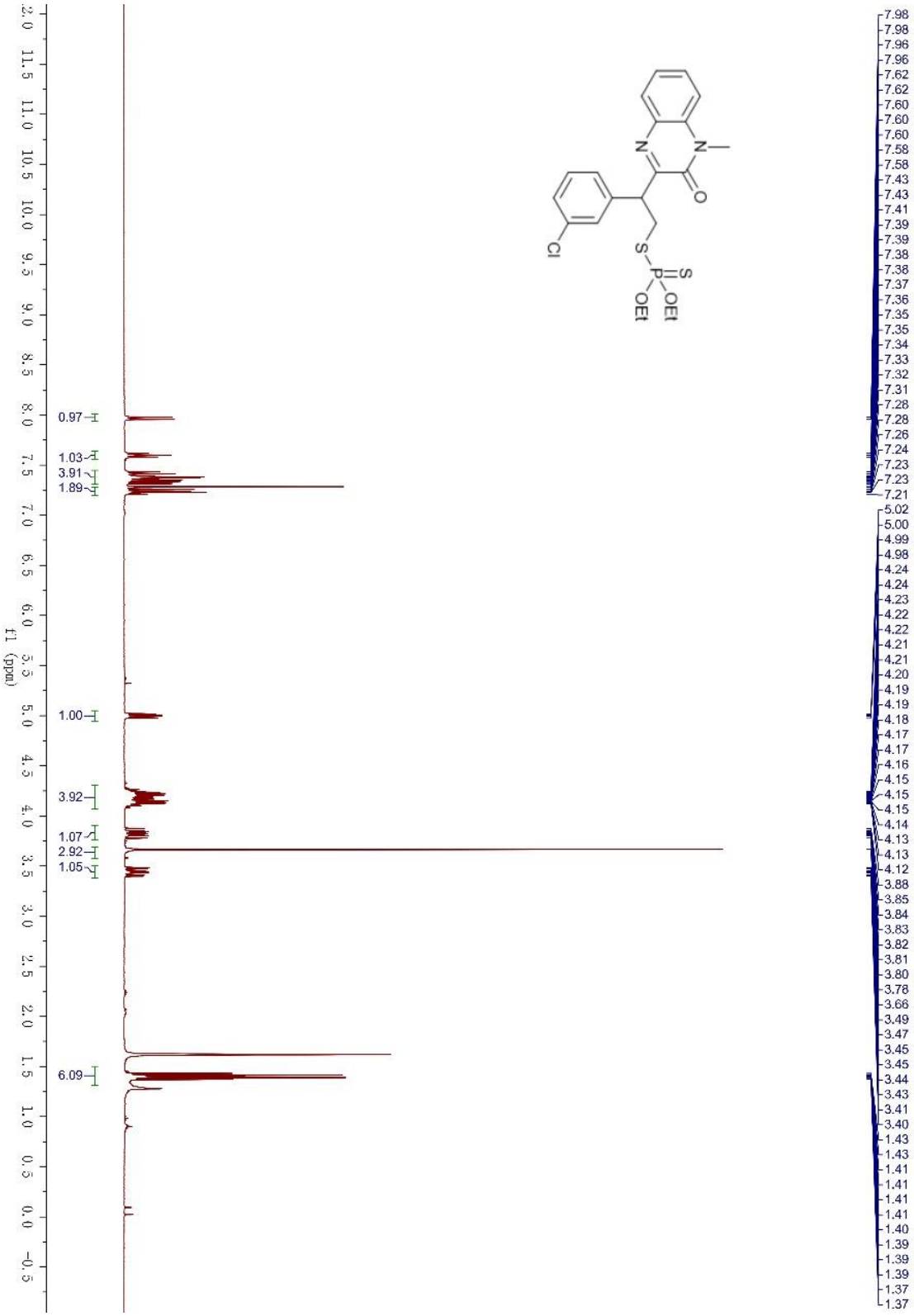
^{1}H NMR of **23**


f1 (ppm)
0.99
1.01
1.05
1.08
3.47
1.03
1.00
4.14
1.07
3.06
1.10
3.15
6.02
7.98
7.97
7.96
7.95
7.58
7.56
7.42
7.40
7.32
7.32
7.30
7.29
7.28
7.22
7.21
7.20
7.06
7.05
4.24
4.23
4.23
4.22
4.22
4.21
4.20
4.20
4.19
4.18
4.17
4.16
4.16
4.15
4.15
4.13
4.13
4.11
3.83
3.65
3.44
1.44
1.42
1.41
1.40
1.39
1.37

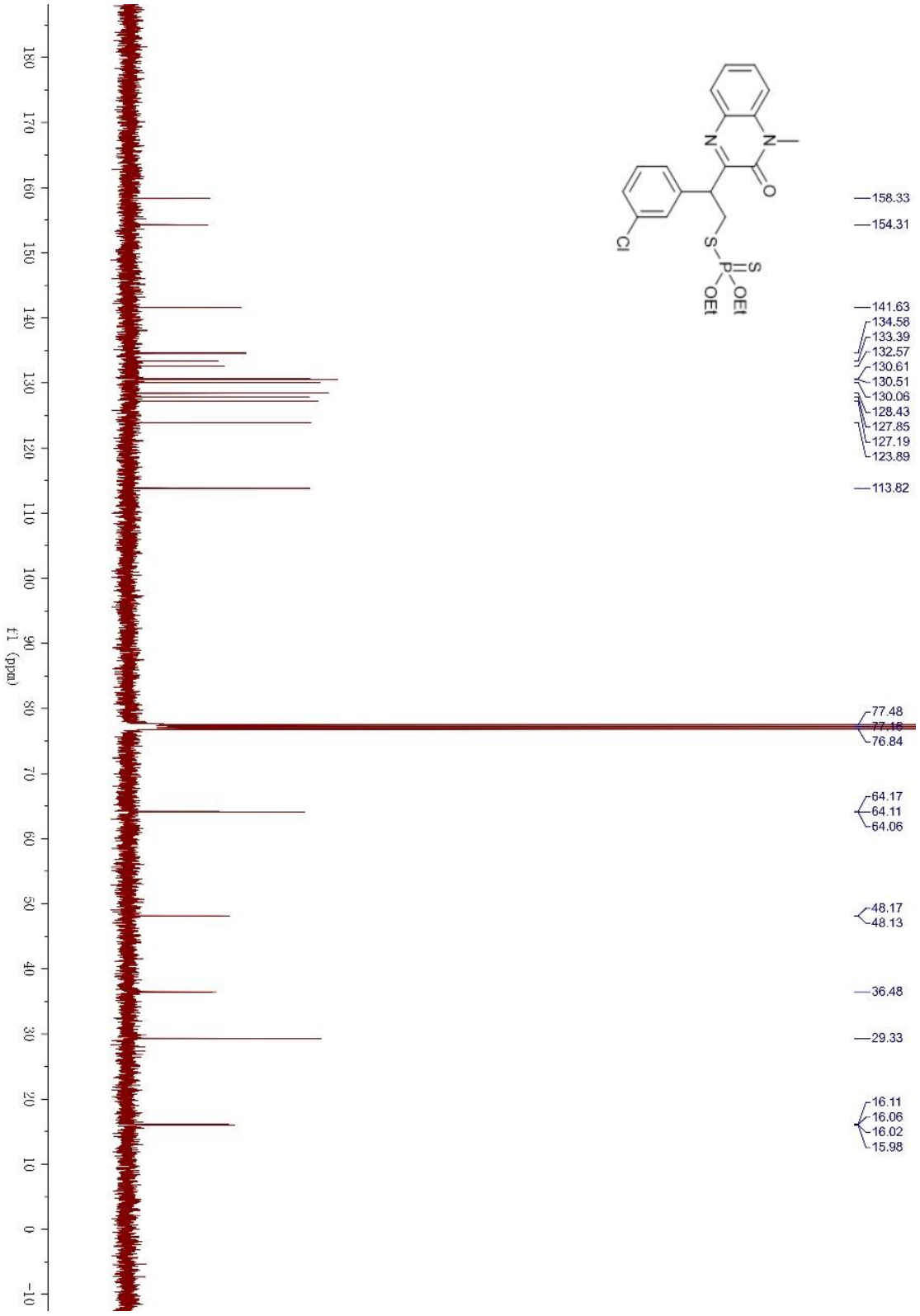
^{13}C NMR of **23**


158.94
154.36
139.49
138.43
133.35
132.60
130.39
130.31
129.27
128.67
128.42
125.58
123.72
113.74
77.48
77.16
76.84
64.03
63.97
63.91
48.48
48.44
36.52
36.48
29.27
21.59
16.09
16.05
16.01
15.97
f1 (ppm)

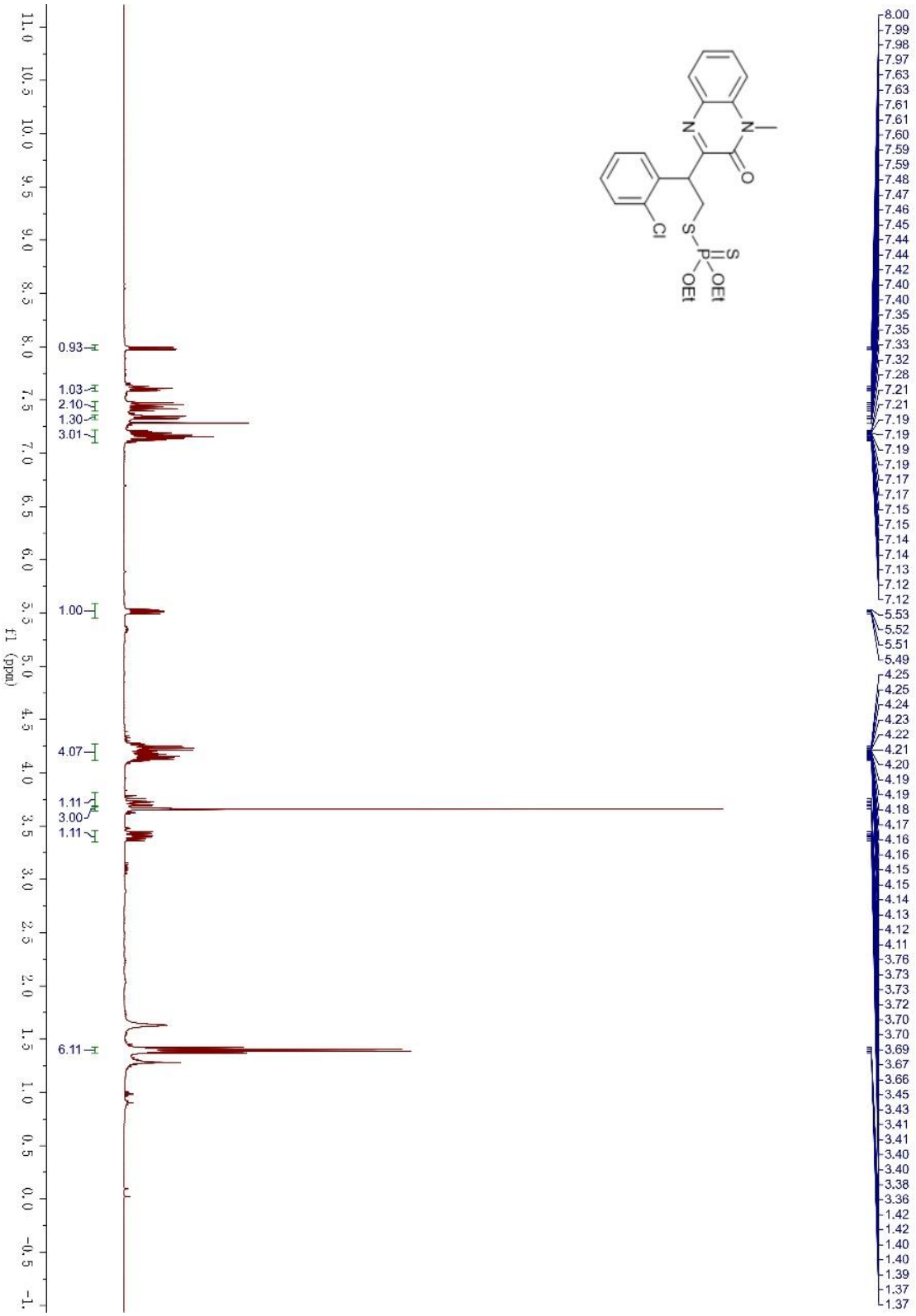
^{1}H NMR of **24**



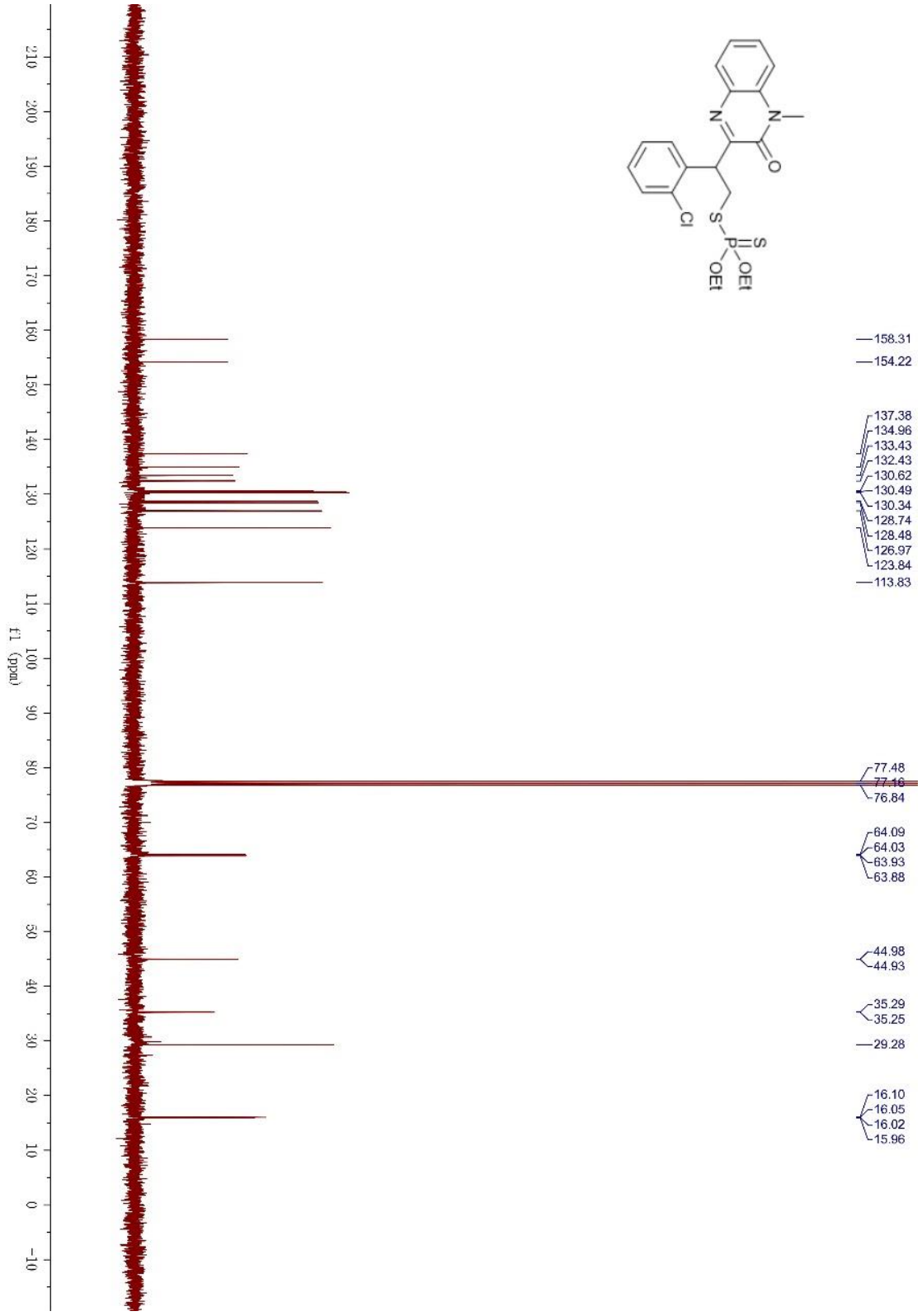
^{13}C NMR of **24**


158.33
154.31
141.63
134.58
133.39
132.57
130.61
130.51
130.06
128.43
127.85
127.19
123.89
113.82
77.48
77.16
76.84
64.17
64.11
64.06
48.17
48.13
36.48
29.33
16.11
16.06
16.02
15.98
f1 (ppm)

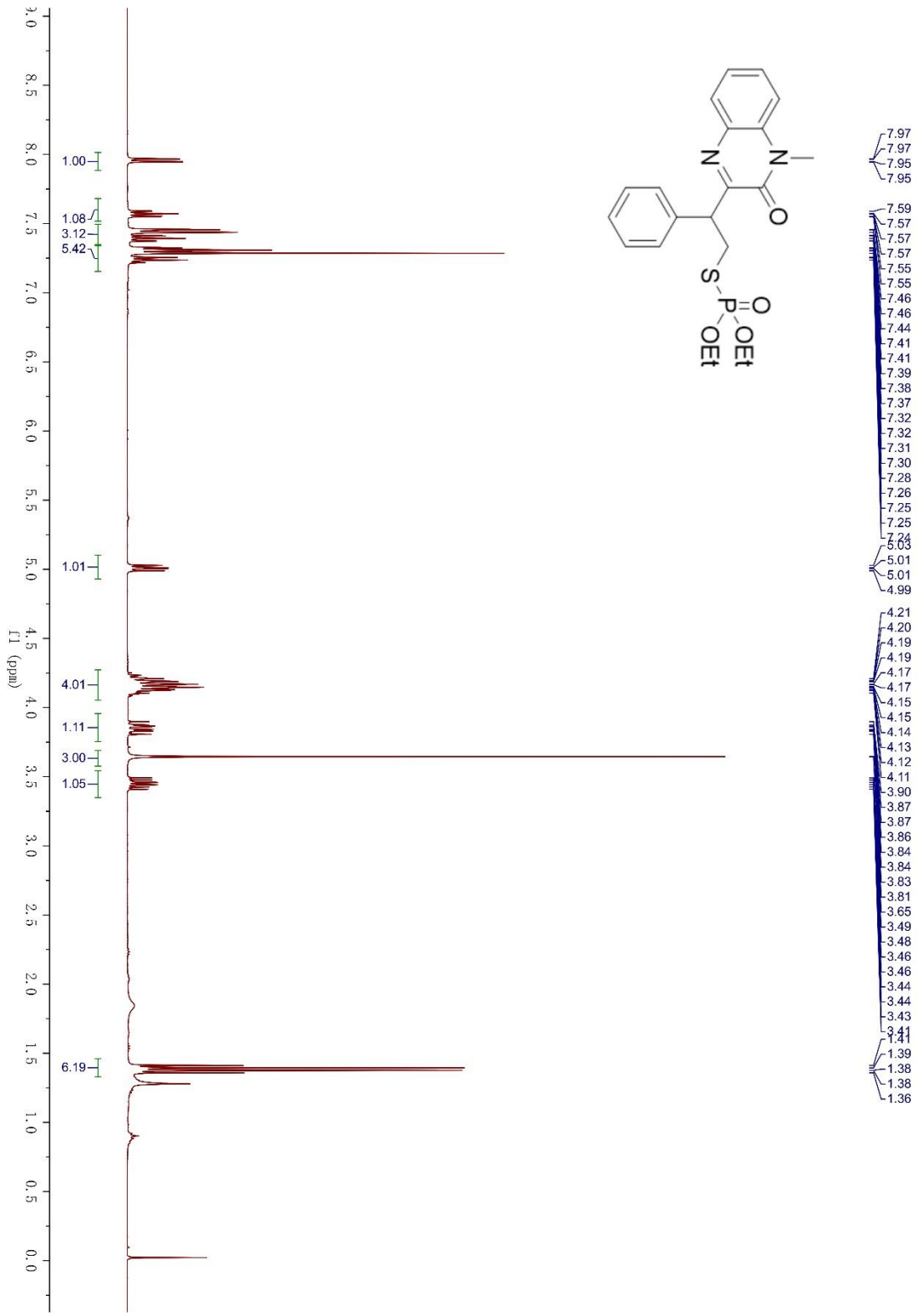
^{1}H NMR of **25**



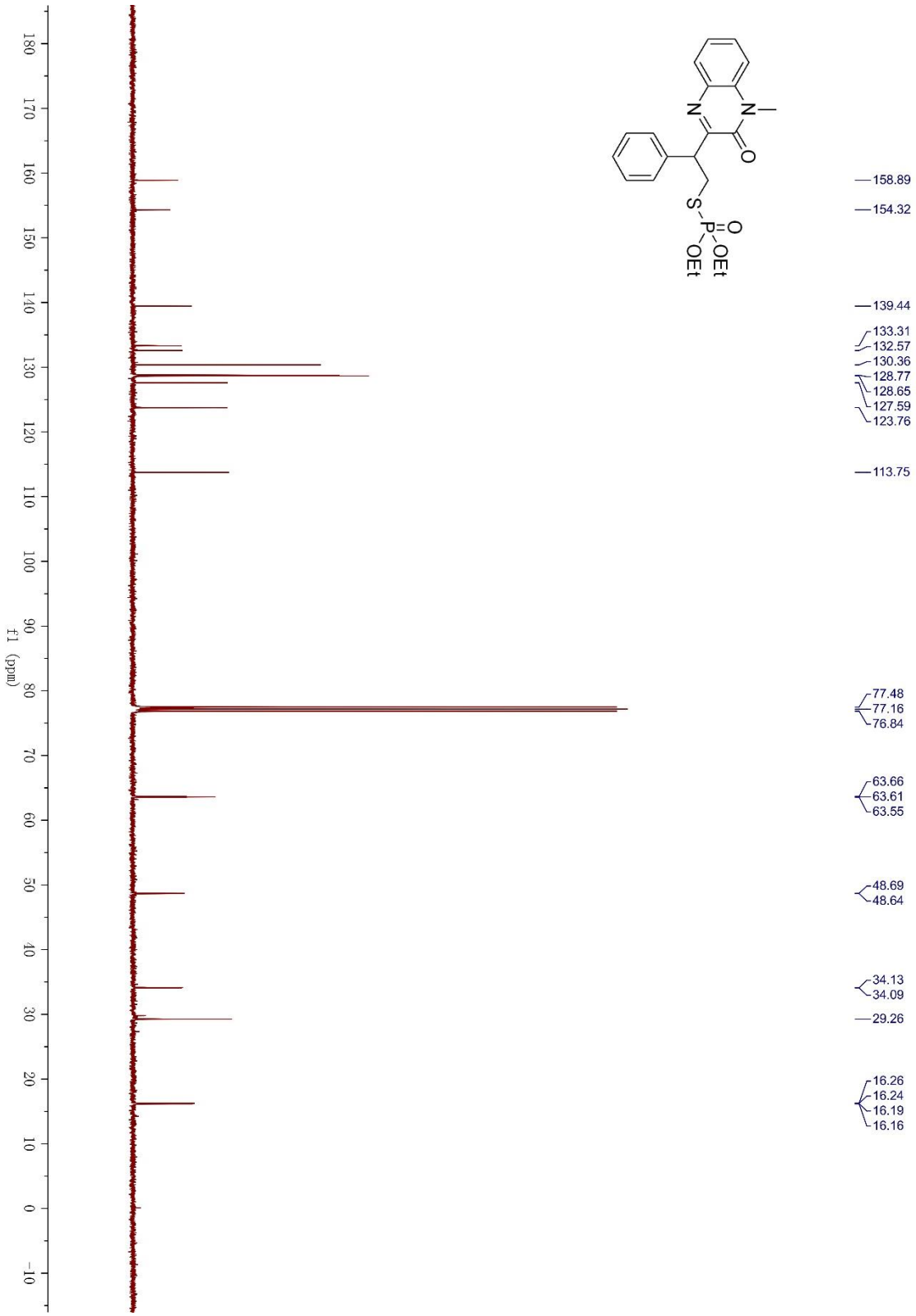
^{13}C NMR of **25**


158.31
154.22
137.38
134.96
133.43
132.43
130.62
130.49
130.34
128.74
128.48
126.97
123.84
113.83
77.48
77.16
76.84
64.09
64.03
63.93
63.88
44.98
44.93
35.29
35.25
29.28
16.10
16.05
16.02
15.96
f1 (ppm)

^{1}H NMR of **27**


1.00
1.08
3.12
5.42
1.01
4.01
1.11
3.00
1.05
6.19
f1 (ppm)
7.97
7.97
7.95
7.95
7.59
7.57
7.57
7.57
7.55
7.55
7.46
7.46
7.44
7.41
7.41
7.39
7.38
7.37
7.32
7.32
7.31
7.30
7.28
7.26
7.25
7.25
7.24
5.03
5.01
5.01
4.99
4.21
4.20
4.19
4.19
4.17
4.17
4.15
4.15
4.14
4.13
4.12
4.11
3.90
3.87
3.87
3.86
3.84
3.84
3.83
3.81
3.65
3.49
3.48
3.46
3.46
3.44
3.44
3.43
3.41
1.41
1.39
1.38
1.38
1.36
N
N
O
S
P
O
OEt
OEt

^{13}C NMR of **27**


158.89
154.32
139.44
133.31
132.57
130.36
128.77
128.65
127.59
123.76
113.75
77.48
77.16
76.84
63.66
63.61
63.55
48.69
48.64
34.13
34.09
29.26
16.26
16.24
16.19
16.16
f1 (ppm)